REKLIM

Helmholtz Climate Initiative
Regional Climate Change

THE CHALLENGE OF CLIMATE CHANGE | Questions of our time. Answers we need.

Regional climate change - causes and effects

NEWSLETTER No. 3

October 2013

HELMHOLTZ ASSOCIATION

The climate change challenge

Collaborative climate research

The new REKLIM Newsletter No. 3 marks a further step in documenting the scientific results and findings of the Helmholtz Climate Initiative and conveying them to the public as information relevant for decision-making processes. Aside from the summaries of the 10 research topics, the newsletter presents the new Internet portal „meereisportal.de“ developed in REKLIM, which contains background information, expertise as well as a map and data archive regarding the topic of sea ice. It is intended to serve as a German source of comprehensibly prepared information and data on the climate changes, that increasingly take place predominantly in the polar regions. Furthermore meereisportal.de shall arouse interest in this topic among diverse target groups through up-to-date reporting on research expeditions relating to sea ice as well as sensitise them to this topic to a greater degree.

Another feature supplementing the different research subjects and topics is the presentation of brief profiles of several young researchers so as to convey a more personal picture of the research initiative. Particularly the large number of papers in the junior researcher field (PhD candidates and postdocs) contribute to the success of the initiative through their research input and by virtue of the interdisciplinary and multidisciplinary approach in the specific fields develop a sustained basis for Earth and environmental research.

Climate change that emerges at different levels forms the scientific basis for specific topics, whether the polar regions with their direct impacts due to decline in sea ice or the increasing changes in the permafrost regions involving greater emission of methane or destabilisation of the coastal landscape. The flooding in Germany and in the neighbouring Eastern European countries in early summer of this year showed how vulnerable the infrastructure and thus people living in the regions con-cerned are. The material damage is tremendously high and it is the most expensive natural disaster that ever hit Germany. The emotional damage is inestimable.

The REKLIM network thus consciously works not only on improving the natural science basis for regionally based climate projections, but also on transdisciplinary topics, such as climate and health (e.g. the indirect impacts of climate change on air quality through trace gases, aerosols and allergen carriers like pollen and thus on human health) or in a socio-economic context, where risk assessments for necessary avoidance measures as well as adaptation to climate change are involved. This wide variety of topics demonstrates the strength of the network and is presented on the basis of several selected examples in the 2013 Newsletter.

Prof. Dr. Peter Lemke (AWI)
Scientific Coordinator of the Helmholtz Climate Initiative REKLIM

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Impressum

Coordination office
Helmholtz-Verbund REKLIM
Scientific coordinator:
Prof. Dr. Peter Lemke (AWI)
Managing director:
Dr. Klaus Grosfeld (AWI)
Coordination assistant:
Marietta Weigelt (AWI)

Contact:
Alfred-Wegener-Institut
Helmholtz-Zentrum für Polar-
und Meeresforschung

Dr. Klaus Grosfeld
Tel.: 0471-4831-1765
E-mail: Klaus.Grosfeld@awi.de

Dipl.-Geogr. Marietta Weigelt
Tel.: 0471-4831-1750
E-Mail: Marietta.Weigelt@awi.de

www.reklim.de
E-mail: info@reklim.de

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Text and figures:
Members of the Helmholtz-Verbund
REKLIM

Editing and design:
Prof. Dr. Peter Lemke (AWI)
Dr. Klaus Grosfeld (AWI)
Dipl.-Geogr. Marietta Weigelt (AWI)

Spokespersons for the topics:

Topic 1: Prof. Dr. Klaus Dethloff (AWI),
Prof. Dr. Hans von Storch (HZG)
Topic 2: Prof. Dr. Peter Lemke (AWI),
Prof. Dr. Heinrich Miller (AWI)
Topic 3: Prof. Dr. Ursula Schauer (AWI)
Dr. Torsten Sachs (GFZ)
Topic 4: Prof. Dr. Sabine Attinger (UFZ),
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Topic 5: Prof. Dr. Johannes Orphal (KIT),
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Topic 6: Prof. Dr. Christoph Kottmeier (KIT),
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Topic 7: Prof. Dr. Bernd Hansjürgens (UFZ),
Prof. Dr. Hans von Storch (HZG)
Topic 8: Prof. Dr. Ralf Tiedemann (AWI),
Prof. Dr. Achim Brauer (GFZ)
Topic 9: Prof. Dr. Johannes Orphal (KIT),
Prof. Dr. Andreas Wahner (FZJ)
Topic 10: Prof. Dr. Reimund Schwarze (UFZ)
Prof. Dr. Beate Ratter (HZG)

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Content

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1 Coupled modelling of regional Earth systems

How does the development of the climate depend on the interaction between atmosphere-ocean-ice and land surfaces? What effect do natural and anthropogenic processes have?

Motivation

REKLIM's Topic 1 focuses on development of horizontal and vertical high-resolution regional climate system models that couple the subsystem models for the atmosphere, ocean, sea ice, land and aerosol chemistry. The objective is to interpret the observed changes in various regions using regional model simulations. In addition, the so far fuzzy global climate projections are to be refined at a higher resolution for the regional scale. Since increasing spatial resolution means processes and interactions in the climate system have to be depicted and represented in greater detail, the feedbacks also change with the large-scale atmospheric teleconnection patterns. This question will be examined in newly developed global climate models capable of regional refinement.

Within REKLIM the Alfred Wegener Institute (AWI) focuses on the Arctic region using regional Earth system models (RESM). The Helmholtz-Zentrum Geesthacht (HZG) develops these RESM for Germany and northern Europe while the Karlsruhe Institute of Technology (KIT) and the Helmholtz Centre for Environmental Research (UFZ) concentrate their development efforts on Germany and Central Europe. In future, the Helmholtz Centre for Ocean Research (GEOMAR) will be involved in Topic 1 with regional ocean modelling in the North Atlantic and the Baltic Sea region.

Clouds in the climate system of the Arctic

Clouds in the Arctic represent one of the biggest uncertainties related to climate modelling of this region because they influence numerous processes in the climate system (e.g. radiation budget, temperature, precipitation). It is therefore of utmost importance to obtain the best possible representation of clouds in climate models. The HIRHAM5 regional climate model was applied in a sensitivity study in order to investigate the influence of different parameters within the cloud scheme on the calculated cloud cover in the Arctic (Klaus, 2013). For this purpose the model was driven with data from the ERA-Interim global reanalysis of the European Centre for Medium-Range Weather Forecasts (ECMWF) and the results were compared to observation data from the MODIS satellite. Changes were made to a shape parameter that influences the calculation of the total cloud cover as well as a limit value for the formation of cloud ice that controls the Bergeron-Findeisen process of development of large droplets in clouds.

Fig. 1.1 shows the cloud cover over the modelling area of the Arctic for November 2007, firstly for the control run (original parameters), secondly for the sensitivity run (modified parameters) and finally for the observation data of the MODIS satellite. The sensitivity run displays a significantly reduced cloud cover in comparison to the control run, especially over the Arctic Ocean. The comparison with the satellite data demonstrates that this less pronounced cloud cover corresponds much better to observations.

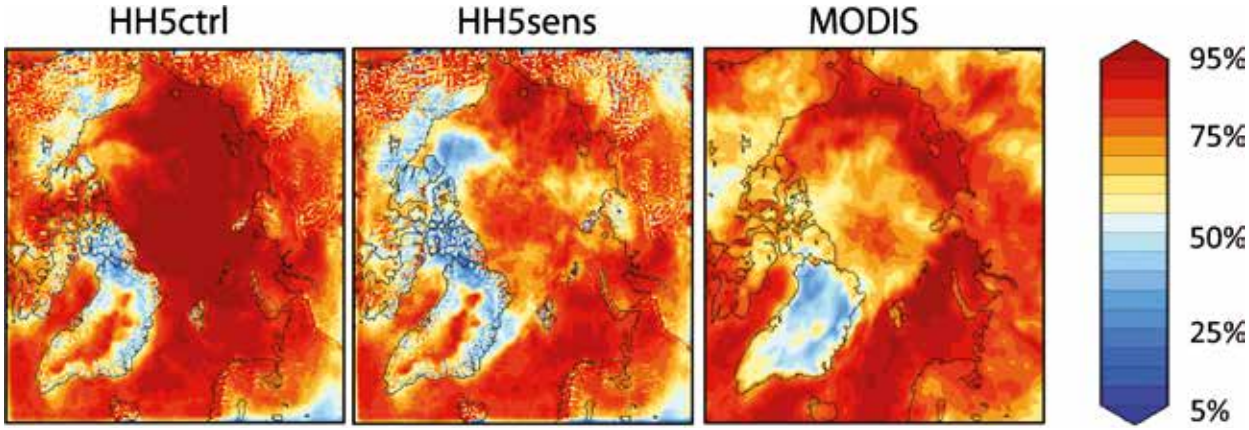

Fig. 1.1: Cloud cover over the Arctic for September 2007 from a control run (HH5ctrl), a sensitivity run (HH5sens) and observations (MODIS). (Graphics: Daniel Klaus, AWI)

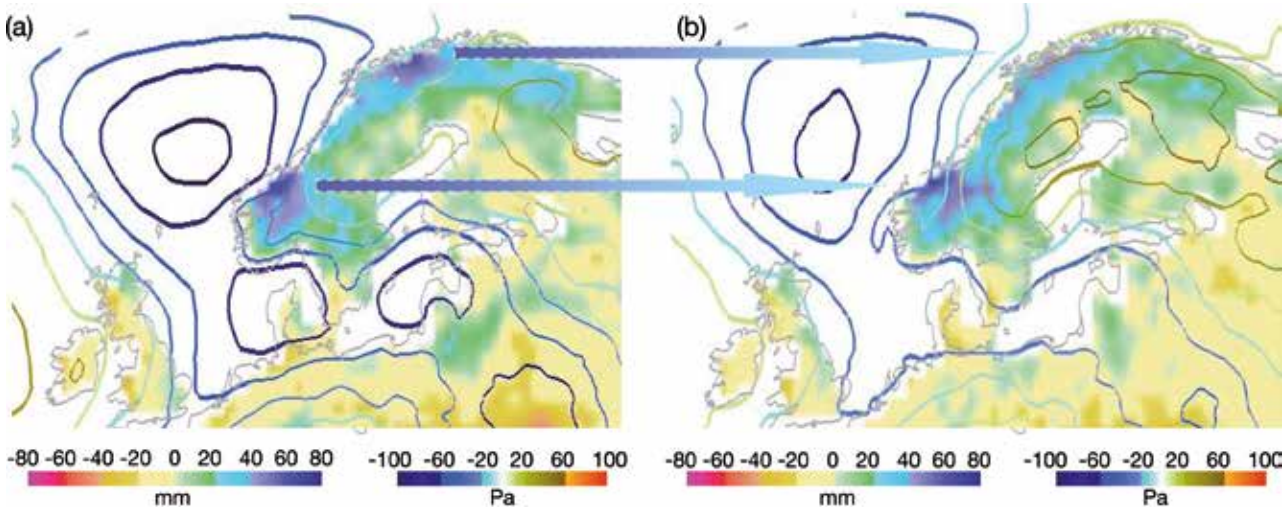

Fig. 1.2: Differences in precipitation (mm/month, colour coding) in comparison to reference data (WATCH) for CCLM (a) and COSTRICE (b). Differences in the reduced sea level pressure (Pa, contours) in comparison to reanalysis data (ERA-Interim). Both averaged over the summer 1998-2002. (Graphics: Ha Hagemann, HZG)

Atmosphere, ocean and sea ice feedbacks

COSTRICE (the model system consisting of the regional models for atmosphere (CCLM=COSMO-CLM), ocean (TRIMNP) and sea ice (CICE), as well as a coupler (OASIS) for the exchange between the model components) was updated with new model versions for atmosphere and ocean. A case study for the period 1997-2002 shows the influence of the coupled model system in comparison to independent calculations with the individual components. Differences are perceptible, e.g. in the amount of sea ice, the temperature and the sum of the heat fluxes on the ocean surface as well as in the precipitation over the bordering land areas. The pattern representation of the North Atlantic oscillation (NAO) is achieved better with COSTRICE than with the individual components. The reduced surface pressure at sea level calculated by the CCLM atmosphere model alone is too low for the North Atlantic, North Sea and Baltic Sea, which may explain the big difference in precipitation compared to reference data (Fig. 1.2a). This difference is reduced due to the feedbacks between atmosphere, ocean and sea ice in COSTRICE (Fig. 1.2b).

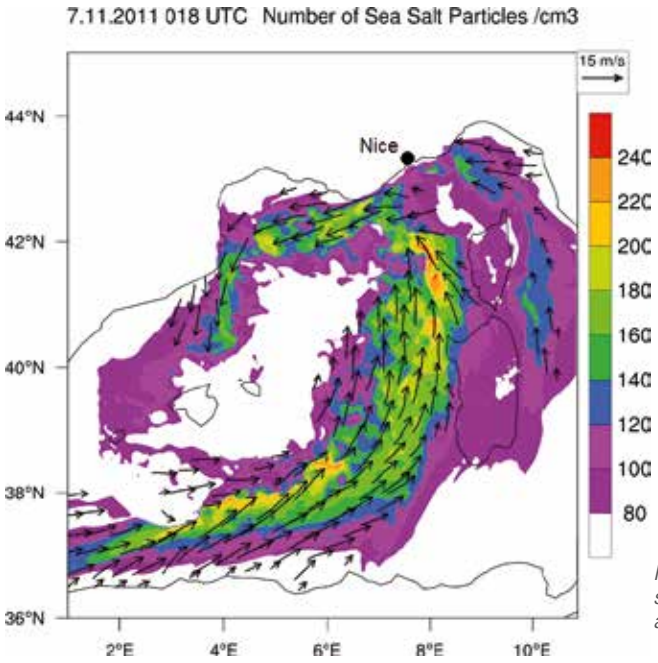

Fig. 1.3: Wind field (vector arrows) and numerical density of sea salt particles (colour coding) for 7 November 2011 at 20 m above sea level at 18:00 UTC. (Graphics: Isabel Kraut, KIT)

Influence of sea salt particles on the development of a medicane in November 2011

A medicane is a tropospheric low pressure area that can arise over the Mediterranean, usually in autumn. It is similar to a hurricane, thus the neologism of medicane from Mediterranean Sea and hurricane. A circular cloud-free eye is surrounded by a nearly symmetrical wall of clouds. The wind speed of a medicane rarely reaches the level of a real hurricane and also the physical dimensions are smaller. Nevertheless, medicanes cause considerable damage when they hit land due to extreme precipitation, flooding and high wind speeds. Every year up to two medicanes are observed in the Mediterranean region. A good forecast of such systems is therefore indispensable.

The higher the wind speeds over the sea surface, the more sea salt particles are emitted into the atmosphere. As a result of the high wind speeds produced by a medicane, a large number of sea salt particles enter the atmosphere, where they influence cloud formation and precipitation. The latter alter the heat balance due to scatter and absorption of radiation. Moreover, as cloud condensation nuclei they may influence the hydrological cycle and thus the physical properties of the cloud.

The COSMO-ART model system, which describes the interaction between aerosol particles and clouds, is used to determine this influence. A medicane that occurred in November 2011 is simulated, once with a description of sea salt emissions and once without. The additional treatment of sea salt leads to changes in total precipitation, particularly at coastal cities. Taking sea salt into account improves, for example, the precipitation forecast in Nice. Fig. 1.3 shows the simulated wind field and numerical density of sea salt particles for 7 November 2011 at 20 m above the sea level at 18:00 UTC.

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2 Sea-level changes and coastal protection

How large are the losses of the continental ice masses (particularly on Greenland) and how does the sea level react to melt water and ocean warming?

In terms of human perception, changes in the sea level are only of significance on a long time scale. That is why active coastal protection primarily targets avoidance of hazards resulting from flooding due to the tides or storm surges. Without active coastal protection in the form of dike construction an area of around 7,500 km² on the German North Sea coast with a population of 4.8 million people would be threatened by flooding twice a day. However, precisely because active coastal protection also involves high financial expenditures, long-term changes in the sea level are a significant parameter. According to current findings, this measured value amounts to 3.1 +/- 0.6 mm a year and experts reckon with a global mean rise in the sea level of 18 – 59 cm by the end of the century. Factors that change the sea level on long time scales include contributions of glacier and ice sheet melting as well as thermal expansion of the ocean due to warming. On a regional scale land uplift and subsidence as a consequence of tremendous shifts in land masses also have an impact, whether due to recent melting of the ice sheets or as a result of post-glacial relaxation processes in the deep Earth.

