Dust assessment and evolution via meteorological satellites

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EUMETSAT satellites

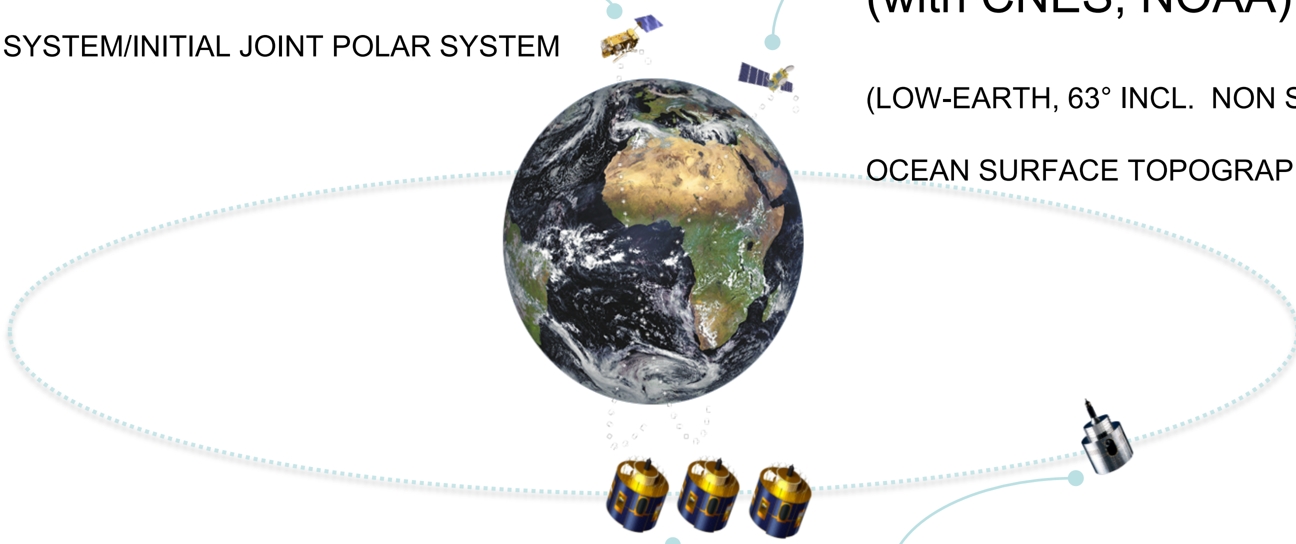
METOP A-B
(LOW-EARTH, SUN – SYNCHRONOUS ORBIT)

EUMETSAT POLAR SYSTEM/INITIAL JOINT POLAR SYSTEM

JASON-2 and 3
(with CNES, NOAA)

(LOW-EARTH, 63° INCL. NON SYNCHRONOUS ORBIT)

OCEAN SURFACE TOPOGRAPHY MISSION



METEOSAT 8-9-10-11 (2nd GENERATION)

METEOSAT- 11: Stored at 3.4°W

METEOSAT-10: FULL DISK IMAGERY MISSION AT 0° (15 MN)

METEOSAT- 9: RAPID SCAN SERVICE OVER EUROPE AT 9.5°E (5 MN)

METEOSAT- 8: BACK UP AT 3.5°E

METEOSAT 7 (1st GENERATION)

INDIAN OCEAN DATA COVERAGE MISSION AT 57°5 E
(UNTIL END 2016)

After 2016, perhaps Meteosat-8 at this location

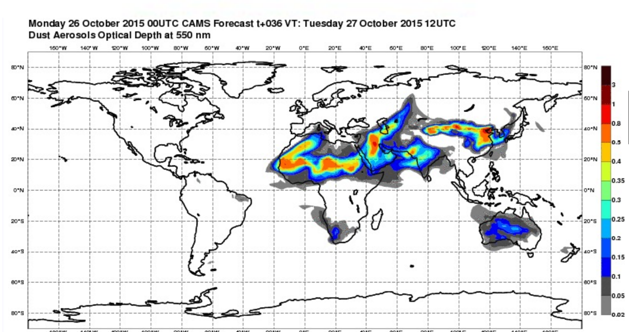
Instrument - Product - Application

L0 - raw measurement (count)

L1- calibrated <u>image</u> (units)

L2 – <u>product</u> (purpose, classes)

L3 – quality controlled (reliability)



L4 – <u>model</u> output (future propagation)

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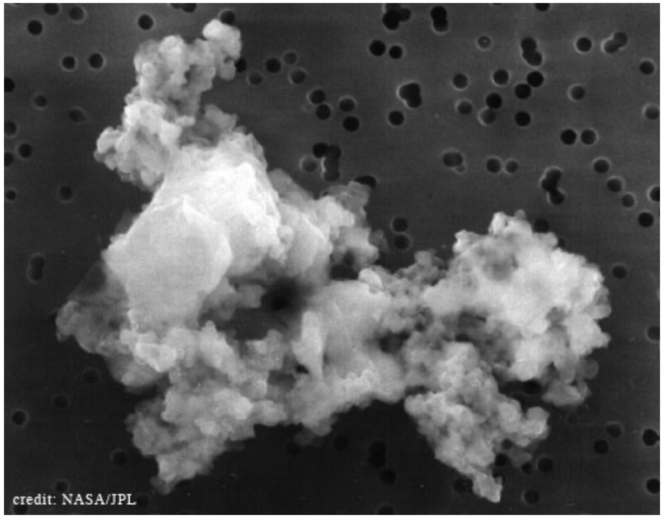
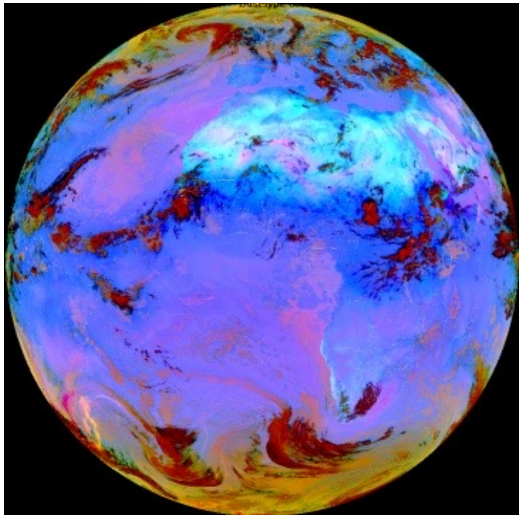
Can a satellite see dust particles ?



← Dust particle 10 µm →



← Earth globe 10 Mm →

- From micro to mega, twelve orders of magnitude difference in size
- 10^{12} kg in the atmosphere (10^{-7} of atmospheric mass) = fill all lorries!
- Disputed human contribution to global cooling (S.K. Satheesh, 2006)
- Inert tracer for atmospheric circulation
- Life vector (Saharan protozoa and bacteria to the Caribbean)

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For land areas, infrared is more efficient

Best contrast ?	DAY	NIGHT
IR		
VIS		

Choose the field with best contrast between free-surfaces and dust areas

Ocean	DAY	NIGHT
IR	strong	strong
VIS	very strong	A/N/A

Desert	DAY	NIGHT
IR	very strong	weak
VIS	weak	A/N/A

Consecutive days in Fuerteventura, January 2010

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Double detection from Meteosat

- On infrared imagery, dusty air appears cold in contrast to the hot **daytime** land surface.
- At **night**, the thermal difference between the background and the dust lessens. Dust is not raised in the absence of thermals or convection.
- On solar imagery over **water**, dust is easy to notice. Over **land**, however, the dust plume and dry surfaces look similar. Time animations evidence dust over ground.

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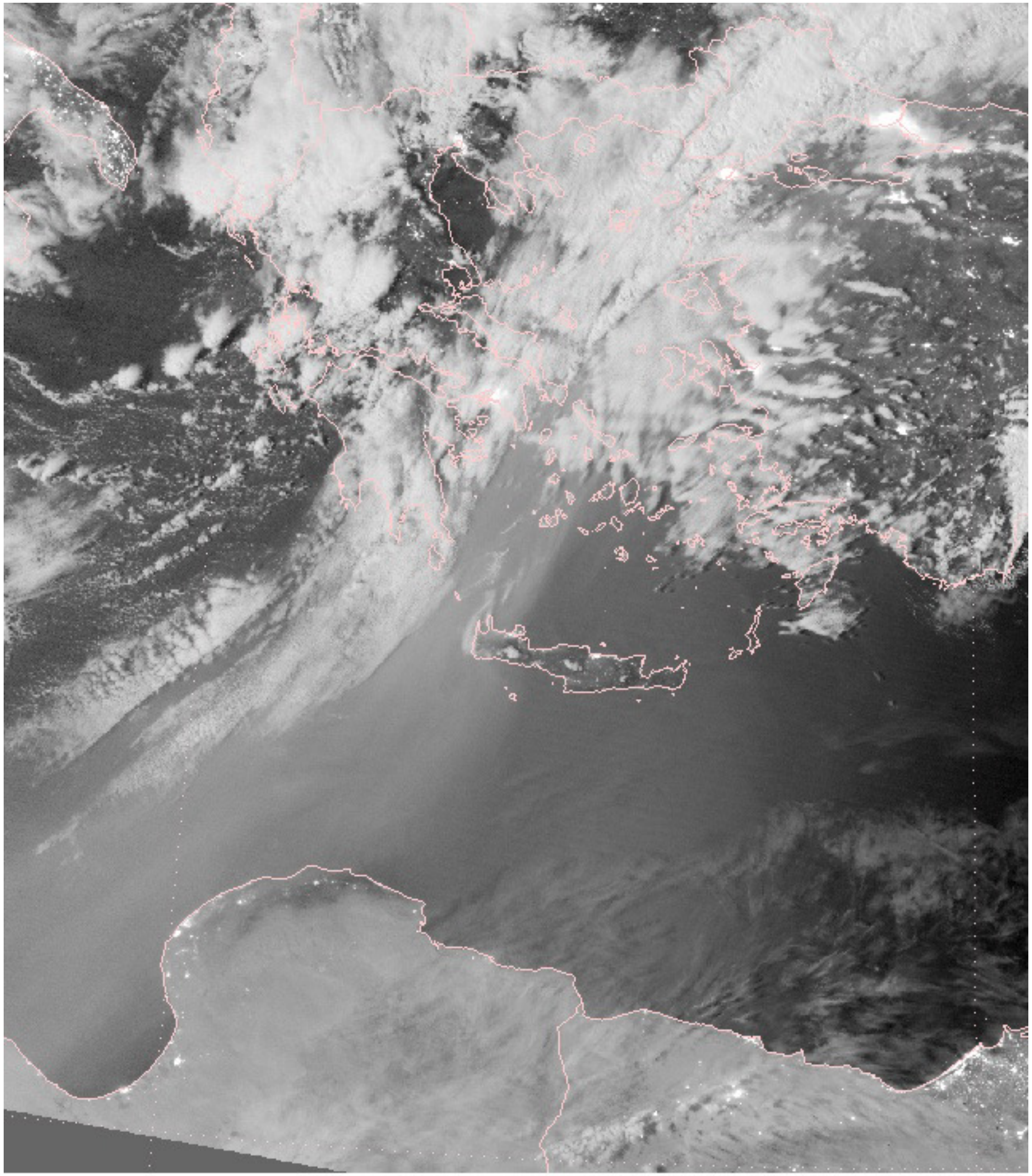

