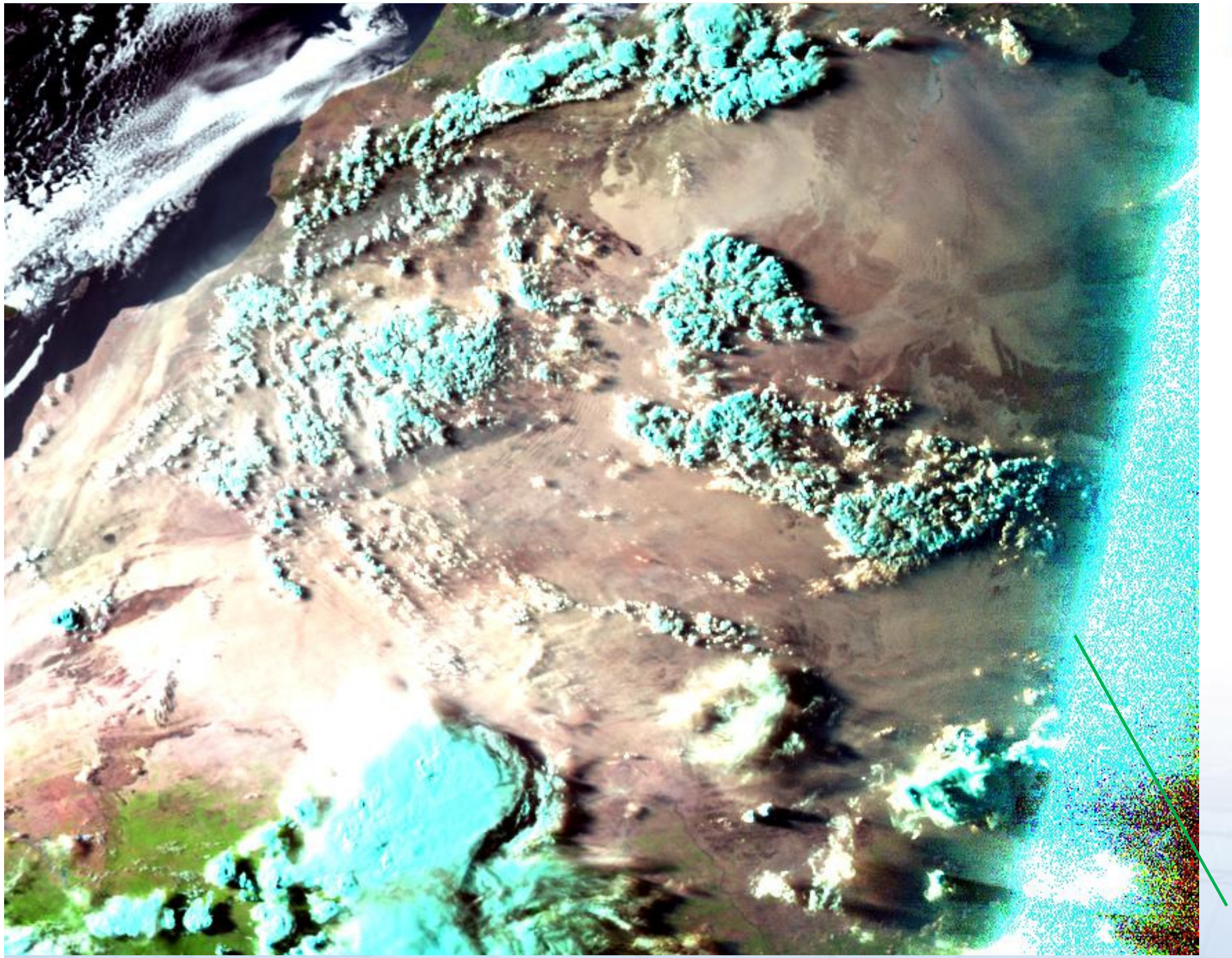
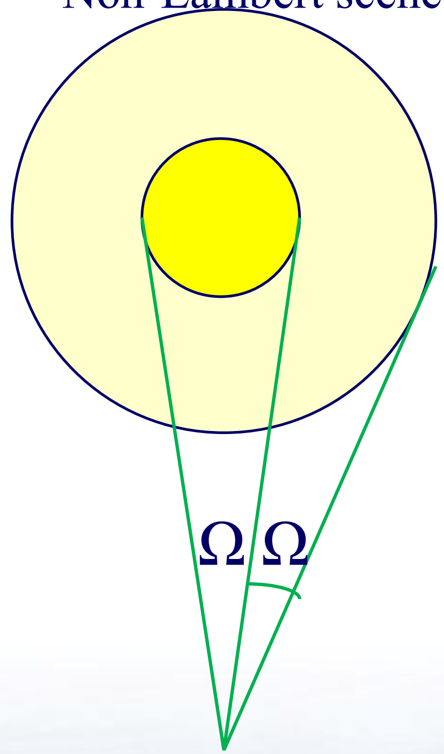
Lambert's approximation

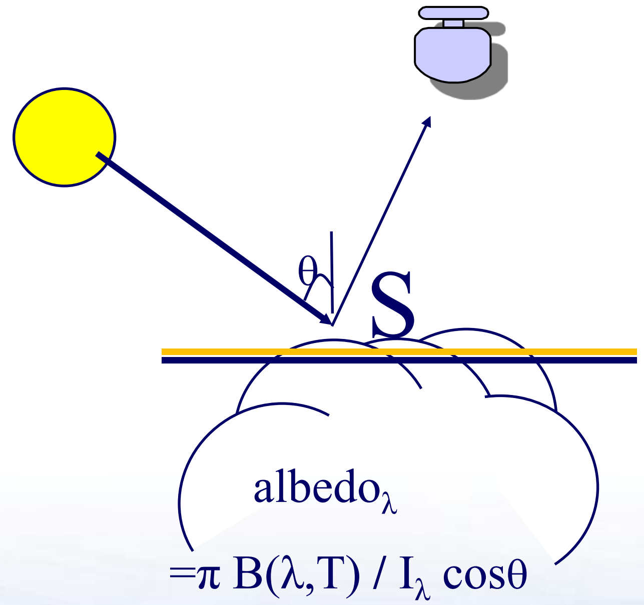


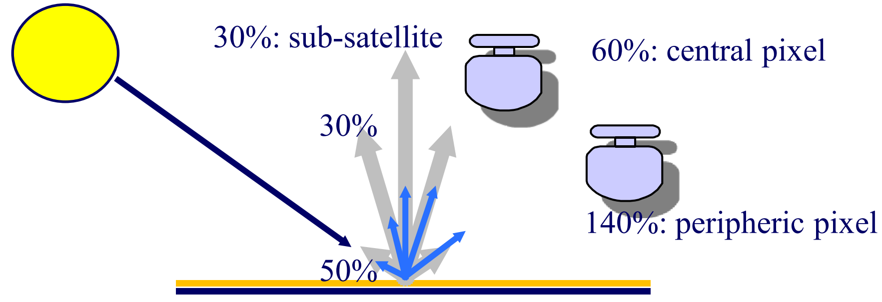


- Lambert: same brightness close and far from the boundary of a spherical target
- Lambert examples: rough ocean surfaces or snow, non-directional reflection
- Non Lambert: desert surfaces or sun glint on oceans, **directional** reflection

EUMETSAT

Scattering albedo





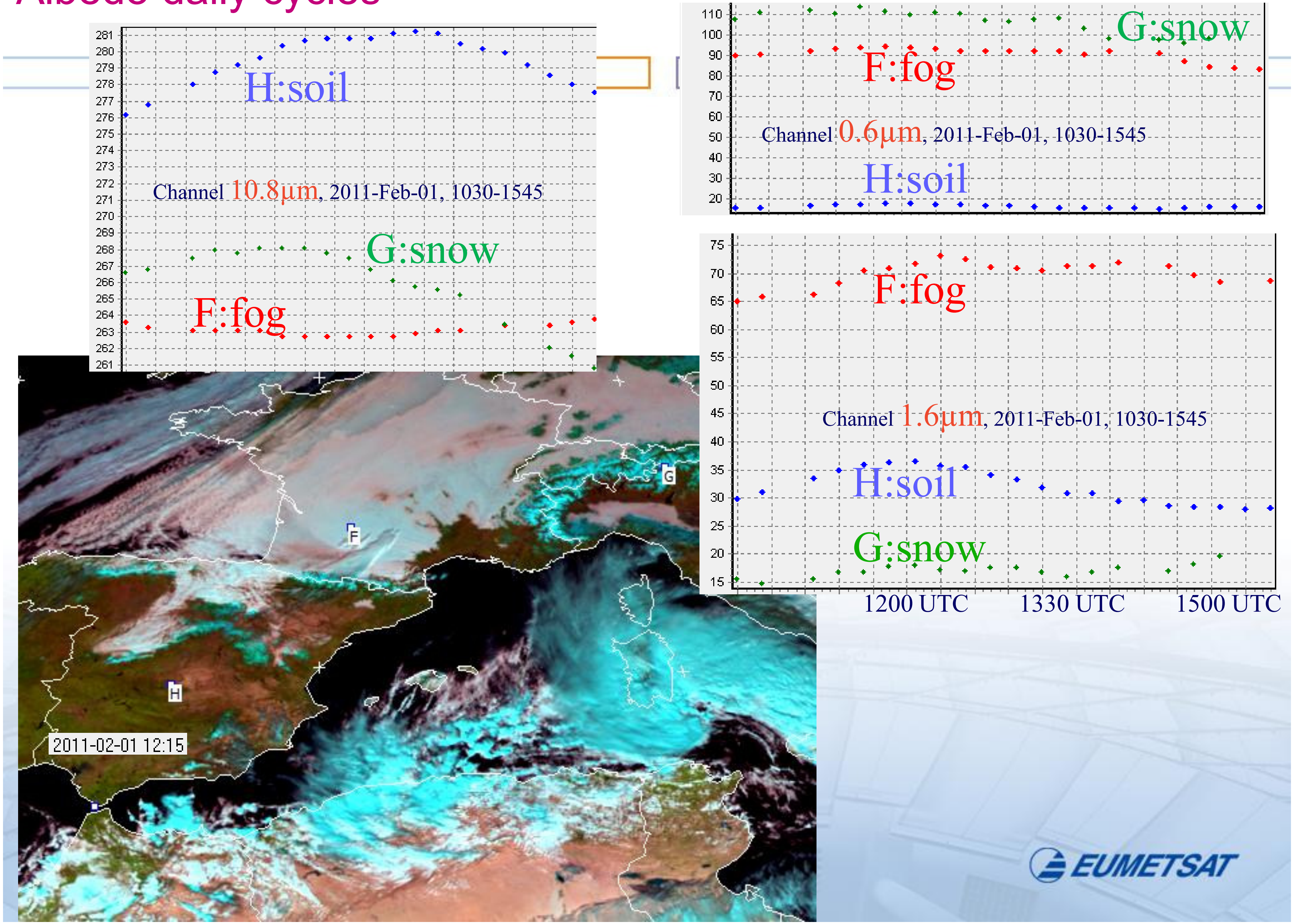
$I_\lambda \cdot \cos\theta \cdot S \cdot \text{albedo}_\lambda \cdot \Omega / \pi =$ Solar power reaching the satellite sensor

Does albedo depend on illumination θ ?

(White) albedo should be constant if properly calculated. It depends on illumination if the calculation is simplified or we use partial data (a single slot of Meteosat).

It also depends on pixel location

Albedo daily cycles



EUMETSAT

The impact of illumination direction on the albedo calculation

Where is the retrieved albedo more dependent on the time of the day?

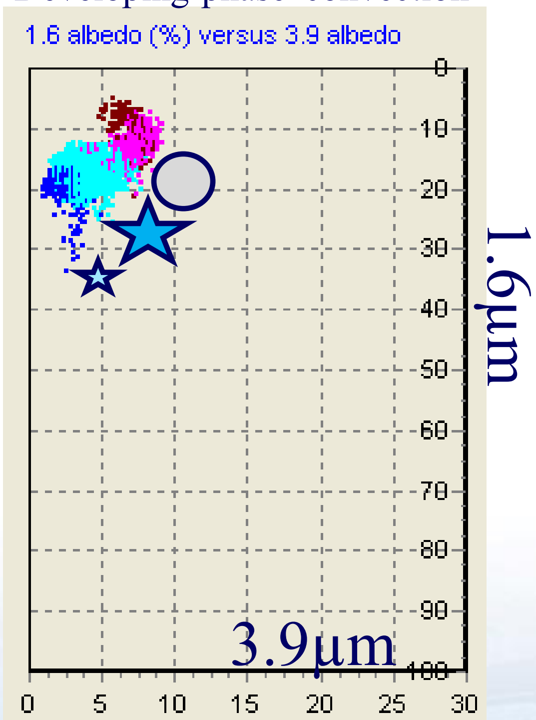
a. On cloud, where reflection varies with direction.
   But too variable to isolate the effect of illumination

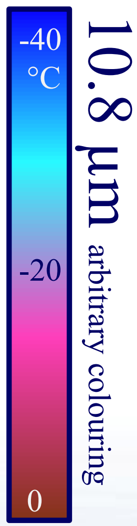
b. On oceans, where calm waters act as mirrors.
   But albedo is low and affected by Rayleigh dispersion

c. On tropical land, where surfaces stay constant in the course of the day.
   That is my preference, too

d. On snow, where Snel behaviour is relevant
   Not very directional, when a pixel contains many different slopes

Towards ice and size vertical profiles





Both SIZE and ICE reduce particle reflectivity

At lower levels, ice particles are bigger and less icy than at high level.
Reduced or increased reflectivity at lower levels??

Reduced at 1.6µm, the channel more sensitive to...
ICE / SIZE ??

