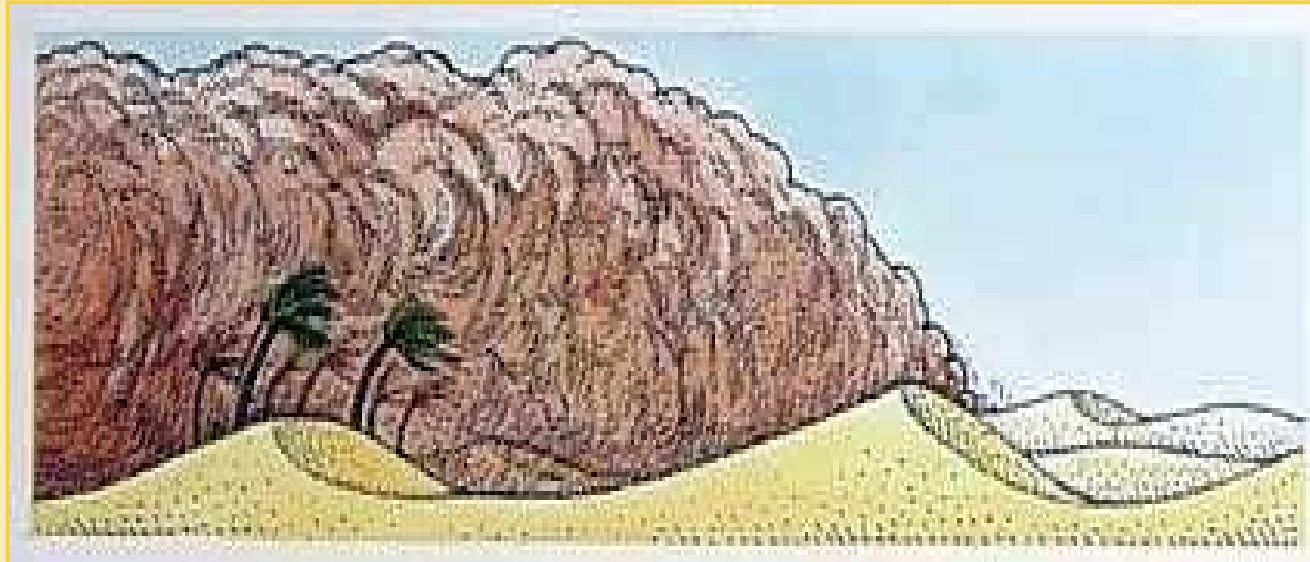


A Global View of Atmospheric Sand and Dust: Occurrence, Prediction and Impacts



Leonard Barrie, Director LBarrie@wmo.int

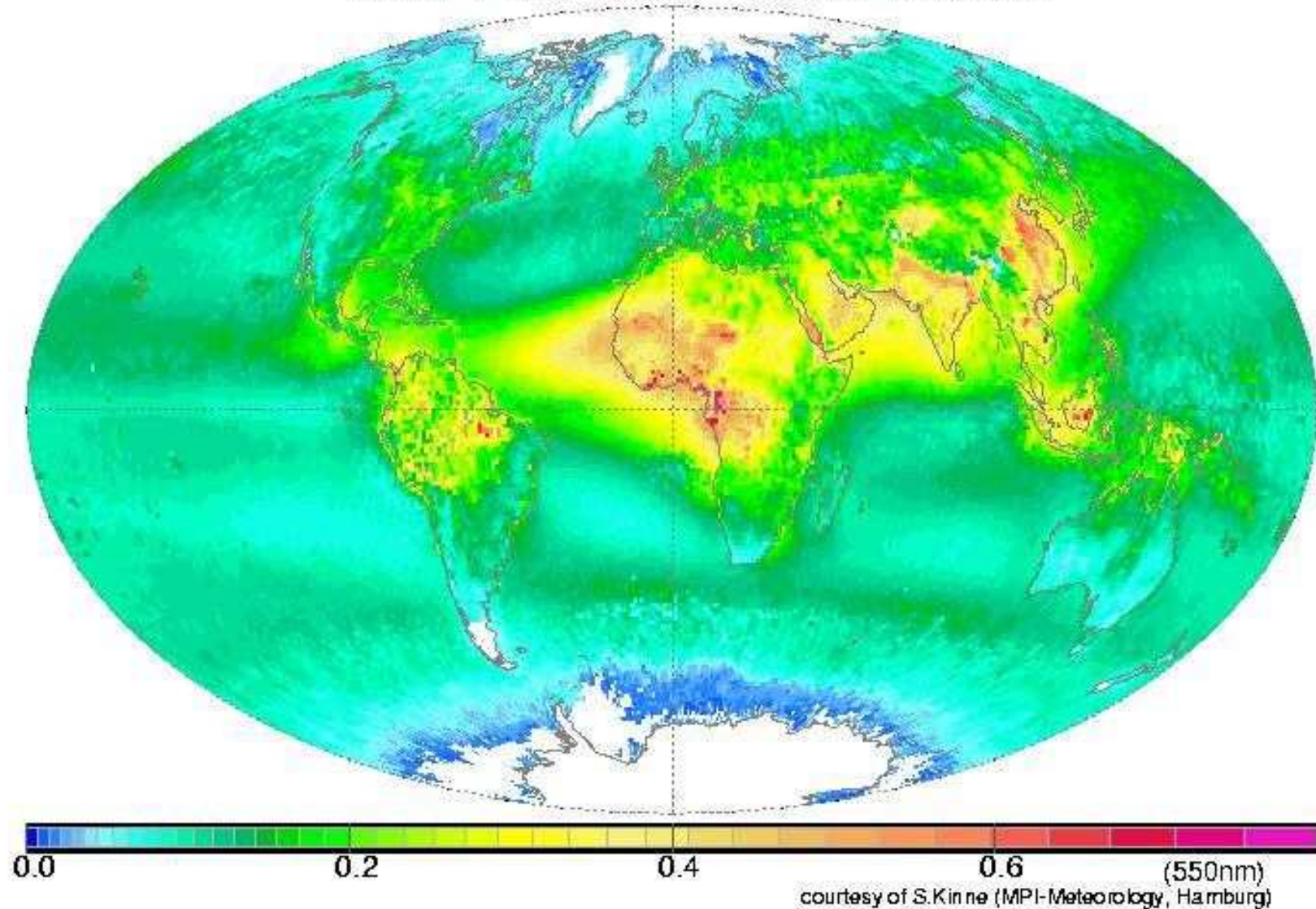
Slobodan Nickovic, Scientific Officer, snickovic@wmo.int

Research Department

World Meteorological Organization Geneva

Lectures On Atmospheric Mineral Dust and Its Impacts, 13 Nov 10 Barcelona

SATELLITE COMPOSITE of AOD



A best estimate of the global distribution of annual average tropospheric aerosol optical depth (AOD) compiled by combining data from six satellites (operating for limited periods between 1979 and 2004). Observations for a region were selected using ground-based AOD observations as guidance (courtesy of S. Kinne MPI, Hamburg, Germany).

Kaufman et al.
J. Geophys. Res., 110, 2005

10 JUN 2004

MODIS

TERRA

+

AQUA

fine fraction [-]

