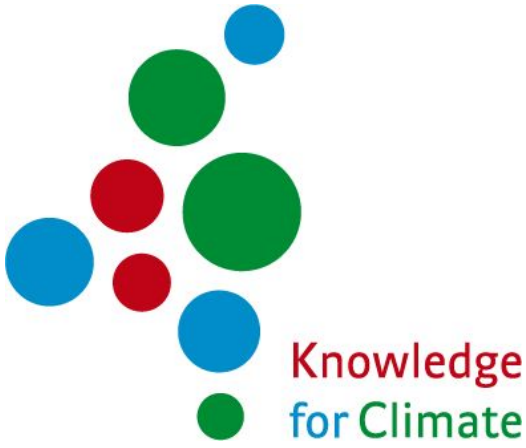
Midterm Report Theme 6:

High-Quality Climate Projections



KfC report number 62/2012

Midterm Report Theme 6:

High-Quality Climate Projections

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1. Introduction

1.1 Problem definition

The fact that climate changes are uncertain poses a challenge when developing adaptation strategies with a long time horizon. Our aim is to mitigate this problem, by studying methods to quantify uncertainty, and developing, where possible, methods to assign probabilities to climate projections. Furthermore, various methods are investigated to obtain information at small spatial/temporal scales, and on regional differences within the Netherlands, for example due to land characteristics (cities) and the influence of the North Sea. Also, we improve the coupling and consistency between models of regional climate change and hydrology, agriculture, ecosystems, spatial planning and air quality. Jointly with our stakeholders, we will explore the effectiveness of different methods for providing the information on climate change, its effects and uncertainties to the adaptation community.

1.2 Mission

The consortium will provide the best information available on regional climate, now and in the future. We deliver information about extreme weather events as input for societal impacts in the Netherlands, with the aim to support adaptation processes, particularly with respect to uncertainty issues.

Top 4 ambitions with respect to the scientific and social debate

1. To estimate and quantify regional climate in The Netherlands, including extremes, now and in the future (Work Package (WP) 1)
2. To provide scenarios that guarantee consistency between different variables, both in time and in space. (WP2)
3. To use the information obtained in 1-2 to assess climate impacts in a faster way. (WP3)
4. To integrate information on climate change and impacts for various user groups such that it becomes a comprehensive set that is valuable to a range of decision makers. (WP4)

Scientific purpose in 2014

To realise these ambitions we do the following:

- Performing/analyzing regional and global climate model simulations (WP1 and WP2)
- Providing show cases of high impact future weather situations at very high resolution (WP1)
- Providing coherent time series, and estimates of extremes and uncertainty ranges (WP2)
- Improving the translation of climate scenarios into input for climate projections to various sectors, thereby reducing the time needed to get information on impacts after publication of new climate scenarios, including dealing with uncertainty (WP3)
- Communicating climate change and climate change impacts to users in a combined and consistent way and/or specifying inconsistencies in approaches or data use (WP4)

1.3 Vision

Our society is vulnerable for specific types of weather, such as heavy storms, long periods of draught, and heavy showers with hail. To adapt to these extreme weather events, information about frequency, intensity and form of these events is needed. As consortium we want to provide the best information available on regional climate, now and in the future. What is the best information available for adaptation can only be determined in a dialogue with the stakeholders. Therefore, stakeholders have been included from the start of the project.

Stakeholders made clear that for robust adaptation, additional information is needed. Two key user needs are: 1) integral and consistent information on climate change and impacts and 2) showcases of future high impact weather.
For delivering crucial information for adaptation we as Theme 6 consider it important to:
Provide a state-of-the-art solid scientific basis for both the raw and processed information products.
Improve the link with climate impact research (hydrology, agriculture, ecology, spatial planning and air quality), since stakeholders are especially interested in the impacts.
Bring together in a consistent way (existing and new) climate and impact information from different sectors in one portal: The climate impact guide.
Have a continuous dialogue with the stakeholders, which is required for credibility, salience and legitimacy.

1.4 The red line: Making uncertainties manageable

The project is focused on various aspects of uncertainty that play a key role in decision making with respect to adaptation to climate change.

It is not possible to completely erase uncertainty in climate change decision making. However, there is a suite of possibilities to make these uncertainties more manageable: Reducing uncertainties by gaining knowledge on critical meteorological phenomena, quantifying uncertainties, reducing uncertainty by aiming for high-quality products, aiming for consistent climate projections for various societal sectors (c.q. hydrology, agriculture, ecology, spatial planning and air quality), handing guidelines to go about with uncertainties from various perspectives, taking care of optimal communication with the stakeholders / users, et cetera.

In this project the most relevant approaches (related to the science about the climate system) to make uncertainty more manageable are implemented.

Long before the project started an inventory was made together with stakeholders of the societal vulnerabilities related to weather, climate and climate change.

The various approaches to include uncertainty in decision making on climate change adaption is reflected in the way the project is set up. Each work package handles one or more approaches to handling uncertainty.

Work package one is about reducing uncertainty of societal risks by gaining knowledge about specific meteorological phenomena. Our society is vulnerable to

specific types of weather: heavy storms, long periods of draught, heavy showers with hail. Our society is well adapted to our current climate, the frequency and intensity of extreme weather, extreme meteorological phenomena. As climate is changing the frequency, intensity and shape of the extreme weather events will change too. Work package one is studying the physics of these high impact weather events and the way they evolve as climate is changing.

Work package two is about representations of uncertainty in climate change. Can we estimate the chance of realization of a specific scenario? Can we estimate the chance of a specific extreme event within one of the scenario's. Can we give time series of specific meteorological elements? Can we find ways to quantify the chance of a specific meteorological condition in the future? In work package two we try to answer these questions and thus provide decision makers more quantified information about the uncertainties in adaptation to climate change.

Work package three is about the impacts of climate change to a number of societal sectors. Many decisions in spatial planning involve information on various societal sectors. We aim to provide these societal sectors, hydrology, agriculture, ecology, spatial planning and air quality, with a consistent set of climate impact projections, thus making decision in these sectors more manageable. In addition, the work package also delivers a software framework and procedures that allows the community to quickly generate impact scenarios after the availability of new climate scenarios.

Work package four is about interactive communicating climate change information. Chronologically, this was the first work package we started. We consulted stakeholders/decision makers on their need for information on climate change. These consultations provided us with valuable information that was used to define the project. In the course of the project, when more and more results become available, we keep in close contact to our stakeholders in order to optimize the tools and mechanisms for communicating about the findings and about uncertainty issues.

To the Theme 6 it is very important that the results are accepted by as many as possible actors in decision making in adaptation to climate change. So, decision makers do not have to debate the climate information itself but can focus on the various societal interests and risks involved. This makes the handling of uncertainty in climate change more manageable.

Therefore we aim to provide the best information at hand. A close co-operation with the KNMI team that works on the new set of climate scenarios for the Netherlands is in place. The research is embedded in a broad international scientific network. Various activities are in place to monitor the developments abroad and keep in sync. This is of great importance because of international issues on climate change, for example the management of the Rhine catchment area. Furthermore, there are many initiatives w.r.t. international (European) climate services.

As stated before, it is not possible to completely erase uncertainty in climate change decision making. However, we can make it more manageable to decision makers by providing information that is relevant, useful and useable. That is the aim of this project.

Our stakeholders have been connected to Theme 6 from the very beginning of the project: before the writing of the project plan an inventory was made along the other KfC themes and the hotspots about their demands for climate and impact information. The Theme 6 project plan is based on this inventory and earlier inventories among a broader group of users (Inventarisation of user requirements 2005-2010).

During the programme, Theme 6 will influence the development of climate and impact information by means of an active two-way communication with the different hotspots and with the other Themes of KfC and other stakeholders (ranging from researchers, consultants, to policy makers in different sectors as water, agriculture, health, transport and energy). These stakeholder surveys will sharpen the user requirements, and at the same time convey information about climate change and its impacts to the users. By doing so, it will also prepare users for the upcoming update of the scenarios.

1.5 Context

The KfC programme aims to provide scientifically sound information to enable those responsible for adaptation measures to make robust decisions. In 2006, KNMI published a set of climate change scenarios that serves as a standard for supporting adaptation policies and climate impact research in the Netherlands. A new generation of scenarios will be presented in 2013. The KNMI climate scenarios are the main societal product to which Theme 6 contributes, forming the base for adaptation policy. The collaboration with the KNMInext project is an advance for both projects. Theme 6 makes better KNMInext climate scenarios possible in many ways: in a better scientific foundation, in additional products, in connecting climate information to impacts, and in communication. Also, the KNMI climate scenarios are a well-known product about which users are, for example, easily inclined to follow a workshop.
The data produced in this KfC Theme 6 will be made available to the other Themes of the KfC program. For example, in Theme 2 (Climate-proof fresh water supply) in cooperation with Theme 6 a consistent sets of boundary conditions for the fresh water use in the Netherlands will be developed.

2. Approach

2.1 Programme outline and research approach

The research strategy is formulated and made operational by four work packages. Work packages 3 and 4 address questions of different sectors directly. Work packages 1 and 2 develop knowledge for a next generation of climate change scenarios, currently in development.

WP1: Climate scenario development: mechanisms of local climate change in the Netherlands: Increasing knowledge of processes that directly affect climate in the Netherlands. Since local meso-scale atmospheric dynamics and their interaction with the land/sea surface are important mainly during summer, this season gets most attention here. WP1 focuses on the influence of the land-surface and land use changes, small-scale atmospheric dynamics related to heavy showers and storms and the influence of the North Sea. The aim is that this knowledge on the corresponding high impact meteorological events will narrow down the range of uncertainty involved in adaptation strategies mainly in water management and water safety. Showcases are provided of a new generation climate information obtained from a non-hydrostatic climate model at very high resolution.

