2ND TRAINING COURSE ON WMO SDS-WAS

(SATELLITE AND GROUND OBSERVATION AND MODELLING OF ATMOSPHERIC DUST)

21-25 November 2011, Antalya

Ground observation of mineral dust

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TC Orman ve Su İşleri Bakanlığı

METEOROLOJİ

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BSC

Index

- Aerosols and dust background
- In-situ dust monitoring (PM)
- In-situ dust estimations (Visibility)
- Ground based remote sensing
- Summary


Chad-2004 by Jahi-Chikwendiu
World Press Prize 2004

Aerosols: suspended fine solid or liquid particles in a gas

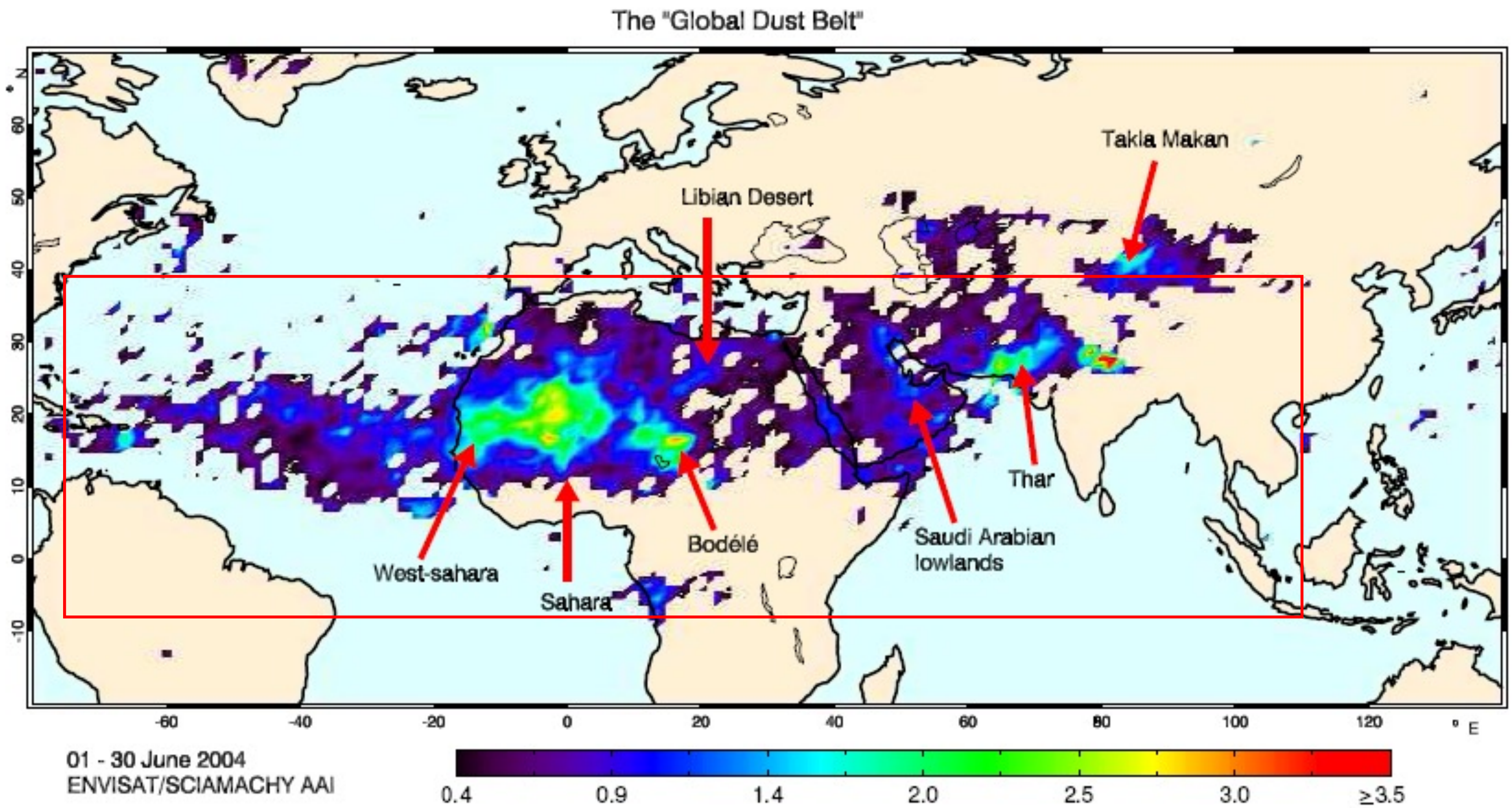
- Size range of particles in the atmosphere, 0.001 to 100 µm (1 µm= 10^{-6} m)

Mineral dust: Coarse aerosols

- One of the main natural sources of atmospheric aerosol particles and has been observed in the most remote regions in the world (Prospero, 1999).

Mineral dust is one of the most important tropospheric aerosols on the global scale

The global distribution is very heterogeneous



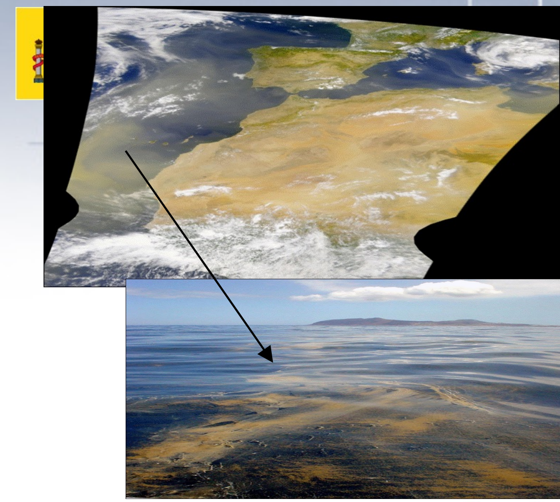
Sahara, Sahel, Arabian Peninsula, Thar desert (Middle East), Aral Sea (Central Asia), Taklamakan desert (China), Gobi Desert (China/Mongolia), Lake Eyre Basin (Australia)

(de Graaf, 2006)

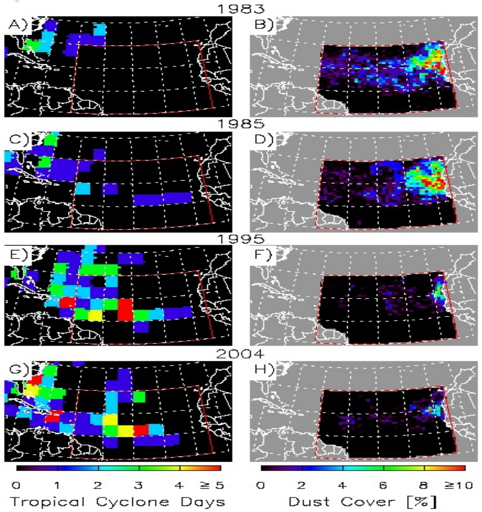
Background

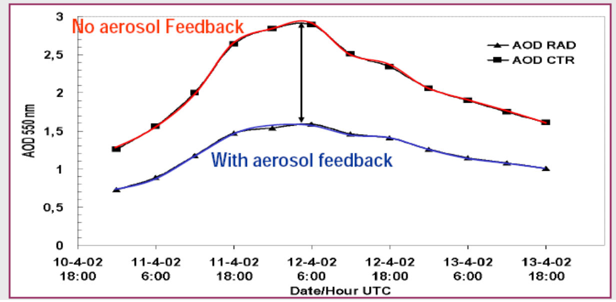
Human Health (Asthma, infections, Meningitis in Africa, Valley Fever in the America's)

Agriculture (negative & positive impacts)



Marine productivity (negative & positive impacts)



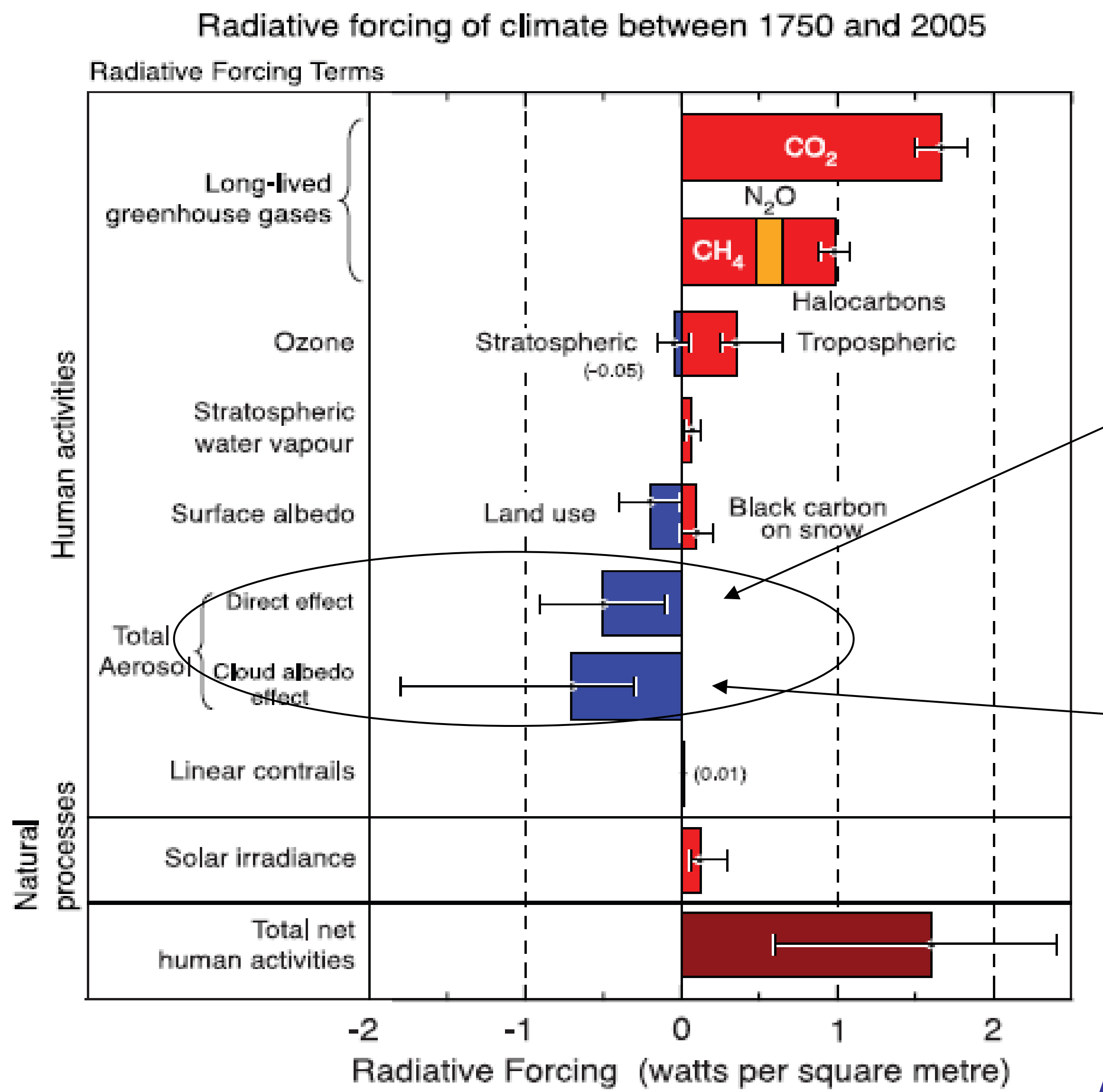


Improved Weather and Seasonal Climate prediction

Industry (Semi-conductor, etc.)

Energy (Thermal solar energy)

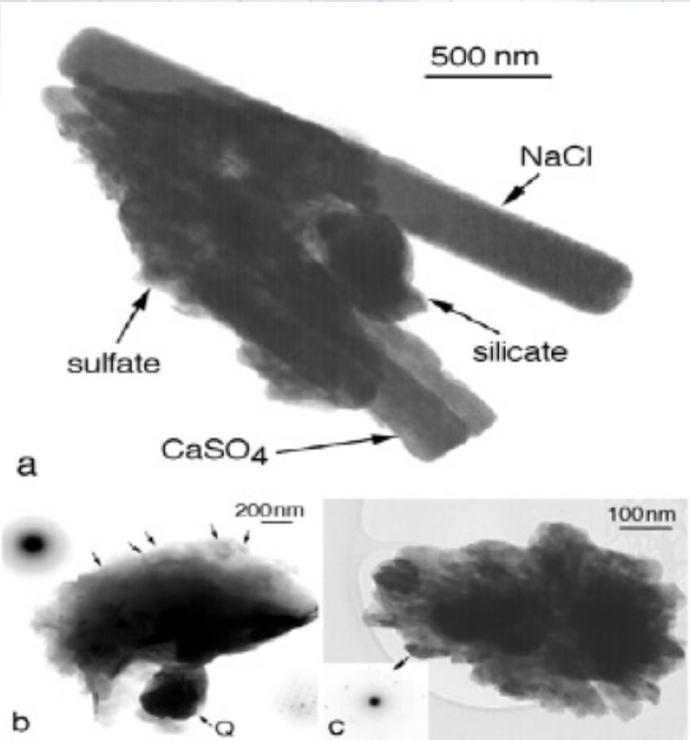
Aviation (air disasters)
Ground Transportation



- The total direct aerosol RF as derived from models and observations is estimated to be -0.5 [±0.4] W m^{-2}, with a ***medium-low*** level of scientific understanding.

- The RF due to the cloud albedo effect (also referred to as first indirect), in the context of liquid water clouds, is estimated to be -0.7 [-1.1, +0.4] W m^{-2}, with a ***low*** level of scientific understanding.

IPCC's Fourth Assessment Report (2007)

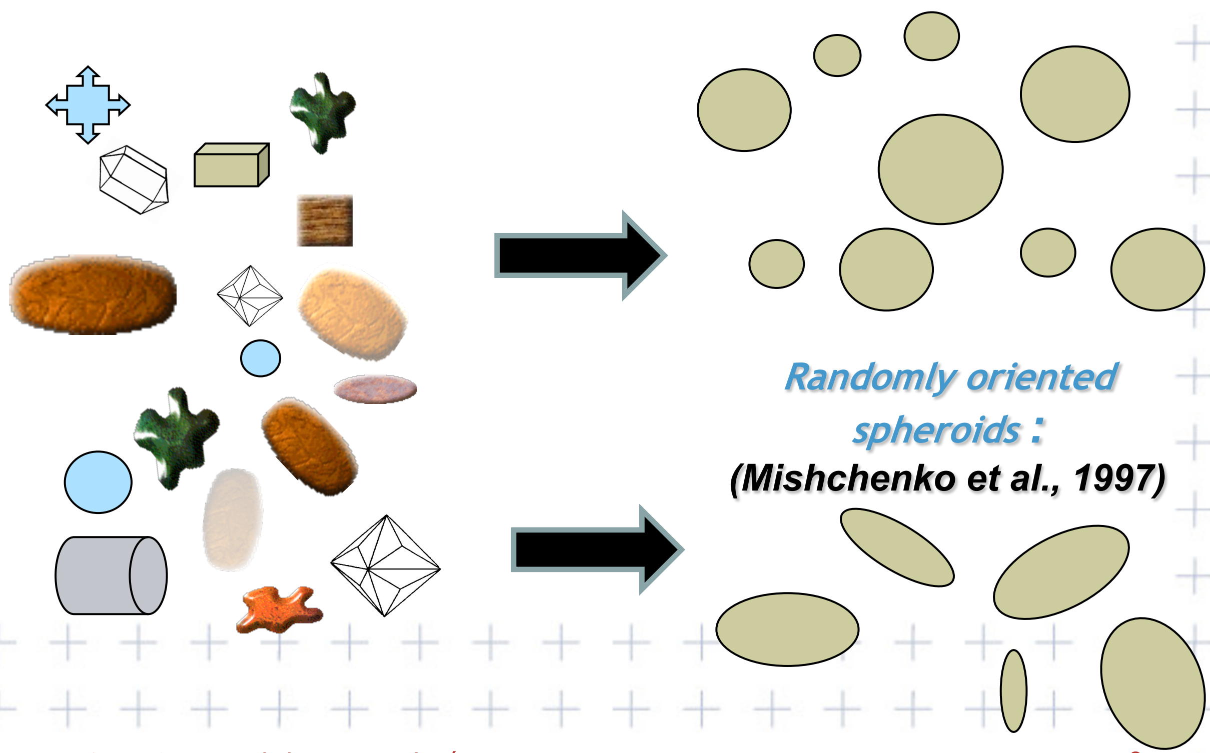


Busek and Posfai, 1996

Dust Particle Images

aerodynamic diameter, measured in microns or micrometers (µm), a unit equal to one millionth of a meter.

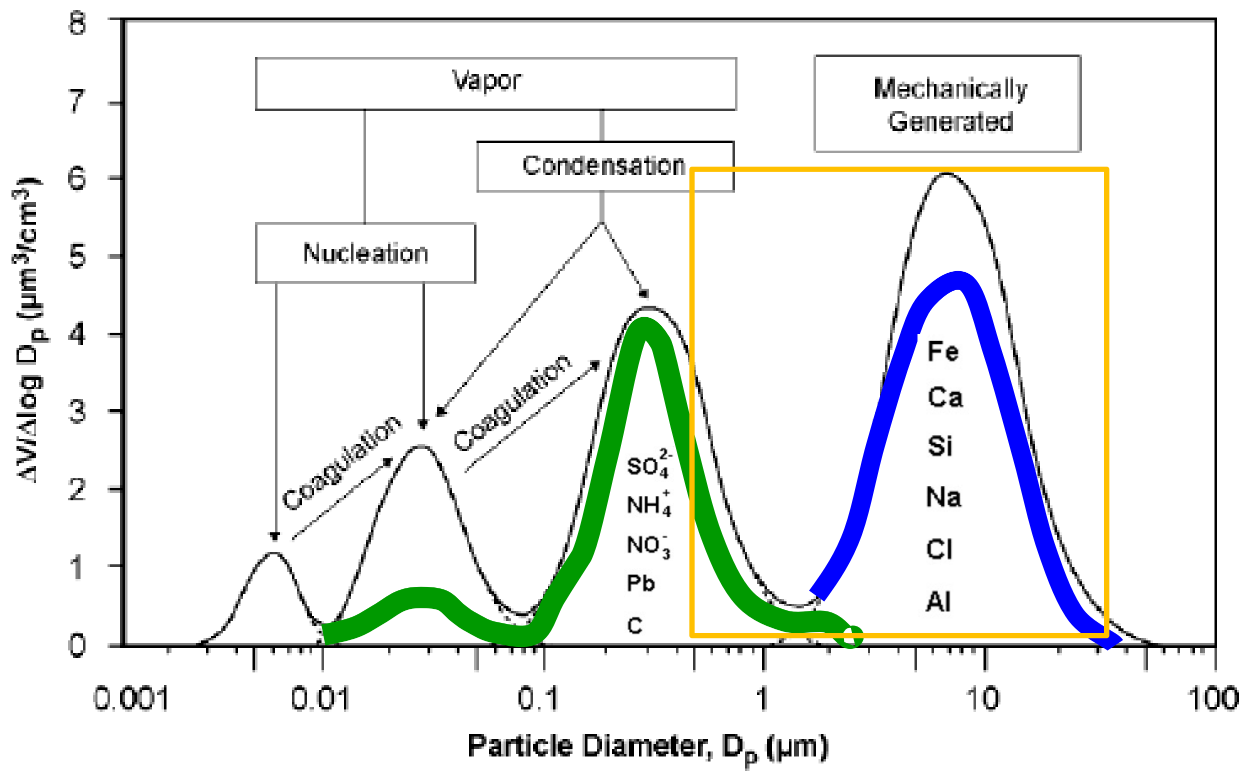
spherical:



PM10 (diameter <10 microm)

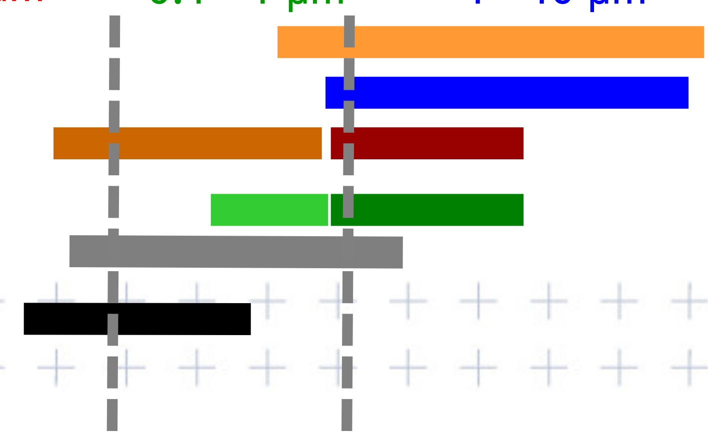
$PM_{2.5}$

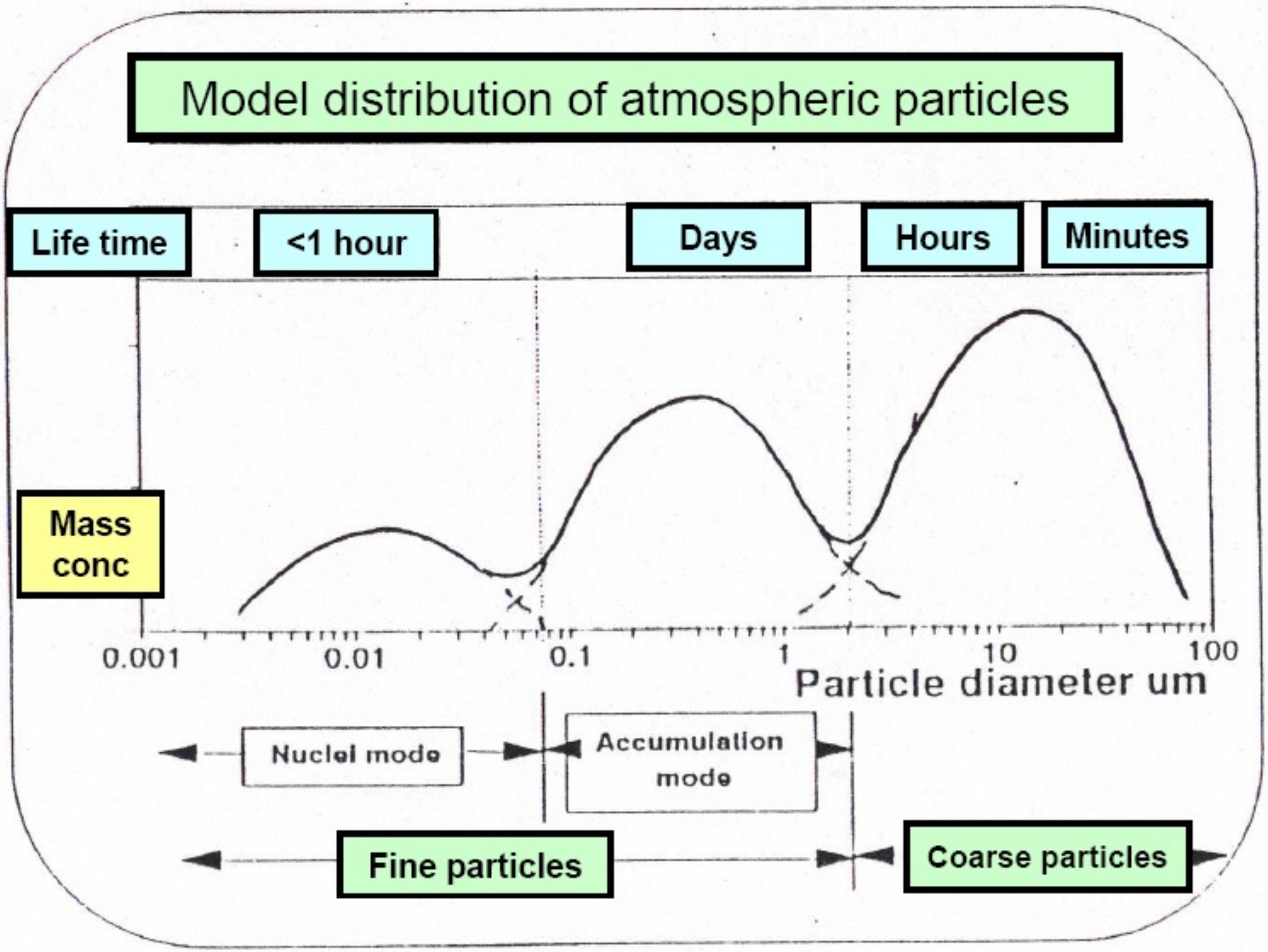
$PM_{2.5-10}$



ultrafine <0.1 µm | accumulation 0.1 – 1 µm | Coarse 1 - 10 µm

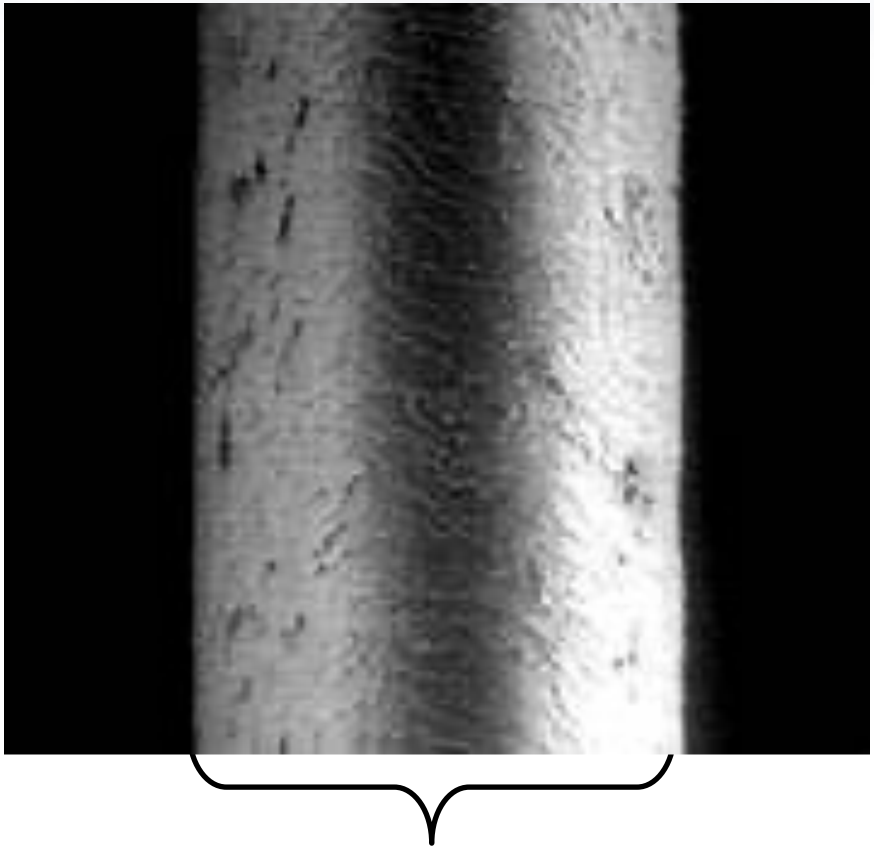
Mineral dust :
Marine salt:
Sulfate:
Nitrate:
Organic aerosol:
black carbon:





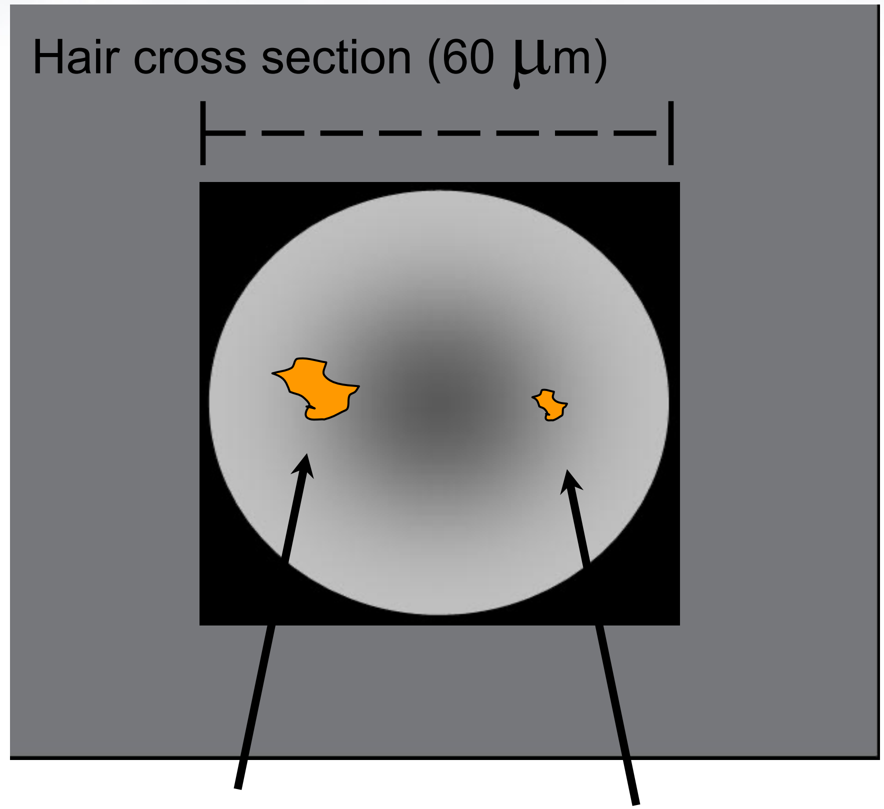
Particles in the Atmosphere: atmospheric residence time Model

