Applications of the SEVIRI window channels in the infrared

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Lesson objectives

- ❖Learn which are the window channels in the infrared portion of SEVIRI
- ❖Review the general characteristics of window channels
- ❖Understand the behaviour of channels at 8.7, 10.8 and 12.0µm for different ground surfaces and cloud types
- ❖Practice and exercise on scene identification through window channel differences, like 10.8 – 12.0µm
- ❖Review the concept of semi-transparency
- ❖Becoming aware of applications to precipitation, sea surface temperature and ash monitoring

SEVIRI CHANNELS

Channel	Cloud (Properties)	Gases (Properties)	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

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Window channels

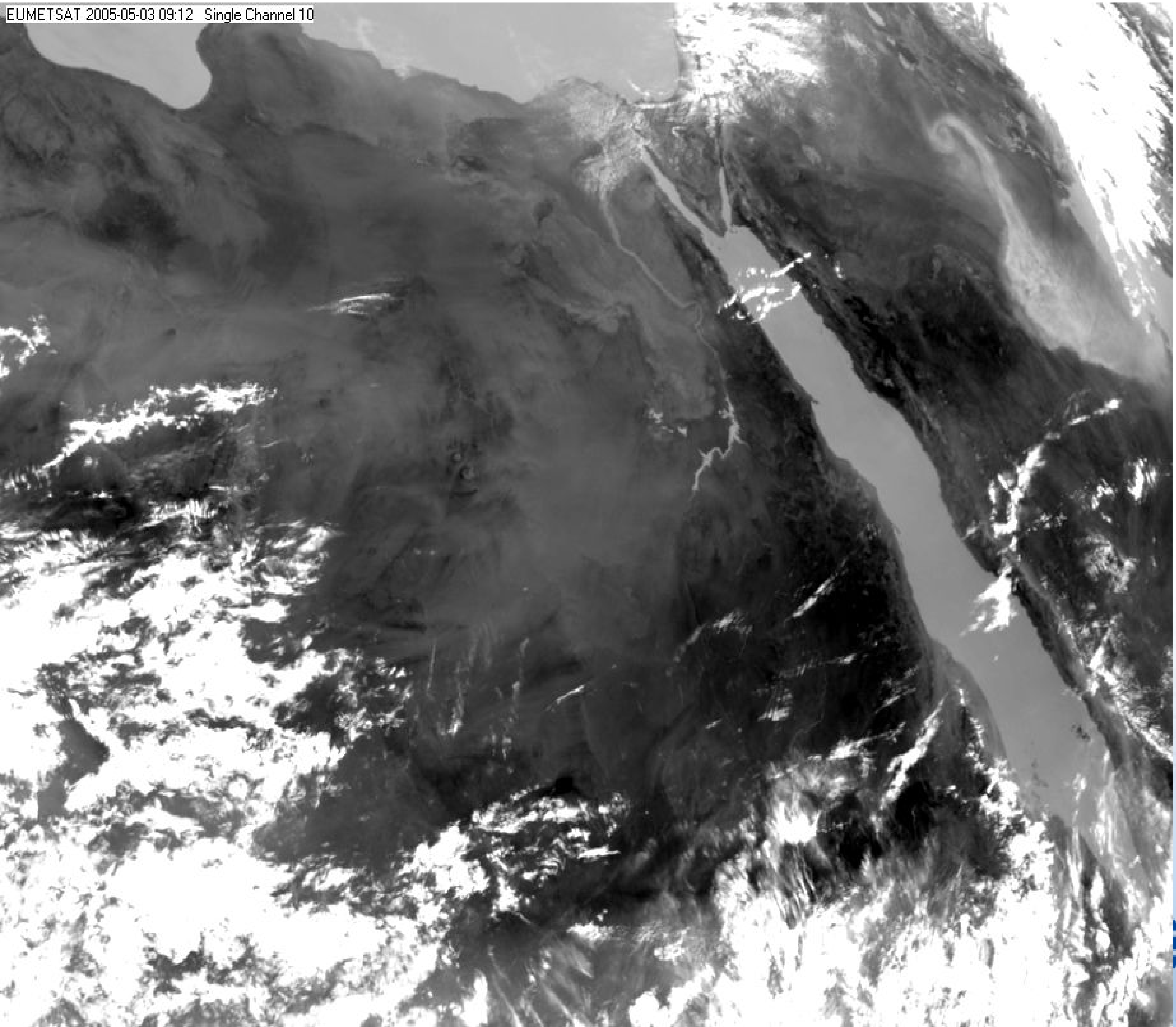
- **Low absorption of radiation** by water vapour

- **Sea Surface Temperature**
  - Land is gray, not black (emissivity < 1)

- **Cloud Top Height**
  - Cloud emissivity increasing with drop size (thin cloud)
  - Thin cloud looks warmer (semitransparency) than thick cloud
  - Skin (a few microns thick) is neither bulk nor air temperature

- **Land-sea** contrast (especially summer and winter)
- Poorer cloud texture than VIS
- Higher cloud opacity than in visible channels

Channels at 8.7, 10.8 and 12.0 µm



Channel 7

Channel 9

Channel10

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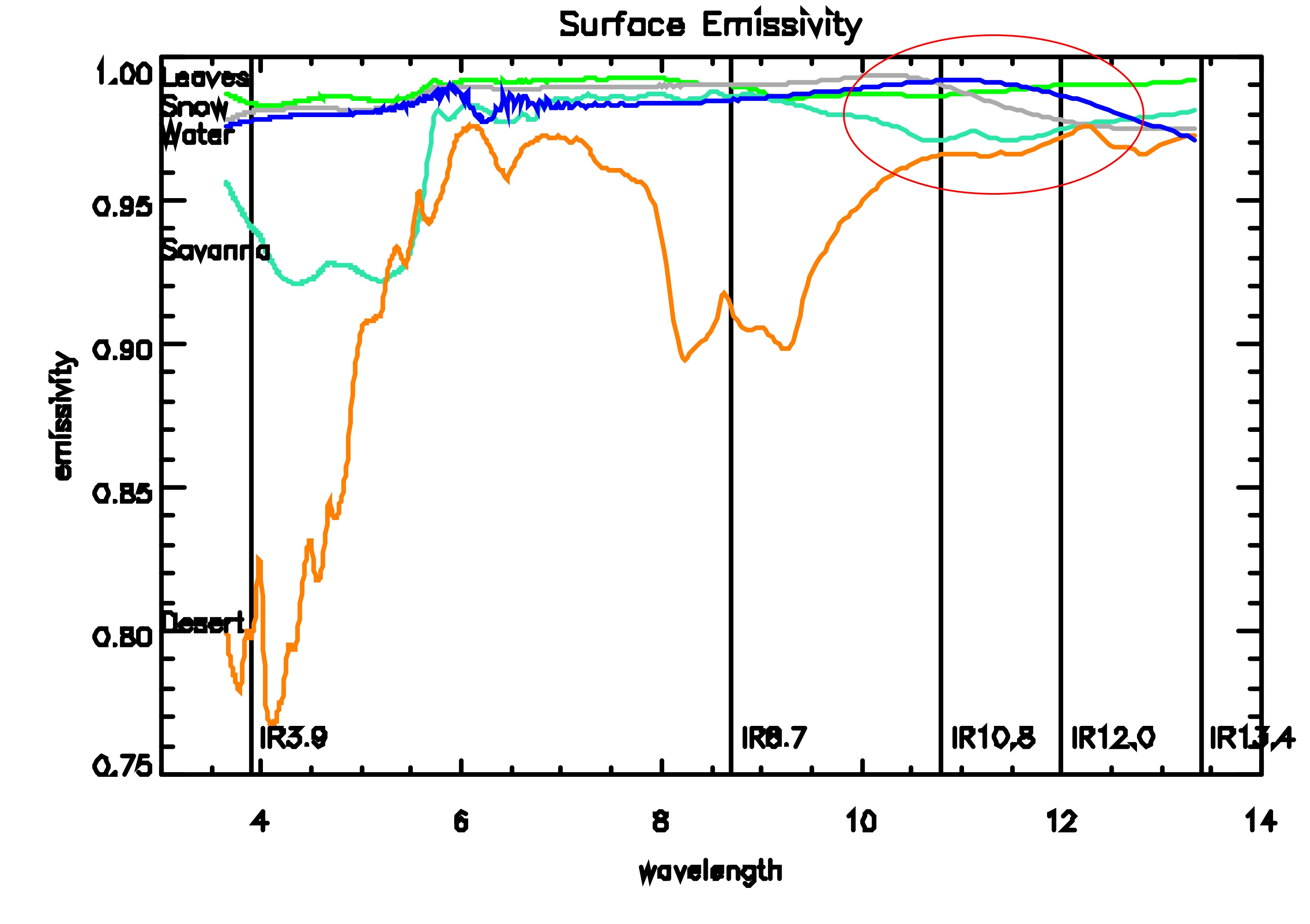
Surface properties



Land emissivity grows from 11 to 12 µm, snow and water emissivity decreases

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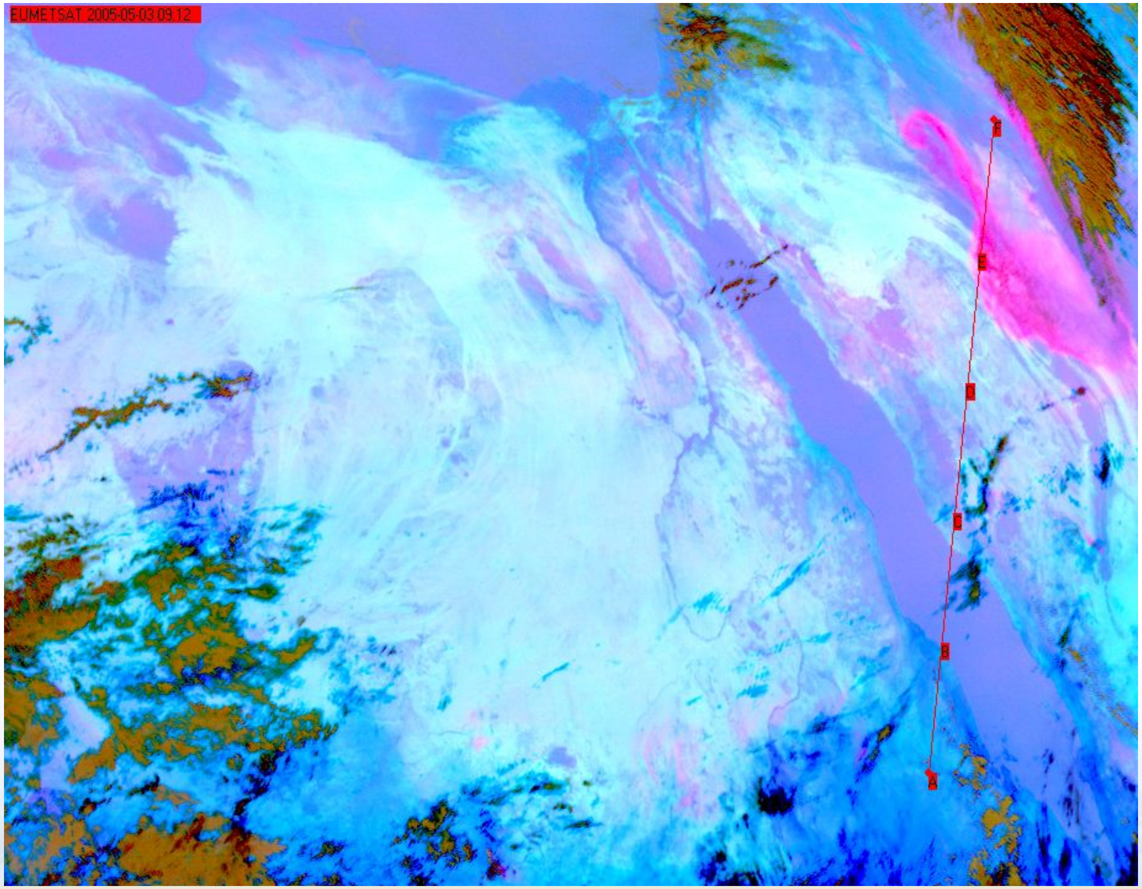
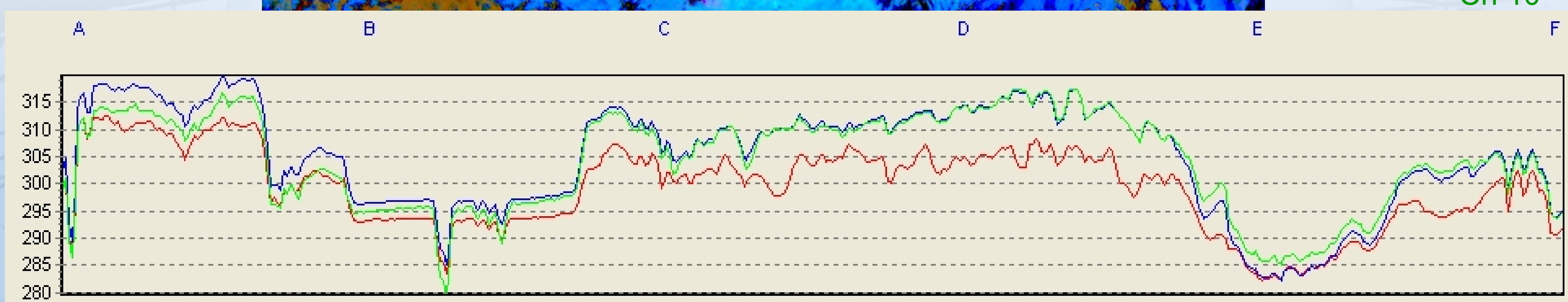
Compositing 8.7, 10.8 and 12.0 µm

