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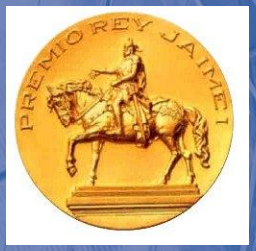
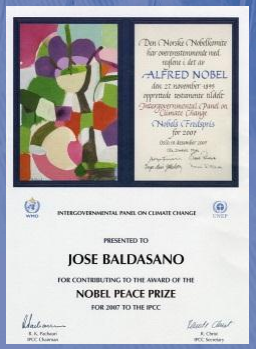
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

THE DUST CYCLE AND IMPACTS



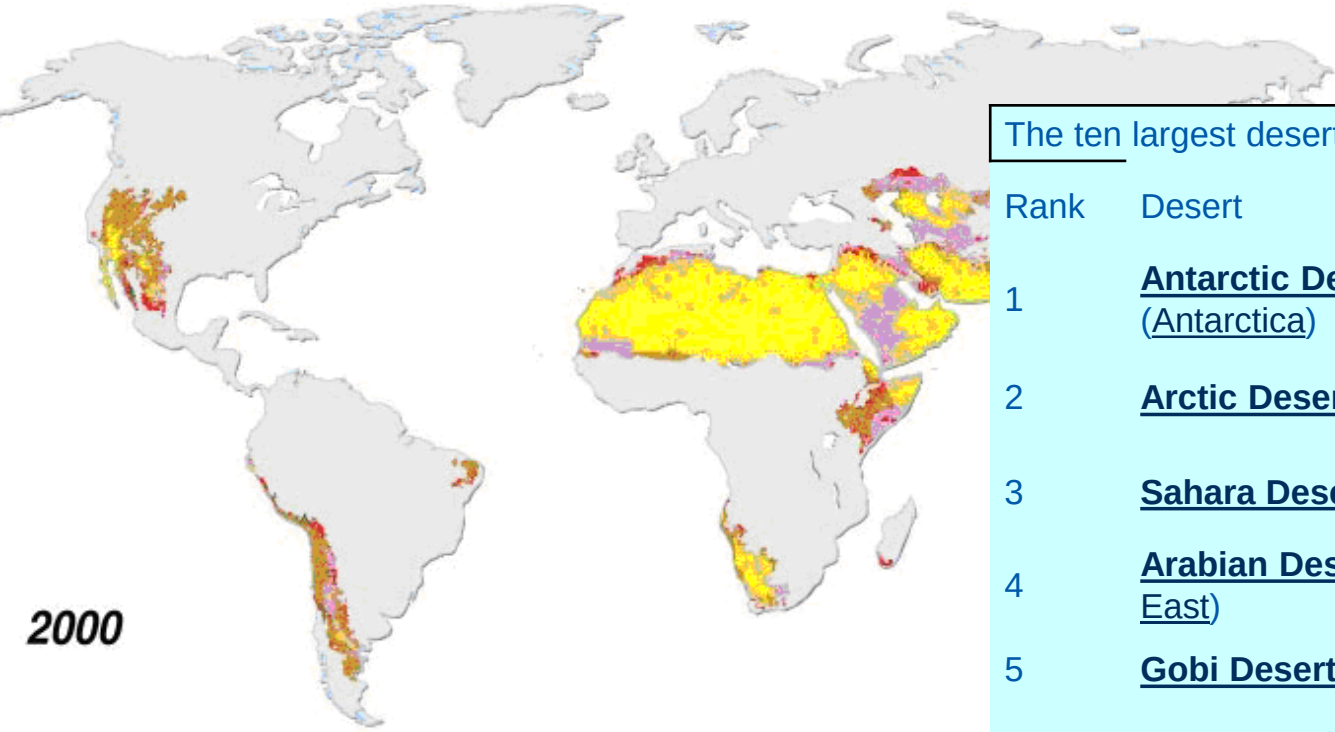


Dr. José Mª Baldasano
jose.baldasano@bsc.es

Barcelona, 5 November 2012

Desert definition?

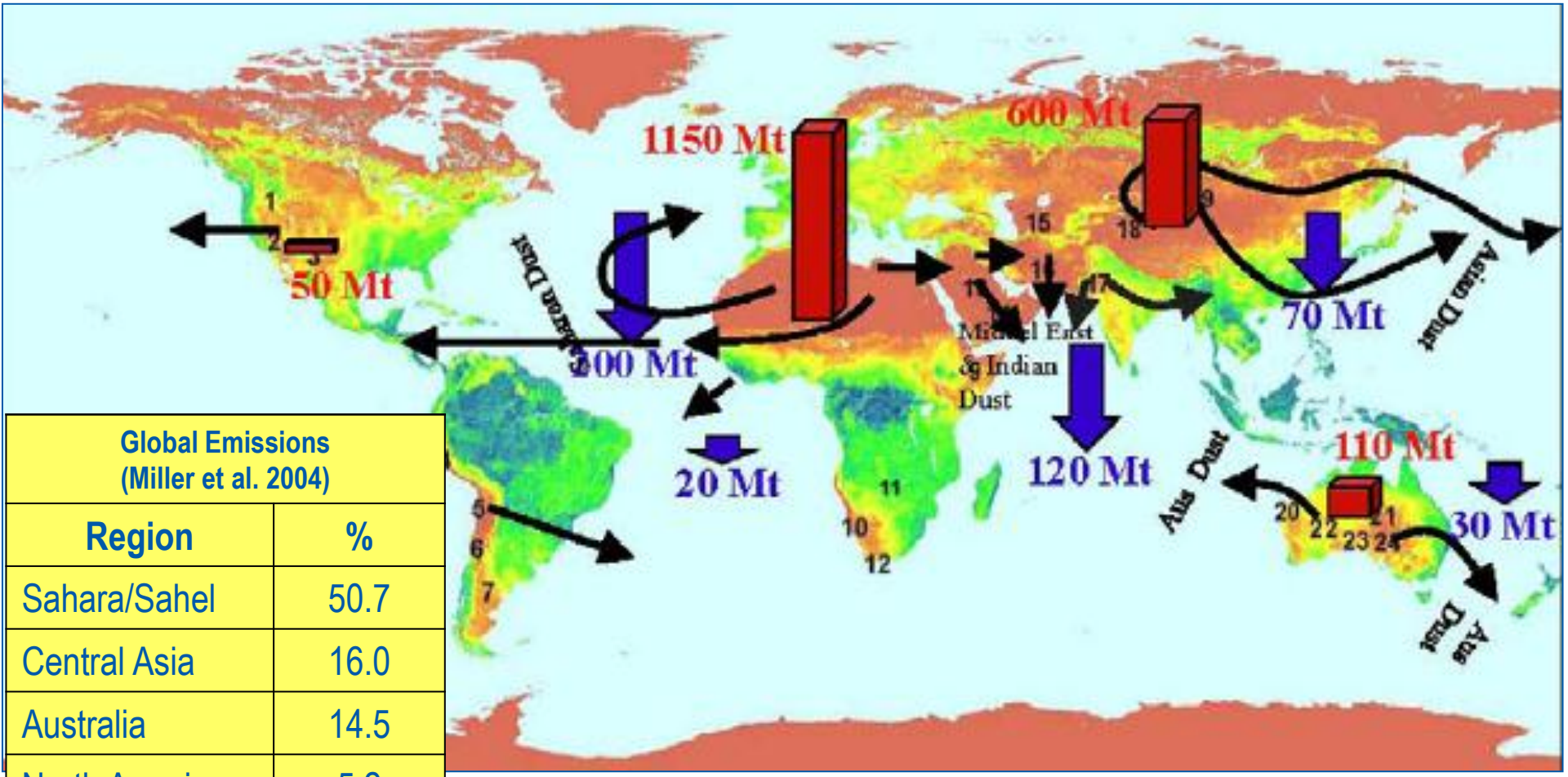
A **desert** is a landscape or region that receives an extremely low amount of precipitation, less than enough to support growth of most plants. Most deserts have an average annual precipitation of less than 400 mm/year. A common definition distinguishes between true deserts, which receive less than 250 mm of average annual precipitation, and semideserts or steppes, which receive between 250 mm and 400 to 500 millimetres.



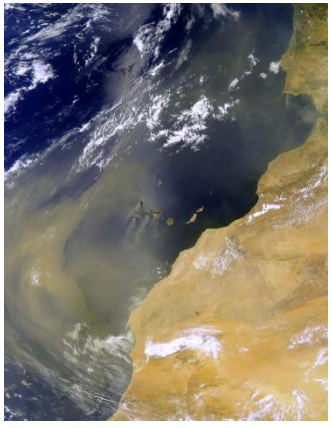
The ten largest deserts'

Rank	Desert	Area (km²)
1	**Antarctic Desert** (Antarctica)	13,829,430
2	**Arctic Desert** (Arctic)	13,726,937
3	**Sahara Desert** (Africa)	9,100,000+
4	**Arabian Desert** (Middle East)	2,330,000
5	**Gobi Desert** (Asia)	1,300,000
6	**Kalahari Desert** (Africa)	900,000
7	**Patagonian Desert** (South America)	670,000
8	**Great Victoria Desert** (Australia)	647,000
9	**Syrian Desert** (Middle East)	520,000
10	**Great Basin Desert** (North America)	492,000

Main routes of dust transport [Shao et al., 2011]

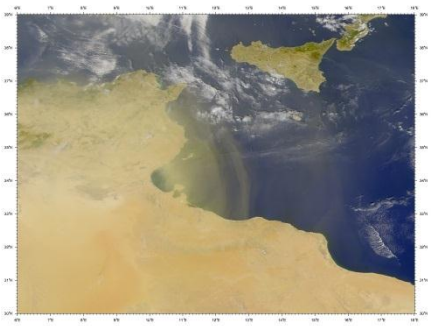


Global Emissions (Miller et al. 2004)	
Region	**%**
Sahara/Sahel	50.7
Central Asia	16.0
Australia	14.5
North America	5.2
East Asia	4.9
Arabia	4.2
Others	4.5



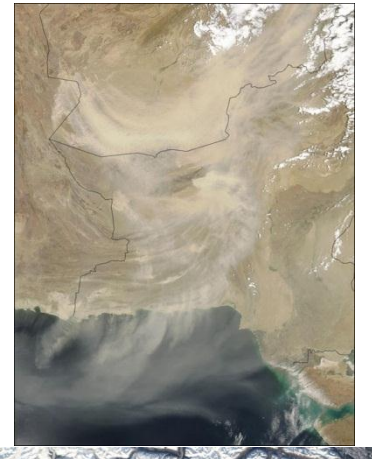
CHINA FOTO PRESS / GETTY IMAGES

La nube se aproxima a una base militar en Golmud



JAD SAAB / AP

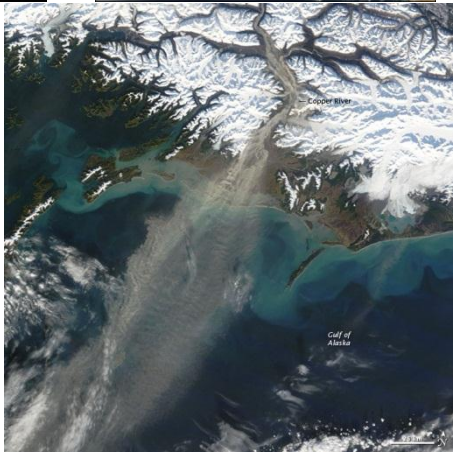
La vida en Riad se interrumpió por la tormenta



La arena envuelve la ciudad de Riad

ROB SCHUMACHER / AP

Arena sobre Phoenix. Esta tormenta de arena se abatió sobre la capital de Arizona la noche del martes; aunque llegó a medir cien kilómetros de ancho y a estar impulsada por vientos de 96 kilómetros por hora, no causó ningún herido



Dust cycle and associated processes

The following components have to take into account in the dust cycle:

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**

Dust emission **is a complex physical process involving entrainment of soil particles by the surface winds.**

