Introduction to Solar Channels

Courtesy: **Veronika Zwatz-Meise**
Jochen Kerkmann
HansPeter Roesli

Khalid Khamis Saif Al-Jahwari

Assistant Director of Forecasting and Observing Practices

PACA, Oman

Overview

- *Quick Review of some basic Remote Sensing Principles*
- *Basic interpretation of different satellite imageries.*
- *Introduction to ch 1, ch 2, and ch 3*
- *Introduction to the HRV channel*

- Earth and atmosphere. All solids, liquids and gases emit electromagnetic radiation.
- Solids and liquids absorb and emit radiation over a range of wavelengths determined by their temperature.
- The hotter the source, the greater is the intensity of radiation emitted.
- This is one of the keys of satellite remote sensing since, *from Planck's function, the temperature of an emitting source can be obtained from the intensity of its radiation*.

In accordance with Wien's law,

- The hot sun emits radiation at shorter wavelengths than the much cooler Earth–atmosphere system.

- Fig. 1 shows the wavelengths of some common types of radiation.
- It also indicates the spectra of radiation emitted by the sun (at a temperature of about 6000 K) and by the Earth and its atmosphere (at temperatures between 200 and 300 K).
- In meteorology these are frequently referred to as ‘solar radiation’ and ‘terrestrial radiation’,

Physical principles

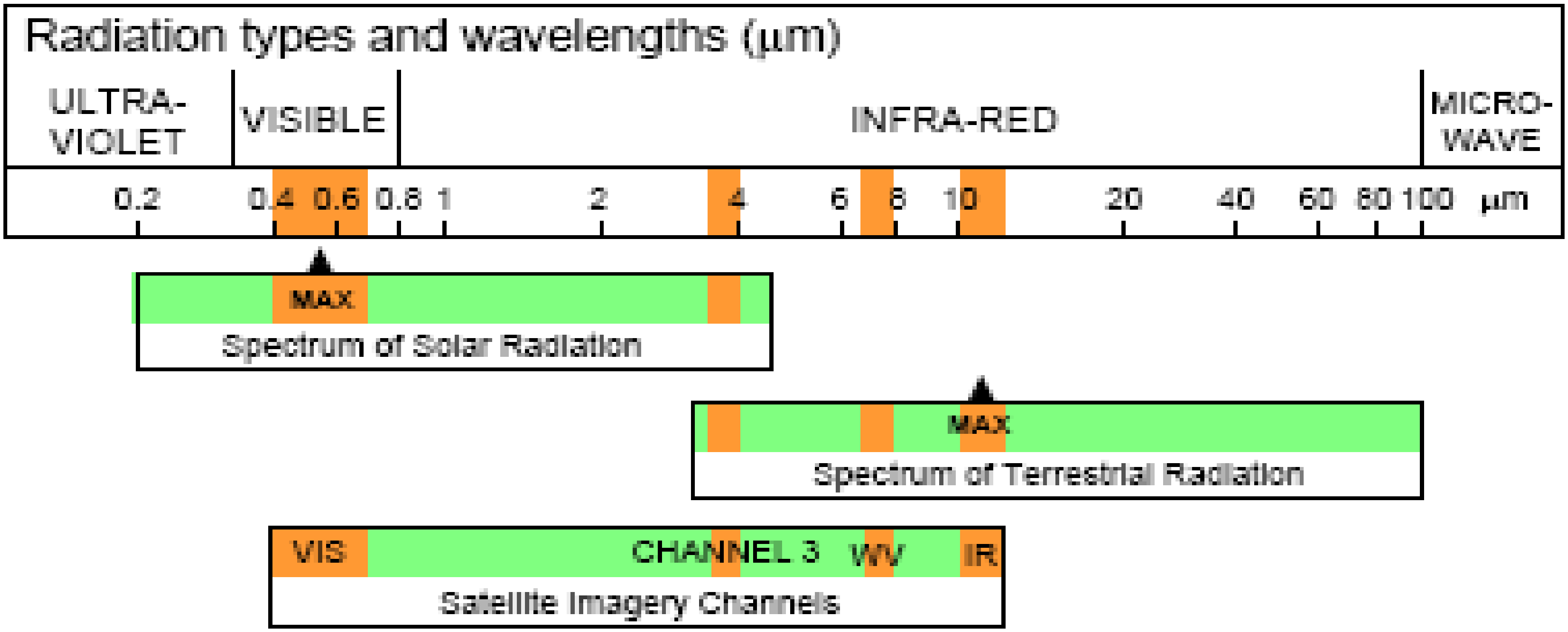


Fig. 1 Wavelengths of different types of radiation and the channels used for satellite imagery. MAX = wavelengths of maximum intensity of emissions from the sun and the Earth–atmosphere system.

Khalid Al-Jahwari Oman Met
khalid_khamis@hotmail.com

- Solar radiation of significant intensity occurs at wavelengths between 0.2 and 4.0 μm.

- The intensity peaks at about 0.5 μm in the visible part of the spectrum.

- Lesser, but still significant, amounts of solar radiation, are found in the ultraviolet and near infrared regions.

- Terrestrial radiation is emitted at wavelengths between 3 and 100 μm, which falls entirely within the infrared region.

- The maximum intensity of the radiation is around 11 μm.

- Unlike solids and liquids, individual gases are not black bodies.

- They only absorb or emit strongly at certain wavelengths which are characteristic of each individual gas.

- Within the visible and infrared wave bands that are important in meteorology, the principal absorbing gases are water vapour, carbon dioxide and ozone, but their effect is far from uniform at all wavelengths.

- As indicated in Fig. 2, each gas is active in certain narrow absorption bands, and there are other regions where the absorption by all the gases is so weak, that the atmosphere is almost transparent.
- ***These regions are known as 'windows' and are utilized for most imagery production.***
- By contrast, satellite soundings of vertical temperature structure in the atmosphere make use of the absorption bands.

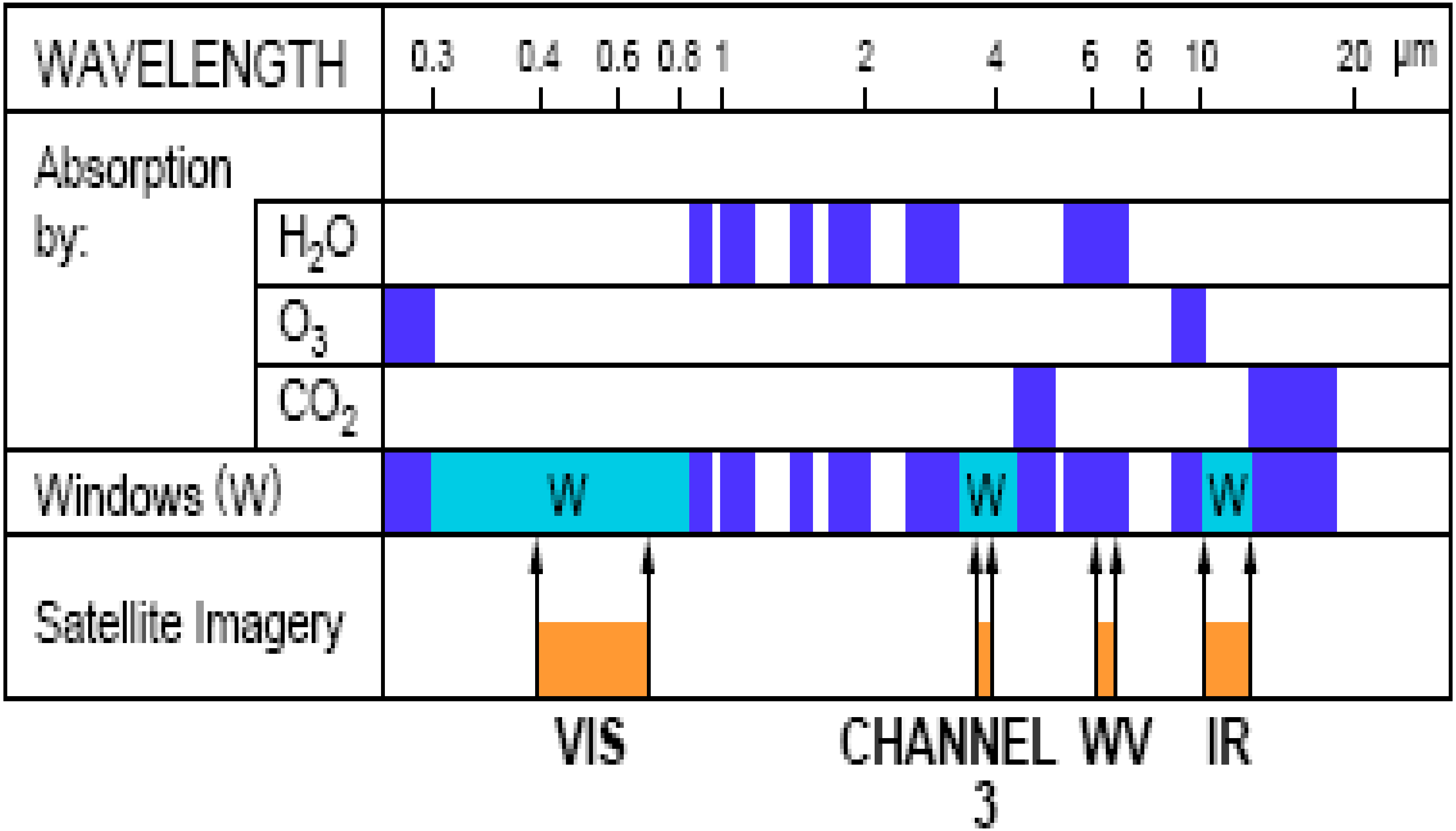


Fig. 2 Absorption of radiation at different wavelengths by atmospheric gases. VIS, IR and channel-3 imagery utilizes wavelengths in atmospheric windows; WV images are derived from emissions in one of the water vapour absorption bands.

MSG SEVIRI CHANNELS

Basic + Airmass + High-resolution VIS Missions

Window	Band (µm)	Absorption	Band (µm)
VIS 0.6	0.56 - 0.71	H_2O 6.2	5.35 - 7.15
VIS 0.8	0.74 - 0.88	H_2O 7.3	6.85 - 7.85
IR 1.6	1.50 - 1.78	O_3 9.7	9.38 - 9.94
IR 3.9	3.48 - 4.36	CO_2 13.4	12.40 - 14.40
IR 8.7	8.30 - 9.10		
IR 10.8	9.80 - 11.80	High Res VIS	1km Sampling
IR 12.0	11.00 - 13.00	HRV	0.4 - 1.1

MSG SEVIRI Channels

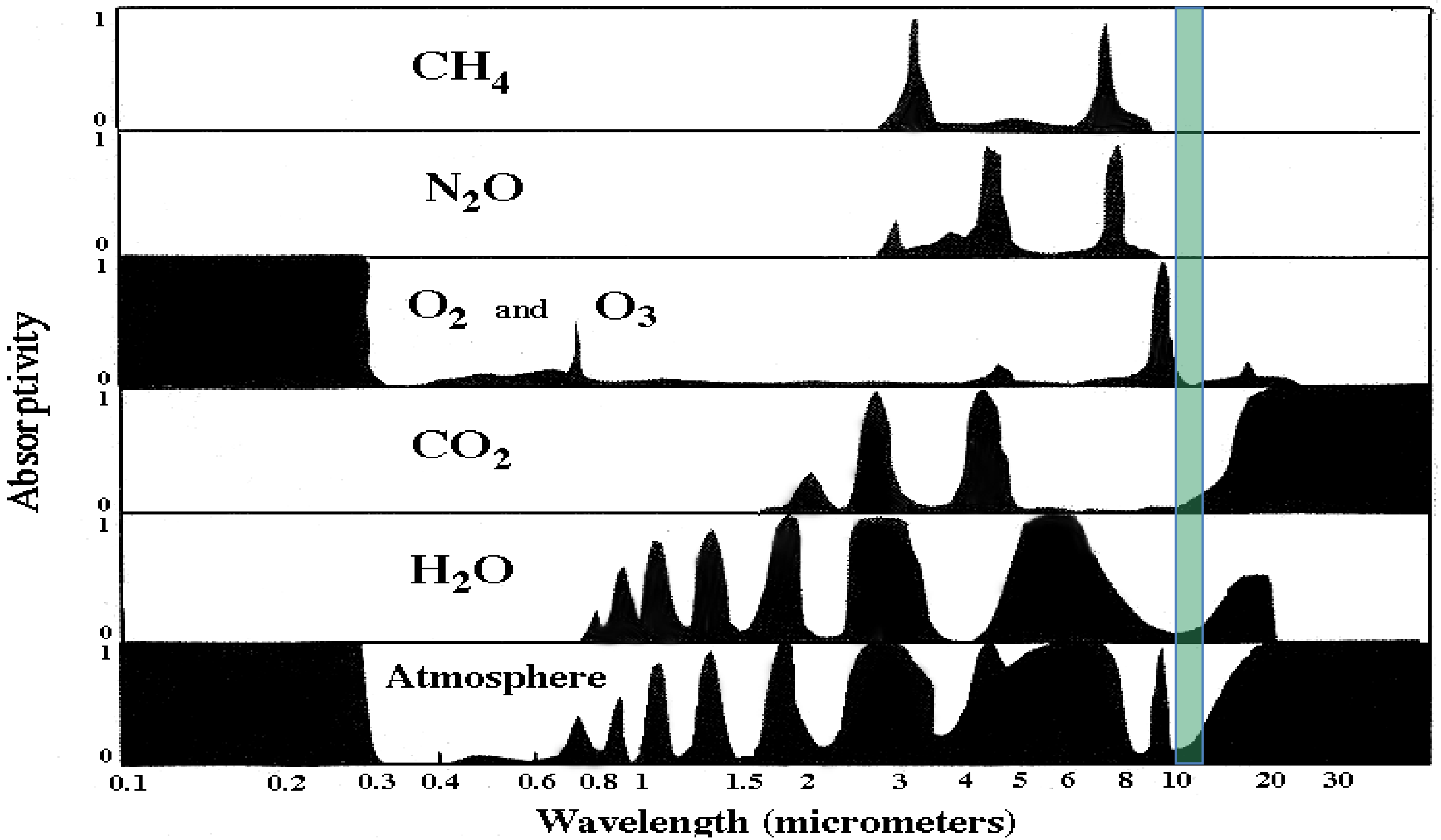
Channel	Main Surface Properties (cloudfree areas, NADIR viewing)
01 (VIS0.6)	surface reflectivity (albedo) at 0.6 µm
02 (VIS0.8)	surface reflectivity (albedo) at 0.8 µm, "greeness" of vegetation
03 (NIR1.6)	surface reflectivity (albedo) at 1.6 µm
04 (IR3.9)	Day-time: surface temperature, surface reflectivity (albedo) at 3.9 µm, surface emissivity Night-time: surface temperature, surface emissivity
05 (WV6.2)	upper-level moisture
06 (WV7.3)	mid-level moisture
07 (IR8.7)	surface temperature, surface emissivity, humidty
08 (IR9.7)	surface temperature, ozone content
09 (IR10.8)	surface temperature
10 (IR12.0)	surface temperature, humidty
11 (IR13.4)	surface temperature, lapse rate between surface and 800 hPa
12 (HRV)	surface reflectivity (albedo, broadband 0.4 - 1.1 µm)

Radiation

Atmospheric Absorption

IR

Fig. 2-9 -- Page 36



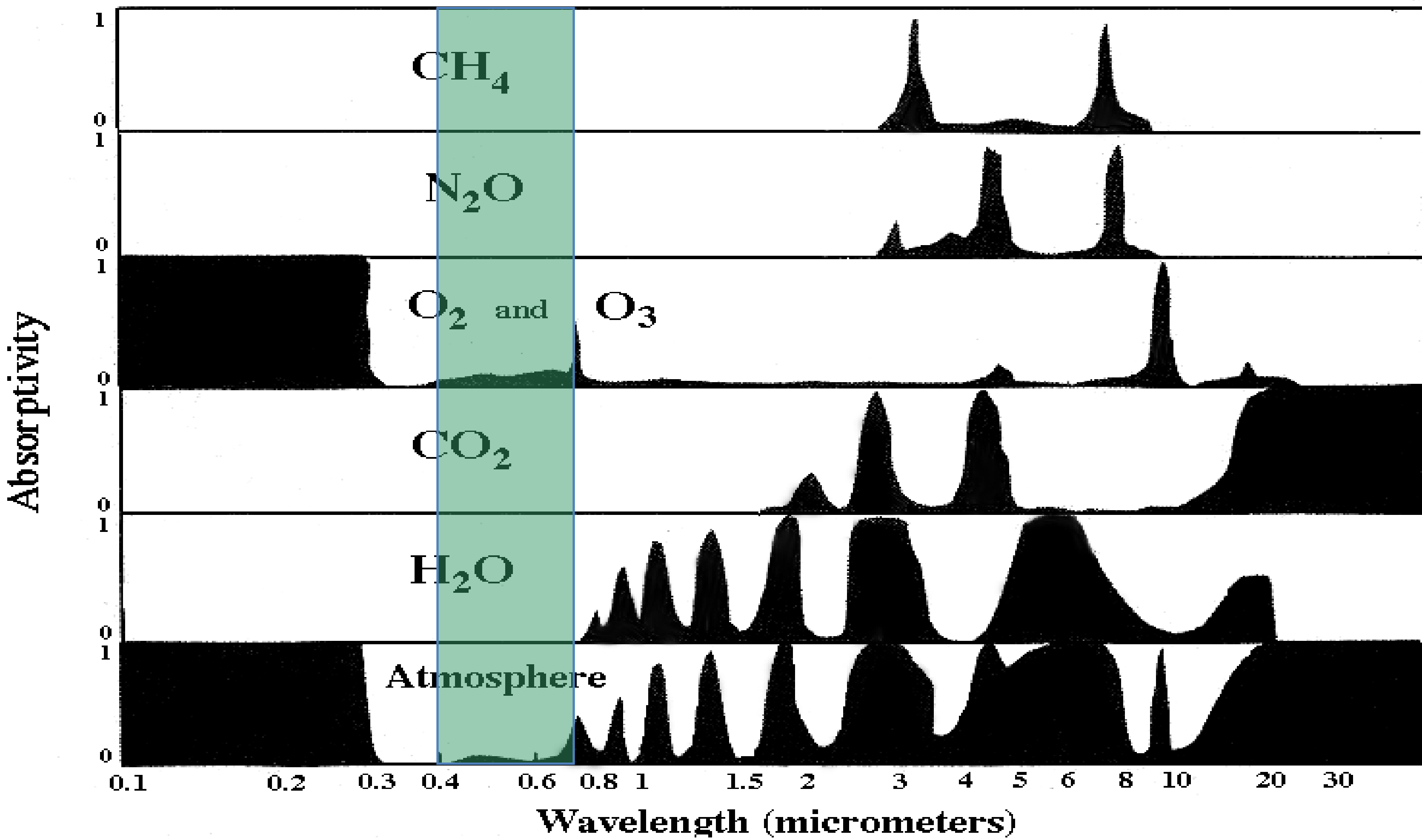
Adapted from: Fleagle and Businger, 1980: *An Introduction to Atmospheric Physics*, p. 232

Radiation

Atmospheric Absorption

VISIBLE

Fig. 2-9 -- Page 36



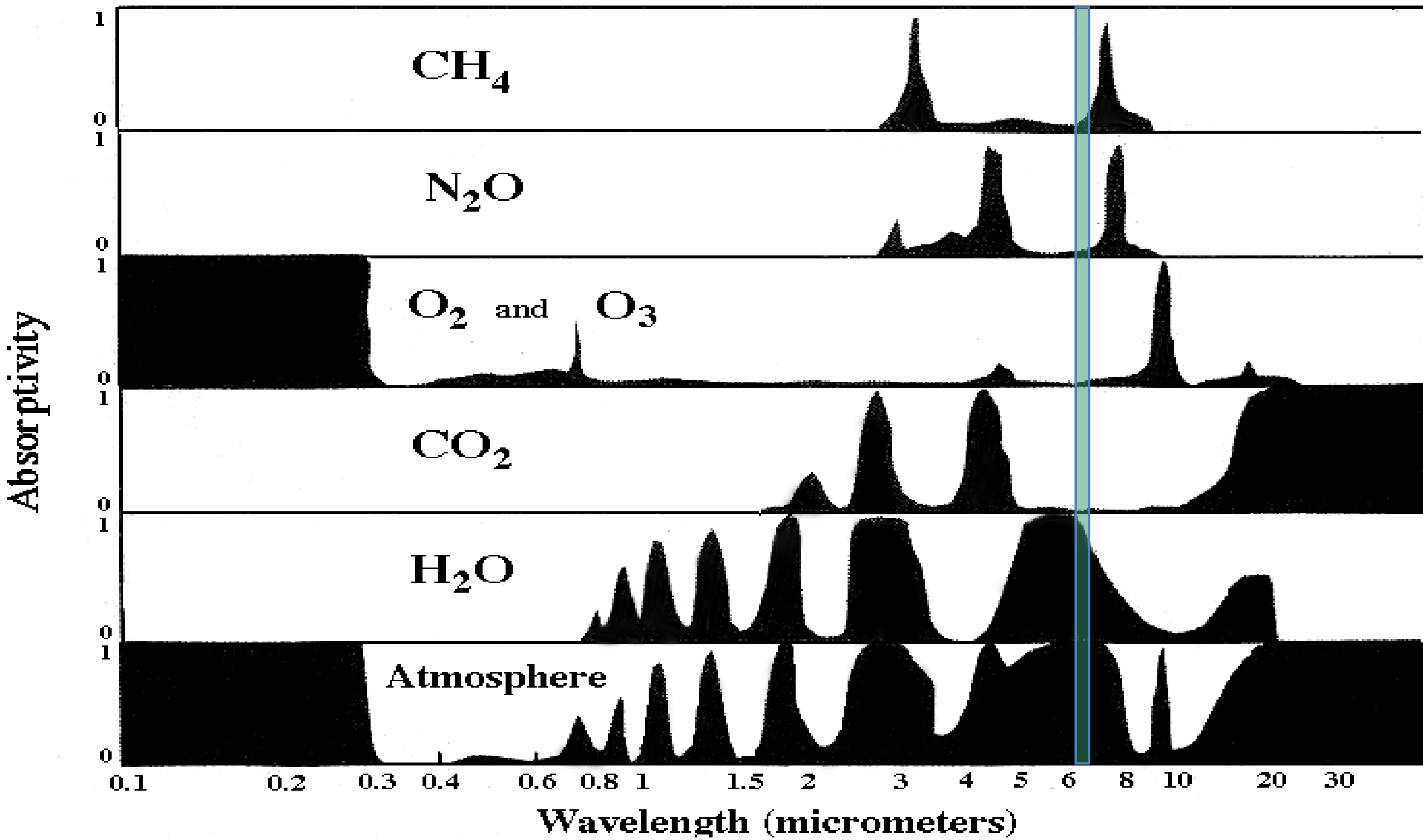
Adapted from: Fleagle and Businger, 1980: *An Introduction to Atmospheric Physics*, p. 232

Radiation

Atmospheric Absorption

Water Vapor

Fig. 2-9 -- Page 36



Adapted from: Fleagle and Businger, 1980: *An Introduction to Atmospheric Physics*, p. 232

Satellite imagery

The images most commonly used operationally are known as:

(a) VIS — imagery derived from reflected sunlight at visible and near-infrared wavelengths;

(b) IR — imagery derived from emissions by the Earth and its atmosphere at thermal-infrared wavelengths;

Satellite imagery

(c) WV — imagery derived from water vapour emissions (6–7 μm);

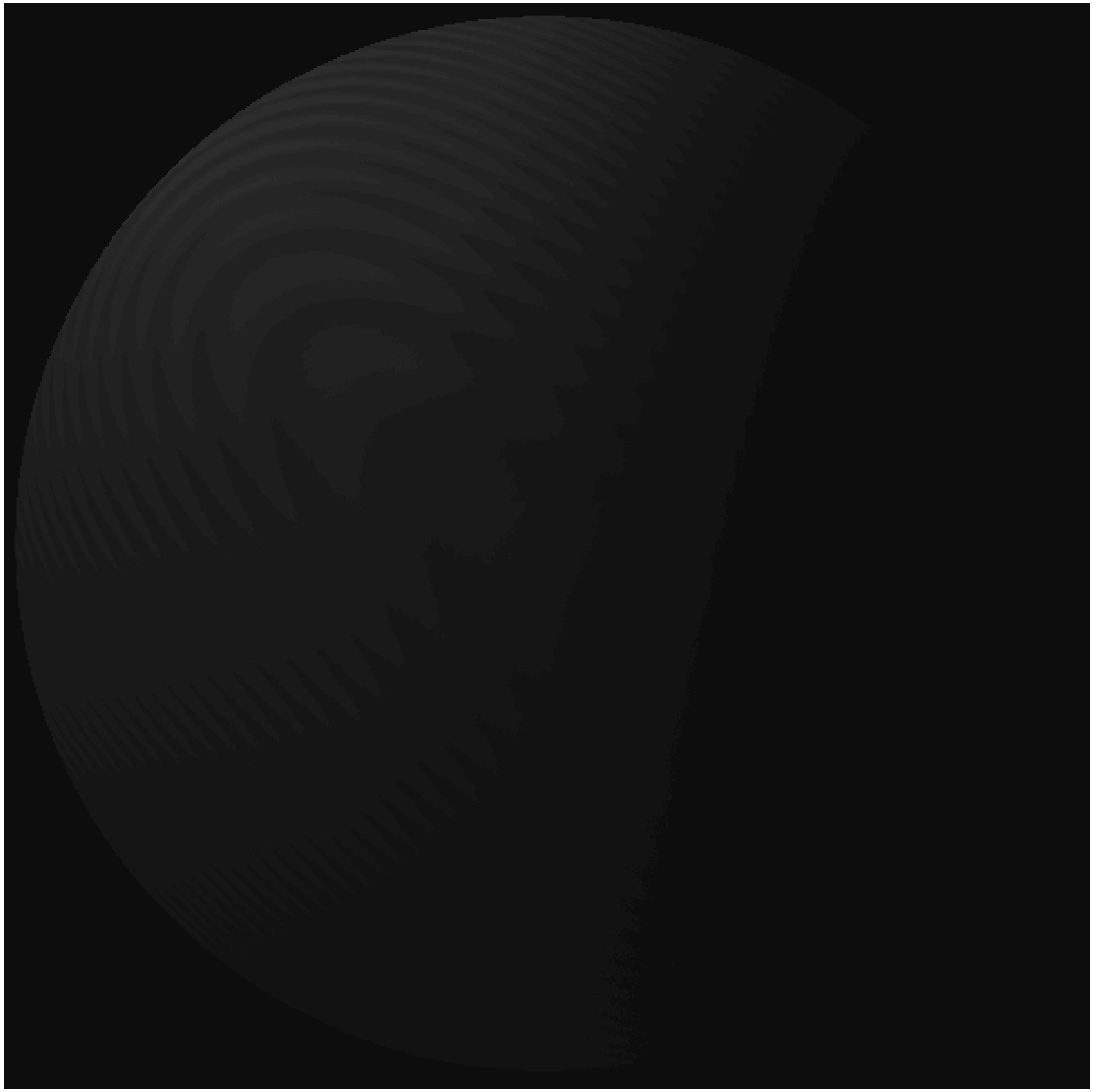
(d) 3.9 μm — imagery from this specific wavelength, which is in the overlap region between solar and terrestrial radiation.

Khalid Al-Jahwari Oman Met
khalid_khamis@hotmail.com

Satellite imagery

- Visible (VIS) imagery is derived from solar radiation scattered or reflected towards the satellite from the Earth–atmosphere system.

- The intensity of the image depends on the albedo, or reflectivity, of the underlying surface or cloud.



MSG-1, 24 April 2003, 00:00 - 16:00 UTC
Channel 01 (0.6 µm)

VIS 0.6/0.8 µm

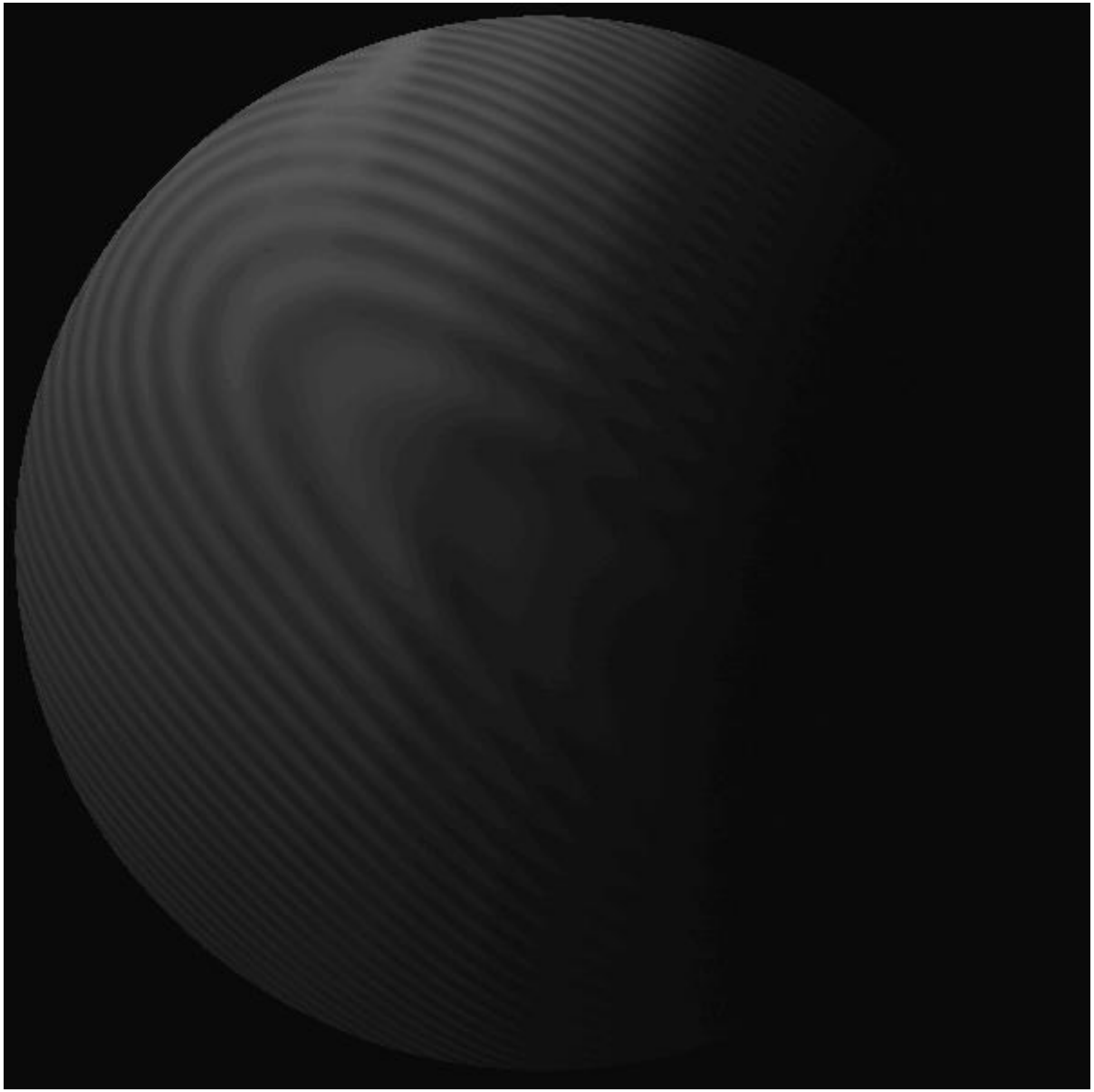
Different greyshades:
different reflectivities

High reflectance

Thick clouds, snow
Sunglint

Low reflectance

Ocean, lakes, rivers



NIR 1.6 µm

High reflectance
- Sunglint
- Desert / Sand
- Low Water clouds

- Ice clouds

Low reflectance
- Ocean, lakes, rivers

MSG-1, 24 April 2003, 00:00 - 16:15 UTC
Channel 03 (1.6 µm)

Satellite imagery

- VIS images are normally displayed in a manner that is familiar to the human eye. Using a black and white color scale ,with different shades of grey indicating different levels of reflectivity, the brightest and most reflective surfaces are in white tones and the least reflective surfaces are black.
- In general, clouds are seen as white objects against the darker background of the Earth's surface.

