Project title: PAMIP: Polar Amplification Model Intercomparison Project
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Report on performed simulations and results

In 2020 we have performed eight PAMIP experiments with ECHAM 6.3 in HR resolution: 1.1 (present-day sea ice, present-day sea surface temperature (SST)), 1.2 (pre-industrial sea ice, pre-industrial SST), 1.3 (present-day sea ice, pre-industrial SST), 1.4 (present-day sea ice, future SST), 1.5 (pre-industrial Arctic sea ice, present-day SST), 1.6 (future Arctic sea ice, present-day SST), 3.1 (future Okhotsk sea ice, present-day SST), 3.2 (future Barents-Kara-Sea ice, present-day SST). Furthermore, we have carried out a thorough analysis of these experiments in terms of temperature, mean flow, waviness, blocking, and EP fluxes. As already concluded in 2019, in response to Arctic sea ice loss the mean flow is changed towards weaker westerlies and a southward shift of the jet stream. In north-eastern North America, eastern Europe / Western Asia, and north-eastern Siberia the winter 2 m temperature is increased while in the south of North America and parts of Central Asia the 2 m temperature is decreased as a response to future Arctic sea ice conditions (Fig. 1).

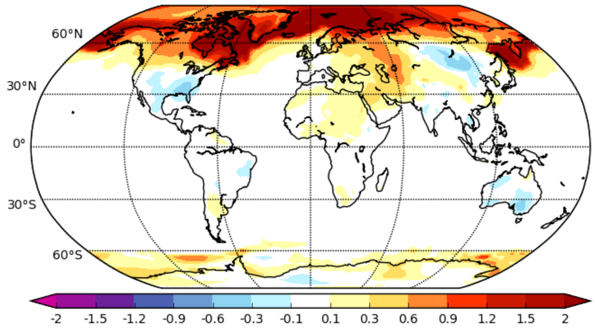

Fig. 1: Response of winter (DJF) 2 m temperature to future Arctic sea ice conditions (2°C warming world) compared to present-day Arctic sea ice conditions while leaving the SST at present-day conditions.

There is a slight tendency to increased high-latitude blocking as a response to future Arctic sea ice conditions and a tendency towards less blocking in mid-latitude areas when considering the blocking index by Davini et al. (2012) (Fig. 2).

