Lectures on atmospheric mineral dust and its impact on human health, environment and economy

Barcelona, November 13, 2010

Ground based observations of mineral dust

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Chad-2004 by Jahi-Chikwendiu

World Press Prize 2004

Aerosols: suspended fine solid or liquid particles in a gas

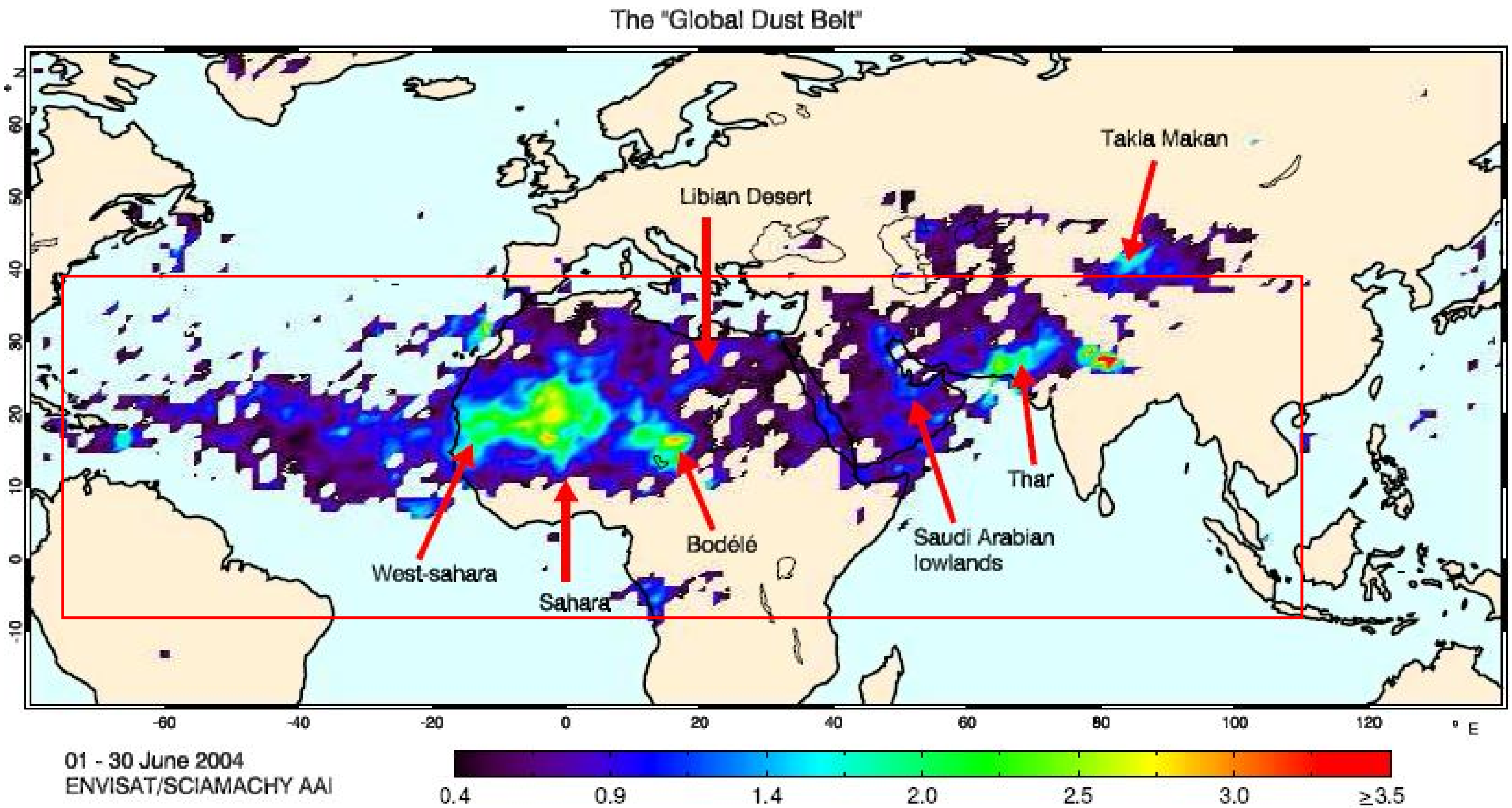
- Size range of particles in the atmosphere, 0.001 to 100 µm (1 µm= 10^{-6} m)

Mineral dust: Cloud Condensation Nuclei (CCN), Giant CCN

- 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



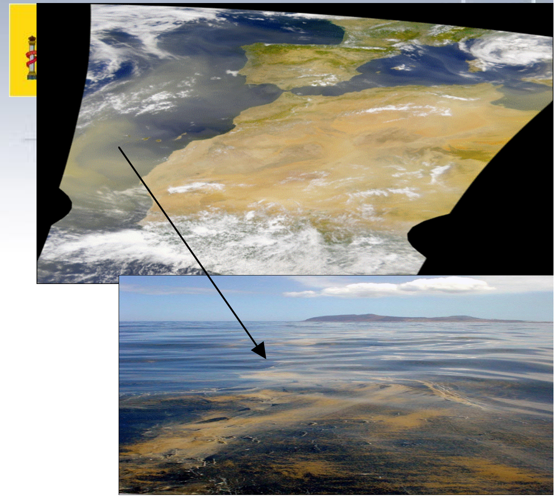
Sahara, Sahel, Arabian Peninsula, Thar desert (Middle East), Aral Sea (Central Asia), Taklamakan desert (China), Gobi Desert (China/Mongolia), Lake Eyre Basin (Australia)

(de Graaf, 2006)

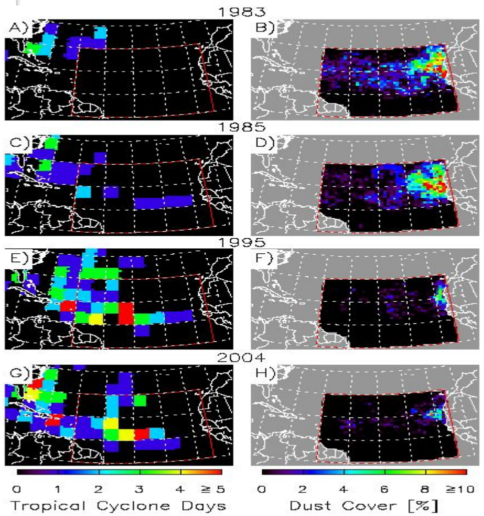
Background

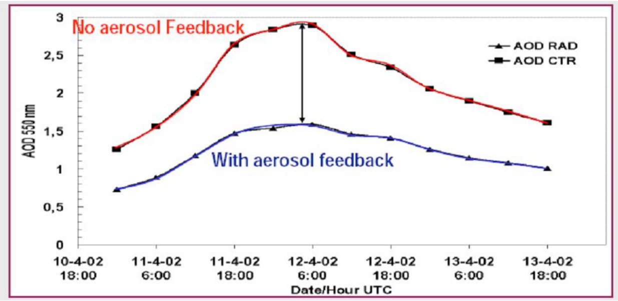
Human Health (Asthma, infections, Meningitis in Africa, Valley Fever in the America's)

Agriculture (negative & positive impacts)



Marine productivity (negative & positive impacts)

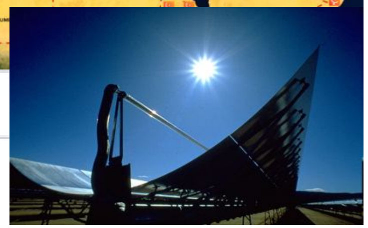




Improved Weather and Seasonal Climate prediction

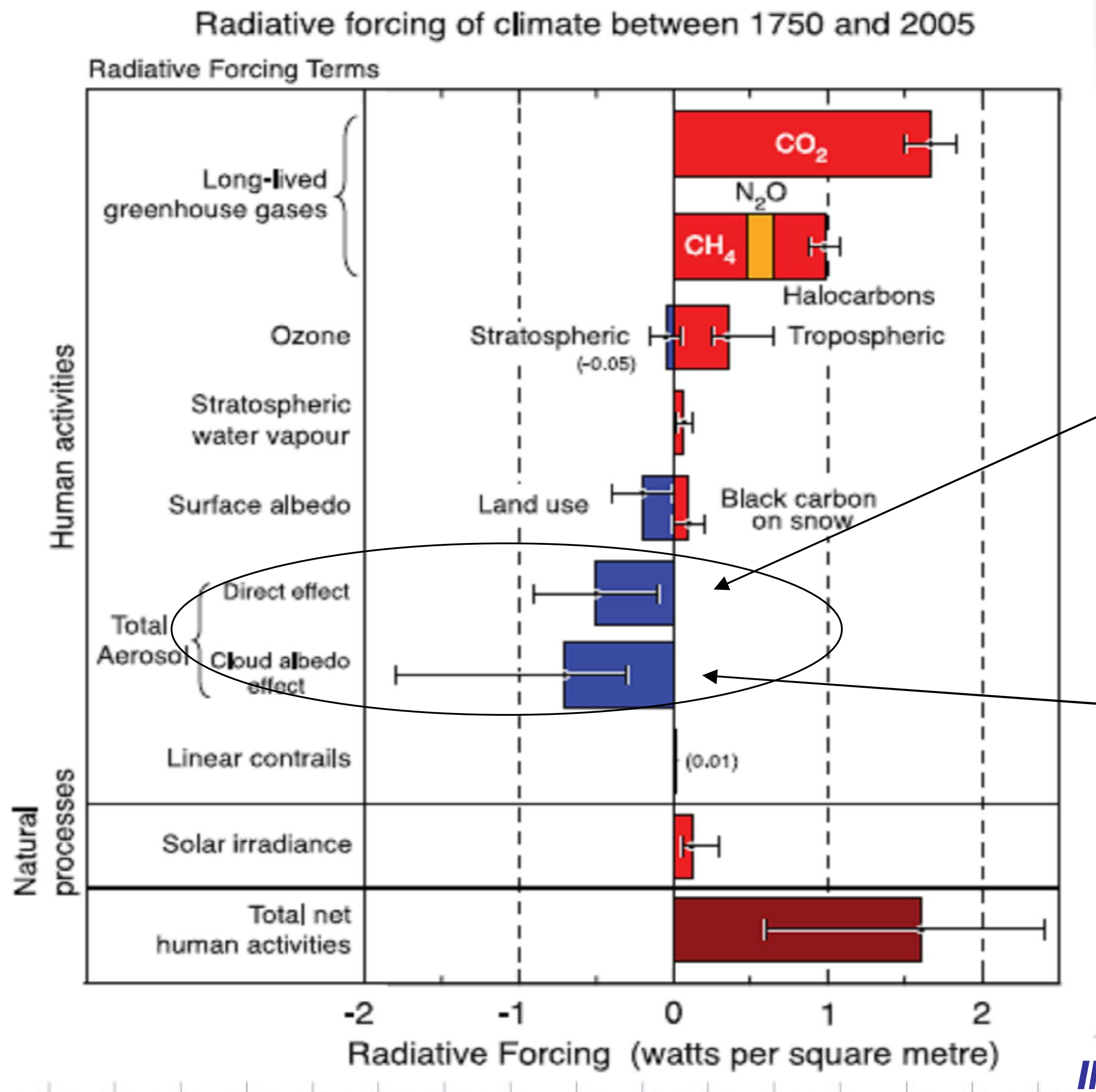
Industry (Semi-conductor, etc.)

Energy (Thermal solar energy)



Aviation (air disasters)
Ground Transportation

Background

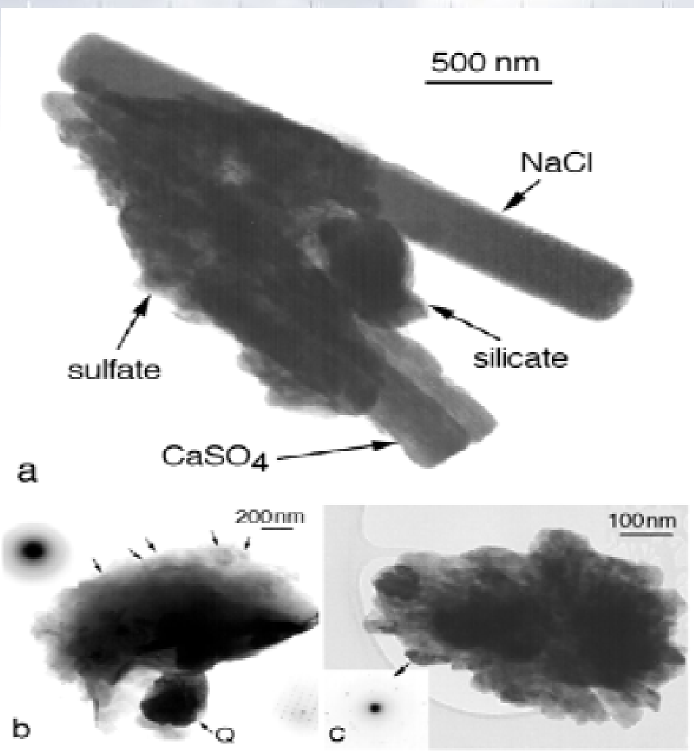


- The total direct aerosol RF as derived from models and observations is estimated to be –0.5 [±0.4] W m^{-2}, with a ***medium-low*** level of scientific understanding.

- 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.

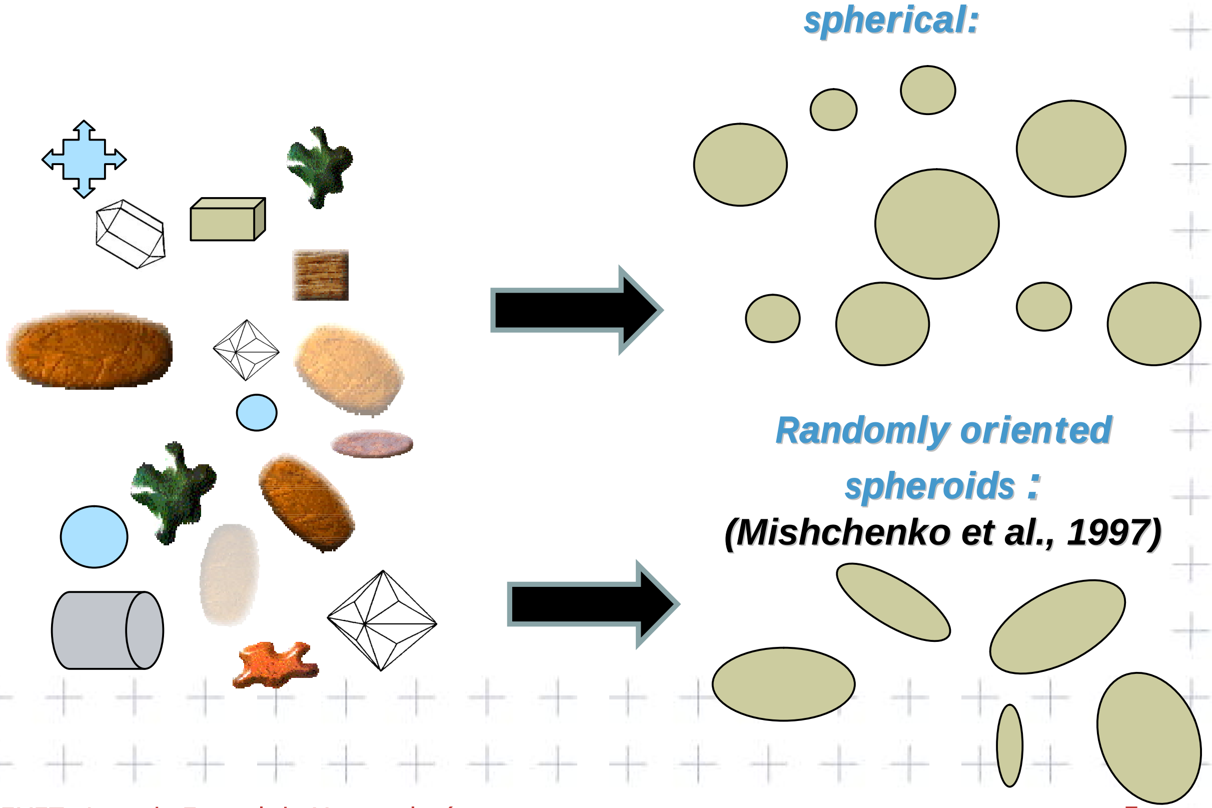
IPCC's Fourth Assessment Report (2007)

Dust Particle Images



Busek and Posfai, 1996

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

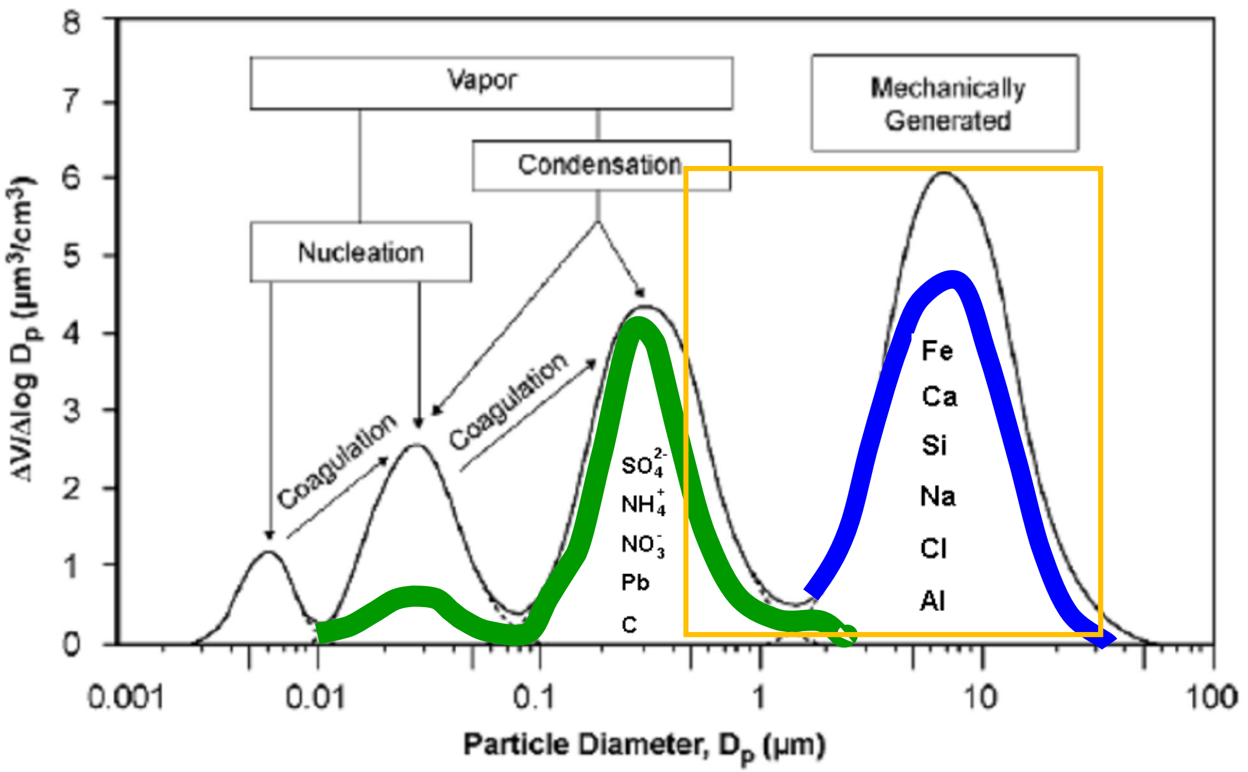


Background

PM_{10} (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 :

