The WMO GAW Aerosol Lidar Observation Network (GALION): status and coordination plans relevant to EarthCARE

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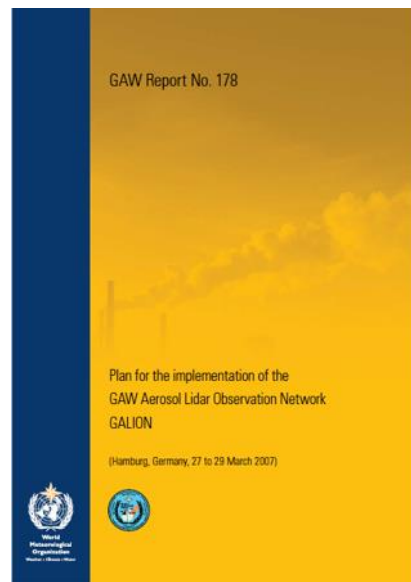Juan Pallotta, CITEDEF Argentina

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   — regional
  CORALNET
  CREST
- MPLNET   — global
- NDACC Lidar

active GALION members, signed agreements with WMO as contributing networks

GAW Report No. 178

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

(Hamburg, Germany, 27 to 29 March 2007)

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)

Asian dust and aerosol lidar observation network − AD-Net

- 96 profiles / day, vertical resolution = 30 m

- 532 nm attenuated backscatter coefficient + depolarization ratio (up to 18 km) & extinction coefficient (with fixed lidar ratio S1 = 50sr, up to 9 km)

- Available in figures and netCDF at: https://www-lidar.nies.go.jp/AD-Net/

- References: Shimizu et al., Opt. Eng. (2017) doi:10.1117/1.OE.56.3.031219

- Contact: shimizua@nies.go.jp

#Realtime data sharing is not applicable to lidars in China

* Last updated March 2022

European Aerosol Research LIdar NETwork − EARLINET/ACTRIS
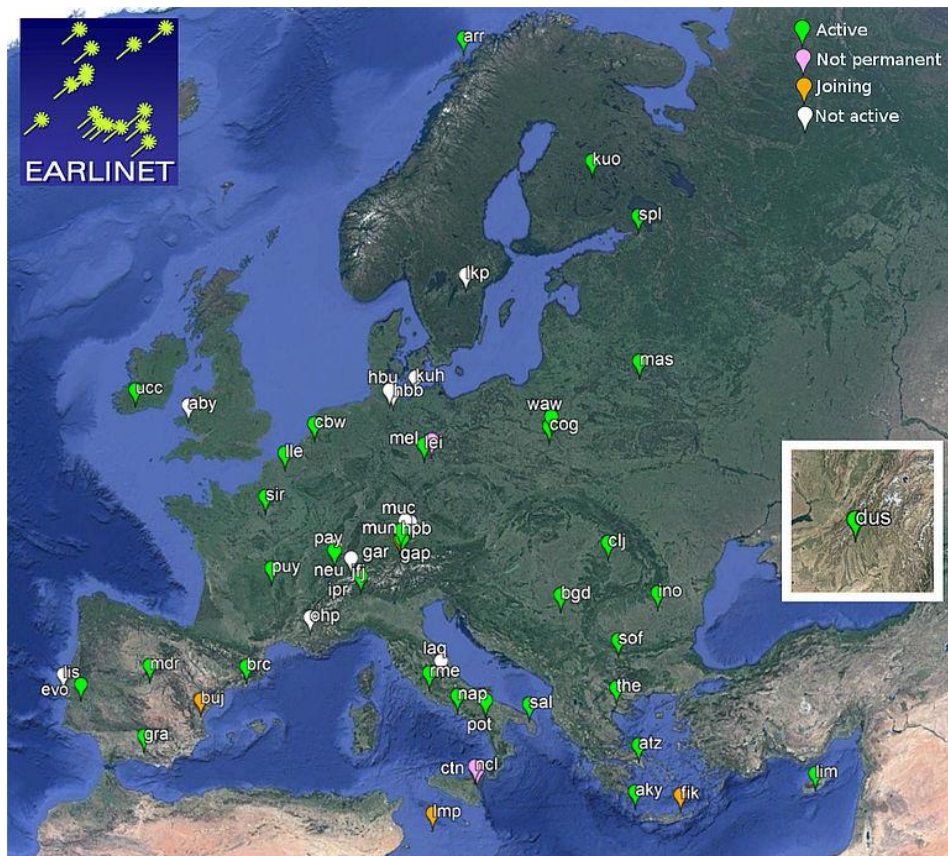
> mainly based on **Raman** lidar systems, able to provide vertical **profiles** of **aerosol extinction** and **backscatter** coefficients without significant assumptions.

