Meteosat solar channels

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Quiz 1

A. How many channels in the human visible domain does include the SEVIRI instrument in Meteosat?

- 4 or more
- 3
- 2
- 1

B. How many SEVIRI channels collect solar radiation reflected by the Earth?

- 5 or more
- 4
- 3
- 2

C. How many solar channels do you use routinely at work?

- 4 or more
- 3
- 2
- 1
- 0

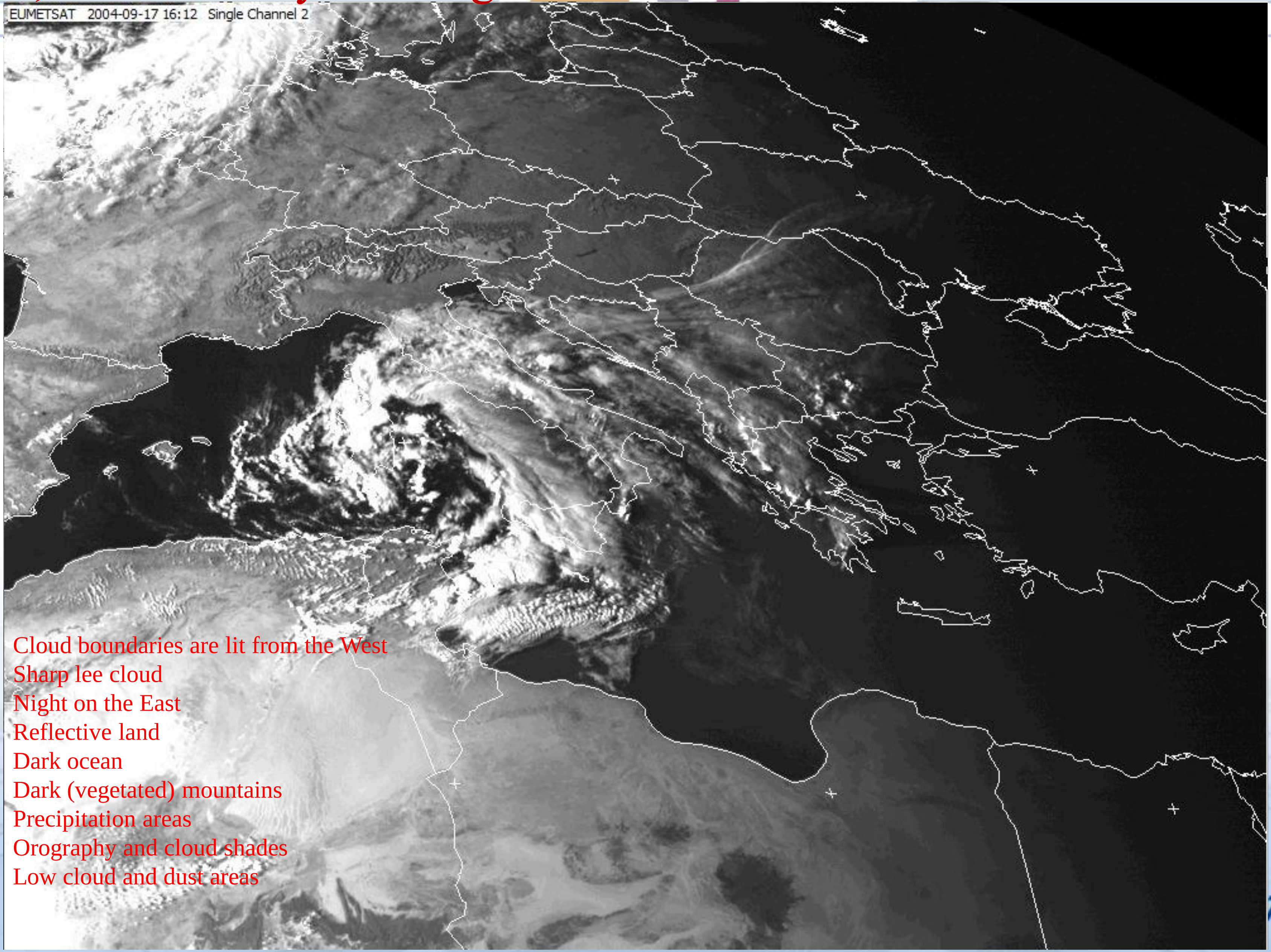
Quiz

Same date-time? Is this June image SOLAR or THERMAL-infrared?

YES NO

Is this solar? YES NO

If not, what would you change to "solarise" it?



SEVIRI CHANNELS

	Properties			
Channel	**Cloud**	**Gases**	**Application**	
HRV 0.7	Absorption <-------------> Scattering; 1 <--------- Emissivity ---------> 0	Broad band VIS	Surface, aerosol, cloud detail (1 km)	12
VIS 0.6		Narrow band	Ice or snow	1
VIS 0.8		Narrow band	Vegetation	2
NIR 1.6		Window	Aerosols, **snow<>cloud**	3
IR 3.8		Triple window	SST, **fog**<>surface, ice cloud	4
WV 6.2		Water vapour	**Upper** troposphere 300 Hpa humidity	5
WV 7.3		Water vapour	**Mid**-troposphere 600 Hpa humidity	6
IR 8.7		Almost window	Water vapour in boundary layer, **ice<>liquid**	7
IR 9.7		Ozone	Stratospheric winds	8
IR 10.8		Split window	CTH, cloud analysis, **PW**	9
IR 12.0		Split window	Land and **SST**	10
IR 13.4		Carbon dioxide	+10.8: Semitransparent-cloud **top**, air mass analysis	11

Meteosat solar channels

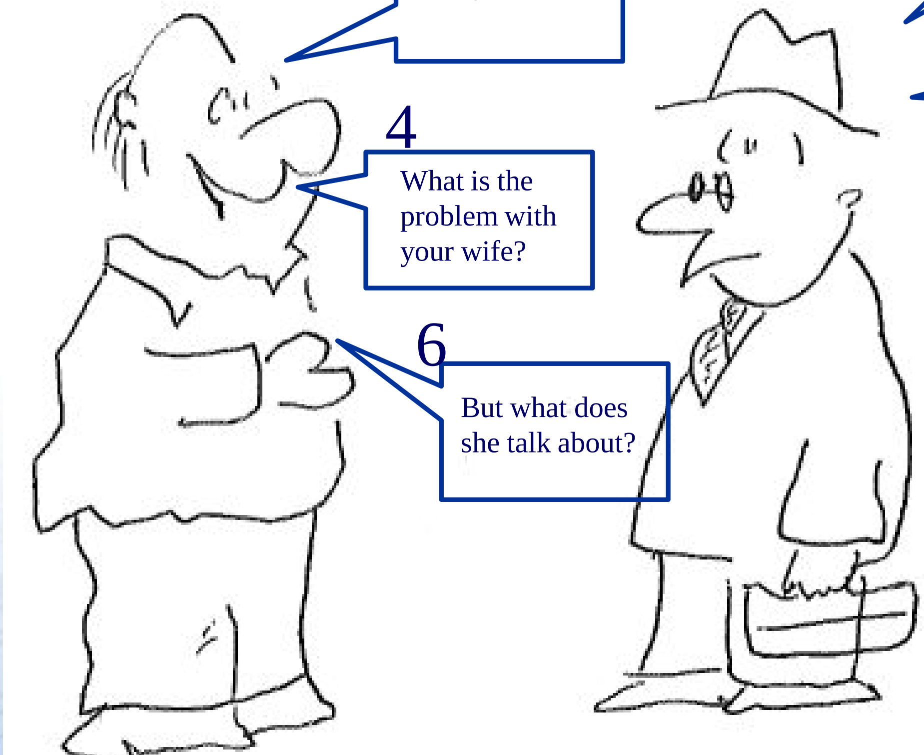
SEVIRI channel similarity

← solar → ←3.9→ ← thermal →

Channel	1	2	3	4	5	6	7	8	9	10
1										
2	0.99									
3	0.82	0.89								
4	0.26	0.35	0.60							
5	-0.47	-0.48	-0.46	0.08						
6	-0.46	-0.44	-0.34	0.42	0.80					
7	-0.61	-0.66	-0.68	0.00	0.80	0.83				
8	-0.60	-0.65	-0.66	-0.02	0.76	0.80	0.99			
9	-0.60	-0.64	-0.68	-0.02	0.82	0.83	0.99	0.97		
10	-0.58	-0.61	-0.61	0.10	0.86	0.91	0.97	0.94	0.98	
11	-0.56	-0.56	-0.49	0.26	0.83	0.97	0.89	0.86	0.90	0.96

- Solar channels 0.6 and 0.8 µm are very similar
- Those two channels are dissimilar of 1.6 µm
- All three have a NEGATIVE radiance correlation with the thermal. Why? GROUND? OCEAN? CLOUD?

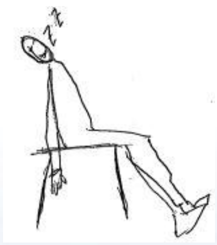
Line talk


START HERE:
1 I do not like coming back home
2 Why is that?
3 My wife...
4 What is the problem with your wife?
5 She talks and talks and talks..
6 But what does she talk about?
7 She does not tell me!

Contents

➢Where is LIGHT absorbed ?

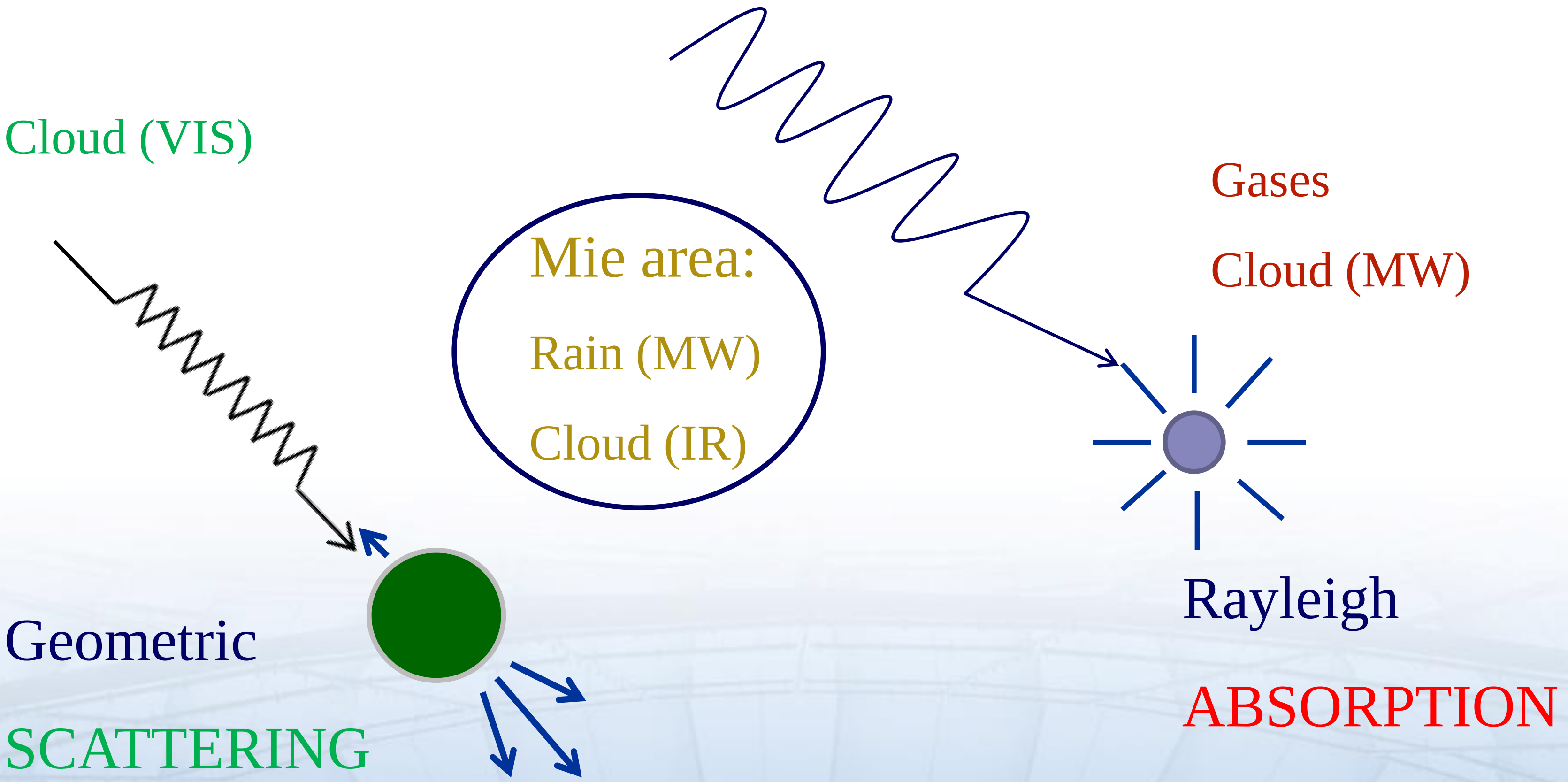
➢Is the neighbour’s GRASS greener?



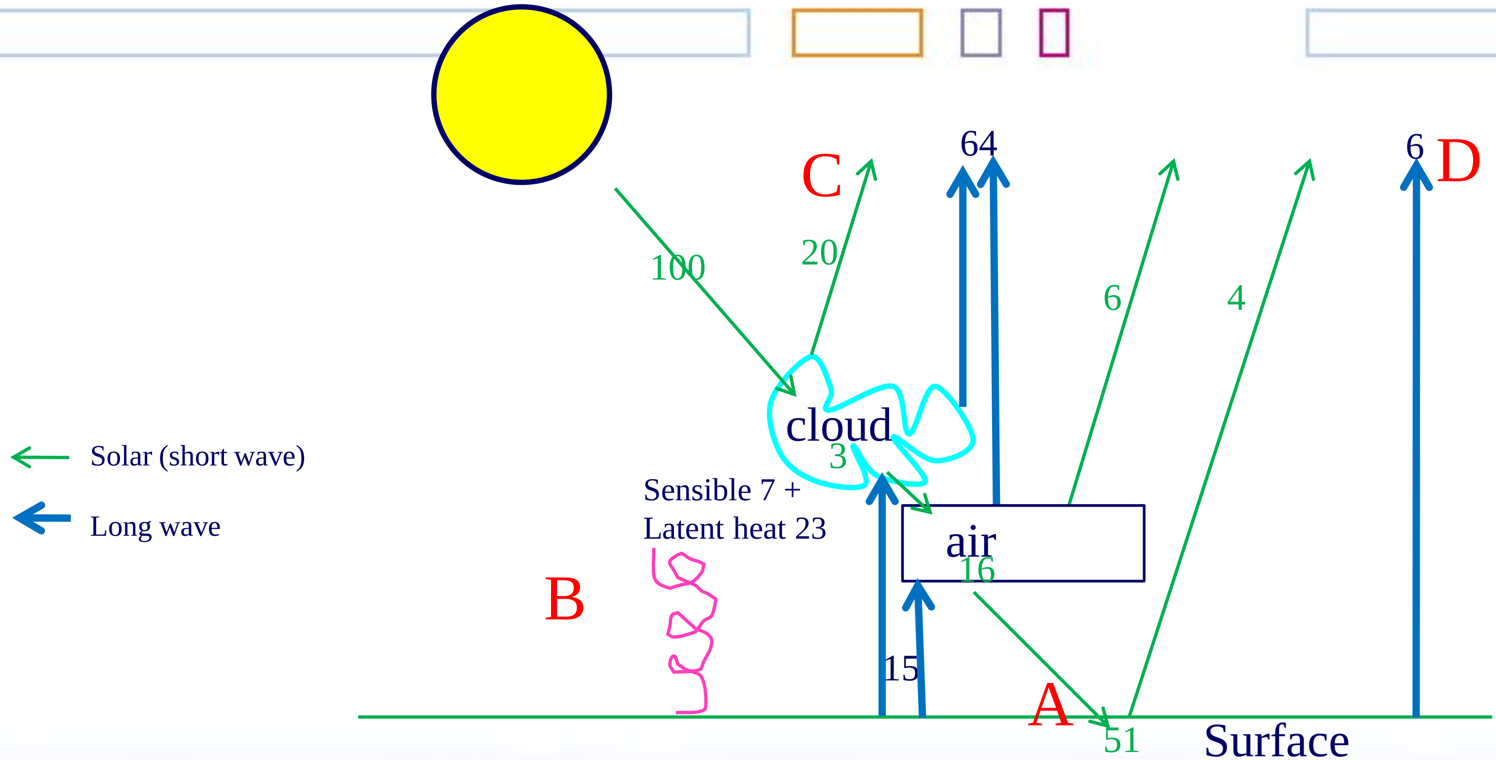
➢Is ICE always cyan?

➢Is DUST enhancing visibility?

RADIATION and MATTER



Balance at top and surface, greenhouse atmosphere



A) **Ocean surface is** the main **absorber** of solar radiation, but cold

B) The atmosphere gets **more** energy from sun and surface **radiation** (34) **than** from **convection** (30)

C) Most solar radiation to space comes from **cloud** (20/30). **Air** contributes more solar radiation to the satellite (6/30) than the **surface** (4/30). Use solar window channels to see the surface!

D) **Only 6/70** of Earth heat at the satellite comes **from the surface**. Focus on IR window channels!

Earth Surface Channel 01 (VIS0.6) Clouds

High reflectance

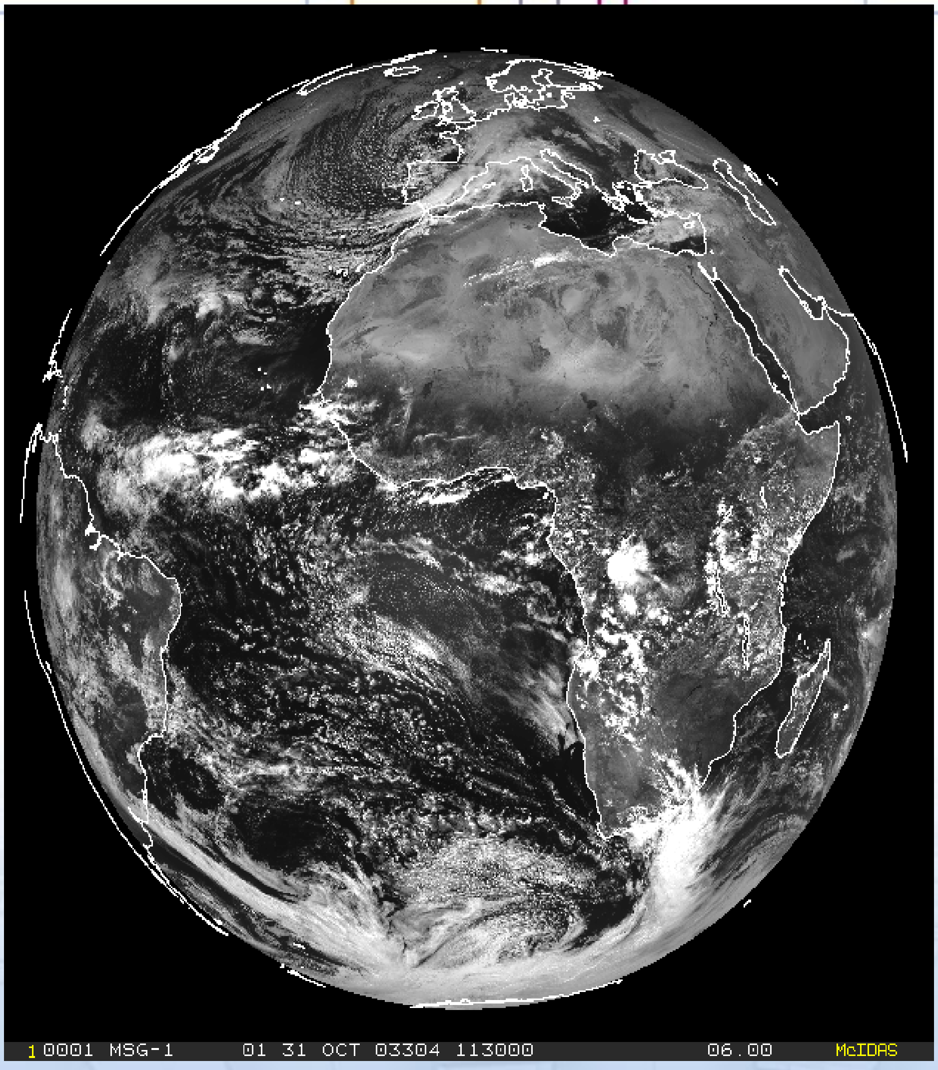
Sun Glint
Snow

Desert

Bare Soil

Forest

Ocean, Sea



31 October 2003, 11:30 UTC

thick clouds

thin clouds over land

thin clouds over ocean

Low reflectance

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Earth Surface Channel 02 (VIS0.8) Clouds

High reflectance

Sun Glint
Snow

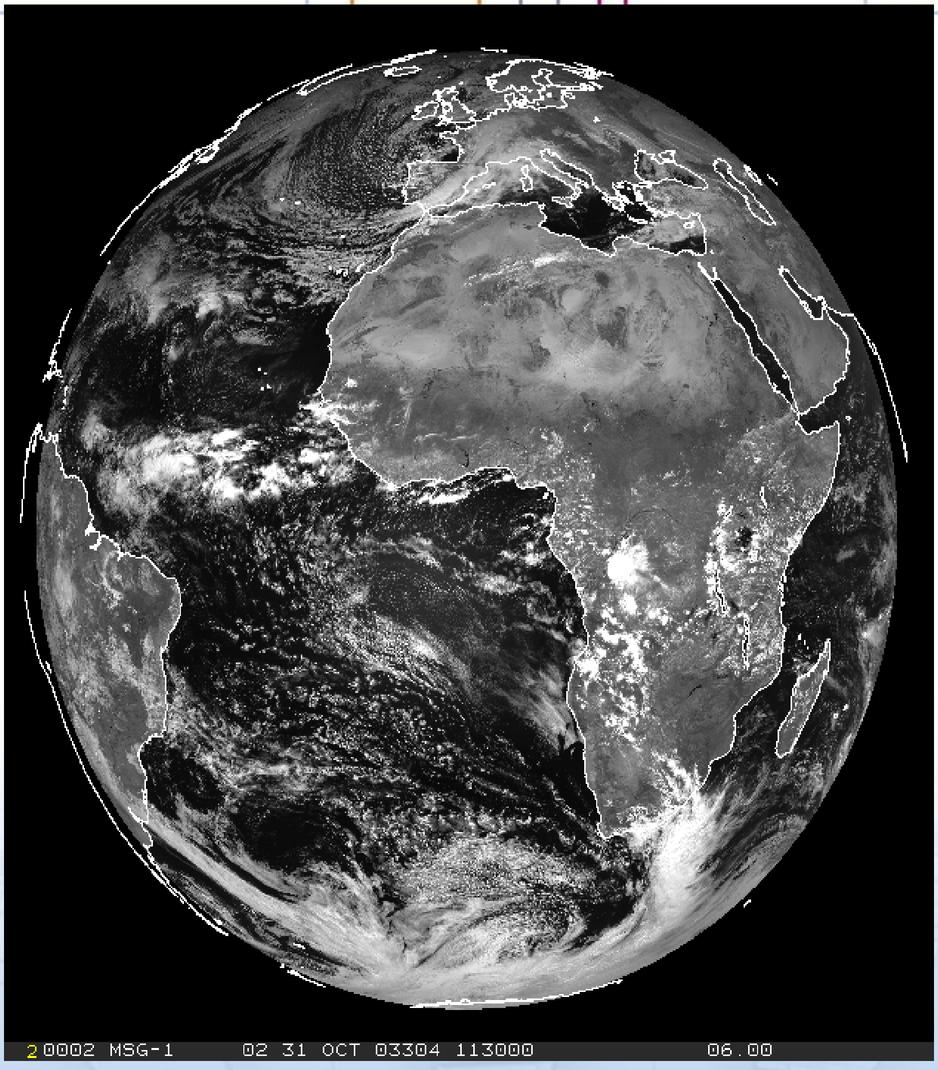
Desert

Gras, Rice fields

Forest

Bare Soil

Ocean, Sea



31 October 2003, 11:30 UTC

thick clouds

thin clouds over land

thin clouds over ocean

Low reflectance

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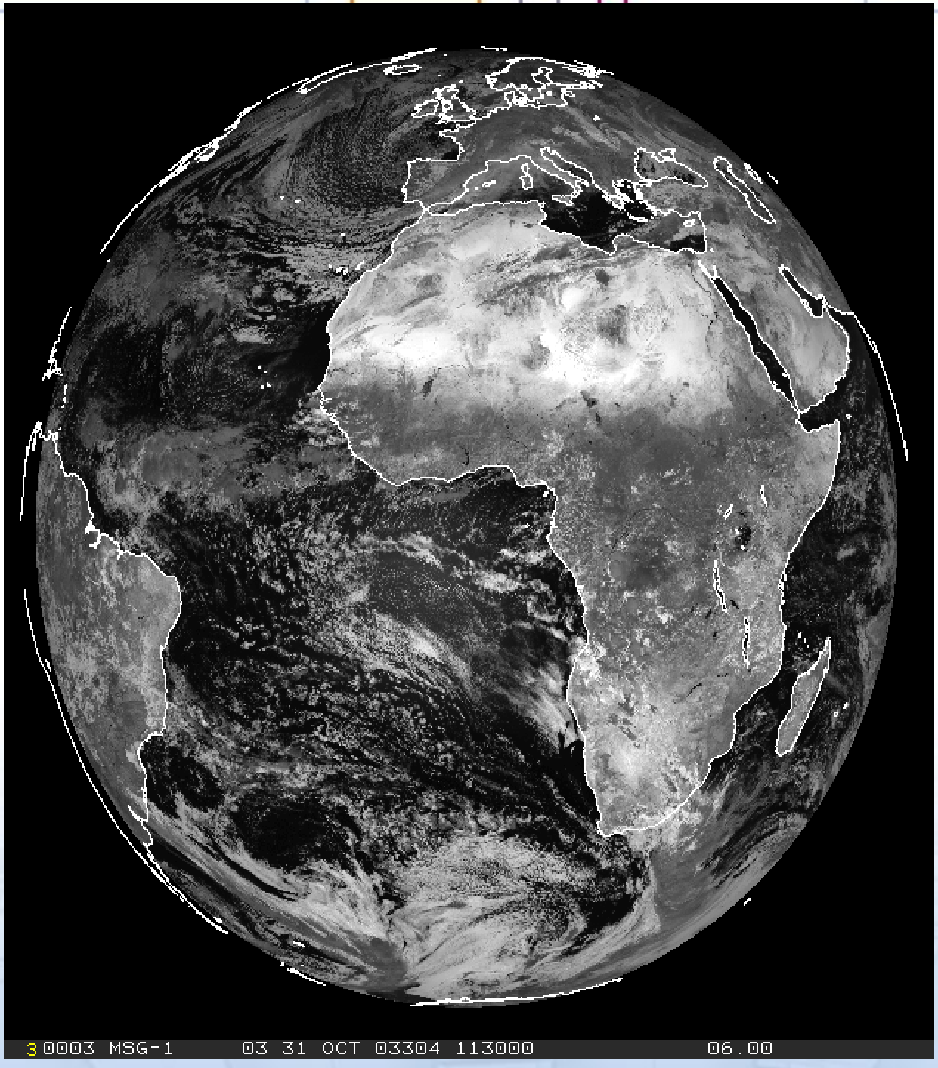
Earth Surface Channel 03 (NIR1.6) Clouds

Earth Surface	Clouds
	High reflectance
Sun Glint Sand Desert	Water clouds (small droplets)
	Water clouds (large droplets)
Gras, Rice fields	Ice clouds (small particles)
Forest	
Bare Soil	Ice clouds (large particles)
Snow Ocean, Sea	*Low reflectance*



31 October 2003, 11:30 UTC

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SOLAR IMAGES

0.6 µm albedo scale:

Cb Snow Sand Shallow or broken cloud Ocean

CLOUD ALBEDO is the result of:

-optical depth= concentration * particle section * layer thickness

-liquid or ice (phase and shape)

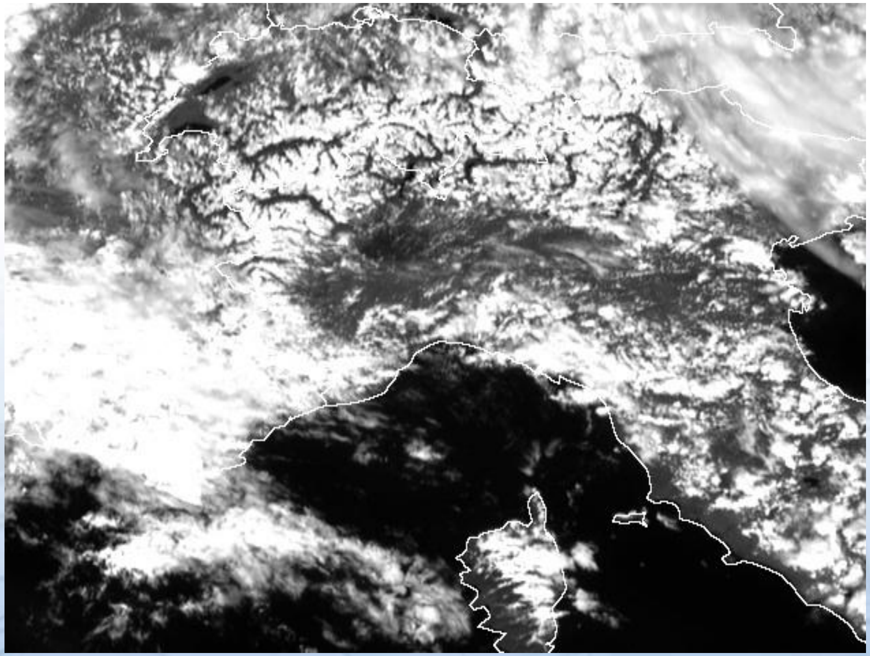
Small droplets more reflective?