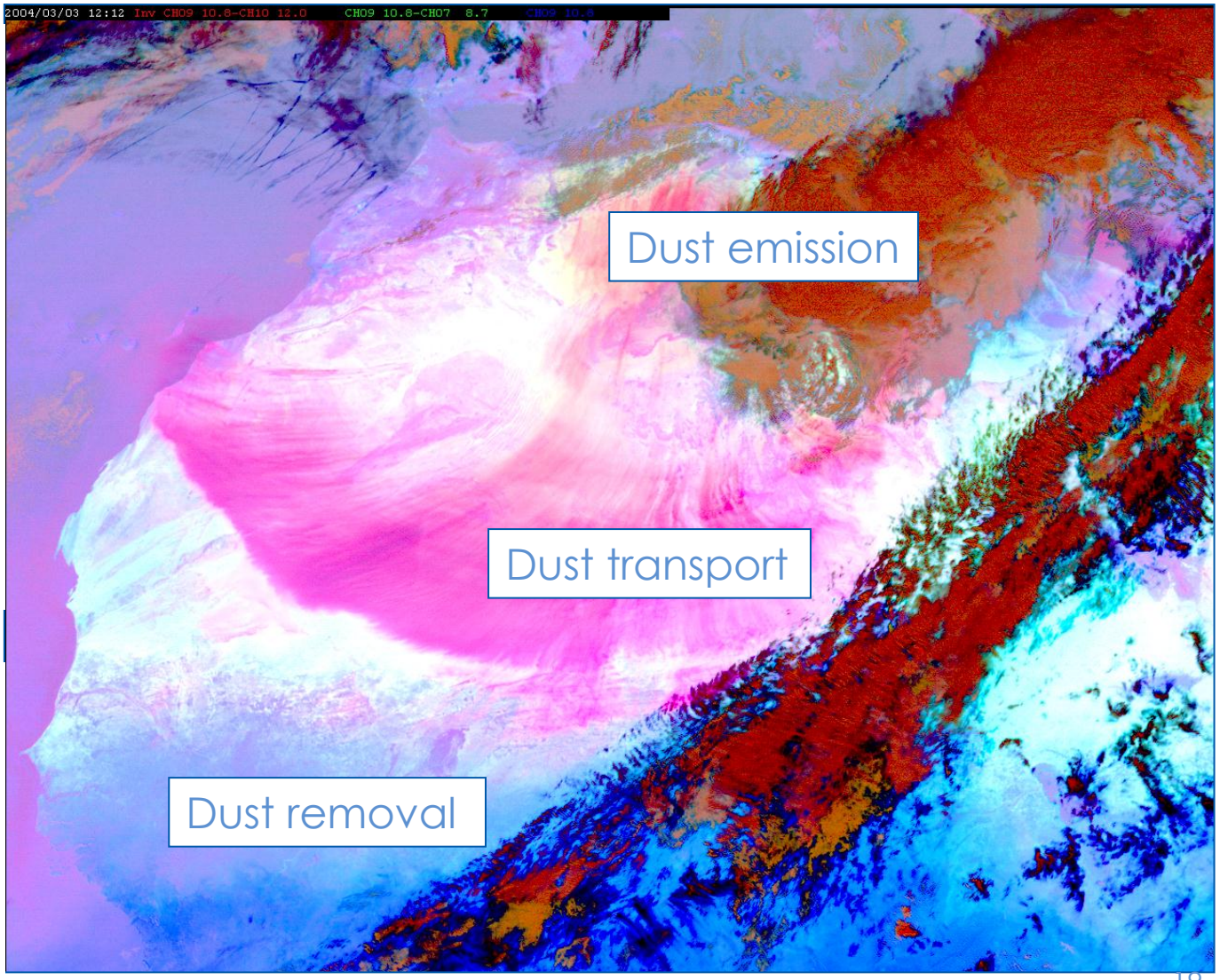
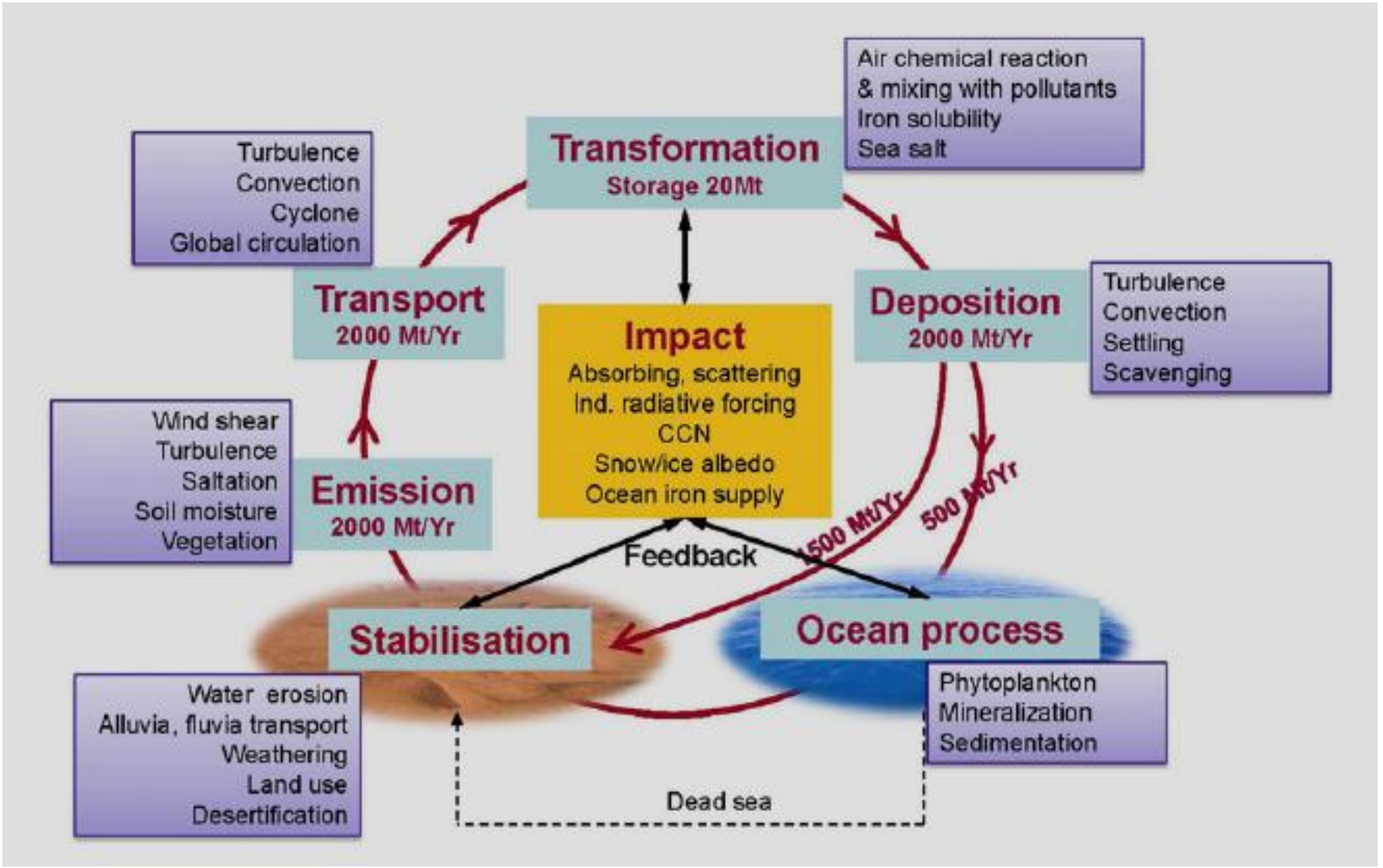
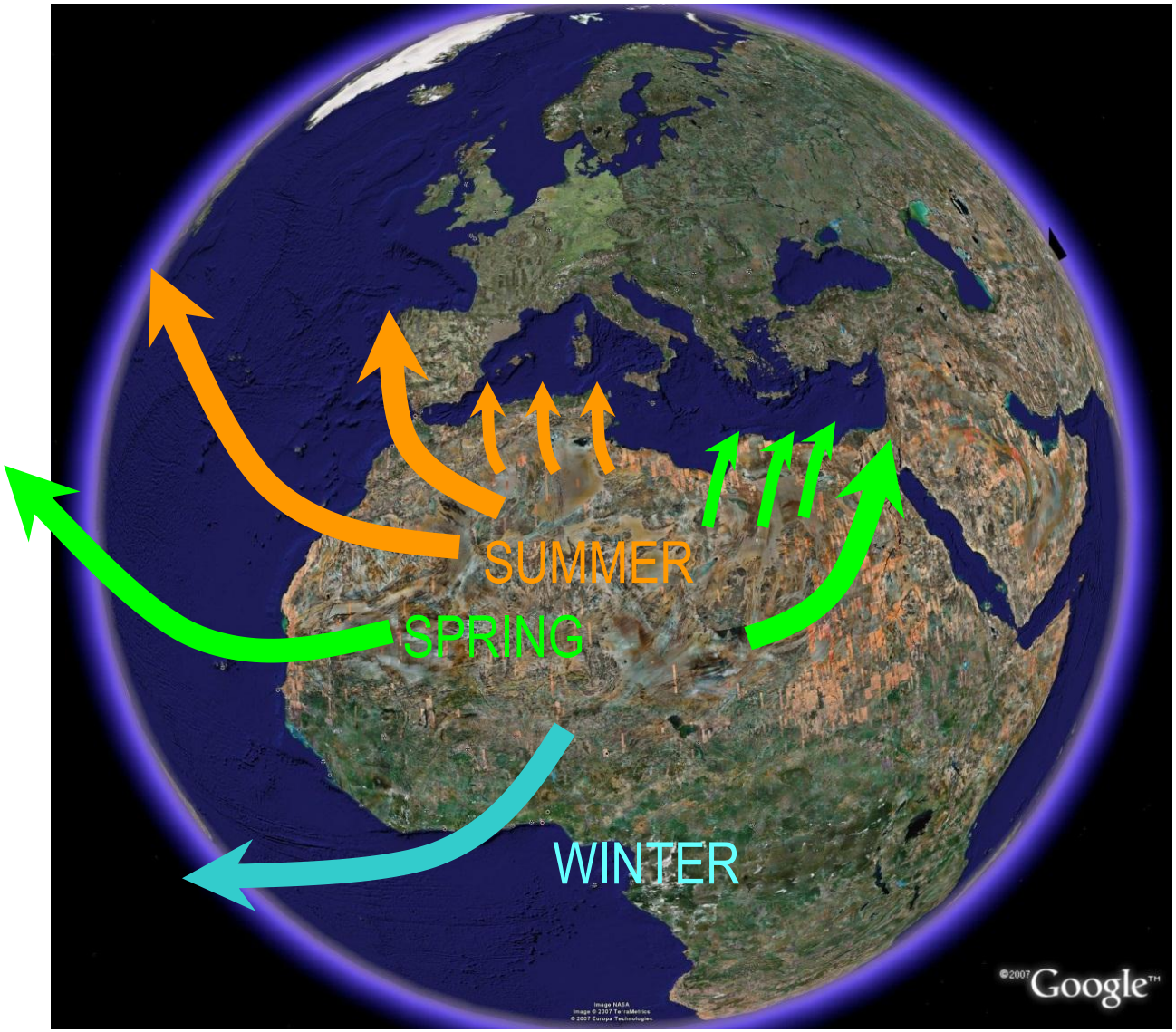


Illustration of the dust cycle in the Earth system and most important dust processes [Shao et al., 2011]

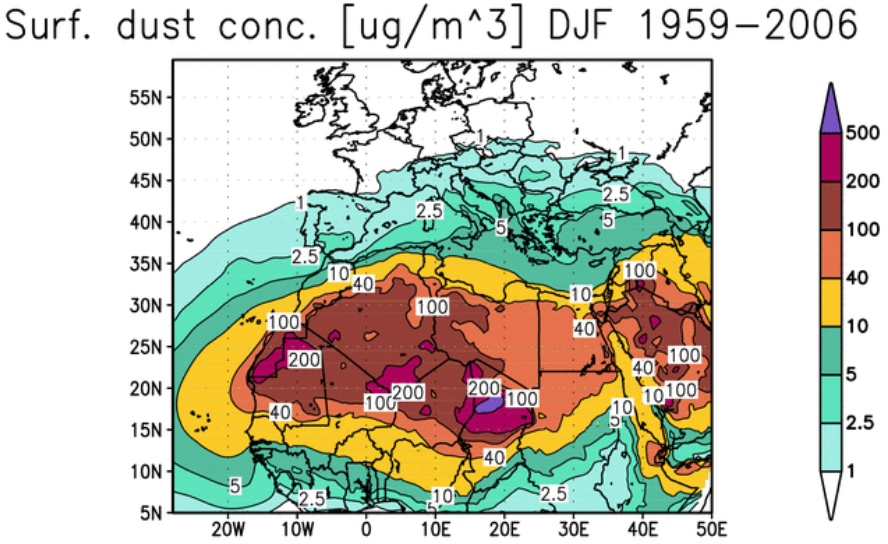


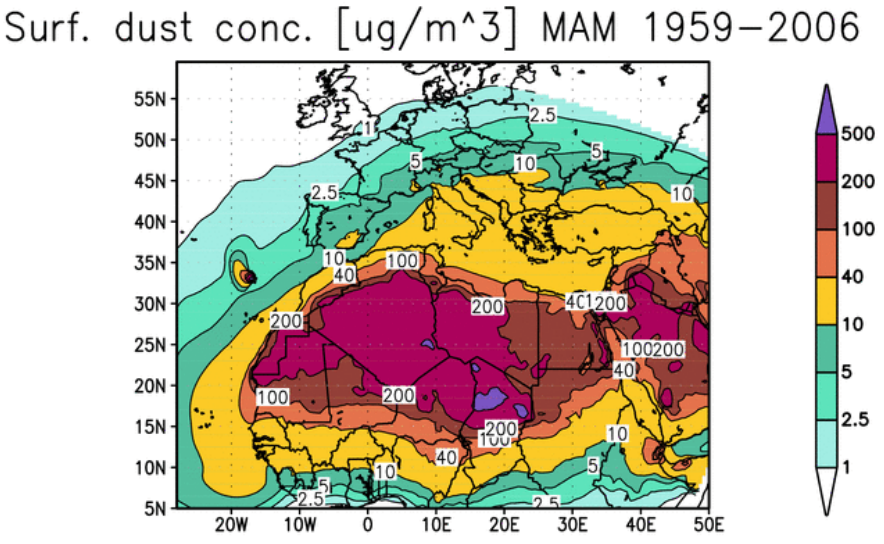
Dust from Sahara desert: major transport patterns

