Climatology and Monitoring of Dust and Sand Storms in the Arabian Peninsula

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The Dust and Sand storms

A dust storm or sandstorm is a “severe weather condition” characterized by strong winds and dust-filled air over an extensive area. A dust storm is distinguished from a sandstorm on the basis of particle size. Dust storms are made up of a multitude of very fine particles while Sandstorms have larger particle sizes that range from .08mm to 1mm.

Dust storm

The fine “dust” particles may be elevated as high as **3km** or more while the “sand” particles are confined to the lowest **3.5m**, rarely rise more than **15m** above the ground.

The Dust storms problems

This phenomenon appears as:

- **A strong turbulent winds**
- **Blowing over desert surfaces**
- **Frequently lift large quantities of fine dust into the air**
- **Visibility can be reduced to a few meters**
- **Producing deep gloom or even total darkness**

Dust storm is the generic term for a serious environmental phenomenon in the Arab countries. Dust storm causes at least the following:

- ✓ **It causes considerable hardship**
- ✓ **It causes loss of income**
- ✓ **It disrupts communications**
- ✓ **It affects peoples' health**
- ✓ **It leads to death of people (in extreme cases)**
- ✓ **It destroy livestock and crops over the affected areas**

The Dust storms Formation

Environmental Factors:

Main environmental factors that affect the probability of occurrence, intensity, and height of dust storms are:

- Wind speed
- Atmospheric stability
- Source region surface characteristics

Additional factors pertaining to the efficiency of a dust source region are:

- Surface heating
- Soil moisture
- Soil type and
- Surface vegetation

In addition, strong surface heating can provide the necessary buoyancy to elevate dust to great heights.

Dust storm frequency and intensity vary largely from one location and event to another.

The Dust storms Impacts

- Smaller dust particles stay in the atmosphere much longer time than the large particles and may be transported thousands of kilometers away.

- This tiny particle can remain airborne for 30 days if it reached a height of 1km and no other vertical accelerations occur.

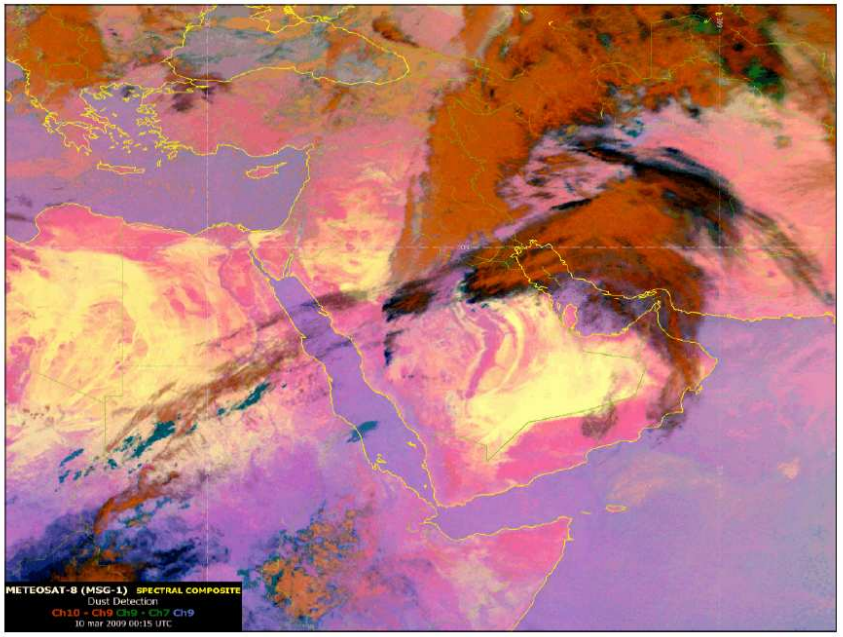
- A dust particles of radius 0.1–1.0μm will spend an average of 14 days in the atmosphere while particles of 3.0-6.0μm remain elevated for an average of 1.1 days.

- Dust from severe dust storms may create low visibilities hundreds of kilometers from their point of origin.

Example of Dust storms impacts

Dust Storm in Riyadh 11 march 2010

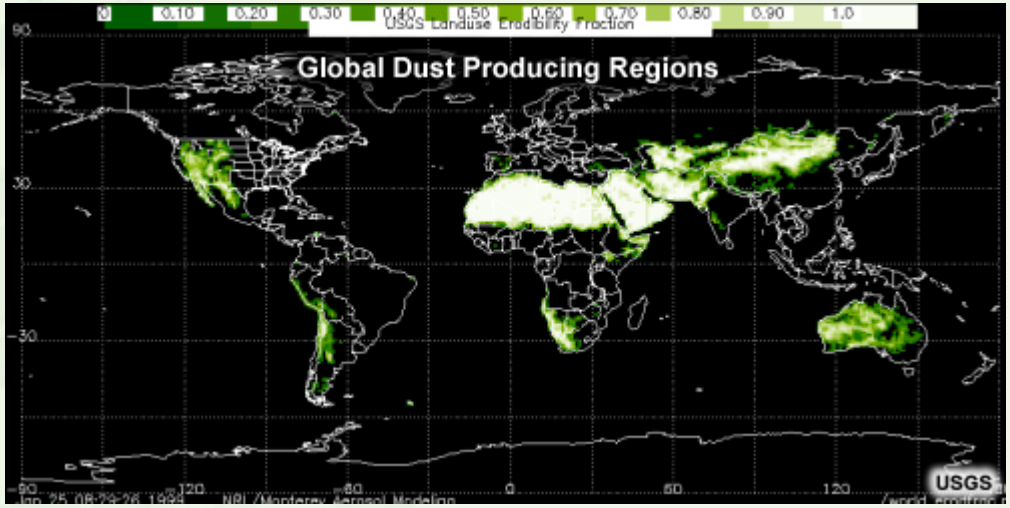
Meteosat-8 (MSG-1) Spectral composite



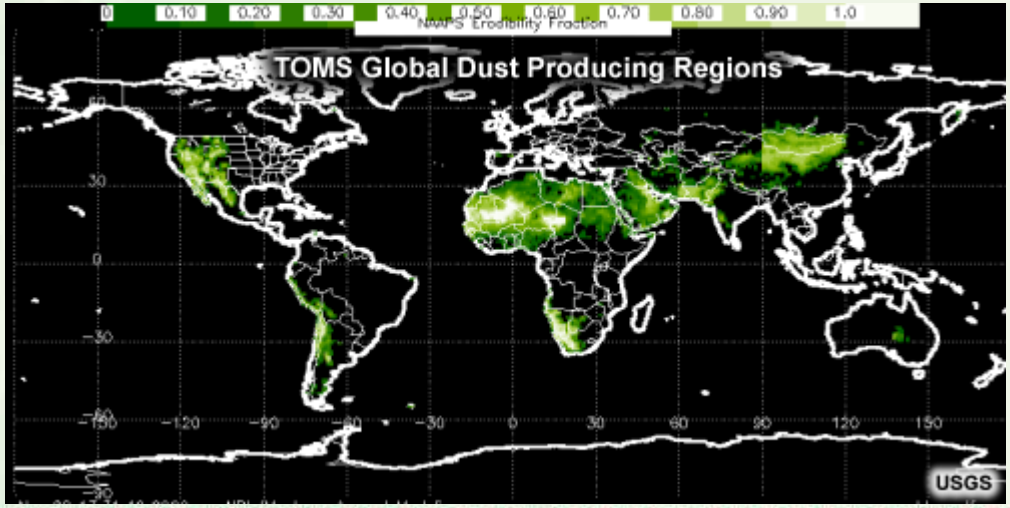
From 09 March – 00:15 to 11 March – 23:30 by 15 minutes interval

Dust storms Global distribution

Dust-prone Regions from Land Cover Types: Identifying dust-prone regions based on land cover characteristics can be refined by incorporating satellite data.



Source Regions from TOMS Aerosol Index: The Total Ozone Mapping Spectrometer (TOMS) Aerosol Index provides a near real-time measurement of aerosols in the atmosphere.