> most of the stations at **different wavelengths**

> currently most of the sites provides also **linear particle depolarization ratio**

> most of the sites have **co-located photometers**

EARLINET is since 2011 integrated in **ACTRIS (Aerosol, Clouds, and Trace gases Research Infrastructure)**

https://www.earlinet.org/

Pappalardo, G., et al., EARLINET: towards an advanced sustainable European aerosol lidar network, Atmos. Meas. Tech., 7, 2389–2409, https://doi.org/10.5194/amt-7-2389-2014, 2014.

Latin America LIdar NETwork — LALINET

LALINET
STATIONS – 2017

2 4 6 8 10 12
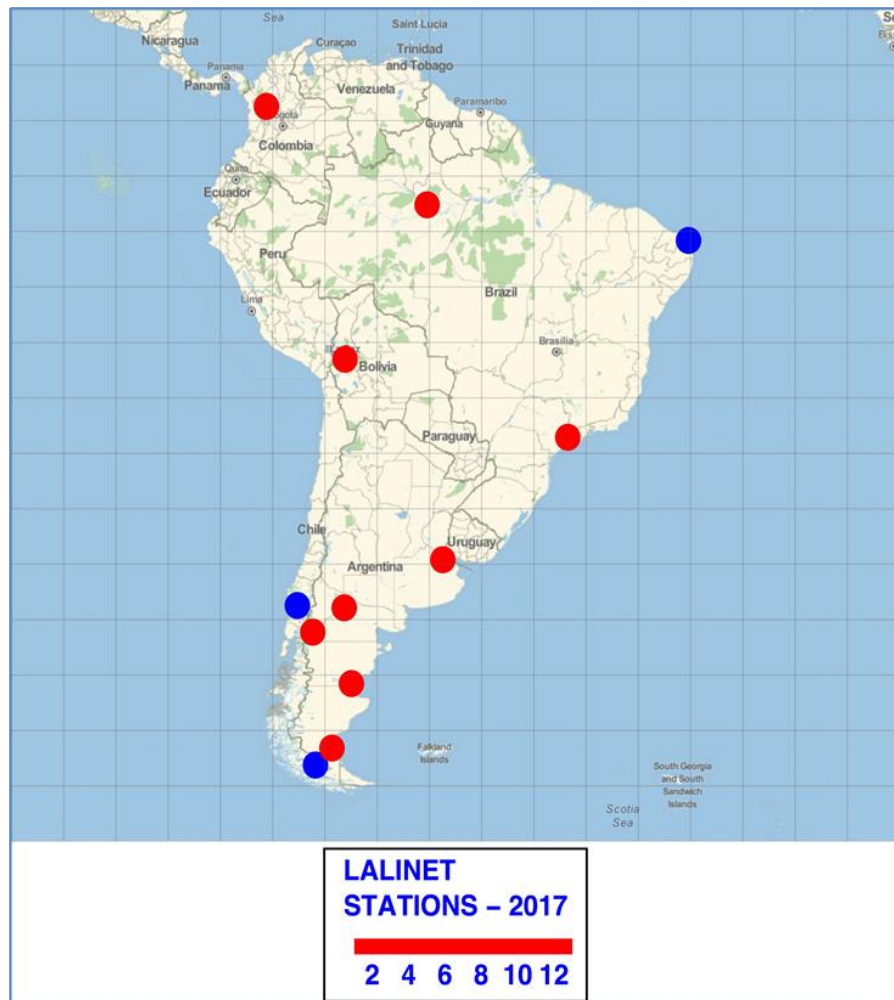
ST.	ID	LAT(S) LON(W)	Channels (nm)
Buenos Aires	AEP	34.56ºS 58.42ºW	1064, 532P & 355P
Buenos Aires	VMA	34.56ºS 58.51ºW	1064, 607, 532P, 387 & 355P
Neuquen	NQN	38.95ºS 68.13ºW	1064, 532P & 355P
Barilo-che	BRC	41.15ºS 71.16ºW	1064, 607, 532, 387 & 355
Commo doro	CDR	45.79ºS 67.46ºW	1064, 532 & 355
Gal-legos	RGL	51.61ºS 69.31ºW	1064, 532P & 355P
Punta Arenas	PAR*	53.13ºS 70.88ºW	1064, 607, 532P, 408, 387 & 355P
S. Paulo	SPU	23º13' 46º28'	1064, 607, 532, 408, 387 & 355
S. Paulo	SPT	VAR	607, 532
Man-aus	MAO	02.60ºS 60.21ºW	408, 387, 355
Natal	NAT	05.82ºS 35.20ºW	1064, 532P & 355P
Temuco*	TMU*	38.74ºS 72.62ºW	1064, 532P & 355P
Medellin	MED	06.26ºN 75.58ºW	532 & 355
La Paz	LPZ	16.54ºS 68.07ºW	1064, 532P & 355P