1.0
0.5
0.0

0.0

0.2

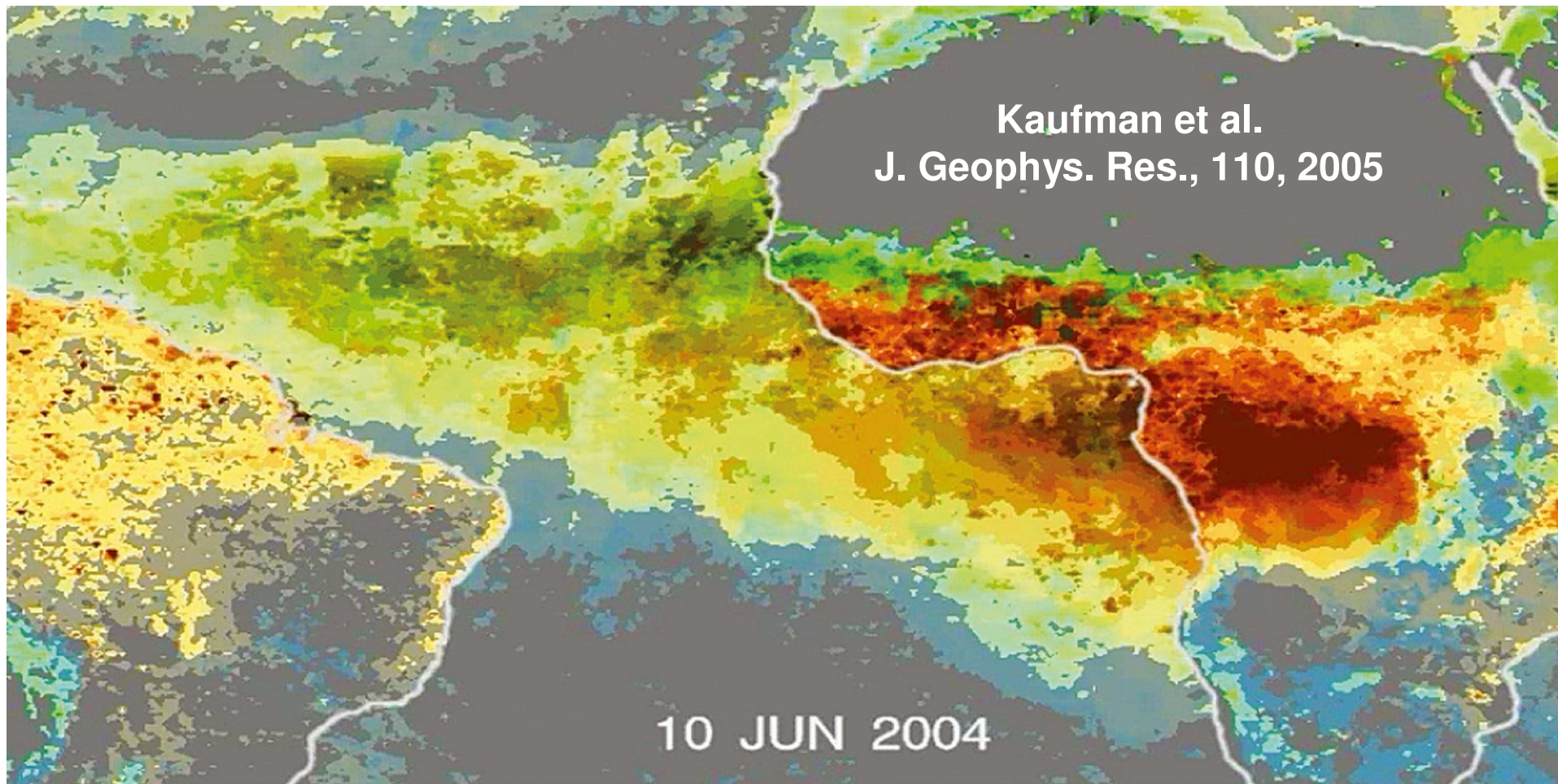
0.4

0.6

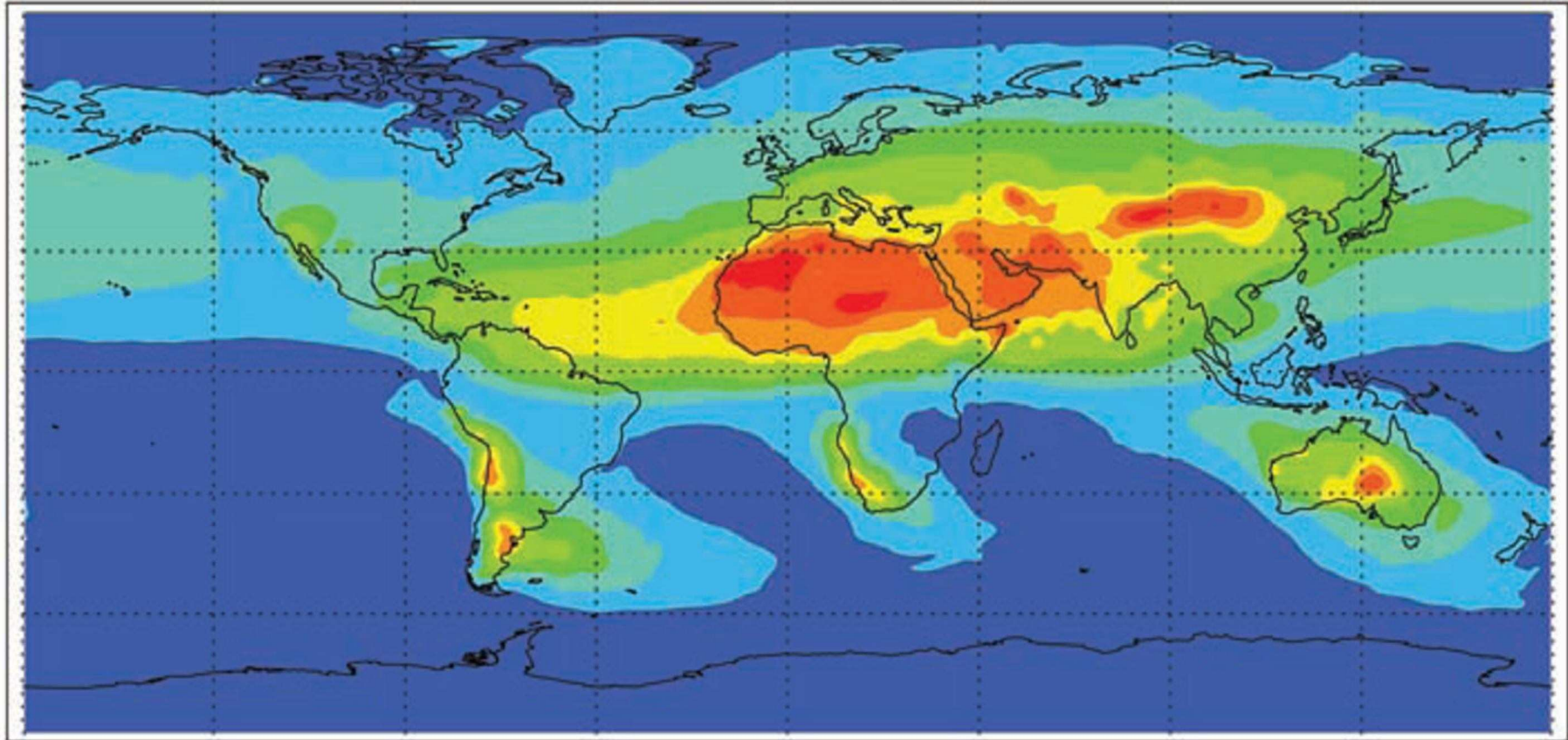
0.8

1.0

aerosol optical depth [-]



Average dust deposition ($\text{g}/\text{m}^2/\text{year}$)



Composite of three published modeling studies that match satellite optical depth, in situ concentration, and deposition observations.

Jickells et al, 2005, Science, Review, Global Iron Connections Between Desert Dust, Ocean Biogeochemistry, And Climate Vol 308 67-71

An Important Component of this Average Distribution of Aerosol are Sand and Dust Storms



A Chinese farmer walks amid a heavy sand storm in Minqin County, northwest of China's Gansu Province. Sand covered about one-eighth of China from April 14 to 18, 2006 and about 330,000 tons of sand fell in Beijing on Sunday night April 10.

SDS Impacts

- Human Health
(Asthma, infections, Meningitis in Africa, Valley Fever in the America's)
- Agriculture (negative & positive impacts)
- Marine productivity
- Improved Weather and Seasonal Climate Prediction
- Aviation (air disasters)
- Ground Transportation
- Industry (Semi-conductor, etc, etc)



SDS Impacts on Respiratory Health: Africa

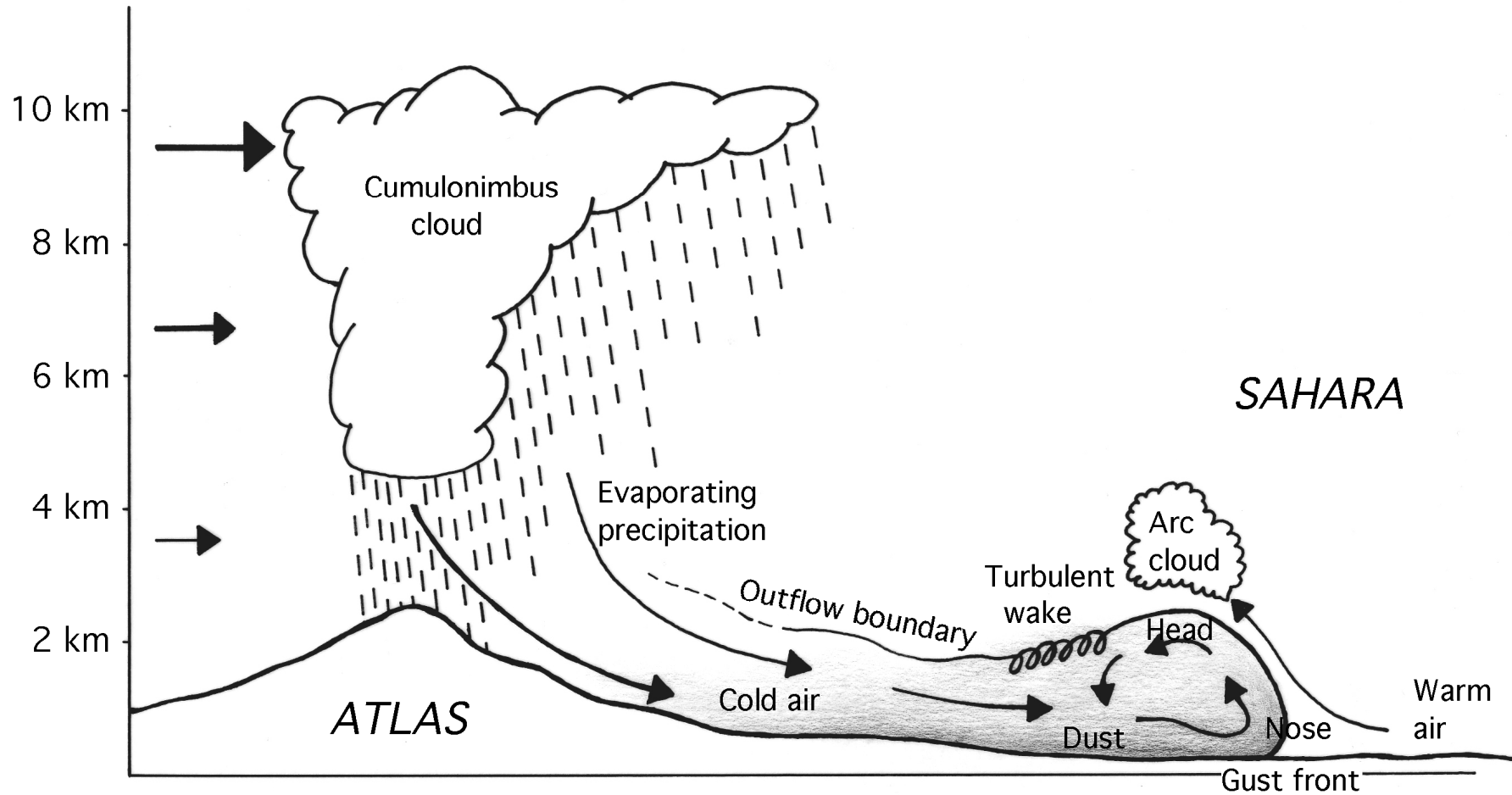
Mali Dust Storm



- Acute respiratory infections among children are one of the major causes of mortality in developing countries, especially in Africa
- Little is known of the effects of dust in Africa. For instance, 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.

(P. Ozer et al , *Water Air Soil Pollution* (2006) 178:79–87)

DUST IS OFTEN PRODUCED BY COLD POOLS ASSOCIATED WITH STRONG CONVECTION

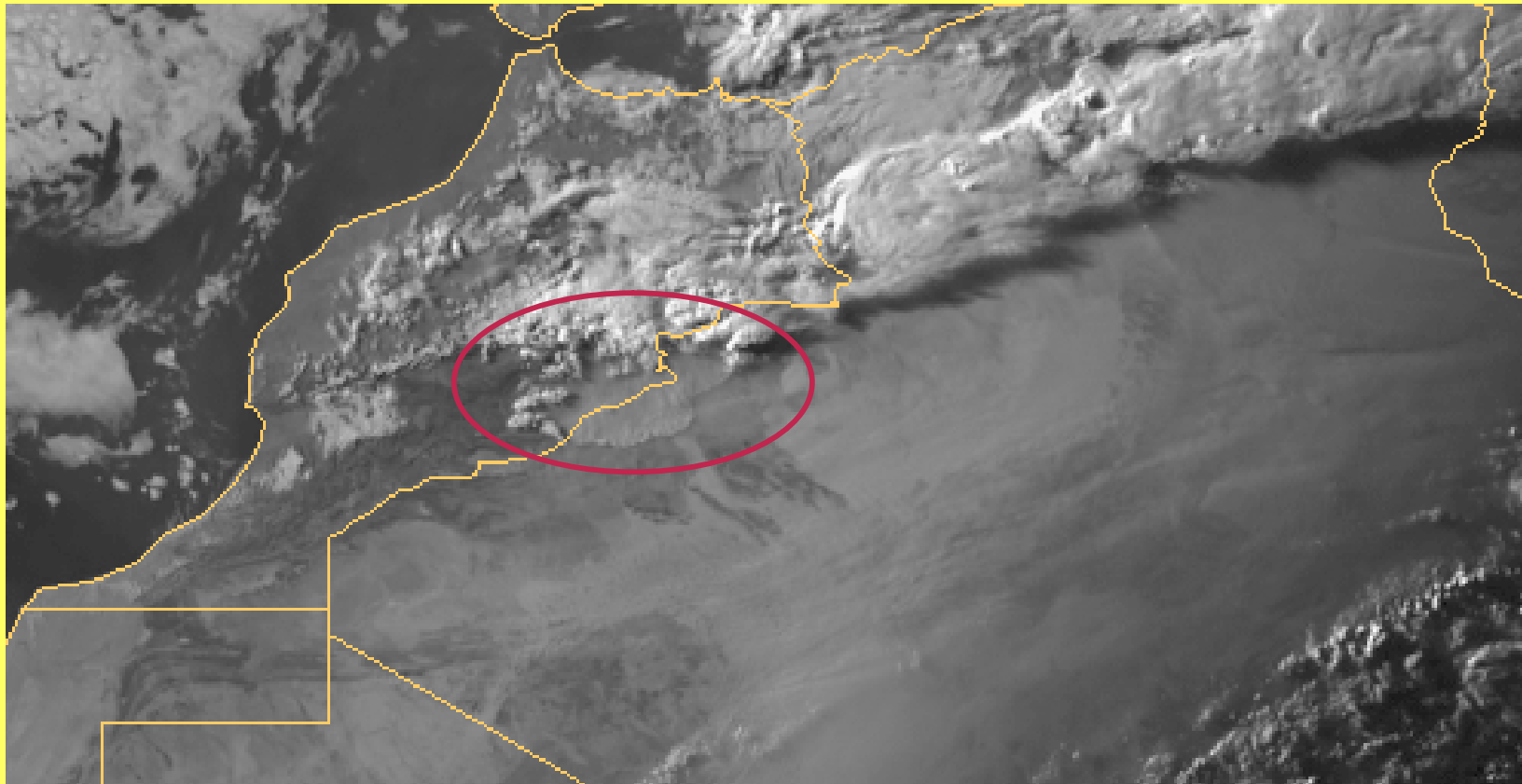


from Knippertz et al., JGR, 2007

SATellite VIEW

Meteosat VIS image

31 May 2006 1800 UTC



from Peter Knippertz *et al.*, *JGR*, 2007

CONCLUSIONS

- Atmospheric density currents (DCs) are caused by **evaporating precipitation**. They produce severe winds, mobilize dust & organize moist convection.
- The Sahara is frequently affected by **convective** DCs in summer and **cold frontal** DCs in winter.
- Numerical **simulations** of DCs require a high resolution and are sensitive to microphysical and boundary layer parameterizations.
- There are still deficits in the observation, operational analysis, forecast and physical **understanding** of atmospheric DCs.

