11th International Precipitation Conference 2013

30 June - 3 July 2013 Ede-Wageningen | The Netherlands

Hidde Leijnse and Remko Uijlenhoet

WAGENINGEN UNIVERSITY
WAGENINGEN UR

Royal Netherlands
Meteorological Institute
Ministry of Infrastructure and the Environment

11th International Precipitation Conference 2013

Royal Netherlands Meteorological Institute (KNMI) and Hydrology and Quantitative Water Management Group, Wageningen University

Editors:
Hidde Leijnse
Remko Uijlenhoet

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The Netherlands

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30th June – 3rd July 2013
De Reehorst Hotel and Conference Centre, Ede-Wageningen
The Netherlands

Editors: Hidde Leijnse and Remko Uijlenhoet

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Welcome

Welcome

Dear IPC11 participant,

On behalf of Wageningen University and the Royal Netherlands Meteorological Institute, welcome to the Netherlands, welcome to the Reehorst Conference Centre in Ede-Wageningen, and welcome to the 11th International Precipitation Conference!

Over the years, the International Precipitation Conference has stimulated the interdisciplinary exchange of ideas and expertise as a way of improving our understanding of precipitation processes, their observations, estimation, modelling and prediction. Beginning with the first conference held in 1986 in Caracas, Venezuela, the series has been an important forum that brings together meteorologists, hydrologists, statisticians and engineers whose research includes interest in precipitation.

Results presented and discussed at the ten previous meetings have been published in numerous refereed journal articles and are often widely cited. The series has promoted the importance of such fundamental aspects of precipitation processes as variability across scales in space and time, strong nonlinearity of the involved dynamical process, and the inherent uncertainty involved in precipitation observations and forecasts.

The International Precipitation Conference is unique in its combination of interdisciplinary and limited size, and it can therefore be very effective in continuing to stimulate interdisciplinary discussions on precipitation research.

The 11th International Precipitation Conference (IPC11) is organised jointly by Wageningen University and the Royal Netherlands Meteorological Institute. The general setup of IPC11 is a three-day topical scientific conference with one plenary oral session and one single poster session, where all posters are on display for the entire duration of the conference. Our aim is that, by avoiding parallel oral sessions and multiple poster sessions, we achieve maximum exposure of all participants to each other's work. We hope, once the conference is over, you will be able to look back on a fruitful meeting and conclude that this goal has been achieved.

As a venue for the conference we have chosen the Reehorst Hotel and Conference Centre, conveniently located within a three-minute walking distance from the Ede-Wageningen railway station, with direct train connections to Amsterdam Airport Schiphol (~1 hour) and other destinations in the Netherlands, such as the cities of Utrecht (~25 min) and Amsterdam (~55 min). A regular bus service (line 88) will bring you to the campus of Wageningen University & Research Centre in less than 15 min and to the city centre of college town Wageningen in ~20 min. For those of you who have a (rental) car, the conference centre is within 1 km from exit 24 of (inter)national highway A12/E35 (Utrecht–Arnhem). National Park "De Hoge Veluwe" and the Kröller-Müller Museum are only a ~30 min bus ride (line 108) from Ede-Wageningen railway station. By the way, 2013 is a fitting year to visit the area, as the city of Wageningen celebrates its 750th anniversary and Wageningen University its 95th anniversary.

As Organizing Committee, we thank you very much for keeping the spirit of the International Precipitation Conference series alive by submitting nearly 200 abstracts. The Program Committee was impressed by the general quality of the abstracts, which made it easier for them to assemble an attractive conference program, with 60 oral presentations (including 9 invited presentations) distributed over 10 oral blocks of 6 presentations each, forming 5 topical sessions, as well as a poster session with over 100 posters!

Finally, we would like to thank our sponsors:the Royal Netherlands Meteorological Institute (KNMI), Wageningen University, the Wageningen Institute for Environment & Climate Research (WIMEK), the Boussinesq Centre for Hydrology, the European Geosciences Union (EGU), the International Association for Hydrologic Sciences (IAHS), the American Geophysical Union (AGU), the Global Water and Energy Exchanges project (GEWEX) of the World Climate Research Program (WCRP), OTT Hydromet, Disdrometrics BV, HKV Lijn in Water, and SELEX Systems Integration. Their support has been instrumental in organizing IPC11.

We wish you a fruitful conference in a friendly environment!

The IPC11 Organizing Committee

Hidde Leijnse, Remko Uijlenhoet, Henk Pietersen and Hedy Wessels

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- Rob Roebeling - EUMETSAT, Germany
- Daniel Schertzer - Université Paris-est, France
- Pierre Tabary - Météo France
- Rolf Reichle - NASA, USA

General Information

Abstracts

This book contains the abstracts of oral presentations followed by the poster abstracts. The posters are arranged per session in alphabetical order of the first authors' last names. The organizing committee does not take any responsibility for scientific of typographical errors.

Oral presentations

All oral presentations will be 15 minutes long (including questions) and will be held in de Schouwburg (theatre).

Posters

The posters are arranged per session in alphabetical order of the first authors' last names. They will be on display throughout the conference and can be found in the Mozart foyer (lobby). Poster sessions are held on all days of the conference.

Lunches and Conference Dinner

During the conference all lunches will be served in the Mozart foyer. On Tuesday 2nd July the conference dinner will be served in Kasteel Hoekelum, situated within walking distance from De Reehorst Conference Centre. All participants of the 11th International Precipitation Conference are cordially invited.

Social Event on Tuesday 2nd July

After the early afternoon session busses are awaiting you in front of the Conference Centre De Reehorst, for a pleasant trip to the Dutch Open Air Museum in Arnhem. You are invited to stroll through this Open Air Museum for a few hours to learn more about historically important Dutch buildings and lifestyles. The Netherlands Open Air Museum uses authentic buildings, objects and stories based on actual events to bring the past to life. The museum, with its farmyards, farmhouses, cottages and businesses, farmer's café and shops, is a hive of activity. After the excursion we will be heading for Kasteel Hoekelum for the conference dinner.

Sponsors

The organizing committee gratefully acknowledges the generous support of the following sponsors:

- KNMI/Royal Netherlands Meteorological Institute
- Wageningen University
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- European Geosciences Union (EGU)
- American Geophysical Union (AGU)
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- IAHS (International Association of Hydrological Sciences)
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- The Wageningen Institute for Environment and Climate Research (WIMEK)
- Disdrometrics
- HKV Lijn in Water
- Vaisala

Program

Program

* *all oral presentations are in the Schouwburg*
* *all posters are on display in the Mozart foyer*

Monday, July 1, 2013

08.30 – 09.00	*Registration*
	Conference Opening *Chairs: Remko Uijlenhoet and Hidde Leijnse*
09.00 – 09.30	Conference Opening *by* ***Frits Brouwer****, Director of the Royal Netherlands Meteorological institute, introduced on behalf of Wageningen University by Arian Steenbruggen*

Oral presentations

Session 1:	**Precipitation Physics** *Chair: Ana Barros*
9:30-9:45 **INVITED**	On raindrops sizes and speeds distributions ***Emmanuel Villermaux***
9:45-10:00	Variability of the drop size distribution in orographic Mediterranean rainfall ***Tim Raupach****, Jacopo Grazioli, Marc Schleiss, and Alexis Berne*
10:00-10:15	Drop breakup dependence on altitude: evidence by MW disdrometer Pludix data ***Franco Prodi****, Federico Porcù, Leo Pio D'Adderio, and Clelia Caracciolo*
10:15-10:30	Low level controls on the microphysics of warm season rainfall in the Southern Appalachians – Observations and modeling ***Anna Wilson*** *and Ana Barros*
10:30-10:45	Hydrometeor distributions around the freezing level observed by continuous videosonde soundings ***Kenji Suzuki****, Satoru Oishi, Ryoichi Watanabe, Midori Matsuo, Mariko Ogawa, Kosei Yamaguchi, and Eiichi Nakakita*
10:45-11:00 **INVITED**	Ice particle growth processes leading to snow precipitation ***Andrew Heymsfield***
11:00-11:30	Poster viewing and coffee

Session 2: **Precipitation Observation**
Chair: Rob Roebeling

11:30-11:45 **INVITED** Status of satellite-based global precipitation
Chris Kidd

11:45-12:00 Retrieval of precipitation from Meteosat-SEVIRI geostationary satellite observations
Jan Fokke Meirink, *Hidde Leijnse, and Rob Roebeling*

12:00-12:15 Multi-sensor precipitation estimate from MSG satellite at EUMETSAT
Marie Doutriaux-Boucher *and Rob Roebeling*

12:15-12:30 Development and field deployment of real-time precipitation sensors using cell-phone communications
Ben Siegfried, *Adam Wolf, Kelly Caylor, Justin Sheffield, Eric Wood, Marielle Gosset, and Frédéric Cazanave*

12:30-12:45 Characterization of precipitation features over CONUS using quantitative precipitation estimates derived from TRMM satellite and Stage IV data for the period 2002-2012
Olivier Prat *and Brian Nelson*

12:45-13:00 Evaluation of satellite rainfall products by comparison with gauges or radar : how to account for the uncertainty in the ground truth in the derived statistical scores?
Marielle Gosset

13:00-14:00 Lunch

Session 2: **Precipitation Observation**
Chair: Pierre Tabary

14:00-14:15 High resolution radar observations of intense rainfall: cellular structures in rain fronts
Herman Russchenberg

14:15-14:30 An error-based selection criterion to mitigate the effects of C-band attenuation in the UK radar composite
Caroline Sandford *and Nicolas Gaussiat*

14:30-14:45 ANTILOPE: hourly rainfall analysis over France merging radar and rain gauges data
Olivier Laurantin

14:45-15:00 Radar-derived precipitation estimates in the Swiss Alps
Marco Gabella, *Urs Germann, Ioannis Sideris, and Marco Boscacci*

15:00-15:15 Towards improved quality control of radar data for the OPERA data centre
Robert Scovell, *Nicolas Gaussiat, and Marion Mittermaier*

15:15-15:30 High resolution precipitation measurements during the HYMEX campaign: Preliminary results
Joël Van Baelen, *Jimmy Zwiebel, Sandrine Anquetin, Brice Boudevillain, and Yves Pointin*

15:30-16:00 Poster viewing and coffee

Session 2: Precipitation Observation
Chair: João de Lima

16:00-16:15 **INVITED** Recent findings in atmospheric monitoring employing microwave communication networks -- Tel-Aviv University
Pinhas Alpert, *Hagit Messer-Yaron, Rana Samuels, Yoav Lieberman, and Noam David*

16:15-16:30 A dual-frequency dual-polarization monostatic microwave transmission experiment for precipitation and humidity observation
Christian Chwala, *Harald Kunstmann, and Uwe Siart*

16:30-16:45 Long term country-wide rainfall maps from cellular communication networks
Aart Overeem, *Hidde Leijnse, and Remko Uijlenhoet*

16:45-17:00 On improving the accuracy of weighing measurement techniques at low precipitation rates
Luca Lanza, **Matteo Colli**, *Emanuele Vuerich, Scott Landolt, and Roy Rasmussen*

17:00-17:15 Operational real-time spatiotemporal raingauge-radar combination in Switzerland
Ioannis Sideris, *Marco Gabella, Marco Sassi, and Urs Germann*

17:15-17:30 Temporal variability of DSD observed during the HyMeX SOP in South of France
Brice Boudevillain, *Guy Delrieu, Sahar Hachani, and Nan Yu*

17:30-19:00 Poster viewing and drinks

Tuesday, July 2, 2013

Session 3: **Precipitation Modelling**
Chair: Harald Kunstmann

9:00-9:15 **INVITED** — High resolution modeling of clouds and precipitation near a meteorological supersite
Harmen Jonker*, Jerome Schalkwijk, and A. Pier Siebesma*

9:15-9:30 — Hindcast simulation of the extreme rainfall event in in Genoa (Liguria, Italy) on November 4th, 2011
Antonio Parodi, ***Elisabetta Fiori****, Albert Comellas Prat, Luca Molini, Nicola Rebora, Franco Siccardi, David Gochis, and Simone Tanelli*

9:30-9:45 — Verification of high resolution precipitation forecasts
Emiel van der Plas*, Kees Kok, and Maurice Schmeits*

9:45-10:00 — Exploring the impact of land cover and topography on rainfall maxima in the Netherlands
Herbert ter Maat*, Eddy Moors, Ronald Hutjes, Bert Holtslag, and Han Dolman*

10:00-10:15 — Towards a high-resolution climatography of seasonal precipitation over the south-eastern Mediterranean
Dorita Rostkier-Edelstein*, Yubao Liu, Pavel Kunin, Wanli Wu, Amir Givati, and Ming Ge*

10:15-10:30 — Convective rain cells: radar-derived spatio-temporal characteristics, synoptic patterns and a high resolution weather model
Nadav Peleg *and Efrat Morin*

10:30-11:30 — Poster viewing and coffee

Session 3: **Precipitation Modelling**
Chair: Alin Carsteanu

11:30-11:45 — New challenges for multifractals and precipitations
Daniel Schertzer*, Ioulia Tchiguirinskaia, and Shaun Lovejoy*

11:45-12:00 — Non-linear, scaling effect of statistical inhomogeneity on Z-R relationships
Sebastien Verrier*, Laurent Barthès, and Cécile Mallet*

12:00-12:15 — Validation of a spatio-temporal multifractal model of small scale rainfall variability with the help of dense networks of point measurements
Auguste Gires*, Ioulia Tchinguirinskaia, Daniel Schertzer, Alexis Berne, Alma Schellart, and Shaun Lovejoy*

12:15-12:30 Generating space – time synthetic storms for a hydrological study
Alan Seed, *Phil Jordan, Clive Pierce, and Eva Kordomenidi*

12:30-12:45 Rainfall field estimation using simulated microwave link information
Manuel Felipe Rios Gaona, *Aart Overeem, Hidde Leijnse, Marc Bierkens, and Remko Uijlenhoet*

12:45-13:00 Structural analysis of intermittent rainfall: the dry drift
Marc Schleiss, *Sabine Chamoun, and Alexis Berne*

13:00-14:00 Lunch

Session 4: **Precipitation in Hydrology and Water Resources**
Chair: Witold Krajewski

14:00-14:15 **INVITED** Urban impacts on rainfall and flooding
Jim Smith

14:15-14:30 High resolution rainfall estimates based on X-band radar technology for urban hydrological modelling
Marie-Claire ten Veldhuis and **Herman Russchenberg**

14:30-14:45 The impact of the spatio-temporal variability of rainfall on flood generation
Athanasios Paschalis, *Peter Molnar, Simone Fatichi, Paolo Burlando, and Stefan Rimkus*

14:45-15:00 **sponsored by EGU** Spatial variability of small-scale alpine snowfall and snow accumulation using a polarimetric X-band radar
Alexis Berne, *Danny Scipion, Rebecca Mott, and Michael Lehning*

15:00-15:15 Understanding lowland (flash) floods: analysis of the 2010 flash flood in the Hupsel Brook catchment and comparison with other recent lowland floods
Claudia Brauer, *Ryan Teuling, and Remko Uijlenhoet*

15:15-15:30 **INVITED** From rainfall nowcasting to rainfall hazard assessment
Daniel Sempere-Torres *and Marc Berenguer*

15:30-18:30 Social event, Excursion to Open Air Museum, Arnhem

18:30-23:00 Conference dinner in Kasteel Hoekelum, Bennekom

Wednesday, July 3, 2013

Session 5:	**Precipitation Statistics and Climatology** *Chair: Daniel Schertzer*
9:00-9:15 **INVITED**	Dependencies of (sub)hourly precipitation extremes on atmospheric temperature and moisture: relations with observed trends over the past century and future climatic change ***Geert Lenderink****, Erik van Meijgaard, Geert Jan van Oldenborgh, and Jessica Loriaux*
9:15-9:30	Characteristics of extremes for convective and stratiform precipitation ***Peter Berg****, Christopher Moseley, and Jan Haerter*
9:30-9:45	Spectral characteristics of monsoon rainfall from observations, reanalyses, and simulations ***Hsiao-ming Hsu****, Joseph J. Tribbia, Julio Bacmeister, John Fasullo, Gerald Meehl, and Christine Shields*
9:45-10:00	Analysis of the spatio-temporal variability of dry and wet events in mainland Portugal, using the standardized precipitation index *Fátima Espírito Santo,* ***Isabel de Lima****, Vanda Pires, and Álvaro Silva*
10:00-10:15	The diurnal cycle of coastal precipitation in West Africa - Observations and climate model simulations ***Uwe Pfeifroth****, Bodo Ahrens, Jörg Trentmann, and Richard Müller*
10:15-10:30	Uncertainty in the future change of extreme precipitation over the Rhine basin: the role of internal climate variability ***Saskia van Pelt****, Adri Buishand, Jules Beersma, and Bart van den Hurk*
10:30-11:30	Poster viewing and coffee
Session 5:	**Precipitation Statistics and Climatology** *Chair: Alexis Berne*
11:30-11:45	Simulation of intermittent rainfall fields with prescribed advection: Revisiting some statistical properties of precipitation fields ***Jean-Dominique Creutin*** *and Etienne Leblois*
11:45-12:00	Towards spatially inhomogeneous stochastic simulations for flow-dependent nowcasting of orographic rainfall ***Loris Foresti*** *and Alan Seed*
12:00-12:15	The observation scale of rainfall measurements and its impact on their use for hydrology and the initialization of mesoscale NWP ***Geoff Austin****, Paul Shucksmith, Sijin Zhang, and Luke Sutherland-Stacey*

12:15-12:30 Copula-based approaches in hydrometeorology: RCM bias correction and precipitation data fusion
Harald Kunstmann*, Stefanie Vogl, Patrick Laux, Ganquan Mao, Sven Wagner, and Hans Richard Knoche*

12:30-12:45 From pointwise testing to a regional vision: an integrated statistical approach to detect non stationarity in extreme daily rainfall. Application to the Sahelian region
Gérémy Panthou*, Théo Vischel, Thierry Lebel, Guillaume Quantin, Anne-Catherine Favre-Pugin, Juliette Blanchet, and Abdou Ali*

12:45-13:00 The statistical properties of intense rain storms in Switzerland and their dependencies
Peter Molnar*, Ladislav Gaal, Jan Szolgay, Simone Fatichi, and Paolo Burlando*

13:00-14:00 Lunch

Session 5: Precipitation Statistics and Climatology
Chair: Isabel de Lima

14:00-14:15 **INVITED** On variational downscaling, fusion and assimilation of precipitation with emphasis on sharp fronts and extreme intensities: A unified framework via regularization
Efi Foufoula-Georgiou *and Mohammad Ebtehaj*

14:15-14:30 To know what we cannot know: Global mapping of minimal detectable absolute trends in annual precipitation
Efrat Morin

14:30-14:45 Multifractal IDF and non-conservation of the rain rate
Ioulia Tchiguirinskaia*, Daniel Schertzer, and George Fitton*

14:45-15:00 Identification of errors and uncertainties within precipitation data sets
Chris Kidd*, Xin Lin, and Arthur Hou*

15:00-15:15 Precipitation regimes in the Southern Appalachians – An overview of key hydrometeorological processes
Ana Barros*, Anna M. Wilson, Gregory Cutrell, and Douglas Miller*

15:15-15:30 Using scaling fluctuation analysis to quantify global and regional precipitation and to estimate anthropogenic effects
Shaun Lovejoy *and Isabel de Lima*

15:30-16:00 Conference closing

Oral presentations

Session 1

Precipitation physics

Monday, July 1st 2013

Schouwburg

1.1 On raindrops sizes and speeds distributions

Villermaux, Emmanuel

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Like many natural objects, raindrops are distributed in size. By extension of what is known to occur inside the clouds, where small droplets grow by accretion of vapor and coalescence, raindrops in the falling rain at the ground level are believed to result from a complex mutual interaction with their neighbors. We show that the raindrops polydispersity, generically represented according to Marshall-Palmer's law (1948), is quantitatively understood from the fragmentation products of non interacting, isolated drops. Both the shape of the drops size distribution, and its parameters are related from first principles to the dynamics of a single drop deforming as it falls in air, ultimately breaking into a dispersion of smaller fragments containing the whole spectrum of sizes observed in rain. The topological change from a big drop into smaller stable fragments --the raindrops-- is accomplished within a timescale much shorter than the typical collision time between the drops. This scenario also accounts quantitatively for the anomalous distribution of raindrops speeds.

1.2 Variability of the drop size distribution in orographic Mediterranean rainfall

Raupach, Tim; Grazioli, Jacopo; Schleiss, Marc; Berne, Alexis

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We present a preliminary analysis of the small-scale variability of the drop size distribution (DSD) of orographic precipitation bands in the western Mediterranean. In the framework of the Hydrological Cycle in the Mediterranean Experiment (HyMeX; see http://www.hymex.org), we deployed seven OTT Parsivel disdrometers to the Cévennes region in France, as part of the special observation period (SOP) for Autumn 2012. The disdrometers collected information on the raindrop size distribution (DSD) over a period of three months, from September to November 2012. Several rain events ranging from strong convective to orographic stratiform rain were measured; thus our collected dataset allows us to investigate the spatial and temporal variability of the DSD in orographic Mediterranean rainfall. All disdrometers used in this study were collocated with rain gauges, and there was one pair of collocated disdrometers. The quality of our data is good, as confirmed through agreement between the disdrometer measurements and those of the collocated rain gauges. We examine two differing rainfall events from the special observation period, with a focus on the local-scale (several kilometers) variability of the DSD across two dimensional space. We compare the variability found in a strong convective frontal event to that found in a longer statiform event, and quantify the variability for each event. The results of this study are relevant to improve rain rate estimation from the various operational and research radars deployed in the area for HyMeX, as well as to validate the parameterisation of the microstructure of rainfall in numerical weather models.

1.3 Drop breakup dependence on altitude: evidence by MW disdrometer Pludix data

Prodi, Franco; Porcù, Federico; Pio D'Adderio, Leo; Caracciolo, Clelia

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That drop break-up should depend on altitude is expected, given the relationships among fluid resi stance, air density, air viscosity and surface tension of water. However laboratory experiments on break-up are difficult to perform and cannot reproduce the natural conditions. On the other side impact and optical disdrometers detect drops falling in a relatively small volume and seem to be unable to give evidence to such a dependence. Pludix, an X band CW microwave disdrometer has been operated at three locations at different elevations: Ferrara, 15 m a.s.l., Wasserkuppe, 950 m a.s.l. and LinZhi, Tibetan Plateau at, 3300 m a.s.l., and archives of data has been generated at the three sites. A sub set of data for each location has been selected showing a well defined break-up signature. The analysis of this data sets has generated the first evidence of the break-up dependence on altitude, with break-up position in the power spectrum shifting towards higher frequencies with increasing altitude, and drop sizes resulting from 4.55 +-0.35 mm of Ferrara to 3.16+- 0.3 mm of LinZhi. The results are discussed in terms of the reduced air density and collision kinetic energy (CKE). They are expected to be the basis for a better microphysical description of the process.

1.4 Low level controls on the microphysics of warm season rainfall in the Southern Appalachians – Observations and modeling

Wilson, Anna; Barros, Ana

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Over the past three years, two Micro-Rain Radars (MRRs), collocated with tipping bucket rain gauges and optical disdrometers, have been deployed in the Southern Appalachian mountains to investigate the spatial and temporal variability in the vertical structure of the atmospheric column and the evolution of microphysical properties at different time scales. Observations made during this period will be discussed for the purpose of characterizing the primary warm season atmospheric patterns in the region. Analysis shows spatial variations of up to 2 km in the active depth of the atmosphere. In the inner mountain region, this depth is much shallower than that in a nearby mountain pass, although the elevation at the inner mountain region is higher. Additionally, findings point to the importance of low level (shallow) processes regionally. To investigate these observations further, a mass and number conservative model of rain shaft microphysics that numerically solves the stochastic advection-coalescence-breakup equation in an atmospheric column was used to simulate precipitation events that occurred in the warm season during 2011 and 2012. Dynamic simulations of the evolution of the drop spectra within a one-dimensional rain shaft were performed using boundary conditions retrieved from vertically pointing radar (VPR) measurements taken by the MRRs. In these simulations of realistic rain events, the VPR observations are imposed at the top of the rain shaft. Time series of model profiles of integral parameters such as reflectivity and rain rate were subsequently compared with estimates retrieved from the MRRs and other available surface instrumentation. Results indicate the importance of low level seeder-feeder processes occurring in the region, in particular the interaction of pre-existing low level clouds and fog with moisture advected into the area. Analysis of the relative contributions of microphysical processes in these interactions is presented within the context of developing applications for understanding vertical profiles from satellites. Correlations among these processes and associated evolution in time and space of drop size distribution mass spectrum parameters (mass weighted mean diameter and its standard deviation) are explored.

1.5 Hydrometeor distributions around the freezing level observed by continuous videosonde soundings

Suzuki, Kenji; Oishi, Satoru; Watanabe, Ryoichi; Matsuo, Midori; Ogawa, Mariko; Yamaguchi, Kosei; Nakakita, Eiichi

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In this study, we carried out the continuous videosonde soundings of a long-lasting rainband over the East China Sea in the Baiu monsoon rainy season. Videosonde is a balloon-borne radiosonde that acquires images of precipitation particles via a CCD camera. The videosonde system consists of a CCD camera, a video amplifier, an infrared sensor, a transmitter, batteries, and a control circuit. The system has a stroboscopic illumination that provides information on particle size and shape. Interruption of the infrared beam by particles triggers a flash lamp and particle images are then captured by the CCD camera. Precipitation particles are classified as raindrops, frozen drops, graupel, ice crystals, or snowflakes on the basis of transparency and shape. One of the advantages for the videosonde is to capture images of precipitation particles as they are in the air. Because the videosonde can obtain particle images without contact, it can measure particles neither bouncing nor destroyed, which is different from a film-capture-type sonde. In the previous studies, several hundred videosondes have been launched into clouds in climatologically different areas and have contributed to better understanding of the precipitation mechanisms. However, it was impossible to launch videosondes continuously into the same precipitation systems in a short time because we had only one expensive receiver. Suzuki et al. (2012) developed a new videosonde receiving system, and we have succeeded in the continuous launching of the videosonde for the first time on 20 May 2012. Videosonde observations of Baui Monsoon clouds were conducted as part of the in-situ campaign observation by a C-band polarimetric radar synchronized with videosonde (Nakakita et al., 2009), which were carried out at Okinawa Electromagnetic Technology Center of National Institute of Information and Communications Technology (26º29′N, 127º50′E). On 20 May 2012, a Baiu stationary front was located over the Okinawa Island, and we experienced heavy rain of 71.1 mm from 09 JST to 13 JST. Six videosondes were launched into the different developing stages of the rainband. In the cases of the developing stage, frozen drops were observed from 0ºC to -15ºC. Graupel were also detected in the same altitude. On the other hand, in the mature stage, we observed them between 5ºC and 0ºC layer, and graupel were dominant in between 0ºC and -5ºC. It was supposed that freezing processes and graupel formation processes near the 0ºC was different in the different developing stages.

1.6 Ice particle growth processes leading to snow precipitation

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In my talk, I will use data collected from thirteen field programs from the Tropics to Arctic to describe features of ice formation and growth and snowfall generation. The data are collected from almost 2M km of in-situ sampling in ice clouds generated by large-scale lifting and deep convection. I will examine ice concentrations as a function of temperature and compare these to laboratory measurements of ice nucleus concentrations. I will show how closely the ice water contents compare to the difference between water and ice saturation vapor densities and compare the IWCs for convective and stratiform-generated clouds. I will then show some general properties of ice size distributions and show a new formulation for ice fallspeeds as a function of pressure altitude based on the shape and drag characteristics of ice crystals. Aspects of lidar and radar remote sensing of ice cloud retrievals from spaceborne satellites will be discussed.

Session 2

Precipitation observation

Monday, July 1st 2013

Schouwburg

2.1 Status of satellite-based global precipitation

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The global observation of clouds and precipitation has evolved with the development of Earth observation satellites over the last 50 years or so. This presentation provides an overview of the status of precipitation estimation from satellite-based systems. Starting with a brief history of meteorological satellites, the presentation will concentrate upon those with precipitation-retrieval capabilities, together with the methodologies used in the identification and estimation of precipitation. The observations from current missions will be outlined, such at those from the geostationary visible/infrared imagers and the low-Earth orbiting passive microwave imager and sounding instruments, particularly detailing key instrumentation. The current status of precipitation products will be presented; quasi-operational 'global' precipitation estimates are now readily available at resolutions up to 0.1 degree, 3-hourly. The results of a number of inter-comparison studies will be summarised providing an indication of the overall performance of these techniques, as well as highlighting some deficiencies within these estimates; these inter-comparisons provide invaluable information to both the algorithm developers and the user community. The presentation will conclude by outlining current research avenues, such as the identification and retrieval of precipitation over the higher latitudes where snowfall dominates, together with the status of near-future missions, such as the Global Precipitation Measurement mission, scheduled for launch in 2014.

2.2 Retrieval of precipitation from Meteosat-SEVIRI geostationary satellite observations

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Recently, significant progress has been made regarding the retrieval of precipitation occurrence and rate from visible-infrared (VIS-IR) passive satellite imagery. It has been shown that precipitation rates can be accurately derived during daytime. Thus, with geostationary satellite instruments, such as the Spinning Enhanced Visible and InfraRed Imager (SEVIRI) onboard Meteosat Second Generation (MSG), it is possible to observe the diurnal cycle of precipitation with high spatial (3x3 km2 sub-satellite) and temporal (15 minutes) resolutions. This is a great improvement compared to low-earth orbiting satellites that reach about 3-hourly sampling. In this presentation we will briefly introduce the MSG-SEVIRI precipitation retrieval approach, which builds on the retrieval of cloud properties. The validity of the precipitation observations will be demonstrated with a number of validation efforts, including comparisons against microwave-based satellite data, surface-based weather radar observations and rain gauge measurements over Western Europe and central Africa,. Then we proceed with specific case studies, highlighting the usefulness of the VIS-IR precipitation estimates for nowcasting, and for analysing the diurnal cycle of precipitation during daylight hours. The MSG-SEVIRI derived cloud and precipitation products are freely available and can be viewed in near-real time at http://msgcpp.knmi.nl.

2.3 Multi-sensor precipitation estimate from MSG satellite at EUMETSAT

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The Spinning Enhanced Visible and InfraRed Imager (SEVIRI) instrument onboard the geostationary satellite Meteosat Second Generation (MSG) is used at EUMETSAT since 2004 to derive operationally a real time precipitation product. The Multi-Sensor Precipitation Estimate (MPE) product retrieves rain-rates each MSG image in original pixel resolution. The high spatial and temporal resolution of IR images from geostationary satellites enable sufficient precipitation retrievals to resolve the very patchy structure of precipitation. However, infrared and visible spectral bands are not able to directly observe rain that occurs below clouds. In the microwave spectral range, the cloud droplets are small enough to become transparent and the larger rain droplet will interact with the microwave radiation. Hence the scattering by hydrometeor and absorption by liquid water in the microwave spectral range can be used to determine the rain-rate much more directly. The technique to derive MPE is a so-called blending technique that uses instruments onboard geostationary and polar orbiting satellites. The passive microwave data from the SSMIS instrument onboard polar orbiting satellite DMSP-F16 and the brightness temperature in the infrared channel from SEVIRI onboard MSG geostationary satellites are combined in order to take advantage of the two systems. The product is currently derived at the EUMETSAT central facility for all available Meteosat satellites in real time. As MPE is mostly suitable for deep convective precipitation, the focus of the current EUMETSAT product is mainly on users in Africa. It has been shown that the MPE algorithm is stable and reliable for the retrieval of real time precipitation. However it is not state-of-the-art anymore and some improvement of the product could be considered. KNMI developed the MSG Cloud Physical Properties (CPP) algorithm that uses cloud microphysical properties retrievals to detect rain and estimate rain-rates. MSG CPP has demonstrated high accuracy and precision for stratiform and convective rain-rate retrievals over Europe and Africa during day-time. This paper will present the MPE product in details and its comparison with other existing algorithms, like the CPP algorithm used in the Nowcasting Satellite Application Facility. We will discuss the possibilities to combine MPE with algorithms like CPP, and extend the applicability of MPE to other climate regions and other precipitation regimes.

2.4 Development and field deployment of real-time precipitation sensors using cell-phone communications

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A central issue with satellite-derived precipitation is adequate validation from ground-based observations. This problem is particularly acute in regions outside Europe and North America, where there are a variety of obstacles including (a) long latency between data collection and eventual transmission, (b) sparse coverage of existing stations, and (c) non-reporting "ghost" stations that have instrumentation but do not routinely report data. We have developed an inexpensive, low power sensor pod that uses cellular communication. The wireless transmission allows the sensor pod to transmit environmental data onto the GSM network, and from there onto the internet for real-time monitoring and prediction applications. The modular design of the pod allows a wide variety of sensing modalities to developed, in particular for hydrometeorological phenomena. Because the power requirements of the pod has been carefully managed to reduce demand, the battery size and power input requirements (e.g. from solar) are low, which allows for a small form factor, about the size of a beer can. The production costs of the core device are under $200 (without sensors). The design of hardware and software will be open source to encourage wider production, utilization, and sensor engineering in the developing world. We will present an overview of the functionality and design of the hardware and software of the sensor pod and the backend data transmission and management, using a deployment in Burkina Faso as a case study. In this campaign, the pods transmitted tipping bucket rain gauge data at 5 minute intervals from gauges around Ouagadougou to support radar precipitation retrievals during the monsoon. This data will also be used for real-time validation of satellite rainfall retrievals. A central goal for the Burkina Faso deployment is a "proof of concept" for the establishment of a global validation network for GPM satellite retrievals where local investigators will be able to collect and share in real time precipitation and weather information using low-cost sensors that utilize phone and internet technology.

2.5 Characterization of precipitation features over CONUS using quantitative precipitation estimates derived from TRMM satellite and Stage IV data for the period 2002-2012

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The precipitation patterns and hydro-climatic extremes over CONUS are investigated using long-term records (2002-2012) of satellite and radar based data. We use precipitation data from the TRMM suite of products: TRMM PR 2A25 (5-km resolution/one daily overpass) and TRMM Multi-satellite Precipitation Analysis (TMPA) 3B42V7 (25-km/3-hr). Satellite based products are compared over the same period with the NCEP Stage IV product, which is a near real time product providing precipitation data at the hourly temporal scale gridded at a nominal 4-km spatial resolution. The comparison of satellite and ground based precipitation estimates over CONUS is performed over the concurrent period 2002-2012. Each product has differing resolutions, which presents challenges but also provides opportunities for inter-comparisons of the coarser TRMM products with the finer Stage IV products. The goal of this study is two-fold. The first aspect of this work focuses on deriving diurnal, seasonal, and yearly trends as it concern the temporal frequency and spatial distribution of precipitation patterns. The second aspect of this work focuses on the characterization of extreme events such as floods, droughts, and extreme precipitation events that occurred over the period of study (2002-2012). In particular, the frequency and spatial distribution of precipitation extremes are evaluated for each precipitation sensor as well as the ability of each precipitation product to capture precipitation extremes. In addition we investigate the impact of the spatial and temporal resolutions on each of these variables.

2.6 Evaluation of satellite rainfall products by comparison with gauges or radar : how to account for the uncertainty in the ground truth in the derived statistical scores ?

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In the framework of the new French-Indian mission Megha-Tropiques, dedicated to the water and energy budget in the tropics an inter-tropical ground validation plan (MTGV) has been set up. The ground validation data set includes weather radar for the validation of instant rainfall retrieval and gauges networks for the validation of gridded daily accumulations. Both dedicated super sites and operational network are used. The dedicated sites host dense networks of gages or weather radar and provide a ground truth with a relatively low uncertainty but they are limited spatially and do not cover the whole variety of tropical climatic and environment conditions. The operational network are useful for regional/continental scale validation but their sampling uncertainties are high because of network scarcity in the Tropics. One challenge in MTGV is to account for the uncertainties in the ground truth in the evaluation of the products. Furthermore the most recent rainfall products, such as the TAPEER rainfall accumulations provided with MT, come with a tentative uncertainty or error bar that also needs to be considered in the validation. We will present the methods we are developing to investigate the impact of the uncertainties in the surface reference rainfall on the Satellite products evaluation. The bloc-kriging framework is used to quantify the estimation variance associated to daily rainfall averages that is compared to the satellite gridded rainfall. MC like simaltion methods are used to analyse the impact of these uncertainties on the FAR, Misses , correlation and frequency distribution of the residuals per rainrate classes that can be computed when comparing satellite and surface rainfall. The problem is more complicated when radar data is used as a reference rainfall as error models for radar based rainfall are still incomplete especially in tropical zone where attenuation is important.

