

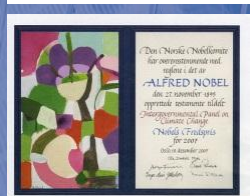
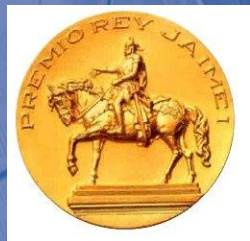


**Barcelona  
Supercomputing  
Center**

*Centro Nacional de Supercomputación*

# THE DUST CYCLE AND IMPACTS

Dr. José M<sup>a</sup> Baldasano  
[jose.baldasano@bsc.es](mailto:jose.baldasano@bsc.es)



Barcelona, 5 November 2012

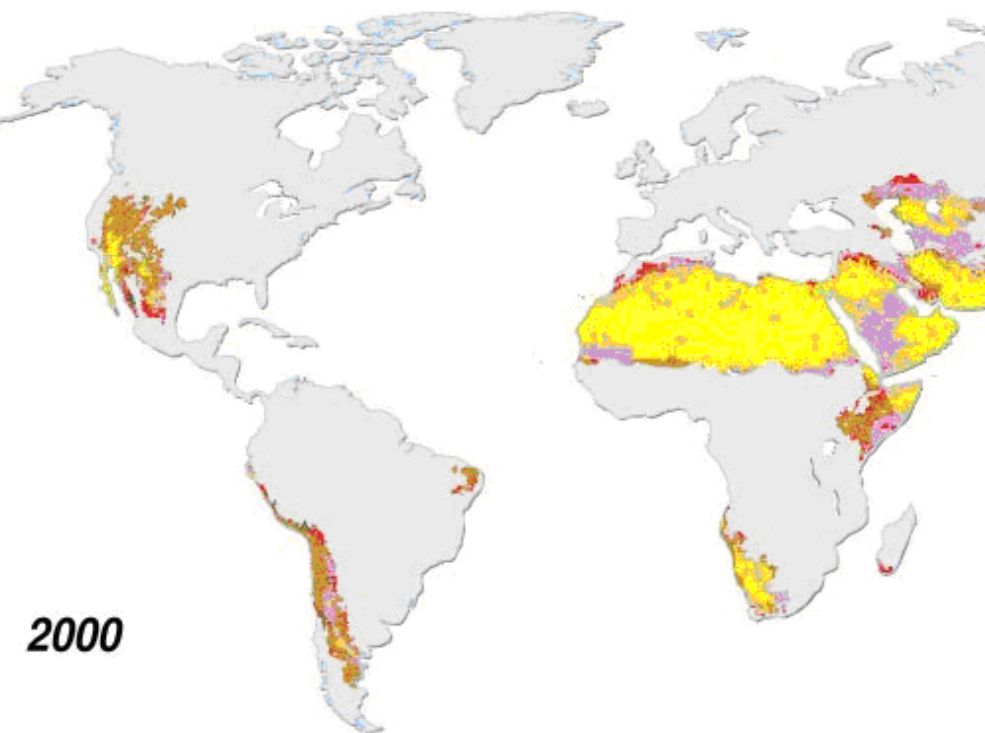
# Desert definition?

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.



## Landcover and landuse

 Desert

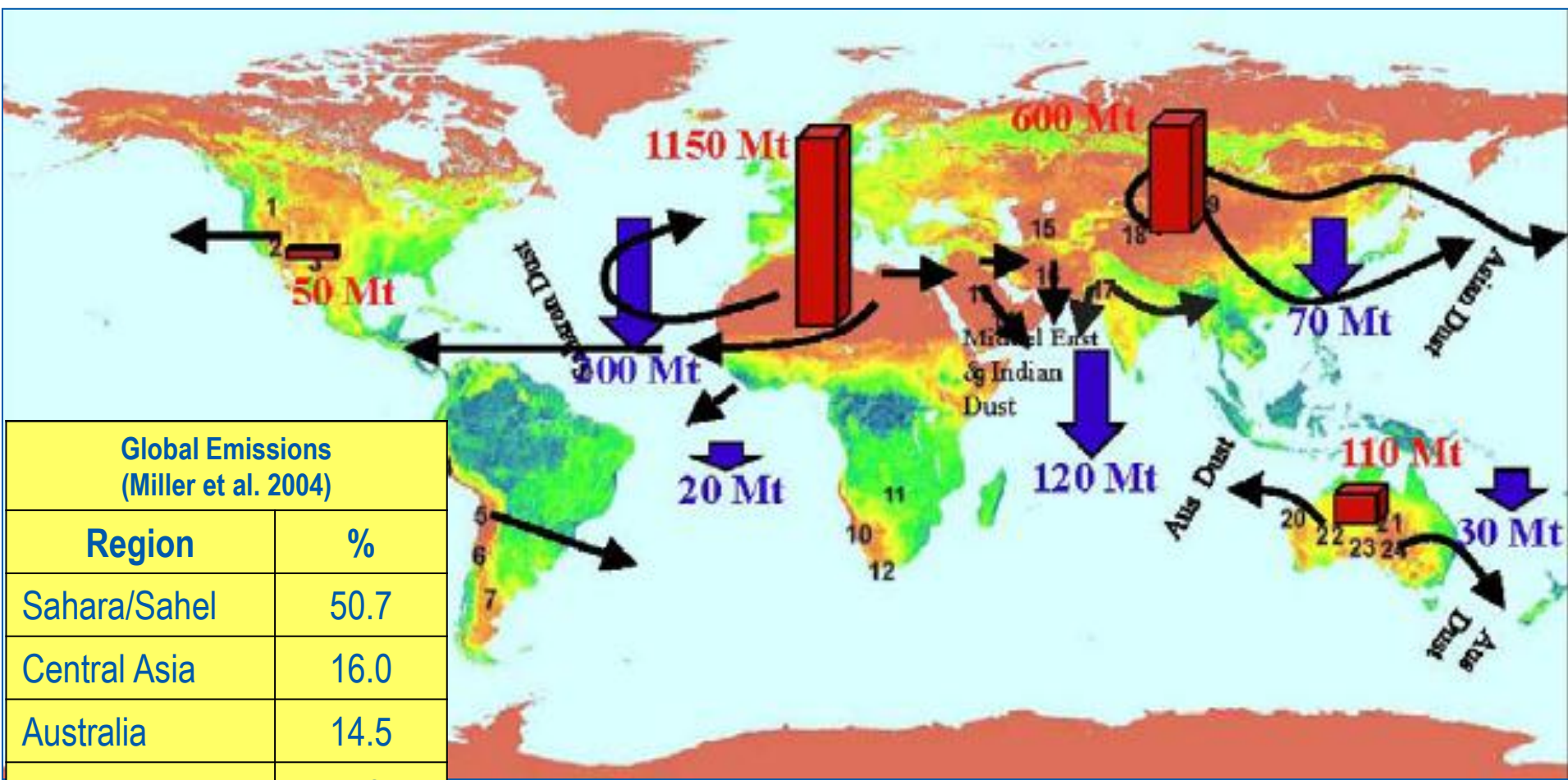


2000

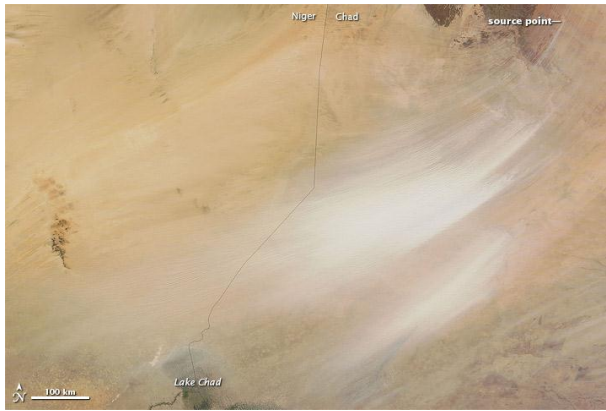
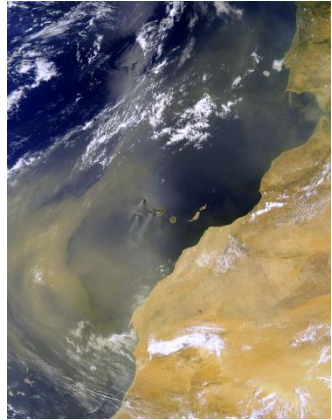
### The ten largest deserts'

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

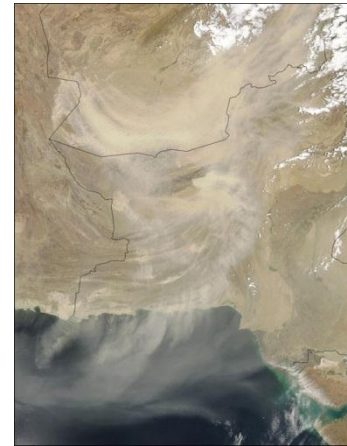
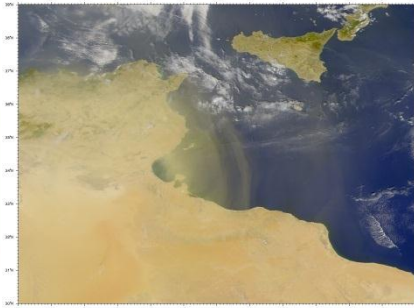
# Main routes of dust transport [Shao et al., 2011]



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



La nube se aproxima a una base militar en Golmud  
CHINA FOTO PRESS / GETTY IMAGES



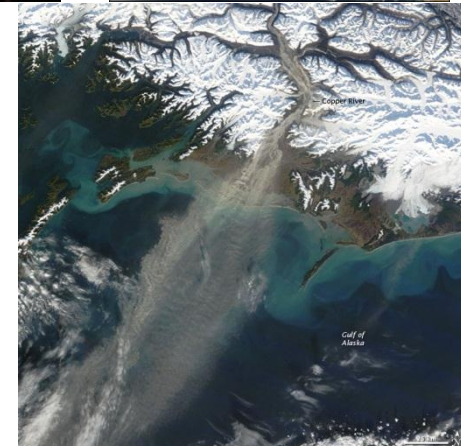
La vida en Riad se interrumpió por la tormenta  
JAD SAAB / AP



