EarthCARE Stratospheric Aerosol Optical Depth and Its Impact on ICON Climate model

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climate change initiative
ACTION4COOLING

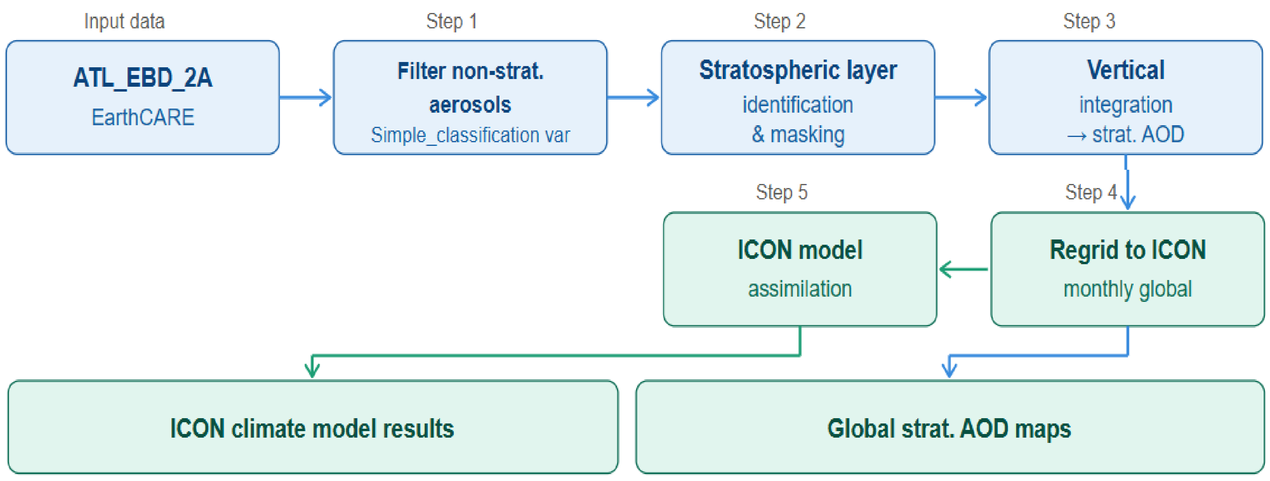
Background and motivation

Stratospheric aerosols influence Earth's radiative balance, weather and climate and play a key role in Solar Radiation Modification (SRM) through Stratospheric Aerosol Injection (SAI). Volcanic eruptions provide natural analogues for studying the evolution and climatic impacts of stratospheric aerosol perturbations.

The observational gap: Global climate models typically rely on climatological background values or stratospheric AOD (SAOD) from passive sensors (e.g. limb measurements[1]). Vertically-resolved SAOD fields are not routinely available for model assimilation.