Satellite imagery

- Conventional infrared (IR) imagery is derived from terrestrial radiation window regions, and this provides information on the temperature of the underlying surface or cloud.
- However, since the emitted radiation must traverse the Earth's atmosphere before reaching the satellite, it is modified during its passage by atmospheric absorption and re-emission.

Satellite imagery

- In the window regions, the modification is small.
- Most of the radiation reaching the satellite originates from the Earth's surface or from the clouds, and is largely unmodified by the atmosphere.
- This permits the easy operational use of satellite imagery by forecasters.

Satellite imagery

- The conventional way of displaying IR images in black and white is to present them so that they are consistent with the appearance of the VIS images by having the clouds appear in white shades against the darker background of the Earth.

Satellite imagery

- Since temperature normally decreases with height, the IR radiation with the lowest intensity is emitted by the highest and coldest clouds, and these appear whitest.

- This is convenient but it is the reverse of the procedure used for VIS images where the lowest reflectivities are shown in black.

Satellite imagery

- Water vapor (WV) imagery is derived from the radiation emitted by water vapor at wavelengths which are not in an atmospheric window.
- Emissions from water vapor at low levels in the atmosphere will therefore not normally escape to space.

Satellite imagery

- If the upper troposphere is moist, the radiation reaching the satellite will mostly originate from this (cold) region and be displayed in white shades, following the IR imagery color convention.

Satellite imagery

- Only if the upper troposphere is dry will radiation originate from water vapour at warmer, mid-tropospheric levels and be displayed in darker shades on the imagery.

- Radiation in the 3.9 μm channel is made up of scattered solar radiation and radiation emitted by the Earth and its atmosphere.

Satellite imagery

- Since the former contribution is only present by day, the interpretation of imagery in this channel is complex and varies from day to night.

Basic interpretation of VIS imagery

- *General principles*
  - In the black and white display of VIS images, darker shades represent low brightness (i.e. low intensity of reflected radiation) and the lighter shades high brightness.

Basic interpretation of IR imagery

- *General principles*
  - IR imagery indicates the temperature of radiating surfaces. In black and white, warm areas are shown in dark tones and cold areas in light tones.
  - Clouds generally appear whiter than the Earth's surface because of their lower temperature.

- *General principles*
  - In this respect, IR and VIS images have some resemblance, but in others there are important differences between the two types of image
  - Because cloud-top temperature decreases with height, IR images show good contrast between clouds at different levels (unlike VIS imagery).

- *General principles*
  - During the day, the land may appear darker (warmer) than the sea but at night may appear lighter (cooler).

Khalid Al-Jahwari Oman Met
khalid_khamis@hotmail.com

- *General principles*

  - IR imagery is inferior to VIS in providing information about cloud texture because it is based upon emitted and not scattered radiation.

  -

Basic interpretation of WV imagery

- *Principles of operation*
  - WV imagery is derived from radiation at wavelengths around 6–7 µm.
  - This is not an atmospheric window but is a part of the spectrum where water vapour is the dominant absorbing gas.
  - It has an absorption band centred on 6.7 µm.

Basic interpretation of WV imagery

- *Principles of operation*
  - WV imagery is derived from radiation at wavelengths around 6–7 μm.
  - This is not an atmospheric window but is a part of the spectrum where water vapour is the dominant absorbing gas.
  - It has an absorption band centred on 6.7 μm.

- *Principles of operation*

  – Fig. 11 shows the relative contribution, as a function of pressure, of the radiation reaching the satellite in the (Meteosat) WV channel.

  – As the relative humidity decreases, so the main contribution to the radiance received at the satellite comes from lower in the troposphere.

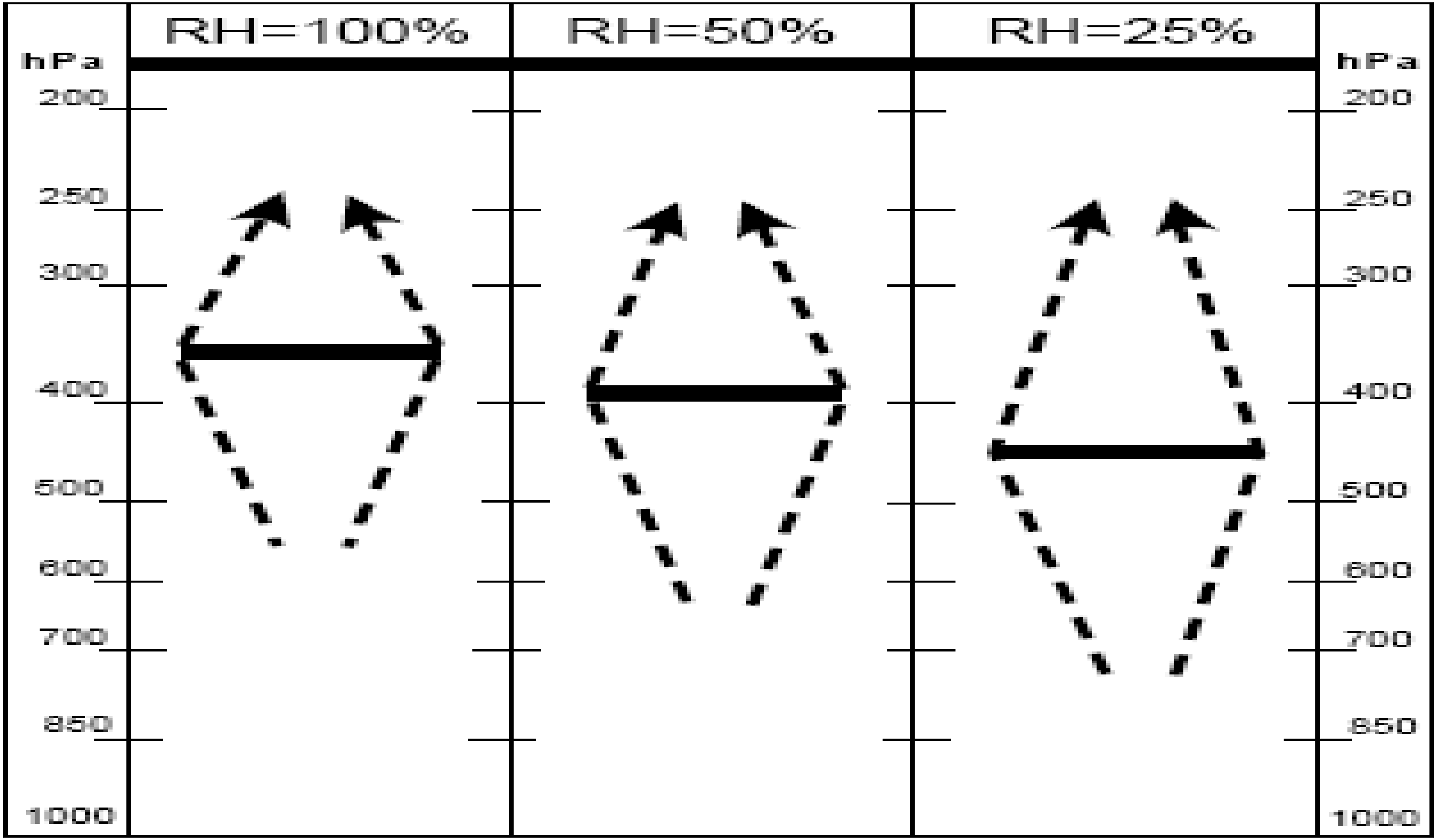


Fig. 11. A diagram of the approximate levels from which radiation in the WV channel reaches a satellite, for three values of tropospheric relative humidity. The dashed arrows span the levels from which some significant radiation may reach the satellite. The thick lines indicate the levels of maximum contribution.

- *Principles of operation*

  - WV imagery is usually displayed with the emitted radiation converted to temperature, like normal IR imagery.
  - Since temperature decreases with height, regions of high upper tropospheric humidity appear cold (light) and regions with low humidity appear warm (dark).
  - In other words, when the upper troposphere is dry, the radiation reaching the satellite originates from farther down in the atmosphere, where it is warmer and appears darker on the image.

Interpretation of WV imagery

- In a normally moist atmosphere, most of the WV radiation received by the satellite originates in the 300–600 hPa layer, but when the air is dry some radiation may come from layers as low as 800 hPa.

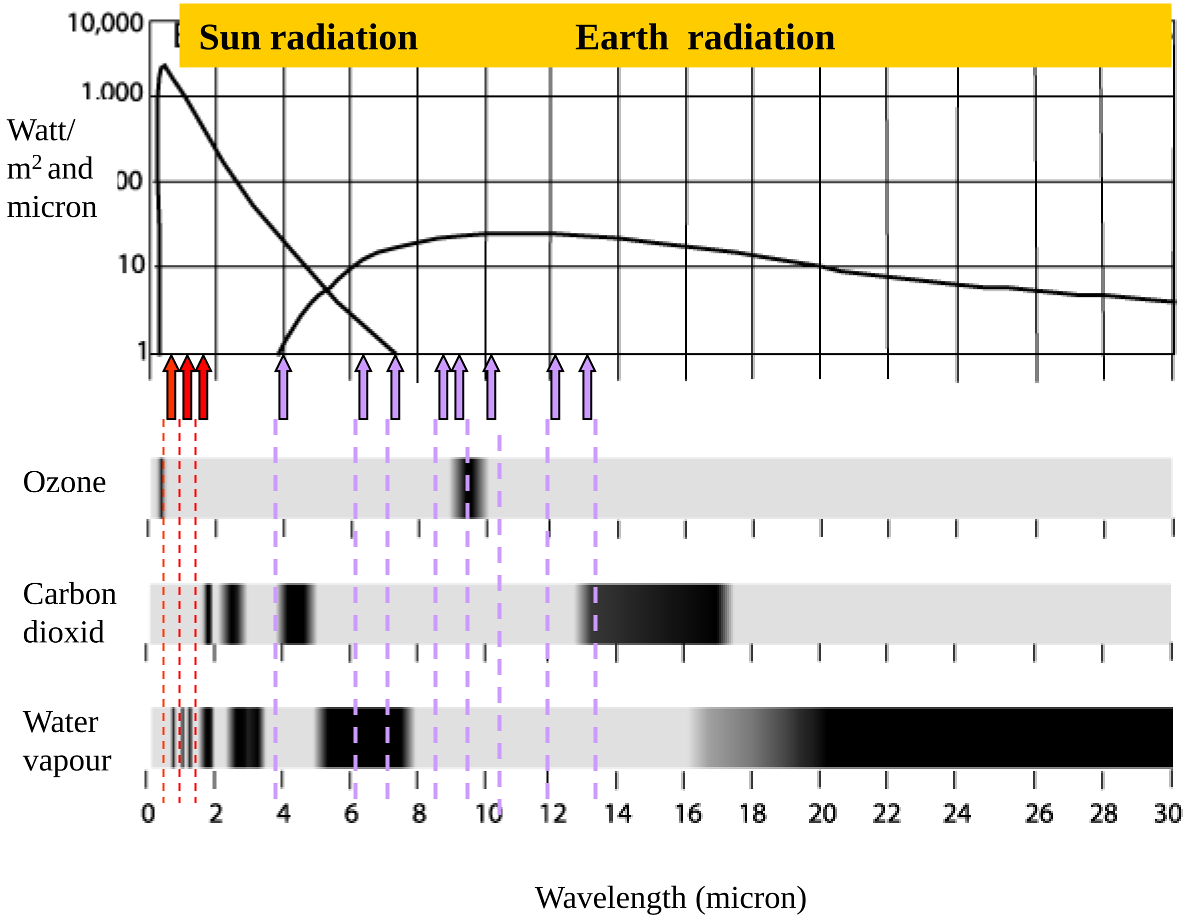
- It is particularly important to note that even when a WV image indicates a very dry upper troposphere, there may well be moist air near the surface.

- Moist air or cloud in the lower half of the troposphere is not depicted well in WV imagery.

All MSG channels

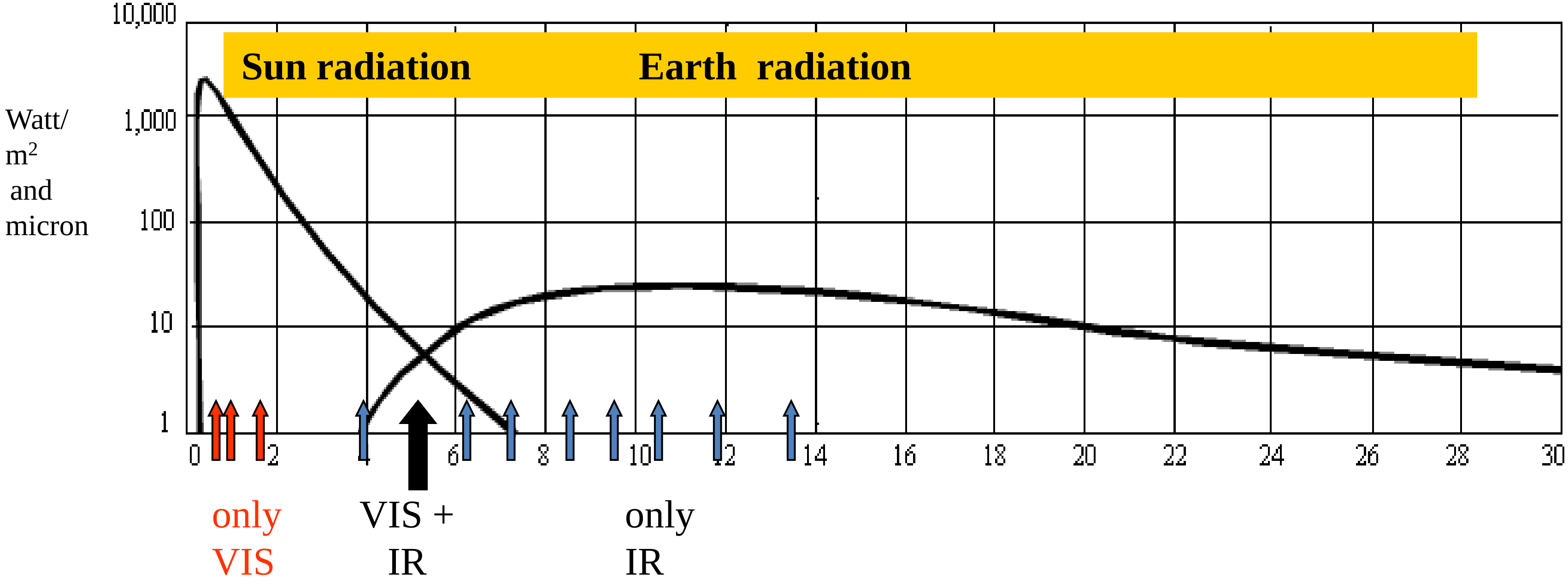
- Channel 01: VIS 0.6 μ
- Channel 02: VIS 0.8 μ
- Channel 03: NIR 1.6 μ
- Channel 04: MIR 3.9 μ
- Channel 05 WV 6.2 μ
- Channel 06: WV 7.3 μ
- Channel 07: IR 8.7 μ
- Channel 08: IR 9.7 μ („Ozon“)
- Channel 09: IR 10.8 μ
- Channel 10: IR 12.0 μ
- Channel 11: IR 13.4 μ („CO_2“)
- Chanell 12: HRV (High Resolution Visible)

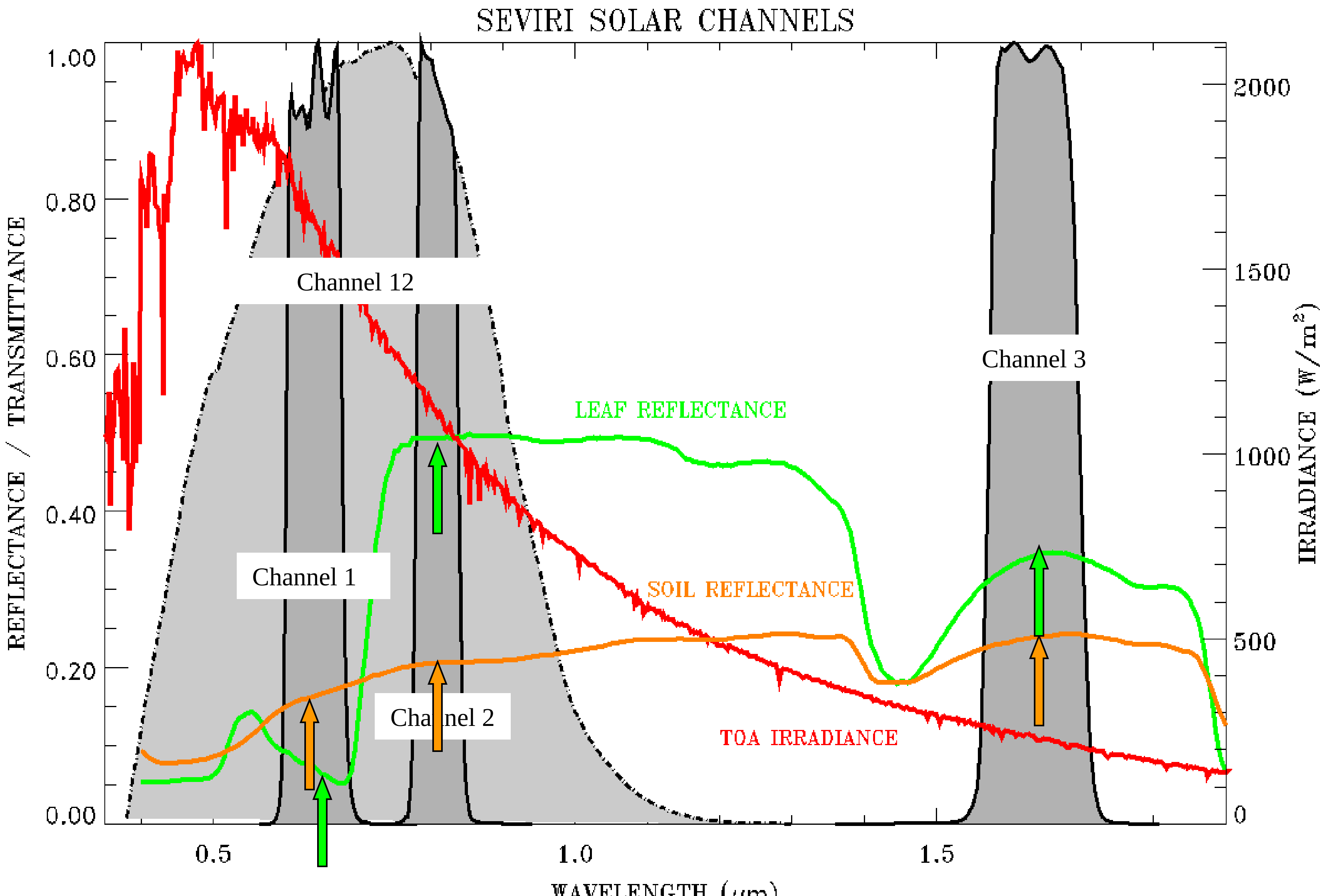
Ch01: 0.6 μ
Ch02: 0.8 μ
Ch03: 1.6 μ



Comparison of radiation sources sun - earth

- For wave length < 5 µm solar radiation is dominant
- For wave length > 5 µm radiation of earth is dominant
- Ch01, 02, 03, 12: only sun radiation
- Ch04: both: radiation from sun and earth
- Ch 05, 06, 07, 08, 09, 10, 11: only thermal earth radiation





Solar energy spectrum
Source:
EUMETSAT

Comparison of soil reflectance in the three VIS channels

Comparison of leaf reflectance in the three VIS channels

Figure 3a

Application areas for the solar channels

- Recognition of cloud because of reflected sun radiation
- Recognition of snow/ice because of reflected sun radiation
- Discrimination of water and ice cloud
- Recognition of earth surface characteristica (soil, vegetation)

- In these channels there are an O3 absorption band (around 0.6) and weak WV absorption lines

METEOROLOGICAL USE OF SEVIRI CHANNELS

VIS 0.6/0.8 μm

- Cloud and fog detection
- Cloud classification
- Cloud tracking
- Aerosol observation and volcanic ash clouds
- Vegetation monitoring
- Snow and Ice monitoring
- Flood monitoring
- Atmospheric wave patterns

Similar channels on many meteorological satellites.

METEOROLOGICAL USE OF SEVIRI CHANNELS

NIR 1.6 µm

- Snow and cloud/fog discrimination
- Cloud phase (ice or water)
- Particle size
- Cloud liquid water path
- Aerosol information (except desert dust)

Similar channel on AVHRR, ATSR and MODIS

MSG Channel VIS0.6

Land Surface

sun glint

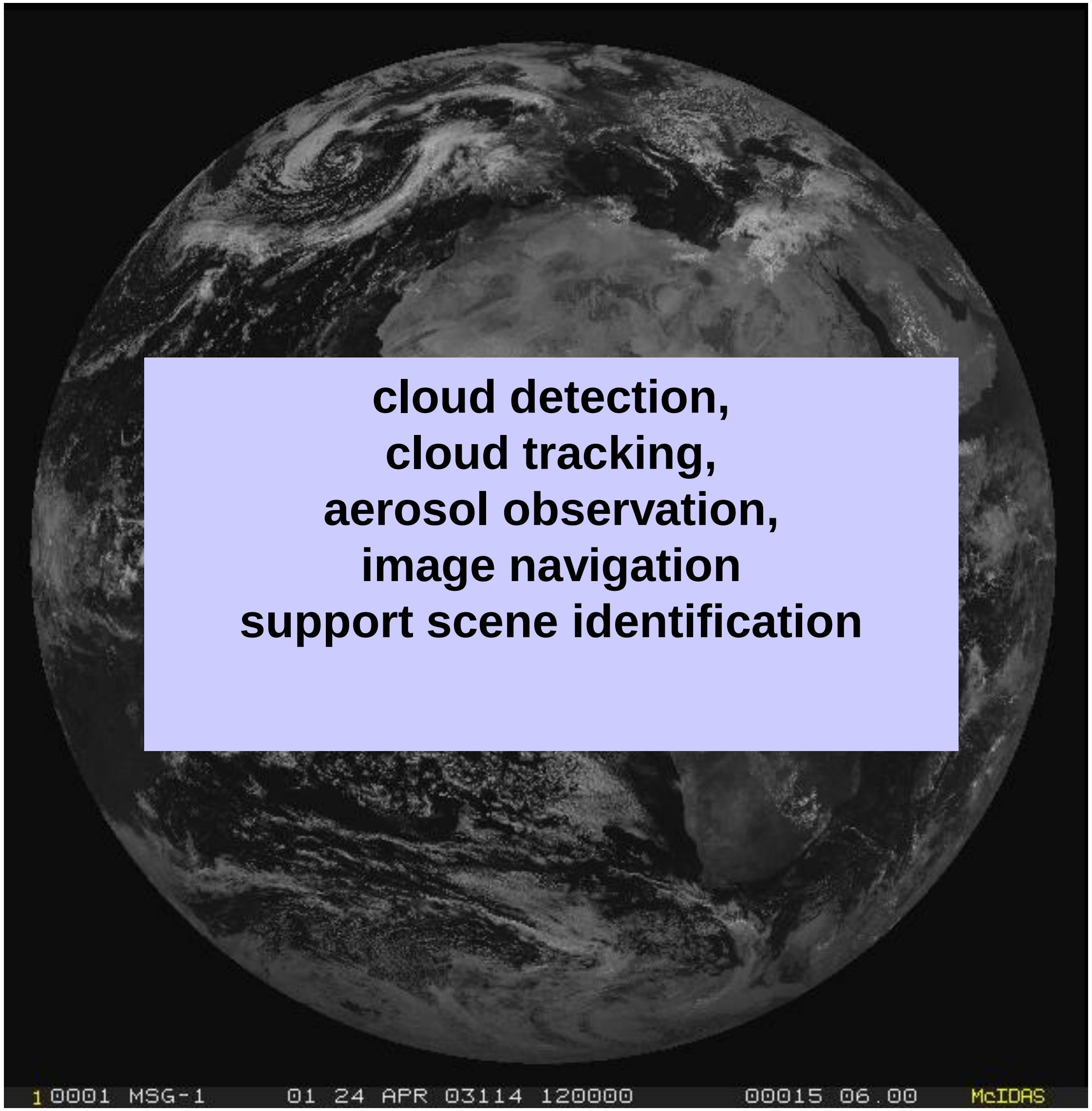
snow

desert

bare soil

forest

sea



cloud detection,
cloud tracking,
aerosol observation,
image navigation
support scene identification

Clouds

high reflectance

thick clouds

thin clouds over land

thin clouds over sea

low reflectance

MSG Channel VIS0.8

Land Surface

sun glint

snow

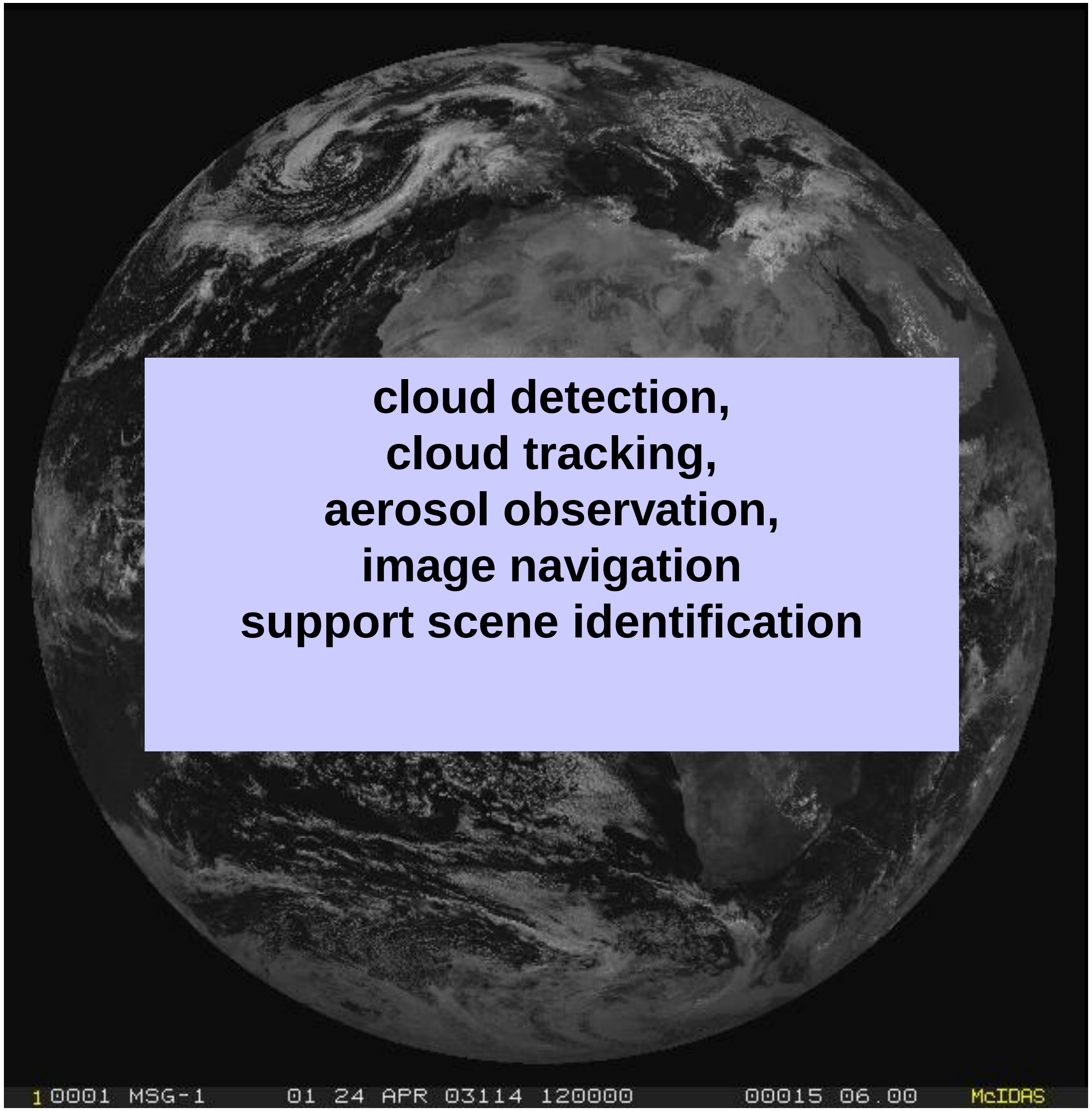
desert

grass etc.

forest

bare soil

sea



cloud detection,
cloud tracking,
aerosol observation,
image navigation
support scene identification

