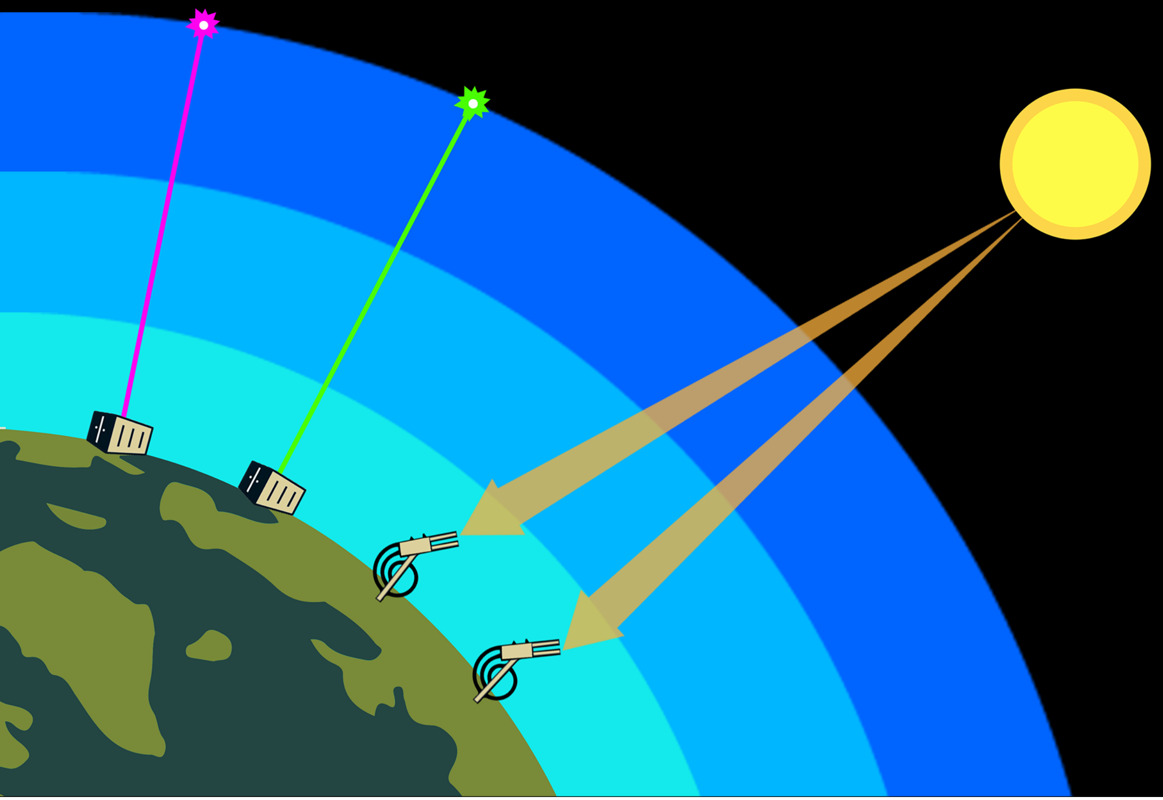
National Aeronautics and Space Administration



NASA Atmospheric Composition Ground Networks Supporting Air Quality and Climate Applications

Part 5: Introduction to the Micro-Pulse Lidar Network (MPLNET)

Carl Malings (Morgan State University) & Judd Welton (NASA Goddard Space Flight Center)

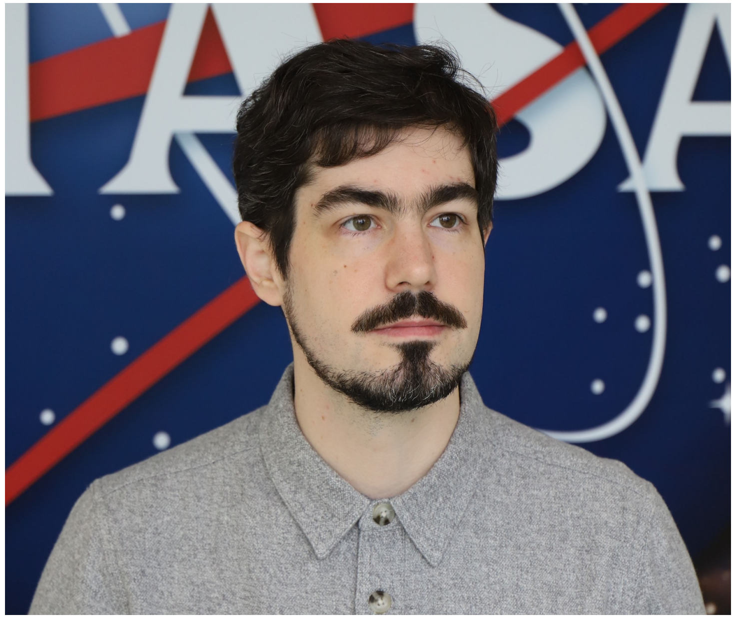
August 22, 2024

Part 5 – Trainers

Dr. Carl Malings

Assistant Research Scientist

Morgan State University, GESTAR-II



Dr. Judd Welton

Principal Investigator, MPLNET

NASA GSFC

Part 5 Objectives

By the end of Part 5, participants will be able to:

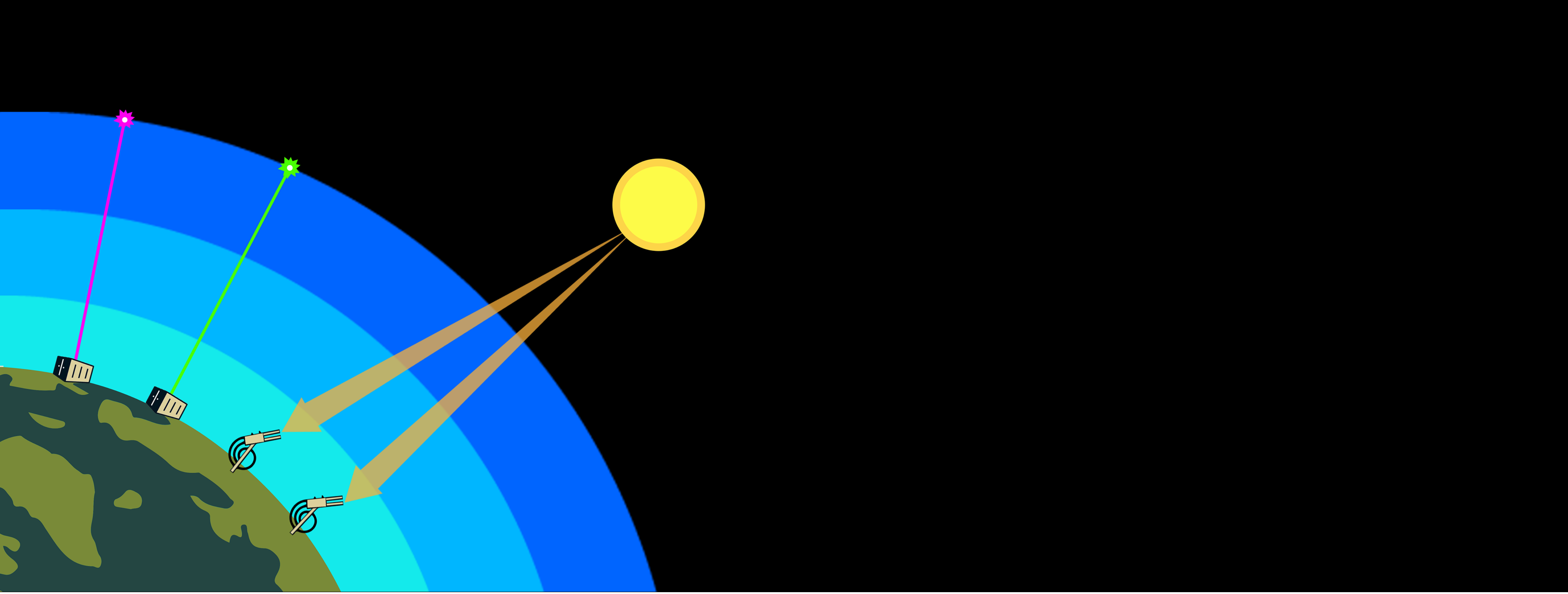
- Identify the basic characteristics of the MPLNET instruments used by NASA for ground-based active remote sensing of aerosols, clouds, and the planetary boundary layer.
- Recognize how MPLNET sustains global long-term observations, supports air quality and climate applications, and complements satellite observations.
- Access relevant MPLNET data for a given location and application purpose.

Review of Prior Knowledge

Network	Type	Primary Measurands	Number of Sites	Vertical Coverage
AERONET	Passive	Aerosols (Optical, Microphysical, Radiative)	~600 Active	Total Column
Pandora (PGN)	Passive	Trace Gases (Ozone, NO_2, Formaldehyde)	168 Official	Total Column, Near-Surface, Lower Tropospheric Profiles
TOLNet	Active	Trace Gases (Ozone Vertical Profiles)	12 (3 Fixed, 9 Transportable)	Tropospheric Profiles (0-15 km)

How to Ask Questions

- Please put your questions in the Questions box and we will address them at the end of the webinar.
- Feel free to enter your questions as we go. We will try to get to all of the questions during the Q&A session after the webinar.
- The remainder of the questions will be answered in the Q&A document, which will be posted to the training website about a week after the training.



Introduction to the Micro-Pulse Lidar Network (MPLNET)

Introduction to the Micro-Pulse Lidar Network (MPLNET)

Principal Investigator:
Judd Welton, NASA GSFC Code 612

MPLNET Staff:
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Larry Belcher, SSAI GSFC Code 612
Jasper Lewis, UMBC GSFC Code 612
James Campbell, Naval Research Lab
Simone Lolli, CNR Italy
Lisa Nalborczyk, SSAI GSFC Code 612

All our international network partners

and AERONET

Windpoort, Namibia MPLNET Site

Agenda

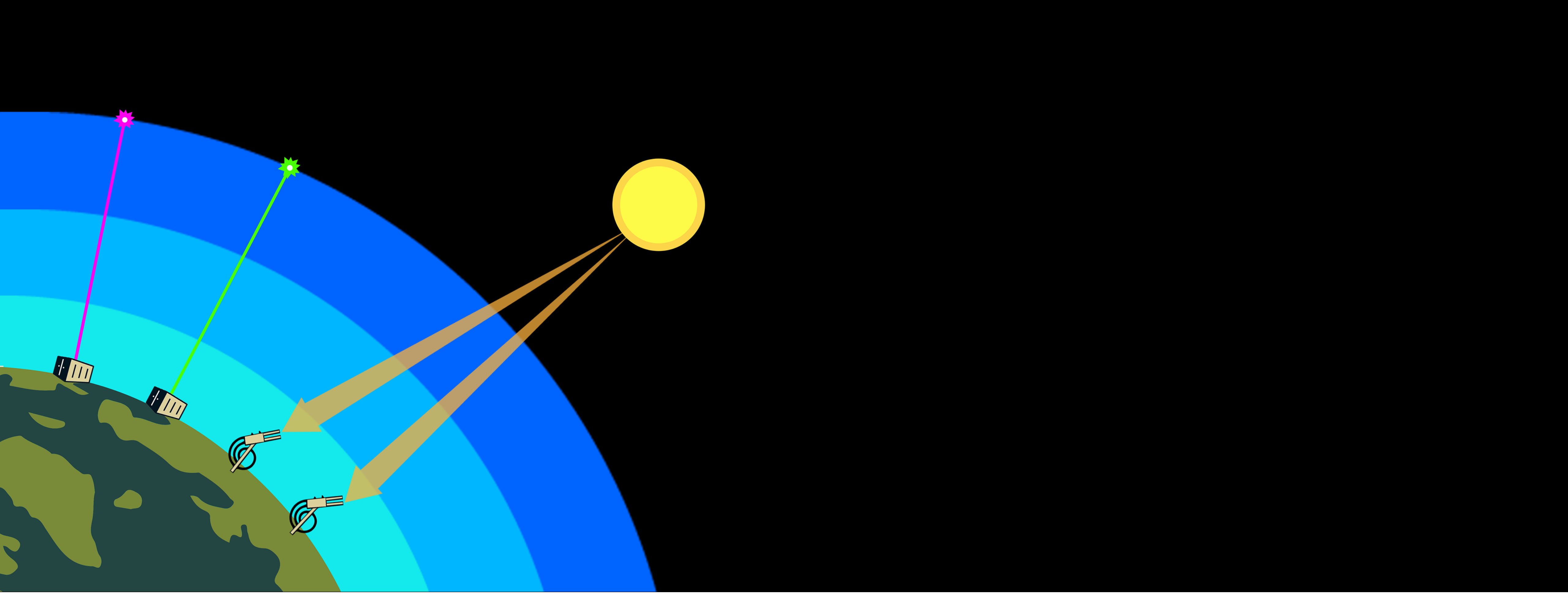
Introduction and Lidar Overview:
MPLNET Introduction and objectives
Introduction to elastic backscatter lidar
Interpreting lidar data

MPLNET Project and Data:
Network sites, organization, history
Data Products
Products in Development

MPLNET Website and Data Access:
Tour of website
Data browsing
Data access / download

Case Study Examples:
Smoke, Dust, and PBL studies and applications

Conclusion: Access to Global Lidar Data
WMO GAW Aerosol Lidar Observation Network (GALION)



MPLNET Introduction and Lidar Overview

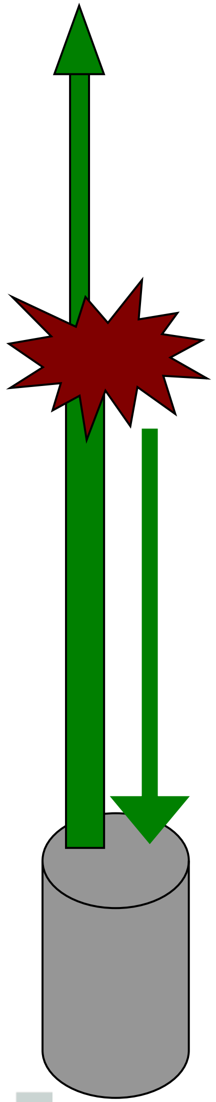
Introduction: MPLNET was funded in 1999, and began operations in 2000

Develop a long-term, global lidar network to profile aerosol and cloud vertical distribution and properties at key AERONET sites, supporting:

- Domestic and international aerosol and cloud research
- Climate change and air quality studies
- NASA satellite and sub-orbital missions
- Aerosol modeling and forecasting

MPLNET is funded by the NASA Radiation Sciences Program & Earth Observing System, with significant contributions from our many site partners

MPLNET Introduction: Elastic Backscatter Lidar



Lidars are like radars, but instead of using microwaves they use laser light (UV, green, or red).

Radars profile clouds, rain, severe weather.

Microwaves are ideal for thick, larger particle layers like clouds and rain.

Backscatter Lidars profile aerosols and thin clouds.

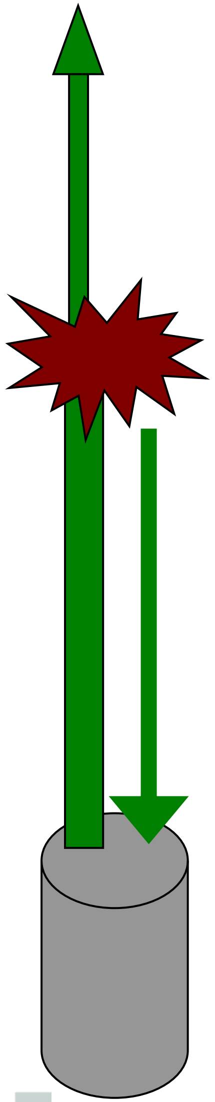
Visible light is ideal for smaller particles like aerosols.

Lidars transmit short pulses of laser light into the atmosphere.

A small portion of the light **backscatters** (180°) from particles in the atmosphere and is collected by a telescope, and recorded using a detector and data system.

MPLNET uses this "elastic backscatter lidar". There are also advanced lidars that utilize other techniques (Raman, High Spectral Resolution – HSRL) as well as others that measure winds, ozone, water vapor, temperature, etc.

MPLNET Introduction: Elastic Backscatter Lidar Provides Optical Proxies



The **altitude** of the particle is determined from the time between pulse transmission and signal reception, using the speed of light (which is constant).

The light is attenuated as it travels up and back through the atmosphere by scattering and absorption, in total referred to as **extinction**.

The backscatter and extinction parameters in the measured signals are the optical properties of the aerosol and clouds.

The laser light is often **polarized** in one orientation/state.

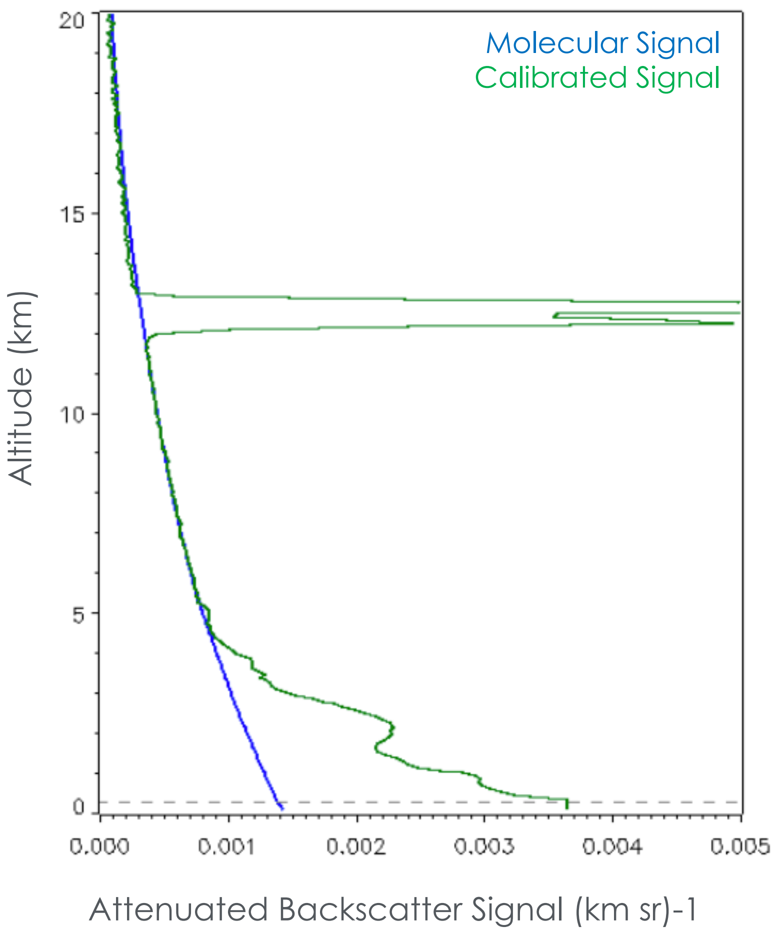
Scattering from non-spherical particles (dust, ice clouds) depolarizes the emitted light by an amount proportional to the non-sphericity of the particles.

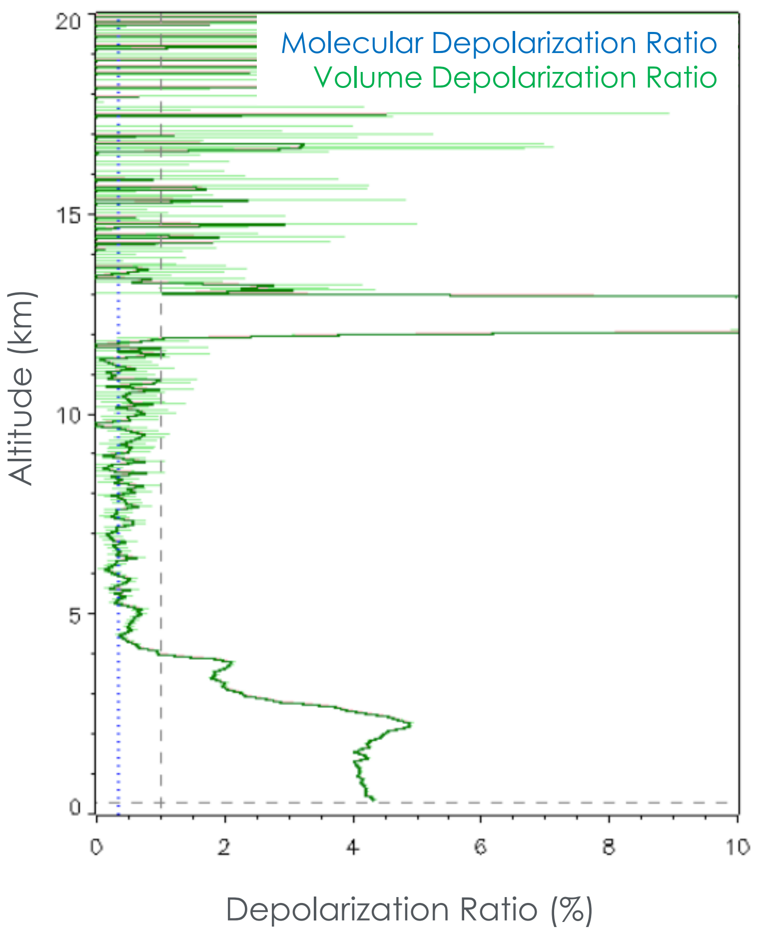
Polarized lidars can measure the **depolarization ratio** which is proportional to the particle's degree of non-sphericity.

The remote sensing data from the lidar provides optical proxies for vertical profiles of aerosol and cloud concentration, composition, and shape.

MPLNET Introduction: The Lidar Signal and Depolarization Ratio

- **The backscattered signal is continually attenuated** as it propagates through the atmosphere.
- The transmitted pulse eventually becomes fully attenuated resulting in loss of information above that height.
- Signals are nosier and attenuate at lower altitudes in daytime (solar background noise).





MPLNET Introduction: The Micro Pulse Lidar

1st Commercially Available
Autonomous Eye-Safe Lidar

Suitable for Network Operations

Developed at NASA in the early 1990s, patented and licensed for commercial use

Sold commercially since 1995
Science and Engineering Services Inc
Sigma Space Corporation
Leica Geosystems
Droplet Measurement Technologies

Elastic Backscatter Lidar with Green Laser (532 nm)

Atmospheric Profiles from 250 m to 30 km
 1 minute temporal resolution
 Polarized ~2008

MPLNET Introduction: Primary Job of MPLNET

- Install and operate MPL sites and collect and archive the data.
- Calibrate instruments and transform raw data to Level 1 signal products. **These are useable signals.**
- Retrieve cloud, aerosol, and PBL properties and provide Level 1.5 and 2 quality assured data products.
- Provide the data products to the public and assist with interpretation of the data and collaborative research.

MPLNET Introduction: Raw Data to Atmospheric Parameters

Atmospheric Parameters we want:

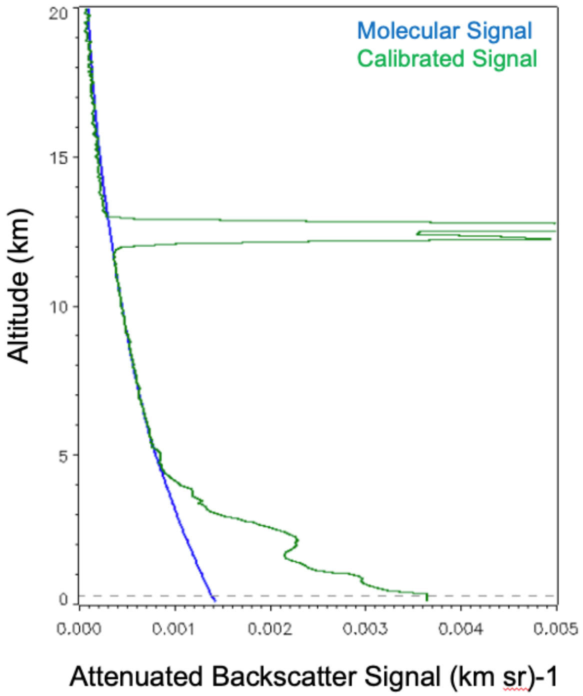
β: backscatter

σ: extinction

$$P_{NRB}(r) = C\left(\beta_M(r) + \beta_P(r)\right)e^{-2\int_0^z \sigma_M(r')dr'}e^{-2\int_0^z \sigma_P(r')dr'}$$

M: molecular

P: particle (aerosol, cloud)



MPLNET Introduction: Raw Data to Atmospheric Parameters

Atmospheric Parameters we want:

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Aerosol optical depth from surface to range r

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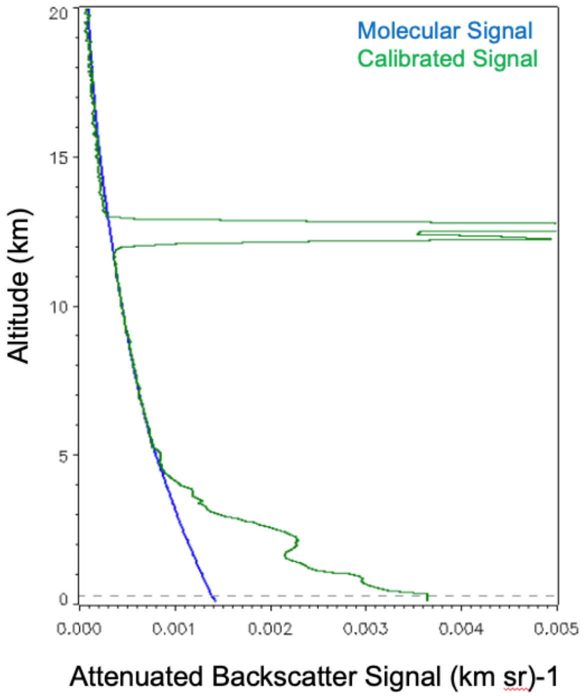

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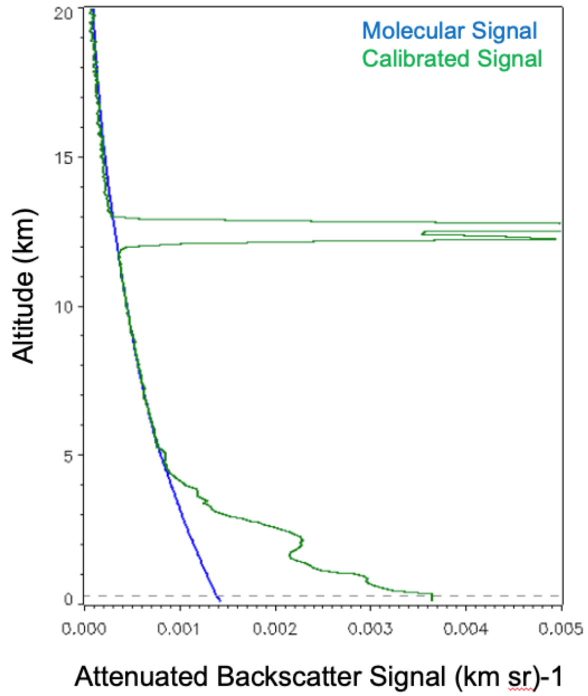


MPL Raw Data Parameters:

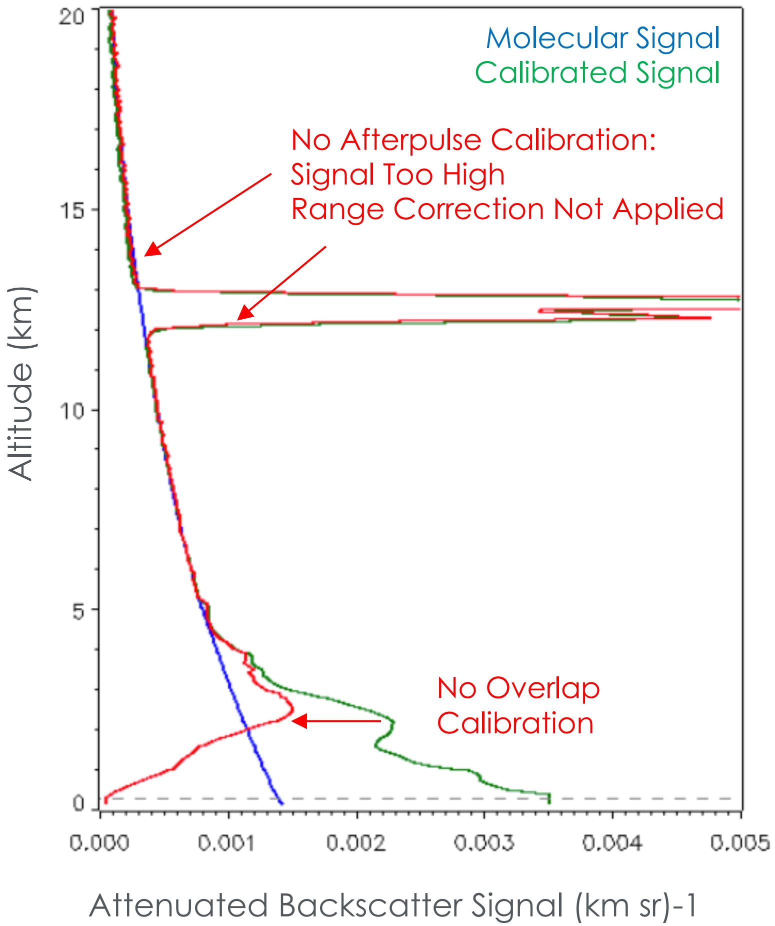
Measured or set by data system
Laser Energy, Solar Background (noise), Range, Diagnostic Temperatures

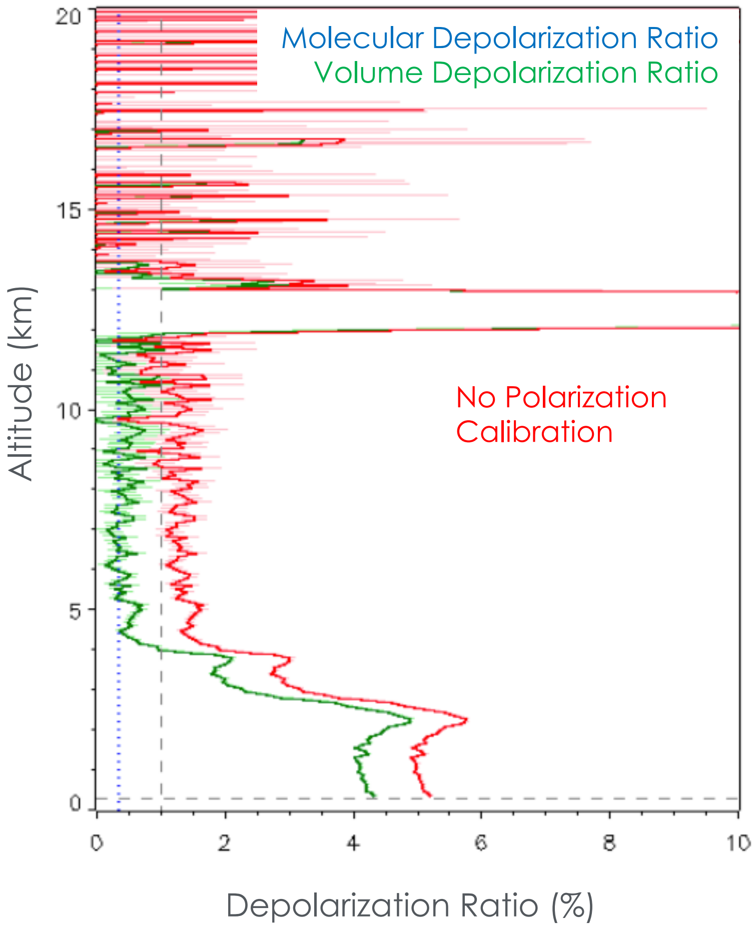
Require Post-Processing Calibration
Detector: deadtime and dark count calibrations
Laser-Detector Crosstalk: afterpulse calibration
Receiver Overlap: calibration for near range signal loss
Polarization: calibration required for accurate (low bias) depolarization ratios
Lidar Receiver Efficiency Parameter: C (lidar constant) convert to SI units

The Appendix provides more in depth discussion of lidar signals, calibration, and processing.

MPLNET Introduction: MPL Calibrations

- **Detector and Afterpulse Calibrations** are done onsite by our partners every 1-2 months. Sent back to GSFC and calibrations are processed.
- **Overlap and Polarization Calibrations** are done prior deployment, and updated every 1-2 months.
- Overlap calibrations are performed using a wide field of view receiver (additional data channel). Polarization calibrations are done with both lab and measured data.





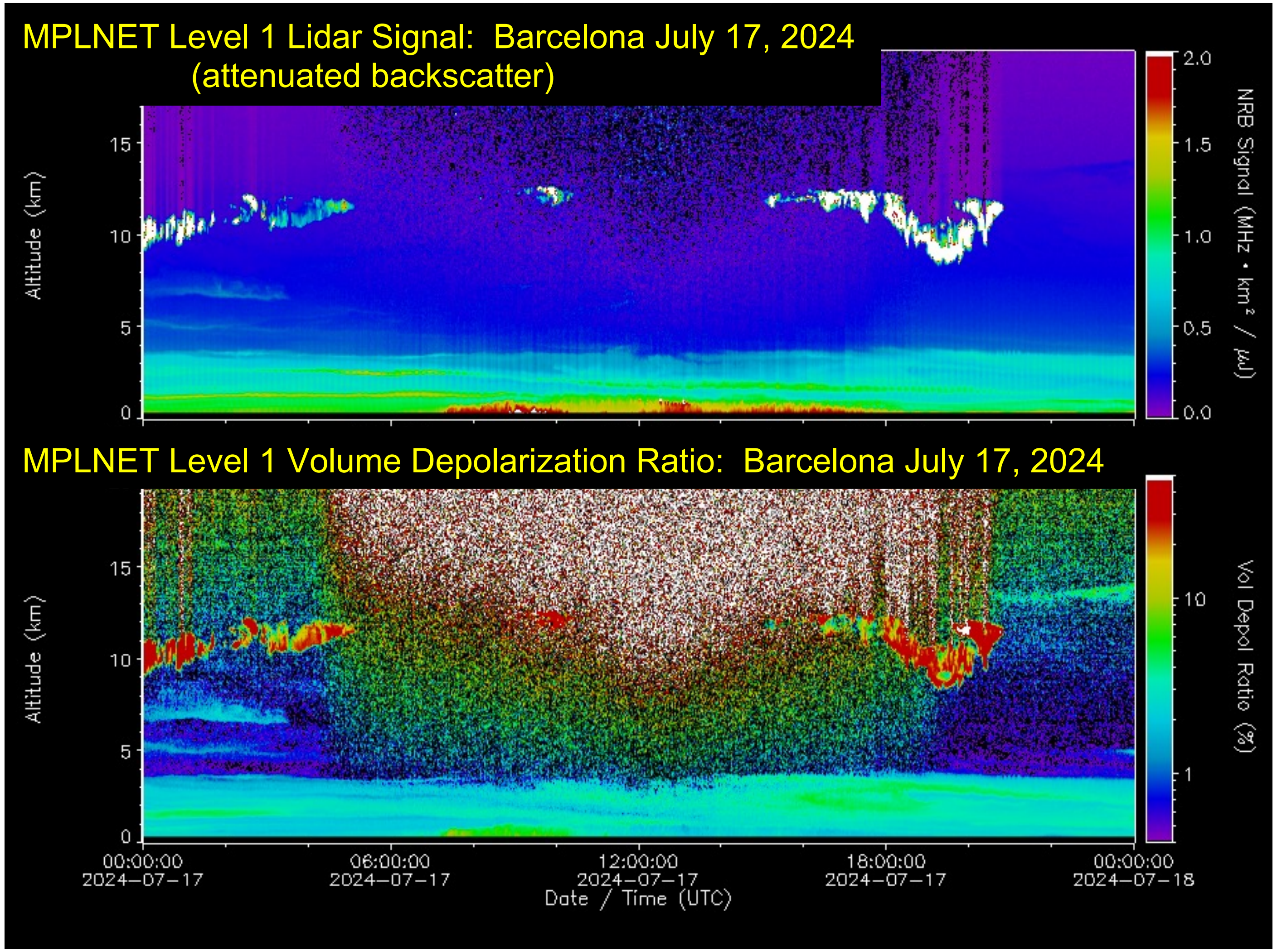
MPLNET Introduction: Interpreting Lidar Data

Lidar data are often displayed as 2D representations of the atmosphere.

X axis is time and **Y axis is altitude**.

The data variable is represented by a color map, with values for each time/altitude grid box.

These images can represent the native time and range resolution of the data, be averaged over those scales, or also be regridded to larger or smaller resolution scales.



