Drought monitoring

with old and new satellites

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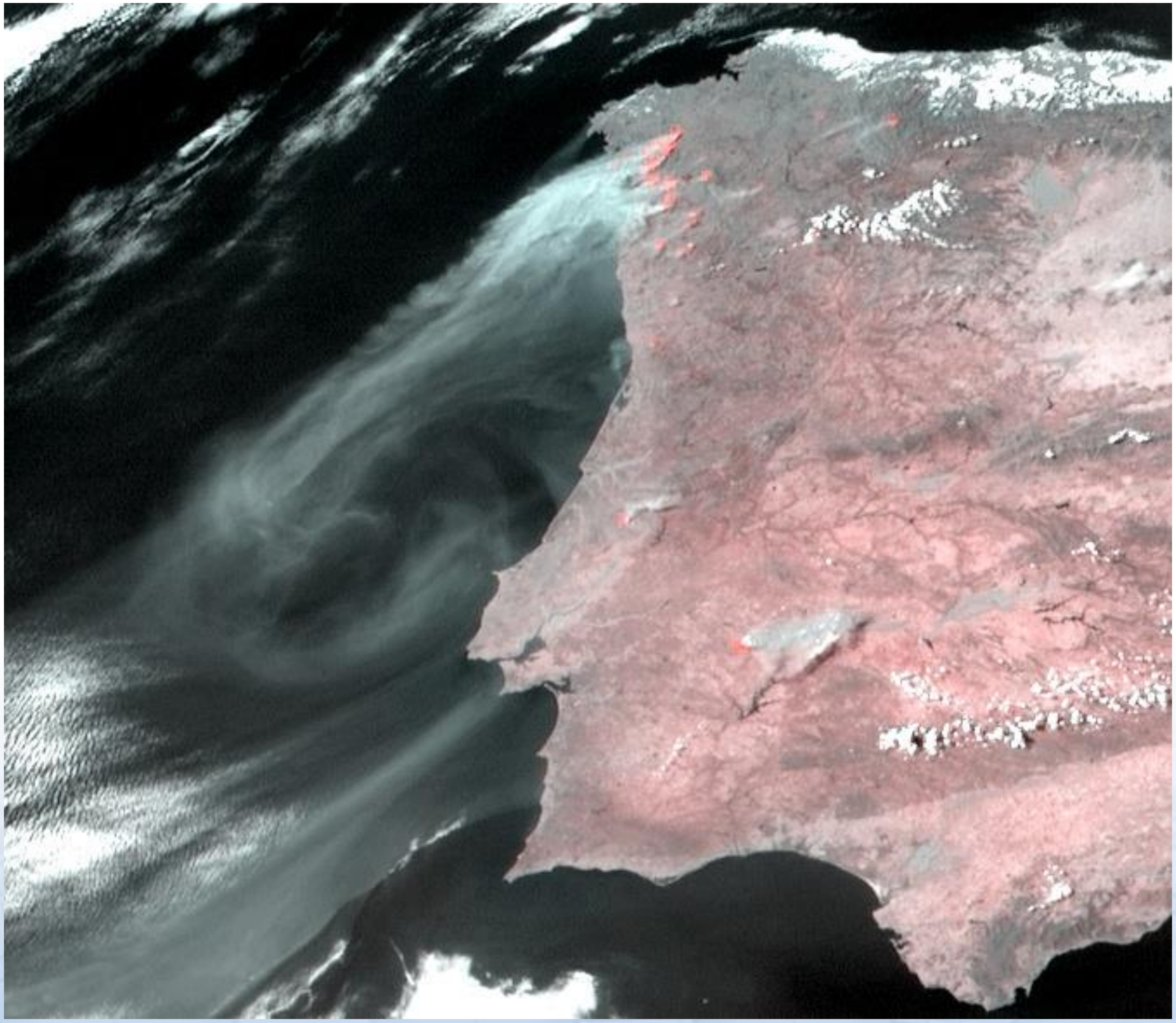
Contents

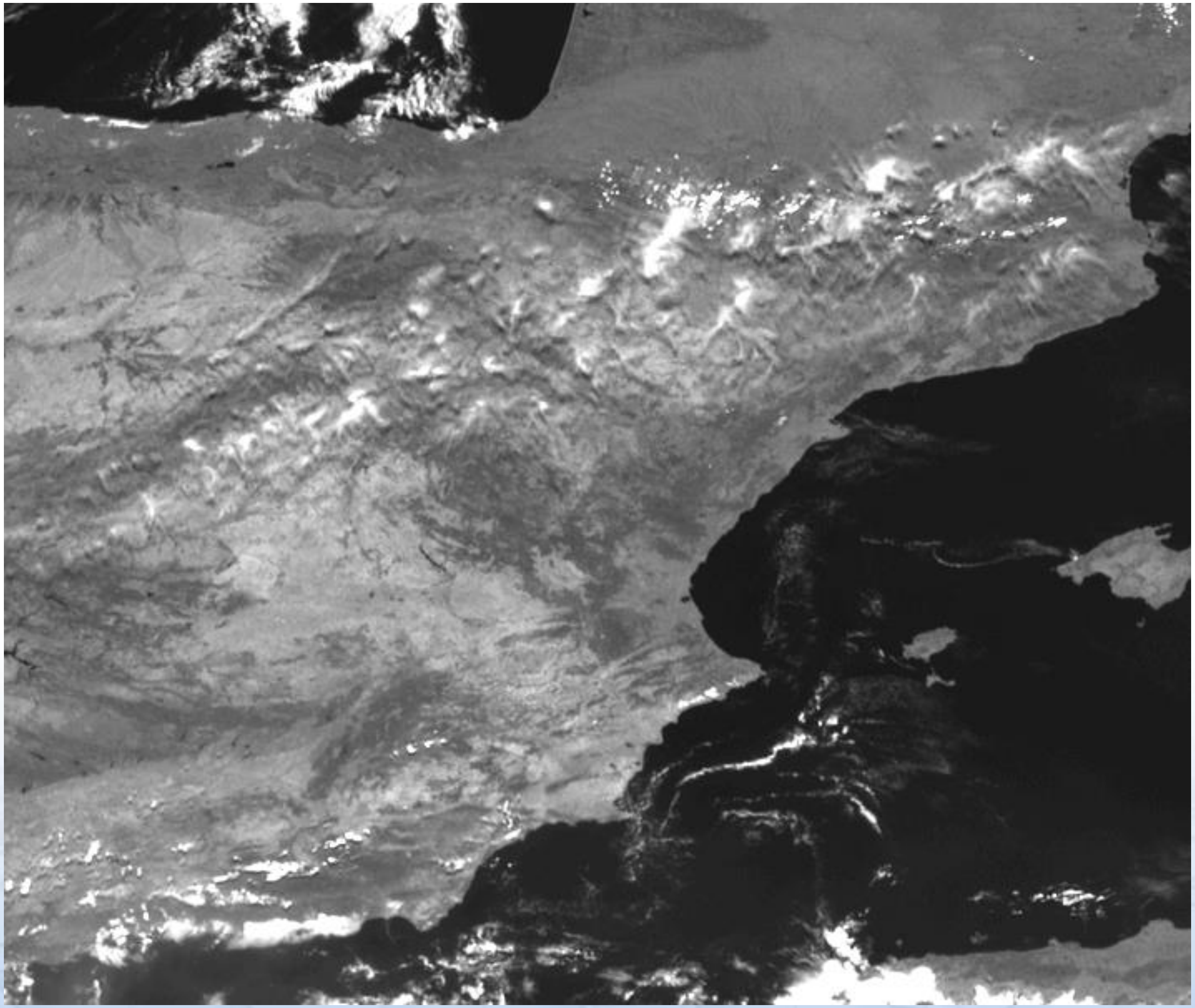
Fire and...



Meteosat: channel 3.9µm colouring HRV

2006-July-7 16:00

... drought



Meteosat-10 HRV

2015-Aug-5 12:00

Drought versus fire

Average (high reflectivity values)

Predictable?

Drought

Extended
(many pixels)

Accumulated
climate-like

Maximum (extreme values)

Unpredictable?

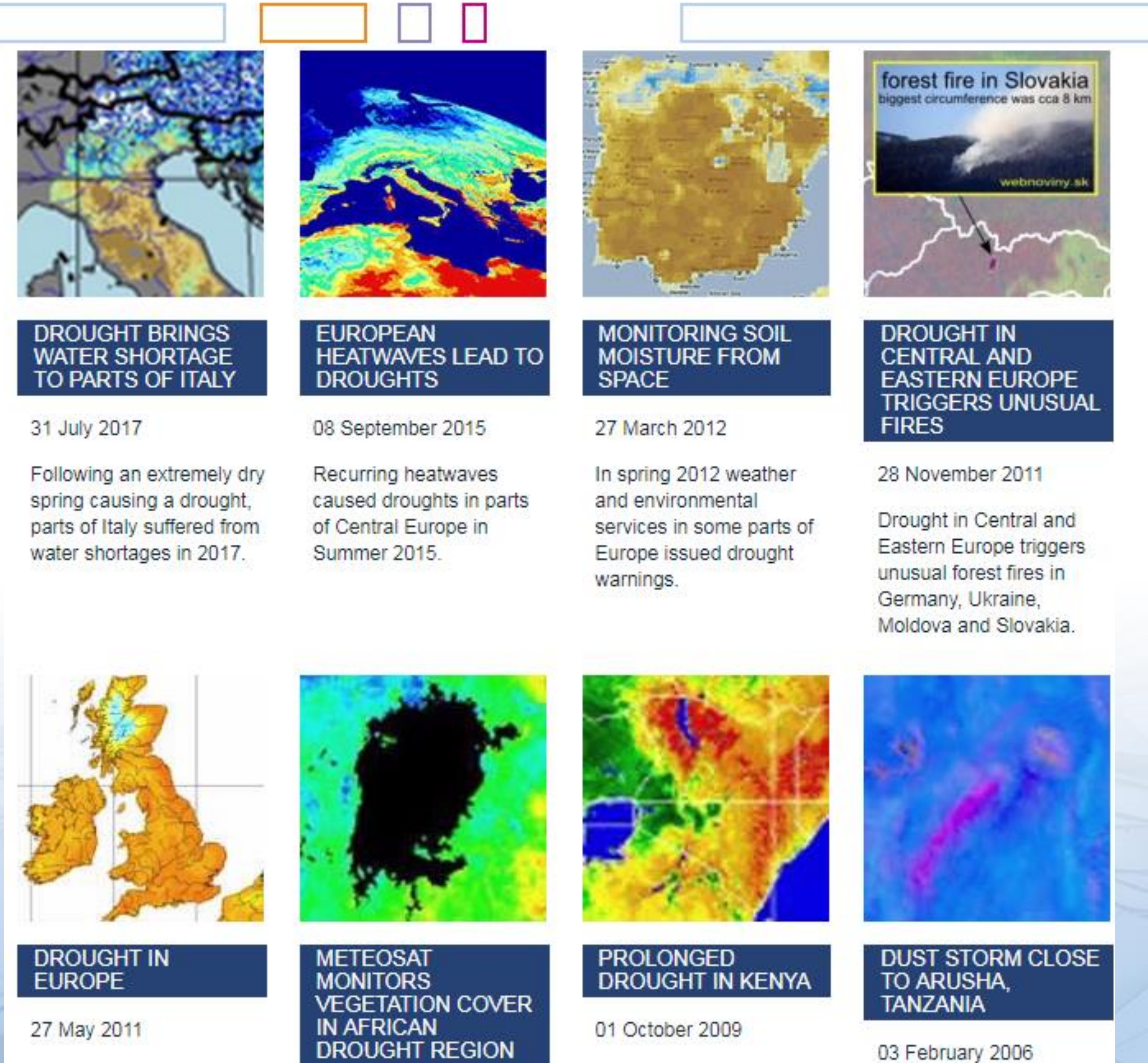
Fire

Localised
(sub-pixel or few pixels)

Instantaneous
weather-like

Image library: FEATURE: drought

Drought satellite monitor
Trigger for fires
Cumulative effect for years
Dust connection



DROUGHT BRINGS WATER SHORTAGE TO PARTS OF ITALY

31 July 2017

Following an extremely dry spring causing a drought, parts of Italy suffered from water shortages in 2017.

