The NASA Micro Pulse Lidar Network: Update and Version 3

Principal Investigator:
Judd Welton, NASA GSFC Code 612

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

All our international network partners

And of course
AERONET

New MPLNET Motto

Objective: **Version 3 Became Operational in November 2021**

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

- 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 and Earth Observing System, with significant contributions from our many site partners

South Pole

Namibia

Barbados

Thailand
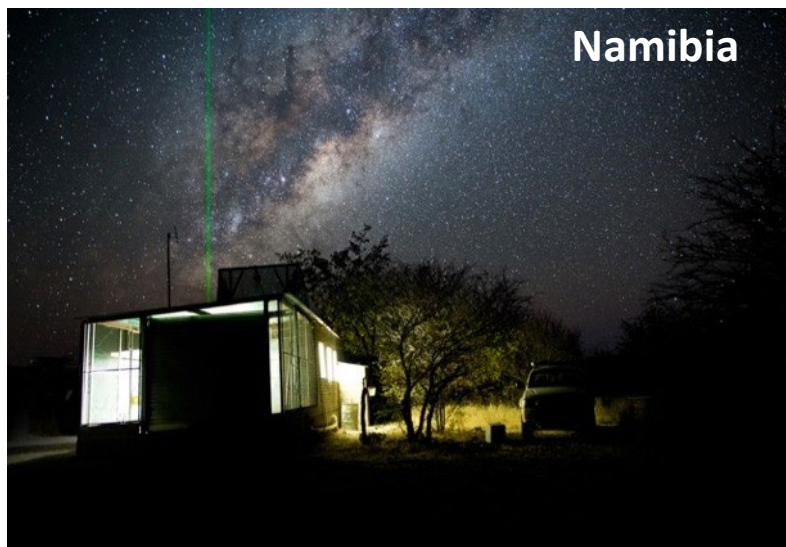
1st Commercially Available **Autonomous Eye-Safe** Lidar:
- Suitable for Network Operations

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

Green Laser (532 nm)

Atmospheric Profiles from 250 m to 30 km

Polarized ~2008

MPL

miniMPL

Control Laptop

Best performance
More expensive
Larger
Currently unavailable

Good performance
Less expensive
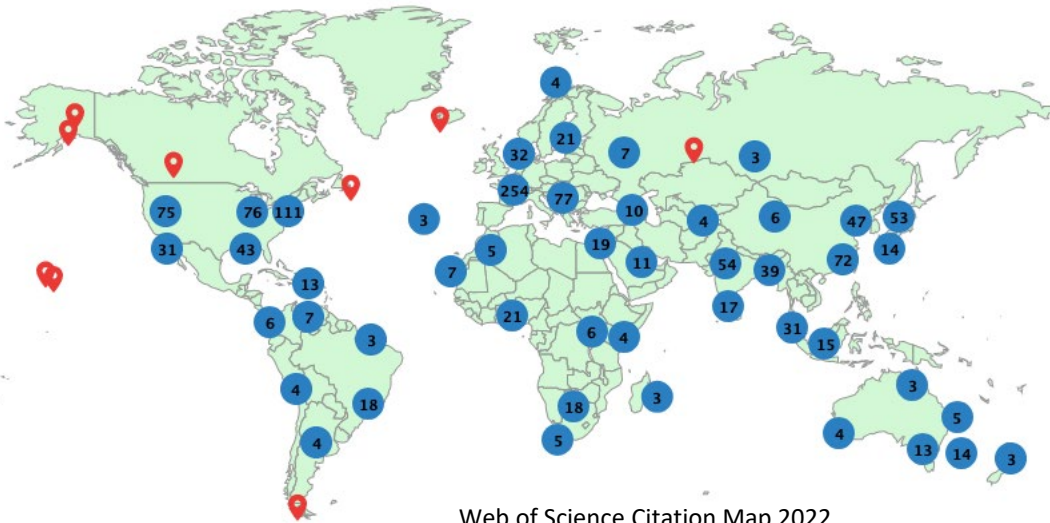Smaller, easier to ship/install

Global Backscatter Lidar Network: 2000 - current

- 80 sites total (26 active, 54 inactive). 28 countries, 46 partners.
- 6 more sites in planning
- Continuous (day/night) operations
- 97% of network co-located with AERONET

Instrumentation:

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

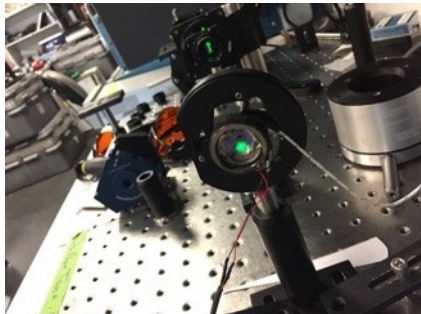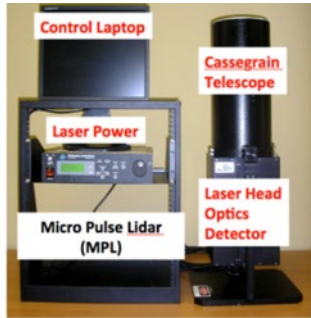**Citation Map of MPLNET publications: lead and co-author**

Web of Science Citation Map 2022
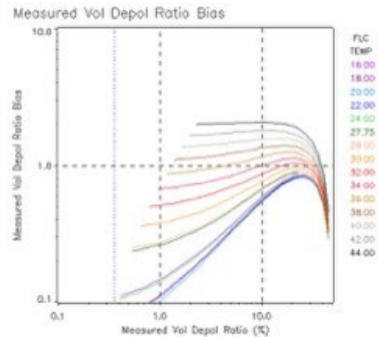
MPLNET Sites: 2000 - current

Hurricane Fiona hit our sites in Puerto Rico and Halifax in same week

Active
Inactive
Planned

Instrument Development

Polarized MPL   Polarized miniMPL
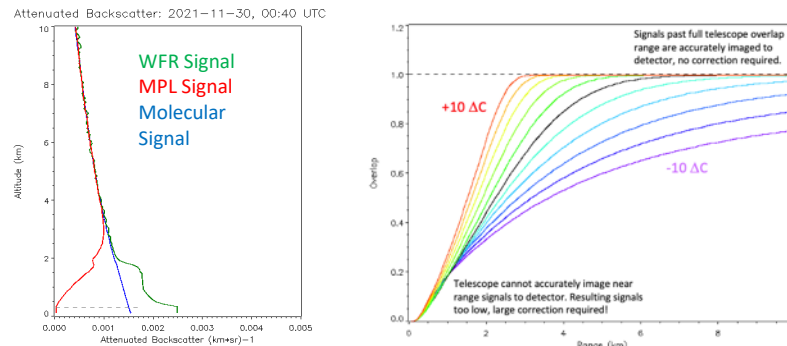

Now supported!
Level 1 Data only

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

Commercial Wide Field Receiver

in review

New commercial solution provided by AE
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

**Deployment to all sites staring FY23**

New Enclosures

New commercial solution provided by AE
Single unit design, easy to ship & setup
MPL and miniMPL sizes
Single TEC unit and much more efficient design
Better temperature control in hot/cold env
Full featured control panel with diagnostics
Computer connection, remote control
Scalable design, room for extensions

Development of new data products and improvements to existing ones: Cloud Product

- Improved Cloud Detection
- Estimates of Thin Cloud Optical Depth and Extinction
- Cloud Phase
- Hourly & Daily Cloud Fractions (column and low, mid, high level)

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.
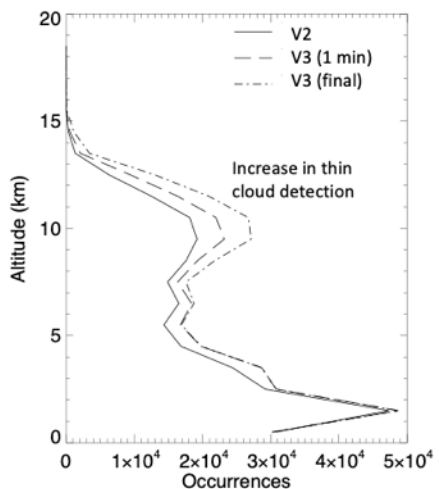
Cloud detection comparison 2012 GSFC: Older V2 results (detection only at 1 minute temporal res). V3 algorithm results at 1 minute, and the final multi-temporal results.
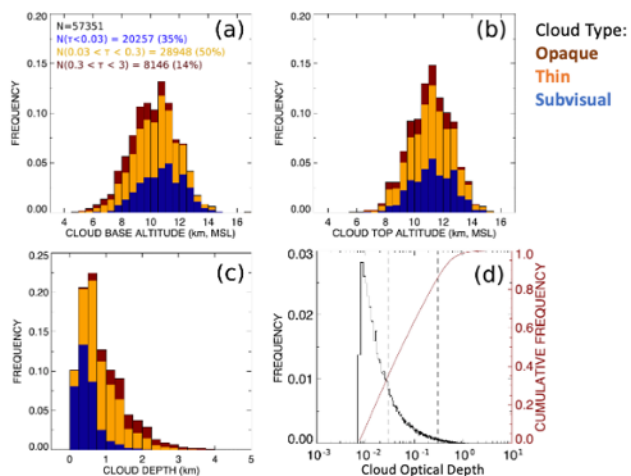
Cloud statistics for 2012 GSFC from the new V3 algorithm: Cloud base and top altitudes, and cloud depth. New in V3: estimates of cloud optical depth (up to signal attenuation).

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.
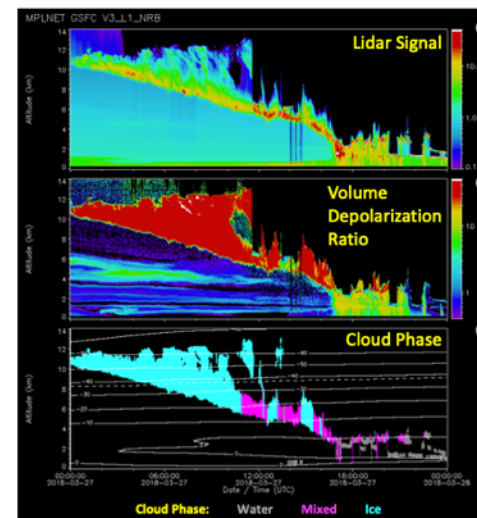
Figure 6. Frontal cloud system at GSFC on 27 March 2018: NRB (a), volume depolarization ratio (b) and phase mask (c). Altitude bins where the signal uncertainty is twice the signal strength have been suppressed for easier viewing. Note the use of a log scale for the NRB. The phase mask indicates liquid 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.
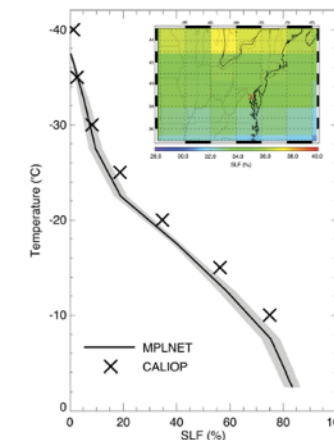
Figure 9. Supercooled liquid fraction (SLF) averaged over GSFC (2015–2019) from MPLNET (solid line) and CALIOP (black × observations. The inset shows the horizontal distribution of CALIOP SLFs at the −20 °C isotherm surrounding GSFC (indicated by the red ×). The CALIOP SLF profile is calculated using 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.