La arena envuelve la ciudad de Riad



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  
ROB SCHUMACHER / AP

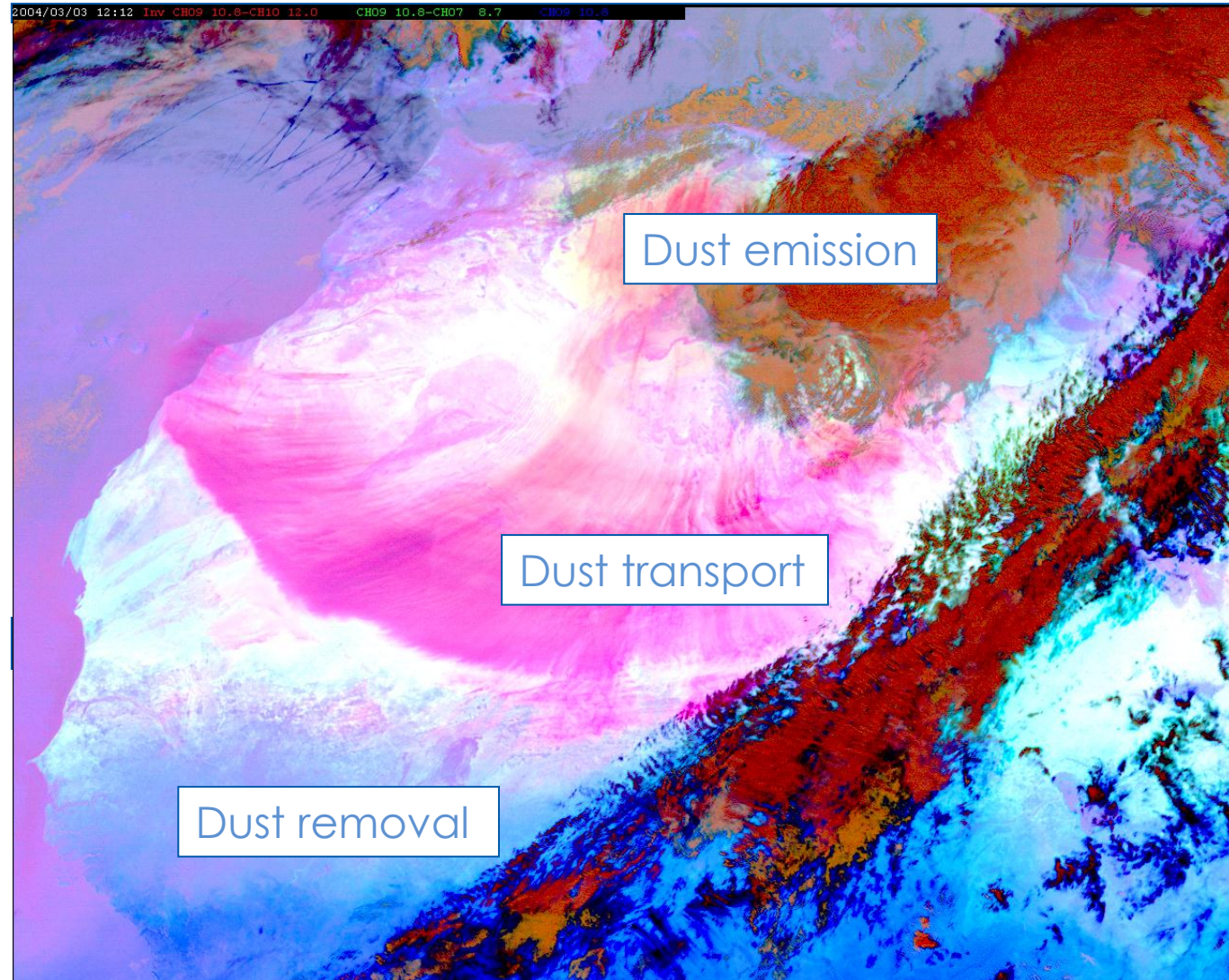


# Dust cycle and associated processes

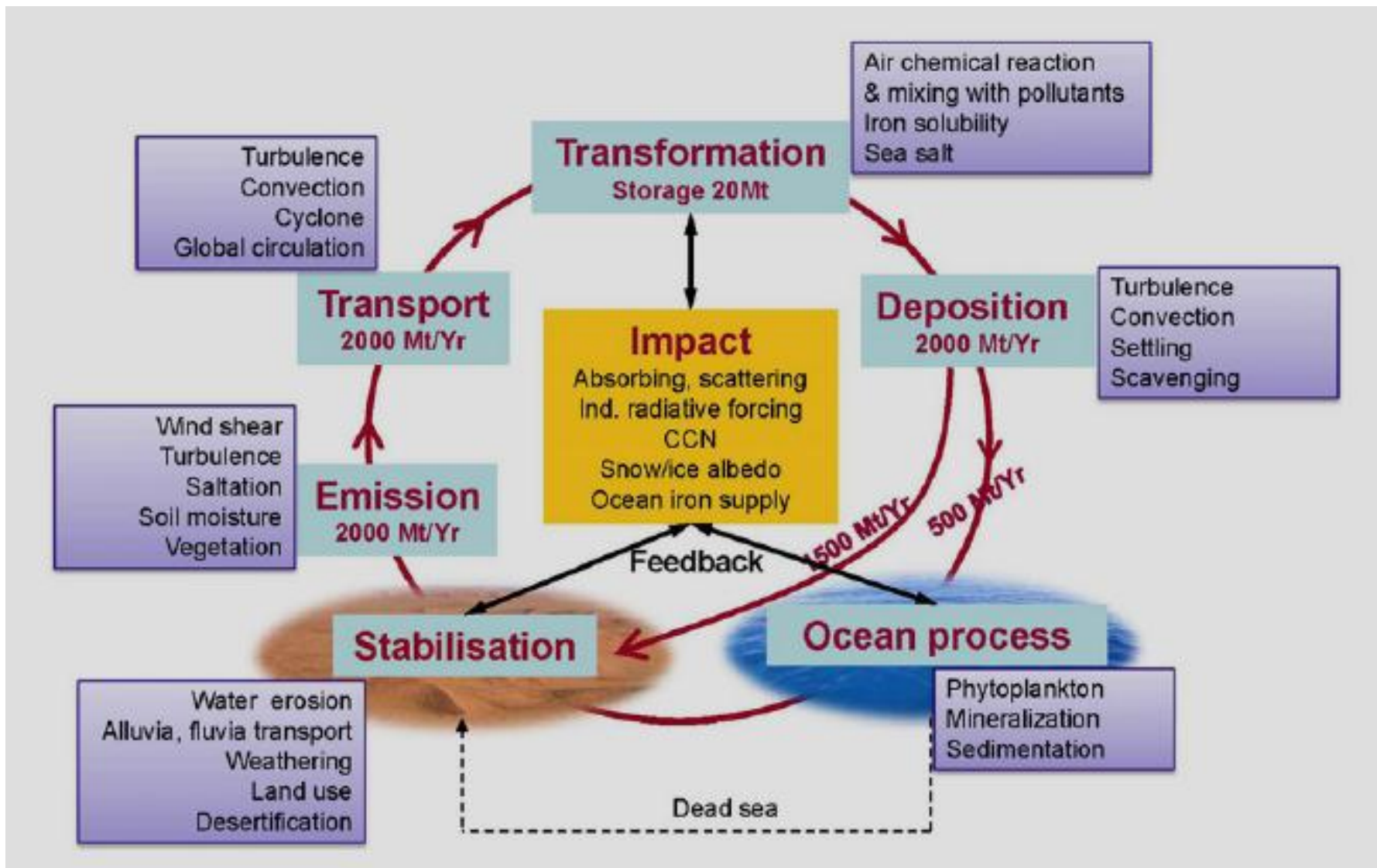
The following components have to take into account in the dust cycle:

**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

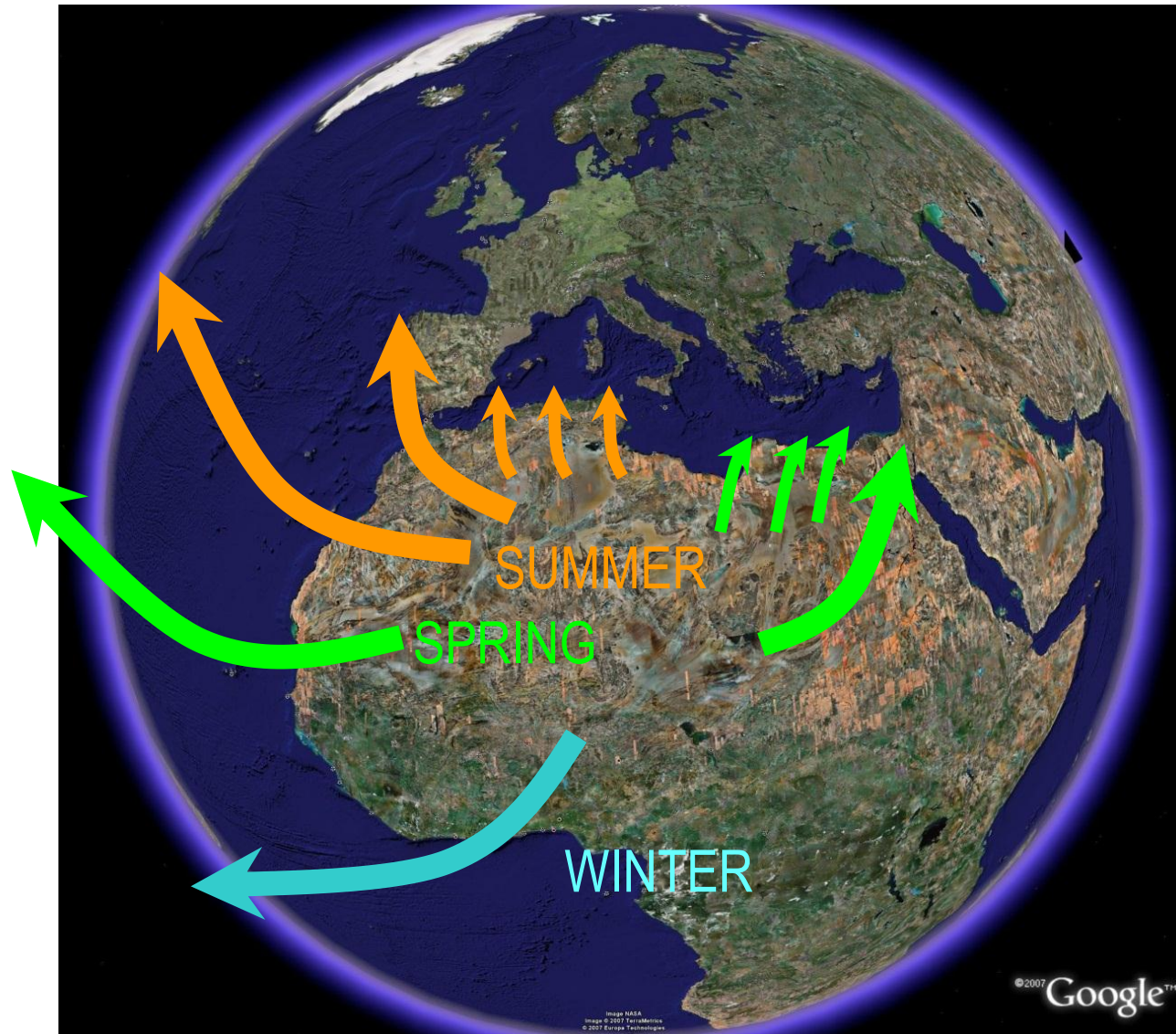
**Dust emission** is a complex physical process involving entrainment of soil particles by the surface winds.



# 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

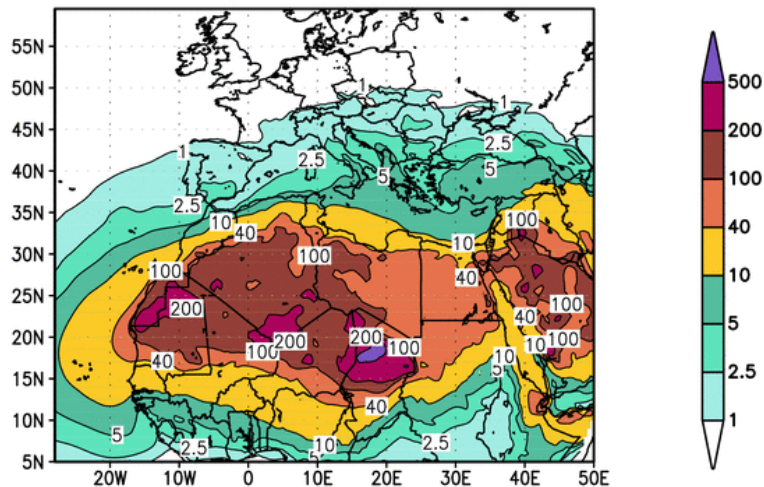




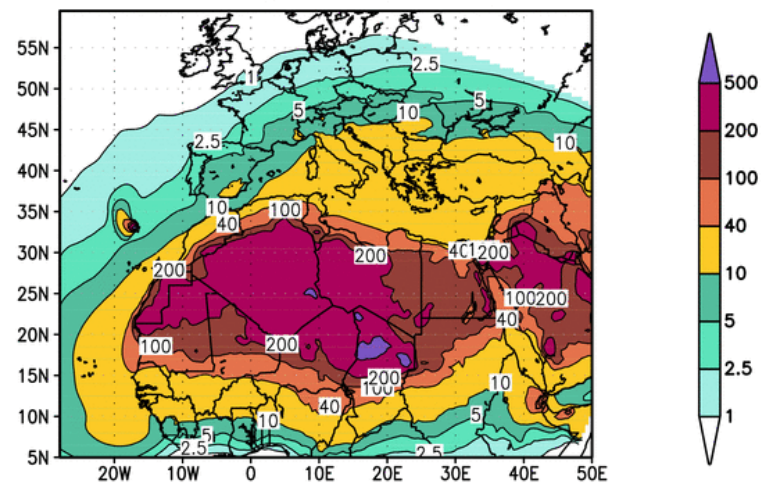
# Retrospective analysis of Saharan dust

## Seasonal Average 1959-2006: surface dust concentration

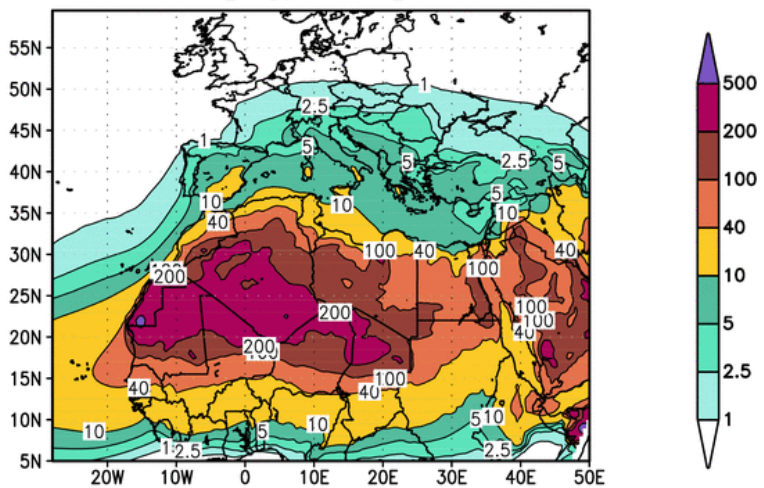
Surf. dust conc. [ $\mu\text{g}/\text{m}^3$ ] DJF 1959–2006



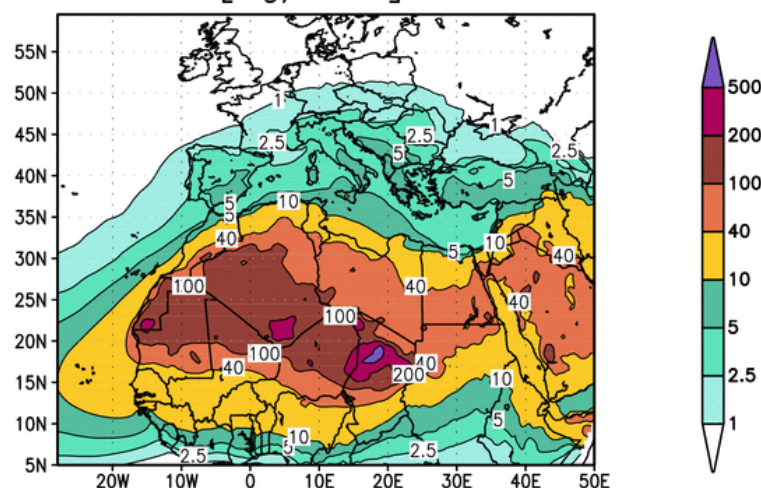
Surf. dust conc. [ $\mu\text{g}/\text{m}^3$ ] MAM 1959–2006



