In 2021 the focus was on the experiments with the inclusion of the stratospheric ozone chemistry. We decided to extend the ensemble size of the reference experiment 1.1 (present-day sea ice, present-day sea surface temperature (SST)) to 300 after having realized that the signal only becomes robust at this ensemble size (Streffing et al., 2021). This has also been acknowledged by the international PAMIP community. We extended the ensemble size for both the HR version without and with interactively coupled stratospheric ozone chemistry (SWIFT). In addition, we started to compute experiments 1.5 and 1.6 with stratospheric ozone chemistry and plan to finish this work with the remaining computing time of 2021.

We used the extended ensembles of the PAMIP experiments 1.1 performed with ECHAM 6.3 (Exp11) and ECHAM6.3 coupled to SWIFT (EXP11T) in HR resolution to analyse how the interactively coupled stratospheric ozone chemistry can induce changes in the stratospheric circulation.

Polar cap mean temperature in Fig. 1 is a measure for the state of the polar vortex during winter. A stratospheric warming indicates a more instable or even collapsing polar vortex, whereas a cool stratosphere corresponds to a stable vortex. The difference between the two PAMIP 1.1 ensembles shows a stratospheric cooling in early winter, some pulses of warming during late winter and a warming in March. Furthermore the lower stratosphere shows an almost continuous weak cooling throughout the winter. None of these anomalies are significant. Nevertheless, the signal indicates an improvement, since Stevens et al. 2013 find that the stratospheric polar vortex is too warm in ECHAM6. In particular very early vortex weakenings are potentially reduced when SWIFT is enabled in the model.

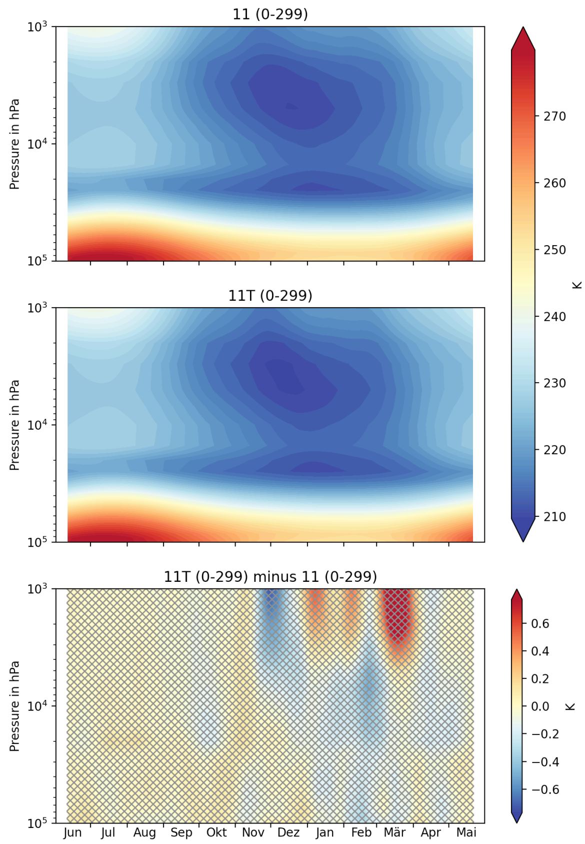

Figure 1: Temperature difference averaged over polar cap between 65°N and 88°N in K. Top row: climatology of the PAMIP 1.1 ensemble. Middle row: climatology of the PAMIP 1.1T ensemble. Bottom row: difference between 1.1T and 1.1. Differences with FDR corrected significance below 0.95 are hatched.

To further analyze the occurrence of preferred stratospheric circulation patterns, we perform a regime analysis. It is based on daily fields of the geopotential height fields at 10 hPa north of 60N for the extended winter season from December to March for the combined model experiments 1.1 and 1.1T. 5 stratospheric circulation patterns have been detected by applying k-means cluster analysis. Fig. 2 shows these five patterns which reveal from left to right: a strong polar vortex (SPV), a less strong polar vortex (LSPV), a weak polar vortex (WPV), a polar vortex displaced towards Eurasia (DVEUR), and a polar vortex displaced towards North America (DVNAm). These patterns are in agreement with patterns detected by Kretschmer et al. (2018) for reanalysis data.

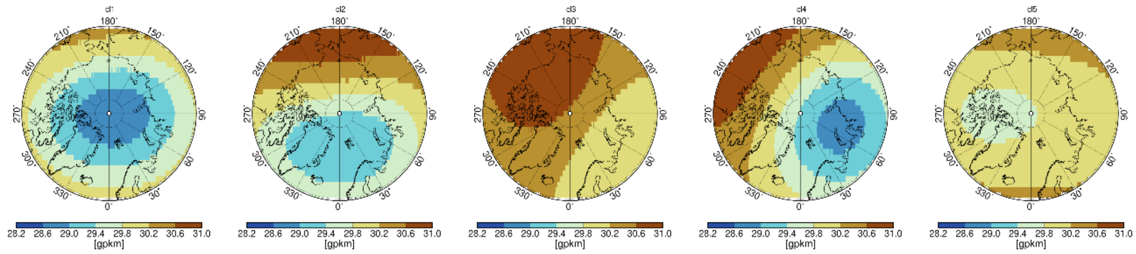

Figure 2: Mean geopotential height fields at 10hPa of the 5 stratospheric circulation regimes over the region north of 60N for the combined model experiments 1.1-1.1T (enlarged ensemble). From left to right: strong polar vortex (SPV), less strong polar vortex (LSPV), weak polar vortex (WPV), polar vortex displaced towards Eurasia (DVEUR), polar vortex displaced towards North America (DVNAm).

Changes in the frequency of occurrence of the five different circulation regimes between the model experiments 1.1 and 1.1T are shown in Figure 3. Color highlighting gives an easy view on increasing (red) and decreasing (blue) significant changes. Overall, the interactive ozone chemistry impacts the frequency of occurrence of circulation pattern most strongly in late winter, where in March we detected less frequent SPV and DVNAm occurrence, whereas WPV and DVEUR occur more often for the coupled ECHAM6-SWIFT experiment. In early winter (December), this response is almost inverse, except for the DVEUR (no changes) and the LSPV events (decreasing occurrence in all months for the coupled experiment). In particular the increase of SPV and decrease of WPV occurrence in early winter corresponds with the results in Fig. 1 indicating that the interactively coupled stratospheric chemistry leads to colder polar-cap mean stratospheric temperatures in early winter.

	WPV	SPV	DVNAm	LSPV	DVEUR
D	−2.1	1.1	2.1	−1.2	0
J	0.9	−0.4	1.2	−1.7	0
F	−1.5	0.9	1.3	−1.7	1
M	1.3	−1.2	−1.6	−1.1	2.6

Figure 3. Frequency changes of stratospheric circulation regimes in percent of days during the given month between ECHAM6 model experiments 1.1 and 1.1T. Regime names are explained in the text and Fig. 2. Coloring defines significance: 95% (lighter colors), 99% (darker colors)

References:

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