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# Interactive versus prescribed ozone in the ICON-ART climate model: How is the spectrum of variability changing?

**Jennifer Schroeter,** Marleen Braun, Roland Ruhnke and Peter Braesicke

Institute of Meteorology and Climate Research, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

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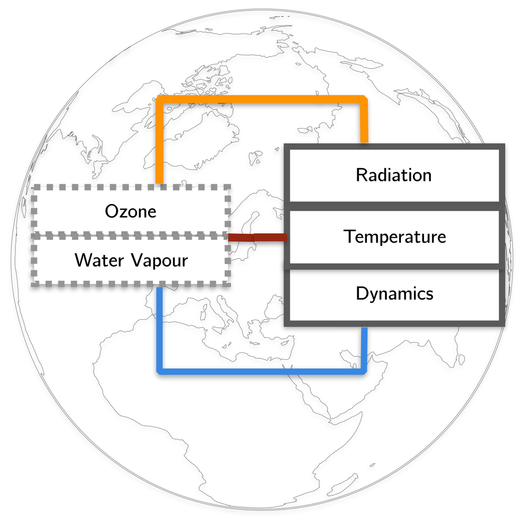
## Introduction




Atmospheric composition studies on weather and climate time scales require flexible, scalable models. The ICOsahedral Nonhydrostatic model with Aerosols and Reactive Trace gases (ICON-ART) provides such an environment.

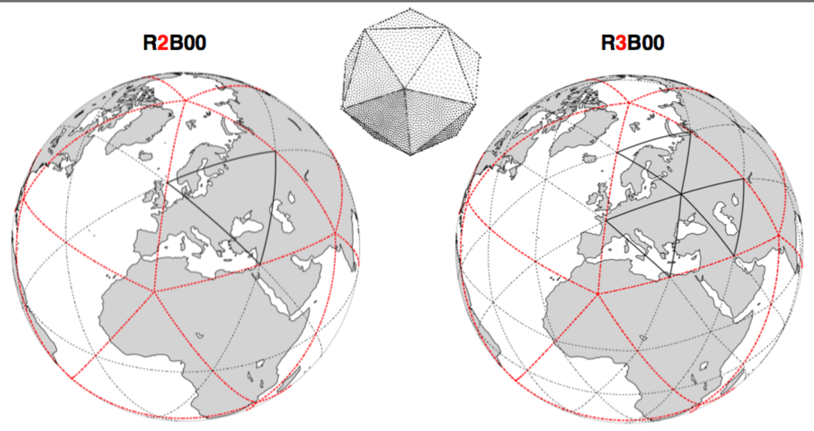
The flexible infrastructure of the ICON-ART system allows the implementation of many different composition schemes, including simple and complex stratospheric ozone chemistries for studies on different time-scales.

Ozone in the atmosphere influences the thermal structure of the atmosphere. The interactions between stratospheric ozone, radiation and dynamics are strong and complex.

In this study we use ICON-ART to investigate the influence of altering stratospheric ozone in timeslice experiments on our climate.

We discuss the influence of ozone in a changing climate on the surface temperature over Antarctica. Future experiments will also focus on the influence of changes in sea ice cover (e.g. sea ice absence) and CO2 increase (e.g. 2xCO2 experiment).

## General information about ICON-ART




Nonhydrostatic model equations - acceleration term dw / dt no longer neglected. Same dynamical core can be applied across scales - temporal and spatial. Uses icosahedral grid structure - offers local grid refinement (nesting).

Used for operational weather forecasting (Deutscher Wetterdienst) and climate predictions (Max Planck Institute for Meteorology).

Tracer and metadata structures are inherited within ICON-ART. This structure allows for tailor-made configurations of ICON-ART in weather and climate applications that are easy to configure and run well.

