MSc Thesis

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1 Model Comparison

1.1 Surface temperature gradients

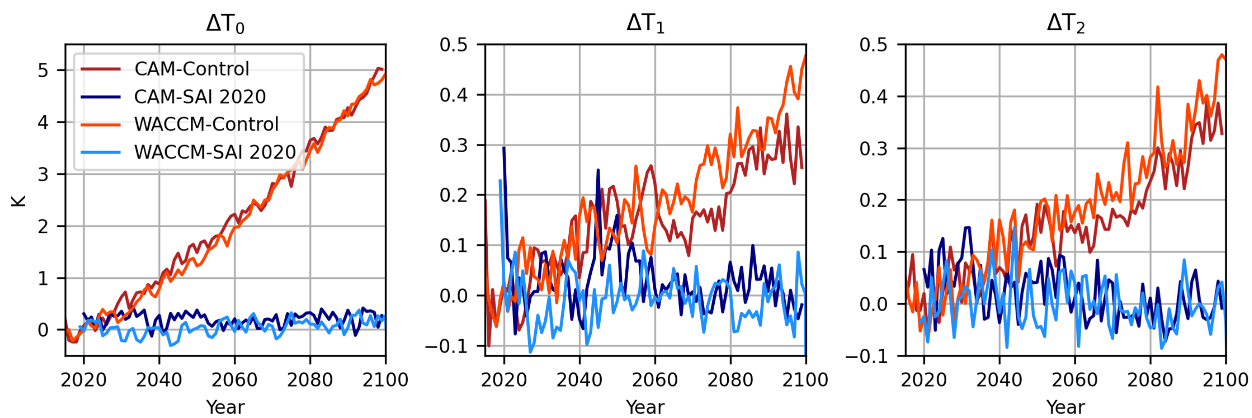

Figure 1: Temperature gradients T_0, T_1, T_2 as compared to 2016-2025 mean, for Control and SAI2020 scenarios in CAM and WACCM

The surface temperature gradients as described by Kravitz et al. are shown in Figure 1, we learn:

- The global mean surface temperature T_0 is very comparable in both scenarios between the models.
- Early century CAM-SAI2020 might be slightly higher, but in later century shows very similar behaviour to WACCM-SAI2020.
- Pole-to-pole gradient T_1 shows similar behaviour in the first few years, both WACCM and CAM show a clear increase compared to control after initialisation, followed by a stark drop down to reference levels.
- Early-mid century CAM-SAI2020 possibly more variability compared to WACCM-SAI2020, late century very similar.
- -> expected because the earosol field was taken from late century.
- Inter-hemispheric temperature T_2 also shows very similar behaviour in both scenarios.

- possibly more variability in early century CAM-SAI2020 compared to WACCM-SAI2020, but both seem to show a decrease in variabilty in late century.

TO DO:

- Apply some statistical analysis on these sets? Or is qualitative analasys enough? Maybe running mean and standard deviation? nah
- titels ipv y-labels maken

