Development of a new methodology for particle turbulent flux retrievals using remote sensing techniques

NASA's fleet of satellites and ground-based remote sensing routinely retrieve information on atmospheric particulate matter. These particles are important because they can affect climate, weather, and people's health. Satellite and ground-based sensors can obtain information on aerosol extensive properties (i.e., scattering and absorption coefficients) that depend on both the nature of the aerosol and the amount of the aerosol and intensive parameters (e.g., Ångström exponent, submicron scattering and absorption fractions, depolarization, extinction-to-backscatter ratio, backscatter color ratio) that relate to intrinsic properties of the aerosol itself. Using theoretical models and algorithms aerosol microphysical and radiative characteristics are obtained. In contrast to remote sensing, in situ monitoring is widely used for measuring the major inorganic and organic species and turbulent fluxes. Both are needed for improved understanding of sources and sinks of the aerosol, capturing how aerosols modify convection intensity and precipitation, and separation of the effects of air pollution and meteorology on local air quality. Since particulate matter is suspended in the air, particles are moved by upward- and downward-moving air currents. However, aerosols are not passive tracers. The theoretical and modeling studies have shown that aerosols have strong dynamic feedback (both suppression and invigoration) on convection through absorption of solar radiation, condensational growth, and ice-related processes. However, due to the complexity of the problem, discrepancies remain in both the sign and magnitude of the aerosol feedbacks on convective activities and clouds. Capturing how aerosols modify 1) Climate variability and change and 2) Weather and air quality are the focus of two major themes outlined by the National Academies of Sciences, Engineering, and Medicine (NASEM) 2017 Decadal Survey for Earth Science and Applications from Space. Since remote sensing allows repetitive, long-term large area coverage, parameters needed for improved quantification of coupled cloud-precipitation states and dynamics were recognized as Designated Observables by the Space Studies Board of the Decadal Survey.

In this project, we will take advantage of emerging active remote sensing approaches for the retrieval of vertical turbulent fluxes of particle mass and chemical composition proxies. This will be achieved by combining two existing remotely sensed instruments: a Doppler Lidar and the High Spectral Resolution Lidar (HSRL). The derived flux values will be compared to in situ measurements taken during the U.S. DOE Atmospheric Radiation Measurement (ARM) Field Campaign at the Southern Great Planes (SGP) site in Oklahoma. As the field study is already funded through the NSF EArly-concept Grants for Exploratory Research (EAGER) and DOE, the information required for the method evaluation (i.e., aerosol size distribution, chemical composition, hygroscopic properties, size-selected vertical turbulent fluxes) will be provided at no cost to the current study.

Because of its low cost and broad spatiotemporal coverage, the new methodology developed here could benefit the future ground, airborne, and space-based missions. High-quality extensive datasets collected through this methodology will support observation-based understanding of fundamental aerosol-cloud dynamical/microphysical processes. By developing a link between remote sensing and aerosol vertical turbulent fluxes, it can provide a new constraint for air quality models that can be successfully used over the regions with few or no ground stations. The methodology developed in the proposed work will also be beneficial to the larger scientific community by providing a step towards reducing the uncertainty in climate projections.