WP2: Climate scenario development: time series, extremes and probabilities: Developing knowledge for a new generation of climate scenarios for the Netherlands. We quantify uncertainties in newest global and regional climate simulations, using probabilistic methodologies applied to regional extremes and climate impacts thus making uncertainty issues in adaptation more manageable. In addition, a more complete picture of climate change is obtained by providing examples of synoptic weather events in a future climate setting consistent with the KNMI'06 scenarios. This will give insight into the vulnerability of infrastructure. For sea level projections, the focus is on further understanding of processes contributing to sea level changes. The knowledge is used for the development of new climate change scenarios.

WP3: Scenario development for climate change impact: Improved coupling and consistency between models for climate and hydrology, ecology, agriculture, and air quality by incorporating relevant mechanistic links and formalizing these is a (software) framework. By the coupled models the propagation of uncertainty on the effects on natural resources is studied. Also projections of land use change are incorporated. The derived information on the impacts is summarized in different forms for presentation to the adaptation community. In a case study we consider how uncertainties are taken into account when developing adaptation strategies. This should result into recommendations of best practices for providing projections and their uncertainties for future boundary conditions.

WP4: Climate services: The importance of communication of climate information (including uncertainties) to stakeholders is often underestimated en may result in limited or incorrect use of data. Therefore, we focus on improving information exchange in the chain of climate research – impact/adaptation research – decision making and vice versa. We pre- and post-process climate data and provide assistance during use of the data and information (tailoring). Tailoring is not limited

to climate data, but also includes climate impact data. Practical tools are developed to visualize the data on different temporal and spatial scales through web interfaces. Information is given on the assumptions behind the information, on the interaction between disciplines, and on how the information can be interpreted.

Coherence and interaction

The project is organized in a chain (see Figure 1) from production of high quality climate projections to the specific information required by a variety of stakeholders. Crosscutting themes are dealing with uncertainty and integration of monodisciplinary approaches. WP1 is about reducing uncertainty through analyzing regional climate feedbacks. In WP2 an attempt is made to assess uncertainty with probabilistic methods. WP3 and WP4 are about translating to impacts, mapping the uncertainties and communicating to various societal sectors.

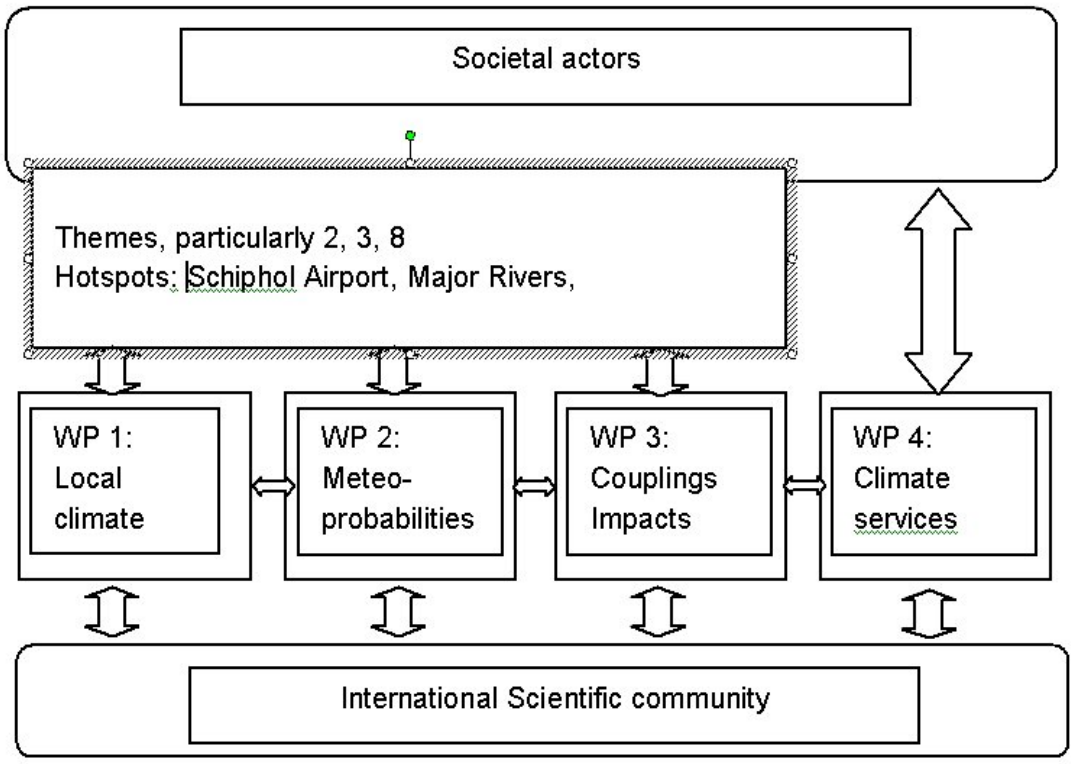

Figure 1. Coherence and interaction of Theme 6 - High-quality Climate Projections.

The chain is especially connected to the international scientific community by WP1-2. In these fields of research already a lot of international cooperation exists. At the side of WP3 and WP4, the project and its participants are well connected to society. The work on impacts and climate services is less internationally organized, although there are several initiatives (e.g. JPI-Climate) in which the researchers are also involved.

WP1 provides results from regional climate simulations to WP2 where they are used to assess uncertainties, and to WP3 where they are used to estimate climate change impacts. On its turn WP1 gets large-scale driving conditions from simulations performed in WP2 in order to downscale these further by employing non-hydrostatic

models to the km-scale. These very high resolution cases studies are inspired by user requirements from WP3/4 and from the different hotspots involved (Schiphol, in particular). The cases provide insight into the high impact weather conditions that may occur in future climate that set conditions to adaptation measures.

WP2 provides information on uncertainties at different time and spatial scales to be used for coupling to impacts. It makes use of regional climate model simulations performed in WP1, and simulations performed within the wider scientific community. Information on how climate impact modelers and end-users use uncertainty to develop adaptation strategies is provided by WP3 and WP4 in order to provide guidance to developing new climate scenario information in WP2. Information on uncertainties and new methodologies of generating time series is also provided to (and exchanged with) WP4.

WP3 incorporates a larger variety of scientific fields. Consistency is preserved by two general activities. All scientists contribute to the research towards more general approaches to coupling effect models to climate models. Secondly, all scientists contribute to analysis of the selected specific sectors. WP3 obtains information on climate change (high resolution, time series and uncertainty estimates) from WP1-2, and provides information on climate change effects and impacts for different sectors as well as recommendations for presentation of scenarios for different sectors to WP4.

WP4 aims to disseminate the information that comes available from WP1-3 to a broader public, where necessary modified into a form appropriate for the intended stakeholders. Researchers from WP1-3 are asked to review the modified results. Information on how stakeholders use and perceive uncertainties in order to provide guidance to developing new scenarios are proved to WP1-2. WP4 cooperates with WP3 to create an integrated dataset on climate change and its impacts for a limited number of combinations of climate scenarios, spatial scenarios and time horizons. WP4 organizes stakeholder consultations, and asks scientists from WP1-3 to participate in this. WP4 gives feed back on stakeholder needs to WP1-3.

2.2 Cooperation with other KfC themes.

It is found to be rather difficult to realize good connections with the other KfC themes. After several attempts to get input from other themes, little feedback is given during the project. Possible partly because additional questions are not clear yet and partly because of high work pressure and the complexity of the whole program. However, we keep the KfC themes connected by informing them through our newsletter and invitations to our workshops (in 2010, 2012 and 2013). In the 2012 workshops the KfC themes have explicitly formulated requirements for Theme 6/ the KNMInext scenarios during a lively panel discussion. A Theme 6 roadshow to inform about Theme 6 and get input for further user requests is planned for interested themes in the beginning op 2013.

Within WP4 there are budget reservations for user questions from and support of other Themes (Climate Information Services, expert pool). No concrete requests have been submitted until now. This is according to our expectations, as additional questions will arise in the last half of the programme.

Within the KfC programme the possibilities for a booklet about the impacts of climate change to KfC sectors is discussed. Idea is to compile this booklet together with all KfC-themes about a half year after the publication of KNMInext. This idea will be further developed in 2012/2013 and issued in 2014.

We co-operate with Theme 2 on freshwater supply, where WP3 provides probabilistic information on discharge of the major rivers, and on the effect of upstream irrigation on the flow coming into The Netherlands. Here, researchers from Theme 2 tapped into the tool from WP3 to extract the required information on precipitation deficit and flow in the Rhine/Meuse catchment. Other combined work focuses on the joint probability of high flows in the major rivers and high surges at sea.

In the Autumn School 2012 Dealing with uncertainties in research for climate adaptation, researchers of different themes are brought together to share their knowledge and learn about what information is needed for robust adaptation.

2.3 Stakeholder collaboration

Strategy

- Actively approach target groups
- Ongoing contact with stakeholders/users
- Influence of stakeholders/users
- As fast as possible, but with sufficient basis
- Tuning with partner organizations

Aim communication

- Inform about climate change and impact information
- Explain how scenarios and information can be used (and how not)
- Make an inventory of users' requirements
- Create (public) support

Target group

We consider our target group to be the professional users of climate information from the whole chain of knowledge within a broad range of sectors (a.o. hydrology, nature, agriculture, health, transportation and construction):

- Impact researchers
- Companies
- Intermediaries
- National/regional governments, policy makers
- NGO's
- Etc.

Messages

- The KNMInext scenarios succeed KNMI'06. KNMInext includes the most recent scientific insights and gives more information;
- Climate in the Netherlands may change in the following way ……;
- The climate in the Netherlands in about 50 to 100 years ahead can not be described with just one picture of the future;
- The KNMI climate scenarios are a useful tool to map the range of impacts of climate change and to check which adaptation measures are robust.