Clouds

high reflectance

thick clouds

thin clouds over land

thin clouds over sea

low reflectance

MSG Channel NIR1.6

Land Surface

sun glint

desert

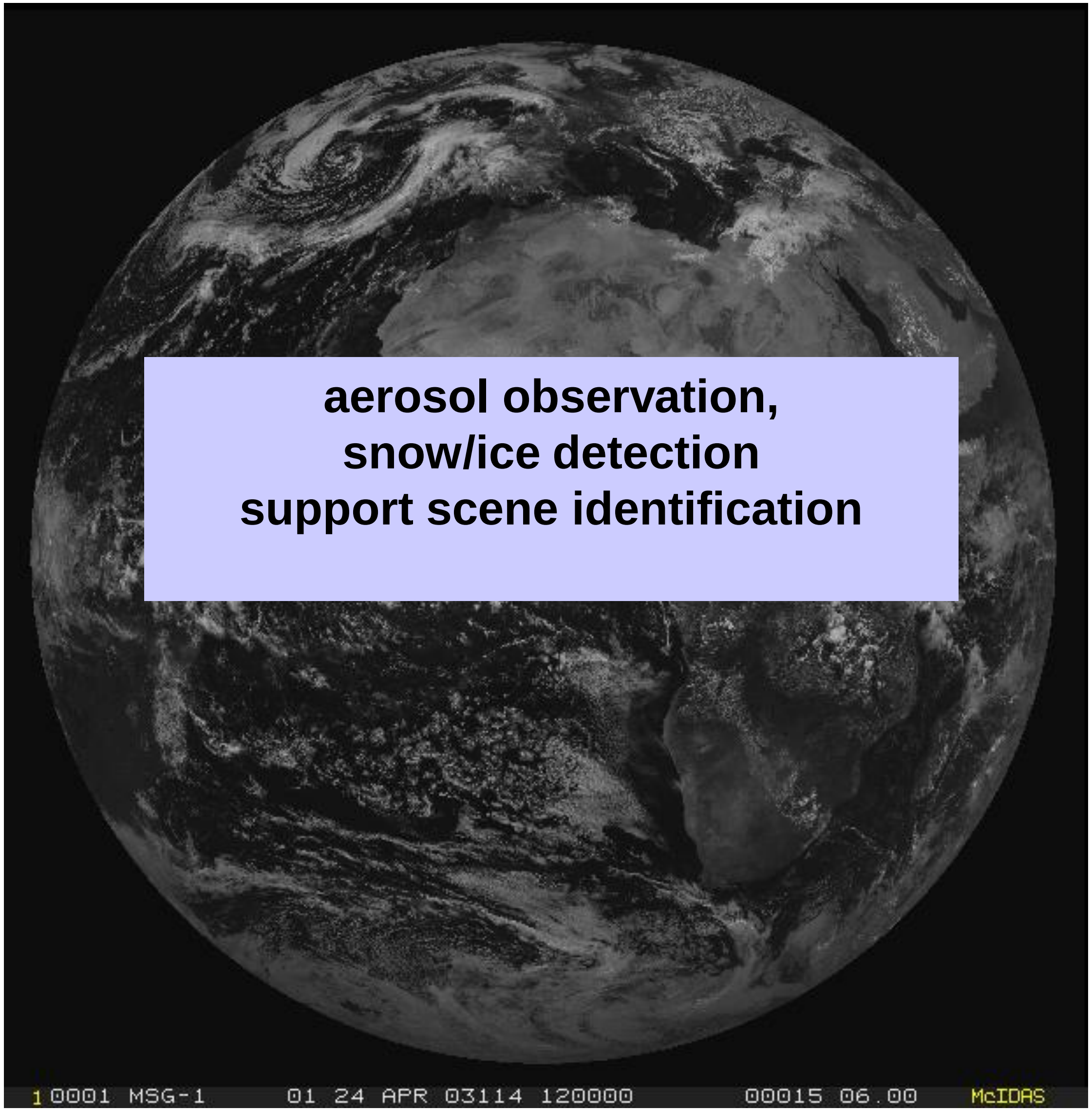
grass etc.

forest

bare soil

snow

sea



aerosol observation,
snow/ice detection
support scene identification

Clouds

high reflectance

water clouds with small droplets

water clouds with large droplets

ice clouds with small particles

ice clouds with large particles

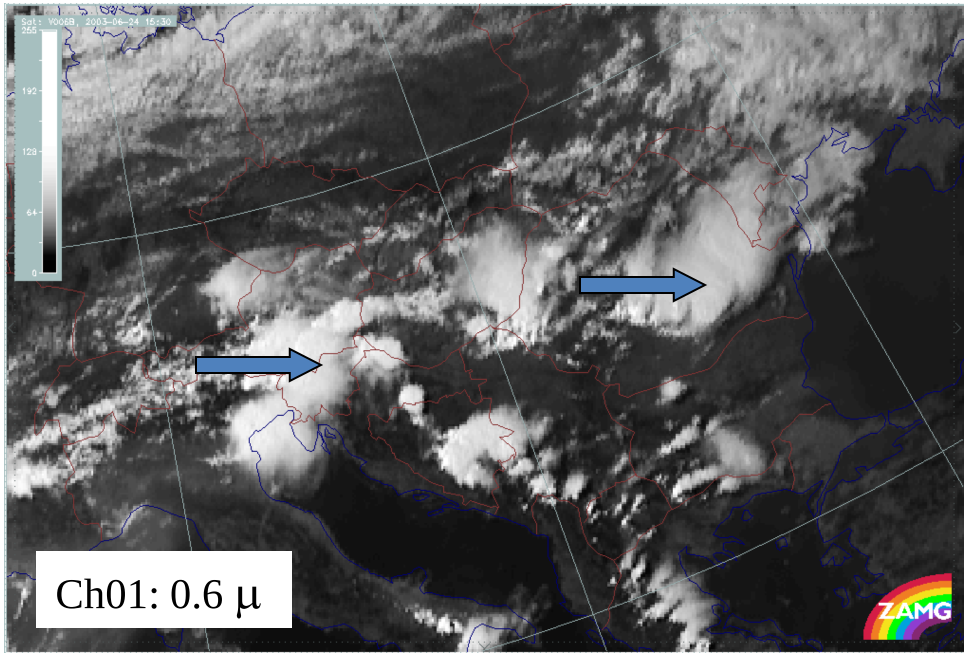
low reflectance

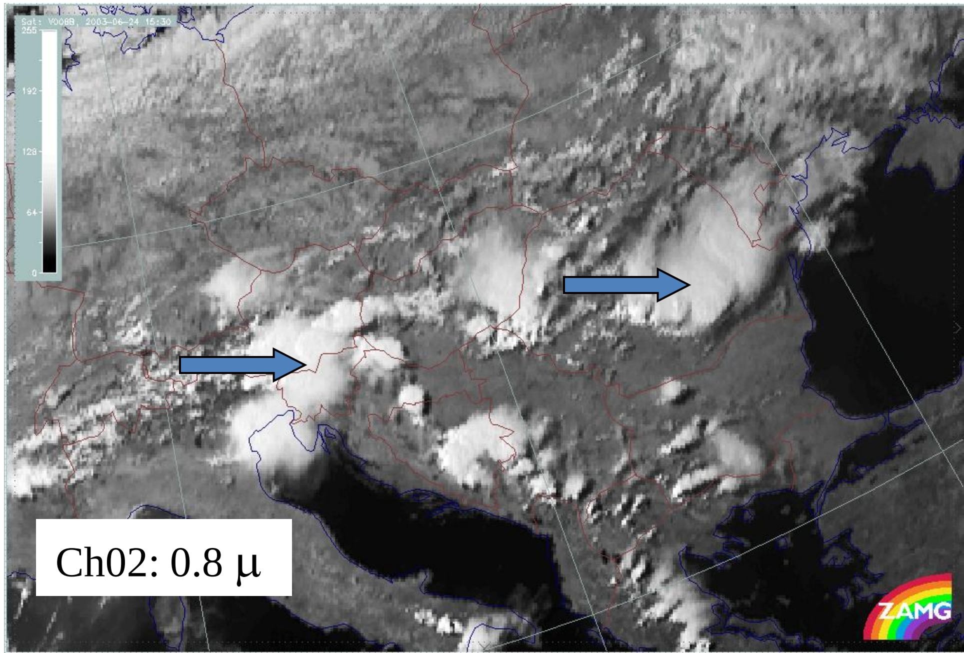
Ch01: 0.6 μ and Ch02: 0.8 μ

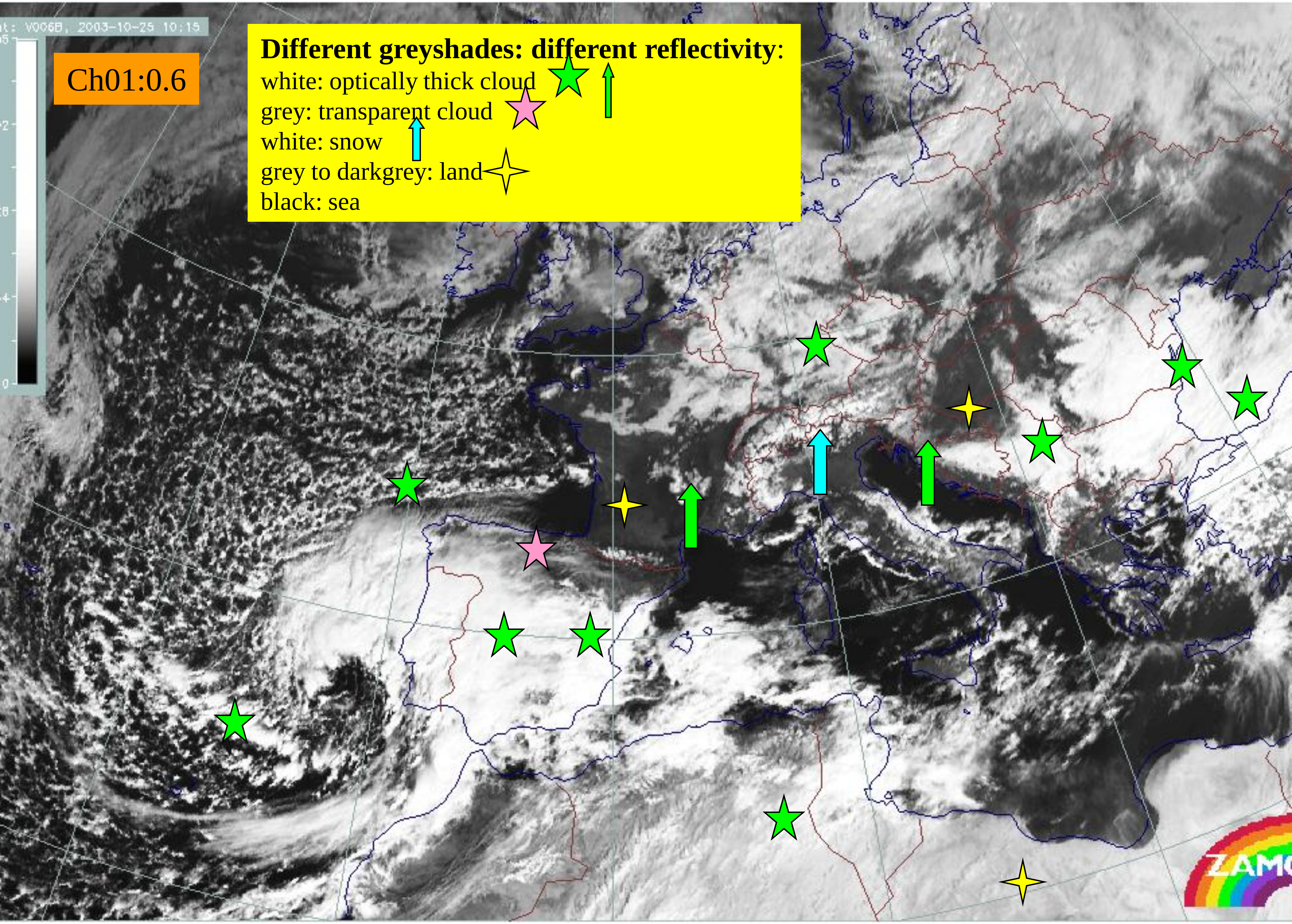
- NOAA and MSG VIS channels are comparable

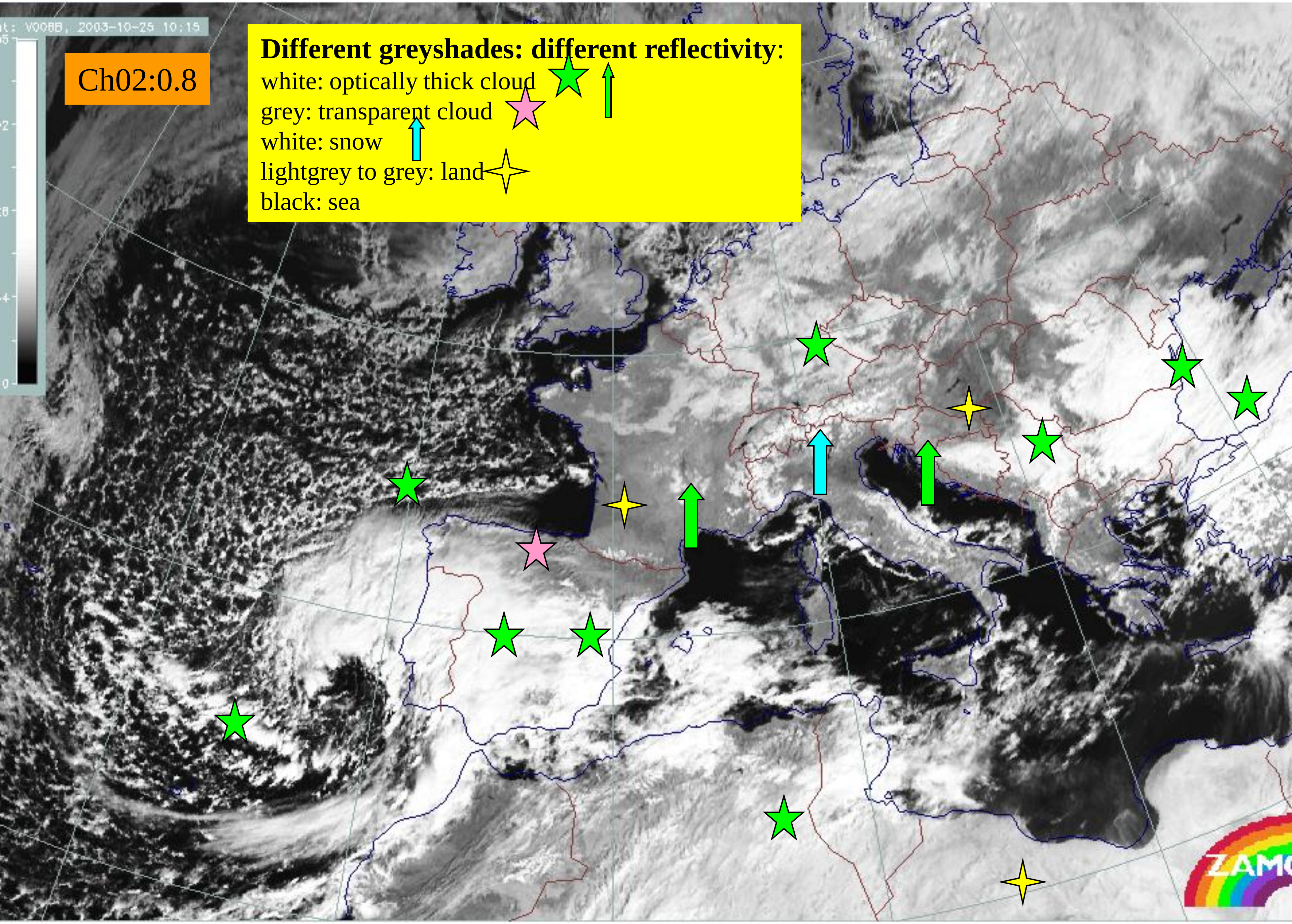
VIS 0.6 and VIS 0.8: clouds

- Both channels: recognition of cloud because of reflected sun radiation



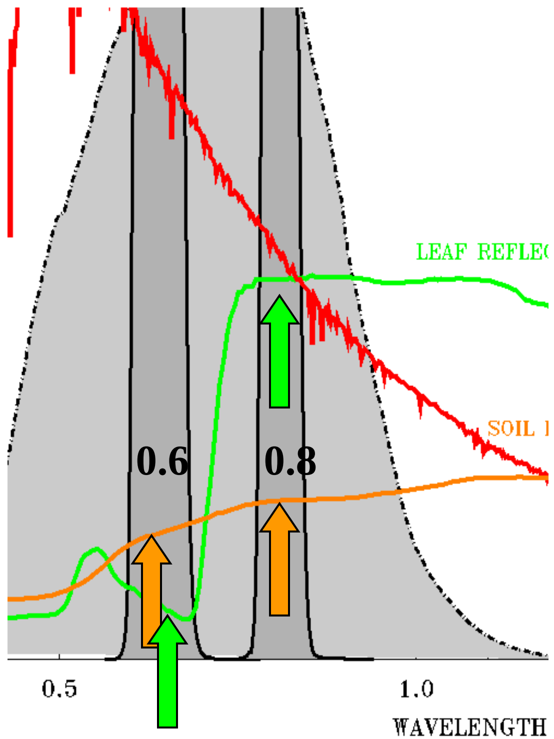


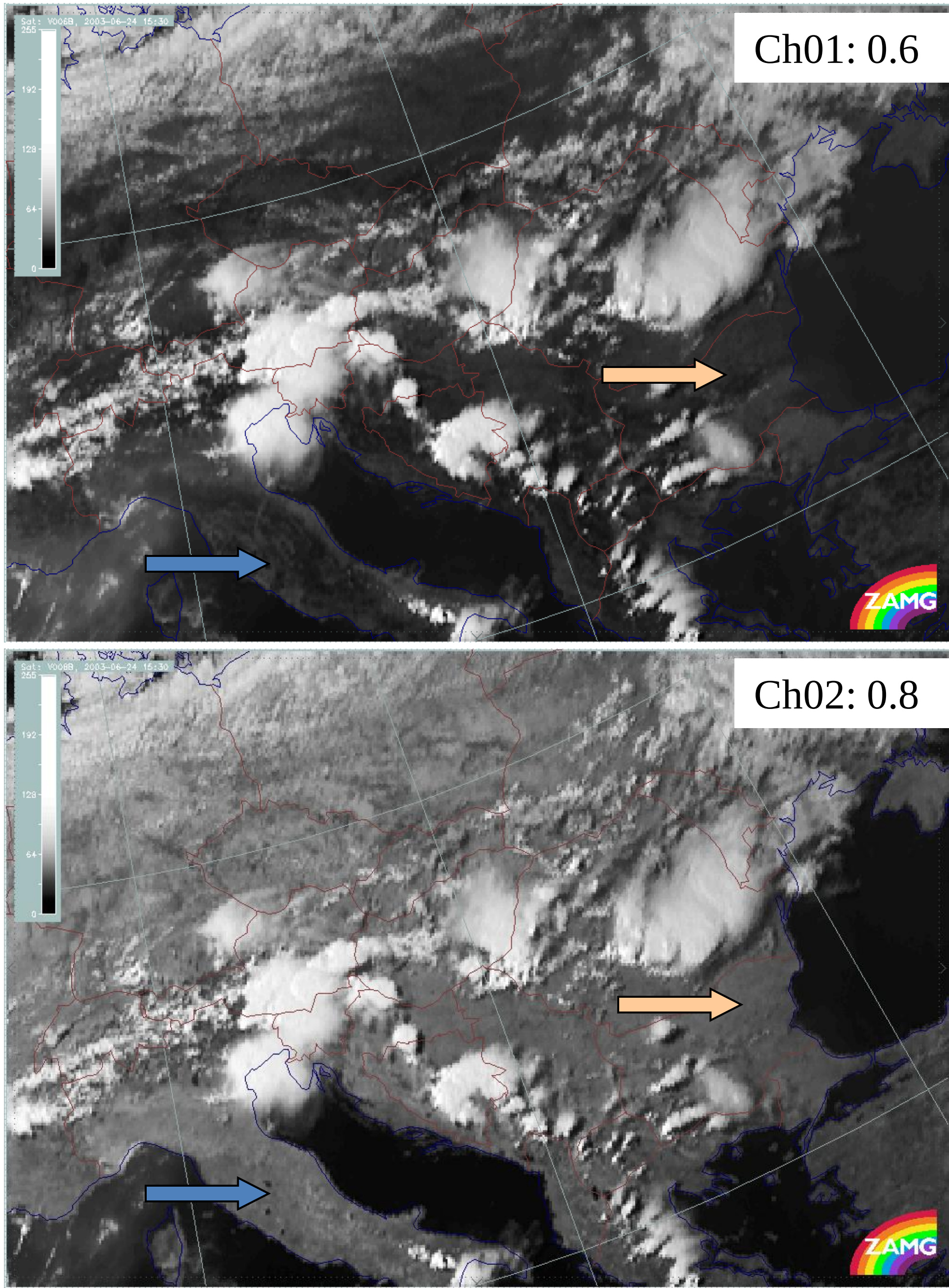

Ch01:0.6
Different greyshades: different reflectivity:
white: optically thick cloud
grey: transparent cloud
white: snow
grey to darkgrey: land
black: sea


VOOBB, 2003-10-25 10:15
Ch02:0.8
Different greyshades: different reflectivity:
white: optically thick cloud
grey: transparent cloud
white: snow
lightgrey to grey: land
black: sea

VIS 0.6 and VIS 0.8: land surface

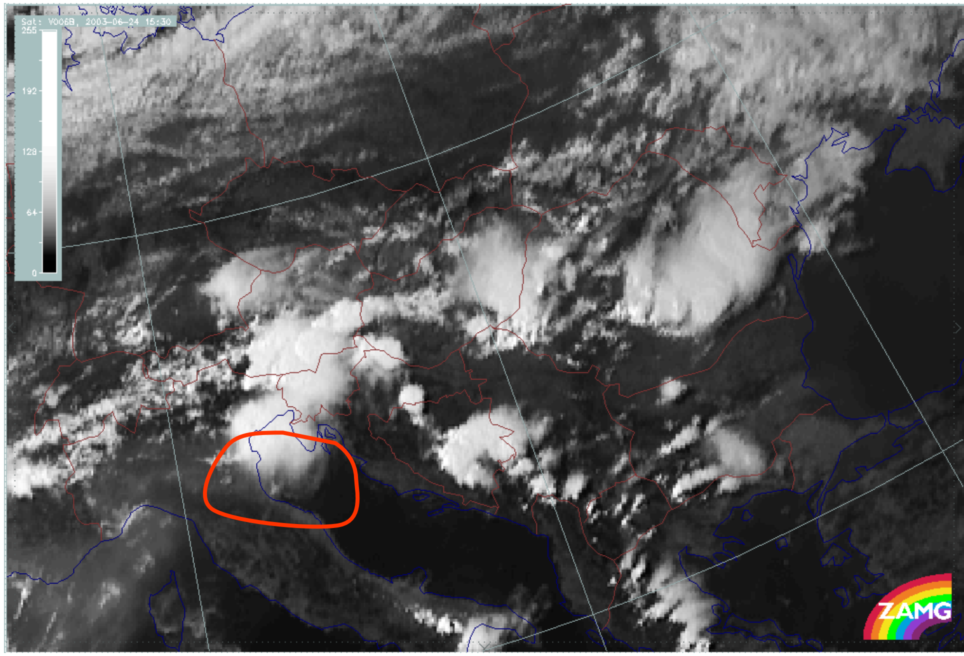
- In VIS 08 better recognition of surface structures because of higher reflectance of soil and leafs

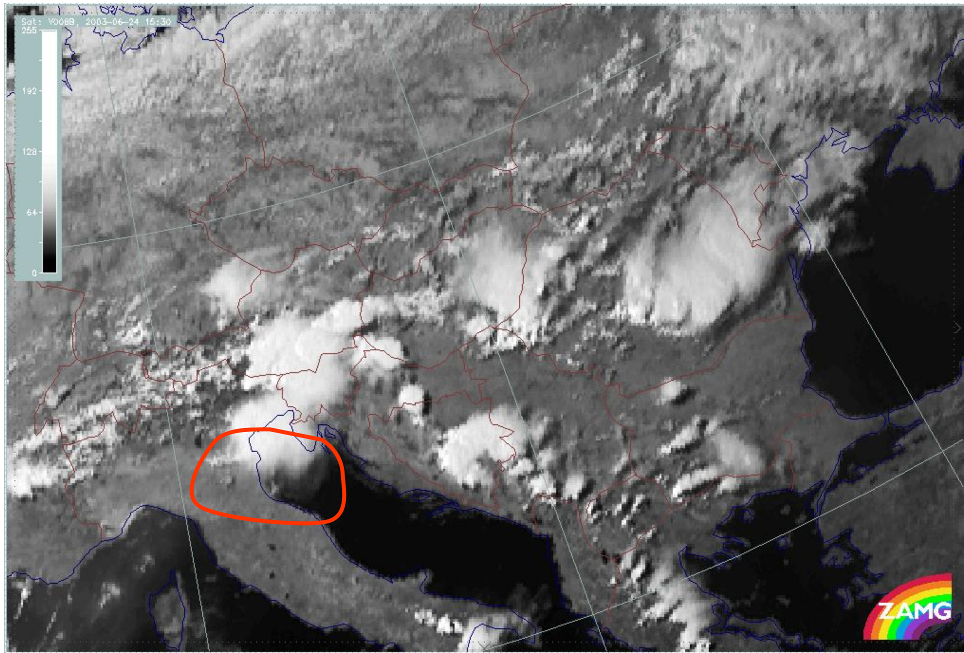


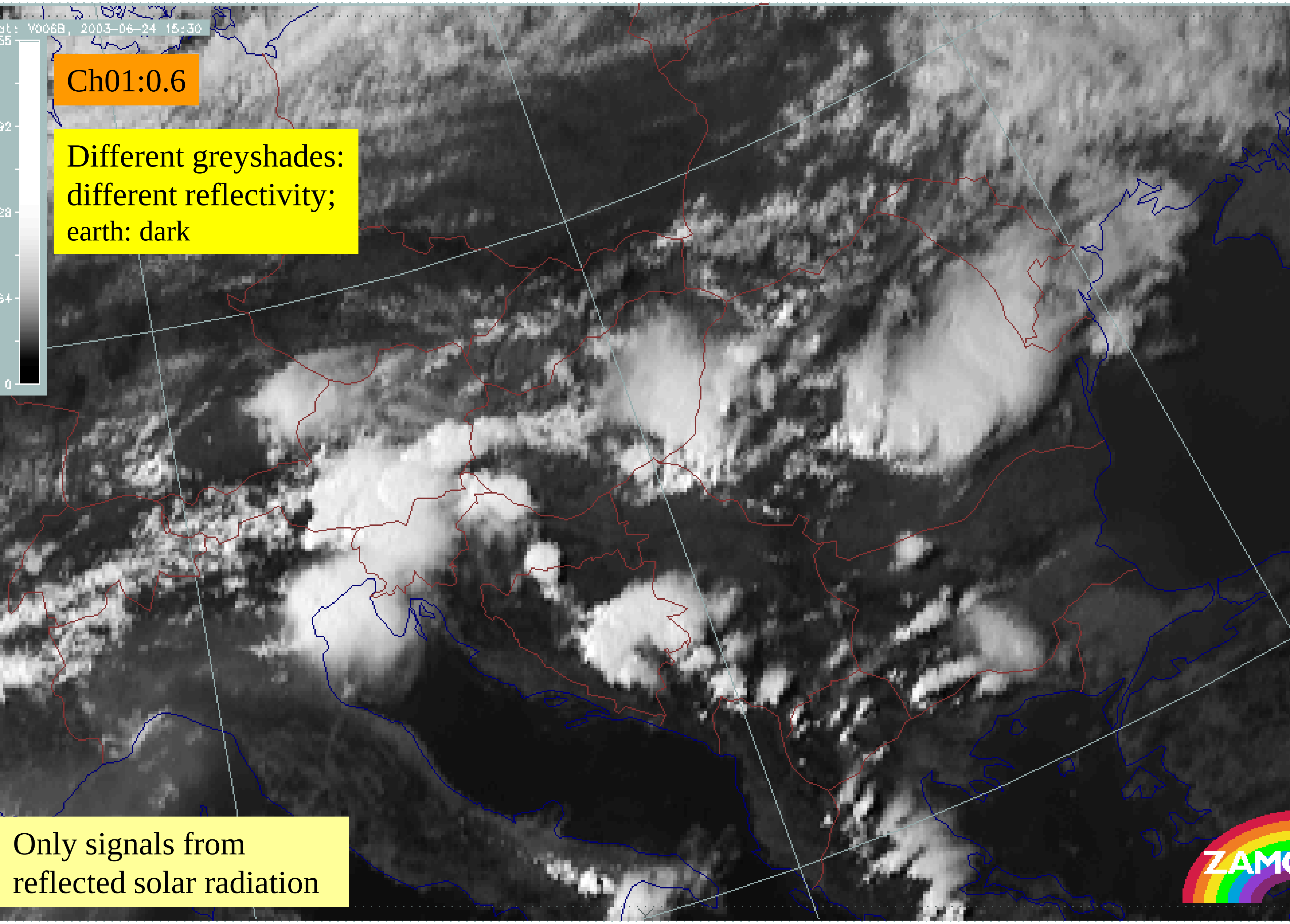


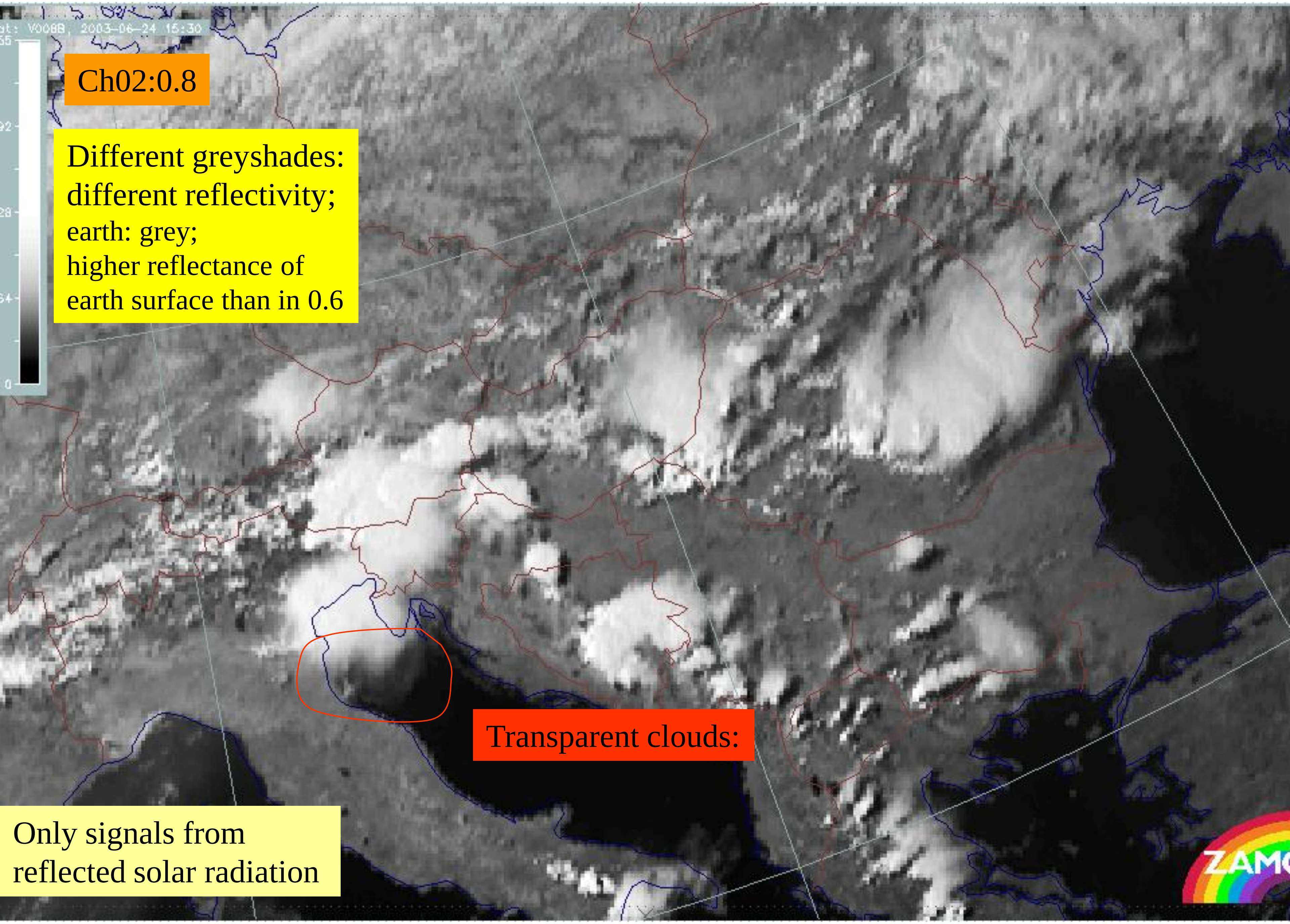
VIS 0.6 and VIS 0.8: transparent cloud

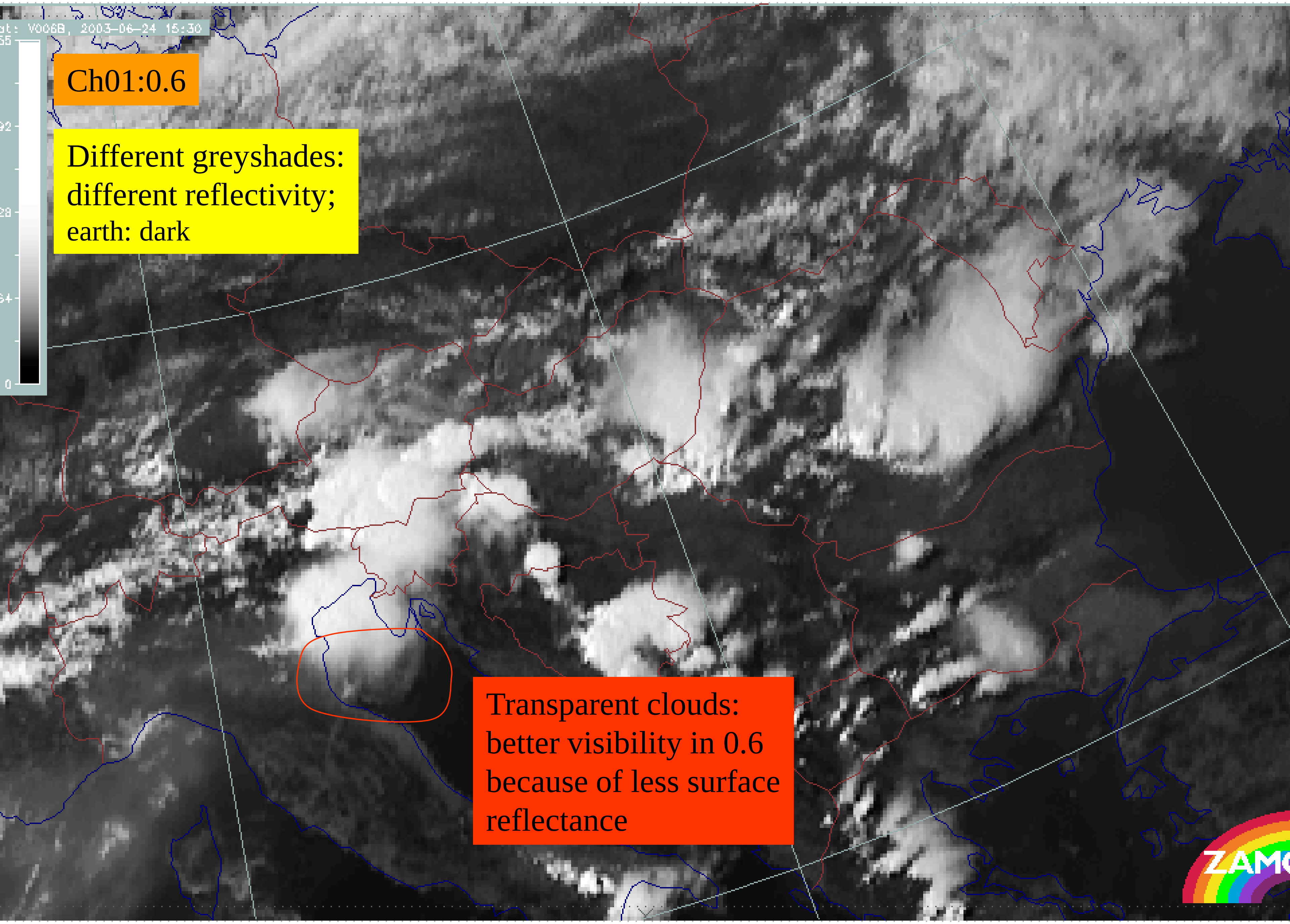
- Transparent clouds better visible in Ch01 0.6 beause of less reflectivity of surface