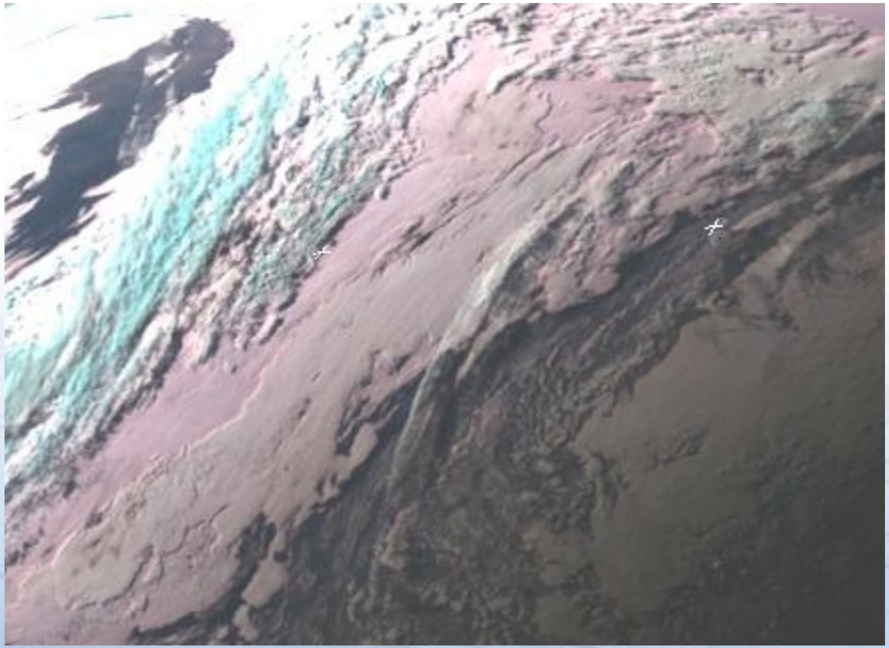
For the same volume, which distribution presents more section to the radiation?

Updrafts prevent droplet merging, and keep reflection strong

Special solar features

-**Shades**: oblique sun, vertical structure. Reflective boundaries
-**Water content** is related to optical thickness thru particle size
-**Texture** (local standard deviation): cloud type. Sc from St
-**Clouds** versus dendritic more permanent **snow**
-**Thin** Ci: frequently not detected, more visible over ocean. Better in IR





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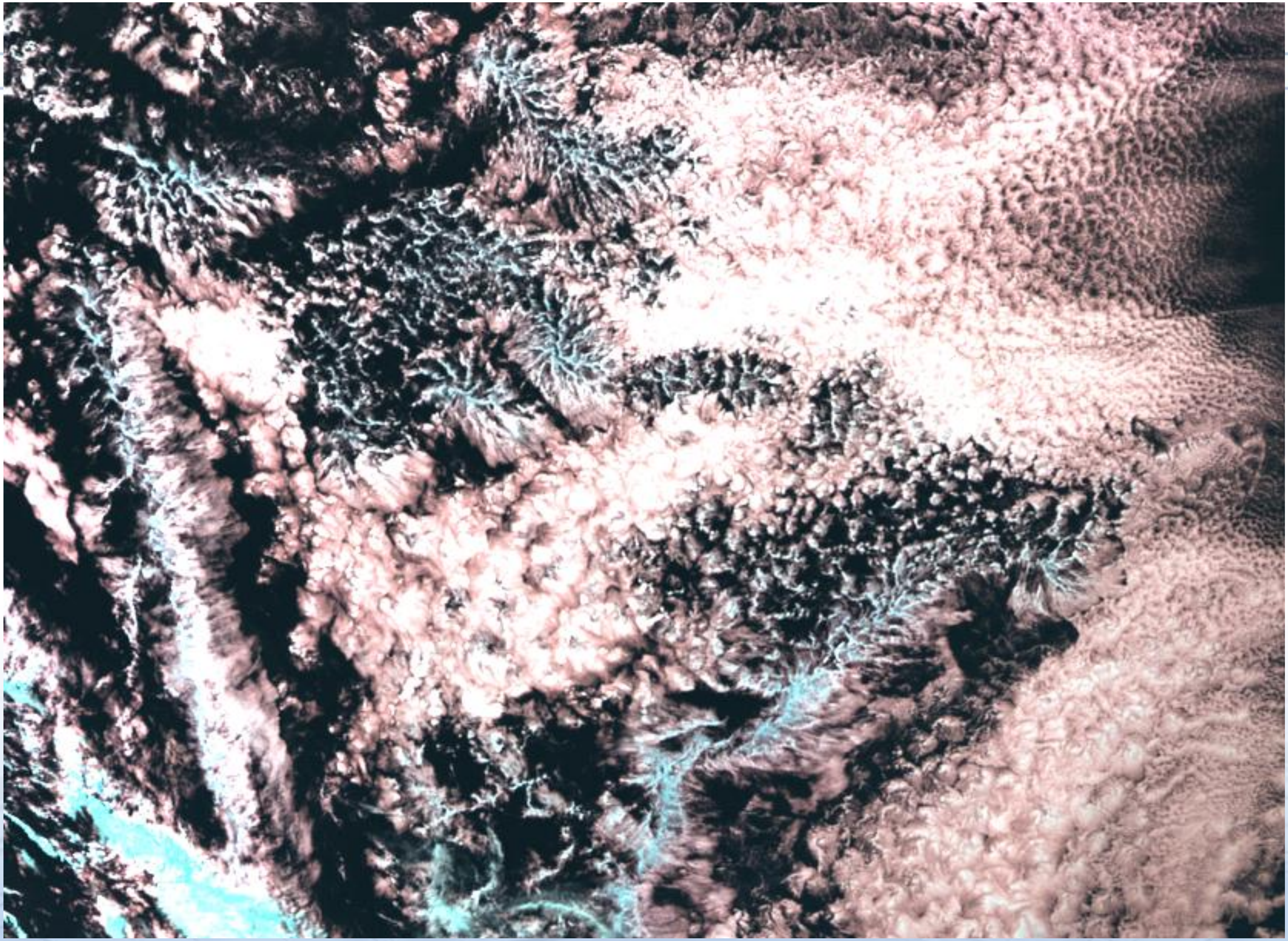
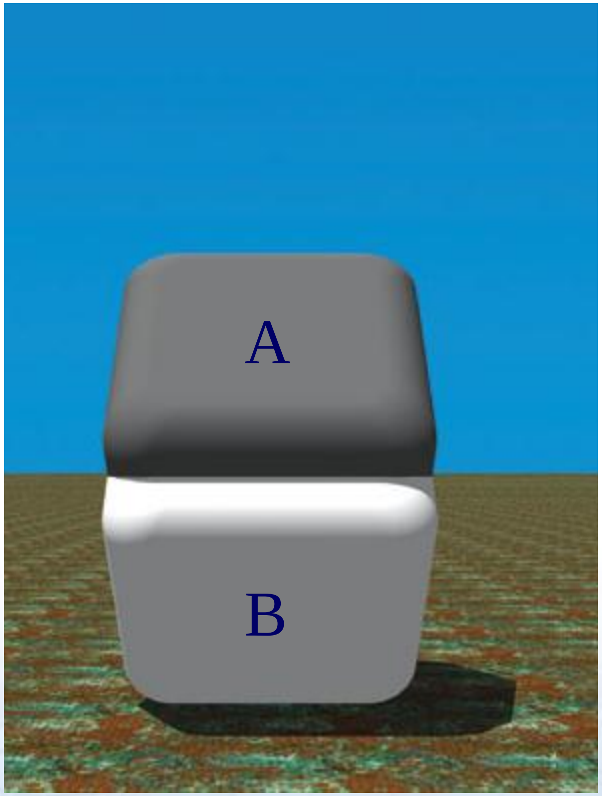
Meteosat solar channels



Meteosat-9 Atlantic Ocean around -10E -15N, 2011-05-31 15 UTC

Which mountain range is this?

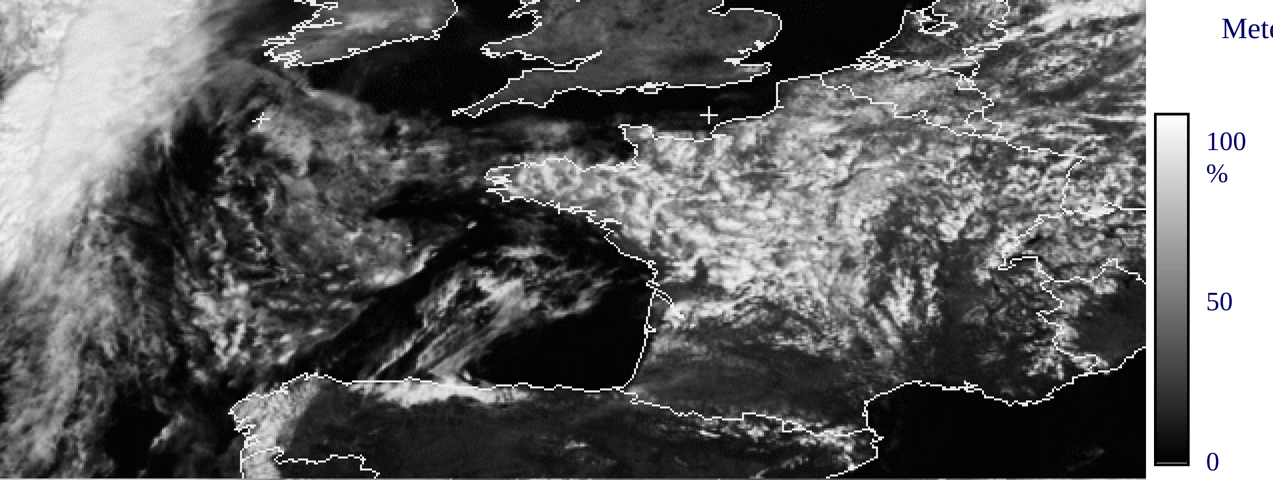
Do you believe your eyes?



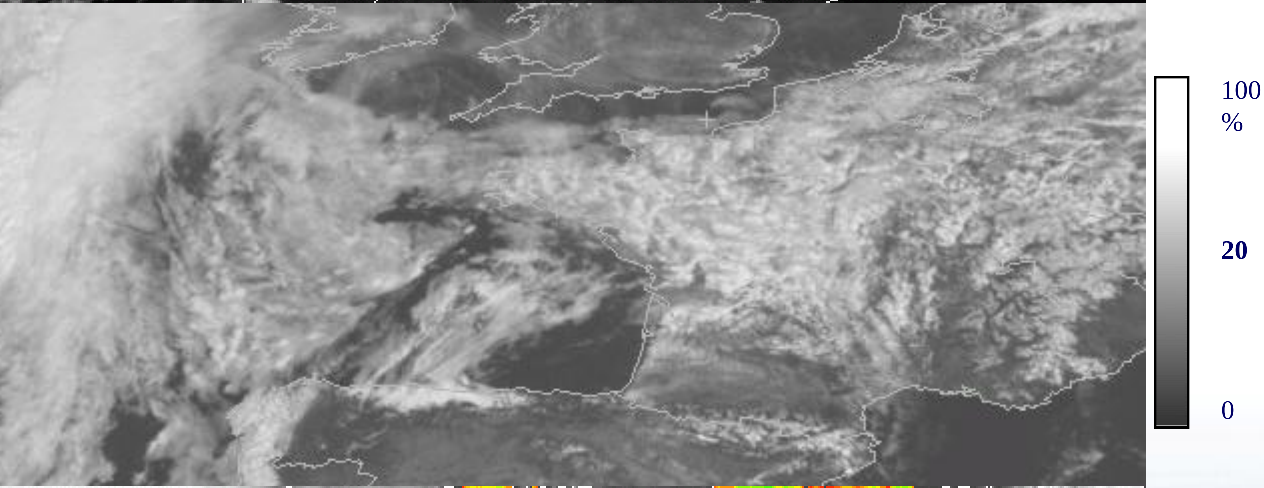
Which is darker: A or B ?

Believing that colour is intrinsic to objects (colour constancy) leads to delusion

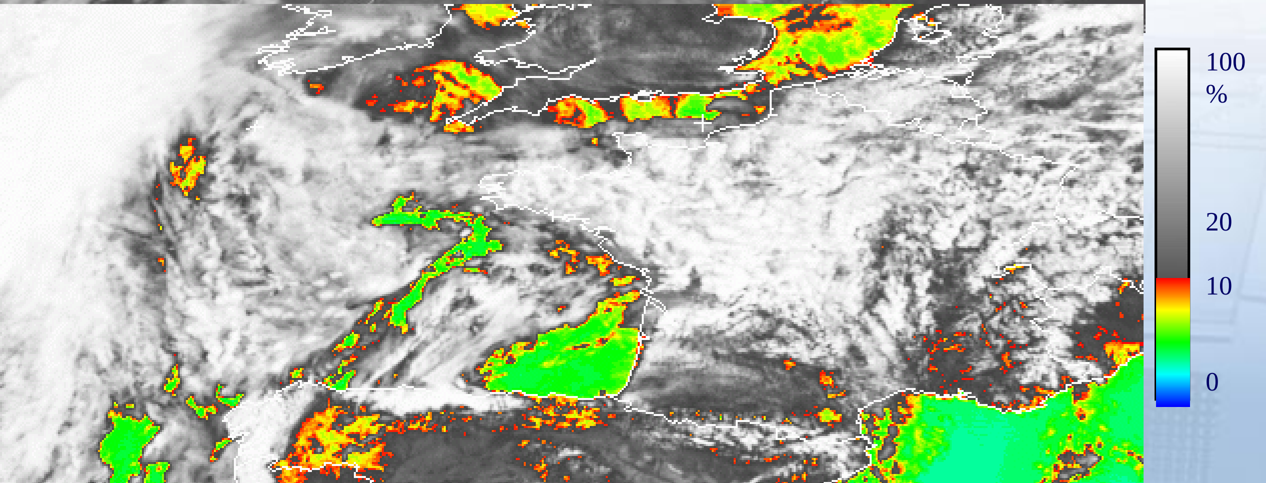
Meteosat channel2 2011-06-14 12 UTC



Linear rendering

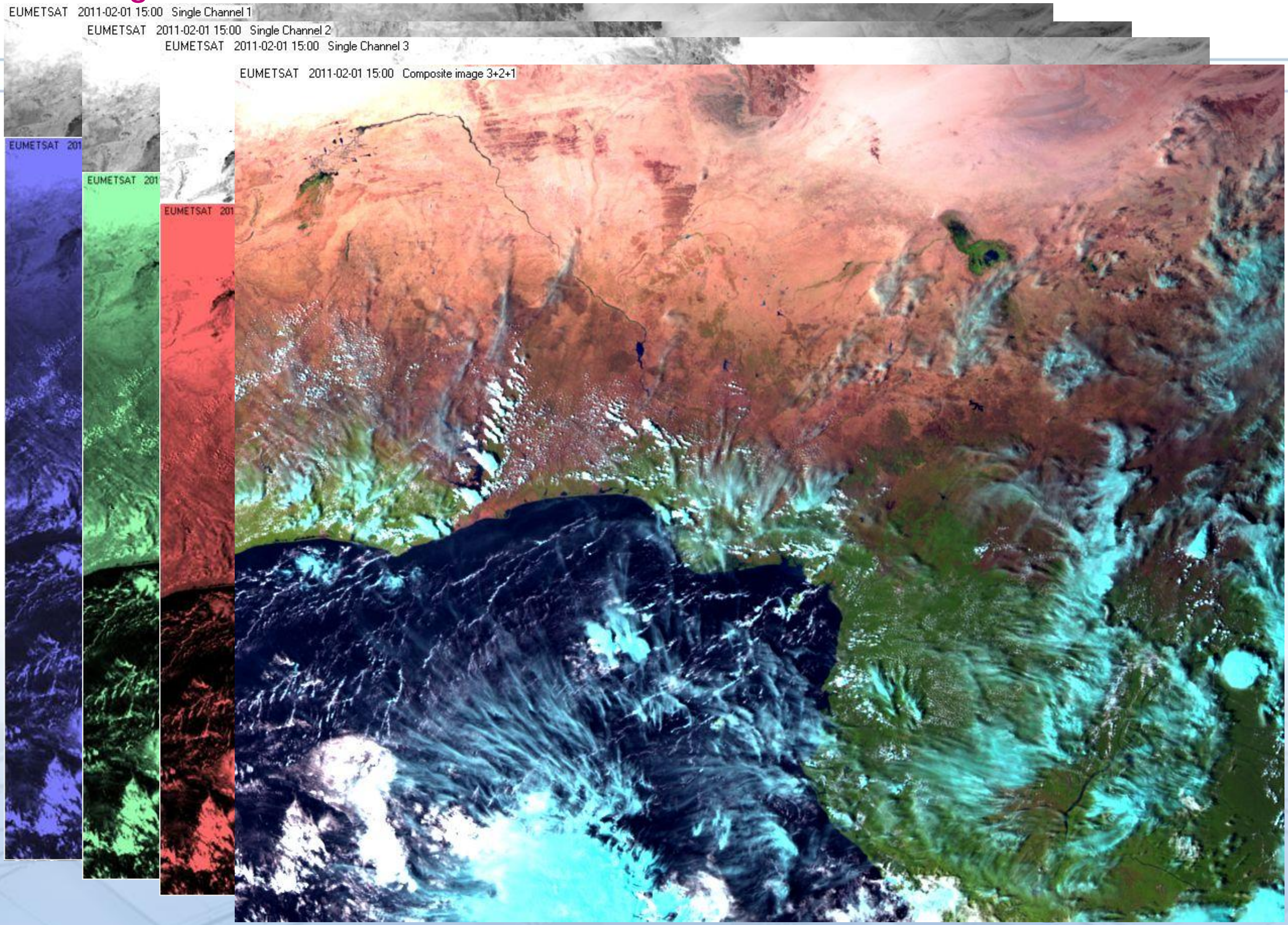


Gamma correction

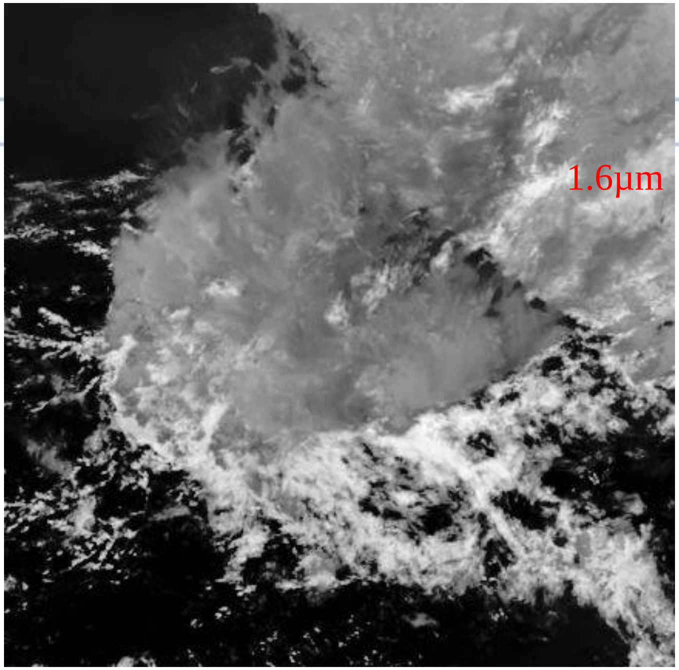


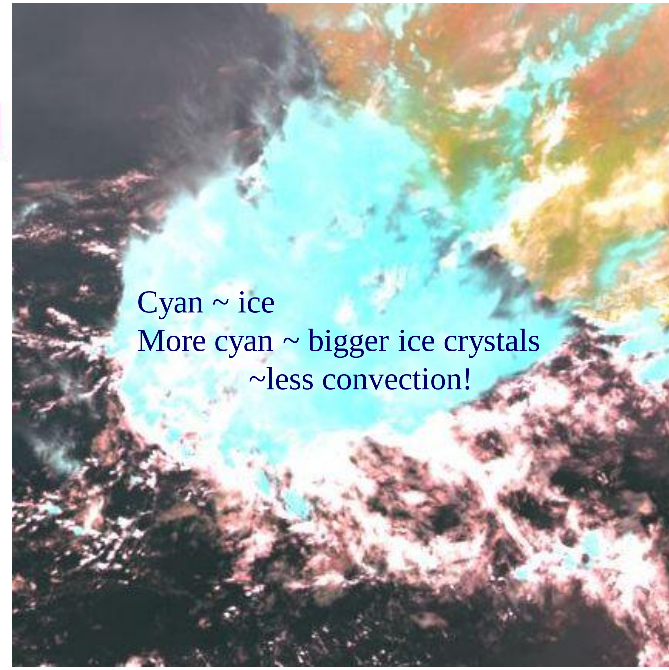
Colour slicing

Combining solar channels

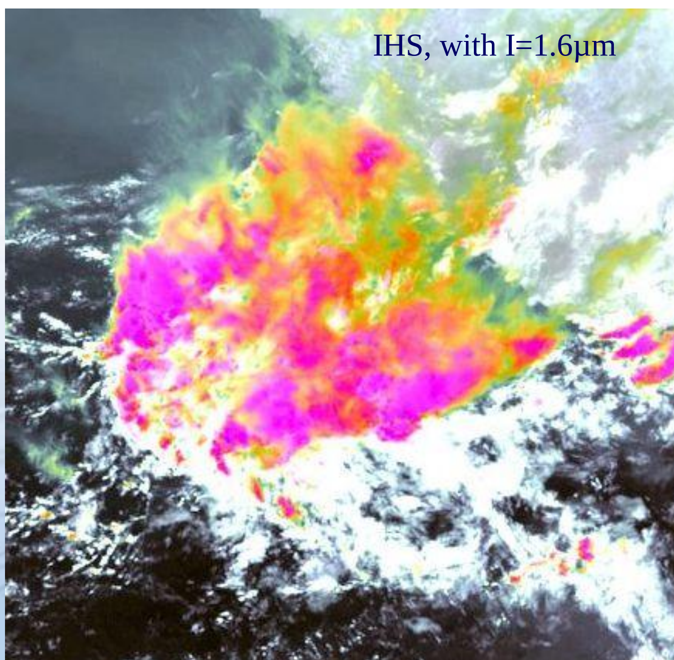


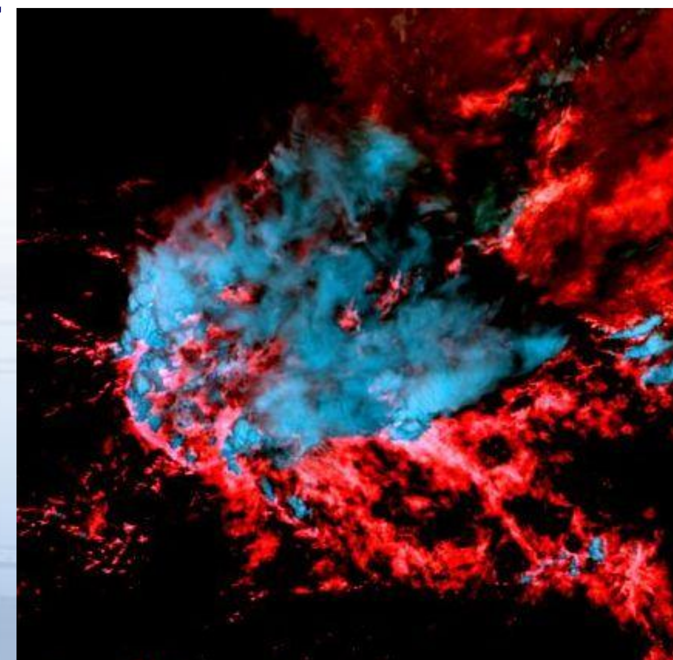
Meteosat solar channels



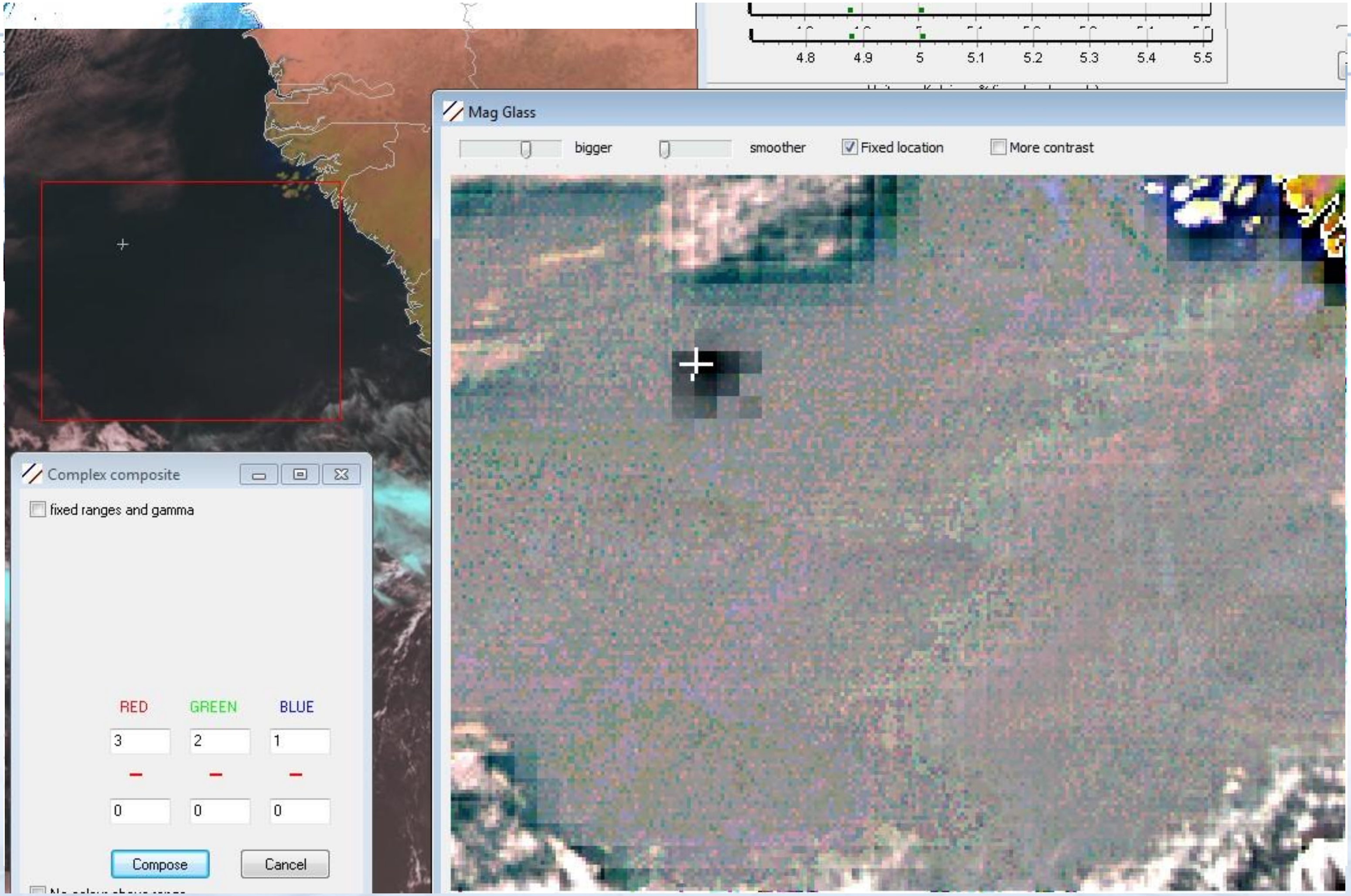


RGB=321 → enhancement





Meteosat solar channels



Enhancement: For areas of uniform values on the three channels

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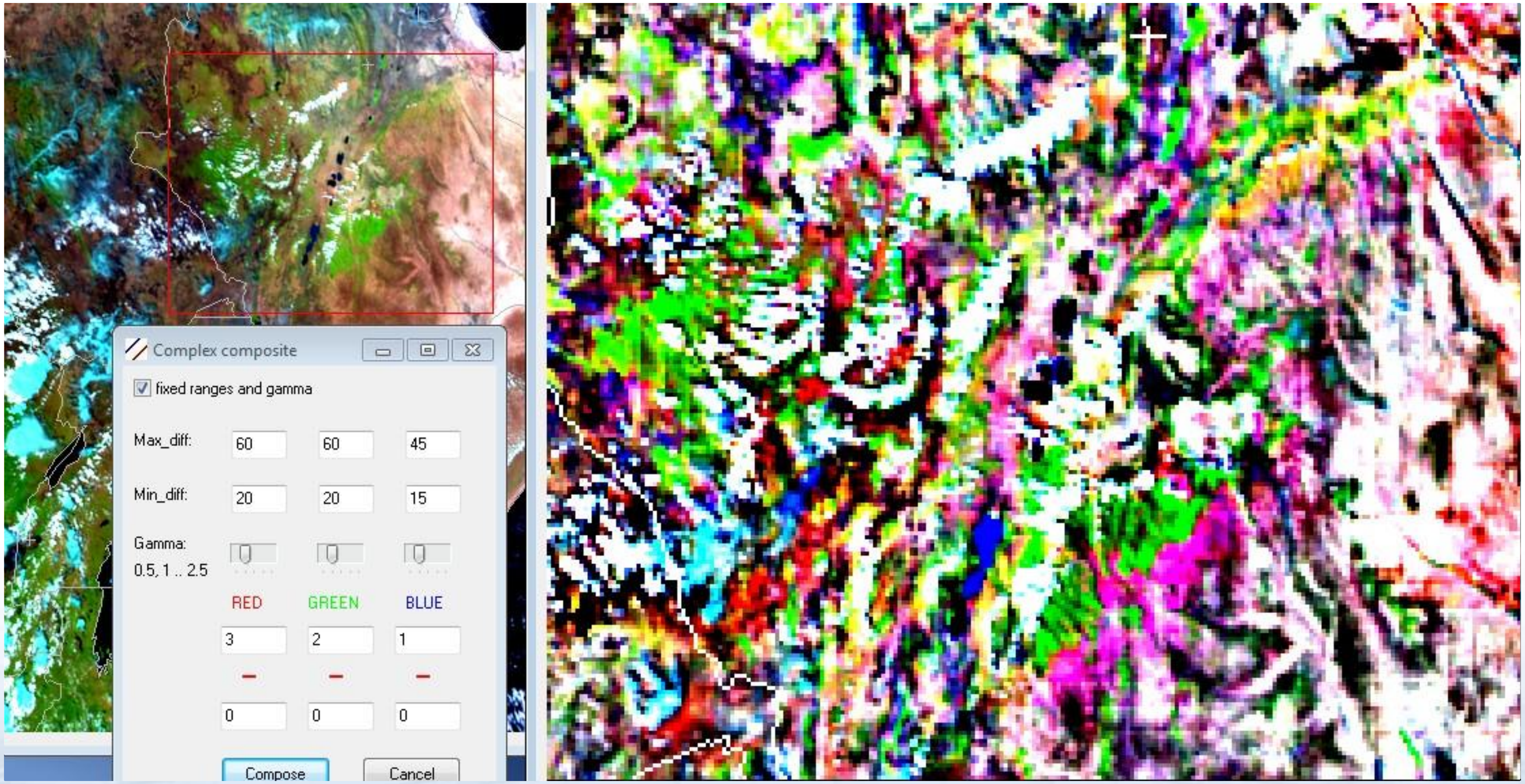
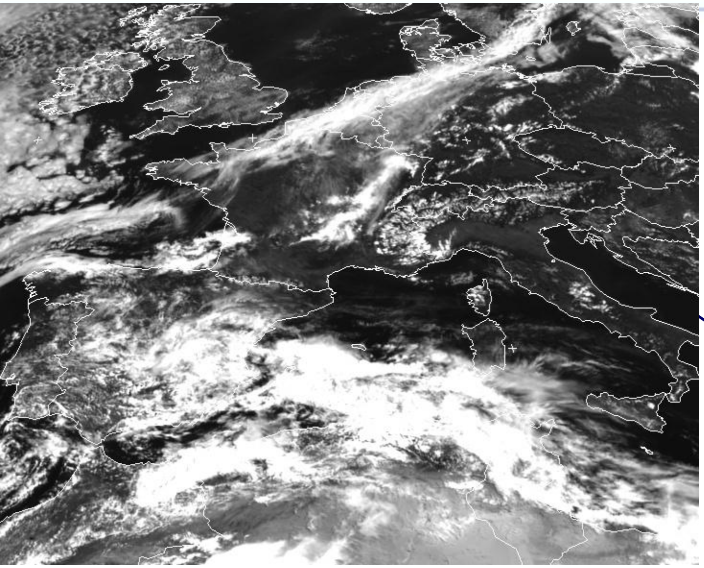
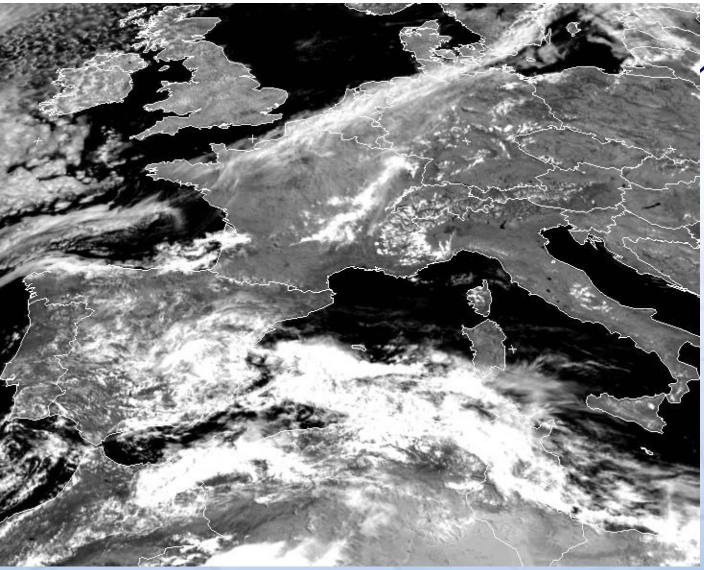


