Modelling land surface fluxes of CO2 in response to climate change and nitrogen deposition

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Danish Coasts and Climate Adaptation (COADAPT)

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Watershed land use effects on lake water quality in Denmark

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Nutrient losses from anthropogenic non-point sources is today of particular importance for the ecological quality of numerous freshwater lakes world-wide. However, mitigating these losses is complex, because of influences from several interacting factors (e.g. nutrient cycling processes and complex nutrient transport pathways), which, in turn, are affected by spatial differences in past and present land use, management and landscape characteristics. To improve understanding of the linkage between freshwater ecosystems and their watershed we examined a comprehensive dataset from 204 Danish lakes, for which the influence by point sources were assumed negligible. Relationships (R2) between in-lake total nitrogen (TN) and total phosphorus (TP) and the proportion of agricultural land use in the watershed were relatively strong: 39-42% for deep lakes and 21-23% for shallow lakes. Even stronger relations were found between TP and the proportion of agricultural land for lakes with rivers in their watershed (55%) compared to lakes without (28%), indicating that rivers mediate a stronger linkage between surface activity and lake water quality. Examining relations between TP and TN to land use within different near-freshwater land zones as contrast to the entire watershed showed generally improvement with size of zone (25, 50, 100, 200 and 400 meters), but were by far strongest using the entire watershed. Proportion of agricultural land use in the entire watershed was also a better explanatory of lake water quality relative to estimated nutrient surplus at agricultural field level.

Our findings somewhat contrasts typical strategies of management policies that mainly target agricultural nutrient applications and implementation of near-water buffer zones, and this study suggests that transport mechanisms within the whole catchment are important for the nutrient export to lakes. Hence, the whole watershed should be considered when managing nutrient loadings to lakes, and future policies should ideally target measures that reduce the proportion of cultivated land in the watershed to successfully improve lake water quality.

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Tbc.

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Sea level rise projections in the Baltic region

Aslak Grinsted, Centre for Ice and Climate, University of Copenhagen

A review of recent projections of the major contributions to sea level rise is compiled into a projected sea level rise budget. This budget is combined with the distinct spatial fingerprints of each contributor to yield a best estimate of local sea level rise in the Baltic by 2100. The glacial Isostatic adjustment from the decay of the Fennoscandian ice sheet is corrected for to reveal a projection of relative sea level rise in the Baltic. In addition to the best estimate, a high-end scenario is also calculated.

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Overview of the model component in ECOCLIM

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As part of the Danish strategic research project ECOCLIM: Ecosystems Surface Exchange of Greenhouse Gases in an Environment of Changing Anthropogenic and Climate forcing a model system will be developed. This model system will be based on both terrestrial and marine ecosystems in order to be able to describe the exchange of GHG with main focus on carbon dioxide (CO2) and the exchange above the Danish terrestrial biosphere as well as above Danish waters including fjords. The construction of the model system is based on data from new, existing and previous field experiments and on improved ecosystem and atmospheric models. We will use the model system to 1) quantify the potential effects of climate change on ecosystem exchange of GHG and 2) estimate the impacts of changes in management practices including land use change and nitrogen (N) loads. Here the various model components will be introduced and the scientific questions that we will investigate will be discussed.

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Changes in drought statistics over Europe in the twenty-first century

Cathrine Fox Maule and Peter Thejll, Danish Climate Centre, DMI

We are investigating how the occurrence of drought over Europe will change under a changing climate in the twenty-first century. From the ENSEMBLES database we have selected 11 GCM-RCM combinations all run from 1951-2100 under the A1B scenario. We have calculated the Standardized Precipitation Index and the self-calibrated Palmer Drought Severity Index from the output of the climate models and analysed how the mean and variance of the drought indices changes in the future for nine different regions covering Europe. We see a North-South dependency in the clarity of the results along the Western European landmass, in accordance with expectations based on large scale circulation.

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A COordinated Regional climate Downscaling Experiment (CORDEX)

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Vulnerability to Climate Change - the Concept in a Danish Context

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Climate change impact assessment on urban flooding in Aarhus - First results

Henrik Madsen, Maria Sunyer, Dan Rosbjerg, and Karsten Arnbjerg-Nielsen; Henrik Madsen: DHI

Climate model projections from 15 regional climate models (RCM) from the ENSEMBLES data archive have been used for estimation of future extreme rainfall characteristics in Aarhus. Two different statistical downscaling methods were applied, using, respectively, a direct estimation of the changes in the extreme value statistics of the RCM data, and application of a stochastic weather generator. The results show a large variability in the projected changes in extreme precipitation between the different RCMs and the two downscaling methods considered. Analysis of sub-daily rainfall projections indicates a larger increase of extreme rainfall statistics with decreasing duration. Urban flooding in Aarhus was simulated with a model that dynamically couples a hydraulic model of the drainage system and a 2D overland flow model. Scenarios representing current and future climate were analysed using synthetic design storms derived from the estimated extreme rainfall characteristics.