## Experimental setup

**Timeslice Experiment**

- Mean conditions 1998 - 2002: SST/SIC + GHG
- Free running linearised ozone scheme based on LINOZ [1]
- Taylor-Expansion for lifetime $\mathcal{T}$ of ozone tracer
- Ozone initialised for year 2000
- Ozone is transported - has sources and sinks and radiative interactions
- 50 years of simulation

**Experiment I - POC**

Polar ozone chemistry included

$$\tau_{\text{psc}} = \begin{cases} 10 \text{ days} & \text{for } \vartheta < 92.5^\circ \text{ and } T < 195\text{K} \\ \infty \text{ days} & \text{else} \end{cases}$$

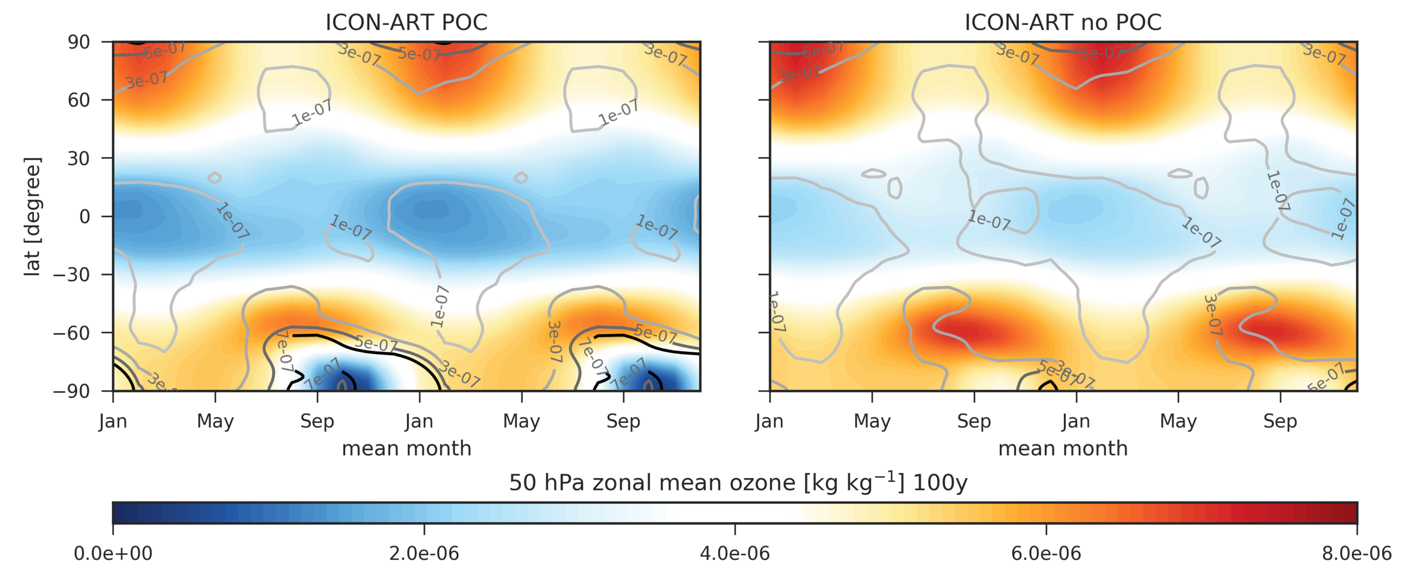
**Experiment II - noPOC**

Polar ozone chemistry neglected

$$\tau_{\text{psc}} = \infty \text{ days}$$

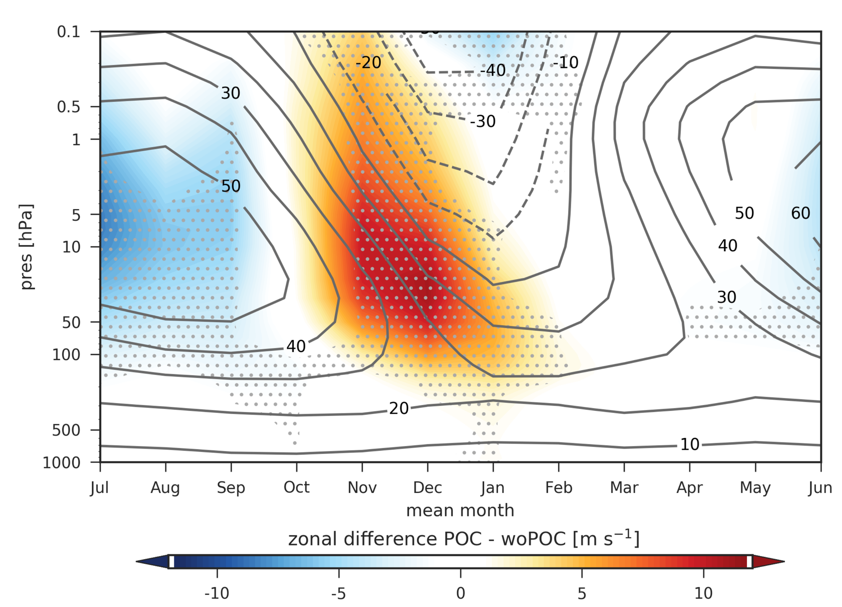
