Multiple scattering measurements from a ground-based network of micro-pulse lidars?

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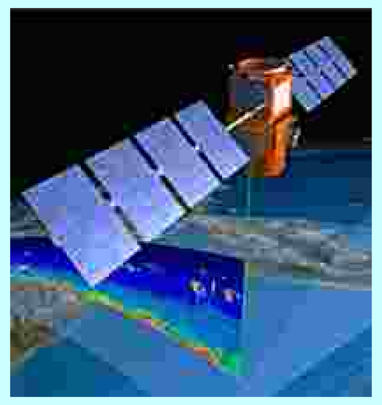
Abstract

MPLNET is a collection of ground-based micro-pulse lidar systems stationed around the globe to provide long-term observations of aerosols and clouds. Unlike CALIOP backscatter signals, the narrow field of view used and small beam geometry normally limits the effects of multiple scattering in aerosol layers and clouds for MPLNET data. More recently, a data set is being generated at NASA-GSFC using a simple dual field of view MPL configuration that is being considered for use at some MPLNET sites. The dual-FOV set-up allows in-field lidar calibrations as well as quantification multiple scattering effects. The additional multiple scattering results are currently being evaluated for potential to provide long-term statistics on cloud multiple scattering and determination of cloud micro-physical properties. Such data could help in assessing correction algorithms applied to space-borne lidar measurements that are impacted by multiple-scattering.

Multiple Scattering & CALIOP



The occurrence of multiple scattering in the atmosphere continues to be a subject of considerable interest. Recognized as an important parameter for radiative transfer effects, significant questions of been studied for a variety of aerosol and cloud types [1-3] . Modeling efforts to predict multiple scattering using analytical, Monte Carlo, and other techniques [4] have been developed in addition to methods to retrieve scattering coefficients and effective diameter of cloud droplets from lidar measurements[5,6].

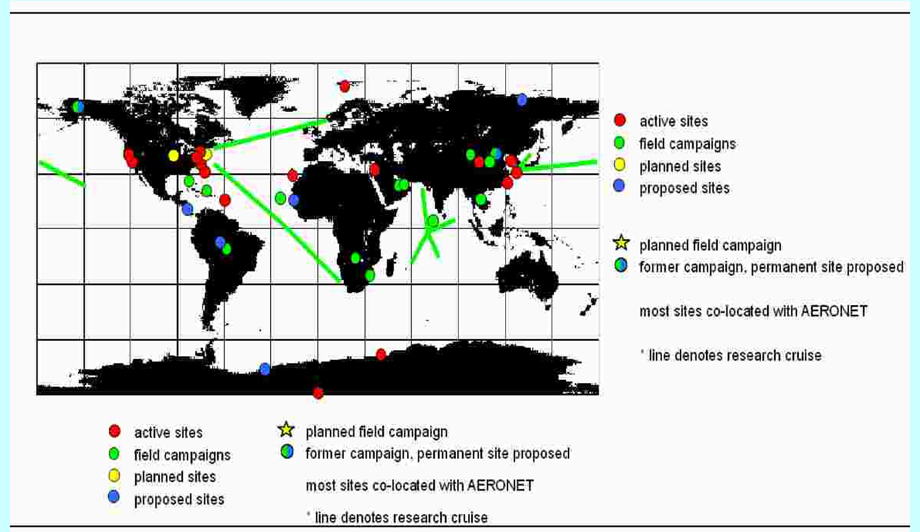
Due to the large footprint geometry, CALIOP Measurements are impacted by multiple scattering effects [7]. In aerosol layers and clouds where multiple scattering occurs, excess signal is introduced in the backscatter return that is dependent on particle size, density, and scattering phase function.

To obtain extinction and AOD retrievals from space-borne lidars such as ICESAT/GLAS and CALIPSO/CALIOP, retrieval algorithms rely on analytical approximations, supplemental data, or look-up tables to account for multiple scattering contributions. If not correctly accounted for, multiple scattering contributions can lead to errors in the retrieved data products.

