Dust ground based observations

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Outline

- Dust component -typing
- Why GB measurements
- Measurements at the surface
- Columnar measurements
- Profiling measurements

Aerosol typing – why relevant

Knowing the type of the aerosol can help to:

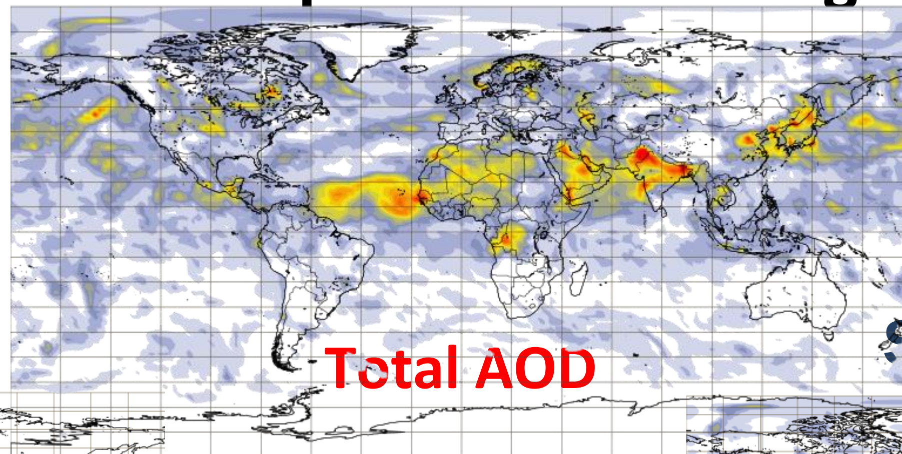
- **understand** sources, transformations, effects, and feedback mechanisms.
- **improve** accuracy of satellite retrievals; test aerosol models; and
- **quantify** assessments of aerosol radiative impacts on climate.

CAMS example

Copernicus Atmospheric Monitoring System

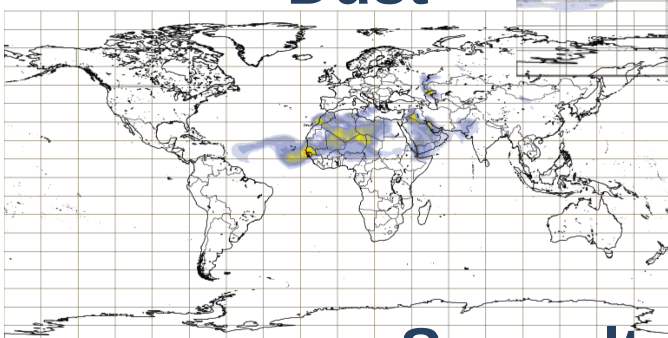
Forecast 15 May 2021 03 UTC

http://atmopsphere.copernicus.eu

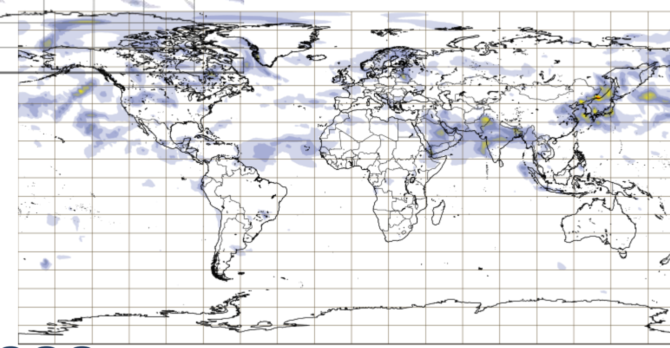


Total AOD

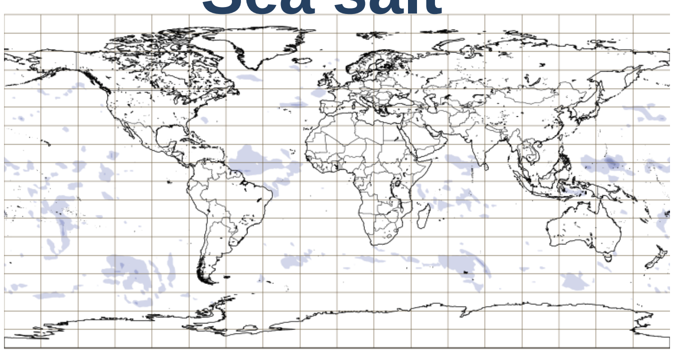
Dust



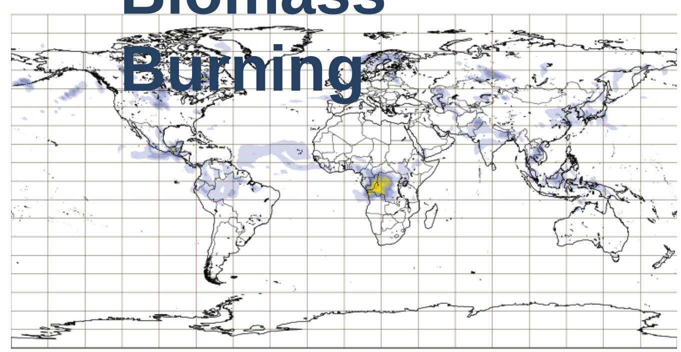
Sulphate



Sea salt



Biomass Burning



Dust component & aerosol typing

DUST *word is used very often to mean desertic particles....*
*but **DUST** is also used in different communities for coarse particles in general*

<u>Important to avoid not-needed confusion</u>

- Within remote-sensing community
- With respect to near-surface and modelling communities
- Taking into account observation user communities

How to know about aerosol types

MODELS

- Emission inventory
- Emission model
- Meteorological field for transportation

MEASUREMENTS

Sampling

- Chemical composition
- Size characterization
- Shape observation

Remote sensing

- Optical properties characterization

How to know about aerosol types
The general approach

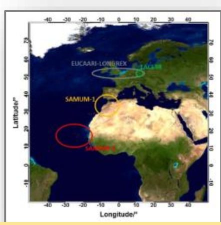
Identify the source for defining the aerosol characteristics

Investigate characteristics for understanding the source

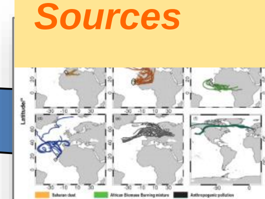
More common in Ground Based observations

More common in satellite observations

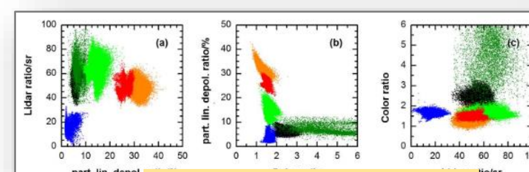
Input for defining automatic procedures for typing



Measurements



Sources



Procedures

Dust component - Definition

NOMENCLATURE

Different platforms use different names for “the same” aerosol type.

Just one easy example:

DUST

- Sand
- Dust
- Polluted dust
- Coarse
- Dust mixture

In some cases different names are also indicating some differences in physical meaning.

Dust component - Identification

***DUST** is typically identified thanks to its asphericity and dimension.*

- ❑ **Angstrom exponent + Angstrom exponent curvature [AERONET-Gobbi 2007]**
- ❑ **Desert region [AERONET-Catrall 2005]**
- ❑ **Particle Depolarization Ratio + Attenuated Backscatter+ Location [CALIPSO- Omar 2009]**
- ❑ **Particle Depolarization Ratio [EARLINET- Gross]**
- ❑ **Particle depolarization Ratio + Angstrom +Lidar Ratio + Backtrajectories [EARLINET Wandinger 2010]**
- ❑ **Brigthness temperature at 800 and 1200 cm^{-1}+ clean scenario reference [IASI Clarisse 2013]**
- ❑ **Radiances /models for AOD + Angstrom + SSA [MISR Kahn 2015]**
- ❑ **Reflectance at 440, 412 and 2130 nm [MODIS, Ciren 2013]**

Dust component - Identification

- ❖Different observables
- ❖Same observable : Different “thresholds”?

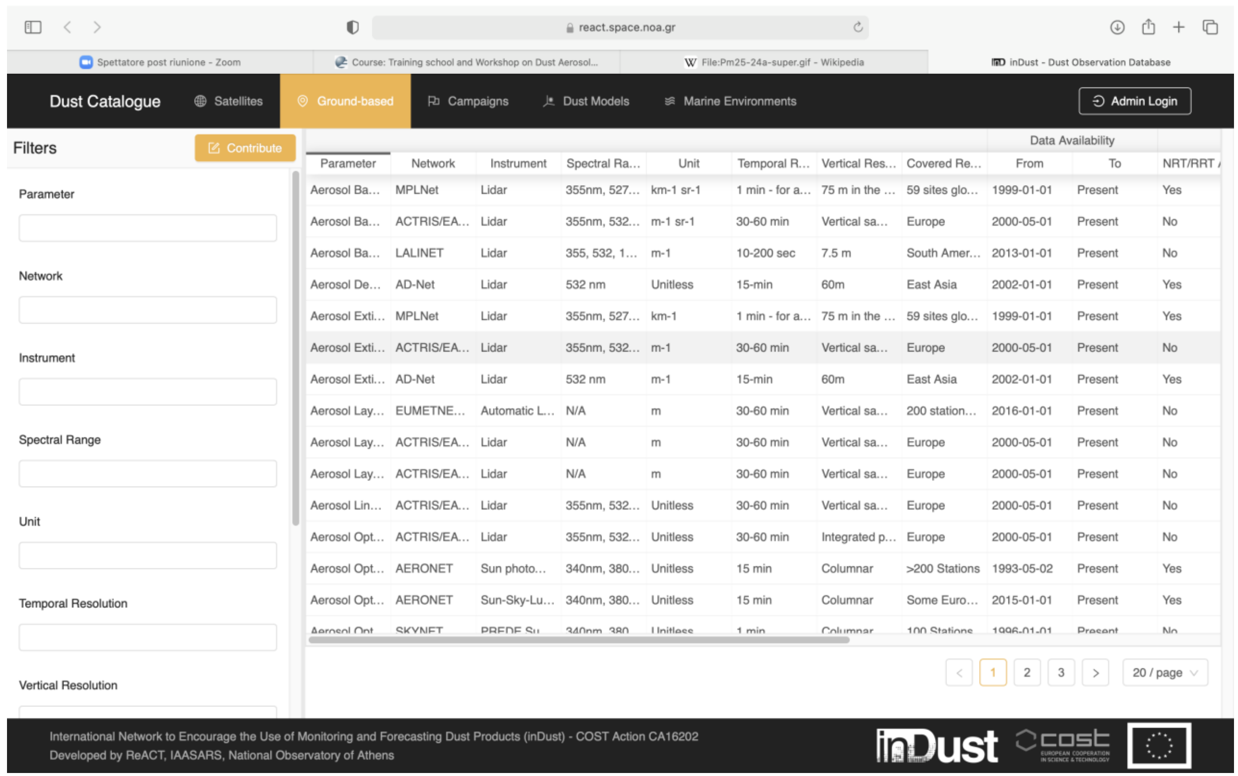
Linear Depolarization Ratio 0.3-0.35 Pure Dust [HSRL Burton]
Linear Depolarization Ratio >0.2 Pure Dust [Omar et al., 2009]

- ❖Combination of observables
- ❖External constraints

How do the different observables change as a function of particle properties changes?

