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Arctic Amplification Experiments

In InterDec, we are analyzing atmospheric model experiments performed in collaboration with AWI (Alfred-Wegener-Institut) and the Polar Amplification Model Inter-comparison Project (PAMIP, Smith et al 2019, Cohen et al 2018). A number of experiments have been considered, with the ECHAM6 atmosphere model, forced with combinations of present day (pd), preindustrial (pi) and future sea ice concentration (SIC) and sea surface temperature (SST). Here we summarize preliminary results from the three experiments (see Table 1).

Table 1. *PAMIP experiments (excerpt from Smith et al 2019)*

No.	Experiment name	Description	No. of years	No. of realizations
1.1	pdSST & pdSIC	Time slice forced by climatological monthly mean SST and SIC for present day conditions	1	100
1.2	piSST & piSIC	Time slice forced by climatological monthly mean SST and SIC for preindustrial conditions	1	100
1.3	piSST & pdSIC	Time slice forced by preindustrial SST and present day SIC	1	100

The goal of the time slice experiments is to isolate the atmospheric short-term response to sea ice changes, a first step in addressing the challenge of separating the impacts of Arctic Amplification, internal variability and background warming.

The focus is on Artic Amplification, because of its potential to impact the climate of Eurasia. To search evidence for the sea ice loss impacts, the responses to the combined and separate changes in SIC and SST are compared, making use of the experiments described in Table1. Given the potential role of the stratosphere in enhancing the midlatitude response to sea ice loss (e.g. Screen et al 2018), the responses of the high latitude (60°N) zonal mean zonal wind are compared (Figure 1).

The combined change in SIC and SST leads to a weakening of the tropospheric westerly jet (negative anomalies, Figure 1a) for the entire extended winter season, from October to March. This weakening is indicative of a southward shift of the eddy-driven jet and it is particularly strong from mid-November to end December and in March. In the stratosphere, two episodes of vortex weakening are seen: around mid-December and end of February.

Next, the contributions of either the SIC or the SST changes to the zonal wind response are separated. Clearly, the SIC change (Figure 1b) leads to a general weakening of the high latitude zonal winds, both in the troposphere and the stratosphere. In the stratosphere, the episode of mid-December reported previously is found again and a following one appears at the end of January. Given the continuous occurrence of pulses of negative anomalies in the troposphere from October to March, it seems that the troposphere is responding to the SIC change throughout the season, roughly independently from the stratosphere. The stratospheric episodes may have however contributed to reinforce subsequent tropospheric pulses.