Background



Human Hair

(60 µm diameter)

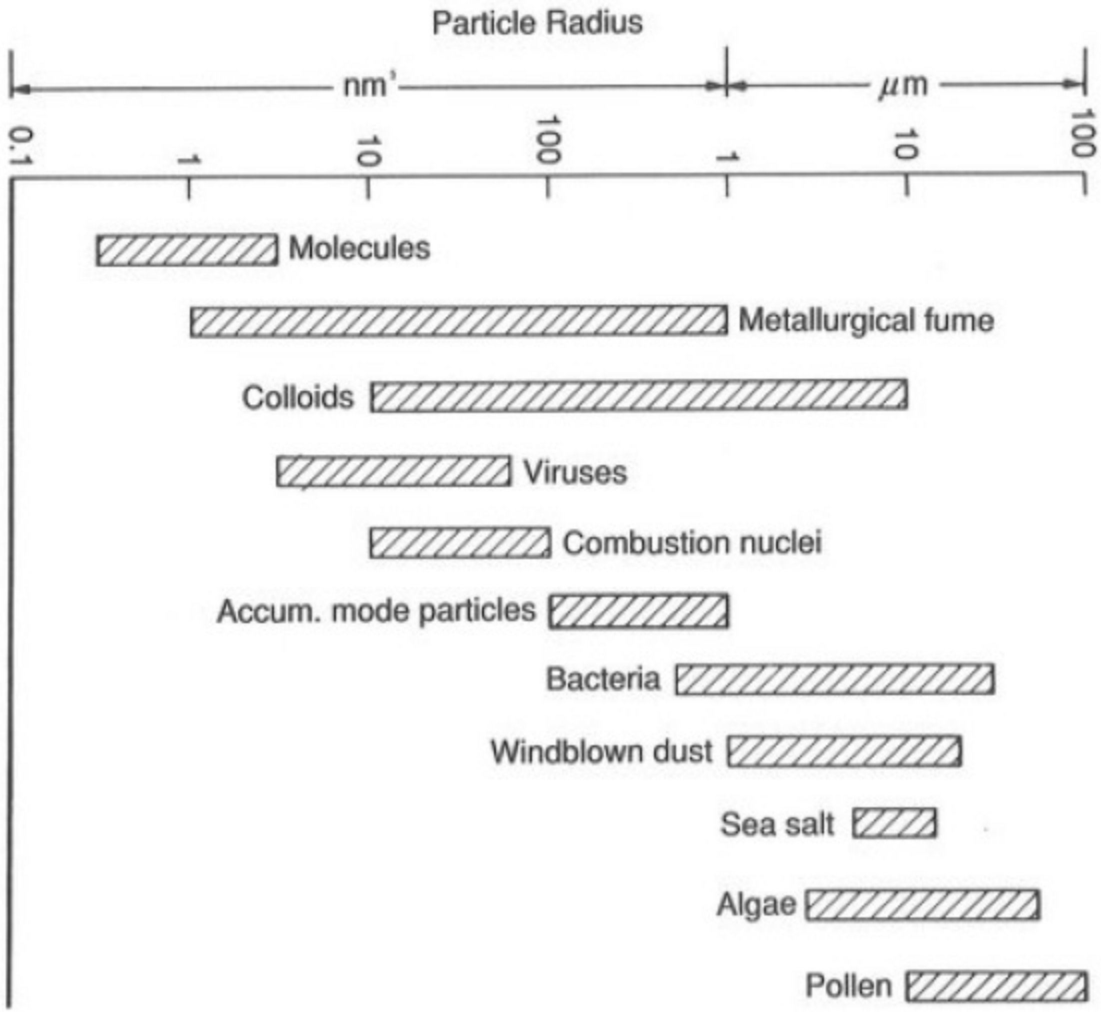


PM_{10}

(10 µm)

$PM_{2.5}$

(2.5 µm)



Size of different atmospheric aerosols, from (Graedel and Crutzen, 1994)

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Conventionally **dust refers to soil particles <0.6 mm (600 um)**

but...

only those particles below 0.1mm (100 µm) can be transported by suspension

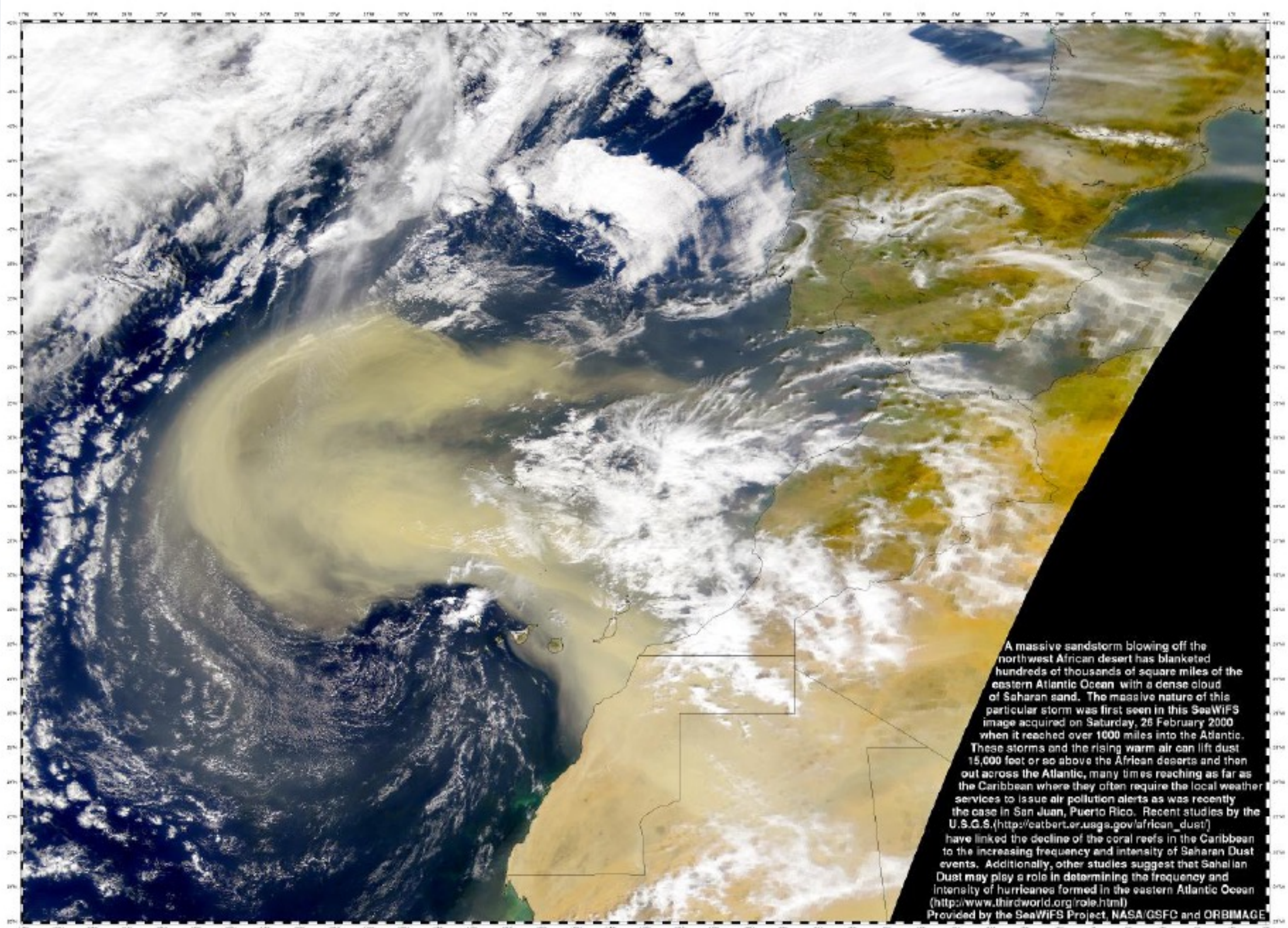
Dust particles move in one of three modes of transport depending on particle size, shape and density of the particle:

- The **suspension** mode includes dust particles < 0.1 mm (100um) in diameter. The fine particles may be transported at high altitudes (6-8 km) and over distances of thousand kilometers.

- The **saltating** particles [i.e. 0.01 (10um)<diameter<0.5 mm (500um)] leave the surface, but are too large to be suspended.

- The remaining particles (>0.5 mm) (500um) are transported in the **creep** mode. These roll along by the wind impacting particles upon the land surface, favoring the movement of other particles.

Background

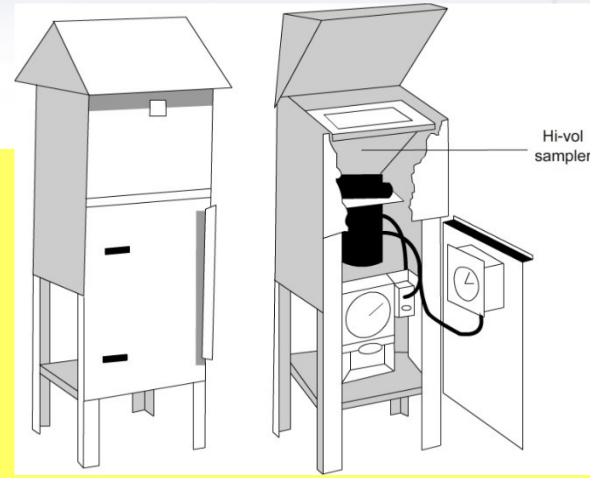

A massive sandstorm blowing off the northwest African desert has blanketed hundreds of thousands of square miles of the eastern Atlantic Ocean with a dense cloud of Saharan sand. The massive nature of this particular storm was first seen in this SeaWiFS image acquired on Saturday, 26 February 2000 when it reached over 1000 miles into the Atlantic. These storms and the rising warm air can lift dust 15,000 feet or so above the African deserts and then out across the Atlantic, many times reaching as far as the Caribbean where they often require the local weather services to issue air pollution alerts as was recently the case in San Juan, Puerto Rico. Recent studies by the U.S.G.S.(http://catbert.er.usgs.gov/african_dust/) have linked the decline of the coral reefs in the Caribbean to the increasing frequency and intensity of Saharan Dust events. Additionally, other studies suggest that Sahelian Dust may play a role in determining the frequency and intensity of hurricanes formed in the eastern Atlantic Ocean (http://www.thirdworld.org/role.html)
Provided by the SeaWiFS Project, NASA/GSFC and ORBIMAGE

In-situ measurements (PM)

PM_{10} and $PM_{2.5}$ measurements in air quality networks

1. Reference method: gravimetric method

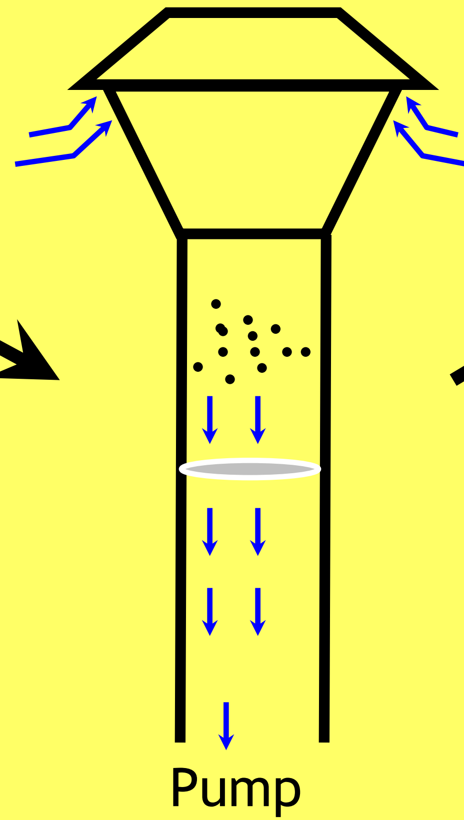
$$PM = \frac{(W2-W1)}{Volume} \ \mu g/m^3$$



Blank filter

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

- Filter weight (W1)



Sampled filter

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

- Filter weight (W2)

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Common Gravimetric Ambient Aerosol Sampling Techniques

- High volume methods: TSP, PM_{10}, $PM_{2.5}$, Air Toxics Sampler (Ultrafine particles -UFP-)
- Low volume methods: (PM_{10}, $PM_{2.5}$, PM_{Coarse})

Micro-Balance room

- Filters conditioning 48-h, HR=50±5 % and T=20±1ºC
- balance, LVS resolution >= 5 digits (0.00001g)
- balance, HVS resolution >= 6 digits (0.000001g)

This sample filter is equilibrated at some set of thermodynamic conditions for a period of time before and after sampling. Through the use of a laboratory gravimetric balance, the difference in pre- and post-sample weights yields the PM mass collected. Knowing the volume of air passed through the filter allows the determination of the PM mass concentration.

In-situ measurements (PM)

PM_{10} and $PM_{2.5}$ measurements in air quality networks

1. Reference method: gravimetric method

LVS: 2.3 m^3/h

Low Volume Sampler

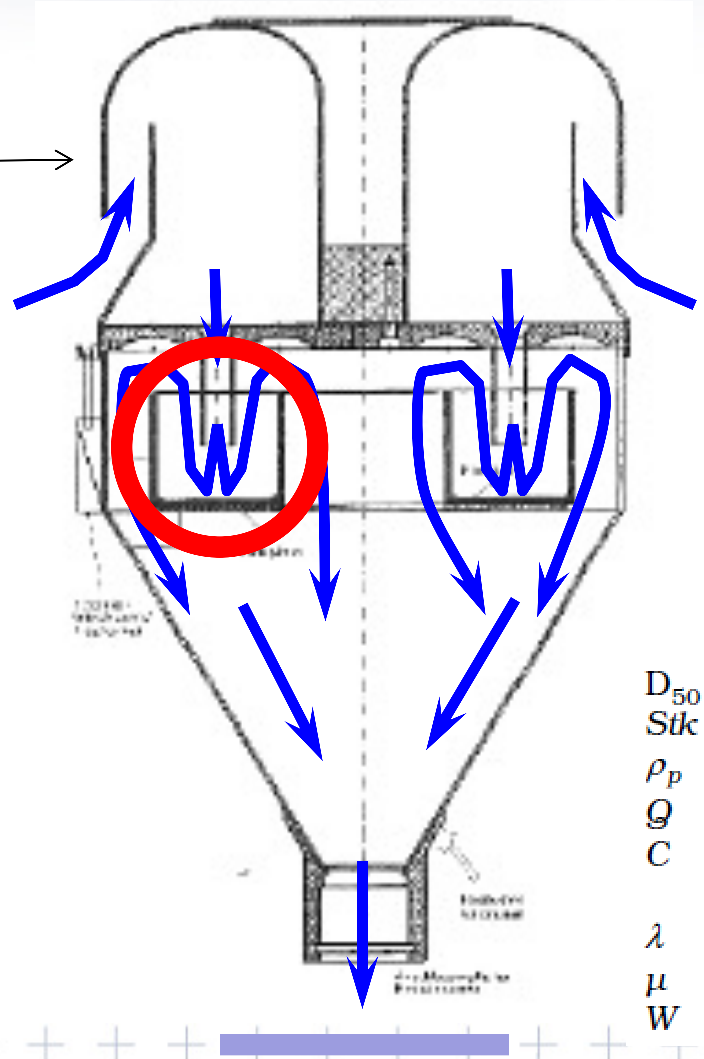
HVS: 68 m^3/h

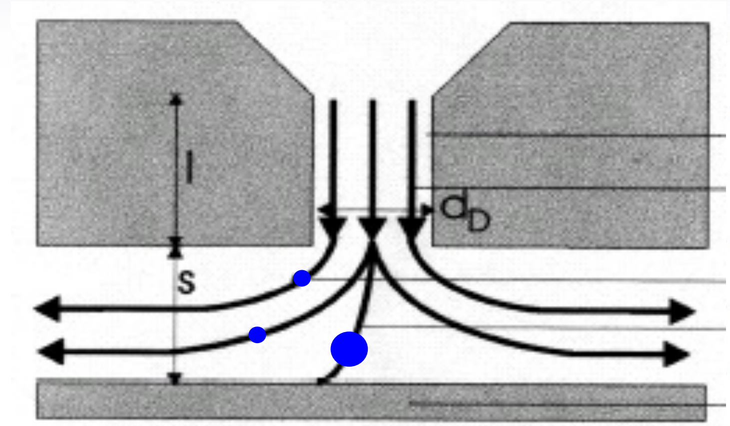
High Volume Sampler

WRAC: 1966 m^3/h

Wide Range Aerosol Classifier

In-situ measurements (PM)





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

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.

In-situ measurements (PM)

Complete PM gravimetric method set-up at Izana Atmopsheric Research Center

Weight filters conditioned room

PM_{10}

$PM_{2.5}$

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Common Gravimetric Ambient Aerosol Sampling Techniques

- Advantages: Recognized reference method, low capital cost
- Disadvantages: Limited time resolution (typically 24-hr), long turnaround times, labor intensive, and gravimetric lab maintenance/cost

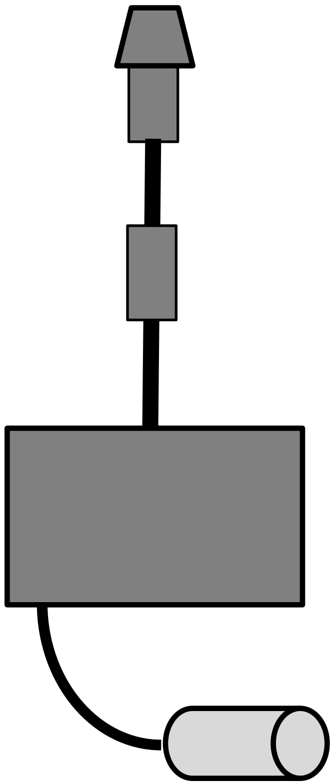
Common Continuous Ambient Aerosol Sampling Techniques

$$(Dm / Dt) / (DV / Dt) = mg/m^3$$

- Tapered Element Oscillating Microbalance
- Beta (Electron) Attenuation
- Light Scattering, Absorption, and Extinction

PM_{10} and $PM_{2.5}$ measurements in air quality networks

2. Automated analyzers



1. Impactor PM_{10} / $PM_{2.5}$
2. RH reductor / heater
3. Sensor (Beta radiation attenuation or Tapered Oscillating microbalance-TEOM-) → instead of weighting filters
4. Pump / Flow meter

Continuous measurements om PM (PM10, PM2.5, PM1 or TSP)

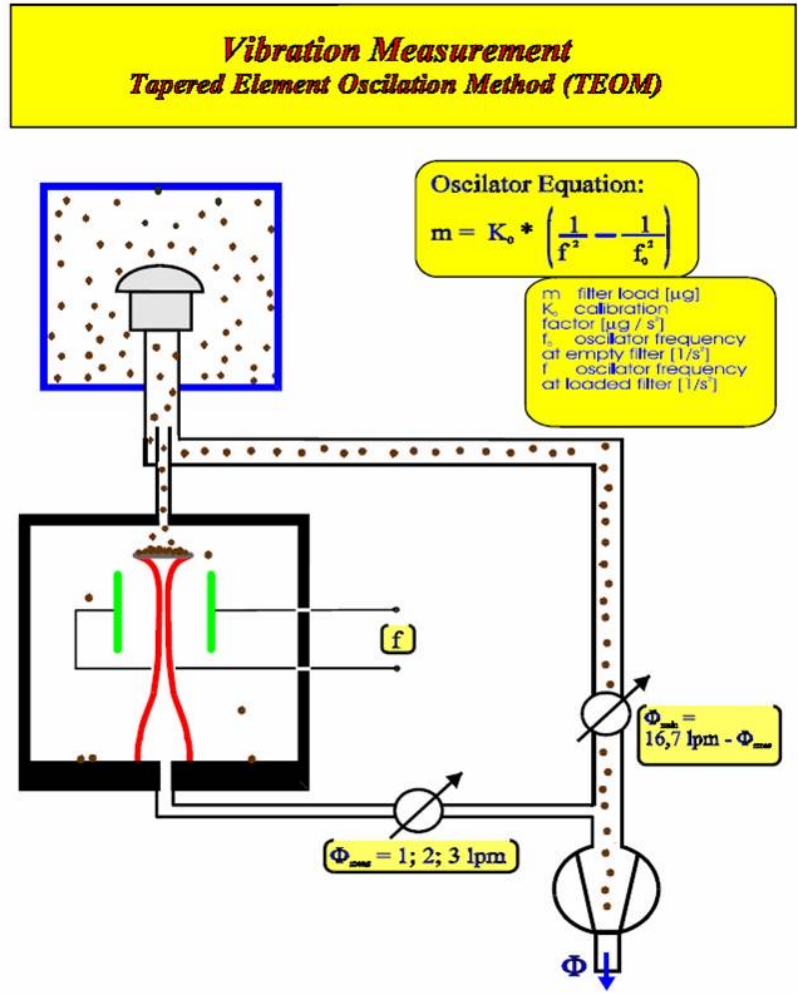
PM with Tapered Oscillating microbalance-TEOM- (1)

The system can be considered a simple harmonic oscillator through which the following equation can be derived:

$$\Delta m = K_0 \, (1/f_f^2 - 1/f_i^2)$$

Where:
fi = initial oscillation frequency of the system;
ff = oscillation frequency after the addition of mass;
K0 = calibration (spring) constant of the initial condition.

TEOM mass detectors or microbalances utilize an inertial mass weighting principle.



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PM with Tapered Oscillating microbalance-TEOM- (2)

Advantages

- Continuous method
- Highly time resolved
- High resolution
- instantaneous turnaround

Disadvantages

- Temperature dependency:
  - Volatile losses
  - Seasonal and regional dependencies
- Affected by vibration
- Manual filter changes necessary
- Complex systems require some skill
- X2 or X3 capita cost
- External calibration against reference method

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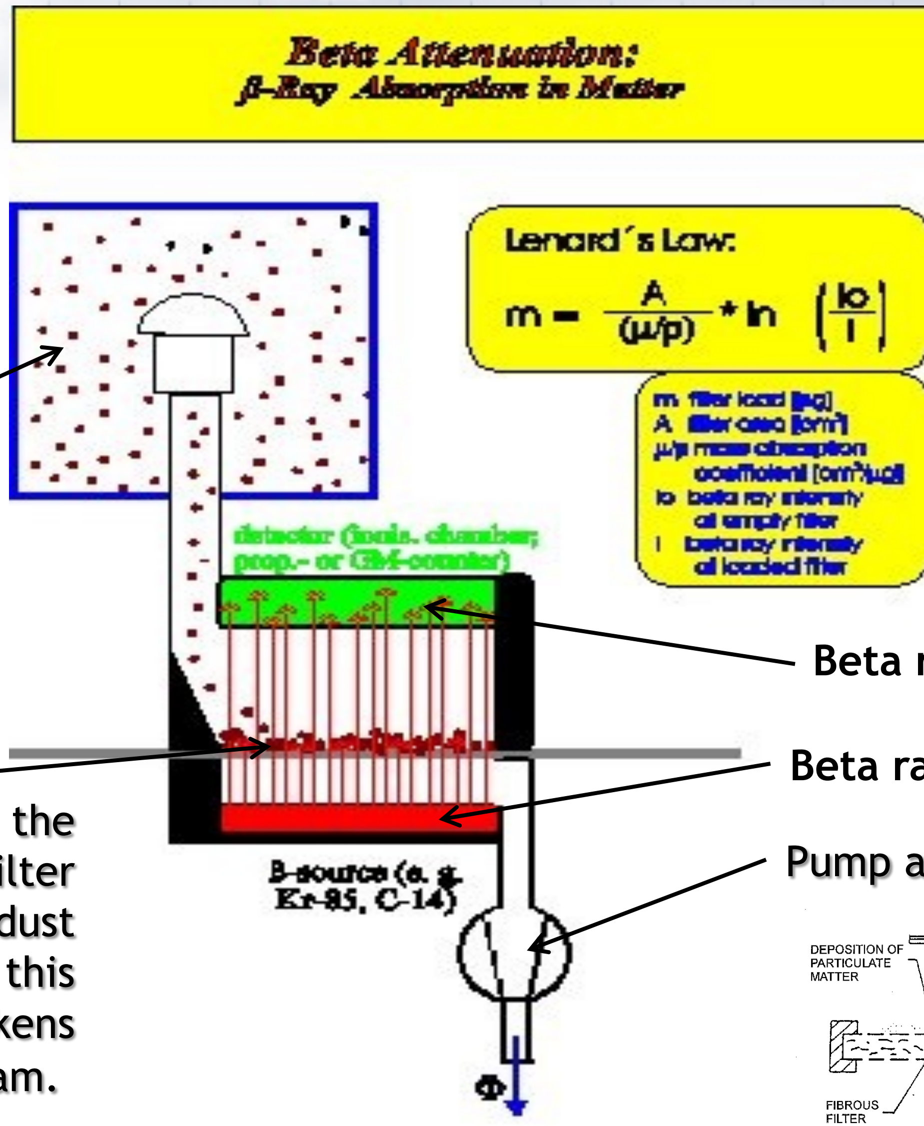
PM with Beta atenuation (1)

Beta rays are radiation emitted by electrons during the nuclear decay of radioactive elements. Elements such as Krypton-85 or Carbon-14 may be used.

Ambient air is sucked through the sample system



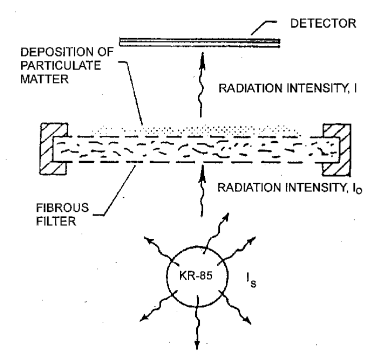
The absorption of beta rays through the filter and the deposited Particulate matter is described by the Lenard's law

Beta rays detector

Beta rays source (Kr-85)

Pump and flowmeter

Dust particles contained in the air are deposited on the filter continuously. The layer of dust is building up and this increasing dust mass weakens the intensity of the beta beam.