EUROPEAN HEATWAVES LEAD TO DROUGHTS

08 September 2015

Recurring heatwaves caused droughts in parts of Central Europe in Summer 2015.

MONITORING SOIL MOISTURE FROM SPACE

27 March 2012

In spring 2012 weather and environmental services in some parts of Europe issued drought warnings.

DROUGHT IN CENTRAL AND EASTERN EUROPE TRIGGERS UNUSUAL FIRES

28 November 2011

Drought in Central and Eastern Europe triggers unusual forest fires in Germany, Ukraine, Moldova and Slovakia.

DROUGHT IN EUROPE

27 May 2011

METEOSAT MONITORS VEGETATION COVER IN AFRICAN DROUGHT REGION

PROLONGED DROUGHT IN KENYA

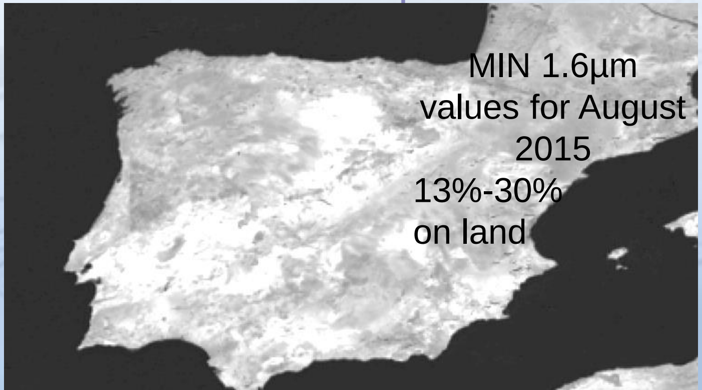
01 October 2009

DUST STORM CLOSE TO ARUSHA, TANZANIA

03 February 2006

Monitoring drought with satellites

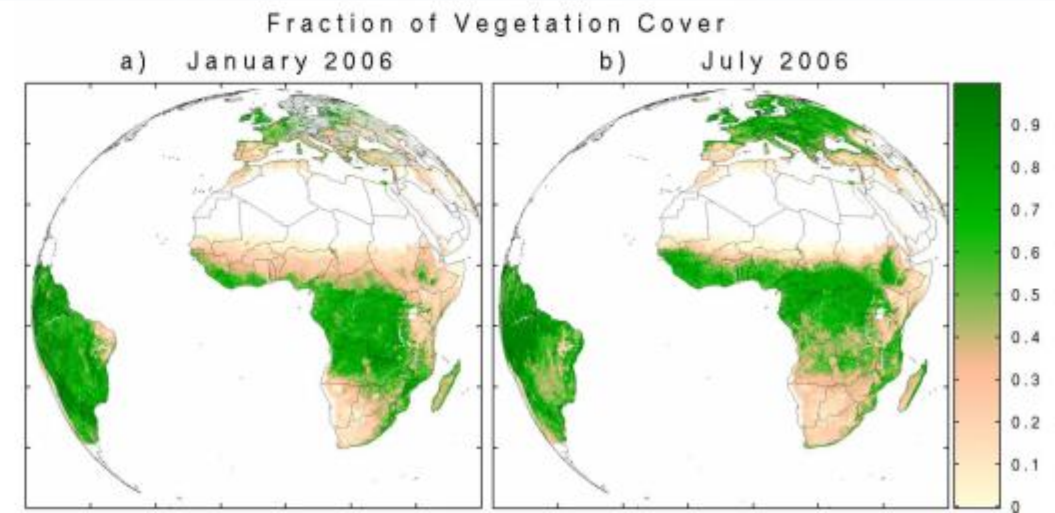
- **DROUGHT (extensive)**
  - High values in reflectivities and brightness temperatures (BT)
  - Low variability in reflectivities and BT (little cloud)
  - Low emissivities in the IR window, e.g. as calculated by LSA SAF
  - Can be monitored through the fractional vegetation cover (FVC)
  - Stands out in series as **accumulation** events
  - Channel 0.8-1.6µm



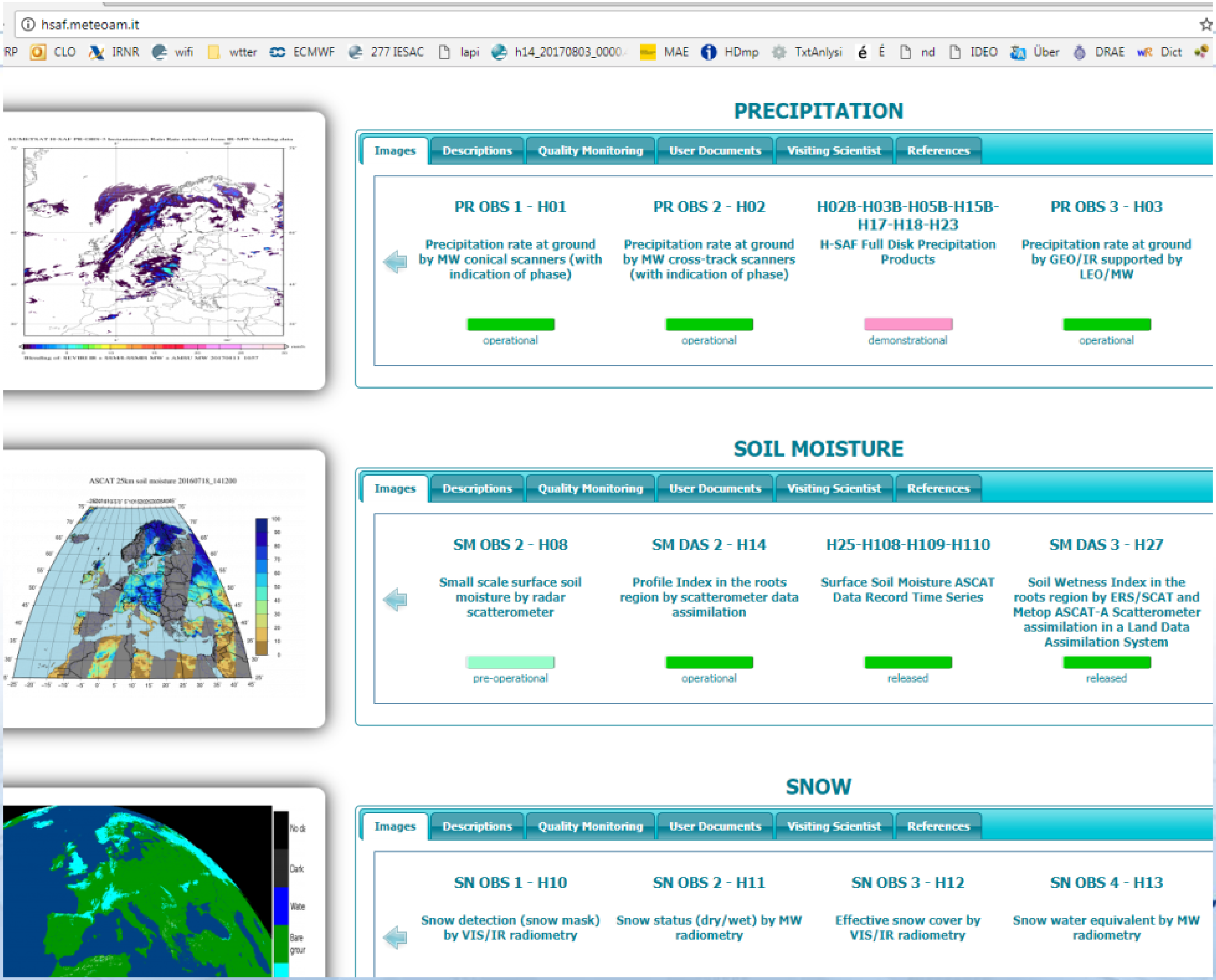
MIN 1.6µm values for August 2015

13%-30% on land

- **FIRE (intensive)**
  - Hot spots at 3.9µm channel
  - Scars with low reflectivity
  - Smoke and pyro-cumulus at height
  - Optimal sensitivity in the near infrared
  - Stands out in series as **exceptional** events
  - Channel 3.9µm



Hydrology SAF



PRECIPITATION

PR OBS 1 - H01
Precipitation rate at ground by MW conical scanners (with indication of phase)
🟩 operational

PR OBS 2 - H02
Precipitation rate at ground by MW cross-track scanners (with indication of phase)
🟩 operational

H02B-H03B-H05B-H15B-H17-H18-H23
H-SAF Full Disk Precipitation Products
🟪 demonstrational

PR OBS 3 - H03
Precipitation rate at ground by GEO/IR supported by LEO/MW
🟩 operational

SOIL MOISTURE

SM OBS 2 - H08
Small scale surface soil moisture by radar scatterometer
🟩 pre-operational

SM DAS 2 - H14
Profile Index in the roots region by scatterometer data assimilation
🟩 operational

H25-H108-H109-H110
Surface Soil Moisture ASCAT Data Record Time Series
🟩 released

SM DAS 3 - H27
Soil Wetness Index in the roots region by ERS/SCAT and Metop ASCAT-A Scatterometer assimilation in a Land Data Assimilation System
🟩 released

