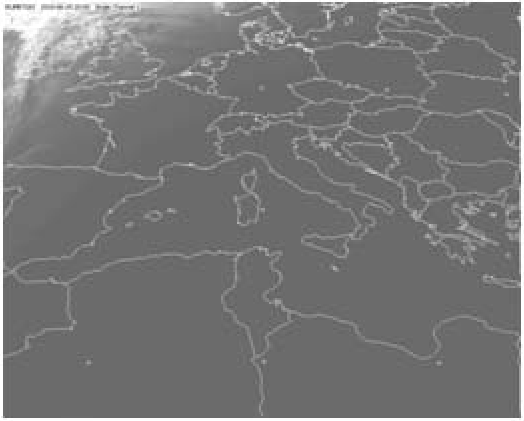
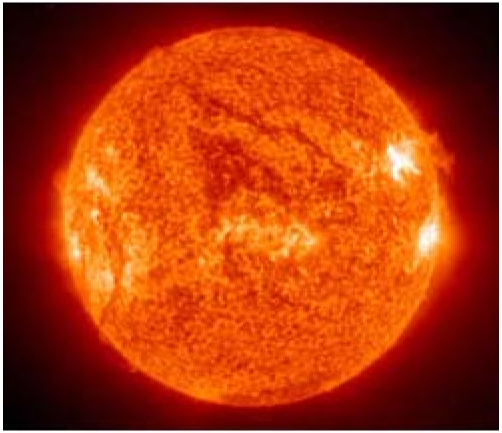
Meteosat solar channels

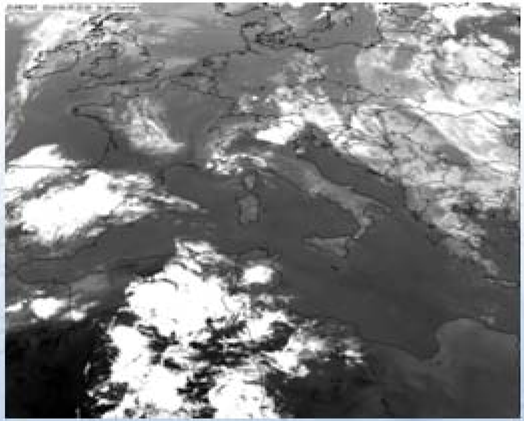
jose.prieto@eumetsat.int

EUMETSAT

Which IMAGE is VISIBLE ?

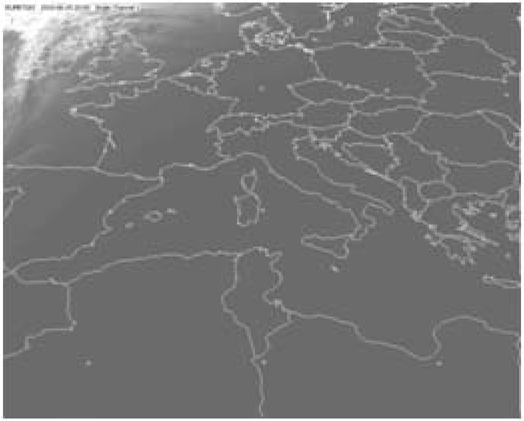


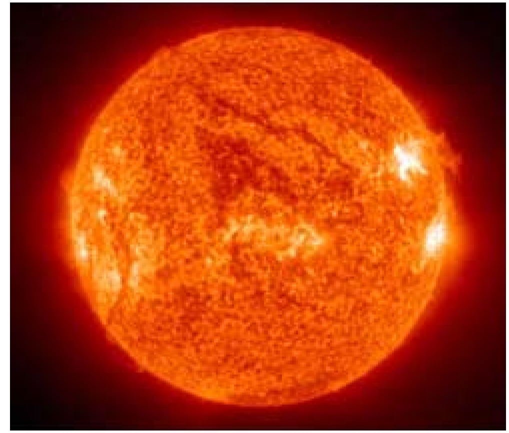




Which IMAGE is VISIBLE ?

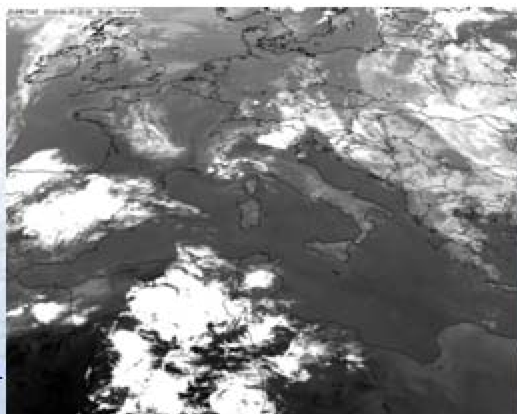
0.6μm





Soho

10.8μm



India

Most images are visible, fewer are SOLAR

EUMETSAT

SEVIRI CHANNELS

	Properties			
Channel	**Cloud**	**Gases**	**Application**	3
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

EUMETSAT

Meteosat solar channels

SEVIRI channel similarity

← solar → ←3.9→ ← thermal →

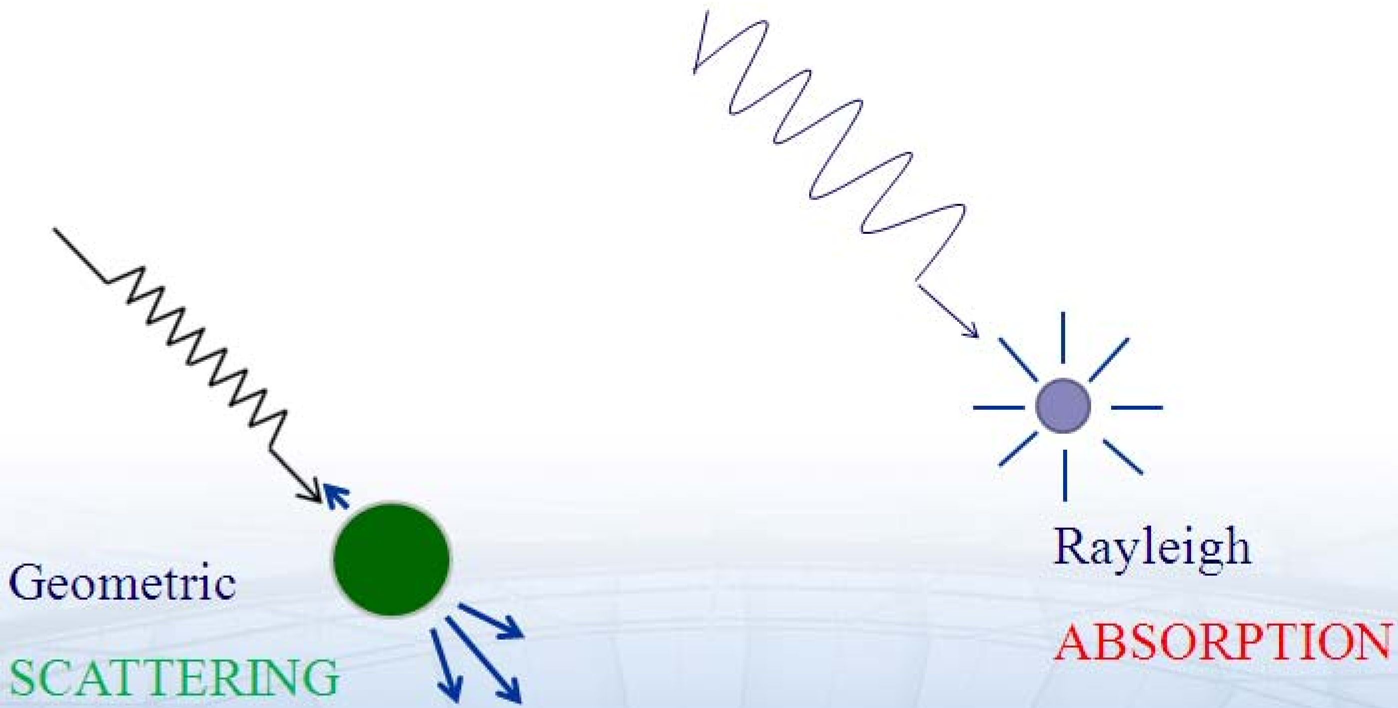
Channel	1	2	3	4	5	6	7	8	9	10
1										
2	0.99									
3	0.82	0.89								
4	0.26	0.35	0.60							
5	-0.47	-0.48	-0.46	0.08						
6	-0.46	-0.44	-0.34	0.42	0.80					
7	-0.61	-0.66	-0.68	0.00	0.80	0.83				
8	-0.60	-0.65	-0.66	-0.02	0.76	0.80	0.99			
9	-0.60	-0.64	-0.68	-0.02	0.82	0.83	0.99	0.97		
10	-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 low correlation with the thermal

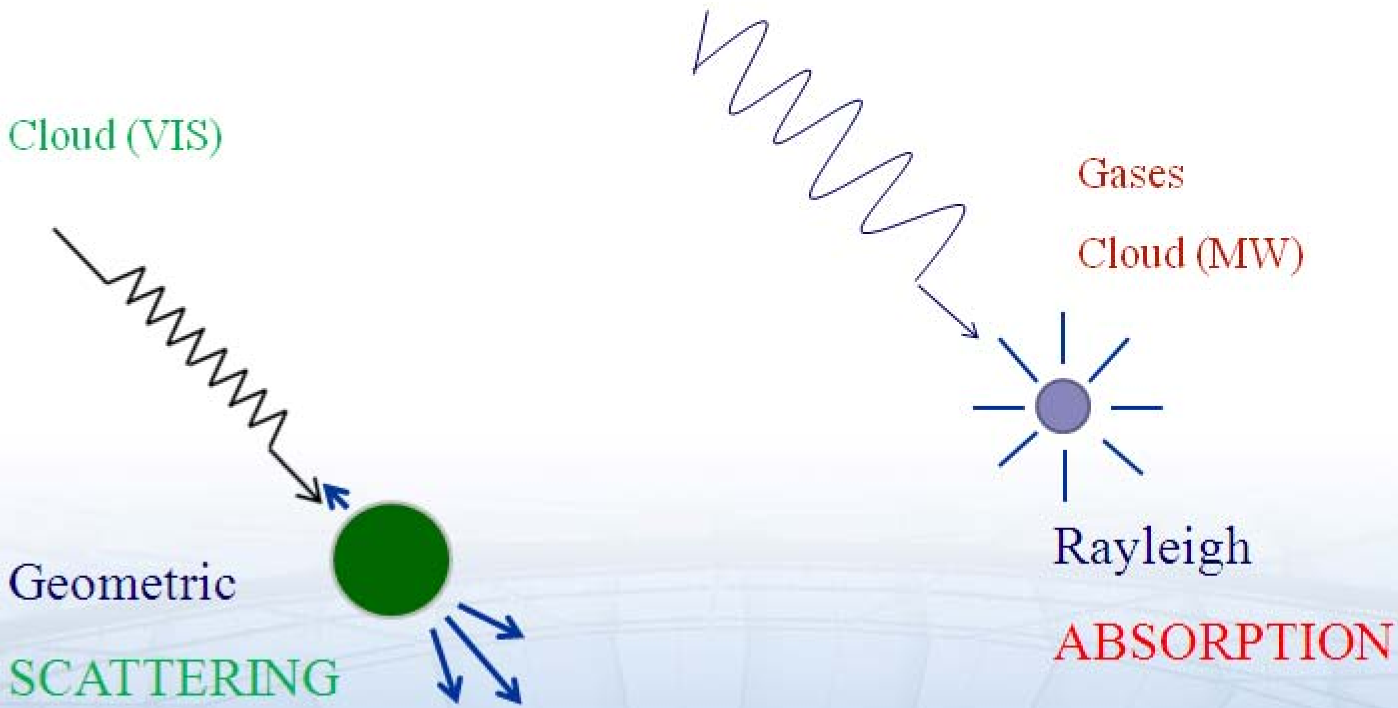
Contents

Contents

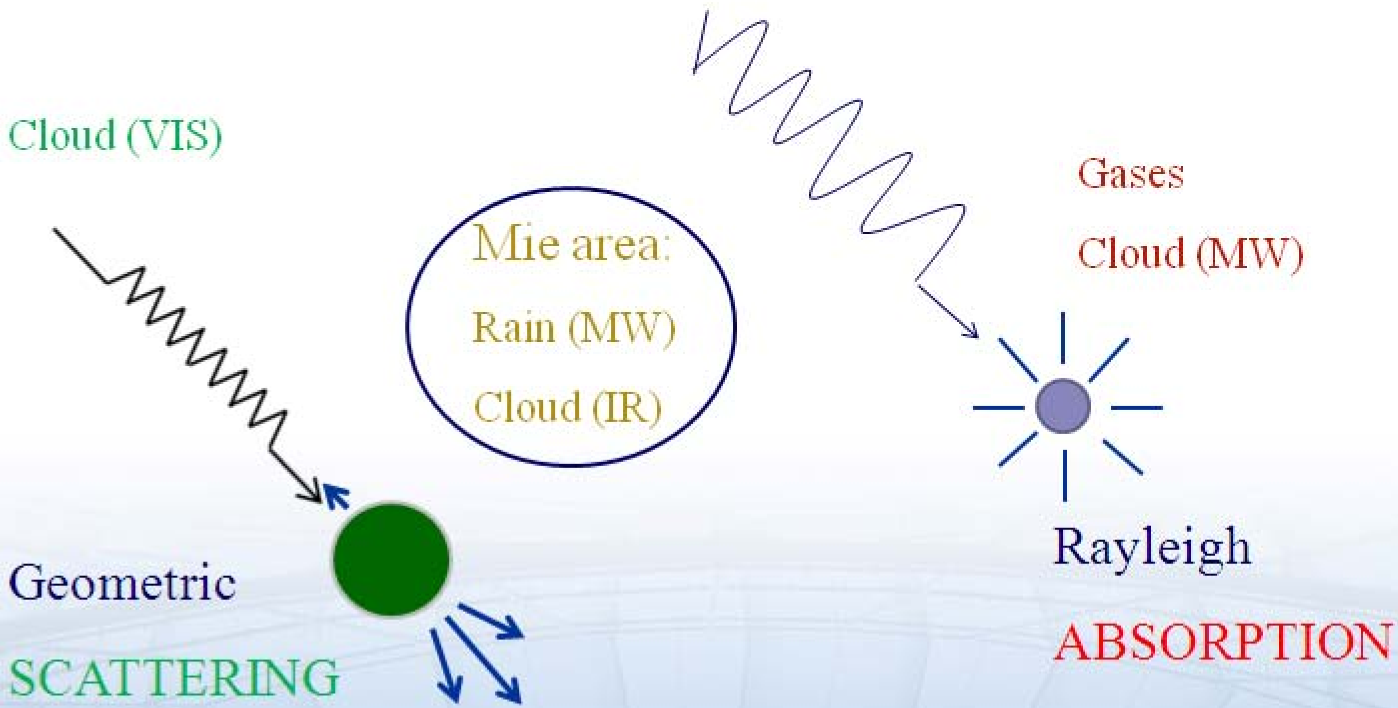
RADIATION and MATTER



RADIATION and MATTER



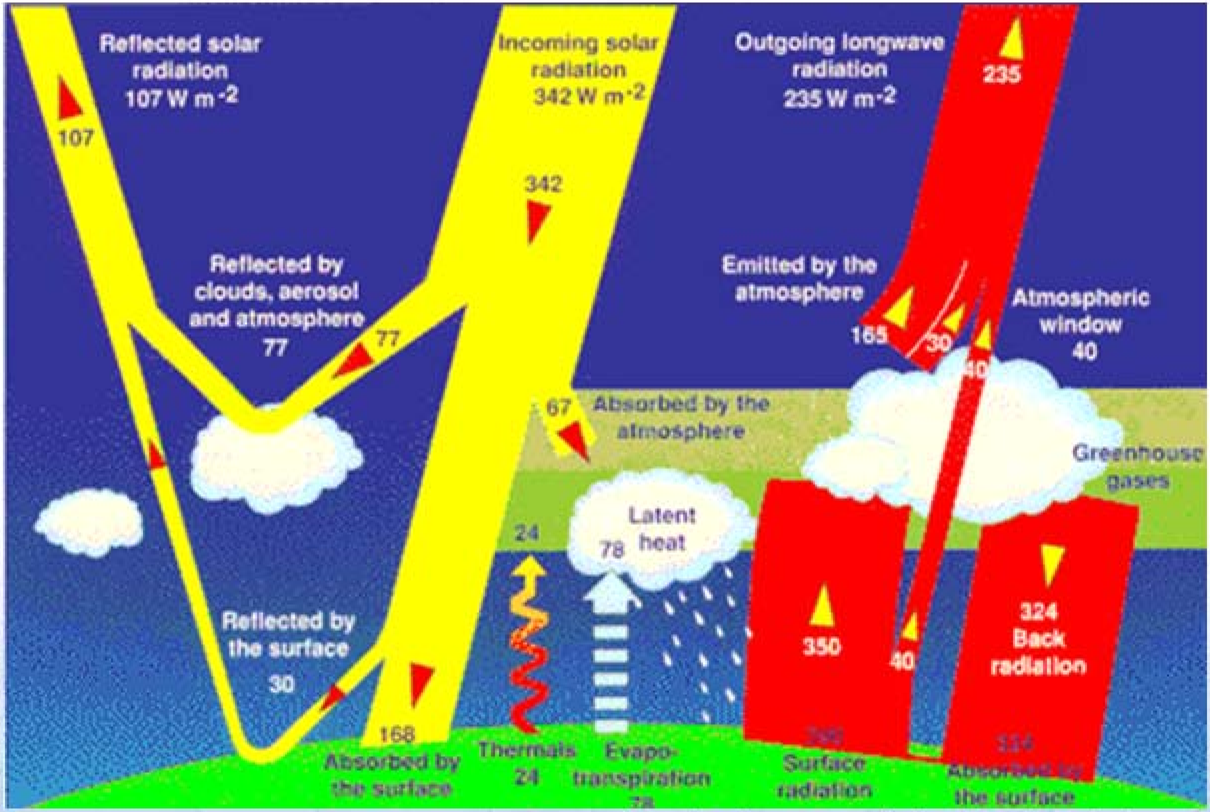
RADIATION and MATTER



EUMETSAT

Meteosat solar channels

Top of the atmosphere: solar + thermal = 0



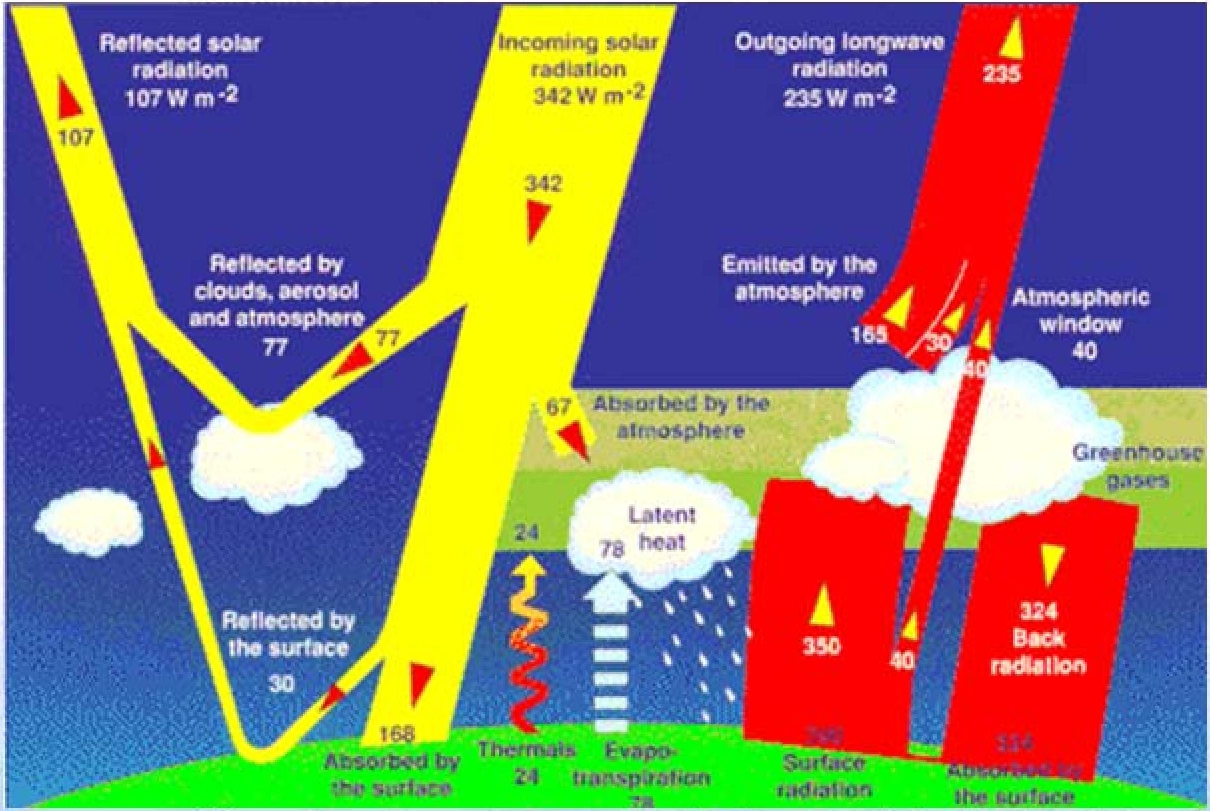
http://asd-www.larc.nasa.gov/ceres/brochure/clouds_and_energy.html

<u>Reflectors</u>

Cloud G
Land
Plankton
Ocean
Oil slicks
Humidity
Aerosol
Air

Top of the atmosphere: solar + thermal = 0

Classify the reflectors:
Rayleigh
Geometric
Mie



http://asd-www.larc.nasa.gov/ceres/brochure/clouds_and_energy.html

Reflectors

Cloud G
Land
Plankton
Ocean
Oil slicks
Humidity
Aerosol
Air

Which is not a reflector?

EUMETSAT

Earth Surface   Channel 01 (VIS0.6)   Clouds

High reflectance

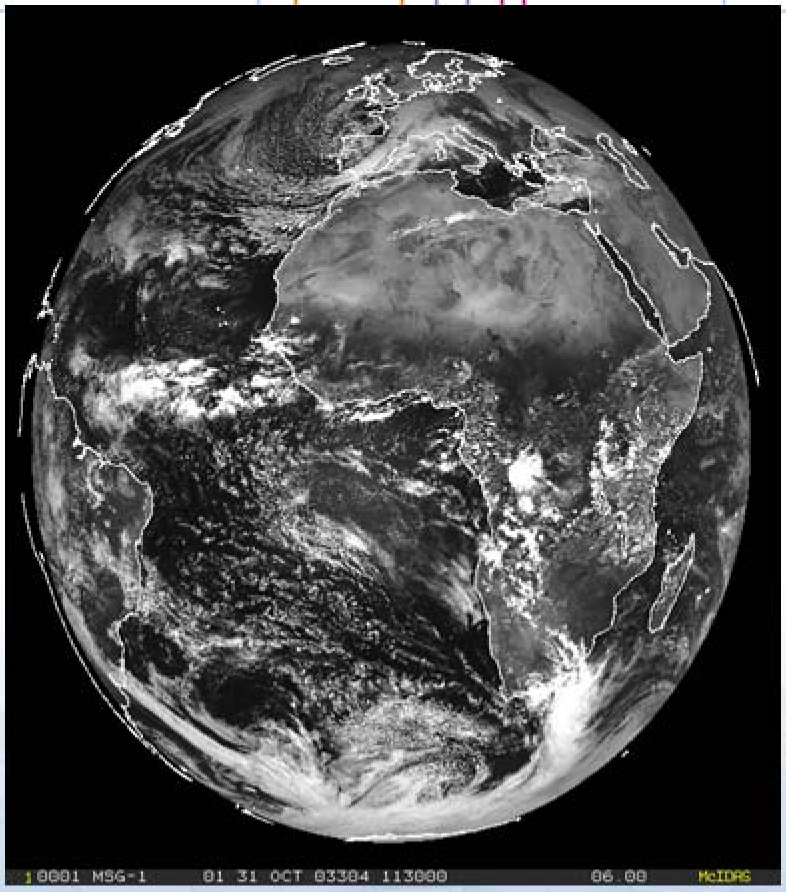
Sun Glint
Snow

Desert

Bare Soil

Forest

Ocean, Sea



31 October 2003, 11:30 UTC

thick clouds

thin clouds over land

thin clouds over ocean

Low reflectance

EUMETSAT

Earth Surface Channel 02 (VIS0.8) Clouds

Sun Glint
Snow

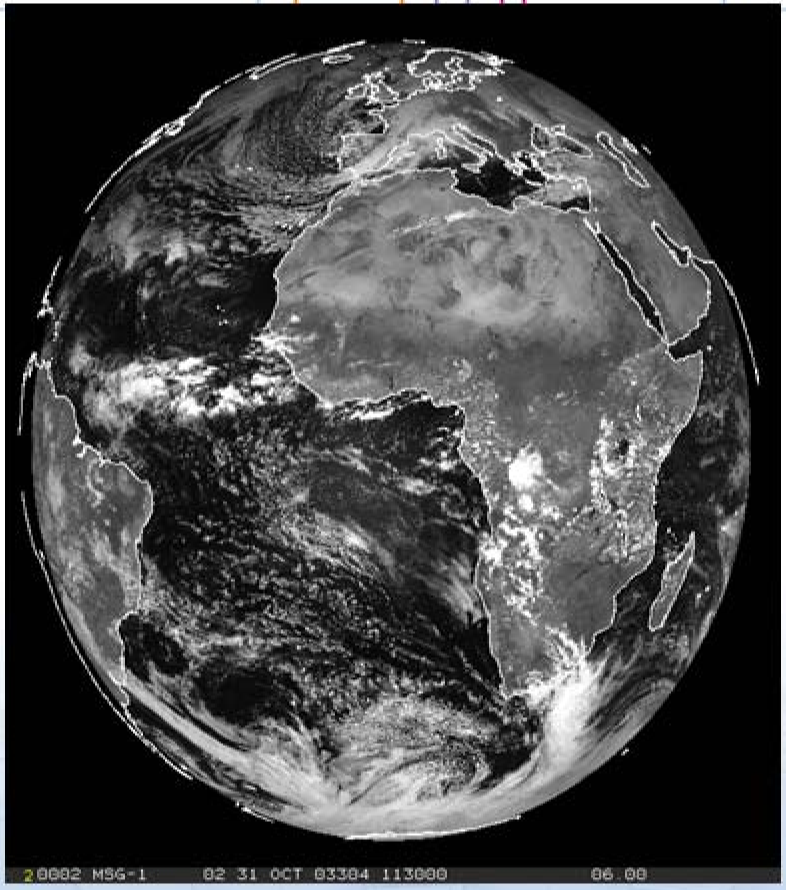
Desert

Gras, Rice fields

Forest

Bare Soil

Ocean, Sea



High reflectance

thick clouds

thin clouds over land

thin clouds over ocean

Low reflectance

31 October 2003, 11:30 UTC

EUMETSAT

Earth Surface — Channel 03 (NIR1.6) — Clouds

High reflectance

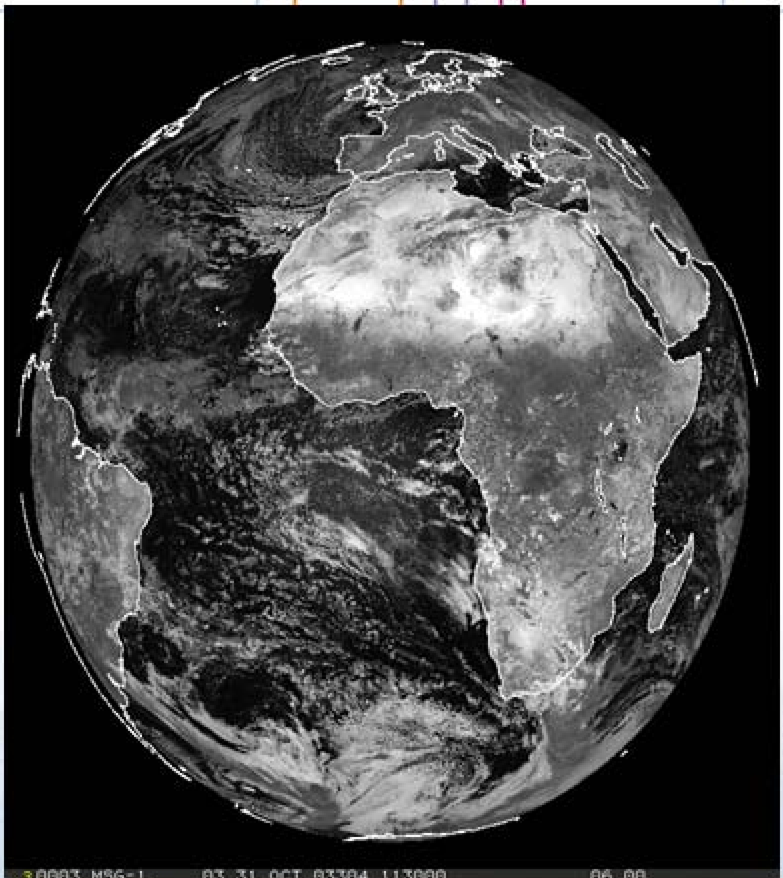
Sun Glint
Sand Desert

Gras, Rice fields

Forest

Bare Soil

Snow
Ocean, Sea



31 October 2003, 11:30 UTC

Water clouds (small droplets)