snpp DNB - 2015-02-01 23:45UTC

Dust at the moonlight

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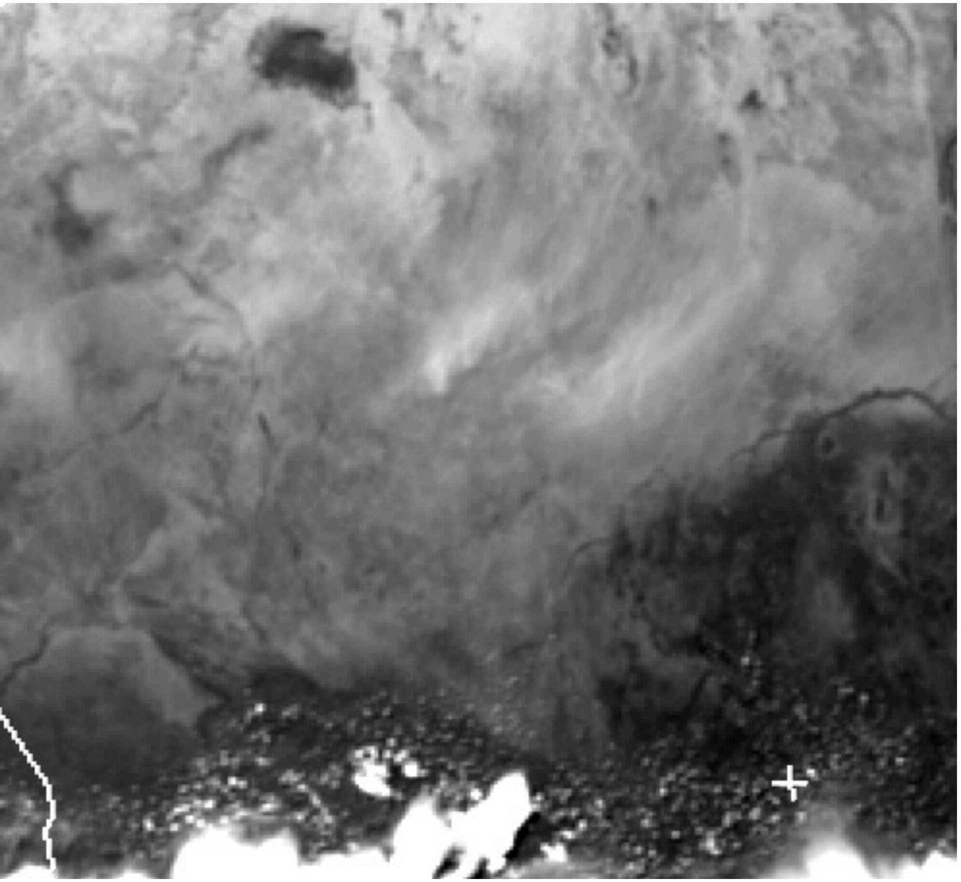
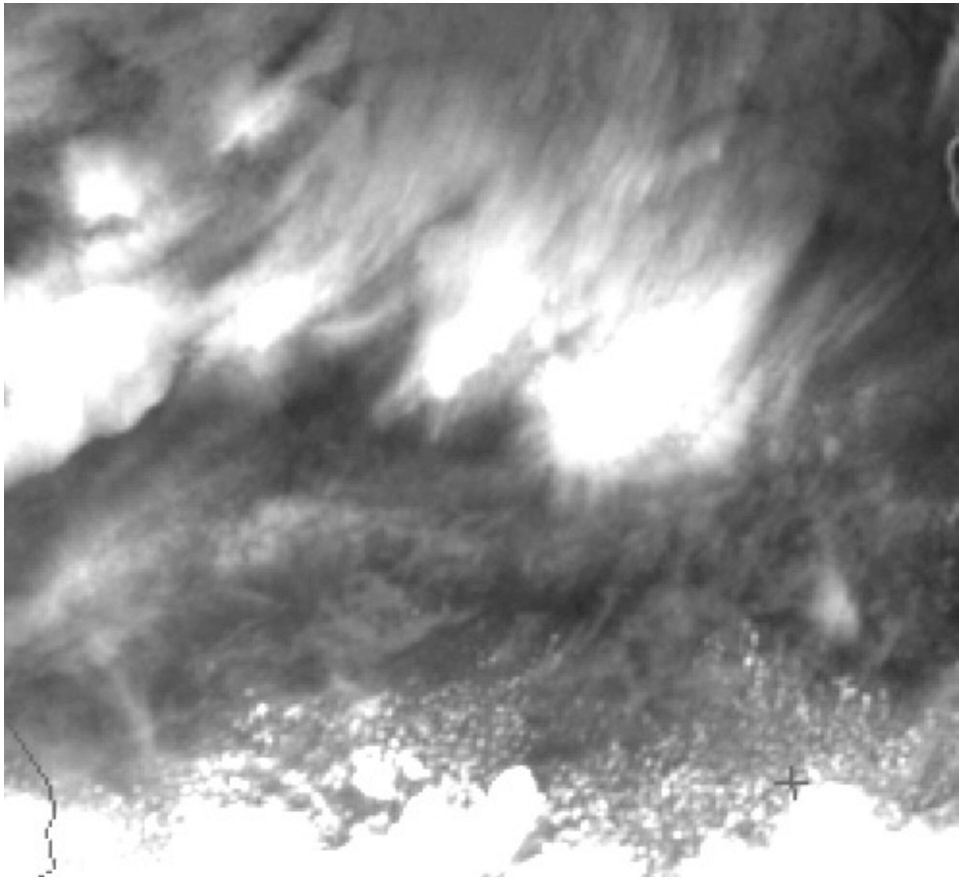
Dust on solar and infrared images



2004-05-13 13:00 UTC, 0.8 µm

- Dust **reflects** back solar energy to space
- Midday, unfavourable reflection conditions



Same date and time, 10.8 µm

- Dusty air rises (**cools** down)

Desert scene, Sudan

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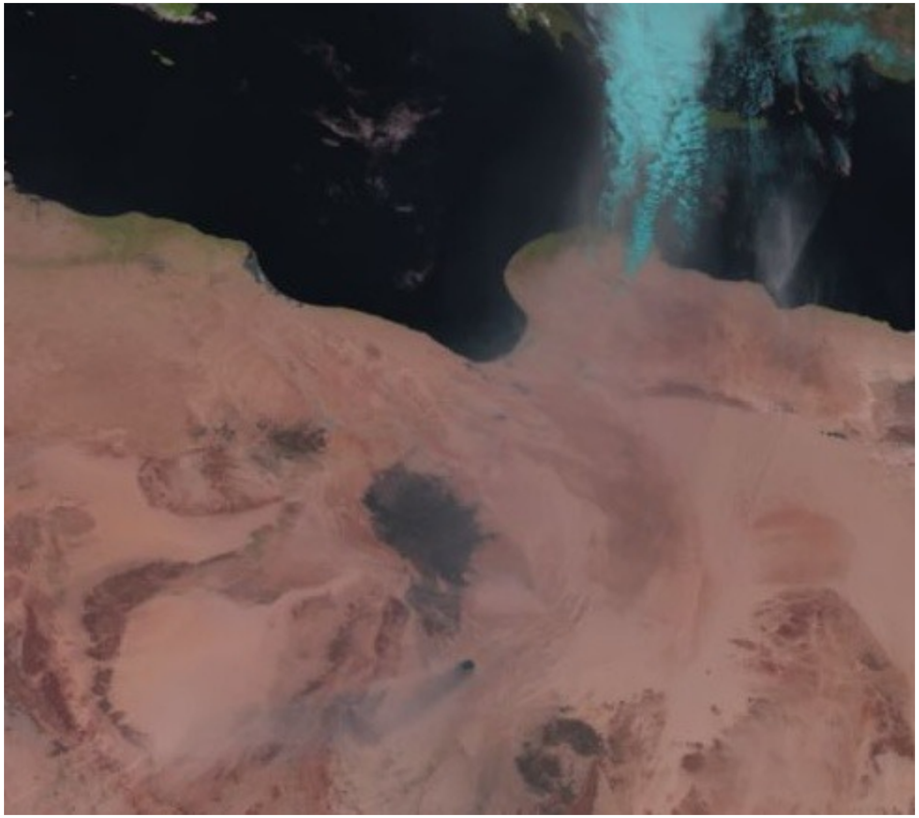
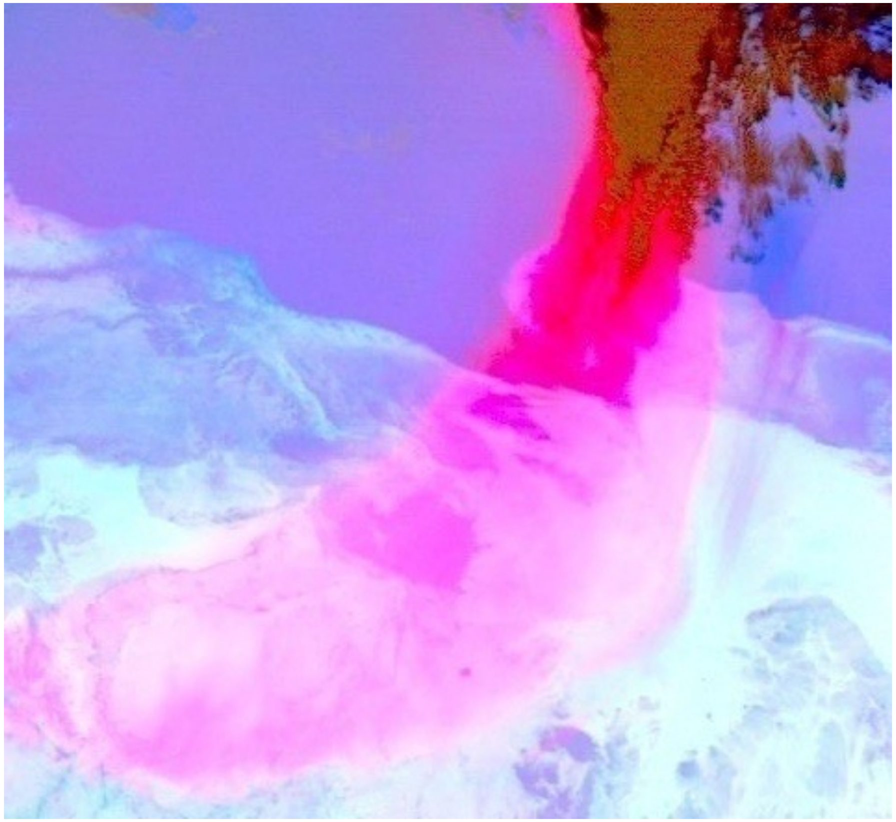
DUST RGB composite: the strength of infrared for dust detection



