

Introduction to Sand and Dust Storms



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WMO OMM

World Meteorological Organization
Organisation météorologique mondiale

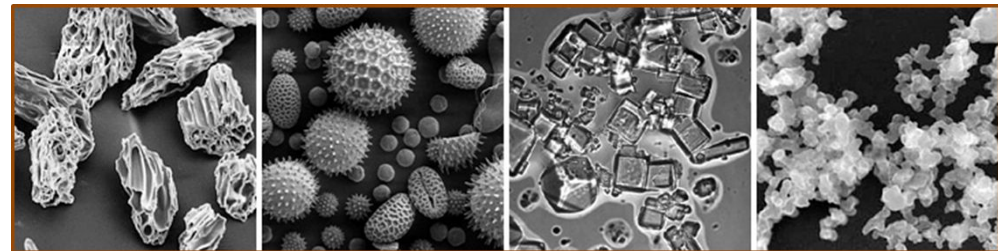
Atmospheric aerosols

Atmospheric aerosols are suspensions of liquid, solid, or mixed particles with highly variable chemical composition and size distribution. **Aerosol** particles are either emitted directly to the **atmosphere** (primary **aerosols**) or produced in the **atmosphere** from precursor gases (secondary **aerosols**).

The present considerable differences in:

- Size range (1nm to 100 μ m)
- Chemical composition
- Sources of emission

Source
<https://earthobservatory.nasa.gov/features/Aerosols>

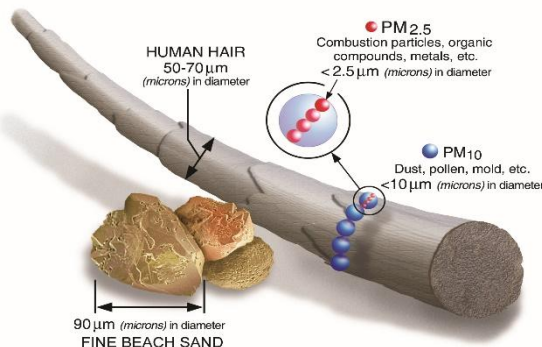


Volcanic
Ash

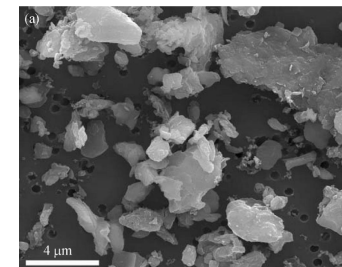
Pollen

Sea-Salt

Soot



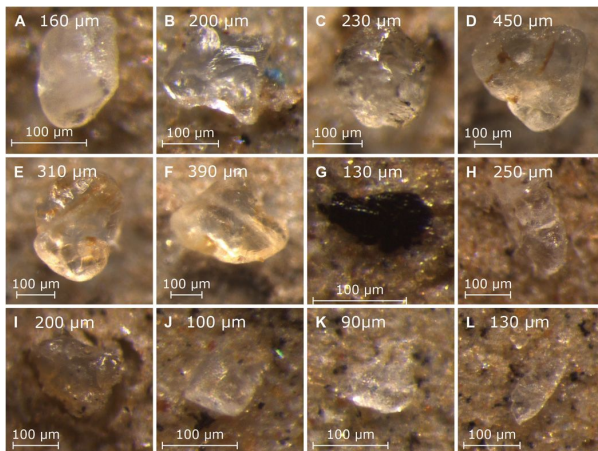
Extracted from EPA website



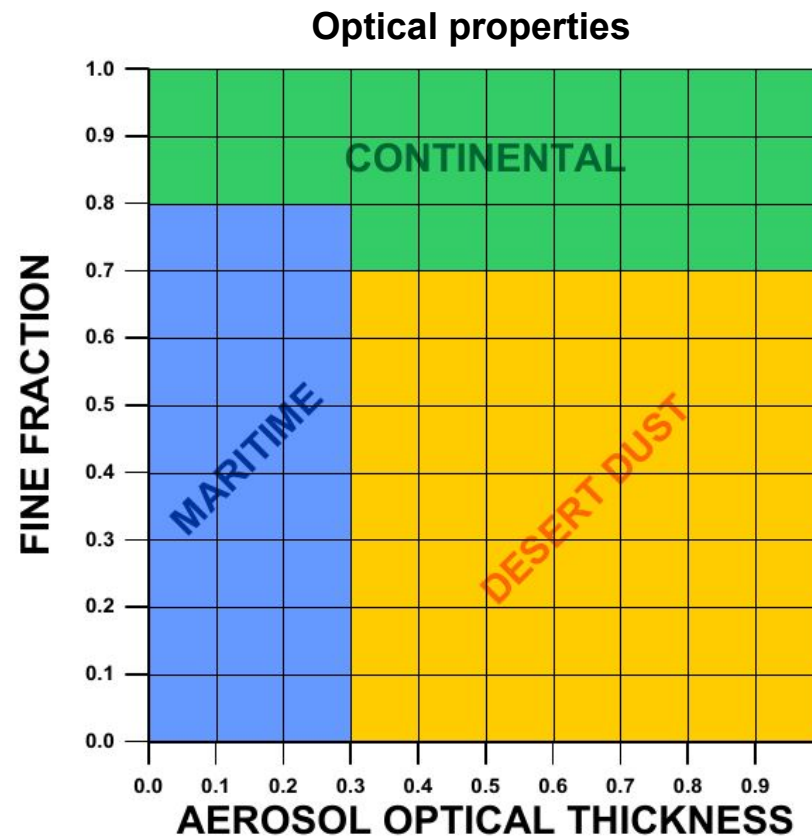
Mineral dust

Atmospheric aerosols

Desert dust can be characterised by its coarser size, irregular shape and large absorption.

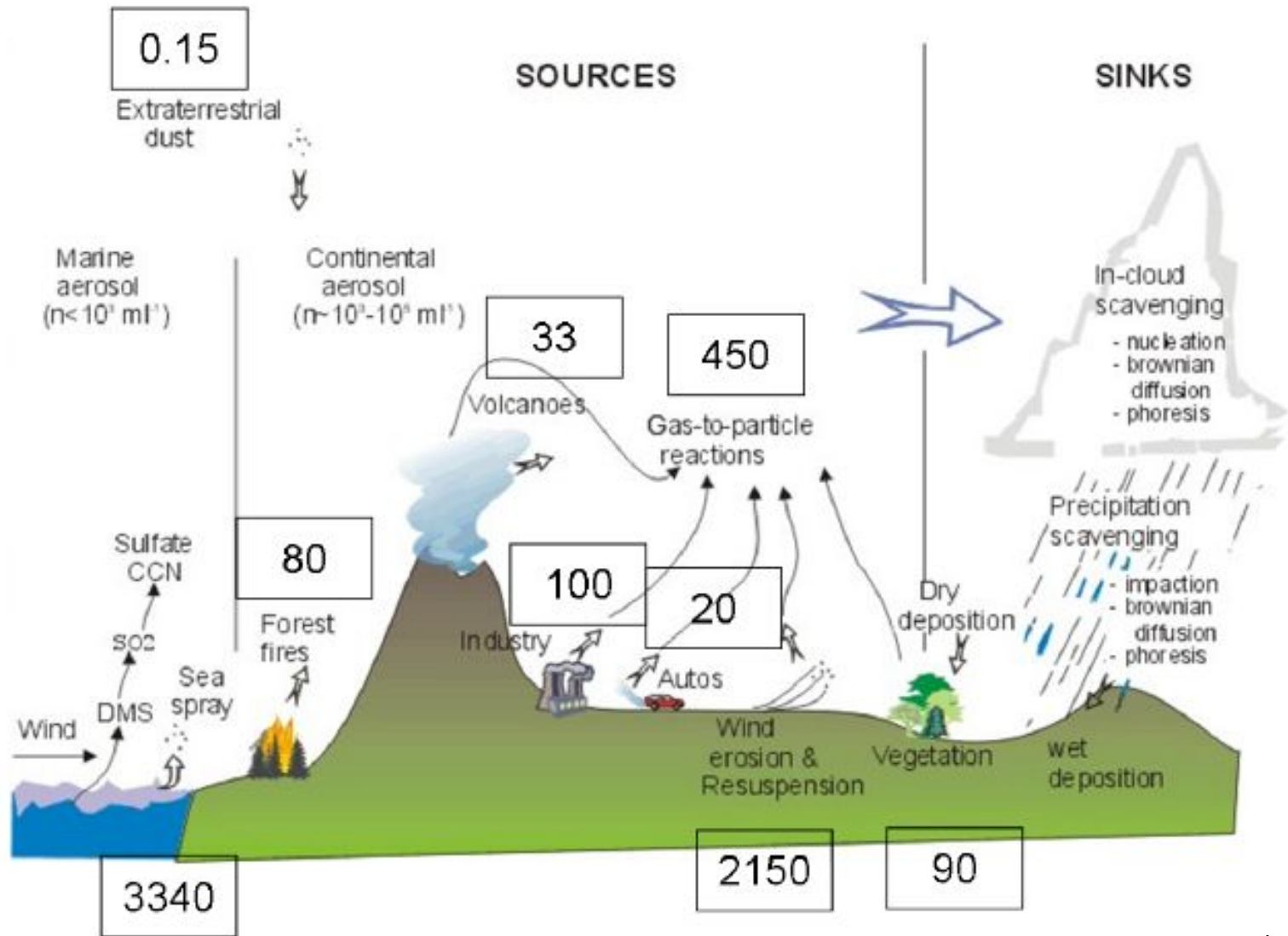


Extracted from Kok et al., 2021



Extracted from Barnaba and Gobbi, 2004

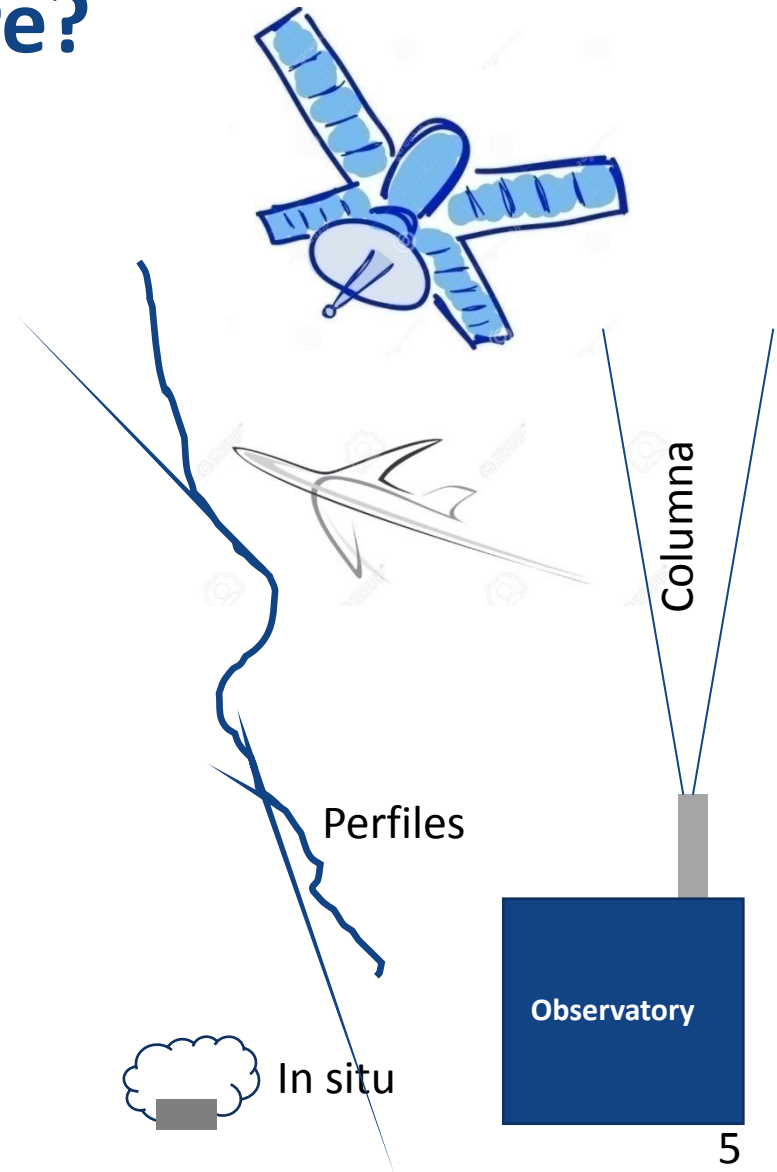
Atmospheric aerosols



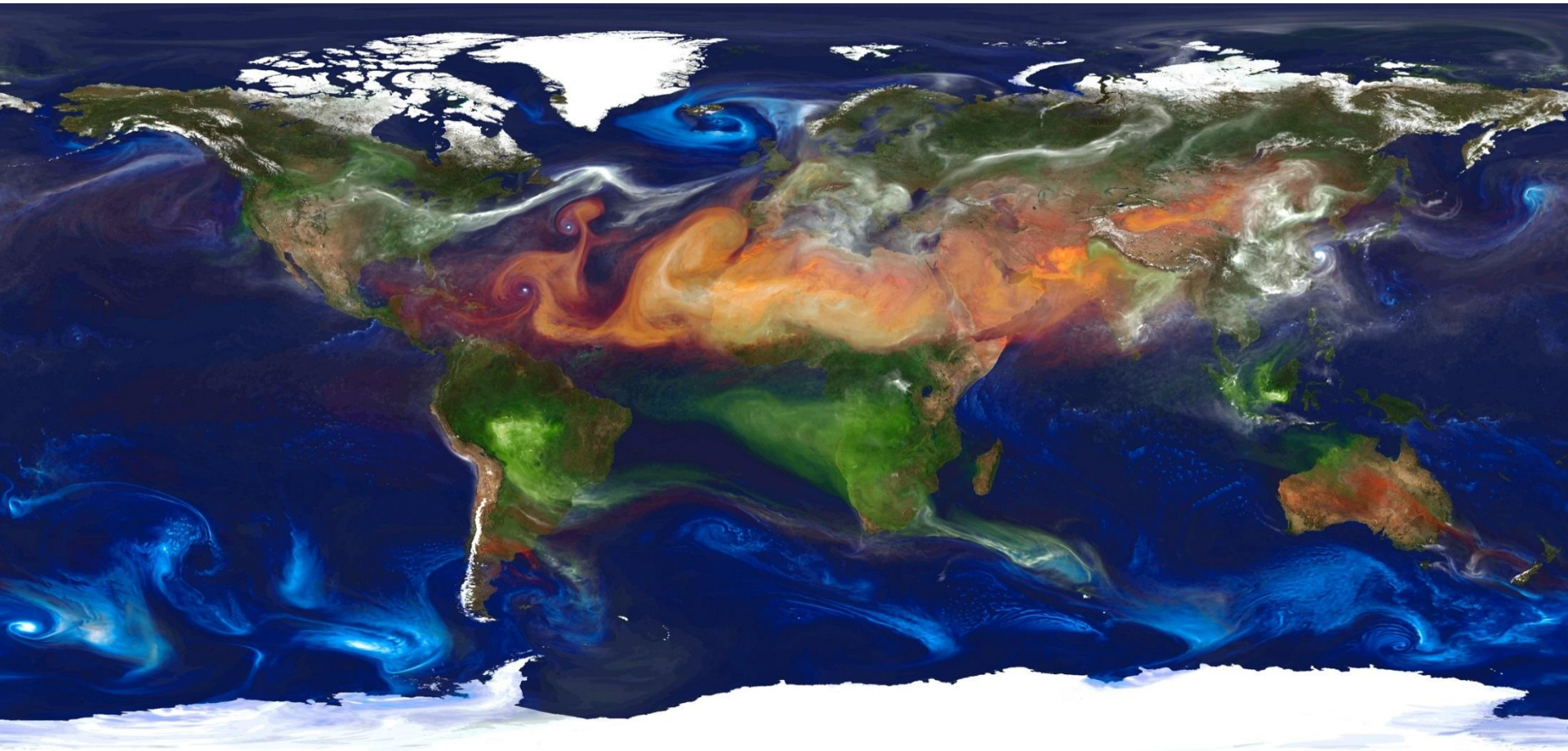
Estimates in mass (in Mg/year)

How we can characterize the state of the atmosphere?

