Karlsruhe Institute of Technology

Institute of Meteorology and Climate Research
Atmospheric Trace Gases and Remote Sensing

Simulation of the Polar UT/LS during the Arctic Winter 2015/2016 with ICON-ART

Christopher Diekmann, P. Braesicke, J. Eckstein, S. Johansson, D. Rieger, R. Ruhnke, J. Schröter, B.-M. Sinnhuber

Karlsruhe Institute of Technology, Institute for Meteorology and Climate Research, Herrmann-von- Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany

Introduction

This study aims at the investigation of dynamical and chemical processes in polar regions during the arctic winter 2015/2016, with special focus on the Upper Troposphere and Lower Stratosphere (UT/LS). Main tools hereby are chemical and artificial tracers, simulated within ICON-ART. Appropriate tracers need to be considered in order to be able to monitor processes like catalytic ozone loss and denitrification. When analyzing polar processes a realistic representation of the polar stratospheric vortex is one of the fundamental tasks due to its influence on dynamics and chemistry in high latitudes. Results obtained with ICON-ART are evaluated against measurements from the POLSTRACC campaign and a simulation with the Climate-Transport-Model EMAC.

ICON-ART

ART (*Aerosols and Reactive Trace gases*) extends the global nonhydrostatic model ICON (DWD, MPI-Met) by the spatiotemporal simulation of chemical substances and aerosols. Parameterized chemical tendencies are added to the tracer-framework from ICON in order to simulate chemical tracers.

➢ *Model setup*

- Simulation time: 02.12.2015 – 22.03.2016
- Resolution: horizontal: R2B06 (~ 40km), vertical: 90 levels up to 75km
- Initialization: IFS-Data (meteorology), EMAC-Data (chemistry)
- Forecast mode: re-initialization of dynamical core with current IFS-Data at 00 UTC, smooth transport for trace gases

POLSTRACC *(POLar STRatosphere in a Changing Climate)*

POLSTRACC as airborne HALO campaign has been monitoring the north polar UT/LS during the arctic winter 2015/16. The measuring time period covered the vortex phases

development (Dec. '15),
consolidation (Jan. - Mar. '16),
dissipation (Mar. '16)

➢ *Scientific objectives*

- Structure of tropopause region
- Ozone depletion
- Polar stratospheric clouds (PSC)
- Cirrus clouds

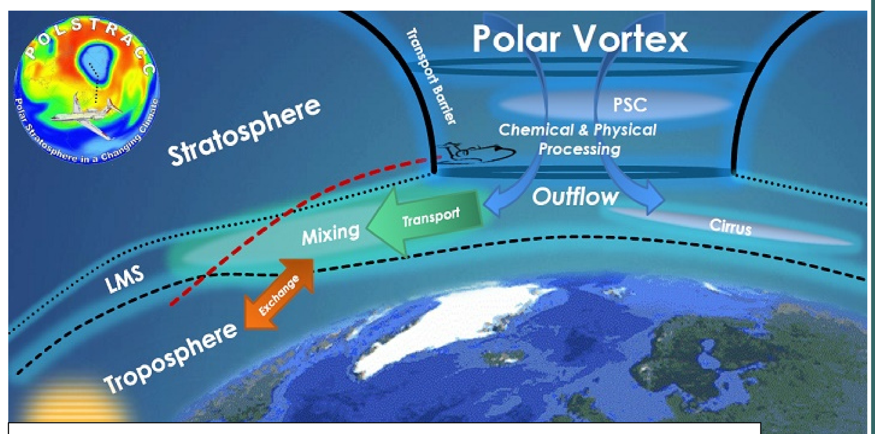

Fig.1: Overview of the structure and processes within the Lowermost Stratosphere (LMS) [1].

Artificial Tracers

Tracers can be set with artificial values for identifying air masses and their origins. After an initialization they act as passive substances.

➢ *height tracer for northern hemisphere*:

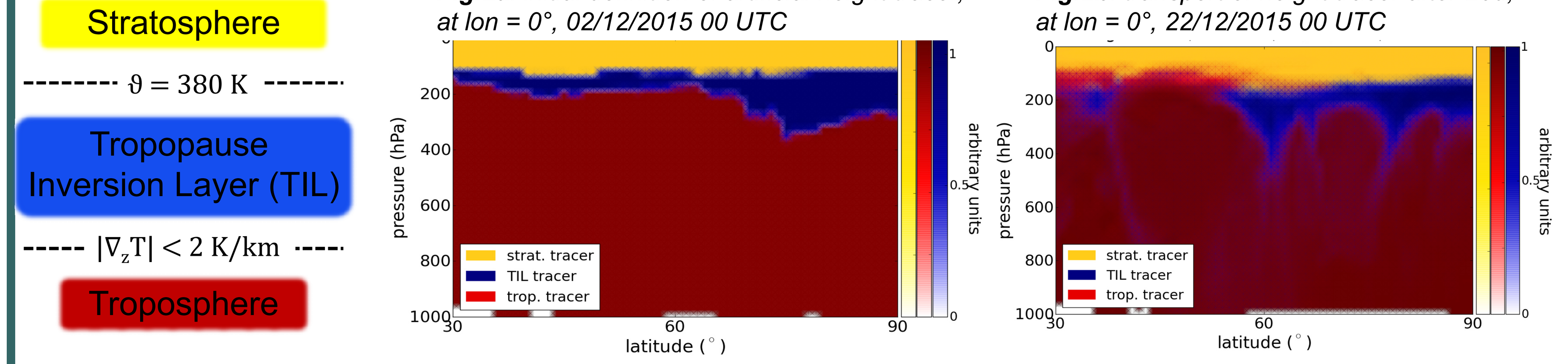

Fig.2a: initial definition of artificial height tracer, at lon = 0°, 02/12/2015 00 UTC

Fig.2b: transport of height tracer after 20d, at lon = 0°, 22/12/2015 00 UTC

Chemical Tracers

➢ *O_3:*

- linearized chemistry using a first-order taylor expansion [2]
- lifetime-based calculation of non-linear ozone loss with τ_{cat} = 10d when temperature falls below T_{cat} = 195K

➢ *N_2O:*

- simplified N_2O/NO_y-scheme including photolysis and oxidation of N_2O as source for reactive nitrogen (NO_y) [3]
- as NO_y mainly consists of HNO_3 within the polar UT/LS it can be used for HNO_3 relevant processes as de- and renitrification caused by HNO_3 containing PSCs

Simulating the Winter 2015/16

➢ *Flight analysis (Fig.3):*

- ICON-ART is able to reproduce measured profiles reasonably
- stratospheric ozone loss is underestimated

➢ *Polar vortex (Fig.4):*

- N_2O in ICON-ART shows good agreement with results from EMAC (T106L90) [5]
- ICON-ART simulates a stronger vortex

➢ *N2O – timeseries (Fig.5):*

- stronger polar subsidence in ICON compared to EMAC
- as comparison with passive N_2O shows, N_2O is an inert tracer for the troposphere
- N_2O-desctruction takes place for p < 100 hPa as stratospheric source for forming HNO_3 to build up PSCs

➢ *Further steps:*

- Analyzing high-resolution simulations (R3B07, ~13km) for small-scale effects as tropopause folding events
- Adjusting T_{cat} and τ_{cat} for obtaining realistic polar ozone profiles
- Testing radiation feedback of modified ozone
- Testing influence of vertical resolution

