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Investigating atmospheric transport processes of trace gases with ICON-ART on different scales

Jennifer Schröter, Roland Ruhnke, Daniel Rieger, Heike Vogel, and Bernhard Vogel

Institute of Meteorology and Climate Research, Karlsruhe Institute of Technology (KIT), Hermann-von-Helmholtz-Platz 1, D-76344 Eggenstein-Leopoldshafen

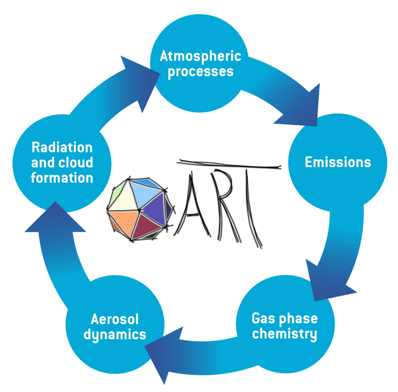
jennifer.schroeter@kit.edu

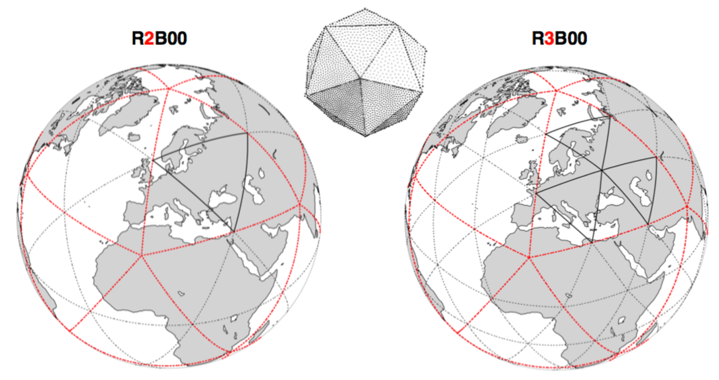
Introduction

The ICON-ART[1] model is an extension of the non-hydrostatic modelling framework ICON[2], jointly developed by the German Weather Service (DWD) and Max-Planck-Institute for Meteorology (MPI-M), and is used for numerical weather prediction as well as for future climate predictions. ICON-ART is developed at KIT with the goal to simulate interactions between trace substances and the state of the atmosphere.
In this study, we present results of the ICON-ART extension, including the full gas-phase chemistry module.Two simulations are performed with ICON-ART. The first one with physics parameterisations for the numerical weather prediction (NWP) and the second one with parametrisation for climate simulation in order to investigate the dynamical influence on the distribution of long-lived as well as of short-lived species by comparing both simulations.

General information about ICON

ICON = ICOsahedral Nonhydrostatic modelling framework





ART = Aerosols and Reactive Trace substances

The extended modelling framework ICON-ART is developed in an analogous way to its predecessors COSMO-ART[3]. For the dynamics (transport and diffusion) of 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 developed a photolysis module for ICON-ART, based on CloudJ[4] which was extended by an interface which allows to interact with ICON-ART.The gas-phase chemistry module is based on MECCA[5].

AMIP simulations

AMIP (Atmospheric Model Intercomparison Project) style experiment
Initialisation: ECMWF analysis 1979-01-01T00:00:00Z
Duration: At least 10 years of simulation
Resolution: R2B4 grid (160 km)
ICON Modi: NWP and climate (AES).

SST / SIC	[6]
spectral solar irradiation	[7]
greenhouse gases (CO2, CH4, N2O, CFCs) RCP 8.5	[8]
O3 concentration	[9]
tropospheric aerosol	[10], [11], [12]
stratospheric aerosol	[10], [11], [12]

Investigating tape recorder as velocity indicator of upward Brewer-Dobson circulation

