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Site report: Netherlands - Cabauw

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Summary and Purpose of Document

This document contains an overview of the Cabauw measurement program with respect to GRUAN requirements. It also raises current questions on processing of data towards climate standards, on possible data distribution practices, and on climate monitoring of “difficult” parameters.

CABAUW EXPERIMENTAL SITE FOR ATMOSPHERIC RESEARCH (CESAR) – THE NETHERLANDS: AN INITIAL GRUAN ATMOSPHERIC PROFILING STATION

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INTRODUCTION

The Cabauw Experimental Site for Atmospheric Research (CESAR) is situated at 51.97 N, 4.93 E in a rural flat grassland region between the cities of Rotterdam and Utrecht in the Netherlands. Cabauw is the meteorological research site of KNMI and was originally established in 1974. In the first 20 years of its existence most work focused on exchange processes between the earth and atmosphere, using the 200m tower, which is instrumented with turbulence flux equipment at regular height intervals. In the mid – 1990's, the scope of the work was progressively expanded to include research on the interaction of clouds, aerosols and radiation, the evaluation of climate and weather models, the validation of satellite retrievals and the monitoring of climate. To this end additional remote sensing and radiation equipment was installed at the site.

Figure 1. Location of Cabauw, the Netherlands.

Although KNMI is Cabauw site manager, it is not solely responsible for running and maintaining all of the scientific instruments there. In fact, a number of Dutch universities and scientific and technological research institutes are organized in the CESAR – consortium with the specific aim to jointly plan and execute their research activities at Cabauw and to share responsibility in running field programs. CESAR provides an important platform for collaboration in the field of atmospheric sciences and over the years has attracted many international research groups to temporarily locate their measurement activities to Cabauw as part of EU – sponsored campaigns, i.e. CloudNet, EUCAARI, in the area of land/atmosphere interaction, and cloud/aerosol/radiation studies.

CESAR's strength lies in the capability for integrated profiling of the atmospheric column. The Integrated Profiling Technique (IPT) [*Lohnert et al, 2007, JGR*] combines information from the multi-sensor measurement platform to construct a vertical profile of the state of the atmosphere with high spatial and temporal resolution. Table 1 provides a list of most of the measurement systems, the research institute responsible for operation, and the GCOS Reference Upper Atmospheric Network [GRUAN] priority rating.

GRUAN PRIORITIES

WMO/TD No. 1379 [*GCOS – 112*] provides a priority setting for measurement systems at reference profiling stations in order to guide operators to adjust their observations to GRUAN observation requirements. The GRUAN priority setting has been put forward based on scientific principles, with the view that over time more instruments would be added with advice from the GRUAN lead centre. Here, we first comment on the CESAR observations in relation to the GRUAN priorities. At the end of this paper we comment on instrumental precision and accuracy requirements for climate monitoring in relation to scientific and economic considerations.

GRUAN priority 1

Radiosondes are launched at 12 hour intervals at the WMO-KNMI launch site in de Bilt [52.10 N, 5.18 E] which is at a distance of 22.19 km from Cabauw. The new Vaisala RS92 Sensor is used and standard pre-launch calibrations are performed by experienced personnel. During field studies [such as the EUCAARI – IMPACT campaign May 2008] [http://www.atm.helsinki.fi/eucaari/] a system to launch and record radiosondes is temporarily located

at Cabauw to provide profiling at higher time resolution but with the earlier RS versions of the Vaisala radiosonde system.

Table 1. List of instruments routinely operated at CESAR, responsible institute, and GRUAN priority.

	Instrument	Responsible institute	GRUAN priority
	Radiosonde [at de Bilt]	KNMI	1
Tower – based in situ	H20, CO2, T turbulence	KNMI	other
	T, q, u, v [state var.]	KNMI	1
	CCN counter	KNMI	other
	Aethalometer	RIVM	other
	GRIMM opt. part. counter	RIVM	other
	MARGA sizer / compos.	ECN	other
	Nephelometer	TNO	other
	SMPS particle sizer	TNO	other
	PTR–Mass spectrometer	IMAU	other
Remote sensing	Wind / RASS profiler	KNMI	1
	35 GHz cloud radar	KNMI	2
	Ceilometer	KNMI	2
	UV backscatter lidar	KNMI	2
	BSRN [LW and SW]	KNMI	2
	GPS (3)	KNMI,TUD	1
	Sun photometer (3)	KNMI,TNO	2
	3 GHz cloud/turb. radar	TUDelft	2
	10 GHz scanning radar	TUDelft	2
	IR backscatter lidar	RIVM	2
	Raman lidar	RIVM	2
	Microwave radiometer (2)	KNMI, ESA	2
Ground in situ	Methane, radon	ECN	2
	PM2.5, PM10	RIVM	2
	NOx, O3, SO2	RIVM	2
	Rain, ground water, disd.	WUR	other
	Soil heat flux, T	WUR	other
	Aethalometer	RIVM	other