PM with Beta atenuation (2)

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

- **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:

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

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

Common Continuous Ambient Aerosol Sampling Techniques

$$(Dm / Dt) / (DV / Dt) = mg/m^3$$

Advantages

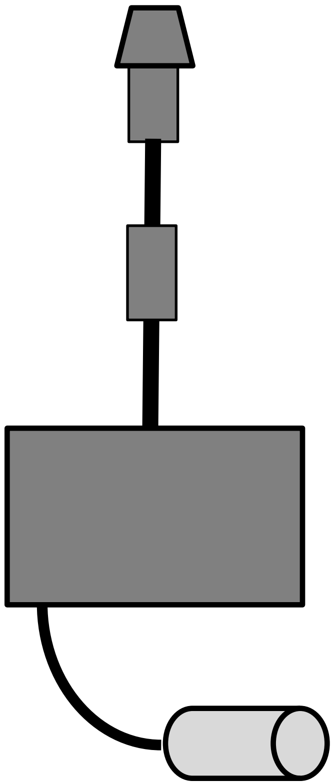
- Continuous method
- Highly time resolved
- High resolution
- instantaneous turnaround
- Low operational cost

Disadvantages

- Temperature dependency:
  - Volatile losses
  - Seasonal and regional dependencies
- Affected by vibration
- Manual filter changes necessary
- Complex systems require some skill
- X2 or X3 capita cost
- External calibration against reference method

PM_{10} and $PM_{2.5}$ measurements in air quality networks

2. Automated analyzers



beta

TEOM

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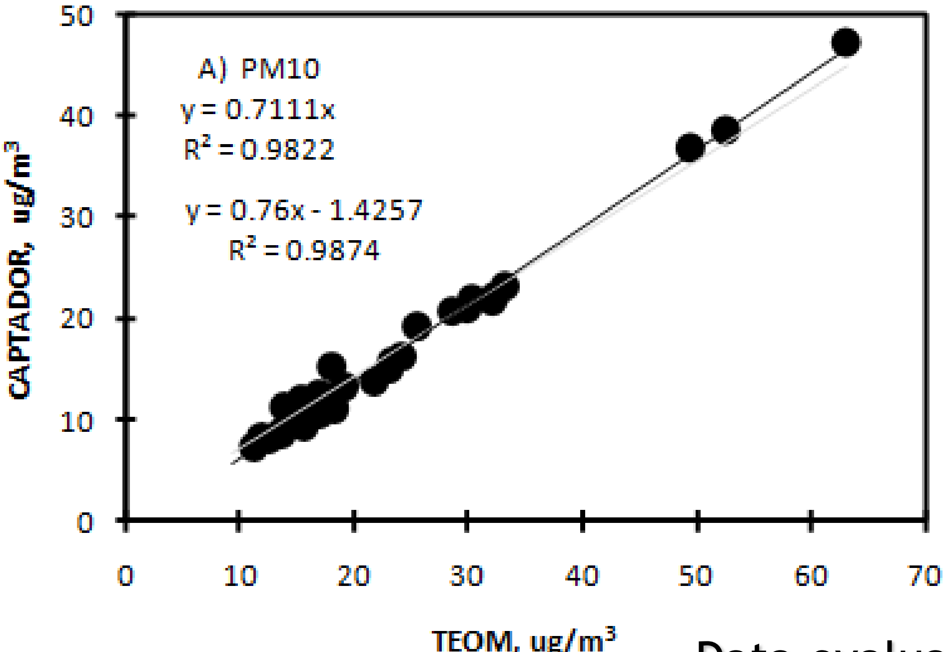
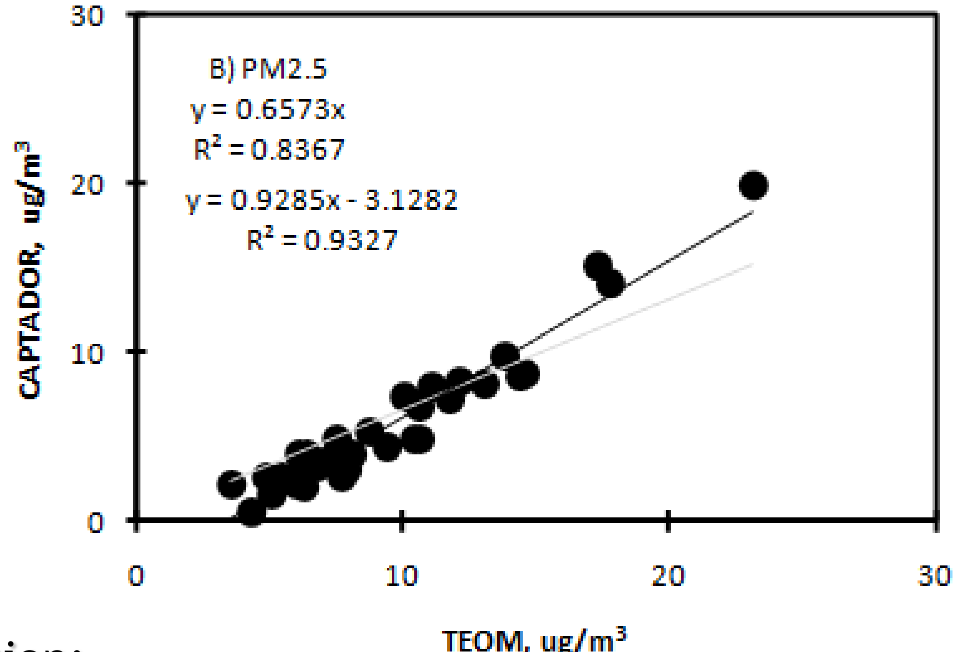
PM_{10} and $PM_{2.5}$ measurements in air quality networks

Intercomparisons





<u>Data evaluation:</u>

Data from continuous analyzer are valid if they fit A or B:

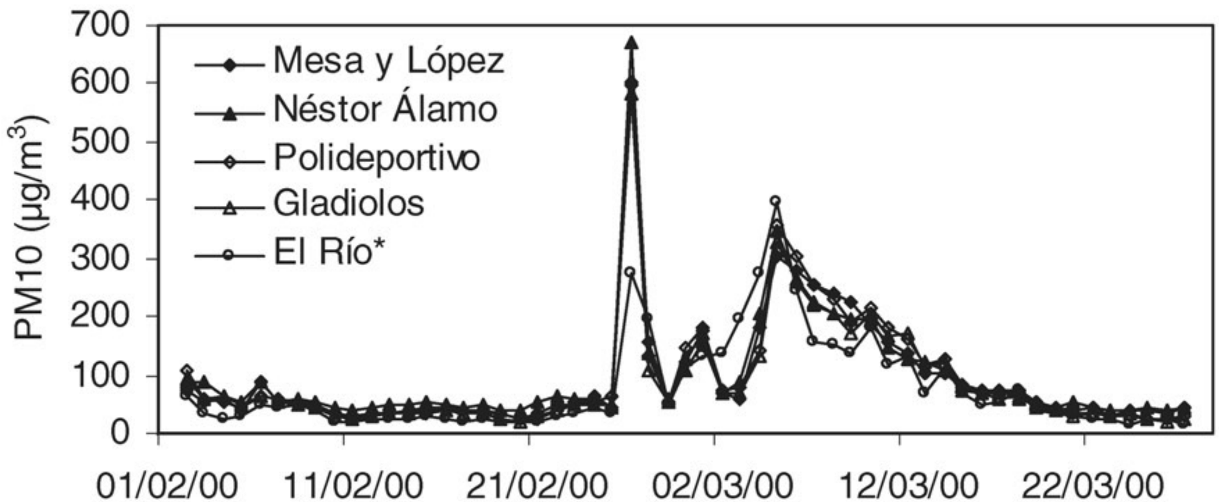
A) $Y=a\cdot X$; $r^2 \geq 0.8$

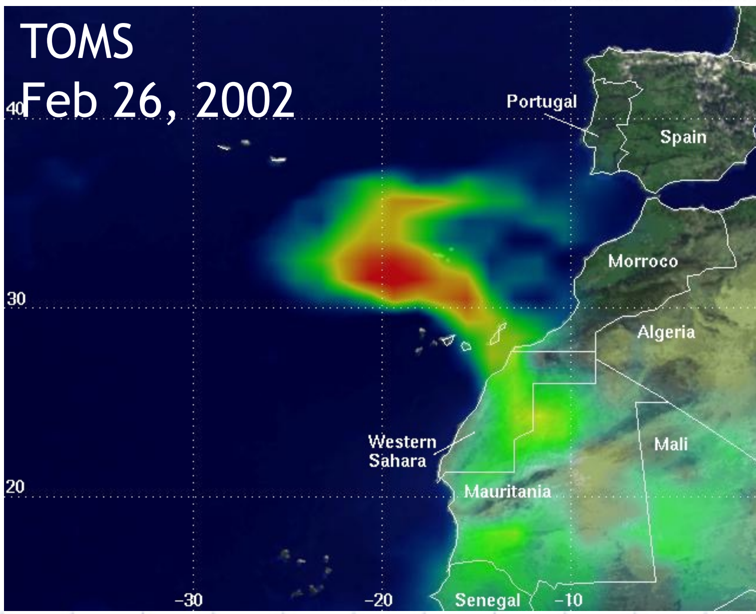
B) $Y=a\cdot X + b$; $r^2 \geq 0.8$; $abs(b)<5$

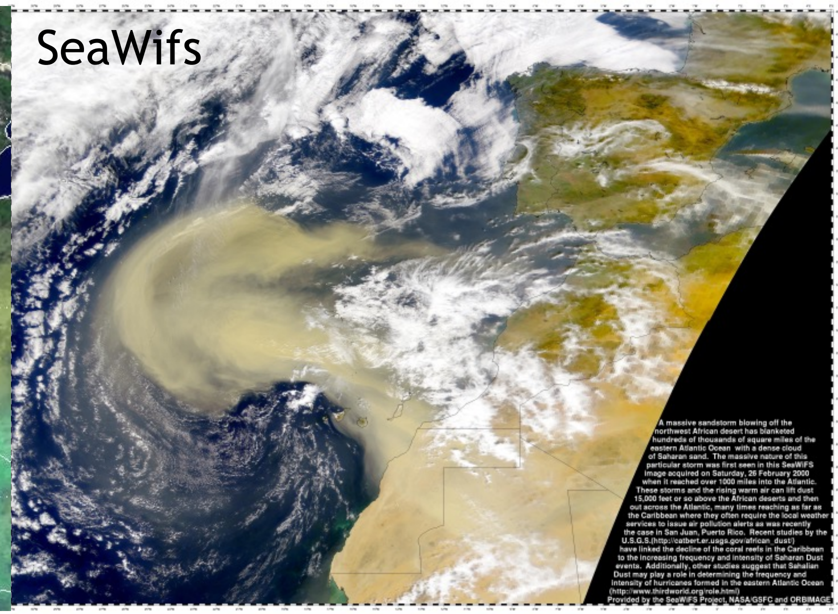
Y= Reference Method (gravimetric method),
X= Automatic analyzer

In-situ measurements (PM)

Air quality stations at Tenerife Island







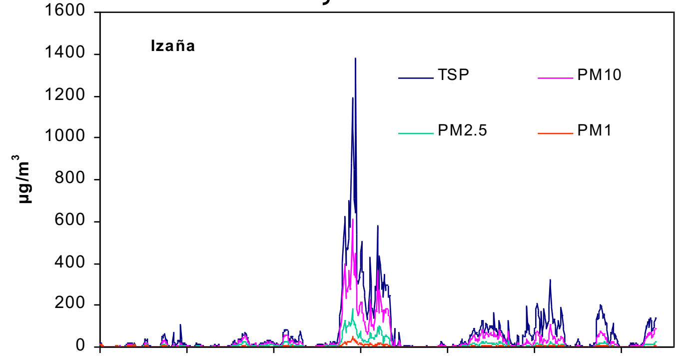
Viana et al., Atmospheric Environment , 2002

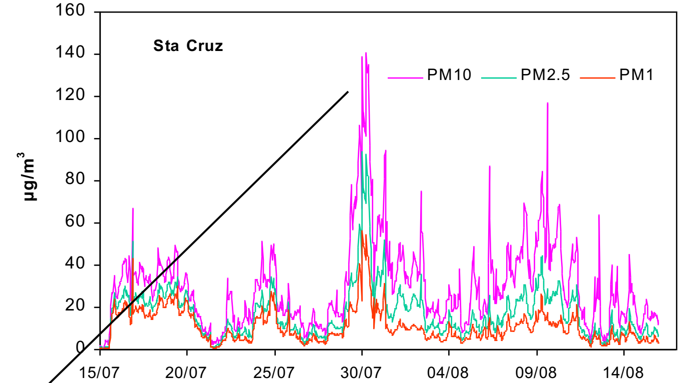
In-situ measurements (PM)

Chemical characterisation of TSP and PM2.5 at Izaña and Sta. Cruz during the MINATROC field campaign (July, 2002)

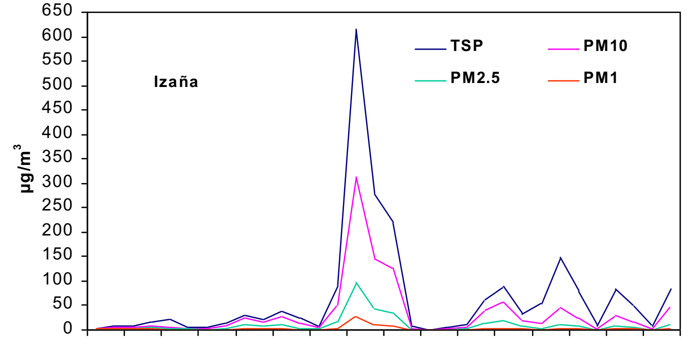
Alastuey et al., 2003

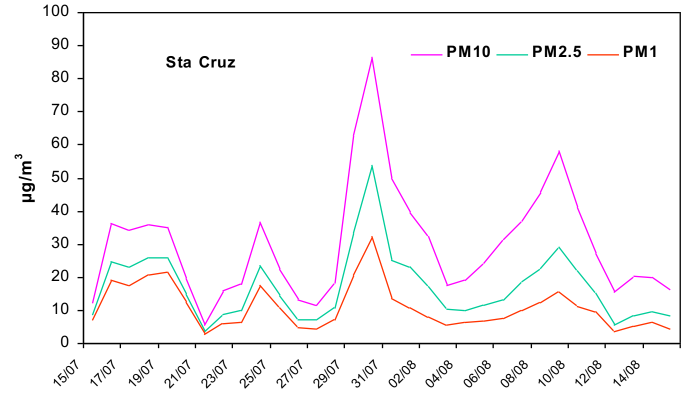
Hourly means





Daily means





In-situ measurements (PM)

Chemical Analysis: methodology (CSIC; Alastauey and Querol)

60 parameters/filter

ACIDIC DIGESTION

Inductively coupled plasma
Atomic Emission Spectroscopy

Major elements ICP-AES

Al_2O_3	Ca	K	Mg
Fe	Ti	P	Na
CO_3^{2-}	ind. Ca		
SiO_2	ind. Al		
SO_4^{2-}	ind. Na		

Inductively coupled plasma
Mass spectroscopy

Trace elements (40) ICP-MS

As, Ba, Bi, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Ga, Gd, Ge, Hf, La, Li, Mn, Mo, Nd, Ni, Pb, Pr, Rb, Sb, Sc, Se, Sm, Sn, Sr, Ta, Th, Ti, Tl, U, V, W, Yb, Zn, Zr

WATER EXTRACTION

Soluble anions and cations

NH_4^+	FIA C.
SO_4^{2-}	IC
Cl^-	IC
NO_3^-	IC

Ion Chromatography

ELEMENTAL ANALYSIS

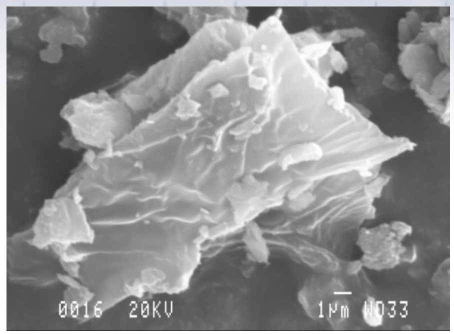
C Elemental A.

DETERMINED

75-85 % PM mass

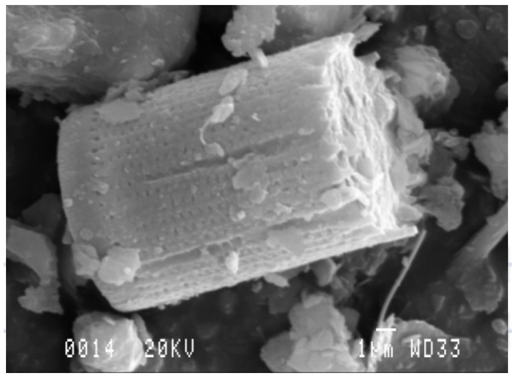
In-situ measurements (PM)

	A) PM10				B) PM2.5			
	Factor 1 mineral	Factor 2 primario fuel oil	Factor 3 marino	Factor 4 secundario fuel oil	Factor 1 mineral	Factor 2 primario fuel oil	Factor 3 secundario fuel oil	Factor 4 marino
OM+EC		**0.75**				**0.87**		
Al	**0.91**				**0.88**			
Ca	**0.81**				0.71			0.47
K	**0.83**		0.45		0.78			
Na			**0.90**					**0.71**
Mg	0.59		**0.76**		0.66			**0.61**
Fe	**0.91**				**0.89**			
$SO_4^{=}$	0.41	0.40	0.54	**0.57**	0.49	**0.61**	**0.51**	
NO_3^-	0.47		0.55	0.46	0.64			0.44
Cl^-			**0.88**					**0.88**
NH_4^+				**0.86**		0.53	**0.63**	
P	**0.80**				0.47			
Ti	**0.94**				**0.94**			
V		**0.90**				**0.94**		
Mn	**0.92**				0.78			
Co	0.55	0.52			0.40	0.61		
Ni		**0.85**				**0.94**		
Cu	0.53						**0.61**	
Zn				0.51			**0.87**	
As	0.54	0.43			0.53	0.56		
Cd	0.75				0.64		**0.50**	
Pb	0.51		0.42		0.67			
Expl.Var	8.09	3.40	3.72	2.25	7.30	4.68	2.90	2.50
Prp.Totl	0.37	0.15	0.17	0.10	0.33	0.21	0.13	0.11



- Saharan air masses mainly consist of clays, quartz, feldspars, and calcite.

- Fresh water diatoms and pollen particles from North Africa have also been identified at Izaña.



In-situ measurements (PM)

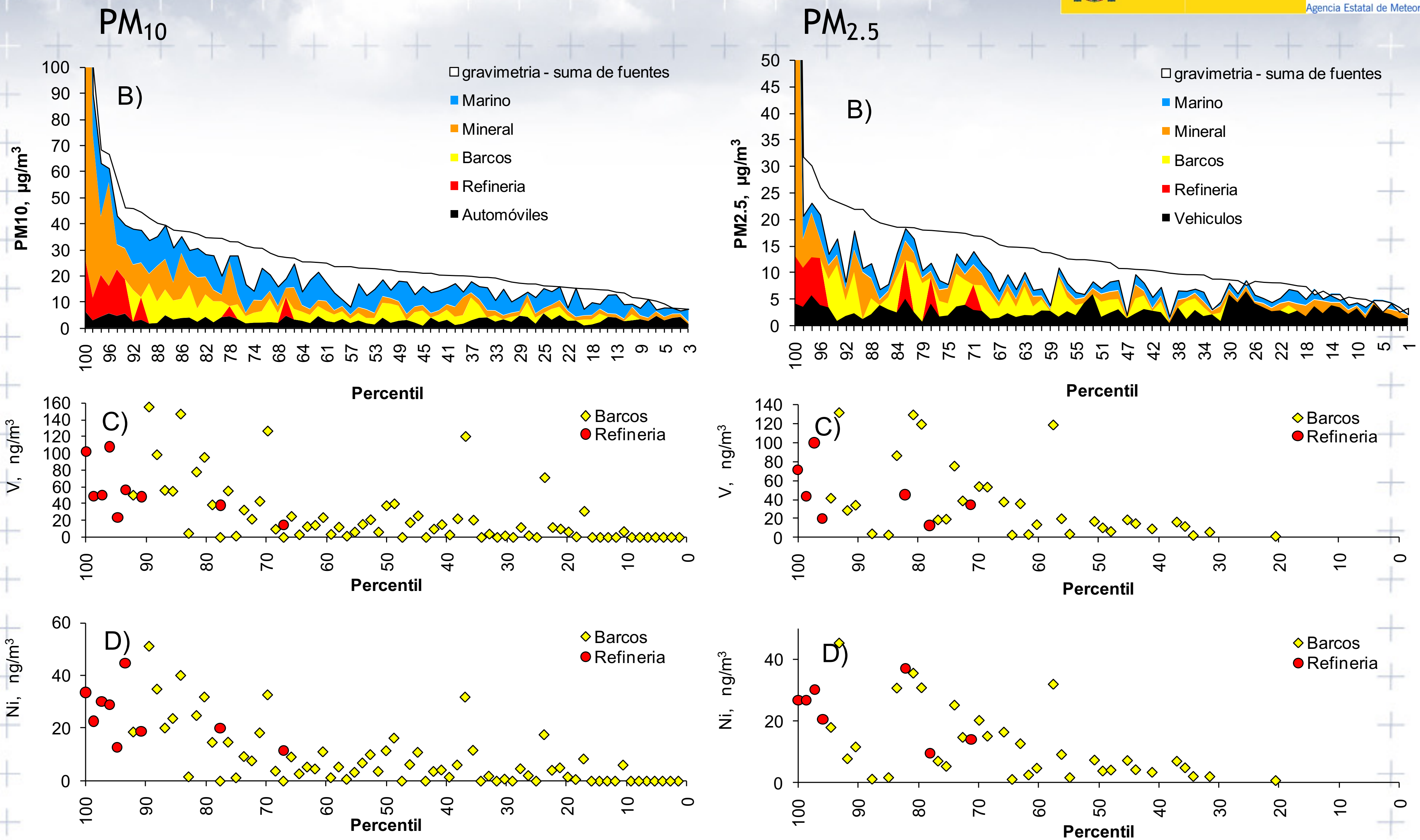
PM_{10} > 50 µg/m³

Tabla 11. Episodios en los que se supera el valor límite diario para partículas PM10 (50 µg/m³). A) Contribución de fuentes. B) Composición de cada fuente antropogénica de PM10. C) Información complementaria. En A) % indica la contribución a la media de cada fuente a la concentración de PM10; Natural = Mineral + Marino; Antropógenico = Barcos + Refinería + Automóviles. En C) unidades: V (µg/m³), Ni(µg/m³), SO_2 (µg/m³) y $SO_4^=$ (µg/m³).

A)	26/04/2008		21/01/2008		02/04/2008		11/11/2008		29/06/2008	
	µg/m³	%	µg/m³	%	µg/m³	%	µg/m³	%	µg/m³	%
PM10	376.4		100.6		68.5		66.8		56.6	
Σ contribuciones	319.1	85	89.9	89	63.3	92	61.3	92	43.1	76
Mineral	270.4	72	62.9	63	22.3	33	39.6	59	9.4	17
Marino	21.0	6	15.3	15	20.5	30	5.4	8	11.1	20
Barcos	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Refinería	20.9	6	8.8	9	16.1	23	10.6	16	17.9	32
Automóviles	6.8	2	3.0	3	4.4	6	5.7	9	4.8	8
Mineral + marino	291.4		78.1		42.8		45.0		20.5	
Antropógenico	27.7		11.7		20.5		16.3		22.6	

Rodríguez et al., 2009

In-situ measurements (PM)

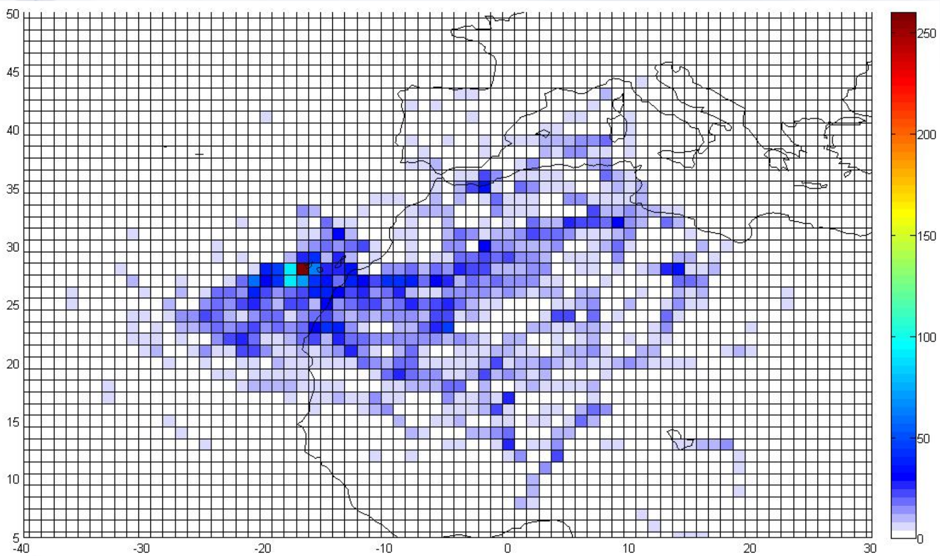


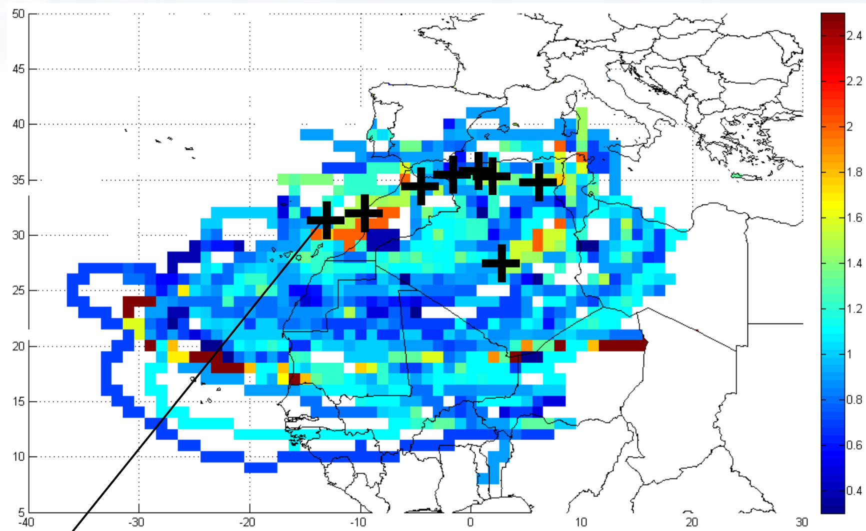
Santa Cruz de Tenerife source apportionment study by receptor modeling

Rodríguez et al., 2009

In-situ measurements (PM)

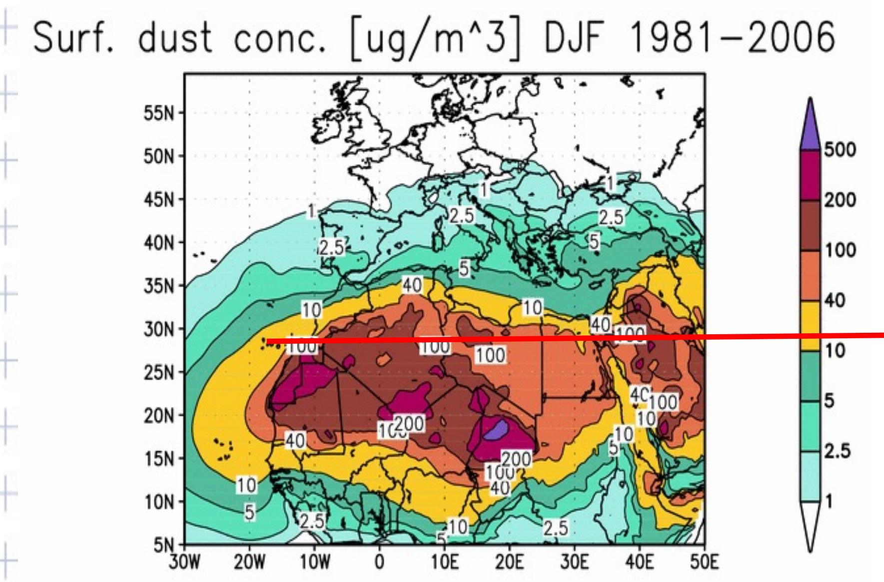
PM10>10ug/m3



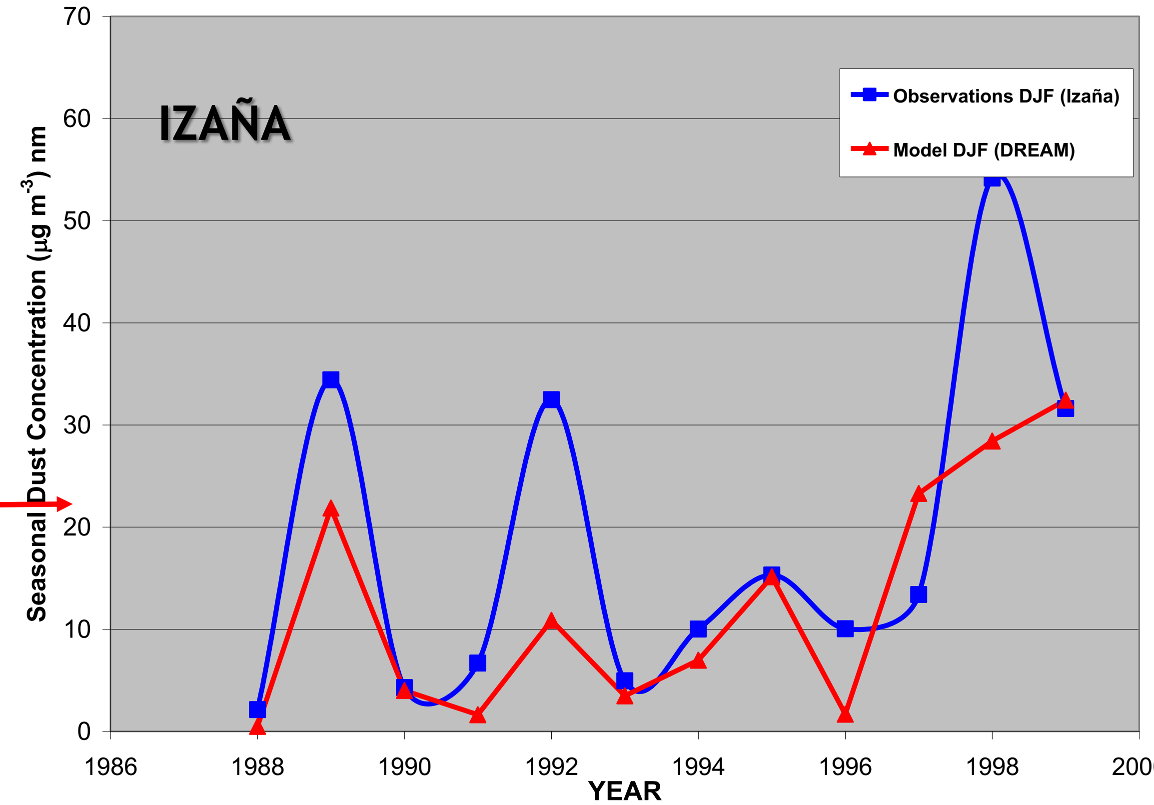


SAMIR (33.68ºN, -7.43ºE)
Refinery (125,000 bpd)