Water clouds (large droplets)

Ice clouds (small particles)

Ice clouds (large particles)

Low reflectance

EUMETSAT

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)

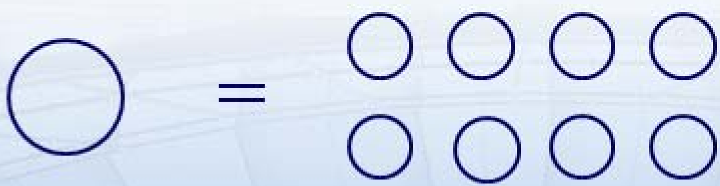
-crystal shape

SOLAR IMAGES

0.6 µm albedo scale:

CLOUD ALBEDO is the result of:
-optical depth= concentration * particle section * layer thickness
-liquid or ice (phase)
-crystal shape

Small droplets more reflective? More section for the same amount of water:



section=4
volume=8

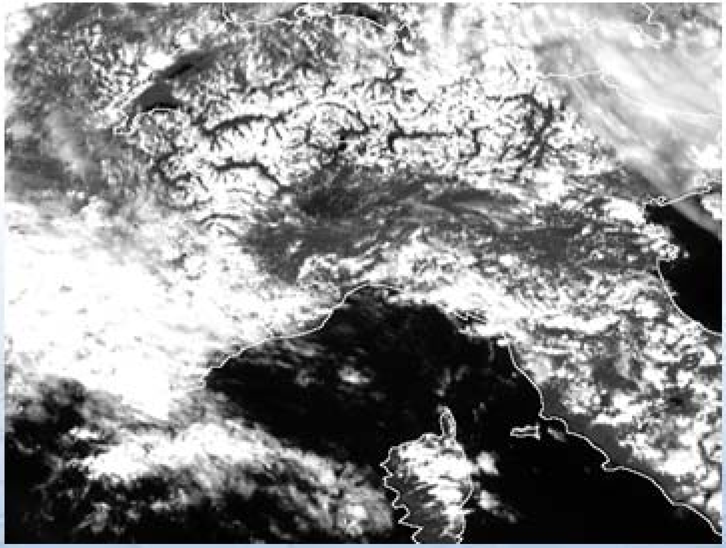
section=8
volume=8

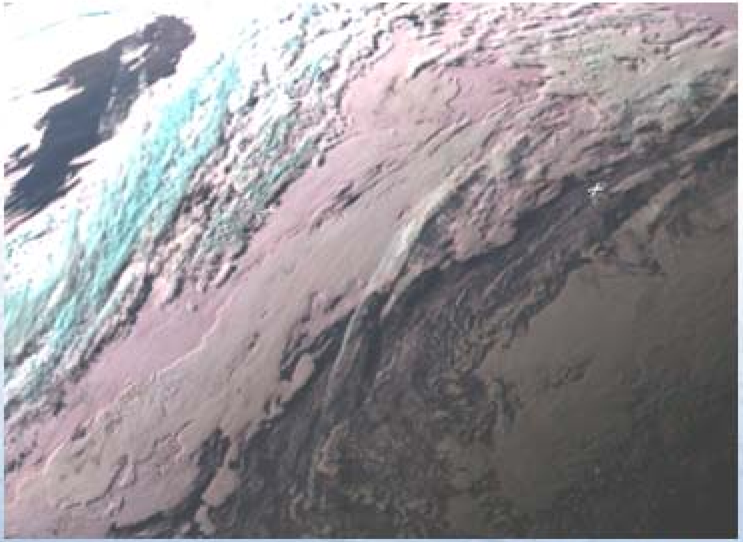
In addition, smaller droplets are more efficient reflectors

EUMETSAT

SOLAR images characteristics

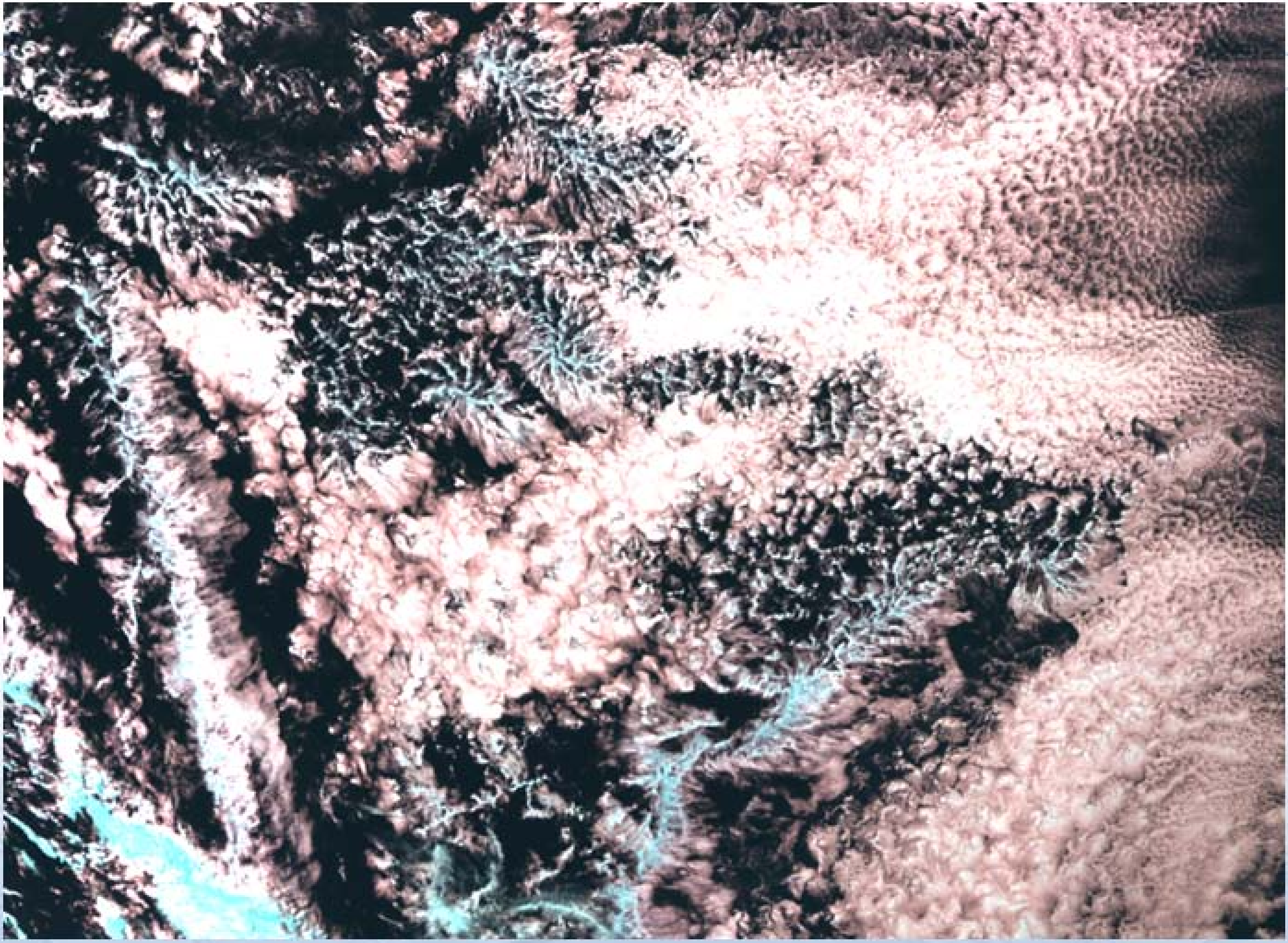
-**Shades**: oblique sun, vertical structure. Reflective boundaries
-**Texture** (local standard deviation): cloud type. Sc from St
-**Clouds** versus dendritic more permanent **snow**
-**Thin** Ci: frequently not detected, more visible over ocean. Better in IR



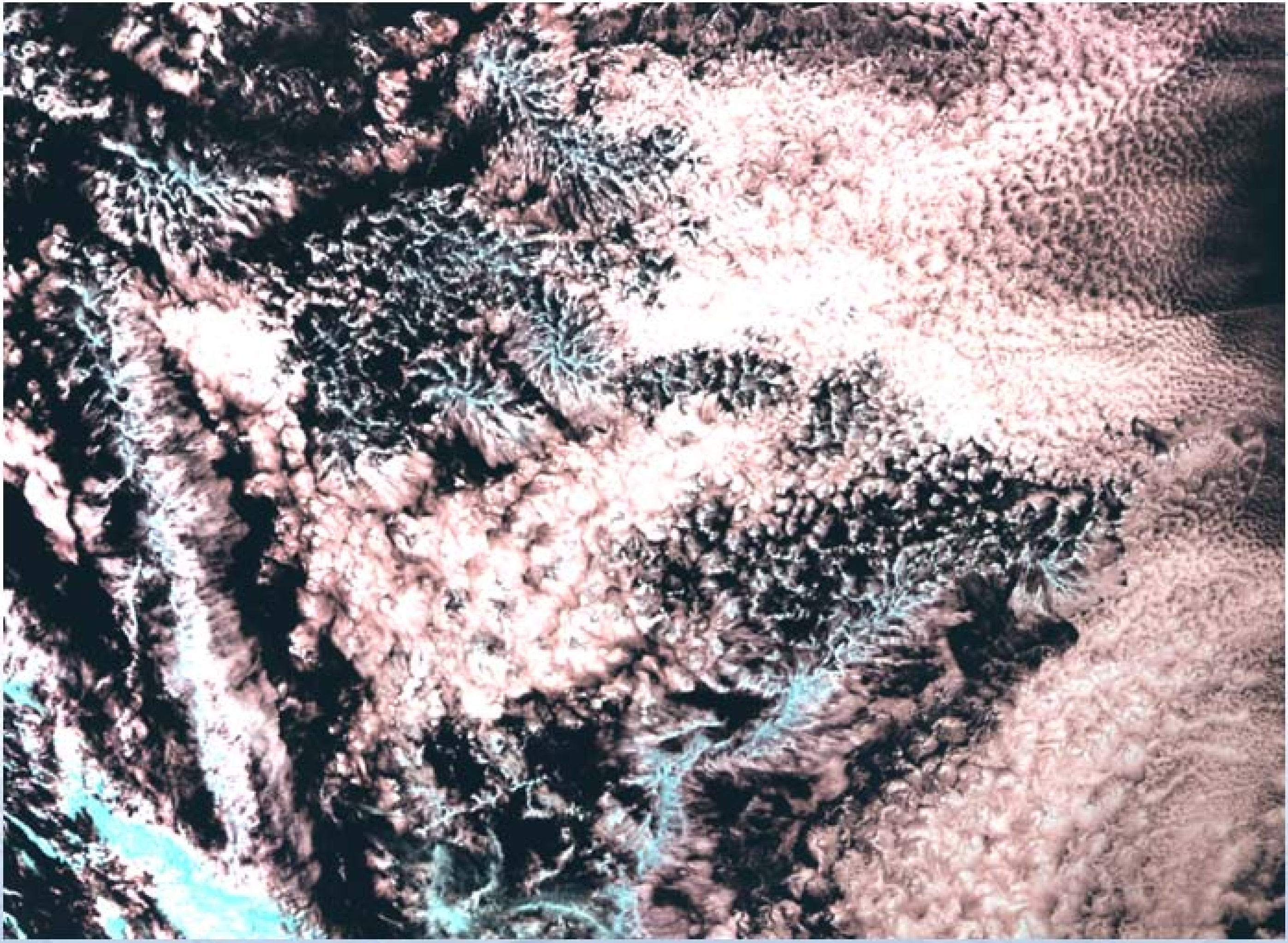


EUMETSAT

Meteosat solar channels



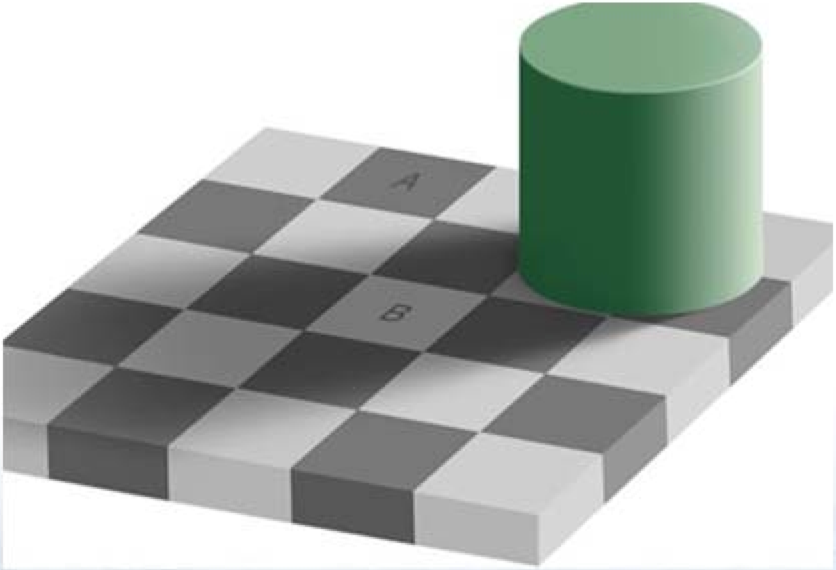
Which mountain range is this?



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

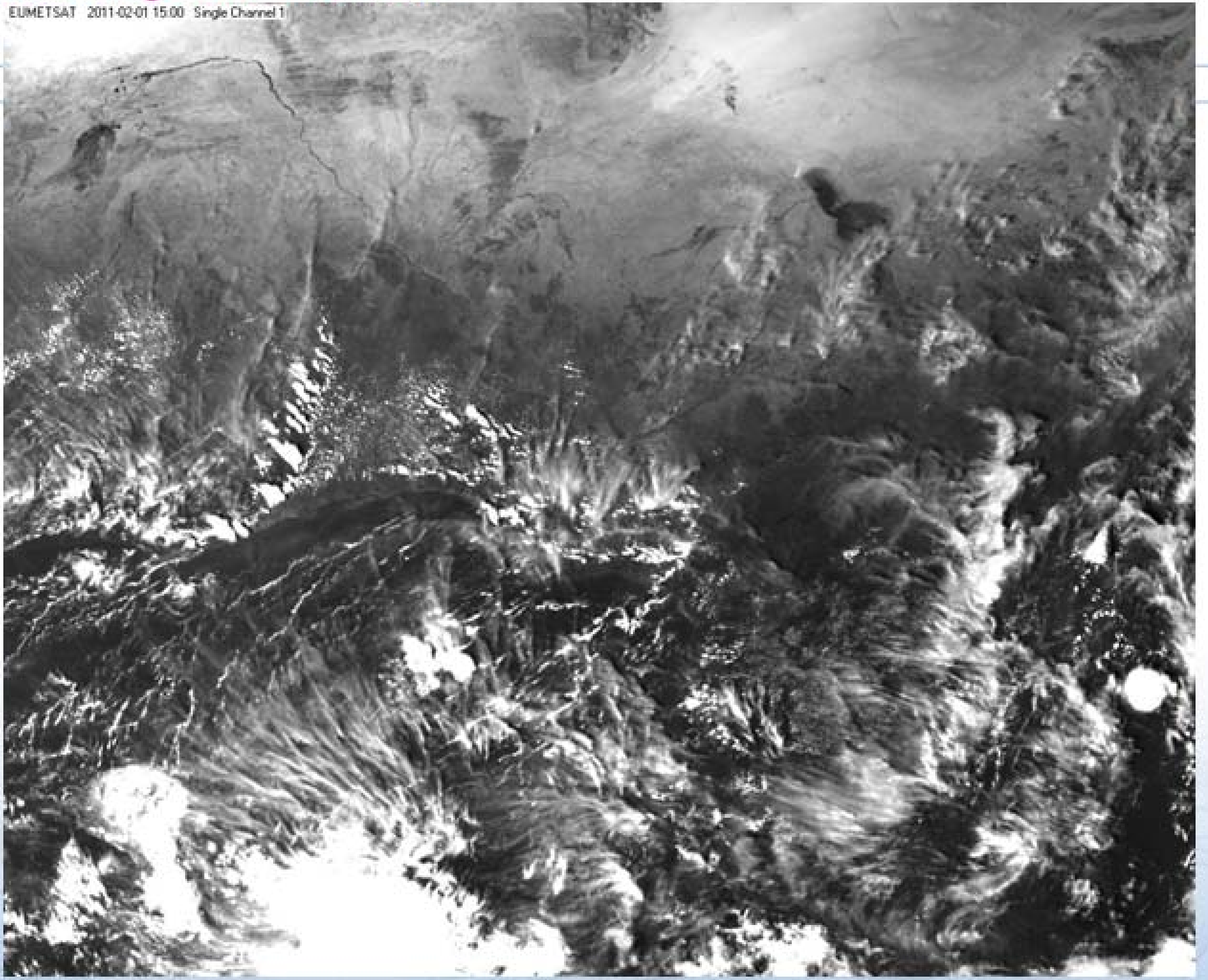
Which mountain range is this?

I can not believe my eyes



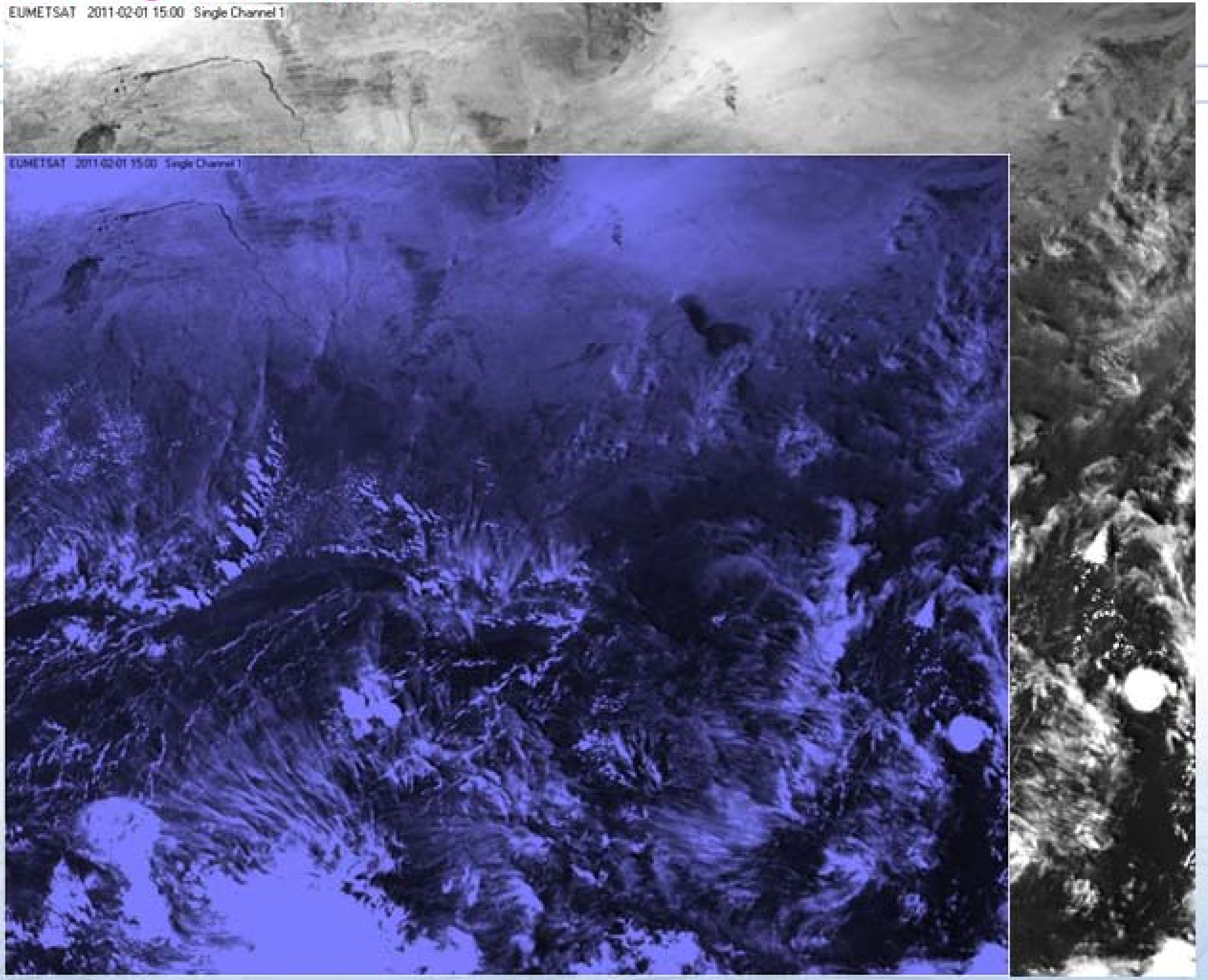
Which cell is darker: A or B ?

