Méthodes d'observation

Observation Methods
(focus on dust)

(MAC2/3.5b/380)

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Aerosols exist in the atmosphere as a natural origin

Without aerosols there would no be clouds!

Aerosol

"Solid and liquid matter suspended in a gas"

exemple: spray (l+g), dust (s+g), smoke (s+g), vapor (l+g)

Atmospheric aerosol

"Solid and liquid matter suspended in the **atmosphere**"

exemple: atmosphere (g+l+s), cloud (l+g),….

Introduction

WMO OMM Global Atmospheric Watch Programme

As the WMO/GAW indicate, *"knowledge of aerosol radiative properties is needed for the evaluation of effects of aerosol particles on climate and air quality (visibility)"*

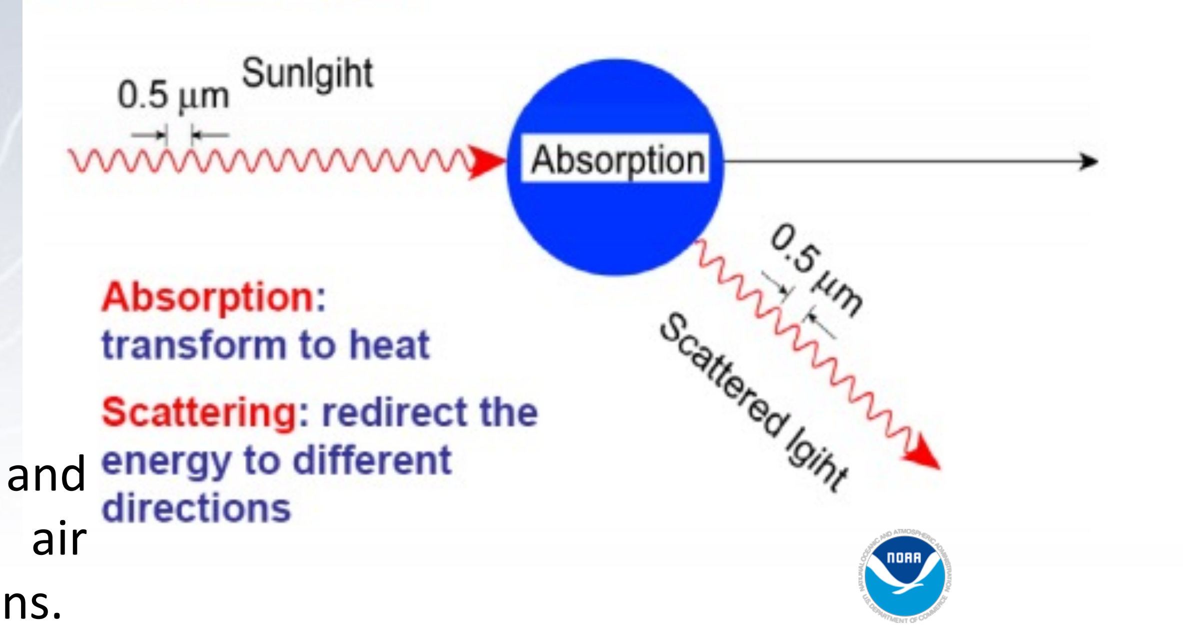
"The fundamental quantity of interest for these applications is the aerosol particles cross-section for light extinction per unit volume of air"

⇩

Ext=Abs+Sct

(aerosol) particle light extinction coefficient

σ_{ep}



GEOPHYSICAL FLUID DYNAMICS LABORATORY

In the atmosphere: aerosol particles can scatter and absorb solar and infrared radiation altering air temperature and the rates of photochemical reactions.

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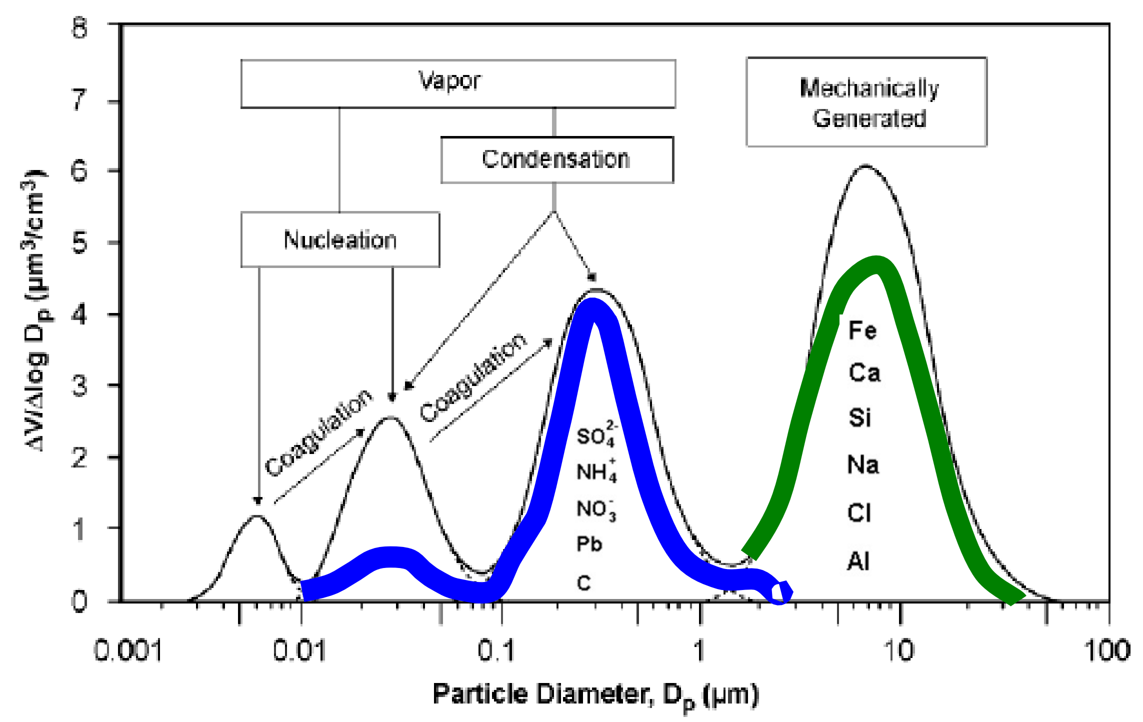
Observation: size and composition

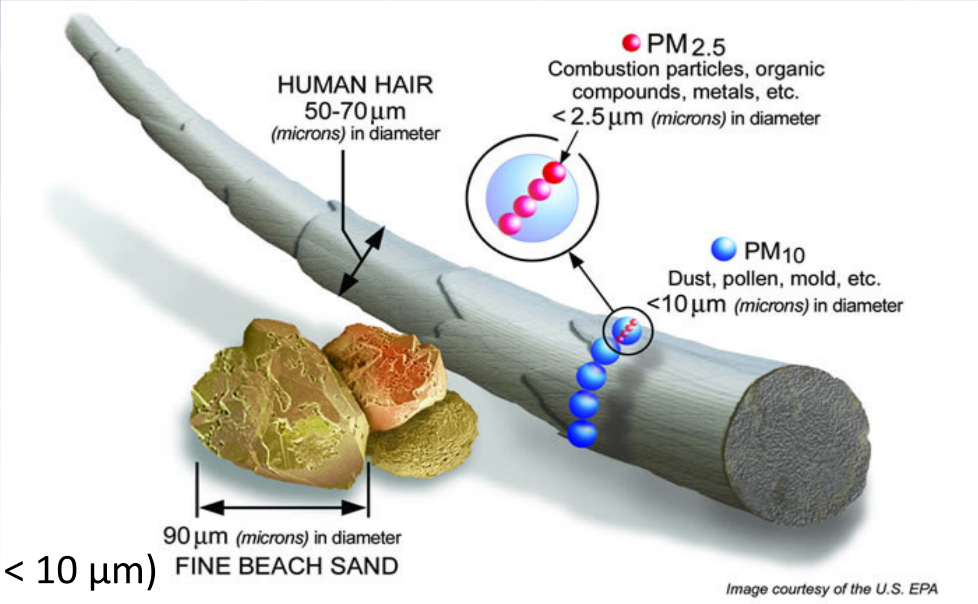
Microphysical properties: concentrations, size distribution
Optical properties: absortion and scattering



Size: **1nm – 100μm (10^{-9} – 10^{-4} m)**

< 1nm: ➔ **Å**

> 100μm: ➔ does not remain in suspension



In terms of Air Quality:→ Particulate Matter PM

PM10 mass concentration (µg/m^3) of all aerosols smaller than 10 µm (particles with Ø < 10 µm)

PM2.5 mass concentration (µg/m^3) of all aerosols smaller than 2,5 µm (particles with Ø < 2,5 µm)

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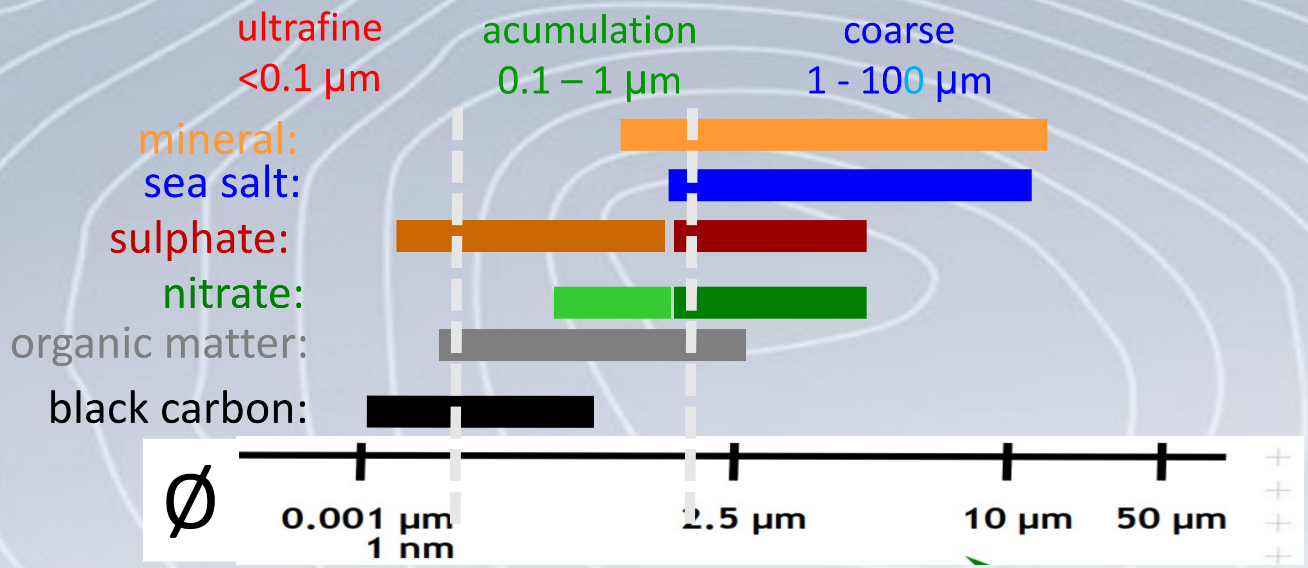
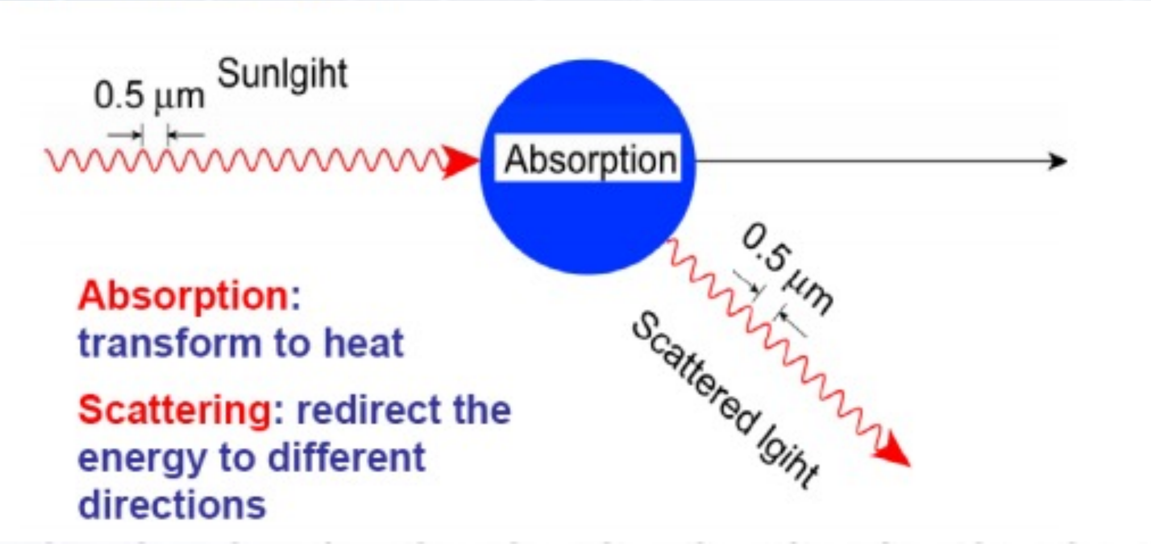
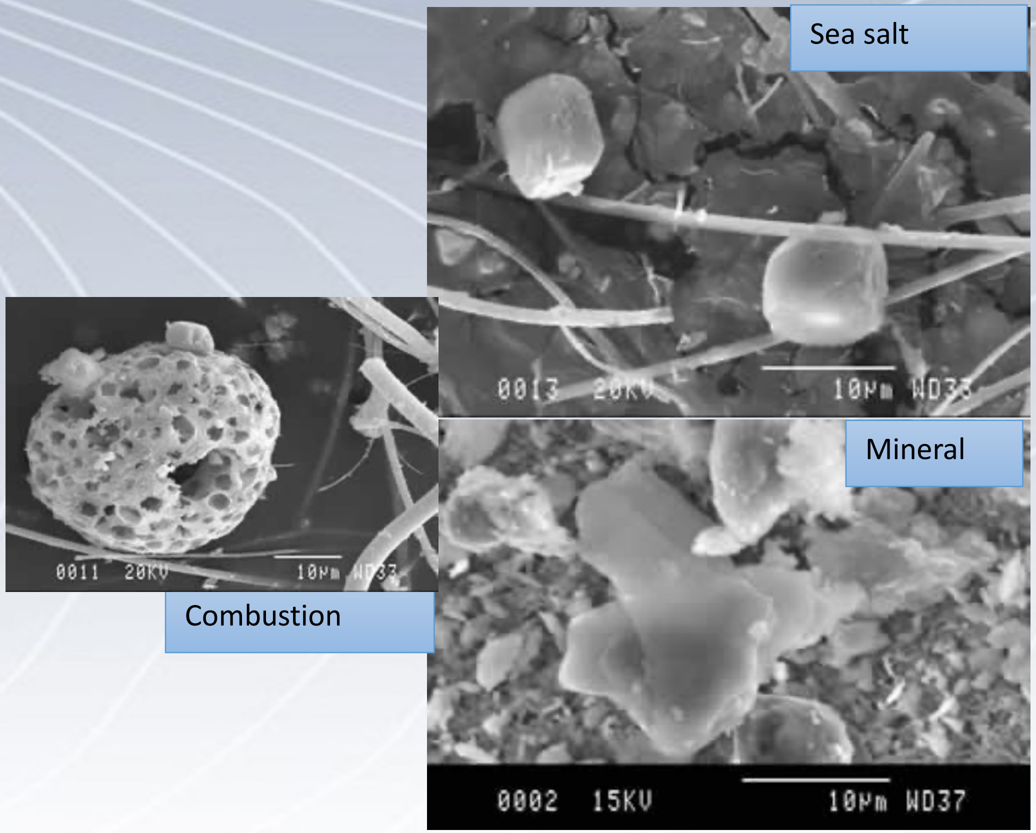
Observation: size and composition

Microphysical properties: concentrations, size distribution

Optical properties: absortion and scattering



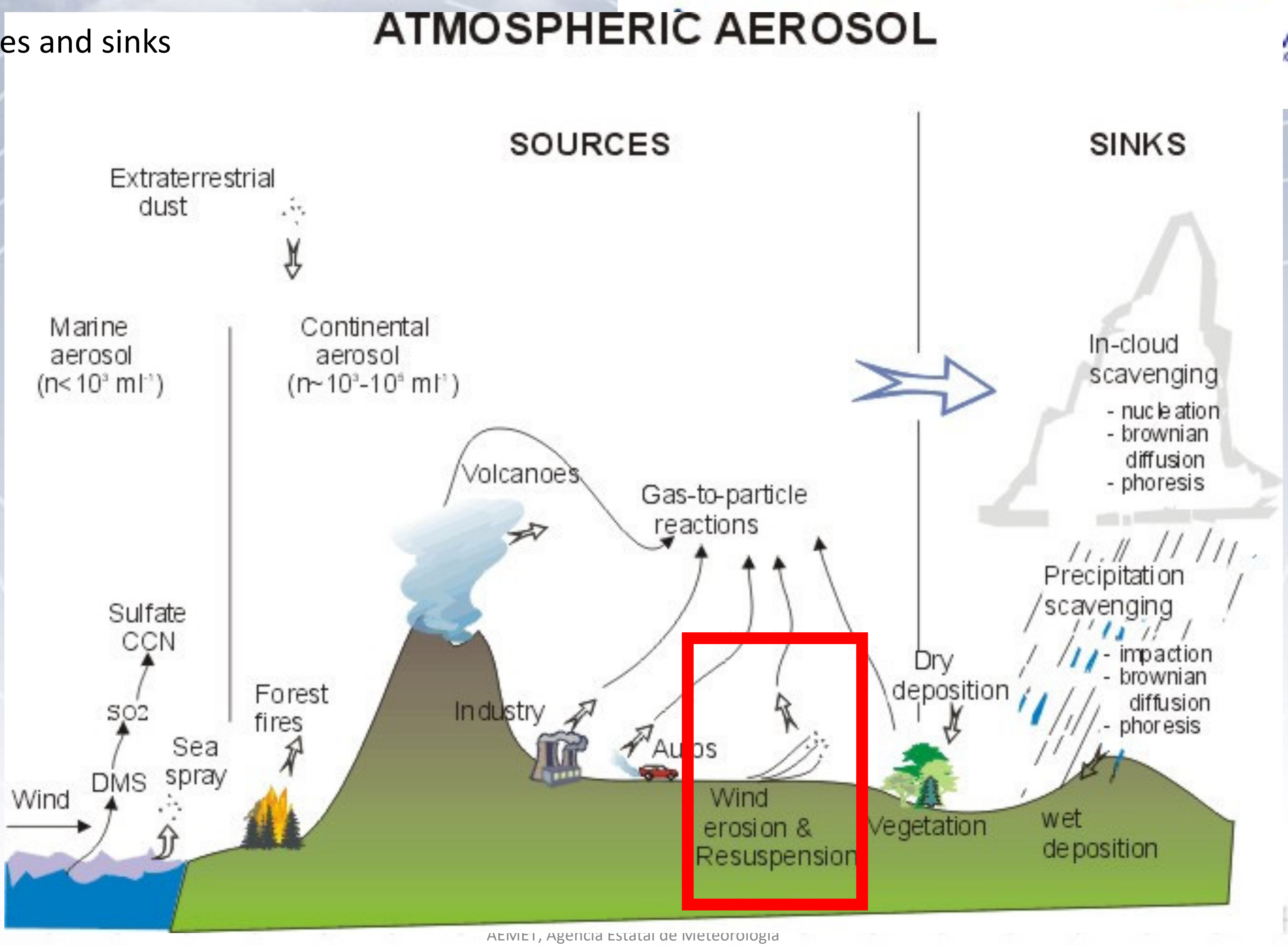




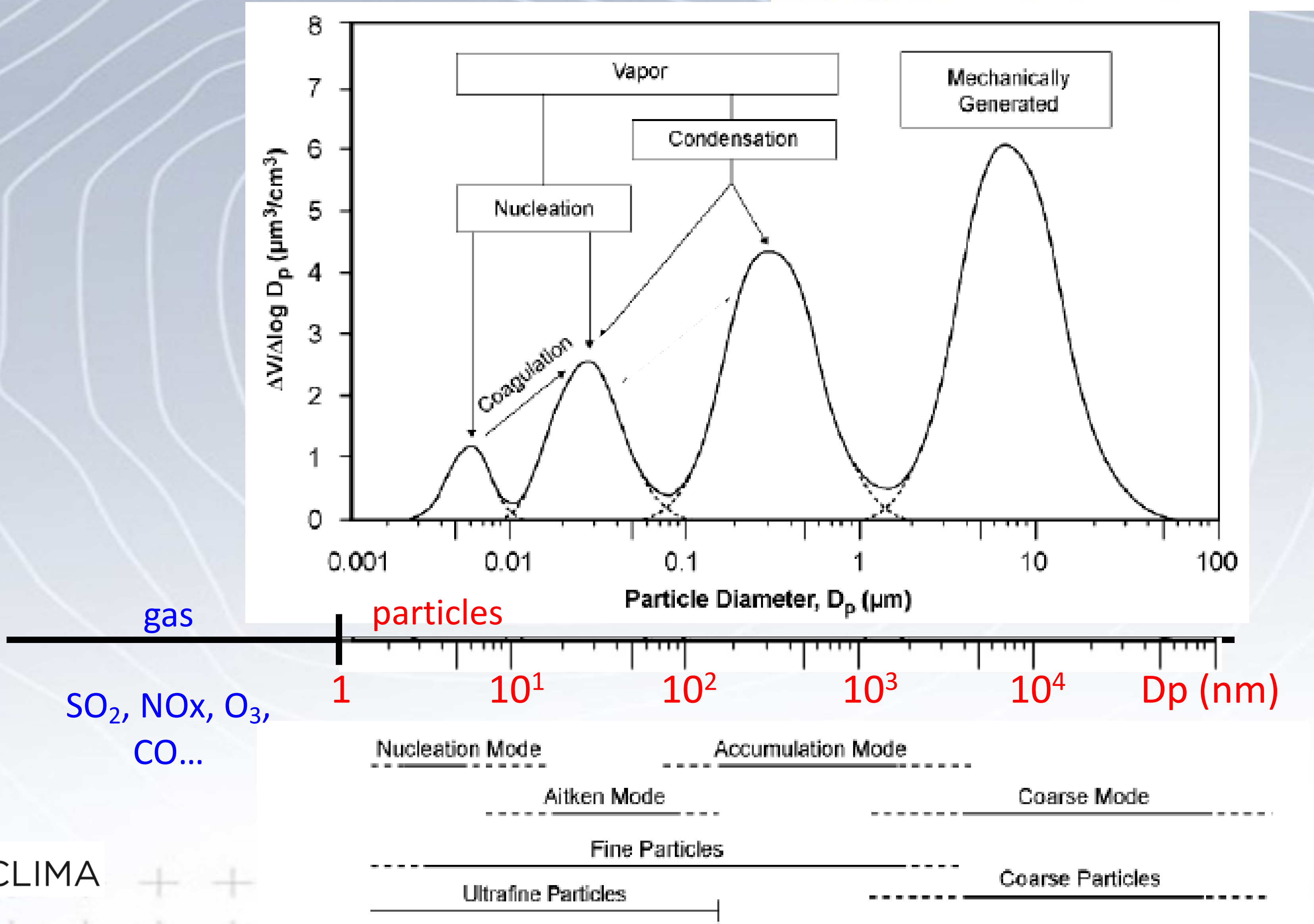
Images thanks to"Grupo de Geoquímica Ambiental del Instituto de Diagnóstico Ambiental y Estudios del Agua", CSIC

Introduction

Sources and sinks



Introduction



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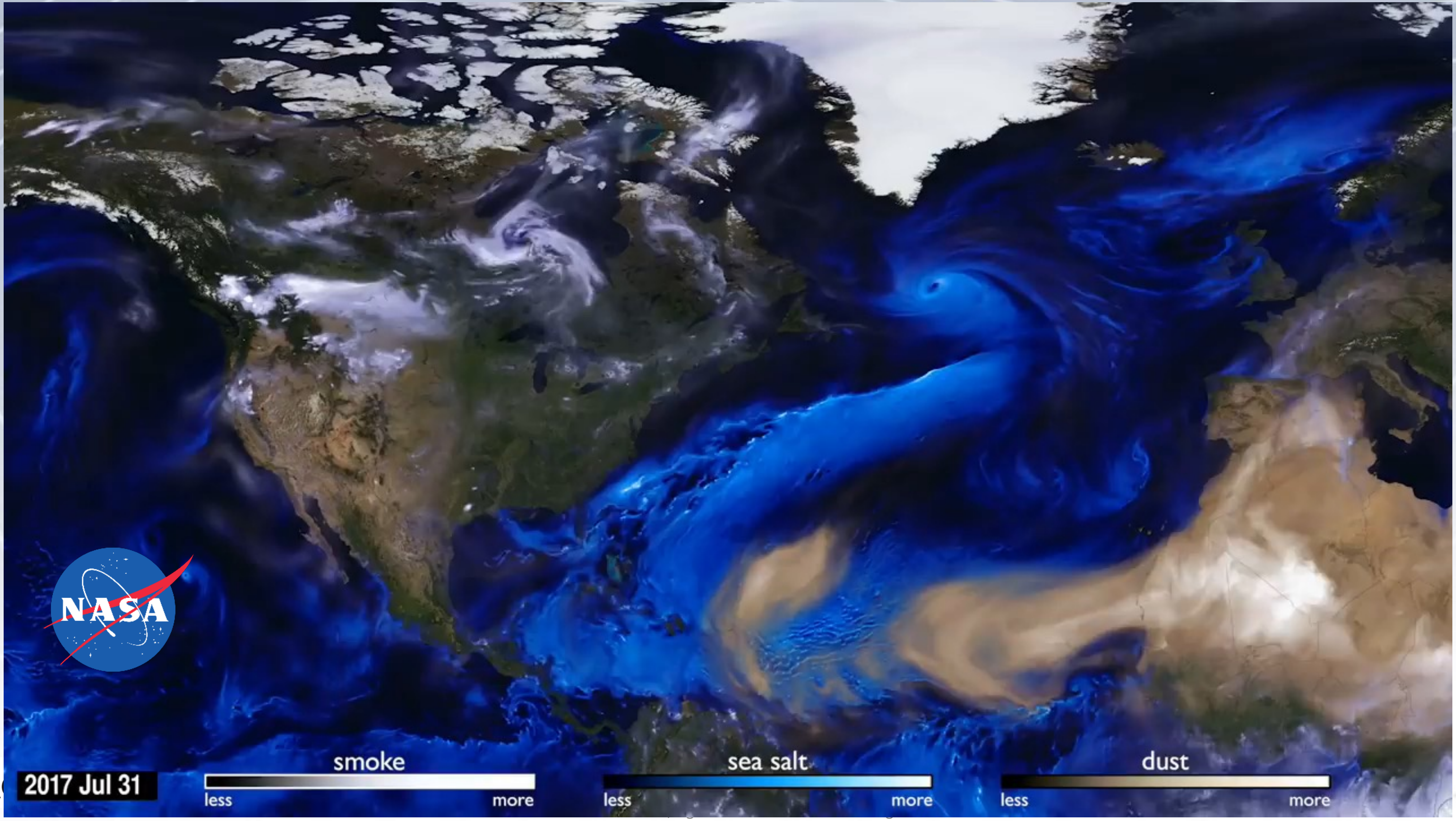
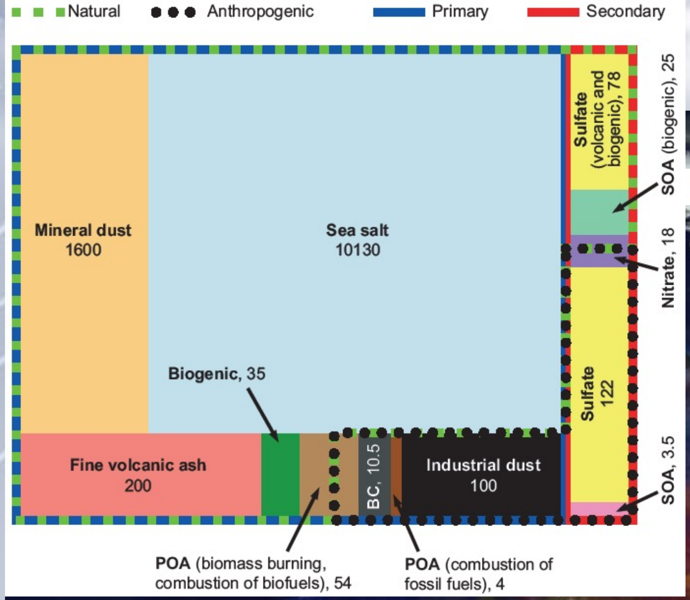
Introduction

Sources and skins

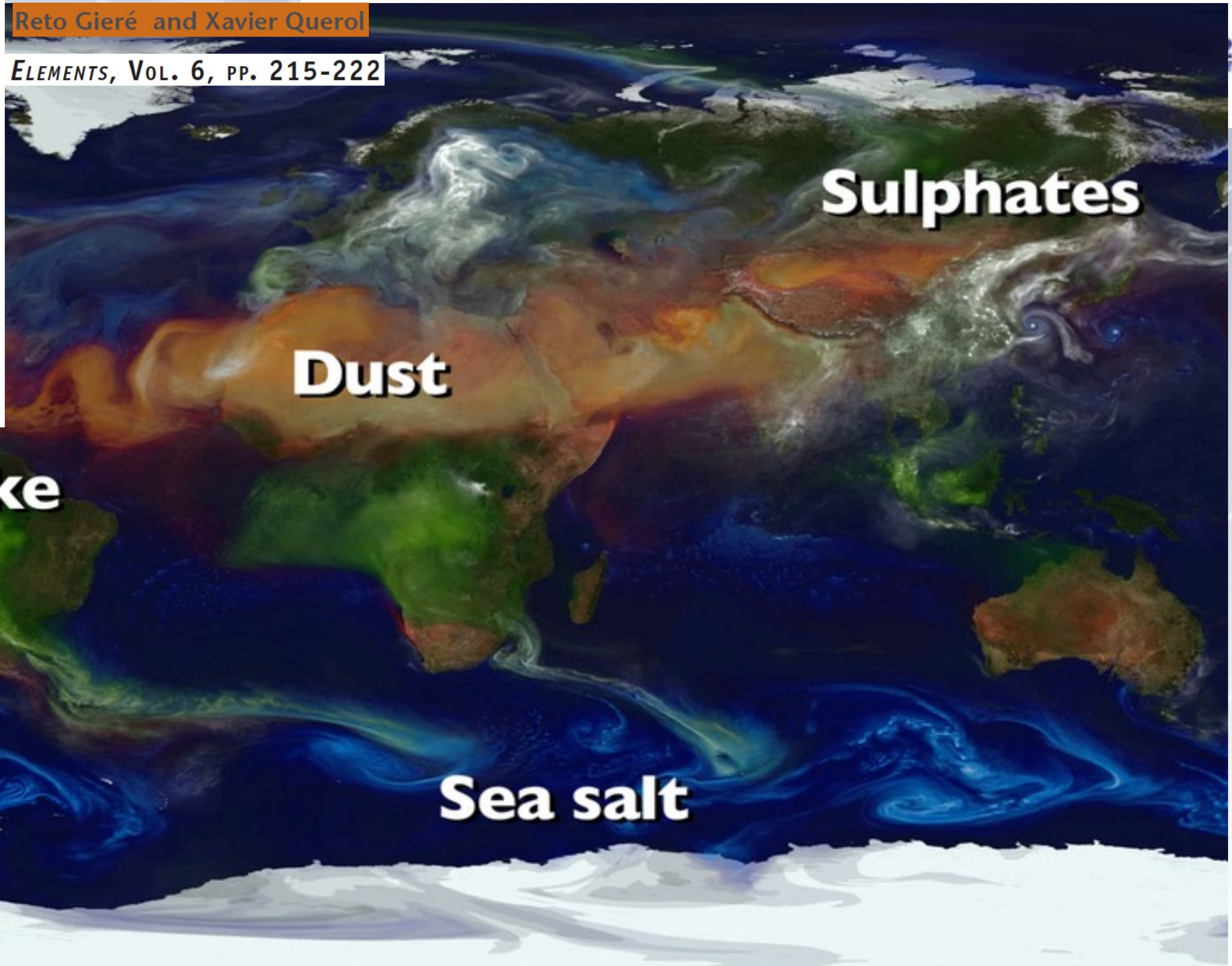




Solid Particulate Matter in the Atmosphere

Reto Gieré and Xavier Querol

Elements, Vol. 6, pp. 215-222



Absorbing components:
- Smoke (partially Black Carbon)
- Dust

Non-absorbing components:
- Sea salt
- Sulphates

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Introduction

Dust optical depth at 550 nm. Avergae value 2003-2015

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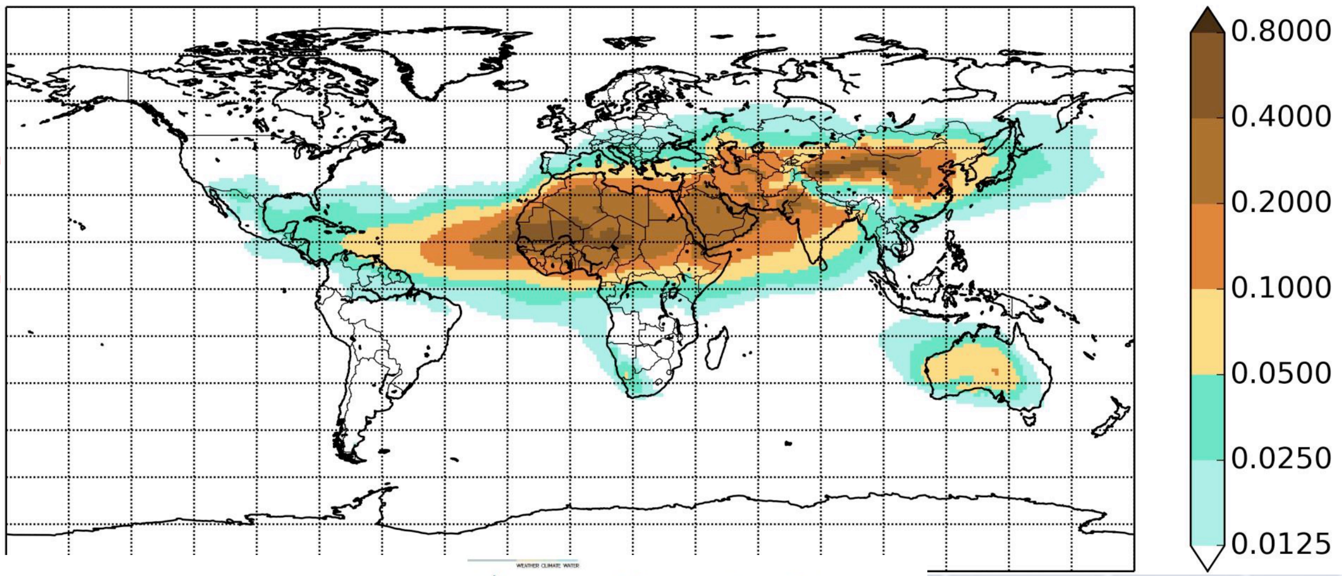
dust belt