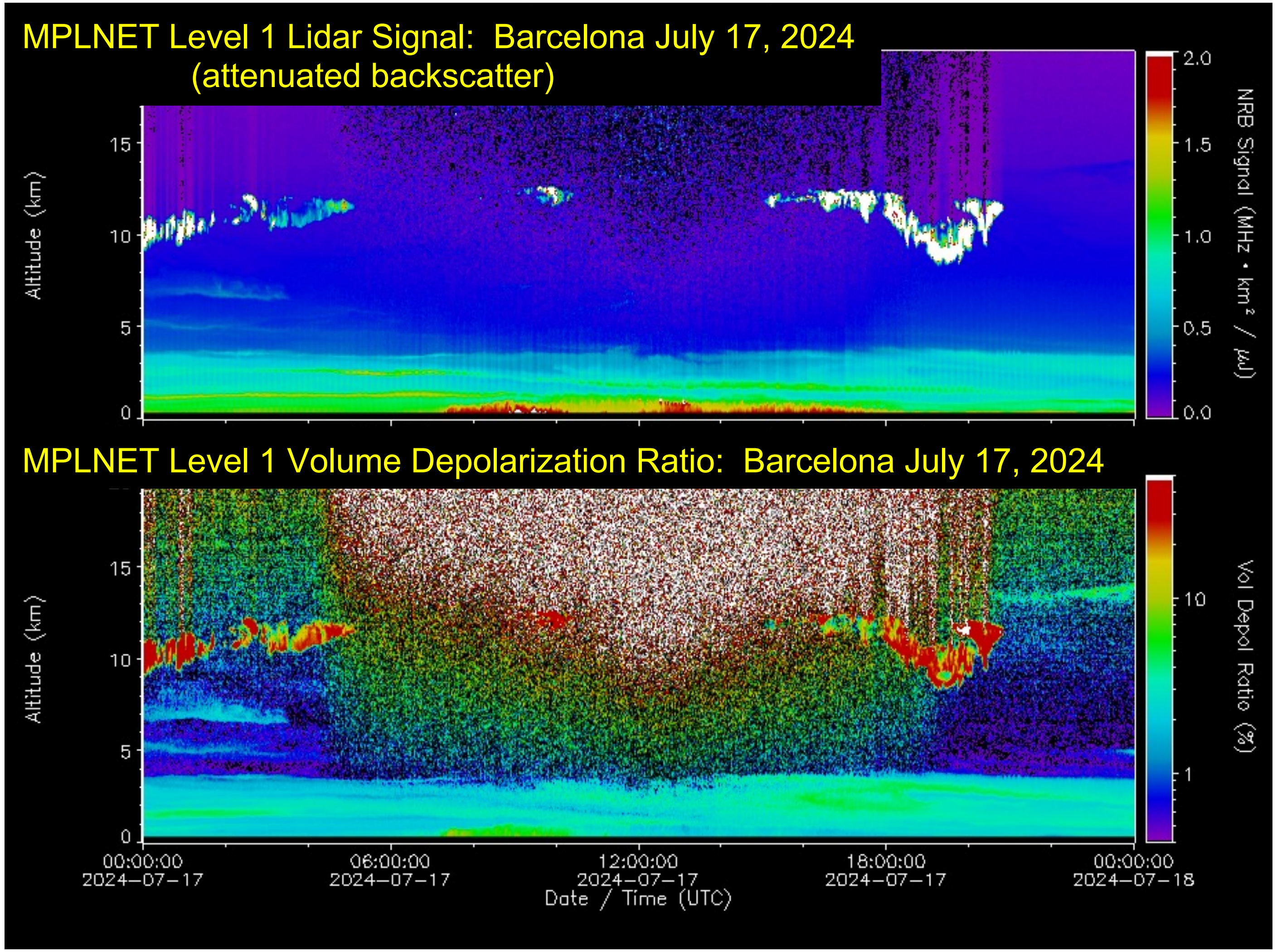
MPLNET Introduction: Interpreting Lidar Data

MPLNET Level 1 signals are shown at right top, and volume depolarization ratios at right bottom.

Signals attenuate with increasing altitude, so apparent intensity/strength of the signal at higher altitudes does not necessarily indicate high or low concentration in that layer.

Depolarization ratios indicate the sphericity of the particles, not the concentration!

high depol ratios = non-spherical
But:
volume depol ratios ≠ particle depol ratios



MPLNET Introduction: Interpreting Lidar Data

MPLNET Level 1 aerosol backscatter signals are shown at right top, and aerosol depolarization ratios at right bottom.

Signals attenuate with increasing altitude, so apparent intensity/strength of the signal at higher altitudes does not necessarily indicate high or low concentration in that layer.

Depolarization ratios indicate the sphericity of the particles, not the concentration!

high depol ratios = non-spherical
But:
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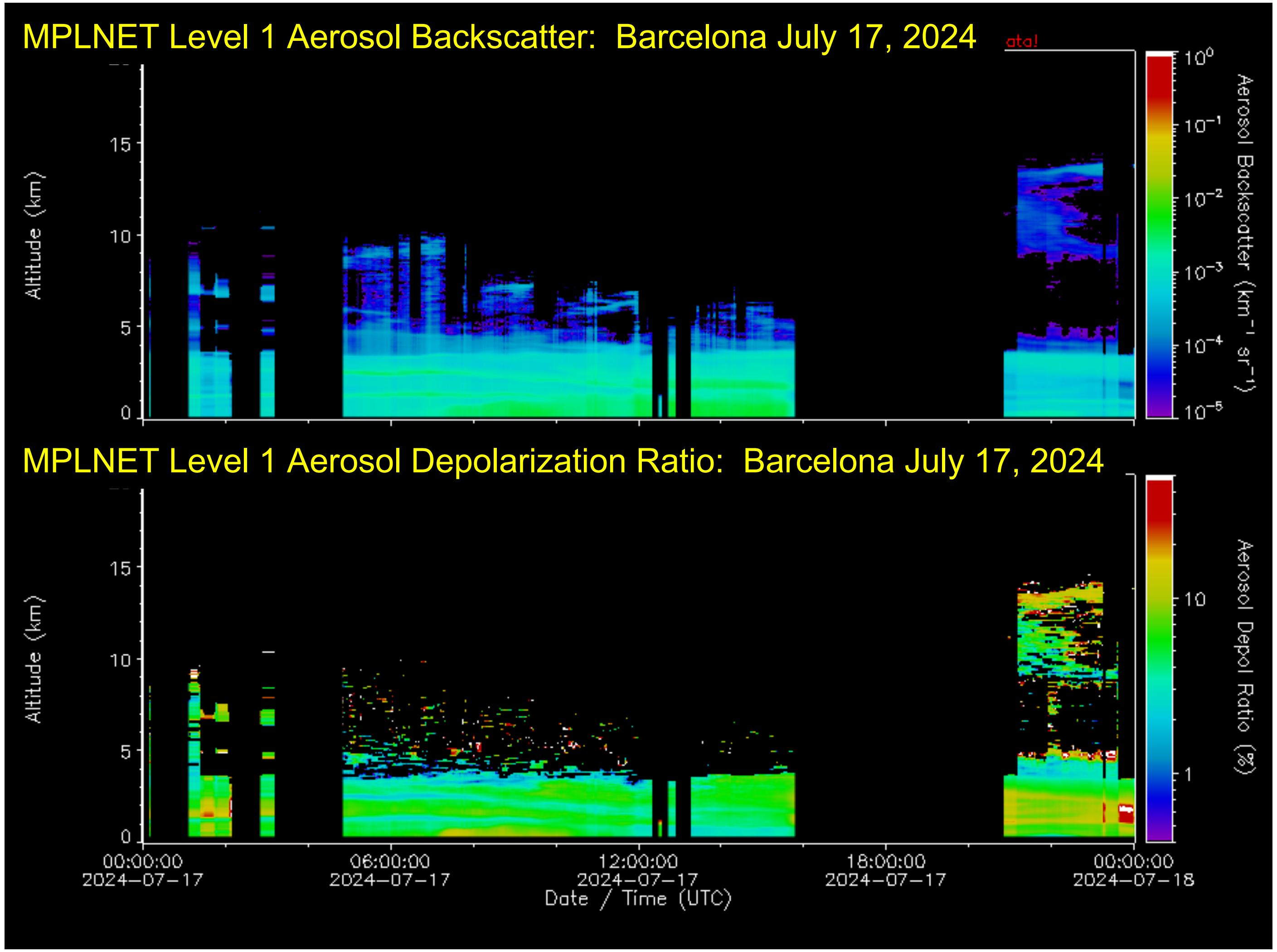
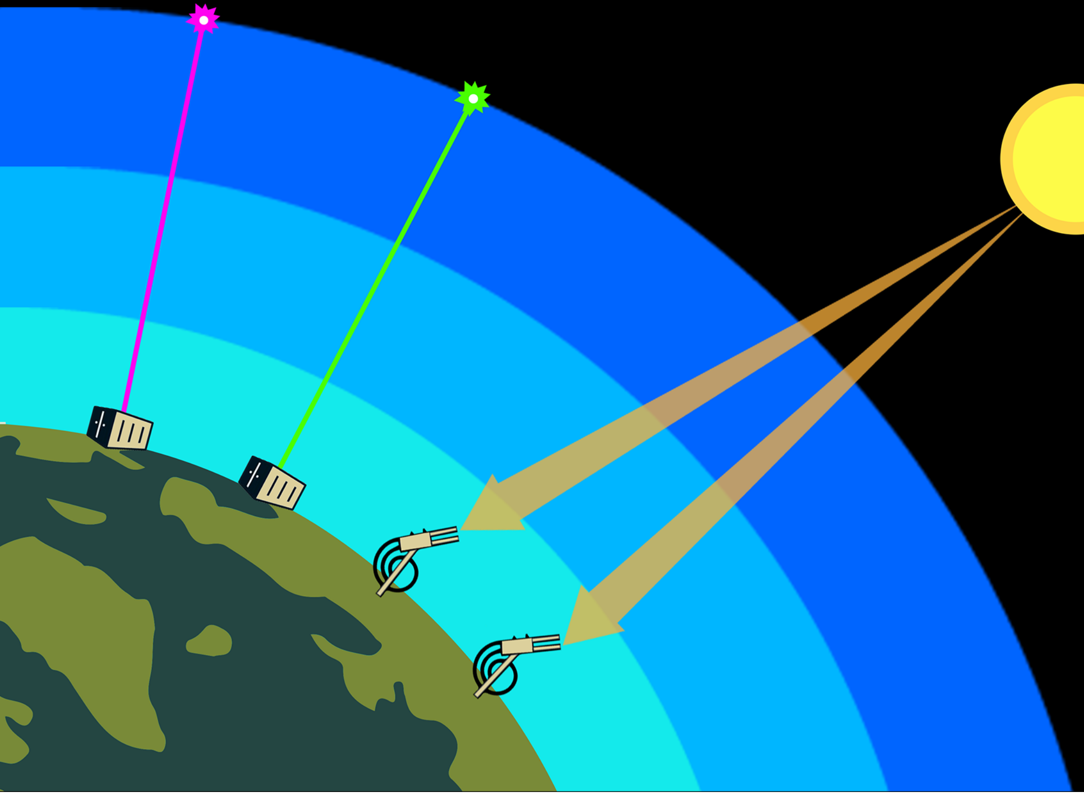




MPLNET Project and Data

MPLNET Project Overview: Network & History

MPLNET Sites: 2000 - current

- 85 sites total
- 28 operational, 57 closed, across 28 countries
- 10 more sites in planning
- colocation with AERONET

MPLNET History:

- Three Version Releases
- Version 1 and 2 (2000 – 2021)
- Version 3 (V3) Released in Nov 2021
- Version releases include new instrumentation, data products, and/or data processing capabilities
- Version 2 and 3 data are available on our website

MPLNET Sites: 2000 – Current

[MPLNET Website](#)

MPLNET Project Overview: Instrumentation & Operations

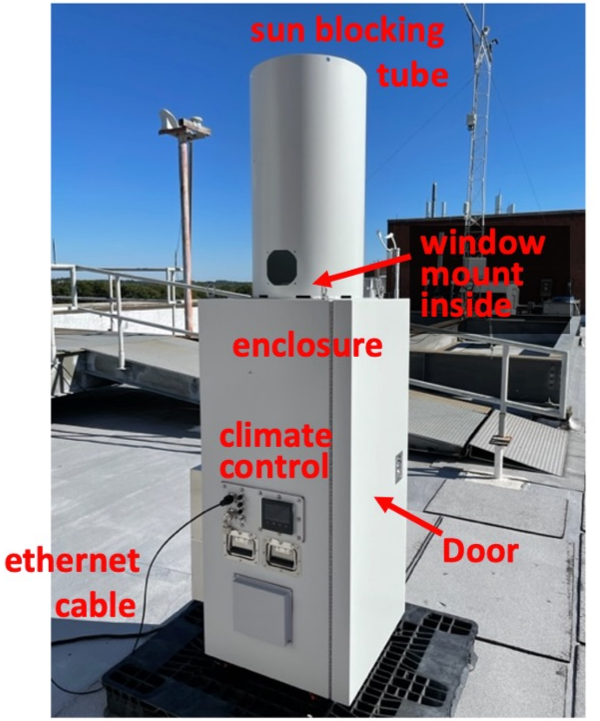
Instrumentation:
- Micro Pulse Lidar, miniMPL
- Eye safe, green backscatter lidar
- Polarized in early 2000s
- Entire network has polarized MPL since ~2016

Installation Options:
MPLNET provided enclosure or
partner provided lab, trailer, enclosure

miniMPL in mini-enclosure

MPL in Standard Enclosure

Note: the miniMPL also fits in the standard enclosure



Operations:
- Federated Network (NASA + partners)
- Continuous day/night data
- Data resolutions: 1 minute temporal,
  30 or 75 meter vertical
- Raw data transmitted to central MPLNET server hourly
- Automated processing of data, products available near-real-time (hourly)

MPLNET Project Overview: Data Product Suite

Modernized Data Product Suite and aligned with AERONET V3

V3 Product	Descriptions
NRB	Lidar signals; volume depolarization ratios; diagnostics
CLD	Cloud heights; thin cloud extinction and optical depths; cloud phase
AER	Aerosol heights; extinction, backscatter, and aerosol depolarization ratio profiles; lidar ratio
PBL	Surface-Attached Mixed Layer Top and estimated AOD
Product File Formats	
Formats	MPLNET V3 products are NETCDF 4, CF compliant files. Subsets for each product may be selected to reduce file sizes.

- Suite of 4 products grouped by theme, each containing variables and diagnostics
- **Standardized format, netcdf4**, CF compliance, **full error propagation from raw data**
- Online "Algorithm Theoretical Basis Documents (ATBDs)"
- **All L1 and L1.5 products available in NRT (< 1 hour)** via automated data transfer and processing system
- **QA flags in all products**
- NRT QA screen applied at L1.5, final QA at L2
- L3 products in development (created from L2 data)

Online Version and Product Descriptions

MPLNET Project Overview: Data Product Levels Table

Modernized Data Product Suite and aligned with AERONET V3

Product Levels	Availability	Calibration	QA Screen	Ancillary Input
L1_NRB L1_CLD L1_PBL L1_AER	Automated Browse: Near Real Time Download: Next Day *	intial, ongoing field calibrations	none	GEOS5 Forecast NRT, reprocessed next day with GEOS5 Assimilated, AERONET L15 AOD
L15_NRB L15_CLD L15_PBL L15_AER	Automated Browse: Near Real Time Download: Next Day *	intial, ongoing field calibrations	L15	GEOS5 Forecast NRT, reprocessed next day with GEOS5 Assimilated, AERONET L15 AOD
L2_NRB L2_CLD L2_PBL L2_AER	**After post calibration and AERONET L2**	intial, ongoing field calibrations, post calibration, additional‡	L2	GEOS5 Assimilated, AERONET L2 AOD

* Near real time data can be provided to site partners and forecasting/modeling centers

† L2_AER products subject to availability of L2 AERONET data

‡ Additional L2 calibrations may include corrections for instrument temperature and manual inspection of data

Online Version and Product Descriptions

MPLNET Project Overview: Variable Confidence Flags

Modernized Data Product Suite and aligned with AERONET V3

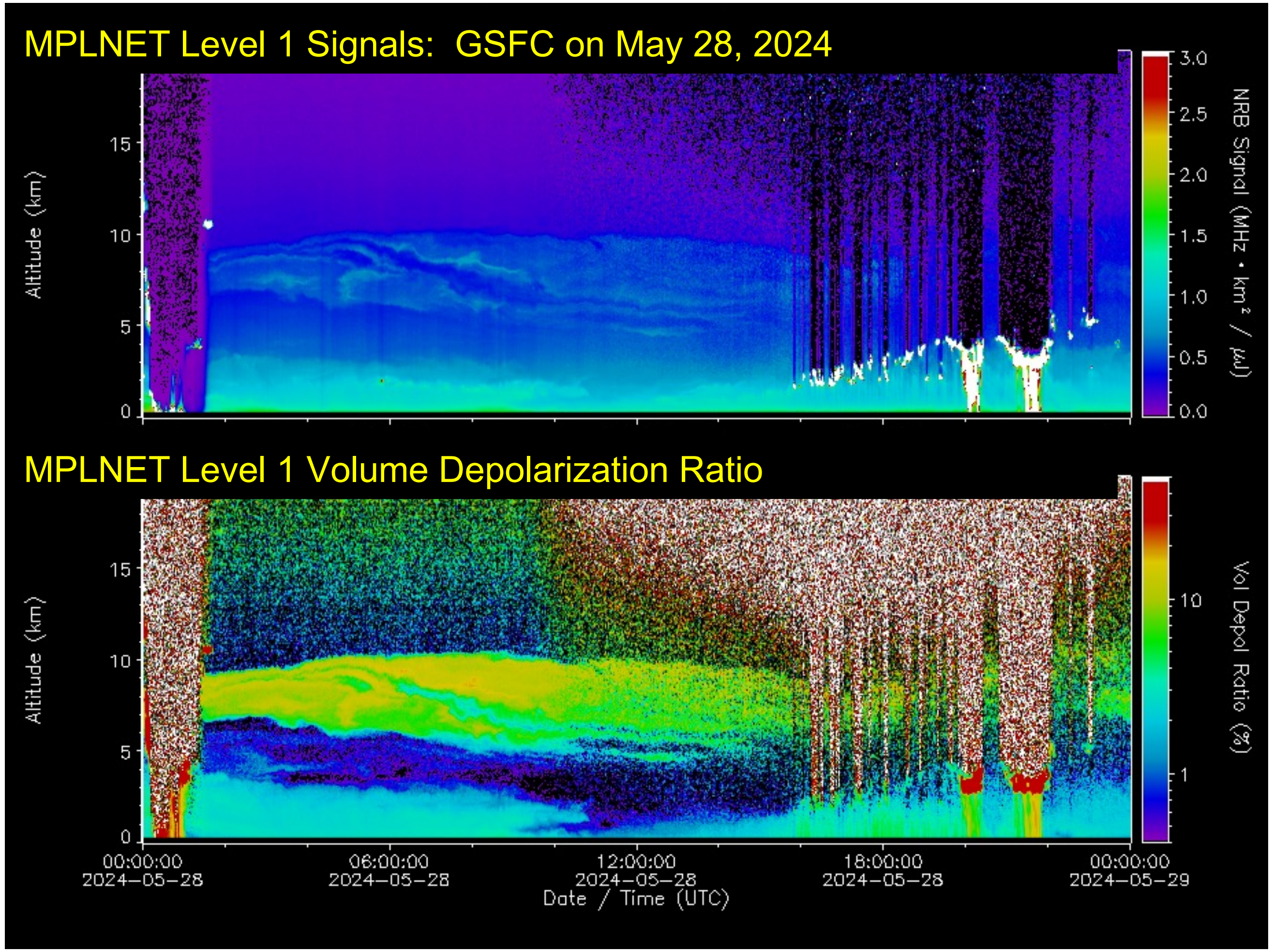
Version 3 Variable Confidence Flags
- New for Version 3, in all products
- Based on maturity of variable algorithm and QA flags

QA Confidence Level	Value	Descriptions
n/a	0	Only set if variable has no QA inspection applied.
High	1	Long history with variable and QA procedures results in high confidence
Moderate	2	Lower confidence in an ancillary data input results in lower overall QA confidence
Low	4	Reserved for variables that are new and require more study to elevate confidence
Fail	8	Data fail QA screen, variable data replaced with NaN

Online Version and Product Descriptions

MPLNET Project Overview: Version 3 Signal Product (NRB)

- Lidar signal (total, co and cross polarization)
- Volume Depolarization Ratio
- Error variables for all
- QA flags



References:

Campbell, J.R. et al, 2002. Full-time, Eye-Safe Cloud and Aerosol Lidar Observation at Atmospheric Radiation Measurement Program Sites: Instrument and Data Processing, J. Atmos. Oceanic Technol., 19, 431-442.

Welton, E.J., and J.R. Campbell, 2002. Micro-pulse Lidar Signals: Uncertainty Analysis, J. Atmos. Oceanic Technol., 19, 2089-2094.

Berkoff, T.A., et al, 2003. Investigation of overlap correction techniques for the Micro-Pulse Lidar NETwork (MPLNET). IGARSS 2003. 2003 IEEE International Geoscience and Remote Sensing Symposium. Vol 7, 4395-4397, doi: 10.1109/IGARSS.2003.1295527.

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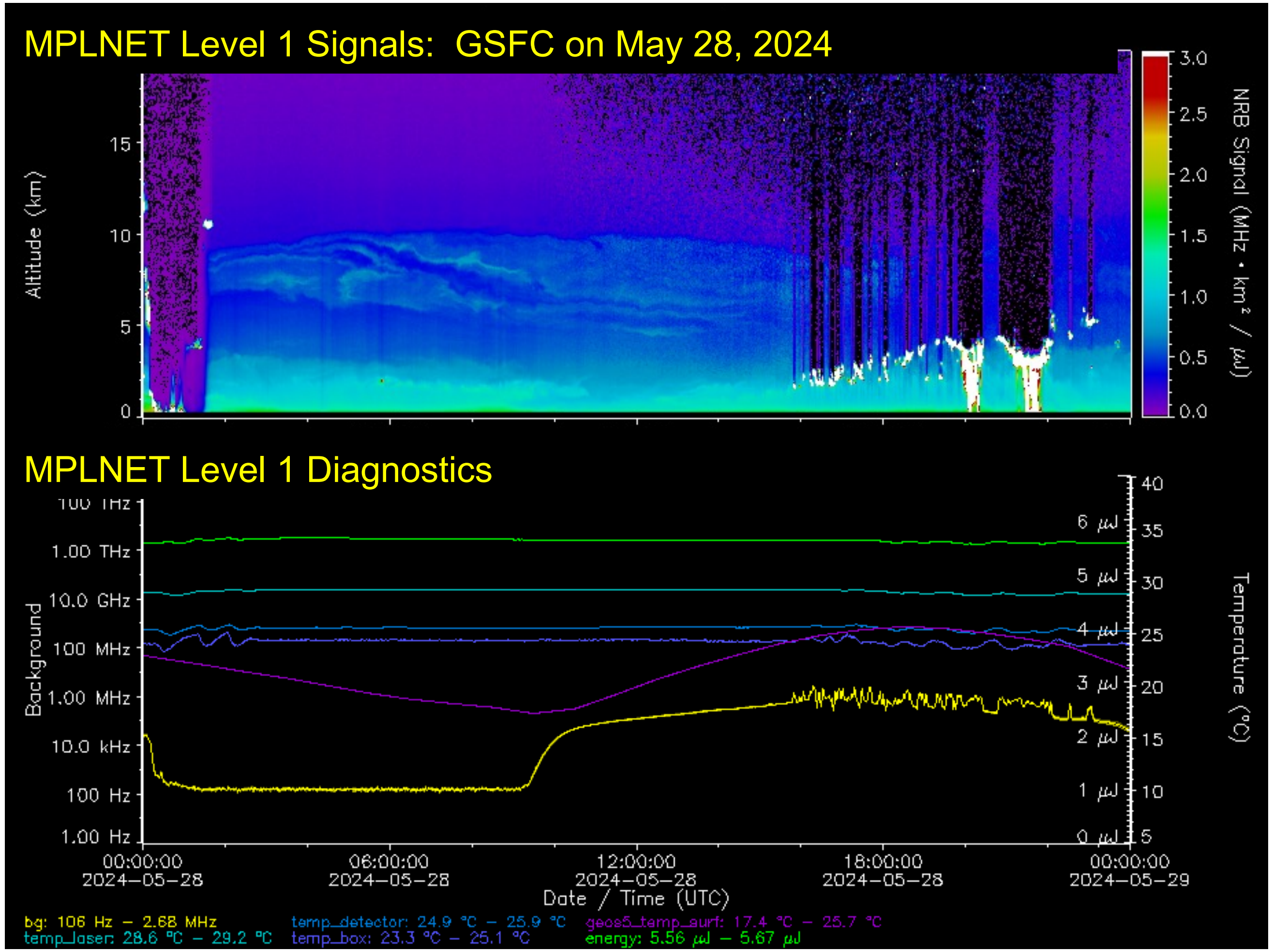
MPLNET Project Overview: Version 3 Signal Product (NRB)

- Lidar signal (total, co and cross polarization)
- Volume Depolarization Ratio
- Error variables for all
- QA flags



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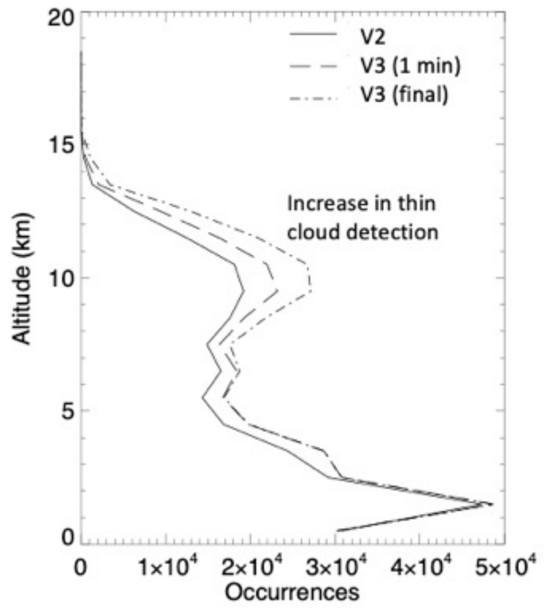
MPLNET Project Overview: Cloud Data Product (CLD)

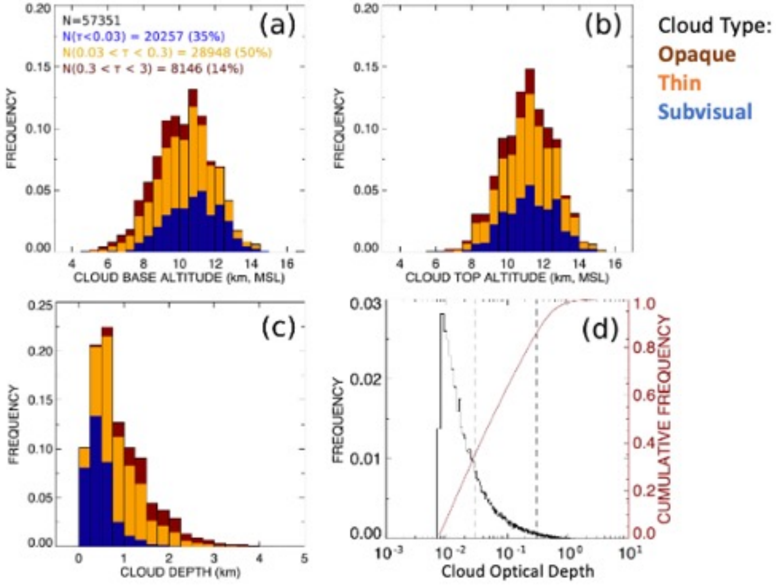
- Cloud base and top heights
- Cloud Mask
- Hourly & Daily Cloud Fractions (column and low, mid, high level)
- Estimates of Thin Cloud Optical Depth and Extinction
- Cloud Phase (water, ice, mixed, unknown)

Lewis, J., J. Campbell, E. Welton, S. Stewart, and P. Haftings, 2016: Overview of MPLNET Version 3 Cloud Detection. *Journal of Atmospheric and Oceanic Technology*, 33, 2113–2134, doi: 10.1175/JTECH-D-15-0190.1.

Improved detection of thin clouds in V3



Cloud detection comparison 2012 GSFC: Older V2 results (detection only at 1 minute temporal res). V3 algorithm results at 1 minute, and the final multi-temporal results.



Cloud statistics for 2012 GSFC from the new V3 algorithm: Cloud base and top altitudes, and cloud depth. New in V3: estimates of cloud optical depth (up to signal attenuation).

MPLNET Project Overview: Cloud Data Product (CLD)

Lewis, J.R., J.R. Campbell, S. Lolli, S.A. Stewart, I. Tan, and E.J. Welton, 2020. Determining Cloud Thermodynamic Phase from the Polarized Micro Pulse Lidar. Atmos. Meas. Tech., 13, 6901–6913, https://doi.org/10.5194/amt-13-6901-2020.

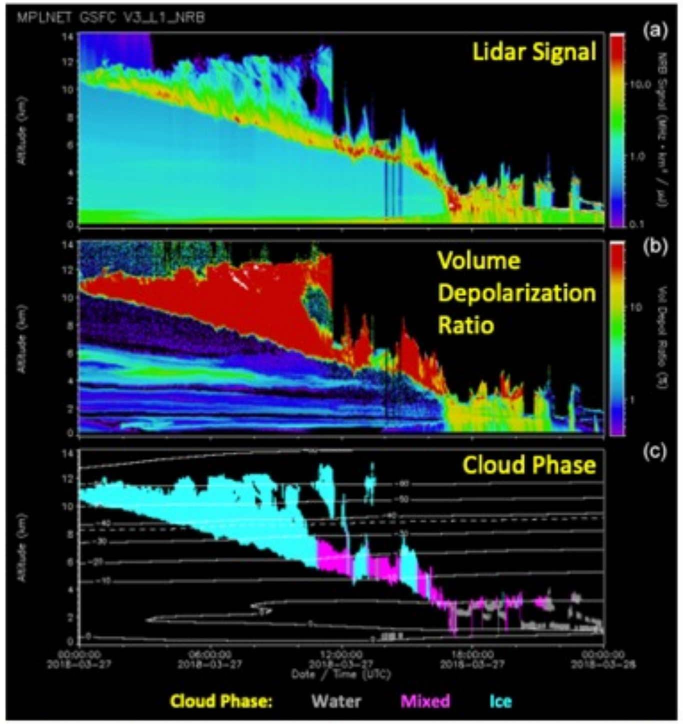


Figure 6. Frontal cloud system at GSFC on 27 March 2018: NRB (a), volume depolarization ratio (b) and phase mask (c). Altitude bins where the signal uncertainty is twice the signal strength have been suppressed for easier viewing. Note the use of a log scale for the NRB. The phase mask indicates liquid water clouds (grey), mixed-phase clouds (magenta), ice clouds (cyan), and unknown phase (pink). The GEOS-5 temperature is shown by the contour lines (in 10 °C intervals). The −37 °C isotherm is indicated by the dashed contour line.

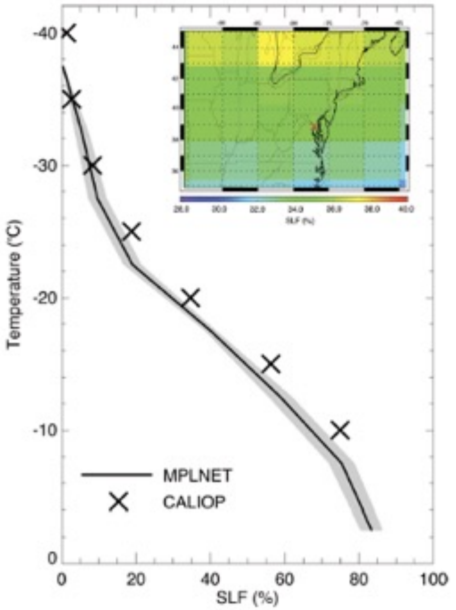


Figure 9. Supercooled liquid fraction (SLF) averaged over GSFC (2015–2019) from MPLNET (solid line) and CALIOP (black ×) observations. The inset shows the horizontal distribution of CALIOP SLFs at the −20 °C isotherm surrounding GSFC (indicated by the red ×). The CALIOP SLF profile is calculated using the 2.5° latitude × 5° longitude grid box containing GSFC. The shaded area indicates the standard error for MPLNET observations. CALIOP standard errors are less than 0.7 at all isotherms.

MPLNET Project Overview: Cloud Data Product (CLD)

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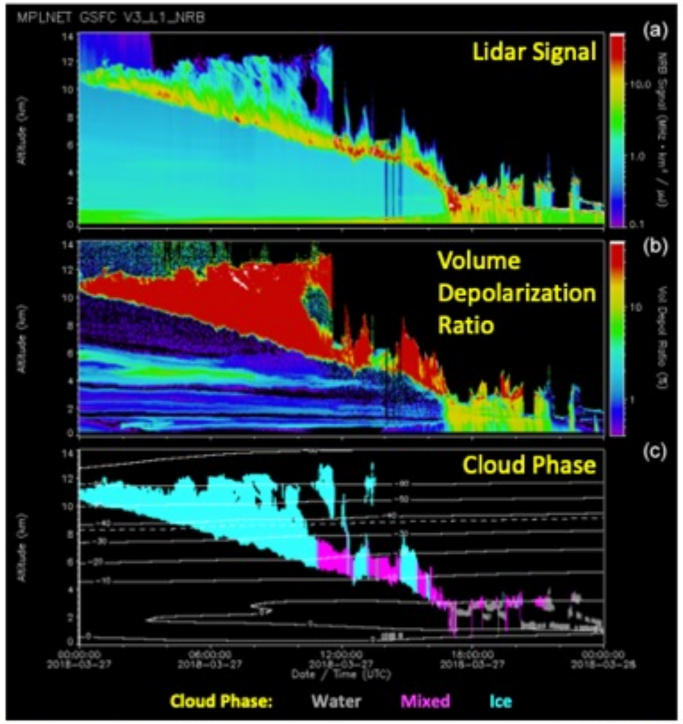

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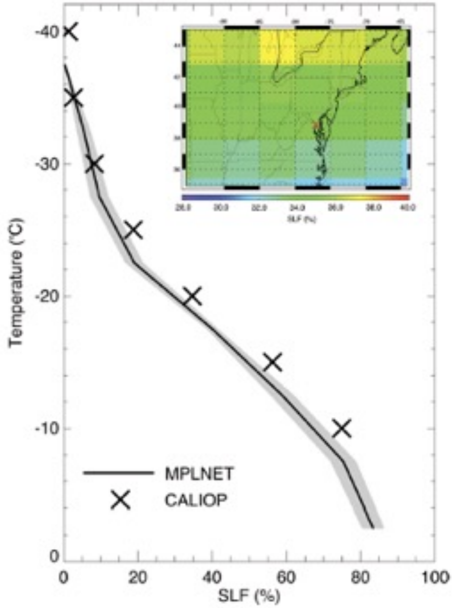

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There have been many publications examining cirrus clouds using MPLNET and CALIPSO combined observations

MPLNET Project Overview: Cloud Data Product (CLD)

Lewis, J.R., J.R. Campbell, S. Lolli, S.A. Stewart, I. Tan, and E.J. Welton, 2020. Determining Cloud Thermodynamic Phase from the Polarized Micro Pulse Lidar. Atmos. Meas. Tech., 13, 6901–6913, https://doi.org/10.5194/amt-13-6901-2020.

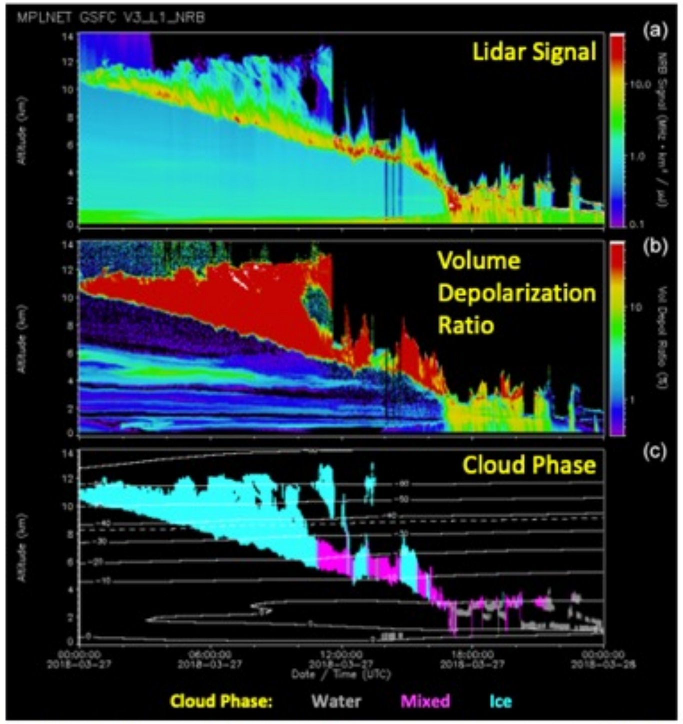


Figure 6. Frontal cloud system at GSFC on 27 March 2018: NRB (a), volume depolarization ratio (b) and phase mask (c). Altitude bins where the signal uncertainty is twice the signal strength have been suppressed for easier viewing. Note the use of a log scale for the NRB. The phase mask indicates liquid water clouds (grey), mixed-phase clouds (magenta), ice clouds (cyan), and unknown phase (pink). The GEOS-5 temperature is shown by the contour lines (in 10 °C intervals). The −37 °C isotherm is indicated by the dashed contour line.

