Decadal climate predictions – a challenge

The Max Planck Institute for Meteorology (MPI-M) has for years provided global climate projections for the 21st century, calculated with its Earth system models. With these projections, the MPI-M has actively contributed to the IPCC assessment reports. The planning horizon of politics and society, however, does not correspond to the multi-decadal timescales represented in these projections, and decision makers are therefore more interested in how the climate will change in the next 10 to 30 years. Predictions over this timeframe are one prerequisite for improving decisions by industry and society on how to adapt to future climate change.

The MPI-M addresses the demand for decadal climate predictions in the framework of the research program MiKlip (from the German "**Mi**ttelfristige **Kli**ma**p**rognosen", decadal climate predictions), which is funded by the Federal Ministry of Education and Research in Germany (BMBF). The MiKlip team at the MPI-M can now show first promising results for predicting North Atlantic surface temperatures.

Decadal predictions constitute a challenge for climate research, because new climate prediction systems must be constructed to produce, for this comparatively short time period, reliable statements on the development of climate and its accompanying extreme weather conditions.

The development of the current prediction system in the framework of MiKlip is led by Prof. Jochem Marotzke at the MPI-M. The main objectives of MiKlip are to promote fundamental research in the research area of decadal climate predictions and to achieve a pre-operational level of the new decadal climate prediction system. The next step would be to produce regular predictions for the public.

The decadal climate prediction system is based on the Earth system model MPI-ESM, which was also used for the latest long-term projections for the IPCC. The prediction system is continuously being improved with the help of research results obtained within MiKlip, and current efforts are focused on the third generation of the system. The predictions presented here were produced with the second generation.

Why the need for new model systems for decadal predictions?
On timescales of years to decades, climate patterns depend not only on the anthropogenic atmospheric greenhouse gas concentrations but also on the natural variability of the climate system. The natural variability arises from external forcings such as fluctuations in solar radiation or volcanoes, and from the internal variability of the climate system. The internal variability is mainly chaotic, but there are clear indications of a long-term "memory" of several internal processes on decadal timescales. Decadal climate prediction aims to use the memory of these slow processes; the inertia of the ocean and its key processes play a central role. Thus, information on the current ocean state, such as observed ocean temperature and salinity, are being assimilated into the model and used for the predictions. The initial conditions obtained in this way are crucial for decadal climate predictions; for long-term projections, they are largely irrelevant.

Hindcasts
The quality of predictions is determined from retrospective predictions of the past, so-called hindcasts. MiKlip has already established skill in predicting important climate quantities. Hindcast skill has improved markedly in the course of the three prediction system generations that have been used to date, for example for ocean surface temperatures. Furthermore, hindcast skill was found for European summer surface temperatures, extra-tropical intense cyclones, the quasi-biennial oscillation, and the Atlantic Meridional Overturning Circulation (AMOC). Skill is generally higher in the later generations of the system.

Surface temperatures in the northern North Atlantic (the subpolar gyre) are particularly well represented in the hindcasts of all three generations of the system. This gives the scientists confidence in the ability of the system to produce useful predictions for this region.

Predictions

The prediction for the coming ten years was generated from an ensemble of ten simulations with the second generation of MiKlip model system. These ten simulations were initialized with the initial conditions from 1 January 2014 and were calculated for ten years (2014-2023). By subtracting from the prediction the climatological mean of the years 1971-2000, calculated from the CMIP5 (Coupled Model Intercomparison Project Phase 5) long-term simulations, a so-called anomaly prediction is obtained.

