Polar Stratospheric Clouds in ICON-ART

Michael Weimer[1] (michael.weimer@kit.edu), Ole Kirner[1], Jennifer Schröter[2], Roland Ruhnke[2], and Peter Braesicke[2]
[1]Steinbuch Centre for Computing, [2]Institute of Meteorology and Climate Research

ICON (ICOsahedral Nonhydrostatic)

- Meteorological model developed at Deutscher Wetterdienst (DWD) and Max Planck Institute for Meteorology (MPI-M) (Zängl et al., 2015)
- Operationally used for weather predictions at DWD since January 2016
- Local grid refinement with two-way interaction

ART (Aerosols and Reactive Trace gases)

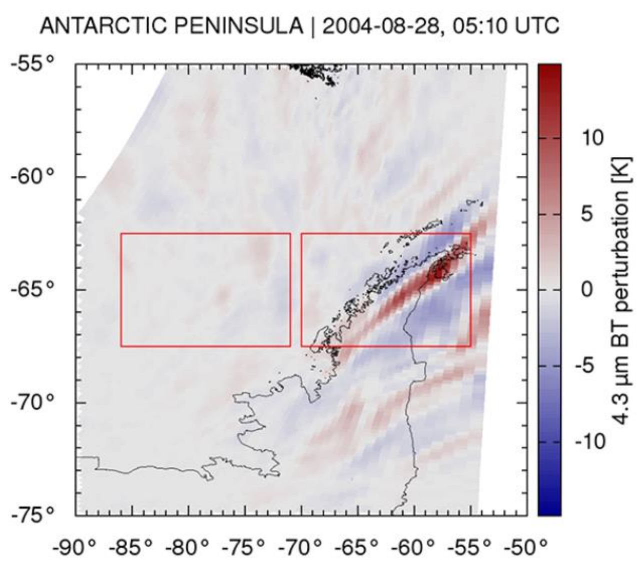
- Extension for ICON to calculate aerosols and atmospheric chemistry and their feedback to the state of the atmosphere (Rieger et al., 2015)
- Flexible tracer concept: the variety of experiments can be setup without changes in the code (Schröter et al., 2018)

Polar Stratospheric Clouds (PSCs)

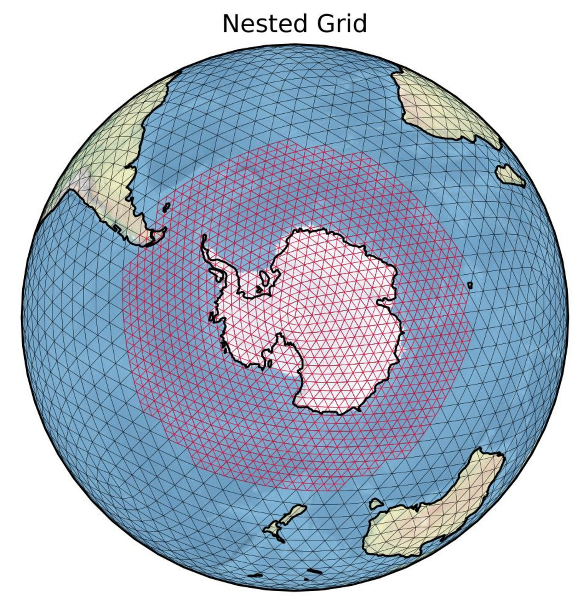
- Catalyse reactions during polar night that lead to the ozone hole as soon as the sun rises
- Three types of PSCs:
  - STS clouds: liquid Supercooled Ternary Solution droplets (H_2SO_4, H_2O, HNO_3)
  - NAT clouds: solid Nitric Acid Trihydrate particles ($HNO_3(H_2O)_3$)
  - Water ice clouds (like cirrus clouds in the troposphere)

Goal of this work

- Evaluation of heterogeneous chemistry on PSCs in ICON-ART with satellite data
- Investigation of interaction between PSCs and gravity waves
- First application of local grid refinement (nest) in chemistry with ICON-ART
- Nested region around Antarctic Peninsula



