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Investigating convective tropospheric transport processes and large scale stratospheric dynamics with ICON-ART

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1. Introduction

- The ICON (ICOsahedral Nonhydrostatic) modelling framework is a joint development by the German Weather Service (DWD) and the Max-Planck-Institute for Meteorology (MPI-M). ICON is a global model with the possibility for regional refinement over selected areas with two-way interactions. It is used by the DWD for numerical weather predictions and will be used by MPI-M for climate projections.
- We extended ICON by modules for gas-phase chemistry and aerosol dynamics (ART, Aerosols and Reactive Tracer gases). Up to now, ICON-ART accounts for multiple aerosols[1]. Additionally, several gaseous tracers have been introduced. For the dynamics (transport and diffusion) of aerosol and gaseous tracers, the original ICON tracer framework is used. For the model physics, numerical time integration follows a process splitting approach separating physical processes. Each process is called independently via an interface module. Currently, the processes of emission, dry and wet deposition, sedimentation, and first order chemical reactions are included.
- We will present both, long term and short term simulations of different chemical and artificial tracers to account for the potential of ICON for simulations on climatological timescales as well as the prediction of single events from the troposphere up to the stratosphere.

2. Key Questions

- What is the dynamical behaviour of ICON on different time scales ?
- What is the ability of ICON-ART to simulate vertical transport in the troposphere as well as of large-scale stratospheric dynamics ?

3. Simulations

	Long-term	Short-term
Grid	R02B04	R02B06
No. Cells	20 480	327 680
No. Edges	30 720	491 520
Resolution [km]	157.8	39.5
Period	ERA-INTERIM 1979-2014	Vortex split / TORERO Sep 2002 / Jan 2012

4. Long-term Simulations

- A suitable measure for large scale transport mechanism on climatological timescales is the so called age of air. This artificial tracer is emitted only at the bottom layer, has no source or sink terms in the atmosphere and its emission increases linear with time. At start-up it's initialized with an assumed age of air which ranges from 0 at bottom to 7 years at top layer (Fig. 1).

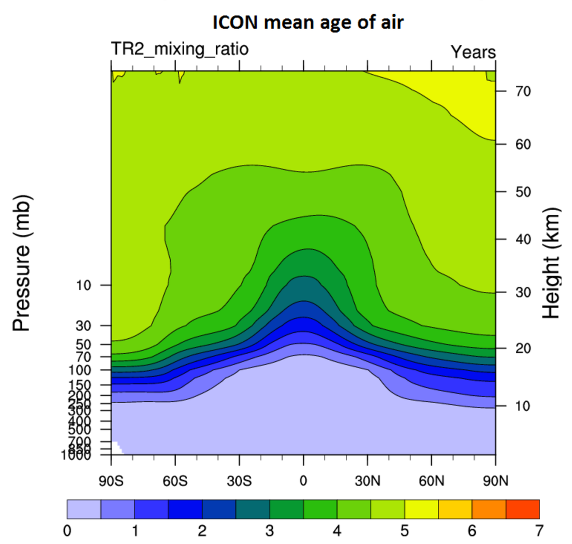

Fig. 1: Zonal and time mean of age of air in years

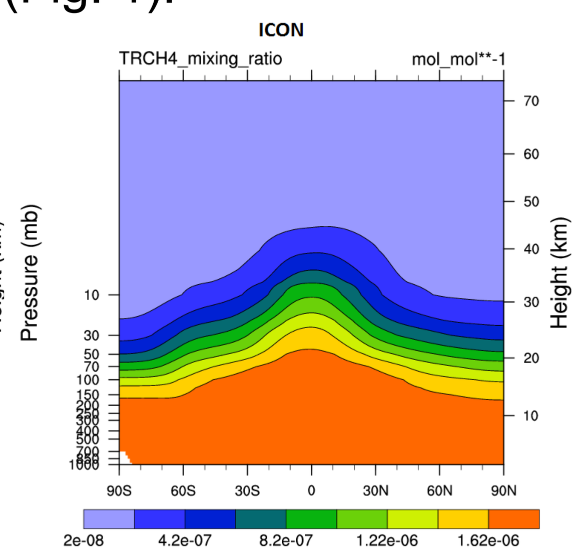

Fig. 2: Zonal and time mean of methane mixing ratio (ECMWF)