BSC-DREAM validation against TSP at Izana



Winter



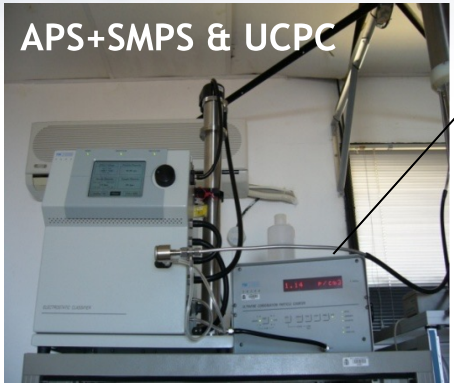
R=0.79

In-situ dust concentration validation: Izaña GAW station-DREAM

Pérez et al., 2008

In-situ Aerosol/ African-dust characterization

Number size distribution of coarse, fine and ultra-fine particles (3nm-20µm) (APS + SMPS)



Ultrafine Condensation Particle Counter (UCPC): Counts number concentration (up to 10^5 cm^{-3}) of particles of the size 3 nm and higher

Scanning Mobility Particle Sizer (SMPS): Measures particle size distribution in 15-770 nm mobility diameter range. (resolution 64 chan/decade)

Total and backward scattering coefficients (3λ) (integrating nephelometer)

TSI 3-wavelength Integrating Nephelometer

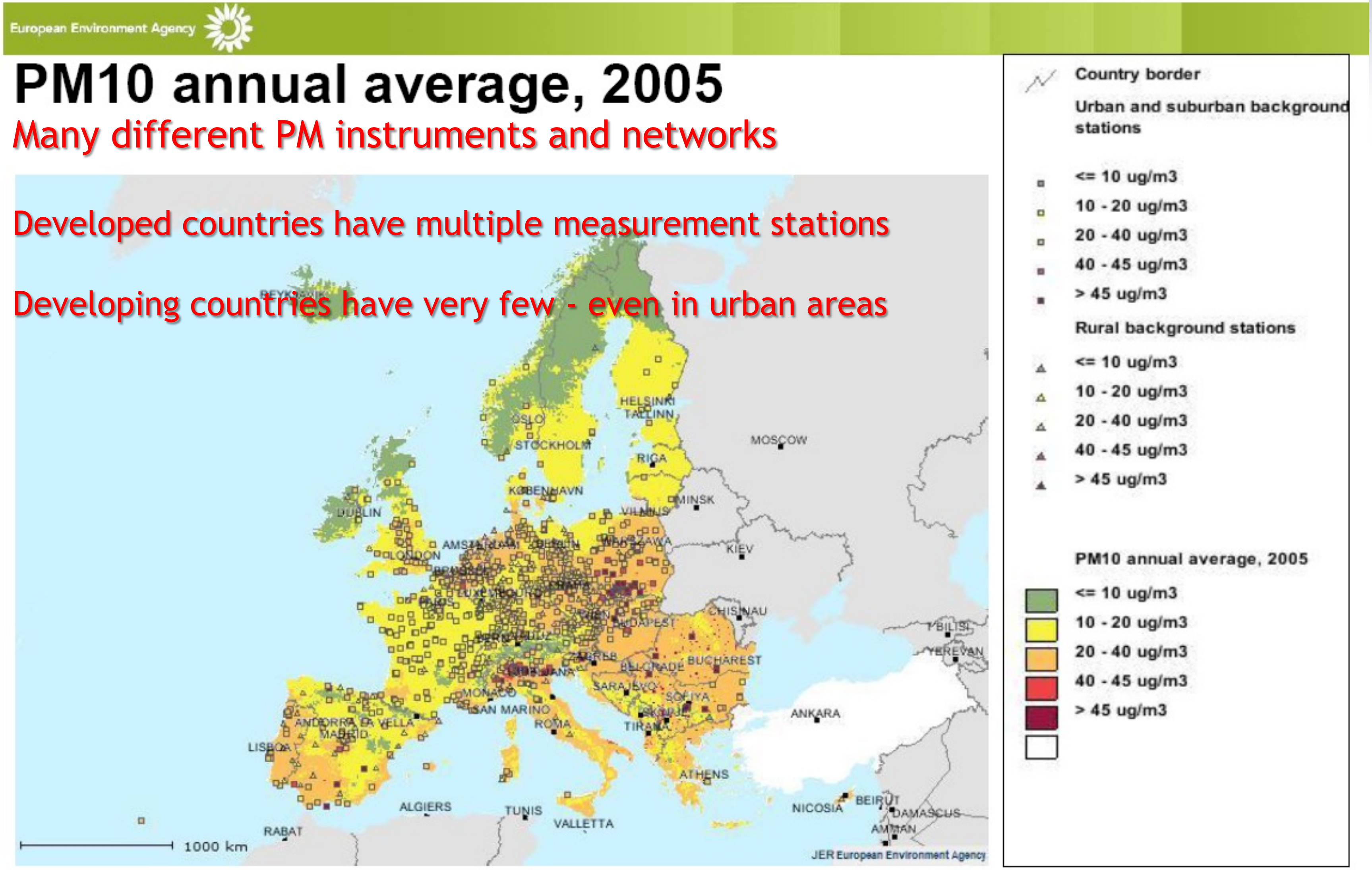
Measures total- and back-scattering coefficients at 3 wavelengths: 700 nm (red), 550 nm (green), and 450 nm (blue)

Absorption scattering coefficients (1λ) (MAAP)

MAAP or Aethalometer

Measures mass loading of black carbon (µg/m^3)

In-situ measurements (PM)



Many different PM instruments and networks

Developed countries have multiple measurement stations

Developing countries have very few - even in urban areas

- ~ 100 PM2.5 & PM10 stations in Europe in 2003 (~ 1600 PM10-only stations). Mostly daily (24h) average data are available.
- Measurement principles: TEOM, beta-attenuation, gravimetry

From ground observations…

to ground estimations…

Visibility

WMO - visibility

The greatest distance that a black object of "suitable dimensions," situated near the ground, can be seen and recognized when observed against a background of fog

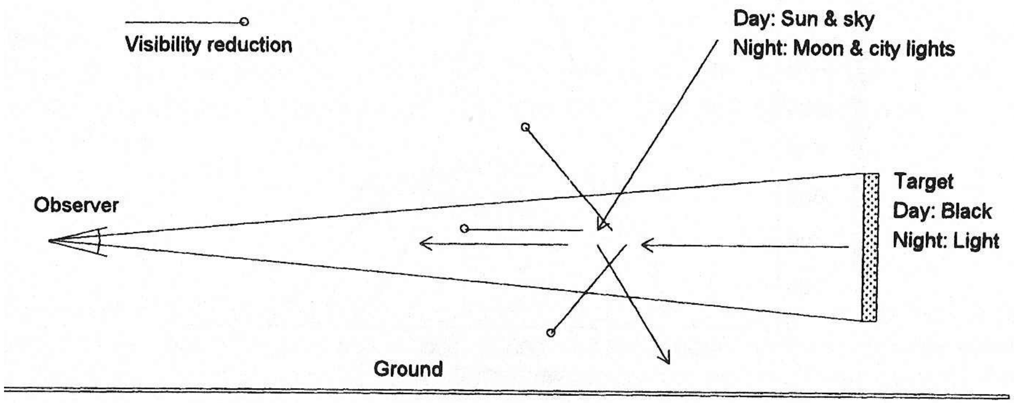


Fig. 11-1 Visibility reduction by scattering.