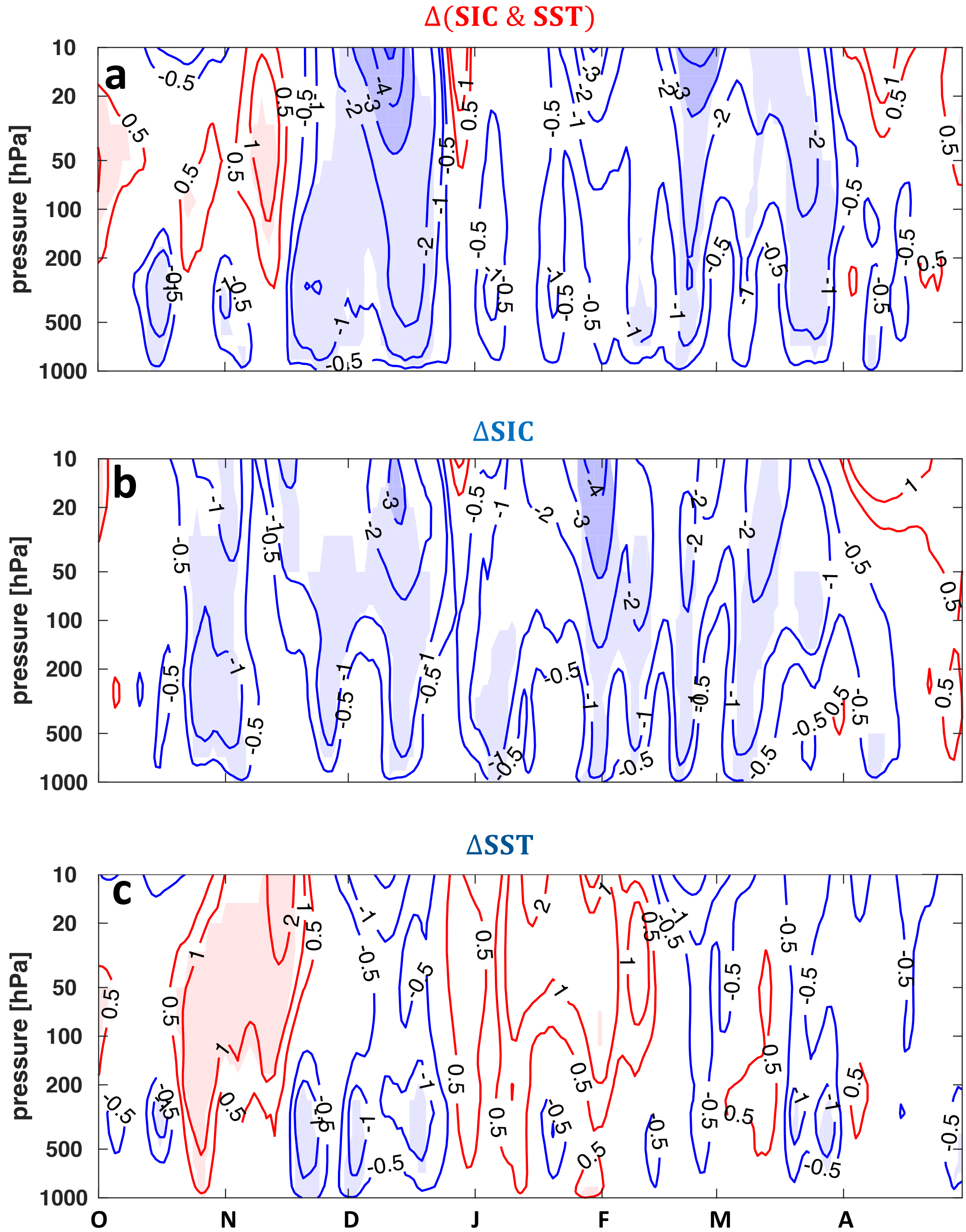

Figure 1. *Response of the zonal mean zonal wind (ms[-1]) at 60ºN, 5-day running mean daily evolution from 1 October to 30 April, ECHAM6 model, PAMIP experiment differences: (a) experiment 1.1 minus experiment 1.2; (b) experiment 1.3 minus experiment 1.2; (c) experiment 1.1 minus experiment 1.3. Shades: 90% significance level.*

The response to the SST change (Figure 1c) is instead generally insignificant. The exception is at the end October and in early November, when a positive anomaly is found. This positive anomaly is the signature of a stronger and poleward shifted tropospheric westerly jet, the typical response of the atmospheric circulation to global warming (Manzini et al 2014). The response to the SST change appears therefore to slightly opposes the response to the SIC change, so that the net effect of the combined response may be insignificant, as for instance during the month of January (Figure 1a).