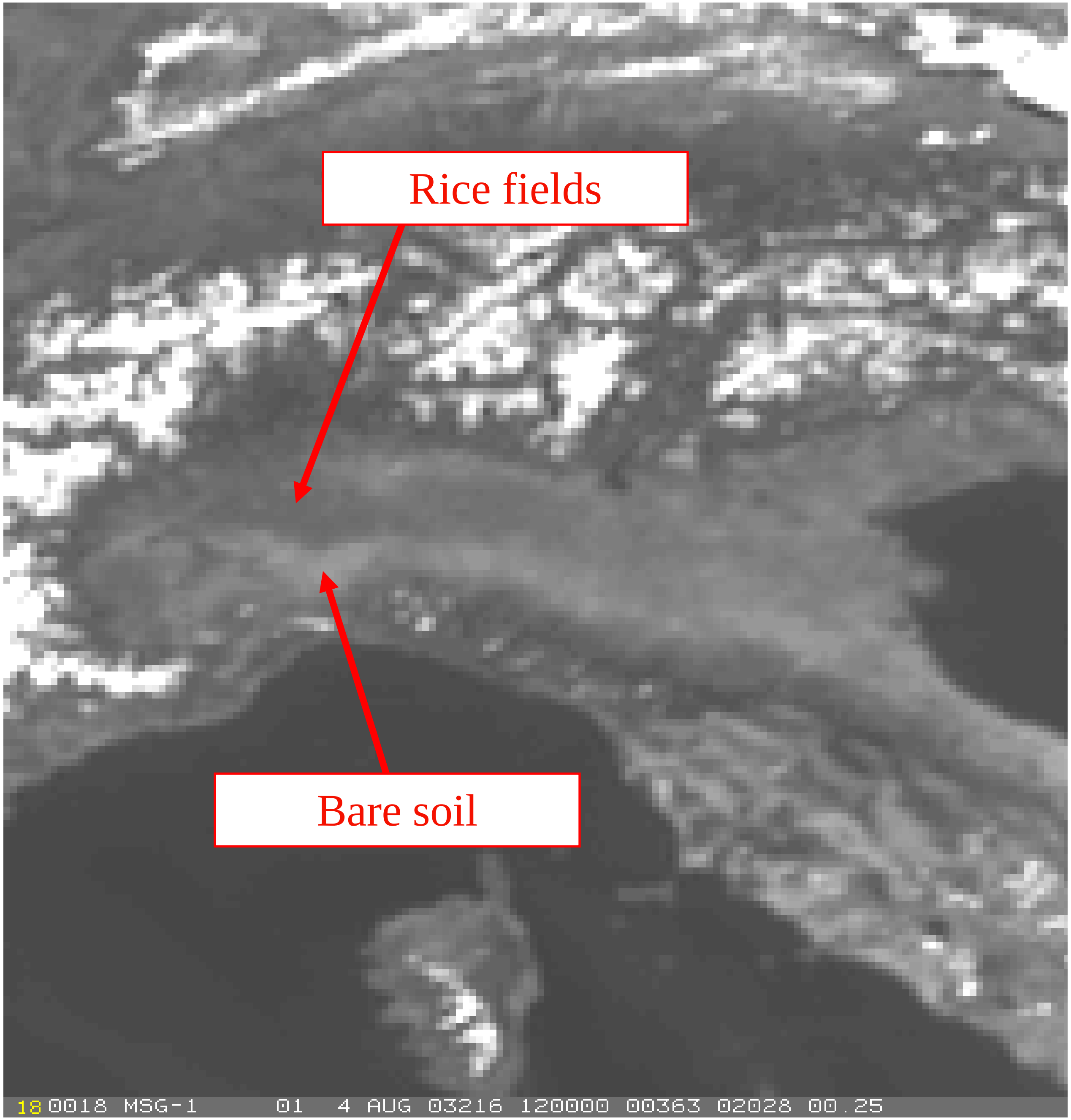


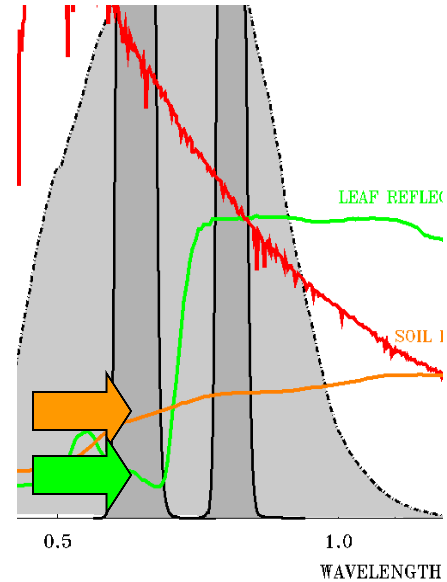



Ch01:0.6
Different greyshades:
different reflectivity;
earth: dark
Only signals from
reflected solar radiation
V006B, 2003-06-24 15:30
ZAMG


Ch02:0.8
Different greyshades:
different reflectivity;
earth: grey;
higher reflectance of
earth surface than in 0.6
Transparent clouds:
Only signals from
reflected solar radiation


V006B, 2003-06-24 15:30
Ch01:0.6
Different greyshades:
different reflectivity;
earth: dark
Transparent clouds:
better visibility in 0.6
because of less surface
reflectance
ZAMG

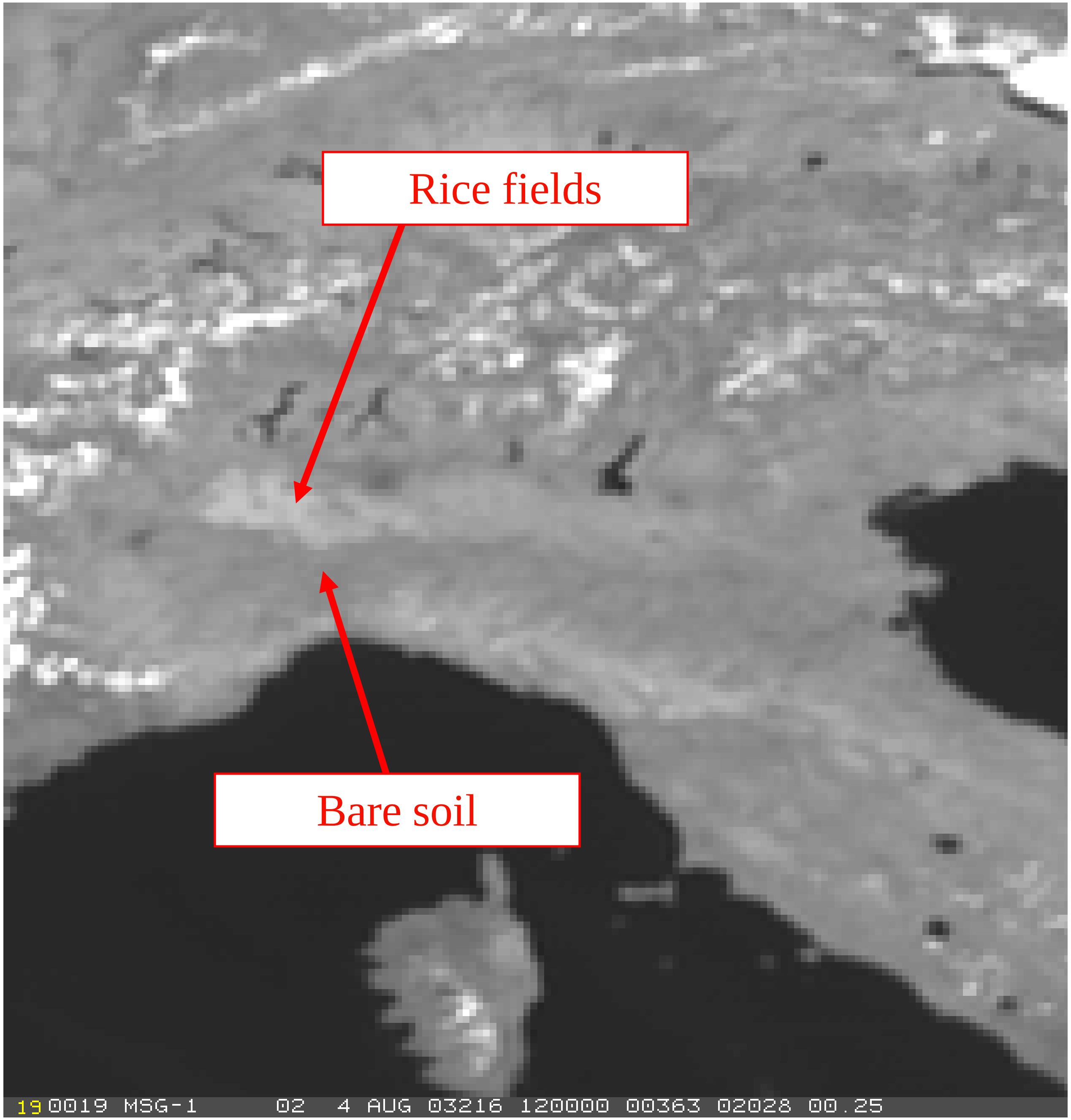


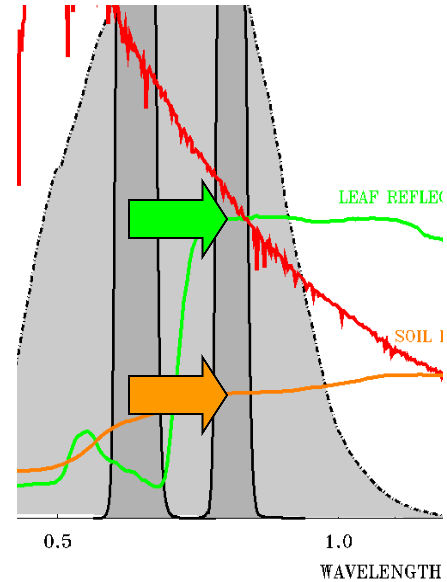


VIS0.6:

veget. area:	dark
bare soil:	bright
snow/clouds:	white

MSG-1
4 August 2003
12:00 UTC
Channel 01 (0.6 µm)

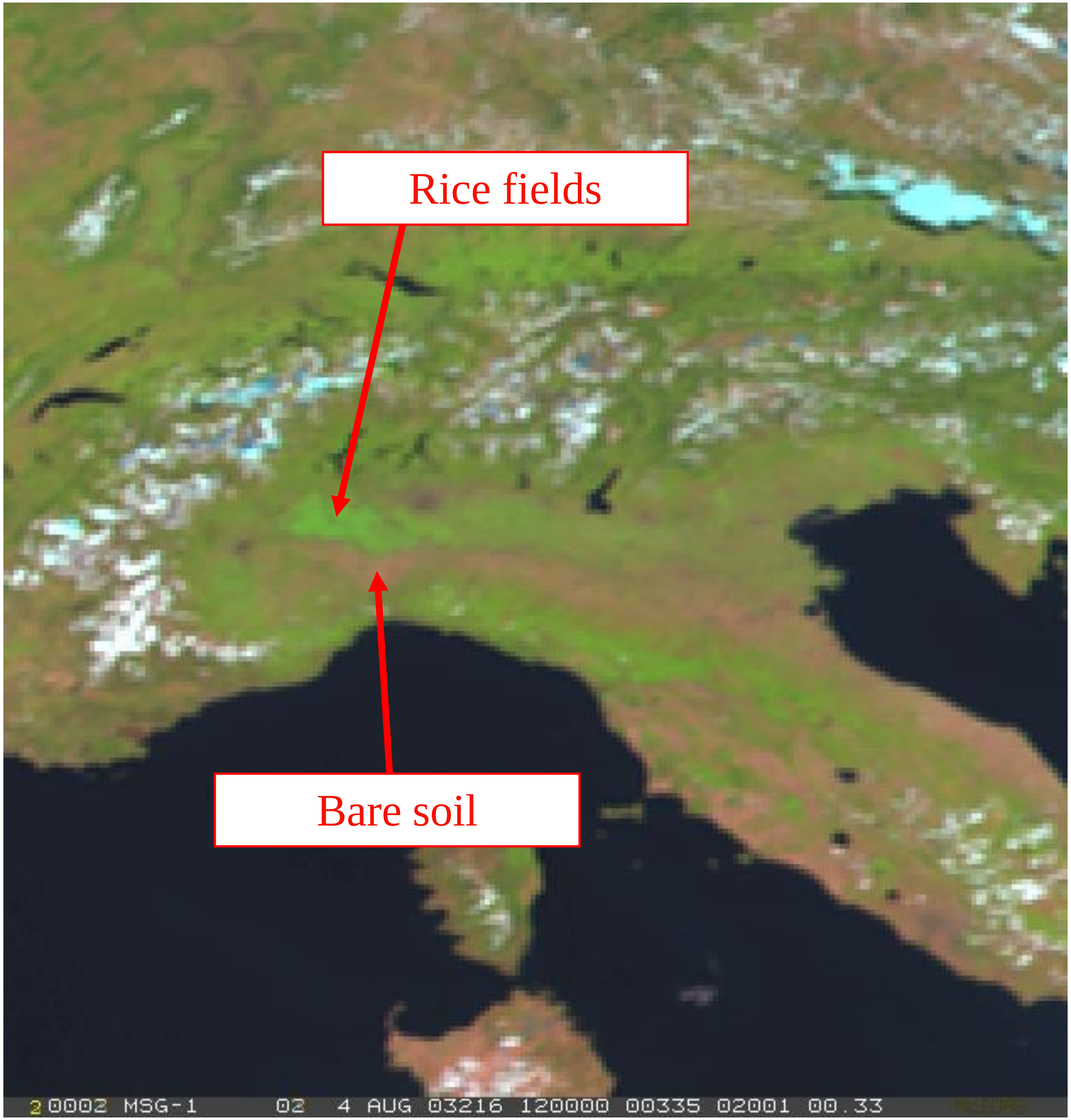




VIS0.8:

veget. area:	bright
bare soil:	darker
snow/clouds:	white

MSG-1
4 August 2003
12:00 UTC
Channel 02 (0.8 µm)

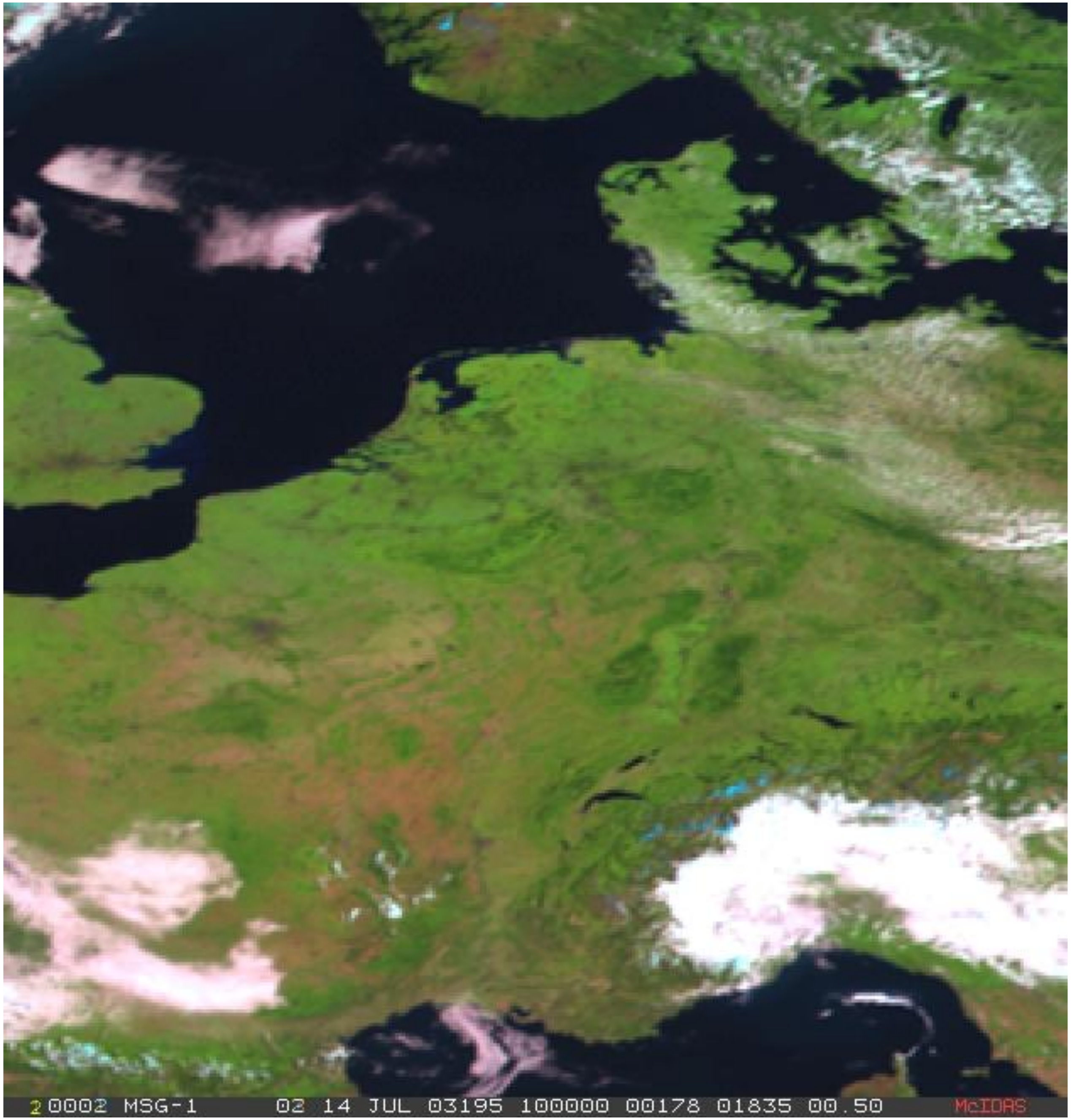


Vegetation Mapping in Northern Italy

RGB 03-02-01

veget. area: green
bare soil: reddish

MSG-1
4 August 2003
12:00 UTC
RGB Composite
R = NIR1.6
G = VIS0.8
B = VIS0.6

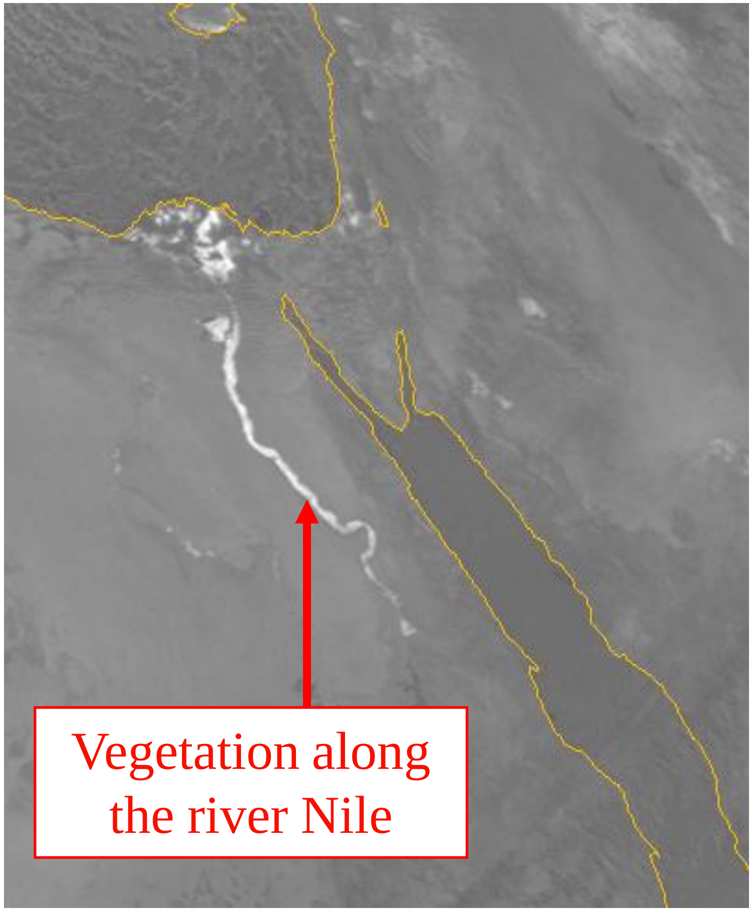


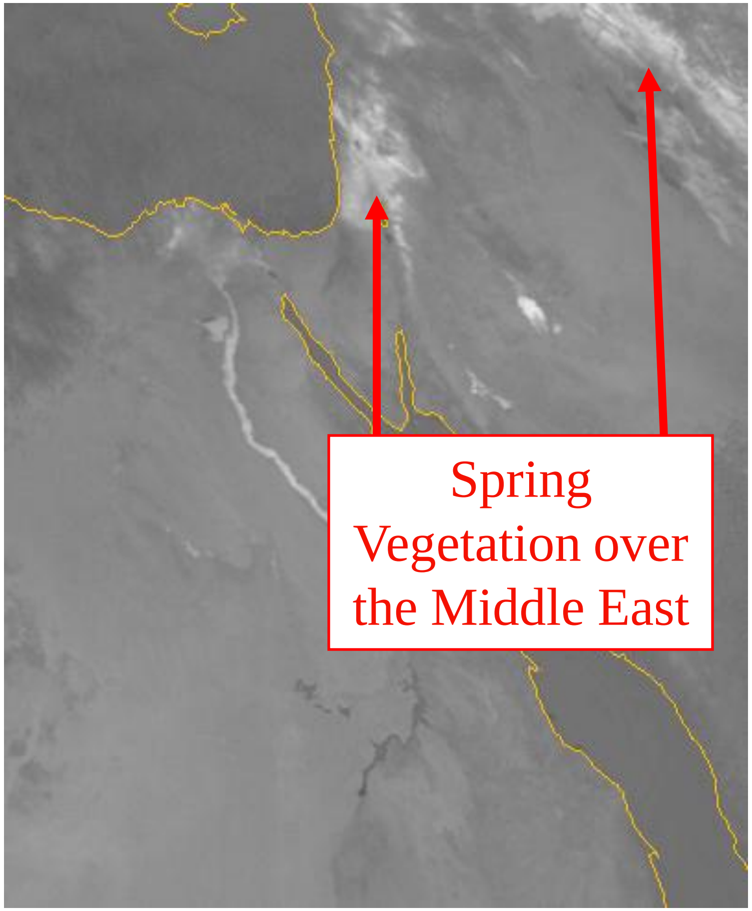
Vegetation Mapping in France & Germany

MSG-1
14 July 2003
10:00 UTC
RGB Composite
R = NIR1.6
G = VIS0.8
B = VIS0.6

Slide 55

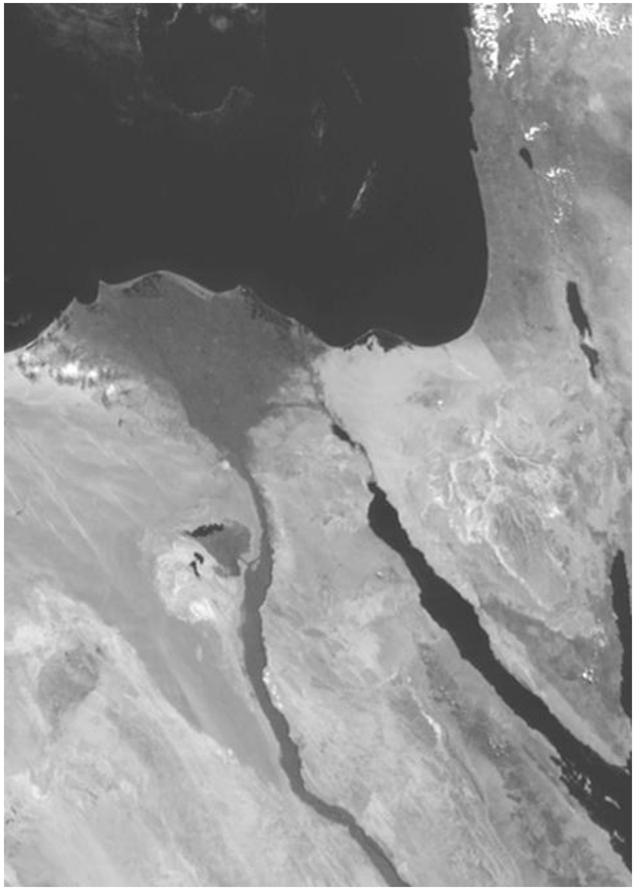
Vegetation Mapping



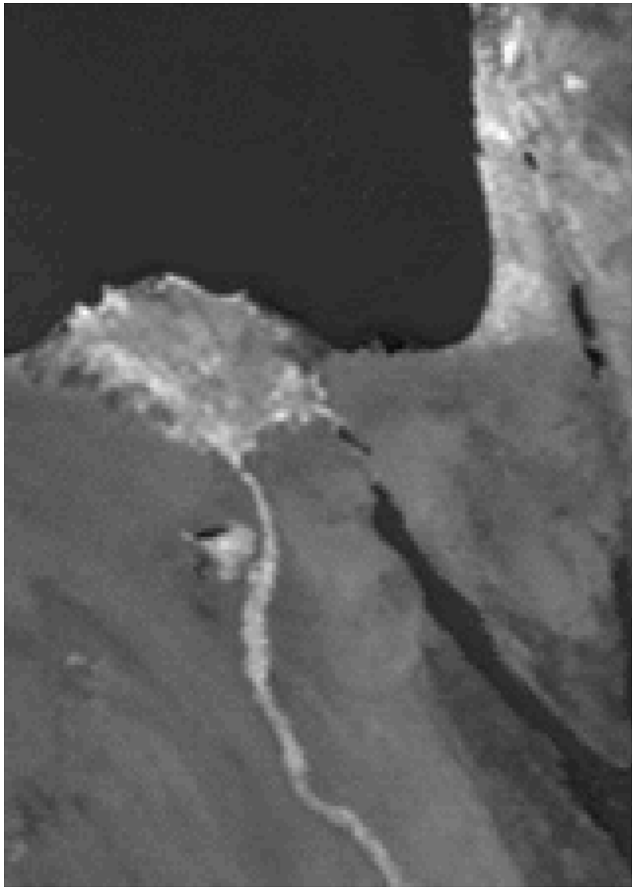


Difference between Channel 2 (0.8 µm) and Channel 1 (0.6 µm) [BRIT]
MSG-1, 24 Feb 2003 12 UTC (left), 24 Apr 2003 12 UTC (right)

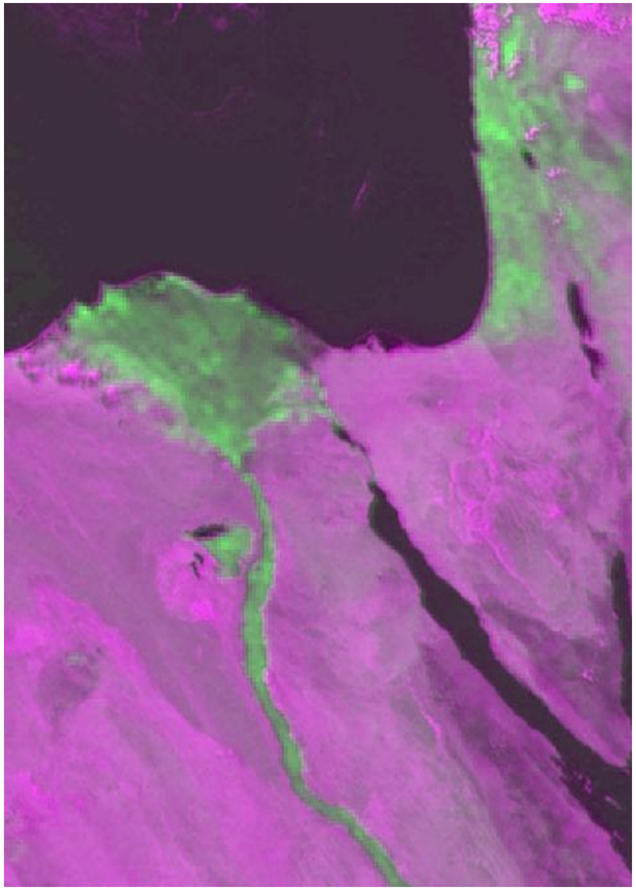
Vegetation Mapping



Channel 12 (HRVIS)