Dust storms Regional (Middle East / West Asia)

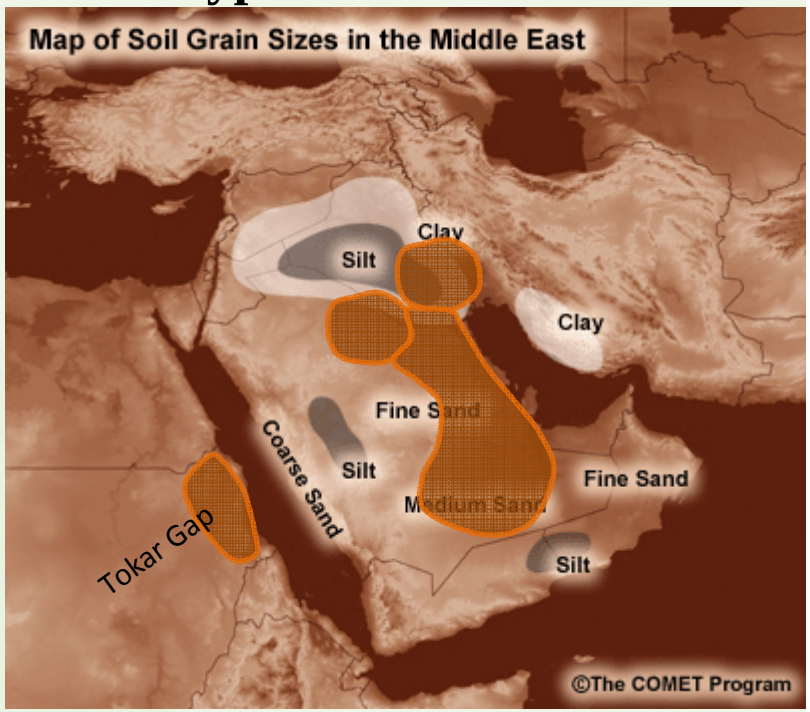
In Middle East/ West Asia regions, some areas are much more prone to dust storms than others due to differing soils and climate.

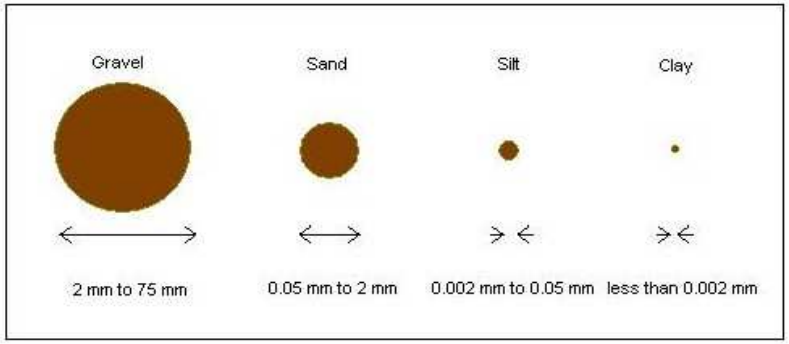
Even in bare desert, the sandy areas, such as those found on the Arabian Peninsula, generally do not generate dust storms.

Areas with silt- and clay-rich soils, most common in Iran and Iraq, which are responsible for most dust storms.

In this region, these fine-grained soils are found in areas of dry lake beds and river flood plain deposits.