Solar RGB composite based on channels at 1.6, 0.8 and 0.6 μm



IR RGB composite based on channels at 8.7, 10.8 and 12.0 μm

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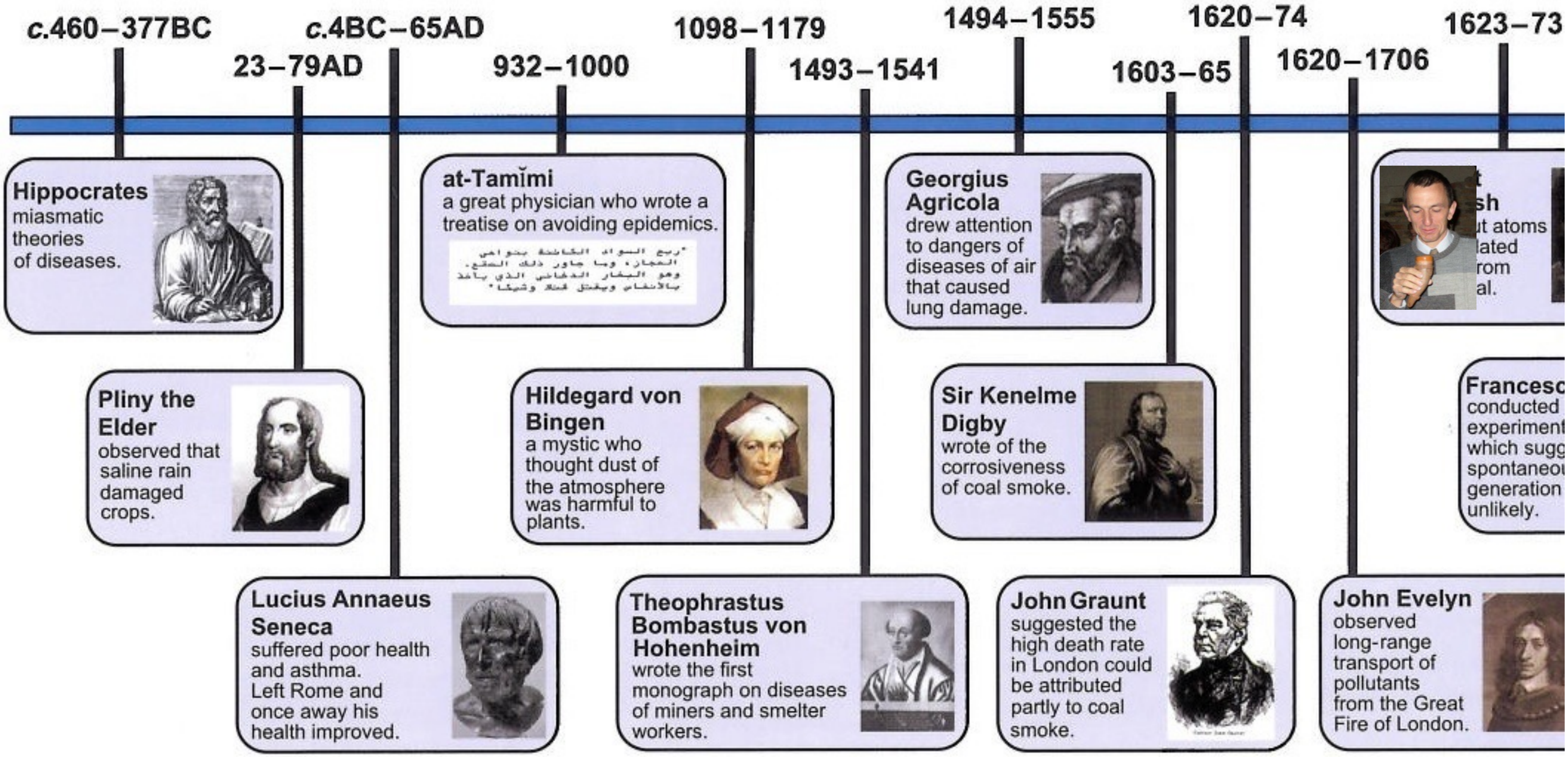
Aerosol and health



World Atlas of Atmospheric Pollution. Editor: R. S. Sokhi

Impact on: agriculture (fertile fields), climate (radiative balance), aviation (ash in routes)

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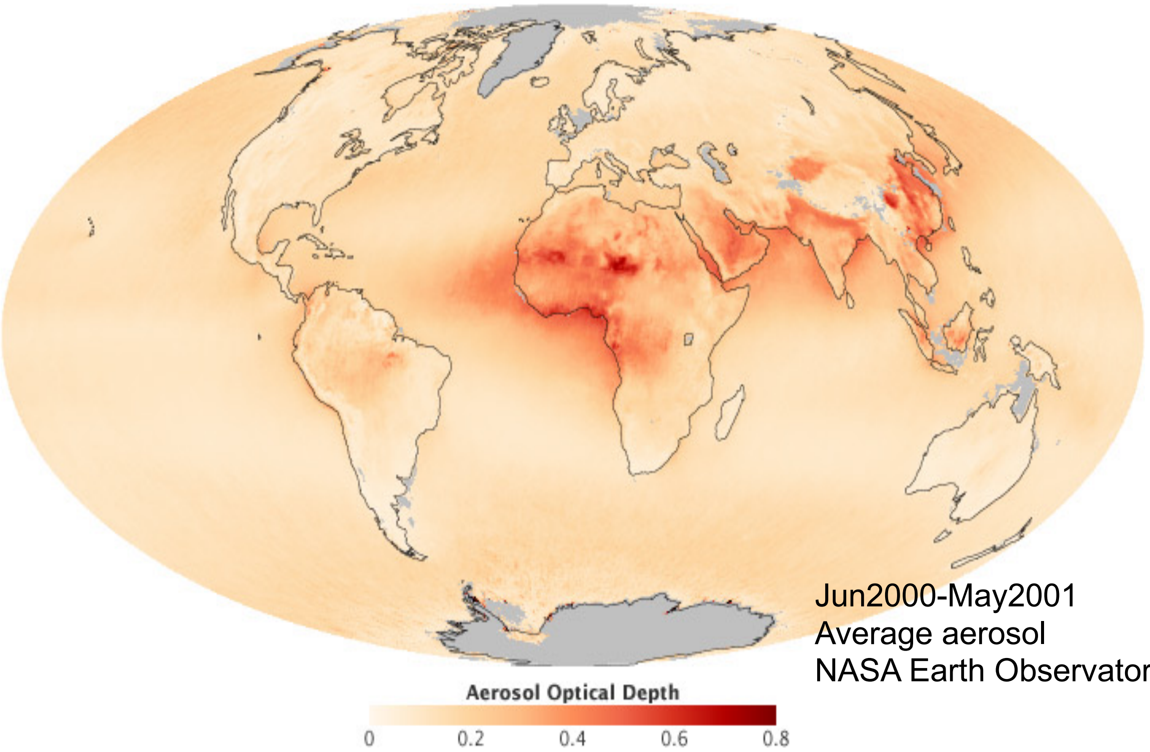
Air transports dust and much more



Jun2000-May2001
Average aerosol
NASA Earth Observatory

AEROSOL

Dust
Marine salt
Smoke
(biomass burn, industrial carbon) HUMAN
Ash
Pollen
[Cloud droplets and ice crystals ?-Not an aerosol]

Forward fraction=exp(-AOD)

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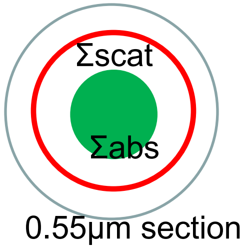
Dust characteristics

- Dust storms occasionally reach 5 km **height**, frequently thicker than 1km

- Over land, dust optical depth is typically around 0.5 or 2 for storms, in the visible range. Efficient **thickness** in the IR is about 40% of those values.

- Dust absorbs and scatters **infrared** radiation in the **Mie** region

- Aerosol **density** average in the atmosphere 10^{-7} kg/m3 (optical depth 0.1)



- Dusty air ~ AOD=1 ~ 1 mg/m^3 ~ 1 g/m^2

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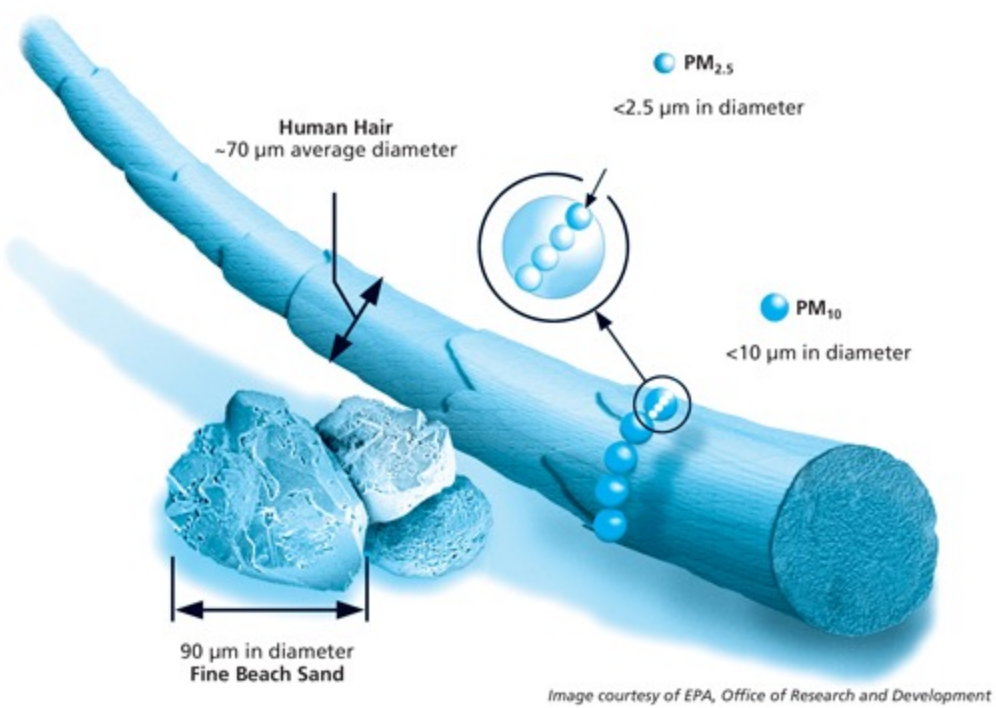
Using infrared channels for dust detection



- Meteosat thermal channels detect PM2.5 and PM10 in high atmospheric levels

- In addition they indicate the probable origin and current location of similar particles close to the ground

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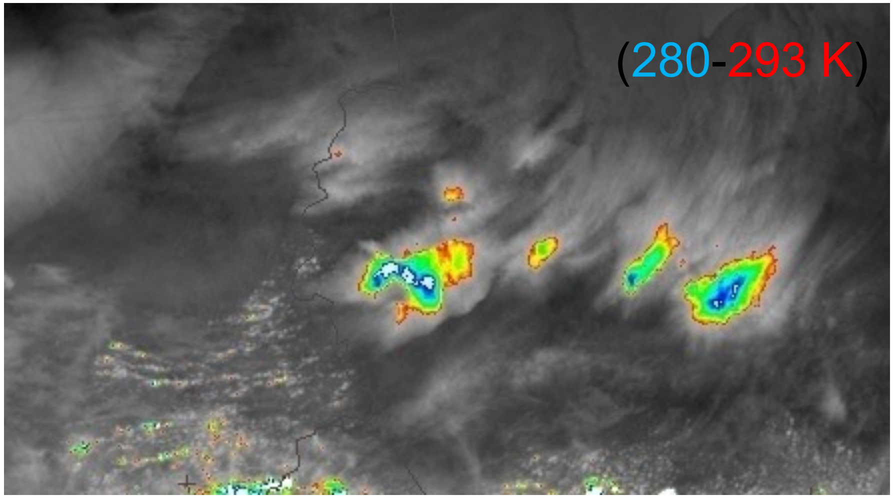
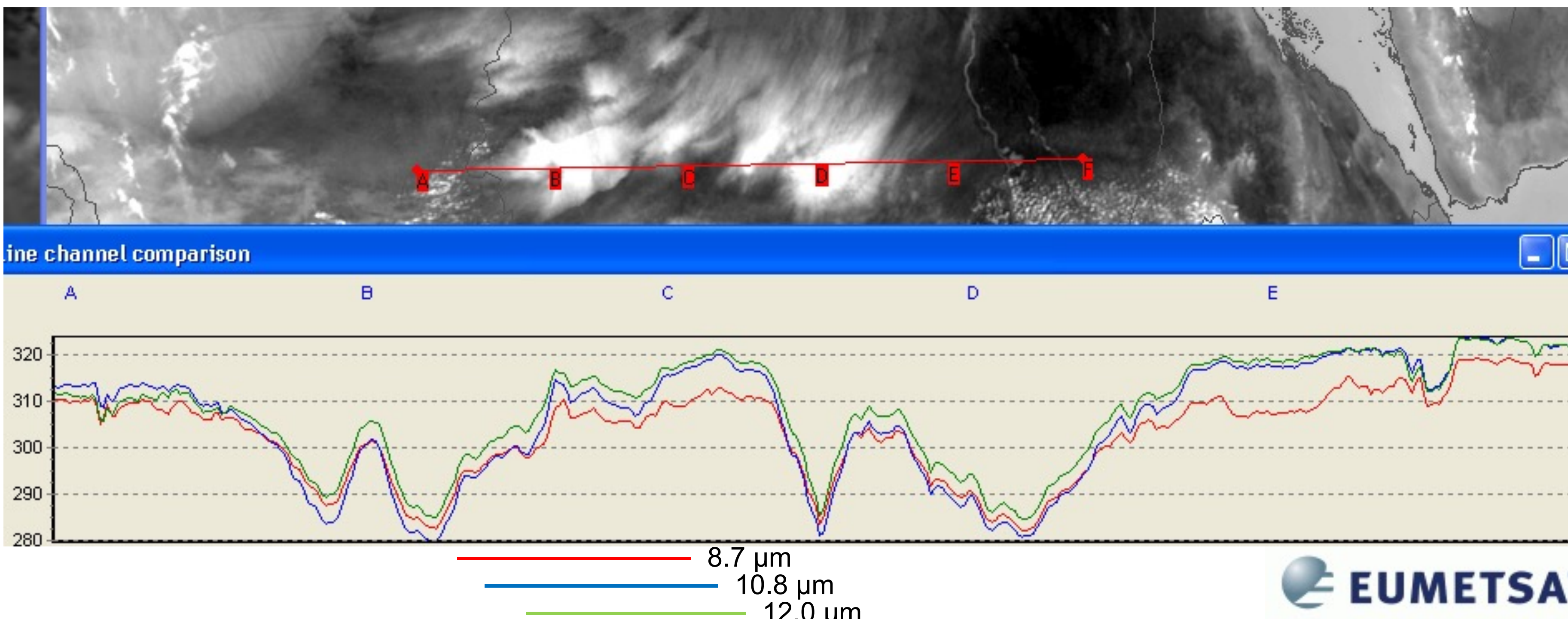
Dust seen at a single infrared (IR) channel