Difference Ch02-Ch01



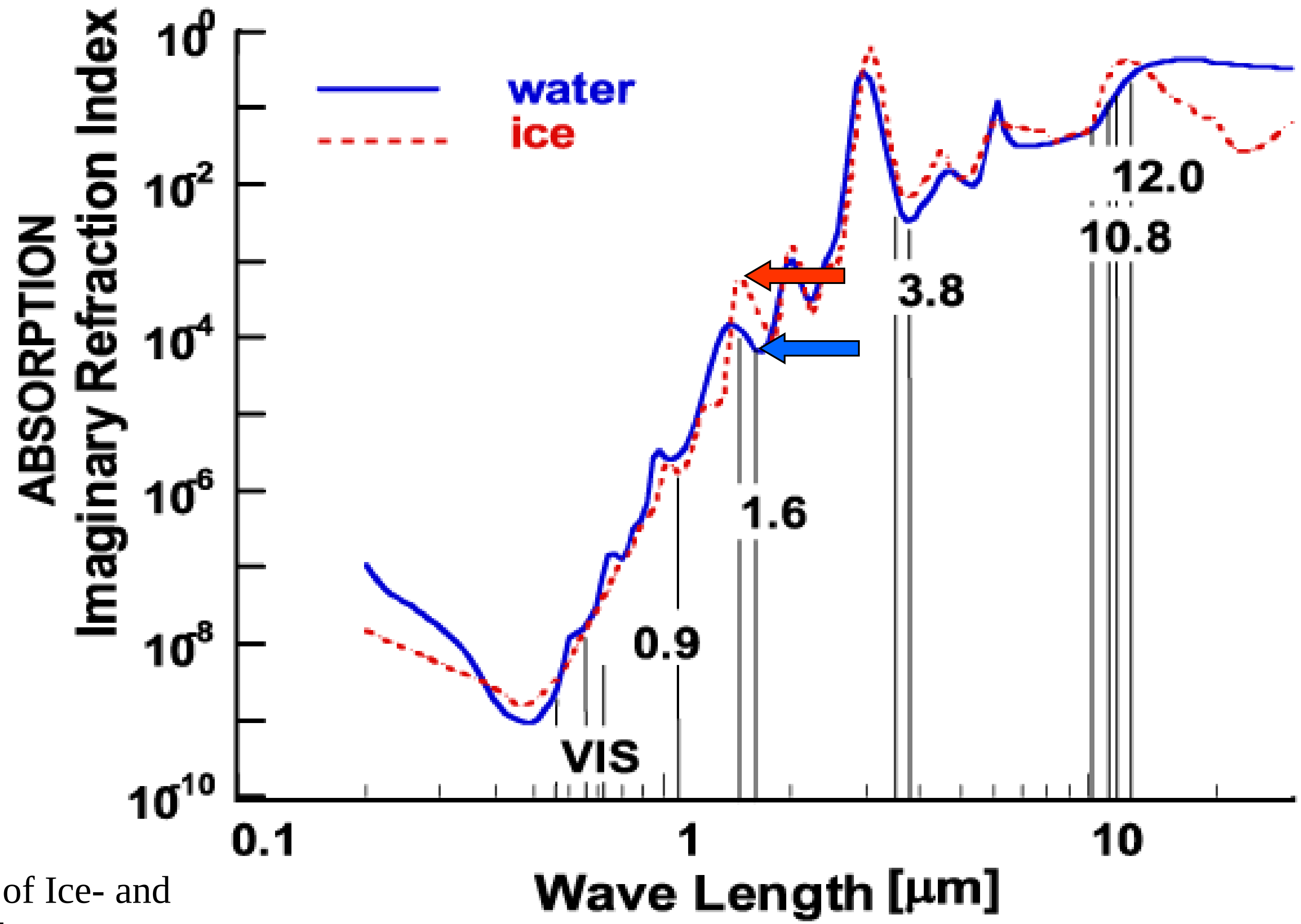
RGB Ch12_Diff02-01_Ch12

Vegetation Monitoring using MSG Visible Channels
3 June 2003, 12:00 UTC

Ch03: 1.6 (NIR)

- NOAA and MSG NIR channel is comparable

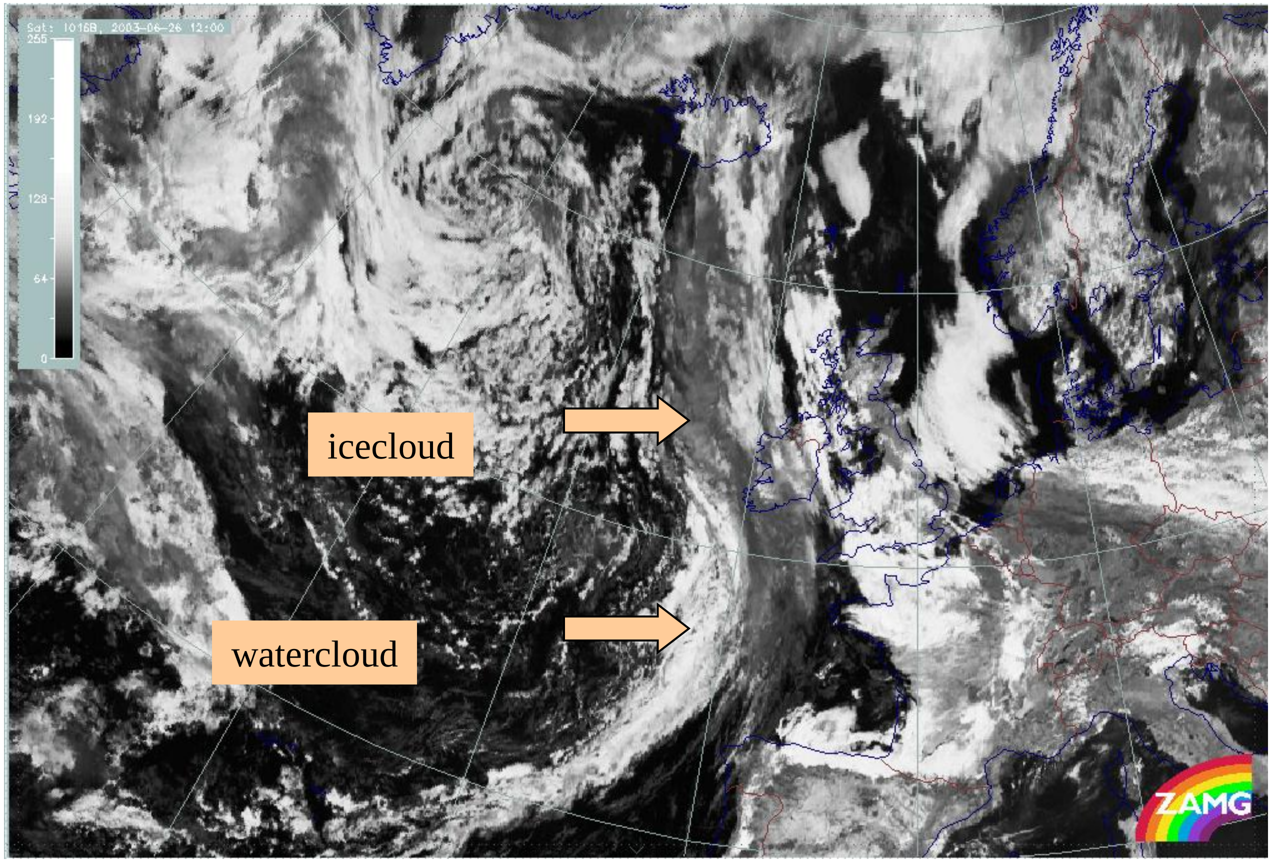
Different Absorption of Ice- and Watercloud in 1.6 µm
Higher absorption in the ice phase



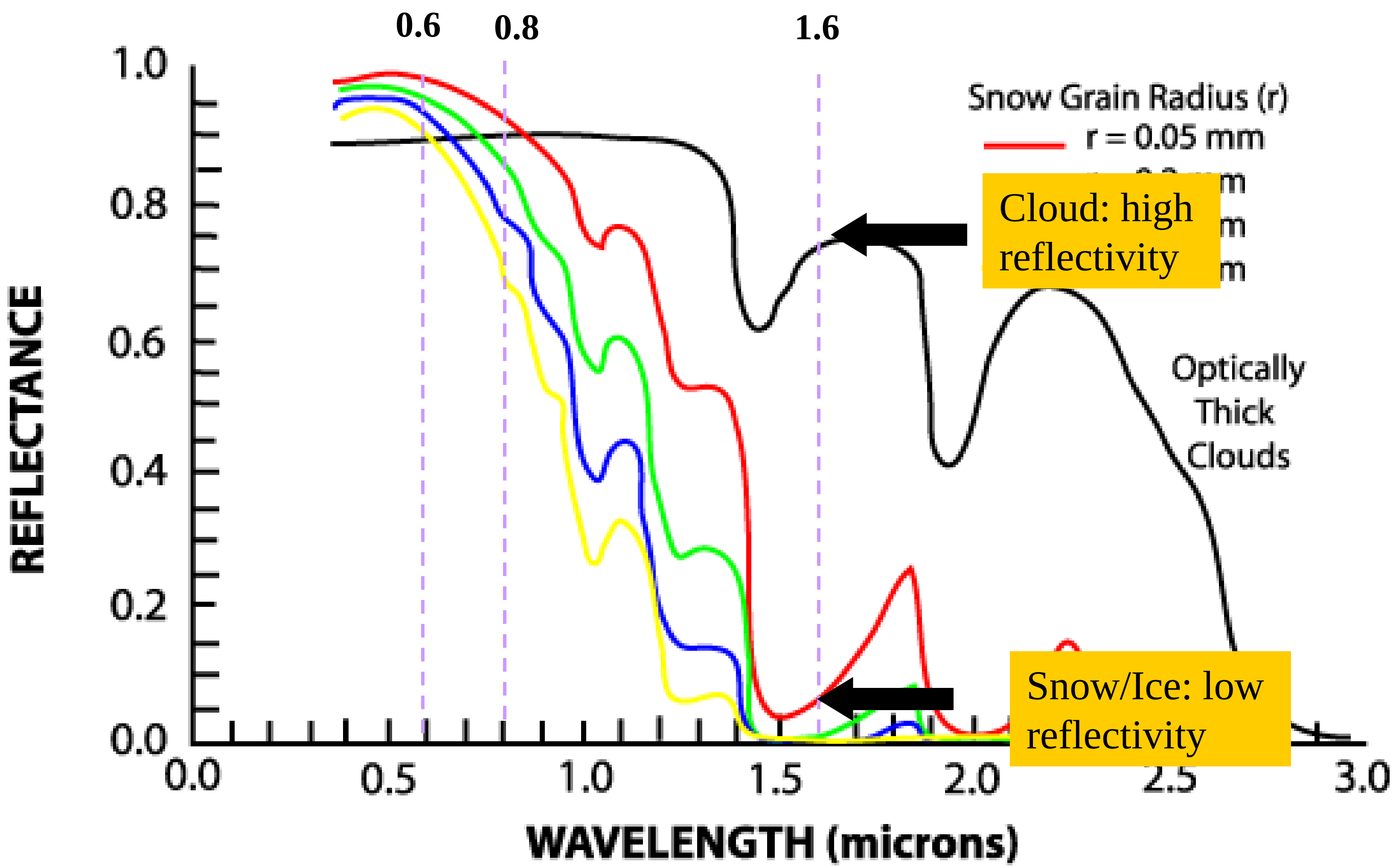
Absorption of Ice- and
Water cloud
After Source:
D. Rosenfeld

NIR 1.6: cloud

- Different appearance of ice - and waterclouds because of stronger absorption in the icephase
  - Waterclouds: white
  - Iceclouds: black

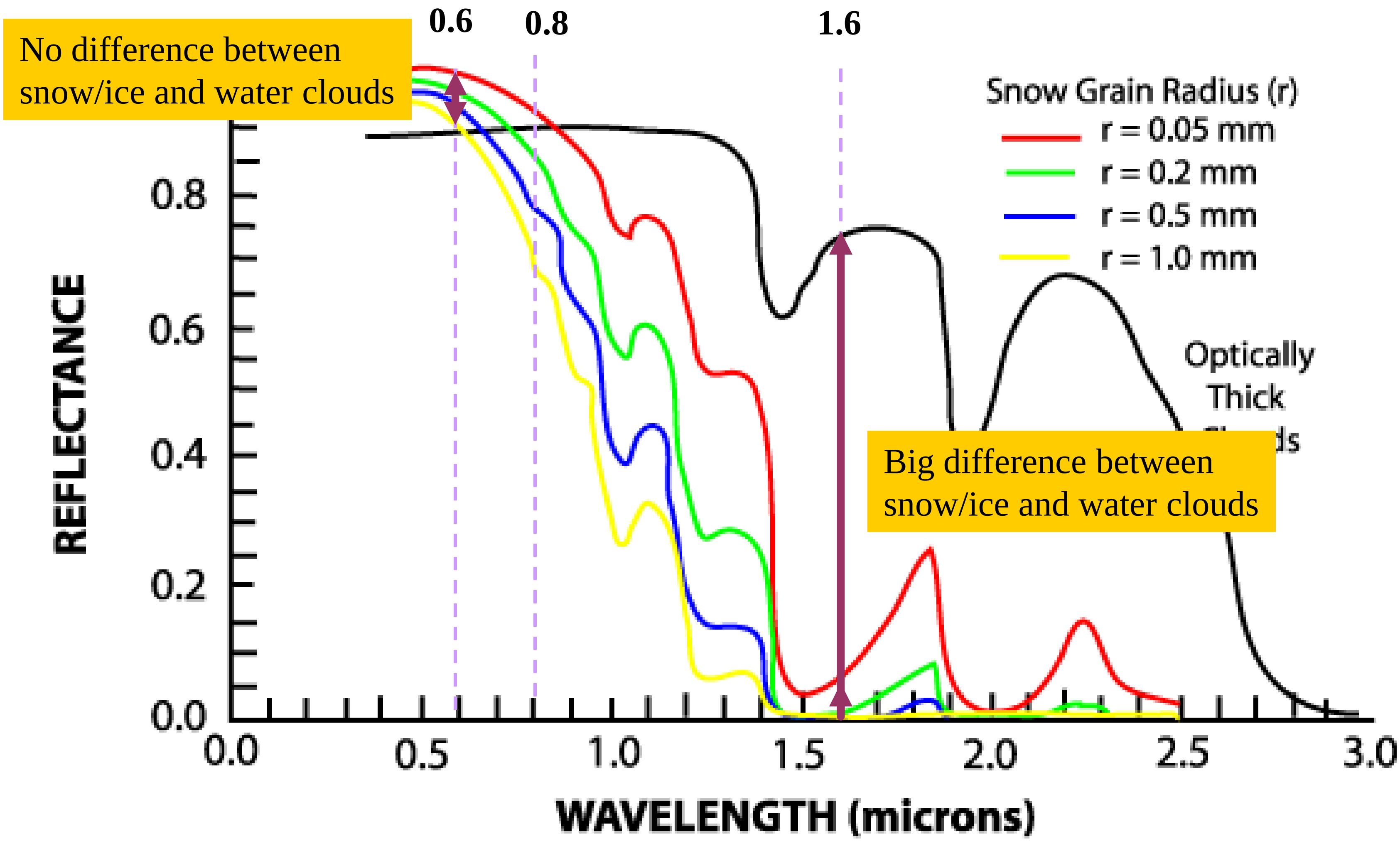


Different Reflectivity of Ice/snow and Watercloud in 1.6 μ



After source: EUMETSAT

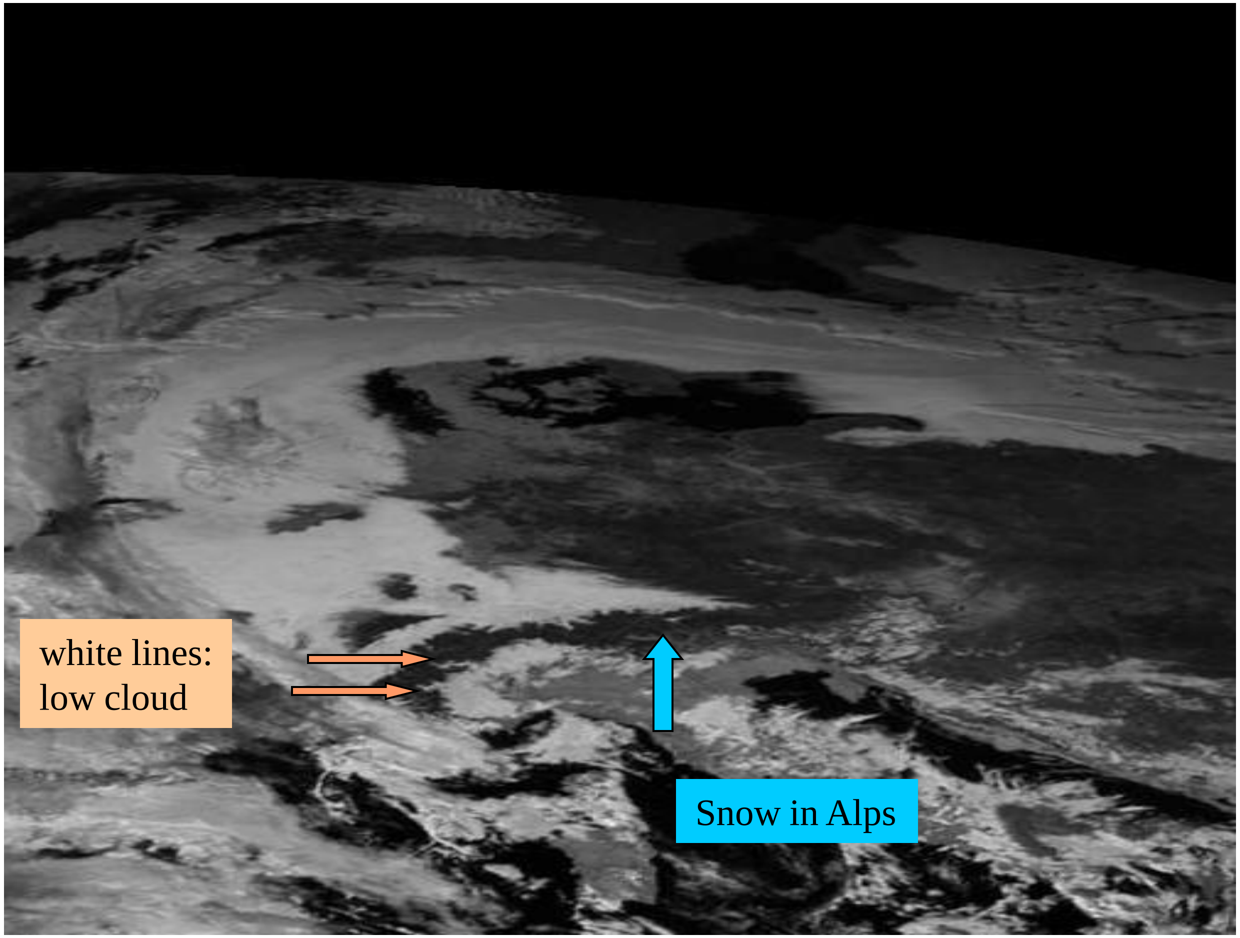
Different Reflectivity of Ice/snow versus Watercloud in 0,6, 0,8 and 1.6 μ

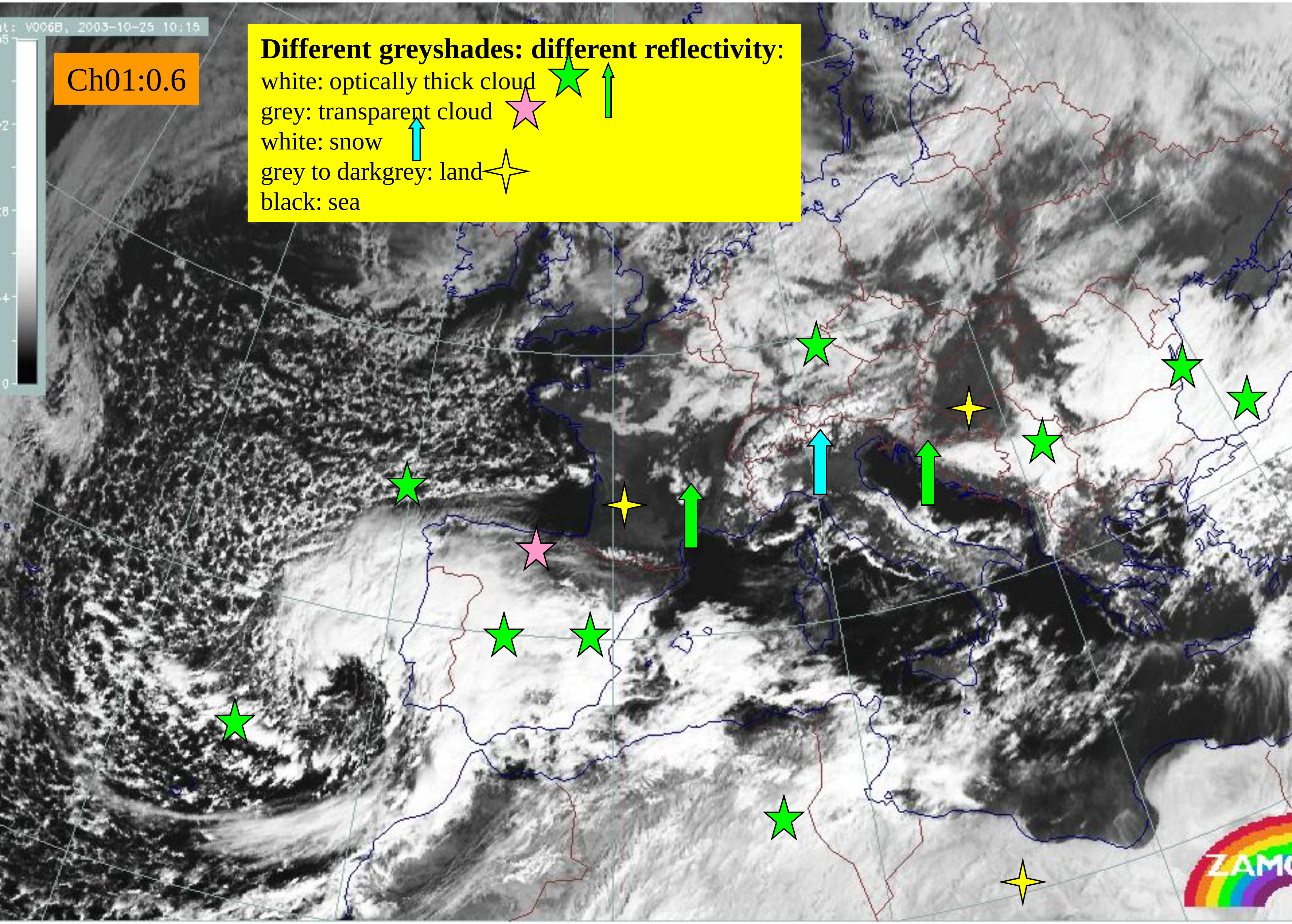


After source: EUMETSAT

NIR 1.6: Snow

- Snow: Different appearance of water clouds above snow and ice
  - Snow + Ice: black
  - Water clouds: white

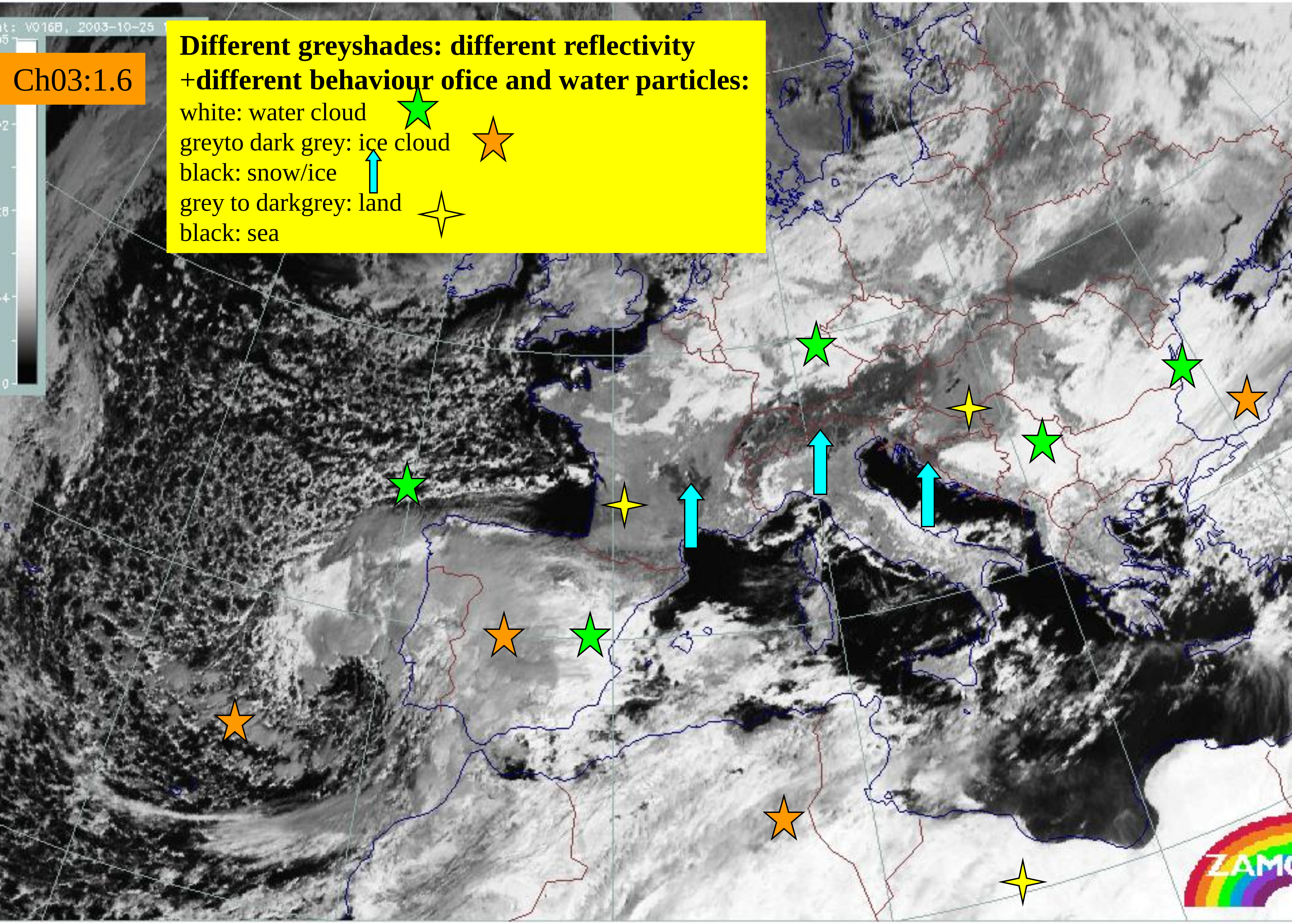



V006B, 2003-10-25 10:15
Ch01:0.6
Different greyshades: different reflectivity:
white: optically thick cloud
grey: transparent cloud
white: snow
grey to darkgrey: land
black: sea

Ch03:1.6

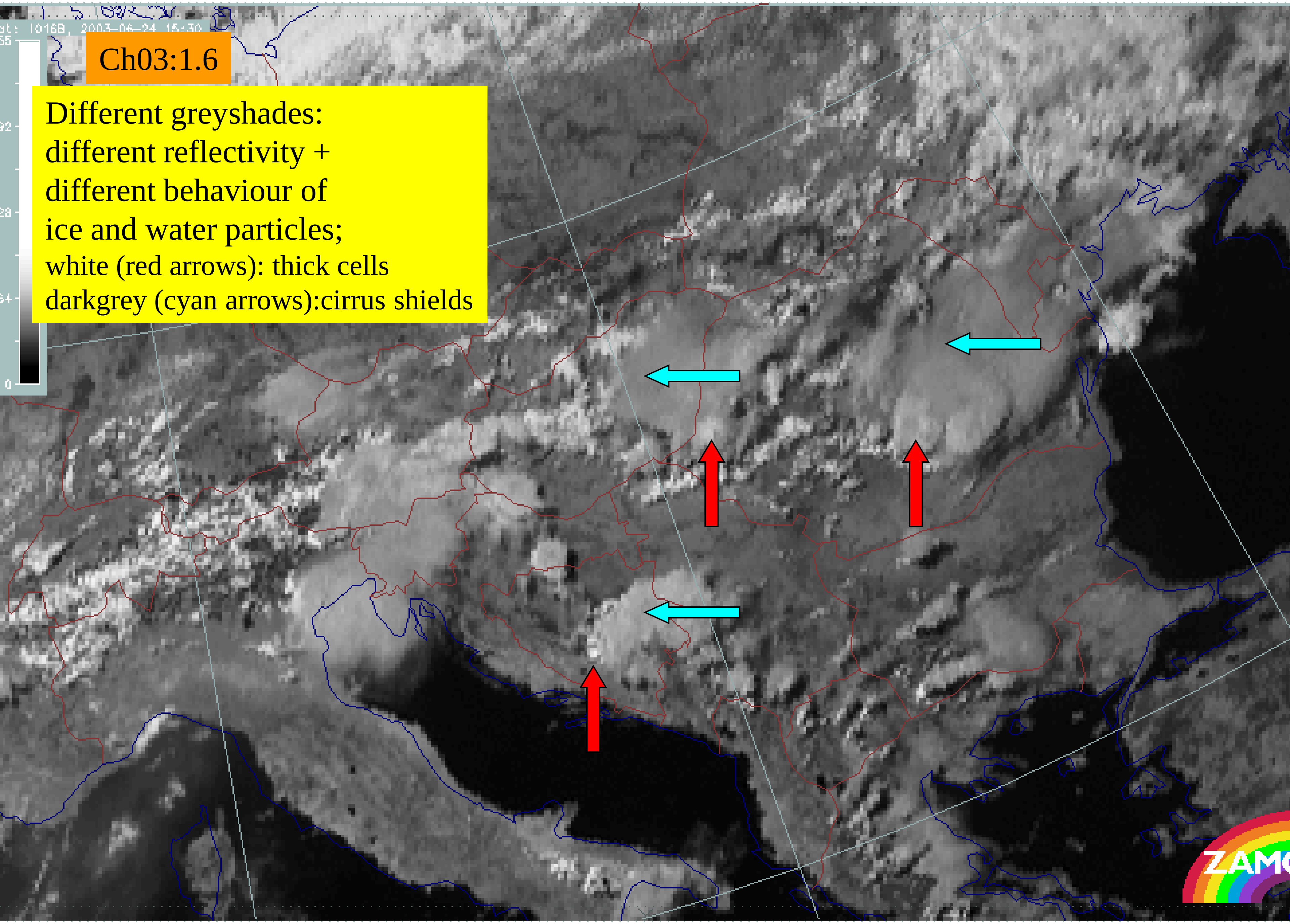
Different greyshades: different reflectivity
+different behaviour ofice and water particles:

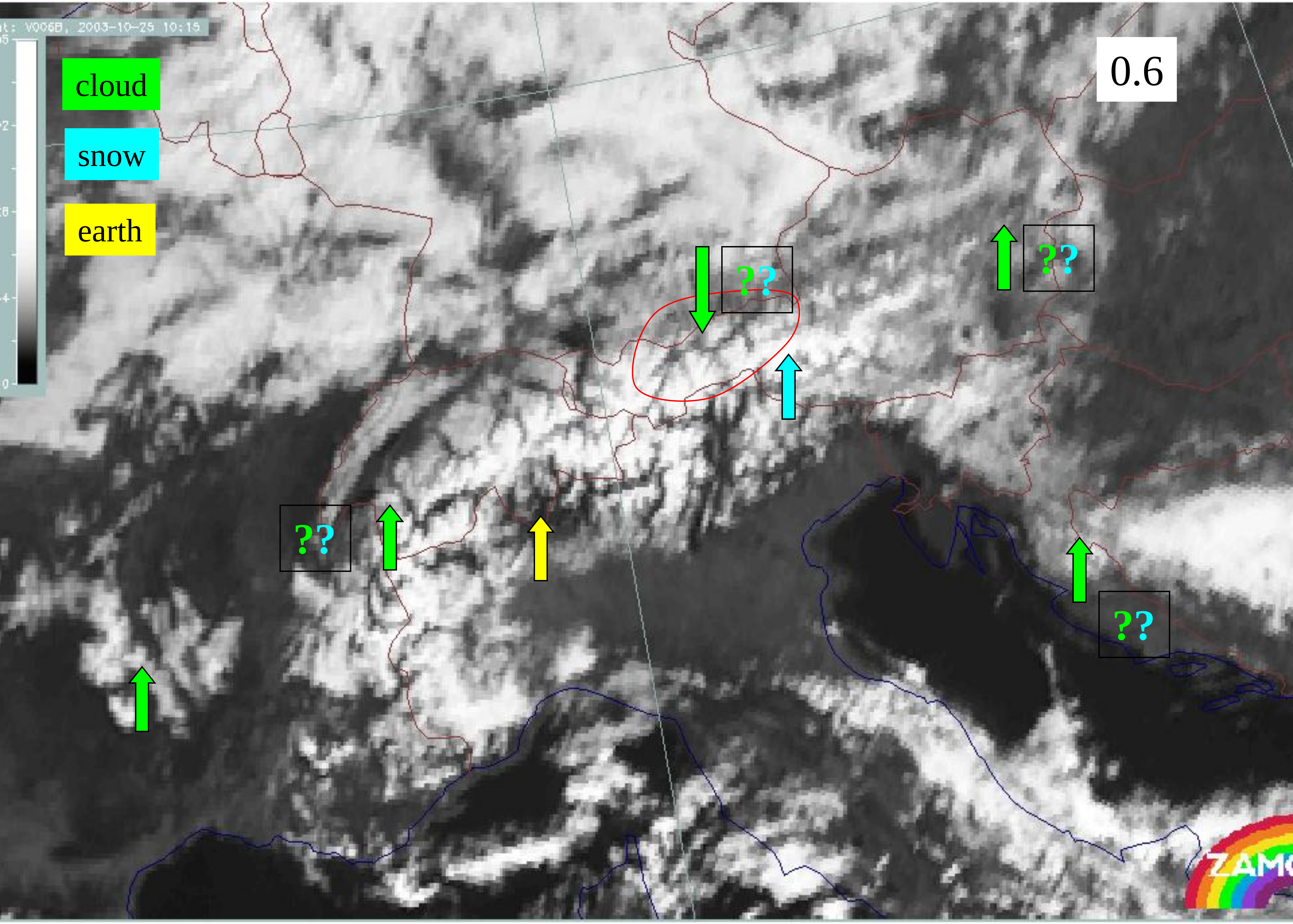
white: water cloud
greyto dark grey: ice cloud
black: snow/ice
grey to darkgrey: land
black: sea



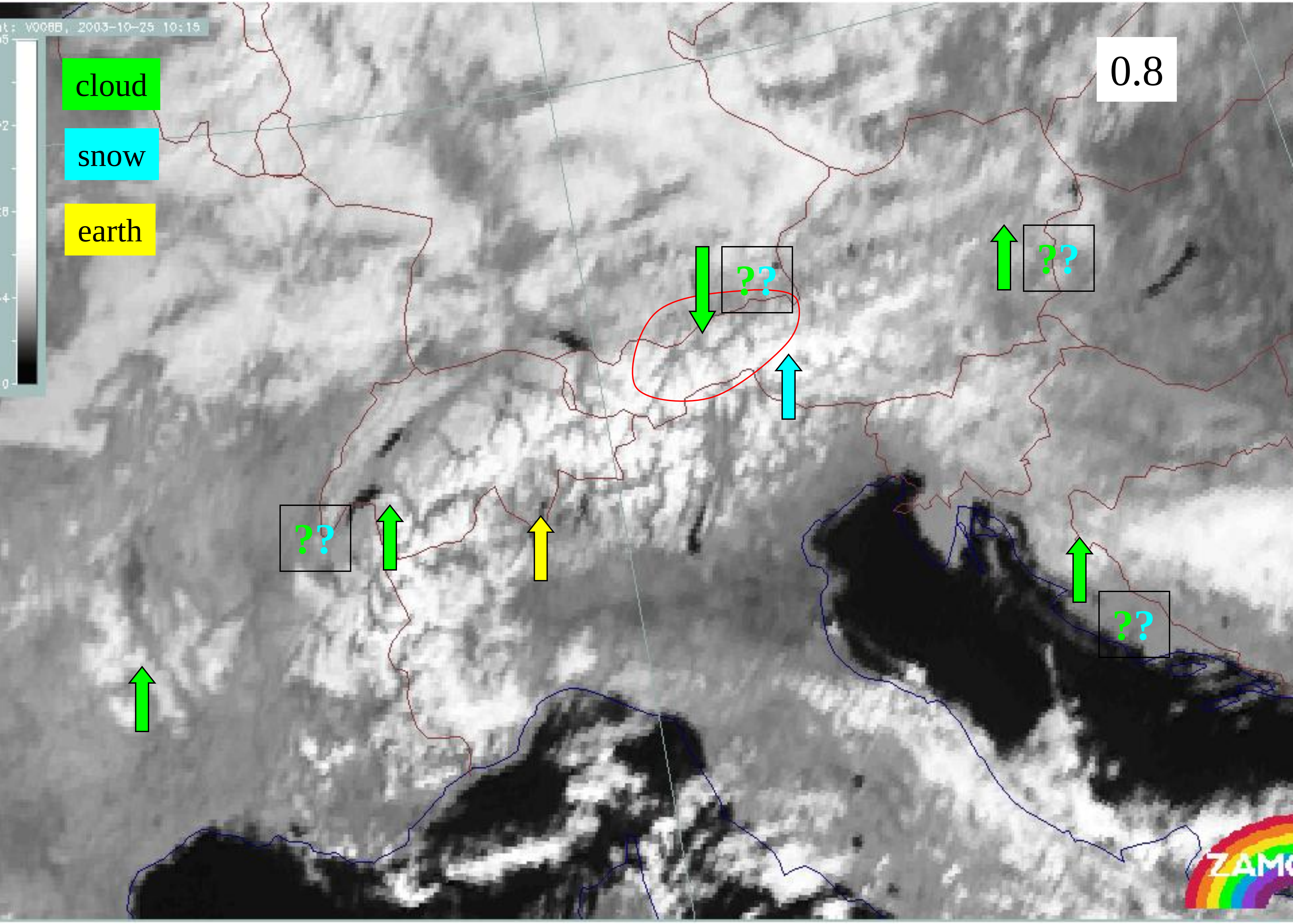
Ch03:1.6

Different greyshades:
different reflectivity +
different behaviour of
ice and water particles;
white (red arrows): thick cells
darkgrey (cyan arrows):cirrus shields

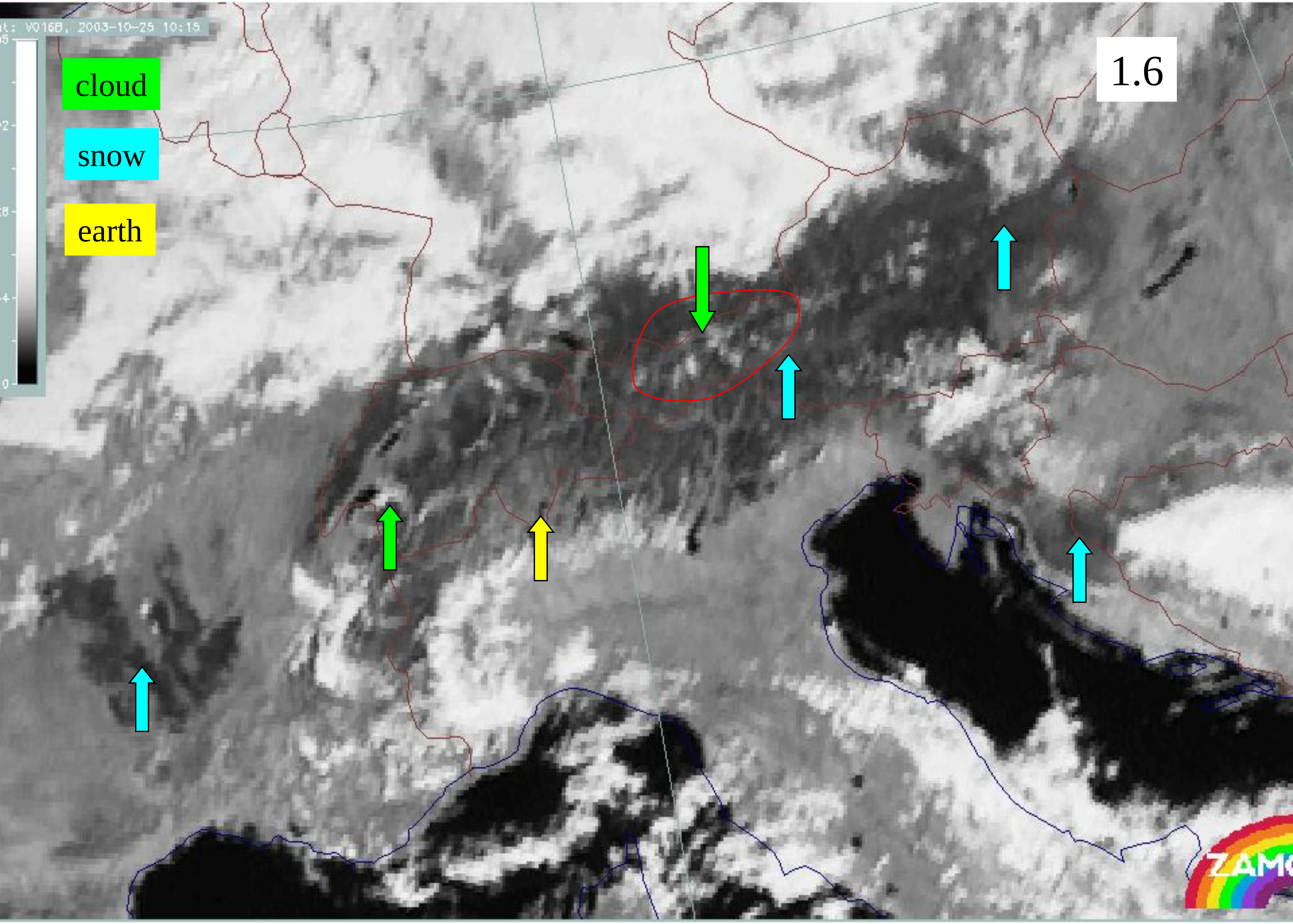


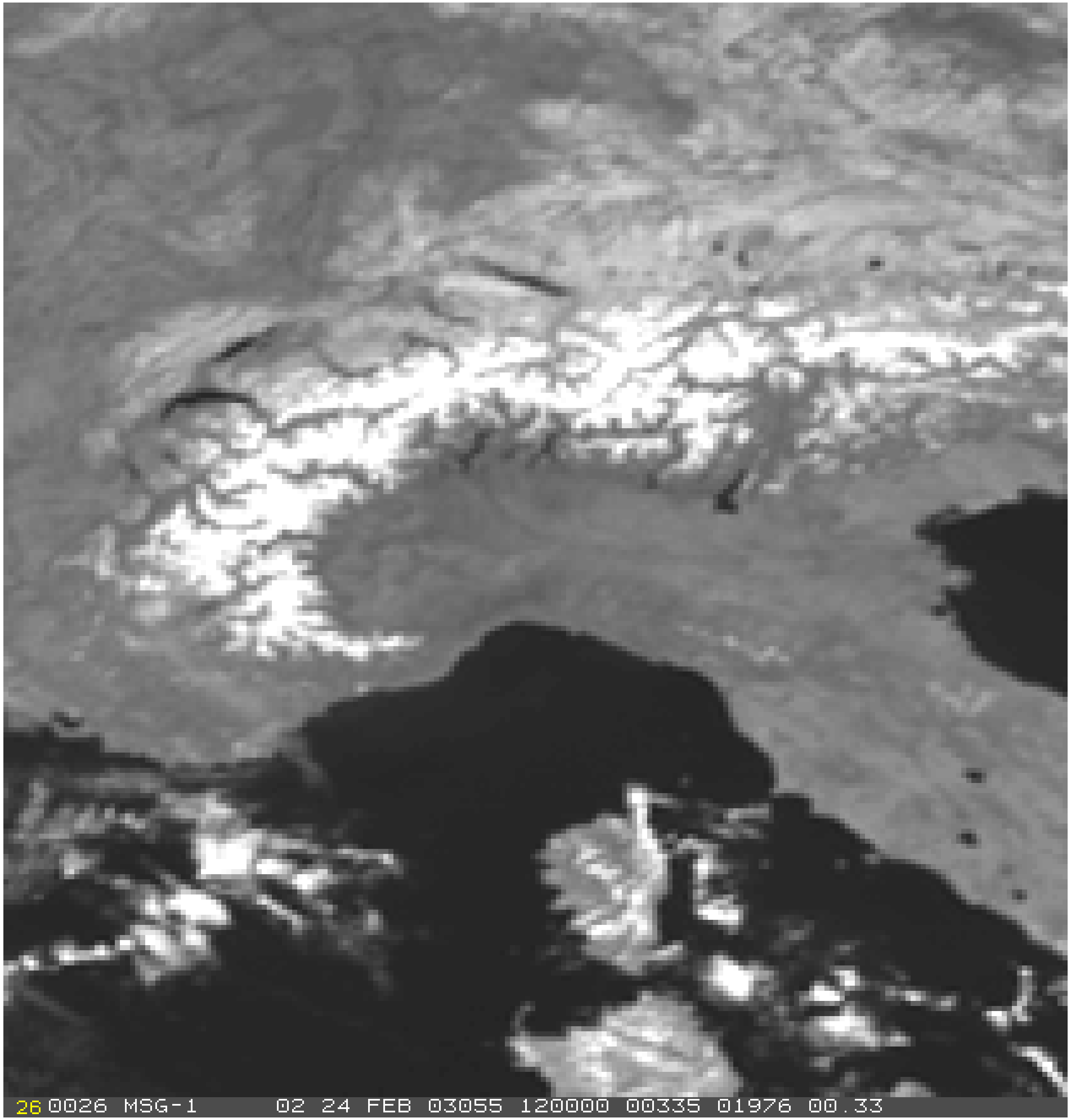


V006B, 2003-10-25 10:15
cloud
snow
earth
0.6
??
??
??
??
ZAMG



cloud
snow
earth
0.8
??
??
??
??

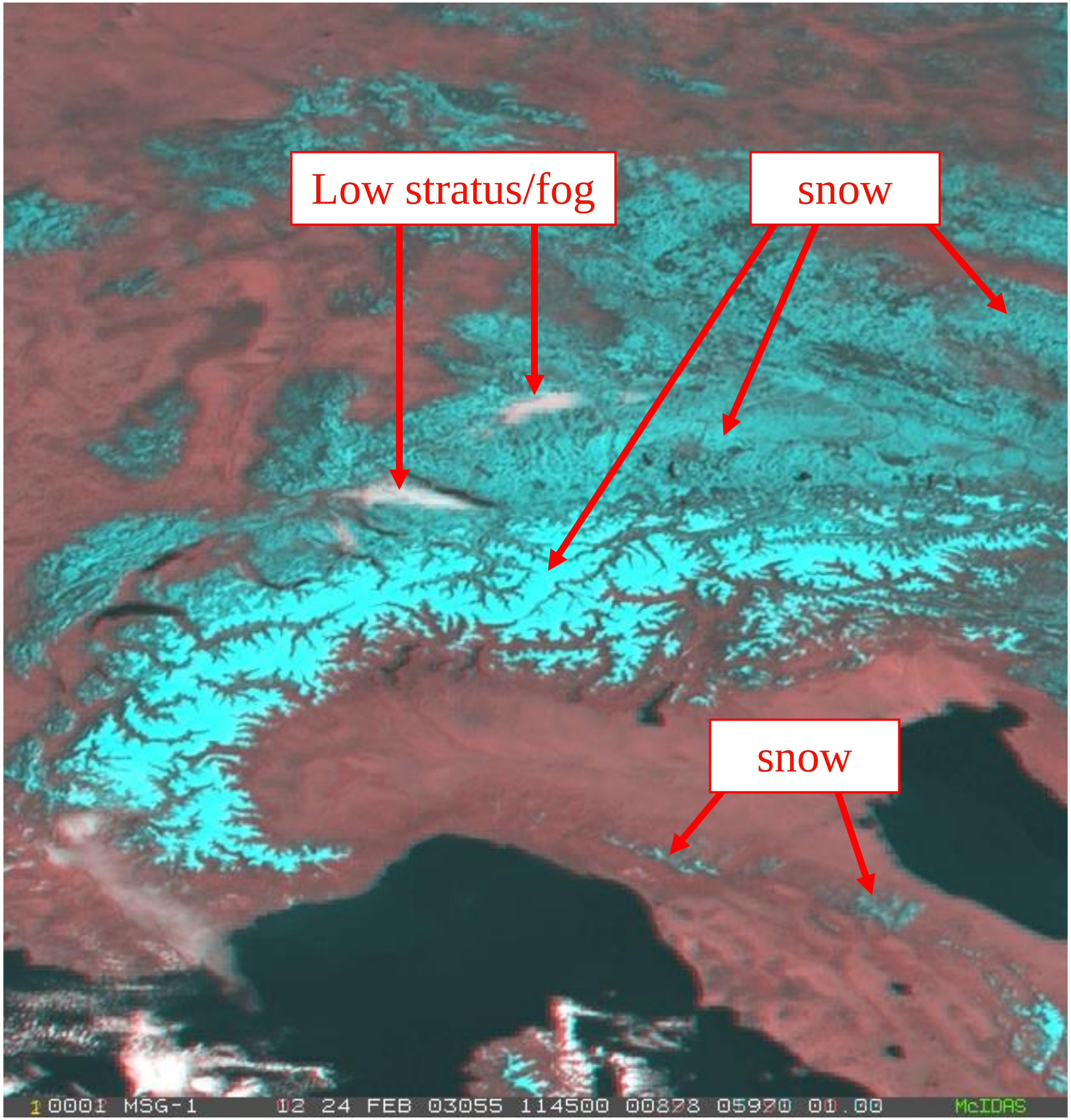

cloud
snow
earth
1.6



Snow and Ice Monitoring

Problem of discriminating between snow and clouds in VIS channels

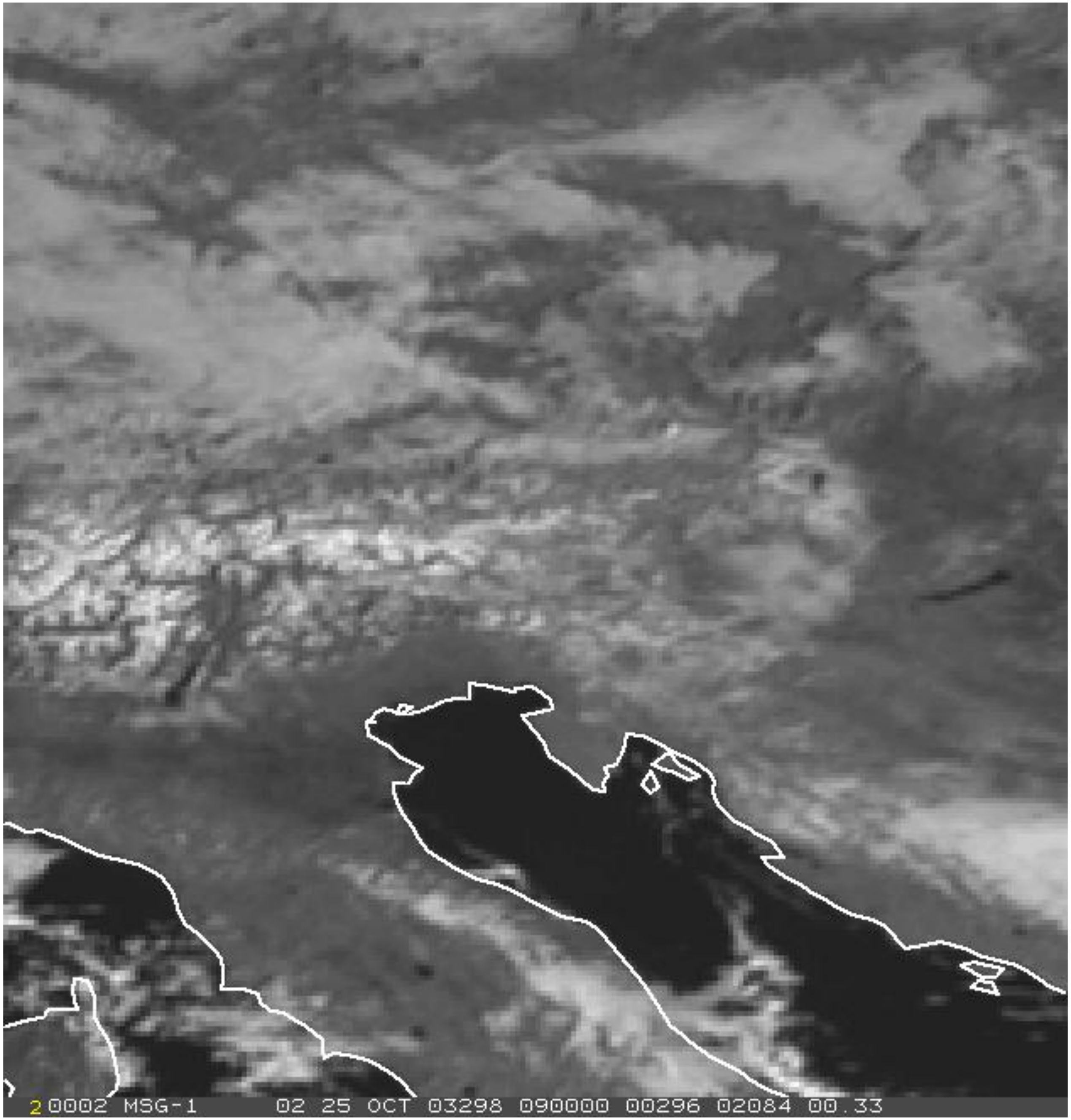
MSG-1
24 February 2003
12:00 UTC
Channel 02
(VIS0.8)



Snow and Ice Monitoring

NIR1.6 channel helps to discriminate between snow and clouds

MSG-1
24 February 2003
11:45 UTC
RGB Composite
R = NIR1.6
G = HRV
B = HRV

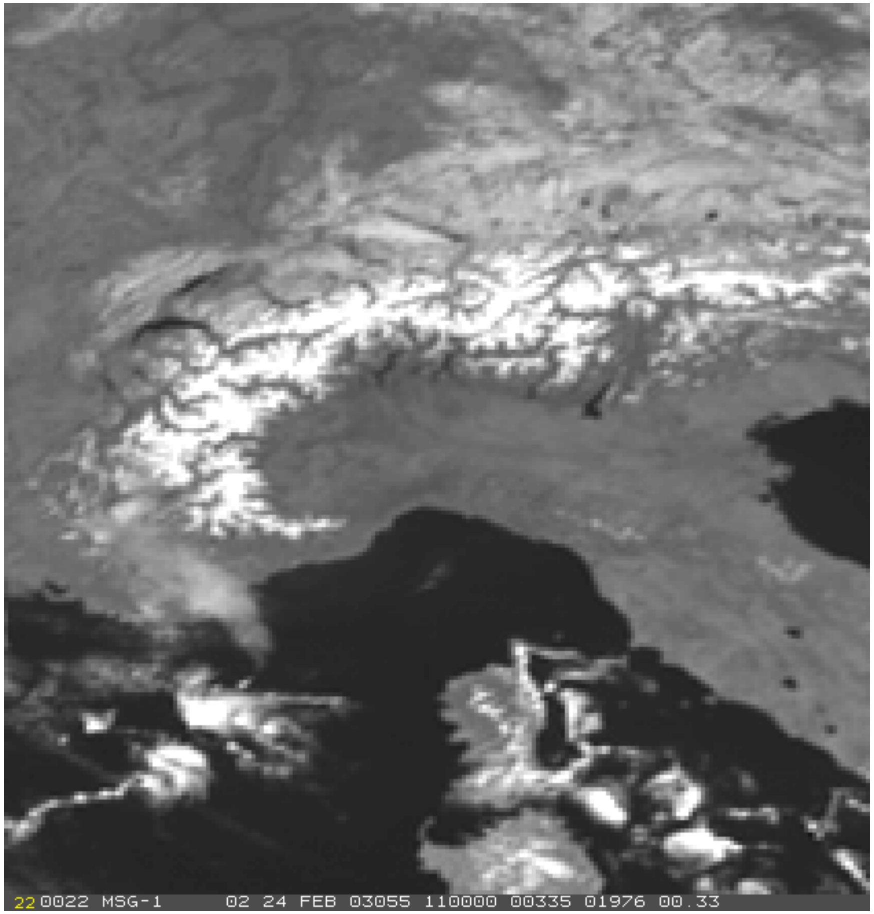


Snow and Ice Monitoring

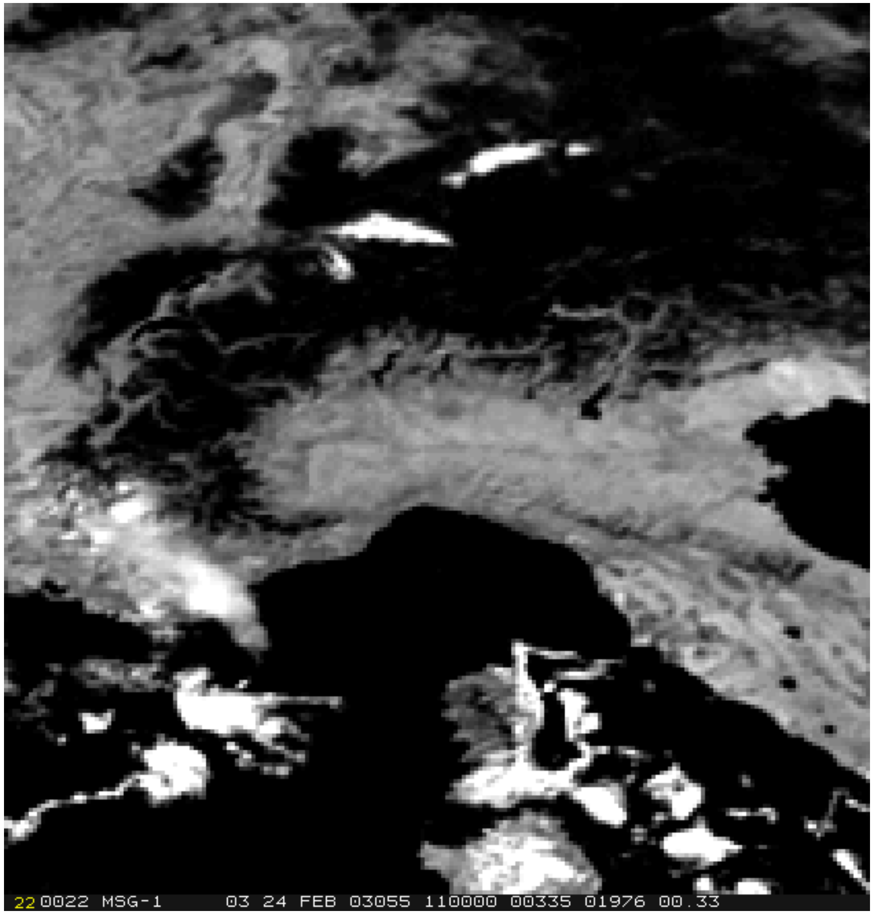
Problem of discriminating between snow and clouds in VIS channels

MSG-1
25 October 2003
09:00 UTC
Channel 02
(VIS0.8)