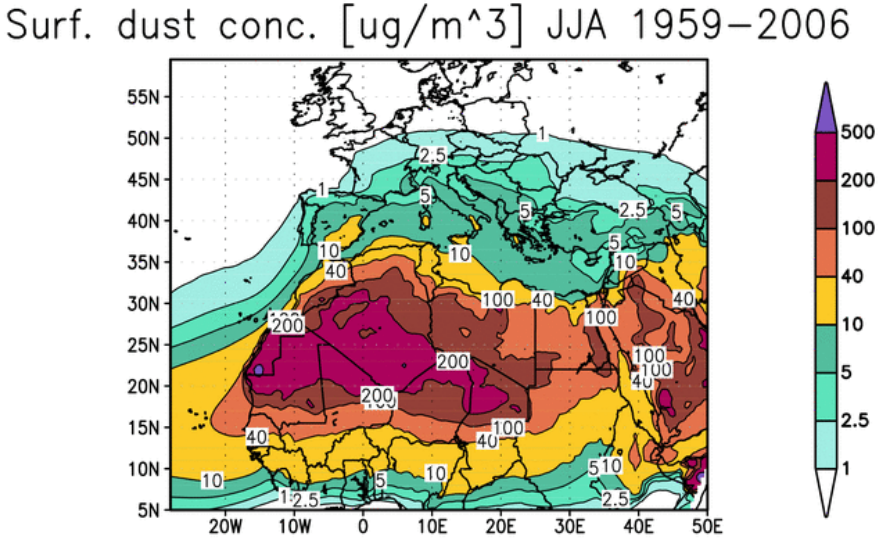


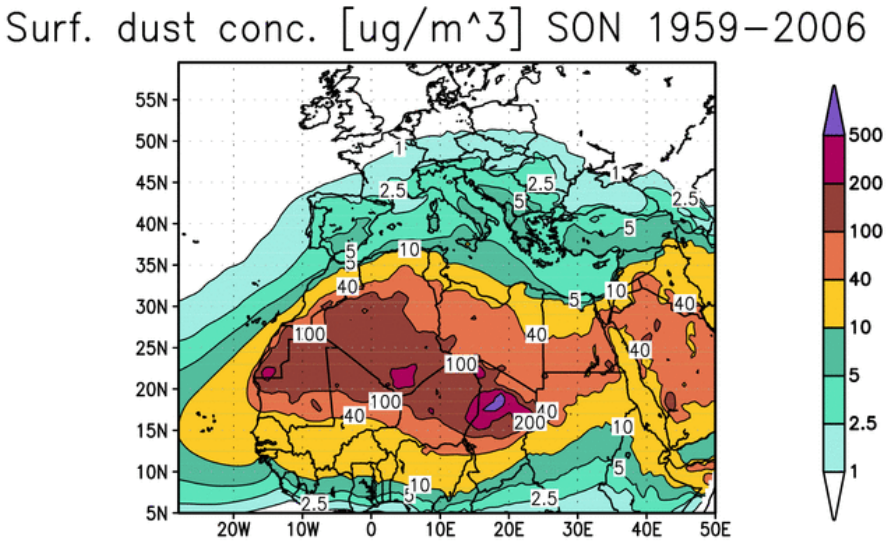
Retrospective analysis of Saharan dust

Seasonal Average 1959-2006: surface dust concentration

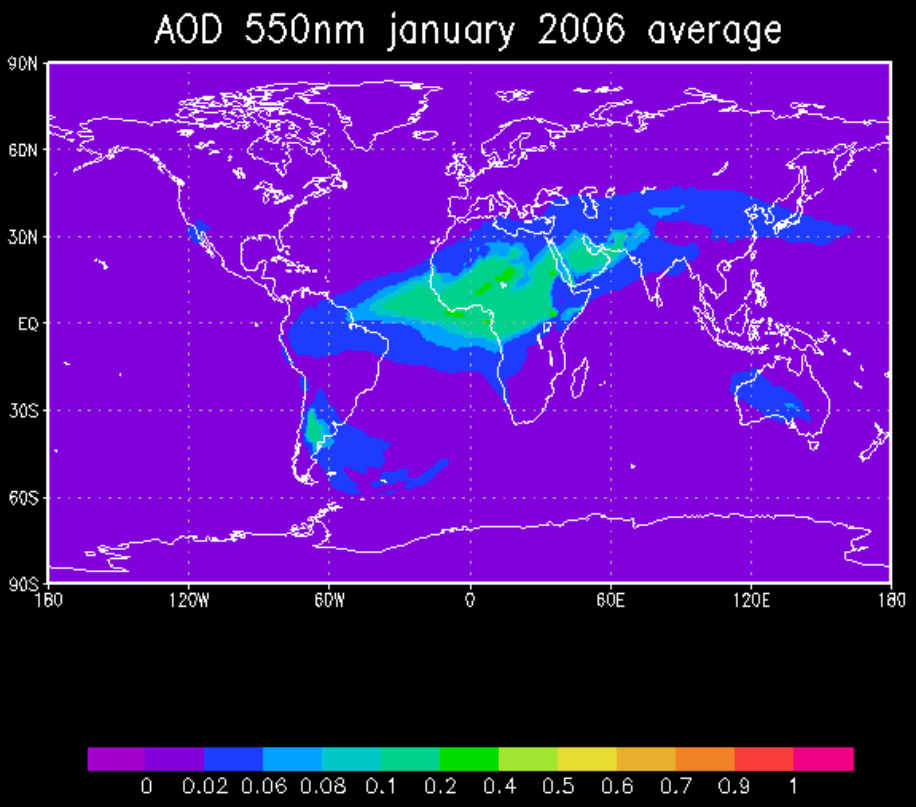


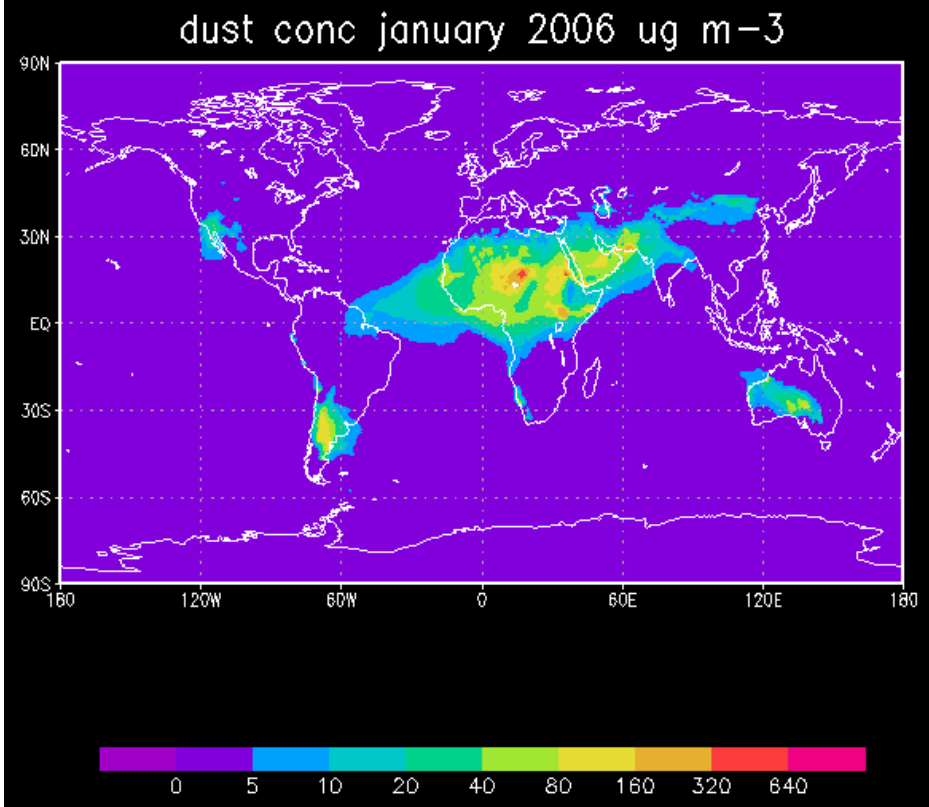




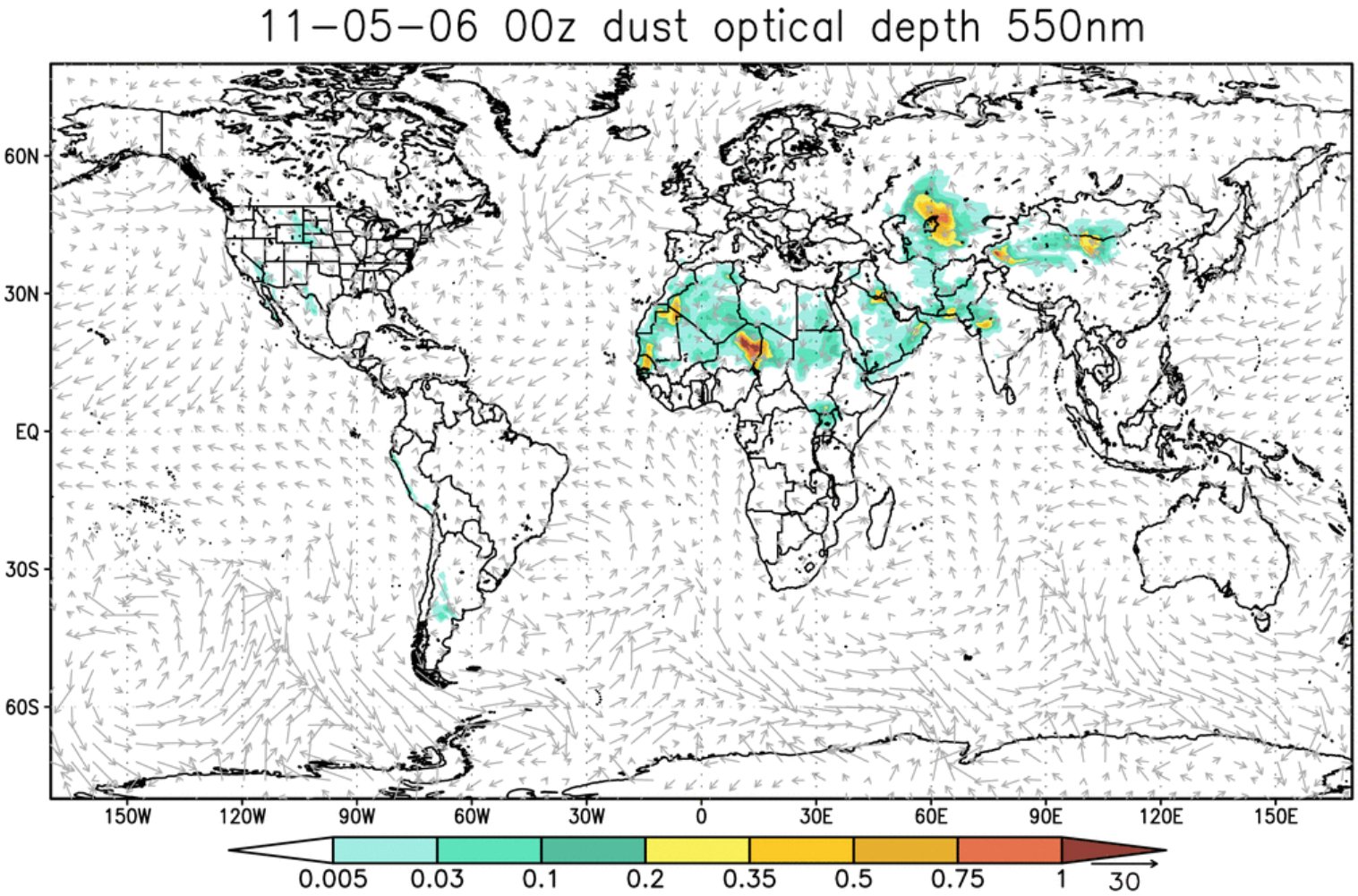


2006 Annual simulation





Global dust simulations with NMMB/BSC-Dust



11-25 May 2006: Samum Campaign period

0.3333 deg meridionally (37 km)
64 vertical levels resolution, equivalent to operational GFS resolution

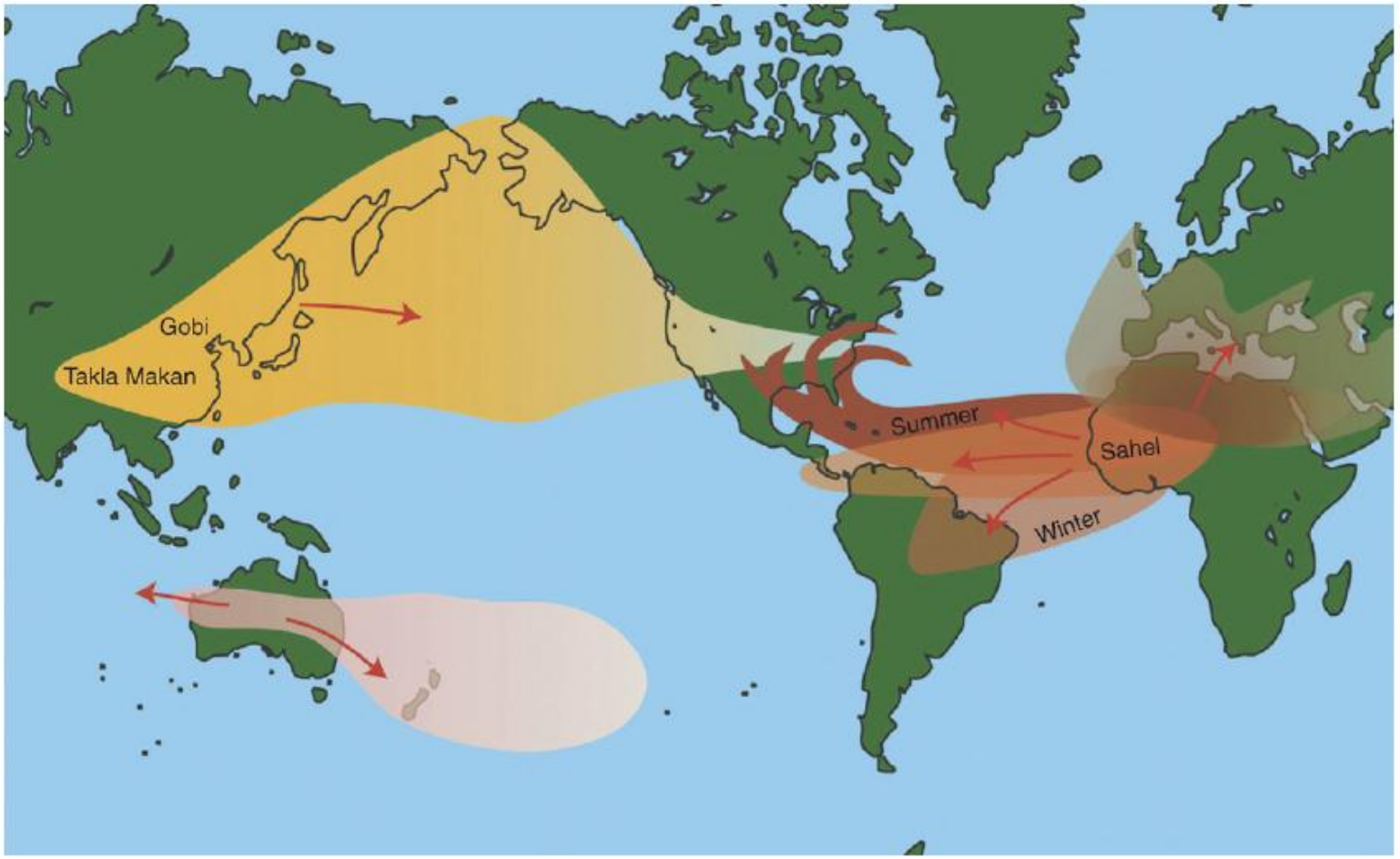
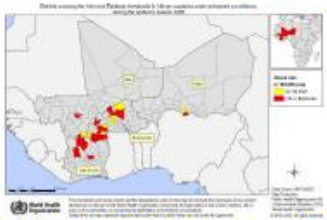


Figure 1.5: Principal pathways of the two major global dust transport systems. The African dust exerts a strong seasonal component with summer trade winds carrying the dust towards North America and the Caribbean and winter dust flow shifted to South America and the Amazon rainforest. Throughout the year, dust storms from northern Africa cross into the Mediterranean and Europe. Asian dust from the Gobi is transported to the Pacific mainly during dust events in spring. Extracted from Kellogg and Griffin [2006].