-Variable limits for colour enhancement
-Uncertain nature of the cold area (cloud?)
-Possible mixture of cloud and dust

2004 May 13th 13:00 Meteosat **10.8µm**
colour-enhanced (left) and gray-enhanced (below)



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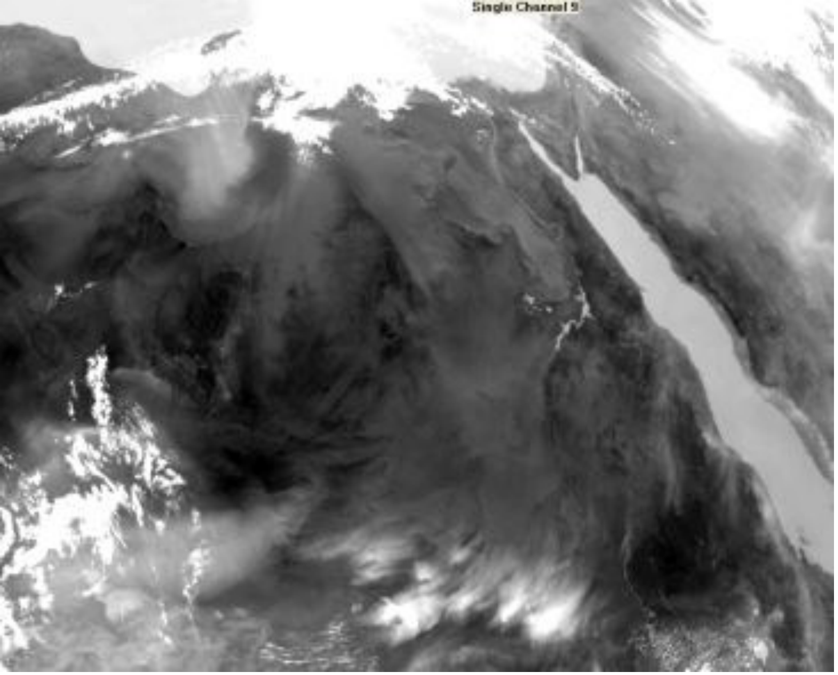
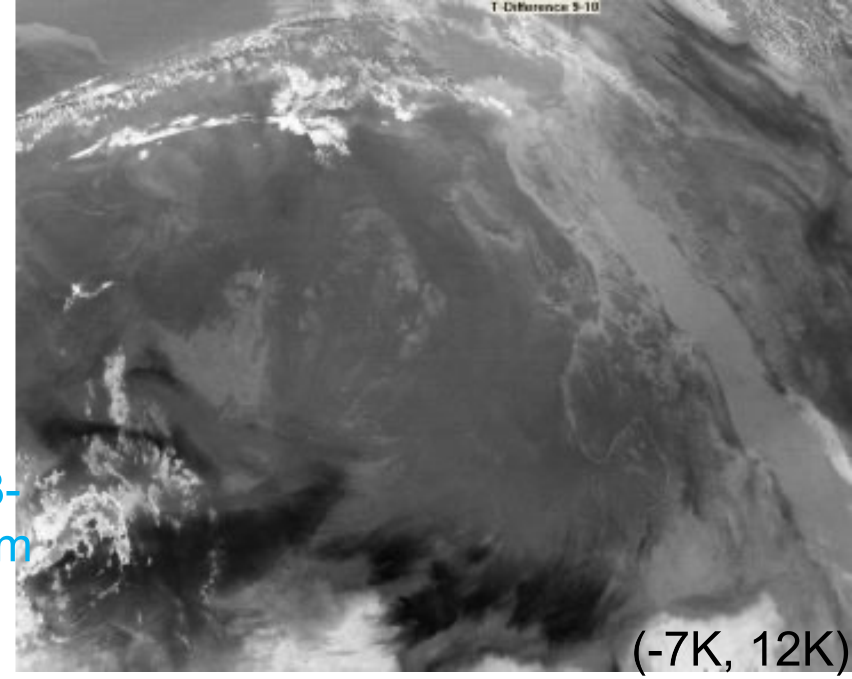
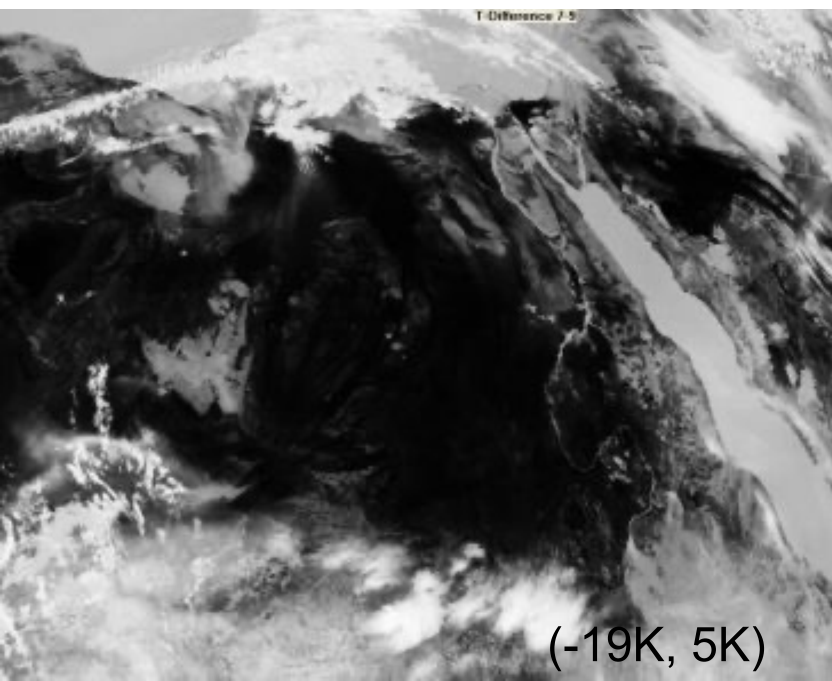


10.8µm

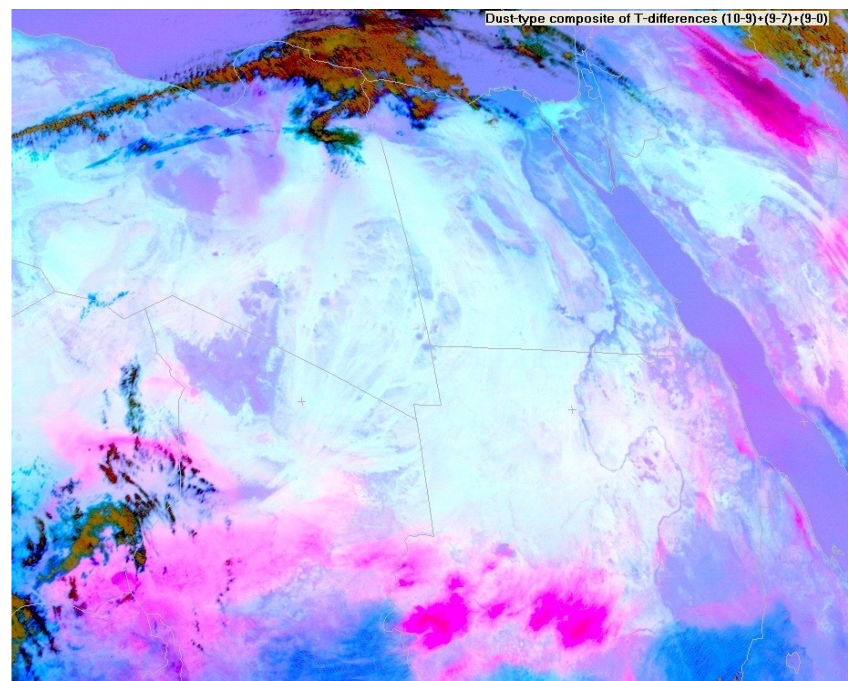
10.8-
12µm



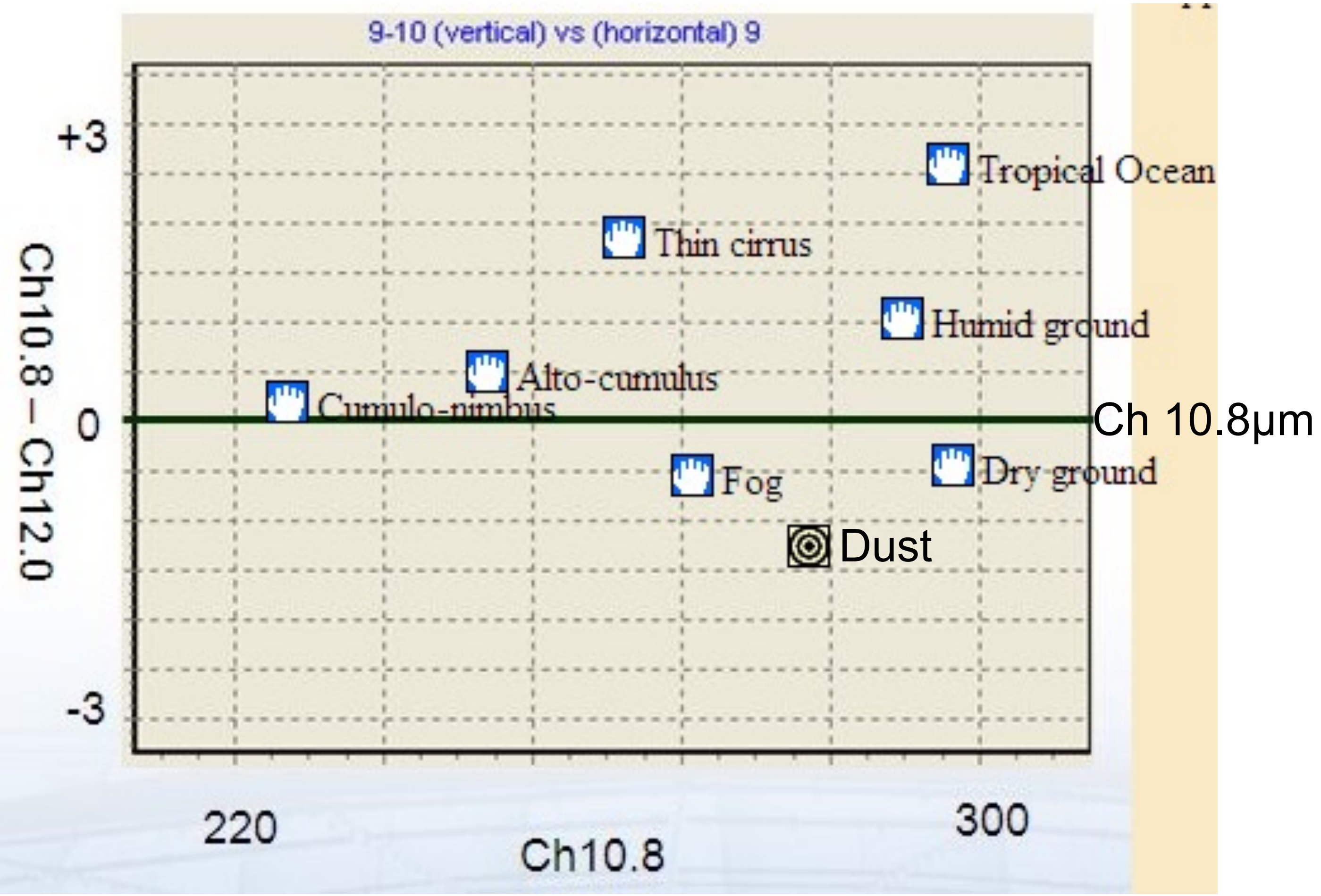
Ch9 (*upper left*), two independent differences, and all together as colour