2.7 High resolution radar observations of intense rainfall: cellular structures in rain fronts

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In the first days of January 2012 several small fronts passed over The Netherlands, leading to intense rainfall in most of the country. The water management system in the Northern districts had difficulty in dealing with the surplus of water in the canals and rivers, and as result several dams and dykes started to leak and almost collapsed. The passing rain events were measured at Cabauw Experimental Site for Atmospheric Research CESAR with set of advanced instrumentation, most notably an X-band and S-band Doppler-polarimetric radar – augmented with the C-band KNMI weather radar. The outstanding feature of the radars at CESAR is the high spatial resolution: better than 30 meter. Such high resolution reveals a wealth of detail of the physical processes in clouds and precipitation, not seen with the standard atmospheric radars. In this particular case we will show how small, intense cells of precipitation develop in the fronts, and the similarity of the spatial and dynamical structure of those cells to, the more commonly studied, supercellular convection.

2.8 An error-based selection criterion to mitigate the effects of C-band attenuation in the UK radar composite

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A radar network with significant overlap, such as the UK C-band network, provides a selection of horizontally coincident data for use in rain rate estimation. To exploit this effectively we require a compositing algorithm that can accurately discriminate between data of different quality. In this work we present the new UK operational compositing criterion and demonstrate its effects in strongly attenuating situations. The UK centralised processing system (RADARNET) uses a single-scan compositing algorithm, with no vertical averaging. Until 2012 this algorithm selected, at each point, the surface rain rate estimate calculated from the measurement with the lowest available beam height. This minimised uncertainties due to non-homogeneous vertical profile of reflectivity (VPR), which can be significant at mid-latitudes where most precipitation is stratiform. However, in strongly attenuating conditions height-based selection was seen to cause underestimation, and occasionally detection failures in the composite, even where some radars detected rain. In this work we demonstrate the benefits of using additional information to identify "best data" for rain rate composites. A calculated rain rate can be expressed as a function of measured reflectivity, through the corrections and transformations applied by the processing system. For RADARNET the major transformations are an attenuation correction, VPR adjustment and reflectivity-to-rain-rate conversion. By propagating measurement uncertainty through these functional transformations, an estimate of rain rate error can be obtained. We define a quality index relating directly to this estimated error, which can be used for composite data selection. The compositing skill of the quality index is evaluated with respect to the previous criterion using case studies and gauge measurements. Visible improvements in the composite can be seen in strongly attenuated cases, with no significant changes for more typical precipitation events. Gauge-radar comparisons support these findings, showing that the quality index matches - and can exceed - the statistical performance of the previous criterion. Quality index compositing was implemented operationally on the UK system in November 2012.

2.9 ANTILOPE: hourly rainfall analysis over France merging radar and rain gauges data

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ANTILOPE is a quantitative precipitation estimation (QPE) combining radar and rain gauges data whose goal is to provide a real-time rainfall analysis all over France on an hourly basis. It delivers a rainfall estimation with a spatial resolution of 1 km, near 15 min after the considered hour. Input radar data are 5-minute QPE mosaics covering France, resulting of the compositing of the 24 individual radar images of the French radar network. Radar data undergoes several treatments prior to compositing, like ground-clutter rejection, partial beam-blocking, VPR and advection corrections, and adjustment to rain gauges measurements. Input rain gauges are those available at computation time (near H+10 min) in the meteorological database of Météo-France. This data set contains gauges from the real-time ground observation network of Météo-France but also those provided by extra networks, which finally represents from 800 to 1200 available gauges measurements every hour. ANTILOPE implements an algorithm of convective cells detection applied on each 5-minute radar image in order to separate the large and small scale components of the precipitation field (corresponding respectively to stratiform rainfalls and showers or thunderstorms). In the initial method the large scale part was estimated using ordinary kriging of hourly rain gauges measurements, while the small scale part – which may not be captured by the rain gauge network – was given by the sum over the hour of the convective cells identified in radar images. Today, an adjustment of the radar-based convective rainfall estimates to gauges is done. A new version is being worked on – to be released in mid-2013 – which will use the stratiform part of radar data as well and more advanced kriging techniques (including automatic non-parametric estimation of 2D correlograms of rainfall fields) to combine radar and gauges data. This version should also integrate an uncertainty information to qualify the final QPE in addition to the 9 deciles already provided. A real-time control of rain gauges measurements is also implemented in ANTILOPE, which has been done so far by comparisons to the radar QPE or to surrounding gauges. A simple extra control using satellite cloud classification is ready for the upcoming version, and, when available, the environmental classification of the different sites – relative to precipitation observation – will also be used to reject a gauge or to set a priority among very close gauges. Besides, ANTILOPE hourly reanalyses are computed the day after to take advantage of the increased number of available gauges, which is close to 2000.

2.10 Radar-derived precipitation estimates in the Swiss Alps

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Estimating precipitation at the ground in an operational manner is one of the most demanding tasks of a weather radar network, especially in a mountainous region such as the European Alps. It puts high needs and requirements on many aspects of the system design: starting from optimal siting and rapid volumetric scanning, through high hardware stability, automatic hardware monitoring and remote control, to meticulous quality control and physically-based radar-reflectivity-to-precipitation-at-the-ground transformation techniques. In the Alps particular attention must be given to visibility and ground clutter issues. In 2011 MeteoSwiss started renewing extending its operational C-band weather radar network. The three radar systems have been replaced by state-of-the-art polarimetric Doppler radars with receiver-over-elevation design. Two additional radar sites are being built on mountain tops in order to improve radar coverage in the inner-alpine regions, particularly (Wallis and Grisons). The software architecture is completely renewed and the algorithms are re-written. This is a welcome opportunity to revisit the strategy for quantitative precipitation estimation by combining experience from the past with recent findings from science and technology. The paper presents results from the previous generation Doppler network as well as preliminary results from the new Dual-pol, digital-receiver Swiss radar generation and the adopted QPE strategy. The major elements of the strategy are: - a new scan program to obtain over the whole country as many high quality measurements close to the terrain as possible, -an external transceiver system which is used as part of the acceptance test procedures to verify several system specifications including polarimetric parameters, -a revised algorithm for the rejection of non-weather echoes and the combination and compositing of all remaining valid measurements in order to get robust estimates of precipitation at ground, -a plan how to obtain quantitative precipitation measurements from the two new inner-alpine radar sites at 2900 meters above sea level, -a (co-)kriging-with-external-drift technique developed for real-time radar-raingauge merging in the Alps, and finally, -first thoughts about the benefits and limitations from polarimetry in a mountainous context.

2.11 Towards improved quality control of radar data for the OPERA data centre

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The OPERA Data Centre (Odyssey), which became operational in 2011, is responsible for processing centrally the radar data received from 172 European radars. The radar data volumes are typically received every 5 minutes and combined into radar composite products (Rain Rate, Maximum Reflectivity and Hourly Accumulations) that cover the whole of the Europe at a resolution of 2km, with 15 minute updates. The first version of Odyssey produced a composite product but did not include any quality control or correction procedures - the radar data was used as provided by the suppliers. However, recent work has been carried out to incorporate the BALTRAD bRopo module that allows the removal of spurious echoes prior to ingestion into the composite. The most recent version of the bRopo module combines a hit accumulation filter (suggested by the Odyssey team) with image processing algorithms originally designed at FMI to identify speckle, RLAN transmitter interference and return from ships. The hit accumulation filter simply builds up a climatology of radar echo counts (hits) and uses it to systematically reject radar pixels that exceed a chosen hit rate threshold. Much work is needed and planned as part of the OPERA4 program to develop the pre-processing algorithms further and to bring the quality of the Odyssey products close to quality of the national ones. Therefore there is also the need to establish a reference point, using objective verification techniques, in order to monitor future improvements. This paper presents the results of two verification studies carried out first the using the UKMO gauge work and secondly the UKMO EURO4km NWP model to identify biases in the hourly and 6-hourly accumulation fields of the European precipitation composite produced by Odyssey and to evaluate the improvements brought by the first stage of QC development.

2.12 High resolution precipitation measurements during the HYMEX campaign: Preliminary results

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HYMEX (HYdrological cycle in Mediterranean Experiment) is an international measurement campaign that aims at improving our understanding and quantification of processes related to the hydrological cycle in the Mediterranean region at different scales (from the individual event scale to seasonal and inter-annual variability). During the Special Observation Period (SOP-1) conducted from September 5th to November 6th 2012, an important and complementary remote sensing network (operational radars, X band research radars, Micro Rain Radars, disdrometers, and a dense network of rain gauges) has been deployed in the Cévennes-Vivarais region (South of France) in order to investigate the structure and the heterogeneity of precipitations as well as the impact of orography on this structure. This observational network provides us with high resolution data, both in time and space, over different areas of the Cevennes region from the plain, to the higher mountainous areas. Hence, these data will support our research to precisely describe the precipitation systems and their structures. In this presentation, after reviewing the HYMEX campaign background, we will focus on the precipitation study scientific objectives and provide preliminary results of a couple of major events that were observed during SOP-1. The evolution of the synoptic ingredients in which the rainfall event is embedded will be presented as well as the spatio-temporal evolution of the rain pattern. We will also describe and discuss the horizontal and vertical structure and evolution of the precipitation field during this event using high resolution research X band precipitation radars, Micro Rain Radars, disdrometers, and rain gauges data.

2.13 Recent findings in atmospheric monitoring employing microwave communication networks -- Tel-Aviv University

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First, I will present the potential of performing a long-term rainfall monitoring and analysis employing Commercial Cellular Communication Networks (CCCN). Several different methodologies for calculating instantaneous rainfall utilizing CCCN will be reviewed. The test site, located in central Israel, includes up to 70 commercial microwave links while 7 rain gauges are installed in the vicinity of these. The examination of 19 rainstorm events over a 2-year period will be presented. Emerging new avenues in atmospheric research will be reviewed and discussed with a few preliminary examples for fog and water vapor monitoring as well as short-term warning for flash floods. These will include the following topics. Potential for improved mesoscale modeling with data assimilation of surface moisture derived from links; fog monitoring potential as demonstrated through several events of dense fog that took place in central Israel. CCCN measurements were translated into liquid water content measurements from which visibility estimations were derived and were found to be between 50 to 10 meters during the heavy Nov 2010 fog episode. Examples for real-time flood warning in semi-arid area where coverage by rain gauges and/or radar is very limited will be presented. An advanced time for potential warning of about a few minutes to one hour will be shown to exist.

2.14 A dual-frequency dual-polarization monostatic microwave transmission experiment for precipitation and humidity observation

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Precipitation and near-surface water vapor play an important role in modeling the hydrologic cycle. Their accurate quantification however, is still challenging, in particular if high spatial and temporal resolution is required. We present details on the development of a new microwave transmission experiment, capable of estimating precipitation and humidity near the surface with a high temporal resolution. The system is located at a hydrometeorological test site (TERENO-prealpine) in Southern Germany. Path length is kept short at 660 m to minimize the likelihood of different precipitation types and intensities along the path. It uses a monostatic configuration with a combined transmitter/receiver unit and a 70 cm trihedral reflector. The transmitter/receiver unit simultaneously operates at 22.235 GHz and 34.8 GHz with a pulse repetition rate of 25 kHz and alternating horizontal and vertical polarization, which enable the analysis of the impact of the changing drop size distribution on the rain rate retrieval. Due to the coherence and the high phase stability of the system, it allows for a sensitive observation of the propagation phase delay. Thereof, time series of line integrated refractivity can be determined. This proxy is then post-processed to absolute humidity and compared to different station observations. We present the design of the system and show an analysis of selected periods for both, precipitation and humidity observations. The theoretically expected dependence of attenuation and differential attenuation on the DSD was reproduced with experimental data. A decreased performance was observed when using a fixed A-R power law. Humidity data derived from the phase delay measurement showed good agreement with in situ measurements.

2.15 Long term country-wide rainfall maps from cellular communication networks

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Accurate rainfall observations with high spatial and temporal resolutions are needed for hydrological applications, agriculture, meteorology, and climate monitoring. However, the majority of the land surface of the earth lacks accurate rainfall information and the number of rain gauges is even severely declining in Europe, South-America, and Africa. This calls for alternative sources of rainfall information. Various studies have shown that microwave links from operational cellular telecommunication networks may be employed for rainfall monitoring. Such networks cover 20% of the land surface of the earth and have a high density, especially in urban areas. The basic principle of rainfall monitoring using microwave links is as follows. Rainfall attenuates the electromagnetic signals transmitted from one telephone tower to another. By measuring the received power at one end of a microwave link as a function of time, the path-integrated attenuation due to rainfall can be calculated. Previous studies have shown that average rainfall intensities over the length of a link can be derived from the path-integrated attenuation. This is particularly interesting for those countries where few surface rainfall observations are available. Here we present preliminary results of long term country-wide rainfall monitoring employing cellular communication networks. A dataset from a commercial microwave link network over the Netherlands is analyzed, containing data from an unprecedented number of links (~ 2000) covering the land surface of the Netherlands (35500 square kilometres). This dataset spans from January 2011 through October 2012. Fifteen-minute and daily rainfall maps (1 km spatial resolution) are derived from the microwave link data and compared to maps from a gauge-adjusted, climatological radar dataset. The performance of the rainfall retrieval algorithm will be investigated, particularly a possible seasonal dependence. The density of the microwave link network varies considerably between cities (high density) and rural areas (low density). Hence, the influence of the link density on the quality of rainfall maps will be studied.

2.16 On improving the accuracy of weighing measurement techniques at low precipitation rates

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Accurate measurement of precipitation at high temporal resolution (e.g. one minute) continues to be a challenge, particularly during light rainfall and snowfall events. The OTT Pluvio2 weighing gauge (WG) and the GEONOR T-200B vibrating-wire gauge (VWG) are currently being investigated as in-situ field reference instruments for the WMO Solid Precipitation InterComparison Experiment (SPICE) project. In order to verify the robustness of the results achieved in terms of time-averaged rainfall (RI) or snowfall (SI) intensity, the actual accuracy in measurement of real time low RI/SI series at one-minute measurement intervals still has to be understood. Wind effects account for most of the undercatch problems in precipitation gauges, but with proper shielding around the gauge these wind effects can be minimized. Other errors can also lead to undercatch problems including, but not limited to, wetting of the orifice walls during rain, or induced by the heating system during snow, and load cell/vibrating wire sensor sensitivity to temperature changes. To address these issues, laboratory tests were conducted by the WMO/CIMO Lead Centre for Precipitation Intensity in the military airport of Pratica di Mare (Italy) and the NCAR cold chamber utilizing the NCAR snow machine (windless environment). Data was also analysed from outdoor observations taken at the Marshall Field Site (CO, USA) in conjunction with WMO SPICE. The load cell/vibrating wire signal noise and their sensitivity to non steady-state conditions, mainly due to the wind pumping effects related to wind gusts, are critical factors to be accounted for when short sampling period measurements are required. The present work shows how the low precipitation observations can noticeably benefit from the use of a proper signal de-noising algorithm. Taking advantage of this signal filtering technique allows for evaluating the contribution of the wind undercatch, which doesn't require the availability of ancillary wind measurements, is also proposed. The analysis is conducted in a comparative form by using real world observations from different wind shield configurations at the Marshall Field Site.

2.17 Operational real-time spatiotemporal raingauge-radar combination in Switzerland

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A raingauge-radar merging application for Switzerland was deployed recently and has now become part of the radar operational chain, providing hourly-rainfall output in real-time. It is a geostatistical tool, based on well-established studies on the topic. Raingauge adjustments of radar precipitation maps are motivated by the fact that radar-rainfall provides dense terrain coverage, but is characterized by systematic and random errors, while raingauge-rainfall is, in principle, more accurate, but suffers from representativeness problems. Effective combination is not straightforward mainly due to the difference in terms of support (areal versus point). Moreover, any combination method which is part of an operational chain has to be able to cope, successfully and automatically, with any possible scenario (for example, problematic input due to meteorological or topographic complexities, or small number of available wet raingauges). The fact that human intervention is not an option is critical, and asks for enhanced stability to avoid meaningless output. Failures of the variogram fitting process, and artefacts in areas of high uncertainty (far away from the raingauges) had to be offered solutions. How the rainfall map should be produced when the number of wet raingauges is extremely limited had to be addressed. How a quality flag should be assigned had to be answered. Finally, when and why such the algorithm fails has been always a central concern. All the aforementioned questions were addressed during the project “CombiPrecip” of MeteoSwiss (funded by the National Centers of Competence in Research). The finalized application has been tailored to work without human-intervention. A number of innovations have been included in order to meet the required needs: (a) Its stability is enhanced due to using a spatiotemporal (as opposed to spatial-only) modelling, which uses data from both the current and the previous time-states, placed as primary and secondary variables in a co-kriging with external drift scheme. (b) A technique has been implemented so the combination rainfall relaxes towards the original radar rainfall at areas outside Switzerland, which are not covered by raingauges. It uses a morphing approach and introduces the concept of “virtual raingauges”. (c) A disaggregation method is proposed to produce high temporal resolution (5-minutes) rainfall maps in real time. Such maps are useful for hydrological and nowcasting transfer functions, especially for flood prevention and intervention. Overall, the application operates quite satisfactorily, especially in terms of bias reduction which is usually dramatic. Problems in the presence of strong convective cells were expected and are occasionally present; active investigation on this question remains part of our research agenda. We will discuss our experience in building the code, provide results and comment on unsolved problems.

2.18 Temporal variability of DSD observed during the HyMeX SOP in South of France

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During the first Special Observation Period (SOP) of the Hydrological cycle in the Mediterranean Experiment (HyMeX, www.hymex.org) held during fall 2012 in the Northwestern Mediterranean region, an observation network dedicated to rain studies was implemented in the Cévennes region, France. It was mainly constituted by weather radars, micro rain radars, disdrometers and rain gauges. This presentation focuses on the observations performed by the network of 25 OTT Parsivel optical disdrometers which were distributed with inter-distances ranging from a few meters up to about one hundred kilometers. After presenting the observation network, we describe the rainfall events of fall 2012 in terms of temporal variability of the characteristics of drop size distributions (DSD), the total concentration, the mean diameter and the shape parameter of the Gamma model fitted according to the unified formulation recently proposed by Yu et al. (2013). We provide first physical interpretations of intra-event variability of DSD (evolution of precipitating systems) as well as climatological interpretations of inter-event variability of DSD (specific behaviors over mountainous areas, and/or depending on the meteorological situation at synoptic scale). Acknowledgments: EPFL, DLR, LaMP, NASA, University of Barcelona for the provision of the instruments ; people who accepted to host these devices ; Simon Gérard and Martin Calianno (LTHE) for their help in installing and maintaining the network as well as their participation to the pre-processing of data.

References: Yu, N., Delrieu, G., Boudevillain, B., Hazenberg, P., and Uijlenhoet, R., 2013: Unified formulation of single and multi-moment normalizations of the raindrop size distribution based on the gamma probability density function. In revision for *Journal of Applied Meteorology and Climatology*.

Session 3

Precipitation modelling

Tuesday, July 2nd 2013

Schouwburg

3.1 High resolution modeling of clouds and precipitation near a meteorological supersite

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Results are presented of high resolution cloud and precipitation simulations of a full year around the meteorological supersite Cabauw (The Netherlands). The simulations are conducted using the Large Eddy Simulation (LES) methodology which explicitly resolves the dominant turbulent atmospheric motions including cloud dynamics. The LES code has been ported to a GPU (graphical processing unit), yielding such a computational boost that the computations could be done on a workstation. This allowed us to embed the LES model within a large scale weather model and run it continuously for a year, with the large scale weather model providing the large-scale temperature, flow and humidity patterns. In this setting the LES provides an unprecedented high-resolution dataset of three-dimensional cloud structure and precipitation patterns. Since the computational domain was centered around the meteorological tower in Cabauw, the LES predictions can be continuously monitored and evaluated. Finally we show our first steps towards high resolution assimilation of cloud and precipitation observations within the LES.

3.2 Hindcast simulation of the extreme rainfall event in in Genoa (Liguria, Italy) on November 4th, 2011

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The extreme rainfall event that took place in Genoa city on November 4th, 2011 generated a severe flash floods that killed six people. Observational ground instruments displaced on the territory around the city, which nestles between the Tyrrhenian sea and the Apennine mountains (Liguria, Italy), recorded about 500 millimeters of rain in six hours. The finger-like convective system responsible for the torrential event was the impacts on the Mediterranean area of the synoptic-scale meteorological system that raged from West Virginia to Maine from 29th to 30th October and was blamed for at least 13 deaths. It moved across the Atlantic Ocean, generated floods that killed 5 people in Southern France, and finally it arrived over the Liguria sea and produced the severe rainfall on which this work focused. Different sets of numerical simulations of the convective system responsible for this catastrophic event were executed by assessing the sensitivity of the Advanced Research Weather and Forecasting Model (ARW-WRF, version 3.3). Two different microphysics (WSM6 and Thompson) as well as three different convection closures (explicit, Kain-Fritsch, and Betts-Miller- Janjic) have been combined in a cloud-permitting domain configurations (1 km) to gain a deeper understanding of the physical processes underlying the observed torrential event.

3.3 Verification of high resolution precipitation forecasts

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High resolution numerical weather prediction (NWP) models currently achieve a high degree of realism in forecasting precipitation. The higher resolution show the possibly highly localised extremes and e.g. precipitation that forms as a result of very narrow convergence lines that contrast to relatively broad patterns of frontal precipitation. However, it is not at all obvious to show that the high resolution forecast really contains more information than a forecast of lower resolution. Common verification methods tend to favour smoother forecasts, amongst others due to the double penalty problem, especially for localised phenomena such as precipitation. The mismatch may be overcome, e.g. by upscaling to integration areas of increasing size, or by considering the spatial structure of rain areas, so one can compare quantities such as the area, 'center of mass' and angle of a feature between the forecast and (radar) observation. In this paper a method is proposed that seeks to construct a probabilistic forecast out of deterministic forecast data by computing a set of general predictors for precipitation for a given point of interest, based on precipitation forecast data from a NWP model. The resulting exceedance probability may then be verified, and compared between different models. The present and former operational NWP models at KNMI (resp. Harmonie and Hirlam) are compared.

3.4 Exploring the impact of land cover and topography on rainfall maxima in the Netherlands

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The relative contribution of topography and land use on precipitation is analyzed in this paper for a forested area in the Netherlands. This area has an average yearly precipitation sum that can be 75–100 mmhigher than the rest of the country. To analyze this contribution, different configurations of land use and topography are fed into a mesoscale model. The authors use the Regional Atmospheric Modeling System (RAMS) coupled with a land surface scheme simulating water vapor, heat, and momentum fluxes [Soil–Water–Atmosphere-Plant System–Carbon (SWAPS-C)]. The model simulations are executed for two periods that cover varying large-scale synoptic conditions of summer and winter periods. The output of the experiments leads to the conclusion that the precipitation maximum at the Veluwe is forced by topography and land use. The effect of the forested area on the processes that influence precipitation is smaller in summertime conditions when the precipitation has a convective character. In frontal conditions, the forest has a more pronounced effect on local precipitation through the convergence of moisture. The effect of topography on monthly domain-averaged precipitation around the Veluwe is a 17% increase in the winter and a 10% increase in the summer, which is quite remarkable for topography with a maximum elevation of just above 100 mand moderate steepness. From this study, it appears that the version of RAMS using Mellor–Yamada turbulence parameterization simulates precipitation better in wintertime, but the configuration with the medium-range forecast (MRF) turbulence parameterization improves the simulation of precipitation in convective circumstances.

3.5 Towards a high-resolution climatography of seasonal precipitation over the south-eastern Mediterranean

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The present work demonstrates the capability of the Weather Research and Forecasting (WRF) model-based four-dimensional data-assimilation system (WRF-FDDA) to produce a high-resolution climatography of seasonal precipitation in the south-eastern Mediterreanean. The system was used to dynamically downscale global Climate Forecast System (CFS) reanalysis along with continuous assimilation of conventional and unconventional observations. Seven precipitation seasons (December-January-February), including two extreme dry and wet seasons, were generated at 2-km spatial resolution. Verification against rain-gauge observations shows that the WRF-FDDA system successfully reproduces the spatial and inter-annual variability, as well as the timing, intensity and length of wet and dry spells. The best agreement between model and observations was obtained at areas dominated by complex terrain, illustrating the benefit of the high-resolution lower-boundary forcing in the dynamical downscaling process. On the other hand, some biases were observed over coastal flat terrain areas. Objective weather-regimes verification reveals the skill of the climatography for different types of extra-tropical cyclones. While biases are larger at coastal-flat areas under shallow-cyclonic conditions, deep-cyclonic conditions lead to more significant biases at complex-terrain regions. The weather-regimes dependent information may be used for further calibration of the downscaled precipitation.

3.6 Convective rain cells: radar-derived spatio-temporal characteristics, synoptic patterns and a high resolution weather model

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In this study we present the spatiotemporal characteristics of convective rain cells over the Eastern Mediterranean (northern Israel) and their relationship to synoptic patterns following by initial results from a climatically-forced high resolution weather generator based on the rain cell analysis. Information on rain cell features was extracted from high-resolution weather radar data for a total of 191,586 radar volume scans from 12 hydrological years. The convective rain cell features (i.e., cell area, rainfall intensity and cell orientation) were obtained using cell segmentation technique. Cell tracking algorithm was used to analyze the changes of those features over time. Convective rain cells were clustered into three synoptic types (two extratropical winter lows: deep Cyprus low and shallow low, and a tropical intrusion: Active Red Sea Trough) using several NCEP/NCAR parameters, and empirical distributions were computed for their spatial and temporal features. In the study region, it was found that the Active Red Sea Trough rain cells are larger, live for less time and possess lower rain intensities than the rain cells generated by the winter lows. The Cyprus low rain cells were found to be less intense and slightly larger on average than the shallow low rain cells. It was further discovered that the preferential orientation of the rain cells is associated with the direction and velocity of the wind. The effect of distance from the coastline was also examined. An increase in the number and area of the rain cells near the coastline was observed, presumably due to the sea breeze convection. The mean rainfall intensity was found to peak near the shore and decrease with distance inland. The results from this study are used for the development of a high space-time resolution weather generator for creating rainfall ensembles under different climatology scenarios. We will present initial results from this analysis. The weather generator is a stochastic model that generates high resolution rainfall fields that contain convective rain cells preserving the cell space-time characteristics found from the radar record. Furthermore, the weather generator is linked to general circulation model such that ensembles of rainfall fields are generated in both toady and future climates. Those rainfall ensembles will be incorporated into hydrological models of catchments in the studied region for assessing impact of predicted climate change on these catchments hydrological response.

3.7 New challenges for multifractals and precipitations

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Almost three decades ago, multifractals introduced a radical paradigm shift in precipitation modelling: stochastic modelling could become physically based. Indeed, instead of being either stochastic phenomenological models or scale truncated deterministic models, cascade models are based on the symmetries of the precipitation process over a wide range of scale. This provides at once a physical basis and a convenient framework to understand the strong intermittency of precipitation and its extremes. In particular, the ubiquitous scale dependence of hydrological observables, particularly that of a fundamental quantity such as the precipitation rate, was understood as a symptom that theses observables are singular with respect to measures of time and volumes, i.e. they do not admit densities with respect to them as currently assumed. Not only the source of the problem was clarified, but multifractals provided also a means to transform them into scale independent observables. The latter are obviously much more convenient both for observations and modelling. For instance, fat tailed probability distributions are rather generic for multifractal fields. However, multifractals still suffer from important limitations in applications. For a large part this is presumably due to the fact that operational hydrology has long suffered from a divorce with theoretical hydrology. However, this could also be related to the fact that whereas the original idea was to understand the precipitation process as a cascade coupling of wind dynamics and water content, it has been oversimplified into a unique, scalar precipitation rate cascade. This oversimplification had been certainly useful to start with, because the coupling is much more demanding and the techniques to handle it were not yet available. Fortunately, the situation has changed and we will present vector cascades that bring many insights on this coupling and should alleviate many limitations. They bring in fact many challenging questions to precipitation observations.

3.8 Non-linear, scaling effect of statistical inhomogeneity on Z-R relationships

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Rainfall estimation from radar is widely based on non-linear relationships between radar measurements and rainfall intensities (e.g., power-laws relating Z and R). Based on empirical results, some authors (e.g., Jaffrain and Berne, 2012) have shown that the parameters of such relationships are scale-dependent. In the present study, a theoretical interpretation of such properties is proposed. The main idea is that the considerable statistical inhomogeneity of rainfall prevents Z-R relationships to be conservative with scale. Following some mathematical results of multifractals theory (Tessier et al., 1993), we show that the now well-established (multi)scaling properties of rain intensities and reflectivity necessarily constrain Z-R-like laws. In the particular case of classical Z=aR^b laws, b should be conserved with scale while the parameter a should grow as a slow power-law of time/space scale. The predictions of the theory are tested with high-resolution disdrometer data that enable rigorous estimation of rain rates and reflectivity factors over a wide range of time scales. This empirical study confirms the predictions of the theory for multiple Z-R regression methodologies. For the domain rainfall types of the dataset, the prefactor a of Z-R laws increases as a 0.1-power law of time scale. However, convective rainfall events seem to be associated with steeper scaling laws. Additionally, the empirical study has been extended to “normalized” Z-R relationships involving the (N0*, Dm) normalization proposed by Testud et al. (2001). Such relationships were found to be far more stable with scale, emphasizing the role of underlying microphysical variability. Practically, our results point out the need of taking scales into account thoroughly in radar rainfall estimation. Significant errors may arise even with a moderate scale factor (for convective events, the relative error in terms of rainfall accumulation could excess 20% for a factor 5 in resolution). Both ground-based (calibration of radar measurements with gauges measurements) and space-borne radar applications could be concerned. More generally, our approach seems to be relevant for modeling other classical “beamfilling” errors involved in teledetection of atmospheric processes.

References: Jaffrain J., A. Berne, 2012: Influence of the Subgrid Variability of the Raindrop Size Distribution on Radar Rainfall Estimators. *J. Appl. Meteor. Climatol*. 51, 780-785

Tessier, Y., Lovejoy, S., Schertzer, D., 1993: Universal multifractals in rain and clouds: theory and observations. *J. Appl. Meteorol.* 32, 223–250.

Testud, J., S. Oury, R. A. Black, P. Amayenc, and X. K. Dou, 2001: The concept of normalized distribution to describe raindrop spectra: A tool for cloud physics and cloud remote sensing. *J. Appl. Meteorol.*, 40 (6), 1118-1140

3.9 Validation of a spatio-temporal multifractal model of small scale rainfall variability with the help of dense networks of point measurements

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Universal Multifractals (UM) have been extensively used to model and simulate geophysical fields extremely variable over a wide range of spatio-temporal scales such as rainfall. They rely on the concept of multiplicative cascades and enable to characterize the rainfall scaling variability with the help of only 3 parameters. In this paper we validate a refinement of this model in the discrete case that enables to better take into account the numerous zeros of the rainfall field (i.e. a pixel with no rainfall recorded). More precisely the zeros are introduced at each scale within the cascade process dependently on the value of the intensity and in a probabilistic scale invariant way. The results hint at possible standard values for UM parameters for the rainy areas. Theses results are validated with the help of two data sets consisting of dense network of point measurement rainfall devices deployed over areas of approximately 1 km2: 16 optical disdrometers (Particle Size and Velocity, PARSIVEL, first generation) that were deployed for 16 month over the campus of Ecole Polytechnique Federale de Lausanne (Switzerland), and 16 raingauges deployed over the campus of Bradford University. The methodology implemented consists in downscaling a rainfall field with a resolution of 1 km and 5 min (obtained by averaging the rainfall data from the various devices) to a resolution comparable with the point measurements one (few tens of cm and 1 min). The downscaling suggested here consists in retrieving the scaling properties of the rainfall field on the available range of scales and stochastically continuing the underlying process below the scale of observation. Finally the variability among the generated “virtual” point measurement devices is then compared with the observed one. It appears that the results are in agreement with theoretical expectations. The small differences observed between the results for the two rainfall measurement devices are discussed. Finally the consequences of this small scale rainfall variability on the comparison of radar data (whose resolution is of roughly 1 km in space and 5 min in time for operational C-band radar networks of Western European meteorological services) and raingauge data is revisited. For example a set of expected value of standard scores (biais, RMSE, Nash-Sutcliff,...) is provided for several rainfall events in Seine-Saint-Denis (North-East of Paris).

3.10 Generating space – time synthetic storms for a hydrological study

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The Wivenhoe and Somerset Dam Optimisation Study was initiated to improve the dam operating rules for these flood control and water storage facilities in the Brisbane River catchment. This paper presents details of the stochastic space-time multiplicative cascade model that was used to generate an ensemble of synthetic rainfall over a 250 km domain at 10 minute, 1 km resolution that was required for this study. Eight significant storms were identified in the radar archive and a 10-member ensemble for each storm was generated. The duration of the storms varied from 1 to 4 days and represented a range of meteorological conditions. The first step was to derive the time series of the mean areal rainfall, the standard deviation, the slopes of the 2D power spectrum above and below 20 km, and the mean advection for each time step during the storm. A broken line model was fitted to the time series of mean areal rainfall and the two advection components, and quadratic relationships between the mean areal rainfall and the slopes of the power spectrum and the field standard deviation was determined. The broken line models were used to generate a time series of mean areal rainfall and advection for each member of the ensemble for a particular storm. The field standard deviation and the two slopes of the power spectrum were then calculated for each time step in the storm using the quadratic relationships and used to derive the parameters for the multiplicative cascade for that time step. The multiplicative cascade was then used to generate the next field in the synthetic rainfall time series. The paper presents the details of the modelling framework and compares the stochastic fields against the observed storms at a range of scales in space and time.

3.11 Rainfall field estimation using simulated microwave link information

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During the last decade, the potential applicability of commercial microwave-link networks for measuring of precipitation has been widely investigated. The great advantages of such wireless communication networks, when compared to rainfall measuring networks based either on rain-gauges or weather radars, are their higher temporal resolution (with measurements registered every minute in some cases), and their higher spatial resolution given the density obtained by the spatial distribution of these networks, especially in urban environments. The standalone use of these networks is intended for regions in which the conventional rainfall measuring networks are scarce. Notwithstanding, the current trend is more focused on the synergetic coupling of these technology with the already established rainfall measuring networks (including satellite measurements) in order to increase the accuracy not only in rainfall estimation but in rainfall and climate now- and forecasting. The research carried out in here, was based on simulated microwave-link information, aiming the generation of regional and local rainfall fields for the Netherlands. For one specific day, simulated information from 2032 active microwave links was constructed from corrected radar data sets, originally measured by the KNMI C-band Doppler radar. The corrected radar data was also used to validate the estimated results. Assuming the middle of the path-link as a suitable location for placing the path-integrated rainfall values, interpolations were carried out by the geostatistical technique of Ordinary Kriging. For this technique, applied semivariograms were obtained by spherical models fitted to the experimental semivariograms computed for the corresponding data sets, and by seasonal semivariogram parameterizations previously proposed for the Dutch climatology. The estimated rainfall fields depicted good accuracy, at regional and local scales, in areas where microwave link density is higher. Local cases are presented for the cities of Utrecht and Rotterdam. Semivariogram temporal downscaling was carried out for time-aggregated scales of 15-minute, 1-, 3-, 6- and 12-hour. For these scales, estimated rainfall fields were obtained and filtered to account for the percentage of microwave links not registering rainfall attenuation in their signals. The Mean Error (ME), Root Mean Squared Error (RMSE) and Variance Ratio (VR) were computed in order to investigate the bias, accuracy and variability of rainfall field estimations for the different time-aggregated scales. The highest correlation was found for the 6-h aggregated time scale. Overall, good results were obtained for the other time scales, suggesting that the developed methodology based on the Cosine Functions downscaling-technique, for seasonal semivariograms, is suitable for automatic rainfall estimation at small aggregated time scales.