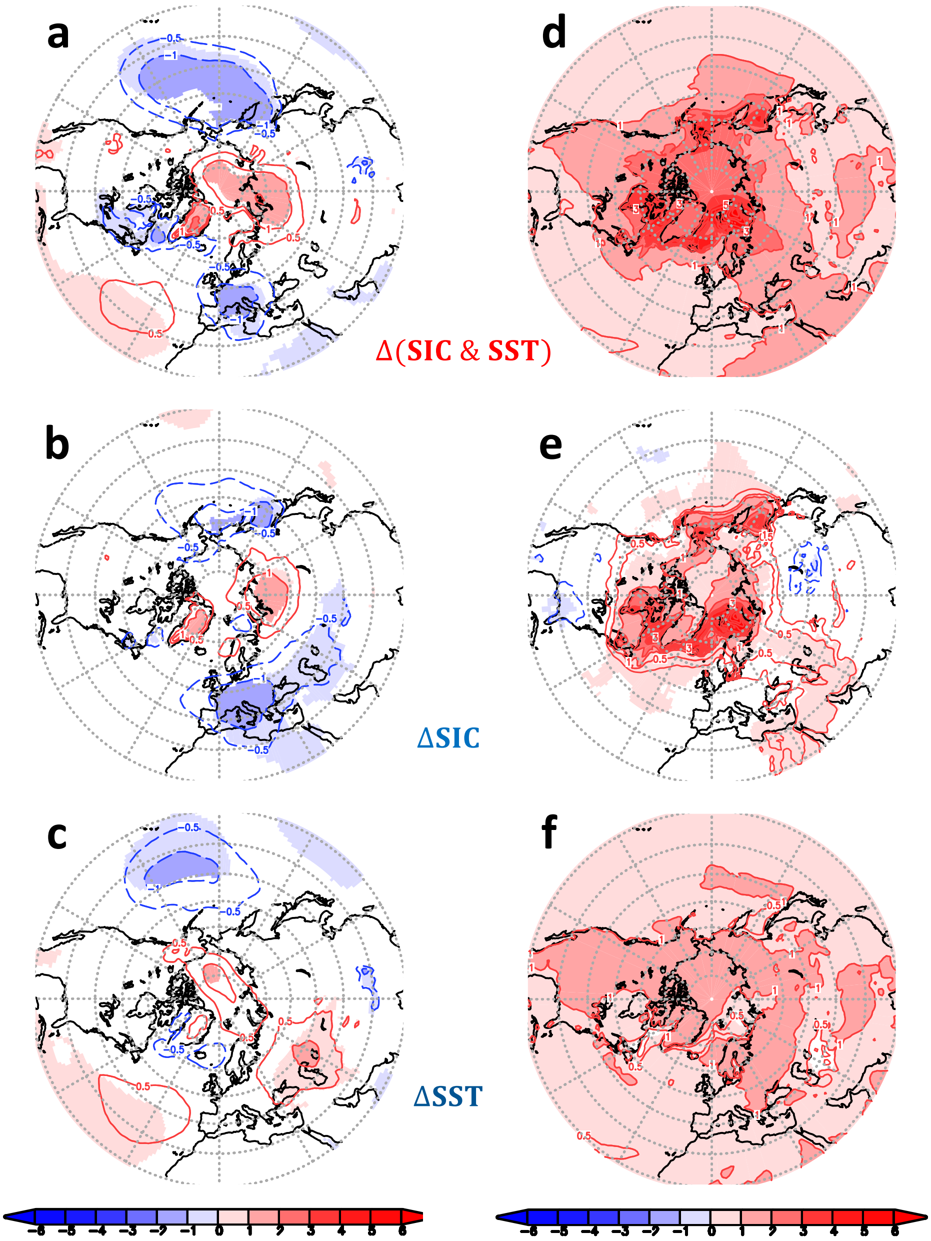

Figure 2. (left) Correlations between the PC1 and AO time series. The pdf of the correlation from the ALL experiment (brown bars) and the SICclim experiment (sienna filled bars). The brown and sienna vertical lines are the corresponding ensemble means. The black line is the correlation in ERAI. (right) Trends in 10 hPa zonal mean zonal wind averaged between 55ºN-65ºN. The pdf of the trends from the ALL experiment (brown bars) and the SICclim experiment (sienna filled bars). Brown and sienna vertical dashed lines (not significant at 5% level) show the corresponding ensemble means. The black vertical dashed line shows the same in ERAI and the associated black horizontal line shows the 95% confidence interval of that trend. From Gohsh et al (2020).

The high latitude zonal wind weakening is generally thought of resulting from higher pressure anomalies in the Arctic, the North Atlantic, and the Eurasian regions (Screen et al 2018). Our experiments show indeed the typical enhancement of the winter Siberian high in response to sea ice loss (Figure 2a,b, December to February averaged response). However, the response over the Artic is absent when only SIC changes are imposed (Figure 2b). In addition, the high-pressure anomaly over the Atlantic is located rather south (south of ~40°N) and it is driven by the SST change (Figure 2c). Therefore, our experiments do not show evidence of a response in neither the Northern Atlantic Oscillation nor the Arctic Oscillation. The equatorward shift of the eddy-driven jet reported in Figure 1 is a consequence of the Siberian high enhancement (north of 60°N) and the low pressure over central and south Europe (south of 60°N).

The large near-surface warming in the local regions surrounding the central Arctic show where sea ice has been changed (Figure 2d,e) from the preindustrial to the present day conditions. The near-surface warming is particularly large over the Barents See. This result confirms the central role of the Barents See region in driving the circulation changes over Eurasia (Figure 2be). Indeed, the near surface temperature response to the SIC change shows a cooling close to the Baikal Lake region and a warming in central Europe (Figure2e). This warming asymmetry in the 50°-60°N latitude band over Eurasia (30°-150°E) is absent when only the SST change is considered (Figure 2f).

In summary, the experiments have shown that the short-term response to sea-ice change from preindustrial to present conditions consists of an enhancement of the winter Siberian high and associated equatorward shift of the eddy-driven jet over central and south Europe. The enhancement of the winter Siberian high may be the result of an increase in atmospheric blocking (Mori et al 2014, Tyrlis et al 2019, 2020). The stratosphere does not play any relevant role, consistently with the ECHAM6 results reported for the InterDec experiments. Overall, the Artic Amplification in these experiments is contained within the Arctic (poleward of 60°N) and the Eurasian continent. Currently, the analysis is extended to include experiments form other models participating in PAMIP, to test the generality of the ECHAM6 results.

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