## Results

**Ozone comparison - monthly zonal mean (50 hPa)**

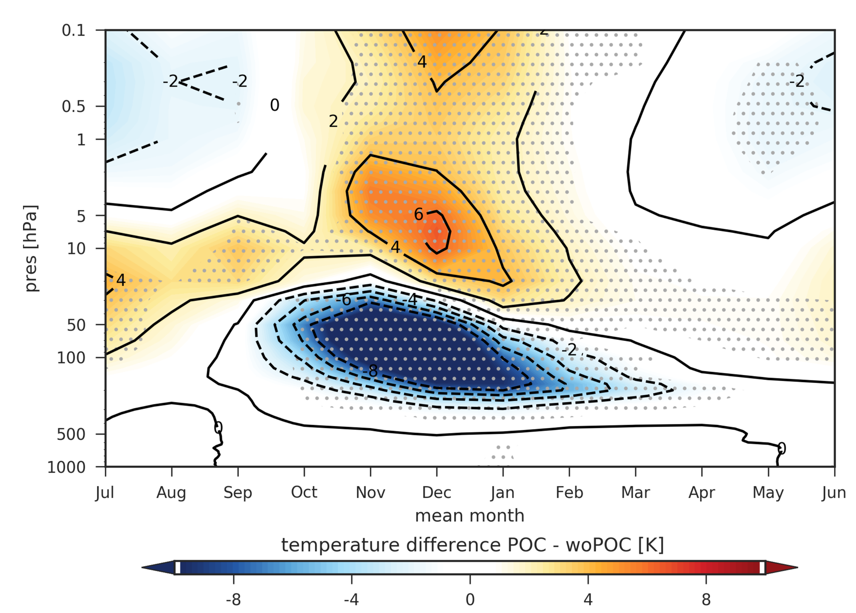



Monthly averaged zonal means of ozone (kgkg−1) at 50hPa (shown twice) for 50 years of timeslice integrations (shaded). Contour lines represent the standard deviations of the monthly means. Left: Simulation with ozone hole; Right: simulation without ozone hole.

**Zonal wind difference - POC minus noPOC**

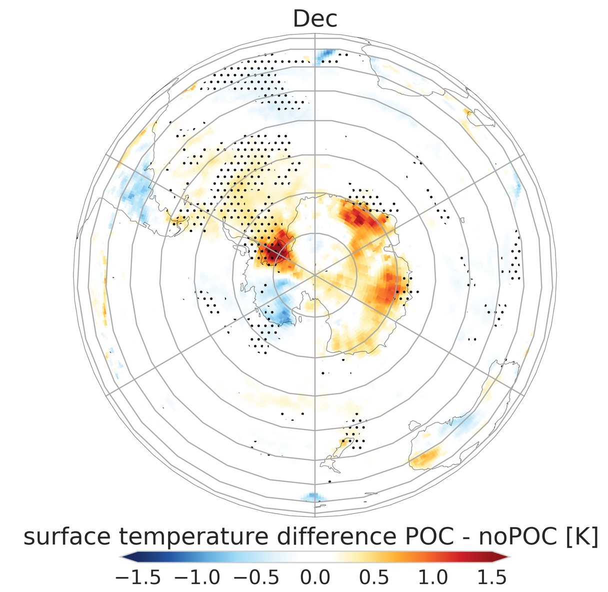



**Temperature difference - POC minus noPOC**




Mean differences of zonal mean zonal wind (left) and temperature (right). For the zonal wind, differences are taken from 50°S to 75°S. For the temperature, the mean is taken from 90°S to 75°S. Dots represent 98% significance. First 10 years are excluded.