SNOW

SN OBS 1 - H10
Snow detection (snow mask) by VIS/IR radiometry

SN OBS 2 - H11
Snow status (dry/wet) by MW radiometry

SN OBS 3 - H12
Effective snow cover by VIS/IR radiometry

SN OBS 4 - H13
Snow water equivalent by MW radiometry

Daily cycles for different soils

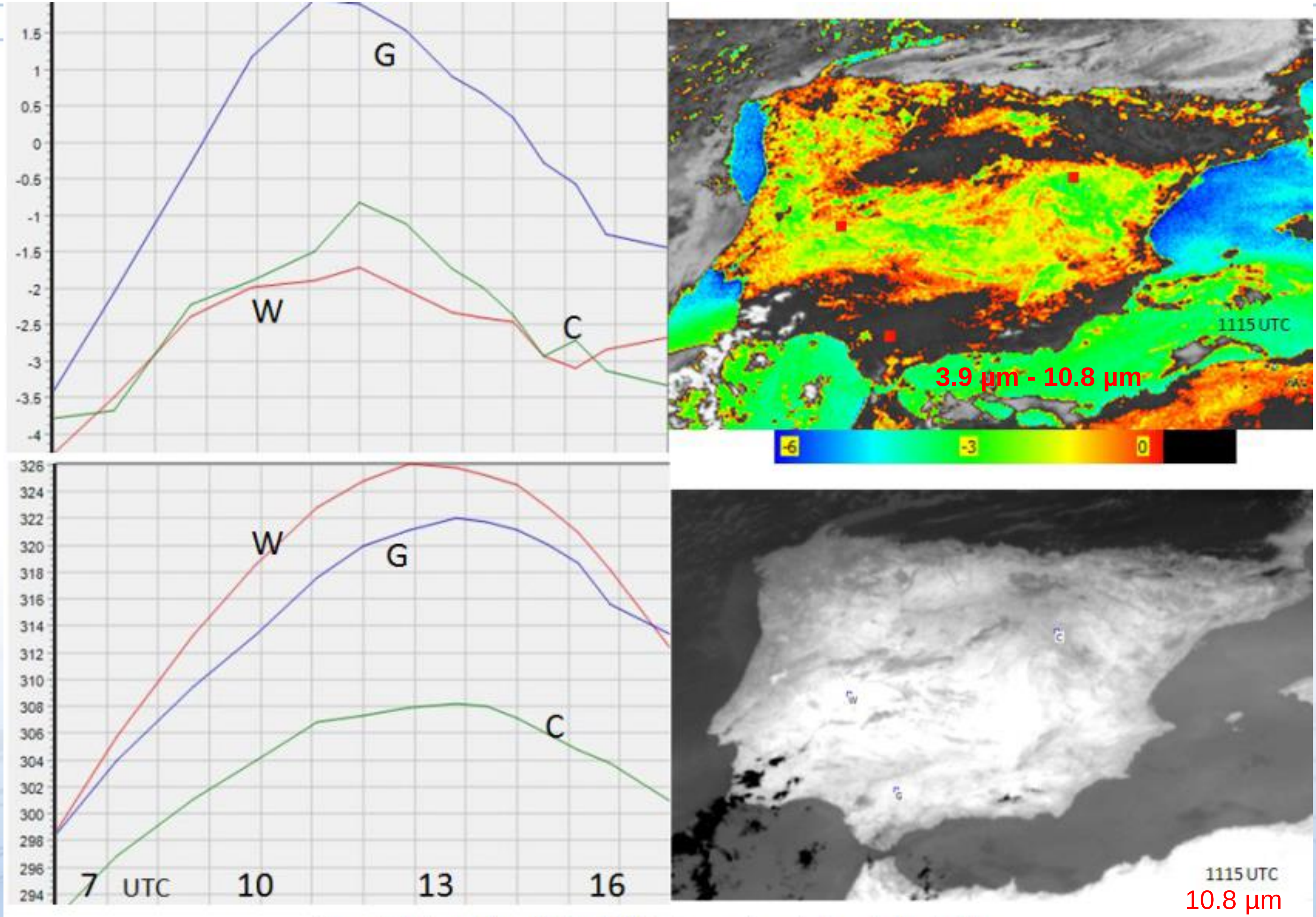
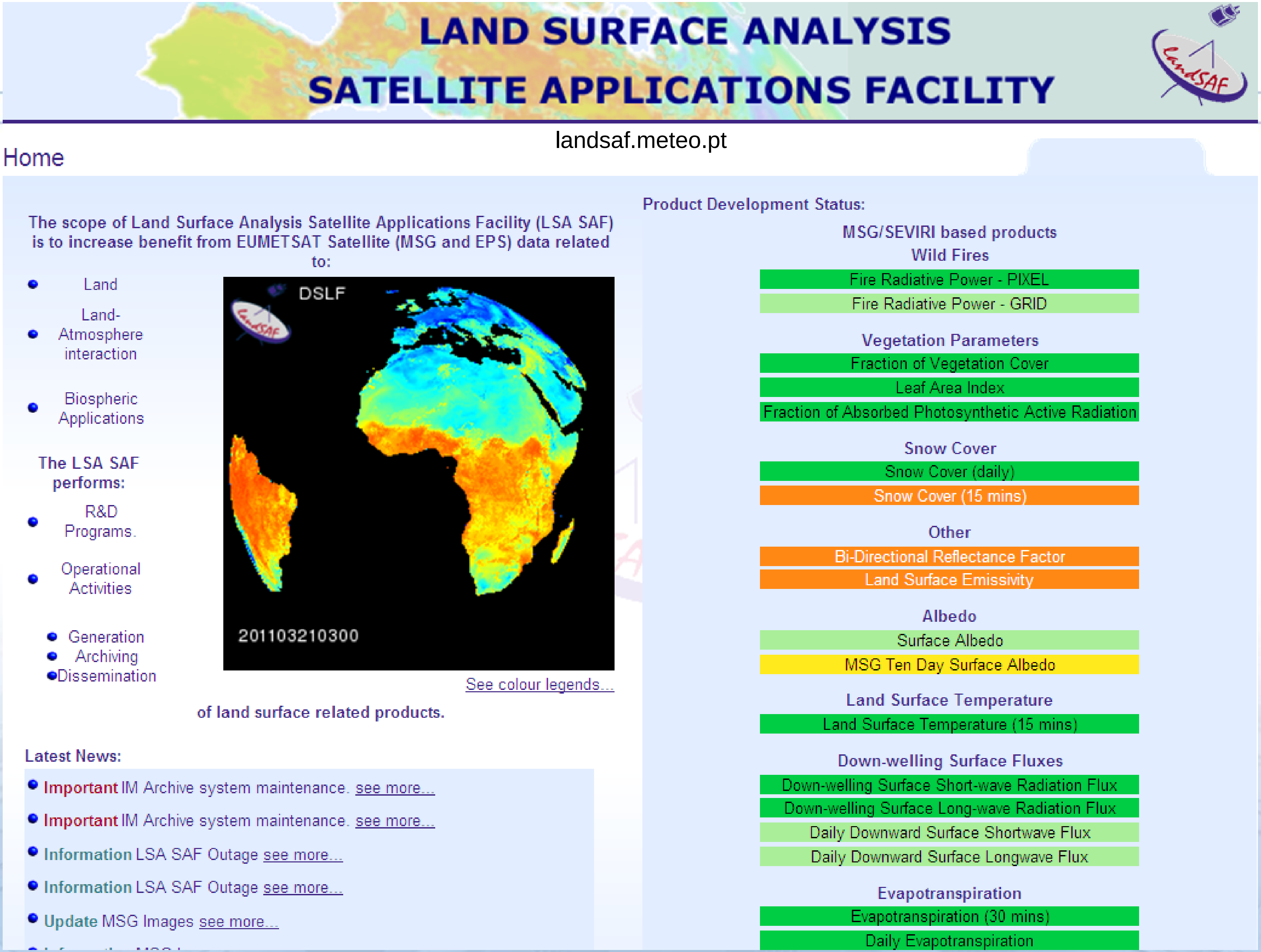


Figure 2: Daily evolution of 3.9 and 10.8µm temperatures for three Iberian locations.



LAND SURFACE ANALYSIS SATELLITE APPLICATIONS FACILITY

landsaf.meteo.pt

Home

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

The long path to monitor drought: from solar to thermal

VIS 0.6
NIR 0.8
SWIR 1.6

solar

Normalized reflectance K_0

BRDF

Training
soil-vegetation

Gaussian fit

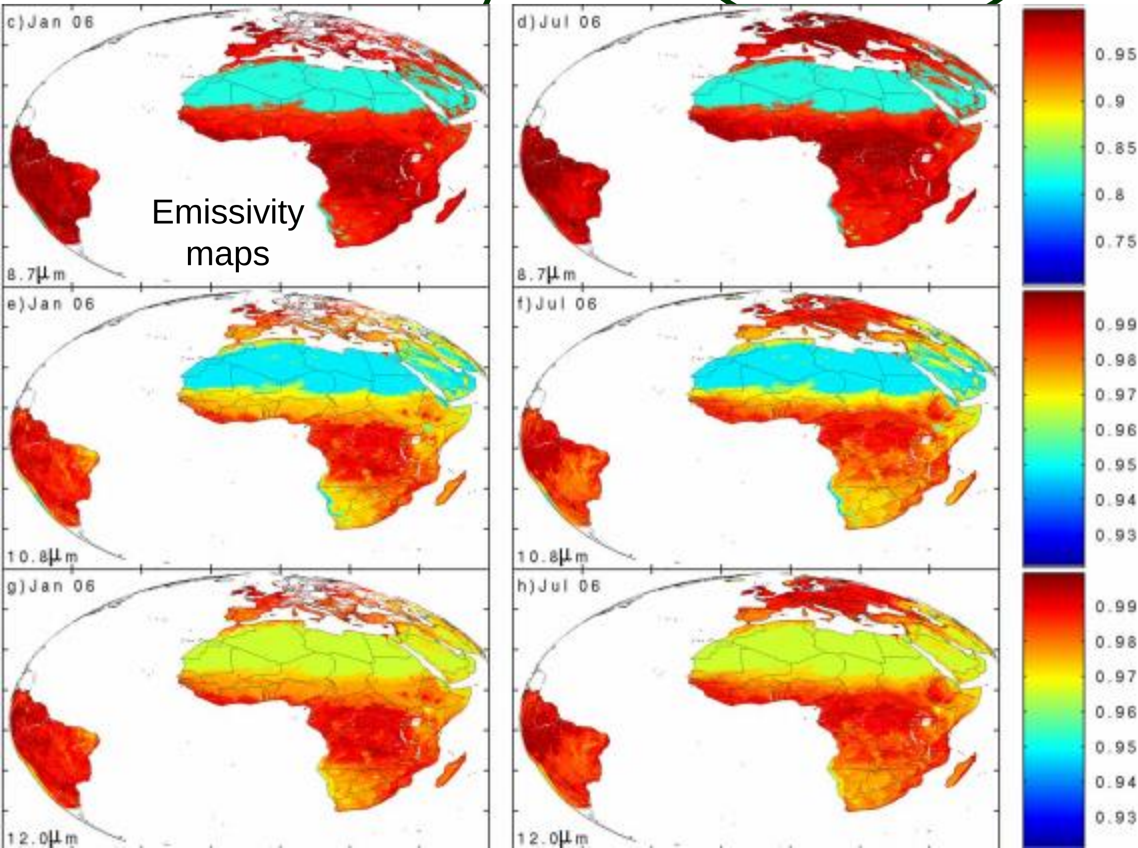
Bayesian class
likelihood

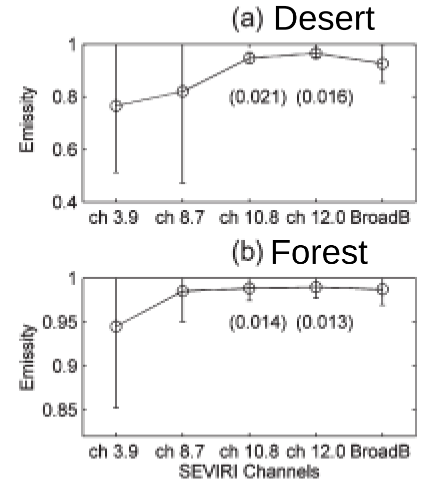
Fractional vegetation
cover (FVC)

