Seasonal to interannual predictability of high northern latitude climate

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Introduction:

The aim of this ongoing work is to analyze the predictability of seasonal to interannual climate conditions in high northern latitudes. One climate mode showing a high potential for interannual predictability is characterized by the formation of sea ice anomalies at the Siberian coast, their propagation across the Arctic towards Fram Strait, anomalous sea ice export through Fran Strait and advection of the sea ice/freshwater signal into the Labrador Sea, where it significantly influences ocean convection, salinity, sea ice distribution, ocean- and air temperature (Koenigk et al., 2006). The potential predictability of climate is analyzed by performing ensemble experiments with a global coupled atmosphere-ocean-sea ice model.

Model, Experiments and Method:

The model used in this study is the Max-Planck-Institute for Meteorology global atmosphere-ocean-sea ice model ECHAM5/MPI-OM (Roeckner et al., 2003; Marsland et al, 2003). The atmosphere model is run at T31 resolution and has 31 vertical levels. The grid spacing of the ocean model varies between about 30 km and 390 km. The model has 40 vertical layers.
A set of 40 ensemble simulations was performed to analyze the predictability. Each ensemble consists of 6 members and all runs were started in January from different initial conditions of a 300-year control integration. In half of the ensembles, the members of one ensemble were differently perturbed by a slight change of the atmospheric diffusion parameter in the first model month. In the other half, a small randomly distributed perturbation was added to ocean temperature, salinity and sea ice thickness. However, it turned out that on the time scales of interest it does not make any difference where a perturbation, if small, is introduced to the system. The prognostic potential predictability (PPP) in the model of a climate variable X at time t is calculated:

$$PPP(t) = 1 - \frac{\frac{1}{N(M-1)} \sum_{j=1,N} \sum_{i=1,M} \left[X_{i,j}(t) - \underline{X}j(t) \right]^2}{\sigma^2}$$

$X_{i,j}$: run i of ensemble j, $\underline{X}_j$: mean of ensemble j, N (M): number of ensemble runs, σ^2: variance of control run.

A PPP of 1 shows perfect predictability while a value of 0 shows no predictability at all. The 95%-significance level (using a F-test) varies between values of 0.2 and 0.3 depending on the decorrelation time of the different variables. Furthermore, the gain of predictability of the ensemble experiments in comparison to the predictability gained by the autocorrelation of the control run is analyzed ($PPPa=PPP-r^2_{auto}$).

Results:

Arctic sea ice thickness shows a high predictability in the first two years in most areas of the central Arctic, the Canadian Archipelago and in the Labrador Sea (fig. 1). A large part of this predictability is due to the persistence of sea ice thickness. However, in an area from the Laptev Sea across the North Pole to Fram Strait and along the east coast of Greenland and in the Labrador Sea, the persistence explains only a small part of the predictability. This gain of predictability is attributed to the advective character of the climate mode mentioned above. Also air temperature and surface salinity show a quite strong gain of predictability in the Labrador Sea in comparison to the predictability by the autocorrelation. The largest PPP of 2m air temperature after one year occurs in the northern North Atlantic and in the northern North Pacific (fig. 2). Here, significant predictability lasts for several years. Beside a relatively high autocorrelation, advection of sea surface temperature anomalies into these areas lead to high and long-lasting predictability. Over the continents and in the ice-covered Arctic, the one-year predictability of air temperature is much smaller than over the oceans. Only in parts of southern Europe, southern Asia and in Alaska, PPP is significant. PPP of spring (MAM) temperature is significant in most of Europe with a lead time of 2 to 4 months. In contrast to air temperature, the predictability of sea level pressure is generally quite small and do not show any land – sea contrast. Also the predictability of the NAO is not significant.

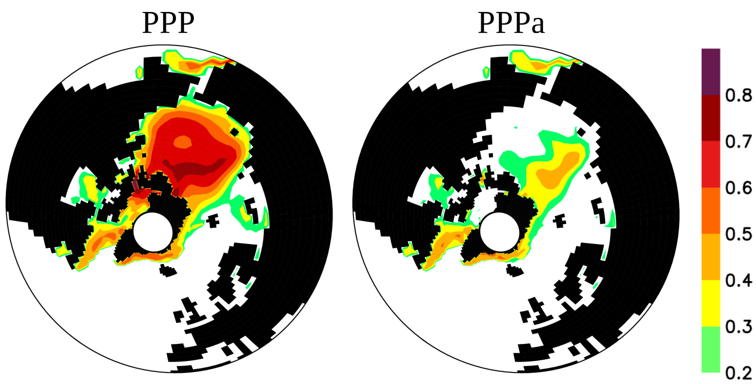

Fig.1: Predictability and gain of predictability compared to predictability of the autocorrelation for winter centered annual mean sea ice thickness after one year.

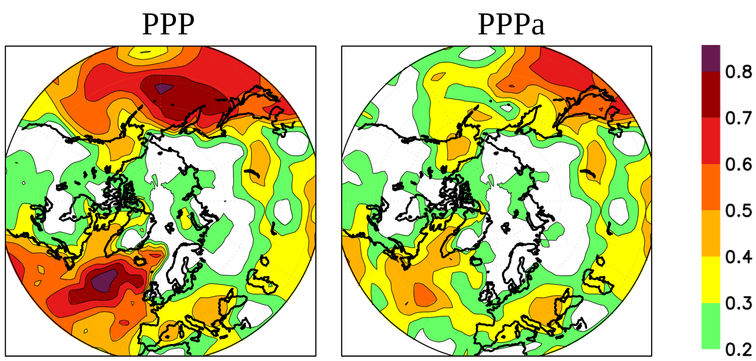

Fig.2: Predictability and gain of predictability compared to predictability of the autocorrelation for winter centered annual mean 2m air temperature after one year.

Outlook:

Further predictability experiments are planned: Sets of ensemble simulations with initial conditions from summer, from high/low NAO-cases, high/low sea ice exports shall be performed. Larger perturbations in the different ensemble members shall be used to get more realistic initial conditions.

References:

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