Surf. dust conc. [ $\mu\text{g}/\text{m}^3$ ] JJA 1959–2006

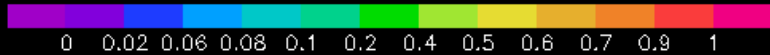
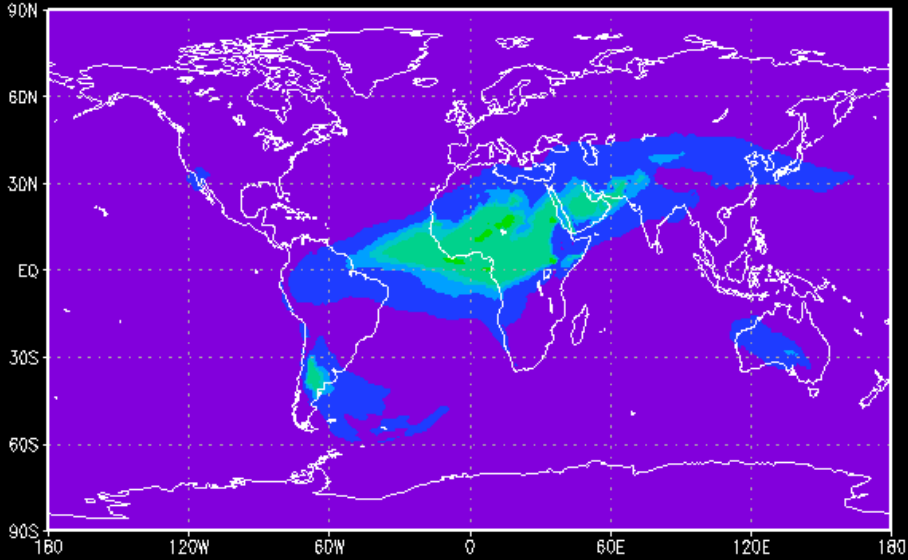


Surf. dust conc. [ $\mu\text{g}/\text{m}^3$ ] SON 1959–2006

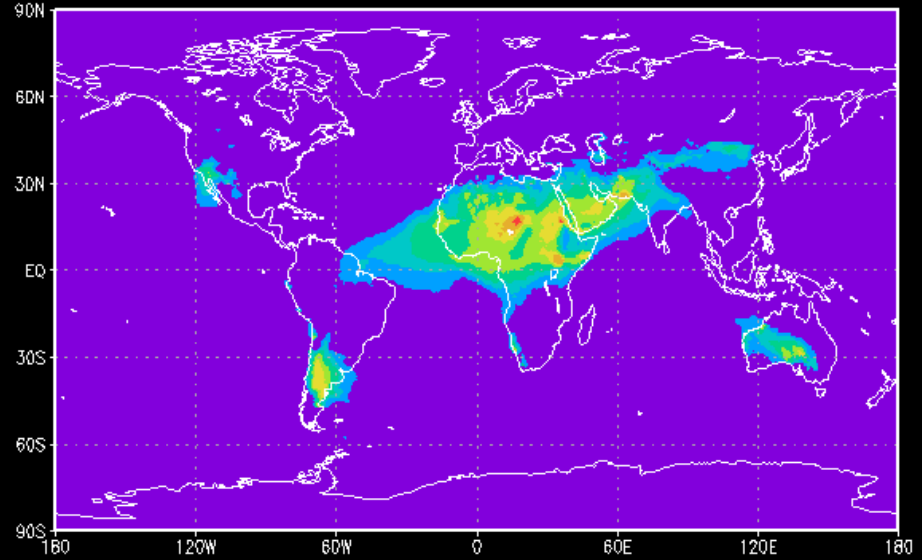


# 2006 Annual simulation

AOD 550nm january 2006 average

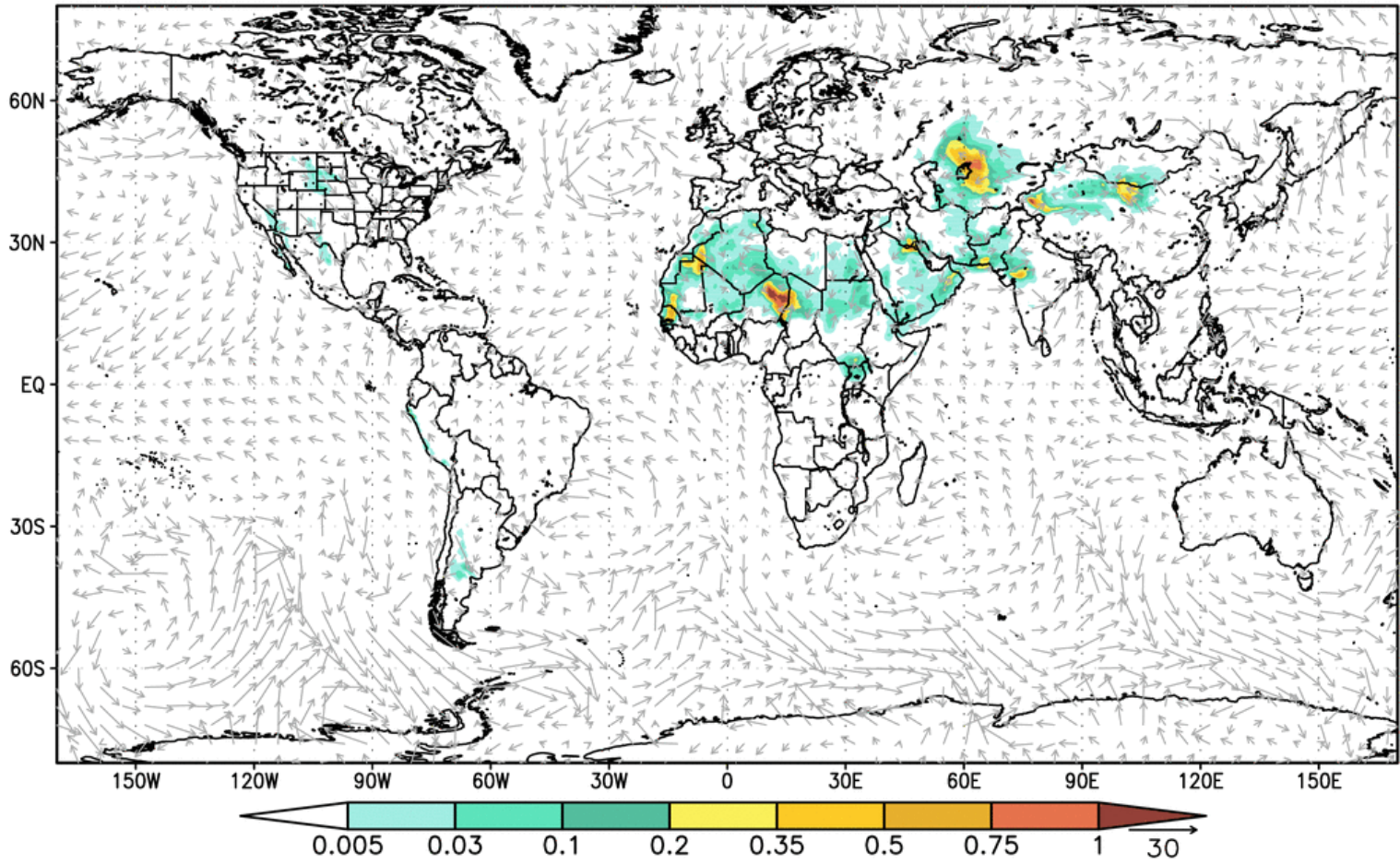


dust conc january 2006 ug m<sup>-3</sup>



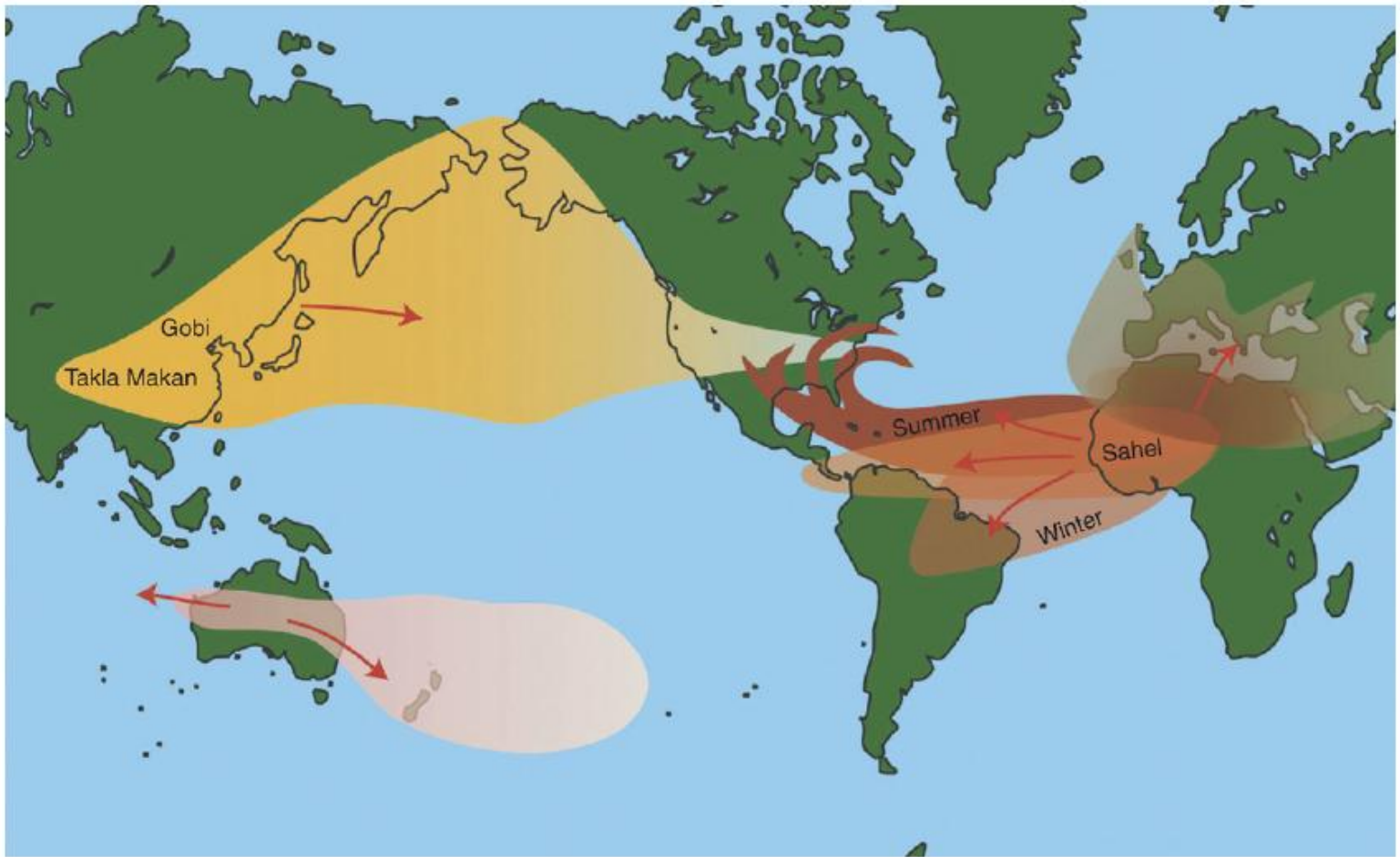
# Global dust simulations with NMMB/BSC-Dust

11-05-06 00z dust optical depth 550nm



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

11-25 May 2006: Samum Campaign period



**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].

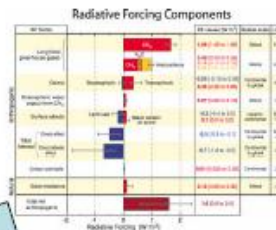
# Mineral Dust Impacts

**HUMAN HEALTH**  
 Bronchial tubes  
 Eye infections  
 Asthma  
 Heart stress

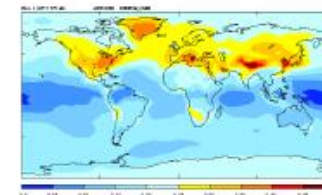


**CLIMATE AND METEOROLOGY**

Dust causes large uncertainties in assessing climate forcing by atmospheric aerosols

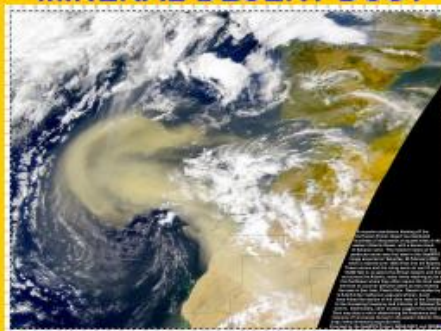


**OZONE CHEMISTRY**



Related to epidemics of lethal Meningitis in the Sahel Belt

**MINERAL DESERT DUST**



**IMPACTS**

**OCEANIC AND TERRESTRIAL BIOCHEMICAL CYCLES**

Iron deposition into the oceans, increasing nitrification processes



**LIFE AND PROPERTY**



**VISIBILITY**

Severe reduction of visibility on road and airports affecting operations



Infection of coral reefs

# Mineral Dust Impacts



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



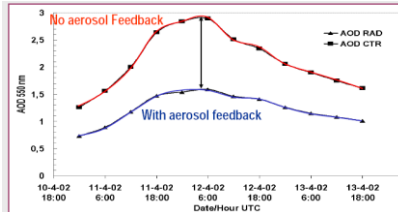
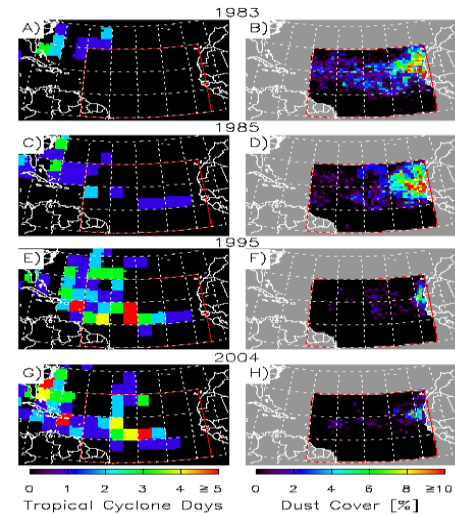
**Agricultura** (impactos positivos y negativos)