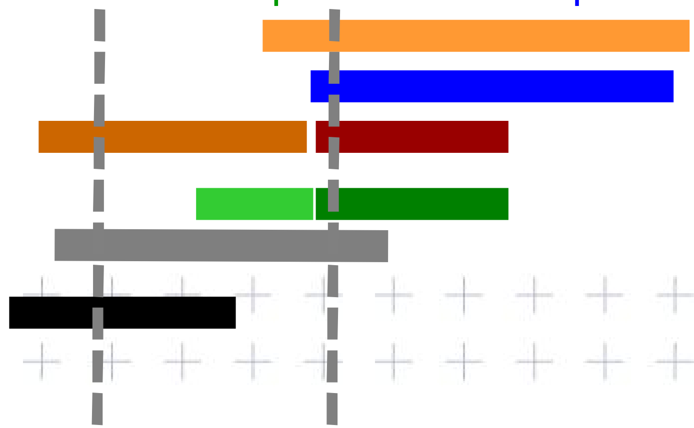
Marine salt:

Sulfate:

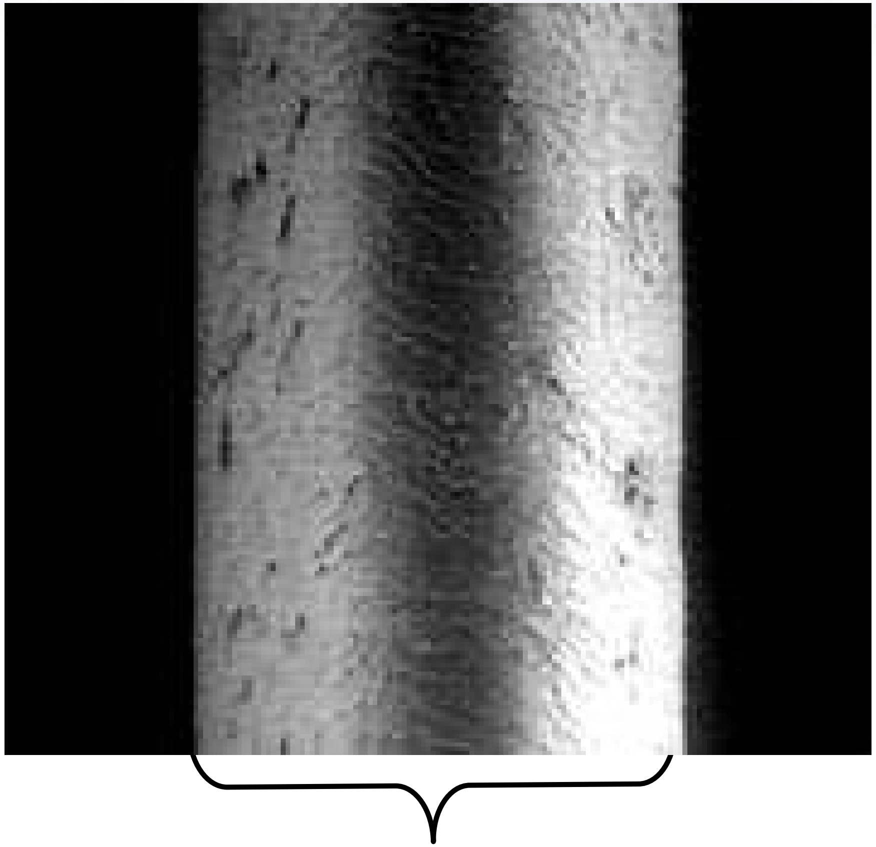
Nitrate:

Organic aerosol:

black carbon:

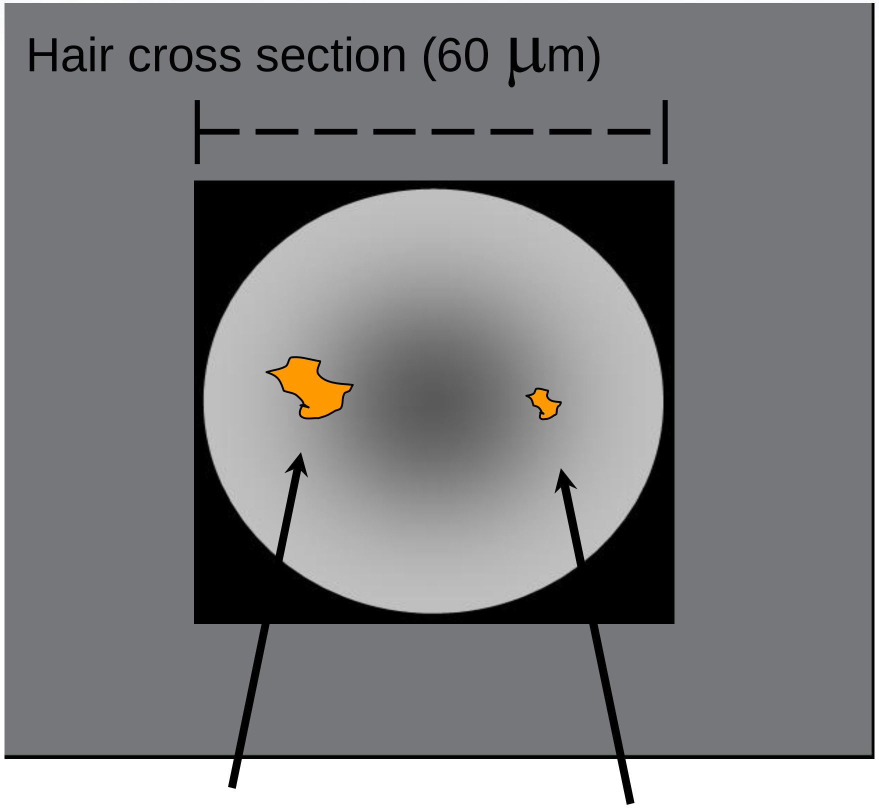


Background



Human Hair

(60 µm diameter)



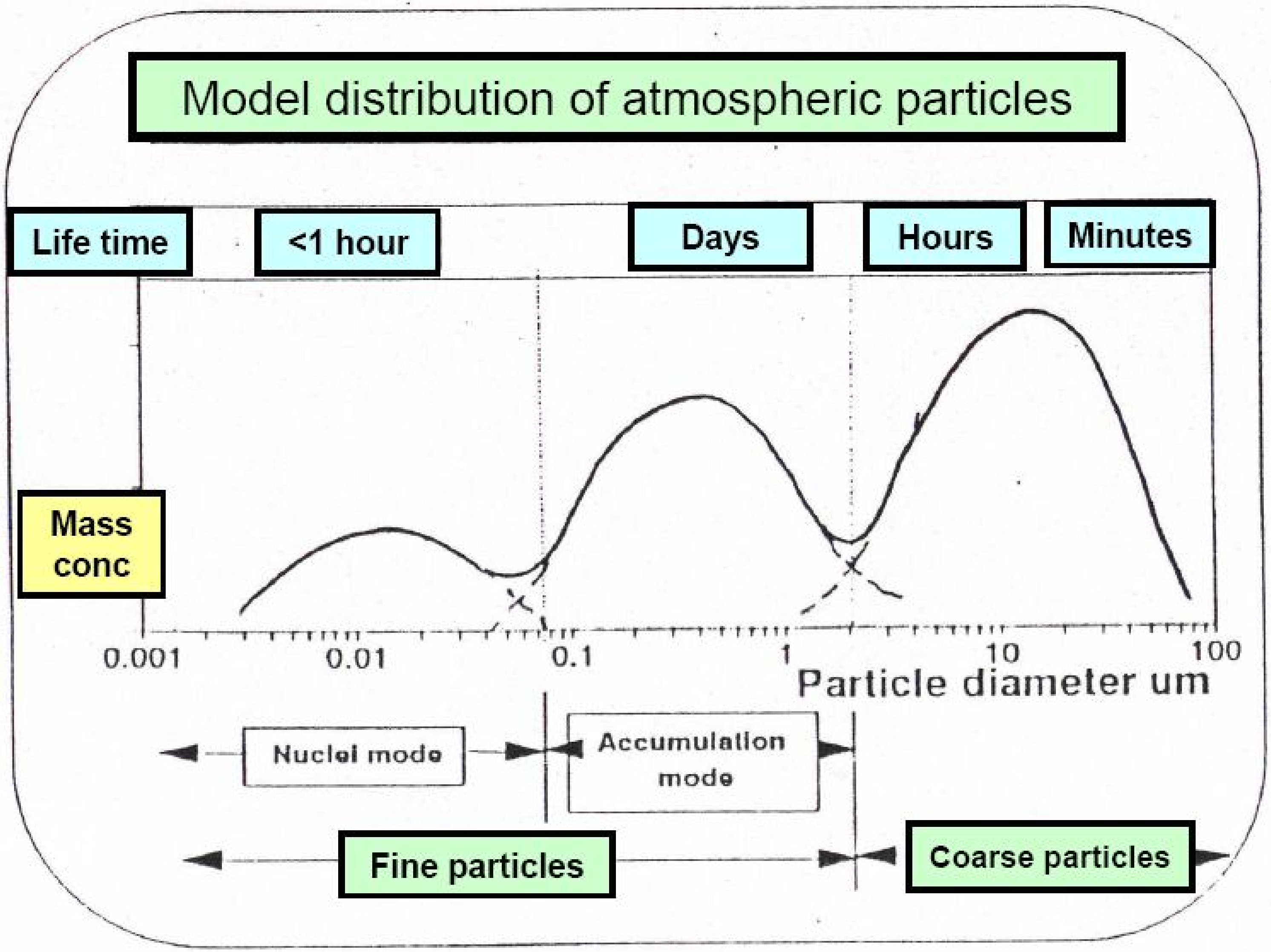
PM_{10}

(10 µm)

$PM_{2.5}$

(2.5 µm)

Background



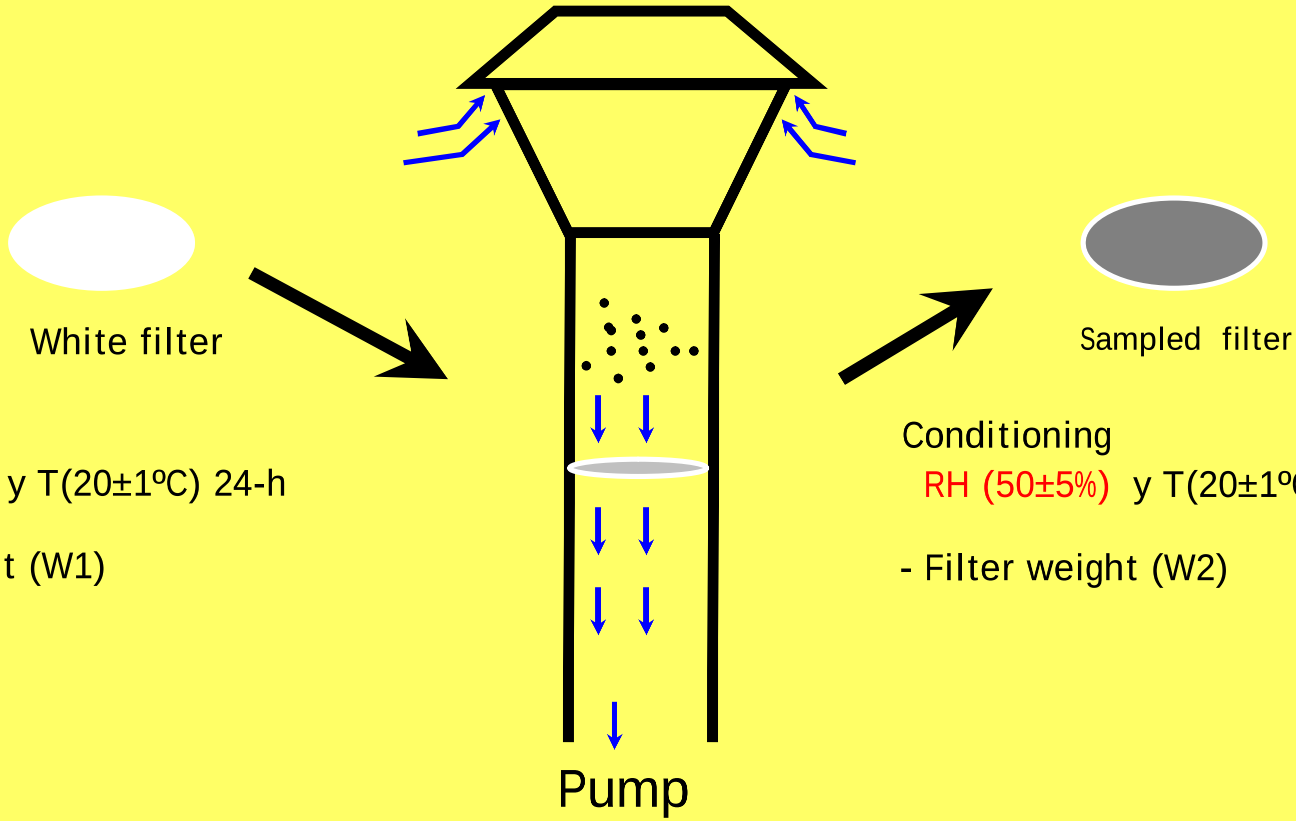
Particles in the Atmosphere: atmospheric residence timeModel

In-situ measurements (PM)

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

1. Reference method: gravimetric method

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



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

- Filter weight (W1)

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

- Filter weight (W2)

In-situ measurements (PM)

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

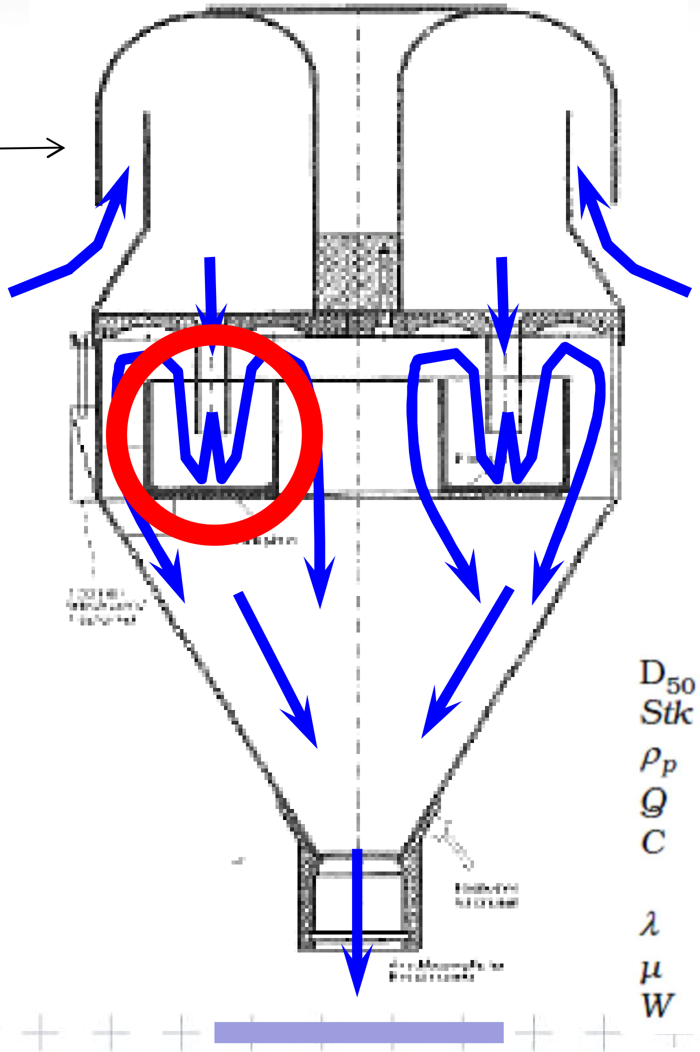
1. Reference method: gravimetric method

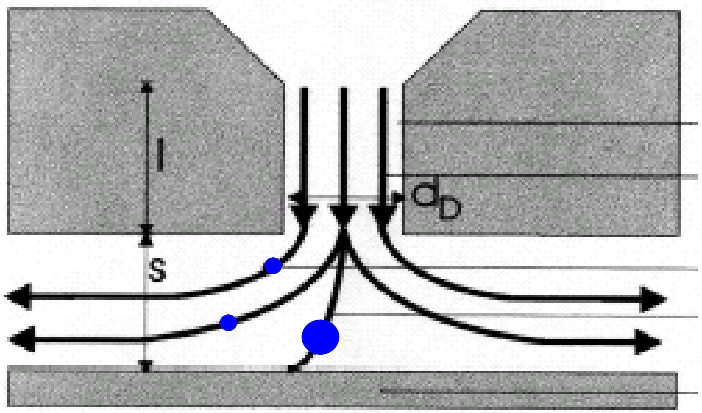
LVS: 2.3 m^3/h — Low Volume Sampler

HVS: 68 m^3/h — High Volume Sampler

WRAC: 1966 m^3/h — Wide Range Aerosol Cla

In-situ measurements (PM)





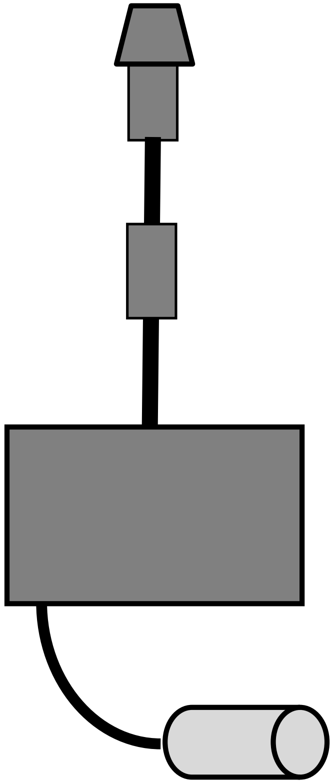
$$D_{50} = \sqrt{\frac{9\pi Stk\,\mu W^{3}}{4\rho_{p} C Q}}$$

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.

