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Sensitivity of the southern hemisphere tropospheric jet response to ozone depletion: specified versus interactive chemistry

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RESEARCH FOR GRAND CHALLENGES

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What role does **interactive chemistry** play in shaping the atmospheric response to SH ozone depletion?

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Prescribed ozone (Chem OFF)

1) missing feedbacks between O_3 chemistry and model physics
2) missing asymmetries in O_3

→ Leads to differences in the climatology of the stratosphere: **Interactive chemistry (Chem ON)** leads to a colder and stronger stratospheric polar vortex (Fig.)

→ Can have an impact on the coupling to the troposphere (shown for the NH in Haase and Matthes, 2019)

→ **Now: Focus on the SH trend!**

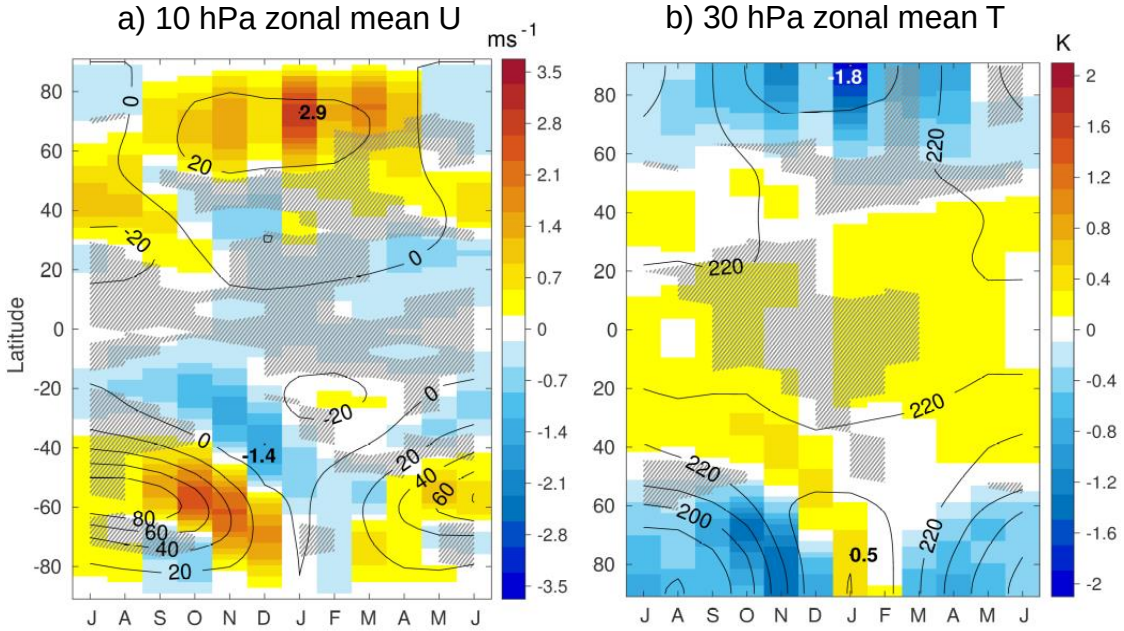

Figure: Chem ON minus Chem OFF ensemble (shading) for a) 10 hPa zonal mean zonal wind and b) 30 hPa zonal mean temperature. Contours represent the climatological mean state for the Chem ON ensemble. Statistically insignificant regions are hatched at the 5% level.

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9-member CCM ensembles for Chem ON and Chem OFF settings

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CESM1(WACCM)

Chem ON

Marsh et al. (2013) + some adaptations following Garcia et al. (2014, 2017) and Smith et al. (2015)

Chem OFF

Smith et al. (2014)

- 1955 to 2013 coupled simulations
- Historical conditions until 2005, following RCP 8.5 afterwards
  - GHGs, ODSs and volcanic aerosols following CMIP5 protocol
  - solar variability following CMIP6 protocol
- Nudged QBO

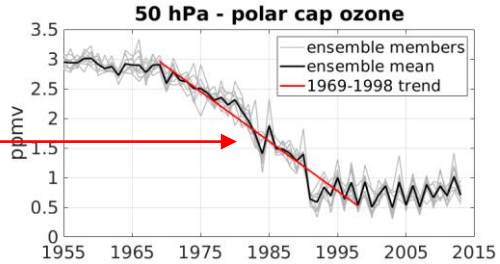
Interactive chemistry module MOZART4

Prescribed daily zonal mean transient ozone fields from Chem ON simulations

SH ozone depletion and its impact on the stratosphere in Chem ON

Strong trend in lower stratospheric ozone from 1969 to 1998

Polar cap trends over this period are shown below:



Temperature trend (**B**) can largely be explained by SW heating rate trends (**C**) (due to O_3 depletion - **A**), but also LW (**D**) and particularly dynamical heating rate trends (**E**) are of importance!