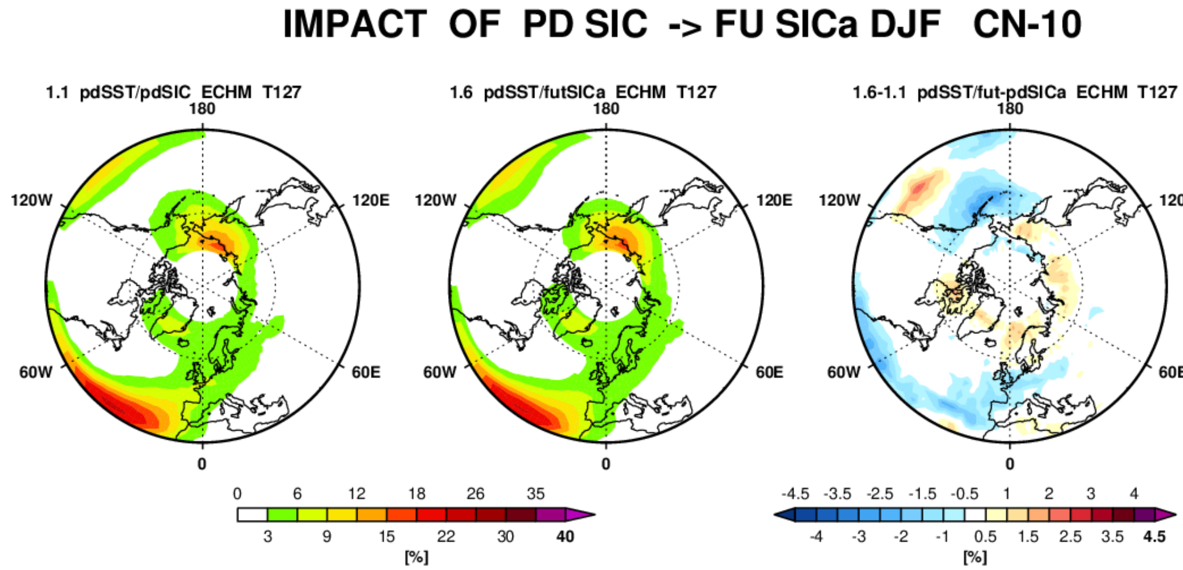

Fig. 2: Winter (DJF) climate of blocking episode frequency obtained by the blocking algorithm introduced by Davini et al (2012) from (left) the ECHAM 6.3 present-day sea ice, present-day SST ensemble (experiment 1.1) and (middle) the ECHAM 6.3 future Arctic sea ice, present-day SST ensemble simulations (experiment 1.6). The right panel shows the difference future Arctic sea ice minus present-day Arctic sea ice.

In response to SST increase, the mean flow is changed towards intensified westerlies and a northward shift of the jet stream. The mean climate is clearly affected but there are only weak changes regarding waviness, blocking or meandering of the flow.

Since stratosphere-troposphere coupling is deemed to be important, to investigate if waviness, blocking or meandering of the flow may be affected by changed sea ice conditions when considering stratospheric ozone chemistry, we performed extensive tests and first simulations with ECHAM 6.3 in HR resolution coupled to the stratospheric ozone chemistry module SWIFT. Romanowsky et al. (2019) show that the inclusion of stratospheric ozone chemistry with SWIFT have a positive impact on large-scale linkages during winter. The more extensive PAMIP simulations have the potential to better understand the processes involved and gain more robust information about future impacts. Figure 3 shows the temperature profile averaged over 65°N to 88°N from 1st of June to 31st of May of the next year of the two 1.6 experiments (future Arctic sea ice with present-day SST). Significant anomalies - in this case a cooling effect from mid-December to end of January - show the potential impact on the large-scale circulation. We found an error in the initialization of the ozone climatology of the SWIFT version implemented for the PAMIP simulations. We now understand how this happened, and tests are ongoing at the moment.