GPS receivers [integrated water vapor] are located at the surface, and at the top of the tower [200 m altitude]. Continuous observations started in 2001 and are routinely processed for NWP purposes. However, for climate monitoring the data need to be reprocessed using more precise satellite orbits. Currently, this is only done for short time segments, and more study will be necessary to ascertain that reprocessed GPS data meet climate monitoring requirements.

A wind profiler has been operational at Cabauw since 1995, recording winds up to an altitude of 3 km [depending on the atmospheric conditions]. A proposal is currently under review to re-process all data from the beginning in order to acquire a long time series with specified accuracy for climate monitoring purposes.

GRUAN priority 2

a) Radiation. Since November 2005, a fully equipped Baseline Surface Radiation Network [BSRN] station has been operational at Cabauw. [http://www.knmi.nl/bsrn/]. BSRN stations adhere to strict quality control principles, and the instruments are calibrated up to traceable standards.

Fig 2. The BSRN station at Cabauw.

b) Aerosols. Additional measurement systems located at the BSRN site include several sun photometers and a multispectral radiometer, to acquire aerosol optical depth and microphysics. Aerosol observations are obtained as part of the AERONET program, and the GAW-PRF network http://aeronet.gsfc.nasa.gov/ and http://www.pmodwrc.ch/worcc/ both of which process aerosol optical depth data to climate quality standards. Additional in situ aerosol probes are on site as part of national and international experimental research programs. They provide data on size and composition but are currently not processed for climate purposes. However, Cabauw is now part of the

Dutch national measurement network of PM - stations, so that PM2.5 and PM10 are monitored continuously [for climate and regulatory purposes]. RIVM's high-performance Raman lidar (Caeli) is complete and will be extensively validated during an intercomparison campaign at IfT in Leipzig. The lidar can provide continuous aerosol profiling throughout the troposphere and is part of EARLINET [http://www.earlinet.org/].

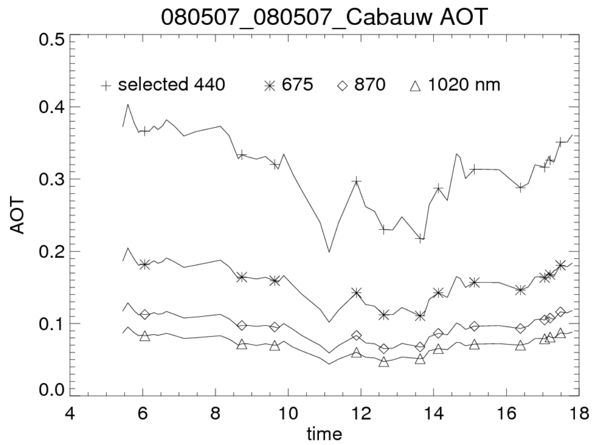

Fig 3: Time series of aerosol optical thickness (AOT) for 4 different wavelengths [8 May 2008].

c) Water vapor. High-resolution water vapor profiling is obtained simultaneously with the aerosol profiles from the Raman lidar. Routine observations will commence after validation is complete. Additional integrated water vapor observations are obtained by means of two microwave radiometers. Both have internal automated calibration procedures, but at present none is processed to climate standards. Also, some visible channels of the multispectral radiometer yield integrated water vapor on a routine quality controlled basis.

d) Clouds. Several complementary systems are available at Cabauw to obtain detailed cloud information, ranging from cloud fractional coverage to altitude distributions. Strong impetus for these measurements was the EU–FP5 CloudNet program 2001-2005 [http://www.knmi.nl/samenw/cloudnet/] CloudNet provided not only a framework for continuous observations of clouds but also for comparing these observations to climate and weather models. The principal modes of cloud observation during CloudNet were a cloud radar, a ceilometer and a microwave radiometer. During the CloudNet program a cloud classification system was developed based on sophisticated processing of the combination of radiosonde, cloud radar, microwave radiometer, ceilometer data and short term weather prediction. Processing of these data is a routine operation. Presently there is an absence of any usable guidelines on processing of cloud data with the aim of making them of the quality to monitor cloud climate.