Dust composite

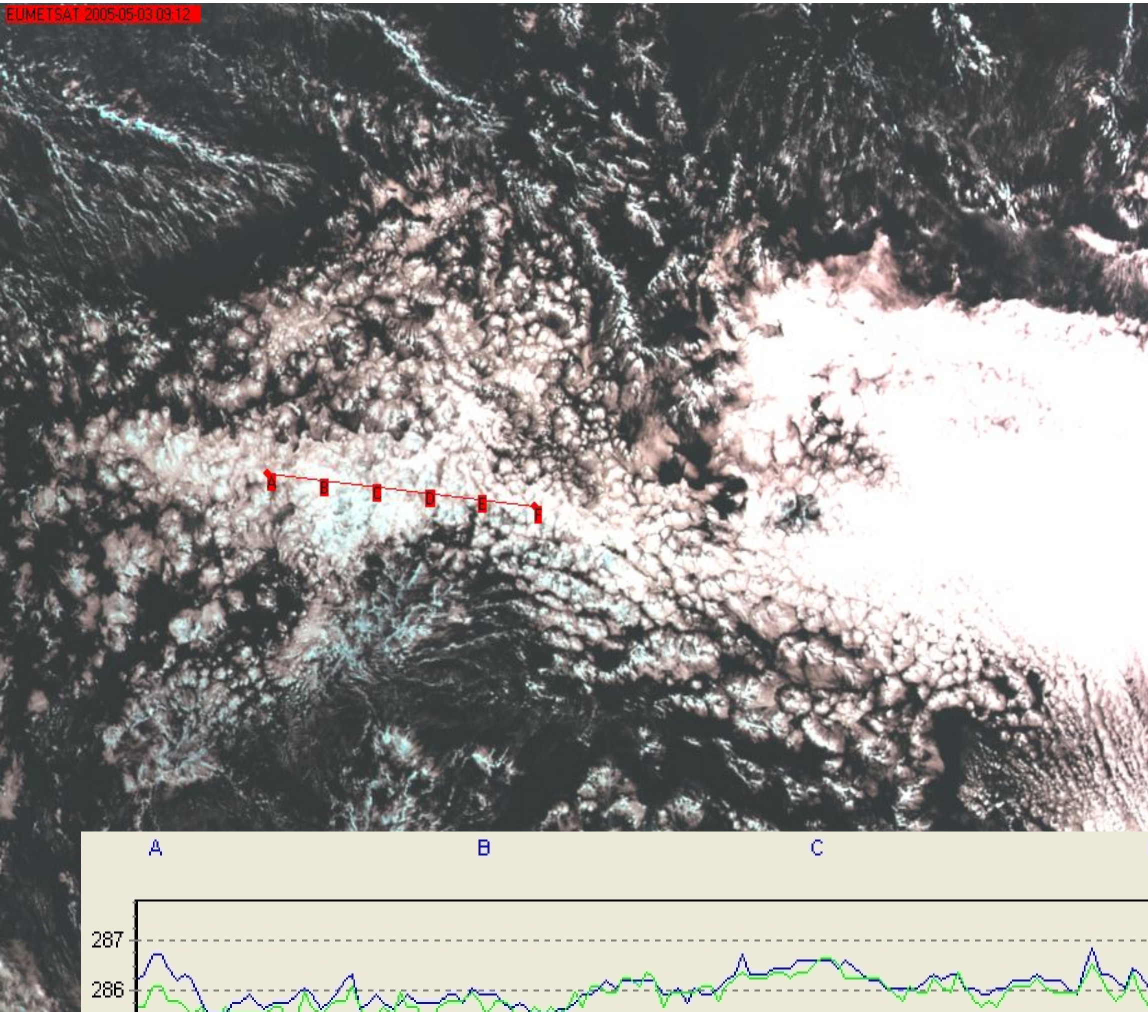
Defined as a EUMETSAT standard for application in a wide range of regions



- Ch 7
- Ch 9
-Ch 10



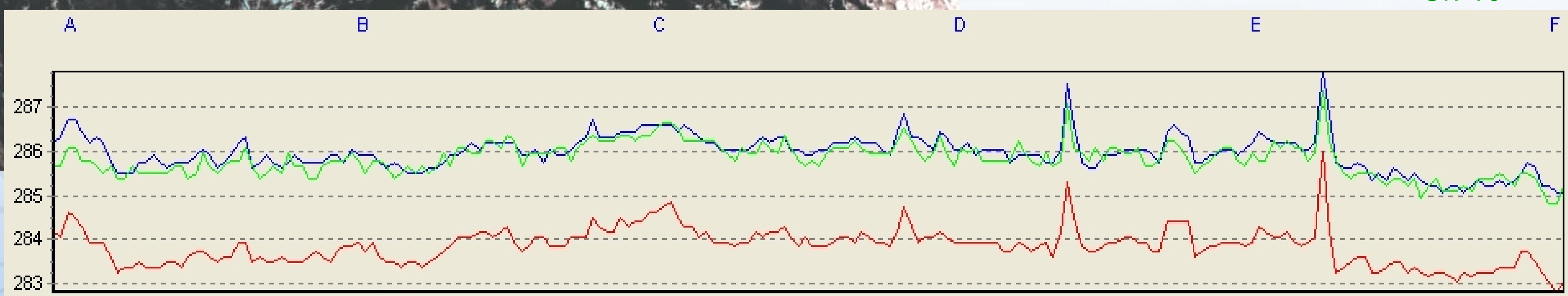
Channel comparison on water cloud



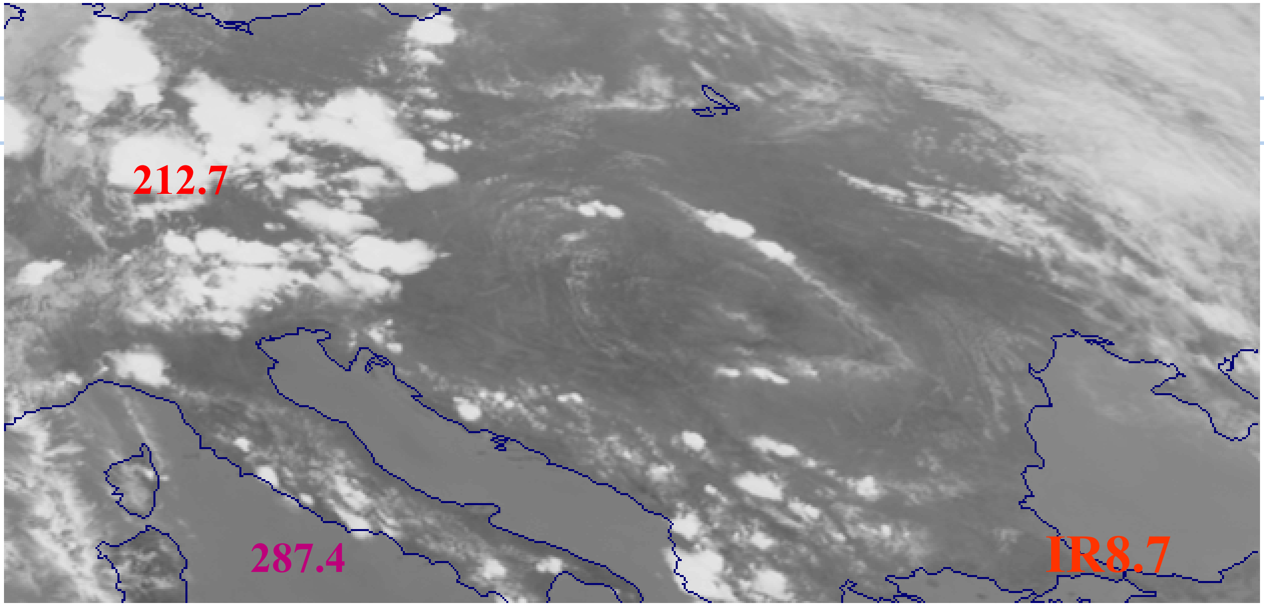
3 May 2005 09:00

Region of closed convective cells over the Atlantic, with probable local scale temperature inversions

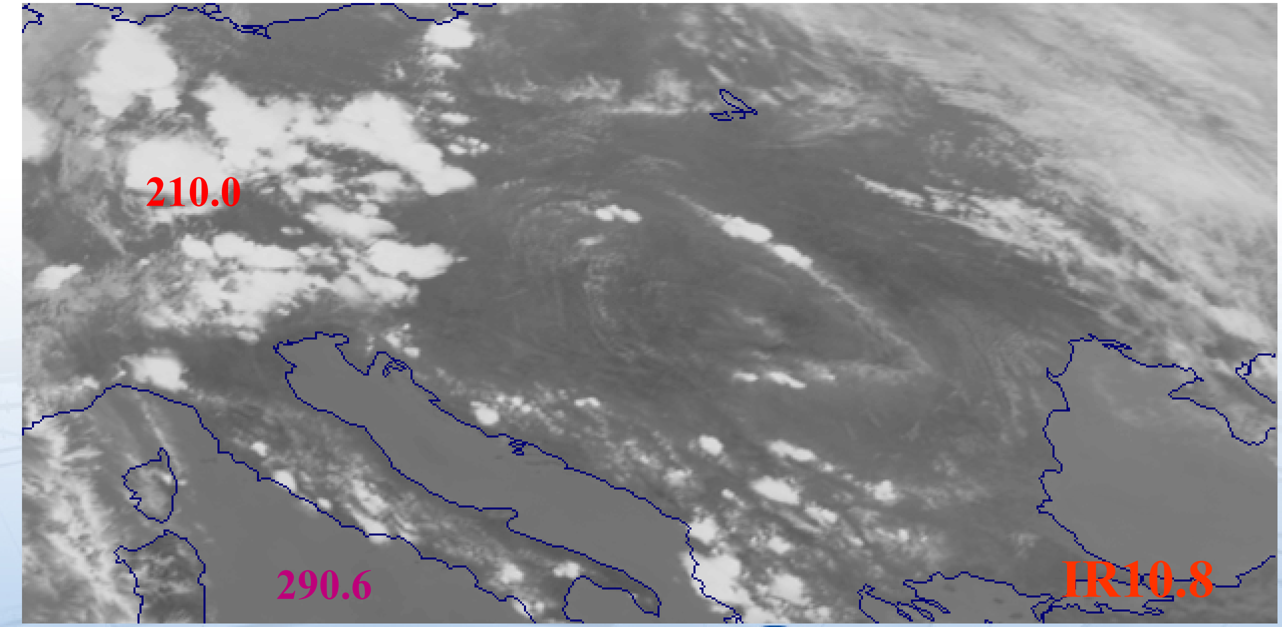
- Ch 7
- Ch 9
- Ch 10



Ice Cloud:
Stronger signal in IR8.7 because of higher emissivity (or cumulus towers)



Cloud free ocean:
Weaker signal in IR8.7 because of water vapour absorption



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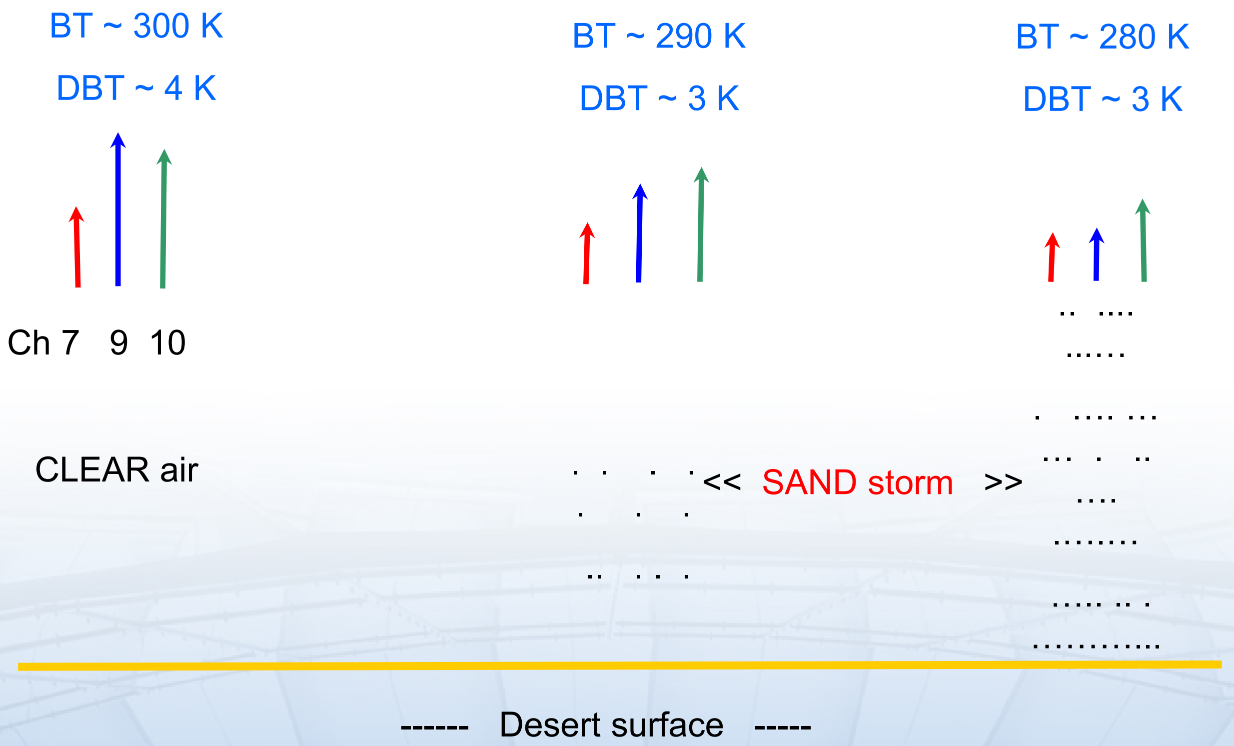
Differences for sand storms