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Risk-based design in a changing climate (RiskChange)

Henrik Madsen, DHI

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Evaluating the influence of long term historical climate change on catchment hydrology - using drought and flood indexes

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(b) Geological Survey of Denmark and Greenland (GEUS)

The purpose of this study is to evaluate past climate changes in a Danish catchment and examine how climate change is manifested through the hydrological system in relation to extreme events. Extreme events as droughts and floods have a profound effect on both economy and ecology of a catchment, affecting both availability and distribution of water. Therefore historical data give valuable information about the impact of past climate changes on occurrence and magnitude of events, and thus indicating how future climate change can be expected to influence extreme events.

The study examines the degree of change in the climatic components; temperature, evaporation and precipitation, followed by an analysis of the hydrological response in discharge. In order to obtain data for a representative time frame of climate change, the time series of discharge was extended using longer time series of precipitation in combination with a simple conceptual rainfall-runoff model. The discharge data are analyzed using a daily threshold method and plotting a SDP-diagram (Stream flow Deficiency Periods). Furthermore it is discussed in what degree the definition of the threshold period affects the results.

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Assessing future climatic changes of rainfall extremes at small spatio-temporal scales

Ida Bülow Gregersen, Henrik Madsen, Dan Rosbjerg and Karsten Arnbjerg-Nielsen; I.B. Gregersen: DTU Environment

The effect of climate change on urban flooding forms the context of the presentation. The general design practises for urban drainage structures are based on simulations using sub-hourly rainfall input and the major impacts of an increased flood risk are expected to occur at similar temporal resolutions. This makes convective storms the dominant rainfall type in relation to urban flooding. The physical processes behind the convective rainfall extremes generate a distinctive inter-spatial correlation structure. Analyses of rainfall extremes from the regional climate model RACMO show a clear deviation from this correlation structure for sub-daily rainfall durations. The results stress that RCM developments must be improved in relation to rainfall extremes and suggests a methodology by which RCM performance can be assessed.

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Development of Decision Support Matrices for Climate Change Adaptation Planning (tbc.)

Jay S. Gregg, Malene Kauffmann Hansen, and Kirsten Halsnæs, DTU Climate Centre

When deciding amongst a suite of various climate change adaptation options, decision makers have to balance uncertainties in potential physical impacts, economic judgements, and political priorities. A decision support matrix is a tool to aid in decision making, by clarifying the decision making

process, highlighting key uncertainties, and identifying critical assumptions. Using a decision matrix allows decision makers to examine how different a priori stakeholder values can impact the adaptation decision. We begin with a simple hypothetical decision matrix and build more complexity by adding multiple adaptation options, multiple risks, and multiple impact variables. The goal is to show where complexities enter into the decision tool, and then present ideas on how best to address these complexities under the context of adaptation planning (tbc.).

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Regional climate change – a first preview from the upcoming IPCC AR5 report

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Scenarios of future land use in Denmark

Jørgen E. Olesen, Department of Agroecology, Aarhus University

Both global and national drivers and trends are expected to lead to major changes in land use in Denmark over the next decades. These drivers can be categorized into four major categories: 1) Changes in demand for biomass products (food, feed, fiber and bioenergy), 2) Changes in technology, in particular within agricultural land use, 3) Changes in priority of land for other ecosystem services, and 4) Changes in environmental conditions (climate change). These drivers will affect land use in Denmark differently conditioned on how extensively Danish land use decisions are being affected by local (national) decisions versus EU policies and global market trends. Within CES a workshop was organized to discuss details of possible scenarios of land use in Denmark with key stakeholders. These stakeholders were asked to reflect on the following main categories of changes in land use and management: 1) Change in overall land use, e.g. agricultural area, arable land, forestry, wetlands etc., 2) Change in farm structure (regional and national levels), e.g. farm size, number of livestock, and 3) Change in agricultural land use and management, e.g. which crops are grown, fertilisation levels. During the workshop four different directions of land use in Denmark were developed, which were summarized in the following headlines: 1) Agriculture for nature (reduced agricultural area and less livestock), 2) Extensive agriculture (reduced intensity in agriculture and less livestock), 3) High-tech agriculture (higher productivity in agriculture but less agricultural land), and 4) Market driven agriculture (increasing agricultural area and higher intensity).