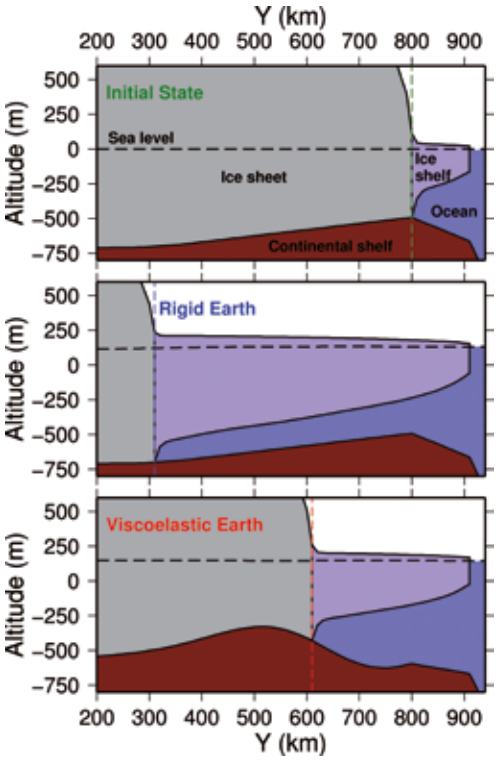

Fig. 2.1: Simulated influence of Earth deformation and change in sea level on the position of the grounding line. Top: initial state. Middle: no Earth deformation, only change in sea level (120 m, similar to after the last ice age). Bottom: Earth deformation and change in sea level. As can be seen, the loss in mass of the ice sheet due to the change in sea level (middle) for the case of deformable Earth leads to a land uplift that contributes to an earlier stabilisation of the grounding line (bottom). (Graphics: Hannes Konrad, GFZ)

Ice mass balance and global impacts

The interaction of the ice sheets with the sea level and the solid Earth are important factors for the ice mass balance and the stability of the inland ice. Variations in the ice thickness thus lead to a deformation of the Earth's surface and gravitational field, as a consequence of which the topography and sea level change relative to the coast. That, in turn, influences the position of the grounding line (i.e. the line as of which the grounded ice gets afloat) and thus the dynamic behaviour of the entire ice sheet. To study these interactions, a coupled model system was developed consisting of a thermo-mechanical ice sheet model (RIMBAY) created by AWI and a viscoelastic Earth model (VILMA) developed by GFZ. The model now makes it possible to consistently simulate the ice sheet and ice shelf dynamics as well as the viscoelastic deformation of the solid Earth, as it takes place primarily on a time scale of millennia. Another special feature of the model is its realistic description of local variations in sea level, as those caused by ground deformation and (gravitationally) self-consistent water redistribution induced by the gravitational field. For a simplified scenario of a rise in sea level – as that documented since approximately the last ice age – initial results indicate a great influence of the Earth's deformation on the position of the grounding line (Fig. 2.1). Aside from a rising sea level, the influence of other variables on the position of the grounding line and the mass balance was examined, such as the warming of the oceans and changes in frictional characteristics at the transition between ice and bedrock. In future, the coupled system will be applied to simulation of the last glacial cycle of the Antarctic Ice Sheet with the aim of gaining a better understanding of the influence of the sea level rise due to the northern hemisphere on the deglaciation history of the Antarctic.

Sea level changes, from the global scale …

Changes in the mass of the world's oceans are an important boundary condition for global ocean circulation models, though they can only be determined with a relatively large degree of uncertainty. With the help of the newly processed data from the GRACE satellite for the period 2003-2013 a time se-

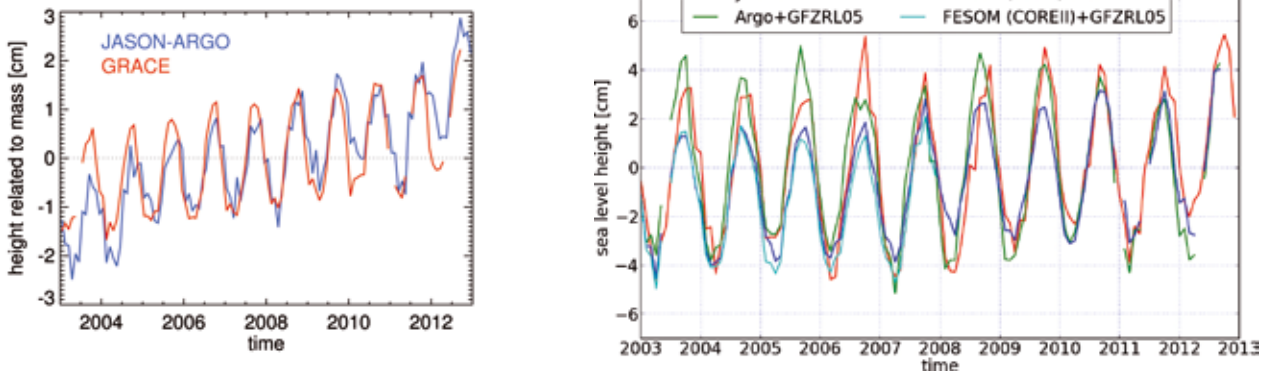

Fig. 2.2: a) Time series of the mass portion of the globally averaged change in sea level between 60°S and 60°N. Red: derived from GRACE satellite data (gravimetry); blue: from the difference of Jason-1/2 satellite data (altimetry) and temperature/salt concentration profiles of Argo floats. (Graphics: Saskia Esselborn, GFZ)
b) Time series of the change in sea level averaged over the North Atlantic. Red: derived from Jason-1/2 satellite data (altimetry); green: (steric) expansion calculated from temperature/salt concentration profiles of Argo floats; dark blue: model result with NCEP forcing; light blue: model result with CORE-II forcing. The last three curves were corrected with GRACE satellite data. (Graphics: Dmitry Sidorenko, AWI)

ries of the global sea level was estimated on the basis of global mass changes (Fig. 2.2a) and compared to combined height measurements of satellite altimeters (Jason-1 and Jason-2) and temperature/salt concentration profiles from Argo floats. Both time series of the mass equivalent sea level show a good concordance and a pronounced seasonal cycle with an amplitude of approx. 1 cm and maximum values in autumn in the Northern Hemisphere. The global trend is also in accordance since 2005 and amounts to approx. 2.5 mm/year. A comparison of these data to simulation results of the FESOM high-resolution finite element sea ice – ocean model, which was driven with NCEP and CORE-II reanalysis atmosphere data, displays a good concordance in the seasonal signal for the thermal expansion in the upper 1000 m in the North Atlantic as well as for the total mass change (simulated expansion plus bottom pressure data from GFZ), but a lower amplitude than the observations (Fig. 2.2b). We presume that the reason for this lies in the atmospheric forcing of the ocean model. Instead of the heat and momentum fluxes occurring in nature, quantities derived from measured temperature and wind data are used that do not exactly reflect the processes existing in nature.

... to the regional scale

By means of altimeter measurements (Jason-1/2), it is possible to monitor the global structure as well as regional changes in the water level. Fig. 2.3 shows the geographic distribution in the North Sea over the last 20 years. The reaction of the sea levels to local changes in air pressure was not eliminated in this process – as is otherwise customary – so as to depict the locally observed water levels. According to these investigations, the sea level in the North Sea has risen everywhere in the last 20 years, minimum values of over 1 mm/year can be found off the Scottish coast, maximum values of up to 4 mm/year in the area around the mouth of the Rhine.

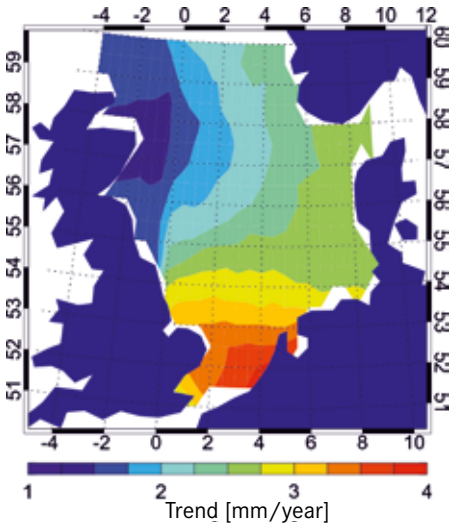

Fig. 2.3: Trend of sea level in the North Sea (April 1993 to December 2012) calculated on the basis of monthly averaged altimeter data. Land elevation and subsidence processes were not taken into account in this investigation. (Graphics: Saskia Esselborn, GFZ)

... to the local scale

Aside from high-frequency variability, the analyses of water level gauge data from the North Sea also show pronounced fluctuations with periods of years to decades. In REKLIM annual mean values for the sea level have been determined for the German Bight since 1924 on the basis of long sea level gauge time series by means of a principal component analysis. This reconstructed mean sea level corresponds well with the altimeter measurements of Topex and Jason-1/2 for the last 15 years (Fig. 2.4). The annual fluctuations of the sea level in the German Bight thus appear to be representative for the entire North Sea. The dominant pattern of the sea level (a north-south gradient over the entire North Sea) explains 80% of the total variability and the corresponding time series shows a very good concordance with the mean sea levels in the German Bight. These results indicate that it is possible to reconstruct the patterns of sea level variability in the North Sea during the last century using a combination of the sea level gauge and altimeter data so that long-term changes can thus be estimated and better assessed.

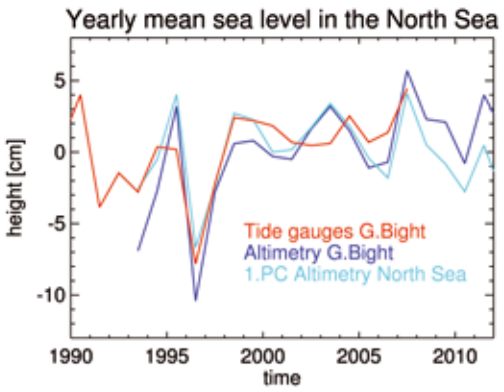

Fig. 2.4: Time series of annual mean of the sea level in the North Sea. Red: amplitude of the first main component from sea level gauge data; blue: mean from satellite altimeter data (Topex, Jason-1/2) for the German Bight in each case; turquoise: amplitude of the first principal component of the altimeter data for the entire North Sea. (Graphics: Frauke Albrechts, HZG; Saskia Esselborn, GFZ)

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3 Regional climate changes in the Arctic: Forcing and long-term effects at the land-ocean interface

What specific changes result for land, ocean, and atmosphere in the shelf sea and permafrost regions of the Arctic due to climate change and what interactions take place?

The focus of oceanic work in the past year was on multi-decade freshwater and sea ice changes in the entire Arctic. At the same time the focal point of the investigations on greenhouse gas fluxes on palaeo timescales shifted to the recent redistribution from submarine and terrestrial permafrost.

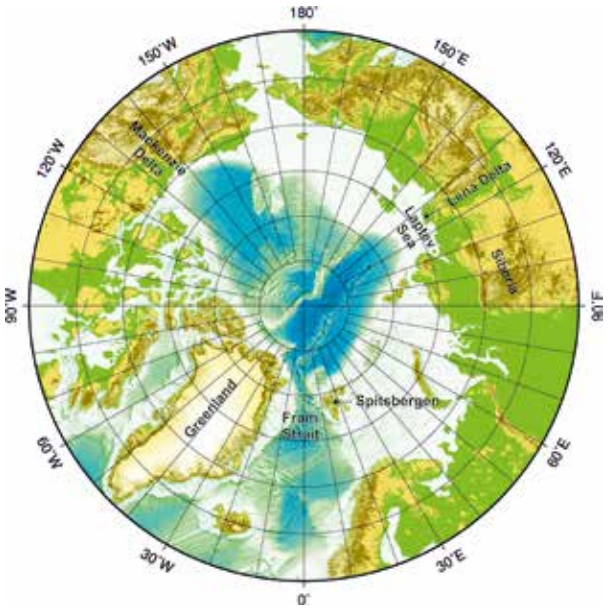

Fig. 3.1: Map with investigation areas designated in the text. (Graphics: Andreas Wisotzki, AWI)

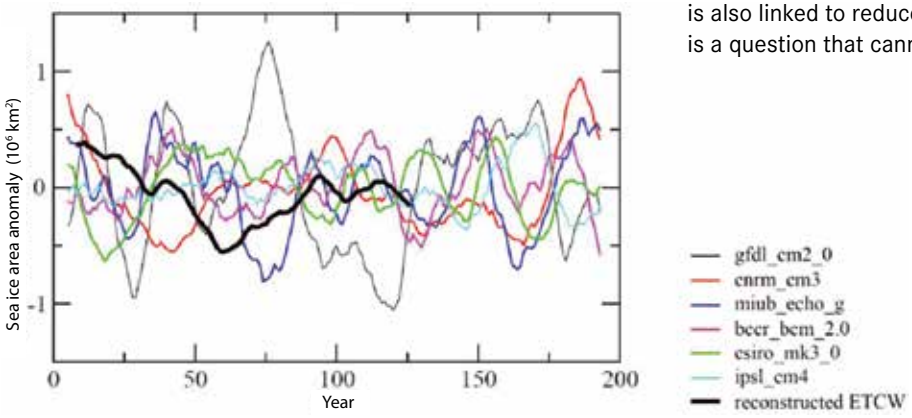

Fig. 3.2: Anomalies of the extent of Arctic sea ice (10^6 km^2) in winter simulated with several climate models (coloured lines) and reconstructed for the period 1880 to 2008 using observed atmospheric temperatures (thick black line). The minimum of the reconstructed anomaly coincides with the maximum temperature of the ETCW. The legend contains the names of the models used. (Graphics: Vladimir Semenov, GEOMAR)

Sea ice changes and ocean circulation

The extent of the Arctic sea ice cover in summer has declined by approx. 50% since the beginning of satellite measurements in 1979. What role do natural influences play, aside from the anthropogenic greenhouse effect? In this connection Semenov and Latif (2012) investigated the dynamics of the "early twentieth century warming", a pronounced warming between 1920 and 1940. The study shows that there must have been a substantial decline in the Arctic sea ice in winter at that time as well. The magnitude of the natural fluctuations was also estimated using climate models. According to the latter, internal fluctuations of the Arctic sea ice in winter may be of the same order of magnitude as the decline during the past decades (Fig. 3.2).

Freshwater from the Arctic may influence the large-scale circulation in the North Atlantic. For this reason a German-Norwegian cooperation has been examining the outflow of freshwater from the Arctic through the Fram Strait since 1998. The time series from measuring instruments anchored throughout the year between Greenland and Spitsbergen were complemented in some years by tracer measurements that permit identification of freshwater of varying origin (continental discharge, ice melt, Pacific inflow). Although a trend in southward transport of freshwater is not yet discernible (Fig. 3.3), data from six tracer recordings show considerable changes in the composition. Presumably they depict fluctuations in the circulation within the Arctic and not changes in the respective sources. Whether the decline in salt-enriched water from ice formation is also linked to reduced ice formation in the Arctic, however, is a question that cannot be answered yet.

