Seminar “Physics and Chemistry of the Atmosphere”,
Institute of Environmental Physics (IUP), Univ. Bremen
Date: 23-May-2025, 14:15
Place: Building NW1, Room S1360

Interpretable Machine Learning-based Radiation Emulation for ICON

Katharina Hafner[1,2], Fernando Iglesias-Suarez[2], Sara Shamekh[3], Pierre Gentine[4,5], Marco Giorgetta[6], Robert Pincus[7], Veronika Eyring[2,1]

1 University of Bremen, Institute of Environmental Physics (IUP), Bremen, Germany
2 Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institut für Physik der Atmosphäre, Oberpfaffenhofen, Germany
3 Courant Institute of Mathematical Sciences, New York University (NYU), New York, NY, USA
4 Department of Earth and Environmental Engineering, Columbia University, New York, NY, USA
5 Earth Institute and Data Science Institute, Columbia University, New York, NY, USA
6 Max-Planck-Institut für Meteorologie, Hamburg, Germany
7 Lamont-Doherty Earth Observatory, Palisades, New York, USA

Earth system models (ESMs) are essential to understand and project climate change. ESMs typically run for decades on coarse horizontal scales in the order of 40-100 km, which requires the parameterization of subgrid-scale processes. The radiation parameterization is one of the computationally most expensive components in ESMs. Machine Learning (ML)-based emulators are known to be faster than traditional parameterizations while retaining accuracy but online tests tend to be challenging. In this study, we develop an ML-based emulator for the ICOsahedral Non-hydrostatic (ICON) model with the RTE+RRTMGP radiation code. This radiation parameterization calculates radiative fluxes based on the atmospheric state and its optical properties. Our emulator uses a bidirectional Long Short-Term Memory (Bi-LSTM) architecture to predict heating rates which is physically motivated by the flow direction of radiative fluxes. We analyze the ML-based radiation emulator using Shapley values and demonstrate that the neural networks learned physically consistent relationships including atmospheric thermal emission and cloud feedback. We implemented the ML-based radiation emulator into ICON and performed simulations with the coupled model that are stable for multiple years while being 4 times faster when running on CPU. The coupled simulation finds an equilibrium that is close to the reference simulation.