



NPDA postdoc programme 2009

Integrating research on the theme sustainable earth and the Knowledge for Climate research programme

Project title:

Bridging the gap between stakeholders and climate modellers: demand-driven adaptation assessment for uncertain changes in weather extremes

Main applicant: **Prof. Dr. A.C. Petersen (PBL/LSE)**

1a. Further details of the main applicant

(Name and address of the applicant, project title and an executive summary are provided through the on-line electronic submission system and will be automatically inserted at the front of the application)

Gender: Male Female

Tenure position: Yes No

Research School: SENSE (through cooperation with IVM)

Website URL: www.pbl.nl/en (institute) and www.uitgezocht.nl (personal home page)

1b. Alternative contacts / co-applicants

i) **Institute for Environmental Studies (IVM)**

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ii) **Royal Netherlands Meteorological Institute (KNMI)**

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The postdocs will be employed by/via IVM and KNMI, respectively. The contracts with NWO will be entered into by these two institutions.

1c. Does the local authority support your application? Yes No

(did you inform your superior and accept your institute/university the conditions for support by NWO or KvK)

1d. Renewed application? Yes No

(in case of renewed application please summarize main changes under item 4) **Dossier nr:**

1e. Applying for:	X Postdoc 1	24 months
	X Postdoc 2	24 months
	X Research costs	€ 40,000 [zie 9a]

1f. Composition of the research group

Name and title	Specialization	Employment/ Institute	hrs/wk
Prof. Dr. A.C. Petersen	Uncertainty; science & public policy	PBL/LSE	4
Dr. M. Hisschemöller	Participatory integrated assessment	IVM	4
Dr. E. Vasileiadou	Social science methodology	IVM	2
Prof. Dr. F.H.B. Biermann	Earth system governance	IVM	1
Dr. W. Hazeleger	Earth system modelling	KNMI	2
Dr. A. Klein-Tank	Climate scenarios	KNMI	2
Prof. Dr. B. van den Hurk	Climate scenarios and feedbacks	KNMI	2
Dr. H. Visser	Statistics; uncertainty	PBL	2
M. Hage, M.Sc.	Stakeholder participation	PBL	1
B. Strengers, M.Sc.	Integrated modelling	PBL	1

2. Populaire samenvatting van de aanvraag (Nederlands)

(if granted, this description will be used for communication purposes by ALW, also to non-specialists)

Maatregelen gericht op aanpassing aan extreme weersomstandigheden hebben te maken met tenminste twee typen onzekerheden. Ten eerste zijn er de onzekerheden die inherent zijn aan mondiale en regionale klimaatmodellen. Ten tweede zijn er de onzekerheden ten aanzien van de consequenties van extreem weer voor (diverse geledingen in) de samenleving. De wetenschappelijke experts op het gebied van de klimaatmodellering zijn bij uitstek in staat om de kansen op een toename van extreme weersomstandigheden (zoals lange periodes van hitte en droogte, extreme regenval in korte tijd, windhozen, enz.) in kaart te brengen en te communiceren naar de samenleving. Het goed voor het voetlicht brengen van de modelonzekerheden – op een wijze die de gebruikers in staat stelt er ook echt rekening mee te houden in hun besluiten – wordt als moeilijk ervaren. Waar het er om gaat de consequenties van extreem weer in kaart te brengen en te communiceren, levert de expertise inzake klimaatmodellen maar een deel van de benodigde inzichten. In de praktijk is de beleving van extreme weersomstandigheden door direct betrokkenen (stakeholders) en hun oordeel over de ernst van problemen en oplossingen minstens zo belangrijk. Het onderhavige project beoogt na te gaan hoe de informatie die experts middels scenariostudies aanleveren kan voorzien in specifieke behoeften van bepaalde (groepen) stakeholders. Met het onderzoek worden drie doelstellingen gediend om bij te dragen aan:

- 1) een geïntegreerde (sociaal- en natuurwetenschappelijke) methodologie voor een vraaggestuurde verkenning van onzekerheden, risico's en opties voor aanpassing aan klimaatverandering,
- 2) kennis inzake de veranderingen in extreme weersomstandigheden voor Nederland, met aandacht voor specifieke sectoren en gebieden in Nederland en inclusief een grondige bestudering van onzekerheden,
- 3) het identificeren en verkennen van opties voor aanpassing aan klimaatverandering, onder andere door het organiseren van een dialoog over extreme weersomstandigheden met klimaatwetenschappers en stakeholders uit relevante maatschappelijke sectoren.

De doelstellingen behelzen resp. methodologie (doelstelling 1), empirie (doelstelling 2) en beleid (doelstelling 3).

3a. Top 5 scientific publications of the applicants related to the proposed research

1. Hisschemöller, M. and Hoppe, R. (2001). Coping with intractable controversies: The case for problem structuring in policy design and analysis. In M. Hisschemöller, R. Hoppe, W. N. Dunn, and J. Ravetz (eds), *Knowledge, Power and Participation Environmental Policy Analysis – Policy Studies Review Annual, vol. 12*, New Brunswick: Transaction Publishers, pp. 47–72.
 2. van de Kerkhof, M., Cuppen, E., and Hisschemöller, M. (2009). The repertory grid to unfold conflicting positions: The case of a stakeholder dialogue on prospects for hydrogen. *Technological Forecasting and Social Change* **76**, 422–432.
 3. van den Hurk, B.J.J.M., Klein Tank, A.M.G., Lenderink, G, van Ulden, A., van Oldenborgh, G.J, Katsman, C., van den Brink, H., Keller, F., Bessembinder, J., Burgers, G., Komen, G., Hazeleger, W., Drijfhout, S. (2007). New climate change scenarios for the Netherlands. *Water Science and Technology* **56** (4), 27–33.
 4. Sterl, A., Severijns, C., van Oldenborgh, G.J., Dijkstra, H., Hazeleger, W., van den Broeke, M., Burgers, G., van den Hurk, B., van Leeuwen, P.J., and van Velthoven, P. (2008). When can we expect extremely high surface temperatures? *Geophysical Research Letters* **35**, L14703.
 5. Visser, H. and Petersen, A.C. (2009). The likelihood of holding outdoor skating marathons in the Netherlands as a policy-relevant indicator of climate change. *Climatic Change* **93**, 39–54.
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3b. Other relevant publications (max 1 page for publications, letter min 10 pts)

