Project:: **1034**

Project Title: **JPI CLIM Belmont-Forum InterDec-MPI: The potential of seasonal-to-decadal-scale inter-regional linkages to advance climate predictions**

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Abstract

InterDec-MPI aims at understanding the origin of decadal-scale climate variability in different regions of the world and the linkages between them by using observational data sets and through coordinated multi-model experiments. How can a decadal-scale climate anomaly in one region influence very distant areas of the planet? This can happen through atmospheric or oceanic teleconnections. Fast signal communication between different latitudinal belts within days or weeks is possible through atmospheric teleconnection, whereas communication through oceanic pathways is much slower requiring years to decades or even longer. Understanding these processes will enhance decadal climate prediction of both mean climate variations and associated trends in regional extreme events.

Several important issues have emerged over the past year from intense scientific discussions, both within InterDec consortium and the larger international scientific community (within the framework of the newly established Polar Amplification MIP, H2020 Blue-Action and APPLICATE projects) and made us readjust the focus of our modelling activities during the first year of the project. Accordingly, a number of sensitivity experiments are currently been performed to test the potentially substantial impact (Nakamura et al., manuscript in preparation) of the chosen daily SST & Sea-Ice boundary forcing data set and of various specifics of the experimental setup (e.g. such as a varying sea-ice thickness vs. a fixed 2m value as currently used in standard ECHAM6.3 stand-alone simulations) on the strength of Arctic-lower latitudes linkages, before proceeding with the planed InterDec coordinated experiments. The impact of model resolution on the atmospheric and coupled model biases that could influence the realism of simulated Northern Hemisphere mid-to-high latitudes teleconnections has also been investigated by employing statistical techniques and sensitivity experiments, as well as dynamical pathways leading to cold climate extremes over Eurasia in the MPI-M Grand Ensemble Historical simulations. Due to the delay in releasing the MPI CMIP6 model configuration we have decided to postpone to 2018 the planned InterDec coupled model experiments.

Pathways leading to cold climate extremes over Eurasia in the MPI-M Grand Ensemble Simulations

Previous studies investigating the impacts of Arctic sea ice depletion on the Northern Hemispheric climate and extreme weather events have reported controversial results. Here we have focused on extreme temperature over central Eurasia and their dynamical precursors in the Stratosphere, Troposphere and Cryosphere in the 100-member MPI Historical Grand Ensemble simulations. The ensemble mean trend of surface air temperature (SAT) during the recent global warming hiatus period (1991-2014) has been found to be dominated by the characteristic signature of the Arctic Amplification featuring a hot-spot of warming over the Kara region. However no evidence of the recent cooling trend over central Asia has been found. With view to investigate whether cold climate extremes and the internal variability associated with them are actually captured by the MPI-ESM1.2 model, we identify episodes of cold/warm extremes over central Asia and investigate their dynamical environment. Our first results suggest that in the troposphere, up to 2 months prior to both early and late winter cold events, an anomalous ridge can be identified over the arctic basin possibly signifying the prevalence of a negative Arctic Oscillation phase (Fig. 1). This precursor signal is earlier and stronger prior to late winter (March) cold events compared to early winter (December) cold events. Most importantly, for March cold events there is also evidence of a precursor in the form of a vortex weakening (Fig. 2). On the other hand for December events, the link between the stratosphere and troposphere is mostly upward.

