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High Spectral Resolution Lidar (HSRL)-Based Methods for Estimating $PM_{2.5}$ During the DISCOVER-AQ and KORUS-AQ Campaigns

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$PM_{2.5}$ (particles with an aerodynamic diameter of less than 2.5 μm) contribute to millions of premature deaths yearly and affect the Earth's radiation budget and climate. The health and climate impacts depend on not just the $PM_{2.5}$ loading but on aerosol chemical makeup as well. The necessity of monitoring $PM_{2.5}$ has been well established; yet doing so remotely remains challenging. We have developed two new methods (referred hereinafter as Model-HSRL-CH and HSRL-CH) for estimating surface $PM_{2.5}$ concentration and speciation [1]. These methods utilize High Spectral Resolution Lidar (HSRL)-retrieved extinction and derived aerosol types [2] in combination with the CATCH algorithm-calculated aerosol type-specific chemical composition to inform $PM_{2.5}$ estimates. In the Model-HSRL-CH method, the model estimates of $PM_{2.5}$ concentration and chemical speciation are iteratively updated using the HSRL-retrieved extinction and types. In the HSRL-CH method, HSRL-retrieved extinction and types, and CATCH-derived type-specific chemical composition are used to estimate $PM_{2.5}$ and speciation without requiring concurrent model runs.

$PM_{2.5}$ estimates derived using the Model-HSRL-CH and HSRL-CH methodologies have been applied to retrievals from the DISCOVER-AQ and KORUS-AQ campaigns and compared to the measurements collected at the United States Environmental Protection Agency Air Quality System (AQS) sites and South Korea's National Institute of Environmental Research (NIER) sites respectively [1,4]. The magnitude of the mean absolute error (MAE) for $PM_{2.5}$ estimated using both models and remote sensing-based methods was much higher for Asian aerosol than North American aerosol. CMAQ model results had MAE of 9.2 and 19.4 $\mu g/m^3$ for DISCOVER-AQ and KORUS-AQ respectively. Iteratively updating the CMAQ results using the Model-HSRL-CH method lowered the MAE by 28-41% (results using GEOS-Chem were comparable). The model-independent HSRL-CH method estimated $PM_{2.5}$ with MAE 33% and 36% lower than CMAQ during DISCOVER-AQ and KORUS-AQ and 39% lower than GEOS-Chem during KORUS-AQ. This presentation will focus on the diverse challenges of deriving $PM_{2.5}$ and chemical speciation remotely for North American and East Asian aerosols.

Keywords: $PM_{2.5}$, air quality, aerosol modeling and remote sensing, algorithm development

References

[1] Meskhidze et al. (2021) https://doi.org/10.1016/j.atmosenv.2021.118250
[2] Burton et al. (2012) https://doi.org/10.5194/amt-5-73-2012
[3] Dawson et al. (2017) https://doi.org/10.1002/2017JD026913
[4] Sutherland et al. (2023) https://doi.org/10.1016/j.atmosenv.2023.119719