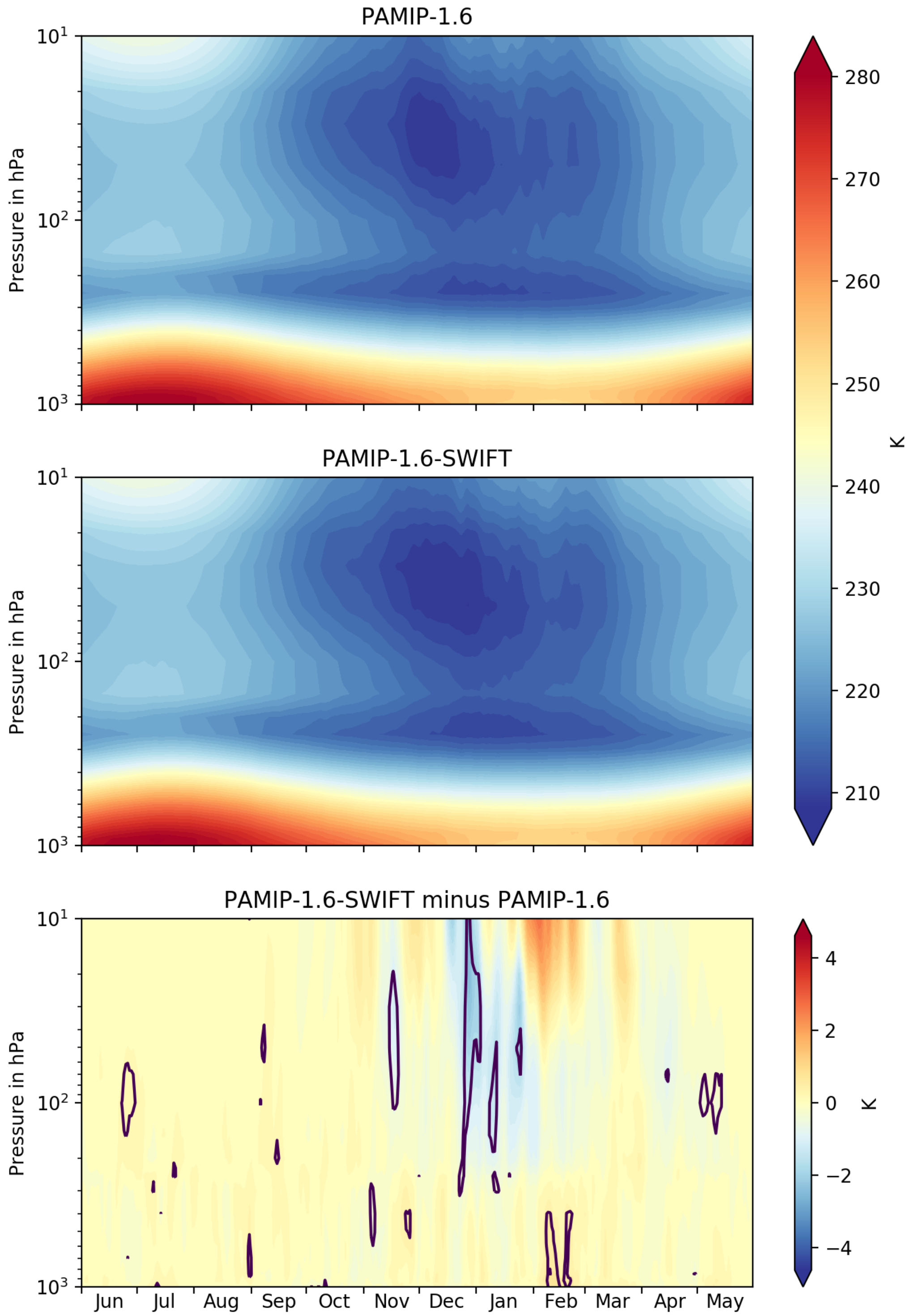

Figure 3: Temperature profile from 1st of June to 31st of May from (upper panel) ECHAM6.3 HR without the stratospheric ozone chemistry module SWIFT, (middle panel) ECHAM6.3 HR with SWIFT, (lower panel) difference with minus without SWIFT. Black lines indicate anomalies exceeding a 95% significance level.

The work is part of the EU projects APPLICATE (coordinated by AWI) and Blue Action (co-led by MPI); in addition, PAMIP is endorsed by CMIP6. Therefore, results are gaining good visibility. It is the first time that polar amplification and its impacts on mid-latitudes is studied in an internationally coordinated way. The data of the correct PAMIP simulations with ECHAM

6.3 without SWIFT have been published at the Earth System Grid Federation (ESGF) node at DKRZ and are therefore accessible to scientists around the world.

Results have been presented beginning of 2020 in Louvain-la-Neuve (Belgium) at the APPLICATE General Assembly. Here they were compared to other model simulations run according to the same protocol. Our results are also used in a paper by Smith et al. (2020), an overview paper on the main results of the PAMIP exercise. In addition, we are working on a paper on our results more specifically regarding troposphere - stratosphere interactions, impacts on blocking and meandering.

References

Davini, P., C. Cagnazzo, S. Gualdi, and A. Navarra, 2012: Bidimensional Diagnostics, Variability, and Trends of Northern Hemisphere Blocking. J. Climate, 25, 6496-6509, https://doi.org/10.1175/JCLI-D-12-00032.1.

Romanowsky, E., Handorf, D., Jaiser, R. et al. The role of stratospheric ozone for Arctic-midlatitude linkages. Sci Rep 9, 7962 (2019). https://doi.org/10.1038/s41598-019-43823-1

Smith et al (2020): Robust influence of reduced Arctic sea ice on mid-latitude winter atmospheric circulation, in preparation