Reduced at 1.6µm (vertical), responding to SIZE
Increased at 3.9µm (horizontal), responding to ICE

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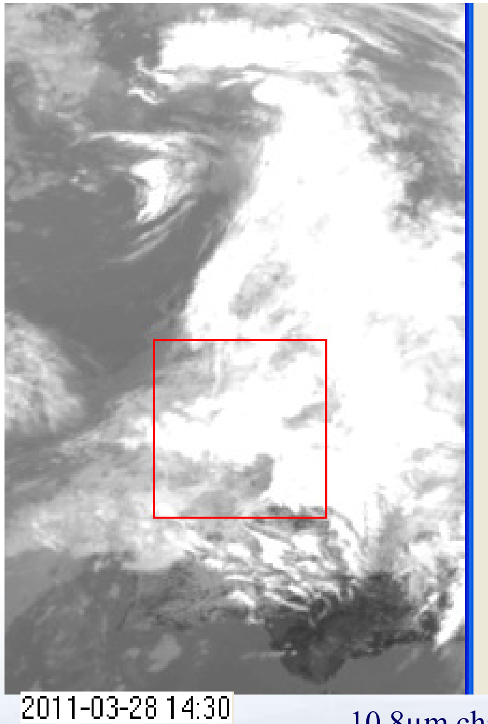
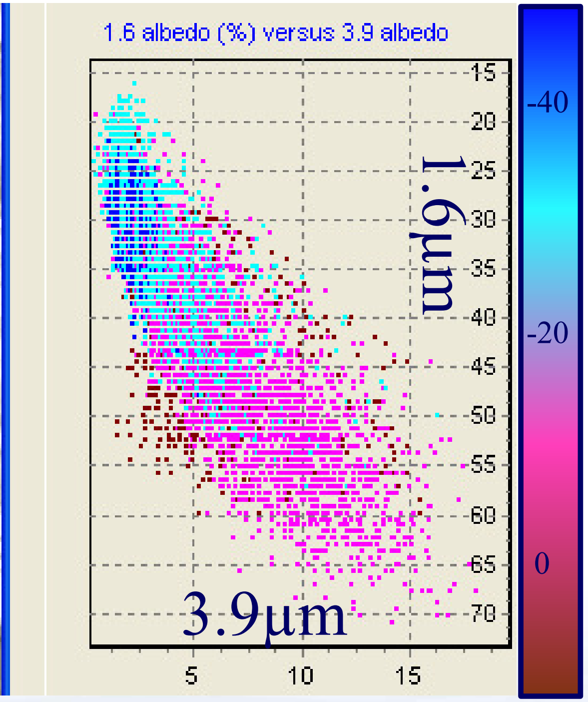


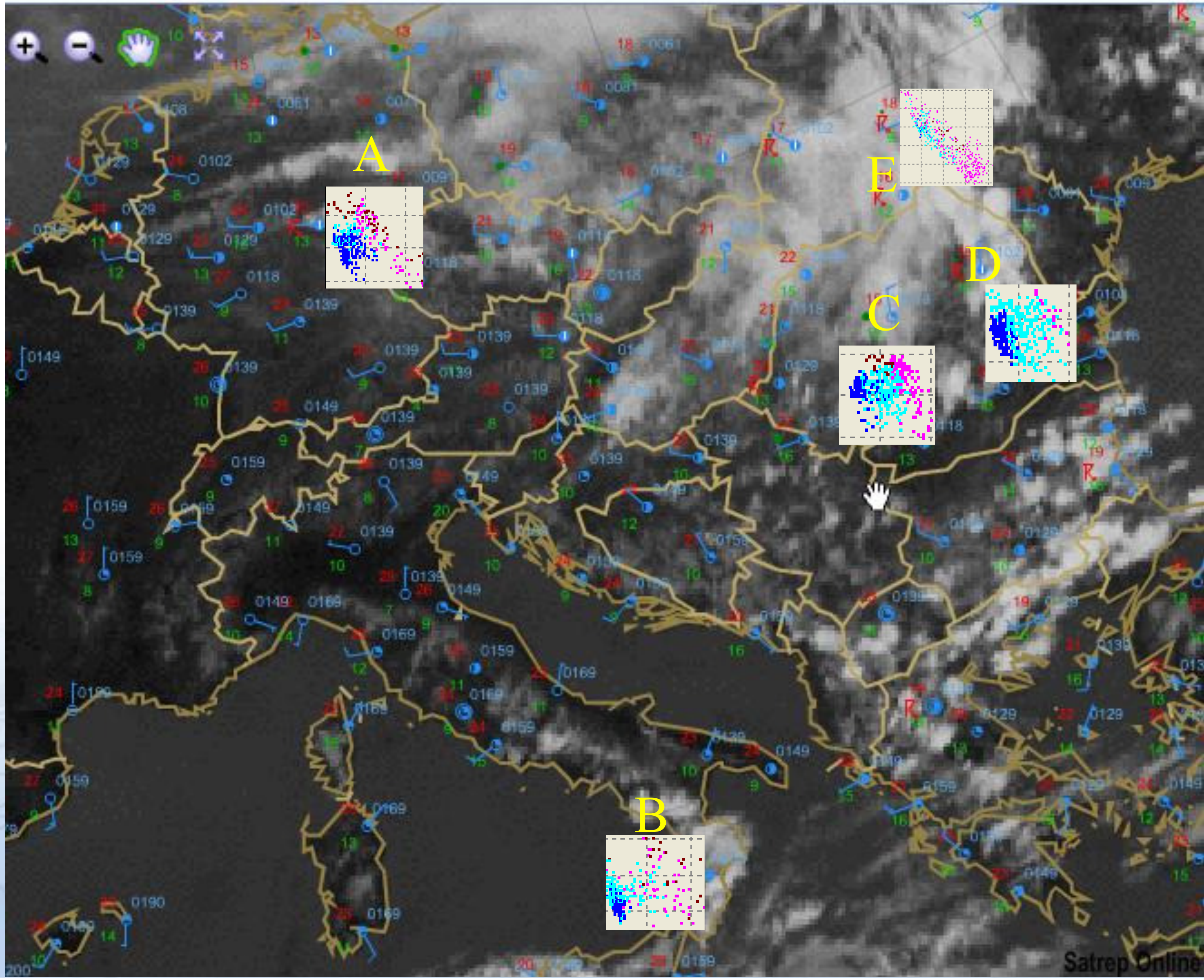


10.8µm channel, colour scale for BT (in °C)

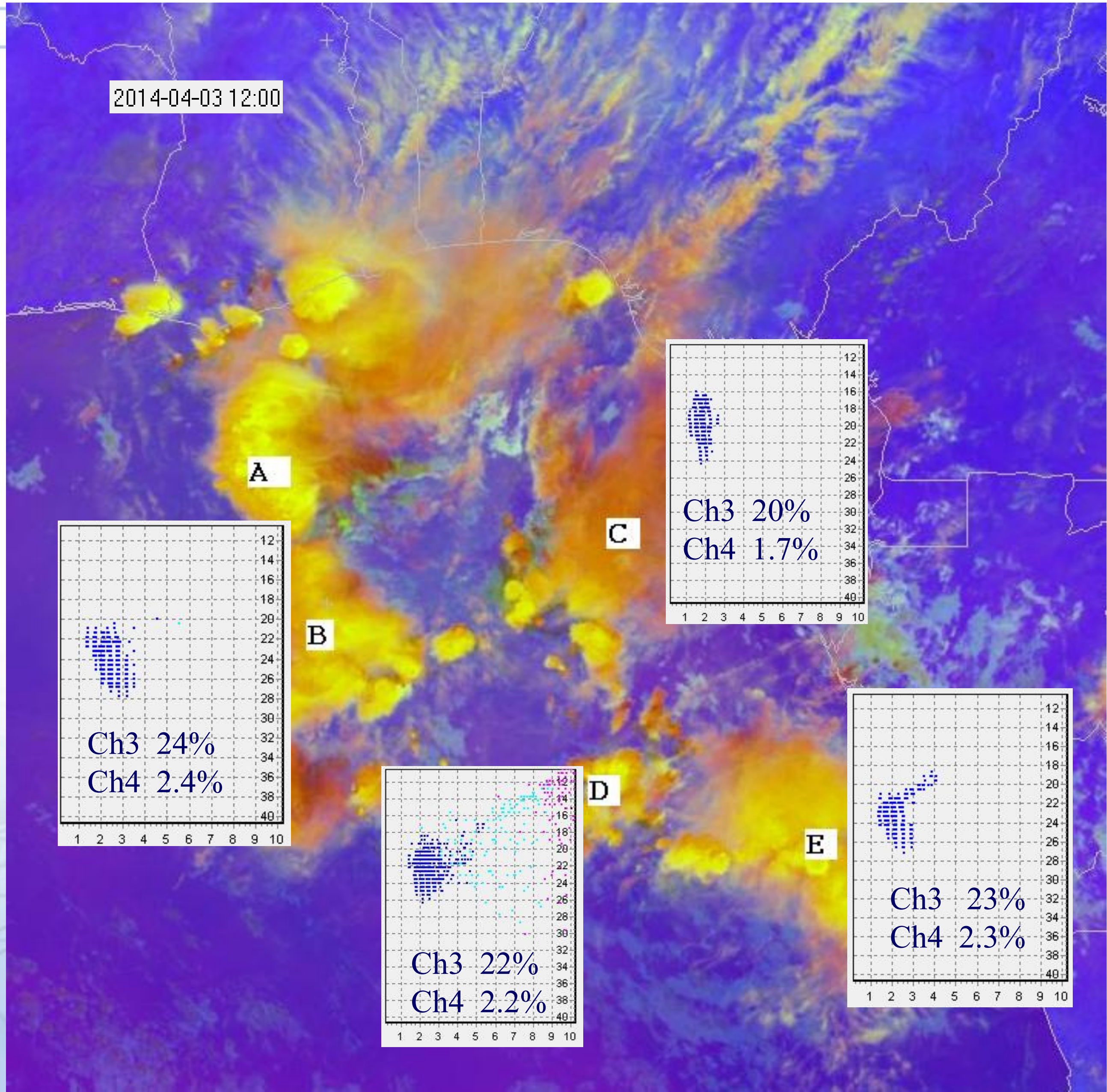
- **Dissolving**-cloud albedos at 1.6µm and 3.9µm show a higher correlation
- The liquid tops vary faster in 3.9-albedo than in 1.6-albedo
- 1.6 is ice-size sensitive, 3.9 is droplet-size sensitive

[1.6µm versus 3.9µm] reflectance technique (convection)

24 May 2010: 1200UTC



[1.6μm versus 3.9μm] reflectance technique (convection)



Average reflectivity on the frozen cloud tops of convection are roughly 10 times higher for channel 1.6μm than for 3.9μm

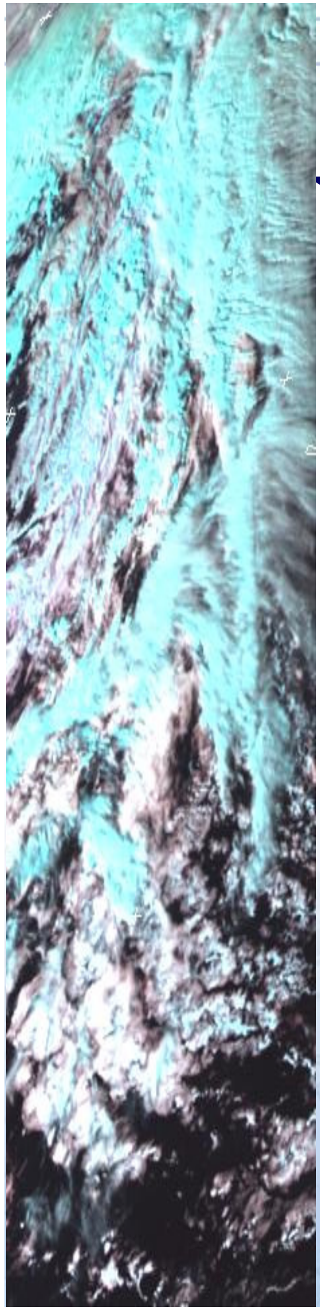
Rule “20+ 10-” for **severe convection** in a region 100km across :

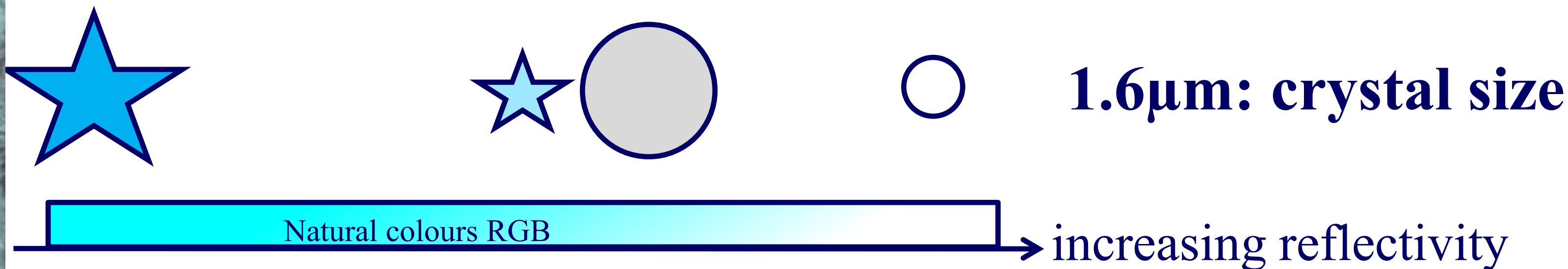
<Ch3> > 20%

Ch3/Ch4 < 10

EUMETSAT

NIR1.6 reflectivity



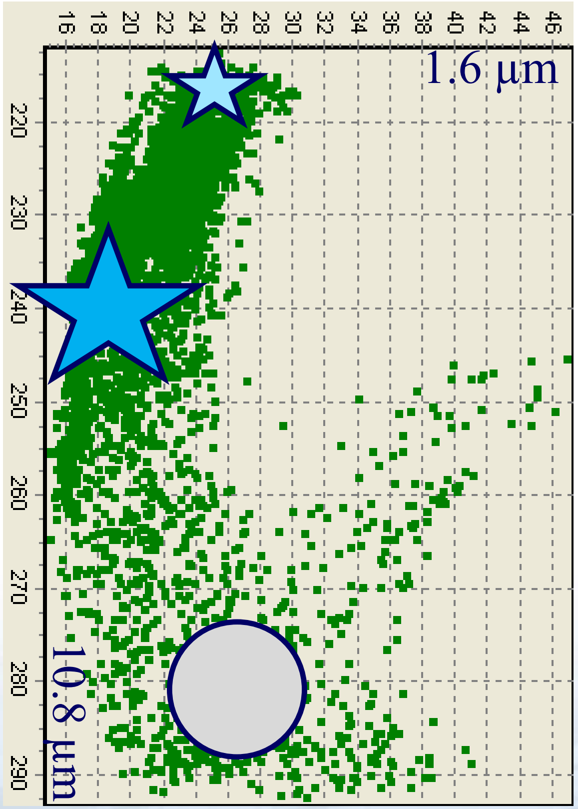


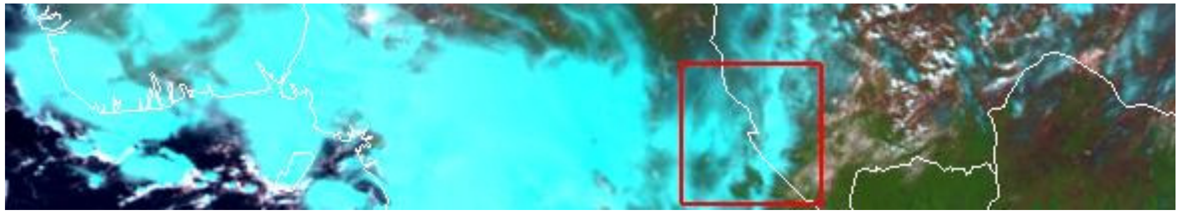
←Cyan colour in the natural RGB marks the presence of ice crystals, but is NOT an indicator of CONVECTIVE severity, related to small crystals.