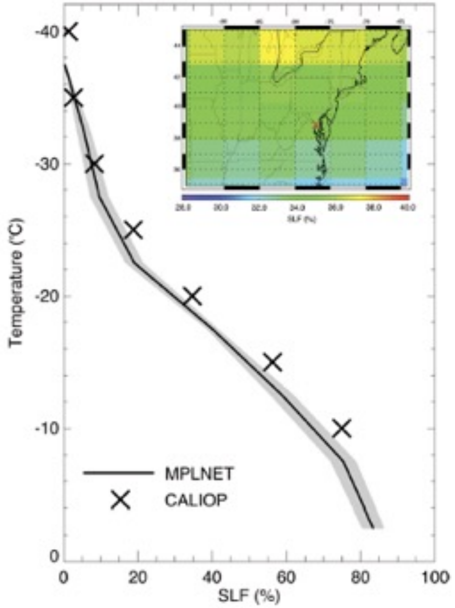


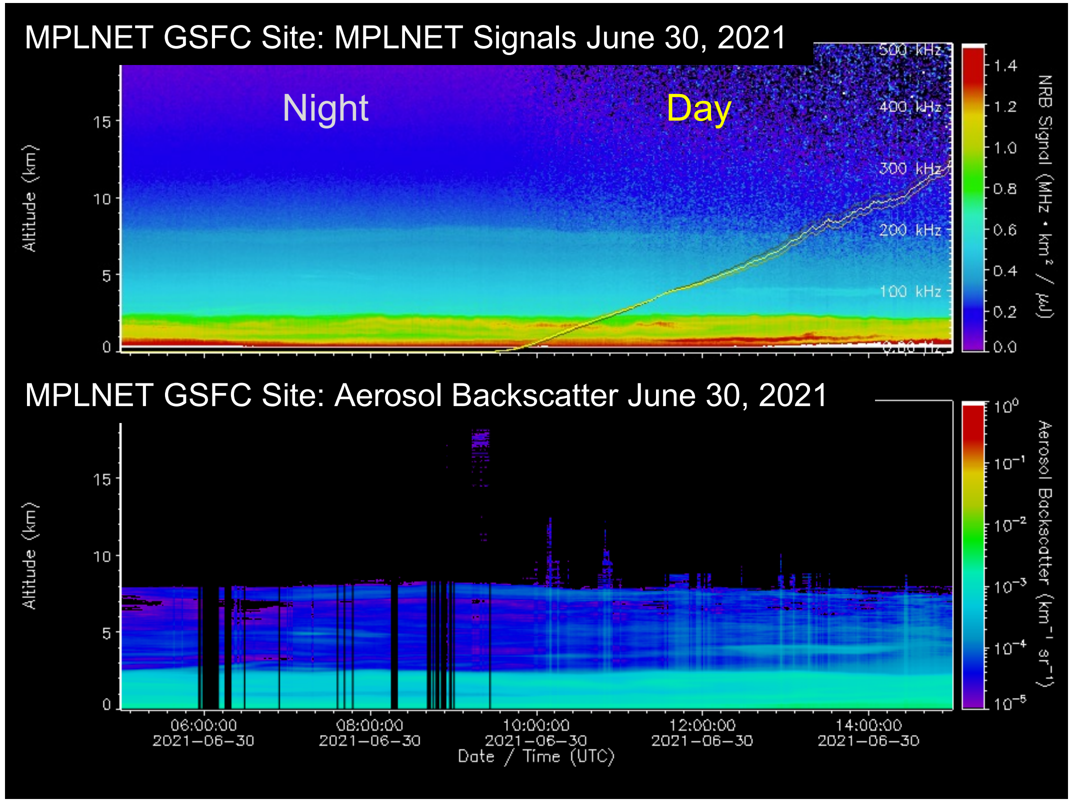
Figure 9. Supercooled liquid fraction (SLF) averaged over GSFC (2015–2019) from MPLNET (solid line) and CALIOP (black ×) observations. The inset shows the horizontal distribution of CALIOP SLFs at the −20 °C isotherm surrounding GSFC (indicated by the red ×). The CALIOP SLF profile is calculated using the 2.5° latitude × 5° longitude grid box containing GSFC. The shaded area indicates the standard error for MPLNET observations. CALIOP standard errors are less than 0.7 at all isotherms.

There have been many publications examining cirrus clouds using MPLNET and CALIPSO combined observations

MPLNET V3 Cloud data were used to validate the new thin cirrus cloud screen used in AERONET V3

MPLNET Project Overview: Aerosol Data Product (AER)

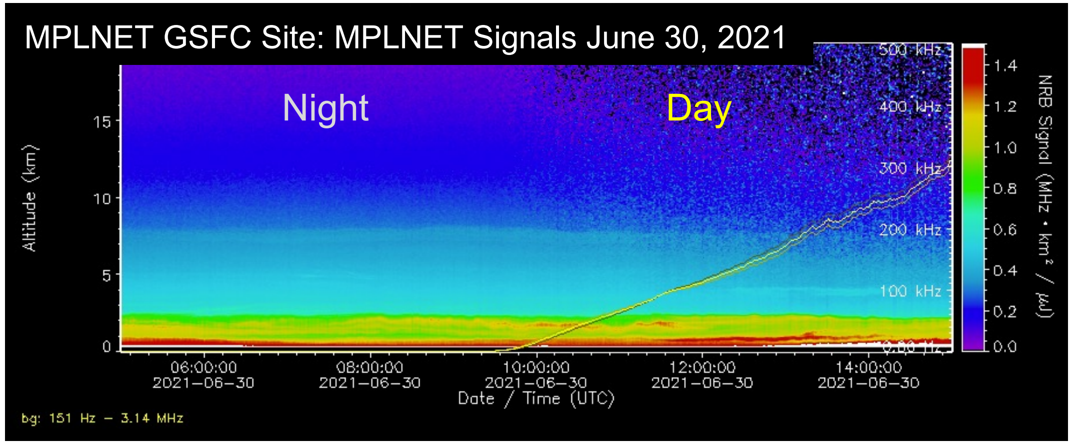
- Aerosol Top Height (top of highest aerosol layer)
- Backscatter and Extinction Profiles
- Lidar Efficiency Parameter C
- Lidar Ratio (extinction to backscatter ratio)
- Retrievals flagged by AOD constraint (day, night, interpolated)



- Same retrieval algorithms traced back to V1, improved implementations
- Addition of AERONET Lunar AOD provides first night-time constraints
  - Higher quality aerosol retrievals and diurnal calibrations
- New variable for polarized data: aerosol depolarization ratio

MPLNET Project Overview: Aerosol Data Product (AER)

Signal data are first cloud screened at 1 minute temporal resolution using CLD product
Running 20 minute signal average is applied, still gridded to 1 minute (but now 20 min resolution)
Cloud screen statistics are kept and used in QA flags



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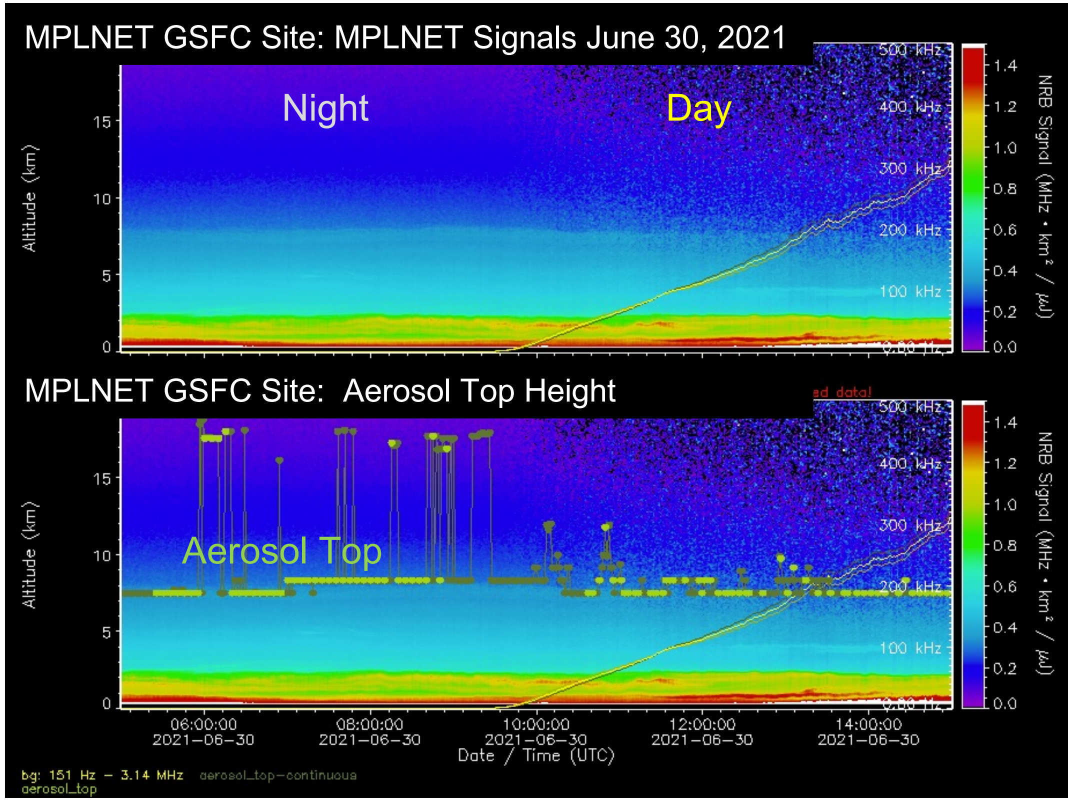

Aerosol Top Height algorithm is applied

Aerosol Top Height References:

Welton, E.J., et al, 2002. Measurements of aerosol vertical profiles and optical properties during INDOEX 1999 using micro-pulse lidars, J. Geophys. Res., 107, 8019, doi:10.1029/2000JD000038.

Welton, EJ., et al, 2007. New Aerosol and Cloud Products from the NASA Micro Pulse Lidar Network (MPLNET). AGU Fall Meeting Abstracts.

MPLNET Project Overview: Aerosol Data Product (AER)

Retrieval of aerosol properties is attempted when AERONET AOD is available. AOD is used as an independent constraint.

$$P_{NRB}(r) = C\left(\beta_M(r) + \beta_P(r)\right)e^{-2\int_0^z \sigma_M(r')dr'} e^{-2\int_0^z \sigma_P(r')dr'}$$

We have two unknowns (β and σ) and a transcendental equation
Solutions provided by Fernald (1972, 1984) and Klett (1981).

Introduce the lidar ratio (below), set an a priori value (typically 50 sr) and solve for β and σ.

$$S = \frac{\sigma}{\beta} = \frac{4\pi}{\omega_o P_\pi}$$

ω_0 is single scatter albedo (absorption)
P_π is the phase function at 180° (size, shape)

MPLNET Project Overview: Aerosol Data Product (AER)

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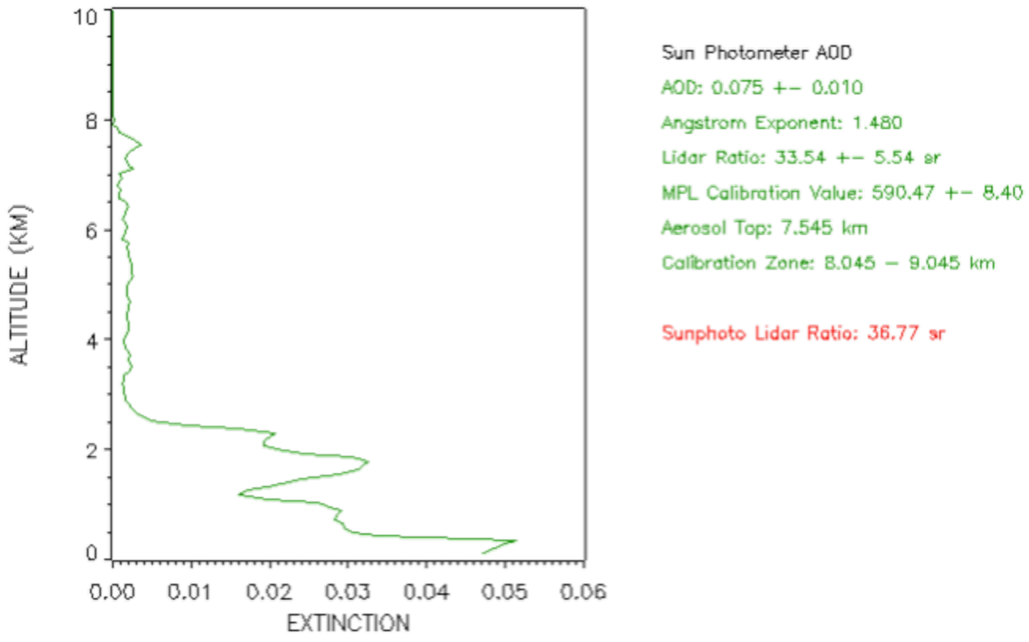
P_π is the phase function at 180° (size, shape)

Constrain retrieval by forcing extinction to integrate to AERONET AOD (Marenco et al 1997, Welton et al 2000).

Set S = 100 sr. Solve β. Calculate new value of S and iterate until convergence.

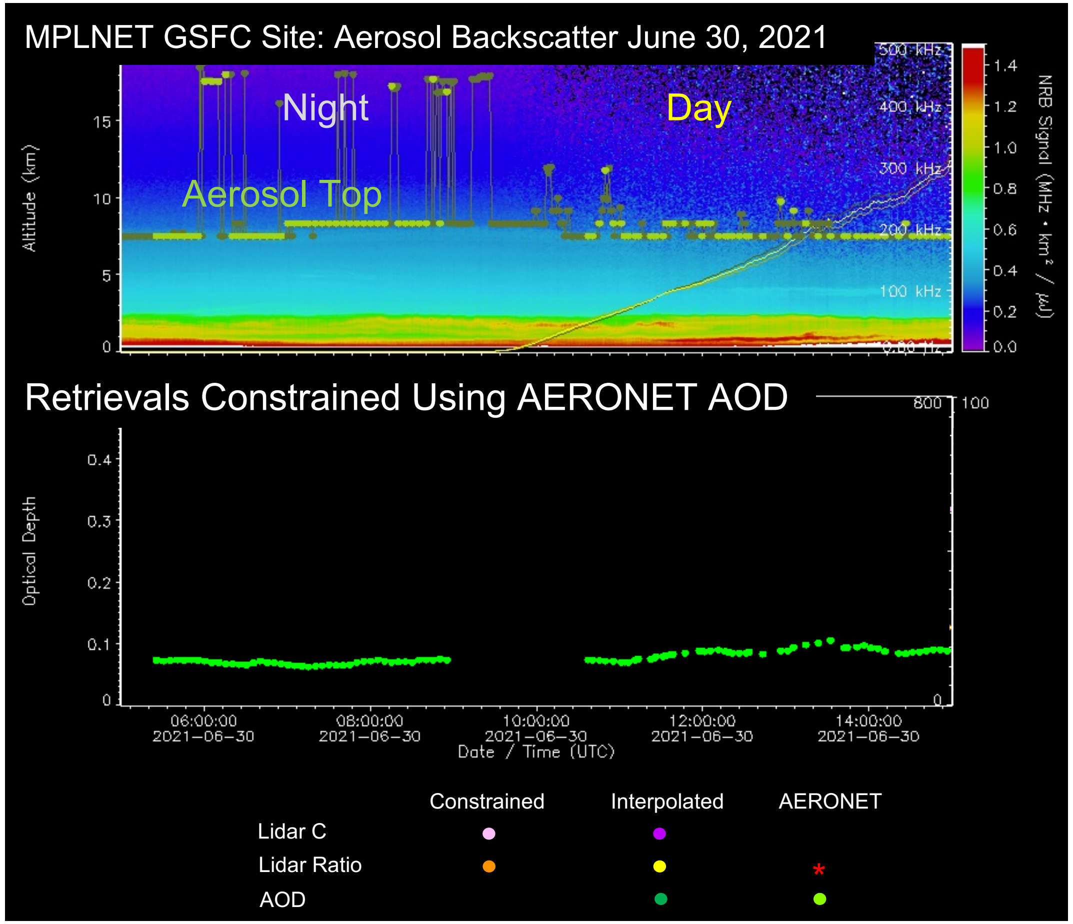
$$S_{new} = \frac{\int_0^{top} \sigma dr}{\int_0^{top} \beta dr} = \frac{AOD}{\int_0^{top} \beta dr}$$

This method does not require a priori specification of the lidar ratio, it calculates a column average value in the solution.



MPLNET Project Overview: Aerosol Data Product (AER)

Aerosol properties are retrieved using AERONET



MPLNET Project Overview: Aerosol Data Product (AER)

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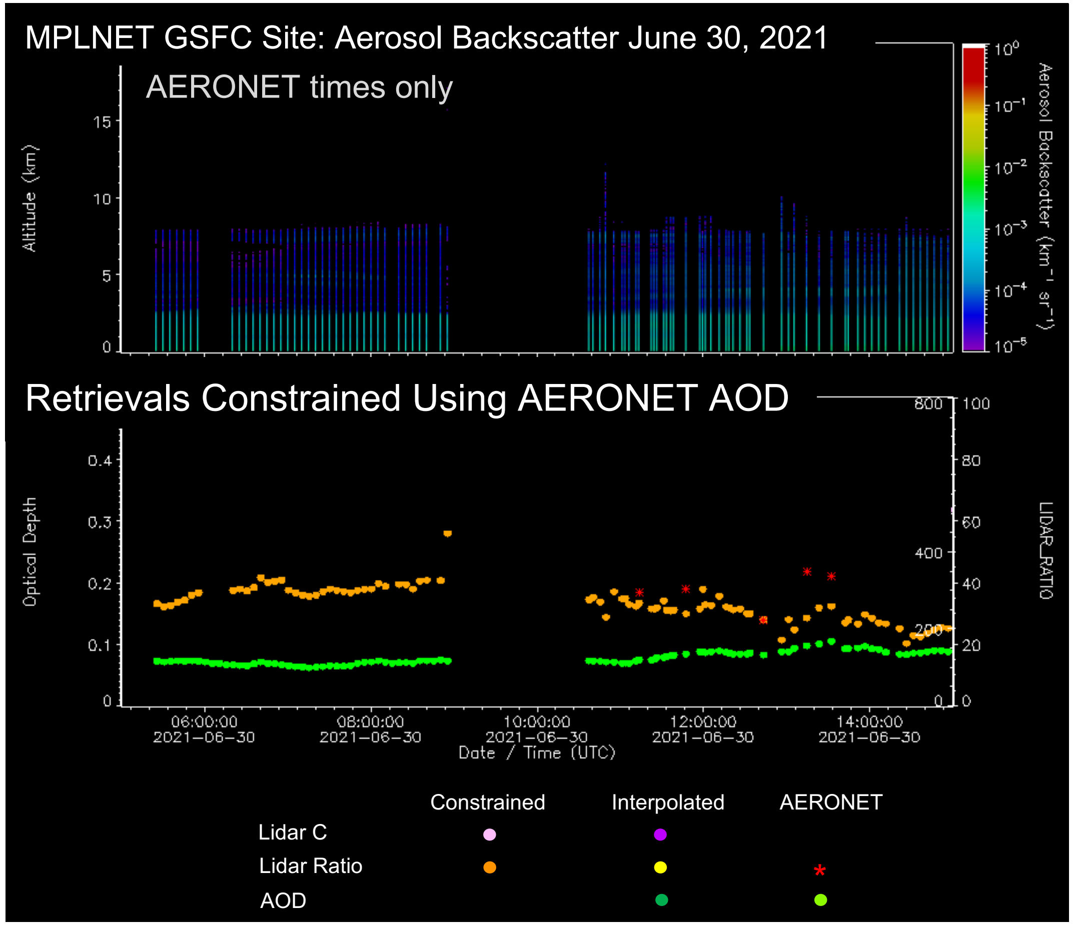

Aerosol retrievals are performed for all AERONET AOD observations

MPLNET Project Overview: Aerosol Data Product (AER)

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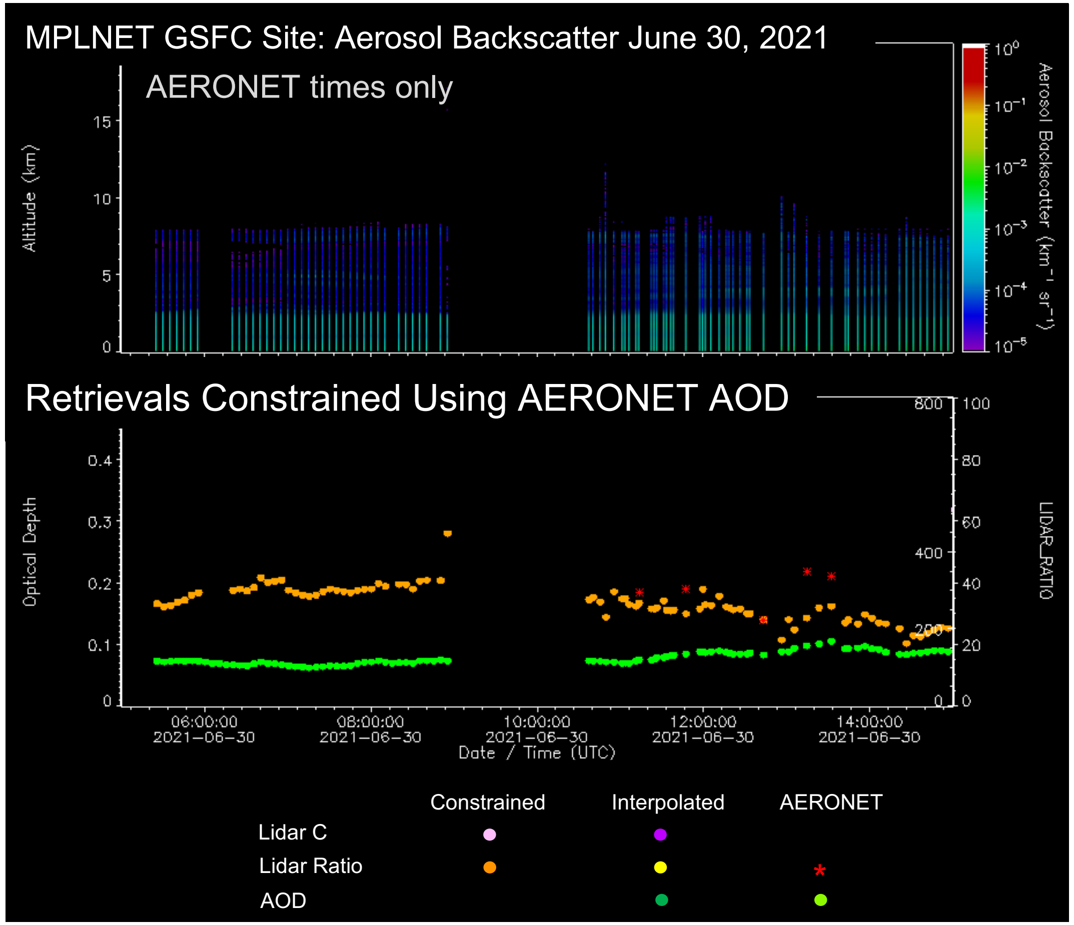

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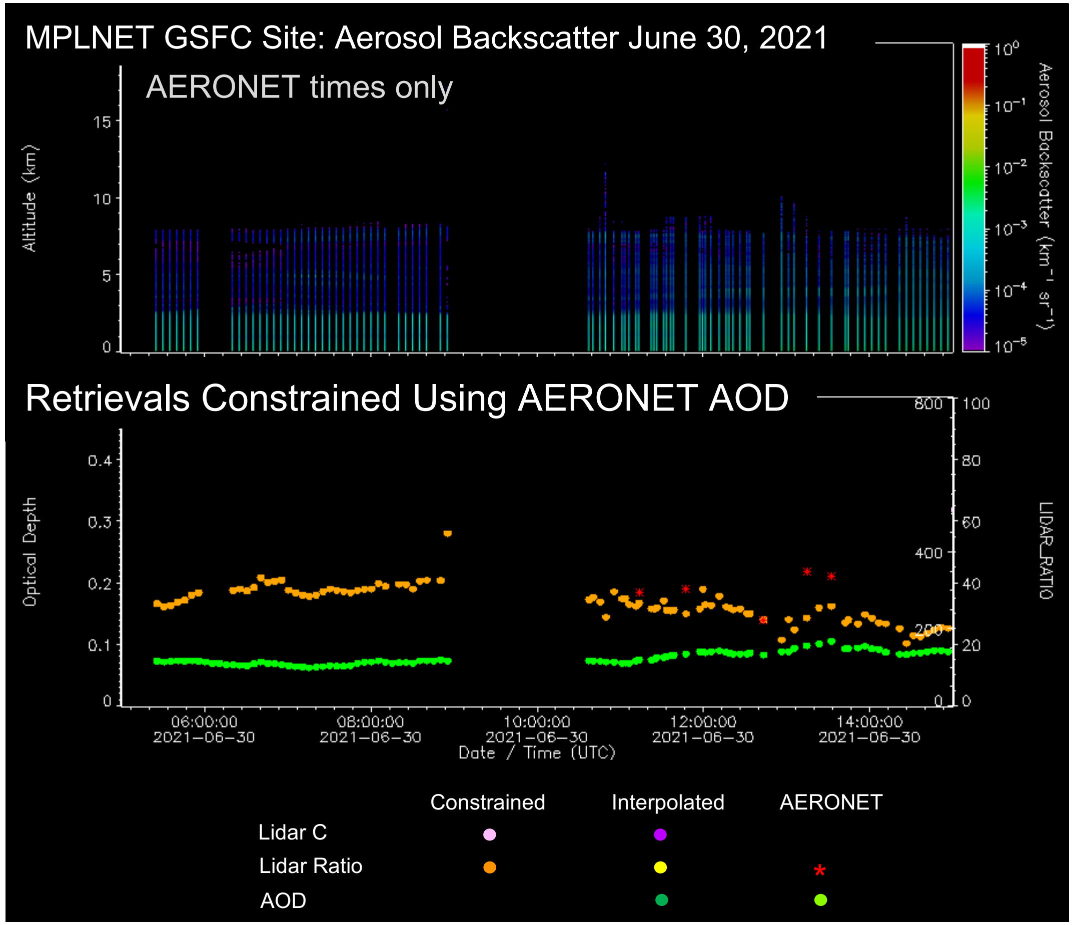

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We can interpolate between AERONET observations using the lidar efficiency parameter C

C is determined using AERONET AOD, and helps track instrument health and produce continuous aerosol retrievals.

At altitude above all aerosol (and no clouds), the lidar signal is:

$$P_{NRB}(r) = C\beta_M(r)e^{-2MOD(0,r)}e^{-2AOD}$$

We solve for C:

$$C = \frac{P_{NRB}(r)}{\beta_M(r)}e^{2MOD(0,r)}e^{2AOD}$$

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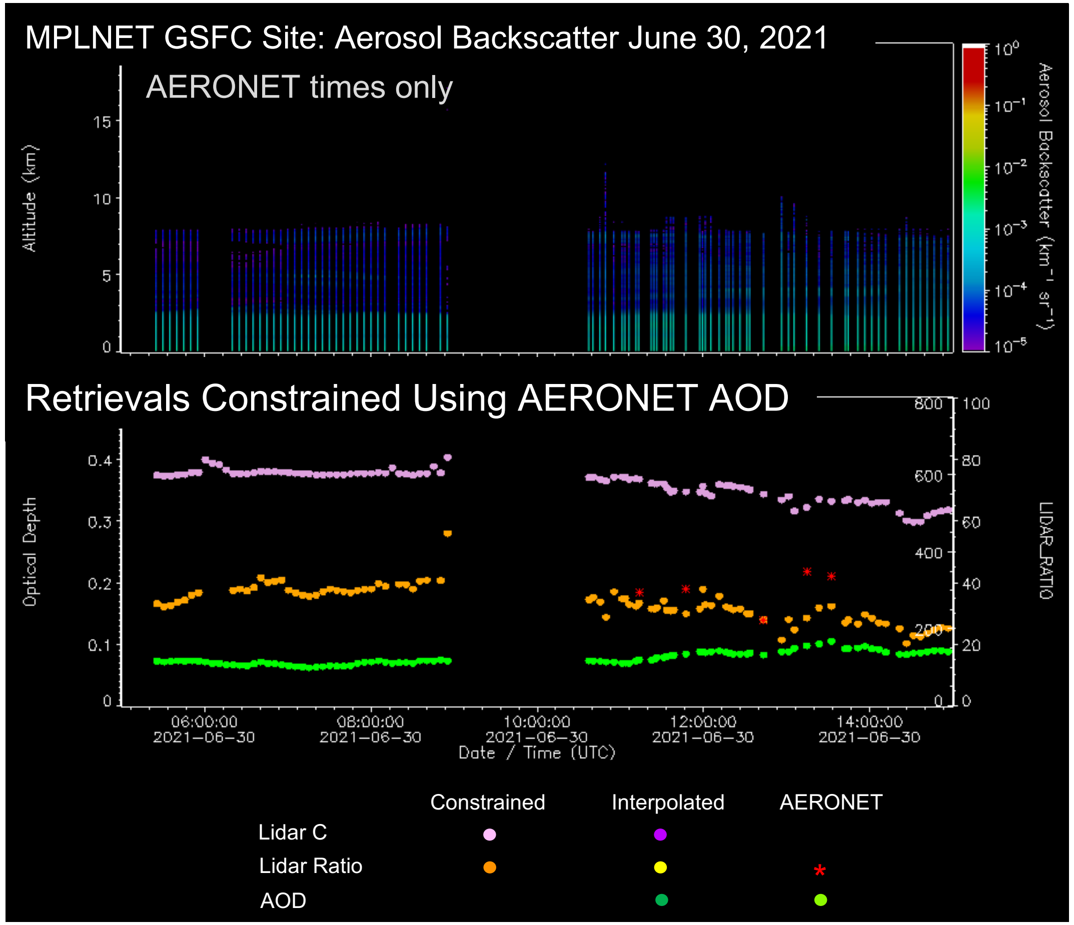

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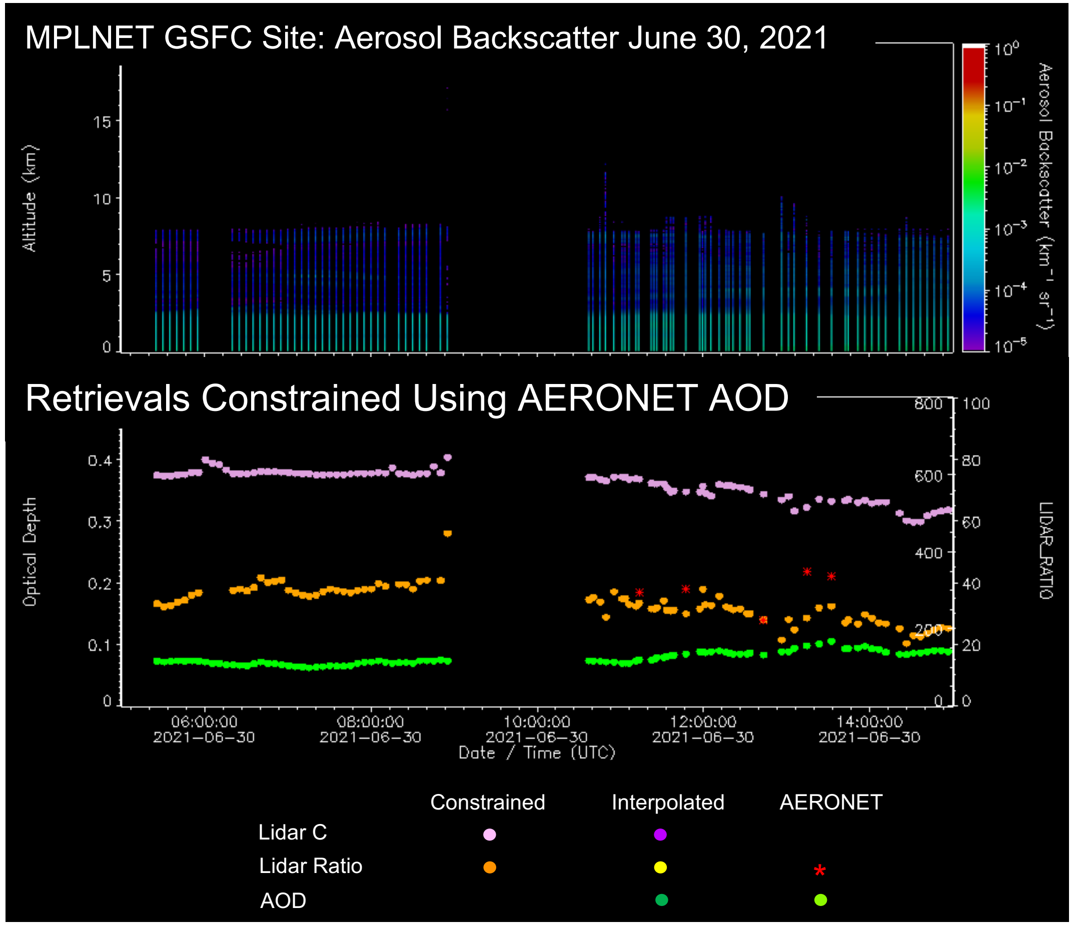

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MPLNET Project Overview: Aerosol Data Product (AER)

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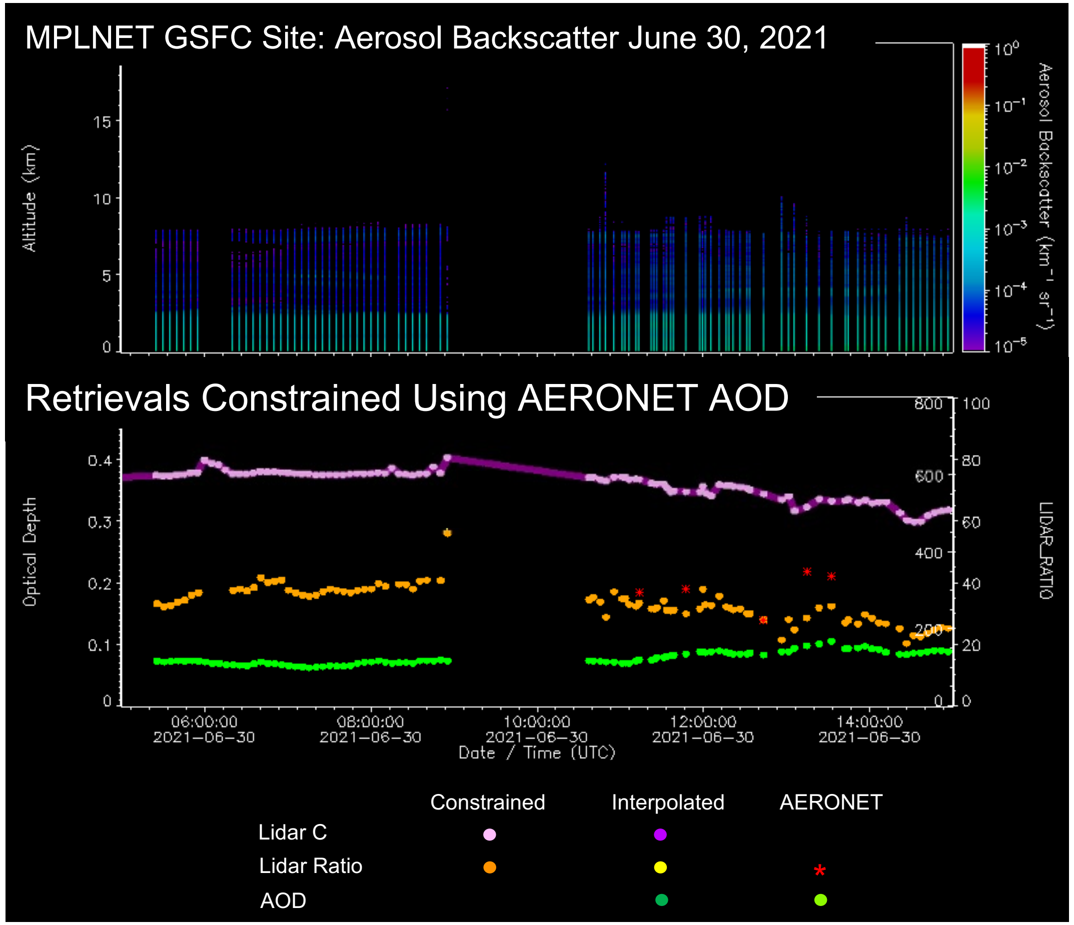