By the applying research group:

- Drijfhout, S.S. and Hazeleger, W. (2007). Detecting Atlantic MOC changes in an ensemble of climate change simulations. *Journal of Climate* **20**, 1571–1582.
- Hage, M., Leroy, P., and Petersen, A.C. (forthcoming). Stakeholder participation in environmental knowledge production. *Futures*.
- Hazeleger, W. et al. (forthcoming). EC-Earth, a seamless prediction system in action. *Bulletin of the American Meteorological Society*.
- Hisschemöller, M. (2005). Participation as knowledge production and the limits of democracy. In S. Maasen and P. Weingart (eds.), *Democratization of Expertise? Exploring Novel Forms of Scientific Advice in Political Decision-Making – Yearbook Sociology of the Sciences, vol. 24*. Dordrecht: Kluwer.
- Hisschemöller, M., and Olsthoorn, A.A. (1999). Linking science to policy: Identifying barriers and opportunities for policy response. In T.E. Downing, A.A. Olsthoorn, and R.S.J. Tol (eds.), *Climate Change and Extreme Events: Altered Risks, Socio-economic Impacts and Policy Responses*. London: Routledge.
- Hisschemöller, M., Eberg, J., Engels, A., and von Moltke, K. (2009a). Environmental institutions and learning: Perspectives from the policy sciences. In J.J. Boersema and L. Reijnders (eds.), *Principles of Environmental Science*. Amsterdam: Kluwer Academic Publishers.
- Hisschemöller, M., Cuppen, E., and Dunn, W.N. (2009b). Stakeholder dialogue as a social experiment. ESF Workshop Mapping Interfaces: The Future of Knowledge, Reykjavik, 15–17 June 2009.
- Jacob, D., Barring, L., Christensen, O.B., Christensen, J.H., de Castro, M., Deque, M., Giorgi, F., Hagemann, S., Hirschi, M., Jones, R., Kjellstrom, E., Lenderink, G., Rockel, B., van Ulden, A.P., and van den Hurk, B.J.J.M. (2007). An inter-comparison of regional climate models for Europe: Model performance in present-day climate. *Climatic Change* **81**, 53–70.
- Petersen, A.C. (2006). *Simulating Nature: A Philosophical Study of Computer-Model Uncertainties and Their Role in Climate Science and Policy Advice*. Apeldoorn/Antwerpen: Het Spinhuis Publishers.
- van der Sluijs, J.P., Hisschemöller, M., de Boer, J., and Klopogge, P. (2001). *Climate Risk Assessment: Evaluation of Approaches. Synthesis Report*. Bilthoven: NOP.
- van der Sluijs, J.P., Petersen, A.C., Janssen, P.H.M., Risbey, J.S., and Ravetz, J.R. (2008). Exploring the quality of evidence for complex and contested policy decisions. *Environmental Research Letters* **3**, 024008, 9 pp.
- van Oldenborgh, G.J., Drijfhout, S.S., van Ulden, A., Haarsma, R., Sterl, A., Severijns, C., Hazeleger, W., and Dijkstra, H. (2009). Western Europe is warming much faster than expected. *Climate of the Past* **5** (1), 1–12.

- Vasileiadou, E., Gandhi, A., and Pahle, M. (2009). Diversity for climate: How can stakeholder consultations help mainstreaming climate change? IARU International Scientific Congress on Climate Change, Copenhagen, 10–12 March 2009.
- Visser, H. (2005). *The Significance of Climate Change in the Netherlands: An Analysis of Historical and Future Trends (1901–2020)*. RIVM/MNP report 550002007. <http://www.rivm.nl/bibliotheek/rapporten/550002007.pdf>.
- Wardekker, J.A., van der Sluijs, J.P., Janssen, P.H.M., Klopogge, P., and Petersen, A.C. (2008). Uncertainty communication in environmental assessments: Views from the Dutch science–policy interface. *Environmental Science & Policy* **11**, 627–641.

Other references with respect to the application:

- Cox P. and Stephenson, D. (2007). A changing climate for prediction. *Science* **317**, 207–208.
- Cuppen, E. (forthcoming in 2009). *Putting Perspectives into Participation: Constructive Conflict Methodology for Stakeholder Dialogues*. PhD dissertation, VU University Amsterdam.
- Dunn, W.N. (2001). Using the method of context validation to mitigate type III error in environmental policy analysis. In M. Hisschemöller, R. Hoppe, W. N. Dunn, and J. Ravetz (eds), *Knowledge, Power and Participation Environmental Policy Analysis – Policy Studies Review Annual, vol. 12*, New Brunswick: Transaction Publishers.
- Gigerenzer, G., Hertwig, R., van den Broek, E., Asolo, B., and Katsikopoulos, K.V. (2005). A 30% chance of rain tomorrow: How does the public understand probabilistic weather forecasts? *Risk Analysis* **25** (3), 623–629.
- Giorgi, F. and Mearns, L.O. (2002). Calculation of average, uncertainty range, and reliability of regional climate changes from AOGCM simulations via the “reliability, ensemble averaging” (REA) method. *Journal of Climate* **12**, 1141–1158.
- Meehl, G.A., Covey, C., Delworth, T., Latif, M., McAvaney, B., Mitchell, J.F.B., Stouffer, R.J., and Taylor, K.E. (2007). The WCRP CMIP3 multimodel dataset: A new era in climate change research. *Bulletin of the American Meteorological Society* **88**, 1383–1394.
- Murphy, J.M., Sexton, D.M.H., Barnett, D.N., Jones, G.S., Webb, M.J., Collins, M., and Stainforth, D.A. (2004). Quantification of modelling uncertainties in a large ensemble of climate change simulations. *Nature* **430**, 768–772.
- Nowotny, H., Scott, P., and Gibbons, M. (2001). *Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty*. Polity Press, Cambridge.
- Raisanen (2007). How reliable are climate models? *Tellus* **59A**, 2–29.
- Smith, D.M., Cusack, S., Colman, A.W., Folland, C.K., Harris, G.R., and Murphy, J.M. (2007). Improved surface temperature prediction for the coming decade from a global climate model. *Science* **317**, 796–799.
- Tebaldi, C., Smith, R.L., Nychka, D., and Mearns, L.O. (2005). Quantifying uncertainty in projections of regional climate change: A Bayesian approach to the analysis of multimodel ensembles. *Journal of Climate* **18**, 1524–1540.
- Tebaldi, C. and Lobell, D.B. (2008). Toward probabilistic projections of climate projections on global crop yields. *Geophysical Research Letters* **35**, L08705.
- van de Kerkhof, M. (2006). Making a difference: On the constraints of consensus building and the relevance of deliberation in stakeholder dialogues. *Policy Sciences* **39**, 279–299.

4. Description of research area(s) and research plan

(max 6 pages, including figures, min 10 pts;
detailed description of objectives, innovative aspects, methodology)

1. Theoretical background

Climatic change abounds with uncertainty, all the more so when we are interested in changes in extreme weather and adaptation options at the regional scale. Not only are uncertainties intrinsic in the climate science (Petersen 2006); societal actors also have different opinions on what specific aspects of climatic change constitute a problem and why. When analysts search for indicators to analyze and communicate information about climatic change, they therefore have to address both scientific and societal dimensions of the problem (Visser and Petersen 2009; Hisschemöller and Olsthoorn 1999). In this project, we address two types of uncertainties. On the one hand, we address uncertainties that are inherent to climate modelling. On the other hand, we address uncertainties with respect to the risks as regards specific harmful impacts of extreme weather events on (sectors of) society, as stakeholders perceive them.

Uncertainty and climate models

Current climate change projections produce a wide range of estimates of the trajectory of climate in the future. For climate adaptation measures, stakeholders are often interested in extremes. By their nature, projections of regional weather extremes are more uncertain than projections of global or continental climate averages. Climate modellers have tried to tackle uncertainties by a number of techniques. Model uncertainty is handled by analyzing multi-model ensembles (e.g. Meehl et al. 2007), by analyzing single-model ensembles with perturbed parameters (Murphy et al. 2004) and with stochastic parameterizations in global models. Internal variability, due to the chaotic nature of the

atmosphere and low-frequency variability in climate, is handled by analyzing large ensembles of one model (e.g. Sterl et al. 2008). Boundary condition (emission scenario) uncertainty is dealt with by applying different kinds of emission scenarios of greenhouse gases and aerosols. Initial condition uncertainty gained interest of climate modellers recently. Multi-decadal predictions, starting from observed initial states are now being developed (e.g. Smith et al. 2008). Different initialization and perturbation techniques are used. This is a new development, which is central in multi-model intercomparisons such as CMIP5 of the World Climate Research Program. Finally, there is awareness of structural uncertainty in climate models, which is often dealt with by expert judgement.

The agreement between climate change simulations and the importance of internal variability depends on the prediction horizon and spatial scale, with internal variability becoming more important at local scales. Also, the variables considered have themselves different statistical properties (e.g. temperature errors are smaller than precipitation errors and precipitation fields are much noisier than temperature fields etc.). For example, there is *large confidence* in global and continental warming due to human emissions of greenhouse gases, there is *some confidence* in continental scale projections of precipitation, but there is only *indicative* climate change information at the local scales (large scale changes modified by local processes).

A relevant and novel development in climate modelling is the construction of multi-decadal predictions. These predictions have a number of advantages compared to earlier climate projections. They sample initial condition uncertainty; they are not affected heavily by scenario uncertainty and they sample internal variability (by means of large ensembles and by actually predicting the interannual/decadal variability). Model structure uncertainty will be smaller as higher resolutions are used (which is possible because these models do not need a long spin up: the ocean initial state is prescribed), which means that the processes underlying interannual/multi-decadal variations are better resolved. However, initialization will cause drift in the coupled model, which needs to be taken into account. Techniques from seasonal forecasting are taken over to deal with this (see, e.g., Smith et al. 2008). Another relevant development is the increase in available regional model output driven by different global models and different emission scenarios. Dynamical downscaling with regional models avoids assumptions on stationarity of downscaling relations that have been often invoked in statistical downscaling methods and also reduces model uncertainty. Both approaches, of multi-decadal prediction and downscaling, are promising for climate adaptation assessment. The higher resolutions will likely lead to better simulation of extremes and the prediction horizon of decadal predictions fits better with many adaptation measures. These two developments thus both introduce new data and have potential relevance for adaptation assessment. They cover another kind of uncertainty as before in CMIP3 multi-model ensembles.