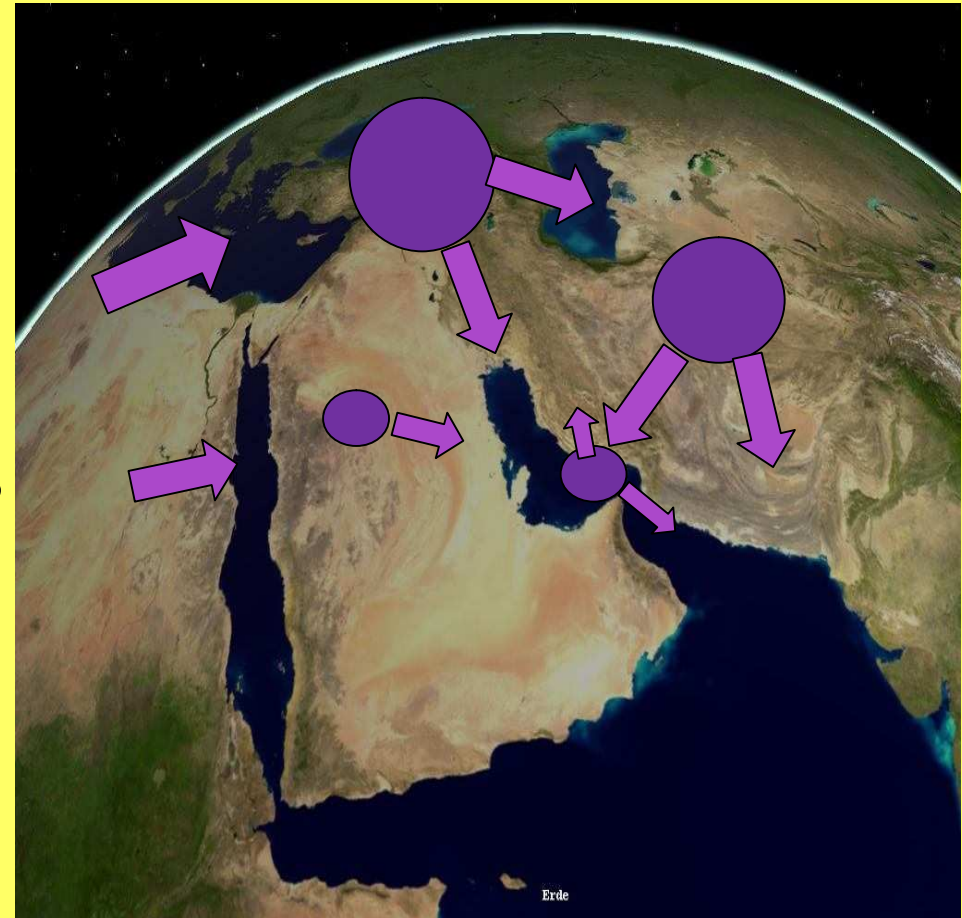


Kuwait 20080616

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

Main Dust sources Affecting Arabian Peninsula

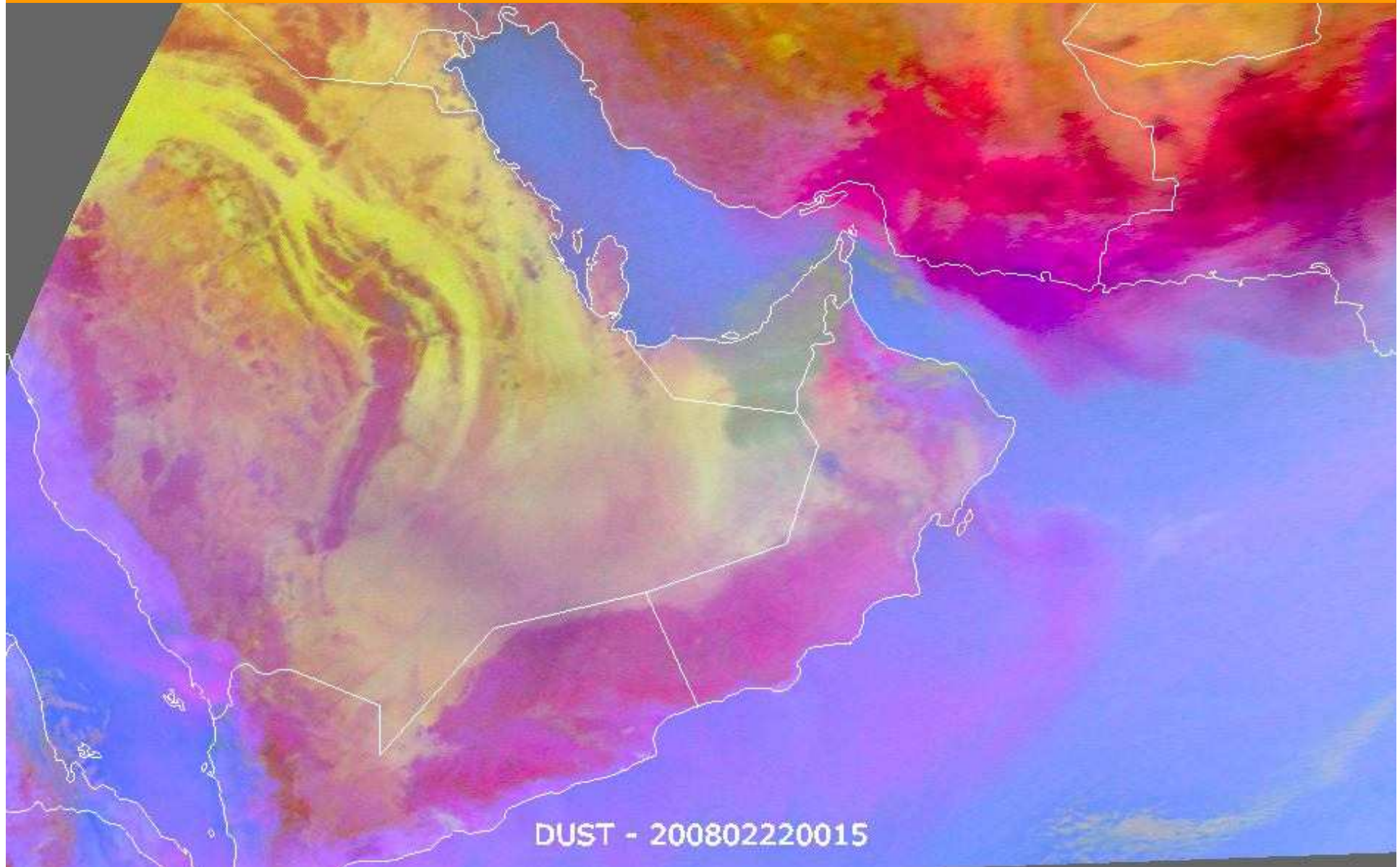
- Tigris and Euphrates rivers basin
- Sistan Basin
- East of Alhejaz Mountains
- Southwest Alhajar Mountains
- Africa



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

Sistan Basin Dust In The Arabian Peninsula

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



ACU-Weather Report

- The first big dust storm of the season shrouded Beijing in orange grit Saturday 20 March 2010. Strong winds blowing across the Gobi desert deposited sand across the Chinese capitol.
- Visibility was reduced to a few hundred yards in Beijing. Winds gusted to 46 mph. Winds just west of Beijing were clocked at 62 mph.





**Hard to Breathe: Friday, March 19, 2010,
Lanzhou in northwest China's Gansu Province**



Beijing China, Saturday, March 20, 2010.

Dust Hits Korea

20-21 March 2010 Korean Times Article

- **The Korean Peninsula experienced its worst case of yellow dust ever recorded leading the Korea Meteorological Administration (KMA) to post a special yellow dust warning for most parts of the country Saturday.**
- **The dust in the air marked 2,684 micrograms per cubic meter in Daegu; 2,408 micrograms in Jindo, South Jeolla Province; and 1,048 micrograms in Sokcho, Gangwon Province. These are the worst figures since the KMA started taking dust density measurements in 2005.**
- **The KMA issues a yellow dust watch when the level of PM10 is 400 micrograms per cubic meter or more for two hours or longer. It issues a yellow dust warning when the level is 800 micrograms per cubic meter or more for two hours or longer. The KMA posted its first such warning in 2007.**
- **The agency asked people to take precautionary measures when going outdoors Dust storms are said to cause or worsen conjunctivitis, respiratory disorders, allergic rhinitis and various forms of eczema.**

Dust In Seoul Korea

20 March 2010



Dust Hits Taiwan

21 March 2010

- The worst-ever dust storms from China forced air quality in Northern Taiwan sharply down Sunday, the Environmental Protection Administration said.
- A total of 24 observation stations across the island recorded more than 1,000 micrograms of dust per cubic meter and a further ten showed values at damaging levels, according to the EPA. Skies turned a yellowish grey as there was no rain to wash away the dust, the Central Weather Bureau said.
- The worst levels of pollution were recorded on the island of Matsu close to the coast of China's Fujian Province, in Keelung on the North Coast and in several Taipei City districts, EPA official Chu Yu-chi said.
- Doctors advised people to limit outside activities to the barest minimum, and to wear masks or even goggles when riding a motorcycle. Patients suffering from breathing problems even before the storm should wait a few days until after it had left before resuming normal outside activities, reports said.
- The number of patients recording breathing problems increased by 20 percent to 30 percent because of irritation by the dust, reports said. People wearing contact lenses felt irritation of the eyes, according to media reports quoting physicians.
- The dust storms combined with a cold front to cut temperatures by 7 degrees, the bureau said.

Dust In Iran 20-24 Feb 2010



MEHR

Dust In Iran 20-24 Feb 2010

“Iran Times”

- Lorestan province has seen more than 100 days of air dust pollution over the past year inflicting an estimated 9 million dollars worth of damage on various sectors of its economy.
- Water dependent sectors and **beekeepers** are believed to have been among the worst hit by the recurring dust storms.
- The meteorology experts have cautioned that the provincial air pollution has risen over 14 times above the normal air quality index.
- The provincial environment director has warned people, especially children and the elderly, not to leave their homes if it is not necessary. Experts warn the exposure to the air dust pollution is particularly dangerous for children, the elderly and those with cardiovascular and respiratory conditions.
- The Kordestan province governor general commented on the unpredictability of the phenomena. “One of the most important issues regarding the air (dust) pollution is that we can not predict when it ends,” and that makes planning for schools and offices increasingly difficult, he noted.
- They urge people not to leave their homes unless it is necessary and that they should wear masks if they go outdoors

Red sand and dust storm hits Australia

- The east coast of Australia including Sydney was hit yesterday by a vast red sand and dust storm originating from interior Australia. According to the Australian Bureau of Meteorology, a cold front in New South Wales caused severe thunderstorms and gale-force winds, whipping up the dust from a drought stricken part of Australia, bringing air traffic to a halt and obscuring the famous Sydney opera house from view. The storm also disrupted ferry and automobile transport and caused a large increase in incidences of asthma and other respiratory problems. It also stripped soil from agricultural areas inland and deposited it in the coastal ocean.
- “The reported level of suspended particulate mass (PM10) in highly populated Sydney was around 1000 times higher than on a clear day” said WMO Expert Len Barrie. “It is fifty times higher than the well established level beyond which impacts on human health are known to occur. Sand and dust storms of such intensity are often seen in other parts of the world particularly in Asia and Northern Africa. The dust is transported well beyond the continental source regions across oceans to other continents and plays an important role in weather, climate, ocean ecosystems and human health”

Sydney Harbor Opera House



School Absentees In Texas Increase After A Dust Storm

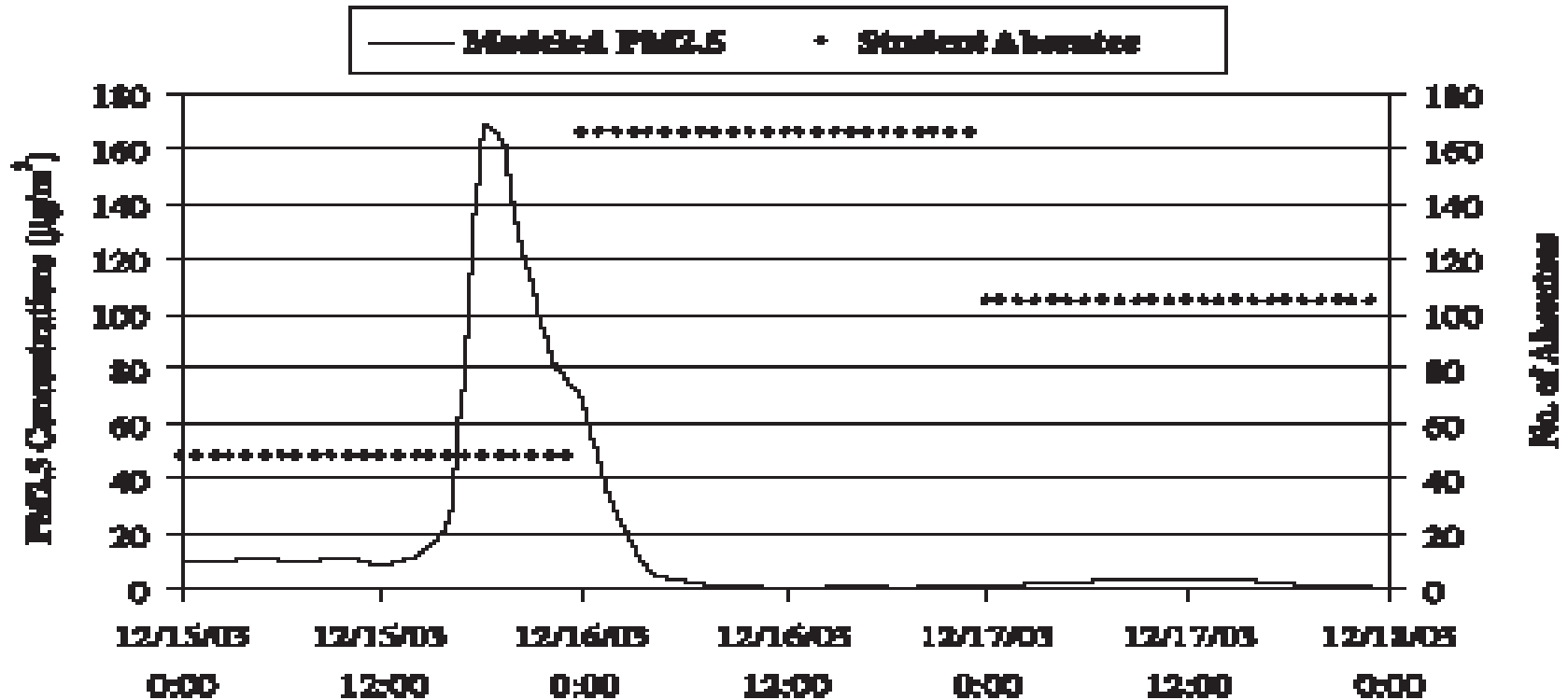


Fig. 18. PM2.5 hourly concentrations and daily number of student absentees at Lubbock, Texas.

