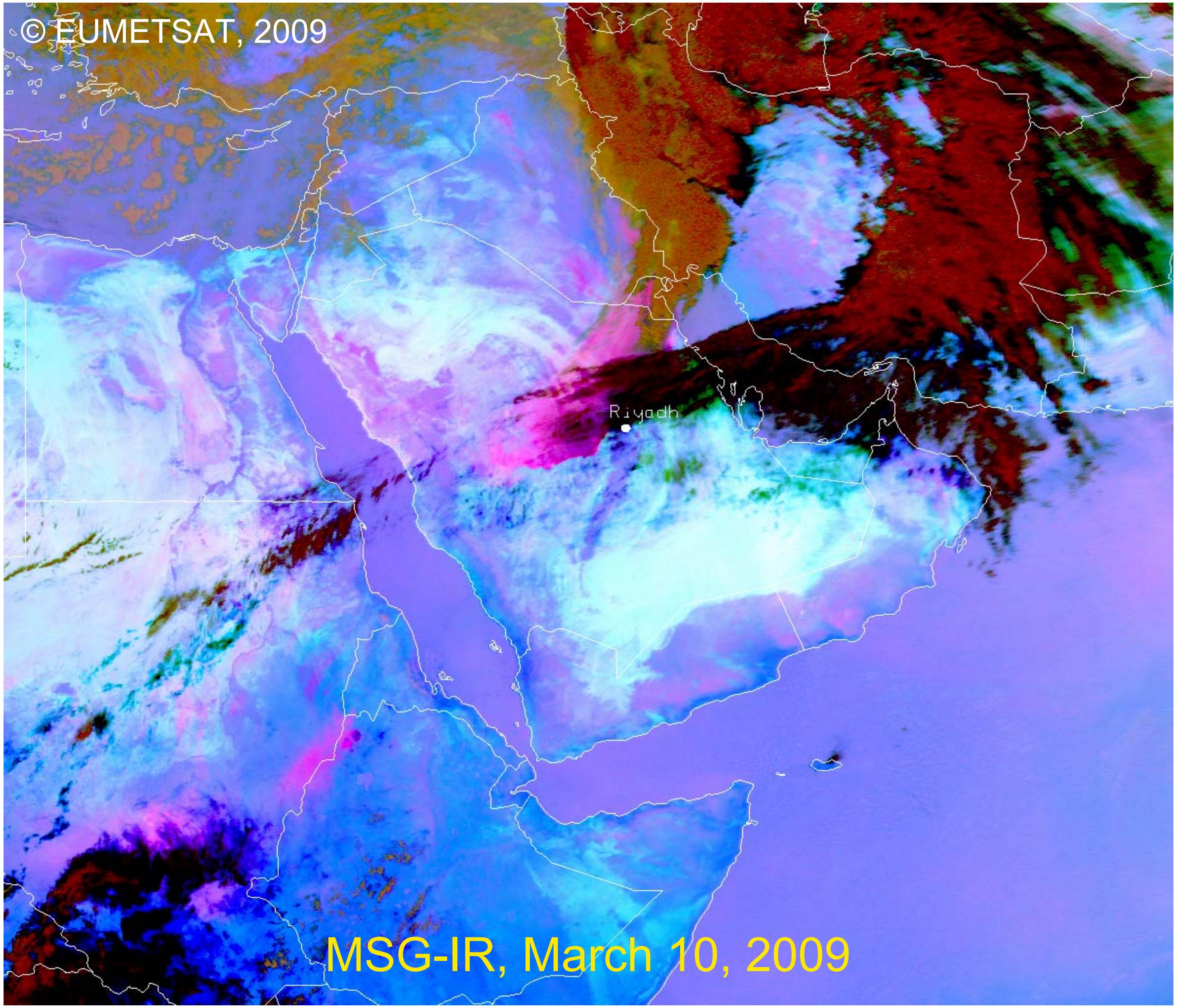
الرئاسة العامة للأرصاد وحماية البيئة
PRESIDENCY OF METEOROLOGY AND ENVIRONMENT
(PME)

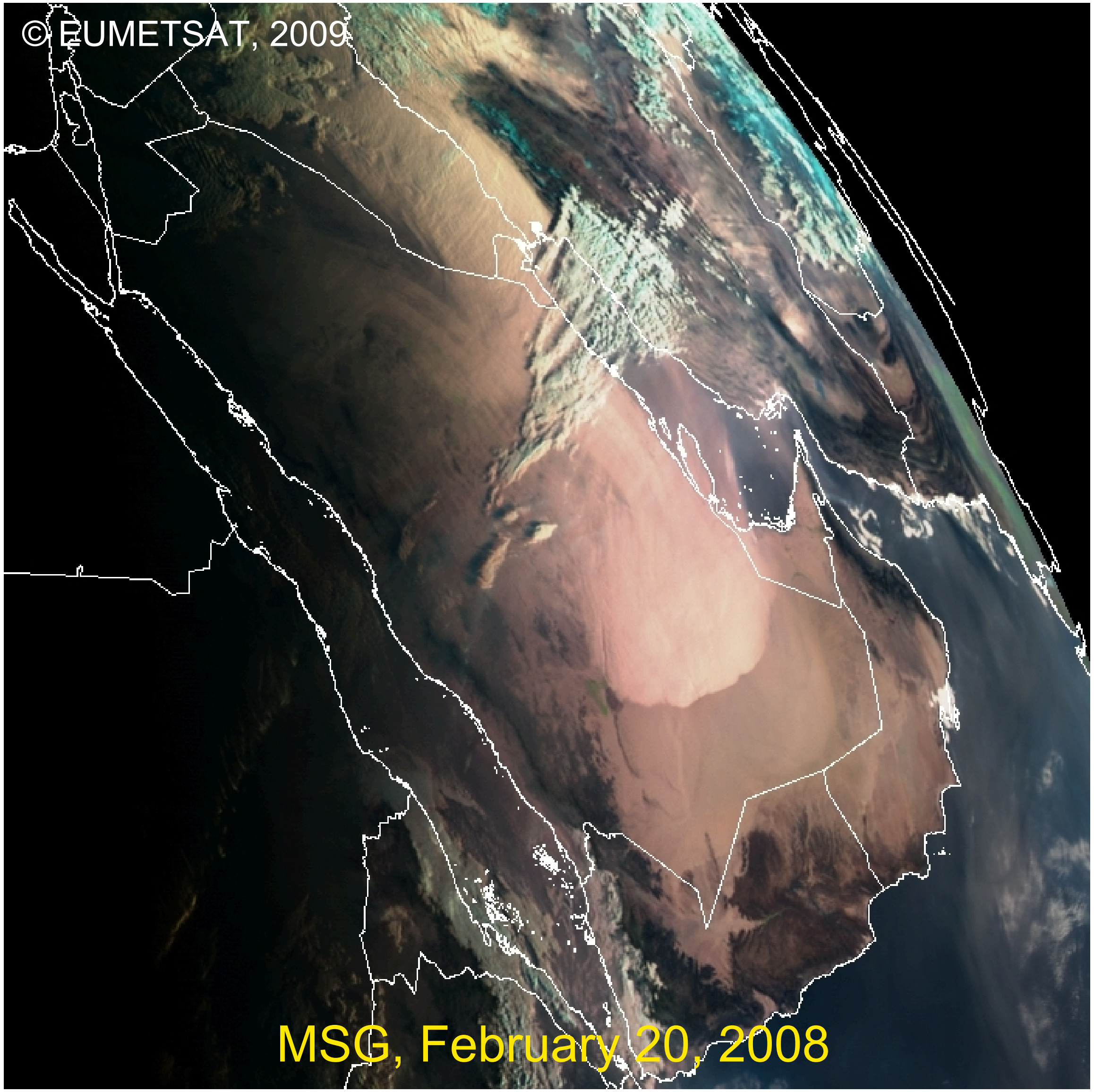
Mineral Dust

Lars Klüser
German Aerospace Center (DLR),
German Remote Sensing Datacenter (DFD)