Vegetation and
bare-ground
tables

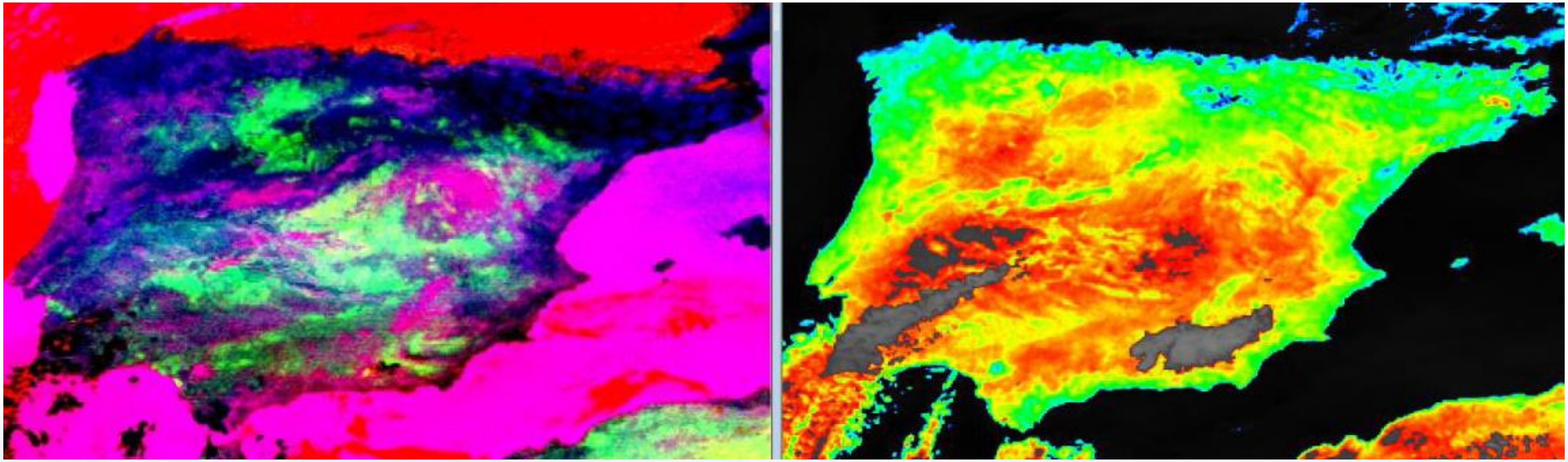
**Land-surface
emissivities**

thermal


Emissivity
maps



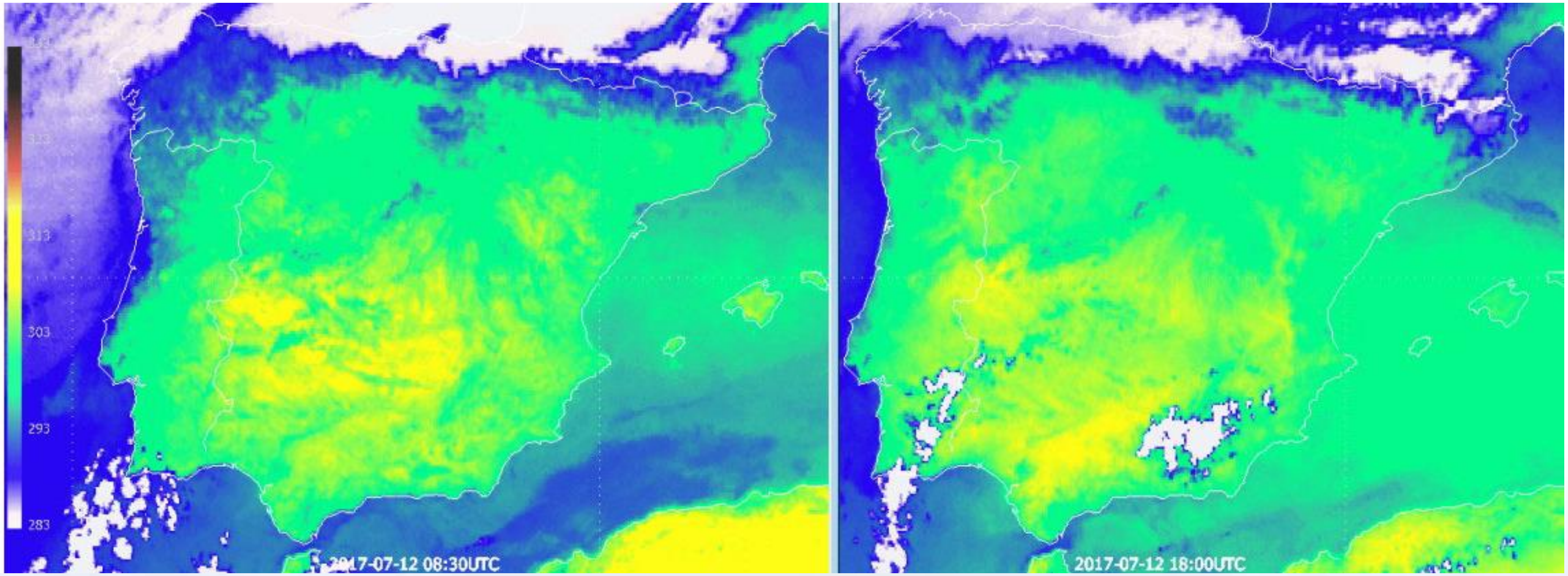
Proxies for soil heating



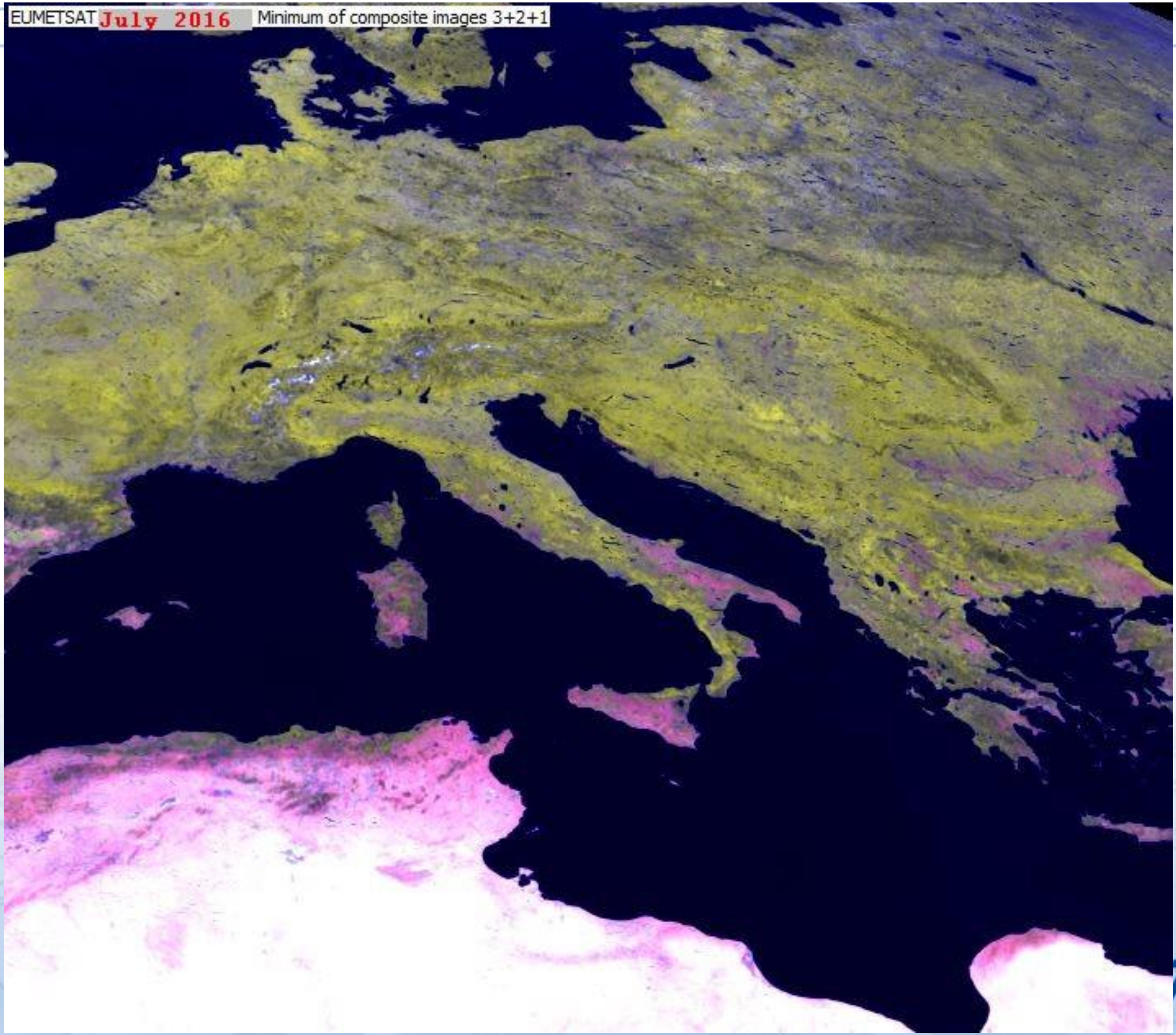
Composite of IR window channel differences
12th July 2017