Development of new data products and improvements to existing ones: **Aerosol Product**

- 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 GSFC Site: Incorporation of AERONET Lunar AOD

Calibration Value, AOD   Lidar Ratio: MPLNET, AERONET
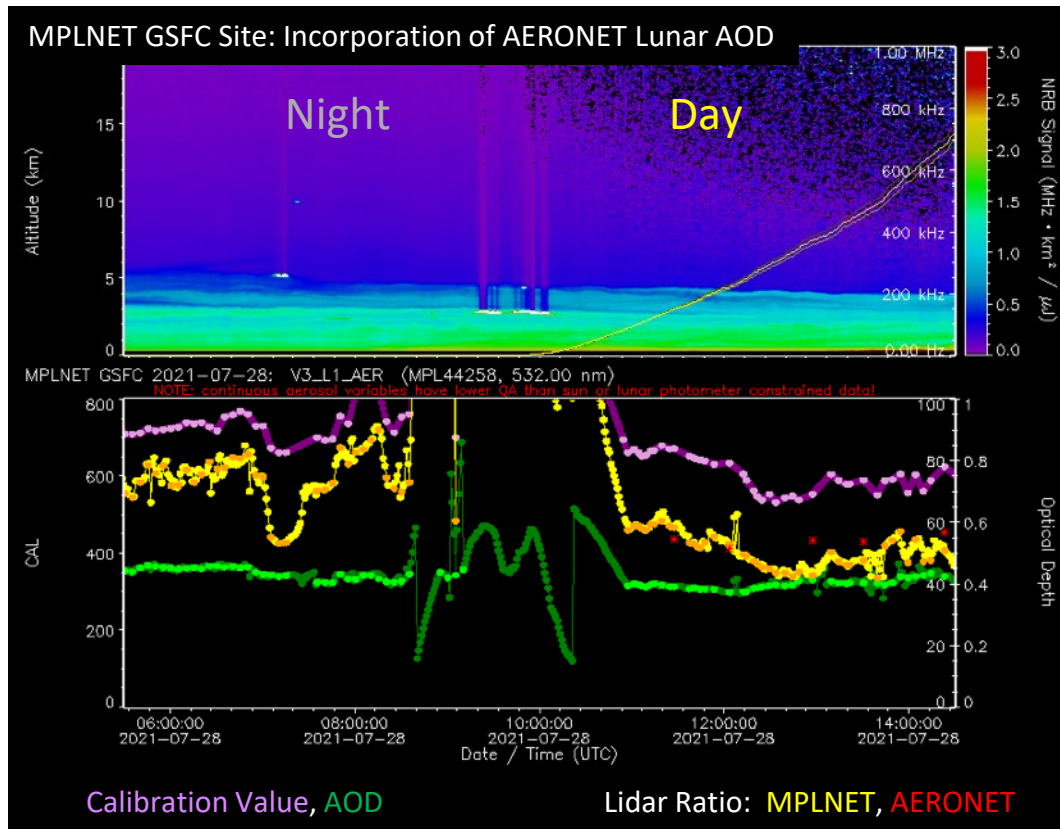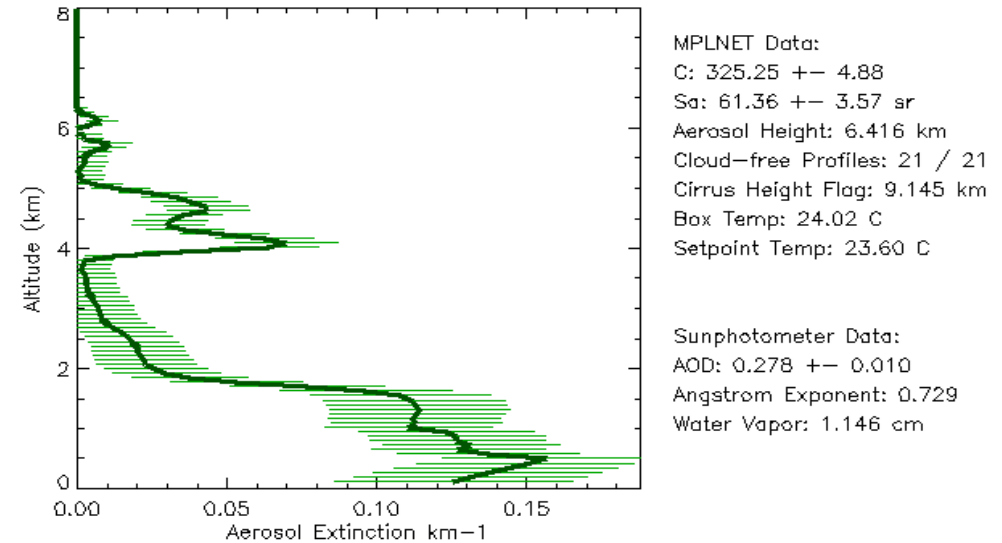
Aerosol Properties:
- Retrievals at coincident AERONET AOD observations
- Using constrained Fernald solution (**Welton et al 2000**): integral of extinction = AOD
- Algorithm calculates the lidar calibration value (C), backscatter and extinction profiles, and a <u>column average lidar ratio*</u>

* If different aerosol "types" are stratified in different layers, then the MPLNET lidar ratio will be a weighted average of all.