Snow - Fog Discrimination



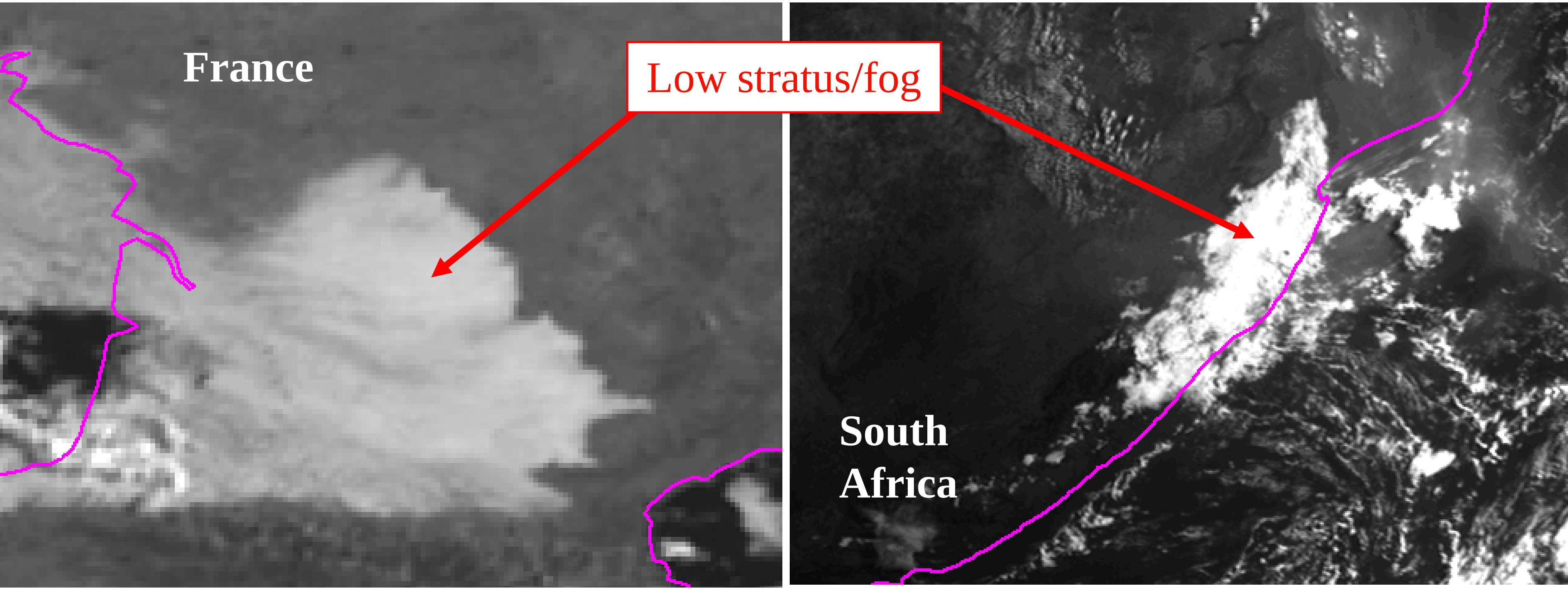
Channel VIS0.8



Channel NIR1.6

MSG-1, 24 February 2003, 11:00 UTC

Fog Detection

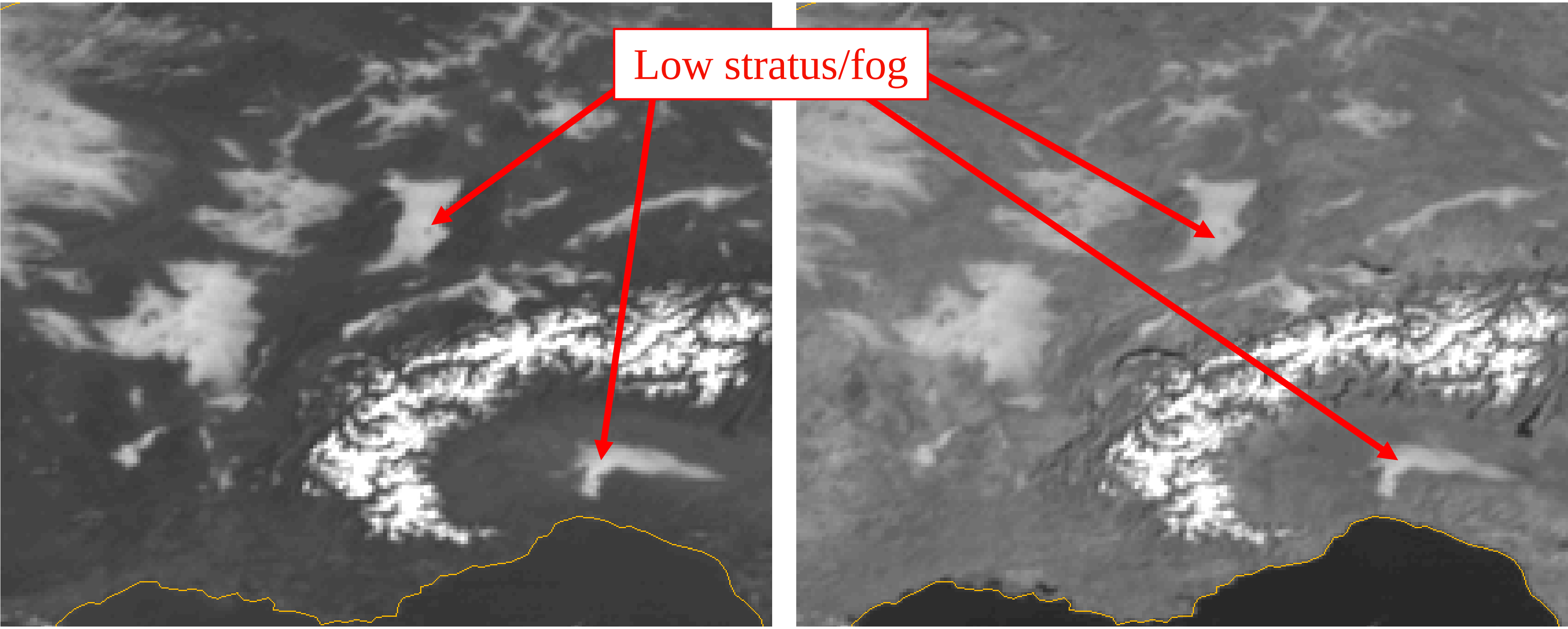


14 July 2003, 8:15 UTC, VIS0.8

24 April, 6:00 UTC, VIS0.6

Detection of fog during daytime with both VIS channels

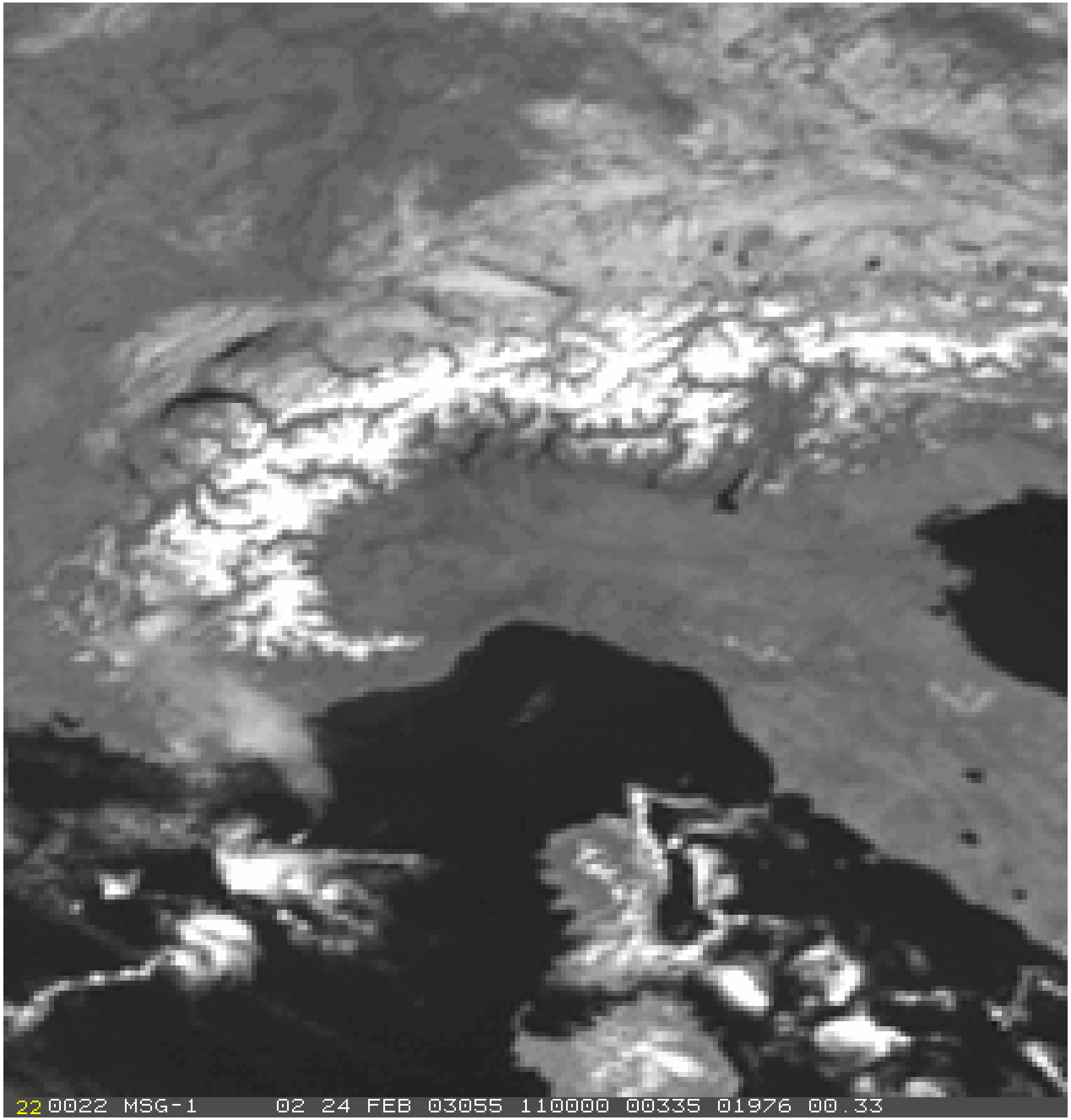
Fog Detection



5 Nov 2003, 8:45 UTC, VIS0.6

5 Nov 2003, 8:45 UTC, VIS0.8

Detection of fog during daytime with both VIS channels, but ...



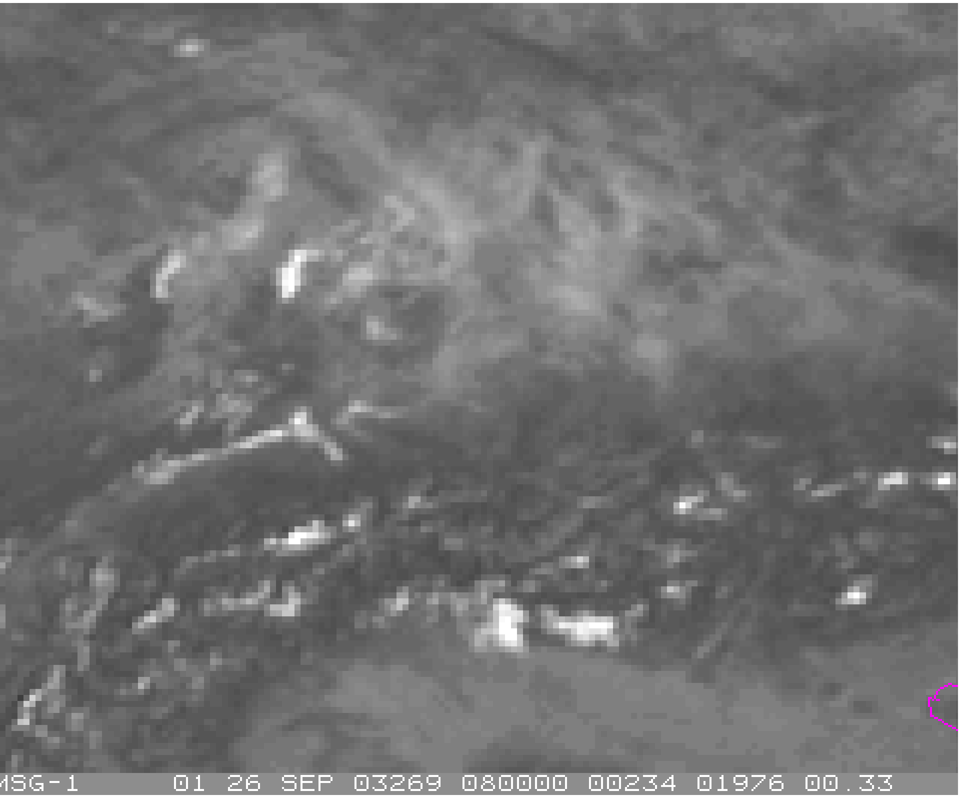
Fog Detection

Non-detection of fog over snow surfaces with VIS channels

MSG-1
24 Feb 2003
11:00-12:45 UTC
Channel 02 (0.8 µm)

Detection of Transparent Clouds

- over land -

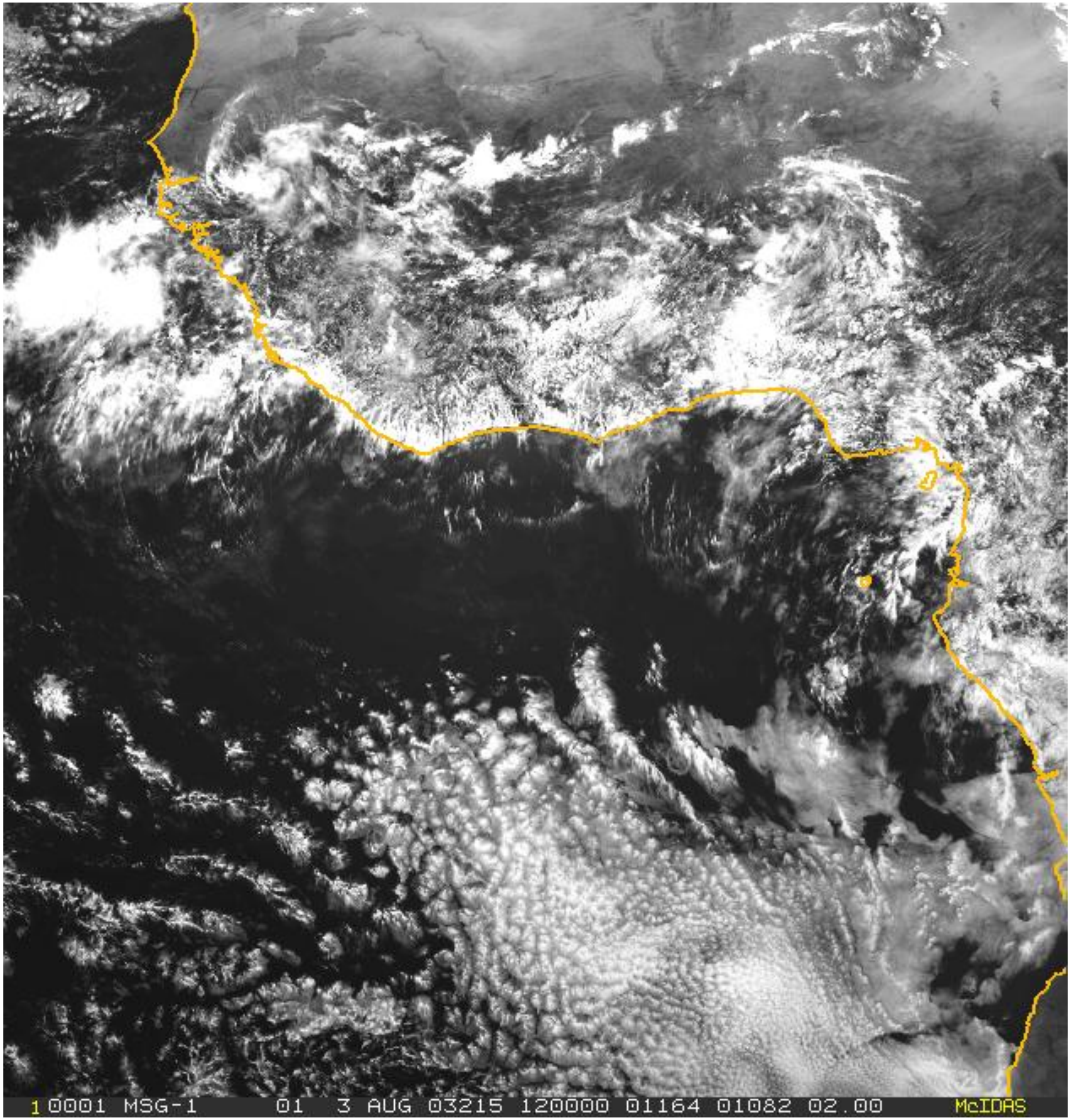


26 Sep 2003, 8:00 UTC, VIS0.6

26 Sep 2003, 8:00 UTC, VIS0.8

VIS0.6 better than VIS0.8 for detection of transparent clouds over land surfaces (less reflectivity of surface)

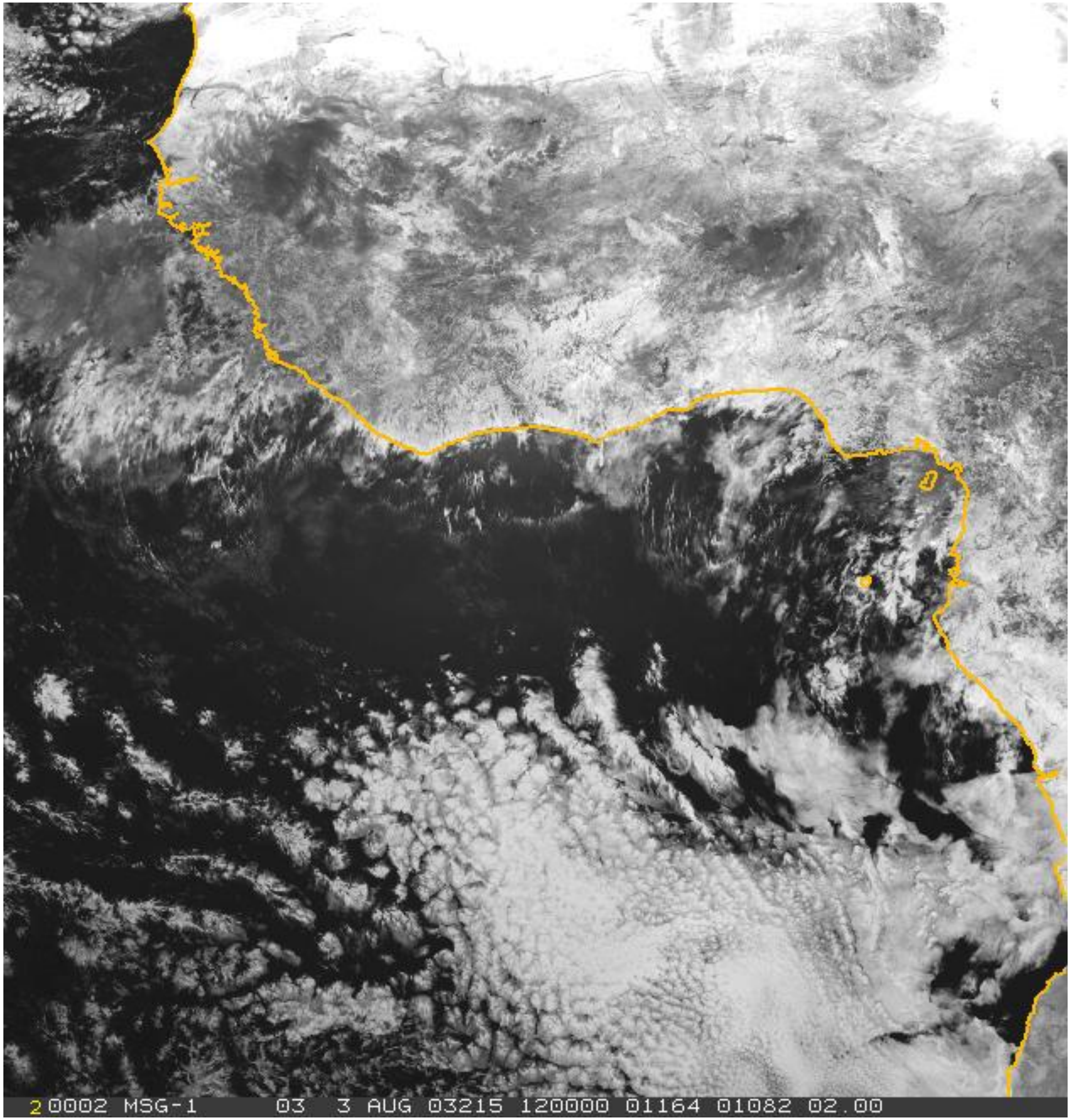
Cloud Phase (Ice/Water)



Cloud phase <u>not</u> observed in VIS0.6 and VIS0.8

"all (thick) clouds are white"

MSG-1
3 August 2003
12:00 UTC
Channel 01 (0.6 μm)



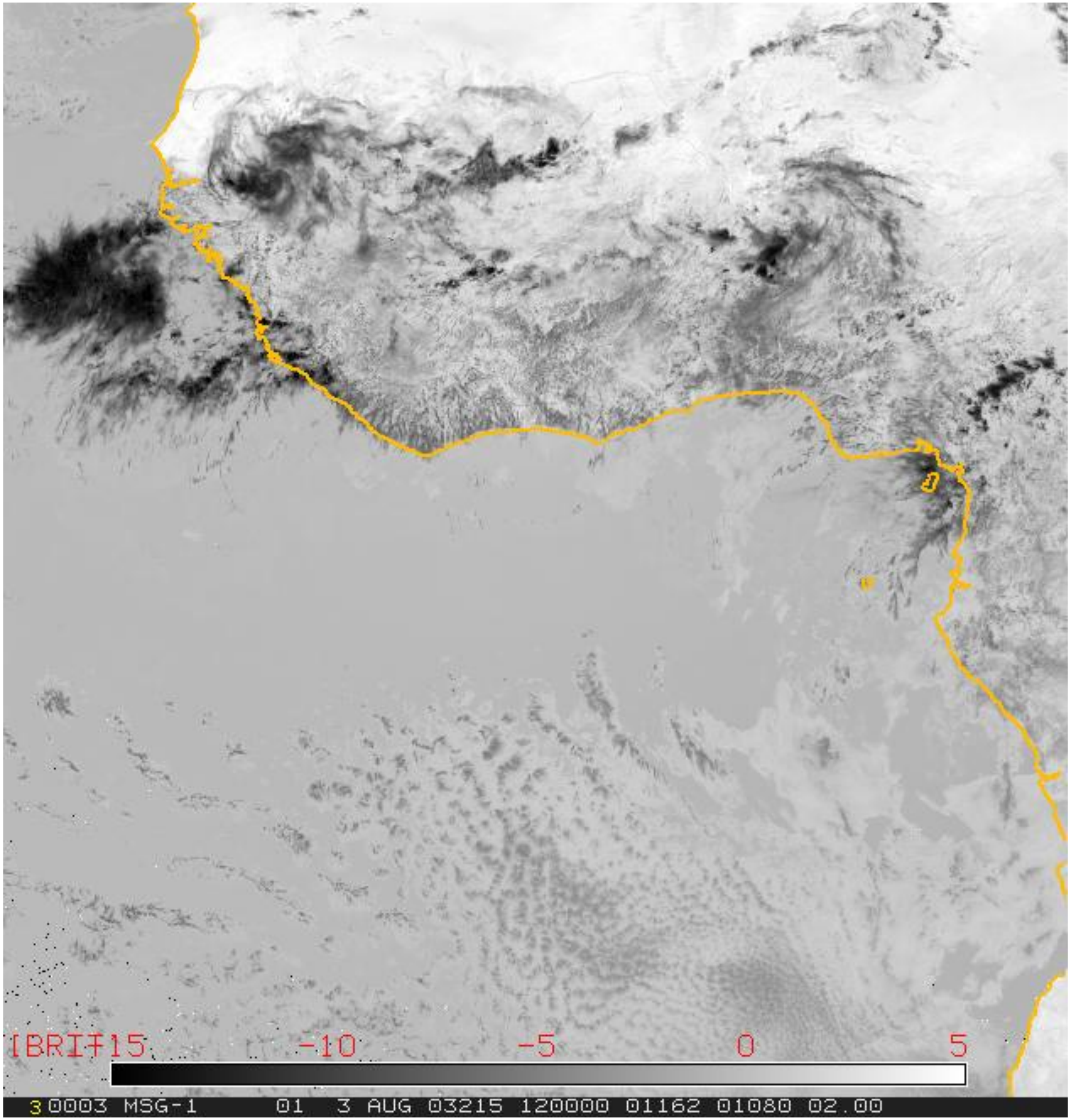
Cloud Phase (Ice/Water)

Cloud phase observed in NIR1.6

"ice clouds are dark, water clouds are bright"

MSG-1
3 August 2003
12:00 UTC
Channel 03 (1.6 μm)

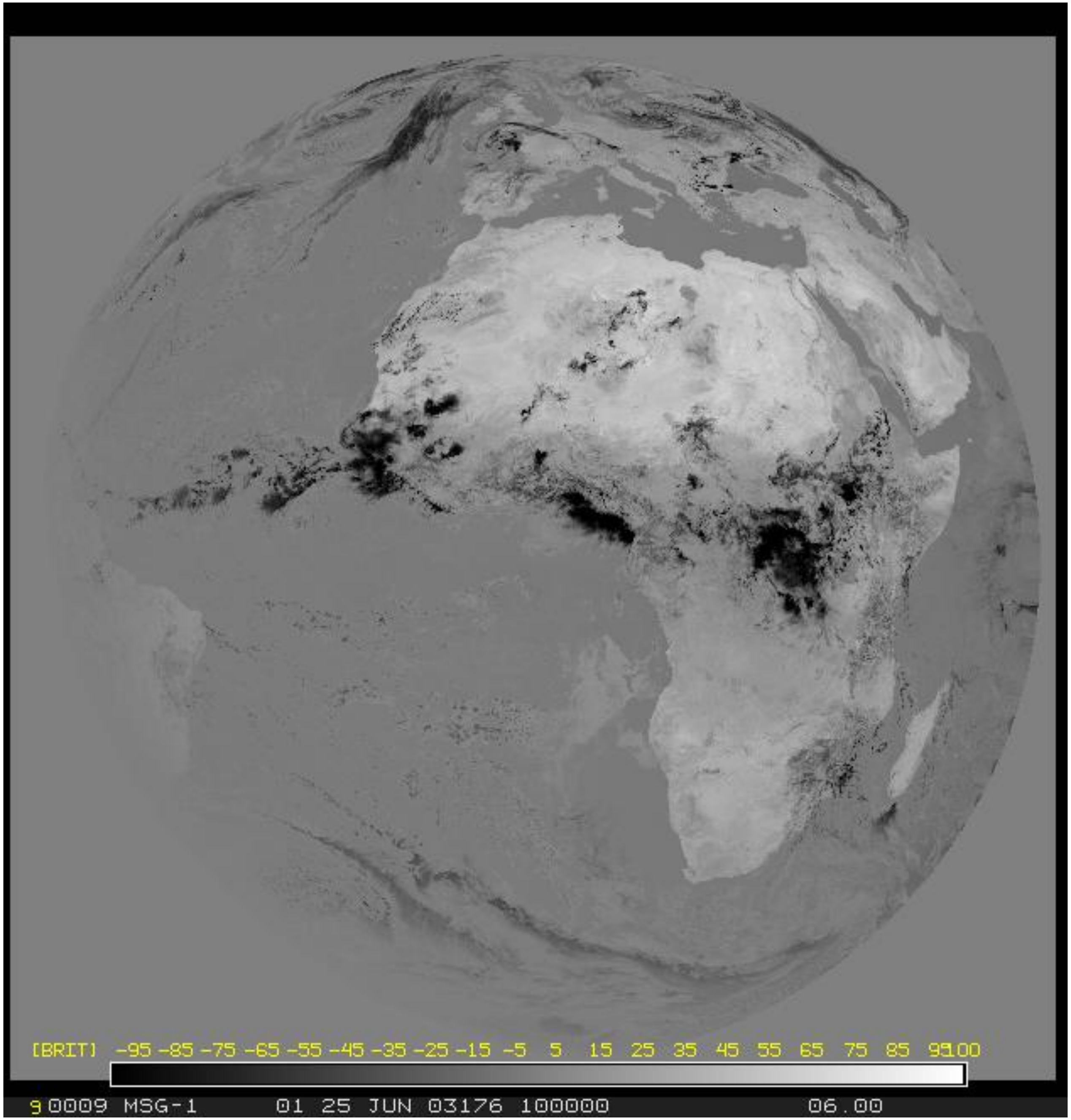
Cloud Phase (Ice/Water)



Ice clouds can be well detected in NIR1.6 - VIS0.6

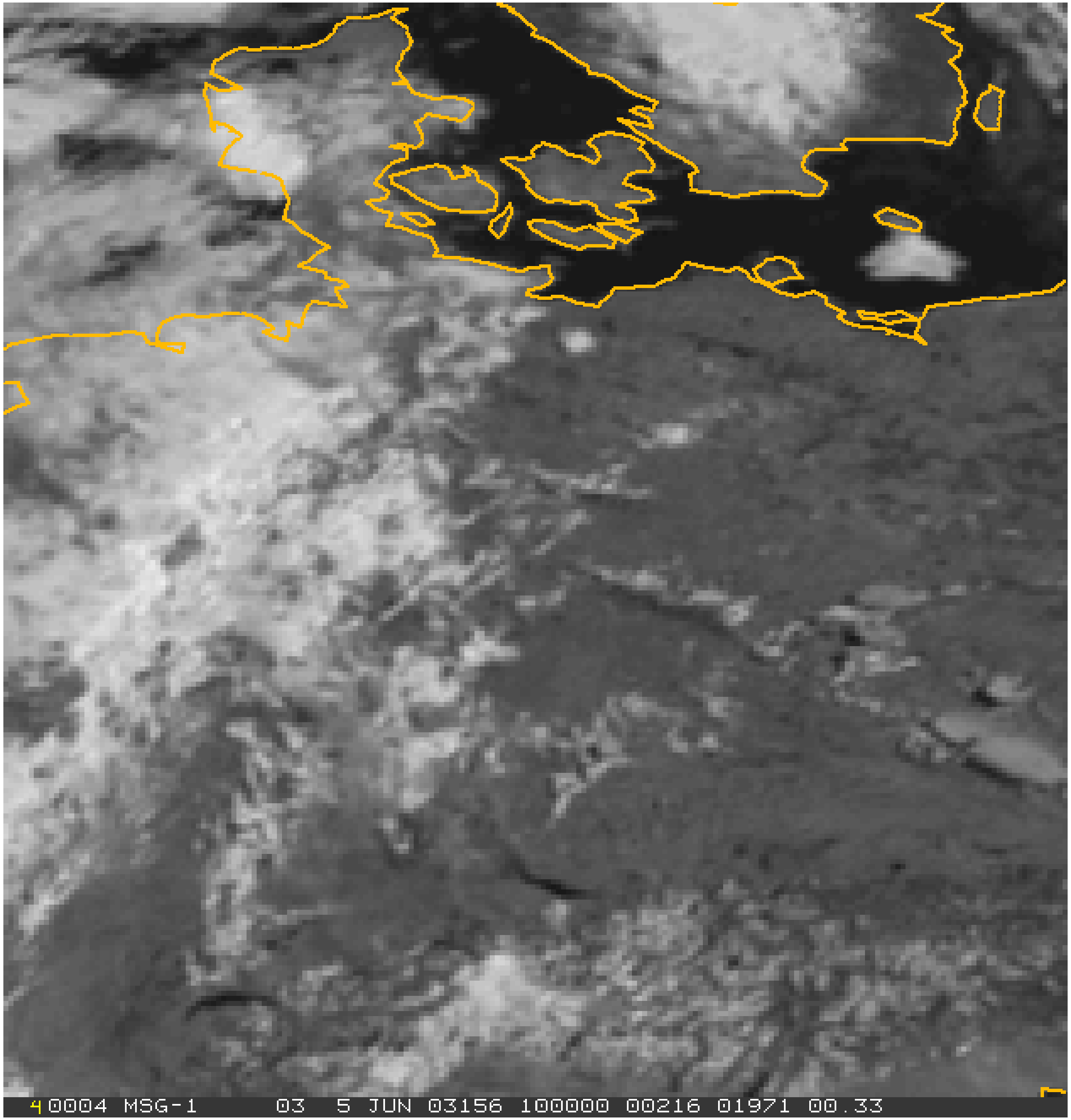
MSG-1
3 August 2003
12:00 UTC
Difference Image
NIR1.6 - VIS0.6

Cloud Phase (Ice/Water)