Enhancement can produce too much colour if the value ranges are wide

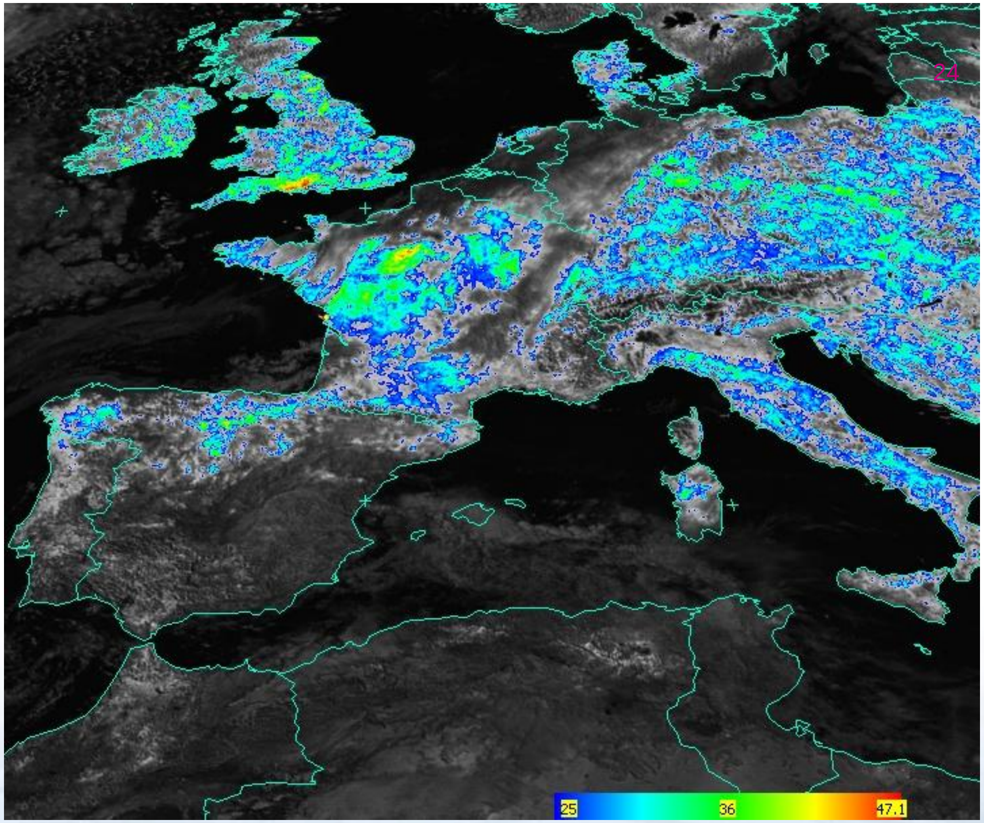
Solar channel differences over land



VIS0.6



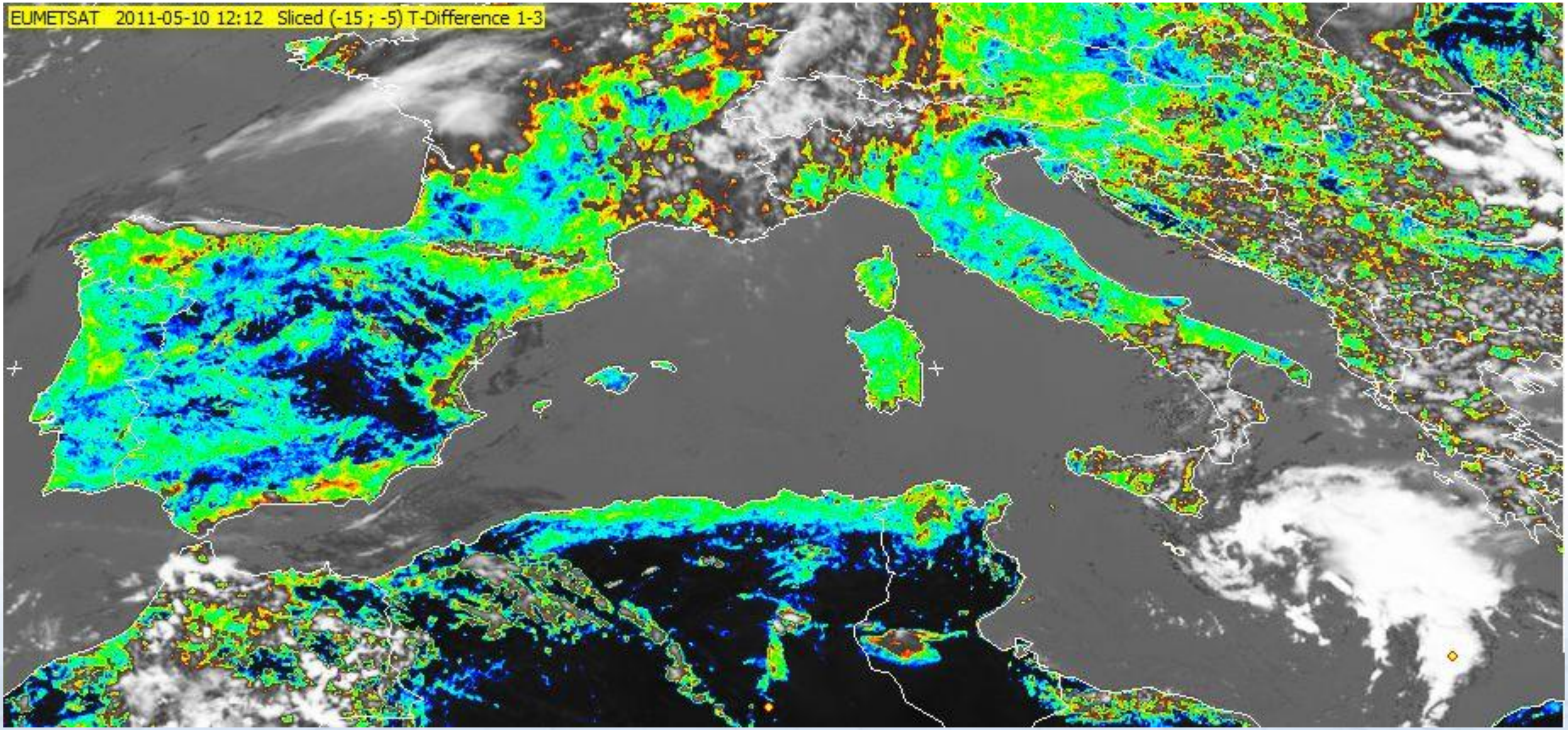
VIS0.8



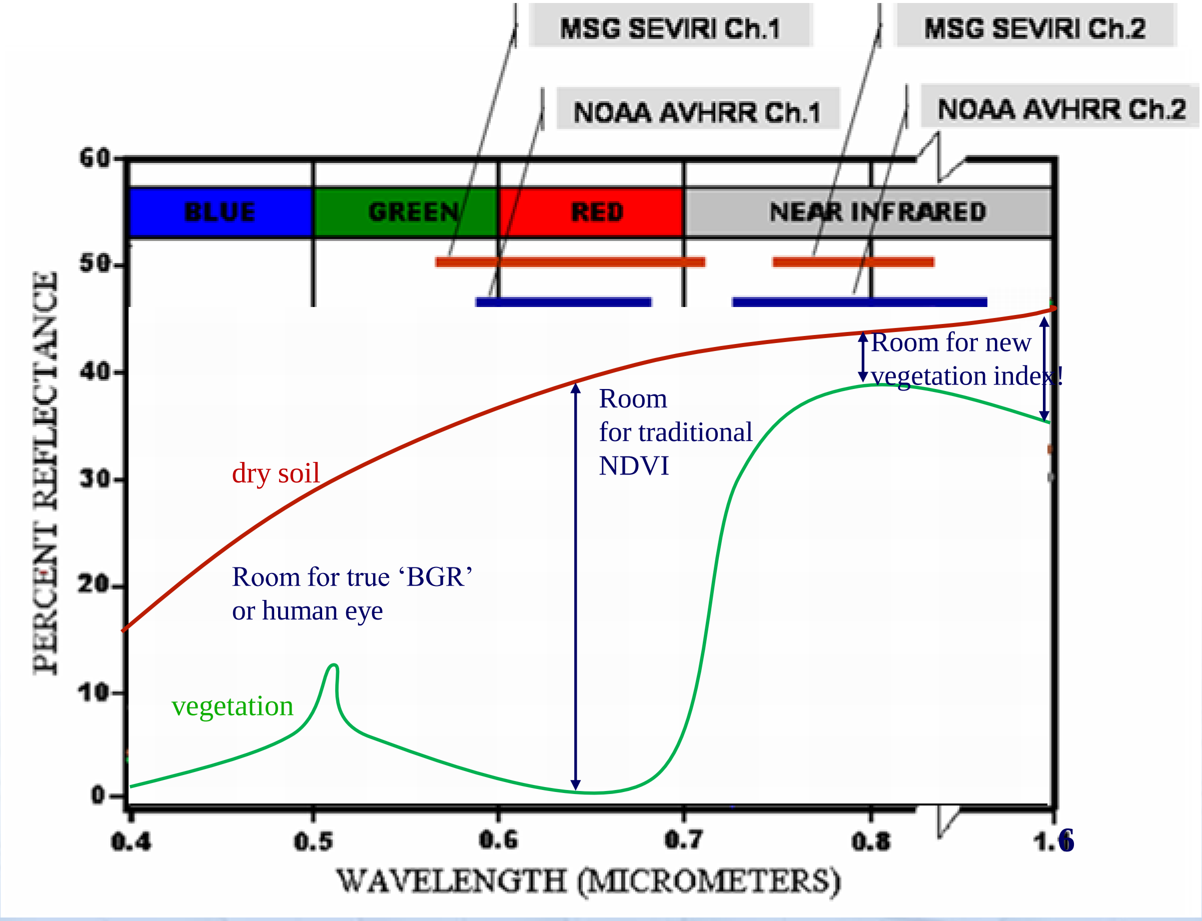
VIS0.8 – VIS0.6 Meteosat 2011-05-19 09:30 UTC

- VIS0.8: higher land surface contribution, especially over vegetated areas
- The difference can be sliced to remove cloud, by restricting to non-cloud high values (+25% ... +50%)

Or with 1.6µm

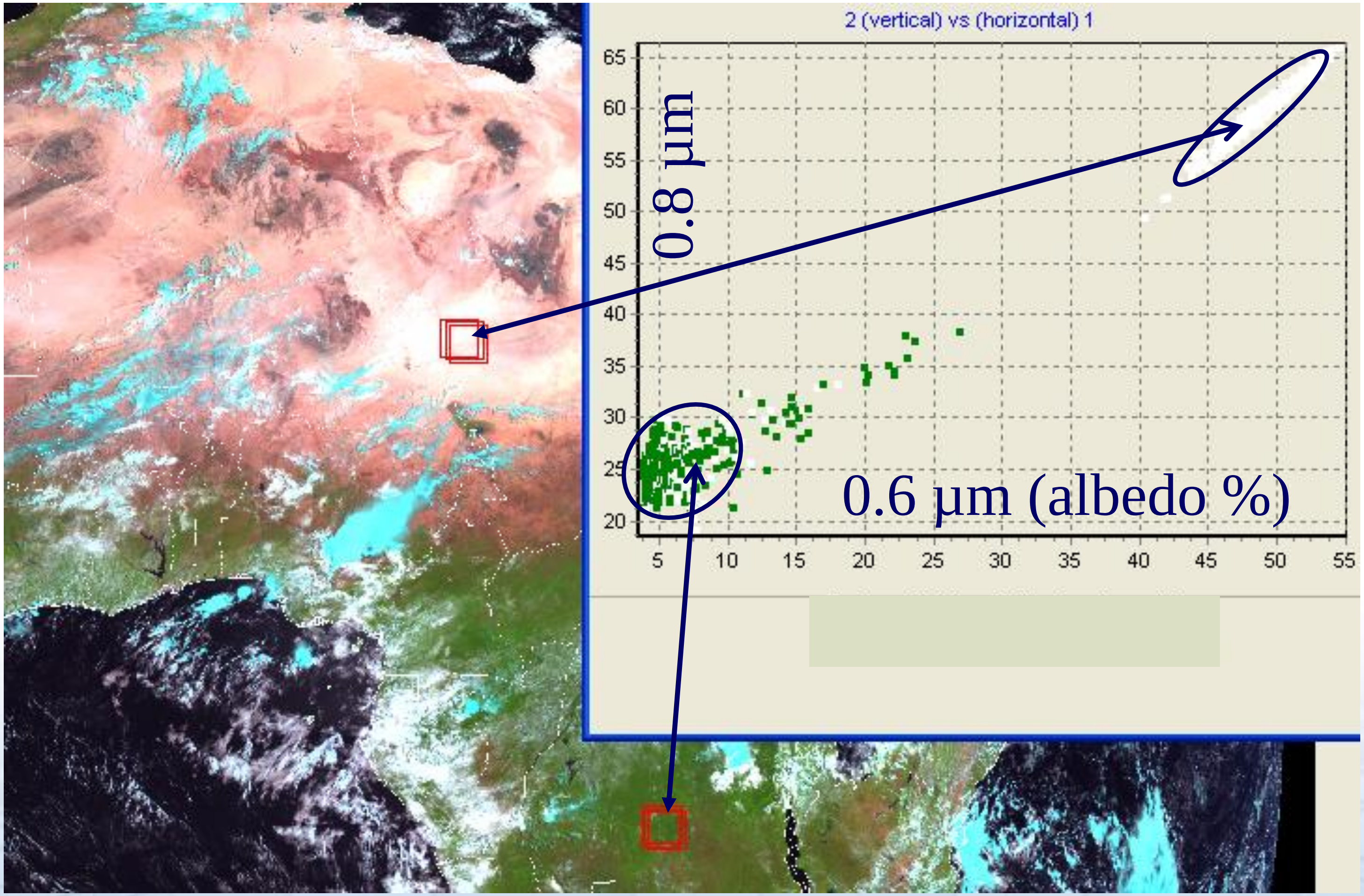


Vegetated and dry soils



The vegetation response to wavelengths in our colour perception is similar to those between 0.6µm to 1.6µm: happy coincidence!

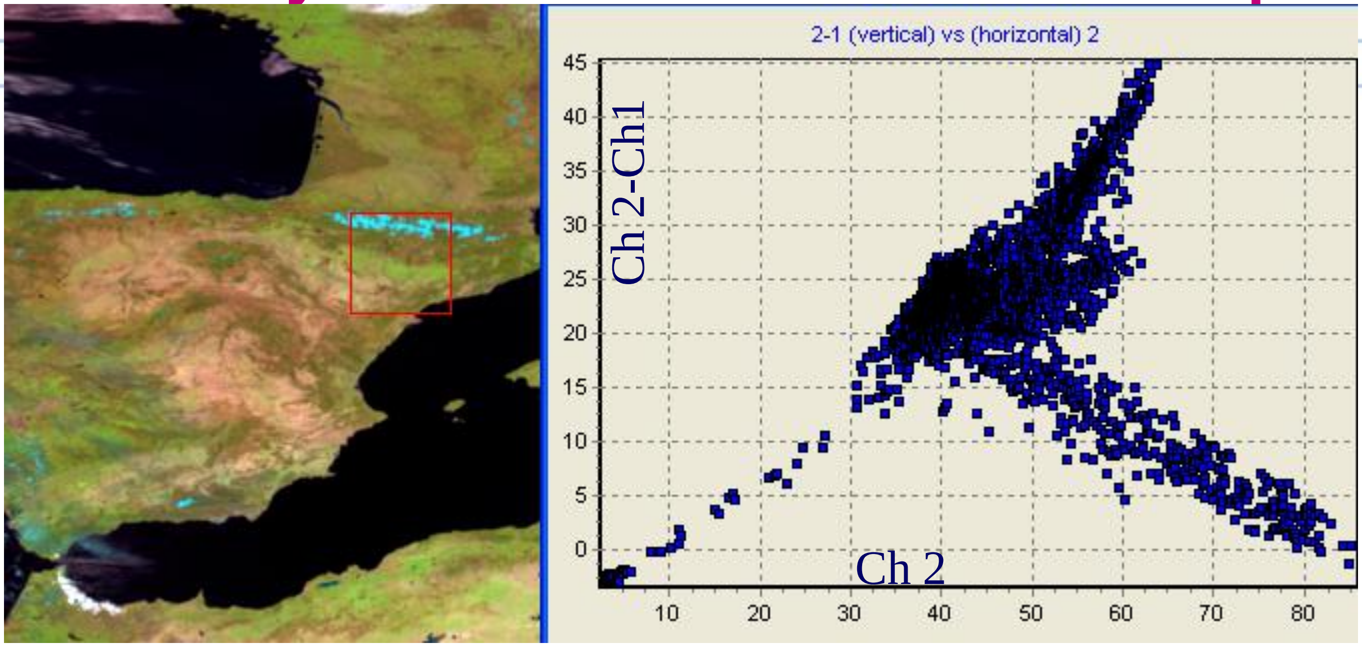
Desert and tropical forest in the solar channels



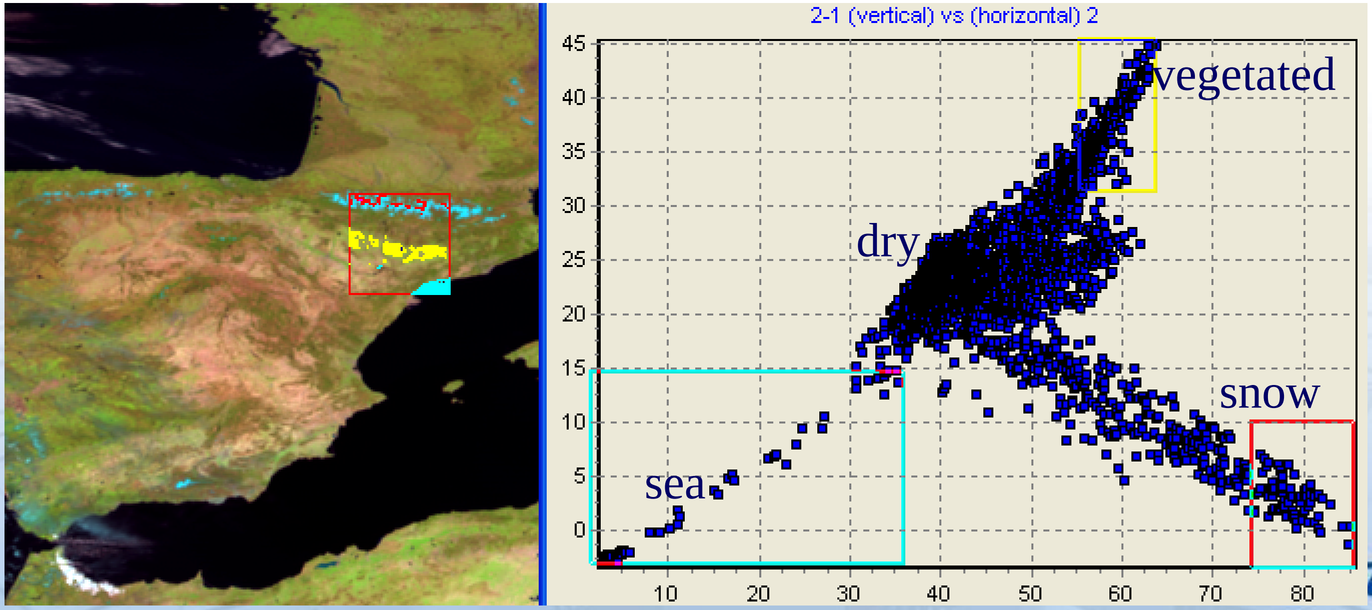
Normalized vegetation index = (2-1)/(2+1)

Exercise: identify the clusters in the 0.6 and 0.8 µm channels

Meteosat-9
RGB Natural colours
2008-04-06
12UTC



Where are the growing vegetation pixels on the graph?



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LAND SURFACE ANALYSIS SATELLITE APPLICATIONS FACILITY

Home

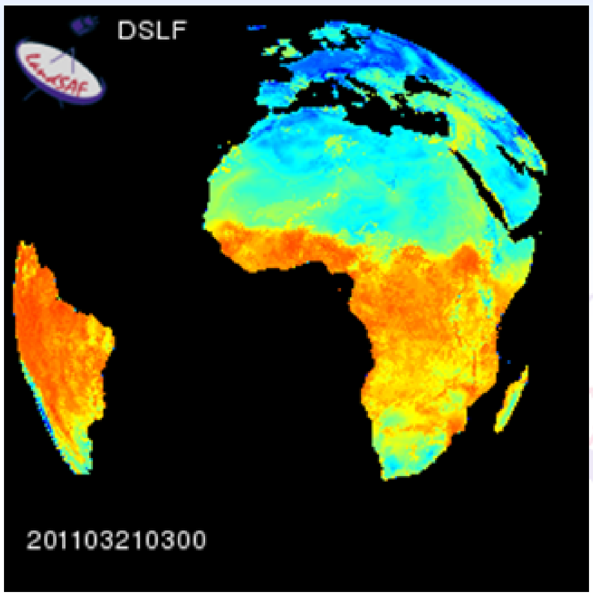
landsaf.meteo.pt

The scope of Land Surface Analysis Satellite Applications Facility (LSA SAF) is to increase benefit from EUMETSAT Satellite (MSG and EPS) data related to:

- Land
- Land-Atmosphere interaction
- Biospheric Applications

The LSA SAF performs:

- R&D Programs.
- Operational Activities
  - Generation
  - Archiving
  - Dissemination



See colour legends...

of land surface related products.

Latest News:

- **Important** IM Archive system maintenance. see more...
- **Important** IM Archive system maintenance. see more...
- **Information** LSA SAF Outage see more...
- **Information** LSA SAF Outage see more...
- **Update** MSG Images see more...