Combining solar channels



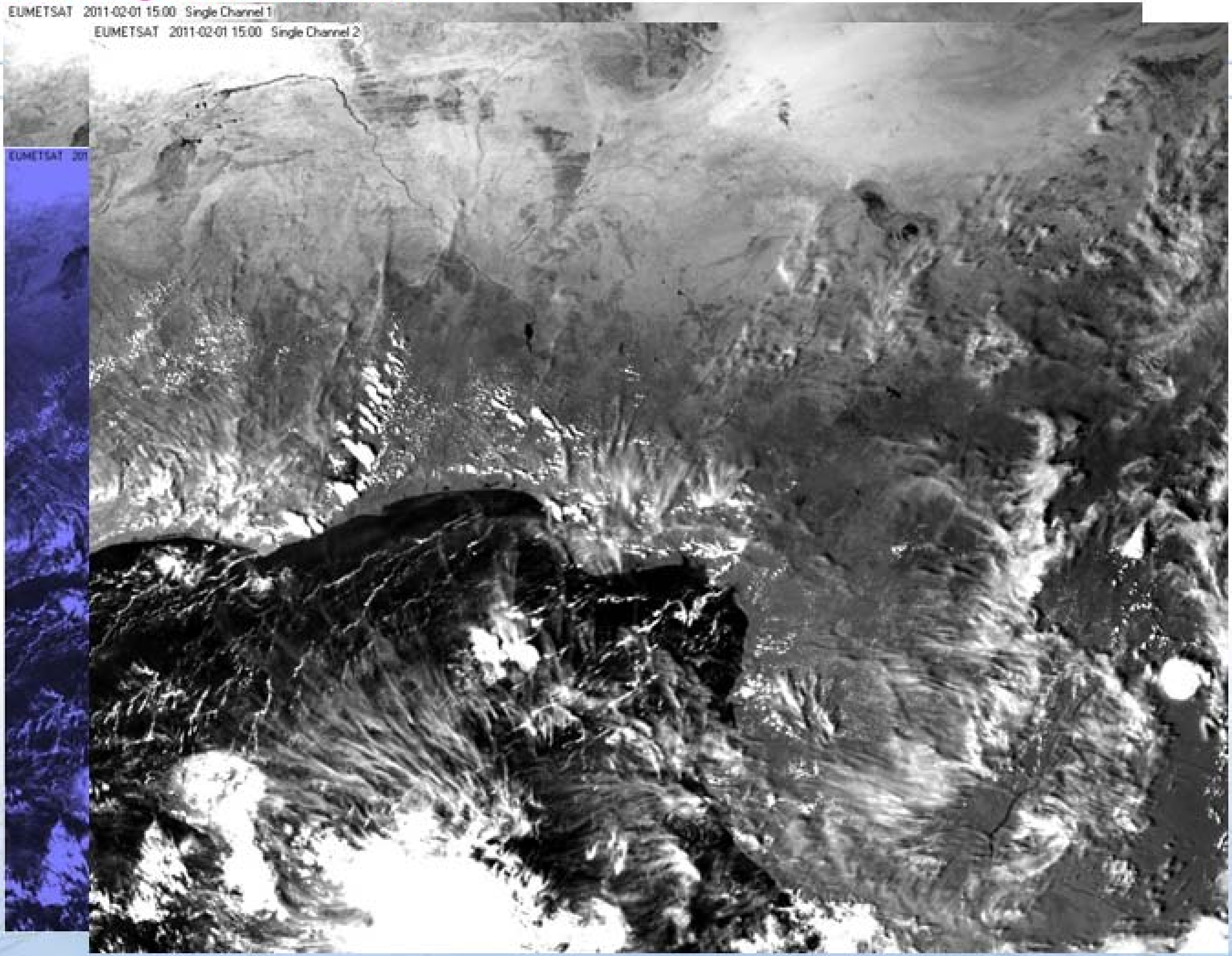
Meteosat solar channels

Combining solar channels



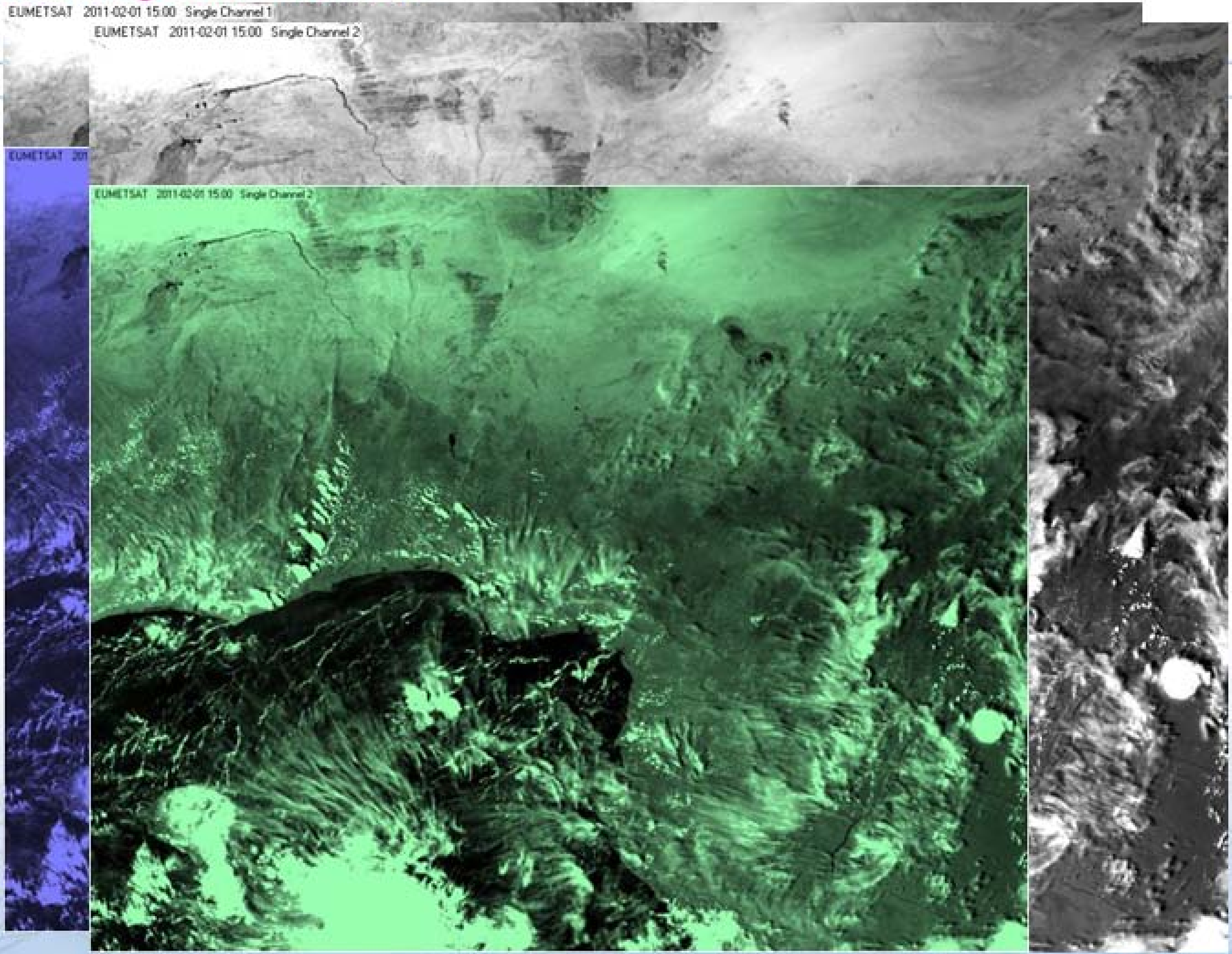
Meteosat solar channels

Combining solar channels



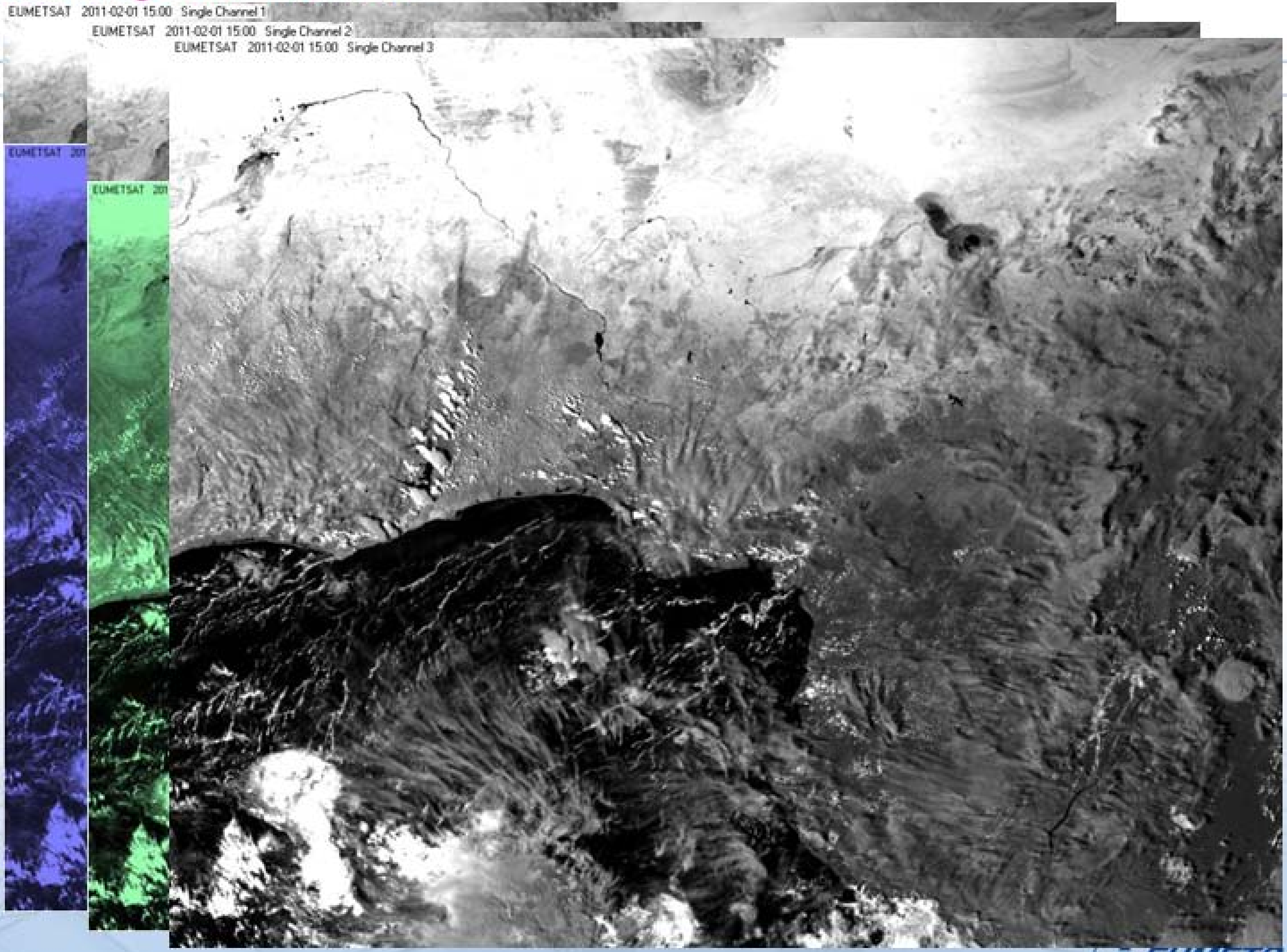
Meteosat solar channels

Combining solar channels



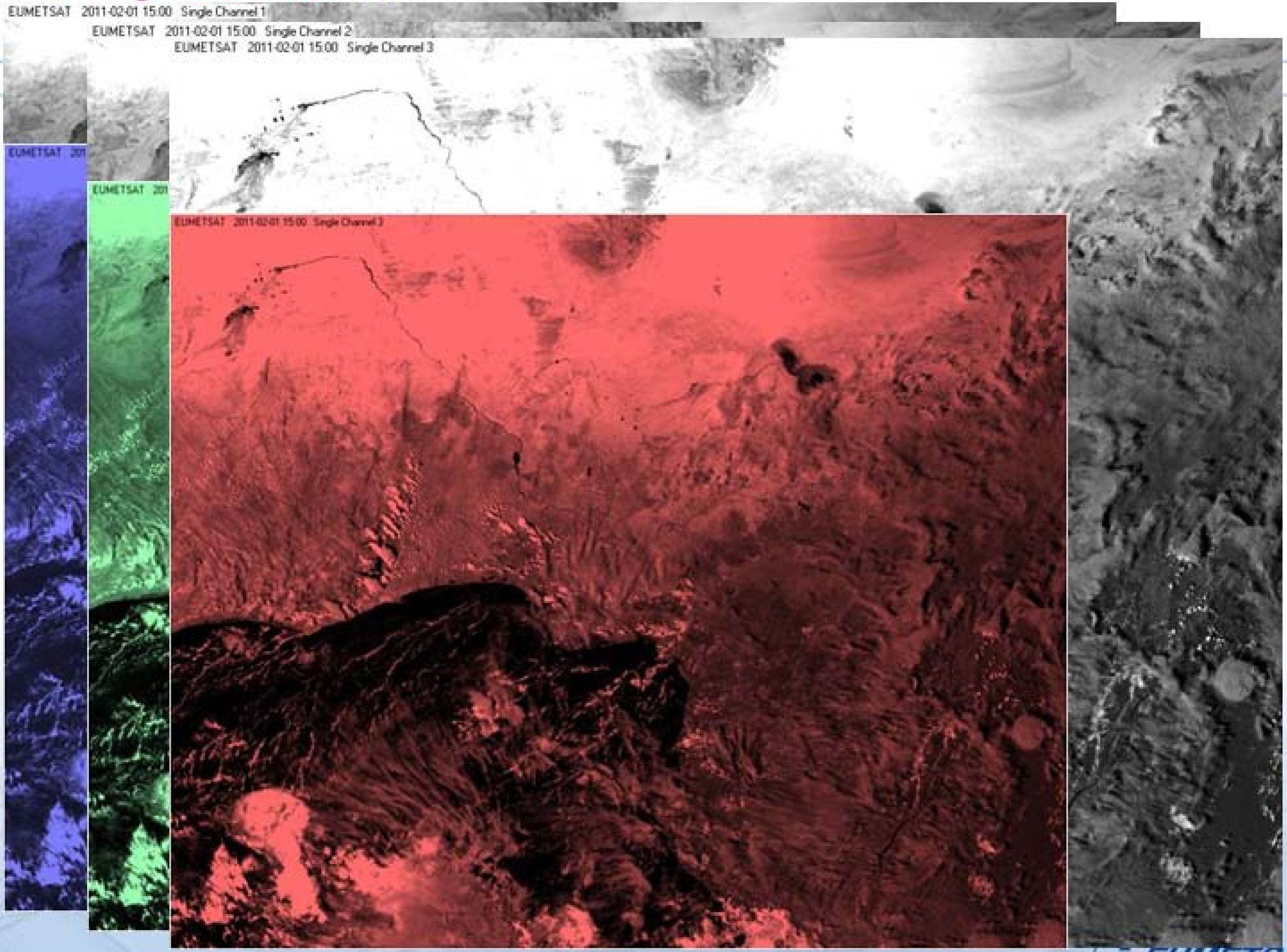
Meteosat solar channels

Combining solar channels



Meteosat solar channels

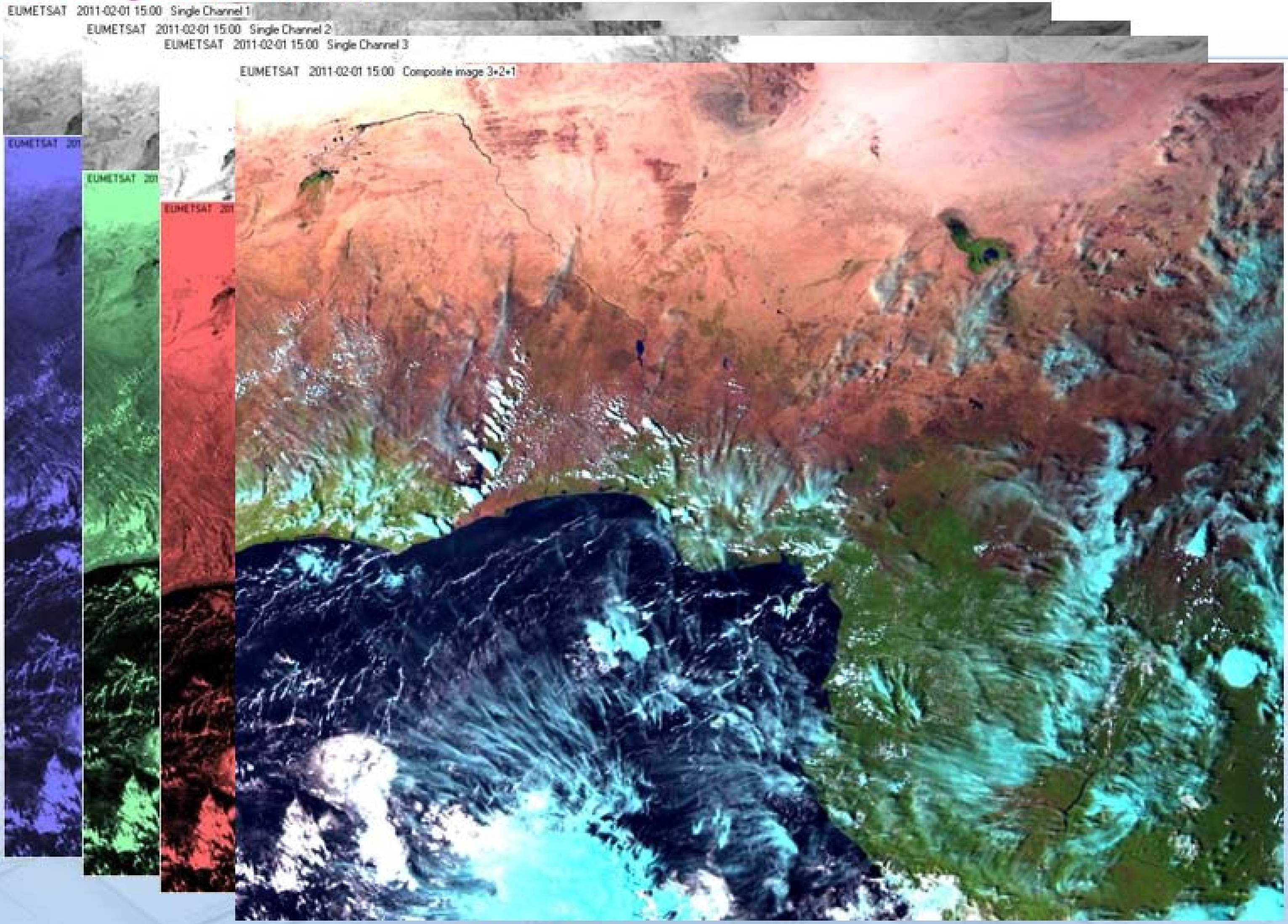
Combining solar channels



EUMETSAT

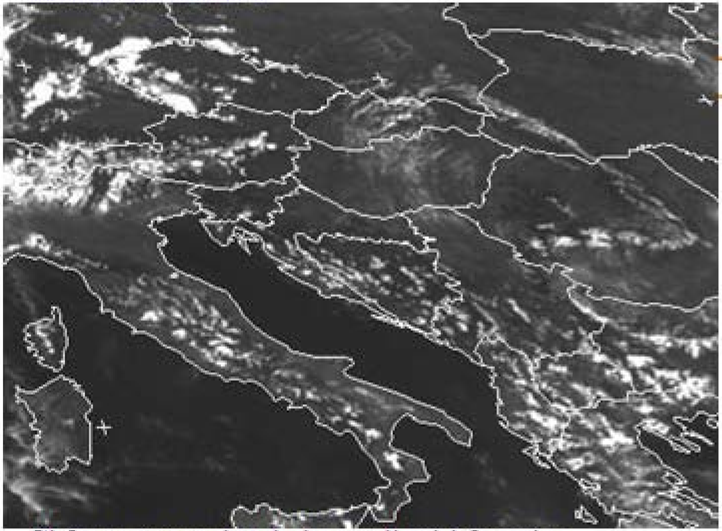
Meteosat solar channels

Combining solar channels



Meteosat solar channels

Ch1 filters out land



Ch2 informs on land vegetation

Ch3 separates cloud phases: liquid from ice

RGB 321 provides land and cloud type information

Meteosat solar channels: displays

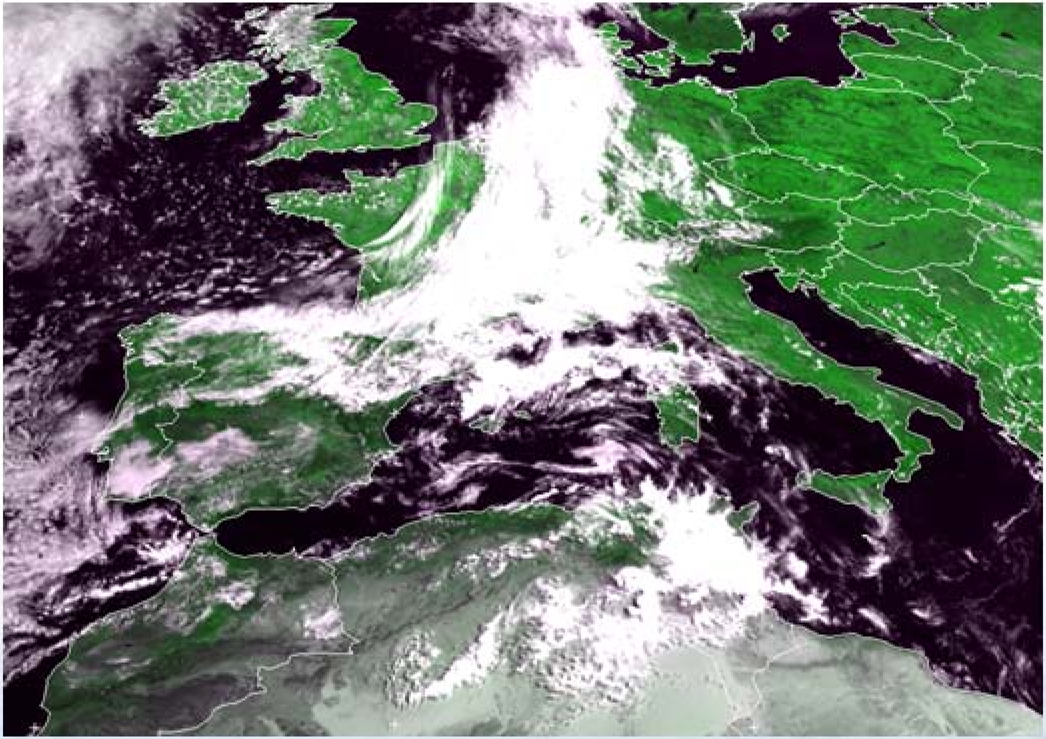
Exercise: how was this image produced?

a. Colour enhancement based on channel 2

b. Colour composite channels 3-2-1

c. Colour composite channels 2-2-1

d. Colour composite channels 1-2-1



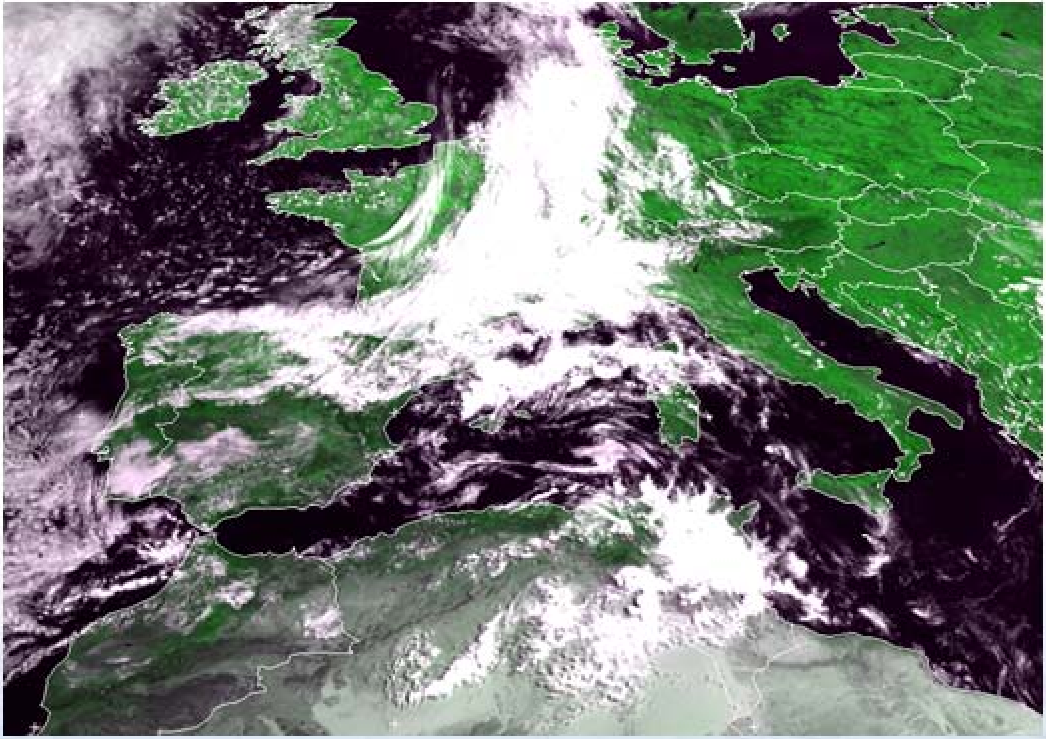
Exercise: how was this image produced?

a. Colour enhancement based on channel 2

b. Colour composite channels 3-2-1

c. Colour composite channels 2-2-1

d. Colour composite channels 1-2-1

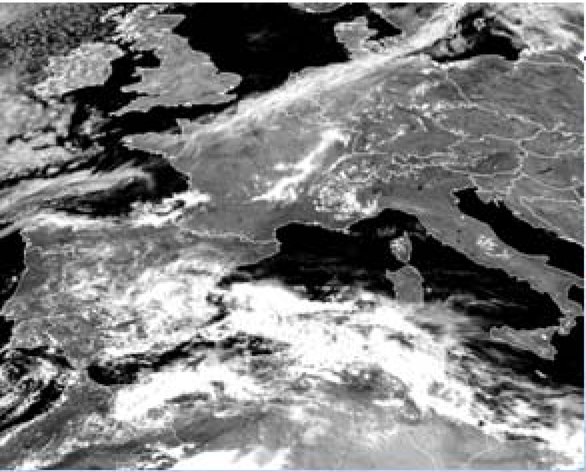


RGB 1-2-1, 2011-05-31 8:15 UTC Meteosat-9

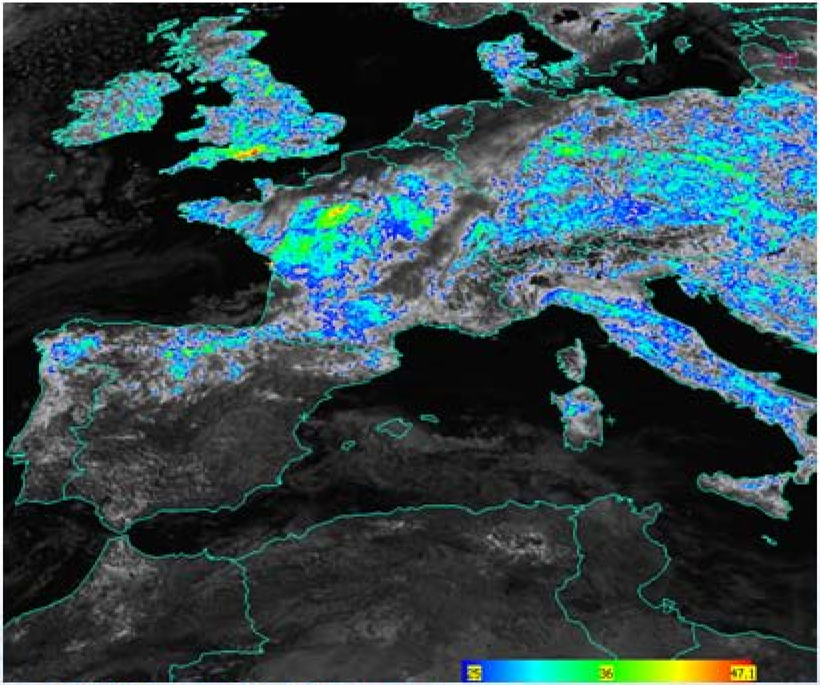
Contents

Solar channel differences over land

VIS0.6



VIS0.8



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

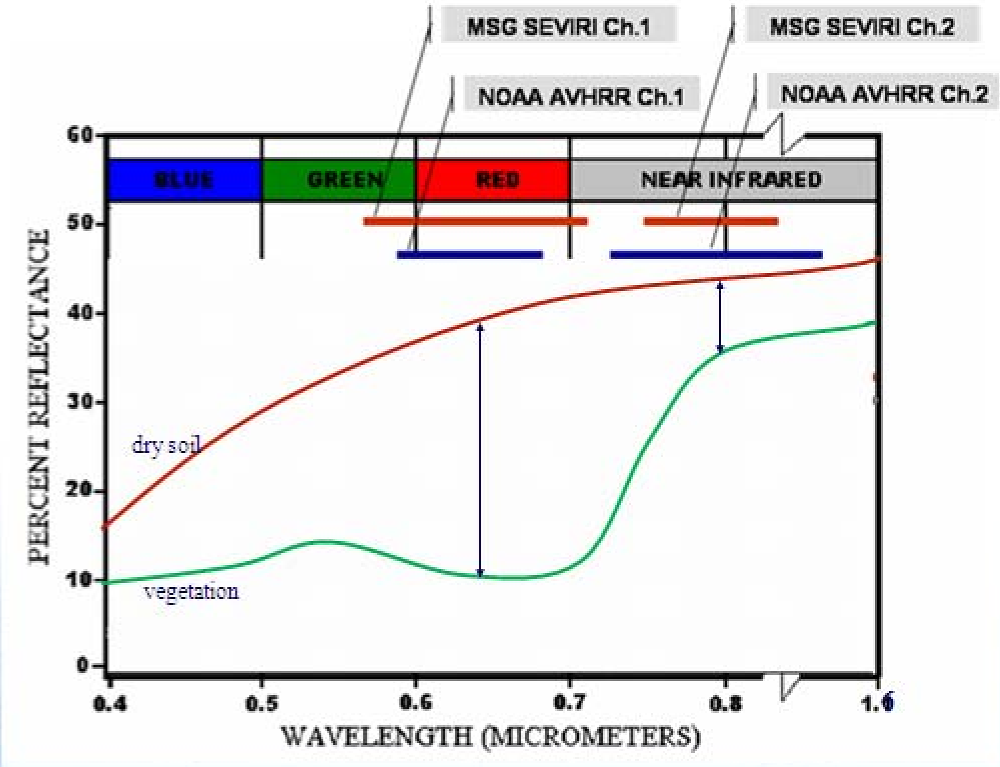
- VIS0.8: higher land surface contribution, especially over vegetated areas
- The difference can be sliced to remove cloud, by restricting to high values (+25% … +50%)

Pixel reflectivity : scale problem

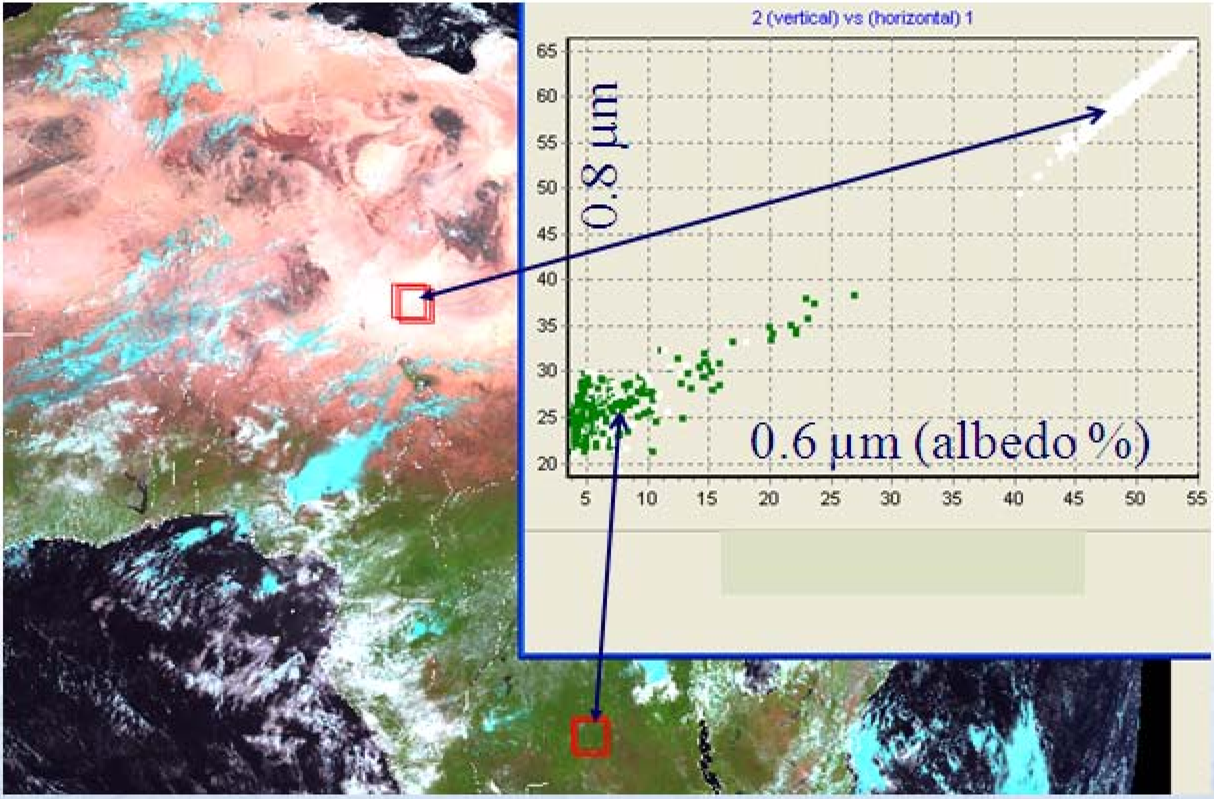
15% difference of albedo differences

EUMETSAT

Vegetated and dry soils



Desert and tropical forest in the solar channels



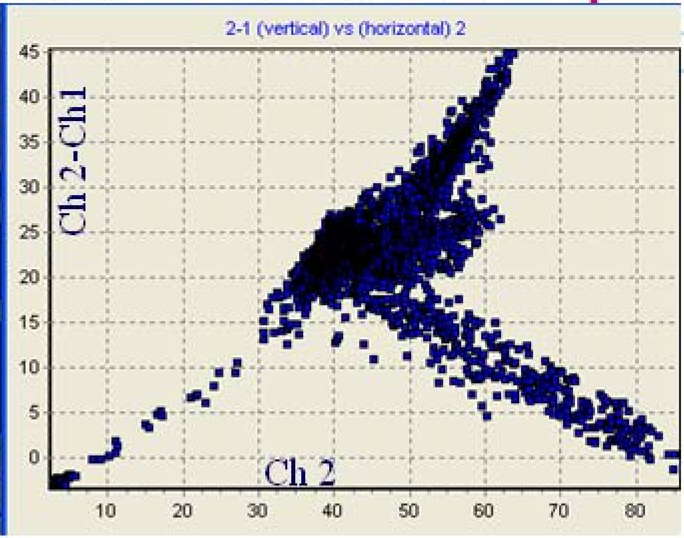
Vegetation index = (2-1)/(2+1)