Cyan is more for areas of probable STRATIFORM precipitation

EUMETSAT

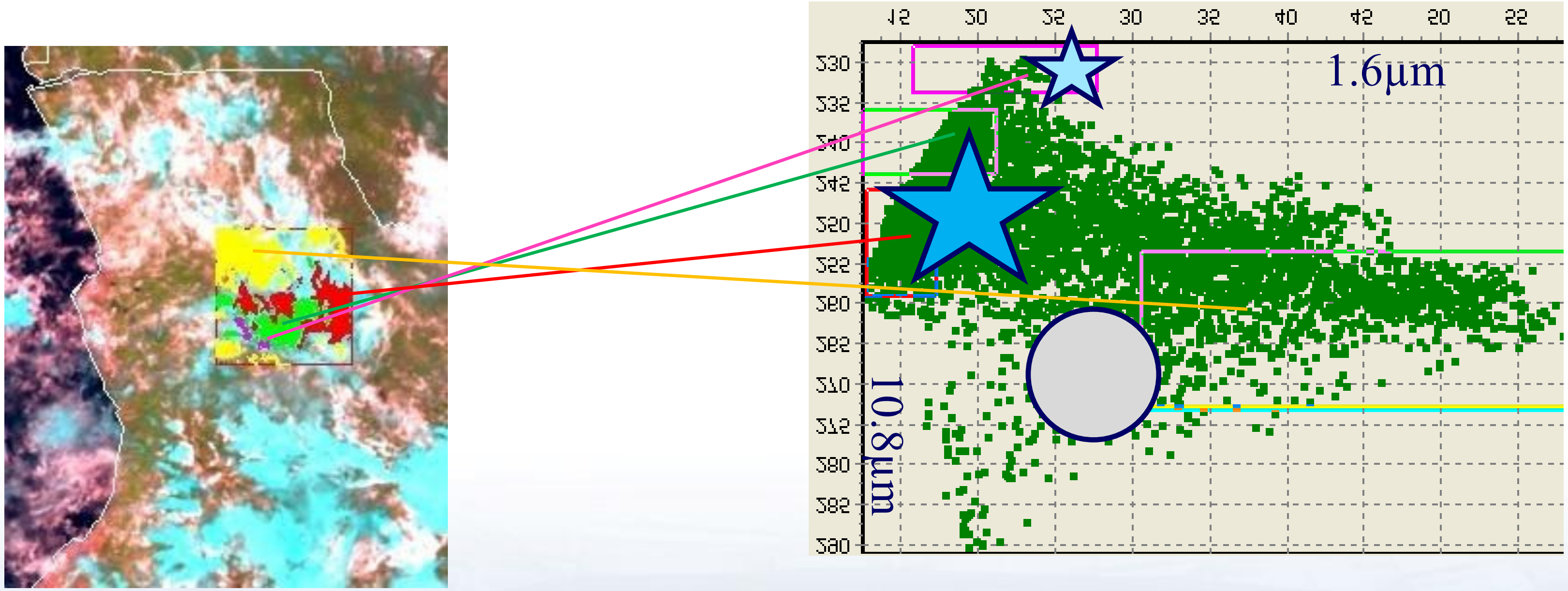
Ice cloud

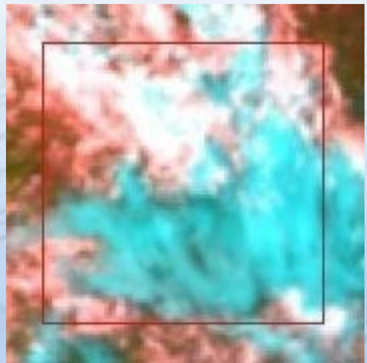




Thin cloud enhances the reflected signal from non-reflective grounds

Classifying ice cloud





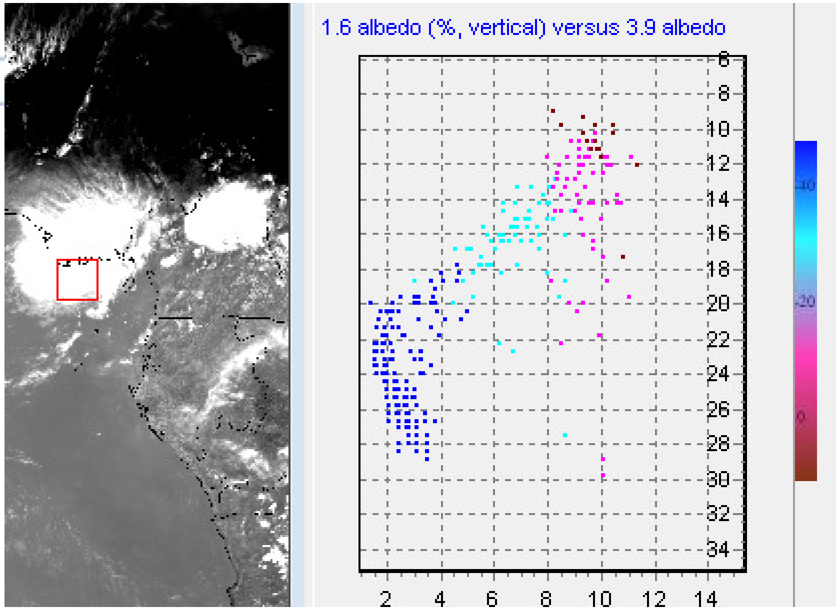
What are the red-coded areas?

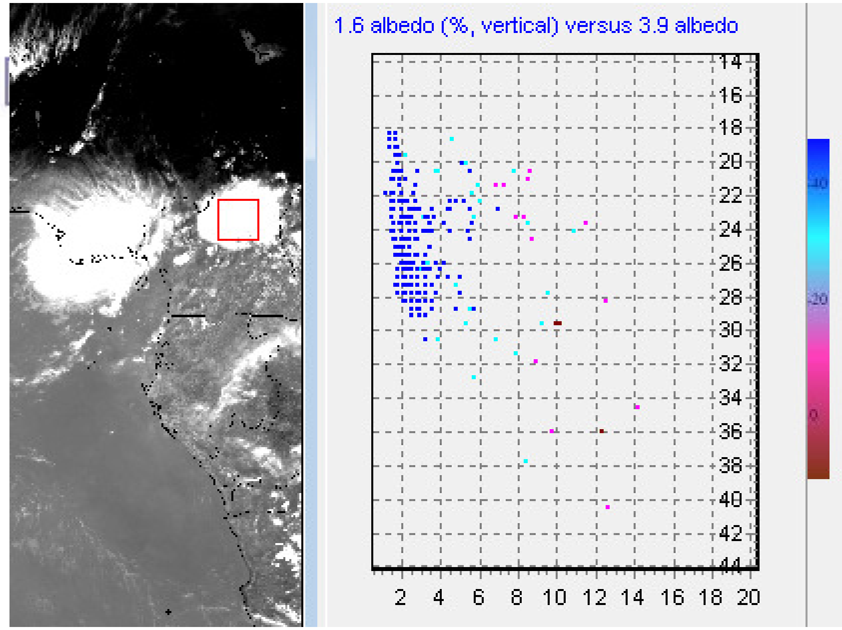
Super cooled water droplets

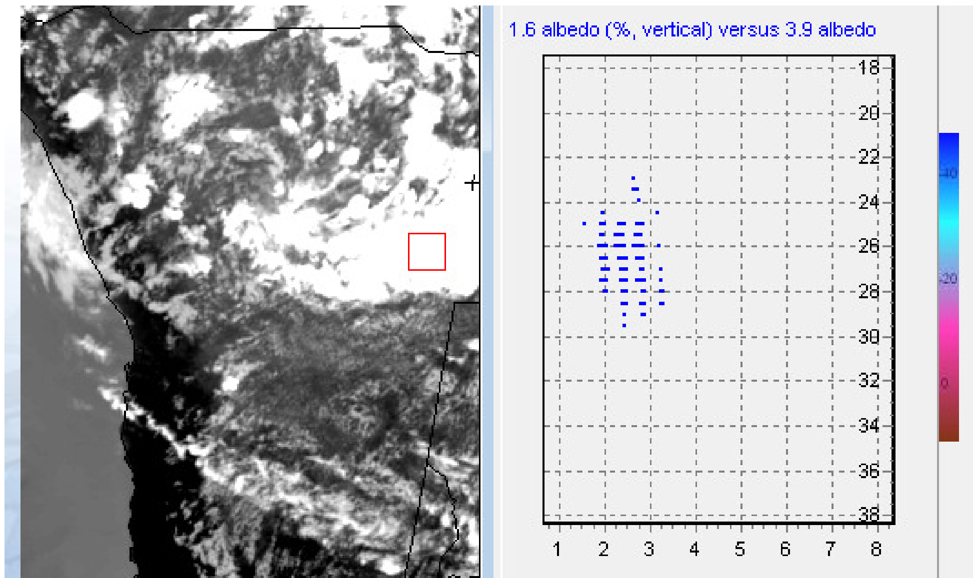
Large ice particles

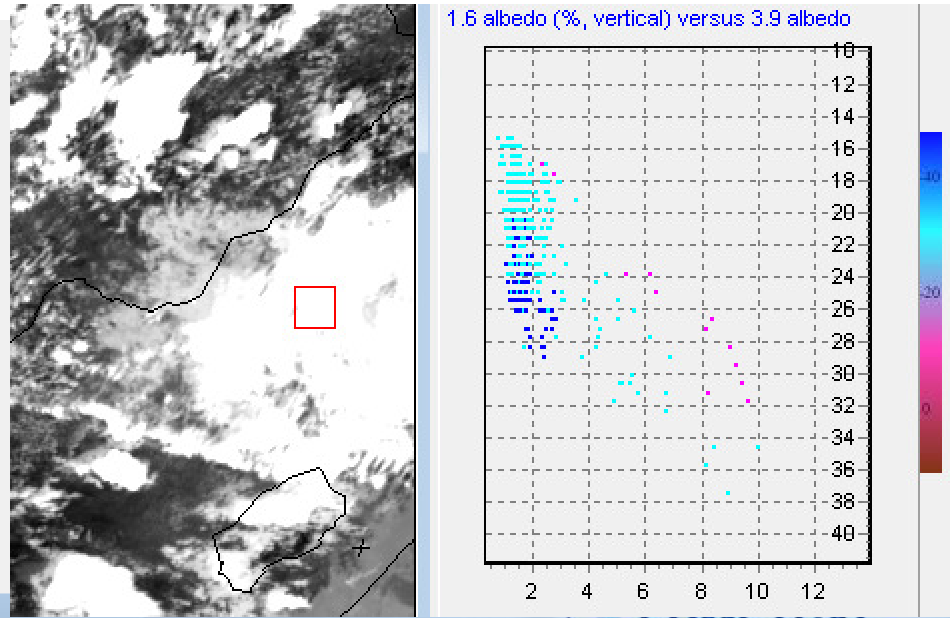
Ice

Small ice crystals


1.6 albedo (%, vertical) versus 3.9 albedo

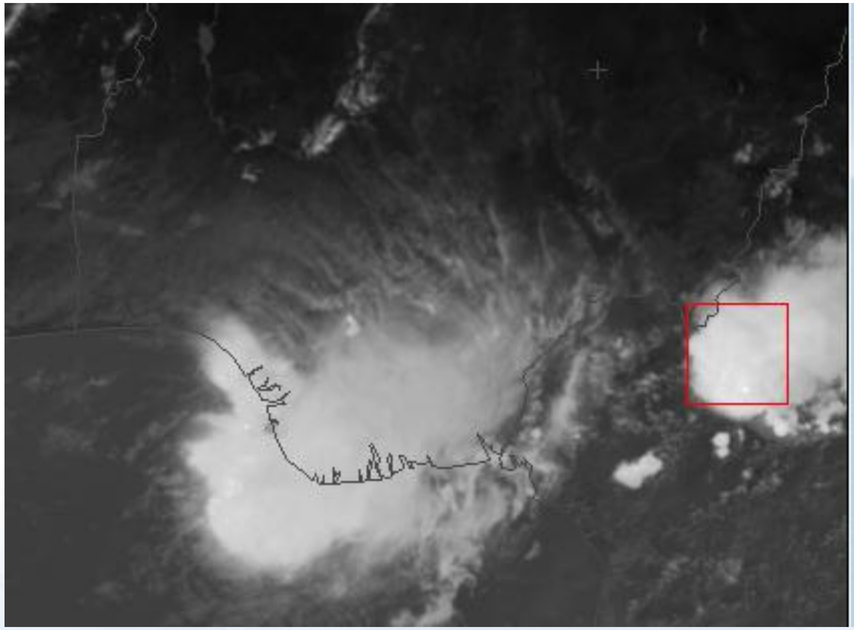

1.6 albedo (%, vertical) versus 3.9 albedo

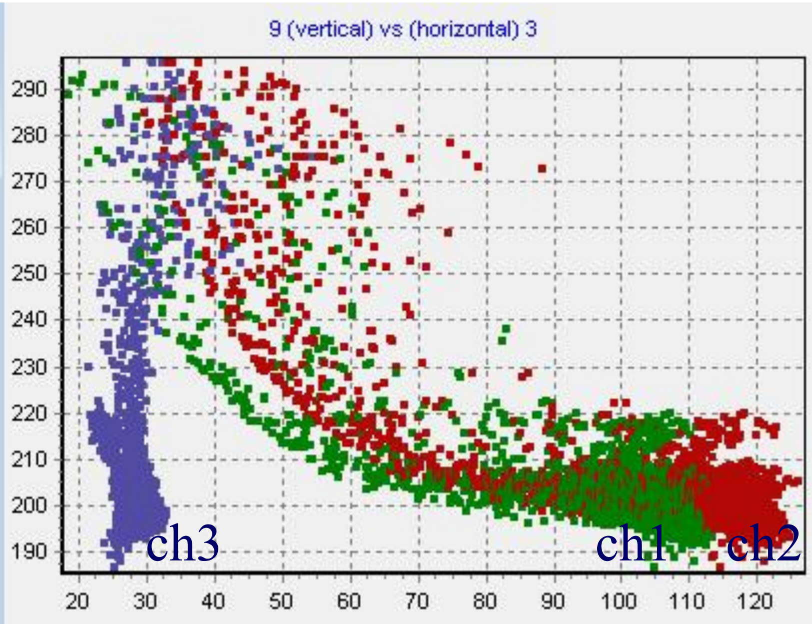

1.6 albedo (%, vertical) versus 3.9 albedo


1.6 albedo (%, vertical) versus 3.9 albedo

EUMETSAT

Physical limit values in clusters





Why 25-33% limits in the 1.6µm reflectivity at 200 K ?