Product Development Status:

MSG/SEVIRI based products

Wild Fires
- Fire Radiative Power - PIXEL
- Fire Radiative Power - GRID

Vegetation Parameters
- Fraction of Vegetation Cover
- Leaf Area Index
- Fraction of Absorbed Photosynthetic Active Radiation

Snow Cover
- Snow Cover (daily)
- Snow Cover (15 mins)

Other
- Bi-Directional Reflectance Factor
- Land Surface Emissivity

Albedo
- Surface Albedo
- MSG Ten Day Surface Albedo

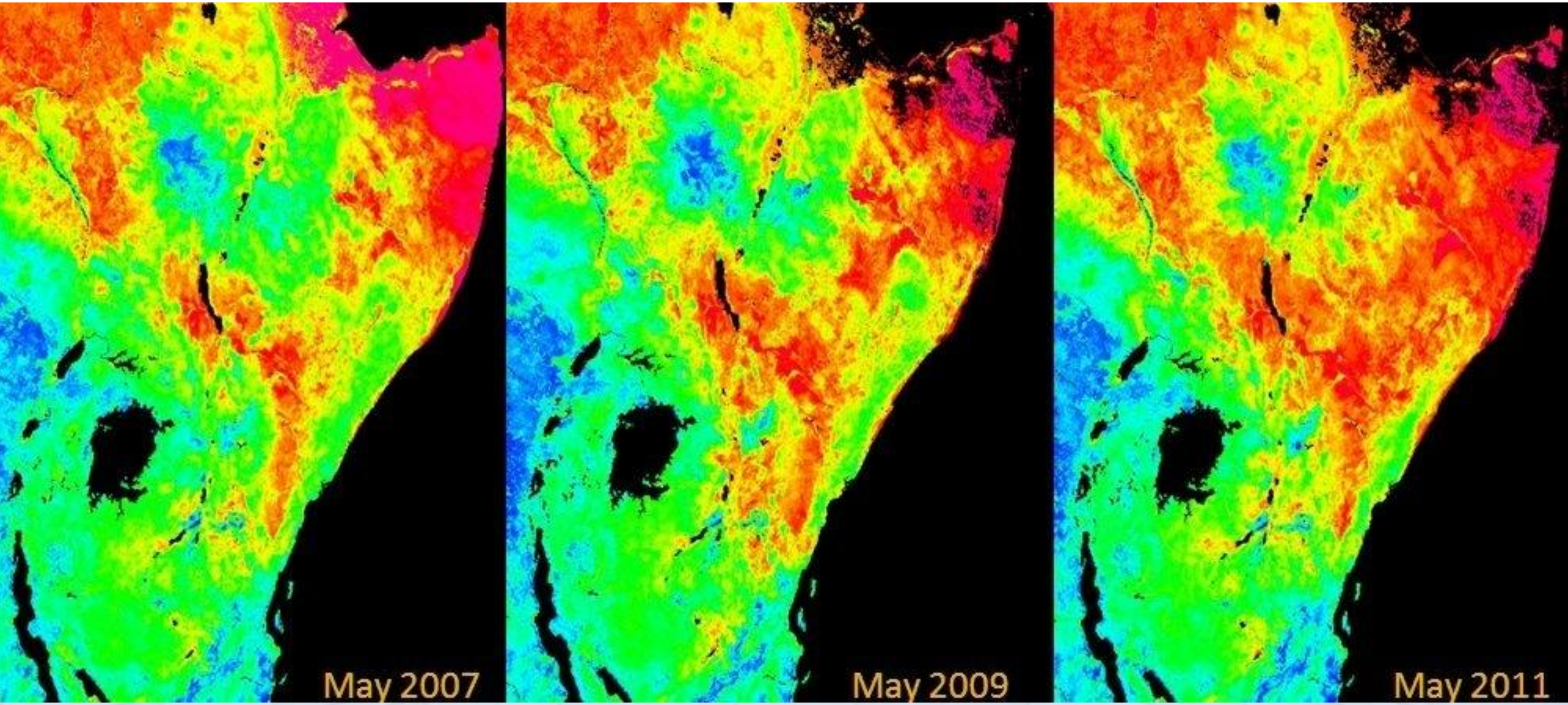
Land Surface Temperature
- Land Surface Temperature (15 mins)

Down-welling Surface Fluxes
- Down-welling Surface Short-wave Radiation Flux
- Down-welling Surface Long-wave Radiation Flux
- Daily Downward Surface Shortwave Flux
- Daily Downward Surface Longwave Flux

Evapotranspiration
- Evapotranspiration (30 mins)
- Daily Evapotranspiration

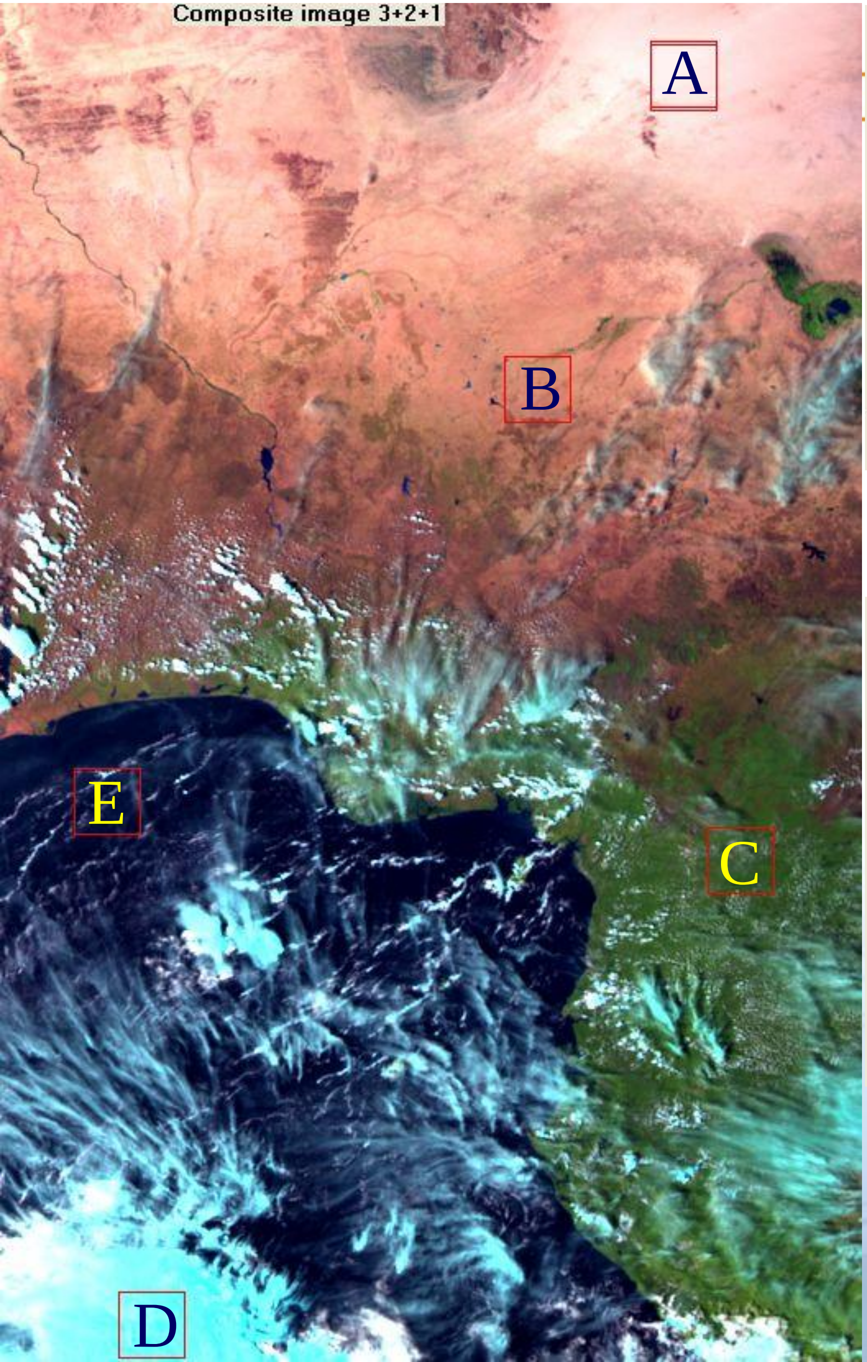
Meteosat solar channels

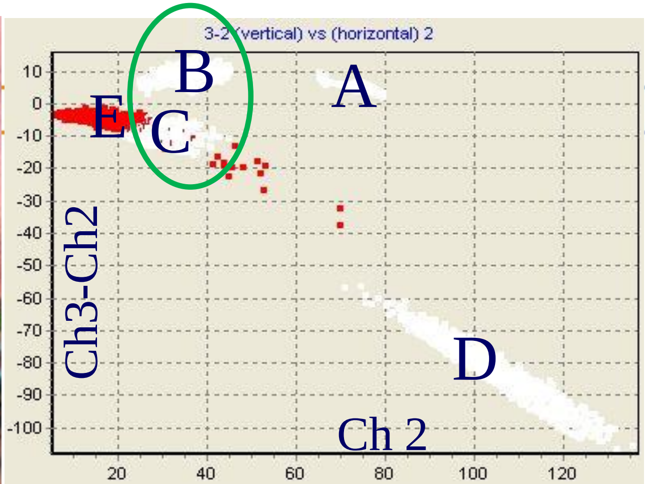
Drought evolution in Somalia



Source: Land SAF archive, fraction of vegetation

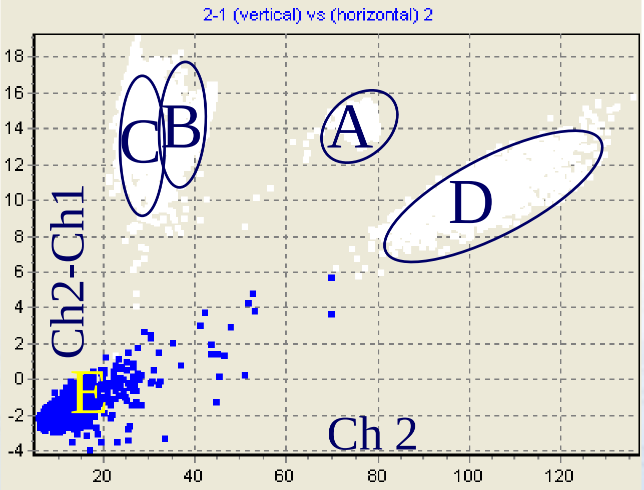
Dry soil shows brown in the natural RGB!





Index (3-2)/(3+2)
B (dry)= 12%
C (vegetated)= -20%

Now, 2-1 in vertical. Your turn!



Index (2-1)/(2+1)
B (dry)= 25%
C (vegetated)= 40%

1.6µm reflects better than 0.8µm on dry ground, but worse in vegetated areas

1.6µm  **0.8µm**

Which kind of soil or cloud is at the arrow point?

Fog

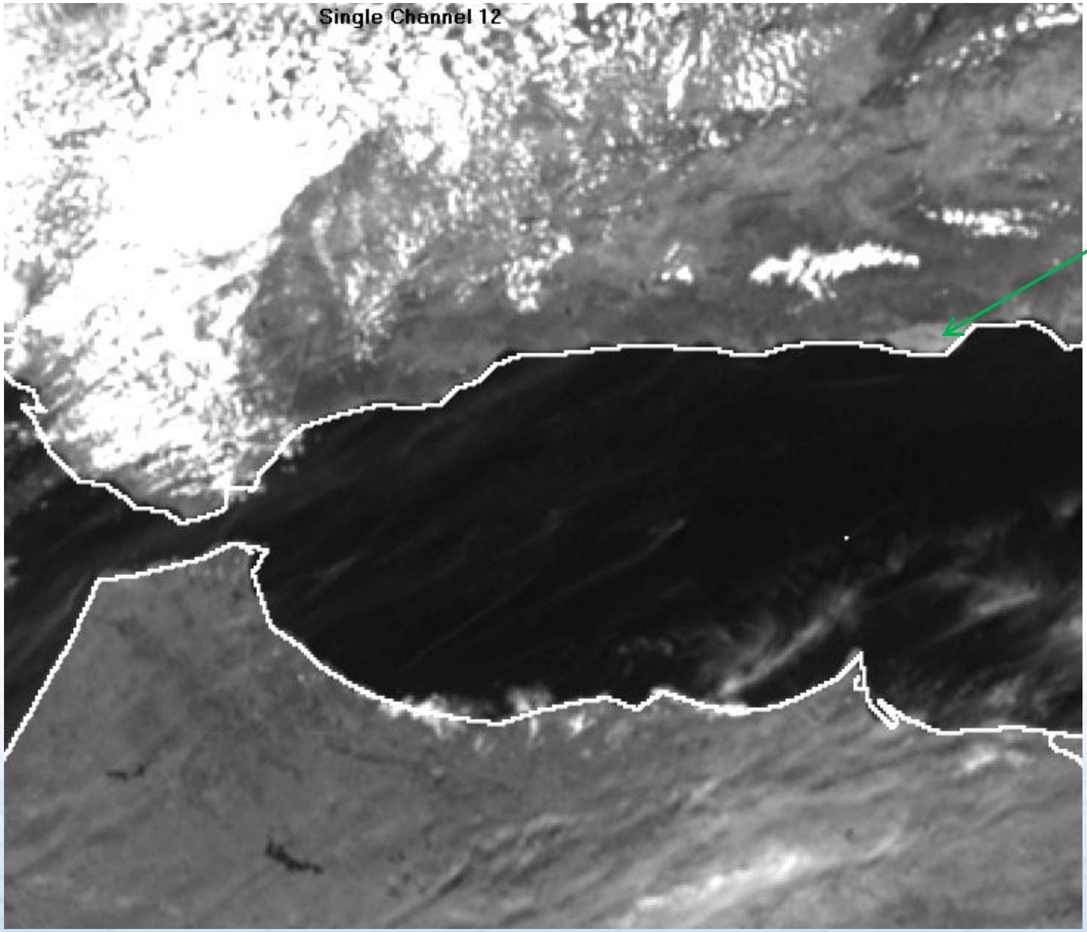
Sand

Glass

Cirrus

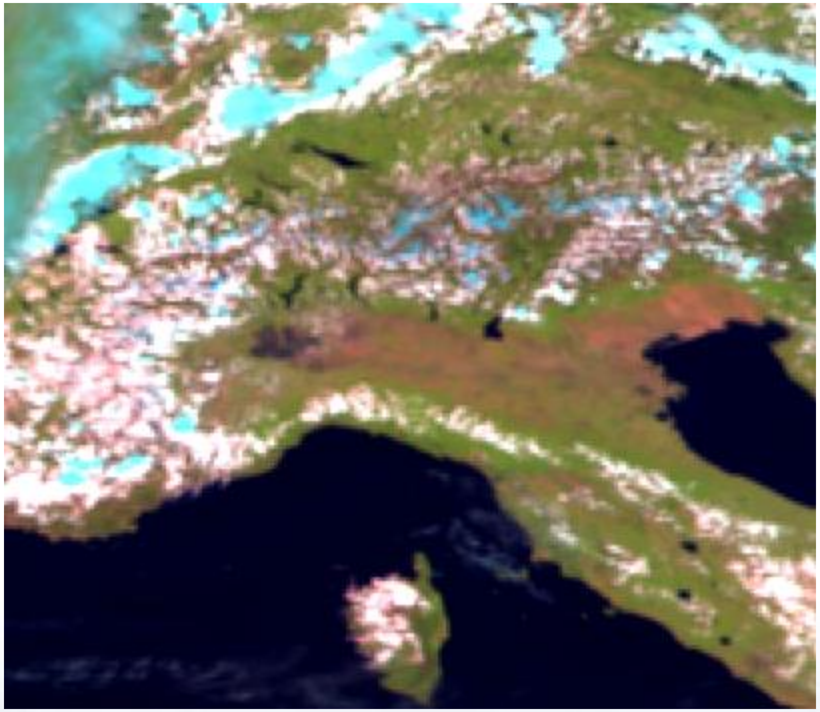
Smoke

Litter

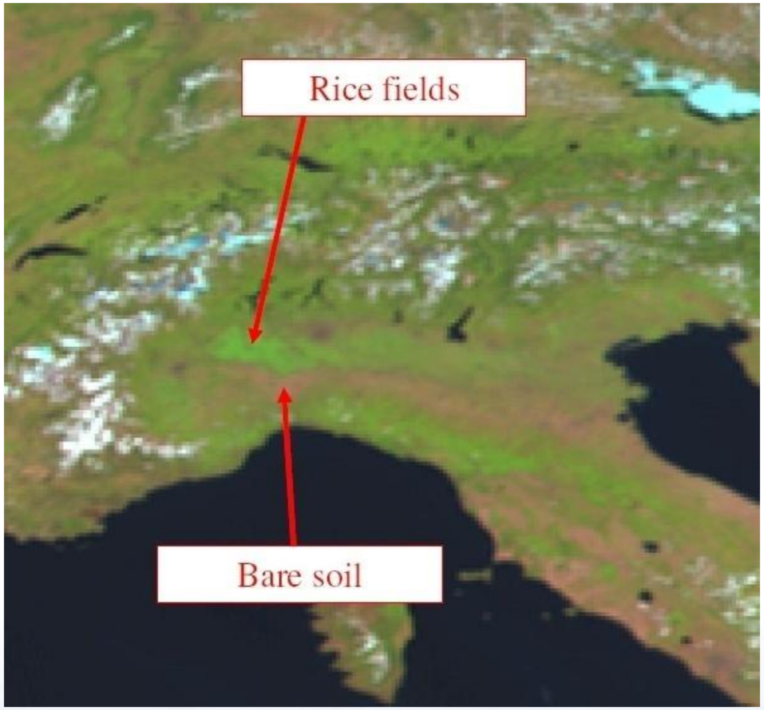


Meteosat HRV 2010-May-08 12:00

Vegetation monitoring

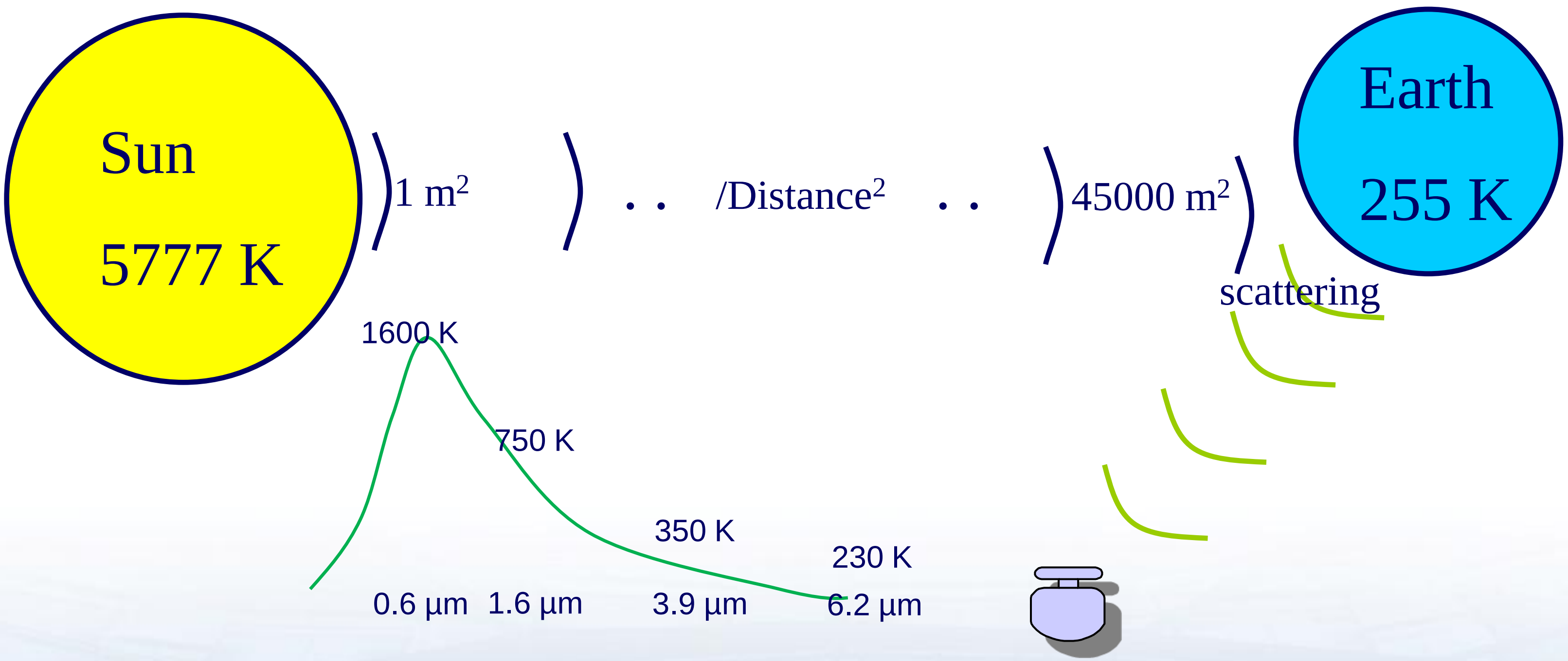


May 2011 Rice fields flooded



Aug 2003 Meteosat Natural RGB

The sun disc is brighter than cloud!



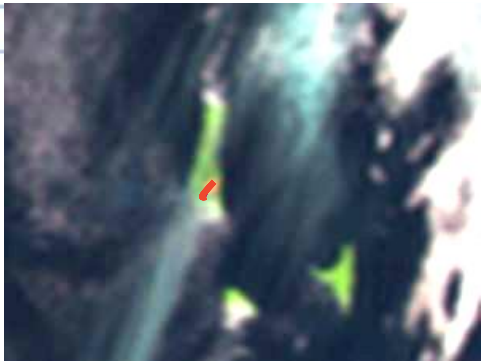
•Sun radiation density at the Earth is that of black bodies at much lower temperatures than its source at 5777 K

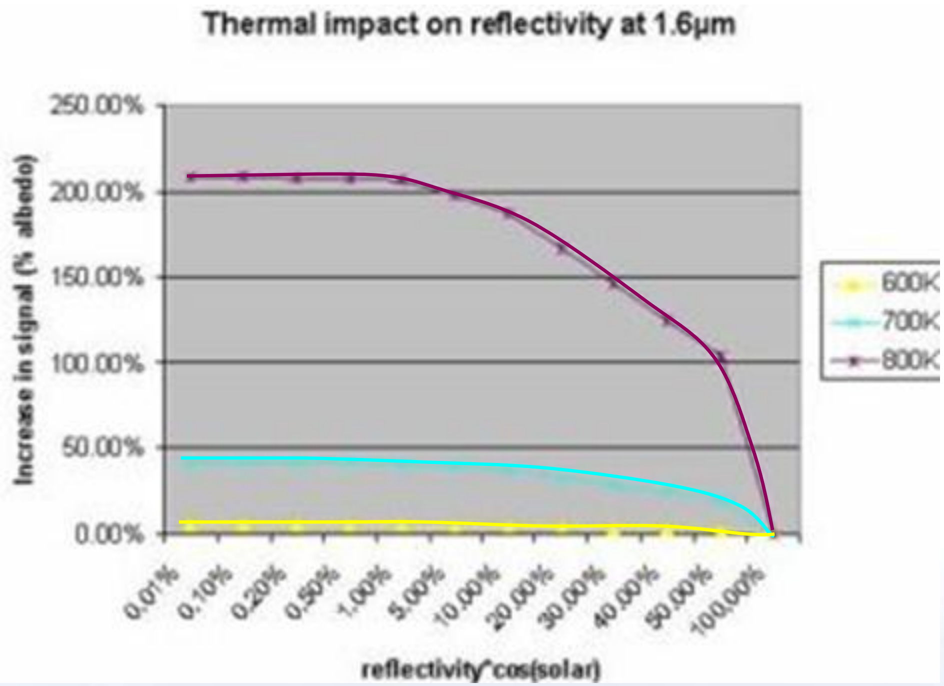
•The brightness ratio between the sun disk and bright cloud, 45000 times, is due to the dispersion of radiation as it travels in all directions.

•At 3.9µm, Earth **emitted** radiation competes with **reflected** solar radiation.

Emission sources in the solar channels

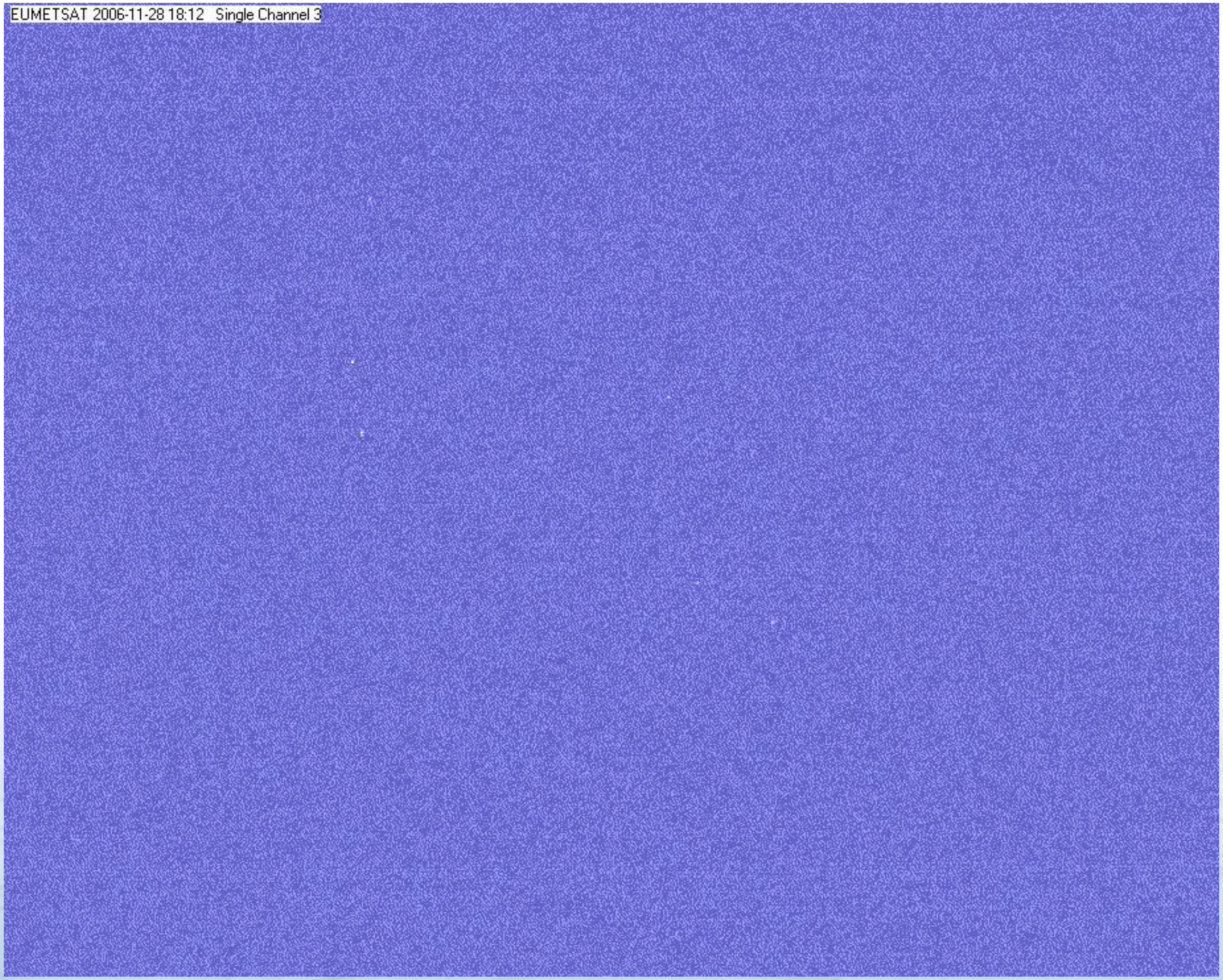
Karthala, Met-8, 29 May 2006, 12:15 UTC
Natural colours RGB 1.6µm 0.8µm 0.6µm



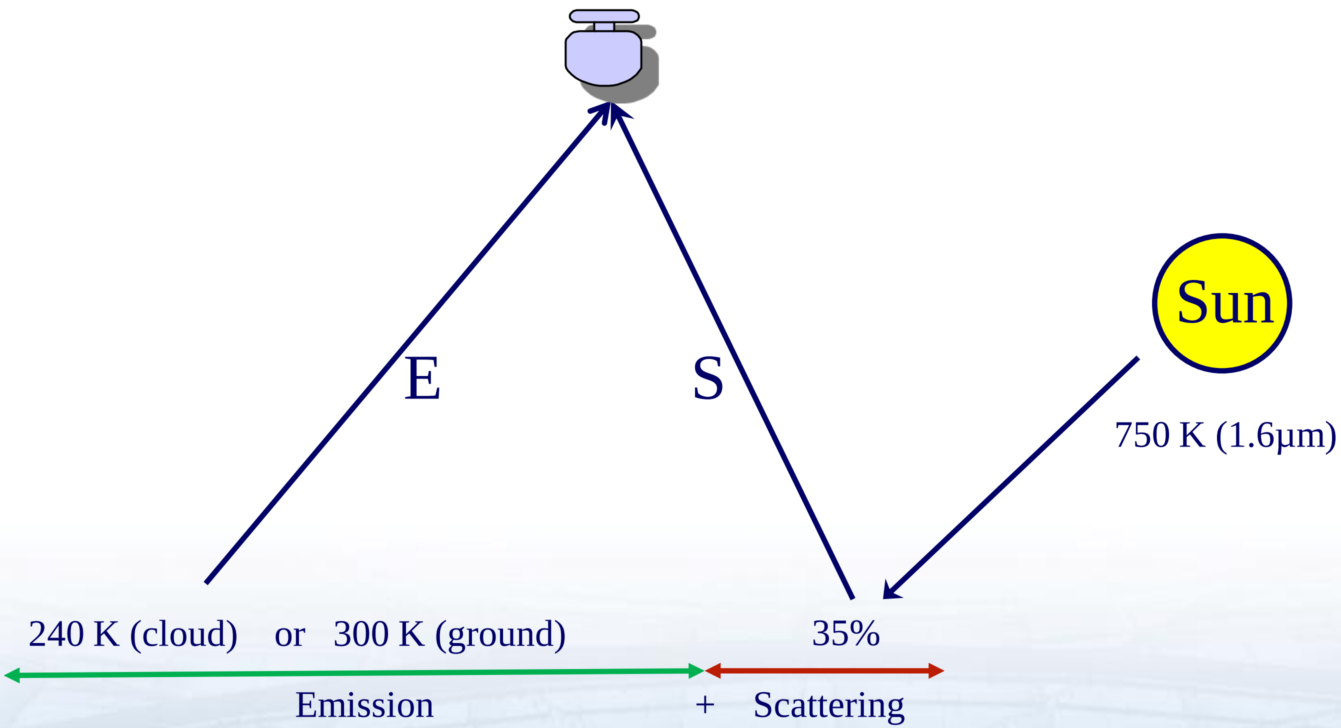


- Very **hot sources** (e.g. lava) **emit** as much as the sun contribution and **enhance** 1.6µm signal
- Sun contribution at 1.6 µm is equivalent of a black body at 750K
- Big fires can be detected at night at the 1.6µm channel

Big fires at 1.6μm, night time



NIR 1.6 is solar-reflected (+ emitted) radiation



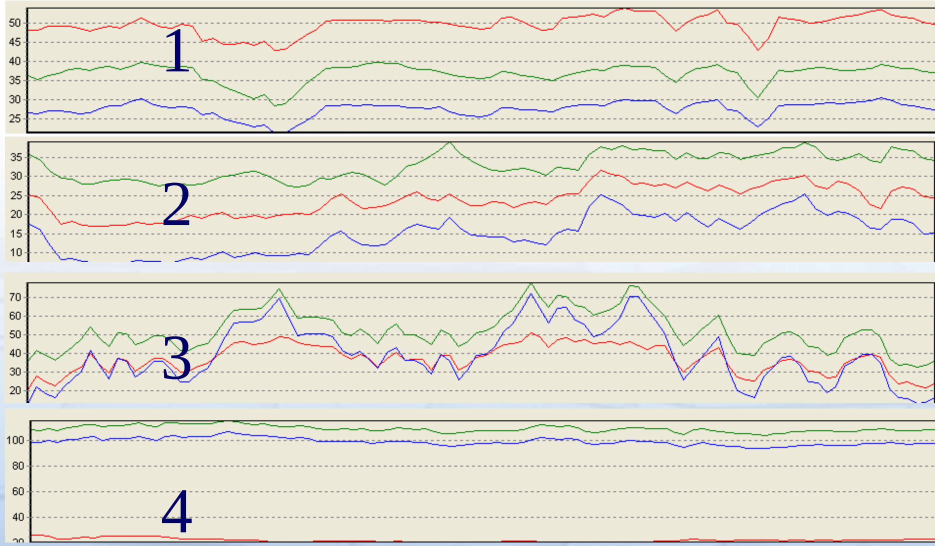
Which contribution is bigger, Emitted or Scattered ?