Development of new data products and improvements to existing ones: PBL Product

- V2 beta PBL product was not officially released (too many bugs)
- V3 PBL product significantly improved using Lewis et al 2013 algorithm
- Further refinements during past 5 years led to better diurnal performance
- Product provides mixed layer height and mixed layer AOD
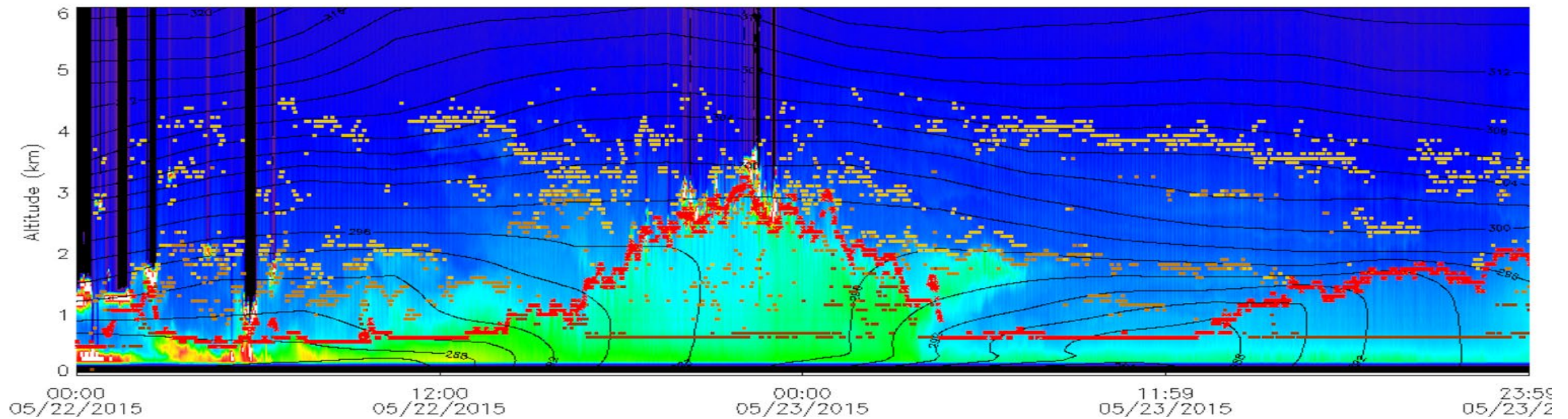
GSFC, USA: 2017-03-16 to 2017-03-20
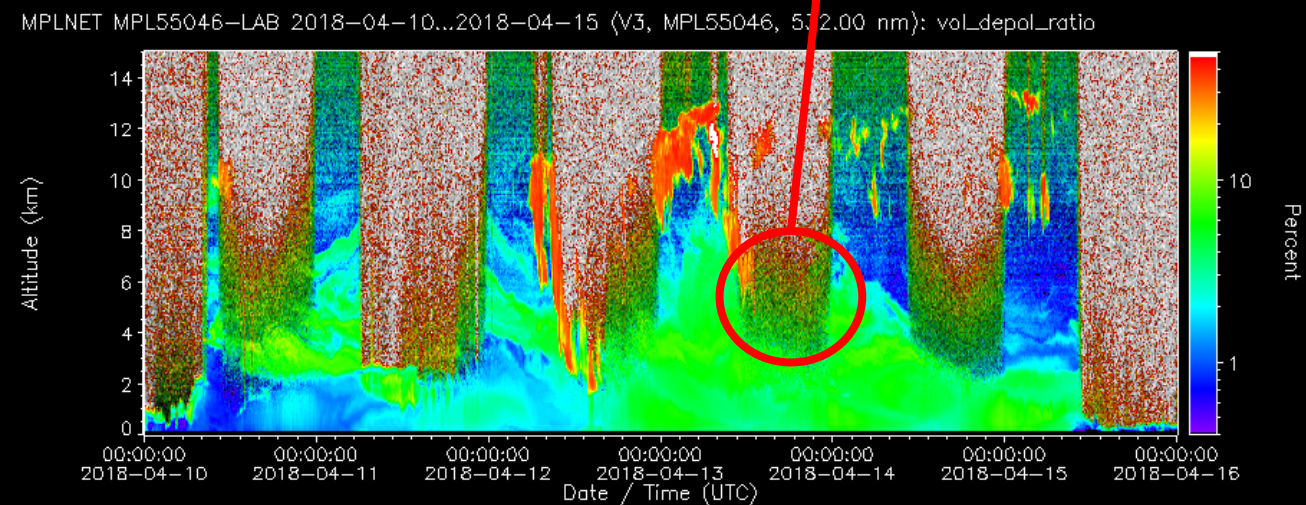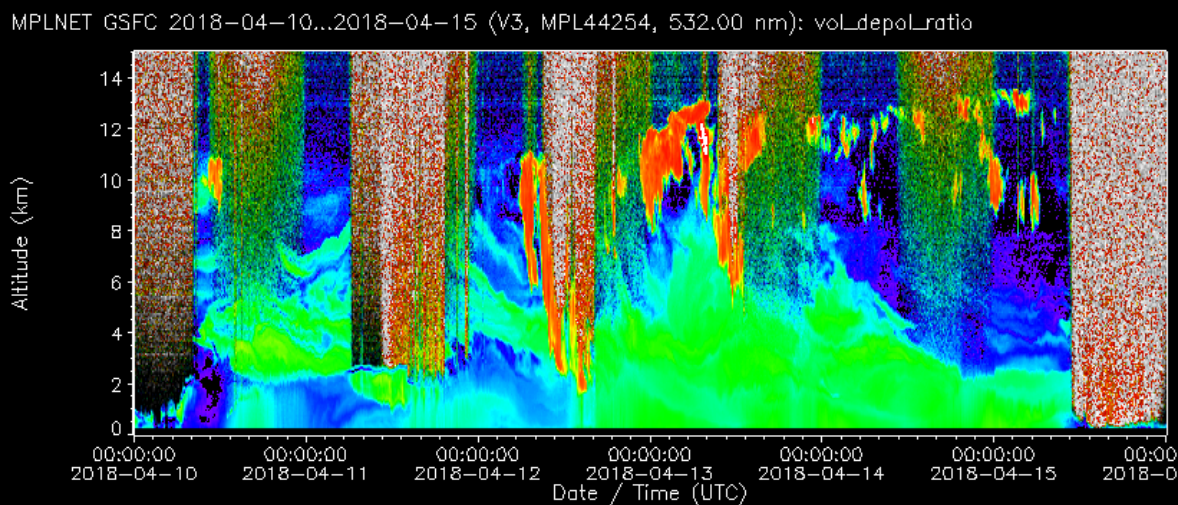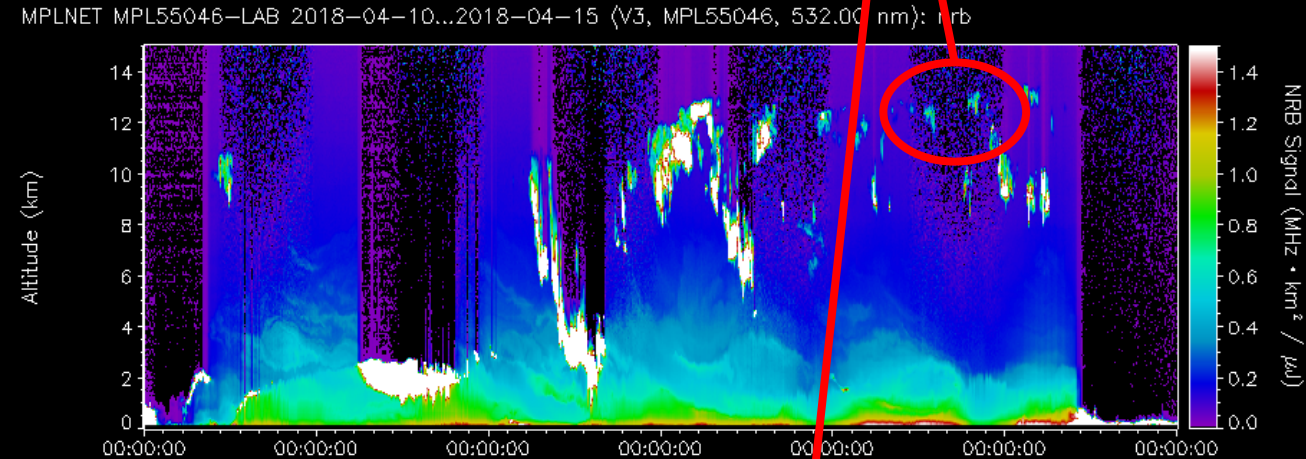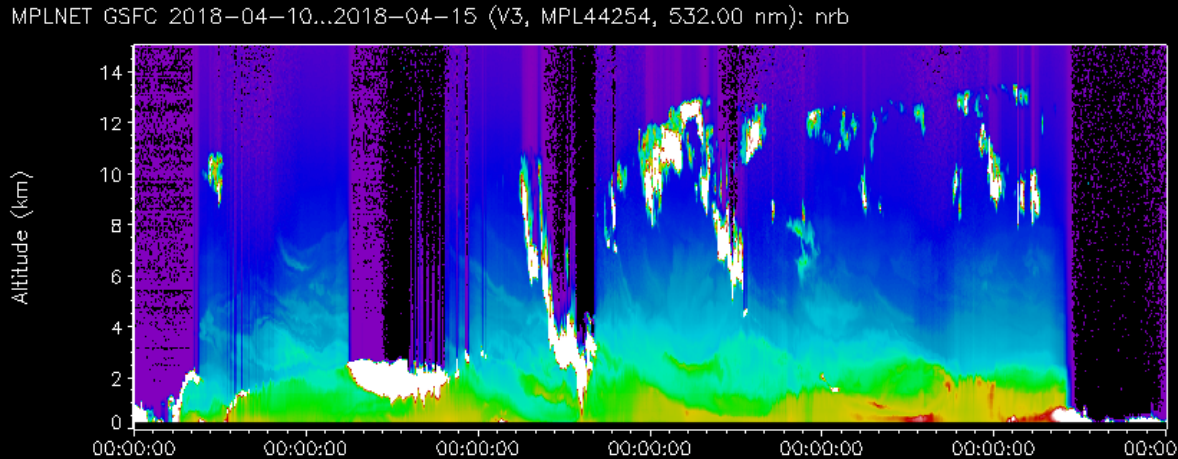
Ragged_Point, Barbados: 2015-07-25 to 2015-07-26
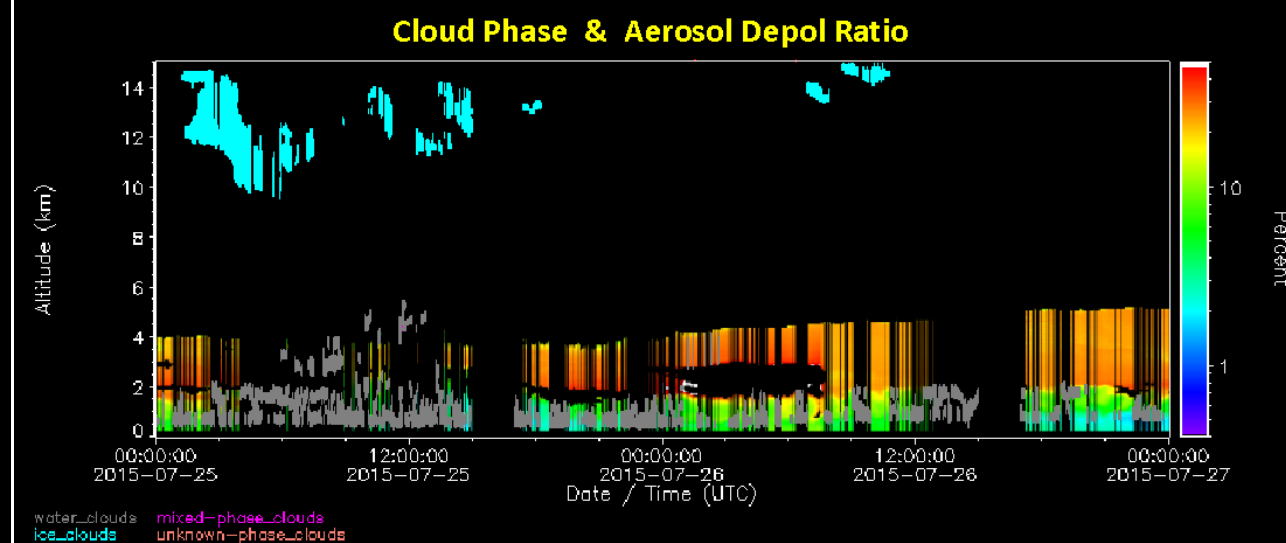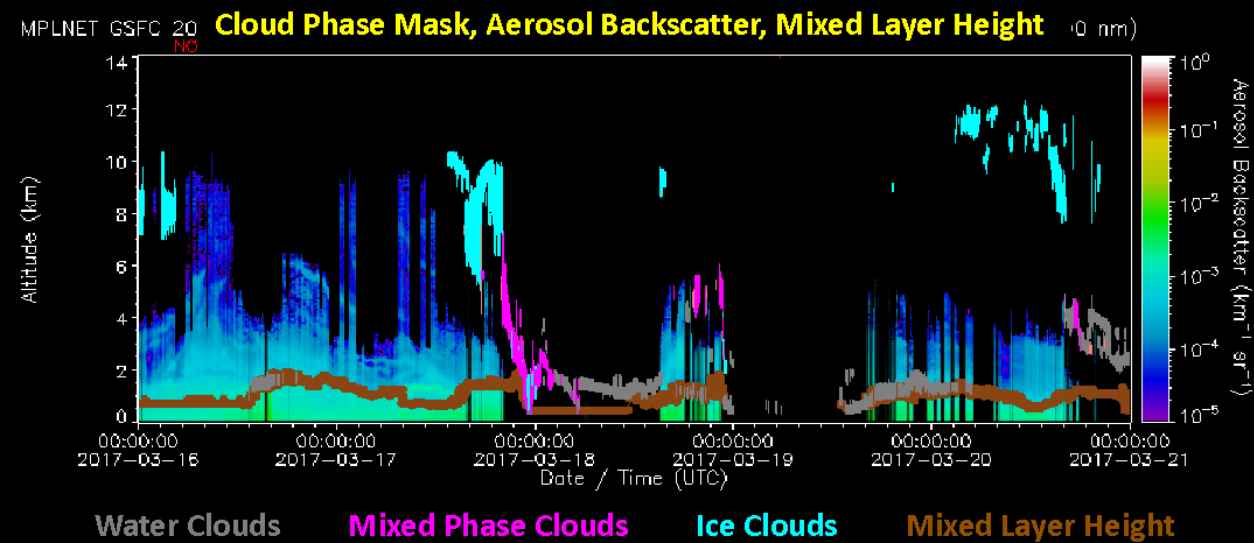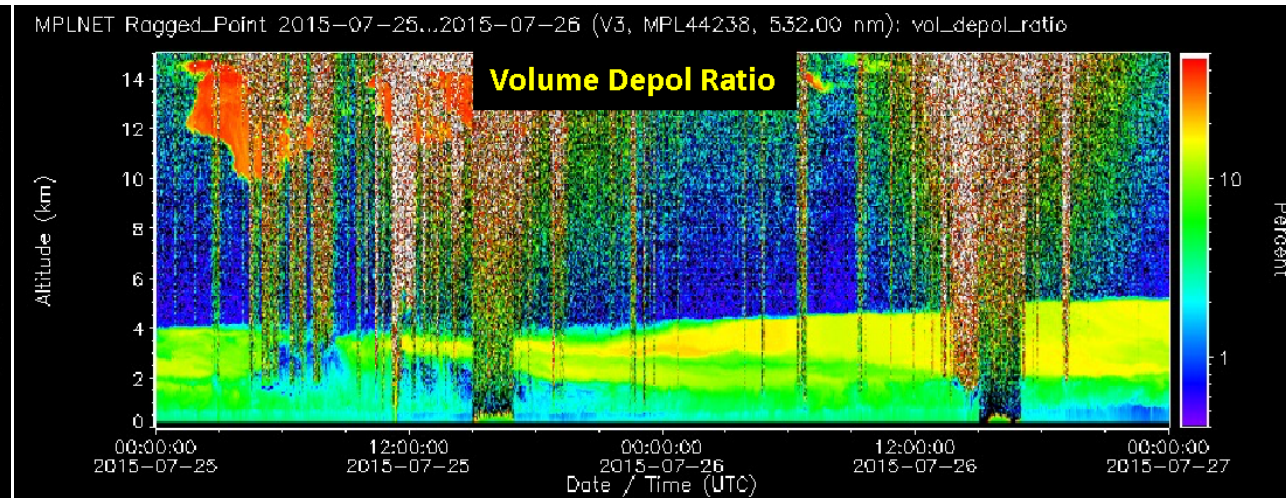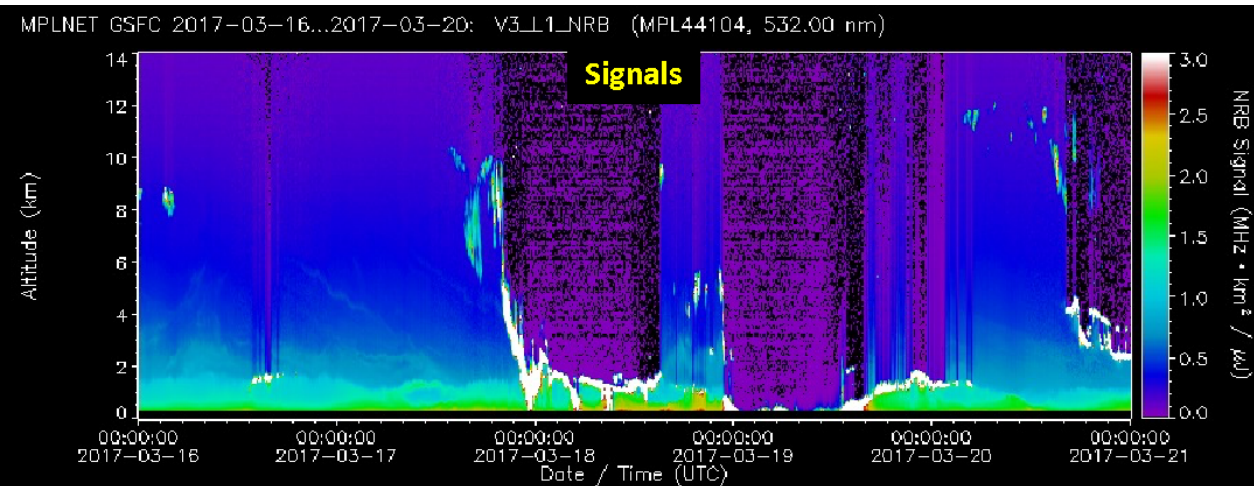
MPLNET Version 3 Development: MPL vs miniMPL