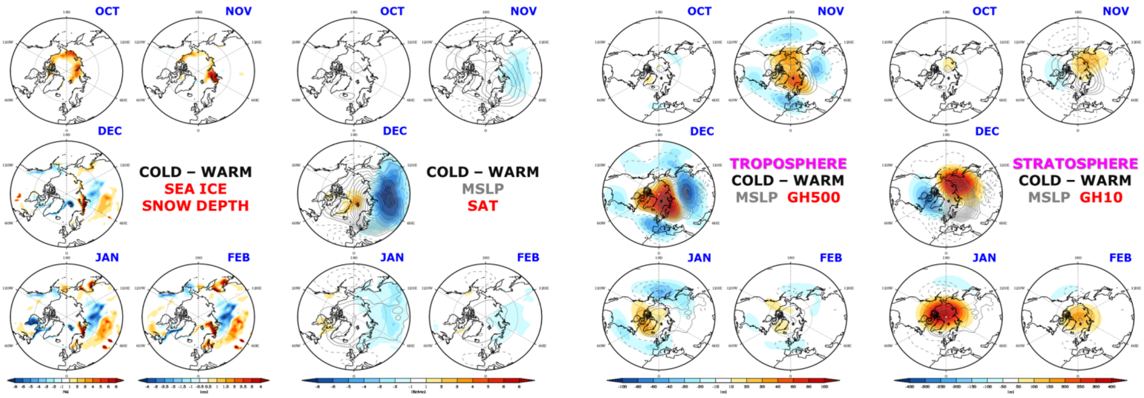

Figure 1. Temporal evolution of composite difference (cold – warm) for MSLP (grey contours, hPa), geopotential height (shades, m) at 10 and 500 hPa, sea ice concentration (shades, %) over water, snow depth (shades, m) over land and SAT (shades, Kelvin) prior and after extreme SAT events over central Asia that are identified in December. Cold and warm extremes are identified based on a quantile analysis performed on the monthly mean timeseries of SAT that is averaged over central Asia. Cold (warm) extremes correspond to the lower (upper) 25% of the identified events during the period 1991-2014.

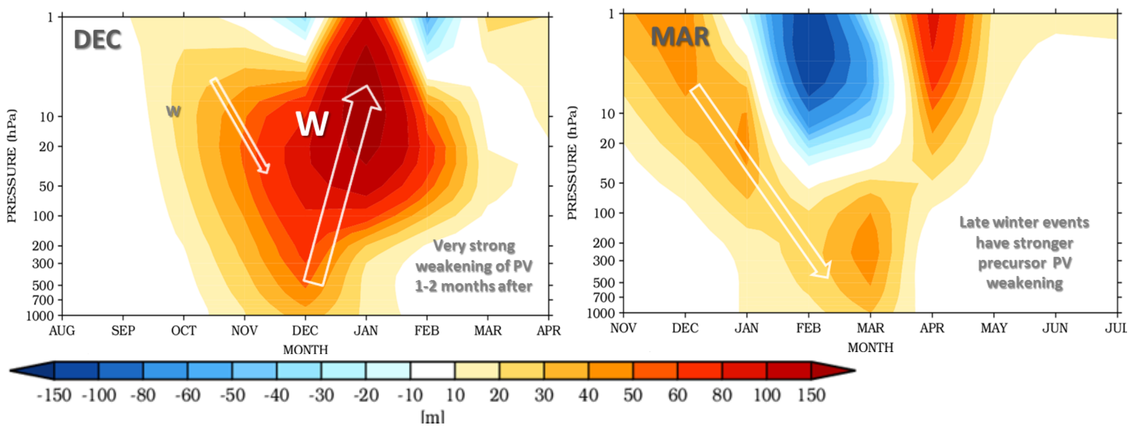

Figure 2. Temporal evolution of the vertical distribution of the Polar Cap Height Index (PCHI) prior and after December (left) and March (right) cold events identified over central Asia. Cold extremes are identified on the basis of a quantile analysis performed on the monthly mean timeseries of SAT averaged over central Asia. Cold extremes shown here correspond to the lower 10% of the identified events during the period 1985-2014. The PCHI is defined as the area averaged Geopotential Height poleward to 70^{o}N. The color shades represent anomalies (in meters) from the corresponding climate for each month. Positive values denote a weakening of the polar vortex.

In our model setup, it is very interesting that a positive sea-ice anomaly over the arctic coast of Asia precedes the cold extremes over central Asia. During the extremes, the sea-ice extent over the Kara-Barents Seas seem to behave like as a 'slave' to the above mentioned large-scale atmospheric circulation. The sea-ice anomaly features an east-west dipole with enhanced sea-ice cover in the vicinity of the Kara Sea and reduced sea-ice cover on the western flanks of the anticyclone where warm atmospheric advection occurs under a stronger southwesterly flow. The amplification of the Ural anticyclone is associated with a diversion of synoptic activity that is typical of blocking occurrence. Namely, a southward displacement in the path of synoptic systems could be connected with less precipitation and thus, decreased snow depths along the northern coast of Asia. On the other hand, higher snow accumulation is observed over central Asia with colder than normal conditions (Fig. 1).