https://lalinet.org

Measurements of 1064 nm, 532 nm and 355 nm from elastic and multi-wavelength lidar systems in order to retrieve backscatter, extinction, lidar ratio profiles, plus backscatter and extinction Angstrom Exponent and Color ratio.

LALINET: The First Latin American–Born Regional Atmospheric Observational Network
https://doi.org/10.1175/BAMS-D-15-00228.1

* Last updated March 2022

NASA Micro Pulse Lidar Network – MPLNET

Global Backscatter Lidar Network: 2000 - current
- 82 sites total (25 operational, 57 closed): 28 countries
- 12 more sites in planning
- Continuous (day/night) operations, colocation with AERONET

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

MPLNET History:
- Three Version Releases: V1 and V2 (2000 – 2021)
- Version 3 Released in Nov 2021

Updates Since ICAP 2022:
- More sites installed, many more in final planning stages (ops by 2024)
- Focus on new sites in western North America near fire sources
- Ongoing V3 reprocessing of older data back to 2000

MPL

miniMPL

https://mplnet.gsfc.nasa.gov

Operational
Closed
Planned
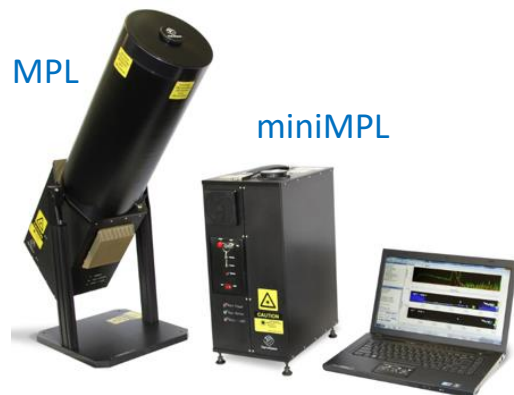
Data Products:
- NRB: Lidar signals; volume depolarization ratios; diagnostics
- CLD: Cloud heights; thin cloud extinction and optical depths; cloud phase
- AER: Aerosol heights; extinction, backscatter, and depolarization ratio profiles; lidar ratio
- PBL: Mixed Layer Top and estimated AOD
- L1 and L1.5 products available in NRT, QA screen applied at L1.5 and L2
- L3 products in development (created from L2 data)

Network for the Detection of Atmospheric Composition Change –   NDACC

NDACC Sites	Aerosols	Ozone	Temperature	Water Vapor	Wind
All times (active and inactive)	20	15	15	15	1
In operation today (active)	10	10	10	10	1

