The dust cycle in the atmosphere

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chair of the WMO SDS-WAS Steering Committee

Training Workshop on Sand and Dust Storms in West Africa, La Laguna, Spain 21 May 2018

Summary

- Atmospheric aerosol
- The cycle of mineral dust
- WMO SDS-WAS

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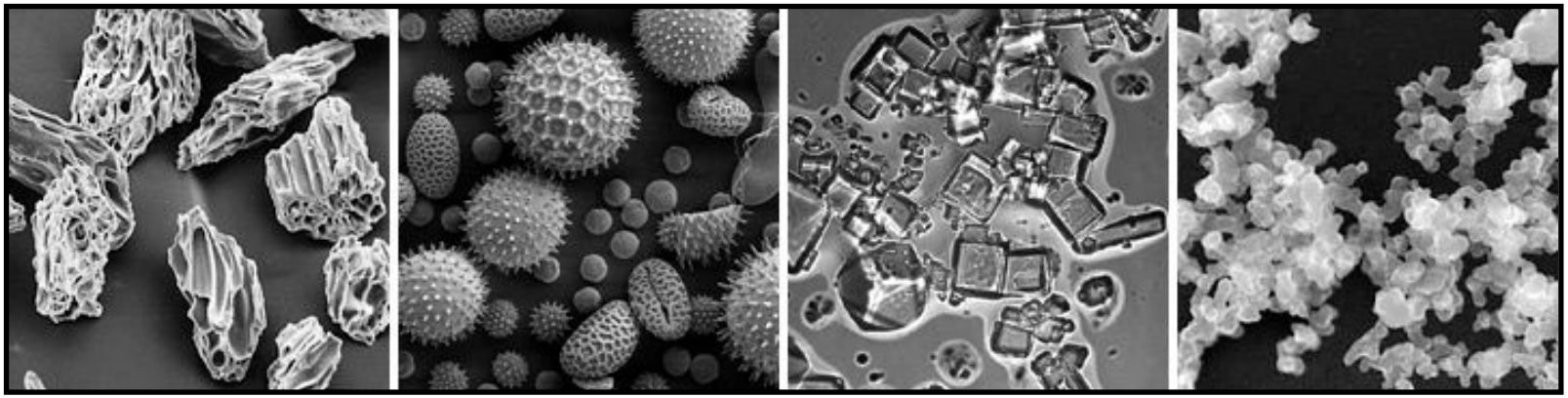
Atmospheric aerosol

Solid or liquid particles suspended in the air

- Types: primary / secondary, natural / anthropogenic particles
- Size: diameter between 0.001 µm (1 nm) and 100 µm approx.
- Chemical and mineralogical composition: diverse
- Optical properties (absorption, scattering): diverse

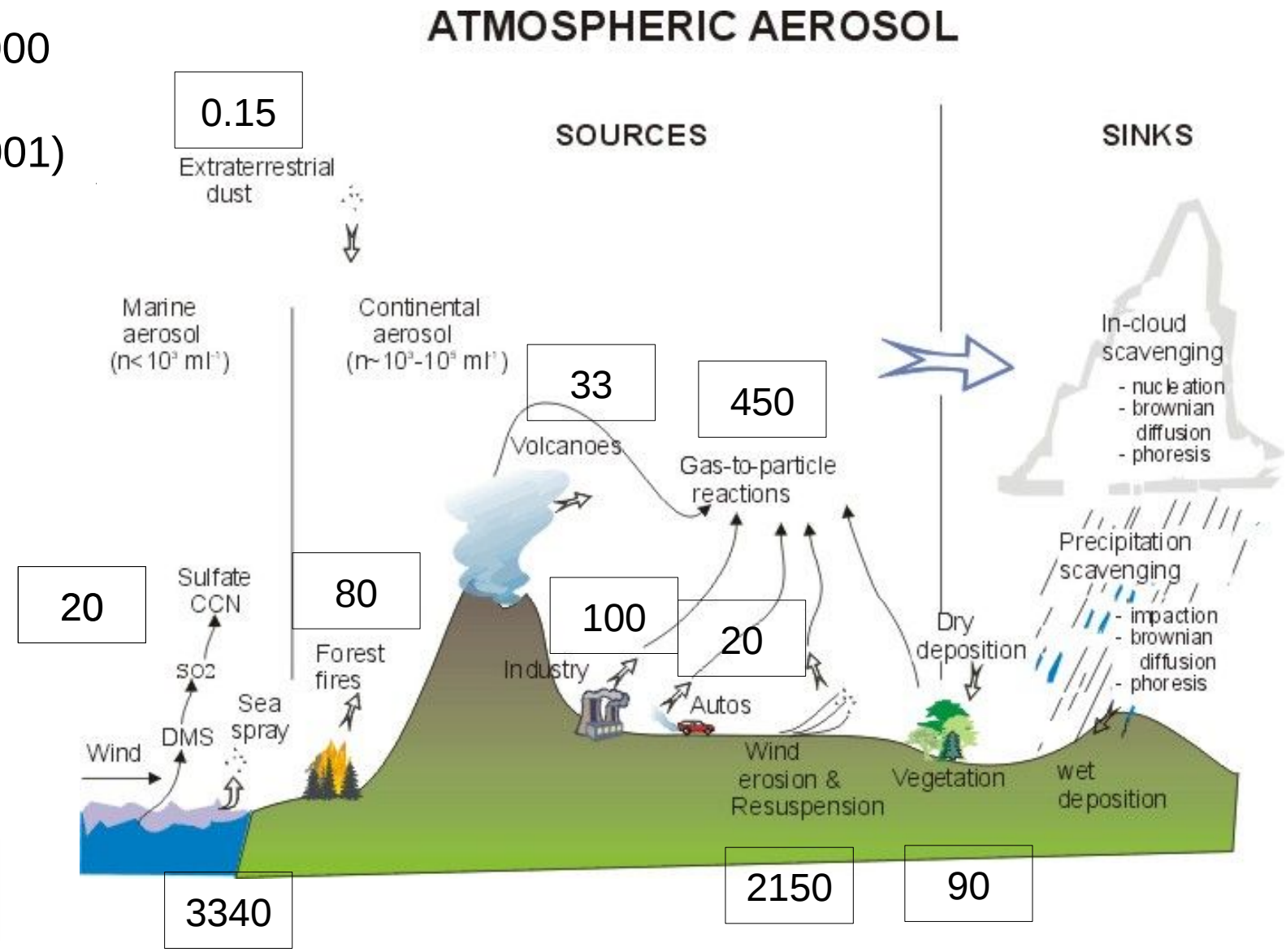


USGS science for a changing world

ASU Arizona State University

Sources of atmospheric aerosol

Year 2000
(Tg)
IPCC (2001)



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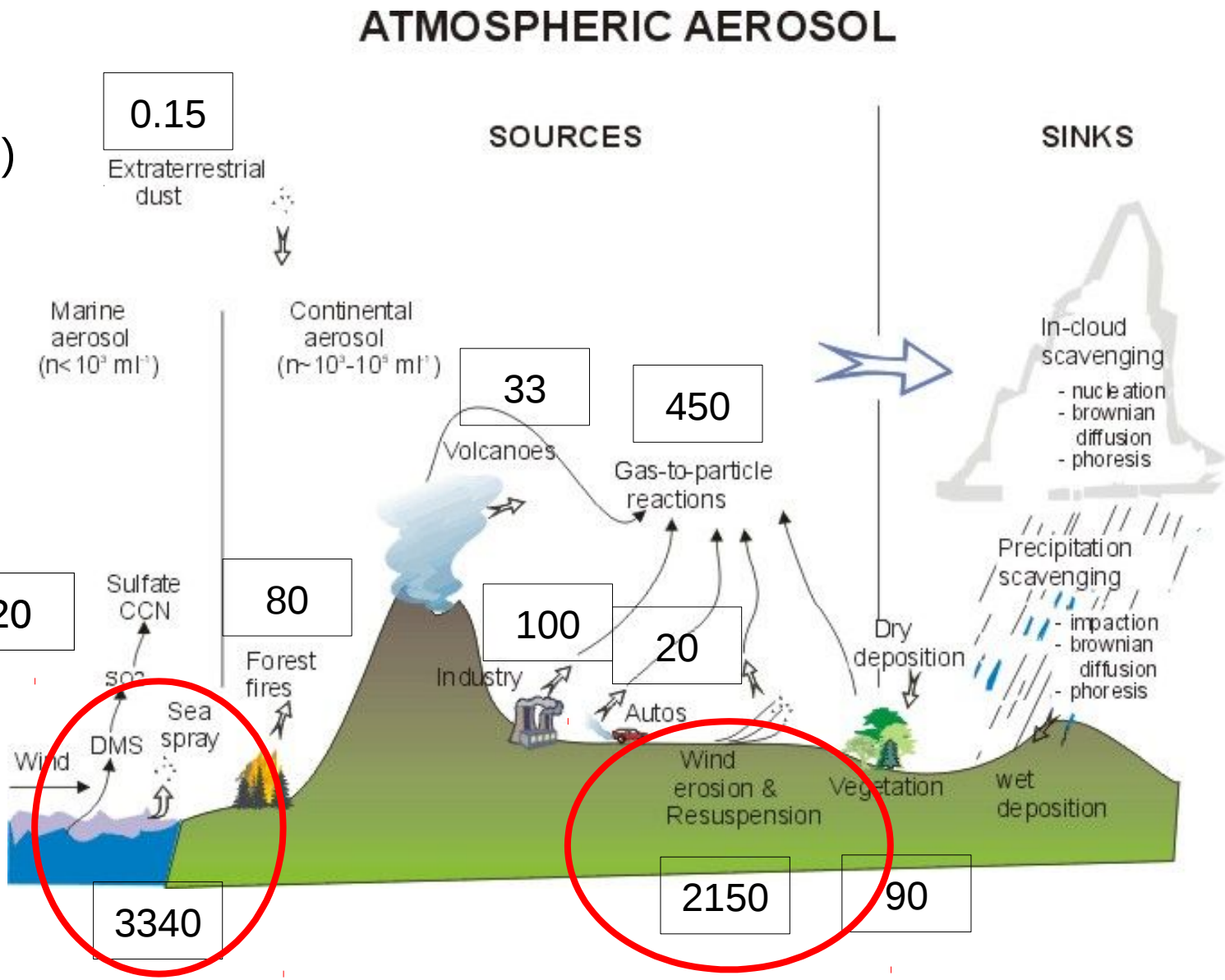
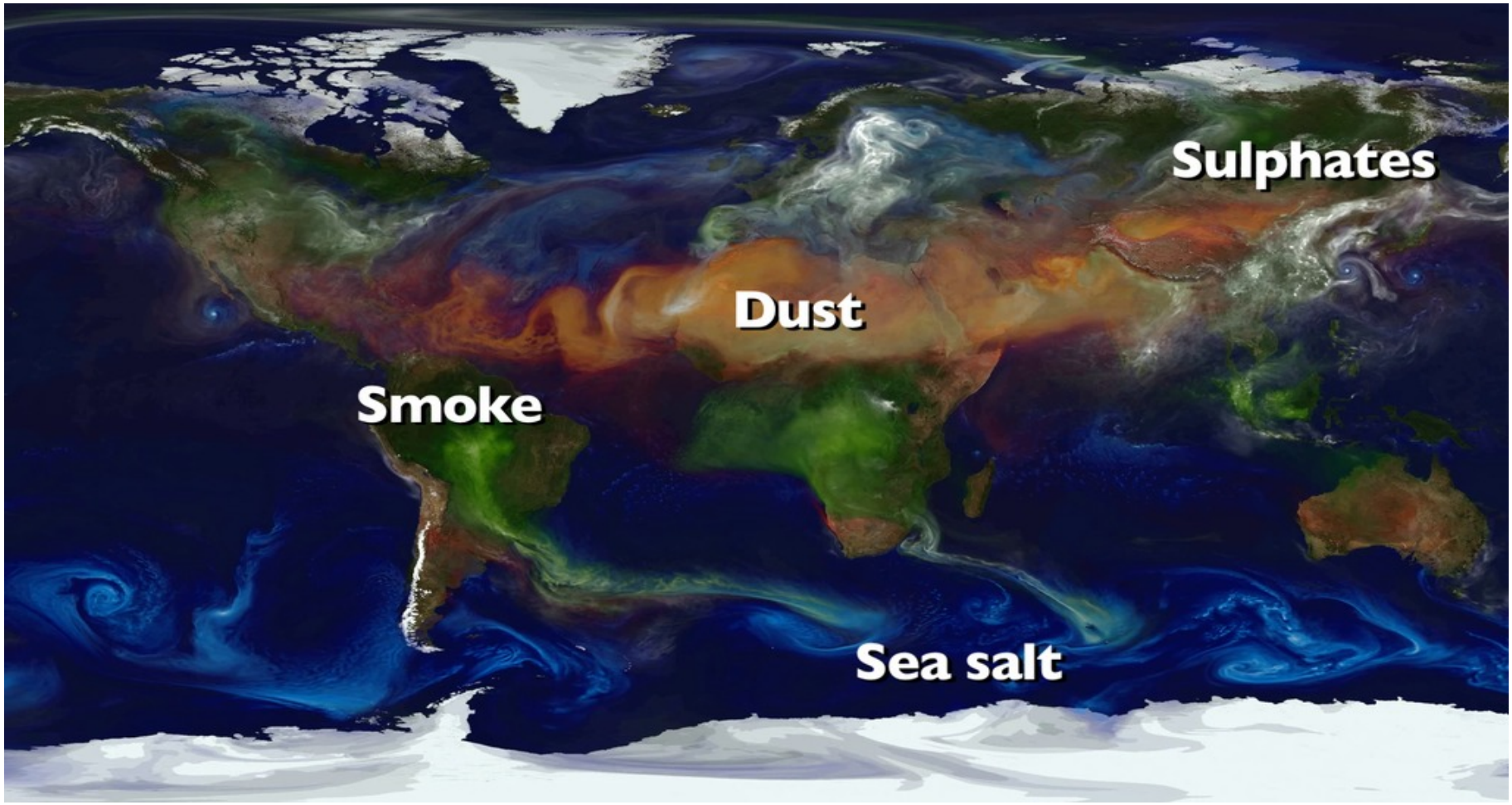


