

# 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

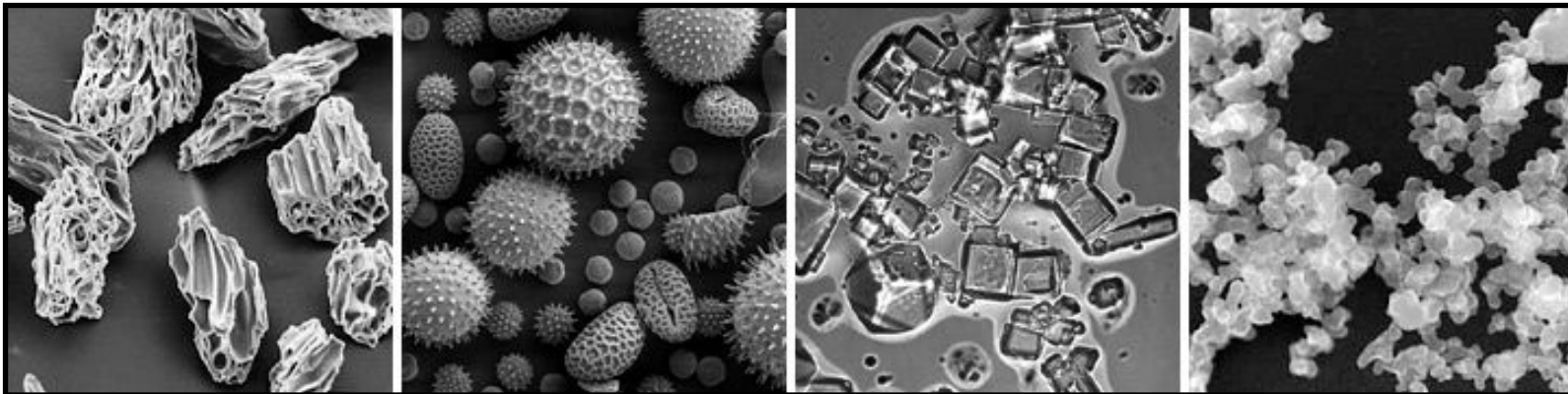
# Summary

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

# Atmospheric aerosol

## Solid or liquid particles suspended in the air

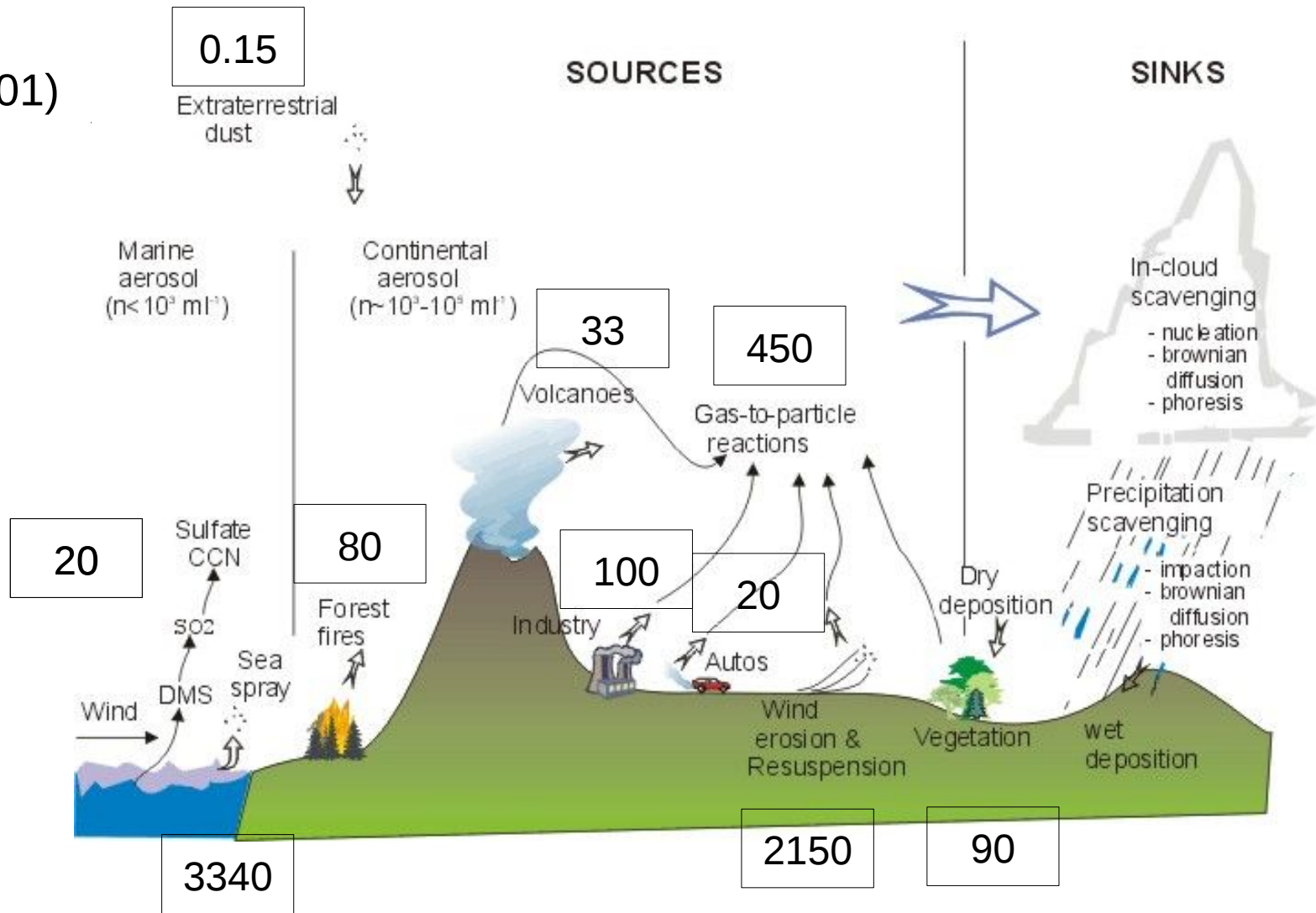
- **Types:** primary / secondary, natural / anthropogenic particles
- **Size:** diameter between 0.001  $\mu\text{m}$  (1 nm) and 100  $\mu\text{m}$  approx.
- **Chemical and mineralogical composition:** diverse
- **Optical properties** (absorption, scattering): diverse



# Sources of atmospheric aerosol

Year 2000  
(Tg)  
IPCC (2001)