Towards a stable high resolution MPI-ESM1.2 model setup

In order to finalize the atmosphere dynamical tuning of the high-resolution model to be used in the PRIMAVERA and InterDec project, we have conducted a control experiment and two sensitivity experiments with the MPI-ESM1.2-XR (T255L95/TP04L40) model. The control experiment uses the standard setting of the two atmospheric gravity wave parameterizations (GWP) active in the MPI-ESM1.2 model. In each of the sensitivity experiments a GWP (*"no orographic GWP"*, *"no non-stationary GWP")* is switched off. The motivation is to test if a reduction of the momentum forcing from the GWPs could lead to an improvement of the mean climate, given that a large part of the wave spectrum is resolved at the XR resolution with respect to previous MPI-ESM versions. To compare the model sensitivity to the GWPs with the model bias, climatology from ERA-Interim re-analysis is used (1979-2016, 38 years in total). Given that the control and the two sensitivity experiments use pre-industrial conditions, the comparison with ERA-Interim needs to consider as well a difference due to climate change in addition to a model bias. Nevertheless, from Fig. 3 (and the additional diagnostics we have carried out) we deduce that a reduction of the momentum forcing by GWPs may be indeed beneficial, given that it would reduce the SLP over the poles and increase it at mid latitudes, and so lessen the bias suggested by the comparison with ERA-Interim. Of interest is as well to note, that also the *non-stationary GWP* leads to a signature on SLP, given its indirect impact on planetary waves.

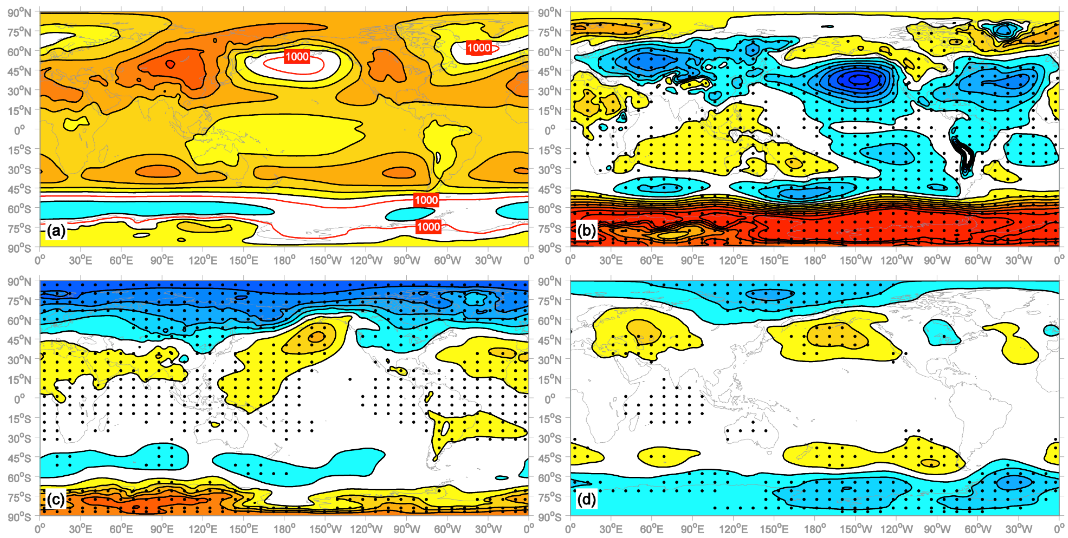

Figure 3: Sea level pressure, December to February mean. (a) Mean climatology from the control experiment. (b) Difference control experiment minus ERA-Interim climatology. (c) Difference "no orographic GWP" minus control experiments. (d) Difference "no non-stationary GWP" minus control experiments. For a, the contour interval is 5 hPa. For b-d, the contour interval is 1.2 hPa, contours start from ± 0.6 hPa. Stippling indicates anomalies that are statistically significant at the $p < 0.10$ level based on a two-tailed Monte-Carlo test.