User involvement

- During the project stakeholders are connected as follows:
- Researchers: via the Climate Impact Guide, a webportal for knowledge transfer1
- (KfC) Researchers (PhDs/postdocs): In the Autumn School 2012 Dealing with Uncertainties in research for climate adaptation. Researchers of different disciplines are brought together to share their knowledge and learn about what information is needed for robust adaptation.
- Impact researchers: In collaborative projects with respect to impact analyses (WP3)
    - Hydrology
    - Ecosystems
    - Agriculture
    - Air quality
- Impact researchers: In collaborative projects with respect to climate services/communication (WP4)
    - Combined website: consistent information about climate, hydrology, ecosystems, agriculture
- KfC themes and hotspots: Within WP4 there are budget reservations for user questions and support (Climate Information Services, expert pool). No concrete requests have been submitted until now. This is according to our expectations, as additional questions will arise in the last half of the programme.
- KfC themes: With the KfC programme the possibilities for a combined booklet about the translation of climate change to impacts is discussed. Idea is to compile this booklet together with all KfC-themes about a half year after the publication of KNMnext. This idea will be further developed in 2012/2013 and issued in 2014.
- KfC theme 2: cooperates with Theme 6 on freshwater supply, where WP3 provides probabilistic information on discharge of the major rivers, and on the effect of upstream irrigation on the flow coming into The Netherlands. Here, researchers from Theme 2 tapped into the tool from WP3 to extract the required information on precipitation deficit and flow in the Rhine/Meuse catchment. Other combined work focuses on the joint probability of high flows in the major rivers and high surges at sea.
- Hotspots: The main target hotspots are represented in the steering group. The representatives are a vital link to the hotspots: they can inform about the hotspot needs and the other way around: inform the hotspots about Theme 6.
- Hotspots: Various partners involved in WP3 and WP4 also participate in hotspot projects, thus making a connection and offering the possibility of constant feedback.
- The broad group of users: Via a newsletter for KNMInext and KfC Theme 6
- The broad group of users: Interactive workshops:

[1] Theme 6 releases data and background information for climate impact analysis through the Climate Impact Guide. This pilot website is a first attempt to give researchers an overview of data and information about climate and climate impacts in the Netherlands. The relations between the sectors are described on the website: the exchange of data between sectors, the differences in use of data and the consequences of these per sector. At the moment information about the following sectors can be found: Climate, Nature, Agriculture, Water and Land use. These will possibly be complemented in the future with air quality (TNO). The information is supplied by KNMI, Wageningen UR (University & Research centre), Deltares, VU University Amsterdam en KWR Watercycle Research Institute.

    - In 2010 the first stakeholder sessions were organized, enabling stakeholders to formulate data requirements, such as on desirable time horizon, temporal and spatial scale and climate variables;
    - In 2012 the second stakeholder sessions were organized concerning requirements for communication: a.o. suggestions for websites, brochures, courses and the need for sector specific summaries of climate information/impacts.
    - In the beginning of 2013 new sessions will be organized to fine tune communication demands and to give stakeholders early insight in the expected information so they will be able to implement the results more easily.
    - In the autumn of 2013 a broader symposium about the content, development and use of the KNMInext will be organized.
- Key governmental organisations and intermediaries: Roadshow with presentations about the KNMInext scenarios and about the impacts relevant to the specific sector;
- Limited group of users: feedback on website, brochure, etc.

2.4 Link with KNMI-next

The approach of Theme 6 is strongly related to the KNMInext climate scenarios. Research and user inventories performed in Theme 6 will be used to improve the KNMInext climate scenarios2 and to provide more elaborate information. The basis of the activities for the development of the KNMInext scenarios (see Figure 2) is done by a KNMI project team. The activities of Theme 6 deliver important contributions:

- A more elaborate scientific foundation (A and B), for example the assessment of information about uncertainties in regional modeling caused by uncertainties in global modeling;
- Additional products, such as case studies of high impact future weather, information about extremes, uncertainties and probabilities, future consistent time series (C);
- The coupling to impacts: climate models are coupled to impact models, so sectors are able to deliver climate impact information shortly after the publication of KNMInext (D);
- The possibility to deliver tailored climate and impact information (E);
- A considerable part of the communication (F), as newsletters and stakeholder consultations and the Climate Impact guide, a web portal which releases data and background information for climate impact analysis.

[2] In 2013 a next generation climate scenarios – known under the temporary working title KNMInext - will succeed the KNMI scenarios dating from 2006

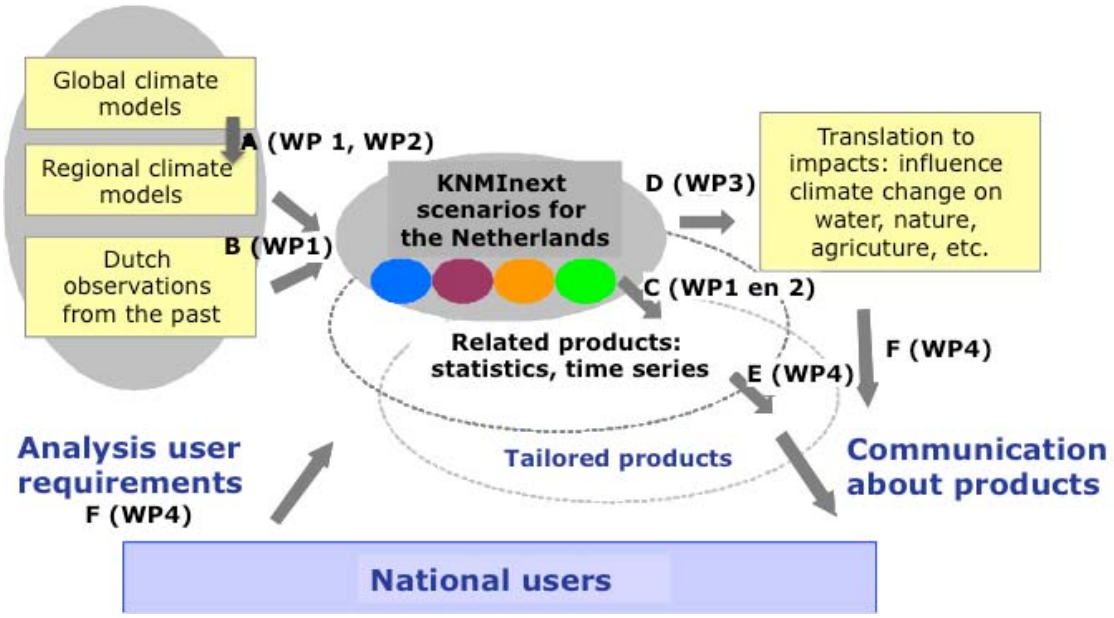

Figure 2. Activities for the development of the KNMInext scenarios. A: the analysis of global climate models and setting up a framework for the scenario's; B: translation to regional climate change; C: developing related products, such as statistics and time series; D: translation to impacts; E: obtaining tailored products; F: Communication with national users

2.5 Contribution to the Delta Programme

Theme 6 contributes to the new Deltascenarios via the KNMInext climate scenarios, in co-operation with the Netherlands Bureau for Economic Policy Analysis (CPB), the Netherlands Environmental Assessment Agency (PBL), and the Netherlands Agricultural Economic Institute (LEI). Although the results won't be available in October 2012, when the Delta Programme plans to start calculation of the impact, the results of Theme 6 make it possible to do an update shortly after the publication of the KNMInext scenarios.

2.6 Benefits of collaboration

- The collaboration with the KNMInext project is an advance for both projects: together a more intense communication is possible and the KNMI climate scenarios are a well-known product about which users are easily inclined to follow a workshop. Also, information from Theme 6 is more easily imbedded in policy, thanks to the connection to the KNMI scenarios which are often already implemented.
- The KNMInext scenarios will appear around the same time - and are based on the AR5 assessment report of Working Group I (the physical scientific aspects of the climate system and climate change). The publication of the WGI report of AR5 is expected to generate much publication about global change, generating the question "What does this mean for climate change in the

Netherlands?" Theme 6 is able to answer this question with the KNMInext scenarios and with its climate impact assessments.

- Collaboration with the Delta Programme gives a strengthened communication. The Delta Programme is a well-known user of our information with very clear social benefits.
- The collaboration with impact institutes is a good chance in delivering direct useable information, more fit to user demands: not separate information streams, but integral and interdisciplinary consistent information.

3. Research results

3.1 Results in context and coherence

In paragraph 2.1 we state that “The chain is especially connected to the international scientific community by WP1-2. In these fields of research already a lot of international cooperation exists. At the side of WP3 and WP4, the project and its participants are well connected to society.” In the following a number of examples are given.

1. From developments in weather forecasting to assessments for the Delta Programme
At ECMWF a method is developed to manipulate the weather model in a structural manner. This implies that simulations can be made that represent specific meteorological conditions, such as high impact weather. For example a very cold period in winter due to a blocking on the continent or a sequence of days with lots of precipitation due to a large north to south pressure gradient. The ECMWF developed this method for weather applications. The participants in Theme 6 are well embedded in this scientific community which opens the opportunity to develop such a method further for climate applications. WP2.3 involves the development of such a method. Recently the PhD-student (after a year of hard work) succeeded in pushing the EC-Earth model into a NOA+ mode. This is a significant step forward, because this will enable (in time) the simulation of meteorological conditions that are crucial for specific adaptation measures. For example: One of the decisions of the Delta Programme is on the Maeslandtkeering near Rotterdam where the river Rhine flows into the North sea. The decision on the large scale infrastructure for adaptation depends on the chance of occurrence of two coinciding events: 1) soft extreme of precipitation in the Rhine basin, which should force the Maeslandtkeering to be open and 2) high sea level due to persistent strong Northwesterly, which should force the Maeslandtkeering to be closed. It is anticipated that with the method developed here it will eventually be possible to study this kind of specific meteorological conditions. It is anticipated that this information on the precipitation will be used in the National Hydrological Model which is utilized in WP3.