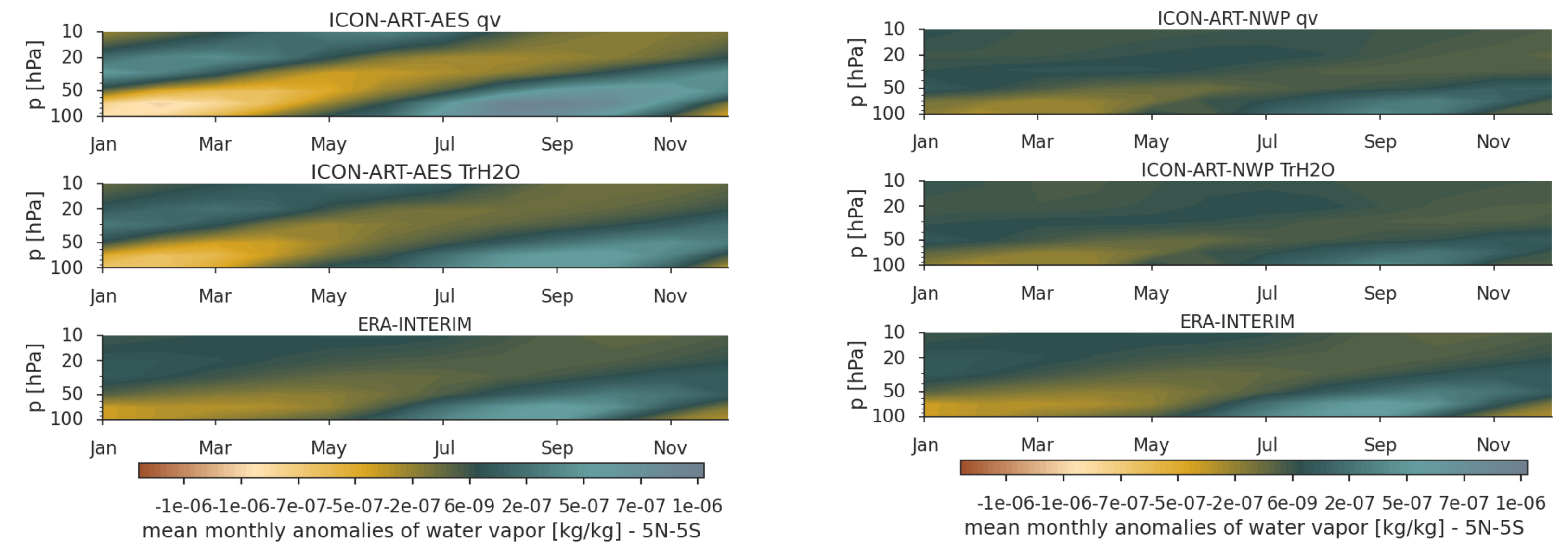


Fig. 1 Monthly mean deviations of mean annual tape recorder (5N - 5S), zonal and meridional mean from 1980 - 1990 . AES indicates ICON-ART in climate mode (left) and NWP in operational mode used by DWD (right). Qv represents the water vapor tracer mass mixing ratio of ICON, and TrH2O the ICON-ART tracer. For comparison the result of the ERA-INTERIM reanalysis is shown.