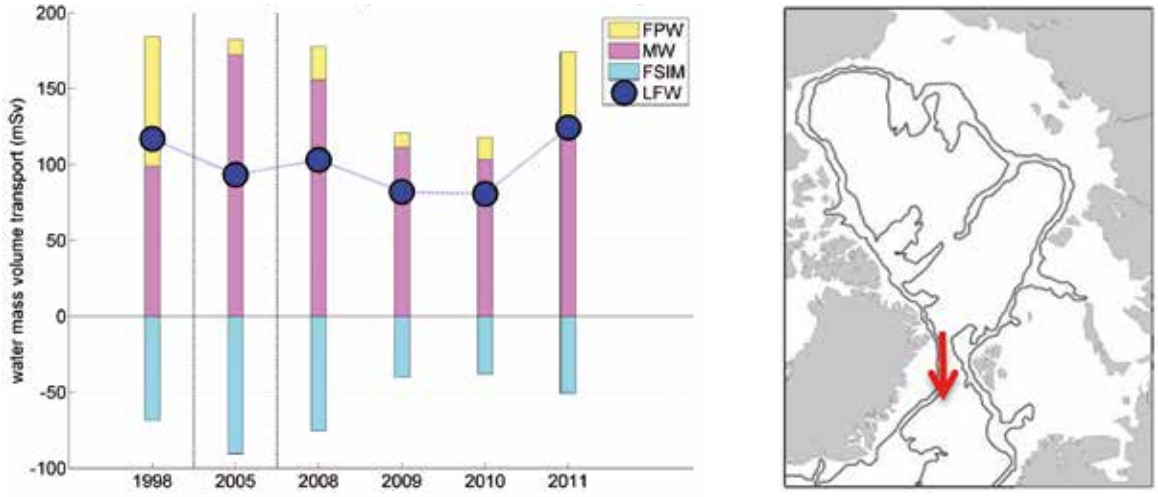

Fig. 3.3: Freshwater transport through the western Fram Strait (11°W to 4°E, red arrow) from temperature, salt concentration, tracer and direct velocity measurements during the respective exposure (positively to the south). Blue circles: total freshwater export relative to 34.9 salt concentration. Transport portions of meteoric water (MW: continental discharge and precipitation) in magenta, Pacific water (FPW) in yellow and net sea ice melt (FSIM) in turquoise. Negative sea ice melt water transport corresponds to southward transport of salt-enriched water from sea ice formation. (Graphics: Benjamin Rabe, AWI).

Climate, carbon, energy and water flows in permafrost landscapes – from local to national scales

A big unknown in feedback mechanisms between Arctic permafrost regions and the climate system is the amount of methane emitted into the atmosphere from permafrost and lakes. In summer 2012 heat, methane and CO_2 fluxes over permafrost in Alaska, Canada and Siberia were measured for the first time from an aircraft or helicopter (Fig. 3.4). The measurement data show a significant coupling to moisture fluxes and, correspondingly, high regional and temporal variability. The central Mackenzie Delta, for instance, emits many times more methane compared to adjoining areas. Long-term measurement fields for permafrost parameters in the Lena Delta and on Spitsbergen were extended and microbiological and geophysical experiments conducted.

Newly implemented operational remote sensing services provide extensive surface parameters of Arctic permafrost landscapes and thus improve, for example, the evaluation of models. The climate of the last decades was reconstructed for Siberia using a regional climate model. An initial comparison of the simulated snow cover with the satellite-derived data shows that the model reconstruction for Siberia supplies more realistic data than conventional reanalysis data records. In addition, the satellite data show in the shallow shelf sea turbidity distributions that indicate resuspension and thus intensive heat transport to the seafloor and the submarine permafrost.

Submarine and coastal permafrost and greenhouse gases on Arctic shelves

To study the submarine permafrost, sediment cores up to 40 m in length were drilled in the Laptev Sea. They are used to determine the variability of the ice content and the deposition environment that control the potential outgassing of methane on the Siberian shelf. The terrain and laboratory data, are incorporated in a model with which the degradation of the submarine permafrost since flooding of the Siberian shelf after the last ice age can be simulated.

Fig. 3.4: The helicopter towed sensor "Helipod" during measurement of turbulent heat and CO_2 fluxes over the Siberian Lena Delta. (Photo: Torsten Sachs, GFZ)

Prof. Dr. Ursula Schauer (AWI), Ursula.Schauer@awi.de | Dr. Torsten Sachs (GFZ), tsachs@gfz-potsdam.de

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4 The land surface in the climate system

What are the regional impacts of climate change on the ecosystem, water resources, agriculture and forestry and how do these in turn affect the climate?

Impacts of climate change on greenhouse gas exchange of grassland soils in the Alpine region

Soils used for grassland represent significant carbon (C) and nitrogen (N) sinks and are currently subject to significant climate warming in the Alpine region. It is not yet known whether this climate change mobilises the C and N sinks of grassland soils such that these elements enter the atmosphere as greenhouse gases. For this reason the Karlsruhe Institute of Technology's Institute of Meteorology Climate Research – Atmospheric Environmental Research (KIT IMK-IFU) set up a field experiment that records the climate-induced change in the source and sink strength of the greenhouse gases carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). For this purpose grassland soil cores (2.5 – 3.5 t) were moved along a naturally existing elevation gradient from higher to lower, warmer sites and thus exposed to the climate conditions expected for the coming decades. In the first year greenhouse gas measurements by means of manual and automatic chambers (Fig. 4.1) showed a significant increase in pedogenic CH_4 uptake under future climate conditions. Likewise soil respiration was stimulated, but the differences between the control and climate change variant were substantially less. The N_2O emissions under climate change conditions were slightly higher only in spring and summer whereas the annual total overall remained less than those of the control variant (Fig. 4.2). This is attributable to more frequent and intensive frost-thaw events under current climate conditions. A preliminary study with smaller soil cores also resulted in moderate changes in the greenhouse gas exchange of grassland soils in the first year. However, a significant decline in the soil C and N concentrations was observed after three years under climate change conditions. Hence, the in-situ climate change experiment on the greenhouse gas exchange of grassland soils now enters its „final phase".

Fig. 4.1: Automatic greenhouse gas measuring system at TERENO location in Rottenbuch. (Photo: Ralf Kiese, KIT IMK-IFU)

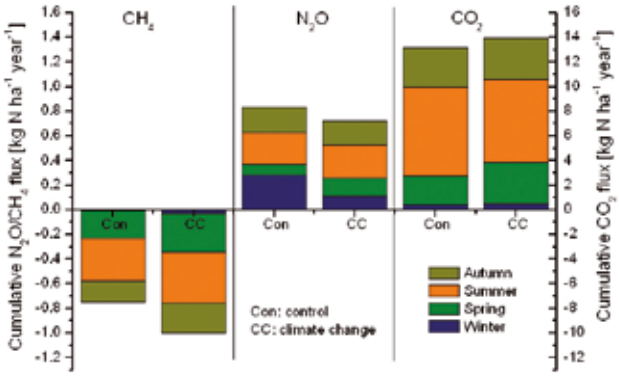

Fig. 4.2: Comparison of seasonal and annual greenhouse gas fluxes from grassland soils under normal and forecast climate conditions. (Graphics: Ralf Kiese, KIT IMK-IFU)

Coupled modelling of vegetation-atmosphere interactions with WRF / Expert-N

The influence of the vegetation description in land surface models plays a major role in regional weather and climate simulations. The ecosystem model Expert-N was coupled to the regional weather and climate model WRF. It contains various submodels for soil processes (water and nutrient transport and/or exchange) and plant growth (agricultural crops, grassland and forest) and can be combined to form a complete soil-crop model. Expert-N was extended in such a way that it is possible to model large-scale plant growth.

Fluxes of latent and sensible heat as well as the atmospheric backward radiation play an important role in connection with coupling. If these factors change, that has impacts on the thermodynamic parameters of the weather model. The simulated plant growth is influenced by the feedback of these changes on the plant growth model (Fig. 4.3). Thanks to the improved mechanistic representation of the plant growth processes, it is possible to achieve a more precise forecast of plant growth and the weather and climate if this higher model complexity leads to more realistic simulations of the leaf area index.

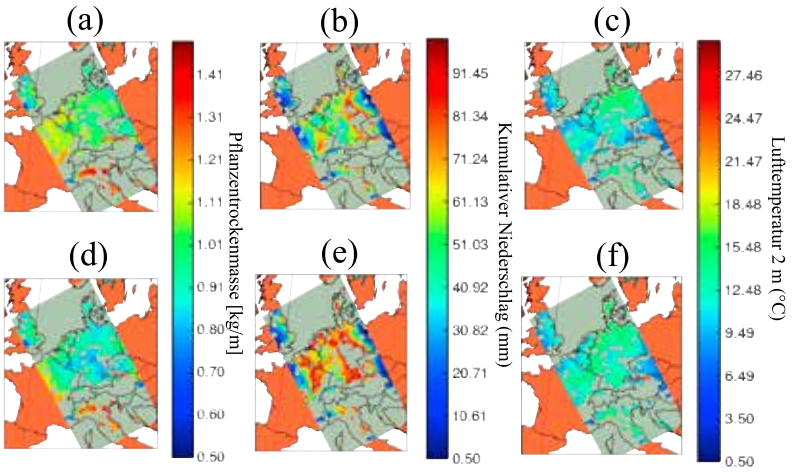

Fig. 4.3: Influence of type of feedback on biomass growth of grassland (illustrations a, d), the cumulative precipitation amounts (illustrations b, e) and the temperatures (illustrations c, f) in September 2010. Illustrations a-c show results of simulations without feedback and illustrations d-f with feedback of the matter fluxes between the land surface model (Expert-N) and the weather model (WRF). (Graphics: Christian Klein, HMGU)

Cultivation of the agricultural areas, which can be depicted well, particularly with mechanistic plant models, has an additional influence on the leaf area index and/or the fluxes.

The influence of soil hydraulic properties on the modelling of land surfaces

To be able to generally model the soil water transport, the hydraulic properties of the soil have to be known. In reality this is unfortunately not the case. However, the soil texture, such as sand and clay content, is monitored routinely by state authorities. For this reason so-called pedo-transfer functions (PTF) are used to determine soil hydraulic properties based on the soil texture. Investigations examined how uncertainties in the PTFs are transferred to uncertainties in predicted hydrological states, such as soil moisture and river runoff (Fig. 4.4). It was shown that observation errors contribute the least to the uncertainties of the water retention curve. Errors in the determination of the soil texture properties, on the other hand, contribute most to the uncertainty. Finally, the representativeness of the chosen calibration data set provides average uncertainty in the water retention curves.

The next step involved an examination of how given uncertainties manifest themselves in prognostic variables of a distributed hydrological model (Fig. 4.5). The river runoff of ground water reacts very insensitively to uncertainties in PTFs while the results in soil moisture depend to a very considerable and nonlinear extent on parameter variations. While the errors in the determination of soil textural properties have the greatest impact on the water retention curves, they largely average out in the hydrological model and thus lead to only minor uncertainties in the model results. However, this is only the case when the errors are distributed randomly in the texture description. In most of the texture data sets important information like soil density is lacking. Different methods for estimating the soil density therefore result in substantial uncertainties, especially for saturated soil moisture conditions. The influence is then just as large as the uncertainty based on the representativeness of the calibration data set.

For this reason knowledge of the soil properties is pivotal for modeling land surfaces. Parameter uncertainties in PTFs influence the soil moisture estimates used, e.g. in analyses of seasonal drought. However, the uncertainties are assessable in the framework of modelling. Our study was able to show that the quality of the input parameters of soil texture properties determines the uncertainty of the output values to the same magnitude. This error is inevitable when modelling and must therefore be determined beforehand and included in the calculated uncertainty of the results.

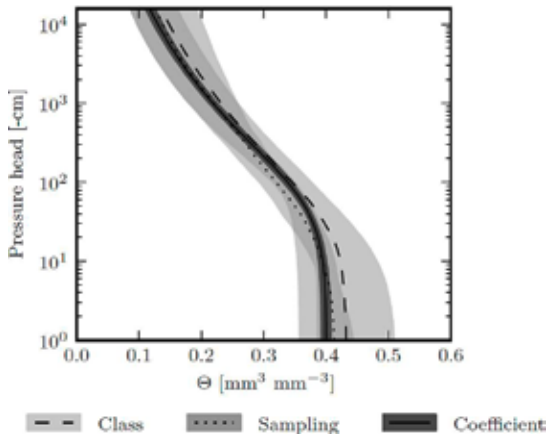

Fig. 4.4: Uncertainty range of water retention curves for three uncertainties for one German soil class: "coefficient" is the uncertainty based on observation errors, "sampling" is the uncertainty based on inadequate representativeness of the calibration data set and "class" is the variation within the soil class. Lines show the medians. (Graphics: Maren Göhler, UFZ)

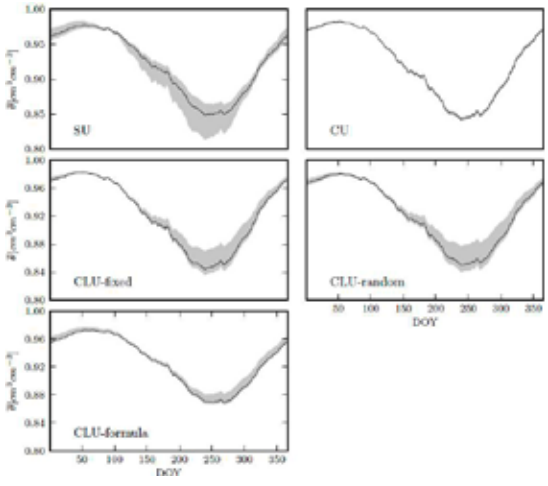

Fig. 4.5: Average soil moisture variability of the catchment area for five different uncertainty cases: SU: representativeness error, CU: observation error, CLU: error in soil textural properties, CLU-fixed indicates a fixed specified density for each German soil class, CLU-random indicates a random value from an observation-based range and CLU-formula calculates the soil density by means of a regression analysis from natural soils. Shaded areas indicate a range between the highest and lowest estimate, lines indicate the median. (Graphics: Maren Göhler, UFZ)

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5 Chemistry-climate interactions on global to regional scales

How is the regional climate affected by changes to the atmospheric composition?

The scientists involved in this topic examine the influence of chemical processes in the atmosphere on the climate system and contribute to the development of coupled chemistry-climate models, which then enable a refined study of regional climate change. The work carried out last year covers a broad spectrum, ranging from the evaluation of satellite measurements to investigation of natural suspended particles right through to improvement of trace gas transport in the tropopause region (boundary between the lower atmospheric region, the troposphere, and the stratosphere lying above that) and studies of the influence of solar variability on the climate system.

Use of satellite data

A case study on the devastating forest fires in southeast Australia in February 2009 showed on the basis of data from the MIPAS satellite instrument that trace gases like hydrocyanic acid, that were emitted by the fires there, reached into the stratosphere and spread globally (Fig. 5.1). Such fires represent a challenge to modelling efforts since both, the intensity of the emissions and the effective altitude at which the emissions enter the atmosphere cannot be determined accurately. In addition, fire emissions are extremely variable and this variability also has to be taken into account in chemistry-climate simulations.

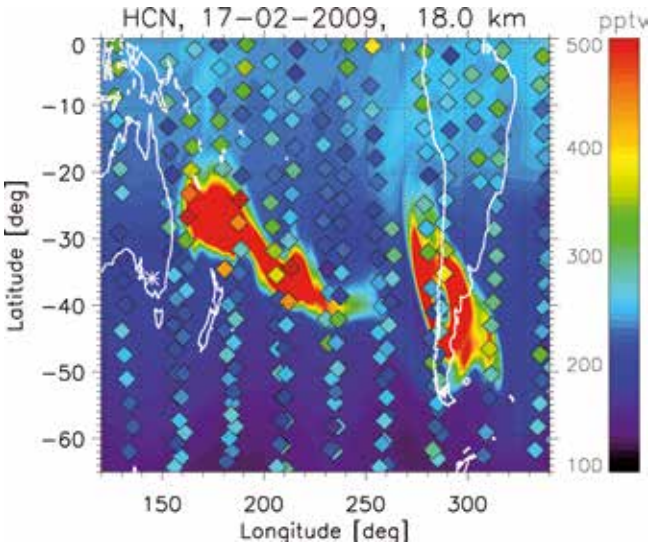

Fig. 5.1: Concentration distribution of hydrocyanic acid from fires in southeast Australia at a height of 18 km (i.e. in the stratosphere) in February 2009. The diamonds represent the MIPAS observations while the coloured areas in the background are model calculations with the GEM-AQ model. (Source: Glatthor et al., 2013)

Other studies utilise the GPS-based radio occultation method. For the first time it was possible to determine realistic horizontal wavelengths and pulse fluxes of gravity waves with radio occultation data from the COSMIC mission on a global scale (Faber et al., 2013). In more recent investigations on temperature variability in the tropical UTLS (region between upper troposphere and lower stratosphere) from combined radio occultation between 2001 and 2013 the already described temperature trend manifests itself in the tropics at an altitude between 17 and 22 km (REKLIM Newsletter no. 2, p. 13, 2012). Currently, work is in progress on verifying and explaining this trend pattern by means of other data records.