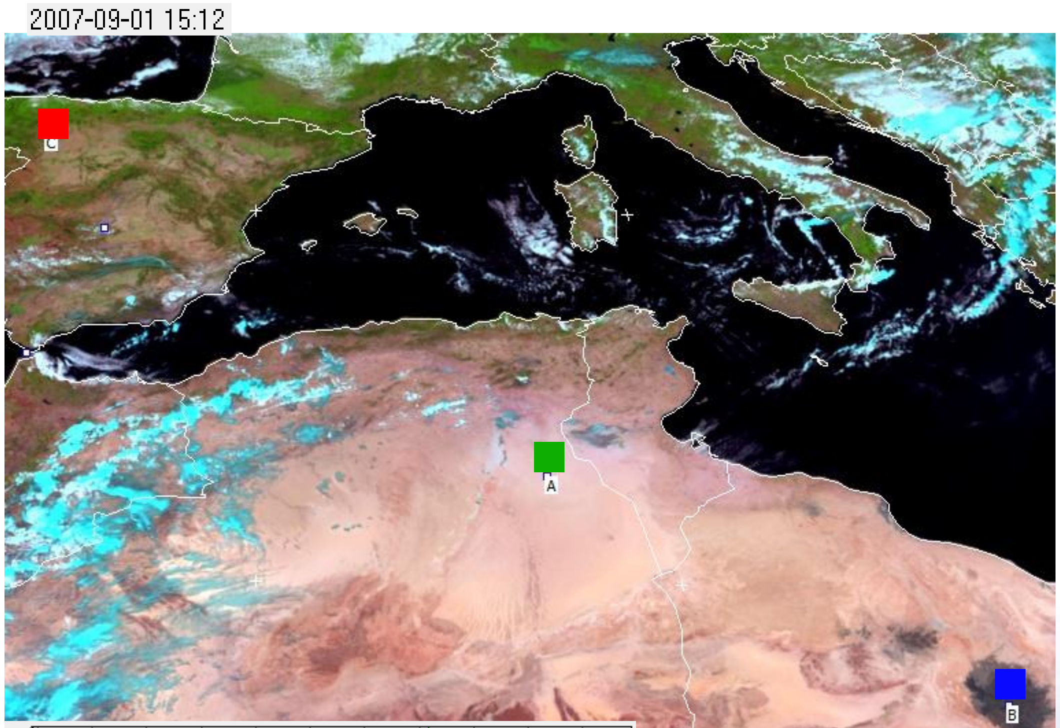
a. Cloud tops are made of non reflective ice crystals, too small to show variation.

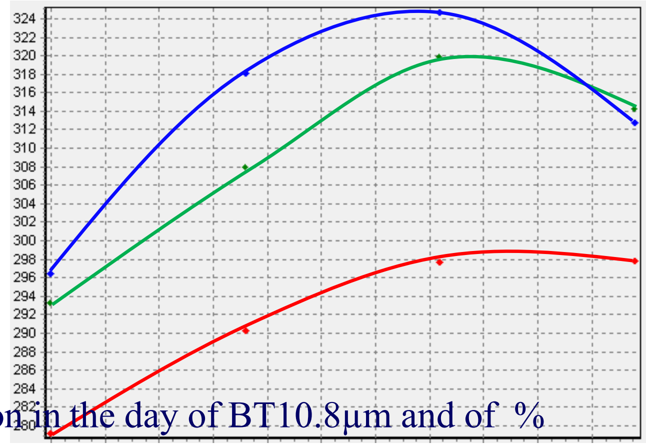
b. Reflectivity at 1.6µm is almost constant for any cloud.

c. Analysed pixels are uniform, all in the same updraft phase.

EUMETSAT

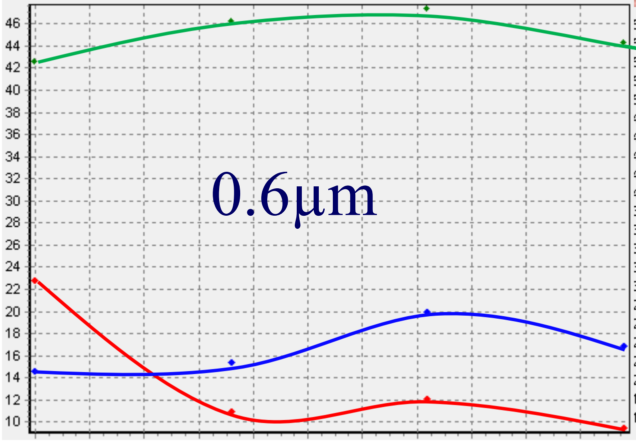
Channel reflectivities on soil

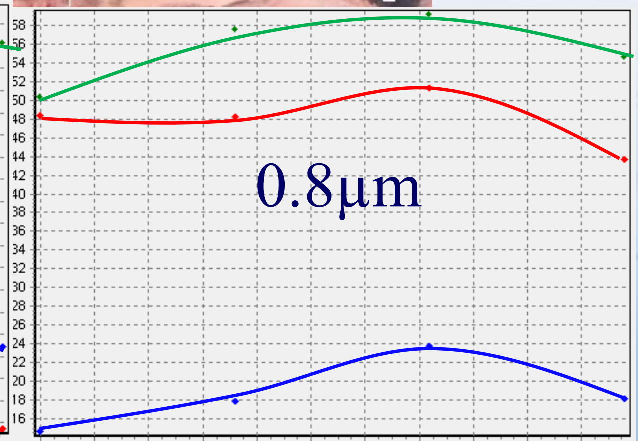


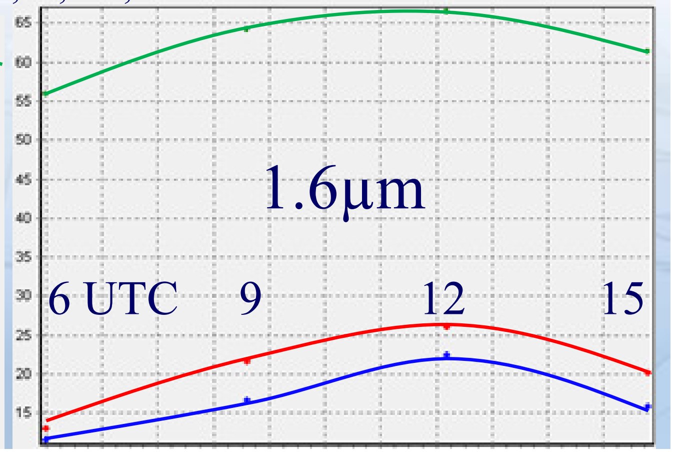


Evolution in the day of BT10.8µm and of % reflectivity at Meteosat channels 1,2 and 3:

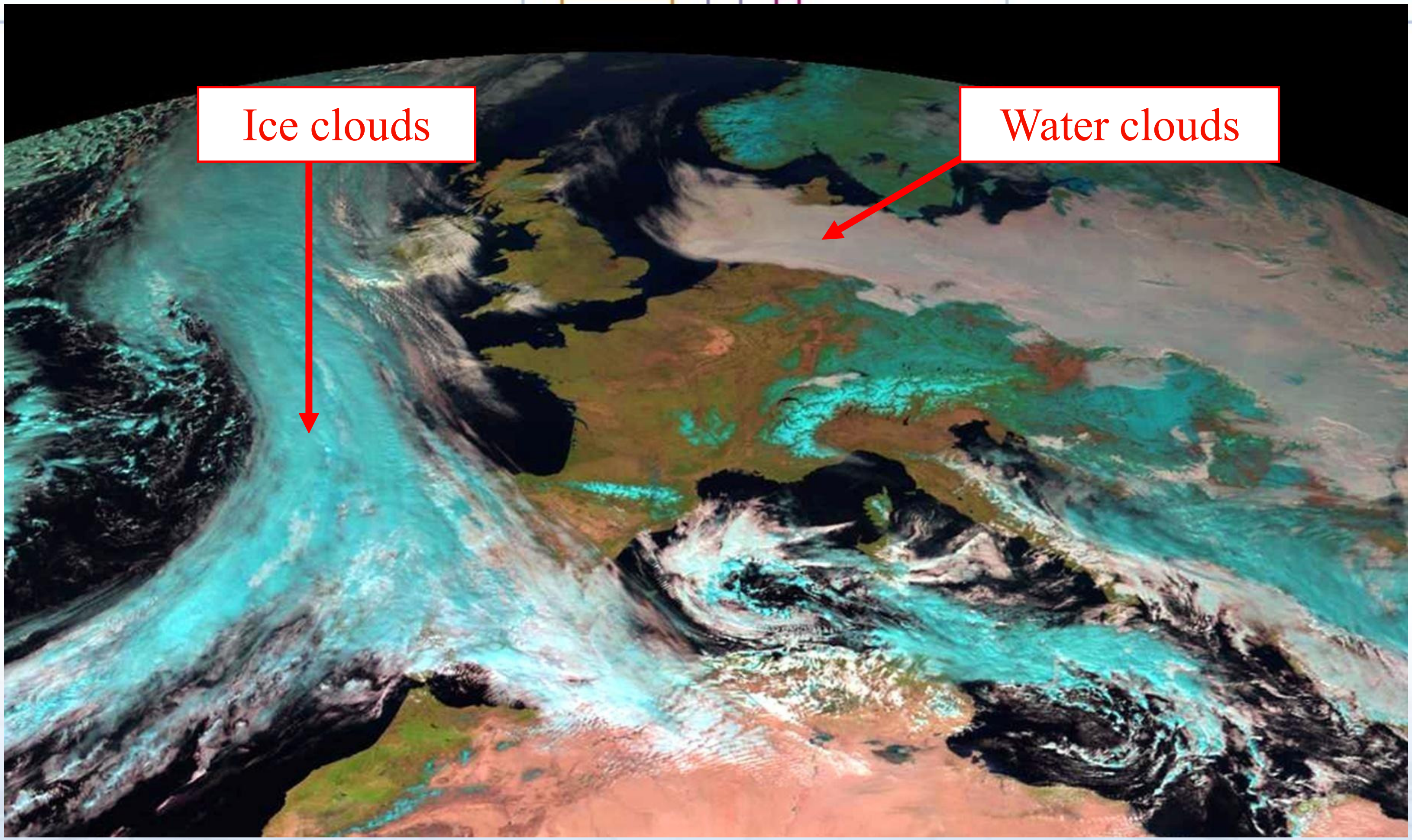
-Simple reflectivity formula shows directionality in reflection for
Sun-sat 90, 47, 15, 47
Solar: 77,41, 26, 54







Cloud Phase (Ice and water)



Cloud phase classification using SEVIRI RGB images

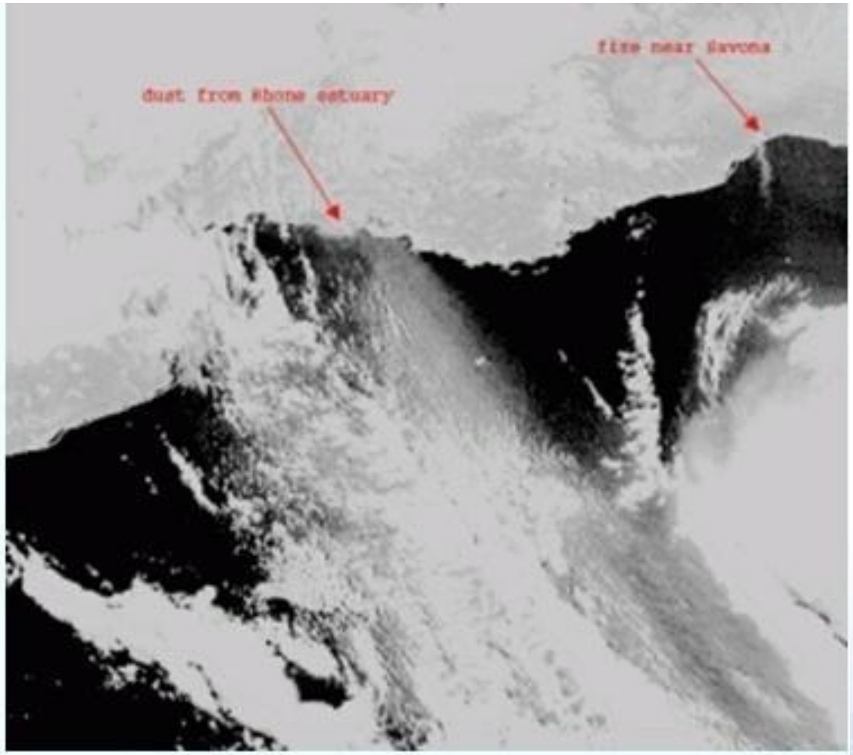
18 Feb 2003, 13:00 UTC, RGB NIR1.6-VIS0.8-VIS0.6