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

2. Automated analyzers

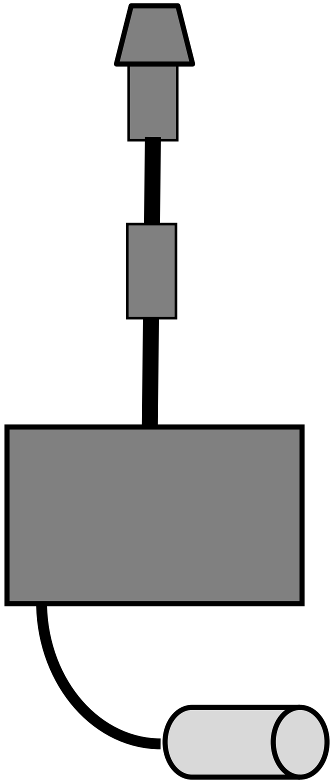


1. Impactor PM_{10} / $PM_{2.5}$
2. RH reductor / heater
3. Sensor (Beta radiation attenuation or Tapered Oscillating microbalance-TEOM-) → instead of weighting filters
4. Pump / Flow meter

In-situ measurements (PM)

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

2. Automated analyzers

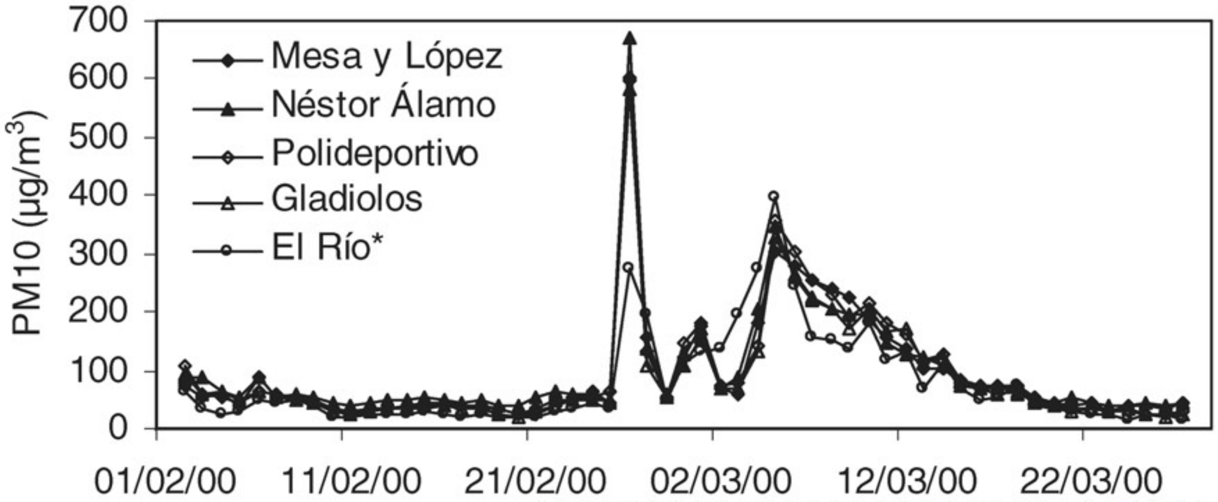


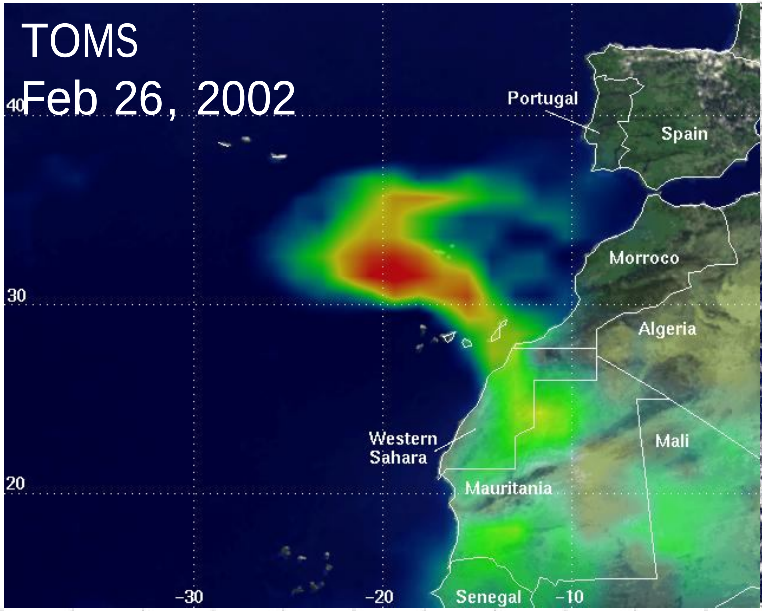
beta

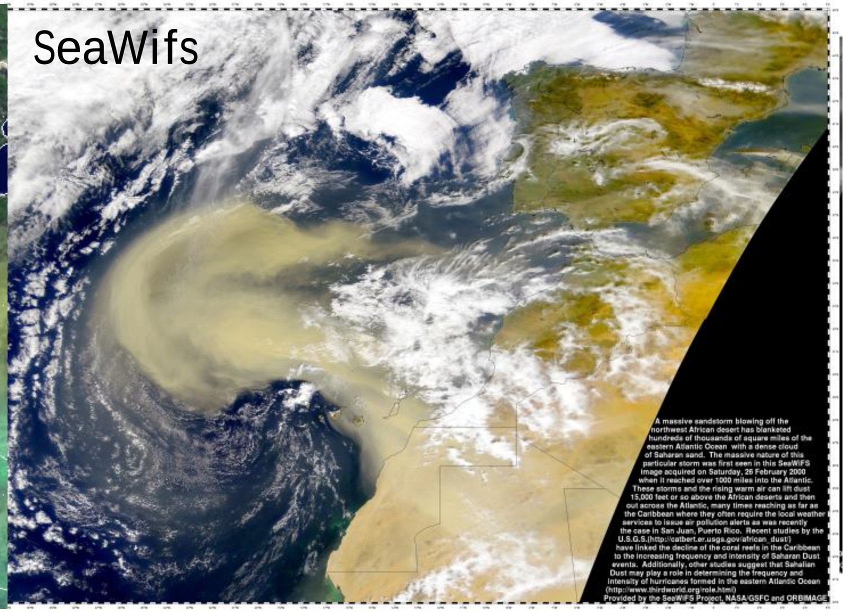
TEOM

In-situ measurements (PM)

Air quality stations at Tenerife Island







Viana et al., Atmospheric Environment , 2002

In-situ measurements (PM)

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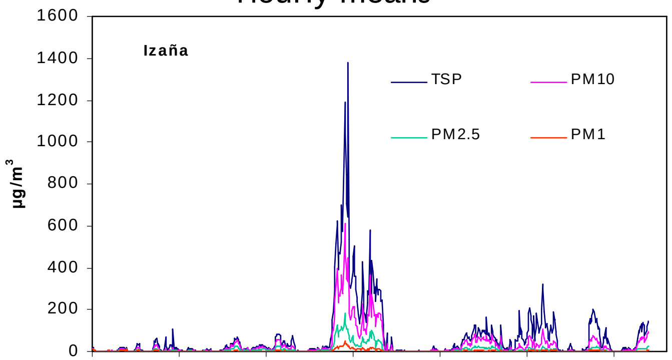
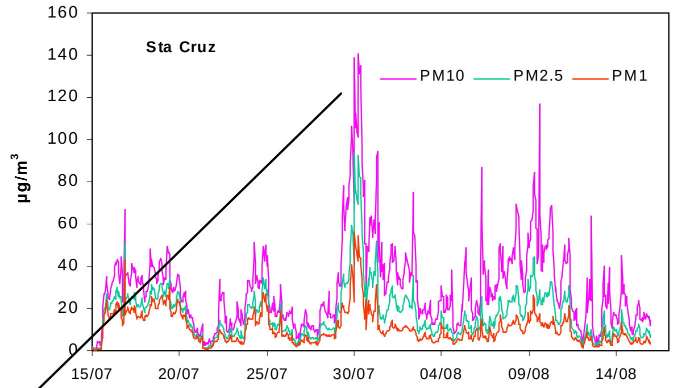
Chemical characterisation of TSP and PM2.5 at Izaña and Sta. Cruz during the MINATROC field campaign (July, 2002)

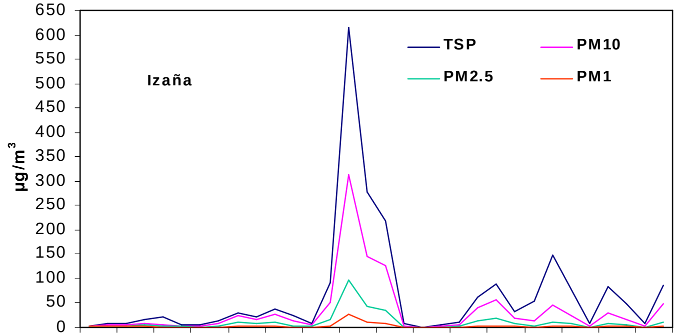
Alastuey et al., 2003

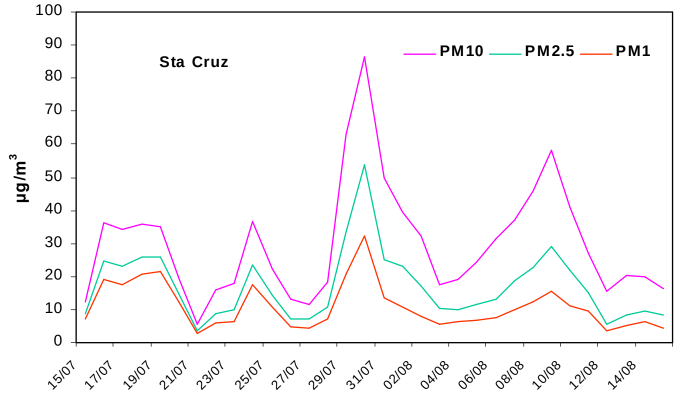
Hourly means





Daily means





In-situ measurements (PM)

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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

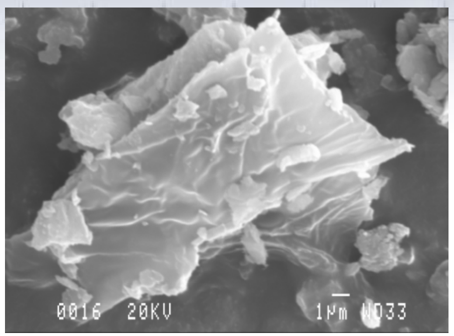
C	Elemental A.

DETERMINED

75-85 % PM mass

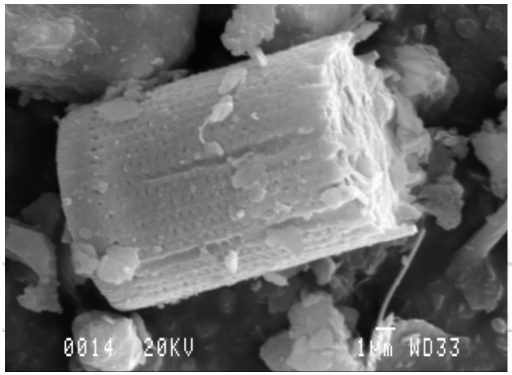
In-situ measurements (PM)

	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)

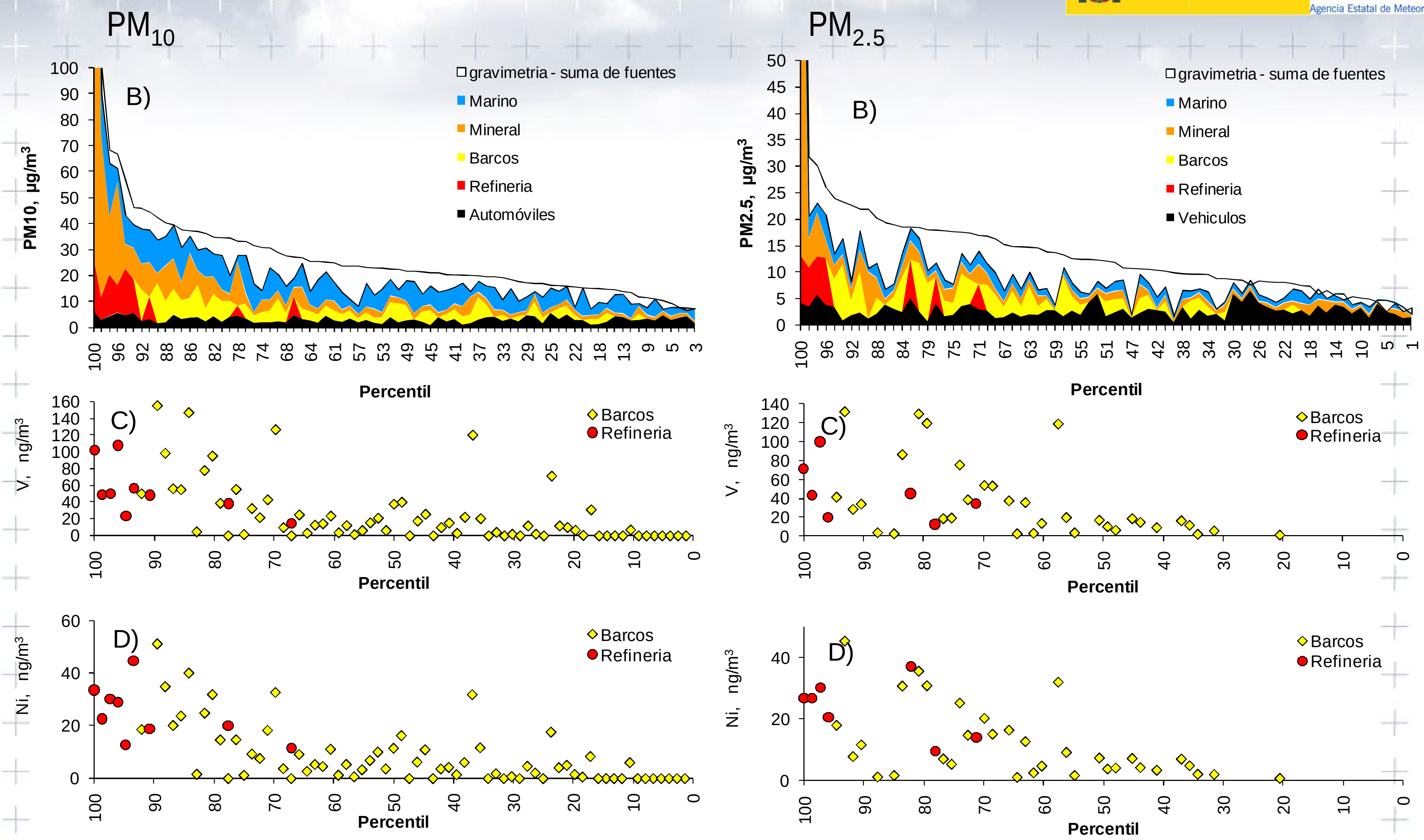
$PM_{10} > 50\ \mu g/m^3$

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)

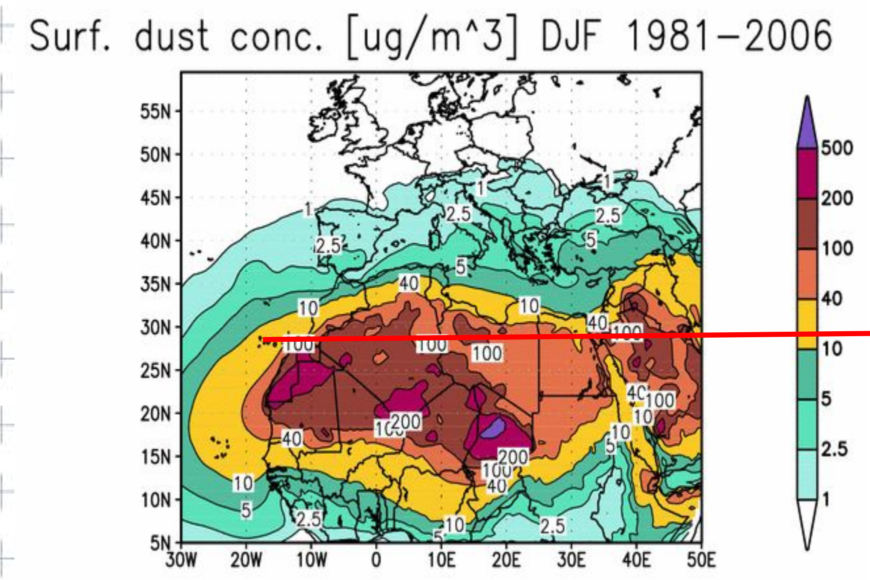


Santa Cruz de Tenerife source apportionment study by receptor modeling

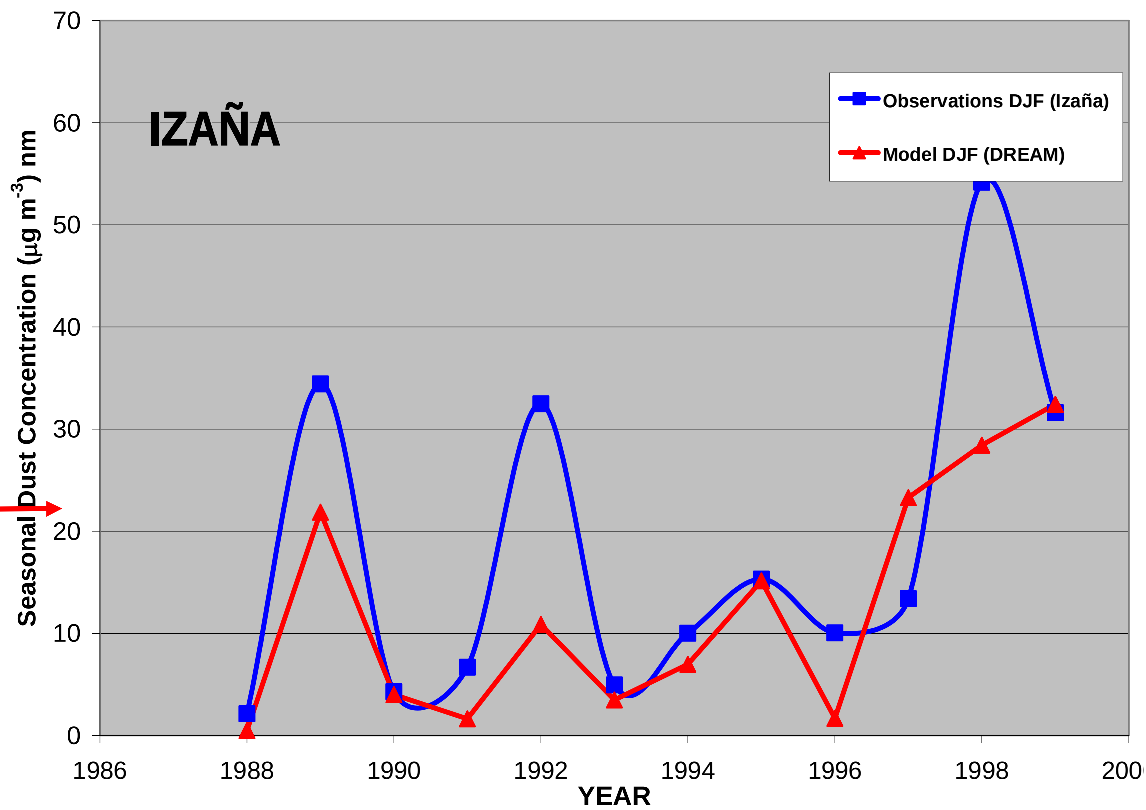
Rodríguez et al., 2009

In-situ measurements (PM)

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 measurements (PM)

The GAW Izaña supersite

In-situ Aerosol/ African-dust characterization

- Number size distribution of coarse, fine and ultra-fine particles (3nm-20µm) (APS + SMPS)
- PM10 and PM2.5 levels and chemical composition (samplers)
- Total and backward scattering coefficients (3λ) (integrating nephelometer)
- Absorption scattering coefficients (1λ) (MAAP)

In-situ measurements (PM)