© AFP

Riyad, March 10, 2009


© EUMETSAT, 2009
Riyadh
MSG-IR, March 10, 2009


© EUMETSAT, 2009
MSG, February 20, 2008

Why dealing with mineral dust?

mineral dust has a variety of impacts
on human life and environment:

- extremely reduced visibility
  (**traffic, human well being**)

- strongly increased boundary layer turbulence (**air traffic**)

- very high particulate matter concentrations (**health, ground and air traffic**)

- different health effects like PM and bacteria transport (**human well being**)

- strong decrease in solar irradiation (**solar energy production**, climate)

- fertilisation of soils and ocean waters (**agriculture, fisheries**, climate)

- suppression of precipitation (**agriculture, human well being**, climate)

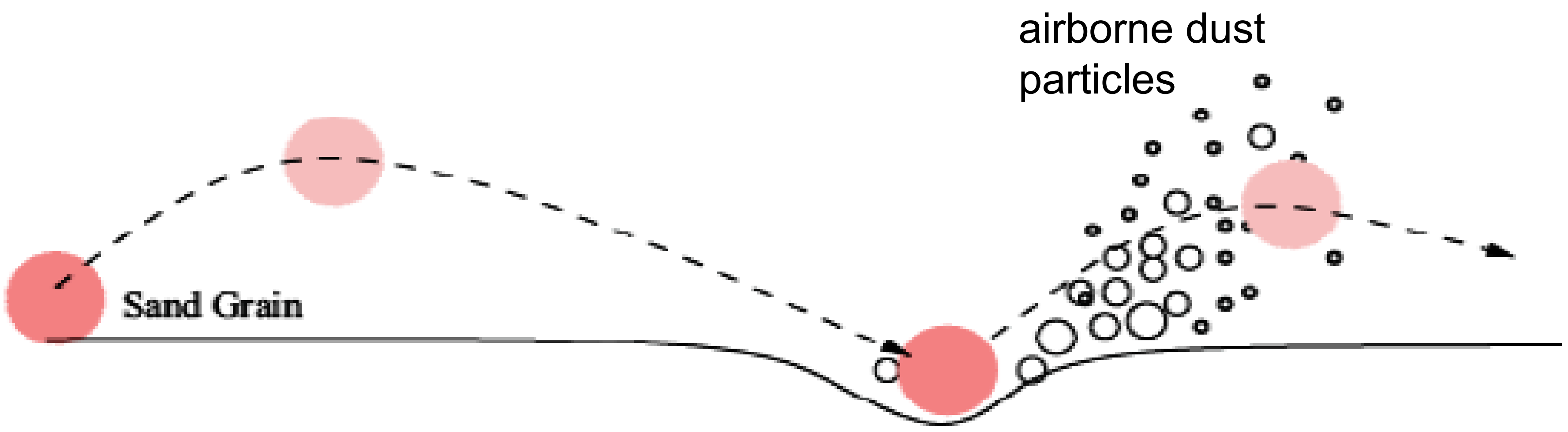
- triggering of extreme precipitation events (**all above**)

dust in the wind...

some facts about mineral dust:

- mineral dust is composed of eroded rocks and the remains of prehistorical ocean beds
- dust mobilisation is a function of surface windspeed and *roughness length*
- Saharan mineral dust uplift: *400-700 Tg* a^{-1}
- mineral dust acts as a long-range transport agent for several bacteria
- dust directly affects climate by radiative effects with magnitude and sign differing (surface-dependent)
- dust and dust air layers locally affect the atmospheric circulation
- during dust storms direct surface insolation is reduced by up to 300Wm^{-2} while diffuse insolation is increased

mobilisation ("activation") of mineral dust



Saltation and *sand blasting*:

- Particles with diameter around 60-75μm are moved first by the windstress.

- Their gravitational impacts mobilise smaller particles (0.01-10μm).

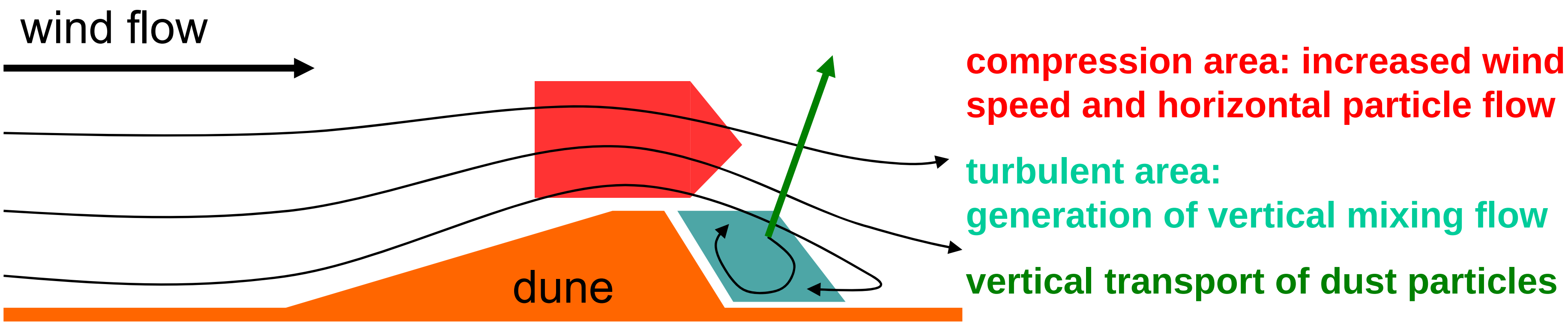
- There is a critical wind speed for dust emission, which has to be exceeded.