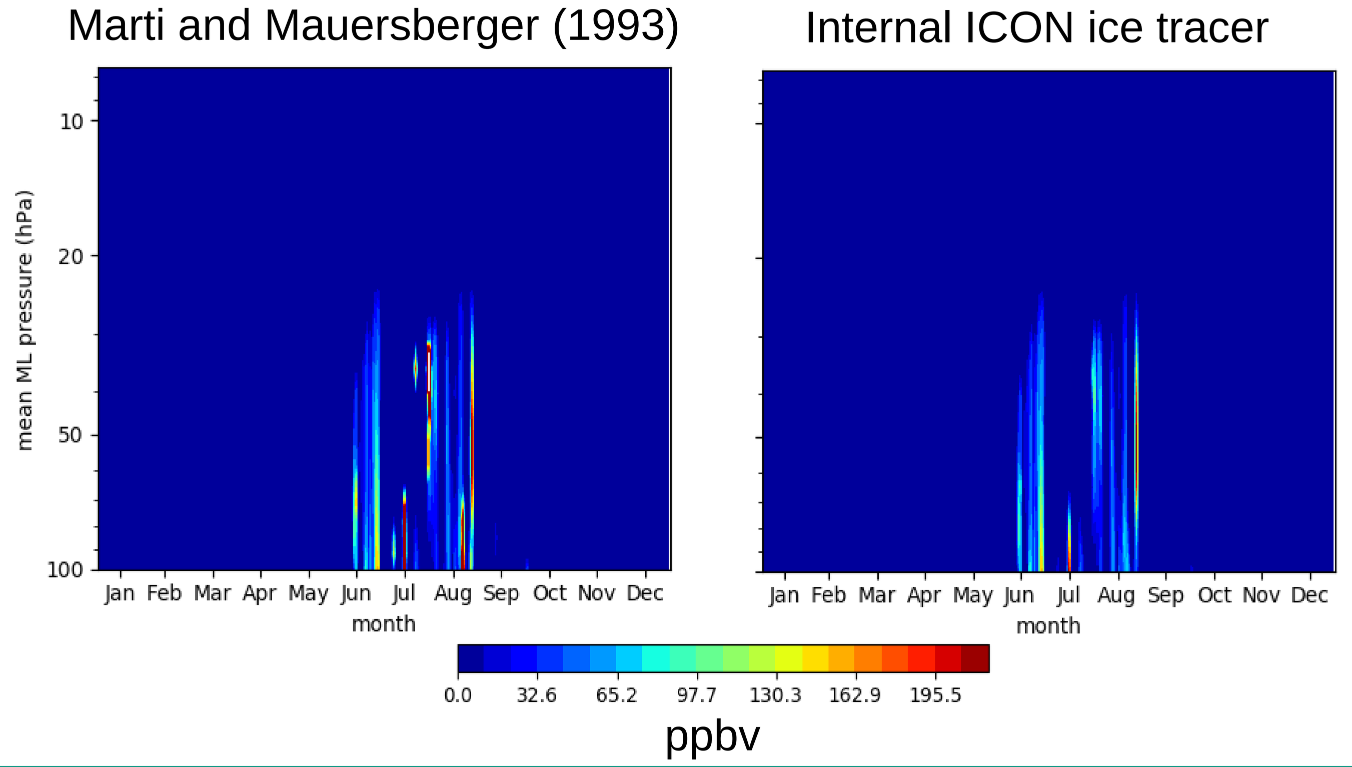
Graphic: Hoffmann et al. (2016)



Ice PSCs in ICON-ART

- Two possibilities:
  1. usually used diagnostic parametrisation
  2. using ICON microphysics also for stratosphere?
- Comparison in a 1-year simulation evaluated at South Pole:
  - general good agreement
  - slight differences during July