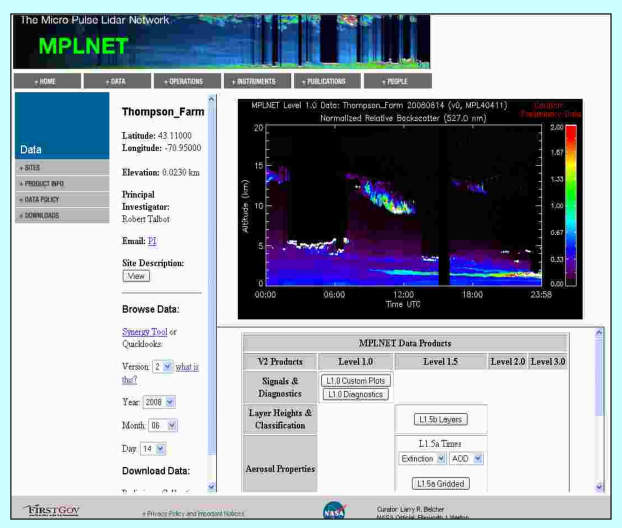
Micro-Pulse Lidar Network (MPLNET)

The NASA Micro-Pulse Lidar Network (MPLNET) is a federated network of Micro-Pulse Lidar (MPL) systems designed to measure aerosol and cloud vertical structure continuously, day and night, over long time periods.

Currently there are 17 permanent lidar sites continuously operating in MPLNET.



Data from MPLNET active sites is posted on a next-day basis for all active sites. Higher level data products include:



PBL, aerosol, cloud Heights:
- Planetary Boundary Layer (PBL) heights
- Cloud base and top heights for multiple layers
- Altitude of the top of the highest aerosol layer
- Vertical Feature Mask (Aerosol, Cloud, PBL, Combinations

Real Time Aerosol Properties:
- Aerosol Vertical Structure
- Layer Averaged Aerosol Extinction-to-Backscatter Ratio (S)
- Aerosol Backscatter, Extinction, and Optical Depth Profiles

The measurement of multiple scattering at multiple MPLNET sites may provide useful information about cloud properties. In this preliminary effort, the use of a secondary receiver for measurements of cloud multiple scattering is being considered as a supplemental component that could be added to existing network sites.

Dual-FOV MPL configuration

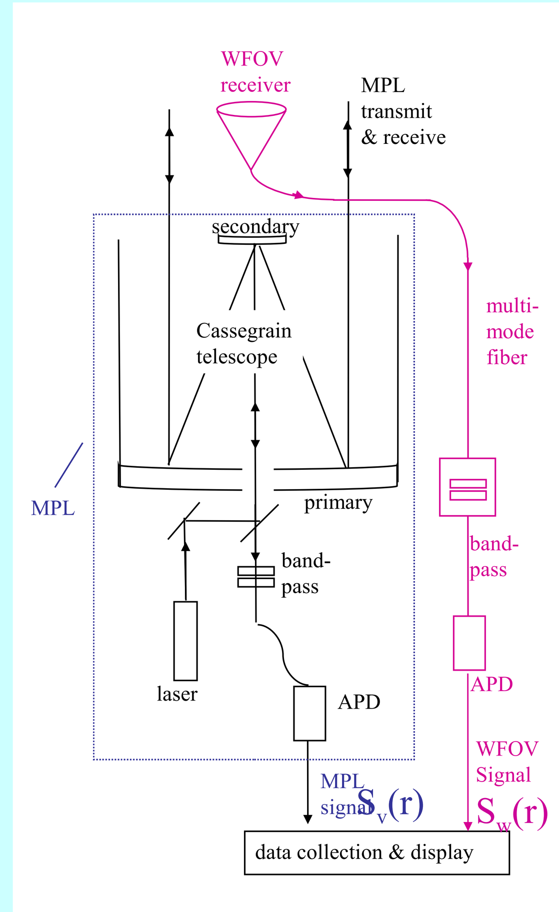
In prior work [8], determination of an MPL's overlap function using a wide field of view (WFOV) receiver co-aligned with the existing MPL beam was used to obtain simultaneous measurements with the normal (narrow) FOV (NFOV) receiver.