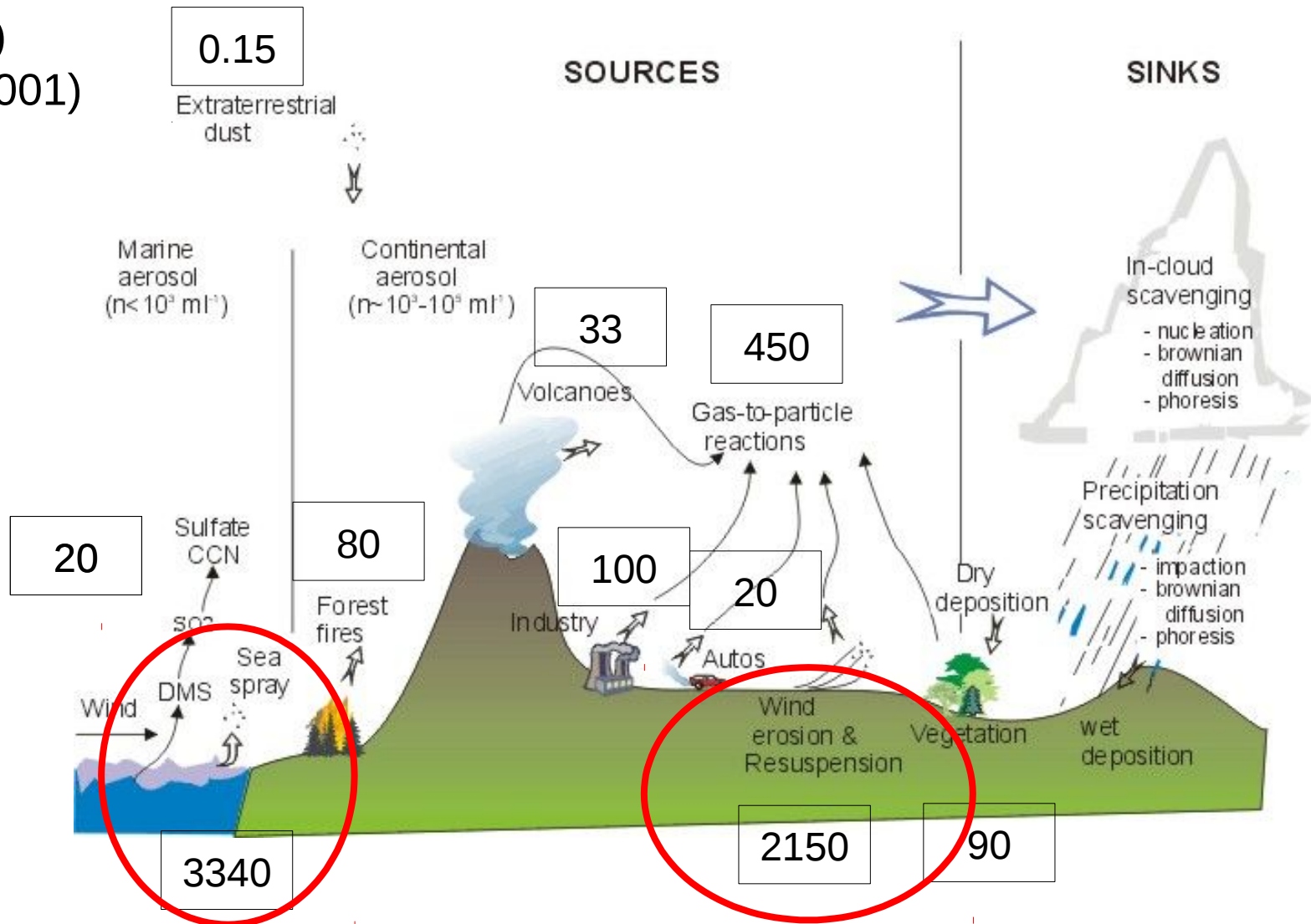
## ATMOSPHERIC AEROSOL



# Sources of atmospheric aerosol

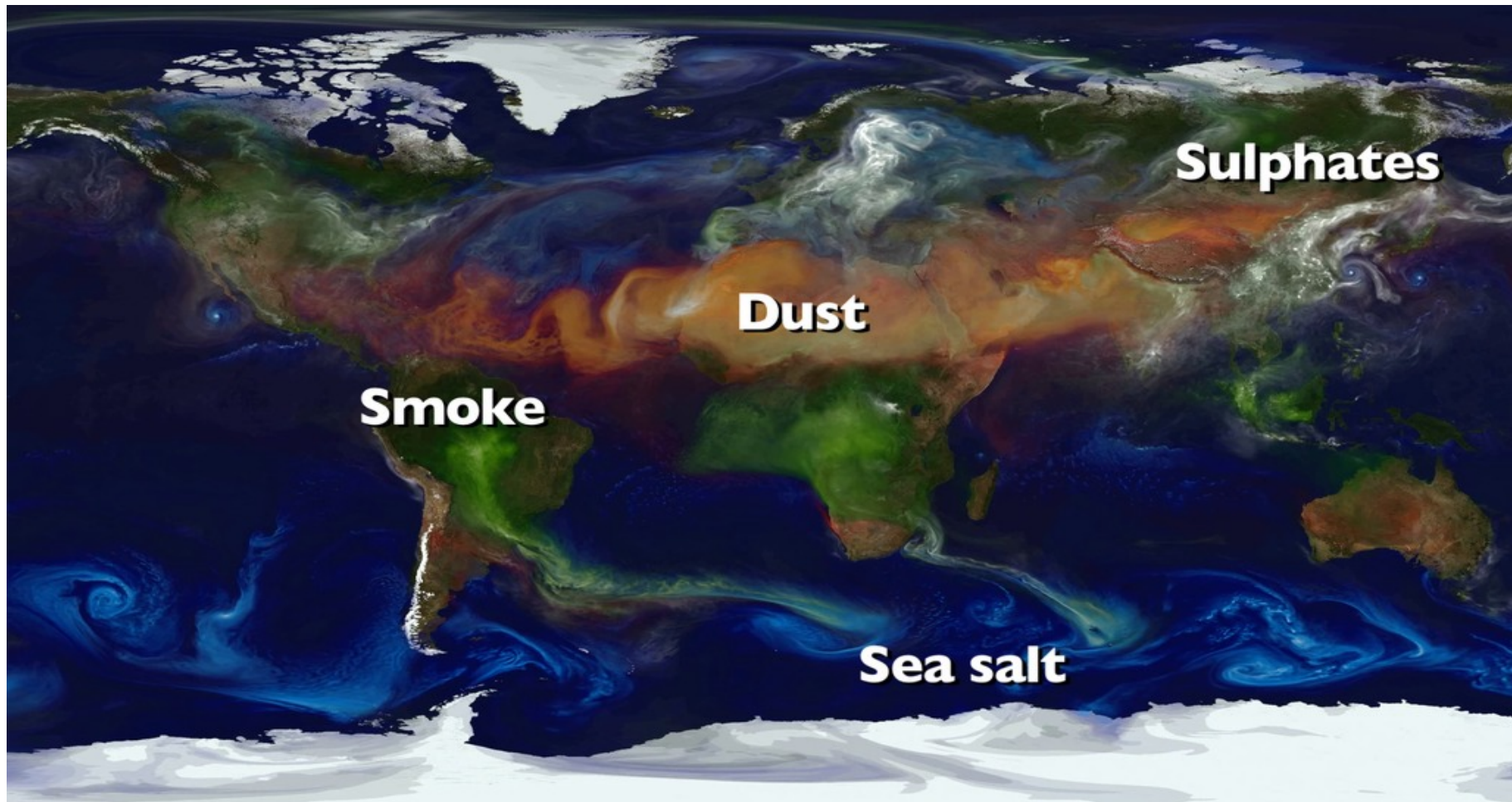
Year 2000  
(Tg)  
IPCC (2001)

## ATMOSPHERIC AEROSOL

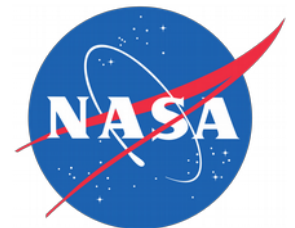




# Geographical distribution of aerosols

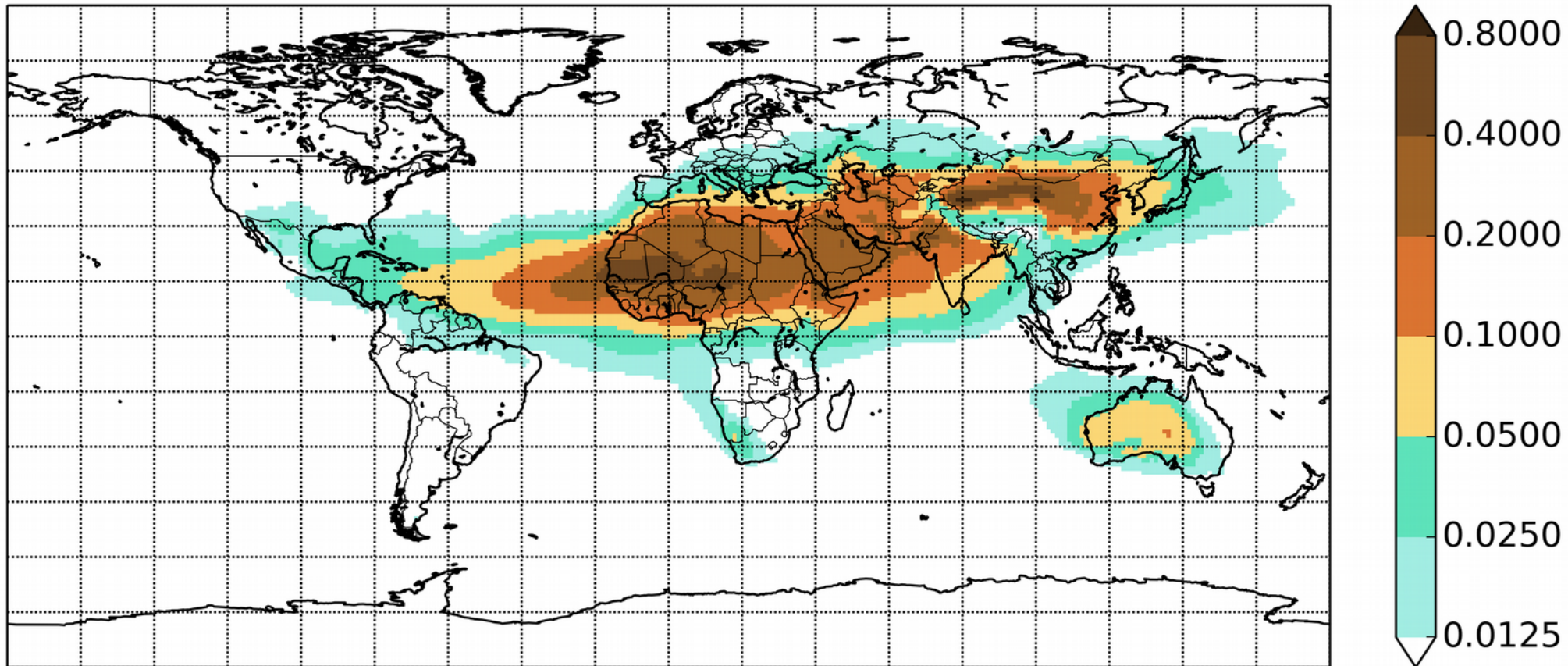


Simulation with GEOS-5



# Grographical distribution of dust

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



Data: CAMS reanalysis  
Picture: WMO SDS-WAS



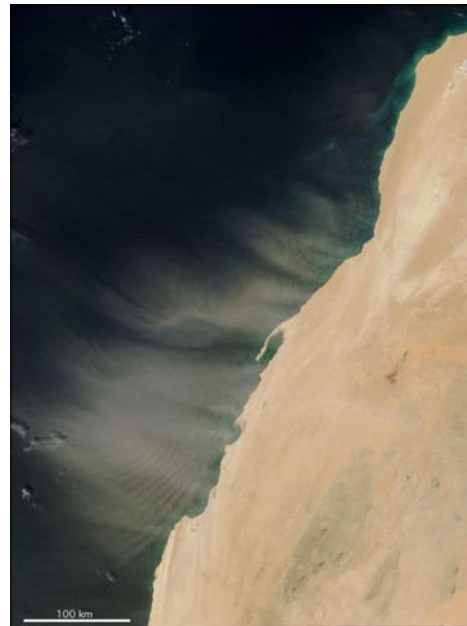
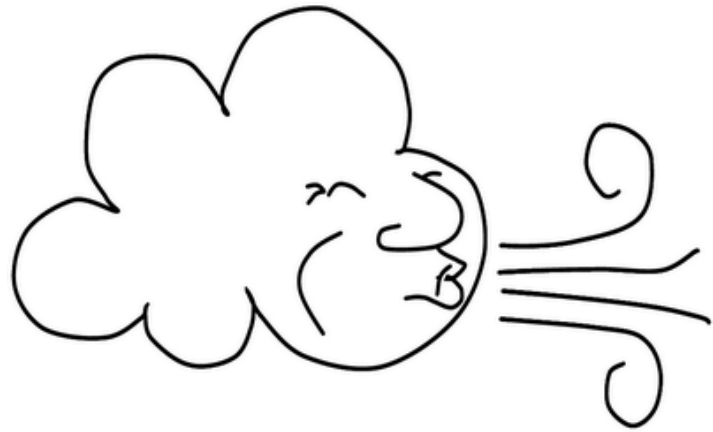
**WMO AIRBORNE DUST  
BULLETIN**  
Sand and Dust Storm  
Warning Advisory and Assessment System