1.2 Reference Height Temperature

1.2.1 Annual Mean Anomaly

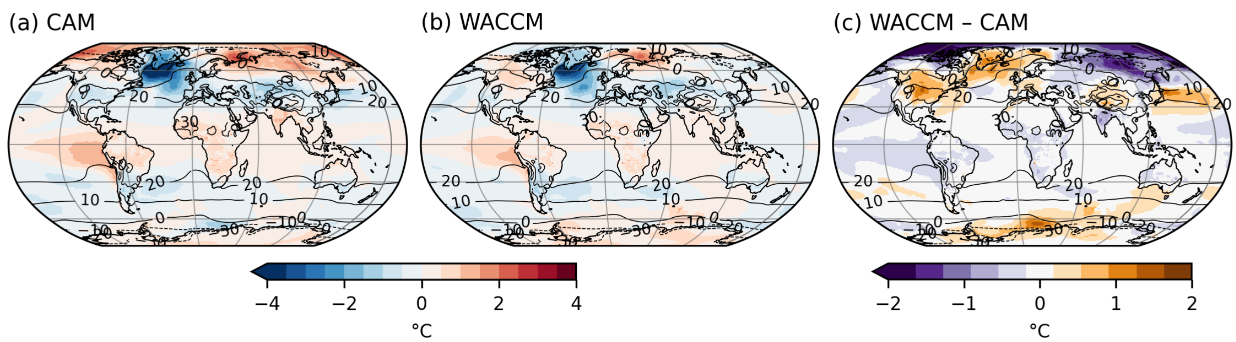

Figure 2: Annual mean reference height temperature anomalies of 2080-2099 SAI2020 scenario compared to 2016-2035 Control scenario in (a) CAM and (b) WACCM. Difference between temperature anomalies shown in (c). 2016-2035 Control mean temperature shown in black contours in 10°C intervals.

The annual mean reference height temperature anaomalies are shown in Figure 2, we learn:

- Spatial patterns of warming and cooling generally similar, warming over equator (especially eastern Pacific), cooling in subtropics, warming over the poles.
- Warming hole over North Atlantic present in both models, due to AMOC collapse in POP2 ocean model used for both CESM2 simulations.
- CAM shows clear warming in the Arctic (>1°C), slight warming in the Antarctic (<1°C)
- WACCM only shows significant warming over Barentsz sea (>1°C) and similar warming over the Antarctic compared to CAM.
- CAM warms more than WACCM in most of the Arctic, excluding Greenland. Tropics also experience slightly more warming in CAM.
- CAM cools more than WACCM in Greenland/North Atlantic, North America, Northwest Pacific and Southern Ocean South of Africa. Les clearly so on Tibetan Plateau.

TO DO:

- extract maximum and minimum temperature anomalies
- Why: difference in warming hole intensity? natural variability? of andere background conditions/fresh water fluxes form atm model
- Check isobars
- Colorbar scale - witte 0 maar hoeveel levels verder? Super custom maken?