mobilisation of mineral dust by dunes

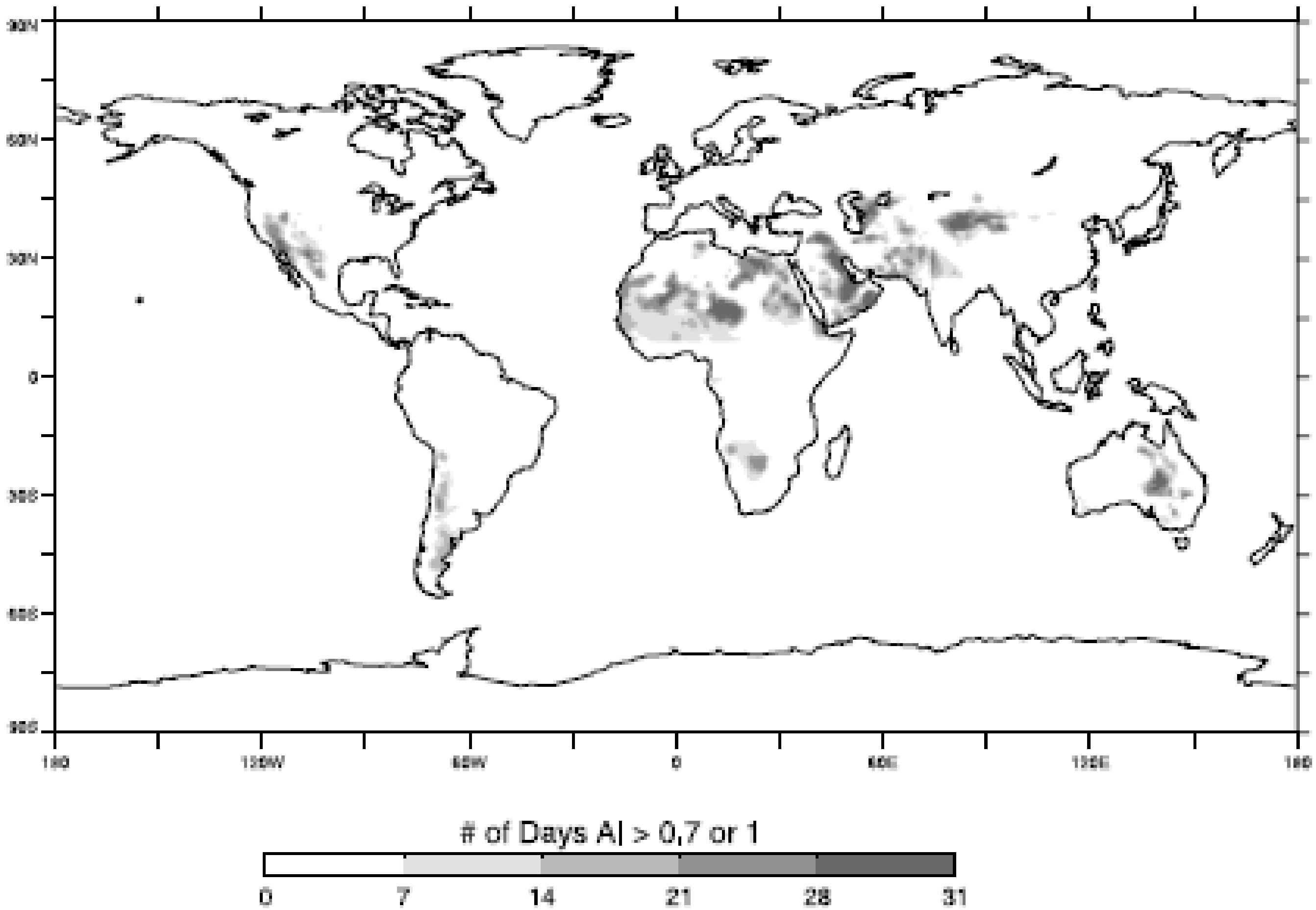
two particle flux regimes from dunes:

- horizontal particle flux
  (mainly sand grains, but also dust particles)

- vertical particle flux
  (mainly dust particles, only few sand grains)



mineral dust source areas



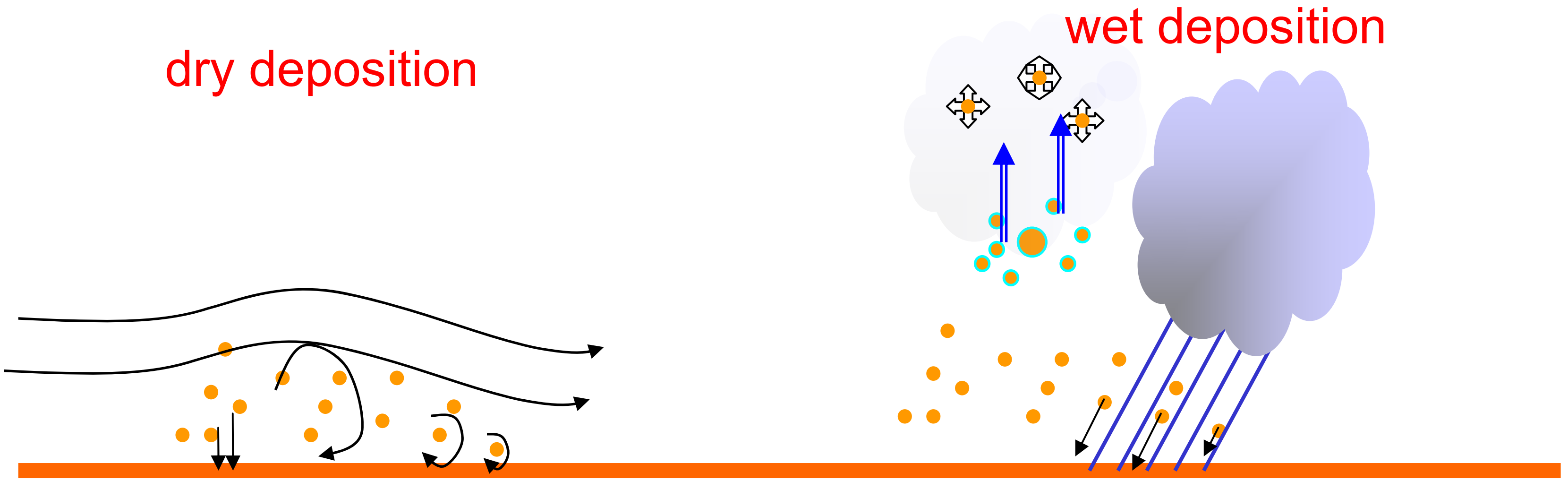
global dust sources from satellite observations (Prospero et al., 2002)

mineral dust deposition

mainly two deposition mechanisms for mineral dust

- *dry deposition*:
  gravitational settling, turbulent down-mixing, breakdown of turbulent momentum fluxes at night

- *wet deposition*:
  „wash out“ by precipitation, dust particles acting as condensation or freezing nuclei and in-cloud transport throughout the atmosphere