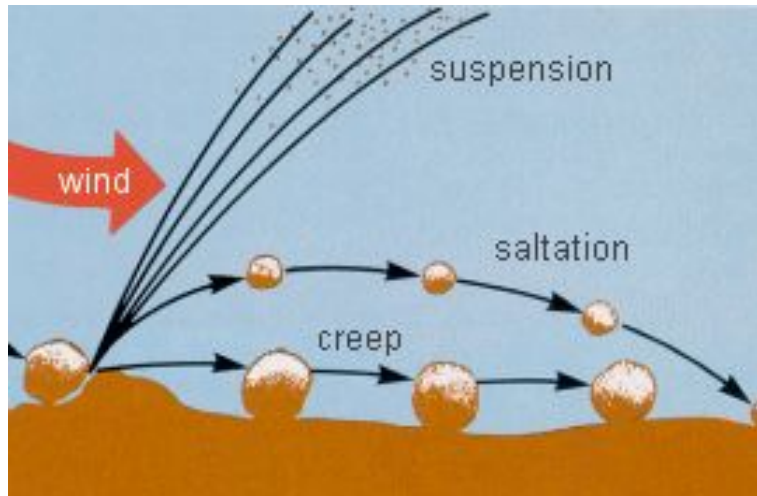
# Summary

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

# The dust cycle

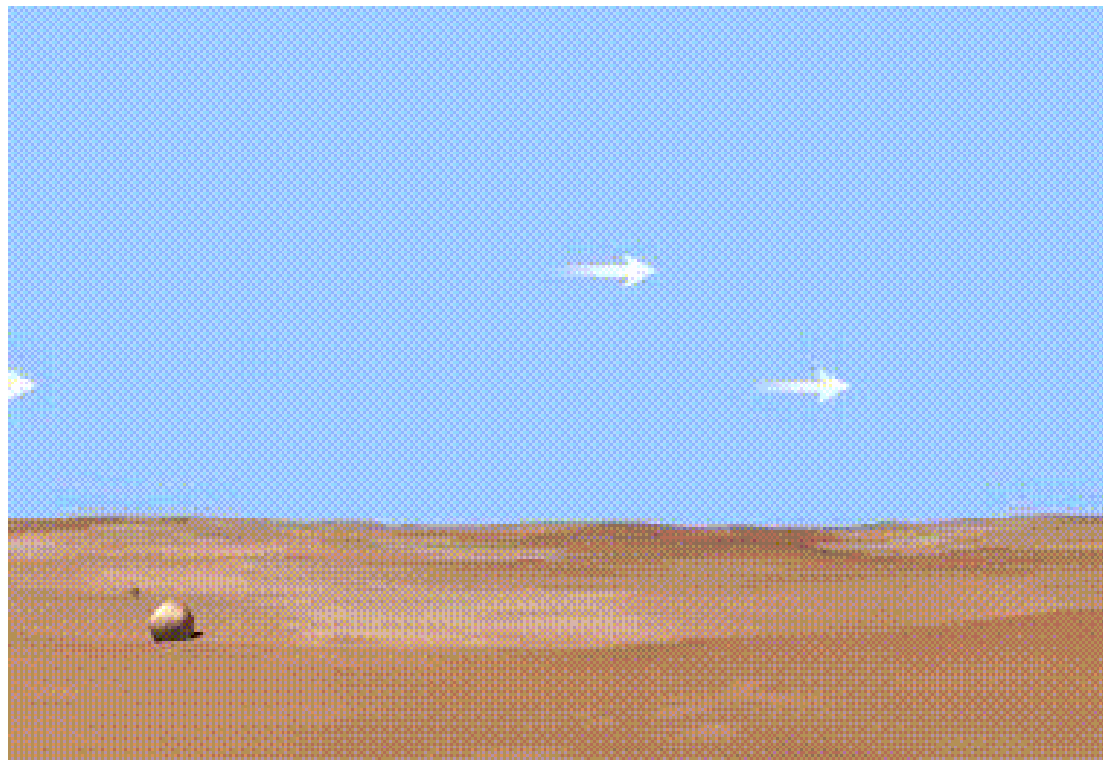


# Dust emission

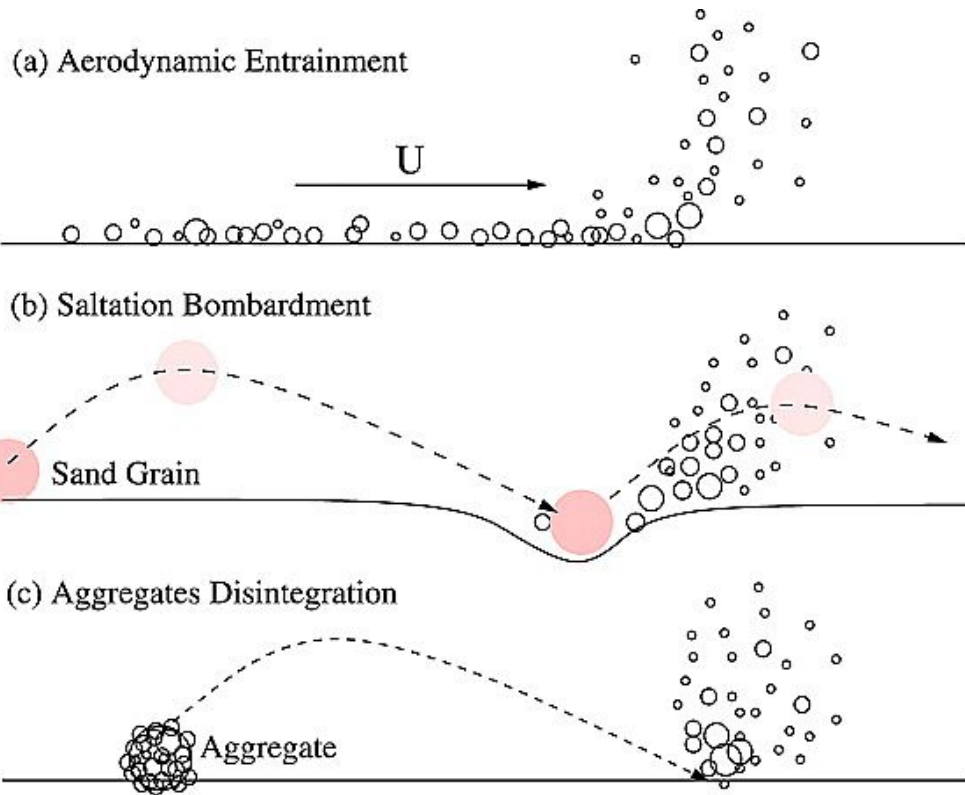


The wind moves the loose particles according to its speed and the size of soil particles:

- creeping ( $> 500 \mu\text{m}$ )
- saltation ( $50\text{-}500 \mu\text{m}$ )
- suspension ( $< 50 \mu\text{m}$ )



# 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)

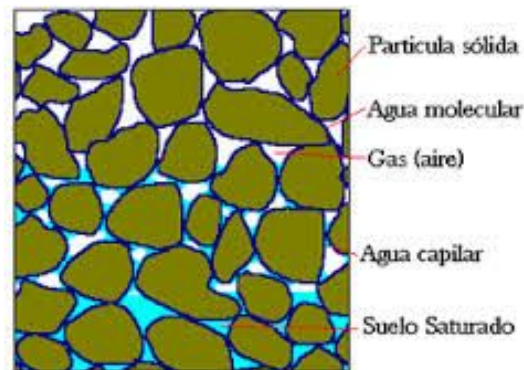


Non-erodible elements (i.e. vegetation)



Crusted soils

Soil humidity



# Dust emission

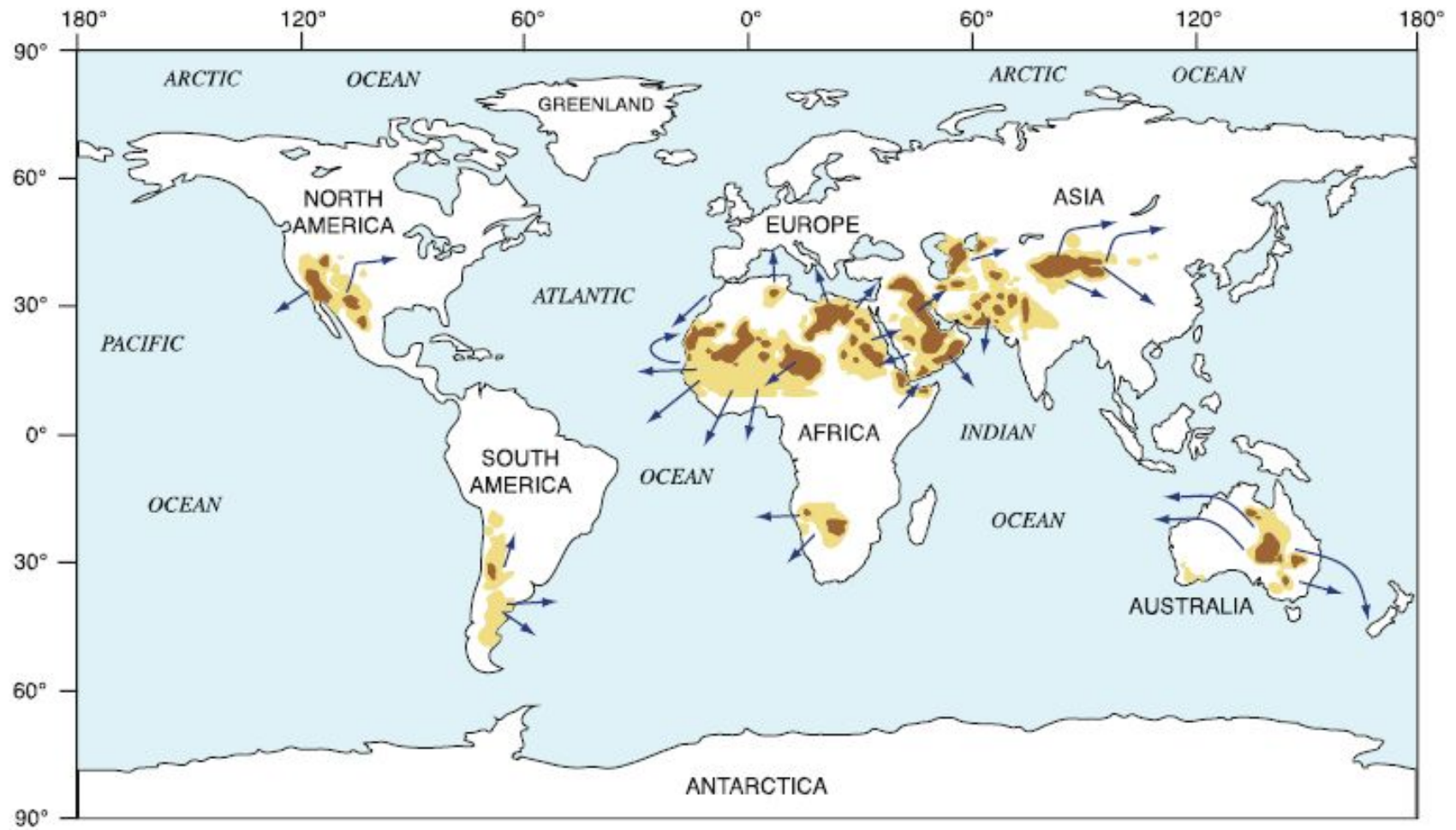
## Soil factors

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

## Meteorological factors

- Wind speed
- Near-surface turbulence

# Sources



# Anthropic sources of dust

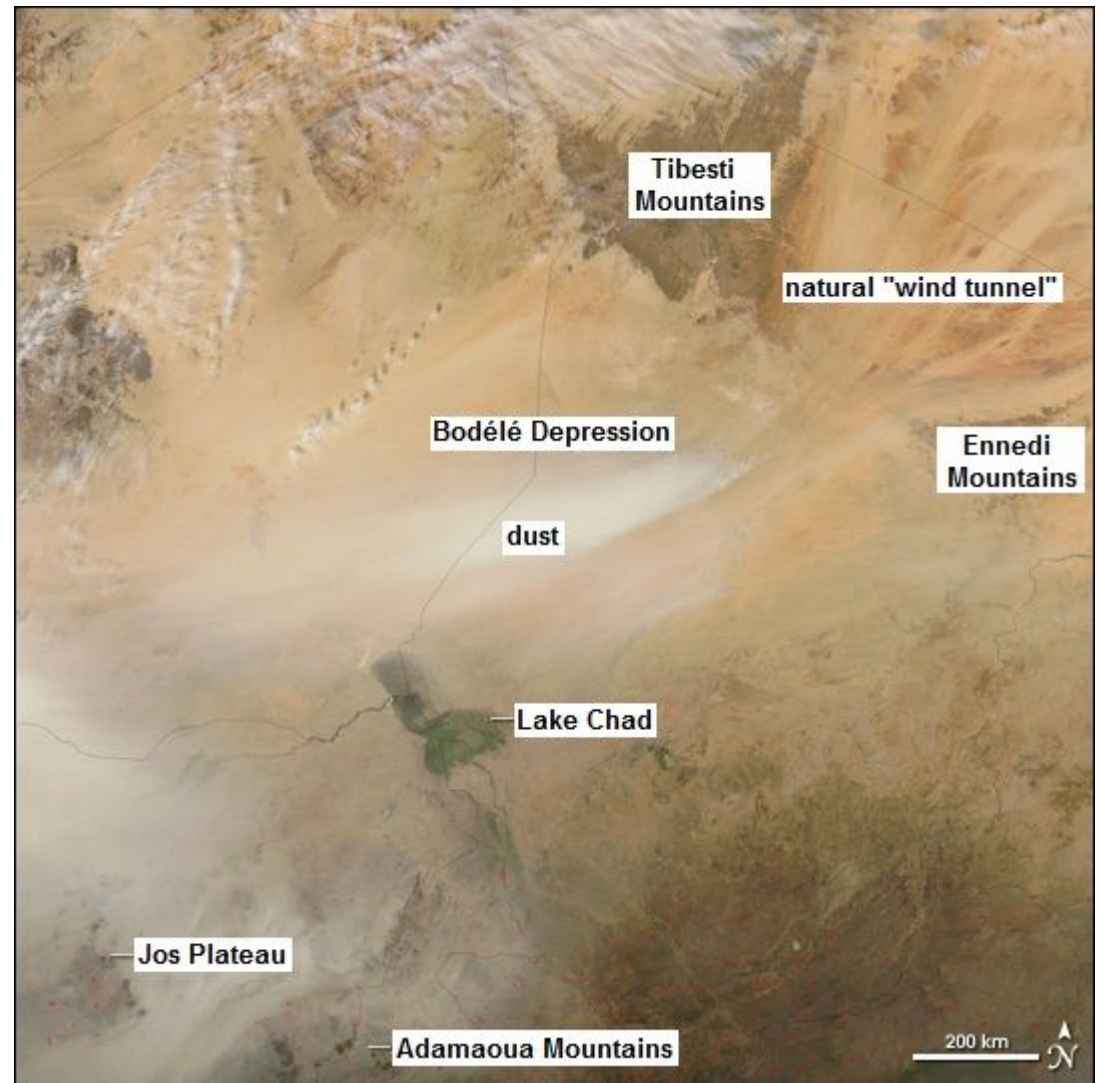
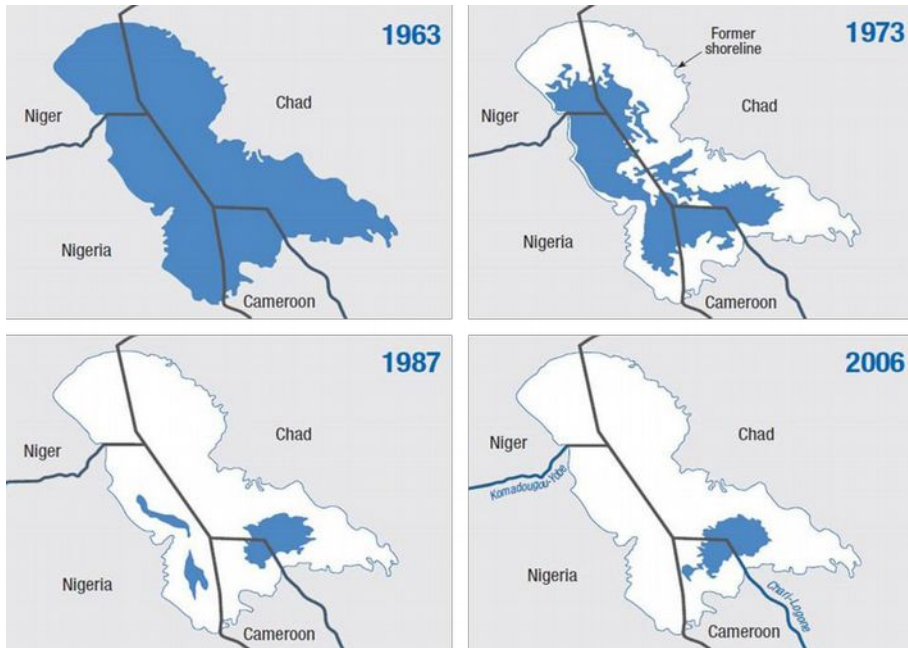
**Anthropic sources** are responsible of a significant part (25-30%) of dust emissions