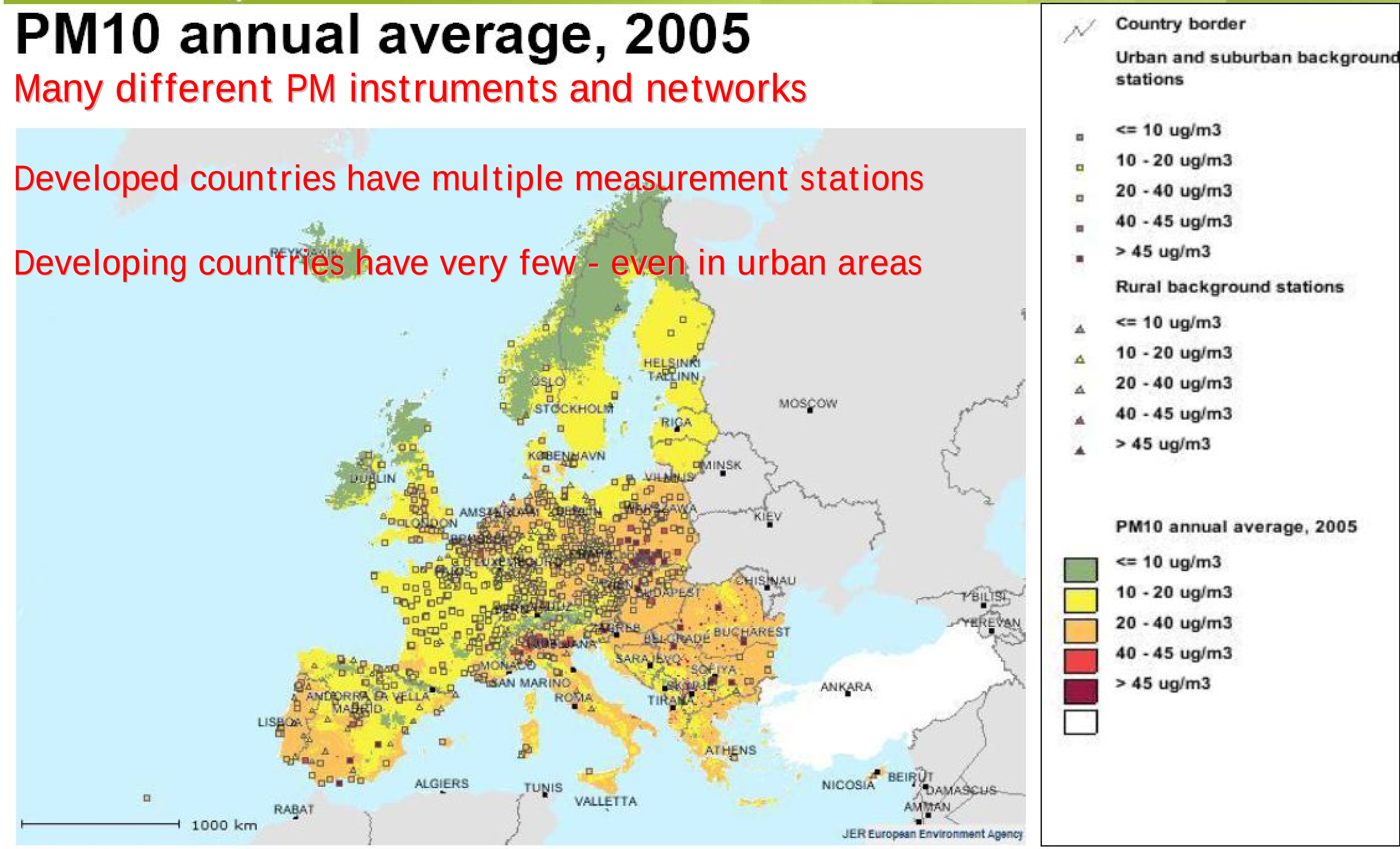
European Environment Agency

PM10 annual average, 2005

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

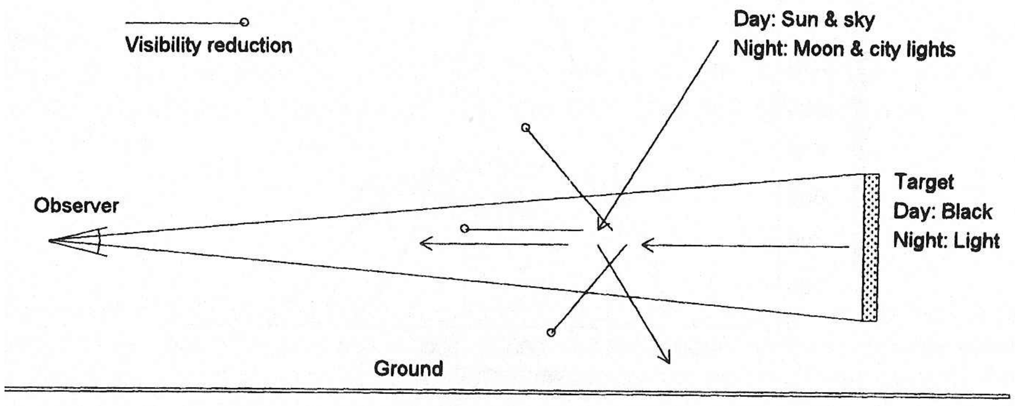


Fig. 11-1 Visibility reduction by scattering.

- **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

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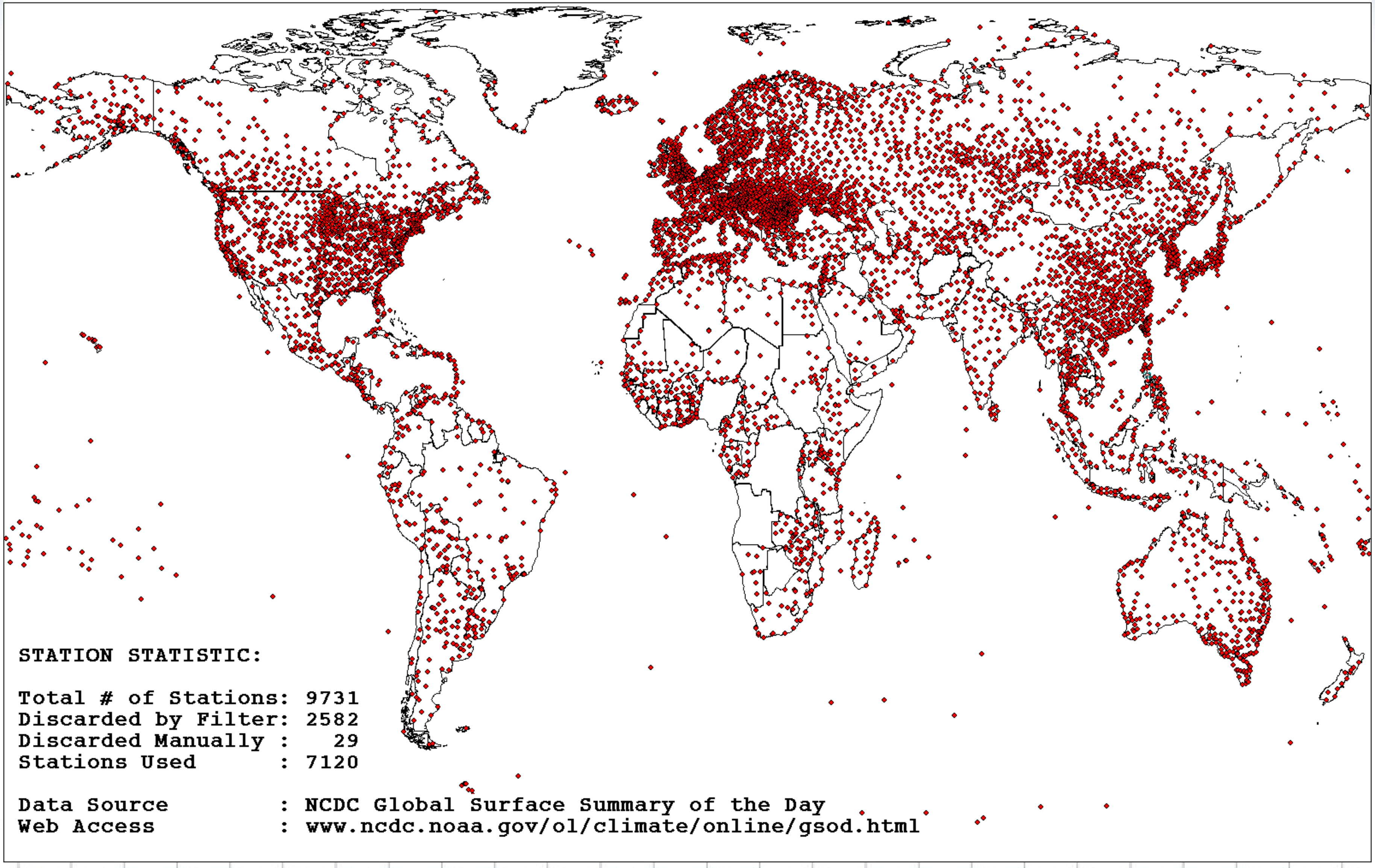
WMO- World Wide Watch Global Surface Meteorological Network



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)

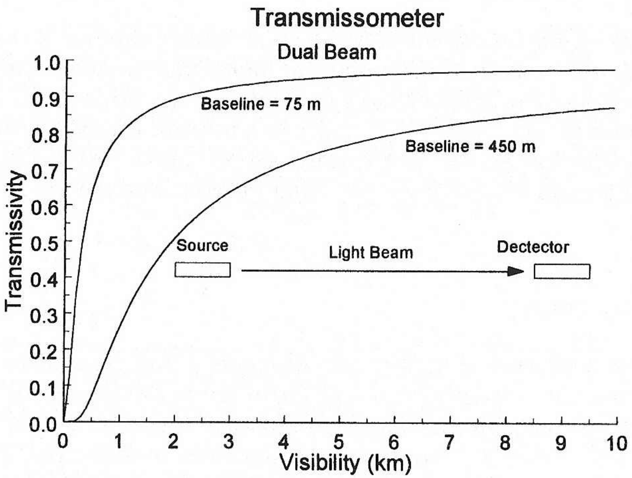


Fig. 11-3 Transfer function for a transmissometer.

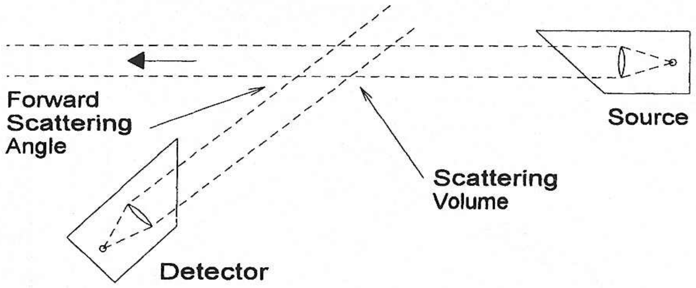


Fig. 11-4 A forward scatter visibility meter.

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)

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

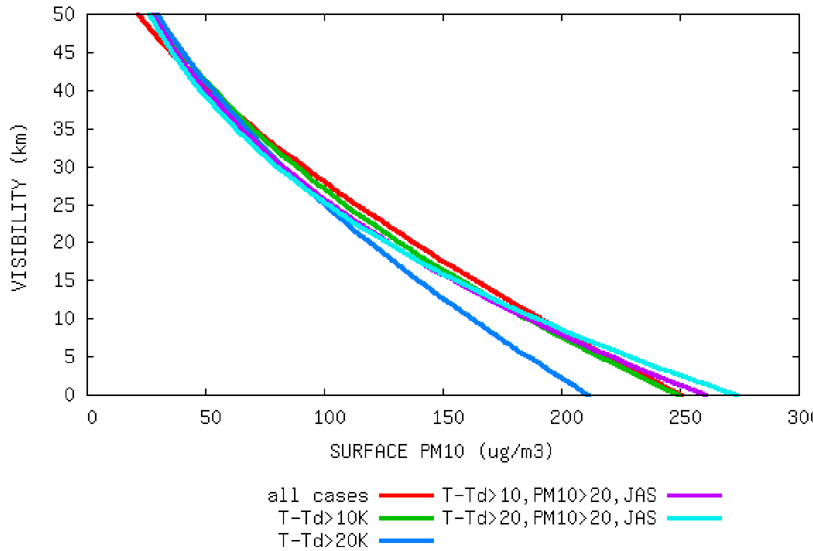
where *C is the TSP concentration in* μgm^{-3} *and VV* is the horizontal visibility in km

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

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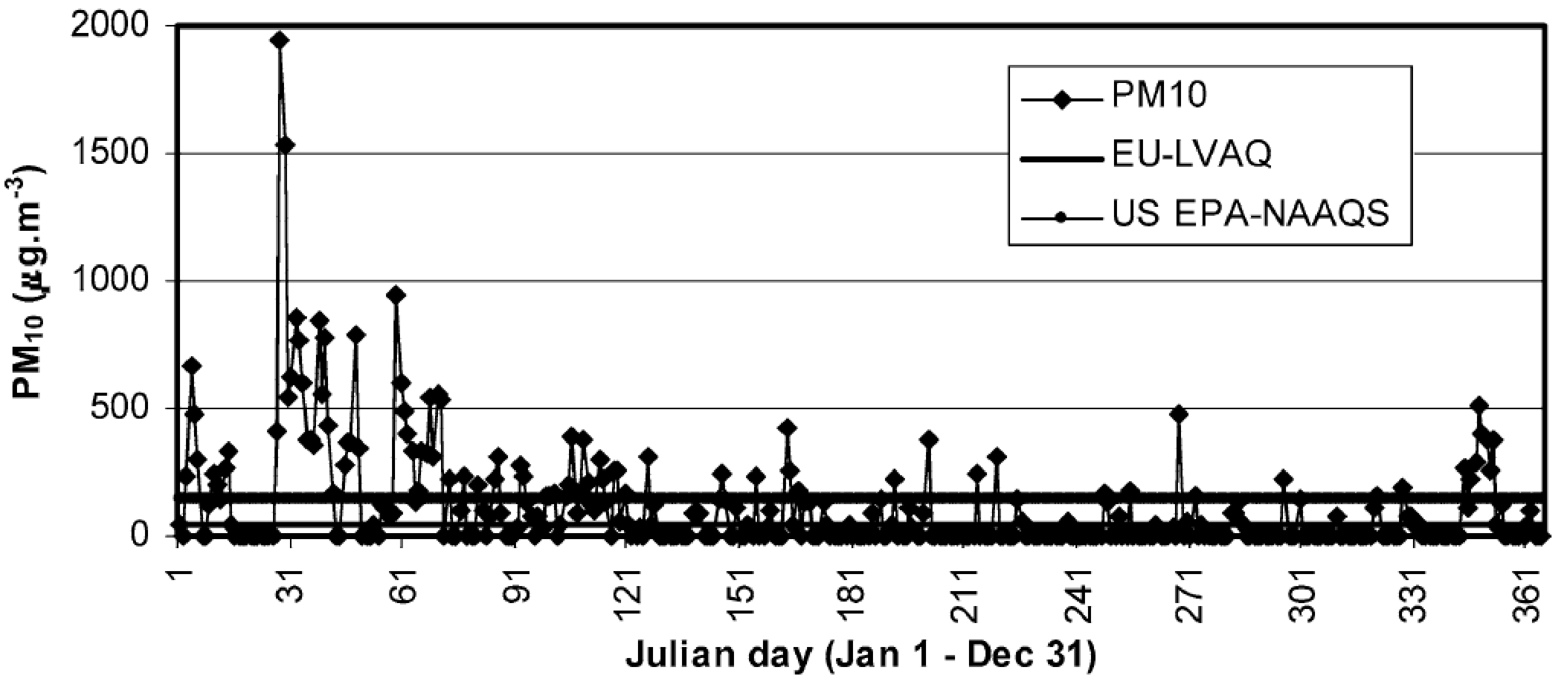
Variations of estimated daily mean concentrations of TSP and PM10 (μgm^{-3}) *due to* Saharan dust events at Nouakchott, Mauritania, in 2000



Ozer et al., (2006): Estimation of air quality degradation due to Saharan dust at Nouakchott, Mauritania, from horizontal visibility data