Lower SNR, retrieval algorithms need further study for L2 results from miniMPL

GSFC MPL (operational)

GSFC miniMPL

MPLNET Version 3 current capabilities

Modernized Data Product Suite and aligned with AERONET V3

Online Product Information: https://mplnet.gsfc.nasa.gov/product-info/

Version 3 Products
- Suite of 4 products grouped by theme, each containing variables and diagnostics
- Standardized format, netcdf4, CF compliance, full error propagation from raw data
- **Online "ATBDs"**

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.

Version 3 Product Levels
- **Aligned with new AERONET L1.5 (QA in NRT)**
- All L1 and L1.5 products available in NRT (< 1 hour) via automated data transfer and processing system
- **New, standard QA flags in all products**
- NRT QA screen applied at L1.5, final QA at L2
- L3 products in development (created from L2 data)

flag_data: flag indicating if elastic signal data are missing

Values	Meanings
0B	ignore
1B	data_exists
2B	data_missing

flag_calibration_I0: flag indicating if elastic signal data calibrations were not applied

Values	Meanings
0B	ignore
1B	all_calibrations_applied
2B	deadtime_calibration_missing
4B	darkcount_calibration_missing
8B	afterpulse_calibration_missing
16B	overlap_calibration_missing
32B	polarization_calibration_missing

flag_temperature_correction: flag indicating if elastic signal data temperature corrections were not applied

Values	Meanings
0B	ignore
1B	all_temperature_corrections_applied
2B	overlap_temperature_correction_missing
4B	polarization_temperature_correction_missing
8B	filter_temperature_correction_missing
16B	detector_temperature_correction_missing
32B	window_temperature_correction_missing

flag_energy: flag indicating possible laser energy problems for elastic signal data quality assurance

Values	Meanings
0B	ignore
1B	no_problems
2B	15%_<_energy_deviation_from_set_point_<=_20%
4B	energy_deviation_from_set_point_>_20%
8B	no_set_point
16B	measurement_fault

flag_temp_box: flag indicating possible box telescope temperature problems for elastic signal data quality assurance

Values	Meanings
0B	ignore
1B	no_problems
2B	2C_<_temperature_deviation_from_set_point_<=_5C
4B	temperature_deviation_from_set_point_>_5C
8B	no_set_point
16B	measurement_fault

flag_temp_detector: flag indicating possible detector temperature problems for elastic signal data quality assurance

Values	Meanings
0B	ignore
1B	no_problems
2B	2C_<_temperature_deviation_from_set_point_<=_5C
4B	temperature_deviation_from_set_point_>_5C
8B	no_set_point
16B	measurement_fault

flag_temp_laser: flag indicating possible laser temperature problems for elastic signal data quality assurance

Values	Meanings
0B	ignore
1B	no_problems
2B	placeholder
4B	placeholder
8B	no_set_point
16B	measurement_fault

flag_temp_flc: flag indicating possible FLC temperature problems for elastic signal data quality assurance

Values	Meanings
0B	ignore
1B	no_problems
2B	placeholder
4B	placeholder
8B	no_set_point
16B	measurement_fault

- All of the detailed flag data are summarized in final QA flag below
- This flag is carried forward to all retrieved products to describe signal quality.

flag_qa: overall QA Flag for NRB product

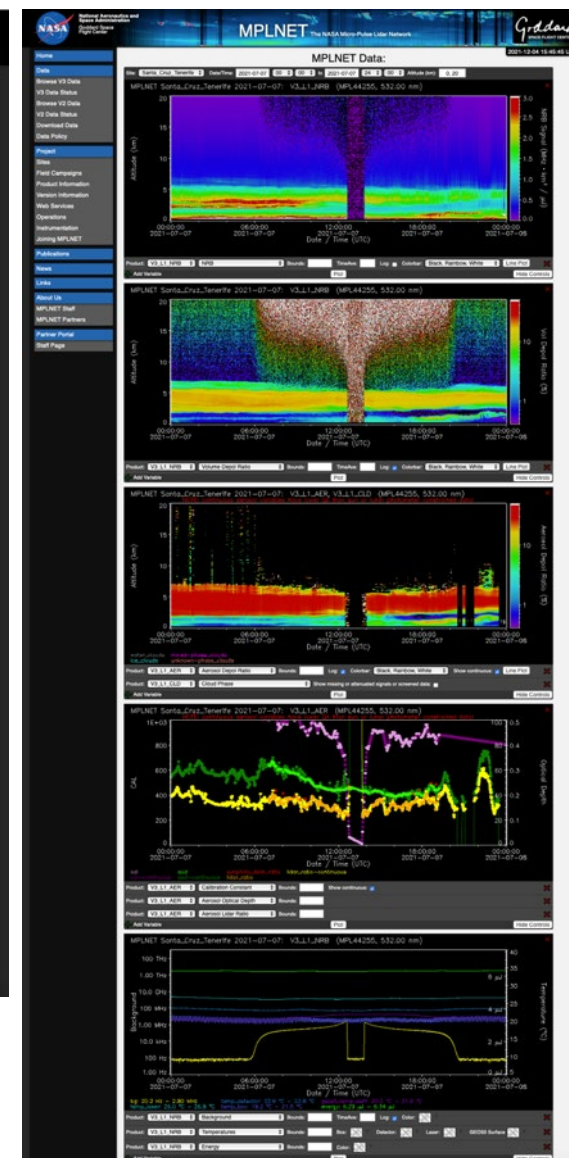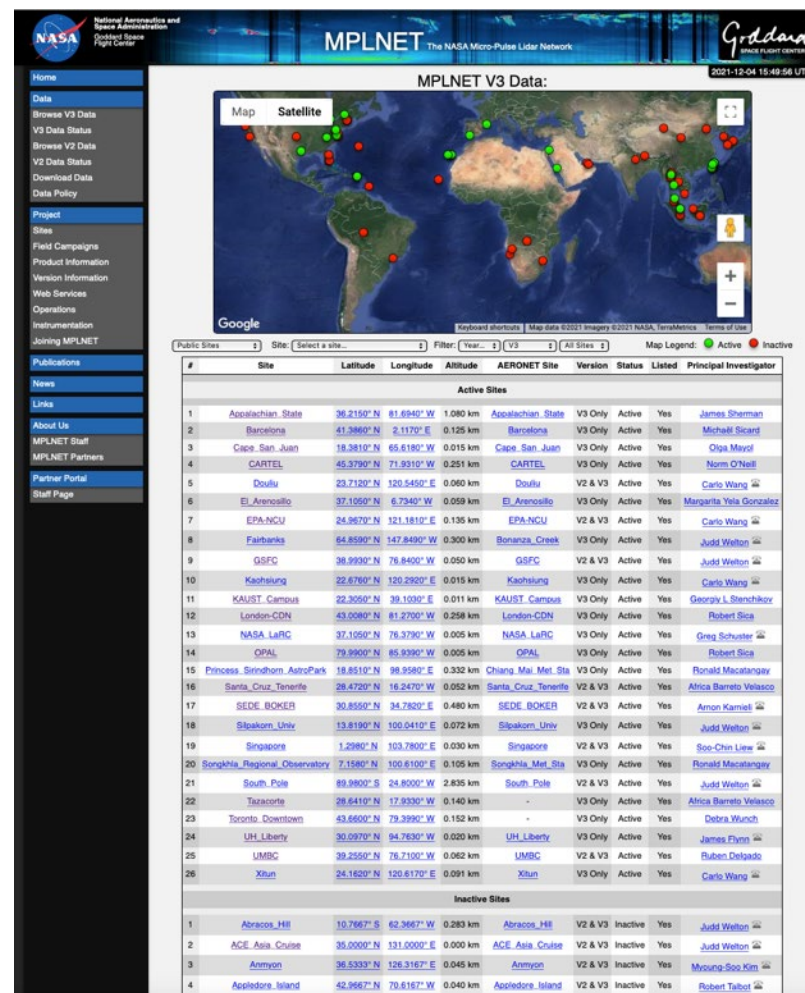| Values	Meanings
0L	ignore
1L	no_problems
2L	flag_calibration_I0
4L	flag_energy
8L	flag_temp_box
16L	flag_temp_detector
32L	flag_temp_laser
64L	flag_temp_flc
128L	flag_temperature_correction