Dust PM 2.5 predicted by Univ. Arizona model and student absentees, Lubbock, Texas; Yin et al, 2005

Estimating the Health Impacts of Intercontinental Transport of Aerosols



Denise Mauzerall
Princeton University

National Research Council
October 20, 2008

Intercontinental transport of fine aerosols and their global impact on premature mortality

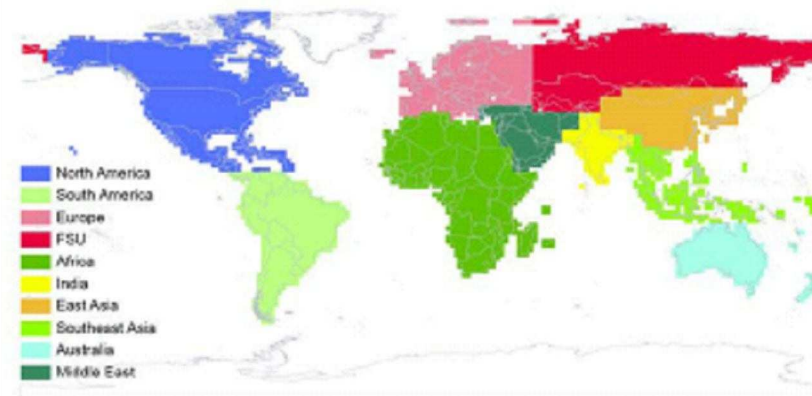
- What is the extent of inter-continental transport of aerosols?
- How large are the health impacts?

Junfeng Liu, D.L. Mauzerall, L.W. Horowitz, P. Ginoux, A.M. Fiore, Evaluating inter-continental transport of fine aerosols: (1) methodology, global aerosol distribution and optical health, in preparation.

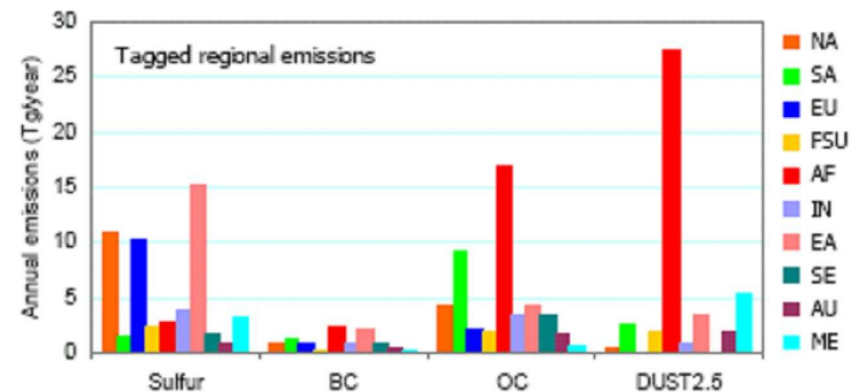
Junfeng Liu, D.L. Mauzerall, L.W. Horowitz, Evaluating inter-continental transport of fine aerosols: (2) Global health impacts, in preparation.

Tagged aerosol tracers

Tracers	10 regional tracers	ROW tracer	Other tracer
SO ₂	Anthro.	bb+ship+volcano	DMS
SO ₄	Anthro.	bb+ship+volcano	DMS
BC1/2	Anthro.+bb	ship+volcano	
OC1/2	Anthro.+bb	ship+volcano	
Dust1 (0.2 - 2.0 μm)	natural	natural	
Dust2 (2.0 - 3.6 μm)	natural	natural	
Dust3 (3.6 - 6.0 μm)	natural	natural	
Dust4 (6.0 - 12 μm)	natural	natural	
Dust5 (12 - 20 μm)	natural	natural	



Ten tagged continental regions



2000 emissions from ten regions

Courtesy Prof. Denise Mauzerall Princeton University

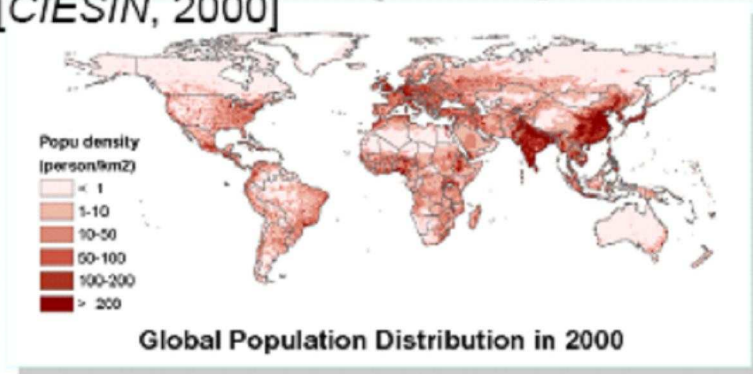
Adult Premature Mortality

[Pope, 2002]

$$\Delta \text{Deaths} = \text{POP} \cdot F_{30+} \cdot I_{\text{ref}30+} \cdot \Delta c \cdot \gamma$$

Each 10 $\mu\text{g}/\text{m}^3$ elevation in PM2.5 is associated with ~4% increase in adult mortality risk.

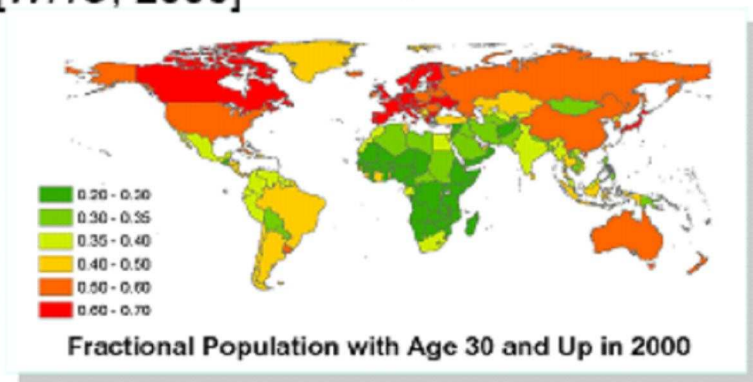
[CIESIN, 2000]



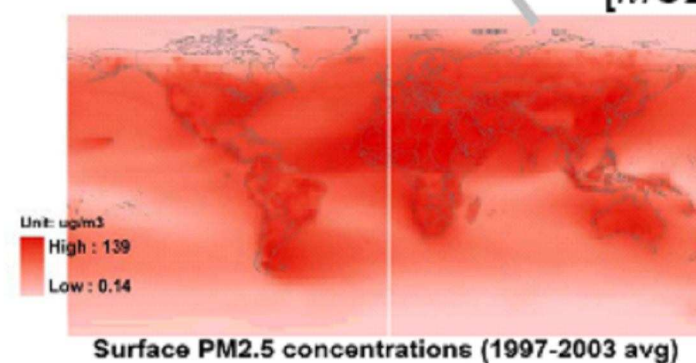
[WHO, 2000]



[WHO, 2000]



[MOZART2]

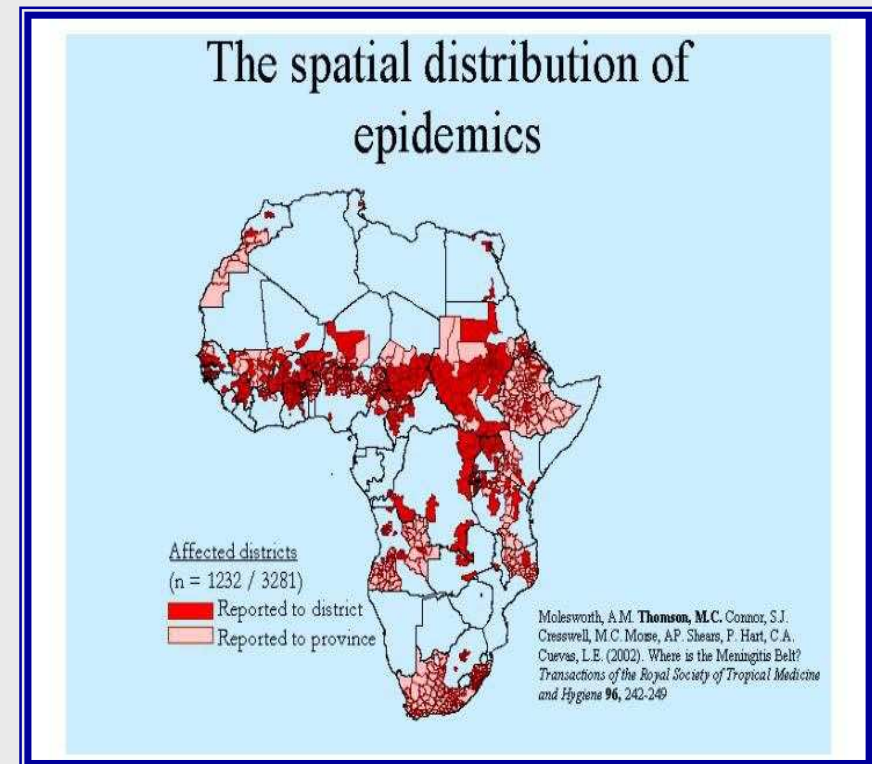


Courtesy Prof. Denise Mauzerall Princeton University

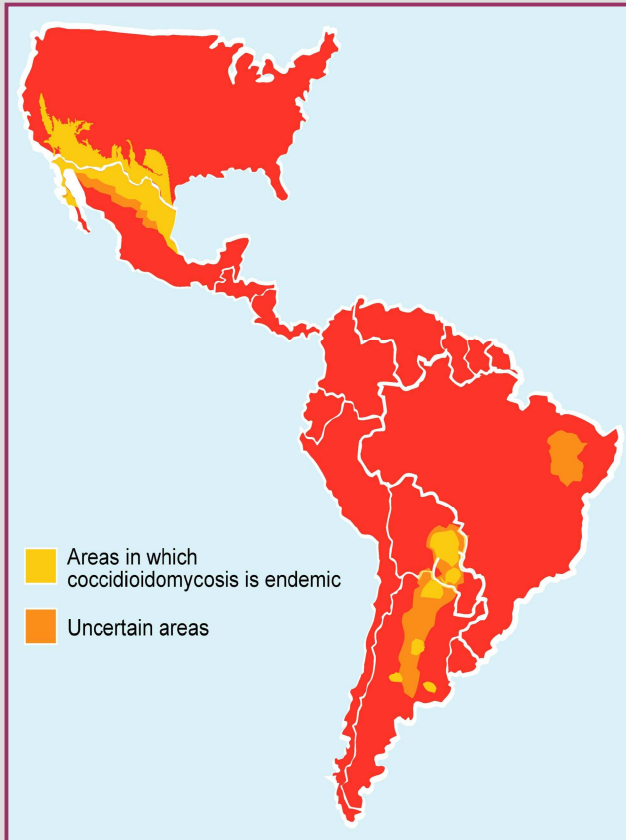
- Dust is the dominant component of inter-continental aerosols, and mostly originates from AF and ME.
- In 2000, intercontinental transport of fine aerosols (PM_{2.5}) was associated with 400,000 premature mortalities (~100,000 from non-dust aerosols) of adults 30 years and older.