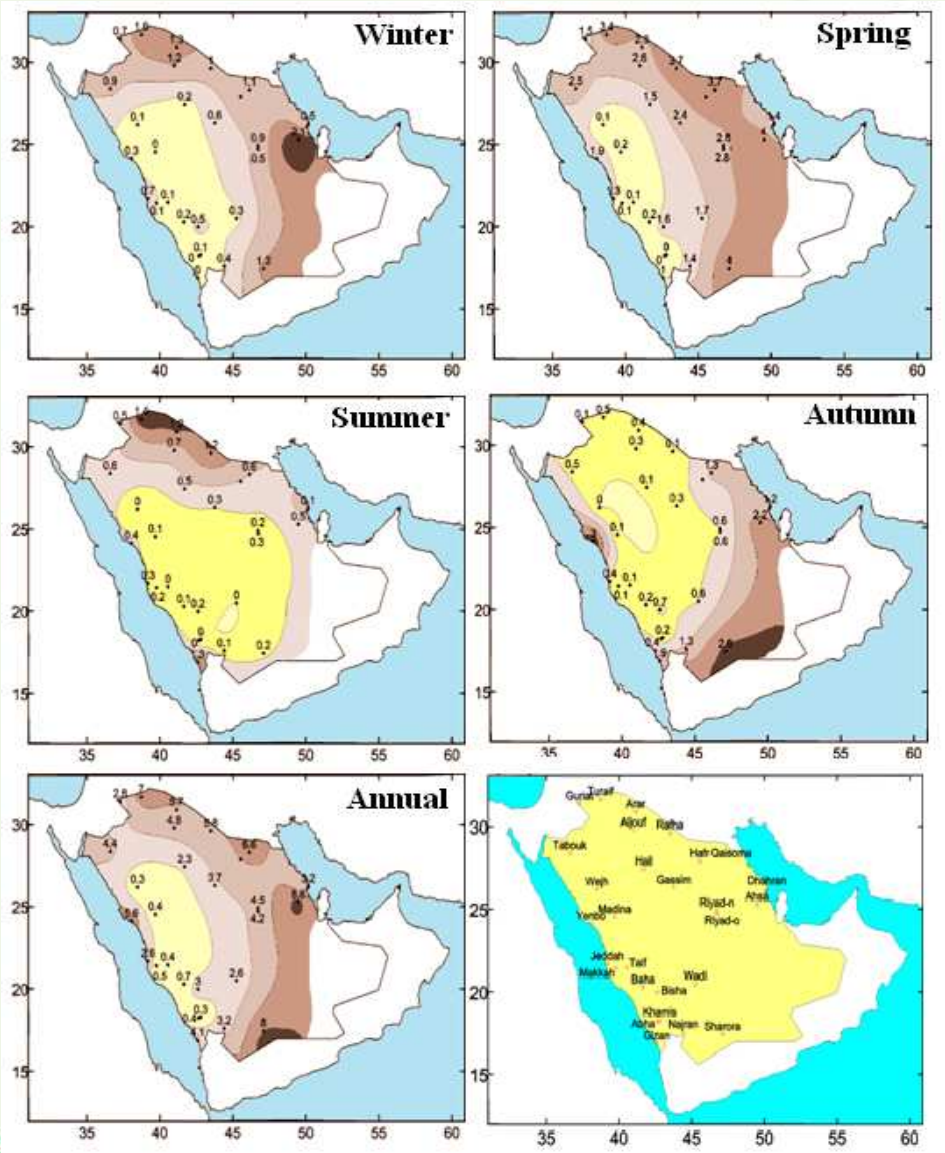
Soil Types in the Middle East





Climatology of the Arabian Peninsula Dust storms

Seasonal and annual rate of dust storms

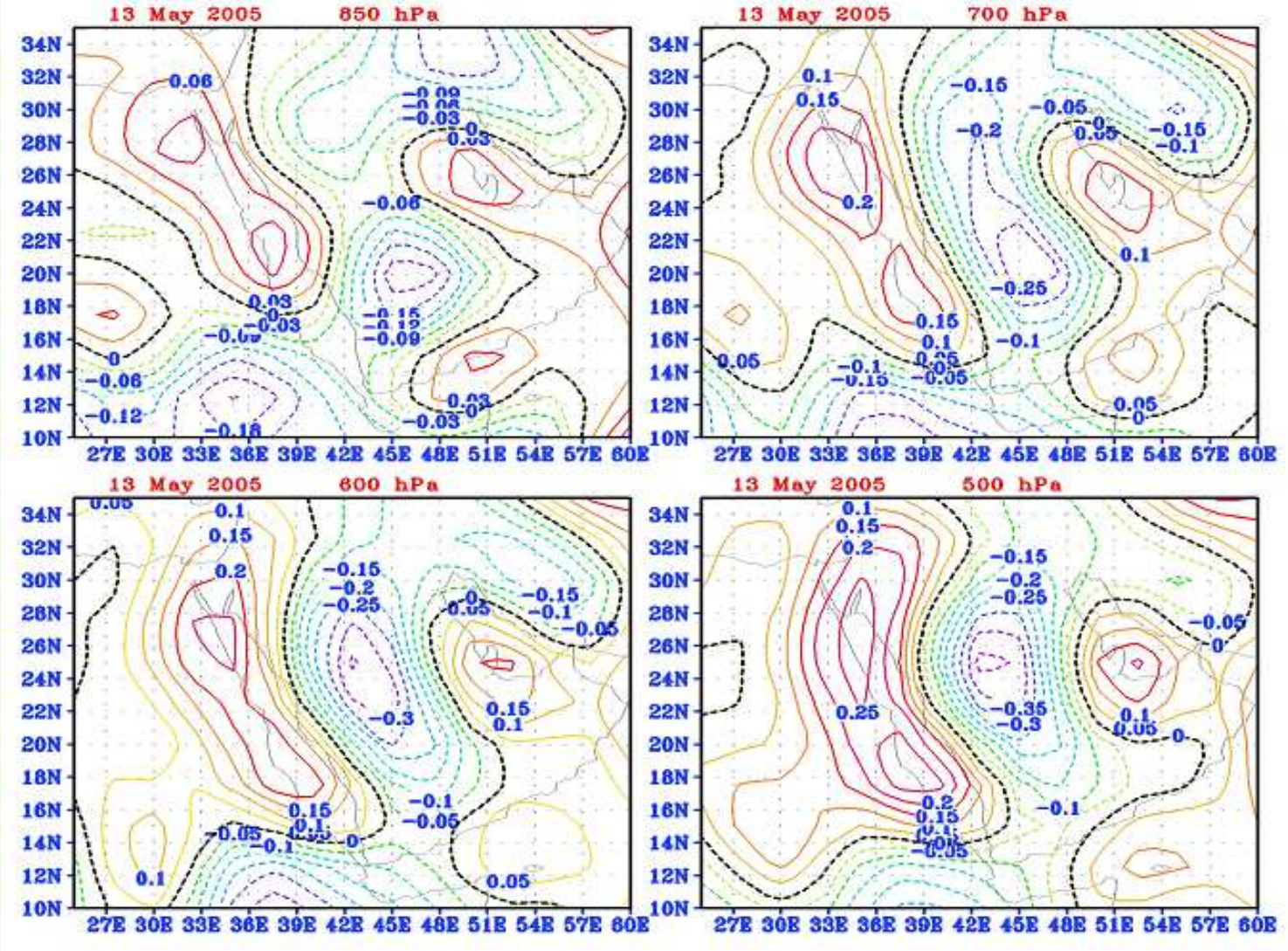


In some seasons and for about 30% of the time, on average, parts of the Middle East, especially Saudi Arabia, are affected by dust storms.

The most vertically extensive dust storms are more likely to occur predominately in the spring and fall when the air masses are typically conditionally unstable.

Dust storms are frequent over all other eastern Mediterranean countries during hot afternoons and in interior desert regions from March through September.

Omega at different atmospheric levels on 13 May 2005



Monitoring of Dust Storms Observational Stations

AERONET data in Dust storms study

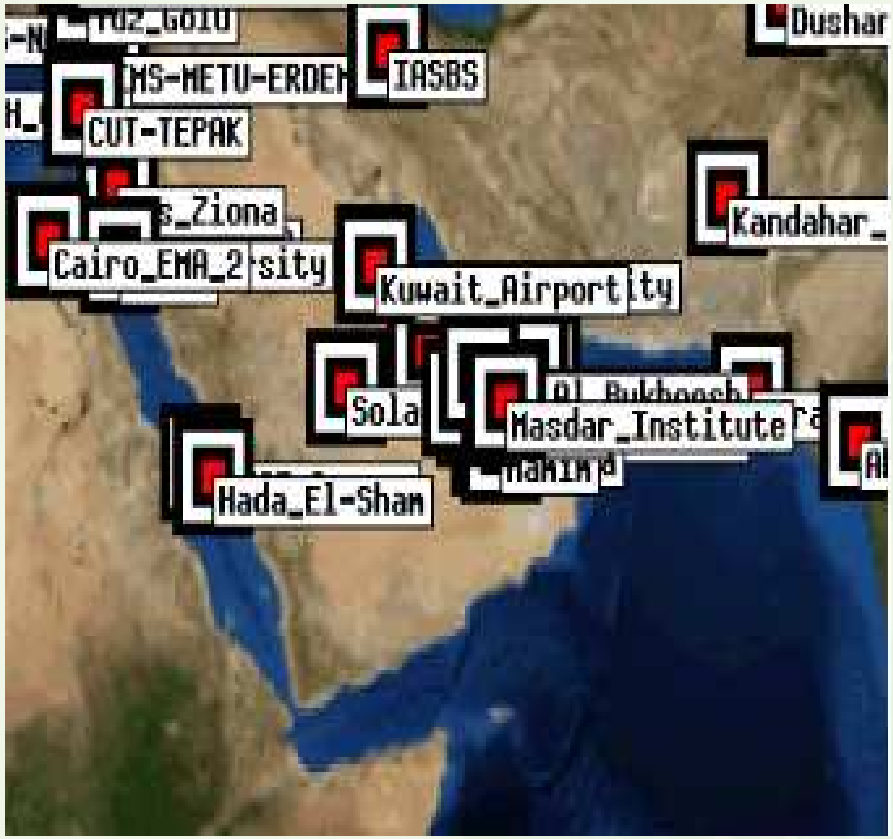
The AERONET (AErosol RObotic NETwork) program is a federation of ground-based remote sensing aerosol networks collaborated on by national agencies, institutes, universities, individual scientists, and partners.
The program provides a long-term, continuous and readily accessible public domain database of aerosol optical depth, microphysical and radiative properties for aerosol research and characterization, validation of satellite retrievals, and synergism with other databases.

Data is available at 3 different quality levels:

- Level 1.0 (Unscreened, Raw data)
- Level 1.5 (Cloud Screened)
- Level 2.0 (Cloud Screened, quality assured)

Some of the most interesting products include:
Aerosol Optical Depth (AOD) at wavelengths (1020, 870, 675,500, 440, 380, 340) in nm.
Angstrom Parameter (α) at the wavelength ranges (440-870), (380-500), (440-675), (500-870) and (340-440) in nm.
Volume Size Distribution, just few to mention in wide output product range.

AERONET sites distribution over Middle East



Arabian Peninsula has 28 sites:

- Saudi Arabia (3)
- UAE (21)
- Bahrain (1)
- Kuwait (2)
- Muscat (1)
- Iraq, Syria, Jordan (0)
- Egypt (3)
- Iran (1)

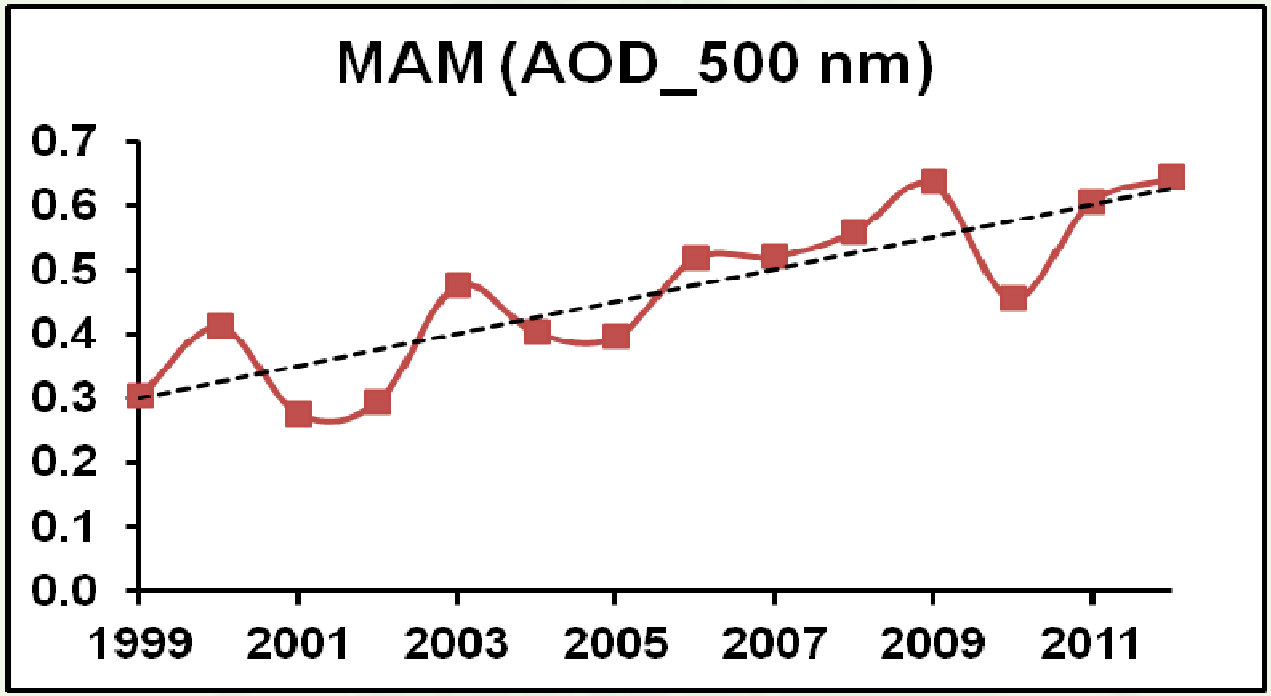
Just 3 locations in Saudi Arabia. Only Solar Village (Riyadh) has long record. Others Two just established.
No station in Jordan, Syria, Lebanon, Iraq.
Need to have more stations in the region.