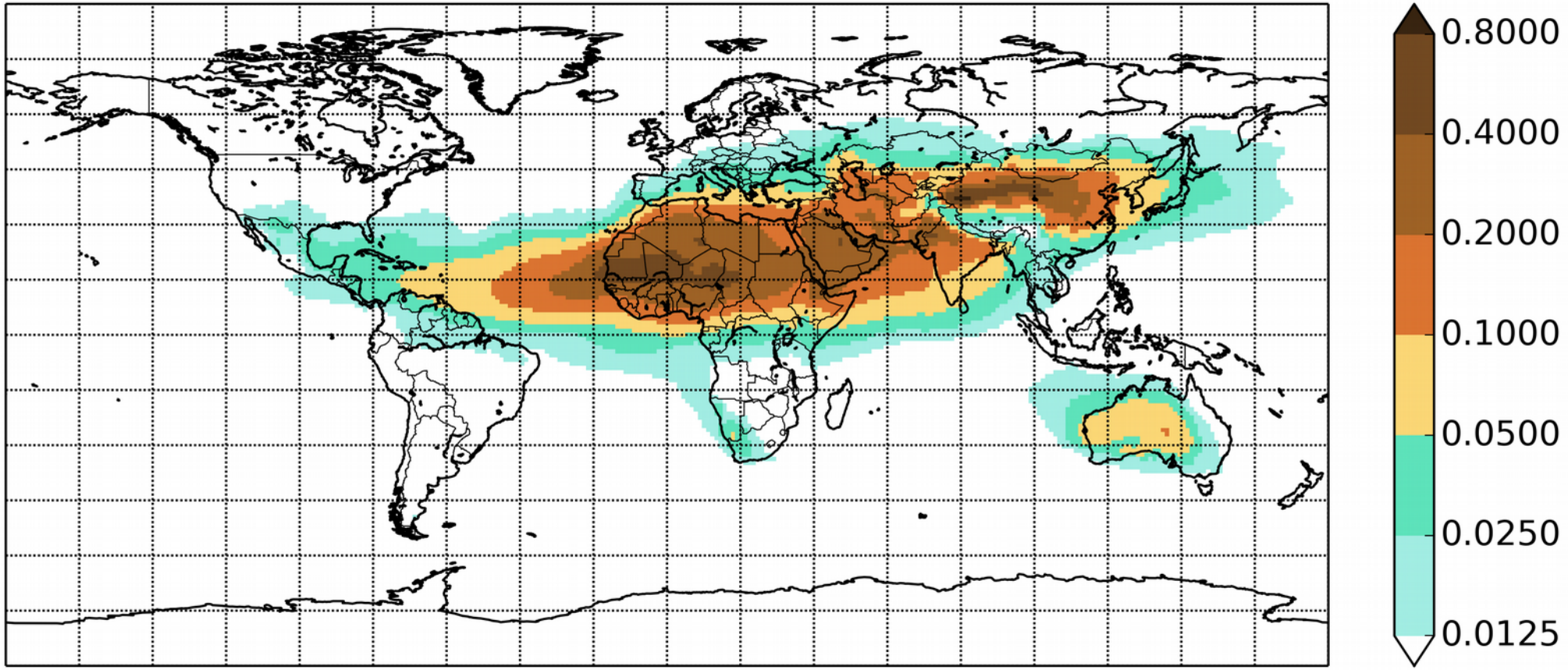
Geographical distribution of aerosols



Simulation with GEOS-5

Grographical distribution of dust

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



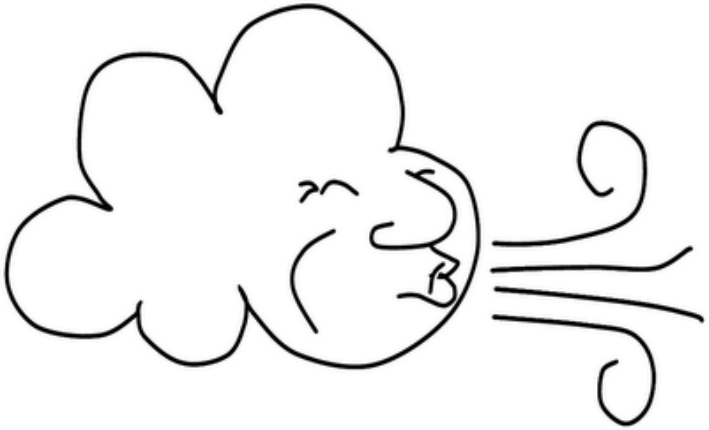
Data: CAMS reanalysis
Picture: WMO SDS-WAS

WMO AIRBORNE DUST BULLETIN
Sand and Dust Storm Warning Advisory and Assessment System

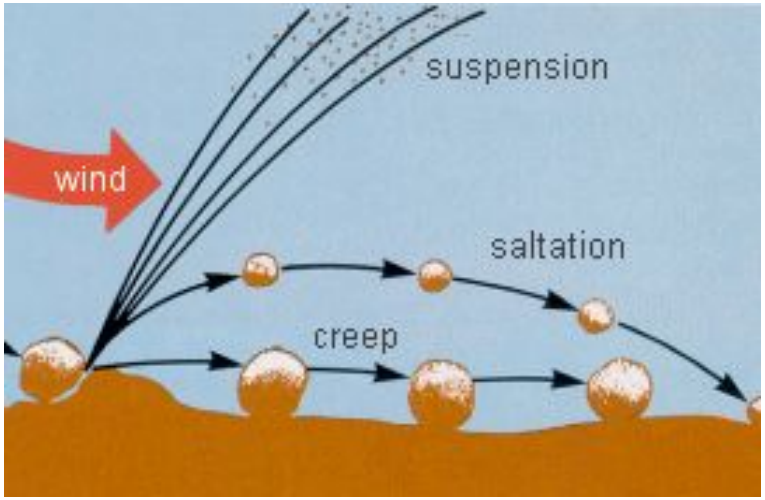
Summary

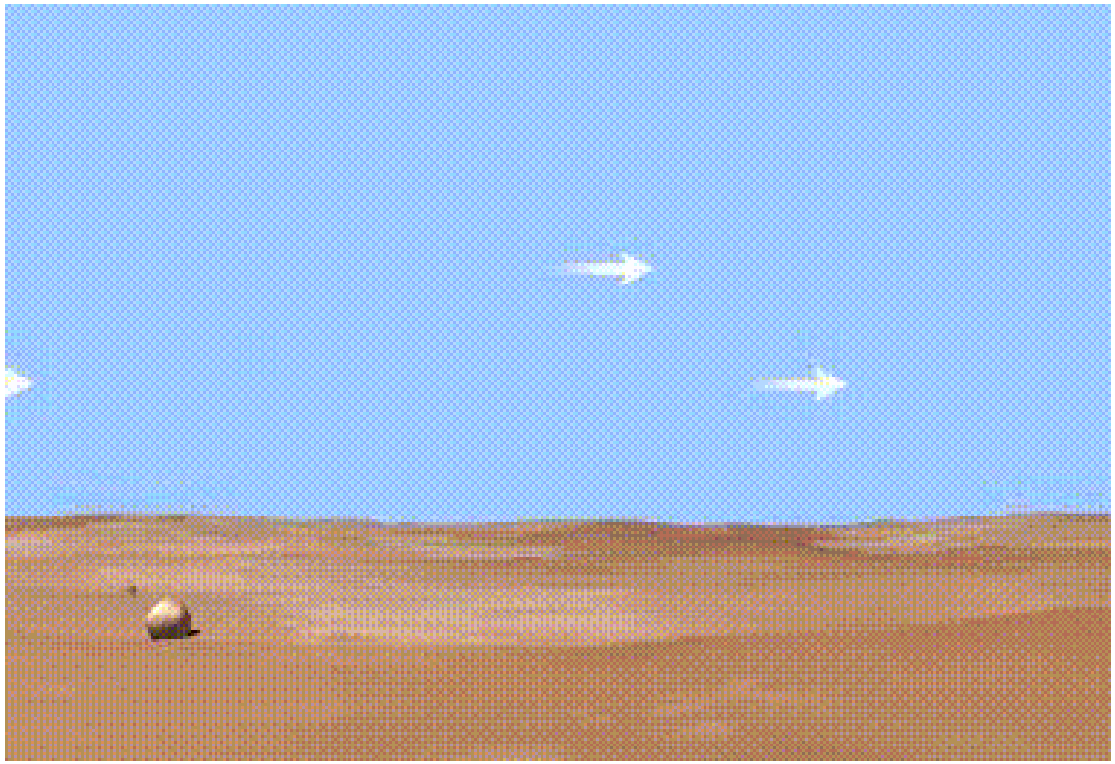
- Atmospheric aerosol
- The cycle of mineral dust
- WMO SDS-WAS

The dust cycle



Dust emission





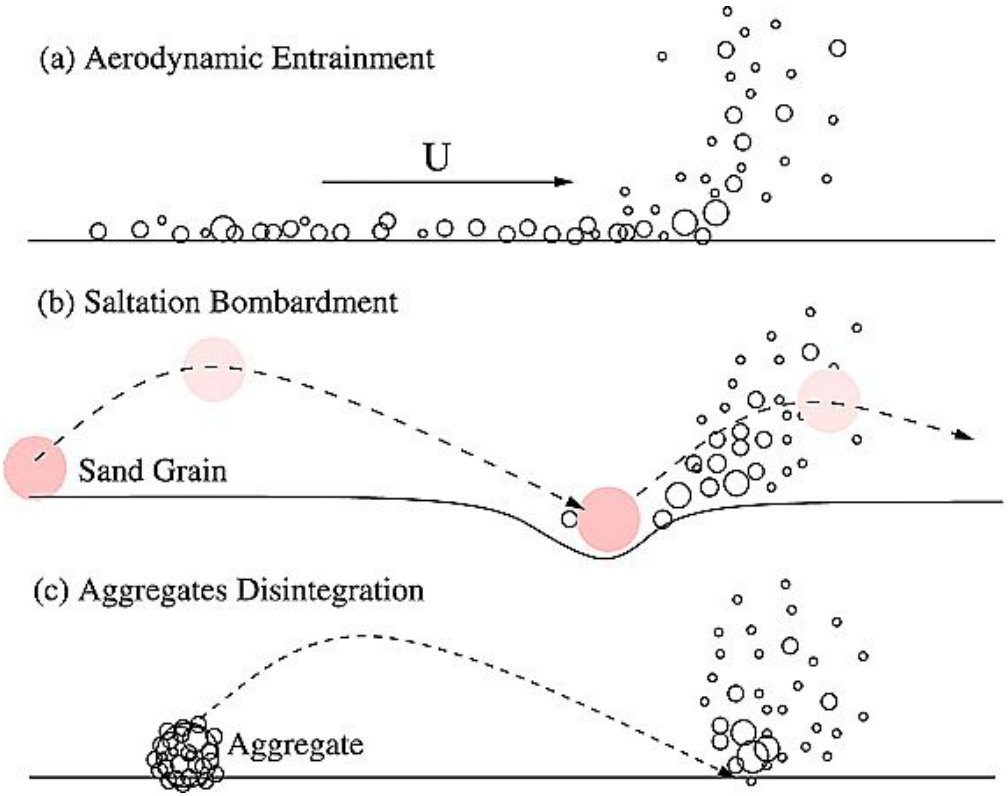
The wind moves the loose particles according to its speed and the size of soil particles:

- creeping (> 500 µm)

- saltation (50-500 µm)

- suspension (< 50 µm)

Saltation & sandblasting



Shao et al. (2011)

- Direct suspension is not so common, because it needs very strong winds.
- Normally, the dust emission is the result of the combination of two different physical processes: saltation (horizontal flux) and sandblasting (vertical flux).
- Sandblasting is a consequence of the breaking of particle aggregates.