→ Next step: comparison to measurements

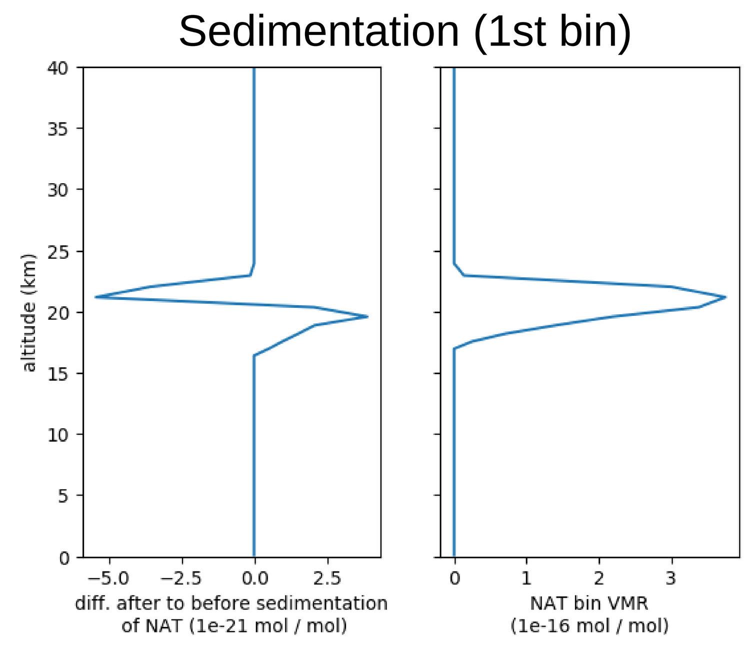


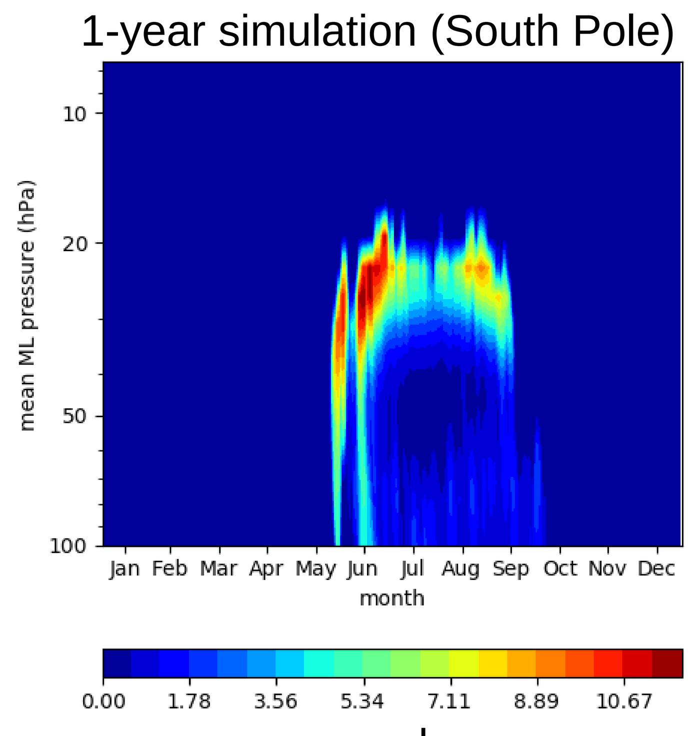
NAT particles

- Based on Carslaw et al. (2002)
- Formed at supersaturation
- Categorised in different size bins (selectable by user)