These are several initiatives under way to acquire insight into the consistency of the target classification processing scheme, including comparisons with derived cloudiness from the BSRN data, with a scanning IR radiometer [Nubiscope] and with an all-sky camera which also yields a cloud coverage product.

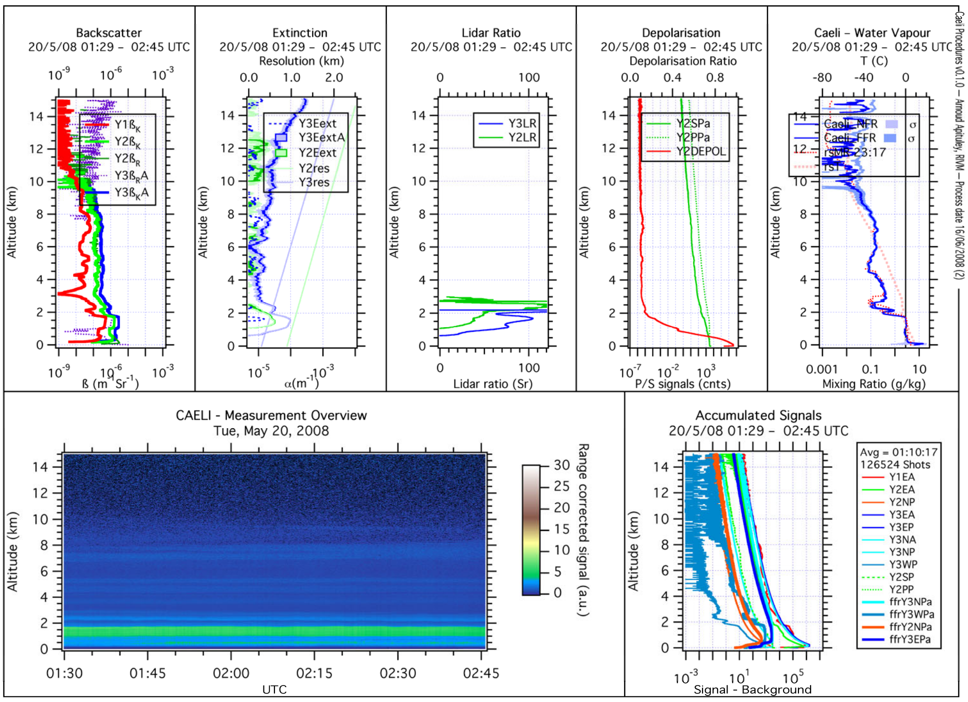

Figure 4. Caeli [CESAR Water Vapor, Aerosol and Cloud Lidar, RIVM] measurements at Cabauw during EUCAARI - IMPACT, taken during a CALIPSO overpass.