8.7-
10.8µm



The 10.8μm-12μm difference (vertical)



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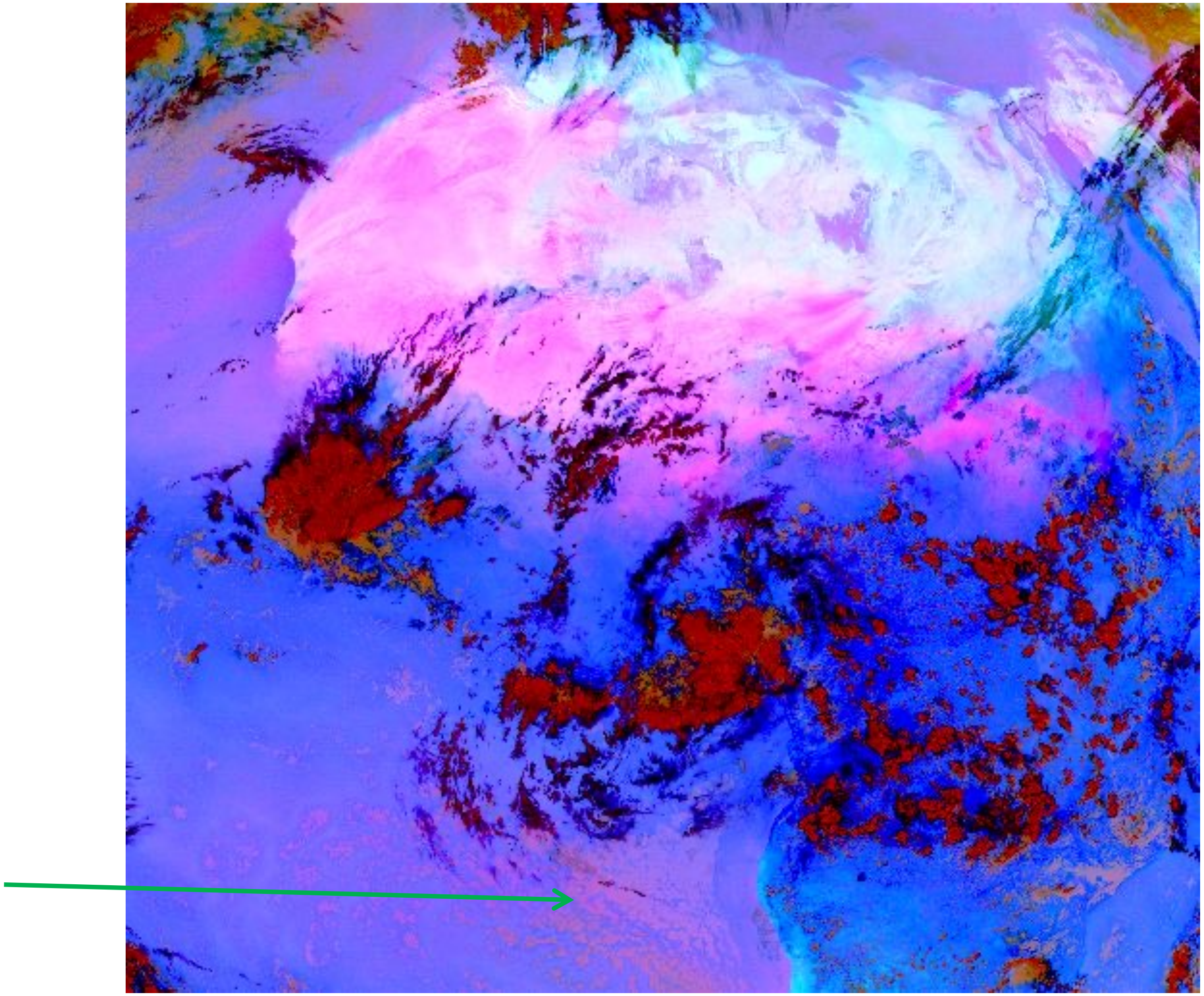
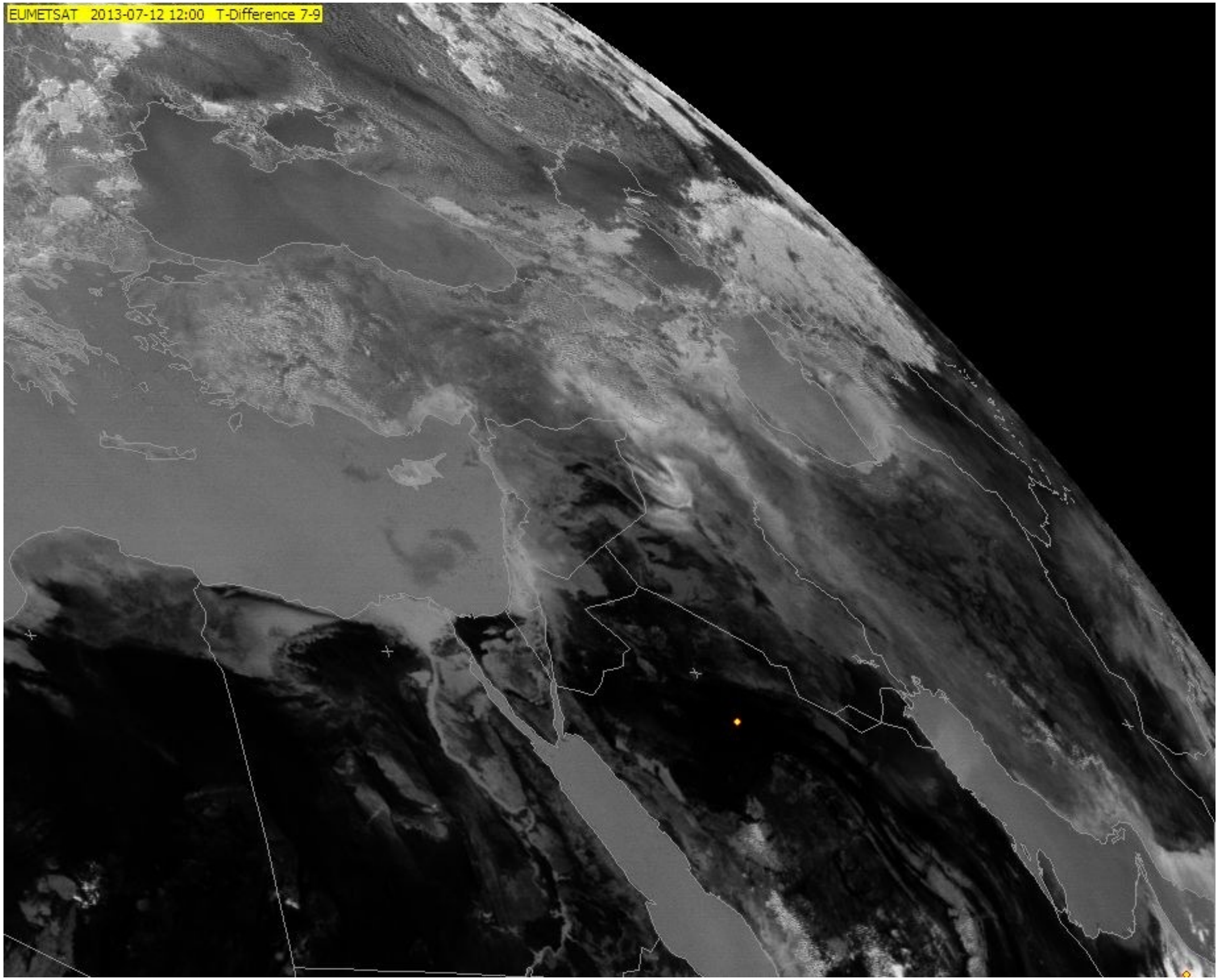
Dust RGB 21 March 2010 12UTC



pink is not always dust



Met-8, 2013 July 12 12UTC, ch9-ch10, ch7-ch9 (-17K to 5K) differences and Dust RGB

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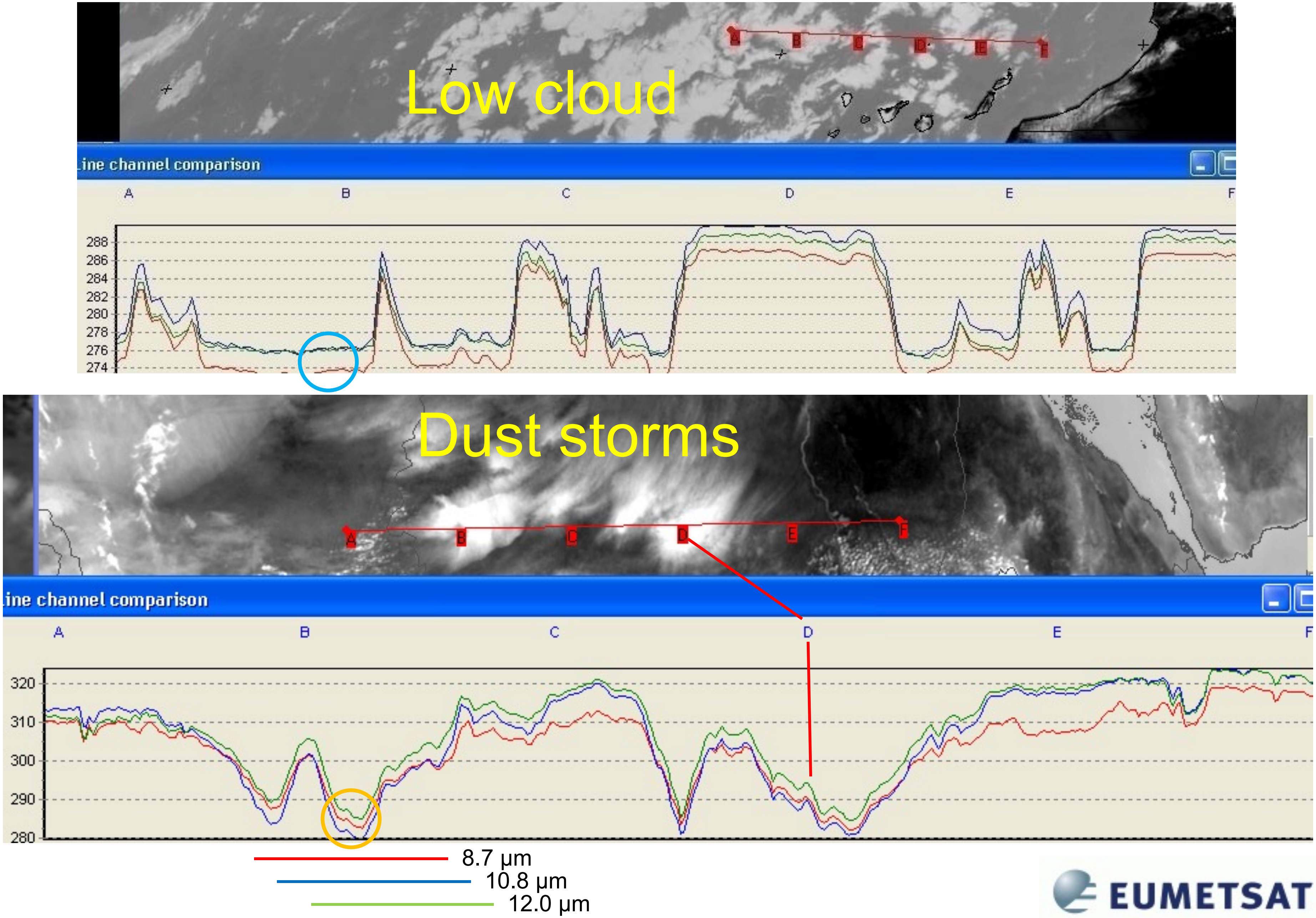
Comparison of water cloud and dust in the IR window