The different complexity of the climate models and different setups make them hard to compare. In practice there is a wide variety of earth system models. Computational constraints imply that choices need to be made between resolution (better resolving relevant processes), model complexity (adding or omitting relevant processes), and ensemble size or simulation length. Regional models have been developed that cover limited areas, for example Western Europe, in order to resolve partially the resolution issue. Regional models have a much higher resolution. However, the driving global model is often dominating the errors in the regional models. Reliability metrics have been developed to judge the different models. For instance, Giorgi and Mearns (2002) use bias of the simulated 20th century climate and the deviation from the multi-model ensemble mean projections as metric. Others have advocated the reliability of seasonal forecasts as a measure and again others focus more on feedbacks in the earth system (see Raisanen 2007 for a discussion on this).

All these uncertainties need to be dealt with by climate scientists and can be represented by way of uncertainty ranges and qualitative information on the methodological reliability of models (Petersen 2006). Formal statistical techniques have been developed to deal with the model uncertainties (e.g. Tebaldi et al 2005, 2008). Mostly Bayesian statistics is used for multi-model ensembles (that is, dealing with model error). In principle, any of the uncertainty types mentioned above could be assessed with these formalisms. It is not entirely clear, however, that this kind of detailed statistical information is informative to stakeholders when developing adaptation strategies (see, e.g., Gigerenzer et al. 2005).

Uncertainty and stakeholders' perceptions of weather extremes

Many stakeholders may accept that climate change constitutes a threat to society, but it may not (yet) come forward as a phenomenon that requires actions they can initiate themselves. For the Netherlands, climate change and the occurrence of extreme weather events are predominantly related to the risk of flooding, which is generally considered a government responsibility. However, future projections for the Netherlands provide a picture which is somewhat more complex. In many cases, adaptation will demand interplay between government, economic actors (businesses) and the general public, which means that climate changes require awareness among society at large. Yet, individuals and economic sectors have already dealt with the weather for ages and have developed knowledge and behavioural responses with respect to weather extremes. This proposal is based on the proposition that fruitful reflection on adaptation options and adaptation governance should start with a thorough investigation into how stakeholders

perceive weather extremes and how they make use of their (practical) knowledge, experience and imagination as to assess risks and possible benefits in the context of future projections. Thereby, the project's conceptual framework draws upon four critical notions from the policy sciences and social psychology. We refer to these as (1) articulation, (2) information, (3) differentiation and (4) learning by interaction.

- 1) Most likely, stakeholders in the Netherlands are not consciously dealing with the weather on a regular basis and weather extremes cannot be easily related to. Hence, we cannot expect most stakeholders to provide a coherent and articulated view with respect to weather extremes and possible responses upon request. We must anticipate that stakeholder perceptions can become articulated in interaction with other stakeholders including climate experts over time. In this process, stakeholders will attach meaning to initially fragmented notions of a partially cognitive, partially, affective nature. An approach targeted at involving stakeholders must enable them to do so, with the help of feedback provided by other stakeholders, experts and the project team itself.
- 2) To elaborate, and, to some extent, nuance the former point, the project will consider that, with respect to weather extremes, some stakeholders will express more articulated notions and stronger views than others. Especially those who are already embedded in the climate change policy–science interface, will be more familiar with the climate projections literature than those who are not or only marginally involved. We may think of policy makers and researchers at national and regional level, who are (some of them for a longer period of time) already involved in assessing climate change impacts and adaptation options (e.g. via recent pilots and hotspots carried out in the context of climate change research programmes in the Netherlands). Conceptually, stakeholder assessment may benefit from a distinction between stakeholders (1) who are already to some extent familiar with the study of climate change impacts and their implications for adaptation governance and (2) who are only to a limited extent informed and / or involved. This distinction is also relevant, as stakeholders from the first category may, in conceptualizing uncertainties and risks associated with weather extremes, draw more upon formal knowledge obtained from reports and oral presentations, whereas those who belong to the second category may, especially in the initial stage of the project, draw upon tacit knowledge and personal experience.
- 3) The involvement of stakeholders with different backgrounds and institutional affiliations will, almost certainly, highlight different views and knowledge claims that are rooted in what maybe labelled as 'different perspectives' (Cuppen, forthcoming in 2009). Differences in perspective may relate to different levels of knowledge and information, including formal as well as personal knowledge and experience. To illustrate, persons working outdoor and indoor are likely to have different perspectives with respect to the weather. Different perspectives may also relate to institutional affiliation or interest. Farmers maybe concerned with respect to extended dry periods in summer, whereas people working in recreation and tourism maybe more concerned with respect to the risk of extreme precipitation. Different perspectives may explain for different assessments of risk and potential benefits of climate changes and weather extremes.
- 4) In a similar vein, different stakeholder perspectives may relate to different, if not conflicting preferences with respect to adaptation options and the distribution of costs and benefits associated with these. It must be realized that, as long as climate change impacts and adaptation governance are explored at macro-level (the world or Europe), adaptation options can, or even must be phrased in a rather general way, such as "Shift to other crops" or "Do not build houses in areas vulnerable for flooding". However, at meso- or micro level (De Randstad, the Northern provinces, or the electricity sector), stakeholder discourse might become more dispersed and even antagonistic ("which crops?", "where can we (not) build?"). Issues that at first glimpse look structured might turn out more complex, however, at the same time, more related to daily practice.

Together, articulation, information, differentiation and learning by interaction, are key elements of problem structuring, which is defined as the articulation, comparison, confrontation, and, where possible integration, of as many different views of a policy problem and its potential solutions as possible (Hisschemöller and Hoppe 2001; Hisschemöller 2005, Hisschemöller et al. 2009a). Problem structuring is considered the appropriate approach for dealing with so-called unstructured problems, i.e. problems that are characterized by large uncertainties and or conflict with respect to the relevance of knowledge and values at stake.