S/E > 10^7 due to Planck's strong dependence on temperature for scene T(kelvin) << 14400 /λ(µm)

Cloud in the solar channels

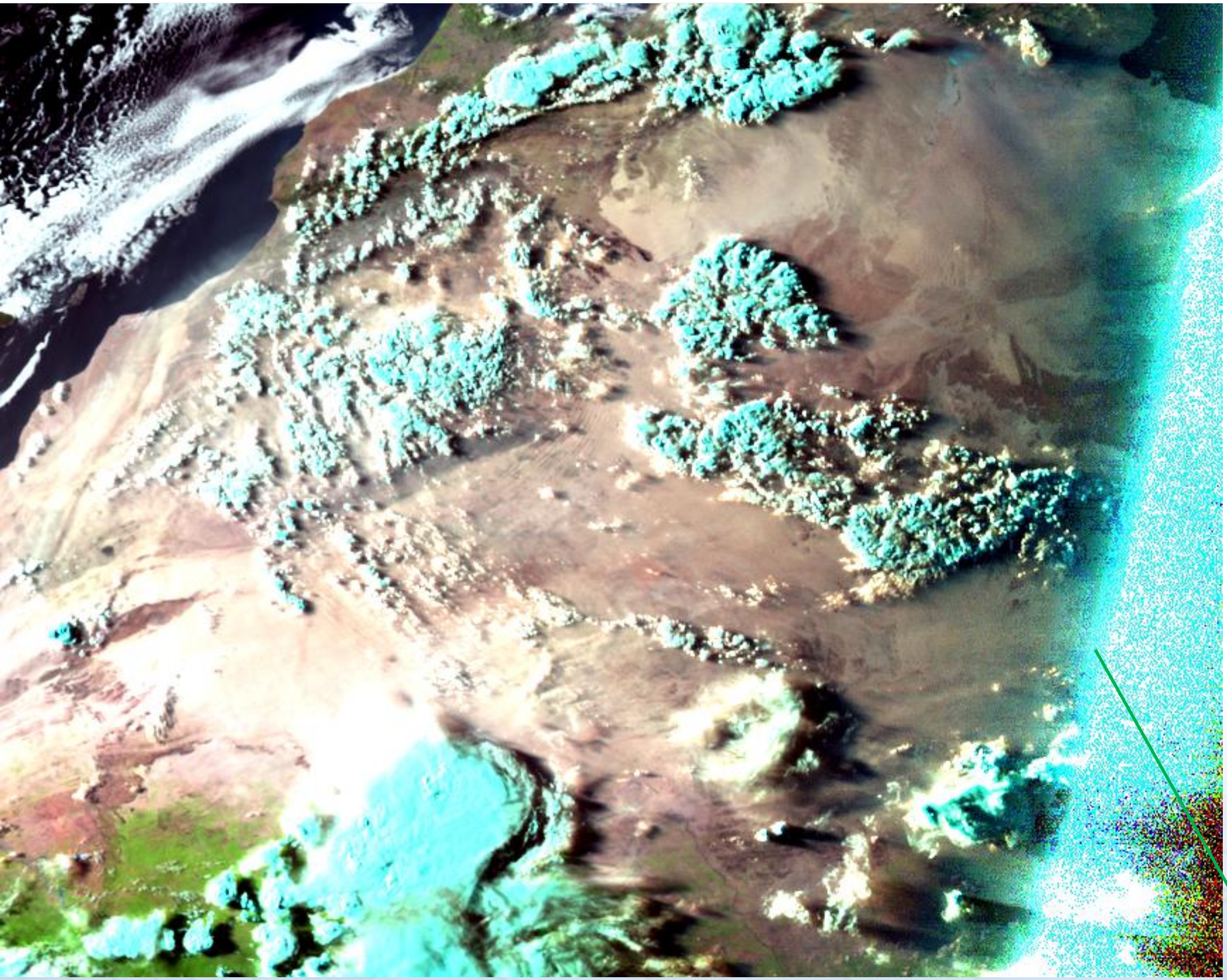
ch3 ch2 ch1 composite

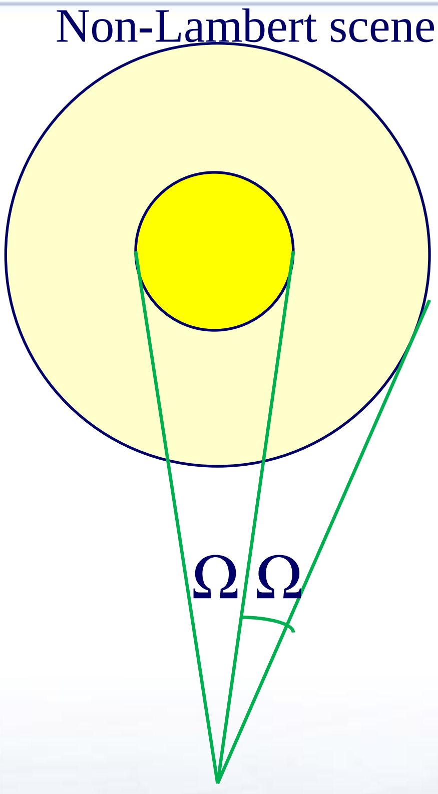
1. Dry
2. Vegetation
3. Thin cloud above vegetation
4. Thick cloud



- Scene “3” is a weighted average of scenes “2” and “4” with the cloud fraction
- 0.8µm is the most reflected radiation by cloud or vegetation, not by dry grounds (1.6µm)
- Ice cloud is less 1.6µm reflective than liquid cloud

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

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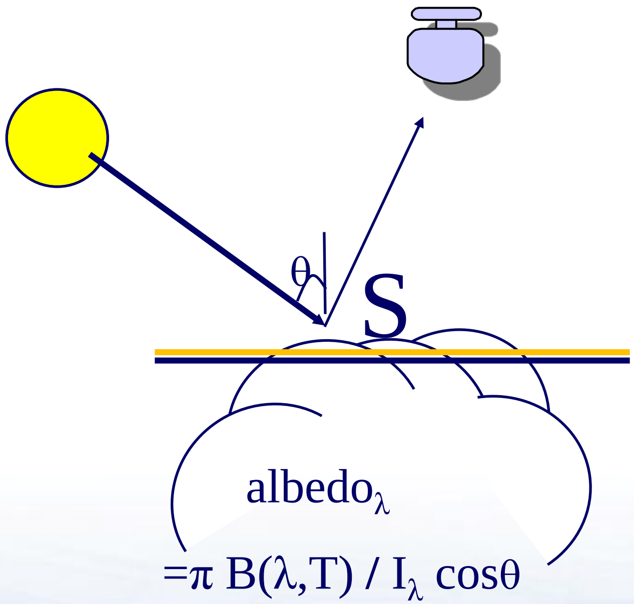
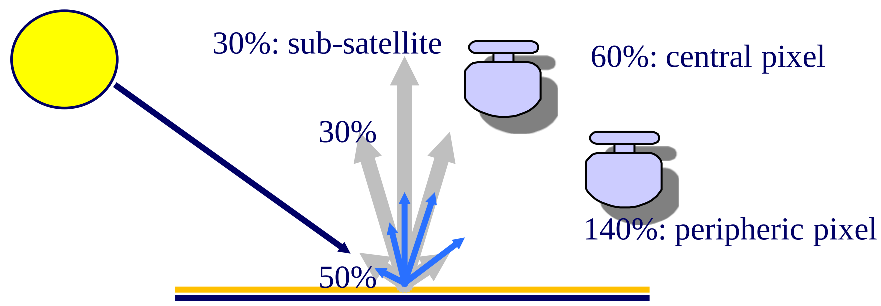
Scattering albedo





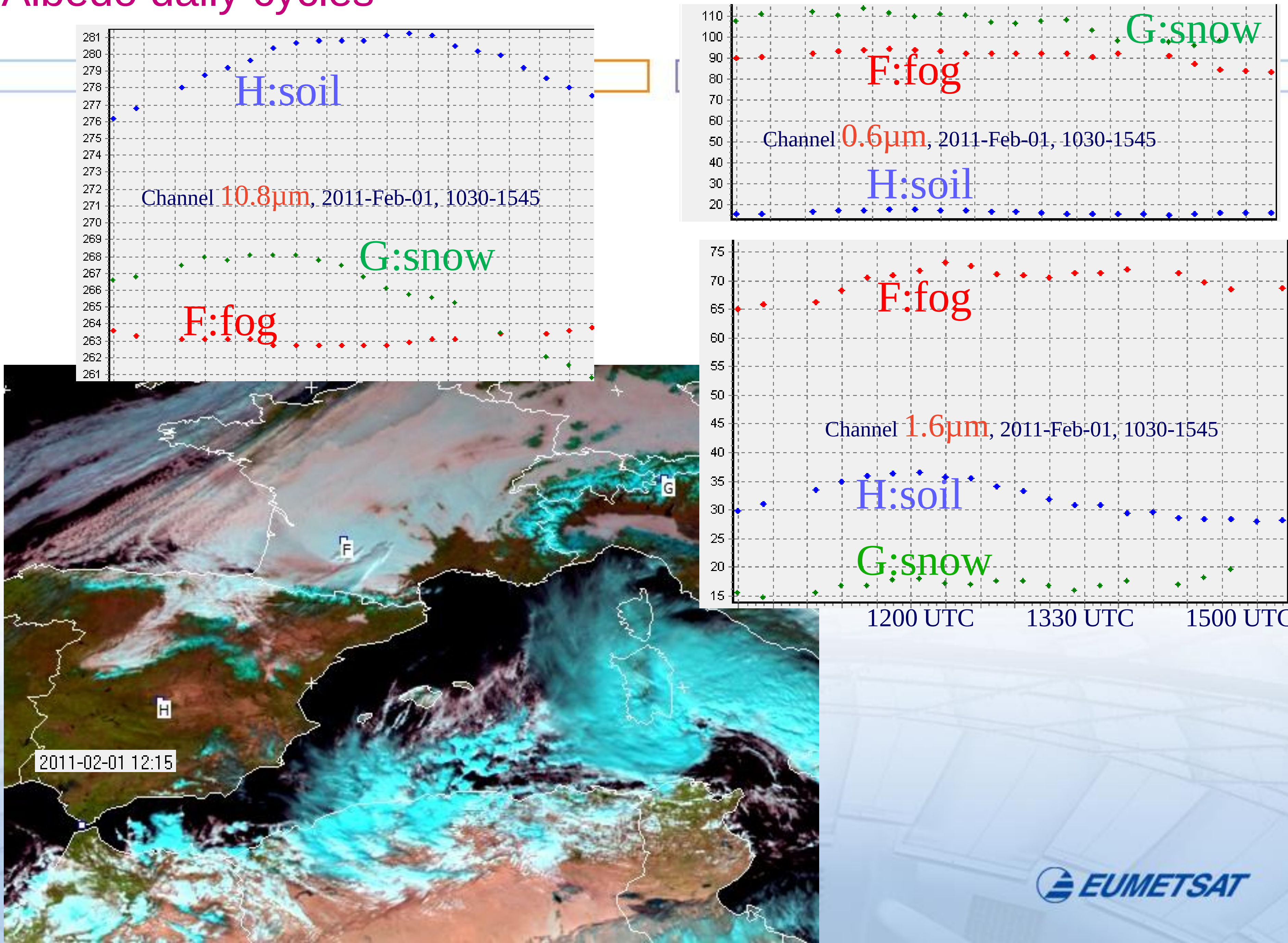
$I_\lambda \,.\, \cos\theta \,.\, S \,.\, \text{albedo}_\lambda \,.\, \Omega/\pi =$ Solar power reaching the satellite sensor

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

EUMETSAT

Albedo daily cycles



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

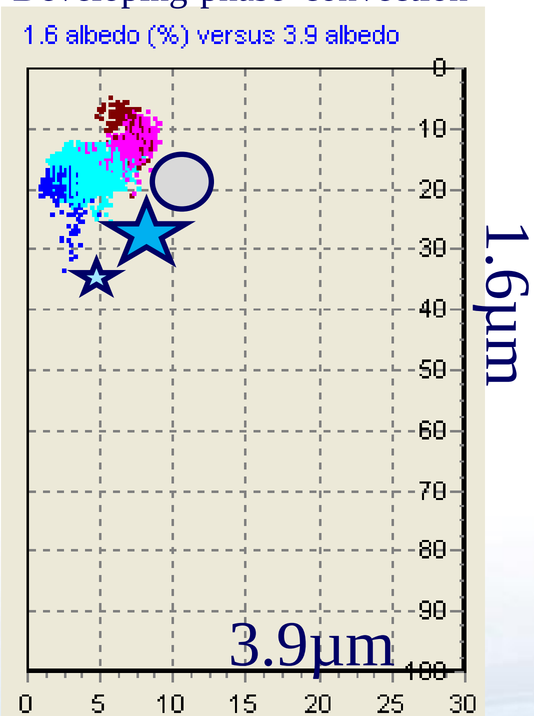
b. On oceans, where calm waters act as mirrors.
   Strong dependency but on low albedo values

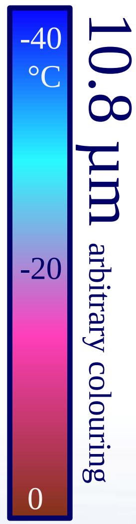
c. On tropical land, where surfaces stay constant in the course of the day. This is the best example

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

Towards ice and size vertical profiles

Developing-phase convection



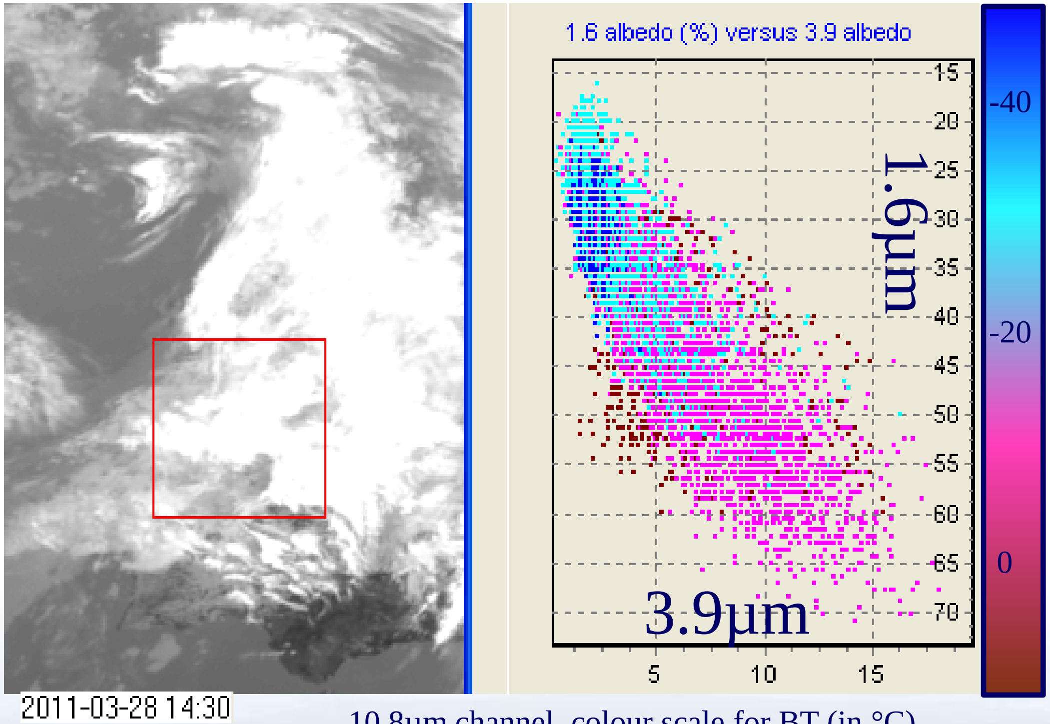


Both SIZE and ICE reduce particle reflectivity

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

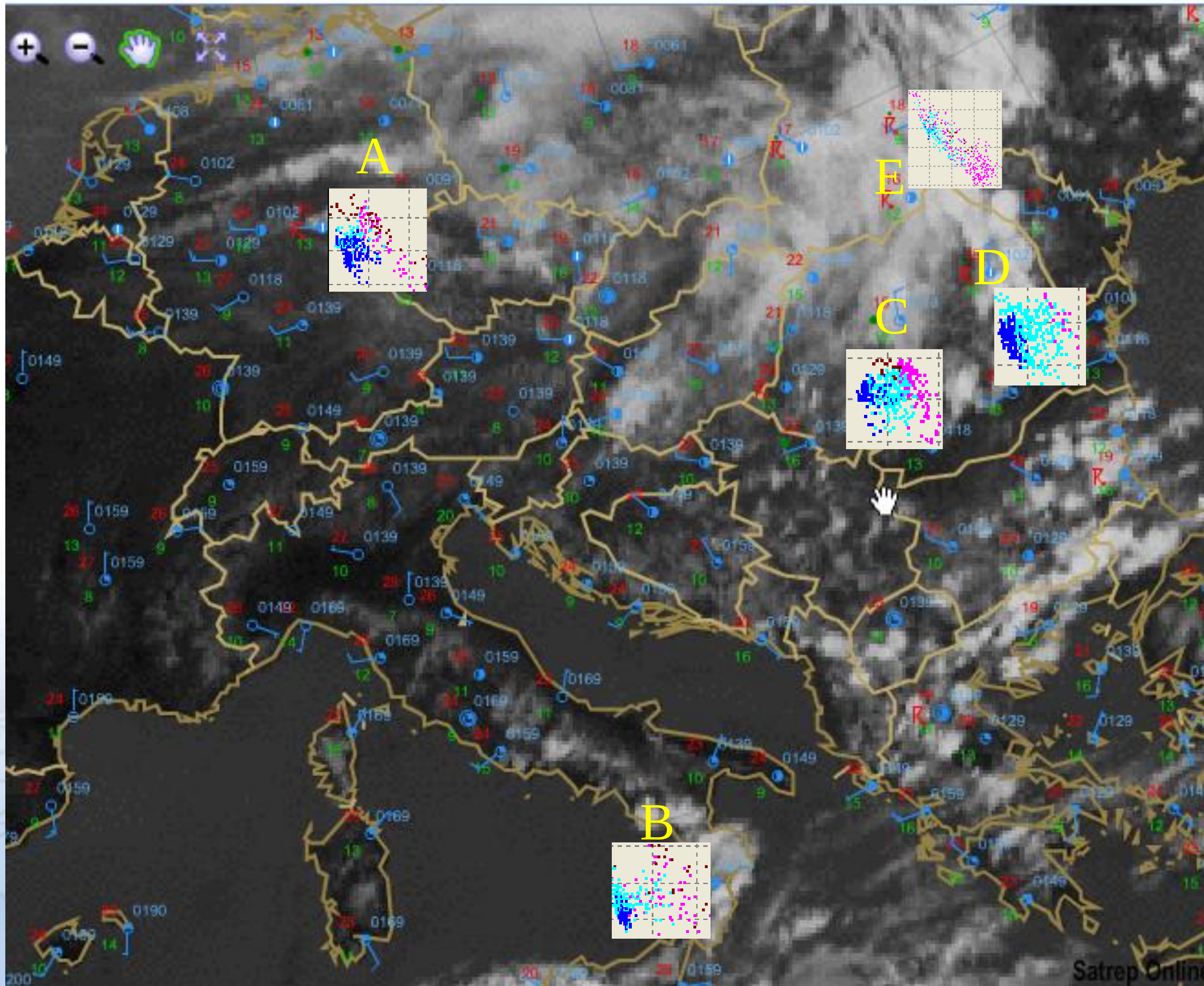


10.8µm channel, colour scale for BT (in °C)

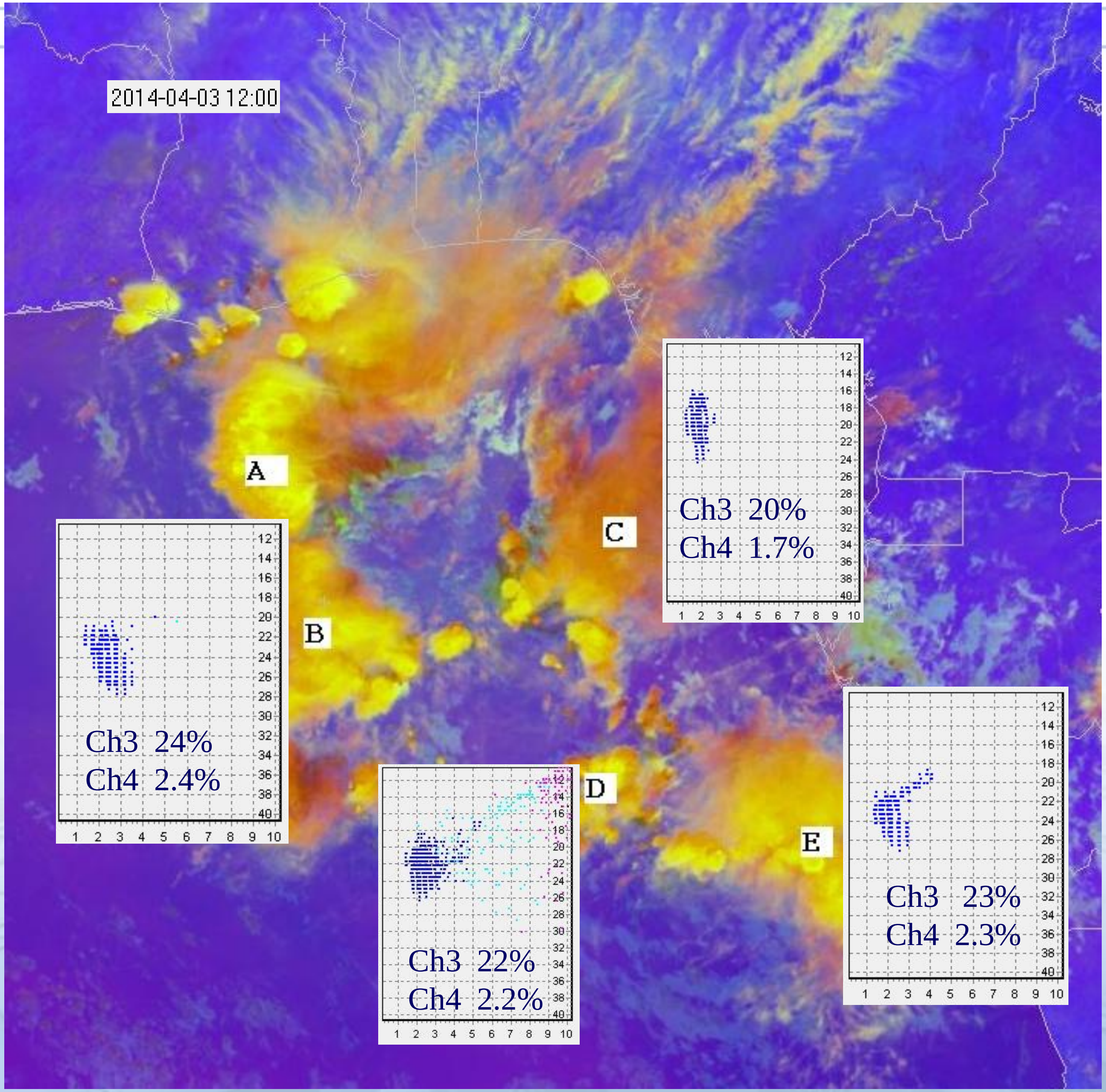
- **Dissolving-**cloud albedos at 1.6µm and 3.9µm show a higher correlation
- The liquid tops vary faster in 3.9-albedo than in 1.6-albedo
- 1.6 is ice-size sensitive, 3.9 is droplet-size sensitive

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

24 May 2010: 1200UTC



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



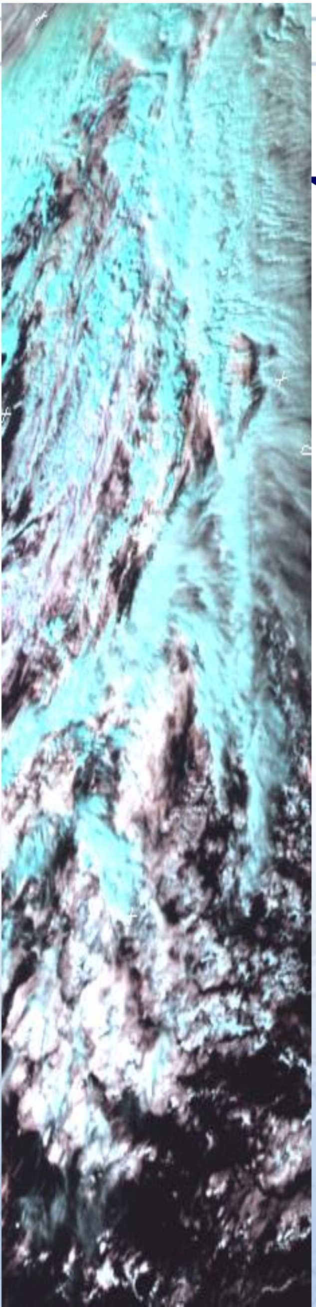
Average reflectivity on the frozen cloud tops of convection are roughly 10 times higher for channel 1.6µm than for 3.9µm

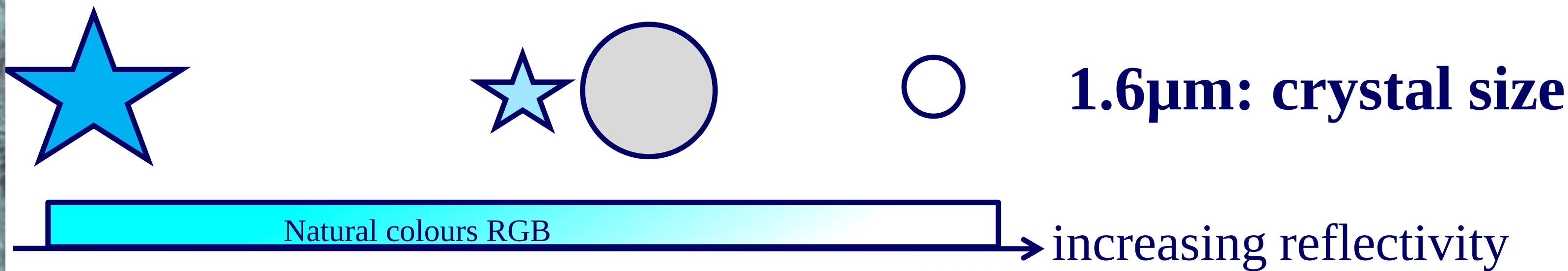
Rule "20+ 10-" for **severe convection** in a region 100km across :

<Ch3> > 20%

Ch3/Ch4 < 10

NIR1.6 reflectivity

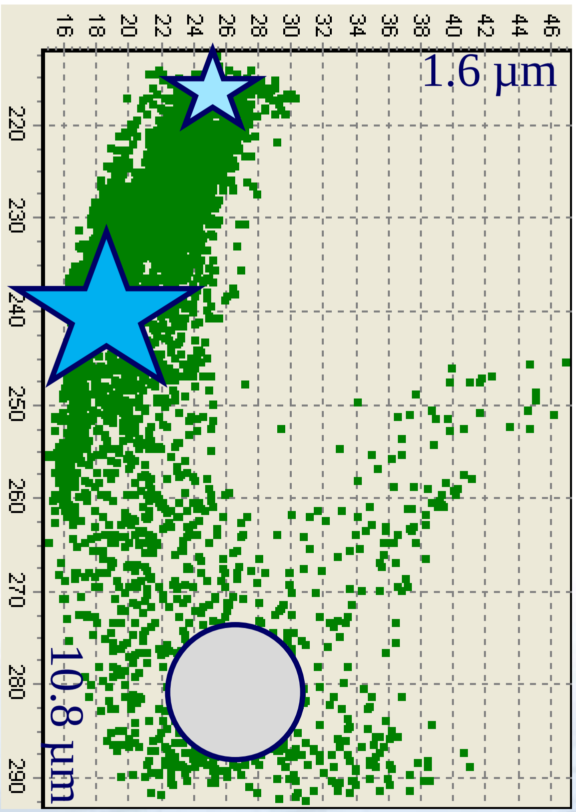


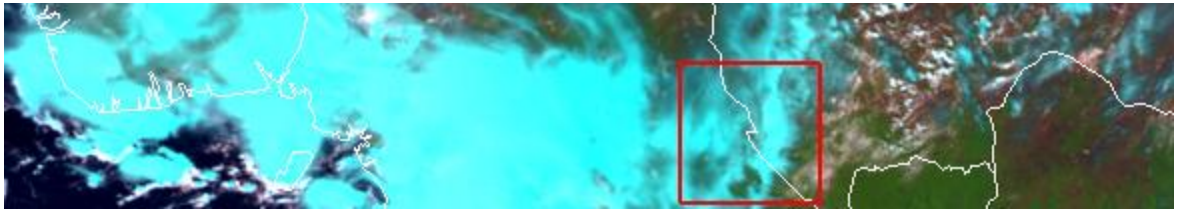


←Cyan colour in the natural RGB marks the presence of ice crystals, but is NOT an indicator of CONVECTIVE severity, related to small crystals.