**Productividad marina** (impactos negativos y positivos)

**Industria** (Semiconductores, etc.)

**Energía** (plantas termosolares)



Radiative Forcing components		RF values (W/m <sup>2</sup> )	Spatial scale	LOSU
Atmospheric				
RF Terms				
Long-lived greenhouse gases	CO <sub>2</sub> , N <sub>2</sub> O, CH <sub>4</sub> , HFCs, PFCs, SF <sub>6</sub>	1.86 (1.49 to 1.83)	Global	High
Ozone	Stratospheric, Tropospheric	-0.48 (0.43 to 0.03) 0.16 (0.14 to 0.18) -0.34 (0.13 to 0.71)	Global	High
Stratospheric water vapour from CFCs		-0.30 (0.15 to 0.95)	Continental to global	Med
Surface albedo	Land Use, Black carbon on snow	0.87 (0.08 to 0.12) -0.2 (0.4 to 0.0) 0.1 (0.0 to 0.2)	Local to regional	Med Low
Total Aerosol Direct effect		-0.5 (-0.9 to -0.1)	Continental to global	Med Low
Total Aerosol Cloud albedo effect		-0.7 (-1.8 to -0.2)	Continental to global	Low
Linear contrasts		0.81 (0.003 to 0.005)	Continental	
Natural				
Solar irradiance		0.12 (0.06 to 0.20)	Global	Low
Total net anthropogenic		1.8 (0.8 to 2.4)		

**Predicción meteorológica** a corto y medio plazo, estacional y climática



**Aviación** (accidentes y operatividad de aeropuertos)  
**Transporte terrestres**

# Respiratory Health: Africa

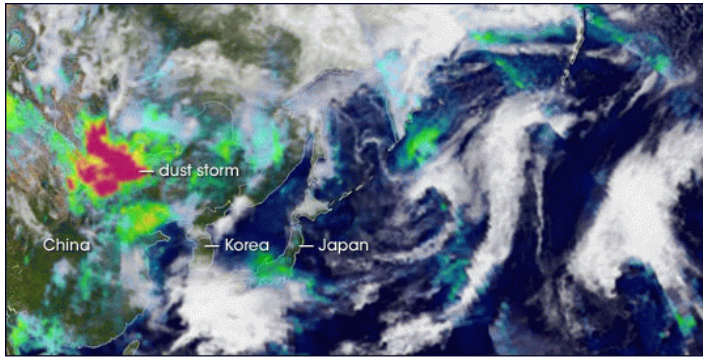
Mali



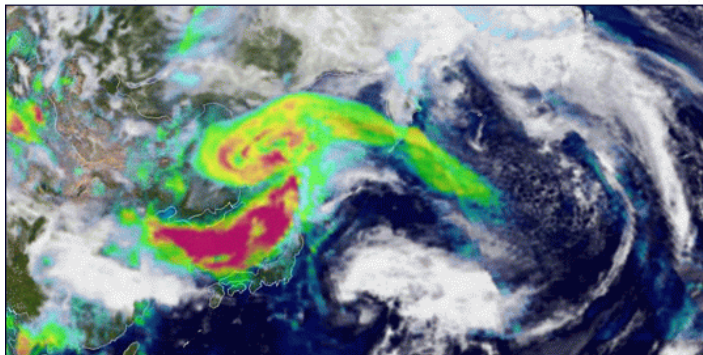
Cuatro refugiadas caminan en medio de una tormenta de arena el jueves cerca de Goz Beida. / REUTERS

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

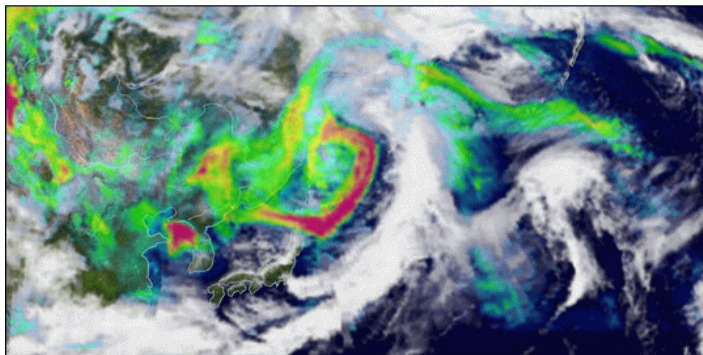
# Respiratory Health: Asia



March 9



March 11

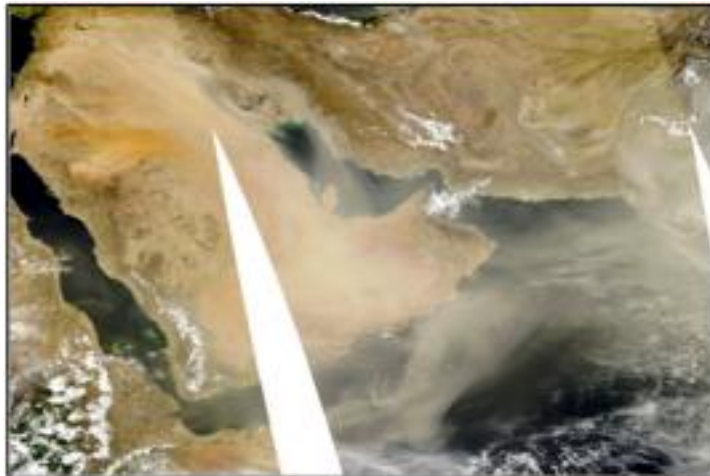


March 13





# 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.

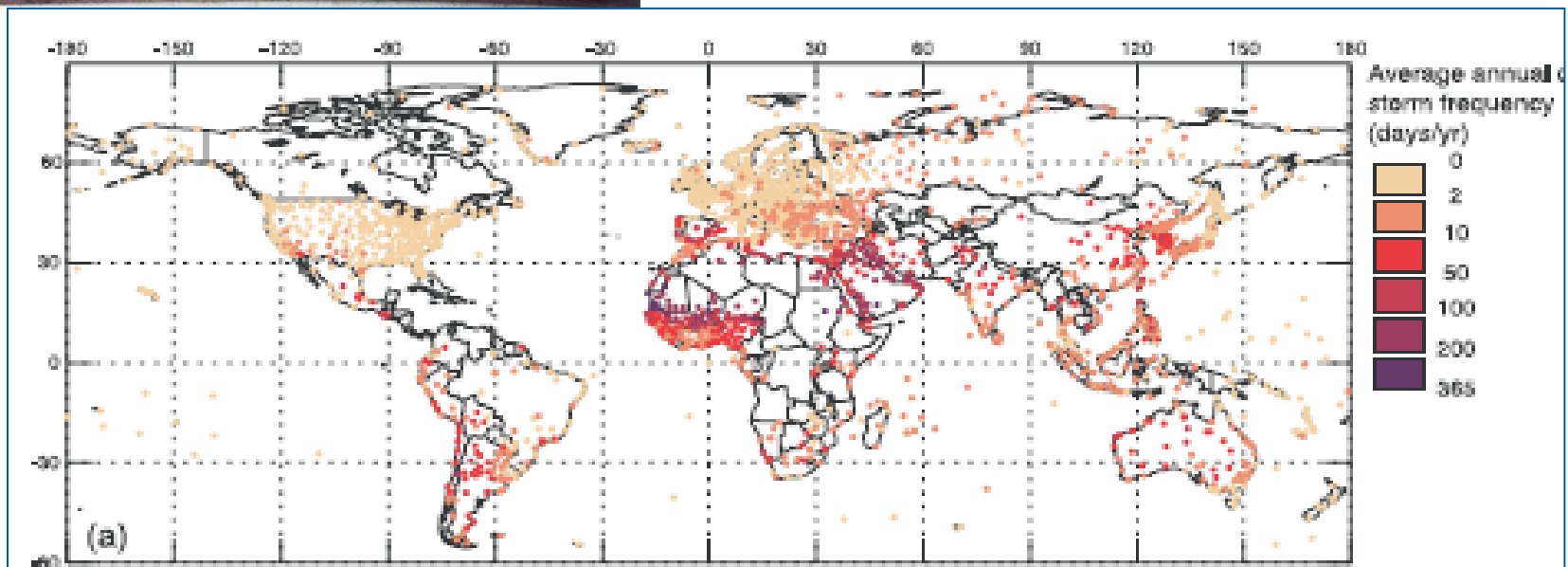
The adverse weather conditions also caused some **problems at airports** around the region, with both Bahrain and Kuwait reporting minor disruption.

# Sand and Dust Storm at 18.04.2012 over Middle Anatolia



# CLOSE-UP VIEW: FREQUENCY

Severe dust storm near Cairo, 2 May 1997



## 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...

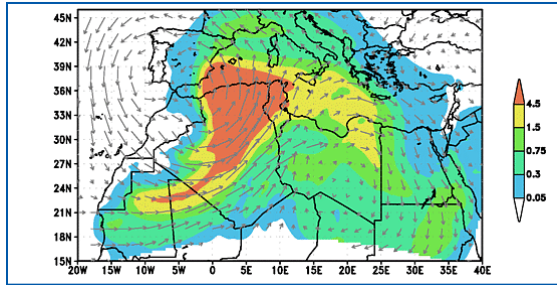
...The control tower lost contact with the plane a few seconds before the incident, just after the pilot sent out a distress call. As soon as contact was lost, emergency vehicles rushed to the area...

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

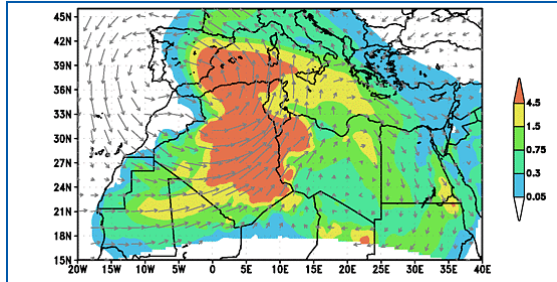


# EGYPTAIR ACCIDENT AGAIN: PREDICTION OF THE SDS

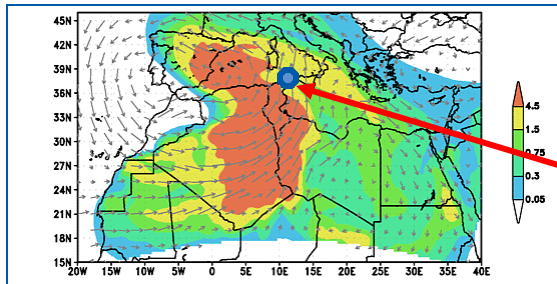
Predicted dust load ( $\mu\text{g m}^{-2}$ )



06 UTC, 7 May 2002 18-hr forecast



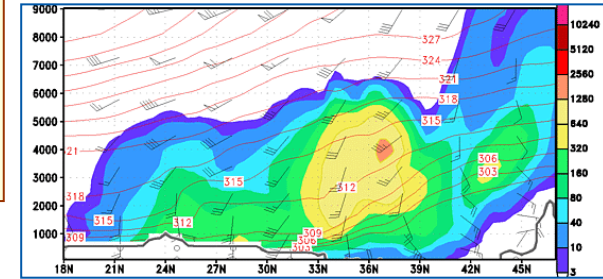
12 UTC, 7 May 2002 24-hr forecast



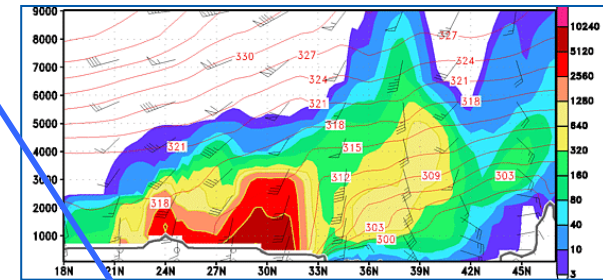
Barcelona

18 UTC, 7 May 2002 30-hr forecast

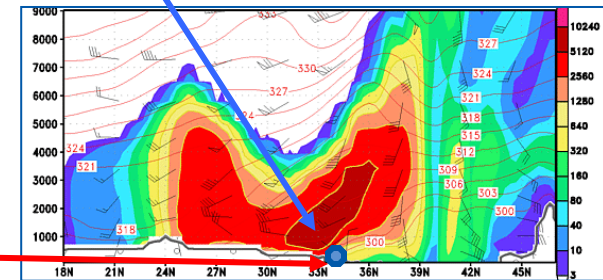
Predicted cross-section dust concentration ( $\mu\text{g m}^{-3}$ )



06 UTC, 7 May 2002 18-hr forecast



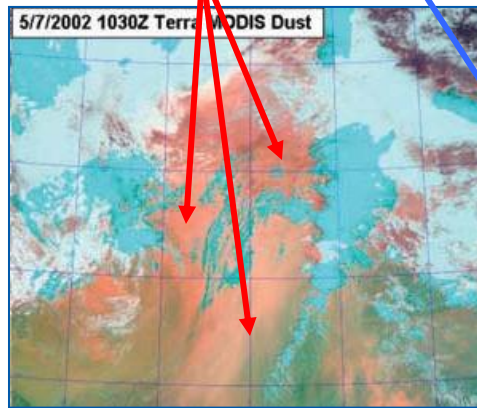
12 UTC, 7 May 2002 24-hr forecast



18 UTC, 7 May 2002 30-hr forecast

- Features of the case:
- Major Mediterranean dust storm
  - Fast moving system
  - More than  $5 \text{ mg m}^{-3}$  in the elevated dust cloud core!