Problem structuring requires dialogue, which is widely considered essential for raising social awareness and social support for environmental governance (e.g. Hisschemöller and Hoppe 2001; Nowotny et al. 2001; van de Kerkhof 2006; Hage et al. forthcoming). The type of dialogue required for problem structuring is primarily a meeting between persons, who would normally be unlikely to meet. The aim is to enable learning through the articulation and exploration of different perspectives. Therefore, it is critical to identify stakeholders from different (policy and knowledge) networks in order to capture the broadest range possible of perspectives and (competing) knowledge claims. It is also critical to start with the assumption that each stakeholder may have relevant knowledge to offer, either scientific expertise or practical knowledge and experience.

2. Aims, objectives and research questions

The general aim of the project is threefold; it is divided into a methodological, an empirical and a policy aim to contribute to:

- an integrated (social and natural science) methodology for demand-driven assessment into uncertainties, risks and options for climate adaptation governance,
- knowledge with respect to changes in weather extremes for the Netherlands, focusing on specific areas or sectors and including a thorough investigation of uncertainties,
- the identification and exploration of climate adaptation options, inter alia through a dialogue on weather extremes including climate scientists and stakeholders from various societal sectors.

The core research question is:

Which indicators of changes in weather extremes are considered relevant by stakeholders in evaluating climate adaptation options and at the same time reliable by climate scientists, in which case they adequately represent both the policy dimension of the problem as well as the scientific knowledge as reflected in simulations of future climate?

Specific objectives and related research subquestions are:

- To articulate the various stakeholder perspectives related to weather extremes and their impacts on the Netherlands.
Research subquestions:
 - 1) *How do stakeholders from different sectors and regions in the Netherlands assess risks and possible benefits associated with weather extremes and their social impacts?*
 - 2) *To what extent do we observe differences between stakeholders already involved in the climate science–policy interface and those, who are hardly or not (yet) involved?*
- To determine the uncertainty range of climate projections and decadal predictions of weather extremes in the Netherlands
Research subquestions:
 - 3) *What types of uncertainty in predictions and projections of extremes dominate for different time horizons and spatial scales?*
 - 4) *What is the added value of decadal predictions to ‘conventional’ climate projections?*
 - 5) *What is the added value of downscaling with regional models?*
 - 6) *How can the uncertainty information on weather extremes in future climate be captured in a limited number of perspectives, or ‘scenarios’?*
- To compare and, where possible, match the ideas put forward by stakeholders (first objective) with scenarios developed by climate scientists (second objective).
Research subquestions:
 - 7) *What are, taking into account the different stakeholder perspectives, salient issues to address?*
 - 8) *To what extent do the scenarios for weather extremes in the Netherlands address the issues raised by stakeholders? If there is a gap, can this be bridged by improving indicators of extremes and associated scenarios?*
- To explore and assess the pros and cons of adaptation options (related to contents as well as procedure for governance).
Research subquestions:
 - 9) *Focusing on specific sectors or regions, which adaptation options can be considered robust given the dialogue between stakeholders and experts?*
 - 10) *Focusing on process, did the process enhance stakeholder learning?*

3. Innovative aspects

The question of gearing model information on the future climate and climate effects at the regional and local scale is not innovative in itself. The innovative aspects are:

Methodological aspects:

- The approach really integrates natural science and social science methodologies for articulating a diversity of perspectives.
- The extreme weather indicators will be co-produced by stakeholders and climate modellers.
- The uncertainty assessment of extremes in future climate will be based on multiple techniques.

- A quasi-experimental design will be used to evaluate the learning impact of the dialogue on participants, using repeated repertory grid analysis. To our knowledge, this has not been done before.

Empirical aspects:

- The latest single- and multi-model ensembles will be used. In particular decadal predictions, including regional model output, have not been used before for informing climate change adaptation.
- The project will deliver uncertainty information that was not available before.

Policy aspects:

- For the first time, specific climate information comes available for taking adaptation measures in the Netherlands that have a relatively short time horizon of up to 30 years.
- Through stakeholder dialogues the project directly contributes to adaptation governance.

4. Methodology

The generation of socially relevant and scientifically robust information on changes in weather extremes will be organized as a user-driven process. Therefore, the project requires a mixed methodology. One postdoc will have a social science background and the other will have a natural science background. In order to be able make the bridge between climate science and its users, both postdocs will have to learn from each other and operate jointly (see working programme under 5). At the same time, the social and natural science will be clearly recognizable in the work carried out at IVM and KNMI.

The basic methodological concept is problem structuring, especially the idea that uncertainty with respect to weather extremes, the seriousness of their impacts and the choice of adaptation options is best addressed by articulating a variety of (complementary and competing) stakeholder perspectives as well as scenarios for weather extremes in the Netherlands.

The project is carried out in three stages. Stage 1 will focus on identifying perspectives on the side of the stakeholders and various scenarios on weather extremes on the natural science part. Stage 2 will focus on analyzing and comparing the results from stage 1. This stage will be concluded with a dialogue workshop for stakeholders and climate scientists so as to discuss social and economic impacts of weather extremes for the Netherlands. During the third stage, the project focus will shift to one or few specific sectors or regions so as to improve the scenarios and to facilitate a stakeholder expert deliberation on options for adaptation governance during a second workshop. In addition, an expert workshop will be held on uncertainty communication. This stage will be concluded with a full project report.

