Meteosat solar channels

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A. How many channels in the human visible domain does include the SEVIRI instrument in Meteosat?
- 4 or more
- 3
- 2
- 1

B. How many SEVIRI channels collect solar radiation reflected by the Earth?
- 5 or more
- 4
- 3
- 2

C. How many solar channels do you use routinely at work?
- 4 or more
- 3
- 2
- 1
- 0
Same date-time?  Is this June image SOLAR or THERMAL-infrared?
YES       NO
Is this solar?   YES   NO
If not, what would you change to “solarise” it?

Cloud boundaries are lit from the West
Sharp lee cloud
Night on the East
Reflective land
Dark ocean
Dark (vegetated) mountains
Precipitation areas
Orography and cloud shades
Low cloud and dust areas
<table>
<thead>
<tr>
<th>Channel</th>
<th>Cloud</th>
<th>Gases</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRV 0.7</td>
<td>Broad band VIS</td>
<td>Surface, aerosol, cloud detail (1 km)</td>
<td></td>
</tr>
<tr>
<td>VIS 0.6</td>
<td>Narrow band</td>
<td>Ice or snow</td>
<td></td>
</tr>
<tr>
<td>VIS 0.8</td>
<td>Narrow band</td>
<td>Vegetation</td>
<td></td>
</tr>
<tr>
<td>NIR 1.6</td>
<td>Window</td>
<td>Aerosols, snow &lt;&gt; cloud</td>
<td></td>
</tr>
<tr>
<td>IR 3.8</td>
<td>Triple window</td>
<td>SST, fog &lt;&gt; surface, ice cloud</td>
<td></td>
</tr>
<tr>
<td>WV 6.2</td>
<td>Water vapour</td>
<td>Upper troposphere 300 Hpa humidity</td>
<td></td>
</tr>
<tr>
<td>WV 7.3</td>
<td>Water vapour</td>
<td>Mid-troposphere 600 Hpa humidity</td>
<td></td>
</tr>
<tr>
<td>IR 8.7</td>
<td>Almost window</td>
<td>Water vapour in boundary layer, ice &lt;&gt; liquid</td>
<td></td>
</tr>
<tr>
<td>IR 9.7</td>
<td>Ozone</td>
<td>Stratospheric winds</td>
<td></td>
</tr>
<tr>
<td>IR 10.8</td>
<td>Split window</td>
<td>CTH, cloud analysis, PW</td>
<td></td>
</tr>
<tr>
<td>IR 12.0</td>
<td>Split window</td>
<td>Land and SST</td>
<td></td>
</tr>
<tr>
<td>IR 13.4</td>
<td>Carbon dioxide</td>
<td>+10.8: Semitransparent-cloud top, air mass analysis</td>
<td></td>
</tr>
</tbody>
</table>
• Solar channels 0.6 and 0.8 µm are very similar
• Those two channels are dissimilar of 1.6 µm
• All three have a NEGATIVE radiance correlation with the thermal. Why? GROUND? OCEAN? CLOUD?
I do not like coming back home. Why is that?

What is the problem with your wife?

My wife...

She talks and talks and talks...

She does not tell me!
Where is LIGHT absorbed?

Is the neighbour’s GRASS greener?

Is ICE always cyan?

Is DUST enhancing visibility?
RADIATION and MATTER

Cloud (VIS)

Mie area:
- Rain (MW)
- Cloud (IR)

Geometric SCATTERING

Gases
- Cloud (MW)

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

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

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

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

Channel 01 (VIS0.6)

Clouds

High reflectance
thick clouds

thin clouds over land

thin clouds over ocean

Low reflectance

31 October 2003, 11:30 UTC

Meteosat solar channels
Earth Surface

Sun Glint
Snow
Desert
Gras, Rice fields
Forest
Bare Soil
Ocean, Sea

Clouds

High reflectance
thick clouds
thin clouds over land
thin clouds over ocean
Low reflectance

Channel 02 (VIS0.8)

31 October 2003, 11:30 UTC

Meteosat solar channels
Earth Surface

Sun Glint
Sand Desert
Gras, Rice fields
Forest
Bare Soil
Snow
Ocean, Sea

Channel 03 (NIR1.6)