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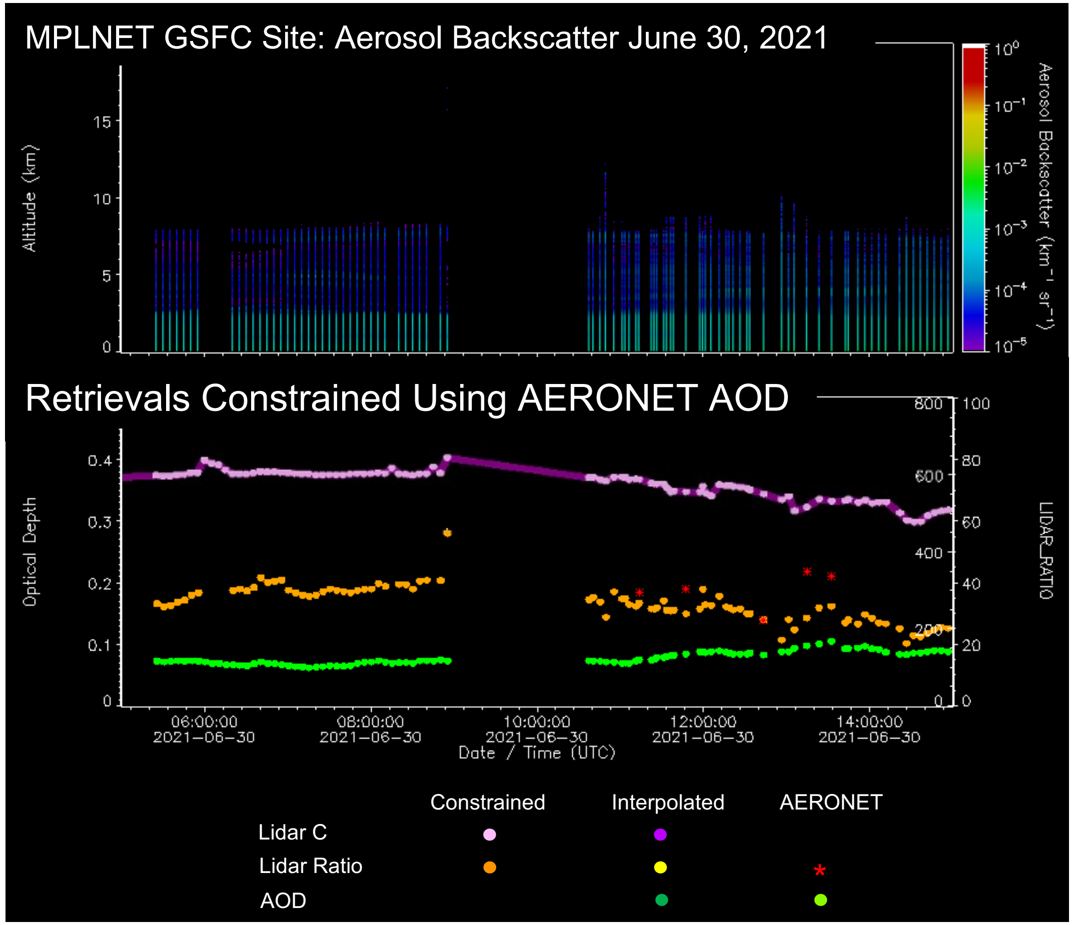


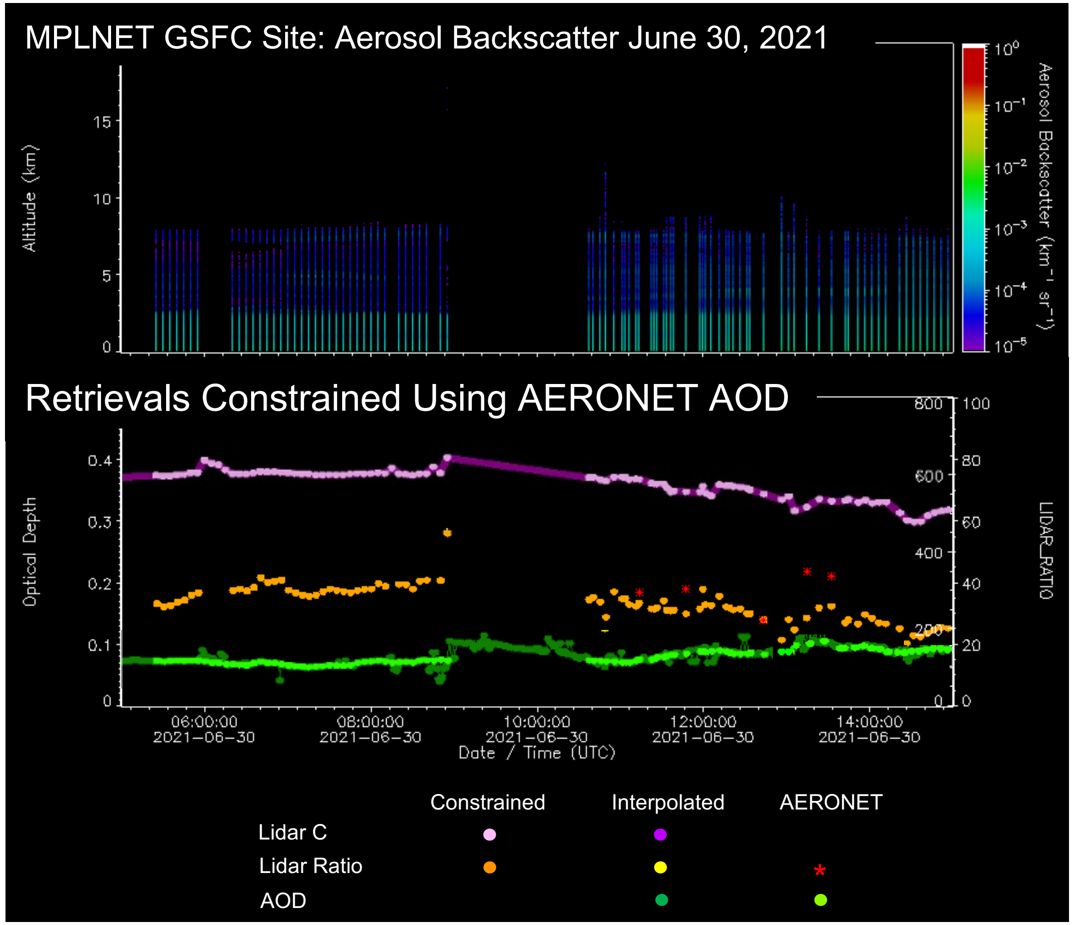
The retrieved C values are interpolated to the 1 minute temporal grid

These are used to calculate column AOD at times without AERONET observations

$$AOD = \frac{1}{2} ln \left[\frac{C\beta_M(r)}{P_{NRB}(r)} \right] - MOD(0,r)$$

MPLNET Project Overview: Aerosol Data Product (AER)

Aerosol properties are retrieved using AERONET



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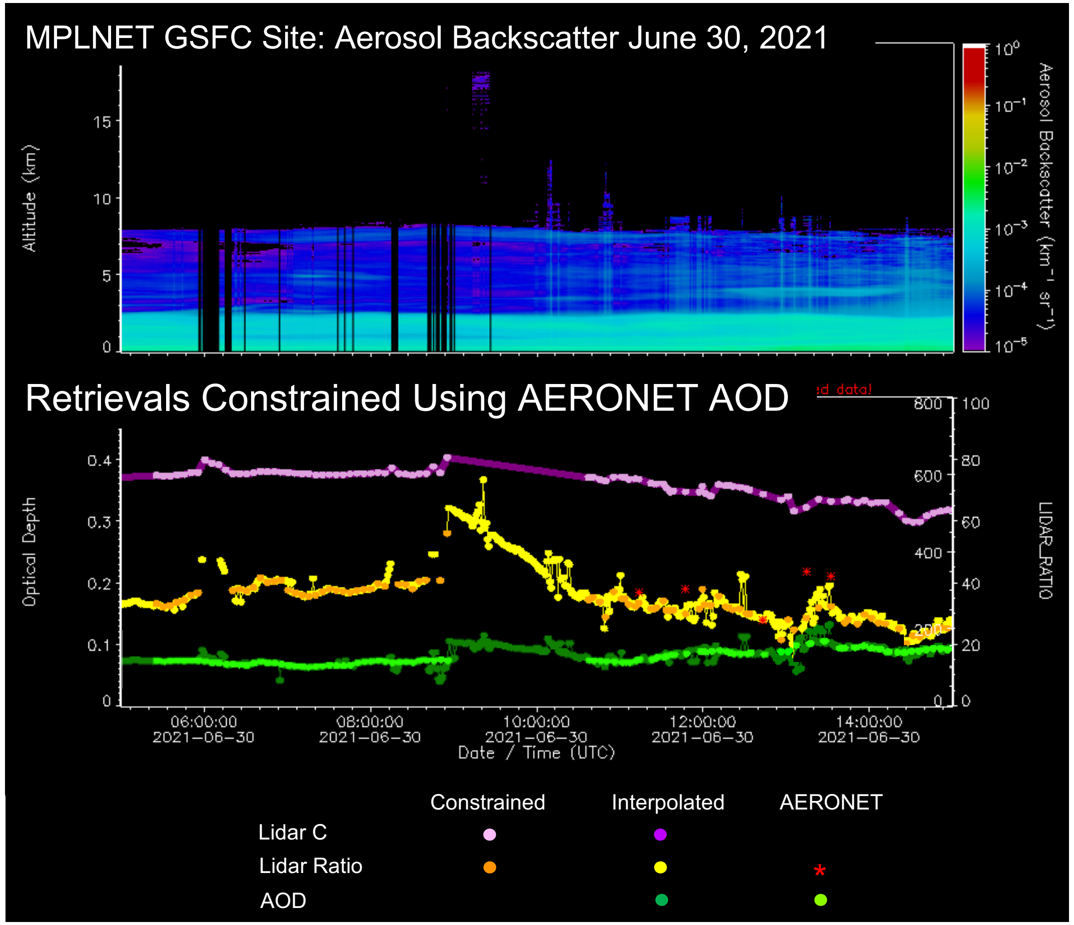

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These are used to calculate column AOD at times without AERONET observations

$$AOD = \frac{1}{2} ln \left[\frac{C\beta_M(r)}{P_{NRB}(r)}\right] - MOD(0,r)$$

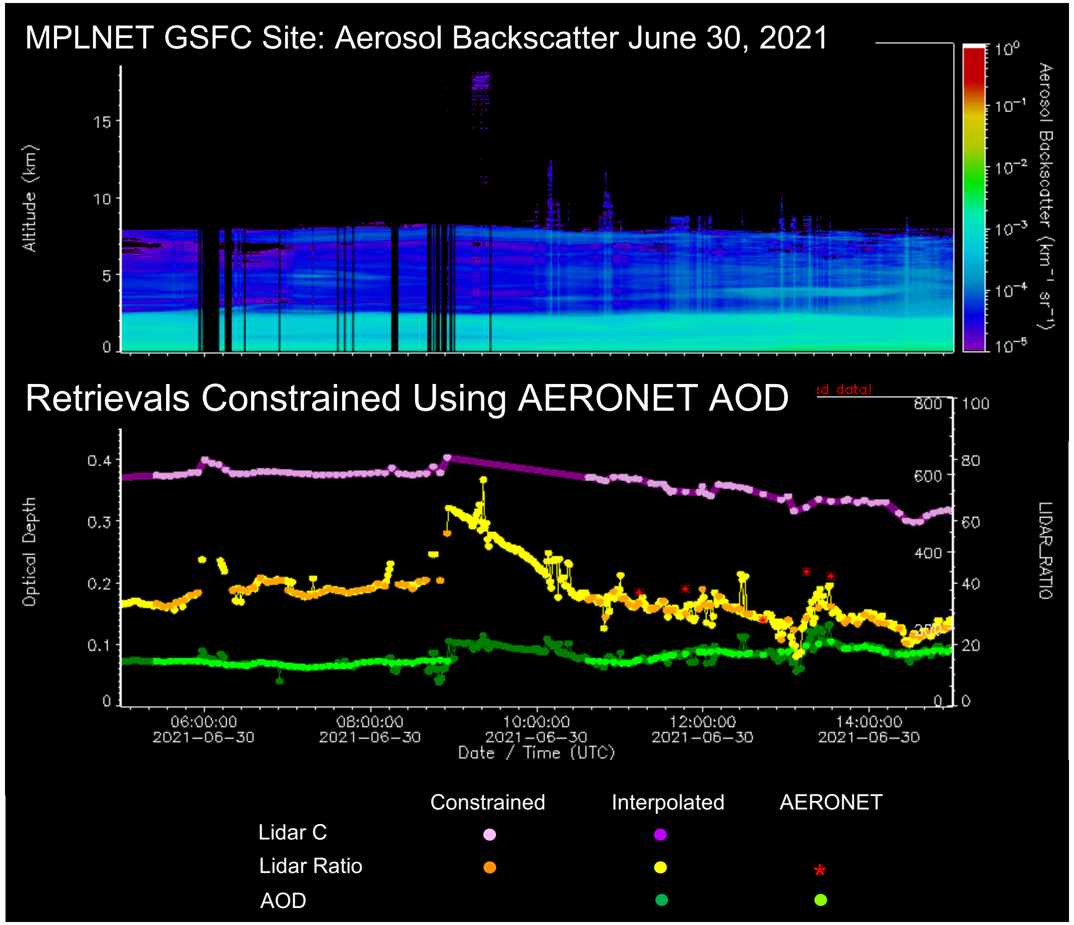
The interpolated AOD are used to retrieve aerosol properties

The final aerosol product contains both constrained and interpolated data, the interpolated will be lower quality.

There are a number of other QA flags in the product, including indication of which AOD was used: day, night, or interpolated.

MPLNET Project Overview: Aerosol Data Product (AER)

Aerosol properties are retrieved using AERONET



Aerosol Retrieval References:

Welton, E.J., et al, 2002. Measurements of aerosol vertical profiles and optical properties during INDOEX 1999 using micro-pulse lidars, J. Geophys. Res., 107, 8019, doi:10.1029/2000JD000038.

Welton, E.J. et al, 2000. Ground-based Lidar Measurements of Aerosols During ACE-2: Instrument Description, Results, and Comparisons with other Ground-based and Airborne Measurements, Tellus B, 52, 635-650.

Welton, E.J., et al, 2018. Status of the NASA Micro Pulse Lidar Network (MPLNET): Overview of the network and future plans, new Version 3 data products, and the polarized MPL. EPJ Web of Conferences, 176, https://doi.org/10.1051/epjconf/201817609003.

MPLNET Project Overview: Aerosol Data Product (AER)

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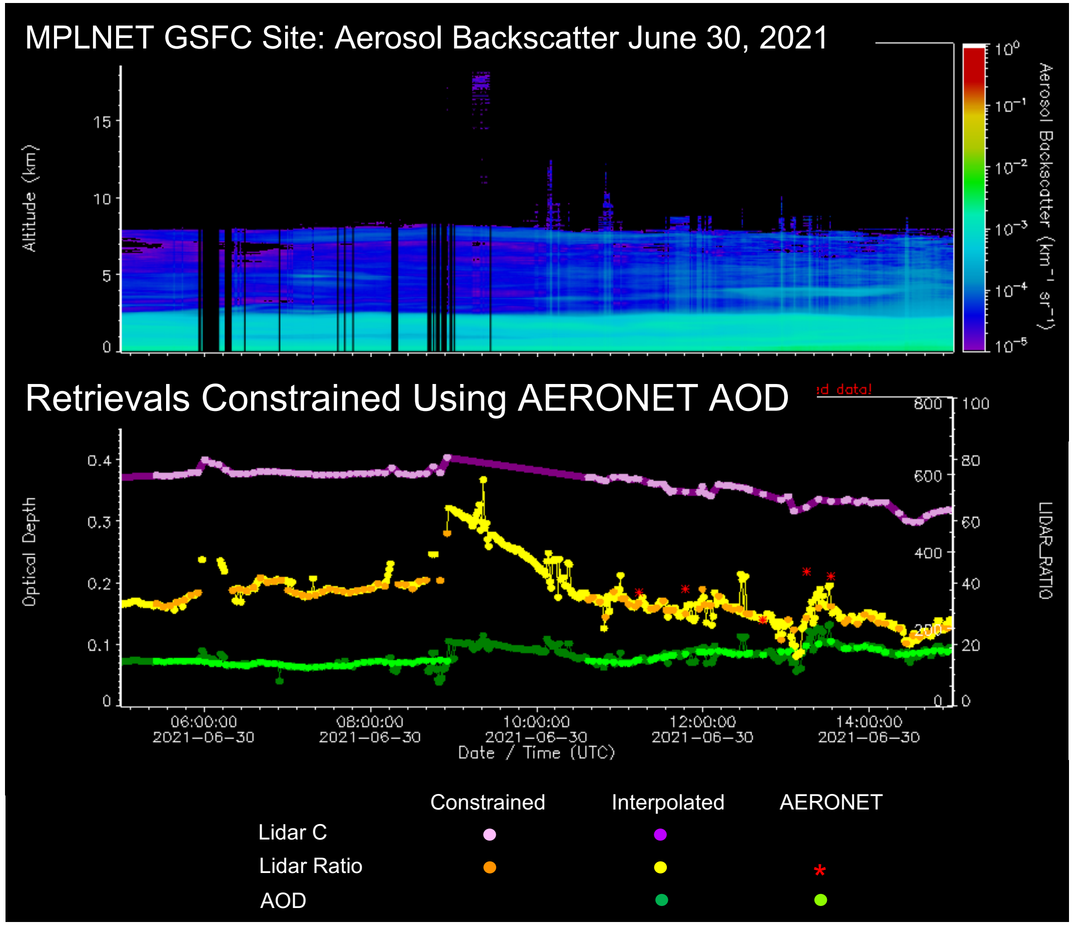

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Welton, E.J. et al, 2000. Ground-based Lidar Measurements of Aerosols During ACE-2: Instrument Description, Results, and Comparisons with other Ground-based and Airborne Measurements, Tellus B, 52, 635-650.

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Caveat: These retrievals assume the lidar ratio is constant. This can bias the results if the lidar ratio changes with altitude. This is a limitation of backscatter lidar and solved by use of raman or HSRL techniques.

MPLNET Project Overview: PBL Data Product (PBL)

- Mixed Layer Height
- Mixed Layer Aerosol Optical Depth
    - AOD only in mixed layer, not column

Lewis, J.R., E.J. Welton, A.M. Molod, and E. Joseph, 2013: Improved boundary layer depth retrievals from MPLNET, *J. Geophys. Res.*, 118, 9870-9879, doi:10.1002/jgrd.50570.

Comparisons of the older V2 mixed layer heights (**black**) with the new V3 results (**red**) below.
New algorithm vastly improves detection of diurnal cycle, and reduces false positive results.
Right panel shows comparison of V3 mixed layer heights with those from radiosonde measurements.

V2 vs V3 Mixed Layer Height

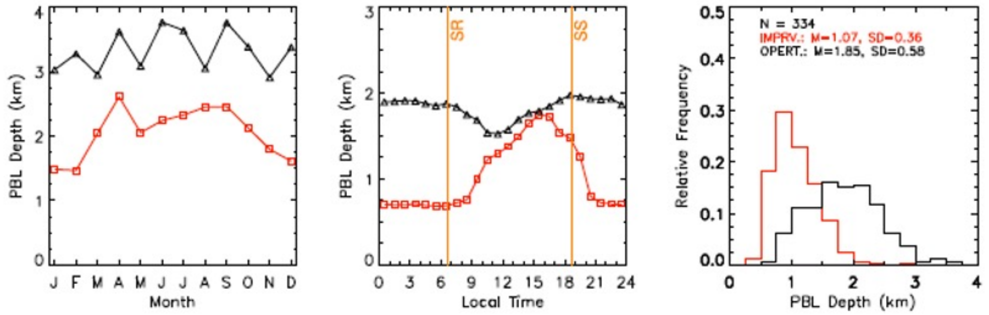

Figure 4. Comparisons of (left) monthly means of the daily maximum PBL height, (middle) annual diurnal cycles, and (right) daily mean probability distributions at GSFC for the 2010 operational PBL retrieval (black triangles) and improved PBL algorithm (red squares). The vertical orange lines in the diurnal cycle indicate the mean times for sunrise (SR) and sunset (SS).

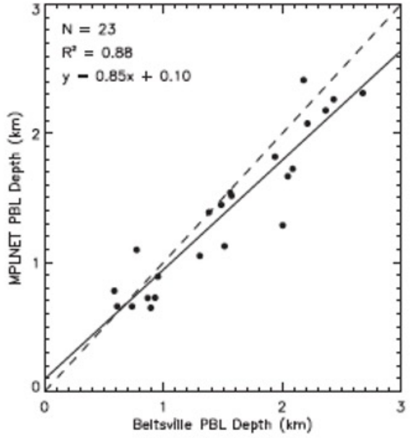

Figure 8. Correlation of radiosonde-derived PBL depths at Beltsville and lidar-derived PBL depths from MPLNET. The dashed line is the unity line and the solid line is the best fit line.

MPLNET Project Overview: PBL Data Product (PBL)

- The PBL product in Version 2 was only beta tested, not released
- V3 - Vast improvement in mixed layer height, especially diurnal performance

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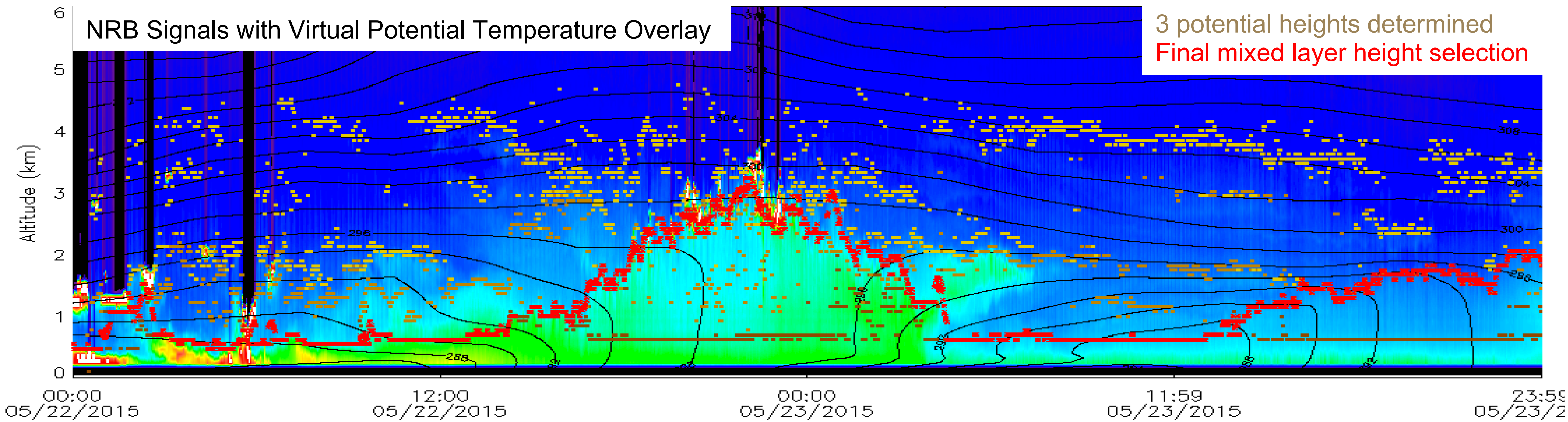

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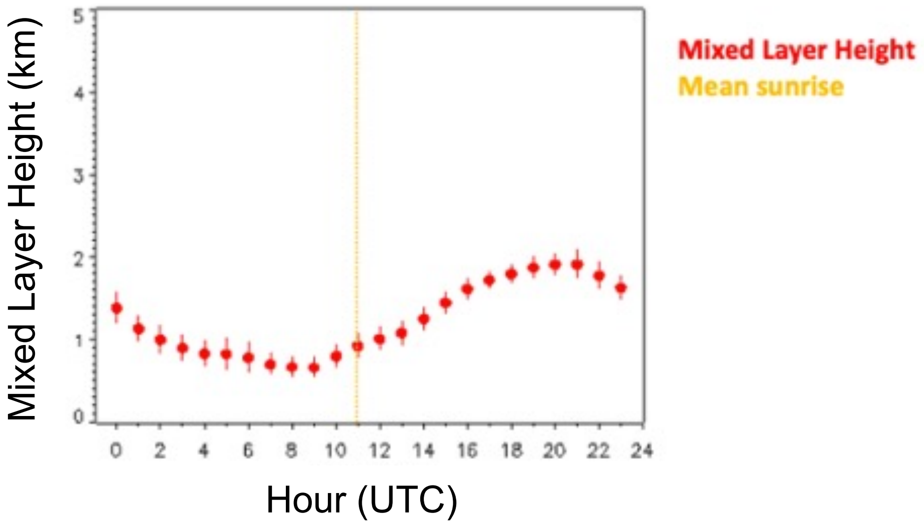
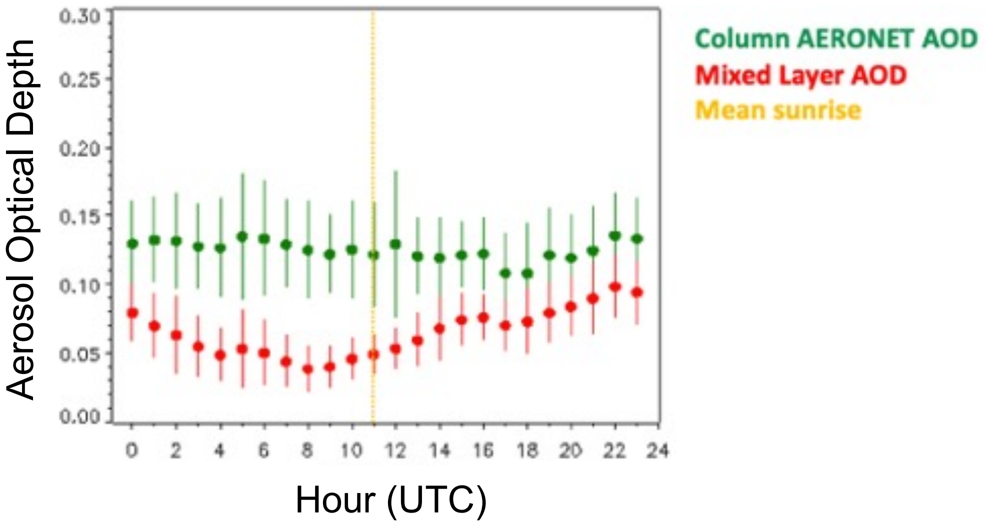
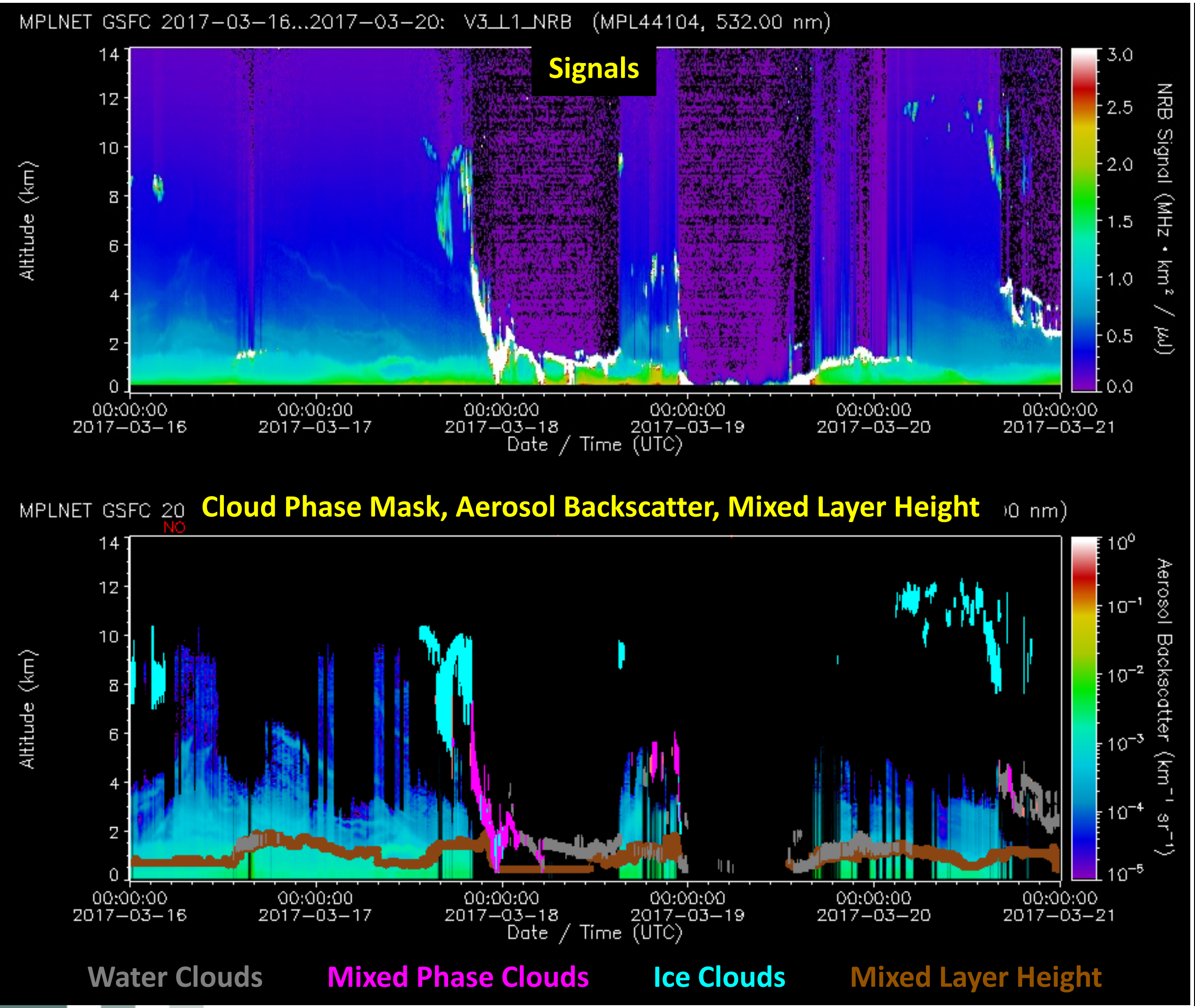
10 Year Climatology GSFC (2010 – 2020)



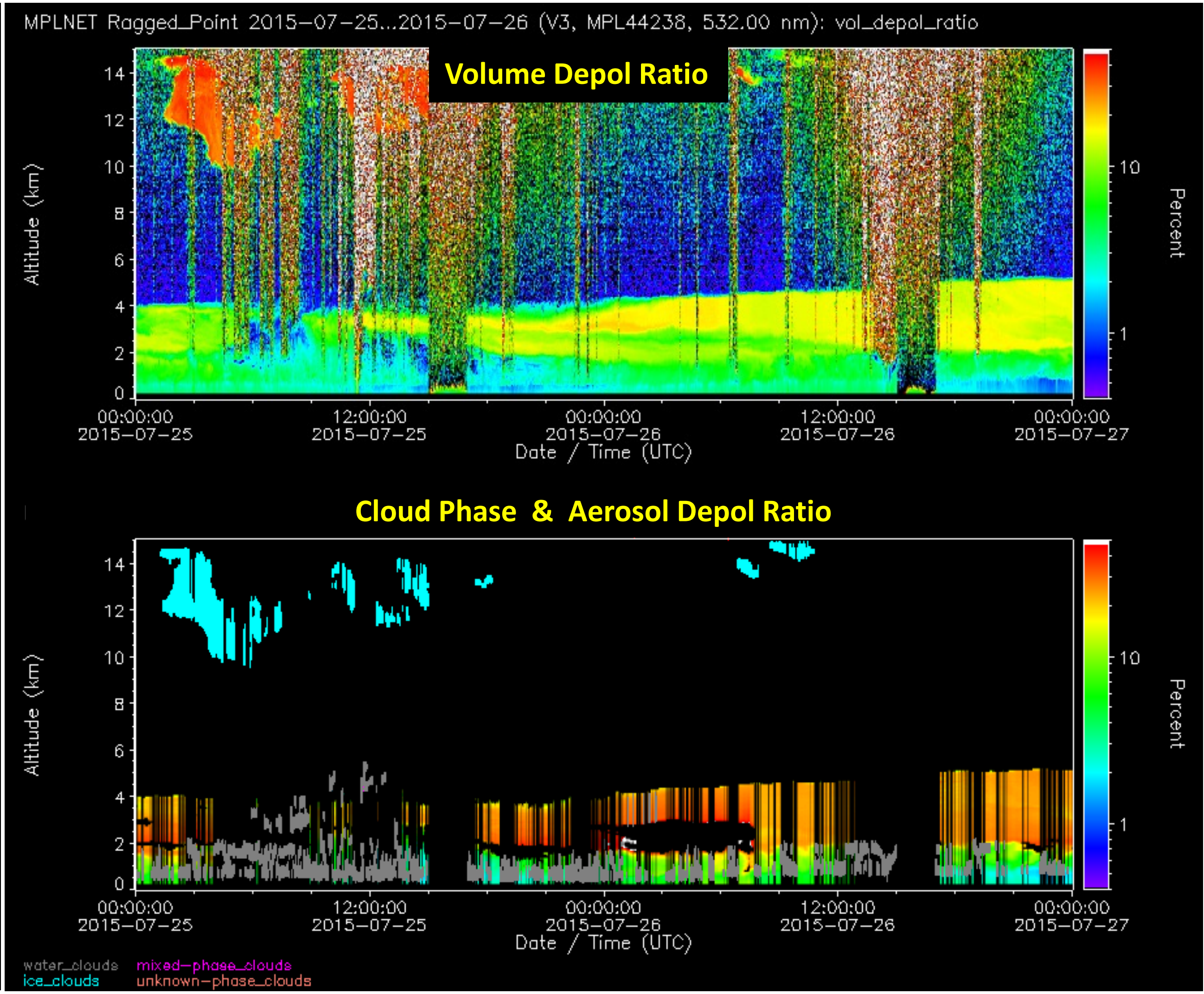


MPLNET Project Overview: Product Examples

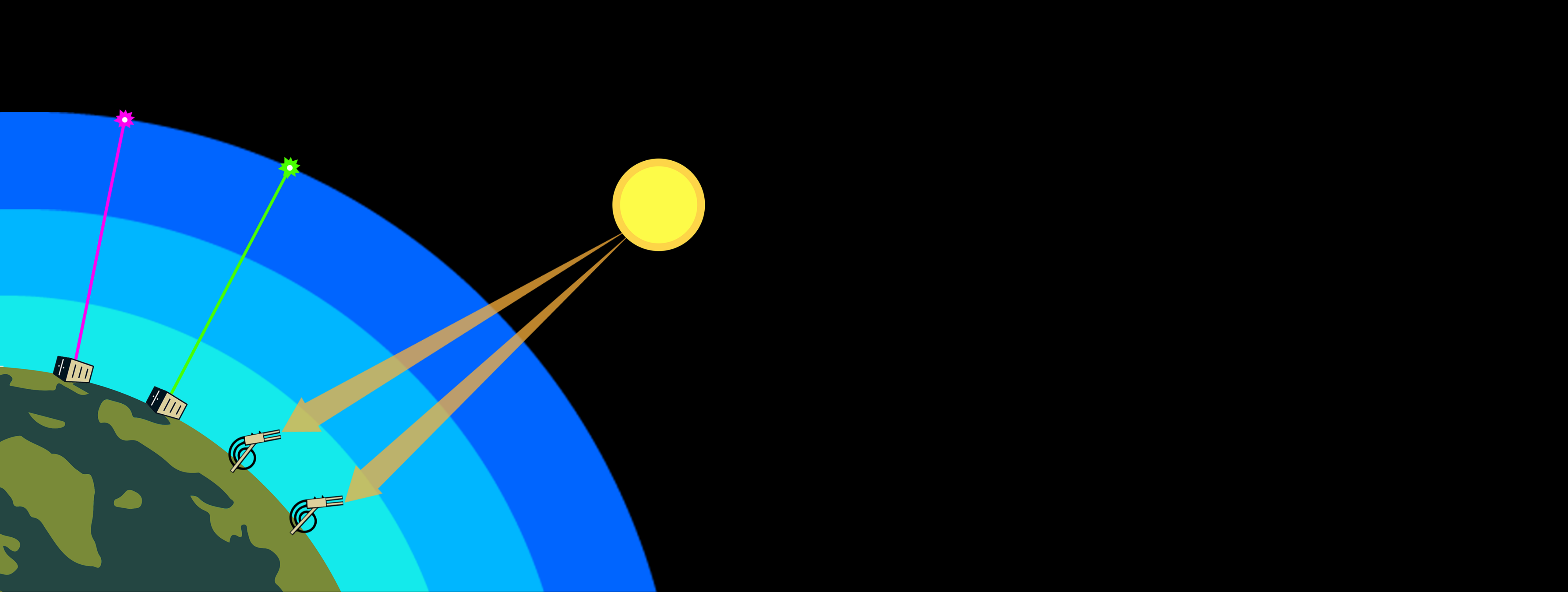
GSFC, USA: 2017-03-16 to 2017-03-20



Ragged_Point, Barbados: 2015-07-25 to 2015-07-26



A Summary of New Products in Development is in the Appendix



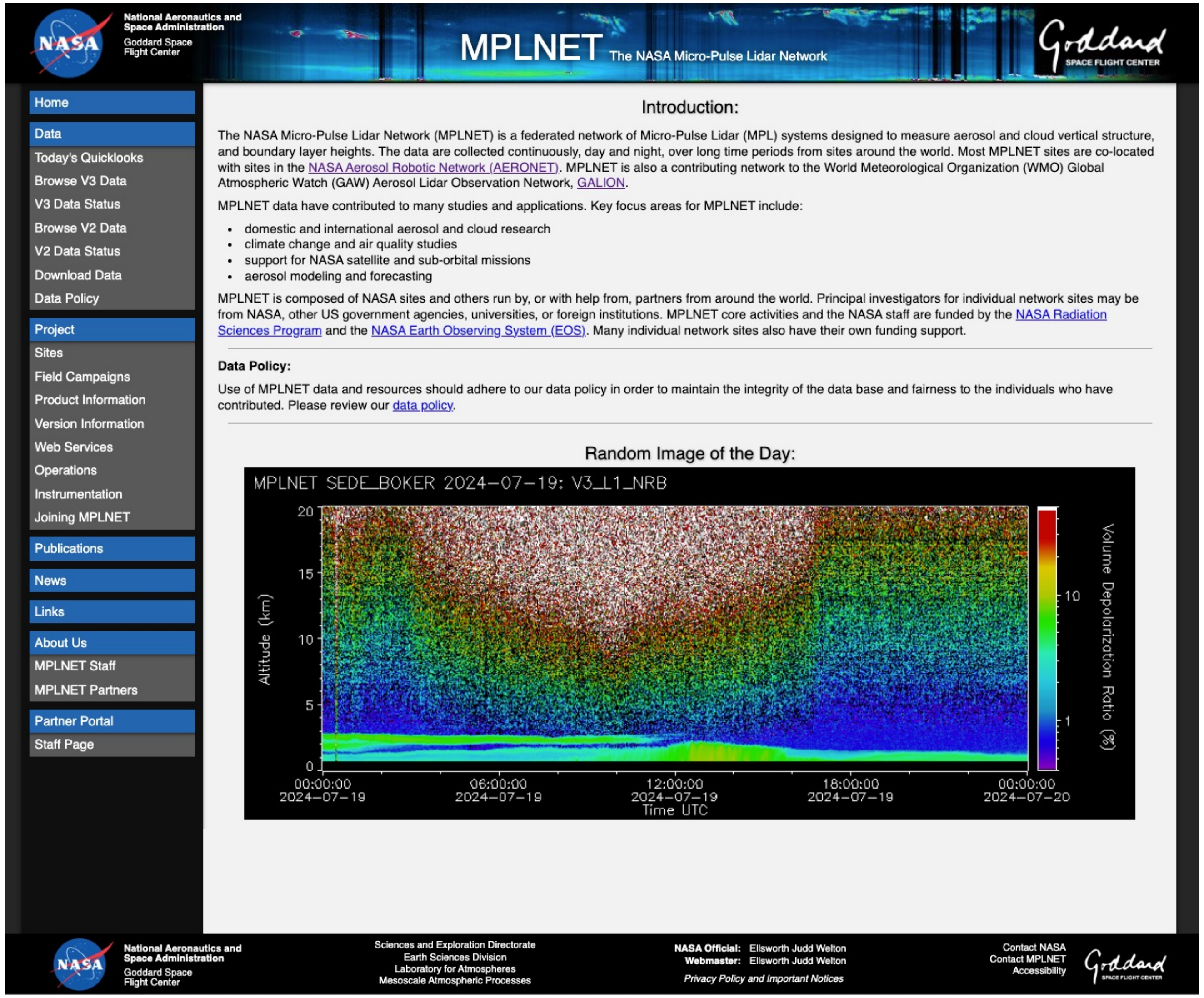
MPLNET Website and Data Access

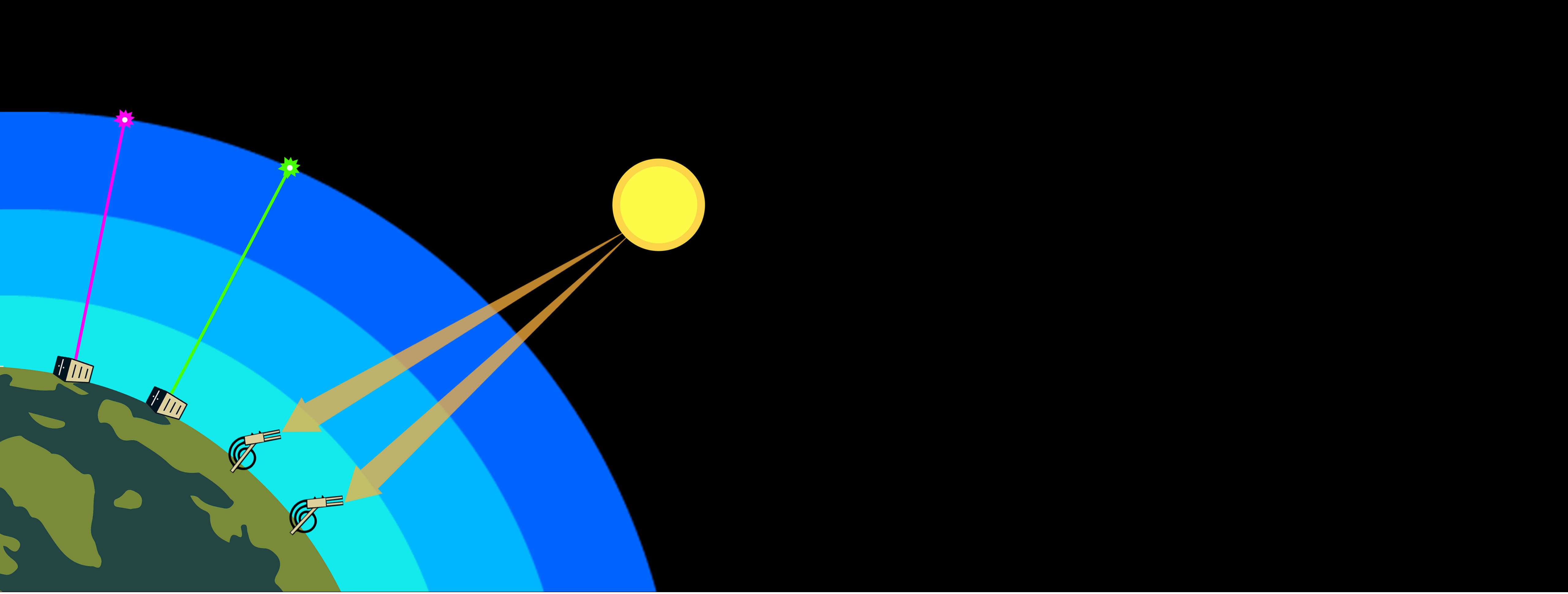
MPLNET Website and Data Access

[MPLNET Website](#) Tour

Topics:

- Project Information
- Find Network Sites
- Browse Data
- Download Data
- Download, Plot, and Metadata APIs





MPLNET Case Study Examples

Case Study Examples:

MPLNET data have contributed to many journal publications, presentations, reports, and thesis/dissertations

Some examples will be shown, a complete list of publications is available on the MPLNET Website

MPLNET has had a global impact on aerosol, cloud, and PBL related research

We have also contributed to unforeseen research projects including the IceCube Neutrino Study in Antarctica

Web of Science Citation Map 2022

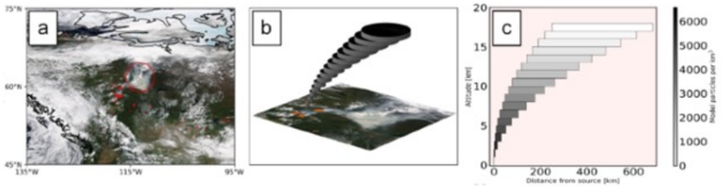
~ 100 Publications

Case Study Examples: Smoke Research & Growing Importance

MPLNET Contributions to Wildfire Smoke Research. Also recognition of a growing problem in the Northern Hemisphere….

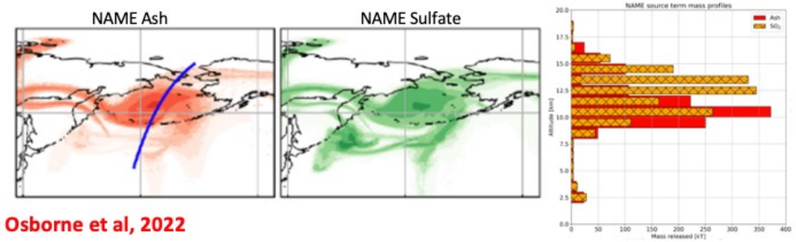
Northern Hemisphere is becoming an increasingly complex aerosol environment from surface to stratosphere for most of the year!

Modeled Emissions Alberta Fire June 2019



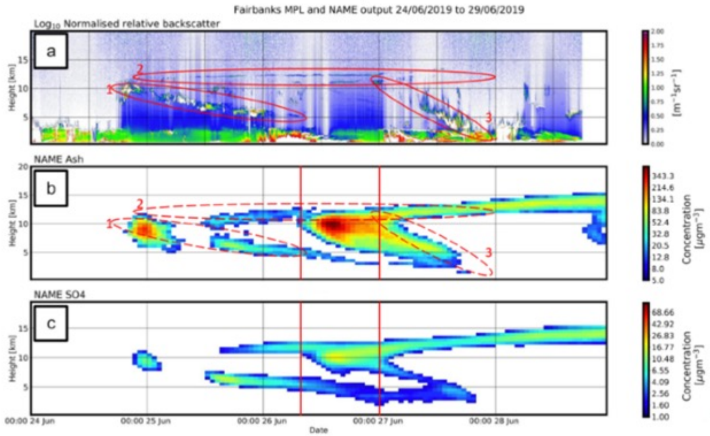
from Osborne et al, 2022

Modeled Emissions Raikoke Volcano June 2019



from Osborne et al, 2022

MPLNET Observations Fairbanks Alaska, Modeled Ash and SO4 Plumes



-------------------- **South East Asian Smoke** --------------------

Salinas, S.V., et al, 2012. Physical and optical characteristics of the October 2010 haze event over Singapore: A photometric and lidar analysis. Atmos. Res., doi:10.1016/j.atmosres.2012.05.021.

Chew, B.N., et al, 2013. Aerosol particle vertical distributions and optical properties over Singapore, Atmos. Environ., 79, 599-613, doi:10.1016/j.atmosenv.2013.06.026.

Wang, S.H., et al, 2015. Vertical Distribution and Columnar Optical Properties of Springtime Biomass-Burning Aerosols Over Northern Indochina During 2014 7-SEAS Campaign, Aerosol Air Qual. Res., 15, 2037-2050, doi: 10.4209/aaqr.2015.05.0310.

Campbell, J.R., et al, 2016. Applying Advanced Ground-Based Remote Sensing in the Southeast Asian Maritime Continent to Characterize Regional Proficiencies in Smoke Transport Modeling. J. App. Meteorol. Clim., 55, 3-22, DOI:10.1175/JAMC-D-15-0083.1.

Lee, J, et al, 2016. Evaluating the height of biomass burning smoke aerosols retrieved from synergistic use of multiple satellite sensors over Southeast Asia. Aerosol Air Qual. Res., 16, 2831–2842, doi:10.4209/aaqr.2015.08.0506.

-------------------- **North American and European Smoke** --------------------

Colarco, P.R., et al, 2004. Transport of smoke from Canadian forest fires to the surface near Washington, D.C.: Injection height, entrainment, and optical properties, J. Geophys. Res., 109, D06203, doi:10.1029/2003JD004248.

Lund Myhre, C., et al, 2007. Regional aerosol optical properties and radiative impact of the extreme smoke event in the European Arctic in spring 2006, Atmos. Chem. Phys., 7, 5899-5915.

Miller, D.J., et al, 2011. Assessing boreal forest fire smoke aerosol impacts on U.S. air quality: a case study using multiple datasets, *J. Geophys. Res.*, 116, D22209, doi:10.1029/2011JD016170.

Loría-Salazar, S.M., et al, 2021. Evaluation of Novel NASA MODIS and VIIRS Aerosol Products and Assessment of Smoke Height Boundary Layer Ratio During Extreme Smoke Events in the Western U.S., J. Geophys. Res. Atmos., 126, https://doi.org/10.1029/2020JD034180.

Eck T. F., et al, A. R. Menendez, 2023. The extreme forest fires in California/Oregon in 2020: Aerosol optical and physical properties and comparisons of aged versus fresh smoke, Atmos. Environ., 305, https://doi.org/10.1016/j.atmosenv.2023.119798.

-------------------- **Volcanic Plumes** --------------------

Sicard, M., et al, 2022. Volcanic Eruption of Cumbre Vieja, La Palma, Spain: A First Insight to the Particulate Matter Injected in the Troposphere. Remote Sensing, 14, https://doi.org/10.3390/rs14102470

Sellitto, P., et al, 2023. Volcanic emissions, plume dispersion, and downwind radiative impacts following Mount Etna series of eruptions of February 21–26, 2021. J. Geophys. Res. Atmos., 128, https://doi.org/10.1029/2021JD035974

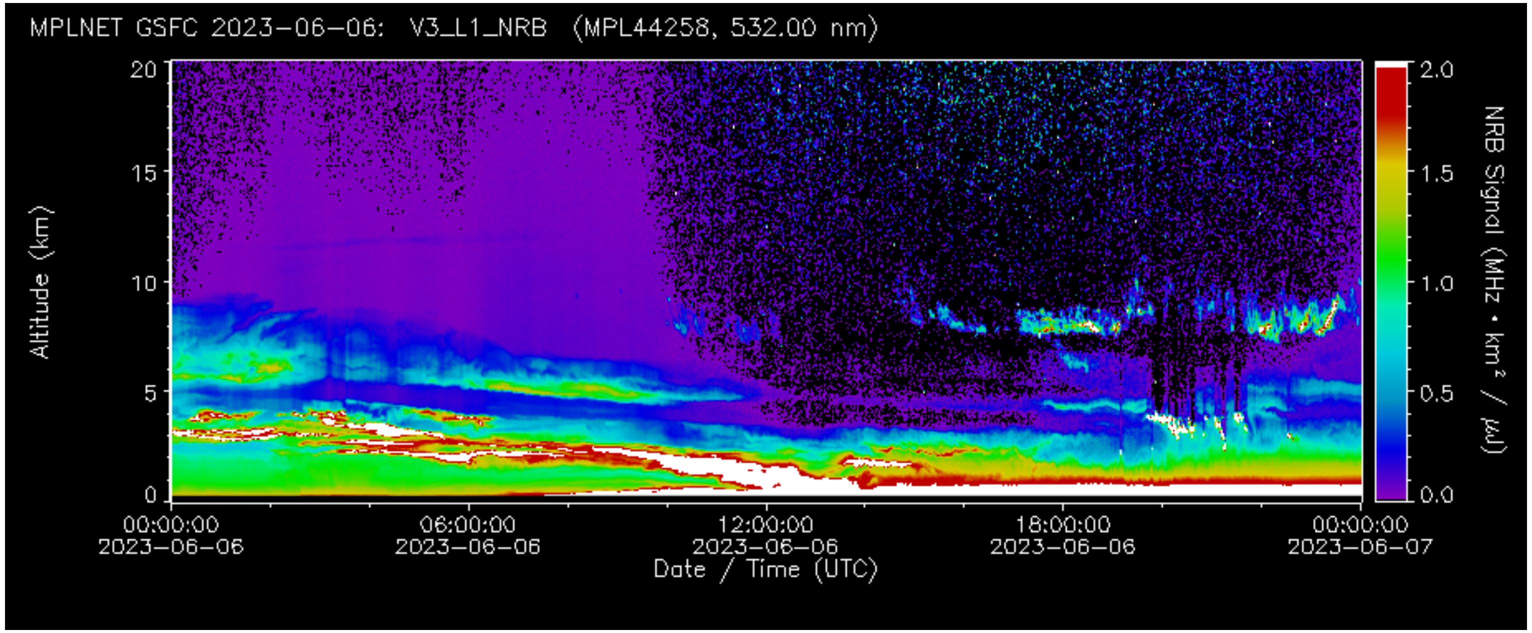
-------------------- **Northern Hemisphere Smoke AND Volcanic Plumes** --------------------

Osborne, M., et al, 2022. The 2019 Raikoke volcanic eruption part 2: Particulate phase dispersion and concurrent wildfire smoke emissions. Atmos. Chem. Phys., 22, 2975–2997, https://doi.org/10.5194/acp-22-2975-2022.

Shang, X., et al, 2024. Monitoring biomass burning aerosol transport using CALIOP observations and reanalysis models: a Canadian wildfire event in 2019. *Atmos. Chem. Physics*., Accepted.

Case Study Examples: Smoke Research & Growing Importance

The "wall of smoke" example from MPLNET measurements at GSFC on June 6, 2023



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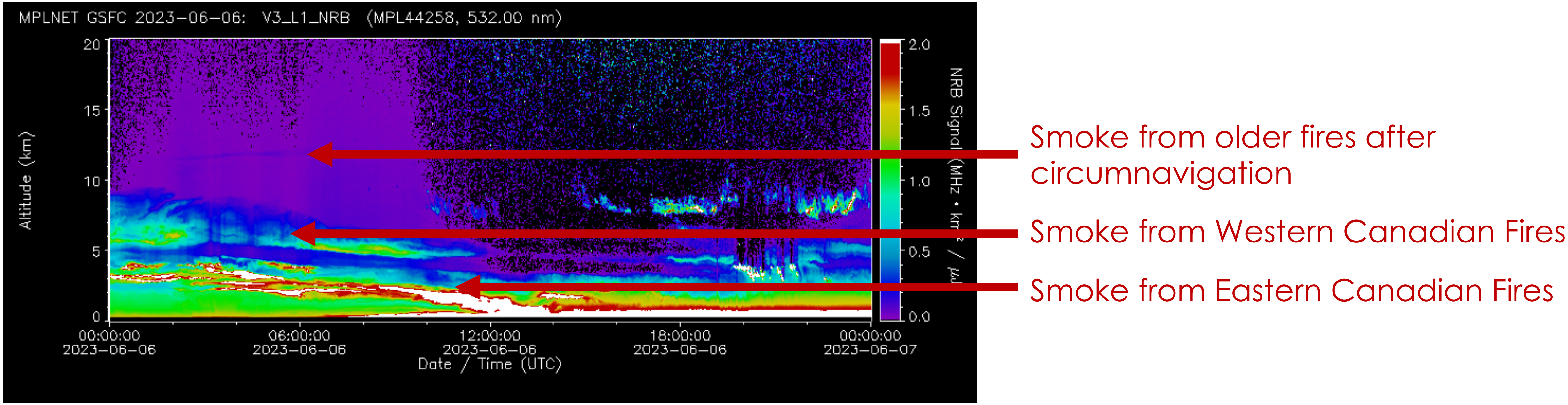

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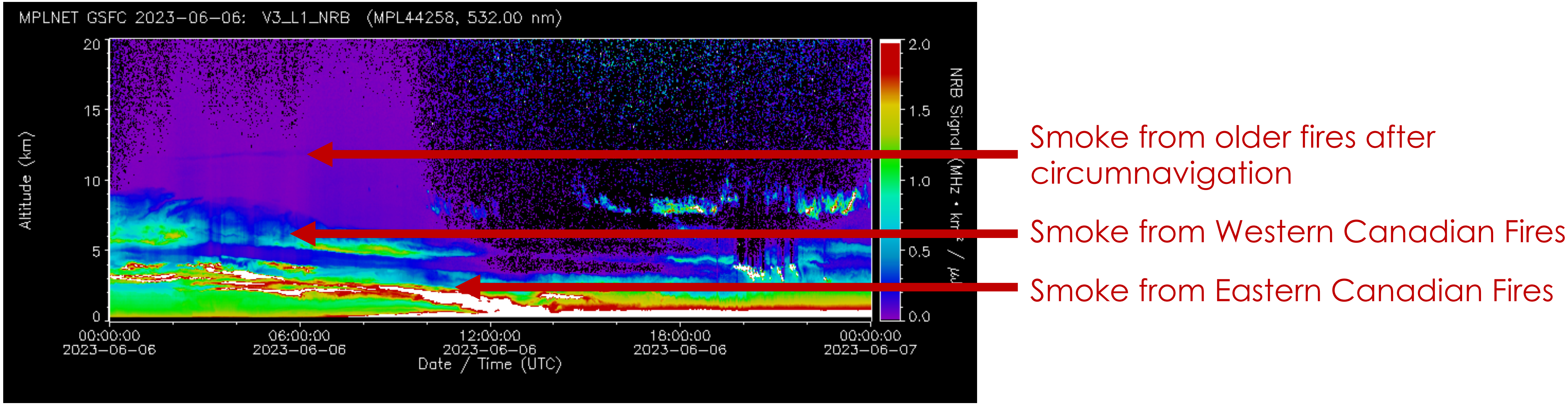

Even one fire can produce a complicated environment based on its life time and cycle, producing different smoke properties and varied layer heights. Add in multiple fires, with different fuel types, and complication increases.

Using remotely sensed data, especially passive observations, must be done carefully to avoid misinterpretations in such conditions. These conditions are becoming prevalent for much of the year.

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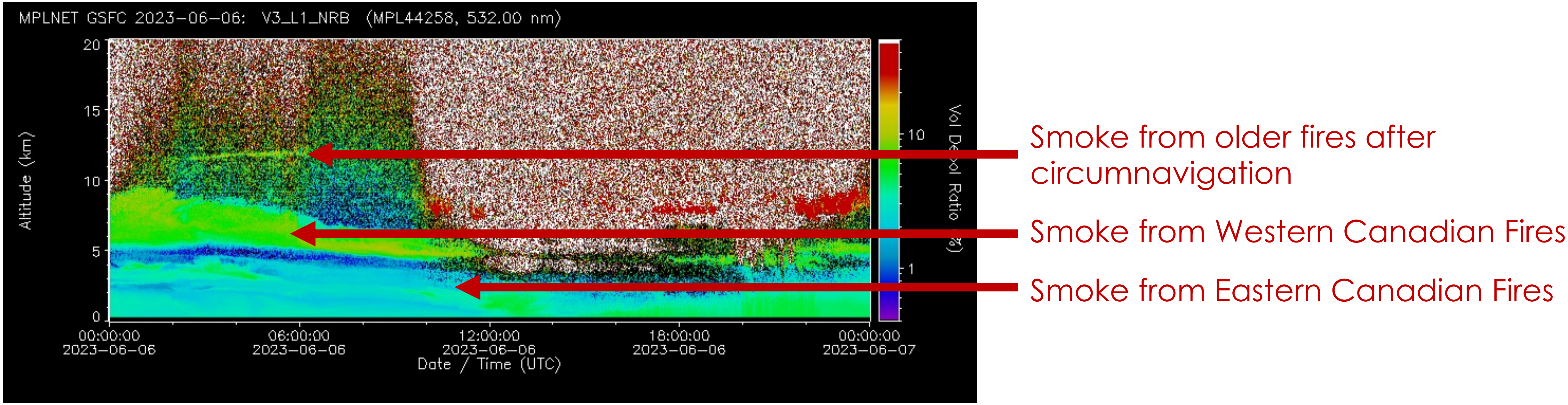

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Case Study Examples: Smoke Injection Heights

Using Lidar to determine smoke injection heights over remote fire sources

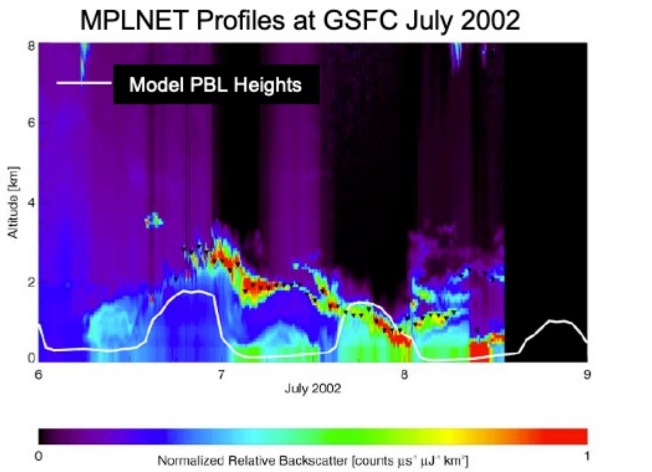
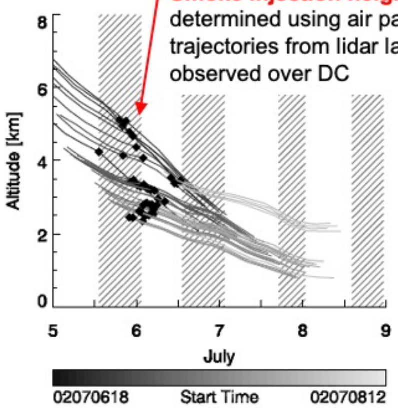


Figure 2. Vertical profile of aerosol backscatter observed at GSFC by MPLNET. The white line is the MATCH PBL height. The triangles indicate the initial altitude used in the back trajectories shown in Figure 3. Note that MPLNET did not collect data after about 12:00 UTC on 8 July 2002 until late on 9 July 2002.

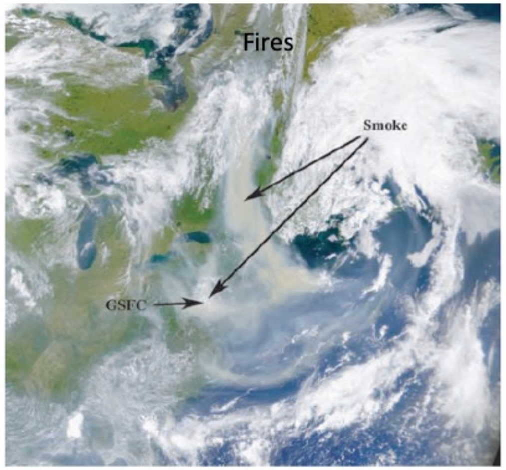


Canadian smoke from fires burning in Quebec during 2002 caused widespread Code Red events and air traffic shutdowns in the Northeast US.

The ability of a smoke plume to transport long distances is determined by its injection height relative to the local PBL. Modeled emission functions need inputs to better constrain injection height.

Wet deposition (cloud scavenging), dry deposition (fallout), and entrainment by the PBL all factor into the long range impact of remote aerosol sources. Lidars observe plume height and cloud interaction to provide input to models.

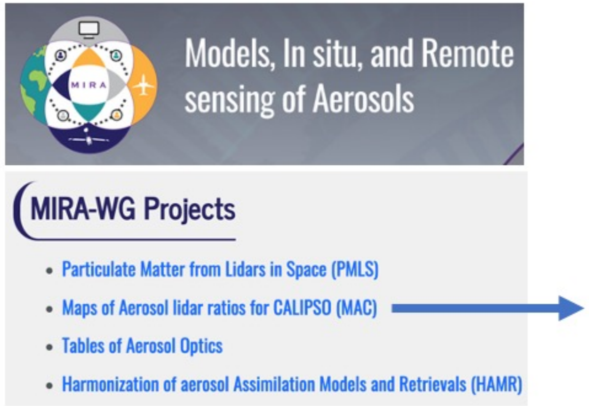
Here, observed plume heights in Maryland from MPLNET were used to determine injection height over the remote fire sources. This can be related back to the fire energy and other source parameters to improve emission modeling.



Colarco, P.R., M.R. Schoeberl, B.G. Doddridge, L.T. Marufu, O. Torres, and E.J. Welton, Transport of smoke from Canadian forest fires to the surface near Washington, D.C.: Injection height, entrainment, and optical properties, *J. Geophys. Res.*, 109, D06203, doi:10.1029/2003JD004248, 2004.

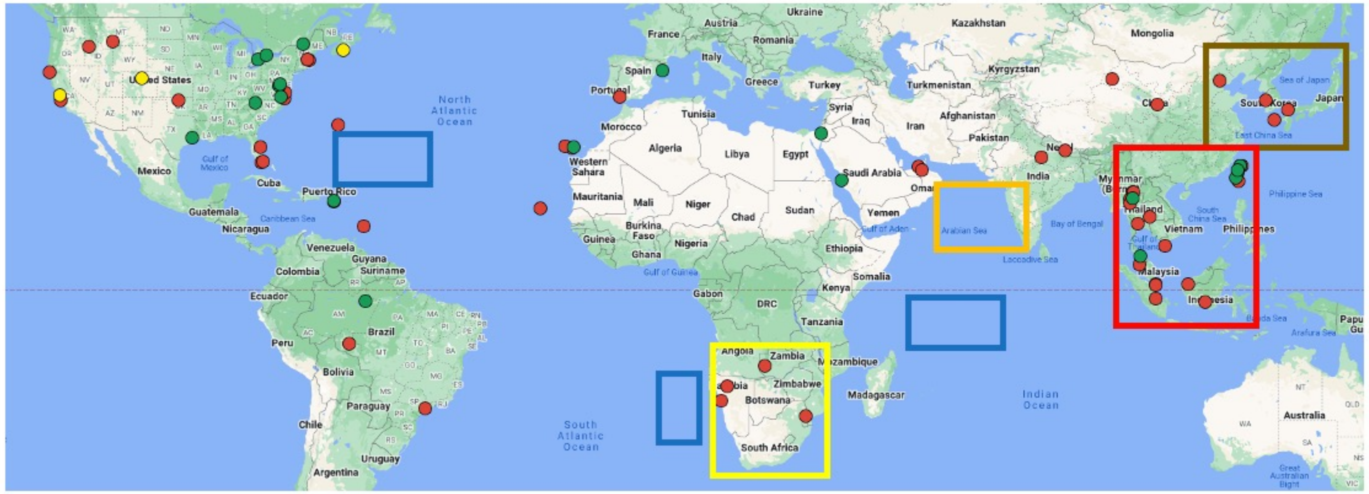
Case Study Examples: CALIPSO Mission Support – algorithm development

MPLNET is supporting development of CALIPSO Version 5 Aerosol Product (the final release)

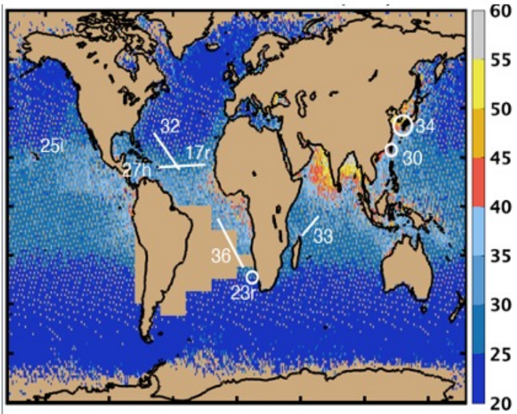


[MIRA Website](#)

MPLNET is providing lidar ratios from under-sampled regions



Marine Environment
CALIPSO Constrained Lidar Ratio Retrievals



	Region	Site	Lidar Ratio (sr)		Aerosol Types	Time Span
			AE < 1	AE > 1		
Orange	India, Indian Ocean	INDOEX-99 Cruise (from India)		43 +- 12	Marine, Pollution	1 month
		INDOEX-99 Cruise (from Middle East)	55 +- 14		Marine, Dust	
		Kanpur, India	39 +- 10	55 +- 14	Pollution, Dust	2 years
Yellow	Southern Africa	Skukua, South Africa	37 +- 3.4	65 +- 10	Pollution, Smoke, Marine	1 month
		Mongu, Zambia		71 +- 6	Pollution, Smoke	1 month
		Windpoort, Namibia	35 +- 13	46 +- 7.5	Dust, Pollution	1 year
Brown	East Asia	ACE-Asia Cruise (Sea of Japan, East China Sea)	55 +- 11	64 +- 9	Pollution, Dust, Marine	1 month
Red	South East Asia	Singapore		52 +- 12	Pollution, Smoke, Marine	2 years
		EPA-NCU (Northern Taiwan, from Pacific Ocean)	30 +- 12		Marine, Pollution	7 years
		EPA-NCU (Northern Taiwan, from China)	40 +- 16		Dust, Marine, Pollution	
		EPA-NCU (Northern Taiwan, from SE Asia)	53 +- 21		Smoke, Marine, Pollution	
Blue	Open Ocean	Aerosols-99 Cruise (NH Atlantic)	32 +- 6		Marine	1 month
		Aerosols-99 Cruise (SH Atlantic)	36 +- 16		Marine	1 month
		INDOEX-99 Cruise (Indian Ocean Tropics)	33 +- 6		Marine	2 months

Case Study Examples: ESA EarthCARE Validation and Joint Research

The ESA EarthCARE mission includes ATLID, the next satellite lidar (in commissioning phase now). Data will be available soon.
ATLID is a polarized High Spectral Resolution Lidar (HSRL) operating at 355 nm.
MPLNET is a member of the ESA EarthCARE validation team.

Task 1: Validate aerosol, cloud, and planetary boundary layer heights using L3 MPLNET products

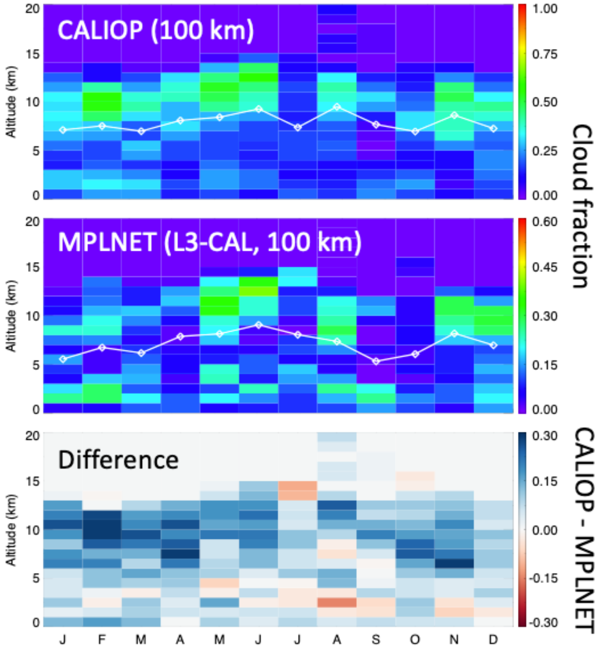
Task 2: Compare drizzle occurrence and properties

Task 3: Evaluate EarthCARE-based cirrus datasets for TOA CRE (top-of-atmosphere cirrus cloud radiative effect)

Examples of EarthCARE validation using CALIPSO data and simulated EarthCARE data

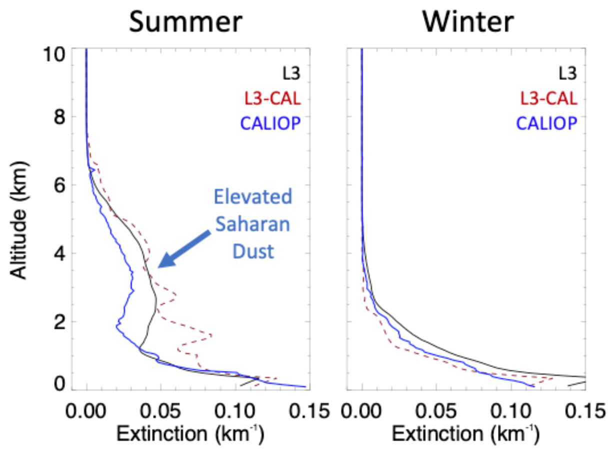
Cloud Occurrence

GSFC (2016 – 2021)



Aerosol Profiles

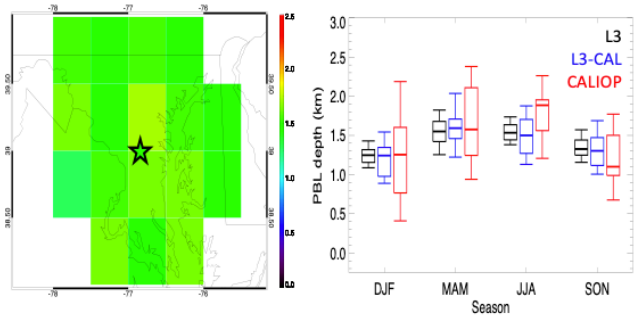
Santa Cruz Tenerife (2018 – 2021)



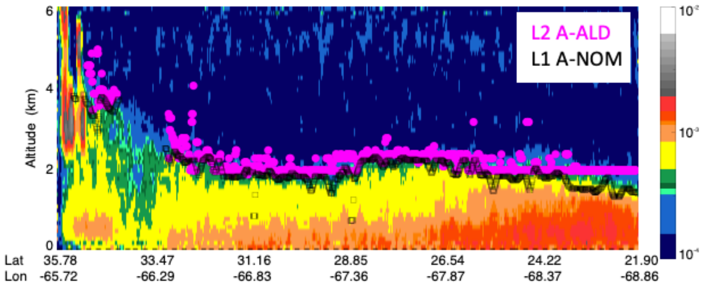
*Due to the difference in MPLNET/ATLID wavelengths, we will not attempt to validate extinction profiles. However, we will evaluate aerosol layer heights

Planetary Boundary Layer Height

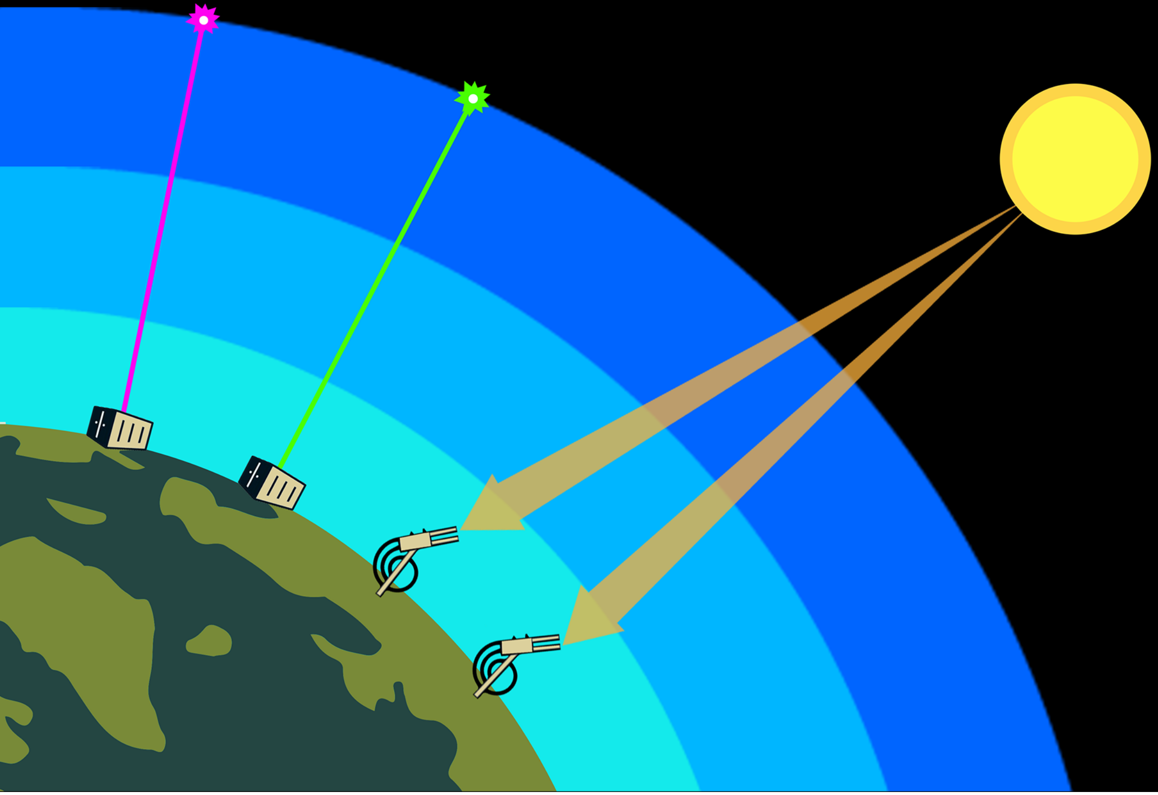
GSFC (2016 – 2021)



Simulated Halifax Aerosol Scene



Other Cases Studies are Available in the Appendix



Conclusion: Access to Global Lidar Data

Conclusion: Access to Global Lidar Data from GALION

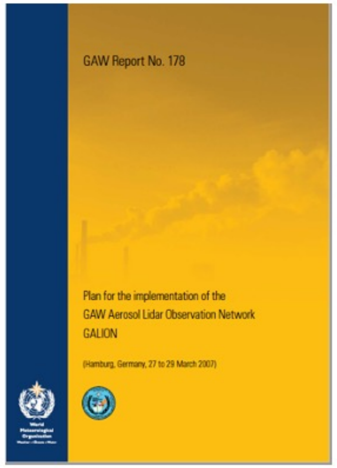
World Meteorological Organization Global Atmosphere Watch Program — GAW

GALION The GAW Aerosol Lidar Observation Network

GALION is a network of lidar networks organized through the WMO Global Atmospheric Watch (GAW) program.