IR 10.8µm day-night variance
12th July 2017

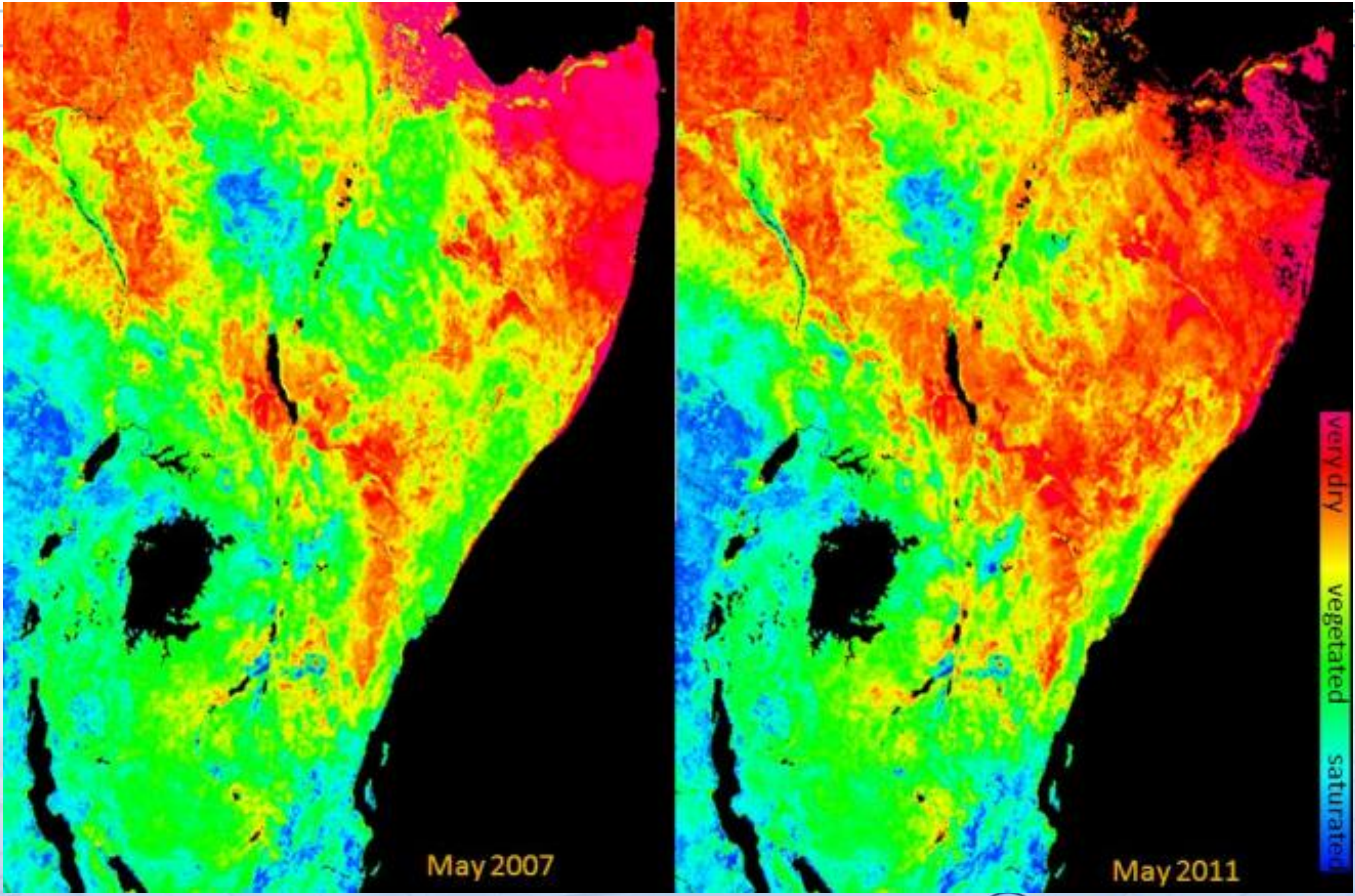
Heating-cooling asymmetry



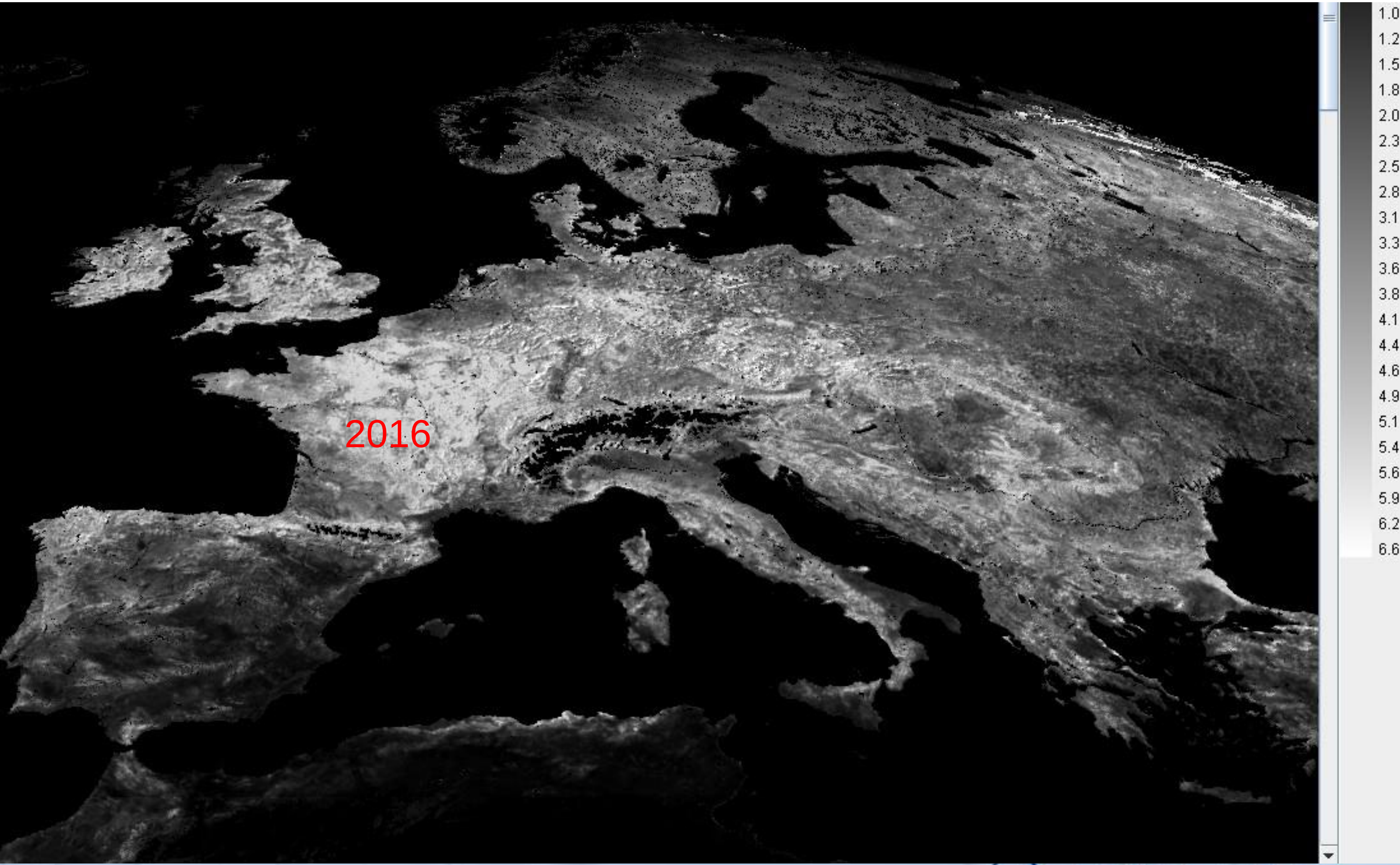
Imagery summaries for drought



Fractional vegetation cover (FCV)

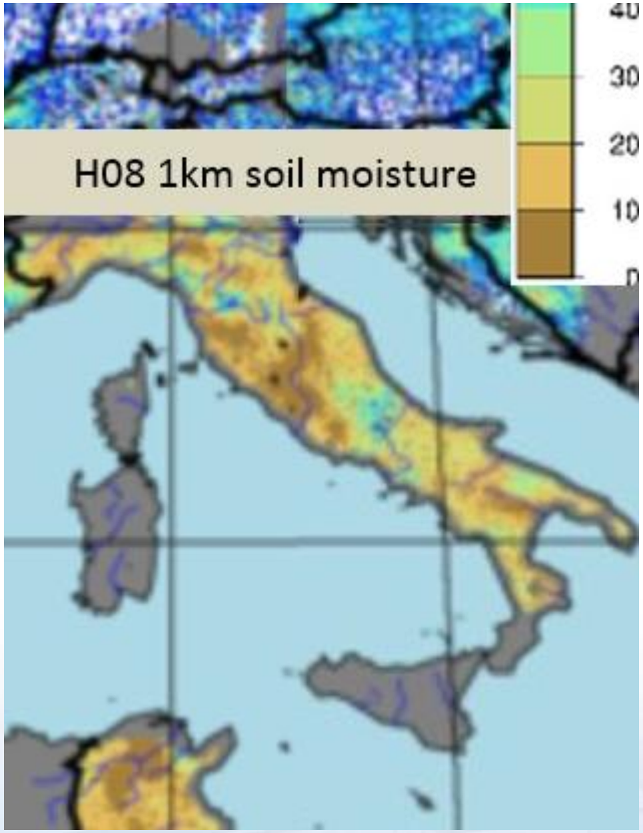


Leaf area index (LAI)

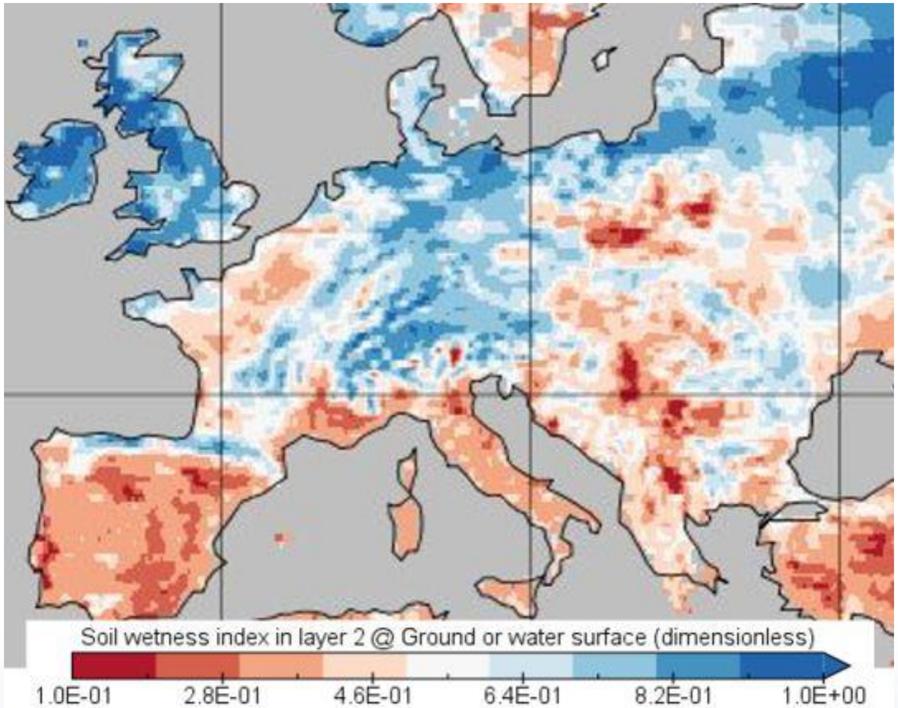


1 June 2016/2017 Leaf Area Index from LSA SAF

H-SAF products from ASCAT (+ models)