3.12 Structural analysis of intermittent rainfall: the dry drift

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A new approach for the structural analysis of intermittent rain rate fields is proposed. It is based on the fact that the average rain rate is not constant over the entire domain and strongly depends on the distance to the closest dry region. We show that this “dry drift” must be estimated and removed from the data before proceeding with the structural analysis (i.e., before computing the sample variogram). Based on disdrometer and radar data, we show that, depending on the type of rainfall, the dry drift explains between 30% and 40% of the total variability of the rain rate field. We also show that the removal of the dry drift produces more stationary fields that have a well-defined variogram with a clear sill and a clear range. In the second part of the presentation, the authors use time series of raindrop size distributions (DSD) to show that similar “dry drifts” apply to DSD-related quantities. It is shown that both the average drop concentration and the average drop diameter significantly decrease when approaching the next/previous dry period. The magnitude and rate of these drifts are, however, very different from one quantity to another. This relative difference in dry drifts for DSD-related quantities has many important consequences for remote sensing and implies, for example, that the prefactor and exponent in the Z-R relationship change when approaching a dry region. The authors explain this effect and discuss different possibilities to take it into account.

Session 4

Precipitation in hydrology and water resources

Tuesday, July 2nd 2013

Schouwburg

4.1 Urban impacts on rainfall and flooding

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Urban impacts on rainfall and flooding are examined through empirical and numerical modeling studies. Urban heat island, urban canopy and urban aerosol effects on flood-producing rainfall are examined through analyses of "long" (~10 years) radar rainfall data sets and through numerical experiments using the Weather Research and Forecasting model. Study sites for these analyses include Baltimore, Maryland; Atlanta, Georgia; Milwaukee, Wisconsin; and Charlotte, North Carolina. We also examine changes to the hydroclimatology of flooding associated with both modification of rainfall and changing land surface processes.

4.2 High resolution rainfall estimates based on X-band radar technology for urban hydrological modelling

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Hydrological analysis of urban catchments requires high resolution rainfall and catchment information because of the small size of these catchments, high spatial variability of the urban fabric, fast runoff processes and related short response times. Rainfall information available from traditional radar and rain gauge networks does no not meet the relevant scales of urban hydrology. A new type of weather radars, based on X-band frequency and equipped with Doppler and dual polarimetry capabilities, promises to provide more accurate rainfall estimates at the spatial and temporal scales that are required for urban hydrological analysis. In the framework of the RAINGAIN project, radars of this type will be installed in two pilot locations, Paris and Rotterdam. The project comprises of four pilot locations in total with various characteristics of weather radar equipment, ground stations, urban hydrological systems, modelling approaches and requirements. Details of the rainfall measurement networks in the pilots will be given, including specifications the newly acquired X-band radars and selected locations for installation in the urban environments. The availability of high resolution weather data augments requirements with respect to the resolution of hydrological models and input data. Urban hydrological models typically consist of a rainfall-runoff module and a hydraulic module for the underground pipe networks. These hydrodynamic models currently have insufficient resolution to incorporate high resolution rainfall. This had led to the development of fully distributed hydrological models, which will be tested in several pilots of the RainGain project. Comparisons will be made between the pilots to analyse sensitivities of the different urban catchments to high resolution rainfall characteristics. Hydrological characteristics of the RainGain pilots will be given as well as foreseen inter-pilot hydrological comparisons based on fully distributed modelling. Challenges with respect to acquisition of high resolution hydrological data will be accentuated.

4.3 The impact of the spatio-temporal variability of rainfall on flood generation

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An open question in hydrology is how the spatial and temporal structure of precipitation affects the response of river basins in terms of streamflow . The impact of the spatio-temporal structure of precipitation on the catchment response can be crucial for flood protection infrastructure especially in areas prone to flash floods such as steep basins of the European Alps. In this study we construct a numerical experiment in order to quantify the impacts of the space-time variability of rainfall on the response of a pre-Alpine catchment (Kleine Emme river basin). First, a new stochastic space-time model with a high spatial and temporal resolution (1 km2; 5 min) is described and its applicability is assessed for the presented case study. The model can effectively simulate most of the important features of high resolution space-time precipitation as captured by weather radars (e.g. storm growth-decay, advection, etc.). For this task a high quality 7 years long (2004-2010) radar record (2x2 km2; 5 min) from the operational weather radar network of the Federal Office of Meteorology and Climatology (MeteoSwiss) is used. Successively, a fully distributed hydrological model (TOPKAPI-ETH) is used to assess the impact of the spatio-temporal variability of rainfall on runoff generation focusing on flood peaks. A detailed sensitivity analysis of the basin response dependent on several descriptors of the spatio-temporal structure of rainfall such as spatial and temporal correlations, storm movement, storm depth and also the boundary conditions of the catchment (e.g., initial soil moisture before the storm initiation) was carried out. An ensemble of rainfall fields with prescribed properties were simulated with the stochastic rainfall model and used as precipitation forcing of the hydrological model. The main results of the study are that basin response is strongly dependent on the high resolution statistical structure of rainfall and also on the basin wetness conditions prior to the storm. The response of a catchment starting from a drier initial state is more sensitive to the spatio-temporal structure of rainfall, whereas the response of the catchment in a wetter initial state is mainly dependent on the rainfall volume. The most important variables that enhance the variability of the runoff generation, especially for dry initial states, are storm advection and temporal correlation of rainfall. Spatial correlation of rainfall was instead found to be of minor importance.

4.4 Spatial variability of small-scale alpine snowfall and snow accumulation using a polarimetric X-band radar

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A mobile polarimetric X-band radar (MXPol) deployed in the Swiss Alps collected valuable and continuous information on small-scale precipitation for the winter seasons of 2009/2010 and 2010/2011. These data were compared to local measurements of snow accumulation collected with Airborne Laser Scanning (ALS) at the Wannengrat area (located a few kilometers from the MXPol) for the winters 2007/08 and 2008/09. The spatial distribution of snow accumulation exhibits a strong inter-annual consistency that can be generalized over the winters in the area. This unique configuration makes the comparison of the variability in snowfall (as seen by the radar) and in snow accumulation (from laser scans) possible over the diverse winter seasons. The spatial variability, quantified by means of the variogram, is shown to be larger in snow accumulation than in snowfall. This indicates that other factors (like wind and turbulence taking place close to the ground) induced by small-scale topographic features govern the snow deposition and accumulation at the ground level in mountainous areas. Further investigation of this question is done by dividing the radar coverage into two disjoint domains at different elevations, roughness, and proximity to the ground. The variability of snowfall appears consistently large and the velocity field is more organized in the vicinity of the ridge, which confirms the influence of the rugged topography on snowfall.

4.5 Understanding lowland (flash) floods: analysis of the 2010 flash flood in the Hupsel Brook catchment and comparison with other recent lowland floods

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On 26 August 2010 the eastern part of The Netherlands and the bordering part of Germany were struck by a series of rainfall events. Over an area of 740 km2 more than 120 mm of rainfall were observed in 24 h. We investigated the unprecedented flash flood triggered by this exceptionally heavy rainfall event (return period > 1000 years) in the 6.5 km2 Hupsel Brook catchment, which has been the experimental watershed employed by Wageningen University since the 1960s. This study aims to improve our understanding of the dynamics of such lowland flash floods. We present a detailed hydrometeorological analysis of this extreme event, focusing on its synoptic meteorological characteristics, its space-time rainfall dynamics as observed with rain gauges, weather radar and a microwave link, as well as the measured soil moisture, groundwater and discharge response of the catchment. We found that the response of the Hupsel Brook catchment can be divided into four phases: (1) soil moisture reservoir filling, (2) groundwater response, (3) surface depression filling and surface runoff and (4) backwater feedback. During this extreme event some thresholds became apparent that do not play a role during average conditions and are not incorporated in rainfall-runoff models. These observations, however, only show how our experimental catchment behaved and the results cannot be extrapolated directly to different floods in other (neighboring) lowland catchments. Therefore, it is necessary to use the information collected in one well-monitored catchment in combination with data from other, less well monitored catchments to find common signatures which could describe the runoff response during a lowland flood as a function of catchment characteristics. Because of the large spatial extent of the rainfall event in August 2010, many brooks and rivers in the Netherlands and Germany flooded. With data from several catchments we investigated the influence of rainfall and catchment characteristics (such as slope, size and land use) on the reaction of discharge to rainfall. We also investigated the runoff response in these catchments during previous floods by analyzing the relation between storage and discharge and the recession curve. In addition to the flood in August 2010, two other floods occurred in The Netherlands in recently. The three floods occurred in different parts of the country, after different types of rainfall events and with different initial conditions. We selected several catchments during each flood to compare their response and find out if these cases are fundamentally different or that they were produced by the same underlying processes and can be treated in a similar manner.

Brauer, C.C., Teuling, A.J., Overeem, A., Van der Velde, Y., Hazenberg, P. Warmerdam, P.M.M. and Uijlenhoet, R.: Anatomy of extraordinary rainfall and flash flood in a Dutch lowland catchment, *Hydrol. Earth Syst. Sci.*, 15, 1991-2005, 2011.

4.6 From rainfall nowcasting to rainfall hazard assessment

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Heavy rainfalls are the cause of a number of hazards affecting our society through the affectation of the outdoor exposed activities and assets. Classically floods, and specifically flash floods, have been considered the main natural hazard directly caused by heavy rainfalls, but this perception is moving towards the new paradigm of "heavy rain induced hazards" as new areas requiring specific hazard assessment appear. Activity areas that are of relevant socioeconomic interest and that range from traffic and transportation (traffic on highways, in-route flight planning...), to outdoor economic activities (construction, agriculture...) or recreation activities (golf, tourism, hiking, fishing, hunting...). Regarding all these weather-affected activities, and more precisely in the case of Flash Floods (torrential floods with response times between 15 minutes to few hours and associated with intense rainfalls that can accumulate over 25% of the annual rainfall in a few hours), the main requirement is to anticipate the occurrence of heavy rainfalls with high spatial and time resolution. Capability that is the crucial point to provide appropriate hazard assessment to be used by civil protection authorities, emergency managers or even directly by the concerned individuals to assume their self-protection under the principle of subsidiarity. The advancements of the last decades in rainfall forecasting with Numerical Weather Prediction models have been completed with the advancements in the techniques to improve very short-term rainfall forecasting (sometimes called nowcasting) using radar rainfall mosaics. The high-resolution of radar-based estimates and their capability to capture the short-term evolution of the rainfall field make them a crucial source of information to anticipate these intense rainfalls. And consequently in the last years we have seen a number of applications showing that radar-based rainfall nowcasting can be successfully applied even to continental radar networks, as those in the USA and Europe. Nevertheless, how to transform these improved high-resolution rainfall nowcasts into efficient hazard assessment still remains the main challenge to cope with. In the last years, a number of projects have been carried out in Europe whose aim was to propose a sensible strategy to deal with this challenge and to develop a number of tools to deal with this paradigm shift in the framework of the implementation of the European Flood Directive and on the Flood Risk Management Plans the Directive requests for prevention, protection and preparedness by 2015. The basic concepts of the proposed methodologies, as well as the main results obtained over several case studies will be the central point of the presentation.

Session 5

Precipitation statistics and climatology

Wednesday, July 3rd 2013

Schouwburg

5.1 Dependencies of (sub)hourly precipitation extremes on atmospheric temperature and moisture: relations with observed trends over the past century and future climatic change.

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Relations between (sub)hourly precipitation extremes on atmospheric temperature and moisture are analyzed with the aim of i) explaining recent trends and ii) projecting possible changes in precipitation extremes in the future. In earlier work, we showed for a large data set from The Netherlands a dependency of hourly precipitation extremes on the daily mean 2 m temperature of approximately two times the Clausius–Clapeyron (CC) relation (14 % per degree) for temperatures between 10 and 22 degrees. Following this paper there has been a debate whether this behaviour is universal, or whether it is a specific property of the data from the Netherlands. Several studies using data from different parts of the world showed a dependency of hourly precipitation on temperature exceeding the CC relation for intermediate temperatures, but with widely different behaviors for high temperatures. We show that using the atmospheric dew point temperature, which relates directly to the actual water vapor in the air, a much more robust behavior is obtained. In fact, precipitation intensities derived from observations of Hong Kong are almost identical (at the same value of the dew point temperature) to those obtained from data of the Netherlands, despite large differences in climatological conditions. Explanations for this 2 CC scaling will be given. Furthermore, we will show that the 2 CC relation explains decadal variations in hourly precipitation extremes in a 100 year time series of De Bilt (The Netherlands). Finally, the results will be discussed in the context of future climate change.

5.2 Characteristics of extremes for convective and stratiform precipitation

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Precipitation extremes can have far reaching consequences for society, and detailed understanding of their characteristics is essential. Fluctuations on nearly all temporal and spatial scales makes precipitation a difficult variable to assess from data records, and different perspectives are necessary. Here, we focus on extreme events and present high spatial and temporal resolution analysis of fixed interval as well as event based statistics (Berg et al., 2013). A data set of about 90 gauges in southwestern Germany each with eight years of data was used along with a radar product with one kilometer horizontal resolution to analyze different statistical characteristics of precipitation. Each of the data sets has a temporal resolution of five minutes. An event is defined as any continuous sequence of precipitation for the gauges, and as a contiguous precipitating region for the radar data. Furthermore, a data set of synoptical cloud observations is used to separate the precipitation events into stratiform and convective types according to the clouds present around the time of observation. Finally, statistics are sampled according to temperature in order to find their scaling and compare to theoretical changes in the water holding capacity of the atmosphere, following Clausius-Clapeyron. Stratiform precipitation is found to be lacking characteristic scales in its intensity distribution. Its extremes furthermore follow the Clausius-Clapeyron rate of change with temperature rather closely, which indicates that a thermodynamical model could be sufficient to predict the scaling. Convective precipitation exhibits characteristic temporal and spatial scales and is more prone to produce extremes at shorter time intervals. Its scaling with temperature is also more pronounced compared to the stratiform type, with approximately two times the Clausius-Clapeyron rate. This could indicate a strong dynamical feedback with aggregation of moisture from surrounding areas. Also the event based statistics show stronger temperature dependence for the convective precipitation and rather featureless behavior for the stratiform events. It is also shown that the total precipitation yield from an event of a given size is obtained from intermediate size convective events, in contrast to the more constant decrease in yield for stratiform precipitation.

5.3 Spectral characteristics of monsoon rainfall from observations, reanalyses, and simulations

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Numerical simulations from the recent versions of NCAR's coupled climate models (CESM1/CCSM4) have suggested there are increases in precipitation in many tropical regions and decreases in subtropical areas, with comparable changes in precipitation across scenarios for near-term climate, and greater scenario differentiation for longer-term climate changes. The rainfall in the monsoon regions is particularly important and interesting because of its large variability seasonally, inter-seasonally, annually, and inter-annually. With available high-resolution rainfall data from observations, reanalyses, and model outputs, the temporal variability of monsoon rainfall is investigated using primarily spectral decompositions to delineate their spectral characteristics, in order to gain further understanding of the monsoon rainfall variability. In addition to distinct frequency peaks, power-law scaling also appears. Results for different monsoon regions will be presented.

5.4 Analysis of the spatio-temporal variability of dry and wet events in mainland Portugal, using the standardized precipitation index

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The distribution of precipitation is characterized by high variability across a large range of time and space scales. The local and regional consequences of this variability that leads to precipitation deficits and surpluses can be different, depending on specific conditions. Thus, there is often the need to use indicators that are easy to compute and that might allow for a general glance into the development of dry and wet hydrometeorological situations and their persistence, which might affect the society, the environment and the economy. The Standardized Precipitation Index (SPI) provides a simple and convenient tool for drought monitoring. However, the SPI can also be used as an indicator of the development of soil wetness and saturation conditions that can enhance flood events. Moreover, because SPI is a normalized index, it is also suitable to provide spatial representations of these conditions, allowing the comparison between areas within the same region. Another advantage of the method is that it can be calculated at various time scales (frequently, in the range from 3 to 24 months) on which precipitation deficits/surpluses can affect different aspects of the hydrologic cycle, reflecting the natural lags in the response (e.g. depletion and replenishment) of the water resources of the land areas of the earth. In this study we use this index to evaluate the spatio-temporal variability of dry/wet conditions in mainland Portugal over a 72-years period (1941-2012). The monthly precipitation data analysed are from 50 precipitation stations scattered across the area. The SPI series were calculated at short (3 and 6-month) and long (12 and 24-month) time scales. The results were mapped for the whole territory using geo-statistical methods, for a spatial resolution of 1 km2; this was carried out using ArcGIS tools. In mainland Portugal, the annual SPI shows a statistically significant increase in the extent of dry extremes and a non-significant decrease in the extent of wet extremes in the period 1941 2012. However, for shorter time scales the behaviour is sometimes contrasting, depending on the season. The analysis of the 3-month spring SPI suggests an increase in the fraction of the territory that experienced severe and extreme drought conditions (with all the stations showing decreasing SPI trends, statistically significant at the 5% level for about two-thirds of the stations);.and a significant decrease in the fraction of the territory that was affected by very wet and extreme wet conditions Contrastingly, a decrease is found in the autumn for the fraction of the area experiencing severe and extreme drought conditions, whereas there is an increase in the area affected by very wet and extreme wet conditions In winter there is an increase towards more widespread events in both the dry and wet extremes; the result is statistically significant for severe and extreme dry events. The results underline the potential usefulness of the SPI index for detecting dry/wet periods and monitoring drought/wetness episodes; this is discussed in the context of the hydrological conditions in mainland Portugal and the regional increasing demand for water.

5.5 The diurnal cycle of coastal precipitation in West Africa - Observations and climate model simulations

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Precipitation and its variability controls human life – especially in the tropics and subtropics. Owing to its high spatial and temporal variability, precipitation is challenging in terms of measuring and modeling. Precipitation is controlled by various processes, ranging from large-scale frontal systems to small-scale convective events. In numerical atmospheric models, processes related to precipitation are often parameterized, which induces additional uncertainty. Hence, there is an essential need for model validation, what in turn requires reliable reference data and validation methods. We are analyzing precipitation data based on satellite and reanalysis products for precipitation diurnal cycles in West Africa in the monsoon season. There we found precipitation diurnal cycles near the coast in satellite observations, which were different in reanalysis products and in COSMO-CLM (CCLM) regional climate model simulations. We also tried to identify processes controlling the observed diurnal cycles. Land-sea contrasts and topographic effects together with the monsoonal flow play a role. We saw that deficiencies in modeling diurnal cycles of precipitation might be caused by insufficient representation of relevant processes and by uncertainties in model parameterizations.

5.6 Uncertainty in the future change of extreme precipitation over the Rhine basin: the role of internal climate variability

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Future changes in extreme multi-day precipitation sums will influence the probability of floods in the river Rhine basin. Climate projections of future precipitation changes are subject to large uncertainties. These uncertainties originate from three sources; model uncertainty, scenario uncertainty and uncertainty due to internal climate variability. In this study the influence of internal climate variability on the uncertainty of the changes projected by climate models at the end of this century (2081-2100) is quantified for a 17-member ensemble of a single GCM and for as set of 12 GCMs from the CMIP3 ensemble. All climate models are driven by the IPCC SRES A1B emission scenario. The single GCM ensemble contains only internal climate variability, while the CMIP3 ensemble contains both internal and model variability. An analysis of variance (ANOVA) model is formulated to disentangle the contributions from models uncertainty between GCMs and internal variability. Both the changes in the mean and characteristics of extremes are considered. To estimate variances due to internal climate variability a bootstrap method was used for the CMIP3 ensemble, which resulted in an ensemble of time-series for each GCM. For estimation of quantiles of the distributions of extreme precipitation amount with long return periods the GCM simulations were post-processed to the local scale using an advanced non-linear delta change approach. This approach uses climate responses of the GCM to modify an observed (1961-1995) precipitation time series. The results show that internal climate variability is estimated to account for about 30% of the total variance in the projected changes in the mean precipitation and explains a larger fraction of the total variance in the projected climate trends of extreme precipitation. The discrimination between model uncertainty and internal climate variability for extreme precipitation is inaccurate due to the large uncertainty of the total variance. This study shows that for this study area an ensemble of 12 climate models is too small to distinguish the influence of model uncertainty in trends of extreme precipitation from that of internal climate variability and that considerably larger model ensembles are needed to successfully do so.

5.7 Simulation of intermittent rainfall fields with prescribed advection: Revisiting some statistical properties of precipitation fields

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This study relies on a classical Gaussian field simulation technique, the turning band method. Our simulator produces sequences of rainfall fields satisfying three key features of actual precipitation systems: i) the skewed point distribution and the space-time structure of non-zero rainfall (NZR); ii) the average probability and the space-time structure of intermittency; iii) a prescribed advection field. The general formulation of the simulated intermittent rainfall fields relies on i) two independent Gaussian functions representing non-zero rainfall and intermittency with distinct Taylor velocities featuring their respective dynamics, ii) an anamorphosis of inverse Gaussian type caring for the skewed distribution, iii) a chosen fraction of intermittency and iv) the combined use of Lagrangian and Eulerian coordinates coping for advection. In this presentation we use the simulator to revisit some classical questions about rainfall variography such as how rainfall accumulation over time and advection influence variograms. We also illustrate the kinematic effect obtained merging advection and Taylor velocity. Illustrations are taken from different case studies in France.

5.8 Towards spatially inhomogeneous stochastic simulations for flow-dependent nowcasting of orographic rainfall

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The Short-Term Ensemble Prediction System (STEPS, Bowler et al., 2006) is an operational ensemble nowcasting system based upon the Lagrangian extrapolation of weather radar images. To reproduce the dynamic scaling of rainfall, radar fields are decomposed into a multiplicative cascade with 8 levels which stochastically evolves in time according to a hierarchy of Lagrangian auto-regressive models of order 1 (AR(1)). The estimation and update of the cascade parameters is performed in real-time. This allows the parameters to change in time, but assumes that they are uniform over the forecast domain. The presence of orography locally modifies the space-time statistical properties of rainfall and can increase its predictability due to the persistent large scale uplift of air masses. Consequently, we expect the cascade parameters and forecast errors to be spatially inhomogeneous according the relative positioning of orographic features with respect to the flow direction. For the analyses we used data from the weather radar composite of eastern Victoria, Australia, a 500 km domain at 10 min, 2 km resolution, covering the period from February 2011 to October 2012. The apparent motion of the rainfall was estimated using the optical flow technique of Bowler et al. (2004). A k-means clustering algorithm was used to classify the optical flow fields into 6 main regimes and to stratify the evaluation of statistics. STEPS nowcasts of 60-min accumulations show systematic biases on the upwind and downwind slopes of terrain features, which can be used to infer rainfall growth and decay processes due to orography. The Lagrangian AR(1) lifetime of rainfall features is approximately a factor two longer on the upwind compared with the downwind slope. This provides opportunities to perform spatially inhomogeneous stochastic simulations which better represent forecast uncertainty in complex orography. The results indicate that the spatial variability of the cascade parameters and forecast skill is significant. At this stage, it is not altogether clear what is the relative importance of the spatial variability compared to the temporal variability and to what extent the classification into flow regimes also accounts for the temporal variability. The spatial inhomogeneity of the scaling exponent of the variance of the cascade levels is the subject of ongoing research. The computation of rainfall and verification statistics is performed by using an online update strategy. This philosophy allows the design of an operational nowcasting system that automatically improves with experience as more data are collected.

References: Bowler, N.E., Pierce, C.E., Seed, A.W., 2006: STEPS: A probabilistic precipitation forecasting scheme which merges an extrapolation nowcast with downscaled NWP. *Q.J.R. Meteorol. Soc.*, 132:2127-2155.

Bowler, N.E., Pierce, C.E., Seed, A.W., 2004: Development of a precipitation nowcasting algorithm based upon optical flow techniques. *J. Hydrol.*, 288:74-91.

5.9 The observation scale of rainfall measurements and its impact on their use for hydrology and the initialization of mesoscale NWP

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Rainfall often exhibits structure at fine spatial and temporal scales that cannot be resolved by typical measurement networks. Even when using weather radars, this observation scale can be of the order a square kilometer and other systems, including raingauges and NWP models trying to represent rainfall patterns can be operating on scales of tens if not hundreds of square kilometers. This fine scale structure which can be obsered by using high space time resolution radars or lidars will result in errors in the estimation of area averaged rainfall since radars averge reflectivity rather than rainfall resulting in sampling errors. Somewhat surprisingly these sampling errors can dominate over other common radar reflectivity to rainfall conversion errors such as uncertainty in the drop size distribution. Using the University of Auckland's portable high resolution X-band radar system, several months of data have been observed at spatial scales of approximately 100 m and at temporal scales of 20 seconds. The high resolution data was then progressively downgraded in both spatial and temporal resolution to simulate lower resolution radar observations. These simulated lower resolution observations were then compared with the highest resolution observations to construct spatial temporal resolution error diagrams for each significant event in the dataset. It is evident from such diagrams that at often used radar measurement resolutions such as for 2 km and 5 minute sampling, this error varies from 17% to 64% of the mean rainfall in a 10 minute rainfall accumulation depending on the event. When running particularly urban hydrological models, the resolution of precipitation measurement can also be vitally important, especially in small catchments. For instance, infiltration of precipitation (and therefore the determination of precipitation excess leading to runoff) is strongly dependent on the rainfall intensity, the maximum values of which can often be underestimated due to the smoothing effects of low resolution observation. Overestimation can also occur in areas close to high intensity rainfall and due to incomplete beam filling and the nonlinearity of the Z-R relationship. Direct radar to raingauge comparisons are particularly prone to discrepancies due to the difference in sampling volumes. The use of radar precipitation estimates to initialize mesoscale NWP models for short term precipitation forecasts needs to be carried out at high spatial resolution to achieve forecasts of reasonable accuracy and resolution. Examples are shown of WRF being initialized with radar data using a high resoluton nudging technique as compared with the conventional VAR technique which is intrinically operated at lower resolution. The results are strongly in favour of the high resolution approach.

5.10 Copula-based approaches in hydrometeorology: RCM bias correction and precipitation data fusion

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The bottleneck for improved hydrological analyses in many cases is still the limited knowledge of the spatio-temporal distribution of precipitation. This holds true both for the limited performance of interpolated station observations in mountainous and poorly gauged regions, but also for the shortcomings and non-uniqueness of fields obtained by indirect precipitation measurements such as radar or microwave links. In parallel, precipitation fields derived by regional climate model (RCM) systems have severe limitations, not only in reproducing correct timing, location and magnitude of precipitation, but also in reproducing means, variances, or the statistical properties and distributions in general. For that reason, there is a strong interest and necessity for statistical techniques both for bias correction and improved combination and merging of different types of precipitation measurements. We present how Copula based approaches can advantageously be used for these purposes in hydrometeorological research. Copulas allow to account for the fact that the dependence structure between two variates is more complex than it can be modelled by the bivariate normal distribution or ordinary dependence measures such Pearson correlation coefficient. It is a rank based approach and allows to separate the dependence structure of the variates form their marginal distributions. Apart from the common way to use Copulas to model extreme values, a strategy is shown which allows to model continuous time series. As the concept of Copulas requires independent and identically distributed (iid) random variables, meteorological fields are transformed using an ARMA-GARCH time series model. We show two hydrometeorological case studies of Copula based approaches: first the local refinement and bias correction of RCM simulations resolution for the alpine region in Southern Germany. And second, an approach to merge radar and station derived precipitation information for the mountainous region of Garmisch-Partenkirchen.

5.11 From pointwise testing to a regional vision: an integrated statistical approach to detect non stationarity in extreme daily rainfall. Application to the Sahelian region.

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Global warming is expected to intensify the hydrologic cycle. Documenting whether significant changes in the extreme precipitation regimes have already happened is consequently one of the challenging topics in climatic research. The high natural variability of extreme precipitation often prevents from obtaining significant results when testing changes in the empirical distribution of extreme rainfall at regional scale. A regional integrated approach is proposed here as one possible answer to this complex methodological problem. Three methods are combined in order to detect regionally significant trends and/or break-points in series of annual maximum daily rainfall: 1. Individual stationarity tests applied to the raw point series of maxima; 2. A maximum likelihood testing of time dependent GEV distributions fitted to theses series; 3. A heuristic testing of a regional time dependent GEV distribution. This approach is applied to a set of 126 daily rain gauges covering the Sahel over the period 1950-1990. It is found that only a few stations are tested as non-stationary when applying classical tests on the raw series while the two GEV-based models converge to show that the extreme rainfall series indeed underwent a negative break-point around 1970. The study evidences the limits of the widely used classical stationarity tests to detect trends in noisy series affected by sampling uncertainties, while using a parametric space and time dependent GEV efficiently reduces this effect. Showing that the great Sahelian drought was accompanied by a significant decrease of extreme rainfall events is the other main result of this study.

5.12 The statistical properties of intense rain storms in Switzerland and their dependencies

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Intense summer rain storms are a primary cause of many natural hazards in catchments and urban areas. In particular events with very high short-term intensities, usually associated with convection, are a concern because they lead to devastating flash floods, soil erosion, urban drainage system overflows, etc. For prediction and design it is imperative to know the key characteristics of such events and estimate reliably their inter-relationships and dependencies. The aims of this paper are (i) to present a method to select intense rain storms in an objective manner and estimate the statistical distributions of their key event properties (rainfall depth, event duration, peak intensity) for a topographically and climatologically complex environment; and (ii) to identify the changes in the occurrence and properties of these events in the available instrumental record, including their relation to air temperature. The results are based on long records (30 yrs) of high resolution (10-min) precipitation data at 60 stations of the SwissMetNet network which cover an altitude range from 200 to 2700 m from which summer rainfall-only precipitation events are extracted. The two main novelties of this study are as follows. First, lightning data are used as a proxy to identify the subset of intense rain storms during which the peak 10-min intensity exceeds a chosen threshold. This identification is based on the observation that storms with strong convective lifting are commonly associated with lightning strikes. The spatial variability of the estimated threshold shows patterns related to the topography and climatology of the region. Second, temporal changes in the convective properties of storms were analyzed, with indication that some measures of convectivity have been increasing in the region in the past 30 years. The relevance of this finding is presented on the relation of storm properties to air temperature measured at the station. The increase in extreme precipitation intensities with air temperature beyond the rate given by the Clausius-Clapeyron relation found by other authors at other stations around the world is not clearly evident at the event scale in our dataset. This is especially true at mountain stations where the station temperature measurements cover a small range and are strongly affected by local topography. The question raised is how representative is the station ground temperature of the precipitation formation processes aloft. However, convective events generally do occur at higher temperatures and a possible shift towards more convective events in the future may as a consequence lead to higher peak rain intensities and therefore higher risk connected with those events.

5.13 On variational downscaling, fusion and assimilation of precipitation with emphasis on sharp fronts and extreme intensities: A unified framework via regularization

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We introduce a unified variational framework that ties together the problems of downscaling, data fusion and data assimilation as ill-posed inverse problems. This framework seeks solutions beyond the classic least squares estimation paradigms by imposing a proper regularization, expressed as a constraint consistent with the degree of smoothness and/or probabilistic structure of the underlying state. We review relevant smoothing norm regularization methods in derivative space and extend classic formulations of the aforementioned problems with particular emphasis on precipitation and land surface hydro-meteorological applications. Our results demonstrate that proper regularization of downscaling, data fusion, and data assimilation problems can lead to more accurate and stable recovery of the underlying non-Gaussian state of interest with improved performance in capturing isolated extremes and jump singularities. In particular, we show that Huber regularization (a smoothed form of L1-norm regularization) in the derivative space offers advantages, compared to the classic solution and Tikhonov (L2-norm) regularization for spatial downscaling and fusion of non-Gaussian multi-sensor precipitation data. Furthermore, we explore the use of Huber regularization in a variational data assimilation experiment where the initial state of interest exhibits jump discontinuities and non-Gaussian probabilistic structure. To this end, we focus on the heat equation motivated by its fundamental application in the study of land surface heat and mass fluxes.

5.14 To know what we cannot know: Global mapping of minimal detectable absolute trends in annual precipitation

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Fresh water resources, human societies, and ecosystems are expected to be strongly impacted by climate change, with precipitation trends being one of the most important elements that will be closely monitored. However, the natural variability of precipitation data can often mask existing trends such that the results appear as statistically insignificant. Information on the limitations of trend detection is important for risk assessment and for decision making related to adaption strategies under inherent uncertainties. This paper reports on an effort to quantify and map minimal detectable absolute trends in annual precipitation data series on a global scale. Monte Carlo simulations were conducted to generate realizations of trended precipitation data for different precipitation means and coefficients of variance, and the Mann–Kendall method was applied for detecting the trend significance. Global Precipitation Climatology Centre (GPCC) VASClimO data was used to compute the mean and coefficient of variance of annual precipitation over land and to map minimal detectable absolute trends. It was found that relatively high magnitude trends (positive or negative) have a low chance of being detected as a result of high natural variance of the precipitation data. The largest undetectable trends were found for the tropics. Arid and semiarid regions also present high relative values in terms of percent change from the mean annual precipitation. Although the present analysis is based on several simplified assumptions, the goal was to point out an inherent problem of potentially undetectable high absolute trends that must be considered in analyzing precipitation data series and assessing risks in adaption strategies to climate change.

5.15 Multifractal IDF and non-conservation of the rain rate

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A classical purpose-oriented way of representing the probability distributions of the maximum rainfall amount at various time scales is the Intensity-Duration-Frequency curves (IDF). The empirical estimate of the probability law is based on rank analysis of the empirical rainfall quantiles. Then a regression analysis is performed to deduce a parametric equation relating the quantiles and durations. Numerous parametric statistical models could be cited as rather standard IDF models. Whereas these parametric models yield similar values near the centre of the distribution (because they were fitted on low order statistics), the extreme rainfall quantiles often differ significantly. This happens because the rainfall data often display long-range dependencies, non-stationarity and clustering of the extremes, and therefore violates these classical theoretical conditions. Thus, there remains a strong practical interest in searching for methods that could incorporate physical principles in the statistical analysis and to derive physically meaningful asymptotic behavior of the IDF curves, for return periods much longer than the length of available historical records. Searching for such a method, during the last decade there have been numerous applications of scaling theories to IDF curve extrapolations. The majority of available theoretical results concerning the scaling of the IDF curves has been obtained either with the 'simple scaling' formalism or with the multiplicative cascade formalism. While the first formalism oversimplifies a multifractal nature of rainfall, the second one assumes the strict equivalence between the duration (of a sliding window for moving average) and the scale of data observation (corresponding to disjoint windows). In a general manner, the scaling behavior of IDF curves strongly depends on how the durations are defined. An additional complexity arises from the fact that zero-rainfall generally introduces a scaling brake between small and large time scales of the rainfall process. A robust procedure to define from empirical data the corresponding conservative flux (that could be directly modeled by a multiplicative process) was recently developed within the framework of a near-wall atmospheric turbulence. This leads to non-ambiguous estimates of the universal multifractal parameters, also extending the scaling range of the empirical data. This procedure was tested on numerous rainfall data. The results demonstrate that the rainfall process should not be considered neither a passive scalar nor a conservative flux. We propose to discusses the real scaling nature of the rainfall, the transforms associated to scaling and changing durations, which yield the multifractal IDF curves.

5.16 Identification of errors and uncertainties within precipitation data sets

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Initial work on comparison of satellite and surface data sets is presented with the ultimate goal of providing a homogeneous combined satellite-surface product that incorporates as much information from all sources as possible. As part of this first stage it is important to establish the accuracy of the individual data sets; measures of confidence are required to assess the contribution of each of the data sets into the final product. Individual data sets sourced from surface radar networks, gauge networks and satellite data sets have their own inherent strengths and weaknesses; through the comparison of the different data sets discrepancies can be identified; these can be analysed to elucidate the sources and provide a measure of confidence in the estimate provided. An initial study focuses on the United States where precipitation estimates from the surface radar network are compared with the spaceborne TRMM precipitation radar (PR). The study identifies many of the known artefacts in both datasets, such as the radar range effect and ground clutter, as well as scan-biases within the PR data. Maps of these artefacts provide vital information for the combination of data from different sources. Extension of these comparisons to extra-tropical regions using IR and modelled precipitation retrievals shows that such data can also be usefully employed to, at present, provide a qualitative assessment of surface radar. The maps of radar performance can be used to identify regions of high-quality information that can be used to assess the uncertainties within the satellite retrievals, as well as providing the necessary information to the radar community in order to improve surface radar data sets.