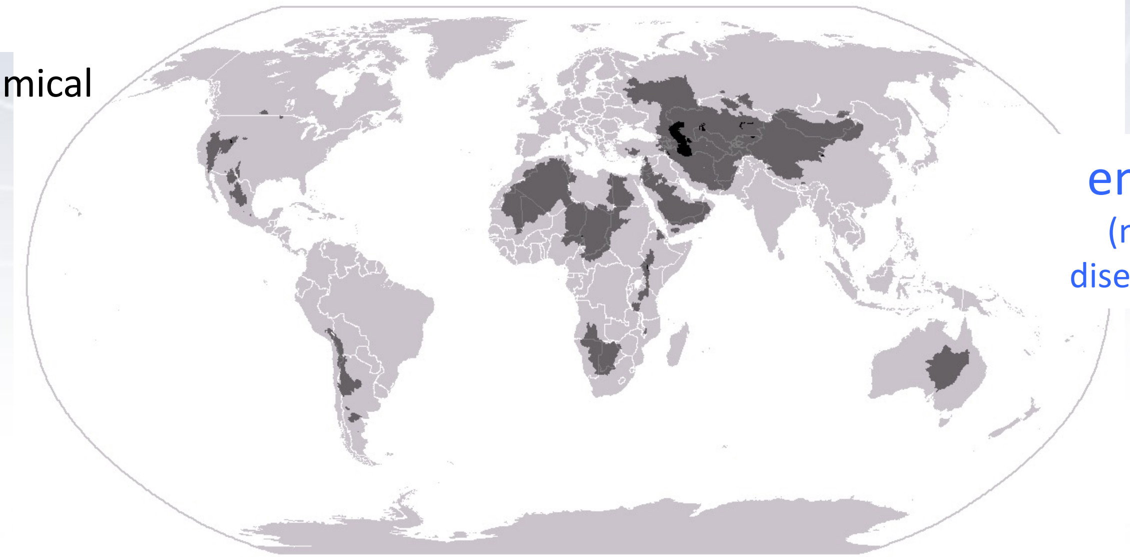
Copernicus

Data: CAMS reanalysis
Picture: WMO SDS-WAS

WMO AIRBORNE DUST

Ratio between different chemical components:

key for studing dust sources



endorheic basins
(no conection to sea, disekated lakes and rivers)

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Introduction

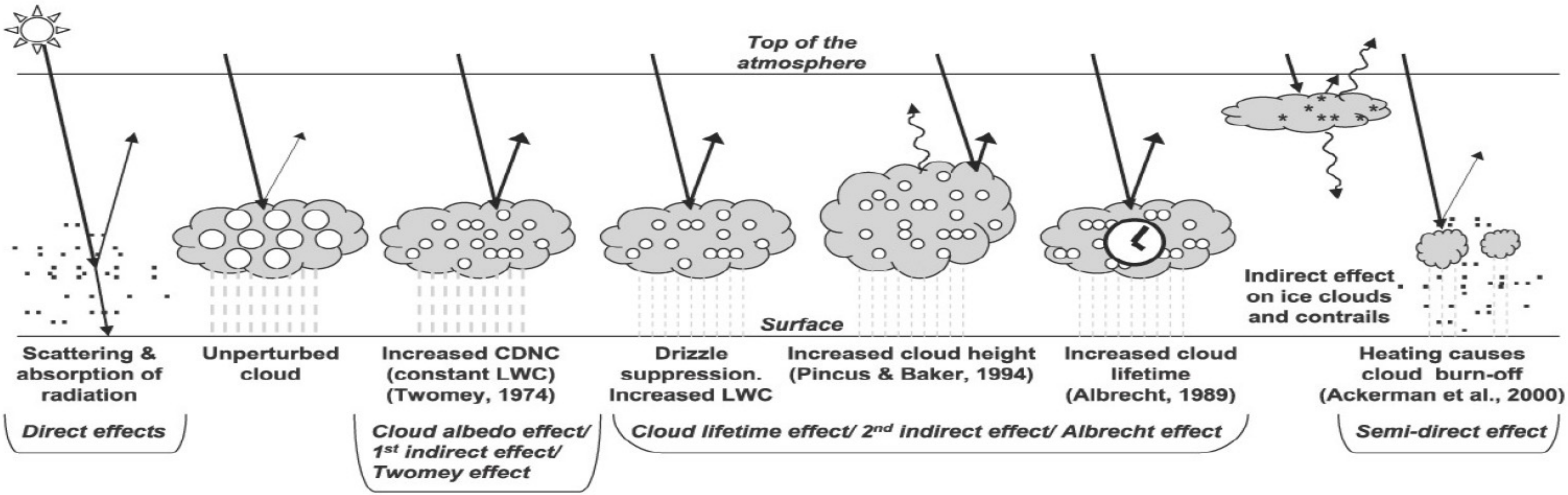
Not only natural dust sources (deserts), but also anthropogenic sources:

- From unpaved road
- From crop land
- From industry
- …

http://www.earthisland.org/

By S. Rodríguez

Effects of Aerosols on Climate Change



IPCC report, 2007

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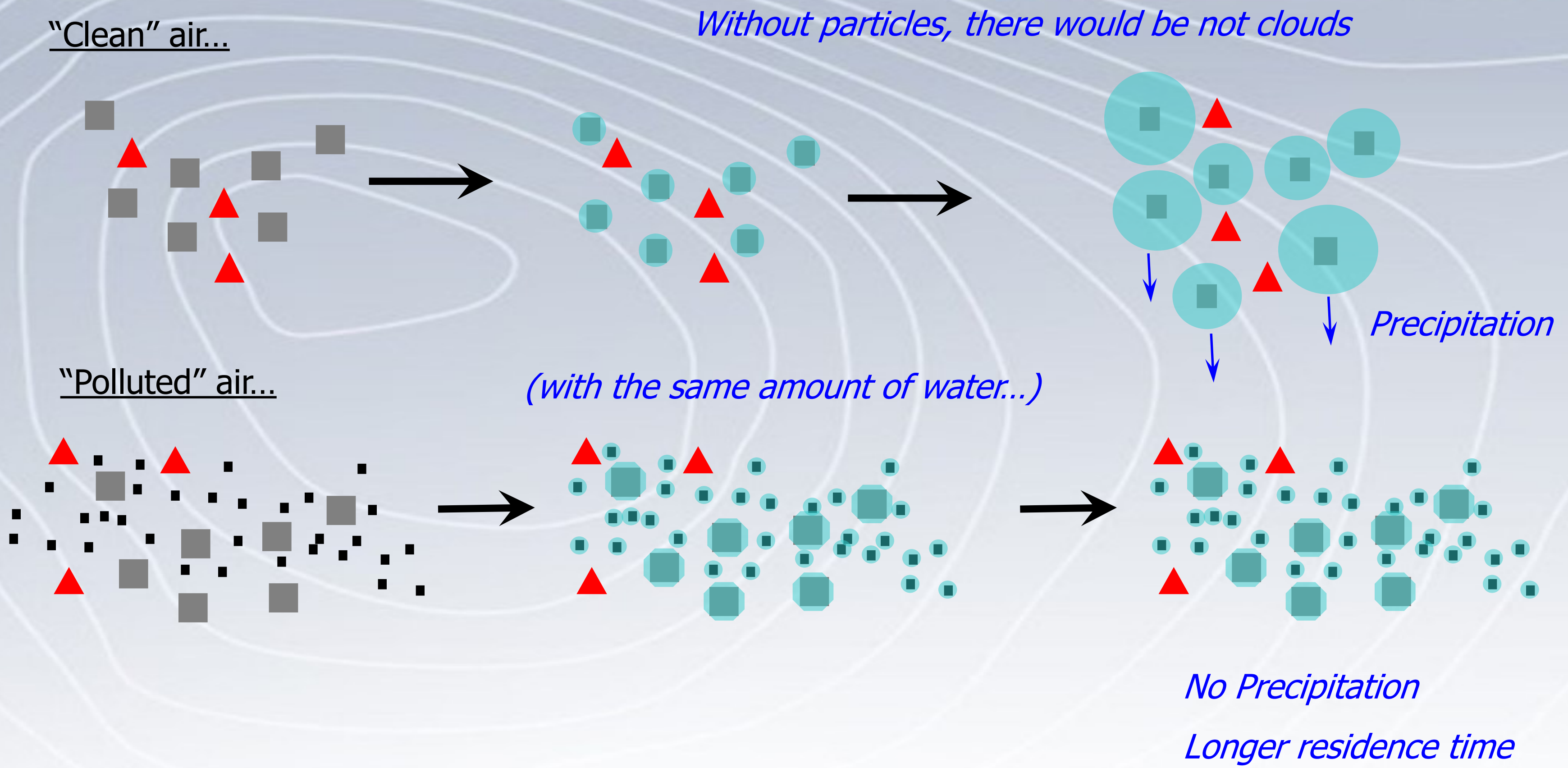
Aerosol-cloud interaction (extension)



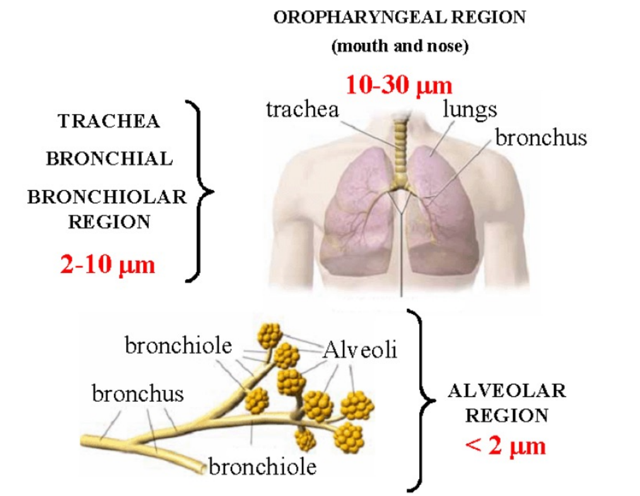
Influence on radiative forcing

the presence of particles decreases the size of the drops of the clouds and increases the life of these

Introduction

Effects of Aerosols on Air Quality

Health effects:



- Asthma
- Pulmonary inflammation
- Hay fever
- Eyes infection
- Respiratory symptoms
- Skin allergy
- …

Visibility effects: could lead in cancellation of flight operations

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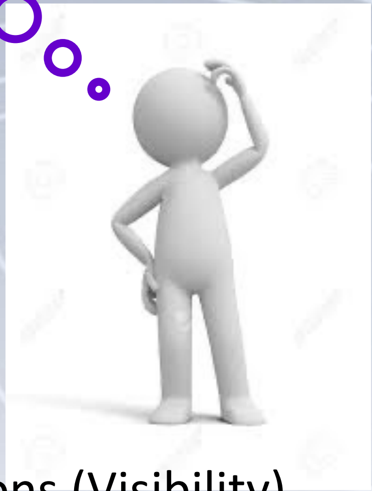
How "to observe" dust…?



INDEX

Ground based observations

- In-situ dust estimations (Visibility)
- In-situ dust measurements
- Ground base remote sensing of dust

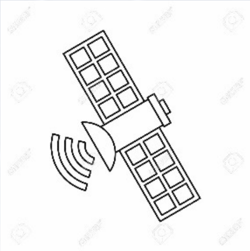
Satellite observations

Some verification tools


Visibility!


In-Situ measurements!


Remote sensing!



Dust forecast products…
Dust-SFC-extinction → visibility
Dust-SFC-Concentration → health
DOD → column total concentration – radiative information

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WMO – visibility

The greatest distance that a black object of “suitable dimensions” situated near the ground, can be seen and recognized when observed.

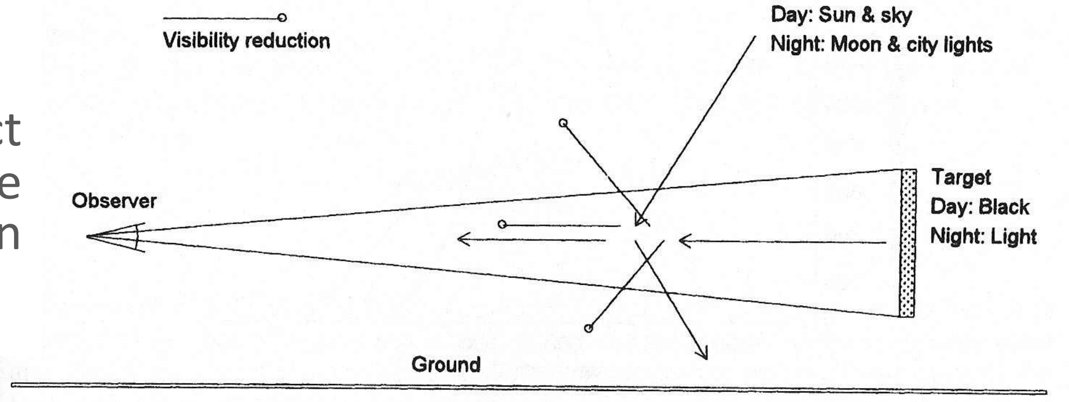


Fig. 11-1 Visibility reduction by scattering.

aerosols are the main cause of visibility reduction

- **Operational surface synoptic weather station reports from Global Telecommunication System (GTS)**
- **Station reports include past & present weather, visibility (km), temperature (°C), dew point temperature (°C), wind direction (°), and speed (knots)**

62733 15.32 35.60 02040818 Dust, not at time of obs. 6 0 18 22 320 2 35.5

62733 15.32 35.60 02041015 Dust, raised at time of obs. 7 0 99. 30 320 6 34.5

62733 15.32 35.60 02041121 -9 -9 -9 -9 20 23 320 2 26.0

62733 15.32 35.60 02041212 -9 -9 -9 -9 20 34 340 3 37.5

Measurement of visibility – **transmissometer**

- It measure the extinction coefficient of the atmosphere
- A light source with one or two light detectors at fixed distances from the source
- Detectors are designed to receive light only from the source direction
- Often located along and parallel to a runway (**runway visual range; RVR**)

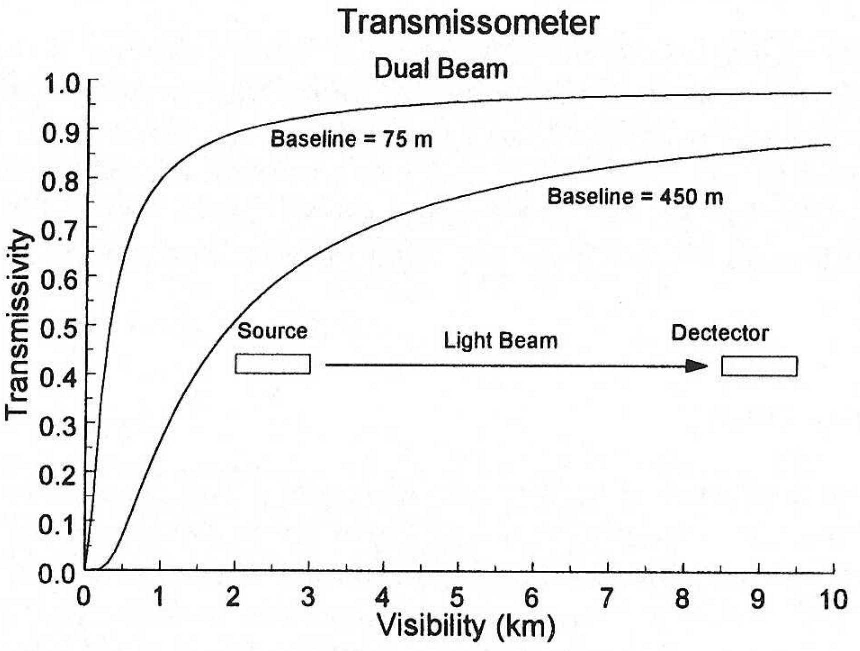
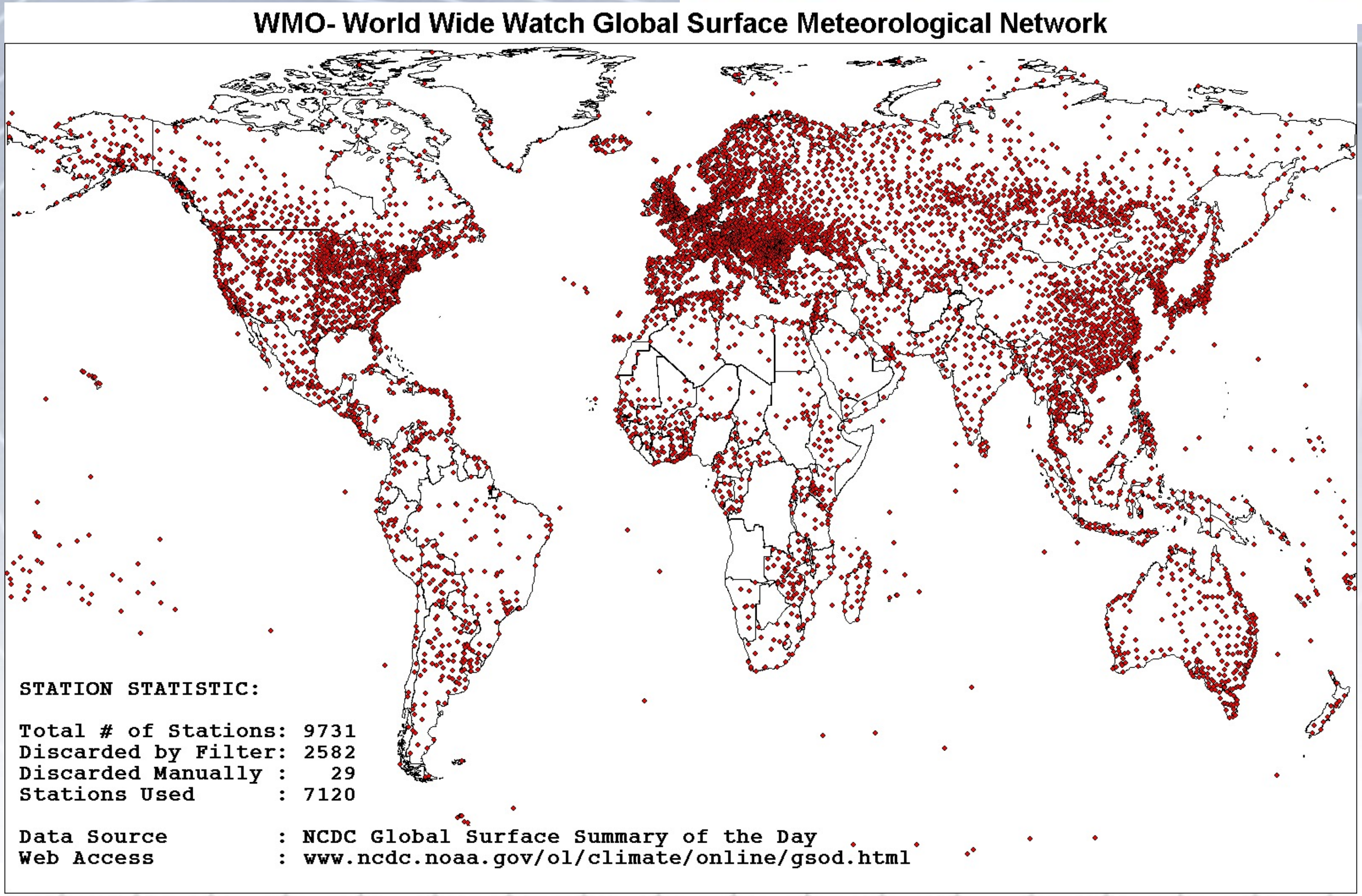


Fig. 11-3 Transfer function for a transmissometer.

Visual range (km) = 3.912 / σ_{ext} (Mm-1)

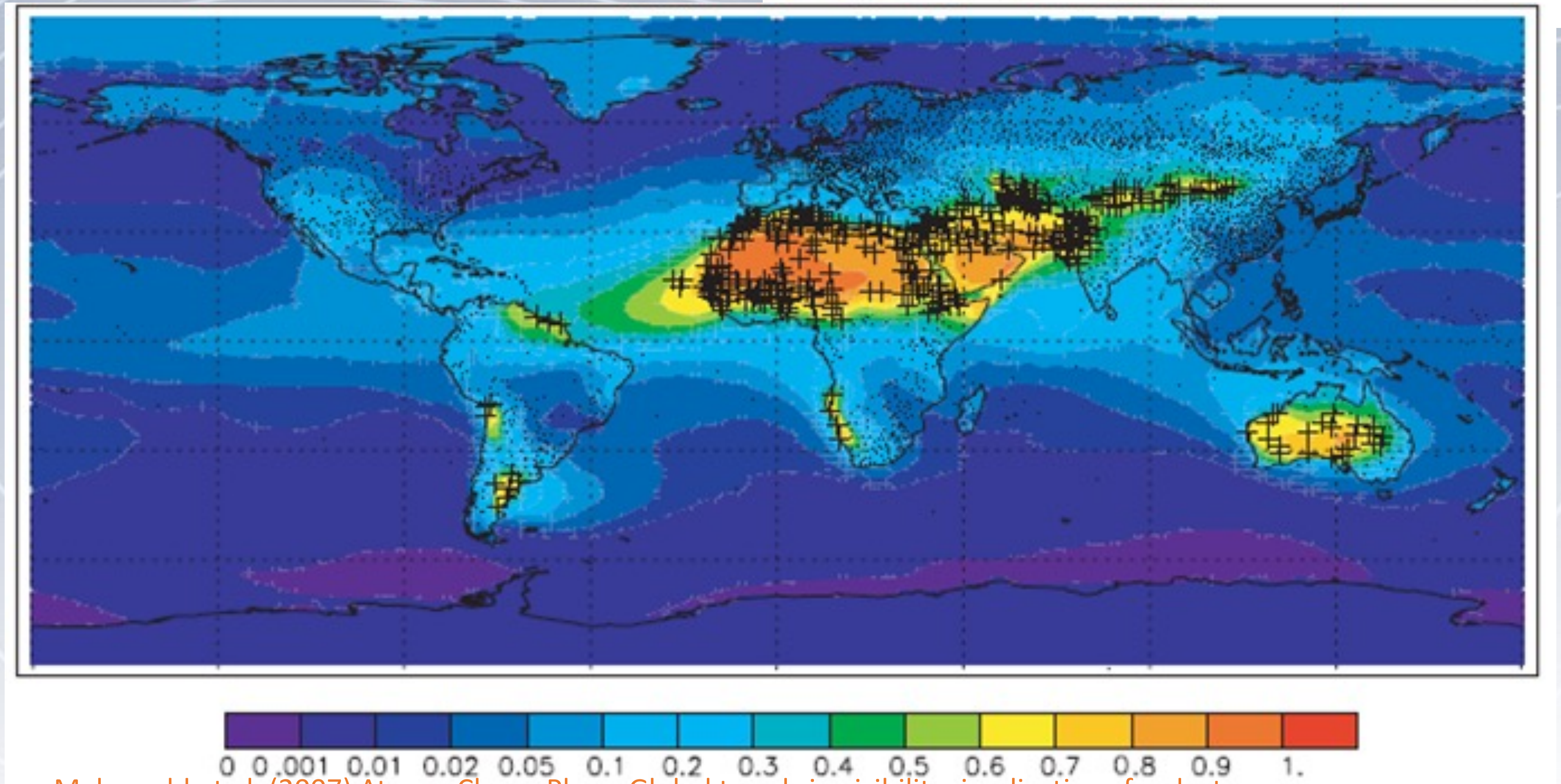
Koschmieder (1924) relationship (TOTAL AMBIENT light extinction coefficient)

Visibility



WMO- World Wide Watch Global Surface Meteorological Network
STATION STATISTIC:
Total # of Stations: 9731
Discarded by Filter: 2582
Discarded Manually : 29
Stations Used : 7120
Data Source : NCDC Global Surface Summary of the Day
Web Access : www.ncdc.noaa.gov/ol/climate/online/gsod.html

Visibility



Mahowald et al. (2007) Atmos. Chem. Phys.; Global trends in visibility: implications for dust sources

Location of visibility stations with more than 30 years of data
Coloured contours show the fraction of surface extinction from desert dust
+ show stations dominated by desert dust
· show other locations

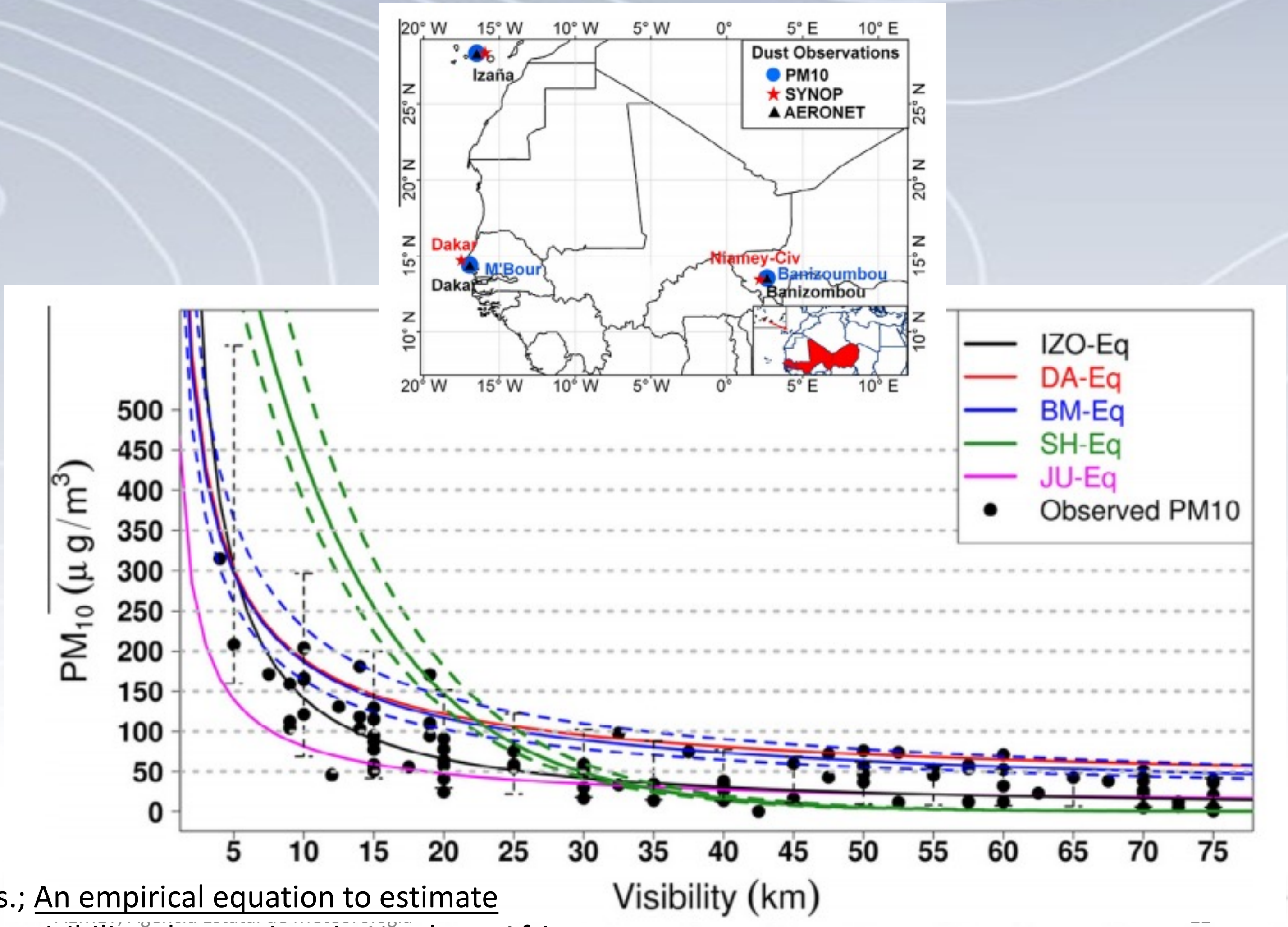
Visibility

Empirical equations to estimate dust concentration (PM10 or TSP in µg/m3) using visibility (V in km) obtained by several authors within the dust belt.

Authors	Code	Empirical equation
D'Almeida (1986)	DA-Eq	$PM_{10} = 914.0\,V^{-0.73} + 19.03$
Ben Mohamed et al. (1992)	BM-Eq	$TSP = 1339.84\,V^{-0.67}$
Shao and Wang (2003)	SH-Eq	$TSP = 3802.29\,V^{-0.84}$; $V < 3.5$ km $TSP = e^{-0.11V+7.62}$; $V \geq 3.5$ km
Dayan et al. (2008)	DAY-Eq	$PM_{10} = -505\ln(V) + 2264$
Jugder et al. (2014)	JU-Eq	$PM_{10} = 485.67V^{-0.776}$

Camino et al. (2015)

IZO-Eq $PM_{10} = 1772.24\,V^{-1.1}$



Camino et al. (2015) Aeolian Res.; An empirical equation to estimate mineral dust concentrations from visibility observations in Northern Africa

Problems with station visibility estimates

1. Human observations are inherently subjective.
2. No all reductions of visibility are due to dust (fog, biomass burning…)
3. Judgment in distinguishing visibility beyond 10 km / lack of geographical references
4. No obligation to report when reduced-visibility is reduced is > 10km.