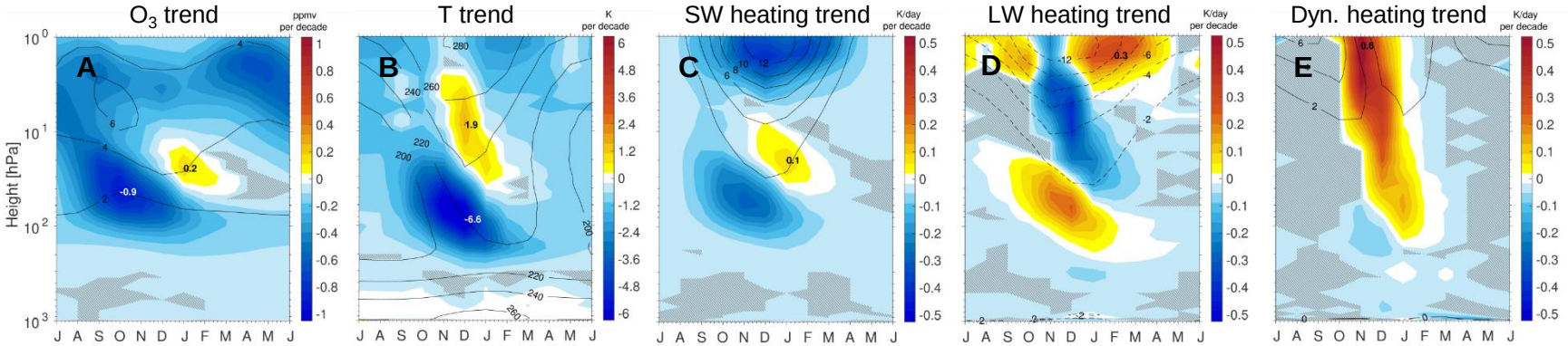


Fig.: 1969-1998 polar cap trend for different variables (shading). The contours indicate climatological values over the same period. Statistically insignificant regions are hatched at the 5% level.

The impact of **interactive chemistry** on the **stratospheric trends**

Chem ON minus Chem OFF trends for polar cap:

Negative T trend is stronger in Chem ON in the lower stratosphere in December

Followed by **positive trend anomalies** compared to Chem OFF above and afterwards

This differences can be explained by differences in **dynamical heating**!