EUMETSAT

Meteosat solar channels

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

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



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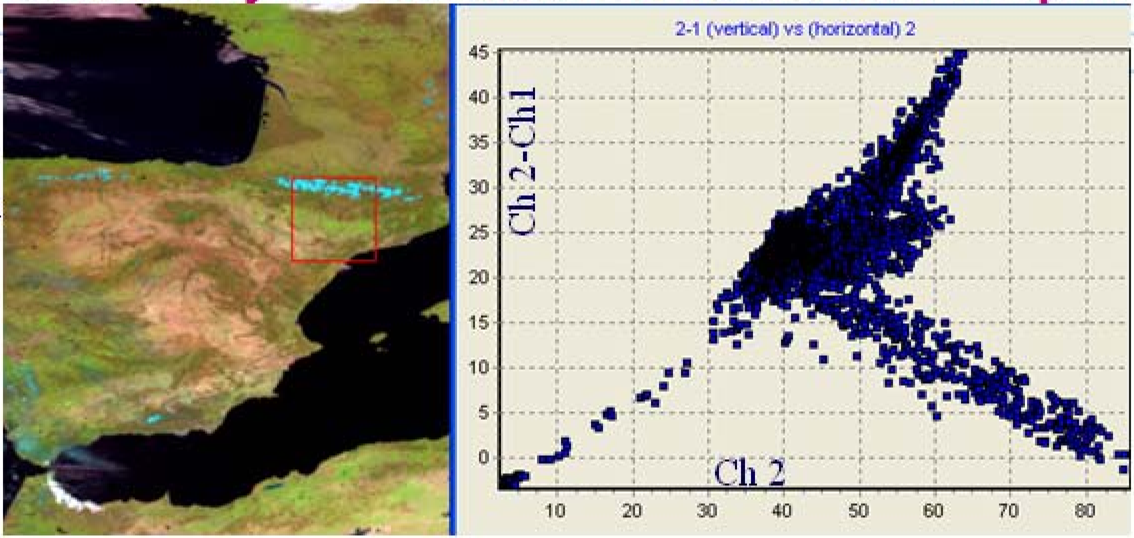
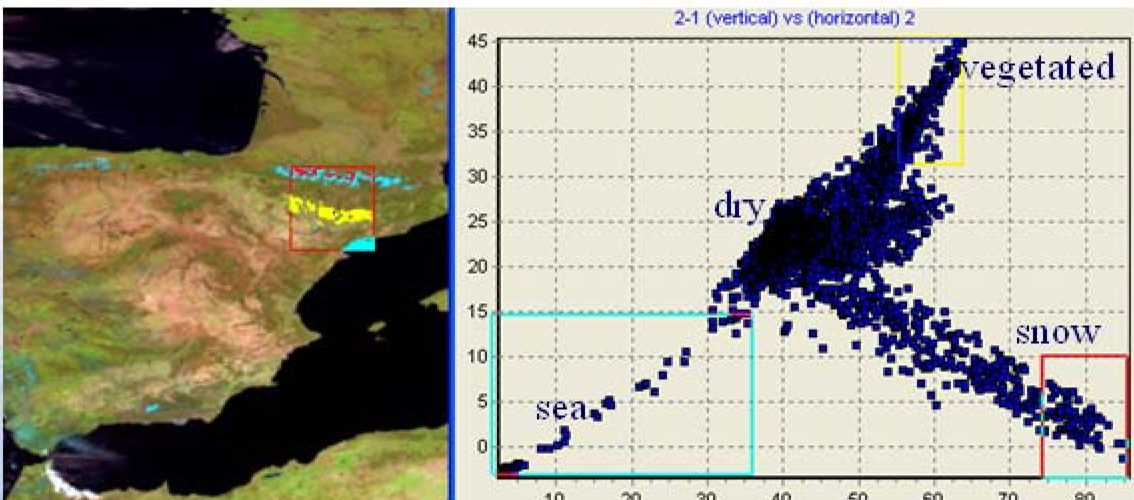
Meteosat-9
RGB Natural colours
2008-04-06
12UTC





EUMETSAT

LAND SURFACE ANALYSIS
SATELLITE APPLICATIONS FACILITY

Home

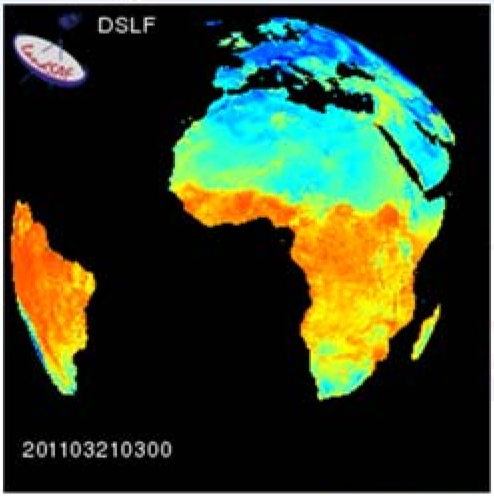
landsaf.meteo.pt

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

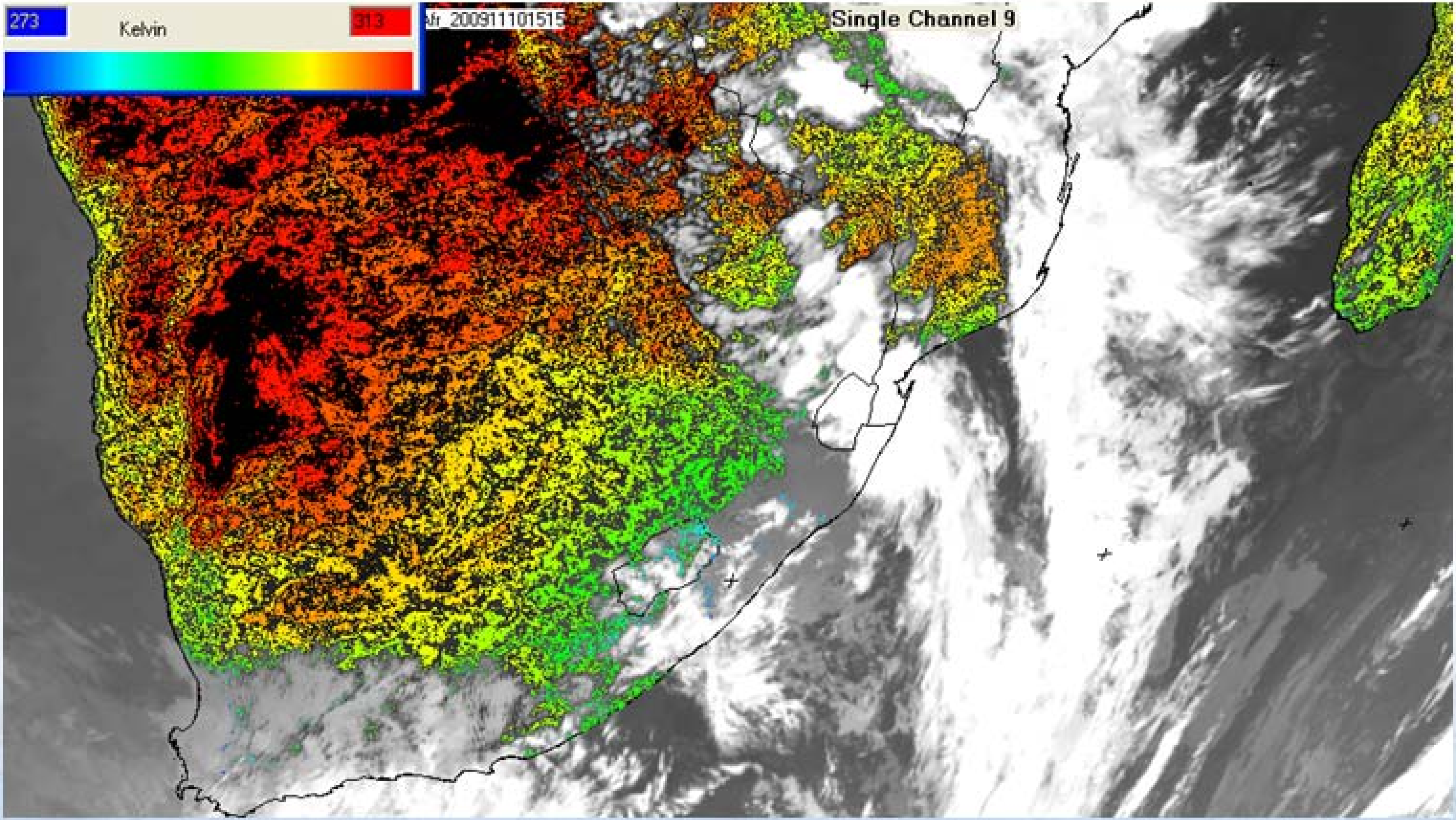
Albedo
- Surface Albedo
- MSG Ten Day Surface Albedo

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

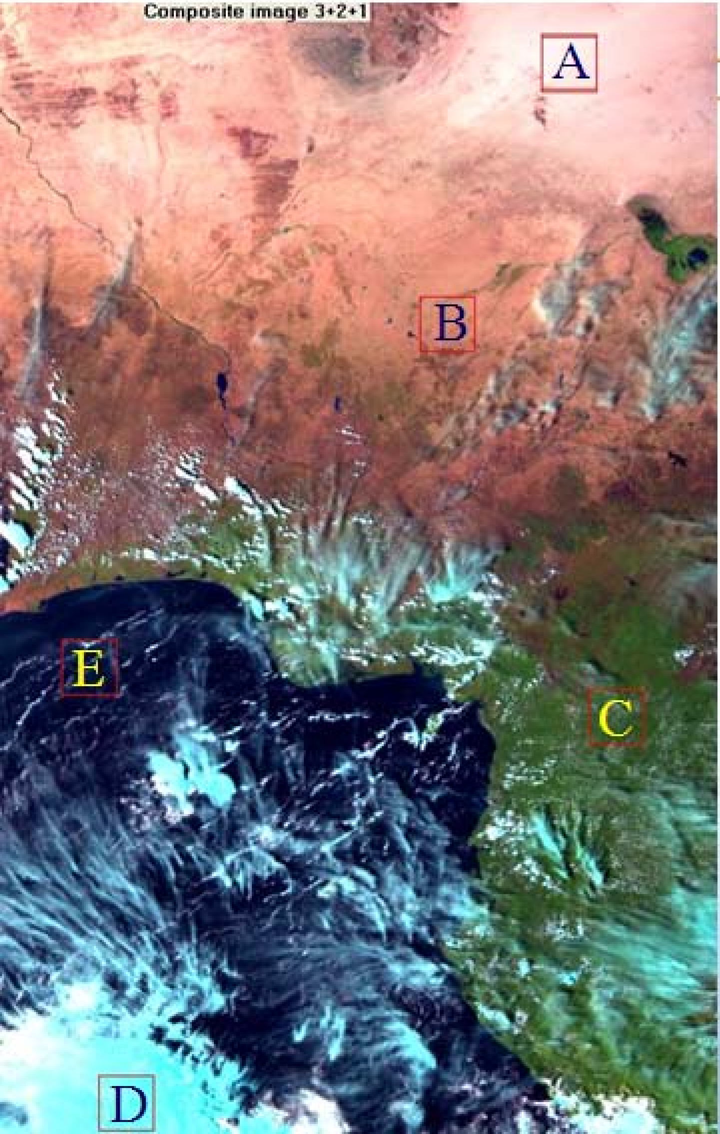
Land SAF “LST” product

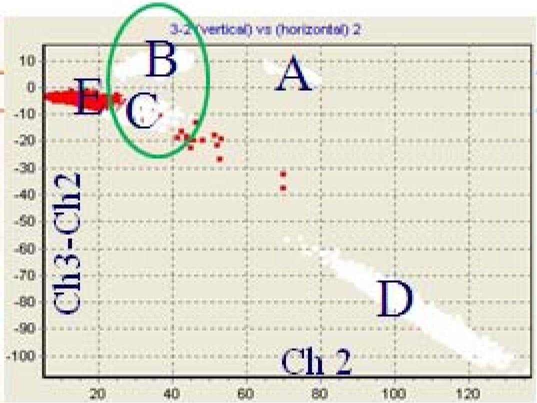


France, 10March 17April 24May

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

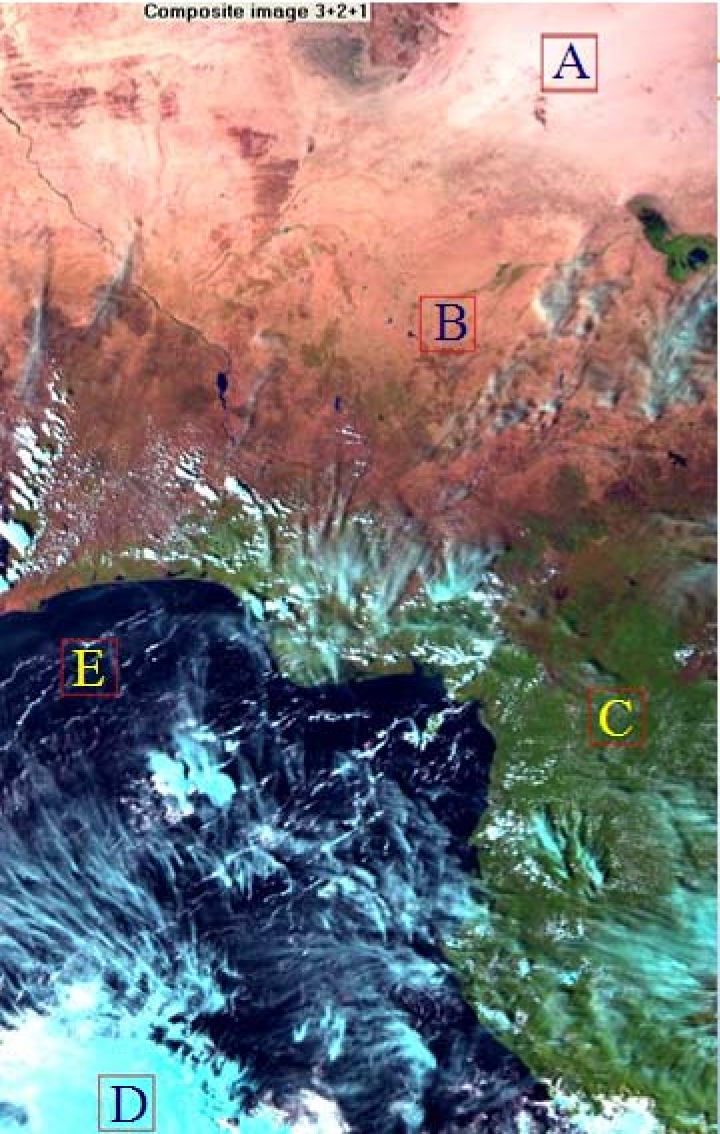
Spain 6April 22May 2010

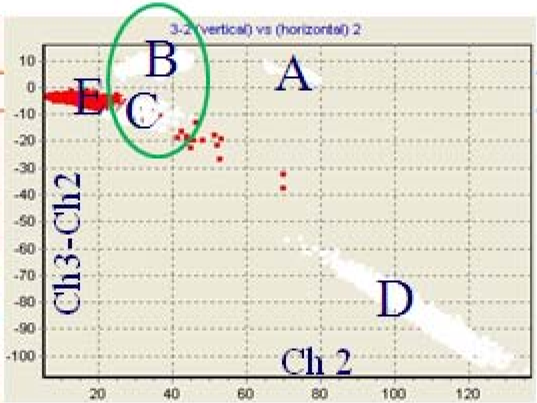




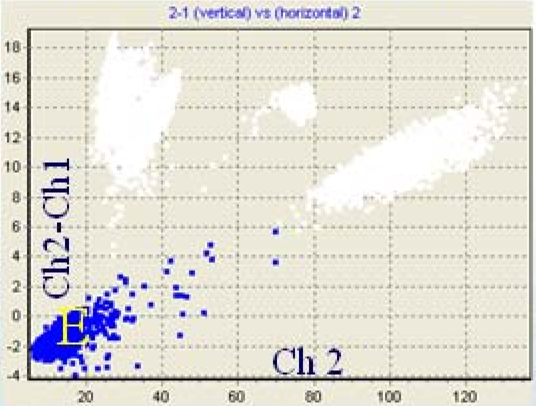
1.6µm reflects better than 0.8µm on dry ground, but worse in vegetated areas

EUMETSAT

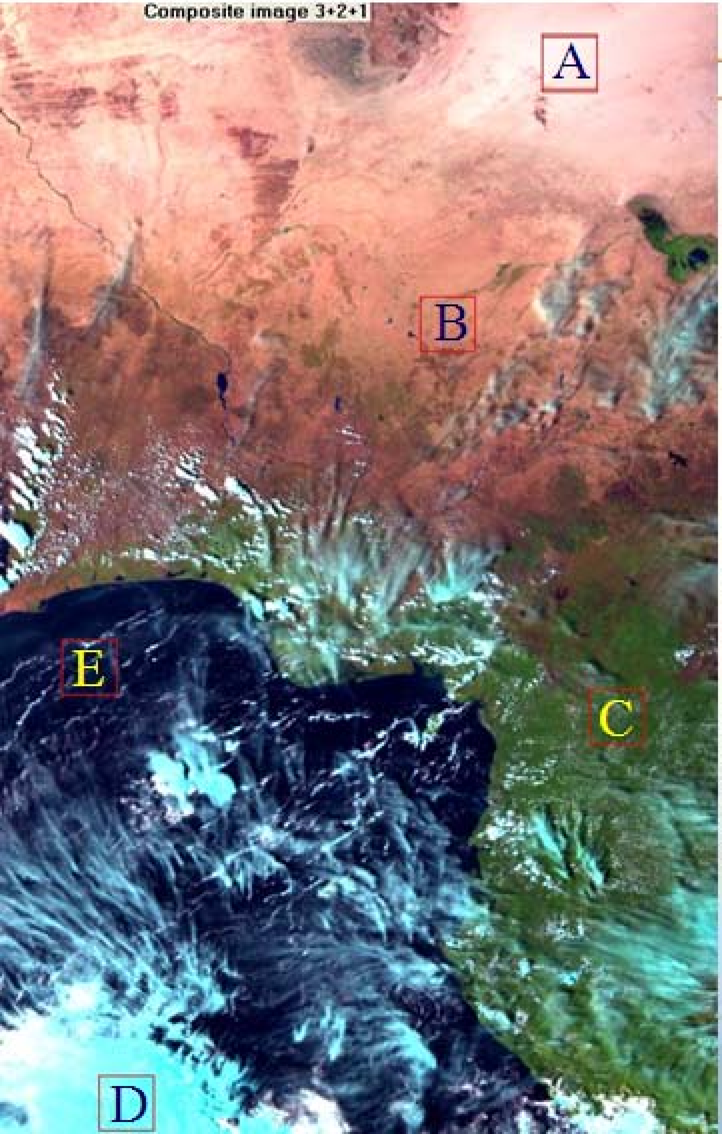


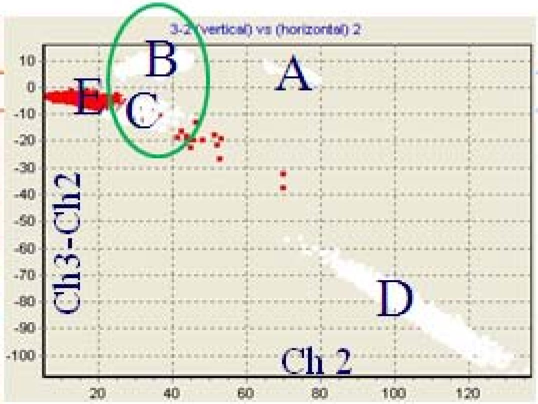


Now, 2-1 in vertical. Your turn!

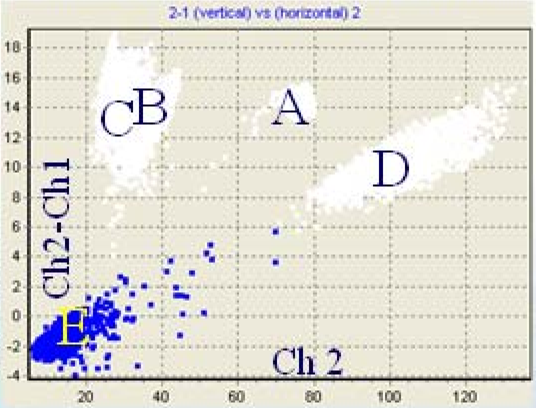


1.6µm reflects better than 0.8µm on dry ground, but worse in vegetated areas

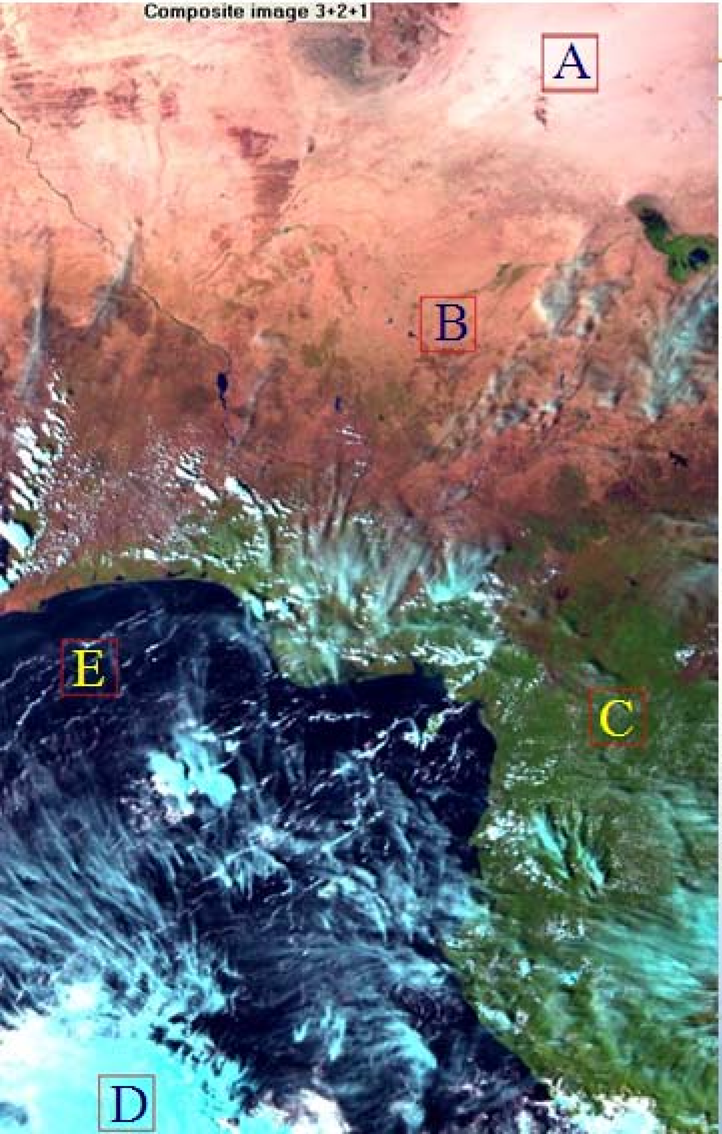


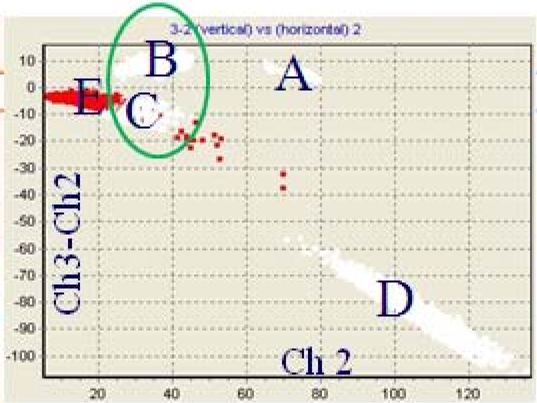


Now, 2-1 in vertical. Your turn!