Mineral Dust Impacts

HUMAN HEALTH

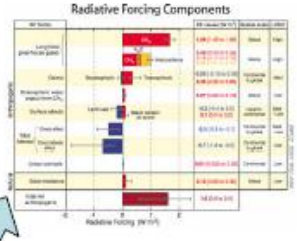
Bronchial tubes
Eye infections
Asthma
Heart stress



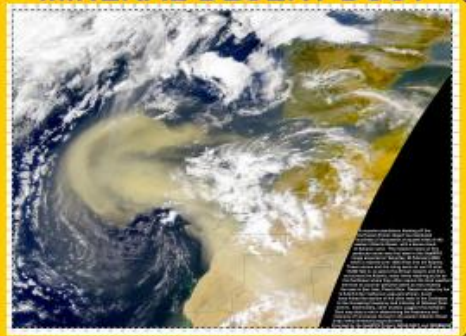
Related to epidemincs of lethal **Meningitis** in the Sahel Belt

CLIMATE AND METEOROLOGY

Dust causes large uncertainties in assessing climate forcing by atmospheric aerosols

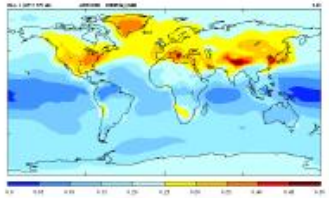


MINERAL DESERT DUST



IMPACTS

OZONE CHIMPISTRY



OCEANIC AND TERRESTRIAL BIOCHEMICAL CYCLES

Iron deposition into the oceans, increasing nitrification processes

VISIBILITY

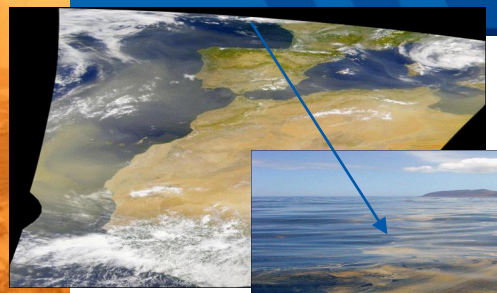
Severe reduction of visibility on road and airports affecting operations

LIFE AND PROPERTY

Infection of coral reefs

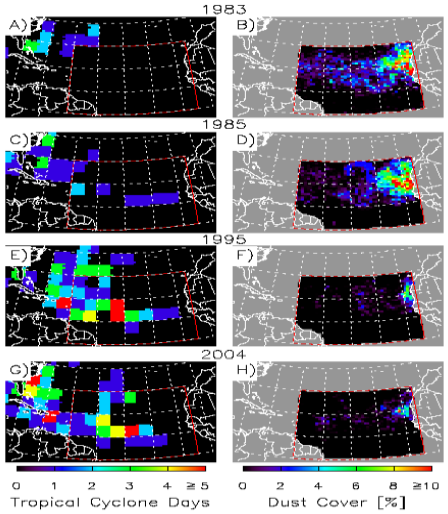
Mineral Dust Impacts

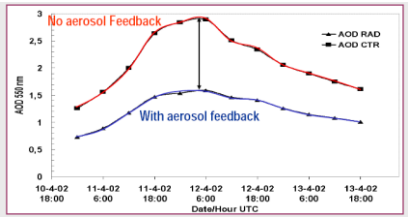
Salud humana (Asma, infeccciones respiratorias, meningitis en Africa, Fiebre del Valle en America)

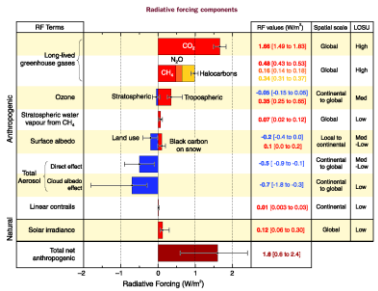


Agricultura (impactos positivos y negativos)

Productividad marina (impactos negativos y positivos)







Predicción meteorológica a corto y medio plazo, estacional y climática

Industria (Semiconductores, etc.)

Energía (plantas termosolares)

Aviación (accidentes y opereatividad de aeropuertos)

Transporte terrestres

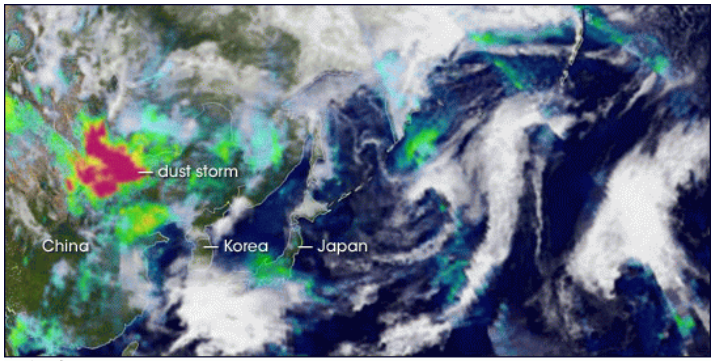
Respiratory Health: Africa


Cuatro refugiadas caminan en medio de una tormenta de arena el jueves cerca de Goz Beida. / REUTERS

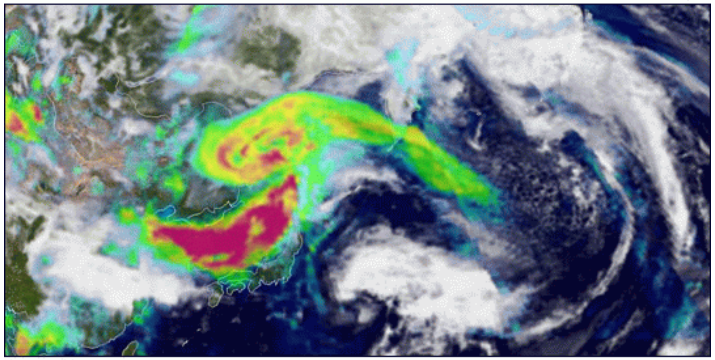
- Acute respiratory infections among children are one of the major causes of mortality in developing countries, especially in Africa (Black et al., 2003; Romieuet al., 2002; Smith et al., 1999).

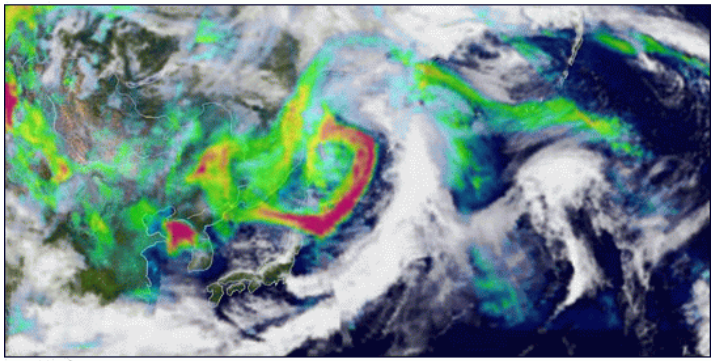
- No studies on the impact of mineral dust concentrations on human health have been carried out in West Africa due to the lack of air quality data.

Respiratory Health: Asia



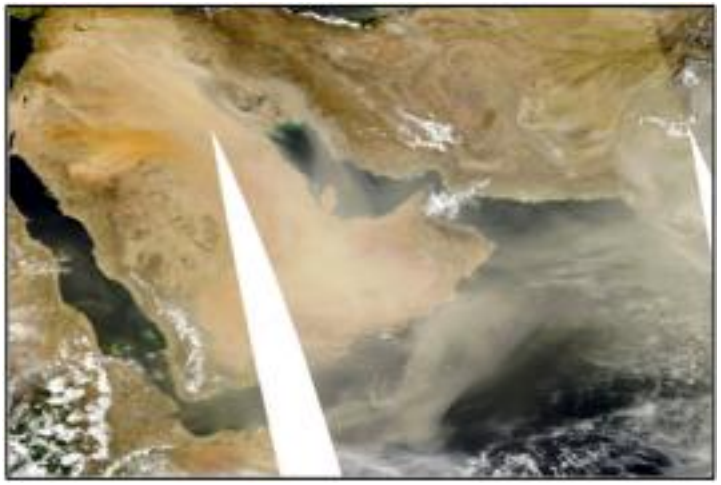
March 9


March 11


March 13

Aerosol Index
0
4

Respiratory health and transportation



Kuwait Times - 22 June, 2008

Sand storms in the northern Gulf have *disrupted oil exports* for several days from OPEC members Iraq and Kuwait.

The storms had prevented seven of eight ships from docking there since Saturday.

www.arabianbusiness.com – 20 June 2008

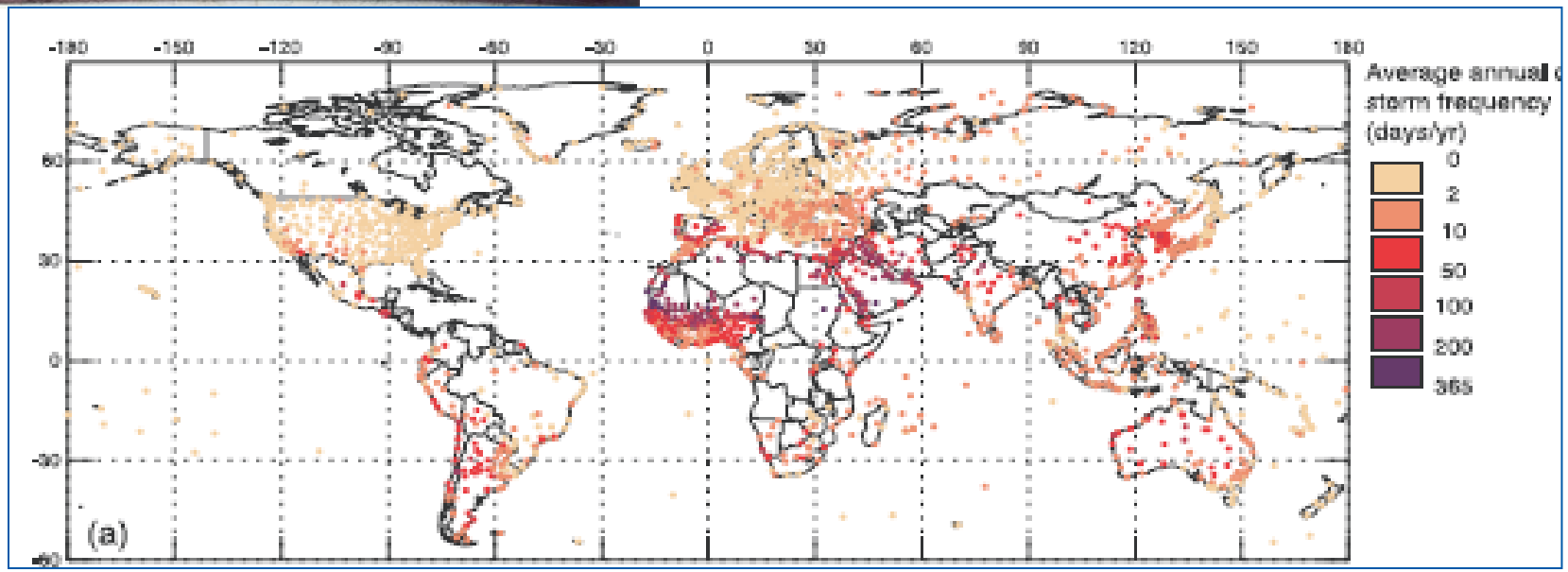
More than 500 **traffic accidents** were reported in Kuwait in the space of just 48 hours on Thursday and Friday, while in Bahrain a further 20 accidents were reported, according to local media.

Hospitals in all three Gulf states reported large numbers of patients being admitted with **respiratory problems.** In Bahrain, more than 150 people required hospital treatment, Bahrain's Gulf Daily News reported.

The adverse weather conditions also caused some **problems at airports** around the region, with both Bahrain and Kuwait reporting minor disruption.

Sand and Dust Storm at 18.04.2012 over Middle Anatolia

CLOSE-UP VIEW: FREQUENCY



Average annual SDS frequency (days/year); Engelstaedtler et al, GRL, 2003

EXAMPLE: FATAL AVIATION ACCIDENT CAUSED BY SDS

http://edition.cnn.com/2002/WORLD/africa/05/07/tunis.crash/index.html

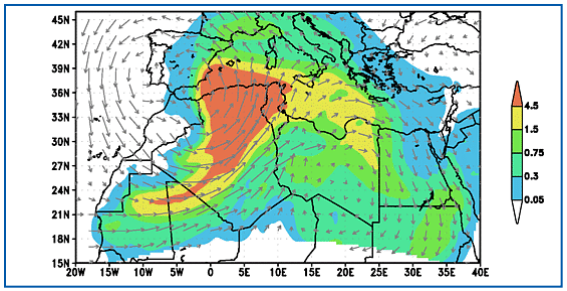
TUNIS, Tunisia (CNN) 7 May, 2002, 17:44 GMT -- An EgyptAir jet crashed on a hillside outside Tunisia's capital Tuesday as the pilot attempted to make an emergency landing, killing at least 18 people, a government official said…

…The control tower lost contact with the plane a few seconds before the incident, just after the pilot sent out a distress call. As soon as contact was lost, emergency vehicles rushed to the area…

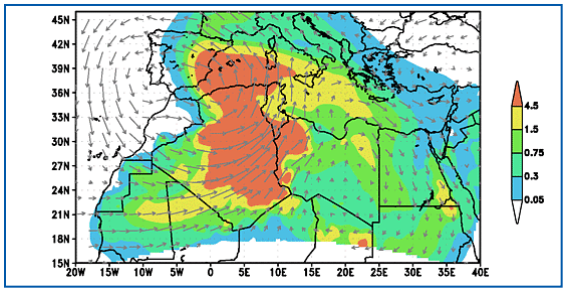
…Weather was foggy and rainy at the time, with **sandstorms** blowing in from the Sahara Desert. ...