Main advantages

1. Reports are abundant and widespread over land. There is information in remote areas (deserts)
2. There are *some* standards
3. Human detected visibility has been correlated well with surface extinction analyses (Husar et al., 2000)
4. Estimations of PM are possible

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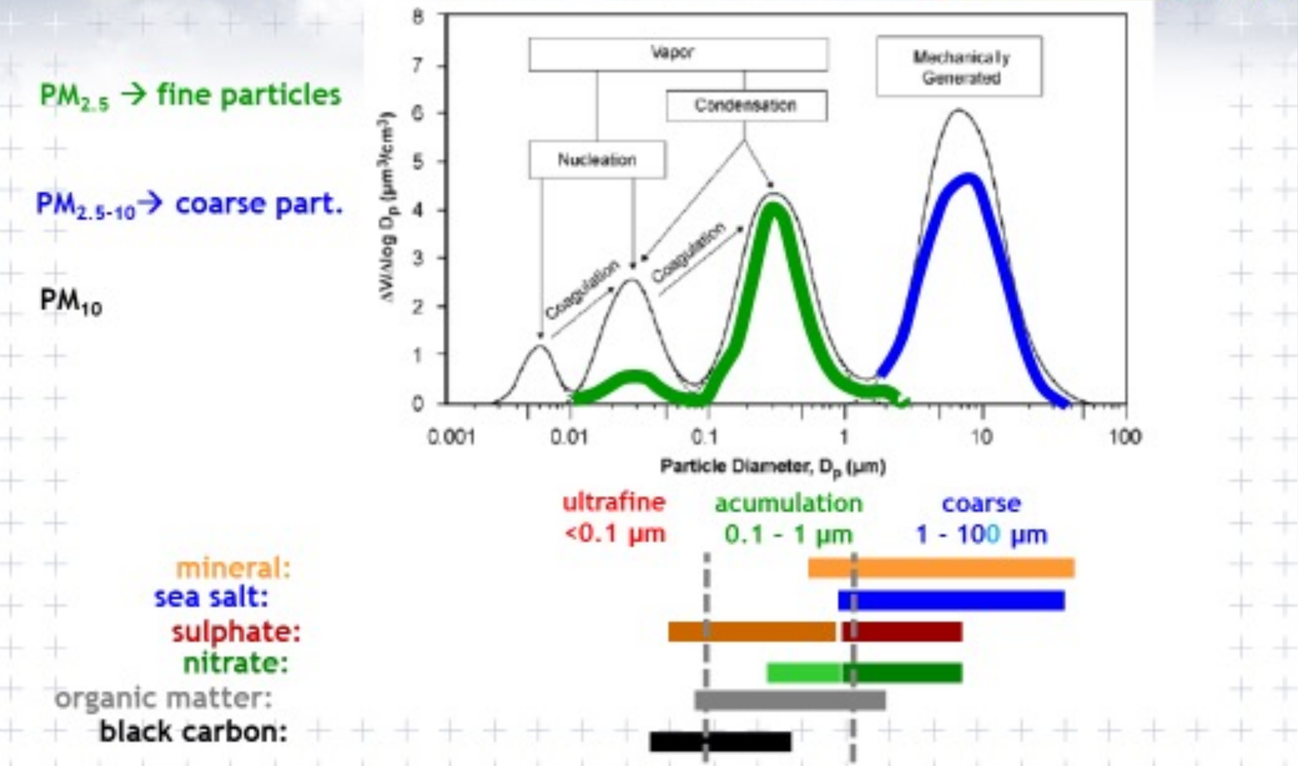
From estimation of dust concentration from visibility information to dust concentration observations…

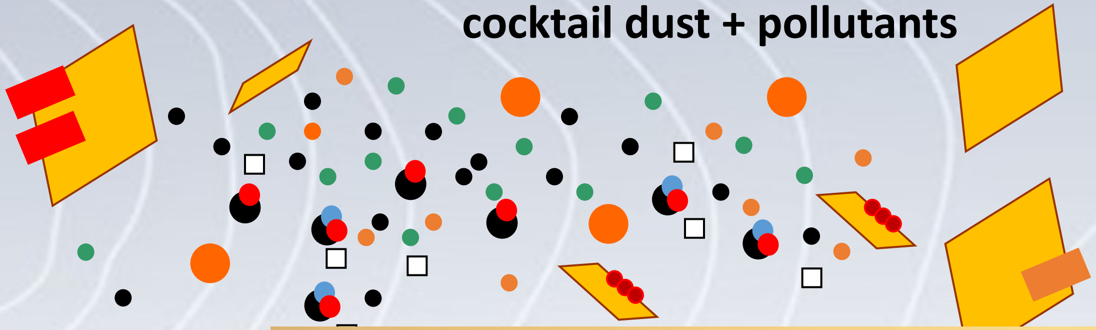
→ In-Situ techniques

How can we measure dust concentration….?
Because what we have in fact is a mixture of dust and others…



people live in cities and breath a cocktail dust + pollutants

aerosols, a cocktail of chemicals:



- dust (mineral)
- sulphate
- nitrate
- organic mater
- black carbón (soot)
- metals (Ni, As, Cd, V, Co...)
- **sea salt**

In air quality, aerosols:

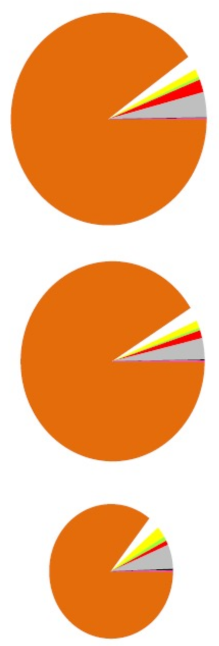
PM_{10}: mass concentration (µg/m³) of all aerosols smaller than 10 µm → inhalable particles

$PM_{2.5}$: mass concentration (µg/m³) of all aerosols smaller than 2.5 µm → alveolar particles

PM_{10}: dust + sea salt + (sulphate + nitrate + organic matter + black carbon +metals) ...

$PM_{2.5}$: dust + sea salt + (sulphate + nitrate + organic matter + black carbon +metals) ...

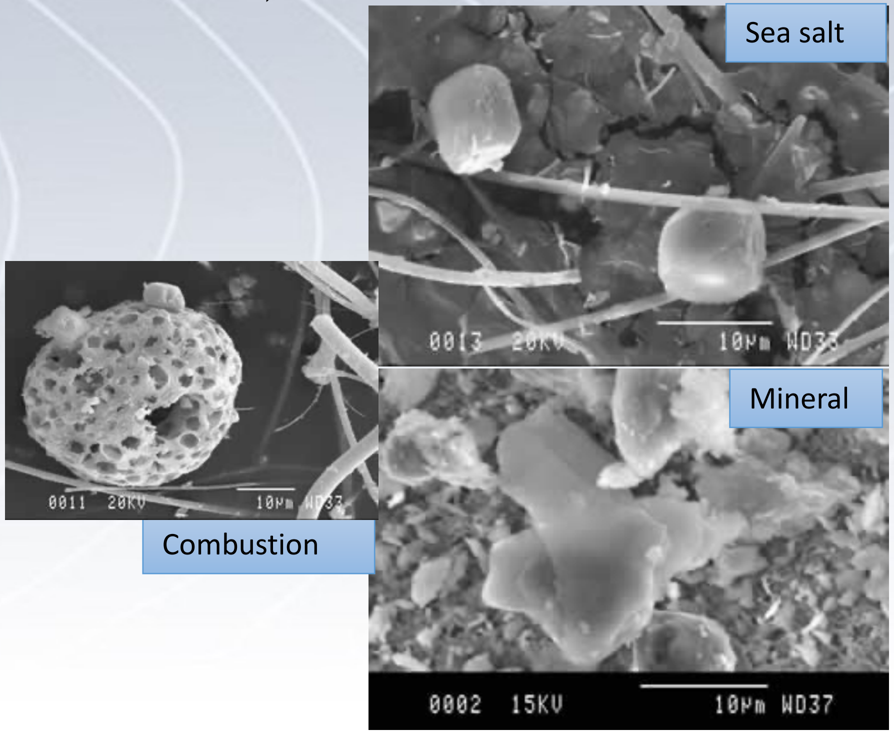
PM_x composition in the SAL (Saharan Air Layer)



PM_T	47.3 µg/m³	
91%	42.6	dust (Al, Fe, Ca, Ti..)
2.2%	1.0	none ammonium-sulfate
1.2%	0.5	ammonium-sulfate
0.4%	0.2	ammonium
1.9%	0.9	nitrate
3.8%	1.8	organic matter
0.2%	0.0 7	elemental carbon

PM_{10}	42.0 µg/m³	
91%	38.3	dust
2.2%	0.9	none ammonium-sulfate
1.2%	0.5	ammonium-sulfate
0.4%	0.2	ammonium
1.3%	0.6	nitrate
3.4%	1.4	organic matter
0.2%	0.0 7	elemental carbon

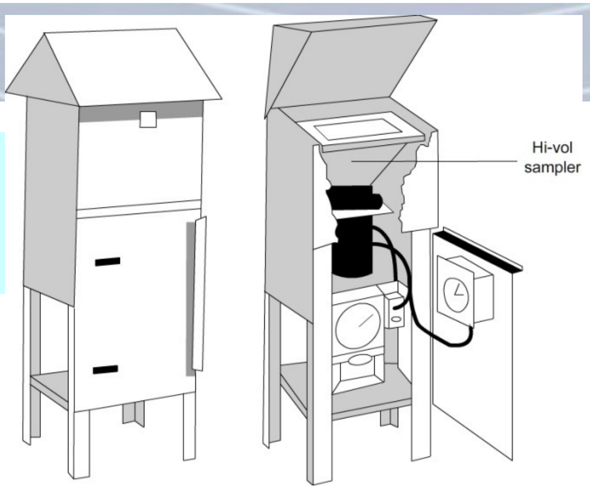
$PM_{2.5}$	18.5 µg/m³	
85%	15.8	dust
3.0%	0.6	none ammonium-sulfate
2.7%	0.5	ammonium-sulfate
1.0%	0.2	ammonium
1.1%	0.2	nitrate
5.8%	1.1	organic matter
0.4%	0.0	elemental carbon

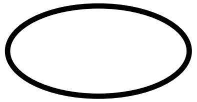


Images courtesy from "Grupo de Geoquímica Ambiental del Instituto de Diagnóstico Ambiental y Estudios del Agua", CSIC

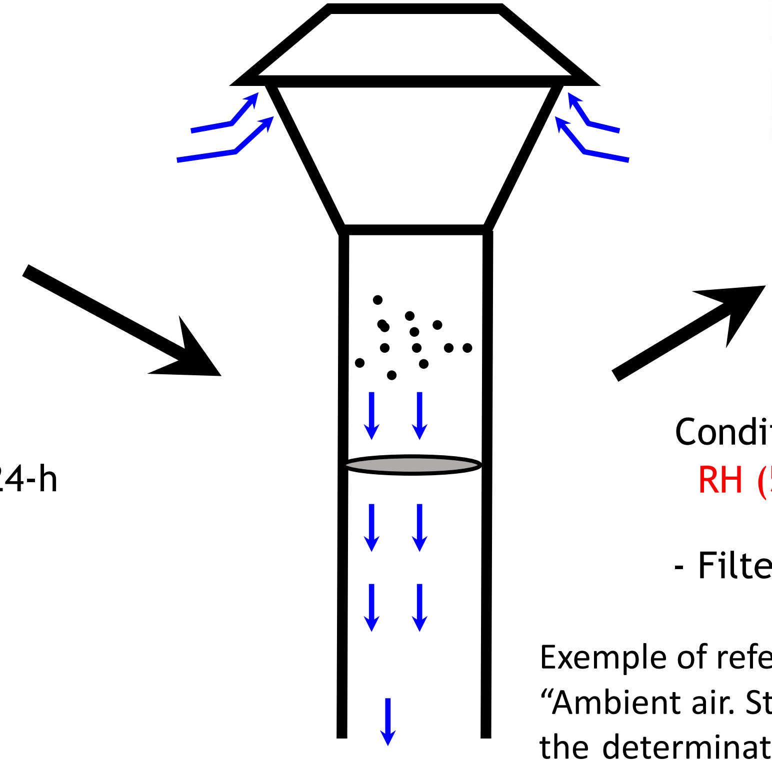
1. Reference method: gravimetric method

$$PM = \frac{(W2-W1)}{Volume} \ \mu g/m^3$$

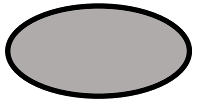




Blank filter



Pump



Sampled filter

Conditioning
RH (50±5%) y T(20±1°C) 24-h

- Filter weight (W1)

Conditioning
RH (50±5%) y T(20±1°C) 24-h

- Filter weight (W2)

Exemple of reference method: EN 12341:2014
"Ambient air. Standard gravimetric measurement method for the determination of the PM_{10} or $PM_{2,5}$ mass concentration of suspended particulate matter"

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TSP, PM_{10}, $PM_{2.5}$, PM_1: aerodynamic diameter

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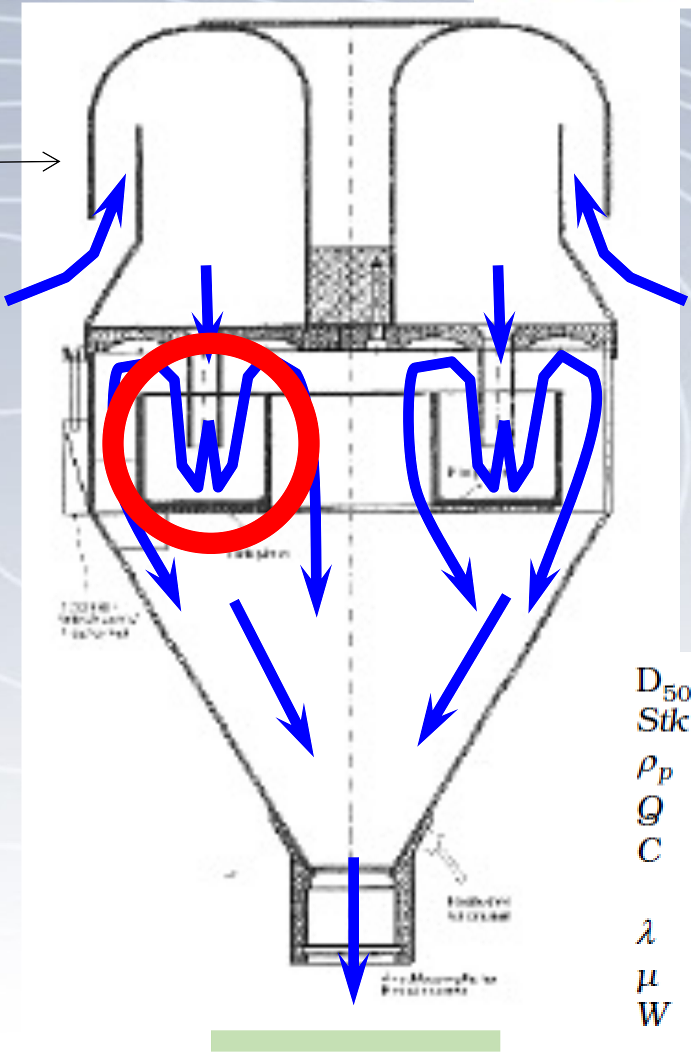
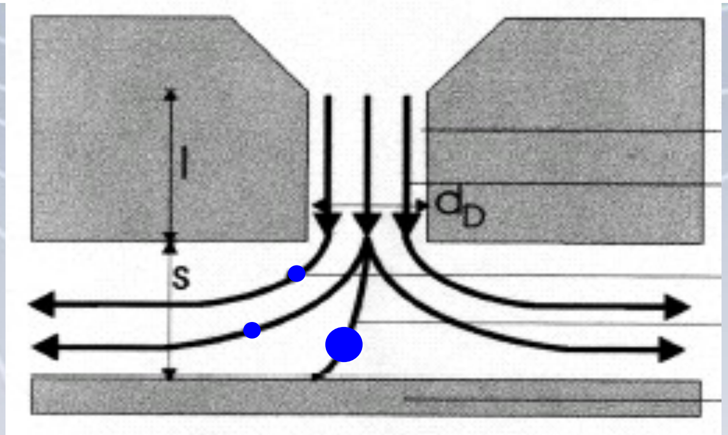


Filter

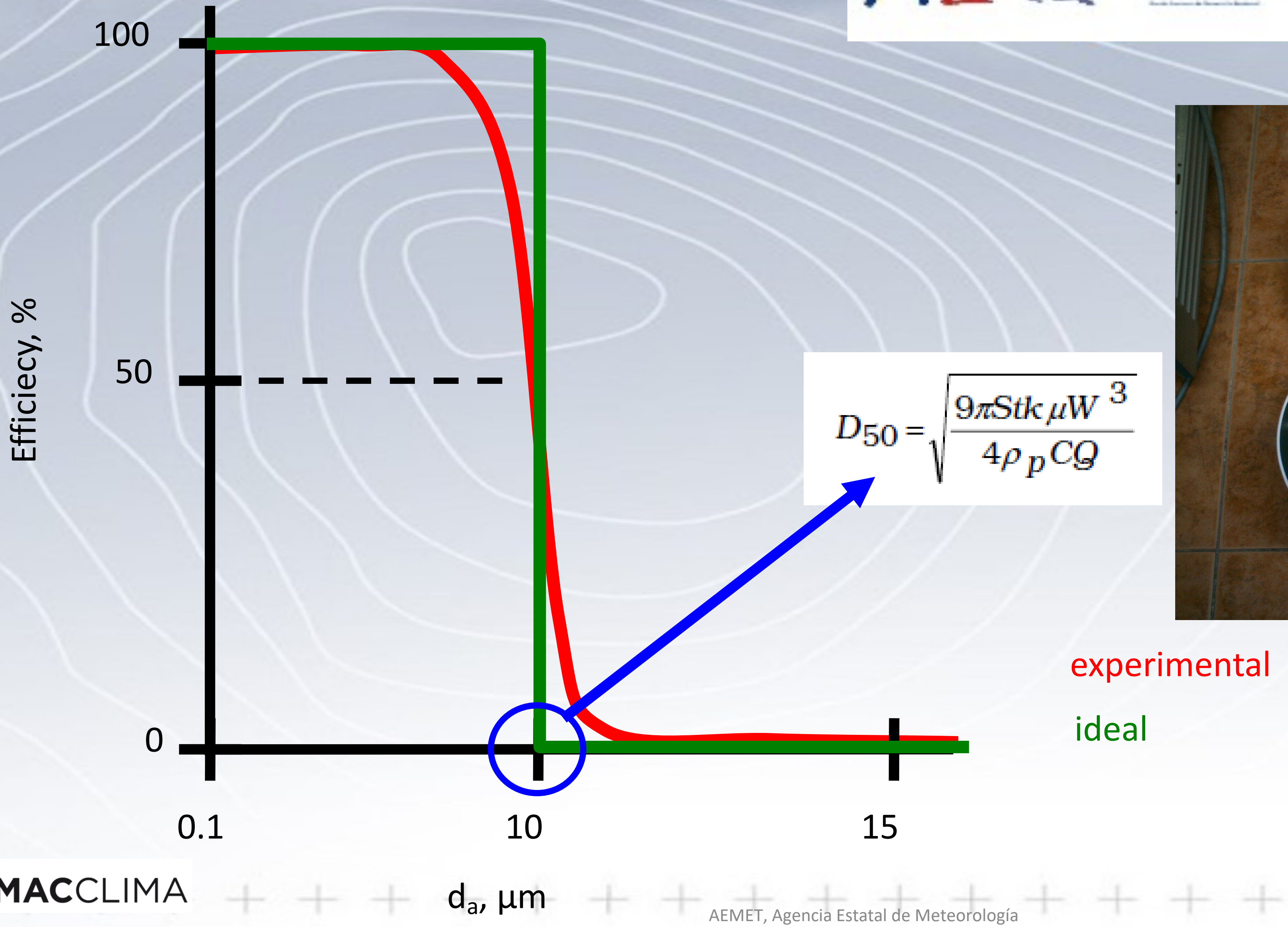


$$D_{50} = \sqrt{\frac{9\pi Stk\,\mu W^3}{4\rho_p C Q}}$$

- D_{50} = particle cut-point diameter centimeter
- Stk = Stokes number = 0.23
- ρ_p = particle density (g/cm^3)
- Q = volumetric flow rate (cm^3/s)
- C = Cunningham slip correction
  = $1 + 2.492\,\lambda/D_{50} + 0.84\,\lambda/D_{50}\exp(-0.435\,D_{50}/\lambda)$
- λ = gas mean free path
- μ = gas viscosity (dyne•s/cm^2)
- W = nozzle diameter (cm)

The Stokes number is a dimensionless parameter that characterizes impaction.

Impactor efficiency



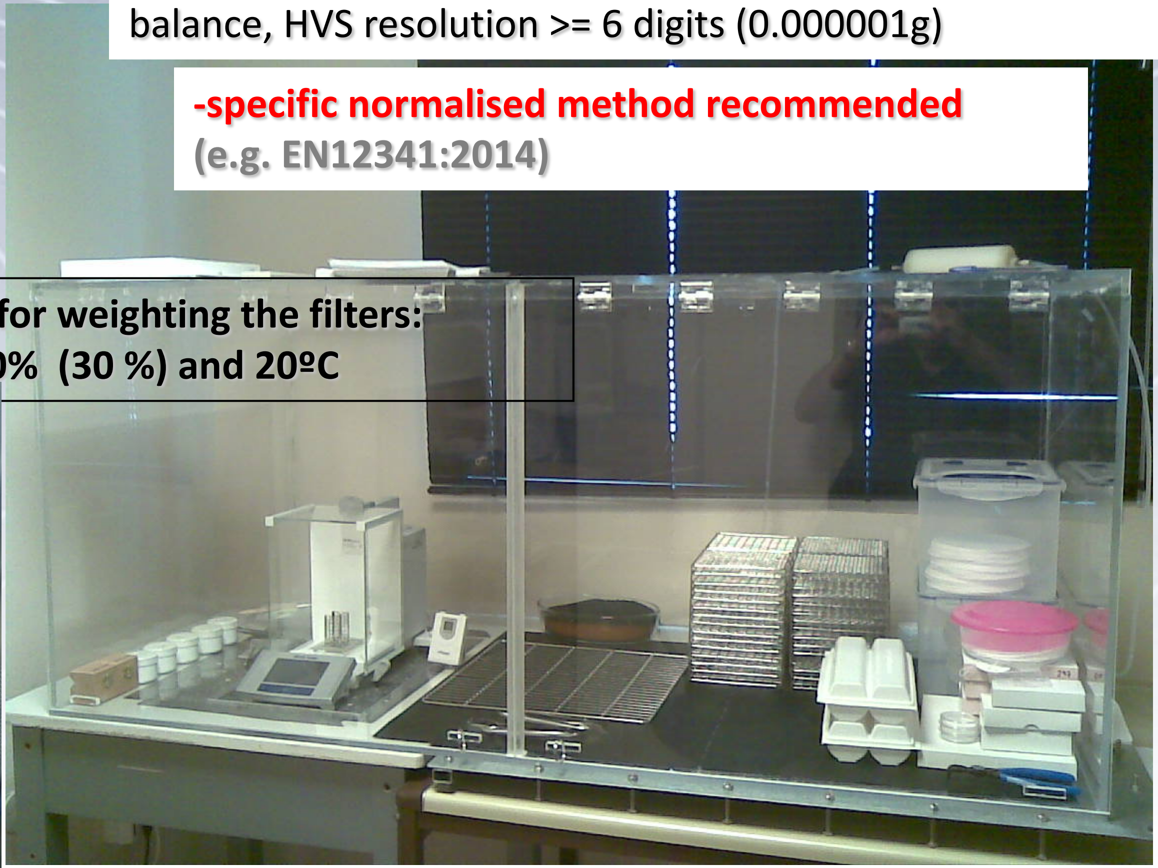
$$D_{50} = \sqrt{\frac{9\pi Stk\,\mu W^3}{4\rho_p C Q}}$$

In-Situ techniques

balance, LVS resolution >= 5 digits (0.00001g)
balance, HVS resolution >= 6 digits (0.000001g)

-specific normalised method recommended
(e.g. EN12341:2014)

Room for weighting the filters:
RH =50% (30 %) and 20ºC



$PM_{2.5}$ PM_{10}

24h pre and post conditioning
No data available until some days…

PM10
Blank filter

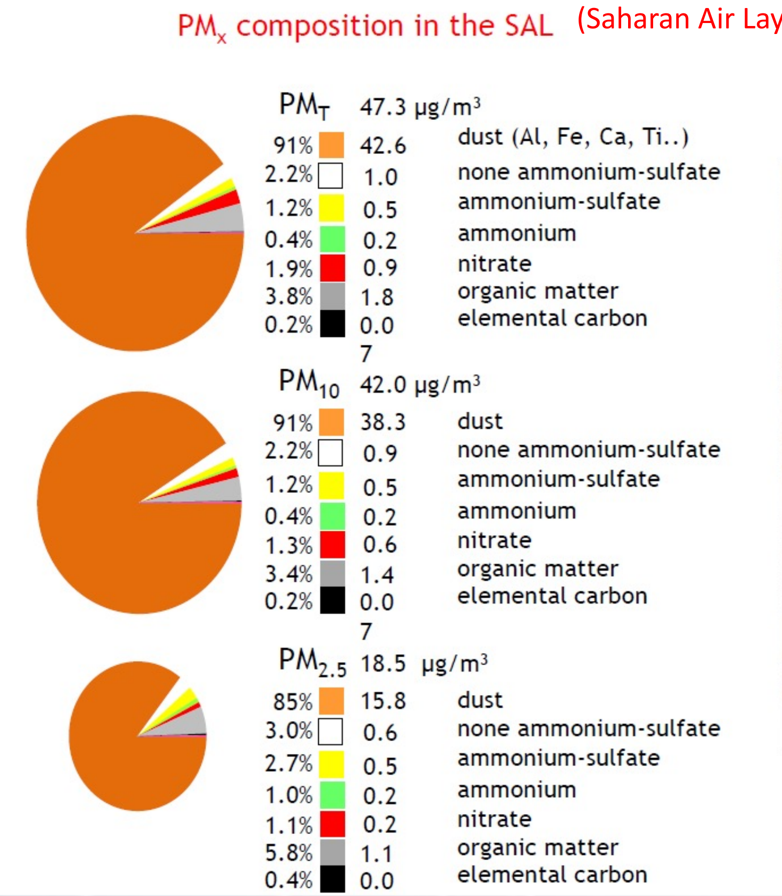
PM10
sample urban air

PM10
sample in dust days

Filters: Quartz, Teflon, Cellulose
(depending on the use after collect it…)

In-Situ techniques

Bulk dust mass concentrations



Bulk chemical characterization is the most widely used technique for identifying and quantifying the presence of dust.

Typical mineral elements are Si, Al, Ca, K, Na, Mg, Fe, K and P (as major elements) and Ti, V, Cr, Mn, Co, Ni, Cu, Zn, As, Sr, Cd, Sn, Sb and Pb as trace elements.

Variability in dust composition is often used to identify dust sources.

Al is included as soil dust tracer (clay mineral). → ratio of each element (X) to Al (X/Al) is used to know the potential source contribution (for exemple Ca/Al, Fe/Al, etc.)

-Rodriguez et al. (2012) A review of methods for long term in situ characterization of aerosol dust (http://dx.doi.org/10.1016/j.aeolia.2012.07.004)
-Rodriguez et al. (2019) Rapid changes of dust geochemistry in the Saharan Air Layer linked to sources and meteorology (https://doi.org/10.1016/j.atmosenv.2019.117186)

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1. Reference method: gravimetric method

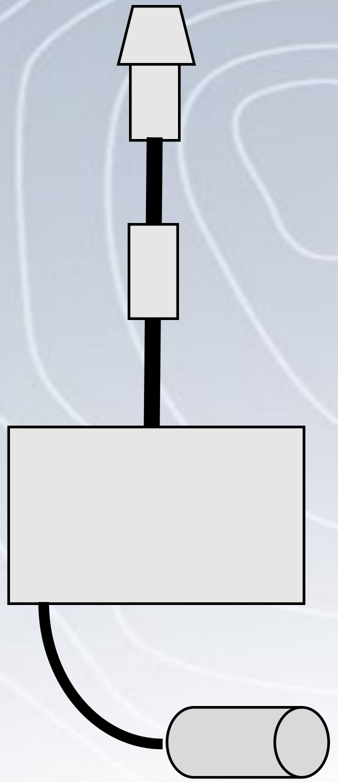
- Advantages:
  - Recognized reference method
  - Low capital cost
  - Possibility to “identified” different types of Aerosols in terms of chemical composition… (bulk dust mass concentration)

Alternative…

2. Automatic Methods

- Disadvantages:
  - Limited time resolution (typically 24-hr)
  - Long turnaround times (pre&post-conditioning)
  - Labor intensive
  - Gravimetric lab maintenance/cost

2. Automatic methods



1. Impactor PM_{10} / $PM_{2.5}$ → same as gravimetric method

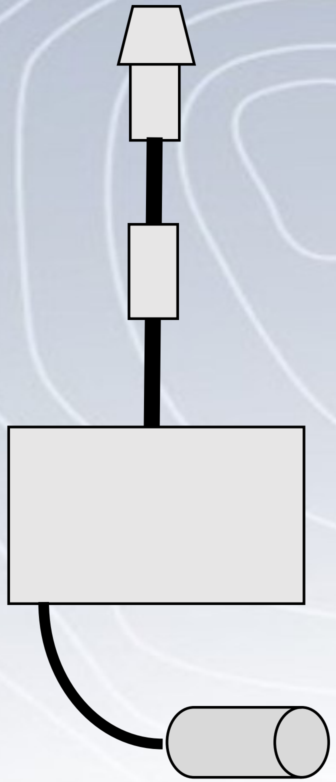
2. RH reductor / heater

3. Sensor (Beta-radiation Attenuation Method –BAM or Tapered Element Oscillating Microbalance-TEOM) → instead of weighting filters

4. Pump / Flow meter → same as gravimetric method

Continuous measurements of PM (PM_{10}, $PM_{2.5}$, PM_1 or TSP)

2. Automatic methods: BAM (Beta) - TEOM



BAM

TEOM

More info at the end of the presentation...