EUMETSAT

Meteosat solar channels

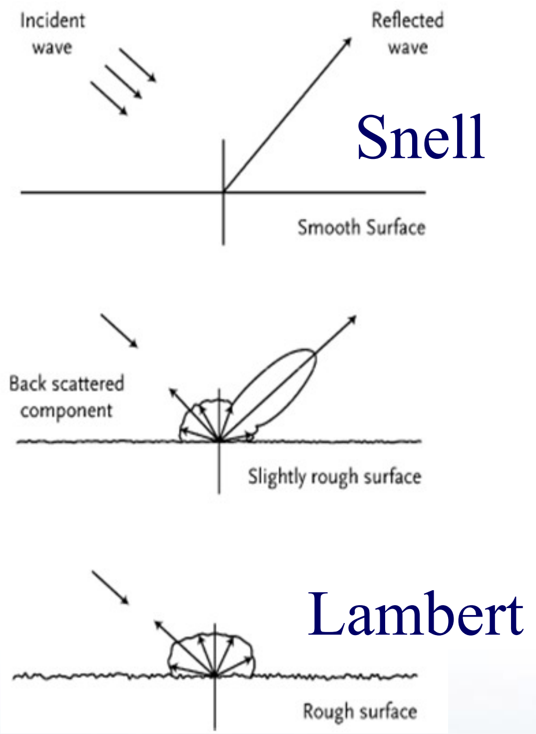
Rough surfaces due to mistral

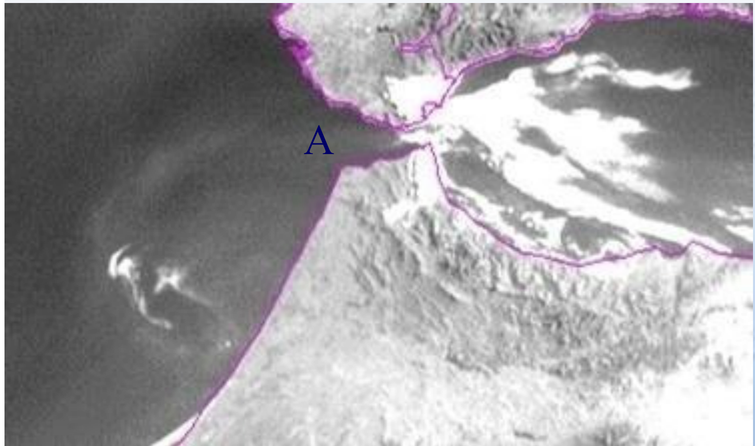
Met-8, 14 February 2005, 13:45 UTC
Channel 12 (HRV)



Met-8, 14 February 2005, 13:45 UTC
Channel 12 (HRV, enhanced)

Sun glint, wind and rough seas





•Sun glint (strong specular sun reflection to the satellite) occurs for a particular geometry Sun-pixel-Satellite, in an area of 1000 km across (geostationary satellites)

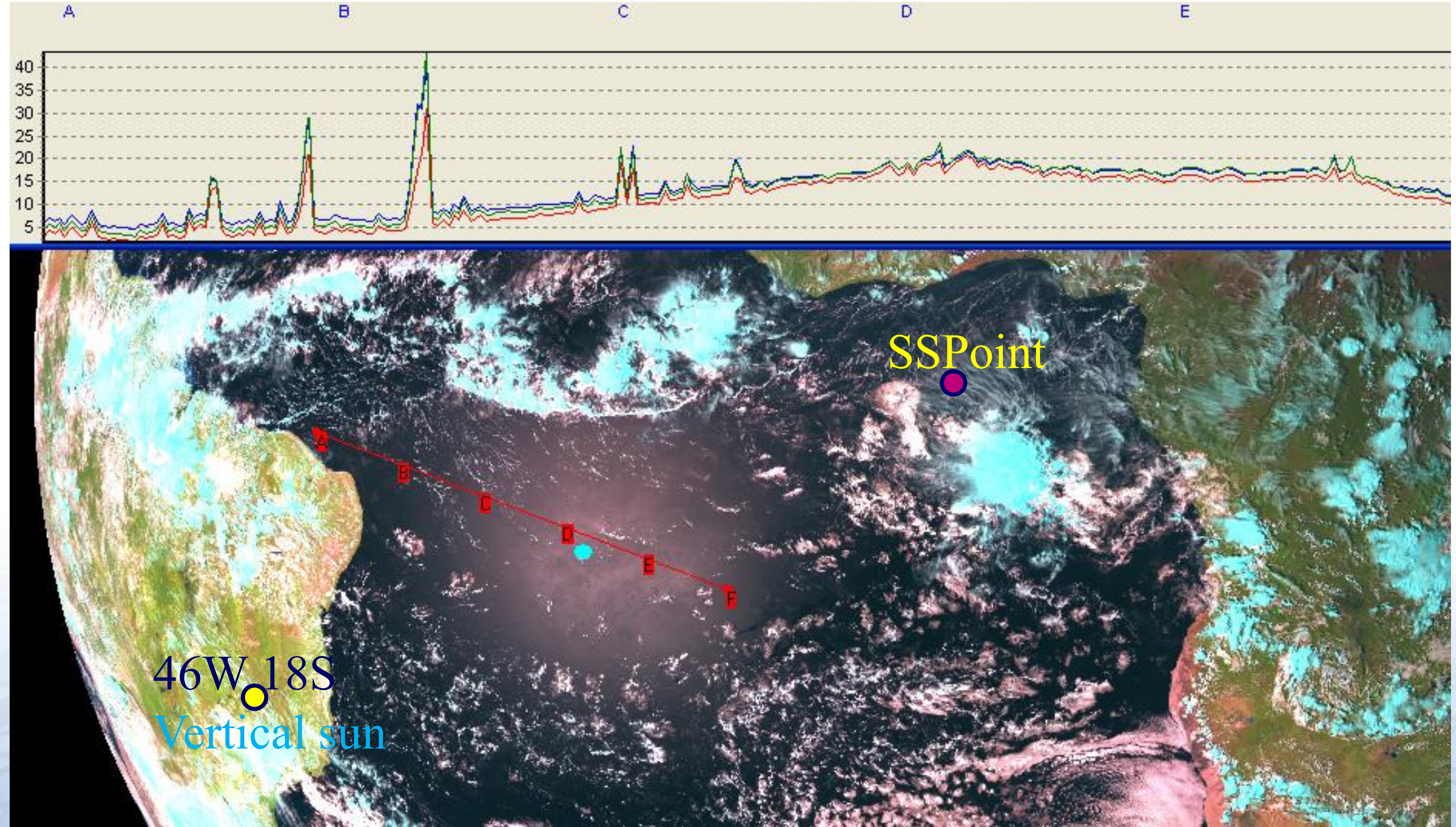
•For areas **far from the sun glint** zone, a weak wind **increases** roughness and scattering to the satellite on the sea surface.

•In the **sun glint zone** itself, the wind **decreases** the scattering to the satellite.

•A **strong** wind can increase reflectance by generating:
- **-foam**
- -jet depression and droplet **condensation**
- -bringing **dust** from land into the see

Ocean reflectivity by \ at	Sun glint area	Far away
No wind	High	Low
Moderate wind	Medium	Medium
Strong wind	Medium	High

Sunglint

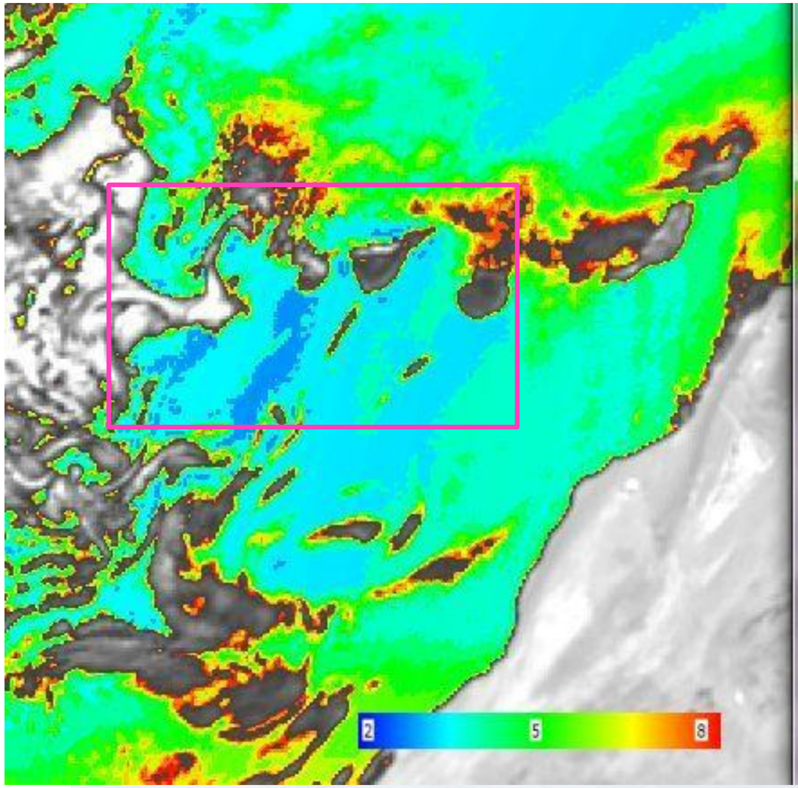


RGB natural Meteosat9, 2011…

2011-02-01 1500 UTC ?
2011-11-10 1330 UTC ?

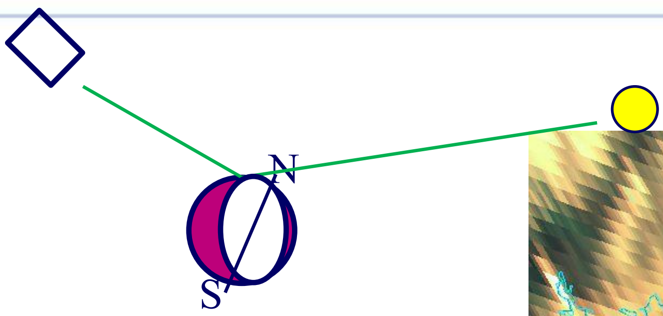
EUMETSAT

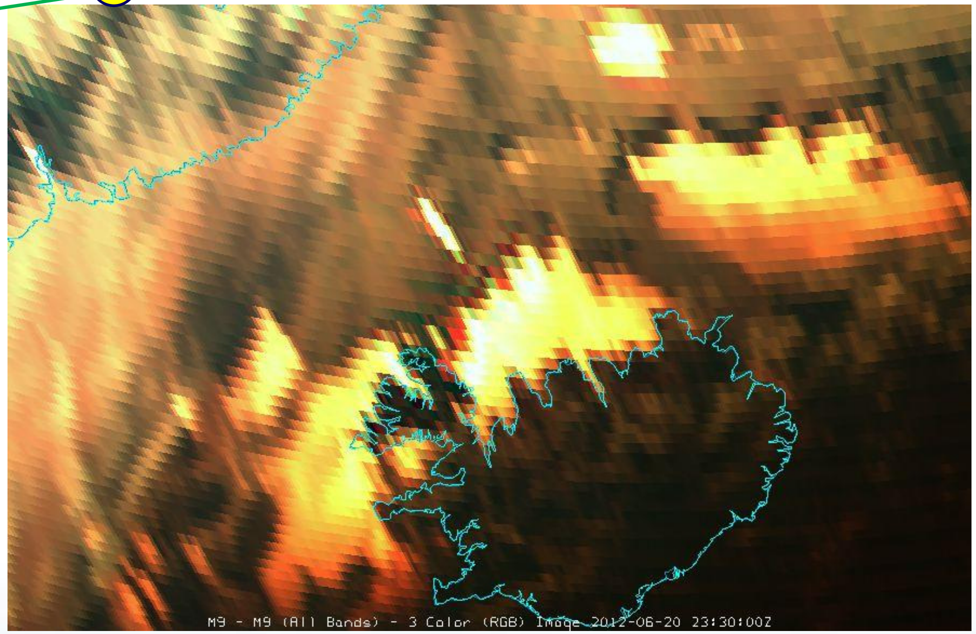
Reflectance on sunglint areas



Meteosat (no sunglint) and Terra Modis (sunglint)
2013-06-15 circa 10:30UTC
What makes the wake white in Modis: cloud, sea roughness, dust?

Ocean reflectivity by \ at	Sun glint area	Far away
No wind	High	Low





2012-june-20 at 2330 UTC Meteosat-9 Natural RGB 321

What are the bright spots north of Iceland?:
Cloud, sea surface, ash? Mind the image date!

Contents

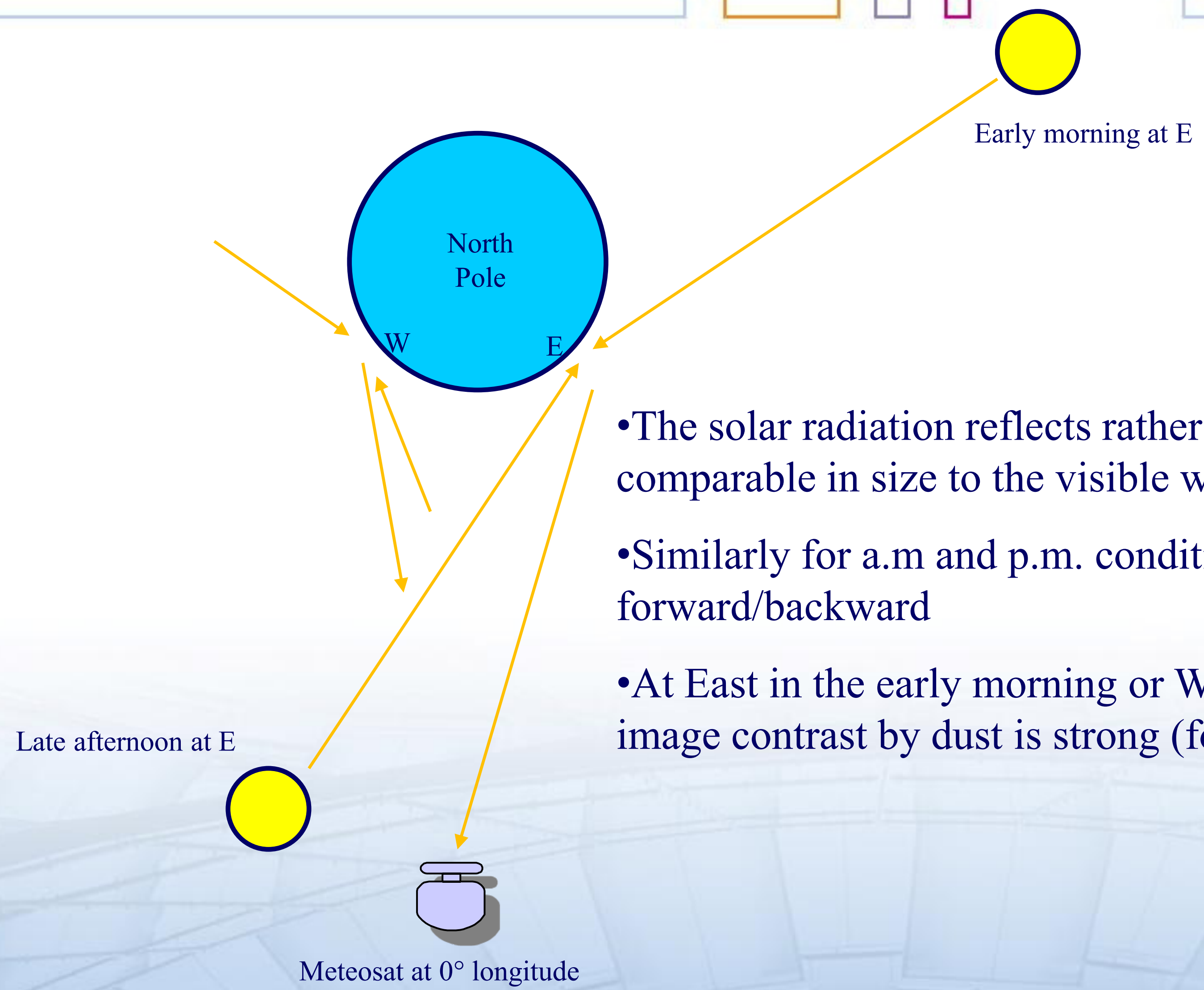
- Solar channels
  - Where you learn how to tell a cloud from a forest
- Vegetation monitoring
  - Where you learn how to tell tomatoes from rice
- Cloud phase and particle size
  - Where you learn how to find ice on planet Earth
- Sun glint
  - Where you learn to avoid squinting on satellite images
- **Aerosol**
  - **Where you learn how to escape from a fire**