dust



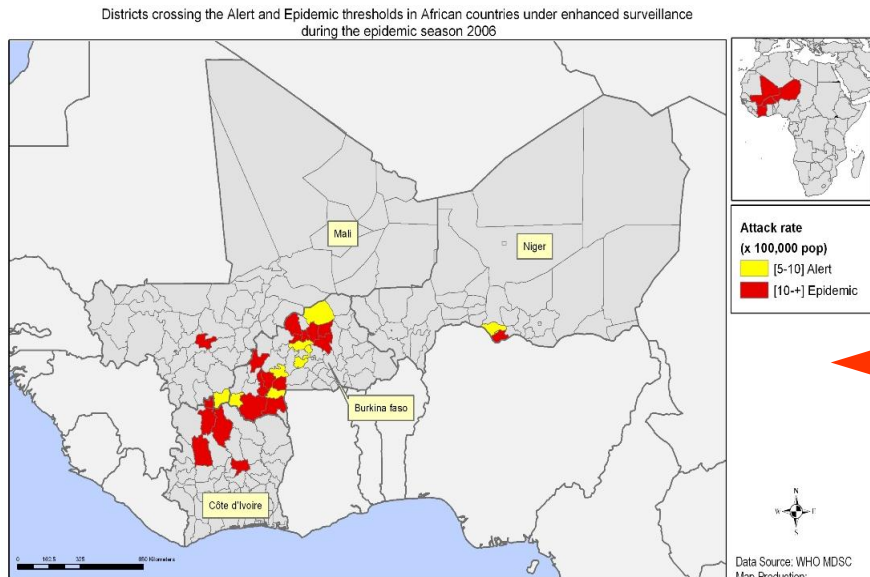
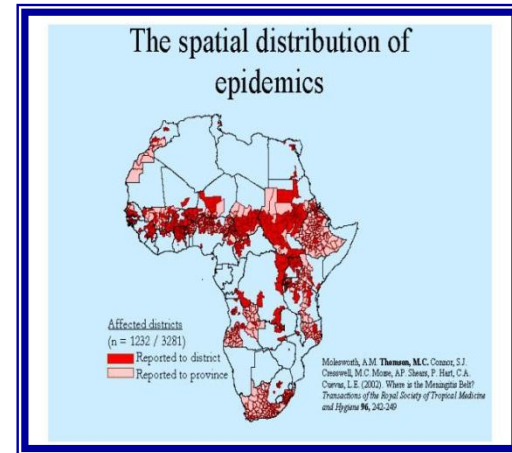
Tunisian dust storm captured by MODIS  
Source: Steven D. Miller, NRL, Monterey

Predictions by DREAM model

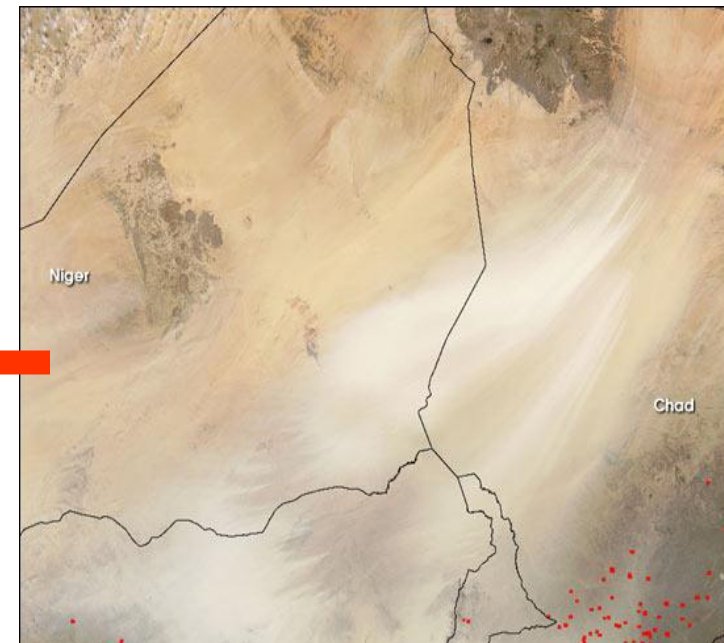
Site of the accident

# 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).



Data Source: WHO MDSC  
 Map Production:  
 Public Health Mapping and GIS  
 Communicable Diseases (CDS)  
 World Health Organization  
 © WHO 2005. All rights reserved



Dust from MODIS

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



The boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted lines on maps represent approximate border lines for which there may not yet be full agreement.

# 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

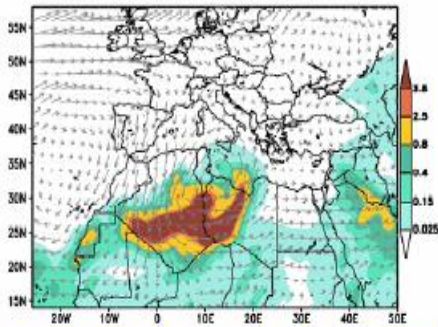
# Refined short-term dust forecasts and dust surveillance in the Sahel region

## Operations

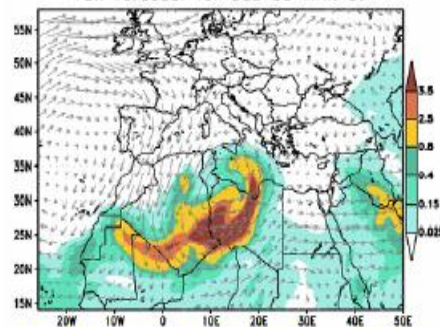
### DUST STORM: 9 MARCH 2007 OVER NORTH AFRICA

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/>

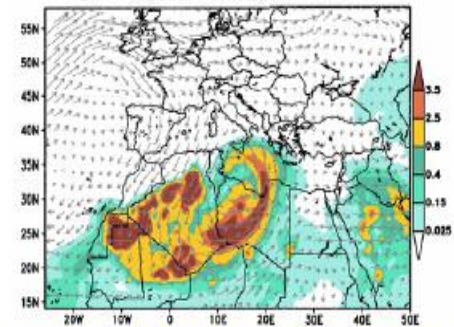
BSC/DREAM Dust Opt. Depth 550nm and 3000m Wind  
12h forecast for 00z 09 MAR 07



BSC/DREAM Dust Opt. Depth 550nm and 3000m Wind  
18h forecast for 06z 09 MAR 07



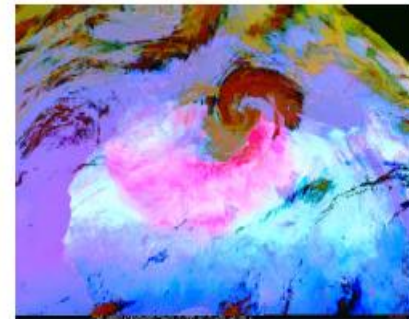
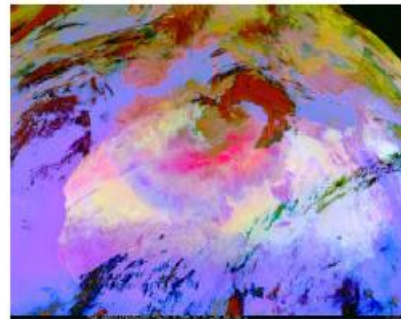
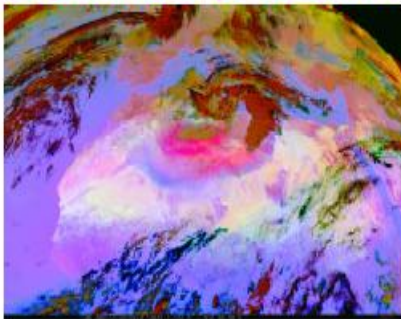
BSC/DREAM Dust Opt. Depth 550nm and 3000m Wind  
24h forecast for 12z 09 MAR 07



Forecasted

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

Dust product – pink colour



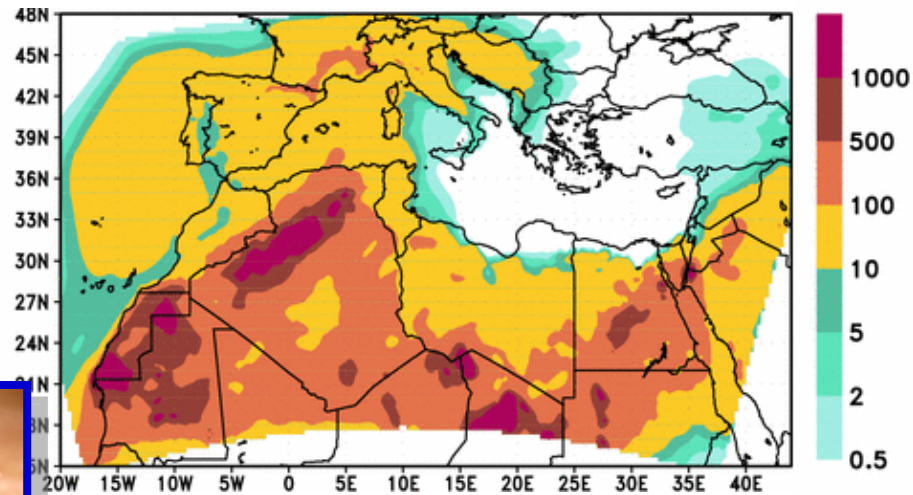
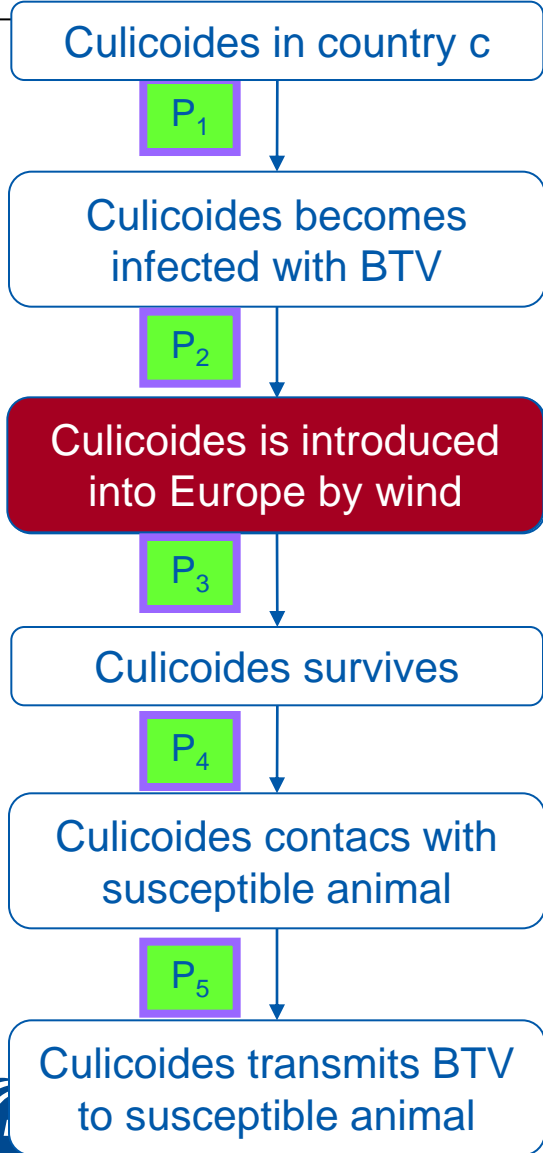
Observed



# Probability of BTV introduction by wind ?

## PATHWAY DIAGRAM

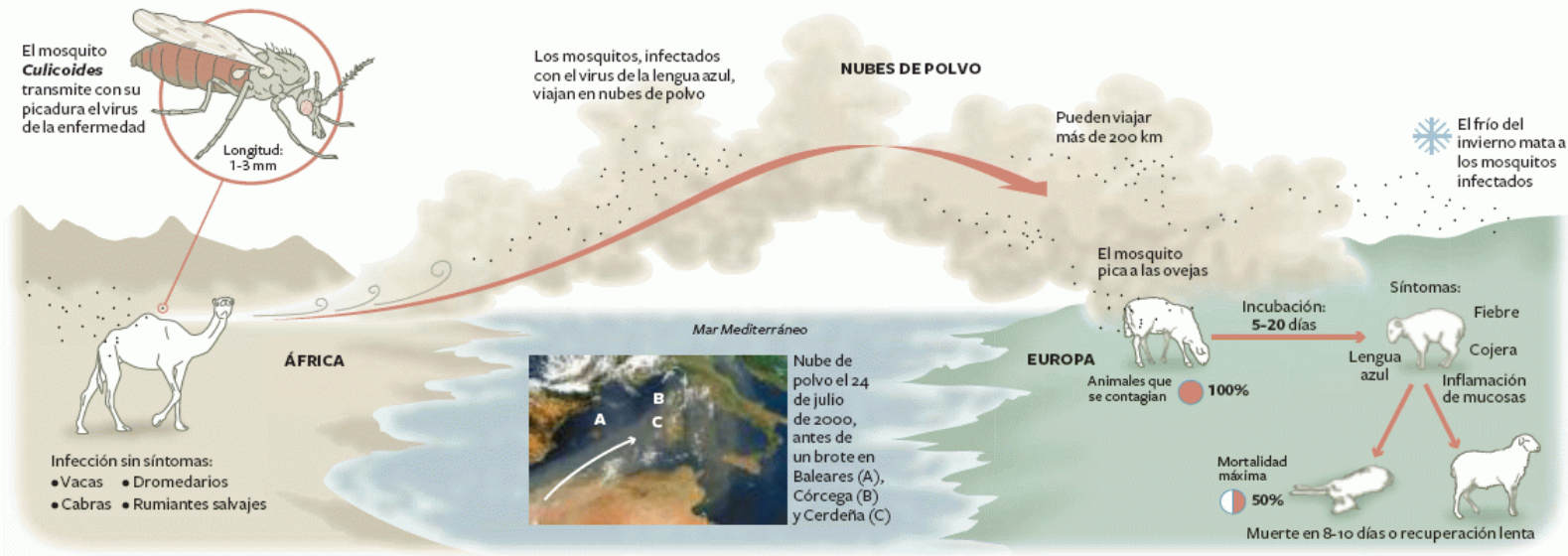
$$P_{ce} = P_1 \times P_2 \times P_3 \times P_4 \times P_5$$