- Satellite measurements
- Ground based remote sensing
- Near surface characterization
- Measurement campaigns
 - *Development of new methods*



Aerosol's extension



Organic Carbon + Elemental carbon

Dust

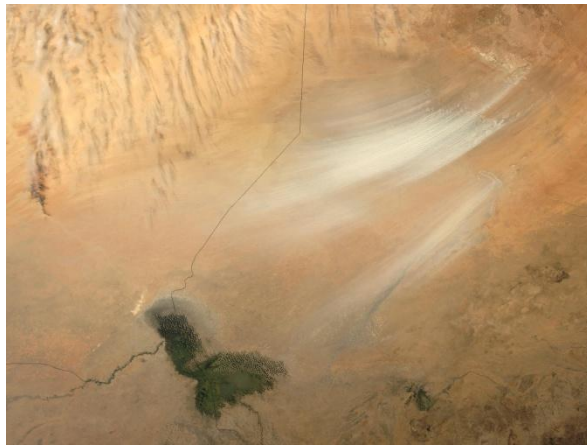
Sulfate

Sea salt

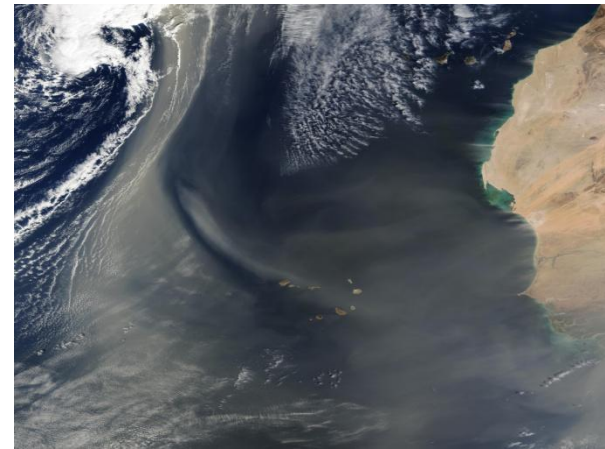
NASA | GEOS-5 Aerosols, AOD550nm

Dust cycle and associated processes

Dust transport is a global phenomenon. However, dust emission is a threshold phenomenon, sporadic and spatially heterogeneous, that is locally controlled on small spatial and temporal scales.



MODIS true colour composite image for March 2005 depicting a dust storm initiated at the Bodélé Depression (Chad Basin)

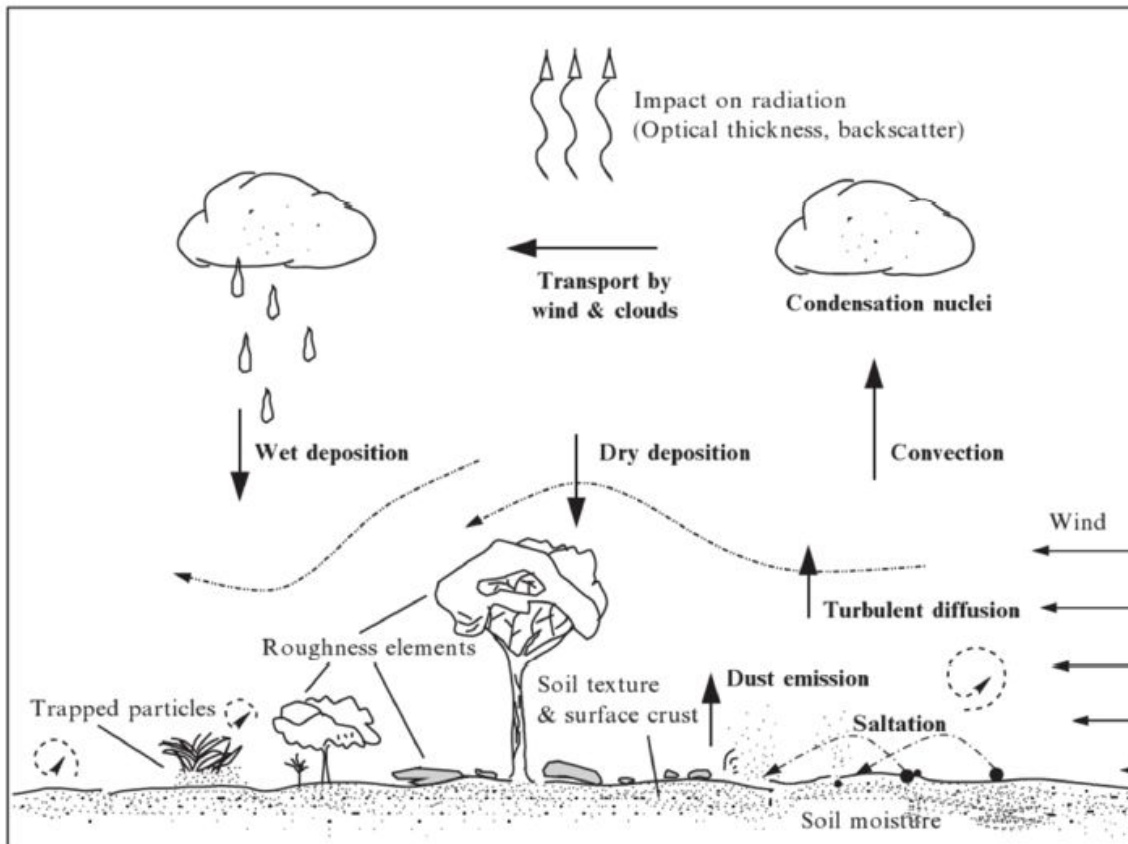


MODIS True color Western Africa – Atlantic Ocean

Dust emission, transport and deposition are sensitive to **surface wind speed** and precipitation, among other factors.

Dust cycle and associated processes

The atmospheric dust cycle and involves a variety of processes:



- Dust emission from dry unvegetable surfaces (dust sources)
- Mid- and long-range transport
- Sedimentation, wet and dry deposition

Extracted from Shao (2008)

Dust cycle and associated processes

Dust Impacts

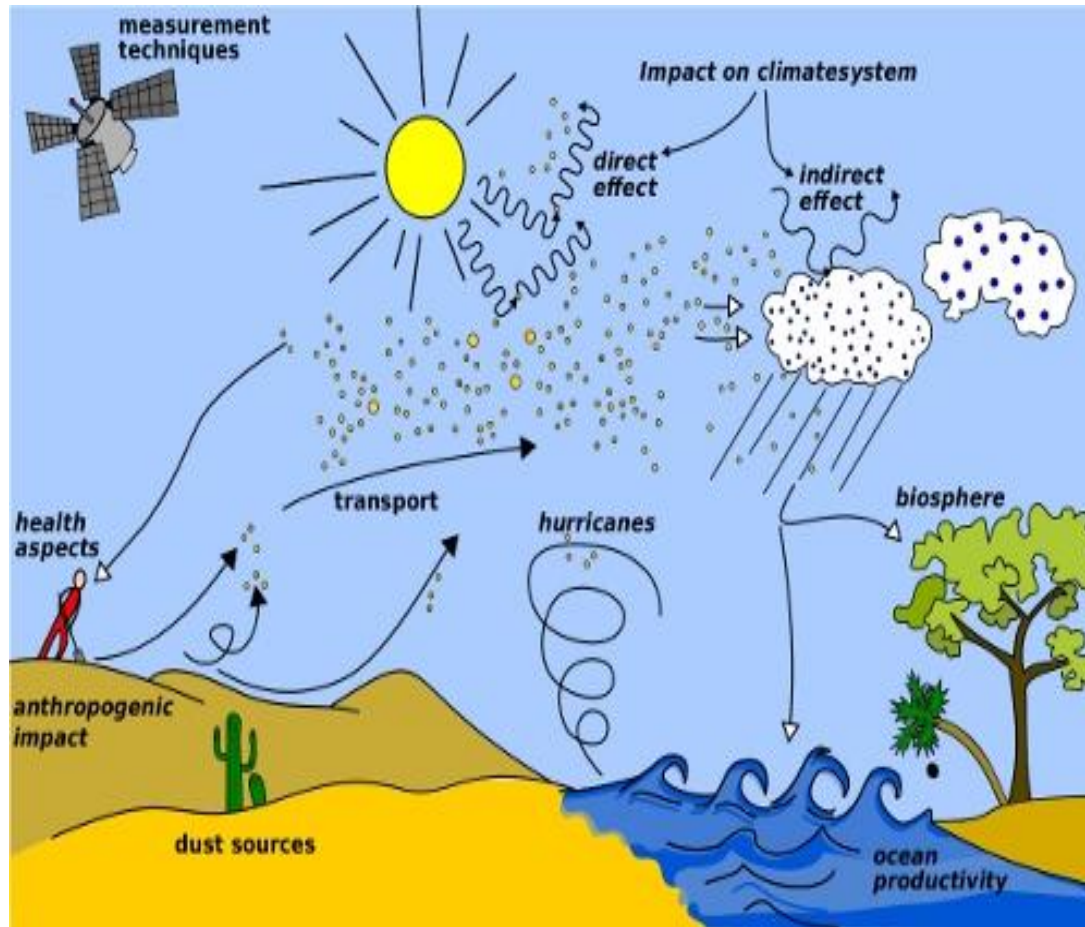


Image from WMO website
(<http://www.wmo.int/pages/prog/arep/wwrp/new/hurricanes.html>)

Ecosystems, meteorology and climate

- *Marine productivity*
- *Coral mortality*
- *Hurricanes formation*

Air Quality and Human Health

- *Respiratory disease (asthma)*
- *Eye infections*
- *Meningitis in Africa*
- *Valley Fever in the Americas*

Aviation and Ground Transportation

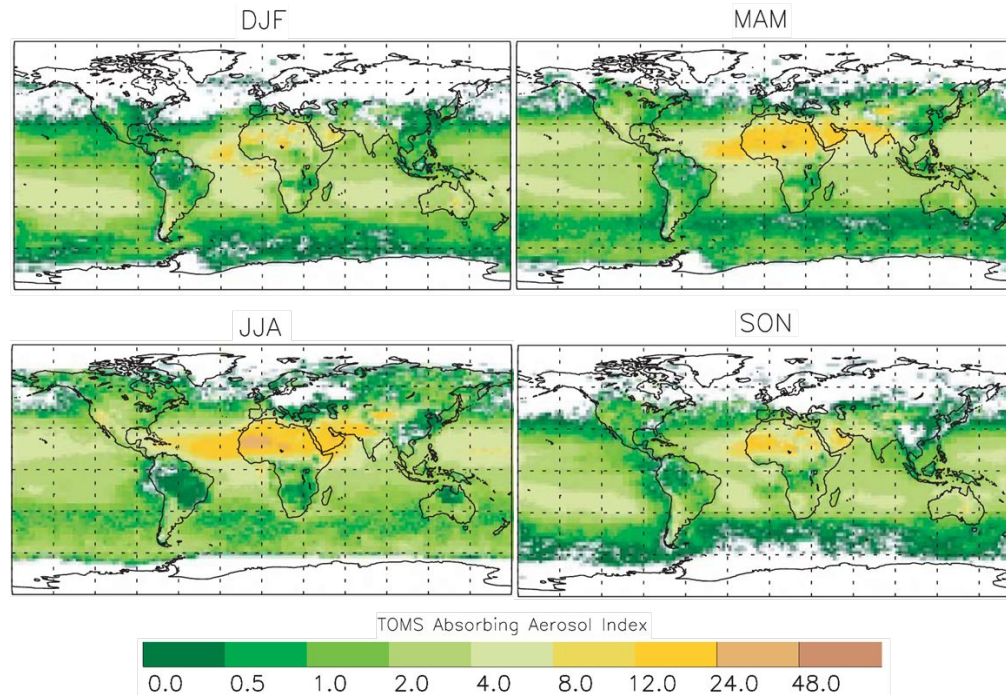
- *Low visibility (i.e. accidents)*
- *Mechanical damages*

Agriculture and fishing

Energy and industry

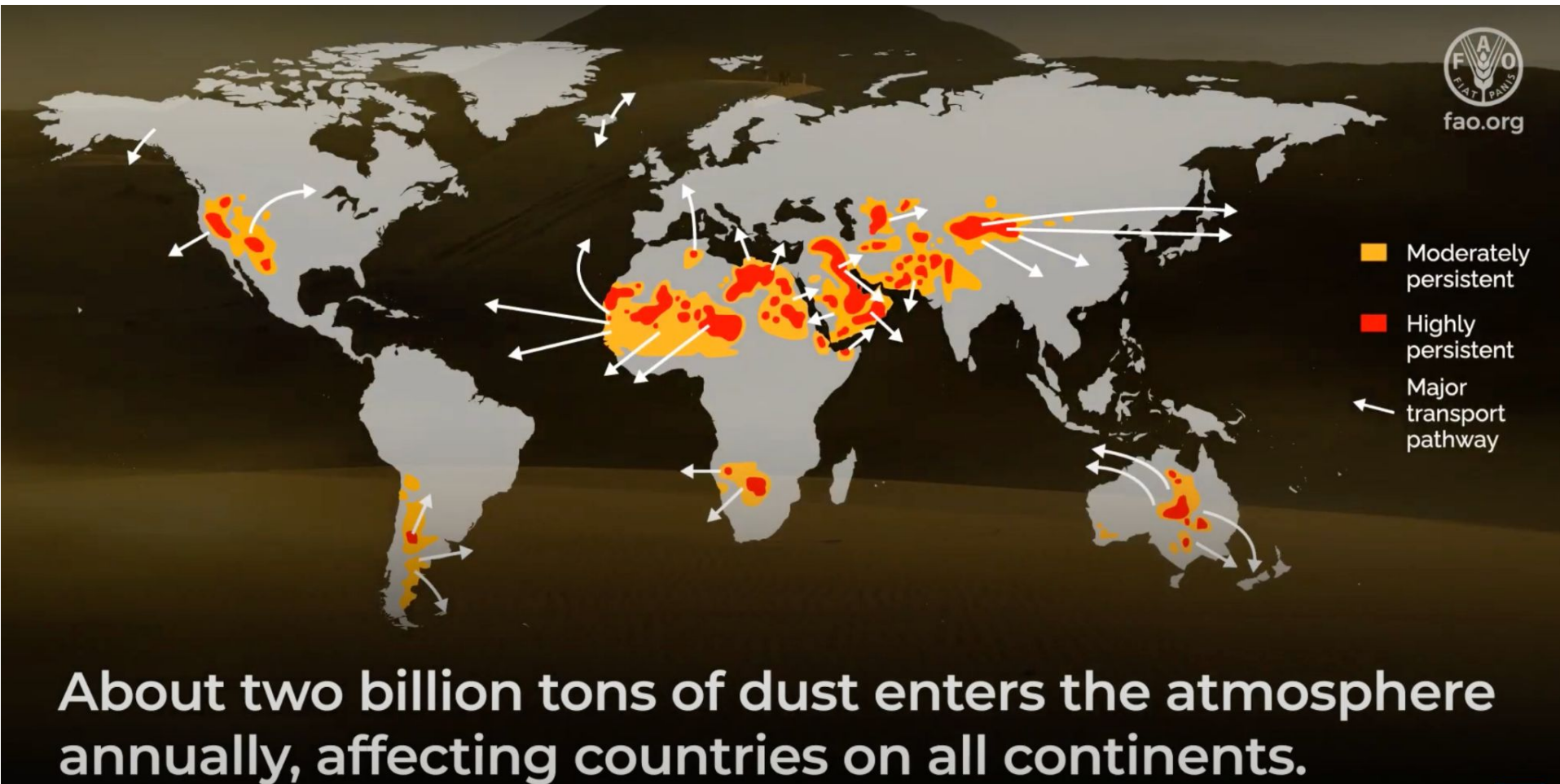
Dust cycle and associated processes

Interannual, decadal and long-term trends



- **Seasonal** dust distribution changes well characterized. Follows seasonal changing weather regimes (mainly) and vegetation changes (in semi-arid areas)
- **Interannual/decadal** changes are controlled by climate and surface modification (land use, desertification). Decadal changes are not well captured by models

Dust cycle and associated processes



FAO Sand and dust storms (SDS): A transboundary issue of growing concern, watch the video https://www.youtube.com/watch?v=RS_oJcqN1vo

Desert dust soil types

Main landscapes of the North Africa
(Photos from Callot et al. 2000) :



A) Central part of Saharan Atlas. In the background, mountains, and in front, an overgrazed plain;

B) Northern part of Saharan Atlas. Esparto grass steppe degraded by a strong anthropic action. The sandy soil disappears, denuding the sandstone substratum;

C) The Great Hamada south-west of El-Abiodh-Sidi-Cheikh;