Dust affects reflection and brightness temperature

Time evolution of solar 1.6µm and thermal 10.8µm for a dusty pixel and for a clear pixel in the North of Morocco

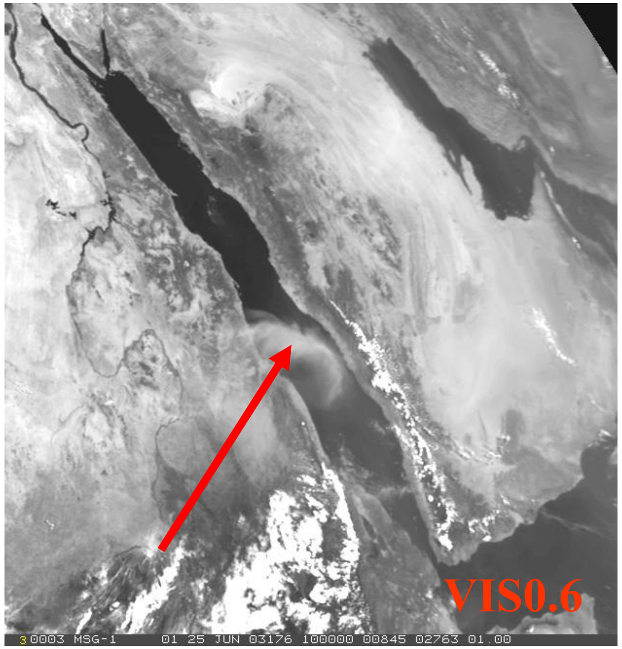
EUMETSAT

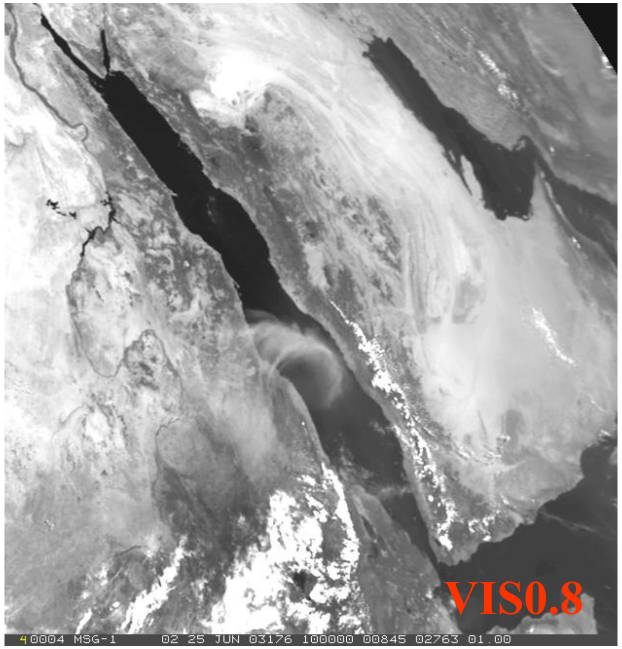
Image contrast for smoke or dust in solar images

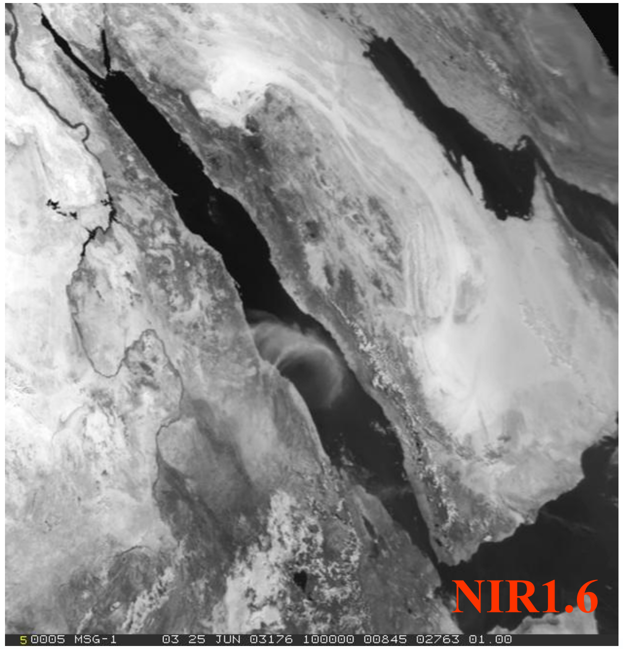


- The solar radiation reflects rather forward on smoke particles, comparable in size to the visible wavelengths (Mie)
- Similarly for a.m and p.m. conditions, except for factor forward/backward
- At East in the early morning or West in the late afternoon the image contrast by dust is strong (forward direction)

Solar channels: aerosol observation





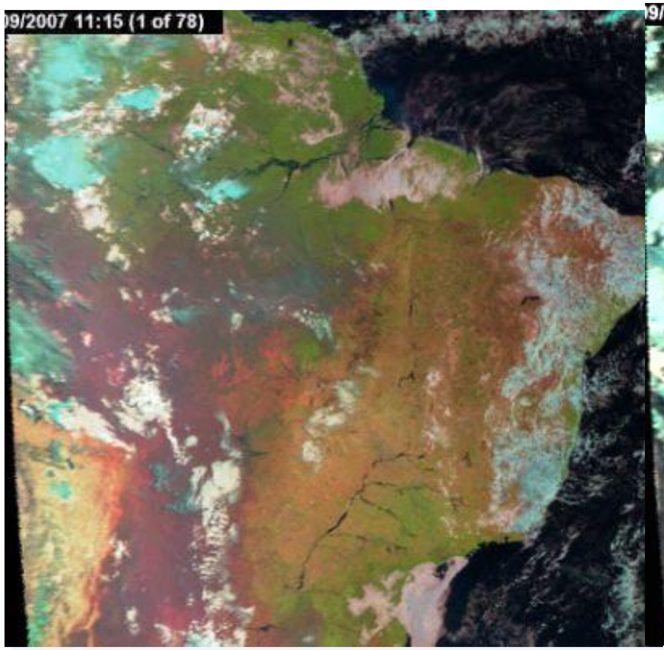


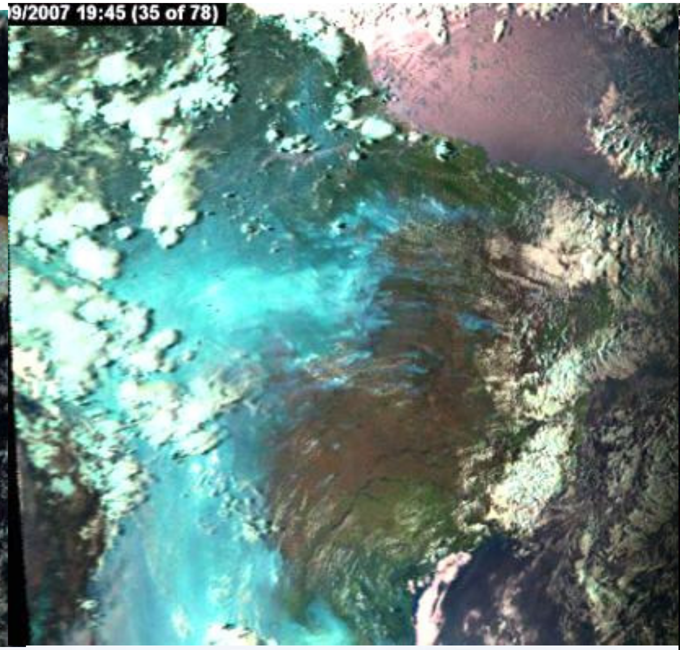
Dust storm over the Red Sea
MSG-1, 25 June 2003, 10:00 UTC

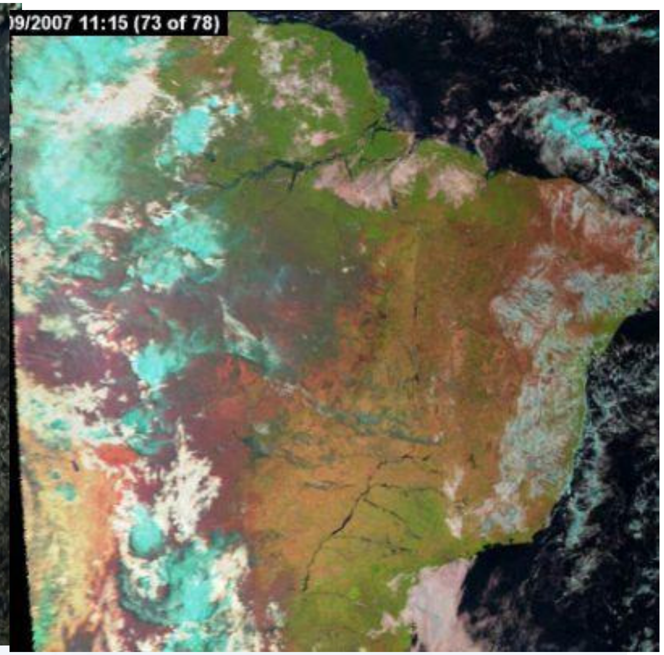
EUMETSAT

Pastures burning and deforestation activity in Bolivia

sunrise | sunset | sunrise





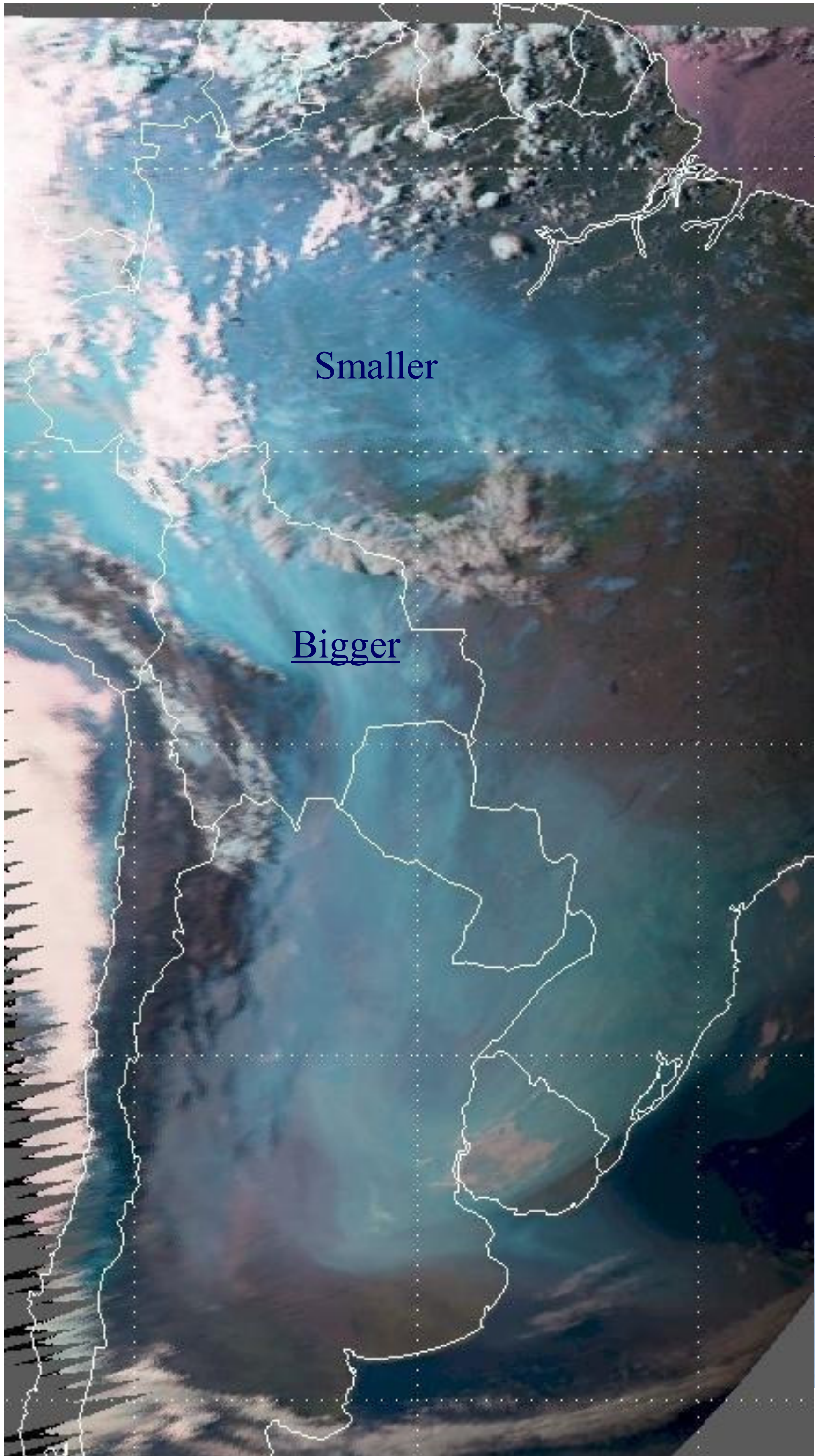


5-6 September 2007, Meteosat-9
Around sunrise and sunset times for central south America

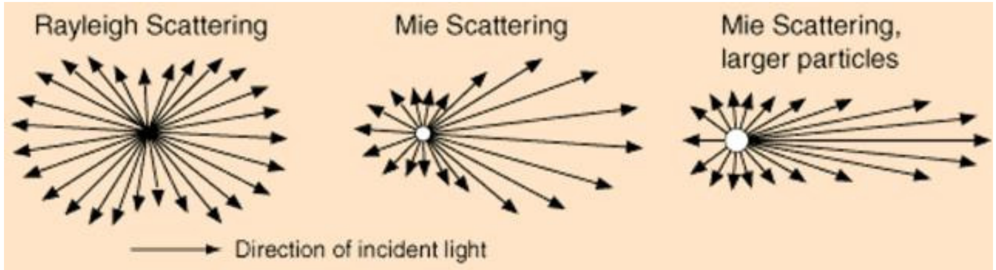
Assuming no major smoke sink or source in 24 hours, the intensity difference is due to directional reflection **(asymmetry factor)**

EUMETSAT

Who made the fire?