Clouds

High reflectance
Water clouds (small droplets)
Water clouds (large droplets)
Ice clouds (small particles)
Ice clouds (large particles)
Low reflectance

31 October 2003, 11:30 UTC

Meteosat solar channels
SOLAR IMAGES

0.6 µm albedo scale:

Cb  Snow  Sand  Shallow or broken cloud  Ocean

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

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

Updrafts prevent droplet merging, and keep reflection strong
Special solar features

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

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

Do you believe your eyes?
Meteosat solar channels

Linear rendering

Gamma correction

Colour slicing
Meteosat solar channels

IHS, with I=1.6µm

RGB=321 enhancement

Cyan ~ ice
More cyan ~ bigger ice crystals
~less convection!
Enhancement: For areas of uniform values on the three channels
Enhancement can produce too much colour if the value ranges are wide
Solar channel differences over land

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

Meteosat solar channels
Or with 1.6µm
Vegetated and dry soils

The vegetation response to wavelengths in our colour perception is similar to those between 0.6\(\mu\)m to 1.6\(\mu\)m: happy coincidence!
Normalized vegetation index = \frac{(2-1)}{(2+1)}
Exercise: identify the clusters in the 0.6 and 0.8 µm channels

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

Where are the growing vegetation pixels on the graph?
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

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
Drought evolution in Somalia

Source: Land SAF archive, fraction of vegetation
Dry soil shows brown in the natural RGB!

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

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

1.6\(\mu\)m reflects better than 0.8\(\mu\)m 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

Rice fields

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

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

At 3.9µm, Earth emitted radiation competes with reflected solar radiation.
Emission sources in the solar channels

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

Which contribution is bigger, Emitted or Scattered?

S/E > $10^7$ due to Planck’s strong dependence on temperature for scene $T(\text{kelvin}) < 14400/\lambda(\mu\text{m})$
Cloud in the solar channels

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

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

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

\[ \text{albedo}_\lambda = \frac{\pi B(\lambda,T)}{I_\lambda \cos \theta} \]

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

Does albedo depend on illumination \( \theta \)?

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

It also depends on pixel location:

- 30%: sub-satellite
- 50%: central pixel
- 140%: peripheric pixel
- 60%: central pixel
Albedo daily cycles

Channel 0.6µm, 2011-Feb-01, 1030-1545

Channel 10.8µm, 2011-Feb-01, 1030-1545

Channel 1.6µm, 2011-Feb-01, 1030-1545

2011-02-01 12:15
The impact of illumination direction on the albedo calculation

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

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

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

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

d. On snow, where Snel behaviour is relevant  
   Not very directional, when a large pixel contains many different slopes
Towards ice and size vertical profiles

Both SIZE and ICE reduce particle reflectivity

At lower levels, ice particles are bigger and less icy than at high level.

Reduced or increased reflectivity at lower levels??

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

Reduced at 1.6µm (vertical), responding to SIZE
Increased at 3.9µm (horizontal), responding to ICE
• **Dissolving**-cloud albedos at 1.6µm and 3.9µm show a higher correlation
• The liquid tops vary faster in 3.9-albedo than in 1.6-albedo
• 1.6 is ice-size sensitive, 3.9 is droplet-size sensitive
[1.6µm versus 3.9µm] reflectance technique (convection)

24 May 2010: 1200UTC
Average reflectivity on the frozen cloud tops of convection are roughly 10 times higher for channel 1.6µm than for 3.9µm.

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

- Ch3 > 20%
- Ch3/Ch4 < 10
NIR 1.6 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.
Thin cloud enhances the reflected signal from non-reflective grounds
Classifying ice cloud

What are the red-coded areas?