- **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

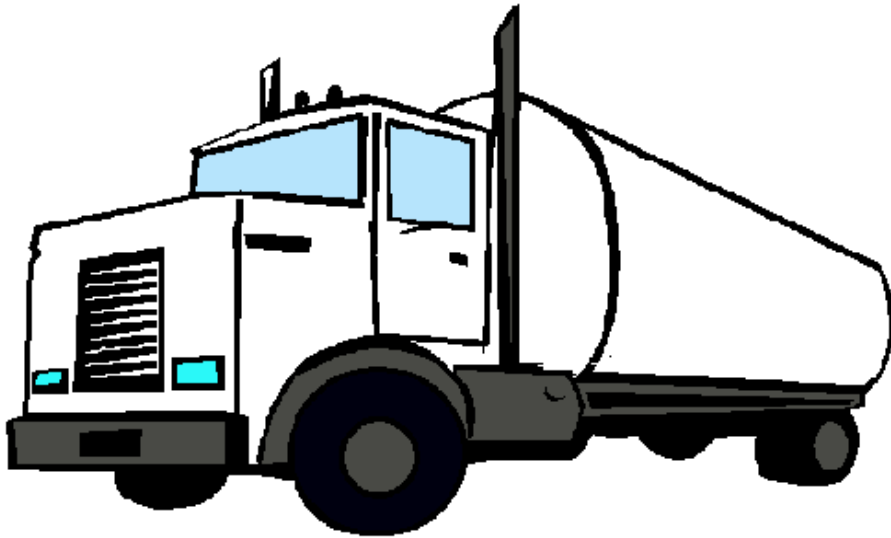


# Total emission

~ 30–60 Tm/s

~ 1000–2000 Tg/yr

50,000,000 lorries

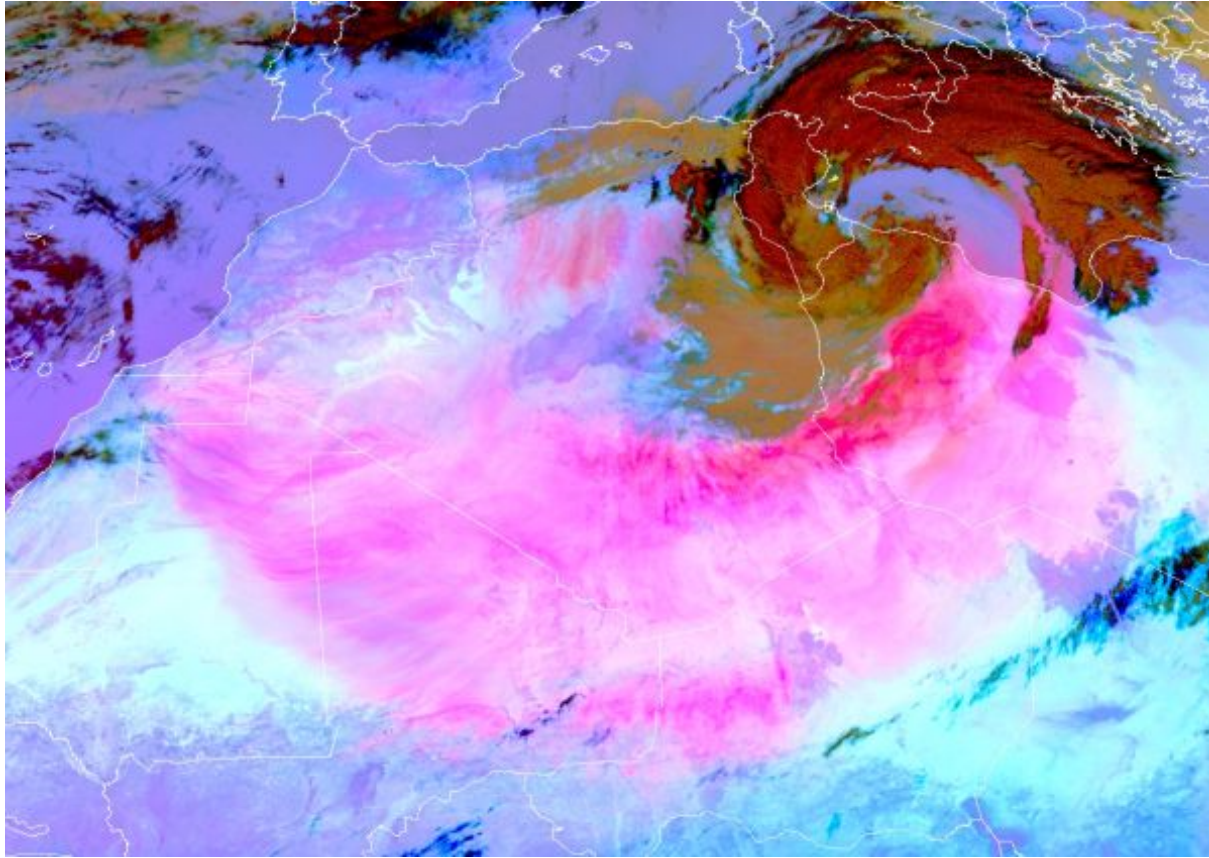


3,000 ULCC



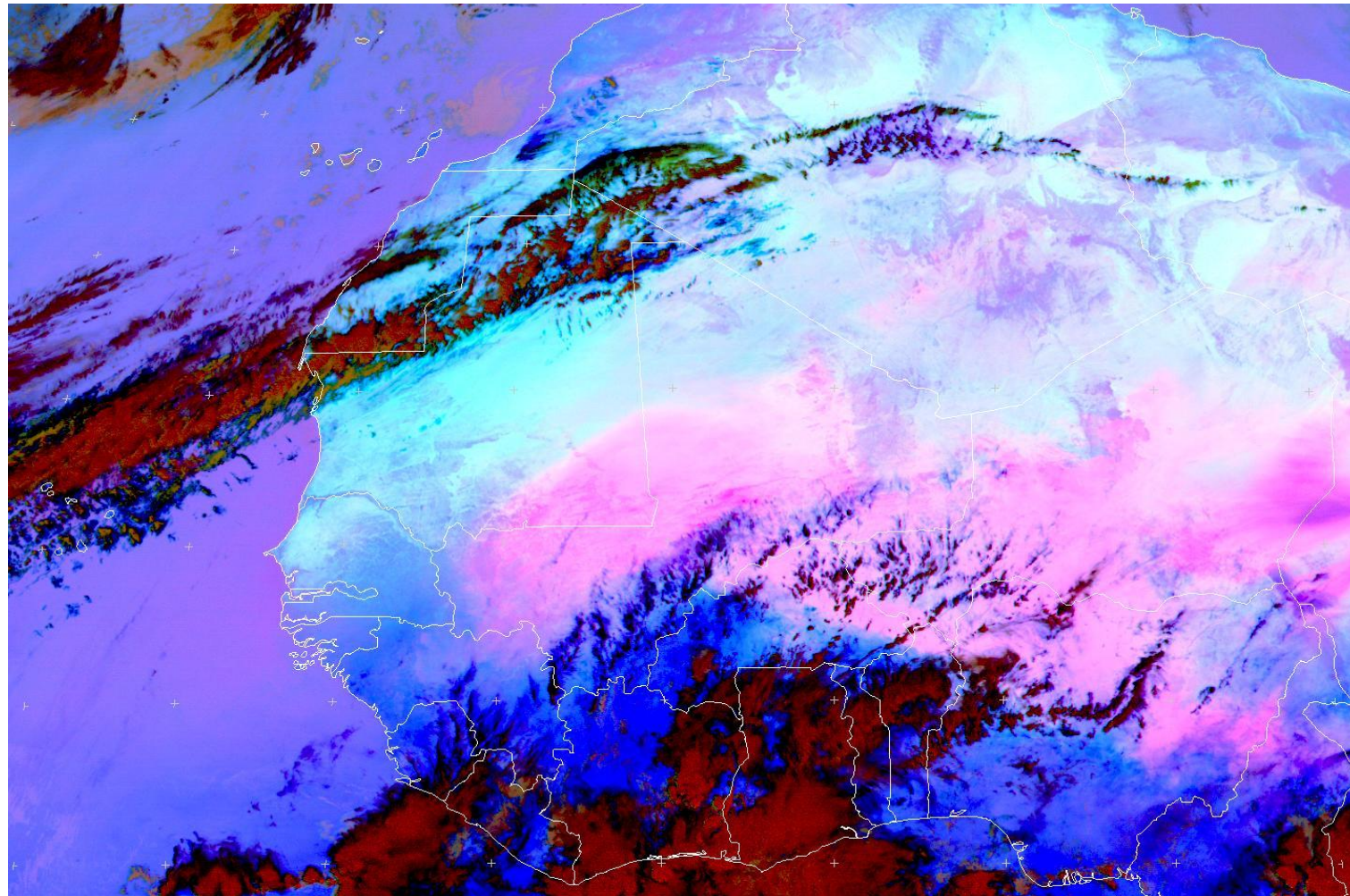


# Processes of diverse scale





# Meteorological conditions



12 apr 2015  
12:00 UTC

MET10 RGB-Dust 2015-04-12 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