Judd Welton (NASA, USA) and Lucia Mona (CNR, Italy) are co-chairs
Guidance and direction provided by steering committee (network heads) and GAW Aerosol SAG

See GAW Report 178 (2008)



Original GALION Networks:

- ● AD-Net
- ● EARLINET
- CIS-LINET
- ● LALINET
- CORALNET
- CREST

(regional)

- ● MPLNET
- ● NDACC Lidar

(global)

● active GALION members, signed agreements with WMO as contributing networks

Name	Affiliation	Role
Eduardo Landulfo	IPEN Center for Laser and Applications, Brazil	LALINET Head
Thierry Leblanc	NASA Jet Propulsion Laboratory, USA	NDACC Lidar Head
Lucia Mona	CNR Istituto di Metodologie per l'Analisi Ambientale, Italy	GALION Co-Chair, EARLINET Head
Atsushi Shimizu	National Institute for Environmental Studies, Japan	AD-Net Head
Ellsworth J. Welton	NASA Goddard Space Flight Center, USA	GALION Co-Chair, MPLNET Head

Objectives: provide long term, coordinated lidar network profiling of aerosol properties to support the following

1. climate research and assessment
2. air quality assessment and forecasting
3. Plume monitoring for special events
4. Satellite cal/val and synergistic research
   - Cover satellite lidar gaps

Motivations:

Global coverage is only achievable by combining efforts of individual lidar networks. We have to work together.

Provide easier and more informative access to our data across all networks, enable coordinated application support

Programmatic planning with other networks (WMO OSCAR, etc)

GALION Website

Information and links about each GALION network are on the website

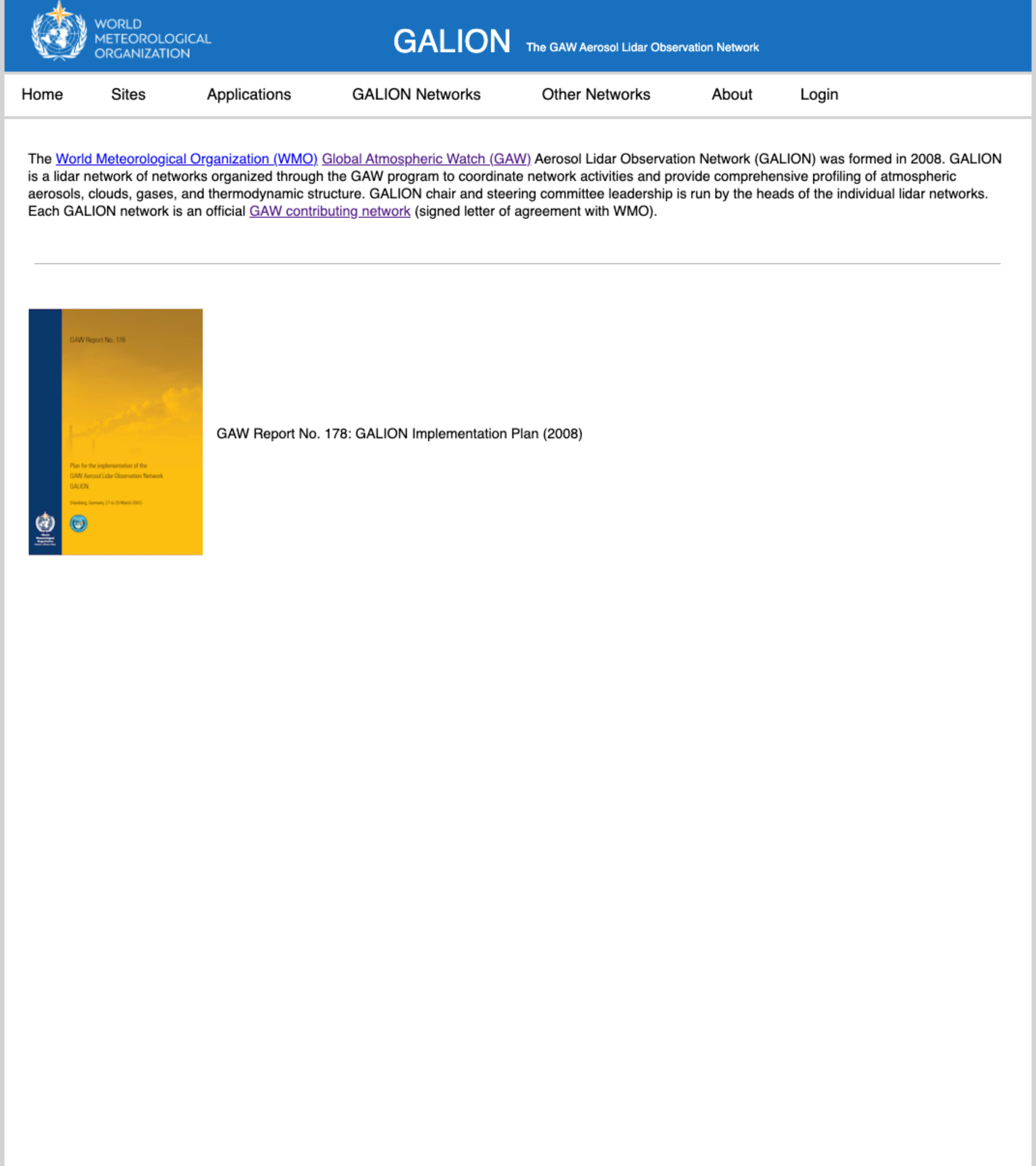
Global projects: GALION

New Data Center and Website

Capabilities

- GALION information and search and discovery
- Automated handshakes with WMO OSCAR database Metadata APIs
- Goal: one source to get aggregated lidar network information and data access

NOTE: we are still updating metadata from networks. The website is functional but some portions will not be public until the metadata are complete. Mainly download of search results.



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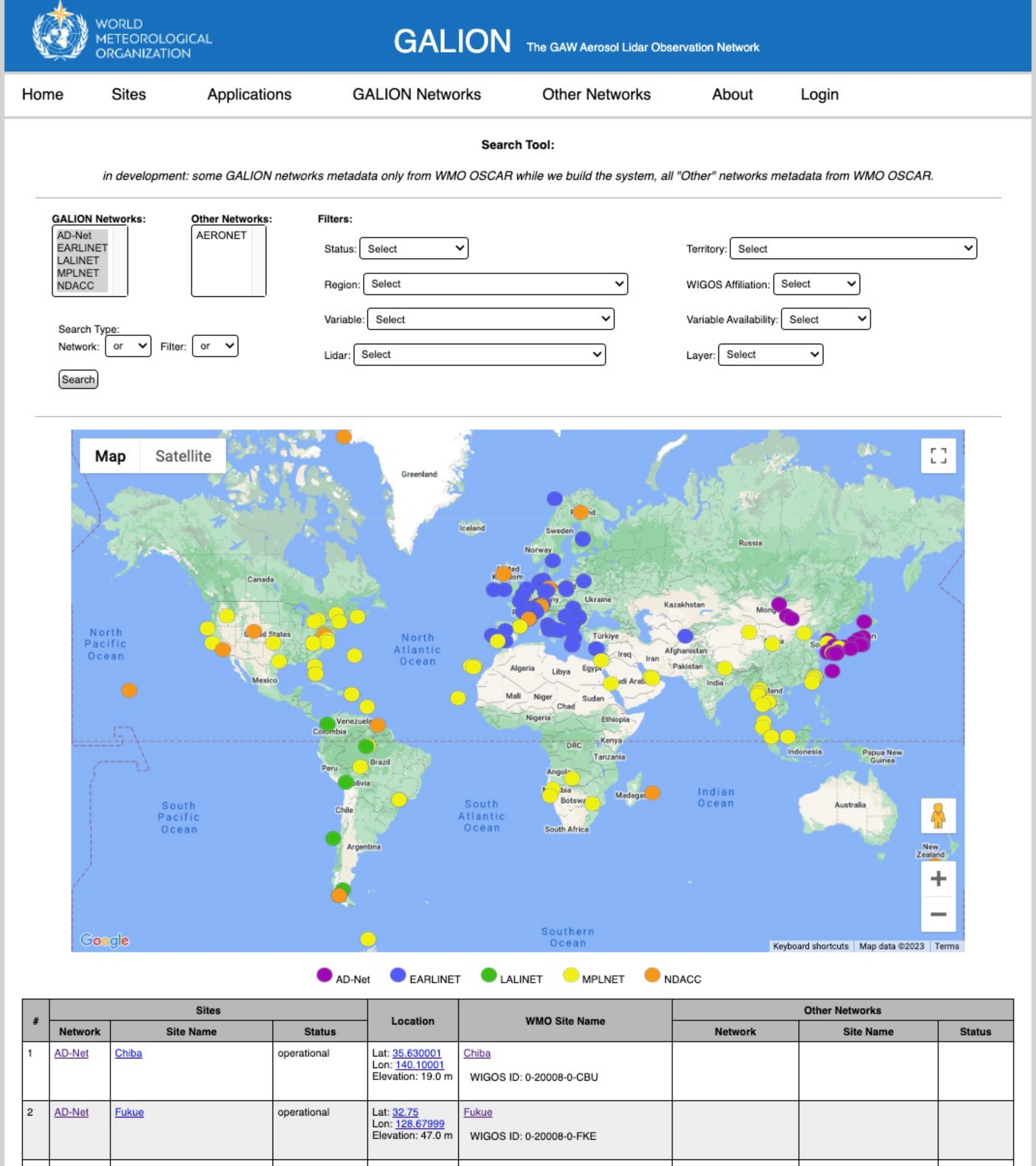

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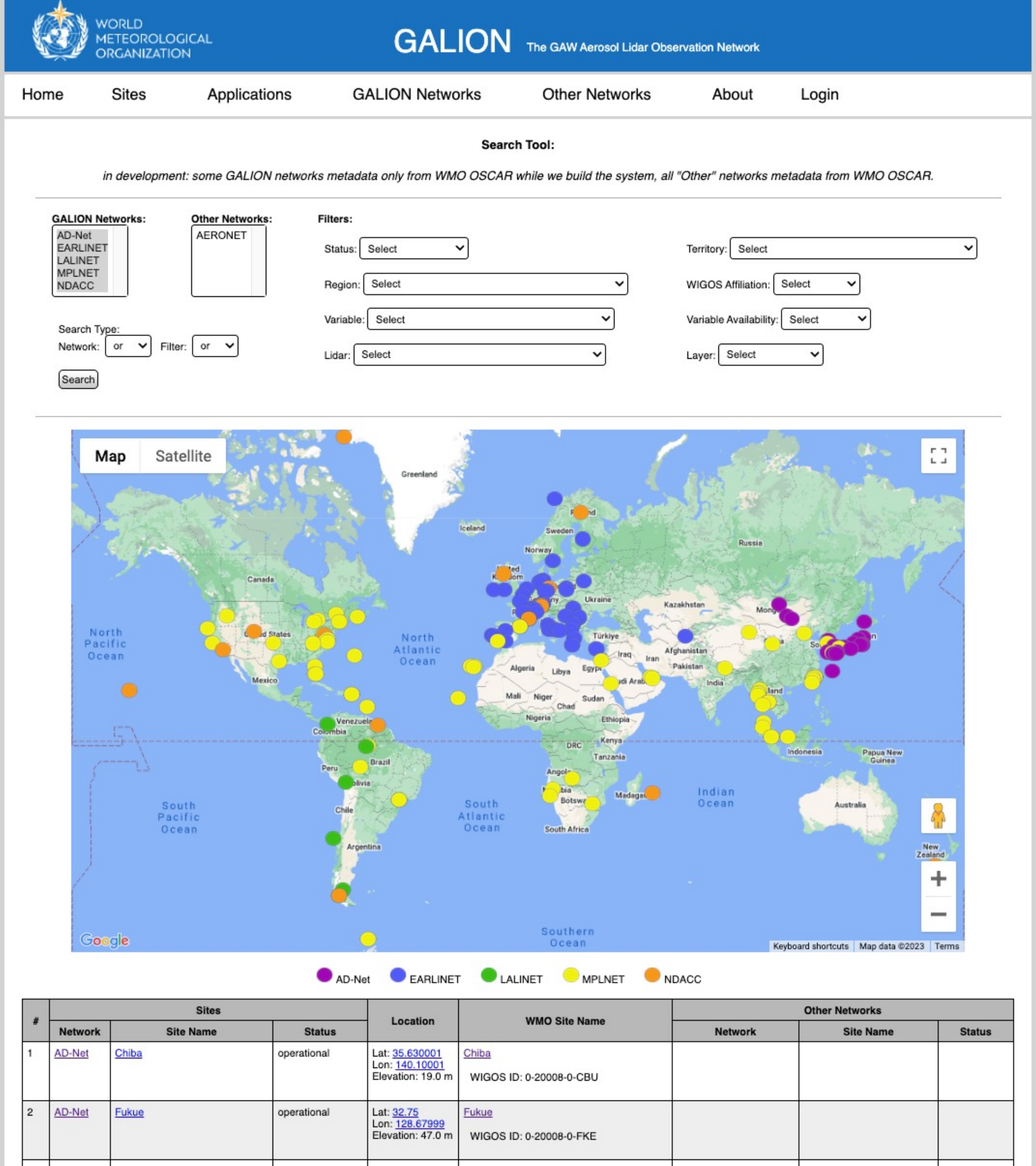
All search features are also available via API



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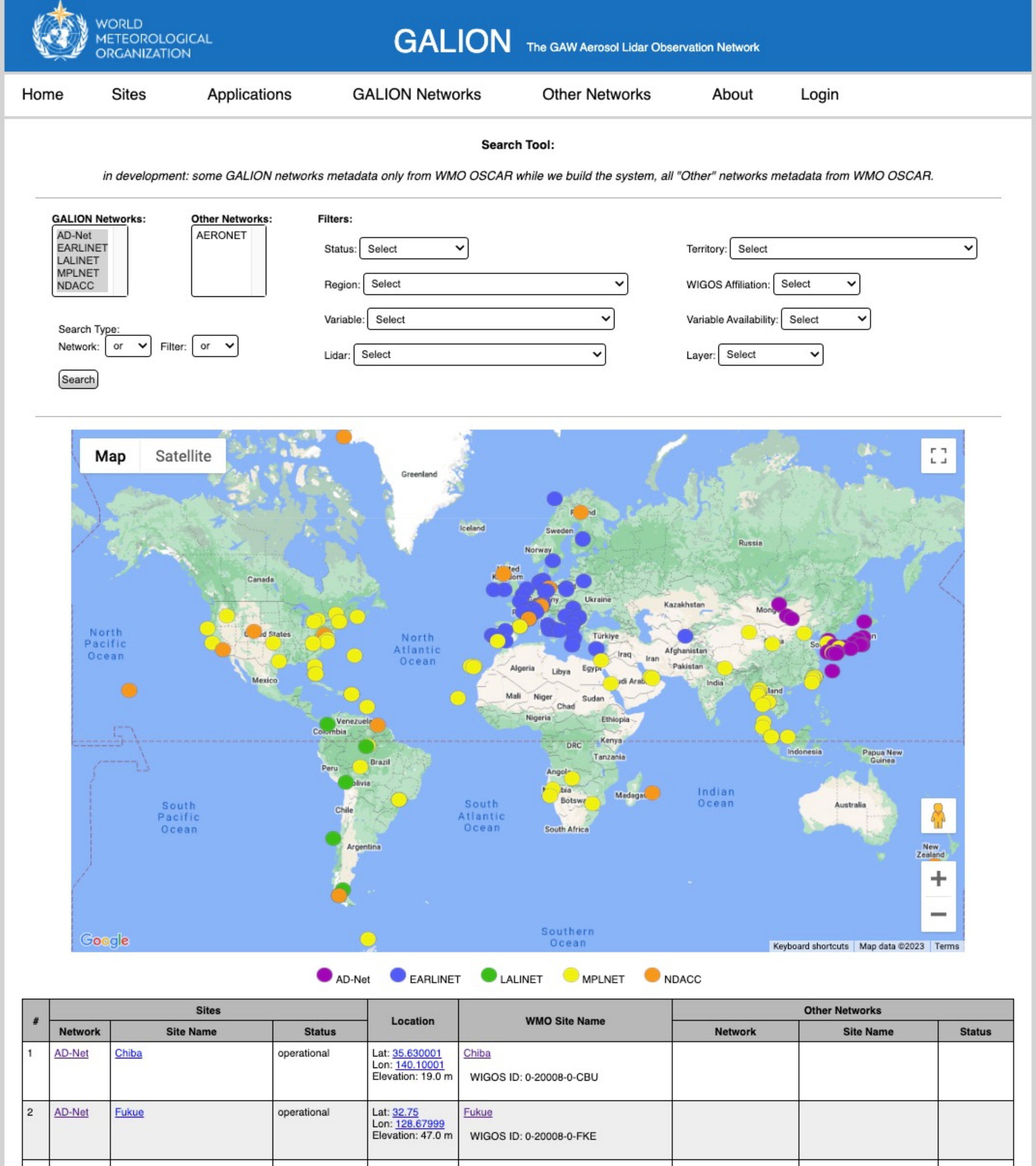
Tools in development (functional but not public*)

- Metadata Downloads
  - GALION JSON format shown previously
  - Site info, contacts, **links to browse images and data files**
- Trajectory Analysis: extract sites along track
  - HYSPLIT
  - KML or csv (lat,lon)
  - Volcanic Ash Advisories



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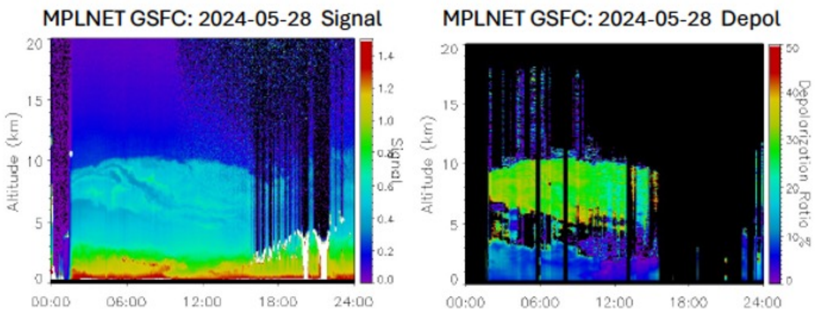
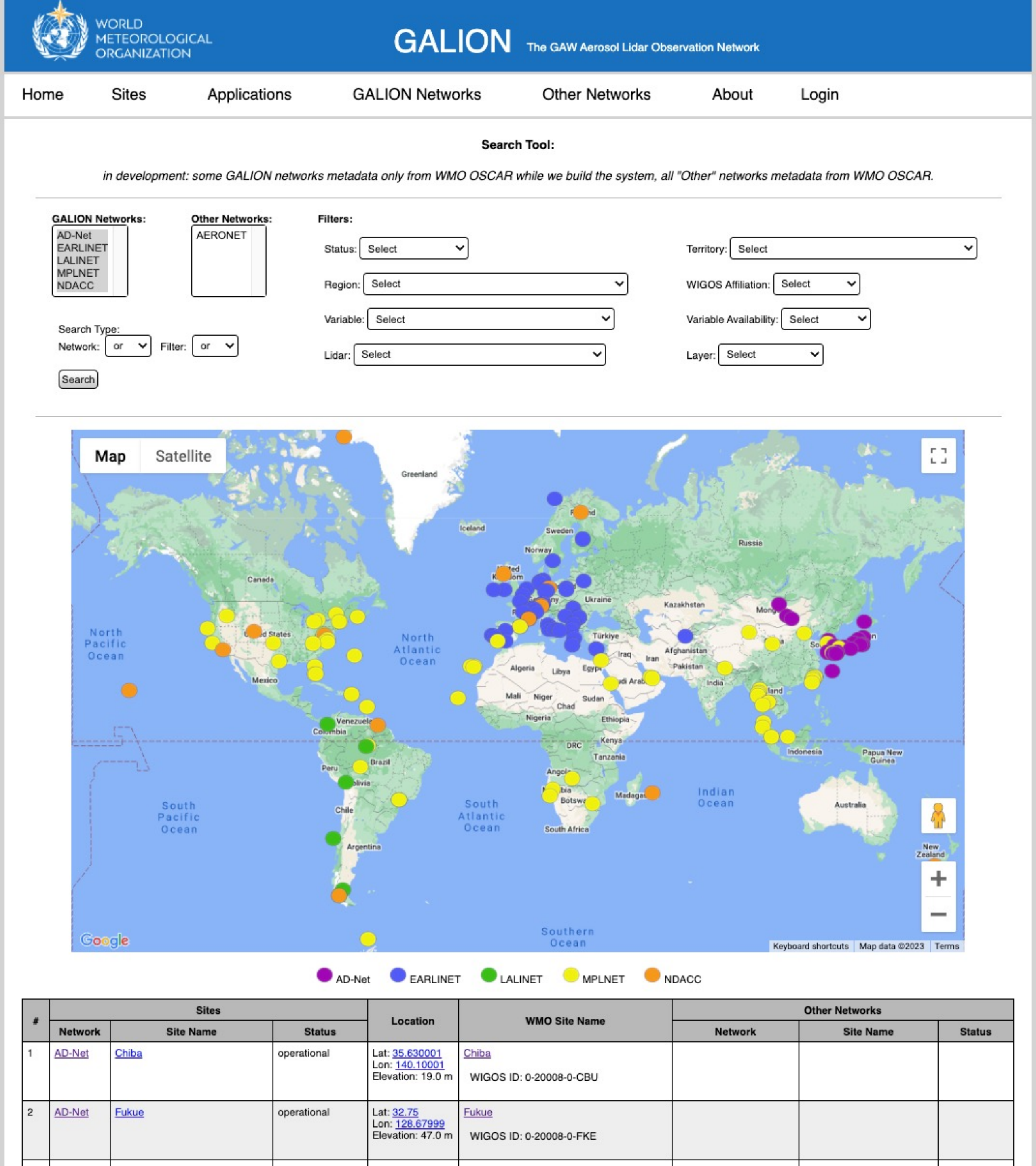


Late in season for Asian Dust Transport to US



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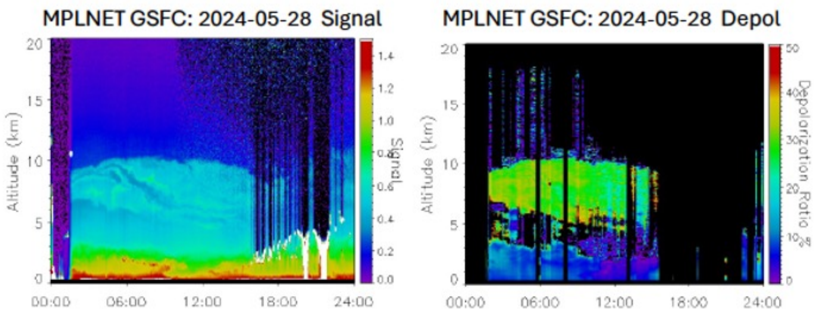

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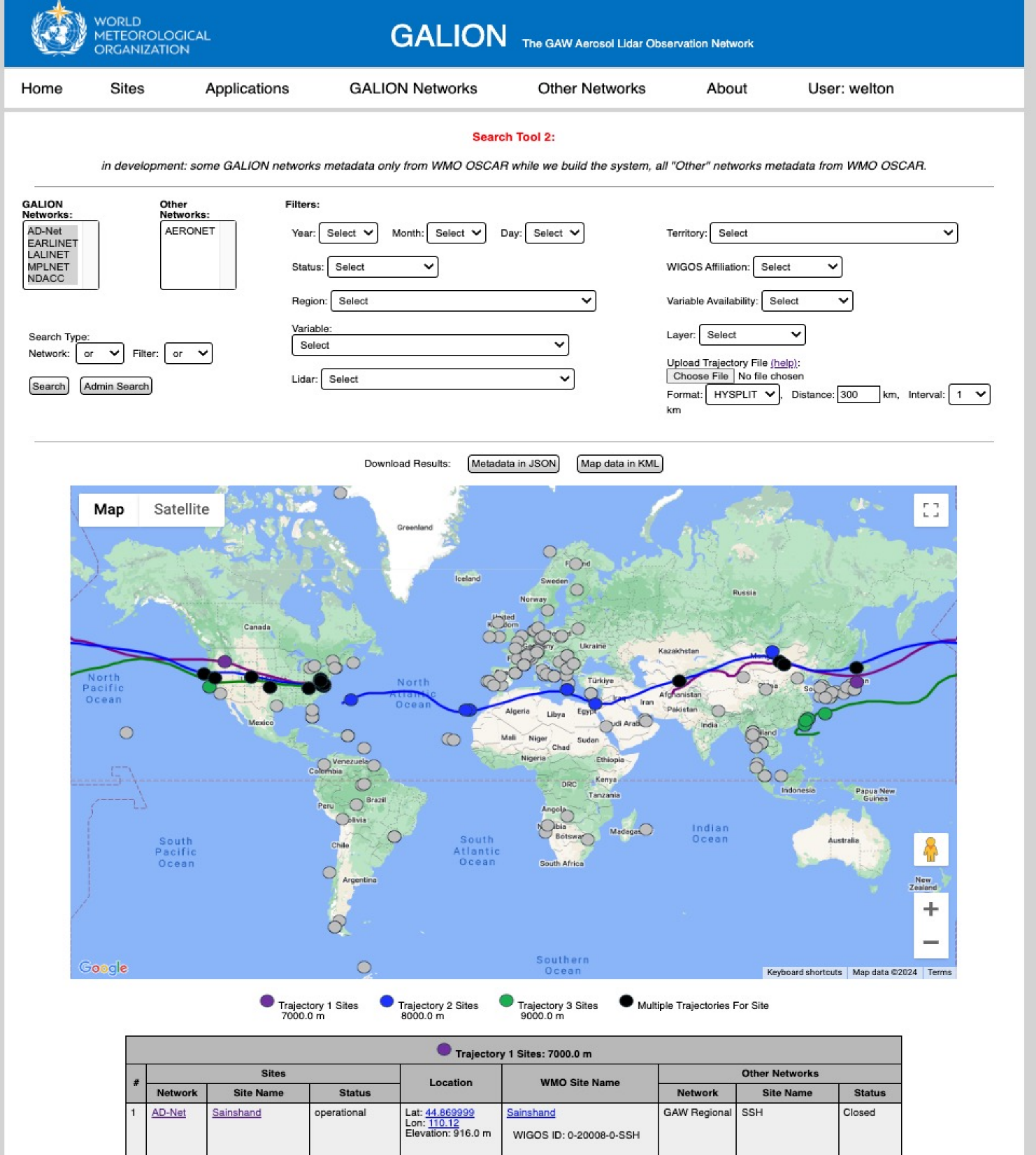

Global projects: GALION

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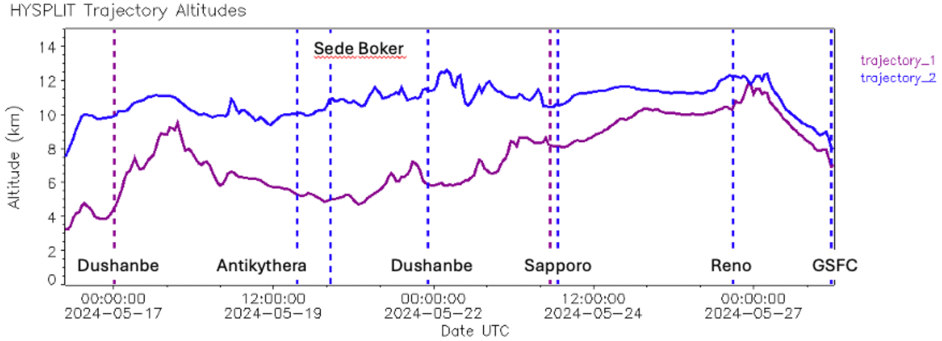

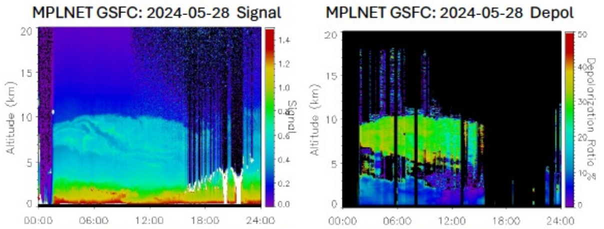

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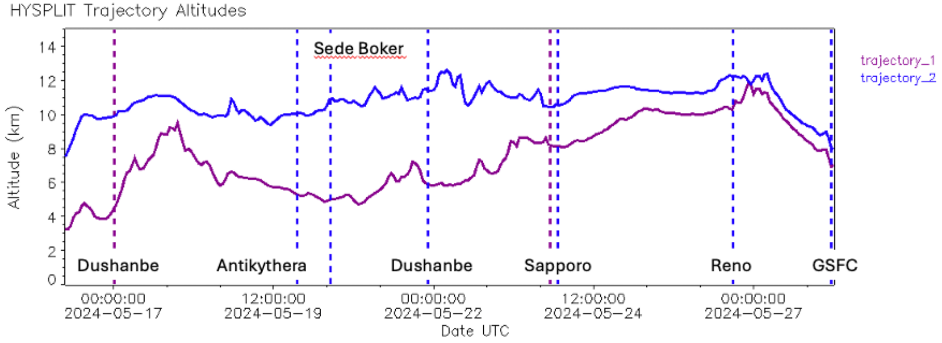

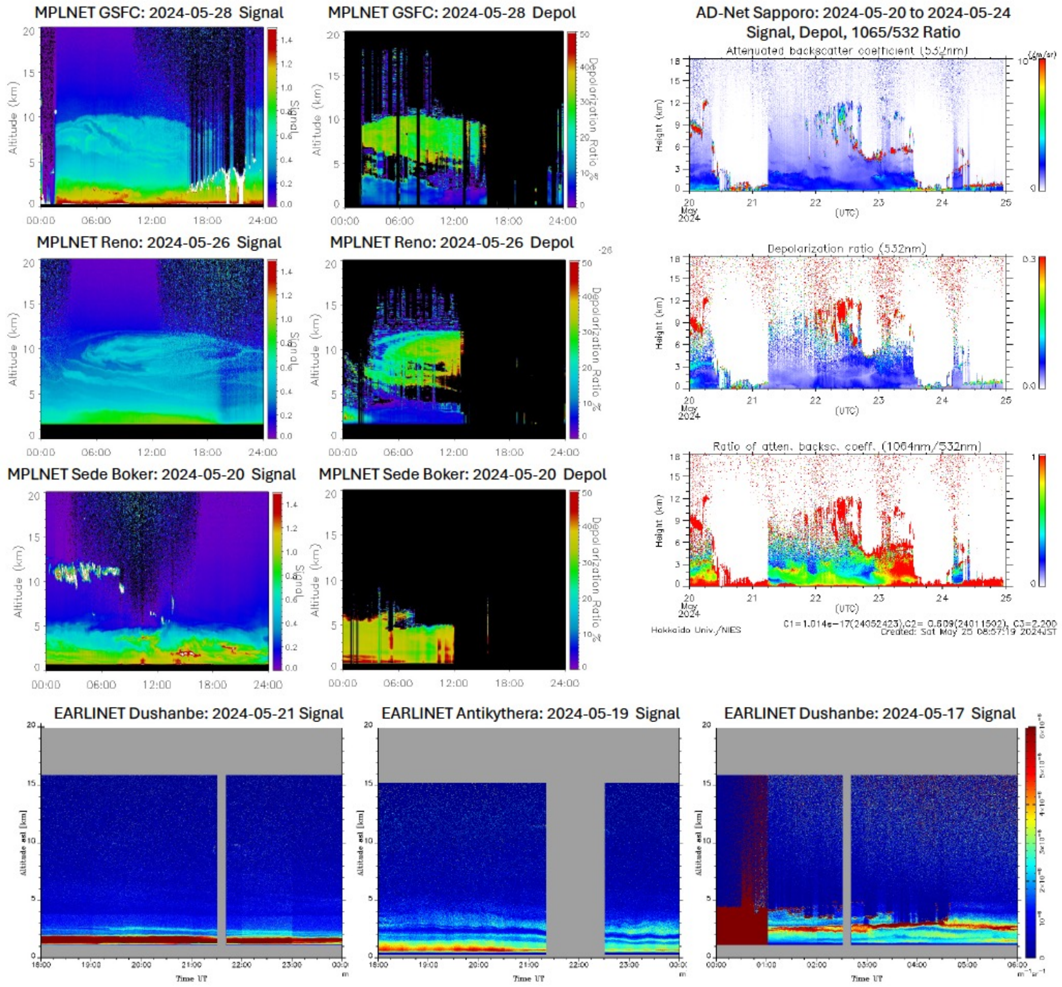

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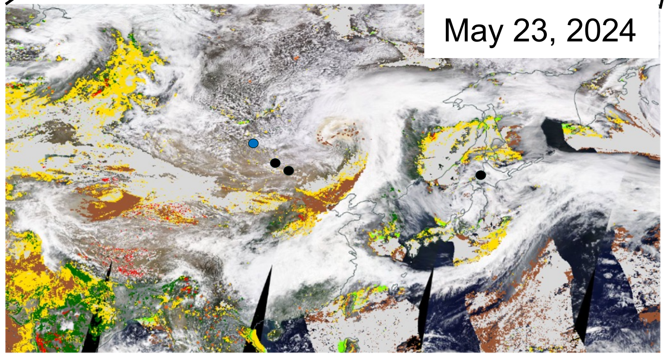