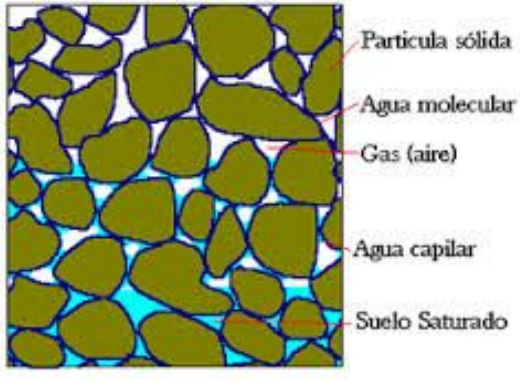
Erosion threshold

A crude estimation of the threshold wind speed for the mobilisation of soil particles would be around **8 m/s**, although it depends on many factors (soil nature and condition, turbulence)

Non-erodible elements (i.e. vegetation)

Crusted soils

Soil humidity



Snow

Dust emission

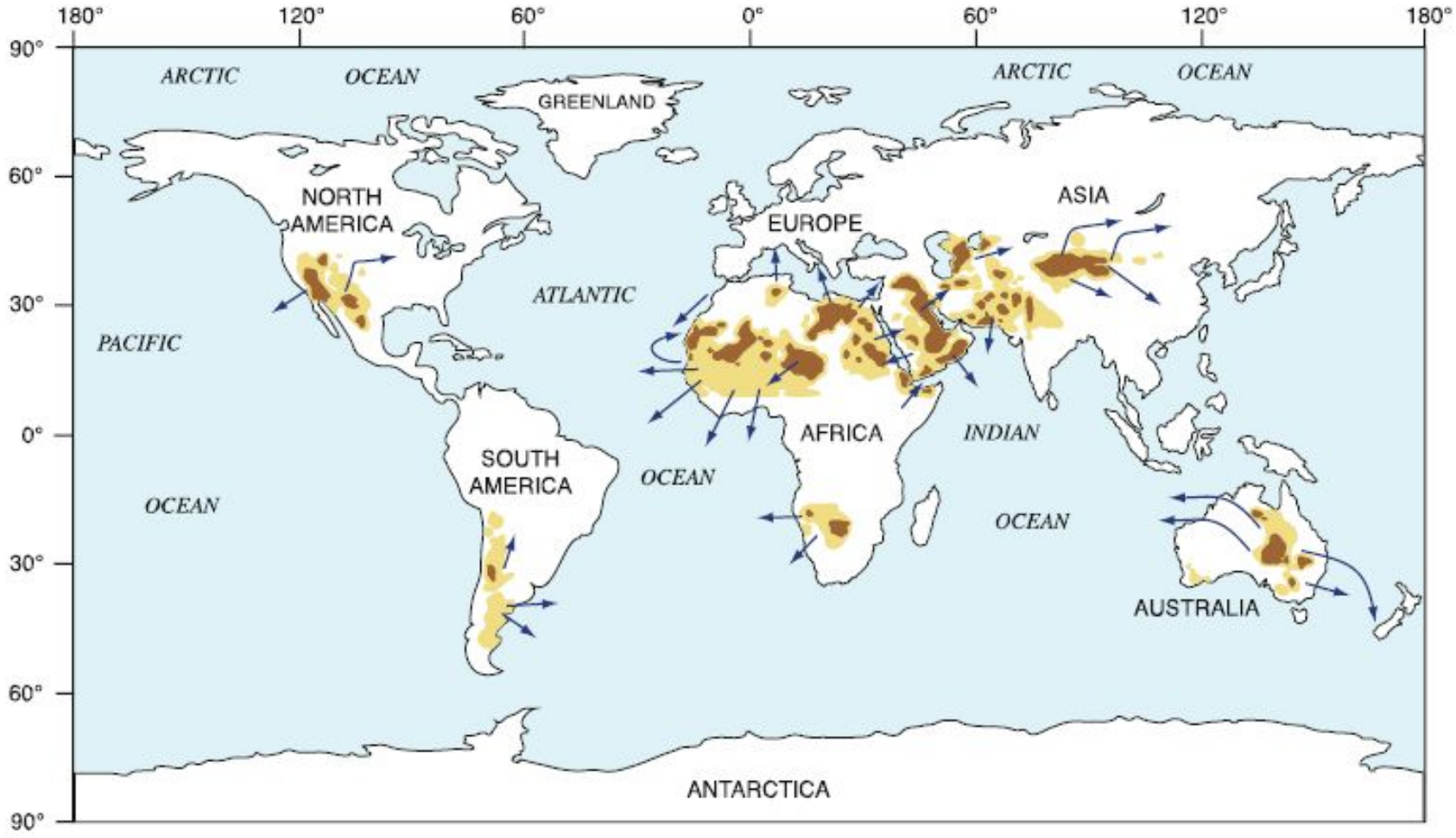
Soil factors

- Soil texture (particle size)
- Soil moisture
- Vegetation
- Snow cover

Meteorological factors

- Wind speed
- Near-surface turbulence

Sources

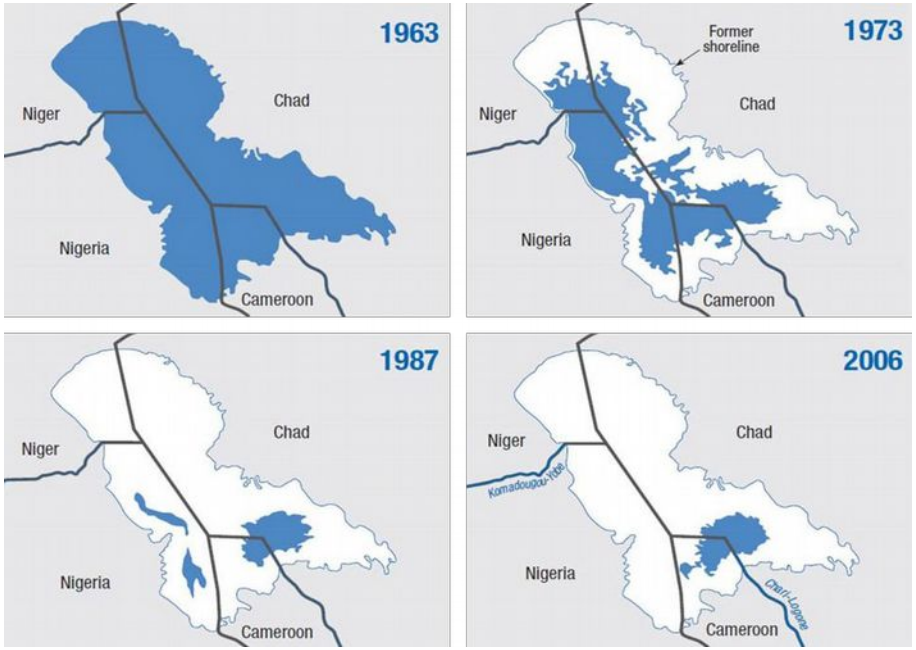

180°
120°
60°
0°
60°
120°
180°
90°
60°
30°
0°
30°
60°
90°
ARCTIC
OCEAN
GREENLAND
ARCTIC
OCEAN
NORTH
AMERICA
EUROPE
ASIA
ATLANTIC
PACIFIC
AFRICA
INDIAN
SOUTH
AMERICA
OCEAN
OCEAN
OCEAN
AUSTRALIA
ANTARCTICA

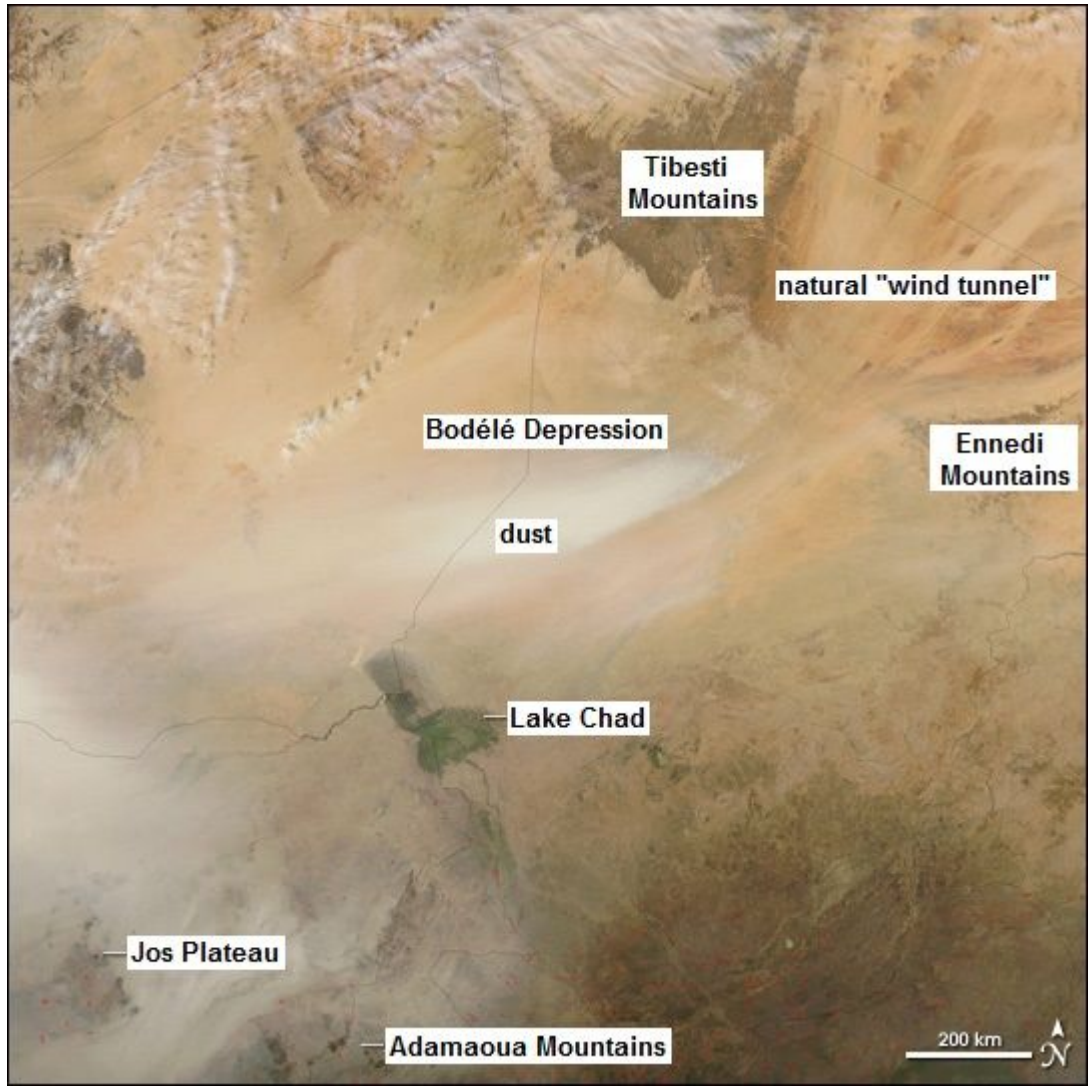
Anthropic sources of dust

Anthropic sources are responsible of a significant part (25-30%) of dust emissions

- Perturbed soils: dessicated lakes and marshes consequence of water overuse, agricultural lands, etc..
- Direct human activity: overcast minery, construction, driving on unpaved roads, ...