- Operational surface synoptic weather station reports from Global Telecommunication System (GTS)
- Station reports include past & present weather, visibility (km), temperature (°C), dew point temperature, 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
```

In-situ estimations

Measurement of visibility – **transmissometer**

- 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**)

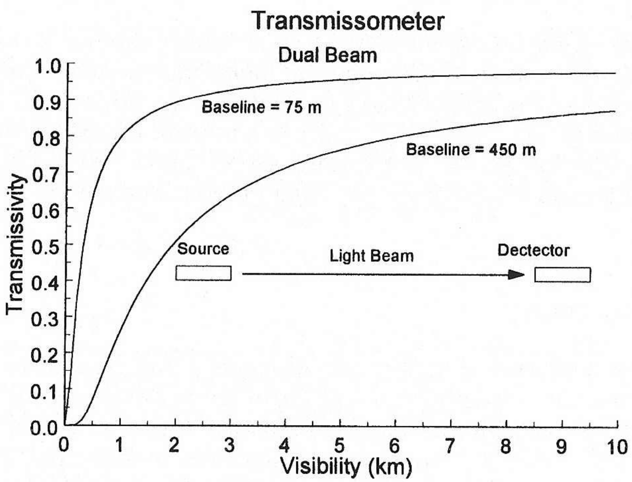


Fig. 11-3 Transfer function for a transmissometer.

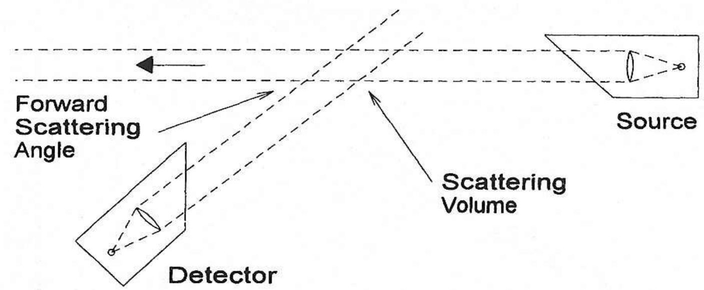
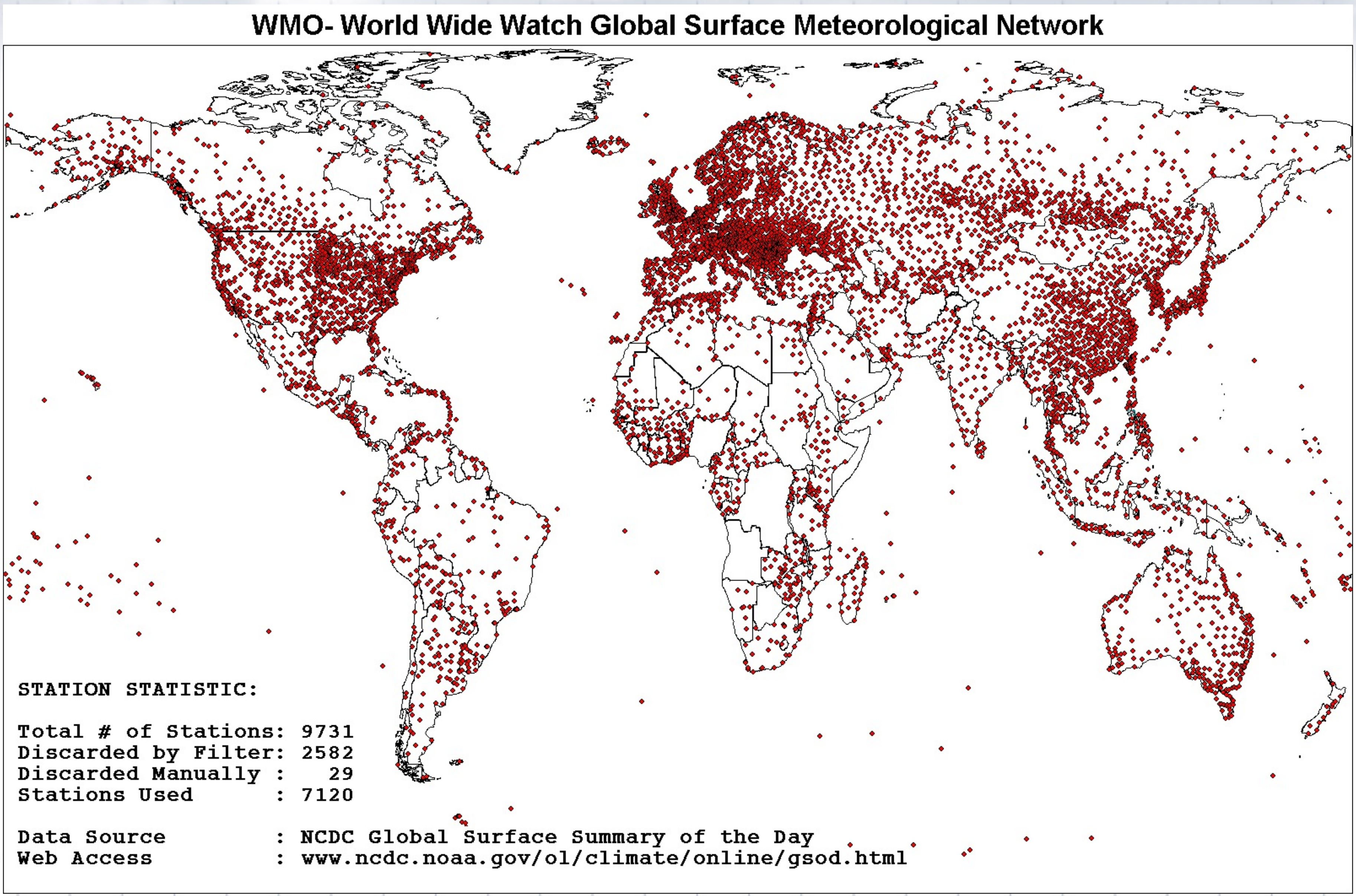


Fig. 11-4 A forward scatter visibility meter.

In-situ estimations



Relation between horizontal visibility and TSP or PM10

Very few studies on the relation between horizontal visibility and TSP or PM10 levels of mineral dust mass concentration have been carried out in Africa.

$C_{TSP} = 1339.84\ VV^{-0.67}$ Ben Mohamed et al. (1992)

$C_{PM10} = 914.06 VV^{-0.73} + 19.03$ D'Almeida's (1986)

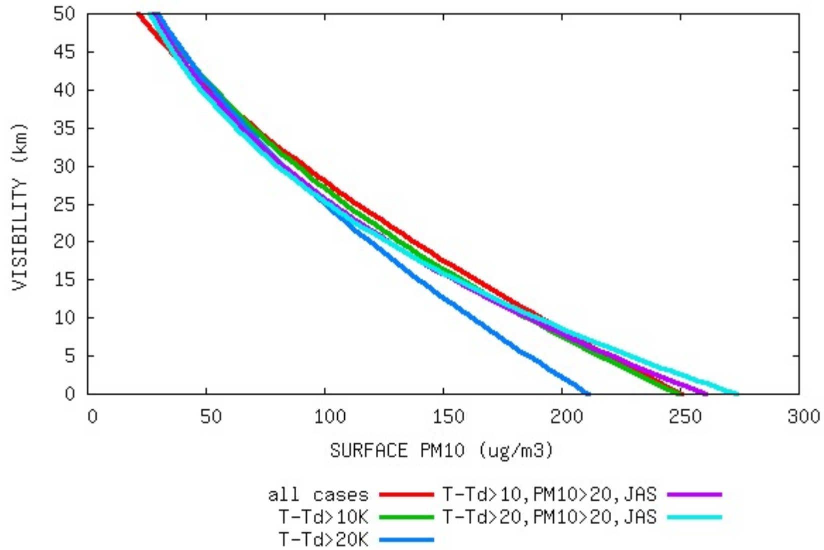
where *C is the TSP concentration in* μgm^{-3} *and VV* is the horizontal visibility in km

E. Terradellas

$Vis=63023-1838(PM_{10}^{0.64})$

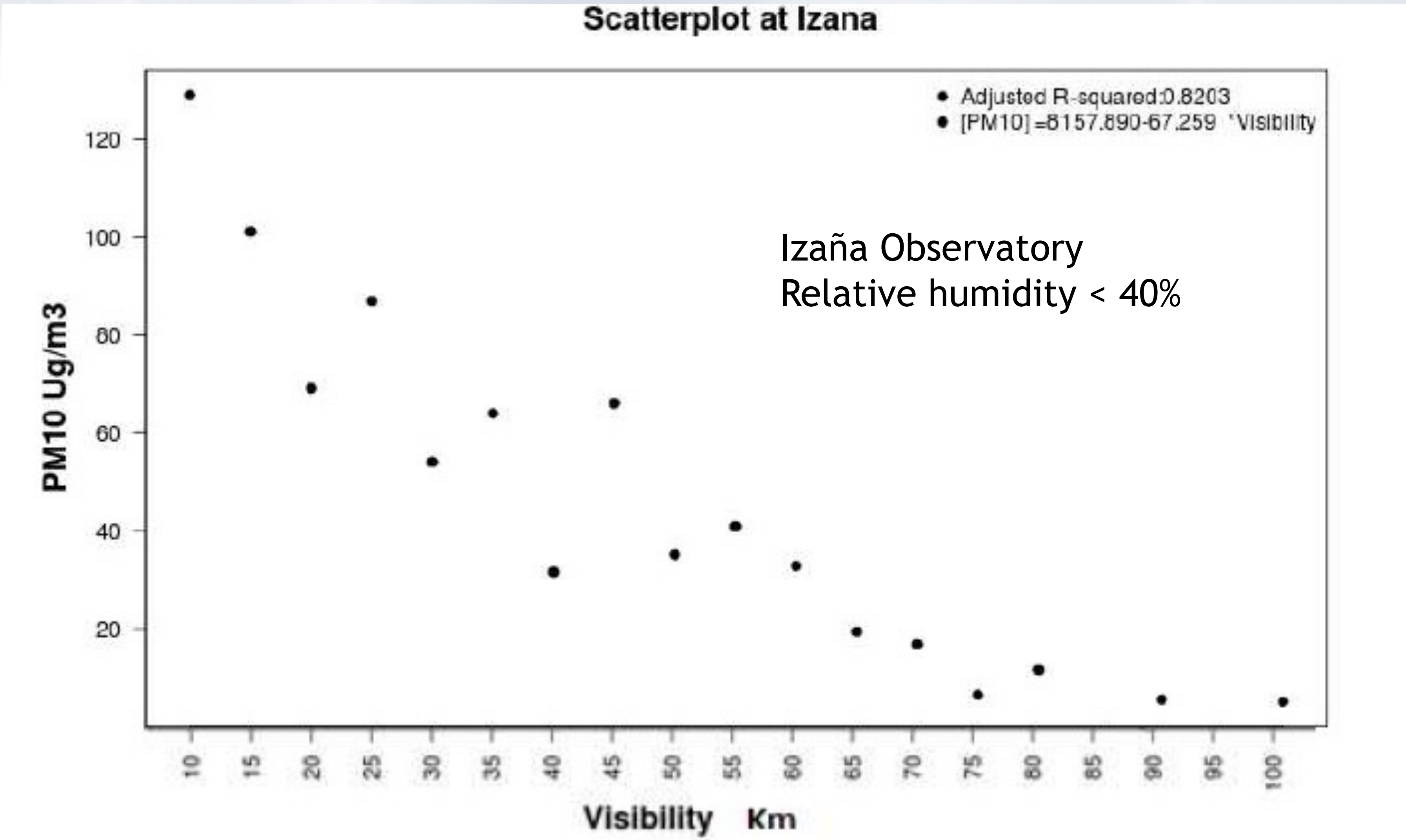
PM_{10} at Izaña

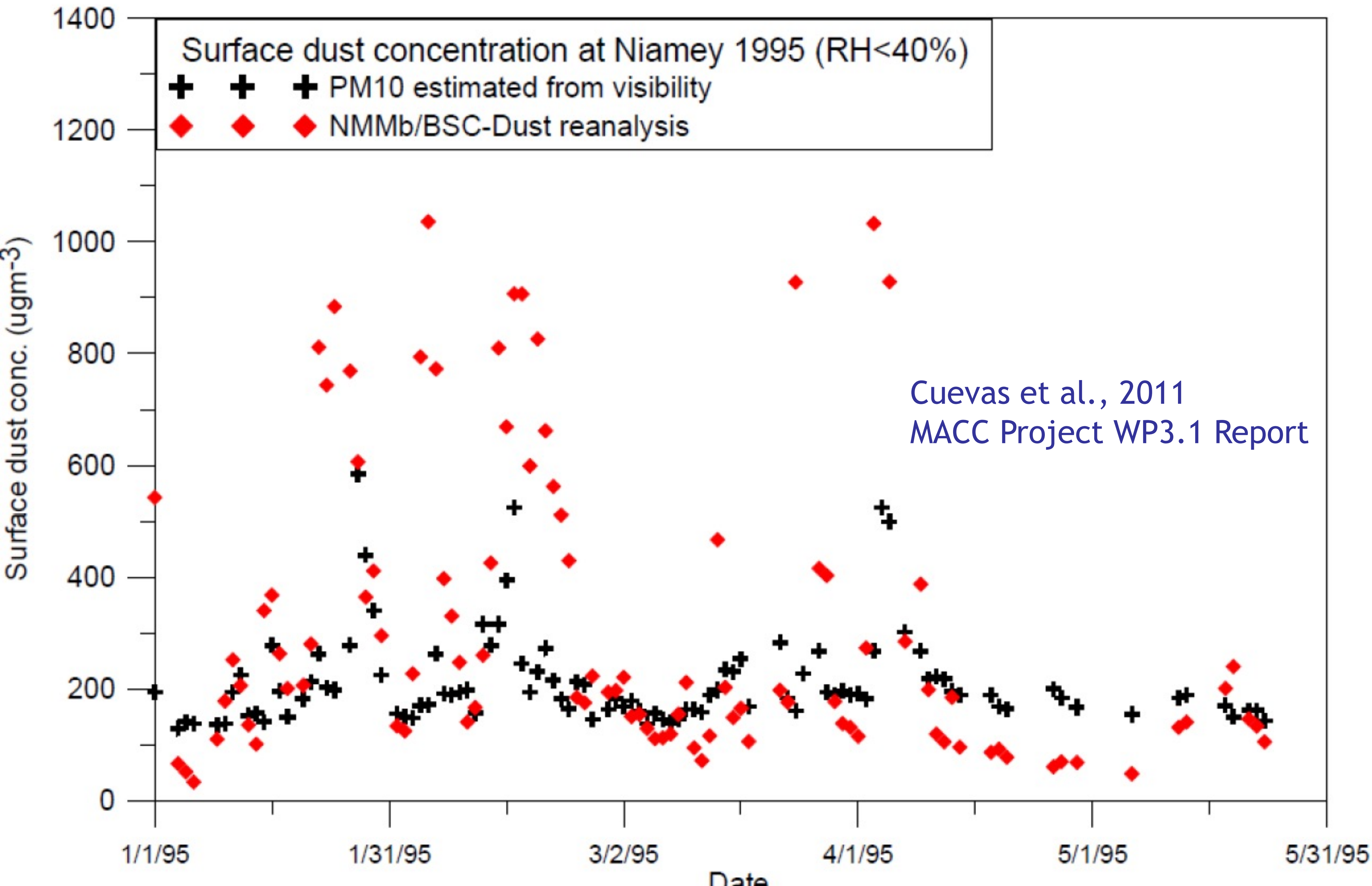
Visibility from SYNOP-Izaña



Identify surface station visibility reports that may be used in simple regression model for estimate ground PM10 or TSP

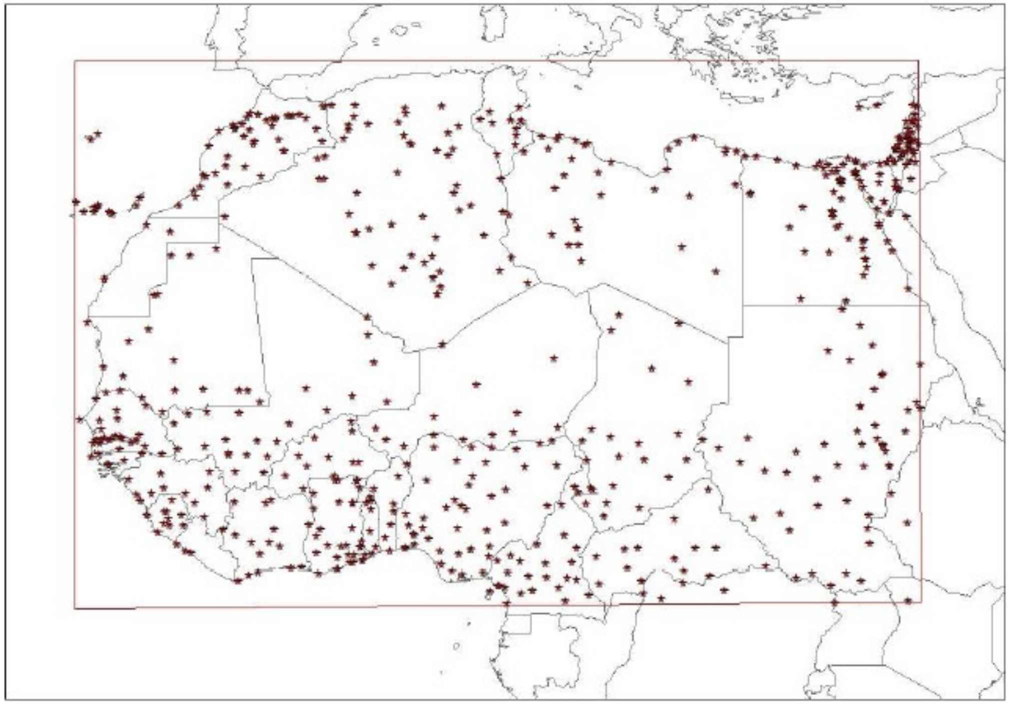
In-situ estimations





Cuevas et al., 2011
MACC Project WP3.1 Report

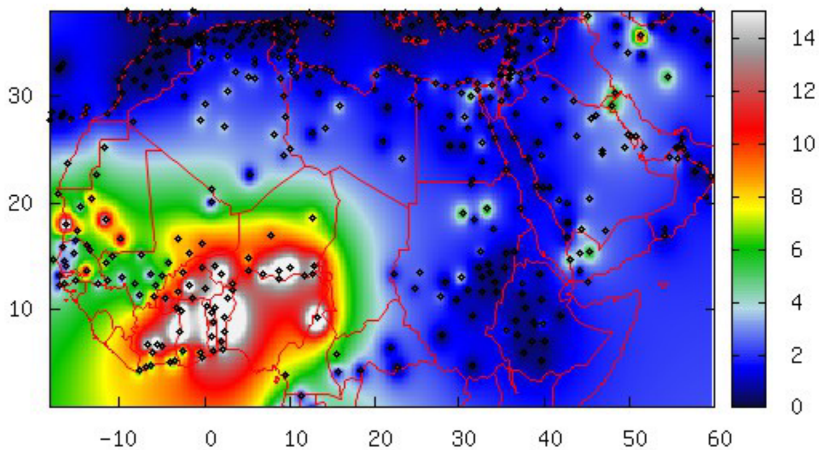
In-situ estimations



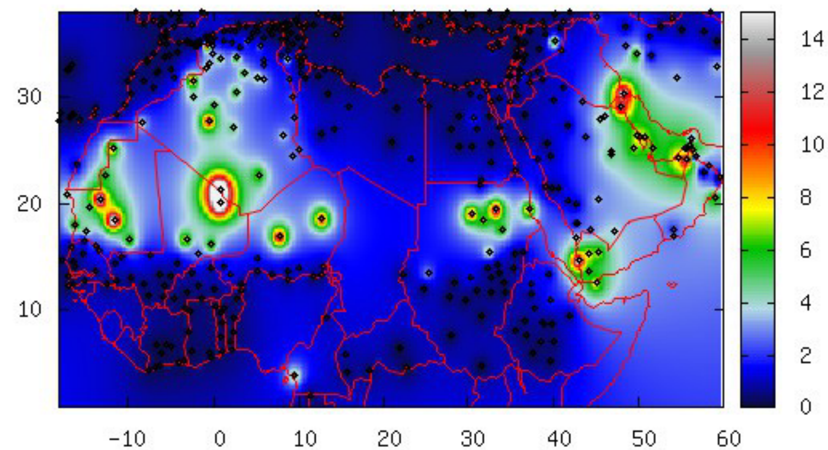
Synop and Metar reports from Met stations

Provided by Enric Terradellas

WINTER



SUMMER



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. Coarse reporting bins
4. Judgment in distinguishing visibility beyond 10 km

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

AERONET Verification	MSG Verification	MODIS Real-Time	Visibility Real-Time

Map Reload

http://www.bsc.es/sds-was/node/46

- < 50 m
- > 50 m And < 2 km
- > 2 km And < 4 km
- > 4 km And < 6 km
- > 6 km And < 8 km
- > 8 km And < 10 km
- > 10 km

Last Update:

2010-11-07 21:37:07

CLICK ON A STATION FOR TIME OF OBSERVATION

Develop a quality-screened station dataset for use in validating dust model forecasts

From ground observations…

to total atmospheric column observations

Sunphotometers

Aerosol Extinction Profiles: 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 Mass Concentration: The columnar aerosol mass concentration ($\mu gm/cm^2$) is the total aerosol mass in a vertical column of atmosphere.

Aerosol Single Scattering Albedo A measure of the effectiveness of scattering relative to extinction for the light encountering the atmospheric aerosol particles.

The scattering and absorption of radiation by a single aerosol particle is expressed by its **complex refractive index** ($n = n_r + in_i$), where the real part represents scattering and the imaginary part represents absorption. The refractive index is strongly dependent on the chemical composition of the particle.

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Aerosol Asymmetry Factor A measure of the preferred scattering direction (forward or backward) for light encountering aerosol particles.

$$g = \frac{1}{2}\int_{-1}^{+1} \cos\Theta \, P\left(\cos\Theta\right)\, d\cos\Theta$$

$$P\left(\cos\Theta\right) = \frac{1-g^2}{\left(1+g^2-2g\,\cos\Theta\right)^{3/2}}$$

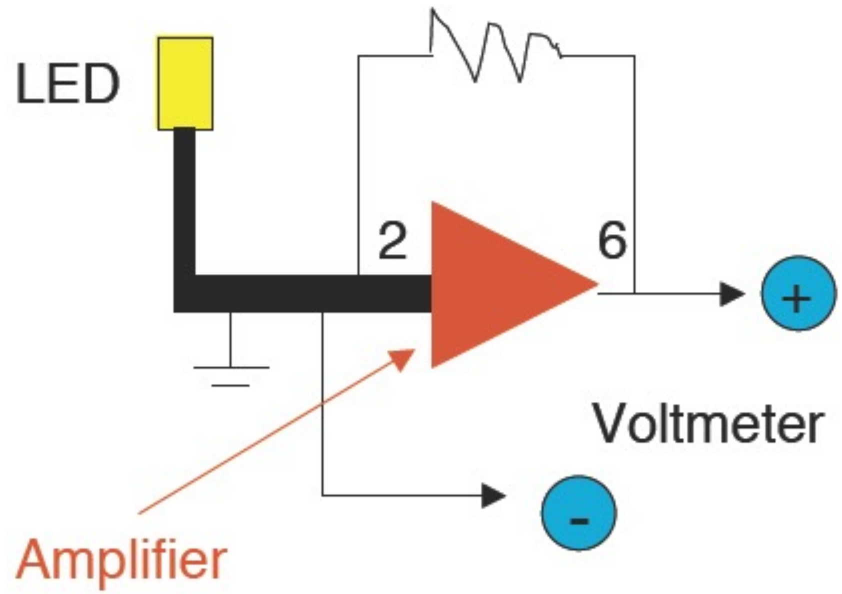
The asymmetry factor approaches +1 for scattering strongly peaked in the forward direction and -1 for scattering strongly peaked in the backward direction.

In general, **g=0 indicates scattering directions evenly distributed** between forward and backward directions, i.e. **isotropic scattering** (e.g. scattering from small particles)

g<0 scattering in the backward direction (i.e scattering angle > 90 deg.), often referred to as backscattering, is **scattering at 180 deg**.

