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Lidar as a passive scalar: understanding a highly variable and complex atmosphere

Strawbridge, K. (1), Lovejoy, S. (2), Radkevitch, A. (2), Stolle, J. (2), Schertzer, D. (3)

(1) Canadian Meteorlogical Services, Egbert, Ontario (Kevin.strawbridge@ec.gc.ca), (2) Physics, McGill, 3600 University st., Montreal, Que. H3A 2T8, Canada, (3) CEREVE, ENPC, 6-8, avenue Blaise Pascal, Cité Descartes, 77455 MARNE-LA-VALLEE Cedex, France

The remote sensing technique of lidar provides a unique understanding of the vertical structure, mixing and transport of aerosols in a highly inhomogeneous atmosphere. Aerosol lidars are a subset of lidars particularly suited to measuring the small aerosol particles (particulate matter), not generally visible to the naked eye, with high spatial and temporal resolution. Environment Canada currently has four aerosol lidar systems; a simultaneous upward/downward airborne lidar called (AERIAL - AERosol Imaging Airborne Lidar), a downward pointing aircraft lidar for small aircraft called SALSA (Small Aircraft Lidar System for Aerosols), a ground-based zenith pointing lidar at the Centre For Atmospheric Research Experiments (CARE) called ALIAS (Aerosol Lidar Instrument for Atmospheric Studies) and a mobile scanning lidar facility also known as RASCAL (Rapid Acquisition SCanning Aerosol Lidar). RASCAL can operate in two primary data collection modes: mobile transects along roads and highways, vertically sampling the atmosphere directly above the vehicle or parked in a single location obtaining scanning profiles from near ground height to the zenith.

The high spatial and temporal resolution of aerosol lidars makes it an ideal candidate for understanding atmospheric dynamics and thus providing experimental observations to test the anisotropy of the atmosphere via strafication characterized by a fractal dimension intermediate between 2D (totally stratified, flat) and 3D (isotropic, unstratified or degreee of stratification independent of scale). The primary observable from lidar is the aerosol backscatter ratio, which is to first order is proportional to aerosol concentration, which is treated as a passive scalar. Airborne, ground-based and scanning lidar systems each provide unique datasets to probe a variety of scaling domains.

The advantage of airborne lidar data is the ability to capture high signal-to-noise data over regional scales. Thus providing a convincing argument for an anisotropic atmosphere obeying the Kolmogorov law in the horizontal and the Bogliano-Obhukhov in the vertical leading to a elliptical fractal dimension of Del =23/9 . In addition, ground-based zenith-pointing lidars allows one to explore the space-time scaling framework. The mobile scanning lidar capabilities of RASCAL, is well-suited for observing point-source emissions from industrial stacks. While the source can be variable, it is possible to observe the distance from source variability as the “puff” propagates downwind from the stack. The distance from source and plume width relationships are investigated by associating a given puff with turbulent eddies within the atmosphere. This can be further complicated by the complex mixing of the plume with the radiative growth of the boundary layer.

A variety of aerosol imagery from each platform will be presented along with evidence of a fractal scaling atmosphere. As a new era of aerosol lidars has now arrived with the successful launch of the CALIPSO satellite (part of the A-Train satellite constellation) in April 2006, so does an opportunity to look at aerosols on a global scale.