Meteosat9, 2010-08-21 2015 UTC



•Smaller wavelengths are reflected by smaller particles (wavelength ~ 3* diameter)

•Smoke particles are small compared with SEVIRI solar wavelengths (Rayleigh scattering)

•Smaller wavelengths are enhanced by forward scattering

•Scattering intensity higher in the western late afternoon

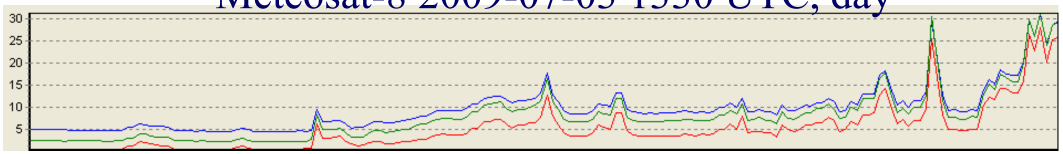
Smaller (0.2µm)	Bigger (0.3 µm)

EUMETSAT

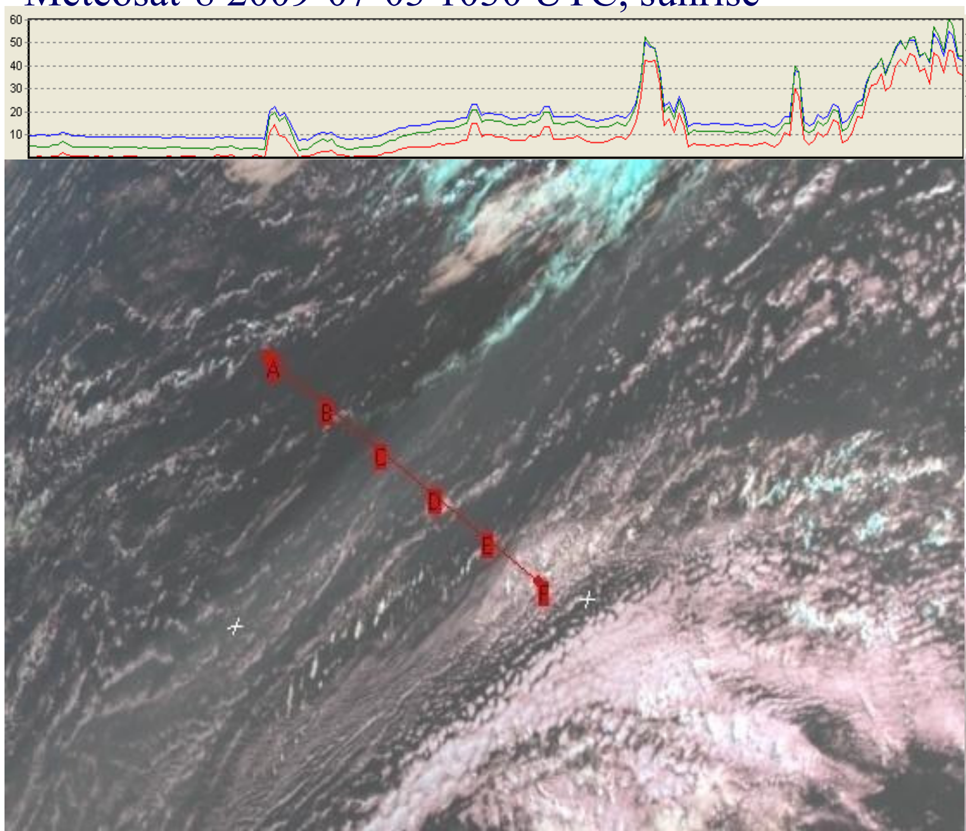
Sun glint hides the dust signal (sunset on the West)

At the western Atlantic, -58E ,18N dust over ocean (C-D), obscured at late p.m by coincident sunglint