g>0 scattering in the forward direction (i.e scattering angle < 90 deg.), often referred to as forward-scattering, is **scattering at 0 deg**. **For larger size or Mie particles, g is close to +1.**

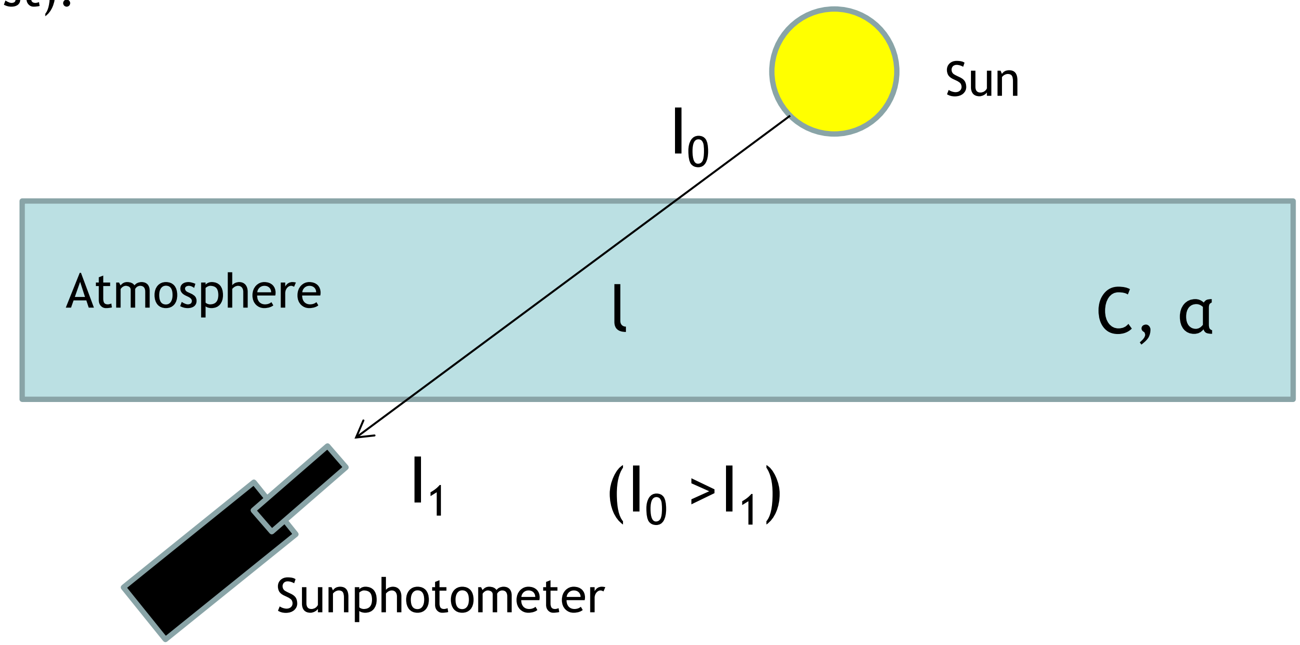
Sun Photometers absorb *direct* sunlight energy with a LED light and convert the intensity into a quantified voltage to measure aerosols in the atmosphere.



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 scattering and less energy transmitted to the surface.

Ground-based remote sensing

Knowing the sunlight's energy at the top of the atmosphere, the thickness of the atmosphere, and the amount of sunlight transmitted to the earth's surface and can allows us to determine the amount of scattering, and thus, the amount of aerosols (dust).



Beer's Law

$$T = I_1/I_0 = 10^{-\alpha l} = 10^{-\varepsilon l c}$$

Transmissivity (T)
Absorption coefficient (α)
path length (ι)
molar absorptivity of the absorber (ε)
concentration of absorbing species in the material (c)
absorption cross section (σ)
density of absorbers (N)

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Langely plot calibration (I00 determination for each wavelenght):

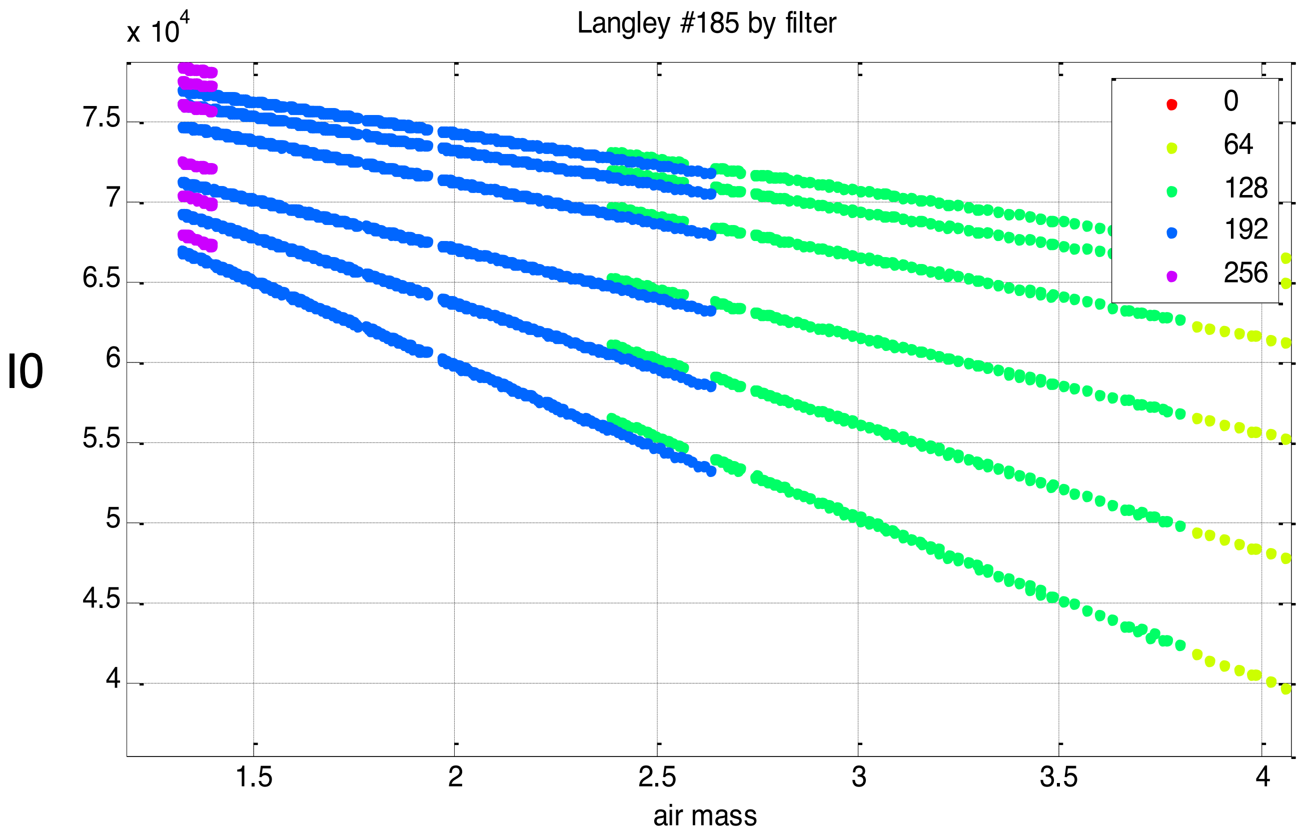
Pristine conditions

No clouds

Stable total ozone and column water vapor

Beer's Law

$$T = I_1/I_0 = 10^{-\alpha l} = 10^{-\varepsilon l c}$$



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.

$$\tau_{ext} = \int_{z=0}^{z=toa} K_{ext}(z)\,dz$$

Angstrom Exponent

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

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

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

i.e. If AOD >~ 0.2 and α<0.7 then we are observing dust (aprox.)

Ground-based remote sensing

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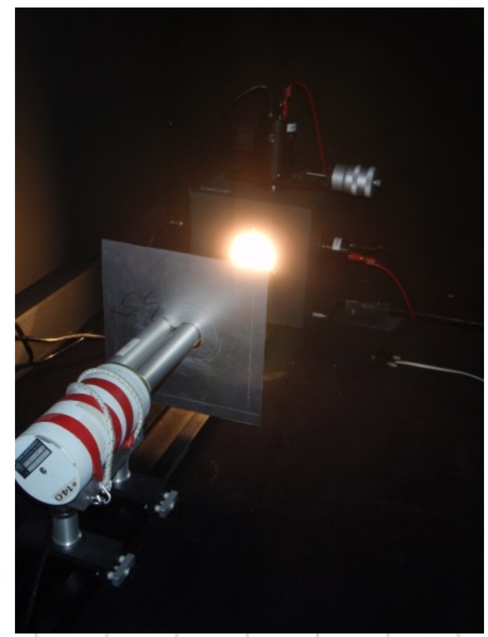
- The **Cimel Electronique 318** spectral radiometer is a solar-powered, weather-hardy, robotically-pointed sun and sky spectral sun photometer.

- A sensor head points the sensor head at the sun according to a preprogrammed routine.

- The Cimel controller, batteries, and the optional Vitel **satellite transmission** equipment are usually deployed in a weatherproof plastic case.



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Direct irradiance
IFOV 1.2º

Principal plane

Diffuse radiance
IFOV 1.2º

Almucantar

Photometer

Sun measurements
Sky measurements

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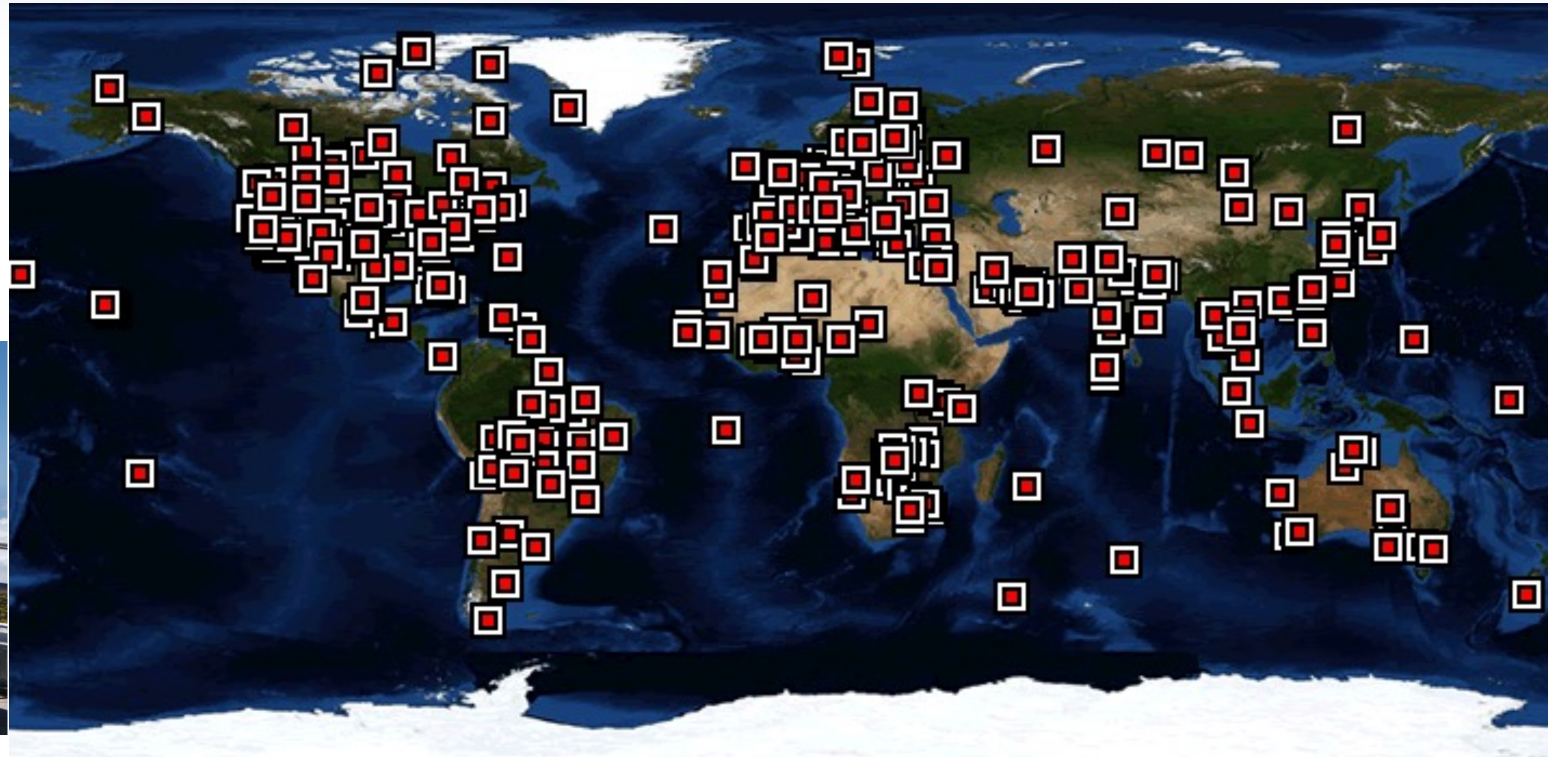
AERONET (AErosol RObotic NETwork)- http://aeronet.gsfc.nasa.gov

CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE



An internationally Federated Network

- Characterization of aerosol optical properties
- Validation of satellite aerosol retrieval
- Near real-time acquisition; long term measurements

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AERONET Data Flows

http://aeronet.gsfc.nasa.gov

Holben et al.
***RSE*, 1998**
Holben et al.
***JGR*, 2001**

Flux measurements

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

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

Calibration and processing information

Mauna-Loa and Izaña

CNRS-University of Lille and University of Valladolid

Eck et al.
JGR, 1999

Aerosol optical depth and precipitable water computations

Smirnov et al.
***RSE*, 2000**

Cloud screening and quality control

Dubovik and King
***JGR*, 2000**
Dubovik et al.
***JGR*, 2000**
***GRL*, 2002**

Inversion products

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

AERONET provides:

- global Aerosol Optical Depth of Dust in near real-time
- robust optical properties of Dust: size distribution, ref. Index, etc. (e.g. Asian Dust has stronger and less spectral dependent absorption than Saharan Dust)
- climatological models that reproduce observed optical properties of aerosol (useful for satellite retrievals)