5.17 Precipitation regimes in the Southern Appalachians – An overview of key hydrometeorological processes

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Observations from a high elevation science-grade raingauge network has been operating for the last five years in the Southern Appalachians show strong spatial gradients with both elevation and landform, as well as large variability at diurnal, monthly, seasonal and inter-annual time-scales consistent with changes in the prevailing orographic precipitation regimes in response to year-to-year changes in large-scale circulation and regional weather patterns. In this region, isolated severe storms can bring as much as 15% of the warm season rainfall (June-July-August-September) over 1-3 hours, and as much as 30% of annual rainfall over 24 hours in the case of tropical storms. In wet years, westerly fronts and shallow convective systems such as during the SE floods of September, 2009 can produce up to 50% of all warm season rainfall in less than a week. Frequent flashfloods and landslides are associated with warm season late afternoon and nighttime convective events, and in particular the passage of tropical storms. Otherwise, light rainfall prevails at all times of the day, especially in the inner mountain region. Evidence from disdrometers and MicroRain Radars suggests that the observed mid-day peak in the diurnal cycle of rainfall on the ridges of the Great Smoky Mountains (GSM) results from strongly localized interactions between low level cloud systems and orographic cap clouds and fog to produce light rainfall. Indeed, the contribution and frequency of light rainfall (intensity lower than 3 mm/hr) is on the order 40% to 60% (up to 80%) in the winter, and 20 to 50% in the summertime. For rainfall rates below 5mm/hr the light rainfall fraction of total rainfall is on average 60% and up to 80% and higher at some locations. Because light rainfall is the most reliable and most frequent form of rainfall in the region, with a contribution on the order of 40-60% of total annual precipitation, it must therefore play a governing role in the regional water cycle, and resilience to drought. This finding has profound implications for long-term hydrologic and climate impact studies, and especially in regions where these hydrometeorological processes are dominant. An overview of the upcoming IPHEX field campaign under the GPM Ground Validation program will be presented.

5.18 Using scaling fluctuation analysis to quantify global and regional precipitation and to estimate anthropogenic effects

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A basic problem in hydro-climatology is to measure trends at decadal and longer scales and to distinguish anthropogenic and natural variability in the precipitation record and to quantify both as functions of scale. Using Haar fluctuations it has been shown that at scales beyond about ten days, positive fluctuations in atmospheric variables - including rain - tend to be followed by (partially) cancelling negative ones. The converging regime is called "macroweather"; however, at long enough time scales macroweather gives way to climate variations where on the contrary, fluctuations increase once again with scale. Anthropogenic changes over the last century also increase the low frequency variability so that it is hard to disentangle them from natural variability. However, as long as we are still in the scaling macroweather regime the natural variability is dominant. For precipitation, this is true for scales at least up 20 - 40 yrs: we must search for anthropogenic influences only at longer scales. This explains why the usual approaches estimating precipitation trends over decadal scales (using only 10 year segments) do not give statistically significant average trends. Similarly, the usual approach uses precipitation data on grids (especially the Global Historical Climate Network, GHCN at 5ox5o, from 1900) but the latter are estimated from station precipitation series with much higher resolutions. From the space-time scaling properties of precipitation, we expect there to be a serious mismatch in scales; this readily explains the large difference in monthly precipitation fluctuation amplitudes (a factor 2.228) when the GHCN estimates are compared with those of the 20th Century Reanalysis (20CR, at 2ox2o, since 1871). In this presentation, we establish the global statistical framework of precipitation fluctuations using the GHCN and 20CR which we divide into land and ocean subsets. We have recently shown that an effective way of estimating anthropogenic effects is to use the CO2 radiative forcings as a surrogate for all the anthropogenic effects. This is quite accurate and works because due to economic activity, the anthropogenic effects are highly correlated. We find that for a CO2 doubling, that over the oceans, we can ascribe 4.5±1.9, 9.8±3.1 mm/month (≈5, 10%) of increased rain rate (depending on whether we relate the precipitation to the forcing without a time lag or with a 20 year time lag respectively). Over the period 1900-2005, these values correspond to 1.73±0.72, 3.73±1.16 mm/decade of annual increase. This is not only larger than the (land only) IPCC estimate (1.08±1.87 mm/decade of annual precipitation for the GHCN data), but unlike the IPCC estimate it also shows a statistically significant trend. Finally, using long station data (particularly from the Iberian peninsula), with the help of spatial scaling properties, we examine these issues in a regional context. We discuss the implications.

Poster presentations

Session 1

Precipitation Physics

Mozart foyer

P1.1 Calibrating synthetic multifractal times series with observed data

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Universal multifractal model (UMM) Schertzer and Lovejoy [1987] is extensively used to simulate time series with multifractal scaling properties. It is perfectly suited for the various geophysical fields where turbulence is involved. In the case of rain, the problem is complicated by the alternation of dry and rainy periods (rain support). Indeed the UMM model does not allow generating zero values and thus to represent dry periods. Moreover the cumulated distribution function (CDF) and the spectrum of the generated series are not consistent with actual rainfall times series. It follows that the use of the standalone UMM model generates synthetic data do not exhibit all the statistical properties of an actual rainfall time series. Our study focuses on a technique of calibration of the UMM model in order to generate rainfall time series with the same statistical properties than actual measurement. The starting point is a rainfall rate time series obtained with a disdrometer with a 15 seconds time resolution recorded for two years (2008 –2010) in Palaiseau, France. The multifractal properties of these data have been previously analyzed in Verrier et al. (2011). The first part of the presentation focus on the properties on the observed data in term of energy spectrum, fractal analysis of the support and in term of multifractal analysis of the rainy periods. UMM parameters are estimated. The rainy and dry durations are analyzed and parameters of gev / Poisson distributions are estimated. In a second part we propose a calibration method of the UMM model: (i) by using the UMM parameters previously found, (ii) by simulating a rain support using a gev / Poisson distribution to account for the alternation of dry and wet periods, (iii) by using a calibration lookup table. The latter is obtained by using a quantile to quantile approach between the simulated and empirical CDFs. Finally, In order to assess the reliability of the simulation process, we have used different multifractal analysis techniques. These results are compared with those of the empirical series. We find that both energy spectra are similar bringing out the same multiscaling regimes. The effect of the calibration on the multifractal properties is discussed. The UMM parameters estimated on the calibrated series are indeed found to be slightly different from those used in the UMM generator. We notice a decrease of the parameter alpha and an increase of the parameter C1. In conclusion, the proposed method shows that given a calibration process, the UMM model is able to reproduce both statistical and multifractal rainfall properties.

References: Schertzer, D., S. Lovejoy, 1987: Physically based rain and cloud modeling by anisotropic, multiplicative turbulent cascades. *J. Geophys. Res.* 92, 9692-9714

Verrier S., C. Mallet, L. Barthès, (2011) Multiscaling properties of rain in the time domain, taking into account rain support biases, *Journal of Geophysical Research-Atmospheres* 116, D20119.

P1.2 A simple bright band model to infer the density of icy hydrometeors

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The Xport radar (X-Band polarimetric) campaign over Niamey (Niger) in 2010 give us the possibilty to assess the vertical variabilty of reflectivity of tropical (Sahelian) convective systems. The tropical radar campaigns of 2010 (Niger) and 2012 in (Burkina Faso) are the majors contributions to the validation of Megha-Tropiques instant rainfall product (BRAIN). Throught the Xport scanning protocol (12 elevation angles every 12 minutes) we have enough resolution to perform a classification of stratiform and convective rain thanks to the bright band (BB) vertical sampling close enough to the radar (50km). After the classification of the rain type we extract the median vertical profile of reflectivity (PVR) in the stratiform part of the radar sourroundings for each scan volume. Then we build a simple bright band model considering: a melting profile, a diameter size distribution of precipitation particles and the density of bright band upper level particles. The refraction index of the melting particles is calculated performing three different models that considers different mixture configuration (ice, air, water distributions). Thanks to Mie scattering calculations over a distribution of particles we deduce the reflectivity at 9.4 GHz. The use of 3 different models of melting and the observed median PVR allowed us to fit the best model considering only as parameters the density and the distribution parameters. We deduce the best mixture model comparing to our observations thanks to the assymetry of the BB peak. Then we were able to reproduce the observed densities of the particles above the bright band.

P1.3 Interpolation of seasonal and annual rainfall using geostatistical method (case study: Tehran provinces, Iran)

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In this study, to perform regional analysis and rainfall estimation of the rain gauges of 16 located in Tehran province, multivariate geostatistical approaches were used. Elevation was introduced as a covariant and effective factor in rainfall. Analysis semivariogram of data and extracting of seasonal and annual rainfall maps obtained by Arc GIS 9.2. For understanding the details of variogram models and statistical fitting parameters GS+ was used. The Root Mean Square Error (RMSE) was used to evaluate the rainfall forecast. Results showed that for estimation of seasonal and annual precipitation, Exponential Cokriging method offer high accurate information on rainfall amounts which is mainly due to the high correlation between elevation and rainfall. Although the correlation coefficients between elevation and rainfall in some seasons is less than other seasons, but it is more than 0.6 in all seasons.

P1.4 Polarimetric signatures of microphysical processes in warm rain

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The impact on the polarimetric radar variables: reflectivity factor (ZH), differential reflectivity (ZDR), and specific differential phase shift (KDP) of selected microphysical processes in warm rain is investigated. This work uses the one-dimensional version of a bin-microphysical model (Prat et al. 2012) that resolves explicitly the evolution of the drop size distribution (DSD) under the influence of microphysical processes throughout the rain column. The computed transient and equilibrium DSDs are used as an input for an electromagnetic scattering model (Kumjian and Ryzhkov 2012) that emulates the evolution of the polarimetric radar variables (ZH, ZDR, KDP). The fingerprint of each individual microphysical processes (drop settling, drop coalescence, aerodynamical breakup, collisional breakup, bounce, evaporation…) as well as the full physic configuration (all processes included with/without updraft/downdrafts) is quantified as a function of the shape of the initial DSD and for different values of the nominal rain rate (RR). In addition, a sensitivity analysis is performed using the most common microphysical parameterizations found in the literature. Theoretical DualPol profiles (ZH, ZDR, KDP) are compared with radar and disdrometer observations collected for stratiform and convective environments. Results indicate that individual microphysical processes display a particular signature and that they evolve within specific areas in the polarimetric radar variable space (ZH, ZDR). The parametric study conducted allows determining their respective domain of predilection. Furthermore, results suggest that because of the unequivocal dependency between microphysical processes and radar DualPol variables, real time DualPol radar rainfall field observations could be of great help to improve microphysical parameterization of drop-drop interactions via inverse problem modelling techniques.

P1.5 Towards understanding the microphysics of raindrops: Experiments at the Mainz Vertical Wind Tunnel on drop oscillation and collision

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Liquid drops with sizes between 50µm and 10 mm can be freely floated in the air stream of the Mainz vertical wind tunnel at their terminal speeds within laminar or turbulent flows with a wide range of environmental conditions. This enables us to perform experiments on the characterization of basic microphysical properties of raindrops including their shapes and axis ratios, oscillation modes and frequencies, and internal circulation. We provide an overview of recently conducted studies. (1) Droplet shapes and oscillations: A first series of experiments was carried out with pure water drops which serve as reference for further intercomparisons of microphysical properties. The shapes and oscillation frequencies of raindrops with different sizes from 0.6 to 7 mm diameter obtained from high speed video recordings were compared to theoretical results. It was shown that the average drop shape is appropriately estimated by an aerodynamic model of quiescent water drops. However, raindrops are oscillating in three modes, in the axisymmetric, the transverse, and the horizontal mode. These modes are always coexisting but their amplitudes depend on the environmental conditions and ongoing processes, e.g., reduced surface tension, or drop-drop collision. The internal circulation in raindrops (with diameter larger than 1 mm) was found to be rather irregular and turbulent. (2) Surface tension effects: Atmospheric raindrops do generally not consist of pure water but may contain additional substances which modify the surface tension and, thereby, influence drop deformation as well as breakup and coalescence, and, thus, the formation of precipitation. A second series of measurements with drops having reduced surface tensions resulted in variations of the terminal velocity, drop shape, mean axis ratio, oscillation modes, frequencies, and amplitudes. It was shown that the models used to compute the above parameters for pure water drops are also suited for raindrops with different surface tensions. Furthermore, depending on the existence of a surfactant film on the surface, drops exhibit the presence or absence of internal circulation. (3) Shapes and oscillation after collisions: In a third series of measurements, the shape and oscillation behavior of raindrops after collision were investigated. Water drops with 2.5 mm diameter were freely floated at their terminal velocities in the wind tunnel while 0.5 mm diameter droplets, which were carried along with the air stream, were colliding with them. The collision efficiency and its dependence on the Weber number and on the eccentricity of the colliding drops showed good agreement with numerical studies. Although the amplitude of the axis ratio was increased by a factor of 4 to 6 directly after collision the average axis ratios were increased by less than 1%. The sizes of the largest drops after collision were nearly the same as before collision and the frequencies of the active fundamental oscillation modes of the drops did not change significantly either. However, during the post collision transient phase the transverse oscillation mode and the whole body rotation dominated while later the oblate-prolate mode again determined the drop shape alteration. It was further found that the decay of the axis ratio variation after collision is adequately described with the viscous decay of a liquid spherical drop. In summary, the presented laboratory experiments provide insight, theory-experiment comparisons, as well as essential parameterizations needed for inclusion in numerical models describing precipitation development. Also the quantification of the oscillation behavior serves for improving the interpretation of radar parameters.

Session 2

Precipitation Observation

Mozart foyer

P2.1 Validation of polarimetric hydrometeor classifications using radar – radar comparisons and web-based reports

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Two approaches are developed to study and validate hydrometeor types retrieved from polarimetric radars. First, an intercomparison between polarimetric radar variables and retrieved hydrometeor types obtained by neighboring radars in overlapping areas is carried out and analyzed. Different pairs of radars are considered (C – C , S – X, …). These comparisons show a good correlation between radars despite several problems such as path attenuation, biases, wet-radome attenuation and calibration errors. The method can be applied to any pair of radars with some overlapping and allows checking the consistency and stability of the retrieved hydrometeor types under different conditions (measurement conditions, wavelength, …). Biases on some radar variables (e.g. ZH or ZDR) can also easily be evidenced by that approach. Second, a method is proposed to validate the presence of hail inferred from polarimetric measurements. The method consists in using reports, videos and pictures posted online on different sites (specialized or social networks). Using this method, a dataset of 192 reports is established. The reports chosen occurred close to polarimetric C-band radars of the Météo France network at three different altitude intervals where three cases of hail are considered : small hail (diameter < 5 mm), large hail (diameter between 5 – 20 mm) and giant, damaging hail (diameter > 20 mm). The three altitude intervals are: below the bright band (BB) minus –500m, in the BB +/- 500m and above the BB + 500m. The corresponding bivariate membership functions were established and the hydrometeor classification algorithm was modified to take the membership functions into account. The first results are promising and show a good agreement between hydrometeor types and data on the ground.

P2.2 Radar and rain gauge merging methods for operational hourly precipitation estimates

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It is now strengthened that benefits can be achieved in quantitative rainfall estimates by blending information from different data sources. Radar-gauge combinations have been widely proposed and exploited over the last decades, as the radar capability of detecting the rainfall pattern is extremely worth, if it can be joint to quantitative measurements by a rain gauge network. Merging techniques range from simple methods proposed to correct calibration error of weather radars, to more elaborated geostatistical methods. A useful review can be found in Goundenhoofdt and Delobbe (2009); nevertheless, a wide statistical literature adopting different approaches exists (see, for instance, Brown et al. 2001 and Fuentes et al. 2008 as examples of spatio-temporal models for radar calibration). In rainfall estimates for operational use some requirements have to be fulfilled. First of all computational cost must be low. Especially for assimilation of rainfall data into hydrological or nowcasting models, the resulting estimate must be available soon after data collection. The rainfall estimate methods should be reliable and not fail during any kind of rainfall events. Spatial and temporal resolution must be appropriate to the application demands. For many uses hourly precipitation at 1X1 km2 are required. In this work the performances of three radar-gauge merging methods are investigated. The first method is a mean bias removal that takes into account the past 96 hours radar-gauge pairs to retrieve one hourly correction factor for the whole map. The second method reconstructs a non-uniform bias correction map. It is a modification of the technique proposed by Koistinen and Puhakka (1981) that in turn follows Brandes (1975). The third method here applied is a kriging of rain gauge observations with a large scale trend linearly depending on radar rainfall estimates at rain gauge sites. Linear and quadratic trends in the coordinates are exploited. The composite of the two radars managed by ARPA-SIMC is used. It covers the Po Valley and part of Northern Italy. Reflectivity undergoes an elaboration scheme to remove clutter, anomalous propagation and beam blocking, then a Marshall and Palmer relation is applied to retrieve the rain rate. An advective algorithm takes into account precipitation movement and integrates in time from rain rate to hourly cumulated precipitation. A network of about 400 quality checked rain gauges is equally divided in two sets, one for merging, the other for verification. The performances in quantitative precipitation estimate are evaluated and the capability to detect rain/no-rain areas is assessed. Hourly observations during September 2012 are considered for this study. The results show a good performance of kriging with external drift as regards quantitative estimates, while, for rain areas detection, methods based on the radar rain field pattern seem to give better results.

P2.3 Global in-situ and regional radar based quantitative land-surface precipitation products of DWD and their (potential) uses in hydro-climatological context

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The Precipitation Monitoring Unit (PMU) of the Department of Hydrometeorology at the Deutscher Wetterdienst (DWD) hosts the Global Precipitation Climatology Centre (GPCC) to make an essential contribution to the Global Energy and Water Cycle Experiment (GEWEX) of the WMO World Climate Research Program (WCRP) and to the Global Climate Observing System (GCOS). The GPCC was established at the beginning of 1989 at DWD on invitation by WMO. The suite of global land-surface precipitation products of the GPCC comprises near-real-time as well as non-real-time products. Near-real-time products are the 'First Guess' and 'Monitoring Product'. These products are based on WMO-GTS data, e.g., SYNOP and CLIMAT reports and monthly totals calculated at CPC. Non-real-time products are the 'Full Data Reanalysis', 'Climatology' and the Homogenized Precipitation Analysis (HOMPRA) under development to replace the 'VASClimO' data set. Most recently GPCC has started issuance of a daily precipitation analysis product ('First Guess Daily') and a monthly global drought index applicable to almost every place (climate region) on the globe. On the regional scale DWD's PMU can take advantage of its network of meanwhile 17 identically built C-band radar systems covering the entire German territory and operated on a homogenized scan strategy since beginning of 2001. The QPE and QPF products yielded have so far been utilized in the context of severe weather forecasting and early warning. Moreover quantitative precipitation products have been generated through online calibration of the radar reflectivity data against automated rain gauges. For the upcoming years we expect to achieve a growing overlap of the characteristic spatial-temporal scales of the different products due to their enhancements in data coverage and resolution. Particular milestone along this development shall be the unprecedented climatological assessment of the radar based precipitation measurement based on a homogeneous re-processing of all high quality radar raw data of the past 12 years and the merging of high-resolution regional precipitation data sets with the global analysis of GPCC that has recently commenced development and reprocessing of bi-decadal (1988-2008) daily data products (rain gauge only and satellite-gauge combined) in contribution to the framework research project MiKLIP (Medium-range climate forecast) funded by the German Ministry for Research (BMBF). The presentation shall give an account on the most recent developments and their use cases in the field of hydro-climatology. For example the decadal radar-reanalysis (see also poster of Winterrath et al.) will provide new insights on the occurrence and ultimately the climatology of short-term heavy precipitation events that have been hardly resolved on purely gauge based climatology's so far. Capabilities and limitations for usages in the field of hazard protection and water management will be discussed.

P2.4 A new method for clutter removal

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A new algorithm for clutter removal has been developed at MeteoGroup. While there are many methods for decluttering a radar image it is often a very challenging task, where no single method is perfect. Access to volumetric or polarimetric data gives more opportunities for the detection of clutter, but these are often difficult to gain access to externally and especially commercially. In most cases a composite CAPPI image is the best available data. This creates a challenge in the detection and removal of clutter. The MG declutter method has developed a tool to remove clutter from CAPPI images as it combines three clutter removal algorithms in a very effective way. The first step is the detect spikes (also called arrows) within the images caused by the sun or other radiation sources. By looking at the radius from a radar location within a CAPPI image the shapes of possible spikes are identified and evaluated. The variation of the reflectivity in the identified areas is is used to make a final decision to mark the area as actual clutter. The second method determines precipitation areas as separate objects. The shape and reflectivity values of these objects determine whether the precipitation objects are clutter or precipitation. A set of histograms of reflectivity of actual precipitation is used to help the identification. Finally a satellite cloud mask, derived from Meteosat data, is used to determine clear air areas where actual precipitation is highly unlikely. Using the same objects identified in step 2 the amount of cloud cover over an object is used to find clutter. A set of parameters can be used to tune the three different algorithms to specific areas and datasets. The current algorithm is now being extended to also include previous images, to detect static clutter areas, as well as additional satellite sources.

P2.5 Spatial precipitation patterns and trends in the Netherlands during 1951-2009

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Significant increases in precipitation have been observed in the Netherlands over the last century. At the same time persistent spatial variations are apparent. The objective of the present study is to analyse and explain these spatial patterns, focussing on changes in means and extremes for the period 1951-2009. To investigate different possibilities for the causes of spatial variations, a distinction was made between 6 regions based on mean precipitation, soil type and elevation, and 4 zones at different distances to the coast. Spatial maxima in mean precipitation inland and over elevated areas are mainly formed in winter and spring, while maxima along the coast are generated in autumn. Daily precipitation maxima are found in the central West coast and over elevated areas. Upward trends in daily precipitation are highest from February to April and lowest from July to September. The strongest and most significant increases are found along the coast. For several seasonal and climatological periods diverging behaviour between coastal and inland zones is observed. We find that distance to the coast gives a more consistent picture for the seasonal precipitation changes than a classification based on surface characteristics. Therefore, from the investigated surface factors, we consider SST to have the largest influence on precipitation in the Netherlands.

P2.6 Comparing European Centre for Medium Range Weather Forecast ERA interim rainfall time series (1999-2011) with actual rain gauge data as input for millet crop yield forecast models in West Africa

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Climate information monitoring has widely contributed to tackle the Food Insecurity problem in Western Africa. Throughout the past years, many International Institutions and non-government organizations have built Food Security Information Systems in which climate information like rainfall play a major role. As part of one of these monitoring systems the European Joint Research Center has developed a web based service to distribute the European Centre for Medium range Weather Forecast (ECMWF) data. These data are available for free and used by many research centers for seasonal monitoring in many parts of the world. Within the framework of the Global Monitoring for Food Security GMFS project (funded by the European Spatial Agency (ESA)), a yield forecast methodology was developed for Western Africa, which combines water balance indicators (dekadal rainfall at grid level and other climate variables), with remote sensing derived phenology. Results of this methodology are very promising. In this study the impact of the different rainfall inputs on the model was tested. Many studies have shown that biases exist between ECMWF rainfall and observations in West Africa, however no to few studies exist on the evaluation of the impact of such biases on crop models or yield forecast models. This study uses the two set of data (rainfall station data observed in Senegal and Niger for the period 1999 to 2011 and ECMWF data) to derive some water balance indicators. The indicators are then used in the early yield forecast models. As a conclusion it can be said that, the ECMWF data led to larger errors in non-agricultural zones. However for the agricultural zones in West Africa the ECMWF data performs better than the rain gauge data due to the reduction of spatial interpolation error and the maintenance of temporal variability over a time series. Finally it can be said that the bias observed between the two data sets can be explained by the characteristics of Africa monsoon in the coastal zone and the continental area. The well know bias between the two datasets in this area is not a limitation for food security assessment in these regions.

P2.7 Assessment of small-scale rainfall variability from NASA GPM-GV dense raingauge network

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In collaboration with its international partners, the National Aeronautics and Space Administration (NASA) is developing a Ground Validation System (GVS) as a contribution to the Global Precipitation Measurement (GPM) mission. As part of this effort, NASA is establishing a state-of-the-art GPM GV rain gauge, disdrometer and multi-parameter radar measurement facility on the Virginia eastern shore (WFF PRF) geared toward validation of NASA precipitation products (spaceborne and/or combined ground and spaceborne retrieval algorithms). During the fall of 2012 and early spring of 2013 a newly-established dense network of 25 dual-tipping bucket rain gauge platforms, situated in an area footprint of 25 km^2 (e.g., scale of an individual GPM dual-frequency radar footprint), recorded a significant number of precipitation events. The observed events ranged in intensity from light to severe and represented a mixture of convective and stratiform rainfall system types. In this work we use the collected data to analyze the small-scale, horizontal variability of rainfall in a coastal environment. Our goal is to address the uncertainties associated with raingauge validation of satellite and radar-based rainfall products.

P2.8 MARG - a C band solid state microwave areal precipitation measurement device

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The water is an essential resource for us so the measurements of its movement throughout the whole cycle are very important. The rainfall is discontinuous in space and in time having large natural variability unlike many meteorological parameters. The widely used method for getting relatively accurate precipitation data over land is the combination of radar rainfall and rain gage data. The typically used radar data is coming from long-range weather radars operating C or S band and coming from mini radars operating on X band which is attenuating heavily in stormy precipitation. Using such radar data we are facing to several constraints: operating costs and limitations of long range radars, the X band radars can be blocked totally in heavy thunderstorms even in short range, dual polarization solutions are expensive, etc. Recognizing that an important gap exists in instrumental precipitation measurements over land a Consortium has been organized and a project is erected for developing a measurement device so called Microwave Areal Rain Gage – MARG - based on FMCW radar principle using solid state transmitter and digital signal processing and working on C band. The MARG project aims to provide an innovative, real-time, low-cost, user friendly and accurate sensor technology to monitor and to measure continuously the rainfall intensity distribution over an area around some thousand square km. The MARG project proposal has been granted by the EU in FP7-SME-2012 SME funding scheme.

P2.9 1-year long operational application of Vertical Profile of Reflectivity in the retrieval of the rain rate at the ground: impact and problems

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The application of Vertical Profile of Reflecitvity (VPR) reconstruction and correction is considered a key point in the framework of precipitation estimate at the ground level from radar reflectivity data, so that several techniques have been developed in the past to address this issue. Nevertheless its operational use opens questions like the spatial variation of the precipitation vertical development, which is due to the mixing of convective and stratiform precipitation or simply to the incline of the bright band, and makes difficult using a unique VPR in the whole area of observation. Another point is the presence of melting layer or snow at the ground level which should be automatically recognized and dealt with, because it produces a variation in the relation between reflectivity and rain rate. In this work are presented the results of a 1-year long operational application of a simple method of VPR reconstruction and correction which applies a single time-space averaged profile, distinguishes between snow, melting and liquid precipitation at the ground level and corrects reflectivity data. No stratiform-convective separation is adopted. Reflectivity corrected data are used to retrieve the intensity of precipitation at the ground level and the hourly cumulated precipitation is obtained with an advective algorithm that takes into account the precipitation movement. The scores respect to the rain gauge hourly cumulated rain during the year are calculated. Thereafter, they are compared to the same scores retrieved in the area close to the domain of VPR retrieval where meteorological phenomena are reasonably more homogeneous . The mean impact of VPR application is evaluated and the effect of the spoiling factors evidenced; moreover some representative cases are analyzed. The results show that the application of the profile correction on the average improves the rain rate estimate, but crucial points, such as hydrometeors phase at the ground and convection, should be dealt with to avoid locally negative effects. Reducing the investigation to the area with homogeneous characteristics to the area of VPR retrieval the skill increases.

P2.10 Polarimetric radar observations during an orographic rain event

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An intense orographic precipitation event was observed with a polarimetric C-Band radar situated ~ 20 km north of the Alps on January 5th 2013. The radar is operated at DWD's metorological observatory Hohenpeißenberg. The event lasted about 1.5 days and in total 44 mm precipitation where measured by the local weather observers. Detailed high resolution observation on the vertical structure of this event is obtained through a bird-bath scan at 90° elevation as part of the operational scanning. This scan is acquired every 5 minutes. In the course of this event, the melting layer descended until the transition from rain into snow was observed. This transition from rain to snow is well documented by the local weather observers and a present-weather sensor. In the course of this event, we find pockets having Graupel-type characteristics above the melting layer which will be analysed in detail. The event is used to verify a new hydrometeor classification scheme.

P2.11 RainStation project implementation plans for Tanzania, Peru and Sri Lanka

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The RainStation project seeks to test the extent to which a dense network of robust rain gauges may support smallholder farming in countries in Africa, Asia, and Latin America. Potentially, food security can be increased both through better understanding and use of local rainfall and through improved micro-insurance possibilities. A low-cost RainStation has been developed that runs on a small solar panel and communicates through GPRS modem. To test the robustness of different gauging techniques, three different rainfall measurement methods will be used simultaneously. The first method is a tipping bucket, using the mechanical and electronic core of the Davis Instruments Vantage Pro station. The second method is the "Delft disdrometer", a recently developed sensor based on acoustics. The third method is the Hydreon Optical Rain Sensor - Model RG-11, which measures rain through image analysis of a transparent dome. The stations will be tested at three agricultural sites, one each in Peru, Tanzania, and SriLanka. Local knowledge institutes will be responsible for testing and maintaining the station. The stations will be adjusted and the best technology will be selected for optimal cost efficiency and robustness. Local businesses will support the further role out. The collected data of the three sensors will be displayed on www.rainstation.org. This project is a partial answer to the recent call of the Secretary General of the WMO to increase registration of weather information.

P2.12 Spatio-temporal interpolation of radar derived rainfall in the presence of signal extinction due to attenuation : Use of conditional simulation based on lagrangian kriging

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Weather radar operating in the X-band frequency are more and more frequent for hydrological applications. This is due to their relative low cost and size (transportability) compare to the S-band or C-band radar commonly used for operational monitoring of weather and rainfall. On the other hand, radar at X-band frequency suffer from a strong attenuation in rain which can be compensated for by using polarimetric techniques. We have been operating an X-band radar in West Africa (Benin, Niger, Burkina Faso) for 3 years as part of hydro-meteorological studies. In these locations where most of the rainfall is from convective origin , attenuation is strong enough to cause total extinction and loss of signals in some of the radar coverage. This extinction introduces range dependant biases in the total rainfall field that cannot be corrected for using the usual polarimetric based attenuation correction techniques. When the radar rain fields are used for hydrological applications or for satellite validation, these range dependant biases in the daily totals, due to misses in the instant rainfall fields cause a problem. A method has therefore be developed to compensate for the 'lost' rainy time steps during the day A spatio-temporal interpolation technique has been developed in order to recontruct the lost areas in the radar rainfield. The method is based on lagrangian (or dynamical) kriging and conditional simulations using Gaussian fields. Preliminary results and evaluation of several methods will be presented.

P2.13 Estimation of rainfall using commercial microwave links in Burkina Faso: preliminary results

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In many countries in West Africa and more particularly in the Sahelian zone, about 78% of the population lives on pluvial agriculture. Yet the rainfall is one of the meteorological variables that know the greater spatial and temporal variability. The rainfall distribution and quantitative precipitation estimation remains a major problem in Africa. Rain gauges in West Africa are deficient and poorly distributed, as for weather radar, the costs of installation and operations are too expensive for these countries. Satellite rainfall products are more and more used but still present some biases. As an alternative, it has been proposed to exploit commercial microwave link attenuation measurement to estimate rain rate. The method has been tested for the first time in West Africa (Burkina Faso, thanks to a partnership between a private mobile operator (Telecel-Faso) and the University of Ouagadougou. Microwave link data at 7 GHz are collected on three links between 21st July and 21stAugust 2012 and compared with rain gauge data and radar data. The figure following shown the experimental set up. The microwave link data filtering method used in this study is adapted from Leijnse et al.2008. The link averaged daily rainfall estimates could be compared with daily rainfall from the nearby rain gages. The quantitative comparison for a total period of one month in 2012 will be presented and the limitations of the study discussed. Over the five rainy days where link rainfall could be compared to rain gauges so far, less than 18% relative bias was encountered. These preliminary results using links at 7GHZ are encouraging and show that microwave links provide anew potential for rainfall measurement in Burkina Faso. They could improve rainfall estimation over the West African region and provide information on the spatial distribution of rain. They could complement other rainfall measurement methods (such as satellite) and contribute to validate global rainfall products in these poorly instrumented regions.

P2.14 Data-driven hydrometeor classification with polarimetric radar

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Hydrometeor classification aims at identifying the dominant type of hydrometeors in the region covered by a polarimetric weather radar. Techniques documented in the literature are mostly based onscattering simulations and fuzzy logic. This involves the arbitrary selection of a set of categorical classes of hydrometeor types and the simulation of their scattering behavior. Then, actually collected radar observations are compared with the sets of simulations through fuzzy logic and one of the categorical classes is assigned to each radar resolution volume. This approach has some limitations. The number and type of the hydrometeor categories is selected arbitrarily and the scattering simulations can be based on unreliable assumptions, especially in case of solid particles. Furthermore, in presence of noises and uncertainties (unavoidable in measurements) it is not guaranteed that different and distinct classes of particle types could be effectively and systematically identified. In the present work we propose a different approach to the classification problem, which is based on observations instead of numerical simulations. The goal is to provide quantitative and motivated criteria for the selection of the number of identifiable hydrometeor classes, and then to verify the potentials of supervised classification techniques that rely on observations and training sets instead of being constrained by scattering simulations. Two polarimetric datasets, collected by an X-band weather radar are employed in the study. The two datasets cover diversified weather conditions, ranging from Alpine precipitation to Mediterranean orographic events. In a first stage, data mining techniques like hierarchical unsupervised classification, are applied to the observations collected, in order to identify how the data are naturally clustered, and to quantify how many discernible groups can be evinced. A second stage involves the creation of a labeled subset of the groups identified, where the categories are defined thanks to in-situ observations and/or visual interpretation of clearly defined radar images by trained operators.Finally, machine learning supervised techniques are employed to propagate the classification to new and not labeled observations. The performance of the proposed classification method is evaluated on a validation data set (classified from trained operators).

P2.15 Measuring rainfall using cell phone links: classification of wet and dry periods using satellites.

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Measuring rainfall using cell phone links: classification of wet and dry periods using satellites. Commercial cellular telecommunication networks can be used for detecting precipitation by looking at the attenuation of the electromagnetic signals transmitted between antennas from microwave links. The attenuation can be translated into a path-averaged rainfall intensity. Not all attenuations are caused by precipitation, so a method is required to remove the fluctuations not related to rainfall in order to prevent overestimation of rainfall. One classification methodology for wet and dry spells is the "link approach" in which a 15 min interval is labeled wet if the mutual decrease in minimum received powers of nearby links in the same interval exceeds two thresholds. Another methodology is to use ground-based radar rainfall intensities to identify wet and dry spells, called the "radar approach". Conditions can be such that these methods can not be used, for example because no precipitation radar is available or the mobile phone network is not dense enough to be able to use the link approach. Satellites can be a good alternative for wet-dry classification (“satellite approach”). Three Meteosat Second Generation products are tested for the Netherlands: Precipitating Clouds, Convective Rainfall Rate and at a later stage Cloud Physical Properties. All products use channels for infrared and visible light and the Precipitating Clouds and Convective Rainfall Rate products both have a separate day and night algorithm. The Cloud Physical Properties product can only be used during daytime. The products are first analyzed visually over a period of four days and compared to the precipitation radar. The Convective Rainfall Rate product is of limited use for wet-dry classification, especially during winter. The Precipitating Clouds product shows more promising results, which are analyzed in more detail. Goal of the research is to have the highest probability of detection while maintaining a reasonable false alarm ratio. The Precipitating Clouds product is used as a wet-dry classification for readily available link data for several days. As the satellite product can not detect the outer area of a rainy cloud well, the areas classified as wet are extended. Testing of the Cloud Physical Properties product is done in the same way. To possible improve the results, the Precipitating Clouds and Cloud Physical Properties products are combined to use as wet-dry classification. Finally, link-based country-wide rainfall maps are derived for the Netherlands employing the different wet-dry classification methodologies (link approach, radar approach, satellite approach). Those maps are compared and validated against a climatological radar rainfall dataset, considered as ground-truth.