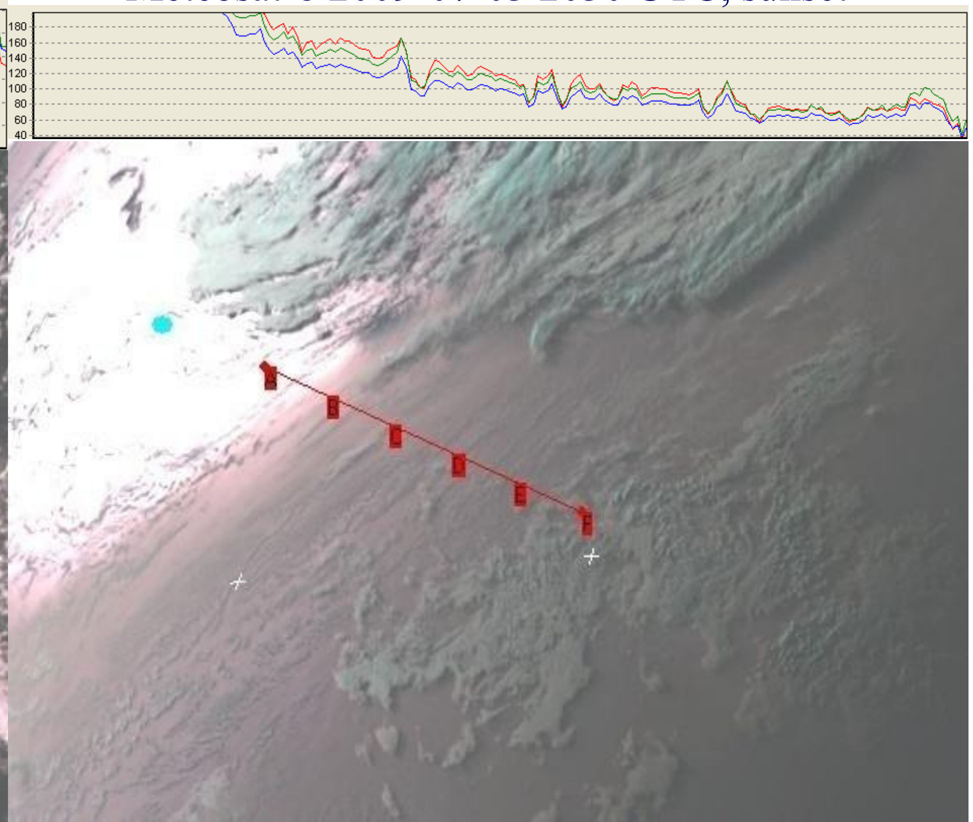
Meteosat-8 2009-07-03 1330 UTC, day



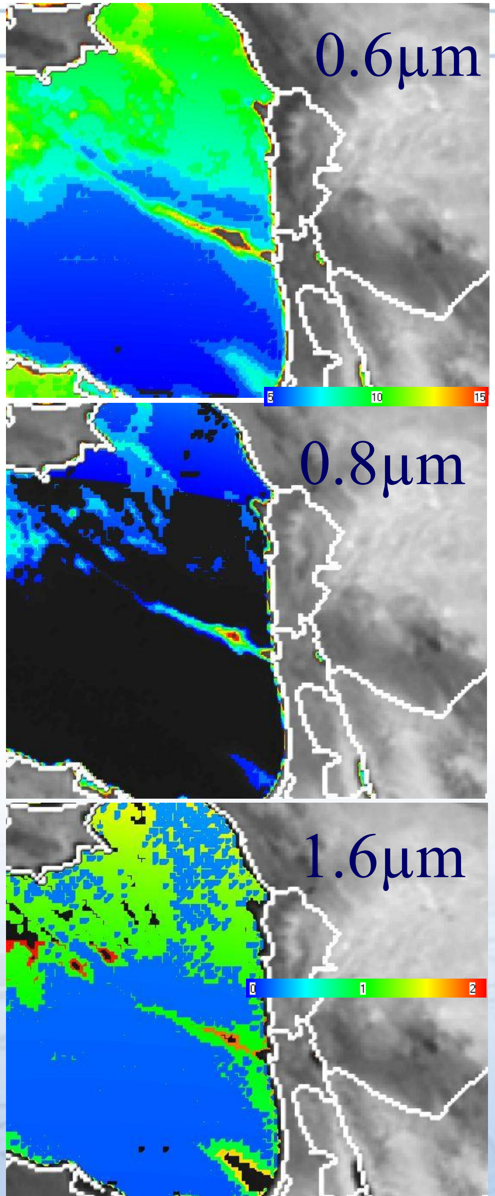
Meteosat-8 2009-07-03 1030 UTC, sunrise

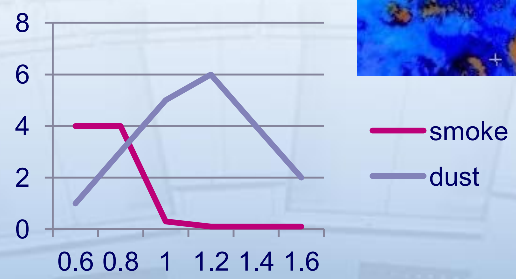


Meteosat-8 2009-07-03 2030 UTC, sunset



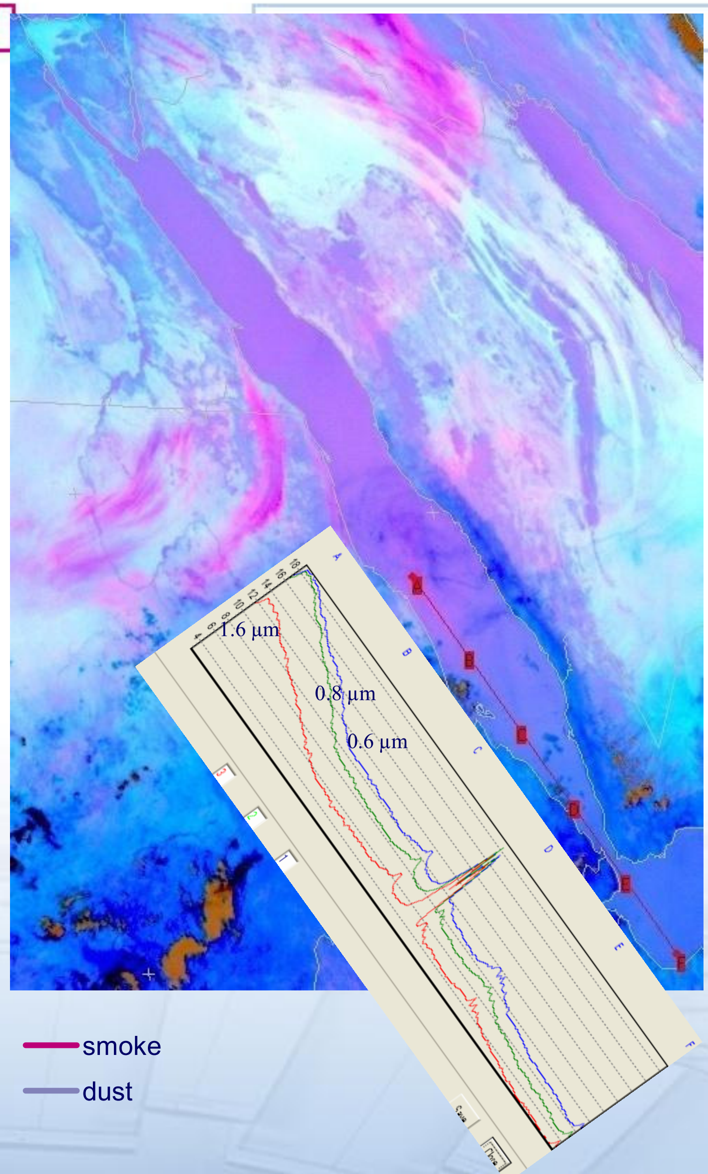
Ash or smoke is smaller than dust





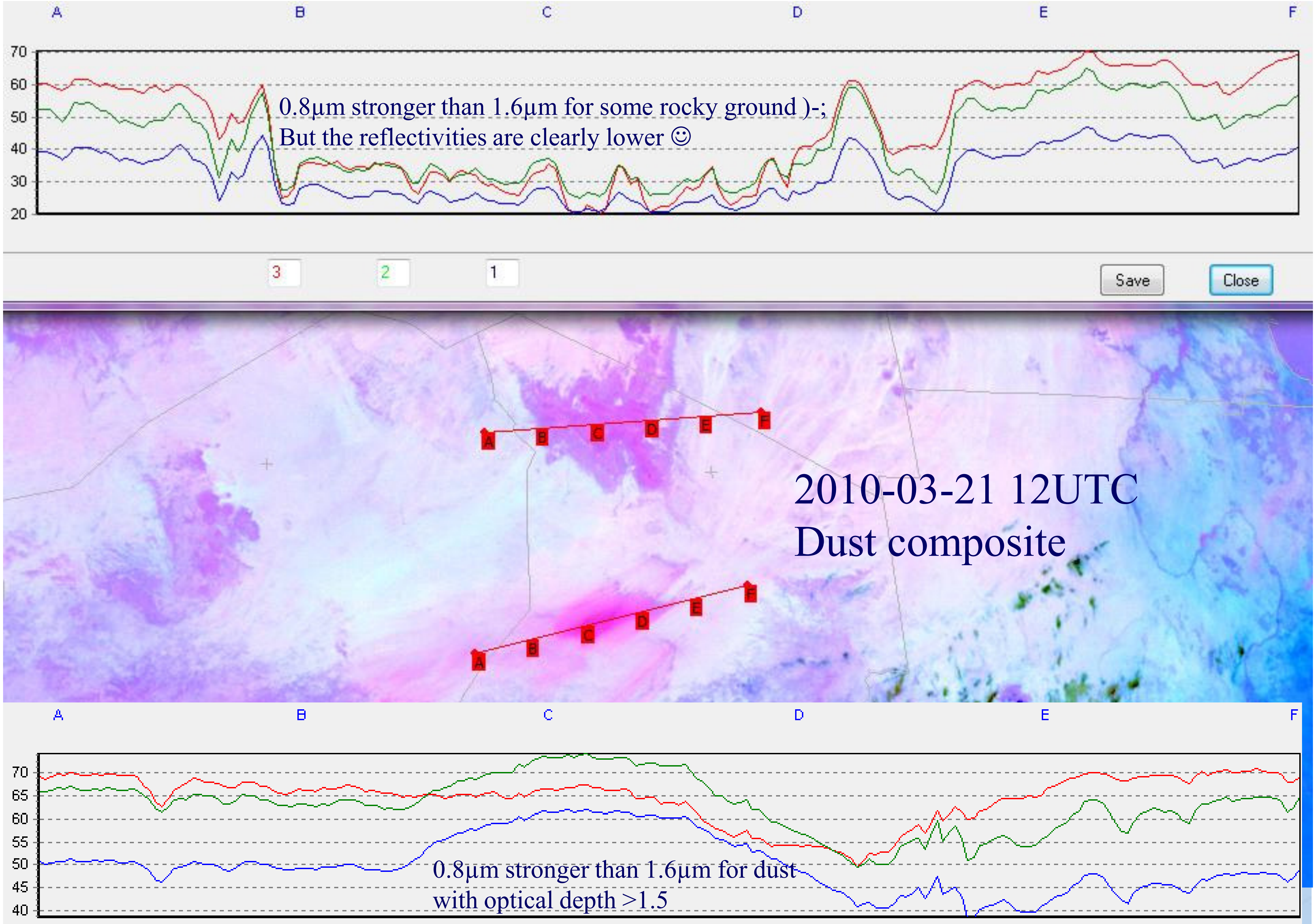
2010-12-03 10UTC Haifa fire **ash** plume (% albedo)
Plume maxima: 20%,15%, 3%

2010-06-23 0845UTC **Dust** over Red Sea



EUMETSAT

Solar channels (0.8µm – 1.6µm) to spot dust



Spotting dust with solar channels

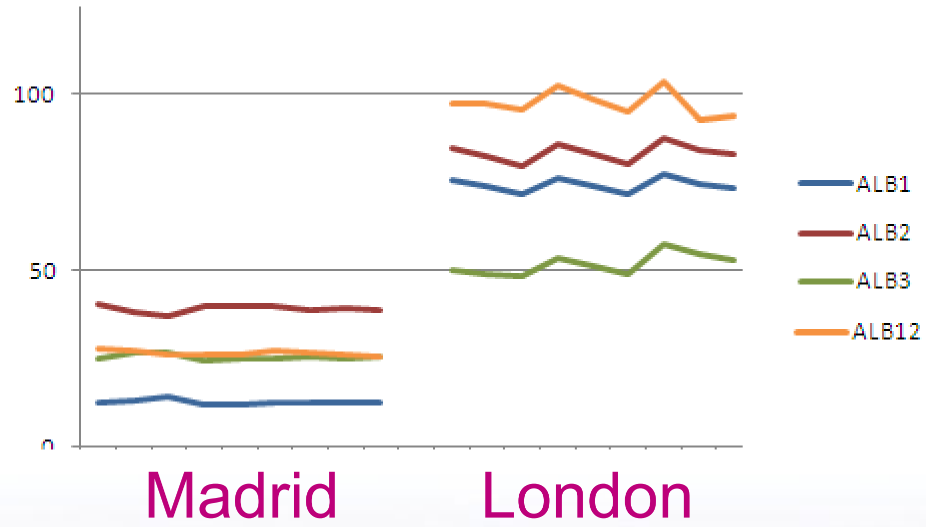
Why does dust increase reflectivity over desert for 0.6µm and 0.8µm (not for 1.6µm)?

a. Backscattering by small particles in the air is more efficient than on ground.
b. Regions with dust above have finer reflective texture on the ground.
c. Multi-scattering in the dust cloud enhances the signal at the satellite.

Which index based on channel numbers 2 and 3 would be adequate for dust?

a. (2-3)*(2+3)
b. (3-2)/(3+2)
c. 2
d. 3/2

Clear and cloudy locations (26-Apr-2010 10:45, 9 neighbours)



•Solar: scale 0% - 100% albedo

•For the clear (dry) scene, 0.8µm provides the strongest reflectance

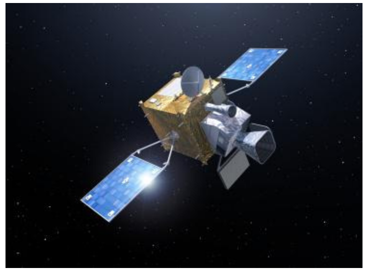
•For cloud over London, 1.6µm is weakest

•HRV is average of the solar channels 0.6 and 0.8µm for land, but above both for cloud cover

Implementation of the EUMETSAT Geostationary Programme

1977 — MOP+MTP | 2003 — MSG | 2018 — MTG






1 observation mission:
- MVIRI: 3 channels
- **Spinning** satellite
1 ton

2 observation missions:
- SEVIRI: 12 channels
- GERB
- **Spinning** satellite
2 ton

4 observation missions:
- Combined Imager: 16 channels
- Infra-Red Sounder
- Lightning Imager
- **3-axis stabilised** satellite(s)
3 ton

... towards 60 years of operations ...

Coordinated with atmospheric chemistry from GMES Sentinel 4

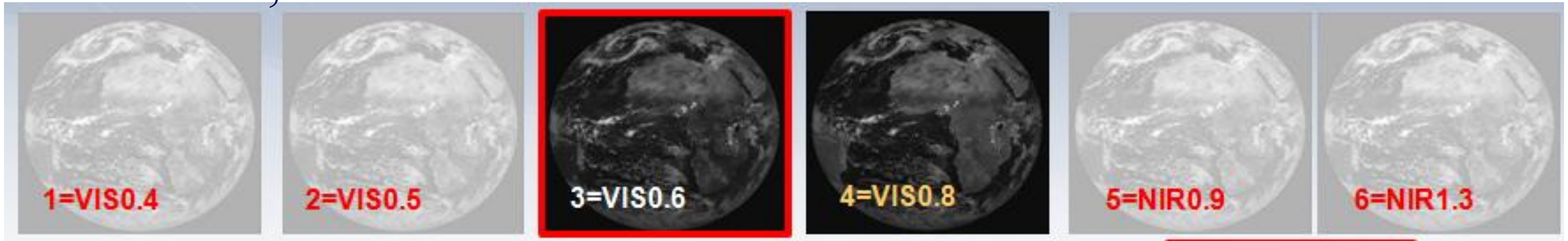
EUMETSAT

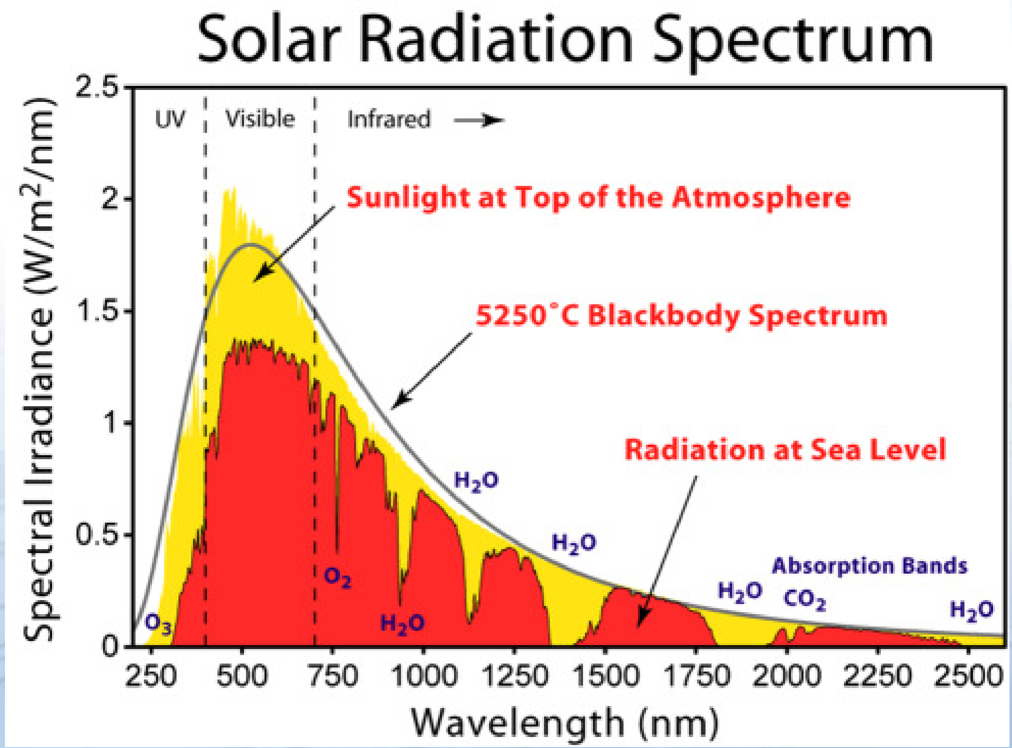
Third generation solar channels

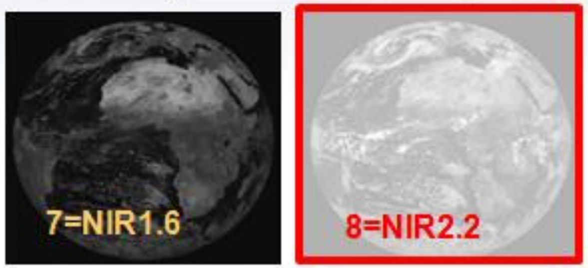
Aerosol, true colour

Water vapour over land

Thin cirrus







Cloud microphysics

Aerosol, ocean colour, flooding

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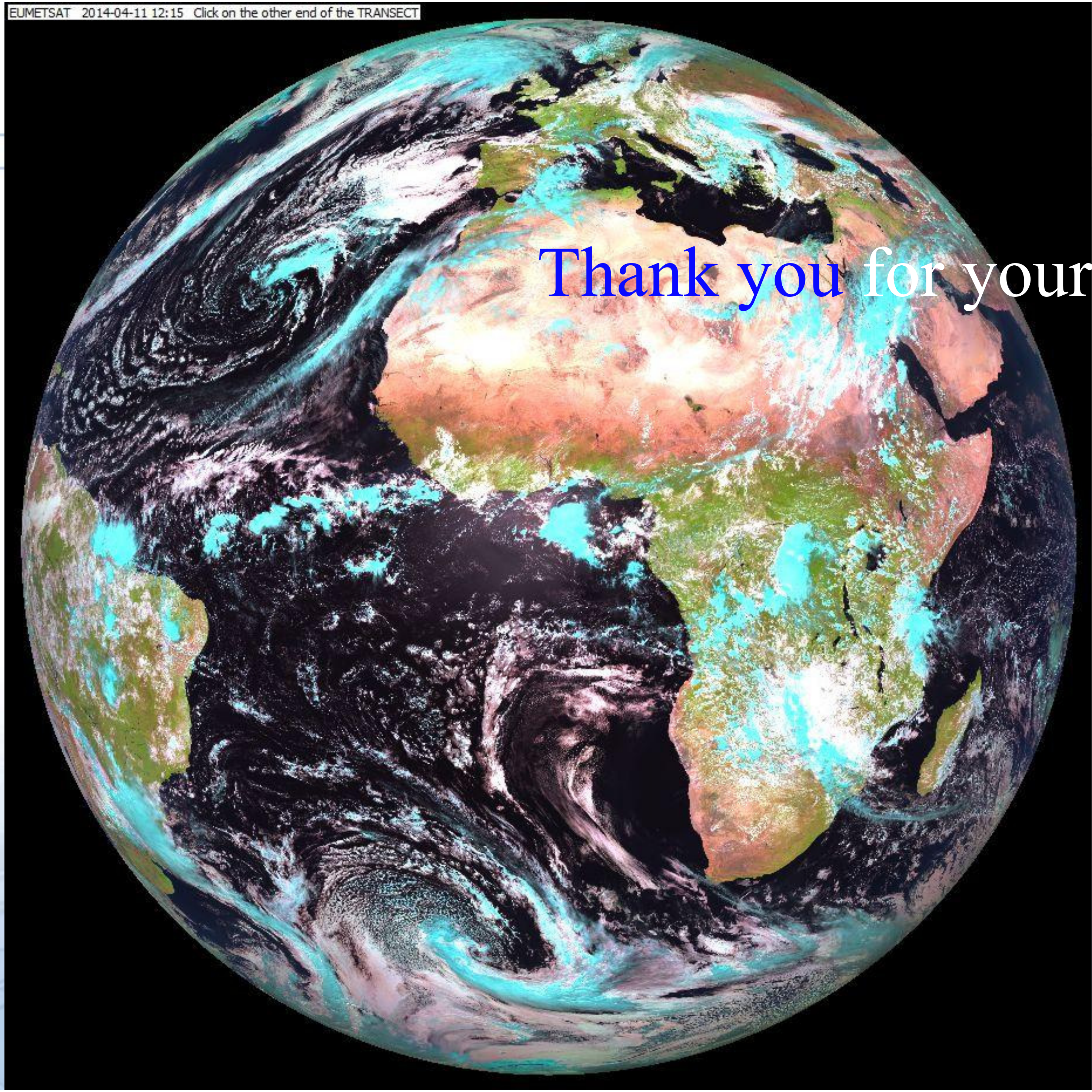
Thank you for your attention



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