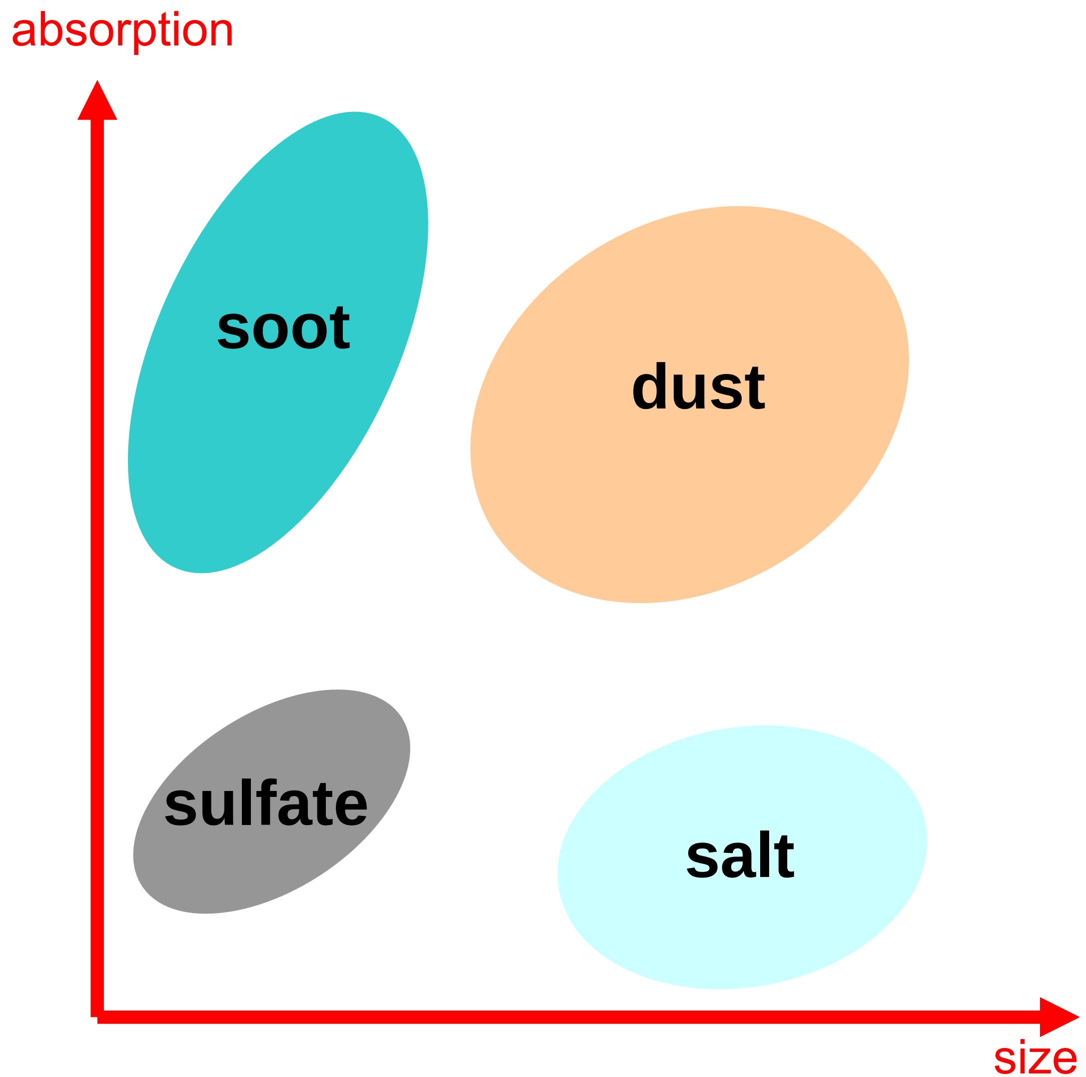
infrared dust remote sensing

AOD$_{IR}$:

$L_{sat} = e^{-(scatt.+ abs.)} \varepsilon L_{sfc}(T_{sfc})$

TIR: λ ~10-12μm

- only large particles of this size affect IR radiation
- dust has the strongest signal in TIR radiation and is present in sufficient concentrations for being detected