EGYPTAIR ACCIDENT AGAIN: PREDICTION OF THE SDS

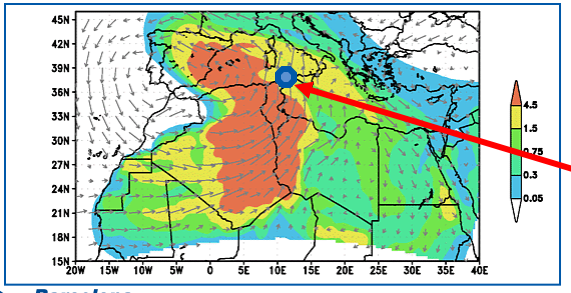
Predicted dust load (μg m^{-2})



06 UTC, 7 May 2002 18-hr forecast



12 UTC, 7 May 2002 24-hr forecast

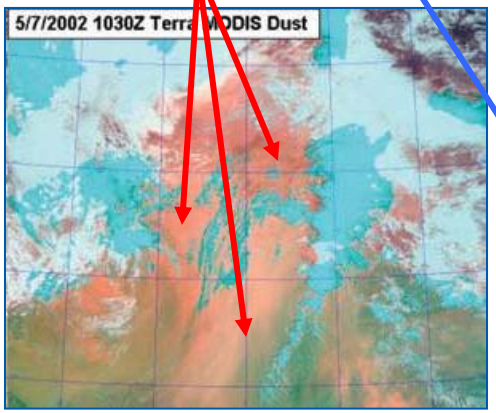


18 UTC, 7 May 2002 30-hr forecast

Features of the case:

- Major Mediterranean dust storm
- Fast moving system
- More than 5 mg m^{-3} in the elevated dust cloud core!

dust

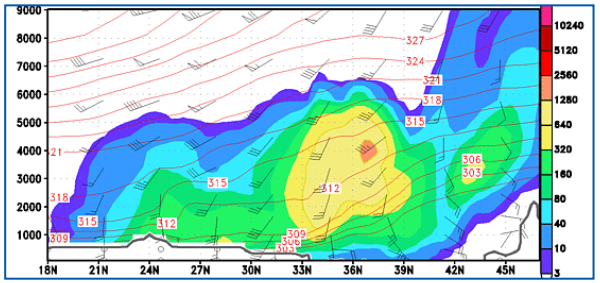


Tunisian dust storm captured by MODIS
Source: Steven D. Miller, NRL, Monterey

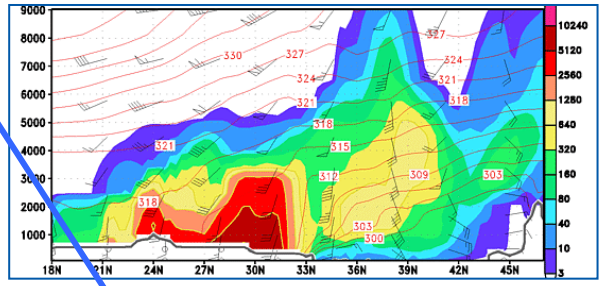
Predictions by DREAM model

Site of the accident

Predicted cross-section dust concentration (μg m^{-3})



06 UTC, 7 May 2002 18-hr forecast



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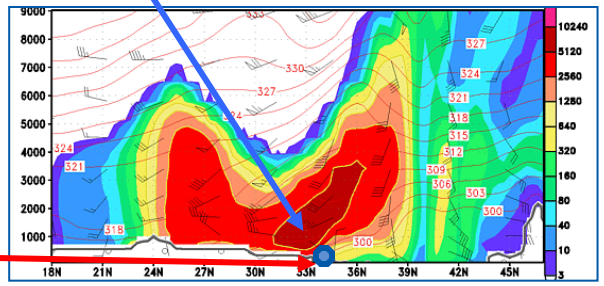


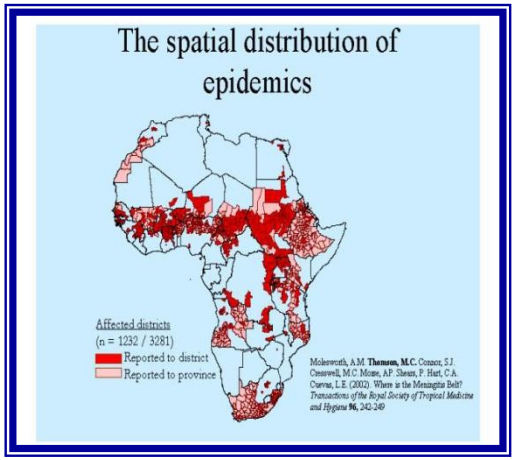
18 UTC, 7 May 2002 30-hr forecast

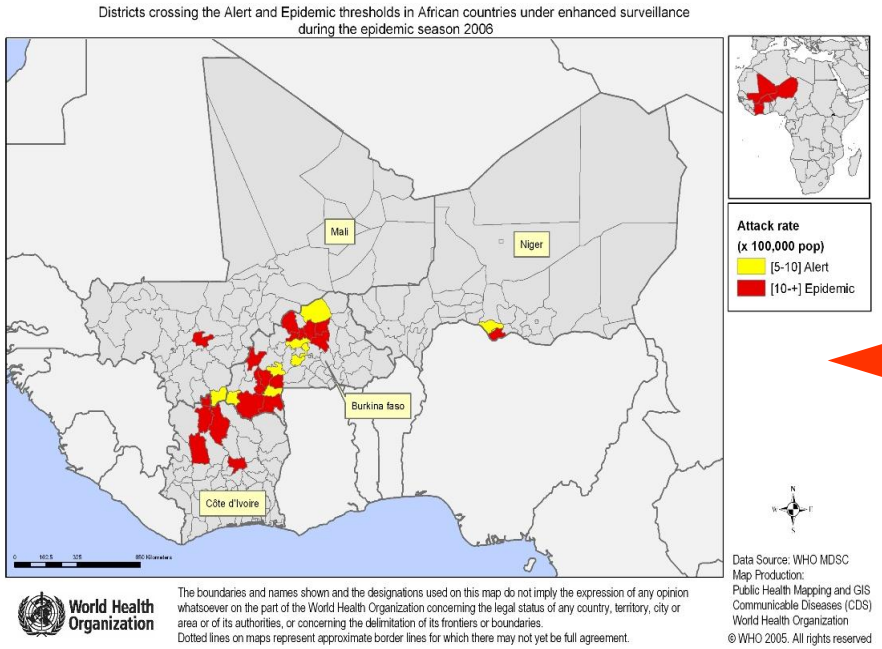
Barcelona

Dust and meningitis epidemics

- Epidemics start during the dry season

- Certain environmental factors, such as low absolute humidity, land cover types and dusty atmospheric conditions, may play an important role (Lapeyssonnie, 1963; Cheesbrough et al., 1995; Greenwood, 1999; Molesworth et al., 2003; Thomson et al., 2006).





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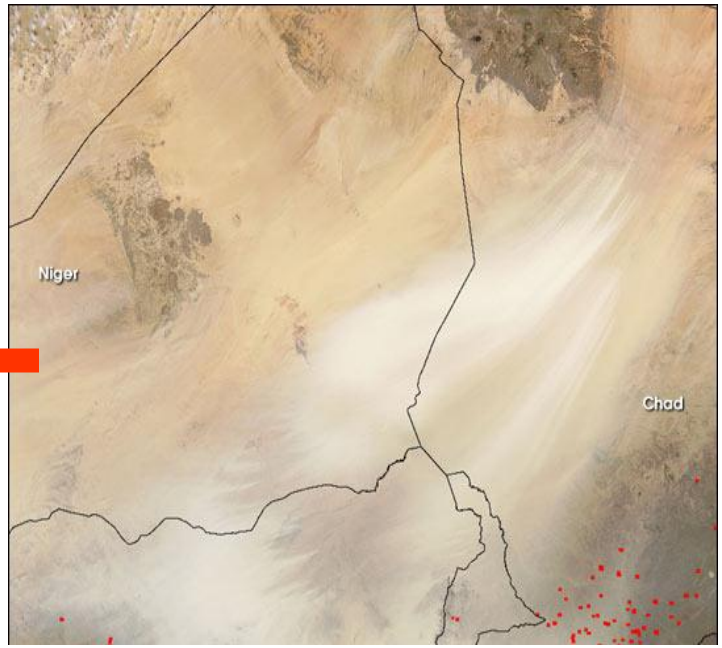


Districts crossing the Alert and Epidemic thresholds in African countries under enhanced surveillance 2006

Dust from MODIS

How can we contribute to improving the knowledge on environmental risk indicators of meningitis epidemics?

Health-related GEMS-MACC project proposal work package:

Sand and Dust forecasting to prevent meningitis epidemics

Objectives:

- Gain scientific knowledge about the relationship between atmospheric mineral dust, general atmospheric conditions and meningitis in the Sahel region
- Improve environmental prediction models for meningitis prevention

Activities:

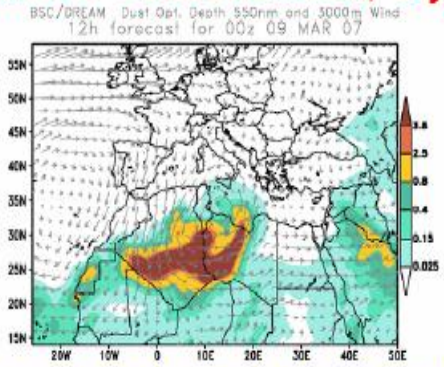
1- Refined short-term dust forecasts and dust surveillance in the Sahel region
2- Retrospective analysis of dust with model and available satellites and its relationship with meningitis in the Sahel
3- Explore links between dust, meningitis and large scale climate indexes

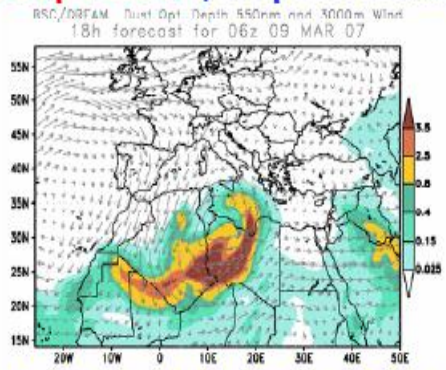
Refined short-term dust forecasts and dust surveillance in the Sahel region

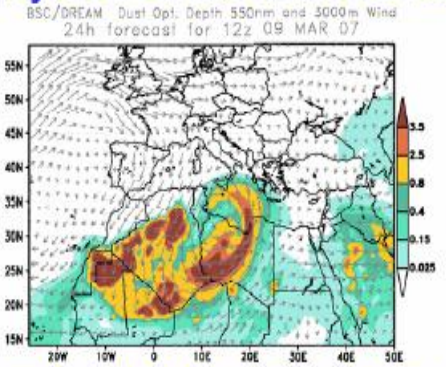
Operations

DUST STORM: 9 MARCH 2007 OVER NORTH AFRICA

Operational 72-h dust forecasts for Europe and North Africa (aerosol optical depth, total dust loading, surface concentration, dry and wet deposition) http://www.bsc.es/projects/earthscience/DREAM/



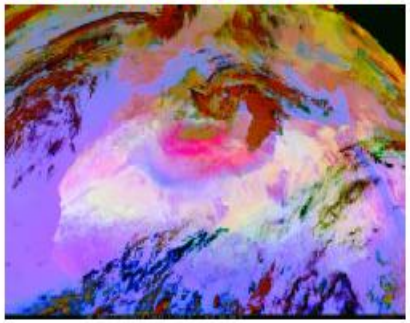


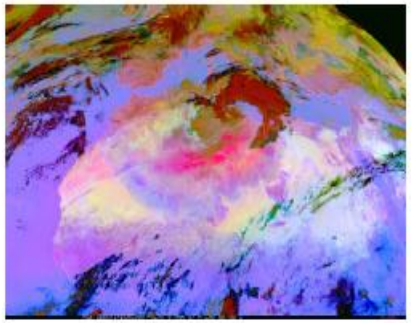


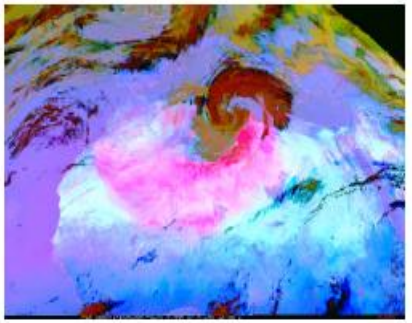
Forecasted

Operational surveillance and model verification with Meteosat Second Generation (MSG) near-real time

Dust product – pink colour







Observed

Probability of BTV introduction by wind ?

PATHWAY DIAGRAM

Culicoides in country c

P_1

Culicoides becomes infected with BTV

P_2

Culicoides is introduced into Europe by wind

P_3

Culicoides survives

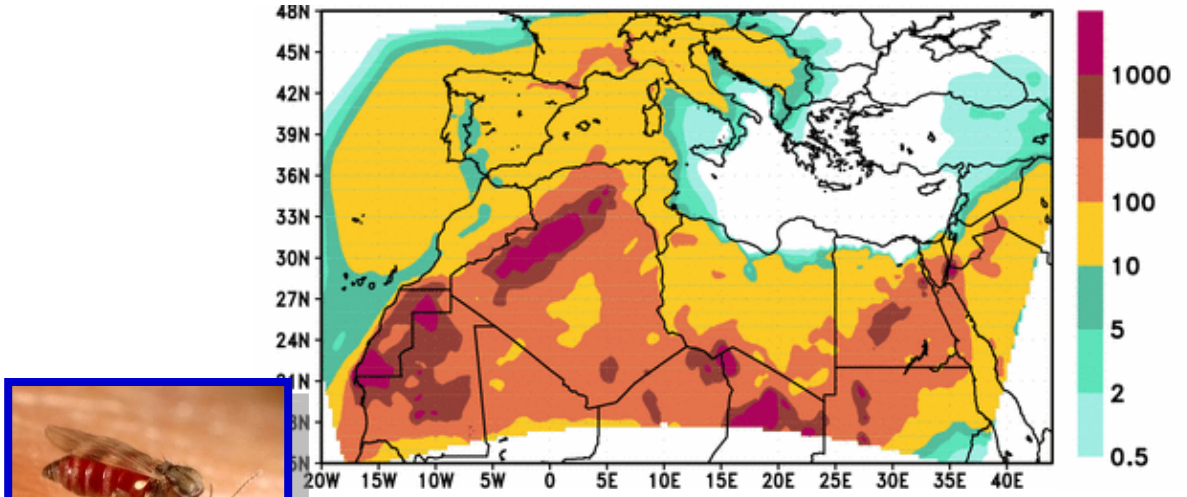
P_4

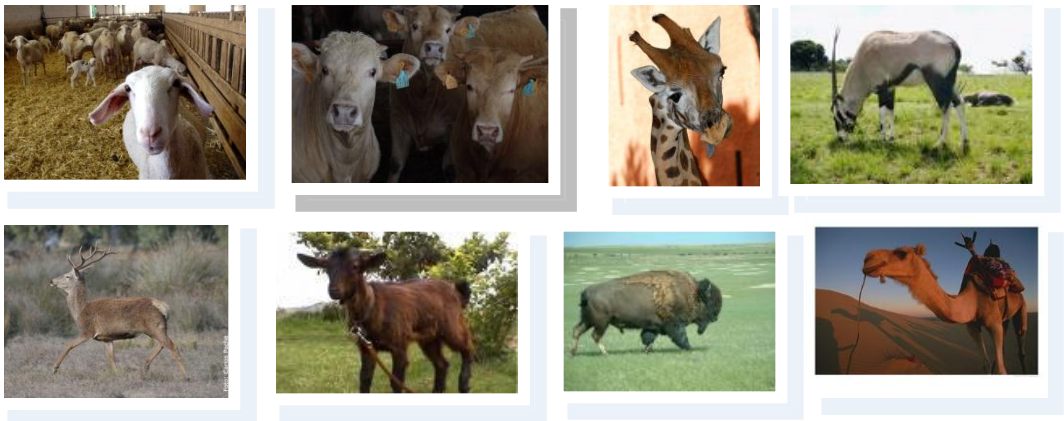
Culicoides contacs with susceptible animal

