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THE NASA MICRO-PULSE LIDAR NETWORK (MPLNET): CO-LOCATION OF LIDARS WITH AERONET SUNPHOTOMETERS AND RELATED EARTH SCIENCE APPLICATIONS

Ellsworth J. Welton[1]*, James R. Campbell[2], Timothy A. Berkoff[3], Sandra Valencia[2], James D. Spinhirne[1], Brent Holben[1], and Si-Chee Tsay[1]
1. NASA Goddard Space Flight Center, Greenbelt, Maryland
2. Science Systems and Applications Inc., Greenbelt, Maryland
3. University of Maryland Baltimore County, Baltimore, Maryland

1. INTRODUCTION

We present the formation of a global-ground based eye-safe lidar network, the NASA Micro-Pulse Lidar Network (MPLNET) – founded in 2000. The aim of MPLNET is to acquire long-term observations of aerosol and cloud vertical profiles at unique geographic sites collocated with sunphotometers in the NASA Aerosol Robotic Network (AERONET) [Holben et al., 1998]. These joint MPLNET/AERONET sites collect data on aerosol and cloud vertical structure, cloud presence, aerosol column optical depth, size distribution, single scatter albedo, and sky radiance. The Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) [Houghton et al., 2001] lists the routine ground-based collection of such data as a priority for future earth observations.

MPLNET network growth follows a federated approach, pioneered by AERONET, wherein independent research groups may join MPLNET with their own instrument and site. MPLNET utilizes standard instrumentation, the micro-pulse lidar (MPL), and data processing algorithms for efficient network operations and direct comparison of data between each site. The MPL is eye-safe, compact, and commercially available, and most easily allows growth of the network without sacrificing standardized instrumentation goals.

Real-time data products (next-day) are available, and include Level 1 daily lidar signal images from the surface to ~20km, and Level 1.5 aerosol extinction profiles at times co-incident with AERONET observations. Testing of our quality assured aerosol extinction products, Level 2, is near completion and data will soon be available. Level 3 products, continuous day/night aerosol extinction profiles, are under development and testing has begun.

An overview of MPLNET is provided here, including network structure, data products, and recent results from aerosol transport studies and satellite calibration/validation. Further information on MPLNET can be found on the web at http://mplnet.gsfc.nasa.gov. Merging network lidar and sunphotometer data with joint satellite observations, back-trajectory analysis, and aerosol transport simulations is the focus of a joint project: BAMGOMAS – Back trajectories, AERONET, MODIS, GOCART, MPLNET, Aerosol Synergism. Initial BAMGOMAS results are presented.

* *Corresponding author address*: Ellsworth J. Welton, NASA Goddard Space Flight Center, Code 912, Greenbelt, MD, 20771, USA; e-mail: ellsworth.j.welton@nasa.gov

2. NETWORK STRUCTURE

The Micro-pulse lidar (MPL) [Spinhirne et al., 1995] is used throughout the network because it fulfills primary MPLNET goals: autonomous operation, eye-safety, and commercial availability. Other eye-safe lidar options are available, but at non-visible wavelengths that are not ideally suited for aerosol observations. In contrast, the MPL is a compact and visible eye-safe lidar system capable of determining the range of aerosols and clouds by firing a short pulse of laser light and measuring the time-of-flight from pulse transmission to reception of a returned signal. The returned signal is a function of time, converted into range using the speed of light, and is proportional to the amount of light backscattered by atmospheric molecules (Rayleigh scattering), aerosols, and clouds.

The evolution of the MPL from the initial Spinhirne et al. [1995] optical design to the type now used in MPLNET is described in detail by Campbell et al. [2002], including on-site maintenance, and calibration techniques. Post-2002 enhancements include fiber-coupled detectors and a new laser system, neither of which significantly alter the basic MPL optical design but do greatly increase system reliability. The MPL currently used in MPLNET is manufactured by Sigma Space Corporation (http://sigmaspace.com), but some older commercial systems are still in use after modification to network standards.

Many MPL systems have been sold worldwide, and individual users have contributed to an expansive and diverse set of research activities. MPL deployments have been conducted during nearly every significant aerosol and cloud campaign since the 1990s. The MPLNET project was designed to coordinate MPL activities in the form of a network, and to provide technical MPL information and data processing methodology to the user community. MPLNET uses a federated network approach, allowing independent research groups with their own MPL to propose to join MPLNET and setup their own site. This arrangement reduces the burden on the MPLNET project to acquire funding to purchase or build new MPL systems, and also serves to incorporate otherwise separate groups into a larger research effort. The MPLNET project performs all instrument maintenance and repair, ensuring that the instruments are in peak condition and the data quality is high. The MPLNET project also performs all data processing and archiving using data processing algorithms discussed in the following section. Figure 1 shows a map of MPLNET sites, field experiments, and ship cruises.