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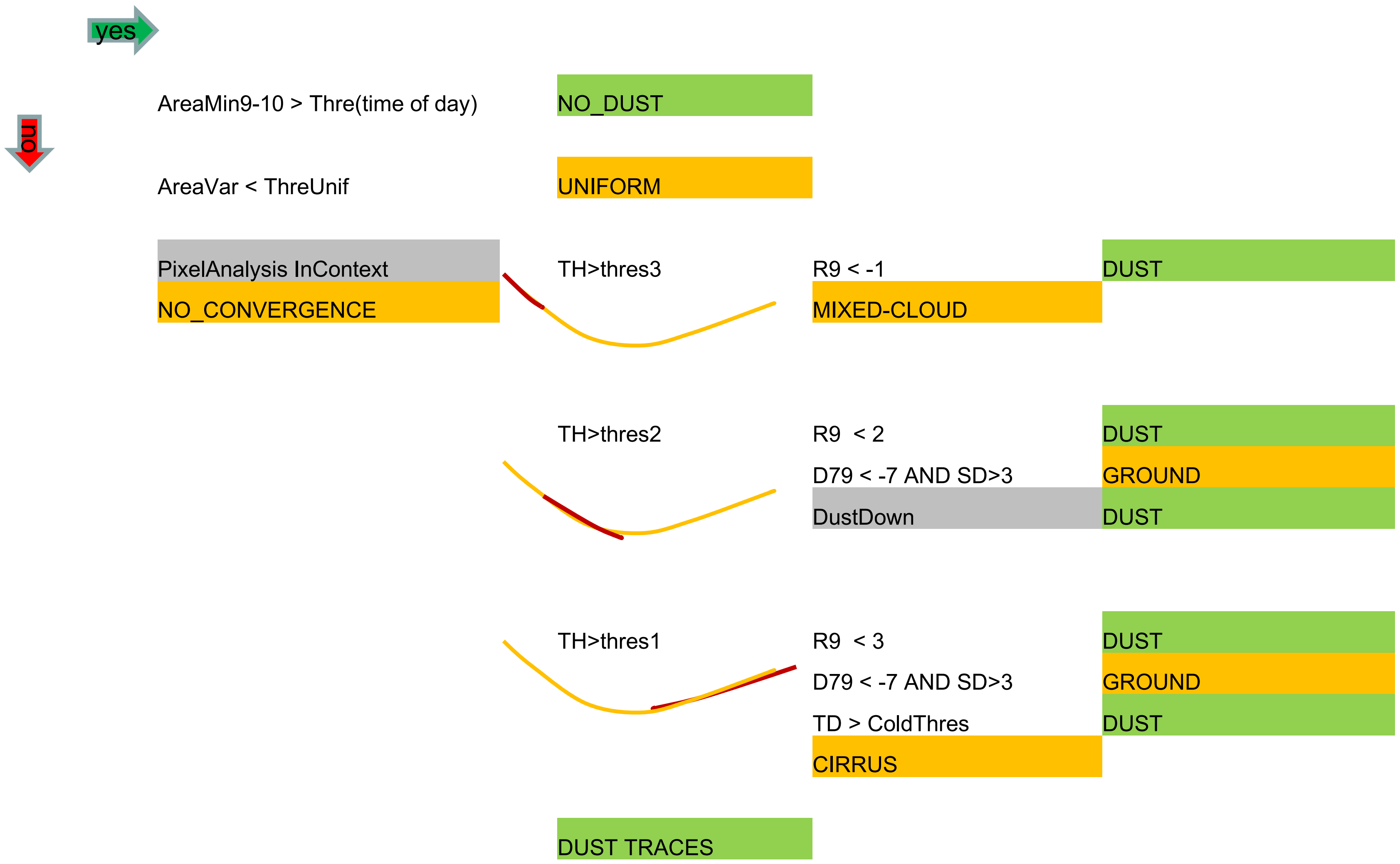
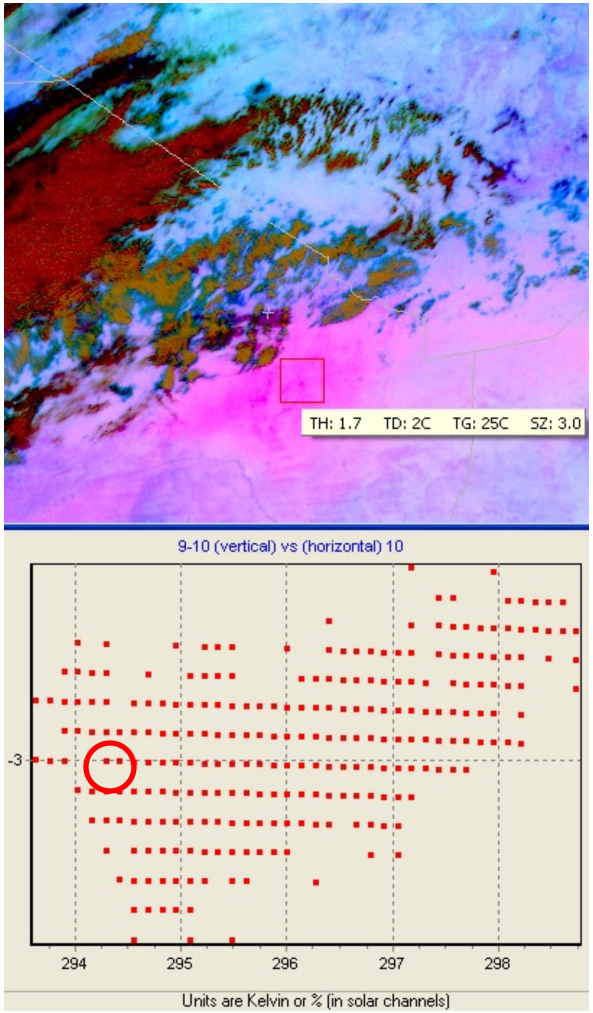
Decision tree

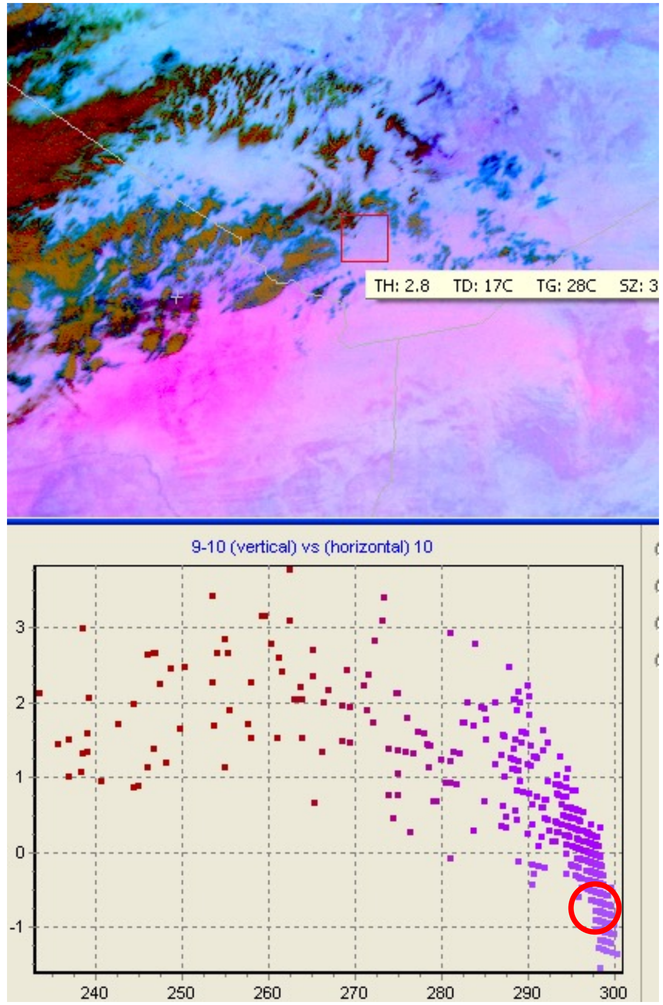


1. Subjective **verification** against masks, images and news media
2. **Verification** from other sources (AERONET, LIDAR)
3. **Inter-comparison** with other methods (Solar)

