Vertical structure of 20th century temperature trends in an ensemble of all-forcing transient GCM runs

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1. Introduction and Data

Atmospheric models as well as theoretical considerations predict an amplification of global warming close to the surface in the Arctic (polar amplification) and in the upper troposphere in the Tropics and Subtropics. Over the last years there has been an active debate whether observations already show evidence for this characteristic or not.

In this study, we look at temperature trends in all-forcings 20th century runs of the global chemistry-climate model (CCM) SOCOL (Fischer et al., 2008) as well as in 2 observation-based datasets (statistical reconstructions (REC1, Griesser et al., 2010), Twentieth Century Reanalysis (20CR, Compo et al., 2011)), focusing on the Arctic (60°N-90°N) and the tropical and subtropical (30°S-30°N) region.

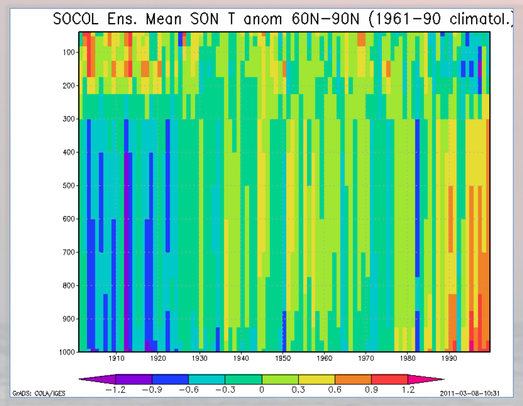

Fig. 1: SOCOL and 20CR SON ensemble mean (EM) T anomalies [K], averaged for 60°N-90°N, relative to 1961-90 self-climatologies.

2.1 Results - Seasonal T anomalies

A direct comparison over the 20th century reveals strongly different magnitudes of seasonal anomalies for the 20CR compared to both SOCOL (**Fig. 1**, note different colour scales) and REC1 (not shown) when averaged over **60°N-90°N**. The range of stratospheric anomalies is much larger in 20CR than in the other datasets, while it is of similar magnitude in the troposphere. Averaged over the Tropics (**30°S-30°N**), REC1 tends to have a smaller anomaly range than 20CR and SOCOL for the overlapping period 1901-57 (not shown).

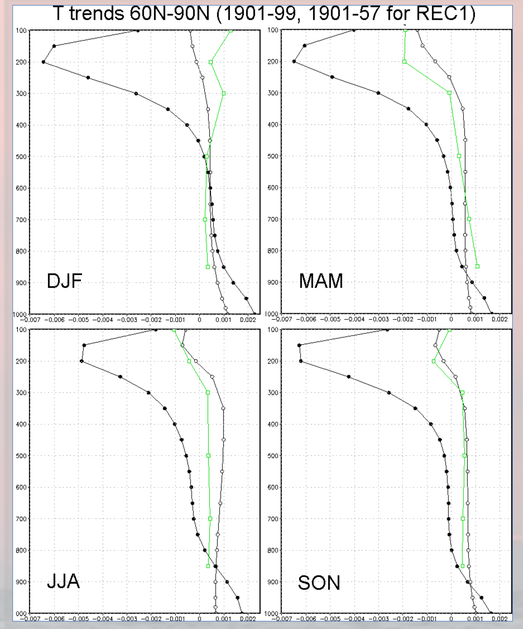

Fig. 2: Vertical profiles of 20th century T trends [K/month], averaged over 60°N-90°N and calculated for the different seasons. Values on the y axis are pressure in hPa. Filled circles: 20CR (EM), empty circles: SOCOL (EM), green empty circles: REC1.

2.2 Results – Vertical profiles of 20th century seasonal T trends

Figures 2 and 3 show vertical profiles of the mean 20th century (mean 1901-57 for REC1) T trends regionally averaged for 60°N-90°N and 30°S-30°N for the 3 datasets. For the latitude range **60°N-90°N**, 20CR shows much larger negative trends in the stratosphere than SOCOL or REC1. A positive trend, which is about twice as strong as in SOCOL at 1000 hPa is found only below 450-750 hPa. (cont.)

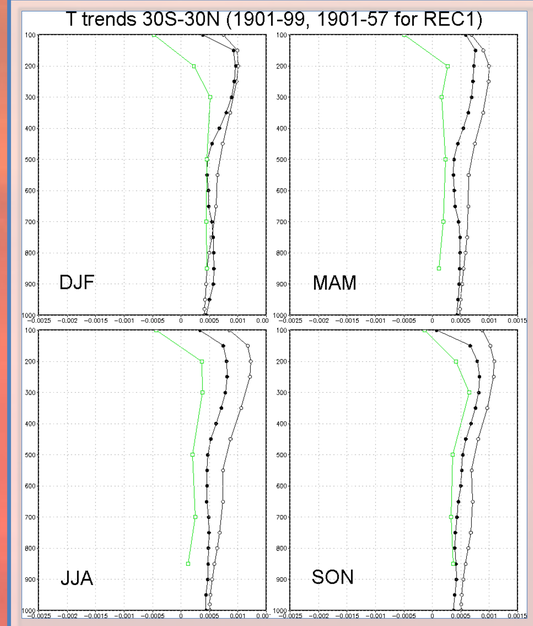

Fig. 3: As Fig. 2, but for 30°S-30°N. Note the different range on the x axis.