3. MPLNET Data Products

Raw data (Level 0) from each MPLNET site are downloaded to the MPLNET server at Goddard Space Flight Center (GSFC) each night. Raw data include 1-minute time averaged photon counts at multiple range bins from the surface to 60 km, at 75 m intervals. Raw data also include instrument parameters such as temperature and laser energy, and are date/time stamped in UTC. The raw data are converted to Level 1 signals using algorithms presented by Campbell et al. [2002] and Welton and Campbell [2002]. Instrument induced effects such as optical overlap and detector noise, and contributions from sources other than the laser pulse (solar background) are corrected during Level 1 processing. Level 1 signals are profiles of particulate and molecular backscatter, multiplied by the two-way atmospheric transmission and an overall calibration value. These signals are useful for qualitative interpretation of aerosol and cloud heights. Level 1 data are archived in daily formats, and are available on the MPLNET website the morning after raw data are received. The top plot of Figure 2 contains Level 1 signals from the first week of May 2001 at GSFC.

Level 1.5 data products include profiles of aerosol extinction and are also produced overnight and results are available the next morning. The level 1.5 algorithm is based on an MPL aerosol retrieval from Welton et al. [2000]. Level 1 signals are averaged for 20 minutes, and co-located aerosol optical depth (AOD) measurements from AERONET are used to separate backscatter from attenuation and produce a profile of aerosol extinction. A simple cloud screen is used to remove signals contaminated by clouds prior to the average [Campbell et al., 2003]. The level 1.5 data are available only at times centered on AERONET observations. Level 1.5 products also include calculations of the MPL system calibration value and the aerosol extinction-to-backscatter ratio (Sa). Correlated AERONET data are included in all Level 1.5 MPLNET data files. Level 1.5 products are near-real-time and are not screened for bad data. Cloud contamination and

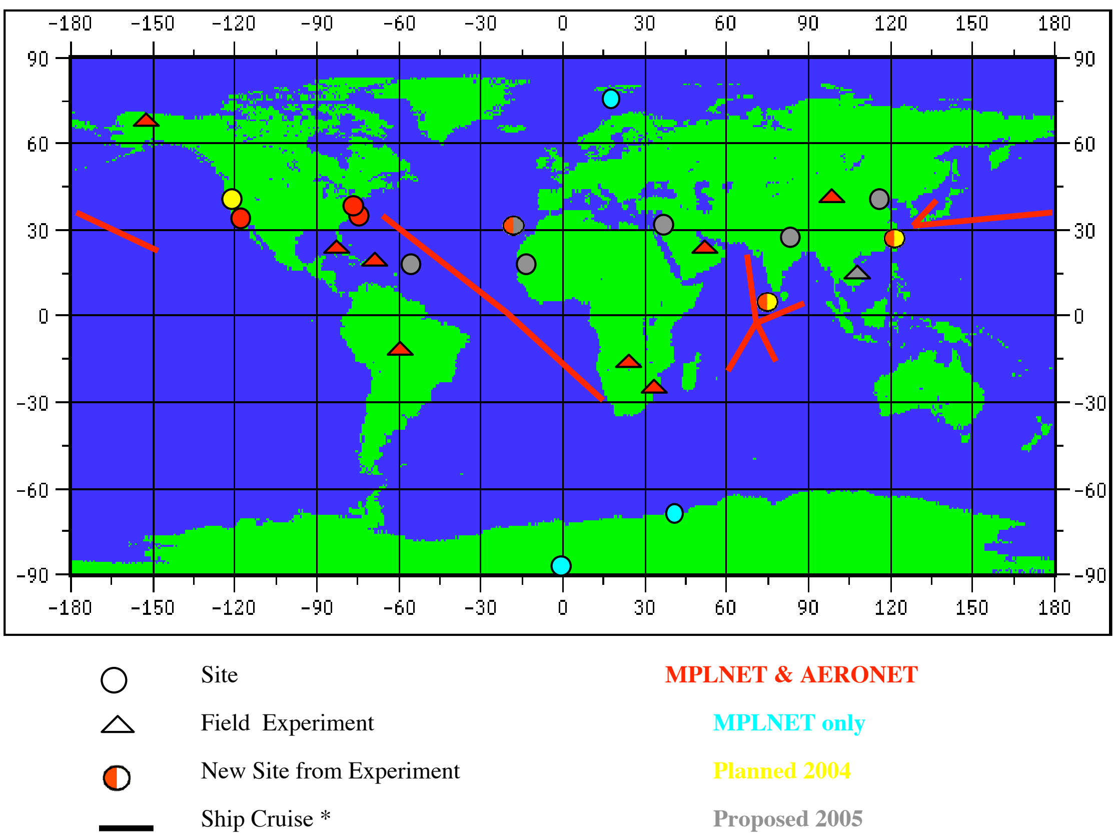

Figure 1. Map of MPLNET sites, field experiments, and ship cruises.