AERONET site Hada Al Sham

AERONET AOD (500 nm) at Solar Village

Seasonal March-April-May (MAM) variation of AOD at 500 nm over the Solar Village in Riyadh.

MAM is composed of the months when we have most of the DUST loading activity in the region. So we see from figure that the AOD has a positive trend. Meaning that the dust activity has been increased significantly during the spring months.



Monitoring of Dust Storms Satellite

Satellite data in Dust storms monitoring

Details of Meteosat Second Generation (MSG) Satellites

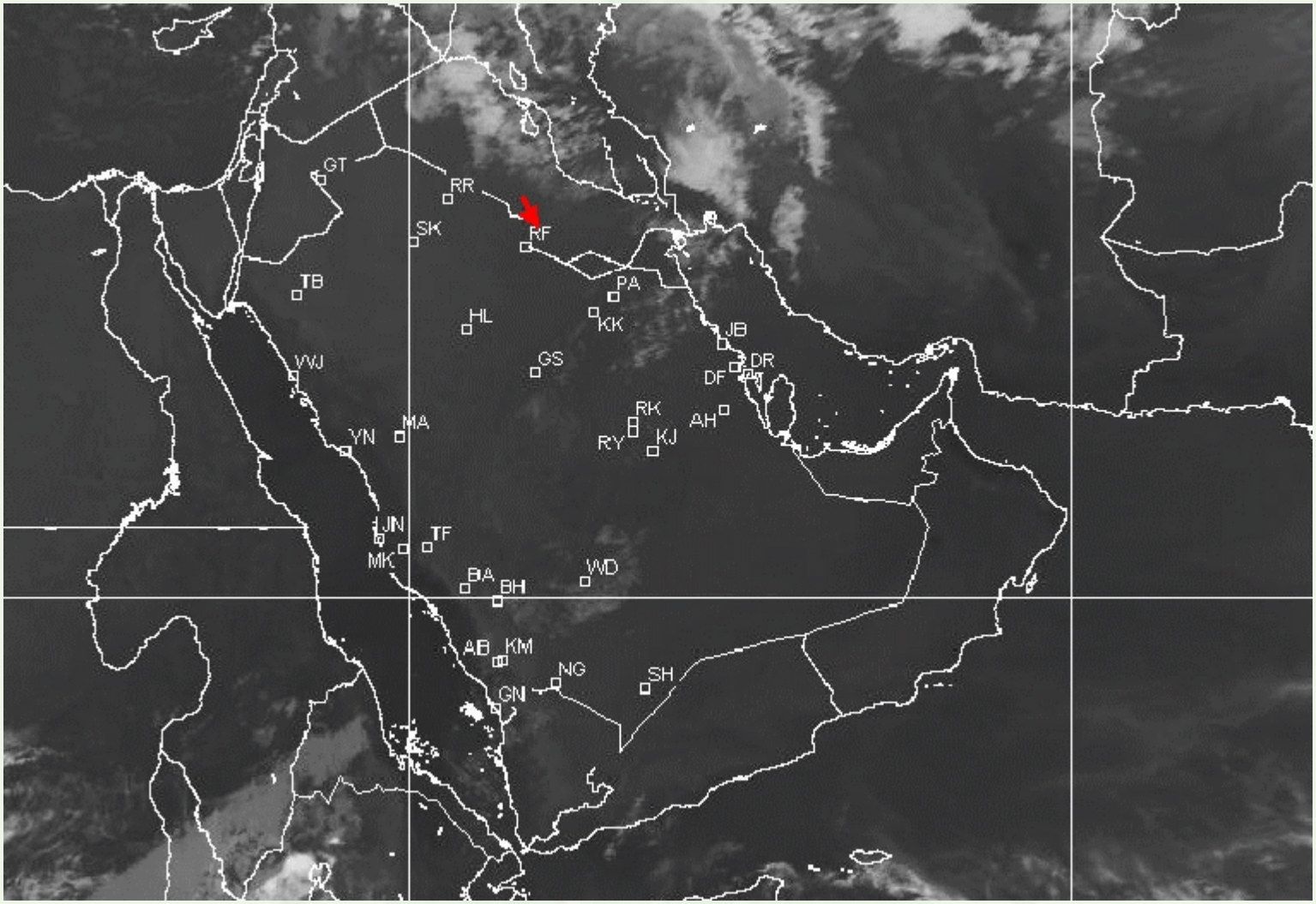
Type of MSG	Sensor Name	Band	Spectral Resolution (µm)	Spatial Resolution (km)	Temporal Resolution (Times)	Radiometric Resolution (Bit)
Meteosat-8	SEVIRI	VIS 0.6	0.56 to 0.71	3	15 minutes	10
		VIS 0.8	0.74 to 0.88			
		NIR1.6	1.5 to 1.7			
Meteosat-9		IR3.9	3.48 to 4.36			
		WV6.2	5.35 to 7.15			
		WV7.3	6.85 to 7.85			
		IR8.7	8.3 to 9.10			
		IR9.7	9.38 to 9.44			
Meteosat-10		IR10.8	9.8 to 11.8			
		IR12.0	11 to 13			
		$CO_2$13.4	12.4 to 14.4			
		HRV	0.5 to 0.9	1		

Dust Event in Saudi Arabia on 12-14 May 2013

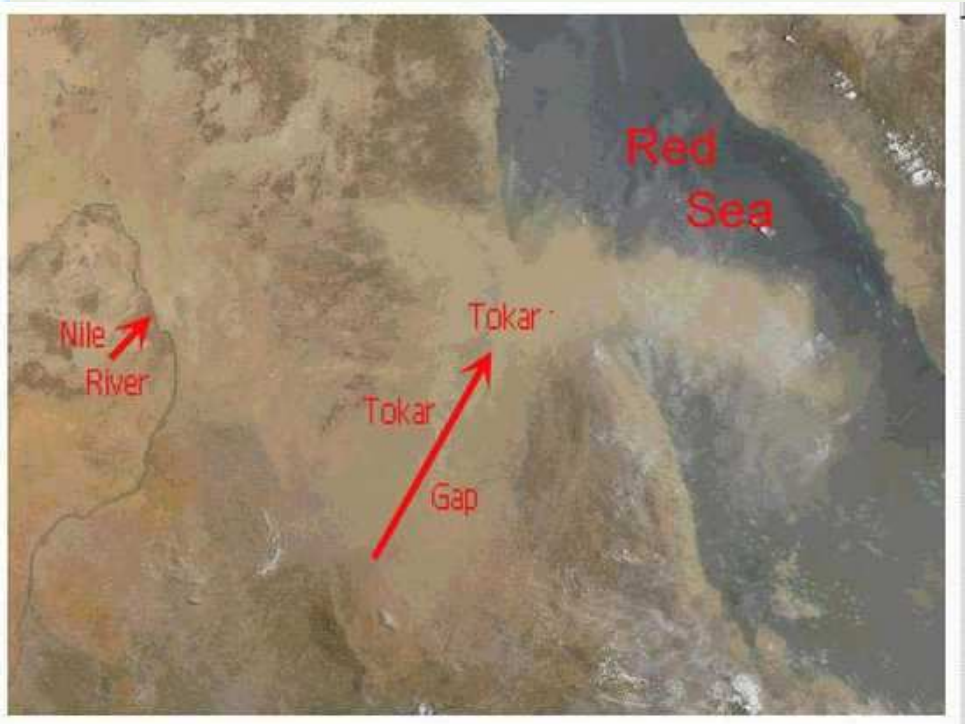
- Spectral Channel IR10.8 (i.e. Channel 9) from Meteosat Second Generation (MSG) satellite is used to monitor the temporal and spatial extent of the event.
- The event was generated over Iraq at 02:00 UTC (12 May) with the geographic location of 31.21°N and 44.25°E near the meteorological station of Rafha (Saudi Arabia).
- With the passage of time, the event steadily increased to expand and started to move towards south and south east directions from its origin.
- While moving in these directions, it hits the met stations of Rafha, Gassim, Qaisumah, Hafer Al Baten, Riyadh and Kuwait.
- The event reached to its peak extent at 13:15 UTC (16:15 SST) and after that the expansion and intensity of the event was gradually started to decrease and the event was ended completely on 14 May 2013 at around 03:00 UTC over the Arabian Gulf.