Investigating monthly mean temperature

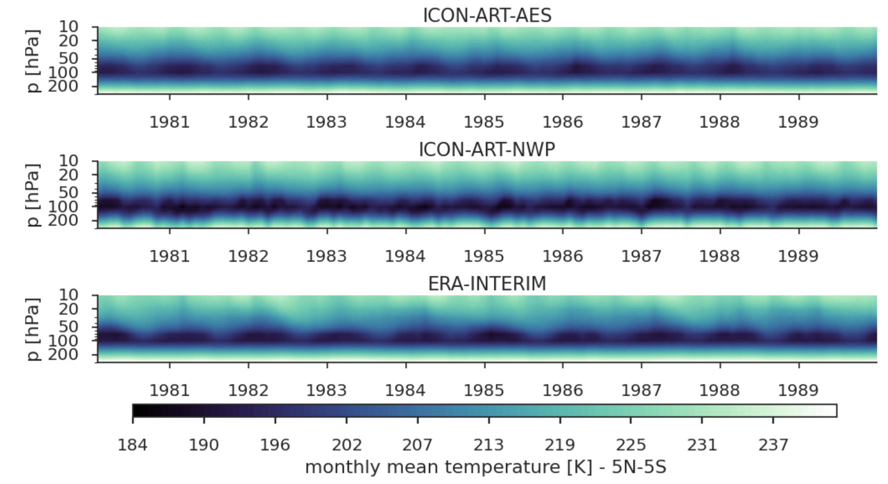
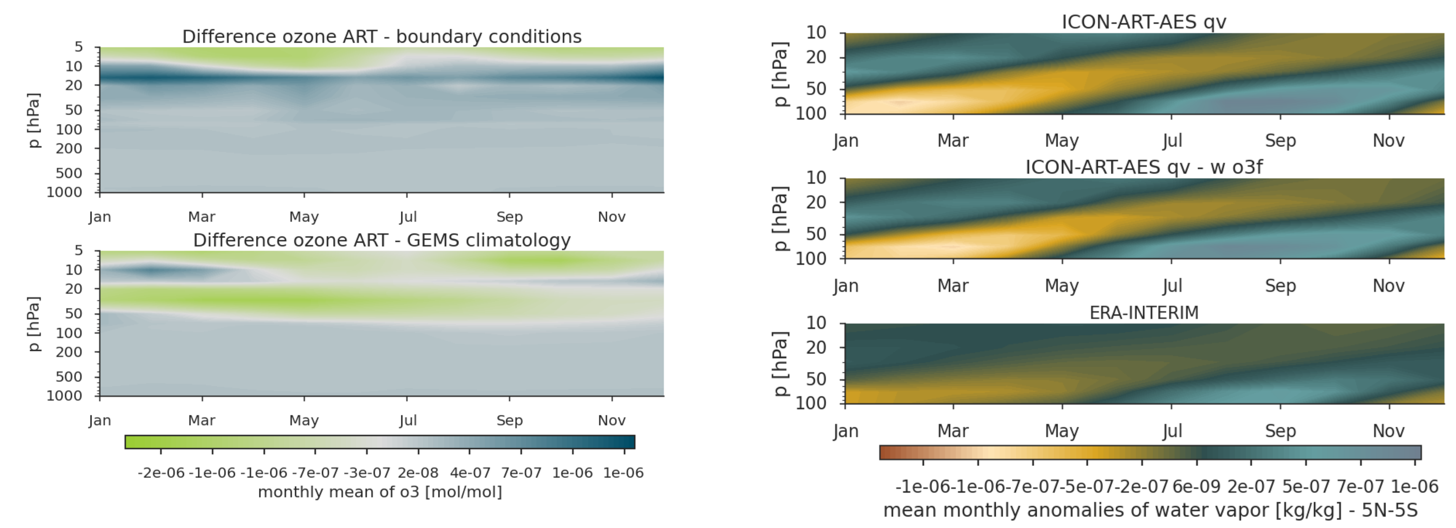


Fig. 2 Color coded zonal and meridional mean (5N - 5S) of monthly mean temperatures within both ICON modi in comparison to ERA-INTERIM. Stratospheric water vapor is strongly dependent on tropospheric temperature and vice versa. Increasing water vapor in the stratosphere induces stratospheric cooling. In contrast, a warmer tropopause region allows an increase of water vapor in the stratosphere.

Influence of interactive ozone feedback by ICON-ART

Fig. 3 Left: Difference between mean monthly ozone distribution with zonal and meridional mean (5N - 5S) calculated with ICON-ART using LINOZ [13] and the GEMS climatology.
Right: Tape recorder with and without interactive Ozone feedback using climate mode. The upward transport velocity seems to be slower, in the ICON-ART ozone feedback simulation.



Small scale experiment - Typhoon Haiyan

Initialisation: ECMWF analysis, 2013-11-05T00:00:00Z, R2B5 grid (80 km), NWP mode using ART with simplified chemistry and full gas-phase chemistry.
Simulation of artificial tracers defined following [14] allows investigation of small scale transport processes.
The chemical gas-phase mechanism is based on RADM-KA[3] and consists of 87 chemical species. The output is done on the native grid, as it can be seen in Fig. 4.