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Modelling land surface fluxes of CO2 in response to climate change and nitrogen deposition

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Climate change, land use variations, and impacts of atmospheric nitrogen (N) deposition represent uncertainties for the prediction of future greenhouse gas exchange between land surfaces and the atmosphere as the mechanisms describing nutritional effects are not well developed in climate and ecosystems models. Recent research indicate the need for incorporating the ammonia (NH3) compensation point in atmospheric N deposition models to quantify the N budget for vegetative surfaces. This poster presents a PhD project within ECOCLIM of incorporating the NH3 compensation point in a coupled photosynthesis-stomatal conductance model to allow more realistic estimation of the predictions NH3 deposition rates and CO2 fluxes of terrestrial ecosystems. Such an integrated model system will improve the understanding of processes responsible for net sources and sinks of CO2 enabling us to predict important climate feedback mechanisms of CO2 between changes in management, land use practise, and climate change.

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Ecosystem services in ECOCLIM

L.L. Sørensen, E. Bøgh, J. Bendtsen, E. Dellwik, T. Friborg, C. Geels, K. Hansen, A. Ibrom, E.T. Jørgensen, M.K. Sejr, and C.A. Skjøth; L.L. Sørensen: Department of Environmental Science, Aarhus University

Surface exchange of greenhouse gasses (GHG) between land/sea and the atmosphere is an important climate feedback mechanism. The processes involved in exchange of GHG needs to be fully understood and accurately quantified in order to increase reliability of climate projections and ensure that actions initiated to reduce anthropogenic GHG emissions are sustainable and not destructive to existing ecosystem services. Therefore it is important to address i.e. land use change in relation to the regulating services of the ecosystems, such as carbon sequestration and climate regulation. At present, the surface exchange of GHG in Denmark and Danish waters is unknown and qualified predictions of the effect of changes in climate or anthropogenic activities are not possible. In ECOCLIM it is a goal to quantify the natural sinks and sources controlling the atmospheric concentration of CO2 and CH4 thus a thorough understanding of the ecosystem processes controlling the uptake or emissions of GHG is fundamental. Here we present ECOCLIM in the context of ecosystem services and the experimental studies within ECOCLIM which will lead to an enhanced understanding of Danish ecosystems.

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ADAPT project: getting climate scientists and engineers to work together

Luca Garré and Peter Friis Hansen, DNV (Det Norske Veritas)

Det Norske Veritas (DNV) is establishing a recommended practice for adaptation to climate change. The purpose of the recommended practice is to assist engineers (and non-experts in climate science at large) in evaluating adverse climate change effects in their design or reassessment of structures and infrastructures. With this aim, DNV has developed a work flow that includes the main phases of a climate change adaptation analysis in a sequential manner. Along with the work flow, an understating of key climate terminology, of the complexity of the climate, of the current-state-of-the-art climate modeling and its limitations will also be included in the recommended practice. The presentation will also address the need for climate scientists to become aware of standard

engineering practices and of the problems engineers face during their activity. Finally, planning and implementing adaptation measures require socio-political competence that will be briefly illustrated. The project is run in collaboration with a number of institutions: The Danish Hydrological Institute, The Bjerknes Climate Research Centre, the Niels Bohr Institute and The National Centre for Atmospheric Research.

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Decision making under risk and uncertainty – development of a framework to aid decisions on climate adaptation

Malene Kauffmann Hansen, DTU Climate Centre

The presentation will build on the initial theoretical work carried out in my PhD study. The focus of the study is on integrated assessment of climate impacts and adaptation options and my aim is to develop of a framework to aid in decision-making under uncertainty – specifically in the area of climate adaptation.

Building on prospect theory and theories of decision-making under uncertainty, a framework will be developed that highlights how uncertainty enters into the decision-making process. Hereby, the framework should allow for a better understanding of the implications of the different sources of uncertainties, hence making it possible to suggest different ways of coping with them. This, in turn, will aid the implementation of (more) optimal adaptation options.

This specific presentation focuses on the initial theoretical considerations underlying these decision processes, and as such it will – along with my PhD study in general – form the initial step of a highly interdisciplinary research process.