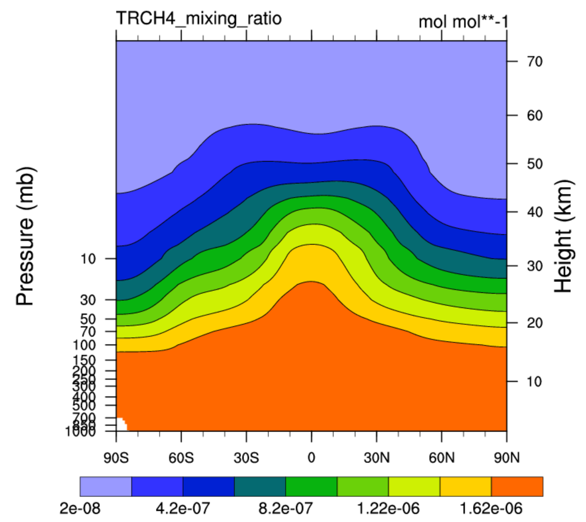

Fig. 3: Zonal and time mean of methane mixing ratio (Brasseur)

- A second tracer added to ICON-ART is methane. Methane is one of the major radiative greenhouse gases and the main source for water vapour in the stratosphere. Despite its importance it's still too simple represented in most numerical models. We present two different methane parametrizations. One following the approach of ECMWF (Fig. 2) the other taken from Brasseur and Solomon (Fig. 3). Both base on a lifetime approach which varies with height.

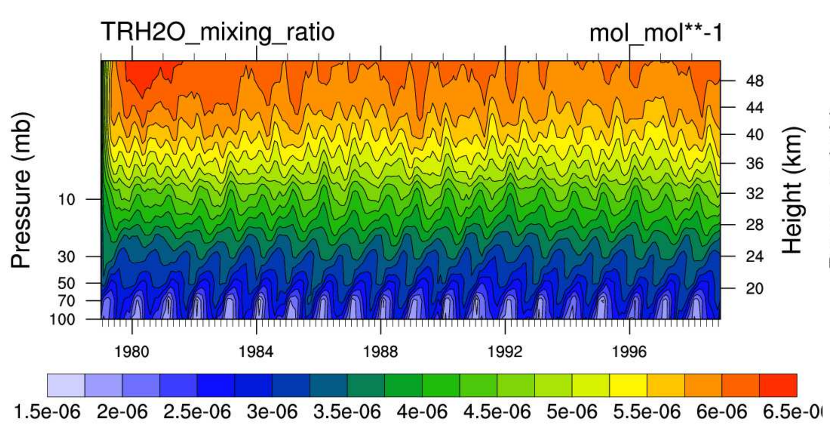

Fig. 4: Zonal mean at equator of water vapour

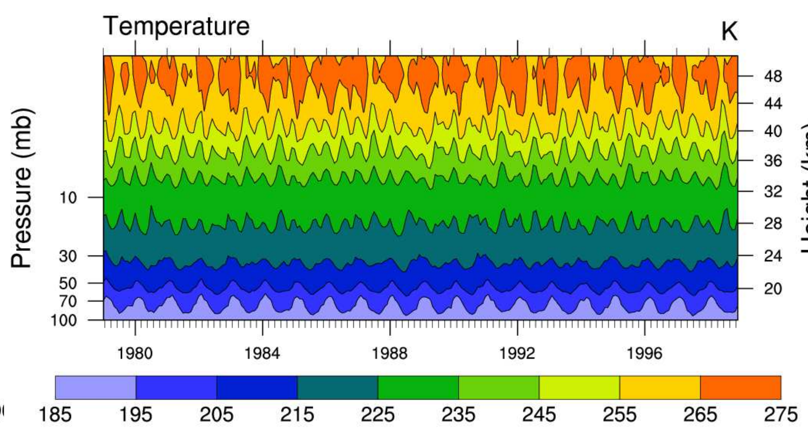

Fig. 5: Zonal mean at equator of temperature

- Another source for water vapour in the stratosphere is the transport through the tropopause. Due to seasonal cycles in tropopause temperatures and therefore dry-freezing of water vapour, the amount which is transported upward differs[2]. This effect, known as the tropical tape recorder, is used to investigate the upward propagating velocity of ICON-ART.