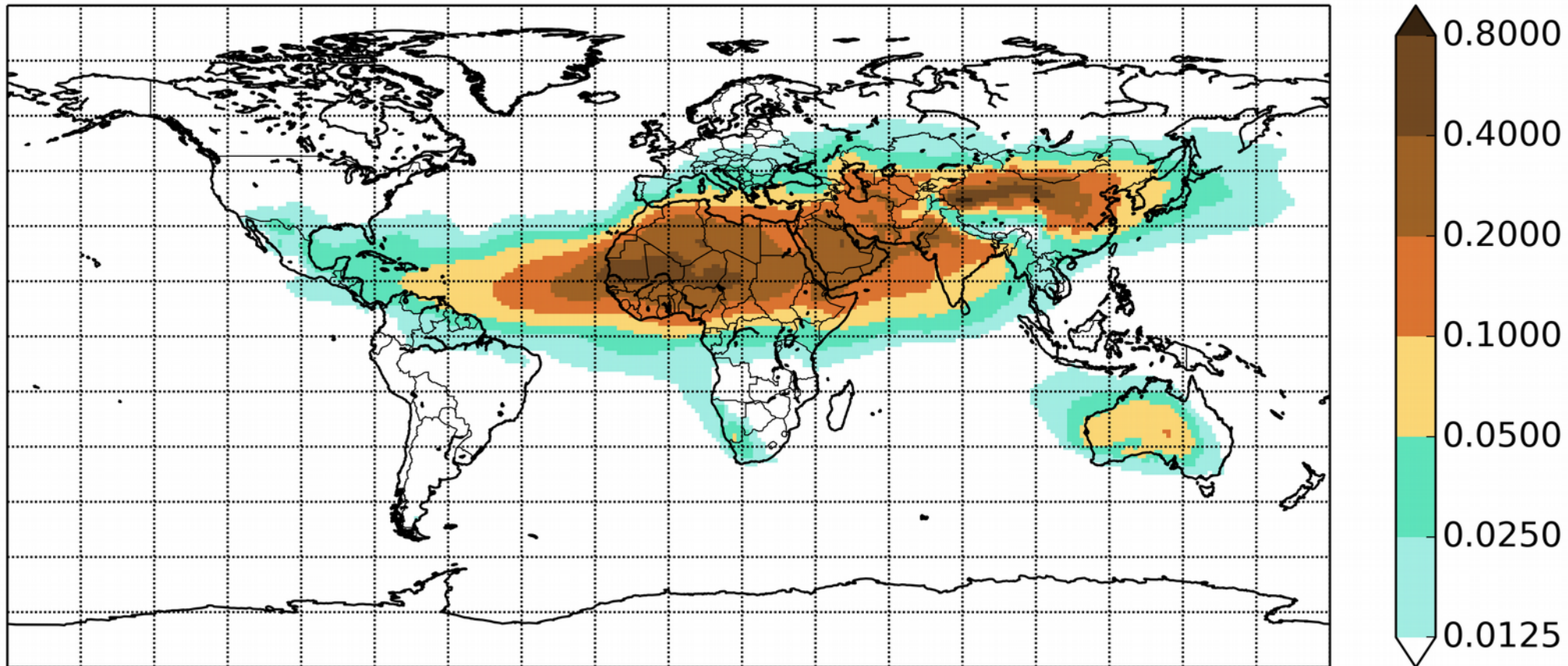
# Transport



29 Jul - 2 Aug 2013

# Grographical distribution of dust

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



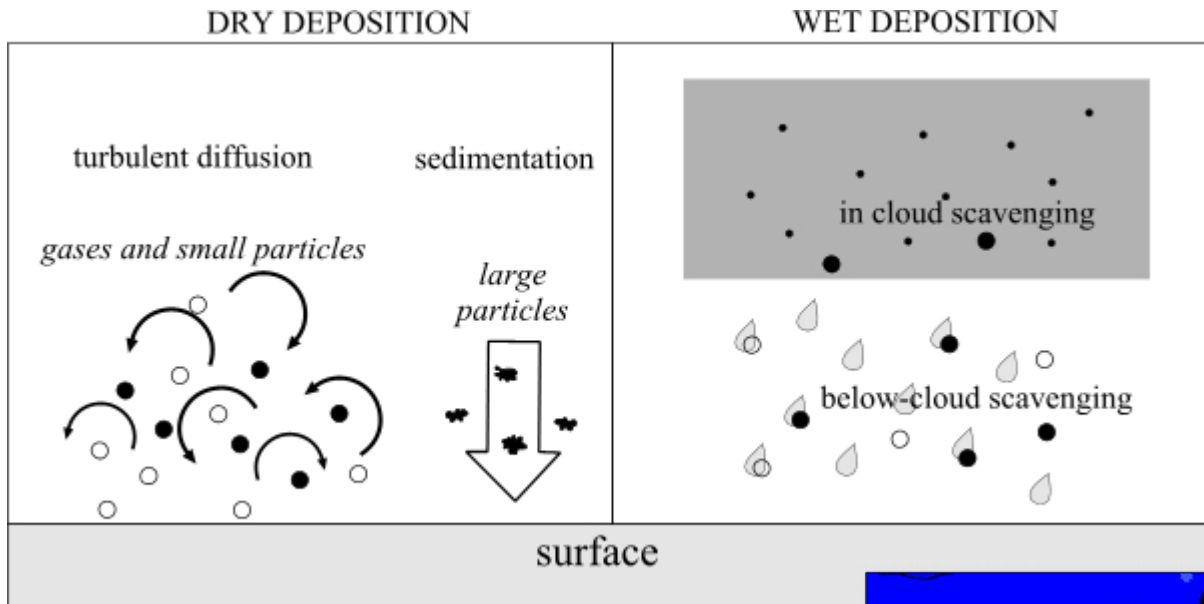
Data: CAMS reanalysis  
Picture: WMO SDS-WAS



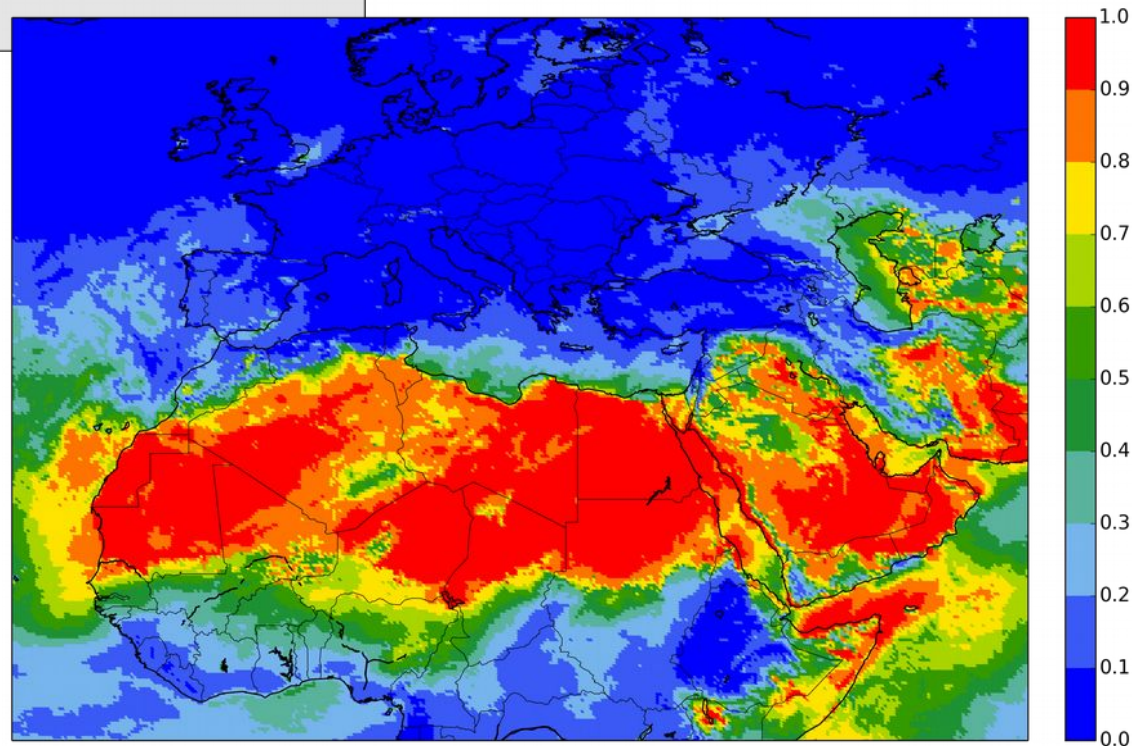
**WMO AIRBORNE DUST  
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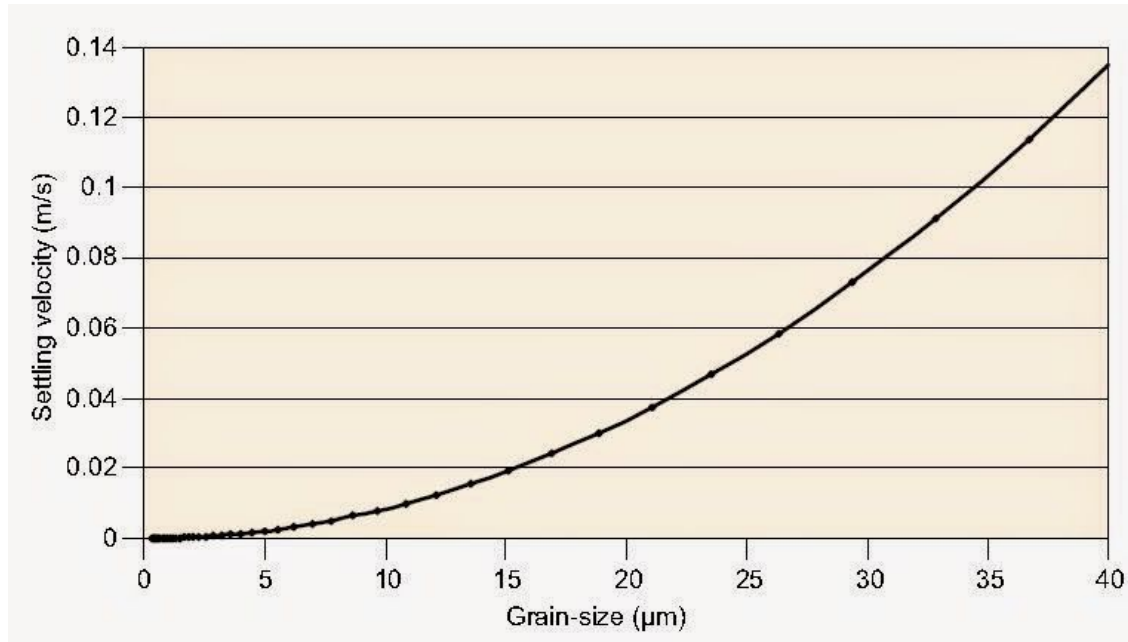
# Deposition



