Project: **1070**

Project title: **Atmospheric Research with ICON-ART (ARIA)**

Principal investigator: **Ali Hoshyaripour, Karlsruhe Institute of Technology**

Report period: **2025-01-01 to 2025-12-31**

The ARIA numerical experiments on Levante in 2025 are separated in three groups from which we report few highlights here.

1. Surface fluxes of gases and aerosols

Vegetation fires: Vegetation fires release a variety of gases and particles, which can be transported over long distances, impacting the atmosphere's radiative balance, weather, and air quality. The transport of these emissions depends on various factors, one of which is the emission height, a source of considerable uncertainty and strongly affected by the heat released by the fire and the atmospheric conditions. We extended the ICON-ART model and are now able to account for heat and moisture release by the fire (Muth eta l., 20205) as well as the emission of aerosols and chemical tracers (Unser et al., in prep). Additionally, we introduced an enhancement factor for the sensible heat release to be used in coarser-resolution model runs to further improve the injection height (Unser et al., in prep). The preliminary results in Fig. 1 show that the model is able to reproduce the observation and is less resolution-dependent.

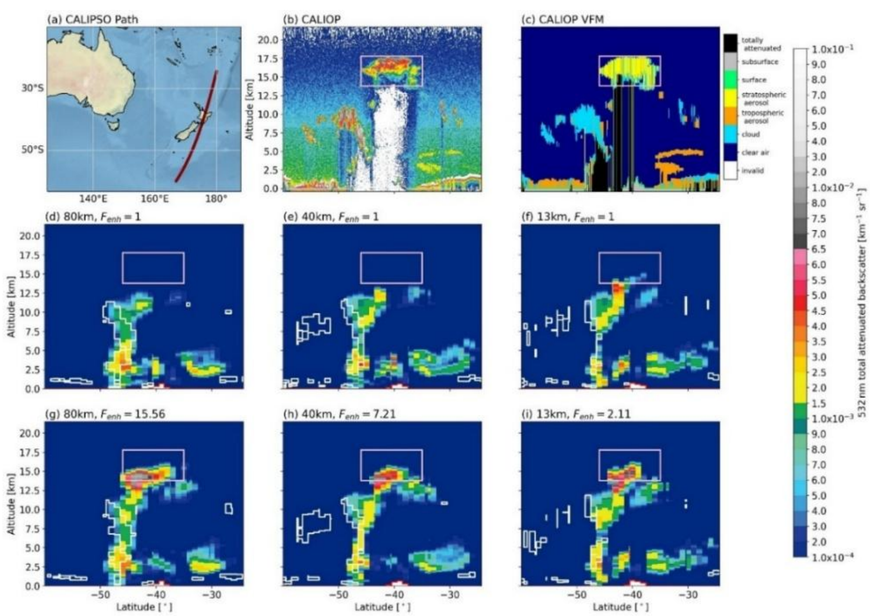

Figure 1: Comparison of model attenuated backscatter with CALIOP satellite data for different resolutions and enhancement factors (Unser et al., in prep).

Saharan dust events: We investigated the 14-19 March 2022 Saharan dust event using storyline simulations. The goal was to understand how it would have developed under the same synoptic situation in a different climate and to quantify the impact of global warming on the entire lifecycle of dust for this specific event and by extension its impact on photovoltaic power generation in Germany. The preliminary results indicate large regional variability suggesting that a general conclusion cannot be drawn at this stage. Due to lack of computational time caused by the significant cuts in the 2025 request, we were not able to perform the ensemble simulations. Further simulations and analysis are now planned for 2026.

2. Aerosol-Radiation-Cloud interactions (ARCI)

Understanding aerosol behavior in the Arctic is critical due to the region's climate sensitivity and influence on global circulation. To improve climate modeling and policy relevance, we conducted two experiments on aerosol emissions and aging. The first examined the transport, transformation, and radiative effects of Siberian wildfire and Raikoke volcanic aerosols, using comprehensive aerosol and chemistry processes. Model validation showed good agreement and clear plume separation (Fig. 2). The second focused on a shorter period to assess aerosol aging by analyzing the core-to-total diameter ratio of coated particles, revealing that condensation processes significantly alter particle properties over time.

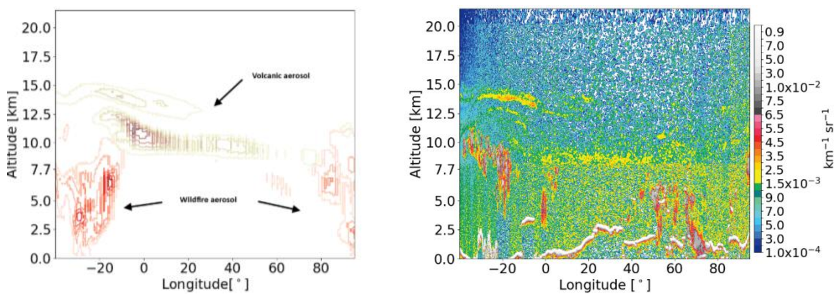

Figure 2: Simulated (left) and observed (right) wildfire and volcanic aerosol plumes

Additionally, we implemented a new CCN activation routine, originally introduced by Abdul-Razzak et al. (1998) and Abdul-Razzak and Ghan (2000), and reviewed and refactored the interfacing of CCN activation of prognostic aerosol between ICON and ART. First evaluations of the newly implemented routine were conducted with idealized simulations of a warm bubble with a predefined, uniform concentration of sea salt (of 2 x 10^9 kg^{-1}) serving as CCN. Since they show reasonable results further evaluations with real-case scenarios are on-going.

3. Machine learning for atmospheric composition modelling

Wildfire behavior is influenced by complex physical processes, including turbulent atmospheric transport, mixing of air with gases from vegetation pyrolysis, and heat transfer between flames and vegetation. A synthetic plume dataset, created by combining the WRF model with the SFIRE fire spread algorithm, simulates diverse fire and atmospheric conditions. Various machine learning models, especially convolutional neural networks (CNNs), are used to refine these predictions (Moradpour et al., submitted). For this part the GPU resources has been necessary. The coupling of this module to ICON-ART is ongoing.

References :

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