Advanced retrieval of aerosol vertical profiles using synergy of EarthCARE ATLID, PACE HARP-2 and various passive spaceborne observations

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We present the efforts which aim to enhance the integration of passive and active observations by combining Level 1 (L1) data from ATLID/EarthCARE lidar and various geostationary (GEO) and low orbit (LEO) imagers. First focuses on aerosol retrieval from coinsident L1 observations from ATLID and HARP-2/PACE multi-angular polarimeter (MAP), while second pursues to extend these developments to non-coincident L1 retrievals of FCI/MTG-I, ATLID/EarthCARE, TROPOMI/S5p and HARP-2/PACE.

Global quantification of aerosol properties relies heavily on space-based measurements, yet distinct limitations exist for individual sensor types. Multi-angular polarimetry provides sensitivity to aerosol load, particle size, and morphology but offers limited information regarding its vertical distribution. Conversely, active lidar observations excel at resolving vertical structure but require prior assumptions regarding aerosol microphysics for stand-alone retrievals. While the synergy of collocated polarimetric and lidar measurements allows for comprehensive interpretation, such approaches are traditionally constrained by the limited spatio-temporal overlap of orbital platforms. This restriction significantly reduces the data volume available for constraining global transport models.

In this context, geostationary observations, such as those from MTG-I, provide extensive coverage within the observed Earth disk. However, the information content of single-view GEO instruments is limited compared to that of MAPs and is insufficient for constraining aerosol type. Consequently, effective synergy between ATLID and GEO instrumentation necessitates the additional inclusion of non-coincident MAP or spectrometric observations from polar-orbiting platforms. Furthermore, the incorporation of non-coincident data significantly increases the volume of observations available for processing, thereby potentially enhancing retrieval accuracy. This approach is particularly advantageous for synergies involving multiple satellite platforms, as it substantially increases the number of usable overpasses. As a result, both the information content and the spatio-temporal coverage of the retrievals are improved, augmenting the overall quality and scientific utility of the synergistic products.

Prevalent strategies for synergistic aerosol retrieval focus primarily on ground-based active and passive observations, often underutilizing recent advancements in lidar technology, such as High Spectral Resolution Lidars (HSRLs). Furthermore, existing frameworks lack the architectural flexibility to integrate diverse lidar configurations with passive measurements for space-borne

applications. We address these limitations by developing new methods for generating global aerosol vertical distribution products with improved accuracy and coverage, using highly optimized forward models (including aerosol and surface reflectance) and the statistical estimation framework of the open-source GRASP (Generalized Retrieval of Atmosphere and Surface Properties) software.
This framework is designed for adaptability, enabling the synergistic processing of various active and passive satellite observations across different spatial, vertical, and spectral resolutions. Crucially, it supports the fusion of both coincident measurements and asynchronous observations acquired from non-aligned orbital overpasses.
Ongoing developments, results and findings will be presented and discussed.

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