I.e., there is even an Arctic mid-to-upper tropospheric cooling trend over the 20th century in 20CR. SOCOL and REC1 compare relatively well despite the different periods (exception: REC1 shows pos. relative deviations in DJF above 400 hPa, and neg. ones in MAM @ 200 hPa and generally in JJA). In the range **30°S-30°N**, the agreement of 20CR and SOCOL is much better. The trend is positive everywhere up to 100 hPa in both datasets. Still, relative differences of the mean 20th century trend are > 50% at some levels, with SOCOL showing greater trends at all levels, except the ones below 700 hPa in DJF. In REC1 trends are generally smaller and, contrarily to SOCOL and 20CR, show a cooling @ 100 hPa (but again for 1901-57).

Figure 4 displays seasonal 20-year moving window T trends for both regions over the 20th century. The anti-correlation of stratospheric and tropospheric anomalies on a long time scale for SOCOL seen in Fig. 1 can also be found in Fig. 4 for shorter time scales. However, for both 60°N-90°N and 30°S-30°N exceptions can be seen for which warming or cooling appears throughout the column. 20CR (60°n-90°N) and REC1 do not show a clear anti-correlation, REC1 presumably due to its low vertical resolution. For the Arctic in 20CR, there is no clear distinction between tropospheric and stratospheric thermal behaviour.

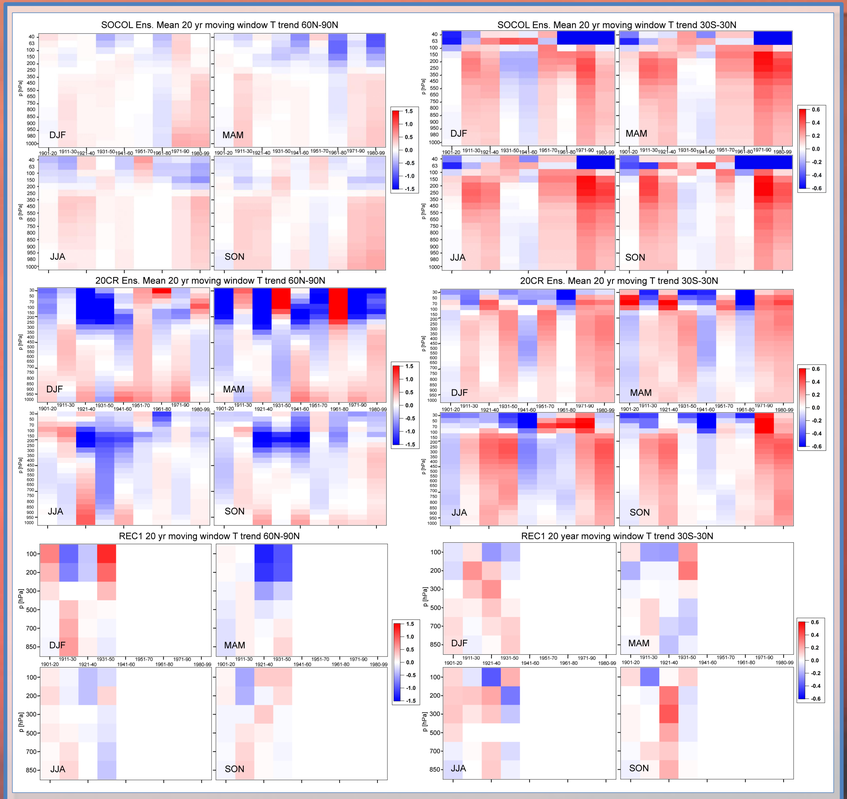

Fig. 4: Seasonal 20-year moving window T trends [K/decade], averaged over 60°N-90°N (left column) and 30°S-30°N (right column). Upper row: SOCOL (EM), middle row: 20CR (EM), bottom row: REC1. Note the different colour scales for the left and the right.

3. Conclusions and Outlook

For both regions, all datasets qualitatively show the expected behaviour (amplified warming in polar lower and tropical upper troposphere), but with largely different magnitudes and with some seasonal differences. Also the decadal variability shows only limited agreement (better in the Tropics), even between 20CR and REC1. The smaller amplitude of variability in the Arctic (SOCOL, EM) can be explained by a much larger internal variability, even on decadal time scales.

It should be mentioned that the uncertainty of both observation-based datasets grows with altitude and that artificial trends might be contained in 20CR due to a changing observational network density and problems with the assimilated sea ice.

The temperature trends found will also be compared to trends in a purely observational dataset, the Comprehensive Historical Upper-Air Network (CHUAN, Stickler et al., 2010). Furthermore, the uncertainty of the 20-year trends in SOCOL will be assessed using the ensemble spread of the 9 runs.

References

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