Dust Observation Catalogue

Realized in the framework of **InDust COST action**, a international effort for establishing a network involving research institutions, service providers and potential end users of information on airborne dust.



https://react.space.noa.gr/indust-inventory/

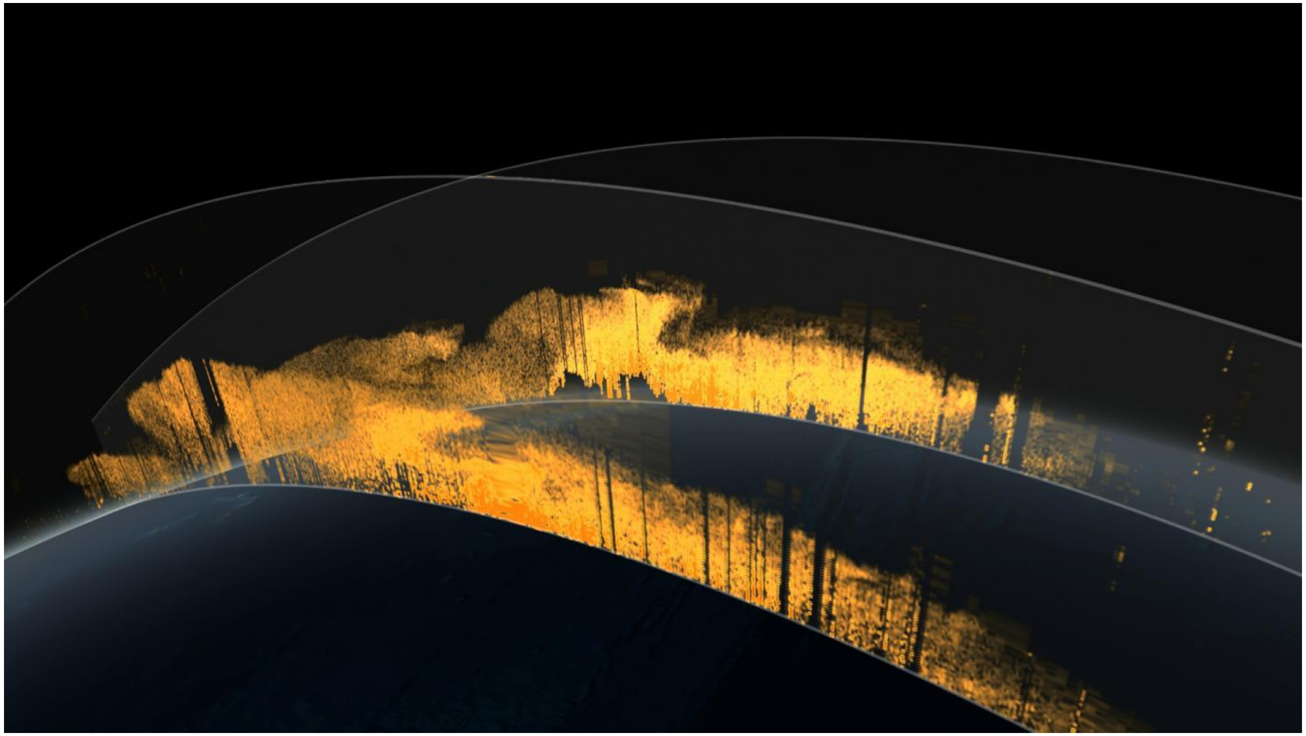
Dust component & aerosol typing

Take home message:

Talking about dust contribution is needed to pay attenction to the meaning of *dust* word and the *method* used for the discrimination.

Why Ground Based measurements

Satellite observations



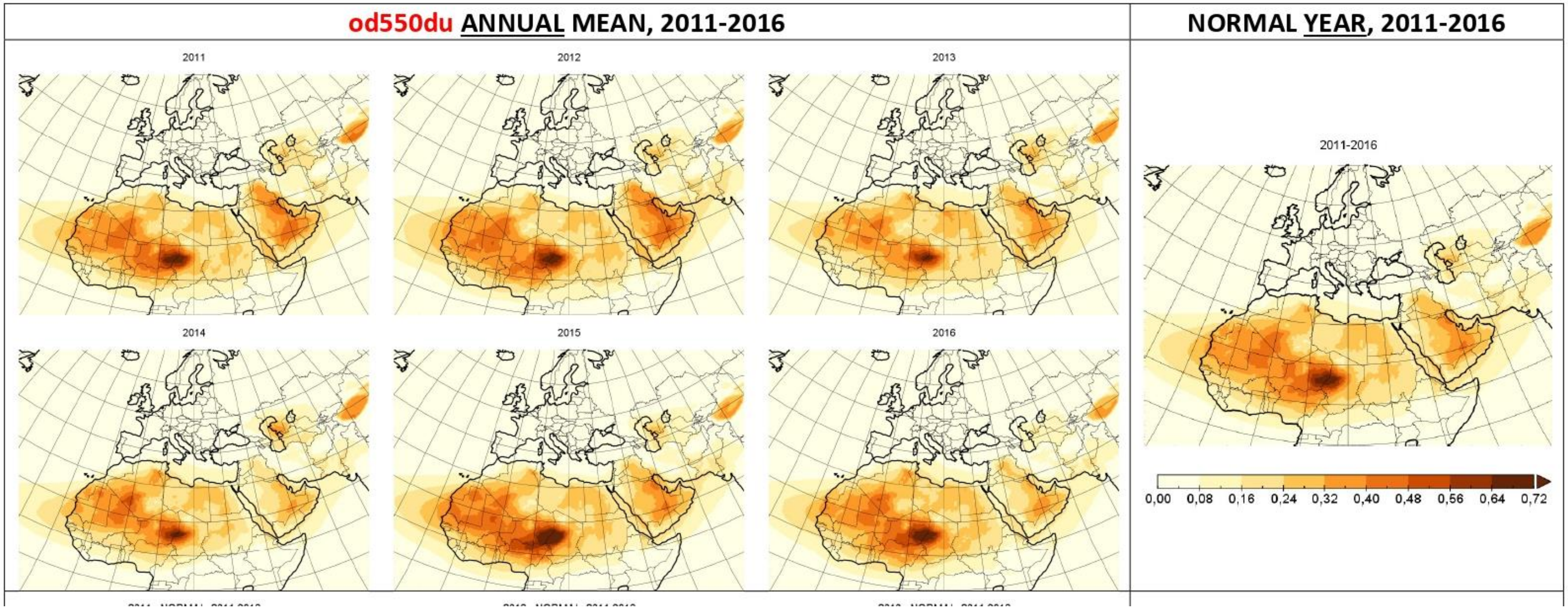
Amazing pictures revealing main paths and features.

Yu, H., et al. (2015), The fertilizing role of African dust in the Amazon rainforest:A first multiyear assessment based on data from Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations,Geophys. Res. Lett., 42, 1984–1991,doi:10.1002/2015GL063040.

Why Ground Based measurements

Models

Global coverage and continuos in time.



MONARCH reanalysis

Why Ground Based measurements

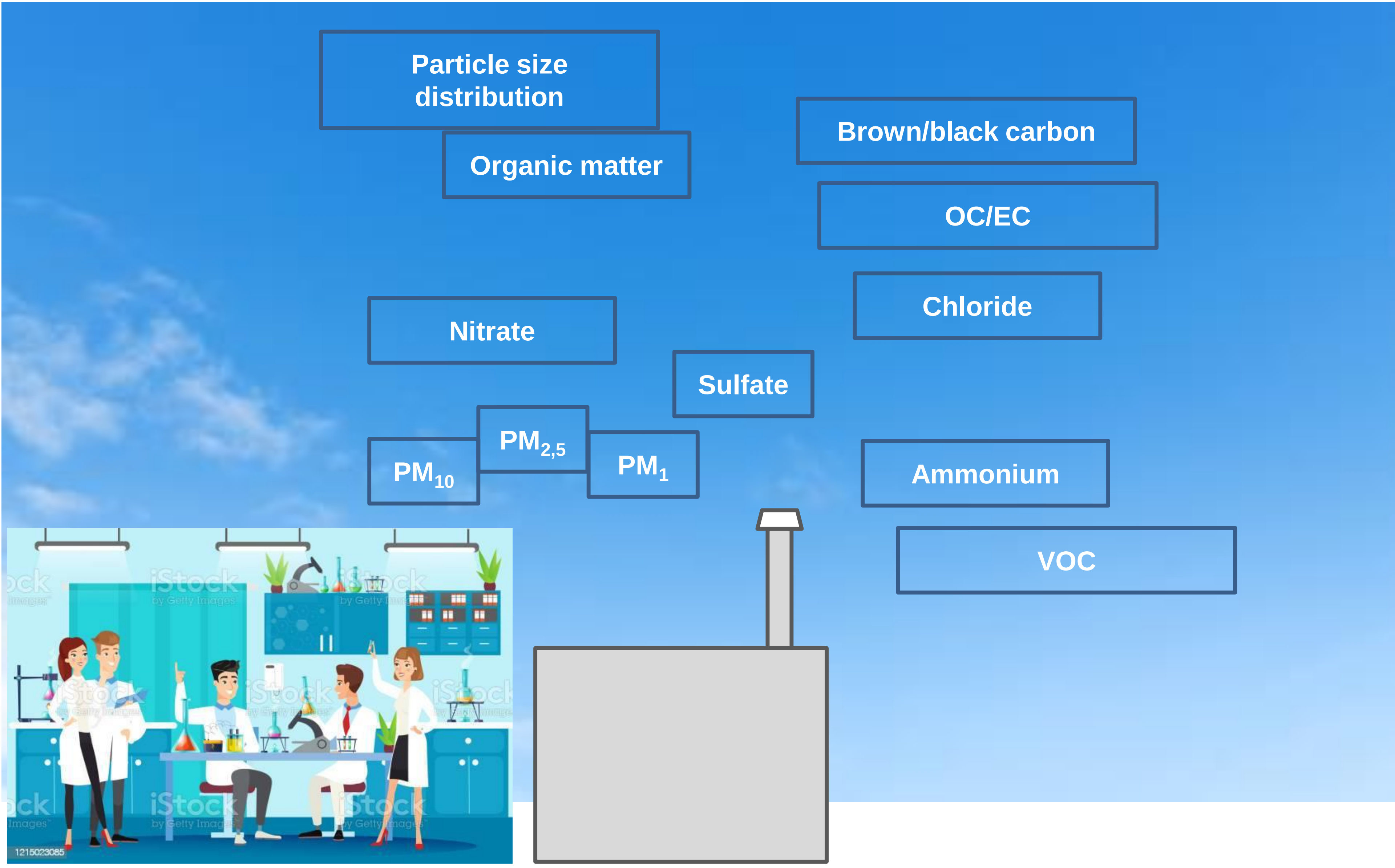
Ground Based measurements are important and needed for:

- Satellite validation
- Satellite algorithm improvement
- Model evaluation
- New method developments

Why?

- Higher possibility to control the measurement
- Strictly QA&QC procedures can be perfomed
- Integration/synergy of instruments more feasible

Measurements at the surface



Measurements at the surface

<u>General concept</u>

sampling the air for **collecting particulate** on filter or **optically investigating** the sample

Measurements at the surface

Different methods for collecting the particulate sample:

gravimetric the most common

Mass of particulate below a certain diameter is obtained:

PM10<10micron

PM2.5 <2.5 micron (fine particles)

PM1<1micron (ultrafine particles)

Chemical analysis can be done for the identification of species present in the sample.

Measurements at the surface

Optical methods allow the determination of many aerosol optical and physical properties like:

- Backscatter coefficient
- Size distribution
- Absorption coefficient
- Organic versus Elemental carbon content

Measurements at the surface

What is of interest for Dust indentification?

- PM10 as indicator of coarse particles
- PM10/PM2.5 as indicator of dominance of coarse particles
- Desert dust presence can be tracked using chemical tracer
  X-ray fluorescence (XRF), Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES), or Ion Chromatography (IC)

There are methods for attributing PM observations to dust events for the aim of Air Quality Directive 2008/50 based on model tools and wind conditions. Spatial investigation needed with background site and temporal consistency.

Measurements at the surface

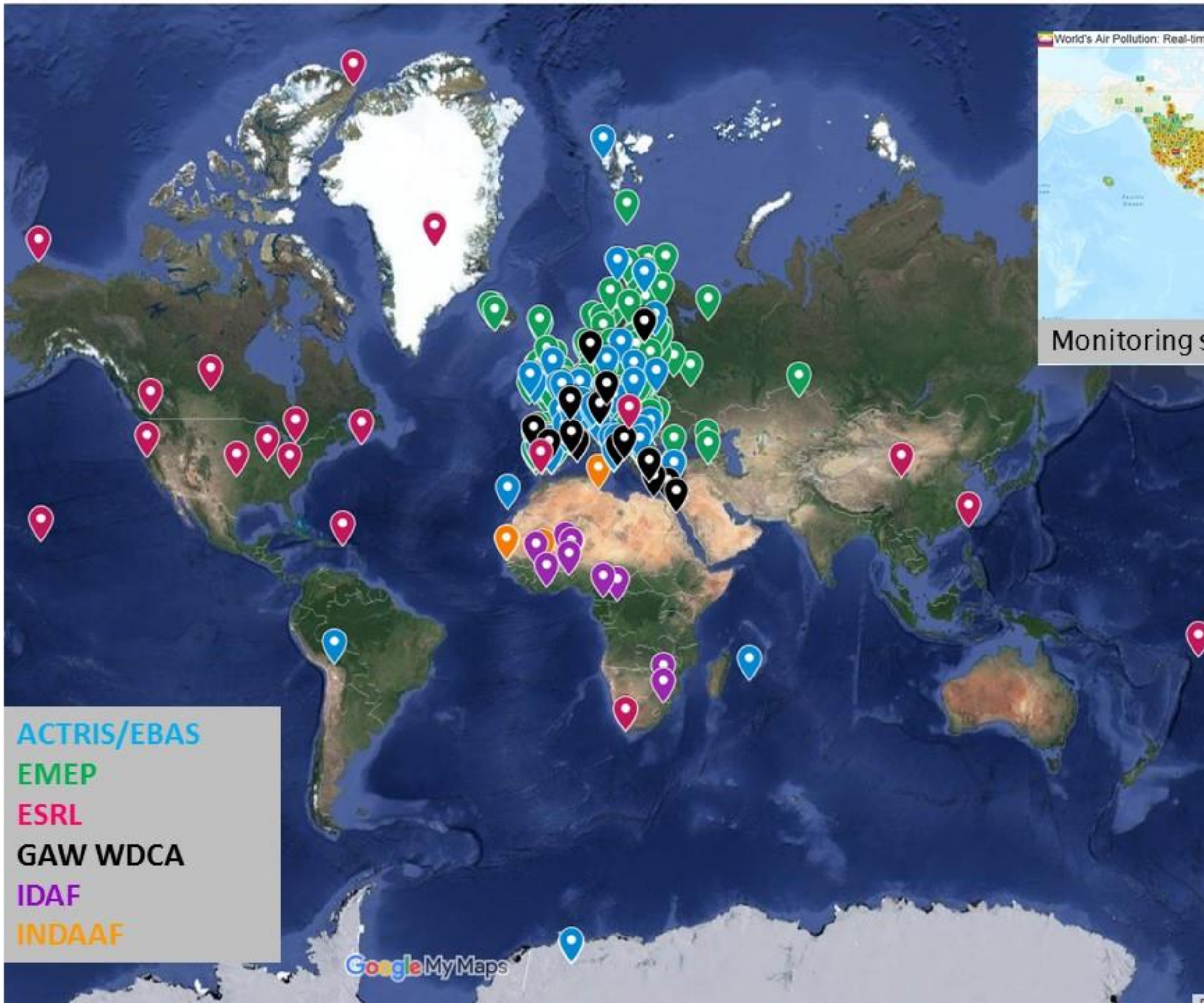
Parameter	Concept	Strengths	Weaknesses	Network/ Programme
PM bulk concentrations	Dust contribution to the collected PM can be estimated considering that dust particles are big particles and that intrusions are anomalies in the PM records	- high spatial density in developed countries - standardized measurement within air quality networks	- not able to directly distinguish dust from other aerosol types - different instruments, measurement techniques and dust contribution calculation methodologies - full-size range of dust not always encompassed by the PM metrics - low spatial density in developing countries	ACTRIS in situ EMEP ESRL GAW-WDCA INDAAF EANET EIONET EPA IMPROVE
PM chemical composition	Presence of mineral elements into PM samples allows the dust contribution estimation	- very reliable estimates of dust component	- very expensive and laborious - difficult to apply routinely - limited availability, mostly limited to short-term campaigns	ACTRIS in situ EMEP GAW-WDCA EANET EIONET EPA IMPROVE

Measurements at the surface

Parameter	Concept	Strengths	Weaknesses	Network/ Programme
Visibility	Visibility in absence of clouds and precipitation is related to aerosol	- good spatial and temporal coverage	- visibility reduction due to the presence of hydrometeors (fog, rain, etc.) - site dependent relationships	□ NOAA ISD □ IMPROVE
Dust deposition fluxes	Deposition on filters or concentration at surface in dust source region can be simply regarded as dust	- limited data availability - heavy measurement load - data heterogeneity		□ CARAGA □ EMEP □ INDAAF □ EANET
Dust physical properties	Absorption photometers, nephelometers, APS and OPC instruments derived size distribution	- standardized measurement techniques - distinctive dust optical properties	- variable spatial density	□ GAW-WDCA

Measurements at the surface

PM bulk concentration



Columnar remote sensing

How it works

Photometer points at Sun and measures radiance at different wavelengths.

Modelling the Solar radiation outside atmosphere and molecular absorption due to gases in atmosphere, observed differences are due to the aerosol presence.

The **Aerosol Optical Depth** is therefore retrived (primary measurement).

Nowadays advanced instruments allow the measurements using Sun, Moon and Star radiation as reference.