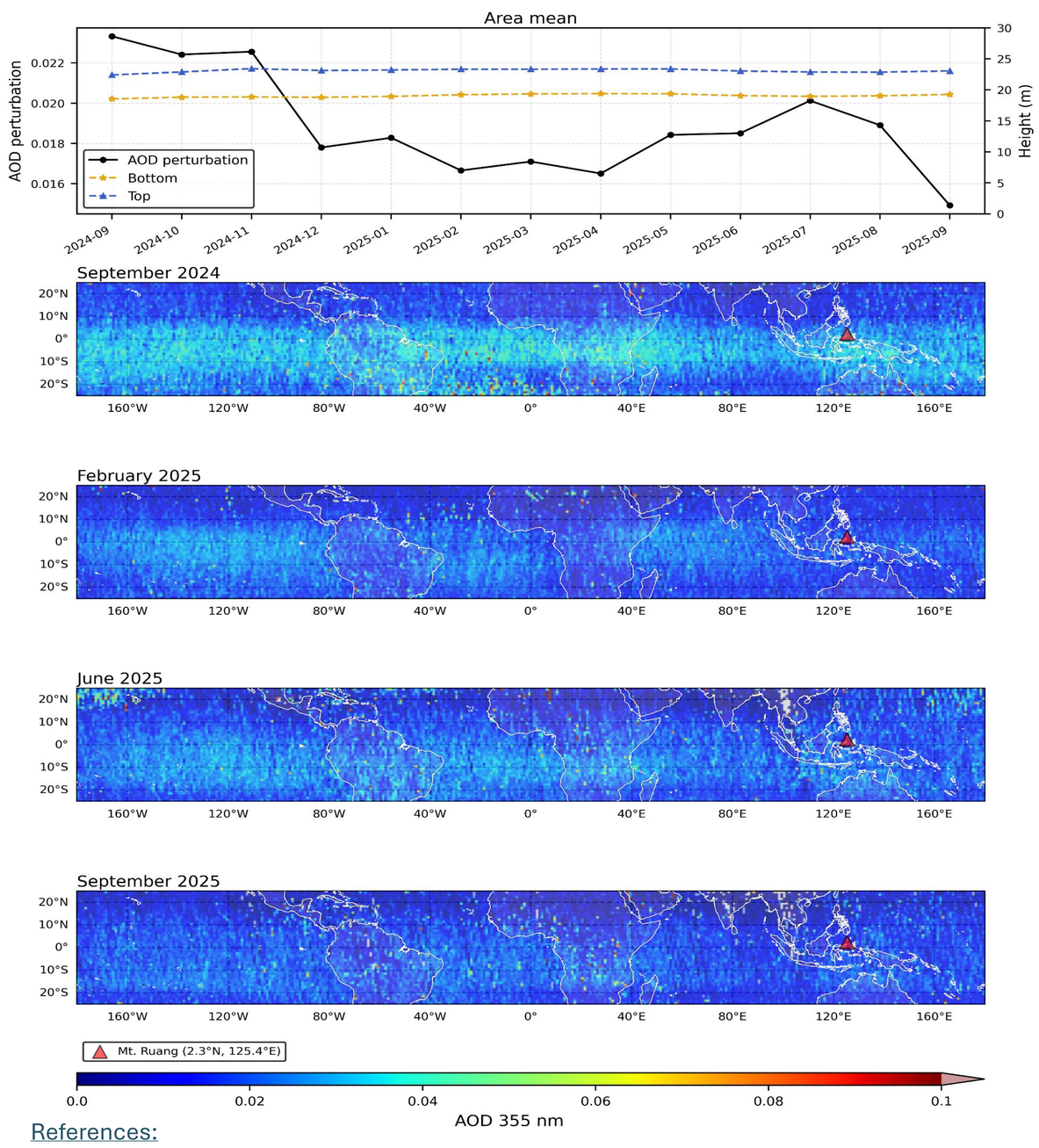
This study: Using EarthCARE/ATLID HSRL observations, we derive vertically resolved SAOD fields at 355 nm on a global scale, following the Mnt. Ruang volcanic eruption (April 2024). The retrieved SAOD perturbations are utilized in ICON model to assess their impact and provide an observational framework for SAI-related SRM studies.