*Courtesy of Thierry Leblanc,
Jet propulsion Laboratory,
California Intitue of Technology*

Long-term monitoring of atmospheric composition

http://www.ndacc.org

NDACC provides a measure of stratospheric AOD contribution to total column
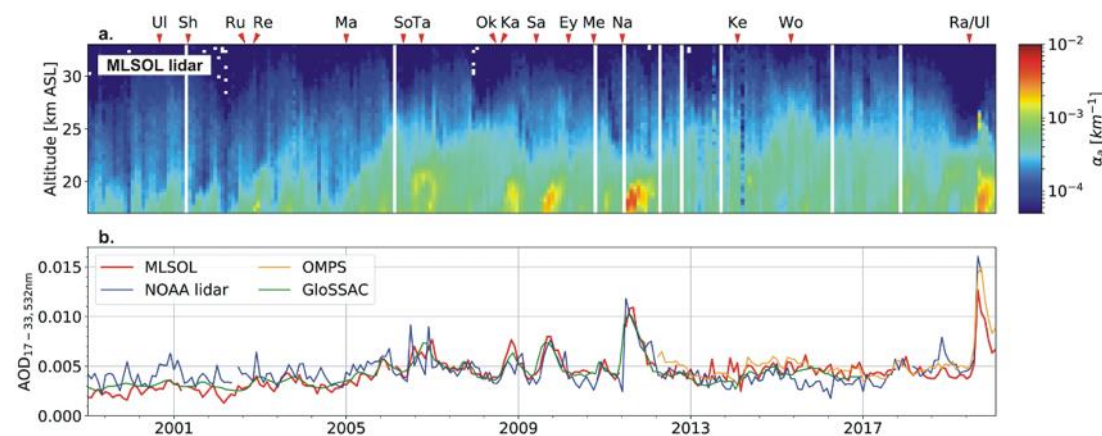
Top: Long term time series of Aerosol Extinction by MLSO
Bottom: Stratospheric AOD from MLSOL and NOAA-MLO lidar, OMPS, and GloSSAC

Chouza et al. ACP (2020): Long-term (1999–2019) variability of stratospheric aerosol over Mauna Loa, Hawaii, as seen by two co-located lidars and satellite measurements, ACP, 20(11), 6821-6839

Leblanc et al., BAMS, State of the Climate 2020, Chapter 2, Sidebar 2.2

* Last updated March 2022

GALION: Operations and Working Groups

GALION operations: from 2008 original report

Due to the variety of lidar instruments and processing systems throughout the contributing networks, it was decided to target a <u>minimum</u> of 2 observations per week.

- Monday and Thursday around sunset
- Some networks continuous 24/7, number growing

Products provided from a given site are dependent upon the capability of the onsite lidar and network.

This system accommodates a tiered approach to data quality based on lidar capability and external observations.

Working groups:

- Methodology
- Technologies
- Quality Assurance
- Applications
- Data Center
  Data Center Working Group formed in Dec 2021
  Welton Lead. Representatives from each network

MPLNET: GSFC Nov 8, 2023: Klyuchevskoy Volcanic Plume

Theoretical Forecast   Default GALION Obs Time
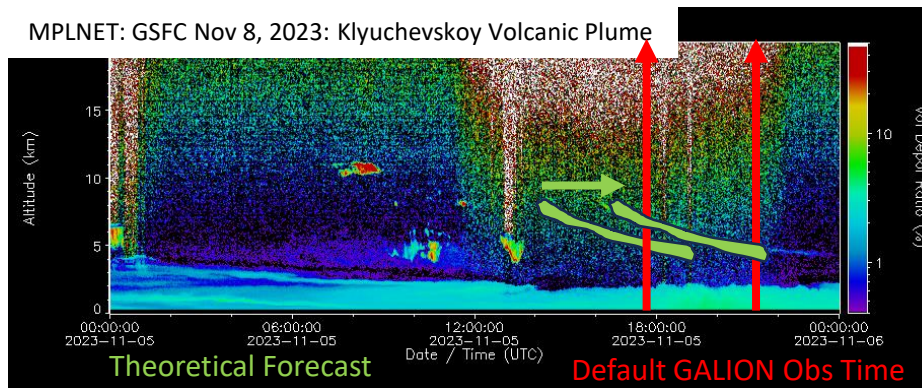
Periodic or Continuous data are important for surface obs:
- Inherently limited spatial information
- We can provide better temporal vs satellite
- More helpful for forecast validation