The supplemental WFOV receiver consists of a 50 mm diameter achromat-meniscus lens combination (efl ~ 85 mm) that focused backscatter light onto a 200 um multi-mode fiber. This receiver was placed in front of the larger diameter (20 cm) MPL telescope and centered within the secondary shadow as shown.

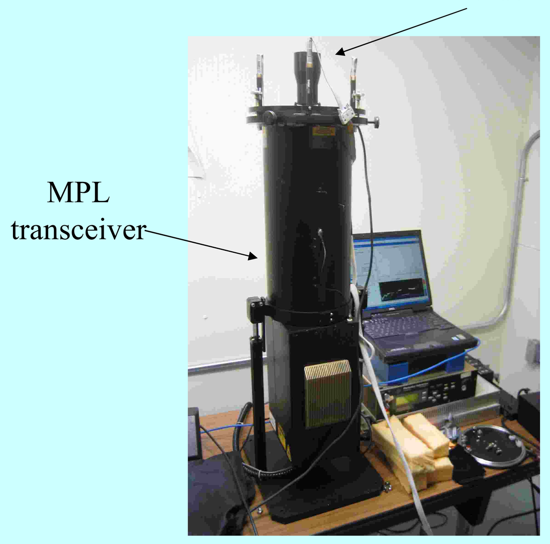
By placing the WFOV receiver within the secondary shadow (MPL non-emission area), effects on transmitted beam properties and energy loss due to obscuration effects were minimized. Light collected by the WFOV receiver was guided via multi-mode fiber to a pair of bandpass filters and then to a Geiger-mode avalanche photodiode (APD).

Co-alignment with the transmitted MPL beam was accomplished by adjusting the angular orientation of the WFOV receiver to maximize signal returns at a far-field range bin.

Schematic of MPL with Wide-FOV receiver



High-repeatable motor controllers are used to align the WFOV receiver that is attached to a 3-arm spider mount placed on top of the MPL telescope



MPL system with Wide-FOV receiver attached to the top of the transceiver

Top view (looking down) of MPL transceiver with Wide-FOV receiver

Dual-FOV Simulations

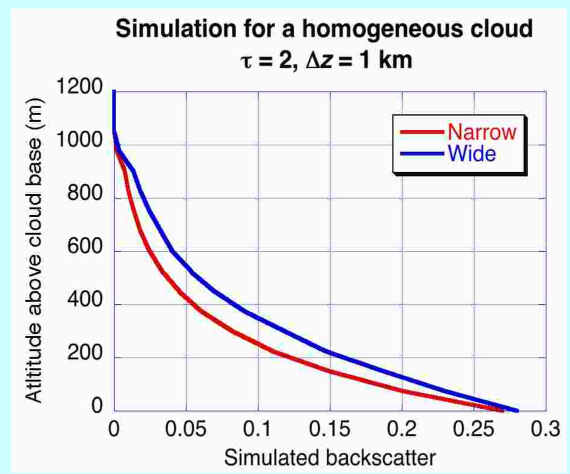
A multiple scattering model, based on a 3-D Monte Carlo simulation with a Mie scattering phase function for liquid-phase clouds is being used to study expected signal returns for a dual-FOV MPL configuration

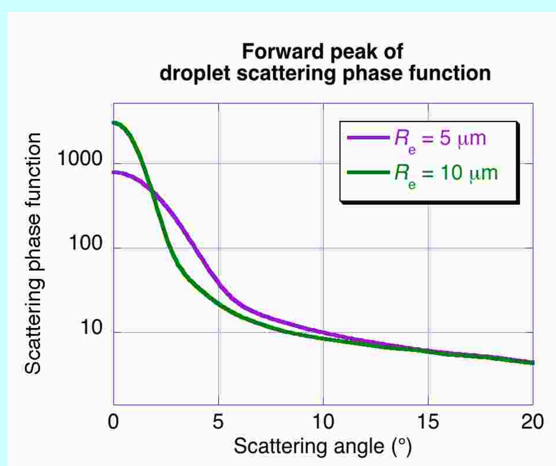
Preliminary results shown here illustrate the expected increase in signal for the wide FOV MPL channel compared to the narrow FOV MPL channel. As expected the wide channel is more sensitive to multiple scattering, and can be used to help quantify its magnitude