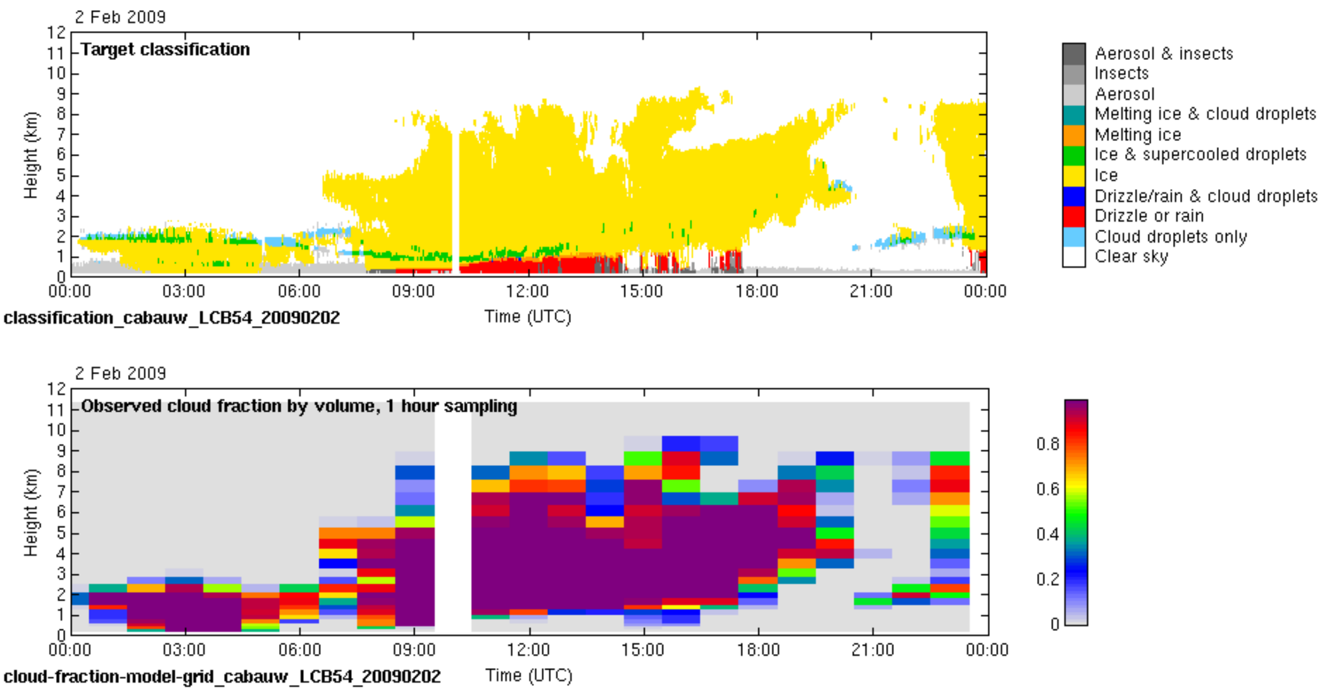

Figure 5. Target classification and 1-hour averaged cloud fraction by volume based on the CloudNet target classification, for 2 February 2009. This processing scheme is now routinely performed on the data.

Recently a 10GHz scanning radar was located on top of the Cabauw tower. Purpose of this project is to augment the routine operation of clouds with a detailed very high resolution two-dimensional image of cloud drizzle and contribute to studies linking precipitation to aerosol and cloud properties.

Furthermore, the 10GHz radar offers new opportunities to link a two dimensional field of clouds and precipitation to very high resolution weather and climate modeling programs.

GRUAN Other Priorities

Table 1 provides a list of additional observations that are routinely performed at Cabauw. None of these observations can be characterized as either GRUAN priority 1 or 2 data, but are crucial to the cohesion of the measurement program at Cabauw and provide the basis of Cabauw as an 'anchor point' for a range of topics, including monitoring, model validation and satellite validation.

At regular height intervals on the tower, turbulent heat, moisture, momentum and CO2 fluxes are measured to record on a continuous basis the energy transfer between the surface and the atmosphere, [http://www.gewex.org/ceop.htm] Together with ground water and soil heat fluxes the energy transfer flux measurements at the tower provide the mainstay of studies of the stable boundary layer [http://www.knmi.nl/samenw/gabls/].

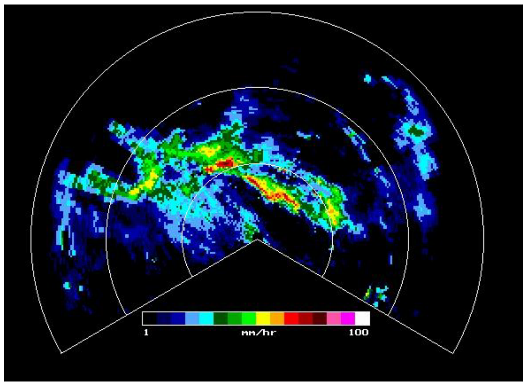

Figure 6. Two-dimensional scan of precipitation using the 10GHz TU-Delft radar at Cabauw.

In 2007, an aerosol inlet was mounted at the 60 m tower level, with the specific aim to facilitate the expansion of the research program to include aerosol size and composition measurements. None of the aerosol observations can presently be viewed as GRUAN climate monitoring data, with the exception of the in situ radon and methane measurement systems run by ECN.

Since May 2008, a cloud condensation nuclei counter (CCN – counter) has been operational at Cabauw. The data from this counter is being used in research to link aerosols to cloud properties.