Climate impact of aerosols

Based on laboratory investigations at the large AIDA atmospheric simulation chamber, new model parameterisations have been developed that describes the ice formation characteristics of biological aerosols (such as spores, pollen and bacteria). Such studies show that some bacteria in particular form good nucleation seeds while other biological particles are worse ice formers than dust. Application of this parameterisation in the COSMO-ART regional model, however, shows that the biological particles are present at cloud altitude only in low concentrations and, therefore, their influence on ice formation in clouds is minor.

Furthermore, REKLIM scientists collaborated on a large-scale study on the influence of soot particles on the climate (Bond et al., 2013) and investigated the influence of aerosols on the Asia summer monsoon (Fadnavis et al., 2013).

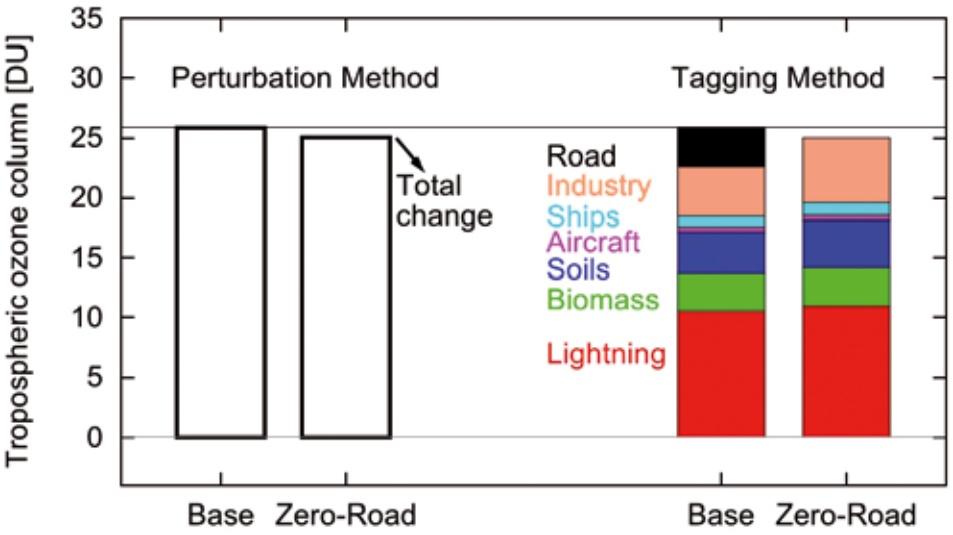

Fig. 5.2: Tropospheric ozone column in Dobson units (DU) for a reference simulation (base) as well as a simulation without road traffic emissions (zero road). Results of the perturbation method are shown on the left and those by means of the tagging method on the right. (Source: Grewe et al., 2012)

Influence of road traffic on air quality and climate in Europe

Road traffic is a major source of nitrogen oxides, carbon monoxide and hydrocarbons, compounds that in summer lead to the formation of ozone, which in turn has a toxic effect on living organisms and plants and is additionally a greenhouse gas. The influence of road traffic on the air quality and climate in Europe is the subject of a study conducted within the scope of a DLR project on the basis of calculations with the MECO(n) model system (Kerkweg and Jöckel, 2012), which can be used from the global scale all the way to resolutions of a few kilometres.

On the basis of specially marked model species ("tagging" method), the reaction pathways of the chemical species are retraced from different sources without disturbing the system, as would be the case with sensitivity calculations with altered emissions. Fig. 5.2 shows a comparison of the two methods by Grewe et al. (2012) that underlines the advantages of the tagging method for the project. The results from the perturbation method (left) would indicate that the contribution of road traffic to the ozone concentration of the troposphere is rather small. If one uses the tagging method (right), however, it is clearly perceptible that the contribution of road traffic is significantly greater. This misinterpretation can be attributed to an increase in the efficiency of ozone production from the other sources if the emissions from road traffic are not present. However, this nonlinearity is not taken into account in the perturbation method.

Transport in the tropopause region

The upper troposphere is of special importance for climate change since greenhouse gases have a considerable influence on the radiation balance of the atmosphere there. Accordingly it is important to accurately represent the transport processes of trace gases, particularly in this region characterised by great concentration differences. Conventional climate models, especially with a relatively coarse resolution, tend to put the trace gases from the troposphere (this also includes water vapour) into the lower stratosphere too quickly. By using another transport scheme, it is possible to avoid this effect (Fig. 5.3).

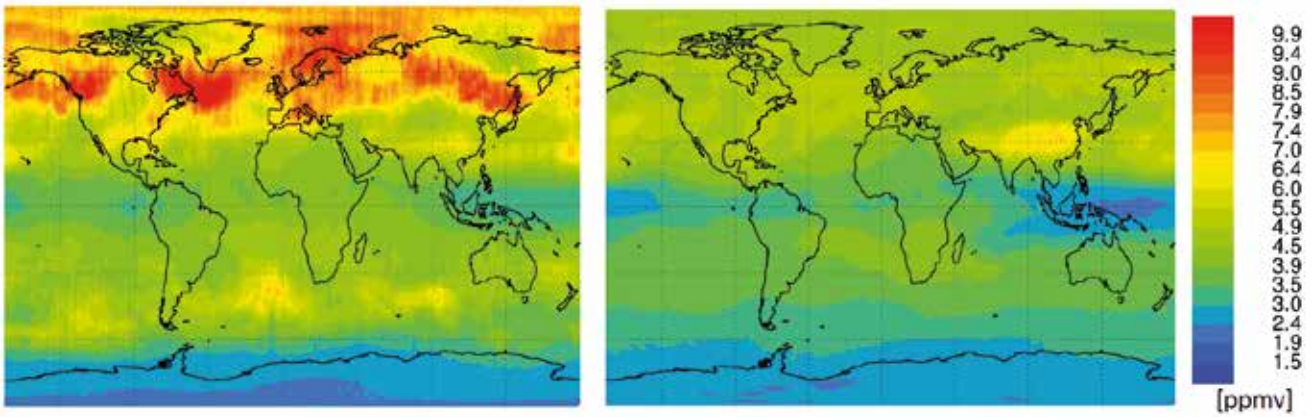

Fig. 5.3: Model simulations of water vapour in the lower stratosphere with two different transport schemes: On the left the results from EMAC with the classic semi-Lagrange scheme, on the right the results with the new coupled trajectory model EMAC-CLaMS. While the water vapour in the classic model is considerably overestimated in the summer hemisphere, initial results of the new model system show lower values here. (Source: Charlotte Hoppe, KIT)

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6 Extreme weather events - storms, heavy precipitation, floods and droughts

How will the severity and frequency of extreme weather events change in a future climate?

In the past years there have occurred in Germany and worldwide a large number of natural disasters that involved substantial amounts of damage and loss of human life. Hurricane Sandy, for instance, led to damage amounting to nearly US$100 billion in October/November 2012. In Germany the consequences of the June flood in 2013 were even more severe than those of the flood of the century in 2002. Although these examples are only singular events, the question arises as to whether and in what way such disasters are influenced by anthropogenically induced climate change as well as by societal and socio-economic changes. Work in connection with Topic 6 encompasses different analyses with regard to meteorological extreme events, such as tropical cyclones, heavy precipitation and related floods as well as hailstorms.

Tropical cyclones over the Northwest Pacific and South East Asia in a regional climate simulation

Powerful typhoons influence the subtropics and their residents in the western Pacific to a greater and greater extent. For the Northwest Pacific, however, several observation data sets ('best track data') of various meteorological institutes show great differences in the trends of tropical cyclone activity for the past decades. Regional atmospheric climate models represent an alternative to observations in this context. They refine global gridded weather data (reanalyses) and thus produce the most homogeneous data records possible.

In this way it is possible to determine changes in the number and intensity of tropical cyclones for the past decades more reliably.

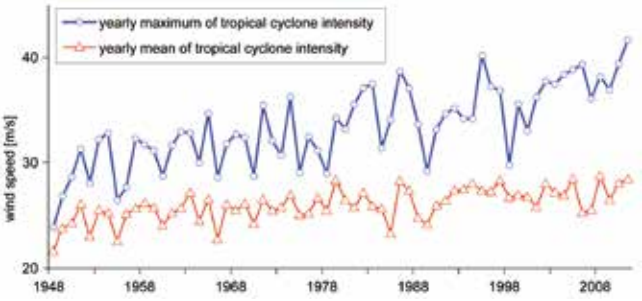

Fig. 6.1: Annual maximum and mean values of the tropical cyclone intensity of all tropical cyclones followed in the CCLM regional model. The intensity is shown as maximum wind speed near the ground. The X axis shows the time in years. (Graphics: Monika Barcikowska, HZG)

The variability of severe tropical cyclones in the regional model shows good concordance with observations, both interannually and for periods of decades. The annual number of days on which tropical cyclones occurred increased between 1948 and 2001. In the last decade, however, there was also a brief decline. In the South China Sea there is an increasing trend, though it is mainly attributable to the rise in weaker storms. In the southeastern section of the Northwest Pacific a declining trend in tropical cyclone activity is emerging. Overall the regional model run describes an increase in terms of number and intensity (Fig. 6.1) and a northwest shift in the paths of tropical cyclones for roughly the last 60 years. This, too, is confirmed by very recent observation data.

The role of hydraulic engineering and climate in flood trends on the Rhine

Depending on the period examined, a clear, in some cases statistically significant increase in flood discharge can be noted at water level gauges along the Rhine. For example, the discharge time series measured at the Worms water level gauge shows a significant relative change in flood discharges from a few percent to as much as 100% in relation to the mean value in the respective period (Fig. 6.2 A). At the German Research Centre for Geosciences (GFZ) scientists looked into the question of which factors primarily determine the discharge trends: climate variability or hydraulic engineering measures, such as channelisation of the main stream of the Rhine in the course of construction of hydraulic power stations on the Upper Rhine in the period from 1955 to 1977, as well as expansion of flood retention areas. By means of model-based homogenisation of flood discharges, analyses were conducted at the German Federal Institute of Hydrology (BfG) enabling reconstruction of discharges without hydraulic engineering measures on the Rhine after 1955. This showed that the relative changes in flood trends would have been up to 25% less (Fig. 6.2 B). That corresponds to the share of the hydraulic engineering measures in the flood increase. The remaining increase signal, adjusted for the influence of the hydraulic engineering measures, appears to be extensive and indicates a large-scale driver, such as climate variability or climate change.

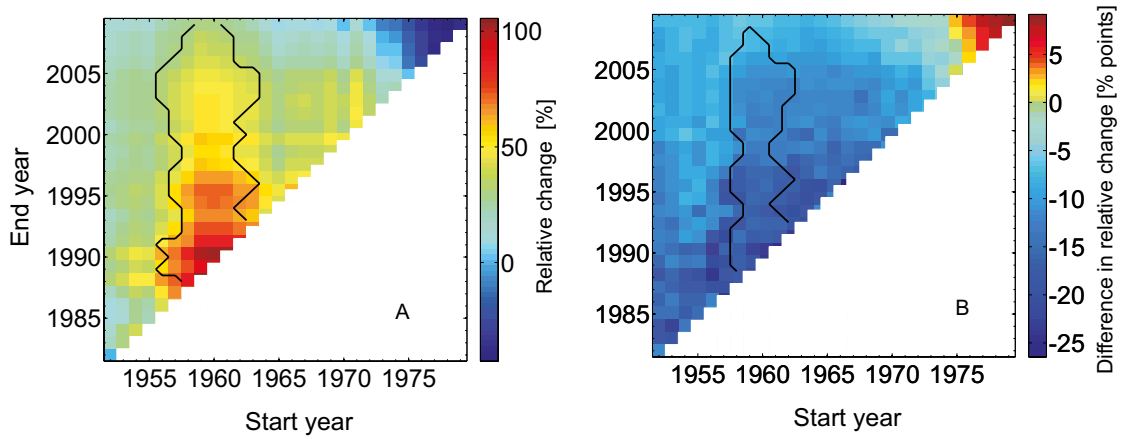

Fig. 6.2: (A) Trend analyses of measured flood discharges for various periods (different starting and end point in the time series) at the Worms water level gauge, characterised by the relative change in discharge in relation to the mean value in the respective period. (B) Difference between relative flood discharge changes in measured and homogenised time series. Black contour lines show statistically significant changes (5% significance level). (Graphics: Sergiy Vorogushyn, Bruno Merz, GFZ)

Meteorological extreme events in regional climate models

A study at the Helmholtz Centre for Environmental Research (UFZ) examined the extent to which RCMs are able to represent observed extremes. For this purpose extreme temperature and precipitation indices were calculated for twelve RCMs of the ENSEMBLE project for the period from 1960-2000 and compared to those from observations (relative deviations from -40% to +40%). In addition, scientists looked at the extent to which an ensemble of several models is able to represent the observed indices better than individual models. The percentage share of the significant indices was selected as the criterion. In this case the percentage "R" of indices that display a significant difference from the observations was defined at each grid cell and then the spatial mean of "R" was formed ("mean R" in Fig. 6.3). The analysis shows that combinations of five or six models display a lower "mean R" compared to the ensemble of all models and can be found through suitable selection methods. One method initially selects the best combination of two models and adds another model step by step (forward elimination). Another method begins with the combination of all models and removes a model step by step (backward elimination). These results illustrate that even the best possible combination (E5 in Fig. 6.3, bottom) still shows significant deviations, especially in the mountainous regions of Germany.

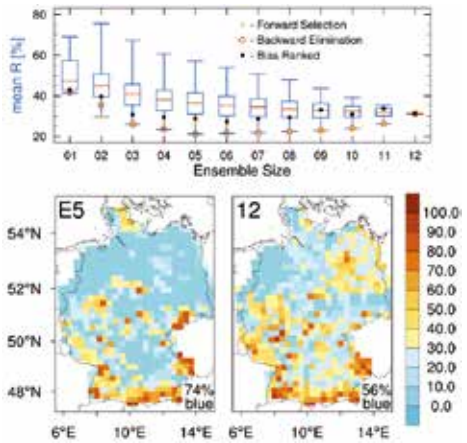

Fig. 6.3: Top: Variability of mean percentage of significant extreme indices (5% significance level) depending on ensemble size (box plots). Furthermore, the "mean R" of the combinations found using different selection methods is shown. Bottom: Spatial variability of the percentage of extreme indices for the best combination of five models that was selected through backward elimination (E5) as well as the ensemble of all models (12). (Graphics: Stephan Thober, UFZ)

Development and application of a logistic hail model

To statistically analyse the temporal variability of hailstorms that are recorded inadequately via operational measurements, scientists at the KIT developed a logistic hail model (multivariate analytical method). In this model approach different meteorological parameters relevant for convection (e.g. convection energy, moisture content, large-scale weather conditions) are combined with one another in a suitable manner. The result is a new index that describes the potential of the atmosphere for formation of hail and is therefore designated as the potential hail index (PHI) (Fig. 6.4). Based on regionalised ERA-40 reanalyses, the PHI shows for Germany a clearly defined north-south gradient with maximum values in the south in the past. On the basis of regression analyses of the PHI, it was thus possible for the first time to show that the hail potential of the atmosphere increased considerably between 1971 and 2000. Applied to an ensemble of seven RCMs, it becomes evident that the potential for hail events will rise slightly in the future. This applies in particular to northwest (excluding the North Sea) and southern Germany.

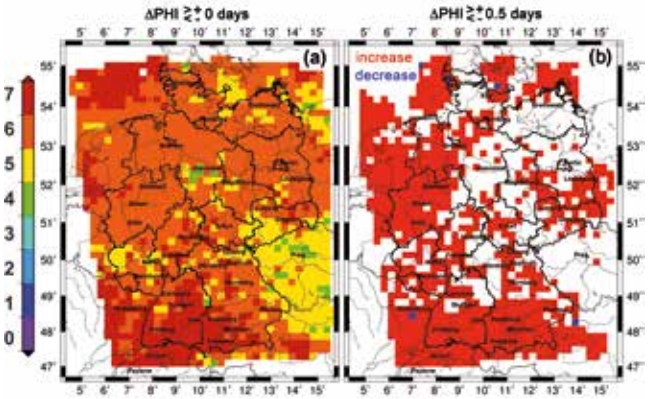

Fig. 6.4: Summary depiction of change in potential hail index PHI between 2021-2050 and 1971-2000 on the basis of an ensemble of seven regional climate simulations: a) number of runs that show an increase, b) only increase or decrease, where red signifies that 5 to 7 models show an increase or 0 to 2 models show a decrease (blue inverse). Here only changes greater than 0.5 PHI in the respective regional run were taken into account. (Graphics: Susanna Mohr und Michael Kunz, 2013)

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7 Socio-economics and management for regional climate change adaptation and mitigation strategies

Integrated climate policies comprise the mitigation of greenhouse gas emissions and adaptation to climate change. Is there an optimal route to be taken?