Ice clouds can be well detected in NIR1.6 - VIS0.6

MSG-1
25 June 2003
10:00 UTC
Difference Image
NIR1.6 - VIS0.6

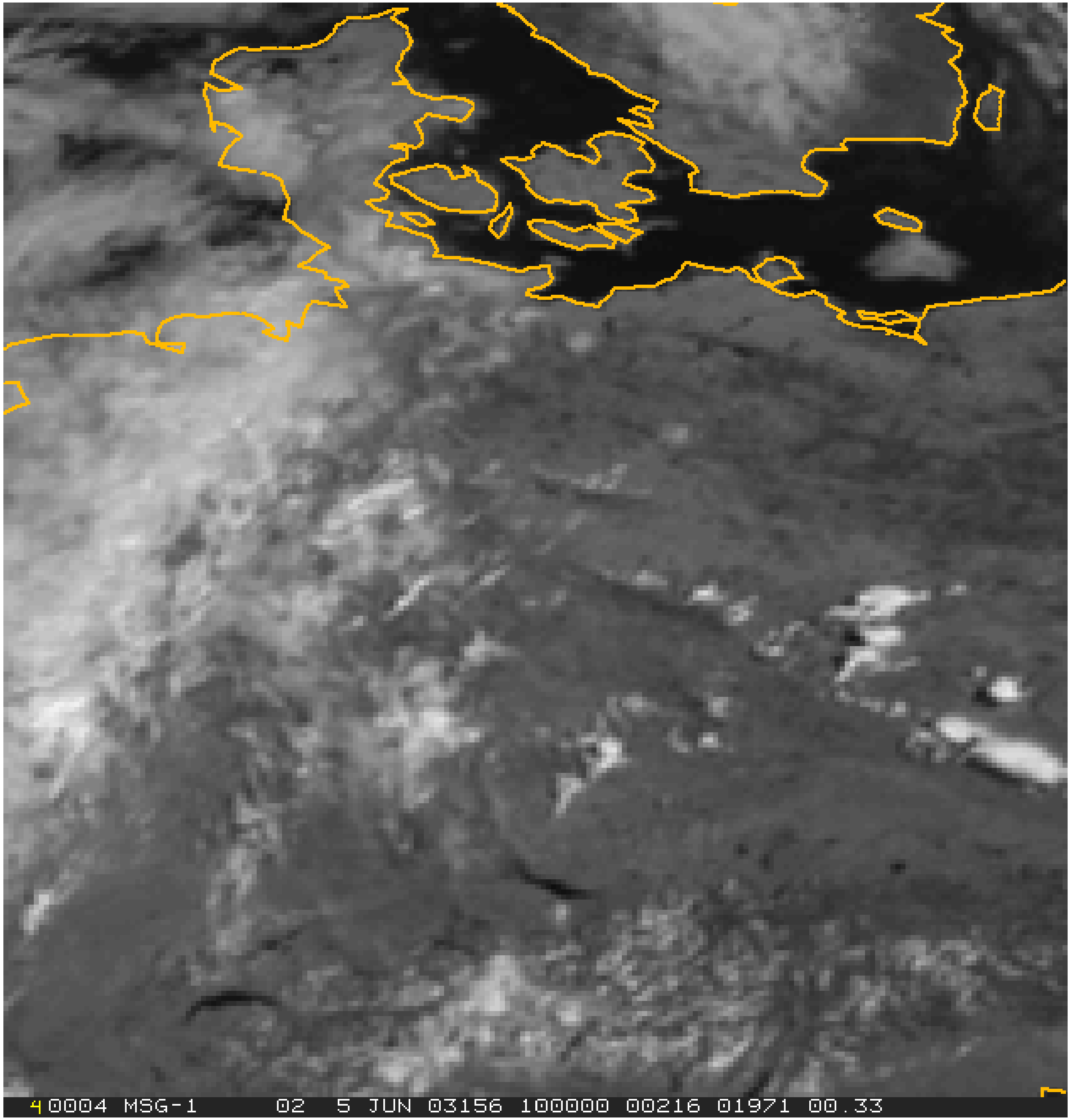


Cloud Phase (Ice/Water)

Cloud phase obs. in NIR1.6

"ice clouds are dark, water clouds are bright"

MSG-1
5 June 2003
10:00 - 13:00 UTC
Channel 03
(1.6 μm)

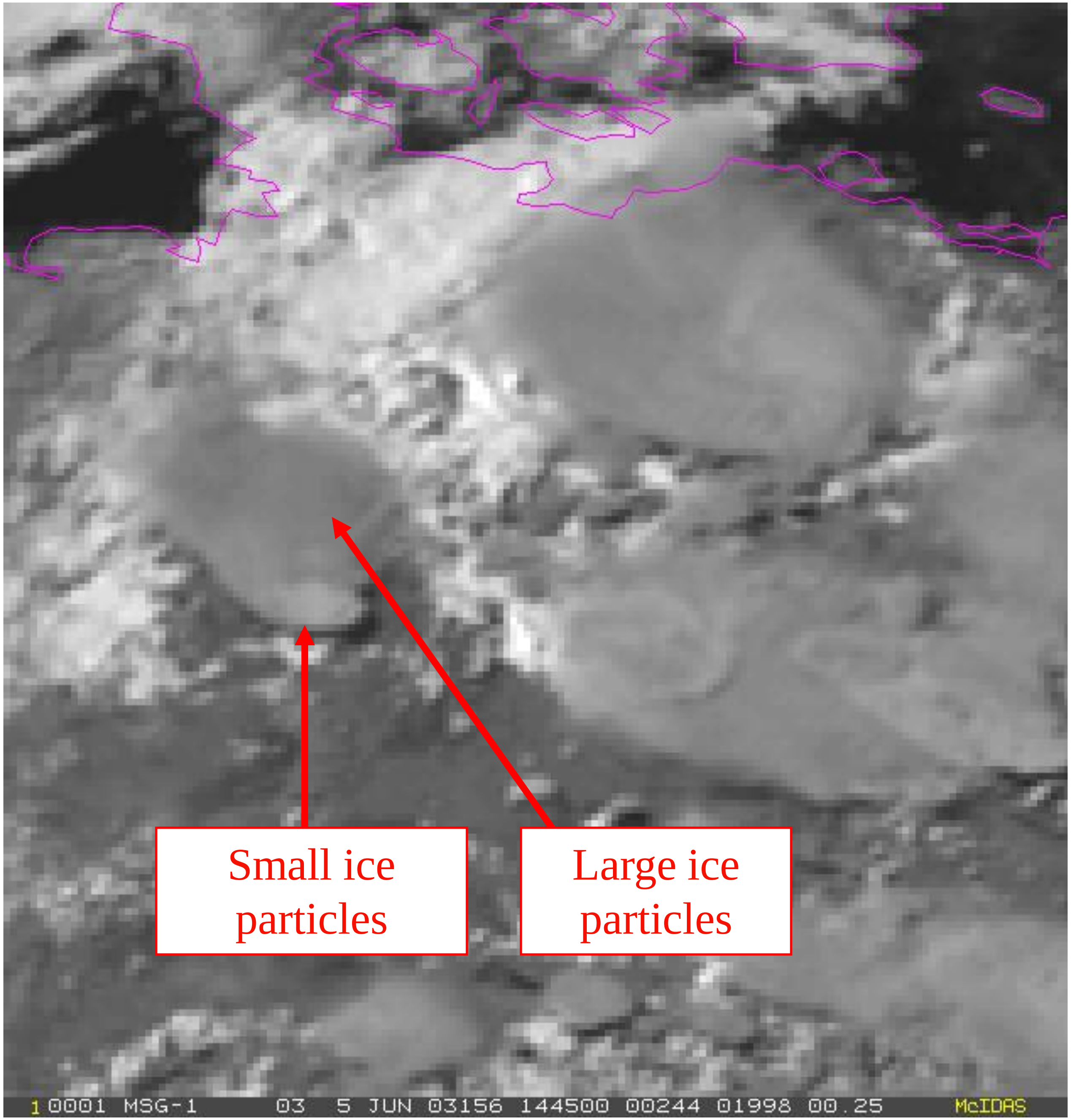


Cloud Phase (Ice/Water)

Cloud phase <u>not</u> obs. in VIS0.8

"all (thick) clouds are white"

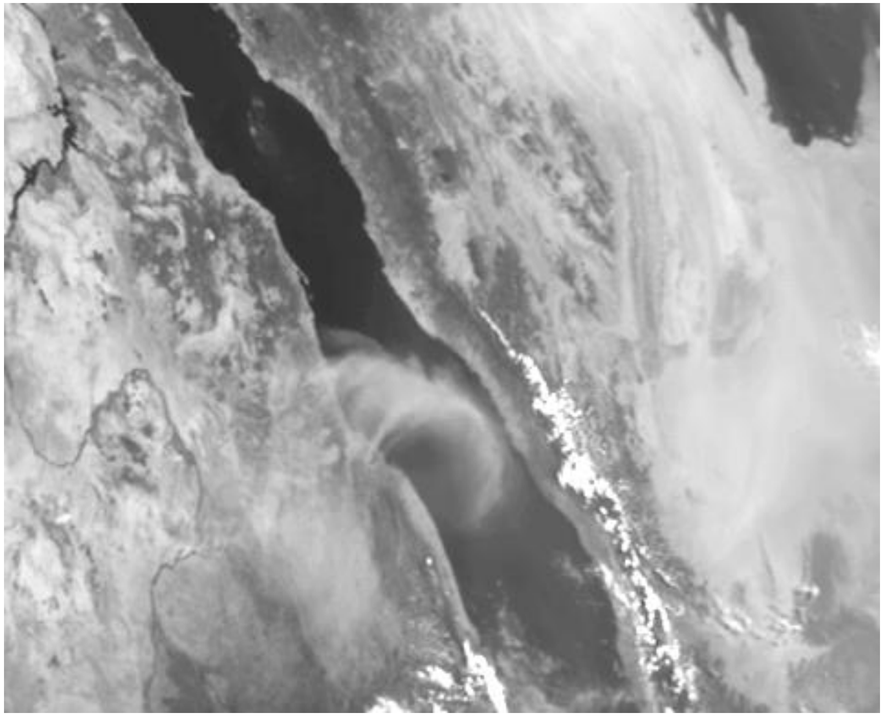
MSG-1
5 June 2003
10:00 - 13:00 UTC
Channel 02
(0.8 µm)



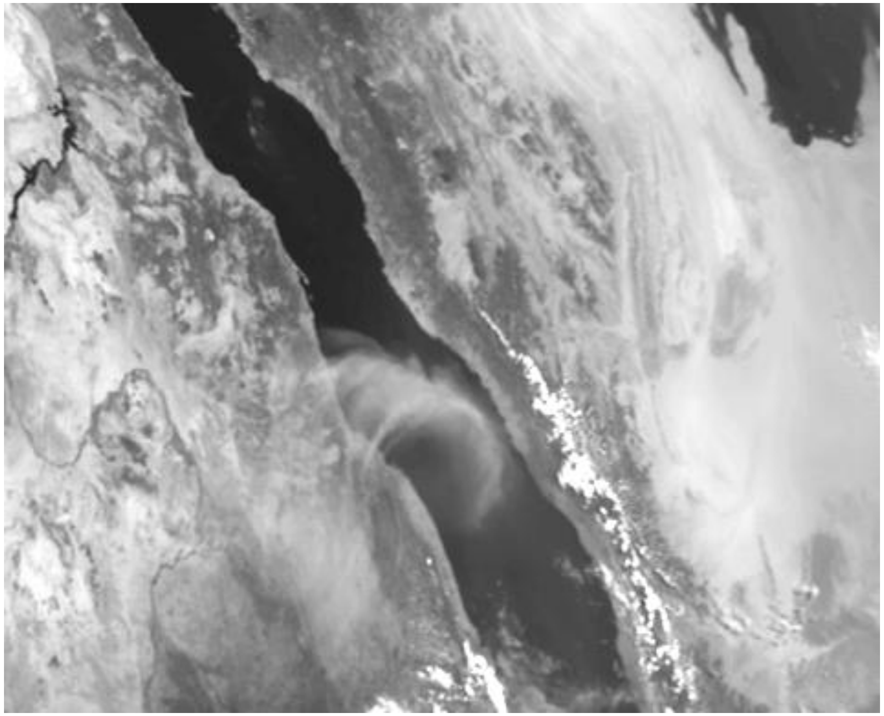
Cloud Particle Size

MSG-1
5 June 2003
14:45 UTC
Channel 03
(1.6 µm)

AEROSOL OBSERVATION



Channel 01 (0.6 μm)

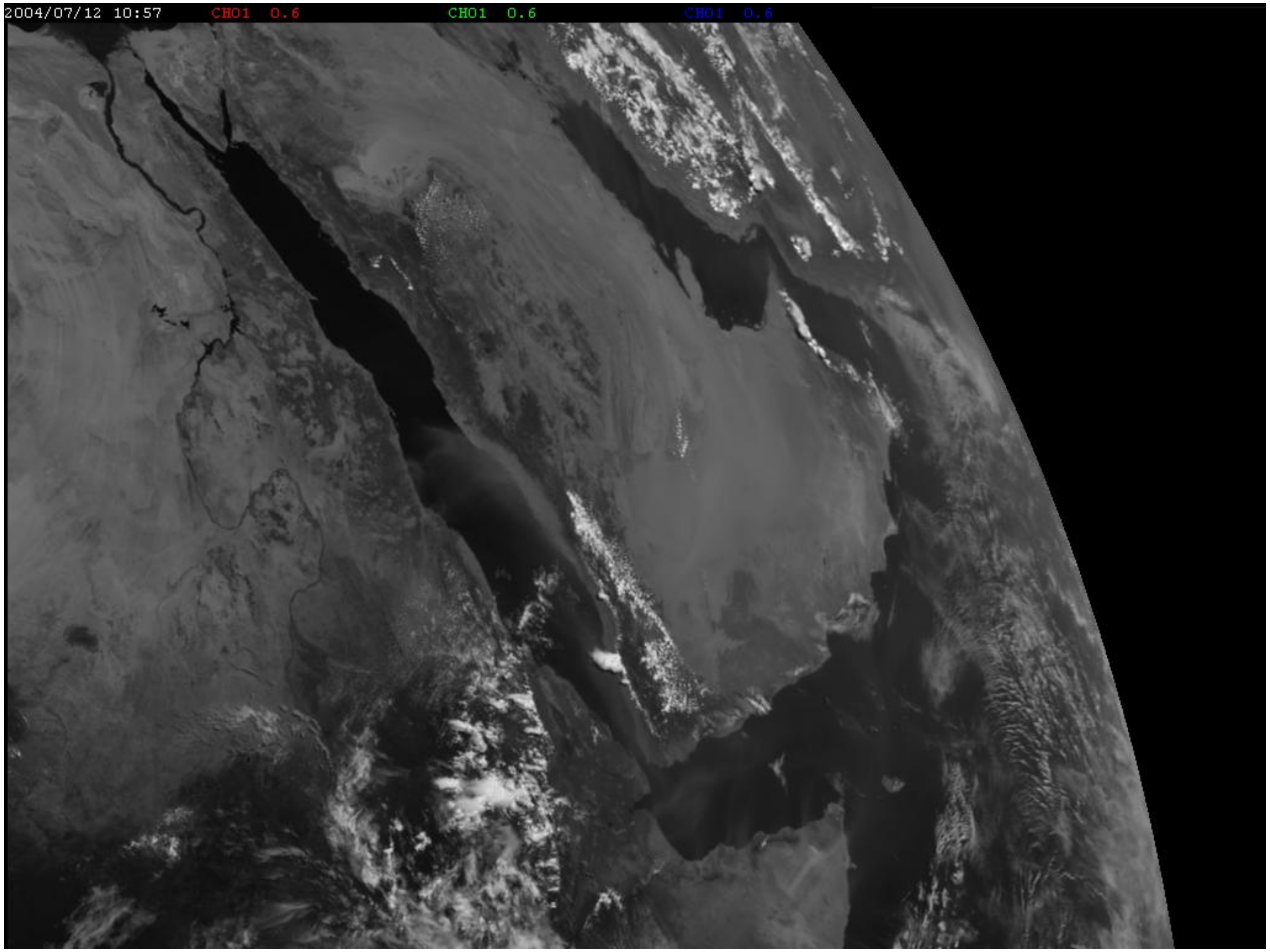


Channel 02 (0.8 μm)

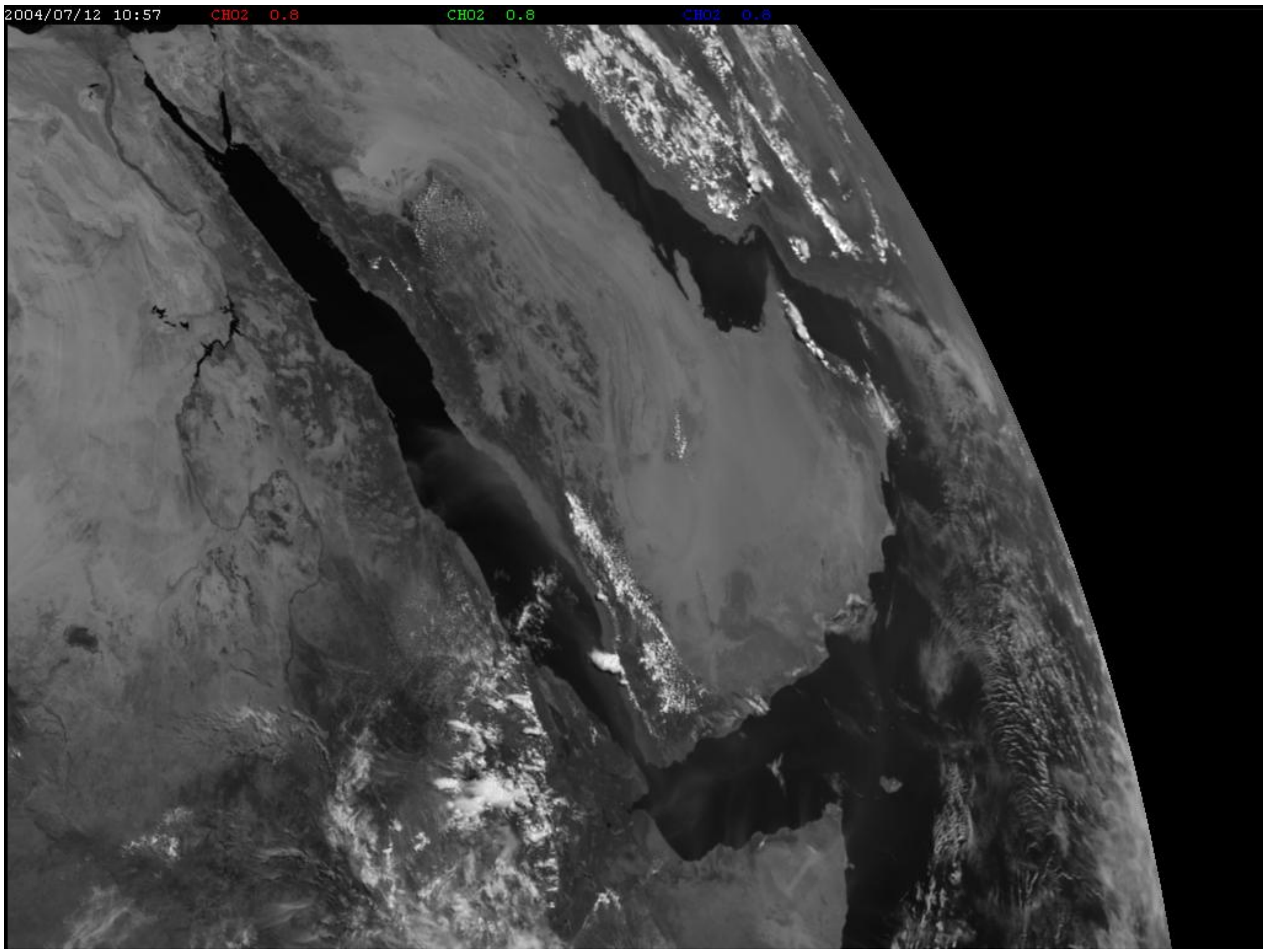
MSG-1, 25 June 2003, 10:00 UTC, **dust storm** over the Red Sea

For dust monitoring: VIS0.6 better than VIS0.8

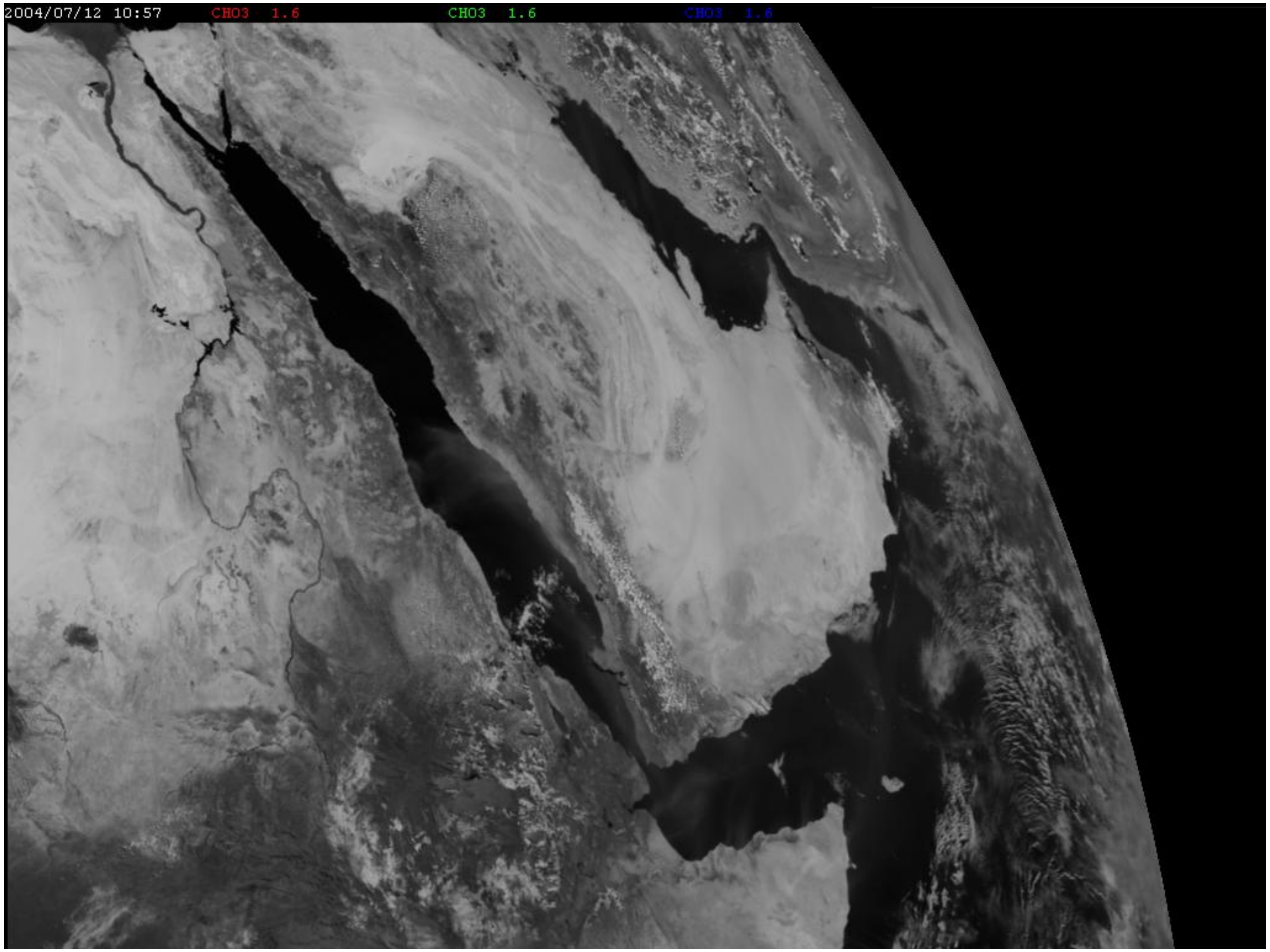
Cha 1, 12th July 2004, 10:57 UTC



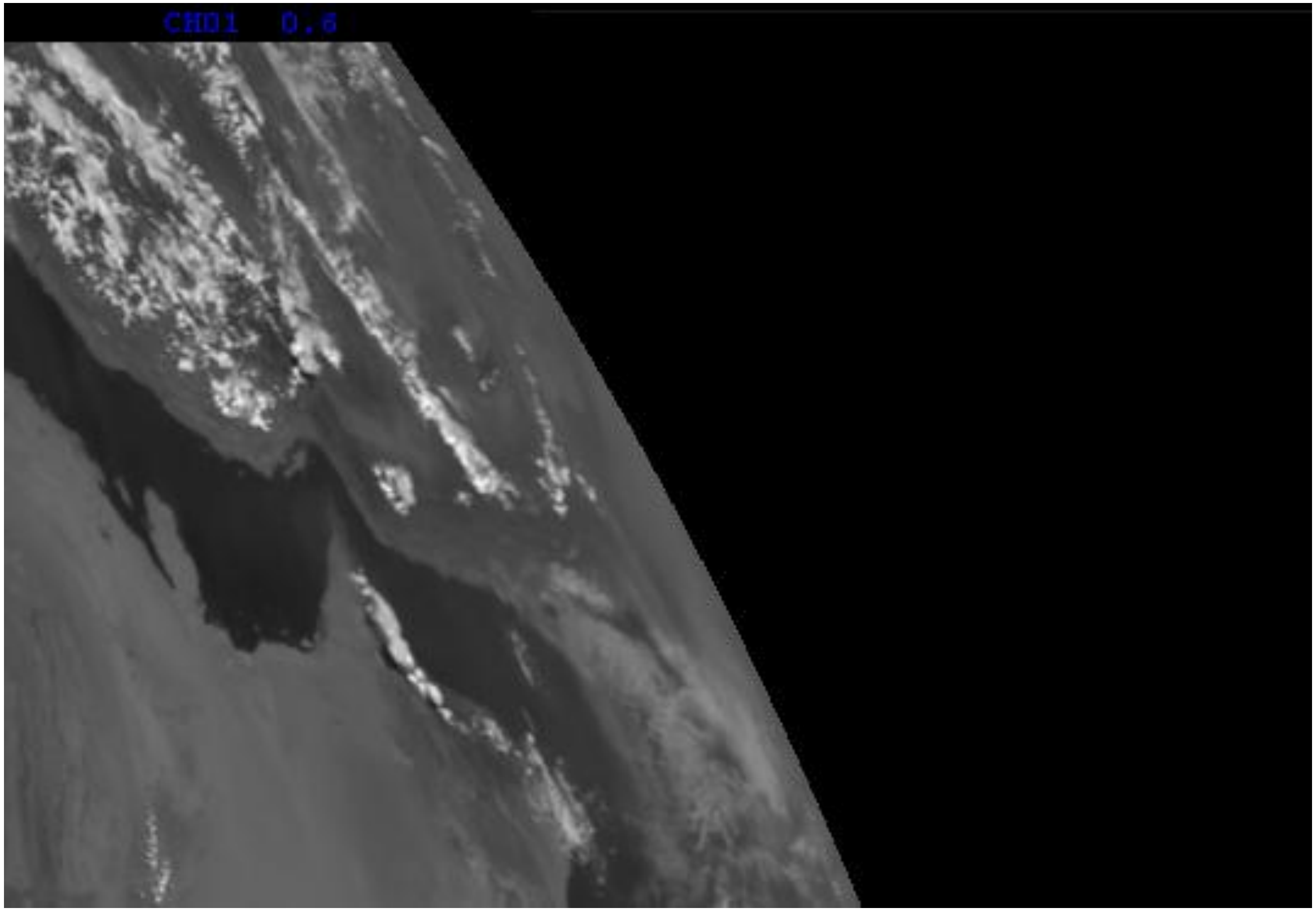
Cha 2, 12th July 2004, 10:57 UTC



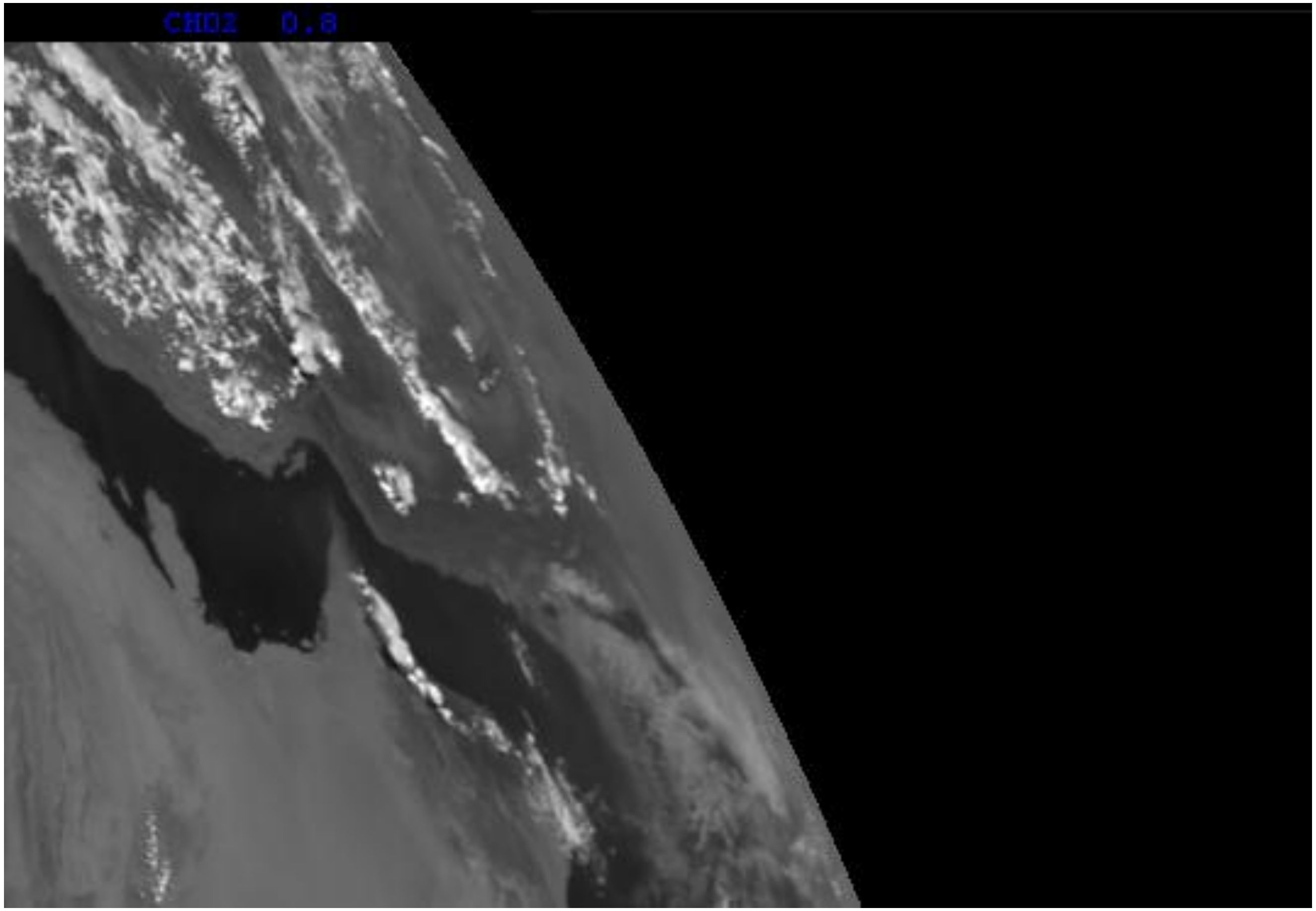
Cha 3, 12th July 2004, 10:57 UTC



Cha 1, 12th July 2004, 10:57 UTC



Cha 2, 12th July 2004, 10:57 UTC



Cha 3, 12th July 2004, 10:57 UTC