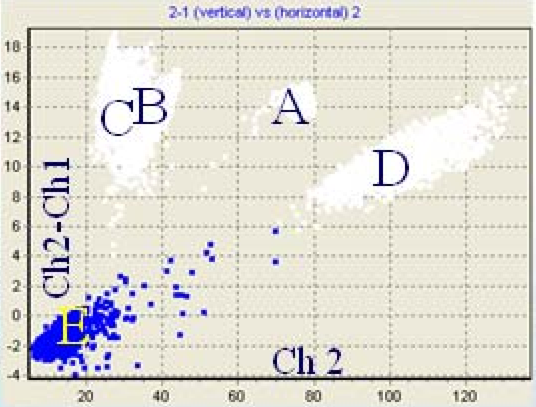
1.6µm reflects better than 0.8µm on dry ground, but worse in vegetated areas





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

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

Fog

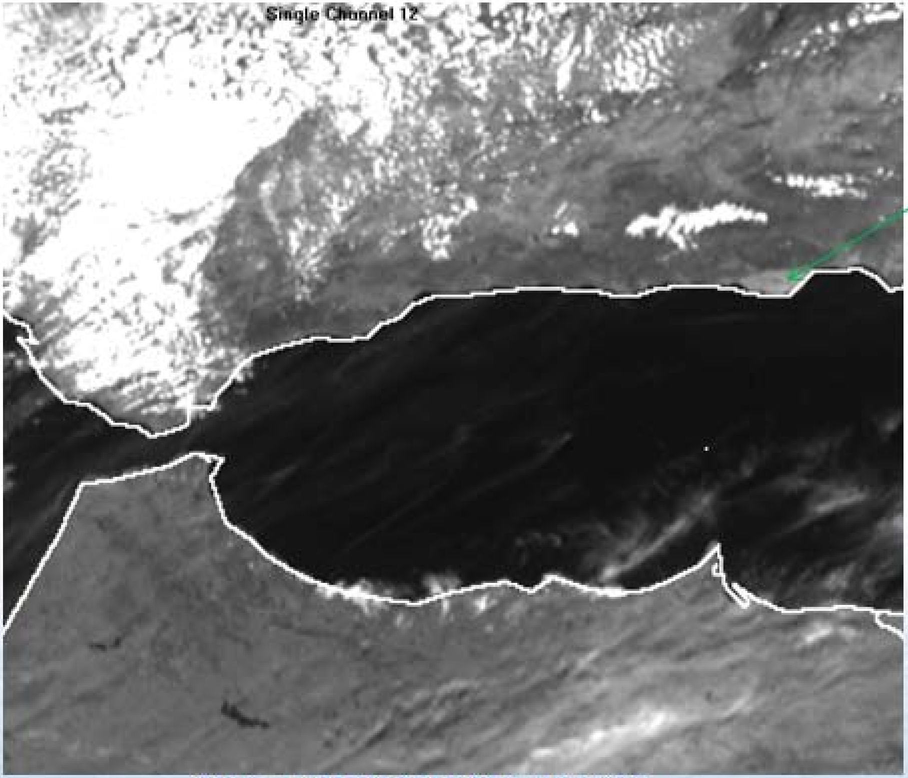
Sand

Glass

Cirrus

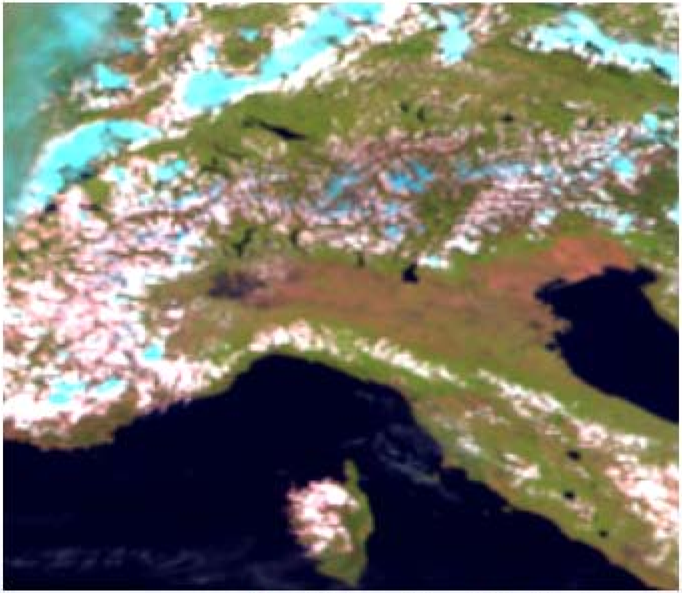
Smoke

Litter

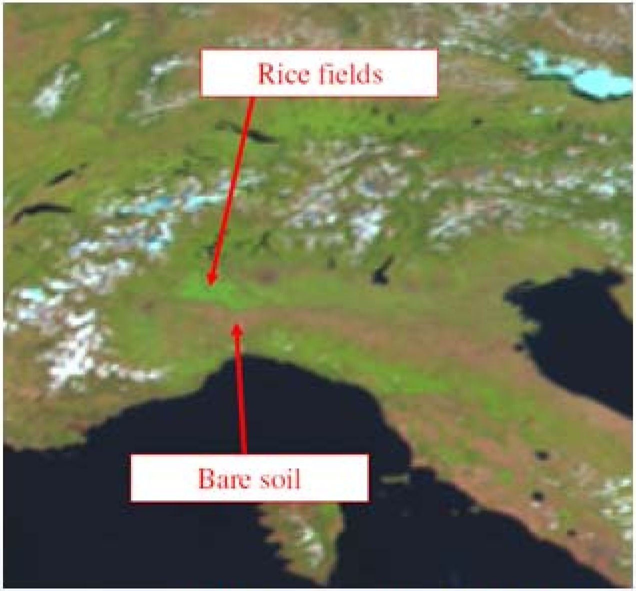


Meteosat HRV 2010-May-08 12:00

Vegetation monitoring



May 2011 Rice fields flooded

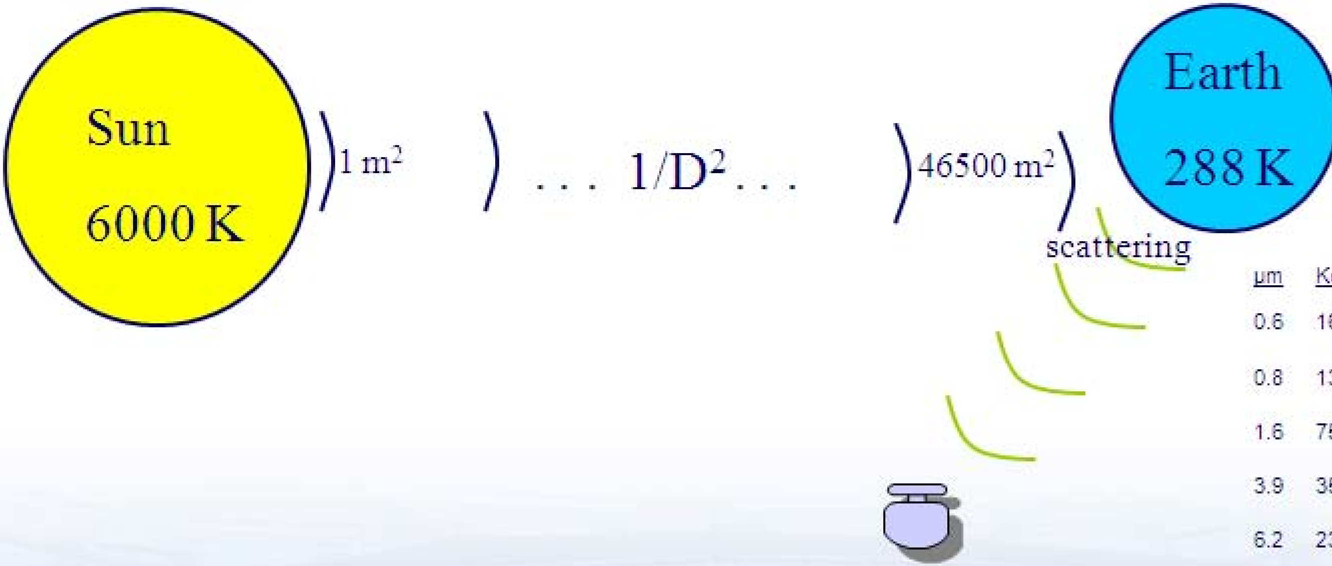


Aug 2003 Meteosat Natural RGB

Contents

EUMETSAT

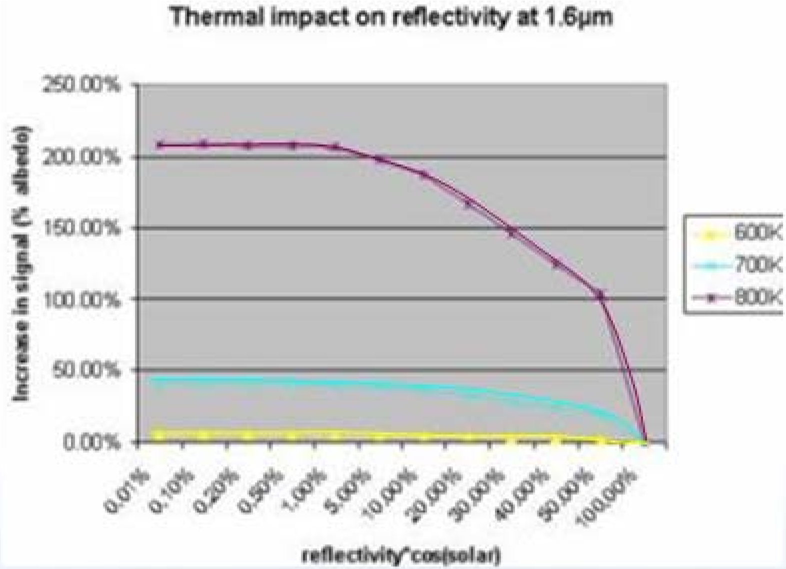
Astronomical factor 46500 (sun apparent size)



µm	Kelvin
0.6	1600
0.8	1300
1.6	750
3.9	350
6.2	230

- This factor explains the brightness difference between sun and moon (together with moon albedo), or between sun and bright cloud.
- As radiation expands in space, it gets the energy density of black bodies at much lower temperatures than 6000 K
- The solar radiation *reflected by the Earth* is equivalent of an *emission* at lower temperature. Earth radiation competes with the sun at 3.9 µm

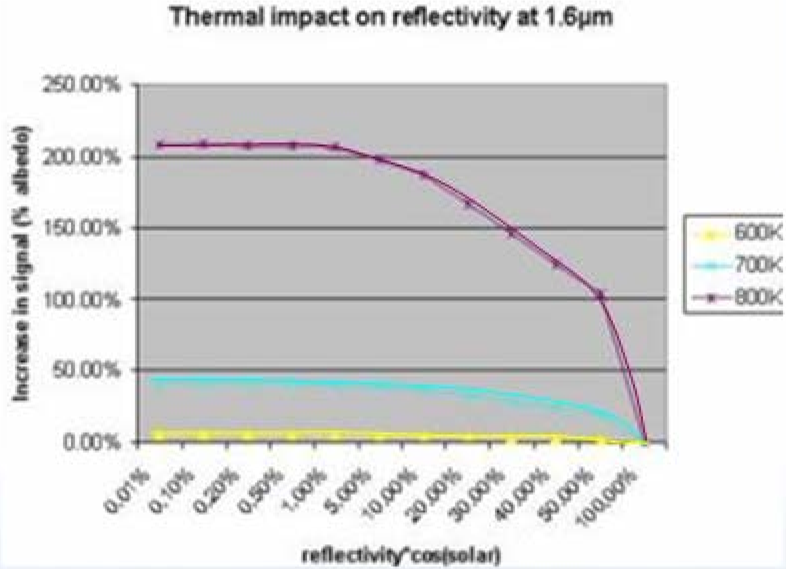
Emission sources in the solar channels !



- 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

Emission sources in the solar channels !

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



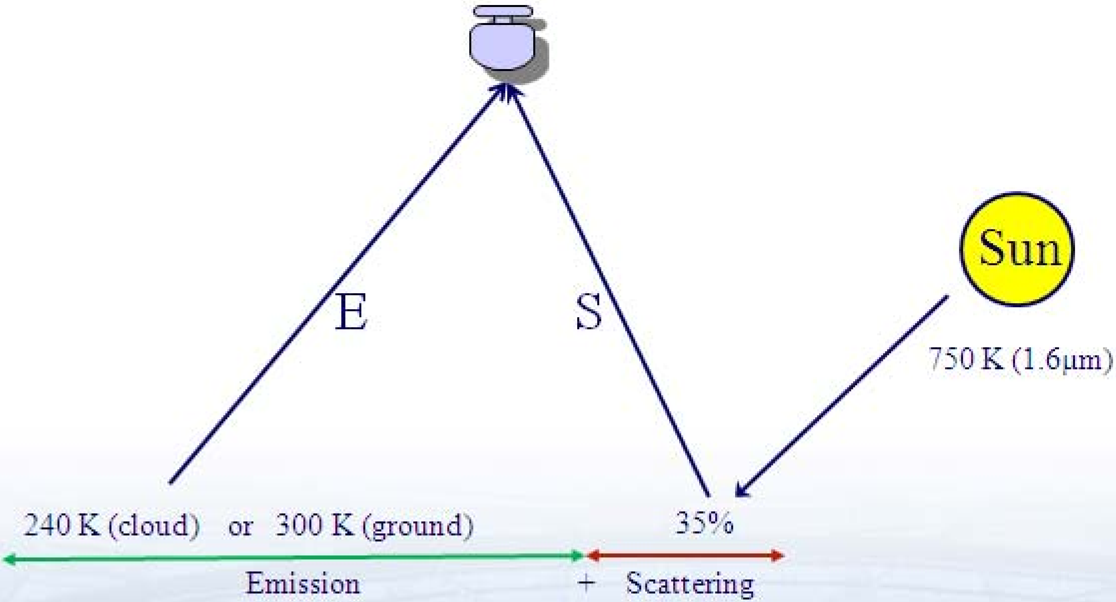
•Very **hot sources** (e.g. lava) **emit** as much as the sun contribution and **enhance** 1.6µm signal

•Sun contribution at 1.6 µm is equivalent of a black body at 750K

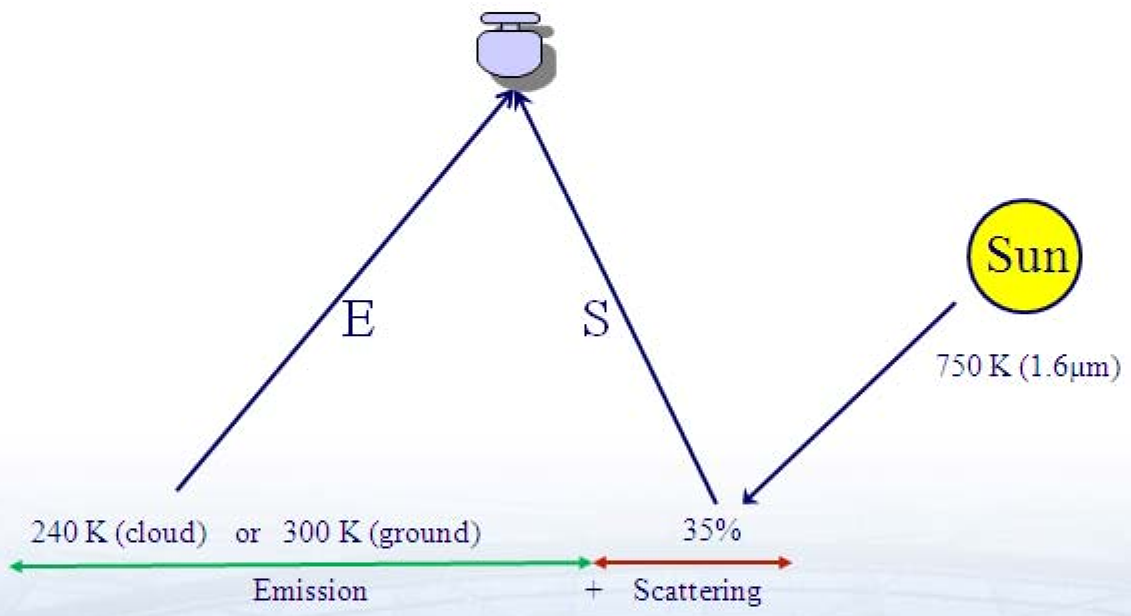
•Big fires can be detected at night at the 1.6µm channel

EUMETSAT

NIR 1.6 is solar reflected (plus emitted) radiation

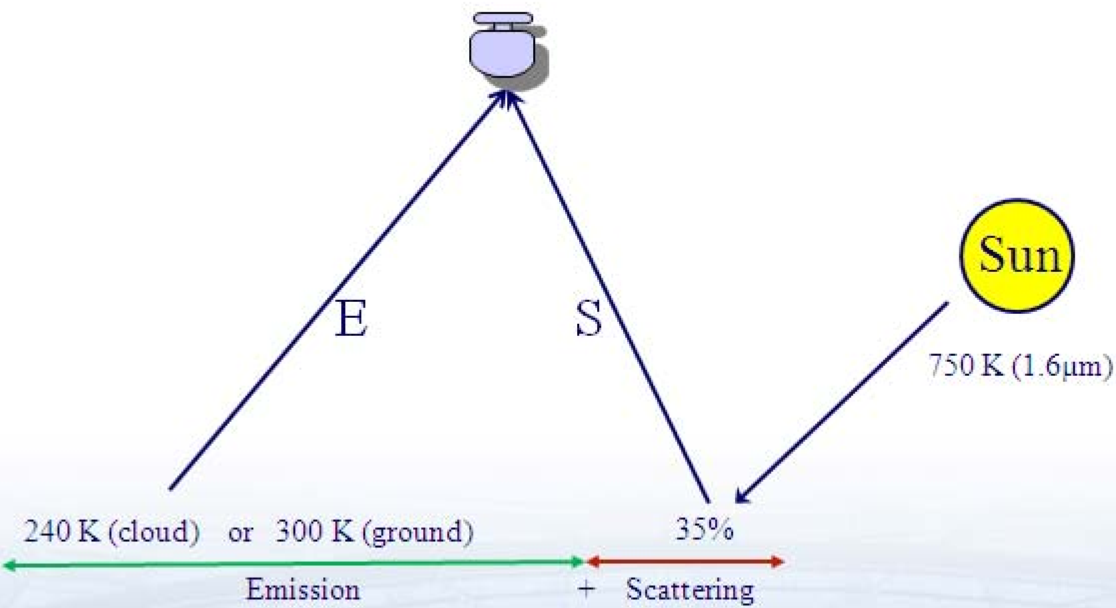


NIR 1.6 is solar reflected (plus emitted) radiation



Which contribution is usually bigger, 'E'mitted or 'S'cattered ?

NIR 1.6 is solar reflected (plus emitted) radiation



Which contribution is usually bigger, 'E'mitted or 'S'cattered ?

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

EUMETSAT

Cloud in the solar channels

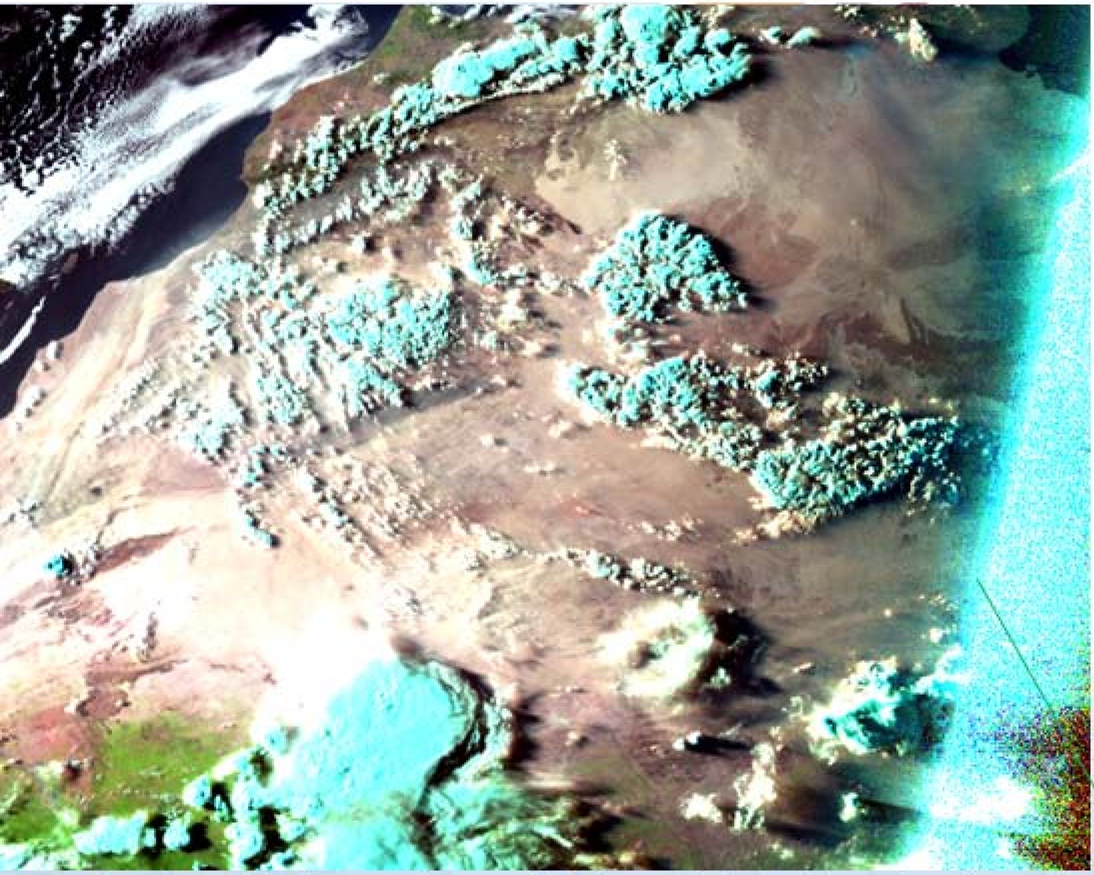
ch3 ch2 ch1 composite

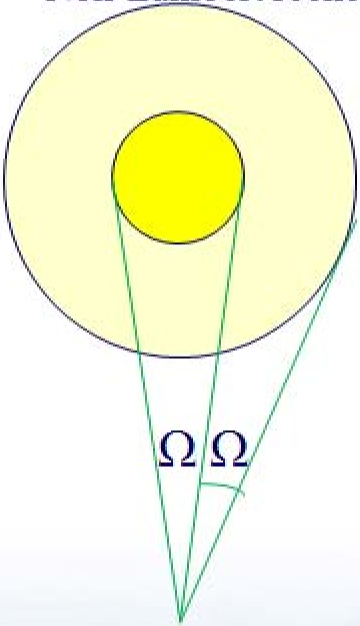
1. Dry
2. Vegetation
3. Thin cloud above vegetation
4. Thick cloud

- 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

EUMETSAT

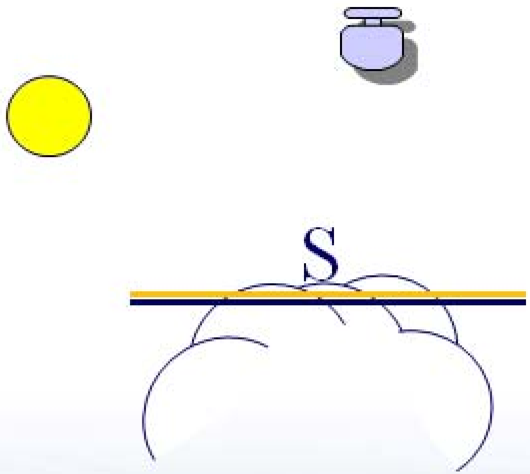
Lambert's approximation



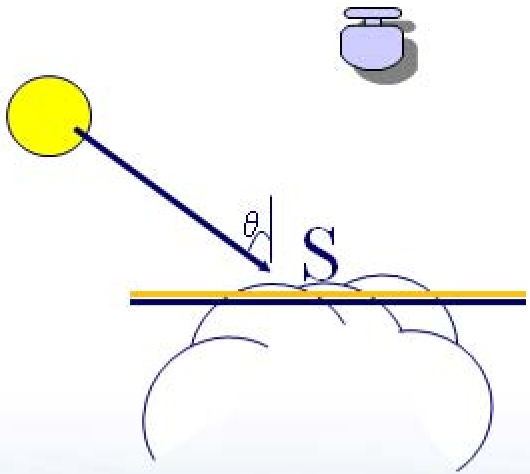


- Lambert: same brightness close and far from the boundary of a spherical target
- Lambert examples: rough ocean surfaces or snow, non-directional reflection
- Non Lambert: desert surfaces or sun glint on oceans, directional reflection

Scattering albedo

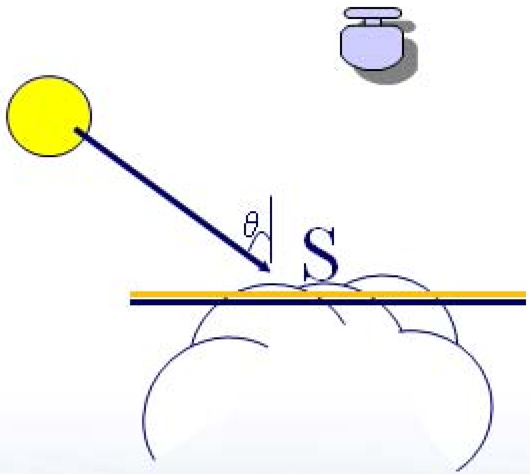


Scattering albedo



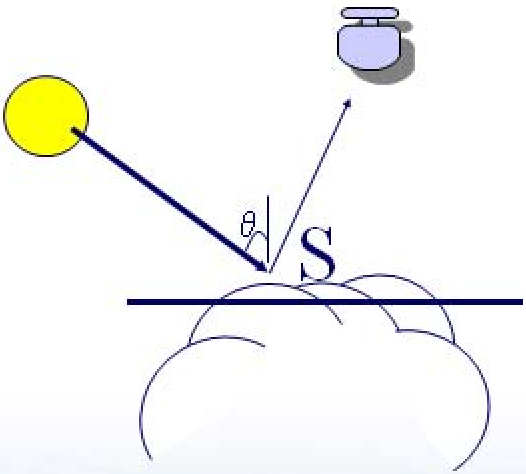
I_{λ}.

Scattering albedo



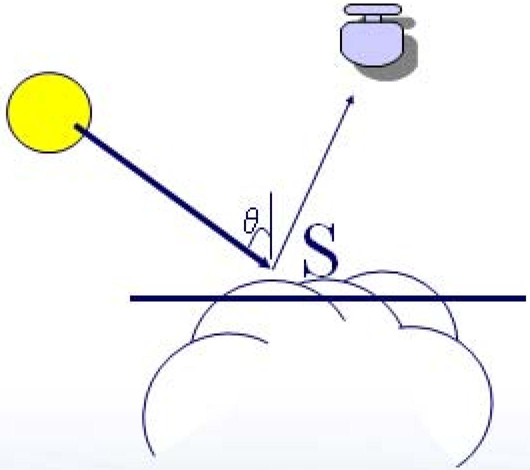
$I_\lambda .\ \cos\theta . S.$

Scattering albedo



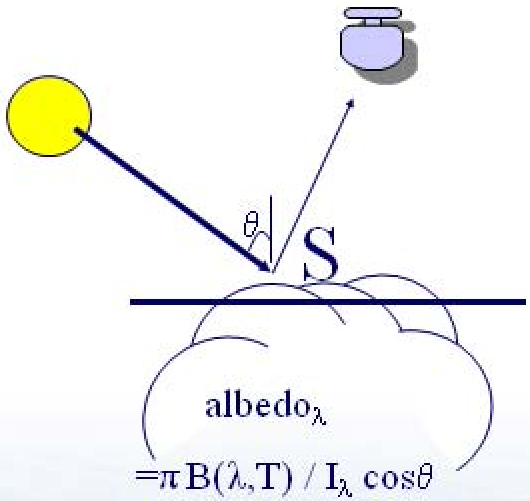
$I_\lambda . \cos\theta . S . \ \text{albedo}_\lambda .$

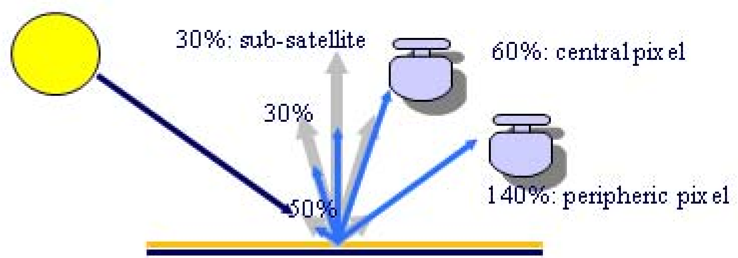
Scattering albedo



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

Scattering albedo





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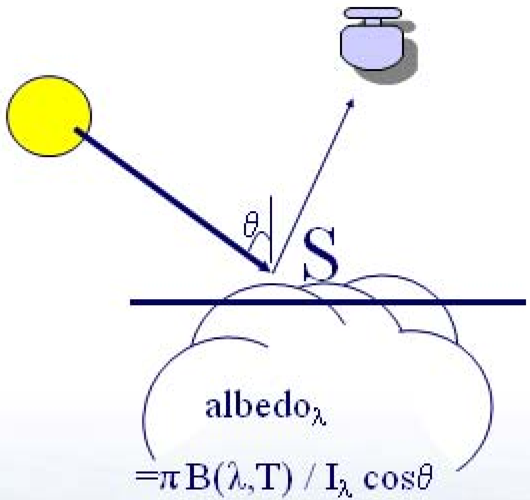
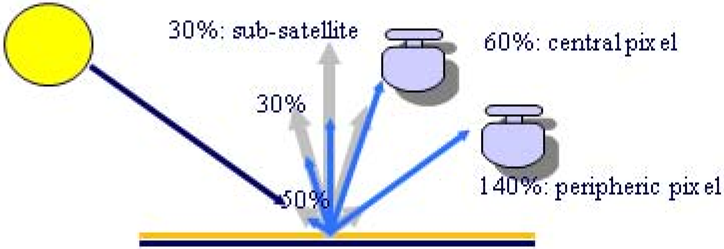
Scattering albedo





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

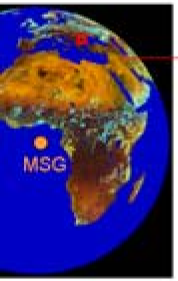
Does albedo depend on illumination θ ?