Dust Event in Saudi Arabia on 12 May 2013
Near Rafha Airport (north Saudi Arabia)
from a plane that was just about to land (elevation 1000m)

Dust Event 13 May 2013

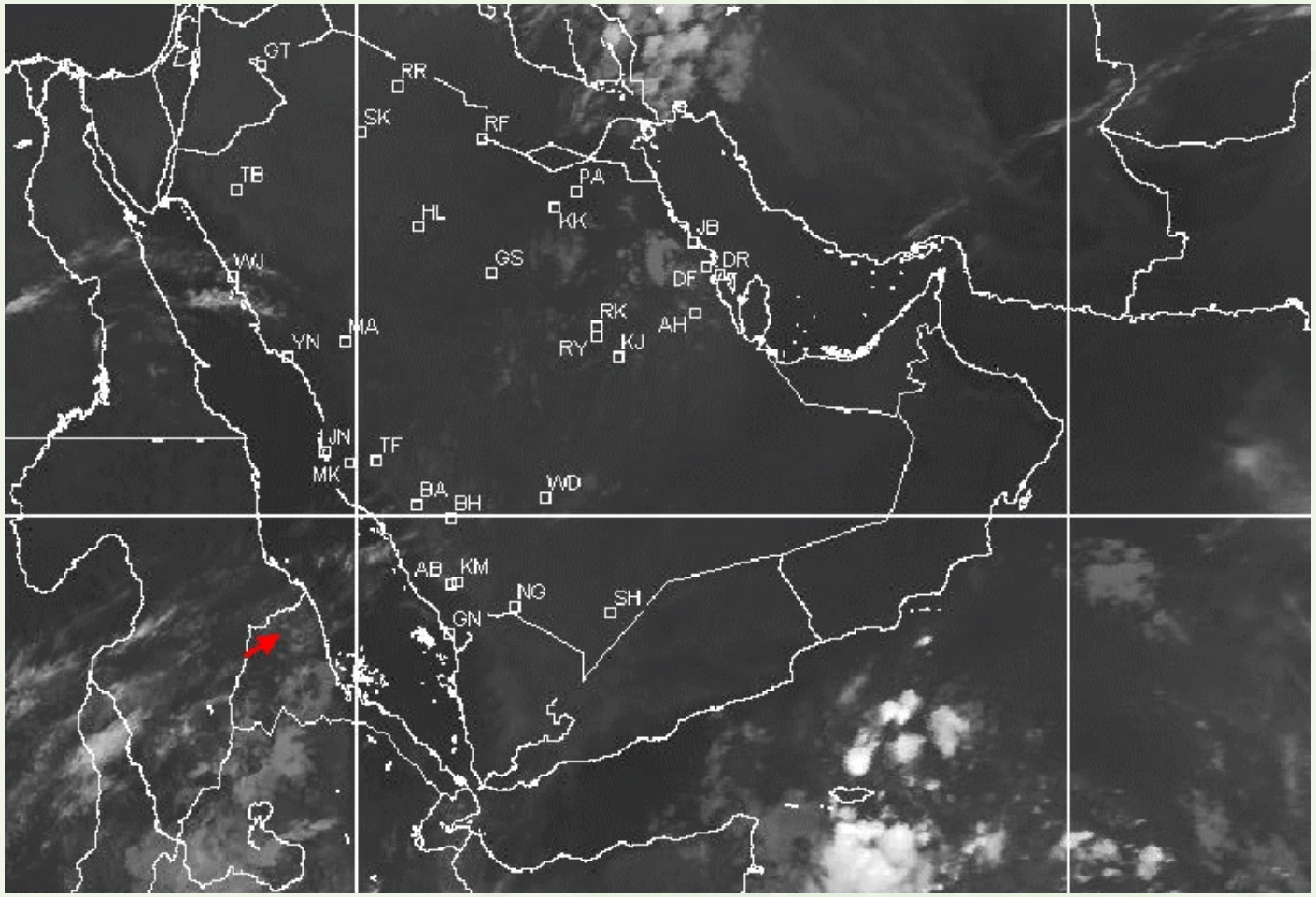


Tokar Gap



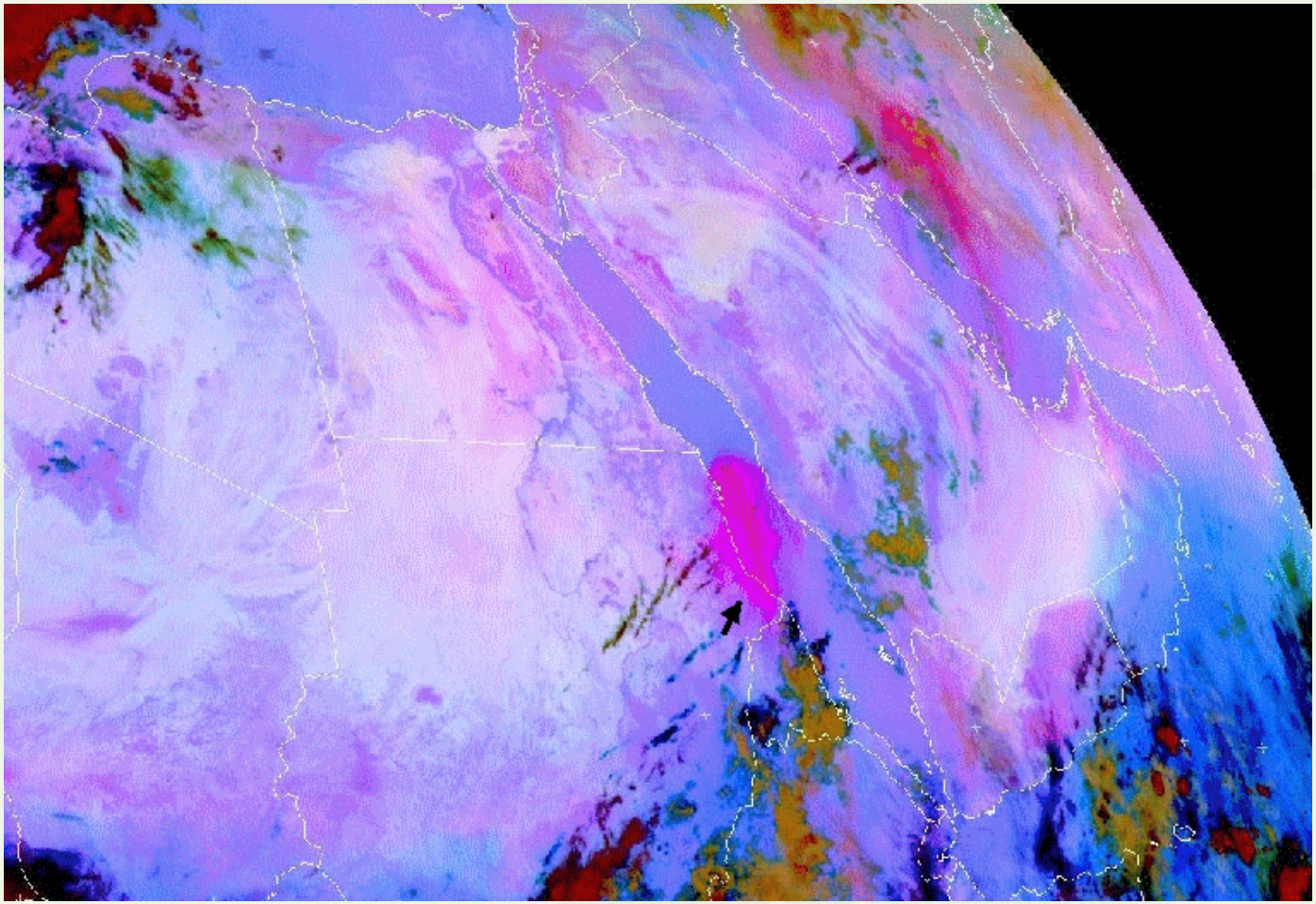
Tokar Gap is shown here. This is one of the dust source areas from which dust storms traversed to the Arabian Peninsula, particularly towards Saudi Arabia.

