Workshop on "Recent advancements in remote sensing and modeling of aerosols, clouds and surfaces",
GRASP ACE Summer school,
Lille, France, May 22-26, 2023

New Algorithm Techniques for Improving Data Products from Backscatter Lidar Sensors

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Backscatter lidar measurements provide cloud and aerosol vertical profiles during nighttime and in complex multi-layer scenes during day, when passive sensors are unable to reliably provide cloud and aerosol properties. Current/previous space-based backscatter lidars such as CALIPSO (2006-present) and Cloud-Aerosol Transport System (CATS, 2015-2017) have been providing essential vertical profiles of backscatter, depolarization, and extinction for over 15 years. New backscatter lidar instruments for future missions such as NASA Earth System Observatory (ESO) Atmosphere Observing System (AOS) are affordable, low risk, and adaptable to multiple spaceborne architectures. These sensors can leverage the technology and algorithm heritage of CATS and CALIPSO, yet advance current capabilities of these space-based lidars (i.e., better signal-to-noise ratios, lower detection limits, more depolarization wavelengths, etc.). In addition to instrument-based performance improvements, new algorithm techniques, such a denoising, machine learning classification methods, and constrained extinction retrievals, have recently been developed and tested.

Traditionally, lidar data processing techniques have relied on (1) averaging of the data both vertically and horizontal to overcome daytime solar background noise, (2) hard backscatter, depolarization ratio, color ratio, and temperature thresholds to detect and classify feature types, and (3) a "one size fits all" lookup table of extinction-to-backscatter ratio. In this talk, we will present a several new methods that:

1. Reduce the daytime solar background uncertainties using autoencoders or wavelet denoising
2. Improve cloud-aerosol discrimination using a Convolutional Neural Network (CNN) trained with CATS data
3. Better classify features into cloud phase and aerosol types using hierarchical clustering methods and CNN
4. Reduce systematic errors in extinction estimates using constrained techniques and more sophisticated extinction-to-backscatter ratio lookup tables.

These advanced techniques and machine learning methods are applicable to future space-based lidar sensors that will be flown as part of the ESO AOS or otherwise.