Methodology & Data



SAOD evolution – Ruang eruption

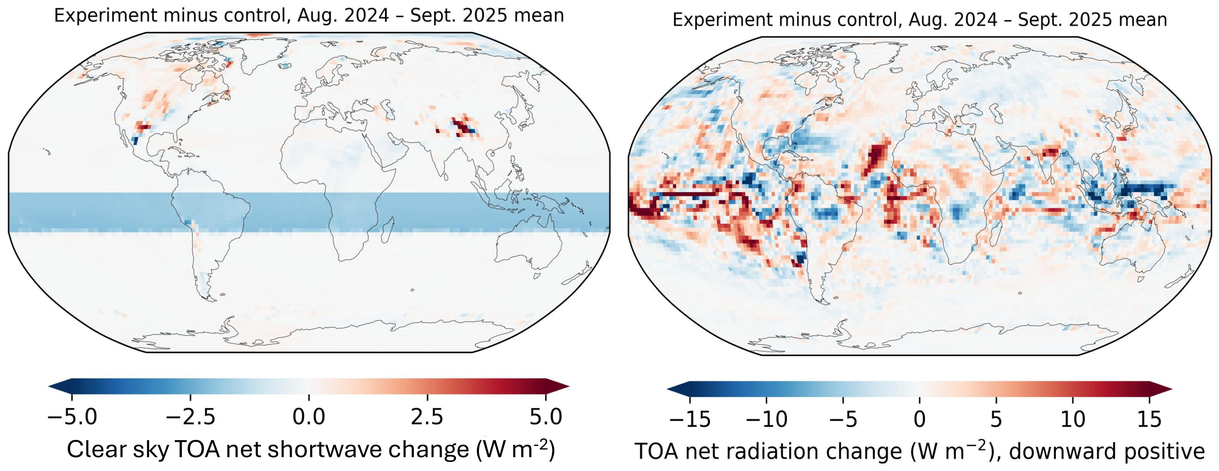
Stratospheric AOD at 355 nm (from top to bottom: Sept. 2024 – Sept. 2025), derived from **the ATL_EBD_2A** product, with **non-stratospheric aerosol filtering** applied and **background removal** based on climatological references (SAGE, CALIPSO[2,3]).



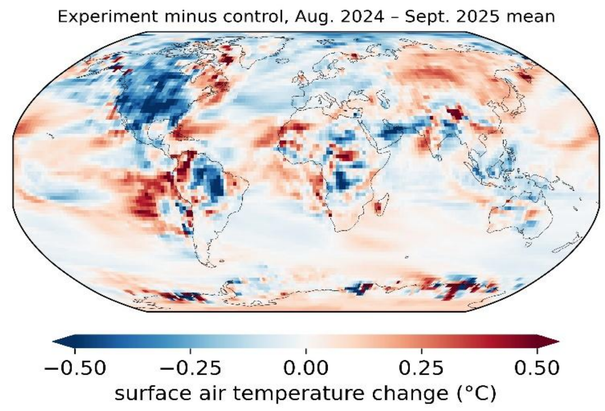
References:
1.Rozanov et al., 2024, 2.Li et al., 2022, 3. Vernier et al., 2011