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

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

MPLNET Version 3 current capabilities

New data center developed with new infrastructure and interoperability

Entirely new data center developed with new infrastructure
- Hardware: 72 cores, 60TB+ storage
- **Full support for near-real time operations**
- **Data communications: now HTTPS**
  - All telemetry from field sites
  - Data delivery to users
- Environment: Ubuntu Linux, mainly IDL based processing with some python and shell scripting
  - Move to ILD 8+, with modern language features
  - **Improved and expanded MPLNET library functions, programs. Object oriented, version control (ops vs R&D)**
- Innovative website design utilizing IDL via custom translator
  - Integrates our processing and database functions directly with HTML and CGI scripting
  - **Rapid development of web based tools, apps, image browsing, APIs**
  - **Network operations managed with series of web based tools, from office/home/field**
- **Interoperability (automated inter-connections with other data centers, cloud computing)**
  - APIs for site metadata, data download, data plot browsing/embedding
  - Working on support for WMO WIGOS metadata framework
  - GALION data center will ensure interoperability between global surface lidar networks

Data Center Tool Examples :   Download Data Options

MPLNET Version 3 current capabilities

Data Center Tool Examples :   Web Services

For ICAP centers:
we can provide NRT accounts (user/pass) for access to our standard products via the download API,
and also develop custom products as needed (subsets, or different variable packaging).

MPLNET Version 3 current capabilities

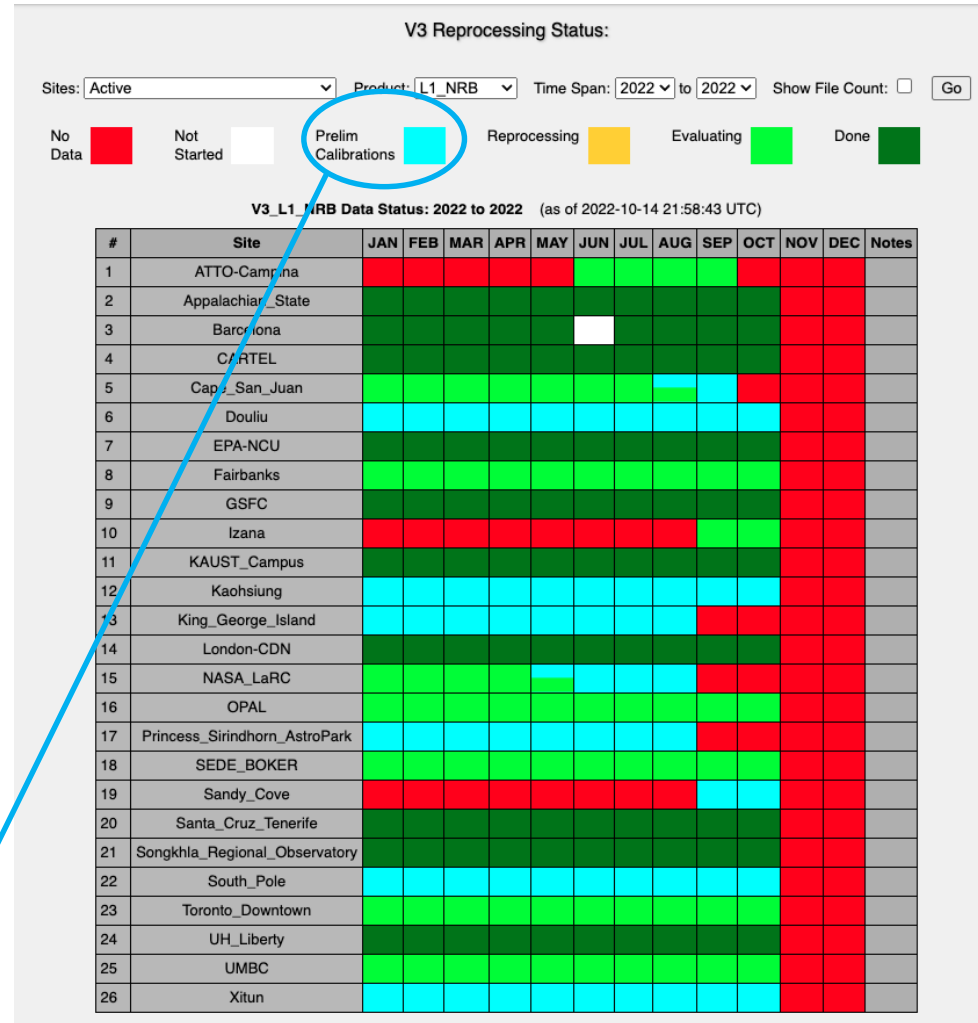## V3 Status: active sites

V3 Officially Released Nov 5, 2021
- **Major delays due to COVID**
- Planned new hires in 2020 were not possible
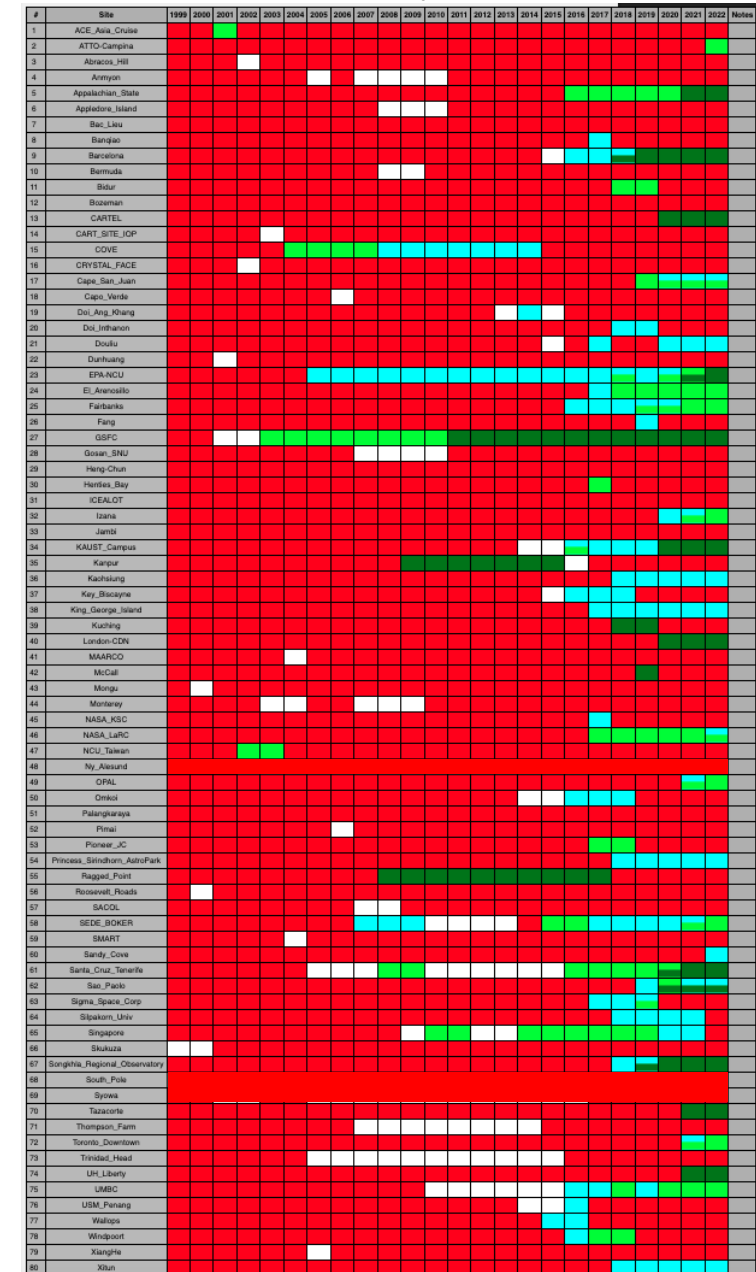
Release Plan
- **Go live with first batch of actives sites**
- **Begin working on remaining active sites**
- **Reprocess all older data**
- Sites with long time record get priority
- Other data needed for publications/studies will get priority also
- Initiate delayed hiring Q1 2022

Further delays: 2022
- Ongoing issues with support contract at NASA Goddard have continued to prevent new hires (programmer/data analyst and technician)

V3 Reprocessing Status:

Sites: Active   Product: L1_NRB   Time Span: 2022 to 2022   Show File Count: ☐   Go

| No Data | Not Started | Prelim Calibrations | Reprocessing | Evaluating | Done |

V3_L1_NRB Data Status: 2022 to 2022   (as of 2022-10-14 21:58:43 UTC)

#	Site	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Notes
1	ATTO-Campina													
2	Appalachian_State													
3	Barcelona													
4	CARTEL													
5	Cape_San_Juan													
6	Douliu													
7	EPA-NCU													
8	Fairbanks													
9	GSFC													
10	Izana													
11	KAUST_Campus													
12	Kaohsiung													
13	King_George_Island													
14	London-CDN													
15	NASA_LaRC													
16	OPAL													
17	Princess_Sirindhorn_AstroPark													
18	SEDE_BOKER													
19	Sandy_Cove													
20	Santa_Cruz_Tenerife													
21	Songkhla_Regional_Observatory													
22	South_Pole													
23	Toronto_Downtown													
24	UH_Liberty													
25	UMBC													
26	Xitun													