Bodélé depression

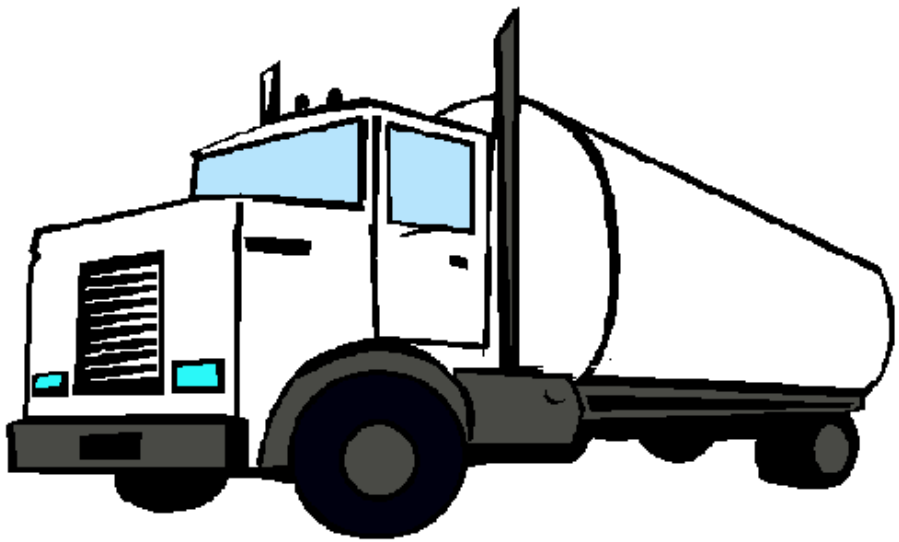




Total emission

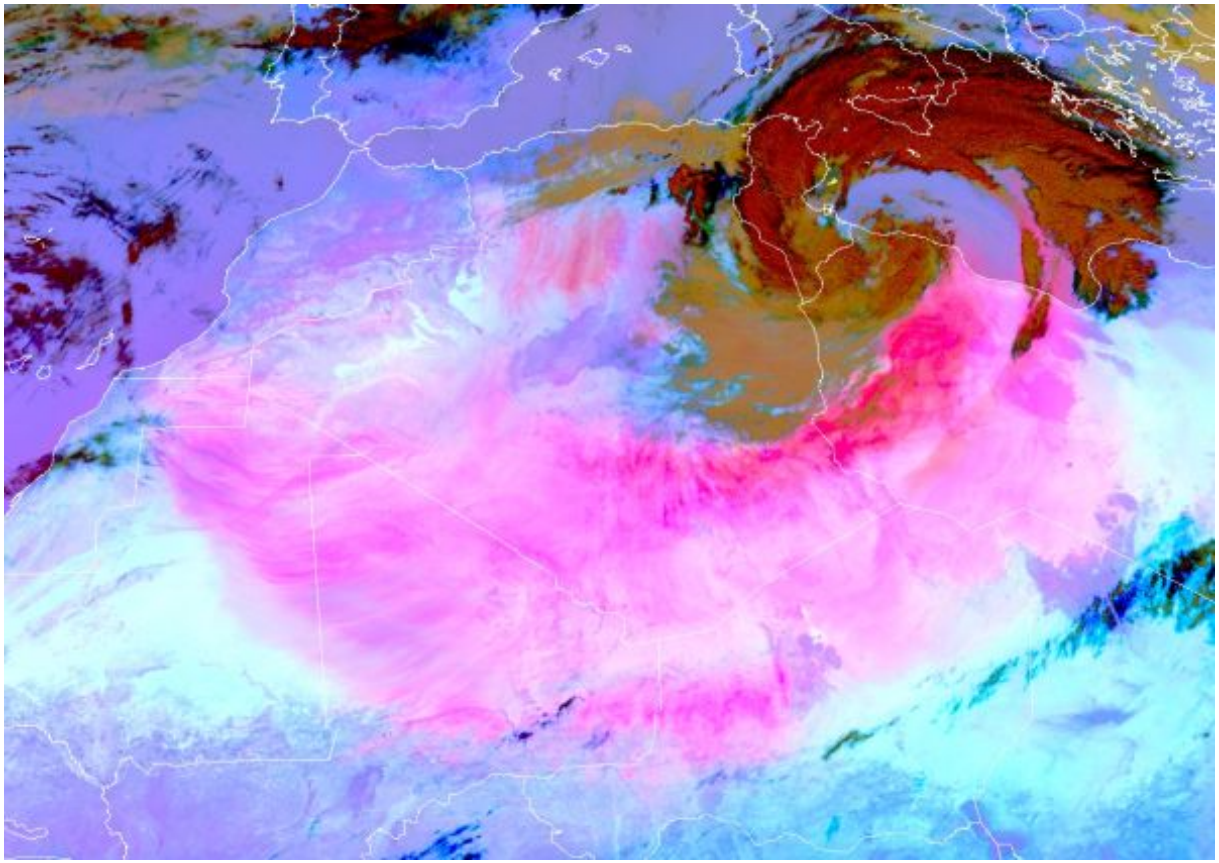
~ 30–60 Tm/s
~ 1000–2000 Tg/yr

50,000,000 lorries

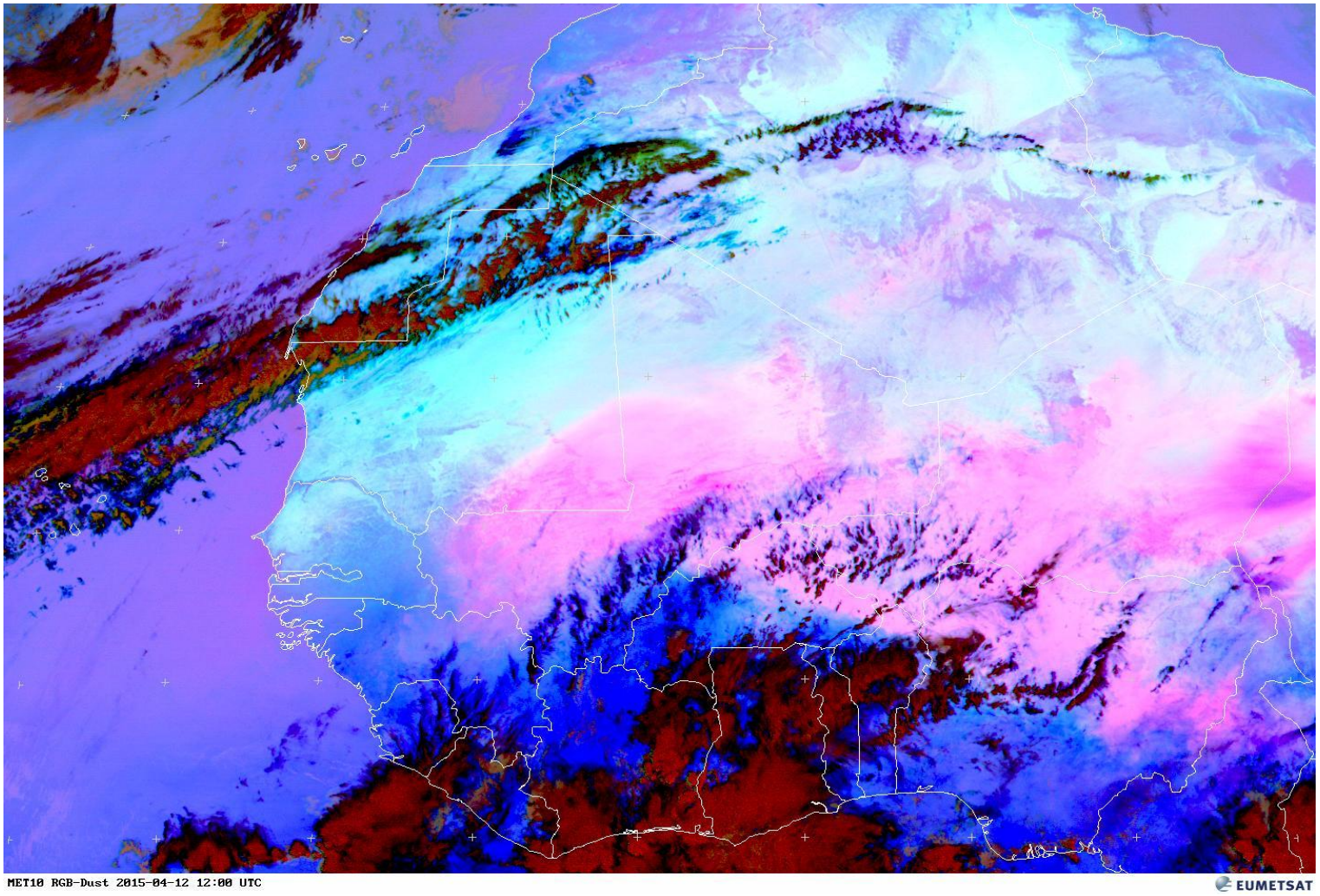


3,000 ULCC

Processes of diverse scale



Meteorological conditions



12 apr 2015
12:00 UTC

EUMETSAT

SYNOPTIC SCALE

- Frontal systems
- Reinforced trade winds

Meteorological conditions

29 Apr – 1 May 2007

MESOSCALE-MICROSCALE

- Convection
- Drainage winds
- Low-level jets (LLJ)
- Gap winds
- ...