1.2.2 JJA and DJF Seasonal Mean Anomaly

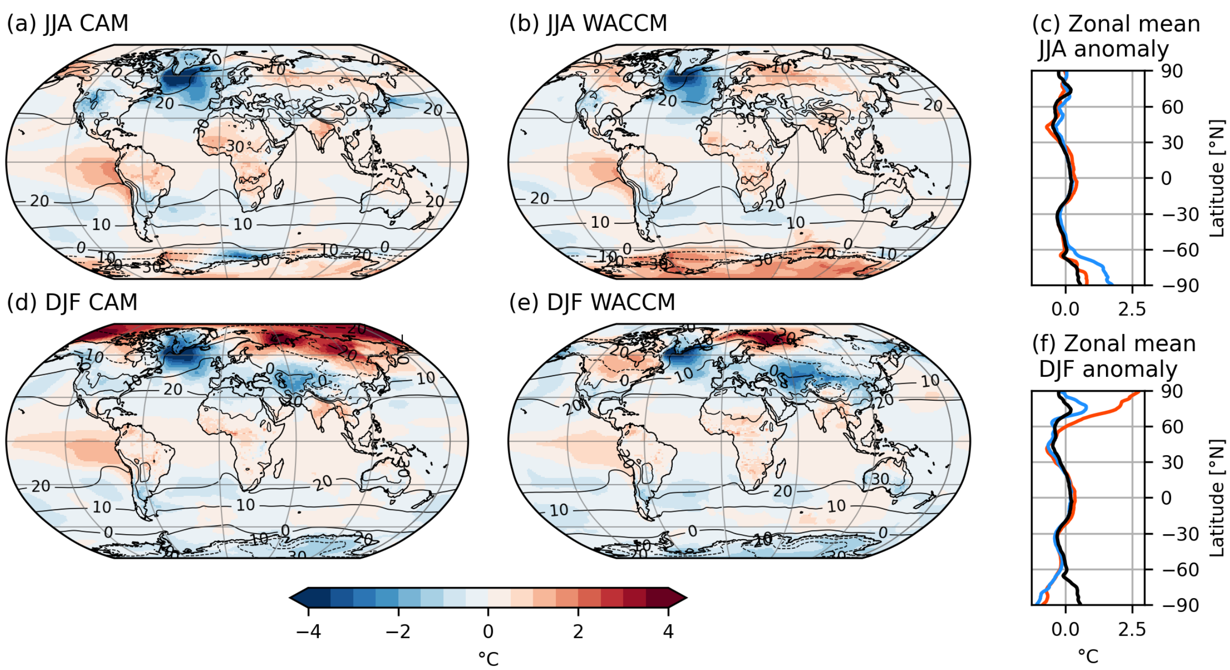

Figure 3: JJA and DJF seasonal mean reference height temperature anomalies of 2080-2099 SAI2020 scenario compared to 2016-2035 control scenario in (a),(d) CAM and (b),(e) WACCM. 2016-2035 Control mean temperature shown in black contours in 10°C intervals. Zonal mean temperature anomalies shown in (c) and (f)

The JJA and DJF seasonal mean reference height temperature anaomalies are shown in Figure 3, we learn:

- In **JJA** the warming hole is the largest anomaly for both CAM and WACCM, showing slight differences in intensity but overall similar extent.
- WACCM shows significantly more warming than CAM over the whole of the Antarctic, also represented in the zonal mean anomaly. WACCM shows slightly more warming over Western Siberia and Norhtern Canada.

- CAM shows more warming than WACCM over the Eastern Pacific, mainly showing warming over an much larger extent. CAM shows slightly more warming over Alaska, Western Africa and South Asia.
- in **DJF** the warming hole is still present in both CAM and WACCM, again larger extent and more intense in CAM.
- WACCM shows slightly more warming than CAM in the interior of Canada/Hudson Bay and slightly more cooling over Central Asia.
- CAM shows much more warming of the Arctic and Eastern Siberia than WACCM, also represented in the zonal mean anomaly. CAM shows slightly more warming over the Eastern Pacific again, as it does in JJA.

TO DO:

- figure out legend for line plot.
- Why: much more warming over Antarctic in WACCM? Possibly ozone hole, other dynamics? 20 jaar voor 2080 ook plotten om te kijken naar natural variability.
- Why: warming of Eastern Pacific, due to known behaviour of ITCZ in CAM?
- THESIS: interannual variability meer onderzoeken voor Arctic.

1.2.3 Annual vs. Seasonal

When comparing Figures 2 and 3 we learn:

- Most of the differences observed between WACCM and CAM are attributable to the winter months in the respective hemispheres.
- Overall the patterns observed in the anomalies are similar, most significant differences are observed in the Arctic and Antarctic.
- annual en JJA DJF samenvoegen
- zonal mean anomaly WACCM en CAM bundelen

1.3 Precipitation

1.3.1 Annual Mean Anomaly

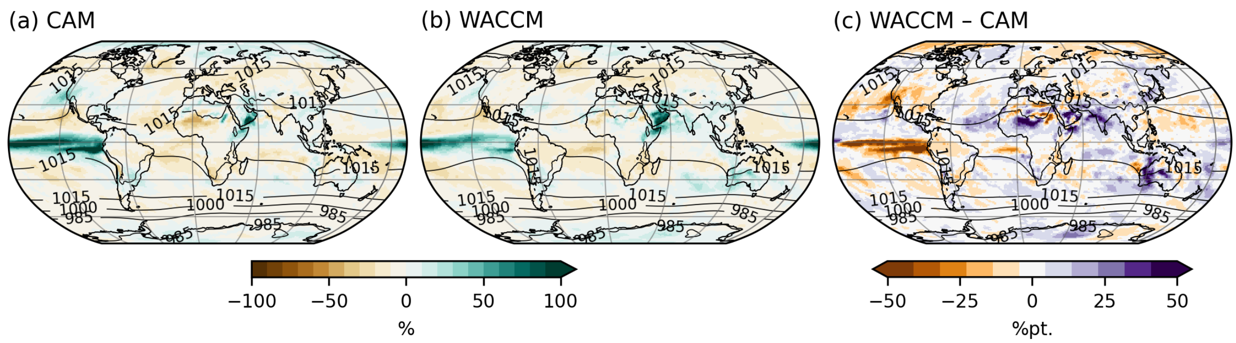

Figure 4: Annual mean precipitation anomalies of 2080-2099 SAI2020 scenario compared to 2016-2035 Control scenario in (a) CAM and (b) WACCM. Difference between precipiation anomalies shown in (c). 2016-2035 Control sea level pressure shown in black contours.