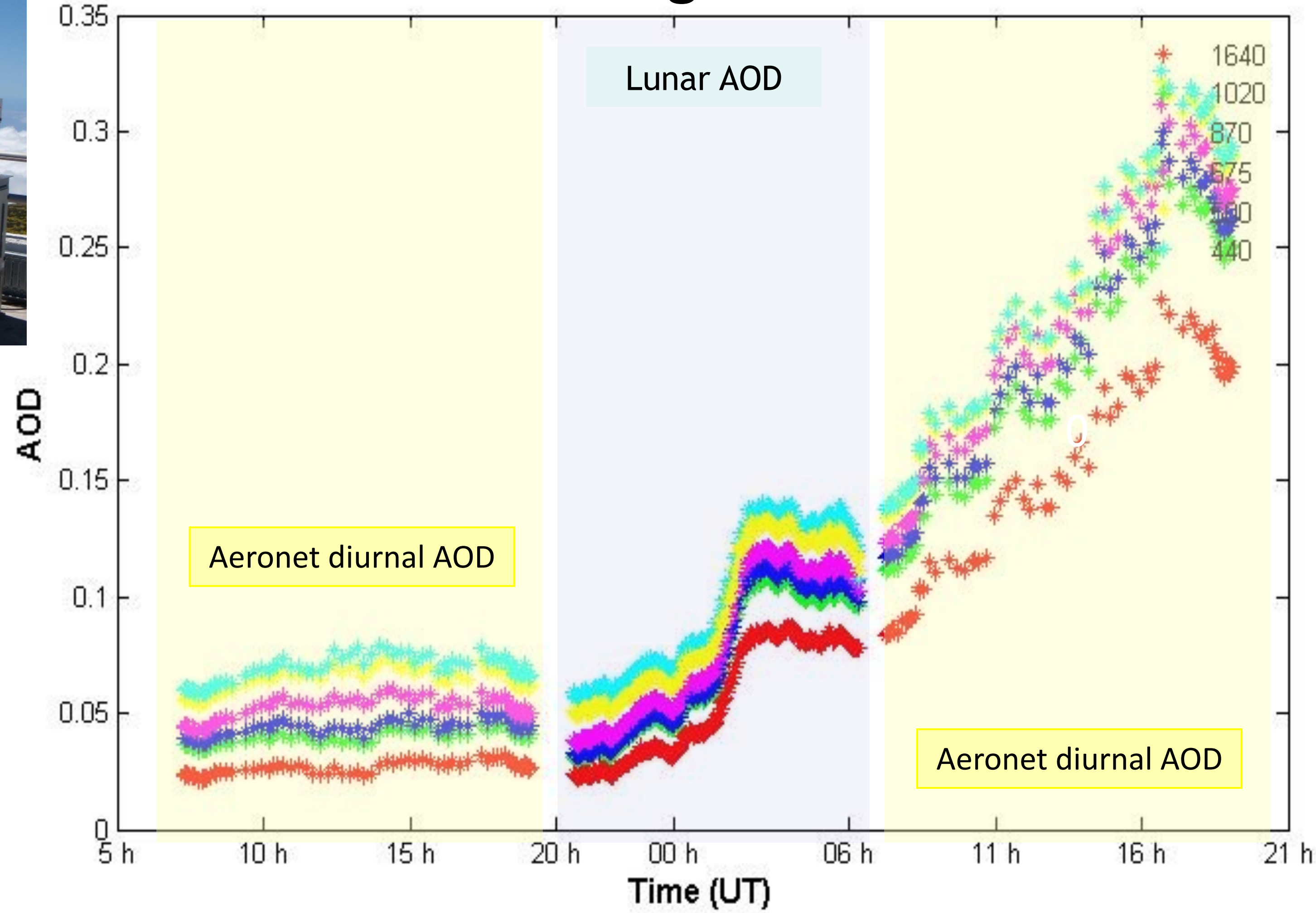
Ground-based remote sensing

AERONET @ Tamanrasset-Algeria
September 2006
Mohamed Mimouni

AERONET @ Cairo
May 2010
Hamza Mohamed Hamza

Ground-based remote sensing

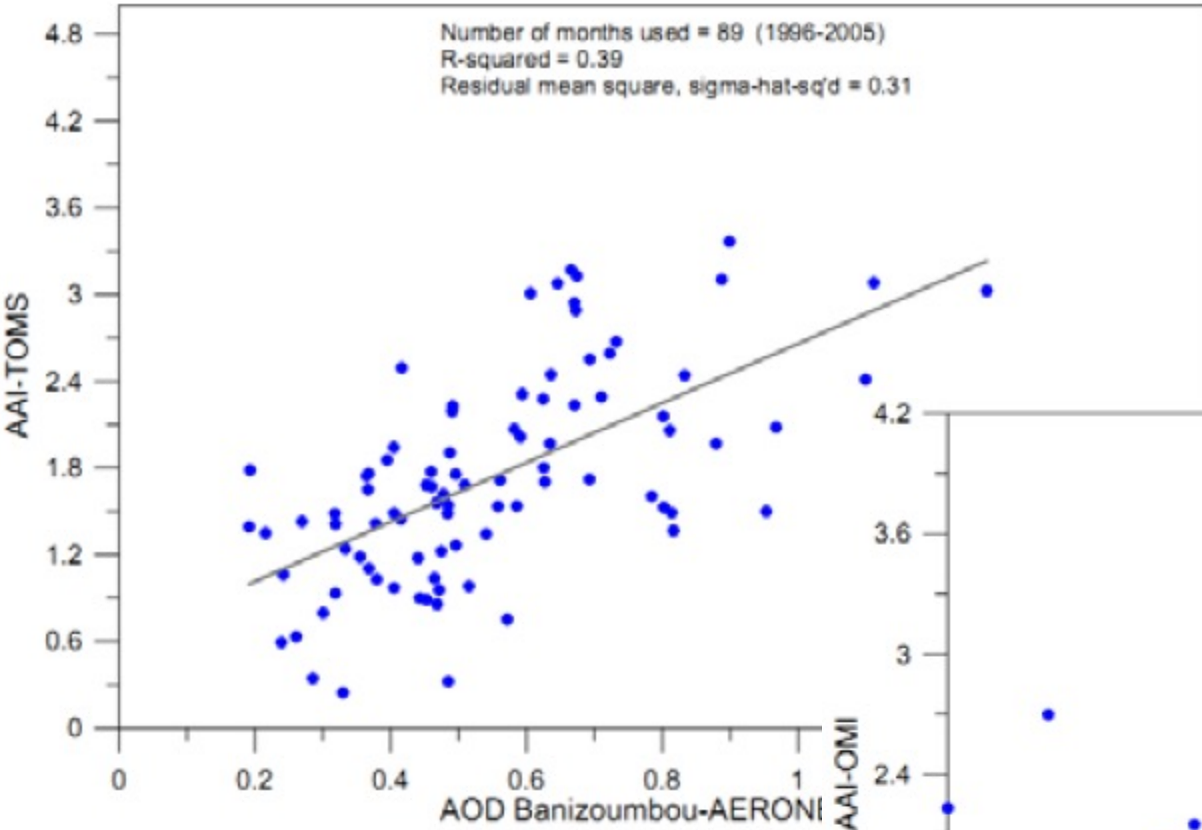
AOD 14 August 2011

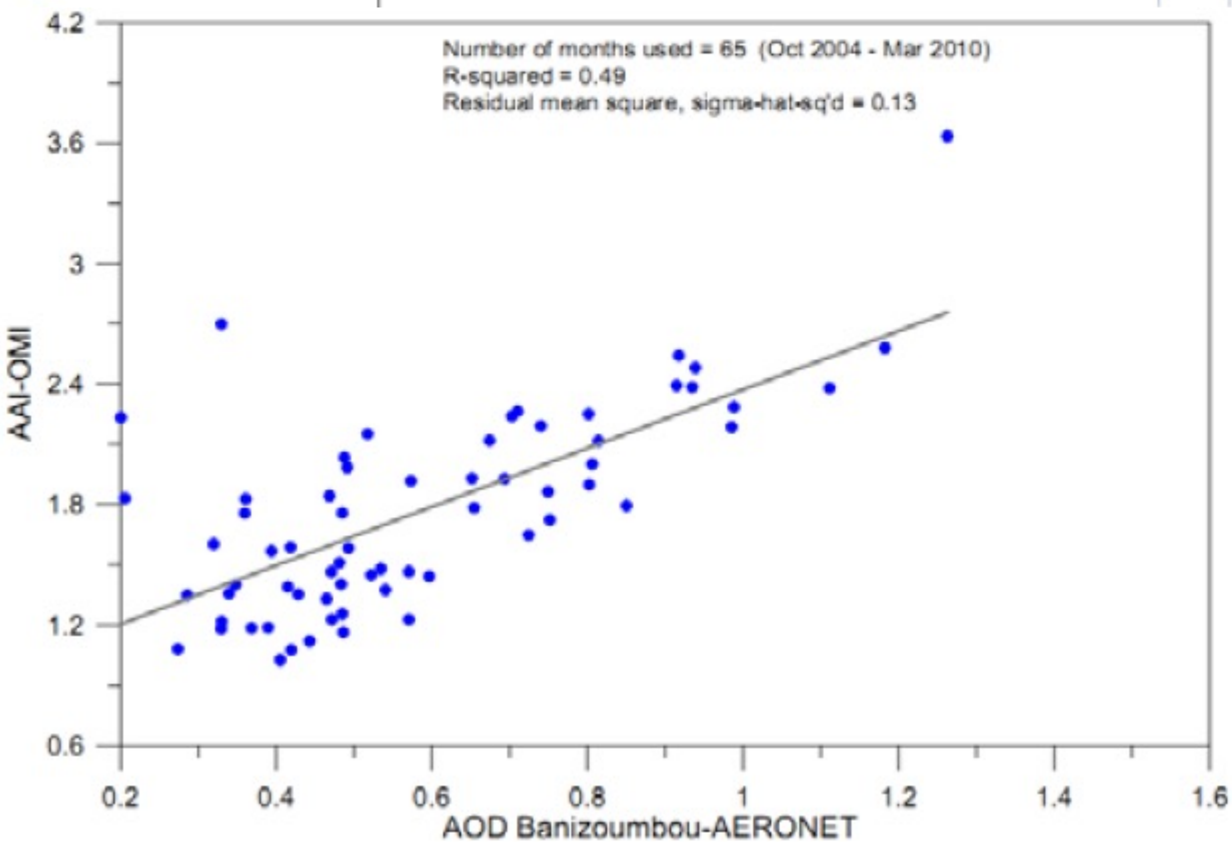


August 13

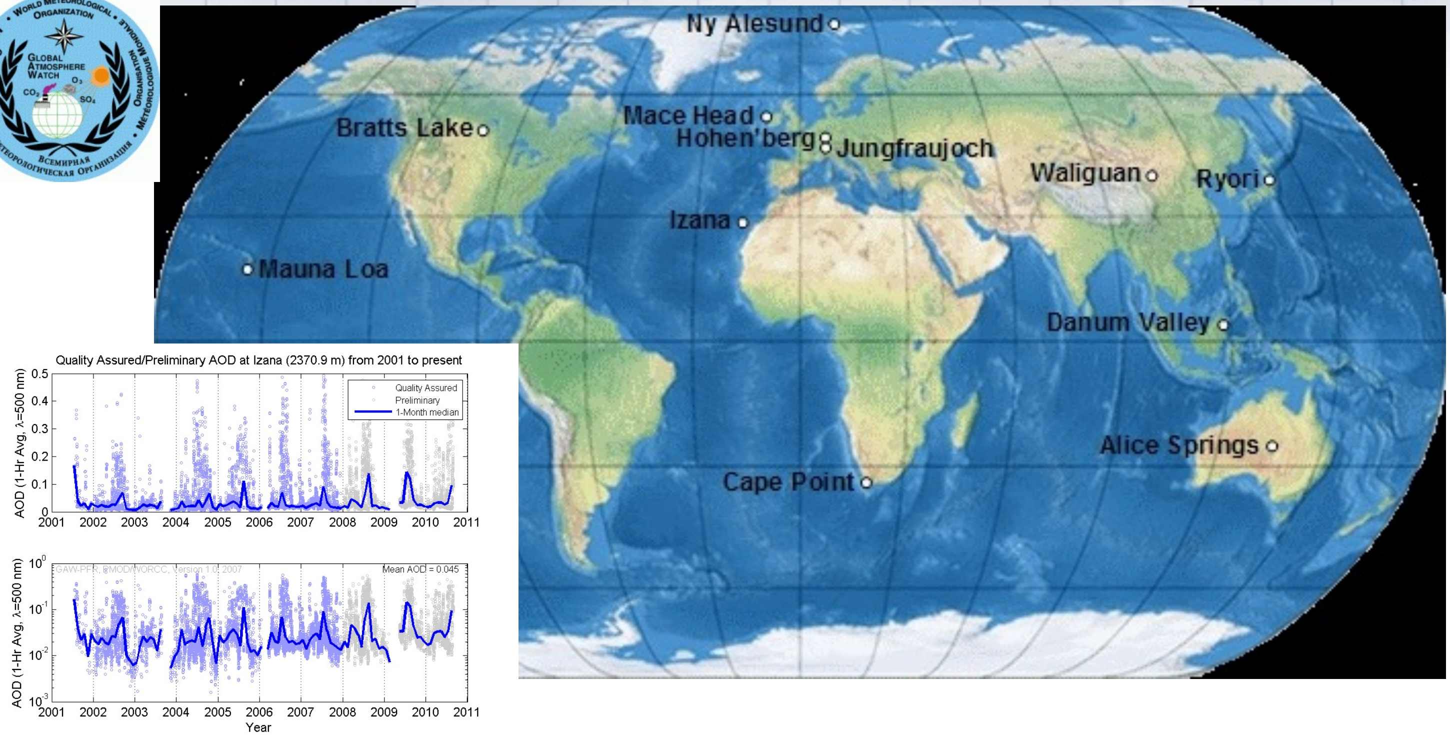
August 14

Ground-based remote sensing





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), Ispra. Data with a 1-minute resolution are available from WORCC upon request.

GAW-PFR provides:

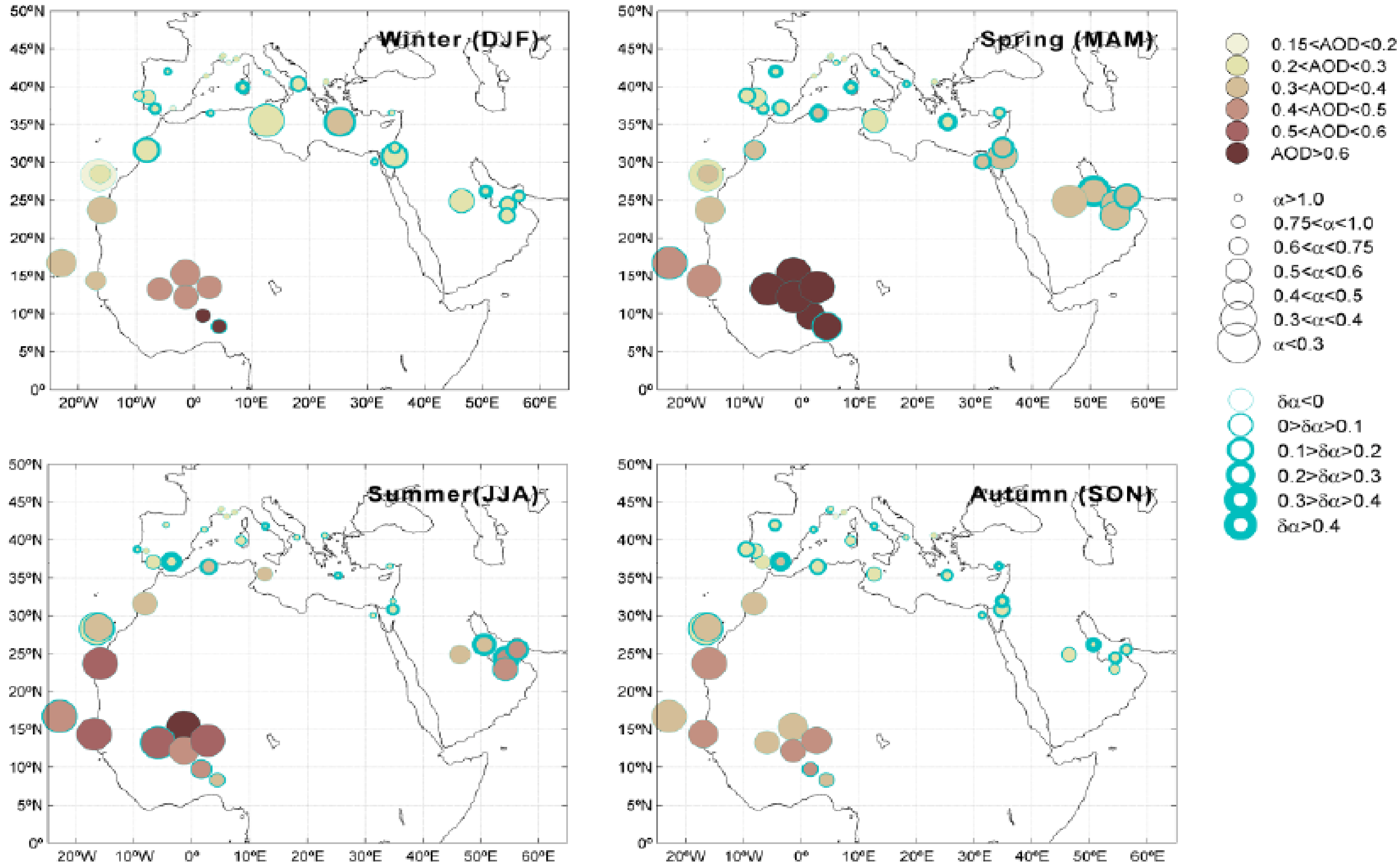
- long-term high-accuracy AOD and Angström Coefficients
- GAW-PFR provides AOD Dust in near real-time

Ground-based remote sensing

Aerosol characterization in Northern Africa, Northeastern Atlantic, Mediterranean Basin and Middle East from direct-sun AERONET observations

S.Basart, C. Pérez, E. Cuevas, J.M. Baldasano, and G.P. Gobbi

(**Atmos. Chem. Phys.** October-2009)



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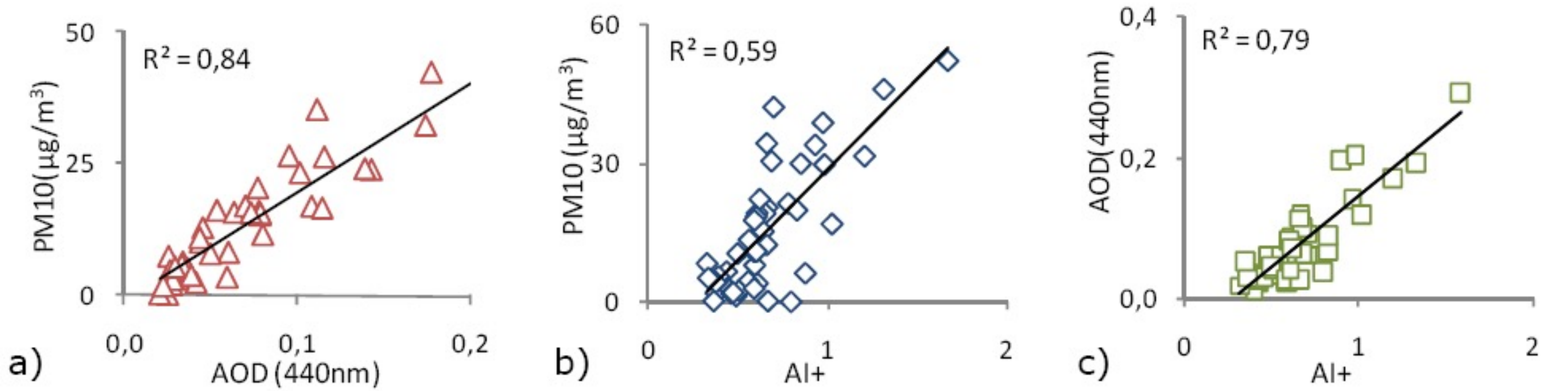


Figure 1. Scatterplot of monthly means of a) AOD vs PM_{10}; b) AI positive values vs PM_{10}; c) AI positive values vs AOD.

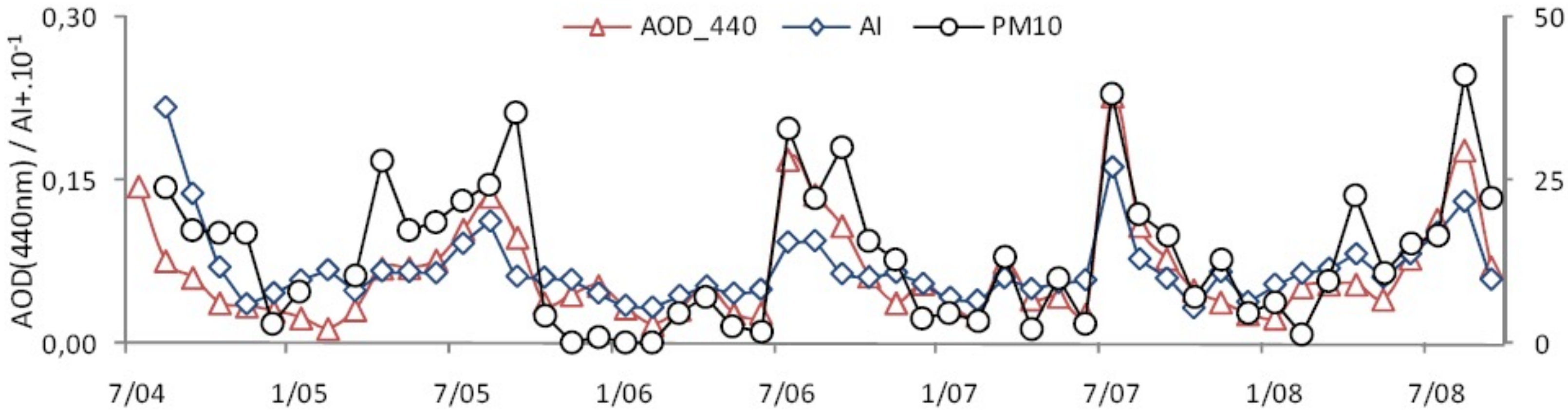
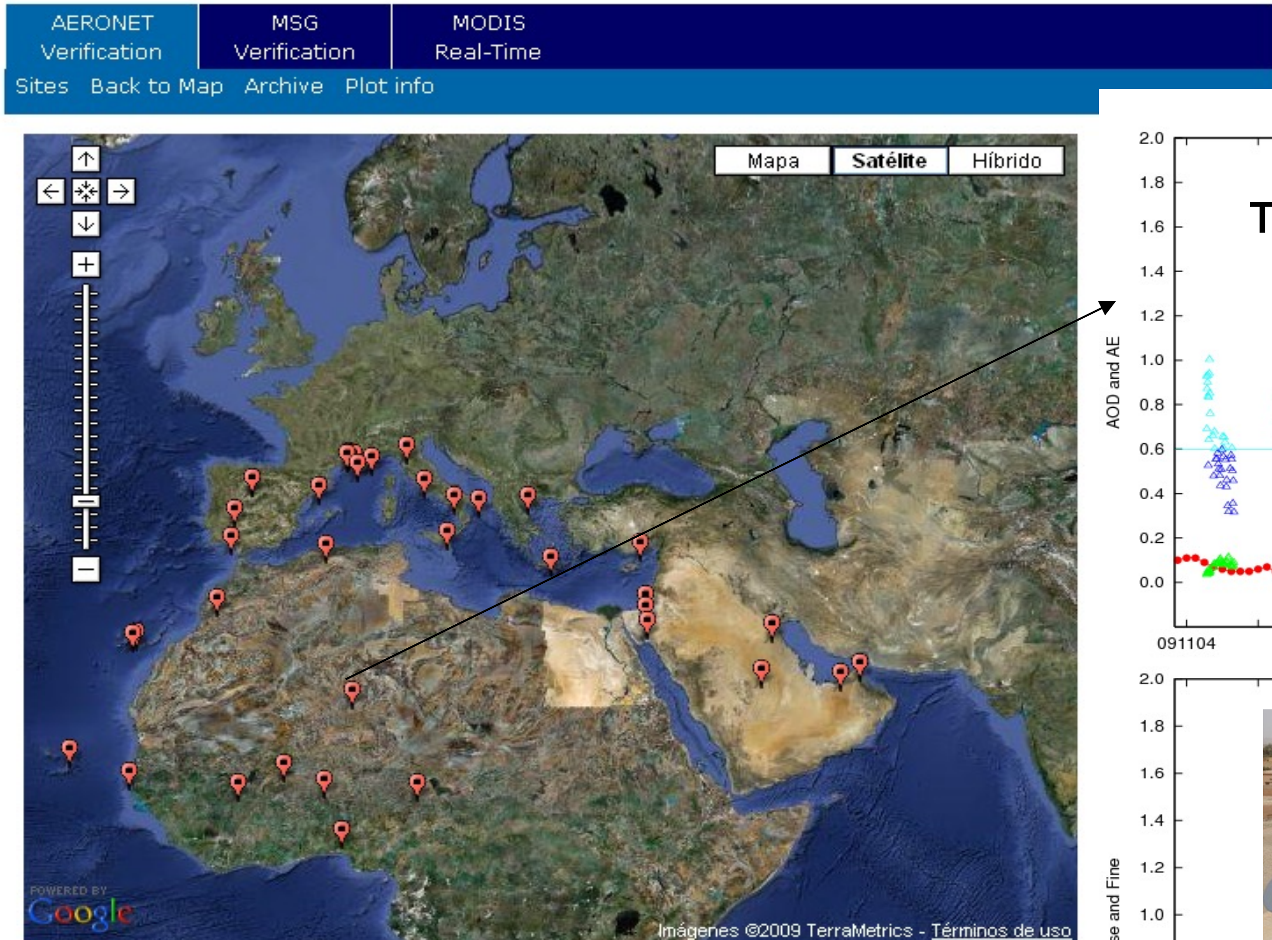
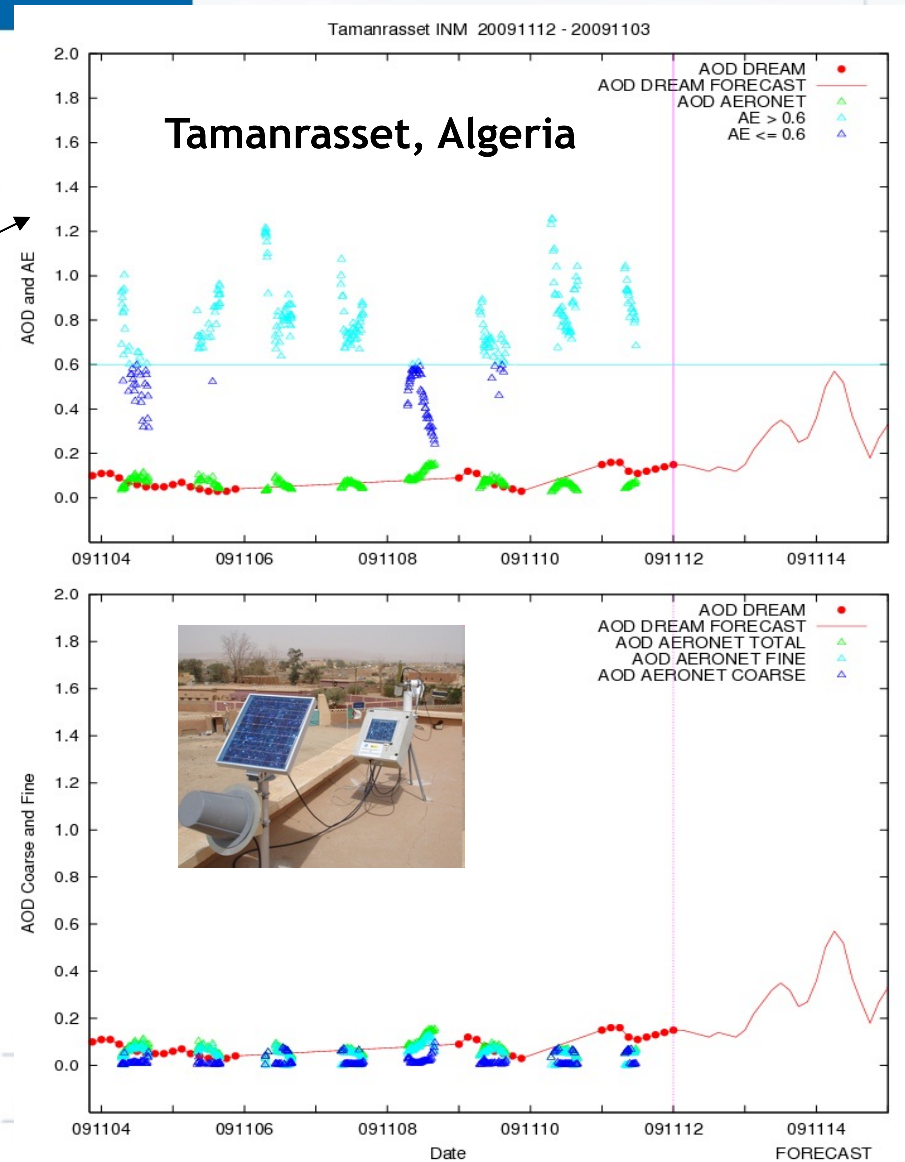


Figure 2. Monthly means of PM_{10} ($\mu g/m^3$), AOD and AI positive values.

Adam et al., 2010 (ACP-Interlaken): Detection of the Saharan dust air layer in the North Atlantic free troposphere with AERONET, OMI and in-situ data at Izaña Atmospheric Observatory

Ground-based remote sensing



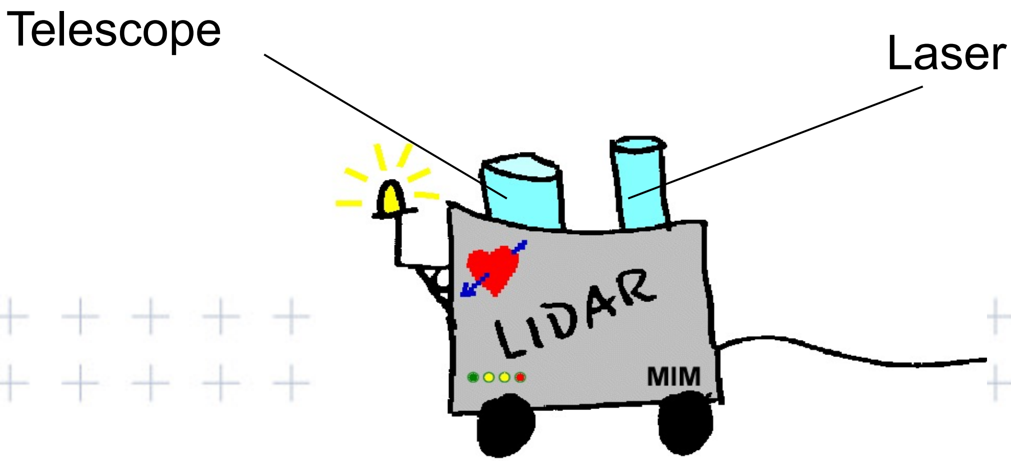


Near real time model verification against AERONET data

From total column observations…

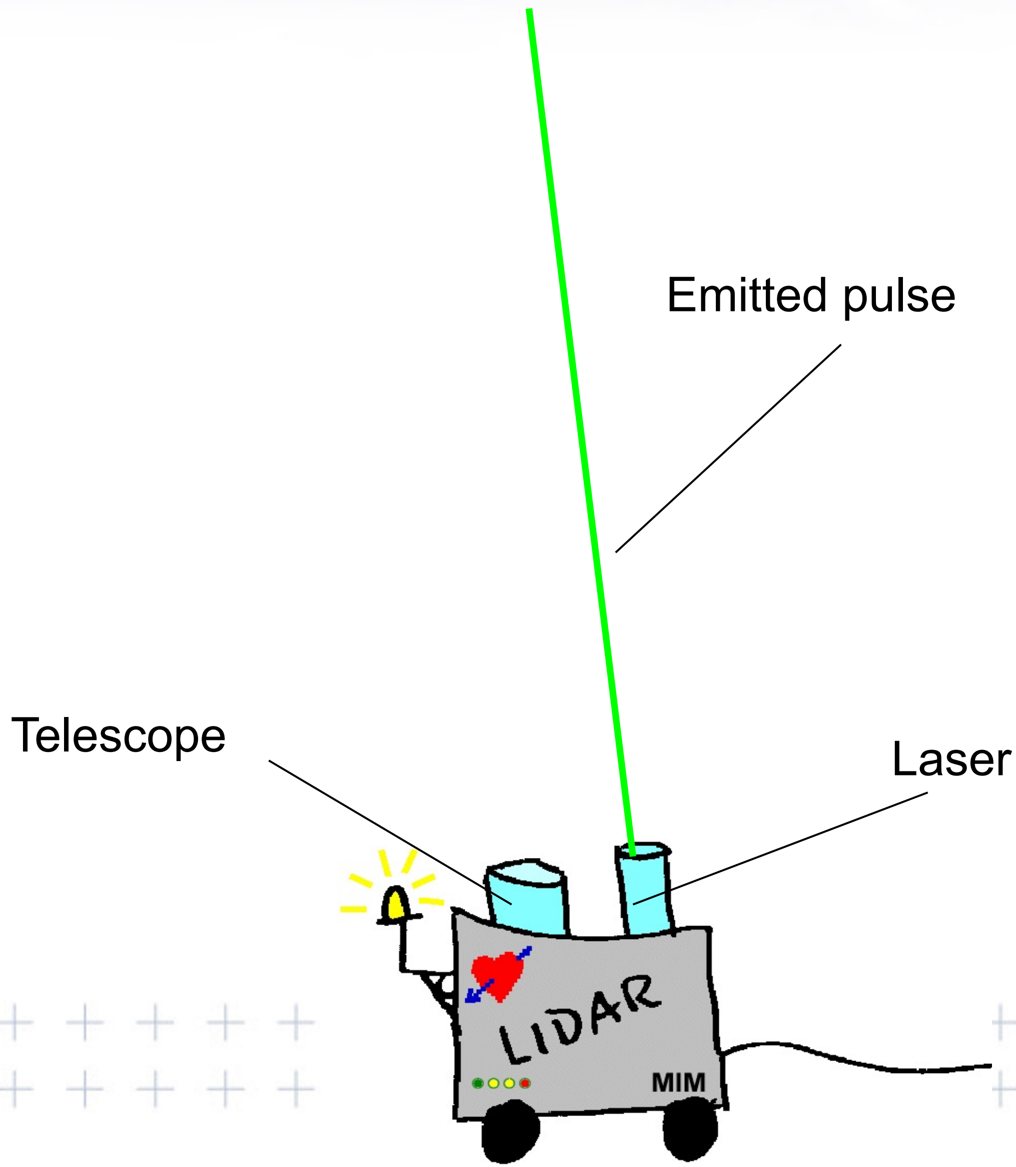
to vertical resolved observations

Lidars



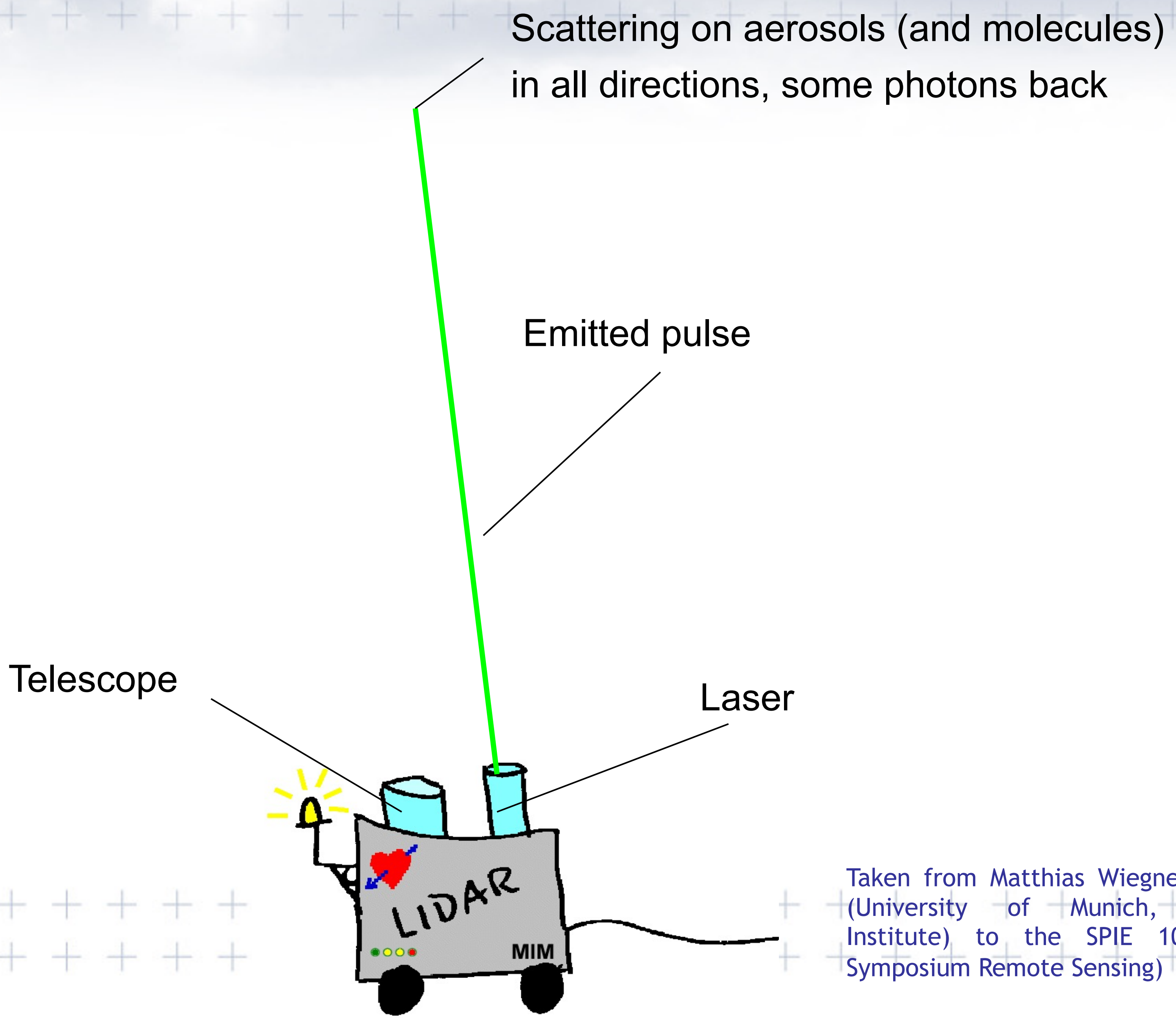
Taken from Matthias Wiegner's presentation (University of Munich, Meteorological Institute) to the SPIE 10 (International Symposium Remote Sensing)

Ground-based remote sensing



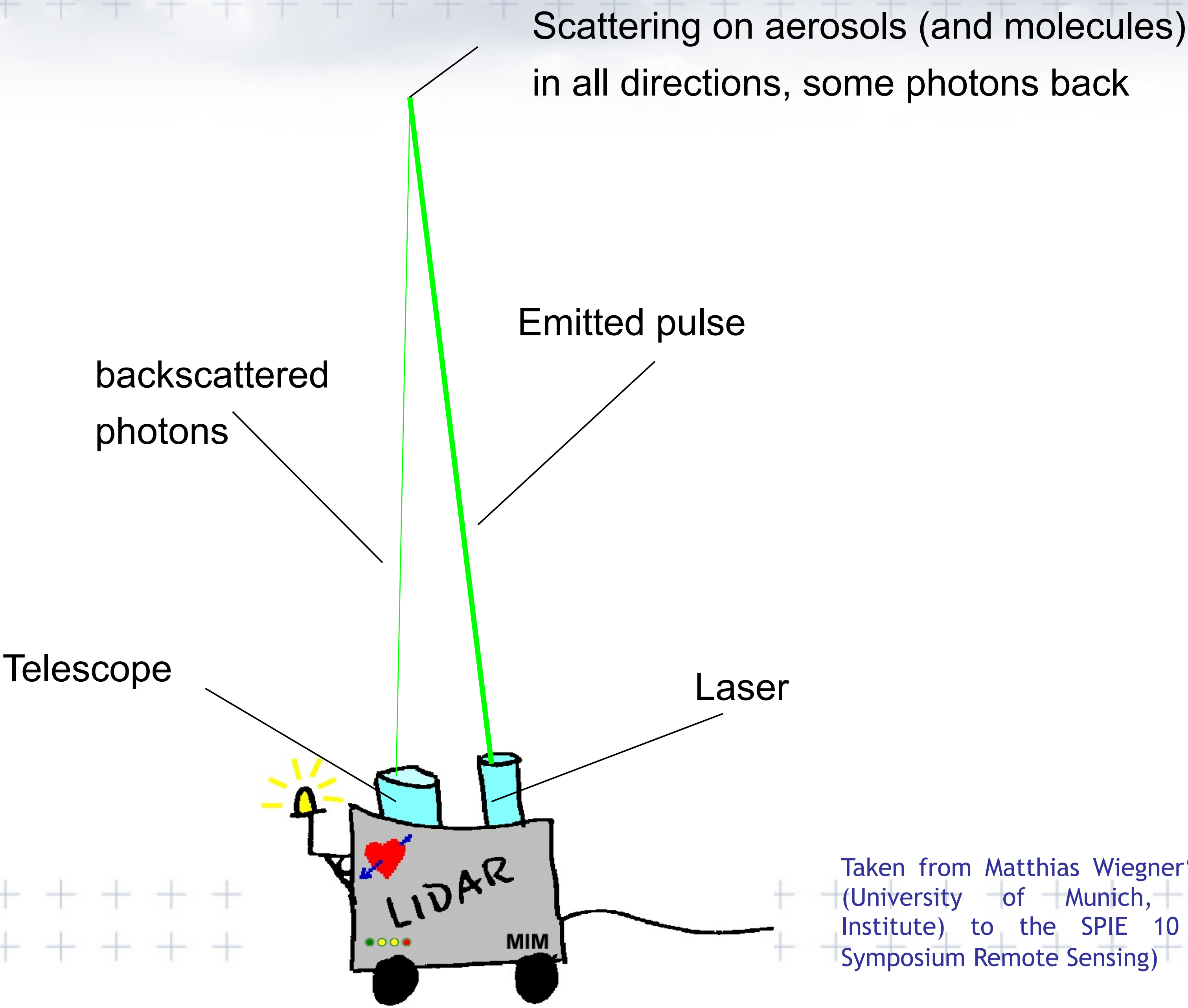
Taken from Matthias Wiegner's presentation (University of Munich, Meteorological Institute) to the SPIE 10 (International Symposium Remote Sensing)

Ground-based remote sensing



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

Ground-based remote sensing

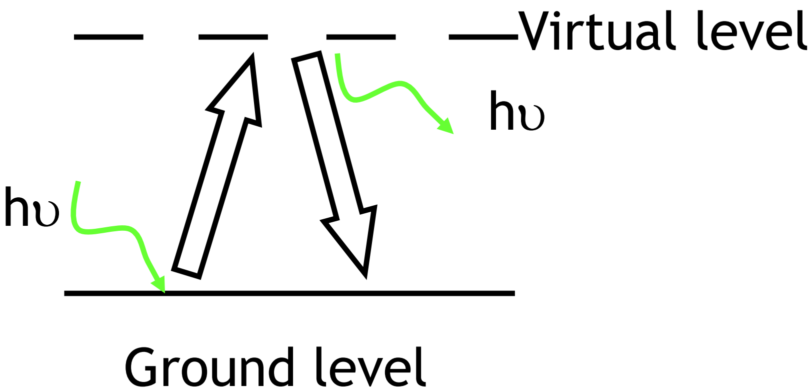


Taken from Matthias Wiegner's presentation (University of Munich, Meteorological Institute) to the SPIE 10 (International Symposium Remote Sensing)

Ground-based remote sensing

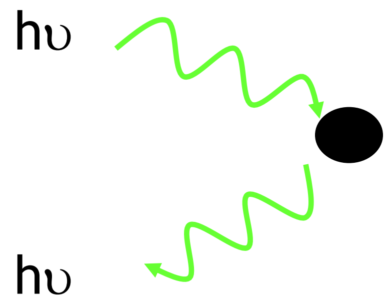
- Rayleigh Scattering

  "Laser radiation elastically scattered from atoms or molecules is observed with no change of frequency"



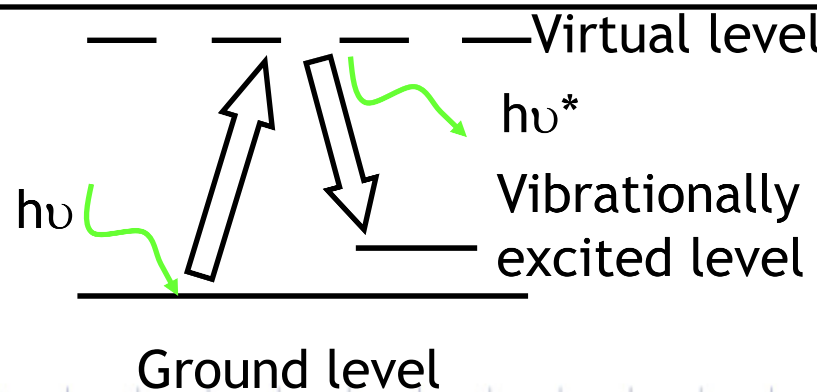
- Mie Scattering

  "Laser radiation elastically scattered from small particulates or aerosols (of size comparable to wavelength of radiation) is observed with no change in frequency"



- Raman Scattering

  "Laser radiation inelastically scattered from molecules is observed with a frequency shift characteristic of the molecule ($h\nu$ - $h\nu^*$ = E)"



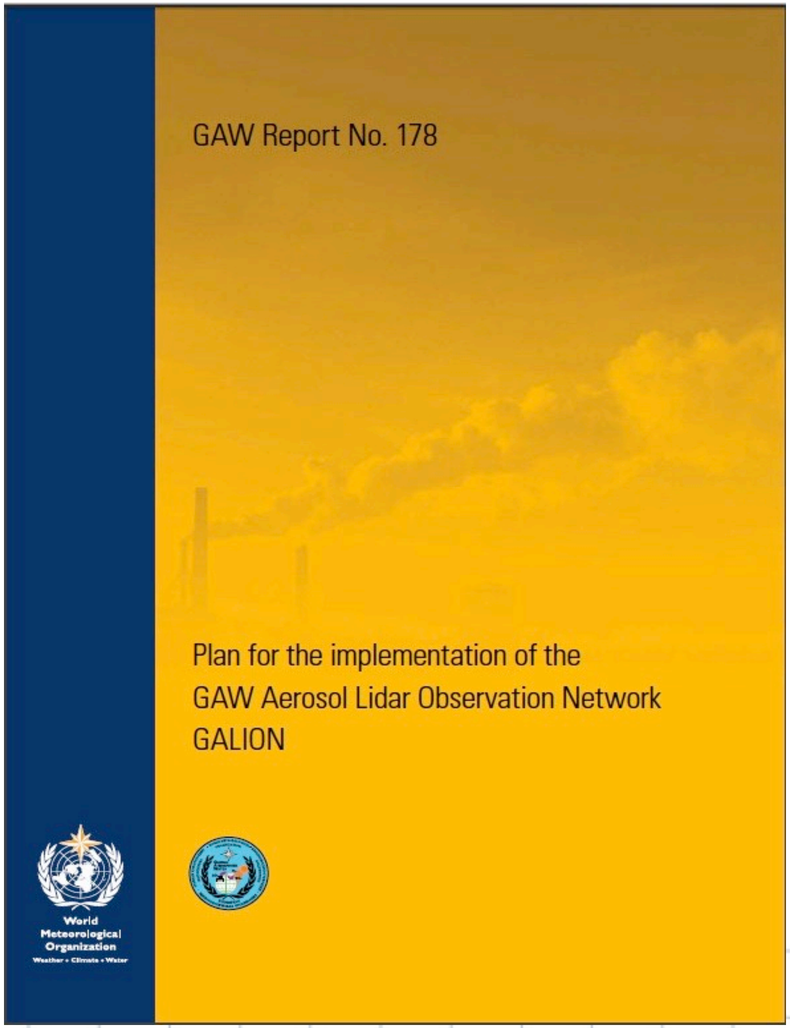
Taken from Laser Remote Sensing Fundamentals and Applications by Raymond M. Measures (pgs 206-207)

Ground-based remote sensing

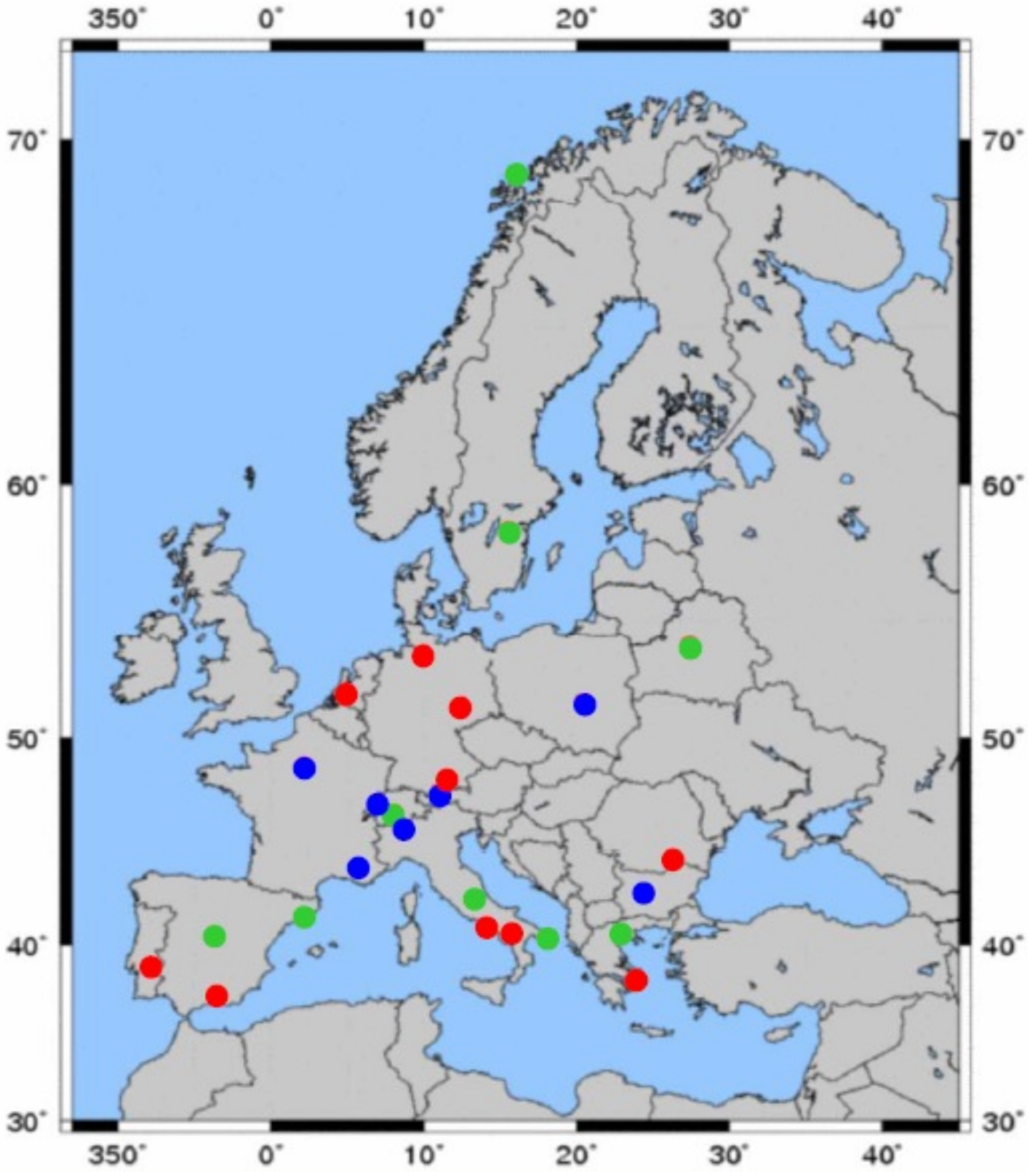
Lidar-Barcelona (UPC)
Raman Lidar
EARLINET-SPALINET

Lidar-Tenerife (INTA-AEMET); Elastic lidar
MPLNET

GAW Atmospheric Lidar Network (GALION)



ftp://ftp.wmo.int/Documents/PublicWeb/arep/gaw/gaw178-galion-27-Oct.pdf



EARLINET

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.

10 EARLINET stations are equipped also with sunphotometers (they are part of AERONET).

26 lidar stations

- **10 multiwavelength Raman lidar stations**

backscatter (355, 532 and 1064 nm) + extinction (355 and 532 nm) + depol ratio (532 nm)

- **9 Raman lidar stations**

- **7 single backscatter lidar stations**