Topic 7 examines questions relating to integrated climate policy in the framework of continuous scientific support and analysis of climate policy negotiations at the international level. Based on the insights resulting from this, two especially urgent research matters were identified and investigated in depth. Firstly, there is a need to critically question the climate financing instruments decided on within the scope of COP 17 (Durban) and COP 18 (Doha) for supporting developing countries with respect to stimulus effects and the ability to provide funds on a long-term basis. Secondly, it is necessary to examine whether the current trend towards prioritisation of adaptation policy measures meets the guiding principle of an optimal climate policy strategy mix.

Climate fund in post-Kyoto process – does the type of financing play a role?

The most recent UN climate conferences paved the way for a new architecture of international climate finance. The latter encompasses instruments for financial support of climate policy measures in developing countries through industrial nations, which essentially appropriate the funds provided for four different purposes. The instruments are thus geared to compensation of the adaptation, mitigation, potential or actual damage costs of the developing countries.

Up to now discussion has been restricted predominantly to the amount of the transfer payments. However, in view of the fact that binding payment pledges are still lacking, it is of essential importance to analyse the economic incentives of the various types of financing. Finally, financing takes place on a voluntary basis so the countries will only be willing to make an effective commitment if they place themselves in a better position by doing so.

Against this backdrop, the Helmholtz Centre for Environmental Research (UFZ) in Leipzig in cooperation with the European University Viadrina in Frankfurt (Oder) examined the four financing approaches for minimal prerequisites for improving the position of donor and recipient countries in the framework of a game theory analysis – see Fig. 7.1 for the model framework. To ensure that improvement in fact comes about, the instruments have to create incentives for enhancing the global mitigation performance through skilful coupling of the transfer payments of the donor countries to certain services in return on the part of the recipient countries (e.g. greater adaptation or mitigation efforts), especially since it is generally acknowledged that this mitigation performance is inadequate in terms of efficiency aspects in the current situation without worldwide climate protection conventions. In addition, the recipient countries in particular have to be induced to make a greater contribution to mitigation as a global public asset. Otherwise the donor countries do not receive anything in return for their transfer payment, thus ruling out the possibility of improving their position through their financial commitment.

The analysis shows that the financing approaches, which are geared to compensation for the damage costs actually incurred and/or the adaptation costs, do not meet the minimal prerequisite for financing contributions and thus are not able

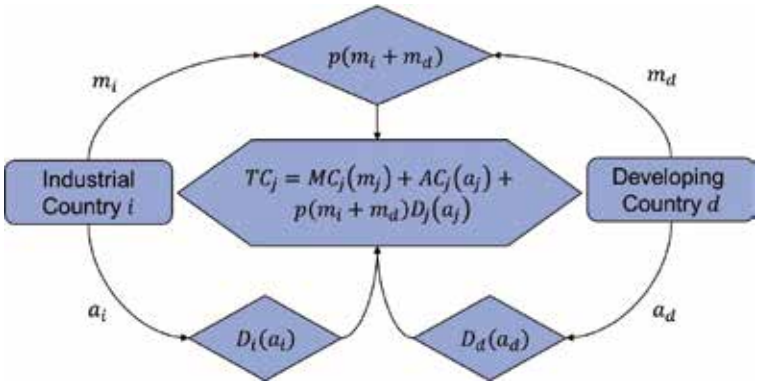

Fig. 7.1 : Game theory model framework (climate financing): Two countries, j=i (industrial country) and j=d (developing country), can counter climate change through mitigation (m_j) or adaptation efforts (a_j). Both strategies involve costs ($MC_j(mj)$ or $AC_j(a_j)$. From the viewpoint of the countries mitigation is a global public asset that diminishes the global probability of damage induced by climate change $p(m_j+m_d)$. On the other hand, the benefit of adaptation is purely of a private nature, i.e. the adaptation efforts of a country solely reduce its damage costs $D_j(a_j)$, but not those of the neighbouring country. The two countries have risk-neutral preferences and thus minimise their national total costs TC_j in the non-cooperative case relevant for the post-Kyoto process. These total costs consist of mitigation, adaptation and expected damage costs. Since emissions are essential for any economic activity, they – and thus mitigation necessarily as well – are specified in the first stage of the game, i.e. before the adaptation effort (second stage of the game). The relevant solution concept is thus the perfect balance in each part of the game. (Graphics: UFZ)

Fig. 7.2: The nuclear power phase-out and decarbonisation of energy production in Germany involve immense (investment) costs. On the one hand, an enormous expansion of energy production facilities is necessary. On the other hand, the power grid has to be adapted to the altered requirements. Thus, expansion of the transmission network, for example, ensures that power primarily generated by means of wind power in the North can be transported to the large consumption centres in the western and southern regions of Germany. (Photo: picture-alliance, ZB)

to guarantee long-term provision of funds. Accordingly, these approaches should be disregarded in future financing negotiations. By contrast, instruments that address the mitigation costs and/or the potential damage costs of the developing countries with regard to climate impacts, such as the NAMA (financing) programme of the UNFCCC (Nationally Appropriate Mitigation Actions) or the fund of the GEF (Global Environmental Facility), are fundamentally suitable for sustained climate financing.

The (optimal) climate policy mix and the strategic importance of climate protection investments and adaptation measures

The option of adaptation to climate change is in the process of pushing climate protection efforts further and further into the background. One of the main reasons for this shift of priority is the view that adaptation represents a significantly more cost-effective option in the climate policy strategy mix than mitigation. This impression is substantiated by the experience with the German energy transition. Here it becomes evident that an ambitious climate protection policy requires massive investments in infrastructure.

Such an orientation of the climate policy strategy mix predominantly to the cost effects of the two options is inadequate, however. Prioritisation of the adaptation option as well as the need for investment mentioned above hold considerable strategic implications with respect to global mitigation efforts that have been extensively ignored thus far in both, the political and the scientific debate. In a game theory model framework designed for this purpose the UFZ in cooperation with the European University Viadrina examined what impacts it would have if these two aspects were taken into account (see Fig. 7.3).

The analysis shows that prioritisation of adaptation measures indicates less readiness on the part of countries to contribute to mitigation as a global public asset and thus inhibits global climate protection efforts. The climate protection investments that have to be made a priori have a similar impact. From the point of view of global efficiency the individual countries deliberately invest too little so as to credibly commit themselves to lower climate protection contributions.

Against this backdrop, the current trend is to assess prioritisation of adaptation critically. To avoid unforeseeable and irreversible damage due to climate change, it is urgently necessary to focus on a balanced climate policy mix that is primarily geared to ambitious climate protection efforts and additionally provides for adaptation measures to cushion inevitable negative impacts of climate change. Only in this way will it be possible to prevent the strategic behaviour of countries from ending in a downward spiral towards less and less mitigation action.

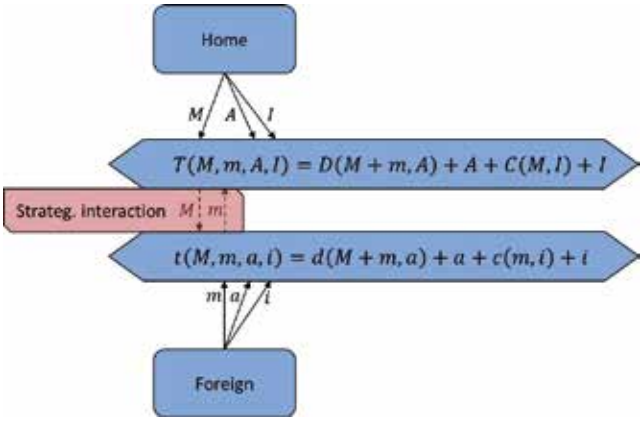

Fig. 7.3: Game theory model framework (climate policy strategy mix): Two countries, domestic (variables and functions in capital letters) and foreign (small letters), can counter climate change through mitigation or adaptation to an extent M, m or A, a. Due to the heterogeneity of the adaptation, A, a both designate the adaptation costs of the respective country. The mitigation costs are depicted by the functions C(M, I) and c(m, i). They can be reduced through investments in mitigation technologies I, i. Based on similar reasons to adaptation, I, i both designate the investment costs. The mitigation activity of each country is a global public asset, i.e. it not only reduces the damage costs of the country itself, but also those of the neighbour and thus provides scope for strategic interaction. By contrast, the damage-reducing effect of adaptation is purely of a private or national nature. Thus, the damage cost functions of the countries are represented as D(M+m, A), d(M+m, a). In the non-cooperative setting on which the current climate policy process is based, both countries minimise their total national costs T(M, m, A, I), t(M, m, a, i), which are composed of damage, adaptation, mitigation and investment costs. Regarding the decision sequence, it must be pointed out that the countries specify the investments in a first step because of the long lead time. Then, the mitigation level is defined before the adaptation level, or vice versa. The relevant solution concept is the perfect balance in each part of the game. (Graphics: UFZ)

AWI | GEOMAR | GFZ | HZG | UHB | UHD | UHH | UP

8 Abrupt climate change derived from proxy data

Which mechanisms, processes and regional climate patterns intensify abrupt climate changes during interglacials and at glacial-interglacial transitions? How different are these patterns compared to the last interglacial, the Eemian, when the average temperature was about 1-2 °C higher than it is now?

Abrupt shifts of the Sahara-Sahel boundary during Heinrich Stadials

The Sahara-Sahel boundary represents the boundary between the hyper-arid Sahara desert, and the sparsely vegetated savanna belt to the south, the Sahel (Fig. 8.1). Life in the Sahel is significantly influenced by the availability of water, and rainfall is usually only delivered during a few months of the summer. In the 1970s and 1980s of the last century the Sahel attracted attention due to a very abrupt and prolonged drought period lasting until today. As such, understanding the causes of desertification in the Sahel, i.e. southwards shifts of the Sahara-Sahel boundary, is very important.

The first scientific studies in the 1970s suggested that the reduction in rainfall was caused by human land use and vegetation destruction in the Sahel, the so-called „Charney hypothesis". The hypothesis states that vegetation removal, which increases the reflectivity of the earth's surface, cooled the earth's surface, stabilizing the atmosphere and thus reducing precipitation. However, throughout the 1980s it also became clear that natural factors could have been responsible for the drought in the Sahel. Instrumental records of the last century indicated a relationship between the large-scale sea surface temperature of the North Atlantic and rainfall in the Sahel. Cold surface water temperatures in the North Atlantic were associated with droughts in the Sahel. However, due to the shortness of the instrumental observational period, it was not clear whether this process also operates on longer time scales. Thus the robustness of the sea surface temperature and precipitation is still uncertain and remains to be tested on longer timescales.

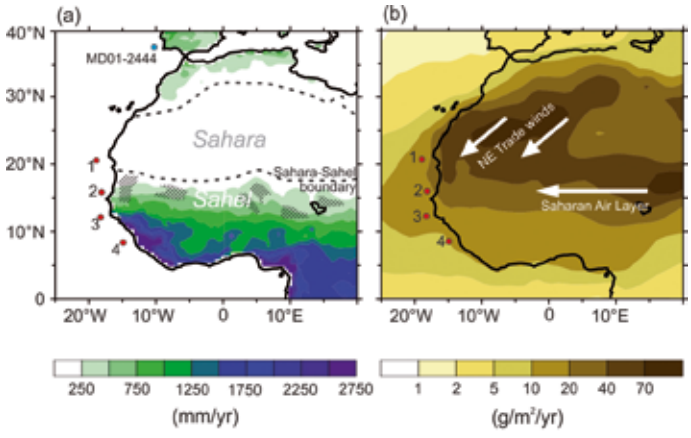

Fig. 8.1. a): Map of West Africa illustrating rainfall distribution (mm/yr). Hatching marks relict sand dunes in the Sahel. Red dots mark core sites (1-4) of our dust records. b) Modern dust deposition (g/m²/yr) illustrating the Saharan dust plume. Modern wind regimes are marked. (Graphics: modified from Collins et al., 2013)

The desertification history of the Sahel

On longer timescales, there is some evidence from the Sahel that the Sahara desert was once much larger than it is today (Fig. 8.1). Hyper-arid and virtually unvegetated conditions in the Sahara Desert today are ideal conditions for the formation and movement of sand dunes. In the Sahel, however, sand dunes are not forming today, because rainfall is too high and vegetation acts to stabilize the dunes. However, relict fixed sand dunes, now covered with vegetation, are present in the Sahel (Fig. 8.1a). They indicate that at some time in the past the Sahel must have been much more arid than it is today – in other words, the Sahara had expanded southwards by about 500 km. It is important, therefore, to determine the causes of these large-scale expansions of the desert. Was it due to sea surface cooling as was proposed for the desertification of the 1970s? Unfortunately, this is hard to answer using the sand dunes: dune formation can only be constrained to broad periods of time because sand dunes are very difficult to date precisely. However, marine sediments from the continental slope off West Africa can provide us with a well-dated record of climate.

In the framework of REKLIM, several sediment cores have been recovered by the MARUM, University of Bremen off West Africa. These sediments represent an excellent archive for the reconstruction of the precipitation in the Sahel because droughts are associated with a huge mobilization of dust – dust is hence an indicator for drought. This dust is transported westwards (Fig. 8.1b) and is deposited on the seabed off the coast of West Africa. Dust content was assessed by the content of Al, Fe relative to K and Si in the sediment. We investigated four core sites along the coast of West Africa (Fig. 8.1) so as to map the past position of the dust plume and Sahara desert.

The core data showed that distinct and abrupt periods of drought, each lasting a few thousand years, have affected West Africa over the past 60,000 years (Fig. 8.2). During these

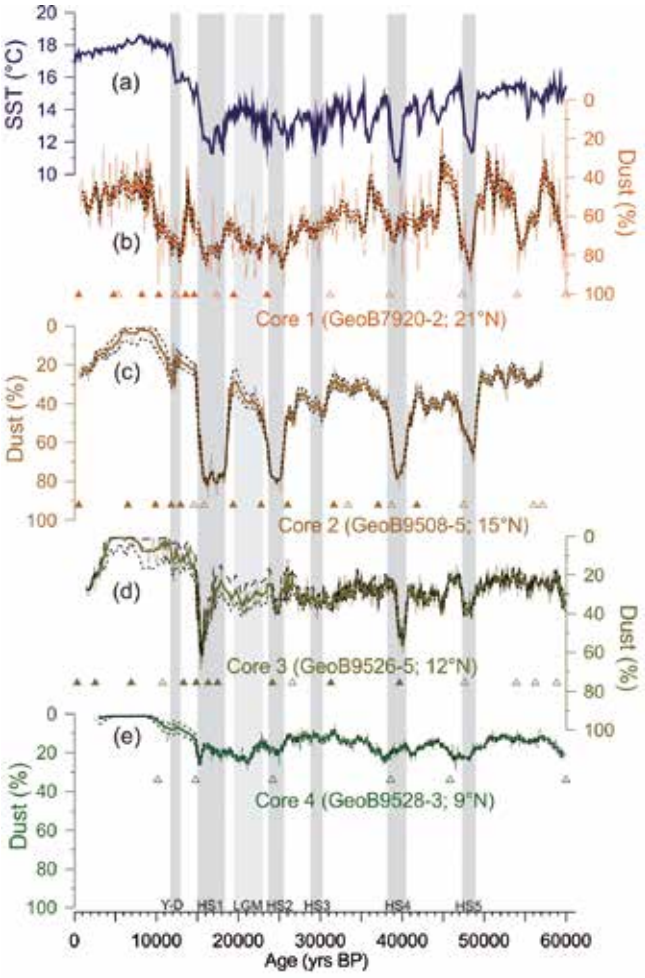

Fig. 8.2. a): Reconstructed sea surface temperature (SST) record of the Iberian margin (Martrat et al, 2007). b – e) Dust content (%) of each of the cores (1-4) from West Africa. Grey bars highlight Heinrich Stadials (HS) 1-5. (Graphics: modified from Collins et al., 2013).