2. High resolution precipitation information for Schiphol area
In a large international corporation a new high resolution weather model, HARMONIE, is developed. In Theme 6 we develop methods to embed this high resolution model into the regional and global climate modeling systems RACMO and EC-EARTH. This enables studying meteorological conditions that may occur in future climate at an unprecedented high resolution. This is of high importance at sharp boundaries such as our coastal area where the temperature difference between sea and land induces special effects. This combination of climate and weather models will be used to study in detail meteorological conditions that are of importance to the spatial planning and infrastructure of Schiphol airport. It is anticipated that WP4 will contribute in communicating this kind of information to our hotspot users.

3. Time series of meteorological parameters for impact studies

Many applications in water management and thus also in adaptation measures use time series of precipitation, temperature and wind. This information is fed info hydrological and other models in order to assess the responses of the system.
Up till recently only observed time series were available. However, if you want to do test on the robustness of your system to climate change this will not do.
Alternatively one could use the output of climate models. In WP2 the skills of the climate models are studied. This is done using global and regional model output from European collaboration in for instance the ENSEMBLES project. This is necessary to improve the models themselves and estimate the quality of the specific parameters for further use. These studies show that climate models are not able to simulate the trends in precipitation in Europe if the fast rise of the temperature in the North sea and the change in prevailingly wind directions is not taken into account (for more detail see the next paragraph). This knowledge will be used in designing the new KNMI-climate scenarios. Furthermore, it will be taken into account when making specific time series for impact studies in WP3. The time series are meant to be a common basis for assessing climate change impacts for the various fields involved in the Theme.

4. Simulation of precipitation trends
Observed precipitation trends in Europe in the past century are not simulated well by climate models. Using high-resolution regional models it has been determined that in winter the atmospheric circulation is the main cause (it changed more than in the simulations) and in summer the sea surface temperature of the Atlantic is the main cause (it has risen more than simulated). This is part of structural model uncertainty common to all climate models and has to be added to the uncertainty determined by the spread of climate model ensembles only. Within KNMInext scenarios we will have to take this into account.
Statistical uncertainty of estimates of rain fall extremes can be reduced by applying a newly developed statistical methodology. A regional peaks-over-threshold model has been developed to estimate the changes in precipitation extremes. Changes in rare events are generally difficult to detect locally. A statistical model that describes the occurrence and magnitude of the extremes at all rainfall stations or grid boxes in a region may markedly improve the estimation of properties of the extreme-value distribution. The regional peaks-over-threshold model was developed using gridded observed daily rainfall data (E-OBS data) for the Netherlands for the period 1951 – 2010. The peaks-over- threshold method considers all precipitation amounts exceeding a high threshold. For the winter season, it was shown that the uncertainty of the return levels could be reduced by about 50%. The statistical model is developed further using the daily precipitation amounts from regional climate model simulations.

3.2 Innovative aspects and scientific output

Work Package 1
High resolution non-hydrostatic climate modeling is a new and rapidly developing field. The motivation for using this kind of models is that they much better resolve the dynamics of convective clouds, meso-scale circulations and their interaction with the surface. These processes are not only important at the local scale, but also at the larger scales for example through tropical convection (and the link with the global large scale circulation) and summertime continental drying due to feedbacks between land surface and convective precipitation. Here, however, we focus on the local scale. One important example is the investigation of the observed temperature

dependency of hourly precipitation extremes (14% per degree) which appears to be considerably underestimated by the present hydrostatic models (about a factor of two), and which could have important consequences for the increase in short duration precipitation extremes. The expected scientific output is a better understanding (and estimation) of how local processes can act as a local driver of climate change and impacts.

There is a widely growing interest in local and sub-daily precipitation extremes as apparent from an increasing number of papers on this issue. The work we do in WP1 on hourly precipitation extremes is trendsetting in this respect with more than 60 citations of our recent work (according to Web of Knowledge) on this subject over the last few years. Furthermore, work is embedded in CORDEX with wide visibility in Europe and worldwide.

Work Package 2

The innovation in WP2 is in the technical and methodological aspects. We will use the latest available climate model output (from EU Ensembles, CMIP5 and other EU projects) to assess uncertainties. New model results will have higher resolution and will be derived from new experimental set-ups, such as decadal predictions which aim for specific climate information up to 2030. High-resolution atmosphere-only results at unprecedented resolution (30 year runs up to T799 horizontal resolution, in collaboration with EC-Earth partners) will be available as well. New techniques will be used to construct time series for extremes, both with statistical models and with climate models. We will use so-called forcing singular vectors in EC-Earth to generate specific weather episodes. This method has not been applied in climate science yet. The most important processes that determine ice sheet calving are not well known and the research will result in a new collection of data and models. Methodologically, the innovation is in the interdisciplinarity as well. The science output is driven by the needs of stakeholders in the hotspots and this will guide the development of future climate scenarios.

The work in WP2 leads to a better understanding of observed changes in climate and how they are represented in models (van Haren et al. 2012). It informs the climate modeling community (e.g. EC-Earth) on regional biases and will lead to improved models and predictions. The standard peaks-over-threshold method for univariate stationary time series is extended for application to multi-site non-stationary time series. A manuscript, entitled “A regional peaks-over-threshold model” has been submitted to Water Resources Research (M. Roth, et al.) The new dynamical techniques that are developed to constrain the simulations of EC-Earth in order to construct physically consistent time series have gained a lot of interest from the scientific community.

Work Package 3

Many couplings exist between climate models and impact models. However, generally these are made separately for different disciplines and carried out by the scientific community. Therefore, impact projections are not easily integrated, e.g. for ecosystems and agriculture and relatively little attention is paid to the practical use of the projections. In this theme we will make couplings based on a consistent set of climate scenarios for a range of impact models where we cover the scale of the entire Rhine basin to the regional scale of the Netherlands. Also innovative in this WP is that we take into account the effectiveness of various impact projects for decision making in the way couplings between climate models and impact models are made.

For hydrology a coupled system of hydrological, hydrodynamical and water demand models has been set-up which covers the area from the Alps to the North Sea. This allows us to investigate the complex interactions that occur in the highly managed Dutch delta area. In addition, the system is set-up using multiple models to account for model (structure) errors. The use of ensembles of meteorological scenarios has already been tested in the system. Later, the effect of different land-uses in the Dutch delta and the upstream basins will be investigated. A separate study was set-up to investigate how flood risk modeling should fit into the overall framework.

A paper "Participatory design of farm level adaptation to climate risks in an arable region in the Netherlands" is currently being finalized, which describes how climate data can be linked to agricultural models an how damages due to extreme events can be estimated. Finally, it describes a concept of how the climate sensitivity of agriculture (at the farm scale) can be determined.

The important link of hydrological and climate models to nature and ecosystem models has been investigated and model linkages have been defined and set-up.

Meteorology has a strong impact on air quality. In order to study the impact of climate change on air quality, two transient scenario runs were performed with the one-way coupled system of a regional climate model (RACMO2) and a regional chemistry-transport model LOTOS-EUROS, covering 1970-2060 on a European scale domain. Results were analyzed for the present-day (1989-2009) and future climate (2041-2060). The most important findings were:

- Both scenario runs predict higher summer ozone concentrations for the future climate;
- For PM, changes in concentrations were only small and models did not everywhere agree on the sign of the change;
- For the present-day climate, the simulations using ECHAM5 and MIROC boundary conditions differed considerably from that using the ERA-Interim and from each other, both in meteorology and in air quality;
- Differences between present-day and future climate were of the same order of magnitude as (or even smaller than, ECHAM5) the difference between the climate simulations and the ERA-Interim simulation for the present-day climate, indicating large uncertainties;
- The effect of expected changes in anthropogenic emissions on future air quality is probably larger than the impact of climate change.

For the Netherlands, an increase in summer average ozone daily maximum concentrations of 0-3 µg/m3 (ECHAM) to 5-9 µg/m3 (MIROC) was found. For PM both models predicted a minor increase (around 0 for ECHAM, 0 to 1 µg/m3 for MIROC). These results are only indicative, given the large uncertainties in the meteorology from climate runs and the incomplete PM representation of LOTOS-EUROS. A single simulation can only be used to study tendencies, not for policy making. These results were written down in a paper for ACP (now published on-line as ACPD discussion paper). The strong point of the research is that we have two climate simulations and ERA-Interim to compare. The results are state-of-the-art science. Concentrations and deposition files are available in NetCDF format and can easily be applied in other models.
The work on uncertainty estimation has thus far focused on estimating Rhine discharge and yielded good results.

Work Package 4

This work package does not focus in the first place on scientific output, but on disseminating scientific data/information to a broader public (scientists, policy makers, etc.) through a web portal, besides the personal contacts between stakeholders and scientists. Innovative in this web portal is the integration of data and information on climate change and the impacts on a wide range of sectors. For this integration we pay explicit attention to background information on how data/information is generated, the way uncertainty is dealt with in the various disciplines, the interactions between sectors and possible gaps in interactions, and the possible consequences for the interpretation of the results.

The web portal (Climate Impact Guide) is a form of Climate Services in a rather broad form. Little is published in scientific journals on experiences with user involvement in Climate services, on the efficacy or different ways of disseminating data and information, etc. This work is at the boundary of the natural sciences and the social sciences. The set-up of this WP is not to produce output in the form of scientific articles, although our experiences may contribute to overviews, discussion papers (e.g. through JPI-Climate or other European projects). At the same time we try to profit from scientific literature on e.g. framing, types of problems (e.g. structured/unstructured), different adaptation strategies, etc.