Cyan is more for areas of probable STRATIFORM precipitation

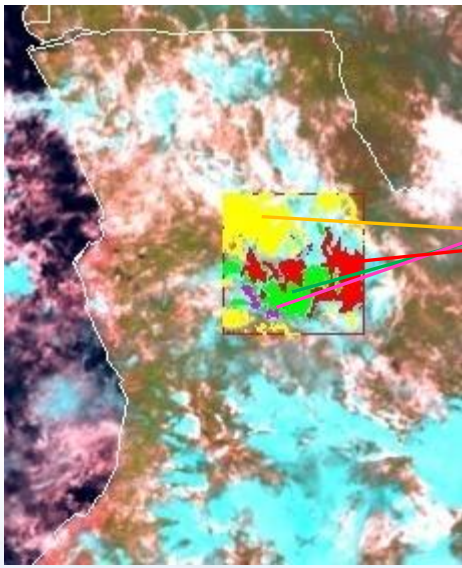
Ice cloud

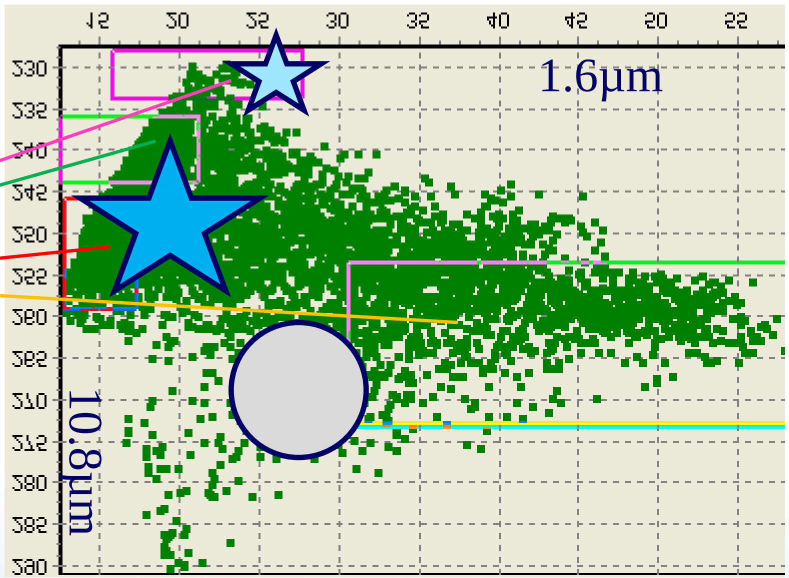


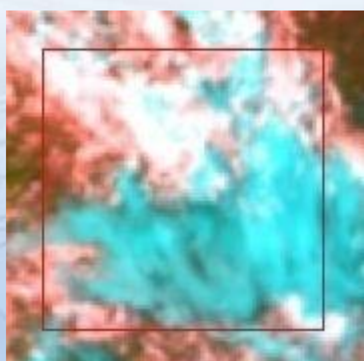


Thin cloud enhances the reflected signal from non-reflective grounds

Classifying ice cloud







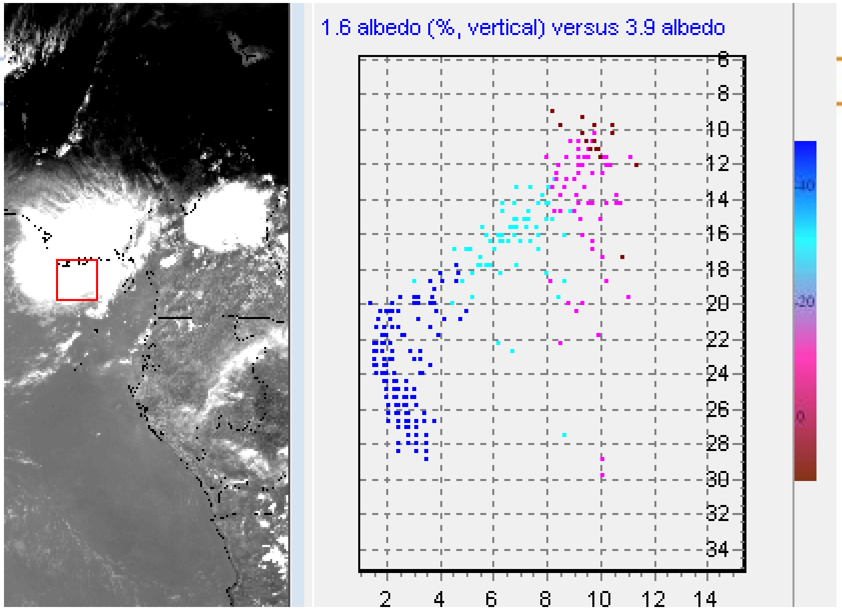
What are the red-coded areas?

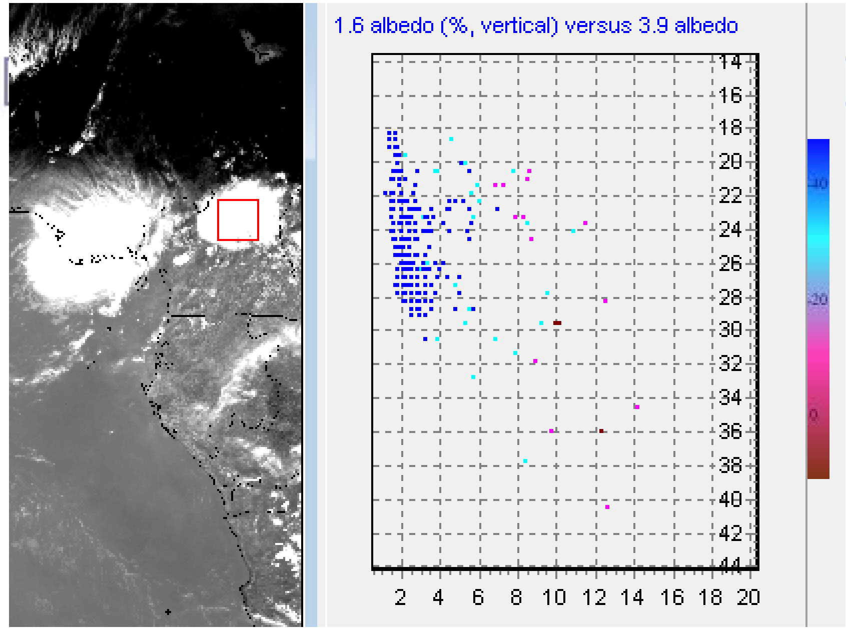
Super cooled water droplets

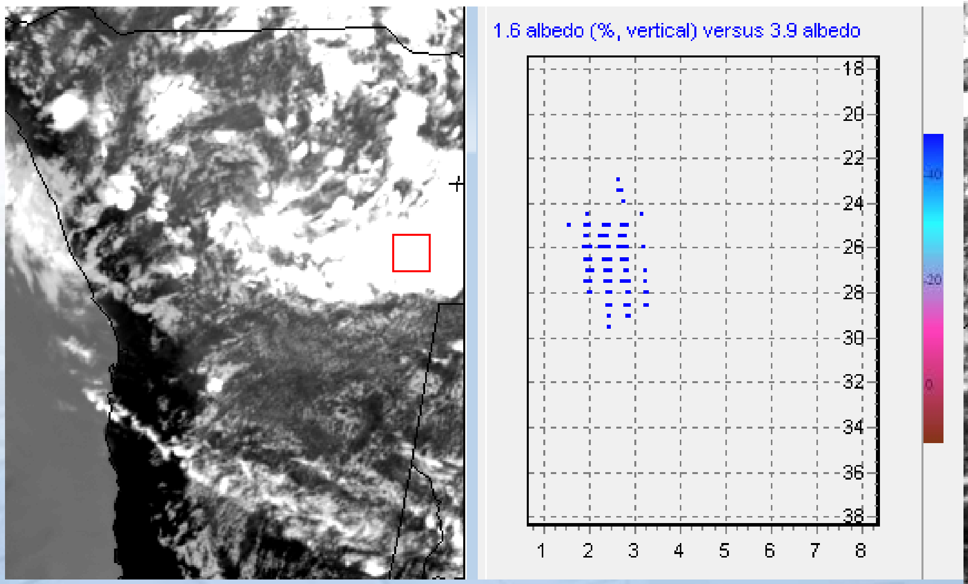
Large ice particles

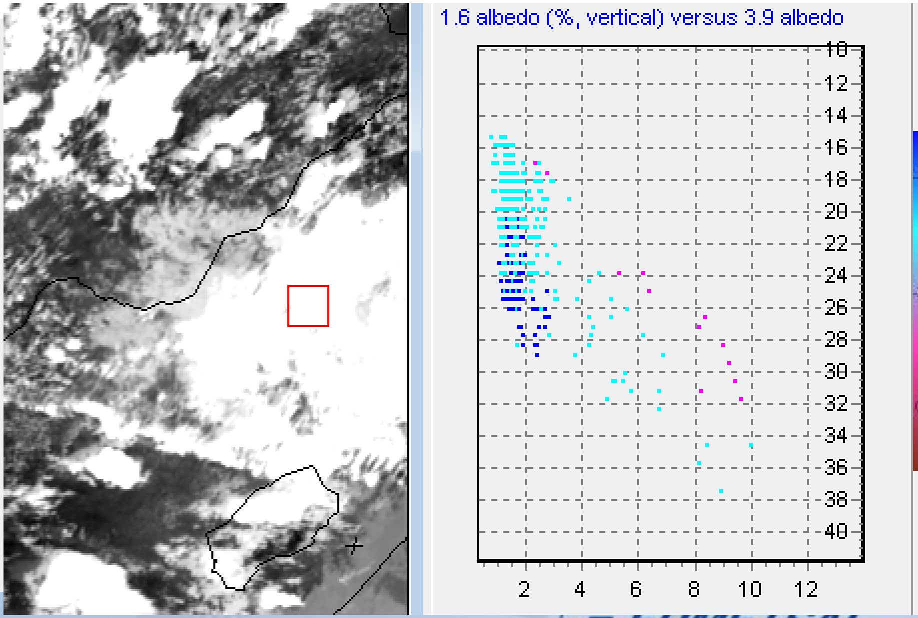
Ice

Small ice crystals

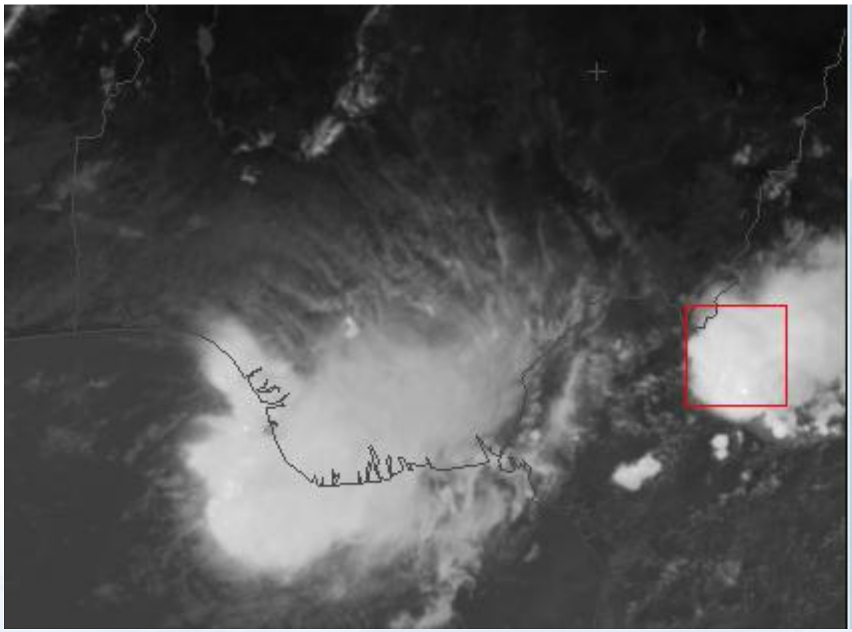

1.6 albedo (%, vertical) versus 3.9 albedo
6 8 10 12 14 16 18 20 22 24 26 28 30 32 34
2 4 6 8 10 12 14

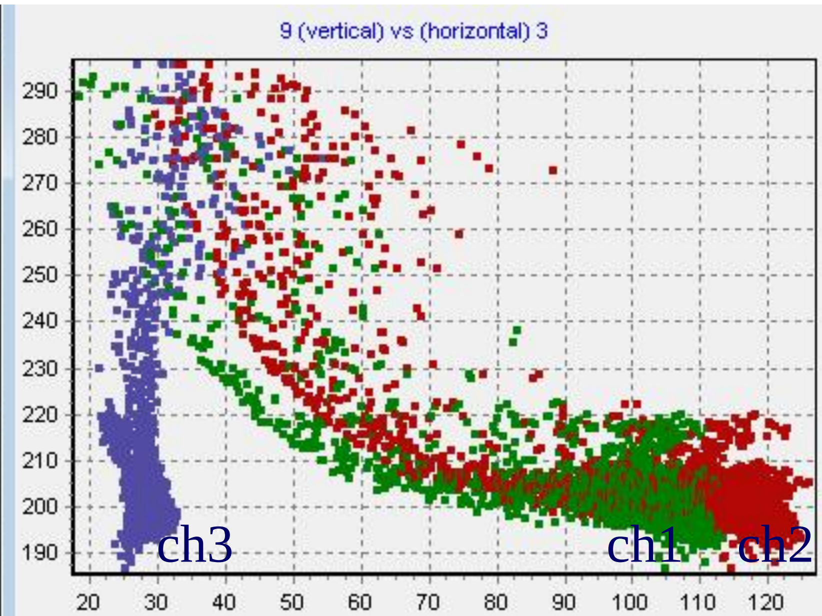

1.6 albedo (%, vertical) versus 3.9 albedo
14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
2 4 6 8 10 12 14 16 18 20


1.6 albedo (%, vertical) versus 3.9 albedo
18 20 22 24 26 28 30 32 34 36 38
1 2 3 4 5 6 7 8


1.6 albedo (%, vertical) versus 3.9 albedo
10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
2 4 6 8 10 12

Physical limit values in clusters: Quiz





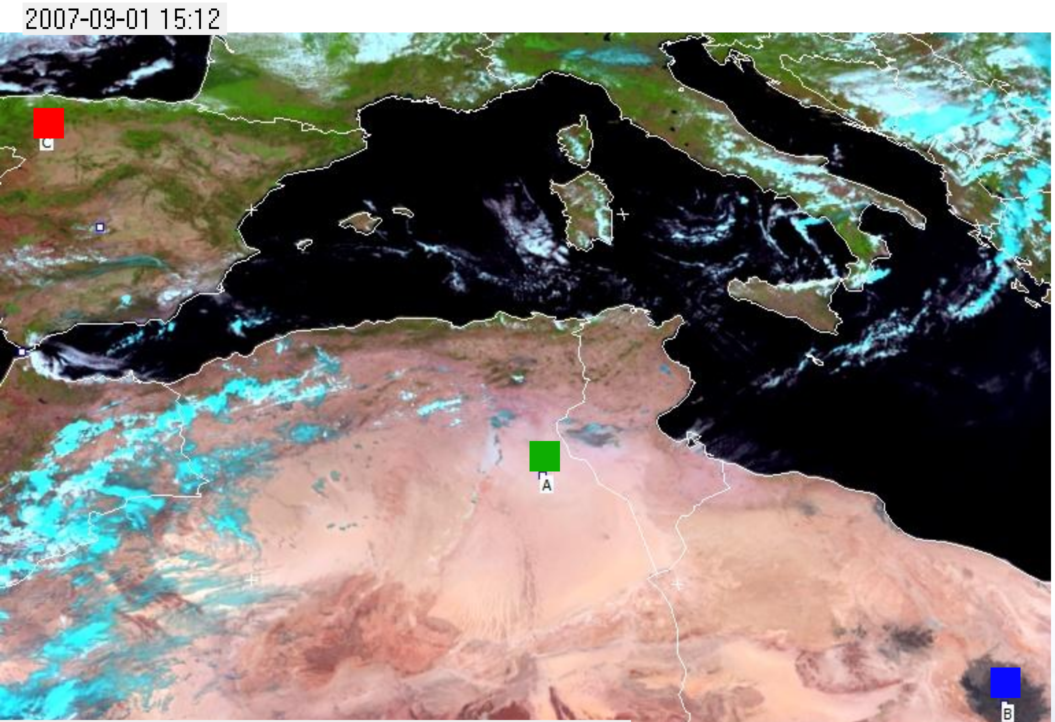
Why 25-33% limits in the 1.6µm reflectivity at 200 K ?

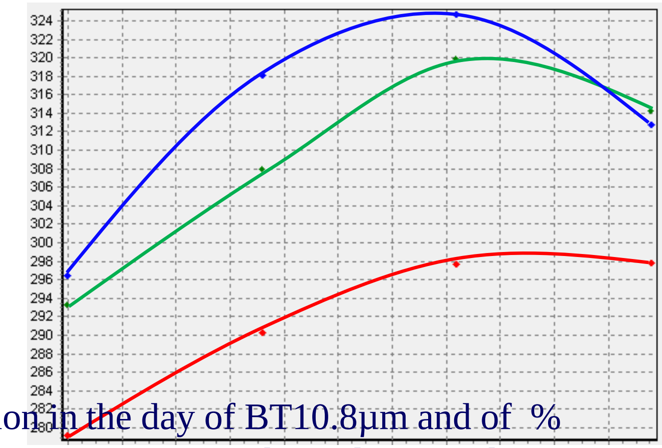
a. For thick cloud, small crystals absorb and cannot be less reflective than 25%.

b. Ice reflectivity at 1.6µm is almost constant for any storm development phase.

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

Channel reflectivities on soil



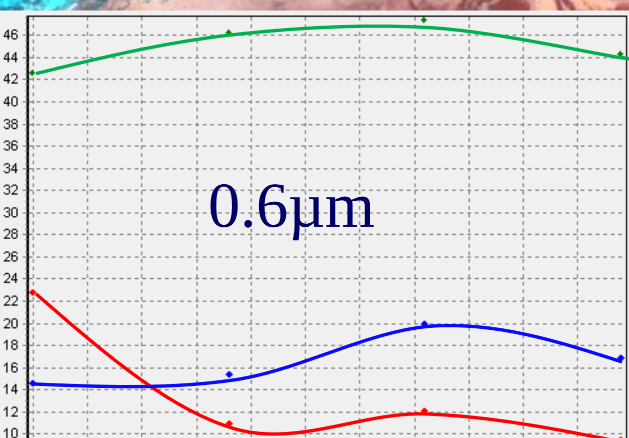


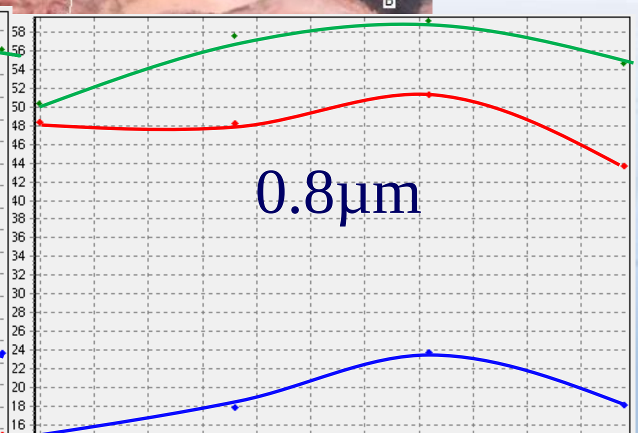
Evolution in the day of BT10.8µm and of % reflectivity at Meteosat channels 1,2 and 3:

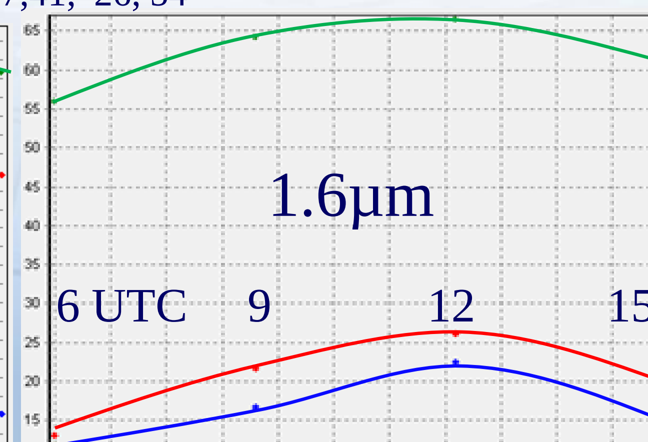
-Simple reflectivity formula shows directionality in reflection for

Sun-sat 90, 47, 15, 47

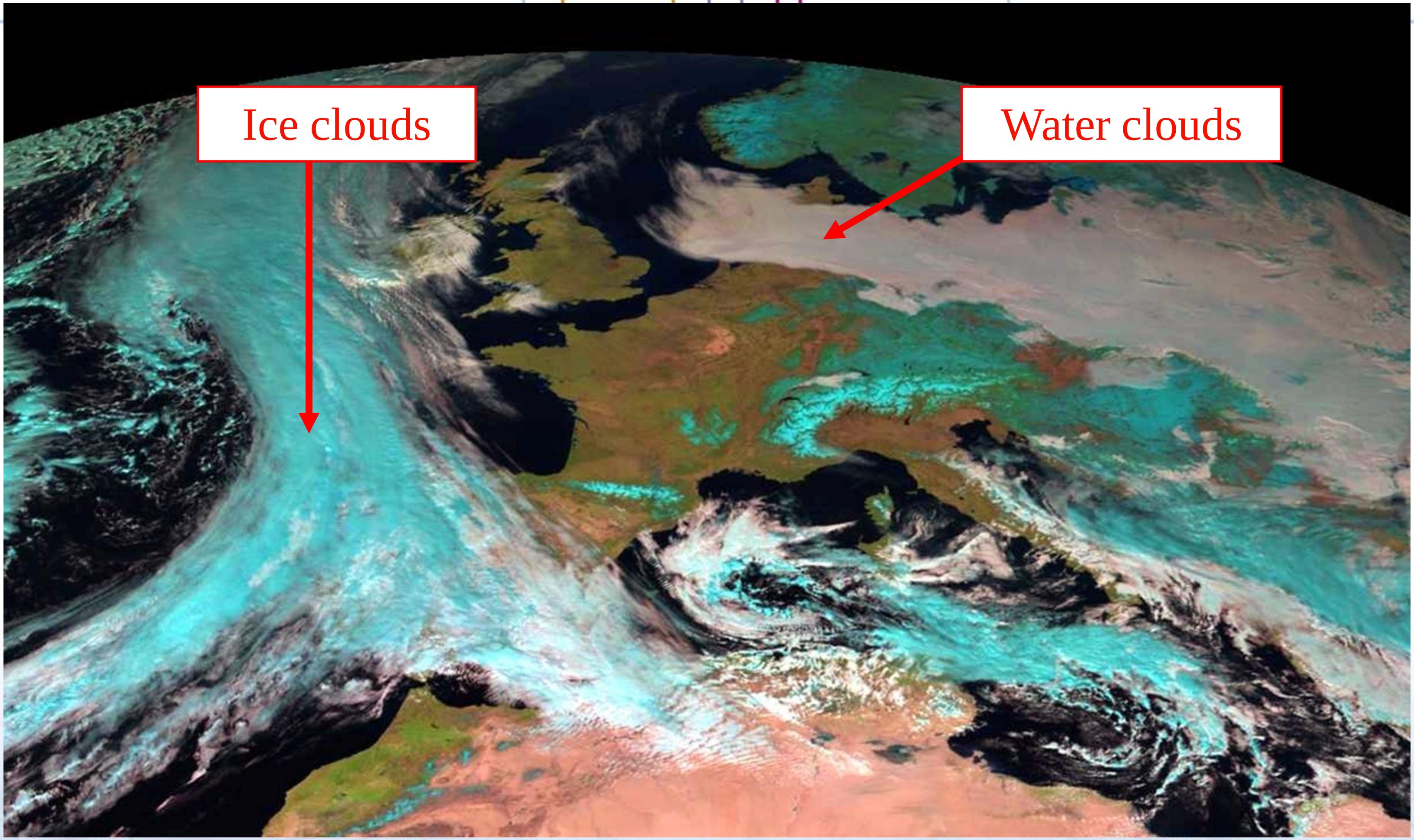
Solar: 77,41, 26, 54







Cloud Phase (Ice and water)

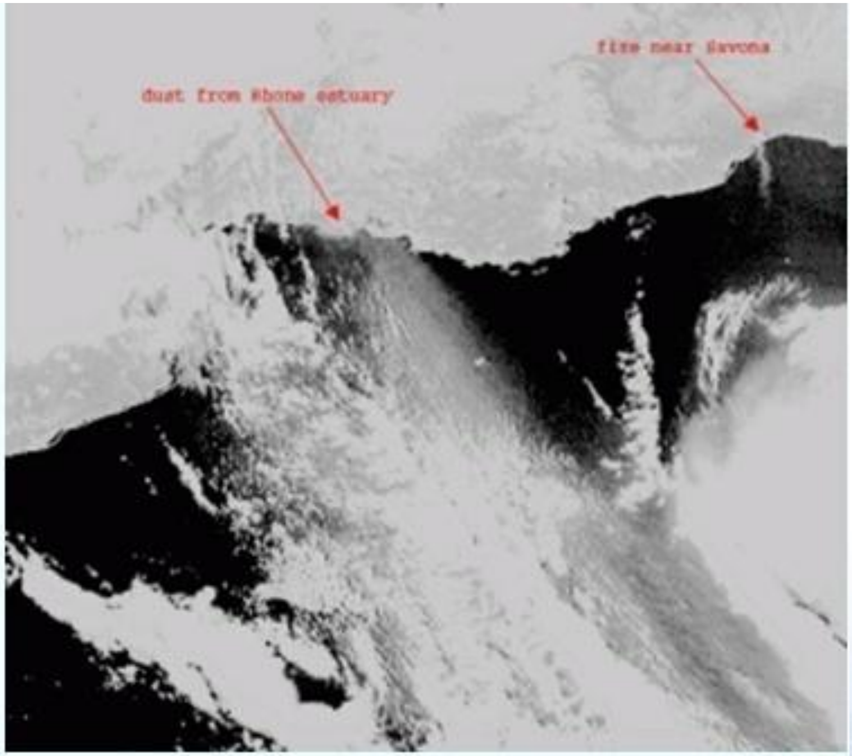


Cloud phase classification using SEVIRI RGB images
18 Feb 2003, 13:00 UTC, RGB NIR1.6-VIS0.8-VIS0.6

Meteosat solar channels

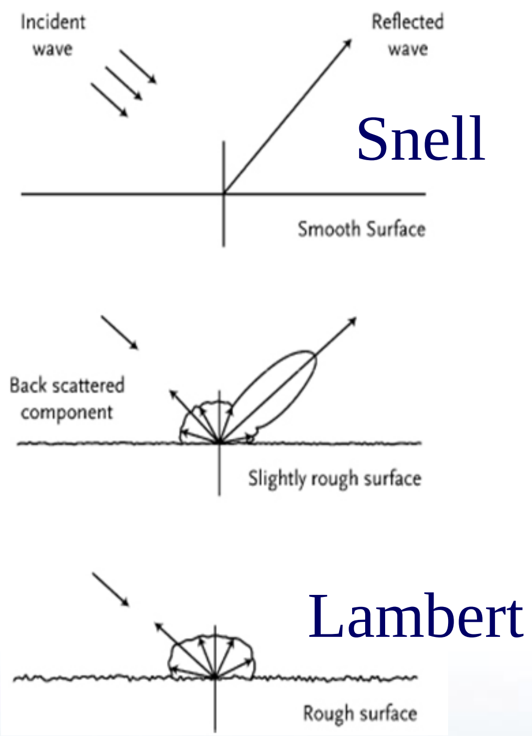
Rough surfaces due to mistral

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.

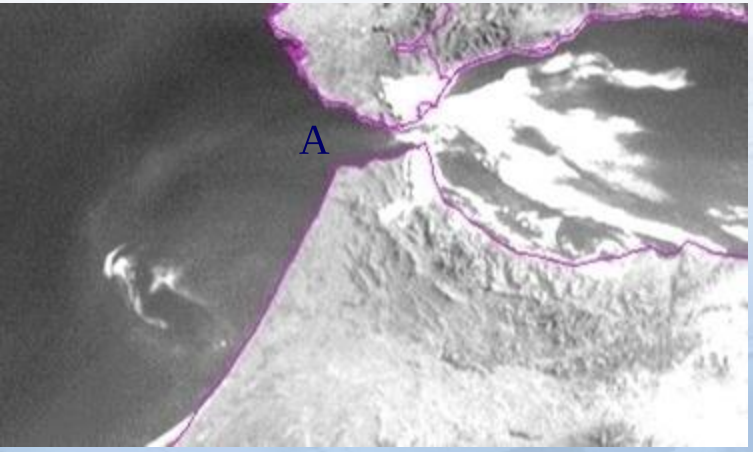
•In the **sun glint zone** itself, the wind **decreases** the scattering to the satellite.