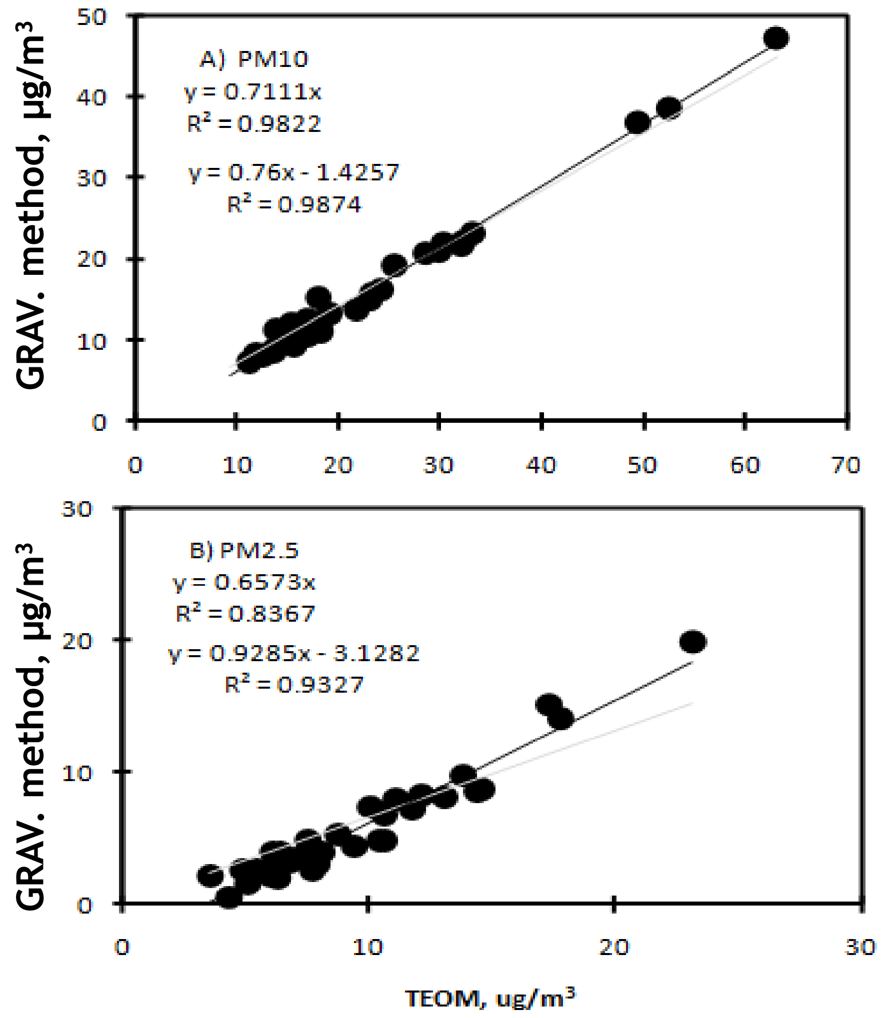
2. Automatic methods: BAM (Beta) - TEOM

- Advantages:
  - On-line measurements
  - Long time stability (> 1 year)
  - Good correlation with gravimetric method
  - US-EPA has adopted it has reference method

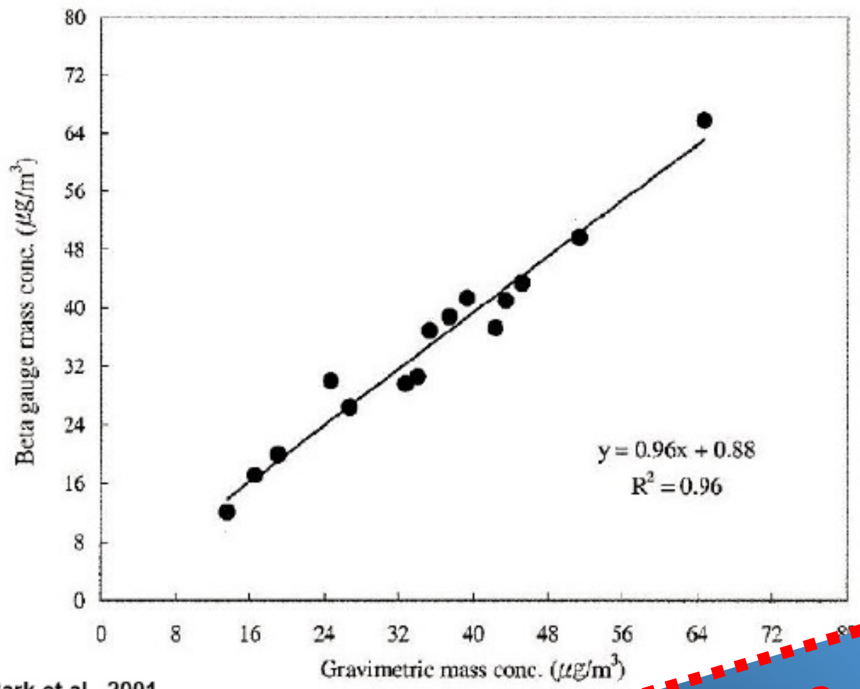
- Disadvantages:
  - Possible dependency of the aerosol chemical composition (BAM)
  - Filters not useful for later chemical analysis (not possible to identified dust composition)
  - Use of radiative sources could need special permission in some countries (BAM)
  - Temperature dependency (volatile losses; seasonal and regional dependencies) (not in the case of a TEOM-DFMS)

Automatic versus the reference gravimetric method

Conversion of the 'automatic PM_{10} and $PM_{2.5}$' data to GRAVIMETRIC EQUIVALENT data



Intercomparisons



Park et al., 2001

Standardization…
… for traceability and intercomparability

2. Automatic methods: Low Cost Sensors

Low Cost Sensors (LCS)
Tomorrow…
A summary available on
https://library.wmo.int/doc_num.php?explnum_id=9881
(published 2018, an update available soon)

INDEX

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- In-situ dust estimations (Visibility)
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- Ground base remote sensing of dust

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From in-situ dust observations to ground base remote sensing…

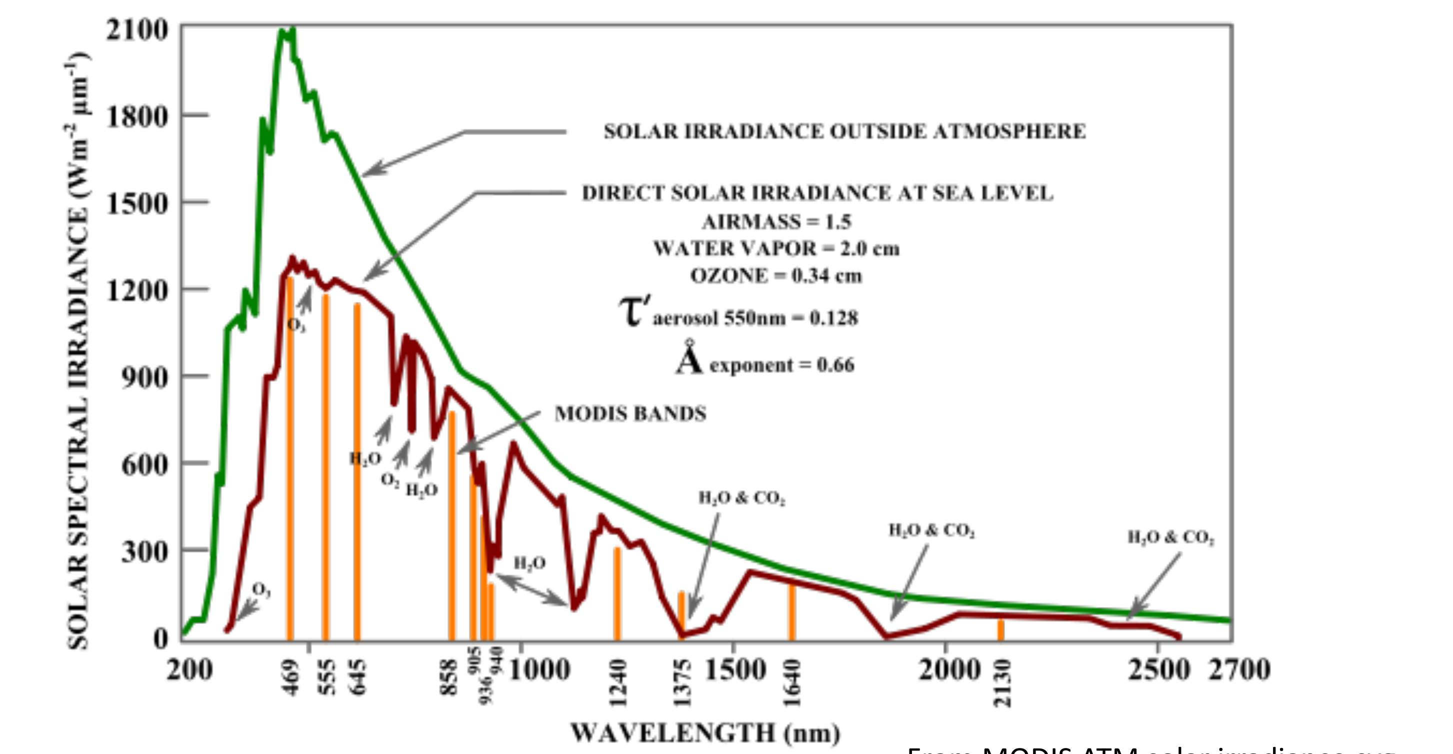
… total atmospheric column observations
(passive remote sensing, based on photometry techniques)

… vertical resolved observations
(active remote sensing, based on lidar techniques)

1. Photometry

The intensity of sunlight at the top of the earth's atmosphere is constant.

While the sunlight travels through the atmosphere, aerosols can dissipate the energy by scattering (Rayleigh and Mie) and absorbing the light. More aerosols in the atmosphere cause more extinction and less energy transmitted to the surface.



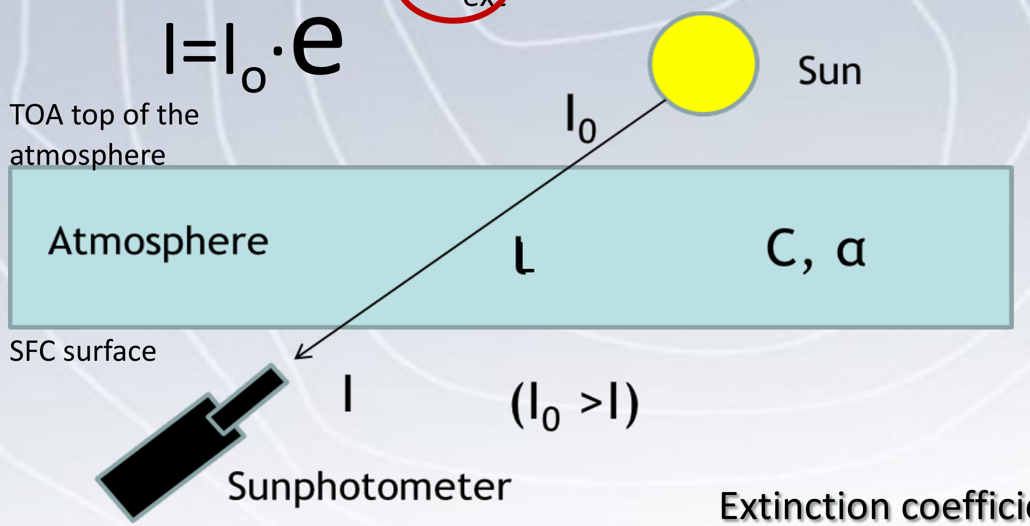
From MODIS ATM solar irradiance.svg

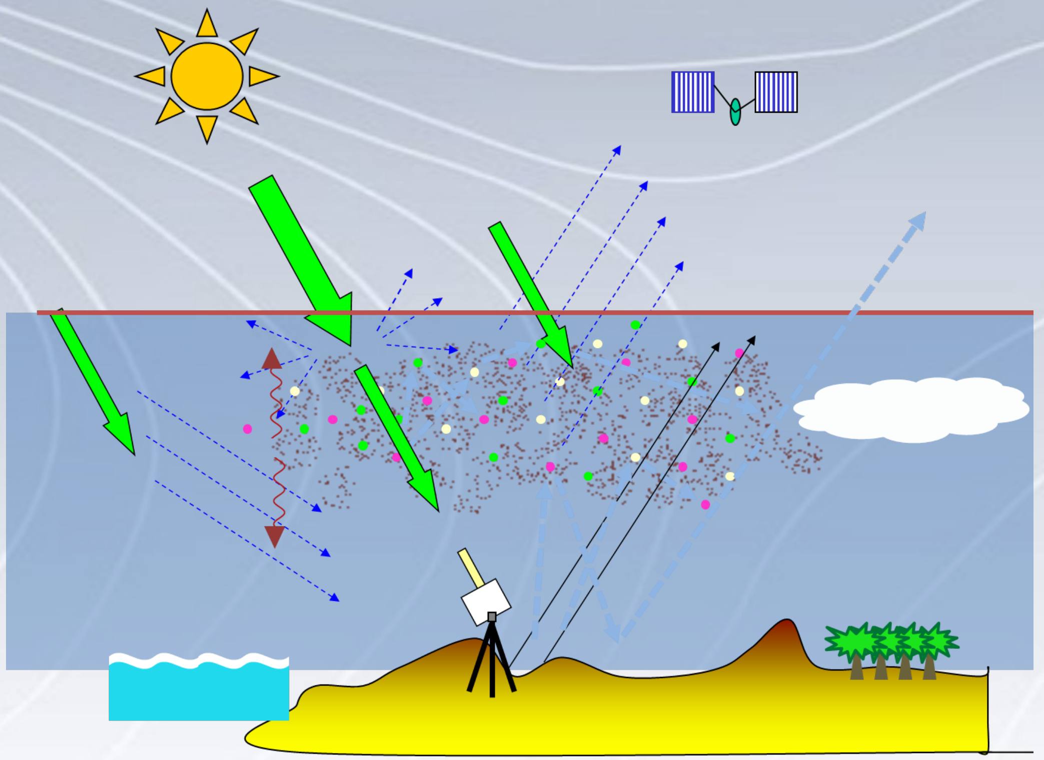
1. Photometry

More aerosols in the atmosphere cause more extinction and less energy transmitted to the surface.

Beer's Law

$$I = I_o \cdot e^{-\sigma_{ext} \cdot L}$$





Extinction coefficient (σext): εC
Path length (L)
molar absorptivity of the absorber (ε)
concentration of absorbing species in the material (C)

aerosol particles cross-section for light extinction per unit volume of air

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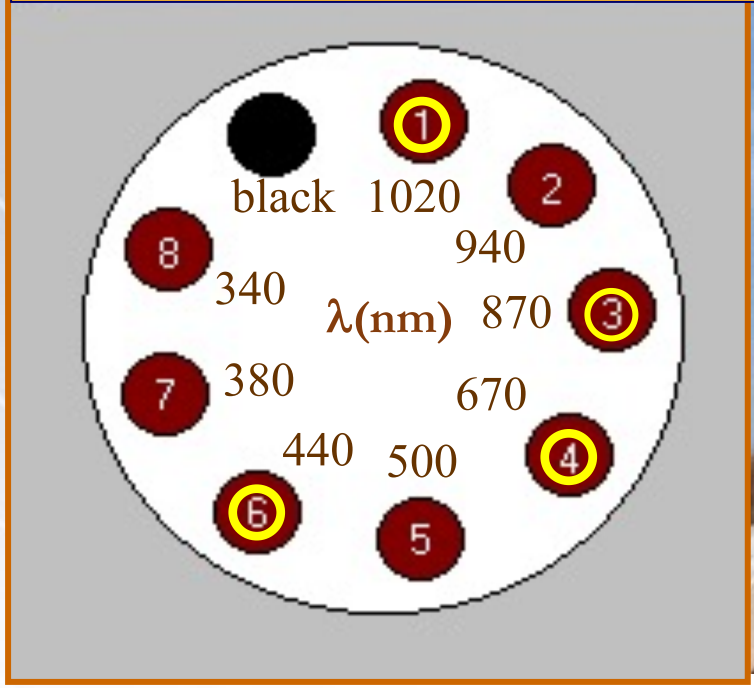
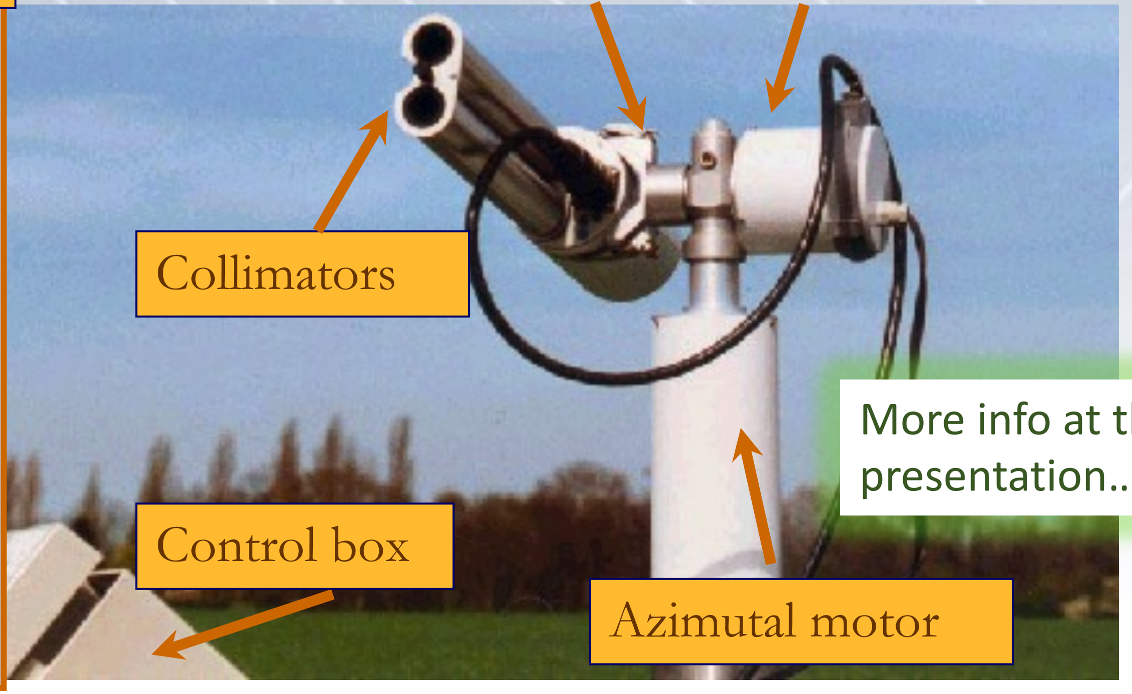
1. Photometry

Sun Photometers measures *direct* sunlight energy with photodetectors (passing a interference filter with a certain bandwidth), convert the intensity into a quantified voltage ➔ to measure aerosols in the atmosphere.

Exemple: Cimel T318

Filter wheel for polarisation model





More info at the end of the presentation…

More info: http://pages.usherbrooke.ca/cimel/index.php/Accueil

1. Photometry

CONCEPTS:

Aerosol Extinction: A measure of attenuation of the light passing through the atmosphere due to scattering and absorption by aerosol particles.

Extinction coefficient is the fractional depletion of radiance per unit path length (also called attenuation). It has units of km^{-1}.

Aerosol Optical Depth (or Thickness)

"Aerosol Optical Depth“ (AOD) is the degree to which aerosols prevent the transmission of light. The aerosol optical depth or optical thickness (τ) is defined as the integrated extinction coefficient over a vertical column of unit cross section.

$$AOD = \int_{z=0}^{z=toa} \sigma_{ext}(z)dz$$

$$I = I_o \cdot e^{-\sigma_{ext} \cdot L}$$

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1. Photometry

Typical AOD ranges

Sky conditions	Green channel	Red channel
Extremely clear (pristine)	0.03 - 0.05	0.02 - 0.03
Clear	0.05 - 0.10	0.03 - 0.07
Somewaht hazy	0.10 - 0.25	0.07 - 0.20
Hazy	0.25 - 0.5	0.20 - 0.40
Extremly hazy	> 0.5	> 0.4

Note that red AOD values are typically less than green AOD values. This is due to the fact that typical aerosols scatter green light more efficiently than red light.

1. Photometry

CONCEPTS:

Angstrom Exponent (α)

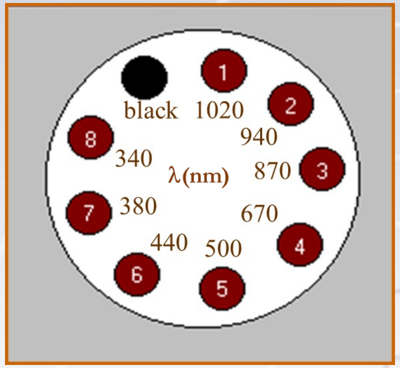
An exponent that expresses the spectral dependence of AOD with the wavelength of incident light (λ). The spectral dependence of aerosol optical thickness can be approximated (depending on size distribution) by:

$AOD \rightarrow \tau_a$

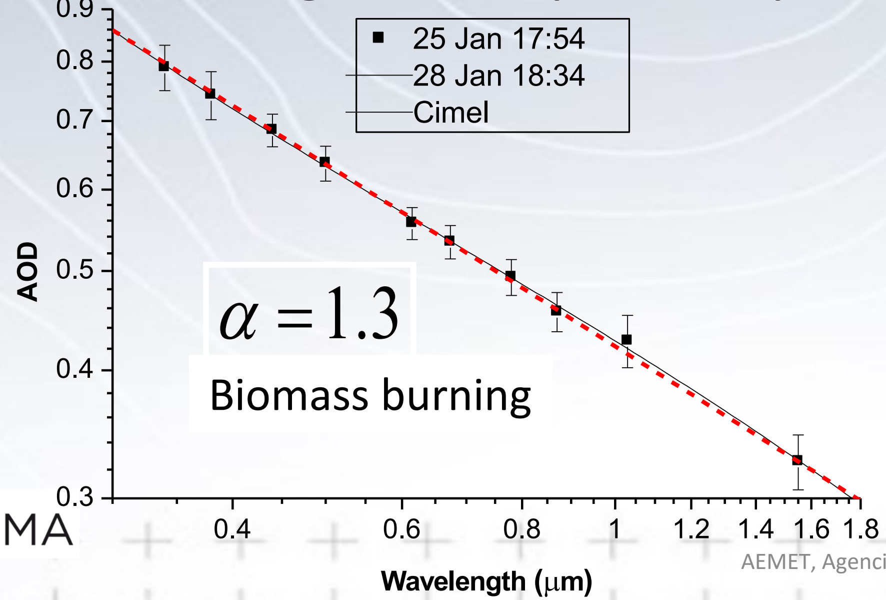
$$\tau_a = \beta \cdot \lambda^{-\alpha}$$

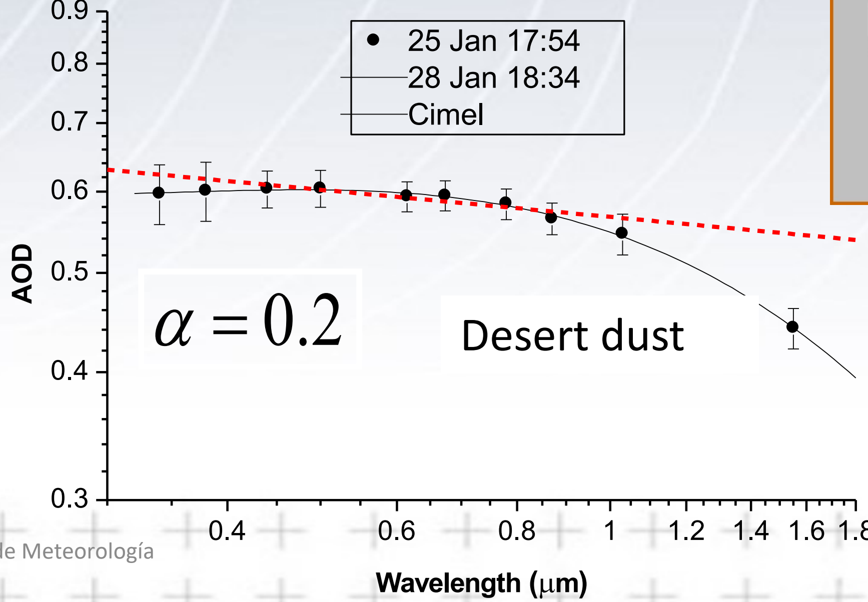
α >> 0.9 FINE particles

α << 0.7 COARSE particles



where α is the Angstrom exponent (β = aerosol optical depth at 1 μm)





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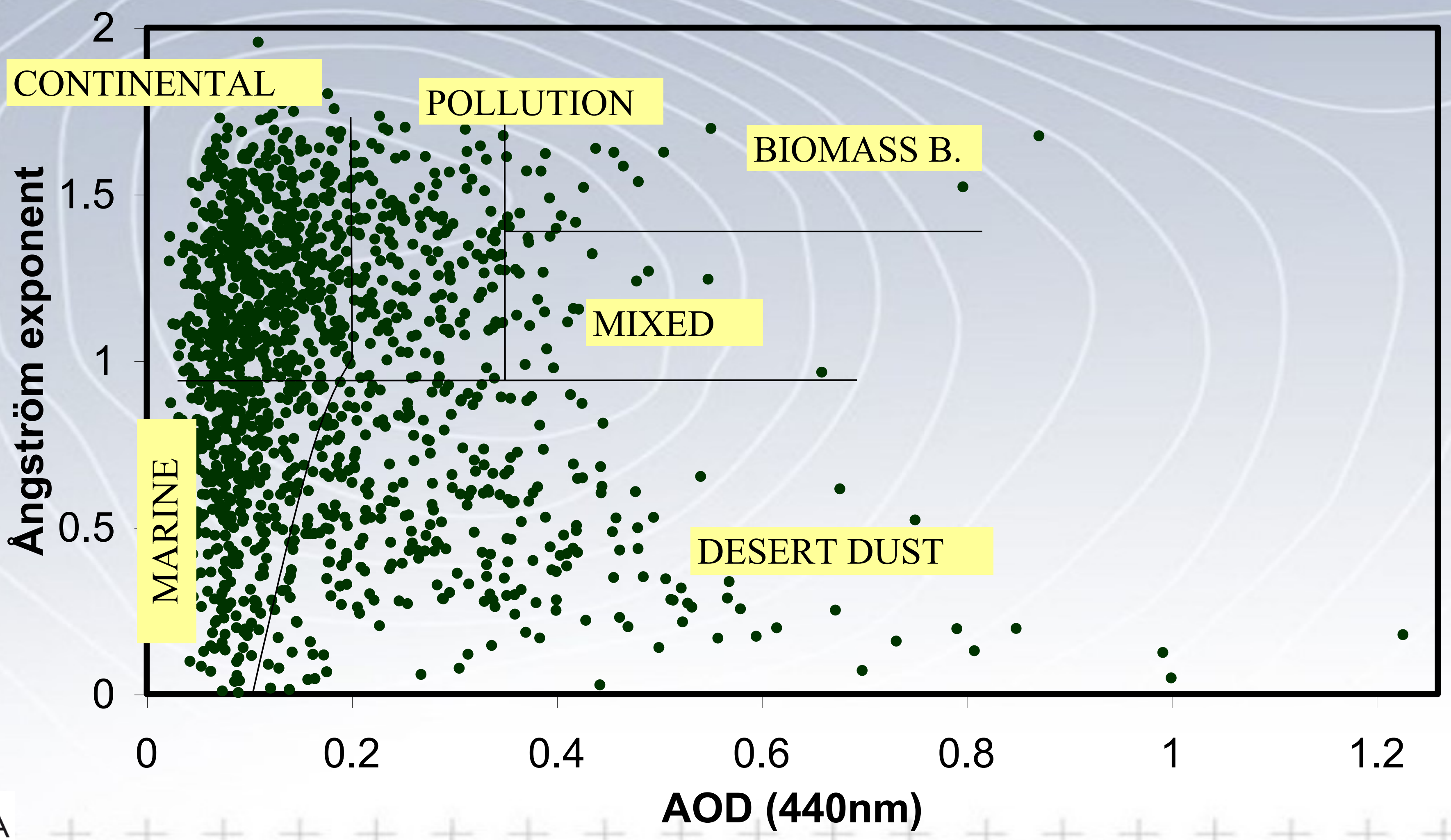
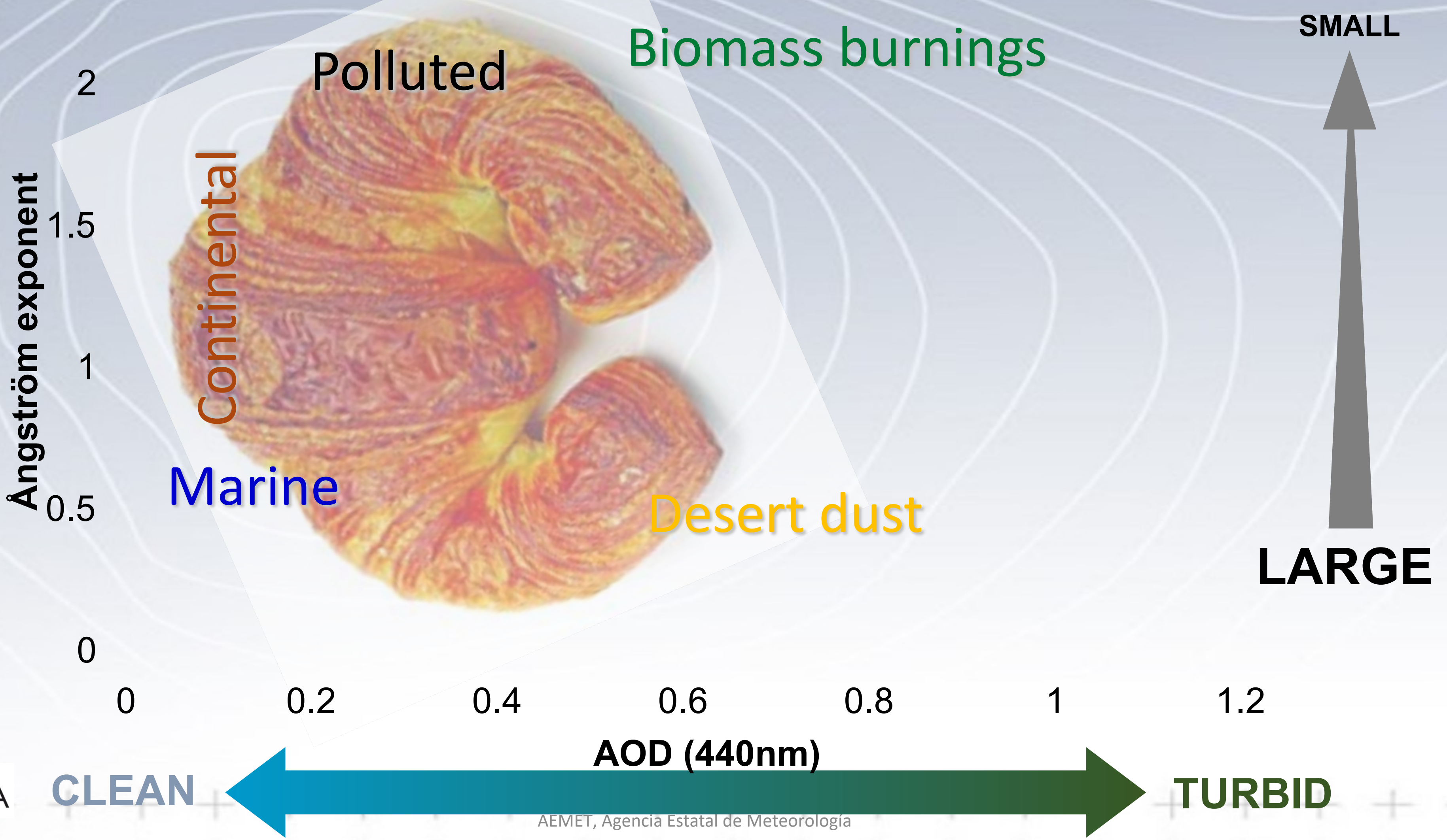
1. Photometry