Meteorological conditions

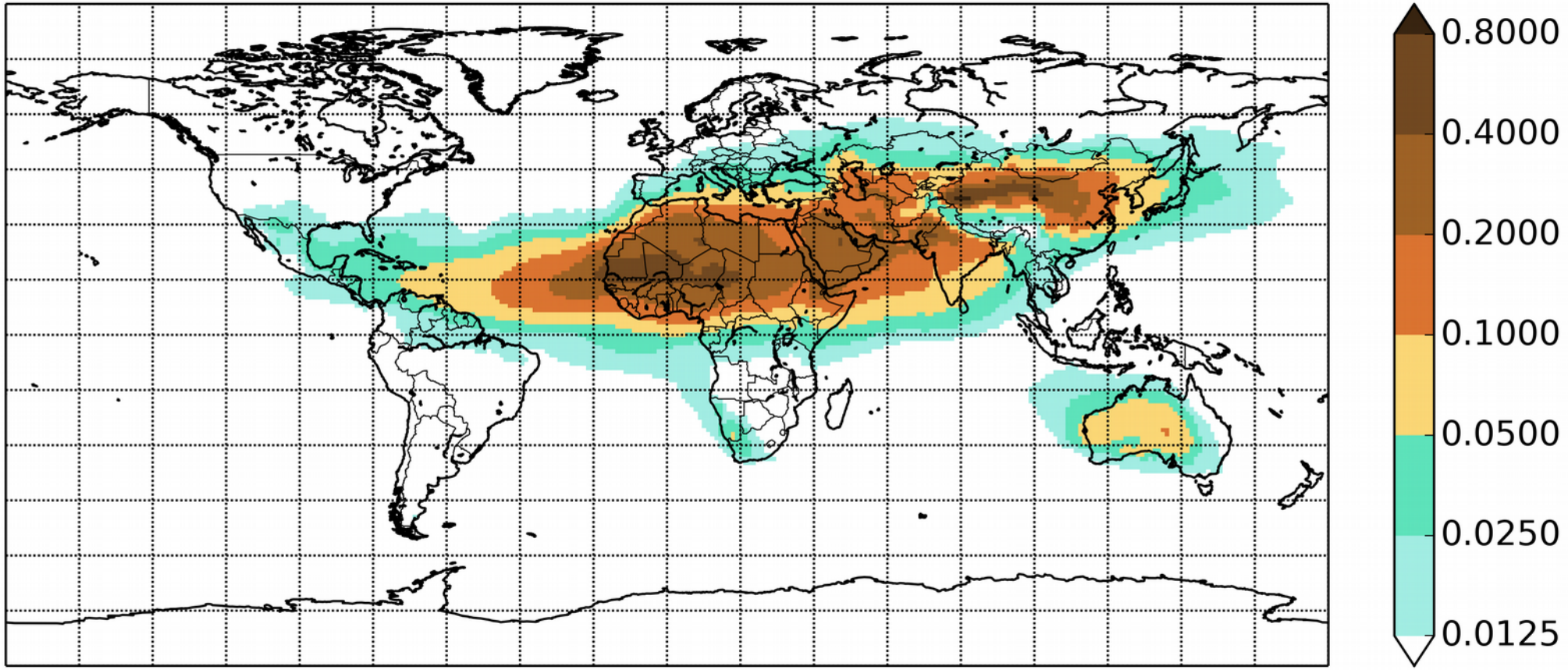
13 – 14 Nov 2009

Transport

29 Jul - 2 Aug 2013

Grographical distribution of dust

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



Data: CAMS reanalysis
Picture: WMO SDS-WAS

WMO AIRBORNE DUST BULLETIN
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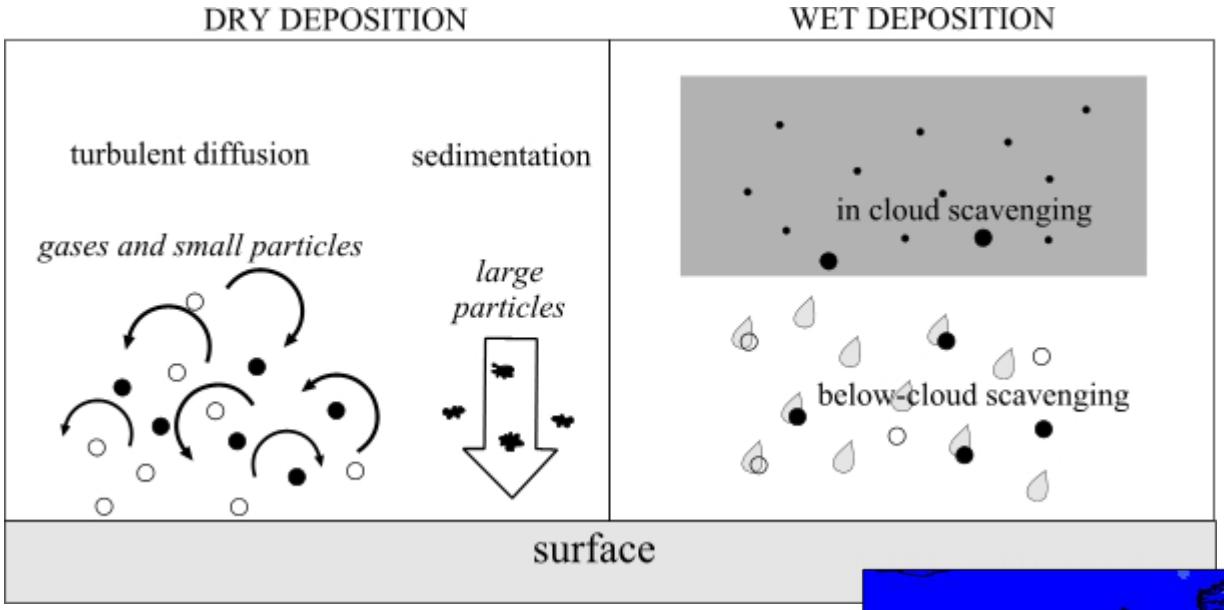
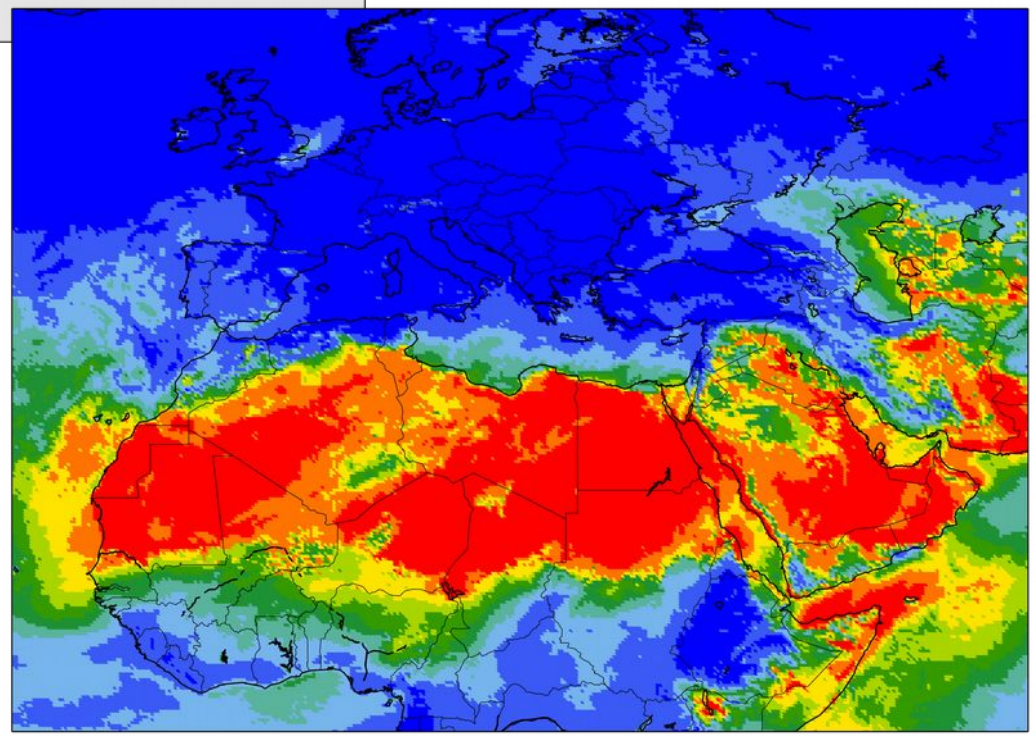
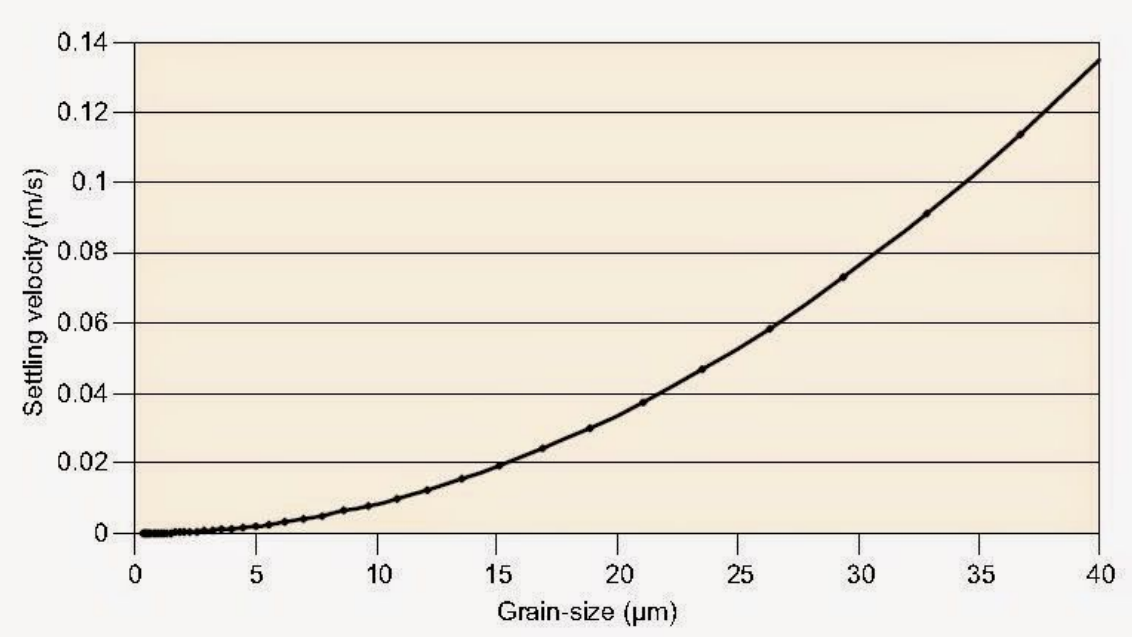
Deposition





Ratio between dry and total deposition

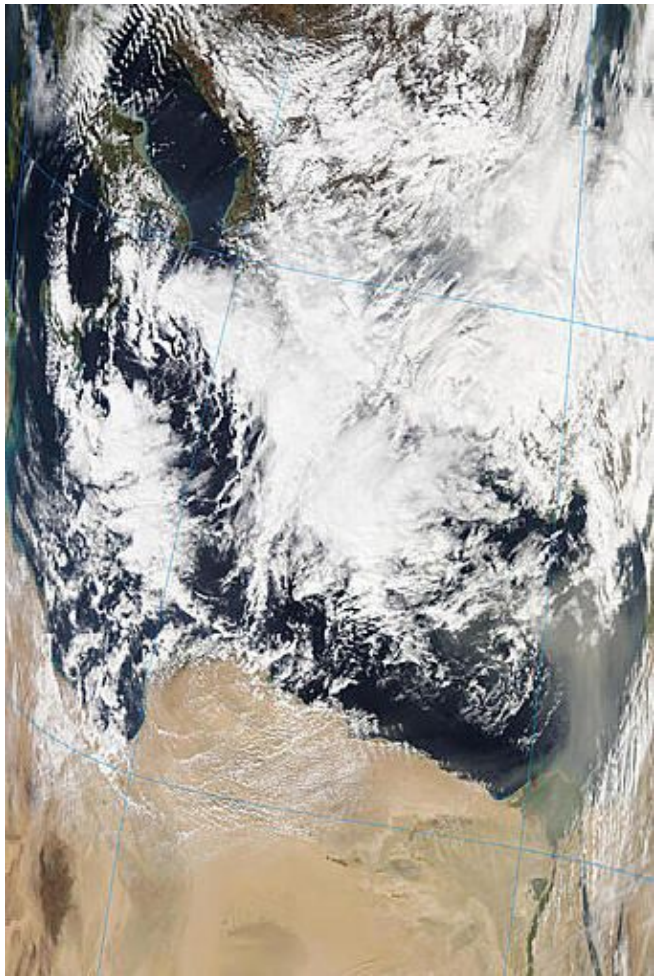
Deposition



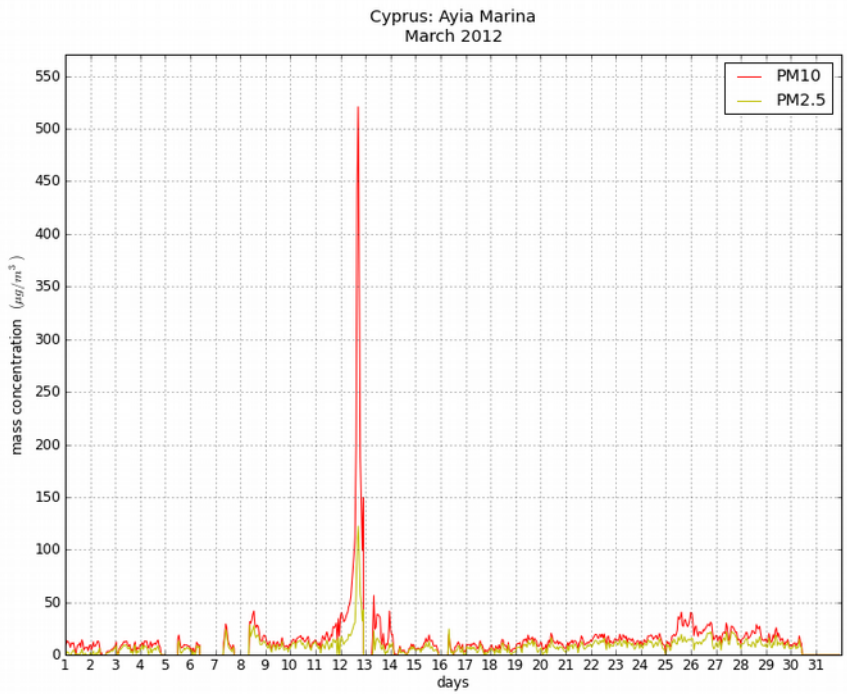
SIZE (µm)	AVERGE LIFETIME (h)
0.1 - 0.18	231
0.18 - 0.3	229
0.3 - 0.6	225
0.6 – 1	219
1 - 1.8	179
1.8 – 3	126
3 – 6	67
6 - 10	28

Tegen and Lacis (1996)