Meningitis

- Meningococcal meningitis occurs worldwide but especially so in dry Sub-Saharan Africa: the "African meningitis belt", including Nigeria, Burkina Faso, Mali, Niger, Chad, Cameroon....
 - It is one of the most feared epidemic diseases in Africa
 - High fatality rates; brain damage
 - Epidemics 1996-7 example: 250,000 people affected, 25,000 fatalities
-
- High probability that meningitis is associated with sand and dust weather
 - WMO SDS-WAS is a partner in the International Meningitis Environmental Risk Information Technologies (MERIT) project,



Health Impacts: Valley Fever

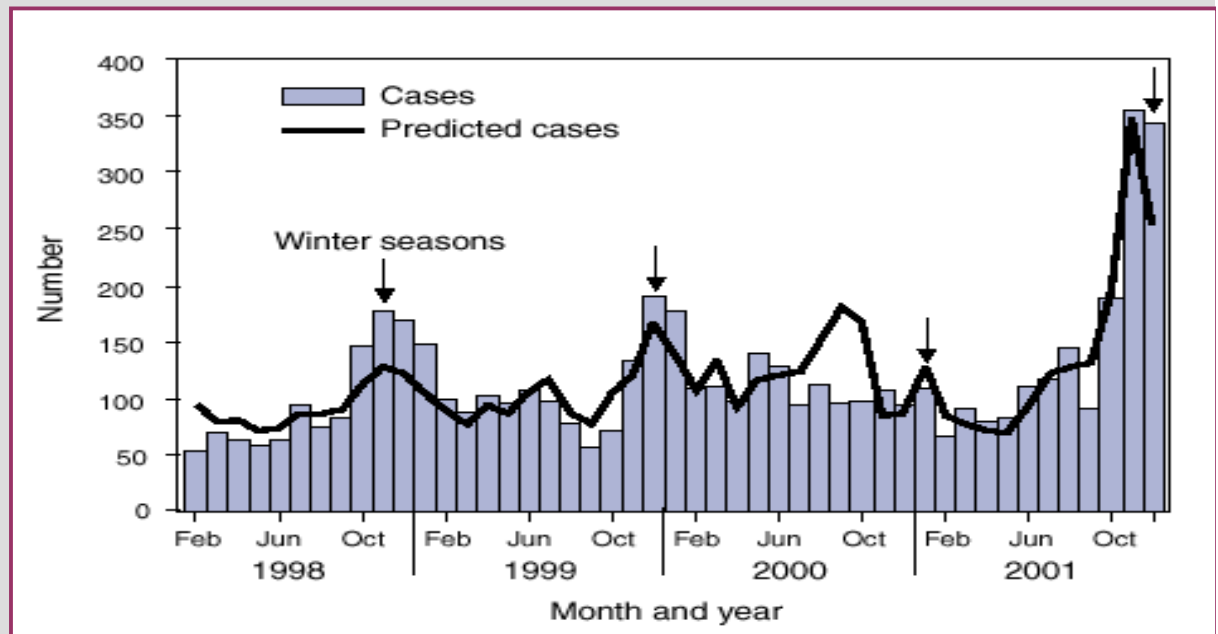


Source: Hector & Laniado-Laborin, 2002



Image Courtesy of M. McGinnis
Copyright © 2000 DoctorFungus Corporation

Valley Fever spores transported by SDS storms



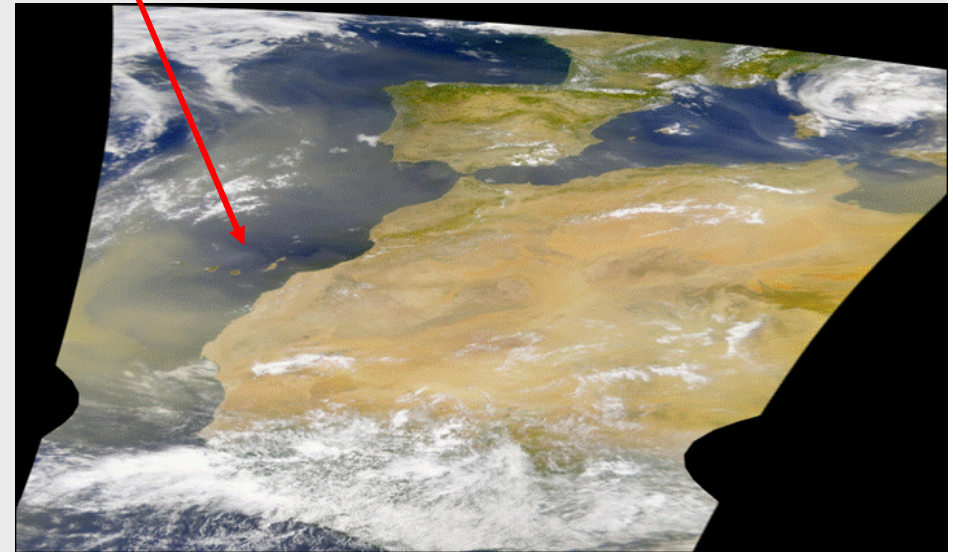
Number of Valley Fever cases in Arizona

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

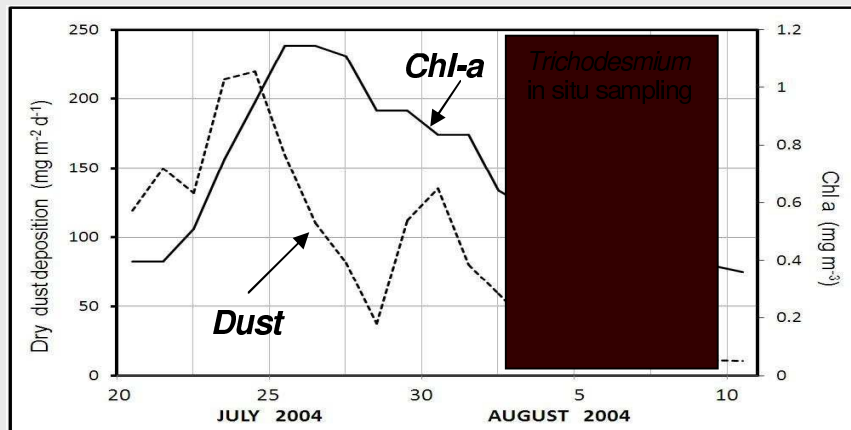
Canary Islands



Bloom of *Trichodesmium* - Canary Islands, August 2004



Dust over W Africa, July 2004



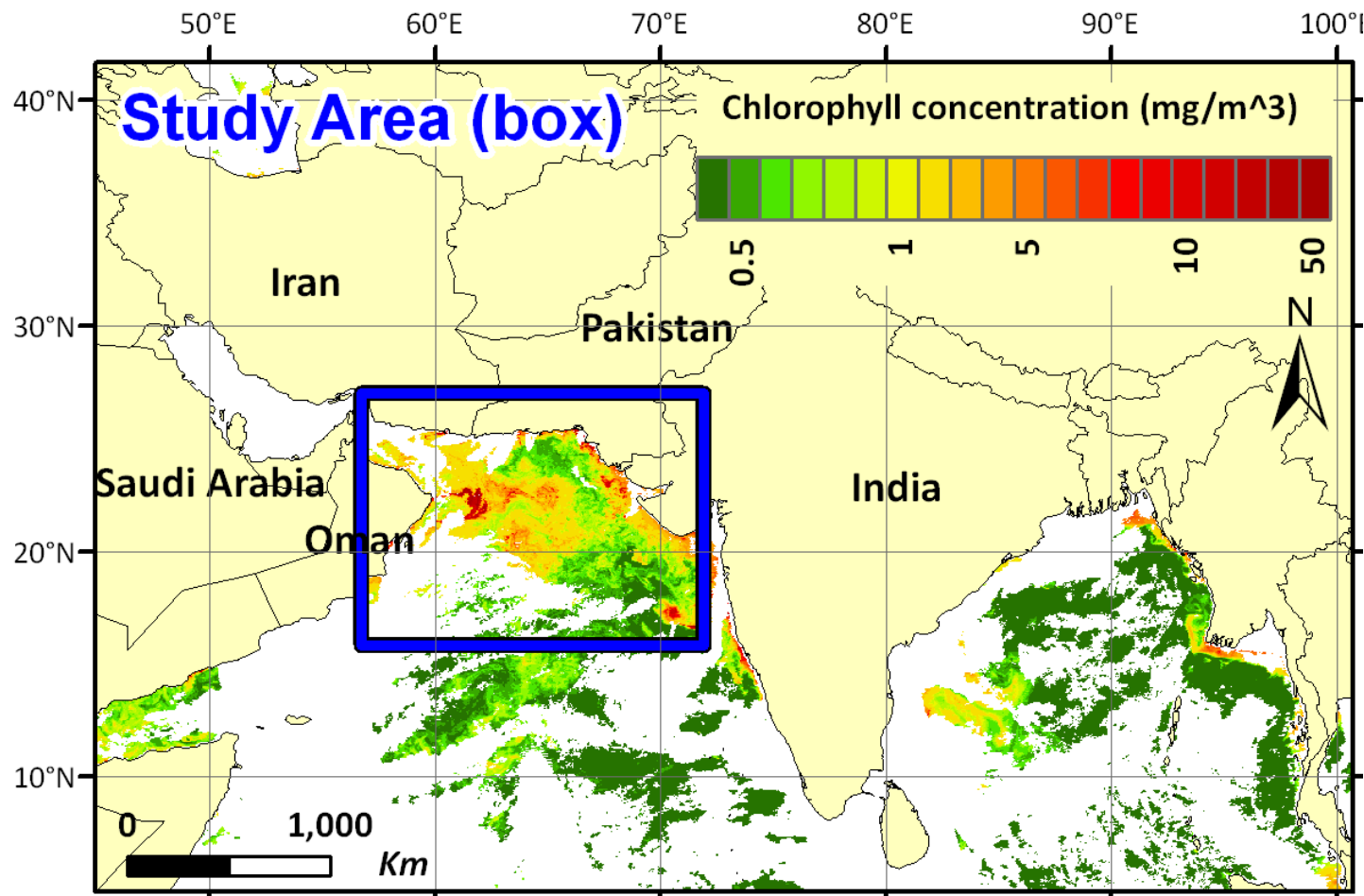
Chlorophyll-a vs. dry dust deposition (model); no upwelling during the event

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

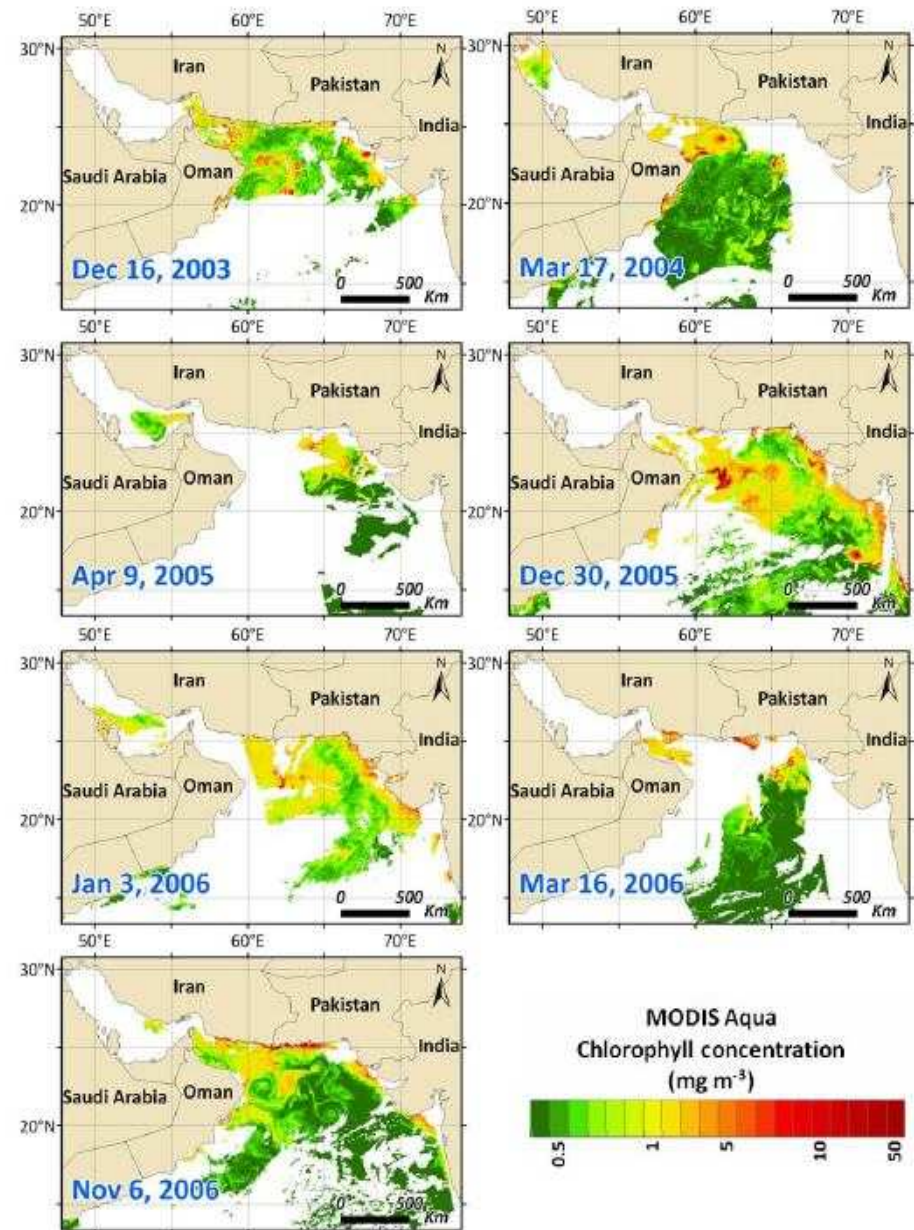
ENHANCEMENT OF OCEANIC PARAMETERS ASSOCIATED WITH DUST STORMS USING SATELLITE DATA