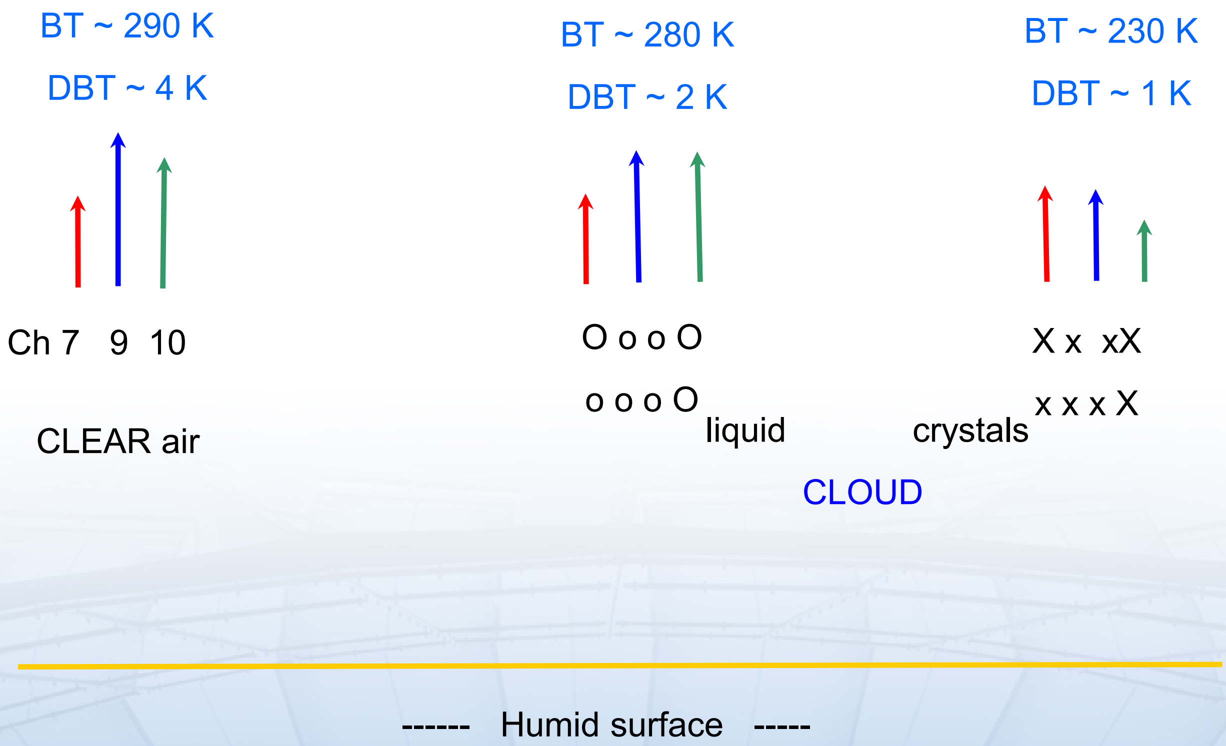
(Sahara) sand absorbs most at 10.8 μm



Brigthness (BT) and differential brightness temperatures (DBT) typical values for the three analysed channels

Differences for cloud

Channel difference 8.7µm-12.0 µm is an ice-cloud index



The 7-9 difference

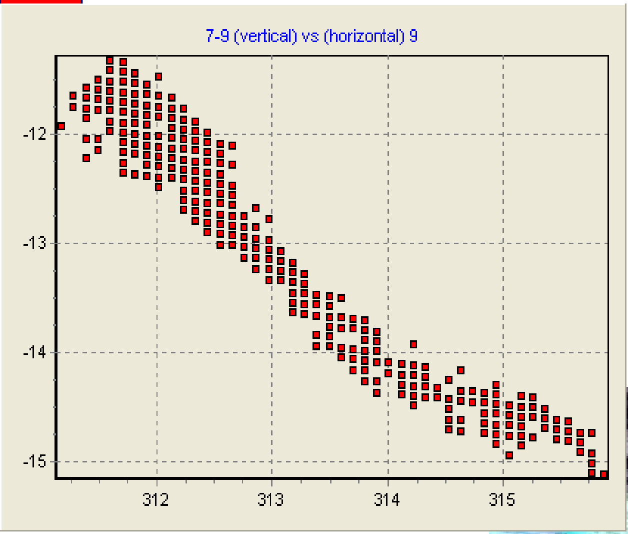
5 June 2003 12:00

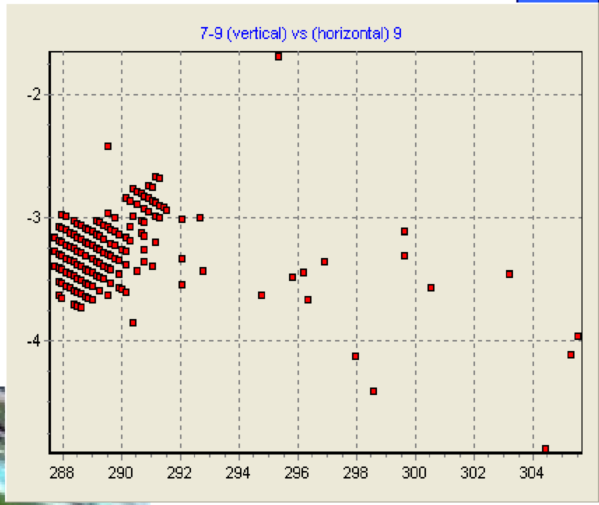
Liquid cloud gulf of Sirte

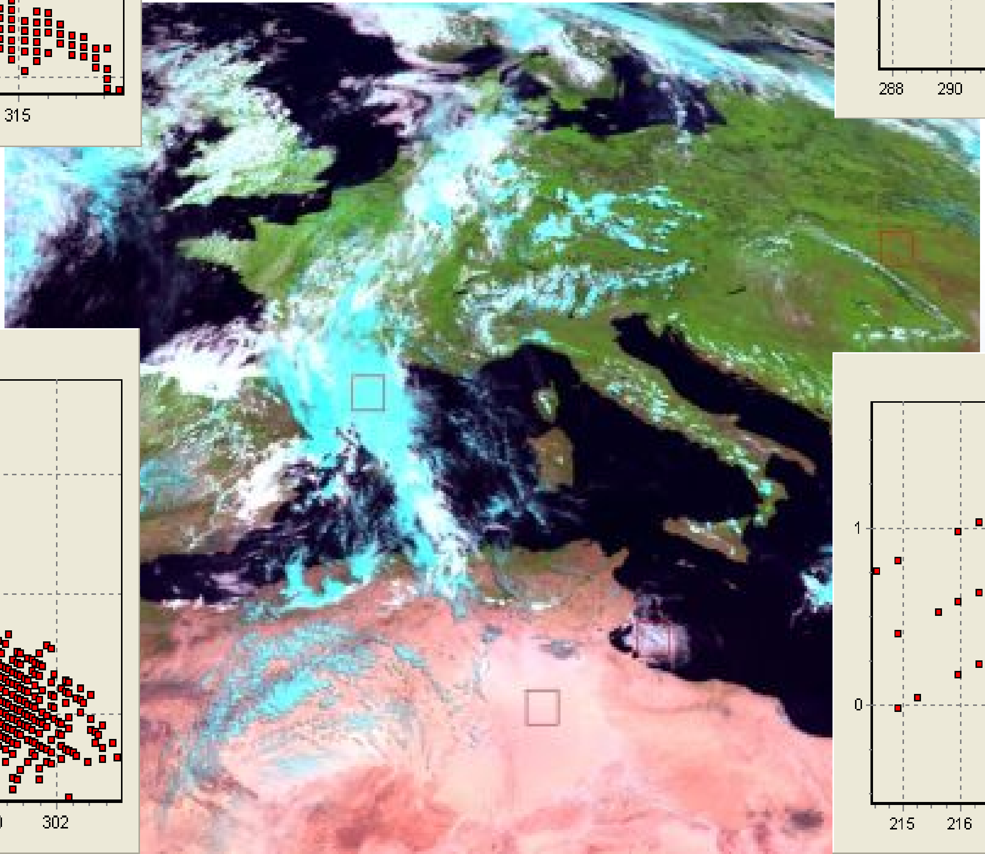
Ice cloud over Pyrenees

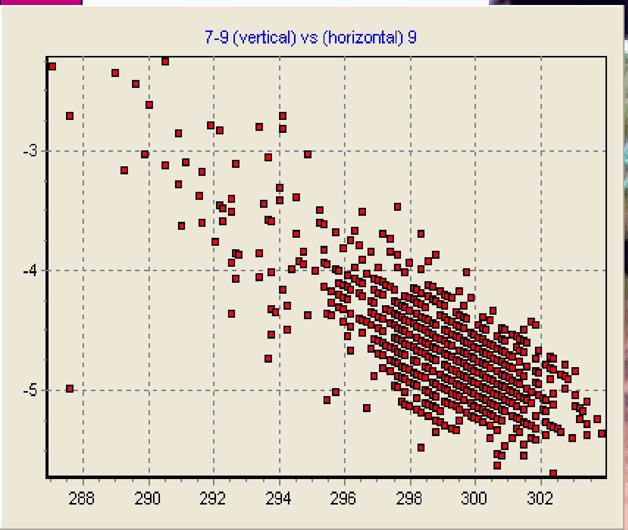
Clear over grass

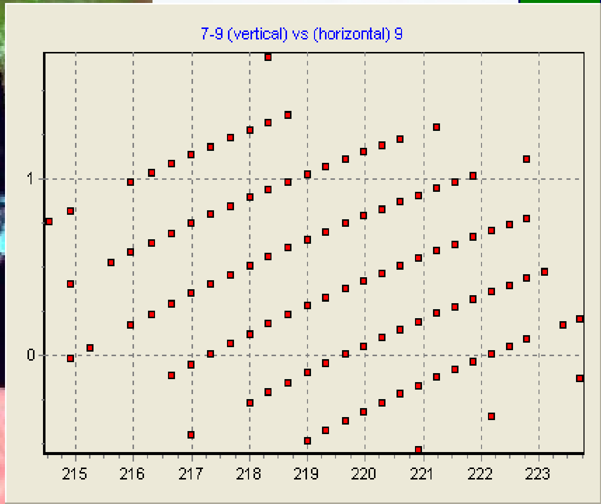
Clear desert











Absorption in the window channels

Absorption \ Channel	*8.7μm*	*10.8 μm*	*12.0 μm*
Water vapour absorption	-3K	-1K	-2K
Cloud absorption (liquid), n'	4%	8%	19%
Cloud absorption (ice), n'	4%	19%	42%
Desert/clay emissivity	85%	96%	98%
Ocean emissivity	Similar in all (99%+)		

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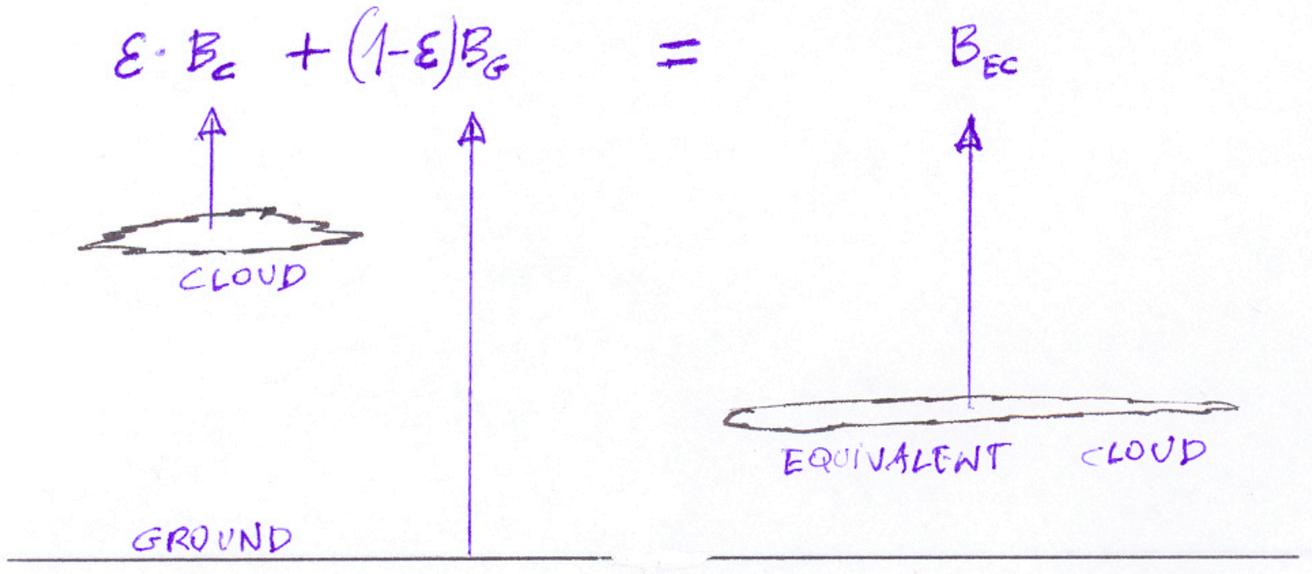
Semi-transparency



- ❖ E*Tc + (1-E)*Tg < BT WARM BIAS!

- ❖ Thin cloud pixels provide two contributions: cloud and ground, with a bias towards the warm source.