## Changes in the variability

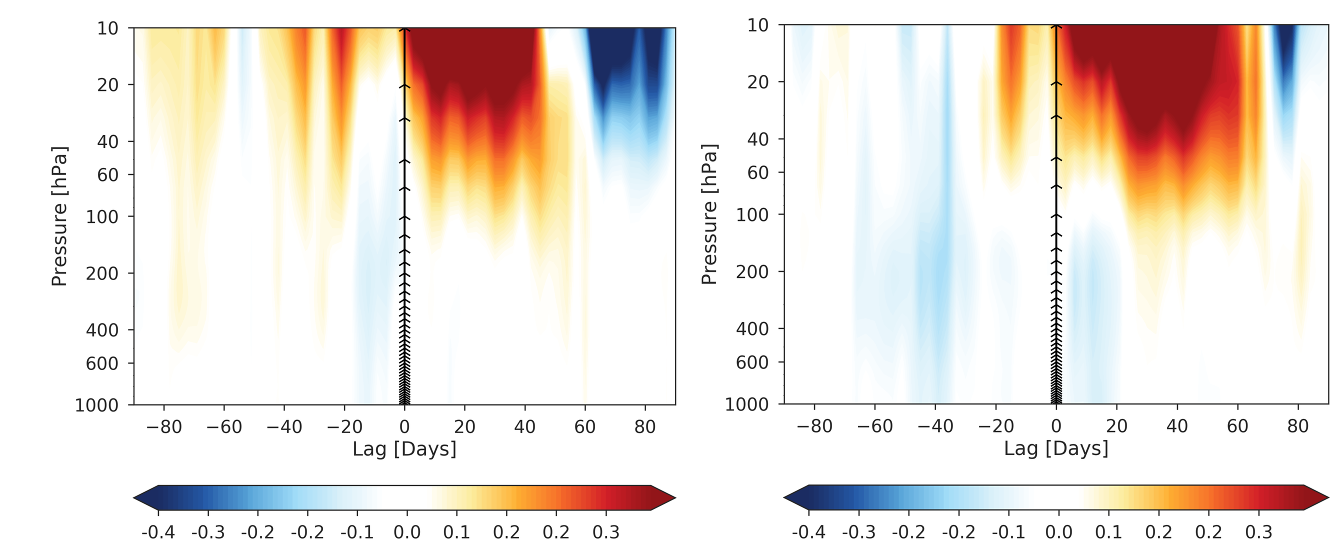



Difference of surface temperature shows significant temperature increase over the Antarctic Peninsula up to 1.5 K. Dotted areas represent 98% confidence interval. The result is comparable to other modelling studies [3].

EOF (Empirical Orthogonal Functions) analysis was applied to monthly mean data at 42 levels from 10 to 1000hPa. The leading EOF at each level was projected on daily data (available every third day) to obtain 3 day SAM (southern annular mode) indices. The 30 strongest events were chosen based on the persistent exceedance of a given threshold for 9 days at 10hPa. A composite of the 30 strongest events is shown with day 0 indicating the day when the chosen threshold was first exceeded.

Both cases show descending positive anomalies that are in phase across various height levels indicating a vertical coupling mechanism. The persistence of strong events is higher for the noPOC case with 60 days compared to 45 days for the POC case.

**POC vs noPOC SAM max events**




## References and further information

[1] McLinden, C. A., Olsen, S. C., Hannegan, B., Wild, O., Prather, M. J., and Sundet, J.: Stratospheric ozone in 3- D models: A simple chemistry and the cross-tropopause flux, J. Geophys. Res.-Atmos., 105, 14653–14665, https://doi.org/10.1029/2000JD900124, 2000.

[2] Schröter, J., Rieger, D., Stassen, C., Vogel, H., Weimer, M., Werchner, S., Förstner, J., Prill, F., Reinert, D., Zängl, G., Giorgetta, M., Ruhnke, R., Vogel, B., and Braesicke, P.: ICON-ART 2.1: a flexible tracer framework and its application for composition studies in numerical weather forecasting and climate simulations, Geosci. Model Dev., 11, 4043-4068, https://doi.org/10.5194/gmd-11-4043-2018, 2018.

[3] Keeble, J., Braesicke, P., Abraham, N. L., Roscoe, H. K., and Pyle, J. A.: The impact of polar stratospheric ozone loss on Southern Hemisphere stratospheric circulation and climate, Atmos. Chem. Phys., 14, 13705-13717, doi:10.5194/acp-14-13705-2014, 2014.

jennifer.schroeter@kit.edu