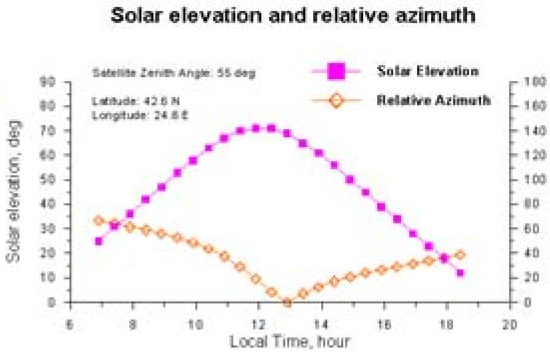
YES, as shown by the formula

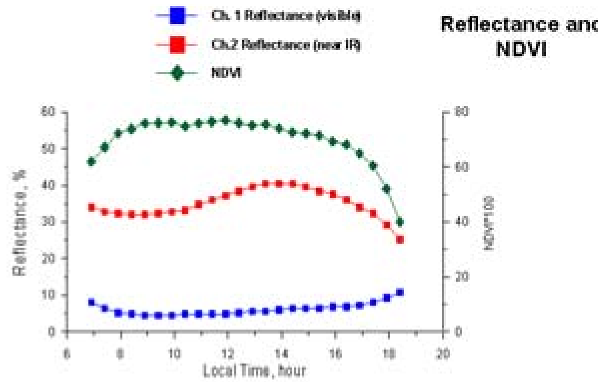
NO, it is a surface characteristic

EUMETSAT

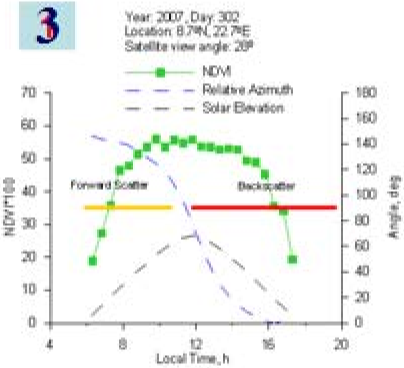
NDVI dependent on sun elevation

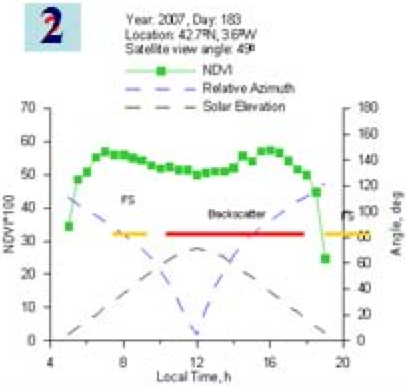


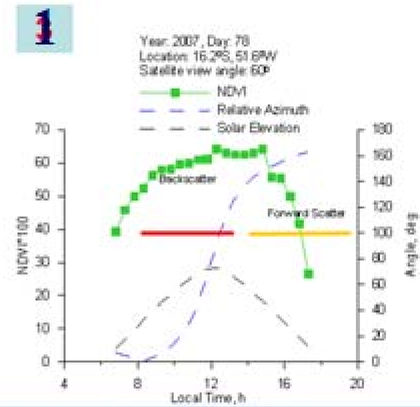




e 23, 2007



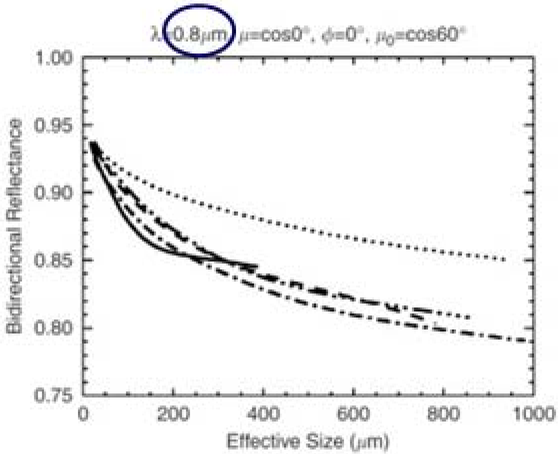


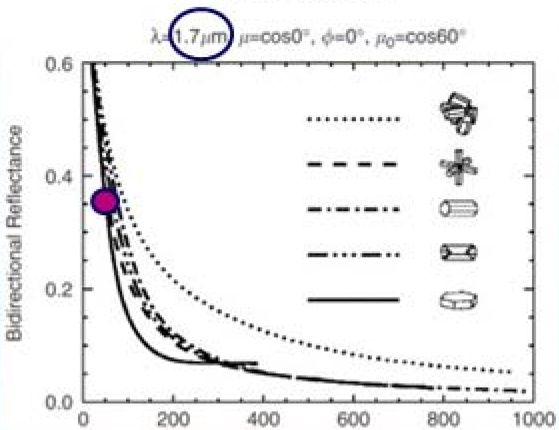


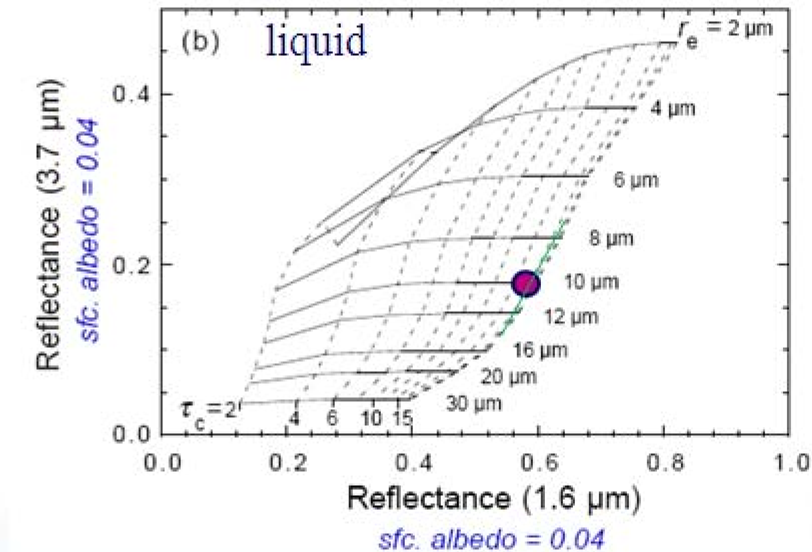
Ertürk, Barbosa (2004)

For land locations, there is almost forward-backward symmetry

Phase and size impact on 1.6µm reflectivity



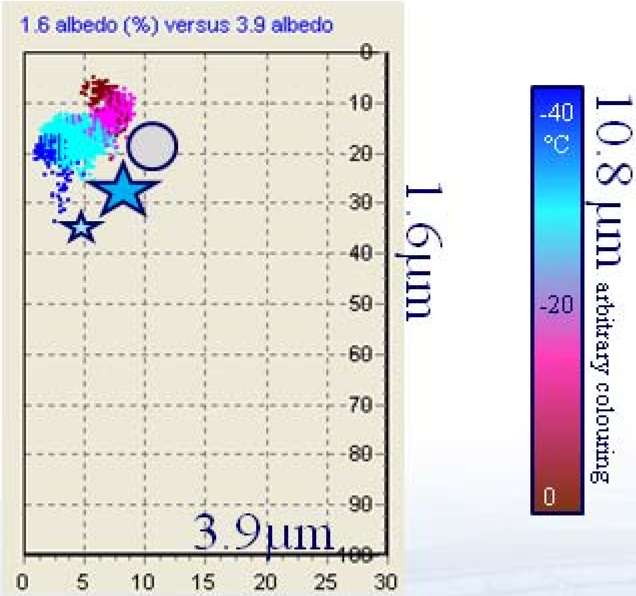




•**Phase**: for the same water content, ice crystal clouds are less 1.6µm-reflective than water droplet clouds (35% and 60% respectively)

•**Size**: 3.9 µm (Mie region) is most sensitive to crystals' or droplets' **size.** Dependence is lower **at 1.6µm** and much weaker at 0.8µm

Towards ice and size vertical profiles

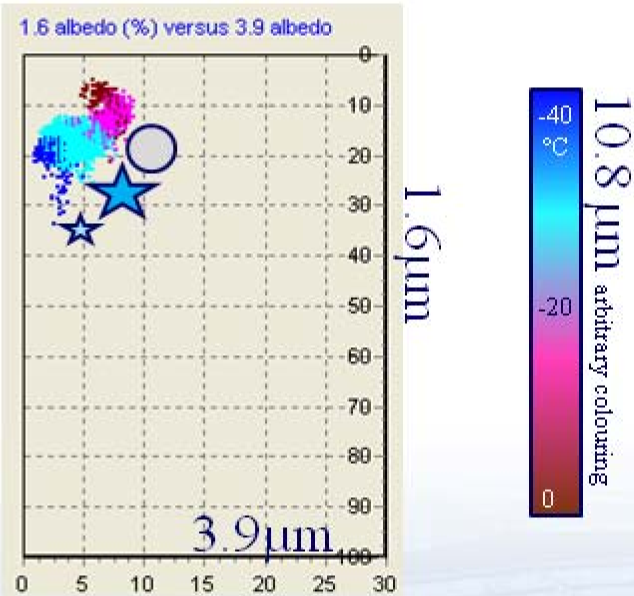


The pure ice particles (blue) turn bigger and more liquid at lower levels (cyan and magenta):

SIZE: Bigger ice particles reduce reflectivity
PHASE: Mixing with liquid droplets increases reflectivity

Look at the graph:
-1.6µm (vertical) is more sensitive to..

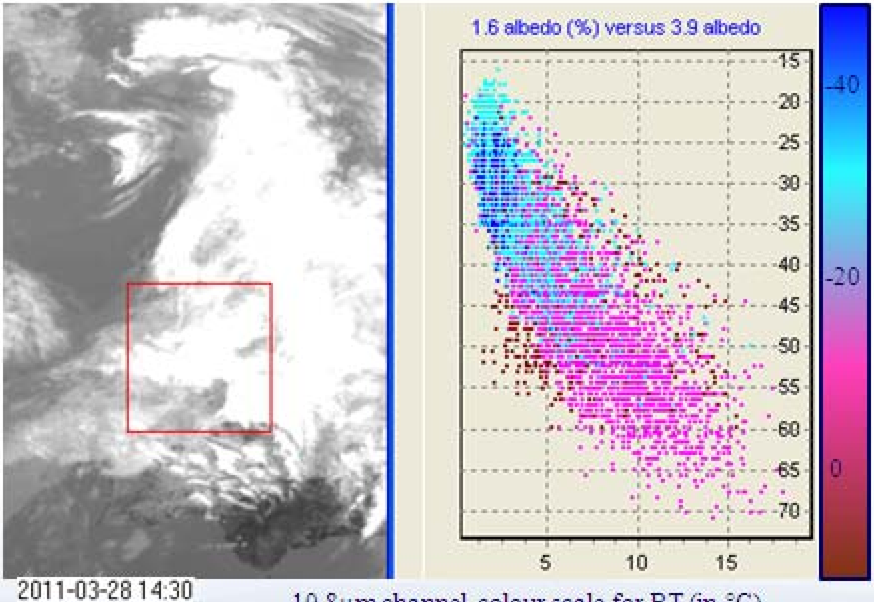
Towards ice and size vertical profiles



The pure ice particles (blue) turn bigger and more liquid at lower levels (cyan and magenta):

SIZE: Bigger ice particles reduce reflectivity
PHASE: Mixing with liquid droplets increases reflectivity

Look at the graph:
-1.6µm (vertical) is more sensitive to.. SIZE
-3.9µm (horizontal) is more sensitive to PHASE



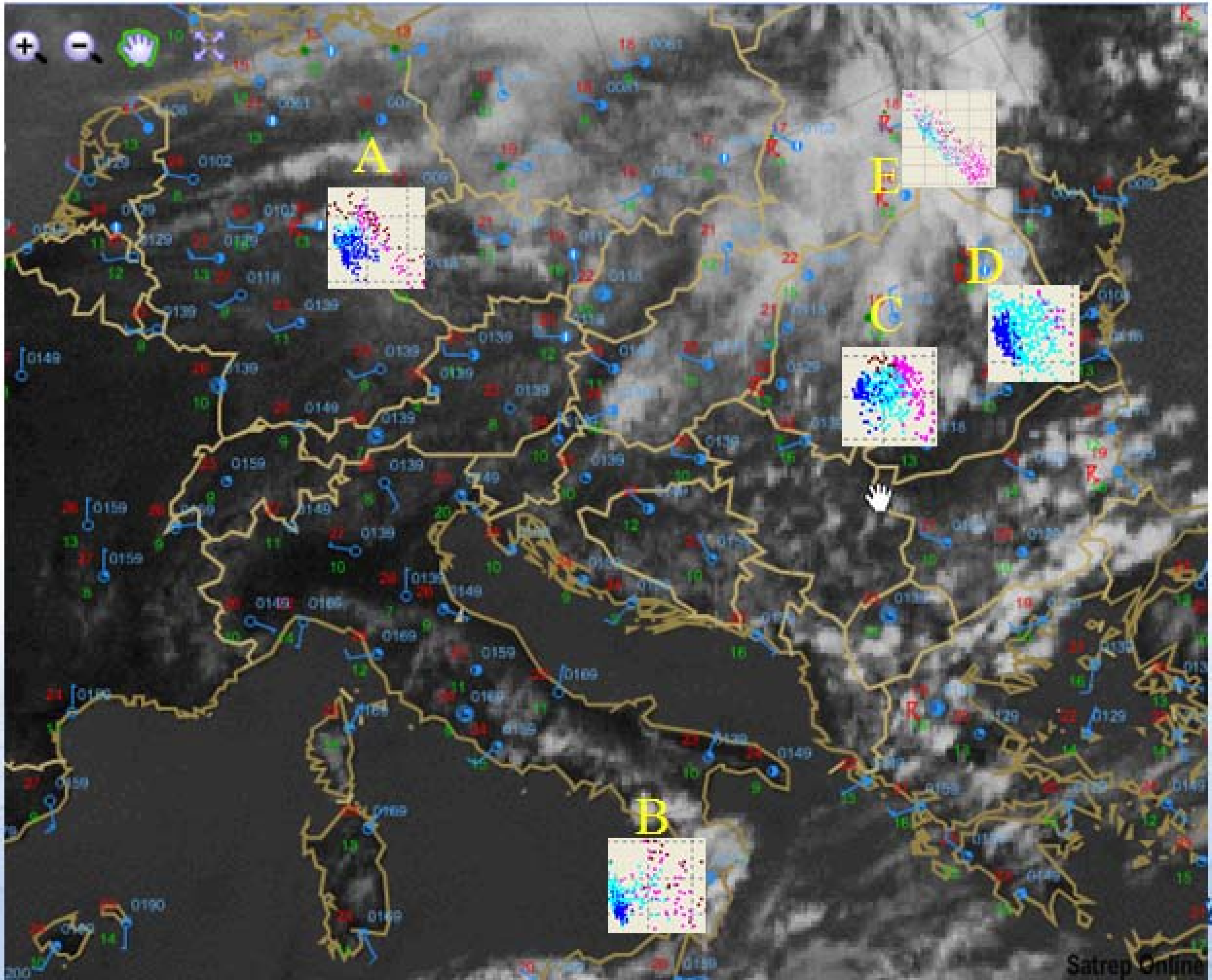
10.8µm channel, colour scale for BT (in °C)

- **Dissolving-**cloud albedos at 1.6µm and 3.9µm show a higher correlation
- The cold ice cloud tops show less variation in the 3.9-albedo
- 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

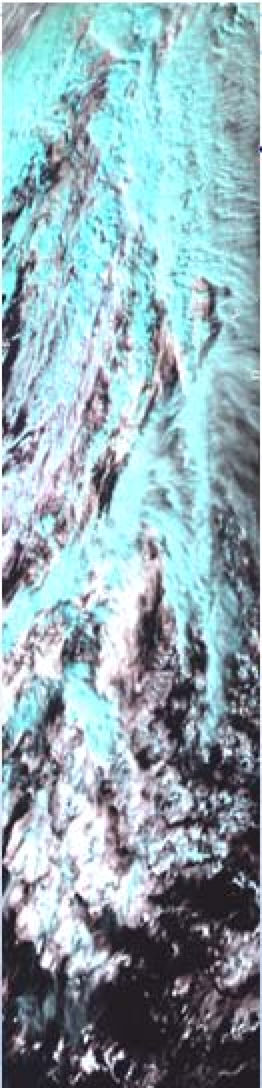
EUMETSAT

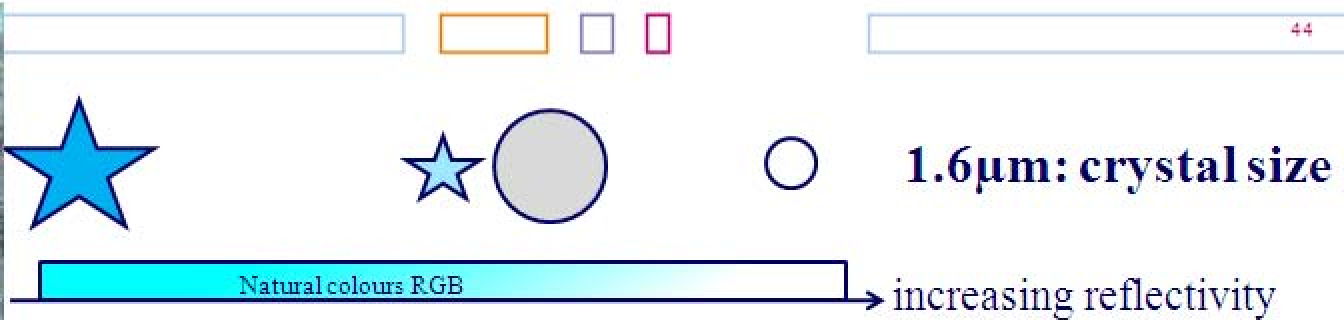
[1.6µm versus 3.9µm] reflectance technique (convection)

24 May 2010: 1200UTC



NIR1.6 reflectivity

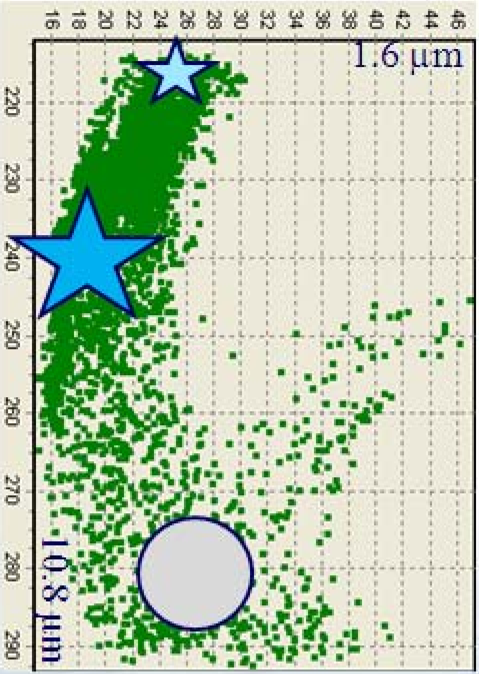


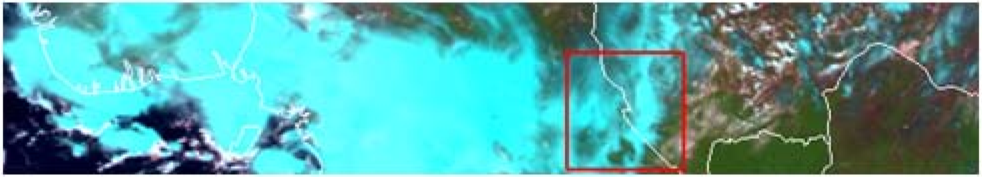


←Cyan colour in the natural RGB marks the presence of ice crystals, but is NOT an indicator of CONVECTIVE severity, related to small crystals.

Cyan is more for areas of probable STRATIFORM precipitation

Ice cloud

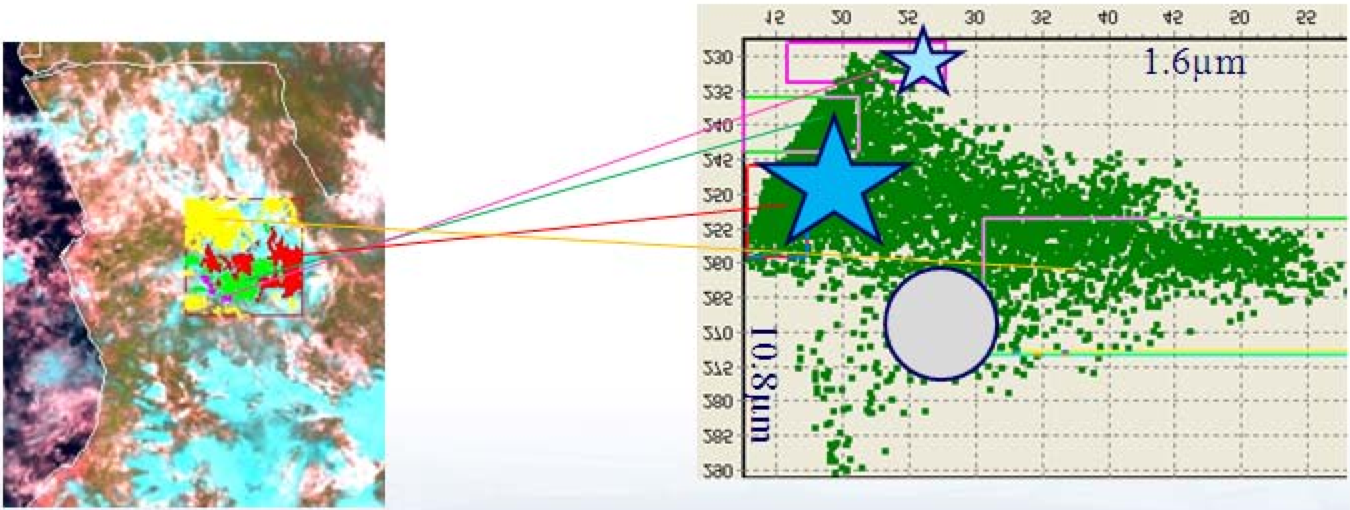


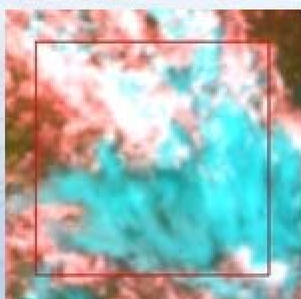


Thin cloud increases the reflected signal for non-reflective grounds

EUMETSAT

Classifying ice cloud

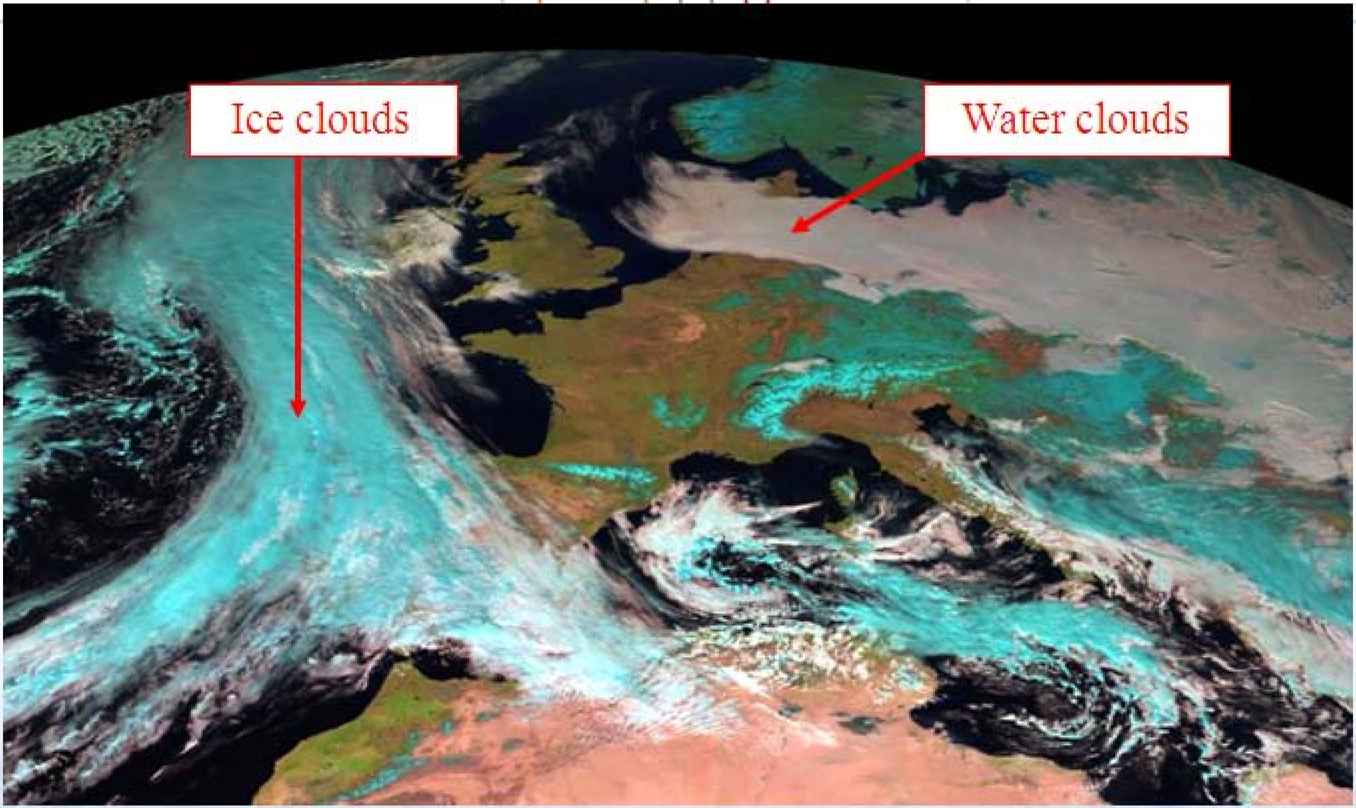




Super cooled water droplets
Large ice particles
Ice
Small ice crystals

Meteosat solar channels

Cloud Phase (Ice and water)



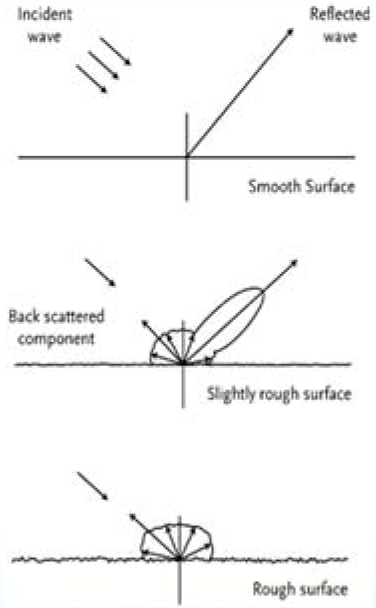
Cloud phase classification using SEVIRI RGB images
18 Feb 2003, 13:00 UTC, RGB NIR1.6-VIS0.8-VIS0.6

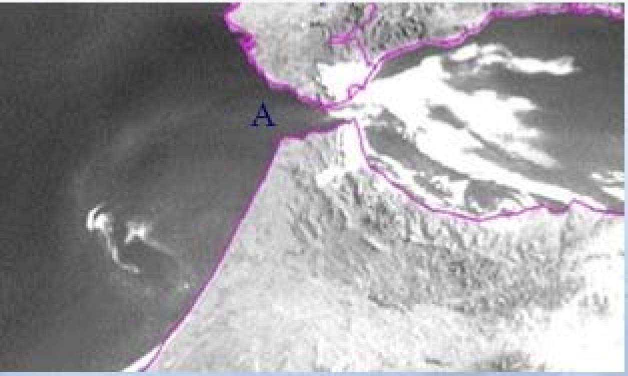
EUMETSAT

Meteosat solar channels

Contents

Sun glint, wind and rough surfaces





- 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** surface roughness and the solar scattering to the satellite on the sea surface.