Ongoing modeling efforts include the study influence of particle size on multiple scattering for the dual-FOV MPL configuration

As shown in the forward droplet scattering plot, larger particles show the expected increase at small angles most relevant for the lidar narrow & wide channels, with the smaller droplets having a bigger influence at larger angles

Future simulations will include backscatter predictions as a function of particle sizes as well as ice crystal cases to more fully evaluate the potential of a dual-FOV MPL configuration





Example Multiple-Scattering Measurements

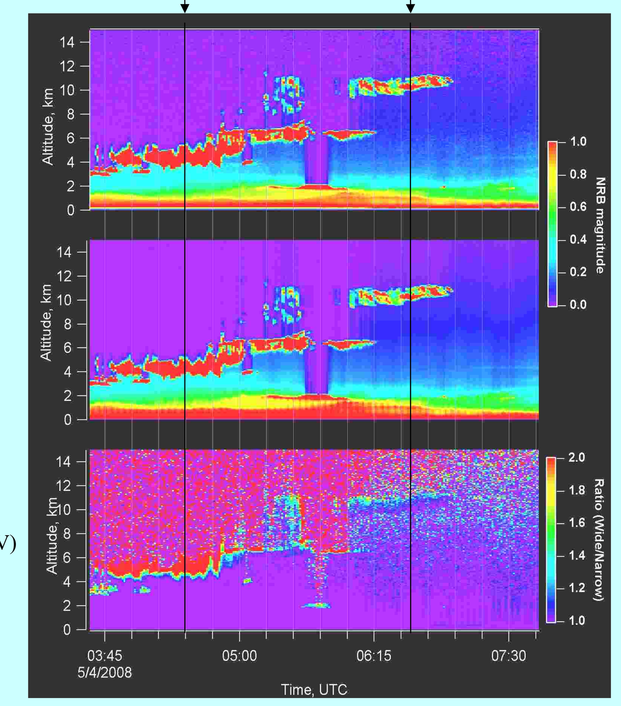
With overlap corrected MPL NFOV data, simultaneous WFOV and NFOV backscatter profiles can be quantitatively compared for all altitudes. WFOV and NFOV normalized relative backscatter (NRB) signals are displayed (equiv. to MPLNET Level 1 data) with a multiplicative constant and offset applied to WFOV signal obtained from clear-sky calibrations. In cases where excess scattering occurs, such as multiple scattering within clouds, stronger signal level would be expected to appear in the WFOV channel. The WFOV/NFOV ratio is also displayed to reveal the amount of excess scattering measured.

CASE #1: Multiple scattering observed in 4-6 km cloud layer

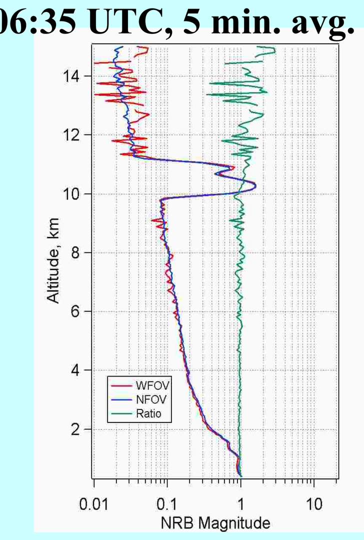
WFOV signal

NFOV signal

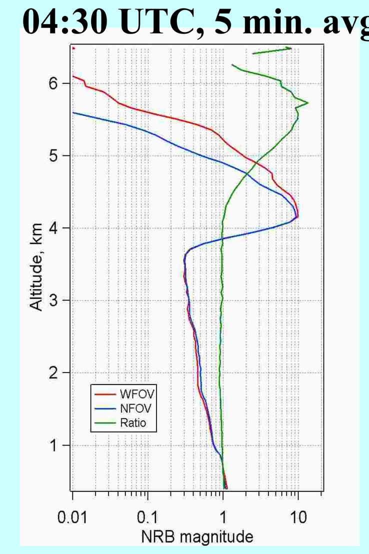
Ratio (W-FOV / N-FOV)



06:35 UTC, 5 min. avg.