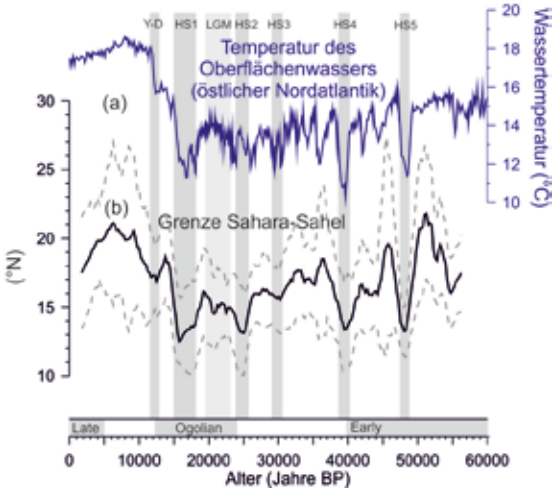

Fig. 8.3. a): Sea surface temperature record of the Iberian margin (Martrat et al., 2007). b) Reconstructed position of Sahara-Sahel boundary (SSB) based on interpolation of dust timeseries between cores 1 to 4. Broad phases of dune formation (Late, Ogolian and Early) that were originally defined based on dating of dunes are marked in grey. Dashed lines show error margins for the position. (Graphics: modified from Collins et al., 2013)

events, the transect of sediment cores down West Africa registered desert-like levels of dust at a position as far 500 km to the south of the present day desert (Collins et al., 2013), suggesting that the Sahara-Sahel boundary shifted southwards at these times (Fig. 8.3). A southward shift of 500 km is in line with the position of relict sand dunes in the Sahel, implying that the sand dunes in the Sahel must have formed during these abrupt and distinct drought periods.

Impact of ocean circulation and ocean surface temperature

Interestingly, comparison with other records of sea surface temperature shows that the desert expansions took place at the same time as excursions to extremely cold sea surface temperatures in the North Atlantic and off the coast of Iberia (Fig. 8.3). These excursions correspond to periods known as Heinrich Stadials which are associated with iceberg discharge in the Northern Hemisphere and a weakened ocean circulation. As such, it seems that natural fluctuations in ocean circulation and sea surface temperature have caused abrupt and dramatic expansions of the Sahara desert in the past.

Outlook

Finally, the Sahara is not the only desert in Africa: the Namib and Kalahari Desert are huge arid areas in southern Africa and represent important areas for understanding sub-tropical southern hemisphere climate. It is hence important to investigate whether these areas were also affected by these abrupt events in the North Atlantic and, if not, which other climate processes have controlled the climate of these regions. Work is currently underway within REKLIM by James Collins and co-workers at MARUM and AWI Bremerhaven, using novel leaf-wax biomarker proxies to investigate the past climate of Namibia.

Fig. 8.4: Sand dune at the Gobabeb Research Centre in the Namib Desert, southern Africa. (Photo: James Collins)

Prof. Dr. Ralf Tiedemann (AWI), Ralf.Tiedemann@awi.de | Prof. Dr. Achim Brauer (GFZ), Achim.Brauer@gfz-potsdam.de

DLR | FZJ | HMGU | KIT | TUM | UK | UKA

9 Climate change and air quality

How does climate change affect the air quality? What are the potential impacts of climate change and air quality changes on human health? How can these various interconnections and reactions be integrated into numerical climate and air quality models? What kind of measured data is required to characterise these effects in quantitative terms?

Changes in global and regional climate have numerous direct and indirect impacts on the air quality and thus on human health. For instance, emissions relevant for air quality due to changes in plant development and the chemical reactions that immediately follow are influenced by altered temperature and radiation fields. Furthermore, changes in large- and small-scale wind fields have impacts on the transport of trace gases, aerosols and allergen carriers (pollen). REKLIM's Topic 9 focuses on the interrelationships between regional climate and air quality so as to be able to make reliable forecasts on the health consequences of regional climate change for the population, particularly in cities and urban agglomerations.

Estimation of potential health impairments due to weather and pollutants in the ambient air in connection with altered climate conditions

Measurements of regional distribution of air pollutants and meteorological parameters

The REKLIM project encompasses, among other things, an estimation of potential health impairments due to weather and pollutants in the ambient air in the Augsburg region. For this purpose the air pollutant distribution was estimated for participants in the KORA study (Cooperative Health Research in the Augsburg Region) from Augsburg and the two adjoining rural districts Augsburg Land and Aichach-Friedberg in 2012. The land use models developed previously in the framework of the EU project ESCAPE (Beelen et al. 2013, Cyrys et al. 2012, Eeftens et al., 2012a and 2012b) served as the basis.

A measurement campaign for recording the small-scale distribution of temperature and humidity in the city of Augsburg was started in December 2012 in order to model the spatial-temporal characteristics of the microclimate in the region examined. For this purpose measuring devices were installed at 32 sites by 31 May 2013 (see Fig. 9.1). The measurements are carried out with weatherproof Hobo Pro v2 data loggers made by Onset Computer Corporation (USA) and designed for reliable use in harsh environments over many years. The measuring range for the temperature extends from -40°C to +70°C and for the relative humidity from 0 % to 100 %. The targeted measuring height is around 2 m above ground, though it may vary depending on the circumstances. The measurement interval is four minutes. Thus, the data loggers have to be read out every three to four weeks.

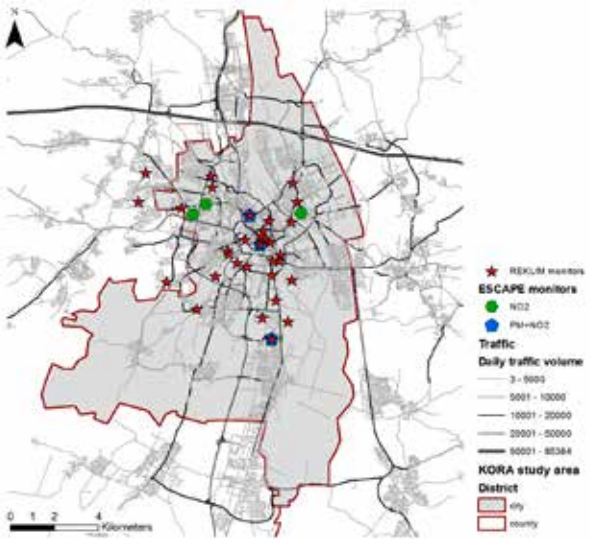

Fig. 9.1: Distribution of REKLIM measurement sites over the city of Augsburg (as of 31 May 2013). (Source: A. Peters, A. Schneider, S. Breitner, T. Kusch, C. Hald, J. Cyrys, HMGU)

Final selection of the sites was based on 44 previously chosen sites for the temperature and humidity measurements in the city of Augsburg.

Estimation of potential health impairments due to weather and air pollutants

An important factor in the interaction of climate change and air quality is the influence of temperature on mortality. This factor was investigated for Augsburg in the period from 1990-2006 (Breitner et al., 2013). In doing so, the number of daily deaths due to natural causes (excluding accidents, suicides, etc.) as well as because of cardiovascular and respiratory causes was compared to changes in the 2-day and 15-day mean values of the daily temperature. Furthermore, gender and age as well as air pollutant concentrations were analysed as possible effect modifiers. In this connection concentrations of particles with a diameter less than or equal to 10 µm (PM10) as well as ozone were divided into three categories each (below the 25th percentile, between the 25th and 75th percentile and above the 75th percentile). The study showed that both, very cold

and very warm temperatures are associated with mortality in Augsburg. For instance, a rise in the 2-day mean temperature from the 90th percentile (19.4°C) to the 99th percentile (24.1°C) led to an increase of 14.6 % in mortality due to natural causes as well as to a rise of 8.7 % and 22.8 %, respectively, in cardiovascular and respiratory mortality. Furthermore, a drop in the 15-day mean temperature from the 10th percentile (-1.4°C) to the 1st percentile (-8.5°C) led to a rise in cardiovascular mortality of 14.1 %. Very old people (over 85) displayed a somewhat greater effect of very high temperatures if at the same time ozone concentration was up.

Influence of climate change and air quality on the allergenicity of birch pollen

Climate change and air quality not only have a direct influence on people, but also an indirect influence on the effects on plants. Allergenic plants are of special interest in this connection (Fig. 9.2). Epidemiological studies show a connection between urbanisation and the increase in allergic diseases. At the same time the scientific basis of this association is still not well understood. Some studies have been able to demonstrate a pro-allergic effect of anthropogenic factors on susceptible individuals. On the other hand, the data available regarding the effect of environmental factors – natural or anthropogenic – on allergen carriers like pollen are sparse and mainly related to exposure studies under laboratory conditions. In this context it has been possible, among other things, to show altered allergen concentrations under the influence of pollutants. Behrendt et al. (2001) describe reduced bioavailability of allergens from grass pollen by virtue of gassing with NO_2 and SO_2 as well as morphological changes in the pollen surface with increased exit of proteins containing allergens due to gassing with aqueous suspended particle extracts. Studies by Eckl-Dorna et al. (2010) examined the effect of ozone on grass pollen and were able to show a rise in allergen concentrations by virtue of ozone gassing. Further studies on pollen of lamb's quarters (Chenopodium alba) and canna pollen (Guedes et al., 2009; Ahmad Majd et al., 2004) were able to detect different expression patterns between urban and rural pollen. Thus far, by contrast, there has been little investigation into how altered pollen properties influence the development and symptoms of allergic diseases.

REKLIM's Topic 9 examines the influence of climate change and air quality on birch pollen as a major allergen carrier with the aim of identifying connections between pollutant exposure, allergenicity of birch pollen and health parameters. It seeks to find answers to the question of the extent to which altered environmental conditions influence the allergenicity of birch pollen and what impacts this in turn has on initialisation of the allergy and its symptoms.

The allergenicity of birch pollen is looked at here through a holistic approach that includes the allergen bioavailability, the so-called pollen associated lipid mediators (PALMs) as well as adenosine, which was only recently identified in pollen. In vitro (in an artificial environment, here: simulation of human dendritic cells and granulocytes) and in vivo (in a living organism) analyses (prick test) round off the studies and improve our understanding of possible mechanisms. These data will help us to understand how climate change and urbanisation influence the allergenicity of birch pollen and, as a consequence, human health in order to develop primary prevention strategies on this basis.

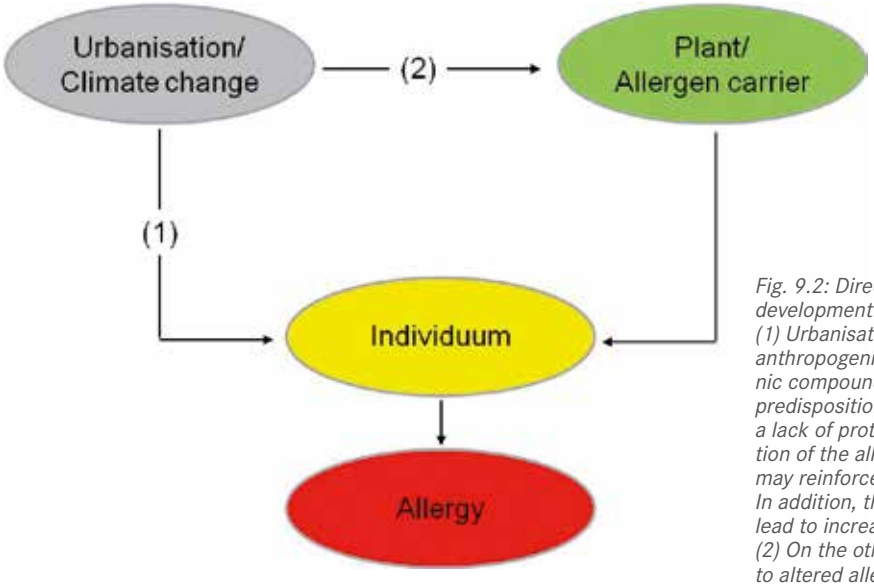

Fig. 9.2: Direct and indirect influence of urbanisation on allergy development. (Source: C. Traidl-Hoffmann, I. Beck, TUM-ZAUM) (1) Urbanisation is associated with increased pollution with anthropogenic factors (diesel emissions, CO_2, O_3, volatile organic compounds (VOC), particles). In individuals with a genetic predisposition these anthropogenic factors in combination with a lack of protective factors may lead to initialisation or aggravation of the allergy. It is a known fact that anthropogenic factors may reinforce allergic symptoms via infection-promoting effects. In addition, they may influence the epithelial barrier, which may lead to increased allergen penetration.
(2) On the other hand, anthropogenic factors may also lead to altered allergenicity of allergen carriers. This altered effect may manifest itself in the form of a reinforced development of allergic diseases or aggravation of the symptoms.

GFZ | HZG | KIT | UFZ | UHH | UKA | UL | UP

10 Risk assessment and risk management for climate adaptation strategies

What risks are related to climate change and how can they be assessed from an economic point of view? How can scientific support be provided to policy-makers and other decision-makers in addressing these risks?

In the framework of REKLIM's Topic 10 the Helmholtz centres involved (GFZ, HZG, KIT, UFZ) combine natural science and social science approaches in order to conduct dynamic risk analyses of climate and socio-economic change. Assessment of future risks and necessary measures at the regional level are tremendously important for successful adaptation to climate change.

Urban areas in particular are extremely sensitive to climate change. Heavy rain, floods and storm surges as well as mid-summer-like heat waves represent substantial climate risks, especially in frequently densely developed and economically intensively utilised urban regions. That is why REKLIM Topic 10 conducts research, for example, on regional risks due to climate change, risk perception and communication in various population groups, local involvement of players in the adaptation process as well as adaptation in the context of uncertainties. The objective is to provide a knowledge and data base for risk communication with the broad public and development of climate adaptation strategies.

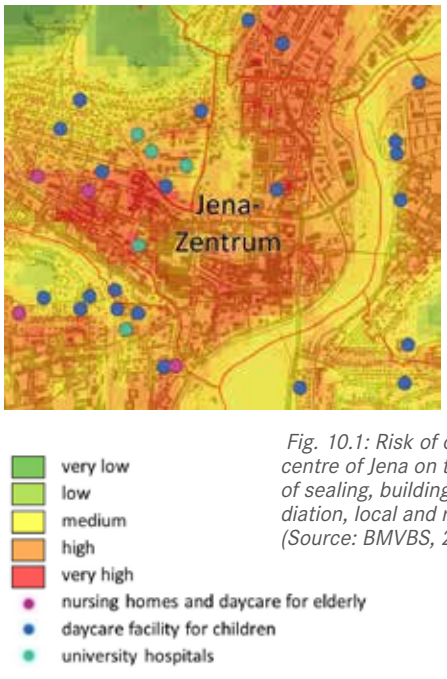

Fig. 10.1: Risk of overheating in the centre of Jena on the basis of the degree of sealing, building structure, global radiation, local and regional wind systems. (Source: BMVBS, 2013)

Assessment and prioritisation of climate adaptation measures – manual for decision-making support in urban climate adaptation

The Helmholtz Centre for Environmental Research (UFZ) in Leipzig has, on behalf of the German Federal Ministry of Transport, Building and Urban Development (BMVBS) with the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR), developed a manual for supporting decision-making processes relating to climate adaptation that describes a simple procedure for economic assessment and prioritisation of action options. The manual takes the reader through selection and assessment of climate adaptation measures, points out relevant questions and structures the assessment and prioritisation process, helps to create a database for making decisions and deal with data uncertainty, explains possible assessment methods and helps to apply them. It thus addresses decision-makers in municipalities and companies who face the challenge of selecting the most advantageous measures for climate adaptation under conditions of uncertainty and limited financial resources.

The process of assessing adaptation measures takes place in five stages:

1. Identification of impact (definition of a specific problem as well as assessment of past and future damage events) (for example: Fig. 10.1)
2. Definition of possible measures (possibly formation of combinations of measures)
3. Definition of assessment criteria and selection of assessment method (possibly weighting of assessment criteria)
4. Data collection for assessment of measures (e.g. municipal adaptation concepts and databases)
5. Prioritisation of action options (e.g. with PRIMATE) (for example: Fig. 10.2)

Furthermore, the manual provides a brief guideline for three assessment methods, i.e. cost-benefit analysis, cost effectiveness analysis and multi-criteria analysis, as well as examples of possible data sources and case studies from the research field (see also BMVBS, 2013).