Methods, Technology, Data Quality

- GALION has established standards and each network has traceable history of peer reviewed calibration and processing methods.

Aerosol Observation Requirements and Data Variables

Parameter (product)	Basic lidar type
Range corrected signal (colour plots of aerosol and cloud distributions)	BL
Attenuated backscatter coefficient (calibrated range-corrected signal)	BL
PBL depth	BL
Aerosol backscatter coefficient	BL+SPM
Aerosol type discrimination (dust, anthropogenic)	BL+DL
Aerosol extinction coefficient (estimate), optical depth, column lidar ratio	BL+SPM
Aerosol extinction coefficient, optical depth, lidar ratio	RL or HSRL
Ångström exponent (backscatter-related)	MBL
Ångström exponent (extinction-related)	MRL
Aerosol type determination (dust, maritime, fire smoke, urban haze)	MRL+DL
Aerosol microphysical properties (volume and surface conc., refractive index)	MRL
Single scattering albedo (aerosol)	MRL

BL: Backscatter lidar   SP: Sunphotometer
DL: Depolarization   RL: Raman lidar
HSRL: High Spectral Resolution Lidar   M: Multi-wavelength

GALION Data Center Working Group: Metadata & Vocabularies
Standardize and Codify Variables, Instruments, etc

Lidar Variables:
Relative_Attenuated_Backscatter
Attenuated_Backscatter
Volume_Depolarization_Ratio
Scattering Ratio

Cloud Variables:
Cloud_Base_Height
Cloud_Top_Height
Cloud_Backscatter
Cloud_Extinction
Cloud_Lidar_Ratio
Cloud_Optical_Depth
Cloud_Effective_Radius_Estimate
Cloud_Depolarization_Ratio
Cloud_Phase

Mixed Layer Variables:
Mixed_Layer_Height
Mixed_Layer_Aerosol_Optical_Depth_Estimate
Mixed_Layer_Aerosol_Optical_Depth

Aerosol Variables:
Aerosol_Layer_Height
Aerosol_Backscatter
Aerosol_Extinction_Estimate
Aerosol_Extinction
Aerosol_Lidar_Ratio_Estimate
Aerosol_Lidar_Ratio
Aerosol_Optical_Depth_Estimate
Aerosol_Optical_Depth
Aerosol_Angstrom_Exponent_Estimated
Aerosol_Angstrom_Exponent
Aerosol_Effective_Radius_Estimate
Aerosol_Single_Scatter_Albedo_Estimate
Aerosol_Volume_Concentration_Estimate
Aerosol_Surface_Concentration_Estimate
Aerosol_Refractive_Index_Estimate
Aerosol_Effective_Radius
Aerosol_Single_Scatter_Albedo
Aerosol_Volume_Concentration
Aerosol_Surface_Concentration
Aerosol_Refractive_Index
Aerosol_Depolarization_Ratio
Aerosol_Type

Instrumentation:

instrument	code	wigos	wigos_name
Backscatter Lidar	BL	341	Backscatter lidar
Raman Lidar	RL	143	Raman lidar
High Spectral Resolution Lidar	HSRL	342	High spectral resolution (HSR) lidar
Doppler Wind Lidar	DWL	142	Doppler wind lidar
Differential Absorption Lidar	DIAL	335	Differential absorption lidar (DIAL)
Integrated Path Differential Absorption Lidar	IPDIAL	320	Integrated path differential absorption (IPDA) lidar
Polarized Lidar	PL	pending	pending
Multi-Wavelength Backscatter Lidar	MWBL	341	Backscatter lidar
Multi-Wavelength Raman Lidar	MWRL	143	Raman lidar
Multi-Wavelength High Spectral Resolution Lidar	MWHSRL	342	High spectral resolution (HSR) lidar
Multi-Wavelength Polarized Lidar	MWPL	pending	pending
Sunphotometer or Sun-Sky Photometer	SP	244	Sun-tracking photometry