The annual mean precipitation anomalies are shown in Figure 4, we learn:

- Most areas in both CAM and WACCM follow 'wet gets wetter, dry gets drier'.
- CAM seems to have an overly active ITCZ over the pacific, though the pattern is similar to WACCM.
- Southern Arabic peninsula and Horn of Africa show similar patterns, now with WACCM showing higher increase in precipitation.

TO DO:

- check slp contours/gooi ze weg, voeg reference neerslag toe
- min/max aanpassen? ITCZ wordt wel raar

1.3.2 JJA and DJF Seasonal Mean Anomaly

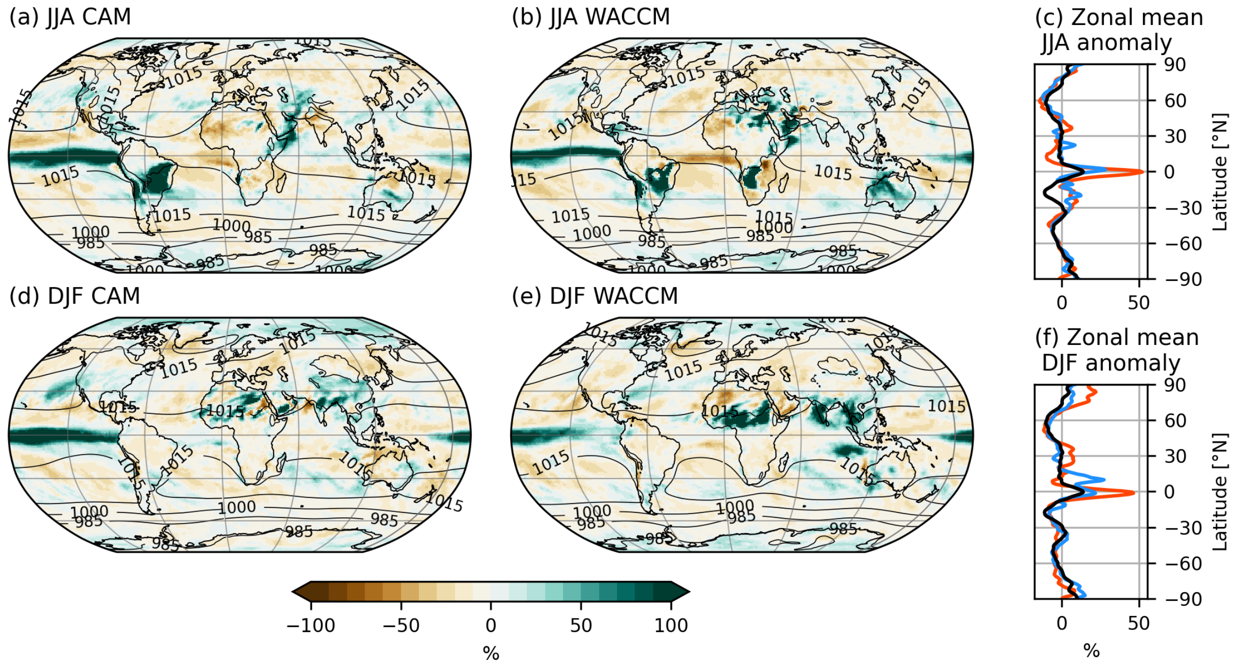

Figure 5: JJA and DJF seasonal mean precipitation anomalies of 2080-2099 SAI2020 scenario compared to 2016-2035 control scenario in (a),(d) CAM and (b),(e) WACCM. 2016-2035 Control mean sea level pressure shown in black contours. Zonal mean precipitation anomalies shown in (c) and (f)