- ❖ The bias is weaker with increasing wavelength: flatter Planck response, lower sensitivity to temperature

- ❖ The bias grows with cloud height (temperature contrast)

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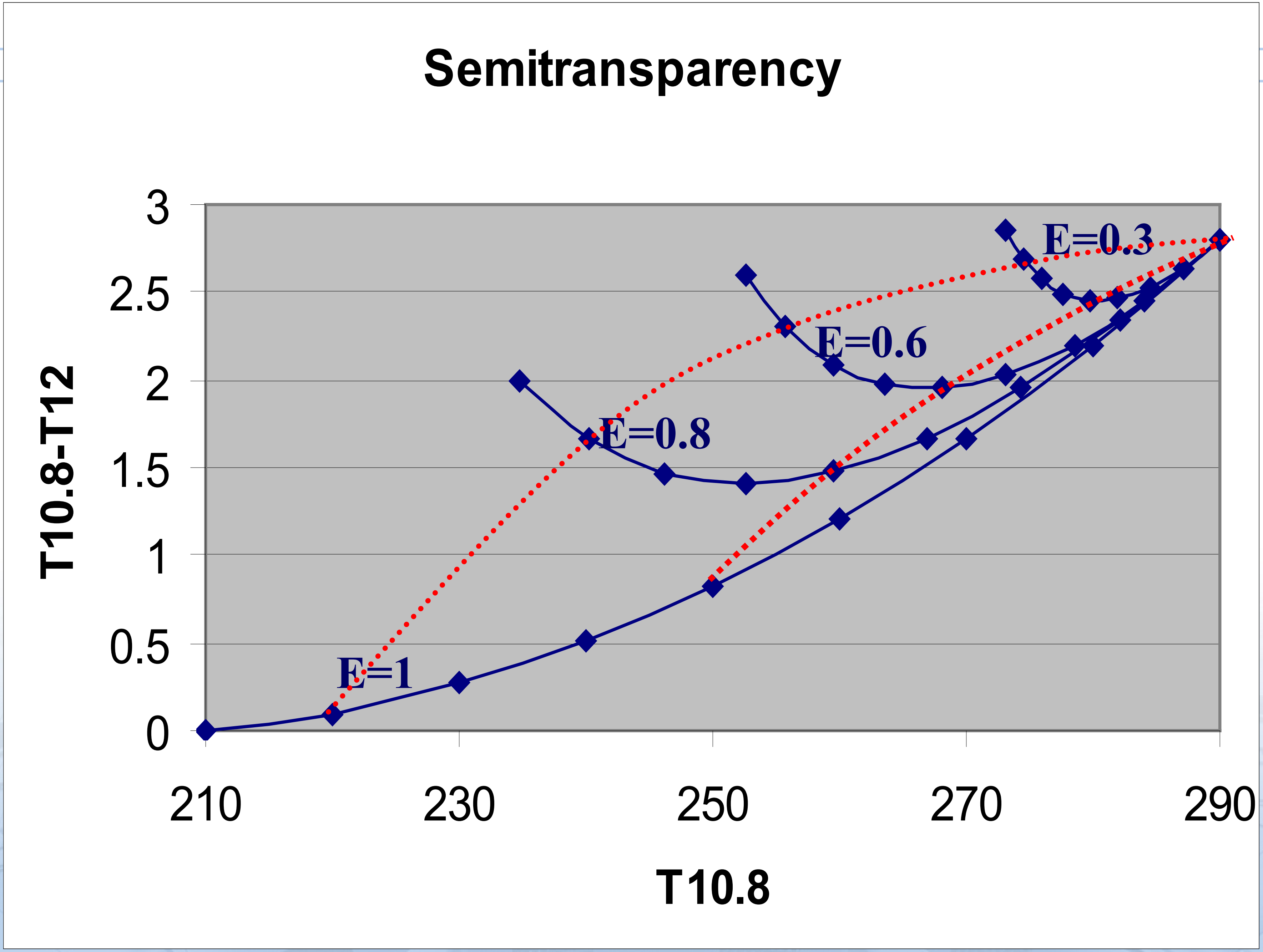
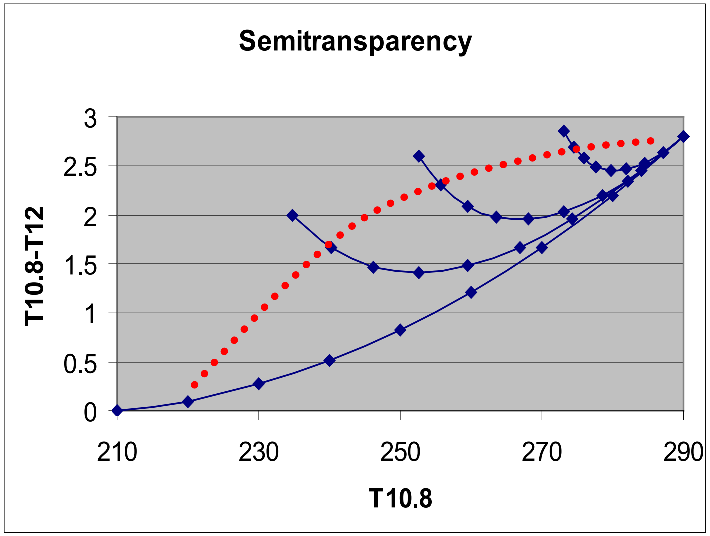
Assume same cloud emissivity in both channels: semitransparency effect



Assume the same cloud emissivity in both channels: semitransparency effect



The right hand side curving upwards in the constant-emissivity lines (in blue) is due to humidity absorption, stronger at 12.0µm

The left hand side curving is due to cloud thinness: ground and cloud do not average temperatures linearly, but with a bias towards the ground temperature (warm end): the higher the difference Tground – Tcloud, the higher the bias

In a typical scene, the cloud temperature is more constant than the fraction of cloud in the pixel (or its emissivity), therefore we observe the red lines (constant temperature) when looking at a group of pixels

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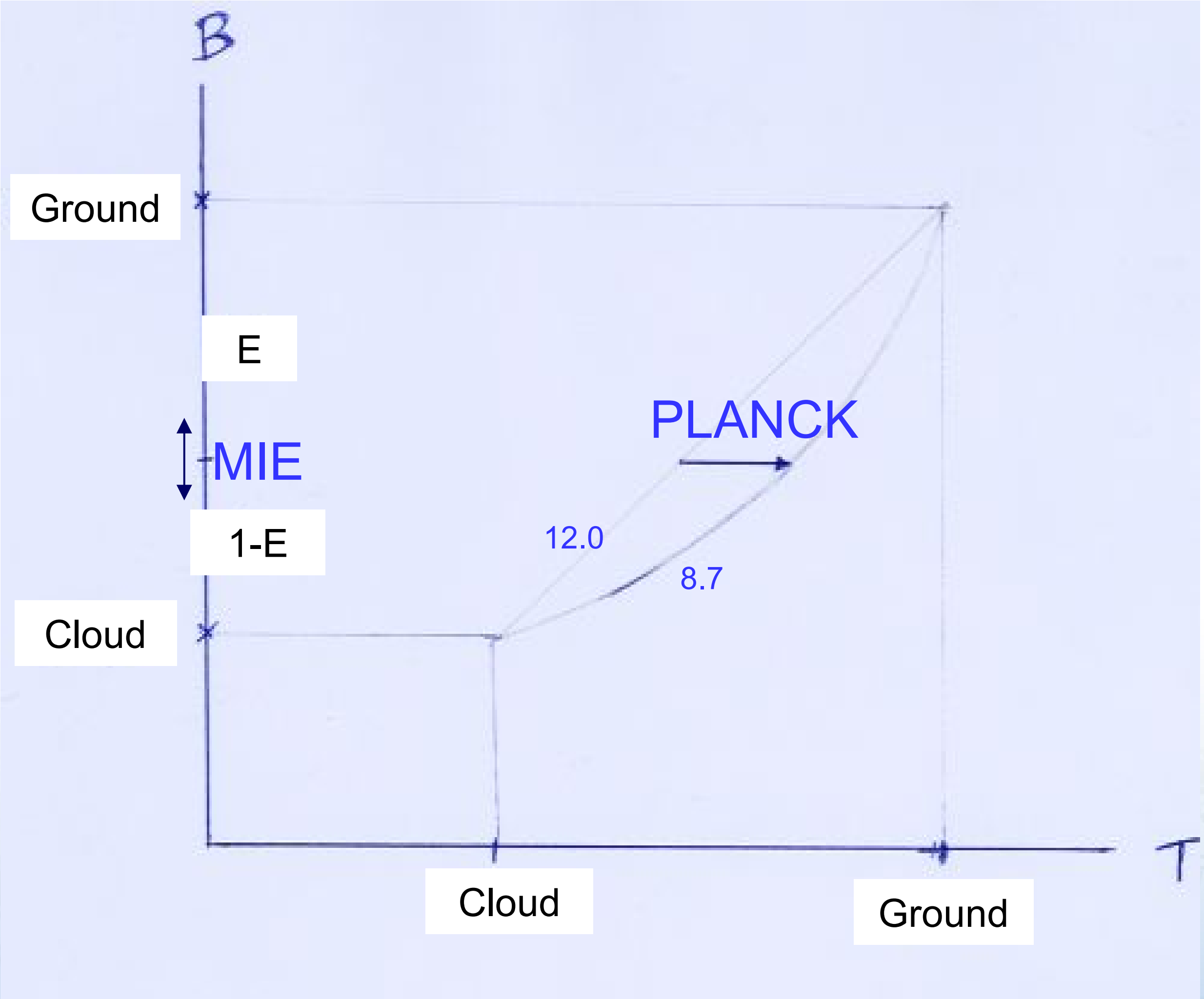
Transparency: Mie and Planck



The channel with the biggest Planck curvature (shorter wavelength) will show warmer signal for a mixture of cloud and ground.

When taking channel differences, the emissivity in both channels will be typically different for the same cloud, even for thick cloud: Mie effect

Planck dependencies: wavelength and temperature

1% temperature change results in a S% increase in the energy count:

S ~ 14400 / Wavelength (µm) / Temperature (K))

- *S=14% at 3.9µm and scene temperature of 260 K*
- *S ~ 4% for a warm scene at the split window*
- *Radiation = Temperature raised to the S-th power: R ~ T ^ S*

- *Inside a pixel,* S determines the *bias* towards the warm part of the signal
- Bigger bias for lower temperatures →

Fire onset is better detected than its progress.

Cloud dissipation is better detected than cloud growth.

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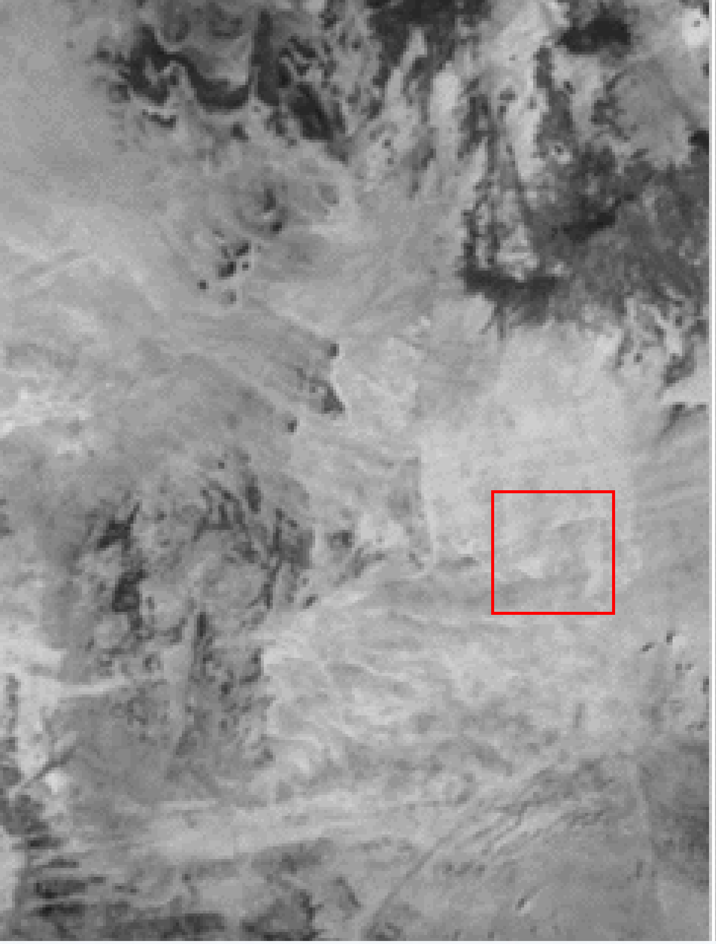
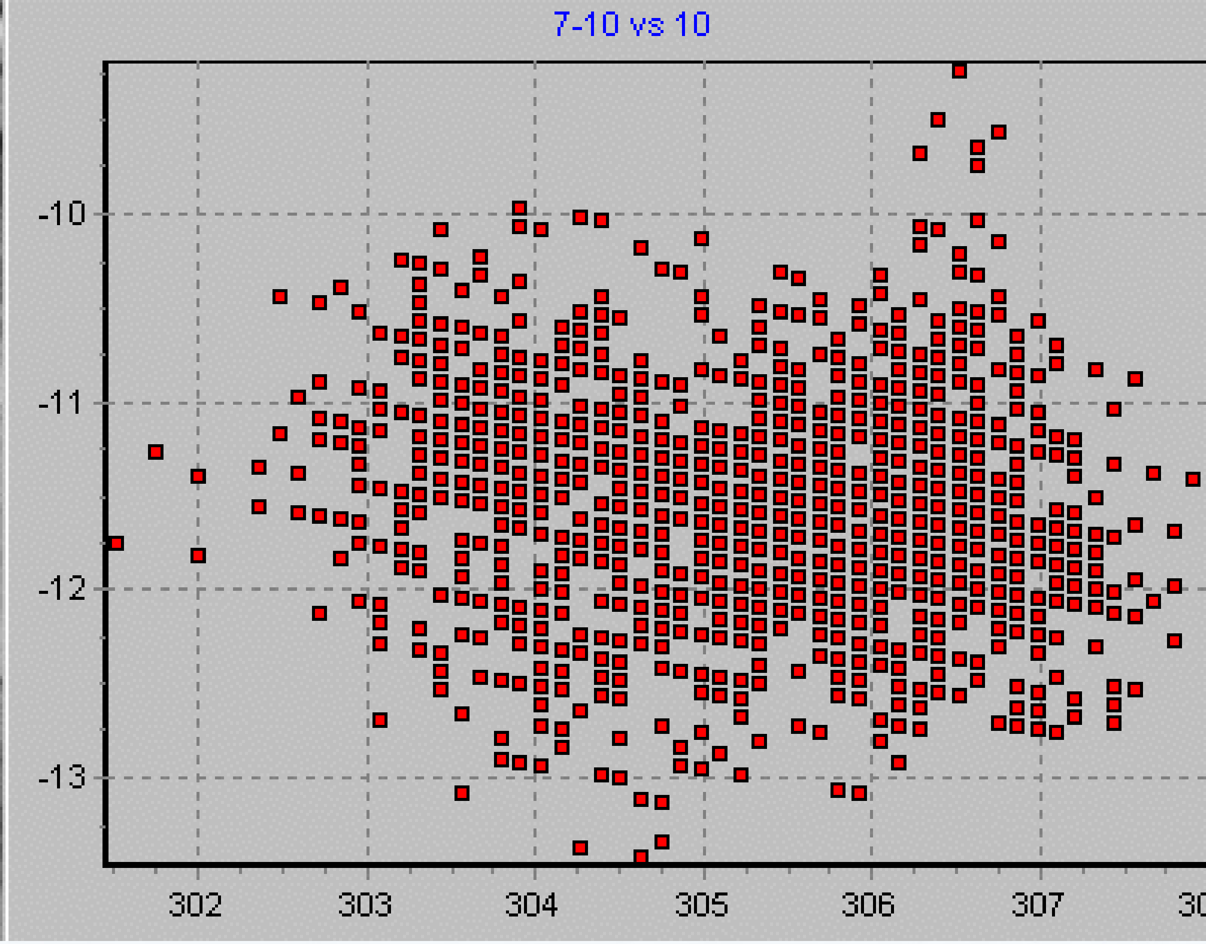
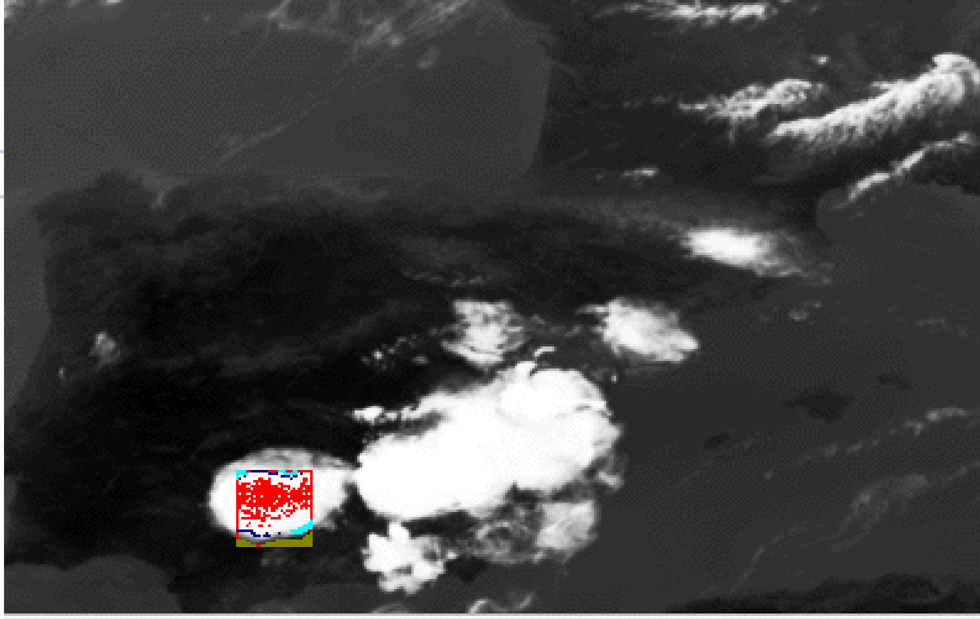
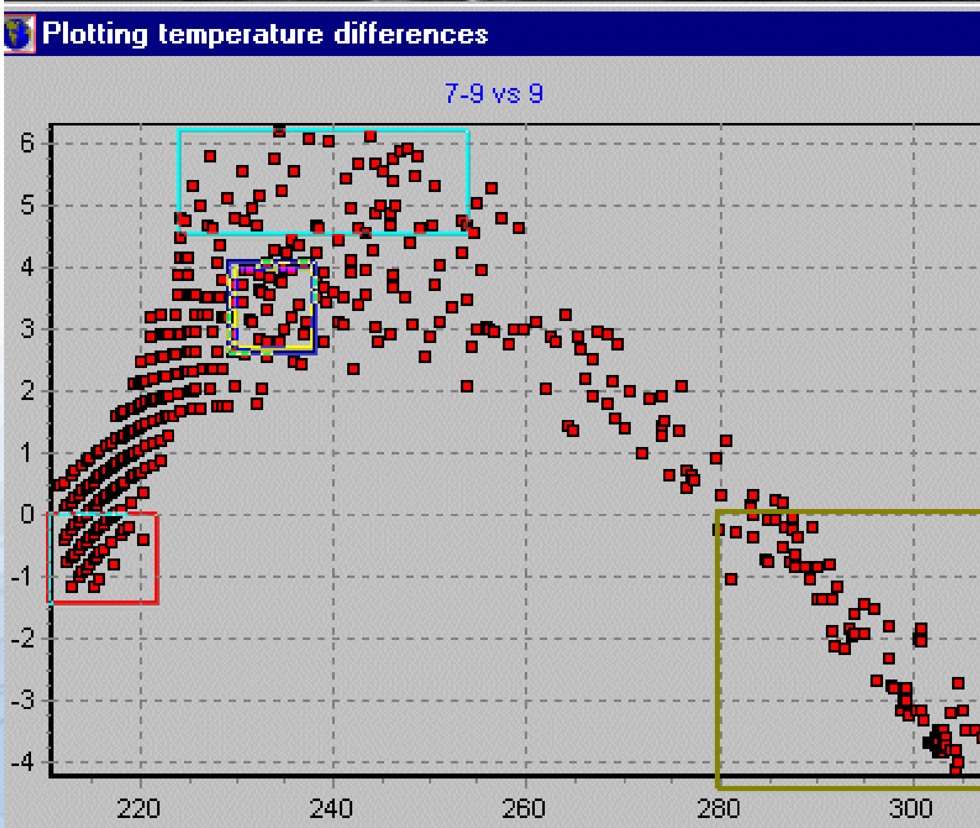