→ Sedimentation dependent on the selected size distribution

→ Next steps: consistency check of sedimentation and comparison to measurements

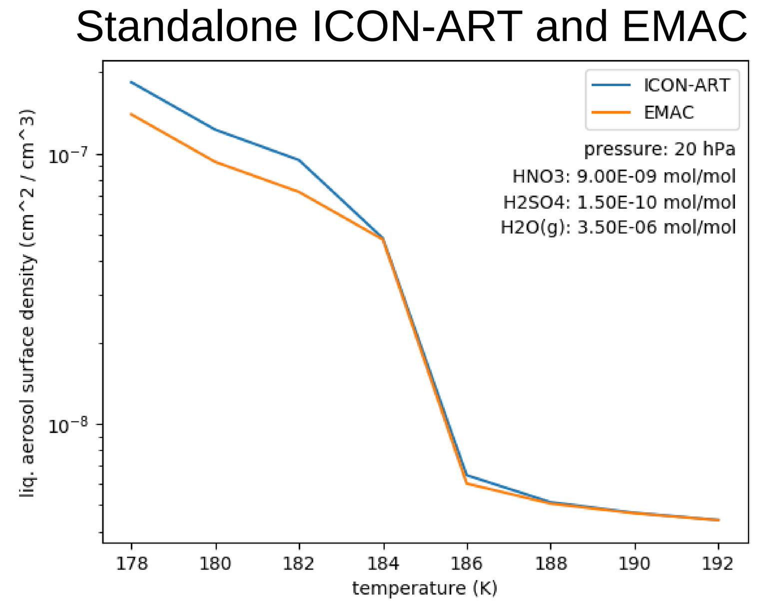


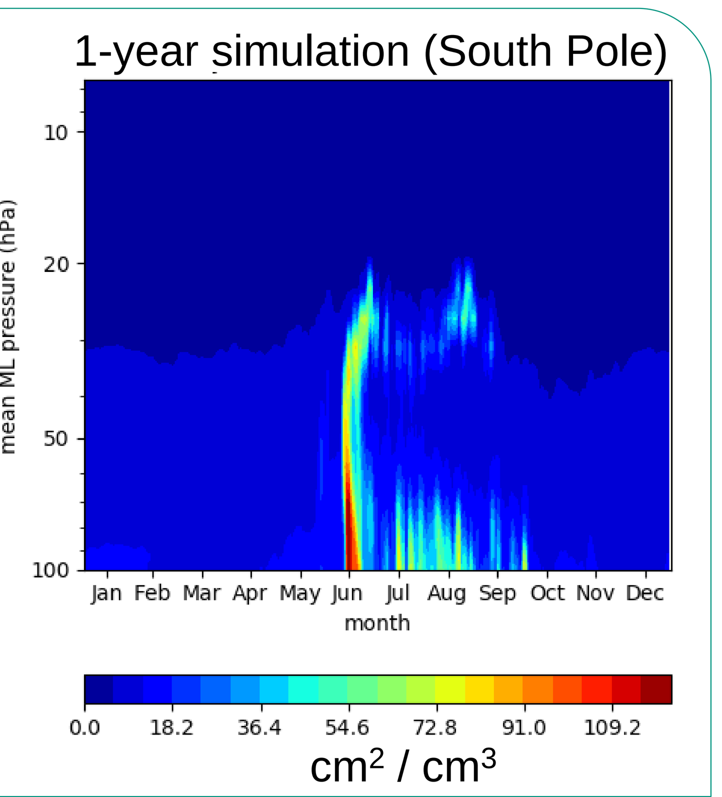


STS droplets

- Based on Carslaw et al. (1995)
- Computes the equilibrium ternary solution between H_2SO_4, H_2O and HNO_3
- Output: surface of STS per volume, reaction probabilities
- Comparison with the PSC scheme in the EMAC model (Kirner et al., 2011)

→ Next step: comparison to measurements





Gas phase chemistry in ICON-ART (cf. Schröter et al., 2018)

- Based on MECCA (Sander et al., 2011)
- Photolysis rates using Cloud-J (Prather, 2015)
- Simplified mechanism to produce HNO_3 and H_2SO_4 with ICON-ART
- Ozone depletion with simplified chlorine cycle

$O_2 + O(^1D) \rightarrow O(^3P) + O_2$
$O_2 + O(^3P) \rightarrow O_3$
$OH + O_3 \rightarrow HO_2 + O_2$
$HO_2 + O_3 \rightarrow OH + 2\ O_2$
$H_2O + O(^1D) \rightarrow 2\ OH$
$N_2 + O(^1D) \rightarrow O(^3P) + N_2$
$N_2O + O(^1D) \rightarrow 2\ NO$
$N_2O + O(^1D) \rightarrow N_2 + O_2$
$NO + O_3 \rightarrow NO_2 + O_2$
$NO + N \rightarrow O(^3P) + N_2$
$NO_2 + OH \rightarrow HNO_3$
$HNO_3 + OH \rightarrow NO_2 + O(^3P)$
$NH_3 + OH \rightarrow 0.2\ N_2O + 0.3\ NO + 0.3\ NO_2 + H_2O$

photolytic reactions:

$O_3 + h\nu \rightarrow O(^1D) + O_2$
$O_3 + h\nu \rightarrow O(^3P) + O_2$
$NO_2 + h\nu \rightarrow NO + O(^3P)$
$NO + h\nu \rightarrow N + O(^3P)$
$HNO_3 + h\nu \rightarrow NO_2 + OH$
$Cl_2 + h\nu \rightarrow Cl + Cl$
$CFCl_3 + h\nu \rightarrow 3\ Cl$

$CH_4 + OH \rightarrow CO + H_2O$
$CO + OH \rightarrow HO_2 + CO_2$
$Cl + O_3 \rightarrow ClO + O_2$
$ClO + O(^3P) \rightarrow Cl + O_2$
$ClO + HO_2 \rightarrow HOCl + O_2$
$HOCl + OH \rightarrow ClO + H_2O$
$ClO + NO_2 \rightarrow ClNO_3$
$ClNO_3 \rightarrow ClO + NO_2$
$Cl + CH_4 \rightarrow HCl + CO + 2\ HO_2$
$CFCl_3 + O(^1D) \rightarrow ClO + 2\ Cl$
$SO_2 + OH \rightarrow H_2SO_4 + HO_2$
$DMS + OH \rightarrow SO_2 + 2\ CO$
$OCS + O(^3P) \rightarrow CO + SO_2$

surface emissions using Weimer et al. (2017)

References

Schröter et al. (2018), Geosci. Model Dev. Discuss., in review

Weimer et al. (2017), Geosci. Model Dev., 10, 2471-2494

Hoffmann et al. (2016), Atmos. Chem. Phys., 16, 9381-9397

Prather (2015), Geosci. Model Dev., 8, 2587–2595

Rieger et al. (2015), Geosci. Model Dev., 8, 1659–1676

Zängl et al. (2015), Quart. J. Roy. Meteor. Soc., 141, 563–579

Kirner et al. (2011), Geosci. Model Dev., 4, 169-182

Sander et al. (2011), Geosci. Model Dev., 4, 373-380

Carslaw et al. (2002), J. Geophys. Res., 107(D20), 8300

Carslaw et al. (1995), Geophys. Res. Lett., 22(14), 1877-1880

Marti and Mauersberger (1993), Geophys. Res. Lett., 20, 363-366