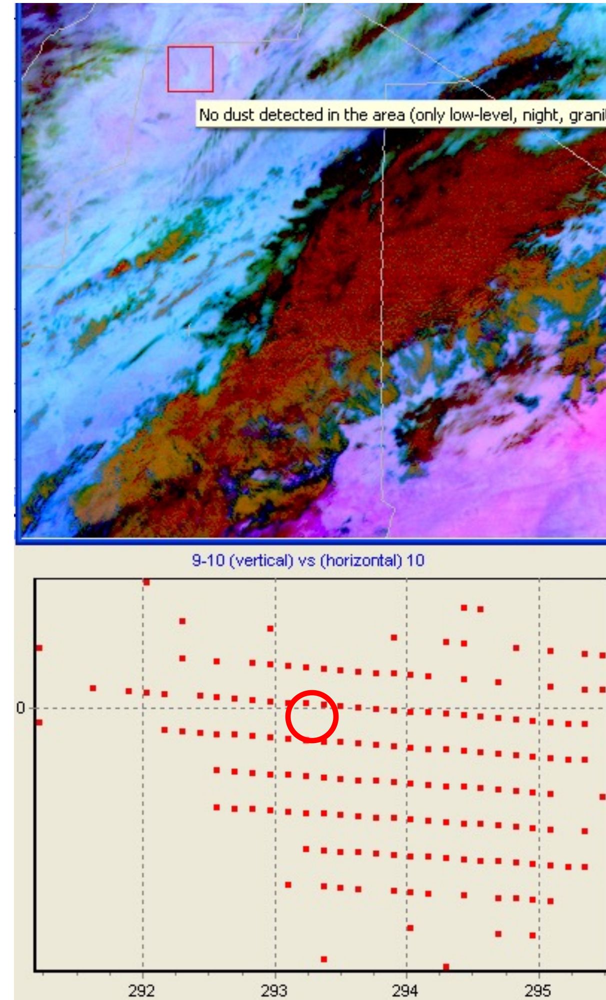
Graphical validation



threshold ch9-ch10 < -1.3K
AOT =1.7, strong depth



threshold ch9-ch10 < -1.3K
AOT =2.8, too strong depth
Due to location of minimum



threshold NOT < -1.3K
AOT not calculated

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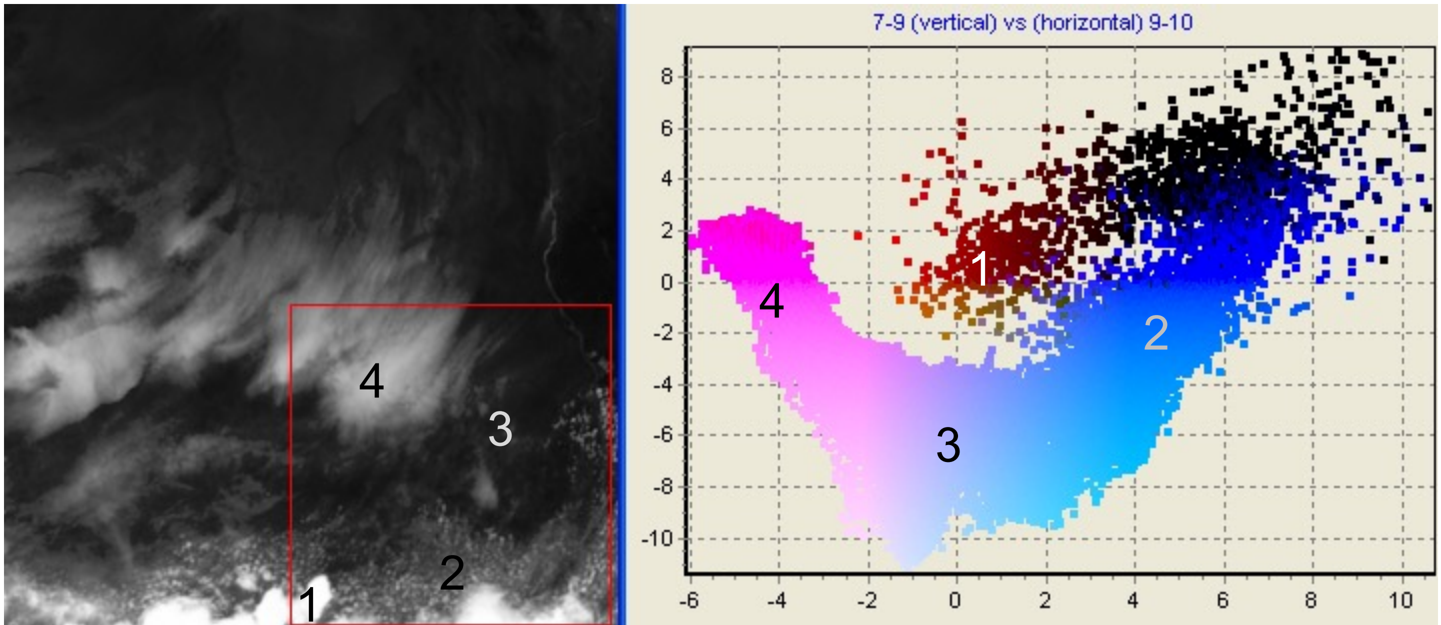
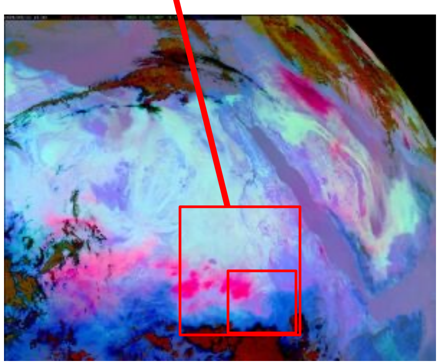
The cloud-to-dust spiral in the differences diagram



2004-05-13 13:00 UTC, 10.8 µm



1: Thick high cloud
2: Broken low cloud
3: Ground, drier air towards 4
4: Dust cloud

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SAMPLE VALIDATION

based on AERONET ground measurements

- ❑ Good agreement (+/- 30%) over **desert** grounds
- ❑ Over the ocean or islands, lack of model sensitivity due to insufficient temperature contrast, dust thinness or **uniform** background for neighbour calculation
- ❑ Better match for **coarse** than for fine aerosol
- ❑ No sample validation done so far for dust temperatures (heights), using ground temperature. This is essential for evaluation of the thermal deficit

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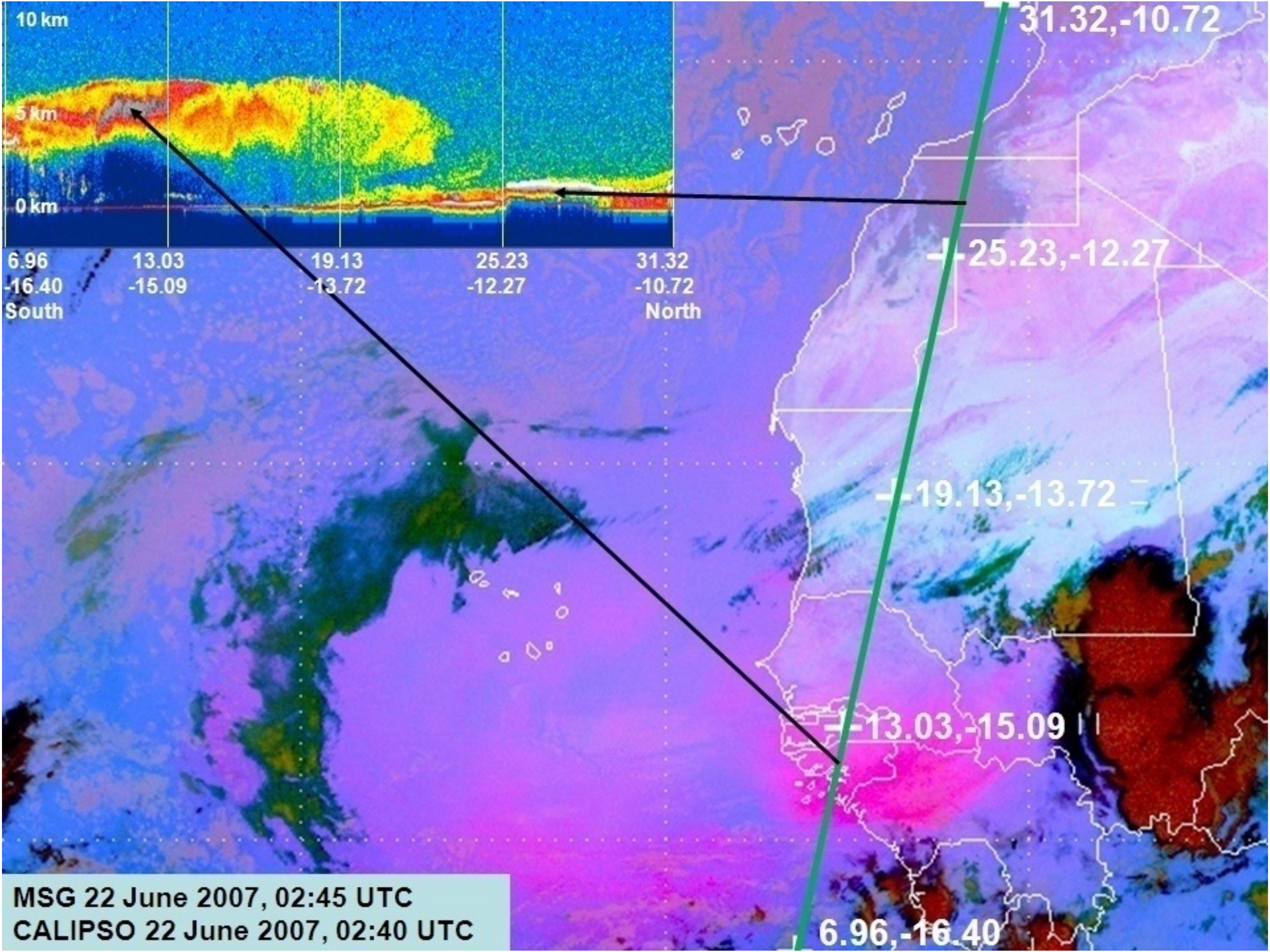
10 km
5 km
0 km
6.96
-16.40
South
13.03
-15.09
19.13
-13.72
25.23
-12.27
31.32
-10.72
North
31.32,-10.72
25.23,-12.27
19.13,-13.72
13.03,-15.09
6.96,-16.40
MSG 22 June 2007, 02:45 UTC
CALIPSO 22 June 2007, 02:40 UTC

Low level dust forming a dust wall in Niamey (courtesy of E. Kploguede)

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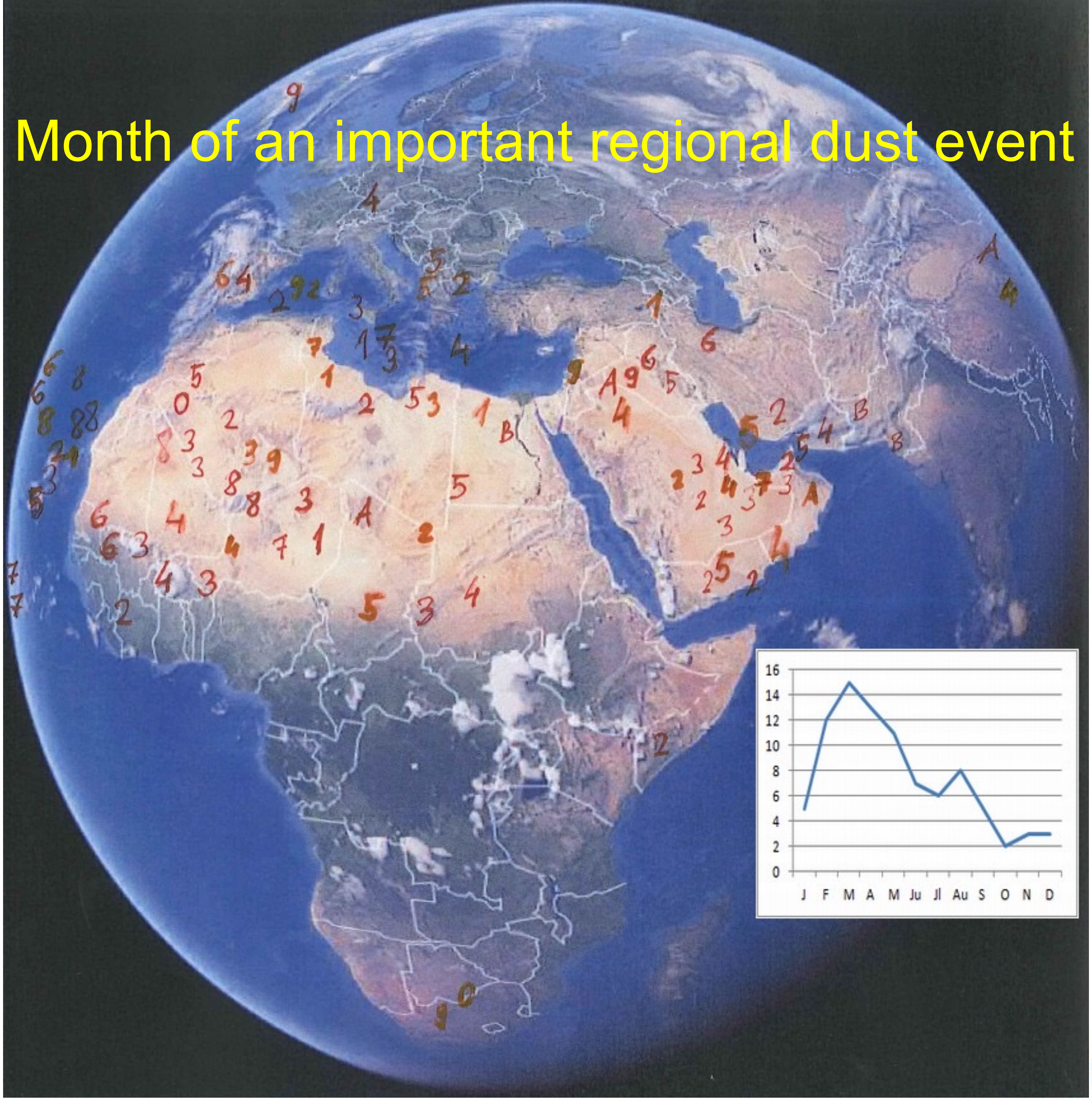
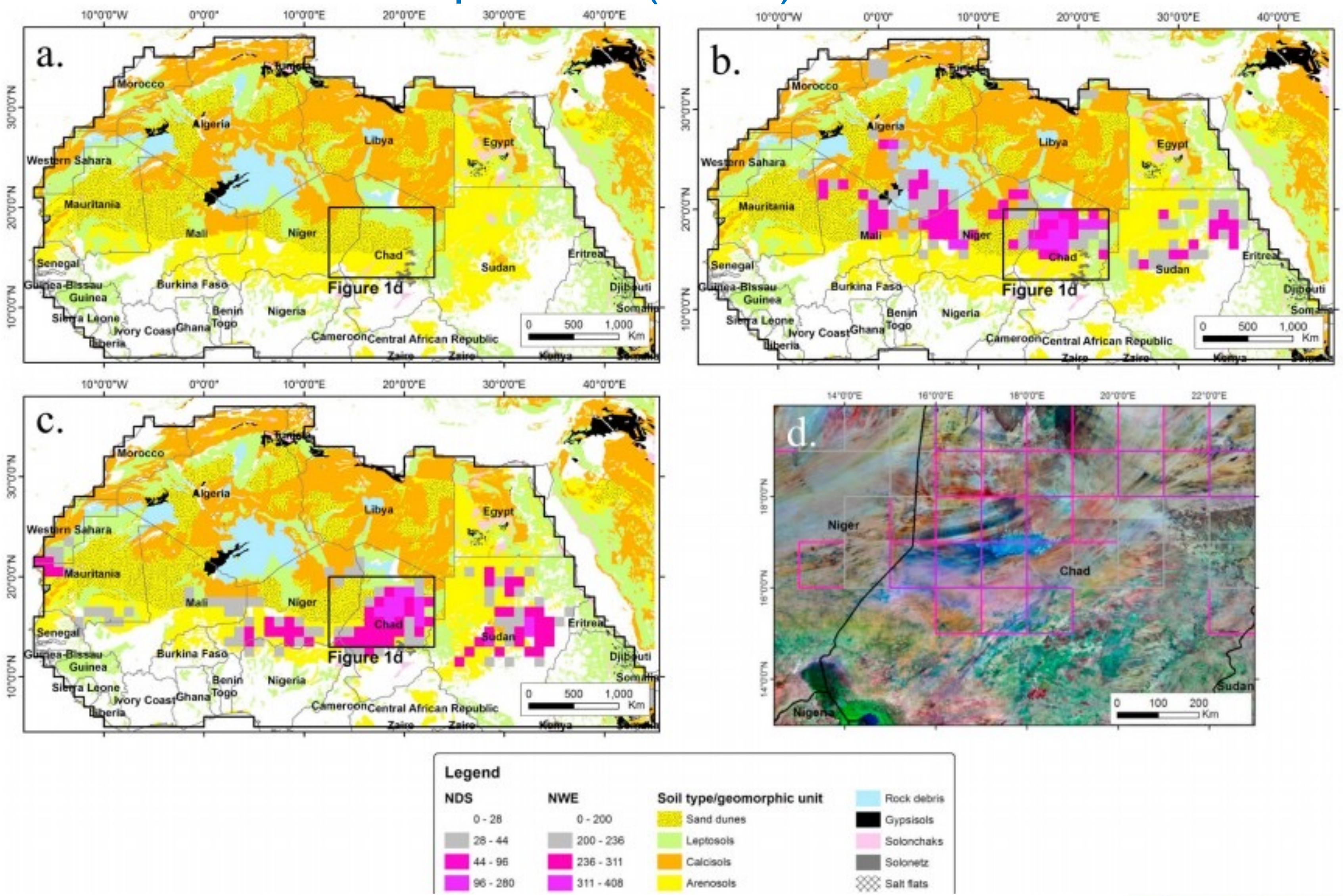
Month of an important regional dust event