The JJA and DJF seasonal mean precipitation anomalies are shown in Figure 5 we learn:

- In **JJA** the ITCZ over the pacific is again overly active in CAM, though again showing a similar pattern to WACCM.
- The higher intensity but similar pattern is also clearly visible in the zonal mean anomaly.
- WACCM shows large spots of more than doubling of rainfall in Brazil and Southern Africa, not very significant still because these areas receive very little rainfall. Same goes for the increase in Australia.
- In **DJF** the ICTZ is even more anomalous in CAM than it is in WACCM, now not showing too similar patterns anymore, mainly not increasing in WACCM in the East Pacific.
- In the Sahara region both WACCM and CAM show patches of doubling precipitation, again this is not significant as this area receives very little rainfall.
- WACCM shows a more intense monsoon in Southern and South-East Asia, whereas CAM shows more limited increase in rainfall in Southern Asia.
- The zonal mean anomaly shows that the Arctic is much wetter in CAM.

TO DO:

- figure out legend
- Why: is WACCM more sensitive for precipitation?
- waar regen niet significant is: arcering en/of weglaten?

2 Lower stratosphere wind

2.1 Eddy Kinetic Energy and Zonal Mean Zonal Wind

From Figure 6 we find:

- EKE around 50°S increases in control, together with U (±5 m/s), decreases in both SAI scenarios
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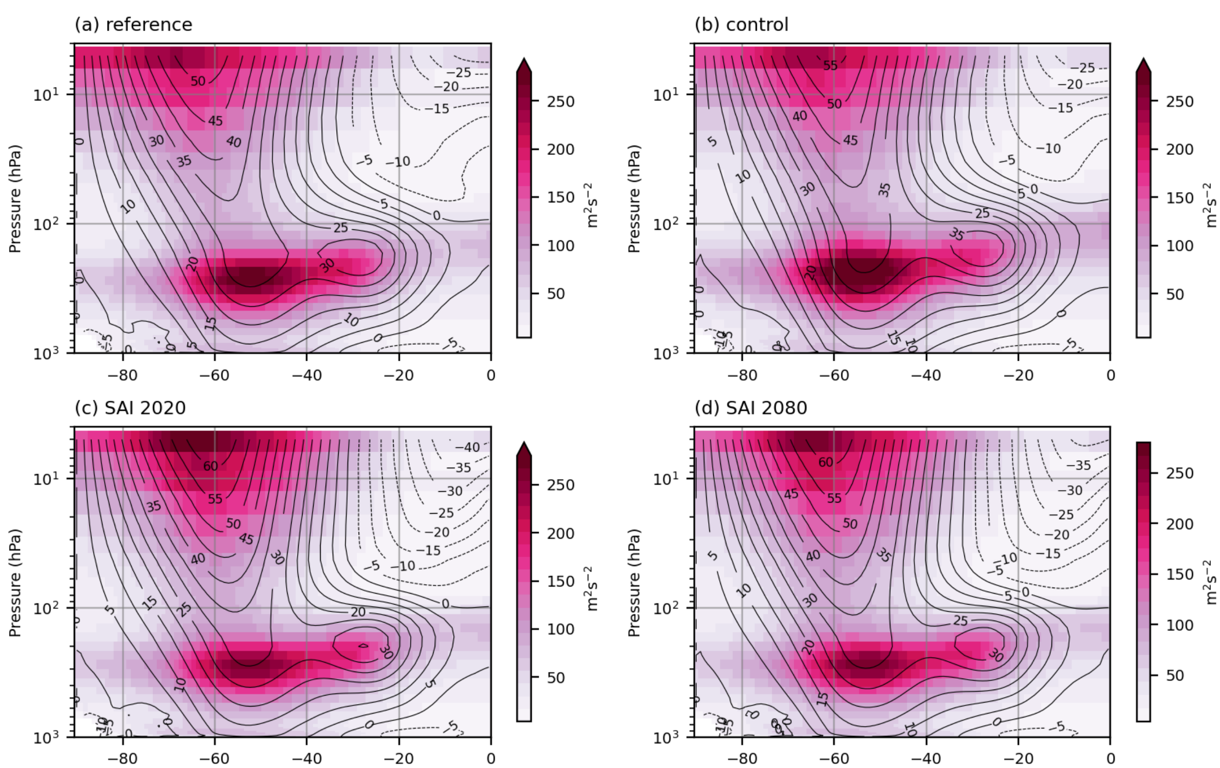