# Regional dust climatology APPLICATIONS: LIVESTOCK

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

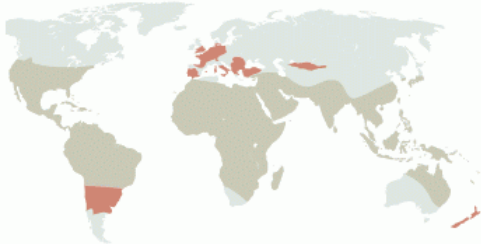
## Transmisión de la lengua azul por el viento



## DISTRIBUCIÓN DEL VIRUS

Los brotes de la enfermedad en Europa se han propagado desde Turquía y el norte de África

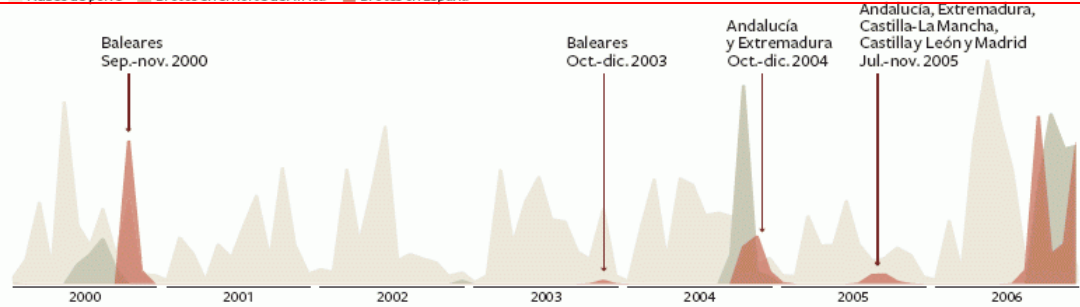
■ Distribución originaria ■ Brotes recientes



## LOS ÚLTIMOS BROTES EN ESPAÑA

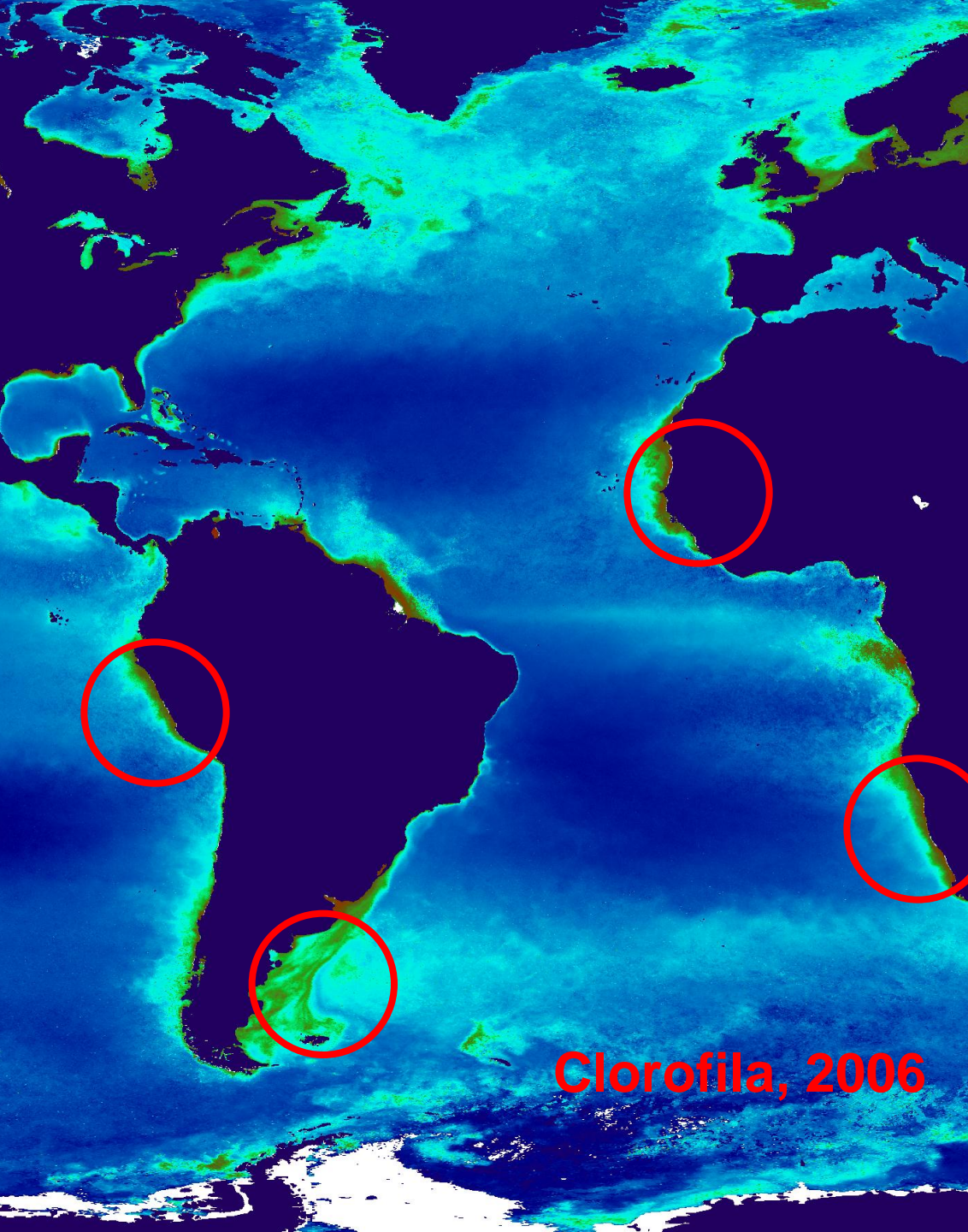
Los brotes en nuestro país vienen precedidos por brotes de la enfermedad en el norte de África o entradas de polvo por vientos del Sur

■ Nubes de polvo ■ Brotes en el norte de África ■ Brotes en España

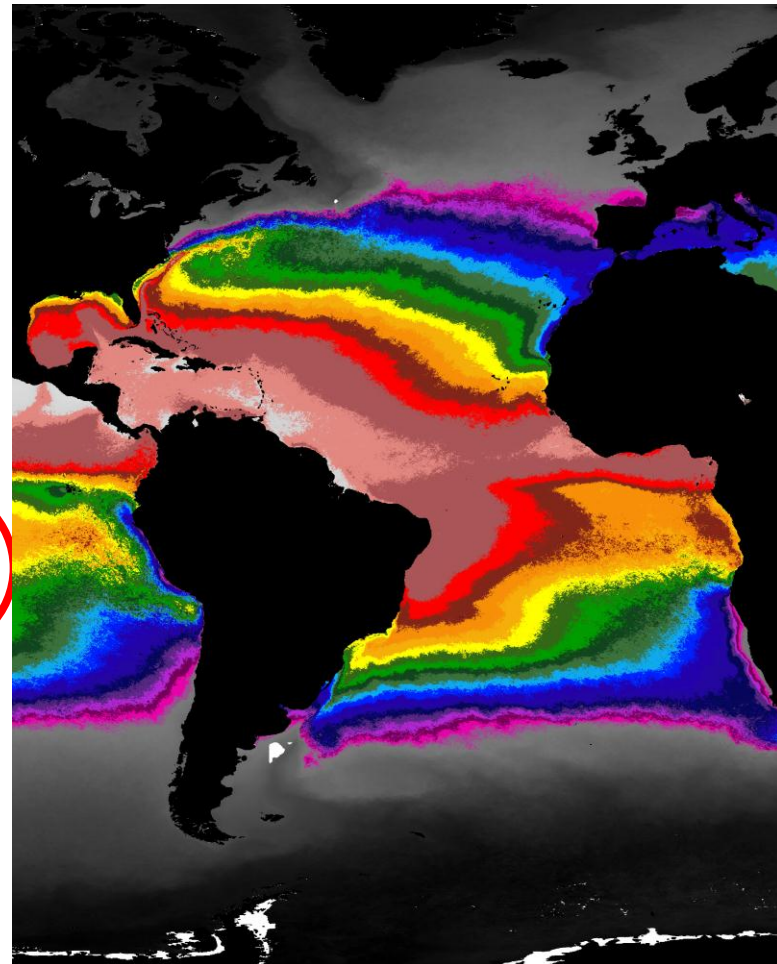


Fuentes: Universidad Complutense de Madrid, Organización Mundial de Sanidad Animal, Ministerio de Medio Ambiente y Medio Rural y Marino, NASA y elaboración propia.

HEBER LONGÁS/EL PAÍS



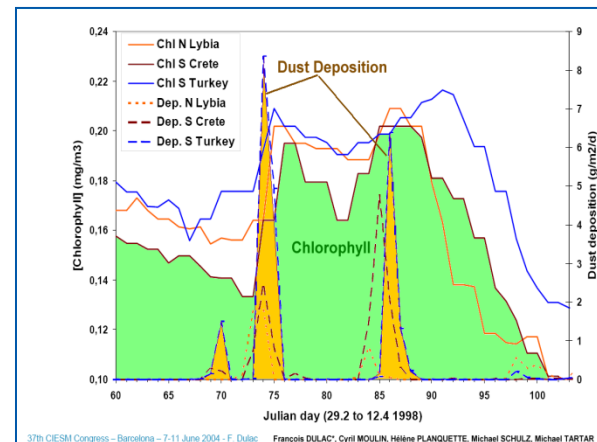
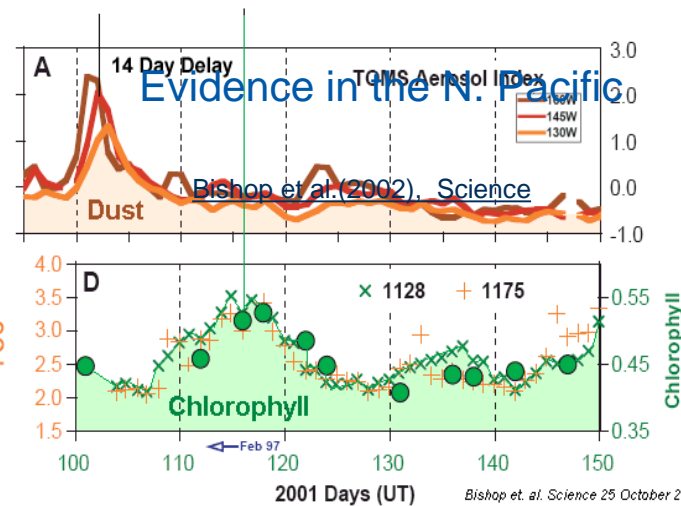
## Sea Surface Temp.



# 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

Oceanic Chlorophyll Stimulation by Atmospheric Dust

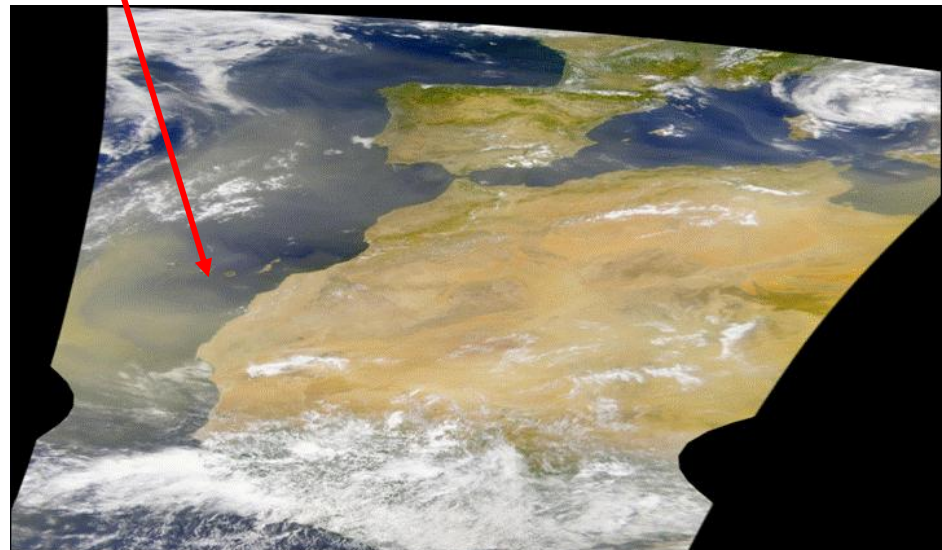


Nutrients in Saharan dust (nitrogen, iron and phosphorus), help to fertilize the huge plankton blooms that occur in the tropical eastern Atlantic