Major effort is recalibrating instrument overlap for all older data
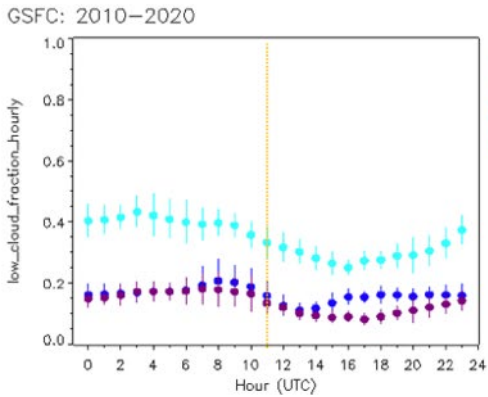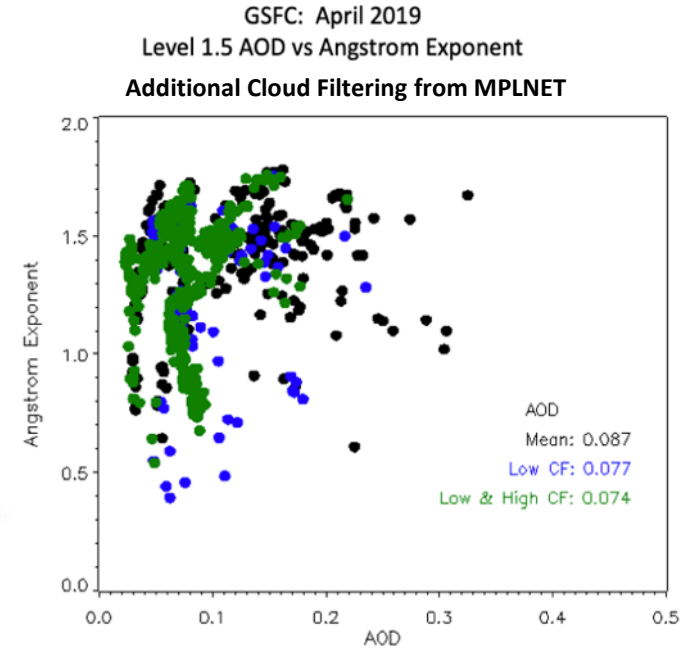
Prelim V3 Results

MPLNET Level 3 Beta Testing: Monthly Diurnal Climatologies
Example – 10 Year Climatology from GSFC
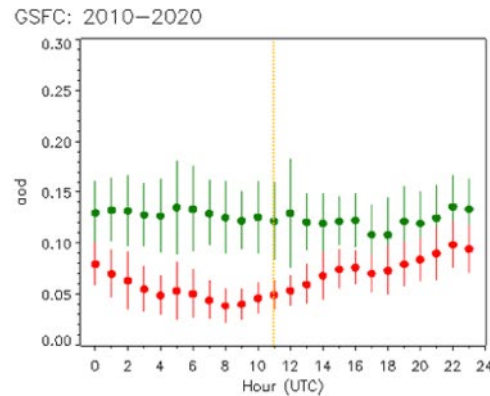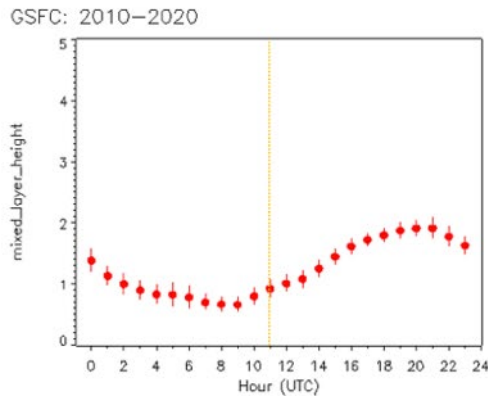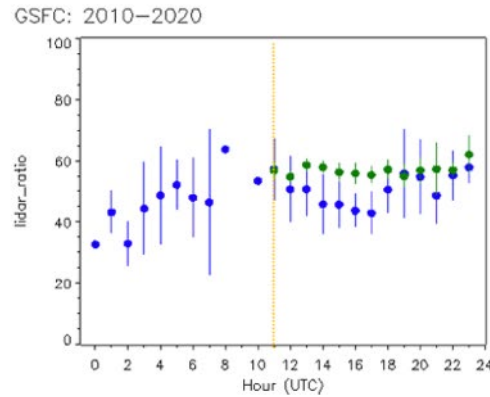
Aerosol properties in cloudy scenes with MPLNET - AERONET

The climatologies provide better statistical results and are more regionally representative than L1.5 or L2 data.

More work is required to understand influence of nearby clouds on AERONET obs

MPLNET Measurements of Light Precipitation Events: Detection and Retrieval of Properties

Importance of detection of light precipitation (below typical radar detection capability)
- Events are frequent, and cumulative totals factor into water cycle
- Contribution to aerosol wet deposition for frequent light rain events
- Aerosol processing at cloud base
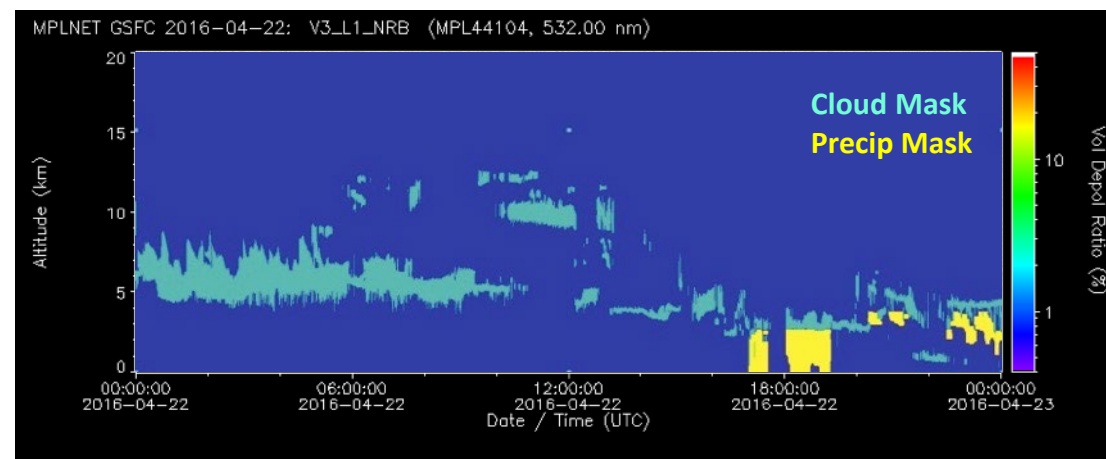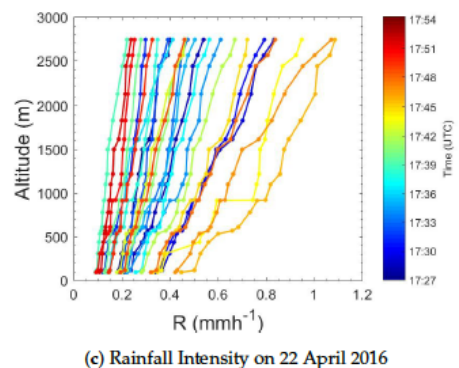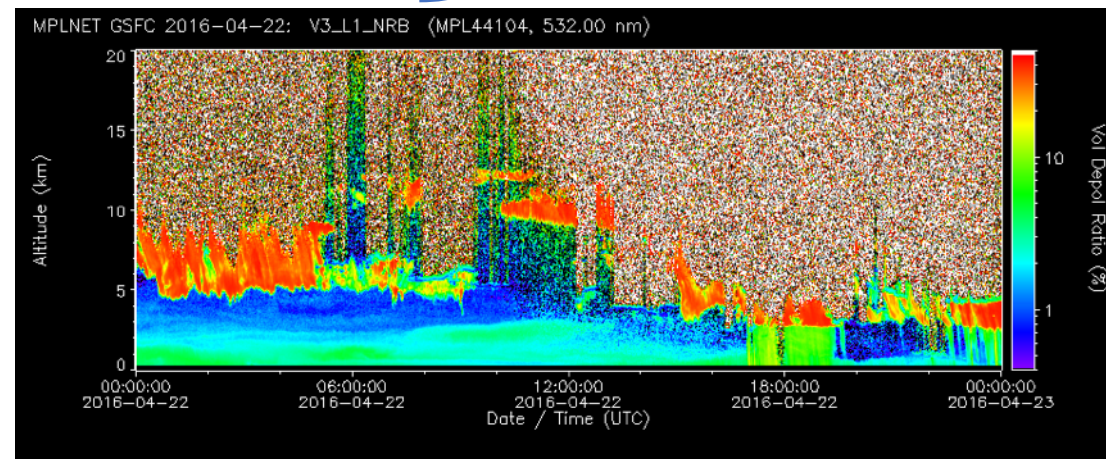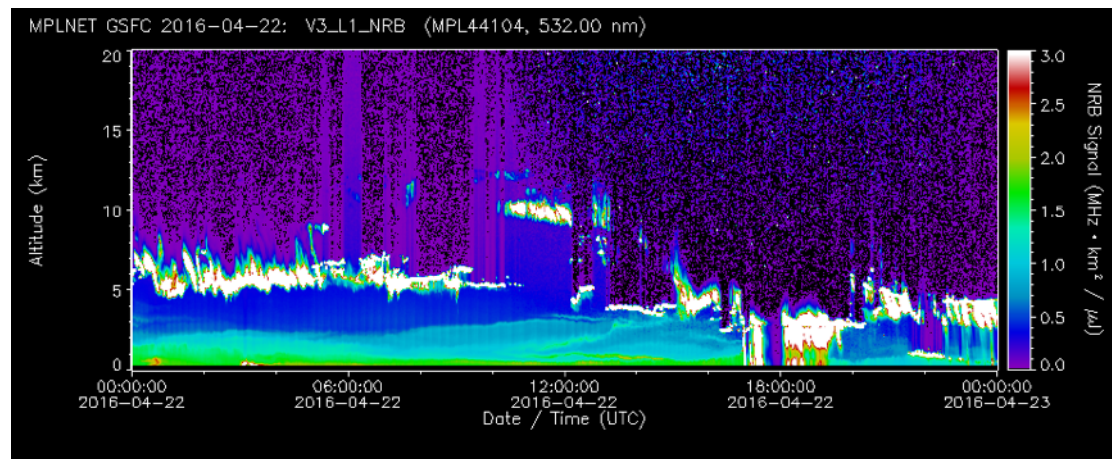
Lolli, et al., JTECH, 2013.
Lolli, et al, JTECH, 2017.
Lolli, et al, Remote Sens., 2018.

Series of papers on proof of concept
Retrieval of rain drop size, rain rate, evaporation rate

Lolli et al, Remote Sens., 2020.

Precipitation Detection Algorithm (future V3 product)

Studies demonstrate ability to retrieve rain rate profiles with co-located disdrometer.