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Climate, Ecology and Sociology; living with uncertainty

Manual Montesino, University of Copenhagen, Department of Agriculture and Ecology

Uncertainty contribution in agricultural impact assessments can be acknowledged by combining scenario approach and statistical methodologies. Scenarios provide internally consistent and narrative descriptions (van de Heijden, 2005) of plausible socioeconomic, politic and climate futures contributing to a large extent to the total uncertainty on impact assessments. New generation of scenarios, which requires joint efforts climatologists, IAM 8 and IAV communities, is being built for the AR5 of the IPCC. The creation process is found at the parallel phase in which climate and socioeconomic scenarios (Shared Socioeconomic Pathways or SSPs) are made separately at the same time. SSPs describe five socioeconomic conditions to underline challenges for mitigation and adaptation (Carter et al., unpublished). The workshop last November 2nd at NCAR facilities aimed to determine qualitative driver descriptions for those SSPs. Now, basic SSPs can be spread to more detailed information for deeper sectoral analysis of food systems Representative Agricultural Pathways (RAPs). In that sense, some questions have to be addressed; (1) How many RAPs per SSPs should be created? (2) How RAPs could be downscaled? (3) How increased dimensionality can be dealt with? (Antle, 2011).

RAPs are required to project the behaviour of the ecological interactions between atmosphere, soil, plant growth and development by using models. However, the large variety of process-based models configured since 1960 to answer different questions has lead to strengths and deficiencies in impact analyses. Therefore, model ensemble studies can achieve synergies (Challinor, 2008) and manage model ambiguity uncertainty by the use of statistical methodologist originally employed by climatologists, such as Bayesian Model Averaging. But models apply empiricism at some degree and are simplified representations of reality. Their ecological explanatory deficiencies become crucial and are highlighted in extrapolated conditions (learned form hydrological studies; Wierenga, 2003; Poeter and Anderson (2003); Højberg and Refsgaard, 2005) such as climate change. Owing to that, uncertainty efficiency can be achieved by using the proper kind of model at the correct time horizon and scale. It can also be reduced by updating the models (Rötter et al., 2011) with the latest discoveries in CO2 fertilization, ozone damage and extreme event effects and crop sensitivity (IPCC, 2007).

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Challenges in quantifying the uncertainty of downscaled extreme rainfall

Maria Sunyer, Henrik Madsen, Dan Rosbjerg, and Karsten Arnbjerg-Nielsen; Maria Sunyer: DTU Environment

Information on future changes in extreme climate conditions is subject to numerous uncertainties. Two major sources of uncertainty arise from the dynamical and statistical downscaling methods applied. Currently, there is not a standard procedure to assess uncertainty in climate change projections. There is lack of agreement on which metrics should be used to assess climate models and, even though there are some guidelines available, there is not agreement on which statistical method is best at downscaling extreme rainfall. The assumptions made during the uncertainty assessment highly influence the results obtained. Therefore, if the results of probabilistic projections are not well interpreted, there is a risk of overconfidence in the results obtained. This and other challenges in deriving probabilistic changes in extreme rainfall at the local scale will be analysed and discussed in the presentation.

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Towards predicting the effects of extreme climate events on grain yield and quality in contrasting wheat genotypes

Marija Vignjevic, Bernd Wollenweber, Jørgen E. Olesen, Aarhus University, Department of Agroecology

The aim of this project is to sustain and improve wheat grain yield and quality under a warmer and more variable climate. Climate variability and changes in the frequency of extreme events are important for yield, its stability and quality. High temperatures severely limit wheat yield. They accelerate plant development and specifically affect the floral organs, fruit formation and the functioning of the photosynthetic apparatus. With an increase in climatic variability, episodic occurrences of high temperature could have an impact at vulnerable stages and be much more damaging to crop yields. By integrating knowledge from soil science, crop physiology and meteorology into mathematical equations, crop models are able to simulate and predict growth,

development, yield and quality of cultivars and species. Differences in the performance of crop varieties within models are described by the use of cultivar-specific parameters. In order to obtain these parameters, two experiments were conducted during the summer of 2011. A field experiment with nine wheat varieties mainly differing in flowering date and a semifield experiment with the same varieties in which we examined the effect of heat stress during grain filling. The results from the semifield experiment will be used in order to verify the modelled results of the field trial.

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Changes in Wind, Wave and Water Level Conditions in Danish Waters due to Climate Change

Morten Rugbjerg and Martin Johnsson, DHI

How does climate change affect environmental impacts and design conditions for wind, waves, water levels and currents in Danish Waters? As these conditions are very important for the design of offshore structures and coastal structures, changes due to climate change should be taken into account. The work which has been carried out and which is being carried out include: (i) Detailed long term wave modelling and hydrodynamic modelling based on RCM winds and surface pressures for a number of GCMs (ii) Extreme value analysis as in a “normal” design hindcast study for a control period and a future period to determine the climate change impact.