Figure 6: Zonal mean EKE in m^2/s^2 (shading) and zonal mean zonal wind (contours) in intervals of 5 m/s, annual mean for reference 2020-2039 and all scenarios 2111-2130

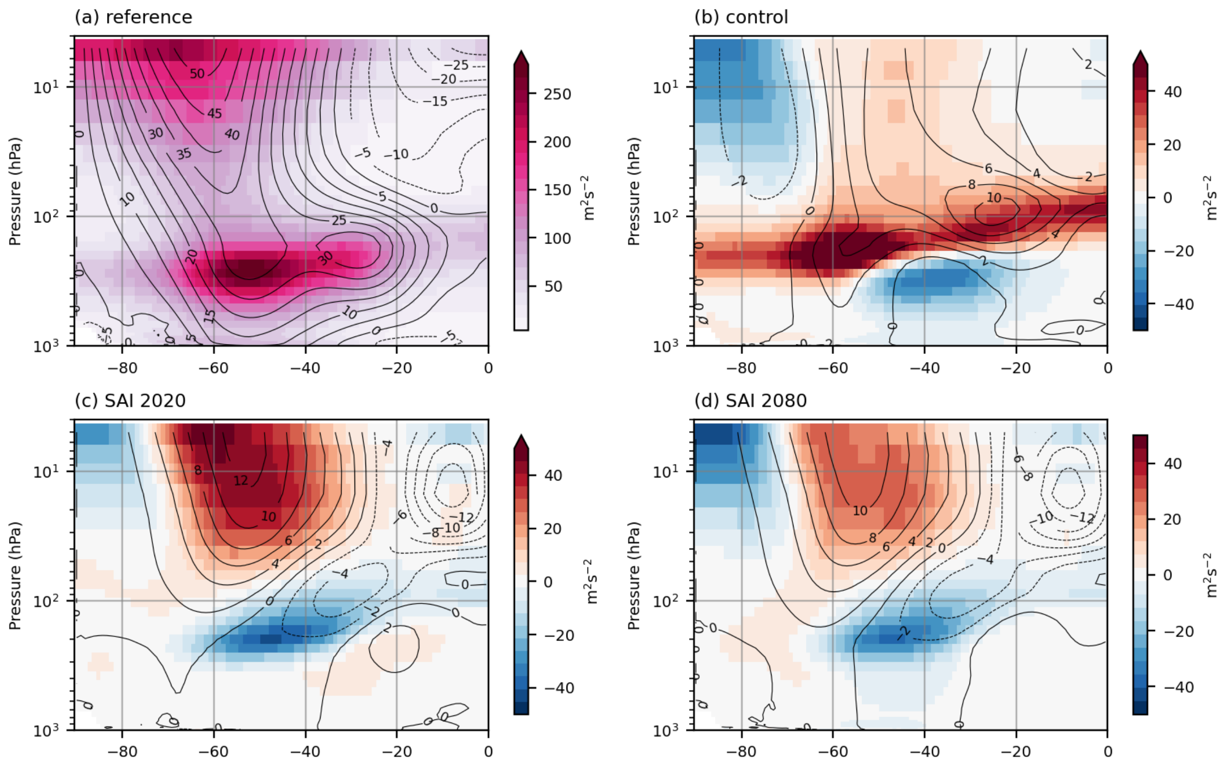

Figure 7: Zonal mean difference EKE in m^2/s^2 (shading) and zonal mean difference zonal wind (contours) in intervals of 5 m/s, annual mean for reference 2020-2039 and all scenarios 2111-2130 compared to reference