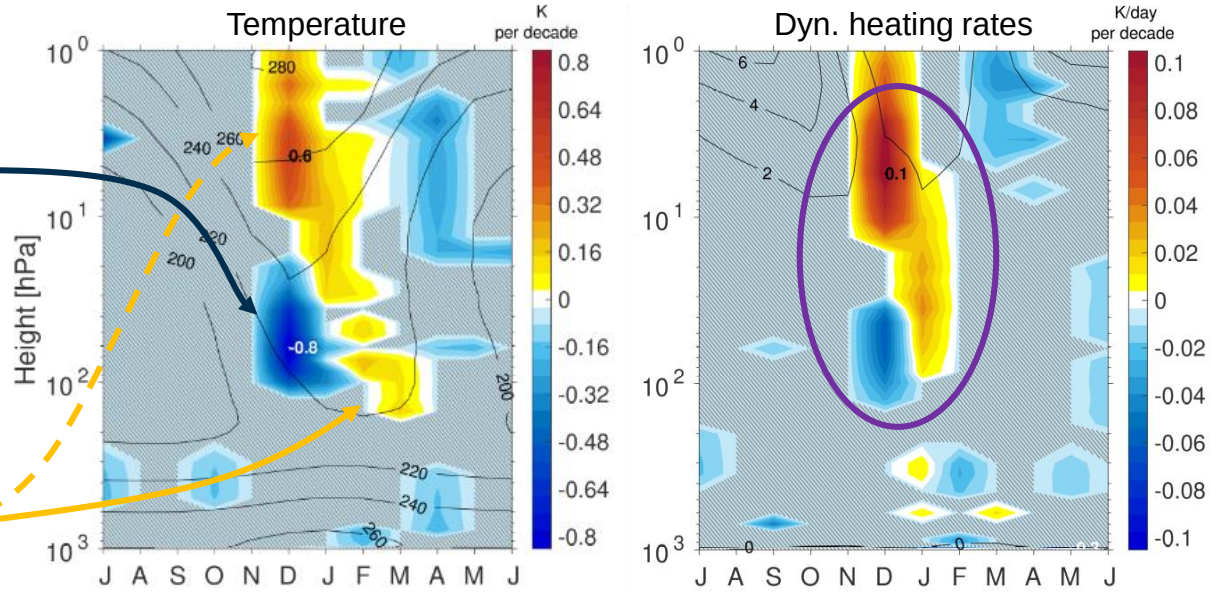


Fig.: 1969-1998 polar cap trend difference between Chem ON and Chem OFF for polar cap temperatures and dynamical heating rates (shading). The contours indicate the respective climatological values for Chem ON over the same period. Statistically insignificant regions are hatched at the 5% level.

The impact of **interactive chemistry** on the **tropospheric jet**

(A) Poleward shift of the tropospheric jet during DJF due to ozone depletion captured in Chem ON
(B) Weaker shift in Chem OFF – especially equatorward flank is effected
(C) Prescribing a 3D ozone field instead, reduces the difference to Chem ON!

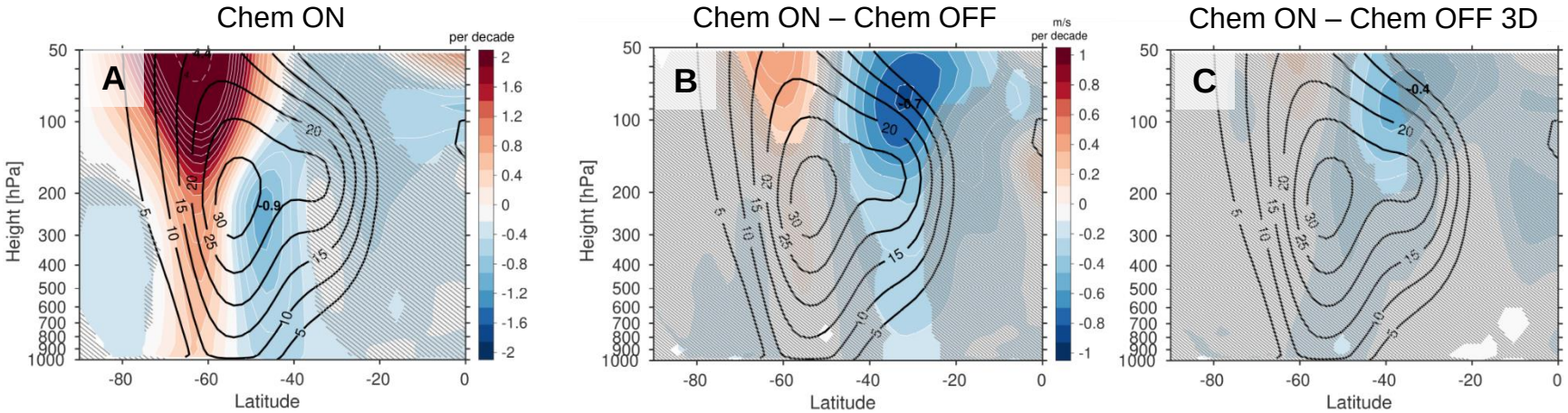


Fig.: 1969-1998 zonal mean zonal wind trend averaged over DJF (shading) for (A) Chem ON, (B) Chem ON minus Chem OFF, and (C) Chem ON minus Chem OFF 3D. Contours show the Chem ON climatology over the same period. Statistically insignificant values are hatched at the 5% level.

Summary

- Interactive chemistry leads to stronger and colder polar stratospheric vortex on both hemispheres
- Interactive chemistry leads to stronger maximum temperature trends in the lower stratosphere compared to prescribed ozone due to differences in dynamical heating rate trends
- Poleward shift of the tropospheric jet is slightly stronger with interactive chemistry
- Missing feedbacks as well as missing spatial asymmetries in the ozone forcing are responsible for these differences!

Reference: Haase et al. 2020 (submitted to ACP discussions)