mineral dust in the thermal infrared

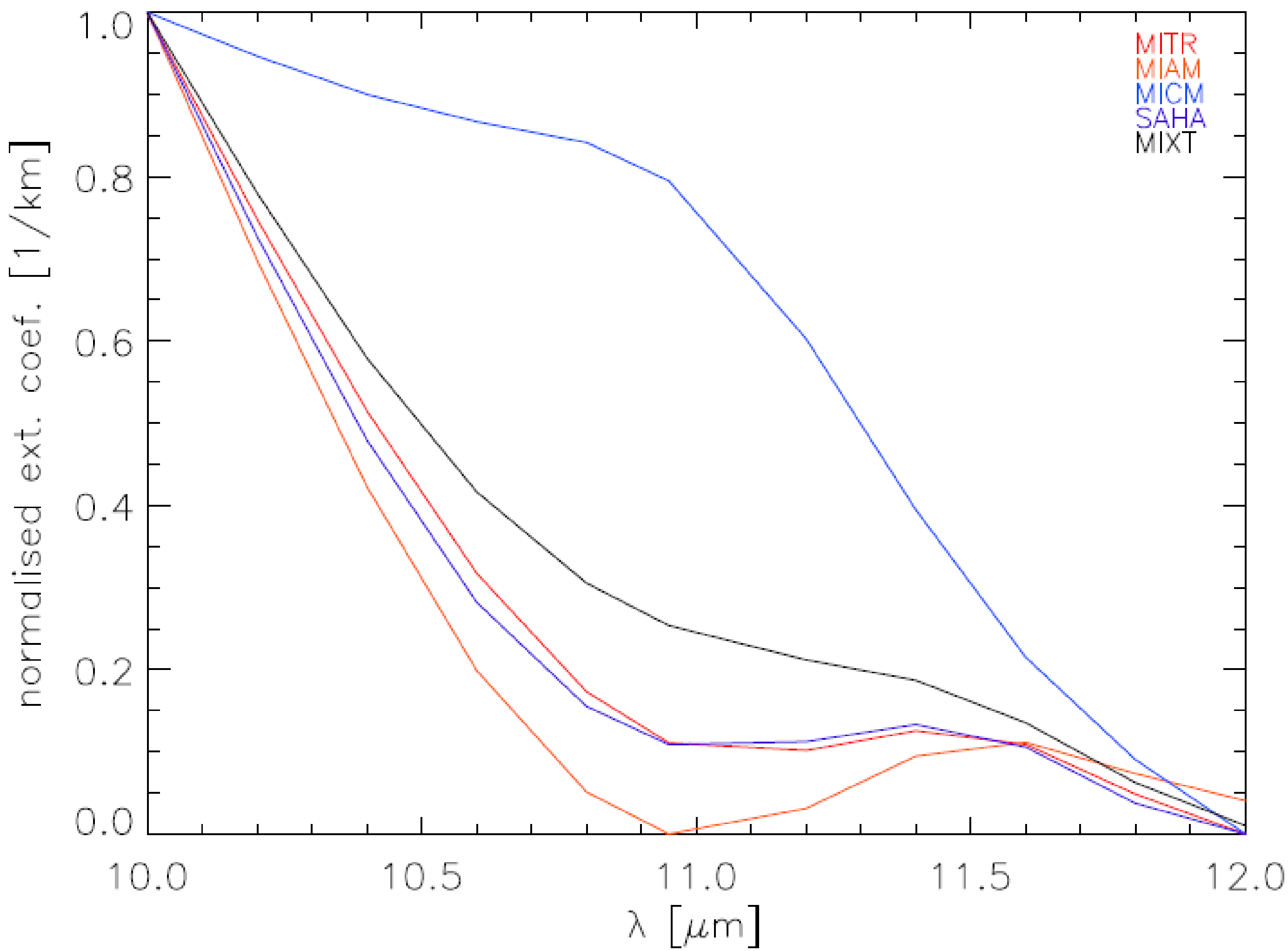
MITR:
transported

MIAM:
accumulation mode

MICM:
coarse mode

SAHA:
Sahara observation

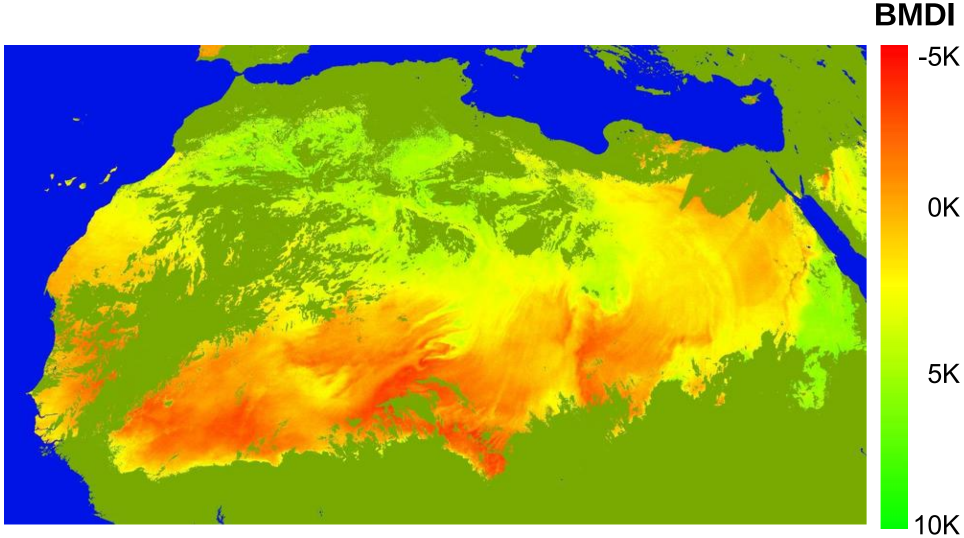
MIXT:
mixture type



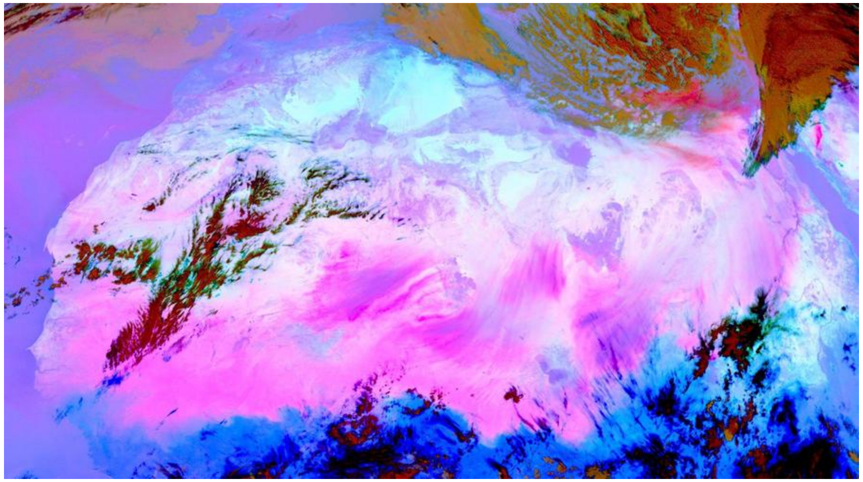
dust storm detection with BMDI

Example for dust detection on MSG pixel scale with BMDI:

The March 2006 dust storm



BMDI values for the Sahara domain on 08.03.2006 (MSG projection)



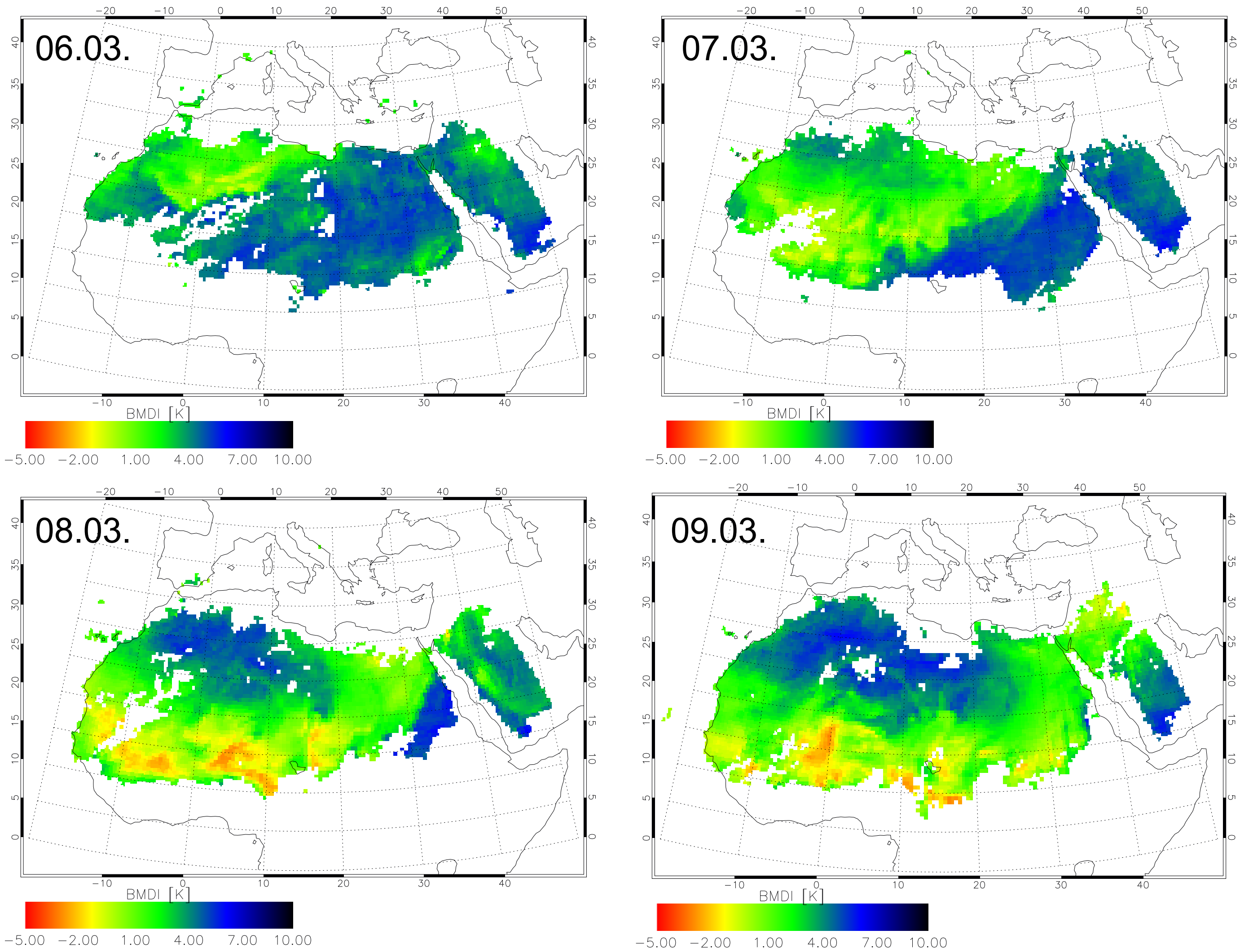
The Sahara domain on 08.03.2006 (12:00 UTC), „dust“ color scheme:
R($T_{12.0}$-$T_{10.8}$) G($T_{10.8}$-$T_{8.7}$) B($T_{10.8}$inv)

No BMDI derived in case of clouds present at 03:00 UTC or 12:00 UTC.

Negative BMDI values indicate very high atmospheric dust load.

