Project:	**1174**
Project title:	**Regional Effects of Absorbing Aerosols and Biomass Burning**
Project lead:	**Dr. Fabian Senf (TROPOS)**
Allocation period:	**1.7.2025 - 30.6.2026**

Overview

The compute project is dedicated to the question of how absorbing aerosols, such as black carbon and dust, influence both regional weather and climate. As part of the Leibniz Campus 'Smoke and Bioaerosol', the research focuses on smoke emissions from biomass burning, in particular on the meteorological conditions and characteristics of forest fires that drive the formation of pyroconvective clouds. Studies conducted within this project used high-resolution simulations with a numerical weather prediction model to investigate the atmospheric responses to several extreme burning events.

Resource Utilization

At the time this report was written, approximately 44% of the granted computing resources were being used by project members, while 35% expired unused and 21% are still remaining. Resources were mainly used by the PhD student in the project, thus supporting early career development. We would like the reduced use of resources to be interpreted as a success, as sufficient high-quality simulation results were achieved in the period to produce a scientific publication and to significantly contribute to the development of a state-of-the-art atmosphere-aerosol-model system. Thanks to the very easy-to-use interface to DKRZ Jupyterhub, an important part of the work and therefore used resources was put into the scientific analysis of the generated simulation data.

Scientific Results

The largest part of the resources of the bb1174 compute project were used to run and evaluate high-resolution limited area simulations with the numerical weather prediction model ICON. Experiments were carried out both with and without a coupling of ICON to the aerosol model HAM-lite. The development of so-called Pyro-Cumulonimbus (PyroCb) events was investigated. PyroCbs are characterized by spontaneously occurring, very strong and deep convection, which is triggered by the extreme heat release from forest fires. Within PyroCbs, very large quantities of biomass-burning aerosols can be transported into the tropopause region and the lower stratosphere where the lifetime of the smoke increases by several orders of magnitude compared to tropospheric smoke. Although pyroCbs have been recognized as an important source of stratospheric aerosol, many aspects of their dynamics are still poorly understood.

To investigate the formation and dynamics of pyroCbs events, first numerical experiments were carried out using the very strong "Australian new years eve pyroCb event" (ANY event) for case studies partly already in the allocation period 2024/2025. The results of this study are now published (Müller et al., 2025).

In this study, we investigate the heat emission threshold at which forest-fire plumes transition into pyroCbs and examine the sensitivity of the pyroCbs to further changes in the total amount of heat released as well as to the latent to sensible heat flux ratio. Our results show a pronounced bimodal

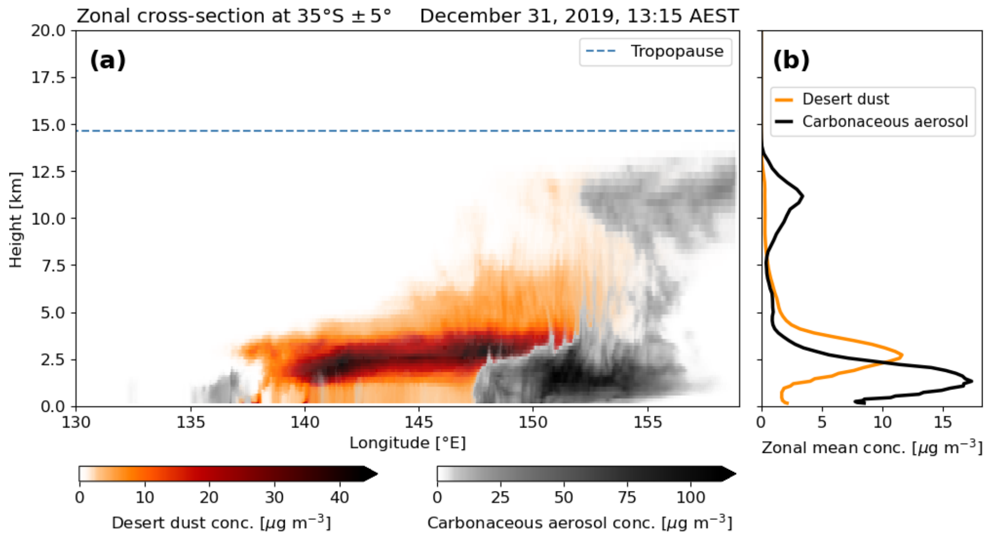

Figure 1: Panel (a) shows the zonal cross-section of aerosol concentrations averaged over the 5°-wide latitude band 35∘S ± 5∘ latitude on December 31, 2019, showing the vertical and longitudinal distribution of desert dust (colored shading) and carbonaceous aerosol from bushfires (grayscale). The horizontal dashed line denotes the approximate tropopause height. Panel (b) shows corresponding zonal mean vertical profiles. See Heinold et al. (2026) for more detail.

behavior of the plumes with an abrupt onset of pyroCb formation when the sensible heat flux exceeds 50 kW m^{-2}. When a cloud is formed within the plume, the smoke injection height is mainly controlled by the sum of the sensible and latent heat flux, while the ratio between the two plays a subordinate role. Encouragingly, a reliable estimate of the total heat flux was found to be sufficient to characterize the behavior of PyroCbs, reducing the need for detailed partitioning of sensible and latent heat.

Based on these findings it also became clear, that the treatment of fire emissions and their injection heights in the high-resolution aerosol–climate modeling system ICON HAM-lite, which is being developed at TROPOS in collaboration with colleagues from the University of Oxford, ETH Zurich, and other international and national partners, is inadequate in the case of severe forest fires, and that improving this aspect will allow for novel and impactfull studies on the dynamics of wildfire-triggered deep convection and the subsequent long-range transport and impact of biomass burning aerosol.

Therefore, a new treatment for heat emissions from forest fires was developed and implemented into the ICON HAM-lite model system. Simulations that make significant use of this novel implementation are now part of a recent publication which is currently under review Heinold et al. (2026). Figure 1 illustrates the new fire-emission capabilities of the ICON HAM-lite model system by showing the vertical distribution and long-range transport of aerosols in more detail using the extreme pyro-convective events during in south-eastern Australia around New Year's Eve 2019/2020 as a case study. Shown is a zonal cross-section of aerosol concentrations averaged over a 10°-wide latitude band centered at 35°S on December 31, 2019. The figure distinguishes between desert dust (colored shading) and carbonaceous aerosol (grayscale shading), originating primarily from the intense bushfire activity in southeastern Australia. Fig 1 b shows the corresponding zonal mean vertical profiles.

References

Heinold, B., P. Weiss, S. De, A. Kubin, J. Müller, F. Senf, P. Stier, and I. Tegen, 2026: Icon coupled to ham-lite 1.0 in limited-area mode: an efficient framework for targeted kilometer-scale simulations with interactive aerosols. *EGUsphere*, **2026**, 1–31.

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