3.3 International context

Work Package 1

- Builds on European FP7 projects IMPACT2C and ECLISE in which high resolution climate modeling is performed, and the data is provided/tailored to end users. Regional modeling efforts are also done within (EURO)CORDEX: a WCRP initiative on coordinated regional model experiments.
- Builds on European collaboration building a non-hydrostatic climate version of the model HARMONIE. The NWP version of HARMONIE is developed with a European collaboration of ~ 10 countries.
- Contribution to a workshop of the UK project CONVEX (http://research.ncl.ac.uk/convex/) and plans for further collaboration. Three weeks visit from Seth Westra of the University of Adelaide (Australia) working together on observations of extreme precipitation.

Work Package 2

- Builds on development of seamless prediction strategies and the development of EC-Earth (European consortium from 11 countries developing an earth system model based on ECMWF forecast systems).
- Builds on different EU Framework projects on models and scenarios: ENSEMBLES, COMBINE, IS-ENES,EUCLIPSE, ICE2SEA. Applicants are actively involved in those projects. Results from these projects will be used.
- In WP2.1 we collaborated with Dr. M. Collins of University of Exeter who is an expert on climate modeling and uncertainties in climate models. He contributed to the scientific papers. In general the work is embedded in ongoing European FP7 projects in which KNMI is involved, such as EMBRACE, ECLISE and the SPECS project that has just been funded. It is expected that methodology developed contributes to the bases of climate services as for instance developed in the Joint Programming Initiative on Climate.

Work Package 3

- Builds on climate projections obtained from the EU Ensembles project and their hydrological effects from the RHEINBLICK project.
- The ESSENCE dataset is used to investigate climate variability and how that translates though he models downstream in the chain.
- The methods and models used in the cooperation between the German Federal Institute of Hydrology (BfG) and Deltares/RWS are compared with those used exclusively within The Netherlands, thus putting Dutch methods in an international context. This focuses on the hydrological models used but also on the climate datasets (current climate) and how the scenarios are generated, either by dynamical downscaling and bias correction or by applying some variation of the Delta method.

Work Package 4

- Exchange of experiences on Climate Services within JPI-Climate.
- Comparison of methods, scenarios, climate services, communication in a boarder crossing case: provision of climatological data needed for river discharges in the Rhine basin. Together with DWD (first comparison of climate scenarios now available).
- Inventarisation of Climate Services in a limited number of European countries, together with SMHI/Lund University (in starting up phase).
- We will try to link to important international initiatives/research on climate change and impacts trough the Climate Impact Guide website).

3.4 Contributions of the consortium to the international climate debate.

The contribution of the consortium to the climate debate occurs for an important part in the form of publications in peer-reviewed journals. For a list of publications see Appendix 3.

Other contributions have been given via Workshops, stakeholder meetings, symposia:

- Workshop Waterscenarios Deltares 2011.
- Presentation at the EGU 2011, By J Schellekens and W. van Verseveld
- Presentations/workshops about KNMInext during Climate Changes Spatial Planning end symposium op 1 December 2011.
- Stakeholder meetings KNMInext/thema 6, February and March 2012.
- Climate course for policy makers of the Ministry of Infrastructure and the Environment, spring 2012.
- Presentation 8 March Vaste Tweede Kamercommissie I&M, A. Feijt
- Presentation 3 April 2012 Delta kennisconferentie, A. Feijt
- Presentation about KNMInext/theme 6 during weather providers meeting, 26 April 2012, A. Klein Tank
- September 2011, Melbourne, Invited speaker at WIRADA science conference (J. Schellekens, http://www.clw.csiro.au/conferences/wirada-symposium/presentations.html)
- Presentation at EGU by A. Feijt (April 2012)
- Presentations for advisory Board KNMInext 5-6 June, 2012, J. Bessembinder
- Presentation for IMAU students (J. Bessembinder, May 2012, examples of research contributing tot the KNMInext scenarios)
- Presentation for JPI-Climate/CIRCLE-2 on user involvement (Bologna, November 2011, J. Bessembinder)

- Contribution to the formulation of the Fast Track Activities within JPI-Climate for the module on Climate Services (inventarisation and analysis of users requirements and climate services in Europe). Started up recently (Bessembinder/Overbeek)
- Tales of Future Weather. Hazeleger et al. Planet Under Pressure conference Londen, March 2012
- Presentation at the NMDC Roadshow (June 2012) by J. Schellekens

The added value of Theme 6 is particularly the strong coherence of this Theme, which is reflected in its contributions to the climate debate.

4. Social Impact

4.1 Relevance of the research programme for national and regional adaptation policies

This research programme aims to provide the best information available on regional climate, now and in the future. Knowledge about climate and climate change is essential for the maintenance of a safe and livable country, to manage climate-related risks to humans, ecosystems, infrastructure, etc. and develop resilience through adaptation strategies. Also, the economic significance of climate knowledge is huge.
We contribute to optimizing these important values by delivering state-of-the-art climate information - fit to user demands - for national and regional adaptation policies.

4.2 Societal questions

The research contributes to societal questions particularly via its importance for many long-term decisions on infrastructure, spatial planning, economy, agriculture, ecology, etc. In the past the society assumed climate to be stationary, but this assumption is no longer valid. To make long-term decisions cost-effective, an estimate is necessary of climate as it will evolve during the lifetime of the object. For any object the type of information that is critical to the decision is different. Sea dikes are dimensioned based on estimates of sea level rise and wind extremes; agricultural investments are based on estimates of availability of water and the return time of adverse weather extremes; investments in wind energy are based on estimates of average wind speed at the height of the rotator.
Impact/adaptation researchers and policy makers find it difficult to manage the uncertainties of our future climate. Therefore they ask to reduce uncertainties, which scenarios are most probable, etc. This Theme ties to make the uncertainties related to climate change more manageable by various ways, particularly by reducing, quantifying and communicating the uncertainties.

The Netherlands is a small country in which almost every inch is used. Climate adaptation measures often have a spatial component. This means that adaptations in 1 sector may affect the proposed adaptation measures in other sectors. This requires integration of impact/adaptation studies. This Theme tries to contribute to this integration in several ways: development of climate data sets that can be used by various sectors at the same time, inventarisation of discrepancies between sectors, integration (e.g. hydrology and land use developments), and communication in a consistent way about climate change and impacts in several sectors

4.3 Societal deliverances

The knowledge generated in this programme will lead to improved climate information services, particularly information on weather and climate extremes, such as information on the occurrence of extremes and maps of return periods of

extremes (average time between the occurrences of extremes exceeding a fixed level). Unique in this Theme is the coupling of climate models to impact models, generating interdisciplinary consistent information. Attention is paid to translating the information on climate change and its impacts to national and local scales, using high-resolution climate models.

The main societal deliverances can be divided in four groups: the KNMI climate scenarios (for a broad spectrum of user groups), consistent and brought together climate and impact information (released by the Climate Impact Guide), climate information for decision making instruments, specific products for the hotspots.

KNMI next climate scenarios

The KNMI climate scenarios are the main societal product to which Theme 6 contributes, forming the base for adaptation policy.
In 2013 a next generation climate scenarios – known under the temporary working title KNMInext - will succeed the KNMI scenarios dating from 2006.
Theme 6 makes better KNMInext climate scenarios possible in many ways: a better scientific foundation, additional products, connecting climate information to impacts, and broader communication.
During the workshops in 2010 and 2012 stakeholders made clear that there is a strong need for the KNMInext scenarios with additional information compared to KNMI'06:

- New scientific insights need to be incorporated in policy; the quick translation of the Fifth IPPC Assessment Report to Dutch climate scenarios is considered valuable;
- Information at higher temporal resolutions is asked for, for example change in shower intensity (per hour) is found to be very relevant for the construction of sewerage systems (urban water management) and the prevention of flooding. For (water)safety information about wind direction and strength per hour/ per three hours is requested;
- Information at higher spatial resolutions is requested as impact models have a higher spatial resolution. As within the Netherlands not much change in spatial differences in climate change is expected, a division in coast – inland and catchments is probably adequate. For some purposes, however, a higher resolution is requested, e.g. for differences between city and countryside and several regions; for the North See and IJsselmeer special attention is asked according to wind and water safety;
- Information on climate change on more climate variables is requested:
- Radiance, clouds and sunshine duration: of importance for groups within agriculture, nature, recreation, health and hydrology (for evaporation).
- variables related to dangerous weather are requested, such as fog, hail, black ice, snow, wind gusts and thunder for transportation, agriculture, insurance and nature. This information may be included in KNMI next, but only in a qualitative way;
- A better estimation of natural variability is needed, with respect to the climate change signal.

Consistent and integrated climate and impact information

During the workshops in 2010 and 2012 a common request was to bring together existing and new climate and impact information. As there are many institutes working on impacts and there are many interactions between the different providers, on overview is needed.

This overview is given in the Climate Impact Guide. The website gives an overview of data which is accessible at different institutes. It also gives an overview of the relation and discrepancies between the data from the different sectors.

Input for decision making instruments
Theme 6 aims to provide the best climate information available for decision making instruments and climate change impact models. Decisions making instruments are used in many decision-areas to calculate the impact of specific political decisions or measures, for example the Deltamodel. The quality of the results of these instruments crucially depends on the quality of the climatological input data.

For example, the Delta Programme uses the Deltamodel. The focus of the Deltamodel is to evaluate the effectiveness of climate adaptation strategies. The boundary conditions are climate, water, agriculture, ecosystems and land use. This kind of boundary conditions will be partly supplied by this Theme 6 project. In addition, Theme 6 (in cooperation with theme 2) provides important information on upstream water inflows to the Deltamodel. Strong efforts are put in providing climate information in a range of formats appropriate for stakeholders' work processes, and in communication on the data themselves and their use. We aim to cover a wide range of disciplines with the project and invest in generic solutions for interfaces to other disciplines.