ICON perturbation experiment results

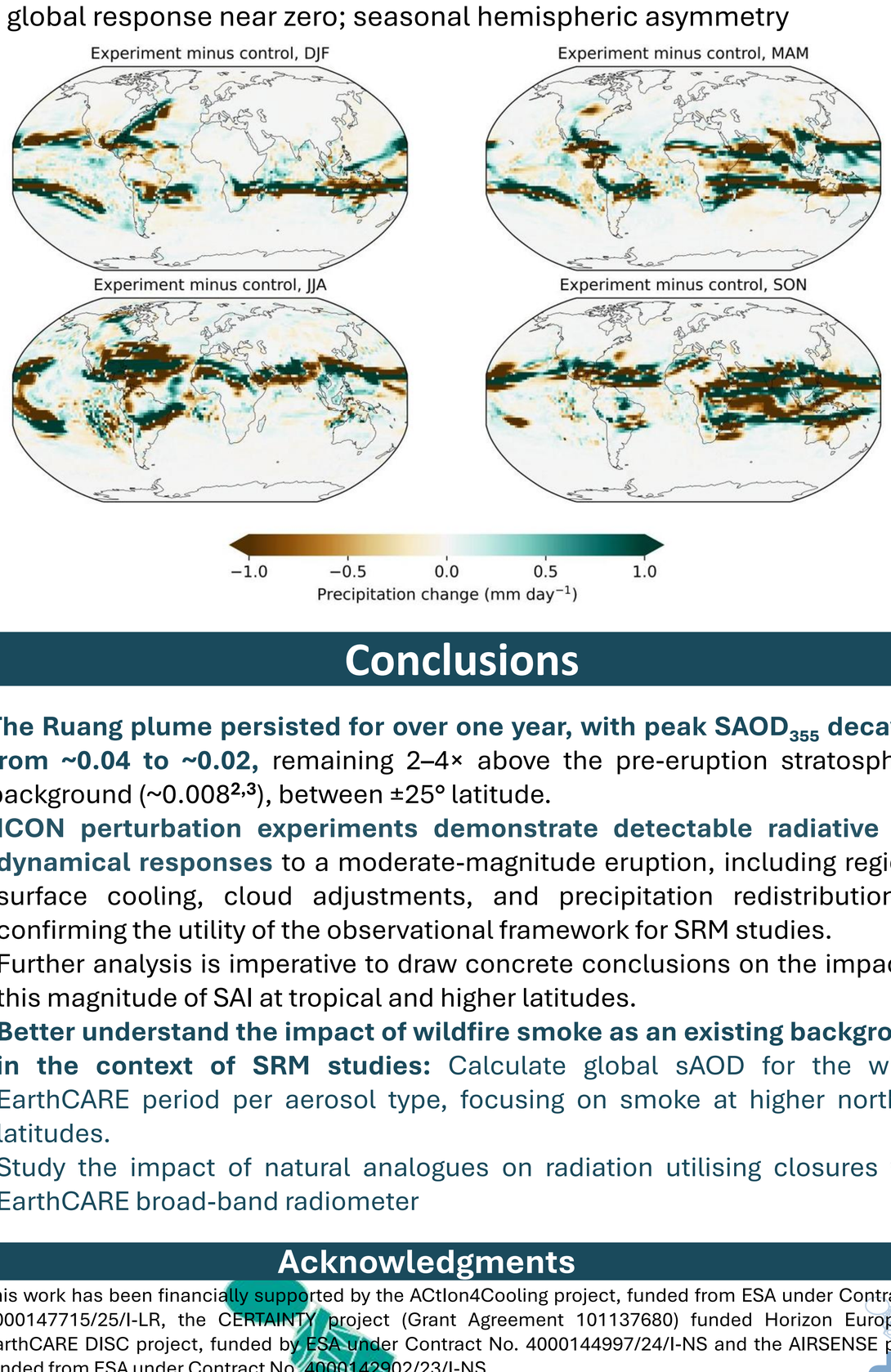
- **Tropical cooling, global near-zero:** clear-sky TOA: -1.9 W m^{-2} in the tropical perturbation band (20°S–0°), −0.32 W m^{-2} globally, **BUT** All-sky TOA / ERF : **+0.8 W m^{-2}** in 20°S–0°, +0.11 W m^{-2} global



- **Surface air temperature:** −0.07 °C tropics, −0.02 °C global



- **Precipitation re-distributes:** tropical drying (−0.03 mm/day) but global response near zero; seasonal hemispheric asymmetry



Conclusions

- **The Ruang plume persisted for over one year, with peak SAOD$_{355}$ decaying from ~0.04 to ~0.02,** remaining 2–4× above the pre-eruption stratospheric background (~0.008[2,3]), between ±25° latitude.
- **ICON perturbation experiments demonstrate detectable radiative and dynamical responses** to a moderate-magnitude eruption, including regional surface cooling, cloud adjustments, and precipitation redistribution — confirming the utility of the observational framework for SRM studies.
- Further analysis is imperative to draw concrete conclusions on the impact of this magnitude of SAI at tropical and higher latitudes.
- **Better understand the impact of wildfire smoke as an existing background in the context of SRM studies:** Calculate global sAOD for the whole EarthCARE period per aerosol type, focusing on smoke at higher northern latitudes.
- Study the impact of natural analogues on radiation utilising closures with EarthCARE broad-band radiometer

Acknowledgments

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