instrument temperature problems are among several possible sources of error. Level 2 data products are identical to Level 1.5, except that they are quality assured by removing bad data. Figure 3 shows an example of Level 1.5 products from GSFC to illustrate these results.

Level 3 data products include continuous day/night aerosol extinction profiles and S values, and are not tied to AERONET observations. Interpolation between successive Level 2 calibration values is performed, generating a calibration function. The calibration function is used to analyze the continuous day/night MPLNET Level 1 signals using the same aerosol retrieval algorithm. The resulting Level 3 data provides an extension of AERONET's AOD capability, and allows for detailed studies of aerosol diurnal effects and transport. The bottom plot of Figure 2 shows an example of Level 3 data retrieved from the May 2001 Level 1 signals.

4. Initial MPLNET Results

MPLNET data have been used for a wide variety of research activities, a few are summarized here. MPL data has contributed to studies of Saharan dust properties during the 2nd Aerosol Characterization Experiment [Welton et al., 2000] and the Puerto Rico Dust Experiment (PRIDE) [Reid et al., 2003]. Welton et al. [2002] characterized the the vertical distribution of aerosols over the Indian Ocean during the Indian Ocean

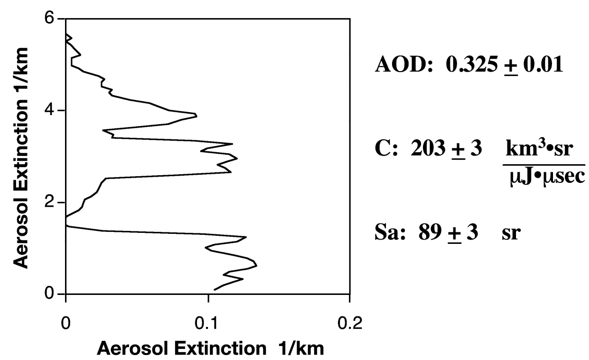

Figure 3. MPLNET Level 1.5 data from 12:00 UTC on May 3, 2001 at GSFC.

Experiment (INDOEX) and Ackerman et al. [2000] studied their effects on cloud formation using MPLNET data. Campbell et al. [2003] characterized smoke plumes over Southern Africa during the Southern African Regional Science Initiative (SAFARI) in 2000. Schmid et al. [2003] analyzed column closure measurements of Asian pollution and dust during the Aerosol Characterization Experiment Asia (ACE-Asia) using MPLNET data collected jointly with other instrumentation. Kahn et al. [2004] utilized MPLNET data and other ground-based and airborne instruments to study dust and pollution plumes during ACE-Asia using MISR. Several different aerosol transport studies