Aerosol Type with diagram AOD-α

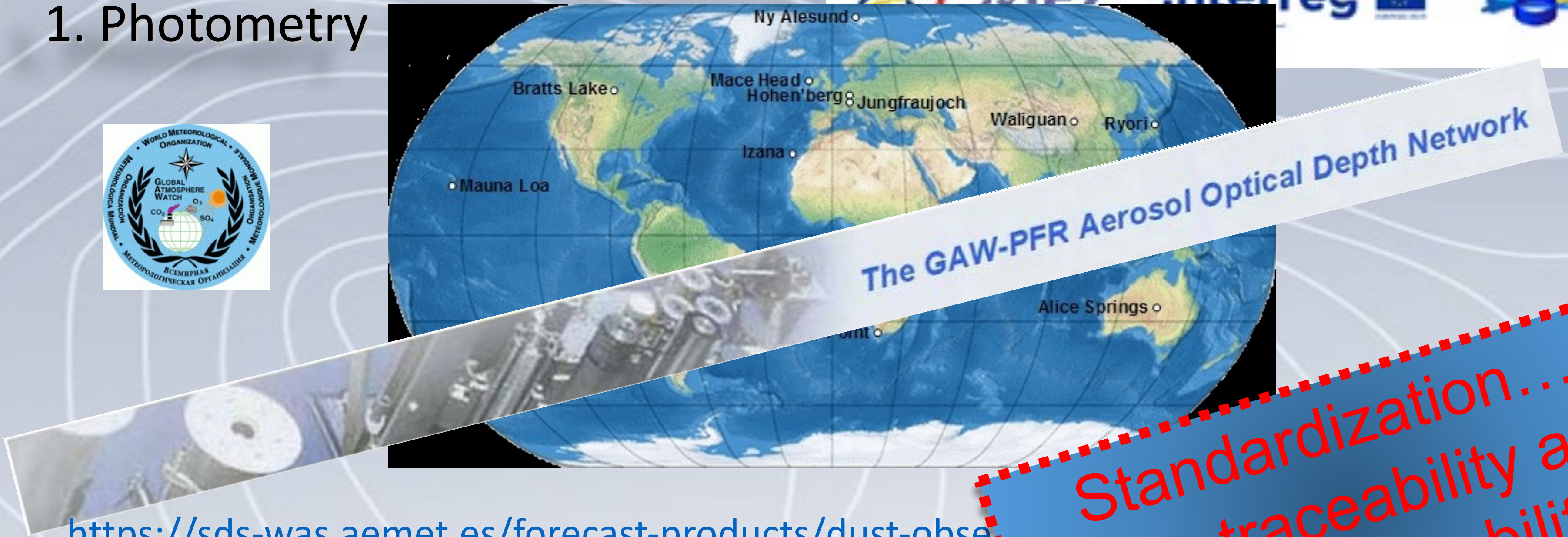


1. Photometry

Aerosol Type with diagram AOD-α

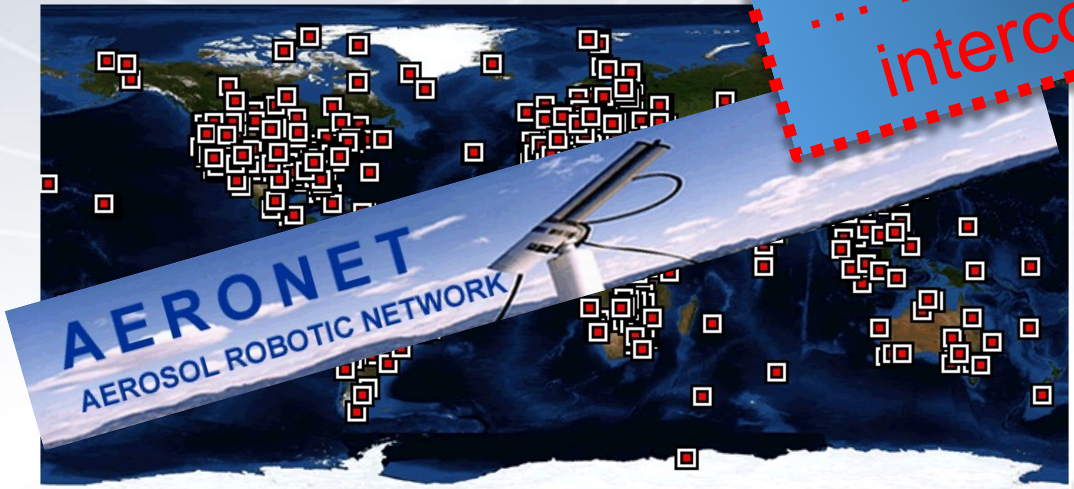


1. Photometry



https://sds-was.aemet.es/forecast-products/dust-obse

Standardization…
… for traceability and intercomparability



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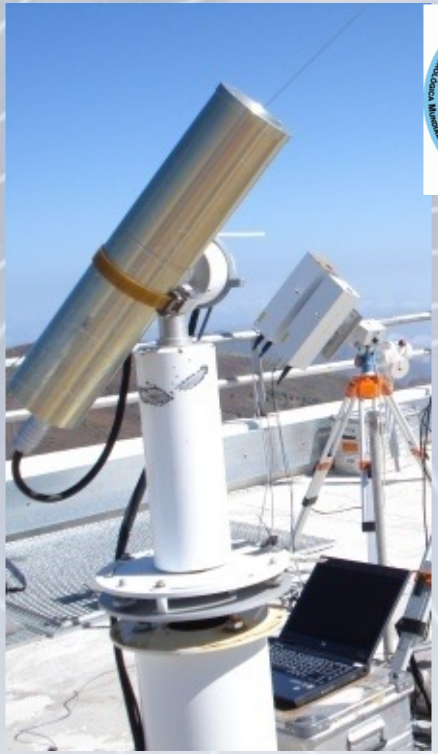
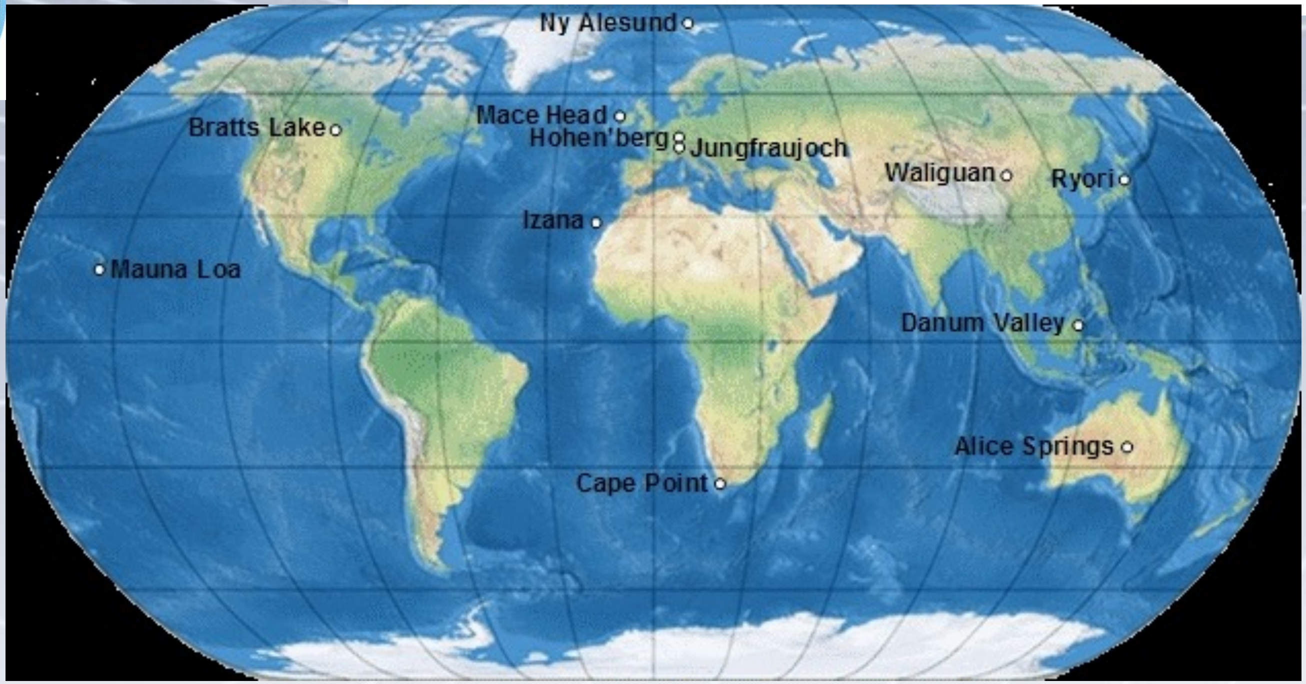
GAW-PFR AOD Network





Classic extinction measurements at the recommended 4 WMO wavelengths 368, 415, 500 and 862 nm using Precision Filter Radiometers (PFRs).

Continuous sampling at a 1- minute frequency by automated systems.

Data products: AOD and the Angström coefficients alpha and beta (no inversions).

Hourly mean AOD archived at the World Data Center for Aerosols (WDCA). Data with a 1-minute resolution are available from WORCC upon request.

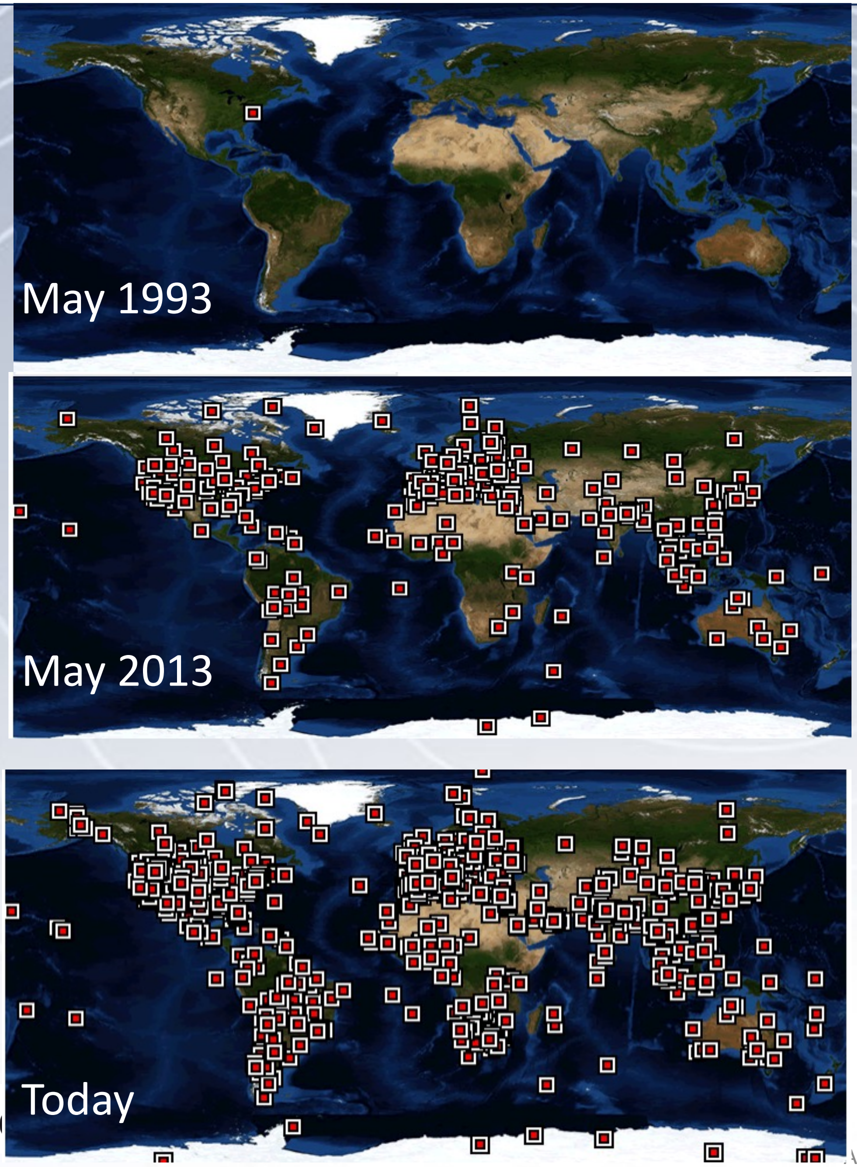
1. Photometry

GAW-PFR provides:

- long-term high-accuracy AOD and Angström Coefficients
- GAW-PFR provides AOD Dust in near real-time

Ground base remote sensing

AERONET Aerosol Robotic Network- More than 25 Years of Obs. and Res.



The AERONET program is a federation of ground-based remote sensing aerosol networks established by NASA and LOA-PHOTONS (CNRS) and has been expanded by collaborators from international agencies, institutes, universities, individual scientists and partners.

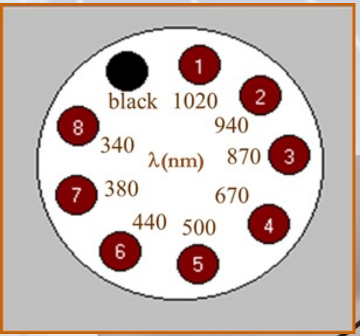
>7000 citations
>400 sites
Over 80 countries
http://aeronet.gsfc.nasa.gov

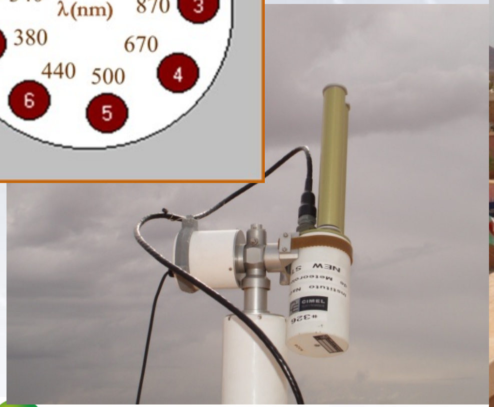
AERONET provides a long-term, continuous public database of aerosol optical, microphysical, and radiative properties for aerosol research and characterization, validation of satellite measurements, and synergism with other databases.

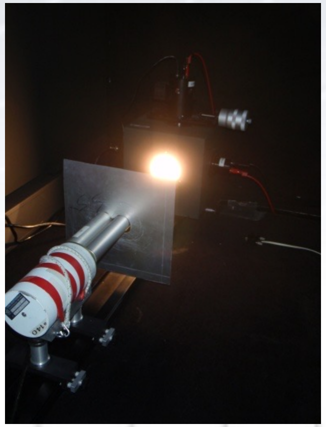
AERONET

1. Photometry: AERONET

- The Cimel Electronique 318-T spectral radiometer is a solar-powered, weather-hardy, robotically-pointed sun, moon and sky spectral photometer.
- A sensor head points the sensor head at the sun/moon according to a preprogrammed routine.
- The Cimel controller, batteries, and the optional Vitel satellite transmission equipment are usually deployed in a weatherproof plastic case.







DAYTIME.

NIGHTTIME

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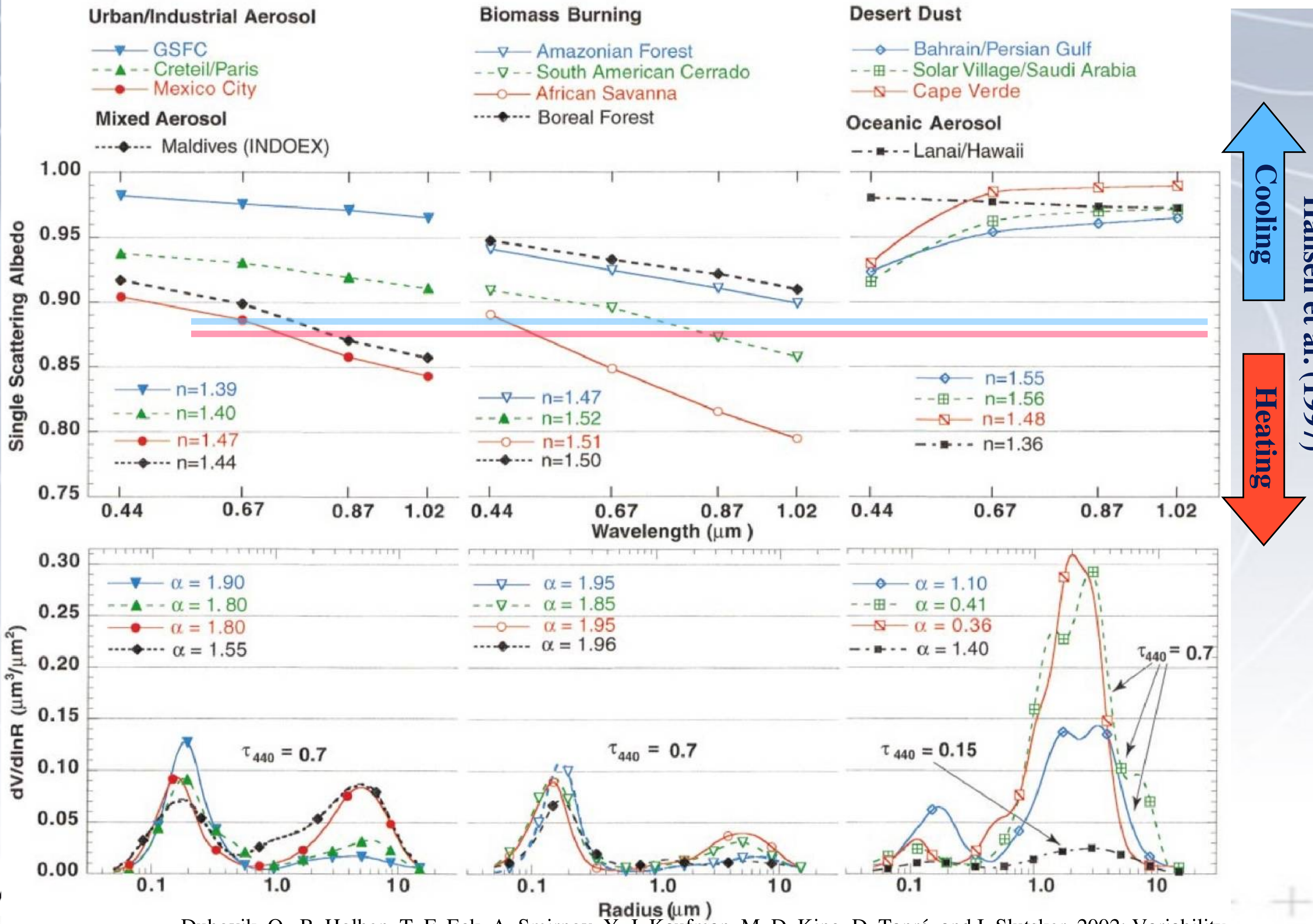
Ground base remote sensing

1. Photometry: AERONET

Aerosol Climatology from AERONET

AERONET Inversion Products



Hansen et al. (1997)

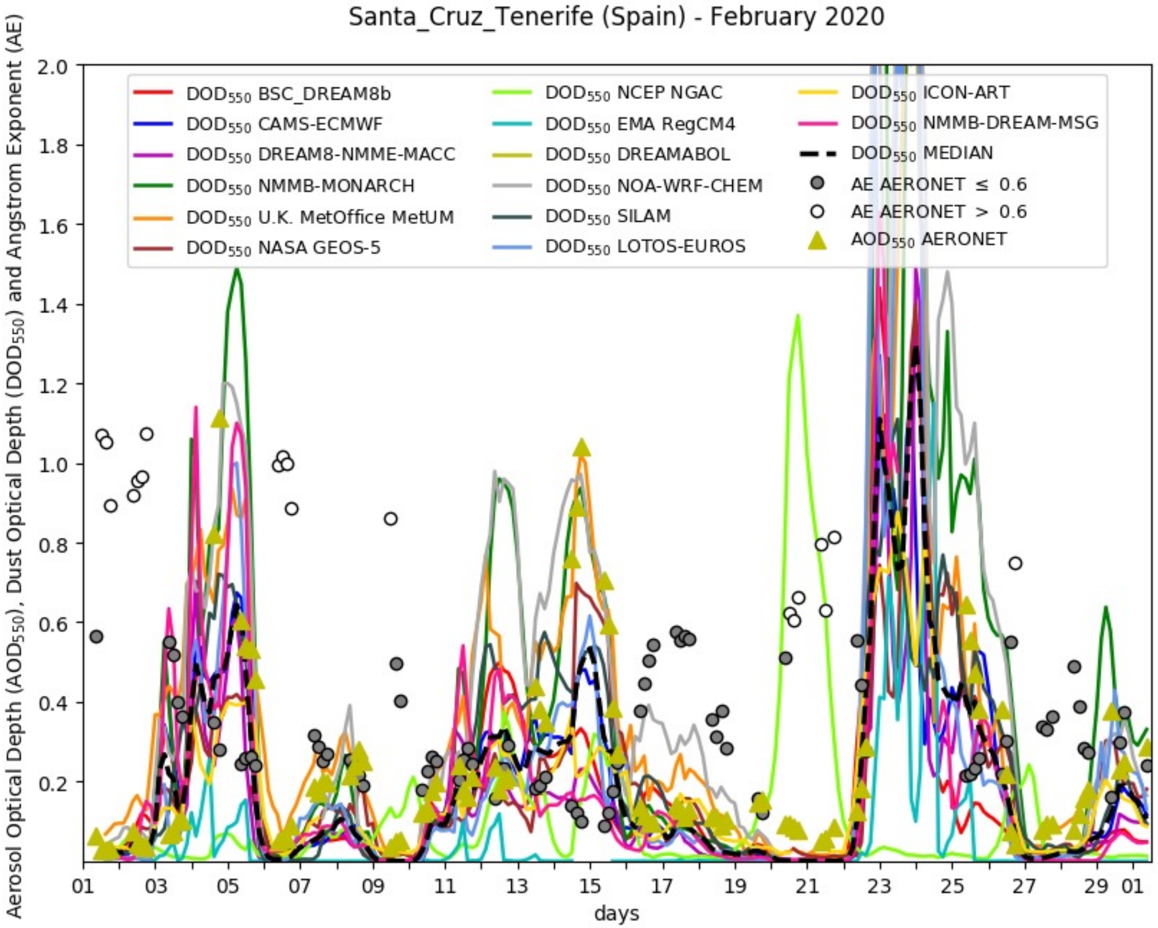
Dubovik, O., B. Holben, T. F. Eck, A. Smirnov, Y. J. Kaufman, M. D. King, D. Tanré, and I. Slutsker, 2002: Variability of absorption and optical properties of key aerosol types observed in worldwide locations. *J. Atmos. Sci.*, **59**, 590–608.

256 citations

Ground base remote sensing

1. Photometry: AERONET

NRT evaluation using AERONET data

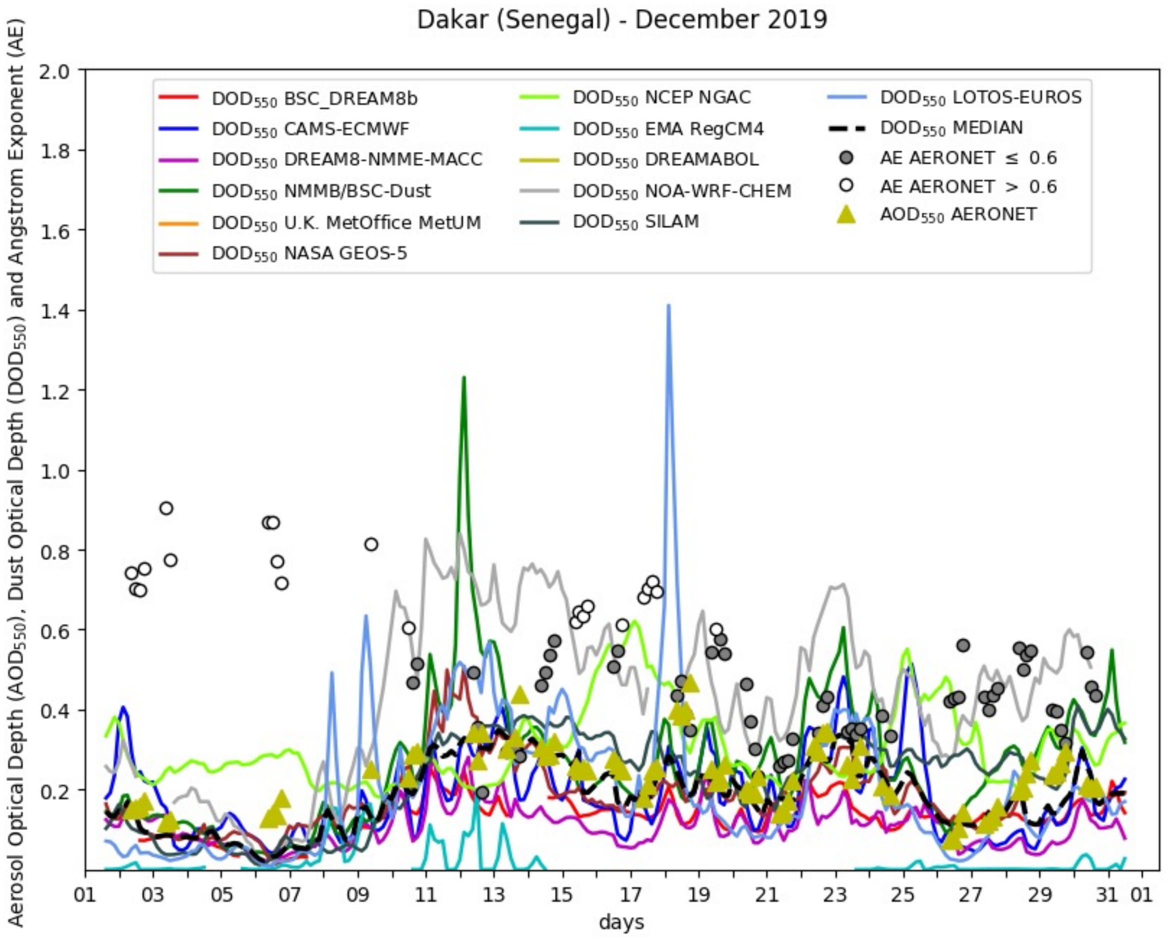


NORTHERN AFRICA-MIDDLE EAST-EUROPE (NA-ME-E) REGIONAL CENTER
WMO Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS)
WMO SDS WAS || Asia Regional Center || America Regional Center

AEMet Interreg MAC 2014-2020 Cooperación Territorial

1. Photometry: AERONET

NRT evaluation using AERONET data



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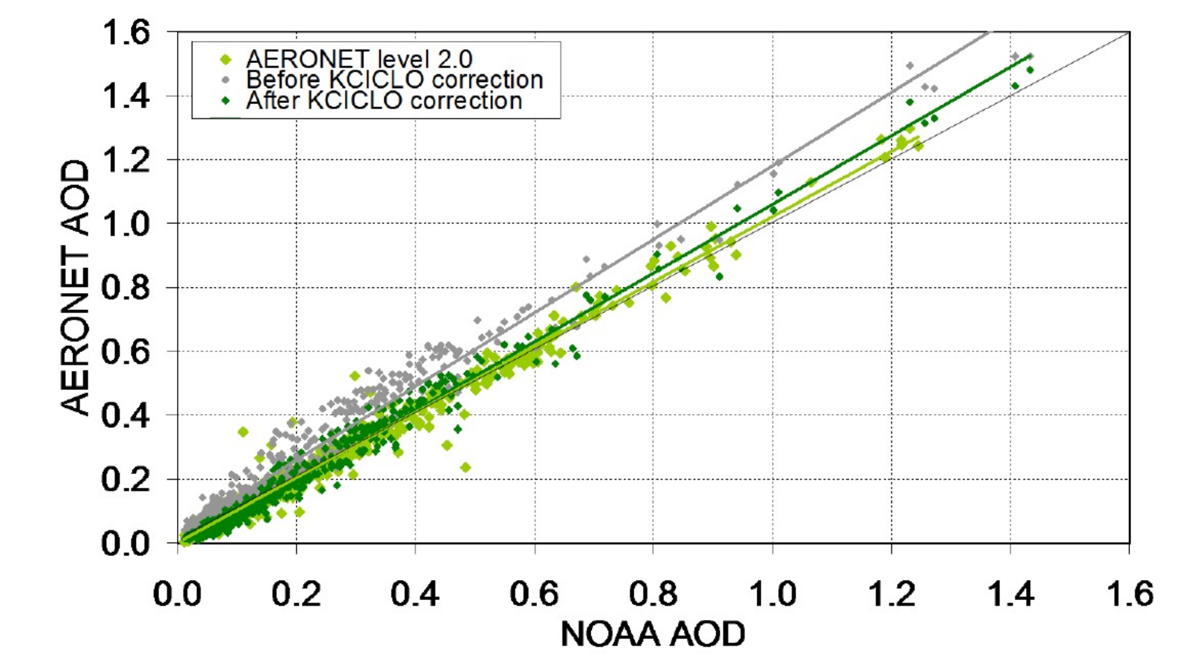
NORTHERN AFRICA-MIDDLE EAST-EUROPE (NA-ME-E) REGIONAL CENTER
WMO Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS)
WMO SDS WAS || Asia Regional Center || America Regional Center

Copernicus
Europe's eyes on Earth

1. Photometry



Correlation between AERONET AOD@440 nm and NOAA AOD@500 nm (since 1994) for time coincident data (within 15 minutes) at Tamanrasset GAW Station (Algeria). The AERONET level 2.0 data (light green) cover the period from October 2006 to February 2009. Correlation coefficient= 0.981 (Guirado et al., 2014)

Stable for, at least, 8 years

1. Photometry: Calitoo handheld sun photometer

Reconsidering hand-held sunphotometers for reporting dust AOD?

Microtops-II, Calitoo-Tenum...