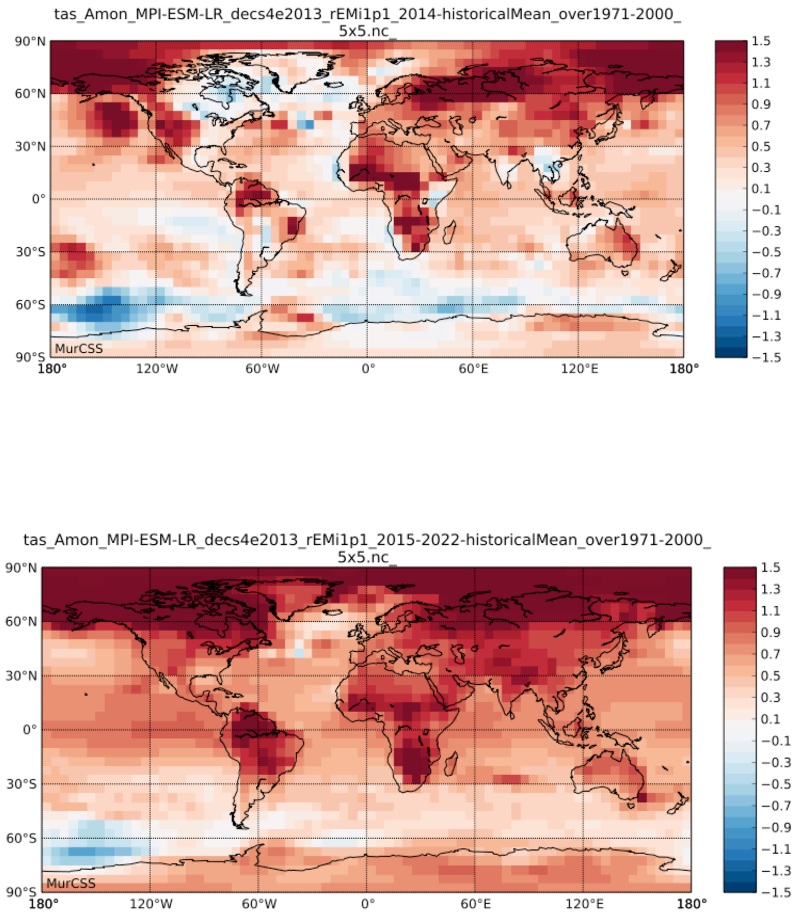

Fig. 1: Anomaly prediction of surface temperature. The upper figure shows the prediction for 2014, the lower figure shows the prediction for the mean over 2015 to 2022.

The current prediction (Fig. 1, upper panel) shows a warming over land for the coming year, in comparison to the climatological mean. In the region where the hindcasts show good predictive skill (North Atlantic), a slight cooling or a stagnation is predicted. For the eight years following, the patterns are similar (Fig.1, lower panel), although the predicted warming is stronger.

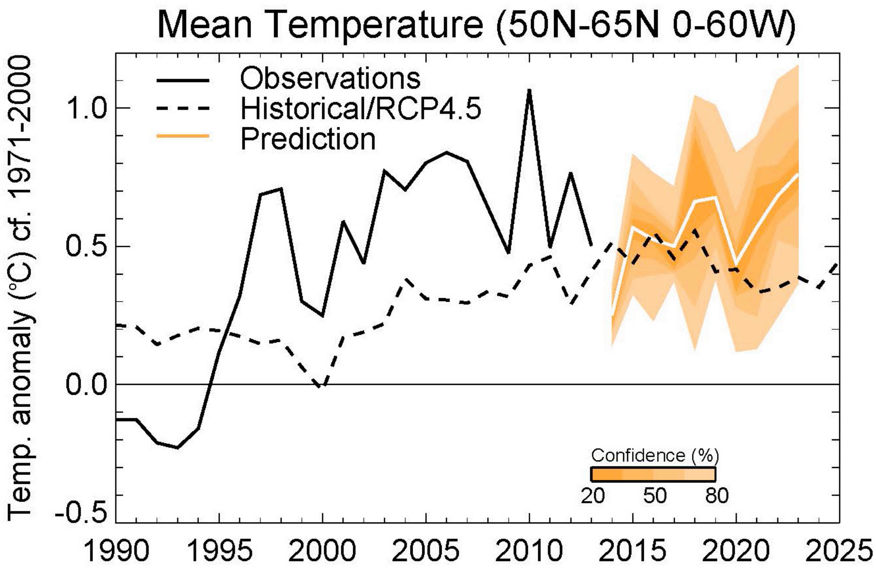

Fig. 2: Anomaly prediction for surface temperature in the subpolar gyre region (in the North Atlantic). The white line shows the ensemble mean of the prediction and the area shaded in orange shows the confidence of the prediction. Observations from the HadCRU dataset (black) and from the non-initialised simulations (black dotted) are shown for comparison.

To investigate further the region in which the hindcasts show good skill, the average prediction for the subpolar gyre region was calculated (Fig. 2). The prediction shows a continuation of the stagnation that was already to be seen in the observations in the years before the start of the prediction.

The accuracy of these predictions is a topic of current research. To aid in this effort, the predictions are analysed in the framework of a multi-model project led by the Hadley Centre, MetOffice, UK, in which MiKlip has participated since the beginning (3rd link, see below). The first comparison was published in 2013 (Smith et al., 2013). The decadal climate predictions of other research institutes show a different evolution of temperatures in the North Atlantic; some models show a cooling instead of the stagnation that was obtained with the prediction system at the MPI-M.
Further research is necessary before the system can be used operationally. But the course is set!

About MiKlip:
MiKlip is funded by the Federal Ministry of Education and Research in Germany (BMBF), comprises 35 sub-projects and 22 German participating research institutions. At MPI-M, the project is led by MPI-M Director Prof. Jochem Marotzke and coordinated by Dr. Freja Vamborg.

MiKlip is organized in five modules: Initial Conditions and Initialisation, Processes and Modelling, Regionalisation, Synthesis, and Evaluation. Within the modules research is pursued with the following foci; determination of initial conditions for decadal predictions, investigation into processes relevant to decadal predictions (e.g. modelling of the cryosphere and the biosphere), the increase of the spatial resolution through regionalisation, and the improvement or adjustment of statistical post-processing for evaluating and validating the system. Finally, the results are brought together by the synthesis module to form a new generation of the decadal prediction system.

Further information:
www.fona-miklip.de
http://www.mpimet.mpg.de/en/science/projects-new/miklip-projekt.html
http://www.metoffice.gov.uk/research/climate/seasonal-to-decadal/long-range/decadal-multimodel

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Publications (bold = authors from MPI-M)

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