Development of GOSAT-2 $PM_{2.5}$ and BC Product Validation Methodology Applicable to an International Observation Network

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[Abstract]

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The Greenhouse gases Observing SATellite-2 (GOSAT-2), launched in 2018, is equipped with the Thermal And Near infrared Sensor for carbon Observation Cloud and Aerosol Imager 2 (TANSO-CAI-2) and aims to observe the amounts of fine particulate matter ($PM_{2.5}$) and black carbon (BC). $PM_{2.5}$ is an extremely important environmental factor with adverse health effects. One of its main components is BC, which also has the third largest positive radiative forcing after carbon dioxide and methane. Thus, monitoring $PM_{2.5}$ and BC is of great scientific significance and expected to contribute significantly to climate change related policies. However, it is difficult to directly compare the satellite $PM_{2.5}$ and BC data with those from existing ground-based measurements, because they capture different physical phenomena. Here, continuous year-round observations with the BC instrument (COSMOS) and various ground-based instruments ($PM_{2.5}$ sensor, sky radiometer, MAX-DOAS, etc.) were started in Chiba, Japan. In addition, intensive observations were conducted three times with the Federal Reference Method (FRM) and the portable Fourier Transform Infrared Spectrometer (EM27/SUN). The $PM_{2.5}$ sensor and FRM $PM_{2.5}$ mass concentration data were found to be in good agreement under dry conditions. The MAX-DOAS observations showed that important relative humidity (RH) information could be obtained together with the aerosol height distribution. Various aerosol optical property data were compared with $PM_{2.5}$ and BC data to investigate their correlations, and it was found that optical parameters that proxy for $PM_{2.5}$ and BC mass concentrations can be derived from simultaneous sky radiometer and MAX-DOAS observations. Detailed theoretical analyses, comparisons with other satellite data, and sensitivity experiments were conducted using the GOSAT-2/CAI-2 aerosol retrieval algorithm to list and quantify the major error components. In addition, machine learning revealed that the fine-mode aerosol optical thickness, planetary boundary layer height (PBLH), and RH are important for the retrieval of $PM_{2.5}$ and BC. We also compared GOSAT-2/CAI-2 data with the optical parameters found in this study as proxies for $PM_{2.5}$ and BC mass concentrations and confirmed that PBLH and RH are important. Thus, the simultaneous observation of sky radiometer and MAX-DOAS not only estimates the uncertainty in $PM_{2.5}$ and BC data, but also evaluates important parameters of the algorithm. Thereby, more precise algorithm evaluation, and eventually, rapid algorithm improvement are expected. Upon these results, we proposed a new international observation network, A-SKY, which deploys both sky radiometers and MAX-DOAS.

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