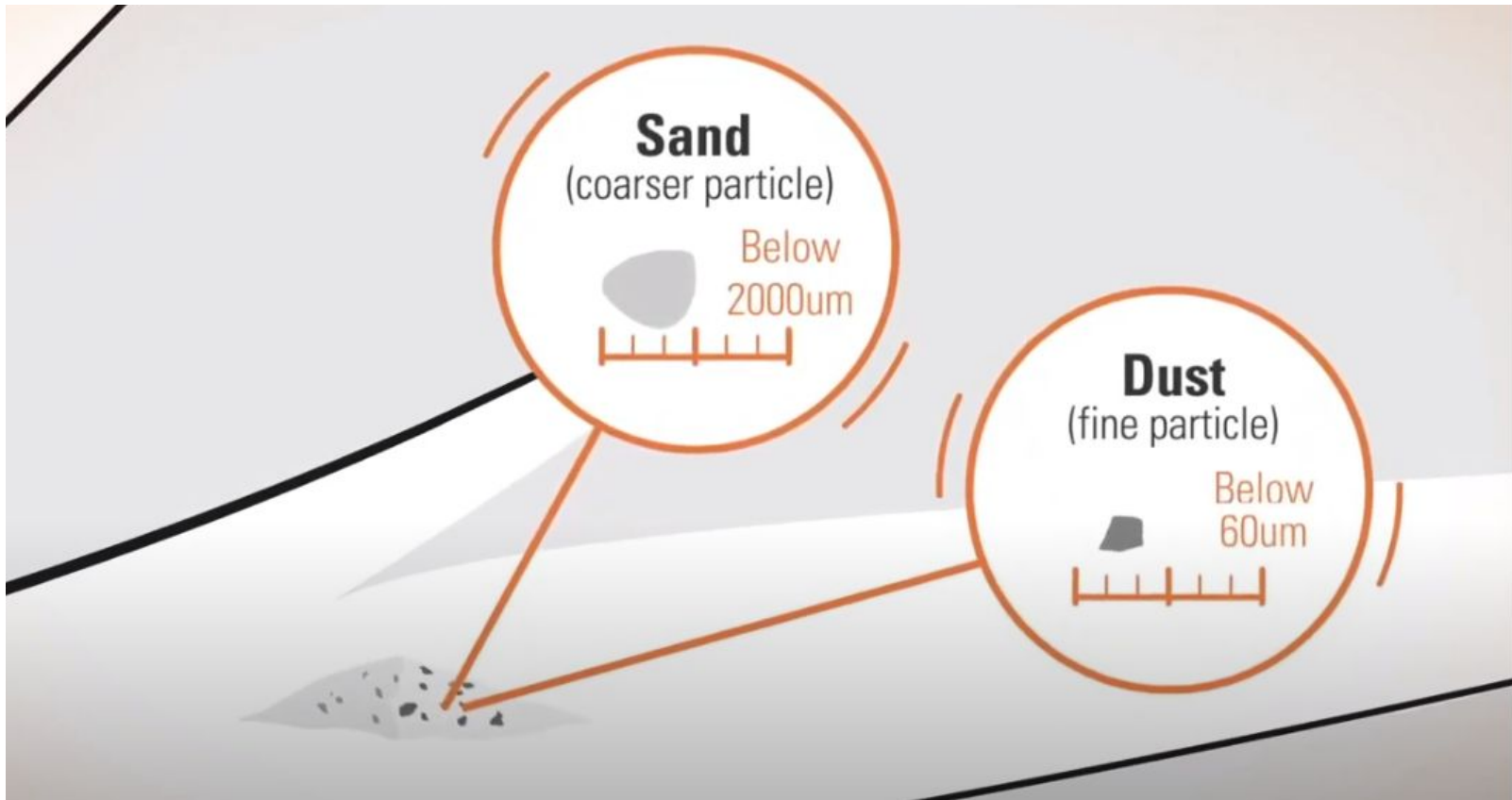
D) Daïa in the Mechfar, at Hassi Cheikh well;

E) North-east of the Great Western Erg: coarse sand interdune corridor with deflation cauldron and palaeolake deposits;

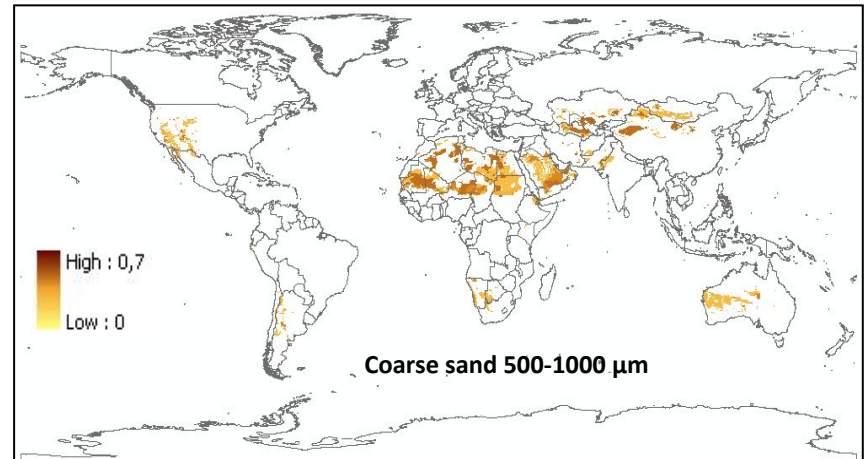
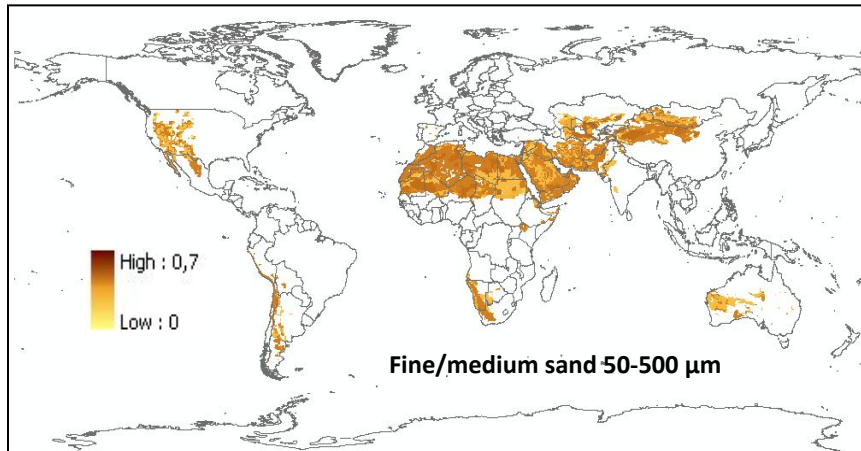
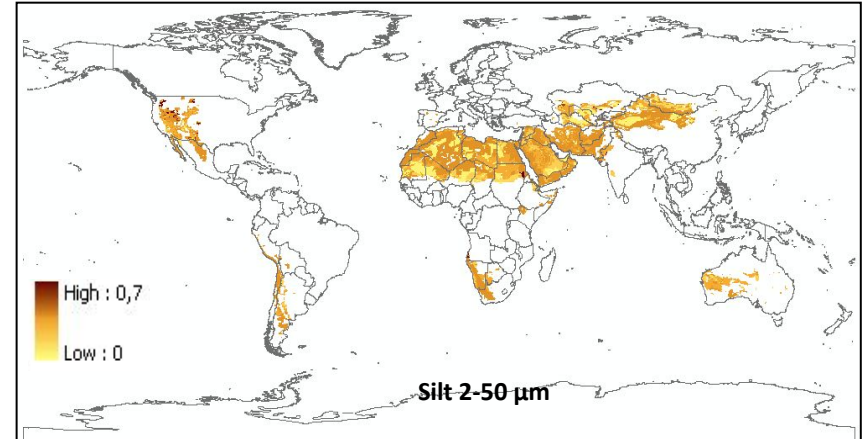
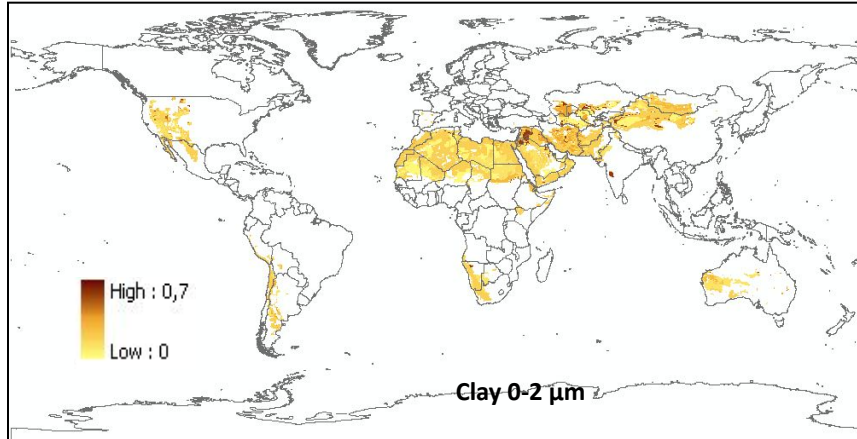
F) North-east of the Great Western Erg: great coarse sand dome dunes, covered by fine sand active dunes.

Desert sources

Definition of sand and dust



Soil size distribution derived from soil texture



Four top soil texture classes according STASGO-FAO 1km database are converted to 4 parent soil size categories following Tegen et al. [2002].

It is a natural phenomena?

Dust emission and resuspension **associated to human activities** are considered anthropogenic sources

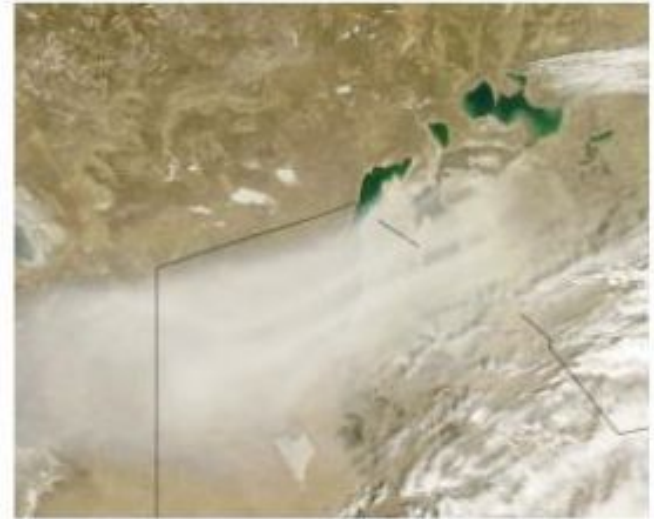
Cattle herds, Chad



Mining, Ohio valley

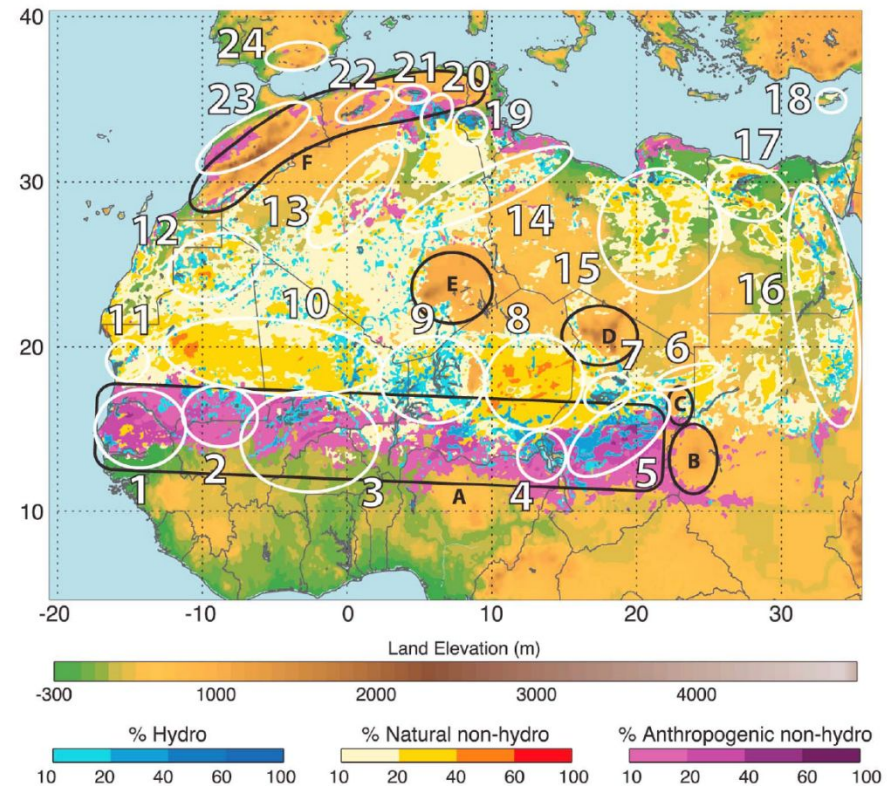
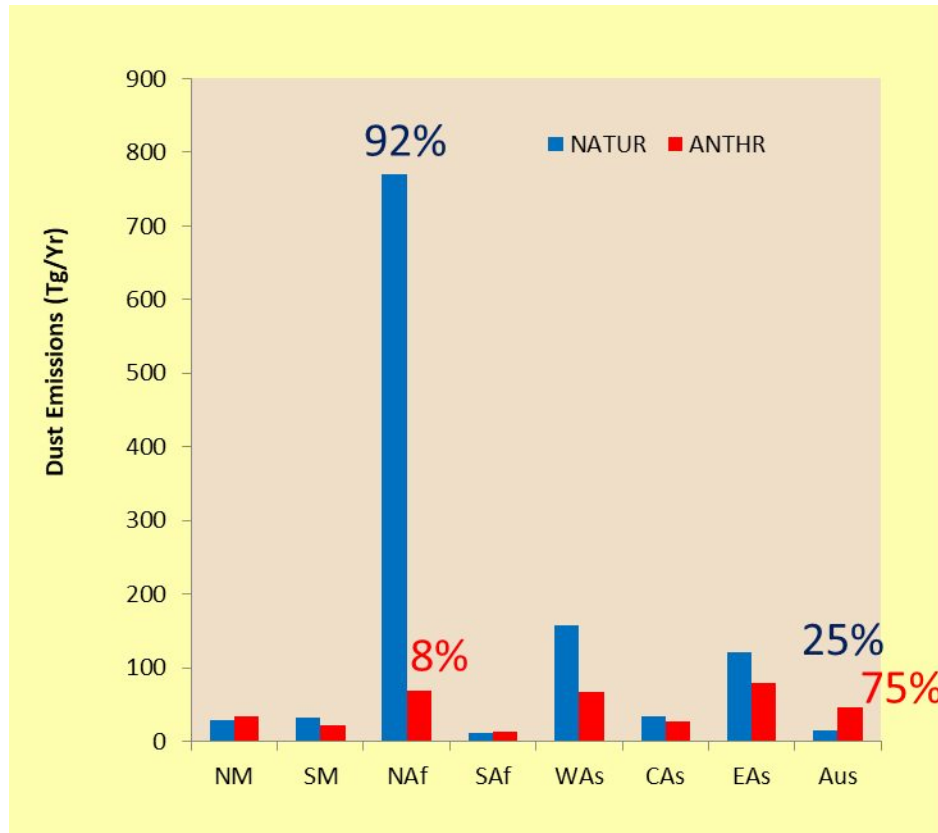


Dust from dry sea bed, Aral sea (Uzbekistan)