Synergy with WMO OSCAR and WIGOS Metadata:
Welton is on the WMO Expert Team for Atmospheric Data Management
Mona is on the GAW Aerosol SAG

GALION Data Center Working Group: Metadata & Vocabularies

Standard Variables Mapped to Instrumentation and other parameters, including WIGOS OSCAR

variable	description	unit	instrumentation	layer	level	wigos	wigos_name	application_area
Relative_Attenuated_Backscatter	uncalibrated lidar signal	1	BL RL HSRL DWL DIAL IPDIAL MWBL MWRL MWHSRL	PBL freeTroposphere UTLS MUS	1	12251	Relative attenuated backscatter	no
	calibrated lidar signal	m-1.sr-1	BL MWHSRL	PBL	1	12248	Attenuated backscatter	no
Volume_Depolarization_Ratio	volume depolarization ratio	percent	PL MWPL	PBL freeTroposphere UTLS MUS	1	no	no	no
Aerosol_Layer_Height	Aerosol layer height	m km	BL RL HSRL DWL DIAL IPDIAL MWBL MWRL MWHSRL	PBL freeTroposphere UTLS MUS	1.5 2	12162	Aerosol layer height	climateMonitoring
Aerosol_Extinction_Estimate	Aerosol Extinction Coefficient	m-1 km-1 Mm-1	BL BL_SP MWBL MWBL_SP	PBL freeTroposphere UTLS MUS	1.5 2	12145	Particle light extinction coefficient	climateMonitoring aeronauticalMeteorology atmosphericCompositionForecasting atmosphericCompositionMonitoring
Aerosol_Extinction	Aerosol Extinction Coefficient	m-1 km-1 Mm-1	RL HSRL MWRL MWHSRL	PBL freeTroposphere UTLS MUS	1.5 2	12145	Particle light extinction coefficient	climateMonitoring aeronauticalMeteorology atmosphericCompositionForecasting atmosphericCompositionMonitoring
Aerosol_Lidar_Ratio_Estimate	Aerosol lidar ratio	sr	BL_SP MWBL_SP	PBL freeTroposphere UTLS MUS	1.5 2	no	no	no
Aerosol_Lidar_Ratio	Aerosol lidar ratio	sr	RL HSRL	PBL freeTroposphere	1.5 2	no	no	no

No map to WIGOS/OSCAR, Some variables are in process of begin added, Some may not ever be added to WIGOS.

Specifies instrument requirements for variables, Units, Atmospheric Layers (PBL – Stratosphere), and mapping to WIGOS/OSCAR

GALION Data Center Working Group:
New Data Center and Website

https://galion.world

NASA AWS Contract to Support GALION Data Center
Django and Python development

Capabilities
GALION information and search and discovery
Automated handshakes with WMO OSCAR database
Metadata APIs
- Upload from GALION networks (Push)
- Developing upload Pull capability (easier maintenance)

Tools in development (functional but not public*)
- Metadata Downloads
- Trajectory analysis

Future Tools
- API Data Downloads (current and common formats)
- Quicklook Imagery
- Volcanic Alerts and Monitoring
- PyroCb/Smoke Alerts and Monitoring
- AQ Support

* Some networks do not have full metadata submissions yet. We are using OSCAR metadata in place of, which lacks some information and is currently out of date. Tools in development and future will not be implemented until metadata archive is complete.