Hotspots
Theme 6 aims to contribute to the hotspots as follows:

Information about precipitation extremes at different scales
Aim: The occurrence of precipitation extremes at different scales is important for many hotspots. Local, hourly (or even sub-hourly) precipitation extremes are mainly important for Schiphol and urban areas (Hotspots Haaglanden and Rotterdam). Precipitation extremes at larger scales are important for the rural area (Hotspots rural areas and shallow waters). The intensity of showers is important for Schiphol airport safety and capacity planning. The hotspots Haaglanden, Rotterdam, and Schiphol airport could all be affected by a possible coastal effect in precipitation.
Achieved mid term result July 2012:
Establishment of dependencies of precipitation extremes on temperature and humidity in the observations across different time scales: from 10 min to daily. A scaling of 14 % per degree appears robust for extremes on a 10 minutes to hourly time scale.

Information about the coastal effect in precipitation
Aim: The long-term climate integration will provide estimates of regional differences in precipitation, in particular concerning the coastal amplification, which are of use for the hotspots Schiphol, Haaglanden, and Rotterdam. Yet, due to the hydrostatic approximation in the model and the resolution (10-20 km) these estimates are expected to be rough, in particular in space. Refinement using non-hydrostatic modeling for selected cases will be done in WP1.3 and WP1.5.
Achieved mid term result July 2012:
A first estimate of changes in coastal precipitation (compared to inland precipitation) is derived from RACMO simulations performed at 10 km resolution. Trends in the observations have also been looked into. Also the ability of the non-hydrostatic model HARMONIE to represent coastal precipitation has been investigated in a hindcast for the month of August 2006.

Future weather show cases of high impact weather at local scale
Aim: WP1 provides a number of showcases of future high impact weather (conveying a full high resolution 3D picture of possible future weather events) and information on regional differences and local extremes (in particular for hotspot Schiphol). In addition, the influence of land surface (changes) on the weather and the development of extreme convective weather in the future climate is explored, which is important in particular for the urban areas (HS Haaglanden/Rotterdam).
Achieved mid term result July 2012:
Technical work to set up the model HARMONIE to be able to provide these high resolution cases has been carried out. Also work on the driving boundaries from Ec-Earth/RACMO has been done.

Information on critical wind parameters
Aim: The measurements provided by WindVisions and the gained insight on the performance of HARMONIE with respect to the critical weather parameters precipitation and wind are direct use for hotspot Schiphol Mainport. It should help in their decision process to make optimally use of runway capacity. Also the evaluation of present-day and future severe events may provide guidelines for Schiphol Mainport of how to respond to a future climate. The research carried out in this project will be useful for other hotspots as well. For example, Rotterdam region, which is interested to obtain more local information on the effects of climate change on their airport, harbour and their water management. Another interested party may be the regional Dutch water boards.
Achieved mid term result July 2012:
The ability to represent these critical weather conditions in HARMONIE has been investigated.

Interaction with the natural system and the managed water system
Aim: WP3 will provide consistent scenarios and tools that may be used by several hotspots. The climate facility can be used to investigate the interaction of both the natural system and the managed water system within The Netherlands. One such example is how the joint probability of high surge and high river flow influences the operation of major structures. In addition, for dry periods the operation of our major reservoir (Lake IJssel) can be optimized for future climate.
Achieved mid term result July 2012:
The climate facility has been used to generate upstream boundary scenarios for the Delta Model including the effects of agriculture and water demand in the upstream areas. In addition, the system was used to generate an ensemble of transient scenarios for the Rhine basin. The latter runs are currently being analyzed.

5. Co-creation

In paragraph 2.3 we described our approach in co-creation with our stakeholders. In this chapter we reflect on the stakeholder collaboration until know, the barriers we met and the chances to deal with these in the coming two years.

Barrier: Making the connection with hotspots and with other KfC themes is found to be difficult. After several attempts to get input from other themes and hotspots, little feedback was received during the project. This might be explained partly because additional questions were not clear yet and partly because of high work pressure and the complexity of the whole programme (everyone speaks a different language, or accent).
Chance: However, we keep the KfC themes and hotspots connected by informing them through our newsletters and invitations to our workshops (in 2010, 2012 and 2013). In the 2012 workshops the KfC themes have explicitly formulated requirements for Theme 6/ the KNMInext scenarios during a panel discussion. We also see the Midterm Review in October 2012 as an important chance to reach the hotspots and themes, as they are all brought together in a stage of their research/project in which they are probably able to formulate additional questions for Theme 6. A Theme 6 road show to inform about Theme 6 and get input for further user requests is planned for interested hotspots and themes in the beginning of 2013.
Project WP4.3 (Expert pool) has some budget to provide data/information for additional questions.

Barrier: It is found difficult to connect policy makers at the national scale. For the 2012 workshop session a separate workshop was organised for policy makers and consultants in March. Most of the participants were working at water boards, local authorities or provinces. Policy makers of the Ministries were less represented. We noticed that for the workshop for policy makers there were more last minute cancels than for the workshop for researchers (and companies and consultants) in February. Reasons for the cancelling were mostly agenda related: there were other last minute priorities, although they seemed to be very interested in the workshop. This more ad hoc agenda management and less willingness to travel/ attend a half day workshop needs another form to connect the The Hague policy makers.
Chance: In 2013 a workshop about KNMInext for policy makers is planned in The Hague.

Barrier: Policy makers ask for more easily accessible information, understandable by the general public. Policy makers need to be able to sell investments to the politics, even more during times of economic crisis. Therefore climate (change) information is needed in a form suitable for politicians, but also for the general public, as common support for investments is essential.
The target group of the Theme 6 communication plan is limited to professionals, there is no extra budget for a more general media campaign with for example short PR movies with prominent people explaining climate change in a easily accessible way.
Chance: Connect to existing (KNMI) projects to reach policy makers, politics and the general public. For example: The update of the KNMI website which will be made more accessible, courses about climate change for policy makers in The Hague (in

2012 first session), delivering climate information for appealing communication products as for example the Waas Game, a serious game about sustainable river management (a collaborative project by Deltares, Utrecht University, Maastricht University-ICIS, Carthago Consultancy, Pantopicon, KNMI, and Twente University).

Barrier: The KNMInext scenarios are published too far at the end of the Theme 6 project to be fully incorporated in the impact scenarios.
Chance: The impact models are prepared to connect more easily to the KNMInext scenarios, so generating impact information after publication of KNMInext will go faster than in 2006 after publication of KNMI'06.

Barrier: Asking what users need also may result in high expectations of what will be delivered later on.
Chance: During the workshops feedback is given on what is possible to deliver and what not. In other words, we work on expectation management, check what users expect, tell them what is possible and what not, about the dilemmas (e.g. higher temporal resolution may result in less spatial resolution).

Barrier: Sometimes there is a discrepancy between what users desire and what is scientifically sound to deliver. E.g. some impact researchers use as input into their models gridded data sets of 250 by 250 m. For climatological data such a high spatial resolution cannot be delivered, since the observational network does not cover all climatological differences at that scale. A gridded data set of 250 by 250 m can be prepared, in principle, however, the users should be aware of the limitations of such a dataset.
Chance: Data with limitations should be delivered with sufficient background information and guidance material, adapted to the way users use this information (which also requires very short and conveniently arranged information). Sometimes the data preferably is supplied only after personal contact.

6. Conclusions and prospects

6.1 Conclusions

In the last years it has become more and more clear that local processes could strongly influence the climate we experience. In WP1 we focus on local processes in convective clouds, the influence of the North Sea and the influence of land use changes. As such it has for example become clear that the intensity of showers could well increase by more than 50 %, and the probability of occurrence of heavy showers (with substantial damage) could increase a factor 5 in the future climate. (We note that recent trends already show a 15 % increase in intensity, equivalent to almost a factor two in the probability of occurrence). Although there is increasing evidence that these processes are important, and we expect a substantial increase in knowledge from this project in the coming years, we note that this type of research is still in an early stage.

The uncertainties in regional climate scenarios are not reduced for new sets of climate simulations. The spread is dominated by the spread from global models. Hence improvements of global models is necessary. Also, bias corrections for climate impacts on hotspots or sectors will remain to be needed. Innovative methods are promising for creating more consistent climate scenarios. Physical consistency is aimed for using high resolution climate simulations in which the circulation is constrained. Multivariate statistical techniques, with better parametric estimations, are being developed and tested to have better quality climate scenarios and reduce the statistical uncertainties of estimates of extremes. Much attention will be given to non-linearity of trends. The effect of spatial dependence on statistical inference may also need further study
A follow-up of the present work on the impact of climate change on air quality could assess several aspects. Examples are the combined impact of emission changes and climate change, using the two-way coupled version of RACMO-LOTOS-EUROS to include aerosol-meteorology feedbacks, and using the newest version of LOTOS-EUROS which represents several PM components better than the current version. These steps were not included in the KfC proposal and are not funded.
The results on impacts of KNMInext scenarios occur relatively fast after publication of KNMInext scenarios. Also, the information on impacts of climate change has become more consistent. There has been an integration of information on the effect of climate change and land use change.

With respect to the dissemination of information, there is an improved Climate Impact Guide website, with more information.

It is difficult to obtain full consistence in approaches, datasets etc. of the different research groups. Yet, the network from Klimaat voor Ruimte (KvR) that now has been continued, is very useful to increase this consistence. Hopefully, this can be continued in the future. Full consistency will not be possible, as the different groups have different interests. KfC enables an increased effort on the KNMI climate scenario's, as was the case for KvR and the KNMI'06 scenarios. In this way, information can better fit to the needs of interested parties, and increases the

usefulness of the climate scenarios and related information. A big challenge is expectation management: we cannot satisfy all users' desires.