Columnar remote sensing

Measured quantities

Aerosol Optical Depth at different wavelength

Angstrom exponent δ : exponent in the power law for AOD with wavelength

$$AOD_1=AOD_2\,(\lambda_2/\lambda_1)\text{^}-\delta$$

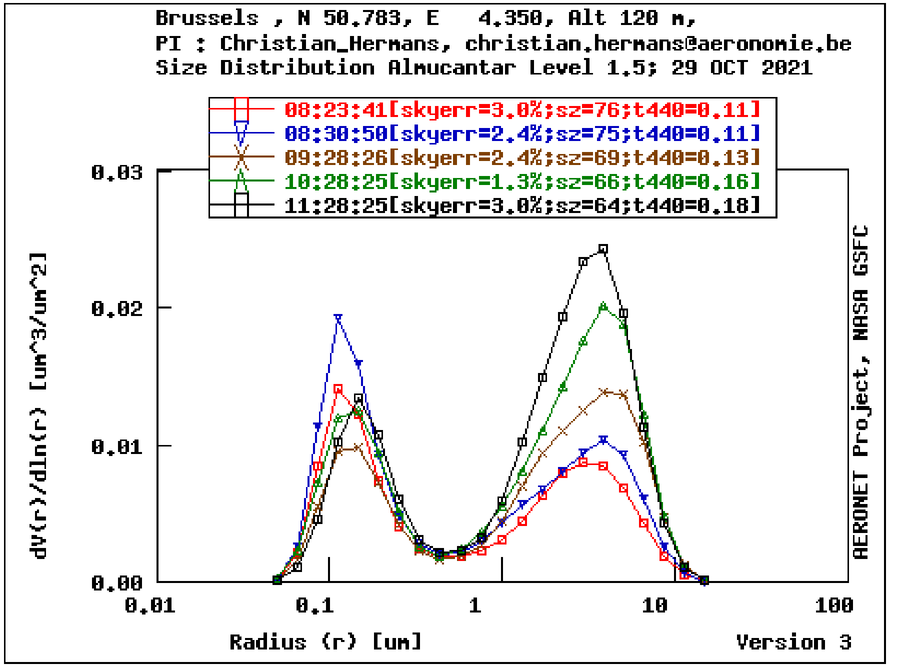
The highest is δ the smaller are the particles.
Values between -1 and 4

δ around 4 for molecules

Inversion products

Size distribution typically up to 10 micron

AOD coarse fraction: Fraction of AOD due to particles larger than 1 micron



Columnar remote sensing

Dust AOD (DOD)

- ❑ Angstrom below a certain threshold (and AOD higher than a threshold too)

  (e.g. Basart et al., 2009; Todd et al., 2007)

- ❑ DOD = AOD for the coarse mode (more appropriate for site distant from the source)

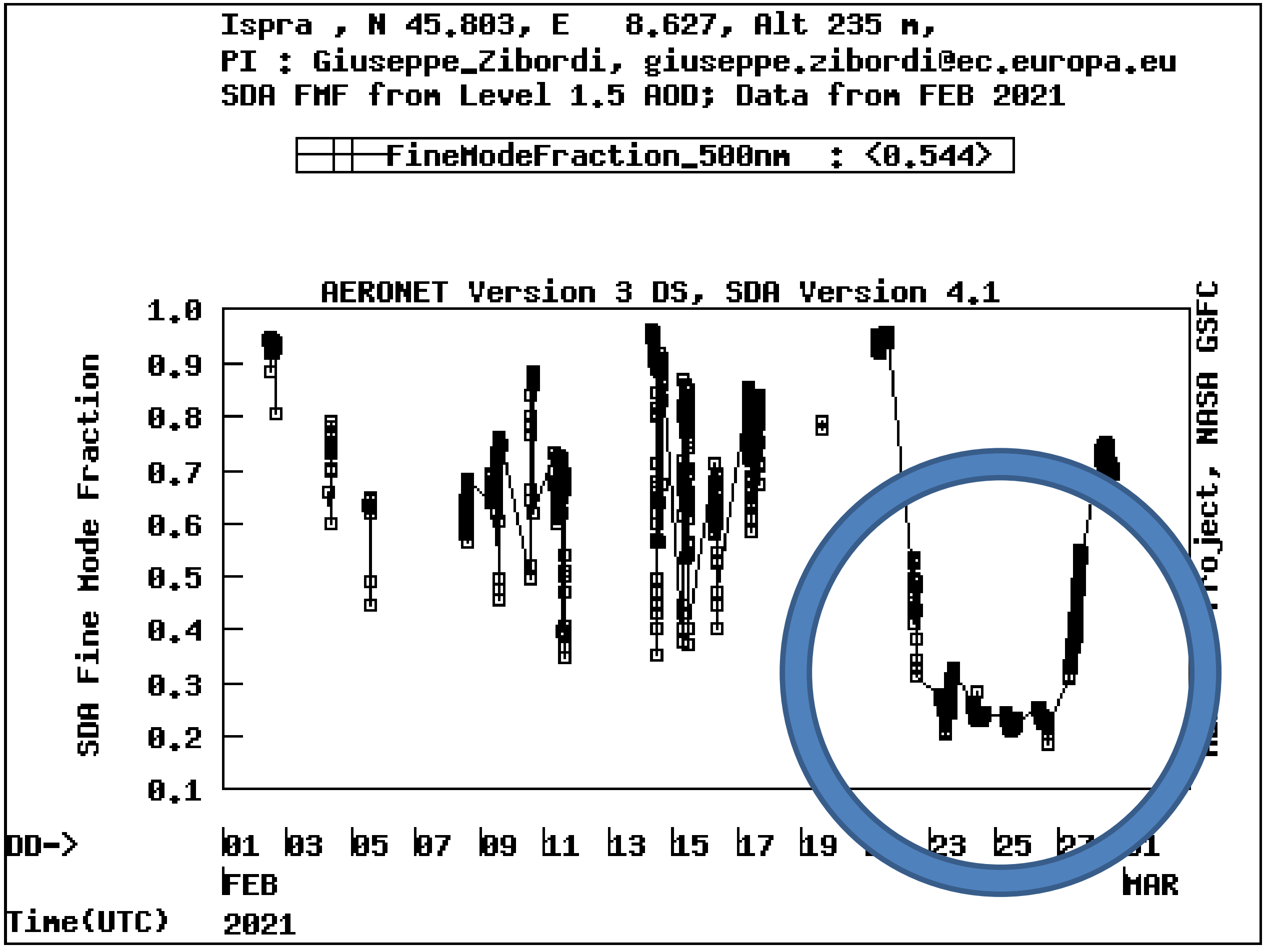
  (O'Neill et al., 2003)

- ❑ Advanced lidar/photometer products provided fine and coarse mode concentration profiles (uncertainty not fully assessed)

  (Dubovik et al., 2014)