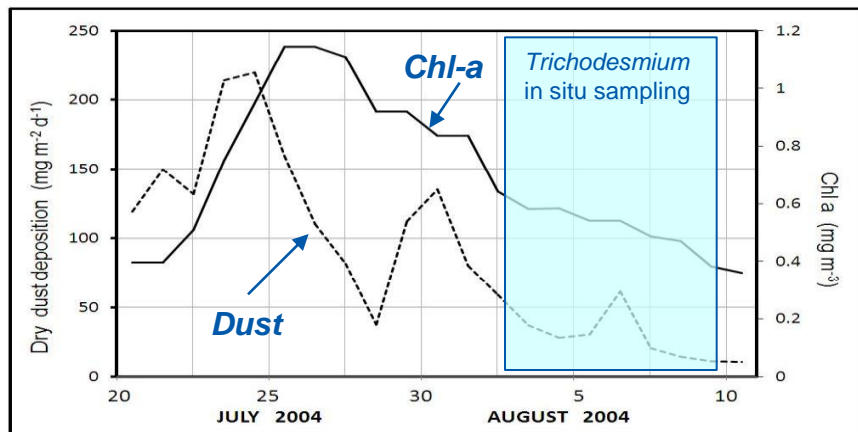


**Canary Islands**

**Bloom of *Trichodesmium* - Canary Islands, August 2004**



**Dust over W Africa, July 2004**

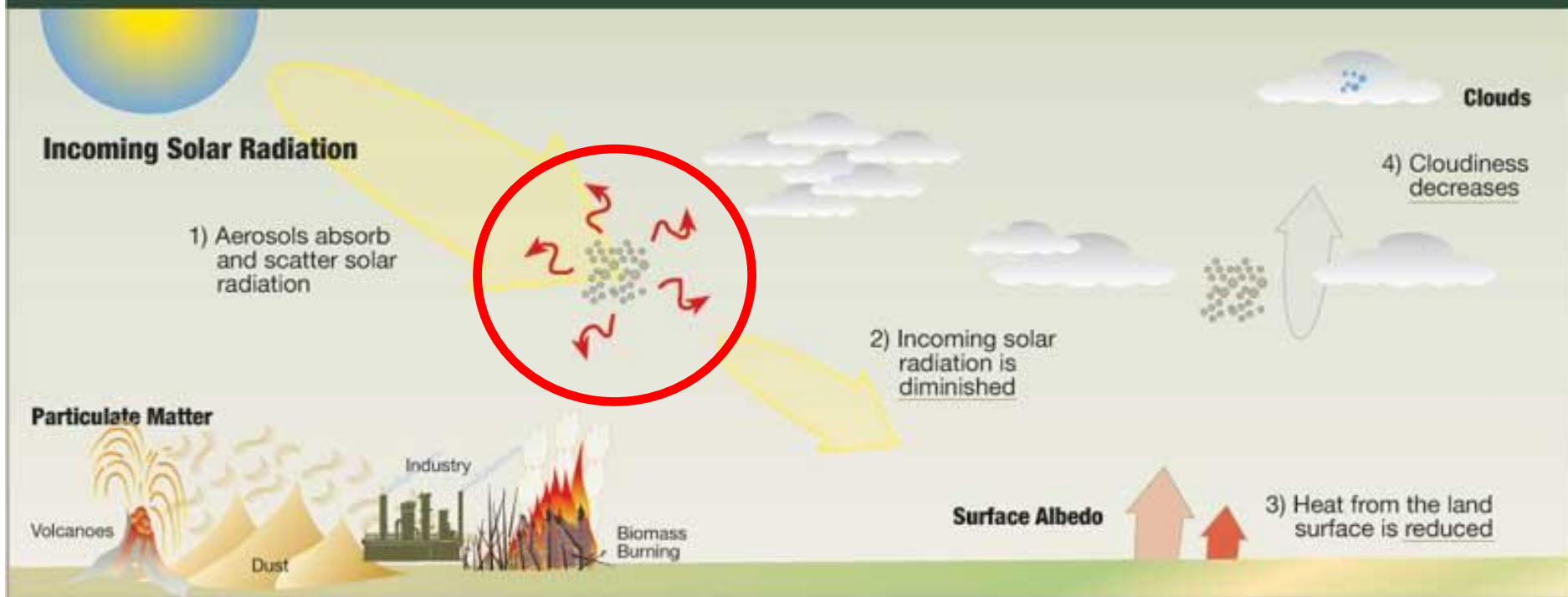


**Chlorophyll-a vs. dry dust deposition (model); no upwelling during the event**

**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**

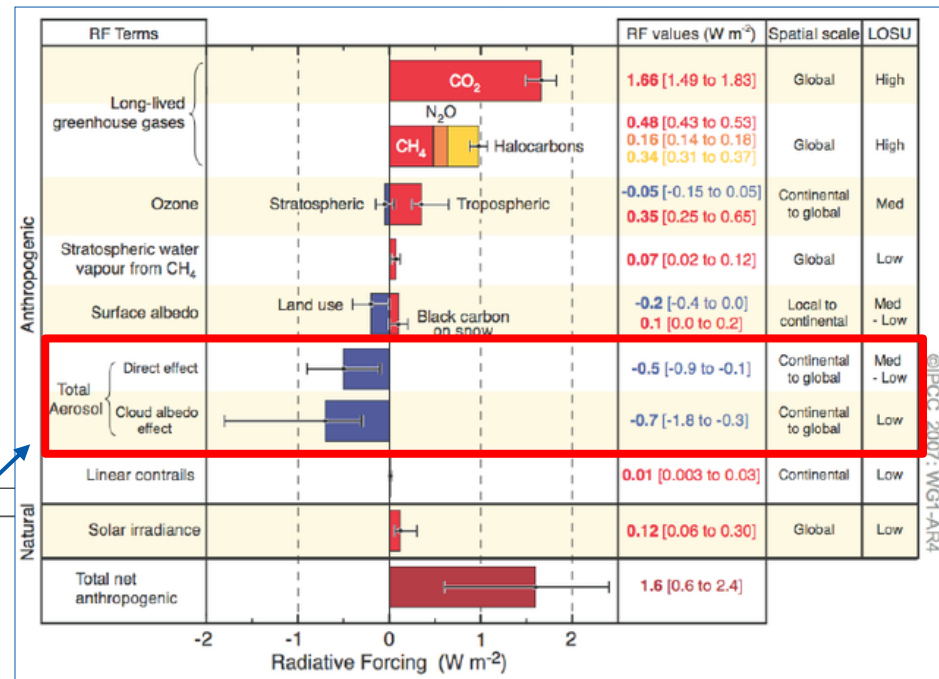
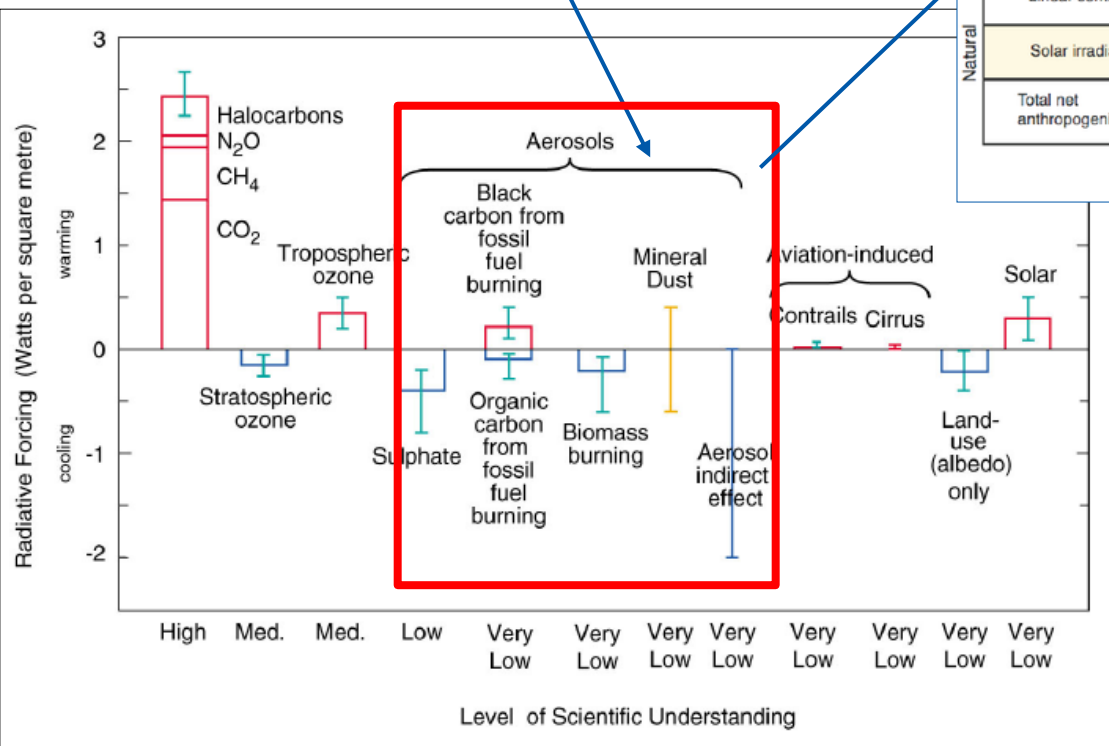
# AEROSOLS → PRESENT CLIMATE CHANGE

## Interactions among Radiation, Absorbing Aerosols, and Cloud Formation



# Radiative effects

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



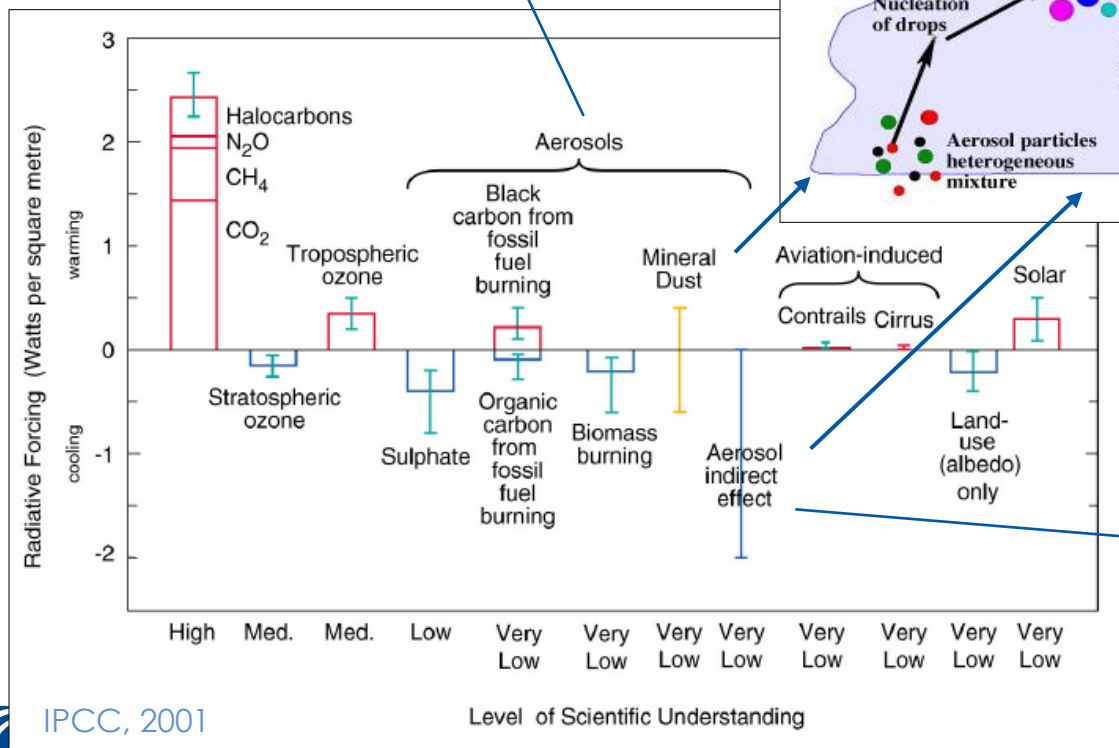
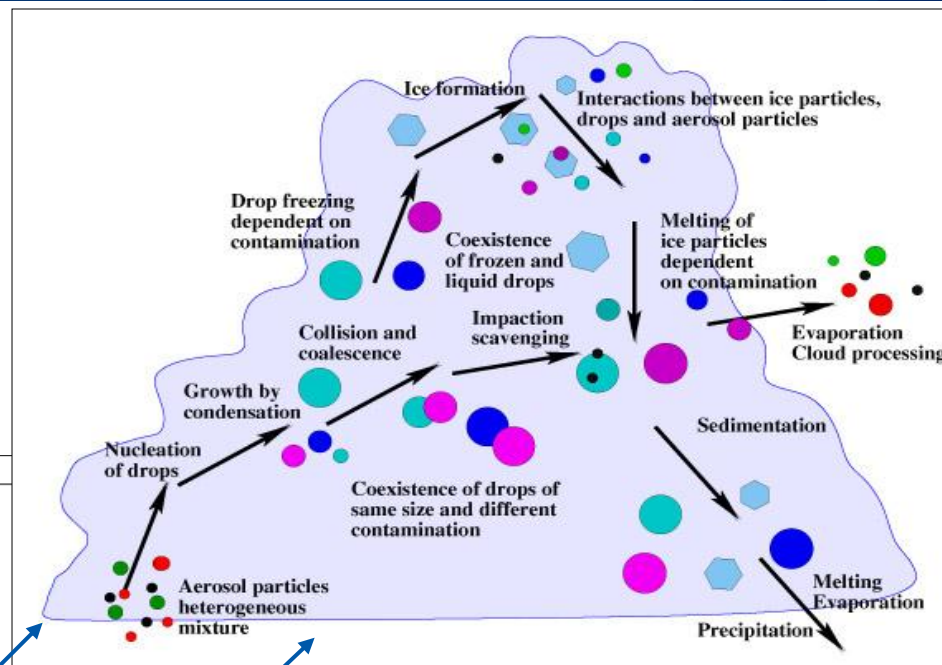
Most recent IPCC report (4<sup>th</sup> assessment) from February 2007