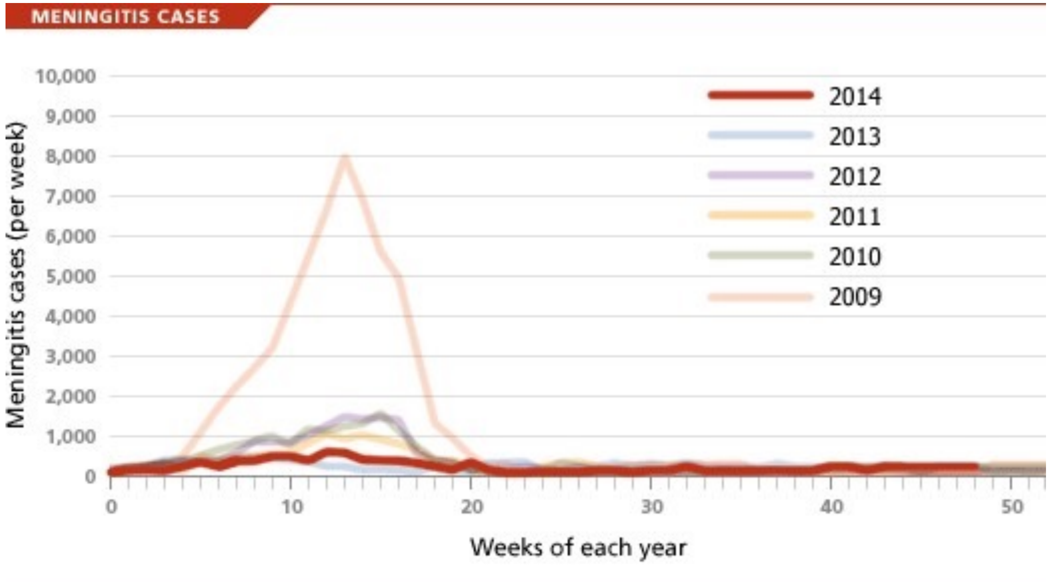


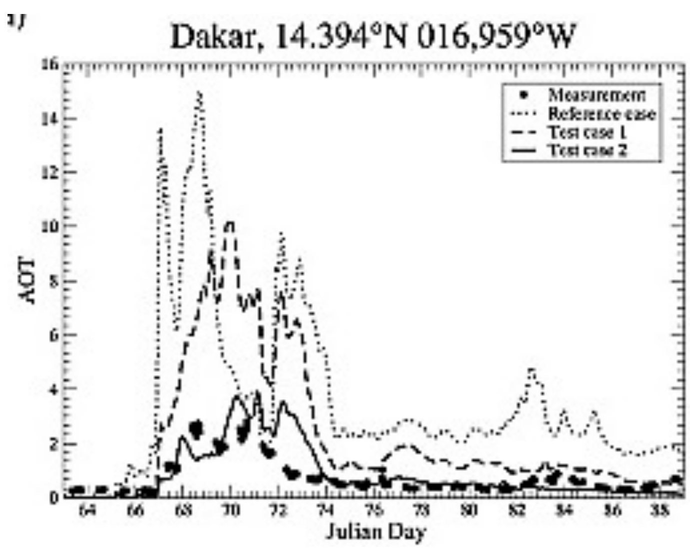
Source:
IMAGE
GALLERY

Dust source activation frequencies, Number of days of dust storm NDS, Number of wind episodes (NWE)

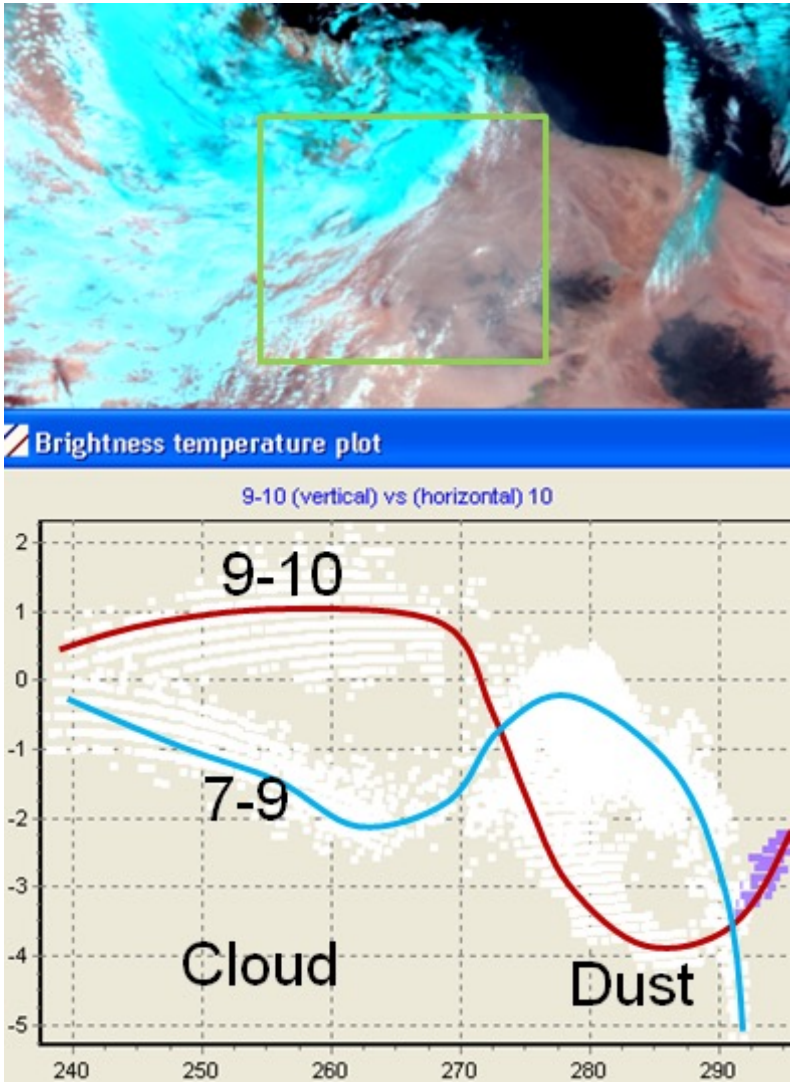


Meningitis cases (several years) and dust concentration (march 2006)





Effect of water condensation on dust



<u>Cloud-dust index</u>: 2*ch9 – ch7 – ch10

>0 for cloud

<0 for dust

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Conclusions

•Meteosat provides continuous coverage of Middle East and Northern Africa through 96 timely observations per day with a 4-km horizontal resolution.

•Infrared channels retrieve thickness and height of the dust, except for thermal inversions.

•Concurrent use of in-situ observations, satellite measurements and numerical models give a full description of the current and future dust distribution.

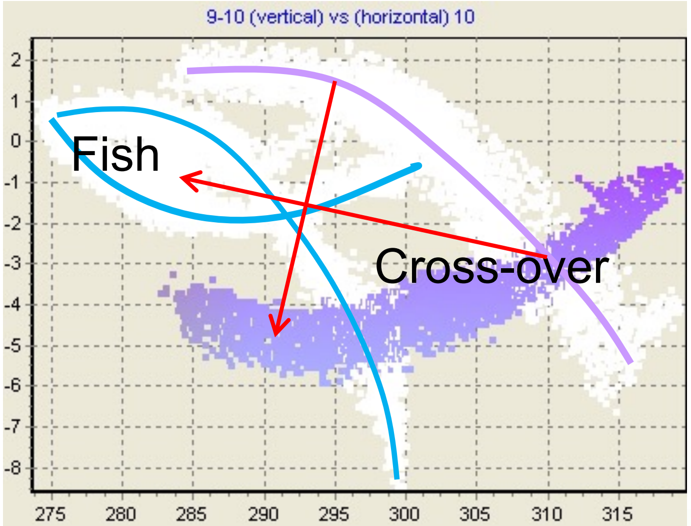
•On-going studies should clarify the influence of dust in epidemics and health levels for countries in the region.

THANKS FOR YOUR ATTENTION !

•List of used events:

- •2004-05-13 12:00, Sudan and Saudi Arabia
- •2008-02-02 06:00, Saudi Arabia
- •2008-03-23 12:00, Libya
- •2009-03-28 18:00, Argentina

http://onlinelibrary.wiley.com/doi/10.1029/2007GL030168/full



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