5. Short-term Simulations

- To test the ability to forecast large scale stratospheric dynamics, ICON-ART was used to simulate the unique Antarctic stratospheric vortex split event in September 2002. Therefore a linearized ozone chemistry was introduced[3]. The parameterization depends on a set of tabulated coefficients for net production, concentration, column of ozone and temperature. Additionally a simple approach for polar chemistry has been used which depends on solar zenith angle and temperature. Ozone VMR was initialized with GEMS climatology.

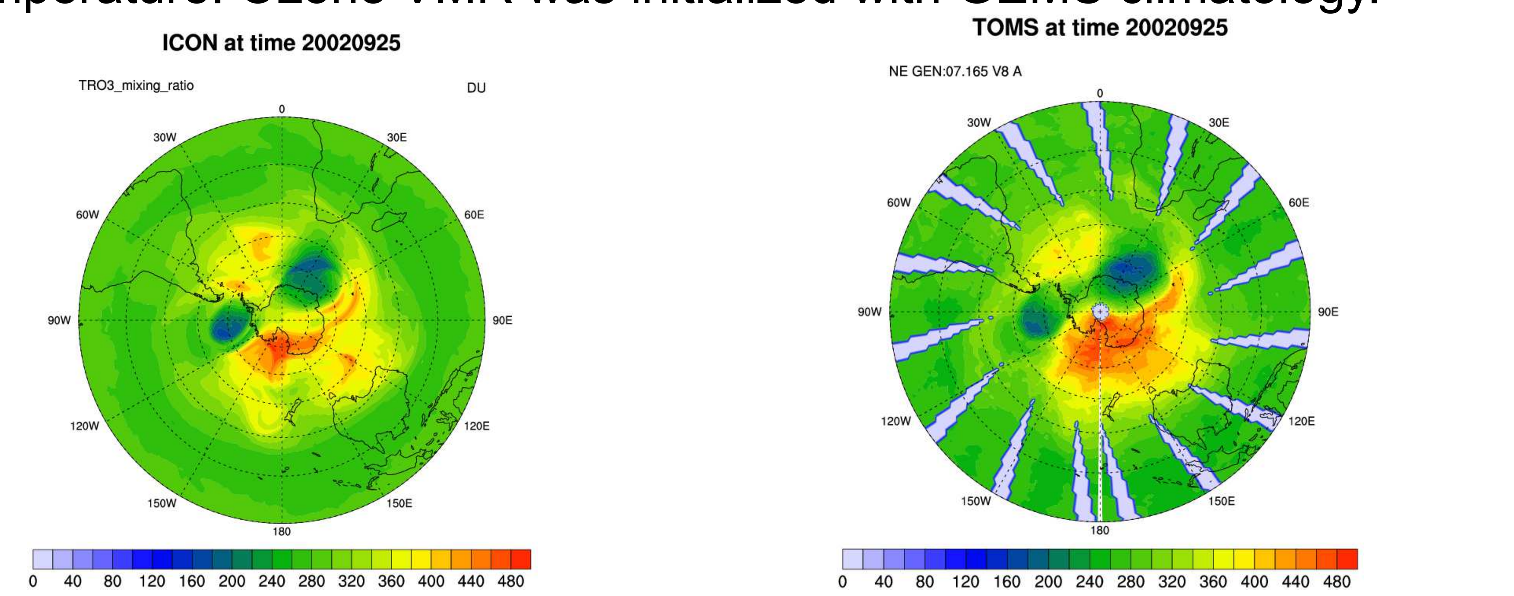

Fig. 7: Antarctic total ozone column in Dobson Units with ICON-ART (left) and measured by TOMS (right)

6. Summary & Outlook

- The results of the long-term simulations indicate that ICON performs well on climatological timescales. Key features of the atmosphere like large scale dynamics and convective transport are in agreement with other model studies, though the upward transport is too fast, leading to too small age of air and a too fast tape recorder in the stratosphere.
- The results of the short-term simulations show that ICON is able to predict the stratospheric vortex split and that the simulated ozone agrees well with TOMS data.
- In future work the effect of feedback mechanism of ozone, changes in greenhouse gases and SST/SIC will be examined. Additionally a second artificial tracer will be added to investigate the convective stratosphere troposphere exchange during the TORERO campaign.

7. References

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