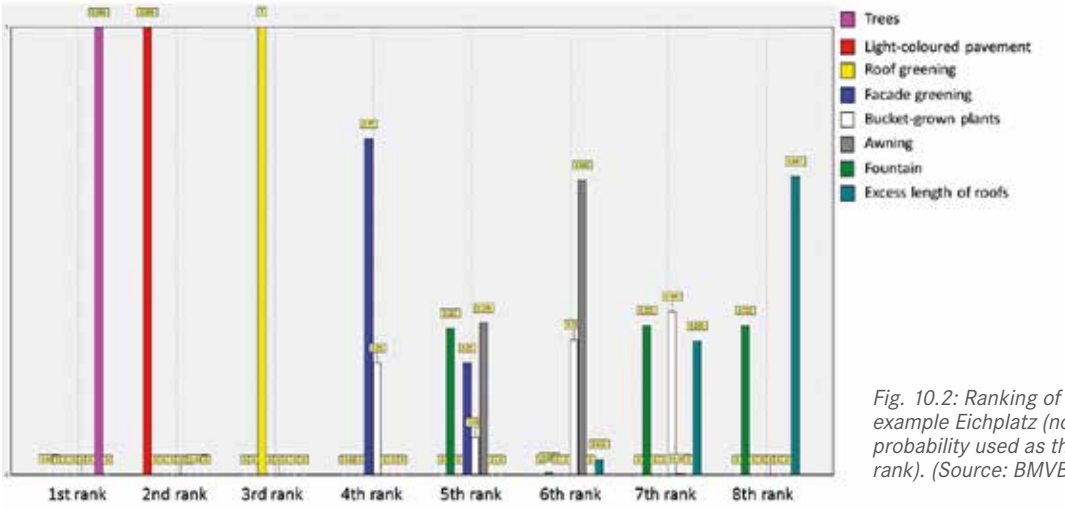

Fig. 10.2: Ranking of assessed measures, case example Eichplatz (note: the figures indicate the probability used as the basis for the respective rank). (Source: BMVBS, 2013)

Integrated approach for urban climate adaptation

More and more big cities are developing broad based adaptation strategies for dealing with the impacts of climate change in the city. In line with the integrated approach (Fig. 10.3) of the "German Strategy for Adaptation to Climate Change" (www.bmu.de/N42783), these strategies attempt to include all relevant sectors and fields, levels and players, e.g. construction/housing, water, energy, transportation, disaster management, environment, health, science, business and social development, various municipal and regional offices and authorities as well as citizens. In the framework of REKLIM and with the help of expert interviews based on Karlsruhe as an example, scientists at the Karlsruhe Institute of Technology (KIT) are examining what factors and effects favour or in the negative case hinder implementation of such integrated approaches at the municipal level and what solutions can be pointed out and developed for overcoming impediments. Special focus here is placed on risk management strategies for extreme weather events in the city (storms, thunderstorms, hail, heat waves, flood/low water level, onset of winter).

Framing climate change among migrants: barriers and opportunities in the adaptation process

Support for climate adaptation measures on the part of the local population is of great importance and there is increasing interest in the question of what influence social inequality has on regional adaptation capacity. In Germany every eighth person is a migrant and the number of immigrants will presumably rise even more in the coming years. For this reason the Helmholtz-Zentrum Geesthacht (HZG) is conducting research into the perception and conceptualisation of climate change among migrants. It also examines such questions as what information sources influence the mental images of climate and climate change. The study includes qualitative interviews in Hamburg with various migrant groups and official organisations involved in the integration of migrants. Its purpose is to analyse different factors, such as temporal, spatial or social distance and uncertainties with respect to the topics of climate change and adaptation, perceived ability to adapt oneself to changes and the role of experience with natural hazards like floods. The objective is to examine how these factors differ between the migrant groups and what impact they have on the adaptation behaviour of migrants. As a result, the HZG hopes to obtain findings regarding the significance this has for regional adaptation in Germany.

Medium-term synergies

Learning from regional climate change can not only take place in an urban context. Comparative work on different precaution mentalities in the population along river courses and along the northern German coast has been carried out at the GFZ, HZG and UFZ and serves as a starting point for cooperation. An initial coordinating editorial meeting took place for this purpose in Hamburg. The focus there will primarily be on cross-centre cooperation for the next funding period.

Fig. 10.3: Integrated approach in adaptation to climate change. (Photo: KIT)

Prof. Dr. Beate M. W. Ratter (HZG), Beate.Ratter@hzg.de | Prof. Dr. Reimund Schwarze (HZG/UFZ), Reimund.Schwarze@ufz.de

Young researchers in the REKLIM network

Who is behind the network? – „We give REKLIM a face“

Teresa Beck (KIT)

Even during her Meteorology studies Teresa Beck was especially excited by numerical simulation of the atmosphere. After she completed her studies with a Diploma degree at the Karlsruhe Institute of Technology (KIT) in July 2012, she started working on **REKLIM Topic 9** “Climate change and air quality”. In the framework of an interdisciplinary doctoral theme between numerical mathematics and meteorology she deals with adaptive methods for model reduction for the simulation of atmospheric chemistry. These methods are aimed at achieving the best possible results at minimal expenditure of numeric costs.

“One thing that particularly fascinates me about the REKLIM project is the objective of enabling a previously unattainable accuracy of detail in numerical simulation by using innovative numeric methods. In this way it is possible for meteorology to draw important conclusions regarding the model, which may lead to better climate forecasts in the long run.”

Daniel Klaus (AWI)

Daniel Klaus discovered the fascination of the Arctic climate system and the exciting problems in modelling it during his Physics studies at the University of Potsdam. He completed this degree programme with very good grades in February 2010 and has been working at the Alfred Wegener Institute in Potsdam since then. As part of his dissertation on **REKLIM Topic 1**, he deals with the simulation of Arctic clouds. On the basis of validation of the HIRHAM5 regional atmosphere model with satellite data in cooperation with NASA-JPL, parameter studies and changes in the cloud parameterisation serve to ensure improved simulation of cloud, radiation and boundary layer processes in the Arctic.

“Improved observations and credible climate models help us to gain a better understanding of the complex physical processes and enable us to correctly assess the impacts of a changing Arctic on the global climate system. The interdisciplinary exchange at REKLIM pools the competencies necessary for this.”

Charlotte Hoppe (FZJ)

Charlotte Hoppe has a degree in Meteorology and has been working on her PhD at the Institute of Energy and Climate Research (IEK-7, Stratosphere) at the Jülich Research Centre since 2011. During her studies at the University of Cologne she worked at the Rhenish Institute for Environmental Research (RIU). There she discovered her interest in working with meteorological models. Now Charlotte Hoppe works with global climate models and is incorporating a new transport scheme into a chemistry-climate model as part of her doctoral work on **REKLIM Topic 5**. This scheme is extremely well suited for describing the tropopause zone. This region of the atmosphere is of decisive importance in climate simulations since even small changes in the trace gas concentrations there may have great impacts on radiative forcing.

“I feel it is important that scientifically sound information on the climate and climate change is communicated through projects like REKLIM.”

Katharina Klehmet (HZG/University of Hamburg)

As a geographer, Katharina has always been interested in the regional characteristics of climate change. During her thesis work she was able to gain experience in regional climate modelling – a field in which she also wanted to write her PhD dissertation. In the framework of **REKLIM Topic 3** “Regional climate change in the Arctic”, the focus of her doctoral dissertation is to provide numerical simulations of present and past climate conditions in Siberia in order to supply a consistent historical data record of diverse meteorological parameters for this region. This climate reconstruction is based on application of the CCLM regional climate model, which previously required a special configuration for Siberia. Aside from processing the model configuration and model evaluation, her particular research interest focuses on an analysis of snow characteristics in Siberia and changes and variability in the latter during recent decades.

Susanna Mohr (KIT)

Susanna Mohr completed her studies and her doctorate at the Institute for Meteorology and Climate Research (IMK-TRO) at the University of Karlsruhe and at the Karlsruhe Institute of Technology (KIT). During her thesis work she examined the future changes of extreme wind speeds for certain occurrence probabilities in the winter period on the basis of an ensemble of regional climate models. As a member involved in **Topic 6**, the focus was subsequently on extreme events in the summer period. The objective of her PhD dissertation was to study the extent to which the frequency and intensity of hail events have changed in the past years. In addition, it was estimated what changes – due to anthropogenic climate change – can be expected in the future.

"What attracts me about REKLIM is the exchange between interdisciplinary research fields and the resulting opportunity to look at my own work from different points of view."

Lidia Romero (GFZ)

Lidia Romero is a Biology graduate and wrote her PhD dissertation on palaeolimnology at the University of Valencia, Spain. In her dissertation she examined pigments of algae in lake sediments on the Iberian Peninsula and used them to reconstruct hydrological changes during the Holocene. Within REKLIM she works as a postdoc in the Paleohydrology working group at the University of Potsdam and at GFZ Potsdam in Section 5.2 (Climate Dynamics and Landscape Evolution). Her research within **REKLIM Topic 8** consists of two basic pillars: on the one hand, she is working on the establishment of an organic-geochemical temperature proxy, the alkenone palaeothermometer for lakes, and on the other hand she is developing a high-resolution climate reconstruction on the Holocene sediment core of Tiefer See (a lake in Mecklenburg-Vorpommern) using organic-geochemical methods as well as substance-specific hydrogen isotope measurements.

Ingo Sasgen (GFZ)

Ingo Sasgen extended his Geophysics studies at LMU Munich through the unusual selection of Satellite Geodesy as a minor subject at TU Munich. This strong interest in Earth observation from space led him to do his doctorate within the Helmholtz Integrated Earth Observing System Project (EOS) at the German Research Centre for Geosciences (GFZ) in 2004. There he devoted his attention to evaluation of the GRACE gravity field data – still very new at that time – with regard to the changes in ice mass in polar regions. In the meantime, for over ten years now the GRACE data have been supplying continuous measurements of the polar ice mass balance that are incorporated into the numerical simulation of the future sea level rise in **REKLIM Topic 2** "Sea level changes and coastal protection".

"What fascinates me about the REKLIM project is the enormous expertise of those involved and how it is pooled in order to answer very targeted research questions. For me it is important to see that the database that I provide is used in simulations and improves their quality."

Gustavo Saiz (KIT)

Gustavo Saiz completed his master's studies and his PhD at University College in Dublin, Ireland, where he studied below-ground carbon dynamics in temperate forest ecosystems. As a junior researcher at St. Andrews University in Scotland and at James Cook University in Australia, he examined below-ground carbon dynamics under tropical environmental conditions in the past seven years. Gustavo took part in extensive and long-lasting field campaigns in more than a dozen tropical countries. His research interest in REKLIM **Topic 4** encompasses the application of stable isotope analysis to the study of past and present tropical vegetation dynamics and their dependence on edaphic conditions on a global scale. Furthermore, he investigates by means of fractioning methods how changes in vegetation impact carbon dynamics in the soil.

Diana Süsser (HZG)

Even during her master's studies of Climate Sciences on KlimaCampus at the University of Hamburg Diana Süsser examined interdisciplinary questions related to climate change mitigation and climate adaptation. Since December 2012 she has been working on her doctorate at the Institute of Coastal Research of Helmholtz-Zentrum Geesthacht (HZG) within the scope of **REKLIM Topic 10** "Risk assessment and risk management for climate adaptation strategies". In her PhD dissertation she looks at individual decision-making processes aimed at providing protection against climate risks using agent-based simulations and analyses how these processes are shaped in coastal communities through social networks. This research targets better understanding for dissemination of knowledge, perceptions and adaptation measures so as to obtain findings for improved adaptation management.

"Above all else, I see the interdisciplinary and cross-institute research in the REKLIM project as a great benefit."

Anna-Katharina Topp (EUV)

Anna-Katharina Topp completed her master's studies in Macroeconomics at the University of Regensburg. In her thesis she examined the question of the extent to which behavioural economics approach contribute to an explanation of the readiness to cooperate in international environmental policy. Since the beginning of 2012 she has been working on her doctorate at the European University Viadrina in Frankfurt (Oder) and is actively involved in the RECAP 15 research project funded by the German Federal Ministry of Education and Research (BMBF), in which she investigates the interaction between adaptation and mitigation measures in international climate policy by means of game theory models. In close cooperation with the Department of Economics of the Helmholtz Centre for Environmental Research joint work was carried out for **REKLIM Topic 7** that Anna-Katharina Topp presented at the past REKLIM workshop in Bad Honnef.

"What attracts me about REKLIM is the lively exchange of knowledge between researchers from the natural and social sciences that fosters mutual understanding and enables development of solid climate policy recommendations."

Climate Office for Polar Regions and Sea Level Rise

Climate consulting at the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI)

Current problems, such as environmental destruction and anthropogenically induced climate change, have an enormous social significance that makes cooperation between natural and social sciences more useful and necessary than ever before. To combine the "two science cultures", the Climate Office designed and organised the German-French workshop "Gateway to the Arctic" (Fig. K.1). The project was supported by the French partner institutes Institut Polaire Français - Paul Emile Victor (IPEV), Centre Europeén Arctique (CEARC) and AWI. The goal of the workshops was to provide young scientists from diverse disciplines a platform enabling them to take a look at the work of other disciplines going beyond their own discipline. The recommendations developed and elaborated on the basis of the workshop regarding continuation of the dialogue will be incorporated into a follow-up event in Brest in November 2013.

Apart from that, the Climate Office supported the kickoff event on formation of a youth climate council in the context of the "Climate City Bremerhaven" process (Fig. K.2). The objective of this politically based platform is to give young people a voice and the opportunity to get involved in the political process with their ideas on climate protection. To pool ideas on the structure and functions of the future climate council, a youth climate conference took place at AWI in Bremerhaven on 10 November 2012. On the basis of these results, a follow up conference took place end of August at which young people were able to vote on the concrete form of the council.

Fig. K.1: IA total of 33 scientists took part in the workshop "Gateway to the Arctic". They came from France, Finland, Sweden, Russia, the Netherlands and the USA. (Photo: Julia Bär, AWI)

Fig. K.2: Kickoff event on formation of a youth climate council at AWI in Bremerhaven on 10.11.2012. Speaker at opening: city councillor in the Environmental Protection Office Anke Krein. (Photo: Susanne Lincke, ecolo)

The other projects of the Climate Office include the long-term "Maritime Centre Elbe Islands" (MZE) cooperation project at the Wilhelmsburg comprehensive school in Hamburg. This project was initiated by AWI, the Hamburg International Maritime Museum, IBA Hamburg GmbH as well as the German Shipbuilding and Ocean Industries Association (VSM). It involves construction of a new school building on approx. 4,000 square metres as a unique learning and research site where pupils come together with representatives from science, business, art and industry in order to "learn through research and conduct research while learning". The school is located in a region with a difficult educational situation, around 18 percent of the pupils of a school year leave the schools without a school-leaving certificate and only 10 percent of the pupils are able to transfer directly to the German dual vocational training system. For this reason the project has received support from the Hamburg Office for Schools and Vocational Education since the beginning of 2012. At the moment Schulbau Hamburg has contracted Gebäudemanagement GmbH Hamburg to prepare the invitation to tender for an international architect competition.

North German Climate Office

Regional climate service for Northern Germany

Our objective is to transform scientific results into information relevant for decision-making processes. For this reason we maintain a close exchange with decision-makers in northern Germany. This dialogue takes place primarily at events and in personal talks. Once a week on average we are guests at diverse social groups from companies, associations, authorities and educational institutions in order to conduct an exchange at the local level with people from the region and discuss opportunities and risks of climate change. Moreover, we receive numerous inquiries with specific questions on climate change in northern Germany. Through the close contact to our users we learn about existing information needs and frequent misunderstandings. Based on these findings, we optimise and expand the information we offer.