3 Polar Nigth Jet

From figure 8 we find:

- temperature lower in all scenarios: stratospheric cooling from increased CO2, most significant in summer months as expected due to higher solar irradiance
- wind speed in ASO higher in both SAI scenarios, consistently above 100 m/s
- earlier development of high winds/PNJ, about 20 m/s in june compared to both reference and control
- occurrence of prolonged sudden stratospheric warming events decreased, as can be inferred from the lower wind speeds and higher temperatures/greater spread at the end of the season
- SSW's could still occur after 2100 in the simulations in all scenarios but likely of much shorter duration, thus not showin up in monthly average values

TO DO:

- extend period to 30 years

- add 30-60°S mean T

From figure 10 we find:

- higher intensity for all scenarios compared to reference
- lower zonal wind speed in eastern pacific, WHY? compare to EKE and absolute wind speeds? appears to be no narrowing of jet

TO DO:

- add gridlines (to all maps)
- line of maximum at 10 hPa in same figure or additional figure?

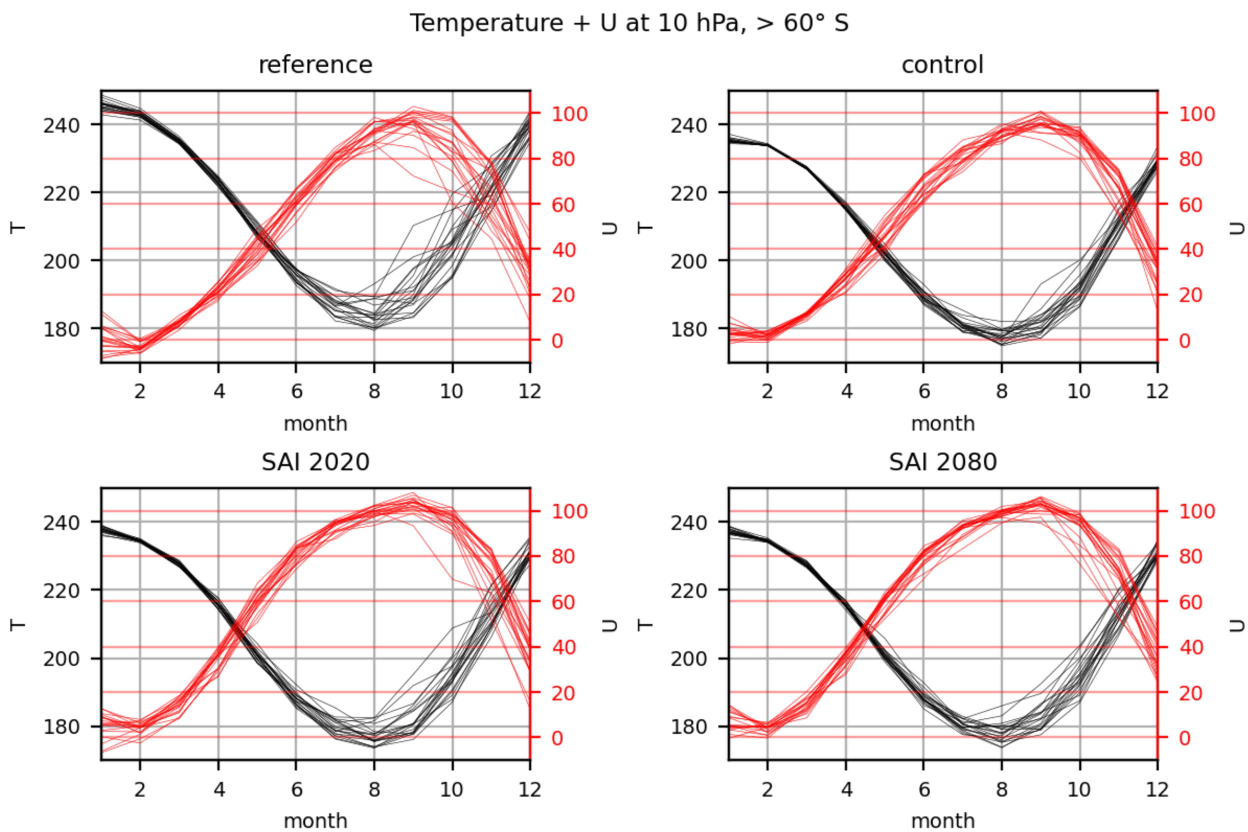

Figure 8: Mean temperature >60°S at 10 hPa in °C and zonal mean zonal wind at 60°S and 10 hPa in m/s. Shown are reference 2020-2039 and all scenarios 2111-2130

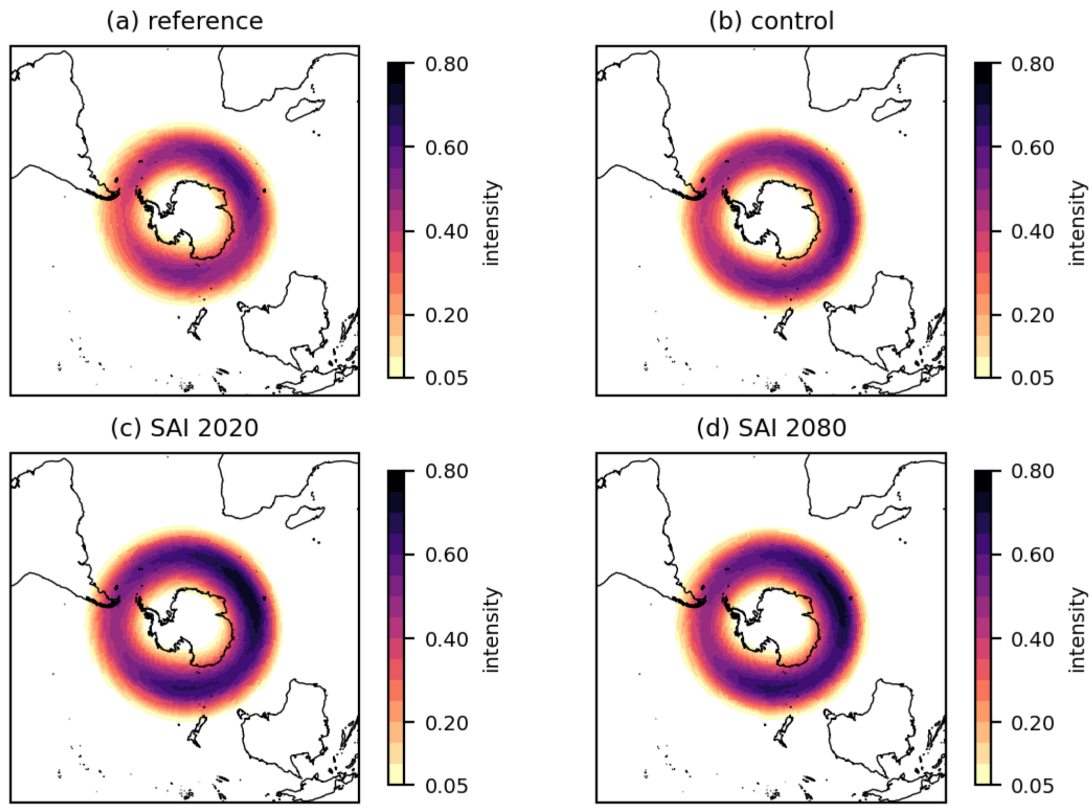

Figure 9: Map of PNJ intensity above 50 hPa (?). Fractional occurence of >90 m/s zonal winds in each grid cell, at each model level in the months august, september and october in each time interaval. Shown are reference 2020-2039 and all scenarios 2111-2130.

Figure 10: Map of PNJ intensity above 50 hPa (?). Fractional occurence of >90 m/s zonal winds in each grid cell, at each model level in the months august, september and october in each time interaval. Shown are reference 2020-2039 and all scenarios 2111-2130.