R.P. Singh et al

*Centre for Earth Observing and Space Research,
College of Science, George Mason University, (rsingh3@gmu.edu)



- Using moderate resolution MODIS Aqua, we have found that major dust storms (AOD $\sim 0.25-0.41$) over the Arabian Sea are associated with chlorophyll blooming (usually 10-22.43 mg/m³) within a period of 1-2 to up to 3-4 days.
- Significant anomalous cooling of the ocean surface (SST) and relatively higher ocean wind speeds (QuikSCAT) occurs during dust storms that may lead to a favorable conditions for blooming.
- The nature and cause of chlorophyll bloom in the semi-enclosed northern Arabian Sea is very important in understanding the productivity and the biogeochemical cycles of marine ecosystem.
- The results have been validated using Indian Remote Sensing Polar - 4 Ocean Color Monitor (IRS P4 OCM) data.



Dust-Forced Heating Of The Lower Troposphere

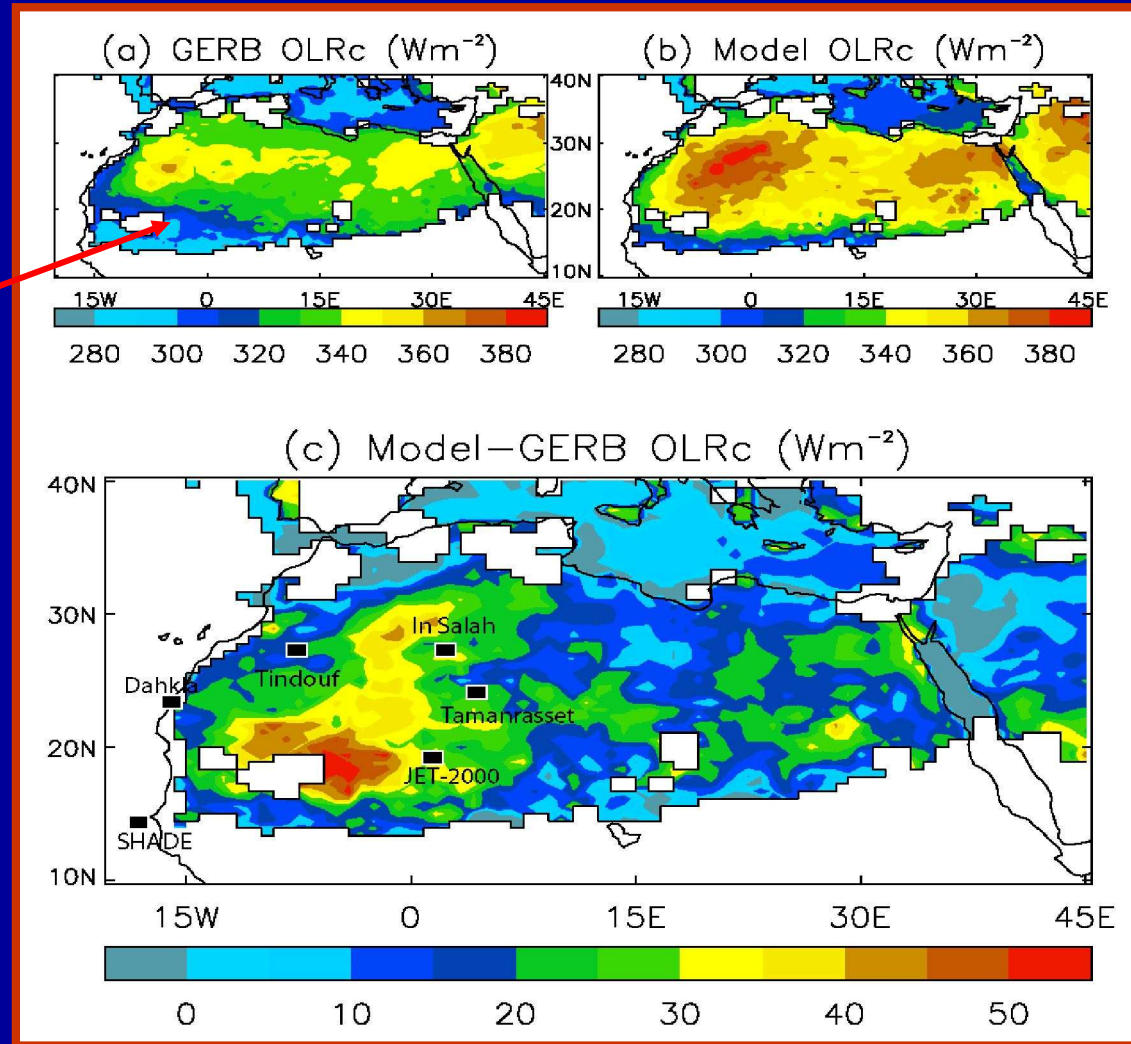
P. Alpert, Y. J. Kaufman, Y. Shay-El, D. Tanre, A. da Silva, Schubert & J. H. Joseph,
NATURE, 395, 1998

- In the eastern tropical North Atlantic Ocean dust aerosols are an important source of inaccuracies in numerical weather-prediction models.
- For the average dust event, the lower atmosphere (1.5–3.5km altitude) is heated by an extra 0.2 K per day by dust. There are 30 events per year.

Failing To Couple Dust To Long Wave Infrared Radiation Means That Weather and Climate Models Overpredict Energy Loss To Space

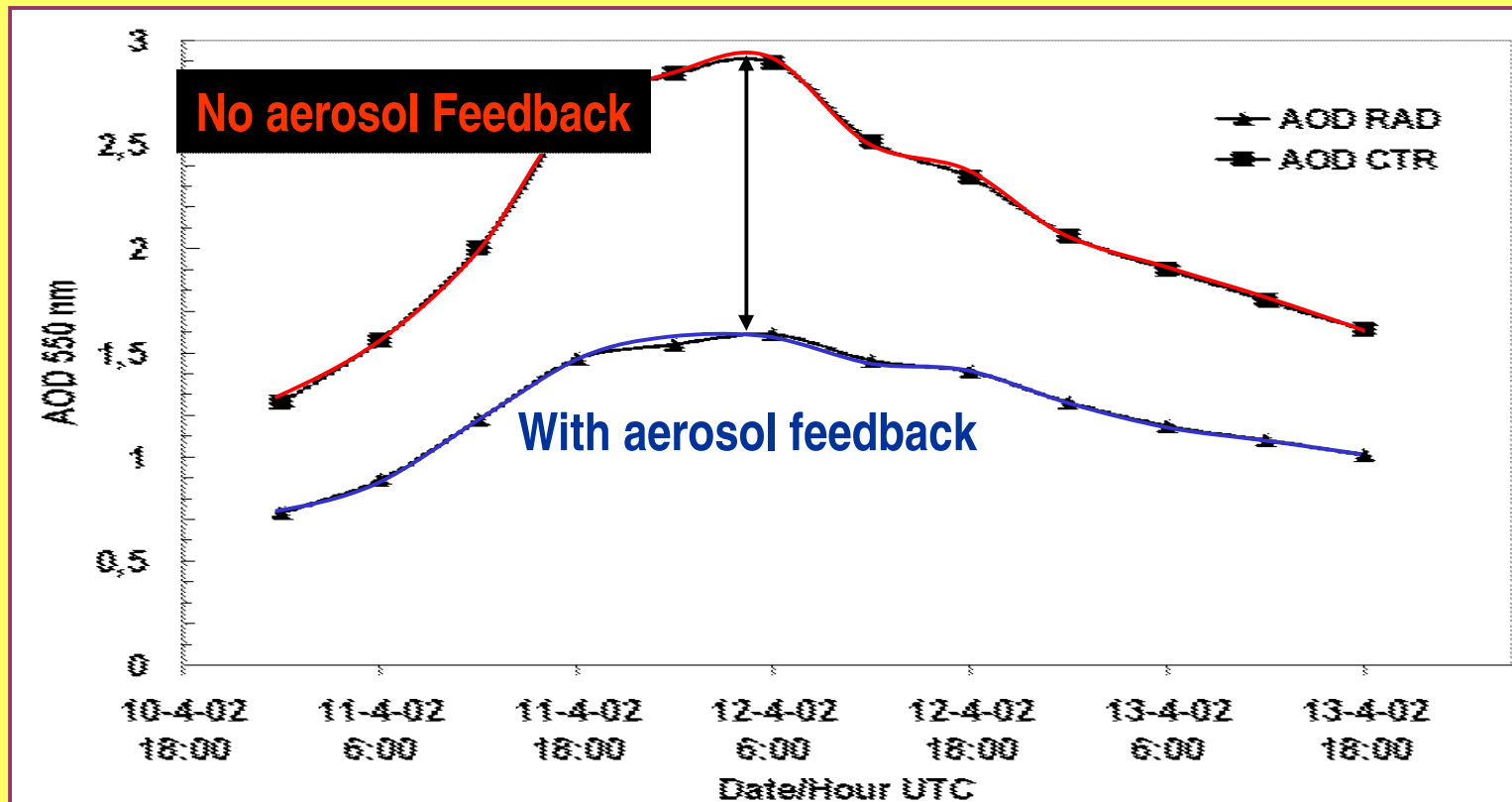
The Geostationary Earth Radiation Budget instrument (GERB) shows significantly less OLR over regions of the desert during July 2003 by up to $\sim 50\text{Wm}^{-2}$ in the monthly mean.