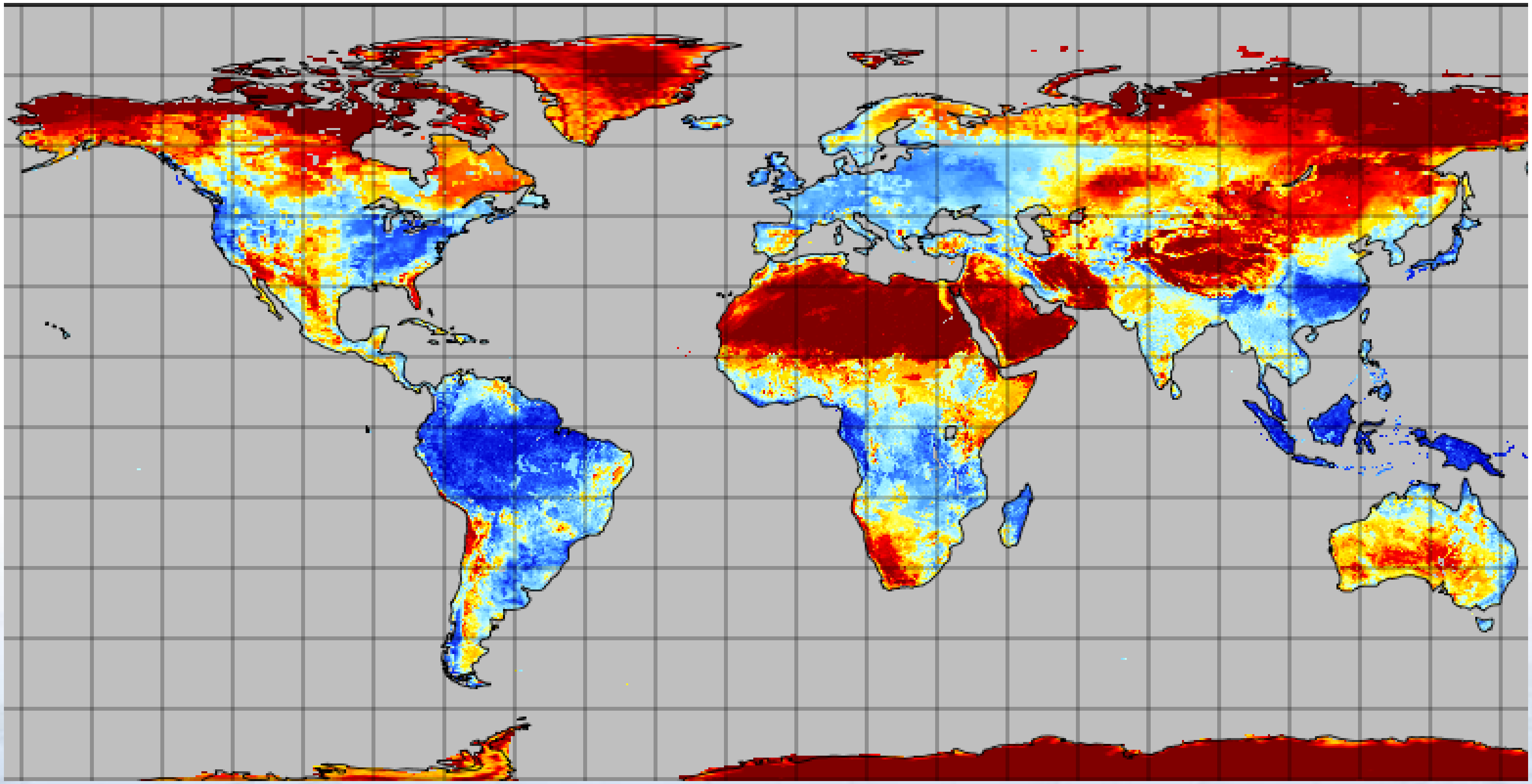
1-2 August 2017
northbound passes
ASCAT



2-3 August 2017 8-27cm
depth layer

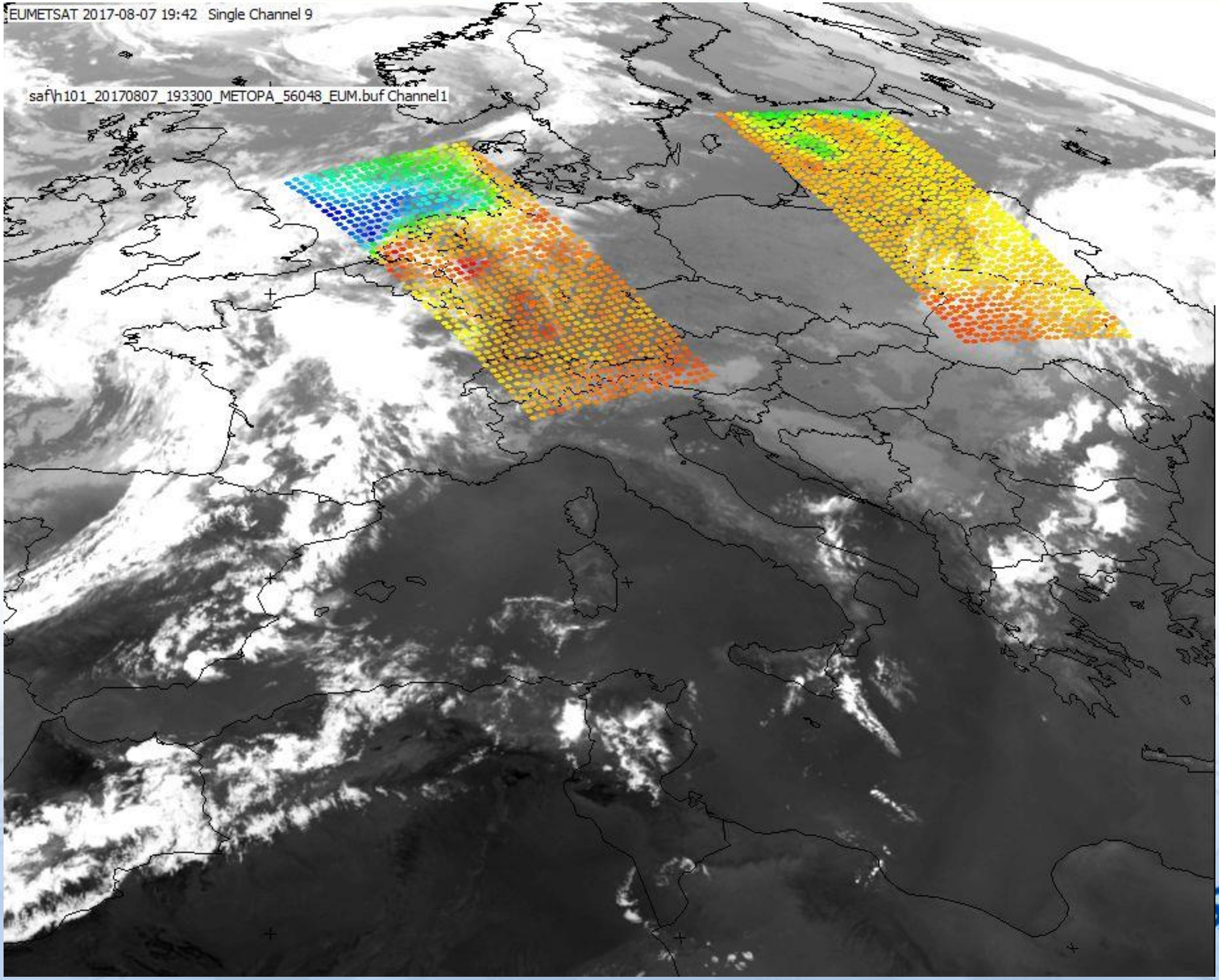
ASCAT on Metop

Soil wetness index in layer 3 @ Ground or water surface

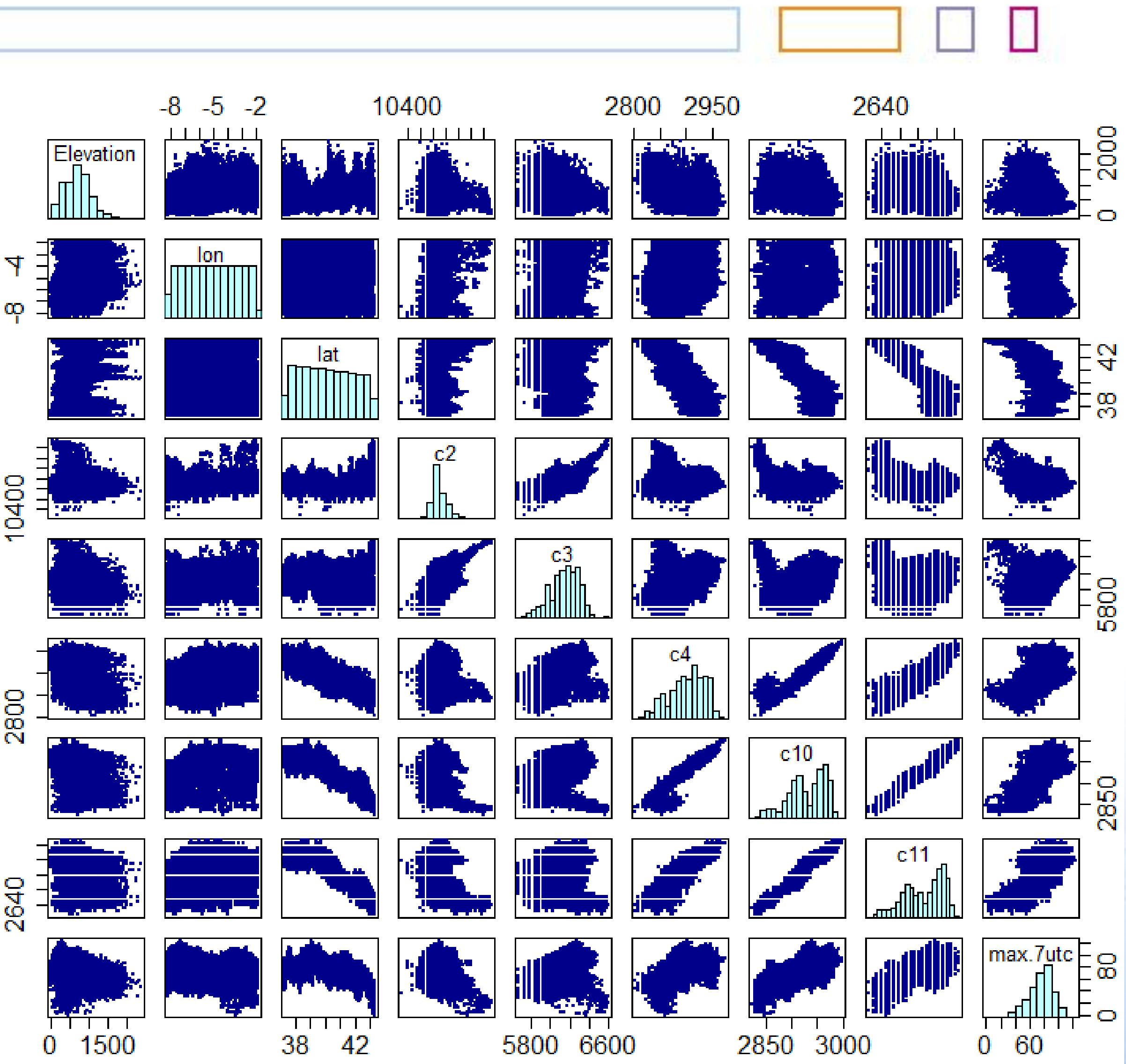


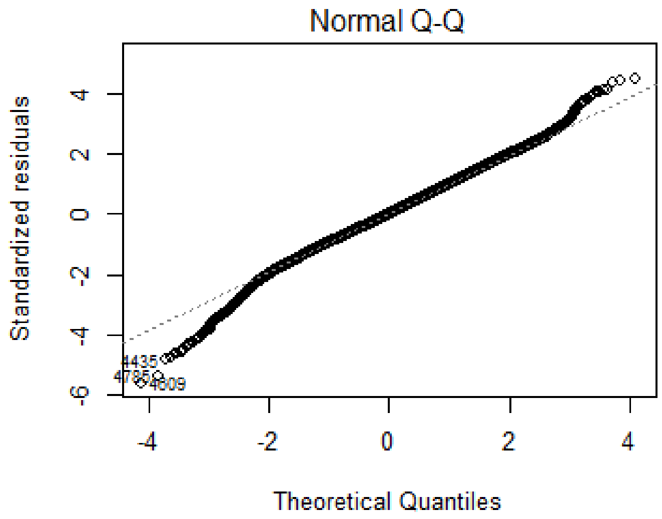
Metop-B ASCAT 13 April 2017
Product H14 from HSAF