Dust Event 22 May 2013



Un-Processed Data (Dust event is not much clear)

Dust Event 22 May 2013



Processed Data (Dust event is very clear)

RGB Composite

R = IR12.0 - IR10.8

G = IR10.8 - IR8.7

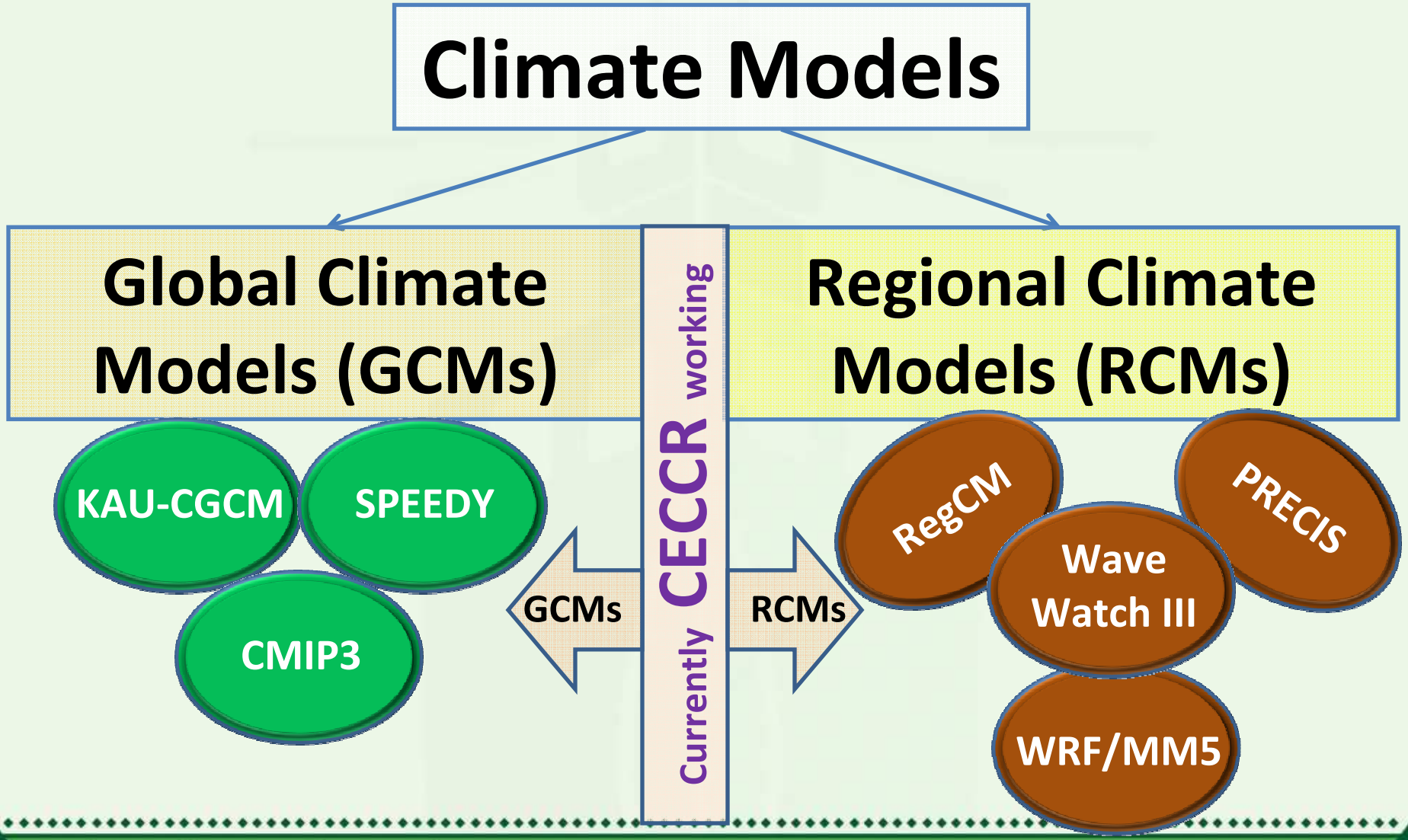
B = IR10.8

Processed Data can be seen in the following link:

http://oiswww.eumetsat.org/IPPS/html/MSG/RGB/DUST/EASTERNAFRICA/index.htm

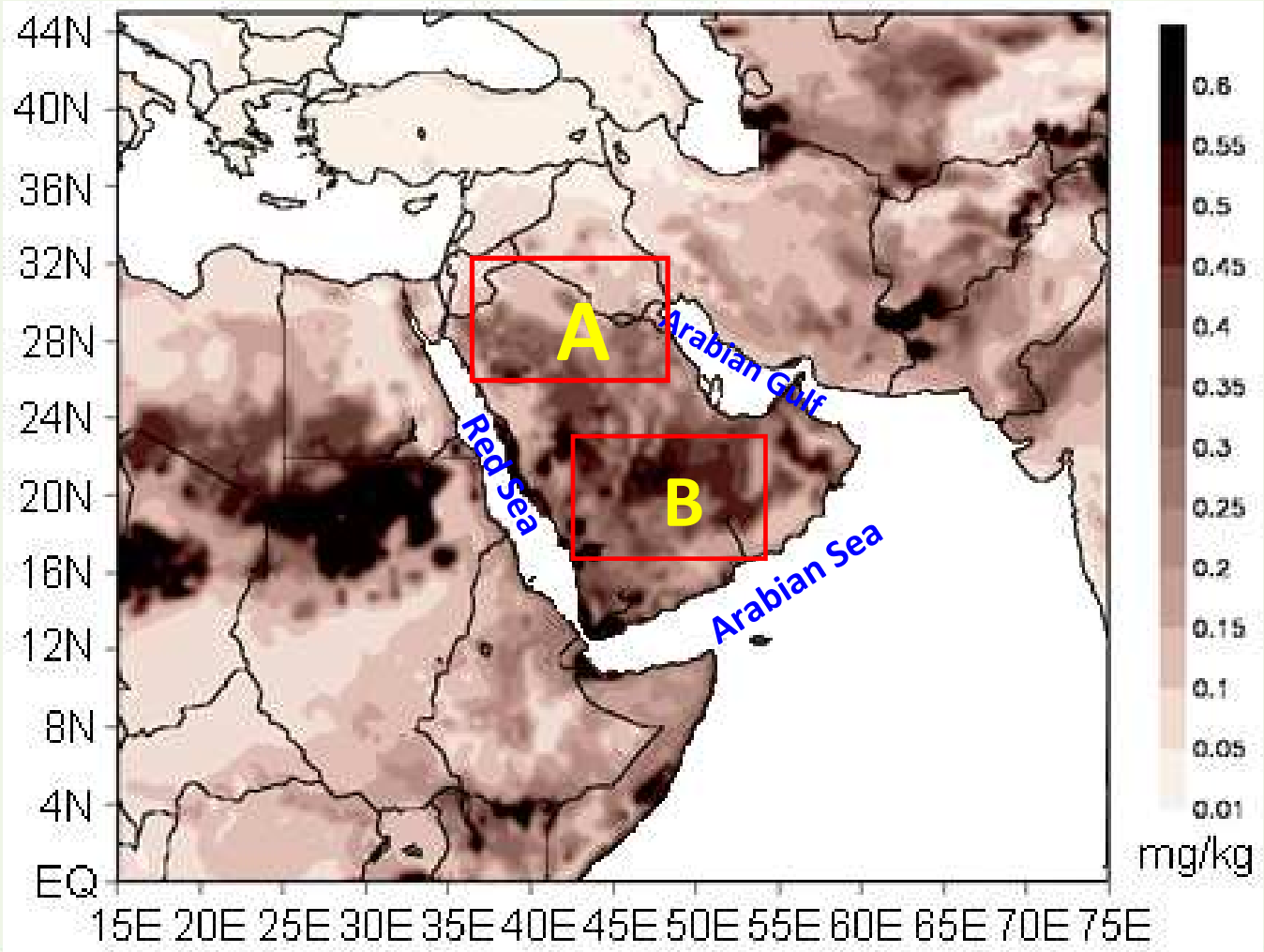
Monitoring of Dust Storms Weather and Climate Models