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Extreme climate events impact on soil water dynamic under heathland ecosystem

Omar Daraghmeh, Leon van der Linden, Claus Beier and Andreas Ibrom; Omar Daraghmeh: Biosystems, Risø DTU

The future climate is projected to be more variable; therefore, studying the effects of extreme climate events on ecosystem functions is an important facet of climate change research. Improving our understanding of how extremes and their impacts will change is important for planning appropriate adaption and mitigation strategies.

Climatic observations and projected climate variability were analyzed using the RClimDex module (CCI/CLIVAR) and an ecosystem model (CoupModel) was used to investigate the impact of future climate variability on the ecohydrological functions in heathland ecosystem (Brandbjerg, Sjælland, Denmark). Modelled data from three different climatic models (ARPEGE, ECHAM5 and BCM) using scenario A1B from the European project ENSEMBLES were used to drive the ecosystem model.

Initial results from the projected climate data analysis of the three different models showed variation in the trends of the different climatic change indices. Furthermore, the companion analysis of the ecosystem response will clarify how much those changes will affect the stability and functioning of the ecosystem and the ecohydrological services it provides.

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A Bayesian Classifier for Climate Model Ensemble Selection

Peter Friis-Hansen and Luca Garré, DNV (Det Norske Veritas)

Several studies today are advocating for and using multi-model ensemble analysis because “there is evidence for combining multi-model ensembles increases the skill, reliability and consistency of model forecasts” and that “combining information from several models is reported to be superior to a single-model forecast”. Bayesian methods have been used to identify optimal weights on ensembles (Rajagopalan et al. 2002, Robertson et al. 2004). In the present study we use an apparently similar Bayesian method to obtain the weights on the ensemble models. However, in our study we use a Bayesian network to set up the mathematical problem. This leads to a more intuitive understanding of the Bayesian model formulation. The updating is made by using the historical relationship between model forecasts of and observations. In the presentation we give a short introduction to Bayesian networks before presenting the Bayesian classifier for climate model ensemble selection. The procedure will be illustrated by application to a test case taken from the Ensemble project in which the precipitation in Ã…rhus has been calculated by 20 different GCM-RCM combinations.

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Nordic Strategic Adaptation Research (NORD-STAR)

Sirkku Juhola and Anne Gammelgaard Jensen; Sirkku Juhola: Aalto University

The Nordic Centre of Excellence NORD-STAR (Nordic Strategic Adaptation Research) aspires to a Nordic region that can adapt sustainably to the inevitable impacts of climate change and the unintended consequences of climate policy. Pursuing innovative science, sound economic analysis and effective communication, NORD-STAR’s goal is to enable Nordic stakeholders to design and implement successful adaptation policy and practice. NORD-STAR fosters a comprehensive and strategic approach to climate adaptation, making a novel contribution to the Nordic adaptation knowledge base.

NORD-STAR presents two key innovations. First, state-of-the-art climate visualisation techniques and policy-analysis tools help to bridge the gaps between adaptation science, practice and policy. Second, by linking climate adaptation with mitigation, NORD-STAR results will help public and private stakeholders at all levels to improve strategy development and decision-making.

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Uncertainty assessment of climate change adaptation options in urban flash floods using an economic pluvial flood risk framework

Q. Zhou and K. Arnbjerg-Nielsen, DTU Environment

Adaptation is essential to deal with increasing flood risk in cities in Northern Europe. Traditional risk-based economic analysis, especially in the urban context, often faces enormous uncertainties when assessing the response impacts of present and future hazard and vulnerability conditions. A single-value estimate is no longer sufficient to identify a robust adaptation strategy; the associated uncertainties must be taken into account in decision making. The methodological foundation of this study is a quantitative flood risk framework integrating various elements (e.g. climate change

impacts, inundation modelling, impacts on assests, and damage estimation) in the climate adaptation evaluation. It is further adpated and extended by embedding a Monte Carlo simulation to estimate the total uncertainties propagated through the whole procedure and identify relative importance of inherent uncertainties in the assessment. The case study is a small urban catchment where no significant city development is anticipated. Two differnet adaptation options are studied, namely pipe enlargement and local infiltrations, which differs from both a physcial, economic and enviornmental point of view. The two adaptation scenarios are compared to a business-as-usual scenario. The results show that even though the uncertainties associated with the two options are very high it is still possible to identify a robust adaptation option on a basis of the net benefits estimated. Pipe enlargement turned out to be more economically beneficial in comparison to local infiltration. Furthermore, the sensitivity analysis indicates the input runoff volumes and damage loss model (including threshold criteria and unit costs) are of high relevance to the overall uncertainty. The study shows the framework is an important tool for achieving an explicit uncertainty analysis of climate adaptation strategies and giving guide for further work (e.g. field data collection) to improve the evaluation.

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The development of the regional coupled ocean-atmosphere model

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