Profiles of rain drop size possible with additional lidar wavelength. (not shown)

(c) Rainfall Intensity on 22 April 2016

Figure 3. Vertically-resolved rainfall intensity computations at different measurement times for the GSFC MPLNET station on 22 April 2016. (a) MPL cross-polar channel signal; (b) cloud base height automatically retrieved by V3 L1 Cloud algorithm; (c) vertically-resolved rainfall intensities, computed with the analytical model solution using disdrometer data and V3 L1 cloud base height retrieval, from 5:27 p.m. UT to 5:54 p.m. UT.
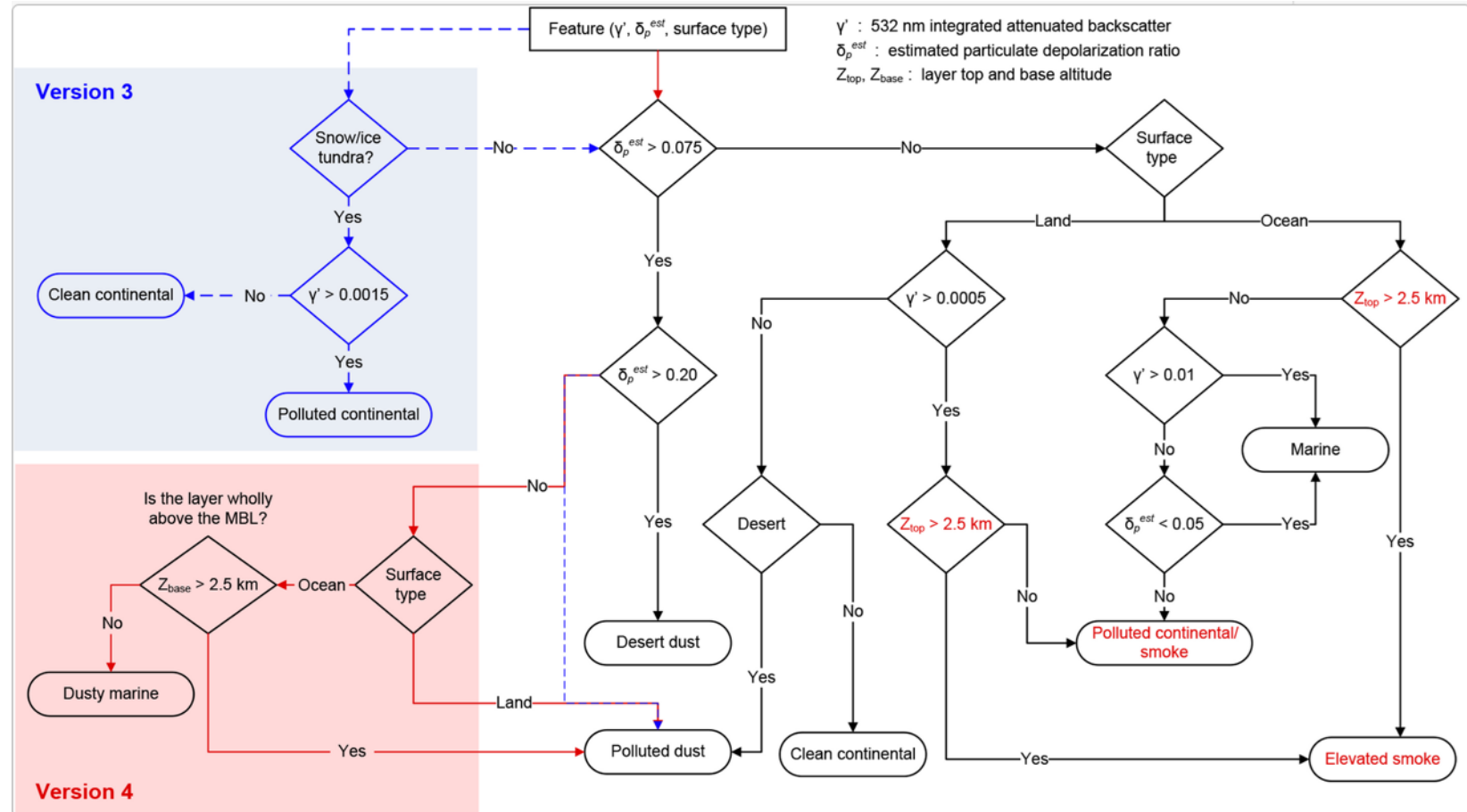
The NASA CALIPSO satellite is nearing end of life, with science operations expected to end in late 2023. Plans are underway to complete a last processing version (V5) to provide final data products from the mission.

CALIOP is a two wavelength (532, 1064 nm) backscatter lidar with polarization capability at 532 nm.

The aerosol products are dependent on determination of aerosol type by layer, and assignment of the aerosol lidar ratio in order to calculate extinction.
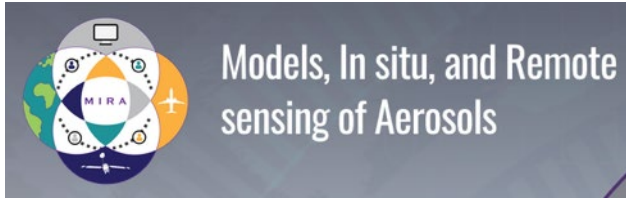
This can lead to large errors in retrieved extinction due to the lack of constraining observations.

V5 plans include a significant overhaul of the aerosol product.

MPLNET is providing lidar ratios from under-sampled regions

Models, In situ, and Remote sensing of Aerosols

MIRA-WG Projects

- Particulate Matter from Lidars in Space (PMLS)
- Maps of Aerosol lidar ratios for CALIPSO (MAC)
- Tables of Aerosol Optics
- Harmonization of aerosol Assimilation Models and Retrievals (HAMR)

https://science.larc.nasa.gov/mira-wg/
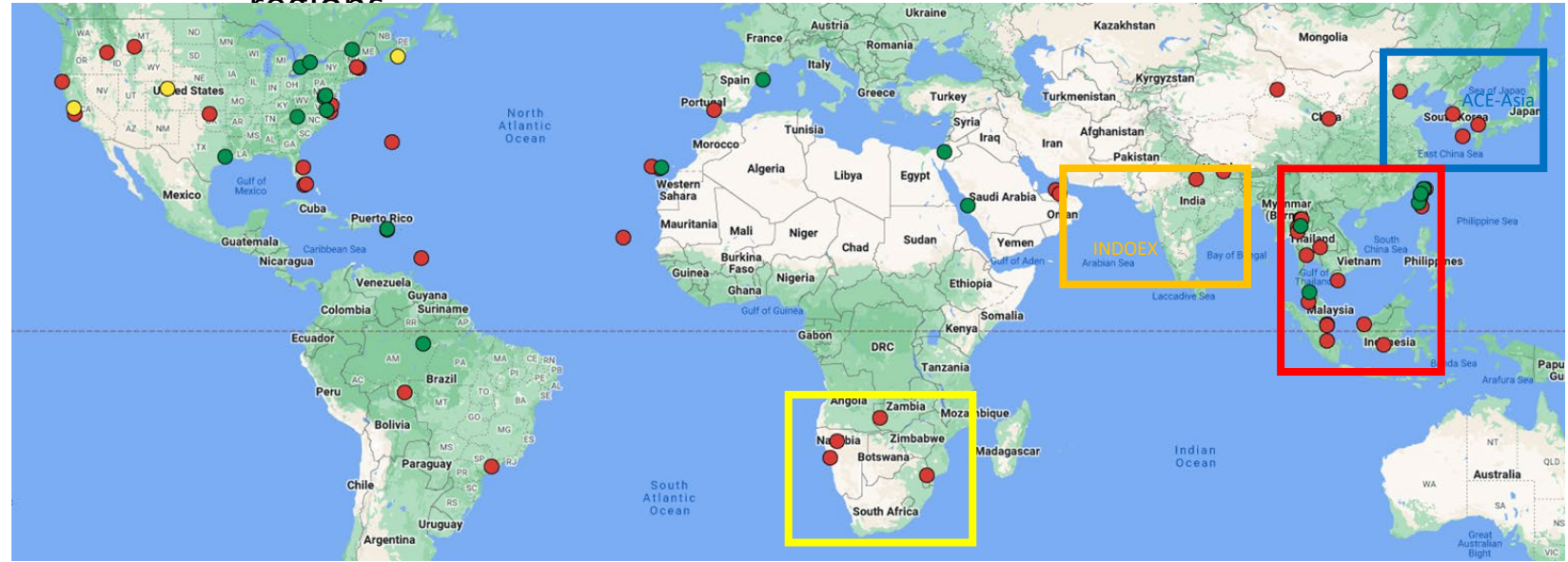
These are pre V3 results

	Region	Site	Lidar Ratio (sr) AE < 1	Lidar Ratio (sr) AE > 1	Aerosol Types	Time Span
🟧	India, Indian Ocean	INDOEX-99 (from India)	43 +- 12		Pollution	1 month
		INDOEX-99 (from Middle East)	55 +- 14		Pollution, Dust	
		Kanpur, India	39 +- 10	55 +- 14	Pollution, Dust	2 years
🟨	Southern Africa	Skukua, South Africa	37 +- 3.4	65 +- 10	Pollution, Smoke, Marine	1 month
		Mongu, Zambia	n/a	71 +- 6	Pollution, Smoke	1 month
		Windpoort, Namibia	35 +- 13	46 +- 7.5	Dust, Pollution	1 year
🟦	East Asia	ACE-Asia Cruise (Sea of Japan, East China Sea)	55 +- 11	64 +- 9	Pollution, Dust, Marine	1 month
🟥	South East Asia	Singapore	n/a	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	

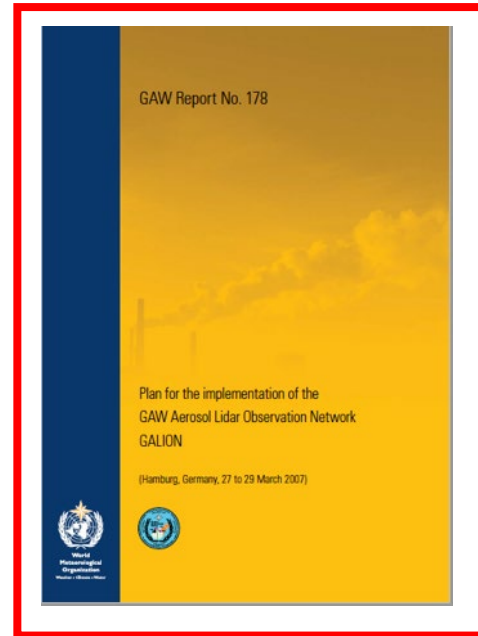**WMO GAW Aerosol Lidar Observation Network (GALION):**
A lidar network of networks organized through the WMO Global Atmospheric Watch (GAW) program. Welton and Lucia Mona (CNR, Italy) are co-chairs.