6.2 Added value of the consortium

- We address our research (also that for KNMInext) partially also to direct needs of society, e.g. by putting accent on coincidences and on the simulation of meteorological analogues. The focus is much more on validation and improving derived climate parameters (e.g. multiday rainfall sums, wind extremes etc). The need for physical and socio-economic consistent multivariate data has become more and more apparent.
- The contact with customers, such as the stakeholder meetings, is pioneering, also at the international level.
- We construct consistent pictures for different societal sectors.
- We continue and strengthen our cooperation with the impact community.
- We improve our knowledge of how the various groups (climate researchers and impact researchers) work, the assumptions that are made, etc. Thereby making it possible to provide more consistent information and guidance on both climate change and its impacts.
- We consider the whole chain from more fundamental research, applied research, impact research and communication.

6.3 Knowledge transfer

Knowledge transfer is an integrated subject in this theme, and has the following aspects:
1. transfer of knowledge between climate scientists (esp. WP 1 and 2);
2. transfer of knowlegde on climate change to the climate impact community (esp. WP3);
3. transfer of knowledge on climate change and its impacts to a broader community and vice verse transfer of knowledge on stakeholder needs to the climate research community (esp. WP4).

Performed activities
Transfer of knowledge between peers through publication of scientific articles (appendix 3) and the attendance of national and international workshops and conferences where our work is presented (appendix 4).
Impact scientists are actively involved to the various projects of WP3 and in contributing to the webportal of WP4.
Communication with the broader community by:
The web portal is providing an overview of available data/informations, the consistency between data/information from various disciplines and how the data can be used;
Newsletters;
Interactive stakeholder sessions.
For more details in undertaken activities to specific groups of users see section 3.1.

Valorisation

The main societal product to which Theme 6 contributes are the KNMInext climate scenarios, which will be published in Autumn 2013. The publication will be accompanied with a press conference, a symposium, a roadshow along governmental organizations and intermediaries and broad attention in scientific and professional journals. With the other KfC themes a combined booklet is planned to translate climate changes to the impacts on the other themes. The newsletters and several workshops contribute to create public support for the new climate scenarios.

Observational data and output from climate and climate impact models will, where possible, be made accessible and can be freely used by third parties. The accessibility will be facilitated by the webportal, which will point to relevant data centres or websites.

Apart from software that is currently copywrite-protected, models developed in this theme can be freely used by third parties. Best practice methods can be made operational by third parties for consultancy purposes.

Examples of released data and information:

- On the Climate impact Guide for all sectors examples can be found on released data and information: http://www.klimaatportaal.nl/pro1/general/start.asp?i=7&j=1&k=0&p=0&itemid=866&folder=Klimaat%20Effect%20Wijzer&title=Home%20Klimaat%20Effect%20Wijzer
- Analysis of global model data as first step in developing KNMInext scenarios for the Netherlands. A First assessment of the available data is given in the newsletter climate scenarios in February 2012 and the link to the defined steering variables for KNMInext. Also the link to the global CMIP5 data is given.
- The website Future Weather with show cases of high impact future weather. Theme 6 is continuing research of the Knowledge for Climate project Future Weather. Attention has given to the website in the newsletters and the Theme 6 website http://www.knmi.nl/samenw/regioklim/FW/index.html

Appendices

Appendix 1. Main structure of the programme, short description of the projects.

WP1 Climate scenario development: mechanisms of local climate change in the Netherlands.

WP1.1 Collaboration with SMHI on modeling results and model development.
In this project we will collaborate with the regional climate modeling section at SMHI on model data exchange and analysis of hydrostatic regional climate model integrations, and development and analysis of the non-hydrostatic model HARMONIE. The main goal is the transfer of knowledge and data between SMHI and the Dutch community.

WP1.2 RACMO climate integrations: estimation influence of SST on coastal precipitation and provision boundaries for non-hydrostatic modeling.
The goal of this project is to extend the regional climate modeling system RACMO2 with a simple module representing the North Sea, and perform a long term climate simulation with this updated system in order to estimate the (long term) statistics of coastal precipitation, and provide boundaries for a selection of cases to be studied with the very high resolution non-hydrostatic models.

WP1.3 High impact weather, with a special focus on wind and precipitation (extremes) at Schiphol Mainport: present-day evaluation and showcases for the future.

WP1.4 The impact of land surface, land use changes and atmospheric boundary layer processes on the future climate at a local scale.
The overall objective of this project is to systematically assess the influence of a (changing) land surface on the regional climate in the Netherlands

WP1.5 Local precipitation extremes derived from non-hydrostatic modeling.
The main goal is to study changes in convective precipitation in the future climate, focusing on small scales and regional differences within the Netherlands.

WP 2 Climate scenario development: time series, extremes and probabilities.

WP 2.1 Assessment of uncertainties in regional climate change
In this project we quantify uncertainties in future climate projections and predictions for different time and spatial scales and for different variables, in order to guide the development of adequate climate change scenarios. We span the entire range of uncertainties between global emissions to ultimately the local climate impact assessment. We use newest model results and refine existing methods of weighting and combining projections, tailored to the use of the information by the stakeholders.

WP2.2 Analysis of extremal behavior under non-stationary climate conditions
The central research question addressed in this project is: “how should we account for a changing climate when assessing and estimating extremes?”

WP2.3 Generating dynamically consistent future climate scenarios under persistently anomalous atmospheric circulation
We here use a state-of-the-art climate model to investigate weather characteristics of a possible climate in 2050, taking into account circulation changes by forcing the model to reproduce, in a dynamically consistent way, the desired circulation change.

WP2.4 Uncertainties related to a rapid disintegration of the Greenland ice sheet and its consequences for sea level scenarios
We focus on the uncertainties caused by the ice dynamical processes, which might lead to a faster diminishing of the Greenland ice sheet. It is attempted to quantify these effects for the next century.

WP3 Scenario development for climate change impact

WP3.1 Exploring effective methods to apply information on climate change and its effects for the design of climate adaptation
Different approaches have been applied in the past to generate scenarios for the development of climate adaptation strategies. In this project we aim to answer the question which approach seems to be most effectively to support the development of climate adaptation strategies in different sectors.

WP3.2 Coupling climate data and agronomic models
This research considers climate risks and address the possible effects of climate change on crop production, product quality and farming systems. The central question is: How can agricultural models be coupled to data and models of climate, land use, hydrology and nature to improve impact assessment of climate change and adaptation strategies in agriculture?

WP3.3 Scenario development for nature using ecosystems models
The aim of this project is to achieve a better insight in the likely ecosystem changes by coupling ecosystems models to climate models such that these coupled models may be applied to a variety of cases. Central research questions are: What is the impact of climate change on nature in general and biodiversity in particular?, and How do uncertainties in climate scenarios affect uncertainties in climate impacts on nature?

WP3.4 Scenario development for water using hydrologic and land use models
In this project the questions to be answered are: 1. How can the FEWS-GRADE system (a modeling system that simulates runoff and river discharge in the Rhine basin) and land-use models be coupled such that both the effects of land use changes are taken into account in the runoff production as well as the changes in land use are taken into account in flood safety? 2. To which extent does the propagation of errors and uncertainty influence the validity of the simulation outcomes?

WP3.5. Coupling of climate and air quality models
We aim to assess the first order impact of the predicted climate change on PM and ozone in the Netherlands. Central research questions are: 1) What is the effect of climate change on PM and ozone levels in the Netherlands?, 2) What are the main

meteorological drivers for the predicted air pollution change? 3) How large is the uncertainty in the predicted air quality change? 4) Does the air pollution change due to climate change counteract the change due to envisaged mitigation of emissions?

WP3.6. Dealing with uncertainty in adaptation application
This project investigates how the understanding of uncertainties can be used in the development of robust adaptation options and decision making.

WP4 Climate services

WP4.1 Integration of data and information (integration of data series and background information on climate change and its impacts in a web portal)
The aim is to improve data and information exchange in the chain of climate research, to impact/adaptation research, to policy making through a web portal.

WP4.2 Climate information services in neighboring countries
The aim is to make an inventory of practices in the field of climate services concerning climate change in European countries, in order to promote more international/European cooperation in the field of climate services.

WP4.3 Expert pool for additional data and advice (Expert pool for additional data and information on climate change and its impacts for KfC).
The aim is to provide additional and essential data and information for KfC hotspots and themes that were not foreseen during the formulation of the project proposals for the second tranche.

Appendix 2. Hotspots involved in Theme 6

Hotspot Mainport Schiphol is involved in WP1.3.
Financial contribution: according to budget plan: € 400.000; this consists of two parts of € 200.000, financed by BV Schiphol and LVNL, respectively; the BV Schiphol part has been formally promised, of which € 17.476 has been received; the LVNL-part has not yet been formally promised.

Hotspot Major rivers is involved in WP2.1
Financial contribution : according to budget plan: € 50.000; this promise has been withdrawn.

