Project: **1070**

Project title: **ARIA**

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The ARIA numerical experiments on Levante in 2023 are separated in four groups. The progress of each group is outlined below.

1- Surface fluxes of aerosols

Vegetation fires release a variety of gases and particles, which can be carried 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. In previous applications, ICON-ART has determined emission heights using a 1D-plume rise model designed for climate models. Our objective is to enhance the resolution of emission and transport simulations. Using satellite observations as a reference, we seek to refine the ICON-ART model to more accurately replicate injection heights. This refinement encompasses considerations of moisture release from the fires, which can trigger additional convection due to latent heat liberation. Furthermore, integrating fire radiative power as an extra heat source can elevate the emission plume. To quantify these effects, we focus on the analysis of the Australian bushfires that occurred in 2019/2020, investigating the influence of moisture release, radiative heat release, and radiation on the transport of aerosols generated by biomass burning. Figure 1 shows the maximum height of biomass burning aerosols and clouds simulated with ICON-ART. The left Figure displays the reference simulation, the right figure displays the experiment that considers moisture and heat release as well as aerosol-radiation interaction. It is clearly visible that the implementation increases the plume height an enables top heights above 12.5 km. This is something the reference simulation lacks, it is known that the implemented plume-rise-model underestimates high plume heights.

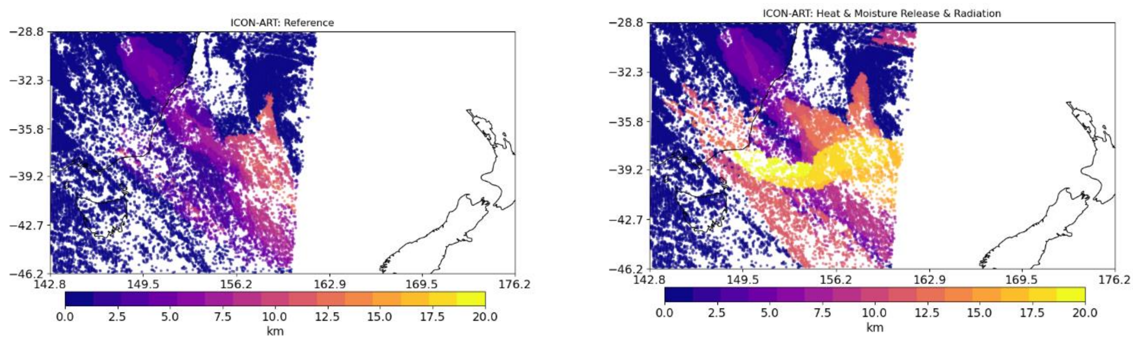

Figure 1: Simulated to height of the biomass burning aerosol and cloud for the reference simulation (left) and the experiment considering heat and moisture release by the fire and aerosol-radiation interaction.

2- Mixing and aging of aerosols

Sea salt is a principal natural aerosol exerting a significant influence on the climatic and chemical properties of the marine atmospheric environment. In addition to its interactions with radiation and cloud formations, sea salt serves as a fundamental supplier of halogens and offers a substantial surface area conducive to heterogeneous reactions, thereby contributing to the modification of atmospheric chemistry. Despite their paramount role, sea salt aerosols persist as one of the most challenging aerosol components to accurately quantify their surface fluxes, encompassing emission, wet/dry deposition, and their overall atmospheric loading. We have performed multi-months simulations with ICON-ART to identify the role of the aging processes on the lifetime of sea salt. Fig. 2 shows the integrated concentration in the atmosphere and the proportion of the respective sink processes that remove the aerosol from the atmosphere over 3 months. The results are shown for the accumulation and coarse mode. It is clearly visible, especially in the accumulation mode, that the concentration decreases due to water uptake and, conversely, the sink processes increase. A strong increase is visible especially in the wet deposition. Here, the efficiency of the removal process increases with increasing aerosol diameter.