P2.16 Estimating the spatial distribution of precipitation using remote sensing proxies and observed data in a tropical mountainous region

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Understanding the spatial and temporal variability of precipitation in tropical high mountain areas remains a key challenge. Point measurements are often not sufficient to capture the strong gradients in the multiple local factors that determine the distribution of precipitation. Remote sensing data is currently providing a new venue for a better quantification of rainfall patterns. Rainfall satellite products as those coming from the TRMM mission are being continuously improved and an ever increasing amount of high- and medium-resolution remote sensing data are becoming available on biophysical terrain attributes. A methodology is presented that combines two TRMM products and remote sensing data on vegetation and topography to quantify the spatial distribution of precipitation in areas where direct observations are lacking. The approach assumes that vegetation cover, the elevation and satellite-derived estimates of precipitation are reasonable indirect measures of ground-based precipitation. The methodology is evaluated for an area in the Andes of Ecuador. The results show that around 40% of the variance in weekly precipitation is explained by these proxies. During the drier periods of the year, vegetation is the strongest proxy. For the wettest areas, the relation between vegetative cover and precipitation saturates and the other proxies take over in the regression models. A leave-one-out cross-validation procedure was applied to test the performance of the methodology. The performance was satisfactory, and as expected related with the density of the weather station network and temporal rainfall variability. Overall we conclude the methodology is useful for areas with very high variable conditions, where sufficient ground-data is available to establish the relationships with the remote sensing proxy datasets.

P2.17 Design, calibration and field test of an acoustic disdrometer designed for distributed measurements

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Design, calibration and first field test results of an acoustic disdrometer, called the Delft-disdrometer, are presented. The Delft-disdrometer is specifically designed to be low maintenance, allowing installation of dense networks without incurring large maintenance costs. Throughout the design of the Delft-disdrometer, focus was placed on robustness a low price to make replacing a more feasible option than repairing, thereby keeping downtime to a minimum. Laboratory calibration experiments showed that for the Delft-disdrometer individual calibration is needed. A field test was carried out to measure the accuracy of the Delft-disdrometer versus state-of-the-art rain-gauges in a realistic situation. The Delft-disdrometer proved capable of measuring precipitation volumes with comparable uncertainties as those of the industry standard Thies LPM and Ott Parsivel, when compared against a calibrated electrical rain gauge. The drop size distributions measured with the Delft-disdrometer are similar to those measured with the Thies LPM and the Ott Parsivel for drops larger than 1 mm in diameter. The experiments with this first prototype show that it is feasible to accurately measure precipitation with the low maintenance Delft-disdrometer.

P2.18 A review of Kriging based rain-gauge – radar merging techniques

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Rain-gauges provide an accurate but highly localised measure of rainfall rates with limited coverage and spatial resolution. Conversely, radars provide high resolution reflectivity measurements of the precipitation across the land and sea, but the estimation of the rainfall at the ground is associated with a large uncertainty that results from calibration errors, attenuation of the signal by the precipitation, the wet radome, or blockages, regional variations of the vertical reflectivity profile and the Z-R relationship. Rain-gauge – radar merging techniques allow information from these two observing systems to be combined to produce a high resolution merged product of greater precision than the Krigged gauge or radar only products. The objective of the present study is to develop a real-time gauge-radar merging product for the UK with a 15 minute accumulation period for use in flood forecasting. Three main criteria have been considered when assessing the performance of a number of geospatial interpolation schemes; gauge density, polling time and degree of correlation within the radar data. The results indicate that Kriging with External Drift (KED) consistently performs best over-all and is the preferred method for merging. KED is the least sensitive of all the merging schemes tested to a systematic decrease in gauge density and a time offset between gauge and radar data. In addition, the scheme works well in both convective and stratiform conditions and is suitable for use with sub-hourly accumulation times. This presentation will give a more detailed discussion of the methodologies covered by the study as well as an in-depth analysis of the results produced. The implications of these findings on the development and upgrading of rain-gauge networks will also be considered.

P2.19 Three dimensional exploration of weather radar data: Real-time validation of local area NWP models using Weather3DeXplorer

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KNMI operates two C-band Doppler weather radars. Post-processing of each radar fills a 3D volume with precipitation data. We present a method where the volume data from the radial scans (in our case 14 cones) is interpolated onto a fixed-height 3D structured grid with a chosen number (15) of Flight Level Cappi's (FLC), where the horizontal part of the grid covers the Netherlands and surrounding countries in stereographic (geo-)projection. Radar data on such a 3D grid is suited for immediate 3D visualization and interactive exploration in the Weather3DeXplorer (W3DX), our Virtual Reality 3D visualization framework for meteorological data. We demonstrate added value of 3D radar data visualization on some recent interesting severe weather situations. In the winter situations we have tested a derived product, called vertical gradient of reflectivity, which clearly shows the melting layer. In more convective situations the height and the vertical profile of precipitation columns are very useful. Our 3D approach also shows limitations of the widely-used pseudo-CAPPI's (1500 m). We are in an experimental stage of 3D visualization use by operational meteorologists. By means of interactive 3D contouring (/iso-surfaces), cross-sections, and fast navigation in time the users can quickly explore the latest 3D radar precipitation measurements. Since this data is practically available in real-time our meteorologists can compare and validate the NWP model predictions (Harmonie and HIRLAM) with these observations.

P2.20 Rainwater sequential sampler for water quality assessment during single rain events

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Rainwater quality is expected to vary in space, depending on geographical location, and in time: from event to event and within individual events. The main aim of this study was to develop a low-cost volume-based sequential rain sampler to exploring the intra-event rainwater quality variability that could: i) combine simple manufacturing, set-up and maintenance, and no power requirements; and ii) provide adequate sampling resolution to monitor single events. The main components of the device include a small flume that distributes sequentially the collected rainwater by 11 sampling bottles that can storage up to 10 mm of rain (0.5 mm for the first two bottles, and 1 mm for each of the other bottles); after all the bottles are filled the additional rain is disregarded. The rain collection area has a diameter of 358 mm. Here we report results of the first tests on the adequacy of the depth resolution of this device to monitor rainwater quality variation within rain events. From the rain events that we have been monitoring in the urban area of Coimbra (Portugal), we selected four events based on the following criteria: i) a minimum rainfall total of 6 mm (to provide data from at least 7 sampling bottles); ii) a minimum of 6 hours of dry weather prior to sampling. In total, we present the analysis of 40 bottle-samples. Several physicochemical parameters were examined, including electrical conductivity, pH, turbidity, nitrates, sulphates, chloride, iron and lead. Empirical distributions of the rainwater contaminants' concentration and quality parameters were determined for each individual rain event. Results show that, in general, the rainwater quality parameters are quite variable during the rain events but respecting a rather well defined pattern: the concentration of the majority of the pollutants analysed was found to be highest at the beginning of the rain events, followed by a rapid decline of the initial value by sometimes more than 70%, and then remained approximately constant as the event progressed. These preliminary tests and results suggest that the volume resolution adopted in the sampler is adequate to detect intra-event rainwater quality variability in single events. Thus, this equipment might be useful as a low-cost solution to explore rainwater contaminants' variations, bearing in mind some practical water quality requirements, such as in rainwater harvesting for drinking purposes, for example. One main drawback is that this sampler does not automatically identifies the end of a given rain event, so the manual identification of the discontinuity in rain and collection of the samples before the next event are required.

P2.21 Evaluation of satellite-retrieved extreme precipitation over Europe using gauge observations

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Reliable estimates of precipitation variability and changes are of high interest for many societal areas including water resource management, agriculture and infrastructure. Due to their severe impact extreme precipitation events are of particular importance. Satellite-retrieved precipitation products with their spatially consistent areal estimates and their good spatial coverage are particularly suited for such applications. However, satellite-based estimates are generally only indirect estimates of precipitation and therefore require a retrieval algorithm to produce a geophysical product that inevitably has shortcomings, which makes it necessary to verify the result against other independent measurements such as in-situ observations. This study evaluates the ability of the satellite-based Global Precipitation Climatology Project One-Degree Daily (GPCP1DD) data set to reliably reproduce precipitation variability and extremes over Europe compared to the European Daily High-resolution Observational Gridded Dataset (E-OBS). The results show that the two data sets agree reasonably well not only when looking at climatological statistics such as climatological mean, number of wet days (rain rates 1 mm), mean intensity (i.e. mean over all wet days) but also with respect to their distributions. The results also reveal a pronounced seasonal cycle in the performance of GPCP1DD which is worse in winter and spring. Both deterministic and fuzzy verification methods are used to assess the ability of the GPCP1DD data set to capture extremes. Fuzzy methods prove to be the better suited evaluation approach for such a highly variable parameter as precipitation because it compensates for slight spatial and temporal displacements. Whereas the deterministic diagnostics confirm other papers' findings on the uselessness of satellite products, the “fuzzy” results show that at larger spatio-temporal scales (e.g. 3 degree / 5 days) GPCP1DD has useful skill and is able to reliably represent the spatial and temporal variability of extremes.

P2.22 Characterizing the error structure of satellite-rainfall estimates over the equatorial island of Singapore

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In this study, three high-resolution satellite-rainfall products are evaluated using 13 years (1998 – 2010) of rain gauge measurements from a dense gauge network in Singapore. The gauge network consisting of 38 gauges within a single 0.25º pixel allowed for reliable estimation of ground reference. The three satellite-rainfall products evaluated are i) version 7 estimates from the Tropical Rainfall Measurement Mission Multi-satellite Precipitation Analysis (3B42-V7), ii) version 1 estimates from Climate Prediction Center morphing technique (CMORPH-V1), and iii) estimates from Precipitation Estimation from Remotely Sensed Information Using Artificial Neural Networks (PERSIANN) algorithm. First, the study characterized systematic errors in above satellite-rainfall products at monthly and annual scales. The probability distribution and temporal structure of random errors are then analyzed for multiple time scales starting from 3 h to 1 week. The results from the study can be employed to generate error-adjusted ensemble rainfall time series conditional on the satellite-based rainfall estimates.

P2.23 Iowa X-band polarimetric radar observations at multiple resolutions during the IFloodS field experiment

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The University of Iowa X-band polarimetric (XPOL) radar system consists of four scanning and mobile Doppler weather radars. These units are equipped with several engineering and operational features particularly suited for studying hydrological processes at smaller scales. The radars are envisaged to capture multiple views of target-of-opportunity storms at high spatio-temporal resolutions. The flexibility in deployment and operation of each of these low-cost XPOL units aids in achieving their research goals. Multiple views of the common weather events will be used for mitigating signal attenuation due to precipitation at the 3 cm wavelength regime. While conventional lower frequency (S- and C-band) weather radar data is limited to 100-300 m range resolution, the Iowa XPOL system intends to provide radar rainfall data at higher range resolutions. These two assumed advantages of Iowa XPOL units - higher spatial resolution and ability to recover an unattenuated composite view – will be extensively examined during the upcoming NASA IFloodS (Iowa Flood Studies) field experiment to be conducted in eastern and central Iowa in spring 2013. The radars have been evaluated for campaign-level operational competence in broad conformity with the NASA Global Precipitation Measurement – Ground Validation (GPM-GV) guidelines. This paper presents the Iowa XPOL observations during the IFloodS campaign. Specifically, it shows numerical analyses of the quality of the data obtained at various range resolutions. The Iowa XPOL radars can be operated to acquire data at range sampling as low as 30 m. The characterization of the decrease in the signal-to-noise ratio and increase in statistical errors in the estimate of polarimetric variables with the increase in range sampling rate is the primary research objective of this paper. Further, this characterization may differ when the radar switches between different processing modes (pulse pair or FFT) or pulsing schemes. The IFloodS campaign will also feature participation of calibrated S-band (~10 cm wavelength) NASA polarimetric (NPOL) radar so as to provide anchor points to validate XPOL observations at multiple resolutions. Finally, a numerical comparison with the co-located S-band WSR-88D radars will be helpful in producing a calibrated XPOL view for the intended analysis in this paper.

P2.24 On raindrop size distributions obtained with electro-mechanical disdrometers

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Raindrop size distribution (DSD) is a key parameter in cloud physics studies, so its actual knowledge is worthy in most meteorological applications. Also, it is well known that DSD varies both spatially and temporally, not only across different storm types but also within a specific storm. Nowadays several instruments are used to obtain DSDs, one of the most common ones being the Joss-Waldvogel disdrometer (JWD). This impact-type, electro-mechanical device is widely accepted as a reference for rain spectra measurements at the ground, although its precise operating physical principle remains unclear. According to its manufacturer, “the JWD transforms the vertical momentum of the impacting drop into an electrical pulse whose amplitude is a function of the drop diameter.” However, laboratory studies have shown the influence of both fall velocity and drop shape on the measured drop size from the impact. This suggests that the electrical pulse is more likely proportional to the force acting on the transducer integrated over the impact time interval, that is, the impulse rather than the momentum. Other studies have shown a number of limitations on the performance of the JWD. An important shortcoming of the JWD is that it cannot measure the actual speed of a falling drop and thus the terminal velocity must be assumed. Several authors have studied the effect of the fall velocity on the assignment of the drop size, and concluded that the JWD cannot properly determine drops larger than 5 mm in diameter and that there is a shift in the DSD towards smaller sizes. Recent findings have shown important deviations of actual drop fall-speeds with respect to their theoretical terminal velocities within the JWD lower measurement range. In the case of drops with sizes smaller than 0.8-mm in diameter, there is a large number of so-called super-terminal drops falling faster than their terminal speeds. Because these super-terminal drops have an “enhanced” vertical momentum, the JWD may detect them erroneously. In this study, raindrops fall speeds measured during actual rain events with two optical array probes deployed in a fixed, vertical fashion, were used to explore the effect on the estimation of the DSD for various rainfall episodes. With this methodology, the actual drop size and fall speed were measured. By using these data, drops were rearranged in new DSDs according to the their momentum, such as an electromechanical disdrometer would do it. The findings presented here indicate that a JWD would overestimate the number of small drops (diameters less than 1 mm), even during calm-wind periods, due to the presence of super-terminal drops. Also, a different size redistribution in the range of large raindrops (diameters larger than 2.5 mm) seems to occur. Furthermore, the measurements during windy conditions show a tendency to a larger overestimation on the counting of small drops when the momentum calculation is used to obtain the DSD.

P2.25 Evaluation of TRMM PR rainfall estimates over Brazil: A contribution of CHUVA project

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This article presents an evaluation of the surface rainfall product version 7 of the Tropical Rainfall Measuring Mission (TRMM) Precipitation Radar (PR) 2A25 over Brazil by comparing with coincident drop size distribution (DSD) measurements collected during the CHUVA Field Campaigns. This comparison is evaluated with the hypothesis that the spatial rainfall distribution observed by the instantaneous TRMM overpasses should be similar with the temporal distribution observed by the ground truth that in this article are represented by drop size distribution (DSD) measurements. During the years of 2010 and 2012, the CHUVA project deployed 5 field campaigns (Alcantara, Fortaleza, Belém, Vale do Paraíba and Santa Maria) that depict maritime and continental precipitating system that vary from warm to depth convective clouds, squall-lines, frontal systems, meso-scale convective systems and isolated convection, which represent a very broad tropical rainfall database. The radar reflectivity factor (Z) and rainfall rate (R) relationships retrieved during the coincident measurements (+1 hour DSD and 50 km radius for TRMM) show that in general 2A25 underestimates the rainfall rate for Z lower than 30 dBZ while it overestimates above. In terms of volumetric rainfall probability density functions (PDF-Vol), i.e., weighted by the total precipitation amount, we found that 2A25 estimates overestimates as much as 13-160% of the median rain rates at Fortaleza, Belém and Santa-Maria and it underestimates at Alcantara. At the higher rain intensities (90% level), 2A25 overestimates as much as 200% at Fortaleza and Belem, while it underestimates by 30-60% at Alcantara and Vale do Paraiba.

P2.26 Dynamics of turbulence in precipitation: Unravelling the eddies

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The Transportable Atmospheric Radar (TARA), located at Cabauw, can be used to retrieve the eddy dissipation rate (EDR). The retrieval of EDR can be done in several ways: 1. Using the Doppler spectral width from a vertically pointed radar (F. Yanovsky, 2005, unpublished); 2. Making a power spectrum of a sequence of vertical Doppler velocities and use the Kolmogorov power relation; or 3. Using the variance from a sequence of vertical Doppler velocities and an analytic relation, derived from Kolmogorov theory (See e.g. O'Connor, 2010). The first method has the advantage that a high spatial resolution can be achieved as only one measurement is needed to obtain the EDR. The disadvantage here is that the Doppler spectral widths are not only determined by turbulence but they are contaminated with other sources. For example Yanovsky et al. (2005) propose a correction for the terminal fall speed distribution to obtain the EDR. In this presentation we present different retrieval schemes for the eddy dissipation rate. As TARA is currently at the CESAR research site, we will compare the EDR with other measurements available at the research site.

P2.27 Country-wide rainfall maps from cellular communication networks

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Accurate rainfall observations with high spatial and temporal resolutions are needed for hydrological applications, agriculture, meteorology, and climate monitoring. However, the majority of the land surface of the earth lacks accurate rainfall information and the number of rain gauges is even severely declining in Europe, South-America, and Africa. This calls for alternative sources of rainfall information. Various studies have shown that microwave links from operational cellular telecommunication networks may be employed for rainfall monitoring. Such networks cover 20% of the land surface of the earth and have a high density, especially in urban areas. The basic principle of rainfall monitoring using microwave links is as follows. Rainfall attenuates the electromagnetic signals transmitted from one telephone tower to another. By measuring the received power at one end of a microwave link as a function of time, the path-integrated attenuation due to rainfall can be calculated. Previous studies have shown that average rainfall intensities over the length of a link can be derived from the path-integrated attenuation. Here we show how one cellular telecommunication network can be used to retrieve the space–time dynamics of rainfall for an entire country. A dataset from a commercial microwave link network over the Netherlands is analyzed, containing data from an unprecedented number of links (2400) covering the land surface of the Netherlands (35500 squared kilometers). This dataset consists of 24 days with substantial rainfall in June - September 2011. A rainfall retrieval algorithm is presented to derive rainfall intensities from the microwave link data, which have a temporal resolution of 15 min. Rainfall maps (1 km spatial resolution) are generated from these rainfall intensities using Kriging. This algorithm is suited for real-time application, and is calibrated on a subset (12 days) of the dataset. The other 12 days in the dataset are used to validate the algorithm. Both calibration and validation are done using gauge-adjusted radar data. Validation results reveal that the global evolution of rainfall fields can be accurately retrieved from the microwave link data. Hence, it is confirmed that microwave links can be useful for real-time rainfall monitoring over large areas. This is particularly interesting for those countries where few surface rainfall observations are available.

P2.28 A comprehensive observational analysis of 2011 fall flash floods in N-W Italy

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Flash-floods induced by extreme rainfall events represent one of the most life-threatening phenomena in the Mediterranean. While their catastrophic ground effects are well documented by post-event surveys, the extreme rainfall events that generate them are still difficult to observe properly. Being able to collect observations on such events do help scientists in better understand and model these phenomena and eventually to characterize these events. To this end, the role of the key ingredients (e.g. unstable air masses, moist low-level jets, steep orography and a slow evolving synoptic pattern) for severe rainfall processes on complex orography have been investigated for two dreadful events occurred in Liguria (N-W Italy) on 2011 Fall, yielding almost 20 casualties and losses of hundreds of millions of euros. The analyses were carried out by means of the available observations both airborne (MSG, MODIS) and ground-based (the Italian Radar Network mosaic and the national raingauge network). Moreover, sea-atmosphere interactions (SSTs from JPL-G1SST and GOS-OISST) and a characterization of these events in terms of their predictability are also addressed.

P2.29 Investigating radar subpixel rainfall variability from preliminary observations of a super dense rain-gauge network

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The increasing use of radar and satellite data in hydrological applications, due to the sparse distribution of rain gauges over most catchments worldwide, requires improving our knowledge of the uncertainties of these data. In 2011, a new super-dense network of rain gauges, containing 27 gauges covering an area of about 4 km2, was installed in northern Israel, representing Mediterranean climate regime. This network was established for a detailed exploration of the uncertainties associated with radar and satellite rainfall resulting from rainfall variability at the subpixel-scale. The gauge–rainfall spatial correlation and uncertainty were examined along with the estimated radar error. The zero-distance correlation between rain gauges was high (0.92 on the 1-min scale) and increased as the time scale increased. A difference was detected in the spatial correlations of the convective and nonconvective rainfall, as the convective rainfall correlation decreases much faster than the nonconvective one. The variance of the differences between radar pixel rainfall and averaged point rainfall (the variance reduction factor) was 1.6% for the 1-min scale. It was also found that at least four uniformly distributed rain stations are needed to adequately represent the rainfall on the radar pixel scale. The radar–rain gauge rainfall difference was mainly contributed by radar estimation errors while the gauge sampling error contributed no more than 22% to the total error. The radar rainfall estimations improved with increasing time scale and the radar-to-true rainfall ratio decreased with increasing time scale.

P2.30 Measuring rainfall with an optical and a microwave link

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The use of microwave links to measure rainfall is gaining scientific interest. A particular reason for the increasing interest in microwave links is because of their abundance in existing infrastructure, particularly in cell phone networks. This could lead to commercial cell phone networks being used to generate rainfall estimates for large regions, which could complement the often limited number of surface rainfall observations. On a local scale, microwave links can give good estimates, but some sources of error are as of yet unresolved. Not only links operating at microwave frequency, but also links at (near) infrared frequencies can be used to estimate rainfall. The relations to convert signal attenuation to rain rates are similar to those employed at microwave frequencies. However, links operating at infrared frequencies have a stronger dependence on drop size distribution. Similar to microwave links, there is existing infrastructure: (near) infrared scintillometers that are commonly used to measure heat exchange over an area. However, the number of infrared links is much smaller than the number of microwave links. In the Ardeche region in the south of France, both a microwave link and an infrared link have been set up in the fall of 2012. Complementing this setup, a disdrometer measuring drop size distributions was deployed at either end of the links. This provides a good opportunity to compare rain estimates. The combination of disdrometers and (particularly infrared) links gives an opportunity to investigate the effects of the drop size distribution on the produced rain estimates. The microwave links give results which are comparable to disdrometers (although the link results are spatially averaged), the infrared links are underestimating the rainfall compared to disdrometers.

P2.31 Sensitivity of Z-R relations to spatial and temporal aggregation based on high-resolution X-band radar data

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Rainfall retrieval using weather radars routinely relies on power-law relations between corrected radar reflectivity (Z) and rain-rate at the ground (R). The non-linear nature of these relations precludes a direct comparison of rainfall estimates employing radar reflectivities measured at different scales. Transforming radar reflectivity into rain-rate using Z-R relations that have been derived for other spatial and/or temporal scales results in a so-called aggregation bias. Aggregation bias can be constrained when including information about the variability of radar reflectivity within a certain scale of aggregation. Here, we investigate the sensitivity of Z-R relations to several spatial and temporal aggregation scales using high-resolution radar reflectivity fields. The data employed in this study consists of one year radar reflectivity fields measured by an X-band weather radar SOLIDAR, located in Delft, The Netherlands. The radar operated with a radial resolution of 120 m, an angular resolution of 1.875 degrees and a temporal resolution of 16 s. Existing Z-R relations were employed to transform reflectivities into rain-rates and to investigate the various effects of spatial and temporal aggregation on the behavior of aggregated Z-R relations. The pre-factor and the exponent of the aggregated Z-R relations systematically varies with aggregation scale. Several descriptors of the spatio-temporal variability of the radar reflectivity field are presented, to establish the links between variability descriptors and systematic aggregation bias.

P2.32 Large- and regional scale controls of precipitation variability and extremes in the Canadian Prairies

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The Canadian Prairies is characterized by the frequent occurrence of droughts and pluvials that significantly affect the region's agricultural activities. To better understand the key physical processes that affect the development of these hydroclimate extreme events, monthly time series of basin-scale surface and atmospheric water budgets were calculated for the 1960-2002 period by using various datasets. Results from correlation analysis performed with the budget components were interpreted with knowledge of hydroclimate processes in the region to clarify the roles of different interacting processes in governing the interannual variability of warm season precipitation. Results of the analysis suggest that the interannual variability, including the development of extremes, of warm-season Prairie precipitation is strongly affected by synoptic activities that occur in its southern vicinity. It was further found that the variability of warm-season synoptic activities that affect the area are controlled by characteristic upper-level largescale flow features that are at least partially forced by sea surface temperature anomalies over the tropical western Pacific Ocean.

Session 3

Precipitation Modeling

Mozart foyer

P3.1 Calibrating synthetic multifractal times series with observed data

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Universal multifractal model (UMM) Schertzer and Lovejoy [1987] is extensively used to simulate time series with multifractal scaling properties. It is perfectly suited for the various geophysical fields where turbulence is involved. In the case of rain, the problem is complicated by the alternation of dry and rainy periods (rain support). Indeed the UMM model does not allow generating zero values and thus to represent dry periods. Moreover the cumulated distribution function (CDF) and the spectrum of the generated series are not consistent with actual rainfall times series. It follows that the use of the standalone UMM model generates synthetic data do not exhibit all the statistical properties of an actual rainfall time series. Our study focuses on a technique of calibration of the UMM model in order to generate rainfall time series with the same statistical properties than actual measurement. The starting point is a rainfall rate time series obtained with a disdrometer with a 15 seconds time resolution recorded for two years (2008 –2010) in Palaiseau, France. The multifractal properties of these data have been previously analyzed in Verrier et al. (2011). The first part of the presentation focus on the properties on the observed data in term of energy spectrum, fractal analysis of the support and in term of multifractal analysis of the rainy periods. UMM parameters are estimated. The rainy and dry durations are analyzed and parameters of gev / Poisson distributions are estimated. In a second part we propose a calibration method of the UMM model: (i) by using the UMM parameters previously found, (ii) by simulating a rain support using a gev / Poisson distribution to account for the alternation of dry and wet periods, (iii) by using a calibration lookup table. The latter is obtained by using a quantile to quantile approach between the simulated and empirical CDFs. Finally, In order to assess the reliability of the simulation process, we have used different multifractal analysis techniques. These results are compared with those of the empirical series. We find that both energy spectra are similar bringing out the same multiscaling regimes. The effect of the calibration on the multifractal properties is discussed. The UMM parameters estimated on the calibrated series are indeed found to be slightly different from those used in the UMM generator. We notice a decrease of the parameter alpha and an increase of the parameter C1. In conclusion, the proposed method shows that given a calibration process, the UMM model is able to reproduce both statistical and multifractal rainfall properties.

P3.2 To quantify potential impacts of rainfall scenarios on SW-GW interactions; A case study on Lower Murray River, South Australia

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In arid and semi-arid regions that evaporation rate is much higher compare with rainfall and no rainfall recharge is plausible, connection between a river and a floodplain aquifer via river bank can be the main source of fresh water to saline floodplain aquifer. The objective of this paper is to show the potential impacts of rainfall patterns in term of intensity and depth on interaction of GW-SW in Lower Murray River in South Australia. This paper, presents the results of physically-based fully integrated numerical modelling (using HydroGeoSphere) of a river and a saline floodplain aquifer. In this regard, different scenarios with rainfall patterns were defined. The results of the defined scenarios were compared with the case study model. Results show that the dynamic of flow and solute in the simulated system was relatively sensitive to the rainfall regime. The hydraulic conductivity of the floodplain top soil layer plays the main role in this process. To sum up, more recharge from rainfall may lead to a less saline floodplain aquifer in compare with current rainfall.

P3.3 Precipitation scaling in the non-hydrostatic weather model Harmonie

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Extreme precipitation events have a large impact on society, as they can cause localized flooding or agricultural crop damage. Changes in the frequency or intensity of extreme precipitation in a warming climate are therefore of general interest. The maximum precipitation rate is limited by available energy and moisture, and as warmer air can hold more water, rainfall intensity can be expected to increase. The Clausius-Clapeyron (CC) equation relates the water holding capacity of air to its temperature, and predicts an increase in intensity of 6 to 7% per degree Celsius. However, observations show that the intensity of more extreme precipitation events increases at almost twice this rate. This is made possible by an increased inflow of moisture through strong convective processes. Although general circulation models show an increase of heavy precipitation with temperature, they are limited by a coarse spatial resolution and an imperfect parametrization of convection. Consequently, they do not reproduce the observed scaling. Here, we investigate the precipitation scaling in a high resolution, convection resolving model. Using the non-hydrostatic weather model Harmonie at a resolution of 2.5 km, we simulate several rainfall events over the Netherlands. The simulations are then repeated with the same relative humidity but with an artificially increased, or decreased, temperature. This allows us to study the same event under different, but plausible climates. We find that the convection resolving model shows a faster than CC scaling. In the convection resolving model we find a dependency of precipitation extremes on temperature well exceeding the CC relation.

P3.4 Development and validation of a polarimetric radar simulator

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A radar simulator for polarimetric radar variables was developed within the research nonhydrostatic mesoscale atmospheric (Meso-NH) model, as an upgraded version of the radar simulator developed by Caumont et al (2006). The simulator allows for a direct comparison between model simulations and polarimetric radar observations, which can be useful for evaluating the capacity of the atmospheric model to realistically describe the processes involved in the formation and interactions of the hydrometeors and, hence, the performance of its microphysical parameterization scheme. The polarimetric radar simulator is fully consistent with the microphysical parameterizations of the Meso-NH model that uses a one-moment bulk microphysical scheme governing the equations of the six following water species: vapor, cloud water, liquid water, graupel, snow, and pristine ice. The simulator takes as input the output of model simulations such as hydrometeor contents, temperature, ice concentration. It produces simulated polarimetric radar data, including reflectivities at horizontal and vertical polarizations, differential reflectivity, differential propagation phase, differential backscattering phase, specific differential phase and cross-correlation coefficient. Polarimetric variables are calculated for each hydrometeor specie and for the combination of all species if different species are present within a given pixel. Attenuation is also calculated and applied to polarimetric variables. The radar simulator is developed based on calculations of electromagnetic wave propagation and scattering at S, C or X bands. Beam bending and beam broadening are simulated. Pristine ice particles are considered to be spherical whereas rain, snow and graupel particles are simulated as spheroids. The following scattering methods are available: Rayleigh or Mie for spheres, Rayleigh for spheroids or T-matrix for spheroids. A comparison between convective-scale simulated polarimetric radar data and observed polarimetric variables is first conducted for a well documented case study. The aim of this comparison is to establish if the different choices made in the scattering module of the simulator such as the parameterization of shape, canting angle, fraction of liquid water in the melting ice species are realistic and ensure a good agreement between simulated and observed polarimetric variables. More comparisons at all radar frequencies and for different types of situations will be carried out in the future. The final objective is to see if and how the information obtained from the polarimetric quantities can be assimilated in a convective-scale model in order to improve short term forecasts.

P3.5 A new cloud overlap scheme in Alaro, and its impact on precipitation fluxes

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Assumptions on how clouds overlap are an important part of the physics in numerical weather prediction models. Two cloud overlap assumptions that are often used are the random scheme, where cloud overlap is random, and the so-called "max-random" scheme, where clouds overlap maximally with the cloud in the layer above. The random scheme typically overestimates cloud cover, while the max-random scheme can underestimate it. The cloud overlap assumptions also have an impact on the precipitation fluxes, through the sedimentation scheme used in the model. In the Alaro model, this is the statistical sedimentation scheme of Geleyn et al, 2009. We investigate the potential improvement in modeled precipitation based on an interpolation between the two schemes by means of a continuous parameter; which can be related to the work of Hogan and Illingworth, 2000. We have implemented this scheme in the moist physics of the Alaro model, with the aim of optimizing the interpolation parameter. We explain the parameterisation of the new scheme, and present the equations used to update the precipitation fluxes when going from one layer to the next. We discuss how changes in the cloud geometry impact the seperate autoconversion, collection and evaporation pseudo-fluxes. We also show the results of ongoing verification experiments using some highly convective periods in 2009 and 2012, for which radar intensities are also available.

P3.6 A link between Arctic sea-ice reduction and extreme precipitation events over the Mediterranean region

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During the last decade, Arctic sea-ice cover has experienced an accelerated decline that has been suggested to drive the increased occurrence of extremely cold winter events over the continental Europe. Observations and modeling studies seem to support the idea that Mediterranean climate is also changing. In this work we estimate potential effects on the Mediterranean basin, during the winter period, of projected Arctic sea-ice reduction. Two sets of simulations have been performed by fixing different values of sea-ice concentrations (50% and 20%) on the Barents-Kara (BK) seas in the CAM3/NCAR atmospheric GCM. Global model simulations have then been used to run RegCM4/ICTP regional model over central Europe and the Mediterranean domain. Results evidence an increase in the occurrence and intensity of extreme cold events over continental Europe and of extreme precipitation events over all the Mediterranean basin. In particular, simulations suggest an increased risk of winter flooding on southern Italy, Greece and Iberian peninsula.

P3.7 Combined method for measurement of rain parameters based on double frequency remote sensing

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Measurements of rain parameters are of great practical interest for municipal services, agriculture etc. The mono frequency methods based on correlation between rain intensity I and radar reflectivity Z are widely used now for measurement of rain intensity. However the coefficients of the such relation have wide range of variation that leads to the essential measurement errors. That is why the double frequency sensing is of great interest because allows to increase reliability of the precipitation measurements. At present three-parameter Gamma distribution of particles sizes is used in the most cases as a rain model because it permits to describe almost any changes in spatial rain structure. But the main problem in this case is impossibility to define all three distribution parameters by measurements of radar cross-sections at two frequencies. This leads to necessity of using additional information about rain to solve inverse scattering problem. Particularly the combined double frequency method was proposed based on correlation dependences between parameters of gamma distribution and rain intensity which were obtained by contact measurement. So it allows to decrease the number of unknown parameters while solution of inverse problem. Thereby proposed method permits to measure profile of main rain parameters including, distribution parameters, rain intensity, drop concentration and water content with taking into account of signal attenuation in the rain and elimination of measurement ambiguity for small rain intensity. Numerical simulation of rain double frequency sensing based on proposed method was performed. It was shown that dependence of differential radar cross-section DRCS (ratio of cross-section at two wavelengths) on rain intensity has ambiguity part for rains of small intensity (< 4 mm/h), when one value of DRCS corresponds to two values of rain intensity. Also an iterative procedure was proposed and studied to take into account signal attenuation. Convergence of the iterative scheme becomes worse for size of resolution cell more than 600 meters due to increase of signal attenuation. But for modern radar with high resolution cell the proposed iterative scheme provides high accuracy of reconstruction of nonuniform profile of rain parameters even for rains with strong intensity. To verify the proposed combined double frequency method the experimental study was performed by comparison of remote sensing data obtained using double frequency radar and contact data obtained using rain gage measurements. To provide experimental study the double frequency incoherent radar (8.2 mm and 3.2 cm) was used with radar constant 7.4 and range resolution 150 m. Also the high-performance rain gauge was developed on the base of electronic balance to verify the data of remote sensing. The preliminary results of experimental study showed that results of remote sensing measurements of mean value of rain intensity differ from contact less than 15 %.