•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

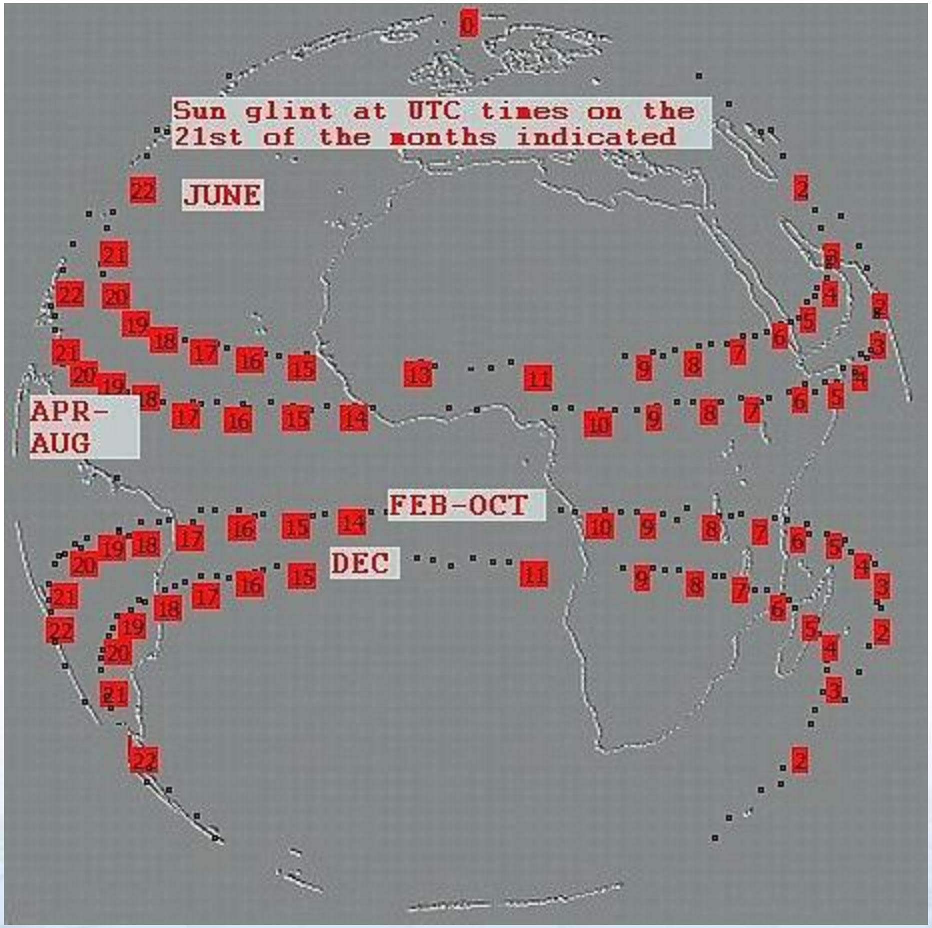
France, 10March 17April 24May

rmany, 23 March 8April 17April 28April 24May

Spain 6April 22May 2010

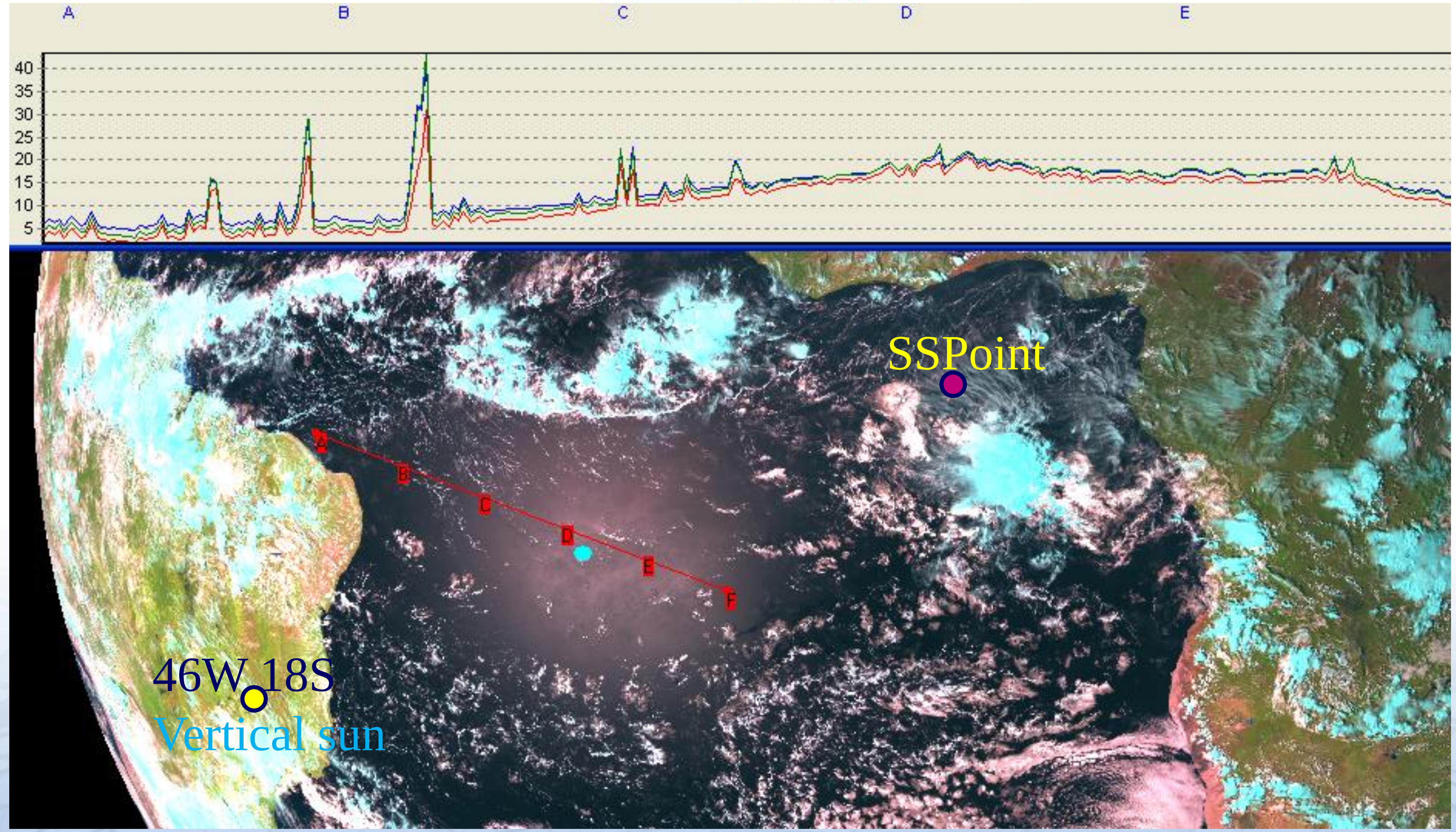
EUMETSAT

Sun glint time and date evolution



The course of sunglint on flat surfaces

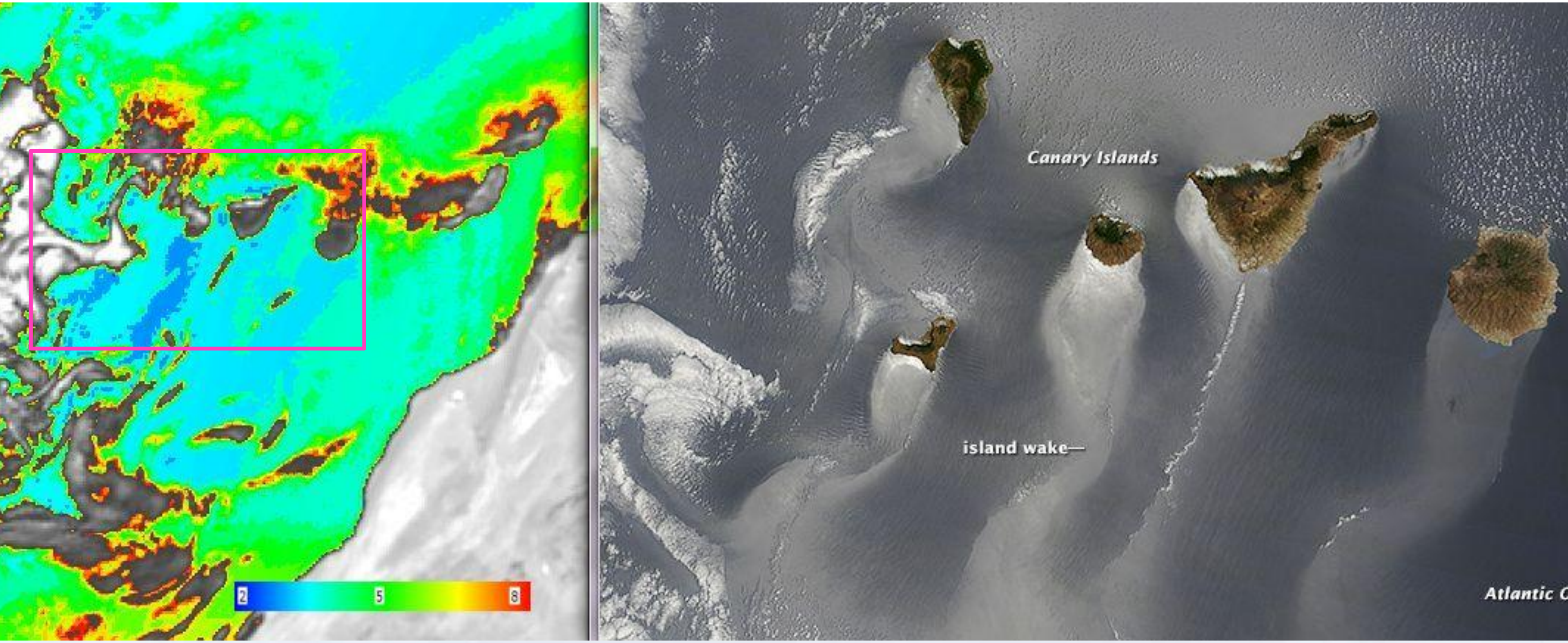
Sunglint



RGB natural Meteosat9, 2011...

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

Reflectance on sunglint areas

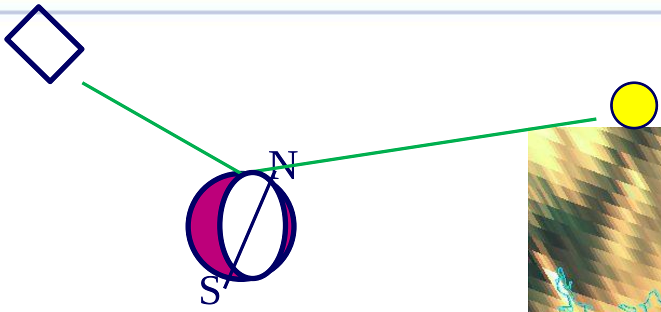


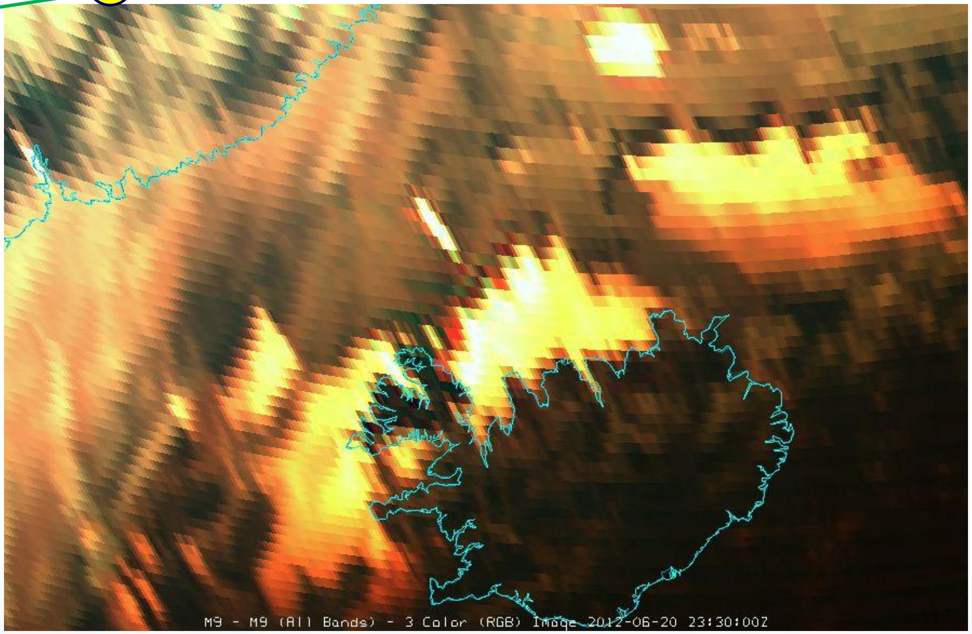
Meteosat (no sunglint) and Terra Modis (sunglint)
2013-06-15 circa 10:30UTC
What turns white in Modis the island wakes: cloud, calmed sea, dust?

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

EUMETSAT

Bright spots north of Iceland





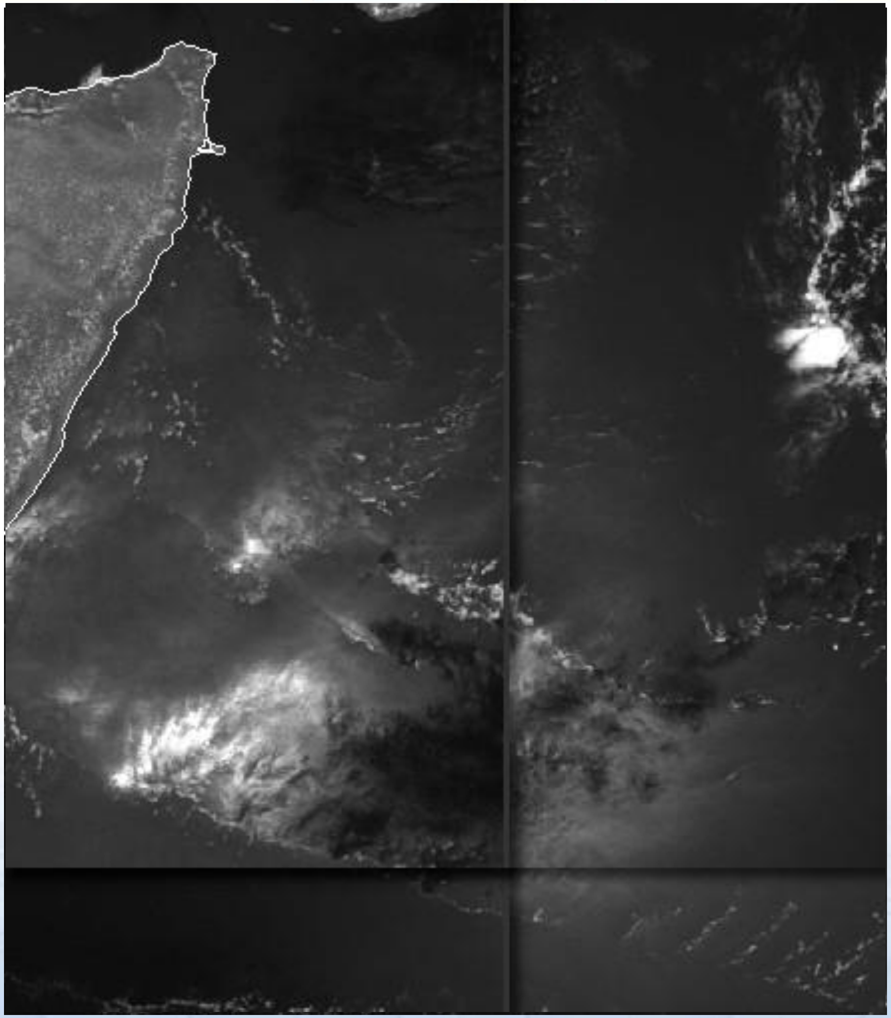
2012-june-20 at 2330 UTC   Meteosat-9   Natural RGB 321

What are they? Cloud, sea surface, ash?

Mind the special image date!

Wind speed maps

Sunglint periods allow the reconstruction of ocean calm areas (in white)



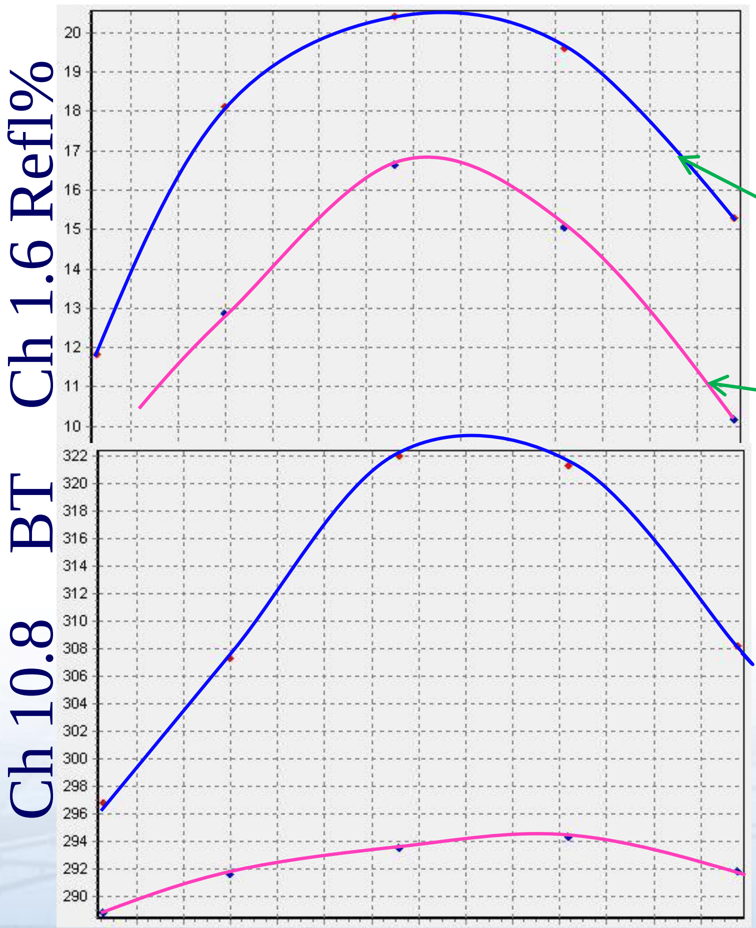
Met-7 Indian Ocean coverage 8:00 - 9:30
2015_Apr_13 7:00

Meteosat solar channels

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

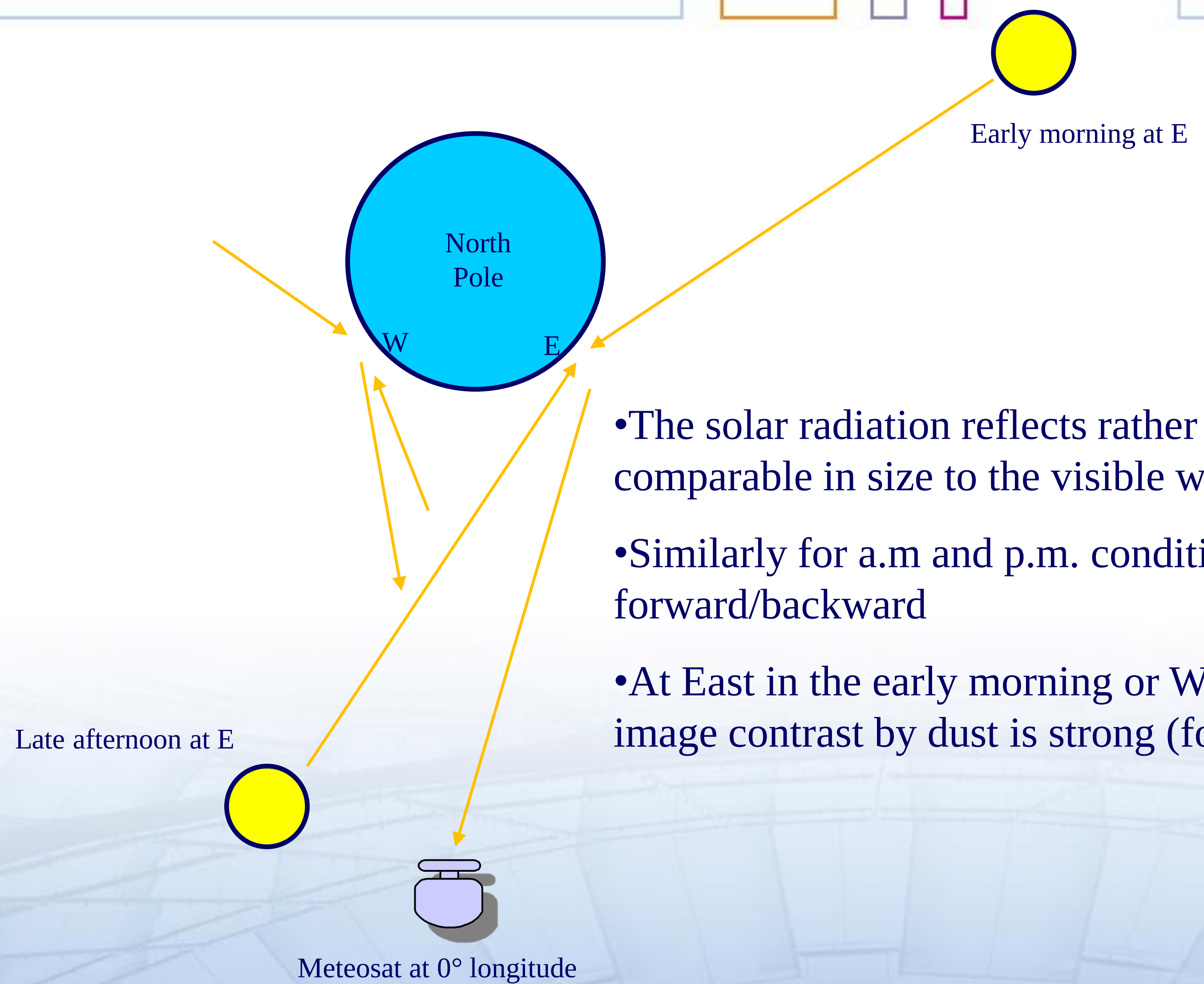


6 UTC 9 12 15 18 UTC

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

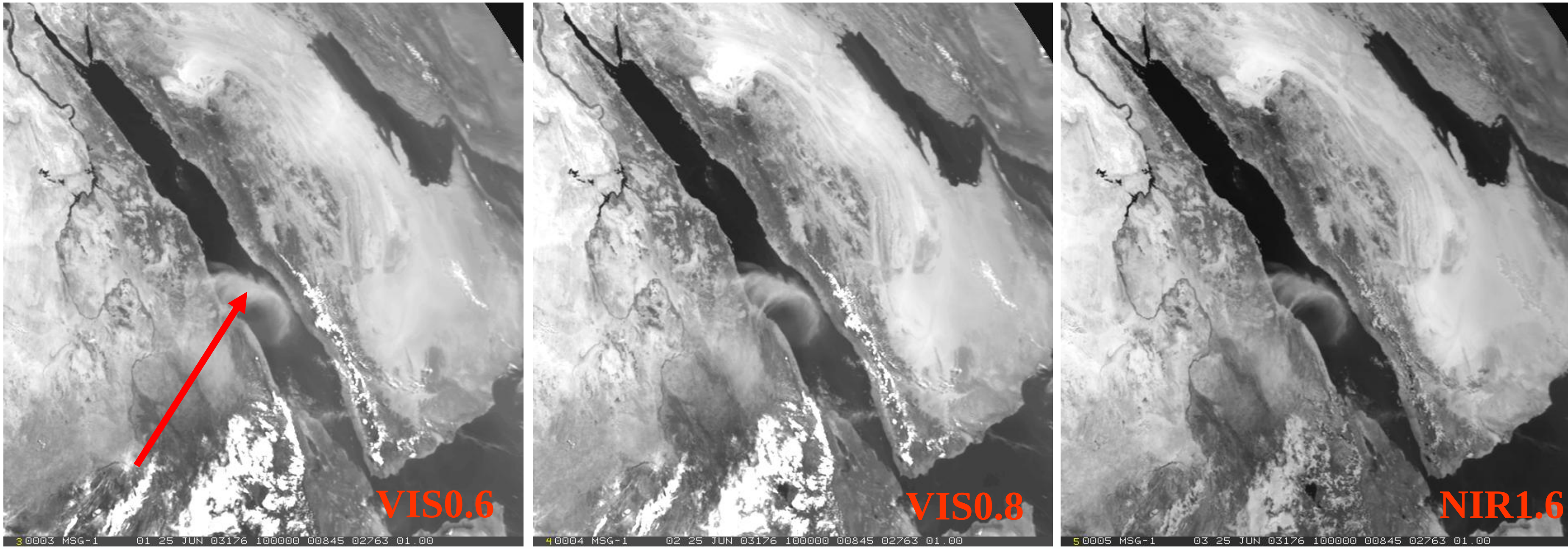
Which line is the dust pixel?

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)

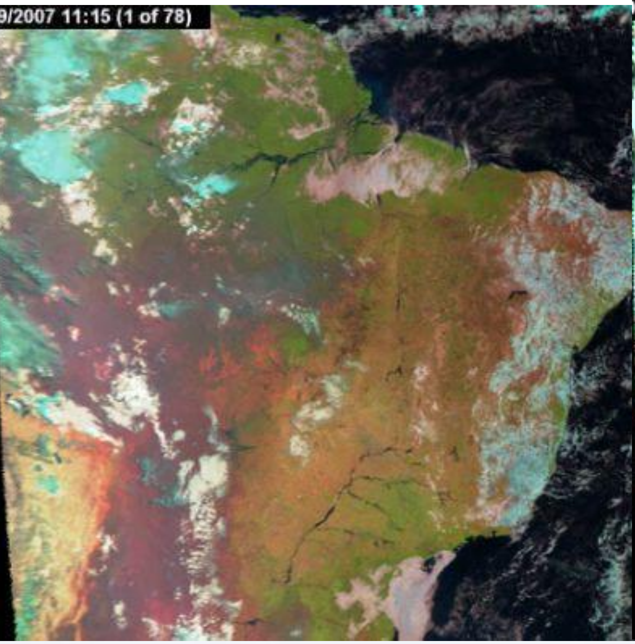
Solar channels: aerosol observation



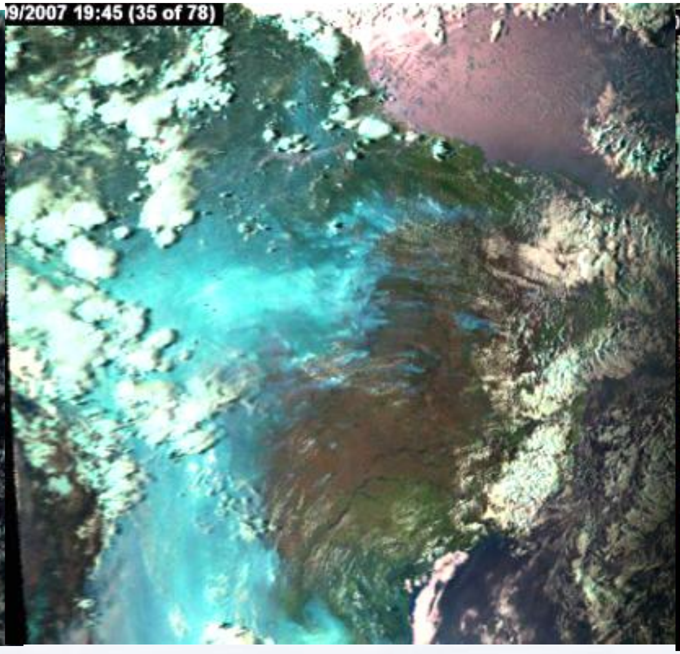
Dust storm over the Red Sea
MSG-1, 25 June 2003, 10:00 UTC

Pastures burning and deforestation activity in Bolivia

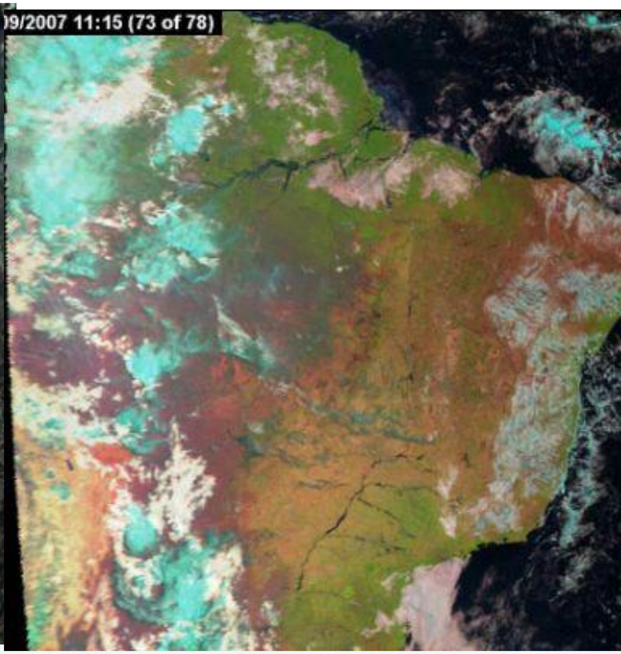
sunrise



sunset

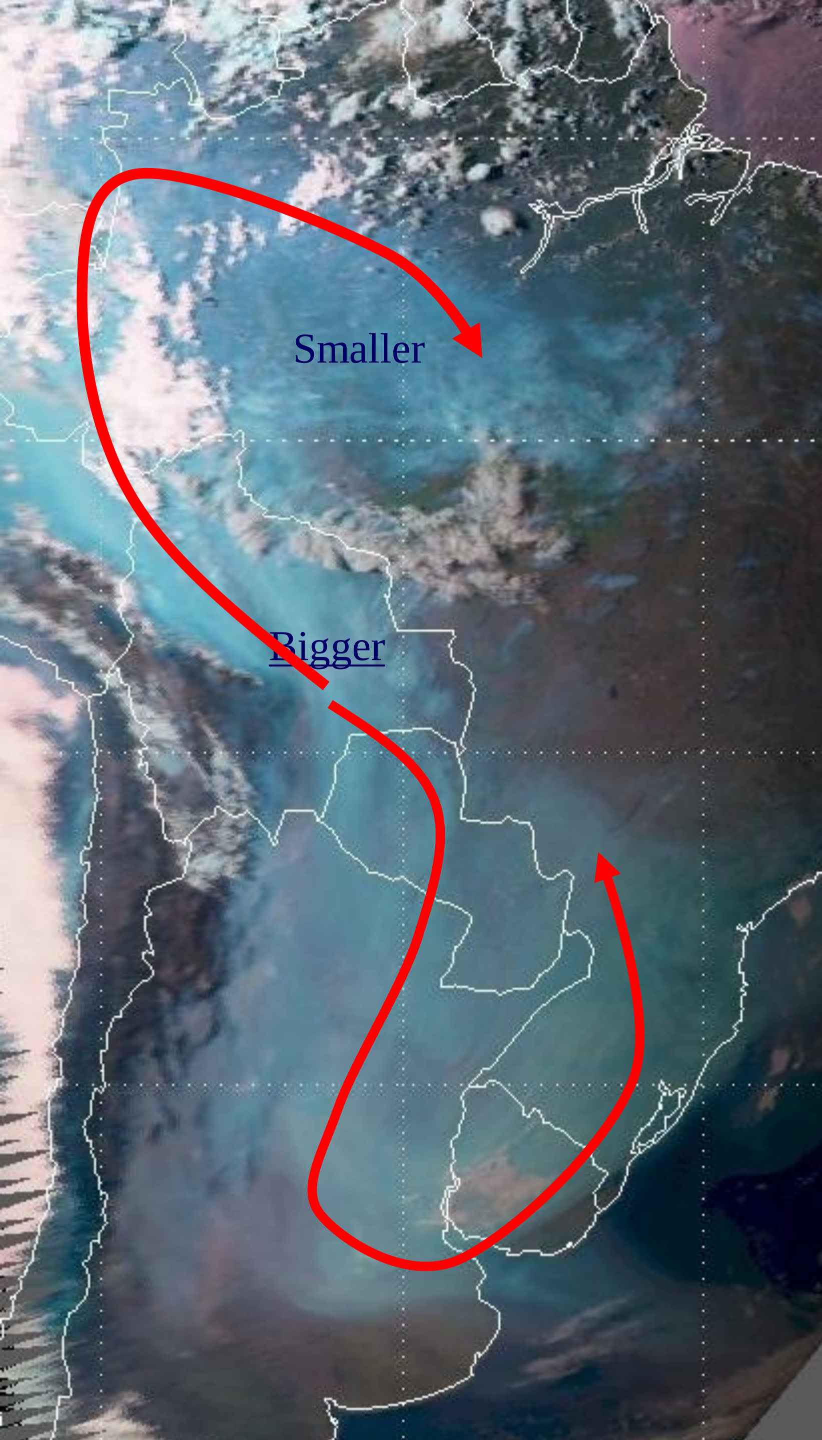


sunrise



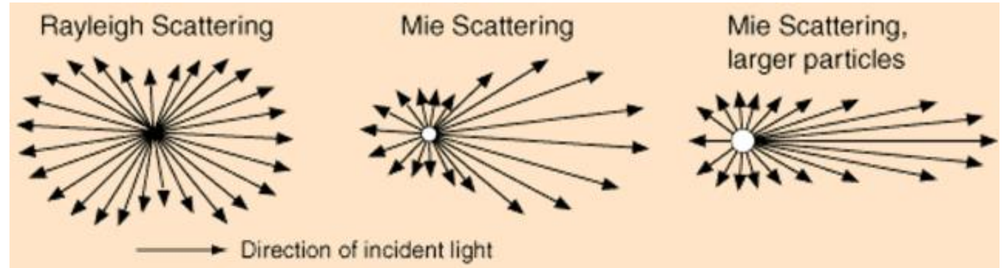
5-6 September 2007, Meteosat-9
Around sunrise and sunset times for central south America

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

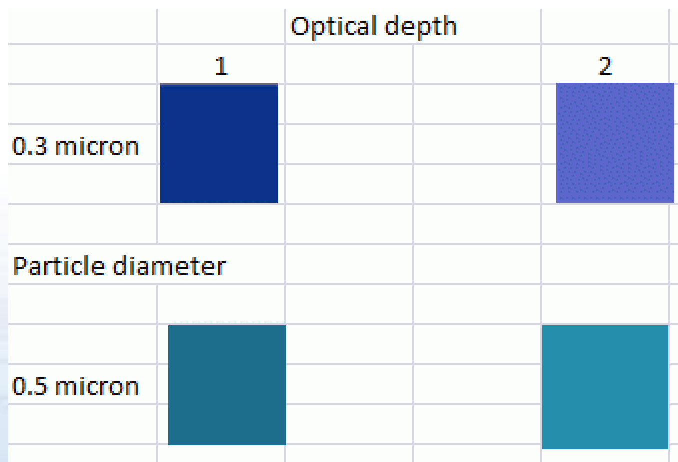


Who made the fire?