Many observations at airports (even in remote regions)
Operated by meteorological observers
Easy data transmission through WMO GTS/WIS communication system

NRT data for model evaluation and data assimilation
NRT data for satellite evaluation
NRT data for dust nowcasting

Calitoo
(handheld sun photometer)
Tomorrow…

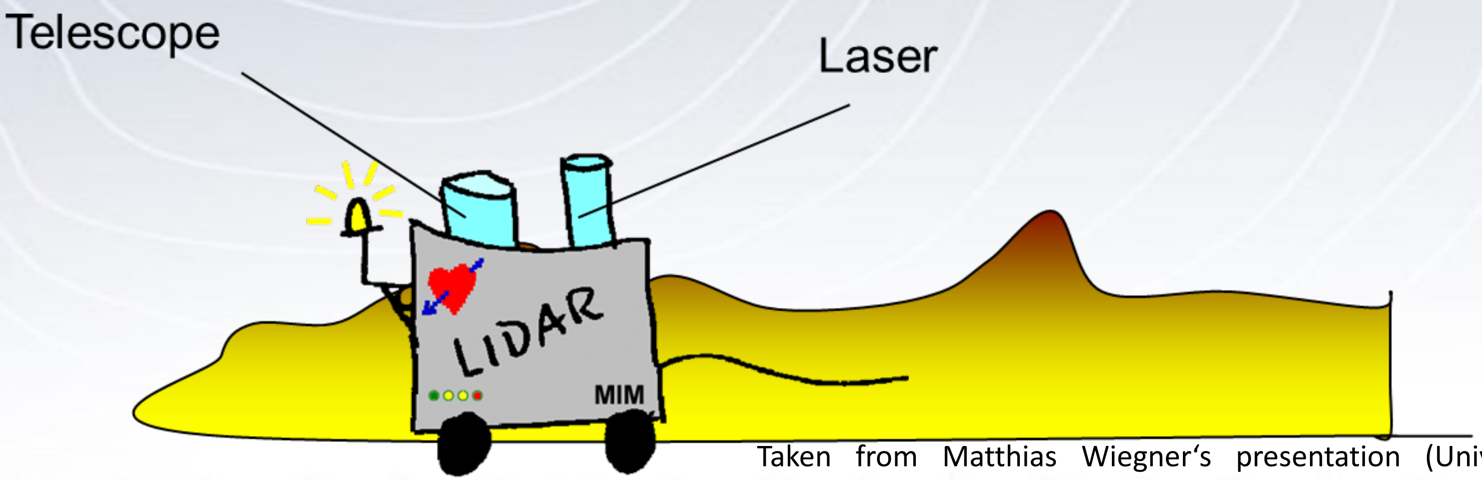
From in-situ dust observations to ground base remote sensing…

… total atmospheric column observations
(passive remote sensing, based on photometry techniques)

… vertical resolved observations
(active remote sensing, based on lidar techniques)

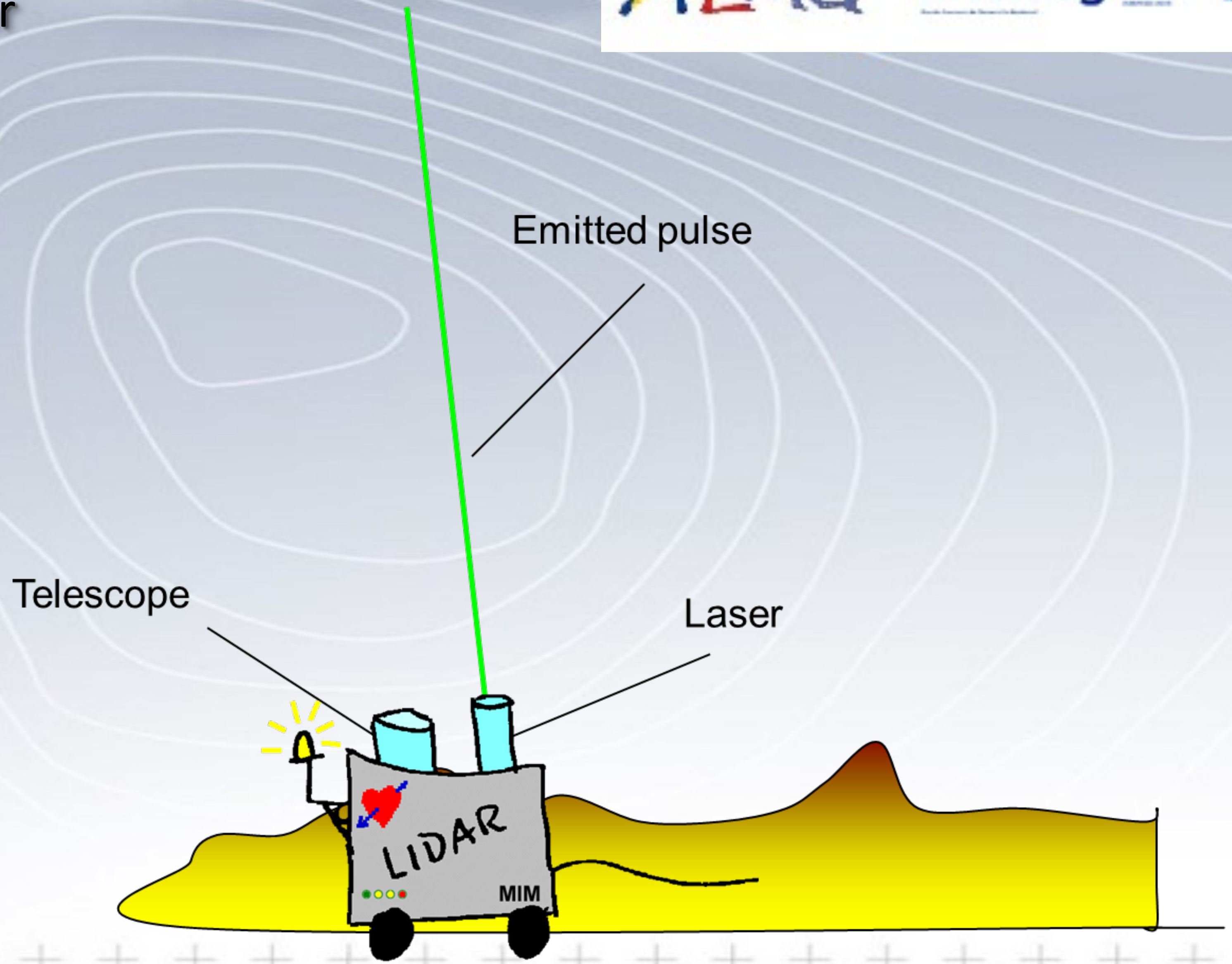
2. Lidar

Light Detection and Ranging, is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth



Taken from Matthias Wiegner's presentation (University of Munich, Meteorological Institute) to the SPIE 10 (International Symposium Remote Sensing)

2. Lidar



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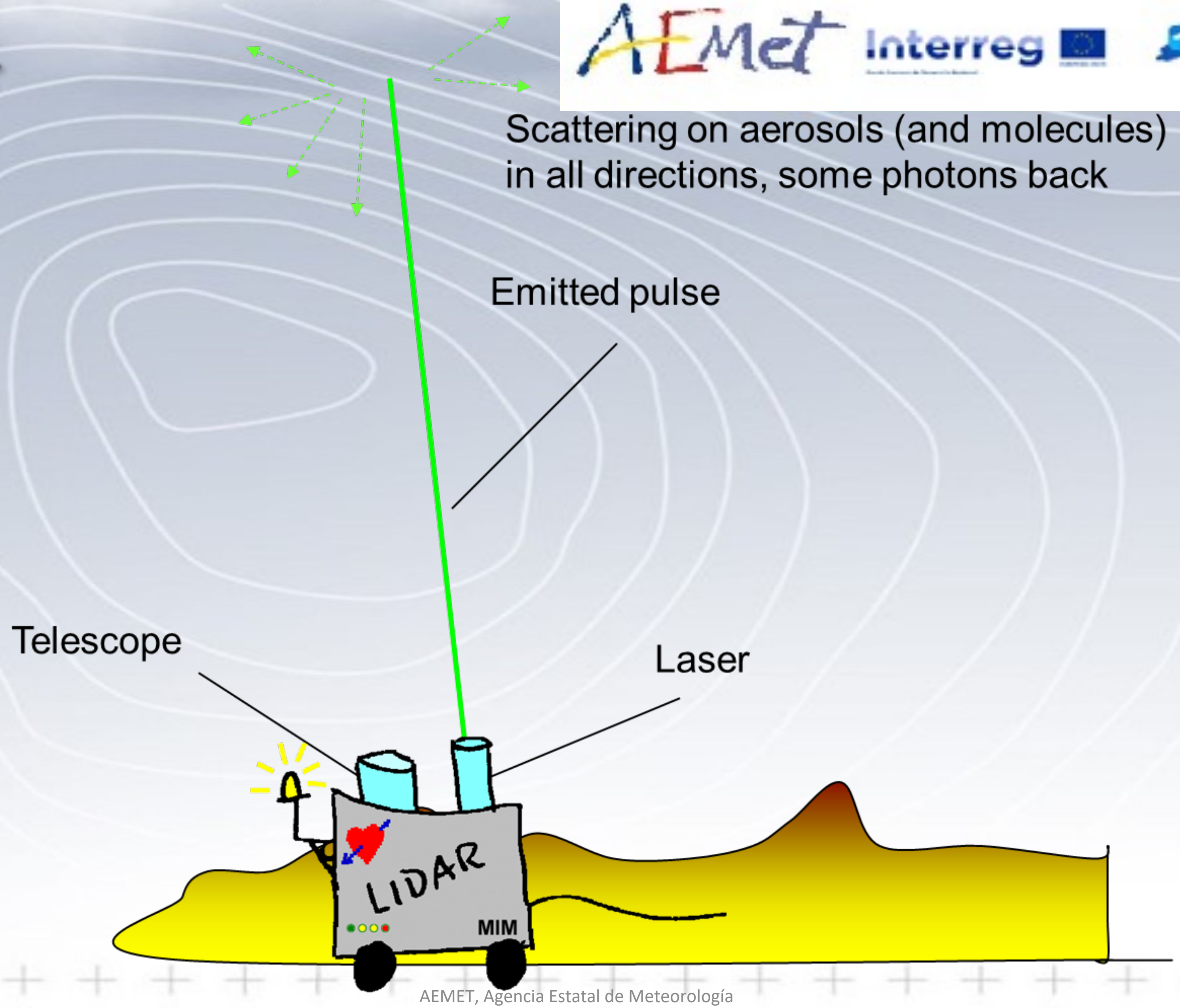
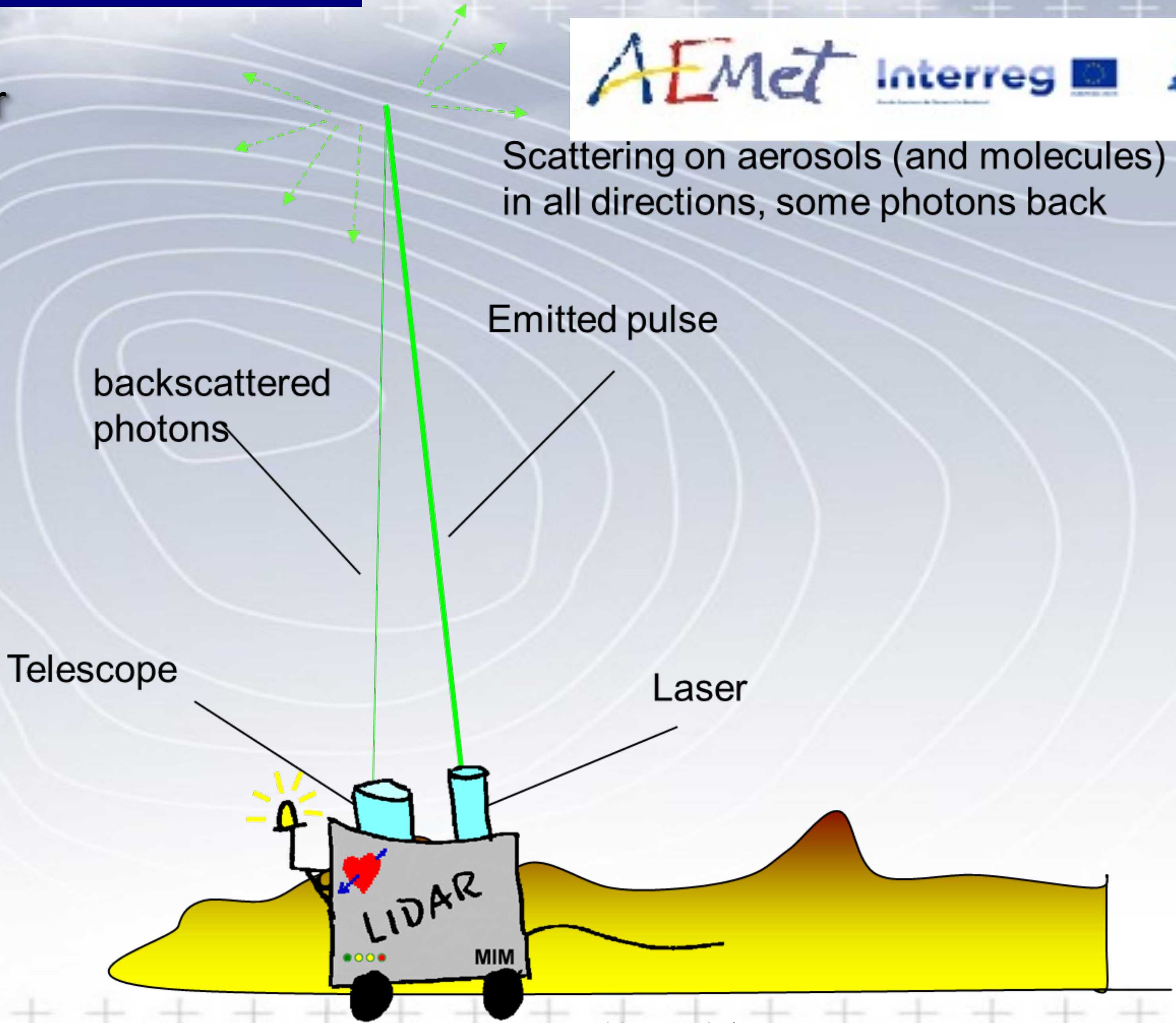
2. Lidar


Scattering on aerosols (and molecules)
in all directions, some photons back
Emitted pulse
Telescope
Laser
LIDAR
MIM

2. Lidar


Scattering on aerosols (and molecules)
in all directions, some photons back
Emitted pulse
backscattered
photons
Telescope
Laser
LIDAR
MIM

2. Lidar

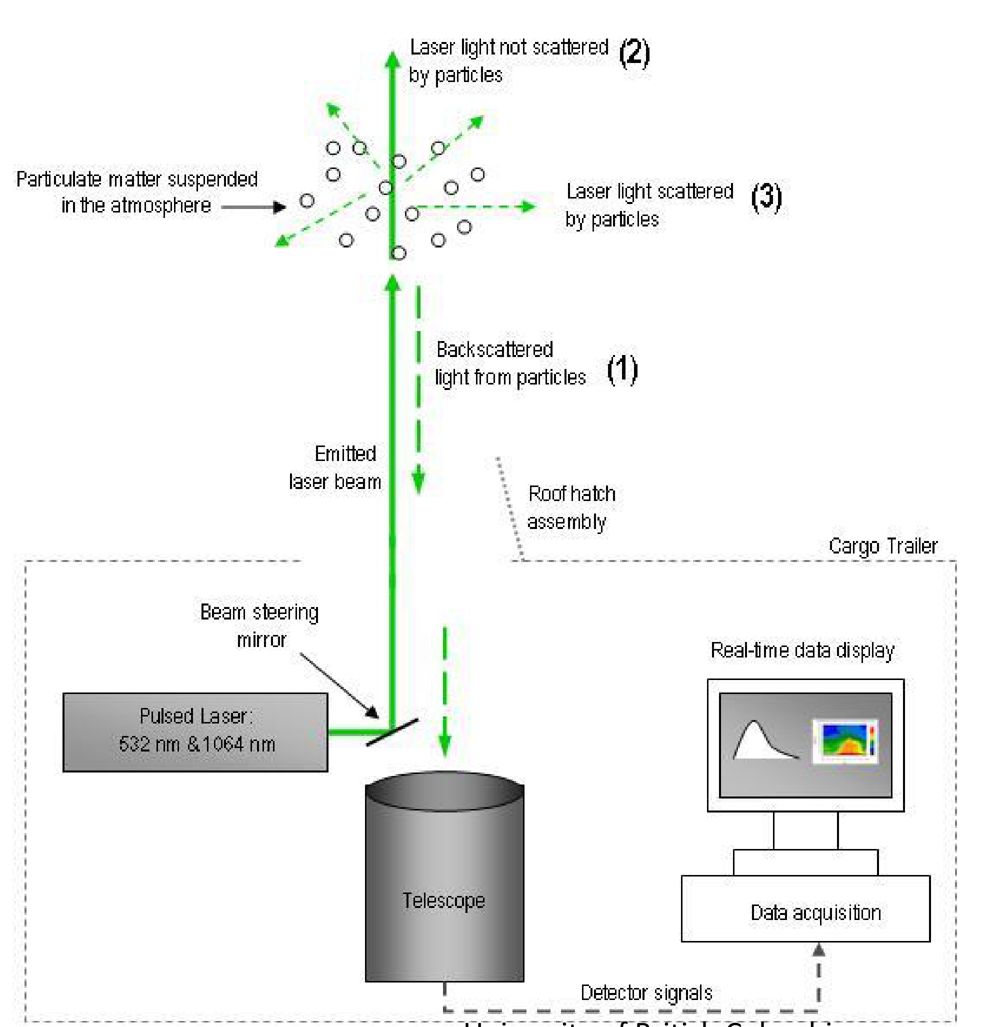
Lidar-Barcelona (UPC)
Raman Lidar
EARLINET

Lidar-Tenerife (INTA-AEMET)
Elastic lidar
MPLNET

ALOMAR (69ºN)

MACCLIMA

2. Lidar



University of British Columbia

Lidar systems retrieve vertical profiles of aerosol optical properties

They measure backscatter and need the lidar ratio (S) to obtain extinction profiles.

(S → gives an estimation of the ratio between light backscattered by particles and the extinction of the atmosphere)

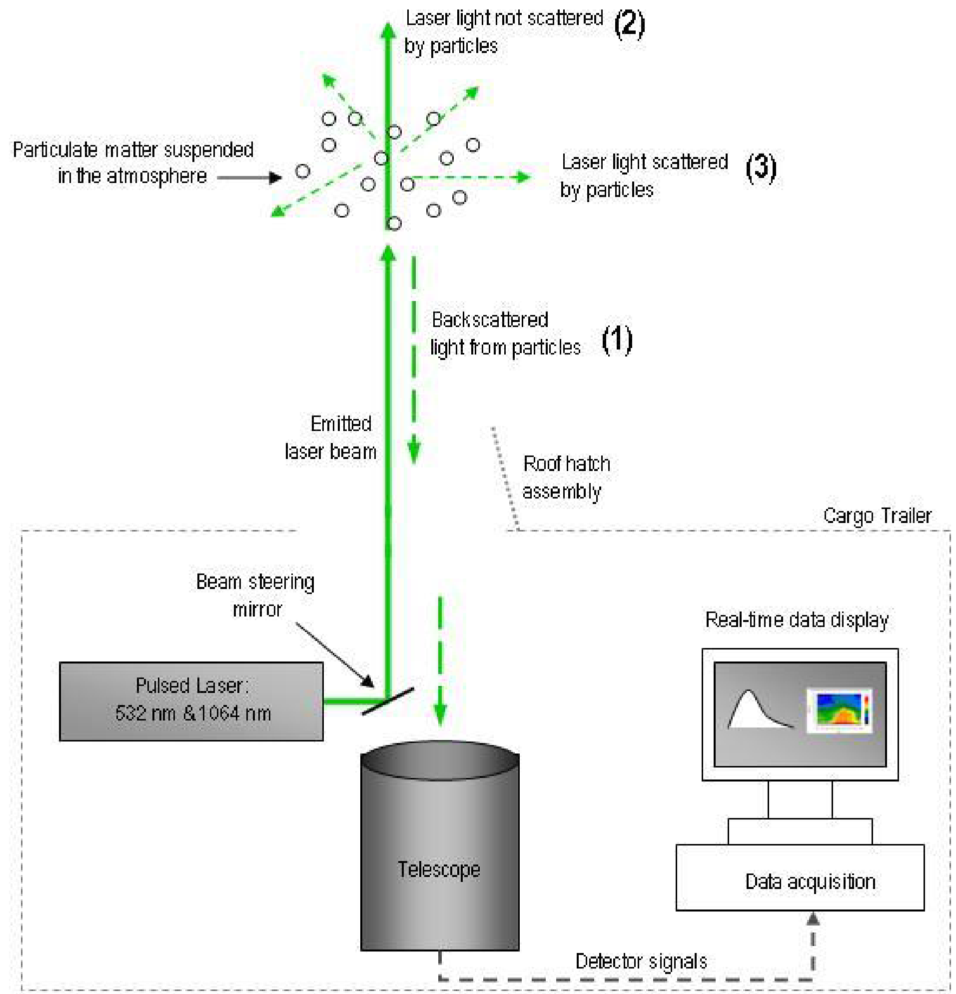
Elastic lidars:

Assuming a S constant along the column (determine through photometry or assuming a type of aerosol…)

Raman lidars:

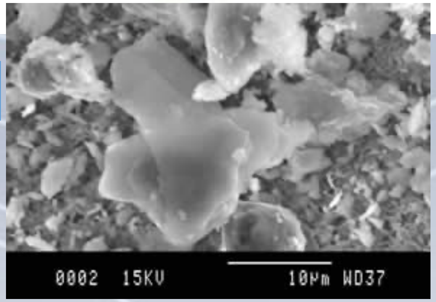
Able to determine S because a more sophisticated systems (more expensive, more power consuming, more technical requirements…)

2. Lidar



University of British Columbia

Mineral



Elastic lidars:
Depolarization ratio provides information on sphericity → dust layers

Raman lidars:
provide better estimations of extinction.

Ceilometer:
(more robust and less expensive) can potentially be installed in remote sites.

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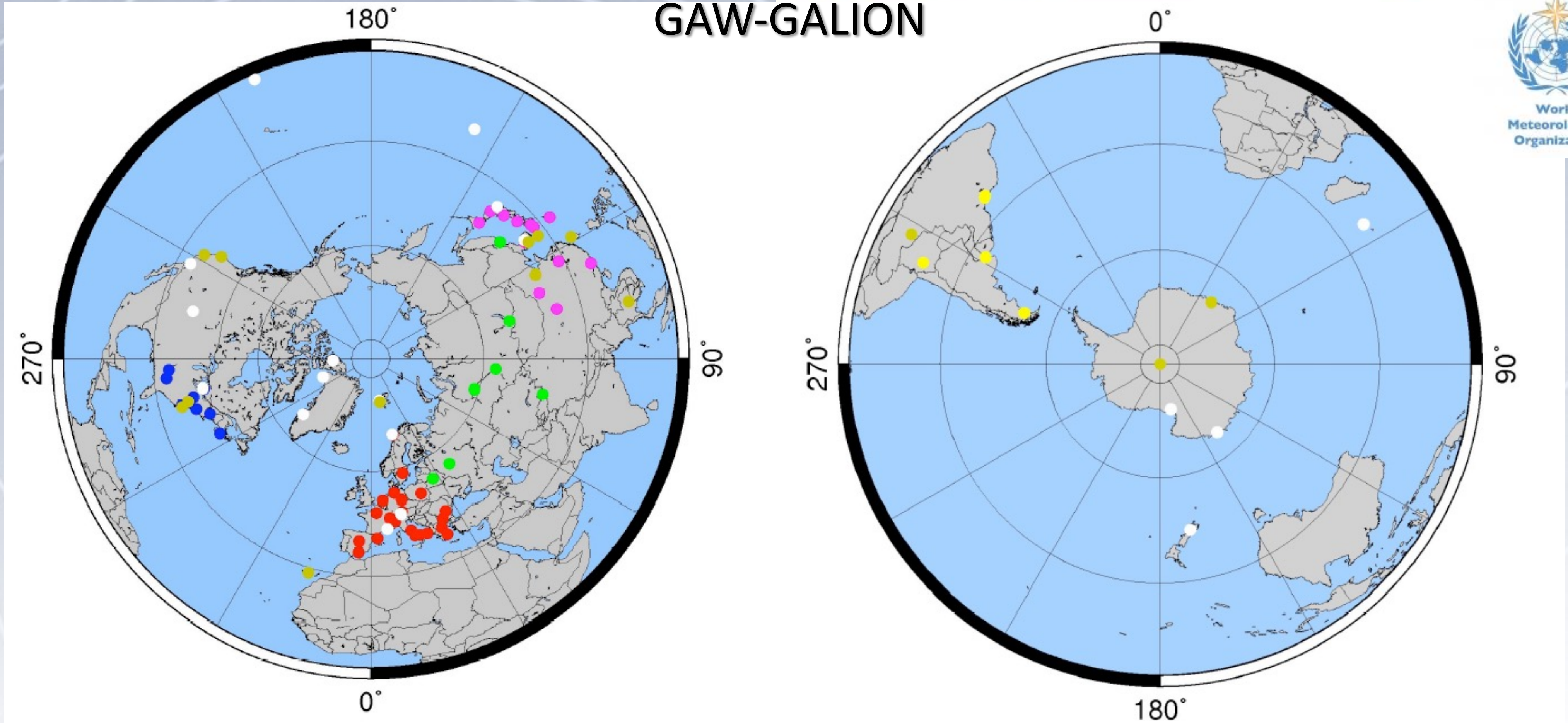
2. Lidar

GAW-GALION



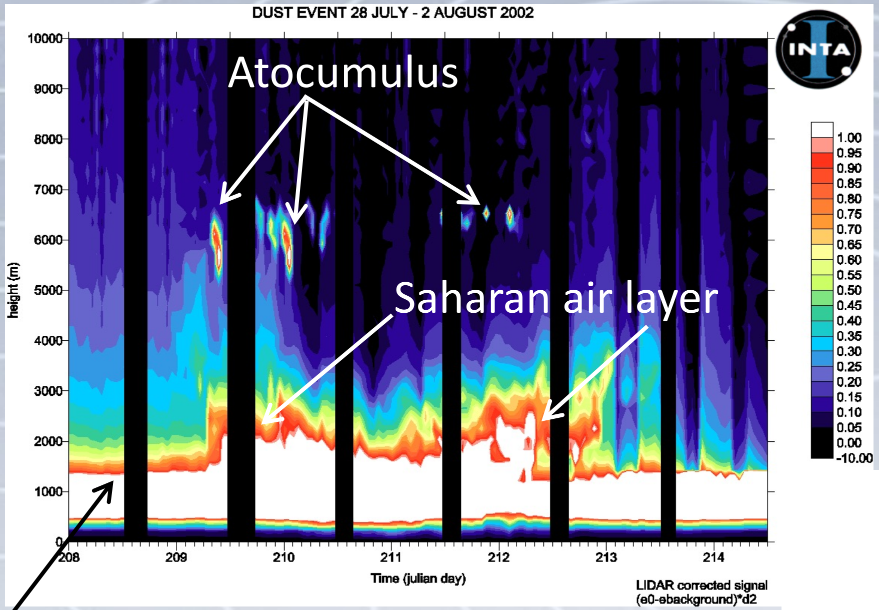
Distribution of stations as available through the cooperation between existing networks: AD-NET , ALINE , CISLiNet , EARLINET/ACTRIS , MPLNET/NASA , NDACC , REALM .

https://www.wmo.int/pages/prog/arep/gaw/documents/gaw178-galion-27-Oct.pdf

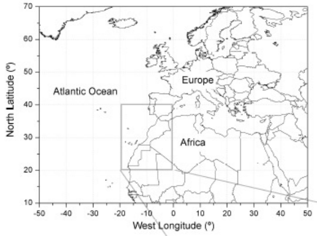
Ground base remote sensing

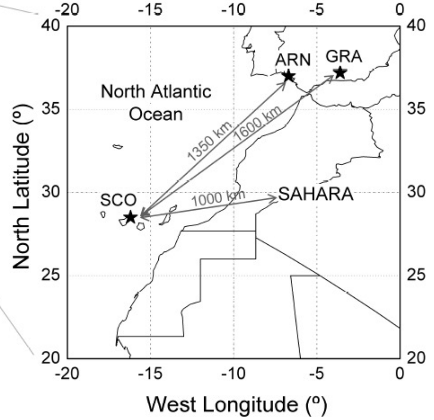
2. Lidar

MPL-Tenerife



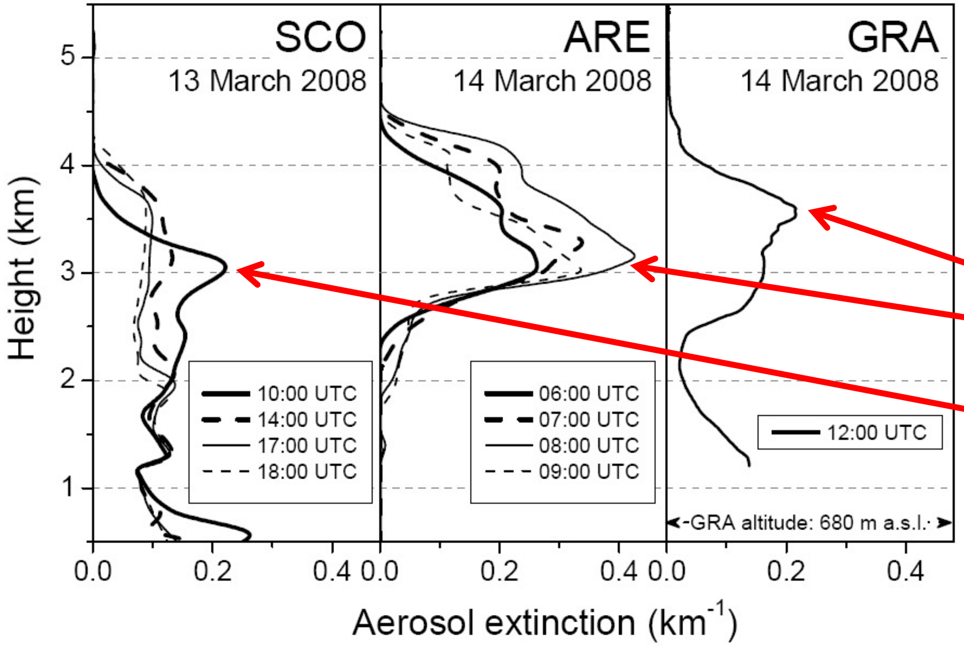
Top of the marine boundary layer

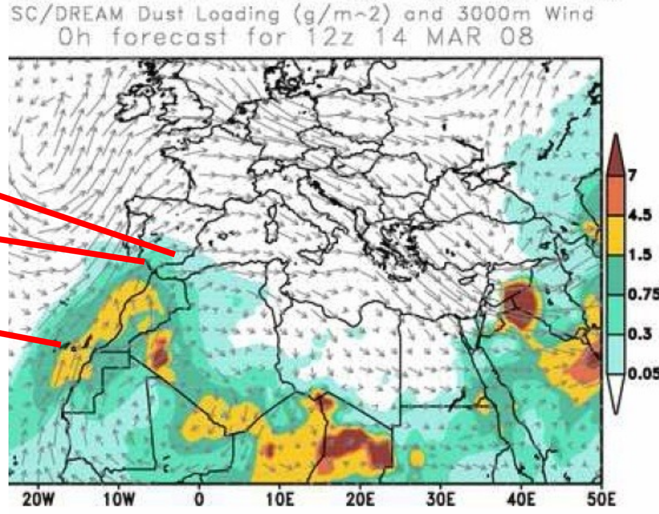




A case study of dust transport from Canary Islands to Iberian Peninsula

Córdoba-Jabonero et al., ACP, 2010



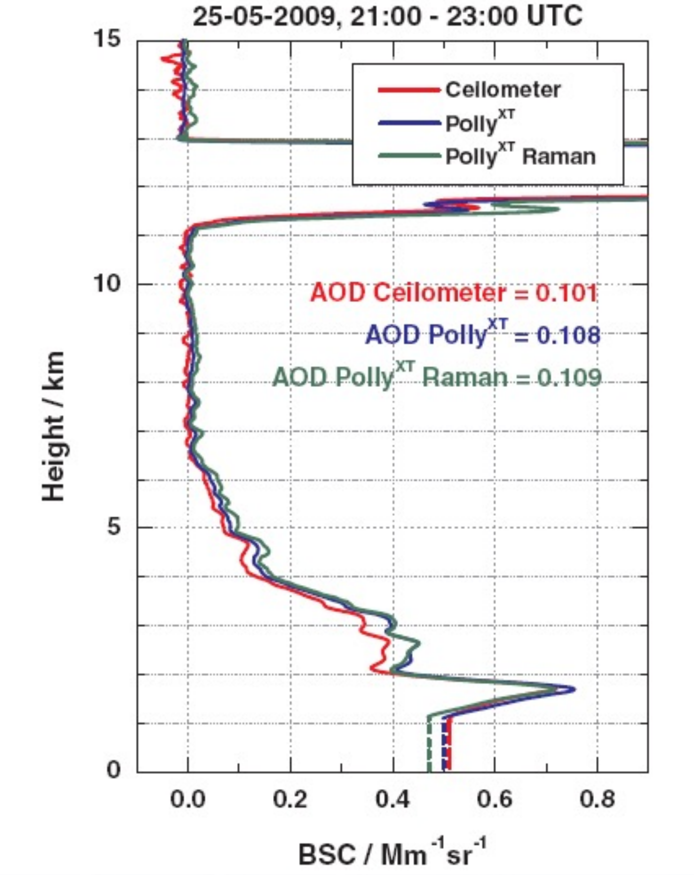


2. Lidar: Ceilometers

Ceilometers are built to detect clouds (running for exemple at airports).

They work in NIR wavelenght for trying to have neglibigle signal of aerosol (in principle, for ceilometers areosols are a perturbation in clouds measurements).