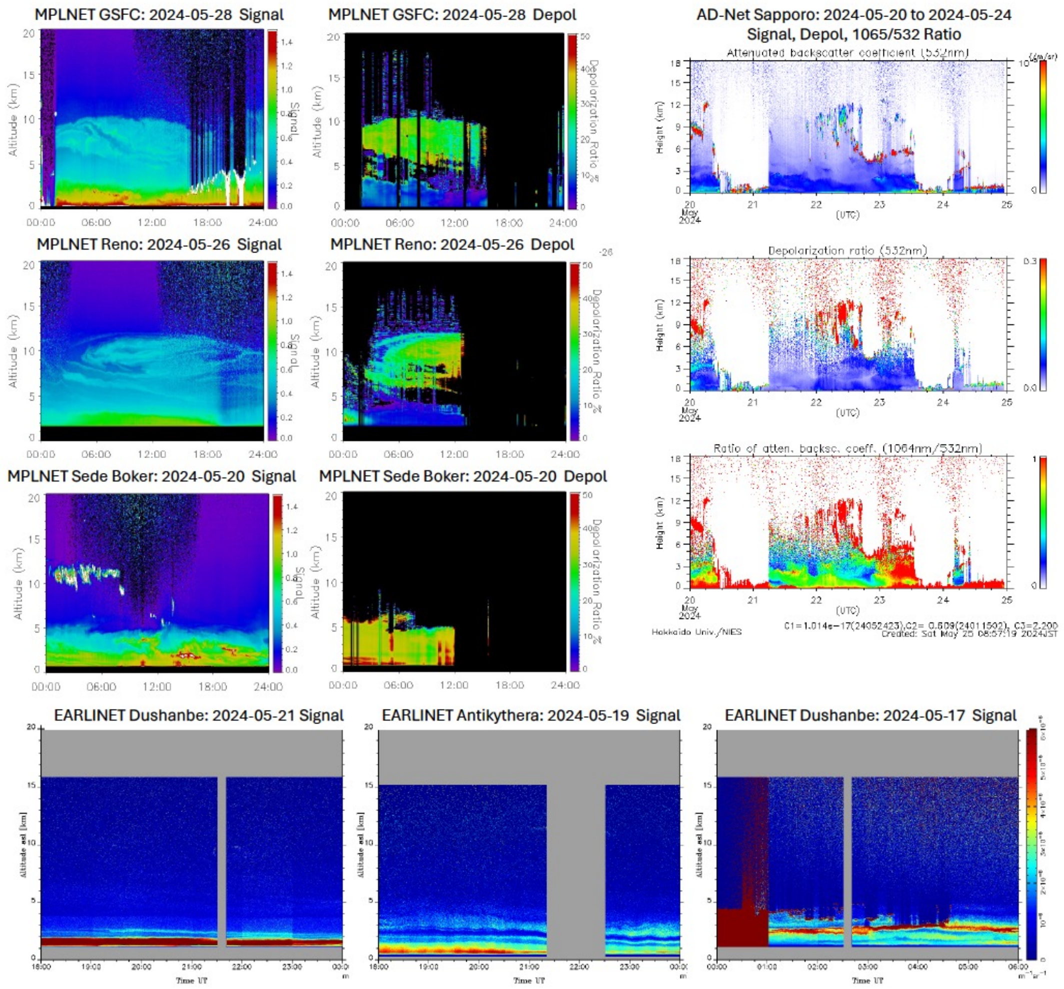
NASA World View

- MODIS Fires
- VIRS Deep Blue Aerosol Type

Dust

Smoke

Mixture



Global projects: GALION

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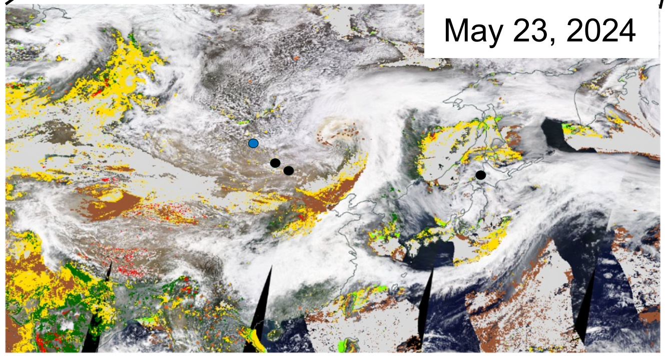
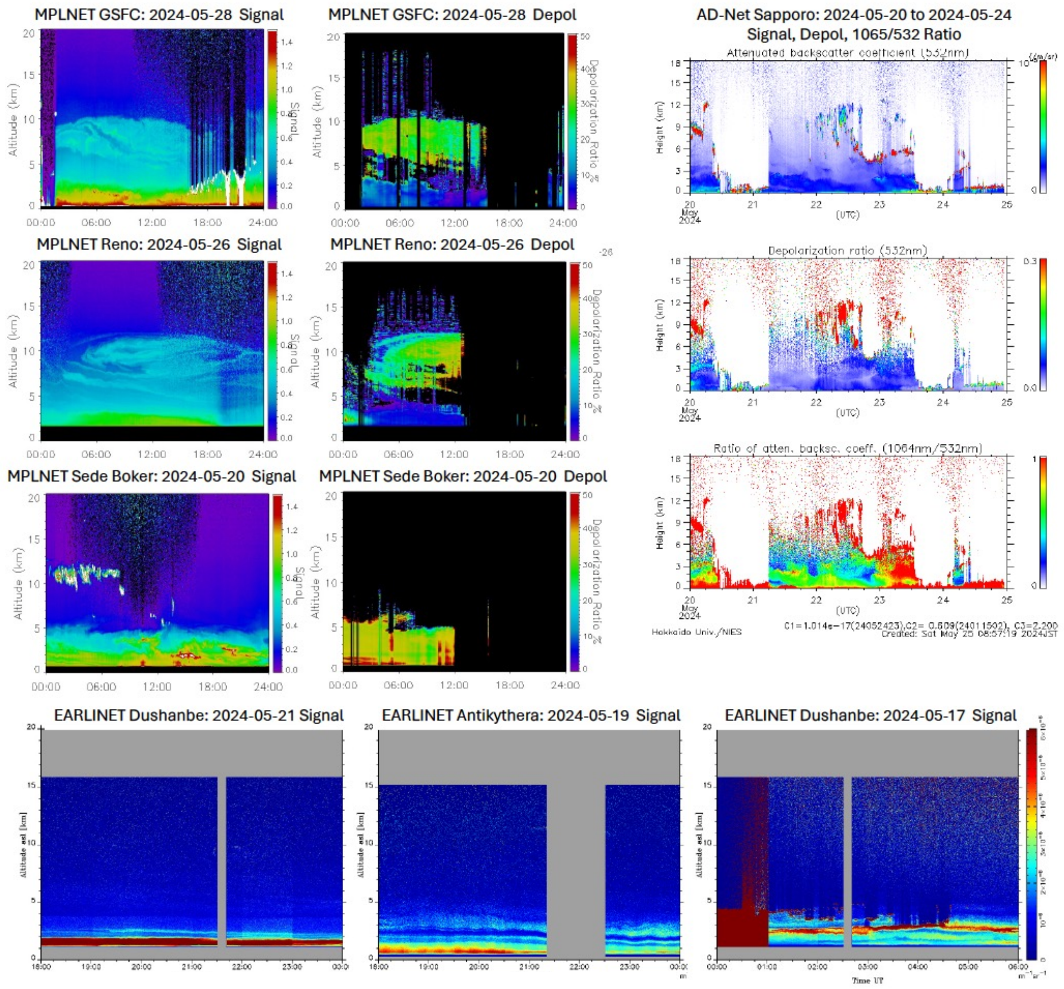
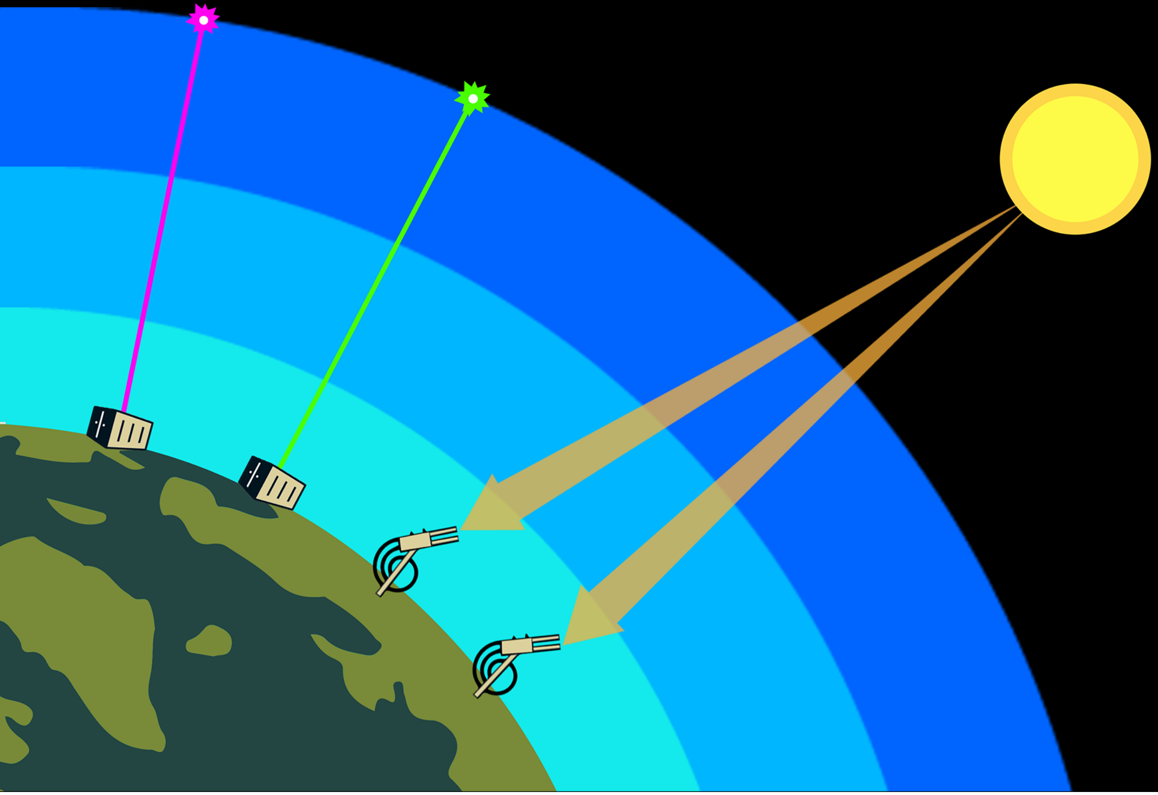




Based on data from multiple GALION networks and NASA Satellite Data, the dust layer originated over Mongolia ~ May 23, 2024. Likely mixed with smoke from fires burning in Siberia

Conclusion

Thank you for your interest in the NASA MPLNET Project



NASA Atmospheric Composition Ground Networks Supporting Air Quality and Climate Applications Summary

Training Summary

Network	Type	Primary Measurands	Number of Sites	Vertical Coverage
AERONET	Passive	Aerosols (Optical, Microphysical, Radiative)	~600 Active	Total Column
Pandora (PGN)	Passive	Trace Gases (Ozone, NO_2, Formaldehyde)	168 Official	Total Column, Near-Surface, Lower Tropospheric Profiles
TOLNet	Active	Trace Gases (Ozone Vertical Profiles)	12 (3 Fixed, 9 Transportable)	Tropospheric Profiles (0-15 km)
MPLNET	Active	Aerosols and Clouds (Lidar Signal, Cloud, Aerosol, PBL)	28 Active (85 total)	Atmospheric Profiles (0.25-30 km)

Homework and Certificates

- **Homework:**
  - One homework assignment
  - Opens on 22/08/2024 (today)
  - Access from the training webpage
  - Answers must be submitted via Google Forms
  - **Due by 05/09/2024**

- **Certificate of Completion:**
  - Attend all five live webinars (attendance is recorded automatically)
  - Complete the homework assignment by the deadline
  - You will receive a certificate via email approximately two months after completion of the course.

Contact Information

Trainers:

- Judd Welton
  - ellsworth.j.welton@nasa.gov
- Carl Malings
  - carl.a.malings@nasa.gov

- ARSET Website
- Follow us on Twitter!
  - @NASAARSET
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Visit our Sister Programs:

- DEVELOP
- SERVIR

Resources

- AERONET Website
  - AERONET stations map
  - AERONET Data Synergy Tool
- Pandora Website
  - Pandonia Global Network
  - Pandonia Network Data
- TOLNet Website
  - Download TOLNet Data
  - TOLNet Data API
- MPLNET Website
  - MPLNET Sites
  - MPLNET Web Services for Data Download and Plotting

Thank You!

MPLNET Training Appendix: Supplemental Material

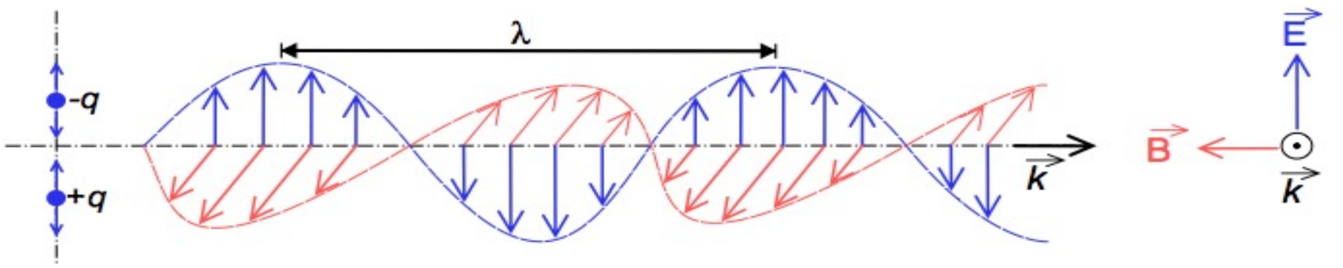
MPLNET Supplemental Material: Remote Sensing 101 Overview

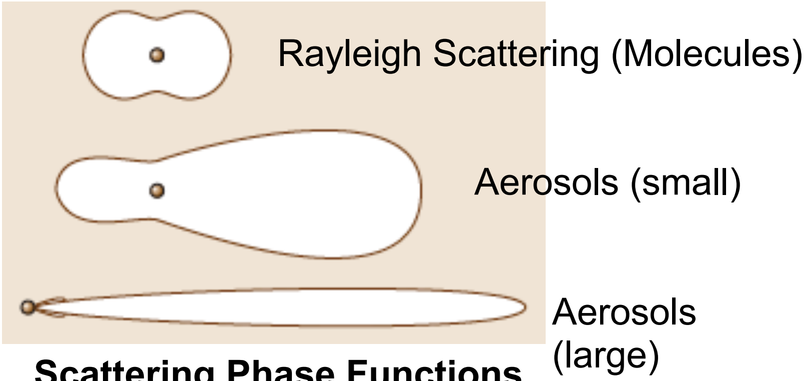
Remote Sensing does not produce a direct measure of aerosol or cloud concentrations and properties. But concentrations and properties determine how they scatter and absorb sunlight, so remote sensing can be used to infer such information.

Incoming light is described by:
- its direction relative to observer
- wavelength (blue, green, red)
- intensity (or power)
- polarization (orientation and form of electromagnetic waves)

The intensity and polarization of light scattered by one particle in a given direction, or the intensity absorbed, is dependent upon particle size, shape, and index of refraction (**composition**).

The total intensity of scattered and absorbed light is dependent upon the number of particles (**concentration**).





Scattering Phase Functions

Most aerosols are from 0.1 to 10 μm in size. Smaller cloud droplets and ice particles also fall into this range. UV-VIS-NIR wavelengths are best to infer concentration and particle properties for this size range.

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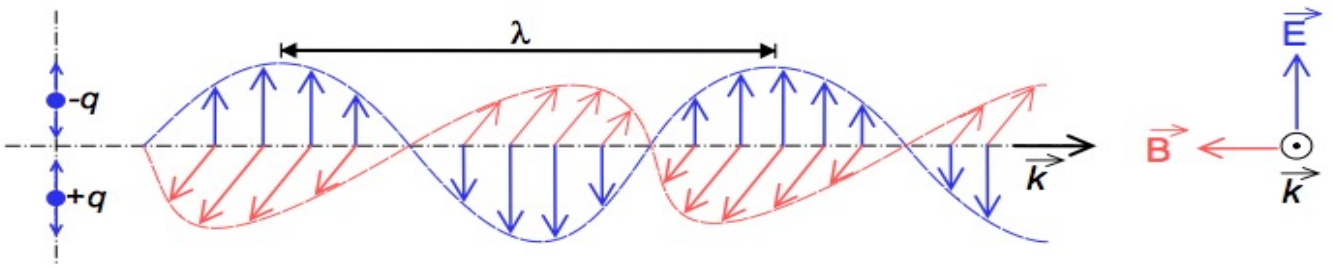
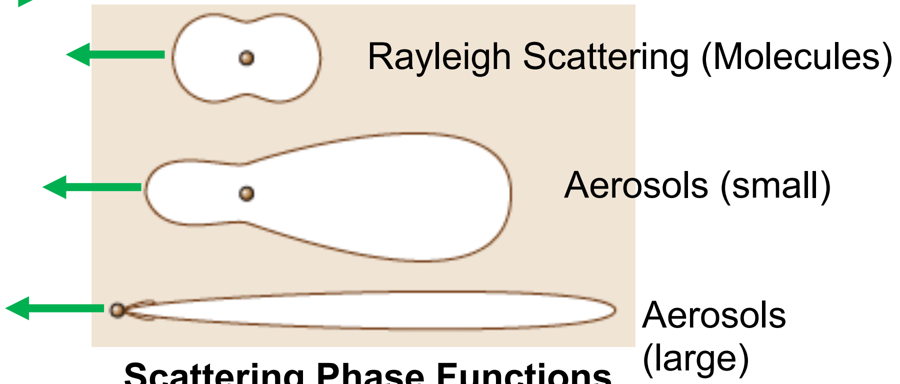
Lidars emit pulses of collimated laser light into atmosphere
Some lidars use fixed polarization, others are depolarized



Lidars are measuring the 180 degree backscattered light



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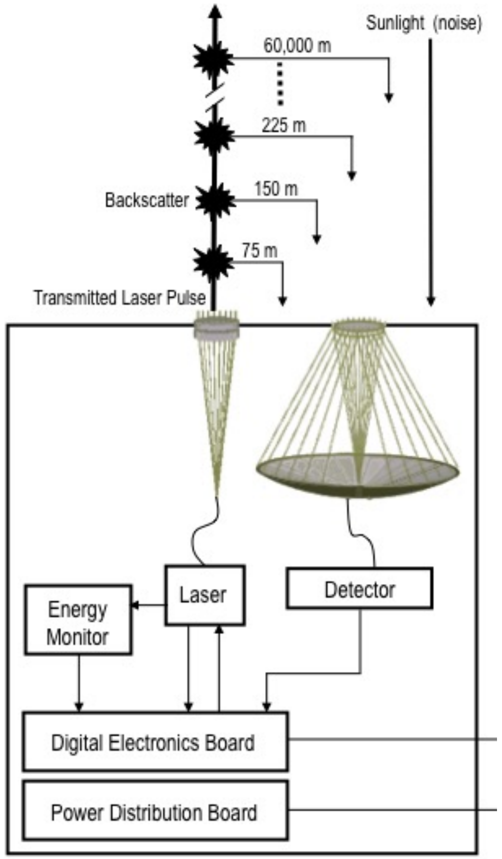
MPLNET Supplemental Material: the micro pulse lidar

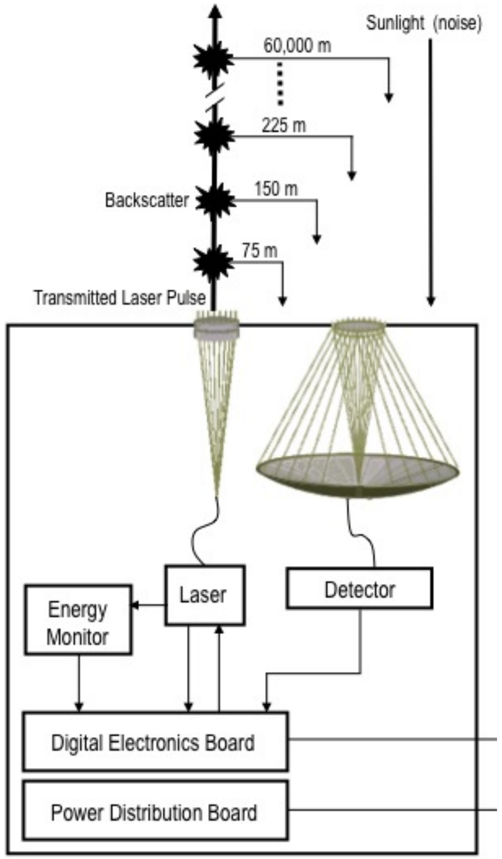


Generic Lidar

Level 0, Raw Lidar Signal (counts/time):

$$P_{RAW}(r) = \left\{ \frac{O(r)E}{Dr^2} C\beta(r) e^{-2\int_0^z \sigma(r')dr'} \right\} + \frac{N_s + N_d}{D}$$

MPLNET Supplemental Material: the micro pulse lidar



Generic Lidar

Level 0, Raw Lidar Signal (counts/time):

$$P_{RAW}(r) = \left\{ \frac{O(r)E}{Dr^2} C \boxed{\beta(r) e^{-2\int_0^z \sigma(r')dr'}} \right\} + \frac{N_s + N_d}{D}$$

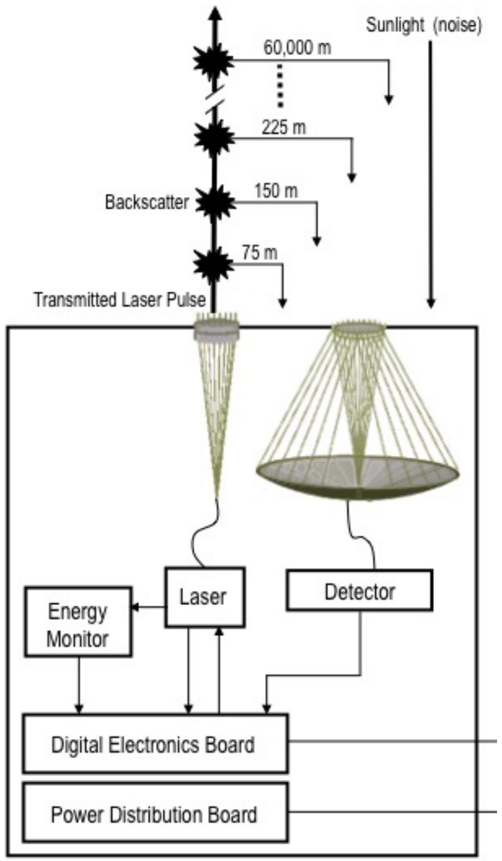
Atmospheric Signal → Attenuated Backscatter

β: backscatter (what we want)
σ: extinction (what we want)

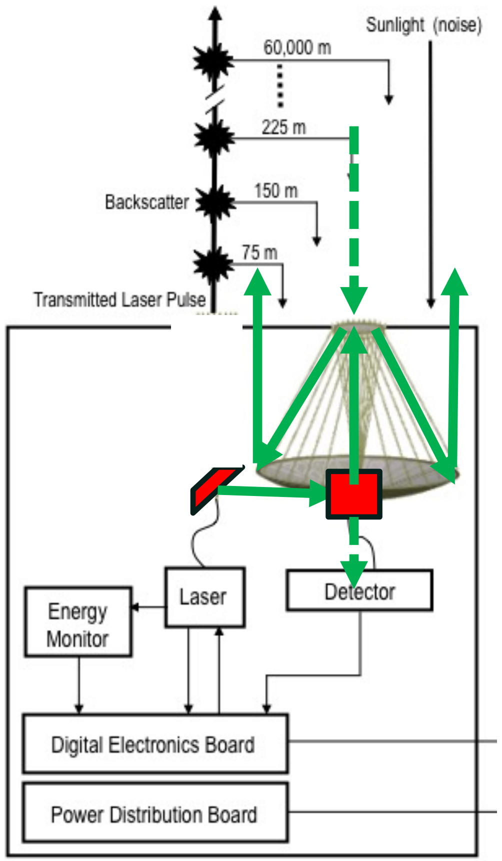
Instrument Parameters: must calibrate and remove

D: detector deadtime
Nd: detector dark count
E: emitted laser energy
O: receiver overlap (near surface signal loss)
C: receiver efficiency parameter
Ns: solar background at laser wavelength (measured with signal)
r: range

MPLNET Supplemental Material: the micro pulse lidar



Generic Lidar



Micro Pulse Lidar

Transceiver design to expand laser for eye safety

Level 0, Raw Lidar Signal (counts/time):

$$P_{RAW}(r) = \left\{ \frac{O(r)E}{Dr^2} C \boxed{\beta(r) e^{-2\int_0^z \sigma(r')dr'}} \right\} + \frac{N_s + N_d}{D}$$

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β: backscatter (what we want)
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Instrument Parameters: must calibrate and remove

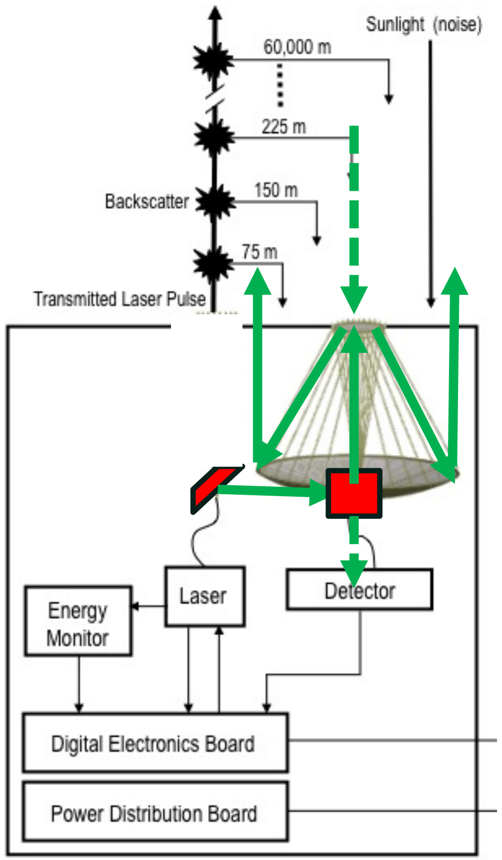
D: detector deadtime
Nd: detector dark count
E: emitted laser energy
O: receiver overlap (near surface signal loss)
C: receiver efficiency parameter
Ns: solar background at laser wavelength (measured with signal)
r: range

$$P_{MPL}(r) = \left\{ \frac{O(r)E}{Dr^2} C\beta(r) e^{-2\int_0^z \sigma(r')dr'} \right\} + \frac{A(r)}{D} + \frac{N_s + N_d}{D}$$

Additional MPL Instrument Parameters: must calibrate and remove

A: afterpulse (laser-detector crosstalk)
O: receiver overlap is typically much longer with a transceiver design

MPLNET Supplemental Material: the micro pulse lidar



Micro Pulse Lidar

Transceiver design to expand laser for eye safety

Primary Job of MPLNET:
Install and operate MPL sites and collect and archive the data. Calibrate instruments and transform raw data to Level 1 signal products. These are useable signals.

Level 1 Signal:

$$P_{NRB}(r) = C\left(\beta_M(r) + \beta_P(r)\right)e^{-2\int_0^z \sigma_M(r')dr'} e^{-2\int_0^z \sigma_P(r')dr'}$$

M subscript: molecular
P subscript: particle (aerosol or cloud)

MPLNET signal data are called normalized relative backscatter (NRB). They include the "receiver efficiency parameter" C, sometimes call the system constant.

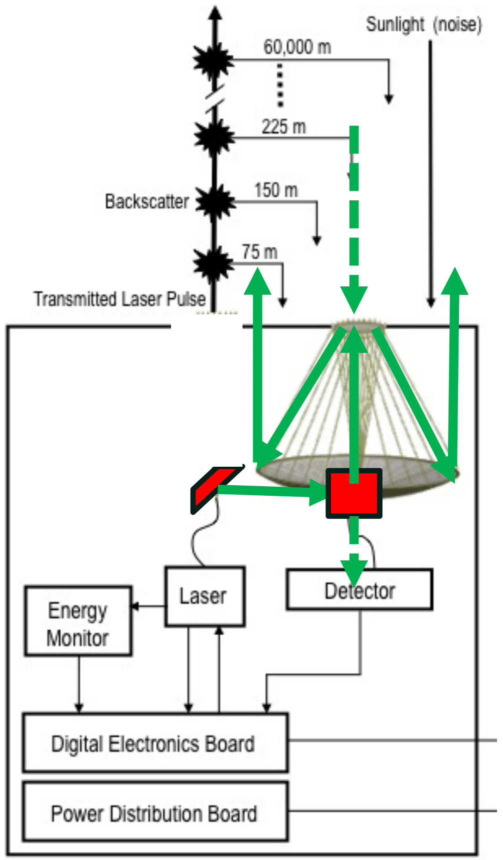
NOTE: The CALIOP lidar on CALIPSO provides attenuated backscatter, calibration and removal of C. This is easier for satellites since they reside in a clean environment.

The polarized MPL uses co and cross polarized signals (in this case linear and elliptical). The ratio of the signals returned from each polarization state is the volume depolarization ratio.

References for processing MPLNET signal data on our website:

- Campbell et al., 2002
- Welton and Campbell, 2002

MPLNET Supplemental Material: the micro pulse lidar



Micro Pulse Lidar

Transceiver design to expand laser for eye safety

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Level 1 Signal:

$$P_{\mathrm{NRB}}(r) = C\left(\beta_M(r) + \beta_P(r)\right)e^{-2\int_0^z \sigma_M(r')dr'}\, e^{-2\int_0^z \sigma_P(r')dr'}$$

particulate optical depth from surface to range z

M subscript: molecular
P subscript: particle (aerosol or cloud)

MPLNET signal data are called normalized relative backscatter (NRB). They include the “receiver efficiency parameter” C, sometimes call the system constant.

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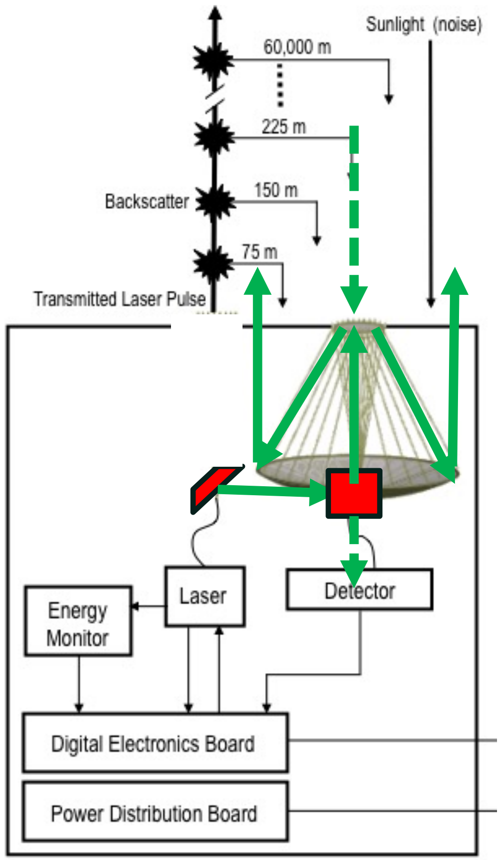

Micro Pulse Lidar

Transceiver design to expand laser for eye safety

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Level 1 Signal:

$$P_{NRB}(r) = C\left(\beta_M(r) + \beta_P(r)\right)e^{-2\int_0^z \sigma_M(r')dr'}\, e^{-2\int_0^z \sigma_P(r')dr'}$$

particulate optical depth from surface to range z

Note:

At altitudes above the aerosol and no clouds:

$$P_{NRB}(r) = C\beta_M(r)e^{-2MOD(0,r)}e^{-2AOD}$$

Molecular terms can be calculated from radiosonde or model (MPLNET uses NASA GOES-5)
C can be determined from the measured signal and AOD from AERONET:

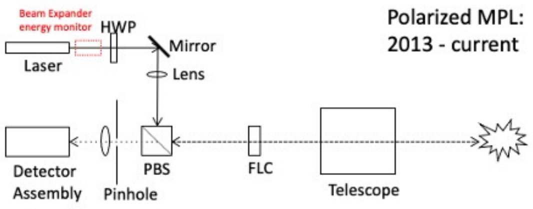
$$C = \frac{P_{NRB}(r)}{\beta_M(r)}e^{2MOD(0,r)}e^{2AOD}$$

Or if *C* is known, then the AOD can be calculated:

$$AOD = \frac{1}{2}ln\left[\frac{C\beta_M(r)}{P_{NRB}(r)}\right] - MOD(0,r)$$

MPLNET Project Overview: Calibrations

Darkcount and Afterpulse



Polarized MPL:
2013 - current

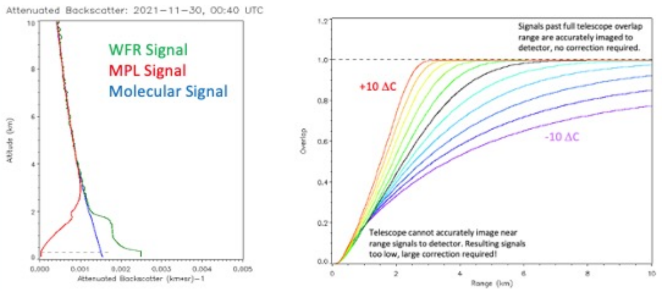
Afterpulse
MPL and miniMPL have additional laser induced noise term due to transceiver design (PBS).
Measured with window covered and nominal laser energy

Darkcount
SPCM (single photon counting) detector
Darkcounts ~ 50 – 100 Hz
Measured with window covered and laser off (tracks health of detector as DC increases near failure)

Site partner performs cals 1-2 months

Overlap

Commercial Wide Field Receiver

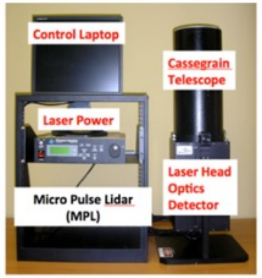


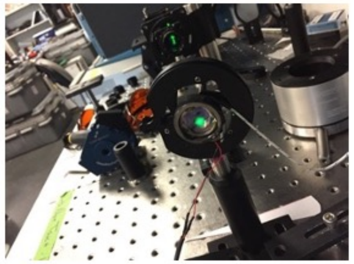
New commercial solution from Aether Embedded
Provides overlap calibration for old and new MPLs
More rugged design, field tested
Controller - Computer connection, remote control WFR data refined and improve MPL optical model

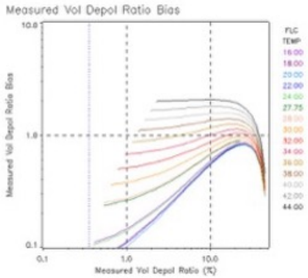
New: calculate accurate overlap from MPL specs

Measure lab and every day onsite (operational data), adjust routinely

Polarization







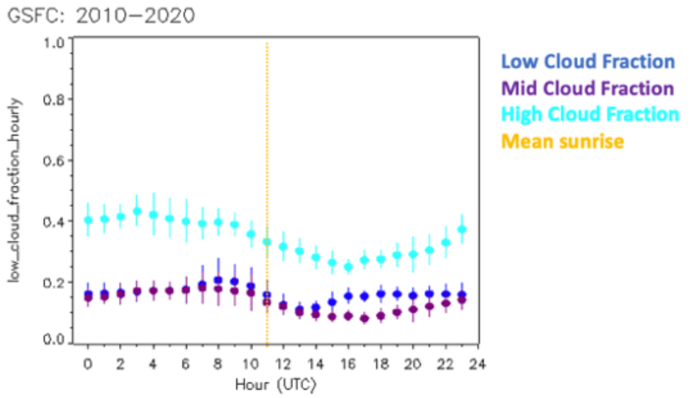
Full support of polarized MPL in Version 3.
Limited support of polarized miniMPL in Version 3 (L1 and L1.5).
Addition of polarized / particle shape product variables.