P_5

Culicoides transmits BTV to susceptible animal

$$P_{ce} = P_1 \times P_2 \times P_3 \times P_4 \times P_5$$

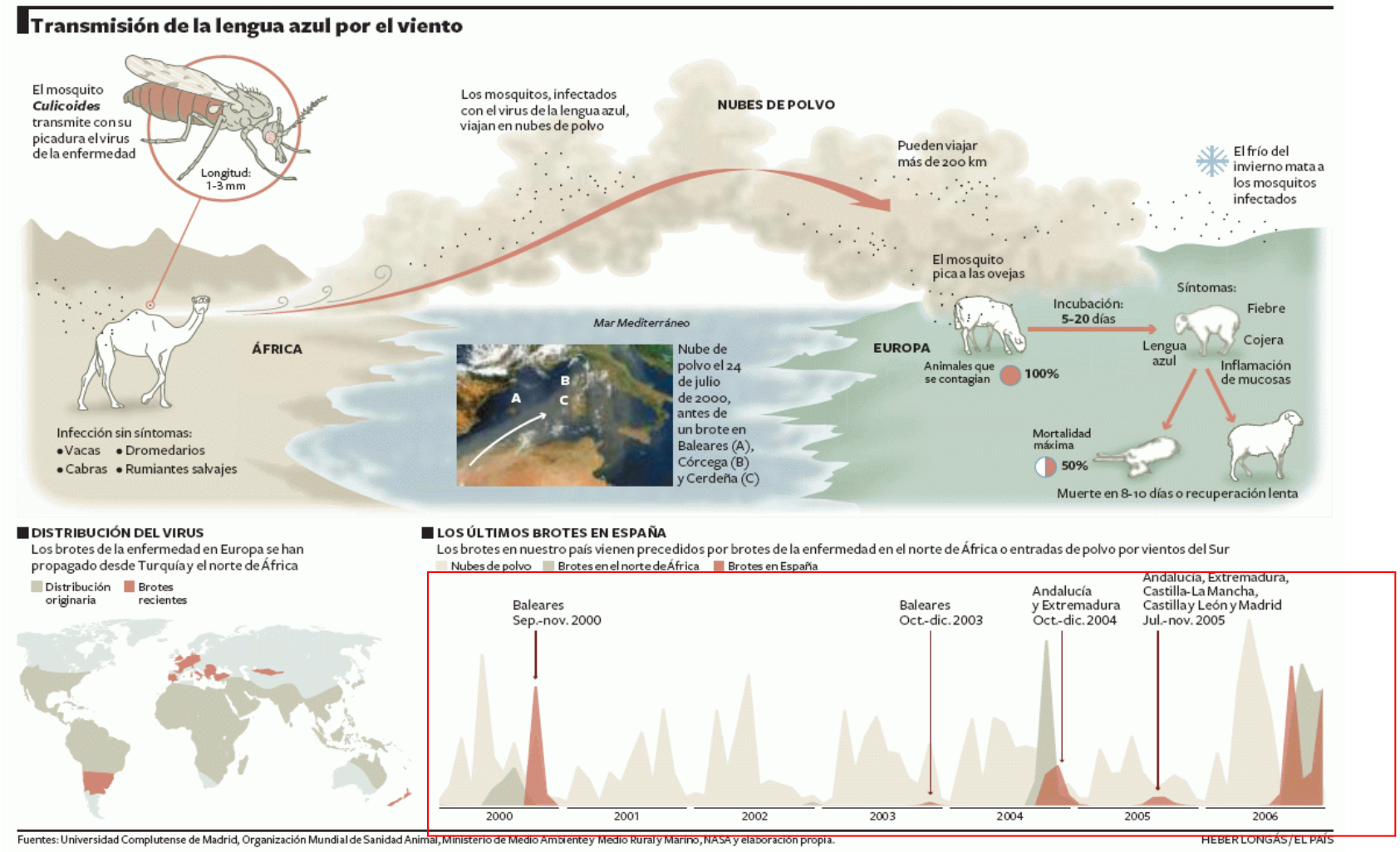




Source: IAH, www.allposters.es, www.bsc.es

Regional dust climatology APPLICATIONS: LIVESTOCK

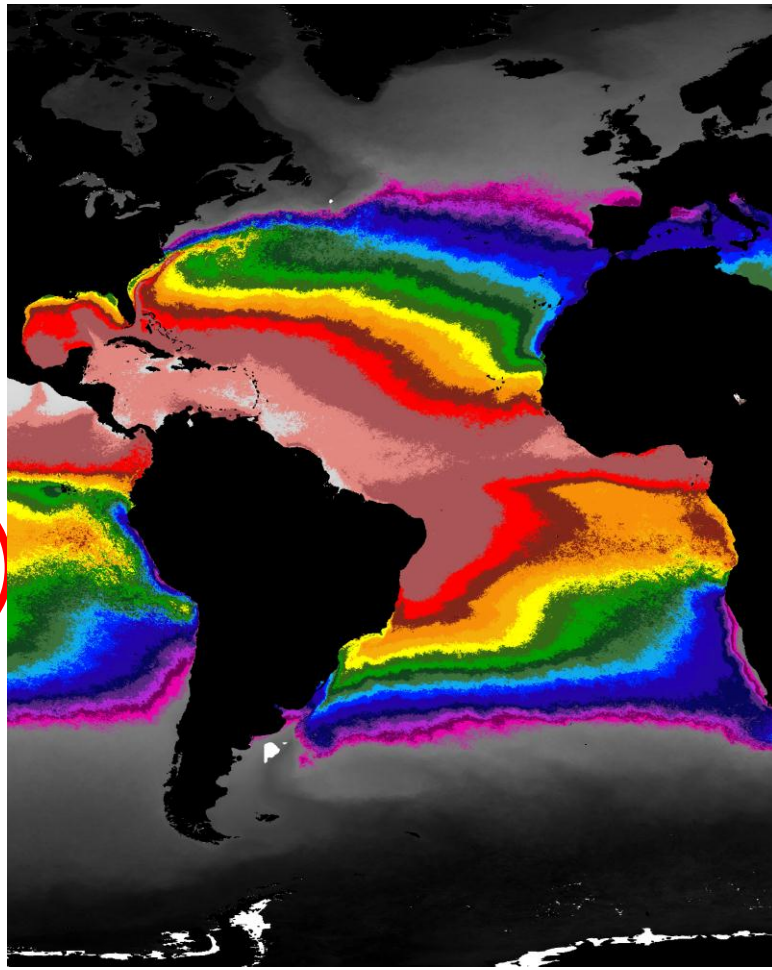
New focus: Blue Tongue virus transported by dusty winds?
In collaboration with UCM (Univ. Complutense de Madrid)



BSC/DREAM vs Blue tongue outbreaks in Spain

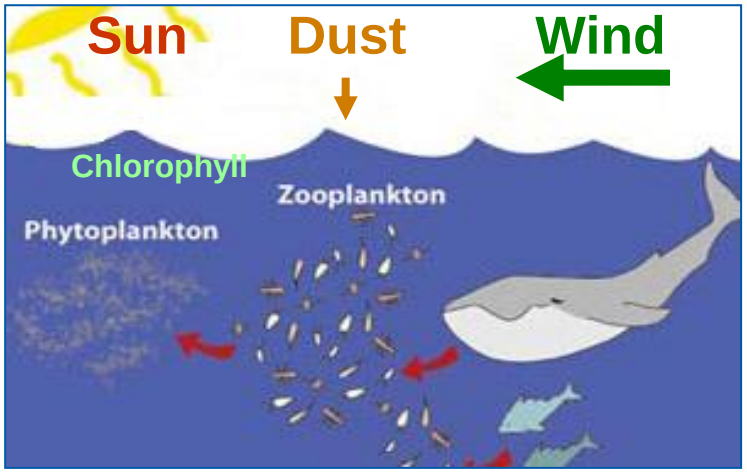
Clorofila, 2006

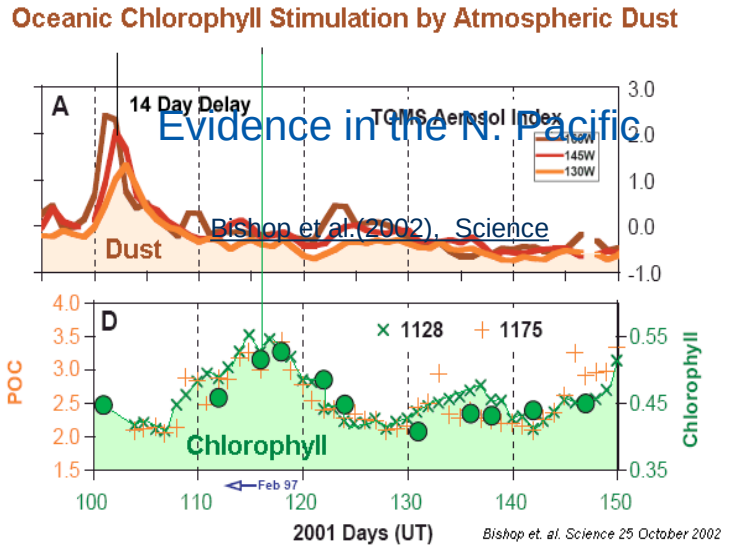
Sea Surface Temp.



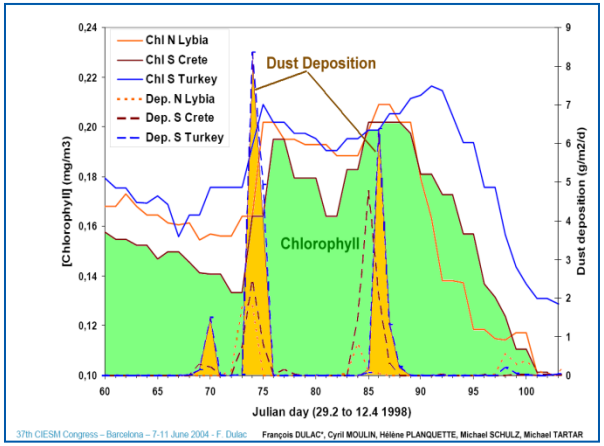
Fertilization by Dust Promotes Oceanic Biomass

- Phytoplankton produce most of the oceanic biomass through photosynthesis
- Iron from atmospheric dust is a key nutrient for phytoplankton and photosynthesis
- However, sun, wind and other factors influence the production of chlorophyll





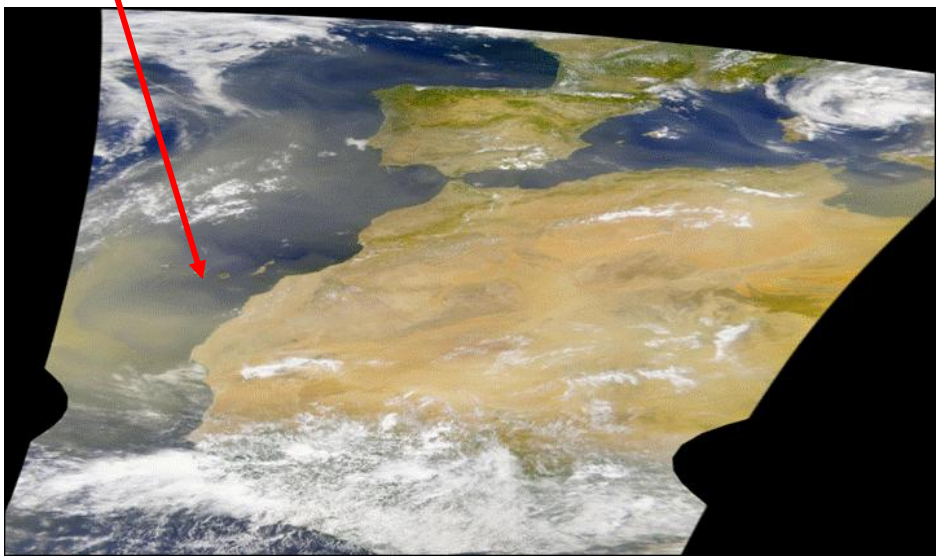
Evidence in the N. Pacific



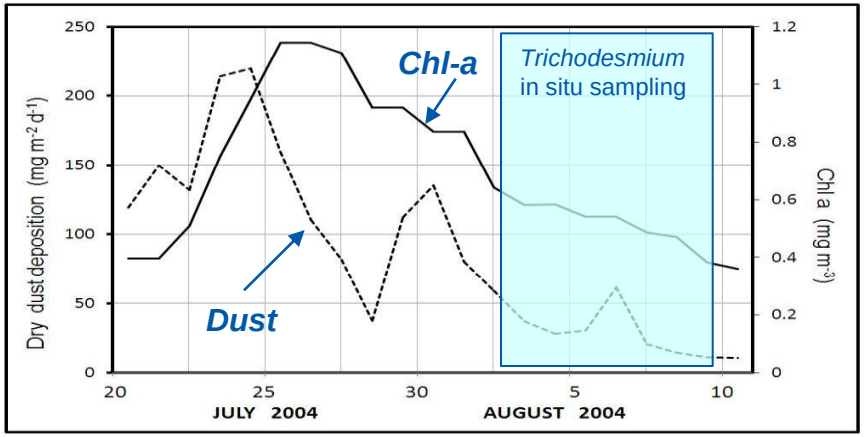
Nutrients in Saharan dust (nitrogen, iron and phosphorus), help to fertilize the huge plankton blooms that occur in the tropical eastern Atlantic