Wet deposition

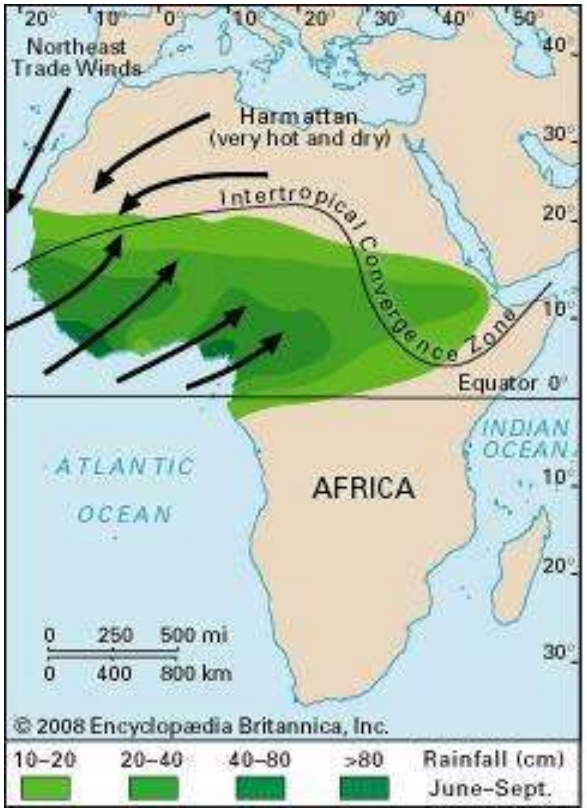


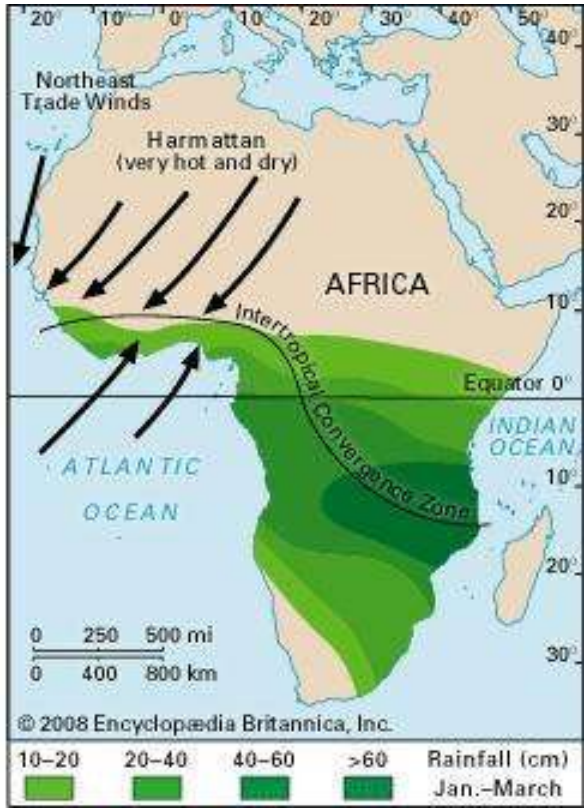
MODIS 12 Mar 2012



PM Ayia Marina, Cyprus, Mar 2012

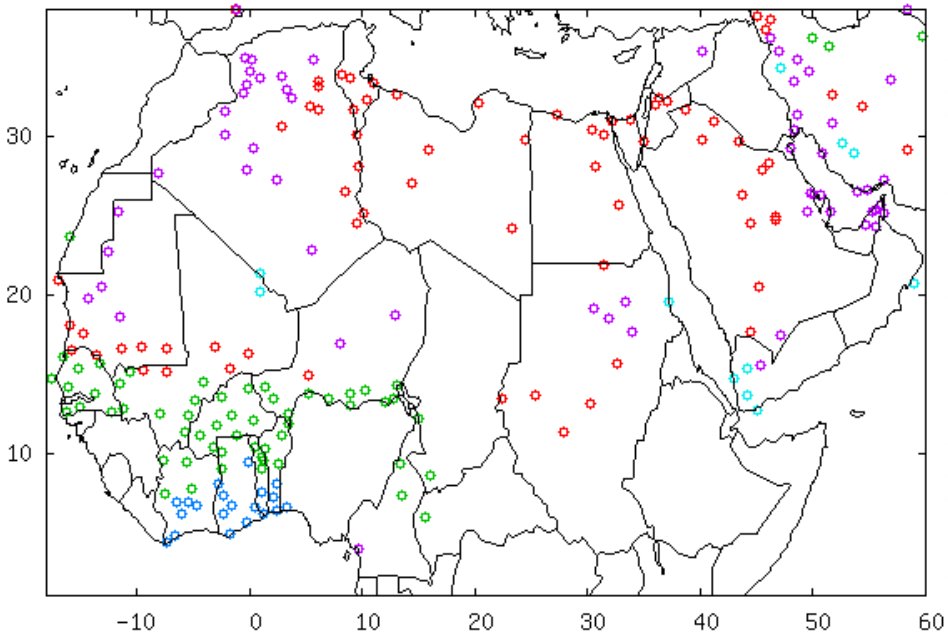
Seasonal variability



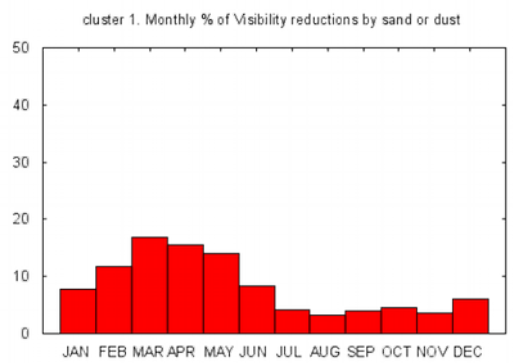


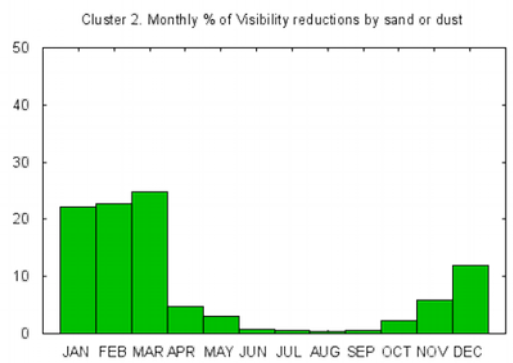
NH summer / winter

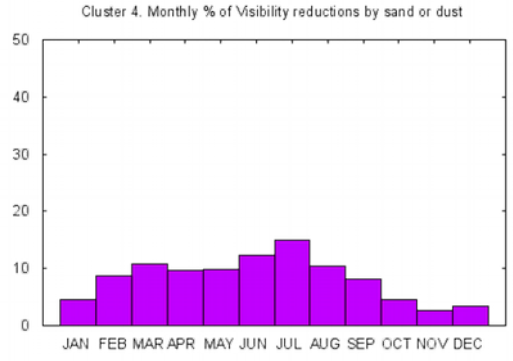
Seasonal variability

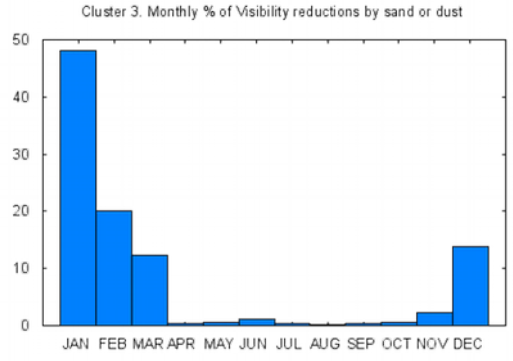


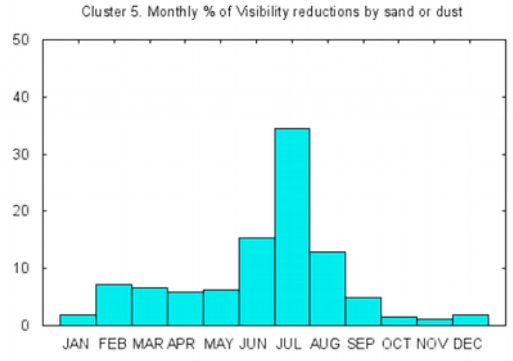
1996-2010









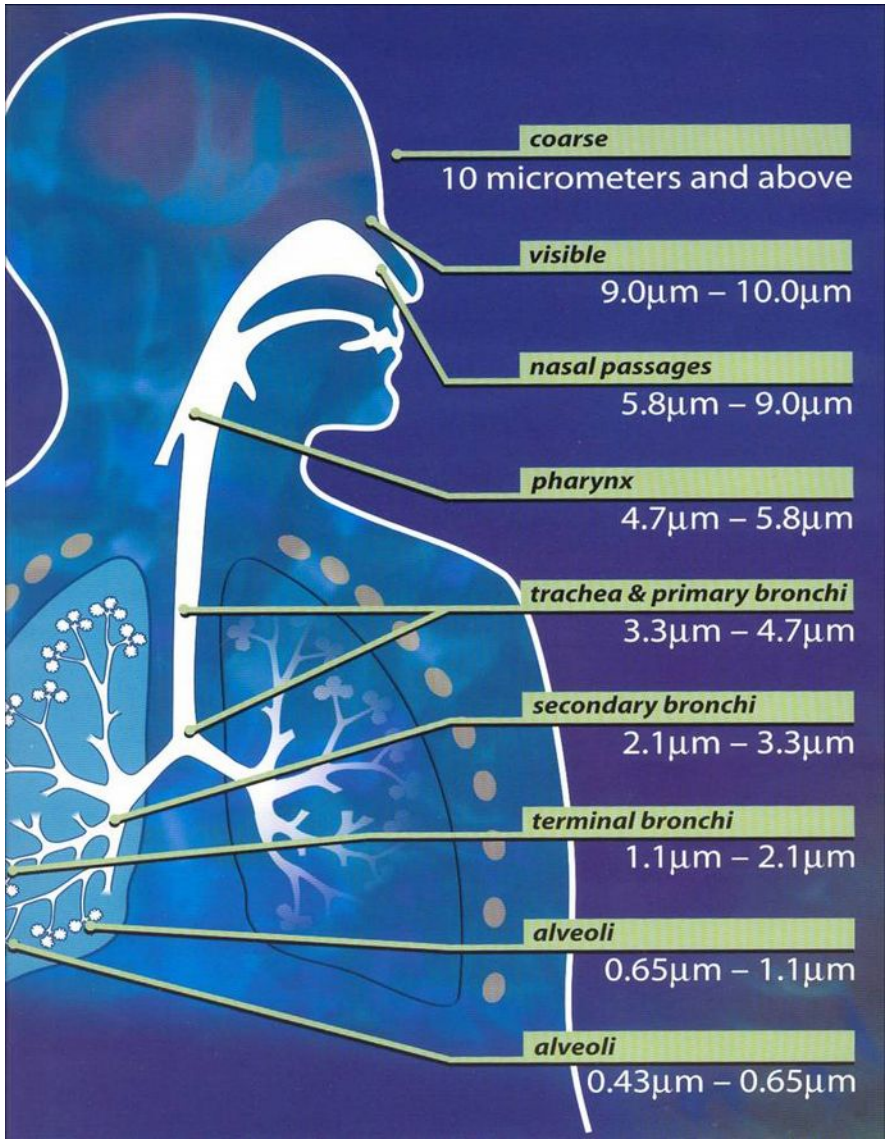


Terradellas et al. (2012)

Dust impacts

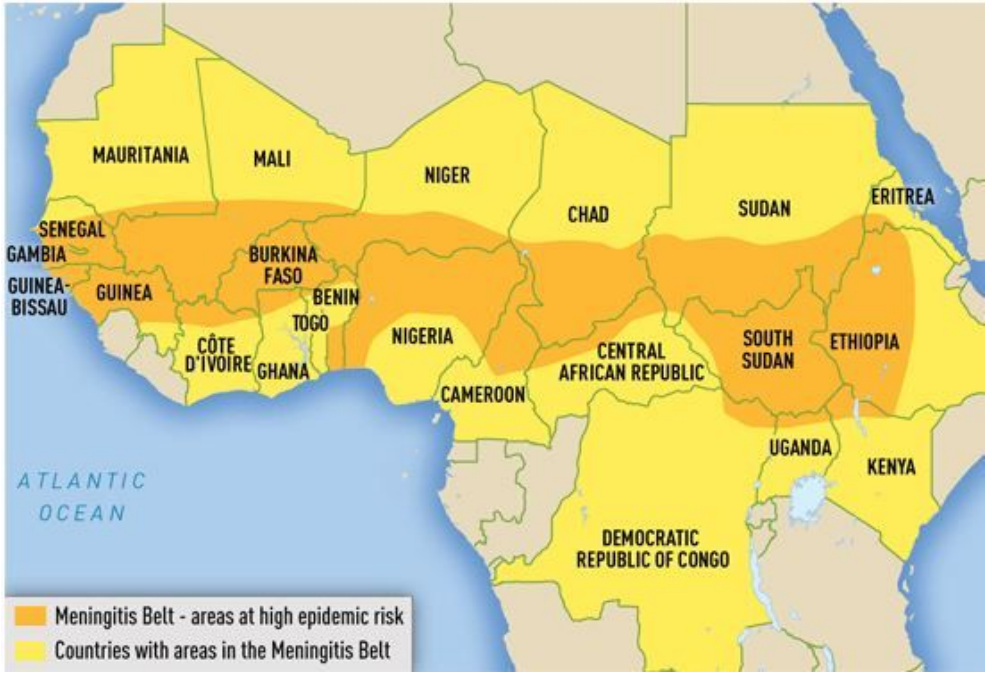
- Air quality & health
- Weather & climate
- Ecosystems
- Transportation
- Energy
- Agriculture, fishing…