Super cooled water droplets
Large ice particles
Ice
Small ice crystals
Why 25-33% limits in the 1.6µm reflectivity at 200 K?

a. For thick cloud, small crystals absorb and cannot be less reflective than 25%.
b. Ice reflectivity at 1.6µm is almost constant for any storm development phase.
c. Analysed pixels are uniform in ice particle size, all in the same updraft phase.
Evolution in the day of BT10.8µm and of % reflectivity at Meteosat channels 1, 2 and 3:

-Simple reflectivity formula shows directionality in reflection for
-Sun-sat 90, 47, 15, 47
-Solar: 77, 41, 26, 54
Cloud phase classification using SEVIRI RGB images
18 Feb 2003, 13:00 UTC, RGB NIR1.6-VIS0.8-VIS0.6
Rough surfaces due to mistral

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

Met-8, 14 February 2005, 13:45 UTC
Channel 12 (HRV. enhanced)
Sun glint, wind and rough seas

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

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

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

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

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<th>Ocean reflectivity by \ at</th>
<th>Sun glint area</th>
<th>Far away</th>
</tr>
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<tbody>
<tr>
<td>No wind</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Moderate wind</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Strong wind</td>
<td>Medium</td>
<td>High</td>
</tr>
</tbody>
</table>
Sun glint time and date evolution

The course of sunglint on flat surfaces

Meteosat solar channels
Sunglint

RGB natural Meteosat9, 2011...
Reflectance on sunglint areas

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

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Bright spots north of Iceland

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

What are they? Cloud, sea surface, ash?

Mind the special image date!
Wind speed maps

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

- **Solar channels**
  - Where you learn how to tell a cloud from a forest

- **Vegetation monitoring**
  - Where you learn how to tell tomatoes from rice

- **Cloud phase and particle size**
  - Where you learn how to find ice on planet Earth

- **Sun glint**
  - Where you learn to avoid squinting on satellite images

- **Aerosol**
  - Where you learn how to escape from a fire
Dust affects reflection and brightness temperature

Time evolution of solar 1.6µm and thermal 10.8µm for a dusty pixel and for a clear pixel in the North of Morocco
The solar radiation reflects rather forward on smoke particles, comparable in size to the visible wavelengths (Mie).

Similarly for a.m and p.m. conditions, except for factor forward/backward.

At East in the early morning or West in the late afternoon the image contrast by dust is strong (forward direction).
Solar channels: aerosol observation

Dust storm over the Red Sea
MSG-1, 25 June 2003, 10:00 UTC
Pastures burning and deforestation activity in Bolivia

Assuming no major smoke sink or source in 24 hours, the intensity difference is due to directional reflection (asymmetry factor)
Smaller wavelengths are reflected by smaller particles (wavelength ~ 3* diameter).

Smaller wavelengths are enhanced by forward scattering.

Scattering intensity higher in the western late afternoon.

Smaller (0.2µm)     Bigger (0.3 µm)

Rayleigh Scattering  Mie Scattering  Mie Scattering, larger particles

Who made the fire?
Sun glint hides the dust signal (sunset on the West)

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

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

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

Meteosat-8 2009-07-03 2030 UTC, sunset
Ash or smoke is smaller than dust

2010-06-23 0845UTC Dust over Red Sea

2010-12-03 10UTC Haifa fire ash plume (% albedo)
Plume maxima: 20%, 15%, 3%
Solar channels (0.8\(\mu\text{m} - 1.6\mu\text{m})\) to spot dust

- 0.8\(\mu\text{m}\) stronger than 1.6\(\mu\text{m}\) for some rocky ground ;-
- But the reflectivities are clearly lower 😊

2010-03-21 12UTC
Dust composite

0.8\(\mu\text{m}\) stronger than 1.6\(\mu\text{m}\) for dust with optical depth >1.5.
Spotting dust with solar channels

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

a. Dust particles reflect back most of the solar radiation, whereas soil does not.
b. Regions with dust above have very reflective ground, more reflective than in the neighbourhood.
c. Scattering in the floating dust is more predominant over absorption than on the ground, made of big particles.

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

a. High values of \((2-3)(2+3)\)
b. High values of \((3-2)/(3+2)\)
c. Small values of 2
d. High values of 3/2

Backscattering depends on concentration
Not always, since dust traverses diverse grounds
Indeed, the dust layer is more backscattering than the ground
Clear and cloudy locations (26-Apr-2010 10:45, 9 neighbours)

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

1977 - MOP+MTP

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

2003 - MSG

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

2018 - MTG

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

Meteosat solar channels
Third generation solar channels

Aerosol, true colour

Water vapour over land

Thin cirrus

Cloud microphysics
Aerosol, ocean colour, flooding
Thank you for your attention