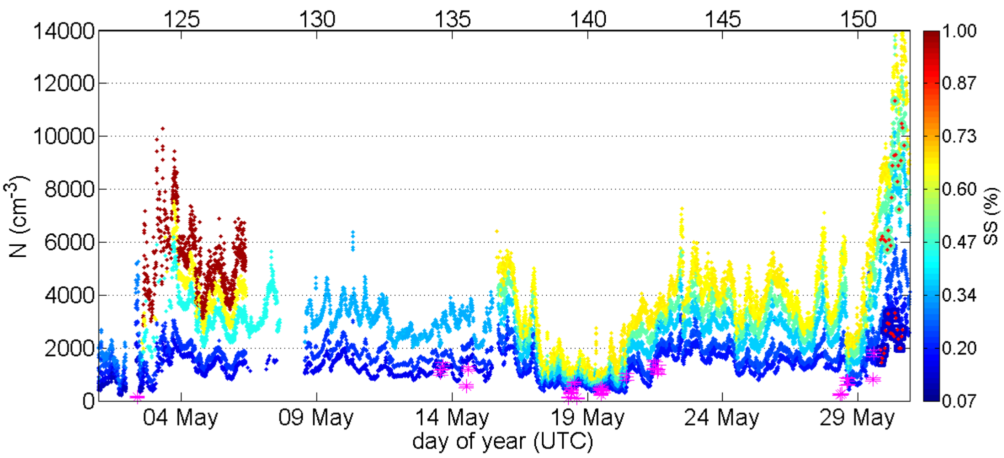

Figure 7. Time series of CCN concentration at Cabauw (60 m level) [May 2008].

DATA AVAILABILITY

Data from CESAR is currently already available under http://www.cesar-database.nl/. However, in the next few months, the site will undergo extensive revision to facilitate the usage by outsiders. An Acceptance Test for a new database facility is planned for March 2009. If the Acceptance Test has been passed successfully the CESAR Database will become operational and all Cesar partners will have the opportunity to share their data with the CESAR colleagues and the atmospheric research community via the CESAR data base web portal. The site will contain a facility so that the user can automatically request data and retrieve these from a web – server. For cloud studies, cloud data processed routinely to Level 2 and 3 [hourly and monthly averages] will be come available as well, interpolated to three different vertical grids, so as to conform to low, mid and high resolution climate and weather model output. Comparative model output from KNMI's Regional Climate Model [RACMO] will then become available as well.

SOME THOUGHTS ON PRECISION, TRENDS, AND THE ECONOMICS OF CLIMATE MONITORING

Appendix 1 of WMO/TD No. 1379 [*GCOS – 112*] makes some important remarks about the precision requirements for any measurements relevant for climate monitoring. 'Measurement precision is closely tied to the frequency of observations and the greater the sample size, the less stringent the required precision'. Furthermore, it is well known that if a large trend is present in the observable, the requirement for precision of the measurement can be reduced as well. Therefore, an important question comes up with respect to the measurement of a climate parameter by different measurement systems: For a given specified precision of the measurement system, how long and at what frequency do we need to measure the climate parameter in order to detect a trend?

This question is not only a scientific but also an economic dilemma. At many institutions money is scarce which impedes the development of climate monitoring programs, so that new investments in expensive and unproven systems are postponed. To illustrate his dilemma we decided to focus on water vapor at the 300 hPa level, which is known to be climatically relevant, but at the same time very difficult to measure with radiosonde systems.

An ensemble of runs made by a regional climate model was used to estimate the expected change in water vapor in the upper troposphere [300 hPa] between 1950 and 2100 over Cabauw [*Boers and van Meijgaard, 2008, Chapman conference, Kona, Hawaii*] . This ensemble is used as a substitute for a 'perfect' climate record of monthly averaged specific humidity of 150 – years long with a trend. Trend analysis was performed using the procedure of Weatherhead et al. [*JGR, 1998*]. The analysis shows that if reference radiosonde measurements were started today, and if such measurements showed no bias, perfect accuracy, and would be performed hourly [which is of course unrealistic] a statistically significant trend would show up after 30 years of observations. The climate record was then sub-sampled to simulate a more realistic program of regular reference radiosonde ascents, and a 10% noise was added to the data. Results indicate that such a reference radiosonde would still need to be launched once every fourth day for a period of 50 years to detect a trend that would be within 20% of the true trend in the observational record. The economic question to ask then is if such trend cannot be better observed by less expensive systems such as a water vapor lidar system that may have less precision but can provide more frequent sampling.

Acknowledgments: *Greg Roberts [MeteoFrance] provided the graph of the CCN – time series [Figure 7]. Bert v Ulft [KNMI] processed the cloud data to level 2 and 3 and provided the plot in Figure 5.*

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