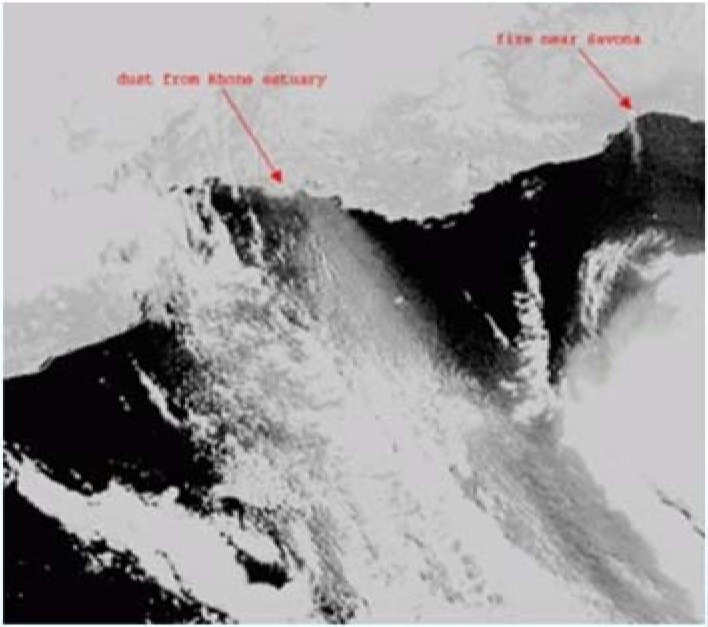
- In the **sun glint zone** itself, the wind **decreases** the scattering to the satellite.

- 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

Rough surfaces due to mistral

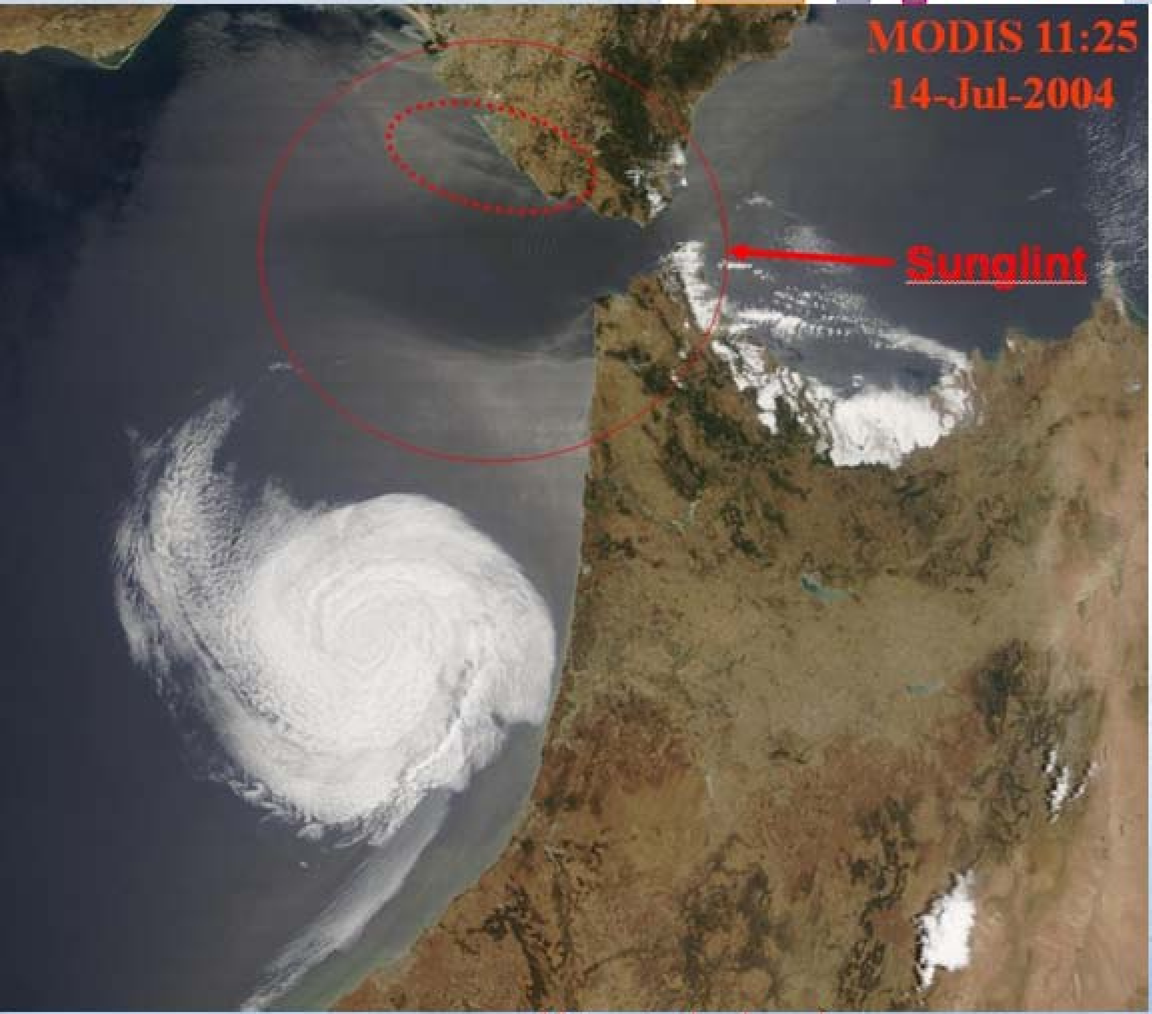
Met-8, 14 February 2005, 13:45 UTC
Channel 12 (HRV)



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

EUMETSAT

Sunglint

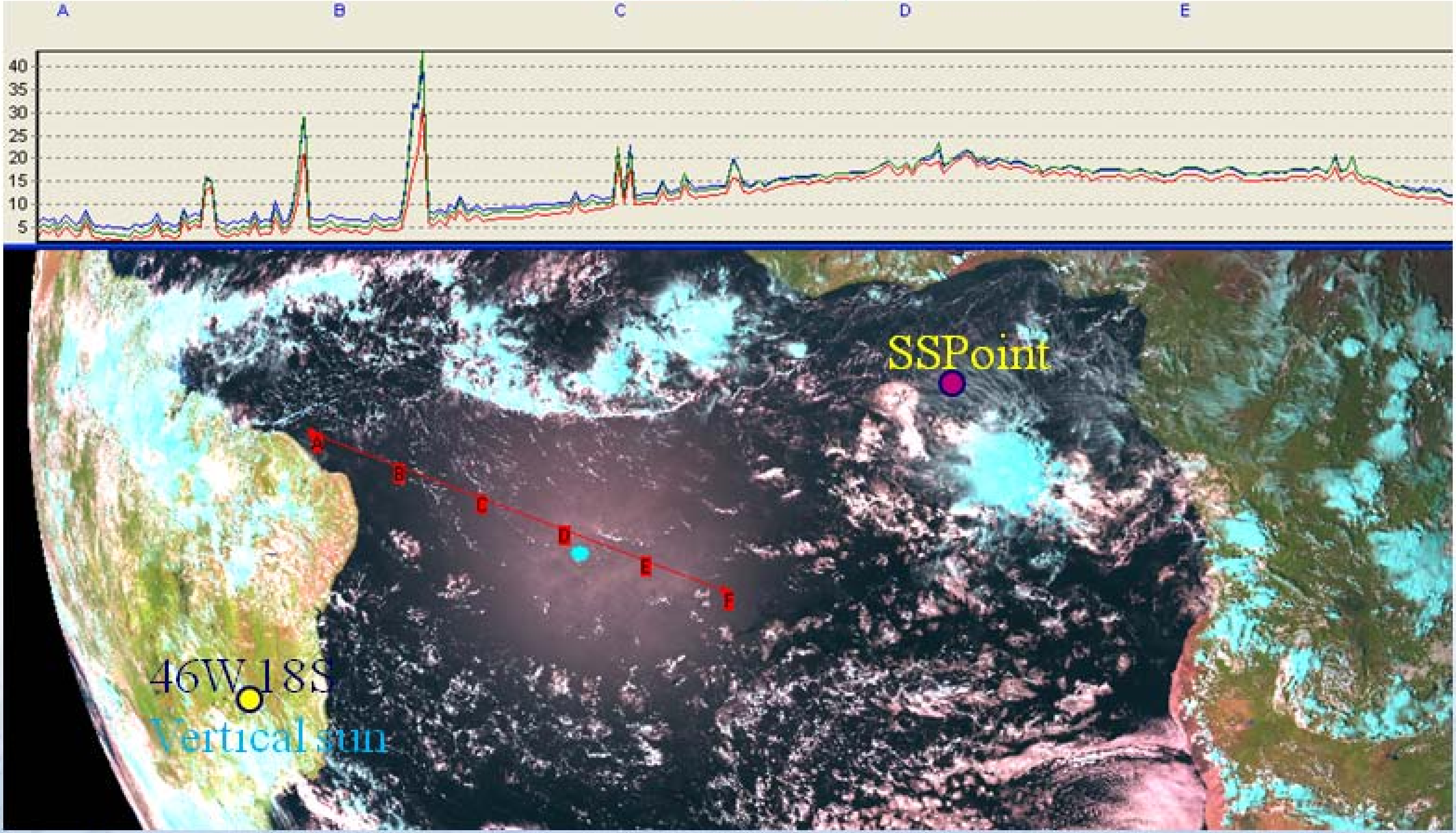


Meteosat solar channels

Dark area inside the sun glint area suggests strong wind
(west of the Strait of Gibraltar)

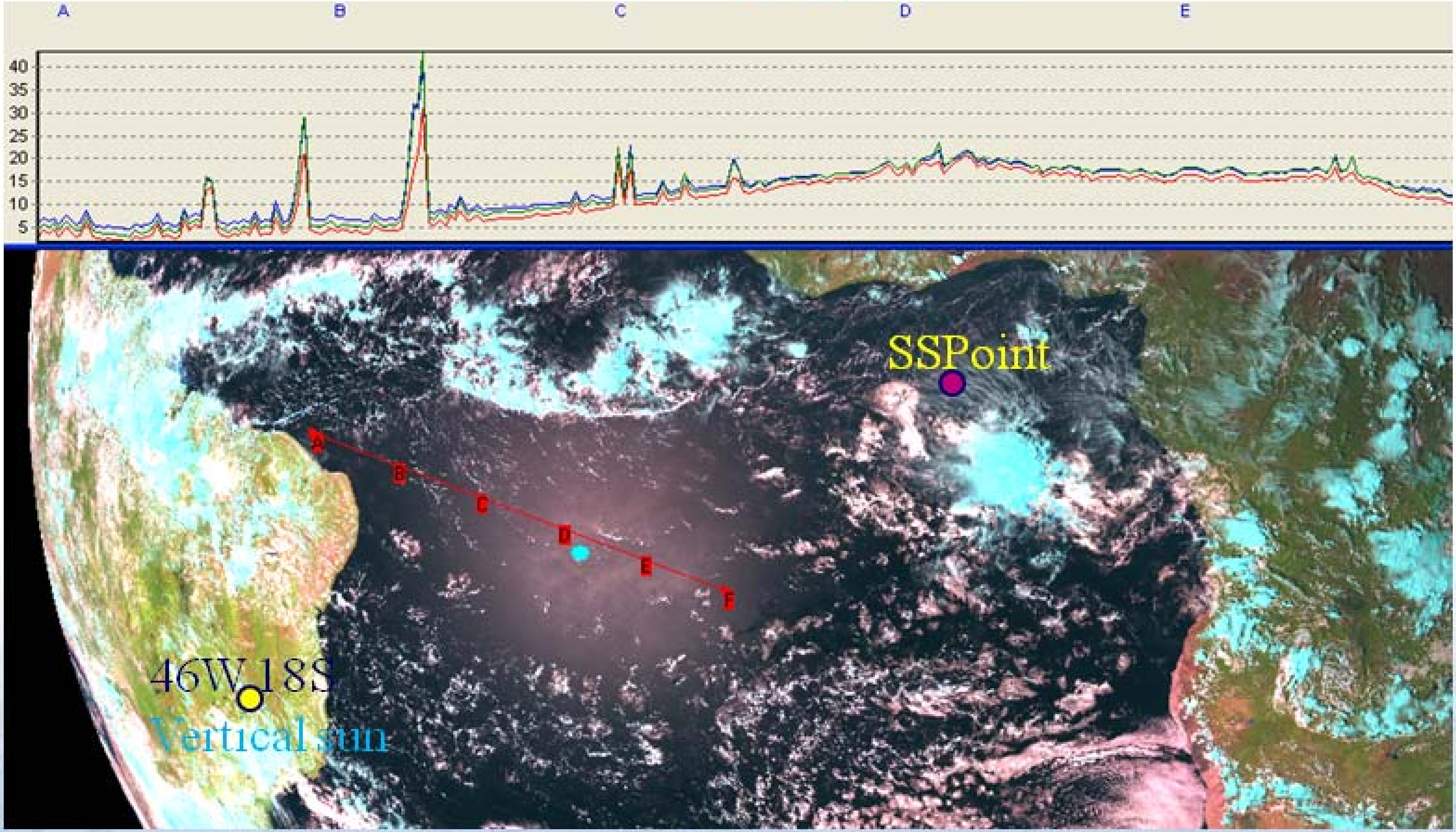
Low mountain range channels the wind

Sunglint



Meteosat9, 2011...forgot the date...

Sunglint



Meteosat9, 2011...forgot the date...

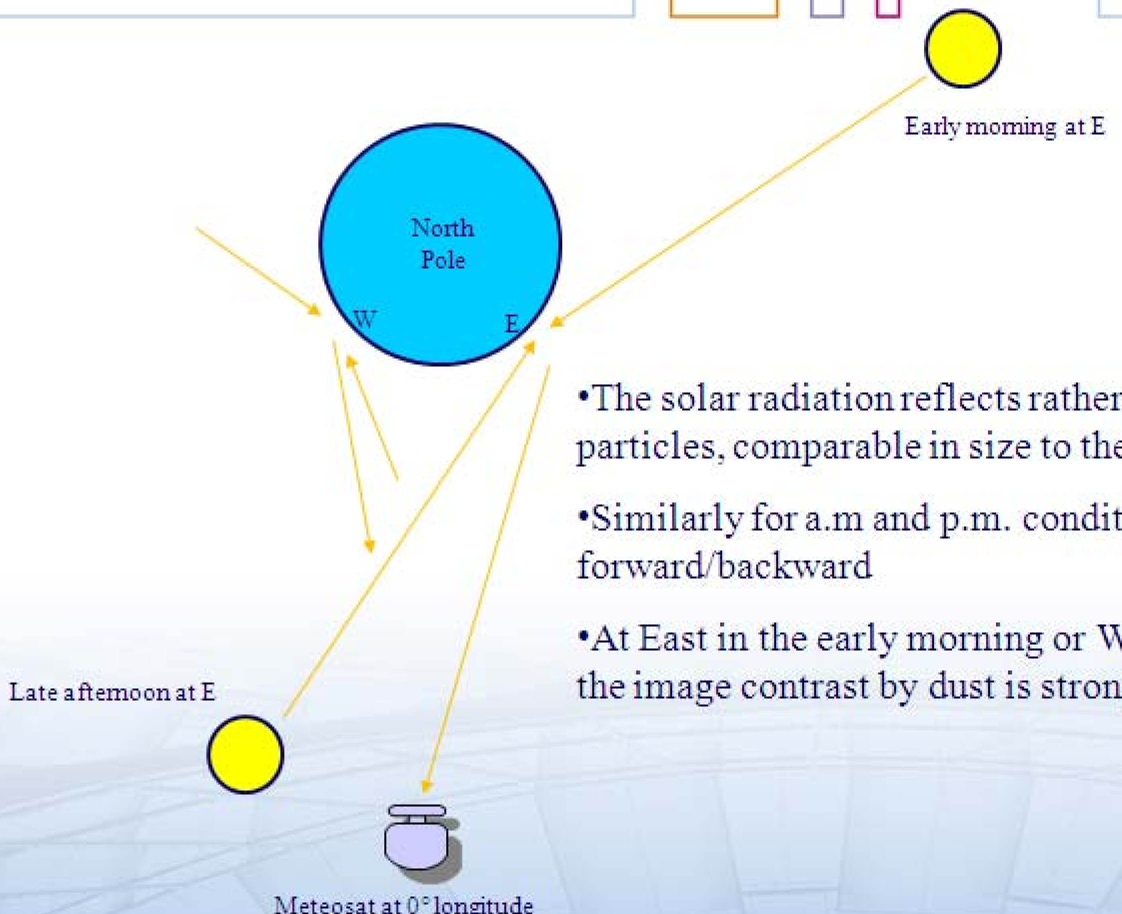
2011-02-01 1500 UTC
RGB Natural

Meteosat solar channels

Contents

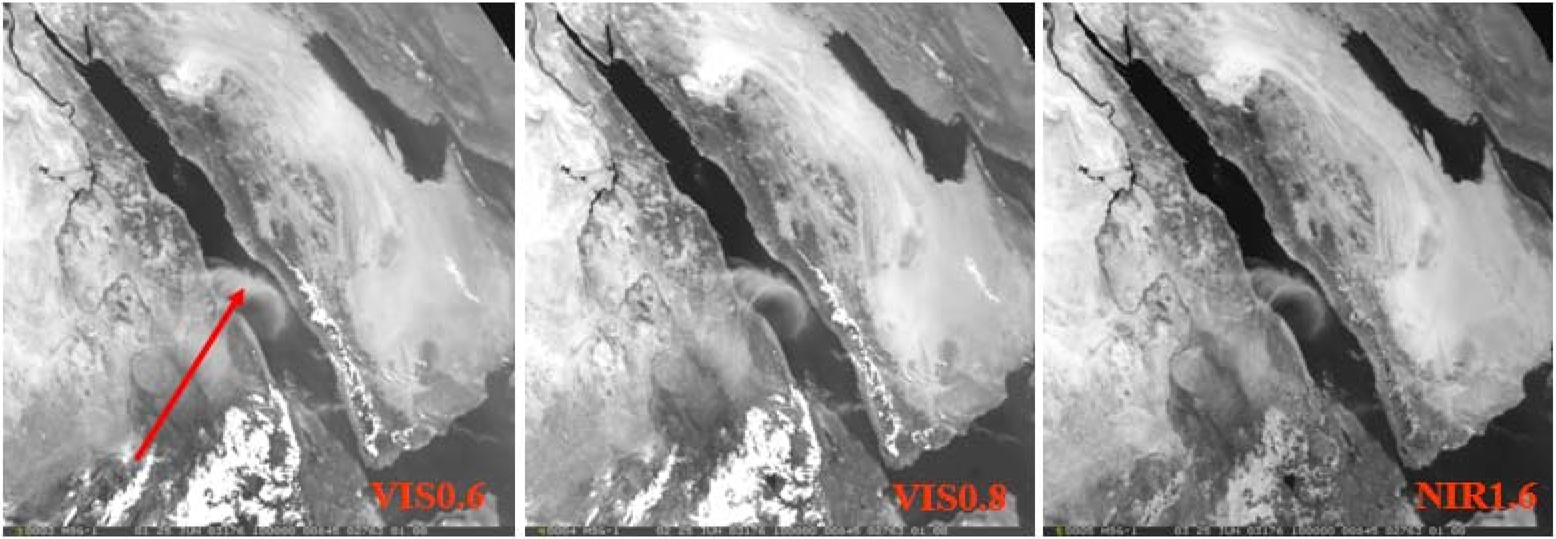
- Solar channels
  - Where you learn how to tell a cloud from a forest
- Vegetation monitoring
  - Where you learn how to tell tomatoes from rice
- Cloud phase and particle size
  - Where you learn how to find ice on planet Earth
- Sun glint
  - Where you learn to avoid squinting on satellite images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

Image contrast for smoke or dust in solar images



- The solar radiation reflects rather forwards on smoke particles, comparable in size to the 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)

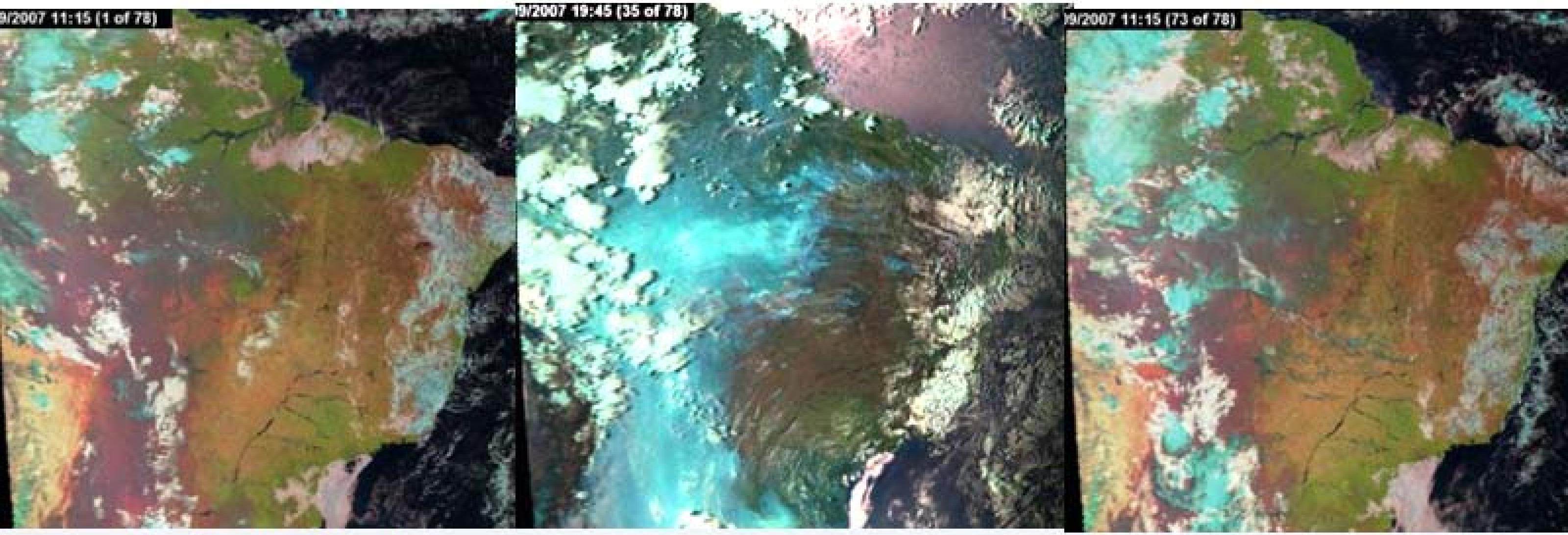
Solar channels: aerosol observation



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

Pastures burning and deforestation activity in Bolivia

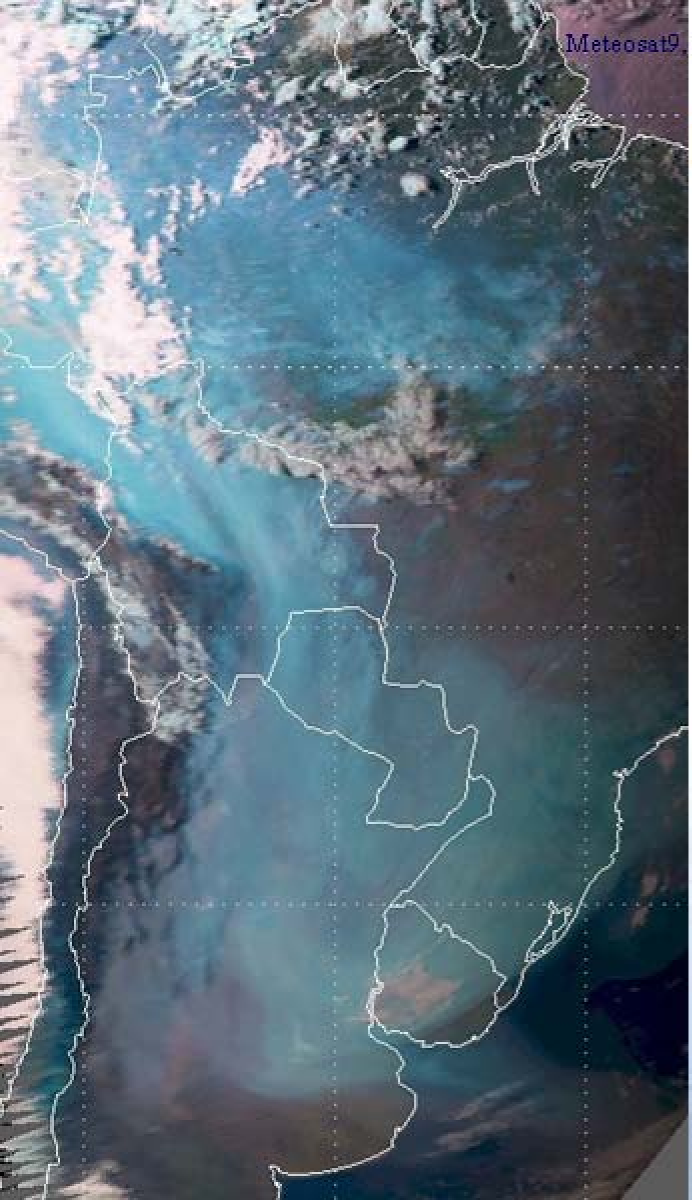
sunrise sunset sunrise

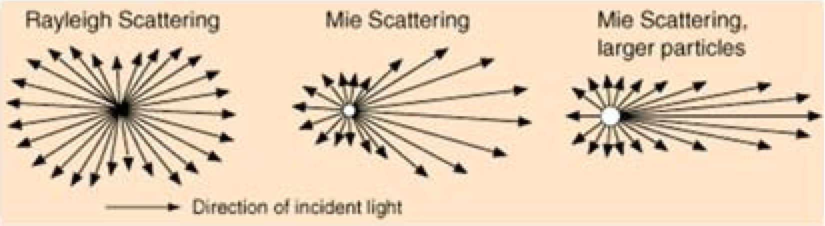


5-6 September 2007, Meteosat-9
Around sunrise and sunset times for central south America

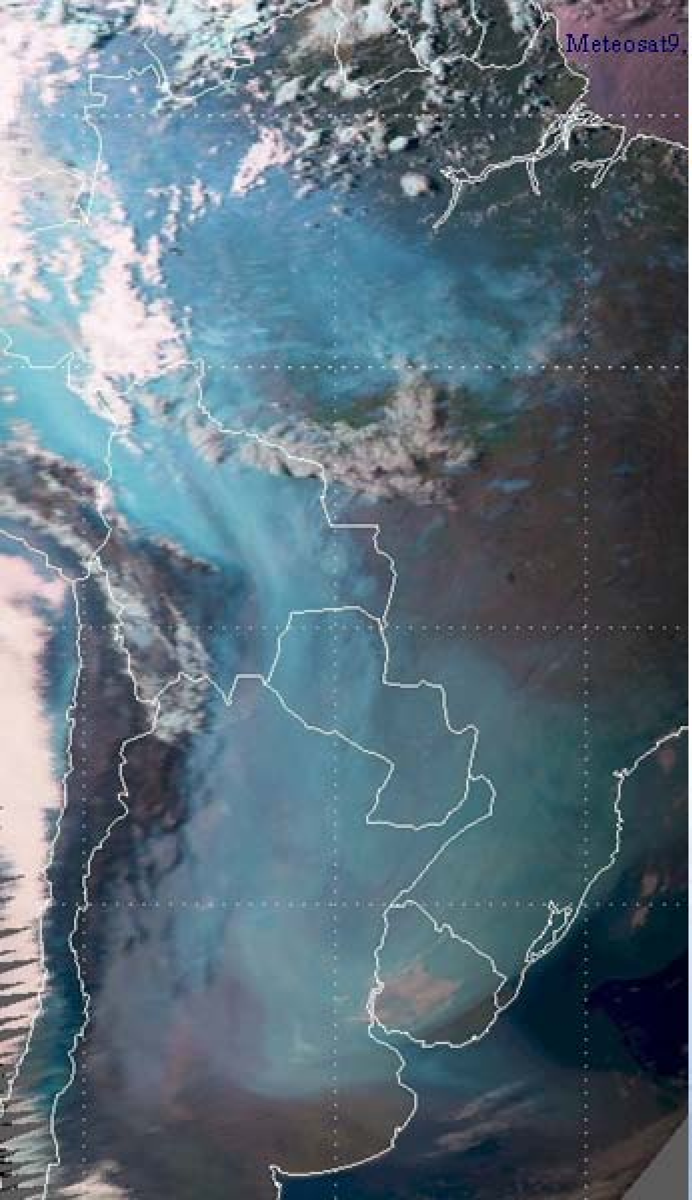
Assuming no major smoke sink or source in 24 hours, the intensity difference is due to directional reflection **(asymmetry factor)**