All of the search engine features shown here are also accessible via API

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Case Study: Alberta Fires May 2023
Back Trajectory May 13
Observed Smoke Heights
El_Arenosillo, Spain MPLNET site

(trajectory analysis from GSFC 3 days
earlier show origin over Alberta, CA)

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GALION JSON Metadata: file snippets

Links to network data:
• Files (FTP/SFTP or API)
• Quicklooks (static images or API)

User Data Downloads:
Search tool provides JSON metadata.
User can easily obtain links to requested data, and automate retrieval with our API

GALION Data Ordering From our Website
Issues to consider:
• Data Policy & DOI/License
• Common file formats
• Open Access or Authentication
  • AD-Net and MPLNET open
  • EARLINET just opened

Quicklook Imagery
• common vs individual images

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Challenge going forward: PyroCb
Dealing with annual smoke distribution in FT – UTLS across NH

Conceptual graphic of quicklook imagery:
May 2023 smoke trajectory analysis example
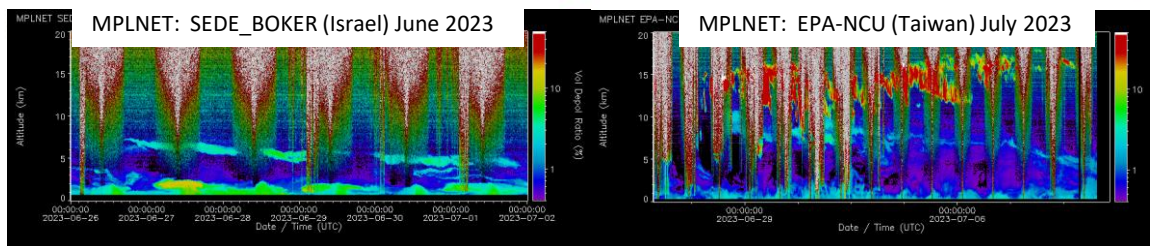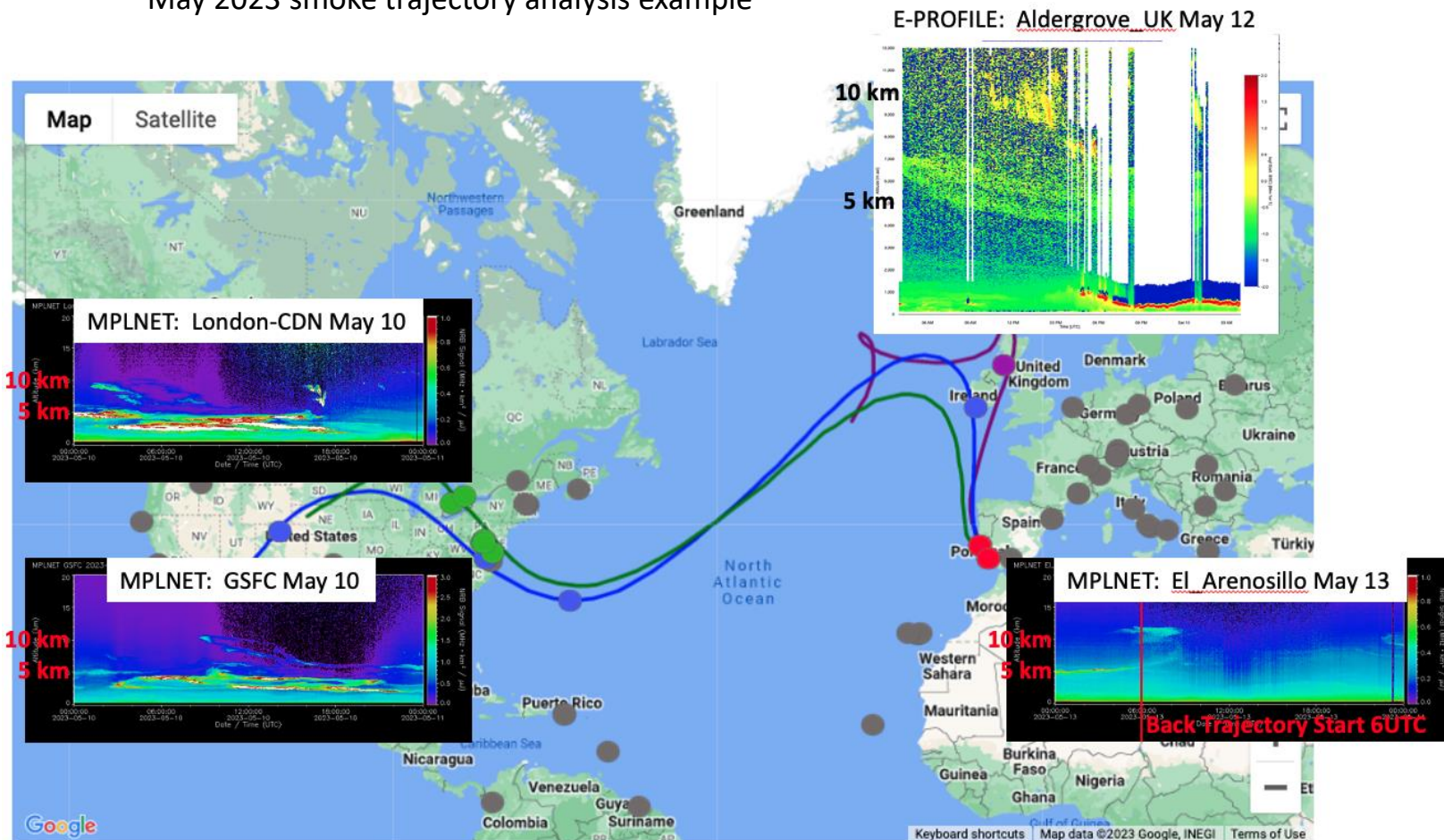
Conclusion: Infrastructure and New Data Center