Stage 1: Identifying perspectives and scenarios

This stage is without doubt the most difficult part, as its careful design and execution will, to a large extent, determine the value, both in terms of scientific and societal relevance, of the project. Therefore, it deserves relatively more attention than the following stages.

During stage 1, collaboration between the postdocs will be provided in two ways. Postdoc 2 will contribute to the stakeholder interviews, whereas postdoc 1 will provide feedback to the scenarios developed / selected by postdoc 2. In order to facilitate the startup of the cooperation, we envisage that both postdocs will physically reside at the same institution for short periods during this first stage.

Postdoc 1 (IVM, social sciences) will design and carry out 35 – 45 in depth stakeholder interviews in order to articulate and map out different perspectives that underlie stakeholder perceptions related to weather extremes in the context of climate change. The method used for the interviews is repertory grid technique. The qualities associated with this method are (1) that it provides a *bottom-up elicitation* of constructs that stakeholders use to understand and give meaning to their observations of society, so they are not guided by questioning, (2) that the interviews take relatively little time (about 1 hour) and (3) that a relatively small sample is needed so as to get the full range of ‘unique constructs’ present in a given social setting, in our case among Dutch stakeholders (potentially) involved in climate change adaptation issues. As policy research indicates, it takes between 15 – 25 interviews before the saturation point is reached (Dunn 2001; van der Sluijs et al. 2001; van de Kerkhof et al. 2009). Therefore, the method can be considered highly efficient. The interview procedure is as follows. Each respondent will be asked to compare three cards at a time, the question being: “To what extent are two of these phenomena similar and different from the third?” The answer to this question provides a bipolar construct, such as ‘destroys crops – indifferent with respect to crops’. The respondent is then invited to rank all pictures according to their position within this bipolar construct and to state a preference for what impacts are most urgent to address. The outcomes will then be statistically analyzed, which will articulate the different perspectives stakeholders use to evaluate weather extremes (e.g. van de Kerkhof et al. 2009).

Since we are especially interested in possible differences between stakeholders closely affiliated with the climate policy–science network and stakeholders who are not, the project will identify two samples of about 20 respondents and compare the results for both groups. We hypothesize that the results for the group ‘closer to the policy–science network’ (including policy makers at national and local level, researchers and stakeholders already involved in climate change research and policy programmes) will match more with the scenario study conducted by postdoc 2 than the group that is less connected to this network. This is important, since we want to identify the broadest range of perspectives and related views with respect to adaptation governance.

Postdoc 2 (KNMI, natural sciences) will focus on extreme weather indicators that are relevant for Dutch adaptation strategies. We will perform a systematic uncertainty assessment of weather extremes in the Netherlands simulated by the latest global and regional climate models. We will do so by analyzing output at regional scales for extreme temperature, extreme wind and extreme precipitation, including combinations of these (possibly with time lags). The simplest method would be to analyze indices, for example by counting events over a certain threshold. A more generic approach is to fit an extreme value distribution to the data of the different models. Using extreme value theory allows us to account for non-stationarity in extremes (e.g. by allowing the parameters of the statistical model to be time dependent). Similar as in Cox and Stephenson (2007) we will do this for different prediction horizons and different sources of uncertainty as worked out below. There are several new elements in our proposed analysis compared to earlier analyses. First, we focus on extremes from climate simulations in the Netherlands using extreme value theory instead of simple indices; second, we use a more extensive dataset since more data is becoming available (in particular the decadal predictions and regional climate model output from EU FP7 ENSEMBLES and CMIP5); and third, we include regional model output in our uncertainty analysis of extremes (recently available to KNMI from EU FP7 ENSEMBLES).

For adaptation different time horizons are relevant, depending on the investment for which a specific adaptation measure is made. Therefore, we will assess the uncertainties at different time horizons. As many adaptation measures have a relatively short time horizon of up to 30 years, the new decadal predictions can be very valuable. There is also a scientific value to these predictions: they primarily sample the initial condition uncertainty and internal variability (the effect of different emission scenarios is more dominant at longer time scales). Of course, model structure uncertainty cannot be neglected at these timescales and has to be addressed too, quantitatively where possible and qualitatively. Decadal predictions are still at its infancy, but they are expected to produce results on both the impact of human emissions of greenhouse gasses and aerosols and contain information on the natural climate variability (see e.g. Smith et al 2007). Since the models used for these simulations do not need a long spin up, they can run at higher spatial resolutions than long scenario runs (in case of EC-Earth, the earth system model used at KNMI, T159 – that is, a horizontal resolution of about 80 to 120 km – and 62 layers).

Here we will analyze regional climate models as well as global climate models. There are less ensemble members for regional models than global models and they are strongly constrained by the boundary conditions of the driving global model. Nevertheless, in the EU FP6 ENSEMBLES project a sizeable number of simulations are made (24 now, primarily with SRES A1b and some with A2 scenario). The data mentioned below are directly available to KNMI researchers because the access is either free (such as CMIP5) or because KNMI participates in the international projects (such as EU FP6 ENSEMBLES). Most data is available at KNMIs Climate Explorer as well (climexp.knmi.nl).