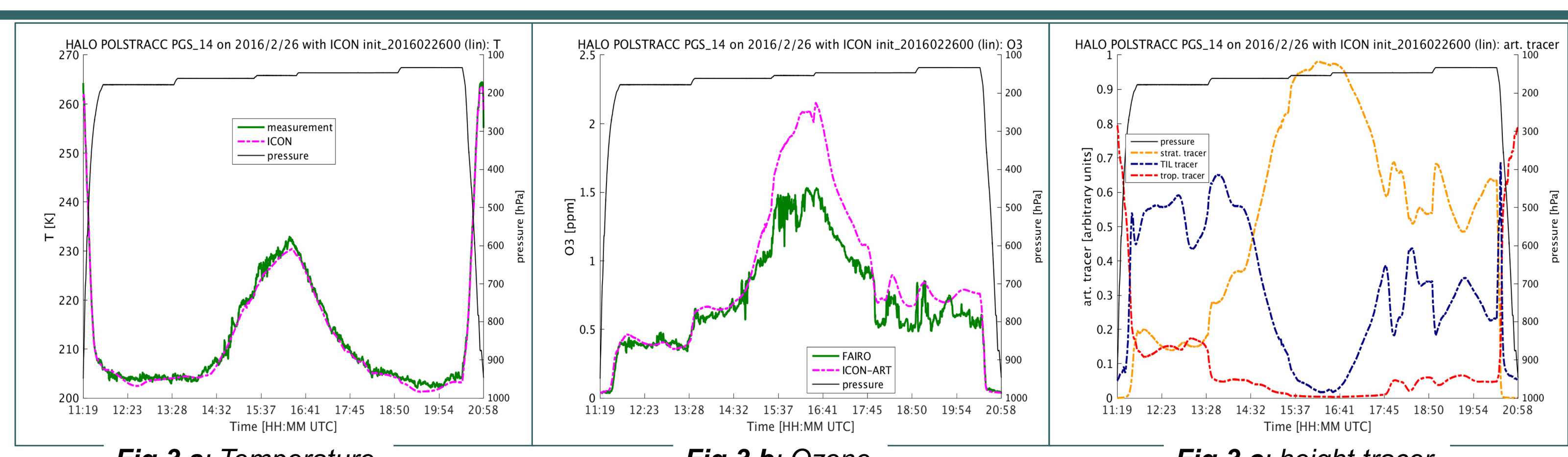

Fig.3.a: Temperature *Fig.3.b: Ozone* *Fig.3.c: height tracer*

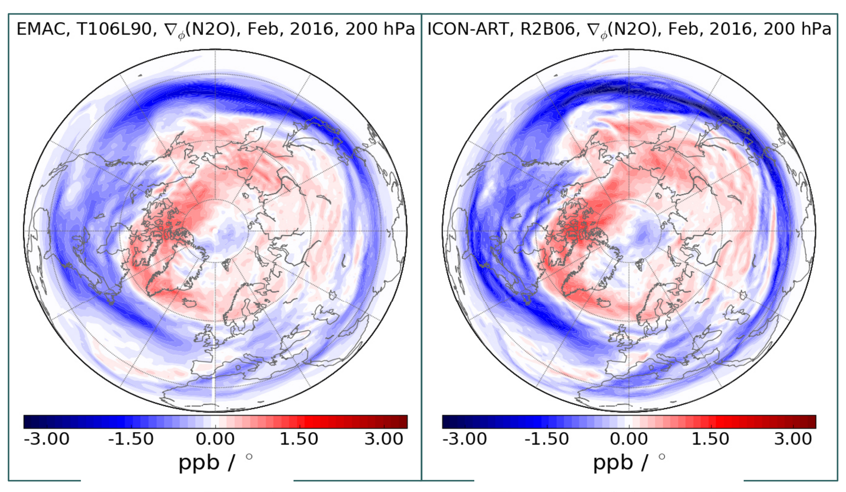

Fig.4.a: EMAC *Fig.4.b: ICON-ART*

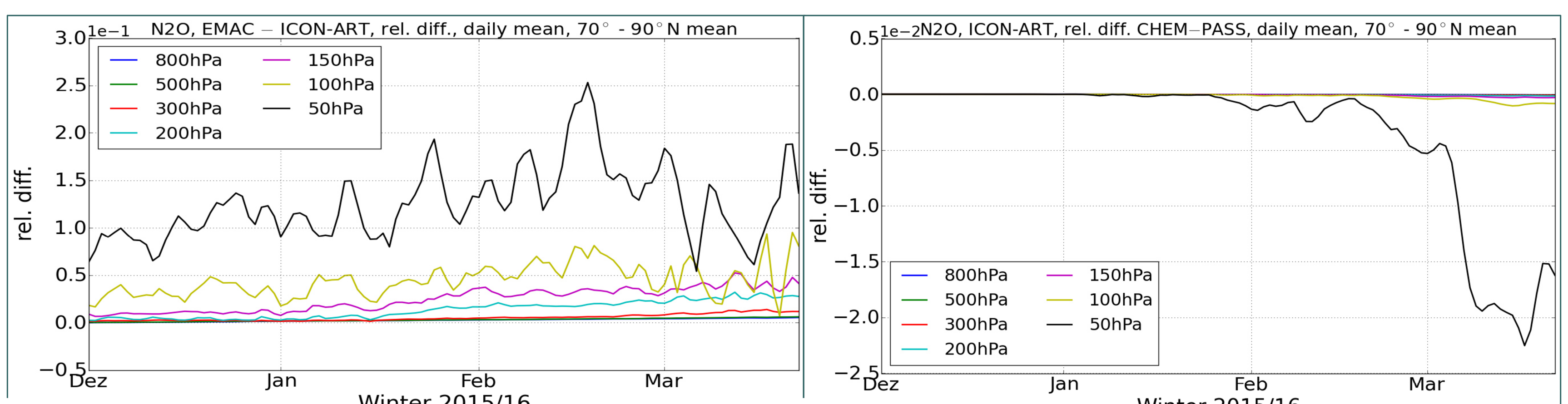

Fig.5.a *Fig.5.b*

➢ *Fig.3: Comparison between in-situ measurements (green) and ICON-ART results (magenta) interpolated on flight tracks (black) for temperature (a) and ozone (b). (c) shows the interpolated values for the artificial height tracer.*

➢ *Fig.4: Monthly mean of meridional N2O-gradient for Feb.'16, interpolated on 200 hPa, for EMAC (a) and ICON-ART(b)*

➢ *Fig.5: (a) Relative difference between daily values of N2O between EMAC and ICON-ART, averaged for 70° - 90° N. (b) Relative difference between daily values of active and passive N2O from ICON-ART, averaged for 70° - 90° N.*

References:
[1] Rieger, D., et al. (2015), Geosci. Model Dev. Discuss., 8, 567-614
[2] POLSTRACC Official Website, Jan. 2017, https://www.polstracc.kit.edu
[3] McLinden, C. A., et al. (2000), Journal of Geophys. Research, 105, 14.653-14.665
[4] Olsen, S. C., et al. (2001), Journal of Geophys. Research, 106, 28.771-28.784
[5] EMAC-Data kindly provided by O. Kirner, KIT