Project: **1070**

Project title: **ARIA**

Principal investigator: **Bernhard Vogel**

Report period: **2021-01-01 to 2021-12-31**

The ARIA numerical experiments on Mistral in 2021 are separated in four groups. The progress of each group is outlined below.

1- Biomass-burning aerosols

Vegetation fires are a natural part of the Earth system. However, the contemporary fire regimes are impacted by human activities and climate change. It is therefore important to have a good understanding of the fire emission impacts on air quality, weather and climate. We extended ICON-ART to simulate the emission, transport and impacts of the biomass-burning aerosols. The model obtains emission fluxes from the CAMS Global Fire Assimilation System (GAFS) and uses the plume-rise model by Freitas et al. (2009) to determine the emission height. A case study of the vegetation fire emissions in Brisbane, Australia during in December 2019 shows good agreement with the measurements (Fig. 1-a). Besides the emission, vegetation fires further modify the surface albedo. This effect was implemented in the model. Figure 1-b shows the difference in short wave upward flux at the surface modified albedo minus reference. In areas of the fires, the upward flux is reduced as the fire reduces the albedo and therefore less radiation is reflected at the surface.

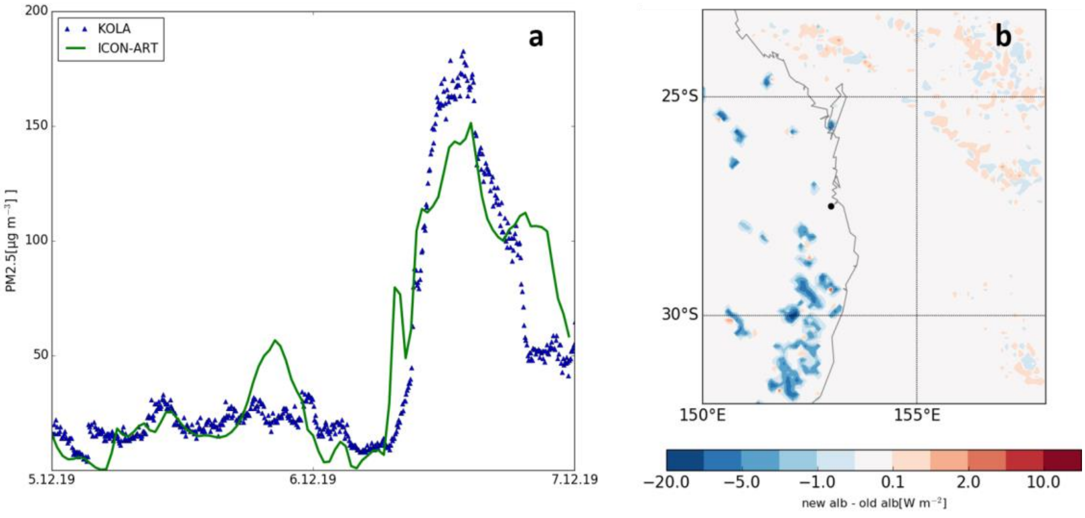

Figure 1: (a) Temporal evolution of $PM_{2.5}$ concentration in Brisbane, Australia. The measurements are taken from the KOALA station by the Queensland University of Technology (blue triangles) and the green line displays the concentration simulated with ICON-ART. (b) Difference in short wave upward flux at the surface, modified albedo minus the reference, at the east coast of Australia. The black dot marks Brisbane.

2- Mixing and aging of aerosols

Operationally used aerosol dispersion forecasting systems nowadays only consider externally mixed aerosols. In the real atmosphere, however, due to aerosol dynamic processes (nucleation, condensation, and coagulation) and chemical reactions, the mixing state of aerosols is internally mixed. We implemented a new aerosol dynamics module (AERODYN) in ICON-ART to account for such processes. The first simulations focus on volcanic eruptions as natural experiments. The results show that the interplay of aerosol dynamics, chemistry and aerosol-radiation interactions controls the evolution and transport of the plume (Bruckert et al., 2021).

3- Aerosol-Radiation Interactions

Within the PermaStrom project, the optical properties of soot and sea salt particles are implemented in ICON-ART. Besides, the model is successfully coupled with new radiation scheme ecRad. Figure 1 shows the variation of aerosol optical depth (AOD) and total absorption in the shortwave induced by mineral dust averaged over 10 days between simulations with ecRad and RRTM both coupled with ART. Internally mixed aerosols (aged aerosols) have different optical properties compared to unaged particles. These optical properties are parametrized by Mie calculations and the results are stored as look-up tables in ICON-ART. With this setup, the feedback of aerosol-radiation interaction on the aerosol transport is studied. Our studies show for various experiments that the aerosol cloud top rises due to aerosol-radiation feedback. Thus, the lifetime of the particles is extended and particles can be transported over larger distances.

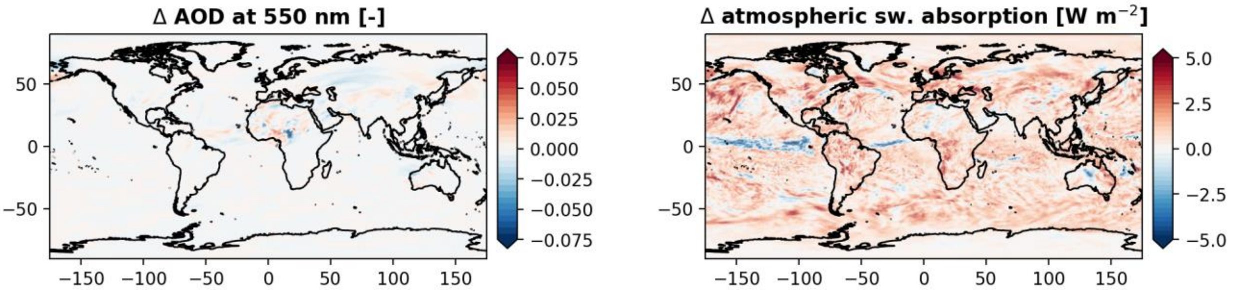

Figure 2: variation of AOD (left) and total absorption in the shortwave (right) induced by mineral dust averaged over 10 days between simulations with ecRad and RRTM both coupled with ART.

4- Aerosol-cloud interactions

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. Therefore, the aerosol concentration has a direct impact on the clouds' hydrometeor spectrum. This in turn affects the clouds' properties, e.g. regarding its radiation interaction or precipitation behavior. Additionally, concerning supercooled clouds, the droplet spectrum may influence the safety of passing aircraft. This is because supercooled water instantaneously freezes when impinging on the aircrafts surface combined with the differing droplet impingement efficiencies depending on its size. 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.

A summary of resource utilization (with rounded values) is given in Table 1. We note that only 70% of our requested resources (both CPU time and workspace) were granted last year. As a result, we experienced huge lack of CPU-time in the first and third quarter of the year. Besides, we did not have enough workspace and had to write on scratch very often. Thus, we could not afford some of the main ensemble simulations that we planned.

Table 1: Resource utilization of the subprojects until 15.08.2021

Project	Compute time (Node hours)
Biomass-burning aerosols	18.000
Mixing and aging of aerosols	80.000
Aerosol-Radiation Interactions	25.000
Aerosol-cloud interactions	56.000
Sum	**179.000**

References:

Bruckert, J., Hoshyaripour, G. A., Horváth, Á., Muser, L., Prata, F. J., Hoose, C., and Vogel, B.: Online treatment of eruption dynamics improves the volcanic ash and SO2 dispersion forecast: case of the Raikoke 2019 eruption, Atmos. Chem. Phys. Discuss. [preprint], under revision, 2021.