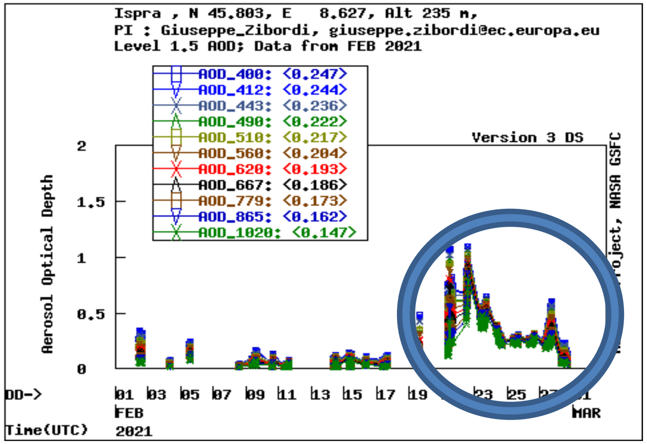
Columnar remote sensing

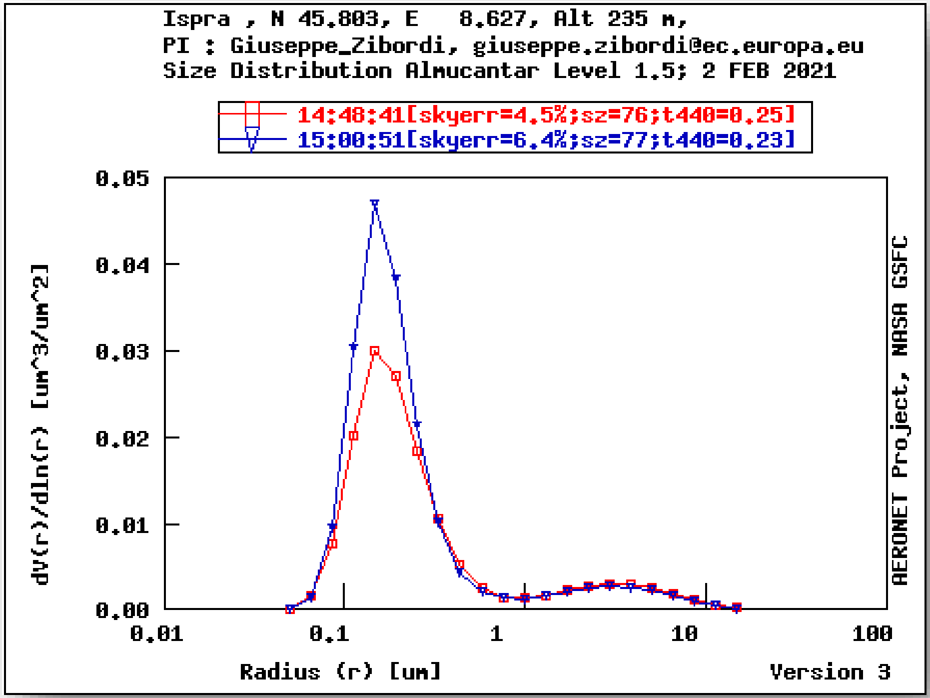
Example

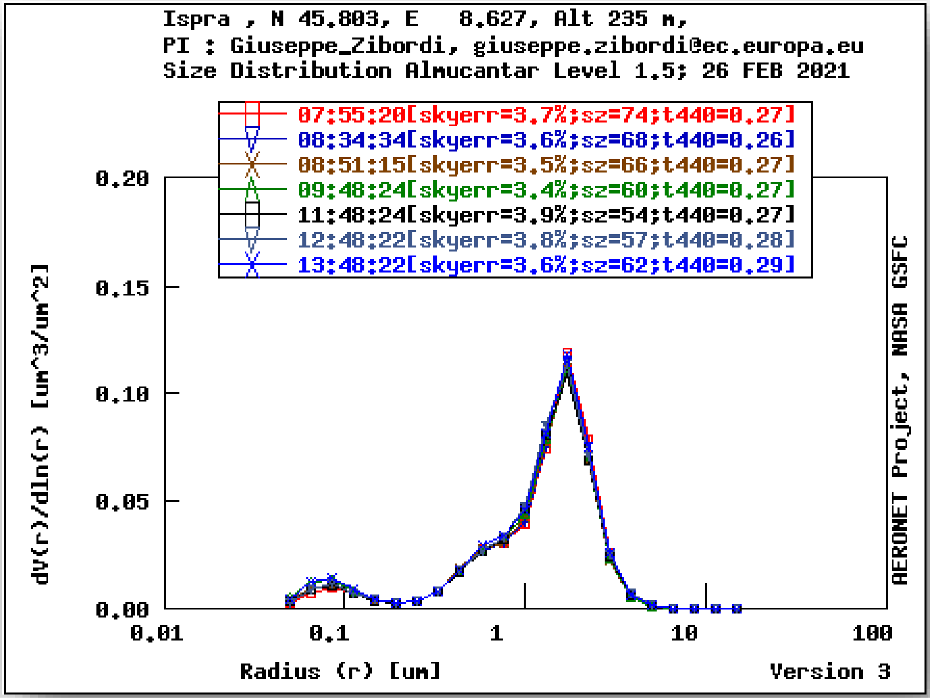


Columnar remote sensing

Example





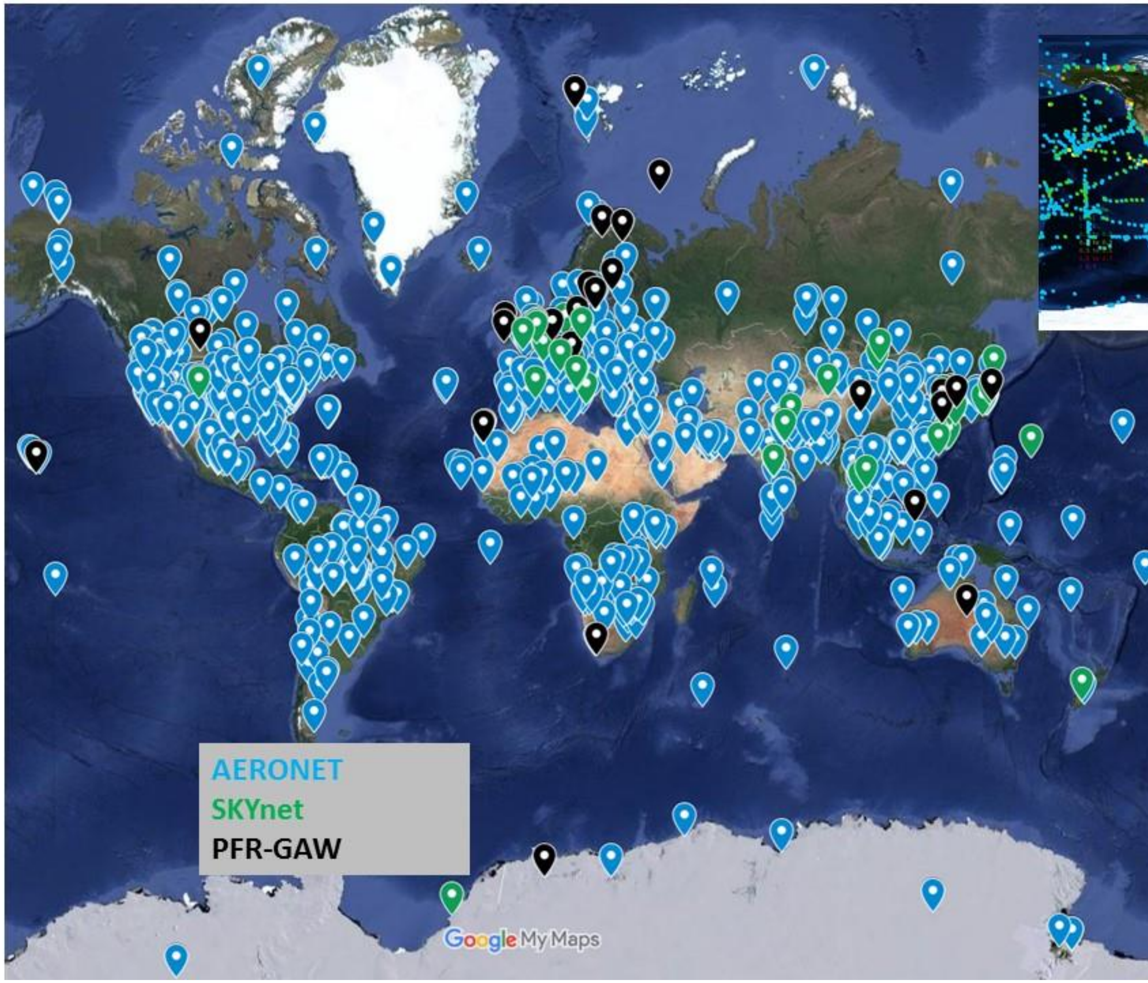


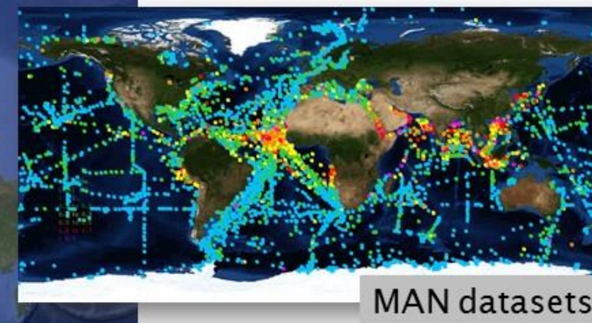
Columnar remote sensing

Parameter	Concept	Strengths	Weaknesses	Networks/Programmes
Dust Optical Depth	Dust contribution to the AOD (primary measurement) is obtained considering that coarse particles are dusty particles	- high spatial density in developed countries - based on well assessed primary products	-different methods (and uncertainty) in dust component evaluation - cut-off in retrieval algorithm (50 µm) not covering the complete dust size distribution - asphericity of the dust particle is still a critical point for inversion products (depending on the used algorithm for the dust contribution estimation) - data are typically limited to daytime condition and not cloudy scenes	AERONET SkyNet PFR-GAW

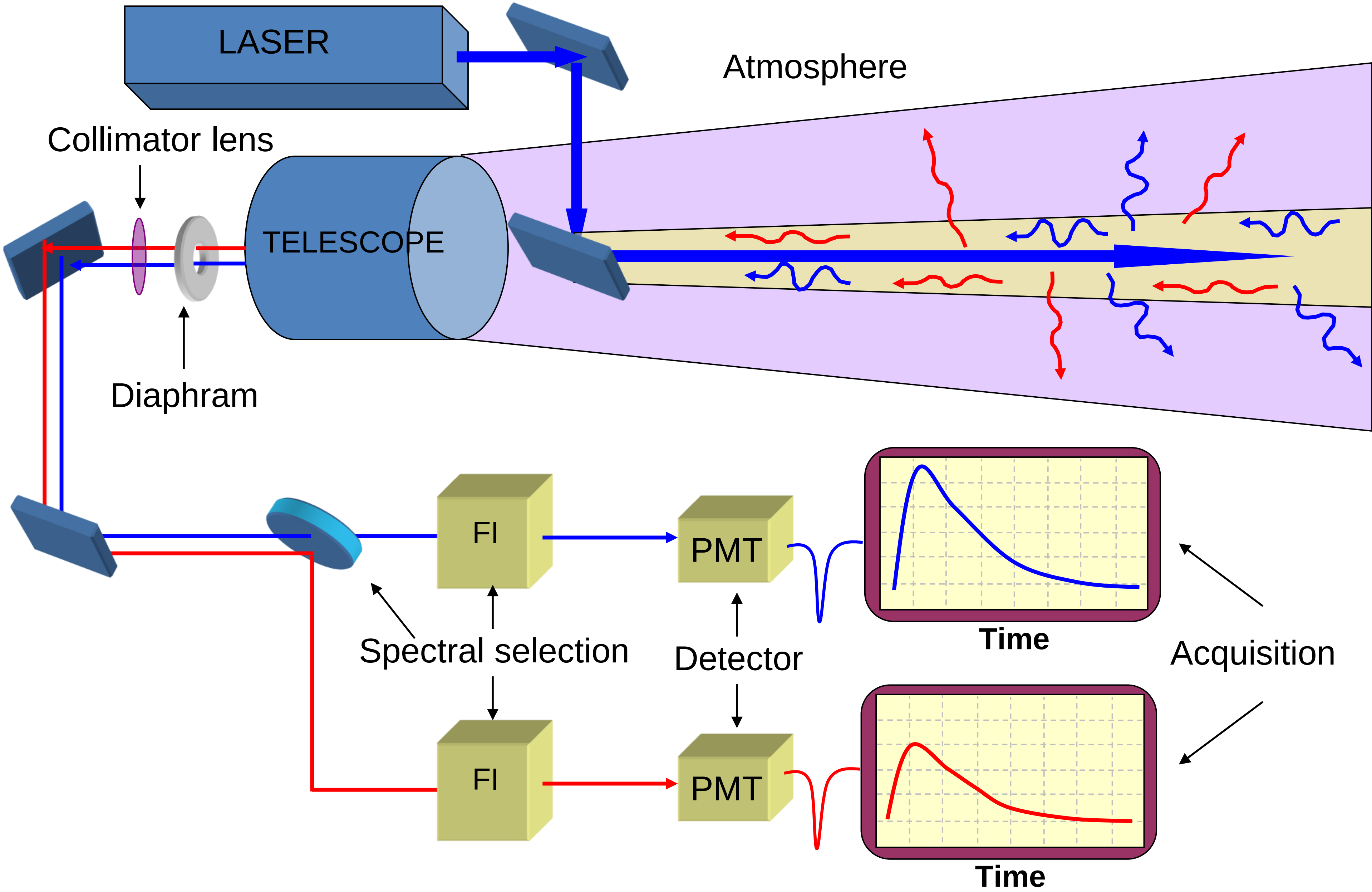
Columnar remote sensing

Dust Optical Depth





Lidar remote sensing



Lidar remote sensing

Measurement techniques

- ❑ Elastic lidar

  Detection only at same wavelength of emitted laser light

- ❑ Raman lidar

  Detection tuned on shift for molecules present in atmosphere for aerosol extinction measurements

- ❑ High Spectral Resolution Lidar (HSRL)

  interferometrically separates the elastic aerosol backscatter from the Doppler broadened molecular contribution.

Ceilometer?