S (sensitivity) in channel 8.7µm and 305K is 5.3

Emissivity estimate: 1.0 -11.5/305 *S =0.8 for that desert.





The difference Ch7 - Ch9

- Water cloud ~ -3K
- Ice cloud ~ 1K
- Snow ~ -2K (water vapour)
- Cloud boundaries < 6K,

since they mix cloud and ground temperatures, in favour of the shorter wavelength

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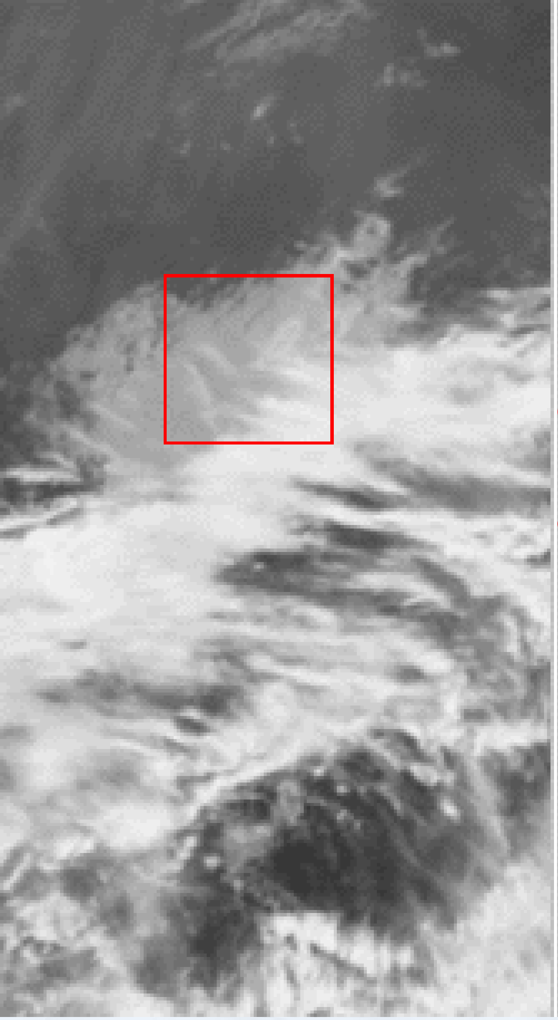

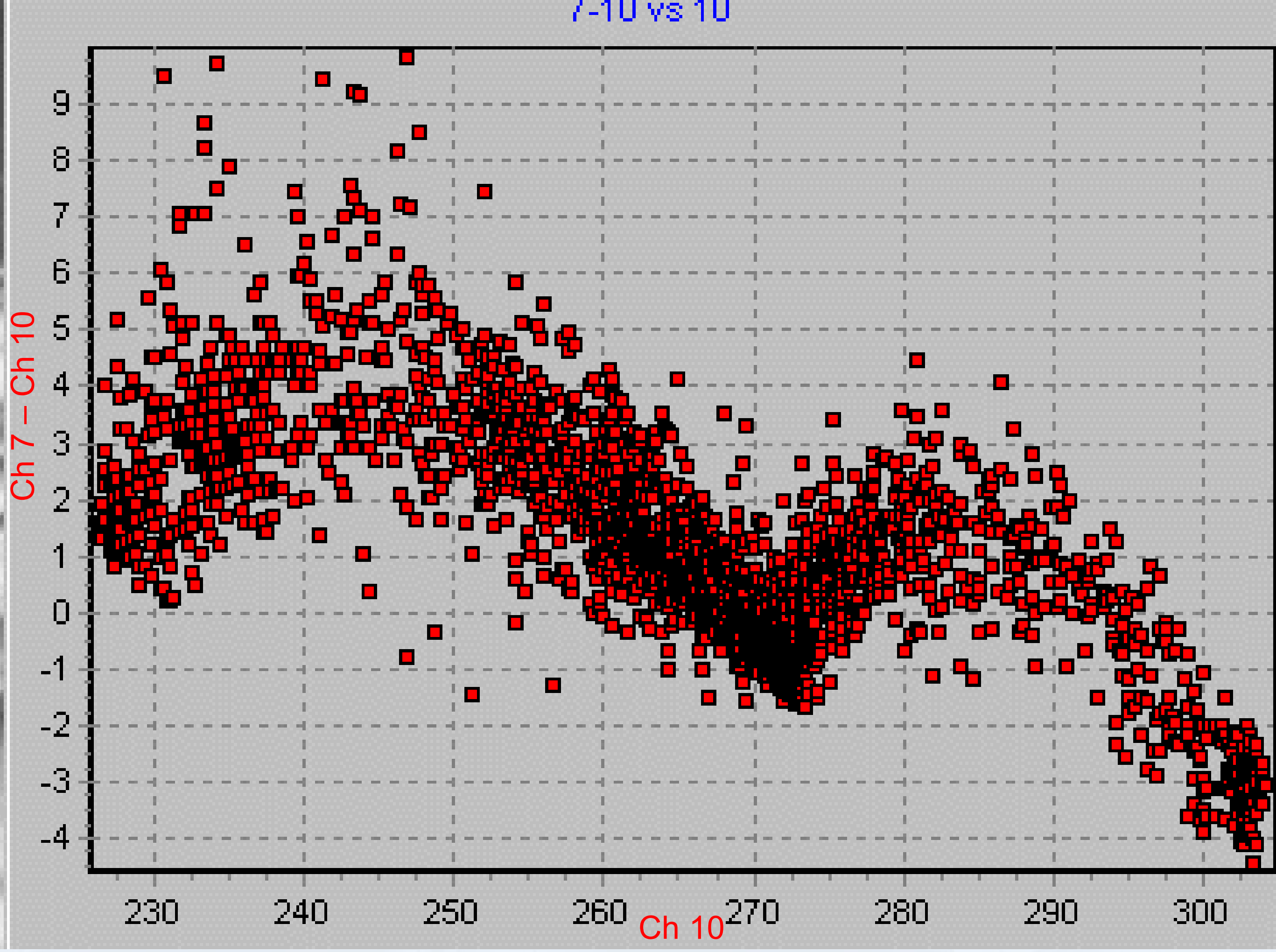

Ch9 17-Feb-03 midday over desert

- ❖Several arcs indicate multilayered cloud
- ❖Pixels with a mixture of scenes show in the highest part of the arcs

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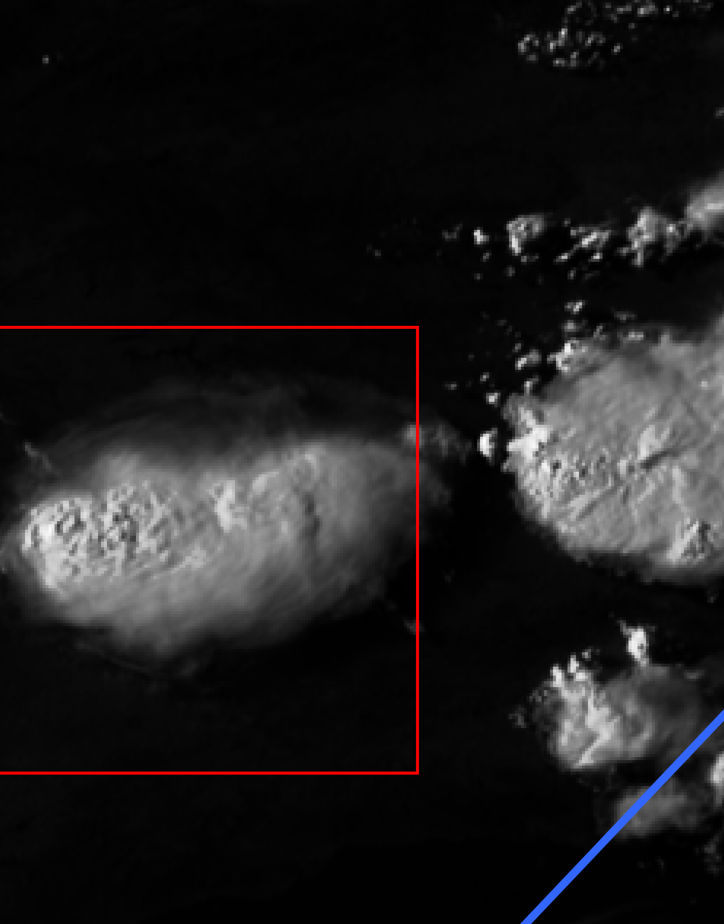
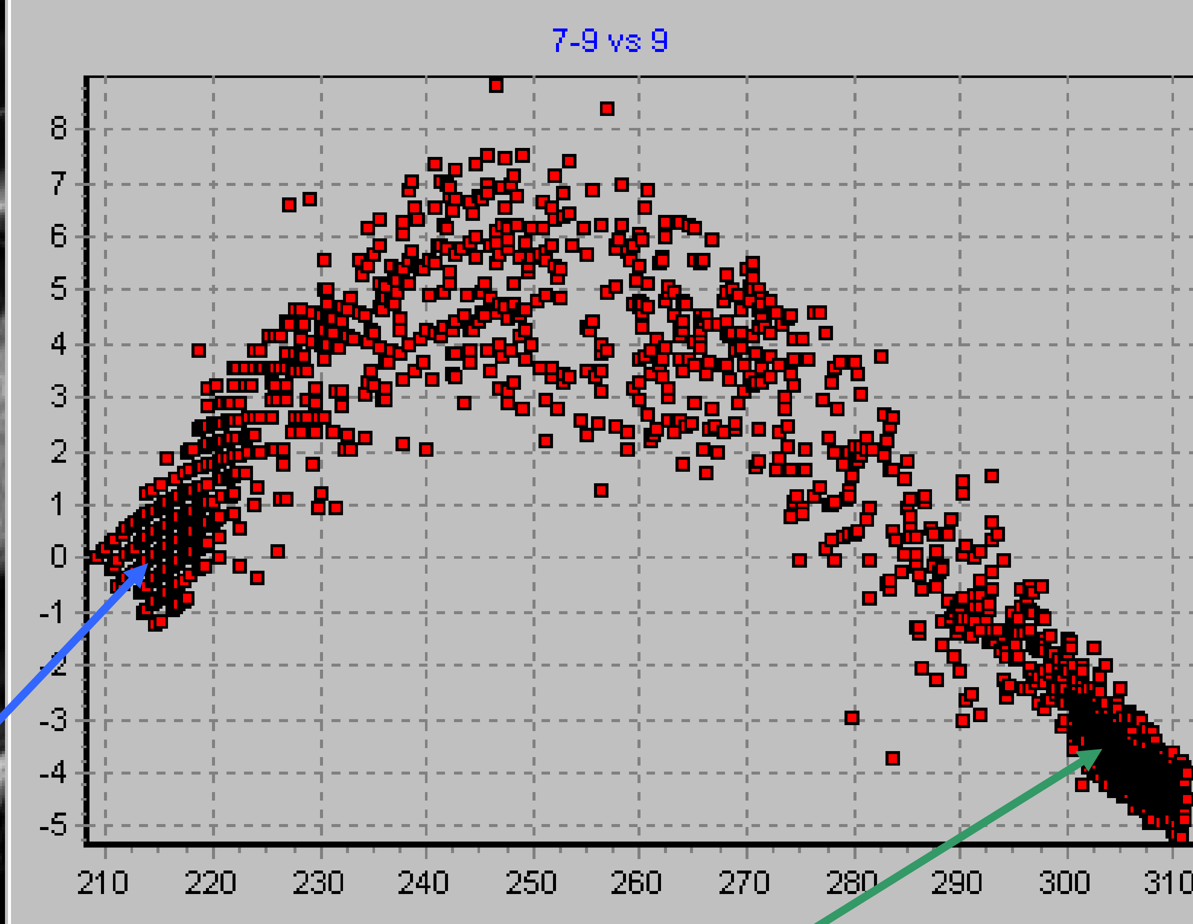