Ratio between dry and total deposition



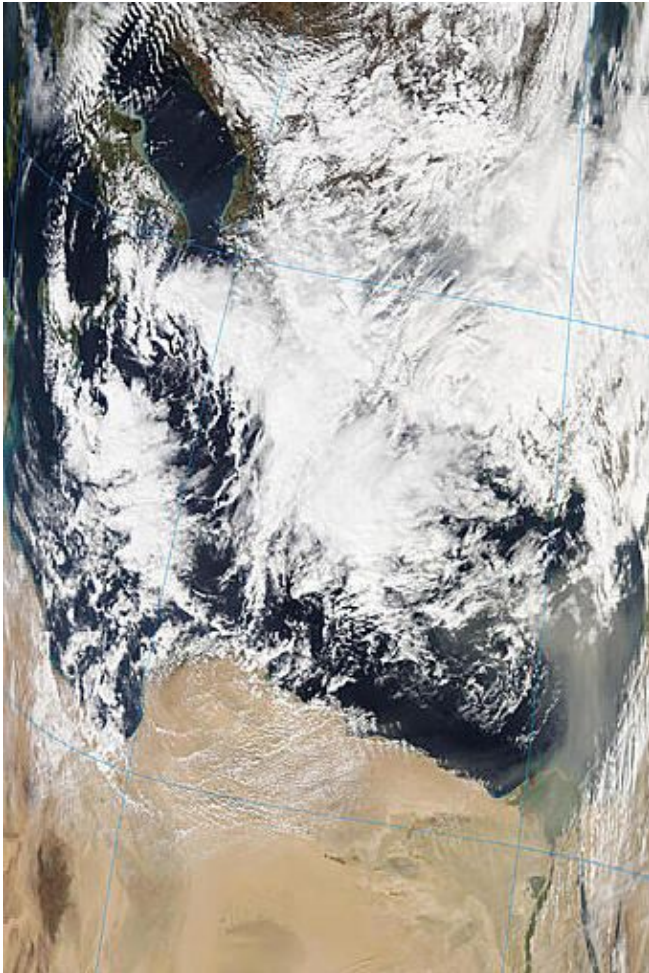
# Deposition



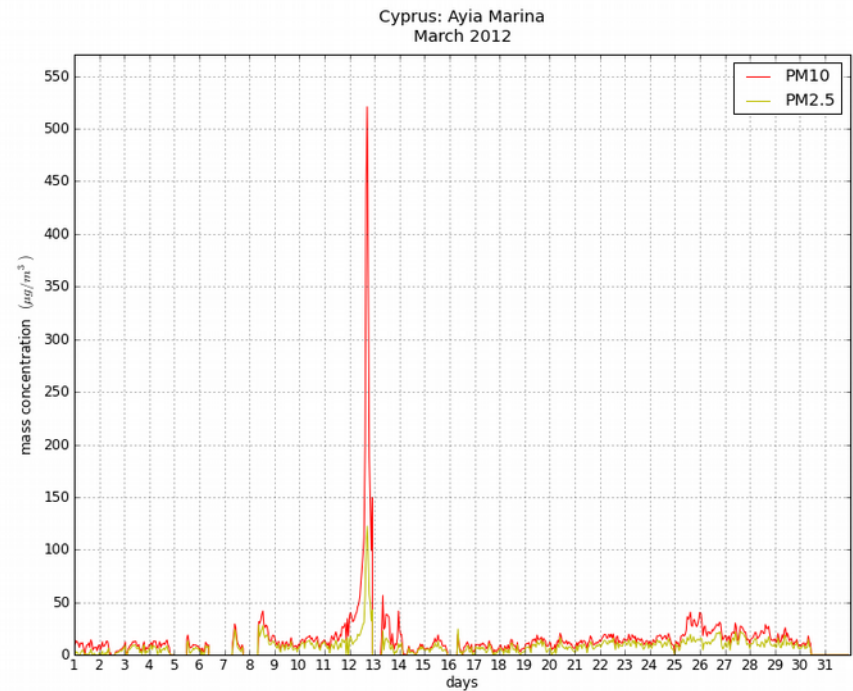
SIZE (μm)	AVERAGE LIFETIME (h)
0.1 - 0.18	231
0.18 - 0.3	229
0.3 - 0.6	225
0.6 - 1	219
1 - 1.8	179
1.8 - 3	126
3 - 6	67
6 - 10	28

Tegen and Lacis  
(1996)

# Wet deposition



MODIS 12 Mar 2012



PM Ayia Marina, Cyprus, Mar 2012

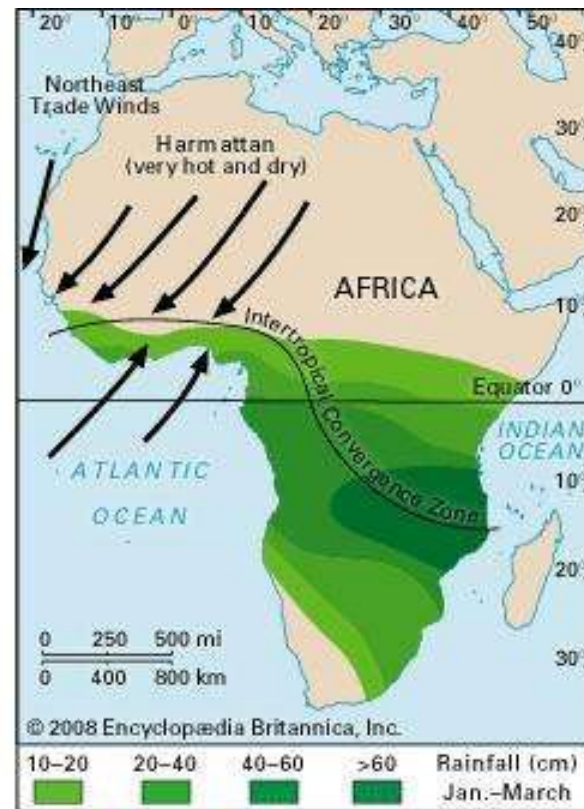
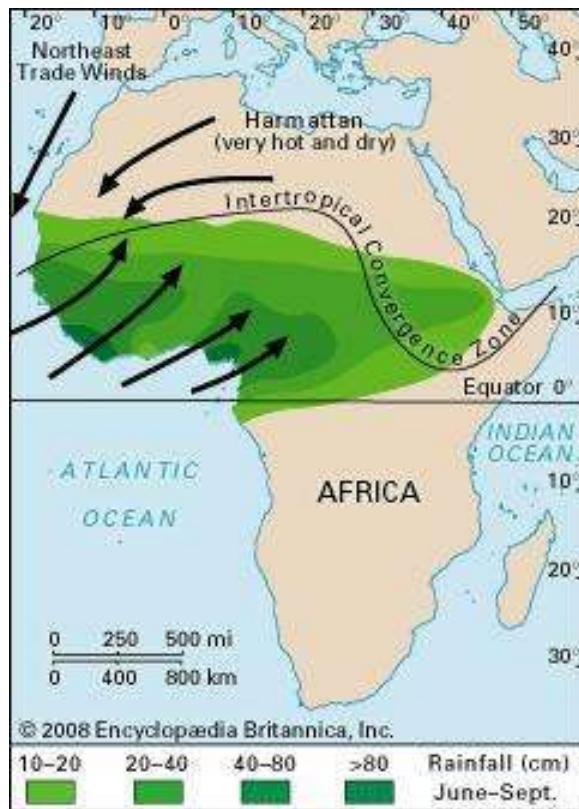


# Seasonal variability

Dry season



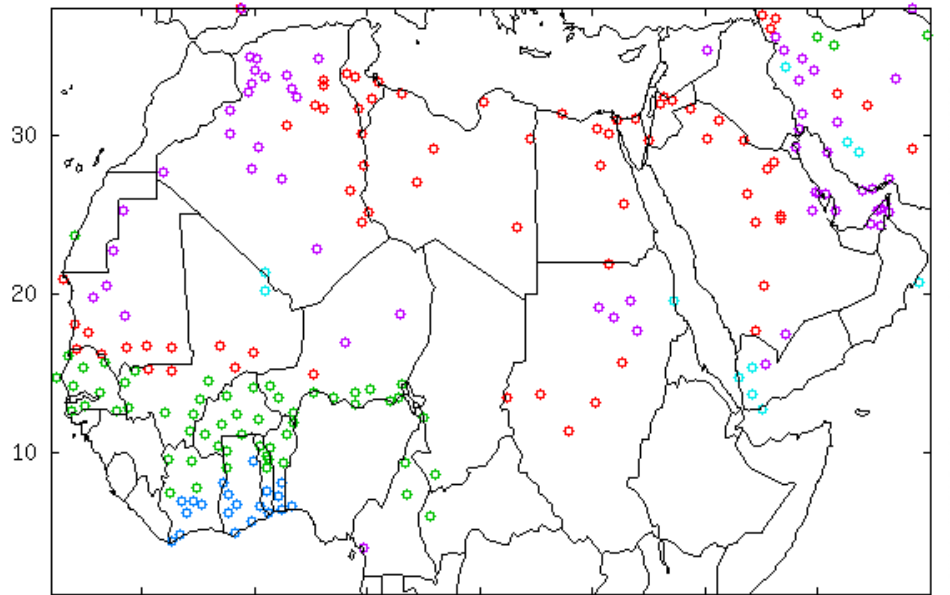
Wet season



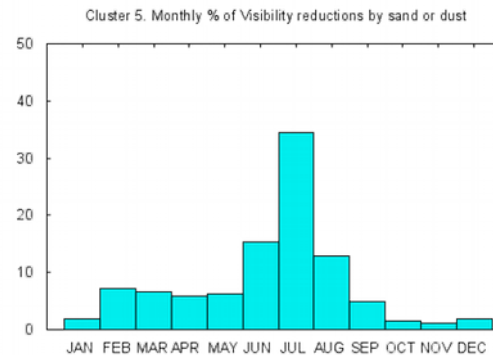
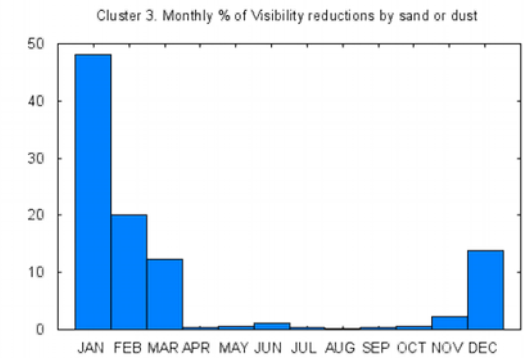
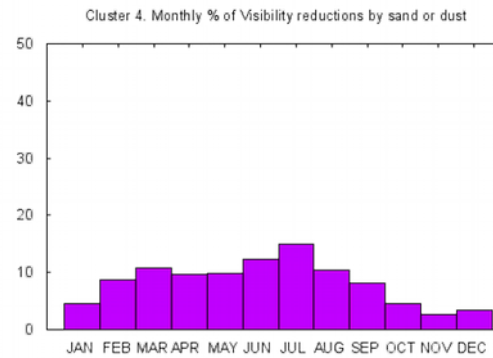
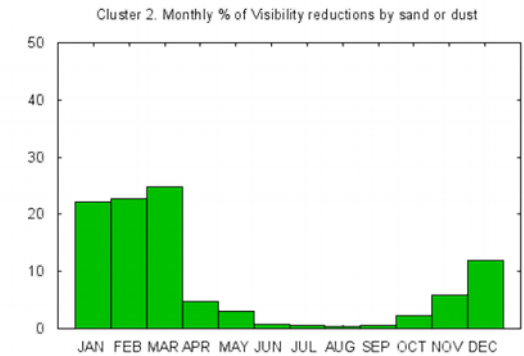
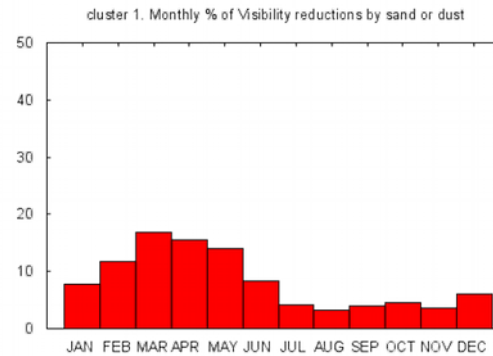
NH summer / winter



# Seasonal variability



1996-2010



Terradellas et al. (2012)

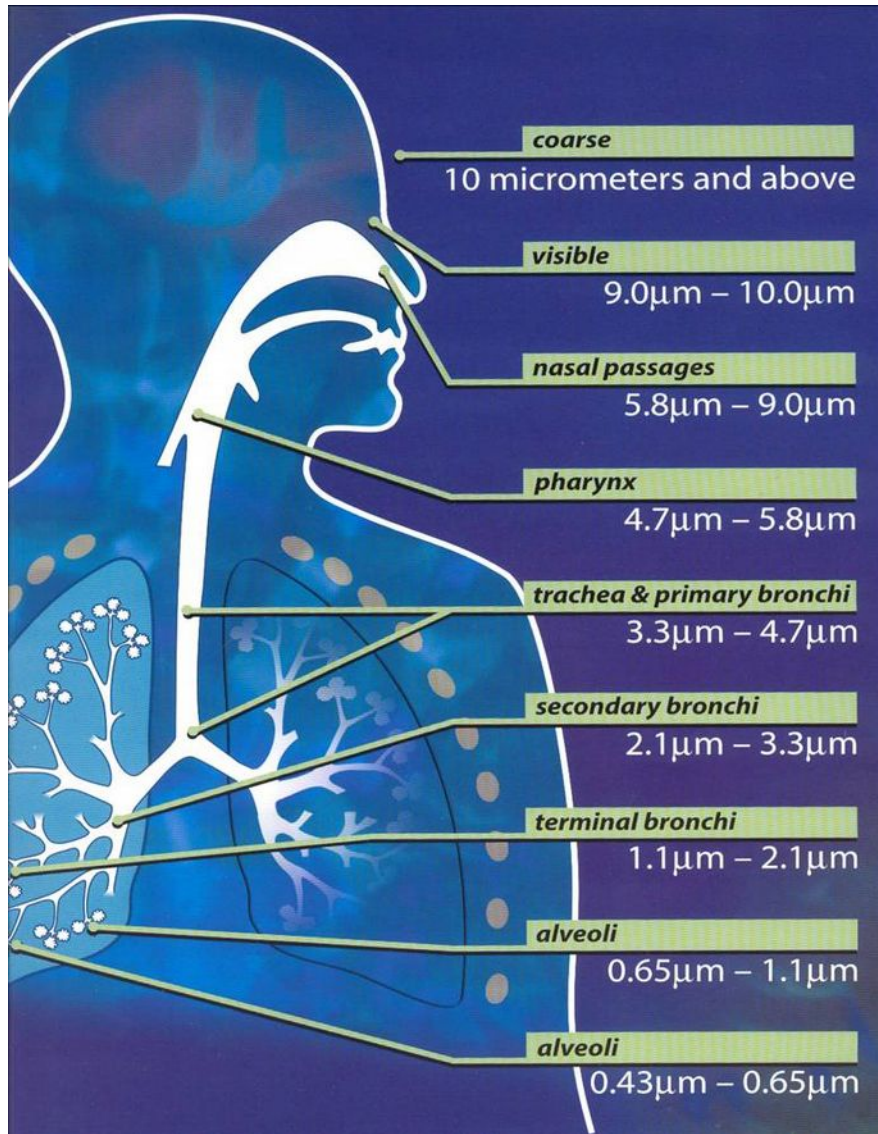
# Dust impacts

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



3:35P	On Time
3:45P	Cancelled
4:15P	On Time
4:24P	Delayed
4:30P	Cancelled
5:00P	On Time
5:12P	On Time
5:15P	On Time