A low power elastic lidar

Lidar remote sensing

Measured aerosol parameters

- ❑ Aerosol backscatter coefficient

  (relevant assumptions if elastic lidar)

- ❑ Aerosol extinction coefficient

  (for Raman and HSRL)

- ❑ Lidar ratio (i.e. extinction to backscatter ratio)

  (for Raman and HSRL)

- ❑ Angstrom exponent

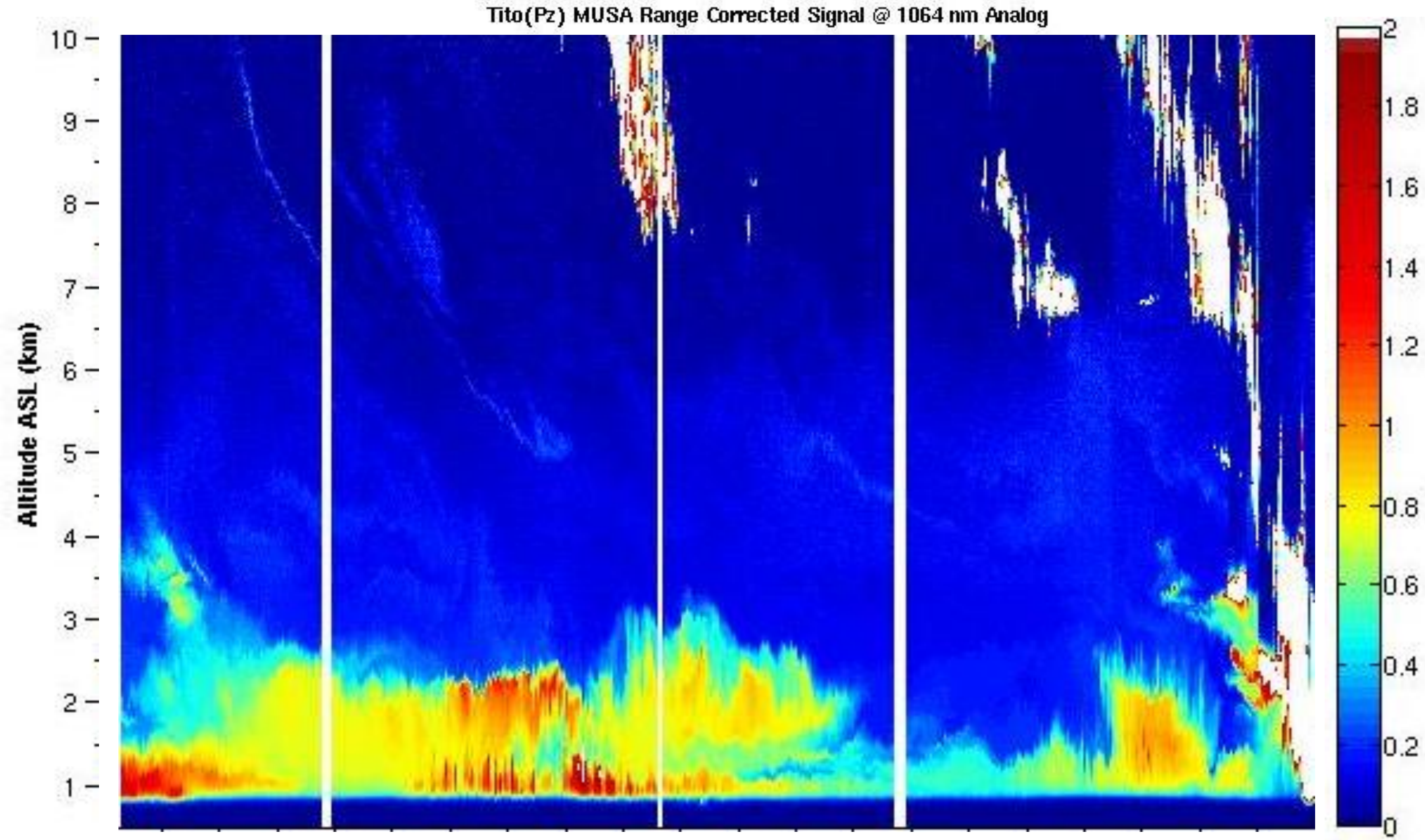
  (for multiwavelength lidar)

If equipped with depolarization channel

- ❑ Volume depolarization ratio
- ❑ Particle depolarization ratio

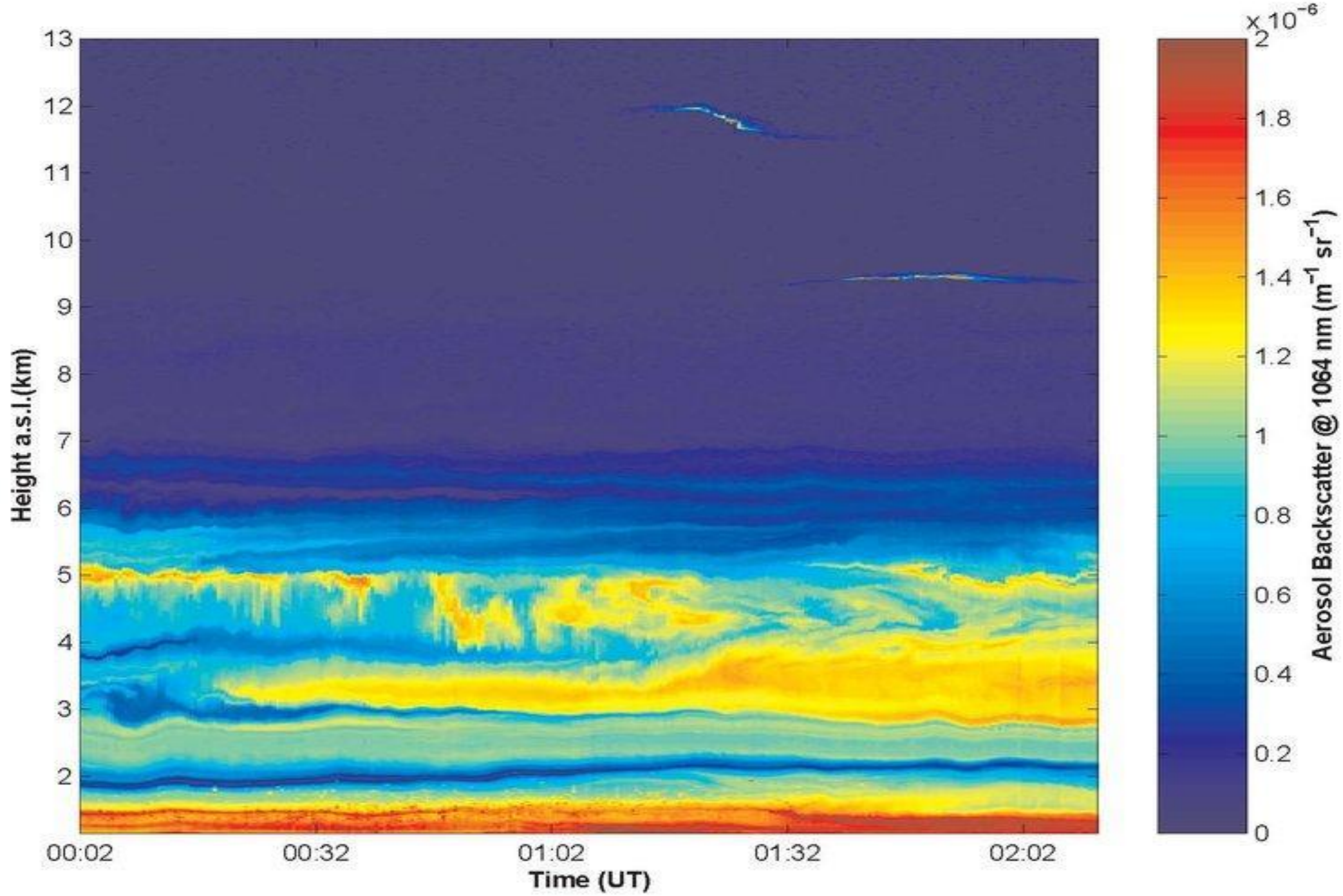
Lidar remote sensing

Example of collected signals



Lidar remote sensing

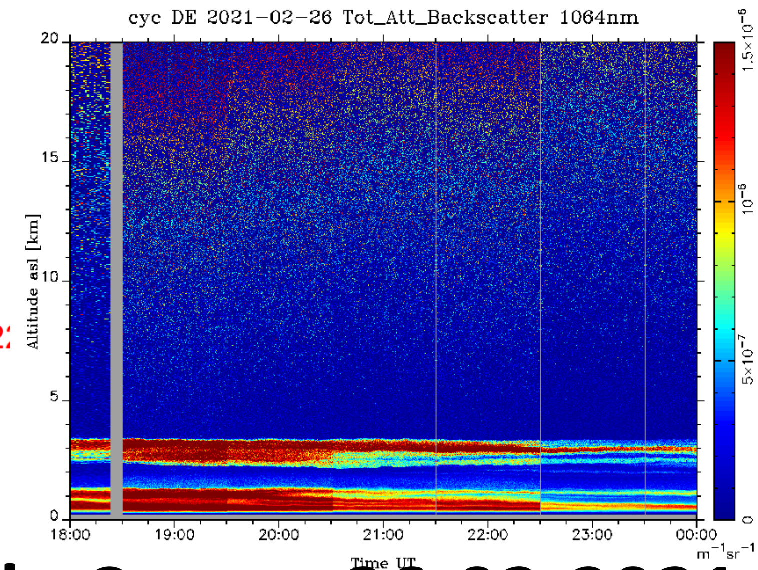
Dust arrival example - 26 June 2006 Potenza IT