Bloom of Trichodesmium - Canary Islands, August 2004

Canary Islands



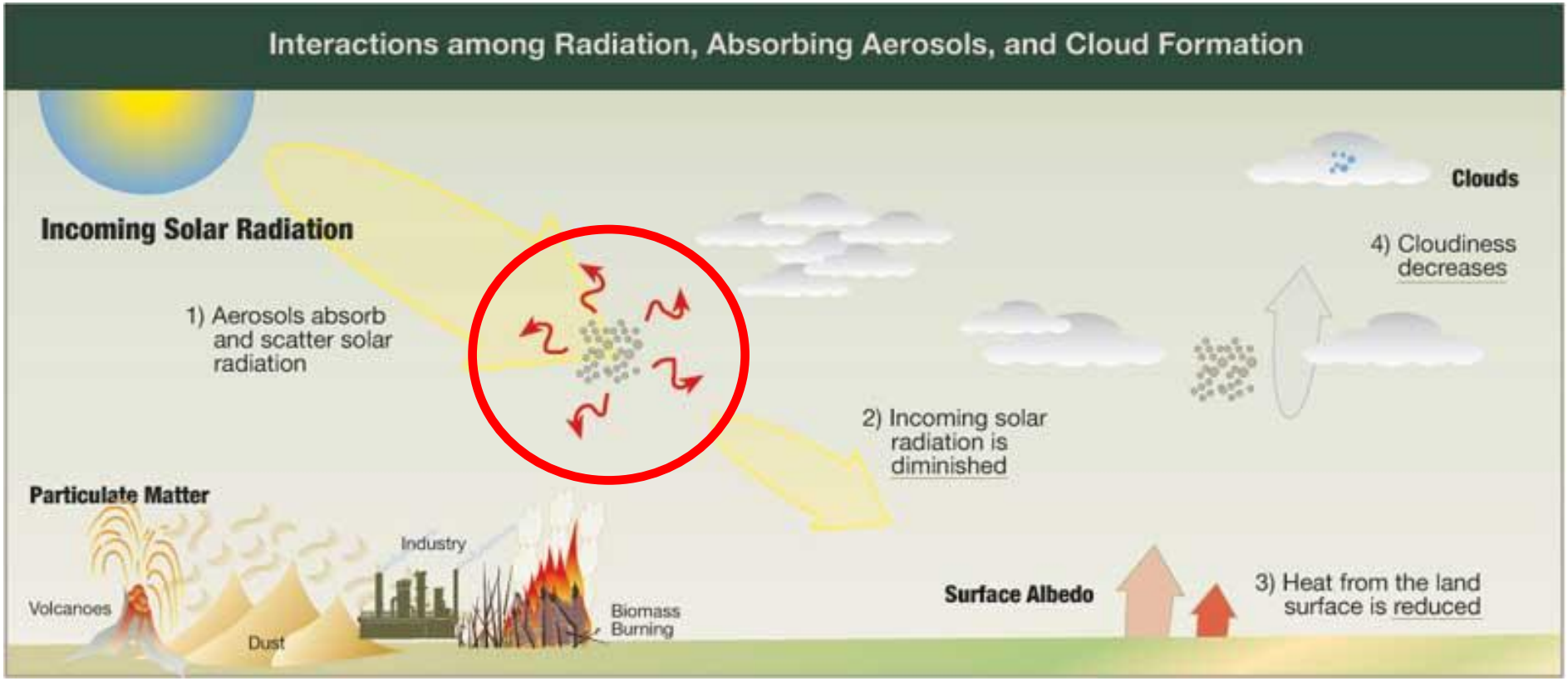
Dust over W Africa, July 2004



Chlorophyll-a vs. dry dust deposition (model); no upwelling during the event

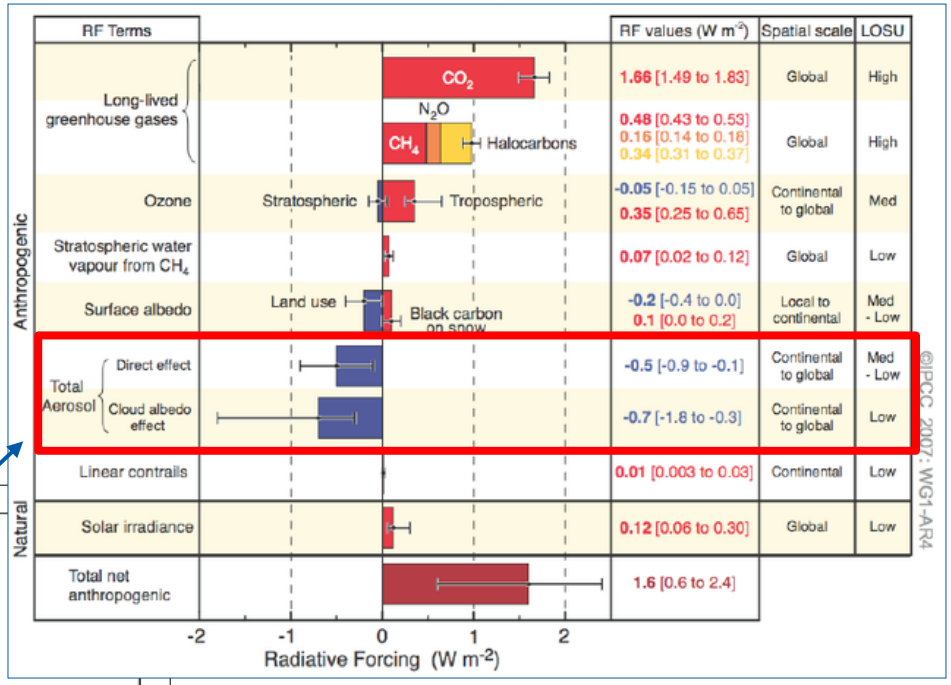
Ramos et al., 2008: Saharan Dust and Bloom of Diazotrophic Cyanobacteria in the NW African Upwelling, Geophysical Research Abstr., Vol. 10, EGU2008-A-11763, 2008

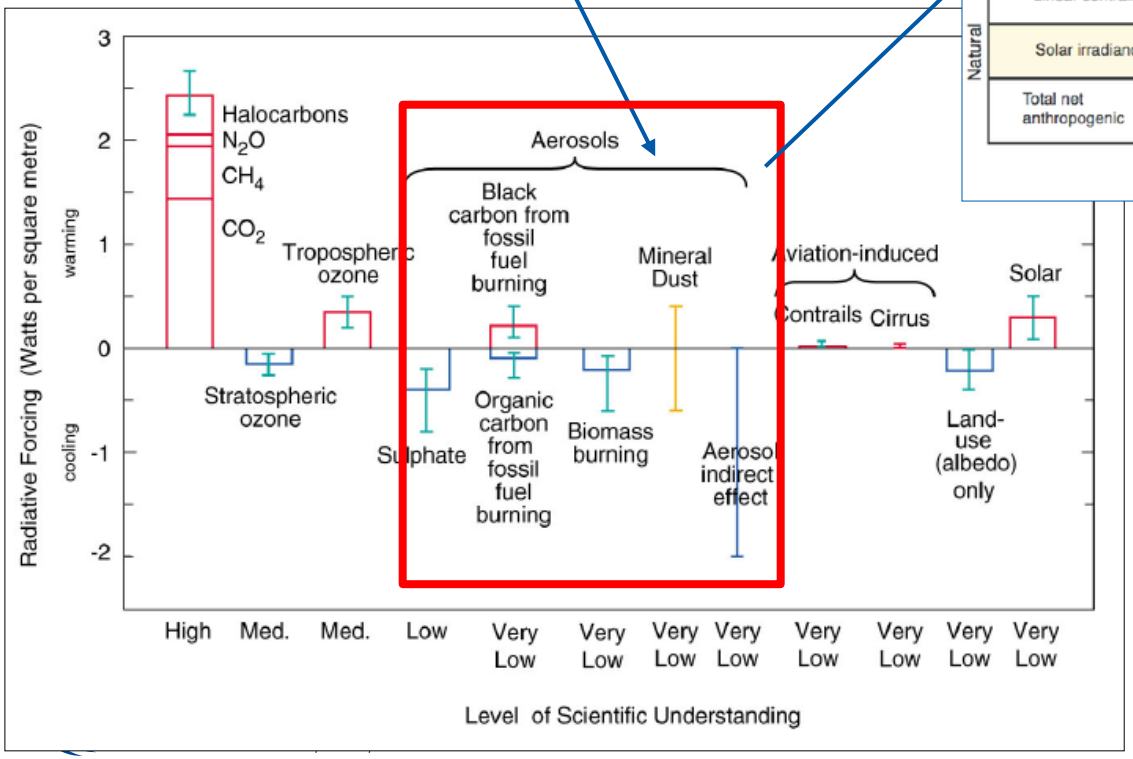
AEROSOLS → PRESENT CLIMATE CHANGE



Radiative effects

Uncertainty imposed on radiative budget **from** aeolian **mineral dust** (magnitude and even sign is not known yet)



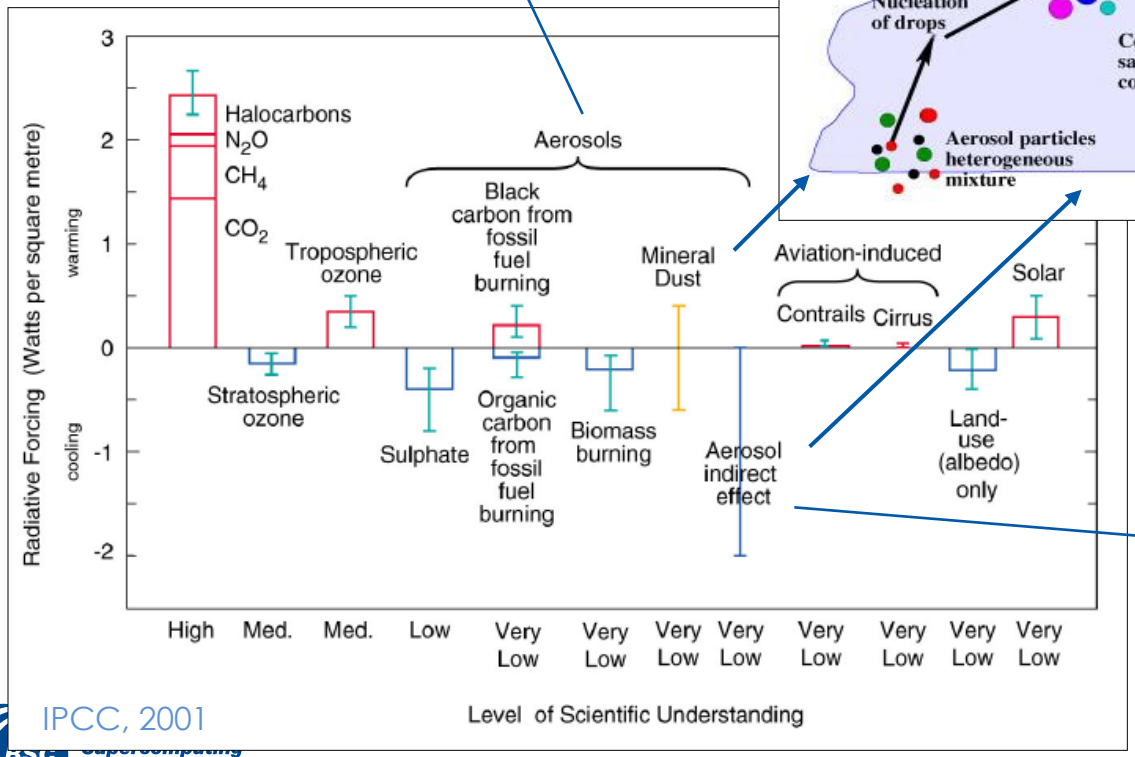


Most recent IPCC report (4th assessment) from February 2007

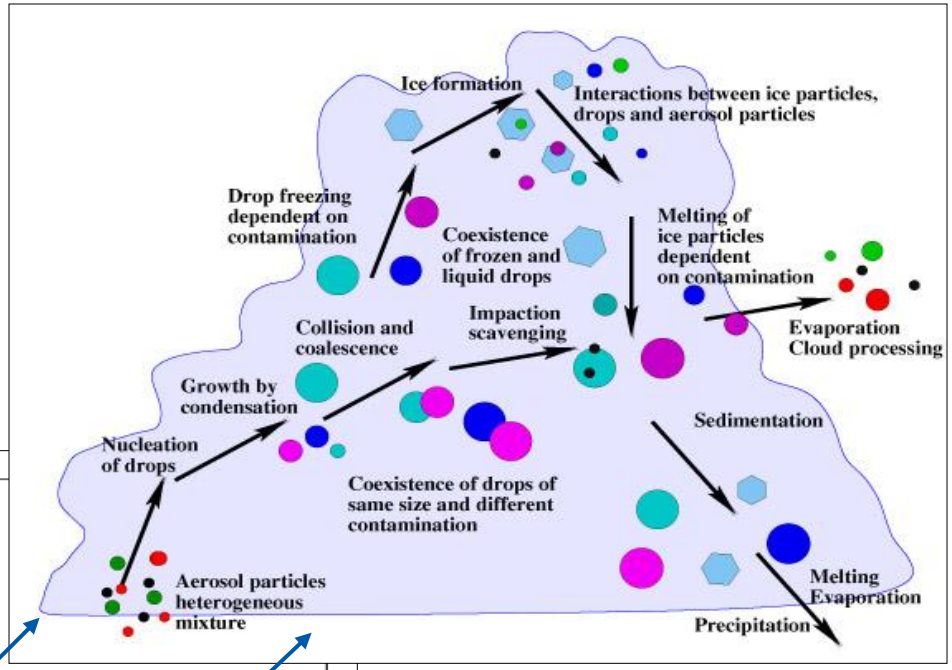
← The global mean radiative forcing for the year 2000, relative to 1750 [IPCC, 2001]

Radiative effects

Direct radiative effect:
- (back) scattering and absorbing of solar radiation and out-going thermal radiation