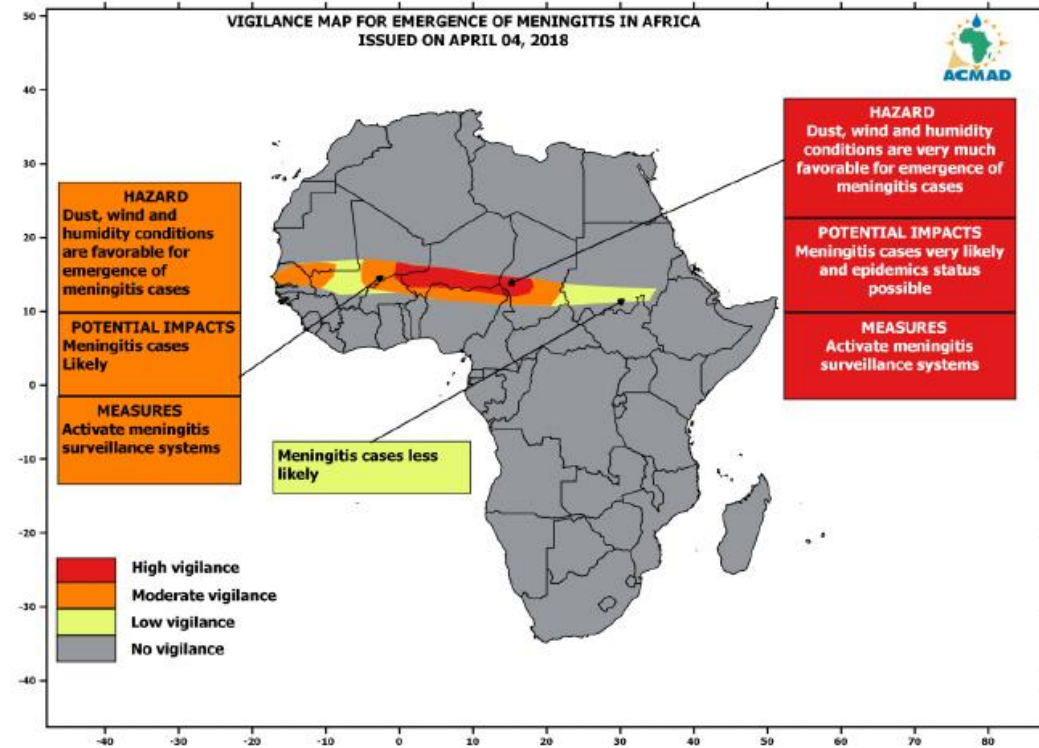
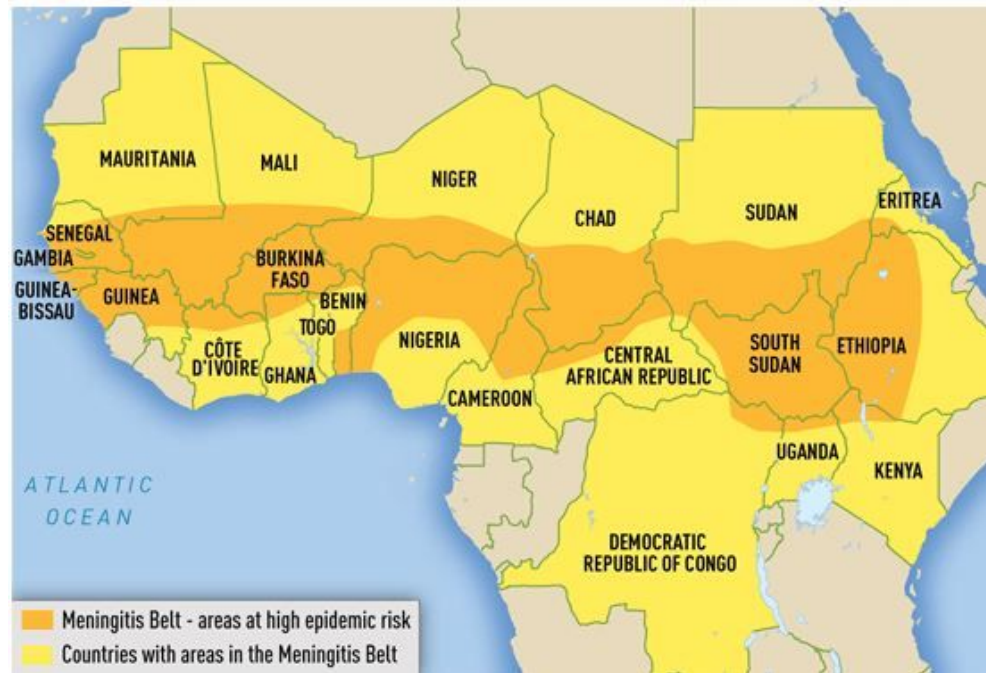
# Health impact



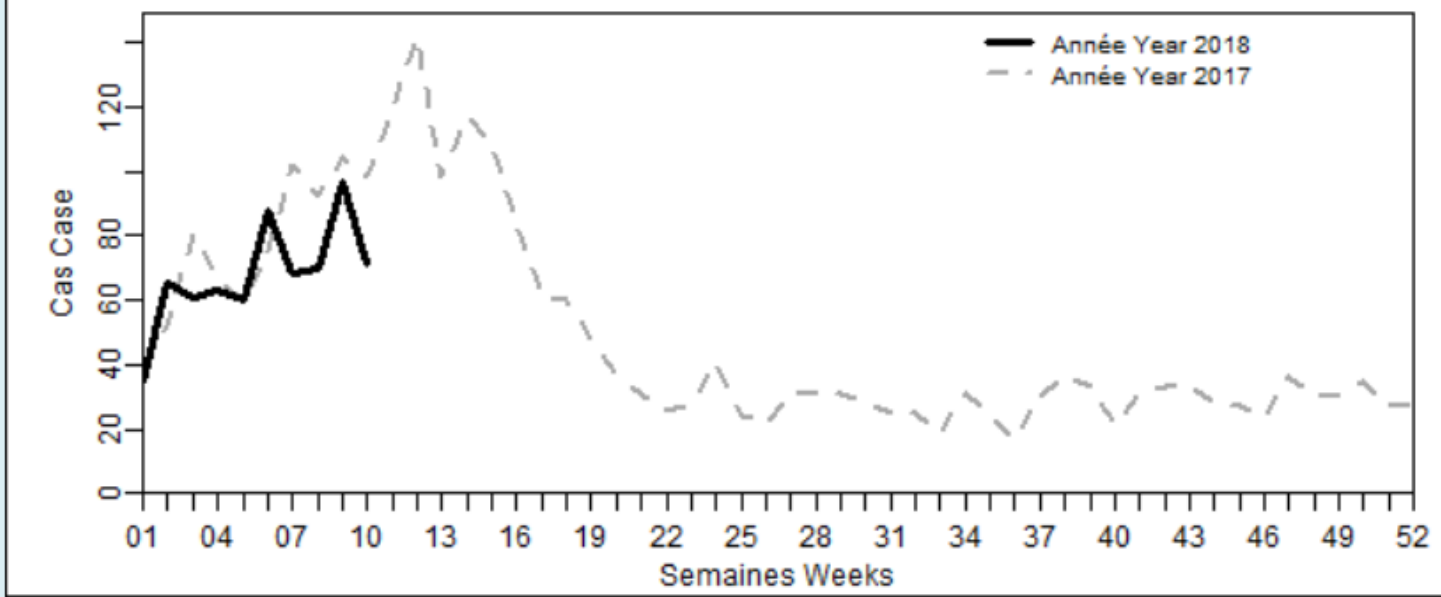
- Particle size
- Chemical and mineralogical composition
- Carrying bacteria, viruses, fungi, ...
- Time and intensity of exposure