In-situ estimations

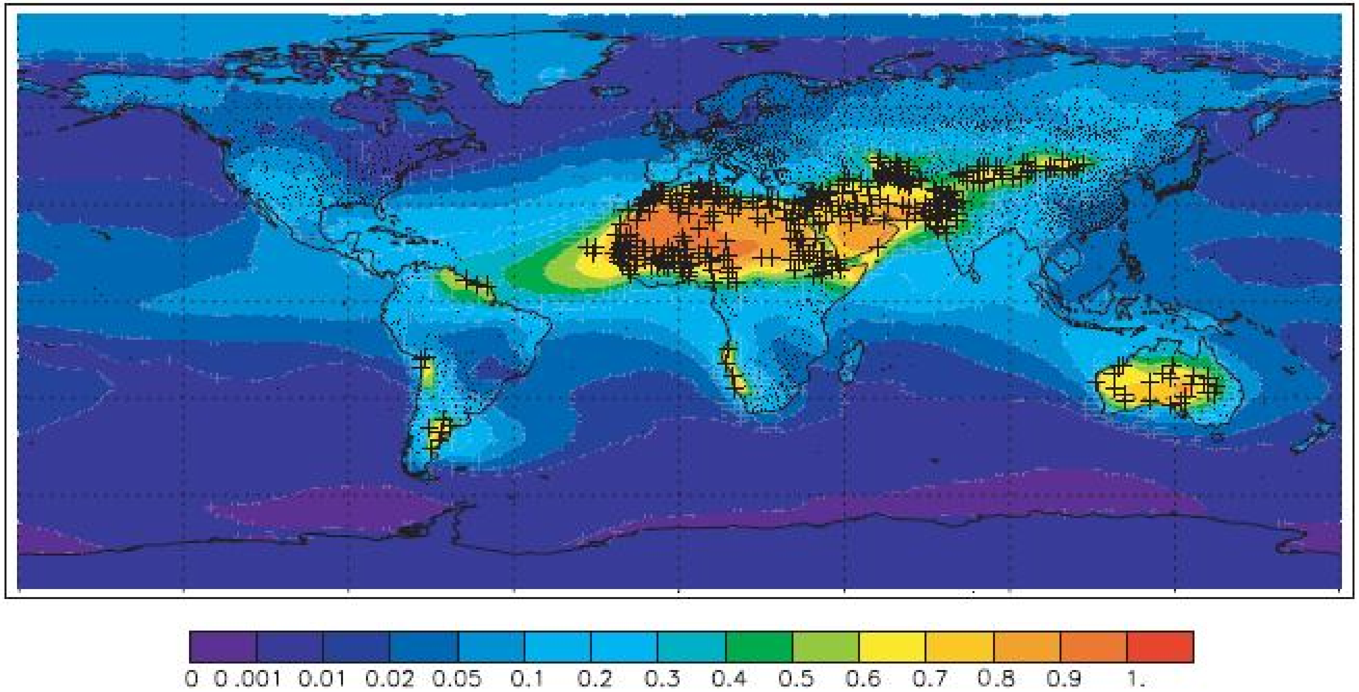
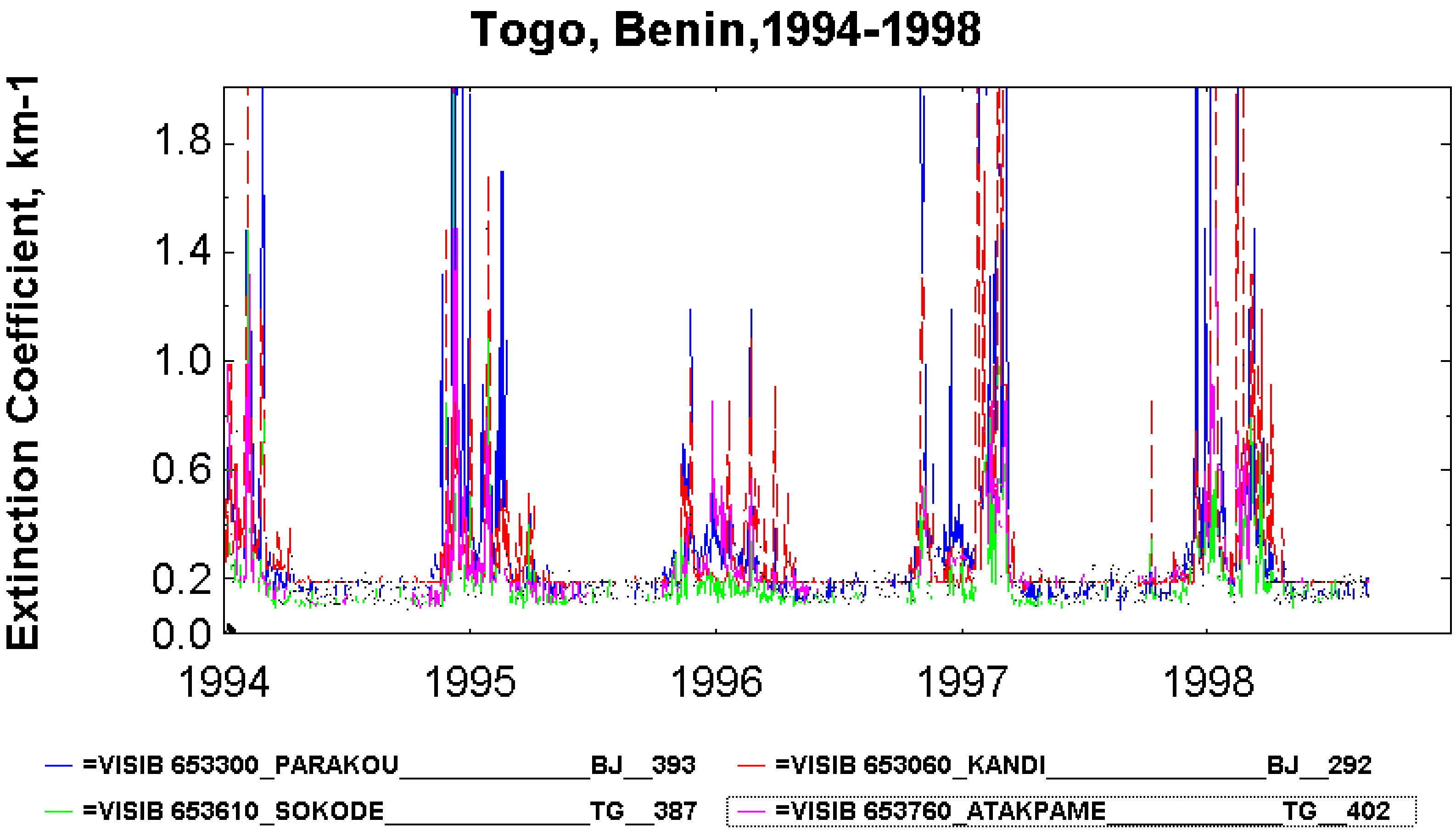


Fig. 4. Location of visibility stations with more than 30 years of data. Colored contours show fraction of surface extinction from desert dust. Pluses show stations in regions dominated by desert dust (>50%), while dots show other locations.

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

In-situ estimations



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

In-situ estimations

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

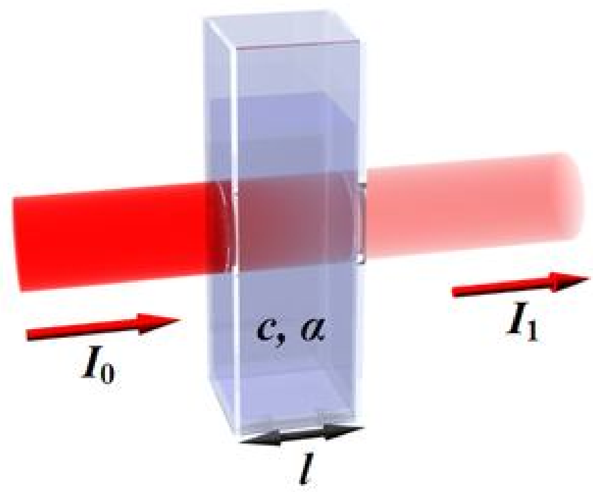
From ground observations...

to total atmospheric column observations

Sunphotometers

- 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 absorbing the light. More aerosols in the atmosphere cause more scattering and less energy transmitted to the surface.



- 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 (ı)
molar absorptivity of the absorber (ε)
concentration of absorbing species in the material (c)
absorption cross section (σ)
density of absorbers (N)

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:

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

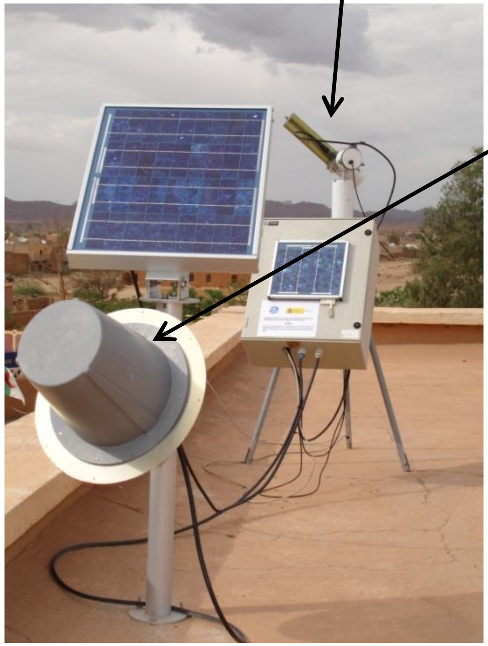
where α is the Angstrom exponent (β = aerosol optical thickness at 1 μm)

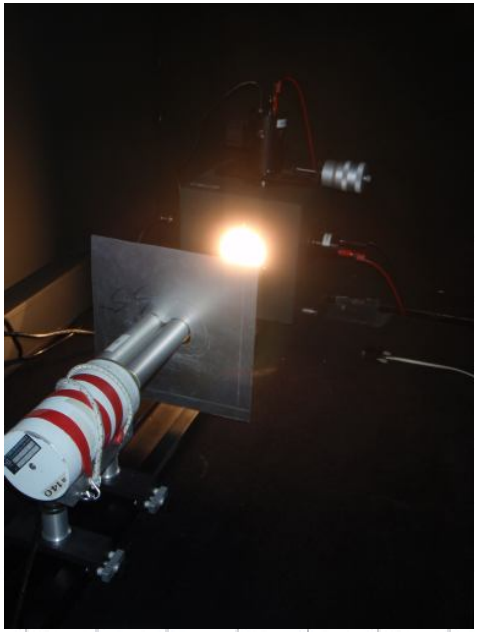
If AOD >~ 0.2 and α<0.7 then we are observing dust (aprox.)

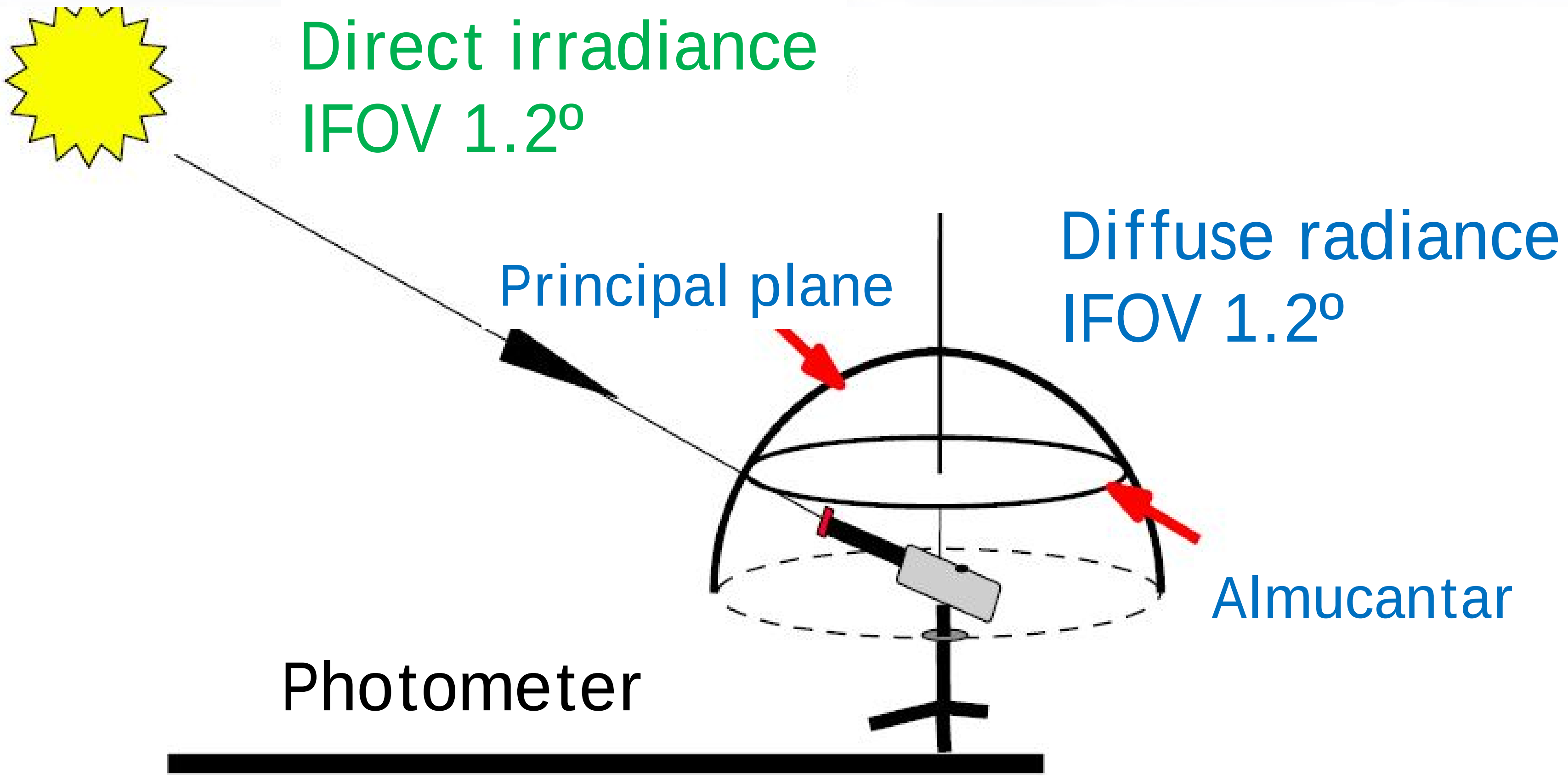
- The Cimel Electronique 318 spectral radiometer is a solar-powered, weather-hardy, robotically-pointed sun and sky spectral sun photometer.

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

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





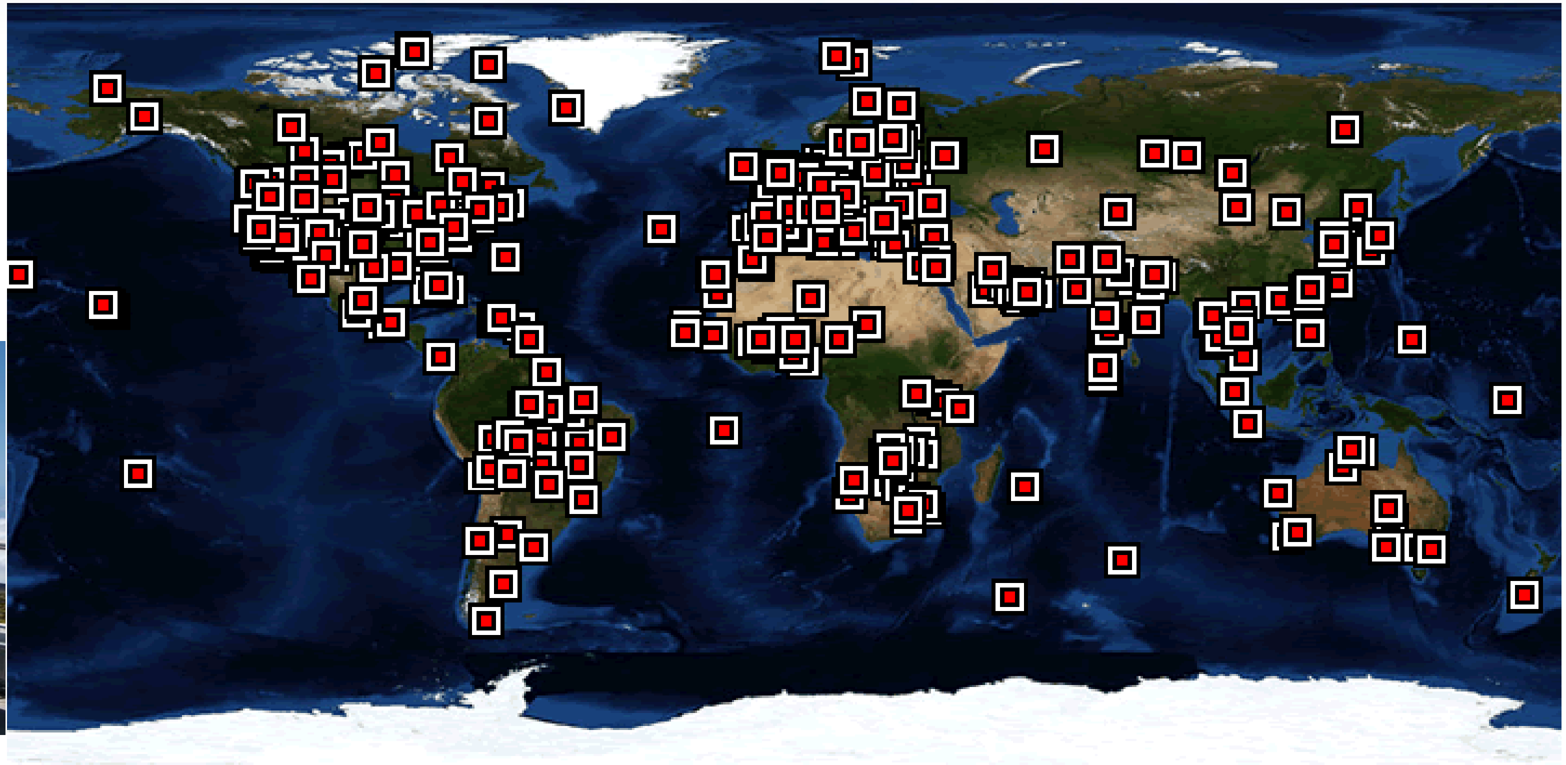


Sun measurements

Sky measurements

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

AERONET Data Flows

http://aeronet.gsfc.nasa.gov

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

Eck et al.
JGR, 1999

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

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

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

Aerosol optical depth and precipitable water computations

Cloud screening and quality control

Inversion products

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

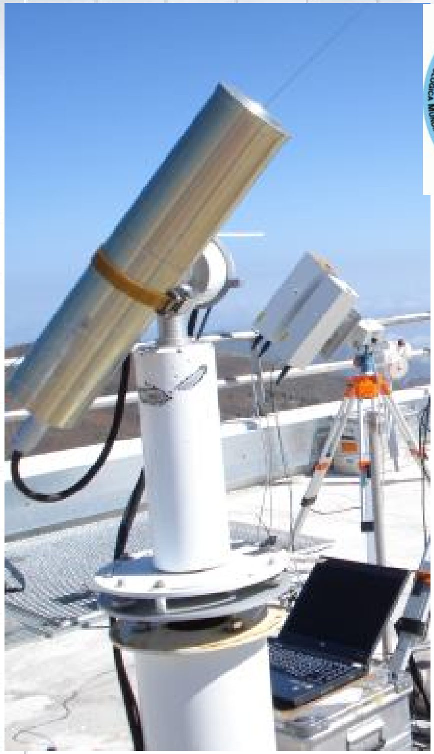
- AERONET provides global Aerosol Optical Depth of Dust in near real-time

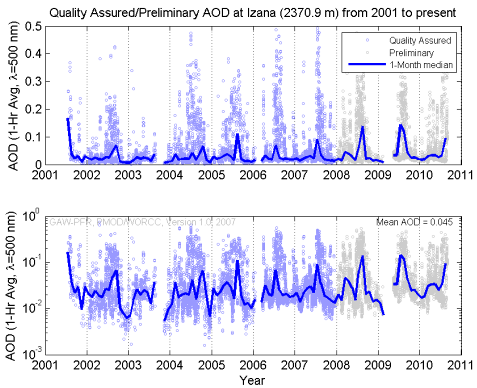
- AERONET provides robust optical properties of Dust: size distribution, ref. Index, etc. (e.g. Asian Dust has stronger and less spectral dependent absorption than Saharan Dust)

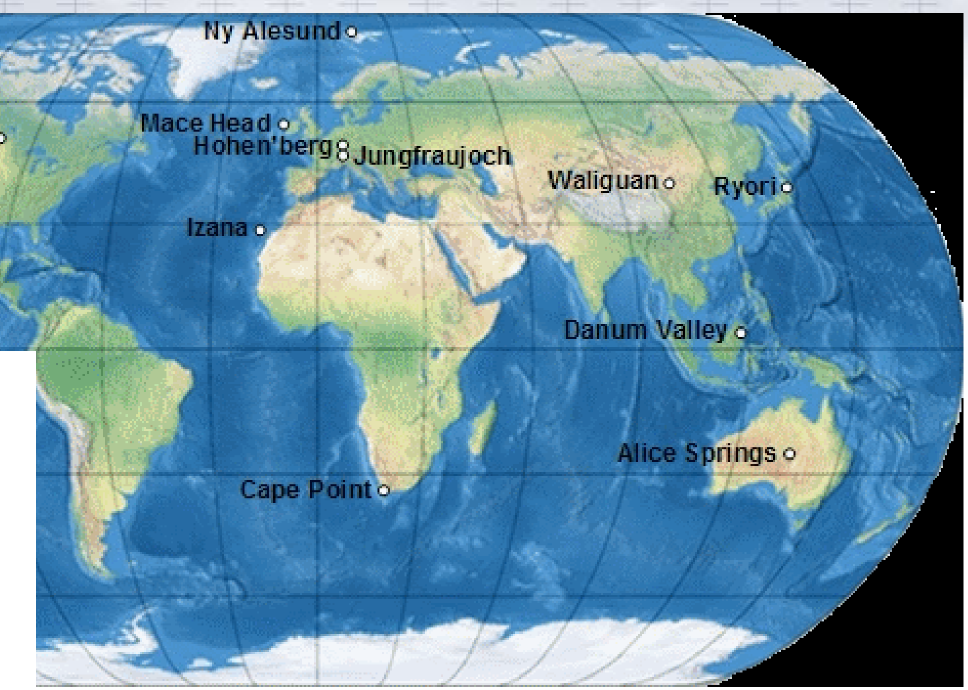
- AERONET provides the climatological models that reproduce observed optical properties of aerosol (useful for satellite retrievals)