P3.8 Numerical scattering simulations for interpreting simultaneous observations of precipitations by a W-band spaceborne and a C-band ground radar

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The spaceborne W-band (94 GHz) Cloud Profiling Radar (CPR) onboard the CloudSat (CS) satellite, which was launched in 2006, is providing valuable information about global cloud properties. This work aims at interpreting collocated time/space observations from CPR on CS and a ground C-band (5.6 GHz) Radar (GR), with the help of numerical simulations of electromagnetic scattering returns from populations of spheres of ice and liquid water. One precipitating cloud system over Apulia region is investigated. CPR-CS and GR images have been geo-referenced, then combined and displayed for analysis. The numerical simulations of the two radar reflectivities are used as a tool in the inversion procedure, aiming at identifying the hydrometeors, in their phase and size distribution, in the cloud volume simultaneously observed by the two radars. The possible vertical profiles of hydrometeors are presented.

P3.9 A data driven rainfall generator for time series of high temporal resolution (NiedSim) - Current state and outlook

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The correct dimensioning of urban hydraulic structures like sewage channels or rain storage reservoirs has always been an issue. Overdimensioning consumes a lot of resources, whereas too small structures bear the risk of system failures. In order to achieve an appropriate design of these structures, hydrological and hydraulic models are applied to estimate discharge values. As sewage channel networks are very fast reacting systems with short concentration times, accurate hydraulic modeling requires precipitation input on high temporal resolution of one hour or shorter. Additionally, sewage systems react in a different manner if the channels and reservoirs are still filled from former precipitation events. Therefore, long rainfall time series of several decades are needed. Precipitation data of long time series with high temporal resolution is not sufficiently available for most areas. As a consequence a synthetic rainfall generator called “NiedSim” was developed by Bárdossy et al. (2000) and is operating since the year 2000. NiedSim is a data driven approach where the precipitation time series is generated within three steps. At first an initial time series of hourly data is set up, followed by a simulated annealing optimization of the hourly time series and the disaggregation into a time series in five minute resolution. In the optimization process pairs of precipitation values of the initial time series are swapped as until its statistical characteristics fit the observed ones. The target values are statistical parameters of observed data that are interpolated on a high resolution grid by external drift kriging. There are some shortcomings in the operational version of NiedSim. First, only time series of single points without spatial correlation can be generated. Second, the initial time series is generated based on fitted theoretical distribution functions of observed precipitation data. Within this model concept the natural variability of precipitation is underrated. Finally, the scaling properties of the generated time series are described inadequately. In the current research several enhancements of NiedSim are planned in order to be able to generate temporally and spatially correlated synthetic rainfall. The regionalization of the precipitation statistics will be based on non-parametric distribution functions using spatial copulas. Copulas will also be used to describe the highly complex scaling behavior of precipitation. Furthermore, a robust approach for precipitation occurrence will be developed. Finally, data of regional circulation models will be used to account for climate effects.

Bárdossy, András ; Giese, Hartmut ; Haller, Bernd ; Ruf, Joachim: Erzeugung synthetischer Niederschlagsreihen in hoher zeitlicher Auflösung für Baden-Württemberg . In: *Wasserwirtschaft* 90(11) (2000), S. 548–553

P3.10 Modelling spatially anisotropic precipitation fields using a multiaffine model and GSI

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Stochastic modelling provides a cost-effective method for acquiring large quantities of high resolution precipitation data with realistic statistical properties to be used as an input for hydrological design studies. Multifractal models based on multiplicative cascades constitute a popular approach for producing rain fields with a correct spatial structure. These models are attractive since in case of spatio-temporal simulation, features of different sizes represented by the levels of the cascade can be given unique velocity vectors independent of other levels, and lifetimes of features can be related to the scale they represent. At present, the standard approach in these models is to assume that the scaling of the rain fields is isotropic in space. However, in reality the precipitation fields are rarely isotropic but often consist of oriented structures. Generalized scale invariance (GSI) is a formalism that defines the notion of scale in anisotropic scaling systems. Use of GSI makes it possible to produce physically realistic multifractal fields with a correct anisotropic scaling structure. Previously multiplicative cascade models have been extensively used to produce isotropic precipitation fields, and GSI has been used together with continuous cascade models (e.g. Universal Multifractals) to produce anisotropic multifractals. Here a multiaffine model based on a bounded lognormal cascade is coupled with GSI-formalism to produce rain fields with an anisotropic structure that varies from level to level in the cascade. Precipitation fields are first generated with known anisotropy parameters and a set of ellipses are fitted to the two-dimensional ensemble average power spectrum of the resulting fields. The GSI parameters of the modelled fields are then extracted from the ellipses and their values are compared to the original parameter values used in generating the fields. Comparisons between the original and estimated GSI parameter values show that the proposed method is able to reproduce the desired anisotropy. At the same time the descriptive statistics of the generated precipitation field comply with the requirements set by the multiaffine model. The method provides a new proposition for spatio-temporal simulation of precipitation fields with adjustable anisotropic spatial structure for features of different sizes, velocity fields and lifetimes, and consequently a new perspective to a more realistic statistical simulation of precipitation.

P3.11 Stochastic modeling of high resolution space-time precipitation fields

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Representing the fine scale structure of precipitation fields both in space and time (~1km2 and ~5min) is a crucial issue in hydrology for example for the prediction of runoff and drainage in urban settings or of flash floods in small mountainous river basins. In these (and many other) cases there is strong evidence that the small scale variability of rainfall significantly affects the runoff response and needs to be properly accounted for. One option is to simulate high resolution precipitation fields by numerical weather prediction models. Although these are based on physical process understanding, several parameterizations are still required and the models are computationally demanding. Another alternative is that of stochastic processes which have been successfully used in operational hydrology for decades. Although there is a vast literature concerning the stochastic representation of precipitation in time, the lack of high-resolution space-time data so far has been a major restriction on developing and evaluating the performance of spatio-temporal stochastic models. In this respect, weather radars can provide the proper data to evaluate such models. In this study, we present a novel stochastic model for high resolution space time precipitation that captures the most important features of the statistical structure of precipitation. The model structure is parsimonious and is based on three different stages (a. A storm arrival process, b. the temporal evolution of areal statistics and c. the full spatiotemporal evolution of the precipitation fields during a storm). The model is validated for an area on the Mediterranean side of the European Alps. The model calibration is based on radar data from the operational network of MeteoSwiss (Federal Office of Meteorology and Climatology). The radar performance in this area is considered optimal. The model is compared against a well-known space-time model for rainfall based on point processes (spate-time Neyman Scott). The main result is that the new model outperforms the spatiotemporal Neyman Scott model both for point scale and areal statistics. The differences are significant especially for fine temporal (< 1 h) and spatial scales (1 km2). The first version of the stochastic model developed for homogenous areas in terms of precipitation statistics is extended in order to be applicable in areas with strong orographic influences on the precipitation structure. The extensions of the model take into account the anisotropy of the precipitation fields, the non-homogeneous occurrence of precipitation and also the spatial variability of precipitation depth. These important extensions are tested is the Alpine area of central Switzerland. Since radar efficiency is low due to beam blockage, clutter etc., a new gridded precipitation product of MeteoSwiss is used for calibrating the model. The product combines the accuracy of point scale measurements by rain gauges and the high spatial resolution of the radar.

P3.12 Implementation of calibration methodology in a multivariable analog model applied to precipitation and snow forecasting

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Dynamic meteorological models have drawbacks in forecasting highly dependent variables of parameterizations or local processes, such as precipitation and snow. Alternatively, statistical models give estimations based on statistical relationships between input variables and output variables without information about related (lineal or non lineal) physical processes. The statistical analog models are based on finding similar atmospheric situations in an historical data base to any particular atmospheric situation to be modeled. The addition of different variables in the analog searching includes heterogeneity that should be taken into account in the mathematical methodology in order to optimize the analog model. The present work shows the calibration process of several analog models for forecasting precipitation and snow in a complex terrain. Moreover, the validation of the analog models is also shown. The calibration process shows a new methodology to find statistical linkages between diverse meteorological variables. Probabilistic results are shown in an area with 15 stations in the Sierra of Guadarrama (inner area of the Iberian Peninsula), highlighting the optimum analog model. The optimised model is also validated using an independent period time. Results of different calibrated models are shown, highlighting how the inclusion of calibration methodologies in an analog model modifies the validation statistics.

P3.13 Summer monsoon rainfall change over Bangladesh using a high resolution AGCM

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Summer Monsoon Rainfall was simulated by a global 20 km mesh atmospheric general circulation model (AGCM), focusing on the changes in the summer monsoon rainfall of Bangladesh. Calibration and validation of AGCM was performed over Bangladesh for generating summer monsoon rainfall scenarios. The model produced summer monsoon rainfall was calibrated with a ground-based observational data in Bangladesh during the period 1979-2003. The TRMM 3B43 V6 data is also used for understanding the model performance. The AGCM output obtained through validation process and made it confident to be used for near future and future summer monsoon rainfall projection in Bangladesh. In the present-day (1979-2003) climate simulations, the high resolution AGCM produces the summer monsoon rainfall better as a spatial distribution over SAARC region in comparison with TRMM but magnitude may be different. Summer monsoon rainfall projection for Bangladesh was experimentally obtained for near future and future during the period 2015-2034 and 2075-2099, respectively. This work reveals that summer monsoon rainfall simulated by a high resolution AGCM is not directly applicable in application purpose. However, acceptable performance was obtained in estimating summer monsoon rainfall over Bangladesh after calibration and validation. This study predicts that near future summer monsoon rainfall on an average may decrease about -0.5% during the period 2015-2034 and future summer monsoon rainfall may increase about 0.4% during the period 2075-2099.

P3.14 Stochastic simulation of intermittent rain rate fields with realistic transitions between dry and rainy regions

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A new geostatistical framework for the stochastic simulation of intermittent rain rate fields with realistic transitions between dry and rainy regions is presented. It is based on the decomposition of the rain rate field into a deterministic trend function called the “dry drift” and a stochastic component represented by a 2nd order stationary random function. The simulator can be parameterized using either radar data or rain rate time series. First, the spatial structure of the rainfall occurrence process (1=rainy, 0=dry) is characterized using an indicator variogram. A series of one-to-one transformations is then applied in order to normalize the (positive) rain rate field and decompose it into the sum of a deterministic trend (i.e., the dry drift) and a 2nd order stationary Gaussian field. The spatial structure of the normalized Gaussian field is described using a variogram. The simulation scheme consists of two steps: first, the sequential indicator simulation algorithm is used to generate a rainfall indicator field with a prescribed indicator variogram (defined previously during the analysis). The sequential Gaussian simulation algorithm is then applied over the rainy areas in order to generate a Gaussian field with prescribed spatial structure (also defined during the analysis). At the end, the Gaussian field is back-transformed into the original parameter space. During the back-transformation, the distance to the closest simulated dry region is used to compute the dry drift and ensure that the simulated rain rate field exhibits realistic transitions between dry and rainy regions.

Session 4

Precipitation in Hydrology and Water Resources

Mozart foyer

P4.1 Evaluating the potential of X-band polarimetric radar-rainfall observations in mountainous hydrology

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Alpine catchments hydrology is strongly determined by orographic effects on the space-time structure of precipitation. Mountain precipitation results from a multitude of processes such as mechanical lifting, enhancement, shadowing etc. Many of these processes are poorly understood, especially at small spatial and temporal scales. As a consequence this limits the predictive capability of hydrological models and our understanding of the majority of the precipitation-related natural hazards occurring in both high elevations and lowlands. This lack of knowledge is mainly due to the intrinsic limitations of our best measurement techniques: raingauges and weather radars. Raingauges provide relatively accurate but only point-like observations, while weather radars produce instantaneous spatially distributed rainfall maps but their operation over complex terrain creates a number of limitations, which make their estimates reliable in a limited space-time domain. A solution to this limitation might be the use of a number of cost-effective short-range X-band radars as complement to raingauges and conventional, large and expensive weather radars. The study focuses on a 64 km2 mountainous basin located in Northern Italy. Rainfall observations from a dense network of raingauges located at different elevation, a C-band operational radar and a locally deployed X-band dual-polarization radar are used to force a semi-distributed hydrologic model. A number of storm events are simulated and compared to investigate the potential of using high-resolution rainfall input from the X-band radar for simulating the hydrologic response. Events have been discriminated on the basis of rainfall intensity, snowfall limit and hydrological response. Results reveal that in contrast with the other two rainfall sources, X-band observations offer an improved representation of orographic enhancement of precipitation, which turns to have a significant impact in simulating peak flows.

P4.2 Relationship between precipitation and runoff in the Nitra River basin in Slovakia

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The main aim of this study is to analyze the long-term trends of water balance characteristics in the Nitra River Basin in Slovakia. Inter-relationships were studied between basic elements of hydrological balance including precipitation and discharges. The research was based on 95-years long time series from period 1916 to 2010. The Nitra River Basin is situated in the western part of Slovakia covering an area of 4,501 km2. The climate in the basin is typical for Central European larger intra-mountainous depressions and lowland areas, covering the whole range of climatic regions from warm through moderately warm and to cold, dependent on altitude. A total length of the Nitra River is 169.7 km, with its main right-side tributaries Nitrica (319 km2) and Bebrava (631 km2). The average altitude is 372 m a.s.l. with the lowest level of 108 m a.s.l. at the closing profile at Nove Zamky and the highest of 1346 m a.s.l. at Vtacnik mount. The input data used for analysis were daily precipitation depths, average daily river discharge and maximum annual discharge series. Six precipitation stations with a time-series length of 95 years (1916–2010) were used for calculation of the areal precipitation using the precipitation gradient approach. Maximum annual discharge analysis showed some changes in long-term trend. Since the 1930`s there has been a slight decrease in extreme discharges, which stopped around 1990 and then there is a slight increase in maximum flow at Bebrava and Zitava gauging stations. At Nitrianska Streda gauging station a significant change in the maximum flow does not occur, the long-term trend is constant during the observation period. The long-term trends of annual precipitation at individual precipitation stations are constant or slightly decreasing. The average annual precipitation during 1916–2010 was 696 mm, varying from 1081 mm in 2010 to 466 mm in 1917. The mean annual runoff at Nove Zamky water gauge was 141 mm and the evapotranspiration 555 mm. The average runoff coefficient was equal to 0.202 (varying from 0.086 in 1933 to 0.361 in 1967). We consider the long-term trend (during 1916–2010) of areal annual precipitation at the Nitra River Basin as well as discharges at the closing profile at Nove Zamky to be constant. Acknowledgements: This work was supported by the Slovak Research and Development Agency under the contract No. APVV-0496-10 and results from the project implementation of the “Centre of excellence for integrated flood protection of land” (ITMS 26240120004) supported by the Research & Development Operational Programme funded by the ERDF.

P4.3 Rainfall nowcasting by combining radars, microwave links and rain gauges

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In this work, measurements from radar, rain gauge, and microwave link are combined in order to provide high-resolution rain rate estimates and short lead time forecasts required by urban hydrology for the monitoring of sewage systems in urban areas. The objective is to retrieve with greater accuracy the rain rate, at the ground level, that is consistent with all the different measurements, incorporating the uncertainty associated with the different sources of information. Each sensor has its drawbacks, but, once the errors of these sensors are correctly parametrized, by combining them the retrieved rain rate improves significantly. We use a 3DVar to find the best estimate for the rain rate, and its error covariance. Short-term rain rate forecasts are then produced by assuming lagrangian persistence. A velocity field is obtained from the radar-derived rain fields, and the rain rate field is advected using the Total Variance Dismishing (TVD) scheme. Since the forecast windows are smaller than 6h, we can assume that the advection, so the propagation model, is linear. This allows us to also propagate the error covariance of the rain rate, and we can use these two in the 3DVar at the next observation time. This approach can be seen as a Variational Kalman Filter (VKF), in which the covariance of the prior is not constant but dependent on time. Idealised experiments show that the VKF is precise and gives good results due to the dynamic error covariance, it is stable and the bias can be kept under control. It is a convenient form for online real time processing, it is easy to formulate and implement. The proposed approach is tested using real data from 14 rain gauges, 14 microwave links and the operational radar rain product from MeteoSwiss located in Zürich (Switzerland).

P4.4 The use of X-band polarimetric radar to assess the impact of different temporal and spatial resolution on a drainage system in Rotterdam urban area.

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Heavy rain precipitation can cause catastrophic flooding events over urbanized areas. Accurate information about rainfall is needed to be able to mitigate consequent damages. Due to the high percentage of imperviousness and low rate of vegetation interception, the reaction of urban drainage catchments to a storm event is short. Therefore, to describe fast runoff processes and short response times, urban hydrological modelling requires high resolution rainfall data. In this work, a X-band horizontal scanner polarimetric weather radar (IDRA) is used to obtain accurate rainfall rate estimates of severe thunderstorms at high temporal and spatial resolutions. Moreover, the impact of deep convection; i.e., high rainfall rates, over urban areas, will be addressed to analyse the hydrological response time of urban drainage systems. A small-scale convective storm case from January 03rd 2012 was observed by IDRA from the Dutch national meteorological observatory CESAR. Rainfall rate estimates obtained from IDRA at elevation scan of 0.500 will be used to analyse urban hydrological responses under rainfall rate temporal resolutions of 1 min and 5 min, and spatial resolutions of 30 m and 100 m. The analysis will be performed in one of the sewer districts of Rotterdam urban area.

P4.5 Radar-raingauge rainfall re-analyses in the Cevennes region, France: methodology and error characteristics

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Within the activities of the Cévennes-Vivarais Mediterranean Hydrometeorological Observatory (http://www.ohmcv.fr), a ~10-year rainfall re-analysis is being produced at LTHE by merging radar and raingauge data. The Cévennes-Vivarais region, prone to heavy precipitation events and subsequent flash-floods, is one of the main target areas of the international HyMeX project (http://www.hymex.org). This project aims at studying the hydrological cycle in the Mediterranean with emphases on the hydrometeorological extremes and their evolution in the coming decades. Establishing long series of rainfall spatial estimates, associated with a relevant description of the estimation errors, is critical in this context. For a window of 160 x 200 km², radar and raingauge data are collected from three operational organisms (Météo-France, Service de Prévision des Crues du Grand Delta and EdF/DTG). Three rainfall products are elaborated, corresponding to varying time resolutions as a function of the magnitude of the rain events: (1) product 1: for each day of the year, rainfall maps (1 km² space resolution; 24-hour time resolution) are produced through ordinary Kriging of the available raingauges; (2) product 2: for a selection of the most intense rain events, radar maps (1 km² space resolution; 15, 30 min, 1-hour time resolutions) are elaborated from the Météo-France radar mosaic involving 4 radars of the ARAMIS network in the considered domain (Bollène, Nîmes, Sembadel, Montclar); (3) product 3 : merging radar and raingauge data yields another series of detailed rainfall maps for the most intense rain events (1 km² space resolution; 1-hour time resolution). For product 2, a simple processing of the radar data is considered with the checking of the data for residual ground clutter and the optimization of an effective Z-R relationship using the daily raingauge measurements, in order to make products 1 and 2 as consistent as possible at the daily time step. The critical analysis of raingauge data is a key component of the procedure: it is performed with a geostatistical technique aimed at detecting raingauge measurements incoherent with those of the neighbouring raingauges. For product 3, the Kriging with external drift (KED) technique is used and systematically assessed with respect to the ordinary kriging (OK) of the hourly raingauges and the hourly radar products through a cross-validation technique. Furthermore, a procedure is implemented to accurately quantify kriging estimation variances for both the OK and the KED techniques, as a practical measure of the estimation quality of product 3. Based on the 12 rain events of the re-analysis prototype realized for 2008, some error characteristics will be presented for a range of spatial (1 – 100 km²) and temporal (1 – 12 h) scales.

P4.6 Conceptual radar rainfall ensemble generation and its impact on the catchment hydrological response during cold season precipitation

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Uncertainty in precipitation input and rainfall-runoff model parameters motivate the usage of an ensemble approach in operational hydrological forecasting. Traditionally, stochastic methods are used to estimate uncertainties associated with the measured input precipitation either obtained from rain gauges or by weather radar measurements. In current paper, two conceptual precipitation uncertainty generation methods are described, which contrary to previously developed approach can directly be obtained from the volumetric information measured by operational weather radar. The first method focuses on the vertical variability of the precipitation field, while the second method identifies the variability in the relationship to convert the radar signal into a rainfall intensity. For the winter half-year of study, results show that in case all sources of error associated with weather radar rainfall estimation are properly accounted for, precipitation estimates are found to be of similar quality as those obtained from in situ rain gauge measurements. Even without bias correction or other forms of radar-gauge adjustment. The total uncertainty in the rainfall estimates for the applied methods locally is about 40% and 10%, respectively. Both conceptual radar rainfall ensemble methods are used to simulate the hydrological response of a medium-sized catchment (1600km2) using 200 optimal parameter sets of a conceptual rainfall-runoff model. Using the corrected radar data the model is well able to simulate the observed discharge response. However, when focusing on the uncertainty in the discharge estimates, results show that the hydrological model parameter variability has a much larger effect than precipitation uncertainty. The latter only adds about 20% and 5% of uncertainty, respectively, for the two different ensemble generation methods. This shows the effectiveness of catchments of this size to filter the large uncertainty of the discrete input signal.

P4.7 Precipitation – the Ob River runoff in Western Siberia and their dendrochronological interpretation for the last centuries

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It is known that hydrologic cycle is one of main component of the climate system and changes in the terrestrial hydrologic budget influence the extent of sea-ice cover in Arctic, freshwater transport into the North Atlantic and deep ocean convection. It notes an increase of air temperature and annual precipitation over the northern Hemisphere during the last century, especially for cold seasons (IPCC, 2007). Also some authors note that the average annual discharge of fresh water from 6 largest Eurasia rivers to the Arctic Ocean increased by 7% from 1936 to 1999 (Peterson et al., 2002). The Ob River is one of the great rivers of the northern Hemisphere (catchment basin is ~3 millions km2, floodplain area is ~40 000 km2, average runoff is 400 km3 yr-1) and transports from south to north an amount of heat of more than 1010 MJ (Odrova, 1980). The Ob plays a crucial role for climate of the floodplain and adjacent uplands during the ice-free period and there are both cooling and warming effects streamflow to air temperature. Precipitation over the Ob catchment basin and discharge in Salekhard gauge station (66°31′N, 66°36′E) during the last century were studied. More than 80% of the Ob runoff comes from basin southward 61°N. Precipitation records of 60 meteorological stations for the cold season (October - April) were compared against the Ob discharge. The Ob basin was shared out 4 basins of the large tributaries: the Tobol (426x103 km2), the Ishim (177x103 km2), the Irtysh (1643x103 km2), the Upper and the Middle Ob (1047x103 km2). For the studied basins there is positive trend of the cold season precipitation since 1950th. Positive correlation between the precipitation and discharge was revealed. Only the Irtysh River has very weak long-term streamflow increase over the last century. The annual discharge of the Lower Ob at Salekhard do not demonstrates the increase of streamflow for period of records (1934-2009). On the contrary, there is weak decrease of the Ob flow since the late of 1970th to present days for the summer time. At the same time there are perturbations of the Ob runoff during hydrological seasons. Causes of the perturbations are discussed. Dendrochronological reconstruction of the Ob discharge for the last three centuries will be presented.

P4.8 Validation of synthetic precipitation time series application for probabilistic sizing of stormwater reservoirs

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Sizing of stormwater reservoirs is crucial for the effectiveness of stormwater drainage systems. Choice of proper retention volume is always a matter of balance between the cost of building system and the cost of the system capacity being exceeded over the lifetime of the system, the former cost being approximately proportional to volume. Current engineering methodology of stormwater reservoir sizing is reorienting from simple calculation techniques, based on the assumption of constant rainfall intensities derived from IDF curves, towards drainage network modeling and probabilistic assessment of necessary retention volumes. Modeling of drainage networks is realized in the environment of specialized applications allowing both for modeling of surface outflow and unsteady flows in sewers, caused by predefined rainfall hyetographs. Resulting outflow hydrographs provide the basis for the calculation of the required retention volume. Stormwater reservoirs can be added as an element of hydrodynamic models and their functioning can be analyzed for different outflow conditions induced by various local rainfall scenarios. Certainly, necessary stormwater reservoir volume varies between rainfall events. However, a sufficiently large set of calculated volumes can be analyzed statistically to produce an exceeded probability plot of necessary reservoir volumes. This plot gives a sound base for the adoption of the optimal stormwater reservoir size with accordance to the desired reliability of the drainage system. Implementation of probabilistic sizing of stormwater reservoirs requires access to long local precipitation time series of high resolution. Particularly in case of urban drainage systems, local precipitation time series used as inputs to hydrodynamic models should exceed 30 years in length. However, such precise rainfall data is frequently unavailable to engineers. We propose to substitute real precipitation time series with synthetic ones. In our research, we verify the appropriateness of this methodology with an example of a local drainage system in Wroclaw, Poland. A hydrodynamic model of a drainage system equipped with a stormwater reservoir at its outflow is developed with the SewerGEMS program. Stormwater outflows are simulated for rainfall events derived from real and synthetic time series. In the case of real time series, simulations are made for 250 events identified from summer rainfall measuring campaigns from 38 years in Wroclaw. A 5-minute time series from stochastically disaggregated daily rainfall totals from the same 38-year period, by means of a microcanonical cascade with a beta-normal generator, are used as synthetic data. For both precipitation datasets, plots of necessary stormwater reservoir volumes versus probabilities of exceed are derived and compared together. Similarities of both plots demonstrate that real precipitation time series may be substituted with the synthetic time series with no change in optimal reservoir sizing.

P4.9 Enabling the use of high-resolution precipitation data from radars in urban water management

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Urban water managers looking for new strategies to make their urban water system more resilient and climate adaptive are often confronted with limited reliable information on urban water cycle components. In urban areas the most important component is precipitation, because in most cities pluvial flooding is the dominant flooding type. Urban water systems are responding rapidly to local heavy rainfall, and space for water storage is limited. Traditionally rain gauges are used for measuring precipitation. Because urban water system analysis requires such a high level of detail on precipitation information, a very dense network of rain gauges (more than 1 gauge per 10 km2) is required, but placing rain gauges in urban areas proves to be both challenging and costly. Many national weather institutes operate one or more weather radars nowadays. This provides a unique opportunity for urban water management to get precipitation information at higher spatial and temporal resolution. However, there are some issues regarding the use of weather radar data: (1) The quality of uncorrected rainfall intensities from weather radar data alone is not good enough for hydrological water system analysis, depending on the weather conditions and the distance of an area from the radar; (2) Radar data as delivered by national weather services are subject to uncorrected measurement errors which have to be postprocessed by the data user; (3) The radar data formats are not easy to use for urban water managers; (4) The available radar composites are derived from only national radars and the composites are often limited to country borders; (5) Timing of delivery and the completeness of the radar data varies, due to variations in the processing chain of the radar data. The joint precipitation data processing tools of HydroLogic and hydro&meteo are able to fill the gap between the information needs of urban water managers and the available rainfall data. These tools have been developed and improved during many years. Radar precipitation is now available on 1x1 km resolution at 5 minute interval, which is derived from five Dutch, German and Belgian radars, adjusted in real-time to over 500 ground observations. The SCOUT tools are used to create the best data quality possible on the basis of radar data and rain gauge monitoring, including adjustment, quality labelling, correction and updating as soon as new data become available. The HydroNET online web tools are used for storage, visualisation (time series, GIS, statistics) and decision support to water managers. The emergence of this high-resolution spatial rainfall data has also been the starting point of a whole new range of online applications. These include highly detailed (0.5 m resolution) hydrological surface-runoff modelling in urban environment and combine radar rainfall data with data from sewer telemetry networks to analyse sewer network response to actual rainfall events and improve sewer maintenance efficiency. At present over 120 water authorities in the Netherlands use these tools for their daily work and the approach is expanded to German and Irish water authorities.

P4.10 Extreme rainless periods in Vojvodina province

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The Vojvodina Province is northern part of the Serbia and it is predominantly agricultural region. Agriculture is a basic section of economy. The climatic conditions of the Vojvodina Province display the features of semi-arid temperate continental climate. Drought period with different duration and time of occurrence during growing season are common phenomenon in Vojvodina Province and sometimes it becomes arid area with pronounced water deficit. The droughts that have occurred in Vojvodina Province in recent years were of dimensions of an elemental catastrophe in respect of agricultural production. Many authors investigated drought analyses in Vojvodina Province. Some of them deal only with precipitation, but the others investigate water balance. Drought with its characteristics is the phenomenon of very complex properties. Using either one or more component such as periods of no rainfall, insufficient rainfall, high air temperature, low relative air humidity, high evapotranspiration, etc, this phenomenon can be determined. Although the many definitions and indicators of droughts exist, the fact is that the main cause of drought is insufficiency of rainfall. Either single component or a number of components can describe drought, but rainless period is the most important for the drought phenomenon and it is taken into consideration in this paper. Extreme dry weather intervals are also synonymously called extreme rainless periods, or droughts. Complete analysis of the stochastic process of extreme dry weather intervals during growing season at meteorological station Rimski Sancevi, Vojvodina Province is carried out in this paper. An application of the method is shown for the part [0,t] of the year which is equal to the growing season, because it is of prime importance for agriculture. Period of this analysis is 1949-2010. The analysis included all available data on extreme dry weather intervals, which are defined as the upper extremes of intervals of no rainfall longer than 15 days. Roughly speaking, the reference value Yr is 15 days for field crops. All important components of the process, such as drought duration, time of occurrence, number of droughts in a given time interval [0,t], the longest drought in a given time interval [0,t], and its time of occurrence, are taken into consideration. Droughts are defined here as the upper extremes of dry weather intervals and are treated as a random number of random variables in an interval of time [0,t]. The method is based on the assumption that droughts are independent, identically distributed random variables and that their occurrence is subject to the Poisson probability law. This is confirmed for analyzed meteorological station. Good agreement is found between the theoretical and empirical distribution functions for all analyzed components of the process. Also, Standard precipitation index for given time interval are determined.

P4.11 Impacts of streamflow data assimilation for flood forecasting using numerical weather prediction

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In this paper, we investigate the performance of an advanced data assimilation (DA) procedure on short-term streamflow forecasting using a distributed hydrological model driven by numerical weather predictions. The sequential DA procedure is based on (1) the multivariate rainfall ensemble generator, which provides spatial and temporal correlation error structures of input forcing and (2) lagged particle filtering to update past and current state variables simultaneously in a lag-time window to consider the response times of internal hydrologic processes. The procedure is evaluated for streamflow forecasting of three flood events in two Japanese medium-sized catchments (Maruyama and Katsura). The rainfall ensembles are derived from ground based rain gauge observations for the analysis step and numerical weather predictions for the forecast step. The ensemble simulation performs multi-site updating using information from the streamflow gauging network and considers the artificial effect of the dam release. Sensitivity analysis is performed to assess the impacts of uncertainties coming from DA such as random state noise and different DA methods with/without objectively-induced rainfall uncertainty conditions. The results show that multivariate rainfall ensembles provide sound input perturbations and model states updated by lagged particle filtering produce improved streamflow forecasts in conjunction with fine-resolution numerical weather predictions. The strength of the proposed procedure is that it requires less subjectivity to implement DA compared to conventional methods using consistent and objectively-induced error models.

P4.12 Combining radar and raingauge observations: the operational experience with the Italian radar composite

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The estimation of rainfall fields, especially its spatial distribution and position is a crucial task both for rainfall nowcasting and for modeling catchment response to rainfall. Some studies of literature about multisensor have suggested that discharge estimations are improved when radar and rain gauge data are combined to estimate input rainfall fields.Sinclair and Peagram (2004) have proposed the Conditional Merging (CM) technique, a merging algorithm which extract the information content from the observed data and use it within an interpolation method to obtain the rainfall maps. The idea is to combine the “real”, but punctual amount of rainfall measured by raingauges with the structure of covariance and correlation of rainfall maps estimated from remote sensors (radar network or satellite constellation). In this work is studied an enhanced algorithm based on CM, called Modified Conditional Merging.. The main innovation respect to classical CM is the estimation of the structure of covariance and the length of spatial correlation λ, for every raingauge, directly from the cumulated radar rainfall fields. The domain of application is the Italy, where are both available a dense network of raingauge measurements (about 2500 stations) and a QPE estimated by the Italian Radar composite. The MCM algorithm can be used in real-time over the whole domain to produce hourly the optimal rainfall maps. An application to several test cases together with the evaluation of algorithm performances are presented and discussed.

P4.13 Toward the optimal resolution of rainfall estimates to obtain reliable urban hydrological response: X-band polarimetric radar estimates applied to Rotterdam urban drainage system

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Weather observations are conventionally performed by single polarization C-band weather radars with a temporal and spatial resolution of 5 min and 1 Km, respectively. However, for urbanised areas, these spatial and temporal resolutions may not be sufficient to detect, monitor, and obtain accurate rainfall rate estimates of fast-evolving weather phenomena. It is also known that, due to the high percentage of imperviousness and low rate of vegetation interception, the reaction of urban drainage catchments to a storm event is much faster than rural ones. Due to land use characteristics of urban areas and also to the small scale of urban catchments (i.e., few hectares up to few square kilometres), it is not uncommon that the time lag between rainfall and runoff peaks is of the order of few minutes. Therefore, to describe fast runoff processes and short response times, urban hydrological modelling requires high resolution rainfall data. In this work, a S-band vertical profiler (TARA) and a X-band horizontal scanner polarimetric weather radars (IDRA) are used to characterize physical processes and obtain accurate rainfall rate estimates of severe thunderstorms at high temporal and spatial resolutions. Moreover, the impact of deep convection; i.e., high rainfall rates, over urban areas, will be addressed to analyse the hydrological response time of urban drainage systems. A small-scale convective storm case from January 03rd 2012 was observed by both, IDRA and TARA from the Dutch national meteorological observatory CESAR. It is expected the new insights will be revealed based on the polarimetric and the high-resolution capabilities from both radars. Rainfall rate estimates obtained from IDRA at elevation scan of 0.50 degrees will be used to analyse urban hydrological response times under different resolutions of rainfall input (from 1 min temporal and 30 m spatial resolutions to upscale 5 min and 1 km) and different hydrodynamic model settings for the rainfall-runoff process, in a highly impervious urban drainage system belonging to Rotterdam urban area.

P4.14 Capturing rainfall variability by coupling atmospheric and hydrologic forecast models

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Australia is one of the driest inhabited continents on earth with extremely variable climate conditions, characterised with high intensity short duration rainfall events or long lasting droughts Murphy et al., (2008). These dynamic climate conditions introduce a challenging task for operational decisions for water supply systems. To enhance Sydney Catchment Authority's (SCA) real-time stream flow forecasting capabilities a Short Term Ensemble Prediction System (STEPS) Bowler et al., (2006) has been introduced to capture rainfall forecast spatial and temporal variability. The STEPS rainfall forecasting scheme merges an extrapolated radar rainfall forecast with a high resolution Numerical Weather Prediction (NWP) to predict the rainfall field over the catchment. An integrated real-time spill forecasting system has been developed to improve SCA's reservoir inflows and spill forecasting capabilities. The system is based on Mike Customised forecasting shell. The HSFP rainfall run-off model is used to simulate the reservoir inflows. The model is operated via a custom made model "wrapper", which enables the forecasting shell to configure the catchment model with real-time rainfall and forecast rainfall information. Early days a scenario based rainfall forecast was used. The scenario, were arbitrary around what will happen in the future. The use of scenarios implies assumptions that in most cases are not verifiable. STEPS probabilistic rainfall forecast provided by CAWRC (Centre of Australian Weather and Climate Research) is utilised to capture the rainfall forecast spatial and temporal variability and to predict the reservoir inflows. The integration of STEPS rainfall forecast and hydrological models using a common interface has greatly enhanced the efficiency, timeliness and quality of reservoir inflow prediction for Lake Burragorang. This forecasting shell monitoring system provides the SCA with multiple levels of notification during flood events in accordance with water supply needs and regulatory requirements. Both the monitoring and predictive information produced by the MIKE Customised real-time forecasting shell enables effective operational decisions under extremely variable climate conditions The forecasted reservoir inflows are used as an input to the hydrodynamic model Mike 11 to route the inflows through the reservoir, thus forecast the timing of the spill and the volume of the spill.