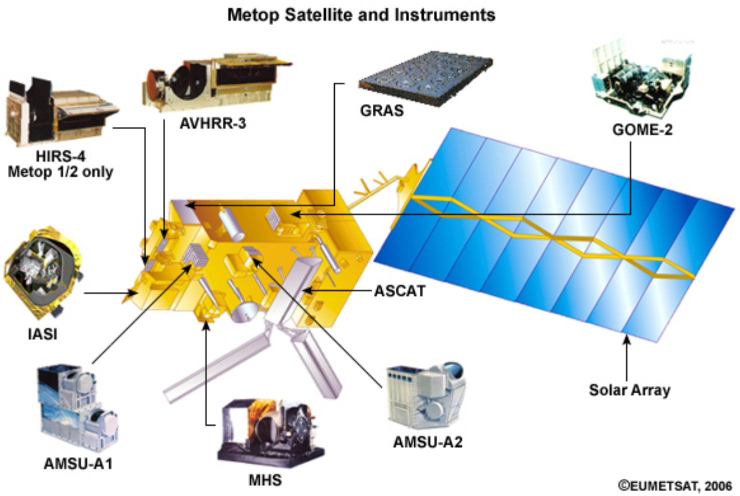
the Bitemporal Mineral Dust Index

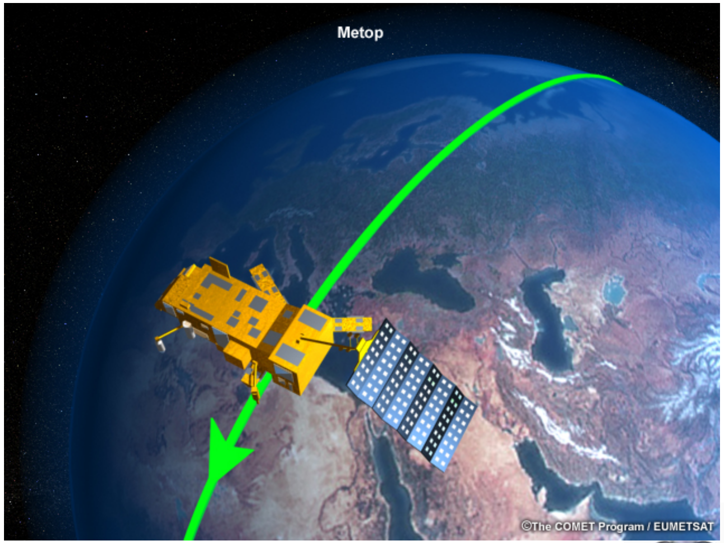
example of daily BMDI dust detection:
the March 2006 Sahara dust storm evolution



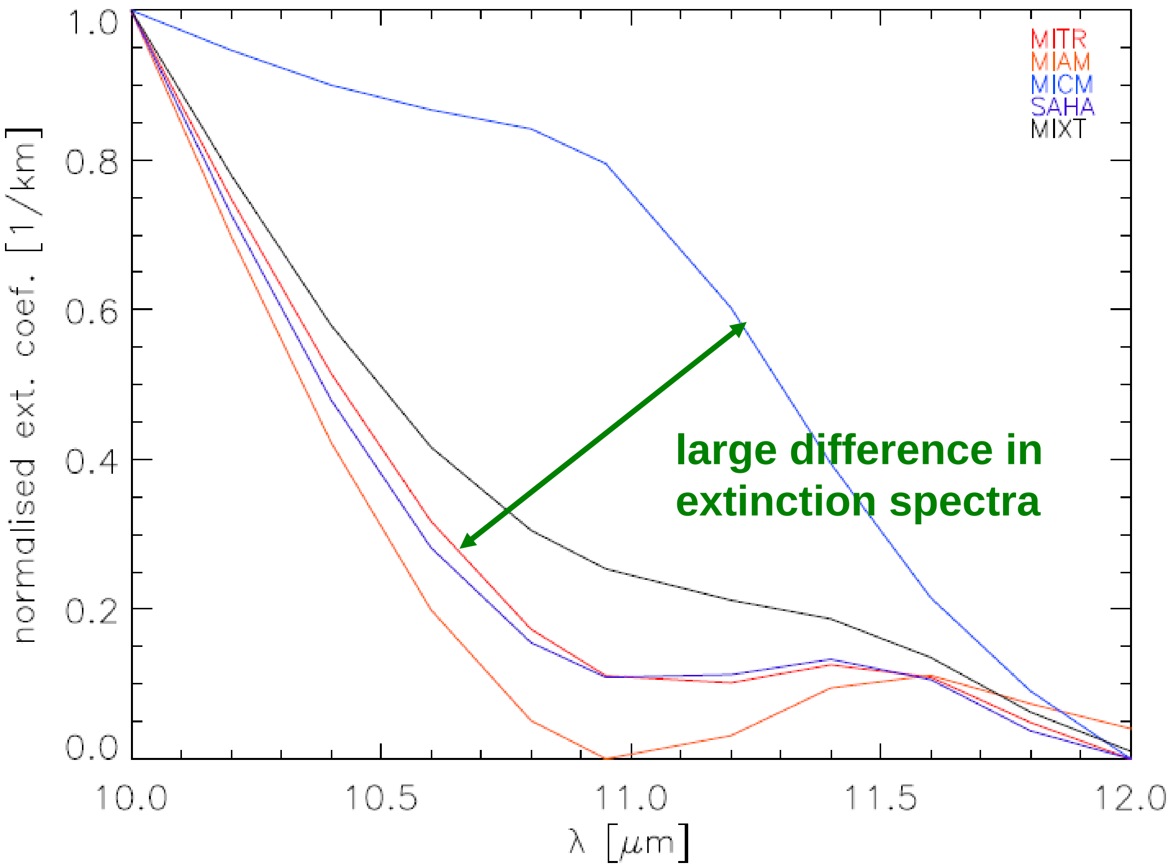
MetOp IASI dust algorithm at DLR

- spectral infrared dust retrieval:
  dust detection day and night
- sensitive to large particles
  (mineral dust) only
  → effective type speciation
- insensitive to background brightness
- 12km pixel size, ~1000km swath