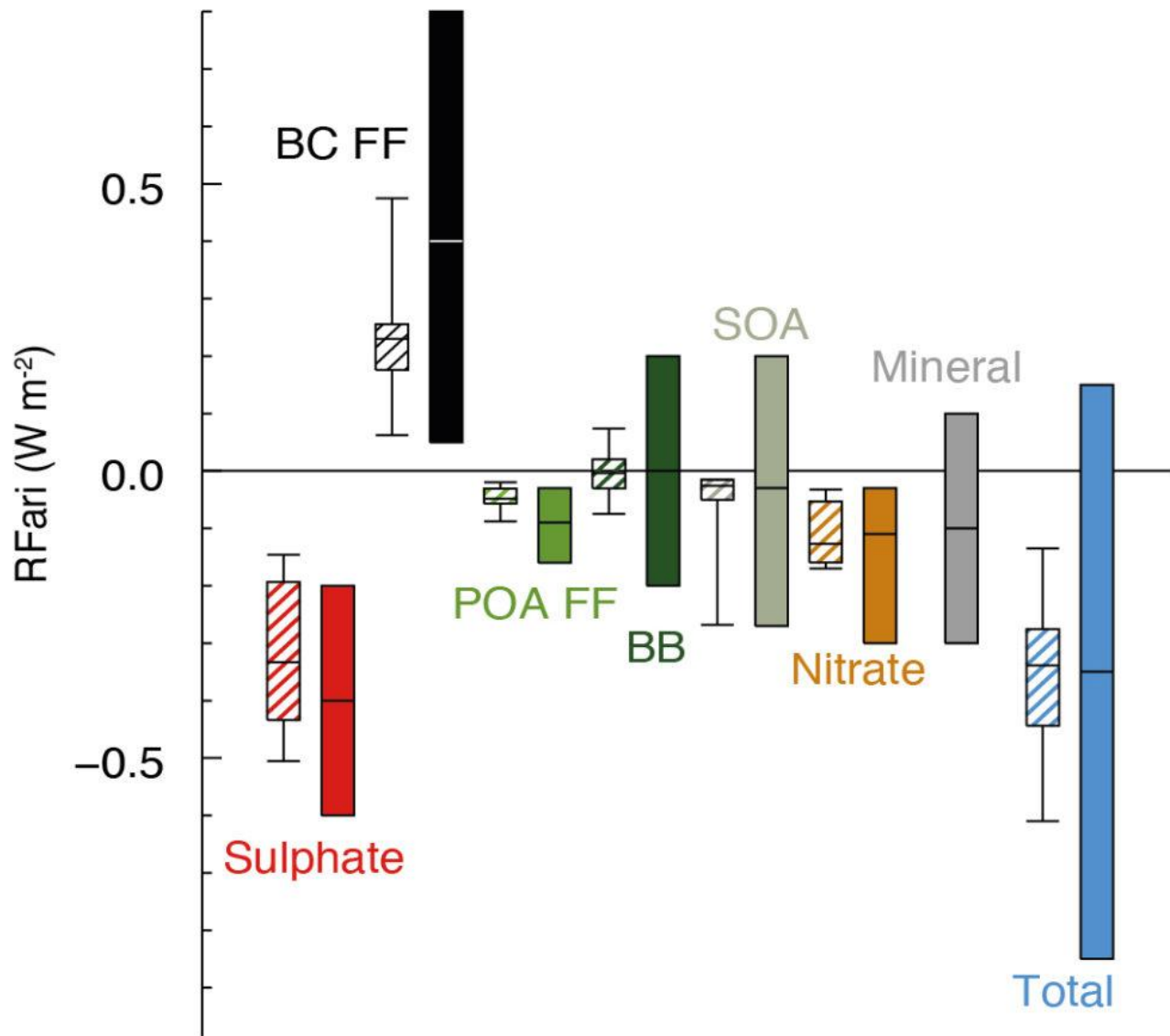


Kathmandu, Nepal, March 2017

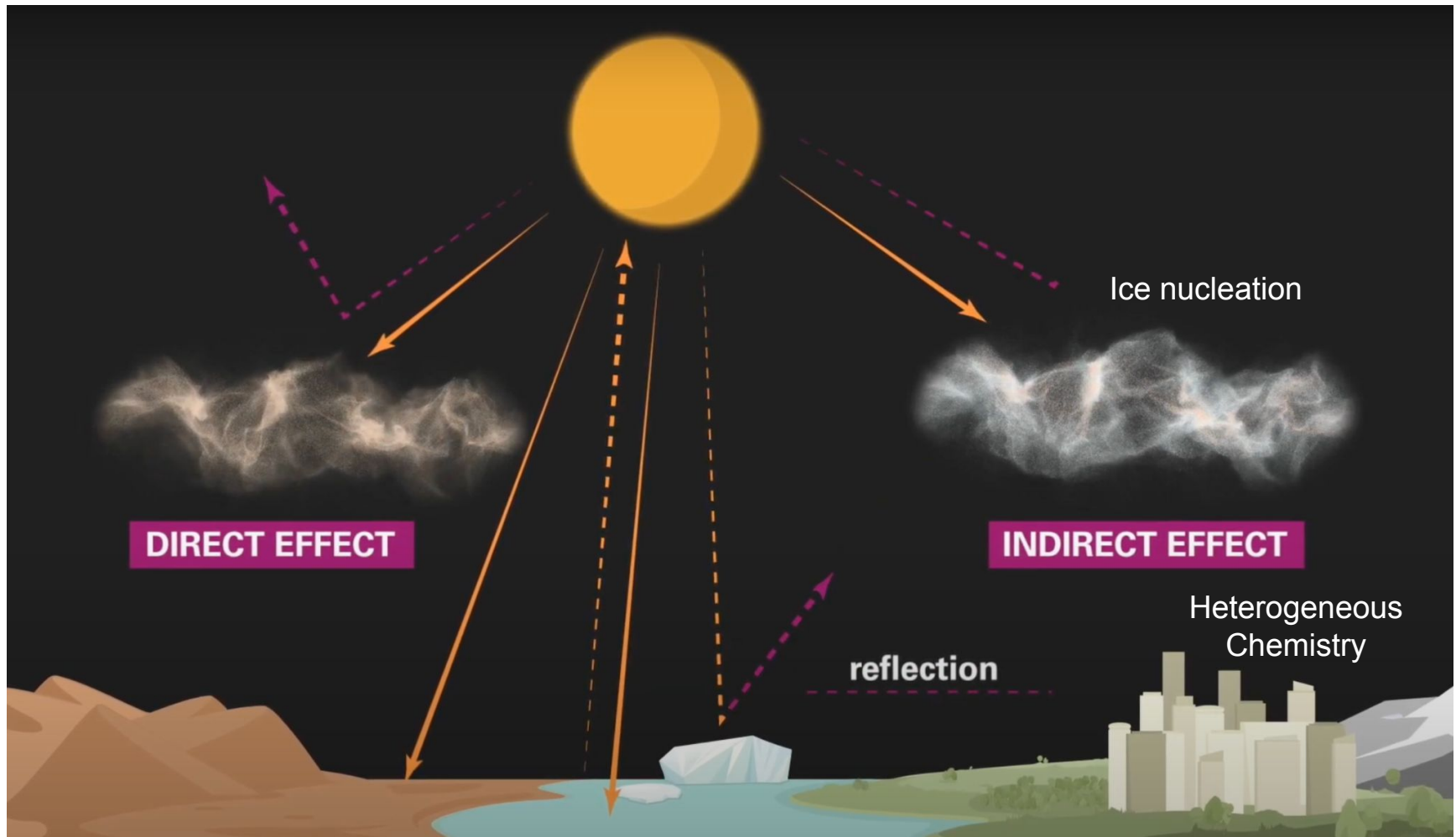
Natural and anthropogenic dust sources



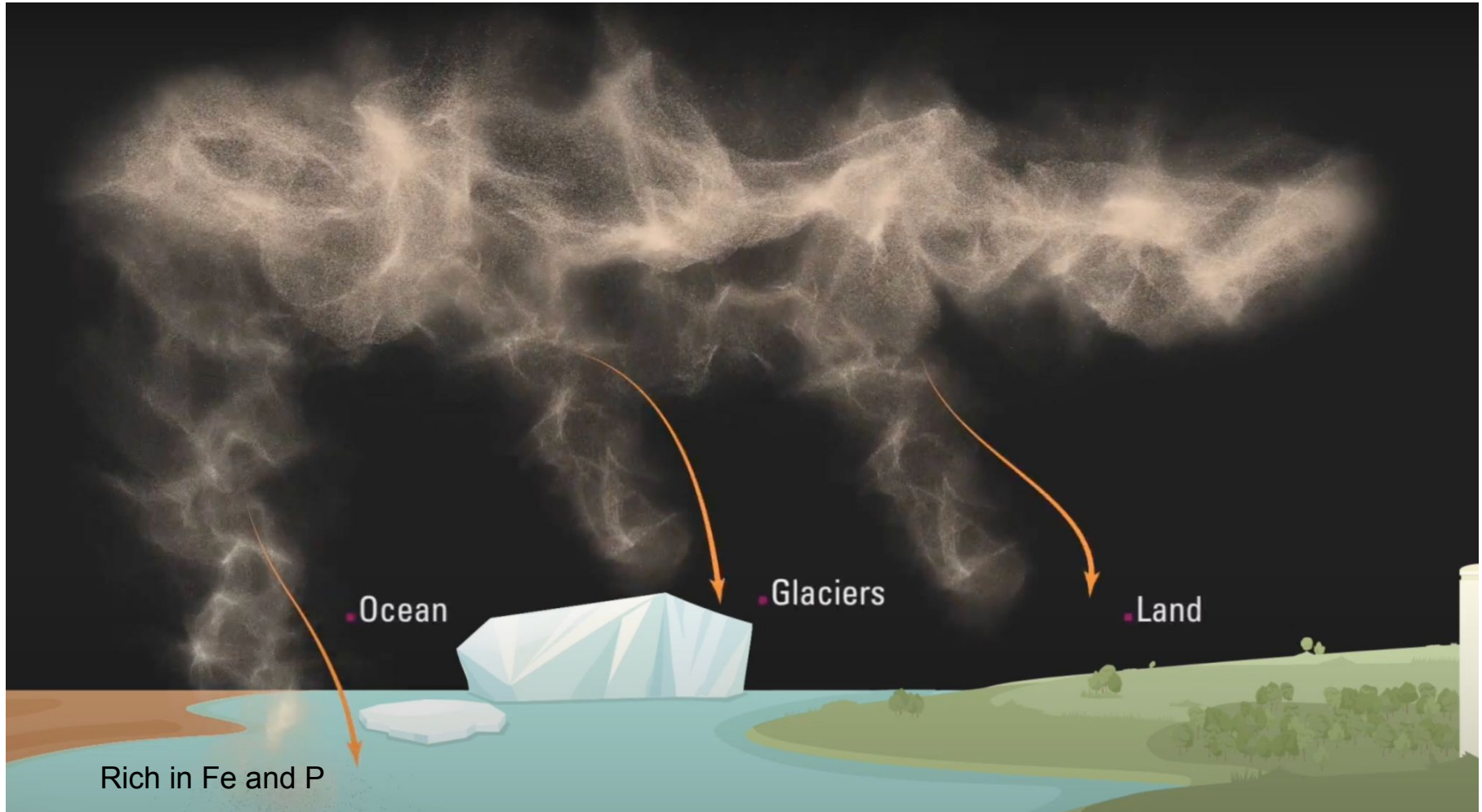
How dust interact with the climate?



How dust interact with the climate?



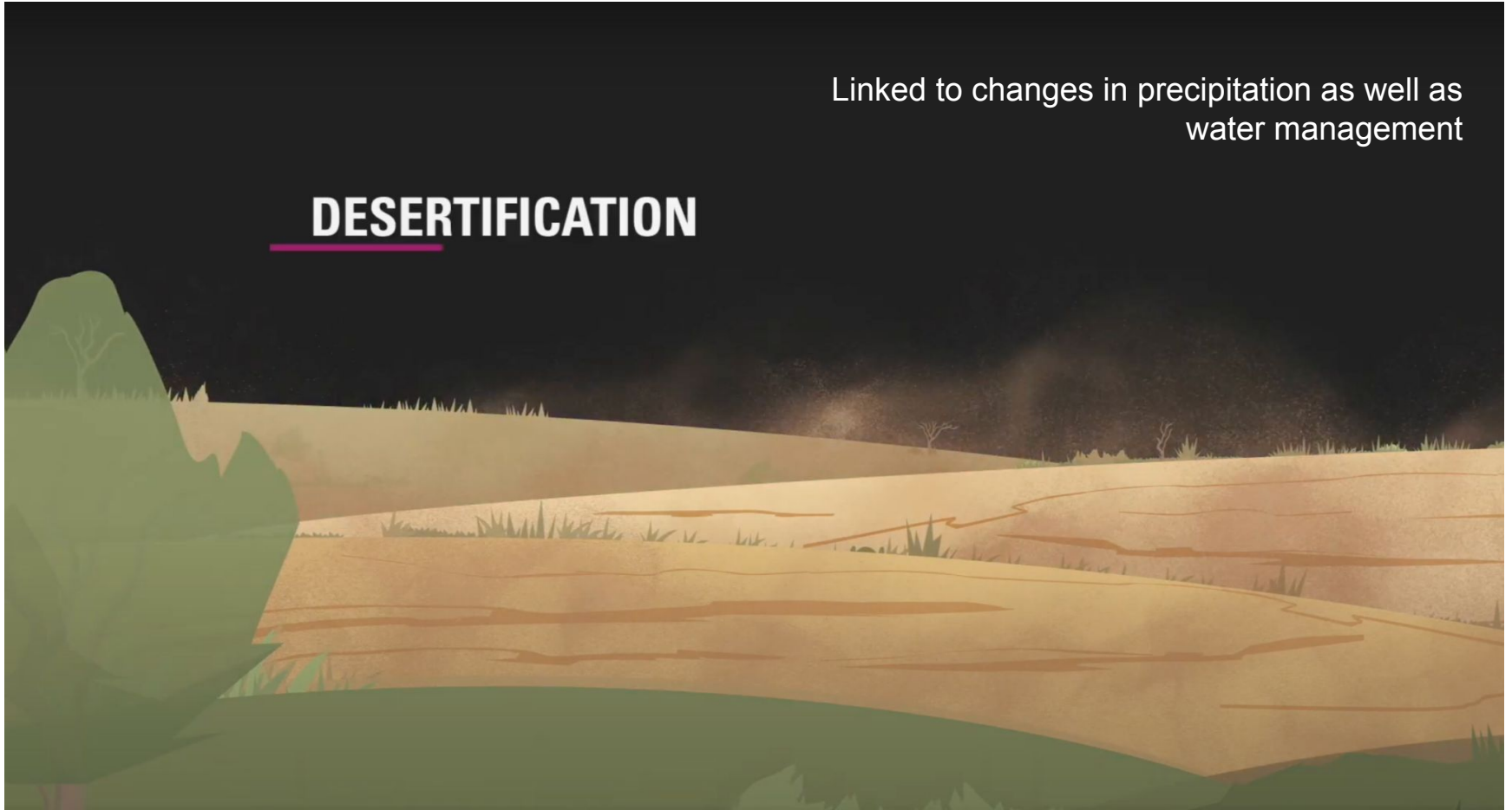
How dust interact with the climate?



How dust interact with the climate?

Linked to changes in precipitation as well as
water management

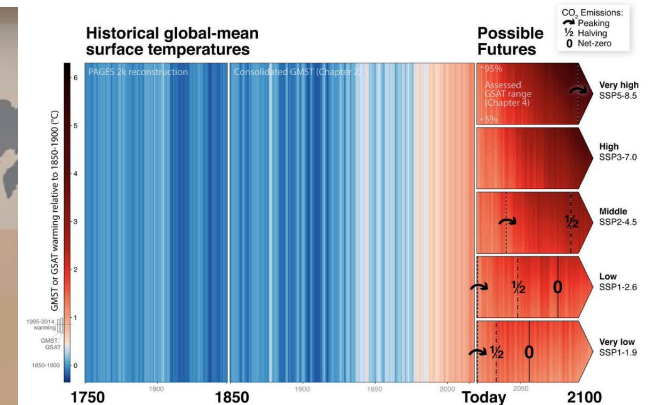
DESERTIFICATION



How dust interact with the climate?