Ground-based remote sensing

GAW-PFR AOD Network







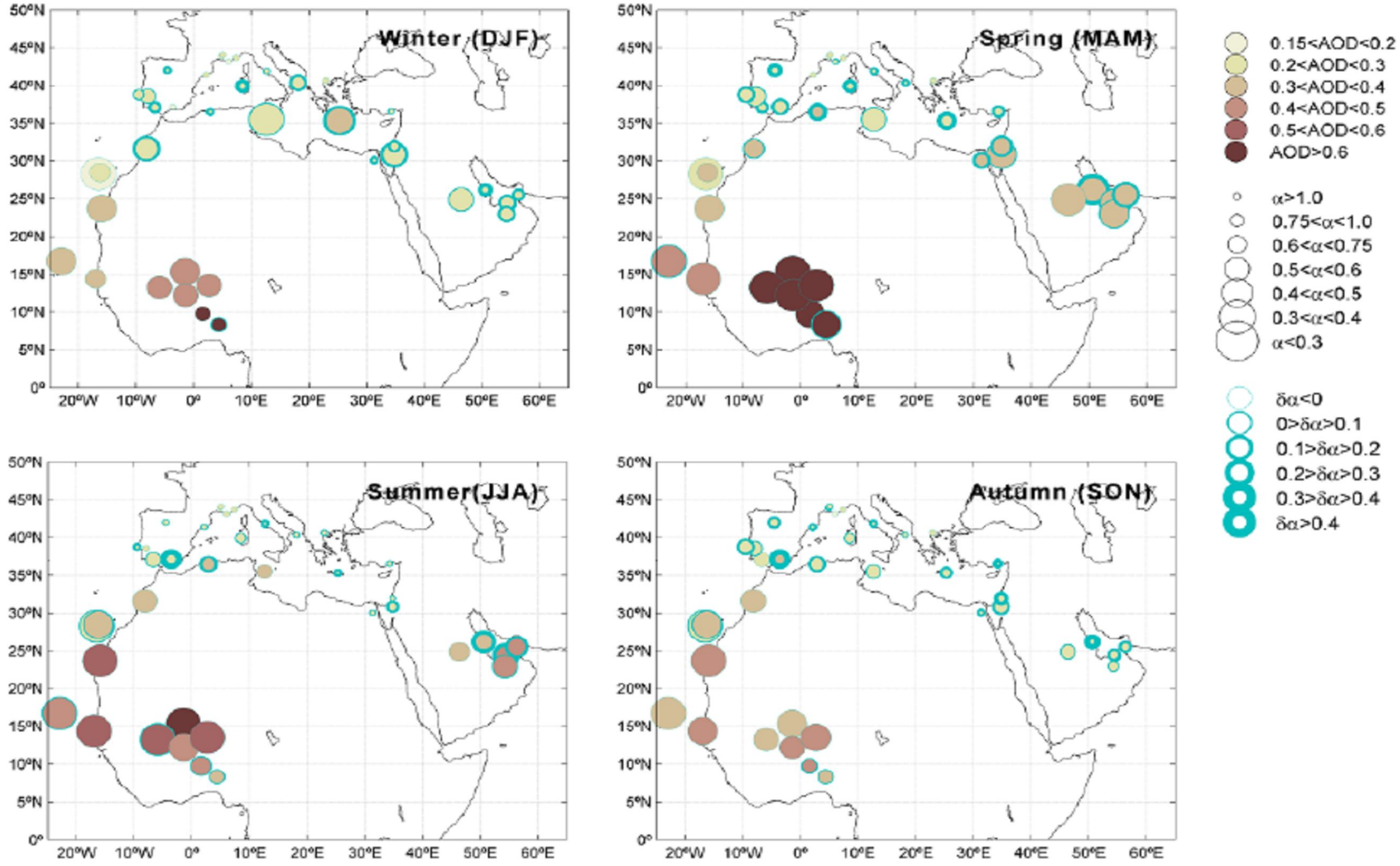
- Classic extinction measurements at the recommended 4 WMO wavelengths 368, 415, 500 and 862 nm using Precision Filter Radiometers (PFRs).
- Continuous sampling at a 1- minute frequency by automated systems.
- Data products: AOD and the Angström coefficients alpha and beta (no inversions).
- Hourly mean 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

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)



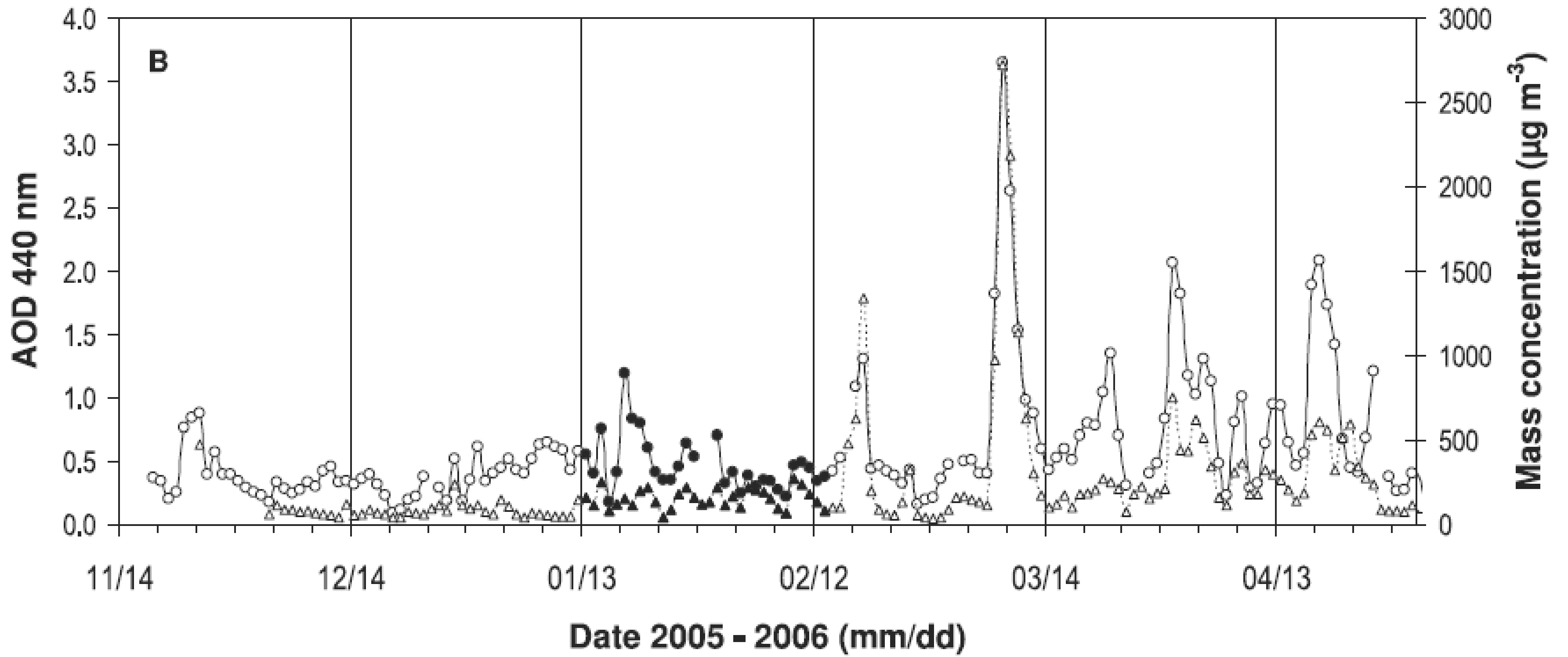


Figure 7. (a) Time series of daily Angström exponent and (b) comparison of daily AODs (circles and solid line) measured at 440 nm by the AERONET sunphotometer with the daily surface level mass concentrations (triangles and dotted line) measured by the TEOM microbalance at the AMMA EOP station. Data collected during the SOP0 measurement period appear in black.

Rajot et al., 2008 (JGR): AMMA dust experiment: An overview of measurements performed during the dry season special observation period (SOP0) at the Banizoumbou (Niger) supersite

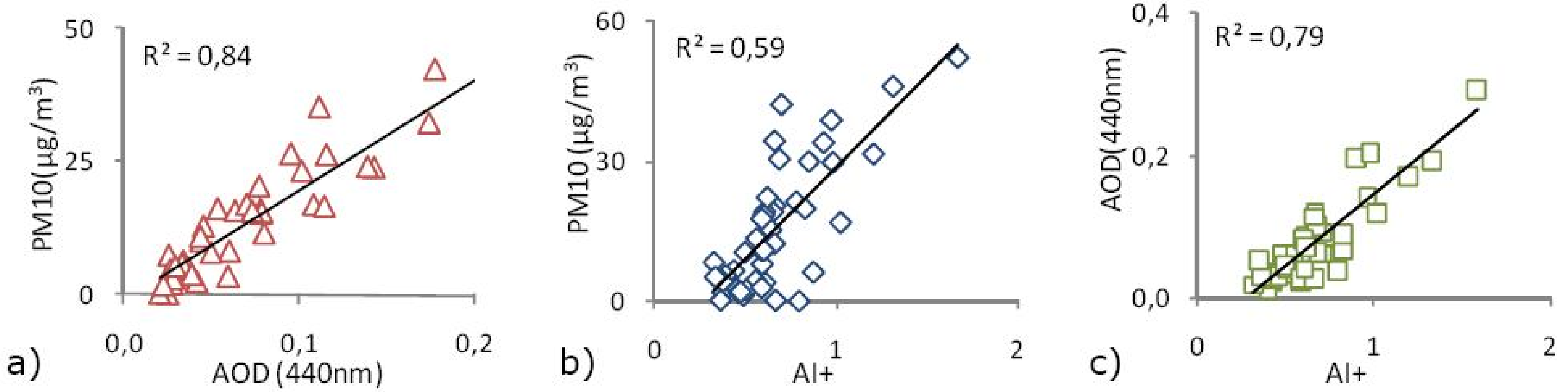


Figure 1. Scatterplot of monthly means of a) AOD vs PM_{10}; b) AI positive values vs PM_{10}; c) AI positive values vs AOD.

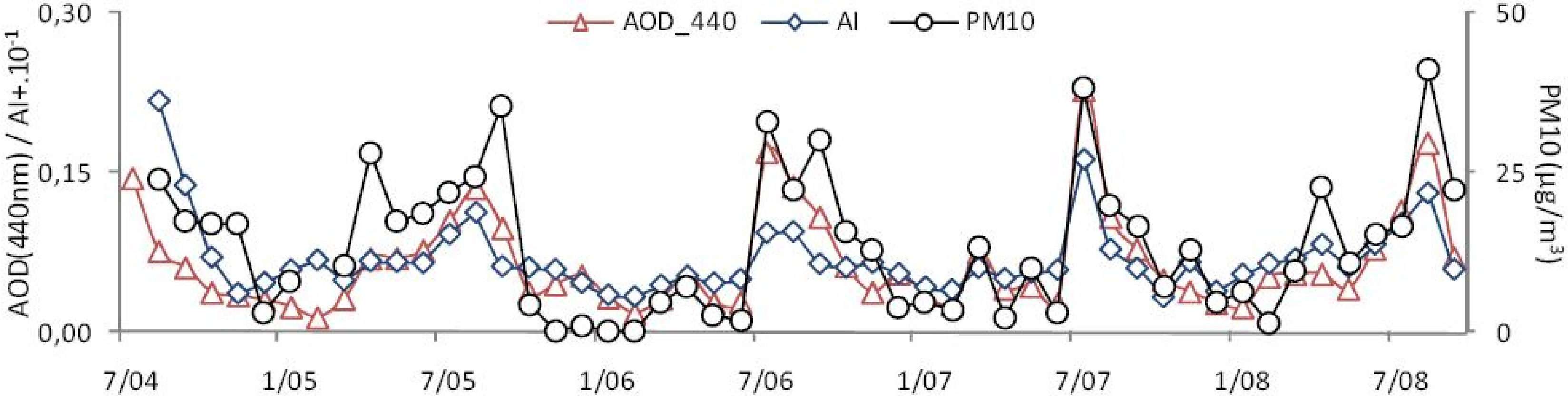
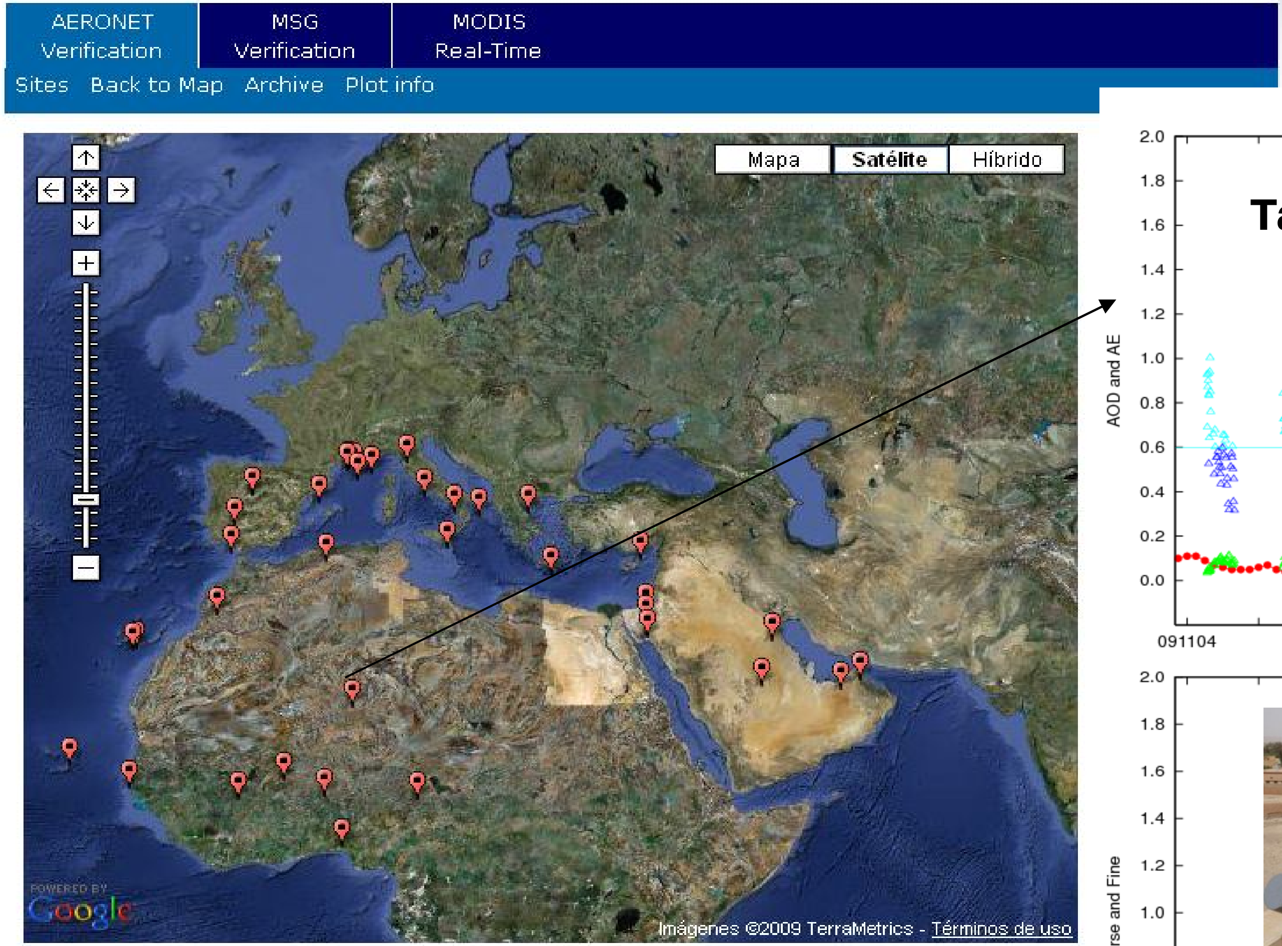
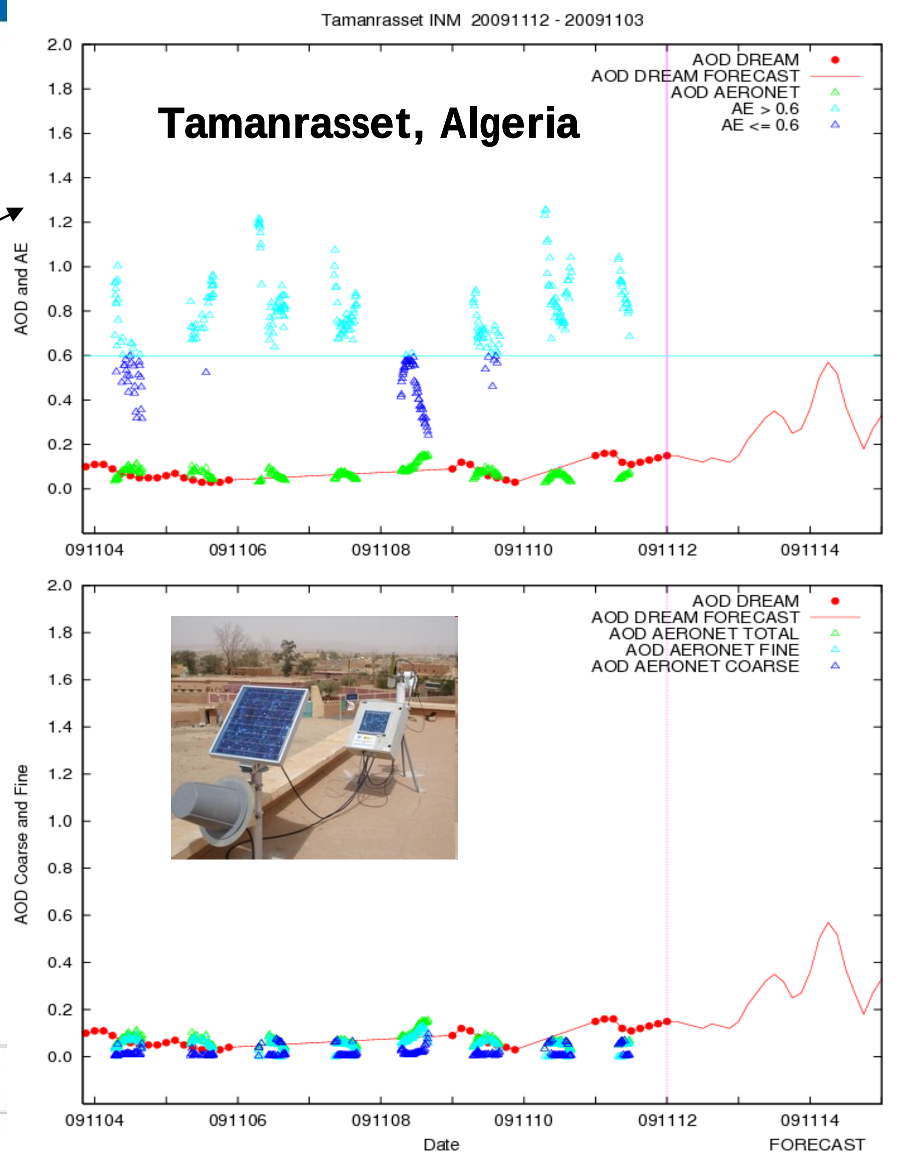


Figure 2. Monthly means of PM_{10} (µg/m³), AOD and AI positive values.