Data from 12Z, July 2003



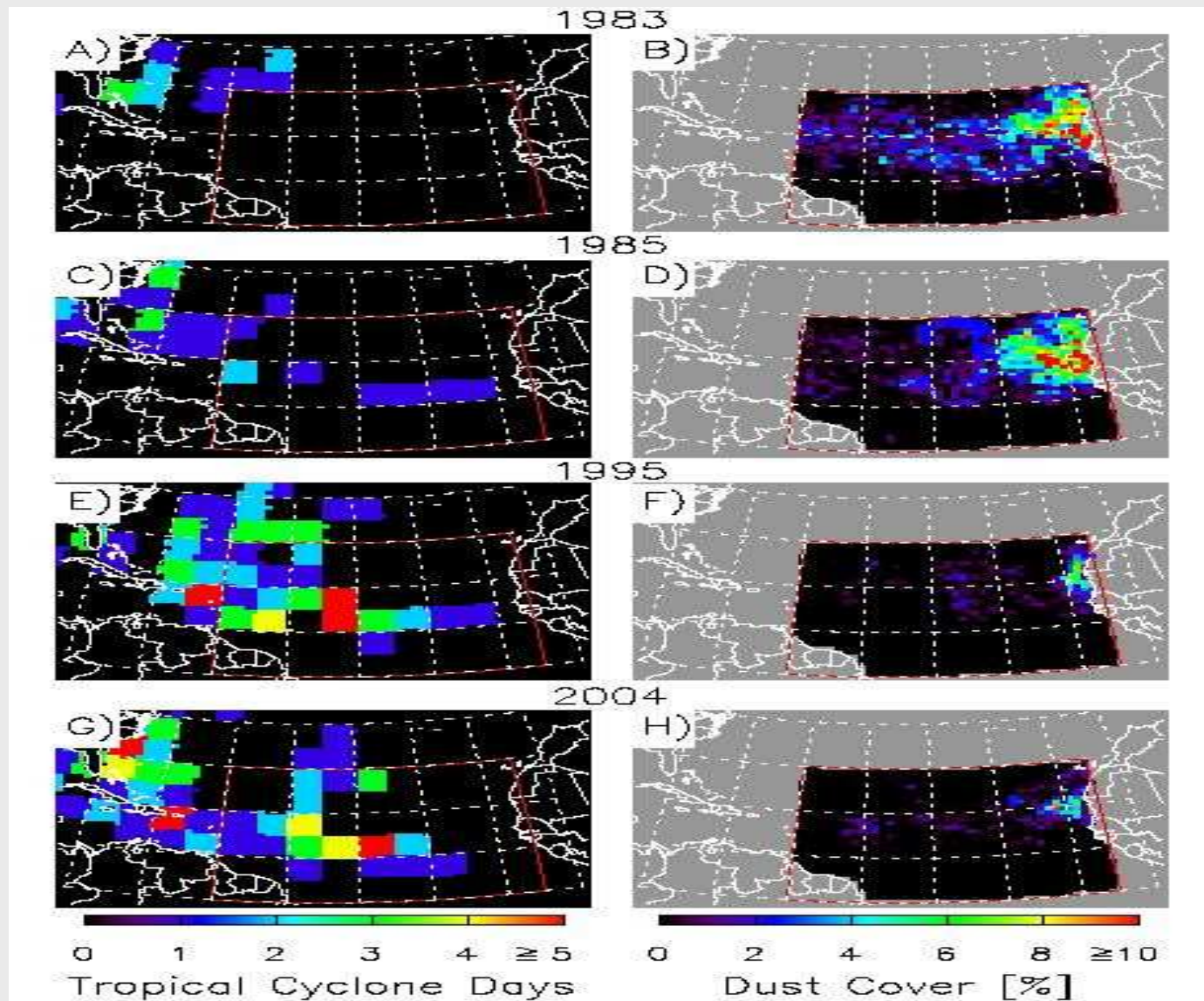
Haywood et al (2008)

Dust Feedback On Radiation Can Improve Weather Forecasts In A Regional Model {Nickovic, 2004}



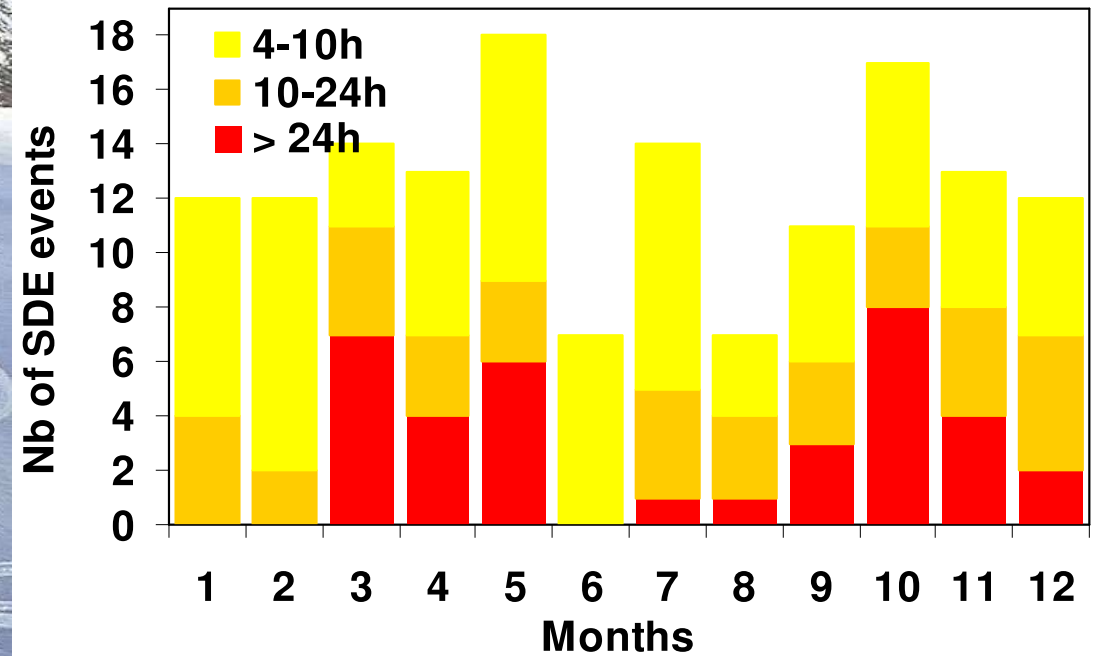
Through negative feedback on winds “dust kills dust”, Perez et al., 2006
The surface cools by ~5 C during strong SDS and air aloft warms

SDS IMPACTS: Dust and Tropical Storms



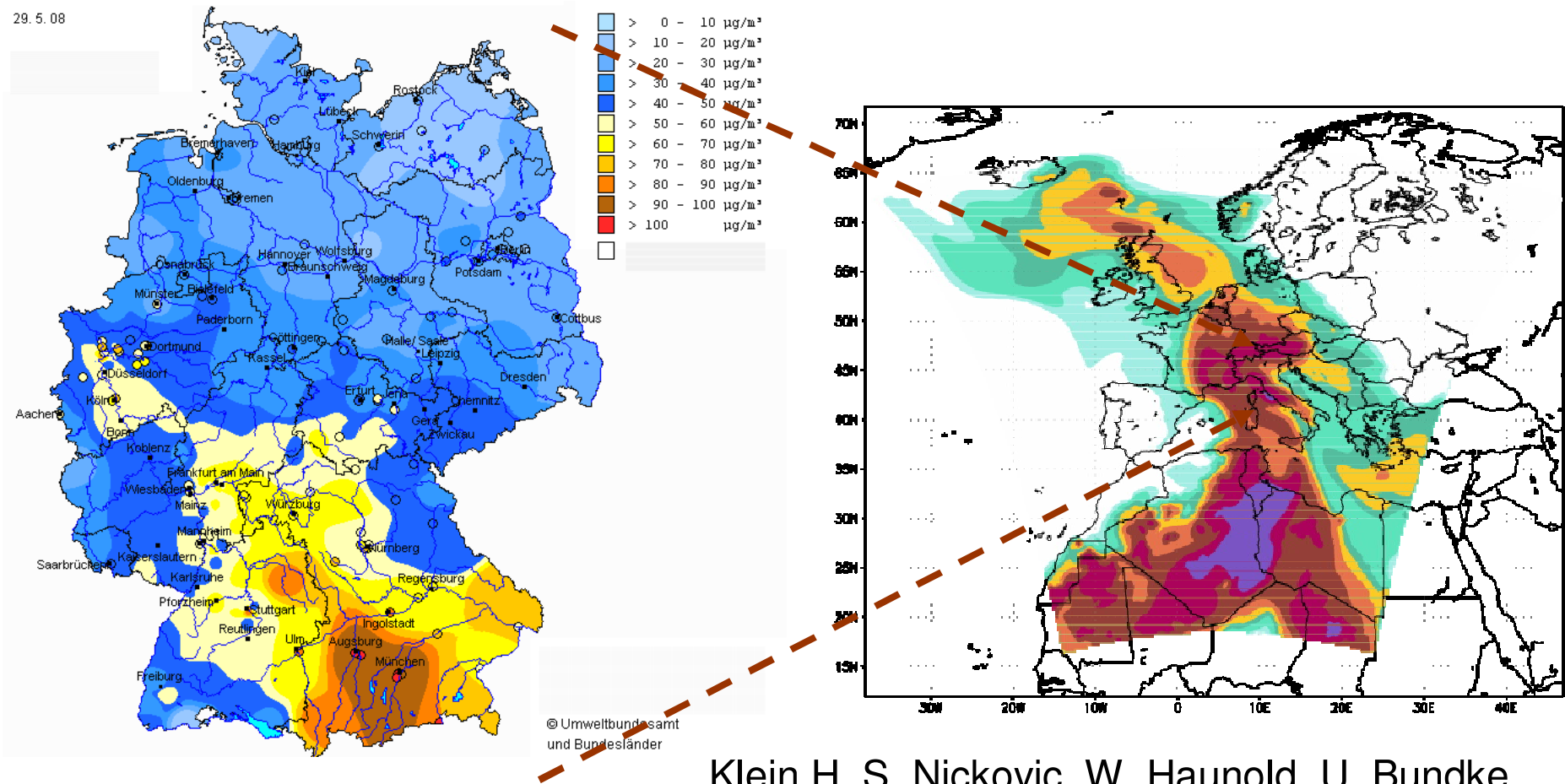
There is a link between Atlantic tropical cyclone activity and African dust outbreaks *Evan et al., 2006 JRL*. Increased % of dust cover in the Eastern Atlantic has a decreased number of tropical cyclones. A hypothesis: cyclogenesis and cyclone evolution is reduced in the presence of sand and dust aerosol. **MORE RESEARCH NEEDED**

Number of Saharan dust events at the Jungfraujoch (2001-2007)



A Large Dust Transport Event Into Central Europe May 2008 Showed Elevated Ice Nucleii

29. 5. 08



Dust-measurements (PM10) –
29.05.08 (Deutsche Wetter
Dienst) [Klein et al. 2008]

Klein H. S. Nickovic, W. Haunold, U. Bundke,
B. Nillius, M. Ebert, S. Weinbruch, L. Schuetz,
Z. Levin, L. A. Barrie, and H. Bingemer ,
Atmos. Chem. Phys. Discuss., 10, 14993-15022,
2010, Saharan dust and ice nuclei over Central
Europe

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

A Global Consortium Helping Society Reduce
Risk Through Research, Assessments and
Forecasts

<http://www.wmo.int/sdswas>

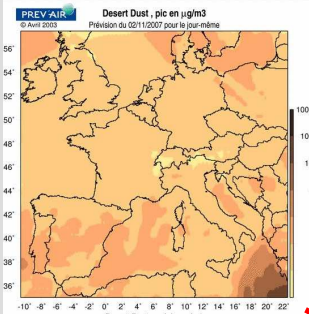
SDS-WAS Mission

To enhance the ability of countries to deliver:

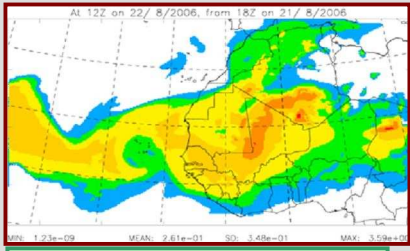
- timely and quality forecasts of sand and dust storms,
- observations of aerosols: sand and dust
- information and knowledge to users in order to reduce impacts

through

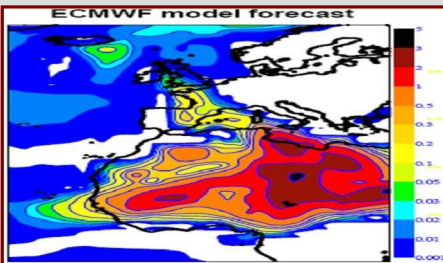
- an international partnership of research and operational experts and users