P4.15 Dutch national rainfall radar project: a unique corporation

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Accurate insight in the dynamics and spatial variability of rainfall amounts is of paramount importance for numerous applications in the field of water management. Dutch governmental organizations for cities, polders and rivers are in need of the same high quality rainfall data and predictions. This project is a technical innovation but also an organizational innovative project: together we come further in the future. This talk reflects on the philosophy of the product, the results and user experiences as well as the ambitions for the future. The National Rainfall Radar integrates data from 6 cross boundary radar stations as well as numerous in situ measurements. The integration of all data sources is based on state-of-the art knowledge of radars and geostatistics. Besides better data, the RainApp facilitates easy access of these data by the internet to facilitate its use in daily practice. The concept and software developed can easily be applied to other countries around the world. The initiative comes from a group of water boards in the Netherlands that joined their forces to fund the development of a new rainfall product. Currently, rainfall data is provided by meteorological agencies. Water authorities have their own ground stations which are not integrated in the radar data. The National Rainfall radar integrates all the available rainfall information in a generic, transparent, efficient and reliable way. Thereby it bridges that cap between consultancy practice and scientific knowledge. Besides the KNMI (Dutch Meteorological Organization) experts from three Dutch universities and Deltares were closely involved in the development. Together with them, methods were tested en verified before making it operational. The National Rainfall Data is a modular software product. The software modules are programmed in open source, which means that experts from all over the world can contribute to improvements. This makes it possible to keep up with new developments and innovations. To guarantee the reliability and robustness, new code is only released after thorough test procedures. A brief overview of the modules: (1) Radar composite module: (a) Integration of raw data from 6 radar stations from KNMI (Holland), DWD (Germany) and KMI (Belgium); (b) Translation of raw radar images for to rainfall intensities per km2 every 5 minute interval; (c) Efficient clutter removal algorithms. (2) Data assimilation module: (a) Calibration of the radar based rainfall with ground truth (raingauges) in real time; (b) Implemented state-of-the art scientific knowledge about geostatistics. (3) Rainfall forecasting module: (a) Nowcasting, every 5 minutes rainfall forecast for every 1 km2 for to 2 hours ahead at 5 minute intervals (under construction); (b) Numerical weather prediction outcomes: lead times up to 10 days. (4) Operational delivery module: (a) Generation of data in widely-accepted formats, allowing for easy integration with other systems; (b) Web access for laptop computers and mobile devices like Ipad.

P4.16 Elimination of non-precipitating echo due to anomalous propagation and wind turbine effects using dual-polarization weather radar

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The study addresses the effect of interaction between wind turbines that are placed far from the radar and anomalous radar beam propagation (AP) in radar-rainfall estimates. The interference of wind turbines in radar observations often leads to significant amounts of rainfall erroneously estimated due to the fact that wind turbines are generally clustered. In this study, the authors propose a novel approach to identify and eliminate wind turbine clutter as well as common AP effects. The approach benefits from the new polarimetric capability recently added to the WSR-88D NEXRAD radars in the United States. The primary objective is to devise a physically sound and fully automated dual-polarimetric method that effectively handles AP features that are hard to characterize using reflectivity data alone. The authors explore the feasibility of using polarimetric variables such as differential reflectivity, copolar correlation, and specific differential phase in addressing the posed issue. Accordingly, they develop a threshold approach for the copolar correlation that is conditioned on horizontal reflectivity values. This conditional threshold method is combined with the existing AP detection algorithm, implemented in the Hydro-NEXRAD system, which uses three-dimensional structure of horizontal reflectivity. The proposed method shows good performance in eliminating non-meteorological radar returns due to AP for the presented cases. The quantitative evaluation of radar-gauge comparison also demonstrates that the method reduces scatter and improves agreement between radar and rain gauge rainfall estimates.

P4.17 The hydrological effects of using high- vs. coarse-resolution rainfall products in a small Dutch lowland catchment

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Hydrological models require rainfall data as input, and it is believed that high-resolution rainfall products will result in a more accurate model outcome than coarse-resolution rainfall products. Nowadays, radars are often used to derive high-resolution rainfall fields, both in space and in time. If such products are used in large catchments to force a spatially distributed hydrological model, then it is very likely that they will result in a more accurate model outcome then if the often small number of rain gauges within the catchment would have been used. It is, however, unclear what the benefits of high-resolution above coarse-resolution rainfall products are if the catchment area is very small. Therefore, the objective of the current study was to evaluate the benefits of having high-resolution (spatial and temporal) radar rainfall above coarse-resolution radar rainfall and rain gauges. This study focuses on the Hupsel Brook catchment, which is a 6.5 km2 catchment in the East of The Netherlands. To evaluate the benefits of high-resolution rainfall products, the Spatial Processes in HYdrology (SPHY) model was forced with radar rainfall products of various resolutions. The highest resolution radar rainfall product (X-band weather radar SOLIDAR, located in Delft, The Netherlands) used in this study has a spatial resolution of 120 m and a temporal resolution of 16 s and covers the period of 1 May 1993 through 30 April 1994. This product is assumed to be the “truth” and was transferred to the Hupsel Brook catchment as being an artificial high-resolution rainfall radar product. The coarser resolution products all originate from this product, being only resampled in space and/or time. Single radar cells were used for the artificial rain gauges. Effects were mainly analyzed on streamflow generation and reduction in evapotranspiration.

P4.18 The concept of evapotranspiration tagging: A case study for the Poyang Lake region in China

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Land – atmosphere interaction analysis still lacks adequate methods for explicitly answering the central question of where precipitated water has originally evaporated, and likewise, where and to which extent evaporated water of one region returns as precipitation in the same or another region. Current approaches for estimating the precipitation recycling ratios are based on Budyko's model, backward trajectories algorithm, Lagrangian techniques, or stable water isotope analysis. We have developed a process based approach and implemented it into the mesoscale meteorological model MM5. It allows to tag the moisture evaporating from a certain region into the atmosphere, and to track it till returning to the land surface as precipitation. For that purpose, the new approach for evapotranspiration tagging includes not only the original physical process modules of MM5, but also new model variables and equations for the tagged moisture, accounting for atmospheric processes like e.g. transport, diffusion, resolvable scale phase transitions and precipitation physics. Our case study investigates, where, when and to which extent the evapotranspirating water of the Poyang Lake region (about 28,000km2) in China, i.e. the largest freshwater lake in China, returns back to the land surface as precipitation. We will present the concept of the method and how the method contributes to the assessment of evapotranspiration origin on regional precipitation.

P4.19 Rainfall reanalysis based on radar- and rain gauge data in the context of distributed hydrological modelling of nested watersheds in the Cevennes-Vivarais region, France.

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In the Cevennes-Vivarais region in France, flash-flood events can occur due to high intensity precipitation events. To better characterize the hydrological response and the dominant processes at work during such events, a number of small-scale nested watersheds (<100 km² typically), sampling various landscapes of the Mediterranean region, is considered in this work. For hydrological modelling, it is important to have an accurate representation of the forcing rainfall event with spatial and temporal resolutions adapted to the hydrological dynamics of the watersheds of interest.

To analyse the effect of rainfall data type and resolution on hydrological modelling, rainfall reanalyses are being produced at varying spatial and temporal scales, and using varying data types. So far, the reanalyses were based on data from the operational rainfall observation systems (ARAMIS- Bollène S-band weather radar, and hourly and daily rain gauge networks of Meteo France, EDF and the Service de Prevision des Crues du Grand Delta) collected by the Cévennes-Vivarais Mediterranean Hydrometeorological Observatory (www.ohmcv.fr). Higher resolution data are available since the autumn 2012 from research rainfall observation systems deployed within the Enhanced Observation Period (2012-2015) of the HyMeX project (www.hymex.org).

Concurrent estimation methods are considered, including Ordinary Kriging of rain gauge data, refined radar data processing and a merging of both data types through Kriging with External Drift. One of the short-term objectives is to produce reanalyses making use of the available research data in order to increase their resolution and fit the requirements for the hydrological modelling of the research watersheds. Preliminary results of these rainfall reanalyses will be presented with a focus on their error structure for a range of spatial and temporal scales.

P4.20 Climate change impact analyis on rainfall extremes and urban drainage

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Under the umbrella of the IWA/IAHR Joint Committee on Urban Drainage, the International Working Group on Urban Rainfall (IGUR) has reviewed existing methodologies for the analysis of long-term historical and future trends in urban rainfall extremes and their effects on urban drainage systems, due to anthropogenic climate change. Current practises have several limitations and pitfalls, which are important to be considered by trend or climate change impact modellers and users of trend/impact results. The review considers the following aspects: Analysis of long-term historical trends due to anthropogenic climate change: influence of data limitation, instrumental or environmental changes, interannual variations and longer term climate oscillations on trend testing results. Analysis of long-term future trends due to anthropogenic climate change: by complementing empirical historical data with the results from physically-based climate models, dynamic downscaling to the urban scale by means of Limited Area Models (LAMs) including explicitly small-scale cloud processes; validation of RCM/GCM results for local conditions accounting for natural variability, limited length of the available time series, difference in spatial scales, and influence of climate oscillations; statistical downscaling methods combined with bias correction; uncertainties associated with the climate forcing scenarios, the climate models, the initial states and the statistical downscaling step; uncertainties in the impact models (e.g. runoff peak flows, flood or surcharge frequencies, and CSO frequencies and volumes), including the impacts of more extreme conditions than considered during impact model calibration and validation. Implications for urban drainage infrastructure design and management: upgrading of the urban drainage system as part of a program of routine and scheduled replacement and renewal of aging infrastructure; how to account for the uncertainties; flexible and sustainable solutions; adaptive approach that provides inherent flexibility and reversibility and avoids closing off options; importance of active learning.

References: Willems, P., Olsson, J., Arnbjerg-Nielsen, K., Beecham, S., Pathirana, A., Bülow Gregersen, I., Madsen, H., Nguyen, V-T-V. (2012). *Impacts of climate change on rainfall extremes and urban drainage.* IWA Publishing, 252 p., Paperback Print ISBN 9781780401256; Ebook ISBN 9781780401263

Willems, P., Arnbjerg-Nielsen, K., Olsson, J., Nguyen, V.T.V. (2012), 'Climate change impact assessment on urban rainfall extremes and urban drainage: methods and shortcomings', *Atmospheric Research*, 103, 106-118

Session 5

Precipitation Statistics and Climatology

Mozart foyer

P5.1 Analyses of Urban Rainfall Climatology Using Long-Term Radar Rainfall Data Sets

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Empirical analyses of rainfall climatology have been carried out for urban environments in the US (Baltimore, New York City, Atlanta, Milwaukee, Charlotte and Kansas City) based on long-term (10+ years), high-resolution radar rainfall fields derived using volume scan WSR-88D radar observations and the Hydro-NEXRAD algorithms. A central objective of these studies is to examine the urban modification of rainfall climatology. To address questions of urban modification of rainfall, empirical analyses based on long-term radar rainfall fields have been combined with numerical modeling experiments. Striking spatial heterogeneities of warm season rainfall have been documented and physical mechanisms associated with these urban-induced rainfall anomalies have been proposed. Lagrangian analyses of storm structure, motion and evolution play an important role in examining urban modification of rainfall, and more generally, in characterizing the spatial and temporal variability of rainfall. Stochastic storm transposition methods, based on "catalogs" of extreme rainfall events have been developed for rainfall and flood frequency analysis in urban watersheds. Long-term radar rainfall data sets have been combined with discharge observations from dense urban streamgaging networks to characterize the hydroclimatology of flooding in urban watersheds, with particular emphasis on the spectrum of the storm event hydrologic response in urban watersheds. In this poster, we synthesize urban hydroclimatology studies based on long-term radar rainfall data sets.

P5.2 Characteristics of extreme precipitation in Romania, on the basis of the intensity – duration-frequency curves

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Extreme precipitation generates flash floods, which, in certain geographic conditions may cause life loss and severe property damage. This study analyses extreme precipitation occurred in Romania, based on they characteristics: intensity, duration and frequency (IDF). Precipitation amounts exceeding certain thresholds are analysed, as selected for various durations (peak-over-threshold concept). Data were collected from 45 weather stations in the 1965 – 2007 interval, over the warm season of the year (April – October). The spatial distribution and the variability of the rainfalls' over time were monitored. Precipitation intensities corresponding to short (sub-daily) durations were rendered cartographically, through various occurrence frequencies (1/10, 1/50, 1/100 years). The temporal variability was analysed with the Mann-Kendall statistics. This paper is the output of the activity developed within CLIMHYDEX project.

P5.3 Statstics of watershed-scale dependence in rainfall, using optimal-contrast harmonic bases

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Regional estimation of rainfall at the scale of a watershed is important whenever a dense network of rain gauges is not available, for hydrologic prediction purposes reaching from flash-flood forecasting to water resources availability planning. The specific location-related precipitation dependence within the watershed, due to factors such as orography or dominant directions of wind and cloud advection, makes it difficult to construct a general algorithm for quantifying inter-site rainfall intensity connections. The present work, however, constructs coherence maps in time-frequency space, which are optimal in capturing common variation modes between sites, even when they are short-lived. The algorithm analyses the correlation between contrast-optimal time-frequency bases at the sites involved, in order to construct the respective time-frequency map. Future developments include the implementation of a multi-dimensional optimization algorithm.

P5.4 Understanding of precipitation process along Nigerian coast

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Rainfall in Nigeria is seasonal and depends on the position of the ITD (Inter-Tropical Discontinuity). Rainfall distribution over Nigeria shows double maxima (June-July and Sept-Oct) the South and single peak(August) in the North. The important questions on rainfall are concerned with the onset, cessation and length of rainy season, the distribution of rainfall amounts through the year and risk of dry spells. Though Calabar, Uyo, Port Harcourt,Lagos Marine enjoys longer rainy season than dry, there exist pattern during rainy season.

The yearly rainfall data used in the present study were collected from Nigerian Meteorological Agency, Oshodi, Lagos office. For detailed studies of the year to year (1981-2010) variations in rainfall over the coast of Nigeria. Statistical technique is used to analyse the data. The stations individual four moving average were determined. So also the state/Area four moving average were determine for all the stations (four stations). The departures of each station from the state/Area four moving average were also determined. The individual stations four moving averages were compared with the departure of each state four moving average from the area average. This is to show the distribution of rainfall over the coast of Nigeria.

The investigation carried out on the coastline of Nigeria revealed that the pattern of mean annual distribution of rainfall along the coast of Nigeria. It shows that rainfall is generally zonal and that the amount of rainfall generally decreases from the coast inland. It can also be deduced from the graph that Little Dry Season (L.D.S) is well pronounced in the coastal area, decreases and irregular in the hinterland. The coastal areas also seem to have their maximum amount of rainfall much earlier than other parts. The first quarter (Jan-Mar) of each year in the period (1981-2010) of study is marked by minimal rainfall and can be regarded as commencement period of rainfall, second and third quarter (April-Sept) have greatest amount of rainfall while the last quarter has the least amount of rainfall corresponding to cessation period.

The present study shows that there are extremely high fluctuations in the year to year rainfall along the coast of Nigeria which is brought about by the absence of (or weakened) organized atmospheric rain-generating system during the rainy season. Therefore,for a sustainable management of water resources to be achieved, the various governments have to incorporate the environmental dimension into their developmental projects, particularly the monitoring, processing and exchange of relevant environmental information such as long-term climate information and prediction.

P5.5 On the estimation of satellite rainfall correlation

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With many satellite rainfall products being available for long periods, it is important to assess and validate the algorithms estimating the rainfall rates for these products. Many studies have been done on evaluating the uncertainty of satellite rainfall products over different parts of the world by comparing them to rain-gauge and/or radar rainfall products. In preparation for the field experiment Iowa Flood Studies, or IFloodS, one of the integrated validation activities of the Global Precipitation Measurement mission, we are evaluating three popular satellite-based products for the IFloodS domain of the upper Midwest in the US. One of the relevant questions is the determination of the covariance (correlation) of rainfall errors in space and time for the domain. Three satellite rainfall products have been used in this study, and a radar rainfall product has been used as a ground reference. The three rainfall products are TRMM's TMPA 3B42 V7, CPC's CMORPH and CHRS at UCI's PERSIANN. All the satellite rainfall products used in this study represent 3 hourly, quarter degree, rainfall accumulation. Our ground reference is NCEP Stage IV radar-rainfall, which is available in an hourly, four kilometers, resolution. We discuss the adequacy of the Stage IV product as a ground reference for evaluating the satellite products. We used our rain gauge network in Iowa to evaluate the performance of the Stage IV data on different spatial and temporal scales. While arguably this adequacy is only marginal, we used the radar products to study the spatial and temporal correlation of the satellite product errors. We studied the behavior of the errors, defined as the difference between the satellite and radar product (with matched space time resolution), during the period from the year 2004 through the year 2010. Our results show that the error behavior of the satellite rainfall products is quite similar. Errors are less correlated during warm seasons and the errors of CMORPH and PERSIANN are more correlated than those of TRMM through the study period. We calculated the correlation distance for the different products and it was approximately 75 km. The results also show that the correlation decays considerably with time lag. Our results have implications for the hydrologic studies using satellite data as the error correlation determines basin scales that effectively can filter out the random errors.

P5.6 Tropospheric circulation features during wet and dry years over West Africa

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This paper describes a composite study comparing some features of the tropospheric circulation over the region of West Africa in the monsoon season for dry (1981-85) and Wet (1998-2004) selected years. Zonal and meridional components of the monthly mean wind are computed directly with NCEP reanalysis data for the summer months limited to May, June and August. The potential temperature and moisture variables are also examined for the periods. The results of our analysis show major contrasts between the characteristics of tropical troposphere in West Africa in the dry and wet years. In 1981-85, the upper and lower troposphere are characterized by weaker flows in coexistent with stronger Africa easterly jet (AEJ) and a southward shift of the major circulation patterns as well as numerous dynamical parameters. The observed weak tropical easterly jet (TEJ) and vertical alignment of the AEJ and TEJ axes enhance the rainfall deficit in dry years. In contrast, during 1998-2004, the troposphere is dominated by stronger flows at lower and upper levels in concomitant with a weaker AEJ and intense northward shift of the zonal and meridional cells circulations. The observed strong vertical coupling between the zonal component anomalies at lower levels (monsoonal flow) and upper levels (TEJ), reflect the opposition in direction of mean winds at these levels. Over the region, the latitudinal location and intensity of the AEJ seems to be imperative, and tend to regulate the instability mechanisms. The instability is observed to be greater in August than in May in all the years. The contrasting convergence of monsoonal flow and the upper divergence associated with TEJ is linked with the activeness of the walker-type cell during the periods. At 925hPa lower level, the Inter-Tropical Discontinuity (ITD) surface positions in the region generally appear to be almost in same locations for both dry and wet years. As consequence, the length of the rainy season becomes unvarying. Instead, the 1998-2004 (wet) years are well dominated by more extreme rainfall. Finally, it is evident that the convective process over the tropical region of West Africa is dynamically influenced by strong upper-level divergence at TEJ level associated with ascent in the lower troposphere, where the disturbances build-up. Contrasts in the monsoon layer between wet and dry years may be related to these fluctuations. The results from this study serve as bases for further work on the tropospheric circulation features over the region of West Africa for an enhance understanding of the regional climate.

P5.7 Rainfall measurement comparison between two types of disdrometers

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Accurate point measurement of the detailed features of rainfall remains a challenge. Tipping bucket rain gauges which are the most commonly used devices simply provide the temporal evolution of cumulated rainfall depth (through the time of each tip usually corresponding to 0.2 mm). Disdrometers, whose operational use is increasing, provide access to much more quantitative information such as the distribution of drops according to their size and velocity. Nevertheless the quantification of the uncertainty associated with these devices is still an open question. In this paper, the outputs of three collocated optical disdrometers recently installed on the roof of the Ecole des Ponts ParisTech are compared. A Campbell Scientific PWS100 and two OTT Parsivel installed perpendicularly are deployed. An interesting point of the experimental set up is that the two devices do not rely the same process; indeed the PWS100 computes the size and terminal fall velocity of each drop passing through the sampling area from the scattered light whereas the Parsivel ones do it from the occluded light. In a first step the raw measured size/velocity matrix (the data is binned) as well as the integrated values such as drop size distribution or its most common moments (rain rate, radar reflectivity) are analyzed for various types of events. Secondly all the moments are analyzed and not only at the maximum resolution but across scales in the framework of Universal Multifractals. They have been extensively used to characterize and simulate geophysical fields extremely variable over wide range of scales such as rainfall. The potential effects of wind are also investigated with the help of the two perpendicular Parsivel. Finally the implications of the observed differences on the algorithm computing rainfall rate from observed radar reflectivity which rely on strong assumptions on the drop size distribution are discussed.

P5.8 Statistics of areal rainfall depths in Belgium based on 10-year volume radar observations

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Weather radars provide precipitation estimates over large areas at high spatial and temporal resolutions. In Belgium, volume scans from two C-band weather radars have been archived since 2002 and 2004. Using the three-dimensional observations allows a careful processing of the reflectivity measurements to derive surface rainfall. It includes the mitigation of non-meteorological echoes and the application of a vertical profile of reflectivity. In a final stage, radar-based estimates of rainfall depths are combined with raingauge measurements. A 10-year statistical analysis is performed for different durations and area sizes. As an application to flood risk assessment, exceedance probabilities of rainfall depth for several catchments are derived. This study will also produce useful information for the verification of regional NWP and climate models.

P5.9 Tracking the temperature response of convective rain cells.

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The statistics of precipitation intensity changes with temperature is complex due to variations on a wide range of spatial and temporal scales. In the light of this complexity, investigations into a basic physical constraint on precipitation intensity, namely that of the Clausius-Clapeyron rate for saturation vapor pressure, were spurred. On short timescales however, recent research has pointed out responses of extreme precipitation to temperature changes in exceedance of the alleged constraint [1–3]. When conditioning on precipitation type [4, 5], evidence has subsequently been built in support of distinct responses of the convective as opposed to the stratiform precipitation type, possibly narrowing down the source of the exceedance. The intensity spectrum in relation to temperature of these two types has been described both in space and time, as reflected by radar and gauge measurements. For a given rain cell, these statistics yield a description of the overall intensity distribution of events. Both for convective event means and instantaneously measured extremes, increases with temperature beyond the Clausius-Clapeyron rate were found. A possible explanation for the high rate may lie in the dynamics of convective events, which allow moisture to be more rapidly transferred to condensation level as temperatures rise. To approach these dynamics in more detail, an empirical characterization of the life- cycle of a convective event – from its build-up to decay – may be more informative and allow more direct comparison to high-resolution process studies [6–8], where events could be followed as they evolve during their lifetime. Using radar data in conjunction with temperature measurements and synoptic observations, we develop a two-tier tracking method of rain cells to mimic an “observer” in a moving reference frame (Lagrangian perspective) which allows us to follow individual events during the full course of their life-cycle as they move under the prevailing atmospheric flow. The aim is to address specifics of the convective life-cycle, and to resolve its temperature response.

P5.10 Trend analysis of long annual and monthly precipitation from Danubian lowland

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This study investigated trends in Slovakia's annual and monthly precipitation totals using daily data from meteorological station Hurbanovo (Slovakia) and monthly data from meteorological station Mosonmagyarovar (Hungary). Hurbanovo station is a representative station for the relatively arid region of the Danubian lowland region and ranks among the best meteorological stations in Central Europe providing sufficiently long, high quality, and homogenous observations. Daily precipitation series since 1871 to 1900 were acquired from historical archives of the Slovak Hydrometeorological Institute (SHMI). The data covering the period after 1901 (up to 2012) were obtained from current SHMI database. Daily rainfall data of 141 years from 1871 to 2012 has been processed in the study to find out the annual and monthly variability of rainfall. We used two types of statistical analyses. First the presence of a monotonic increasing or decreasing trend is tested with the non-parametric Mann-Kendall test and secondly the slope of a linear trend is estimated with the non-parametric Sen's method. Annual and monthly precipitation trends have been identified here to achieve the objective, which has been shown with 141 years of data. In the Mann-Kendall test the Zc statistics revealed the trend of the series for 141 years for individual 12 months and whole time period, which are 0.75, 0.27, -2.33, -3.39, -1.65, 0.26, 0.73, 1.05, -0.82, -2.70, 0.84, -1.12, -2.63 respectively. For January, February, June, July, August and October there is an evidence of rising trend, while Zc value is shoving negative trend in March, April, May, September, October, December and whole time period. Sen's Slope is also indicating slope magnitude for each month for 141 years. Values are depicting either increasing or decreasing trend. This result is quite significant as the months where Mann-Kendall trend analysis has shown negative trend, similar negative slope has been observed for the Sen's Slope and vice versa. The same analysis, for the time period from 1863 to 2012 (150 years), has been done for meteorological station Mosonmagyarovar, situated in the Danube lowland in Hungary. We also evaluated the extreme precipitation events for Hurbanovo station using a set of climate change indices; number of wet days, 1-day and 5-days maximum precipitation, moderate wet days and very wet days showed a well pronounced positive tendency in the cold period of the year particularly in winter. No overall long-term trend was detected in extreme precipitation in summer. A detailed investigation of the precipitation series has to be done in order to correctly assess the water runoff in the future. Only thorough knowledge of the past can help us project the future of the capacity of water resources (water reservoirs). Acknowledgements: This work was supported by the Slovak research and Development Agency under the contract No. APVV-0496-10.

P5.11 Comparisons of the maximum annual rainfall as obtained from a single rain gauge, a network of rain gauges and weather radar.

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The regional annual maximum rainfalls that occur over Edmonton, Alberta and over Ottawa, Ontario in Canada were calculated by three different approaches. Comparisons were subsequently made among the values obtained from: 1) the principal, long-term official rain gauges, 2) the largest observed at any gauge within the regional network of local rain gauges and, 3) the largest 1-km2 calibrated weather radar grid-cell values within an area spanning the rain gauge network. The annual maximum statistics throughout a period of record were calculated for 2-, 4- and 6-hour durations. On average, the maximum rainfalls obtained from the rain gauge network are sixty percent higher than those observed at the principal gauge. Those obtained from the analyses of weather radar data are 260 percent higher. Average return period maximum rainfalls of 5-, 10- and 20-years were determined for all the three durations. The 20-year average return period annual maximum rainfall of the gauge networks were found to be twenty-five percent higher than the principal rain gauge values. The average 20-year return period rainfalls determined from the weather radar data are one hundred-and-thirty percent higher than those of the principal rain gauge. The study presents the advantages of using the rainfall statistics obtained from all the gauges in a network of rain gauges and those obtained by an analysis of weather radar data as compared to using single point rain-gauge statistics for designing water-related infrastructures. Areal reduction factors for convective rainstorms that occur over and near Edmonton, Alberta are also given.

P5.12 People perception about climate change and adaptation in the arid region of Pakistan

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The paper analyzes the people perception regarding climate change and adaptation in the arid region of Pakistan in terms of temperature and precipitation fluctuation, drought and desertification, food scarcity, impact on agriculture, river flow, as well as seasonal fluctuation. According to Khan and Hasan (2012) the arid region of Pakistan shows 0.6inches decrease in precipitation and 1.6 degree Celsius increase in temperature during 1960-2011. The flow of water sector in Pakistan shows a more vulnerable condition from 1937-2004 that will cause a drastic change in Rabi (Winter) as well as Kharif (Summer) cultivation and needs adaptation. The decline in flow of the water in Indus water system will affect the agriculture growth and production in the irrigated areas of the arid region in lower Punjab and Sind Provinces. The main purpose of the work is to know that what is the public opinion regarding climate change, its impacts and how to cope with the problem. Therefore, a questionnaire survey has been conducted in the lower Punjab to know the public opinion about the on going climate change and its impacts on social, economic, demographic, and agriculture sectors. The major questions in the questionnaire are about temperature and precipitation fluctuation, deforestation, overgrazing, drought, desertification, change in the earth geography, wars, change in pressure pattern, population increase, construction of water reservoirs, water resources, current government policies.

P5.13 Climatology of precipitation on the Cyprus territory and potential of their increase

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Some climatological characteristics of precipitation, clouds and temperatures were investigated over the Cyprus territory based on the data of long-term measurements. The analysis of the climatic characteristics led to the following conclusions: 1) The decline of precipitation amount in Cyprus territory from 560 mm (average rainfall for the period 1901-1931) to 459 mm (1980-2010) is marked, i.e. rainfall decreased by 101 mm (18%) in 80 years. 2) Annual temperature in Nicosia was 18.9°C in 1901-1930, 19.3°C in 1931-1960, 19.5°C in 1961-1990 and increased to 20.5°C, i.e. by 1°C during 1991-2008. 3) 82-98% of precipitation fall out in the territory of Cyprus during the period from October to April. 4) In the period from October to April monthly amount of precipitation in the elevated area were registered at average on 41% more than in the lowland area. 5) 59-63 rainy days were observed annually in the lowland part of Cyprus territory and 80-89 rainy days in the elevated territory, i.e. by 35-40% more than in the plains. 6) According to the data of Athalassa meteostation 34 - 65 rainy days were observed during 7 months (October - April) in 2005-2010. The number of rainy days during this period decreased by 21% compared with 1991-2005. 2-8 days (4-12% of the total number of rainy days with $Q > 0.2$ mm) were observed when precipitation fell out from clouds having top temperature $T_{cl} \geq 0^oC$, 21- 46 days (62-71%) and 11- 29 days (23-45%) fell out respectively from clouds with $T_{cl} < -5^oC$ and $T_{cl} < -10^oC$. 7) Clouds having top temperature $T_{cl} \geq 0^oC$ provide in October - April less than 8% of precipitation amount. Clouds with $T_{cl} < -5^oC$ and $T_{cl} < -10oC$ provide in this period respectively 70-88% and 36-61% of precipitation amount. 8) According to the radio-sounding data in Athalassa (2005-2010) wind direction at height 700 mb was in 72% of cases a west or southwest for rainy days. 9) The results of analysis of the climatic characteristics of clouds and precipitation for the territory of Cyprus, the results of numerical simulations and cost estimates of works on cloud seeding make it possible to draw conclusion that there are conditions for airborne and ground-based cloud seeding by ice-forming reagents for obtaining 10-15% additional water in the Cyprus territory, i.e. nearly compensate the observed decrease of precipitation.

P5.14 Dry Days Since Last Rain – DDSLR as an efficient tool for the analysis of the dryness in the Mediterranean basin

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Dryness is a crucial factor in large parts of the Mediterranean basin characterized by a long summer drought and dry-spells during the rainy period. Dry periods between rainstorms are important to geomorphology, hydrology and ecology by influencing processes, such as: runoff and erosion, stream-flow generation, biological soil crusts, etc. Dry-spell (consecutive dry days or days with rain totals below a certain daily rainfall threshold), distribution in various parts of the world were published, however, this approach has two major drawbacks: • The dry period is considered as a whole and therefore it is impossible to follow the drying process. If for example there is a dry-spell of 6 weeks, the lack of rainfall has a certain impact on various processes since the first dry day. However, on the first dry day, the impact is the slightest, and it aggravates as this dry period becomes longer. The impact of the dryness after two weeks, for example, is the same, regardless whether it rains on the next day or the dry period continues for another 4 weeks. • Dry-spells are not dateable. Usually, the timing of the dry-spells is attributed to the month when it started. In the same above example of a dry spell of 6 weeks that started on January 25 and lasted until March 7, in most studies, it will be attributed to January although in that month it was the least severe. One may attribute it to February as the dry period included the entire month or to March, where it reached it maximum severity. However, attributing the dry-spell to the month when it ended may cause a different anomaly. In large parts of the Mediterranean basin, with no rainfall from April or May until September or October, attributing the dry-spell to the month when it ended means that, e.g., there will be no dry-spells in July, which is an absurd. To overcome these limitations of the conventionally used dry-spell approach, a different one entitled: Dry Days Since Last Rain (DDSLR), is suggested, where each day is treated individually. Each rainy day, got a "0" value. The first dry day, received the value "1", the second, the value "2", etc., until the next rainy day, which again received the value "0", and so on. Dry periods were accumulated from one year to the next. In that way, every calendar day got a value (one for each analyzed year) representing it distance (in days) from the last rainy day. Then, the daily DDSLRs' were sorted in an ascending order permitting to present results in a probabilistic manner. This procedure enables evaluating the dryness conditions for every single day throughout the year, regardless its location within the dry spell, thus, eliminating the two mentioned limitations of the dry-spell approach: the evolution of the drying process can be followed easily and the dry conditions are datable appropriately. Results based on daily precipitation records of at least 40 years in about 40 stations across the Mediterranean basin will be presented.

P5.15 An index for the relative contribution of extreme precipitation

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In the analysis of precipitation records with regards to climate change, the emphasis has shifted more and more towards the extreme precipitation amounts in the past years. For example, an increase in the relative contribution of extreme precipitation to the annual or seasonal precipitation total often leads to the conclusion that extremely wet days are relatively becoming more important, with the implication that shape of the probability distribution of daily precipitation is changing. The validity of such implications depends strongly on the definition of extreme precipitation and very wet days. We illustrate this point for the frequently used index R95pTOT, which represents the fraction of the seasonal precipitation contributed by those daily precipitation amounts that exceed the climatological 95th percentile determined over a fixed period. Although useful in itself, this index is often used to conclude whether extreme precipitation increases more than proportional when compared to the mean precipitation. We demonstrate that R95pTOT is also strongly affected by changes in the mean precipitation, and therefore less suitable to detect disproportional changes in the extremes. An alternative index, S95pTOT, is presented that reduces this influence by allowing for variations in the mean. We argue that this index is more descriptive of the distributional shape of daily precipitation than R95pTOT and leads to a more realistic view of how the role of extreme precipitation evolves. Daily precipitation series from more than 1800 stations across Europe were analyzed. Whereas the changes in R95pTOT lead to conclude that the contribution of extreme precipitation to the total becomes more important for the majority of stations in Europe, this conclusion is not supported by the observed changes in S95pTOT and might therefore need to be reconsidered.

P5.16 Investigating the scale-invariance of precipitation with spectral analysis at urban precipitation gauges

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Problems with urban drainage systems functioning gave the impulse for the construction of urban precipitation monitoring systems. Often these are constituted by precipitation gauges networks connected to control units of centralized urban drainage systems. Precipitation data, recorded online through these gauge networks, are used in so called Real-Time-Control (RTC) systems for the development of optimal strategies of urban drainage outflows management. From the practical perspective, the introduction of RTC systems has already resulted in the reduction of overtopping frequencies of drainage networks. From the research perspective, the operation of RTC systems opens the access to new sources of precipitation data recorded over urban areas by modern gauges with high time. Currently, RTC systems also allows for better understanding the variability of urban precipitation fields and permit the intensification of their modeling attempts. In our study we investigate the variability of the scale-invariance of precipitation with spectral analysis among urban precipitation gauges in Warsaw. We use 1-minute rainfall time series recorded in the period 2008-2011 by 25 electronic weighing type gauges deployed around the city by the Municipal Water Supply and Sewerage Company in Warsaw. We use the standard spectral analysis, i.e. we implement Fast Fourier Transform (FFT) numerical method to calculate the power, to investigate the temporal structure of the precipitation data at each gauge. For all gauges we observe a power-law behavior. This scaling behavior holds from small frequencies, corresponding to at least daily time scale up to high frequencies corresponding to the minute time scale. At the very end of power spectrum plots some artificial peaks are observed for the highest frequencies, corresponding to time scales of 2-3 minutes. We believe that they come from step response errors, specific for electronic weighing type gauges. Moreover we distinguish two parts in the power spectrum plots, having different slopes, divided by a visible spectral ‘break’. For all gauges, spectral exponents, for the small frequencies part of plots, are smaller than 1, whereas for the high frequencies part, they are greater than 1. The location of spectral ‘break’ differs among analyzed gauges, and corresponds to time scales from about 20 to 90 minutes. Finally, we use the cluster analysis tool for intercomparison of power spectrum plots among all 25 gauges. As result, we identify 5 gauges displaying scaling properties different substantially from the other gauges. This result, most probably, could be fully explained by the specific location of the 5 gauges. All these are located in specific places like suburbs, cemetery, or airport, of naturally small or even artificially reduced terrain roughness, untypical for the city center. We believe that these conditions strongly influence the local precipitation dynamics.