MSG Channel HRV, 16:00



Semitransparent cloud shows higher difference (in ch7-ch9 or ch9-ch10) than opaque cloud (left hand side of graph) or ground (right hand side of graph)

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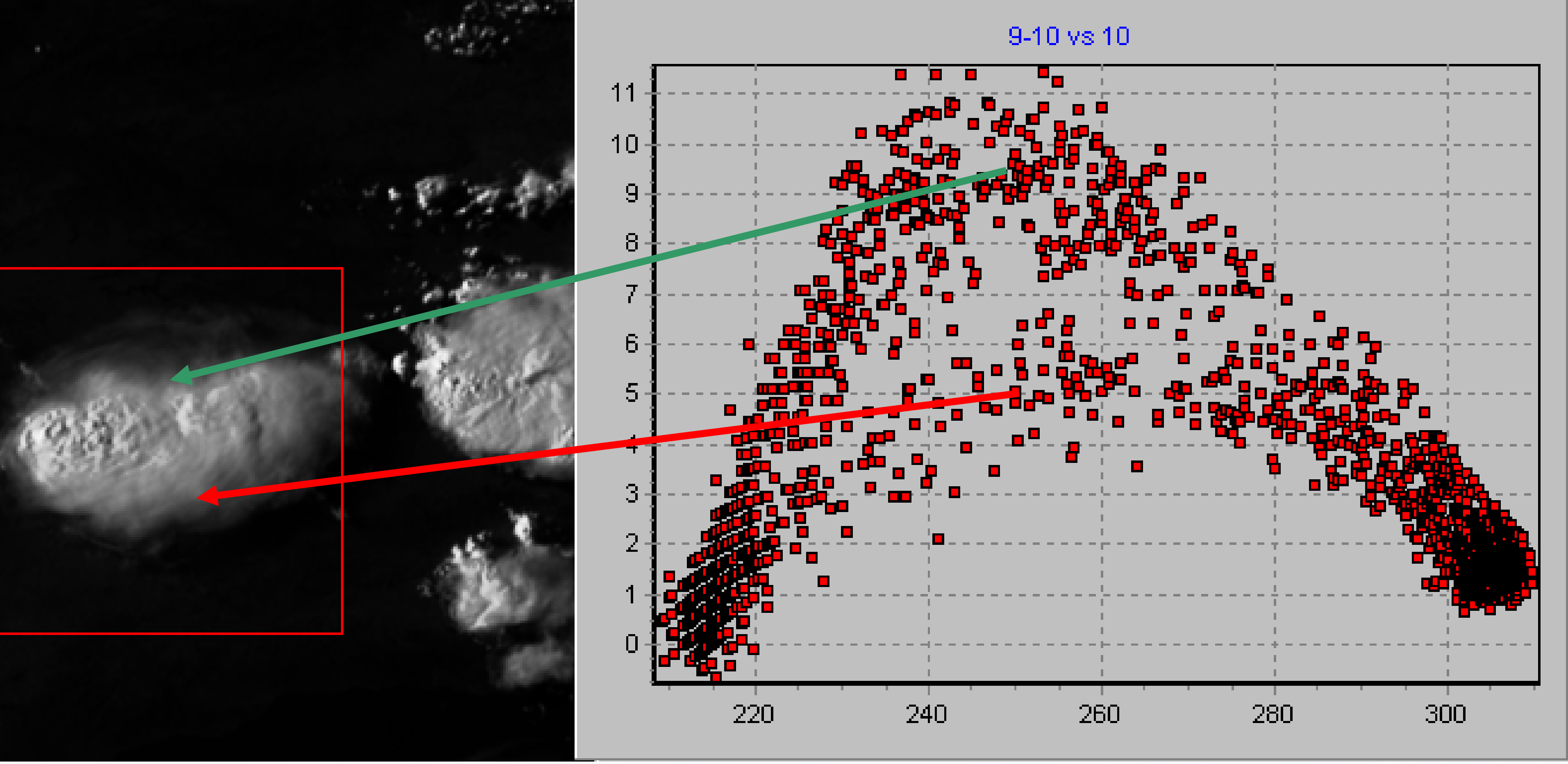

MSG Channel 12, 4-July-2003 16:00

The difference Ch9 – Ch10

- ❖Semitransparent cloud shows higher difference (ch9-ch10) than in (ch7-ch9)
- ❖Double arch: southern boundary is lower in height

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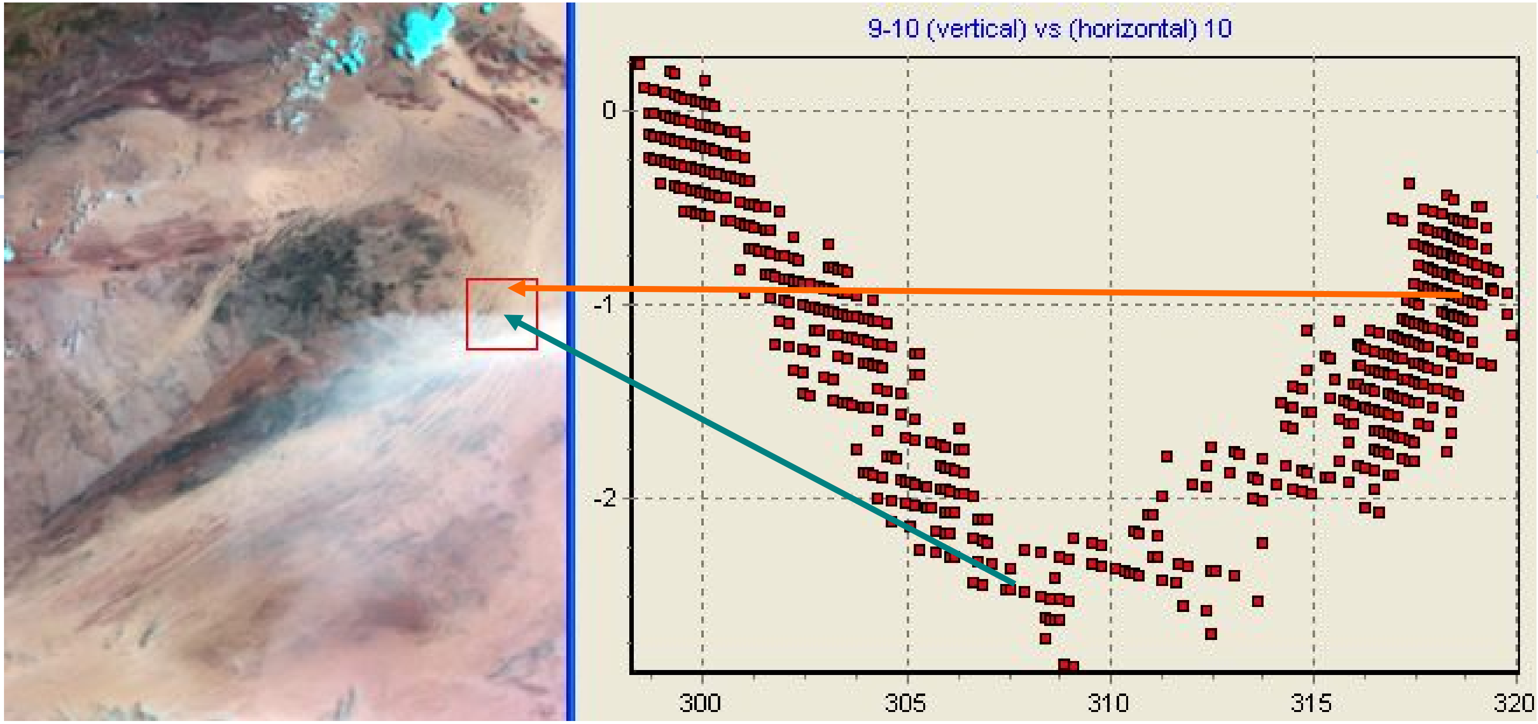

MSG Natural RGB, 4-July-2003 10:00 UTC

- ❖ 10.8µm is more absorbed and backscattered by sand than 12.0µm
- ❖ For sand or ash, reversed arc for the semitransparent pixels

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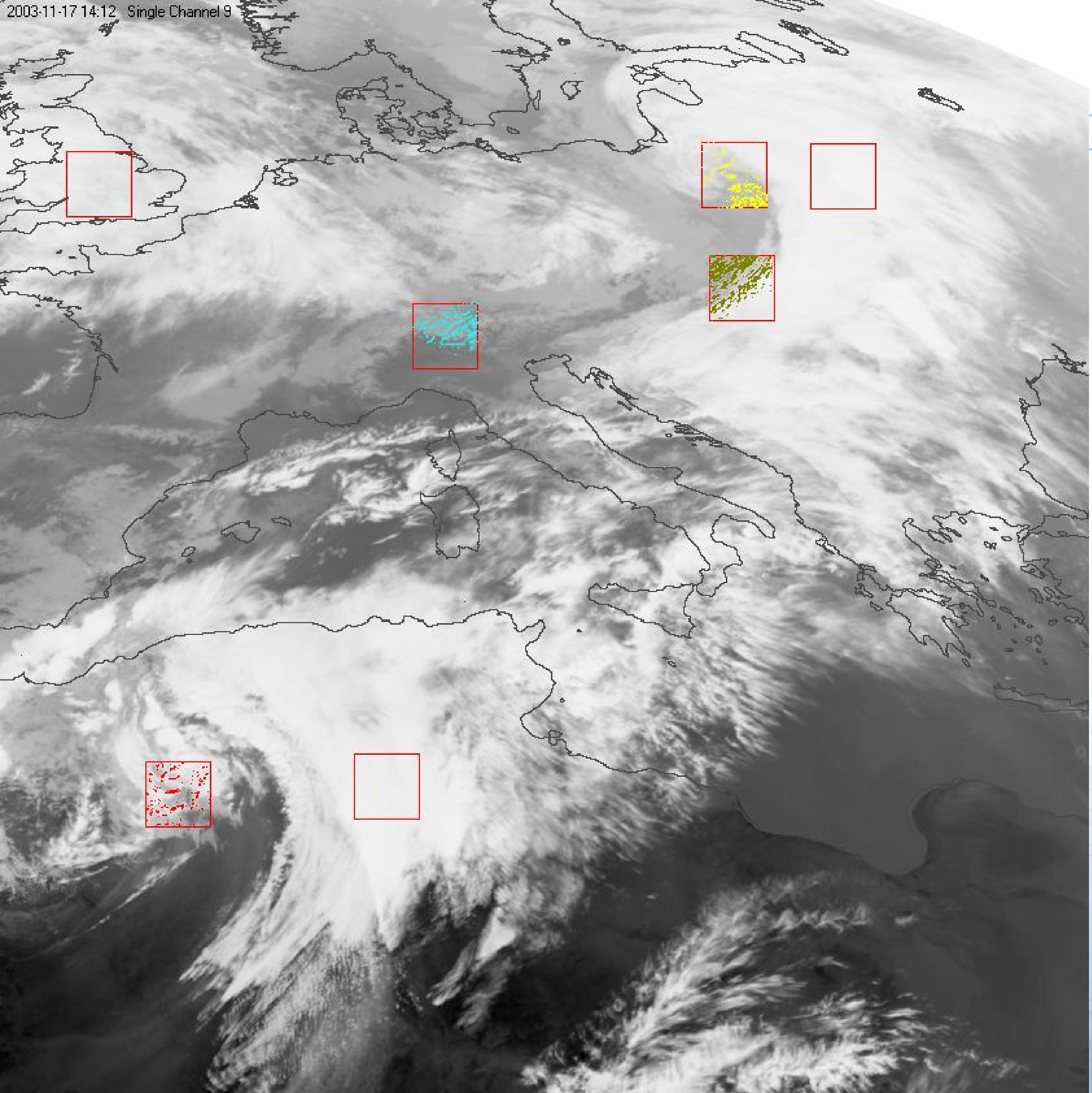