MetOp: IASI dust retrieval

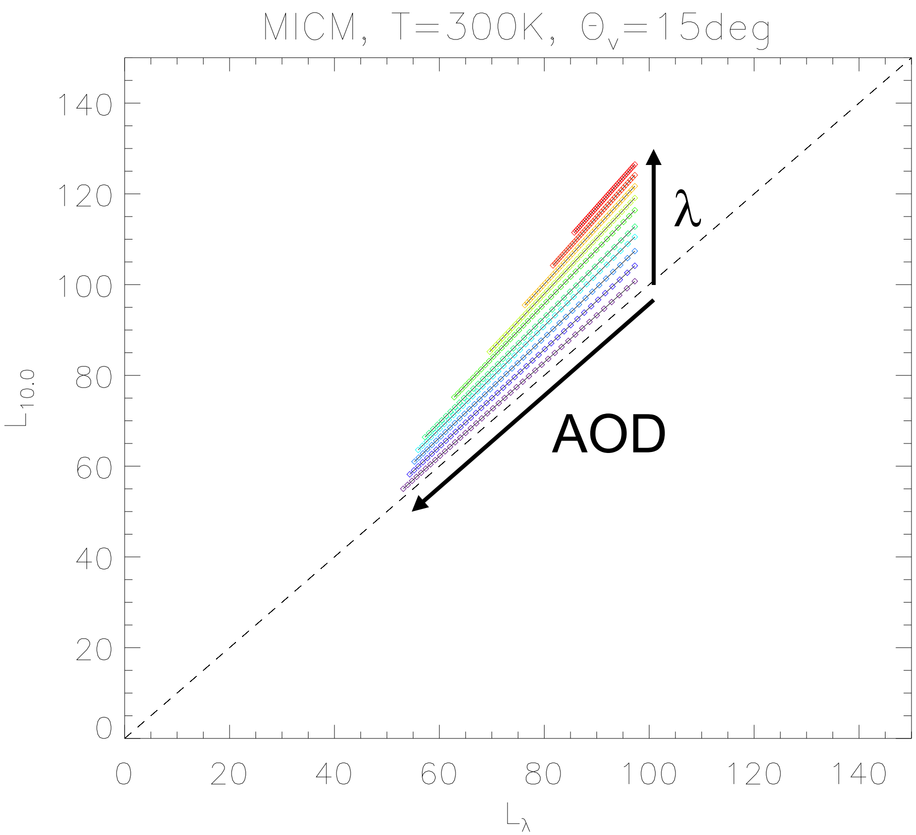


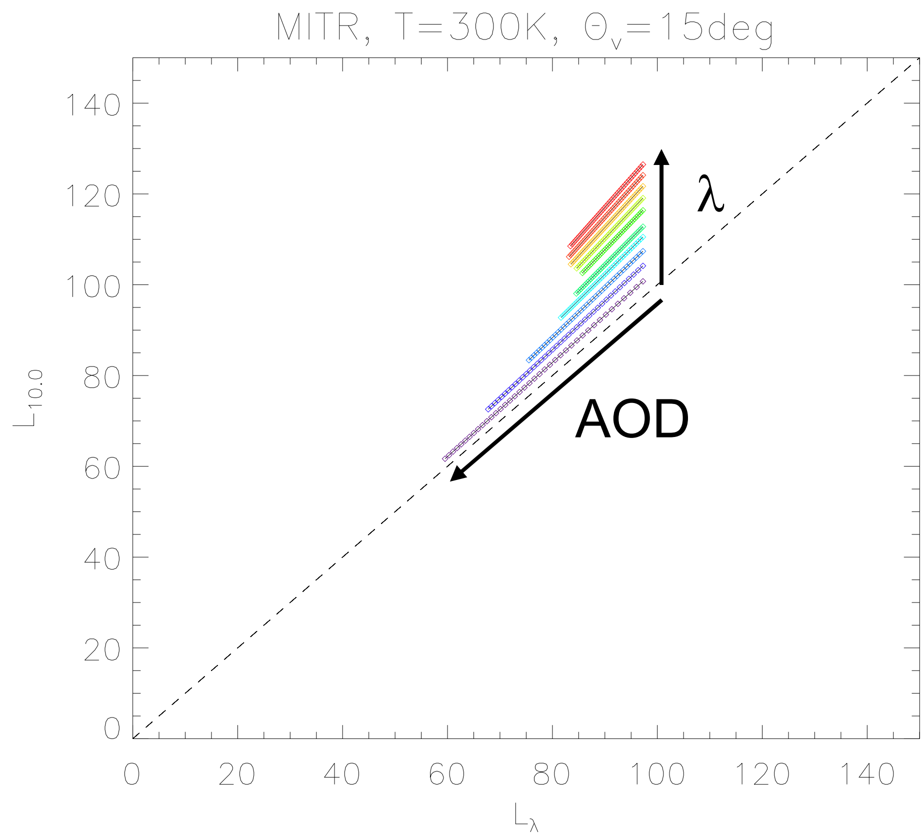
→ linear fit between measured and modelled radiance spectrum gives dust model and quality information

-10 IASI channels between 10.0μm and 12.0μm used to sample spectrum

- slope between 10.0μm and any λ includes AOD information

MetOp: IASI dust retrieval

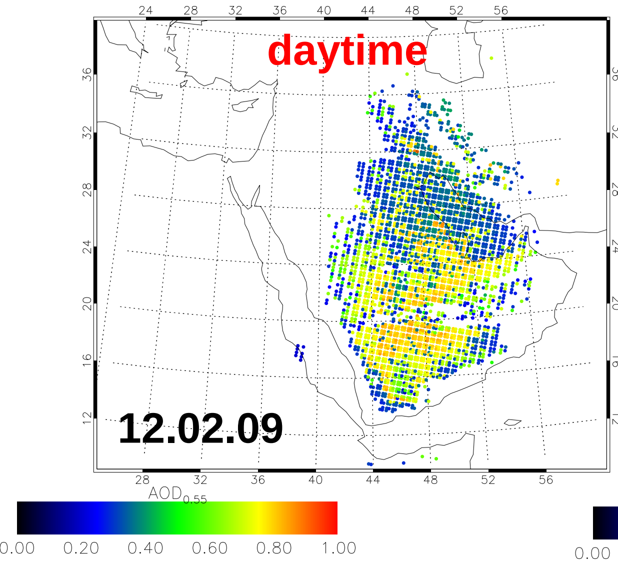


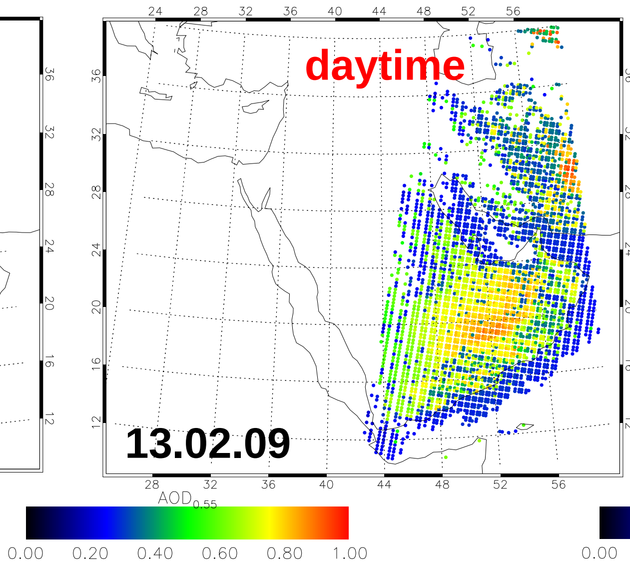


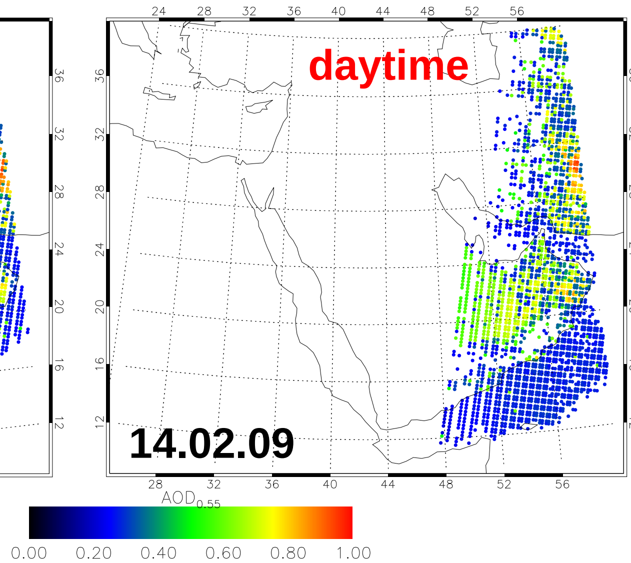
$$AOD_{10.0\mu m} = \frac{1}{\alpha_\lambda(dm) - 1} \ln\left(\frac{L_{10.0\mu m}[IASI]}{\kappa_\lambda(T) \cdot L_\lambda[IASI]} \right)$$

evaluated at 10 wavelengths λ
→ set of 10 values for $AOD_{10.0\mu m}$
→ quality check
→ transfer to 0.55µm