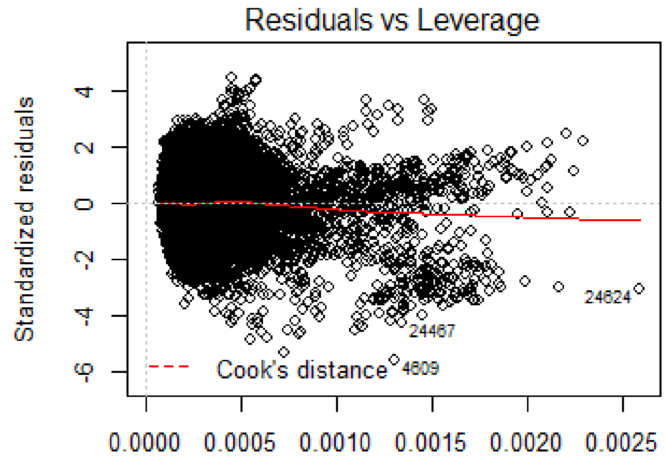
ASCAT double swaths reflectivities



Forecasting heating in the course of the day

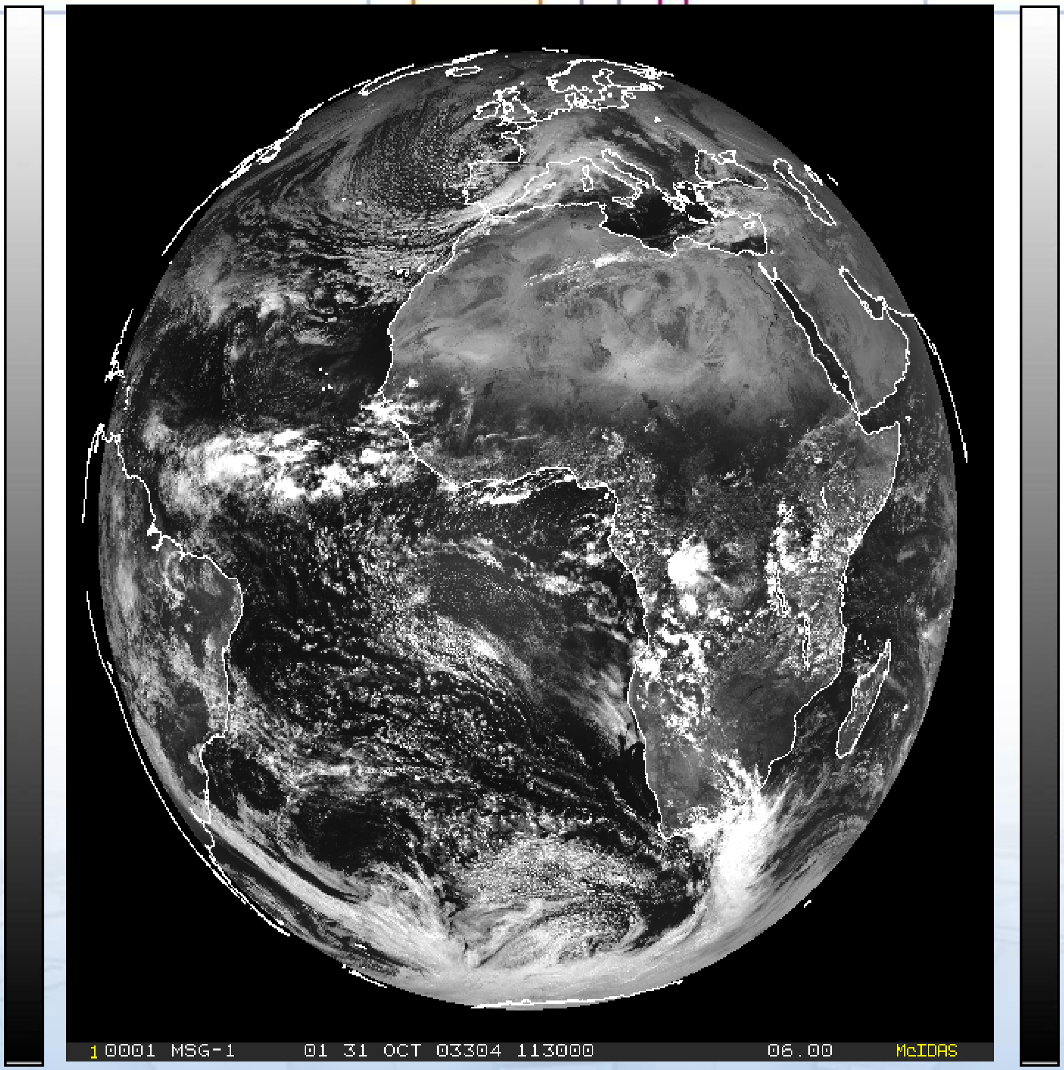






Based on 7 UTC Meteosat **channel** values, a prediction of pixel **heating** is done based on **regression**. The thermal value is better predictor than the solar reflectivities Explained variance= 73%. Typical increase: (20 +-8)K. Resulting uncertainty +-4K

Earth Surface Channel 01 (VIS0.6) Clouds



Sun Glint
Snow

Desert

Bare Soil

Forest

Ocean, Sea

High reflectance
thick clouds

thin clouds over land

thin clouds over ocean

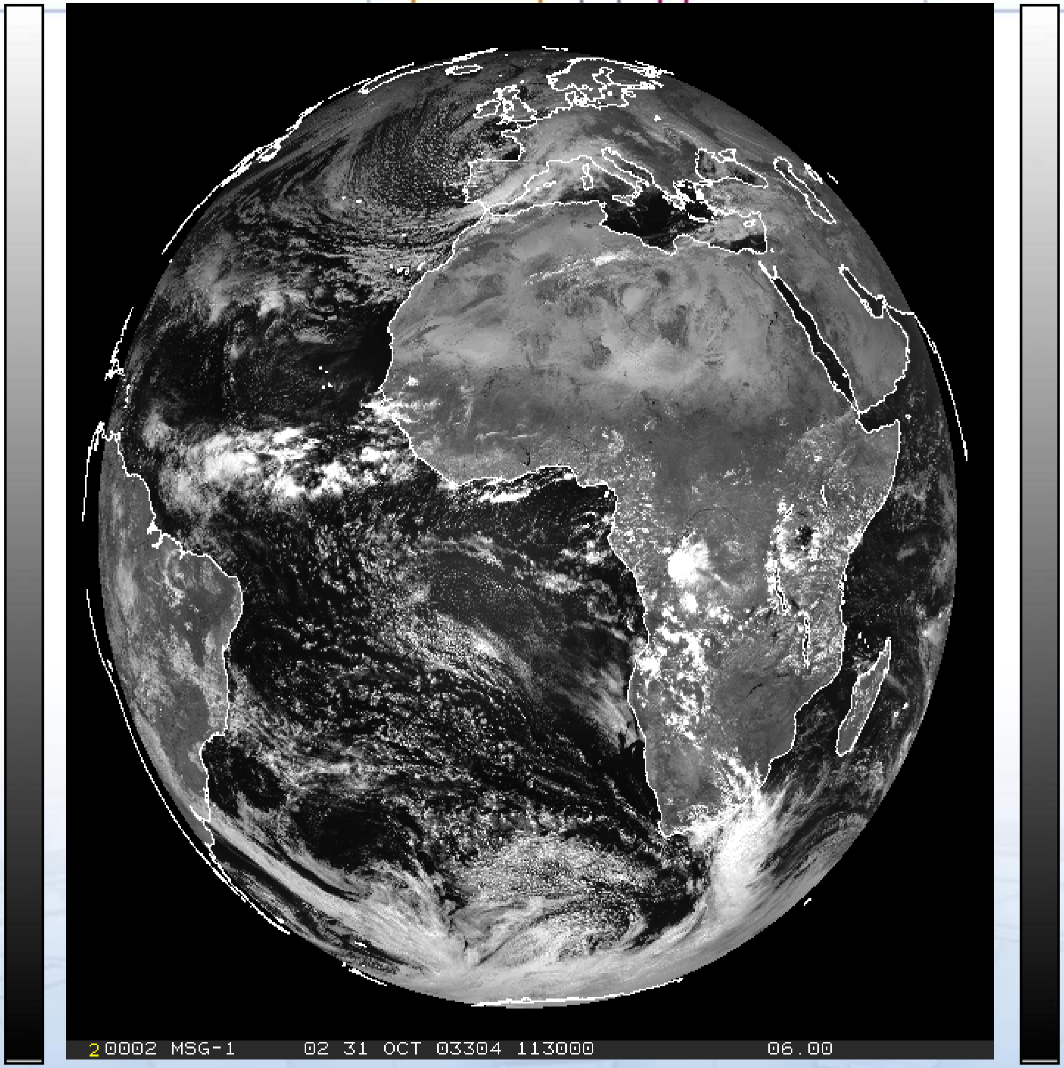
Low reflectance

31 October 2003, 11:30 UTC

Channel 02 (VIS0.8)

Earth Surface

Clouds



31 October 2003, 11:30 UTC

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

EUMETSAT

Earth Surface Channel 03 (NIR1.6)

High reflectance

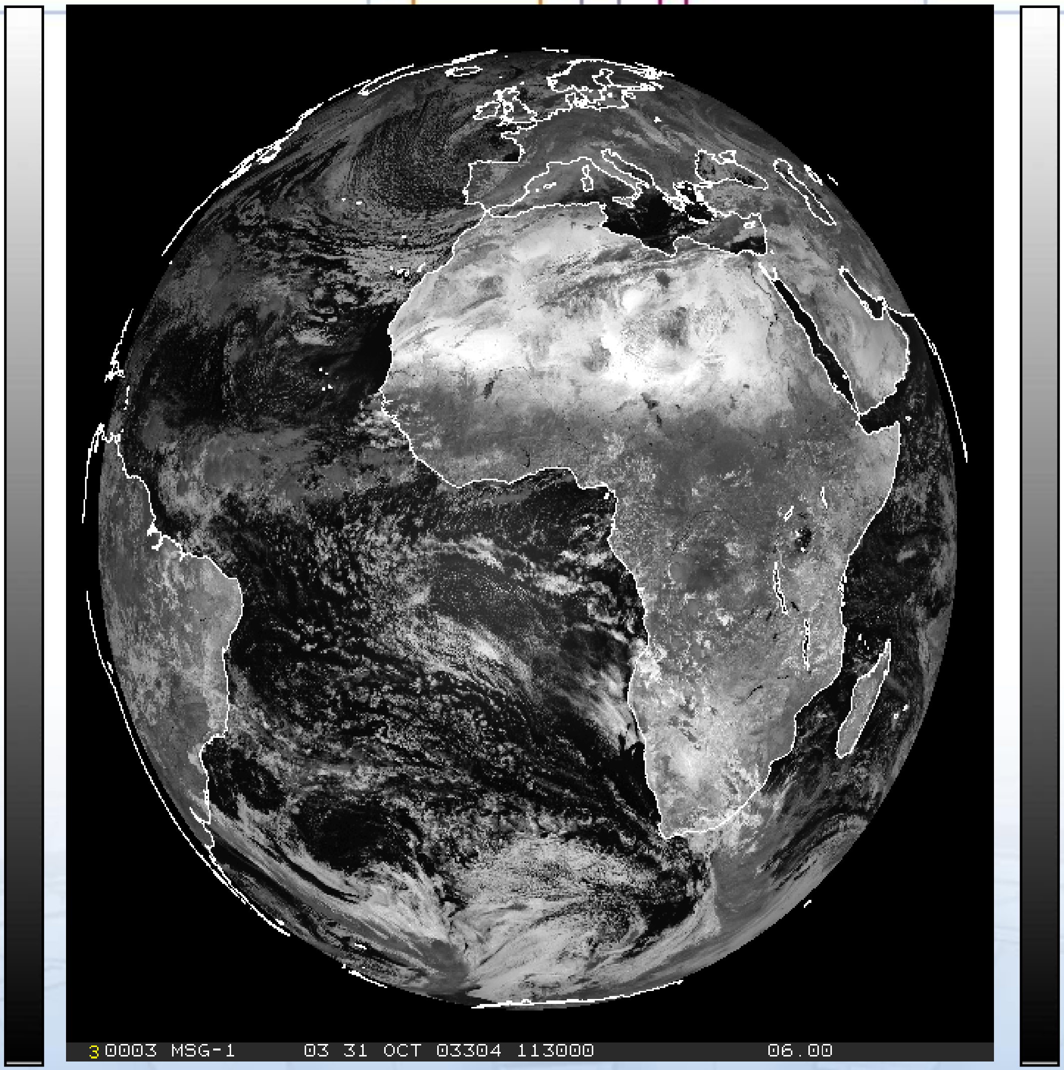
Sun Glint
Sand Desert

Gras, Rice fields

Forest

Bare Soil

Snow
Ocean, Sea



31 October 2003, 11:30 UTC

Water clouds (small droplets)