Forecasting of Dust storms

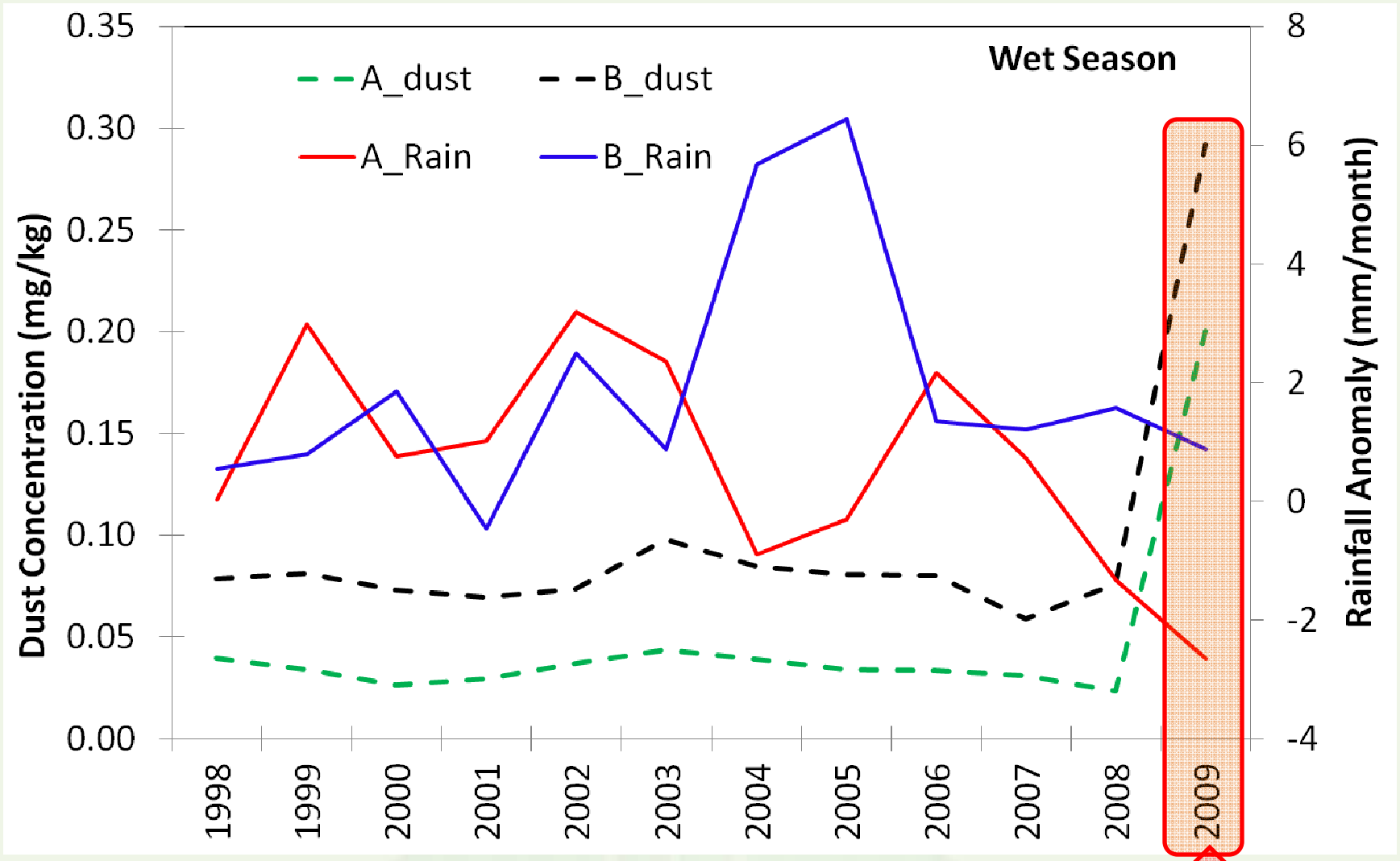


RCM Activity

A Regional Climate Model (RCM) is used to simulate the wet season dust source averaged for 1998-2009. Sub-regions A and B are used later for temperature and rainfall analyses.



RCM Activity

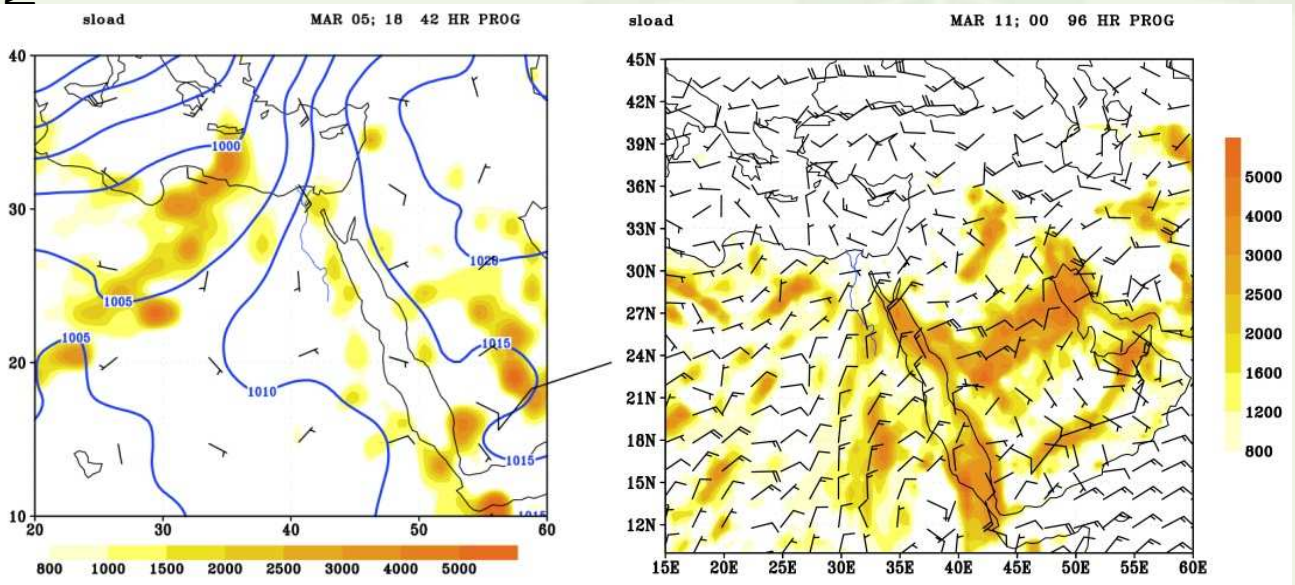


Increase dust concentration reduced rainfall

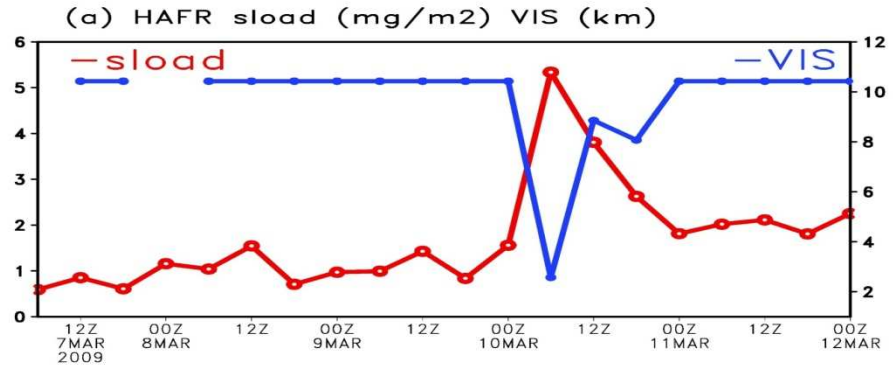
Mesoscale Model

Forecasting of Dust storms

The Weather Researched Forecast (WRF) model which is a mesoscale model with nested domain downscale up to 1 km. It used to forecast all weather feature with spatial scale few km (convection scale) to hundred km (synoptic wave scale).