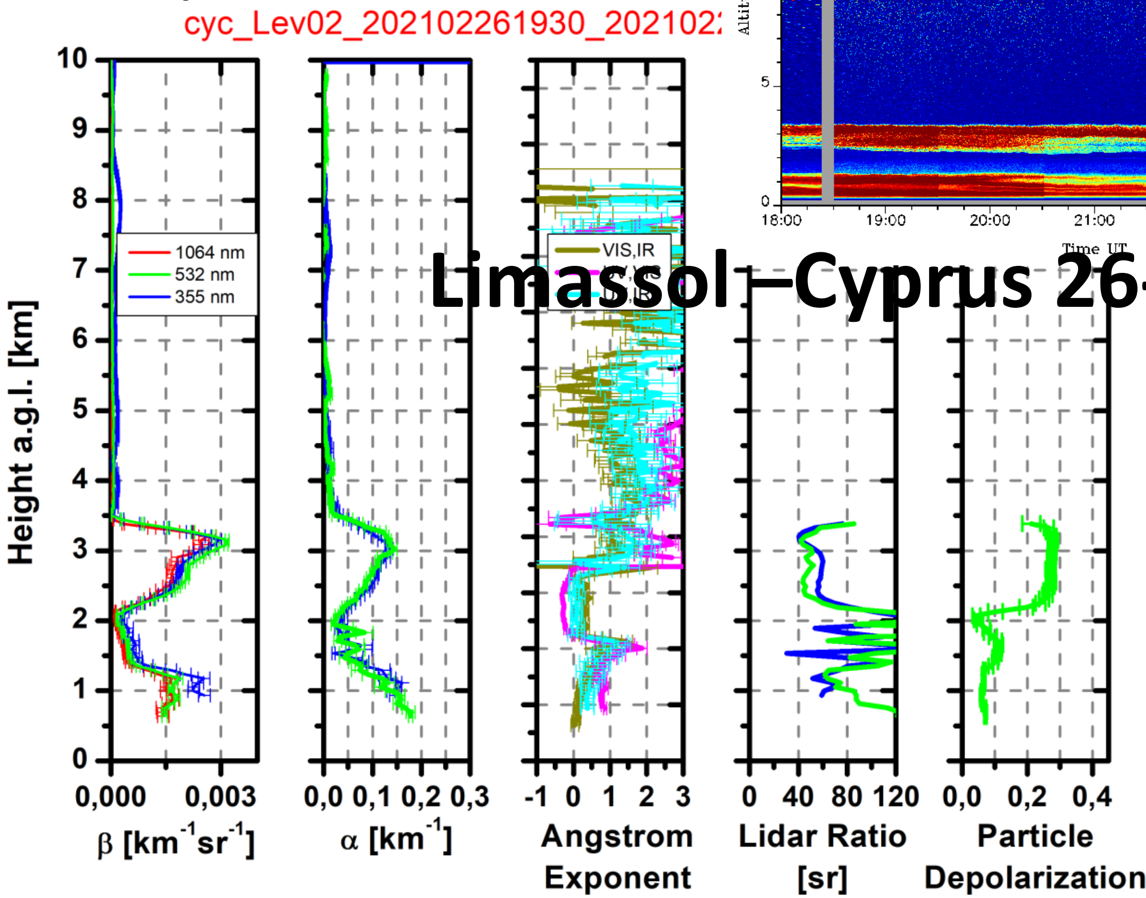


Lidar remote sensing

Dust discrimination

- ❑ Angstrom exponent
- ❑ Particle depolarization





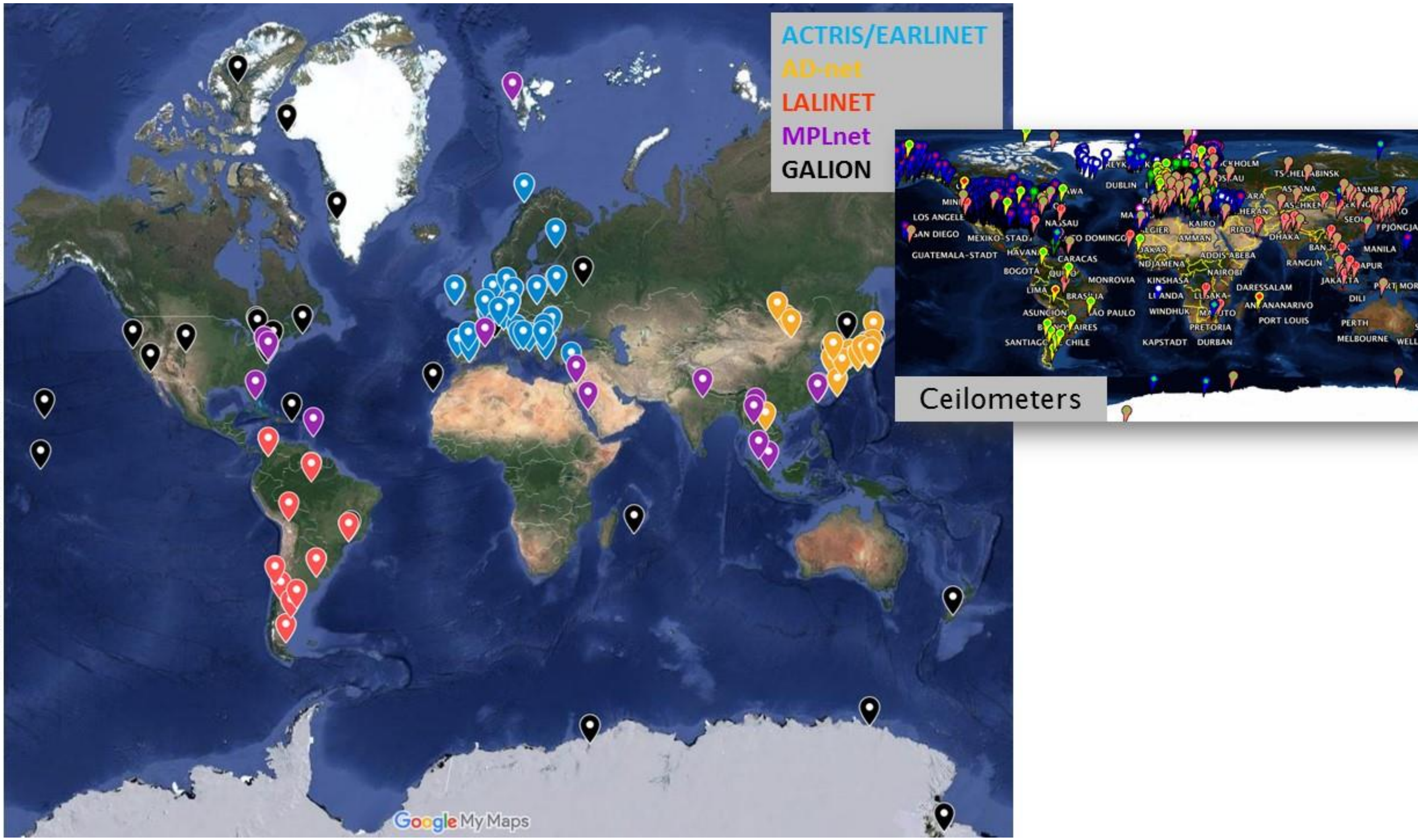
Limassol –Cyprus 26-02-2021

Lidar remote sensing

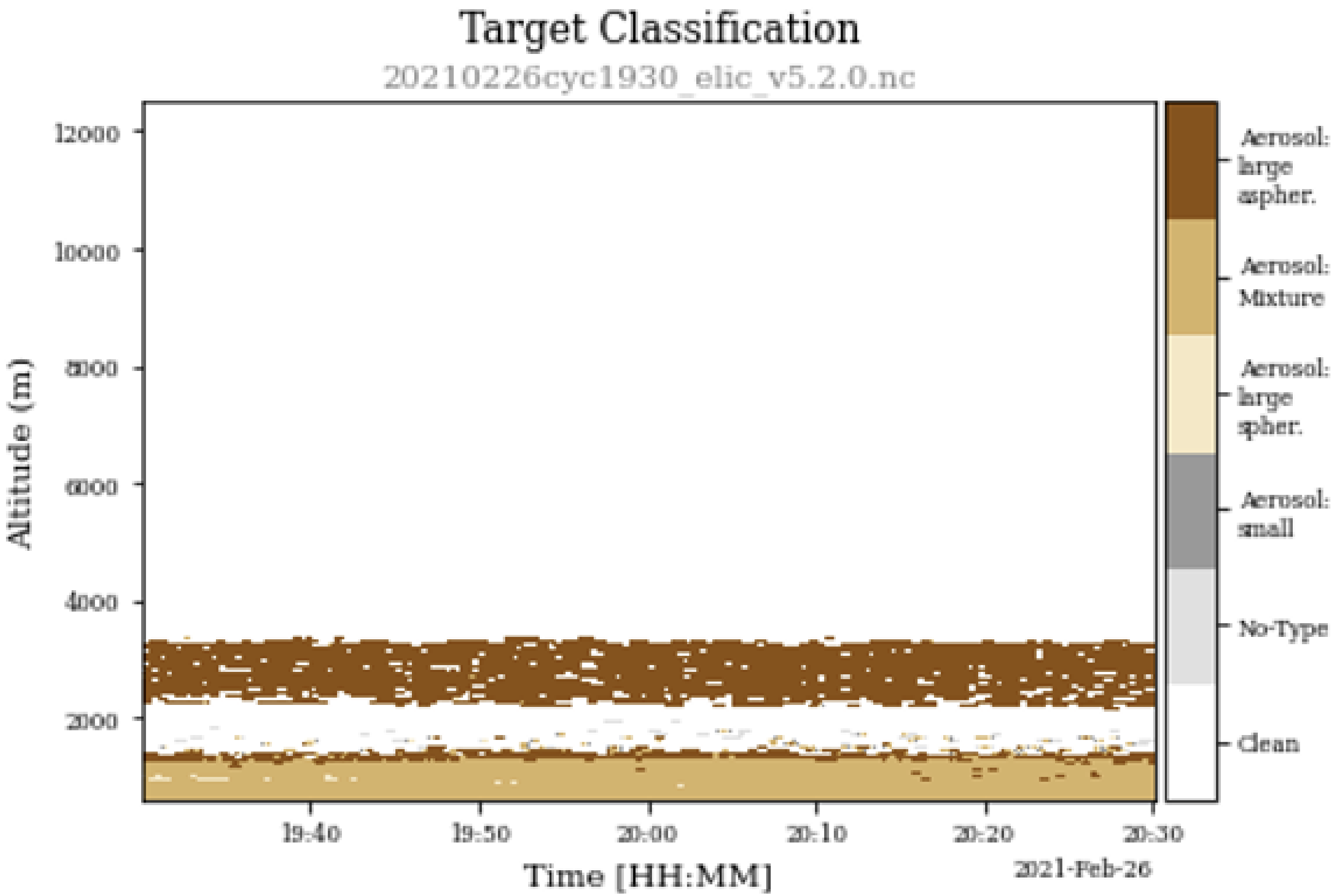
Parameter	Concept	Strengths	Weaknesses	Networks/Programmes
Dust Backscatter & extinction profiles	Particle depolarization measurements enable to identify the dust component in the aerosol backscatter &extinction profiles obtained by lidar measurements	- High vertical resolution - Possibility to investigate co-presence of different aerosol type at different altitudes - Possibility to investigate layer below clouds	- No other depolarizing particles considered in the dust attribution - Different setups mean different assumptions and uncertainties -Typically, not available 24/7 -Lower uncertainty in nighttime condition - Low clouds and precipitation inhibit the measurements	• ACTRIS/EARLINET • AD-net • LALINET • MPLnet • GALION • E-profile(for ceilometers)
Dust Mass Concentration profiles	Dust backscatter profiles are used typically as input for deriving the extinction profiles and then through some assumptions (algorithm) the mass concentration profile	-High vertical resolution - Main required information for aviation purposes - Synergy of lidar and photometer plus retrievals can reduce the total uncertainties	-30-60% for Raman/HSRL lidars (even up to 100% for particles larger than 15µm) -Additional uncertainty for backscatter lidars due to further assumptions (lidar ratio) -Errors of advanced retrieval algorithms still to be quantified -Typically not available 24/7 -Lower uncertainty in nighttime condition -Low clouds and precipitation inhibit the measurements	• ACTRIS/EARLINET • AD-net • LALINET • MPLnet • GALION