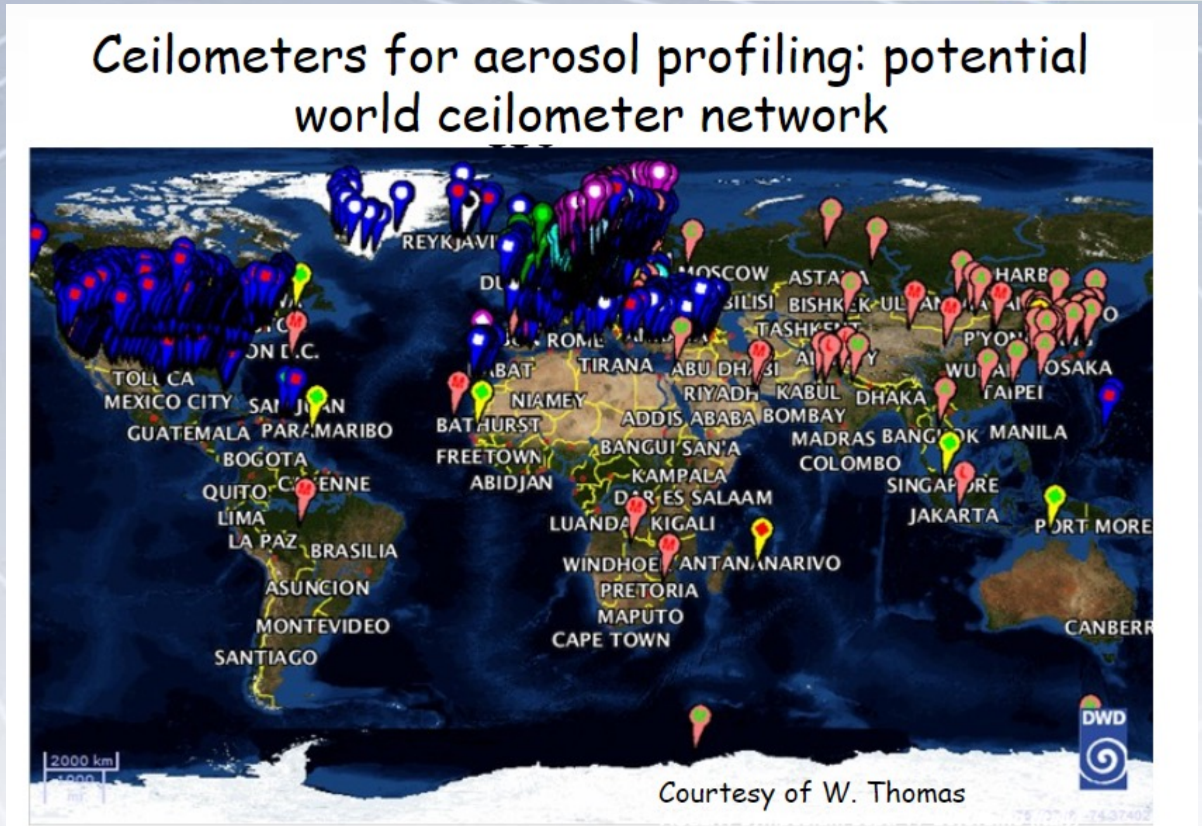
Nonetheless, this low signal could be use to retrieve aerosol properties…



*Heese et al., Atmos. Mes. Tech. 2010, Ceilometer-lidar inter-comparison: **backscatter coefficient** retrieval and signal-to-noise ratio determination*

Desirable for desert regions !!

2. Lidar: Ceilometers



Higher density of observations, despite greater uncertainty

Met Services are replacing **cloud-base** ceilometer networks by **aerosol backscatter profiling ceilometers** (**IR wavelenght**).

Objective: To monitor MLD (Mixing Layer Depth) based on **several hundred profiling ceilometers**

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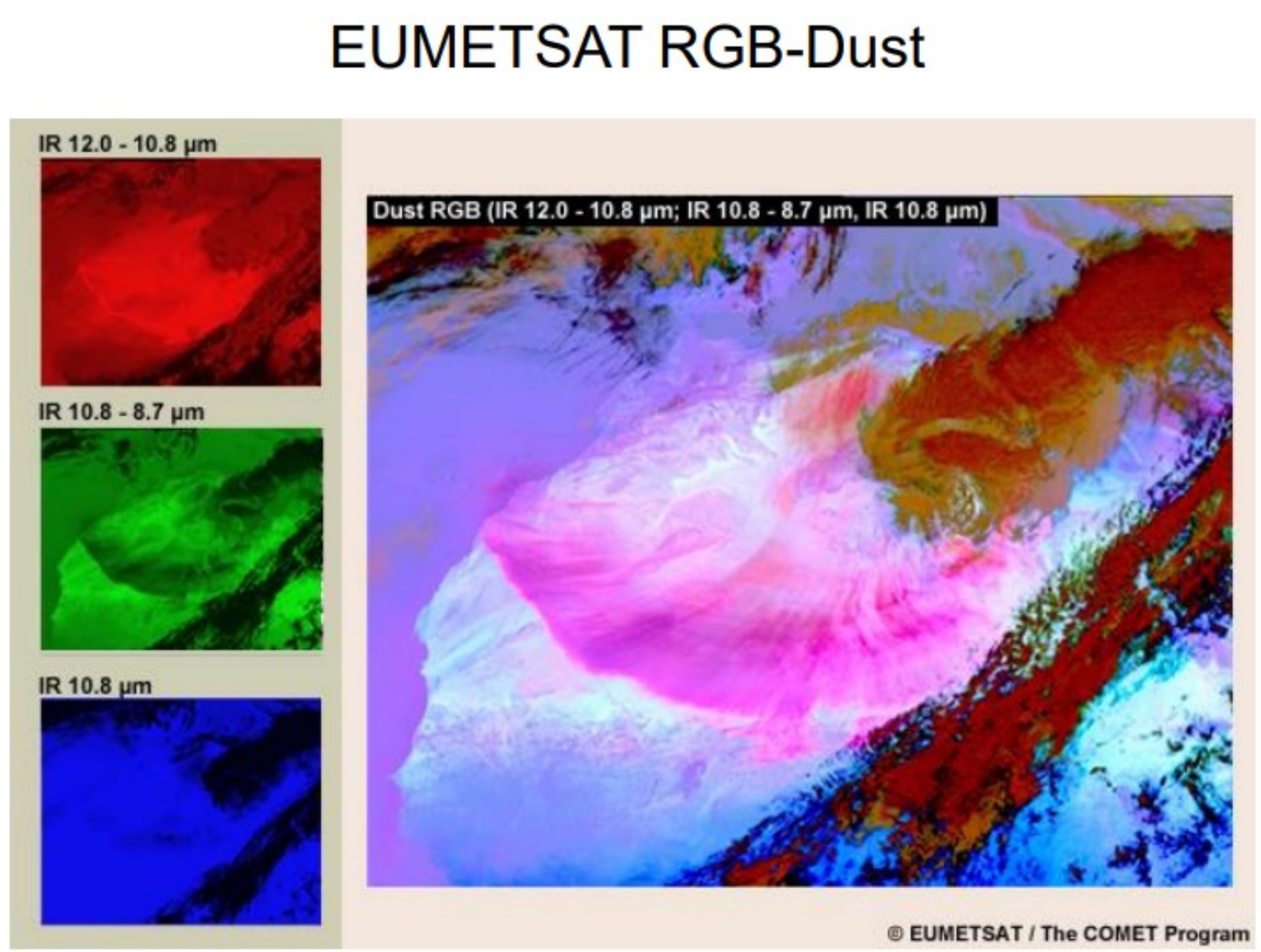
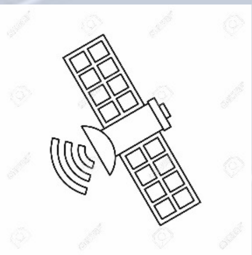
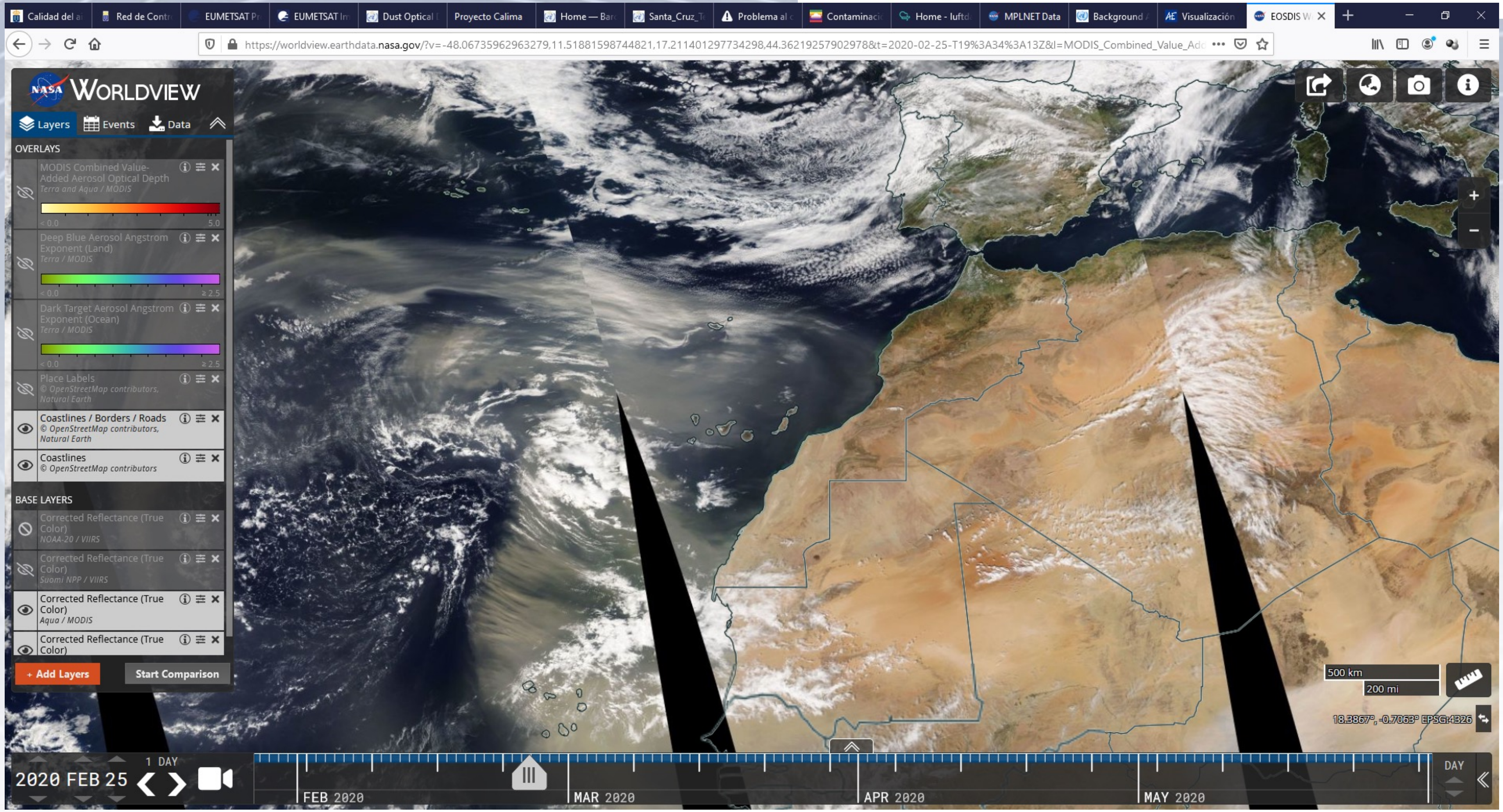
From ground base remote sensing to satellite observations ......



Remote sensing!



Use of layers in Worldview – Earthdata from NASA



https://worldview.earthdata.nasa.gov/

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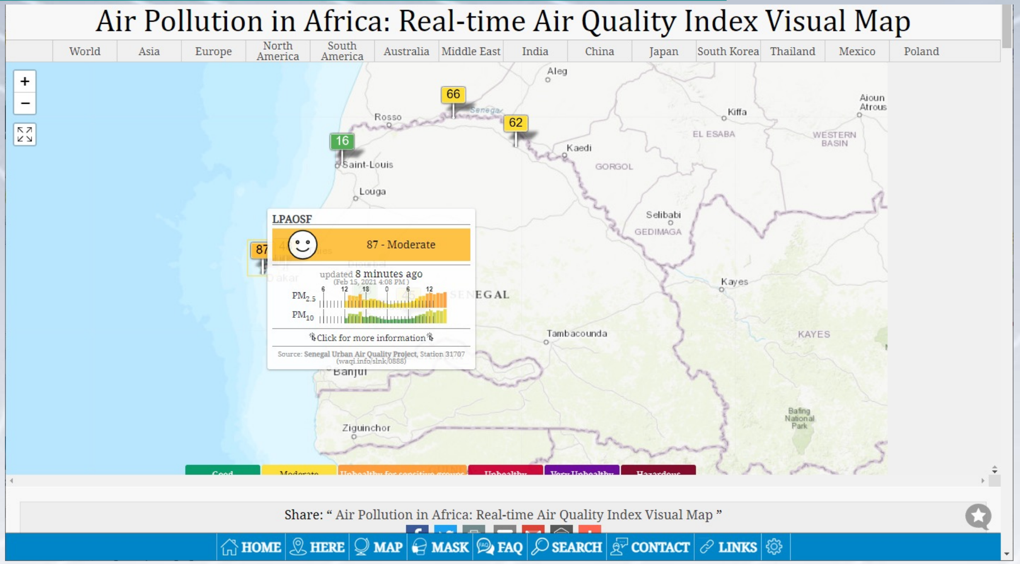
"Verification" tools

Visibility – METAR-SYNOP

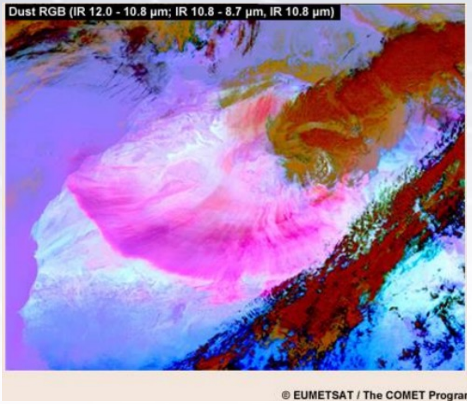
```
•62733  15.32   35.60 02040818 Dust, not at time of obs.          6  0   18 22 320  2 35.5
•62733  15.32   35.60 02041015 Dust, raised at time of obs.       7  0  99. 30 320  6 34.5
•62733  15.32   35.60 02041121                    -9          -9 -9 -9   20 23 320  2 26.0
•62733  15.32   35.60 02041212                    -9          -9 -9 -9   20 34 340  3 37.5
```

SCF Concentration (PM10) – Air Quality Networks (or LCS alternative…)

https://openmap.clarity.io/
https://aqicn.org/map/africa/



Satellite



https://worldview.earthdata.nasa.gov/

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Use of AERONET in SDS-WAS (AOD – exponente Angström) if available…

- AOD is the parameter that is best modeled
- Better monitoring in NRT (availability, standardization and quality)
    - Real-time verification of the operating model (https://dust.aemet.es/forecast-evaluation/near-real-time-evaluation_v3)
    - Real-time multi-model verification (https://sds-was.aemet.es/forecast-products/forecast-evaluation)

If AQ-Networks and AERONET are not available… let's play!

- PM10 Low Cost Sensors…
- Calitoo measurements (AOD and Alpha…)

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Merci!

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Agencia Estatal de Meteorología

WORLD METEOROLOGICAL ORGANIZATION

ADDITIONAL MATERIAL …

Different high volume samplers

Low volume methods: (PM_{10}, $PM_{2.5}$, PM_{Coarse})

- High volume methods: TSP, PM_{10}, $PM_{2.5}$

Low Volume Sampler

LVS: $2.3\ m^3/h$

High Volume Sampler

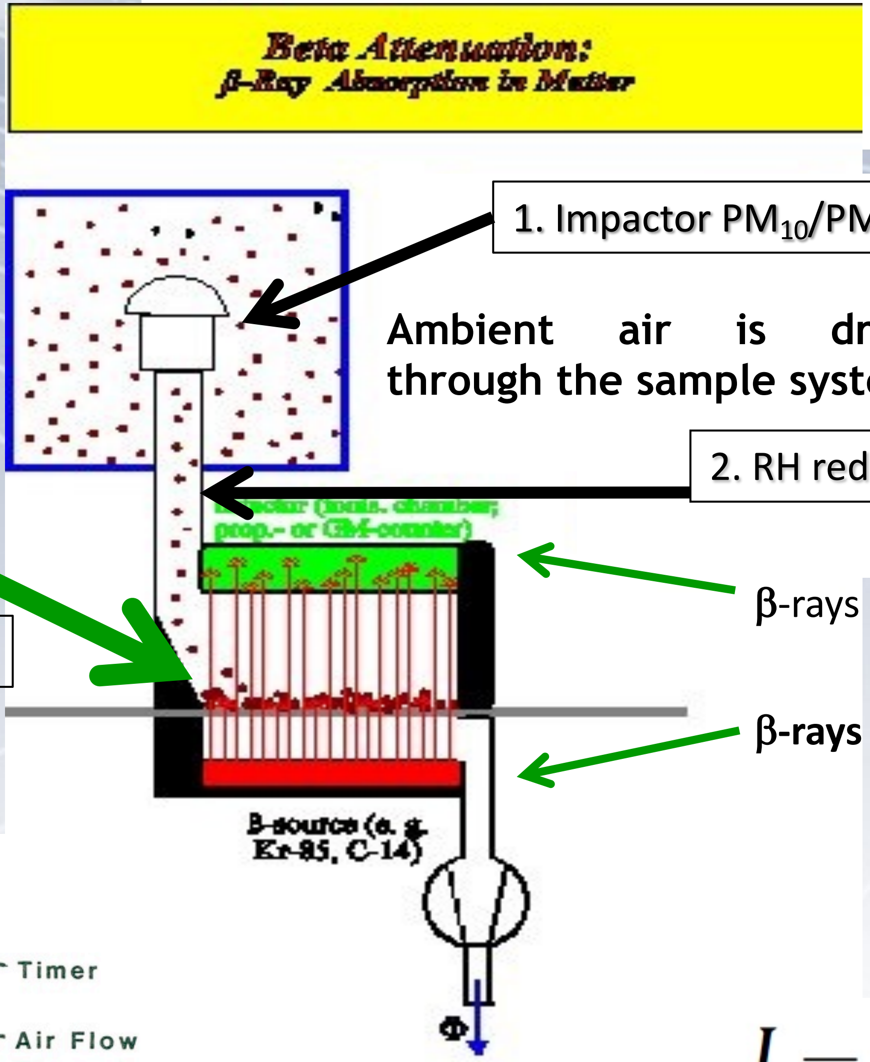
HVS: $68\ m^3/h$

HVS: $30\ m^3/h$

How BAM works (1)

2. Automatic Methods: BAM (Beta)

Dust is deposited on a filter continuously. The layer of dust is building up and this increasing dust mass weakens the intensity of the beta beam.



1. Impactor $PM_{10}/PM_{2.5}$

Ambient air is drawn through the sample system

2. RH reductor / heater

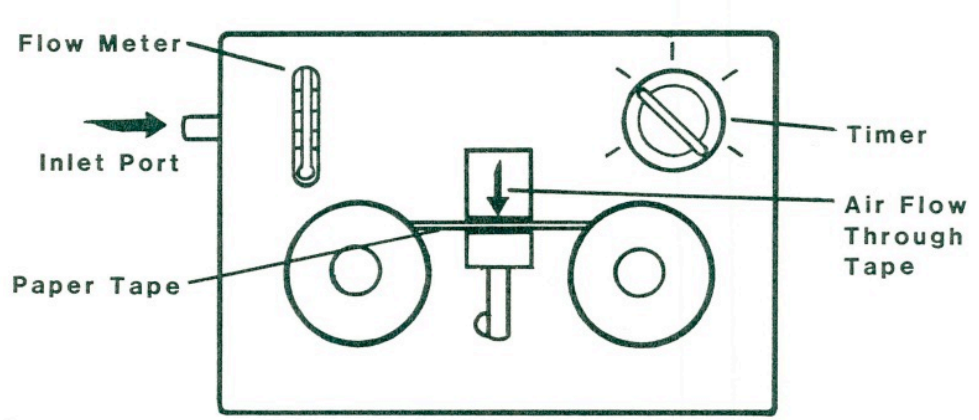
β-rays detector

β-rays source(Kr85)

3. Sensor

4. Pump and flowmeter

$$I = I_o e^{-\mu_\beta \cdot x}$$



How BAM works (2)

2. Automatic Methods: BAM (Beta)

$$m = F_{cal} ln\left(\frac{I_0}{I}\right)$$

- **m:** increasing particle mass [μg]
- **F_{cal}:** calibration factor
- **I_0** beta ray intensity at empty filter
- **I** beta ray intensity at loaded filter

The intensities I_0 and I are measured with the detector system. F_{cal} has to be measured directly during the calibration procedure. This is accomphished by replacing the filter with the element having a known mass (mass calibration kit)

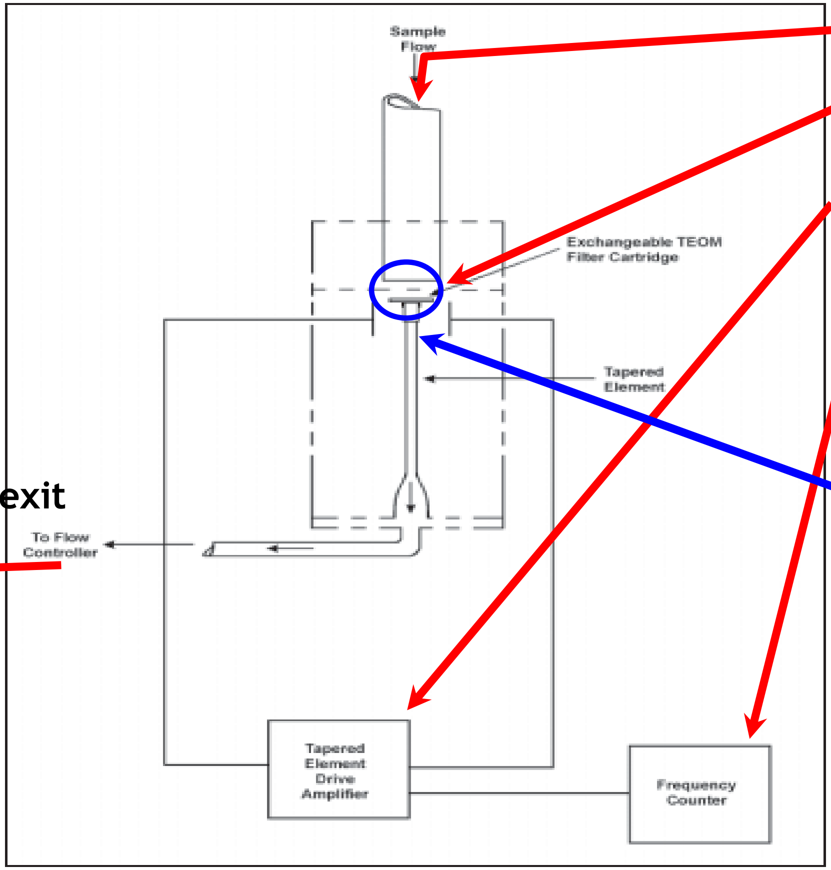
The mass concentration is calculated from:

PMx $$c = \frac{m}{Ft}$$

Where:
c: concentration [μg/m³]
F: measured air flow [m³/h]
t: time [h]

How TEOM works (1)

2. Automatic Methods: TEOM   Tappered Element Oscillating Microbalance



Flow exit

Sampling flow rate (16.67 l/m)

Sample accumalated in the filter

Micro-oscilation of constante amplitue GENERATOR

Frequency sensor

An increase in the amount of sample (dust) accumulated in the filter ➔ decrease in the oscillation frequency

mass=function (frequer

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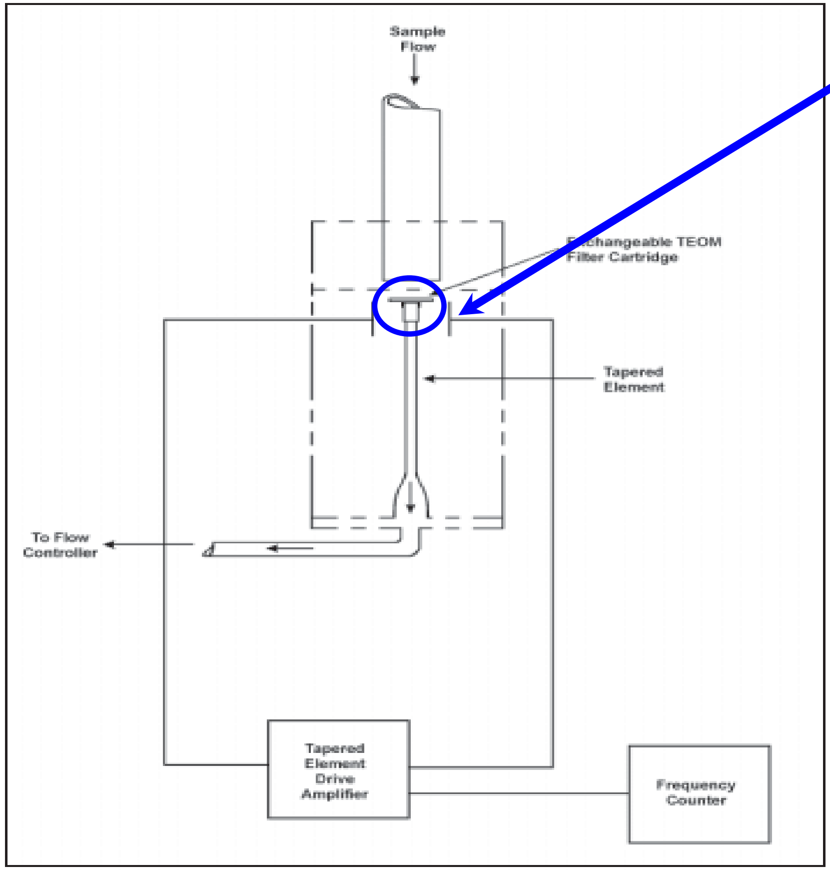
How TEOM works (2)

2. Automatic Methods: TEOM

mass=function (frequency)

more dust ➔ lower oscillation frequency



In a spring-mass system the frequency follows the equation:

$$f = (K / M)^{0.5}$$

where:

f = frequency (radians/sec)
K = spring rate
M = mass

K and M are in consistent units. The relationship between mass and change in frequency can be expressed as:

$$dm = K_0 \left(\frac{1}{f_1^2} - \frac{1}{f_0^2} \right) \qquad (2)$$

where:

dm = change in mass
K_0 = spring constant (including mass conversions)
f_0 = initial frequency (Hz)
f_1 = final frequency (Hz)

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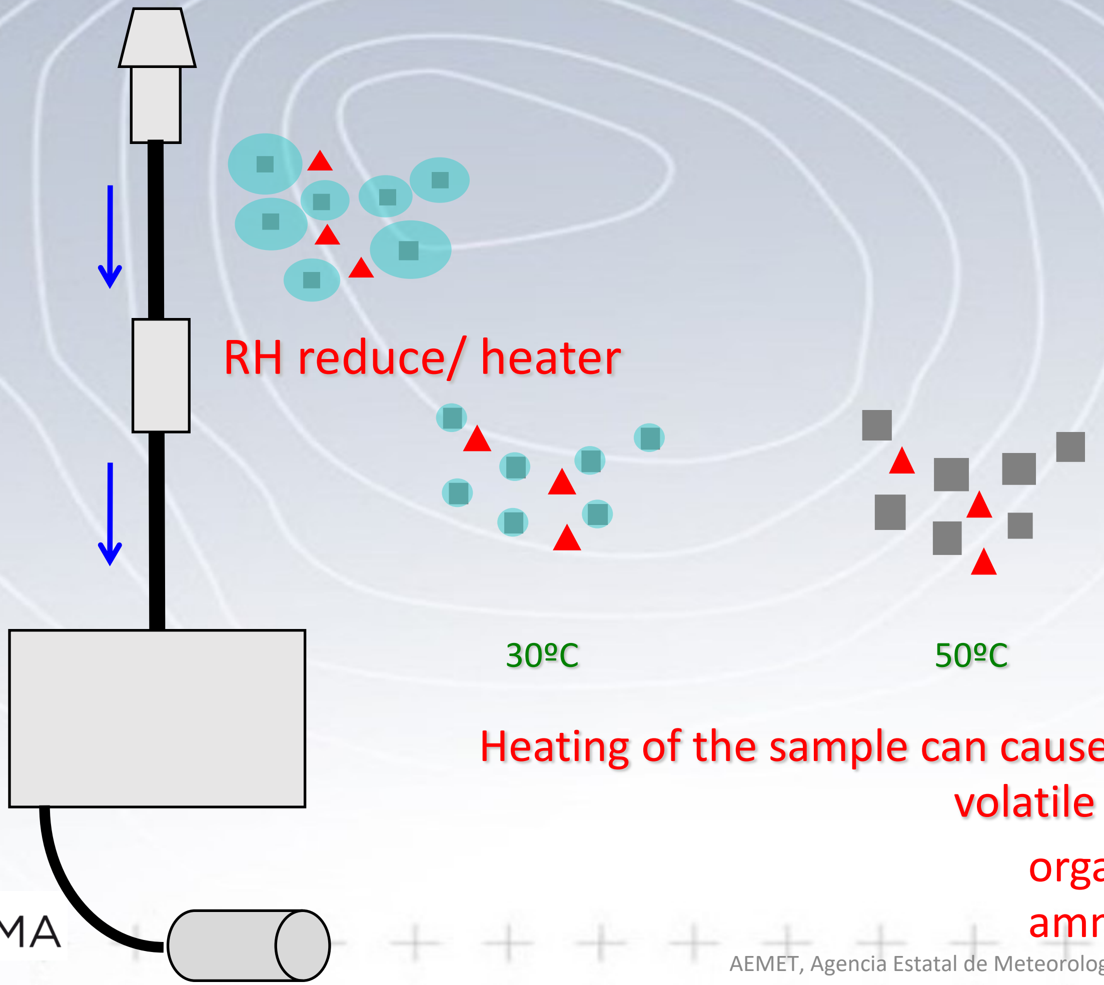
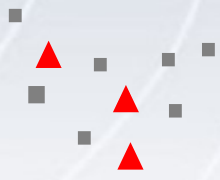
2. Automatic Methods: BAM (Beta) - TEOM

drying of the sample in automatic equipment





beta

TEOM

Heating of the sample can cause evaporation losses of semi-volatile species

organic compounds
ammonium nitrate

2. Automatic Methods: TEOM (FDMS Filter Dynamics Measurements System)

base flow mode: 6 min. → **"Provisional" PM10 concentration PM10'**

reference flow mode: 6 min. → **Evaluation of changes in concentration when filter expose to ambient air without** particles, and determine such chages **ΔPM10.**

The PM10 final concentration will be then:

PM10 = PM10' - ΔPM10

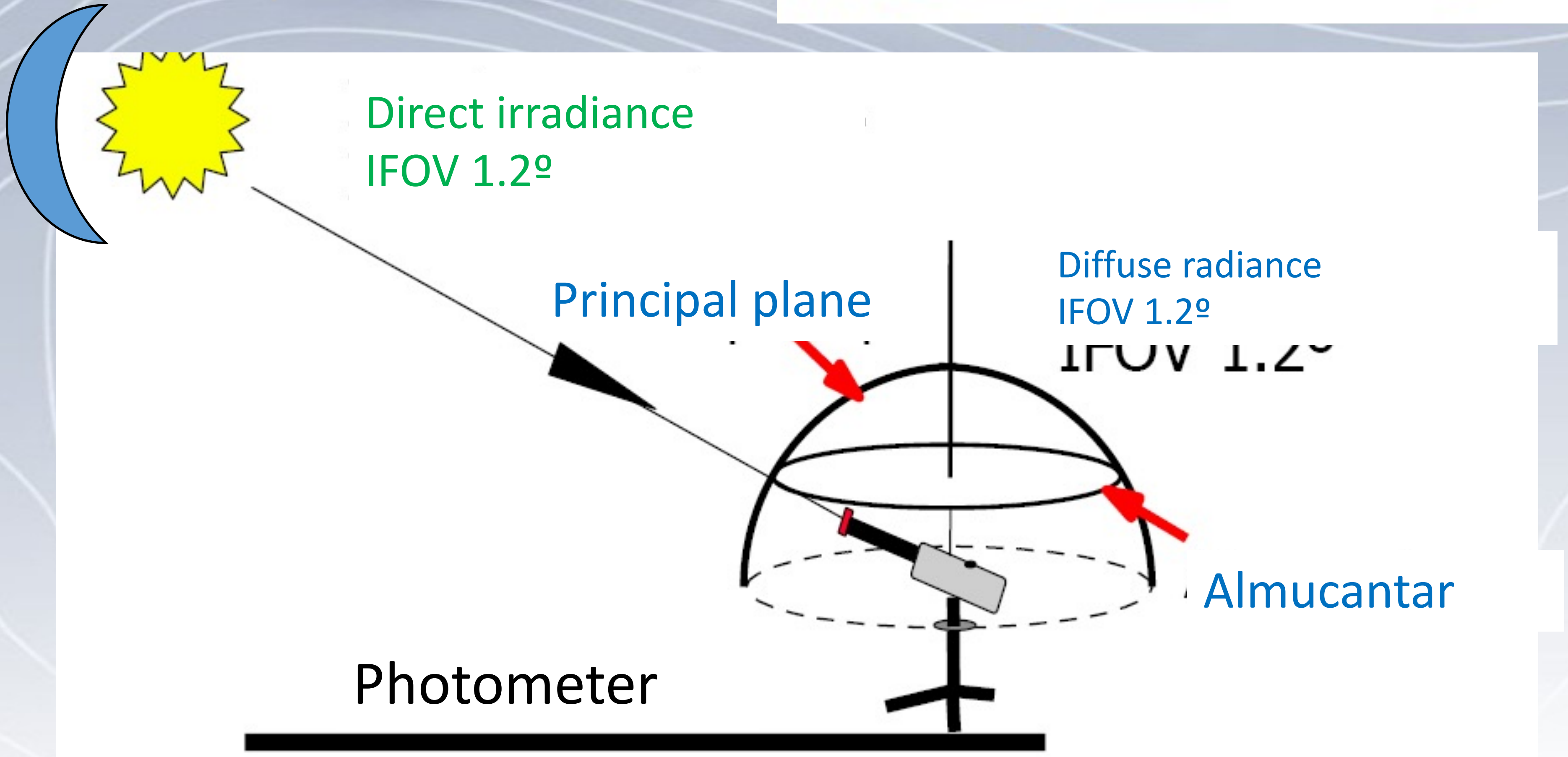
If ΔPM10 > 0 → **Positive artifact for gas reacting over particles on filter**

PM10 < PM10'

If ΔPM10 < 0 → **Negative artifact due to volatilization of particles on filter**

PM10 > PM10'

1. Photometry



Sun/moon measurements

Sky measurements

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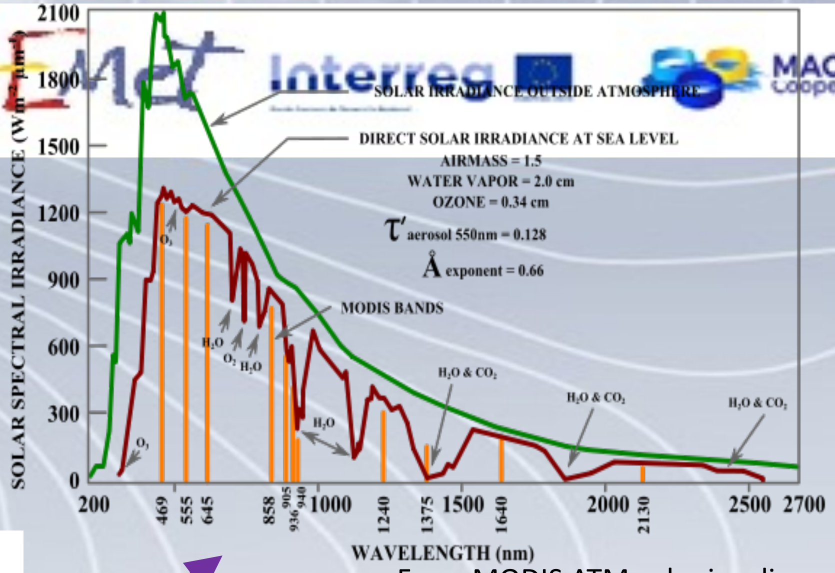
Ground base remote sensing

1. Photometry

Langley plot calibration

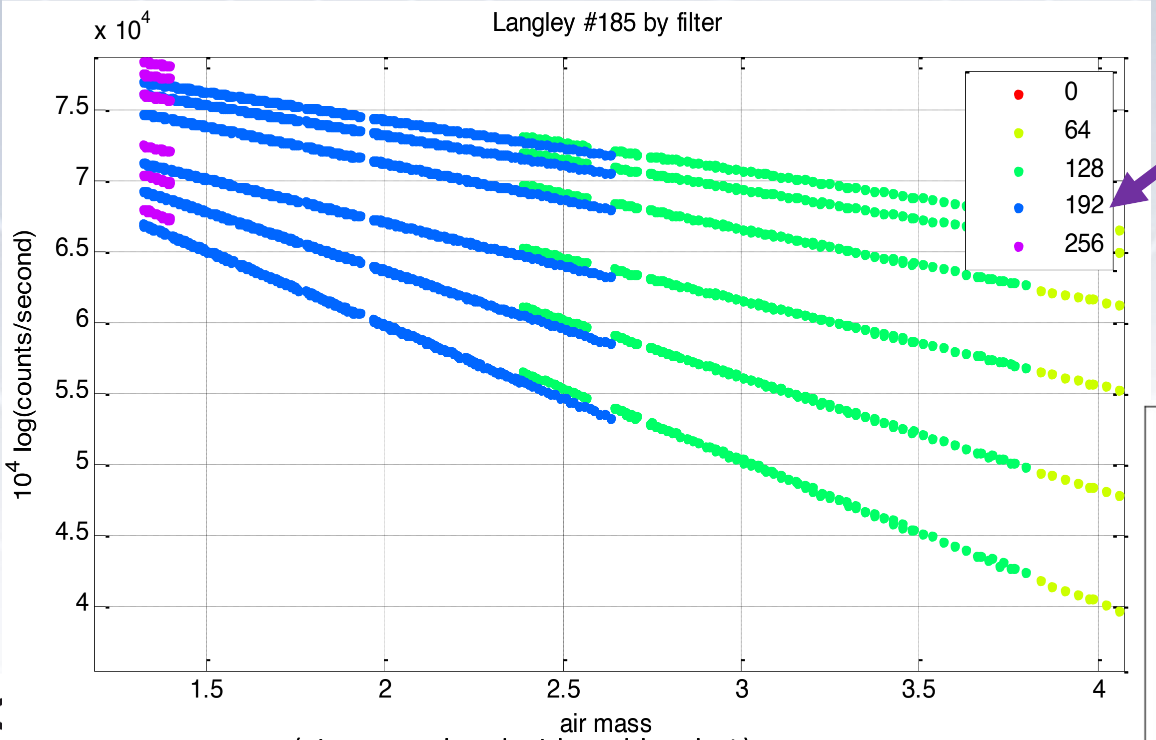
(I_0 determination for each wavelength):



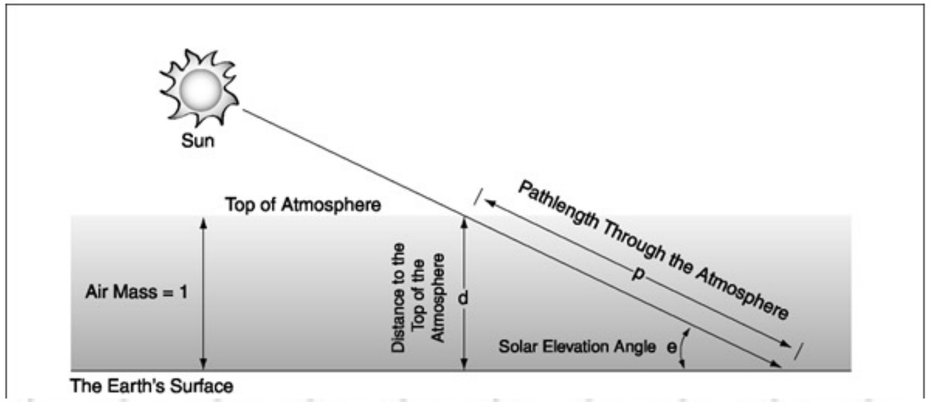
From MODIS ATM solar irradiance.svg

For each wavelengh

$$I = I_o \cdot e^{-\sigma_{ext} \cdot L}$$



(air mass related with pathlenght L)



1. Photometry

$$I = I_o \cdot e^{-\sigma_{ext} \cdot L}$$

$$LnI = LnI_0 - \sigma_{ext} L$$

Langley plot calibration

(I_0 determination for each wavelength):

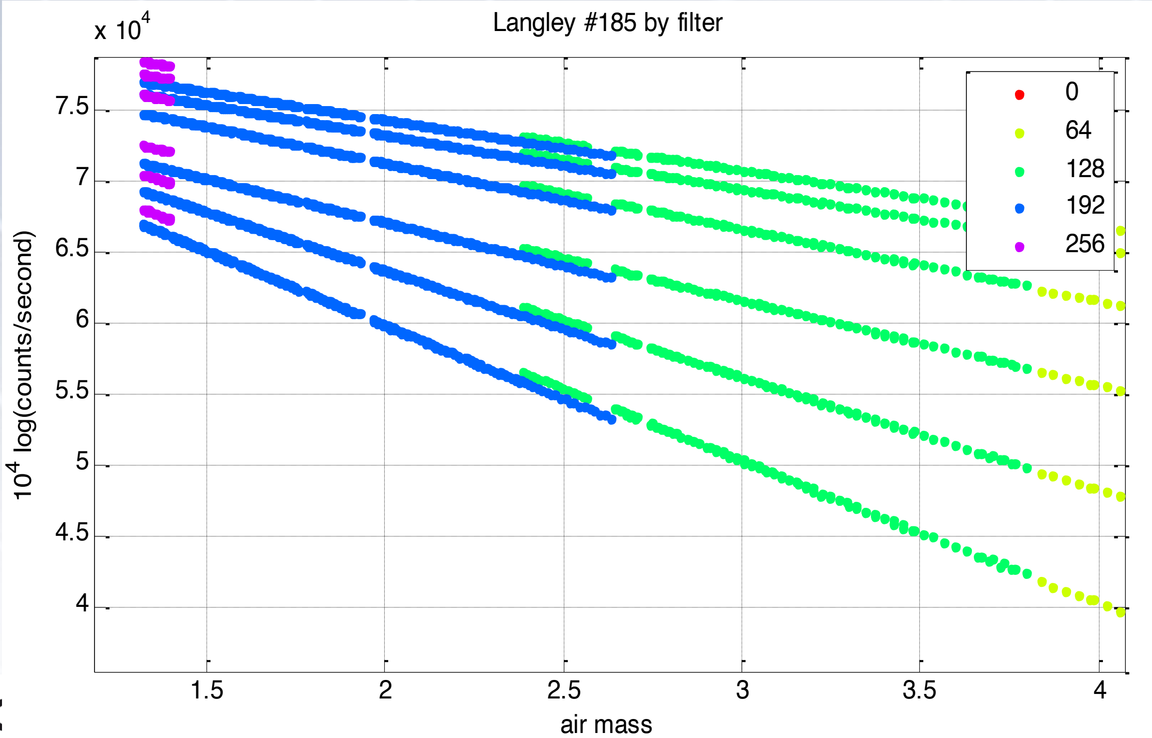
If σ_{ext} is constant during the observation

Pristine conditions (very low and constant aerosol load)

No clouds

Stable total ozone and column water vapor

<u>We can determine I_o</u>



(air mass related with pathlenght L)

1. Photometry: AERONET

AERONET Data Flows

Flux measurements

Direct - λ=340, 380, 440, 500, 670, 870, 940, 1020 nm

Diffuse - λ=440, 670, 870, 1020 nm (alm, pp, pol)

Calibration and processing information

Mauna-Loa and Izaña (masters)

CNRS-University of Lille and University of Valladolid (field)

Aerosol optical depth and precipitable water computations

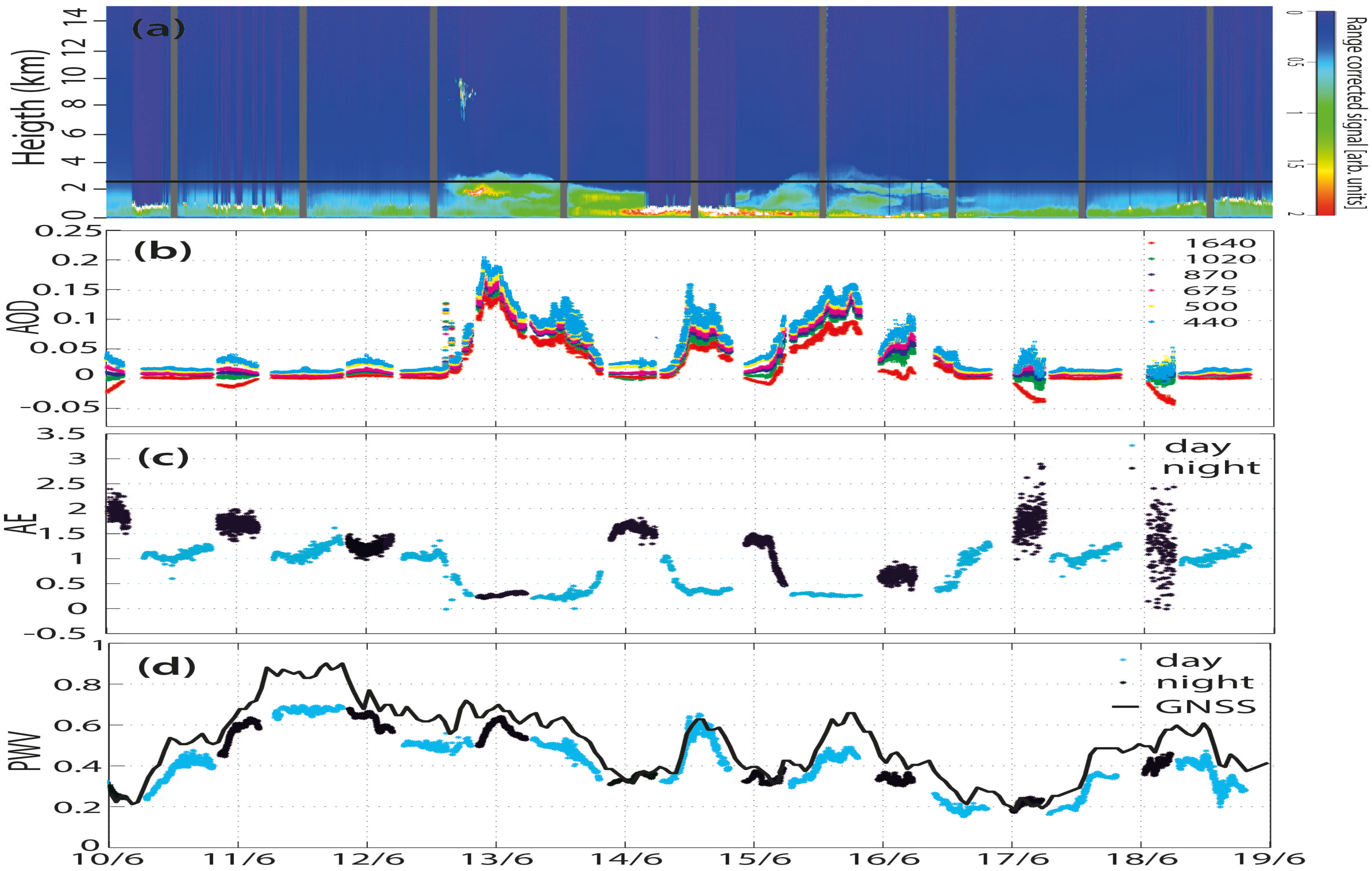
Cloud screening and quality control

Inversion products

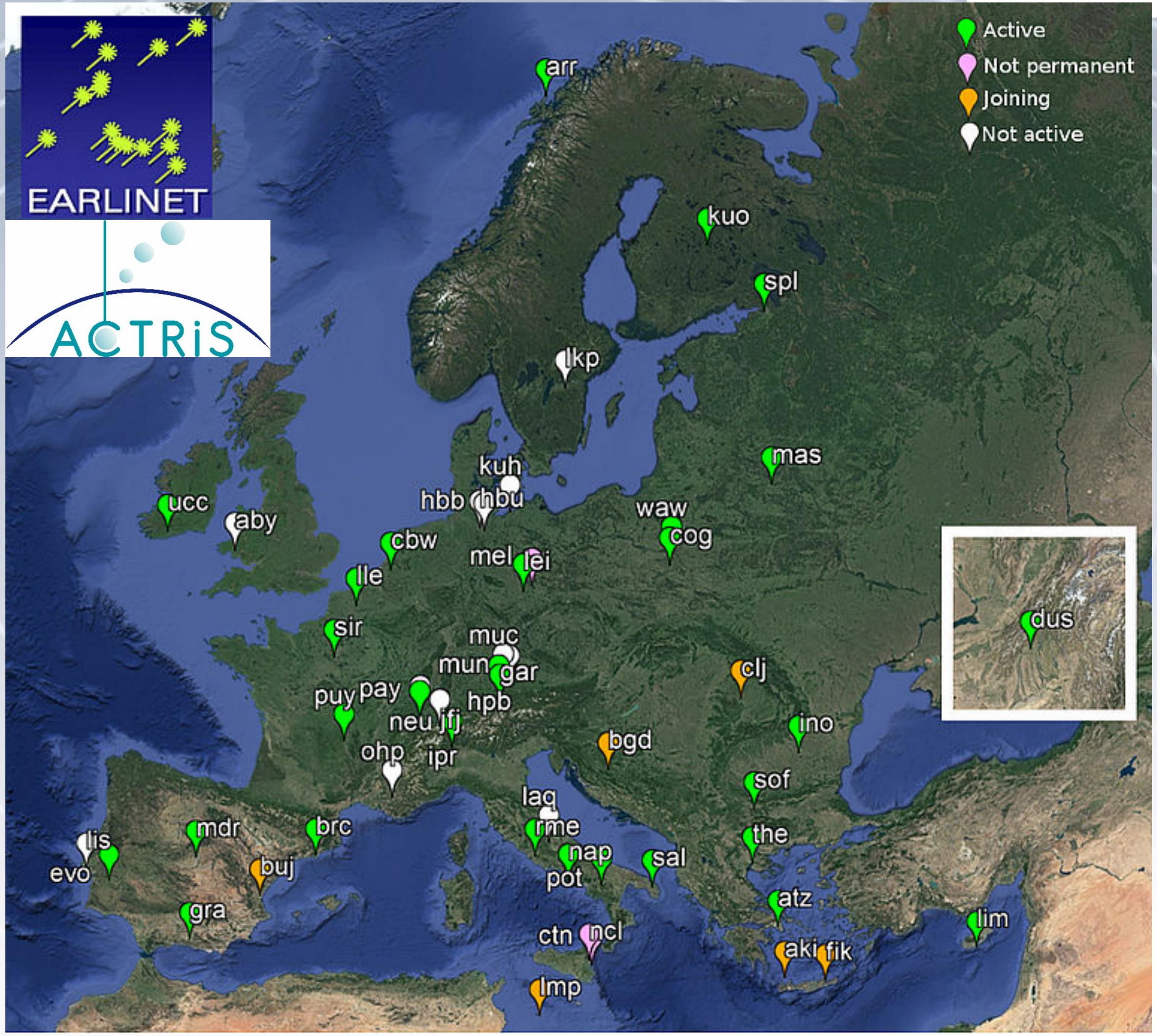
Volume size distribution (0.05 < size <15 μm), refractive index, single scattering albedo (λ=440, 670, 870, 1020 nm)

Ground base remote sensing

1. Photometry: 318-T (day & night)



2. Lidar



EARLINET (**European Aerosol Research LIdar NETwork**) is a network of advanced lidar stations distributed over Europe with the main goal to provide a comprehensive, quantitative, and statistically significant data base for the aerosol distribution on a continental scale.

EARLINET provides independent measurements of aerosol extinction and backscatter, and retrieval of aerosol microphysical properties.

Some of the EARLINET stations are equipped also with sunphotometers (they are part of AERONET)→ synergy.

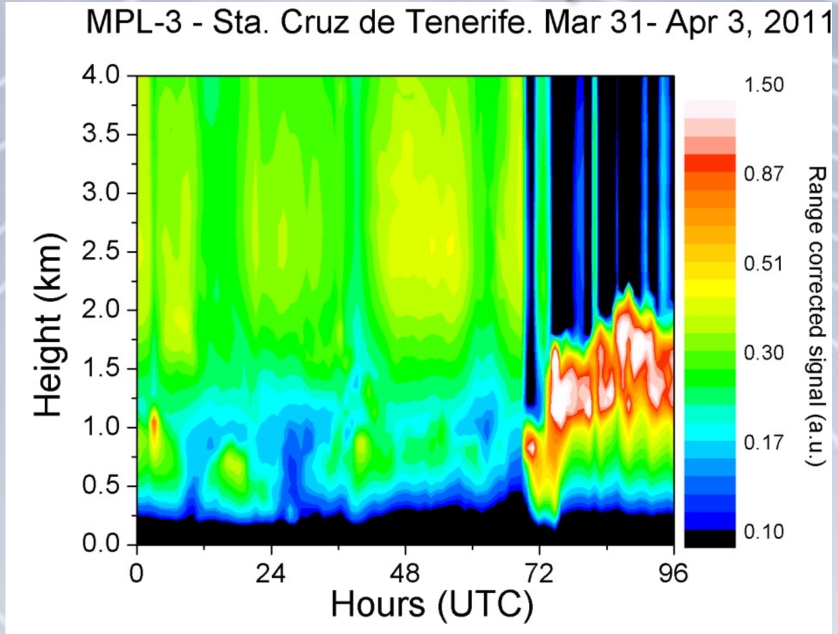
Raman lidars

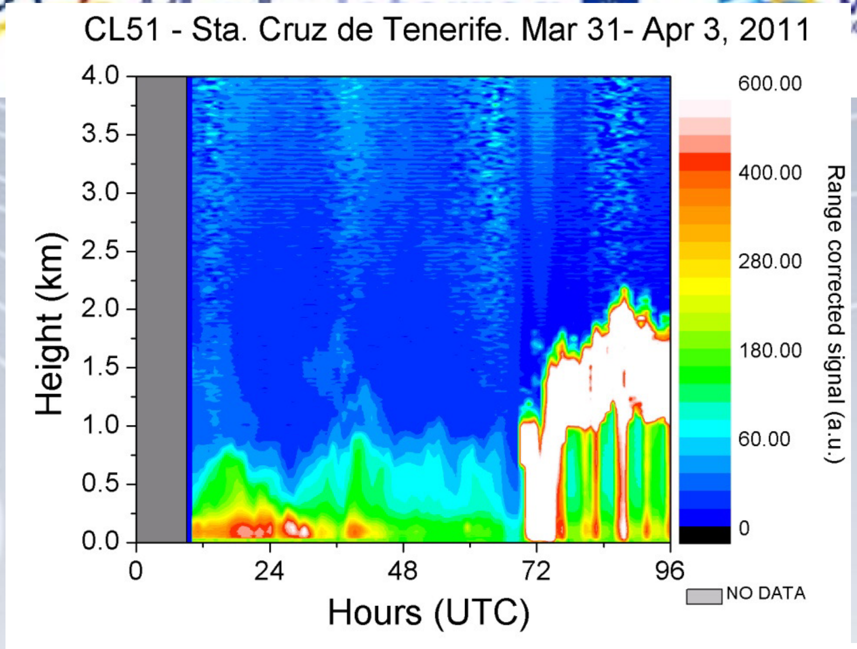
2. Lidar

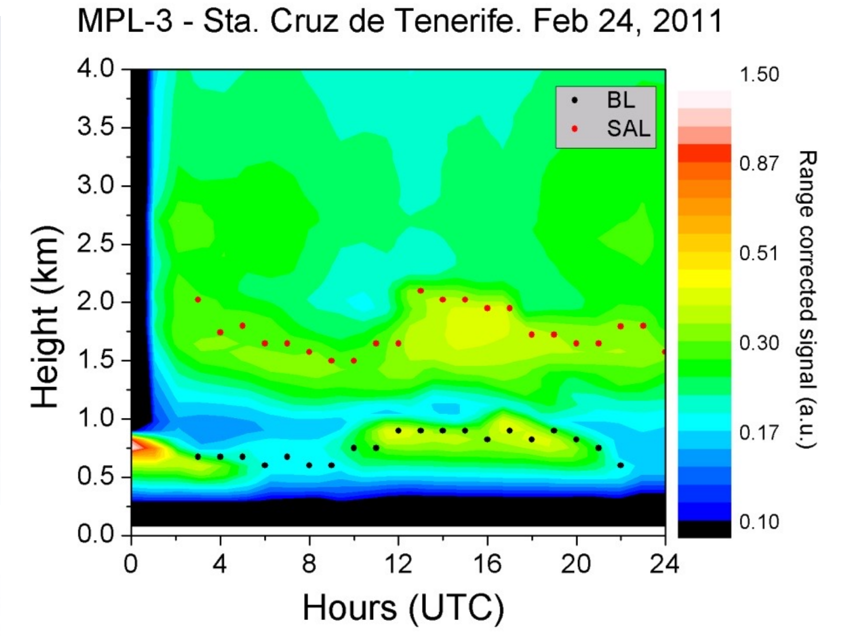
MPLNet: MicroPulse Lidar Network

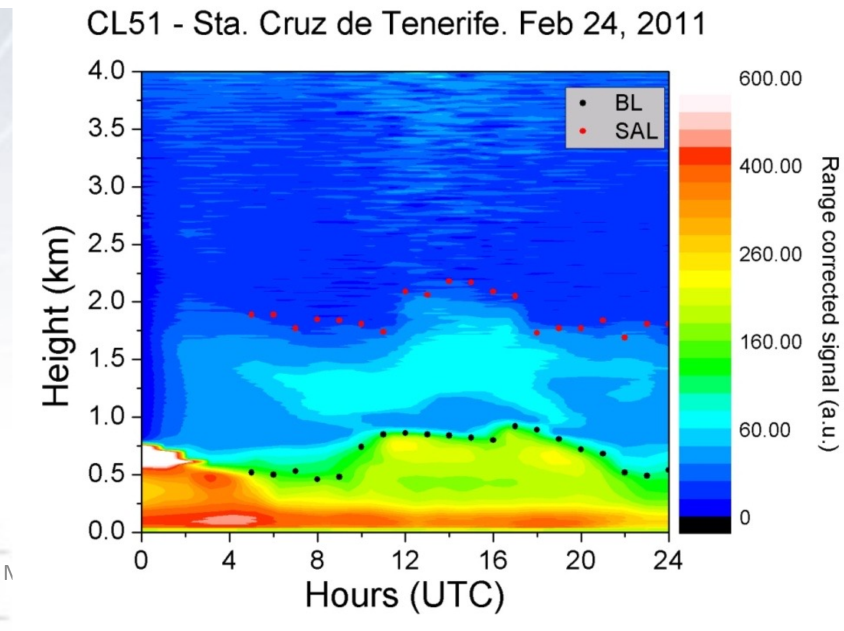
523 nm MPLNET (elastic lidars)
Automatized since July 2005

2. Lidar: Ceilometers - Exemple



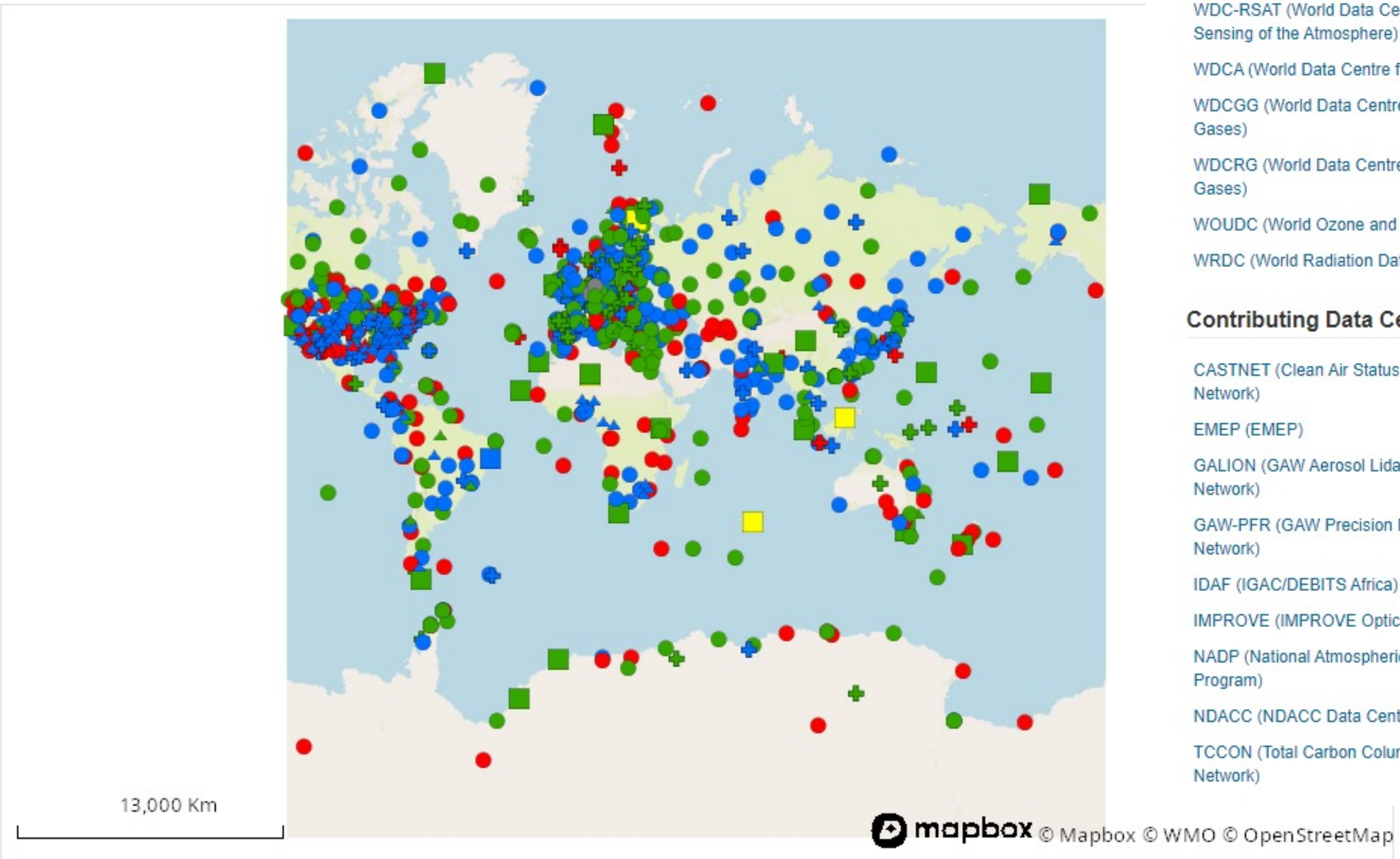






Summary

https://gawsis.meteoswiss.ch/GAWSIS/#/



Global
Regional
Contributing networks
Local
Other networks

Operational
Partly operational
Non-reporting
Closed
Planned
Pre-operational
Stand-by

World Meteorological Organization
Weather · Climate · Water

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Home Affairs FDHA
Federal Office of Meteorology and Climatology MeteoSwiss

GAW World Data Centres

- WDC-RSAT (World Data Center for Remote Sensing of the Atmosphere)
- WDCA (World Data Centre for Aerosols)
- WDCGG (World Data Centre for Greenhouse Gases)
- WDCRG (World Data Centre for Reactive Gases)
- WOUDC (World Ozone and UV Data Centre)
- WRDC (World Radiation Data Centre)

Contributing Data Centres

- CASTNET (Clean Air Status and Trends Network)
- EMEP (EMEP)
- GALION (GAW Aerosol Lidar Observation Network)
- GAW-PFR (GAW Precision Filter Radiometer Network)
- IDAF (IGAC/DEBITS Africa)
- IMPROVE (IMPROVE Optical Aerosol)
- NADP (National Atmospheric Deposition Program)
- NDACC (NDACC Data Center)
- TCCON (Total Carbon Column Observing Network)

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