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Global Transport and Composition of Volcanic and PyroCb Stratospheric Aerosols Observed by EarthCARE/ATLID and ground-based lidars

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ESA's EarthCARE satellite mission launched in May 2024 and carrying Atmospheric LIDar (ATLID) provides high-resolution vertical profiling of aerosols and clouds at 355 nm. Fully operational since August 2024, ATLID has been witness to a significant perturbation of stratospheric aerosol budget following the eruptions of Ruang volcano (Indonesia) in late April 2024 as well as to a major panboreal outbreak of wildfire-generated pyrocumulonimbus (pyroCb) events in Canada and Siberia in late May 2025 that had a hemisphere-scale impact on stratospheric aerosol loading and composition. Using ATLID L1B data together with limb-viewing satellite observations (OMPS-LP and SAGE III), we quantify the stratospheric aerosol perturbations generated by these events, characterize the long-range transport of volcanic and smoke aerosols and contrast their optical properties and dynamical evolution.

To evaluate the ATLID performance in the stratosphere, its data are compared with collocated lidar observations at various locations in both hemispheres and overpass-coordinated balloon flights in France carrying in situ aerosol sensors. The intercomparison with suborbital observations suggests excellent performance of ATLID in the stratosphere and proves its capacity to accurately resolve fine structures in the vertical distribution of stratospheric aerosols.

ATLID observations of the global progression of volcanic and wildfire aerosols align closely with those from OMPS-LP and SAGE III, while uniquely providing continuous coverage through polar night. We show that Ruang aerosols were subject to an unusually massive isentropic transport into the southern extratropics and were most probably entrained by the 2025 Antarctic polar vortex, potentially enhancing the polar stratospheric cloud occurrence and Antarctic ozone hole.

The stratospheric aftermath of the 2025 panboreal wildfire outbreak (POW) was characterized through a synergy of ATLID and ground-based lidar observations within ACTRIS and NDACC networks. The lidar measurements consistently report record-breaking values of stratospheric aerosol backscatter and AOD during the passage of the most intense Canadian pyroCb plume. This plume displayed a pronounced warm anomaly, linked to strong solar absorption by black carbon, and underwent diabatic self-lofting from ~13 km to 20 km altitude. ATLID further indicates that smoke aerosols dispersed across the northern extratropical stratosphere and may have penetrated into the tropics.