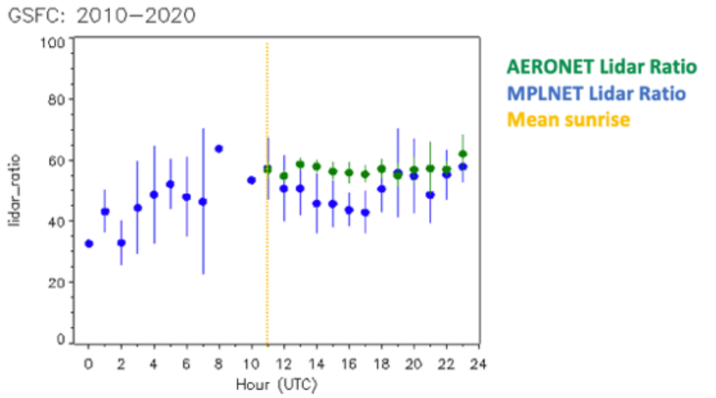
Multi-year system and component performance study completed.
Polarization Calibration Process Developed

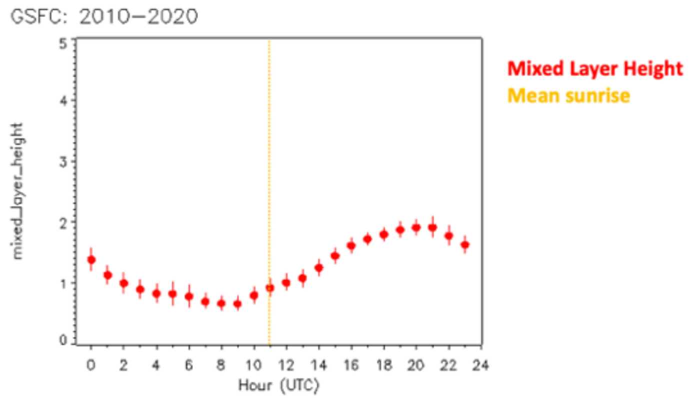
Lab cals, monitor in field, adjust routinely

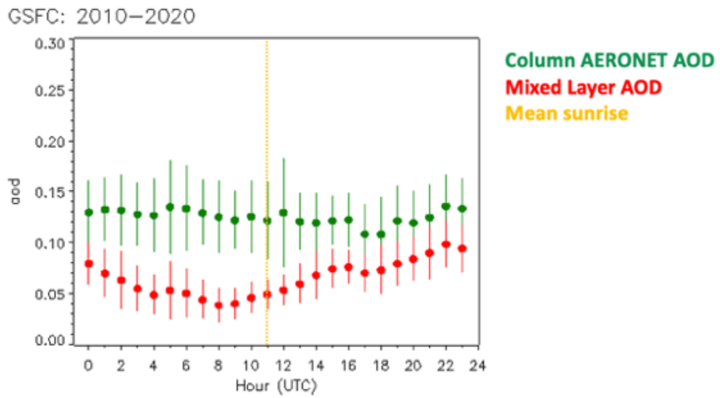
MPLNET Project Overview: Products in Development

MPLNET Level 3 Products: Monthly Diurnal Climatologies
Examples – 10 Year Climatology from GSFC

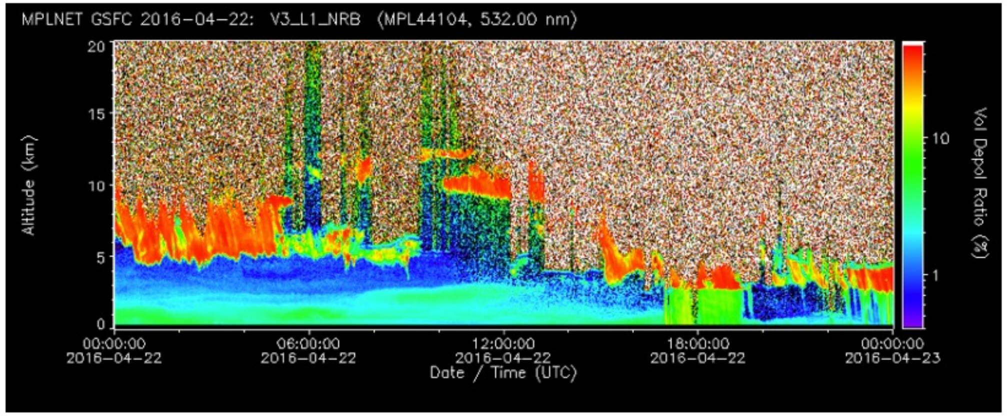


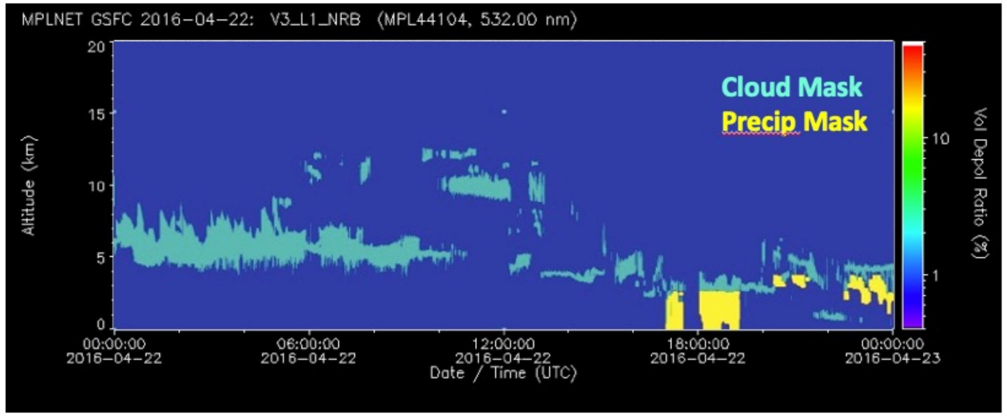






MPLNET Light Precipitation Mask:
Algorithm in development (early example shown)





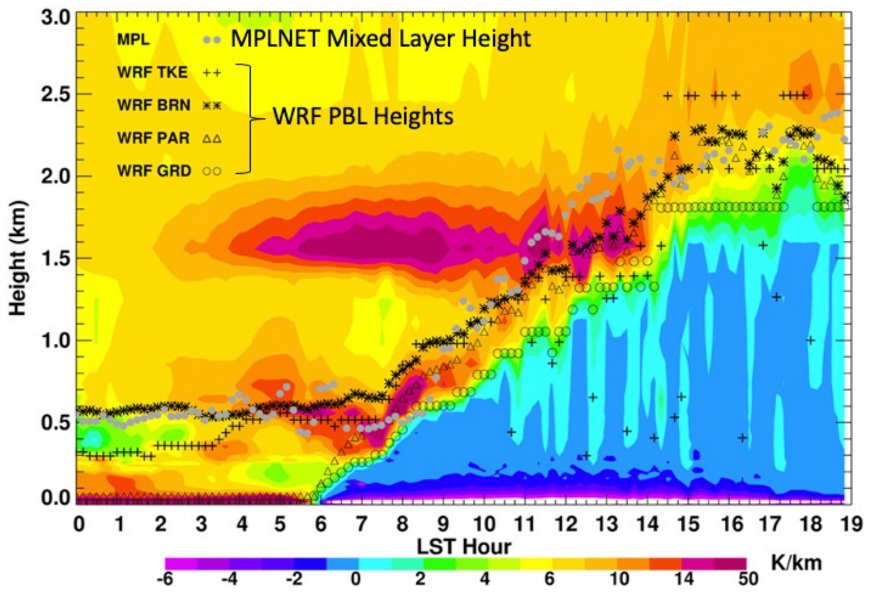
Lolli, et al., JTECH, 2013.
Lolli, et al, JTECH, 2017.
Lolli, et al, Remote Sens., 2018.
Lolli et al, Remote Sens., 2020.

Case Study Examples: Evaluation of Modeled PBL Heights

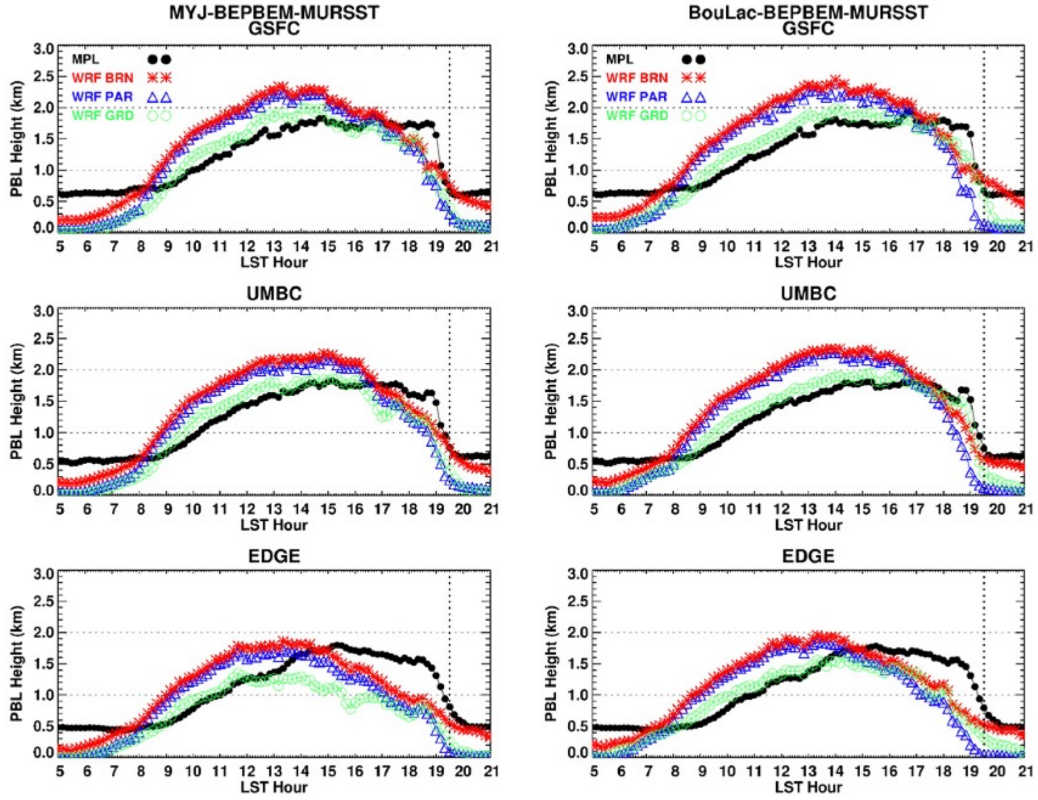
MPLNET support for PBL studies: evaluation of WRF PBL performance in the Chesapeake Bay Area

Various WRF configurations were used, summary of conclusions:

- WRF PBL heights showed more rapid growth and higher peaks than MPLNET
- WRF – lidar differences dependent on model configuration, calculation method, and synoptic conditions
- At inland locations WRF PBL heights descend earlier in the afternoon than MPLNET and radiosonde calculations

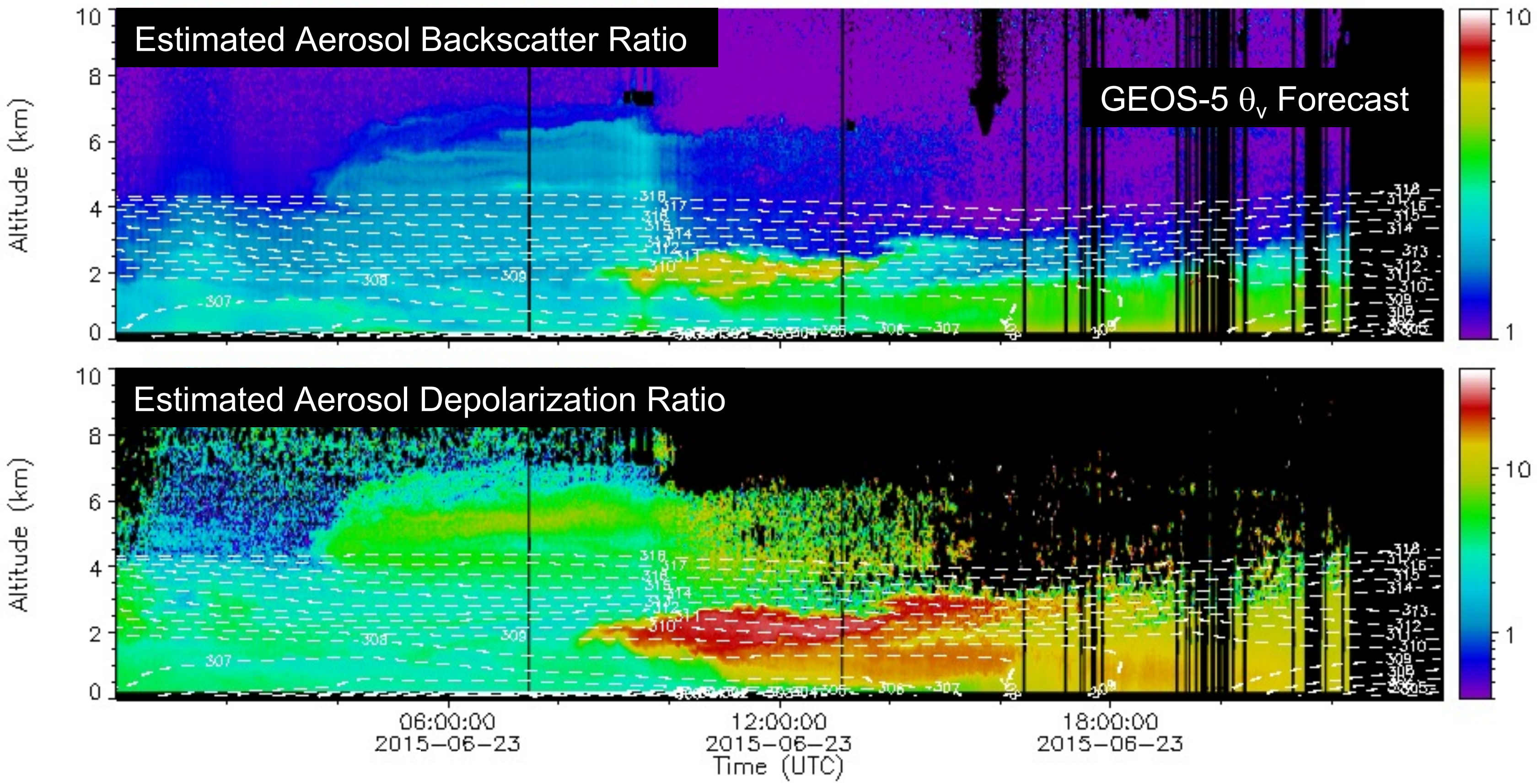


WRF Vertical Potential Temperature Gradients



Hegarty, J., J. Lewis, E. McGrath-Spangler, J. Henderson, A. Scarino, P. DeCola, R. Ferrare, M. Hicks, R. Adams-Selin, and E. Welton, 2018. Analysis of the Planetary Boundary Layer Height during DISCOVER-AQ Baltimore – Washington, DC with Lidar and High-resolution WRF Modeling. J. Appl. Meteor. Climatol. doi:10.1175/JAMC-D-18-0014.1

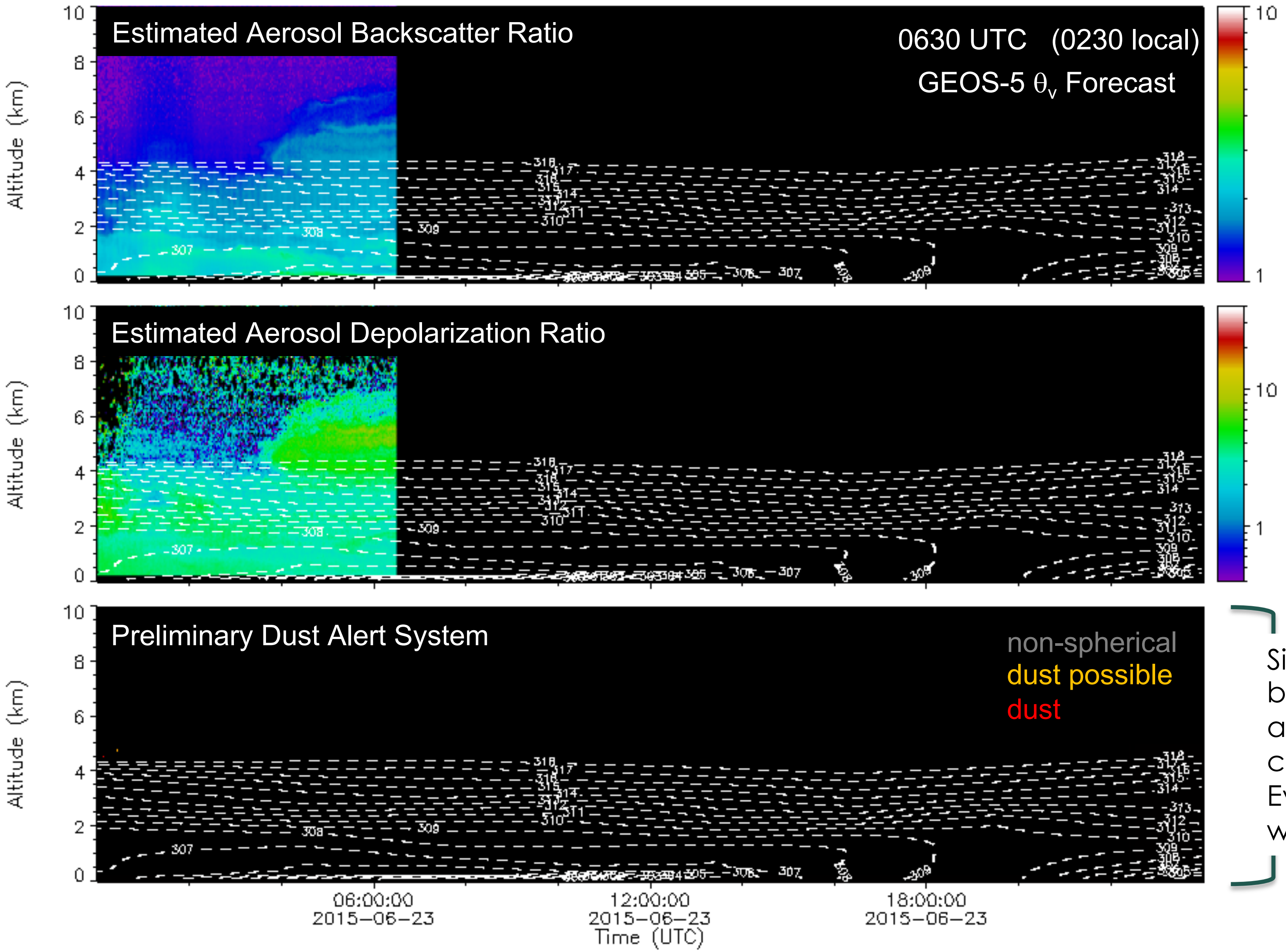
Case Study Examples: Analysis of Dust Event Using Local Lidar



Data show arrival of a dust plume in pre-dawn hours at GSFC Site. The dust eventually mixes in the boundary layer reaching the surface during the day. A quick estimate of the aerosol backscatter ratio (aerosol backscatter/total backscatter) and depolarization ratio can be calculated by fixing lidar ratio to 50 sr. The results can be used to determine an estimate of dust presence. This is demonstrated on the following slides, and can be used to forecast the arrival of dust to the surface. More advanced lidars could do a better job, even the addition of an extra wavelength would be helpful.

Case Study Examples: Analysis of Dust Event Using Local Lidar

During night
No dust yet



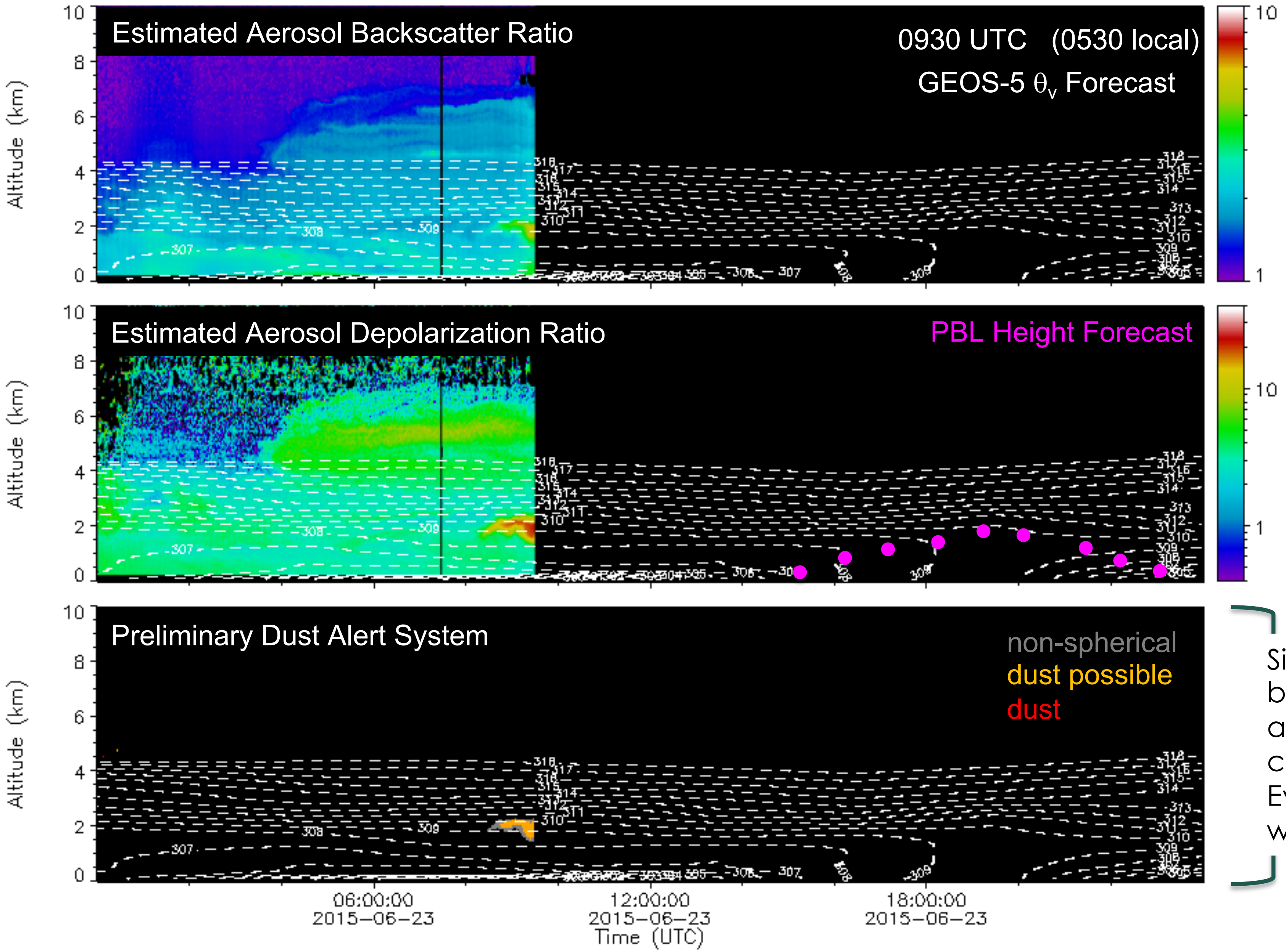
No
Sunphotometer
Required
Just Polarized Lidar

Single wavelength backscatter lidar is limited in ability. Advanced lidars could provide better results. Even just extra wavelength would be helpful.

Case Study Examples: Analysis of Dust Event Using Local Lidar

Potential dust layer appears at 2 km

Forecast PBL heights can be used to determine potential impact



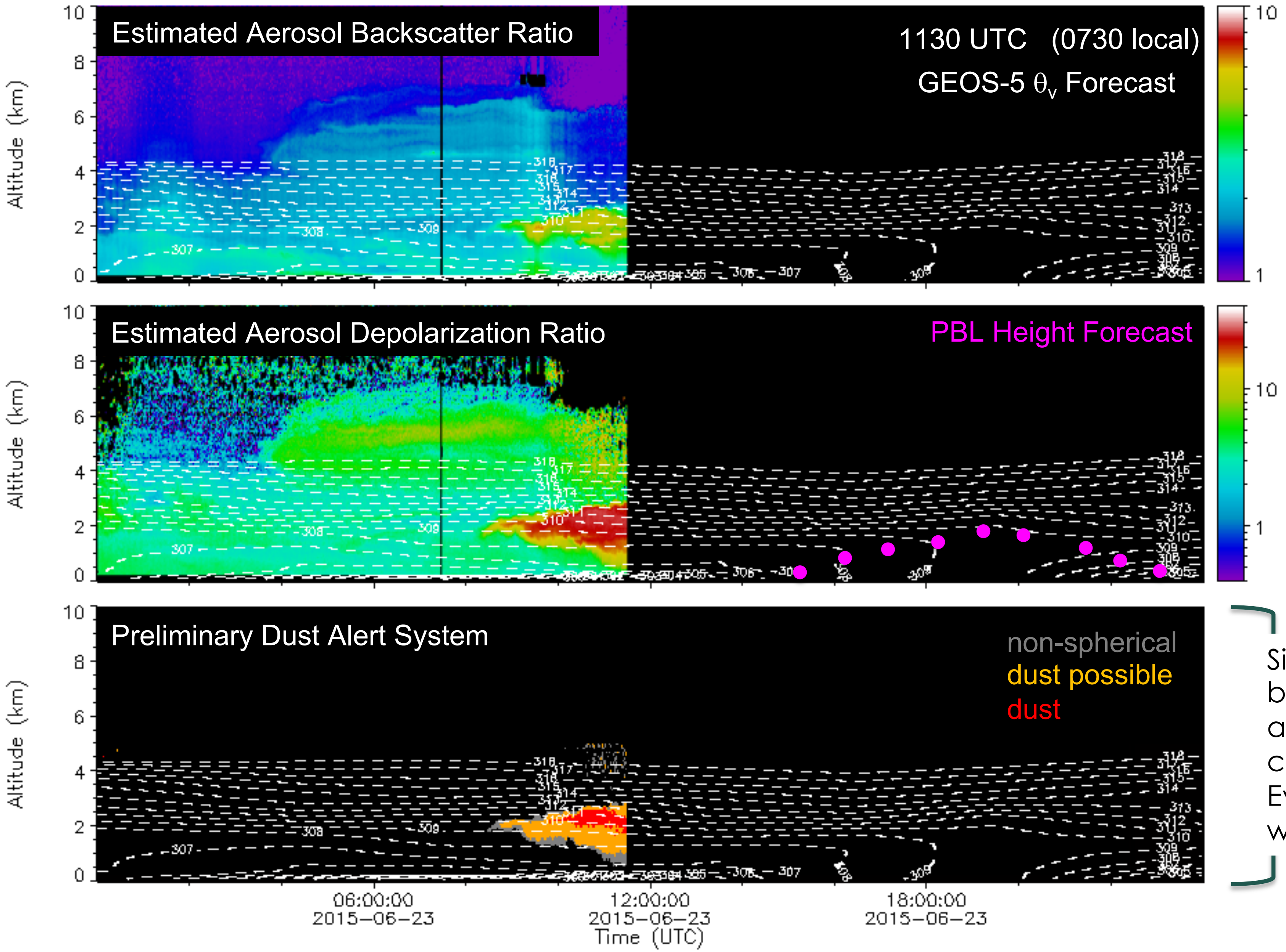
No Sunphotometer Required Just Polarized Lidar

Single wavelength backscatter lidar is limited in ability. Advanced lidars could provide better results. Even just extra wavelength would be helpful.

Case Study Examples: Analysis of Dust Event Using Local Lidar

Dust layer evolves, still above nocturnal boundary layer

At this time, significant dust unlikely to reach surface, majority of dust above 1 km



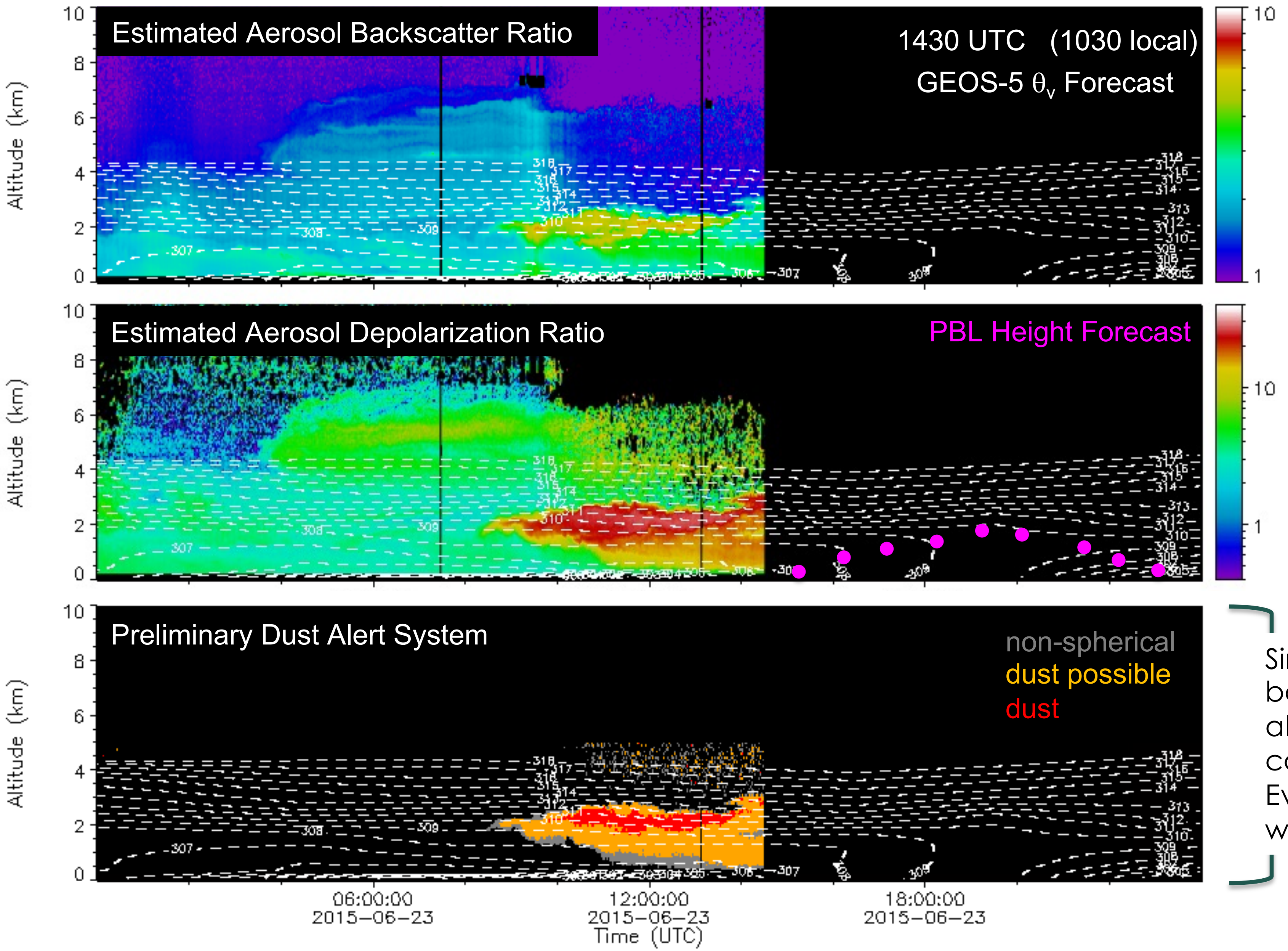
No Sunphotometer Required Just Polarized Lidar

Single wavelength backscatter lidar is limited in ability. Advanced lidars could provide better results. Even just extra wavelength would be helpful.

Case Study Examples: Analysis of Dust Event Using Local Lidar

Dust layer evolves, still above nocturnal boundary layer

Dust closer to surface, dust mixing to surface estimated after 18:00 UTC



No Sunphotometer Required Just Polarized Lidar

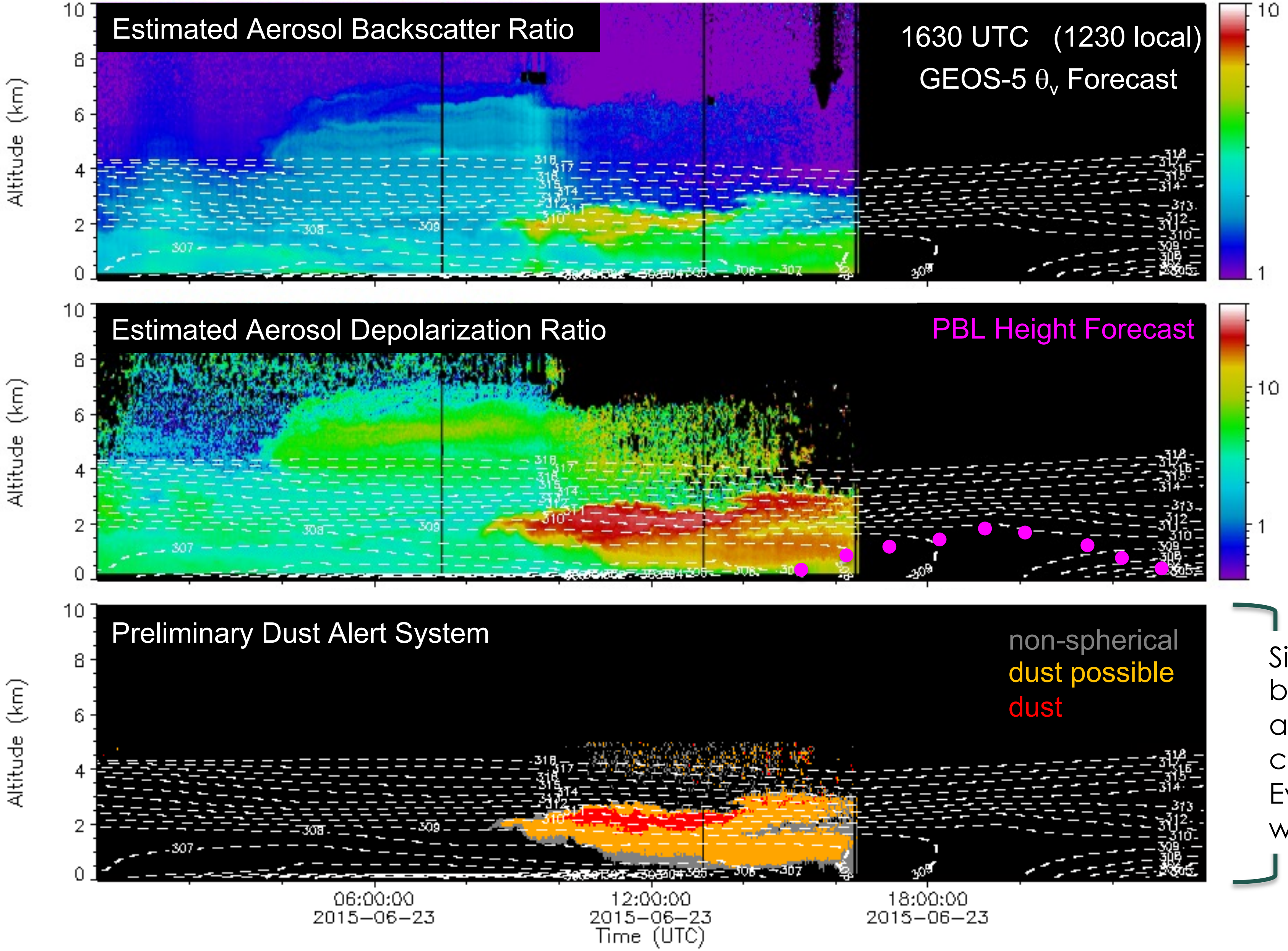
Single wavelength backscatter lidar is limited in ability. Advanced lidars could provide better results. Even just extra wavelength would be helpful.

Case Study Examples: Analysis of Dust Event Using Local Lidar

Dust layer evolves, still above boundary layer

Dust closer to surface, morning boundary layer developing.

Dust mixing to surface still estimated after 18:00 UTC



No Sunphotometer Required Just Polarized Lidar

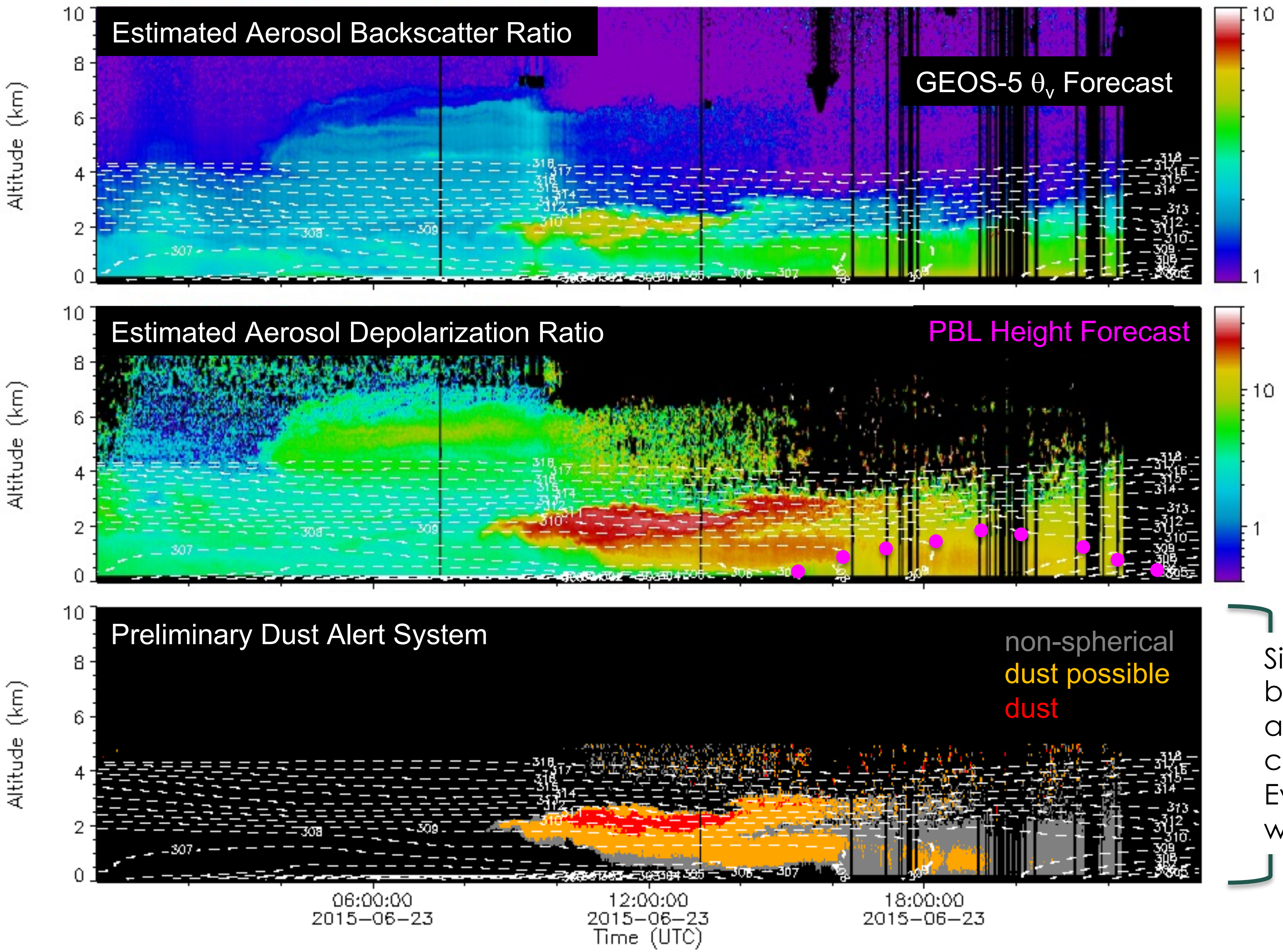
Single wavelength backscatter lidar is limited in ability. Advanced lidars could provide better results. Even just extra wavelength would be helpful.

Case Study Examples: Analysis of Dust Event Using Local Lidar

Full day of data

Well mixed boundary layer

Dust near surface around 18:00 UTC



No Sunphotometer Required Just Polarized Lidar

Single wavelength, polarized backscatter lidar is limited in ability. Advanced lidars could provide better results. Even just extra wavelength would be helpful.