Optical properties and radiative forcing of the Hunga Tonga-Ha'apai volcanic eruption in 2022

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Volcanic aerosol layers from the Hunga Tonga-Hunga Ha'apai eruption (January 15th 2022), off the coast of the Tonga island (20.550º S-175.385º W) in the South Pacific Ocean, were observed with active and passive remote sensing sensors from space. Vertical profiles of aerosol optical (extinction (α), backscatter (β) coefficients, lidar ratio (LR), Ångström exponent (Å), and particle linear depolarization ratio (PLDR)), and geometrical (center of mass (CoM)) properties, were obtained by the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) satellite, in different altitudes and regions. Moreover, the libratran radiative transfer model has been applied in order to estimate the radiative forcing of volcanic particles. The volcano injected large amounts of particles in the stratosphere, found in this study within a longitude range of 106° E to 149° W, in the latitude band of 1°- 44° S, as they were transported from the source westerly, towards the Australian continent, between 15-20 January 2022.

The major findings presented in our work concern the identification of the stratospheric volcanic layers, after 1-2-days transport from the crater (approximately 2000 km away), with CoM from 19.6 km amsl and up to 29.7 km, according to the lidar measurements. The 100 km spatially averaged lidar signals indicated that the layer thickness ranged between 1.5 and 5.0 km. The aerosol optical depth (AOD) was found to vary from 0.01 to 0.22, at 532 nm. Furthermore, the corresponding Å values ranged between -0.34 and 1.45, while the PLDR observations indicated both spherical (0.04±0.06) and irregularly shaped (0.25±0.12) particles. This high variability of the optical properties found to be correlated with the probed layer height, indicating probably mixing process and different compositions. SO_2 observations obtained by the OMI satellite over the region, revealed columnar concentrations varying from 2 up to 13 DU. Assuming that only volcanic particles observed in the stratosphere, we used the CALIPSO aerosol profiles along with the OMIs columnar observations to estimate the vertical distribution of SO_2 at SPT conditions. The latter profiles were fed to the libratran toolbox to initiate radiative transfer calculations.