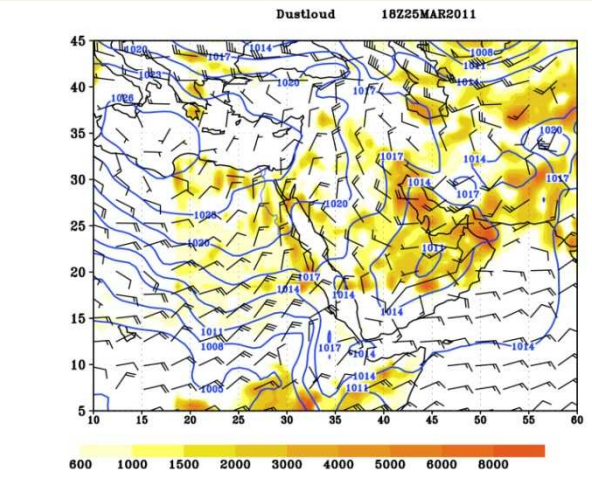
Riyadh: 11 March 2009



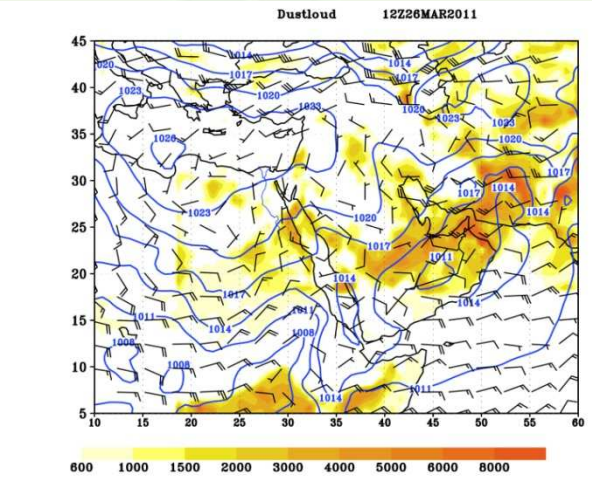
Mesoscale Model

Forecasting of Dust storms

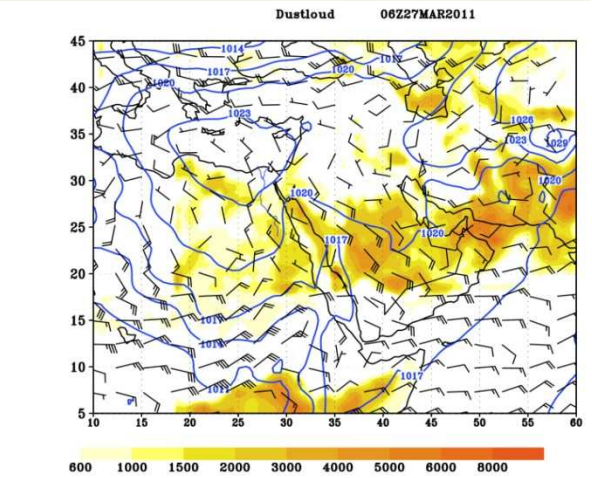
18Z 25MAR 2011



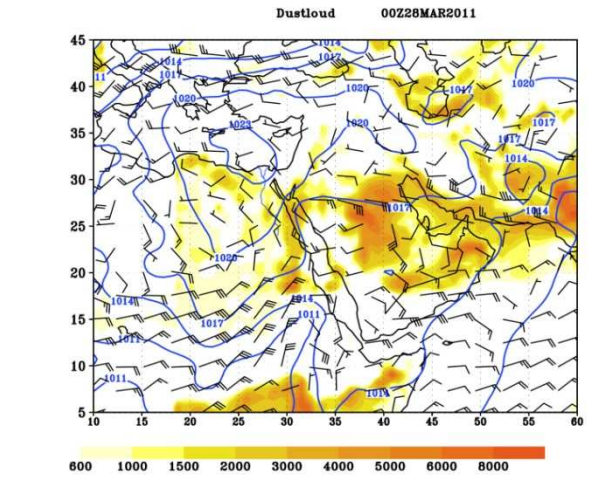
12Z 26MAR 2011



06Z 27MAR 2011



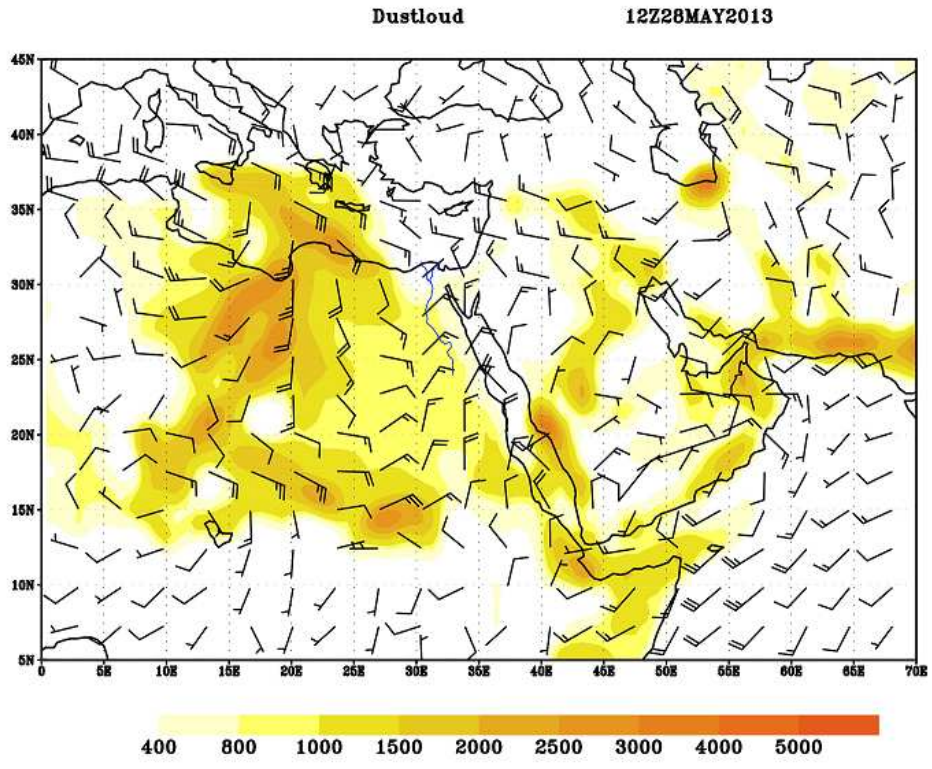
00Z 28MAR 2011



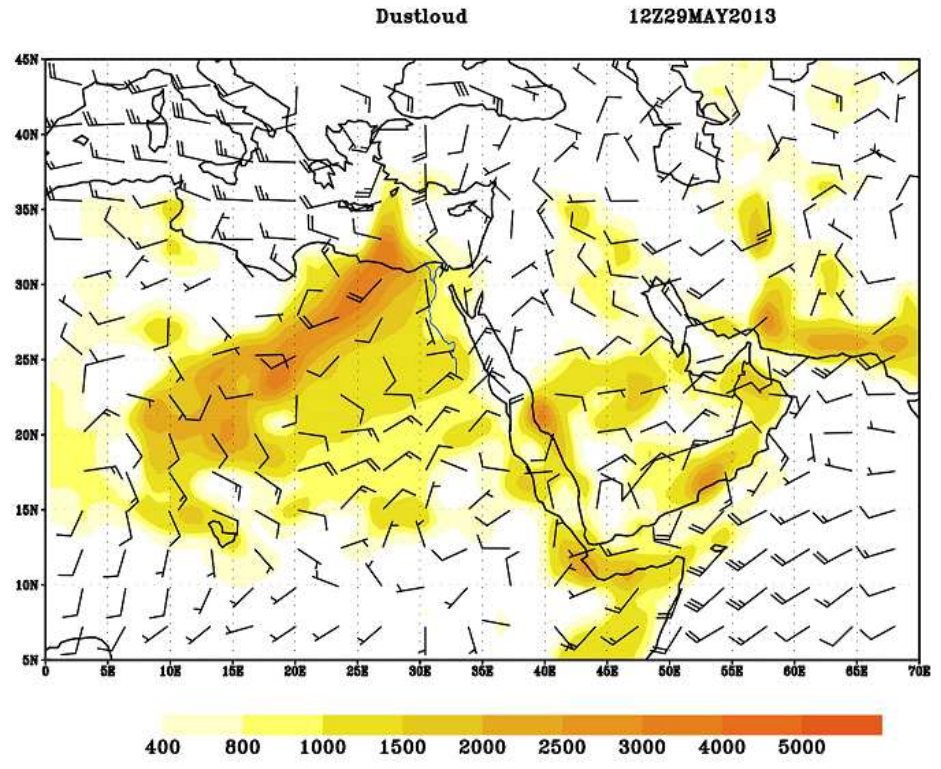
CENTER OF EXCELLENCE FOR CLIMATE CHANGE RESEARCH (CECCR)

Forecasting Dust storms: TODAY & TOMORROW

TODAY: 28 May 2013 Tuesday



TOMORROW: 29 May 2013 Wednesday



CECCR simulated Dust Storm using Weather Researched Forecast (WRF) for Today & Tomorrow. Forecast is performed based on 12UTC boundary conditions of the previous day.

Concluding Remarks

- Preliminary results on dust storms are discussed.
- Detail study (e.g. filter dust from cloud) based on satellite data are required.
- WRF mesoscale model is useful for now-a-cast to short-term forecast of dust storms.
- RCM is useful in long-term forecast of possible dust storms.
- CECCR is working with National/ Regional/ International Institutes involved in Climate Change Research and will continue in expanding dust storms research.

Thank You All