Negative ch9-ch10:

❖ Thermal inversions in humid valleys

❖ Dust cloud

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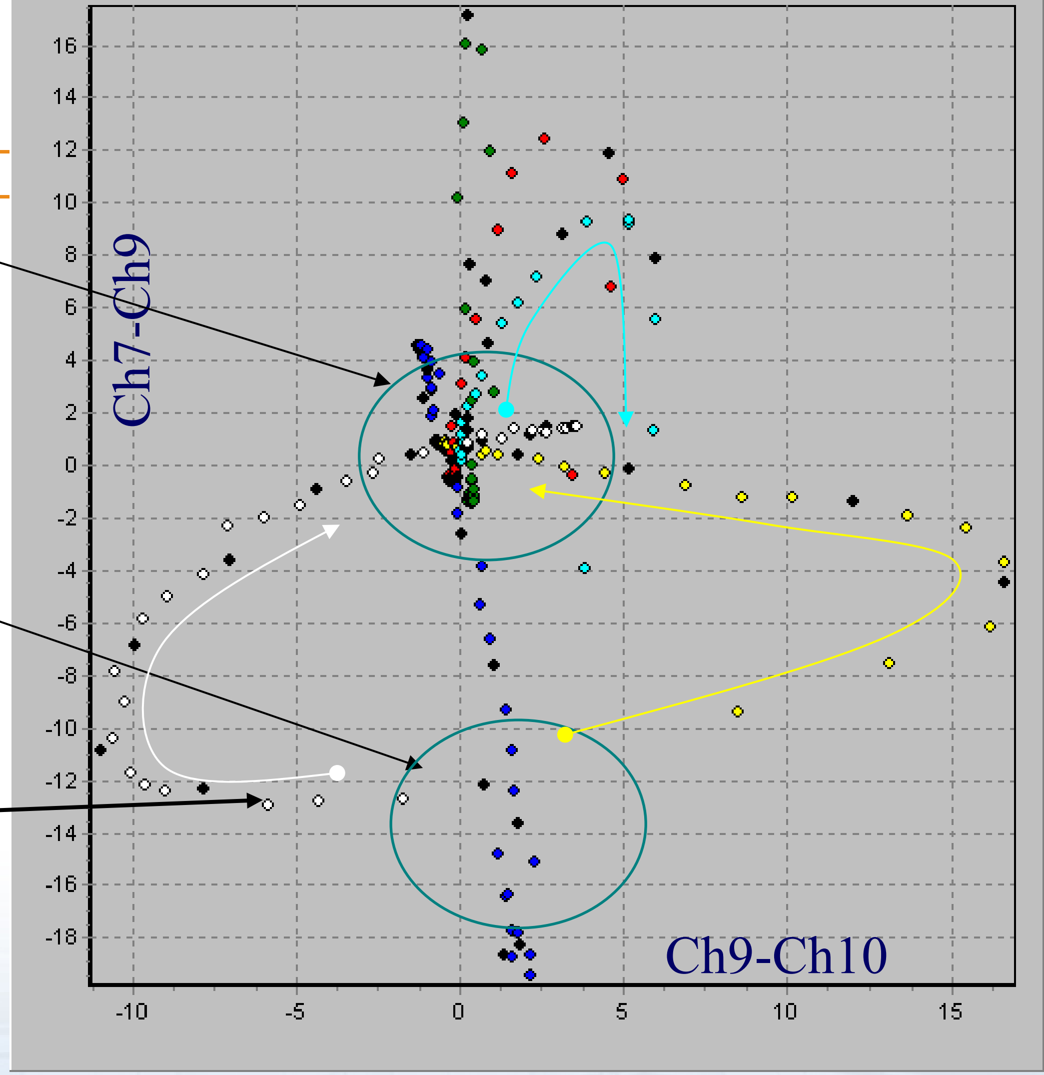
Thick cloud

Thin cloud

(over sandy ground)



- ○○○ very small ice particles
- very small droplets (blue)
- small ice particles (green)
- small droplets (red)
- big droplets (cyan)
- big ice particles (yellow)

❖ Type of particles can be identified for thin cloud

❖ Difficult discrimination for thick cloud

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In the IR, the brightness temperature (BT) depends on:

- 1. Absorption to scattering ratio (for thick cloud)

  The quotient between absorption and scattering efficiencies varies with wavelength and particle size/shape, and determines the cloud emissivity

- 2. Wavelength (for thin or broken cloud):

  Thin cloud favours the BT at the shorter wavelength for emissivities far from unity.

- 3. Humidity (for low cloud):

  Channel at 10.8µm is favoured under humid conditions. Absorption by humidity reduces the 8.7µm signal most.

- 4. Ground emissivity (for clear skies or thin cloud):

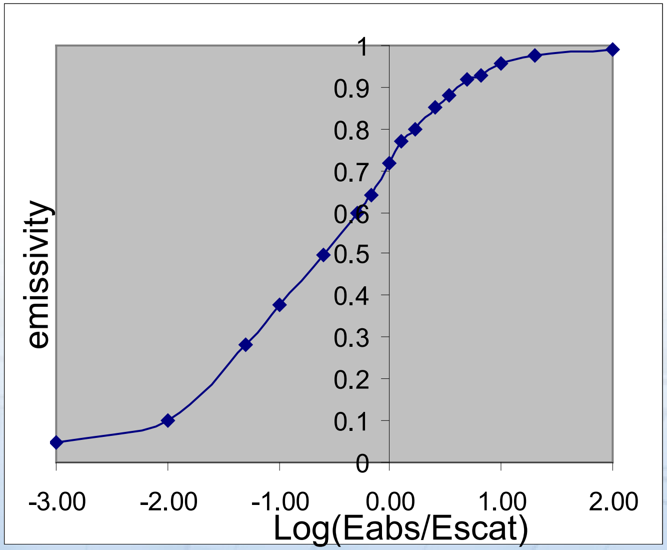
  The emissivity grows for most kind of soils from 11 to 12µm, but decreases for water and snow covered surfaces.

From particle size to emissivity

1) Calculate the size parameter $X=2\pi r_e/\lambda$

2) Use the imaginary refractive index n' (and the real part n) to get the Efficiencies:

(X, n', n) → [*Mie functions*] → (E_{abs} /E_{scat}) ~ cloud emissivity



Example: 3µm ice crystals

At 10.8µm, CE=.995

At 12.0µm, CE=.991

[BT10.8 – BT12.0] ~ 0.3 K

Hardly detectable by SEVIRI

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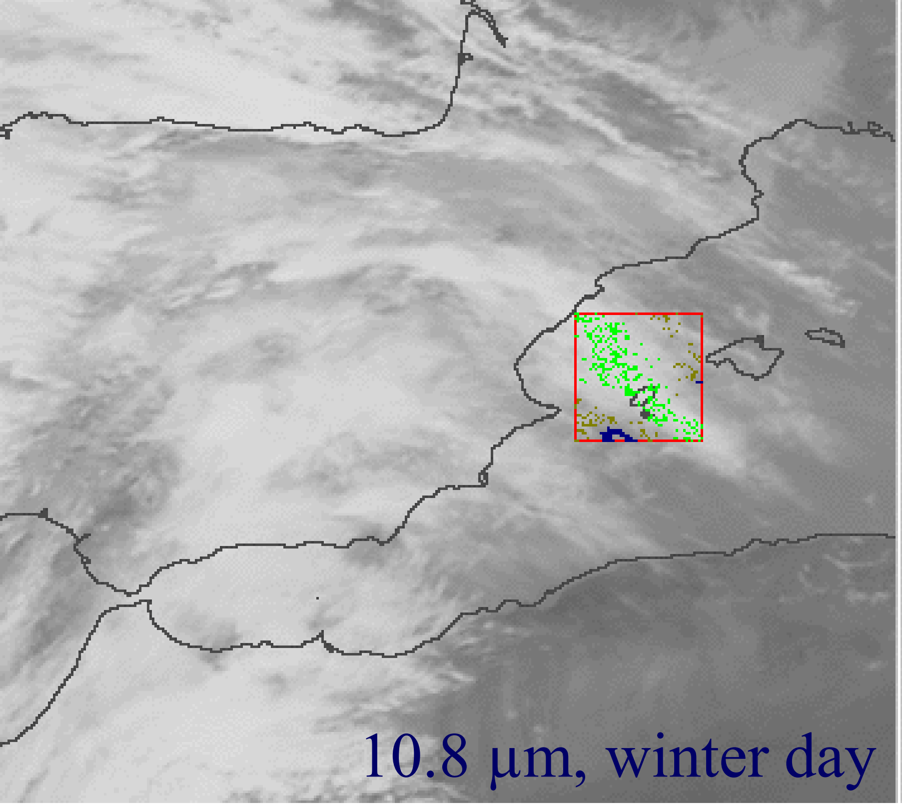

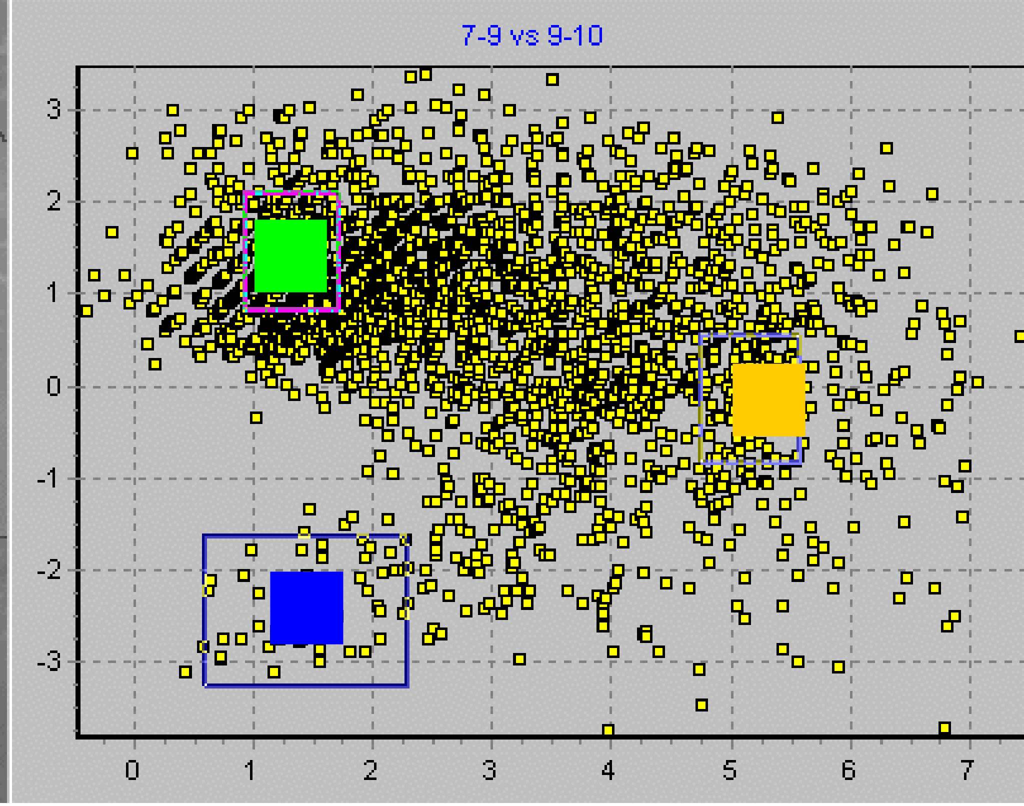

C. Sea

?

A. Ice cloud

B. Thin cloud

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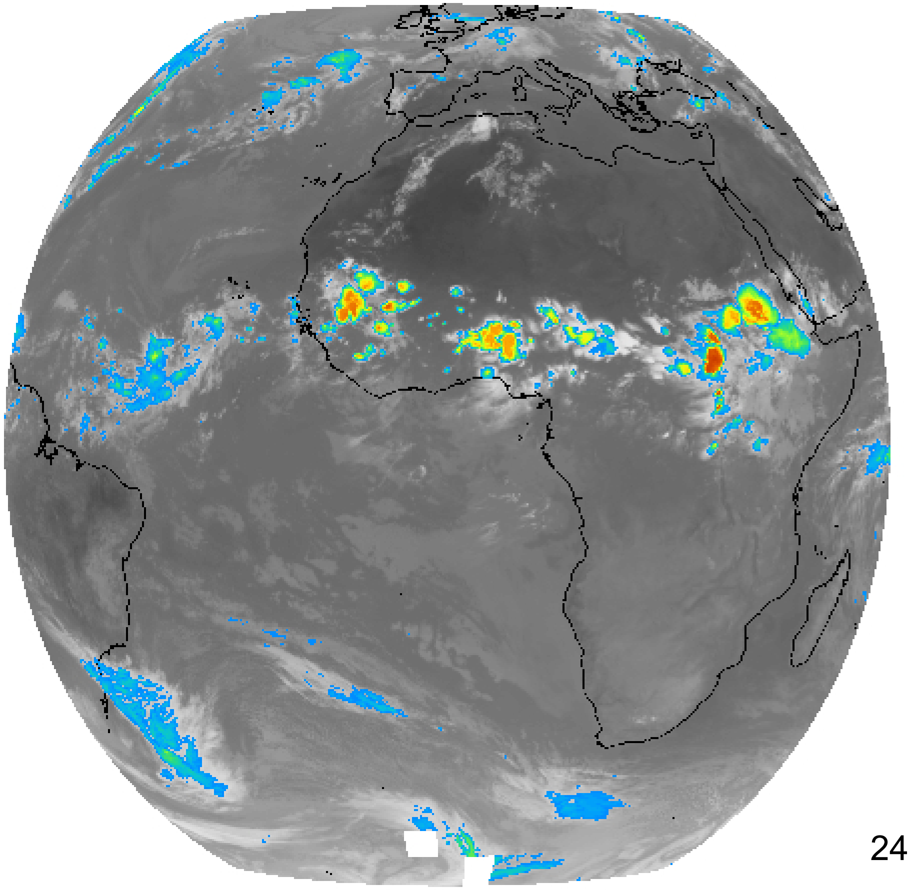
Applications of the split window