← 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



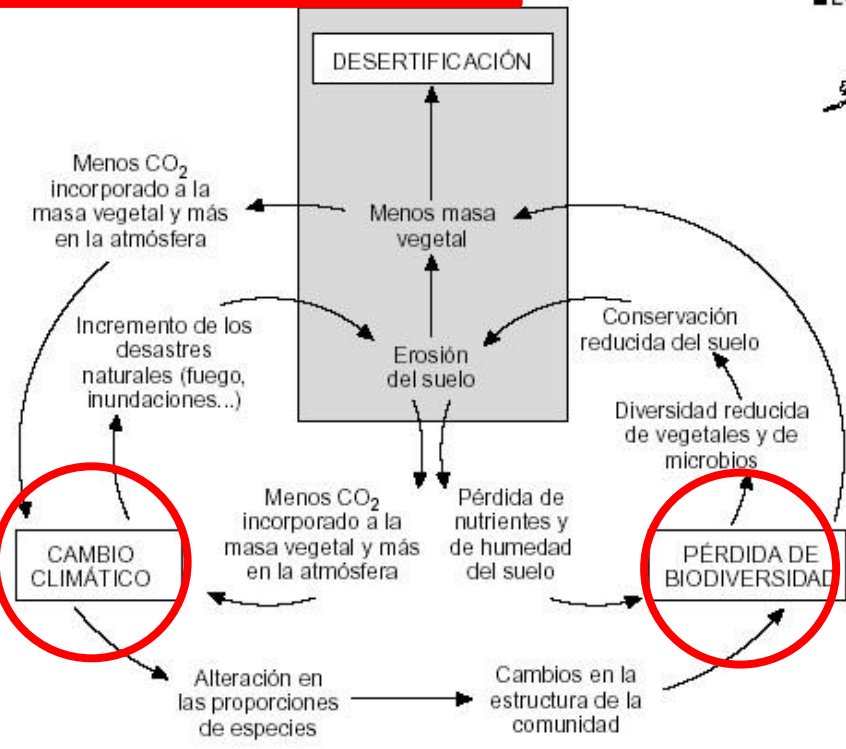
## Indirect radiative effects:

- 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

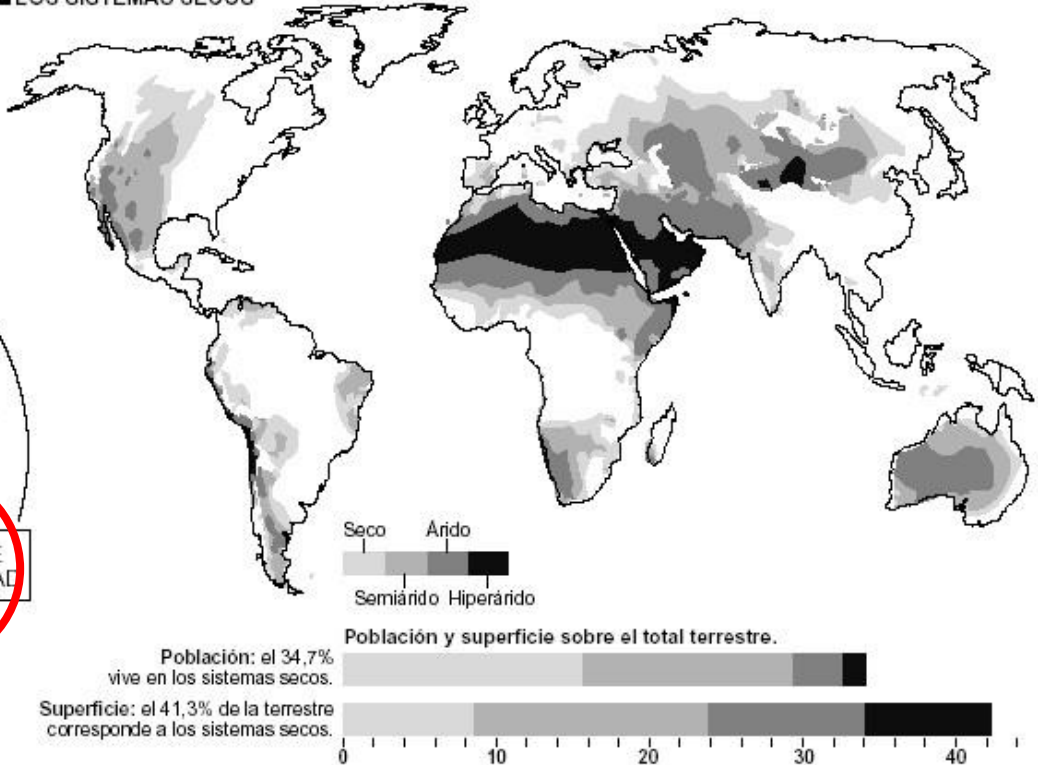


# AEROSOLS → PRESENT CLIMATE CHANGE

## La desertificación en el mundo



### ■ LOS SISTEMAS SECOS

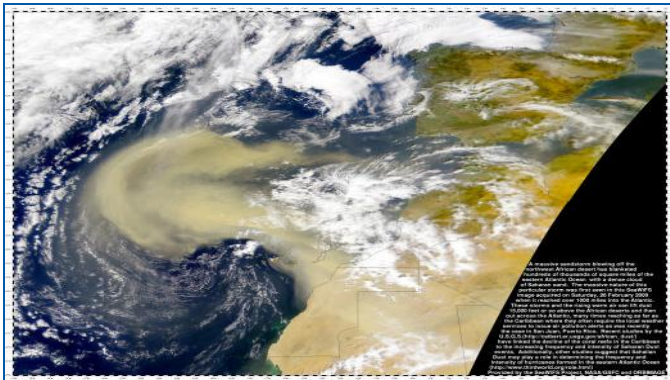
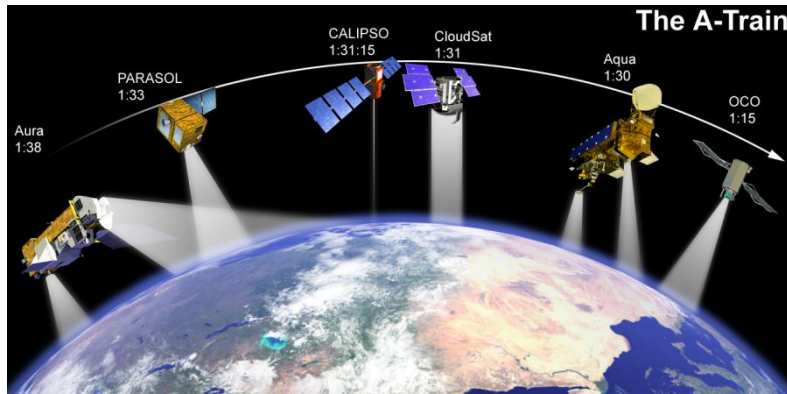


Fuente: ONU

# 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

The screenshot shows the website for the Northern Africa-Middle East-Europe (NA-ME-E) Regional Center of the WMO Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS). The page is titled "Dust forecasts" and lists various models available for comparison. A grid of model thumbnails is displayed, with one model, INCA-LMDzT, marked as "temporarily unavailable".

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

Log in

WMO SDS-WAS | Asia Regional Center

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**Dust forecasts**

You are here: Home > Forecast & Products > Dust forecasts

**Dust forecasts**  
by admin — last modified Oct 15, 2012 04:48 PM

This page allows access to dust forecasts issued by different numerical models. Dust models may have very different characteristics (global or regional, horizontal and vertical resolutions, dust emission and deposition parameterizations, presence or absence of dust assimilation, feedback to the meteorological model, ...). Information on the characteristics and configurations of the models can be found on their respective websites.

**WMO SDS-WAS Regional Center. Compared dust forecasts**

 BSC-DREAM8b	 MACC-ECMWF	 INCA-LMDzT temporarily unavailable
 METEO-FRANCE	 CHIMERE	 SKIRON
 TAU/DREAM-8b	 NAAPS	 DREAM8-SEEVCCC
 U. K. Met Office UM	 TSMS/BSC-DREAM8b	 NASA-GEOS-5
 NMMB/BSC-Dust	 NGAC	

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Dust storm over Alaska  
Oct 31, 2012

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

# WARNING SYSTEMS

## SPAIN:

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CSIC  
AEMET  
CIEMAT

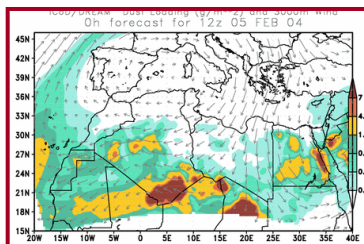
...

Models

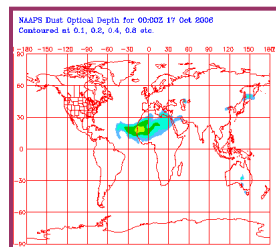


**CALIMA**  
Caracterización de Aerosoles originados por  
Intrusiones de Masas de aire Africanas

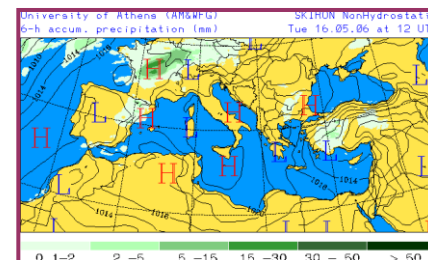
( <http://www.calima.ws> )



BSC-DREAM8b, BSC, España



NAAPS, US Navy, USA



SKIRON, Univ Atenas, Atenas



# ment System (SDS WAS) in on (WMO)

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

by Francisco Benito — last modified May 29, 2012 02:22 PM

**Outstanding**

11 Lectures on Atmospheric Mineral Dust. A few seats are still available

WMO SDS-WAS NA-ME-E Regional Center will be a Regional Specialized Meteorological Center

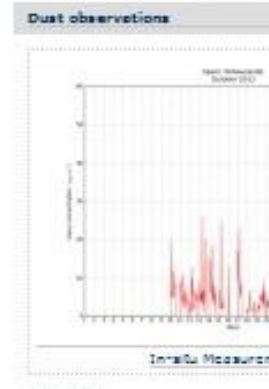
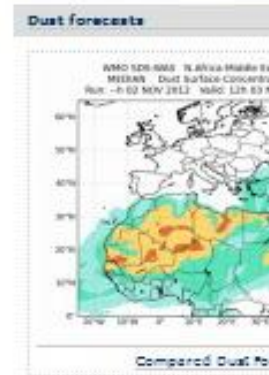
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To be informed about our activities, news and events related to dust, frequency is almost monthly.

Guidance for forecasters

Forecast evaluation

Compared dust forecasts



**Latest News**

Dust storm over Alaska  
Oct 21, 2012

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

Link to NGAC dust forecasts  
Oct 16, 2012

**Upcoming Events**

3rd CLARIME International Workshop  
Nov 05, 2012 - Nov 08, 2012 - Cargèse, France

11 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
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4	5	6	7	8	9	10
11	12	13	14	15	16	17
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### EVENTS & PROGRAMS

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## Dust Storm Forecasting and a Pan-American Sand and Dust Storm System Center

March 5, 2012  
**Professor William Sprigg**  
 Chapman University; University of Arizona



#### About This Lecture

Advances in forecasting arid-region dust events have evolved in the past decade, thanks to radical improvements in atmospheric modeling and remote sensing. In addition, the implications of airborne dust for weather, climate and human health are better appreciated. The role of climate is significant and sets limits for environmental health risk. NASA-sponsored studies within the Applied Science Program have led to quasi-operational dust storm forecasts and simulations for the U.S. Southwest. A somewhat shaky bridge now links airborne dust research to health services. These and other capabilities are culminating in a Pan-American Center for the World Meteorological Organization's (WMO's) Sand and Dust Storm System. The Pan-Am Center will join centers for Asia and Africa/the Middle-East/the Mediterranean to provide global coverage to the WMO program. The three centers are nodes for contributing data, knowledge and tools to advance science and to speed up and expand applications in this area.

[download presentation slides](#)



#### About Professor William Sprigg

Professor William Sprigg holds degrees in atmospheric sciences from Yale University (M.Phil. and Ph.D.),



establish and improve  
the impact of Sand and

and Dust Storm



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November 2012						
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## Northern Africa-Middle East-Europe (NA-ME-E) Regional Center

by Francisco Bernuzzi — last modified May 29, 2012 02:22 PM

### Outstanding

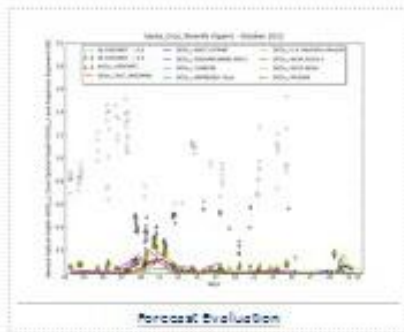
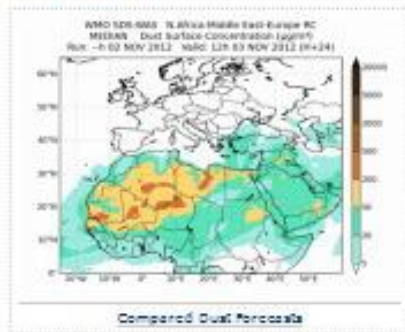
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- WMO SDS-WAS NA-ME-E Regional Center will be a Regional Specialized Meteorological Center
- Guidance for forecasters
- Forecast evaluation
- Compared dust forecasts

### Subscribe to the Public Newsletter!

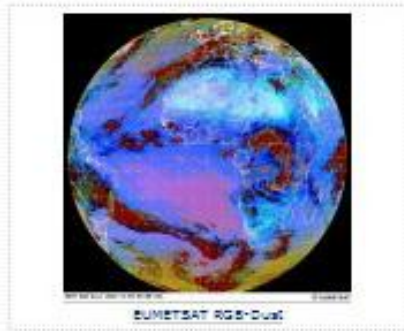
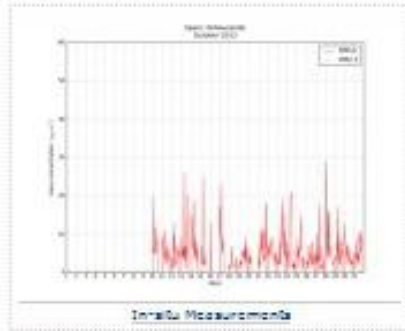
To be informed about our activities, news and events related to dust. Frequency is almost monthly.




### Dust forecasts



### Dust observations



# Thank you for your attention !!!!



Kuwait 20080616

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