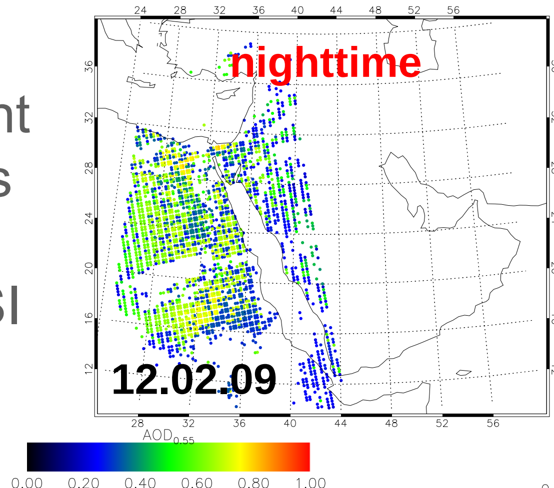
Saudi Arabia dust observations: Feb 12-14, 2009

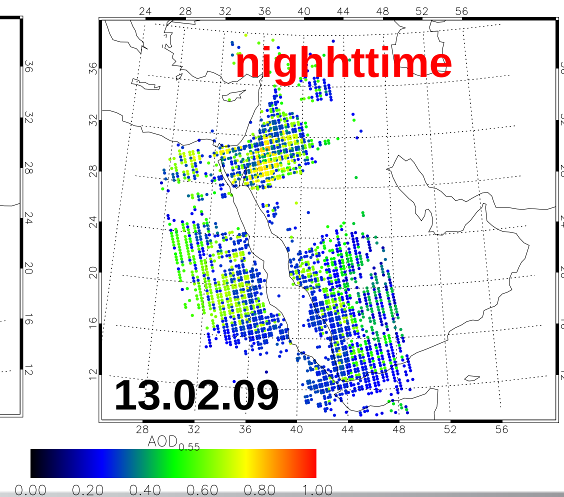






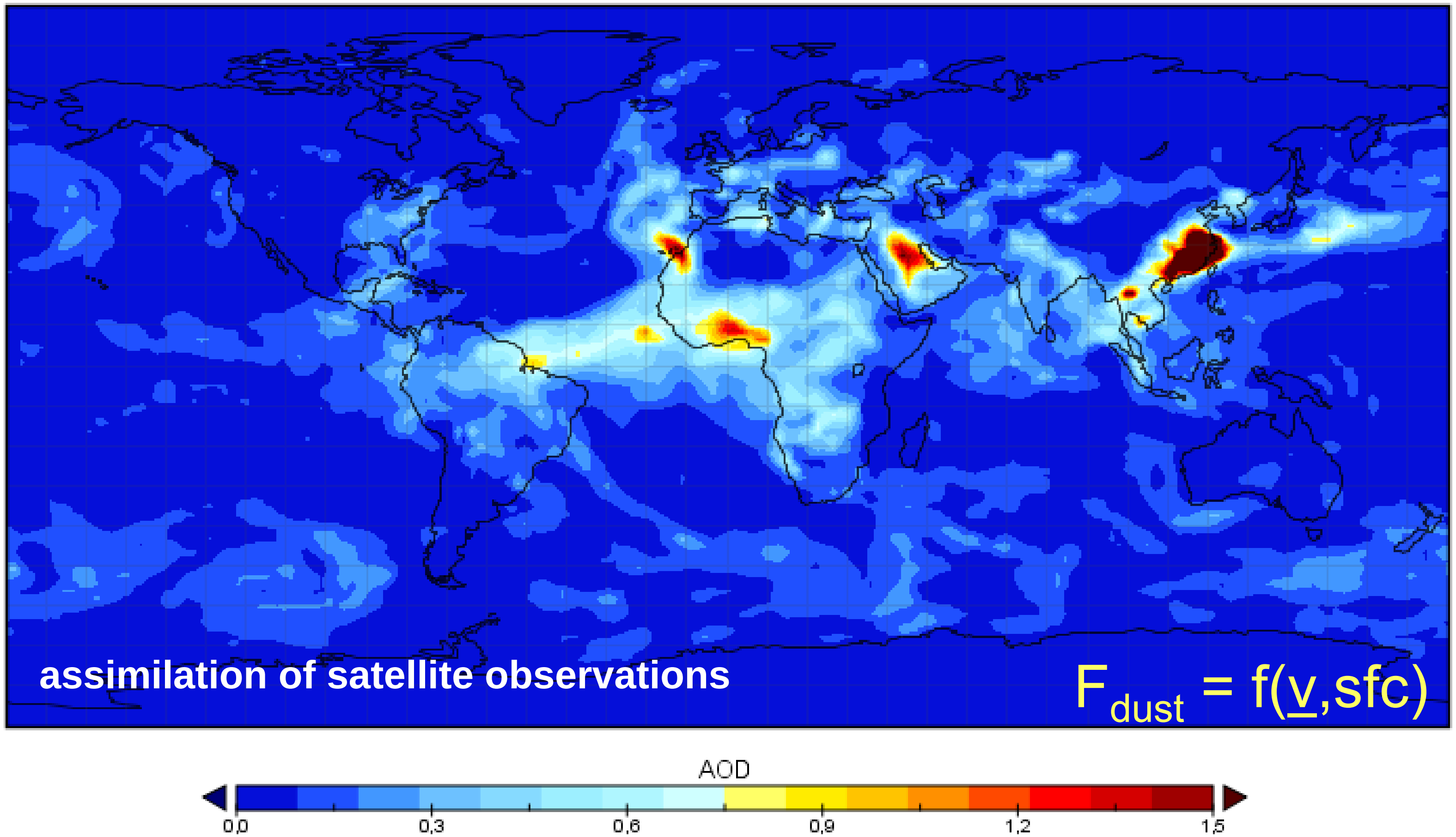
day and night observations possible in TIR with IASI





observations twice daily: better spatial coverage and sampling of dust diurnal cycle

modelling of mineral dust emission and transport



MATCH_DLR AOD, 17.02.2004, 12:00 UTC

summary

- mineral dust mobilisation by a variety of mechanisms
- dust remote sensing over bright surfaces: thermal infrared techniques
- BMDI: daily dust product from MSG
- MetOp/IASI: IR-spectrometer enables dust remote sensing over Saudi Arabia twice daily
- to improve dust forecast: assimilation of satellite observations and modelling is necessary