Retrieving instantaneous faint aerosol extinction based on CALIPSO measurements

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Aerosols significantly affect the Earth-atmosphere energy balance and climate change by acting as cloud condensation nuclear. Particularly, the susceptibility of clouds to aerosols is more pronounced when aerosols are faint. However, previous methodologies generally miss these faint aerosols and their climate effect based on instantaneous observations because they are too optically thin to be detected. The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) can detect vertical properties of aerosols and clouds globally beyond the limitation of passive observation. Previously, a few studies have focused on the retrieval of integrated faint aerosol optical depth, which is not detected by CALIPSO Level 2 product. However, the vertical distribution of faint aerosols has rarely been discussed and verified. Recently, the CALIPSO Level 3 Monthly Stratospheric Aerosol Profile Product was released to study faint aerosols in the stratosphere, but its low temporal-spatial resolution is not sufficient to accurately describe the distribution and impact of faint aerosols. Here, we focus on retrieving faint aerosol extinction based on instantaneous observation of CALIPSO.

Our results show a good agreement between faint aerosol extinction retrievals of CALIPSO and Stratospheric Aerosol and Gas Experiment III on the International Space Station (SAGE III-ISS) product over June 2017 to 2019 during nighttime, with correlation coefficients (R) and root mean square error (RMSE) of 0.58 in logarithmic scale and 0.0008, respectively. Also, the lower bound of retrieved aerosol extinction extended to 0.0001 km^{-1}, much lower than the CALIPSO Level 2 Extinction product (0.01 km^{-1}). However, the related R and RMSE are 0.16 and 0.0034 during daytime, due to the low signal-to-noise ratio (SNR) caused by sunlight.

The retrieved faint aerosol extinction clearly demonstrates the aerosol transport trajectory in the 2019 Australian wildfires missed by the CALIPSO Level 2 Aerosol product, which can be verified by the attenuated scattering ratio from CALIPSO data. Additionally, the retrievals successfully capture the enhanced faint aerosols from Siberian fires in 2019 instantaneously, which are also shown by the CALIPSO Level 3 Monthly Stratospheric Aerosol Profile Product at much lower temporal-spatial resolution. Above results indicate a significant potential for improving the quantification of aerosol impacts on climate change through retrieving instantaneous faint aerosol.