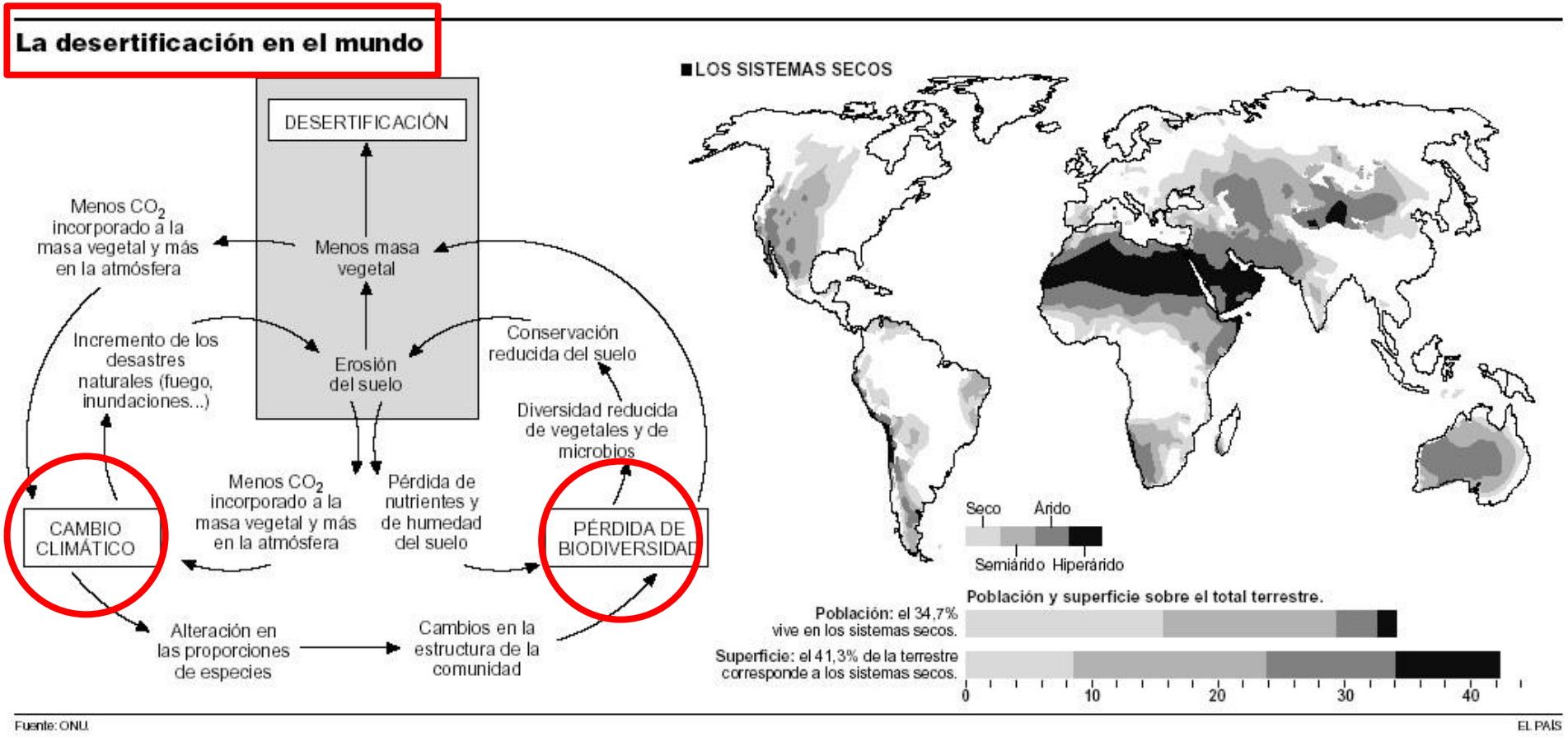


IPCC, 2001



Indirect radiative effects:
- change of physical and microphysical properties of clouds such as brightness, lifetime, structure, size, cloud reflectance
- enhanced precipitation productivity due to their capability to act as CCN

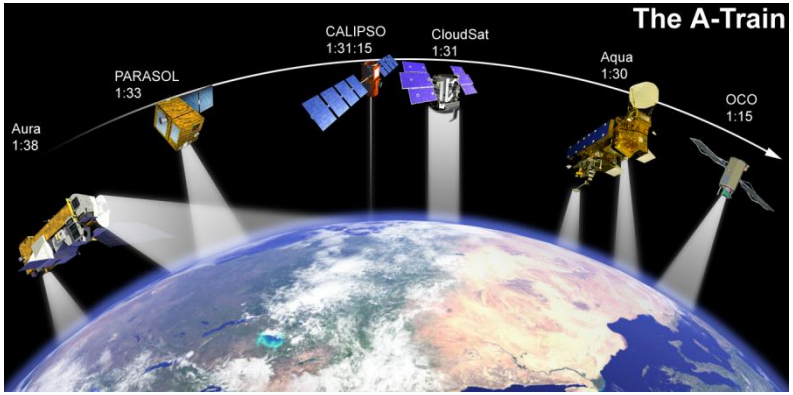
AEROSOLS → PRESENT CLIMATE CHANGE

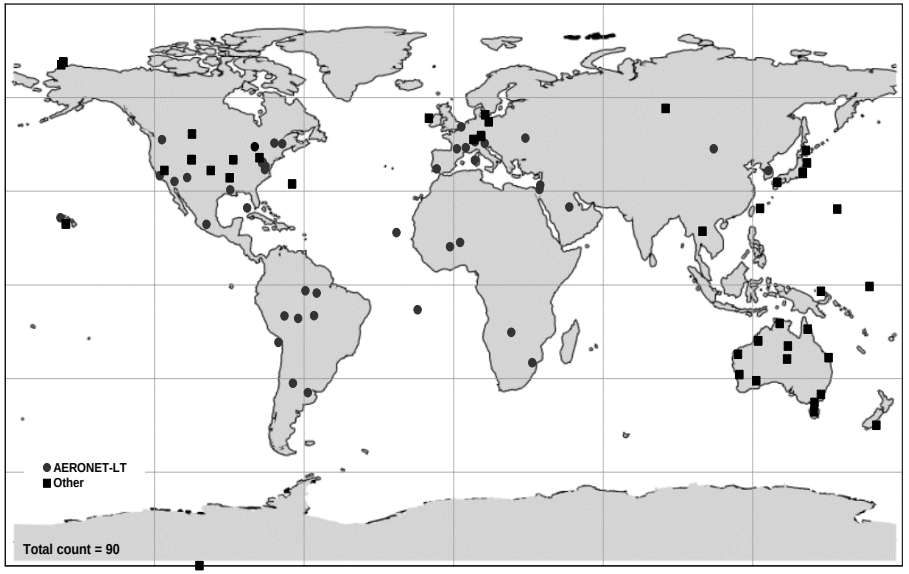


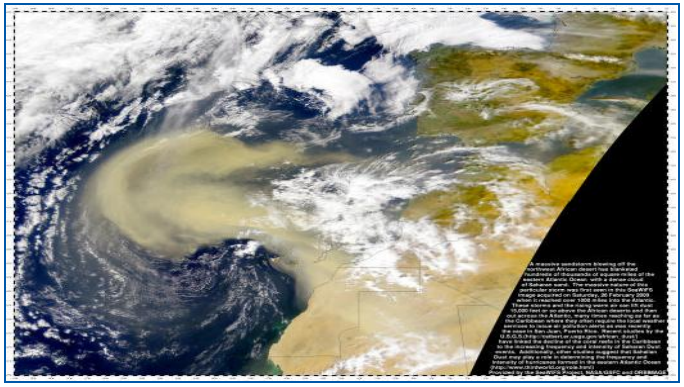
CAN SDS BE MONITORED?

Observations – supporting routine SDS monitoring

- Ground-based measurements (Aerosol Optical Depth, PM10)
- Remote sensing (satellites)







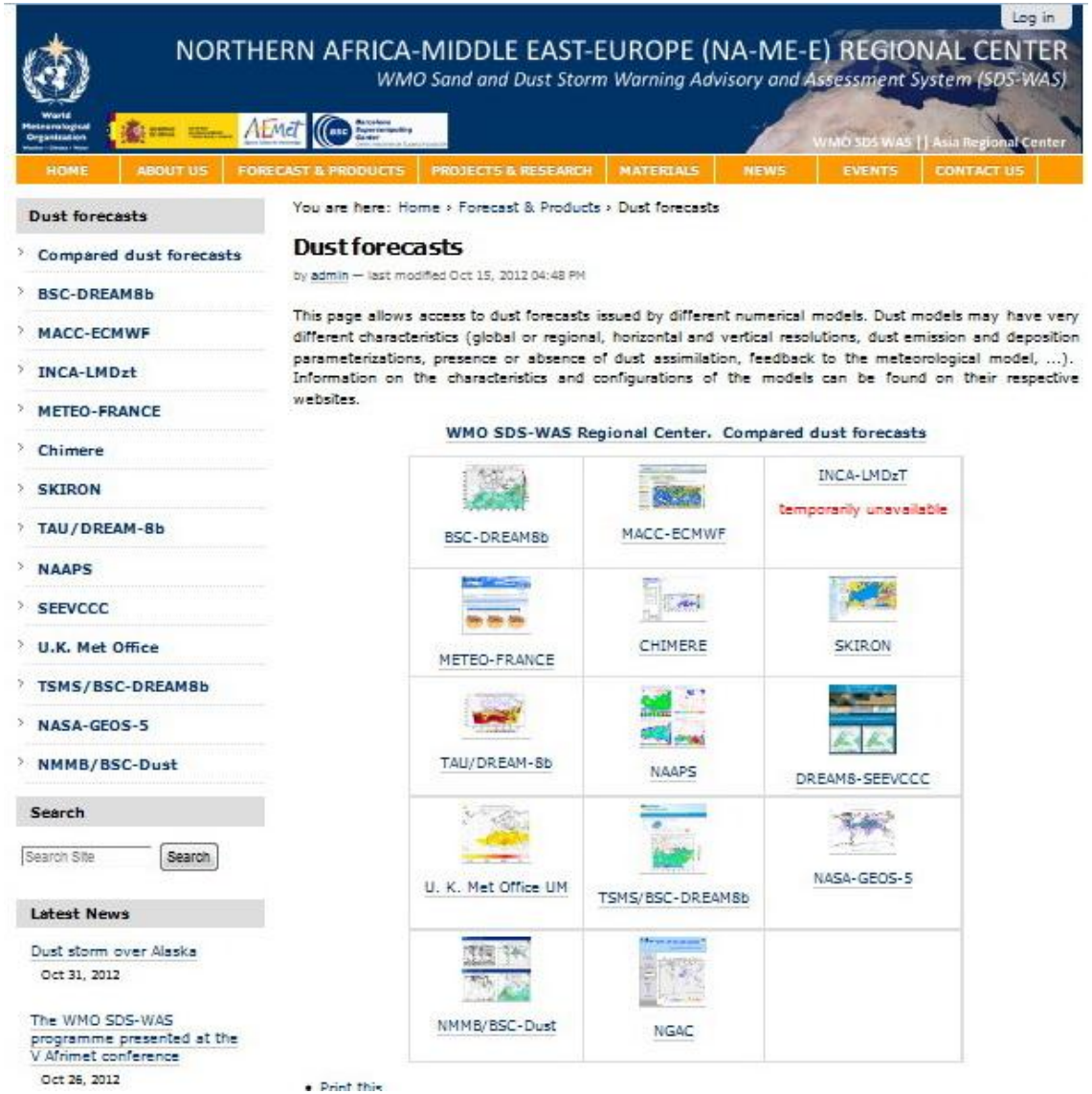
Dust storm off the African coast;
NASA MODIS

Global Aerosol Optical Depth (AOD) Network
International: AERONET, MPLnet, Aerlinet,…

CAN SDS BE PREDICTED?

Mineral dust models – to provide SDS forecasts

Models mainly developed by research organizations and meteorological services



Currently available operational SDS forecast models

WARNING SYSTEMS

SPAIN:

MMA
CSIC
AEMET
CIEMAT
…

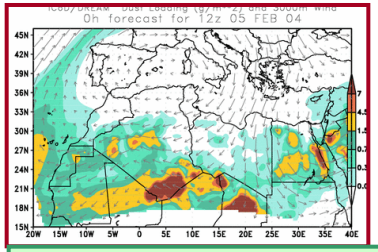
→

CALIMA
Caracterizacion de AerosoLes originados por Intrusiones de Masas de aire Africanas

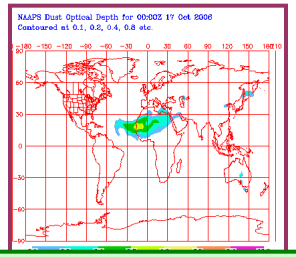
(http:// www.calima .ws)

↓

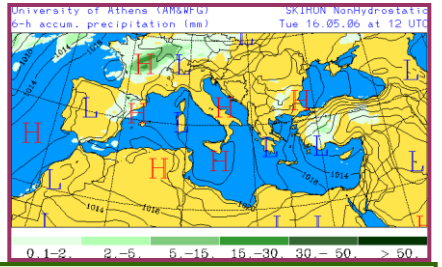
Models



BSC-DREAM8b, BSC, España



NAAPS, US Navy, USA



SKIRON, Univ Atenas, Atenas

ment System (SDS WAS) in on (WMO)

stablish and improve
e impact of Sand and

and Dust Storm

World

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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Latest News

Dust storm over Alaska
Oct 31, 2012

The WMO SDS-WAS programme presented at the V Afrimet conference
Oct 26, 2012

Link to NGAC dust forecasts
Oct 16, 2012

Upcoming Events

3rd. ChArMEx International Workshop
Nov 05, 2012 - Nov 08, 2012 — Carqèse, France

II Lectures on atmospheric mineral dust
Nov 05, 2012 - Nov 09, 2012 — Barcelona, Spain

International Conference on Dust and Dust Storm
Nov 20, 2012 - Nov 22, 2012 — Kuwait, Kuwait

« November 2012 »

Su	Mo	Tu	We	Th	Fr	Sa
				1	2	3
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25	26	27	28	29	30	

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

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

Outstanding

- II Lectures on Atmospheric Mineral Dust. A few seats are still available
- WMO SDS-WAS NA-ME-E Regional Center will be a Regional Specialised Meteorological Center
- Guidance for forecasters
- Forecast evaluation
- Compared dust forecasts

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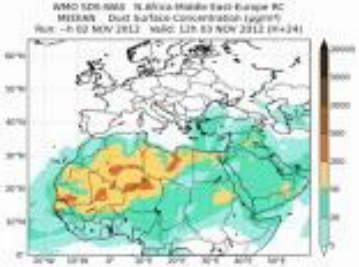
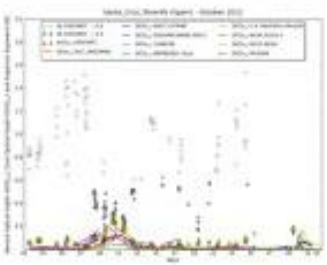
Dust forecasts

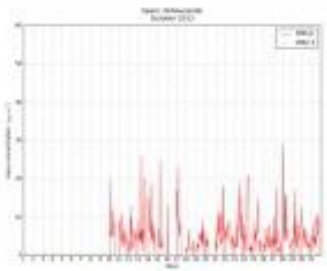


Compared Dust Forecasts

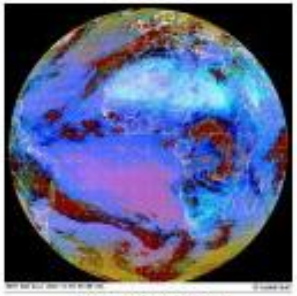


Forecast Evaluation

Dust observations



In-situ Measurements



EUMETSAT RGB-Dust

Thank you for your attention ¡¡¡¡

Kuwait 20080616

Courtesy of Drs. Al-Maskari and Albadi, Oman Met. Service

Barcelona Supercomputing Center
Centro Nacional