04:30 UTC, 5 min. avg.



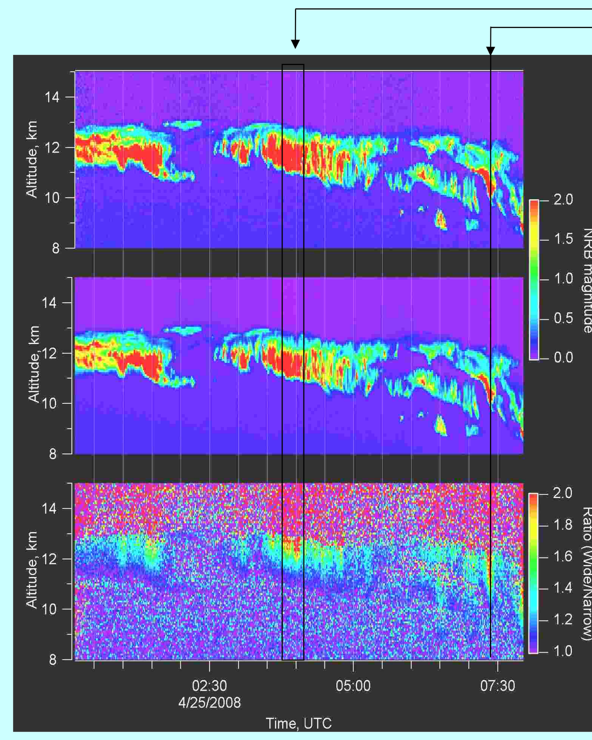
In these examples, high levels of excess scattering are observed in the 4-5 km cloud layer, but not in the 10-12 km cirrus layer later in the day.

CASE #2: Multiple scattering observed in cirrus layer

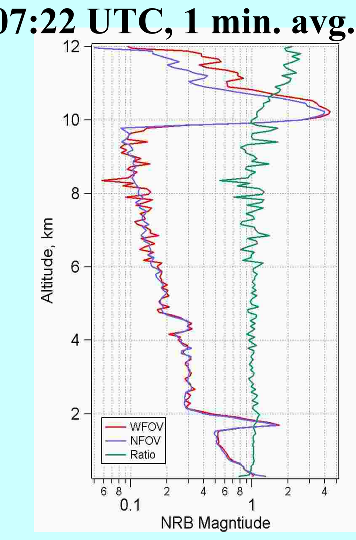
WFOV signal

NFOV signal

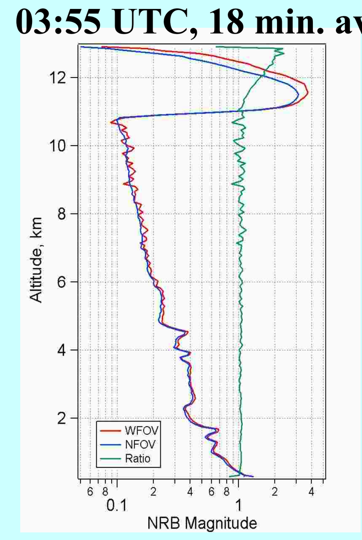
Ratio (WFOV / NFOV)



07:22 UTC, 1 min. avg.



03:55 UTC, 18 min. avg.



On this day, excess scattering is observed in a 11-12 km cirrus layer, with signals as high as 2x greater in the WFOV channel.

Summary & Conclusions

A dual-FOV MPL configuration was used to provide measurement of multiple scattering in clouds and can be implemented with modest additional cost to other sites in MPLNET.

Although performance will be limited during daytime when background levels are high, nighttime results shown here illustrate the capability to measure multiple scattering at cirrus altitudes at night with relatively short averaging times (1-18 minutes).

A 3-D Monte Carlo model is being used to assess the potential of a dual-FOV MPL configuration and its applicability for particle size assessment.

Further studies are anticipated to characterize performance for a variety of cloud types, and assess the use of long-term cloud multiple-scattering statistics at multiple sites to contribute to CALIOP retrievals influenced by multiple scattering.

References

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