Concordance maps in the climate atlas

"What is the most probable climate forecast?" We have been repeatedly asked this question in the past years. The background to why we cannot predict the climate of the future like the weather of tomorrow and therefore have to work with scenarios makes only a small contribution to answering this question. In fact, however, the question points to a major barrier that exists in connection with the use of scientific results in planning processes. Many planning processes are still designed for a defined number, a certain threshold value or a once-in-a-century event. Measures for adapting to climate change, by contrast, require planning that is designed for a very broad spectrum of different climate developments. For such planning our climate atlases now show where all basic climate scenarios correspond to one another and for what parameters in what regions the propositions are (still) unclear. (Fig. K.3)

For the next 30 years, for example, all regional climate scenarios examined are in accordance that it may become warmer. This concordance also applies to the change in derived thermal parameters, such as summer days, hot days, frost days and ice days. Another picture emerges with respect to the change in seasonal precipitation amounts within the next thirty years. Some scenarios show, for instance, an increase in summer precipitation of up to 5% while others see a decline of up to -5%. As of the mid-century (2041-2070), however, all scenarios indicate for the most part a decline in summer precipitation and an increase in winter precipitation for Germany. It thus becomes evident for decision-makers how robust a statement

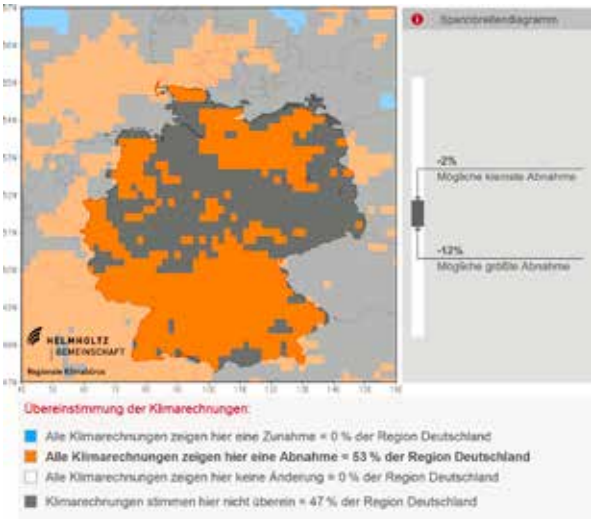

Fig. K.3: Possible change in precipitation in summer up to mid-21st century (2041-2070) in comparison to today (1961-1990). (www.norddeutscher-klimaatlas.de, www.regionaler-klimaatlas.de; available only in German)

is for a certain time window, when the statement becomes robust or whether it remains unclear. A planning example that takes into account possible ranges of climate change is the Schleswig-Holstein coastal protection concept with construction reserve. All scenarios on the global change of the sea level published by the IPCC (2007) indicate a further rise in a range from 20-80 cm by 2100. For this reason a rise in sea level of 0.5 m (so-called climate impact buffer) is used as the basis for coastal protection structures in the planning of measures for adaptation to climate change. Should the sea level exceed this figure, coming generations have the option of adding a top section to the dike at little expense. Adaptation measures on uncertain bases thus become effective with a high degree of probability if options are made available to respond flexibly to later changes. The new concordance maps can supply a major information base for this purpose and point out possible need for action.

UFZ |

Climate Office for Central Germany

Dialogue with regional players on climate impacts and adaptation

The Climate Office for Central Germany at the Helmholtz Centre for Environmental Research (UFZ) shapes the regional dialogue between the public and decision-makers on the one hand and the scientific community on the other hand. We focus on climate impacts for the water balance as well as for biodiversity. Furthermore, adaptation to positive and negative consequences of climate change is another focal point of our work. Special attention is devoted to planning periods and identification of relevant drivers of global change and its regional impacts.

Translation of predominantly natural science knowledge to society is implemented at the Climate Office via such public events as the film series “Globale in Halle”. The documentary film “The Broken Moon” (“Der Zerbrochene Mond”) was shown at the event organised by mohio e.V. and Greenpeace. Afterwards there was a lively discussion with Dr. Andreas Marx from the Climate Office for Central Germany on climate change as well as economic and demographic changes and land use change. A focal topic for the media was the flood event in early summer 2013 in Central Europe (Fig. K.4), which led to severe flooding due, among other things, to the combination of high soil moisture prior to the event and the following extreme precipitation in some cases.

Last year particularly the dialogue with the city of Leipzig was further intensified. The exchange was suggested by the Environmental Protection Office with regard to the topic of adaptation to climate change. Such areas as water management, nature conservation, health and infrastructure were looked at against the background of climate change and solution strategies were discussed. In addition, research gaps were identified and will be closed through cooperation with UFZ, among others, on the topic of “Heat in the City”.

In the framework of a project for the European Environment Agency (EEA) UFZ contributed to the report “Climate change, impacts and risks in Europe 2012”. Meticulous selection and evaluation of the basic indicators of extreme precipitation to soil moisture and drought right through to the distribution of animal and plant species represented a great challenge in the two-year process up to completion of the report. Moreover, the Climate Office was lead author and thus responsible for the section on Terrestrial Ecosystems.

Furthermore, networking of scientists within the scope of the DAAD (German Academic Exchange Service) Science Tour 2012, which made a stop in Leipzig in November, was intensified. Over 30 international guests were able to conduct talks with UFZ researchers on the topic of “Climate change and biodiversity” at the event organised by the Climate Office.

Fig. K.4: Flood in Collmen an der Mulde on 04.06.2013. Numerous media inquiries revolved around the extreme event in June and its impacts. (Photo: André Künzelmann, UFZ)

KIT |

South German Climate Office

Bridge between research and society in Southern Germany

The South German Climate Office at the Karlsruhe Institute of Technology (KIT) has been a contact point for information on climate and climate change since 2007. It provides media, public organisations, decision-makers and citizens sound, comprehensibly prepared and user-oriented knowledge on the climate and the impacts of regional climate change. In doing so, it has access to the research results and expertise of the KIT Centre "Climate and Environment", to which the South German Climate Office also belongs, as well as of other KIT institutes and various other institutions in southern Germany. Moreover, the South German Climate Office initiates and supports scientific projects.

In 2012 it successfully conducted two concept studies. In a one-year project a statistical method for determining urban air quality was developed. Measured data with a high temporal and spatial resolution obtained from an urban train equipped with measuring equipment in the Karlsruhe region were evaluated for this purpose. At the interface between climate research and the construction sector scientists analysed the frequency of occurrence and the regionally differentiated distribution of critical temperature ranges critical for frost damage for a project on classification of the damage impact of frost periods on concrete. The three-year project "Water-related soil erosion as a consequence of climate change" is in the final phase.

In addition, the South German Climate Office carried out a wide variety of activities aimed at imparting expertise in science and society. It supported the "Idea and Cooperation Market" on "Heat in the City" and represented several cooperation offers regarding climate research competencies at KIT. The idea and cooperation market on Climate adaptation initiated by the German Federal Environment Agency (UBA) took place in Karlsruhe in June 2013 as one of three nationwide pilot regions.

Fig. K.5: The brochures and flyers on various climate topics are available at www.sueddeutsches-klimabuero.de/schriften.php. (Photo: Lydia Albrecht, KIT)

Fig. K.6: Open day of Climate Office for Southern Germany at the Science Festival EFFEKTE. (Photo: Andreas Lang, KIT)

In cooperation with the North German Climate Office and the Dutch weather service (KNMI) the South German Climate Office organised a conference session entitled "Regional and National Climate Services - Experiences and New Ideas" at the General Assembly of European Geosciences Union (EGU) in Vienna in April 2013, at which participants from all over the world intensively discussed experience and proven approaches in the field of climate communication.

To strengthen the transfer of climate knowledge to the public, the South German Climate Office prepared flyers for a total of six thematic focal points (Fig. K.5), including "Climate and extreme events" and "Climate and climate modelling", which convey knowledge on climate topics and climate research in a generally comprehensible form.

Another new information offering is the brochure "Your point of view on the climate – places in Karlsruhe". The synopsis represents an impetus for citizens to look at places in their city in connection with climate information.

The information materials were distributed at presentations by the South German Climate Office at different events, such as at the anniversary "25 years Environment Ministry in Baden-Württemberg", at the idea and cooperation market „Heat in the City" in Karlsruhe and at an open day as part of the Karlsruhe Science Festival EFFEKTE 2013 (Fig. K.6).

AWI | UB

meereisportal.de

The new knowledge platform concerning sea ice

An important objective of REKLIM is to make results obtained in various work processes available as a scientific base to decision-makers at all levels of society and to the broad public. Such knowledge transfer is pursued through the new Internet platform “meereisportal.de”. It is the first comprehensive German knowledge platform concerning sea ice in the Arctic and Antarctic. It was developed in the framework of REKLIM as a joint project of the University of Bremen (Institute for Environmental Physics) and the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research under the management of the regional Helmholtz climate offices. Background information, expertise and a map and data archive constitute the three main pillars of the knowledge platform (Fig. M.1).

Up to now a lot of information regarding sea ice was only available in English. The first pillar of the new Web platform therefore primarily pursues the goal of providing comprehensive and comprehensibly prepared information on sea ice in German. Such questions as “How does sea ice form?”, “How is it researched?” and “What role does it play for the climate on Earth?” will be answered on the new knowledge platform. The individual topics will be presented there in a varying depth of analysis and detail.

Another pillar is the extensive map and data archive, in which already more than 7,000 graphically prepared sea ice maps and the corresponding data for the past ten years can be downloaded for further processing by users at the moment. In the near future the first maps on sea ice thickness worldwide will be published on this portal as data products of ESA’s CryoSat-2 satellite.

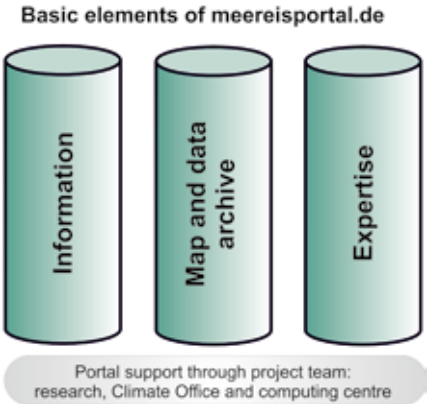

Fig. M.1: The scientific expertise will be provided by the sea ice researcher groups at AWI and at the University of Bremen (IUP). In addition, AWI’s Climate Office for Polar Regions and Sea Level Rise will support the portal. (Graphics: AWI)

Fig. M.2: The homepage of the Internet platform meereisportal.de. (Graphics: AWI)

The third major pillar at meereisportal.de is the outstanding expertise of the two partner institutions with respect to different topics relating to sea ice. This forms the foundation of the knowledge platform and is incorporated into all sections of the portal, resulting in various key quality features for the platform. For instance, the assessments and evaluations accompanying the sea ice measurements are carried out directly by the experts and the latter are also available as contact persons. In addition, the direct linkage of the topics presented at meereisportal.de to scientific questions ensures a high degree of topicality. From sea ice physicists and oceanographers all the way to sea ice modellers – all of these scientists will have a chance to be heard and explain the variety of ways researchers are examining sea ice and on what topics they can provide information (Fig. M.2).

Furthermore, meereisportal.de will offer a place for reports on the expeditions carried out at AWI on sea ice. A first step in this direction has already been taken. The two-month winter expedition of the RV Polarstern, which started on 8 June 2013, has been documented with current pictures, reports and background information at meereisportal.de and thus made available to a broad public.

www.meereisportal.de | Dr. Renate Treffeisen (AWI), info@meereisportal.de

Synthesis

In its four-year period the Helmholtz Climate Initiative Regional Climate Change (REKLIM) has documented its scientific results in approx. 200 publications, including a large number of cross-centre papers that could not have been drawn up without the REKLIM network. The first funding period for the network elapses at the end of 2013 and as of 2014 it will continue to be funded as a cross-programme initiative of the Helmholtz Association of German Research Centres parallel to the individual research programmes of the various centres. At the moment one can summarise the following general results that have been achieved in the individual topics:

1. Regional modelling for the Arctic atmosphere was successfully further developed and expanded by virtue of efficient cloud schemes that were adjusted by comparing them to satellite data. The influence of internal model variability on the extent of Arctic sea ice was examined in a coupled regional climate system model of the Arctic. In the regional model simulations the observed decline in sea ice is essentially determined by changes in the lateral atmospheric boundary forcing. Moreover, Arctic climate processes influence the polar jet streams and teleconnection patterns in the temperate latitudes. Special further developments with regard to coupling with land surface models and models of atmospheric chemistry for improving regional forecasts were implemented successfully.

2. The mass balances for Greenland and the Antarctic were derived from gravitational data of the GRACE mission. Model developments have been pushed forward which serve the purpose of investigating long-term climate change in a fully coupled Earth system model approach with ice sheet and viscoelastic lithosphere response. Diagnostic sea level changes on a global scale all the way to analysis of water level data in the German Bight were examined and characteristic patterns determined on that basis. The latter serve to verify high-resolution modelling of oceanic circulation patterns in key regions.

3. Long-term observations in the Arctic inflow and outflow region of the Fram Strait were continued and the role of the warm inflow from the Atlantic for sea ice development was examined. Furthermore, the network achieved progress in monitoring of the Arctic permafrost and of the associated methane flows that also contribute to verification and development of improved climate models.

4. Measurements, modelling and instrumentation of land surface observatories were boosted. In particular, it was possible to improve parameterisation of the regional energy and water fluxes between the biosphere and atmosphere as well as study the influence of soil hydraulic properties and the description of the vegetation on the modelling of fluxes on the land surface. TERENO observatories thus supply the database for developing new parameterisation methods for model-driven regional climate impact analyses.

5. Through further development of coupled chemistry-climate models to physical and chemical processes in the atmosphere up to the stratosphere the network obtained important findings on the influence of aerosols and trace gases on climate development. Primarily the combination of satellite observations, aircraft measurements right through to experiments in an aerosol chamber regarding cloud condensation contributed to improvement of the models and achievement of more reliable forecasts.

6. The causes of and long-term changes in extreme events, such as storms, hail, flood and drought, were determined and quantified more precisely by virtue of improvements in analytical methods as well as representation of small-scale processes in regional models.

7. Support for integrated climate policy in the framework of scientific assistance supplied innovative arguments for an economically optimal selection of climate policy measures and contributed to better management of the strategic orientation of climate protection investments and adaptation measures in international negotiations.

8. Through the development of new climate proxies in lacustrine and marine sediments and further development and application of model simulations of deep water circulation in the North Atlantic and North Pacific it was possible to gain new findings on the mechanisms how external (solar activity) and internal (melt water inflow in northern hemisphere oceans) factors have an impact on the climate system and what role the respectively prevailing basic climate states plays in this process.

9. Applying climate-induced environmental changes to air quality and health forms a bridge between climate and health research of extremely high social relevance. Initial results on current developments permit clear conclusions for the population, especially in urban agglomerations. Climate scenarios are implemented accordingly.

10. Further development of adaptation research is indispensable for risk assessment and management. Gaps in knowledge were closed and lacking knowledge and related risks were communicated to the broad public so as to be able to develop adaptation strategies on a scientific basis.

Outlook

In September 2013 the Intergovernmental Panel on Climate Change (IPCC) will submit the Fifth Assessment Report (AR5). More than 250 scientists from 44 nations summarised the first section, the “Scientific Basis”, in a multistage procedure from the current state of knowledge of publications examined after 2007. The results will be presented in Stockholm.

In contrast to 2007, when the IPCC report gained great attention due to its statement that climate change in the last 50 years has been caused very likely by humankind and sparked an intense debate on the topic of climate change and climate impacts, the topic today has unfortunately shifted to the background in the public perception. Altogether, five big UN climate conferences (Poznan 2008, Copenhagen 2009, Cancun 2010, Durban 2011 and Doha 2012) have been held without achieving a breakthrough on an international basis or developing a perspective for the Kyoto Protocol, the internationally binding climate convention that expired in 2012. A post-Kyoto treaty is now to be drawn up by 2015.

Regardless of the political difficulties on an international scale and progress in individual cases with respect to efforts to achieve a fundamental reduction in CO_2 emissions, climate change goes on unchecked. In summer 2012 the extent of sea ice in the Arctic reached a historic minimum, extreme events like hurricanes and storms are increasing in frequency worldwide and the last decade was the warmest period since temperature recording began.

However, the findings obtained in the field of regional impacts through research in the REKLIM network fill a decisive gap here by virtue of a regionally specific extension of the scientific base, more detailed investigation of processes and projections to the regional scale by means of modelling. The extensive competence of the Helmholtz Association in the field of Earth and environmental sciences in collaboration with university partners leads to a greater understanding of the processes involved and provision of assistance and advice in a dialogue with those concerned and decision-makers at the local level. In particular, the four Climate Offices, the Climate Service Centre as well as scientific workshops and conferences act as disseminators of our research results at the pulse of the times.

For October 2014 the REKLIM network plans to present its results in the form of an initial synthesis for discussion at an international conference in Berlin and as part of a day for the general public.

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