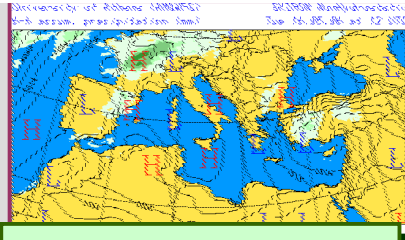
METEOFRANCE



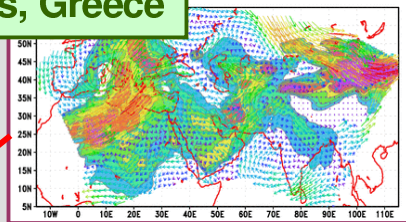
UK MET OFFICE



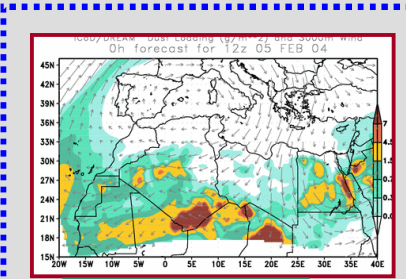
ECMWF



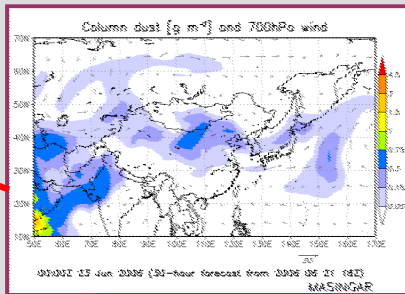
U of Athens, Greece



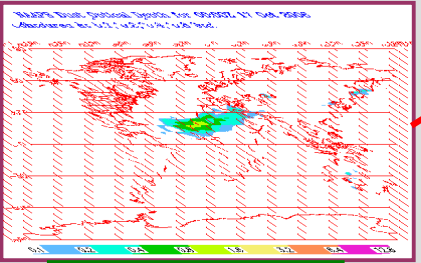
METU, Turkey



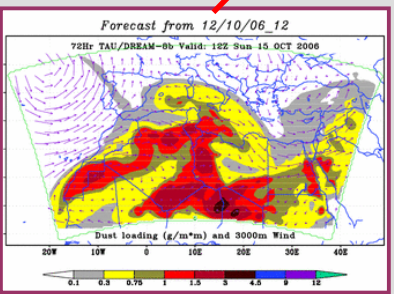
BSC, Spain



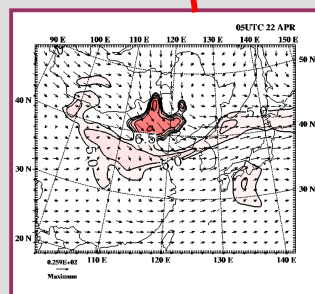
MRI, Japan



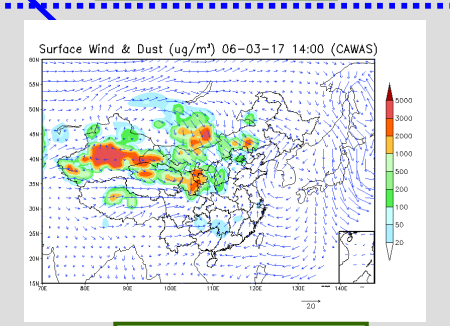
US Navy, USA



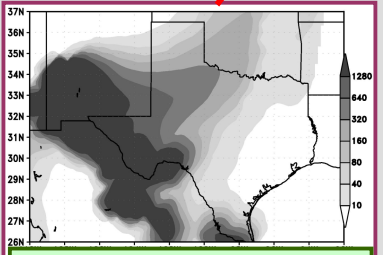
Tel Aviv U, Israel



KMA, S. Korea



CMA, China

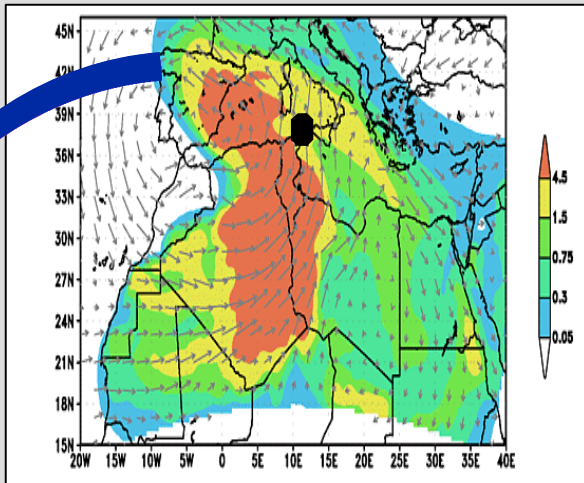


U of Arizona, USA

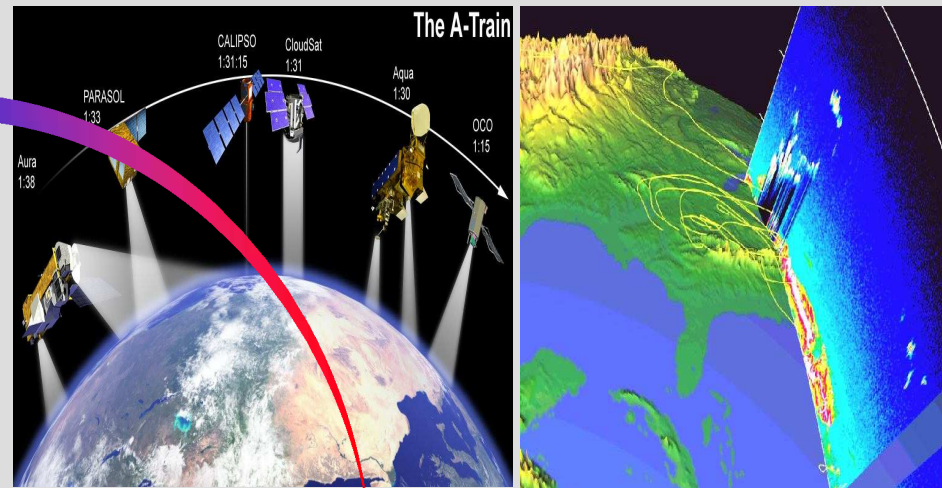
Operational or Research Dust Forecasting Centres

Coordinated Observations and Forecast/Reanalysis Modelling

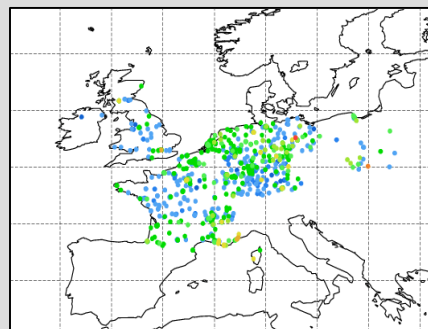
Forecast or Reanalysis Models



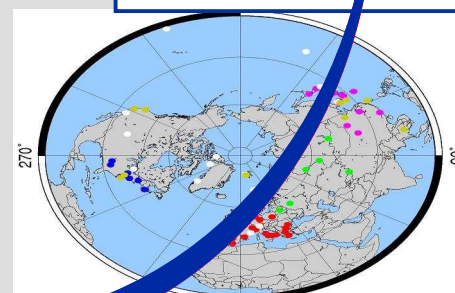
18 UTC, 7 May 2002 30-hr forecast



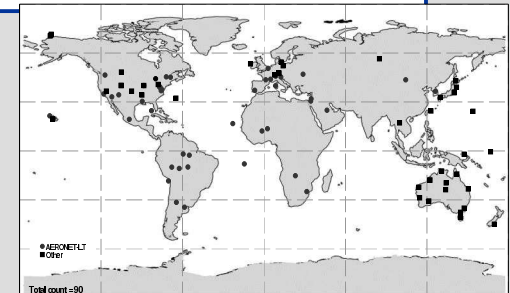
Satellites
(NASA A-Train MODIS/CALIPSO &
&
Geostationary Satellite IR)



European PM10



GALION
Surface-based LIDAR

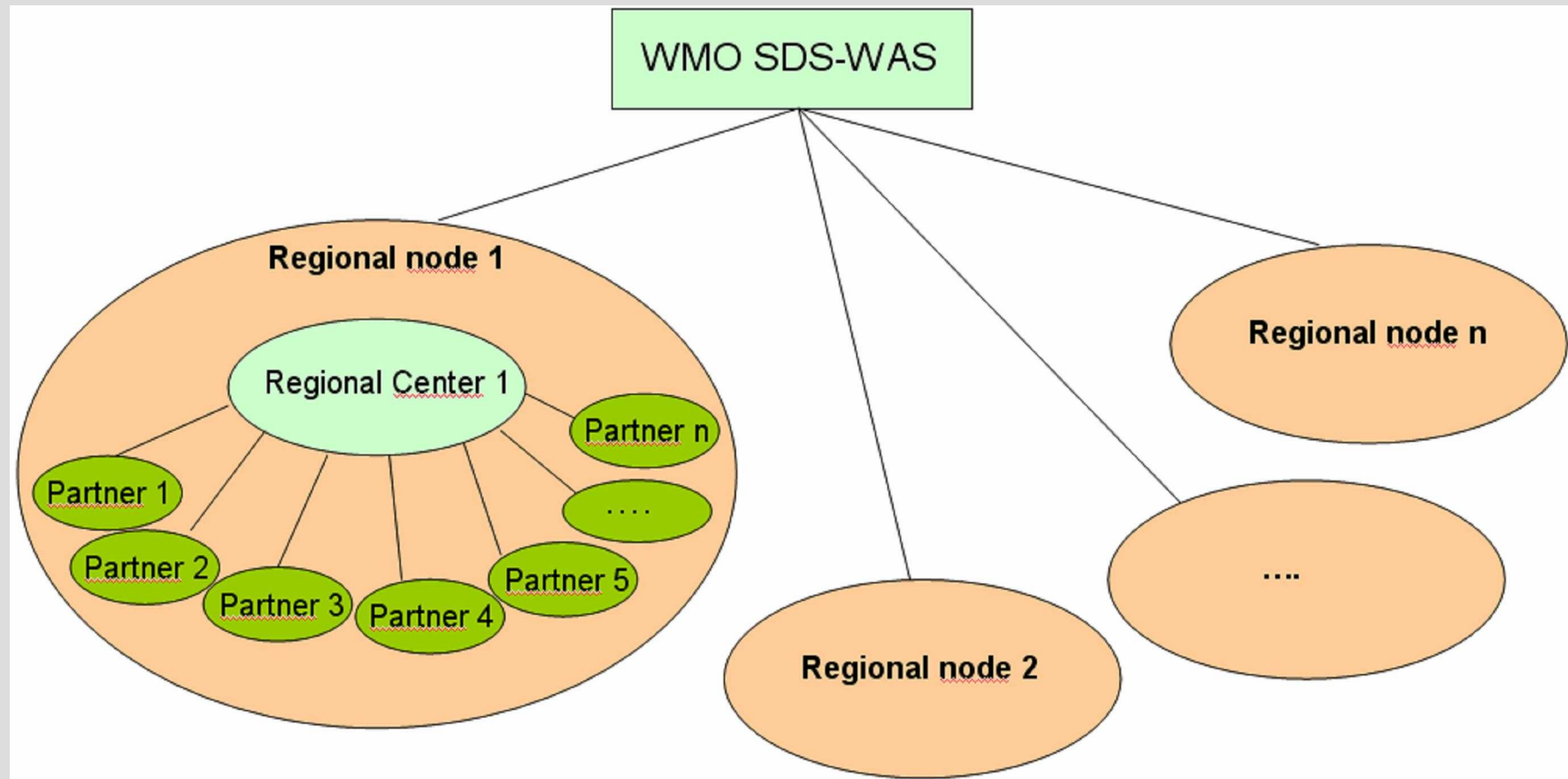


AERONET/SKYNET/PFR
NET/
Surface-based AOD

WMO SDS-WAS History

- **September 2004: International Symposium on SDS**, Beijing, CMA, followed by SDS Experts Workshop
- **2005: WMO Survey** – 40+ WMO Members expressed interest in improving capacities for SDS monitoring, forecasting and assessment
- **2006: SDS Steering Committee** (Shanghai) proposed SDS-WAS.
- **Jan 2007: Ad-Hoc WMO Secretariat Group on SDS-WAS** (research, operational prediction, aviation and agriculture services).
- **May 2007: 15th WMO Congress** endorsed launching of the SDS-WAS.
- **August 2007:** Korean Meteorological Administration hosted the 2nd International Workshop on SDS
- **November 2007:** WMO/GEO Expert Meeting on SDS-WAS (Barcelona Supercomputing Centre); 100 international experts
- **2008:** WMO accepted a China Meteorological Agency offer to host a regional centre for Asia/Central-Pacific node of SDS-WAS, and a Spanish offer to host a regional centre for North Africa, Middle East and Europe.
- **End 2008:** SDS-WAS Draft Implementation Plan and two regional steering groups met for Northern Africa-Middle East and Europe (Tunis) and for Asia (Beijing)
- **May 2009:** WMO briefed the Arab League on SDS-WAS
- **Sept 2009:** Barcelona WMO/ESA Consultation Workshop on SDS Satellite products

A Federated System of Regional Nodes Bringing Modelling, Research, Observations and Users Together



Gaps in SDS-WAS in the Arabian Peninsula in the SDS-WAS N. Africa - Middle East - European Node



A photograph of Uluru, a large sandstone rock formation in Australia, during sunset. The sky is a mix of orange, red, and purple, with the sun low on the horizon. The foreground is a flat, reddish-brown desert landscape with several small, green, scrubby bushes and trees. The overall scene is serene and captures the natural beauty of the Australian outback.

Thank You

Australia