Appendix 3. Deliverables

Brochure (public site)	2010	Thema 6	Feijt, A. (2010). High Quality Climate Projections. Flyer on theme 6, Knowledge for Climate.
Project Factsheet (public site)	2010	Thema 6	Theme 6: Climate Projections Adaptation to Climate Change (2010). Scientific Aspects.
Project Factsheet (public site)	2010	Thema 6	Theme 6: Climate Projections (2010). Societal Aspects.
Project Factsheet (public site)	2010	Thema 6	Theme 6: Climate Projections (2010). Summary.
Project Factsheet (public site)	2010	Thema 6	Theme 6: Climate Projections (2010). Work package 1: Climate scenario development: mechanisms of climate change in the Netherlands.
Project Factsheet (public site)	2010	Thema 6	Theme 6: Climate Projections (2010). Workpackage 2: Climate scenario development: time series, extremes and probabilities.
Project Factsheet (public site)	2010	Thema 6	Theme 6: Climate Projections (2010). Work package 3: Scenario development for climate change impact.
Project Factsheet (public site)	2010	Thema 6	Theme 6: Climate Projections (2010). Work package 4: Climate services.
Project Newsletter (public site)	2011	Thema 6	Newsletter climate scenarios (2011). Issue 1, April 2011, (Knowledge for Climate Thema 6 High-quality Climate Projections).
Report (public site)	2011	Thema 6	Jennifer K. Poussin, Philip J. Ward, Philip Bubeck, Lidia Gaslikova, Aurel Schwerzmann and Christoph C. Raible (2011). Flood risk modelling, VU-IvM report.
Scientific Paper (public site)	2011	Thema 6	Pelt, S.C. van, Swart, R.J. (2011). Climate Change Risk Management in Transnational River Basins: The Rhine. Water resources management (2011) 25:3837\u20133861. DOI 10.1007/s11269-011-9891-1.
Peer reviewed Conference Proceeding	2011	Thema 6	Schellekens, J., Winsemius, H.C., Werner, M.G.F., 2011. Operational modeling systems: How to deal with changes in data. WIRADA Conference, Melbourne 10–16. url: http://www.csiro.au/WIRADA-Science-Sympsosium-Proceedings

Project Factsheet (public site)	2012	Thema 6	Flyer Autumn School (2012). Dealing with uncertainties, 8-10 October.
Project Newsletter (public site)	2012	Thema 6	Newsletter climate scenarios (2012). Issue 2, February 2012, (Knowledge for Climate Thema 6 High-quality Climate Projections).
Scientific paper peer reviewed (intranet	2012	Thema 6	Leeuwen, E. van and Koomen, E. (2012). Adapting Urban Land Use in a Time of Climate Change; Optimising Future Land-Use Patterns to Decrease Flood Risks. Chapter in: Carbon Sequestration in Urban Ecosystems. 2012, Part 1, 21-41, DOI: 10.1007/978-94-007-2366-5_2.
Scientific paper peer reviewed (intranet	2012	Thema 6	van Haren, R., G.J. van Oldenborgh, G. Lenderink, M. Collins and W. Hazeleger (2012) SST and circulation trend biases cause an underestimation of European precipitation trends. Climate Dynamics, doi:10.1007/s00382-012-1401-5.
Scientific paper peer reviewed (public site)	2012	Thema 6	Koks. E.E., Moel, H. de., Koomen, E. (2012). Comparing extreme rainfall and large-scale flooding induced inundation risk-Evidence from a Dutch case-study. Chapter 1 in: Dr. Kumarasamy, M. (ed.) Studies on water management issues. Intech, Rijeka, pp. 3-26.

Appendix 4. List of communication activities

Communication activities within Theme 6

1. Periodic meetings KfC Programme Board and Theme 6 management Planning: twice a year Aim: Monitoring budget and aims of KfC
2. Periodic meetings steering group (members steering group and theme 6 management) Planning: twice a year Aim: Indicating bottlenecks/barriers and connecting to the users/market. The main target hotspots are represented in the steering group. The representatives are a vital link to the hotspots: they can inform about the hotspot needs and the other way around: inform the hotspots about Theme 6.
3. Periodic meeting of work package leaders Planning: twice a year Aim: Indicating bottlenecks/barriers, communication between work packages, feedback about work in progress
4. Periodic meeting focal group (programme management, communication officer) Planning: every other month Aim: Monitoring planning, finance, discuss upcoming (communication) activities
5. Annual meetings for all participants Planning: once per year Aim: The Kick-off meeting in November 2010: getting to know each other (who is taking part in the steering group, who is in the programme management, who is working at the several work packages). Two central themes during the annual meeting in February 2012 were: 1) connecting to society and 2) optimizing intern collaboration.
6. Meeting international partners Planning: connecting to other meetings, several times during the programme. For example, at the annual meeting on February 2012, the international partners were invited and presented their work. Some will possibly join the 2012 Midterm review. Aim: Connecting international partners actively to Theme 6.

Communication activities for other KfC themes and hotspots

7. KfC project days/Midterm Review (organised bij KfC)
Planning: yearly
Doel: knowledge transfer between KfC themes and hotspots

8. KfC Autumn School Dealing with Uncertainties in research for climate adaptation
Planning: 8-10 October 2012
Aim:
Bring together students, researchers (PhDs/postdocs) from all KfC themes ranging from governance, decision management, climate impacts and climate physics and learn on how in all these disciplines uncertainties are treated and communicated. This would help to educate a new generation of students on interdisciplinary climate research.
The students work together on a common frame of reference for the use of scenarios and dealing with uncertainties.

9. Communication about possibilities of tailoring (WP 4) via meetings, mails, websites
Planning: continue
Aim: To stimulate to submit requests for tailoring to Theme 6. Within WP4 there are budget reservations for user questions and support (Climate Information Services, expert pool). No concrete requests have been submitted until now. This is however according our expectations, that additional questions will arise at the last half of the programme.

Communication activities for the broad group of users
Some activities (as 18 and 19) are partly or fully covered by KNMInext budget

10. Interactive workshops
Planning: 2010, 2012, 2013
Aims:

- In 2010 the first stakeholder sessions were organized enabling stakeholders to formulate requirements with respect to required data as desirable time horizon, temporal and spatial scale and climate variables; User requirements were summarized in the KNMI report 'Inventarisation of user requirements 2005-2010'.
- In 2012 the second stakeholder sessions were organized concerning requirements for communication: a.o. suggestions for websites, fora, brochures, courses and the need for sector specific summaries of climate information/impacts and for additional products (as information about uncertainties in time series). The link between Theme 6 and KNMInext was explained. Other KfC themes were connected, which had an explicit role in a user panel which formulated demands for KNMInext and Theme 6.
- In the beginning of 2013 new sessions will be organized to

fine tune communication demands.

General profits:

- Generating public support for the KNMInext climate scenarios and additional products. Stakeholders are getting in an early stage insight in the expected information so they will be able to implement the results (in policy cycli) more easily.
- Stakeholders are getting insight in (the future) available data and information.
- Managing expectations: Users are getting insight in boundaries of climate information;
- The start of a user feedback group on communication means (7 applications) and a presentation pool (3 announcements) for combined presentations on climate change and impacts during the road show (activity nr. 14)

11. Press conference KNMInext scenarios (& further press releases)
Planning: autumn 2013
Aim: To make the general public familiar with the KNMInext scenarios, so that people recognise the scenarios as an important product for climate adaptation.

12. Symposium KNMI next climate scenarios
Planning: autumn 2013
Aim: To present the content, development and use of the KNMInext scenarios to users of climate scenarios, to get public support for the use of the scenarios.

13. Roadshow: Presentations for key governmental organisations and intermediaries
Planning: nov/dec 2013 & first half 2014
Aim: With presentations about the KNMInext scenarios and about the impacts relevant to the specific sector, we want to inform important organisations in company about the content and value of the scenarios. To bring the knowledge inside the organisation and not only to the most active already interested people, we choose to present at the organisation, so the barrier to join the presentation is small.
Target group: sub divisions of the Delta programme, provinces, regional organised local governments, water boards, intermediaries as IPO (provinces), UwV (water boards), NLingenieurs (consultancy agencies), VVM (Environmental professionals) en NIROV (spatial policy professionals).
Who: KNMI presents the KNMI scenarios, other institutes present the impacts to hydrology, nature, agriculture etc.

14. To get attention for the website Climate Impact Guide
Planning: website is on-line since 2010. Continue communication.
Aim: with the website we want to make research results of KNMInext/ Theme 6 (both climate as impact information) more accessible for impact analysis. The website gives an overview of

data which is accessible at different institutes. It also gives an overview of the relation between the data from the different sectors. For the communication about the website, we will connect to existing mailings, newsletters and meetings.
15. Theme 6/KNMInext news items in the KfC newsletter Planning: about four times a year Aim: To inform users of climate information (policy makers, KfC themes about the process to KNMInext and the Theme 6 products to gain public support for the use of the products.
16. Newsletter Theme 6/KNMInext Planning: twice a year Aim: To inform users of climate information about the progress of Theme 6 and the process leading to the KNMI next scenarios.
17. Update KNMI website & KfC website Planning: continue, update KNMI website before publication of KNMInext scenarios Aim: To inform users of climate information about the progress of Theme 6, the process leading to the KNMI next scenarios, guidelines for the use of scenarios, climate information in general.
18. Brochure KNMI next climate scenarios Planning: autumn 2013 Aim: To inform users of climate information about the content, development and use of the KNMInext scenarios for climate adaptation. Examples of the impacts of the scenarios on hydrology and the health sector. These are focal sectors because of the importance of the climate questions from these sectors.
19. Scientific report KNMI next scenarios Planning: autumn/winter 2013 Aim: Scientific basis and justification of the KNMI climate scenarios.
20. Option: Booklet about the impacts of climate change to CfK sectors Planning: spring 2014 Aim: The CfK themes are an important link for the translation of knowledge and services to the specific sectors. For a lot of users not as much climate information is relevant, but the translated Theme specific impact information. With the KfC programme the possibilities for a combined booklet about the translation of climate change to Theme specific impacts is discussed. Idea is to compile this booklet together with all CfK themes about a half year after the publication of KNMnext. This idea will be further developed in 2012/2013 and issued in 2014.
21. Option: Courses about climate change, dealing with scenarios, transforming time series

Planning: 2014 Possibilities need to be discussed further.
22. Update of maps about climate change Planning: 2014 Aim: Climate (change) displayed on maps, according to KNMInext scenarios. Maps are crucial spatial planning and communication in general (policy makers).
23. Articles in professional journals, newspapers Planning: 2013, 2014, 2015 (For Theme 6 publications can be issued from the beginning). Aim: To present the content, development and use of the KNMInext scenarios to users of climate scenarios, to get public support for the use of the scenarios.