Lidar remote sensing

Dust Backscatter Profiles

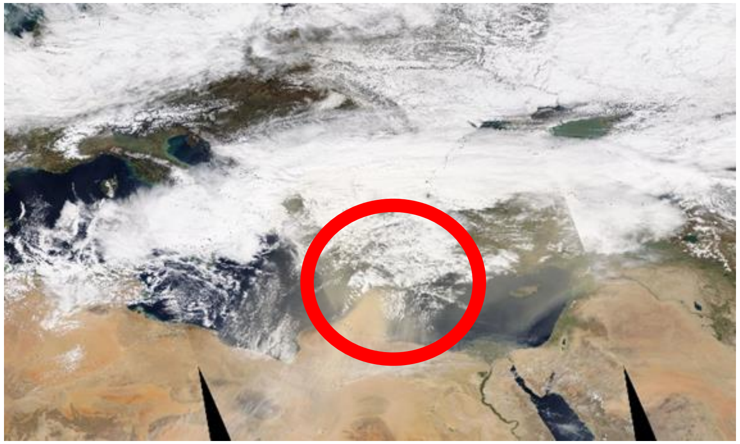


Promising dust lidar product



A lidar Early Warning System

Dust (and volcanic ash) can be a hazard for aviation.



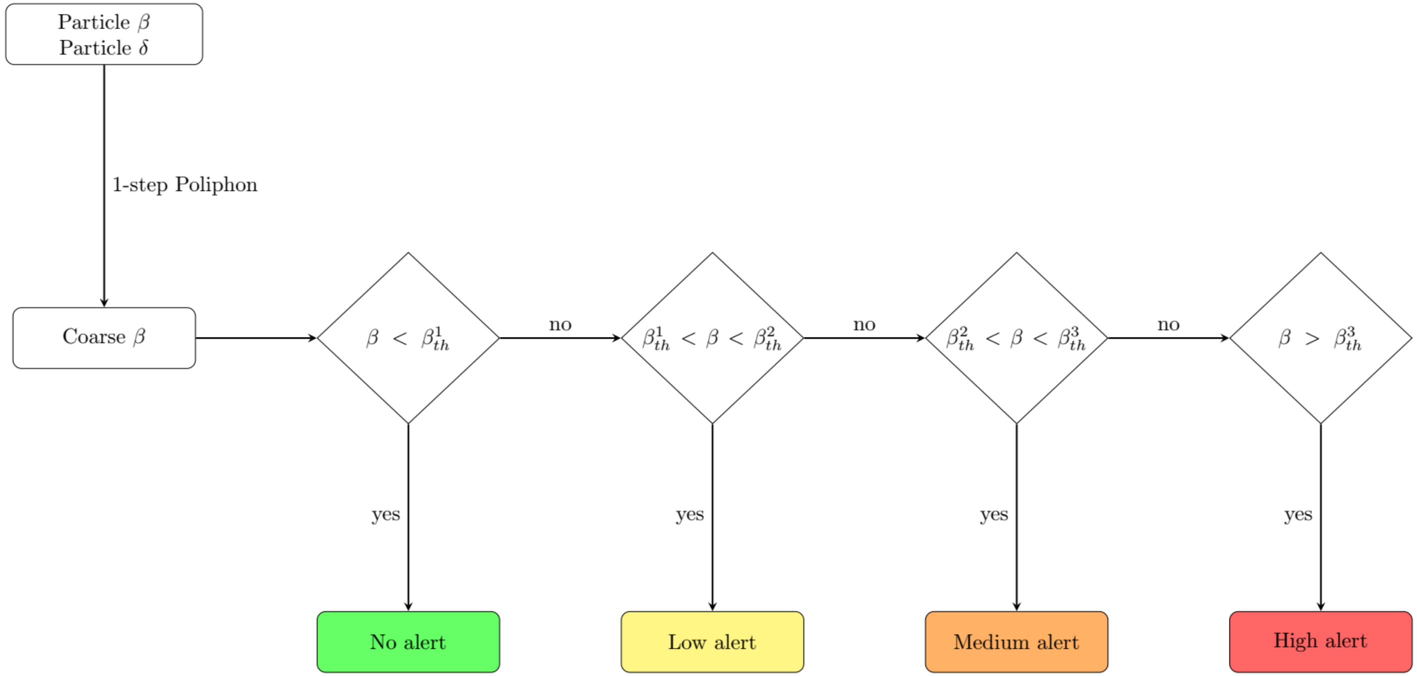
MODIS

Sky turned orange over Heraklion Crete on 22/03/2018

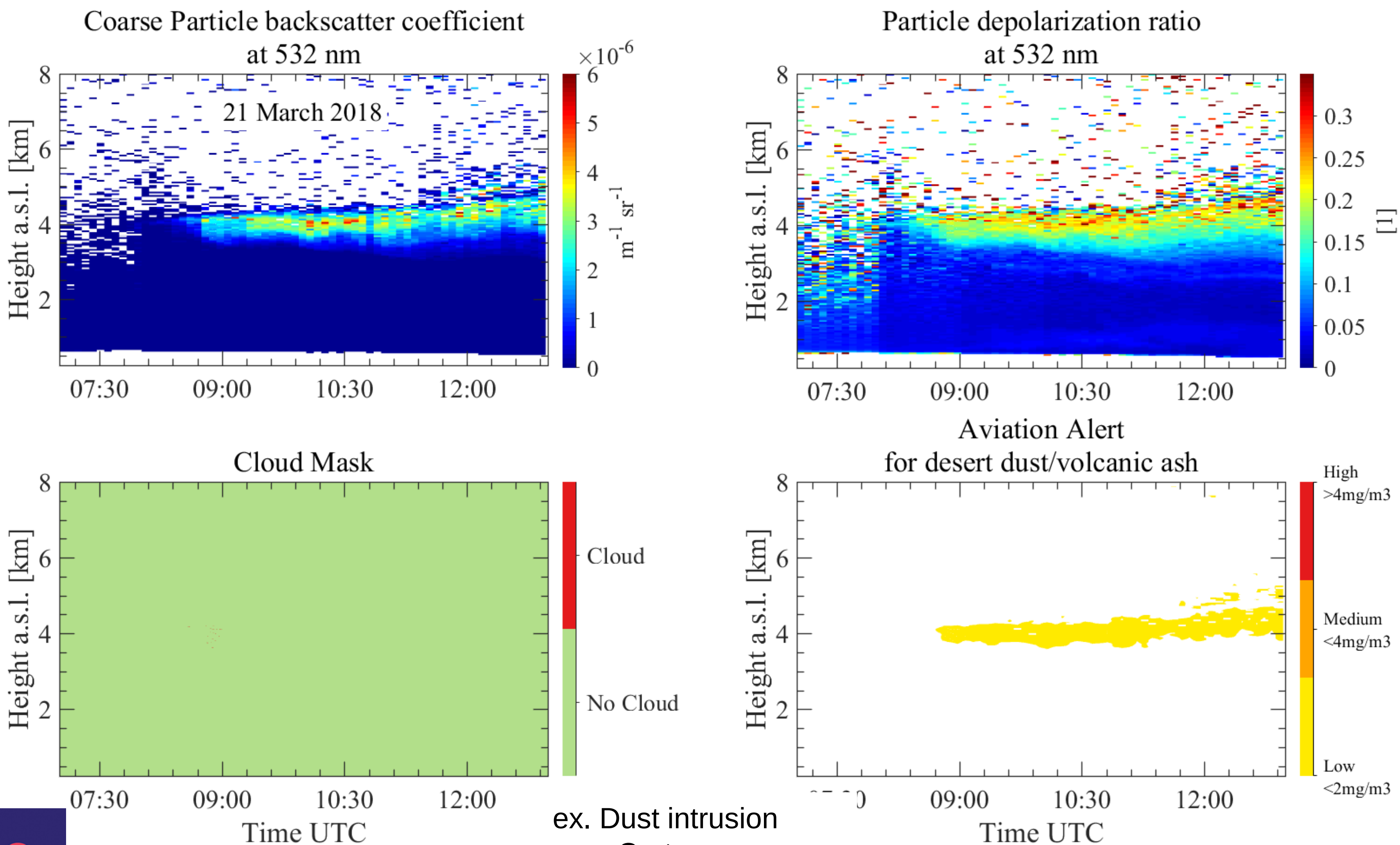
A lidar Early Warning System

The developed methodology (Papagiannopoulos et al., ACP, 2020)

- uses **EARLINET/ACTRIS high-resolution data** for an EWS for volcanic dust/desert dust
- requires **single-wavelength** polarization lidar (i.e., particle β and δ).
- can be applied to other **networks** (e.g., MPLNET, LALINET, ADNET…).



A lidar Early Warning System



ex. Dust intrusion over Crete (Papagiannopoulos et al., 2020)

Take home message

- Dust contribution can be inferred by the different techniques and methods
- Methods are different and differences have to be taken into account
- Pro and cons different for each different technique