P5.17 Synoptic analysis of winter intense precipitation at the coast of the Mediterranean Sea

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This contributions describes the present climate statistics of winter (December-January-February) precipitation events and their link to cyclones and North Hemisphere Teleconnection Patterns along the coast of the Mediterranean Sea. Here a “precipitation event” is defined as a continuous sequence of wet days (daily rainfall above 1 mm), representing a period of continuous precipitation, which is likely caused by the same synoptic condition. Time series at 15 Mediterranean coastal locations are analyzed. For most intensity levels and most locations, precipitations events are linked to the negative phase of the North Atlantic Oscillation (NAO) and of the East-Atlantic pattern (EA). The cyclone tracks that are associated to precipitation events have been identified using the ERA-40 reanalysis data and robust link between intense precipitation and cyclones is shown for all stations, with the probability of the presence of a cyclone within a distance of 20 degrees from each station being associated to intensity of precipitation. Conversely the absence of a cyclone is associated to the duration of dry periods. Cyclone depth, strength of circulation around its center, surrounding synoptic condition, and slow speed of the cyclone are important factors for producing intense precipitation events.

P5.18 Radar-based hail statistics over Belgium, 2003-2012

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The Royal Meteorological Institute (RMI) of Belgium operates a C-band Doppler weather radar in Wideumont for more than ten years. This long term archive of high resolution volumetric reflectivity measurements is an extraordinary source of information that can be used in different statistical studies. It is of particular interest when the data is being post-processed with more extended evaluation techniques. A hail detection algorithm based on the criteria by Waldvogel et.al. (1979) is one of many operational applications these radar data. In this algorithm the Probability Of Hail (POH) is calculated as a function of the radar echo-top and height of the freezing level. POH is convenient in operational mode and can serve as a source of empirical probabilities in the statistical analyses. However, it does not allow to assess the severity of hail events. For this reason, the Severe Hail Index (SHI) algorithm proposed by Witt et. al. (1998) was implemented and applied to the archived radar data. In this study the radar data from 2003 to 2012 of the C-band weather radar with a range of 240 km are used. A ten elevations scan (0.5º-17.5º; performed every 15 minutes) with the best volume coverage and without Doppler filtering was chosen for the application of the hail detection algorithms. Archived data are combined with the temperature profile data extracted from the NWP model ALARO-0 currently operational at RMI. The historical temperature profiles were obtained by dynamical downscaling of the ERA-interim re-analysis; applying a double nesting technique to achieve a high resolution grid. From the temperature profiles, the heights of the (-20ºC)-isotherm for the SHI algorithm and zero-isotherm for SHI and POH algorithms were interpolated. These heights are required in the SHI algorithm for the calculation of the temperature-based weighted function, which is later vertically integrated together with the reflectivity-based weighted function and the hail kinetic energy function in the product. SHI estimates a Probability of Severe Hail (POSH) and a Maximum Expected Size of Hail (MESH). Those two outputs are analysed together with the output of the POH algorithm for the temporal and spatial analysis of the frequency of hail events. It allowed to draw conclusions on the frequency of severe hail events in Belgium. Inter alia was established that: 1) most of the hail storms independently of their severity occur in the period between April and September and this period of the year can be called the Hail Season (HS) for Belgium. 2) At least one out of three hail events per hail season is severe (with the diameter of hail stones ≥ 20mm), however this proportion varies from year to year. 3) On average for the hail seasons in ten years hail storms more often occur within the range of the radar in June, but the severe hail is more frequently detected in May. 4) Hail storms with the largest spatial extension are most often detected by both algorithms around 16:00-18:00 UTC. We conclude that for the accurate spatial statistical analyses inclusion of some quality information is required. This will allow to exclude artefacts related to scanning geometry and non-weather targets (ground echoes, air-planes and interferences) from the spatial analysis. The statistics obtained in this study and conclusions based upon give insight in the severity of hail events, their frequency, and offer additional opportunities for further statistical analysis and also for statistical verification of regional climate models. **References**: 1) Waldvogel, A., B. Federer and P. Grimm: 1979, Criteria for the detection of hail cells. *J. Appl. Meteor.*, 18, 1521-1525. 2) Witt, A., M.D. Eilts, G.J. Stumpf, J.T. Johnson, E.D. Mitchell, and K.W. Thomas: 1998, An enhanced hail detection algorithm for the WSR-88D. *Wea. and forecasting*,13, 286-303.

P5.19 Characterizing small-scale spatial variability of rainfall in Singapore using a dense gauge network

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Hourly rainfall measurements from a network of 49 rain gauges in the tropical island of Singapore are analyzed to characterize small-scale (1 – 45 km) spatial variability of rainfall. The decay of spatial correlations with intergauge distance is parameterized using powered-exponential function. The e-folding correlation distance (distance at which correlation drops to 1/e) varied from 10 km at hourly to 33 km at daily scales. The study also examined diurnal, seasonal and anisotropic patterns in spatial correlation structure of rainfall. The rainfall patterns are smoothest during the first half (December-January) of the northeast monsoon, and most variable during intermonsoon months of April and October. Diurnal analysis of spatial correlations showed that the rainfall patterns are smoothest during the pre-dawn hours between 2:00 and 6:00 h, and most variable during afternoon between 15:00 and 19:00 h local time. The results also showed significant anisotropy in spatial correlation patterns. The correlation contours were elliptical in shape with an average eccentricity of 0.64 and orientation of 99º to the North. The eccentricity and orientation of correlation contours showed considerable monthly variability and dependence on spatial scale. This study is a step towards bridging the scale gap in characterizing rainfall structure in Singapore and the surrounding maritime continental region.

P5.20 Statistical bias correction of WRF precipitation fields for Germany through Copula-based assimilation of REGNIE observation data

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Precipitation information is crucial for many applications in hydrology. Precipitation information obtained by regional atmospheric models are usually biased not only in absolute values but also show difficulties in mimicing the spatial patterns. We present a Copula based method to correct precipitation fields from a regional atmospheric model by merging modelled fields with gridded observation data. As regional atmospheric modeling results we used high resolution (7km/daily) WRF simulations for Germany driven by ERA40 reanalysis data for 1971-2000. REGNIE data from DWD were applied as gridded observation data source which are available on a daily time step on a 1km grid in the same period over Germany. It is upscaled from 1km to 7km for this application. We found that marginal distributions of REGNIE and WRF-ERA40 are different which implies that the statistics of precipitation can not be reproduced very well by WRF-ERA40. The Copula families are different in different grid cells which means the dependence structures between REGNIE and ERF-ERA40 are different in different areas. We also found that the identified Copula dependence structure is varying from season to season. Identified Copula parameters have higher values for the winter season, indicating that the WRF-ERA40 precipitation fields have better performance in this season.

P5.21 Comparison of various evaluation methods of precipitation extremeness

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There is no unified method of defining extreme weather events and quantifying their extremeness since "extreme events are generally easy to recognize but difficult to define". However, correct selection of extreme events is necessary because the selection method can substantially influence results of a study. We review methods which are frequently used for evaluation of precipitation extremeness and present their pros and cons on selected heavy rains from the Czech Republic. Probably the most popular approach is based on comparison precipitation totals at individual sites with a fixed threshold. Alternatively, thresholds are based on the empirical distribution of the variable at the given site (quantiles). More sophisticated methods standardize actual totals by the average annual maximum total or even better, they use return period estimates. In fact, precipitation events always affect at least a small area and differ also in their duration. That is why we need to reflect also the spatial and temporal aspects. The spatial aspect of precipitation extremeness can be considered using the areal average instead of individual point measurements. However, limits of both the affected area and the time period are "fuzzy" (not rigorous); therefore, the extremeness of an event depends on the extent of the considered region and the length of the time window. This problem is usually solved by visualization tools (DAD curves, severity diagrams, etc.) which enable a complex analysis of precipitation events. Because of their graphical character on the other hand, they can be hardly used for a "synthesis" – unambiguous evaluation and comparison of extremeness of events. At this point, we suggest a method of "event-adjusted" evaluation which is based on optimization both the considered area and duration for every precipitation event.

P5.22 Investigating the ability of NWP model to reproduce the observed multiscaling properties of rain and reflectivity fields and its potential for downscaling applications

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Heavy rain events over mountainous terrain present a great challenge for forecasters and are responsible for mountain hazards including flashfloods, landslides and debris flows. Their prediction requires high spatial and temporal resolution and one has to recognize that in some events the resolved scales may be strongly influenced by scales unresolved by model or observations. Taking into consideration that the atmospheric fields can be extremely variable over wide ranges of spatial scales, with a scale ratio of 109-1010 between largest (planetary) and smallest (viscous dissipation) scale, but also that there are clear (statistical) scaling relationships among different scales, as widely shown by a vast literature, it becomes clear the importance of such relationships for numerical modeling sub-grid parameterization and downscaling applications. A critical question is: do parameterizations capture and preserve known observed physical scaling relationships at resolved scales and among resolved and unresolved scales, or to they introduce artificial thresholding and scaling behavior that potentially handicaps forecast skill? Here we conduct an investigation on the ability of the widely used NWP model WRF to reproduce the statistical scaling properties in observed reflectivity and surface precipitation fields, in the Southern Appalachian region. At the higher wavenumbers, the model spectra decay compared to observations, indicating an excess of energy removal by the model's (explicit and implicit) dissipation mechanisms. This behavior is used to define the model's effective resolution. The effect of the particular choice of physical options and parameterizations on scaling behavior on the range of scales resolved by the model is examined. The scaling in the initial conditions and the effect of the model spinup on the scaling properties is also explored. Finally, the knowledge on scaling behavior, obtained from observations and model, is used to perform a statistical fractal interpolation downscaling of surface rainfall fields to be used for hydrological applications.

P5.23 Extreme rainfall distribution mapping: Comparison of two approaches in West Africa.

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In a world of increasing exposure of populations to natural hazards, the mapping of extreme rainfall remains a key subject of study. Such maps are required for both flood risk management and civil engineering structure design, the challenge being to take into account the local information provided by point rainfall series as well as the necessity of some regional coherency. Two approaches based on the extreme value theory are compared here, with an application to extreme rainfall mapping in West Africa. The first approach is a Local Fit and Interpolation (LFI) consisting in a spatial interpolation of the Generalized Extreme Value (GEV) distribution parameters estimated independently at each station. The second approach is a Spatial Maximum Likelihood Estimation (SMLE); it directly estimates the GEV distribution over the entire region by a single maximum likelihood fit using jointly all measurements combined with spatial covariates. Five LFI and three SMLE methods are considered, using the information provided by 126 daily rainfall series covering the period 1950-1990. The methods are first evaluated in calibration. Then the predictive skills and the robustness are assessed through a cross validation and an independent network validation process. The SMLE approach – especially when using the mean annual rainfall as covariate – appears to perform better for most of the scores computed. Using the Niamey 104-year time series, it is also shown that the SMLE approach has the attractive capacity to deal more efficiently with the effect of local outliers by using the spatial information provided by nearby stations.

P5.24 Space-time structure characterization of extreme rainfall: IDAF curves estimation in the Sahel.

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West Africa is known for having experienced major drought events, but during the last decades numerous floods and exceptional inundations have also struck the region. The flood management is now a major concern for West African countries. Floods can occur at different temporal and spatial scales associated either with meso-scale convective systems that can generate exceptional rainfall totals over a small surface area (a few tens of km^2) during a short period of time (a few hours), or with 5 to 20 days rainfall accumulations over a large part of the region that cause unusual flooding over large scale watersheds. Intensity-Duration-Area-Frequency (IDAF) curves are interesting tools for two reasons: they are useful for hydraulic structures design as they provide estimates of the return level of heavy rains for several temporal and spatial aggregations and they are helpful to characterize the severity of storms. Obtaining such curves from rainfall networks requires long series, high spatial density and high time-frequency of records. In West Africa, such characteristics are provided by the AMMA-CATCH Niger network. This network is located in the Niamey region where 30 recording rain-gauges (5 minutes series) have operated since 1990 over a 16000 km^2 area. In this study, the IDAF curves are obtained by separately considering the time (IDF) and the spatial (ARF) scales. Annual maxima intensities are extracted for different spatial and temporal resolutions. The IDF model used is based on the concept of scale invariance (simple scaling) to normalize the different temporal resolution of maxima series to which a global GEV is fitted. This parsimonious framework allows using the concept of dynamic scaling to describe the ARF. The IDAF curves obtained describe the distribution of extreme rainfall for time resolutions ranging from 1 hour to 24 hours and space scales between 1 km^2 and 2500 km^2. The study also shows that the IDAF curves must be build differently whether the objective is to design hydraulic structures or to evaluate the severity of a storm.

P5.25 Heavy precipitation in Albania: A sixty year analyses of daily precipitation

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Precipitations that reach the earth's surface in all their forms are not only a key factor of life on Earth but more one of the crucial parameters in the equilibrium of global water cycle. A very sensitive issue of precipitation can be heavy precipitation associated to severe weather, especially events of high precipitation rate which often produce severe flooding and damages. Because of the craggy relief of Albania with more than 75% of hills and high mountains and many small, steep river basins makes the highly populated Albanian western lowland, very sensitive to the impact of intense rainfalls which produce flash floods. In order to minimize the flooding impact of these areas, we must provide a better forecast of severe weather associated to intense rainfall quantities in short time periods. To provide a better forecast, a better understanding of the behaviour of intensive precipitation episodes is needed. For this reason, a detailed knowledge of the distribution of rainfall intensity in certain time intervals is required. The 24 hours time interval is selected for analysis of precipitation, for a sixty-year time period. As a first step, all the terms of the daily precipitation series were analysed and then, the heavy 24-hour rainfalls were selected for a detailed analyses. Based on a threshold estimation method, a sub-series of intensive rainfall is reanalysed in order to classify the 24 hours quantities into intensive class I, extreme class E and rare class R. Also, for both types of precipitations, many important facts result from the sixty-year panorama of 24h heavy precipitations, facts which may be used as tool for a better heavy precipitation prediction.

P5.26 High-resolution forecasts of seasonal precipitation in the south-eastern Mediterranean: analogues downscaling of global forecasts

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Planning the use of water resources in advance is one of the most important missions in the semi-arid Eastern Mediterranean region. Some relevant areas (e.g. Sea of Galilee and coastal/mountain aquifers) are characterized by complex topography, land use and coast-lines that lead to strong spatial gradients in the observed seasonal precipitation. Global seasonal forecasts provide partial and incomplete information about the expected precipitation amounts due to their coarse spatial resolution of ~200 km grid-size. More accurate and useful forecasts require finer spatial resolution on the scale of a few kilometers. We present a statistical downscaling algorithm that relies on: global forecasts, a technique to find past-analogues synoptic-weather patterns, and the connection between those weather scenarios and the local precipitation. The algorithm was validated using the long term NCEP/NCAR global reanalyses (that represent the “true” state of the large scale flow) at 18 selected stations characterized by significant spatial variability in their seasonal precipitation. The validation proved good skill of the algorithm (e.g. correlation between predicted and observed precipitation amounts of ~0.8). After being validated, the algorithm was then used to downscale operational global-seasonal forecasts issued by NCEP CFS1.0 ensemble during two wet seasons and the results were verified against observations. The verification showed that the method works properly when using operational global forecasts (e.g. correlation between predicted and observed precipitation amounts of ~0.7), too; and reproduces the differences between the stations in most cases.

P5.27 Relationship between extratropical cyclone and convective systems in Kochi, Japan

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Kochi is known to be one of the area where the heavy rain frequently occurs in Japan. About half of heavy rain events are caused by extratropical cyclones. However, such events are caused by various convective systems and we do not understand what convective systems arise in what environments of extratropical cyclones. The present study aims to categorize mesoscale convective systems yielding heavy rain and to investigate relationship between the locations of extratropical cyclones and the categorized convective systems. We checked radar echo patterns when any rain gauges at 29 Japan Meteorological Agency's (JMA)'s observation points in Kochi prefecture recorded more than 50 mm/h and categorized them to five types; quasi-linear convective system, squall line, multi-cell convective system, the convective system fixed at terrain and the other. We extracted 111 echo patterns from JMA radar data for 25 years from 1986 to 2010. The locations of extratropical cyclones and cold/warm fronts when the convective system appeared were also checked from the synoptic charts. Major convective systems are found to be quasi-linear and multi-cell types. The detected numbers of quasi-linear and multi-cell types were 50 and 41, respectively. These systems occurred mainly near the center and the warm section of the extratropical cyclones. The quasi-linear convective systems concentrate four regions and half of them locate along the southwest coastline of Kochi. One the other hand, the multi-cell convective systems covered all over and east half of Kochi Prefecture. When the extratropical cyclones locate in the area between Kyushu Island and Korean Peninsula, the convective systems persist for more than two hours. The extratropical cyclones yielding heavy rain were, however, only 17 percent of total them passing near Japan. We also found that quasi-linear convective systems occurred when the air mass with high equivalent-potential temperature intruded from Pacific Ocean. Its threshold changes with season.

P5.28 Numerical tracking of Middle East cyclones (rainfall generator systems) in the cold period of the year

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This paper deals with the numerical tracking of Middle Eastern cyclones. Cyclogenesis regions and their movement tracks can be determined by respective algorithms. In this paper, re-analyzed NCEP data with the temporal resolution of 24 hours and the spatial resolution of degrees were used for the cold period(December, January, February, and March), of the years 1993-94 to 2002-03. The area under study was in the latitude and the longitude , which includes the Middle East. An algorithm written in language was used for locating the points, and ArcGIS software was utilized for drawing the tracks. The results are as follows: Five main tracks were characterized; the most important tracks originate from western and northwestern areas; each month exhibits its own particular climatology; in January, the tracks tend to extend along the northern Mediterranean area; in March, the Atlantic low pressures increase noticeably; most of the tracks have two- or three- day lifetimes; the effect of topography factor on the formation of cyclogenesis regions is more outstanding than that on leading the tracks; cyclones enter Iran along three main tracks and three sub-tracks; the most important track is the one that enter Iran from the west, originating from Cyprus region; the frequency of occurrence of cyclones exhibits an ascending trend in future.

P5.29 Modern climate changes in air temperature and precipitation in Yemen and neighboring areas

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Estimates of future climate change derived from GCM's models for the territory of Yemen and the neighboring states are ambiguous and depend on the accepted scenario and the type of model used. Therefore, a detailed analysis of modern climate change on the basis of observational data has been realized. For this aim about 50 stations have used, but the series of observations in most cases were of short duration as 25 - 30 years in average. Short-term series of observations were reduced to long-term period by the information in other stations with longer time series. As a result of this procedure the average duration of the series of the air temperature was increased in two times, from 25 - 27 to 44 - 58 years depending on the reference month. Size of series of observations for precipitations has also been increased by more than 2 times and became in average 51 years (with variations from 31 to 59 years) instead of 24 years for the observed data. To assess the modern climate change in long-term series of air temperature and precipitation were used three competing models: stationary model, a linear trend model and a model of step changes, each of them reflects the different physical properties of the climate dynamics. For air temperature as a result it was found that the model step changes a little bit better than the trend model. Despite the fact that no statistically significant differences from the stationary model only 4 cases, but we can assume that the established differences, ranging from 10%, is already of interest for climate monitoring. Such cases were 24-26% for air monthly temperature. Spatial distributions of these differences to a stationary model are shown that the maximum differences take place in transition months: April-May and October. In summer period the most differences to stationary model take place for Saudi Arabia area.

P5.30 The changing character of urban precipitation (case: Jakarta, Indonesia)

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Using a newly available 100-year long record of hourly and daily observations at Jakarta Observatory, the temporal heterogeneity of changes in climate and its variability over Jakarta, Indonesia has been studied. The analyses showed that the total annual precipitation has decreased since 1880, but the mean of daily precipitation in the wetdays is increasing for the last half century. The number of wet days has decreased between 1880 and 2010, while the precipitation exceeding 50 mm is observed to be slightly increased. An increased trend of very heavy rainfall in the 95% and 99.9% percentile in the wet season was detected. The diurnal variation of Jakarta precipitation and temperature has changed markedly. In the wet season (DJF), the morning rainfall has increased in intensity, while in other seasons a delay of the late afternoon rainfall peak has been observed. The diurnal cycle in temperature has increased, with a considerable increase in night-time temperature but little change in day-time temperatures for the latter period. Changes in temporal characteristics of light and heavy precipitation, as well as the diurnal variation of precipitation and temperature lead to hypotheses concerning anthropogenic influence. Some theoretical arguments on Urban Heat Island and aerosol effect precipitation could be linked to our results. The connection with known land use changes and proxy for aerosol track need to be explored.

P5.31 Review and comparison of radar rainfall bias adjustment methods – Applying a 10-year dataset from Denmark

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It is generally acknowledged that in order to apply radar rainfall data for hydrological purposes, be it hydrological modelling, rainfall statistics, or hydrometeorological analyses, adjustments against ground observations are crucial. Traditionally, radar reflectivity is transformed into rainfall rates applying a fixed reflectivity – rainfall rate relationship even though this is known to depend on the changing drop size distribution of the specific rain. This creates a transient bias between the radar rainfall and the ground observations due to seasonal changes of the drop size distribution, and to some extent also due to attenuation effects, beam blockage effects, clutter, etc. Furthermore, abrupt changes in bias can originate from radar hardware recalibration or replacement. There are issues with biases, which partially can be resolved using improved technology such as dual polarization measurements, intercalibration of radar networks, VPR correction, but this is however not possible on historical data in our case, why we must rely on the adjustment against ground observations from rain gauges. The aim of the present study is to develop a complete 10-year dataset (2002-2012) of high spatio-temporal resolution radar rainfall based on a radar observations from a single Danish C-band radar. Within a 100 km range from the radar a total of 76 rain gauges are located. Development of a complete long term series of radar rainfall can be used in a variety of applications such as rainfall statistics especially the extreme value statistics; hydrometeorological analyses; hydrological modelling especially within urban hydrology; flood modelling; developments in radar rainfall nowcasting and numerical weather model forecasting, etc. In order to develop the best possible dataset, and quantify radar rainfall uncertainty we address the bias adjustment by reviewing and comparing different methods. The methods are divided in two categories 1) Bias adjustment methods assuming spatial homogeneity (Mean field bias) and 2) Bias adjustment methods assuming spatial heterogeneity (distributed bias). Under the first category we examine different aggregation time scales such as daily mean field bias adjustment, mean field bias adjustment on small time scales (10 min - 6 hours), conditional mean field bias adjustment, and continuous fixed-volume mean field adjustment. Under category 2 we examine Brandes spatial adjustment and different Kriging approaches in order to investigate spatial variability. Additionally, we show how the temporal resolution of radar rainfall can be increased by a spatial interpolation technique and that this improves the radar rainfall estimates significantly. We evaluate the different bias adjustment methods both with regards to representation of extremes as well as accumulations at monthly and yearly timescales.

P5.32 Precipitation in southern Poland in the 21st century compared to long-term records for the period 1881-2012

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Southern Poland is known for the high variability of its precipitation, which is mainly explained by the region's varied geomorphology and atmospheric circulation. Since the beginning of the 21st century, the area has experienced years of both precipitation surplus and precipitation deficit. These included an exceptionally wet year in 2010 with floods, and dry years in 2011 and 2012 which featured droughts. The study focused on the precipitation characteristics during these years and compared them to the long-term records for the period 1881-2012 also taking into consideration the atmospheric circulation. The data included monthly precipitation totals from six weather stations located at various altitudes and in different types of geomorphological units, including: Bielsko-Biała, Krakow, Rzeszów, Zakopane, Nowy Sącz and Sanok. The greatest anomalies were recorded in May 2010, when precipitation exceeded the long-term average by the factor of five, and in November 2011, when many of the stations recorded no precipitation at all.

P5.33 Bias-correction of precipitation in high resolution RCM simulations: comparison of Copula-based algorithms with standard approaches

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Global and regional climate models (GCMs and RCMs) are of central importance for conducting climate change impact studies that require time series of climatic variables. Usually, the RCM time series cannot be used directly as input for external impact models such as hydrological and agricultural models, because the spatial resolution of RCM does not allow to account for local scale climate variability. This is particularly valid for complex terrain. As a result, there exist significant biases between modelled and observed climate statistics, and further statistical refinement and bias-correction is required to obtain reliable meteorological information at local scale. To correct for the model bias, methods such as linear bias-correction (mean value correction) or quantile mapping (histogram matching) are usually applied. However, these methods are only able to correct for specific types of model uncertainties such as e.g. a scaling error. To assess for the structure of model uncertainty more precisely, the dependence structure between modelled and observed time series must be analyzed. As the spatio-temporal dependence structure of hydrometeorological data such as between modelled and observed rainfall is very complex and cannot be described by a multivariate normal distribution, Copulas can be applied for its modelling. We present a new Copula-based method to bias-correct RCM simulations of daily precipitation in complex terrain. In this study, the Copula-based bias-correction is applied to RCM precipitation data and observations in the region of the Nationalpark Berchtesgaden (Berchtesgaden Alps). This area is characterized by very steep elevation gradients and is correspondingly a challenging region to describe properly the spatio-temporal distribution of precipitation. The performance of the Copula-based bias-correction is compared to standard approaches like mean value correction and quantile mapping. The modelled precipitation fields originate from dynamically downscaling ERA40 with WRF in 7 km resolution for the time period 1970-2000. The comparison is additionally performed for a corresponding climate run (control run 1970-2000) and a future climate projection (2020-2050). Observation data is stemming from 14 meteorological stations in the region of interest. The differences of the three bias-correction algorithms are evaluated. Especially the bias-corrected future climate projection run is analyzed and the impacts of different bias-correction algorithms on the estimation of climate change effects are elaborated.

P5.34 Multidecadal oscillations of rainfall extremes in Europe

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Many studies have anticipated a worldwide increase in the frequency and intensity of precipitation extremes and floods since the last decade(s). Natural variability by climate oscillations partly determines the observed evolution of precipitation extremes. Based on a technique for the identification and analysis of changes in extremes, this paper shows that precipitation extremes have oscillatory behaviour at multidecadal time scales. The analysis is based on a unique dataset of 108 years of 10 minutes precipitation intensities at Uccle (Brussels), not affected by instrumental changes. We also checked the consistency of the findings with long precipitation records at 989 stations across Europe. The past 100 years showed for Brussels and neighbouring regions higher rainfall quantiles for the 1910s, the 1950-1960s, and more recently during both winter and summer of the past 15 years. These conclusions were found consistent for all time scales varying from 10 minutes to the monthly scale. The increase/decrease in rainfall quantiles was due to an increase/decrease in the number of extreme precipitation events and by higher/lower precipitation intensity per event, where the first factor was found most important. The increases were found statistically significant at the 5% confidence level, and were found to be partly explained by persistence in atmospheric circulation patterns over the North Atlantic during periods of 10 to 15 years.

P5.35 Toward a radar-based precipitation reanalysis for Germany – First steps and results

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The area-covering German radar network comprising 17 operational Doppler C-band systems provides a database of paramount importance for temporal and spatial high-resolution precipitation analyses for real-time and - as the archive encompasses twelve years of reflectivity data by now - for climatological applications. Based on the combination of radar based precipitation estimates and comprehensive surface precipitation observations, Deutscher Wetterdienst (DWD) operationally provides high-resolution quantitative precipitation estimation (QPE) products for real-time hydrological applications in the context of flood risk management since 2005. Meanwhile, a valuable database of radar reflectivity and QPE data has accumulated, demanding its reanalysis and evaluation for climatological applications in various subject areas e.g. water engineering, climate monitoring, and climate modelling. DWD has defined two approaches for the quality-controlled high-resolution precipitation reanalysis of the archived data: • the post-correction of six years of operational QPE products and • the reanalysis of radar reflectivity data since 2001. The first short-term approach is based on the archived operational QPE composite products with a temporal resolution of one hour and a spatial grid size of one kilometre squared covering Germany. To allow for statistical analyses with a focus on extreme precipitation events a post-correction suite is applied to the data to eliminate residual false echoes and further enhance data quality. A first reanalysis has been performed encompassing a statistical analysis of extreme precipitation events focussing on the metropolitan region of Cologne. A comparison to classical evaluations based on gauge data shows added value in the monitoring of extreme local precipitation events. The second long-term approach will comprise a complete reanalysis of the reflectivity data applying a consistent analysis suite. It is based on the local five-minute precipitation scans of the 16 (recently extended to 17) operational weather radars of the DWD network since 2001. Furthermore, additional algorithms will be developed in order to improve the high data quality and comply with climatological standards. Well-known error sources and radar artefacts like partial beam blockage, attenuation, and herringbone patterns due to a lack of temporal resolution monitoring fast moving cells to name but a few have to be recognized and corrected for. At the conference, we present the first results of the post-correction approach as well as first steps toward the comprehensive radar-based precipitation reanalysis.

P5.36 Meteobase – online historical and statistical precipitation and evaporation database for water management applications in The Netherlands

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The floods in parts of The Netherlands during September and October 1998 have indicated that regional water systems are susceptible to excessive precipitation. These events initiated a broad discussion on the Dutch water management requirements, which in turn resulted in formulation of standards, documented in the “National Water Management Agreement” (NBW). In order to assess whether the above mentioned standards are met, water managers need detailed information on precipitation and its extremes. In addition, information is required for hydrological model calibration, for the Dutch requirements on ground and surface water regimes (GGOR), and for water availability applications within e.g. the National Hydrological Instrument (NHI) and other policy targets.

The National Foundation for Applied Water Research (STOWA) has requested HKV CONSULTANTS to construct a historical precipitation and reference evaporation database, as well as to provide extreme precipitation statistics to be used by hydrologists and water managers. The aim is to make these data available for model calibration and regional water system standard assessment, in order to create uniformity in the use of datasets by the various water boards and of course also for the improvement of model accuracy. The web-based Meteobase application was developed by HKV CONSULTANTS in cooperation with Siebe Bosch Hydroconsult, having the Royal Netherlands Meteorological Institute (KNMI) as scientific advisor. The database consists of both gridded and station data. Gridded hourly precipitation data consist of rain gauge observations that are merged with rain radar observations, using kriging with external drift. These datasets are available from 1990 onwards at a spatial resolution of 1×1 km2. Grid estimates of daily reference evaporation at 1×1 km2 are obtained using Inverse Distance Weighting. The raster data have been made available for a 20-year period (1990 – 2010) and will be updated on a yearly basis.

Station data of precipitation and evaporation (the latter calculated from both the Penman-Monteith and Makkink methods) are available from 1906 and 1957 onwards, respectively. In addition to the historical data, statistical data for the assessment of the water management standards were derived. Among these data are the (extreme) statistics of precipitation with durations from 1 hour up to 10 days. These statistical data can be applied in relation with state-of-the-art climate change projections, such as the latest KNMI scenarios.

This presentation will show the main methodology of Meteobase and will demonstrate the available tools to obtain better insight in historical precipitation events and extreme statistics, as well as the future development of these extremes in relation to climate change scenarios.

P5.37 A comparison of two in-storm rainfall intensity distributions

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Of great importance to hydrologic and soil erosion models is an accurate probabilistic representation of rainfall intensity, particularly the high intensities, within a storm event. This paper considers two simple 1-parameter probability distribution functions to describe 6-min intensity data for 10 sites from different climate zones in Australia. A storm is defined as a wet period separated by dry spells of 6-hour or longer. A stratified sampling theme was used to select 30 such storms from each of the 10 sites to represent the full data range in terms of rainfall depth among storm events. Traditionally, in-storm rainfall intensities are described with an exponential distribution function in terms of their frequency of occurrence with a single parameter of mean intensity, i.e. total amount divided by the storm duration. Alternatively, in-storm intensities can be described in terms of the amount of rain that occurs within a particular intensity range. While frequency of occurrence is related to the fraction of storm duration for which rain occurs within an intensity range, the second model, originally proposed by van Dijk et al. (2005), is related to the fraction of total rain amount for which rain occurs within the intensity range. The model parameter for the second approach is a weighted average intensity by its contribution to the total rain amount. Our comparative analysis shows conclusively that for most events at all the sites tested, the second approach based on rainfall depth is a superior model to describe the in-storm intensity distribution not only in terms of some well-accepted statistical tests, but also in terms of predicted rainfall erosivity values which non-linearly depend on high rainfall intensities.

P5.38 Monte Carlo significance test as applied to precipitation skill score

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The method for dichotomous (yes/no) forecasts are always used in evaluation of quantitative verification statistics. As one common methods of the dichotomous forecast, the precipitation Threat Score (TS) measures the fraction of observed and forecast events that are correctly predicted over a threshold. It is only concerned with forecasts that count and paid attention to a question that how well did the forecast "yes" events correspond to the observed "yes" events. Once sample data has been gathered through an observational study or experiment time series, statistical inference allows analysts to assess evidence in favor of a population mean from which the sample has been drawn. The methods of inference used to support or reject claims based on sample data are known as tests of significance. A significance test is performed to determine if a test parameter differs enough from a hypothesized value, the hypothesized value of the parameter is called the "null hypothesis". A significance test consists of calculating the probability of obtaining a statistic as different as or more different from the null hypothesis than the statistic obtained in the sample. If this probability is sufficiently low, then the difference is said to be "statistically significant" and some convention levels of 0.05 (95% confidence level) and 0.01 (99% confidence level) are most commonly used. Confidence intervals are closely related to statistical significance testing. In this paper, a confidence interval (CI) is used in significance test to compare the bias of precipitation skill scores and it is most commonly applied when the test statistic would follow a normal distribution. However, the precipitation skill score can hardly follow the normal distribution, so Monte Carlo test is used as a resampling method to assess the significance of precipitation skill score difference between two models. Using Monte Carlo test, we should resampling the skill scores with a random number which is created for time series with 0 or 1 for about times and resample a normal distribution for skill scores for significance test. In this paper, some precipitation skill scores of NCEPGFS and T639 models such as threat score and bias score are calculated from Jun to Aug on 2011. The real daily precipitation observation data are taken from Chinese 2400 rain gauges. Monte Carlo test is used for statistical significance test and the convergence characteristics with different resampling times are also analysed. Results suggest that 10000 times Monte Carlo test looks sufficient and a complete picture of the forecast performance with significant improvement is provided.

P5.39 Climatological distributions and diurnal variations of short-duration heavy rain over China during warm season

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Short-duration heavy rainfall (hereafter SDHR) is one type of severe convective weather, and can directly or indirectly lead to large property and life losses. Based on the qualified hourly rain-gauge data from 876 stations during April-September of 1991–2009 provided by the National Meteorological Information Center of China, the spatiotemporal distribution of SDHR over China during warm season (April-September) is presented, and the comparison between SDHR and MCS diurnal variations is focused on. The frequency spatial distributions of the SDHR denoted by hourly rainfall ≥ 10 mm, 20 mm, 30 mm and 40 mm are very similar to those of heavy rainfall (daily rainfall ≥ 50 mm) over China (excluding Taiwan). However, the frequencies of the SDHR denoted by hourly rainfall ≥ 50 mm are much lower than those ≥ 20 mm/h, therefore, their spatial distributions are also much different. The most active SDHR region is South China, and the second most active regions are south Yunnan Province, Sichuan Basin, south Guizhou Province, Jiangxi Province, the lower reaches of the Yangtze River, and so on. The heaviest hourly rainfall over China (excluding Taiwan) is more than 180 mm (over Hainan Island), and there are lots of SDHR events with hourly rainfall ≥ 50 mm over the inactive SDHR regions, such as the west Xinjiang Uygur Autonomous Region, the middle and east Inner Mongolia Autonomous Region. The monthly variations of SDHR show that the most active SDHR month is July, and August the second most active. The pentad variations of SDHR reveal that the evolvement of SDHR has a characteristic of intermittence, and the most active SDHR pentad is the fourth pentad of July. The SDHR frequencies enhance slowly and weaken rapidly with the advance and withdraw of the summer monsoon over East Asia in the monthly and pentad varitaions of SDHR over China. Over the entire China, the most active diurnal peak is 16-17BT, the second and third active peaks 01-02 BT and 07-08 BT, and the most inactive period 10-13BT. The diurnal variations of SDHR show that the active periods and propagation of SDHR and MCSs are different over different regions with different underlying surface, with a single peak, two peaks, multiple peaks and keeping-active type, which are not only associated with the larger-scale atmospheric circulation, but also closely related to the terrain and land-sea distributions, for example, over South China, Guizhou Province, and Sichuan Province.

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