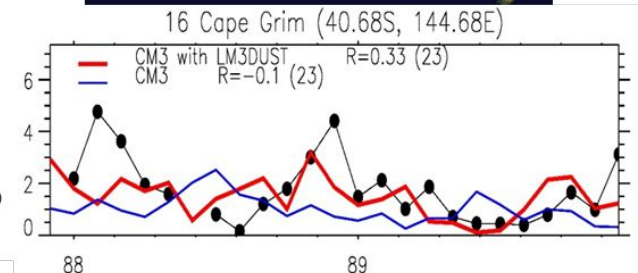
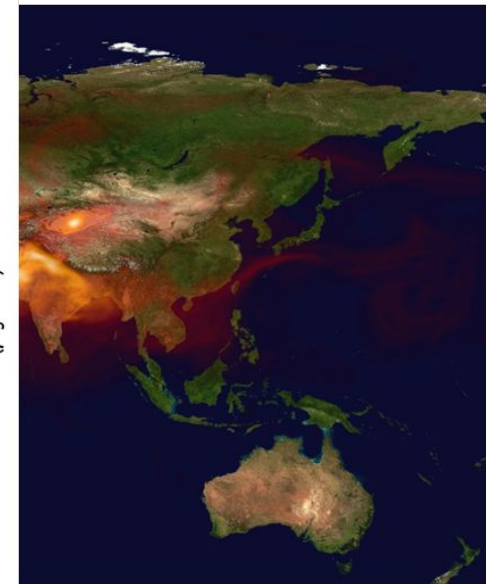
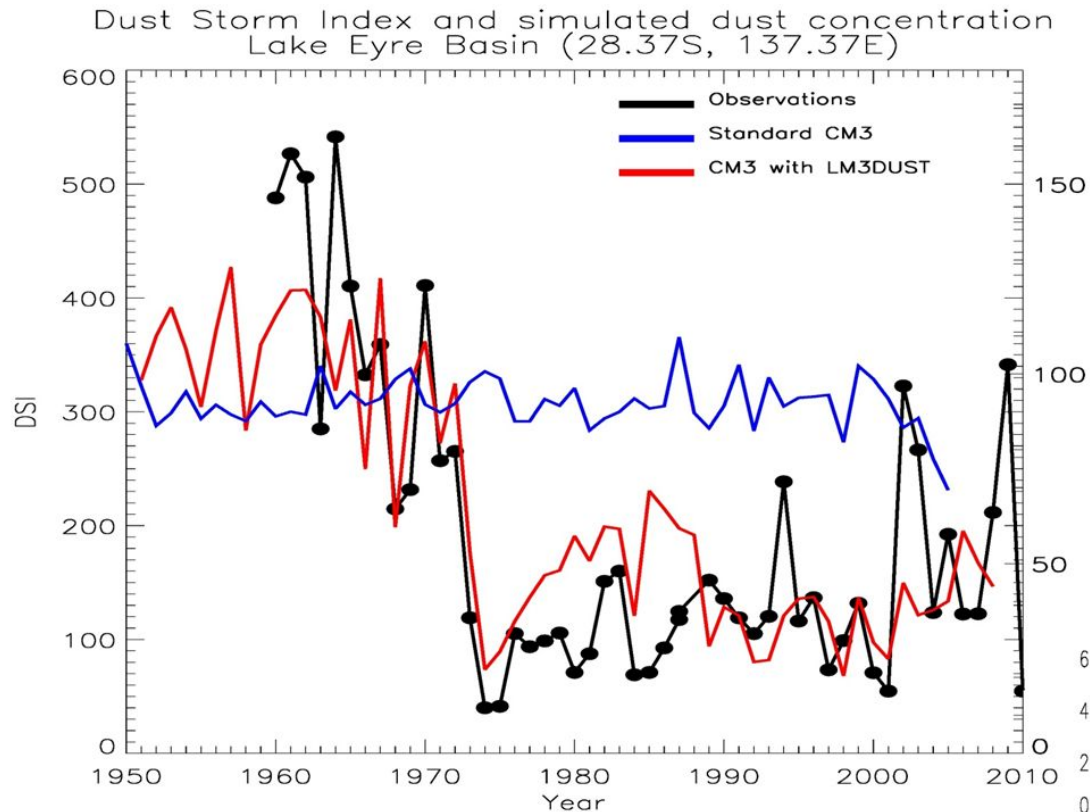
Climate change is emerging new sources
High-latitude dust

Ed Hawkins Twitter account



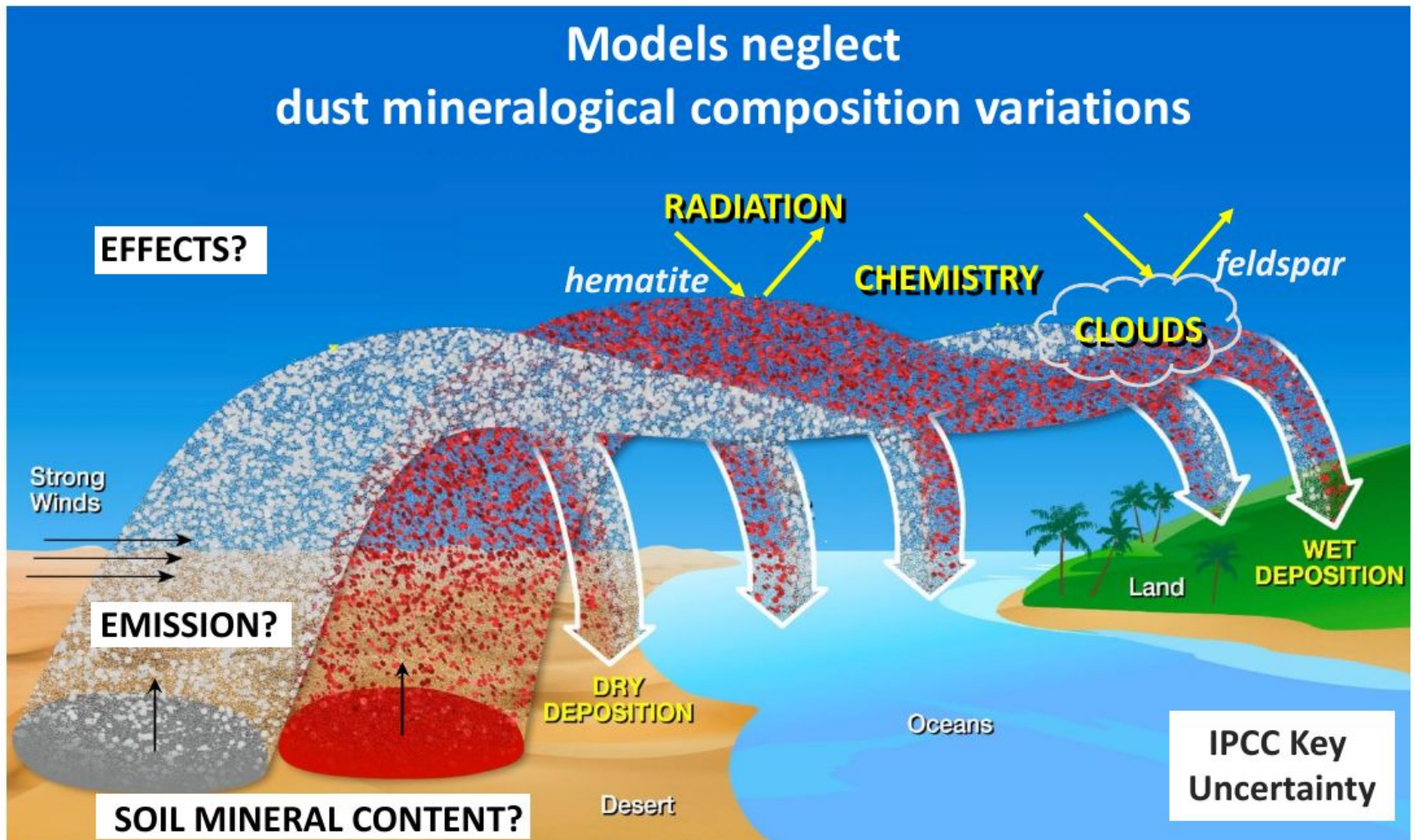
How dust interact with the climate?

Connecting dust emission to dynamic vegetation model and land use change



Following heavy precipitation in early 70s, surface dust concentration dropped by a factor 3 in agreement with Dust Storm Index.

How dust interact with the climate?

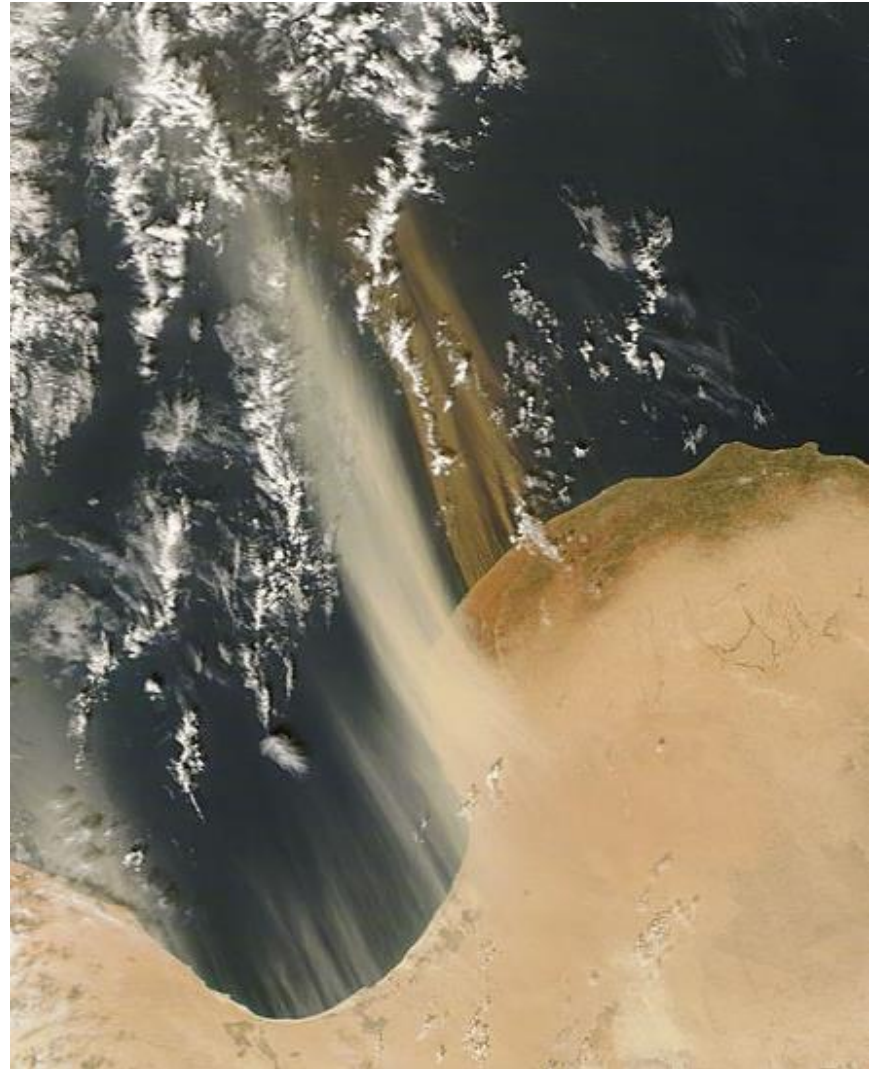


SOURCES: HUMAN DISTURBANCES e.g. agriculture

How dust interact with the climate?

Models and remote-sensing retrievals considers dust a whole aerosol and neglect dust **mineralogical composition** variations

New satellite hyperspectral sensors for mapping the soil: **NASA-EMIT** and **EnMap**



Dust emission mechanisms

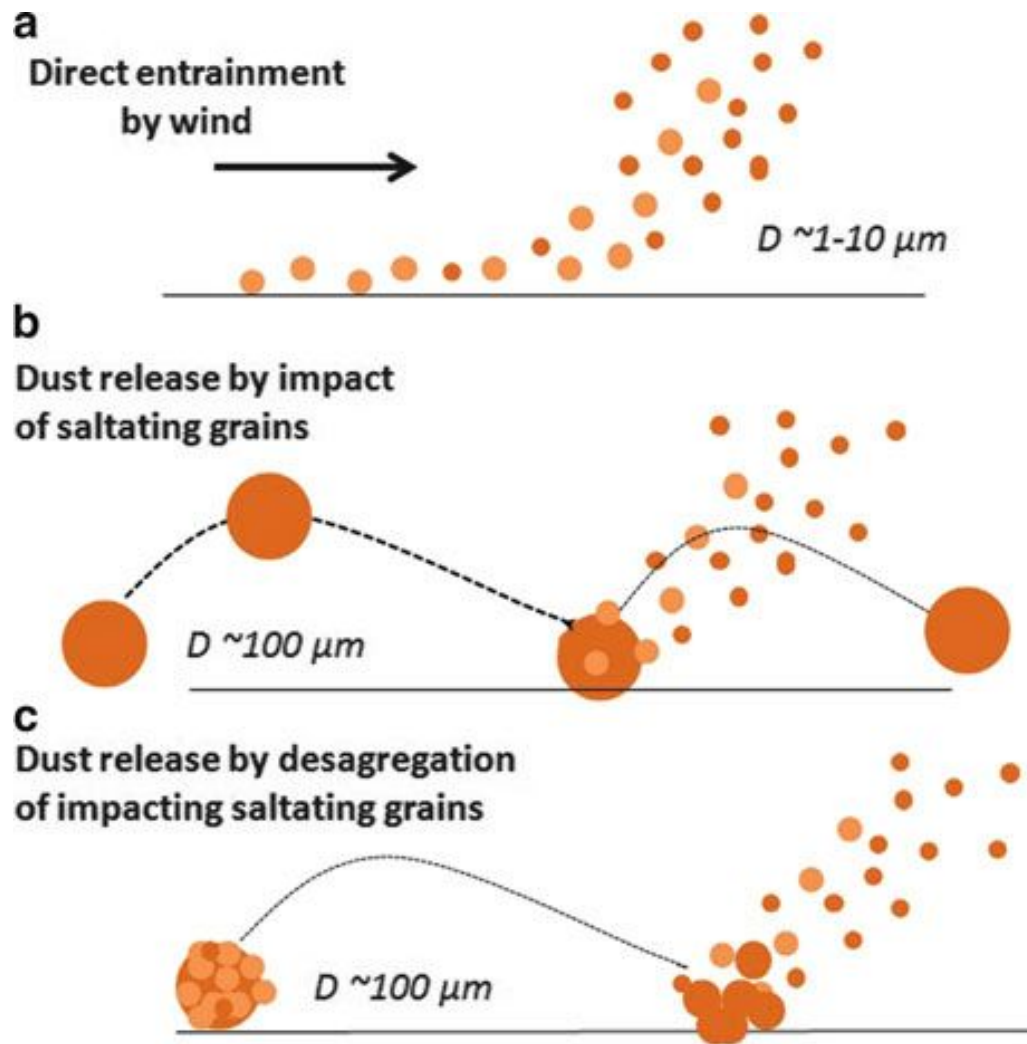
- Complex physical process involving entrainment of soil particles by the surface winds.



- Creep or rolling motion of the largest particles ($> 500 \mu\text{m}$)
- Saltation or horizontal motion of large soil grains (sand) ($50\text{-}500\mu\text{m}$)
- Suspension of dust (after sandblasting or saltation bombardment) ($0.1\text{-}50 \mu\text{m}$)

Movie from the COMET program at <http://meted.ucar.edu/> of the University Corporation for Atmospheric Research (UCAR)

Dust emission mechanisms



Emitted dust mass

&

Size distribution

Dust emission mechanisms

The emission threshold depends on the type and status of the land



Urmia Lake, Iran

Dust emission mechanisms

The emission threshold depends on the type and status of the land



Dry session



Wet session → Flooded soil



Crusted soil



Snow

Dust cycle and associated processes

Types of dust storms:

Synoptic dust storms (large scale weather systems)

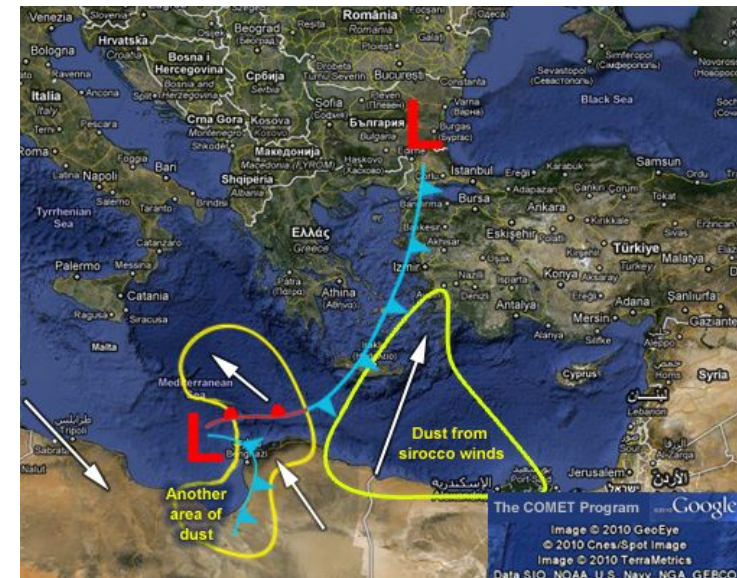
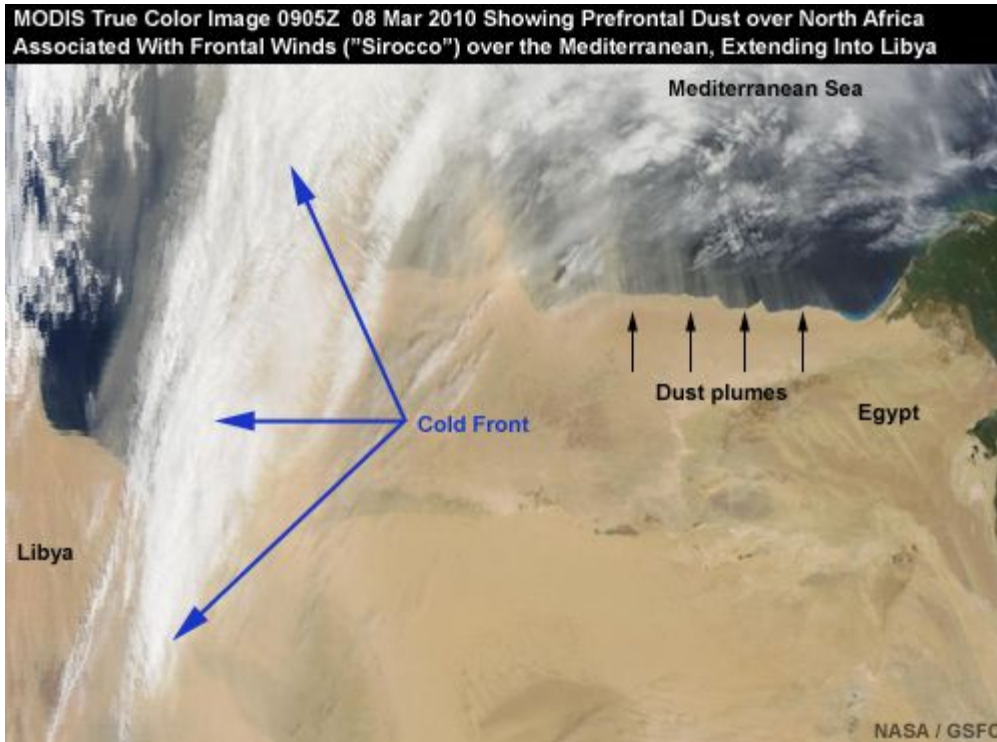
- Prefrontal winds
- Postprontal winds
- Large-scale Trade winds
- ...

