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Modelling of composition-climate interactions with ICON-ART

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The ICON-ART model

- **Ico**sahedral **N**onhydrostatic modelling framework
- ICON is a highly flexible atmospheric modelling system and can be used for global and regional numerical weather prediction and climate modelling applications

- **A**erosols and **R**eactive **T**race gases
- Extension for ICON
- The ART framework allows for the treatment of the spatial and temporal evolution of gases and aerosols within ICON

ICON-ART is jointly developed by DWD, MPI-M, DKRZ, and KIT

Numerical methods and algorithms

- ICON solves the prognostic variables on an unstructured triangular grid, which is based on recursive refinement of a spherical icosahedron (Zängl et al., 2015).
- The vertical discretization is formulated in a height-based terrain-following coordinate system.
- Integration in time is performed using an explicit two-time level predictor-corrector with different time steps for the dynamical core on the one side and physics parameterization on the other side.
- The ART module follows the process splitting concept used for most processes in ICON. For more details about the numerical and technical implementation of ART into ICON see Rieger et al. (2015) and Schröter et al. (2018).
- ICON as a next-generation model is parallelized for hybrid architectures and especially using the Message Passing Interface (MPI). Each MPI process calculates a specific limited area of the Earth and communicates its boundaries to its neighbours. An example of the distribution of the MPI processes in the global domain is shown in Fig. 3.

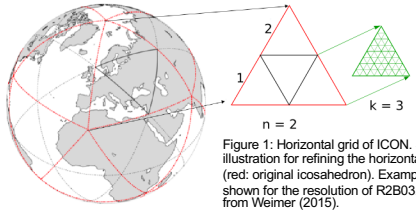
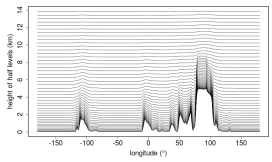


Figure 1: Horizontal grid of ICON. Schematic illustration for refining the horizontal grid (red: original icosahedron). Example is shown for the resolution of R2B03. Figure from Weimer (2015).

Figure 2: Vertical grid of ICON. Lowest model layers at the latitude of Himalaya. Figure from Weimer et al. (2017).



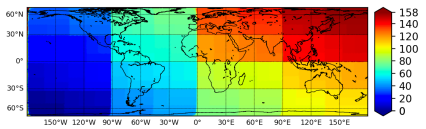


Figure 3: Distribution of MPI processes on global domain for 159 computing MPI processes (not used for I/O).

The scientific projects and simulation goals

MOisture Transport pathways and Isotopologues in water Vapour (MOTIV)	Founded by DFG	The aim of the MOTIV project is to generate progress in one of the key challenges of current climate research by establishing tropospheric water vapour isotopologues as a tool for testing model-based representations with ICON-ART-Iso of moisture pathways from source to sink.
Advanced Earth System Modelling Capacity (ESM)	Founded by Helmholtz	ICON-ART is used to enhance the fidelity of Earth system models by improving the realism of key processes in Earth system model compartments and by establishing a common framework that facilitates the coupling of different Earth system components as well with the implementation of the ensemble-based parallel data assimilation framework (PDAF) into ICON-ART.
HELMHOLTZ Analytic Framework (HAF)	Founded by Helmholtz	KIT is taking part with ICON-ART in the use case “Stratospheric Impact on Surface Climate”.
Digital Earth	Founded by Helmholtz	The atmospheric model ICON-ART will be utilized in show case A “Man-made and natural CH4 and VOC emissions from marine and terrestrial sources in the North Sea region to correlate measured gas fluxes with model runs to validate sensitivities and investigate the impact of such directly measured small scaled fluxes on air quality.
ROle of the Middle atmosphere In Climate (ROMIC-II)	Founded by BMBF	ICON-ART is used in three projects: SOCTOC (Effects of anthropogenic Stratospheric Ozone Changes on climate sensitivity and Tropospheric Oxidation Capacity), SCI-HI (Surface Climate Impacts of Halogen Induced Stratospheric Ozone Changes), and SOLCHECK (Solar contribution to climate change on decadal to centennial timescale)

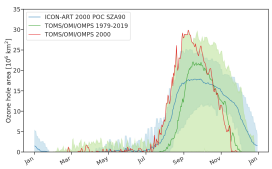
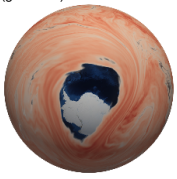


Figure 4: Ozone hole area from the optimized ICON-ART integration with Polar Ozone Chemistry (POC) for the year 2000 (blue) compared with satellite observations (green/red). Satellite data: NASA Ozone Watch

Figure 5: Schematic view of the simulated Ozone hole with ICON-ART.



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