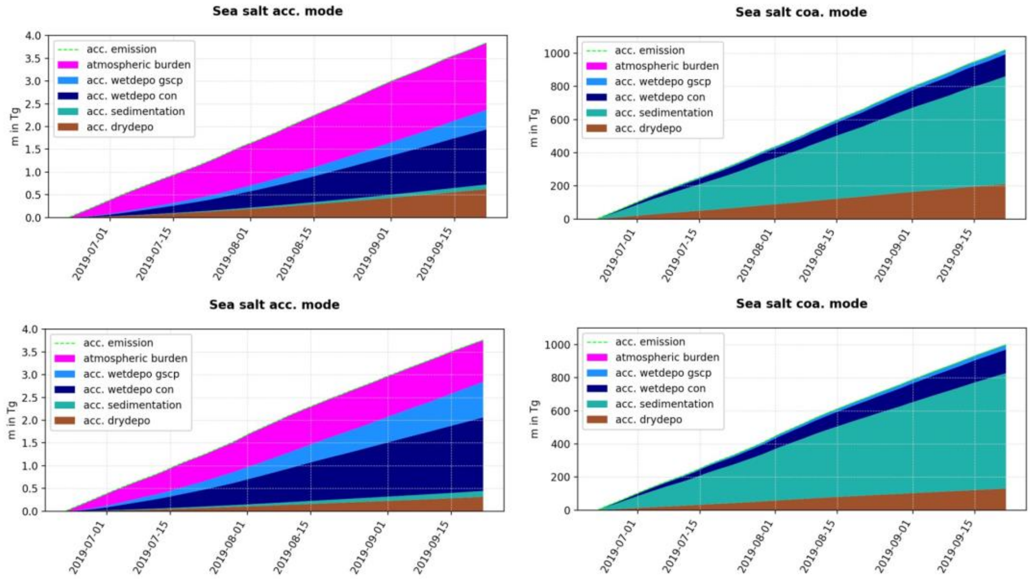

Figure 2: Accumulated dry deposition, sedimentation and wet deposition processes of sea salt each for the simulations without water uptake (top) and with water uptake (bottom) and for the accumulation (left) and coarse (right) modes.

3- Aerosol-radiation-cloud Interactions (ARCI)

Aerosol particles act as cloud condensation nuclei (CCN) and/or ice nuclei (IN) and therefore directly affect the formation and the properties of clouds. A high aerosol number concentration leads to the formation of more and smaller droplets or ice particles compared to a smaller number concentration. We developed ICON-ART to represent the aerosol loads and its impact on hydrometeor spectra more accurately, which is crucial for understanding icing properties of clouds and in forecasting the aircraft icing hazards. The results obtained from high resolution LAM simulation show very good agreement with the observations.

Although in collaboration with DWD we developed the dusty-cirrus parameterization, a major part of the experiments where not feasible because of the lacking coupling between ART and 2-mom scheme. This explains the expiration of about 10000 nh planned for this set of experiments.

4- Machine learning for atmospheric chemistry

It was planned to generate the training data using ICON-ART atmospheric chemistry simulations with very simple (<10 species/reactions) to very complex (>100 species/reactions) chemical mechanisms. After performing the first set of tests, we figured out that the generated data is not suitable for training. The reason was that other processes played a role and it was difficult to attribute the changes to chemistry only. Thus, we decided to move on with box model simulations which were computationally much cheaper. This explains the expiration of about 35000 nh planned for this set of experiments.

Problems:

The main problem was related to the atmospheric chemistry and ACRI simulations explained above. In addition, we observed in several simulation the dependency of the results on the number of nodes. We are working on DKRZ support to understand and solve the problem.

Publications:

Rohde, A., Vogel, H., Hoshyaripour, G. A., Kottmeier, C., & Vogel, B.: Regional impact of snow-darkening on snow pack and the atmosphere during a severe Saharan dust deposition event in Eurasia. Journal of Geophysical Research: Earth Surface, 128, https://doi.org/10.1029/2022JF007016, 2023

Seifert, A., Bachmann, V., Filipitsch, F., Förstner, J., Grams, C. M., Hoshyaripour, G. A., Quinting, J., Rohde, A., Vogel, H., Wagner, A., and Vogel, B.: Aerosol–cloud–radiation interaction during Saharan dust episodes: the dusty cirrus puzzle, Atmos. Chem. Phys., 23, 6409–6430, https://doi.org/10.5194/acp-23-6409-2023 , 2023.