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

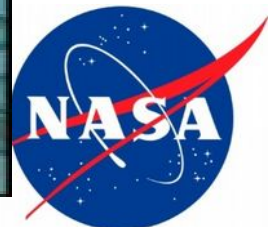
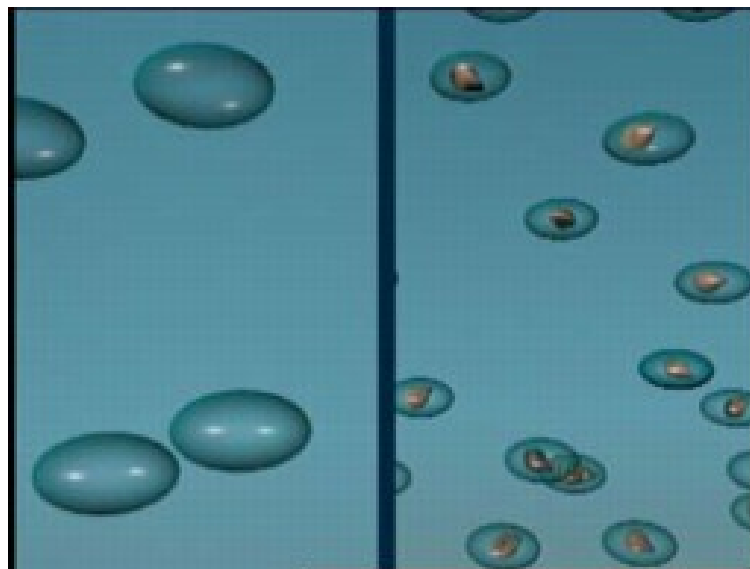
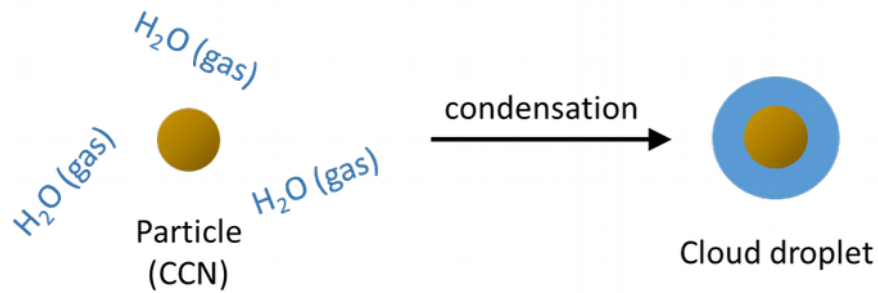
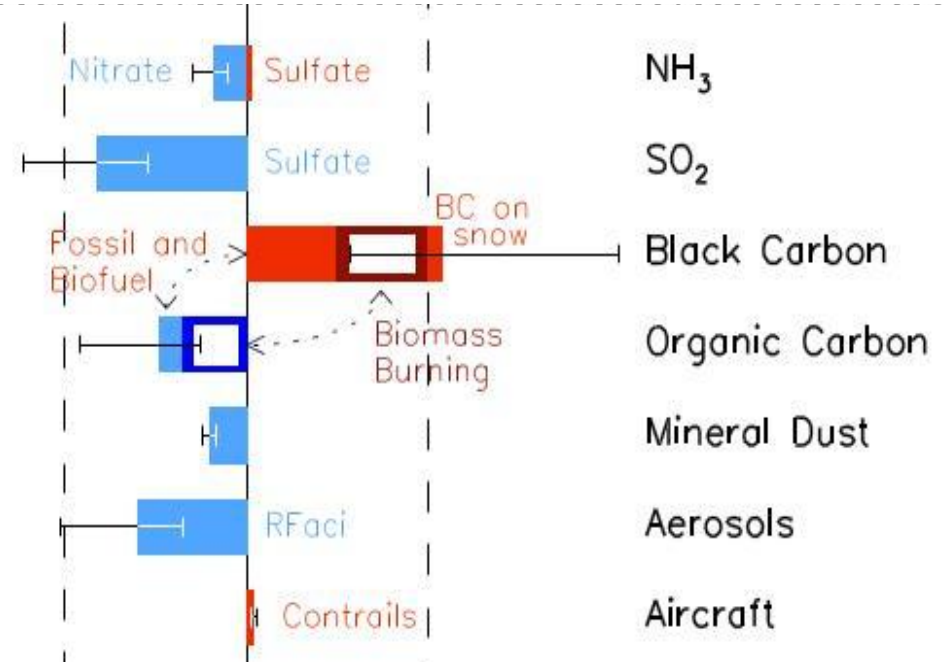
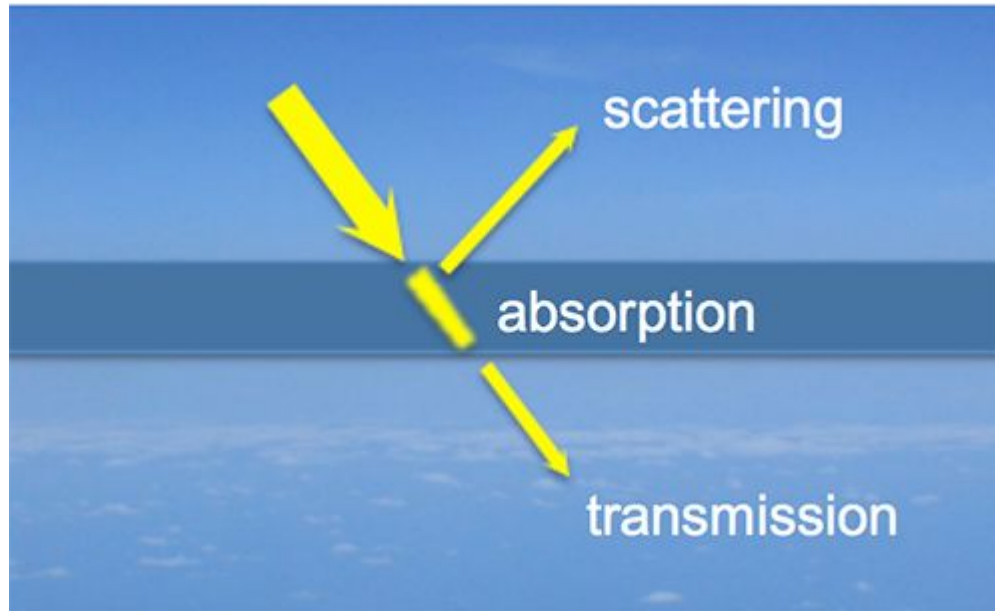


Burkina Faso  
 Cas par semaine Cases by week

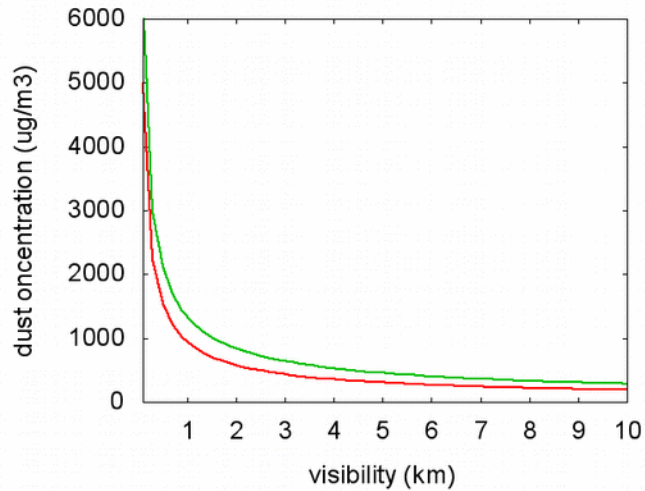




# Impact on weather and climate



# Impact on transportation



D'Almeida (1986)

Ben Mohamed et al. (1992)



Arizona, 29 Oct 2013

11:16 A	CANCELLED
5A 10:30 A	CANCELLED
5A 10:15 A	CANCELLED
7A 6:50 A	DELAYED
7A 7:20 A	DELAYED
10:00 A	CANCELLED
17A 10:10 A	DELAYED

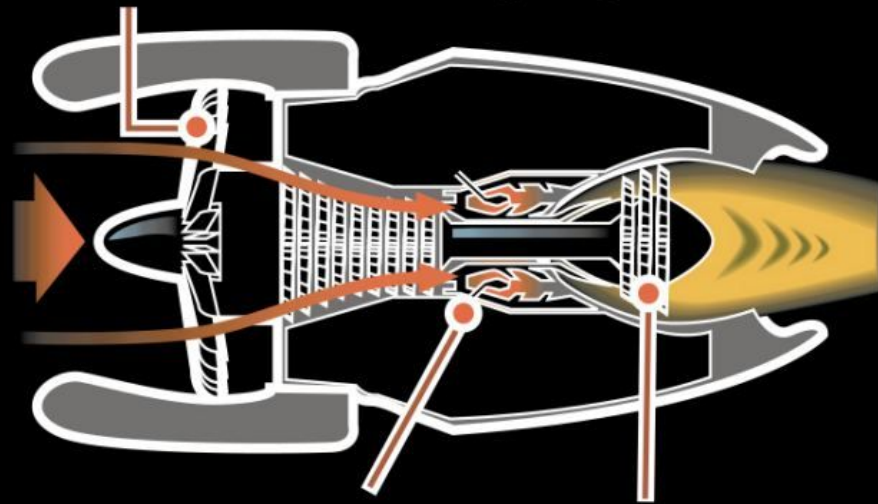


Tunis, 7 May 2002

# Impact on transportation

## **EFFECT ON A JET ENGINE**

**The abrasive dust particles can erode blades reducing engine thrust**



**High temperatures turn the dust to molten glass blocking cooling vents**

**Cooled glass collects on turbine blades, jamming engine**

Volcanic ash is very dangerous for aviation because it melts at less than  $1400^{\circ}$ , the temperature at which the aircraft engines operate, and can cause flares.

Dust particles melt at about  $1700^{\circ}$  and do not cause such flares, but problems of erosion in the engine and on external surfaces of the aircraft.

**More frequent maintenance tasks**



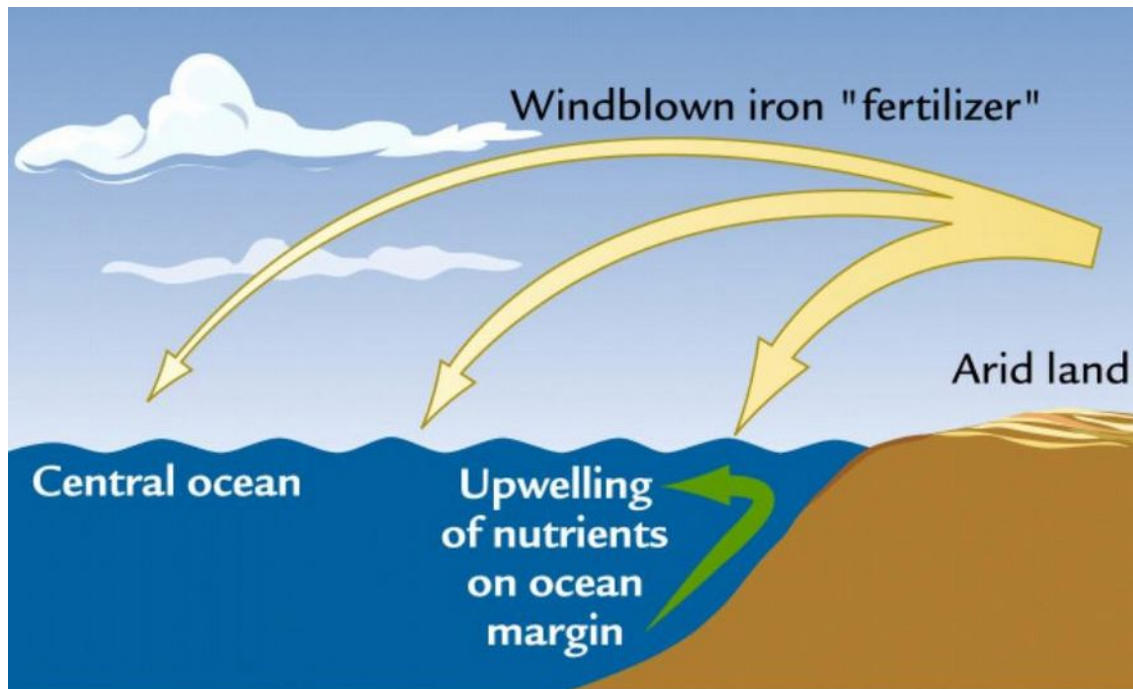
# Impact on solar energy

- 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

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

# WMO SDS-WAS



## **Mission**

Enhance the capacity of countries 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 NAMEEE

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



Nexus II building (UPC campus)



MareNostrum supercomputer





# SDS-WAS Regional Center NAMEE

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

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World Meteorological Organization | ALMet | WMO SDS-WAS | Asia Regional Center

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## Northern Africa-Middle East-Europe (NA-ME-E) Regional Center

by Francesco Serrano — last modified May 29, 2012 03:03 PM

**Outstanding**

- Guidance for forecasters
- 11 lectures on atmospheric mineral dust
- Forecast evaluation
- Compared dust forecasts

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- Satellite data are now available  
Sep 04, 2012
- Comparison of dust models  
Aug 29, 2012
- Lidar data and outlooks  
Aug 29, 2012

**Upcoming Events**

- European Aerosol Conference SAC-2012  
Sep 02, 2012 - Sep 07, 2012 - Granada, Spain
- 2012 EUMETSAT Meteorological Satellite Conference  
Sep 03, 2012 - Sep 07, 2012 - Sosn, Poland
- 9th International Symposium on Tropospheric Profiling

**Dust forecasts**

WMO SDS-WAS - Northern Africa-Middle East-Europe RC  
MISSTN - Dust Surface Concentration (µg/m³)  
Run: - 02 SEP 2012 - 0800 - 03 SEP 2012 01+00

Compared Dust Forecasts

Forecast Evaluation

**Dust observations**

9th International Symposium on Tropospheric Profiling

R&D

<https://sds-was.aemet.es>  
[sdswas@aemet.es](mailto:sdswas@aemet.es)

# Barcelona Dust Forecast Center

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**Training events in Muscat, Oman**

Dust-related training events organized by the Regional Center for Northern Africa, Middle East and Europe of WMO SDS-WAS

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**Dust forecast**

Latest dust forecast for Northern Africa, Middle East and Europe

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Barcelona Dust Forecast Center  
NMMB/BSC-Dust: Res: 0.1°x0.1° Dust Surface Conc. (µg/m³)  
Run: 12h 13 NOV 2013 Valid: 00h 14 NOV 2013 (H+12)

## Operational Forecast

<https://dust.aemet.es>  
[dust@aemet.es](mailto:dust@aemet.es)