The proposed work is to first extract relevant data from different data sets. Then we will determine the uncertainty arising from:

- Internal variability using 17 member ensemble of the global ECHAM5/OM model from the ESSENCE project (Sterl et al 2008, www.knmi.nl/~sterl/essence)
- Initialization using decadal prediction ensembles from the EU FP6-ENSEMBLES and FP7-THOR project and obtained with EC-Earth (for ENSEMBLES runs available to KNMI see: http://www.ecmwf.int/research/EU_projects/ENSEMBLES/table_experiments/index.html)
- Global model uncertainty using CMIP3 (Meehl et al 2007) and upcoming CMIP5 ensemble.
- Emission scenario uncertainty using CMIP3 (Meehl et al 2007) and upcoming CMIP5 ensemble.
- Regional model uncertainty using PRUDENCE and EU FP7 ENSEMBLES output (available regional climate simulations: <http://ensemblesrt3.dmi.dk>)

As mentioned above, we will determine the uncertainty by fitting extreme value distributions to the model output at different spatial scales. Return times of 10 to 100 years will be the main focus, but this may alter, depending on the questions of the stakeholders. In addition this will be done for a range of time horizons, typically 10 years apart from 2010 to 2100. The longer the prediction or projection horizon, the longer the temporal averaging will be. We will complement this by a Bayesian analysis on extremes similar as Tebaldi et al (2005), but applied to different

uncertainties (Tebaldi et al focused primarily on model uncertainty). Most data is available in NetCDF and analysis will be performed using the *R* statistical package or Fortran codes such as developed for KNMI's Climate Explorer.

Stage 2: Comparison and deliberation

During this stage, we will compare the outcomes of the repertory grid analyses with the scenario analysis and feed back our findings to a stakeholder workshop. A part of the interviewees of stage 1 will be invited to take part, as well as experts with relevant climate impacts knowledge. The workshop will select specific extreme weather impacts that deserve priority in policy making, which will be further explored as to define and discuss policy options for adaptation governance in stage 3. The specific design of the workshop itself will depend on the outcomes of the repertory grid analyses.

The stakeholder deliberation on the results of both repertory grid analyses and scenario analysis will enable learning by interaction by the participants involved, will contribute to the emergence of socially robust scientific knowledge and will provide the opportunity for distributed governance on climate change adaptation options.

Stage 3: Improvement of scenarios / identification and exploration of options for adaptation governance

This stage will focus on improving the scenarios on weather extremes and on identifying and discussing options for adaptation governance, thereby focussing on a modelling risk assessment of most heavy impacts for two or three regions or sectors.

Postdoc 2 will use the outcomes of the repertory grid analyses and the feedback from the stakeholders to further refine the extreme weather indicators and improve the uncertainty presentation in new scenarios for the second dialogue workshop. Postdoc 1 will provide the dialogue with an overview of possible options based on literature survey and findings from former policy exercises, as well as possibly a small number of interviews with relevant climate impacts experts. The dialogue group will first explore criteria that, according to the stakeholders and experts involved, should underlie an argued choice for adaptation options, including substantial and procedural criteria. We assume that cost of options related to seriousness of risk will be among these criteria. We expect that adaptation governance will benefit from options that are robust in that they are relevant in case of different risks, such as drought and heavy rainfall, or periods of extreme heat or extreme cold. Most likely, these options are more cost-effective than options that only address one single issue. To illustrate, detrimental impacts on agriculture of extreme precipitation and extreme drought may both be addressed by soil improvement measures.

Next, the dialogue group will match the options identified with the extreme weather impacts it wants to address. The project will not focus on forced consensus among stakeholders arguing from different perspectives, but on identifying arguments pro- and con, thereby using argumentation analysis (cf. Hisschemöller et al. 2009).

As follow ups, postdoc 2 will organize an expert workshop on climate projection uncertainty communication together with the Grantham Research Institute on Climate Change and the Environment of the London School of Economics and Political Science (LSE) and postdoc 1 will carry out an evaluation of the learning impact of the dialogue on participants, so as to assess the value of the demand driven approach explored in the project. This evaluation will be carried out using repeated repertory grid among a selection of workshop participants and non-workshop participants as a control group. Through this, the dialogue will function as a quasi-experiment (Hisschemöller et al. 2009b).

5. Timetable of the project and working programme:

Month (1-24)	Activity postdoc IVM	Activity postdoc KNMI
<i>Stage 1 – Identifying perspectives and scenarios (9 months)</i>		
1–2	Literature study; getting to know home institutions	Literature study; getting to know home institutions
3–4	Preparing interviews	Obtaining data and mapping of available simulations on changes in weather extremes in the Netherlands
5–7	Conducting 30 interviews (jointly)	
8–9	Statistical analysis of repertory grid data	Setting up statistical models and uncertainty analysis for different prediction horizons
<i>Stage 2 – Comparison and deliberation (4 months)</i>		
10–12	Joint comparative analysis of findings on perspectives and scenarios	
12	Preparing first stakeholder workshop	Performing uncertainty analysis and preparing presentation of results
13	First stakeholder workshop: testing the repertory grid results, the appropriateness of the indicators and the communication of scientific uncertainty	
<i>Stage 3 – Improvement of scenarios / exploring options for adaptation governance (11 months)</i>		
14–16	Mapping of adaptation governance options	Development of Bayesian analysis of changes in extremes; improving indicators of extremes and uncertainty presentation based on user feedback
17	Preparing second stakeholder workshop	Performing simulations and preparing presentation of results
18	Second stakeholder workshop: exploring adaptation governance options	
19–20	Evaluation of process impact	Preparing and holding expert workshop on uncertainty communication with regard to regional climate change (with LSE)
20–24	Preparing report and two articles (jointly)	

PBL (Prof. Petersen) will perform the overall management of the project. The core project team will consist of Prof. Petersen, Dr. Hisschemöller, Dr. Hazeleger and the two postdocs. The other members of the research group will offer advice in their areas of specialization.

6. Affiliation with (inter)national research programmes

(including description of existing and planned cooperation)

All three partners (PBL, IVM and KNMI) are strongly involved in the climate change research programmes in the Netherlands (the Climate *changes* Spatial Planning Programme and the Climate for Knowledge Research Programme). This project will collaborate with ongoing projects, pilots and hotspots carried out in the context of these programmes and build on their experience.