Mesoscale dust storms

- Downslope winds
- Gap flow
- Convection (dust devils and Haboobs)
- Inversion downburst storms
- ...

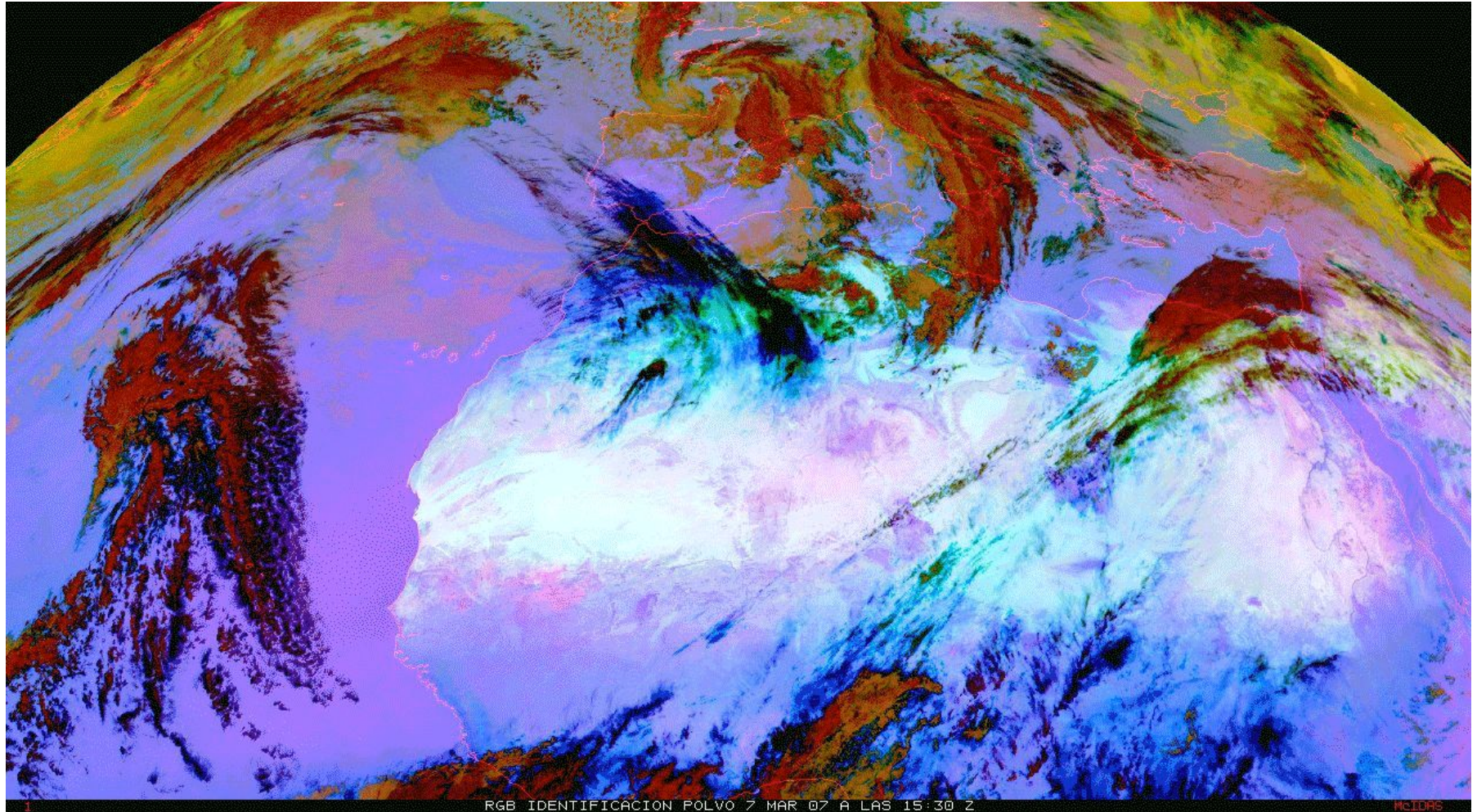
Dust cycle and associated processes

Synoptic dust storms: Pre-frontal



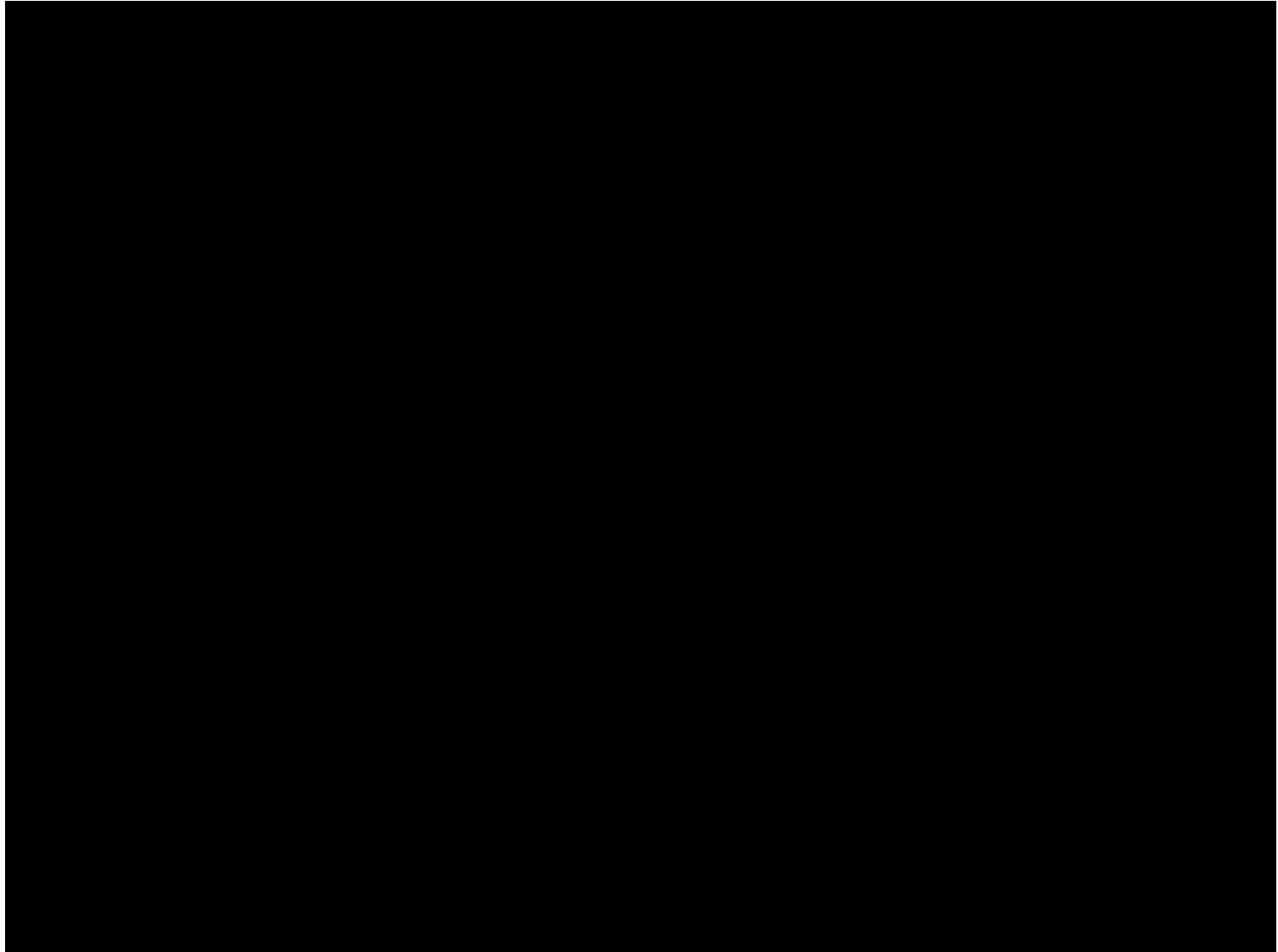
Dust cycle and associated processes

Synoptic dust storms: Post-frontal



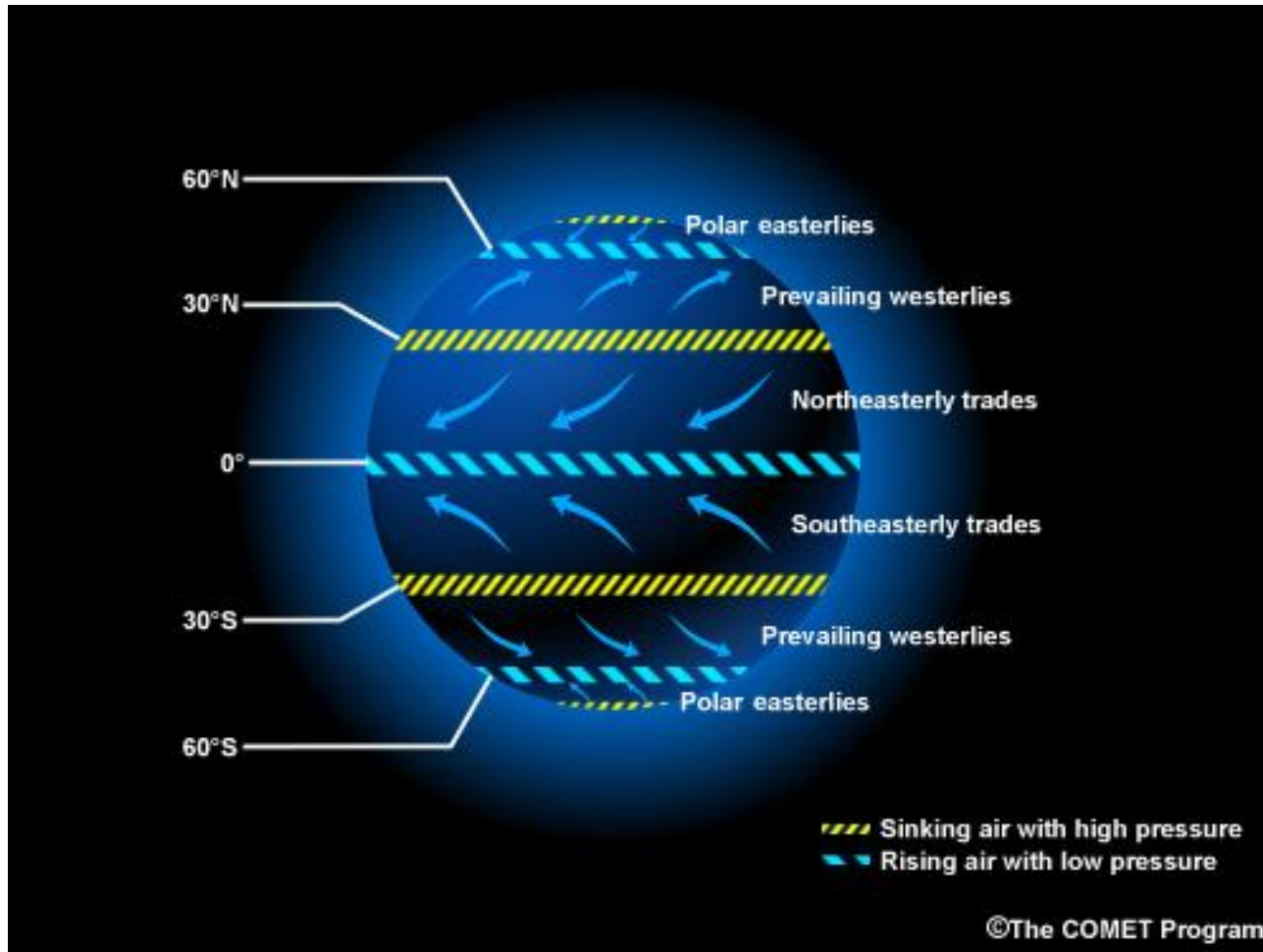
Dust cycle and associated processes

Synoptic dust storms: Post-frontal



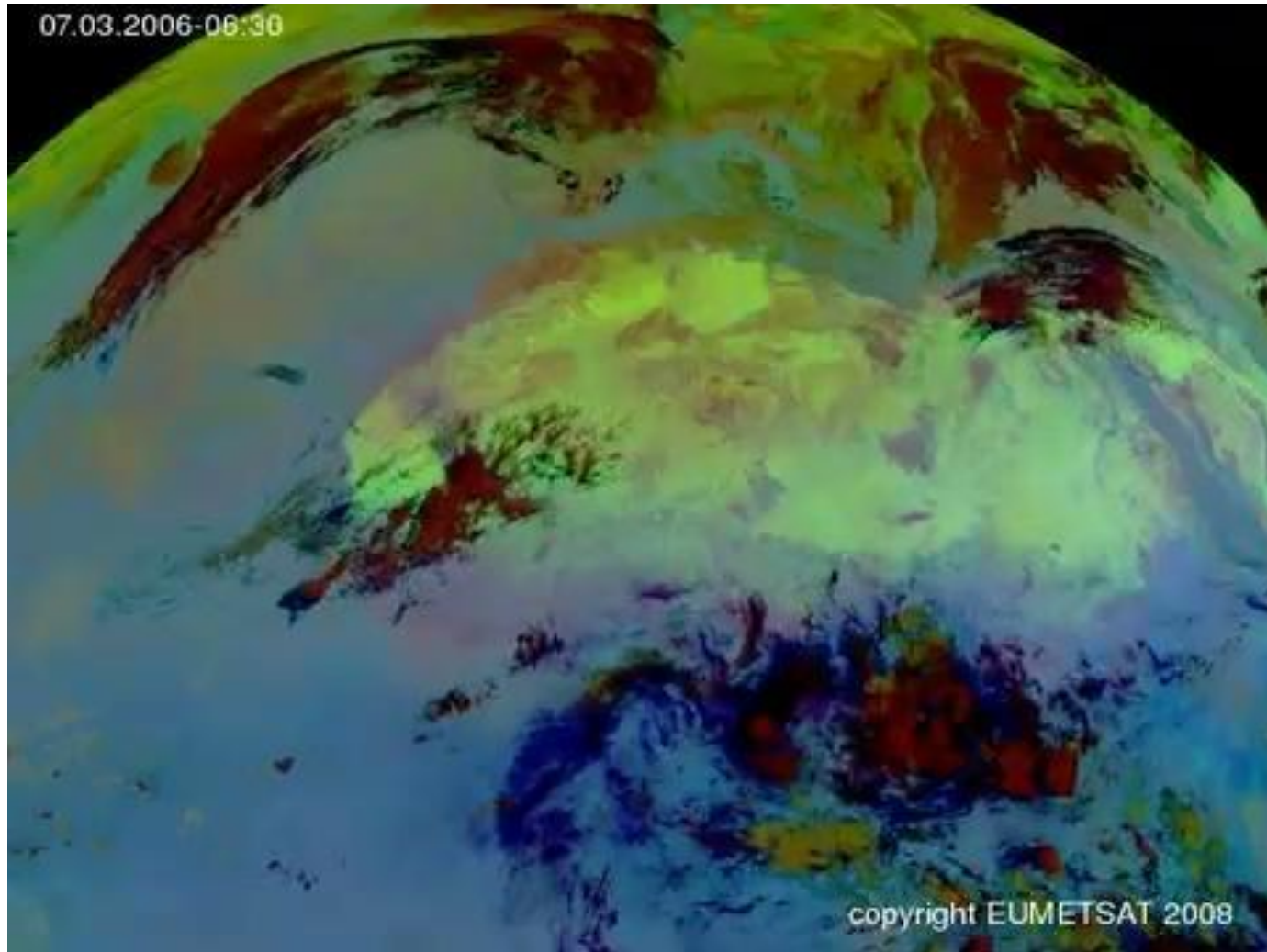
Dust cycle and associated processes

Synoptic dust storms: Large-scale trade winds