Meteosat9, 2010-08-21 2015 UTC



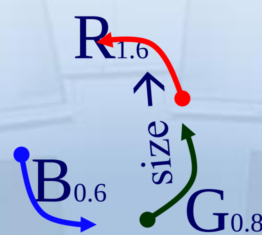
•Smaller wavelengths are reflected by smaller particles (wavelength ~ 3* diameter)



pared with
yleigh scattering)

nced by forward

he western late

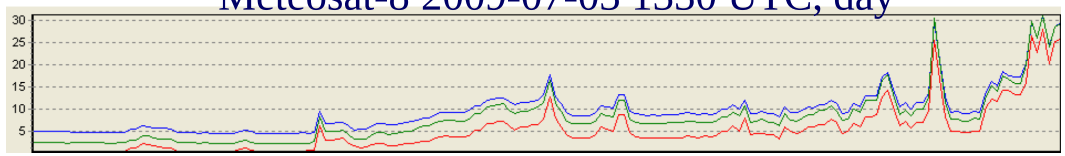


Smaller (0.2µm) Bigger (0.3 µm)

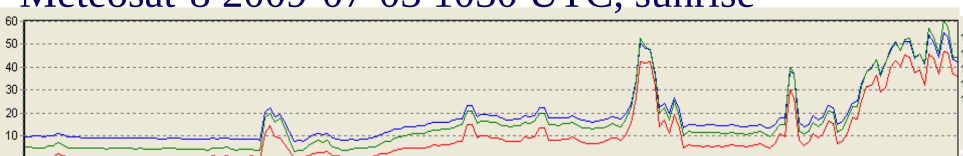
Sun glint hides the dust signal (sunset on the West)

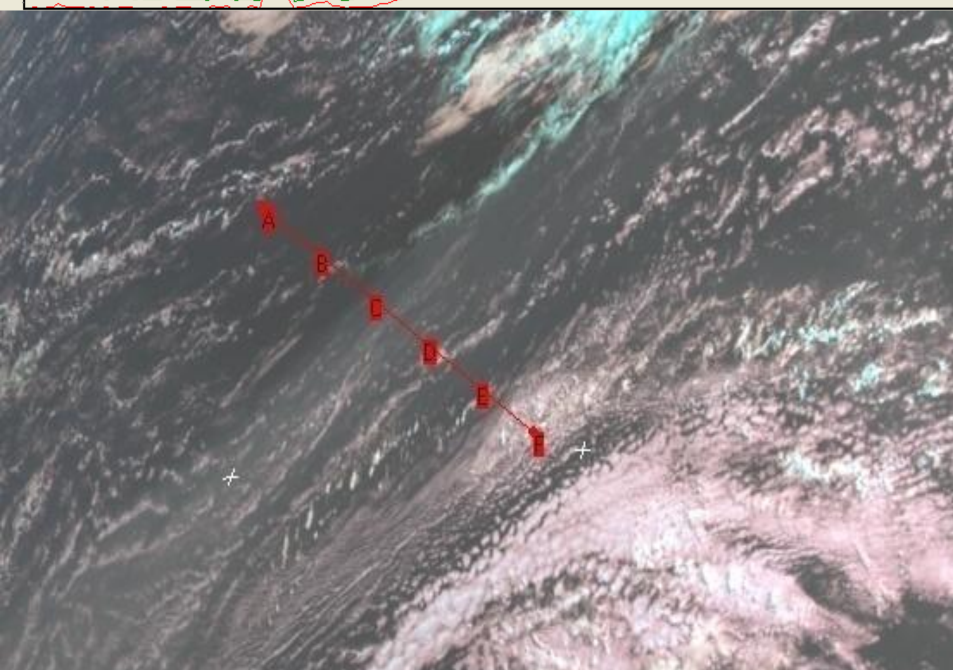
At the western Atlantic, -58E ,18N dust over ocean (C-D), obscured at late p.m by coincident sunglint

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

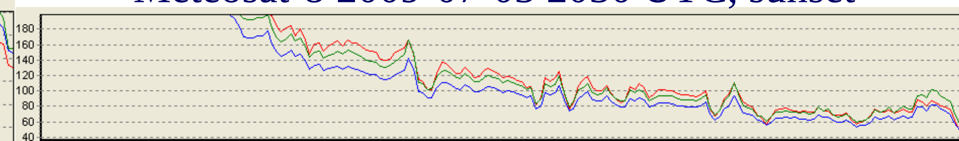


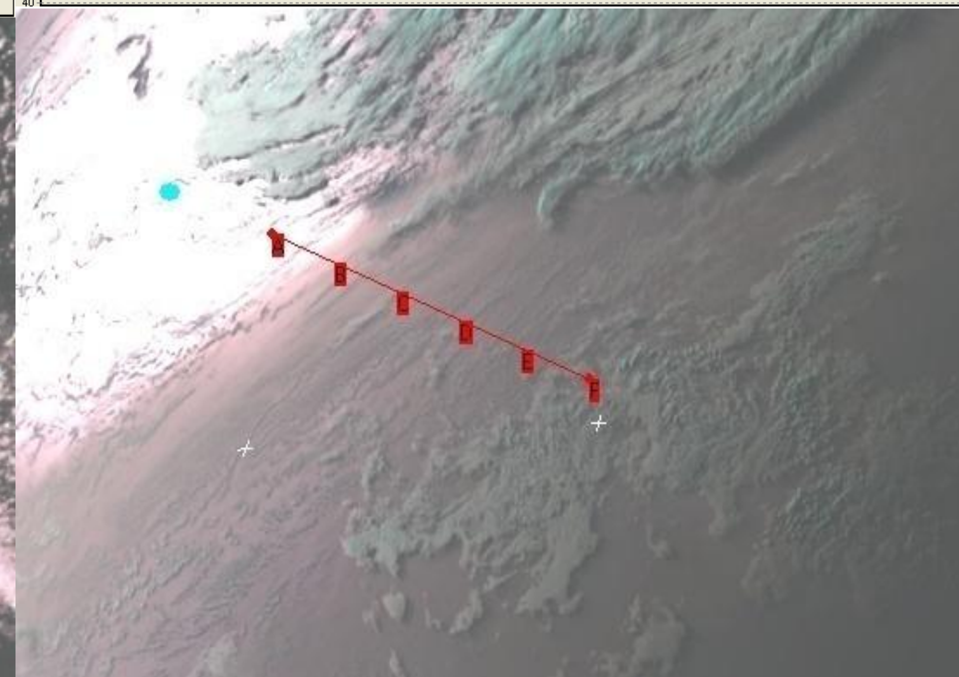
Meteosat-8 2009-07-03 1030 UTC, sunrise



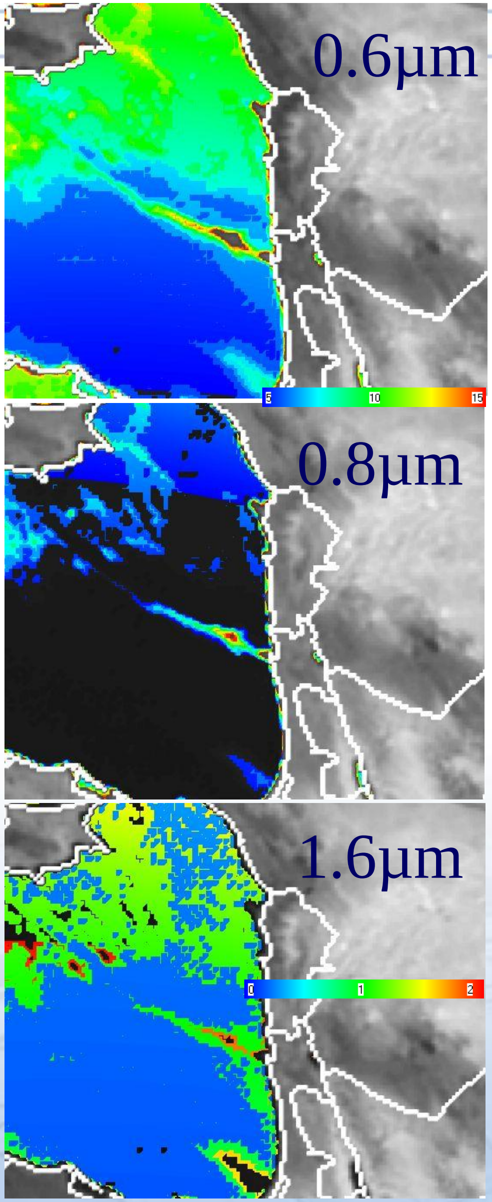


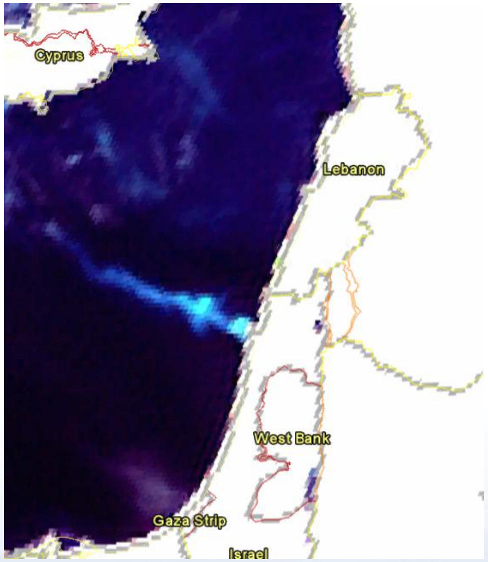
Meteosat-8 2009-07-03 2030 UTC, sunset

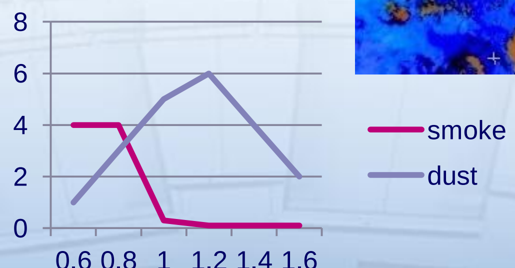




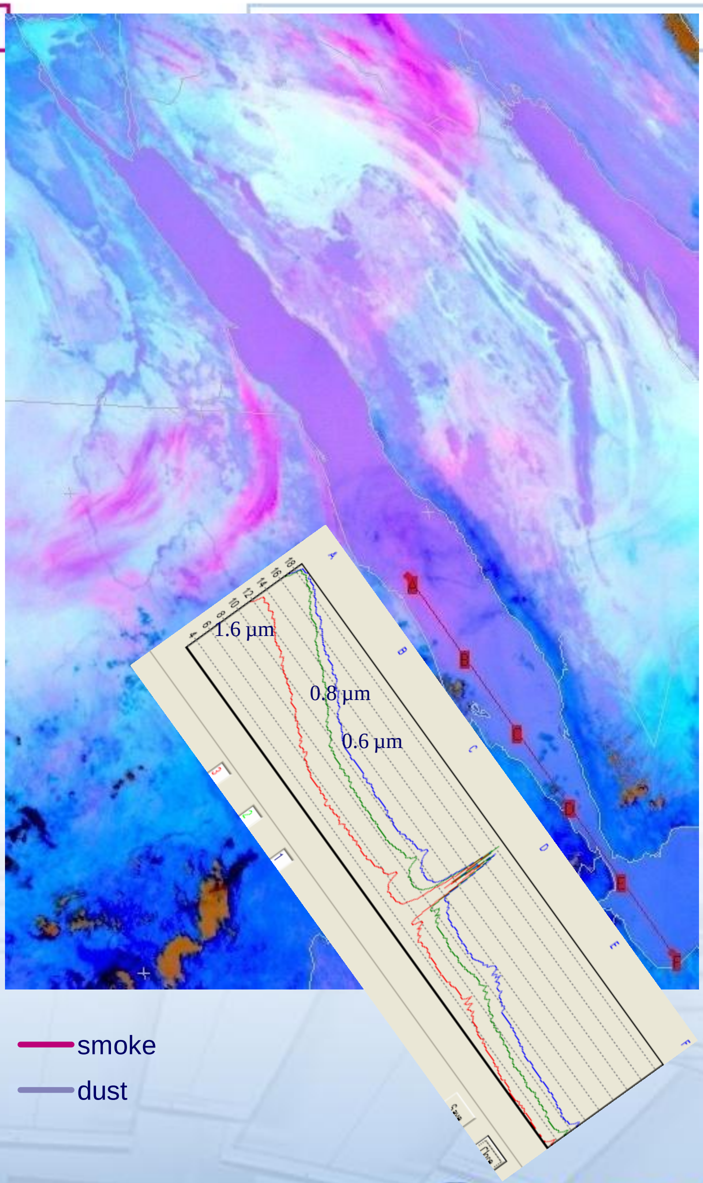
Ash or smoke is smaller than dust





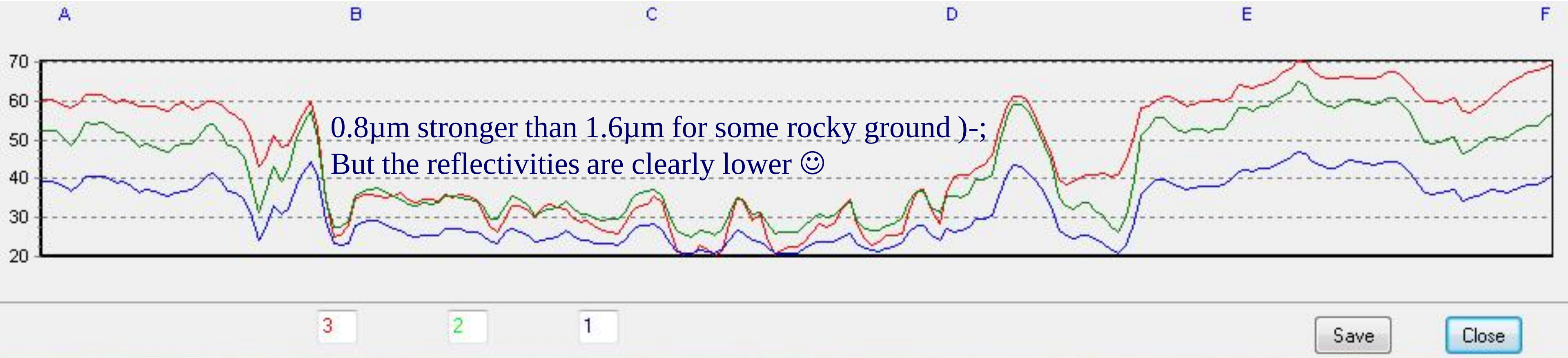


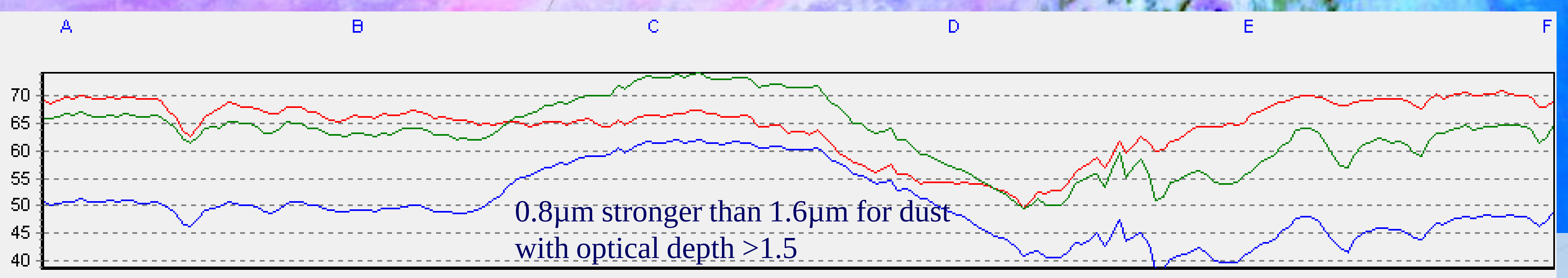
2010-06-23 0845UTC **Dust** over Red Sea



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

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





Spotting dust with solar channels

Why does dust increase reflectivity on desert for 0.6µm and 0.8µm ?

a. Dust particles reflect back most of the solar radiation, whereas soil does not.

Backscattering depends on concentration

b. Regions with dust above have very reflective ground, more reflective than in the neighbourhood.

Not always, since dust traverses diverse grounds

c. Scattering in the floating dust is more predominant over absorption than on the ground, made of big particles.

Indeed, the dust layer is more backscattering than the ground

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

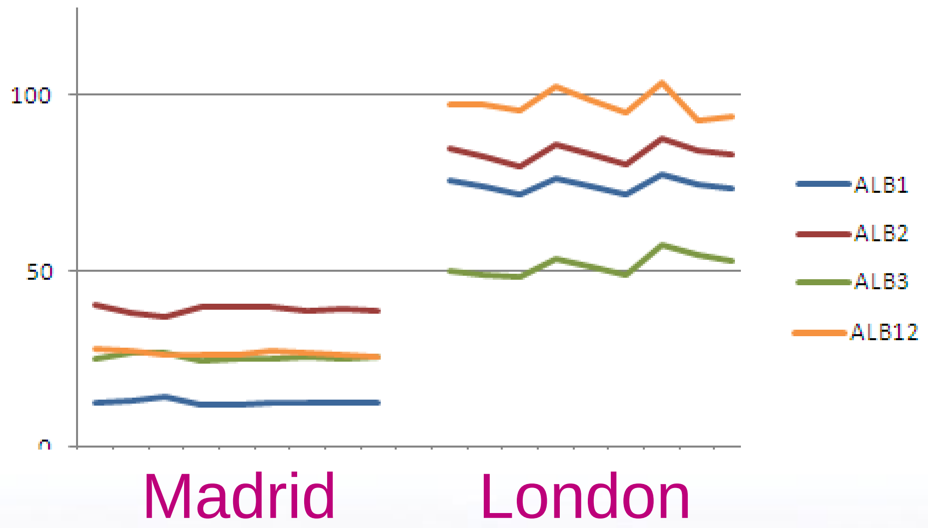
a. High values of (2-3)*(2+3)

b. High values of (3-2)/(3+2)

c. Small values of 2

d. High values of 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

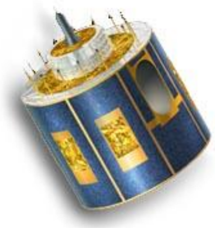
•For cloud over London, 1.6µm is weakest

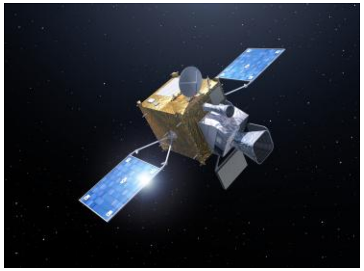
•HRV is average of the solar channels 0.6 and 0.8µm for land, but above both for cloud cover

Implementation of the EUMETSAT Geostationary Programme

1977 **2003** **2018**

MOP+MTP ***MSG*** ***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

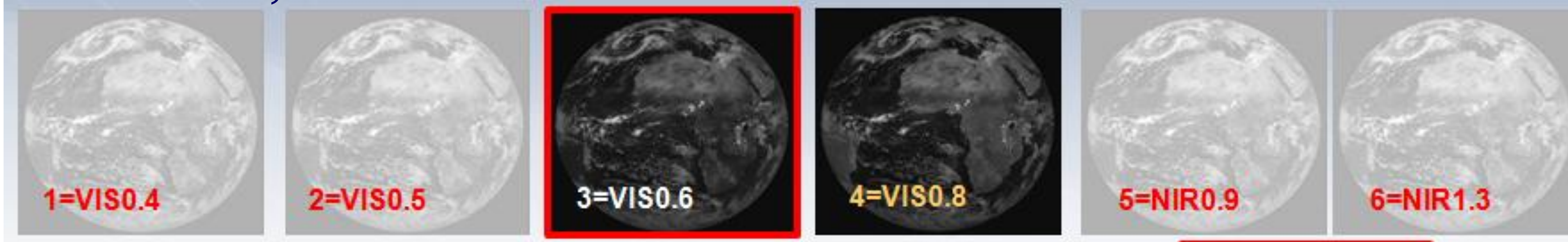
EUMETSAT

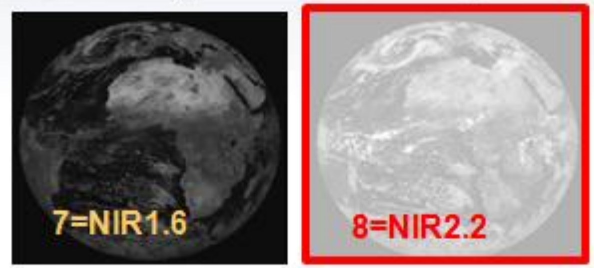
Third generation solar channels

Aerosol, true colour

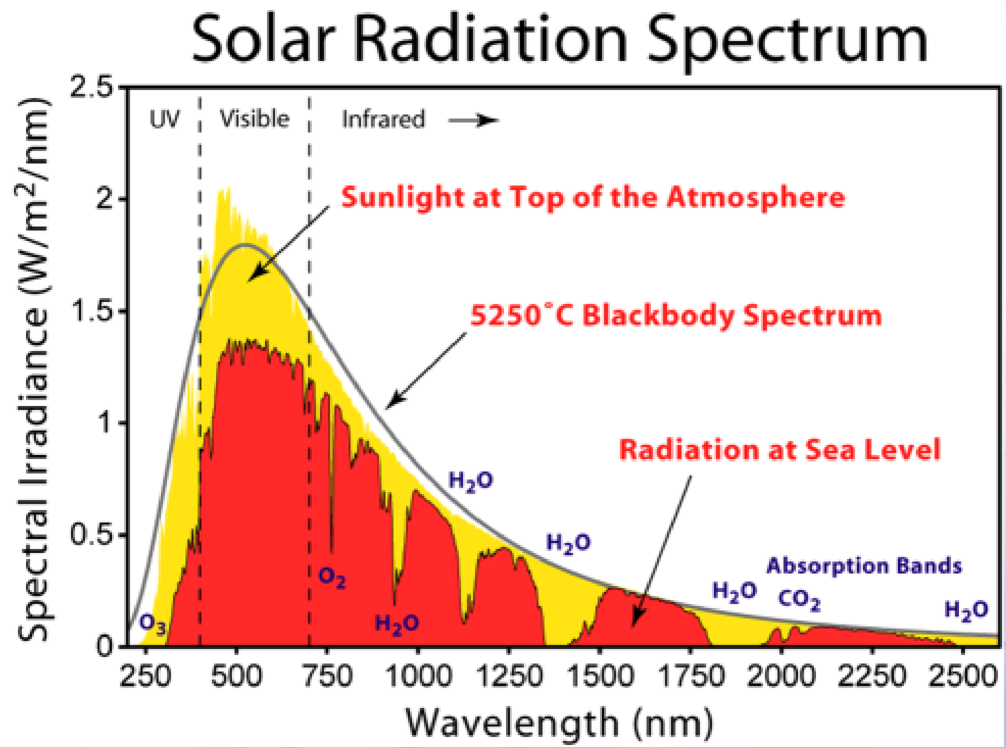
Water vapour over land

Thin cirrus



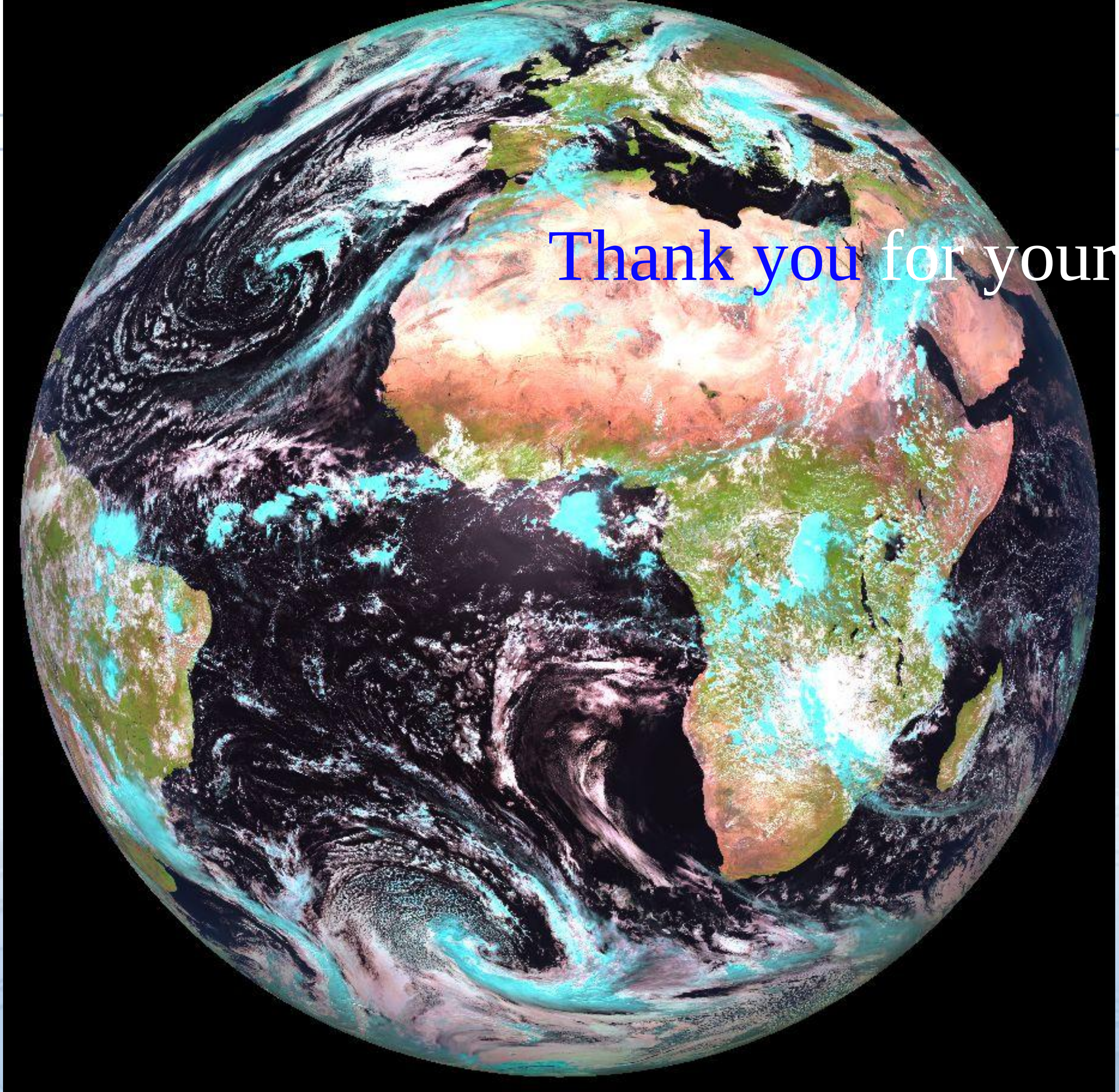


Cloud microphysics



Aerosol, ocean colour, flooding

Thank you for your attention



Meteosat 10
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