Through the appointment of Prof. Petersen, who directs PBL's Methodology and Modelling Programme, as Visiting Professor within the Centre for the Analysis of Time Series and the Grantham Research Institute on Climate Change and the Environment of the London School of Economics and Political Science (LSE), the PBL participates in LSE's research programmes on climate change, which are partially funded by the UK's ESRC and by Munich Re. The main focus of this collaboration lies on uncertainty assessment and communication. In addition, Prof. Petersen is a Research Affiliate in the Political Economy and Technology

Program of MIT's Center for International Studies, where he is involved in a research project on "planned adaptation" as a way of dealing with scientific and technological uncertainty in policy making.

At IVM, the project will be embedded in the Earth System Governance Project coordinated by Prof. Frank Biermann and others under the auspices of the International Human Dimensions Programme on Global Environmental Change (IHDP). At European level, collaboration will be sought with the Transdisciplinarity Network (TD net). Collaboration will relate to both substance and methodology.

KNMI collaborates with other European major climate modelling institutes in the ENSEMBLES project (6th Framework), COMBINE project (7th Framework) and THOR project (7th Framework). In these projects global and regional climate model output has become available or will become available. The Global Climate Division of KNMI, led by Dr. W. Hazeleger, coordinates the decadal prediction work packages in THOR and COMBINE. KNMI collaborates with 20 partners from 11 countries and ECMWF in the EC-Earth project, in which a seamless prediction system is set up. EC-Earth is a state-of-the-art climate model, based on ECMWF's seasonal forecast system that will contribute to the next coupled model intercomparison (CMIP5), which will likely be assessed by the 5th IPCC Assessment. In particular we will assess initial condition uncertainty from the new decadal predictions that are part of CMIP5 near-term prediction simulations. The work is in line with the goals of the World Climate Research Program (WCRP), in particular the need to set up science-based climate services. Within WCRP KNMI has a leading role in CLIVAR and GEWEX. Climate impact assessments are also planned in collaboration with other European institutes, such as the Swedish Meteorological and Hydrological Institute (SMHI). Furthermore, KNMI is coordinating the Climate Knowledge Facility in the Climate for Knowledge Research Programme, through which climate and climate impact information is delivered to stakeholders.

7. Societal significance

Not only the end results of this project, but also the research process itself contributes to a societal process for exploring climate adaptation options with stakeholders. The specific climate information that will come available is therefore expected to be used in decision-making by governments at national and local level as well as private actors on adaptation measures in the Netherlands.

8. Legal requirements

Has been complied with the law and legal requirements with respect to the proposed research, such as 'Wet op Dierproeven' and 'DNA-recombinant legislation'?

Yes

No

Not applicable

9a. Requested budget from ALW

	2009	2010	2011	2012	total
Postdoc 1 (mm)		8	12	4	24
Postdoc 2 (mm)		8	12	4	24
Research costs (k€)					
Student assistant		4	6	2	12
Equipment		7			7
Consumables*		1	2	2	5
Fieldwork		3	3		6

* max. € 10.000,- p/year

9b. Motivation and specification of the requested funds (obligatory)

Motivation IVM research costs:

	€
Student assistant	12.000
Travel (in the Netherlands)	2.000
Workshops organized	3.000
International conferences	2.500

The student assistant is indispensable for assisting in organization and planning of the stakeholder assessment. Especially, the student assistant will schedule and organize stakeholder interviews and workshops and assist in the statistical analysis of interview outputs. From earlier experience, we know that these tasks are time consuming and need to be carried out on a regular basis, which distinguishes them in a clear way from ad hoc secretarial assistance. The assistance applied for can be compared with laboratory personnel in natural sciences research. NWO STW has earlier approved support for this type of assistance in the case of the IVM H2 Dialogue project (programme Sustainable Hydrogen).

Travel is needed for conducting interviews, project coordination, and other activities related to project execution.

Workshop costs relate to arranging suitable workshop accommodations and related costs for the two workshops anticipated in this proposal.

On top of the benchfee for this postdoc (5 k€ for personal scientific career development, not included under research costs), additional funds are requested for international travel to present project results at international conferences (2.5 k€), in order to receive feedback on the research project.

Motivation KNMI research costs:

	€
Desktop workstation	2.000
Blade	5.000
Travel (in the Netherlands)	1.000
International conferences	2.500

The equipment consists of a desktop workstation (2 k€) and a blade at KNMI (5 k€). The postdoc will work on climate model data needs to analyze large amounts of data. The workstation is for simple calculations and analyses, the blade is a rack-mounted computer directly coupled to the mass storage system at KNMI. This facilitates the assessment of Terabytes of climate model output.

On top of the benchfee for this postdoc (5 k€ for personal scientific career development, not included under research costs), additional funds are requested for international travel to present project results at international conferences (2.5 k€), in order to receive feedback on the research project.

10. Financial assistance from (an)other source(s)

PBL and KNMI will fully finance their participation from their own resources. PBL will provide funding for part of the IVM participation, i.e. senior coordination of the stakeholder dialogue, in the context of the Memorandum of Understanding between PBL and IVM. Funding for the expert workshop on climate projection uncertainty to be organized jointly with LSE will be provided by PBL and/or LSE.

11. Relation research programme of university, large institutions, research schools, etc.

This work makes part of PBL's Methodology and Modelling Programme, IVM's Environmental Policy Analysis Department and KNMI's Global Climate Division. The work relates to the SENSE graduate school. It will contribute to the development of climate scenarios made by KNMI and to PBL's studies on climate proofing of the Netherlands.

(No signatures required for electronic submission)