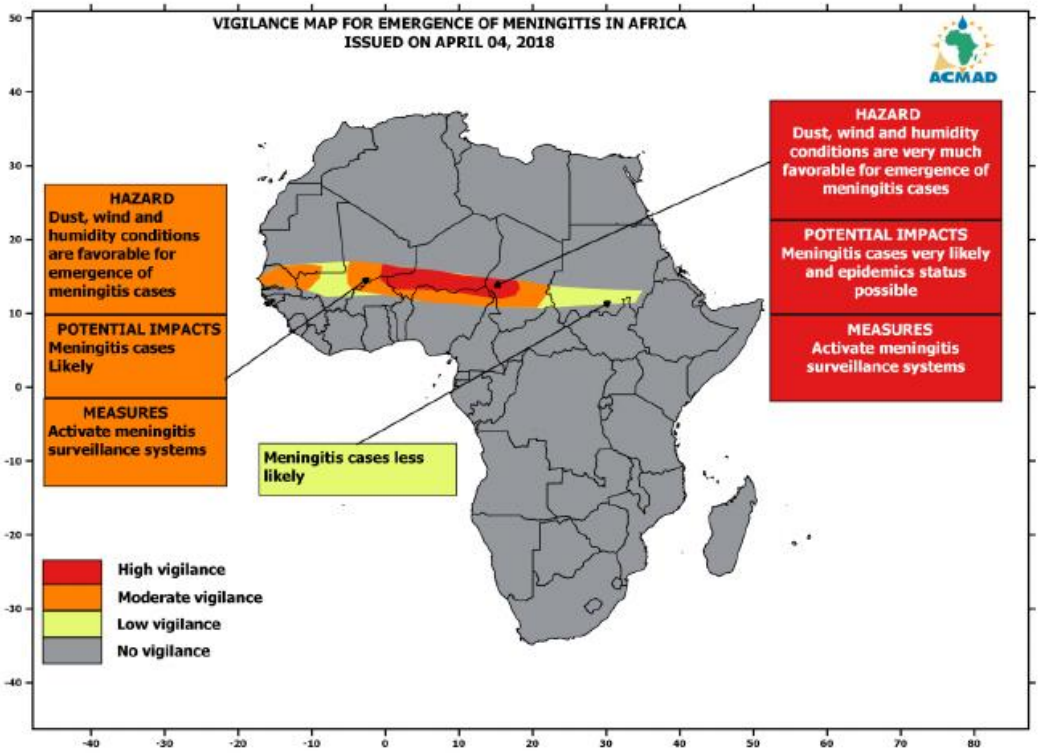
Health impact

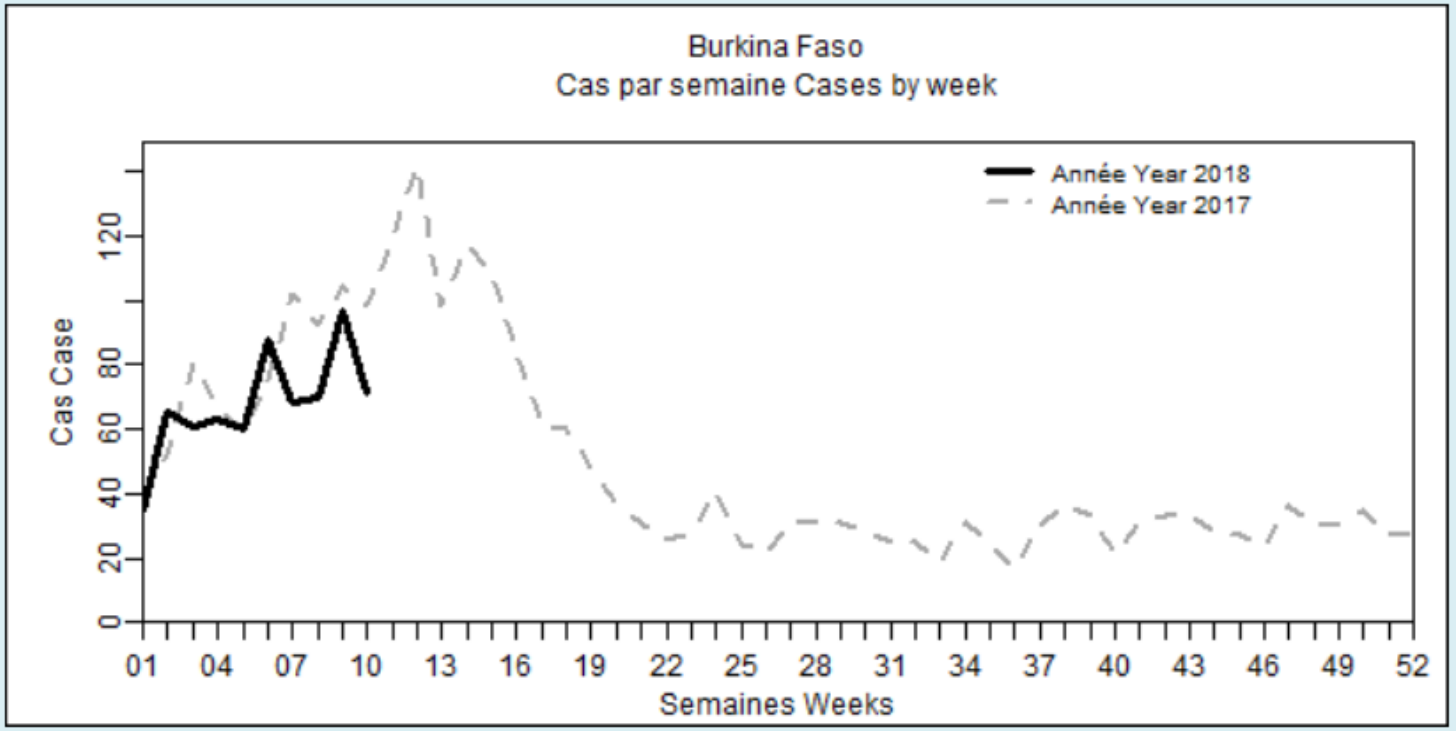


- Particle size
- Chemical and mineralogical composition
- Carrying bacteria, viruses, fungi, ...
- Time and intensity of exposure