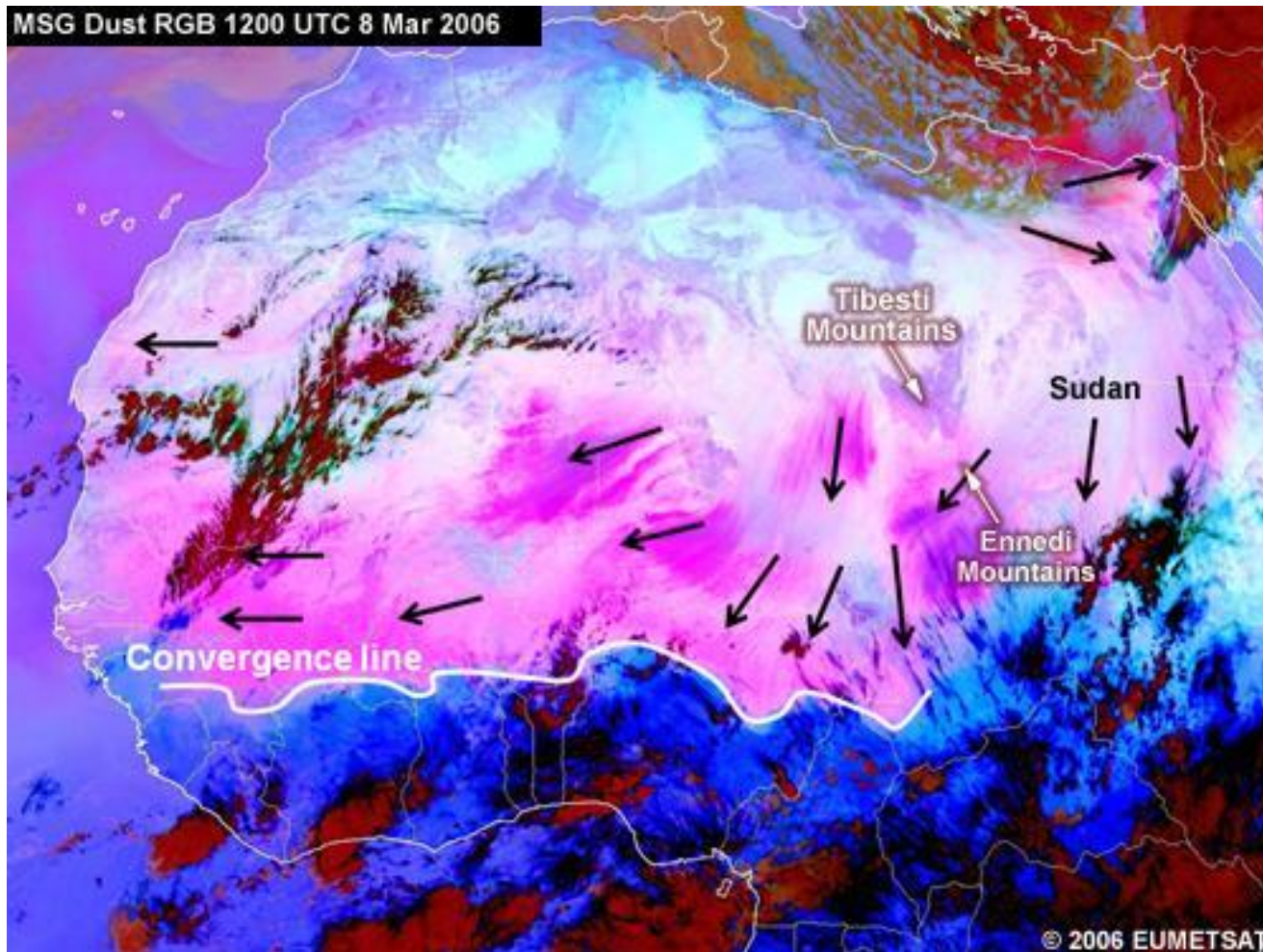
Dust cycle and associated processes

Synoptic dust storms: Large-scale trade winds



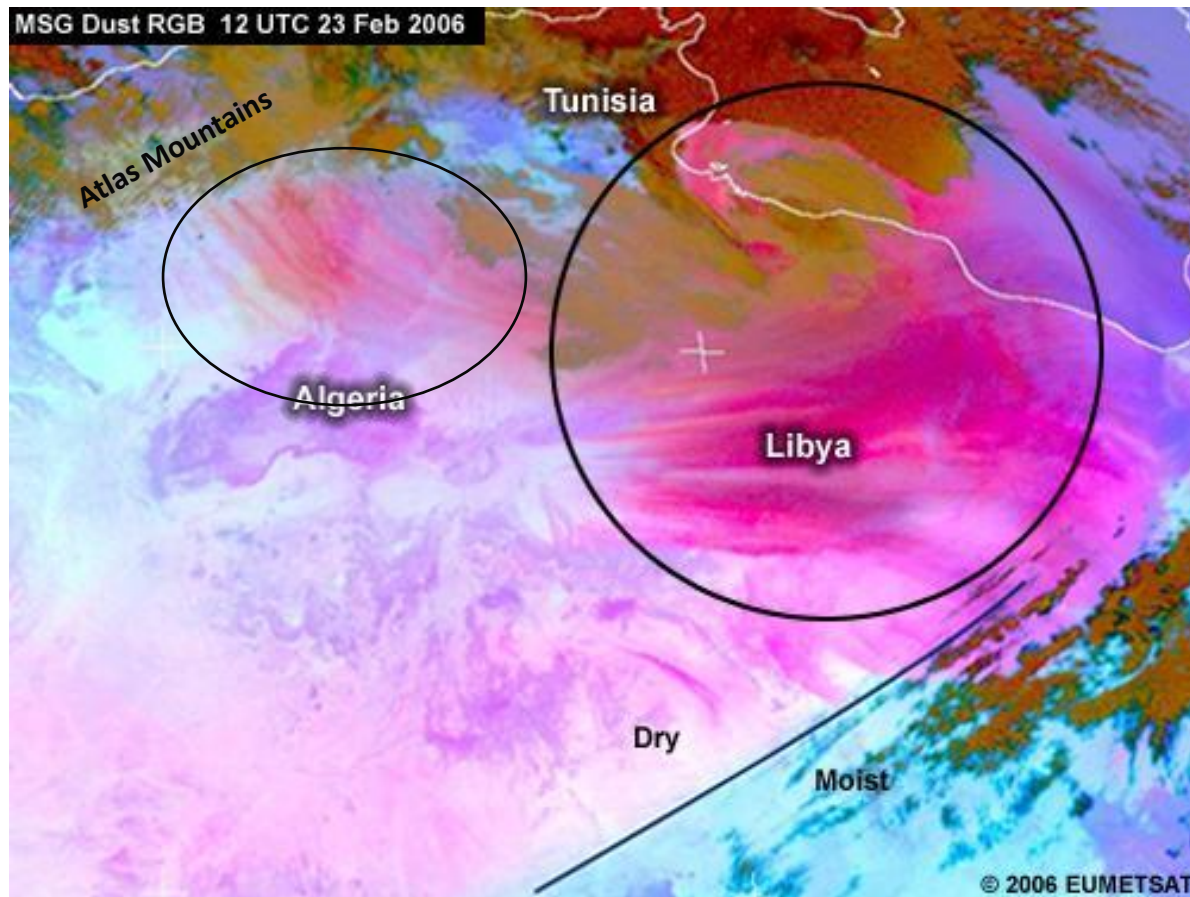
Dust cycle and associated processes

Synoptic dust storms: Large-scale trade winds



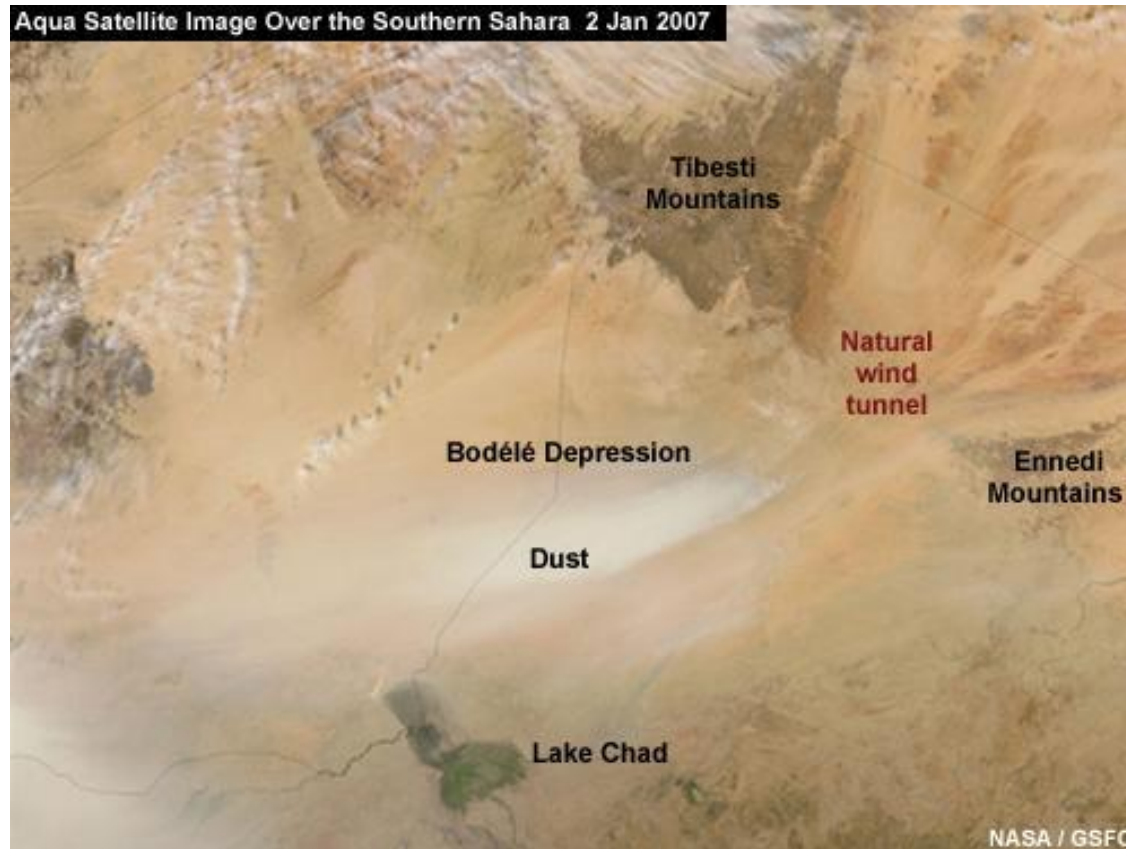
Dust cycle and associated processes

Mesoscale dust storms: Downslope winds



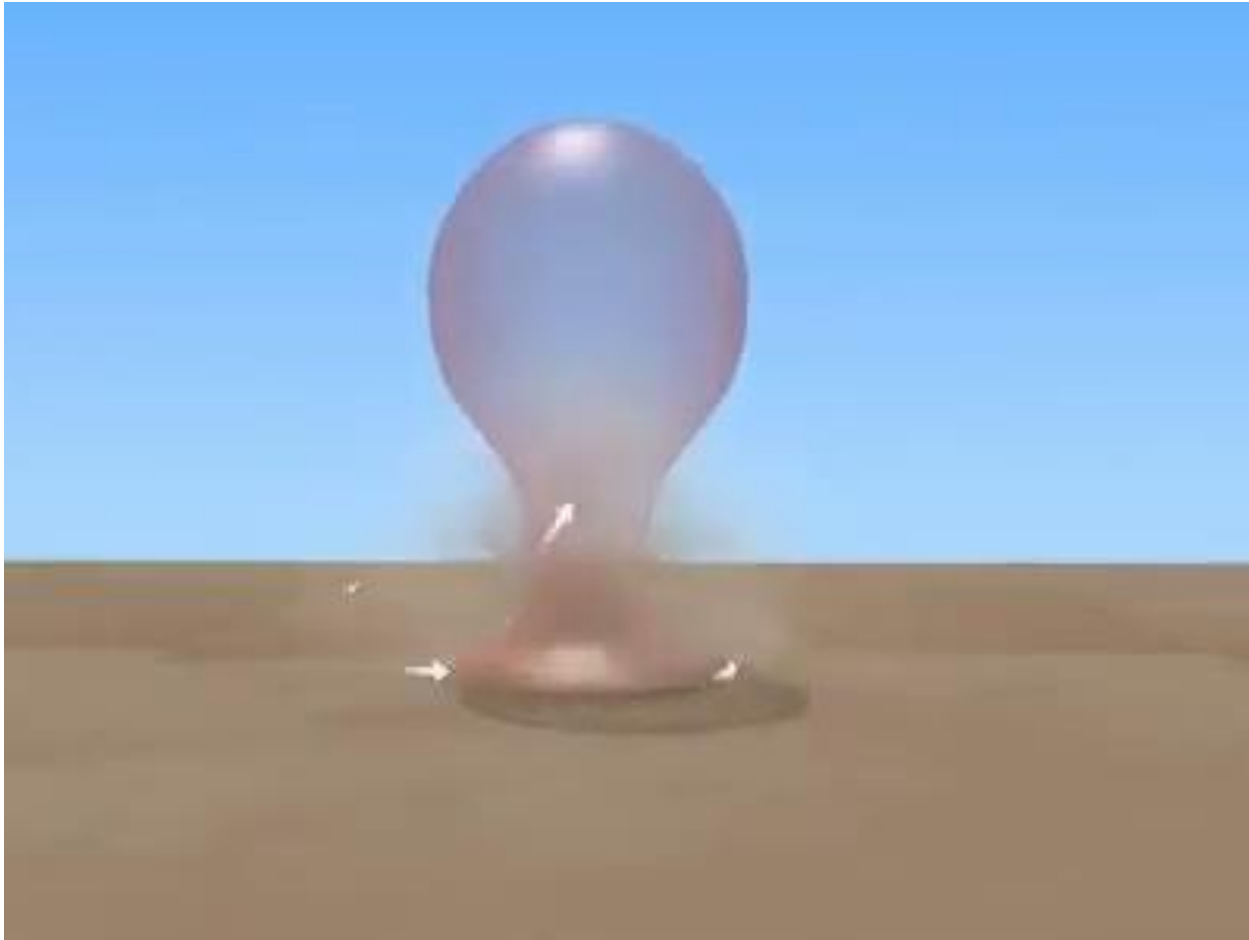
Dust cycle and associated processes

Mesoscale dust storms: Gap flow



Dust cycle and associated processes

Mesoscale dust storms: Dust devils (convection)