- Sea surface temperature
- Cloud top temperature
- Low level humidity
- Aerosol (saharan air layer, SAL)
- Semitransparent cloud
- Precipitation estimates (MPE)
- Clear-sky radiances for NWP

Precipitation estimation



24 July 2005 14:00

Multisensor Precipitation Estimate: IR calibrated with SSM/I

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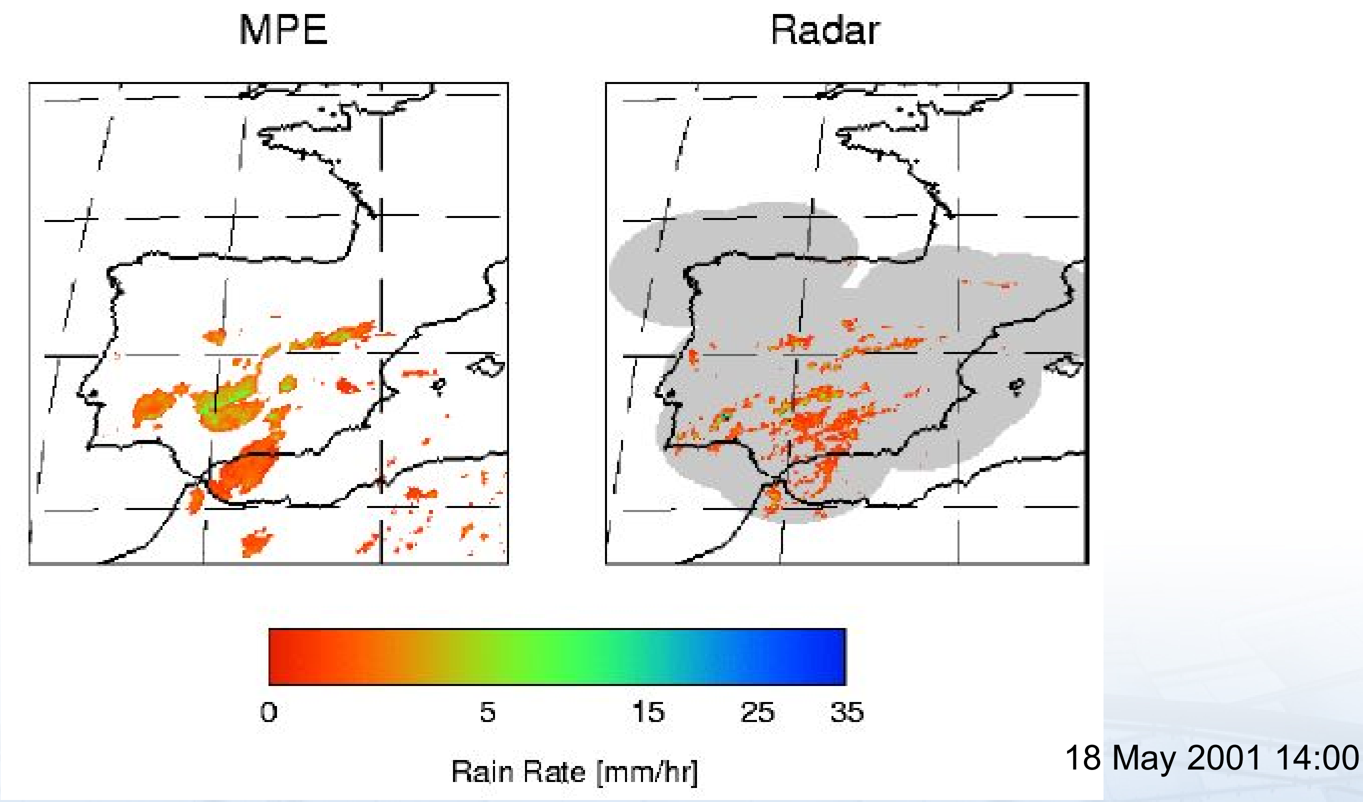
Precipitation estimation



- ❖ Adequate to estimate convective precipitation in tropical regions
- ❖ Underperformance for high latitudes

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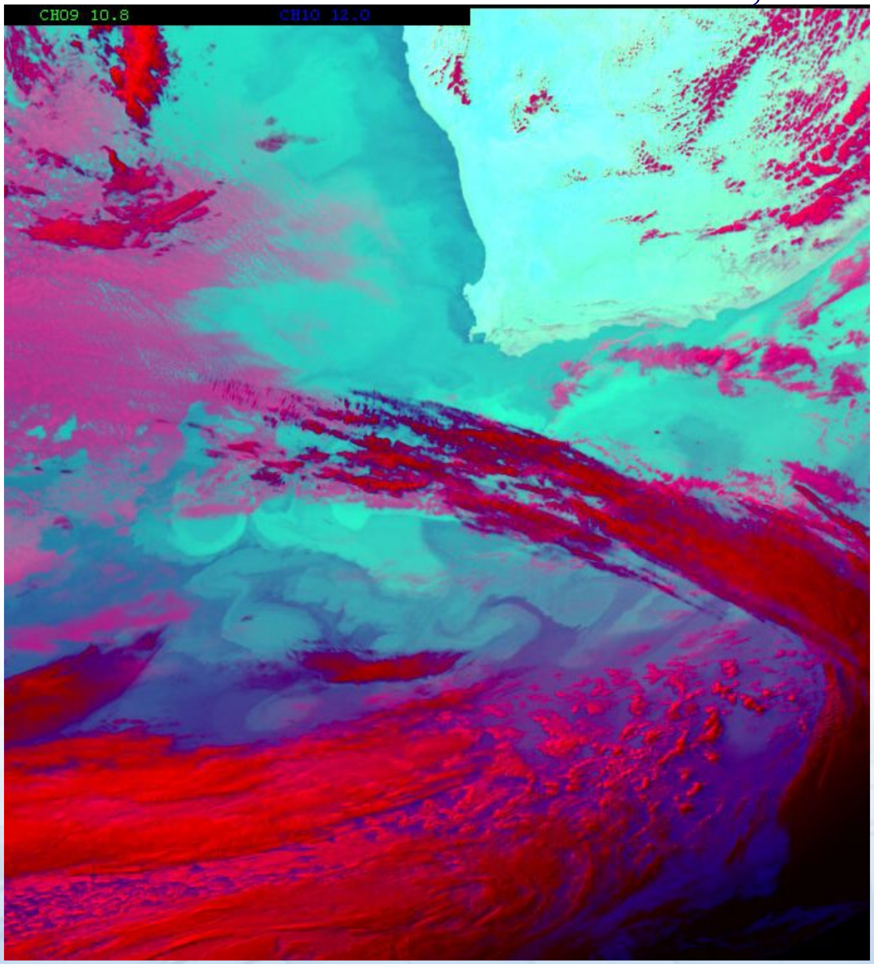
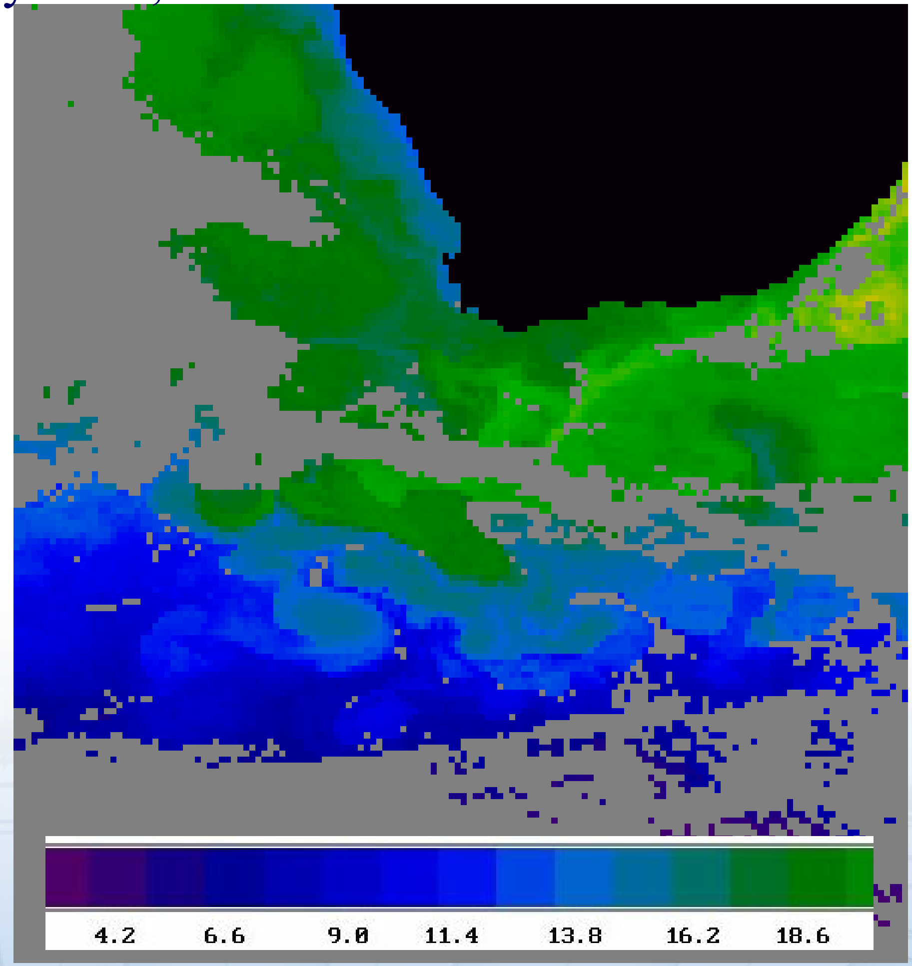
SST Eddies in the South Atlantic

MSG-1, 3 May 2004, 14:00 UTC





RGB Composite 02,09,10

Changes of up to 10K in SST in 100 km

OSI SAF 12-hourly SST Product

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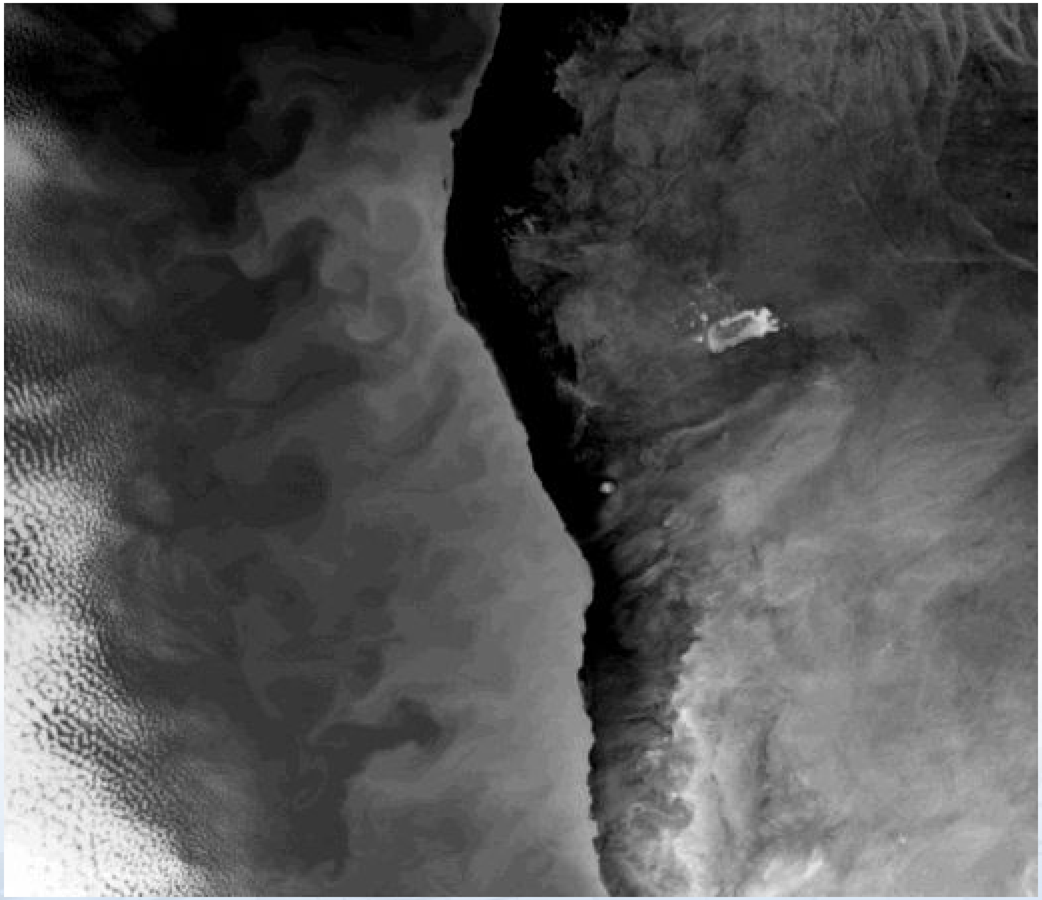
Ocean eddies off Cape Fria (Namibia-Angola)



Meteosat-8 25-5-06 07:45

Best contrast in the early morning

The Sun activates the heat exchange and diffuses the contrast

Aerosol, ash, fumes

- Negative channel difference 10.8 µm - 12.0 µm identifies sand grains and volcanic ash
- Volcanic *gases* show in the window channels, due to line absorption: Channels 7.3µm and 8.7µm respond to SO_2. Negative channel difference (8.7 µm - 12.0 µm) identifies burnt sulphur compounds.
  - *Note*: possible confusion of SO_2 with desert surfaces or dust cloud
- Over clear desert, the strong difference Ch7-Ch9 gets blurred by *dust* (scattering more on 10.8 µm)

Conclusions

- Channels at 8.7µm, 10.8µm and 12.0µm provide information on cloud phase and height, even allow inferences on particle size *for thin cloud*

- Those channels provide information on ground characteristics, in particular for discrimination of humid and arid areas

- A novel application is the monitoring of sand and smoke clouds, as a major risk for air navigation and ground pollution

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