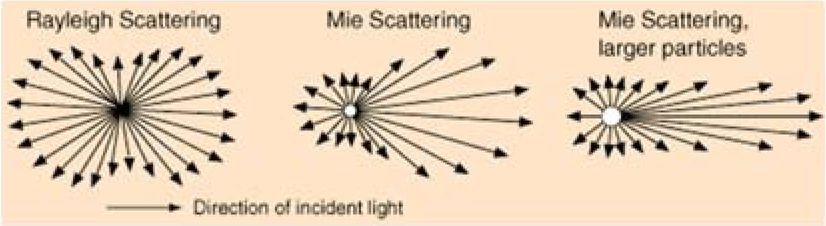
Meteosat9, 2010-08-21 2015 UTC





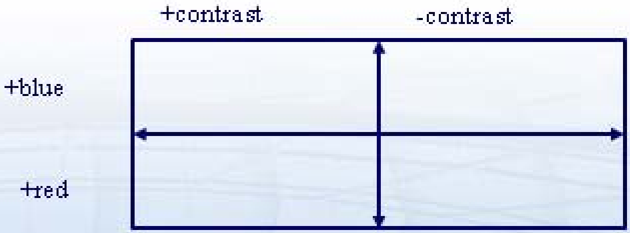
- Smaller wavelengths prefer forward scattering
- Blue-cyan colour due to 1.6 μm Rayleigh scattering
- Scattering intensity higher in the western late afternoon



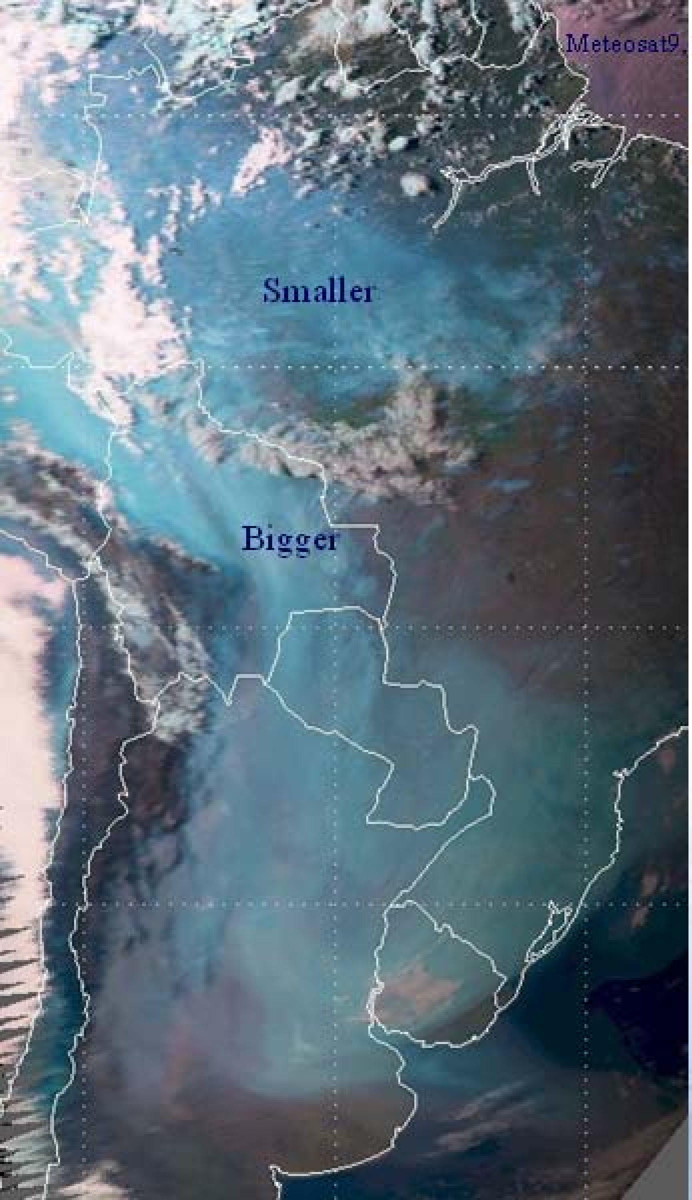


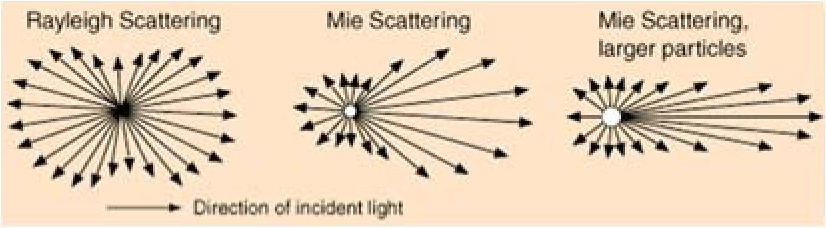
- Smaller wavelengths prefer forward scattering
- Blue-cyan colour due to 1.6 μm Rayleigh scattering
- Scattering intensity higher in the western late afternoon

What if smoke particles were **smaller**? :
More contrast?
Redder or bluer in this RGB hue?



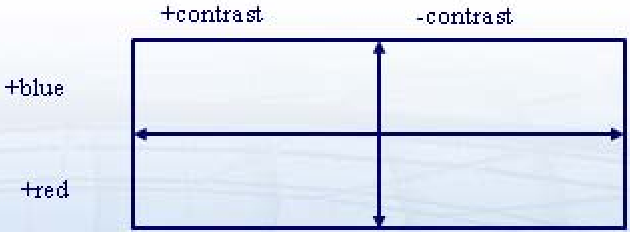
Meteosat9, 2010-08-21 2015 UTC





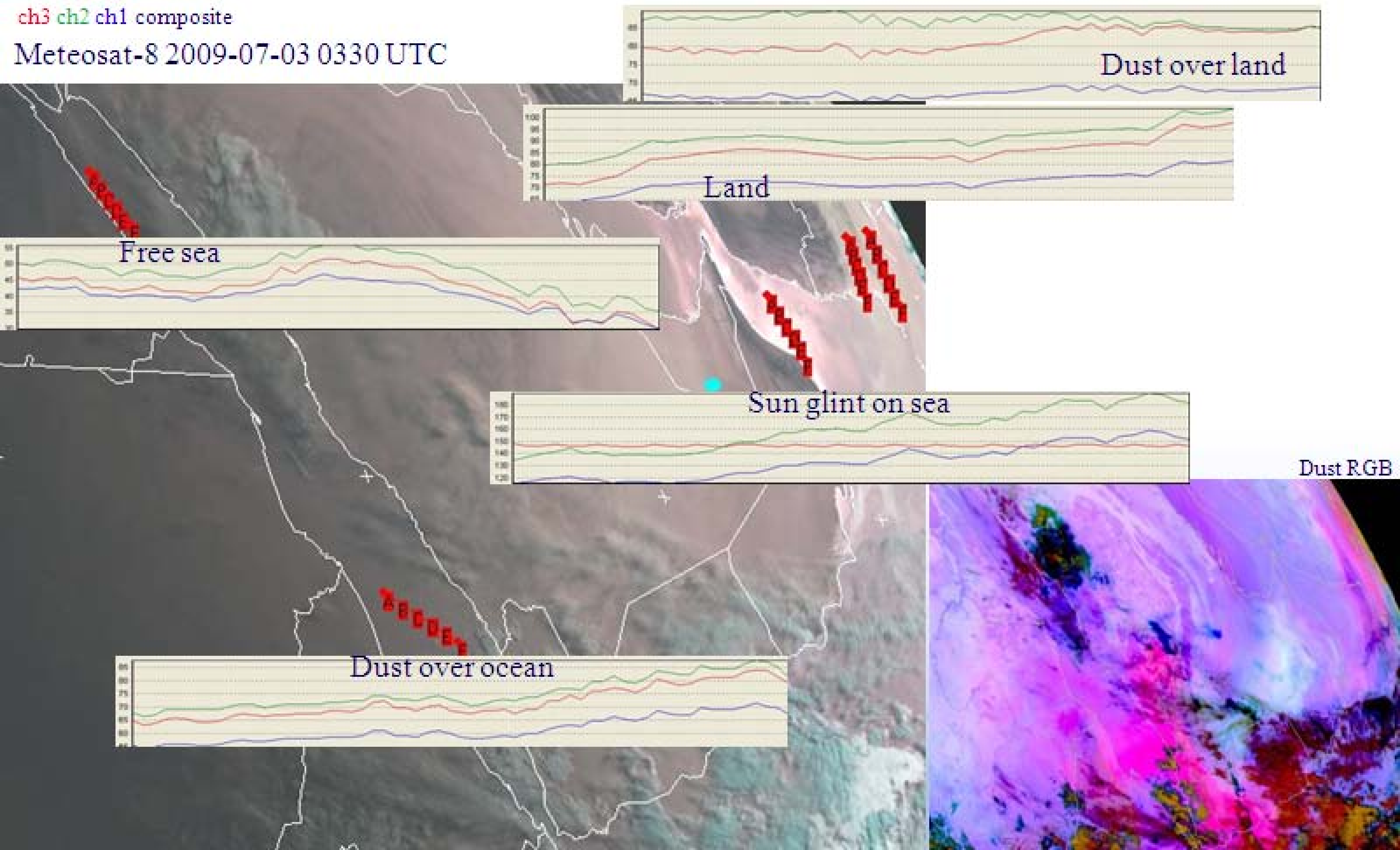
- Smaller wavelengths prefer forward scattering
- Blue-cyan colour due to 1.6 μm Rayleigh scattering
- Scattering intensity higher in the western late afternoon

What if smoke particles were **smaller**? :
More contrast?
Redder or bluer in this RGB hue?



Smaller Bigger

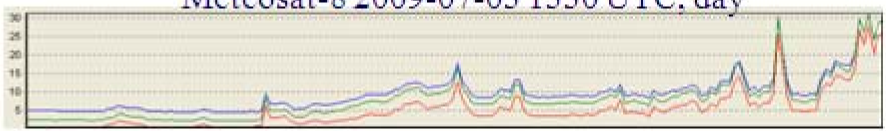
Sun glint and dust



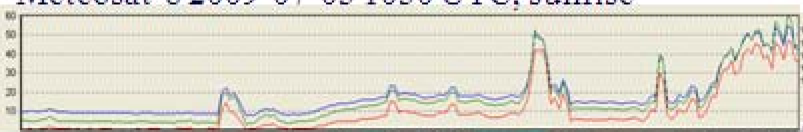
Sun glint hides the dust signal (sunset on the West)

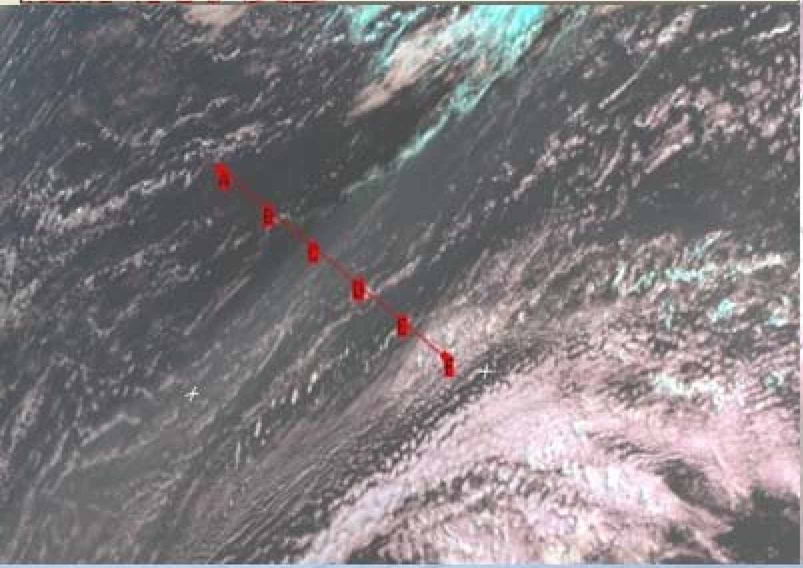
At the western Atlantic, -58E ,18N dust over ocean (C-D), obscured at late p.m by coincident sunglint

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

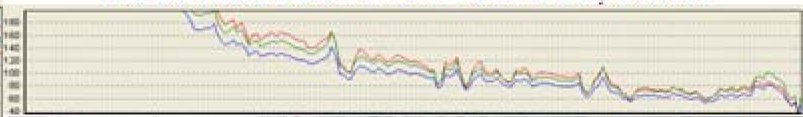


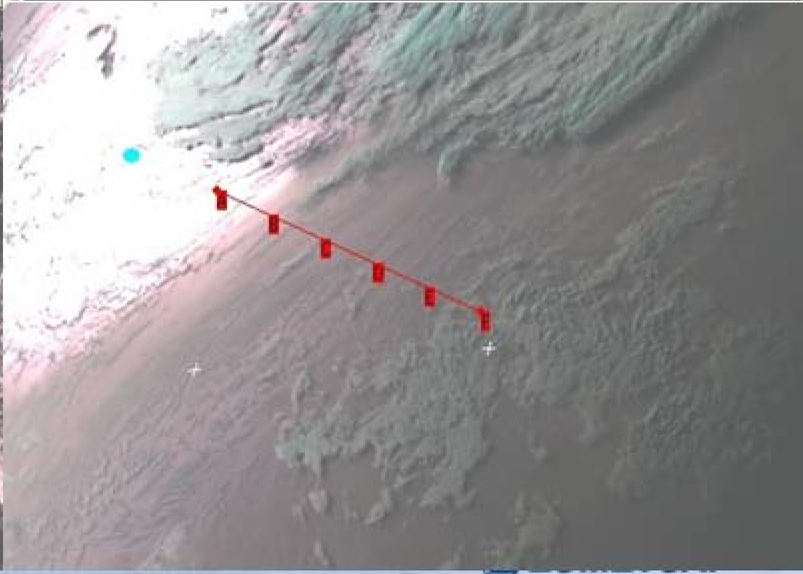
Meteosat-8 2009-07-03 1030 UTC, sunrise



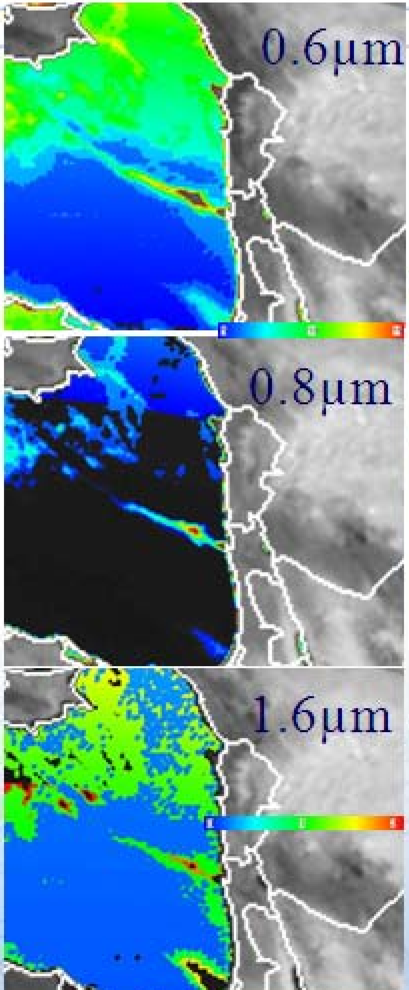


Meteosat-8 2009-07-03 2030 UTC, sunset



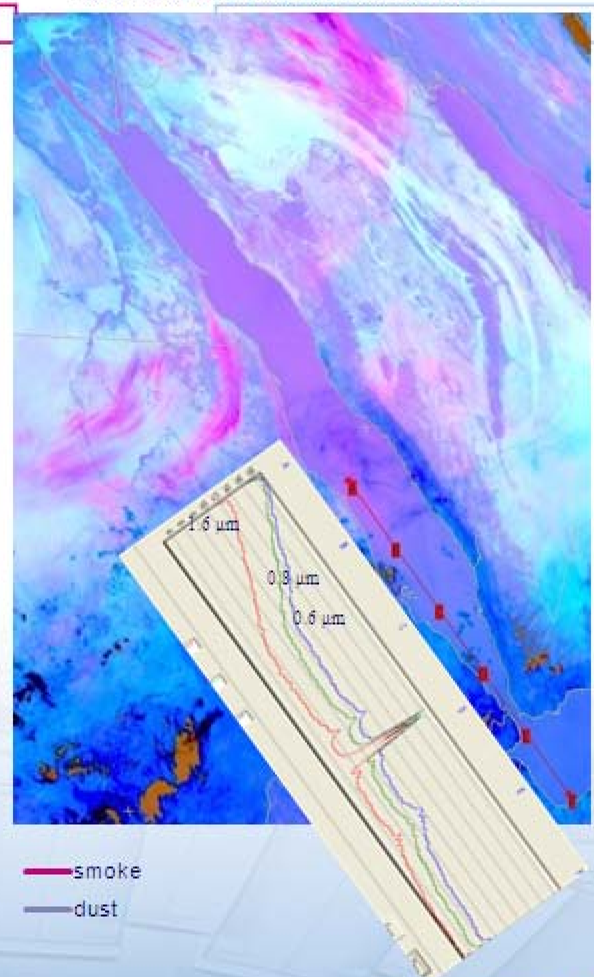


Ash or smoke is smaller than dust



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

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



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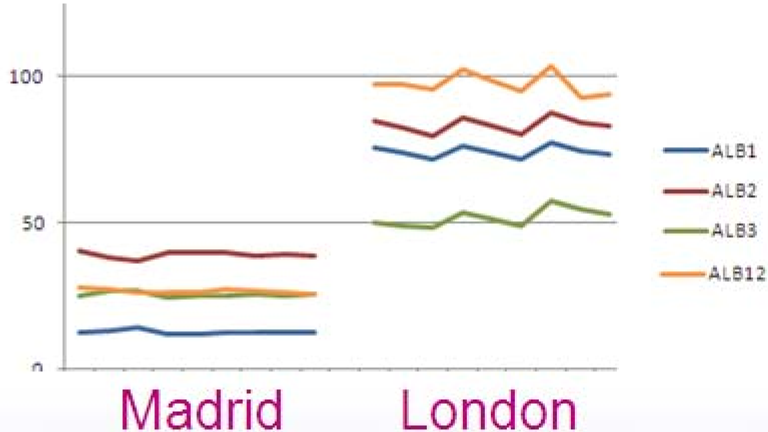
Clear and cloudy locations (26-Apr-2010 10:45, 9 neighbours)

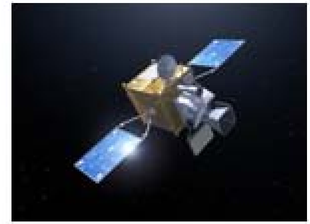


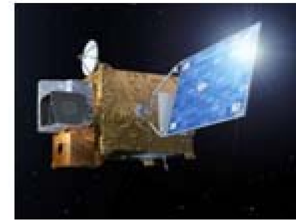
- Solar: scale 0% - 100% albedo
- For the clear (dry) scene, 0.8μm provides the strongest reflectance
- For cloud over London, 1.6μm is weakest
- HRV is average of the solar channels 0.6 and 0.8μm for land, but above both for cloud cover

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

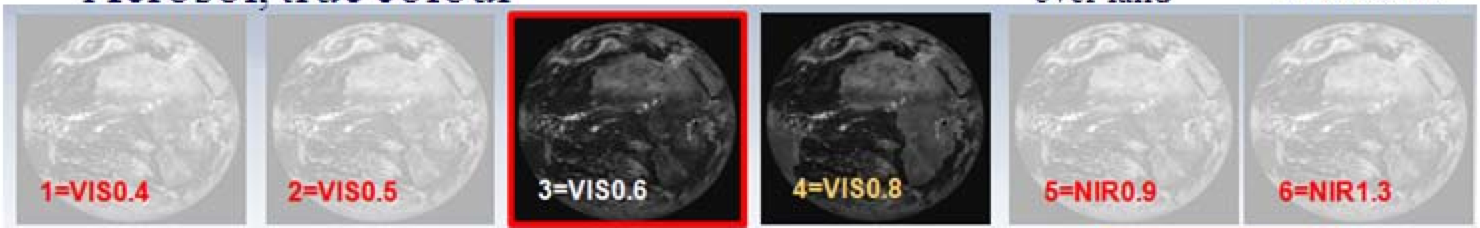
EUMETSAT

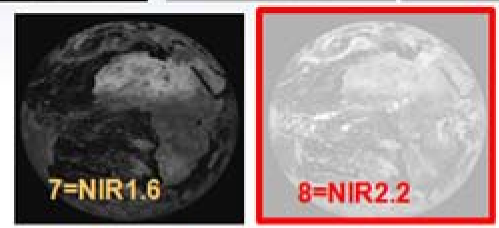
Third generation solar channels

Aerosol, true colour

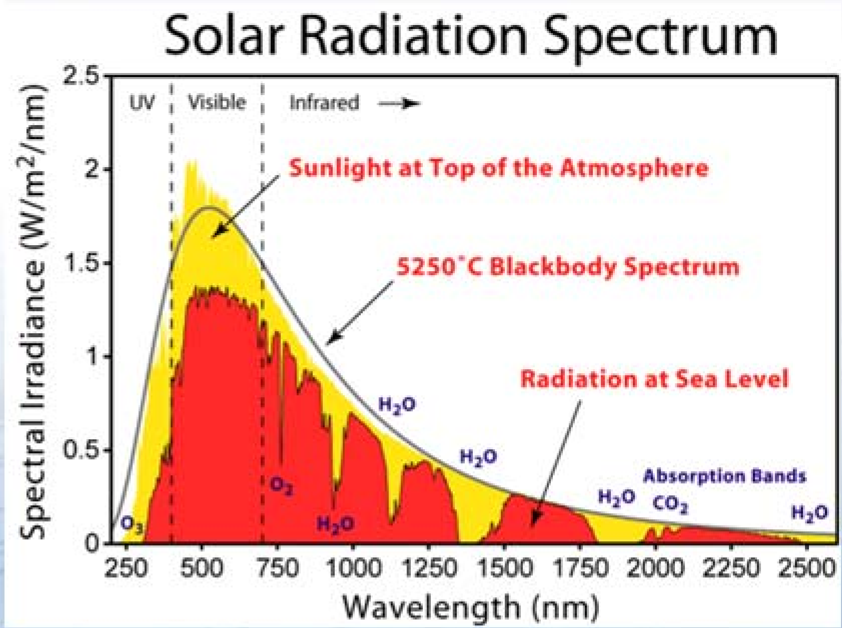
Water vapour over land

Thin cirrus





Cloud microphysics



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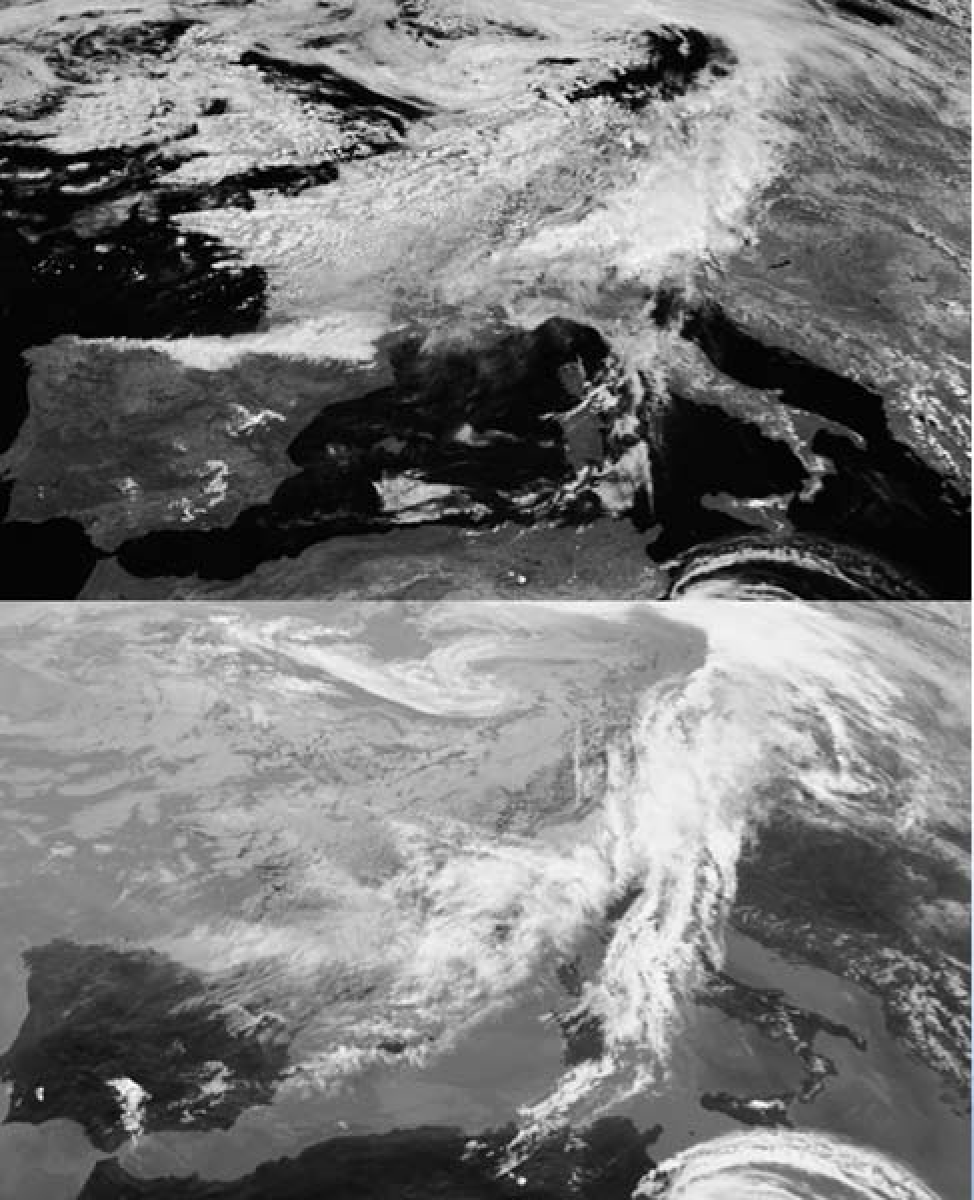
Aerosol, ocean colour, flooding



EXERCISE: Solar versus IR

June image at midday

Which panel is *solar*?

Which panel is *thermal*?

EXERCISE: Solar versus IR

June image at midday
Which panel is *solar*?
Which panel is *thermal*?

Think of temperatures and reflectances for water bodies, land and cloud

Reflectance order:
water – land – cloud

Temperature order:
cloud – water – land

So the first image is ...?
The second is... ?

EUMETSAT

Thank you for your attention

2011-05-19 15UTC