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





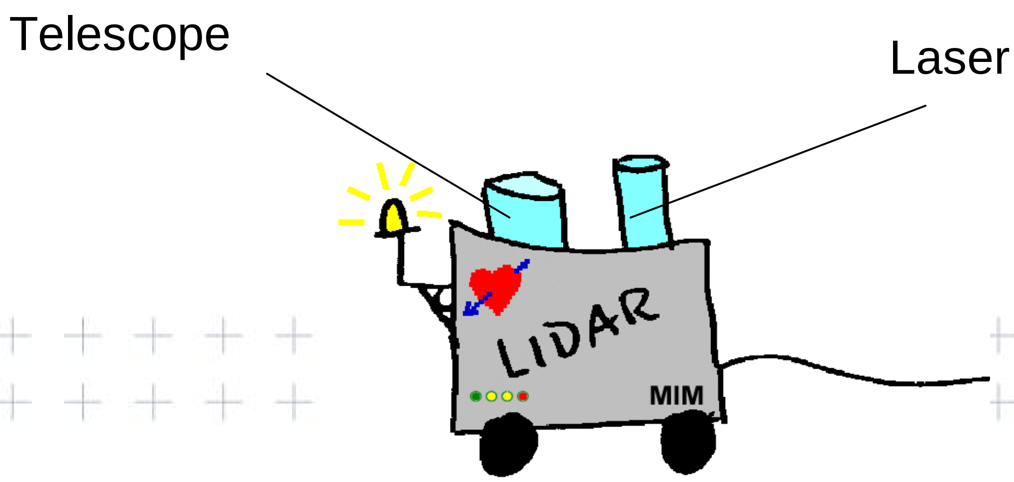
Near real time model verification against AERONET data

From total column observations...

to vertical resolved observations

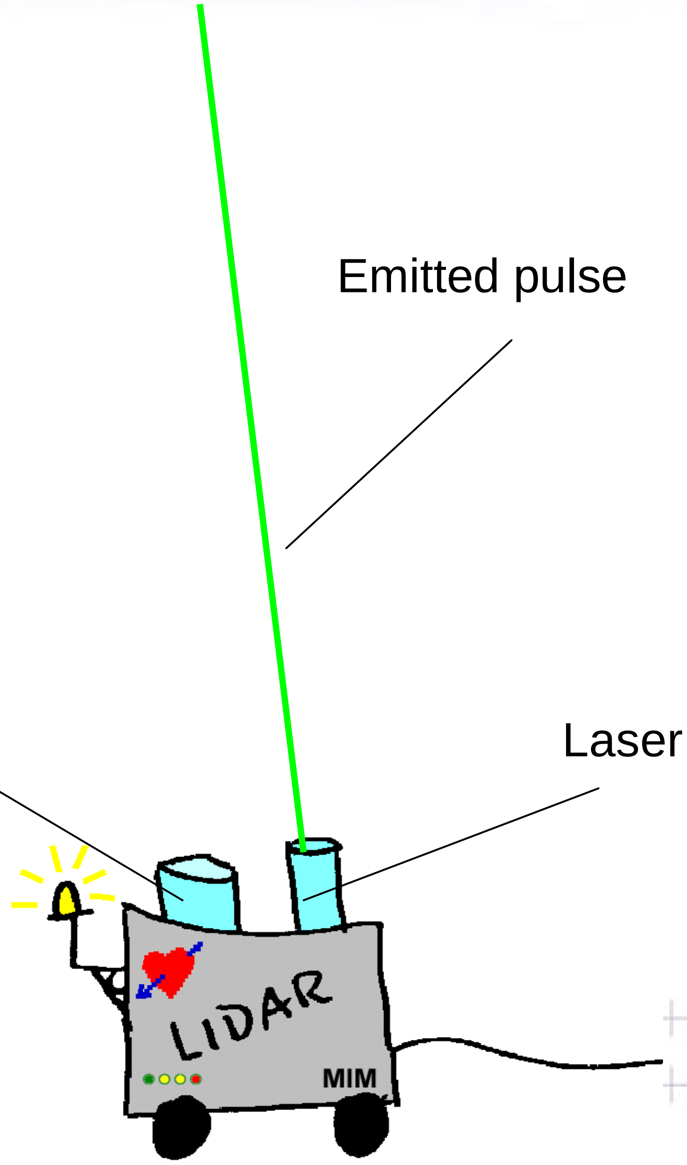
Lidars

Ground-based remote sensing

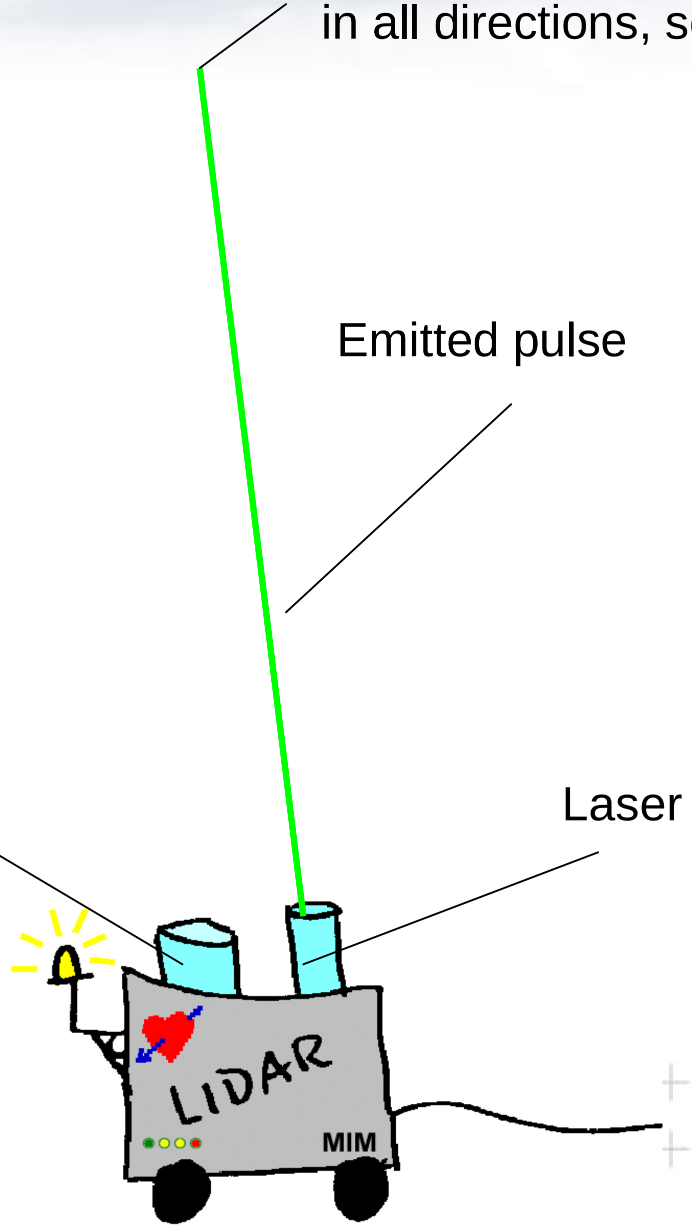


Taken from Matthias Wiegner's presentation (University of Munich, Meteorological Institute) to the SPIE 10 (International Symposium Remote Sensing)

Ground-based remote sensing

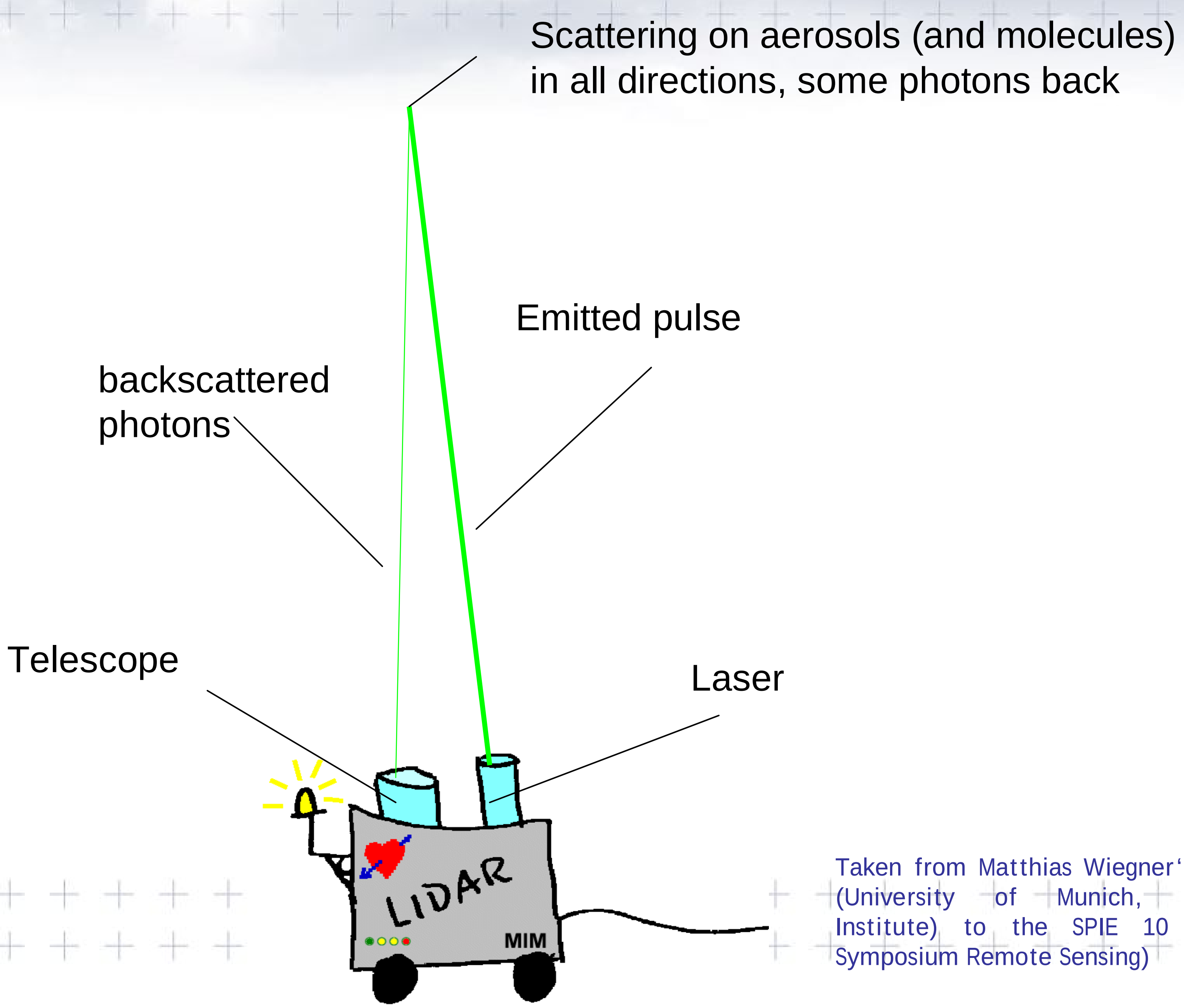


Taken from Matthias Wiegner's presentation (University of Munich, Meteorological Institute) to the SPIE 10 (International Symposium Remote Sensing)



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)

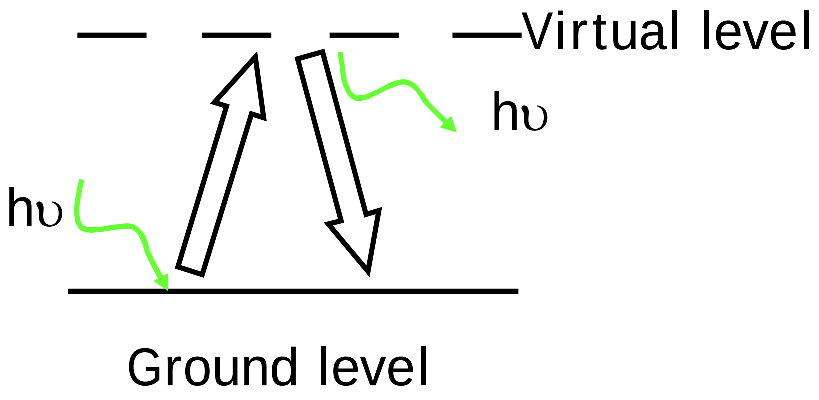
Ground-based remote sensing

GOBIERNO DE ESPAÑA MINISTERIO DE MEDIO AMBIENTE Y MEDIO RURAL Y MARINO

AEMet Agencia Estatal de Meteorología

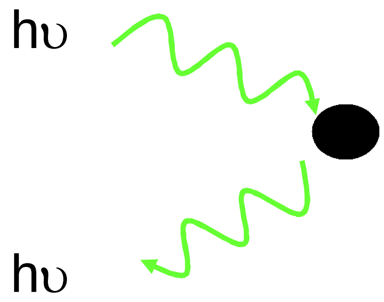
- Rayleigh Scattering

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



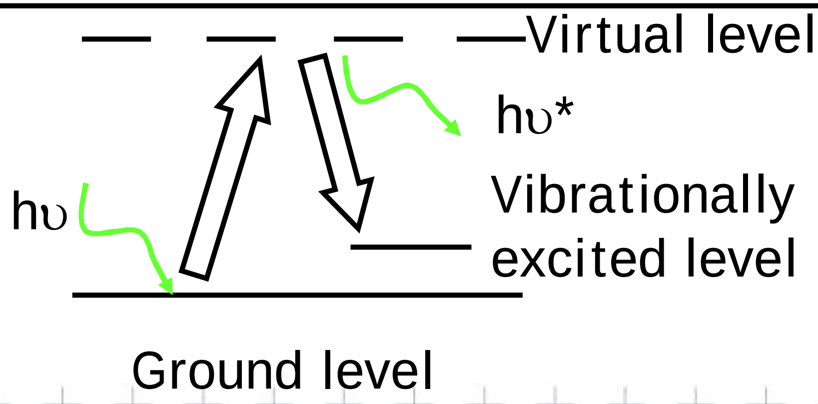
- Mie Scattering

  “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)”



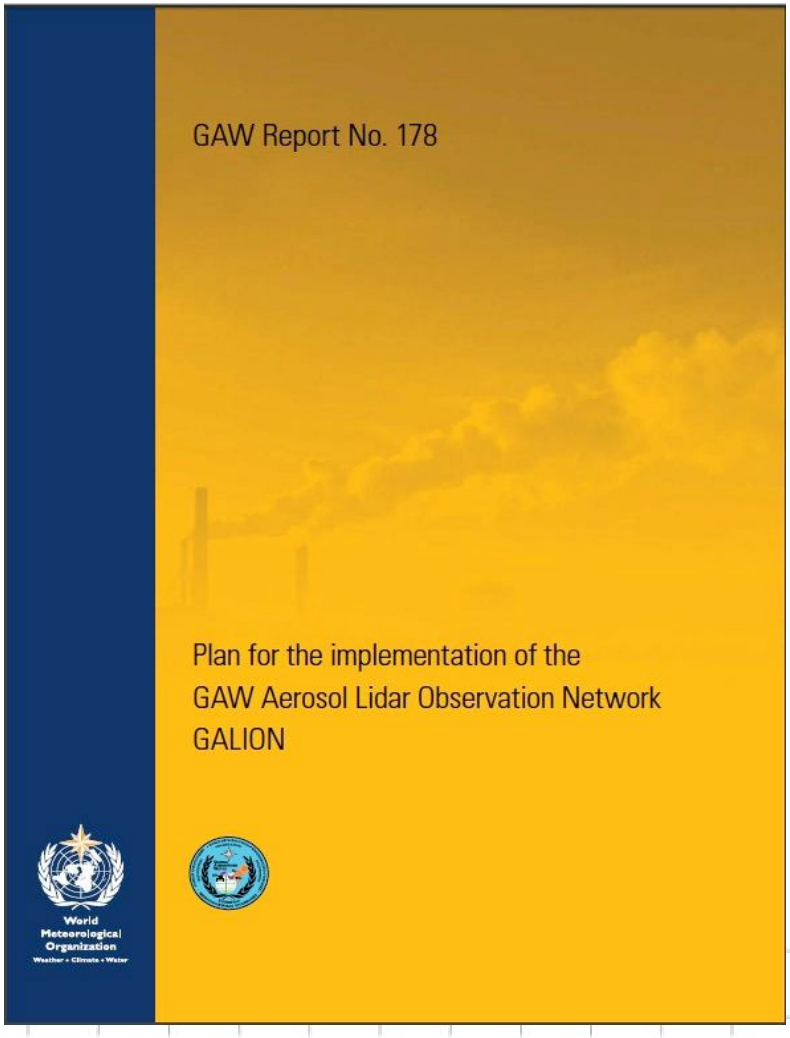
Taken from Laser Remote Sensing Fundamentals and Applications by Raymond M. Measures (pgs 206-207)

Ground-based remote sensing

Lidar-Barcelona (UPC)
Raman Lidar
EARLINET-SPALINET

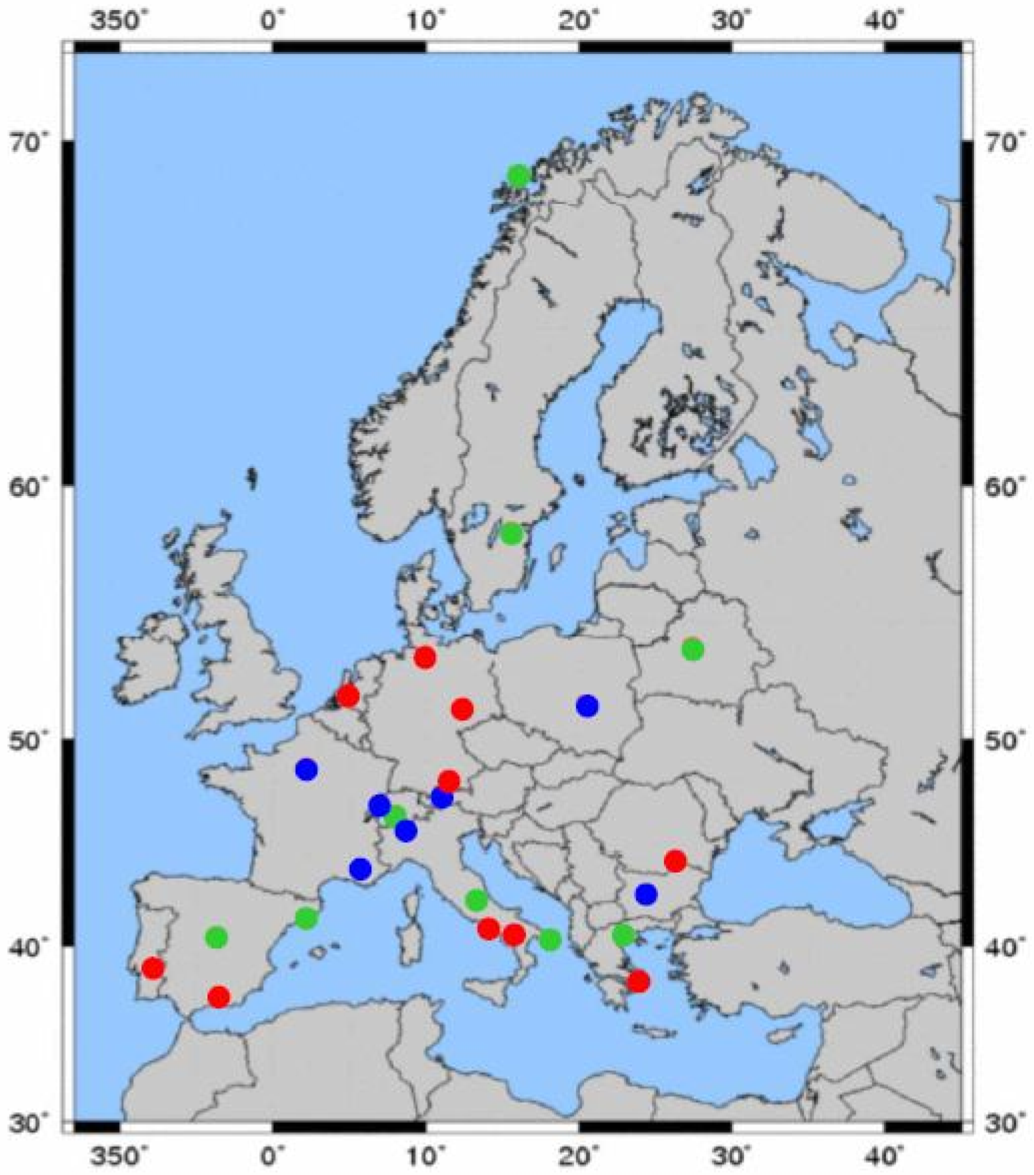
Lidar-Tenerife (INTA-AEMET); Elastic lidar
MPLNET