Map 3-11. Areas with frequent epidemics of meningococcal meningitis



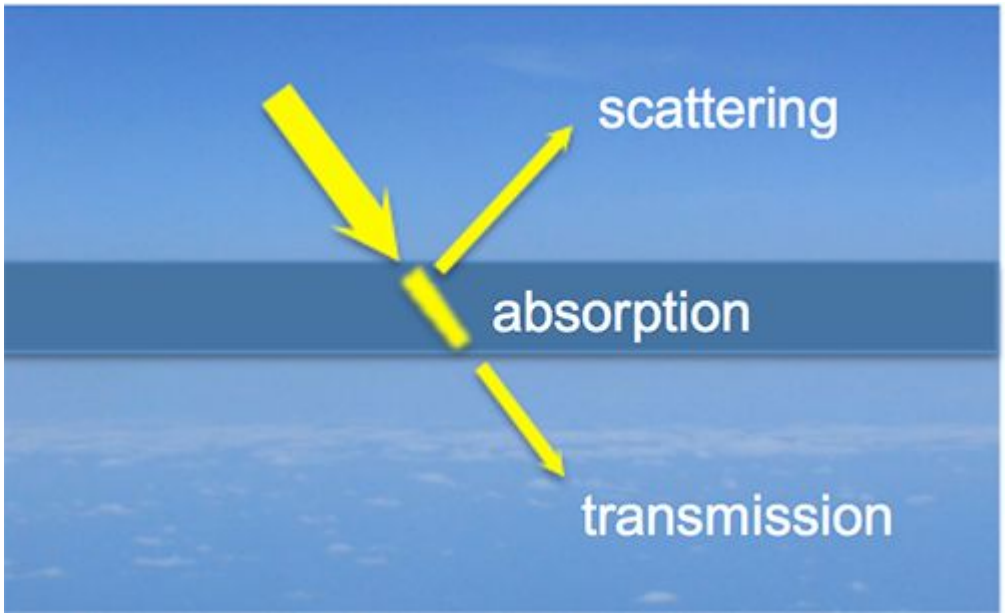


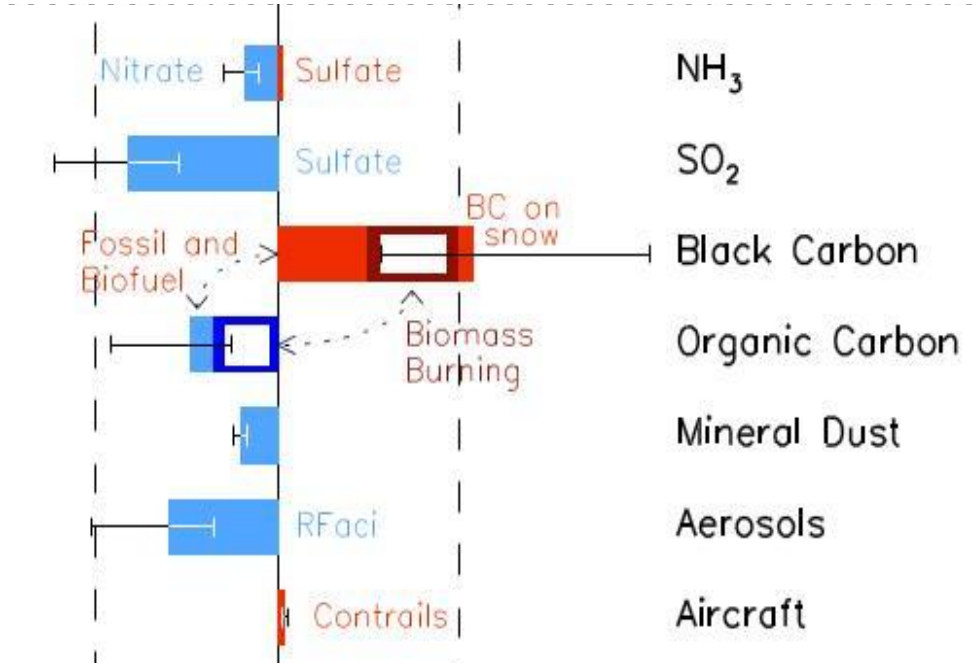


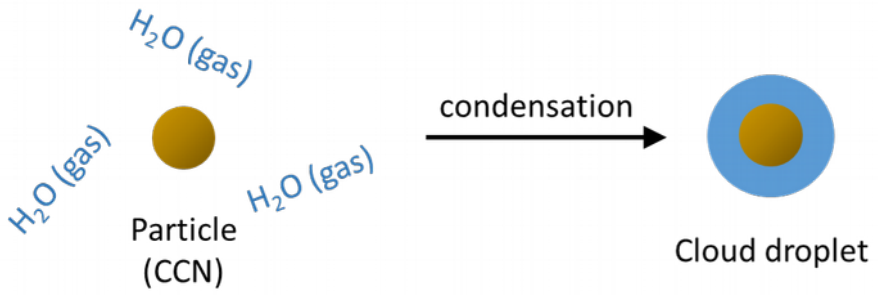
ACMAD

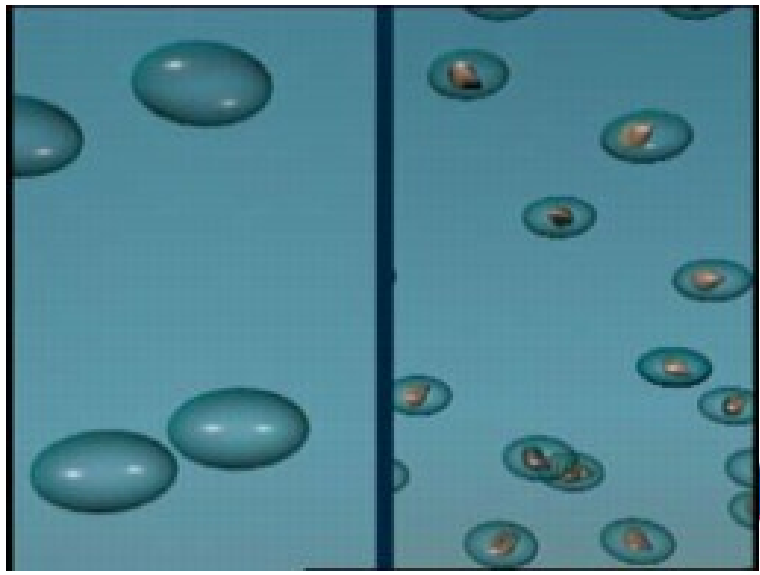
World Health Organization

Impact on weather and climate

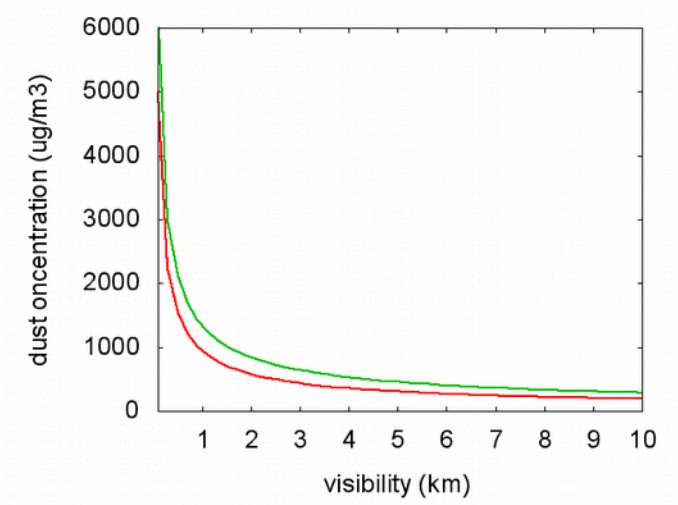








Impact on transportation



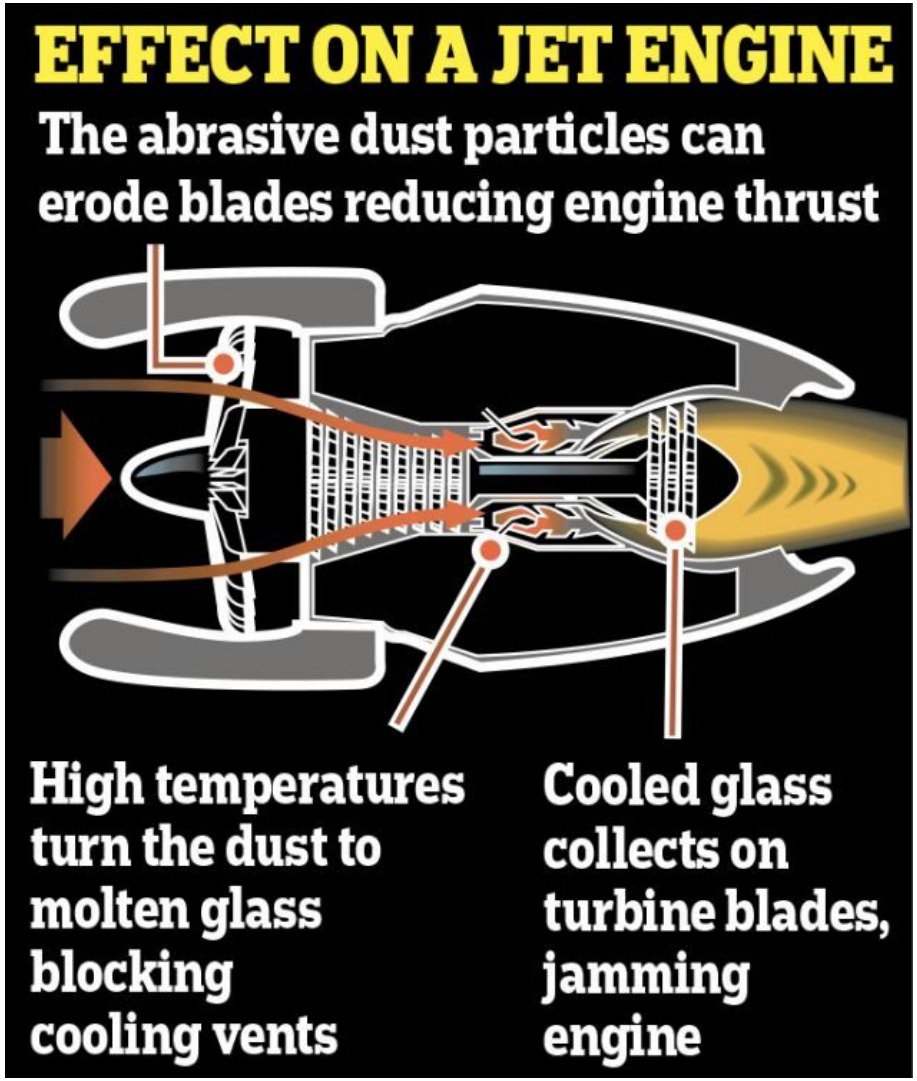
D'Almeida (1986)

Ben Mohamed et al. (1992)

Arizona, 29 Oct 2013

Tunis, 7 May 2002

Impact on transportation



Volcanic ash is very dangerous for aviation because it melts at less than 1400º, the temperature at which the aircraft engines operate, and can cause flares.

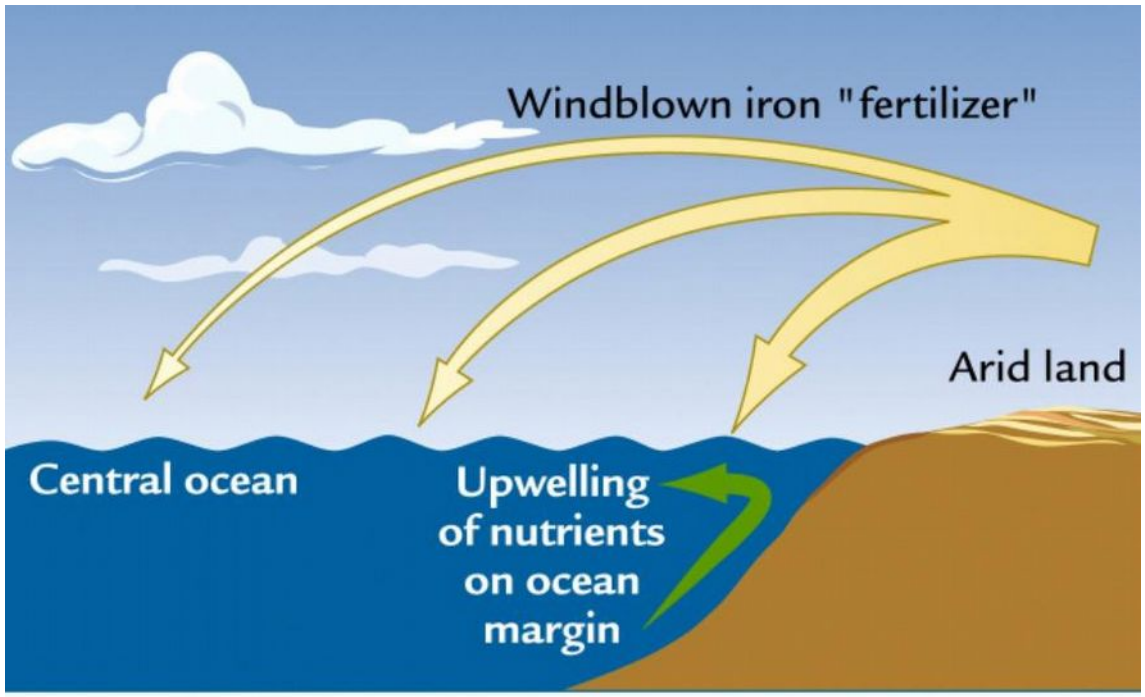
Dust particles melt at about 1700º and do not cause such flares, but problems of erosion in the engine and on external surfaces of the aircraft.

More frequent maintenance tasks

Impact on solar energy

- Reduction of available energy
- Impact on cloud formation
- Reduced efficiency due to dust deposition (soiling)

… also positive impacts



- Dust deposition is a source of micro-nutrients for continental and marine ecosystems
- Saharan dust has been shown to fertilize the Amazon rainforest
- The contribution of Fe and P benefits the production of marine biomass in oceanic areas that suffer from shortage of such elements

Summary

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- The cycle of mineral dust
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WMO SDS-WAS

Mission

Enhance the capacity of coutries to generate and deliver to users observations, forecasts, information and knowledge on mineral dust

Structure

- Regional Center for Northern Africa, Middle East and Europe, Barcelona
- Regional Center for Asia, Beijing
- Regional Center for America, Barbados

SDS-WAS Regional Center NAMEE

The Center is jointly managed by AEMET
and the Barcelona Supercomputing Center

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

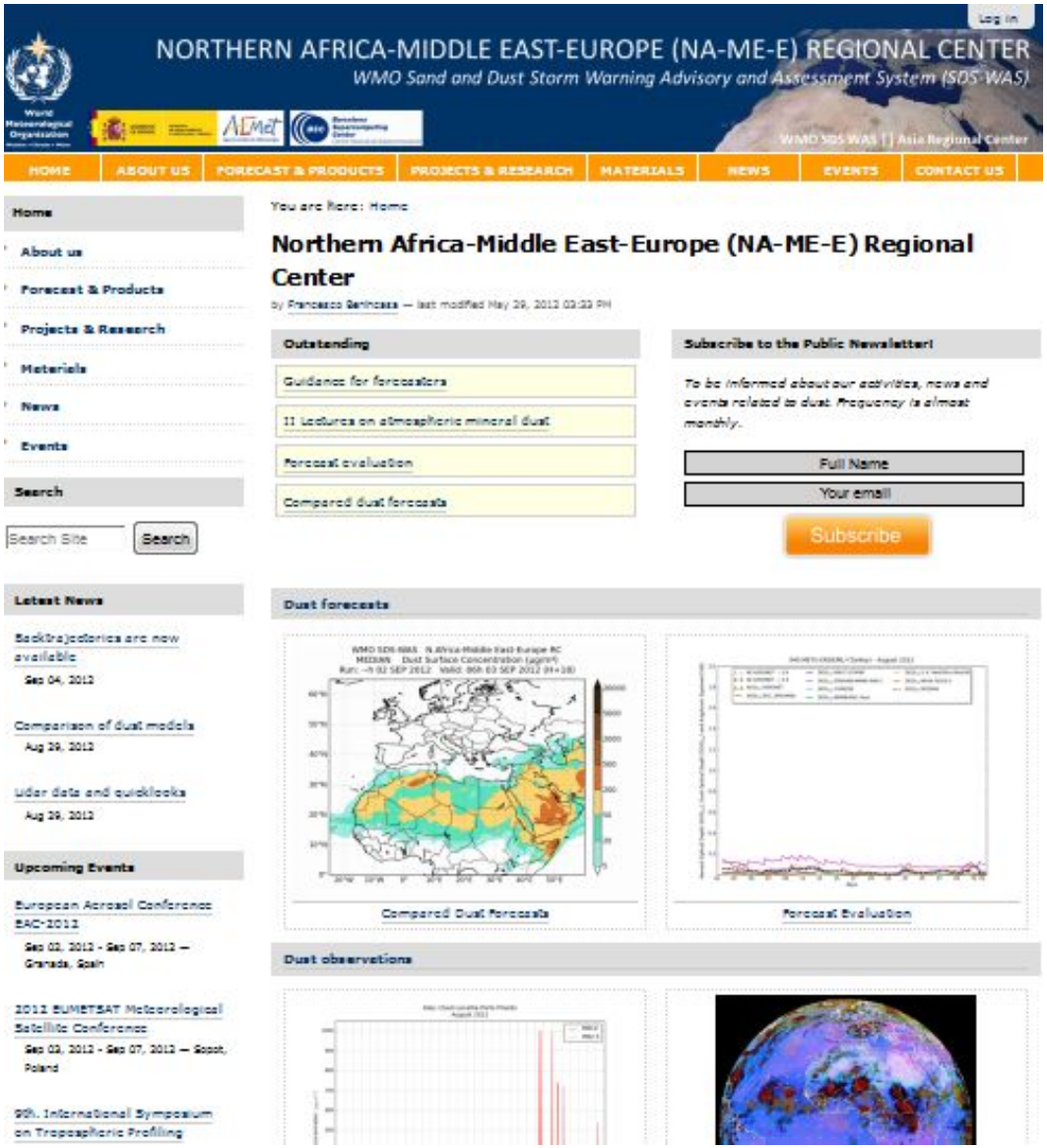
AEMet
Agencia Estatal de Meteorología

BSC
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Nexus II building (UPC campus)

MareNostrum supercomputer

SDS-WAS Regional Center NAMEE



R&D

https://sds-was.aemet.es

sdswas@aemet.es

Barcelona Dust Forecast Center

Operational Forecast

https://dust.aemet.es

dust@aemet.es