Artificial Tracer Transport

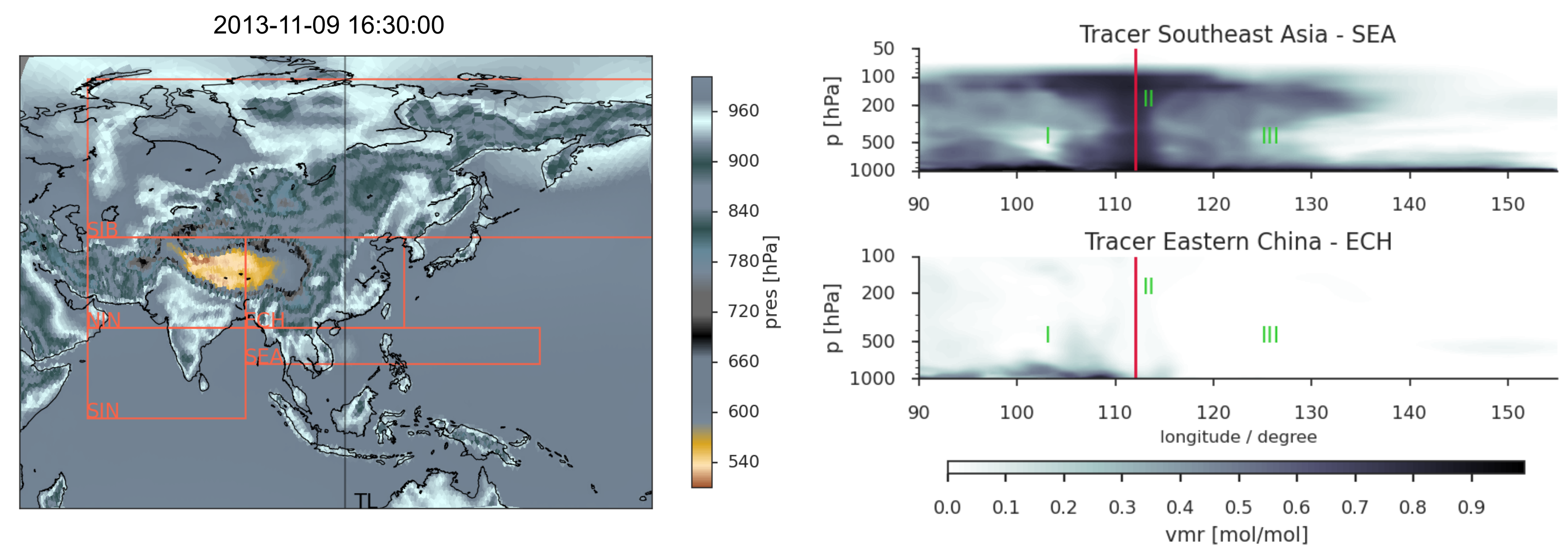


Fig. 4 Left: Pressure on model level 80, with indication of artificial tracer emission regions and location of typhoon center (TL).
Right: meridional mean of respective tracer volume mixing ratio (vmr), the red line indicates the location of TL. Points I, II and III are taken for the results shown in the table below.

Tracer contribution

tracer	sea	ech	sib	sin	nin
I	82.3	17.6	2E-04	2E-03	1E-04
II	97.5	2.49	2E-06	7E-05	8E-06
III	99.9	2E-04	2E-06	2E-09	1E-10

Tab 1: Relative contribution to the sum of tracers in the respective region given in percent.

Gas-phase chemistry

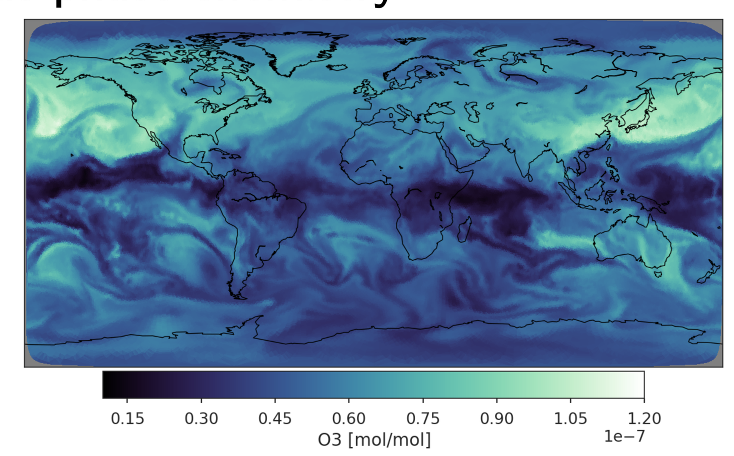


Fig. 5. VMR of Ozone in model level 80 calculated with full gas phase chemistry in ICON-ART. Low values in the region of the typhoon nicely represent the fast upward transport in this region.

2013-11-06 00:00:00 - ICON-ART

Conclusion

The realistic simulation of water vapor throughout the atmosphere is not a simple task to fulfill. Even tough, water vapor is important for radiative processes and thus transport processes. This leads to the problem that stratospheric trace gases cannot be simulated reasonably, if those processes are not captured sufficiently well. We have shown that it is possible to investigate processes determining large scale and small scale transport processes with ICON-ART simulations.

References

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