GAW Atmospheric Lidar Network (GALION)



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

Ground-based remote sensing



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**

Ground-based remote sensing

GOBIERNO DE ESPAÑA MINISTERIO DE MEDIO AMBIENTE Y MEDIO RURAL Y MARINO

AEMet Agencia Estatal de Meteorología

NASA

INTA

Aerosol lidar (MPLNet)

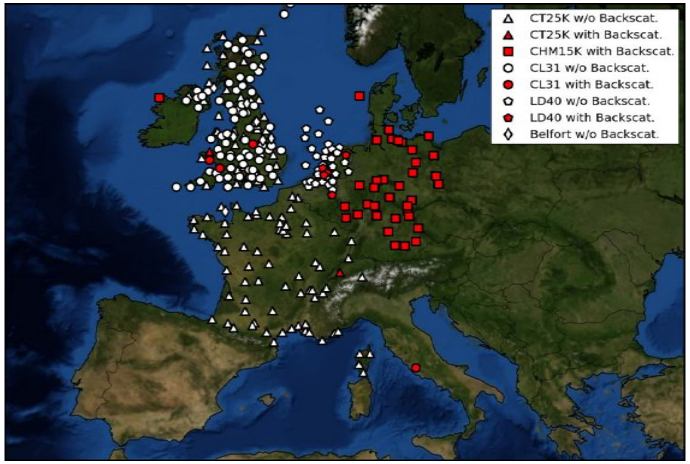
http://mplnet.gsfc.nasa.gov/

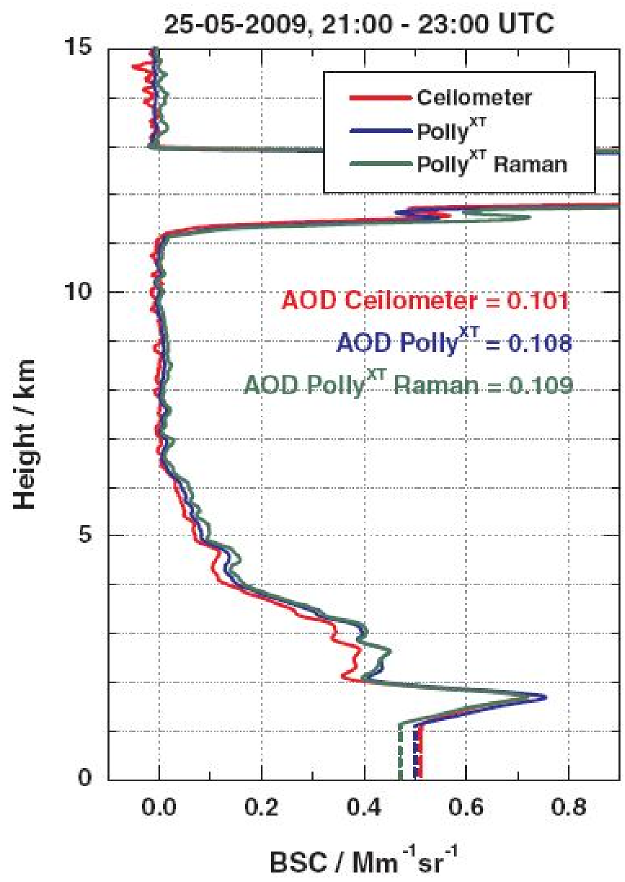
523 nm MPLNET
Automatized since July 2005

Ceilometer network

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

Objective: **To monitor MLD** based on **several hundred profiling ceilometers (100km sampling)**

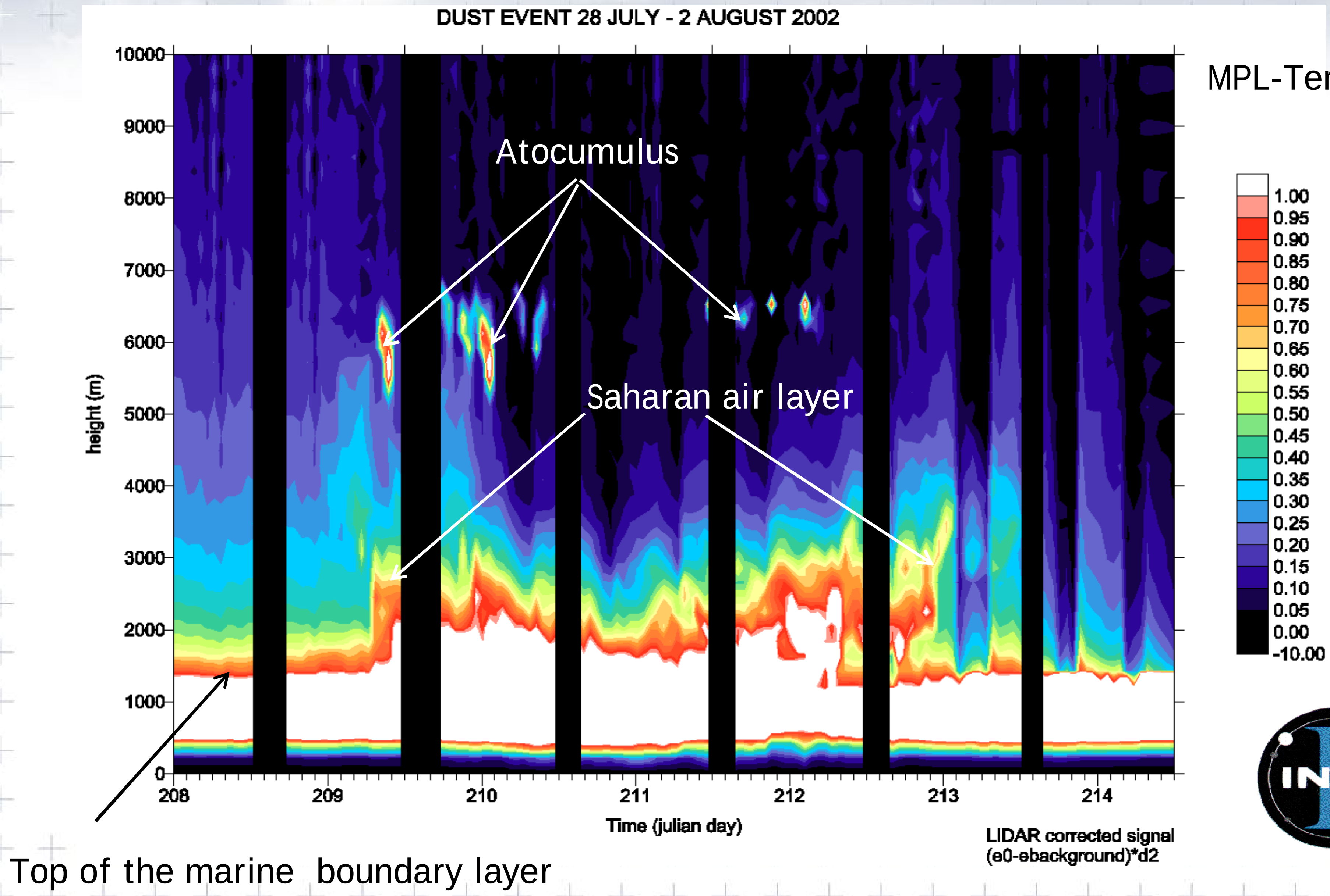


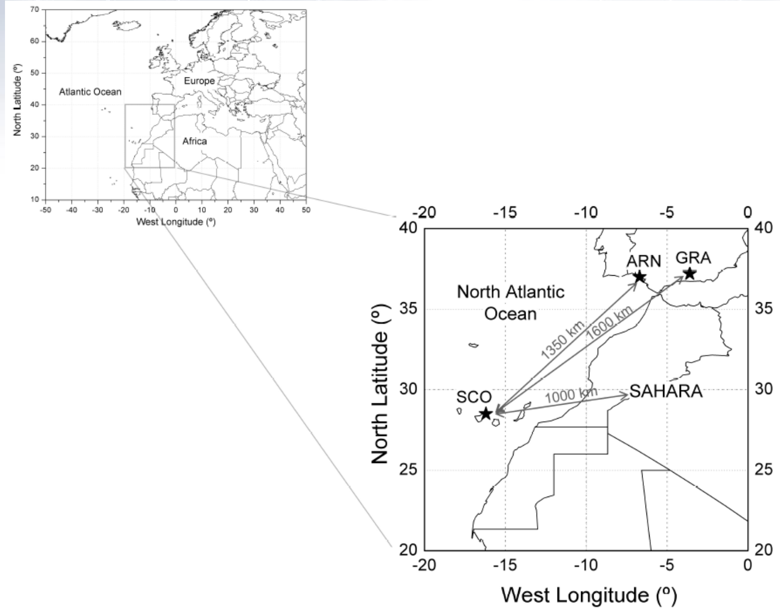


Heese et al., Atmos. Mes. Tech. 2010, Ceilometer-lidar inter-comparison: backscatter coefficient retrieval and signal-to-noise ratio determination

Optimal for desertic areas !!

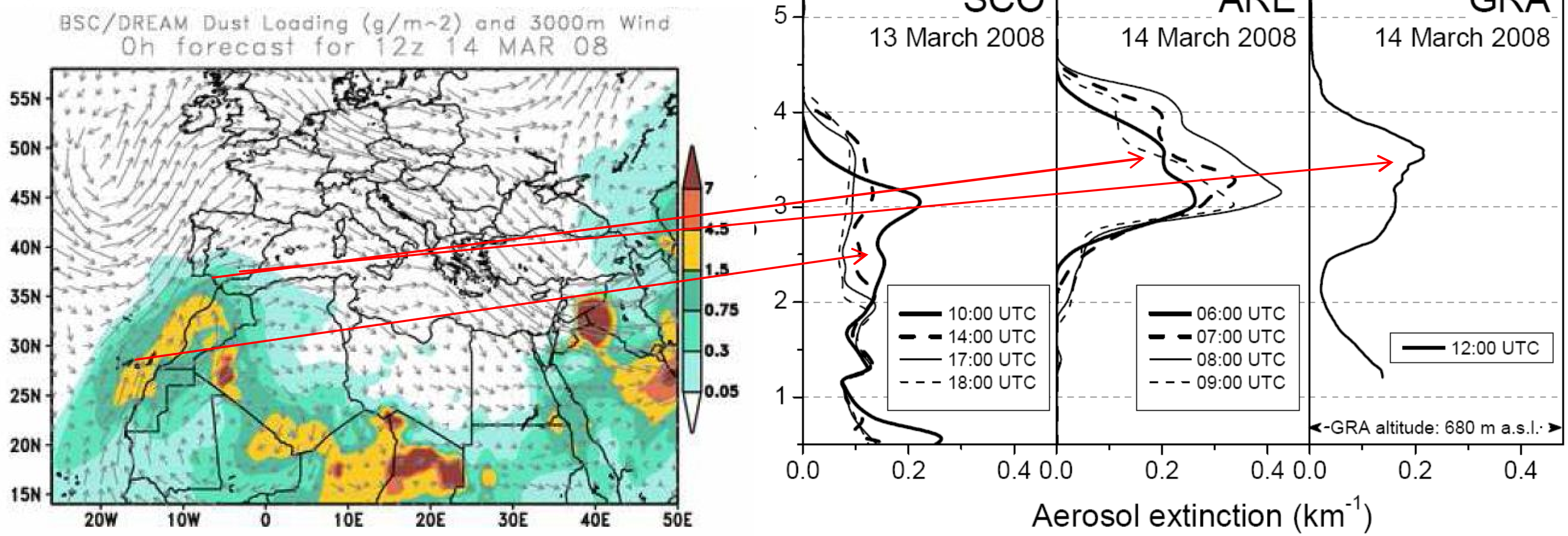
Ground-based remote sensing





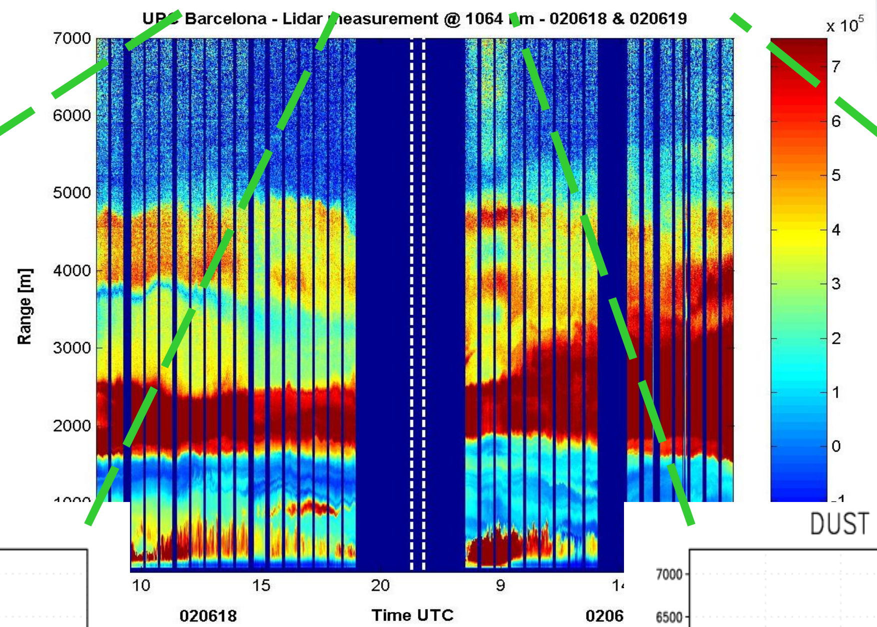
A case study of dust transport from Canary Islands to Iberian Peninsula

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



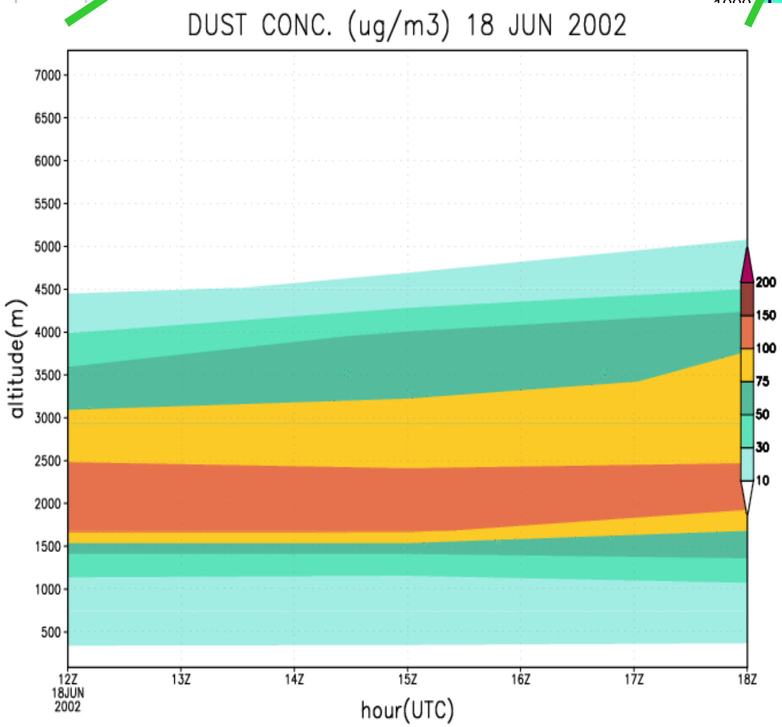
Ground-based remote sensing

Barcelona lidar vs DREAM BSC

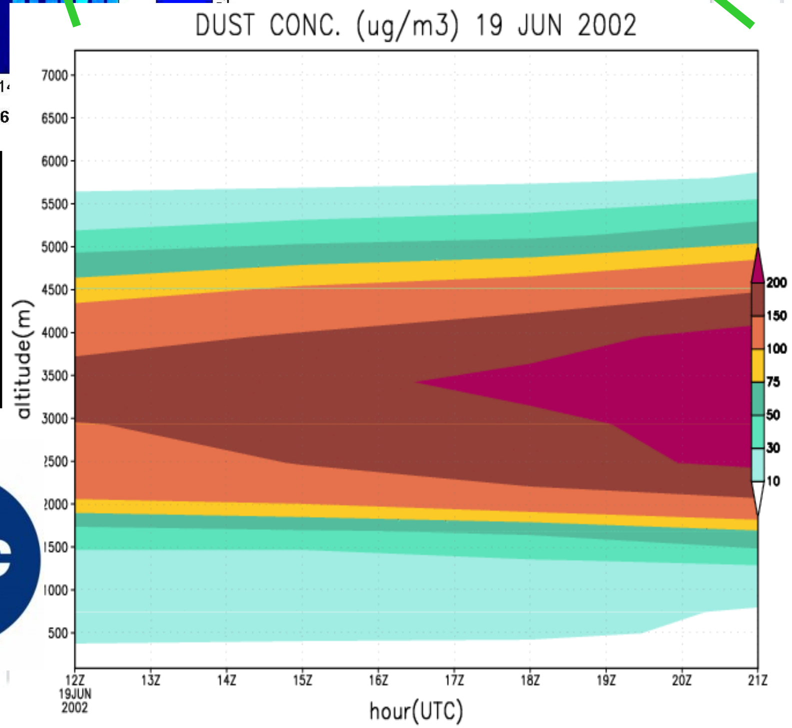


EARLINET: Lidar-UPC, Barcelona

18-19 June 2002



Vertical dust distribution validation: AIRLINET-DREAM



In-situ measurements and surface remote sensing compared to satellite

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

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

Gràcies per la seva atenció

Gracias por su atención

ecuevasa@aemet.es