Dust cycle and associated processes

Mesoscale dust storms: Haboobs

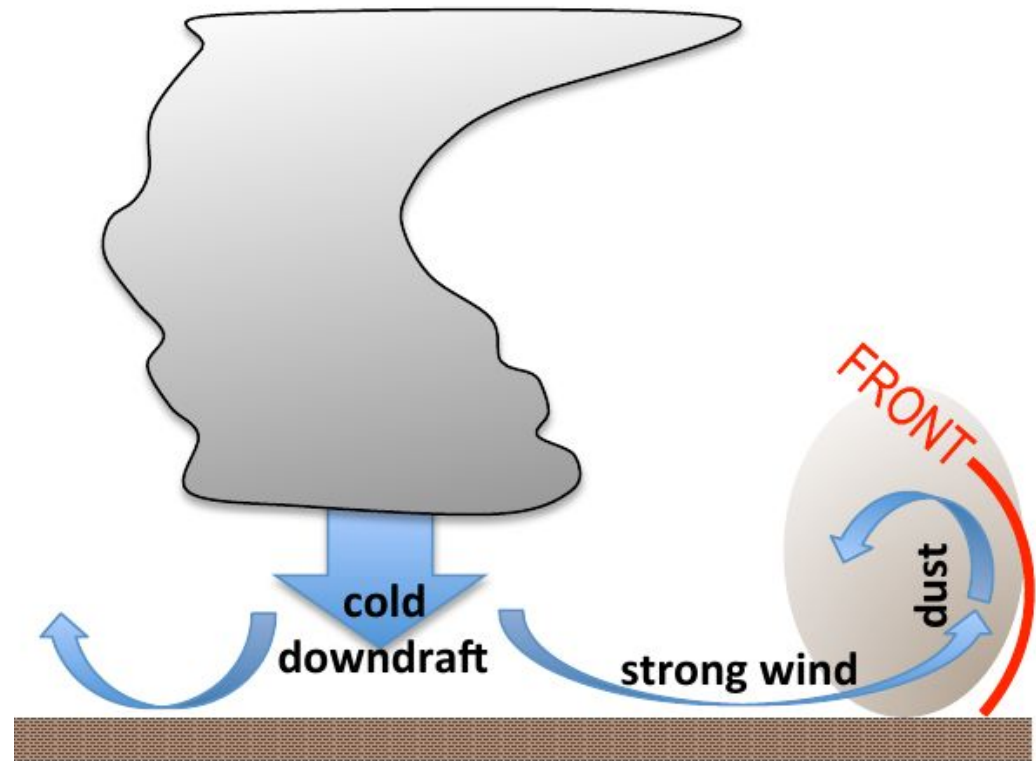


American Roofing, Arizona, US, 25 August 2021

Dust cycle and associated processes

Mesoscale dust storms: Haboobs

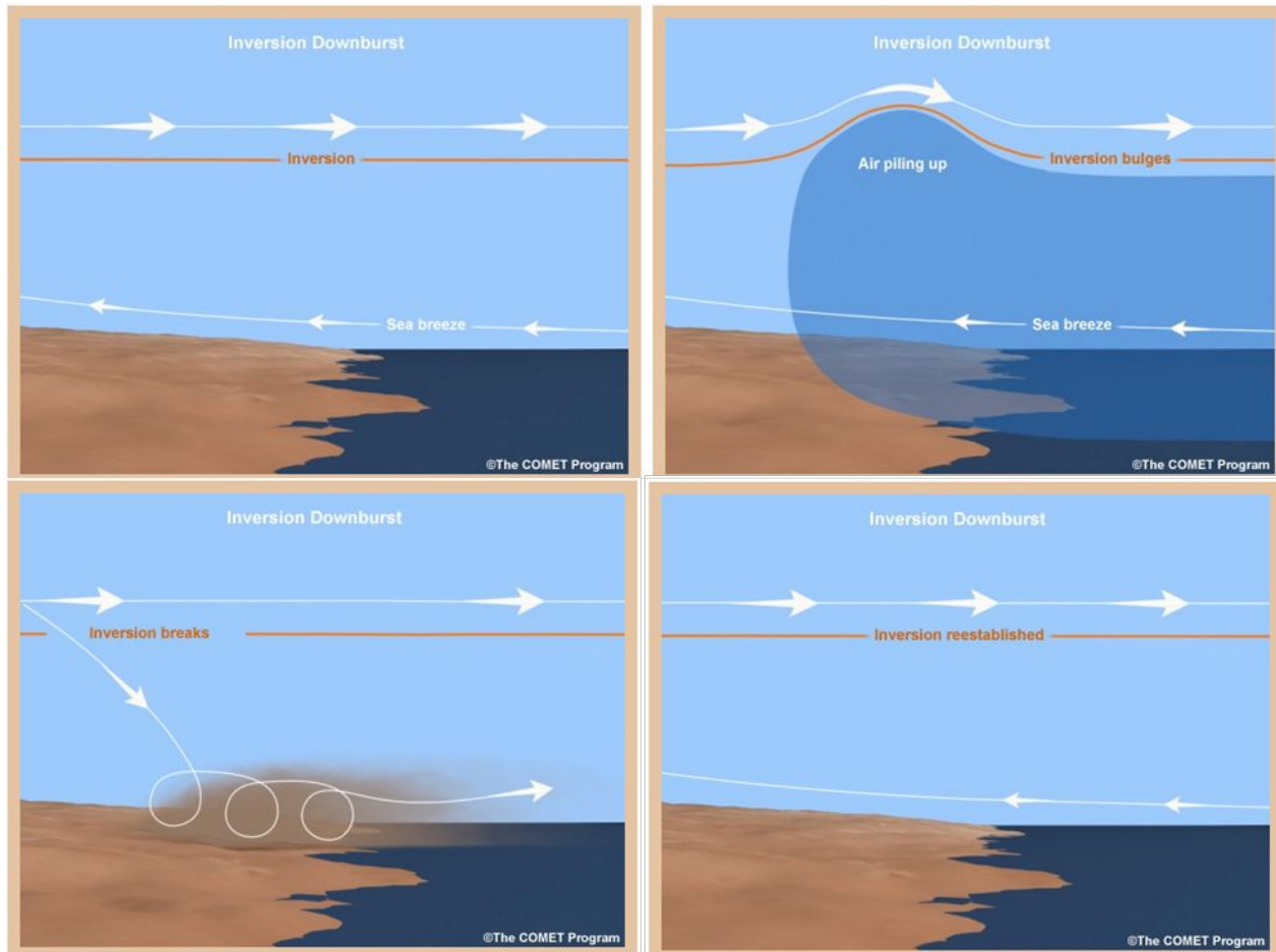
Intensive cold
downbursts from
convective cells
produced high velocity
surface wind, creating
cold front which was
lifting, mixing and
pushing dust



Expected: high wind speed, drop in temperature, rise in humidity, rise in pressure, reduction of visibility.

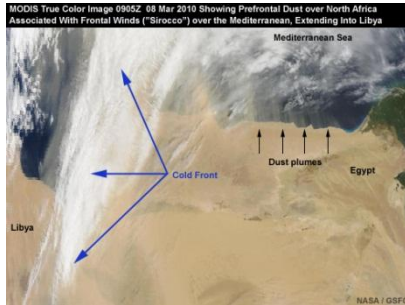
Dust cycle and associated processes

Mesoscale dust storms: Inversion downbursts

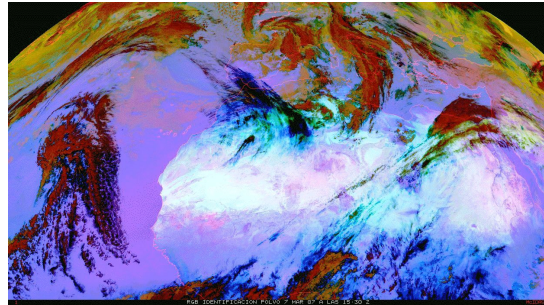


Dust cycle and associated processes

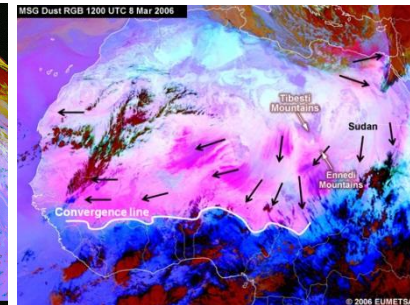
Synoptic dust storms (large scale weather systems)



Pre-frontal winds

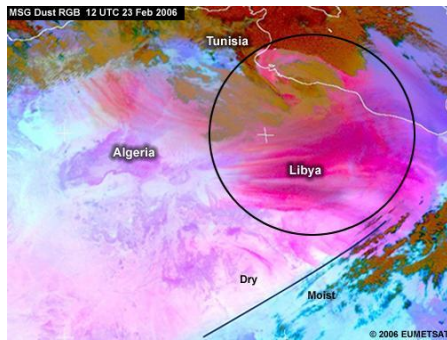


Post-frontal winds

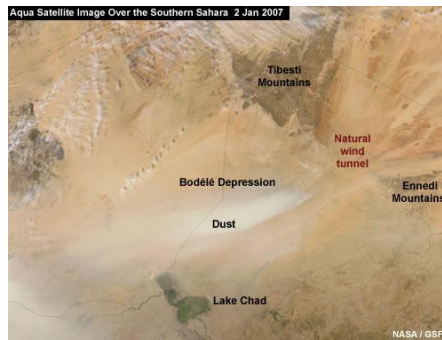


Large-scale trade winds

Mesoscale dust storms



Downslope winds



Gap flow



Dust devils



Haboobs

A piece of SDS history

- Late **80's**:
 - First demonstration that SDS dynamic simulations are possible
- **90's**:
 - First satellite products capable to detect SDS
 - First successful daily SDS forecast test
 - First long-term daily SDS forecasts
- **2000's**:
 - Fast growth in dust observations and forecasting models
- **2010's**:
 - Fast growth in user-oriented applications



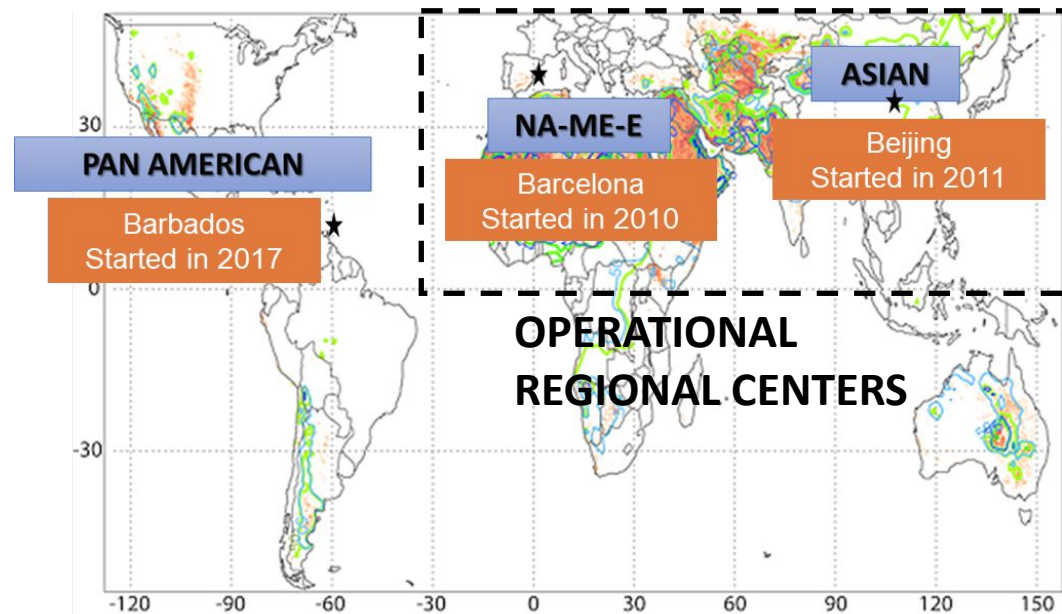
WE ARE **NOW** READY
TO PROVIDE
ADDED-VALUE
DUST **INFORMATION !**

WMO Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS)

Objectives:

- Identify and improve **products to monitor and predict** dust by working with research and operational organizations, as well as with users.
- Facilitate **user access** to information.
- **Strengthen the capacity** of countries to use the observations, analysis and predictions provided by the WMO SDS-WAS.

Regional Nodes and Centers



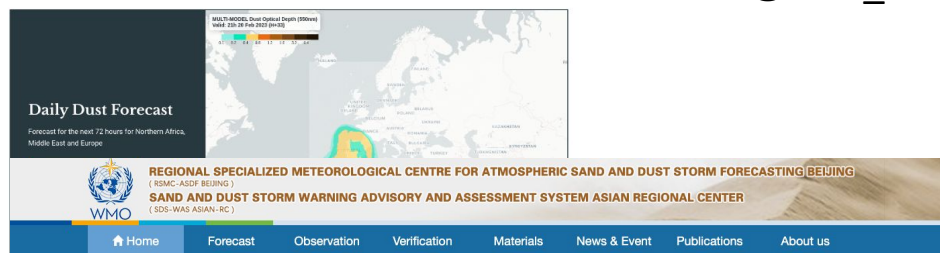
Recently approved a GCC Node and under discussion WASia Node



NAMEE

dust.aemet.es/
@dust_barcelona

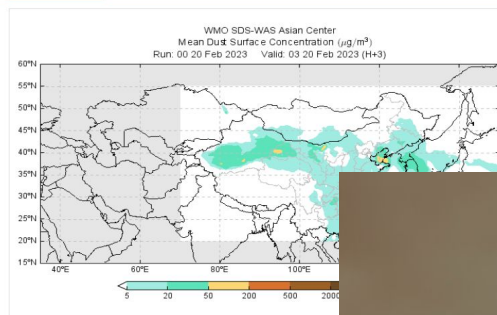
Ernest Werner talk on 2nd March



Asian

www.asdf-bj.net/

Android App

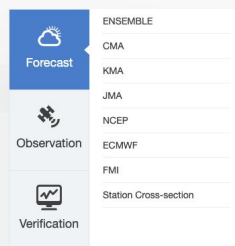


A Strong North Africa Sand & Dust Storm hi...

Mar 15, 2022 22:01 PM

Affected by the cyclone in North Africa, a southeast gale of magnitude 5-6 occurred in northern Algeria at 06:00 on March 14 (UTC), with gusts of magn

Service Products

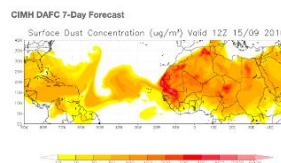


PanAmerican

sds-was.cimh.edu.bb/

Featured Models

The observational system is aimed to a continuous dust monitoring, validation and verification of forecast products and data assimilation into numerical models.





Food and Agriculture
Organization of the
United Nations

UN Coalition on Combating Sand and Dust Storms (SDS)



Convention on
Biological Diversity



Shared Prosperity Dignified Life



Food and Agriculture
Organization of the
United Nations



United Nations
Convention to Combat
Desertification



UN DESA



UN Office for Disaster Risk Reduction



UNEP



United Nations
Climate Change

UN HABITAT
FOR A BETTER URBAN FUTURE



World Health
Organization



WORLD
METEOROLOGICAL
ORGANIZATION



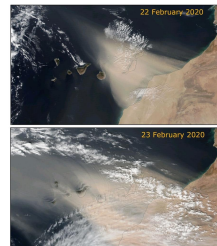
THE WORLD BANK
IBRD • IDA | WORLD BANK GROUP

WMO is leading the working group on forecasting and earliest warning systems

Assessment and awareness

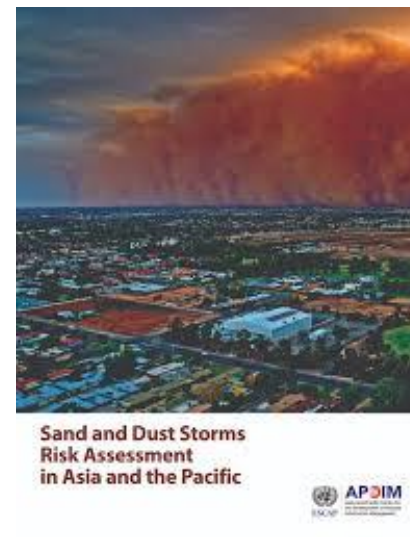


Desert Dust Outbreak in the Canary Islands (February 2020): Assessment and Impacts



Joint publication of State Meteorological Agency (AEMET) and World Meteorological Organization (WMO)

WMO GAW Report No. 259
WWRP 2021-1



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The source of some of the movies and information in this presentation is the COMET® Website at <http://meted.ucar.edu/> of the University Corporation for Atmospheric Research (UCAR), sponsored in part through cooperative agreement(s) with the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce (DOC) © 2007-2011 University Corporation for Atmospheric Research. All Rights Reserved.



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