Information and search and discovery. Centralized coordination with WMO OSCAR

- Better programmatic planning of observations, within GALION and beyond (other networks)

- Easier to find data, automate with APIs

- Continue working on common data browse, data format & download capabilities

Develop applications

- Back trajectory analysis tool (done, testing)

- Future: Coordinated support for WMO SDS-WAS, Volcanic and fire/smoke alerts and monitoring

  - Some networks already contributing to such work, experience & blue prints for future action

- GALION networks are part of EarthCARE Validation Team

  - We are working with EVDC to harmonize validation files with GALION vocabularies and definitions

- FAIR Data Support and Integration

  - Data policies and licenses must be handled appropriately if we merge data across networks

  - Consider integration with WMO Information System (WIS) 2.0 (in dev/testing now)

    - Current WIS/GTS system (closed to NMHS) will end 2030

    - WIS 2.0 offers ability to use standardized discovery and delivery for atmos comp data (same as met data – temperature and pressure)

Conclusion: GALION Activities

Intercomparisons and Coordination Between GALION members

- MPLNET – EARLINET

    - Intercomparisons in 2024 at collocated sites at Barcelona and Payerne

    - CARGO-ACT: new HORIZON project starts March 2024 (EU ACTRIS and USA university and gov members)

        - Develop roadmap for cooperation between EU and USA research infrastructures, including lidar & ceilometer (Mona, Welton)

- EARLINET – LALINET: Heterogeneous network processing

    - EARLINET Single Calculus Chain (SCC) well established. LALINET new Lidar Processing Pipeline (LPP) in development

    - Argentina Weather Service using EARLINET/SCC to process and distribute data

    - Harmonization campaign 2025: comparison of new LPP to SCC processing of LALINET data

Ceilometer Networks: inclusion in GALION (or at least collaboration)

- E-PROFILE: talks underway

- US ASOS (met observation sites): ceilometer profile data (100s of sites) may soon be available. Initial discussions starting.

- US Unified Ceilometer Network (UCN): ceilometers at EPA-PAMS sites (~50). UCN in transition at the moment, talks stalled.

Other Activities

- MPLNET – GRASP: Comparison of MPLNET aerosol retrievals to those from GRASP using the same lidar signal input (MPLNET L1). Paper in prep.

- New GALION Implementation plan? Revive other working groups?