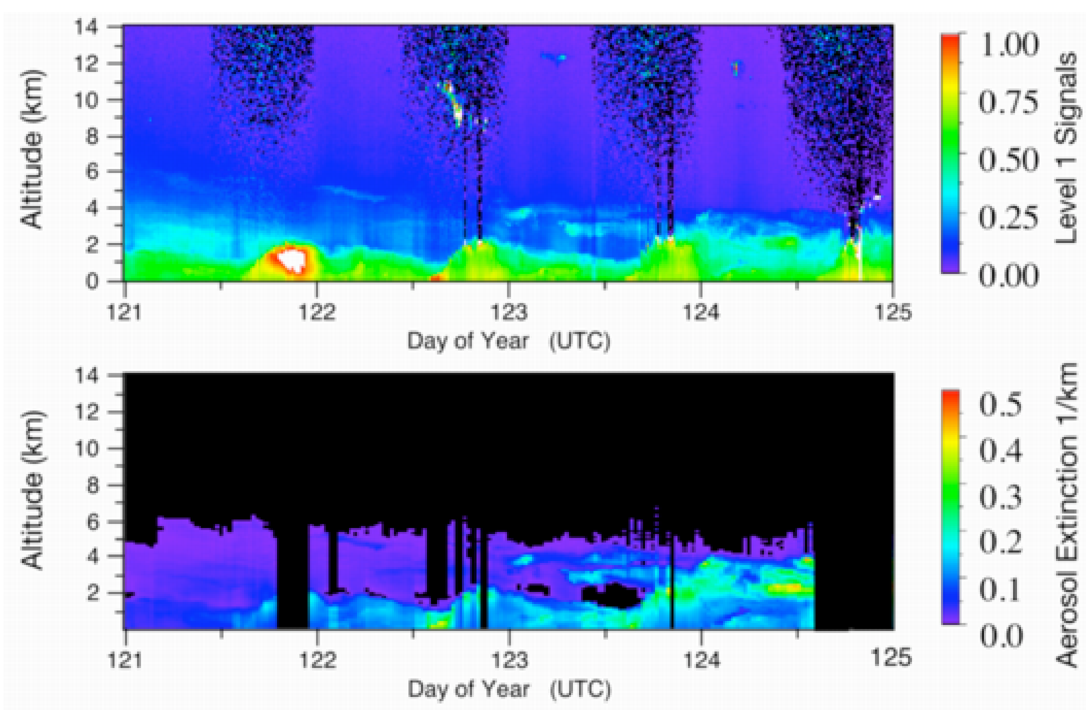

Figure 2. MPLNET Level 1 signals (top) from GSFC on May 1 – 4, 2001. Level 3 aerosol extinction profiles during the same period are shown in the bottom plot.

utilizing MPLNET data have been published, most recently Colarco et al. [2004] studied the influence of injection height and entrainment on the far range optical properties of smoke from Canadian forest fires. Finally, Mahesh et al. [2003] use MPLNET results from the South Pole to characterize the distribution of blowing snow in Antarctica.

MPLNET data is also used to validate several of NASA's satellite sensors. Torres et al. [2004] used MPLNET smoke profiles from SAFARI to validate aerosol height selection in new TOMS aerosol algorithms. In addition, MPLNET data is being used to develop lookup tables (LUT) of the aerosol extinction to backscatter ratio, Sa, for use in analyzing satellite lidar data. Sa must be known a priori when measurements of AOD are not possible. Satellite lidar observations of boundary layer aerosols and some elevated plumes require an Sa LUT to produce profiles of aerosol extinction. The accuracy of the LUT directly determines the accuracy of the final data. MPLNET Sa values from around the world are being compiled to produce average Sa for specific aerosol species and mixtures. These values, and related work from independent researchers, will be used to construct the LUT. Figure 4 shows initial results for Saharan dust and smoke using Level 1.5 Sa values from PRIDE and SAFARI.

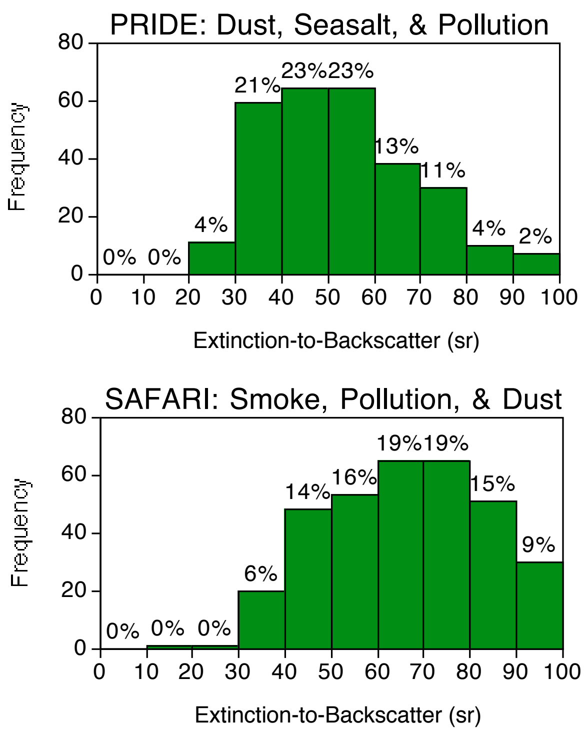

Figure 4. MPLNET Level 1.5 Sa values from PRIDE (top) and SAFARI (bottom) during 2000.

5. Conclusions

MPLNET continues to grow each year, with many new sites scheduled to come online within the next year. Scientific studies similar to those discussed above continue, but new activities have recently begun. The BAMGOMAS - Back trajectories, AERONET, MODIS, GOCART, MPLNET, Aerosol Synergism - project was recently funded. BAMGOMAS incorporates data from different platforms (AERONET, MODIS, MPLNET) and models (GOCART) with back trajectories to provide uniquely correlated aerosol data products. Once online, the BAMGOMAS website will provide easy access to previously disparate aerosol data, and will also provide powerful new aerosol tools to assist researchers with their studies.

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