See GAW Report 178 (2008)

Original GALION Networks:
- 🔴 EARLINET
- 🔴 ADNET
- CIS-LINET ⎤
- 🔴 LALINET ⎥ regional
- CORALNET ⎥
- CREST ⎦
- 🔴 MPLNET ⎤ globa
- 🔴 NDACC Lidar ⎦ l

active GALION members

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

GAW Report No. 178

Plan for the implementation of the
GAW Aerosol Lidar Observation Network
GALION

(Hamburg, Germany, 27 to 29 March 2007)

World Meteorological Organization

Jeff's ICAP Take Home for Data Providers:
- **Easy**
  - Each network provides data, some open
  - Need better, coordinated search and discovery tools and links to data
  - Combined discovery tool with other types of observations (programmatic planning)
- **Fast (NRT)**
  - Some networks already provide NRT, others improving
- **Characterized**
  - GALION has established standards and each network has traceable history of peer reviewed calibration and processing methods.

MPLNET Sites & Other Lidar Networks: GALION

WMO GALION (Welton co-chair)
- EARLINET/ACTRIS
- ADNET
- LALINET
- NDACC* (sites not shown, also global)
- Current focus: building up North American Sites
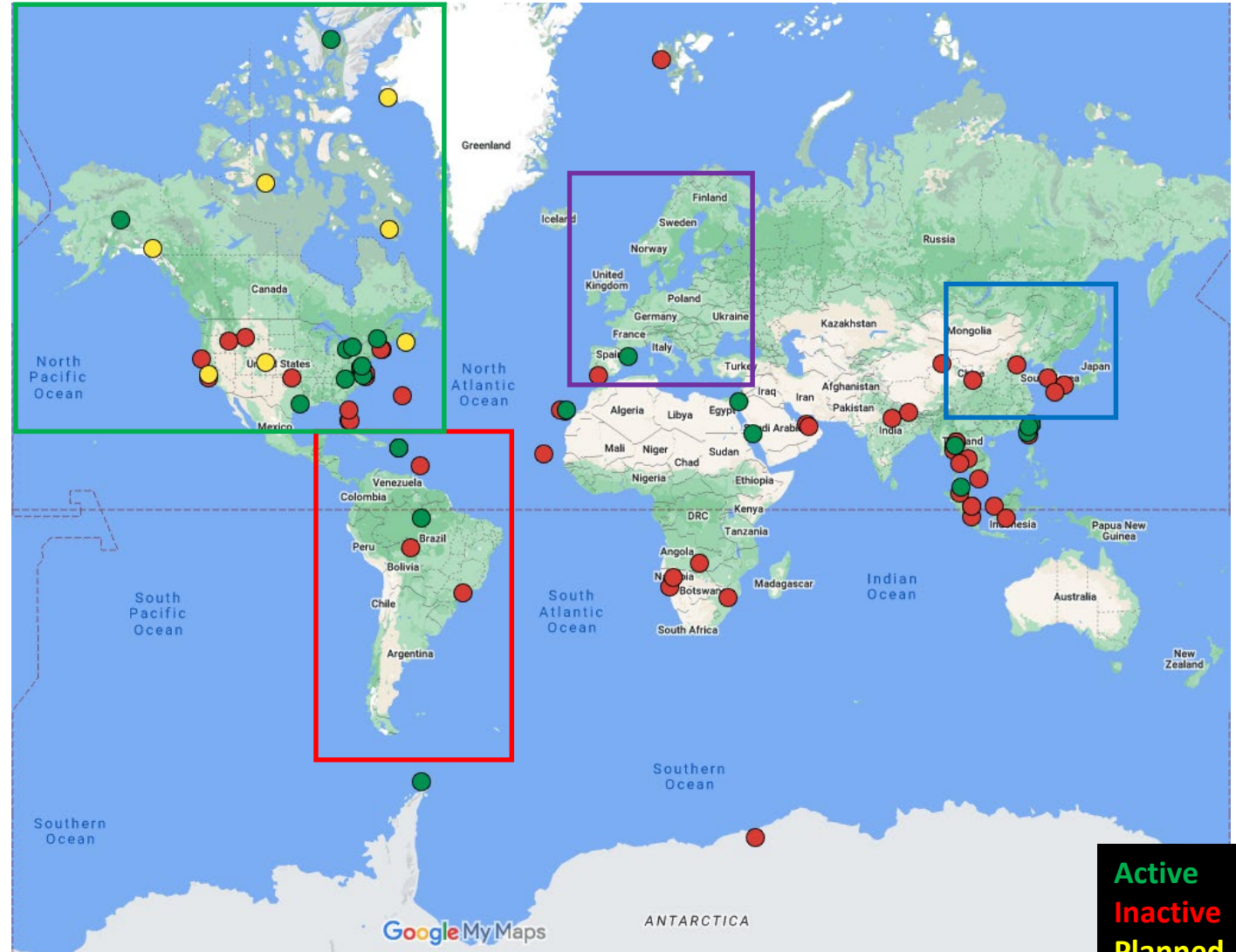
Active
Inactive
Planned

WMO: Expert Team on Atmospheric Composition Data Management

WMO GAW: SAG set objectives, requirements. OSCAR meta-database stores and codifies requirements ⮕ WIGOS Code List

WMO Observing Systems Capability Analysis and Review Tool (OSCAR)
- Global metadata engine for WMO Integrated Global Observing System (WIGOS)
- Offers unique ability to provide integrated data searches across multiple programs, globally

WMO: Expert Team on Atmospheric Composition Data Management

WMO GAW: SAG set objectives, requirements. OSCAR meta-database stores and codifies requirements ▯ WIGOS Code List

Remote sensing and aerosol metadata and vocabulary were poorly maintained
WIGOS Code List: http://codes.wmo.int/_wmdr

Observing Methods Code List: Fixed Lidar Entries

Name	Notation	Description	Types	Status
Backscatter lidar	341	Elastic backscatter light detection and ranging (lidar) typic...	Concept	stable
Differential absorption lidar (DIAL)	335	Light detection and ranging (lidar) with differential absorpt...	Concept	stable
Doppler wind lidar	142	Light detection and ranging (lidar) with Doppler capability (...	Concept	stable
High spectral resolution (HSR) lidar	342	Light detection and ranging (lidar) with high spectral resolu...	Concept	stable
Integrated path differential absorption (IPDA) lidar	320	Light detection and ranging (lidar) with integrated path diff...	Concept	stable
Polarized lidar	343	Light detection and ranging (lidar) capable of determining th...	Concept	stable
Raman lidar	143	Light detection and ranging (lidar) with Raman capability, ty...	Concept	stable

Observed Variable Code List: Added Missing Variables

Aerosol layer height	12162	Height of vertically localized aerosol layer above sea level	Concept	stable
Mixed layer height	12163	Height above the surface to which atmospheric properties (win...	Concept	stable
Height of the top of the PBL	12168	Height of the surface above ground separating the planetary b...	Concept	stable
Aerosol type	12169	Selection, out of a pre-defined set of aerosol classes, that ...	Concept	stable

Observed Variable Code List: Renamed Aerosol Vars, Cleaned up Definitions

Hygroscopic particle size growth factor	12155	A scaling factor describing the particle equivalent spherical...	Concept	stable
Particle effective diameter	12161	The area weighted mean diameter of the aerosol particles.	Concept	stable
Particle effective radius	362	The area weighted mean radius of the aerosol particles.	Concept	stable
Particle light absorption coefficient, PM1	316	A measure of light attenuation due to absorption by aerosol p...	Concept	stable
Particle light absorption coefficient, PM10	317	A measure of light attenuation due to absorption by aerosol p...	Concept	stable
Particle light absorption coefficient, TSP	318	A measure of light attenuation due to absorption by aerosol p...	Concept	stable
Particle light backscatter coefficient	12159	The fraction of incident radiative flux scattered backward at...	Concept	stable
Particle light extinction coefficient	12145	A measure of light attenuation due to scattering and absorpti...	Concept	stable
Particle light hemispheric backscatter coefficient	12158	The fraction of incident radiative flux scattered into all ba...	Concept	stable
Particle light hemispheric forward scattering coefficient	12160	Incident radiative flux scattered into all forward angles, i....	Concept	stable
Particle light scattering coefficient, PM1	322	A measure of light attenuation due to absorption by aerosol p...	Concept	stable
Particle light scattering coefficient, PM10	323	A measure of light attenuation due to absorption by aerosol p...	Concept	stable
Particle light scattering coefficient, TSP	324	A measure of light attenuation due to absorption by aerosol p...	Concept	stable
Particle mass concentration (size fractionated)	367	Mass of particles per unit volume of air, size fractionated	Concept	stable

International GALION Data Center Working Group formed in 2021

Goal build a data center to provide information, search and discovery tools, links to network data, and eventually applications (AQ, volcanic monitoring, etc)

- Easier access to lidar network data
- Programmatic Planning
- Search & Discovery tool based on WMO OSCAR database
- Includes joint search of non-GALION networks and other filters
- Working group composed of members from all GALION networks

- I've spent several months trying to setup a new NASA AWS account for GALION
  - Finally getting close – as only NASA can

GALION Search Page: Test (proof of concept)

Conclusion: Plans for Next 5 Years

Operations:
- Complete Planned Sites
- Maintain Forward-Processing
- Continue V3 Reprocessing of all remaining sites
- Complete development of Level 2 & 3 products
- Develop V4 Products/Code. Planned release year 4-5
    - Improvements to existing algorithms
    - official release of precipitation product
- Continue network expansion
- New Hires

Science:
- Climatological Cirrus Forcing Studies: extend across V3 archive
- Aerosol in Cloudy Skies: large scale investigation of aerosol properties in cloudy scenes with MPLNET - AERONET
- Lidar Ratio Study: Joint MPLNET, Airborne HSRL, CALIPSO, and EarthCARE project under MIRA to improve lidar ratio lookup tables for final CALIPSO processing and EarthCARE/AOS support
- PBL DSI Proposal Support
- EarthCARE cal/val (funding from Lewis et al USPI project)

Partnerships & Synergies: WMO & GALION
- Ongoing efforts to align with WMO world data centers and operational centers (GMAO, ECMWF, etc)
- Welton WMO Team assignments: ET-ACDM team, Ad-hoc AC vocabulary team, Pan-AM SDS-WAS regional steering committee
- Complete initial phase of GALION data center
- GALION
    - revive other working groups
    - Revive North American Ceilometer/Lidar Working Group
- New: Coordinate and provide PBL observations from surface networks

Data Center Interoperability:
- Integrate MPLNET back into AERONET synergy tool (V3)
    - Our current APIs provide what is needed
- Data DOI: requirement going forward
    - Issues with process & data licenses
- Cloud Computing
    - Support for applications that can utilize our API infrastructure
    - We do not currently offer remote data retrieval, only file download Example, no OPenDAP or AWS access capability
    - I am investigating moving MPLNET to AWS, either the entire data center or just provide a data bucket
    - We are already backing up entire data center to AWS: $3000/yr