Aerosol lidar (MPLNet)

http://mplnet.gsfc.nasa.gov/

523 nm MPLNET
Automatized since July 2005

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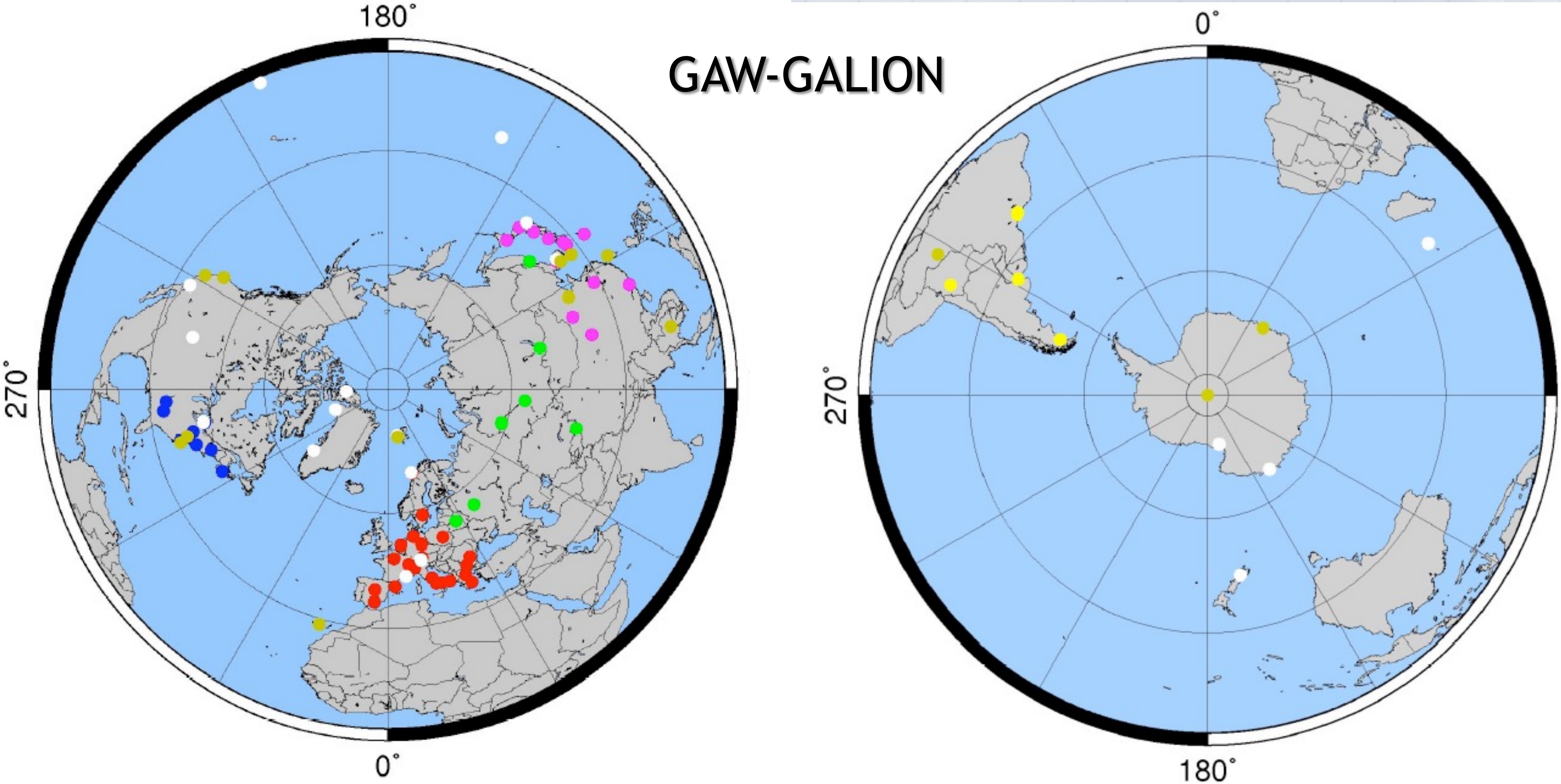
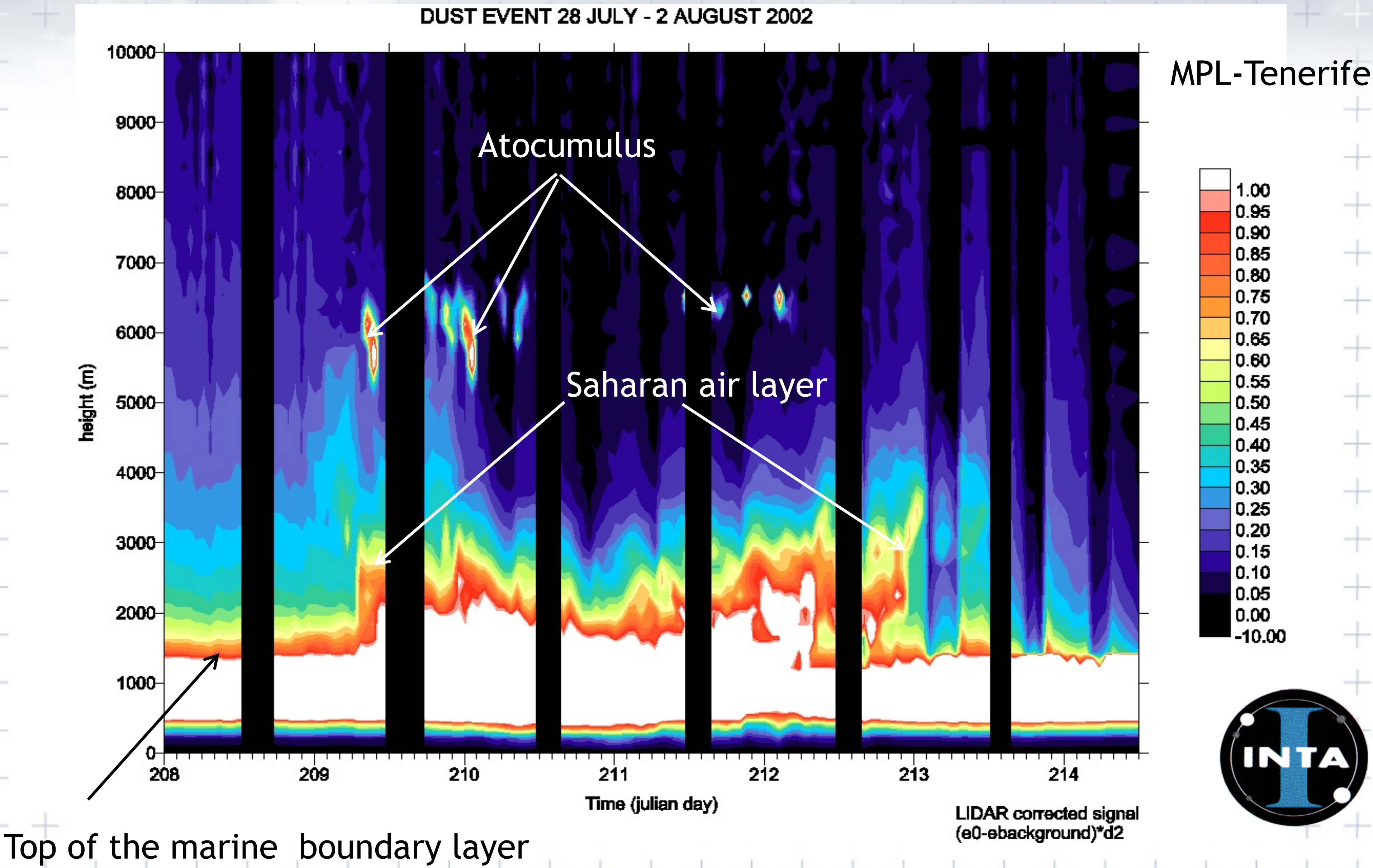
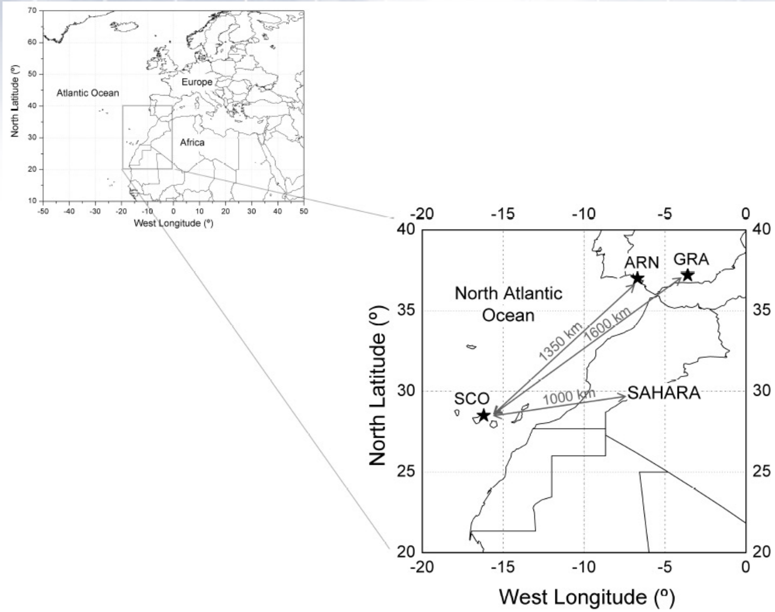
GAW-GALION



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

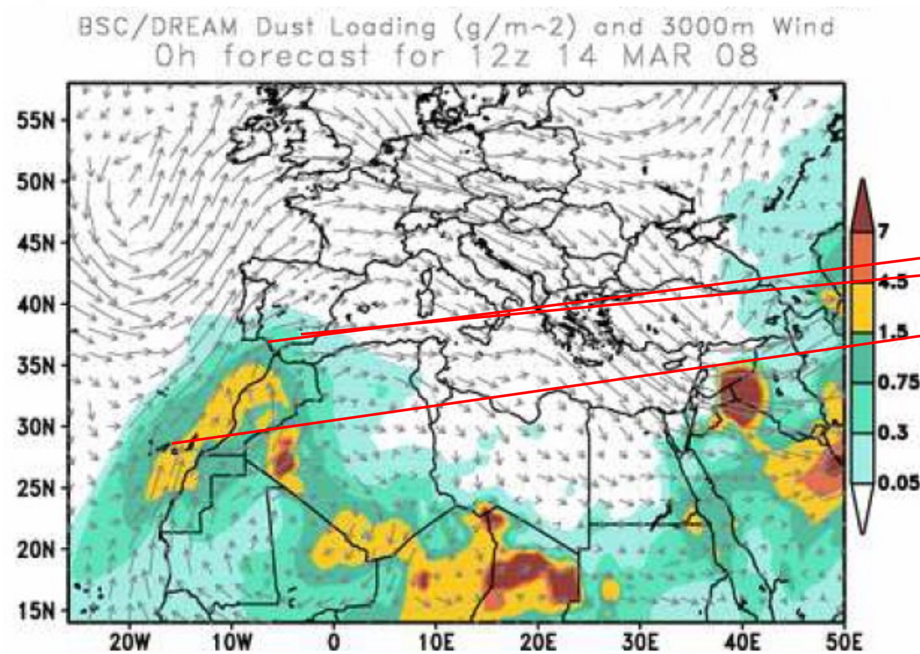
Ground-based remote sensing

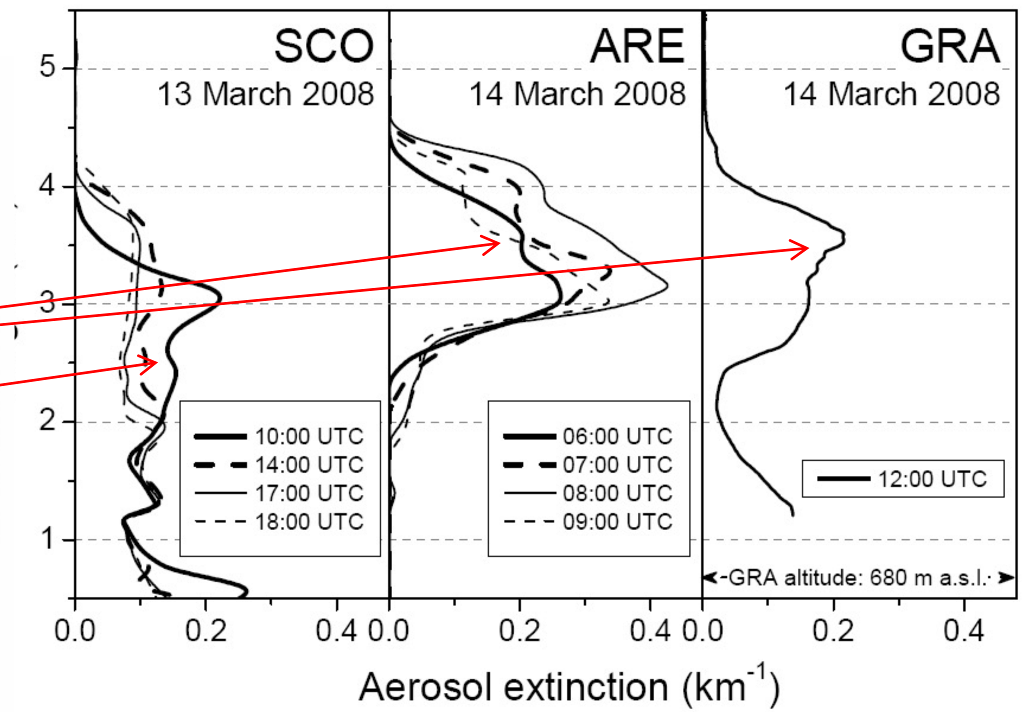




A case study of dust transport from Canary Islands to Iberian Peninsula

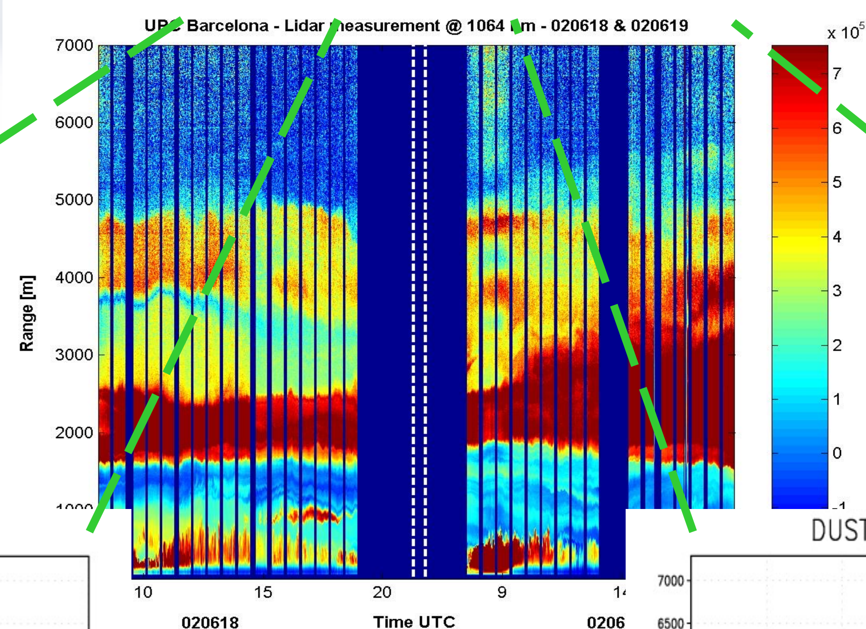
Córdoba-Jabonero et al., ACP Discuss., 2010





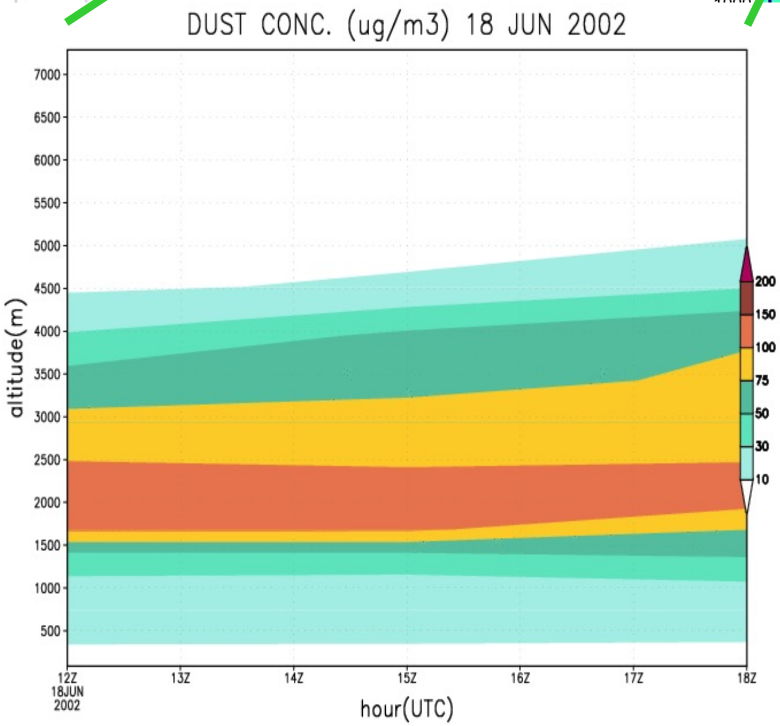
Ground-based remote sensing

Barcelona lidar vs DREAM BSC

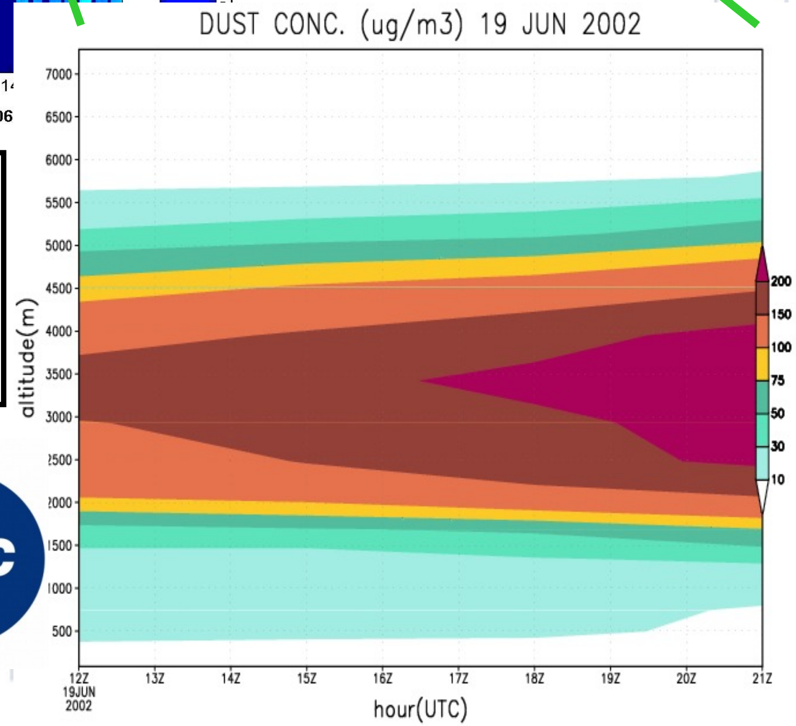


EARLINET: Lidar-UPC, Barcelona

18-19 June 2002

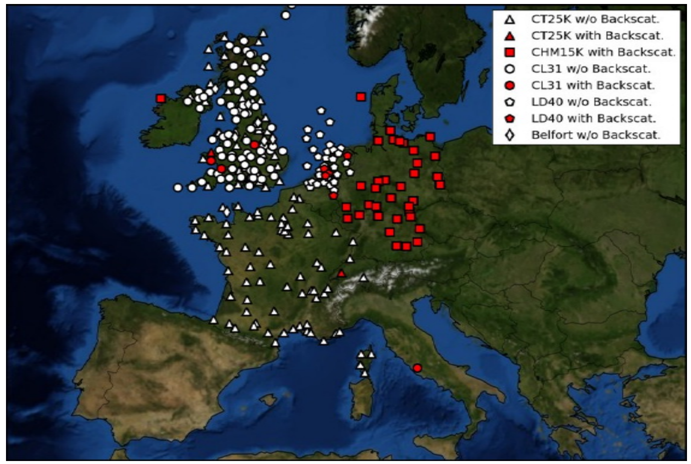


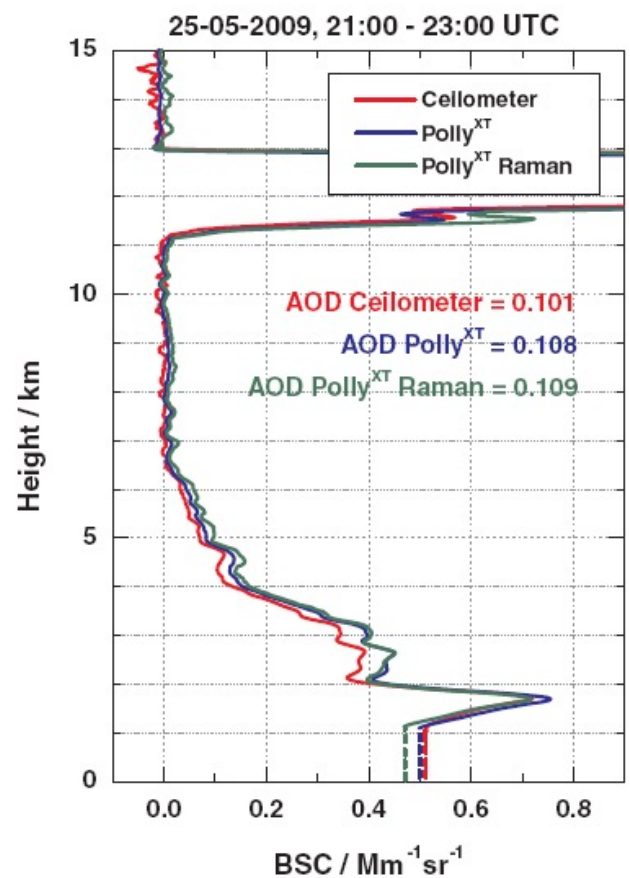
Vertical dust distribution validation:
AIRLINET-DREAM



Ceilometer network

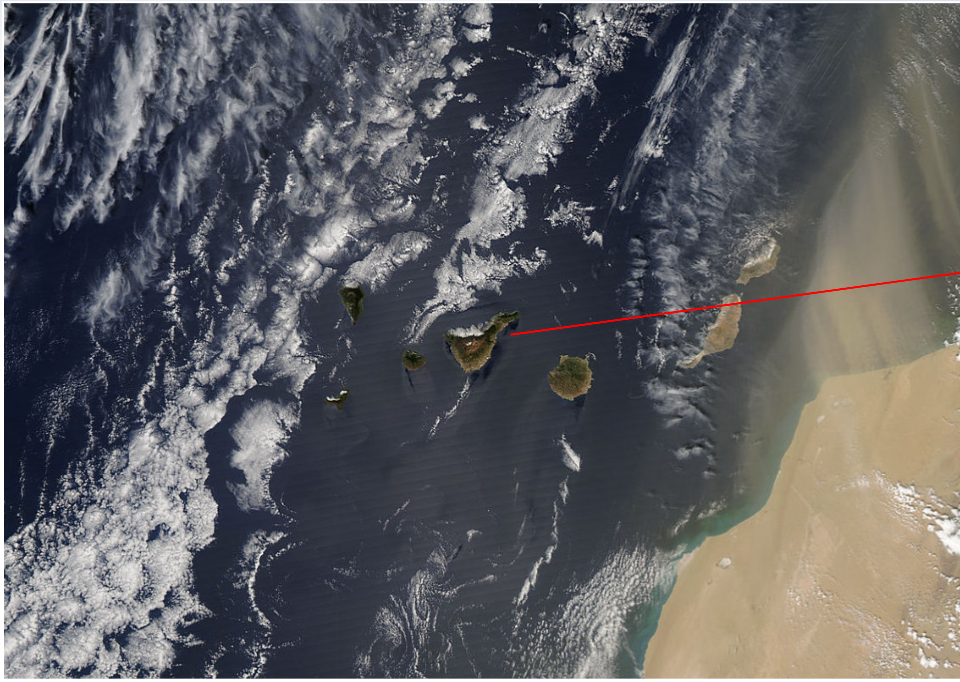
Met Services are replacing **cloud-base** ceilometer networks by **aerosol backscatter profiling ceilometers (IR wavelenght).**
<u>**Objective:**</u> **To monitor MLD** based on **several hundred profiling ceilometers (100km sampling)**





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

Optimal for desertic areas !!



Viasala Ceilometer CL-51

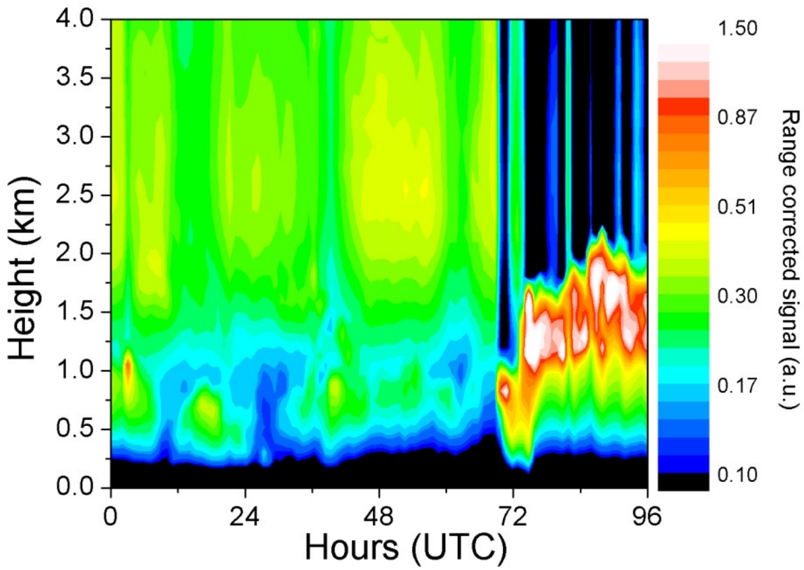
MicroPulse Lidar and Ceilometer inter-comparison during Saharan dust intrusions over the Canary Islands

Y. Hernández, S. Alonso-Pérez, E. Cuevas, C. Camino, R. Ramos, J. de Bustos, C. Marrero, C. Córdoba-Jabonero and M. Gil (2011)

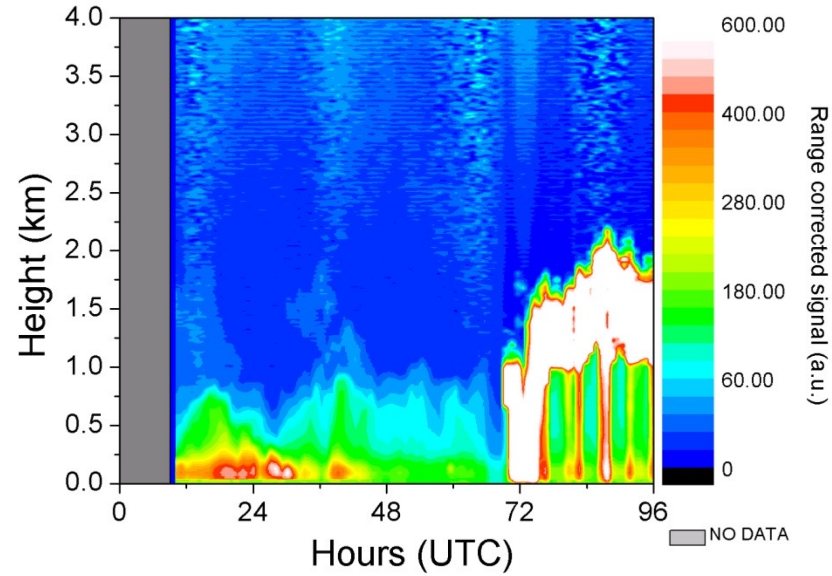
Campaign performed from January to March 2011 in Tenerife island

Ground-based remote sensing

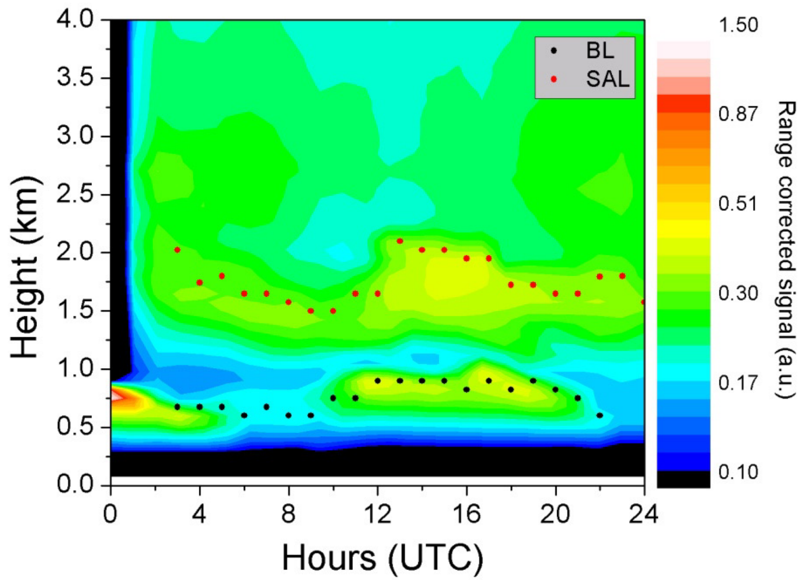
MPL-3 - Sta. Cruz de Tenerife. Mar 31- Apr 3, 2011



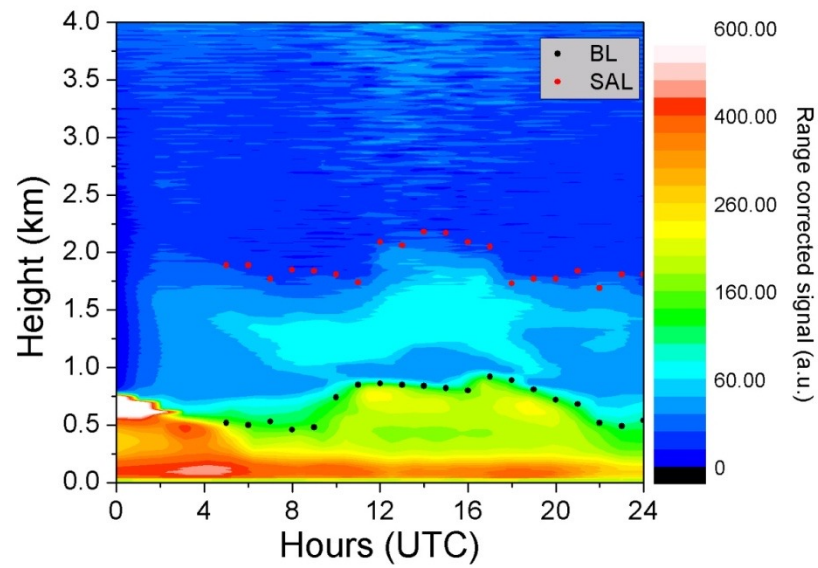
CL51 - Sta. Cruz de Tenerife. Mar 31- Apr 3, 2011



MPL-3 - Sta. Cruz de Tenerife. Feb 24, 2011

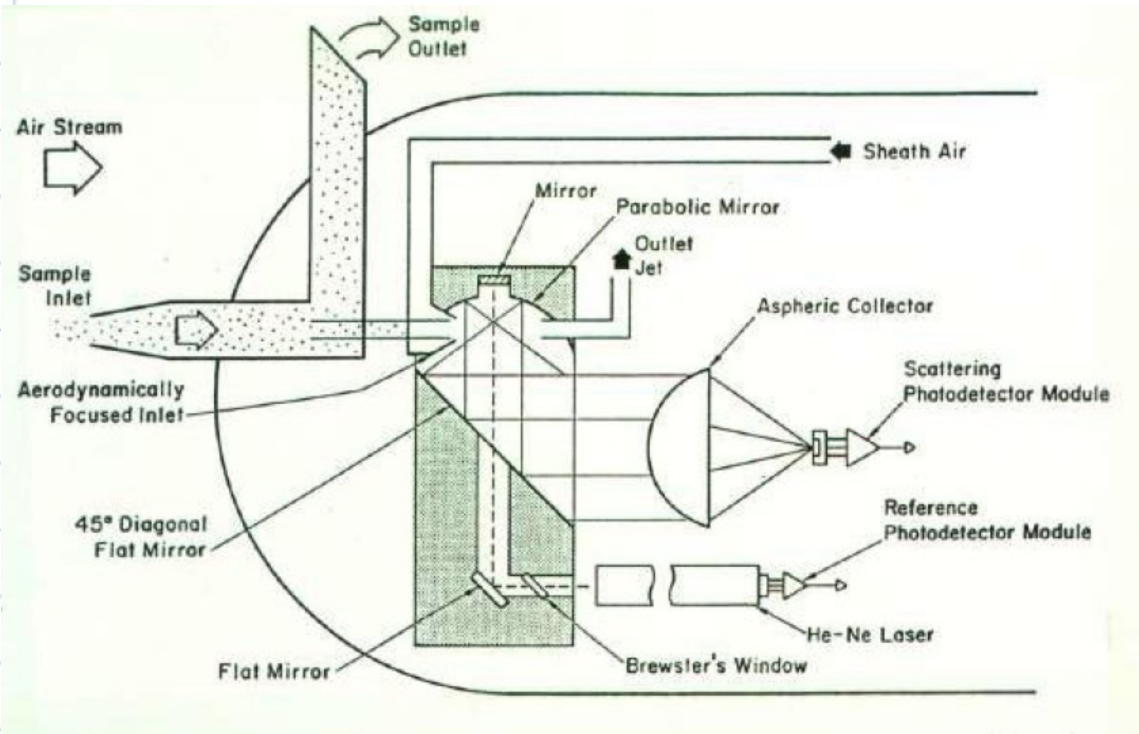


CL51 - Sta. Cruz de Tenerife. Feb 24, 2011



a Estatal de /

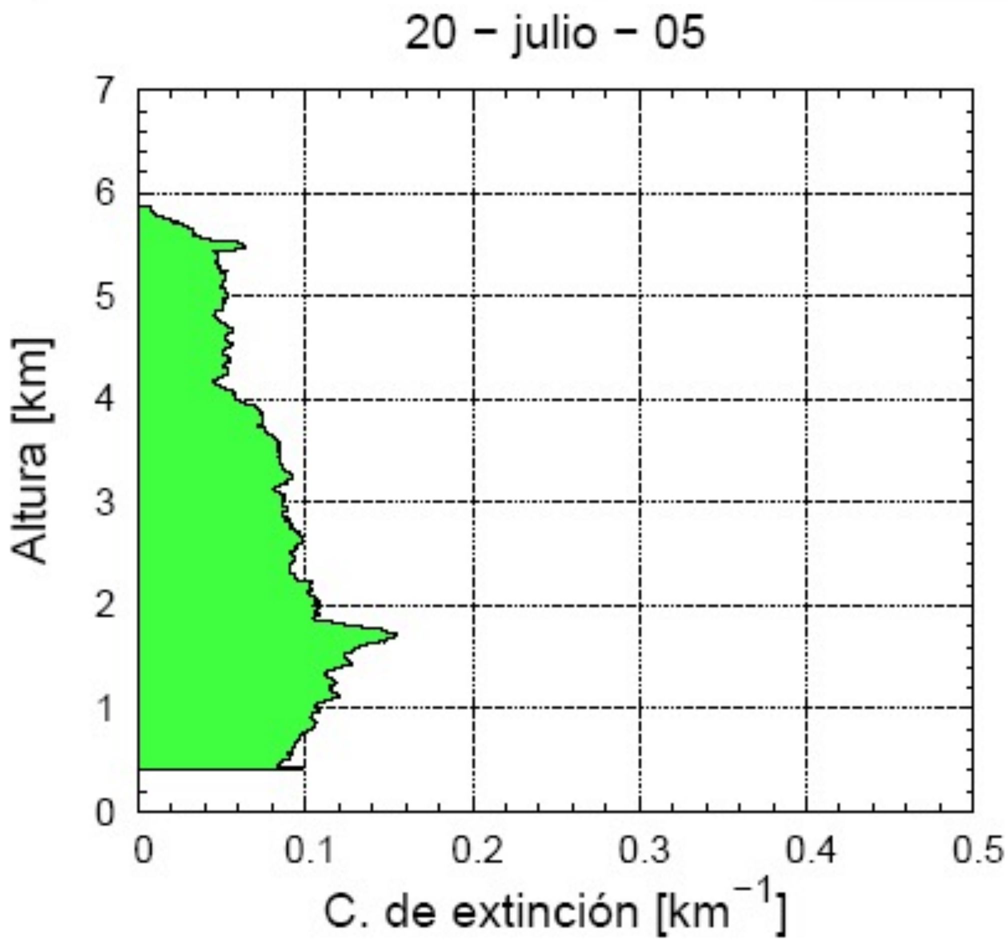
Airborne in-situ measurements

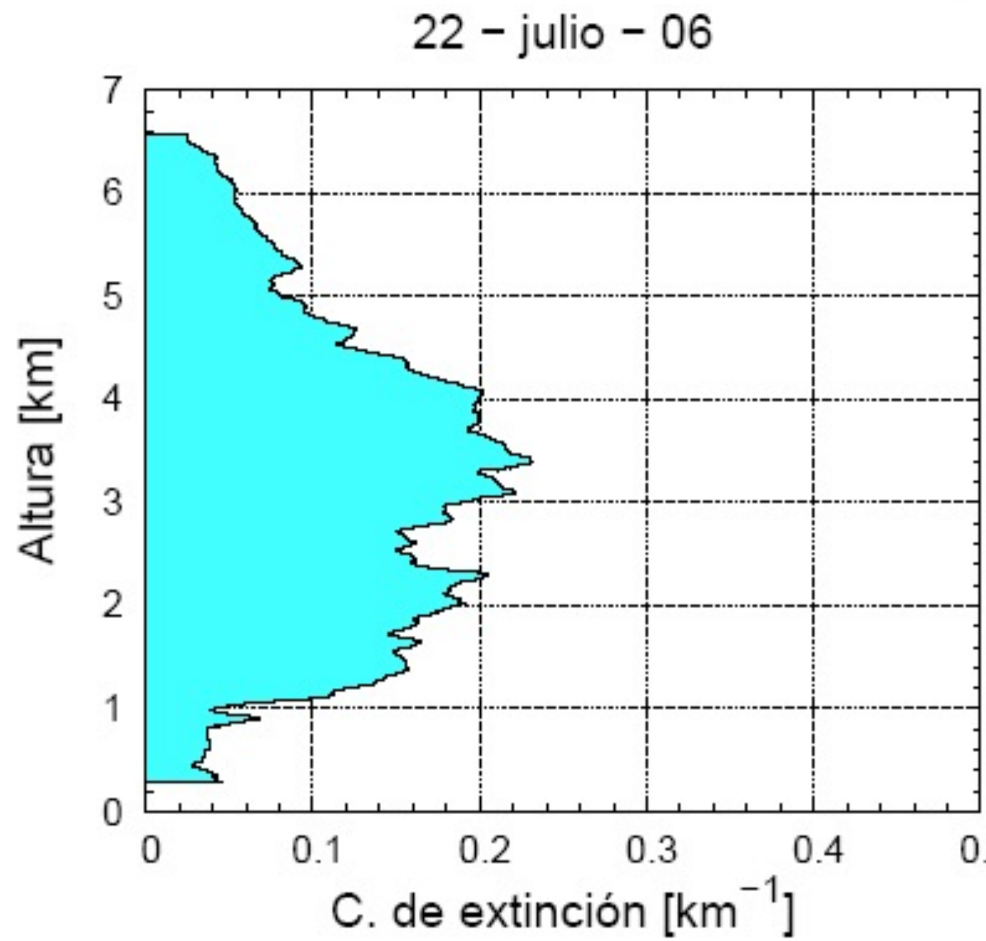


PCASP-100X sonde

Optical counter
0.1 - 3.0 um en 15 channels
Up to 20,000 particles /s
A size distribution /s

Airborne in-situ measurements





Andrey, 2011 (PhD)

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In-situ measurements and surface remote sensing compared to satellite

	Advantages	Disadvantages
In-situ measurements		
Ground-based remote sensing		
Satellite remote sensing		

In-situ measurements and surface remote sensing compared to satellite

	Advantages	Disadvantages
In-situ measurements	- very straightforward; - unique dust physical and chemical information; - universal applicability (no sky conditions dependent) - Time high resolution (minutes)	- intrusive measurements; - local coverage in some sites
Ground-based remote sensing	- high information on dust (transmitted light dominates over reflected); - non-intrusive measurements; - easy access to equipment; - column dust information	- local coverage; - indirect measurements; - very limited capability in presence of clouds (Photom.)
Satellite remote sensing	- global coverage; (global dust) - non-intrusive measurements	- limited on information aerosol (aerosol and surface effects to be separated); - no access to equipment

Summary

Ground-based dust observations are essential for:

- High-accuracy optical and chemical characterization of dust
- Dust model verification, validation and assimilation
- Dust satellite-based products validation

Ground based 'supersites' equipped with complete high-quality dust observation programs (in-situ and remote sensing) constitute unique platforms for satellite-based dust observations and dust models quality assurance

Thank you for your attention

www.aemet.izana.org

ecuevasa@aemet.es