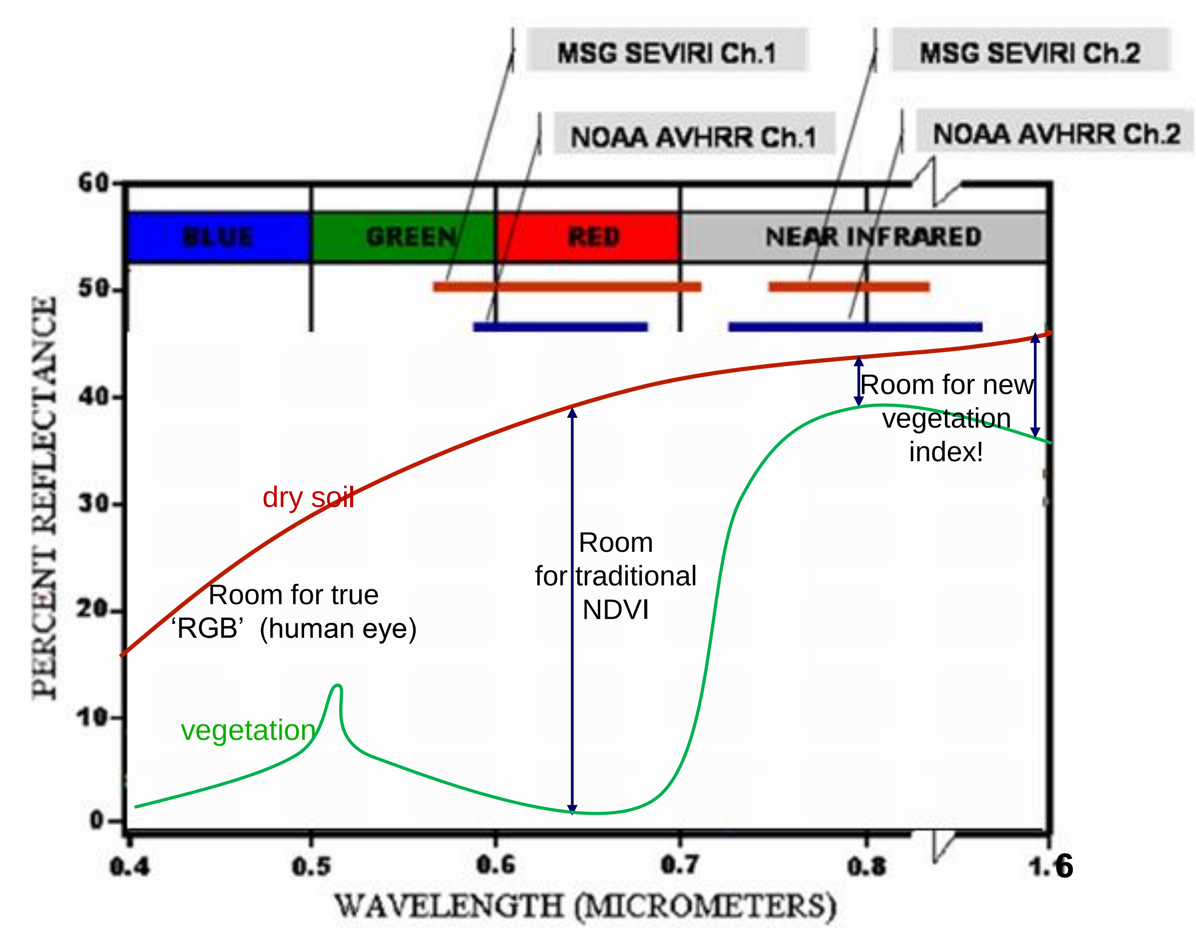
Water clouds (large droplets)

Ice clouds (small particles)

Ice clouds (large particles)

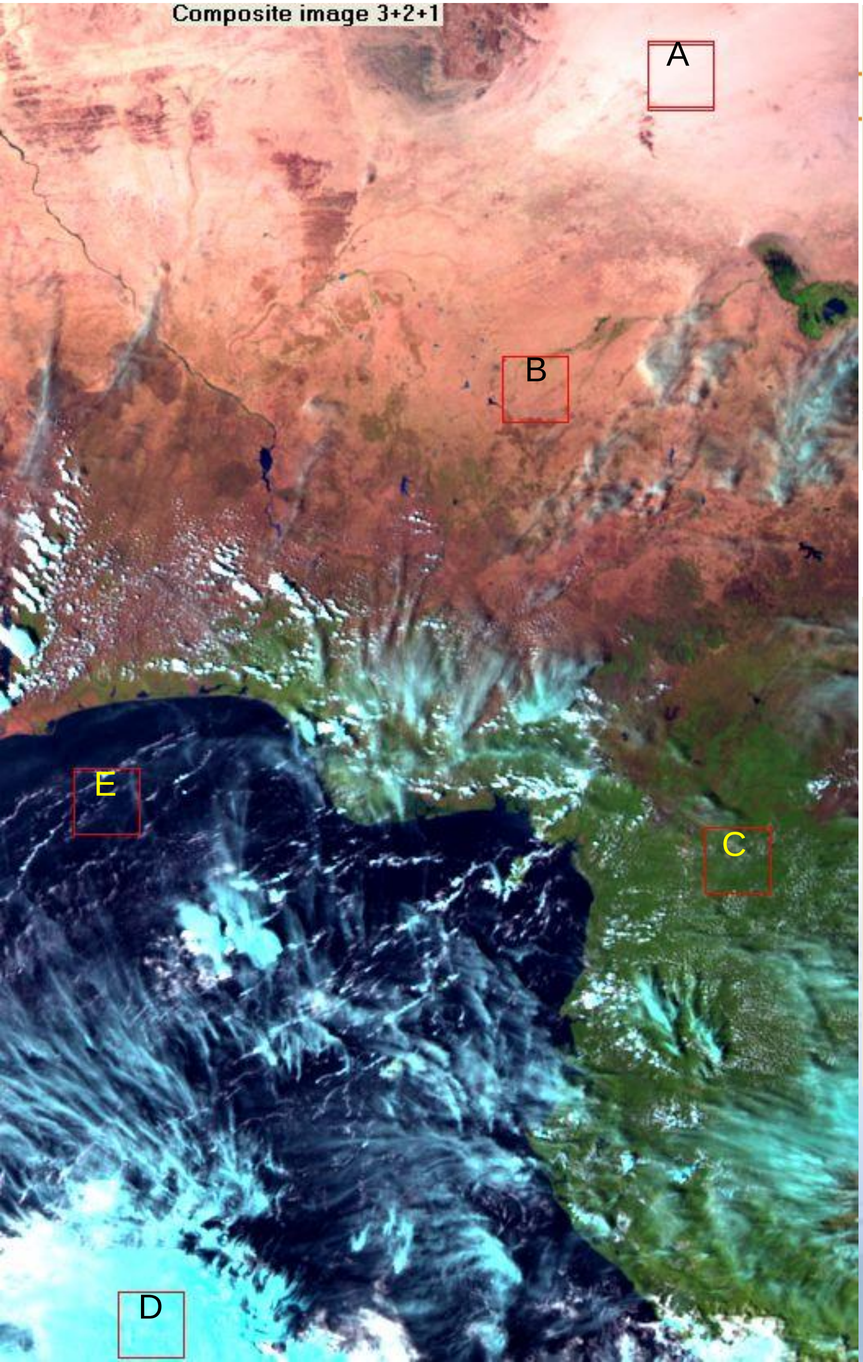
Low reflectance

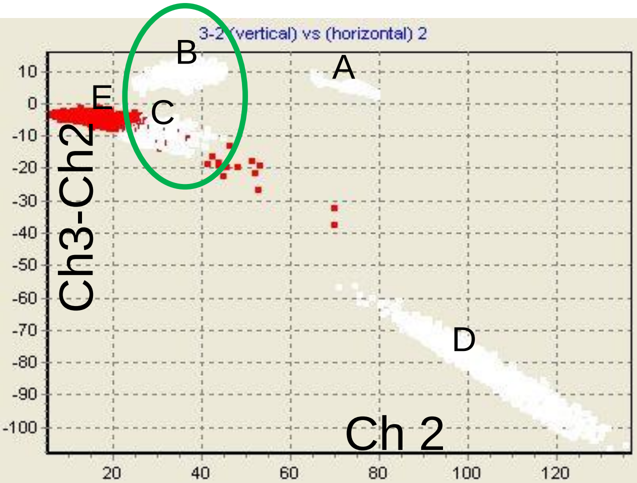
Vegetated and dry soils



The vegetation response to wavelengths in our eye colour perception is proportional to those at 0.6µm, 0.8µm and 1.6µm: happy coincidence!

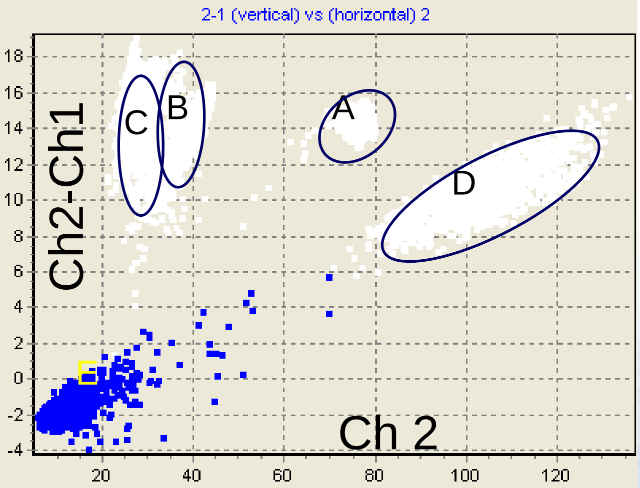
Dry soil shows brown in the natural RGB!





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

Now, 2-1 in vertical. Your turn!

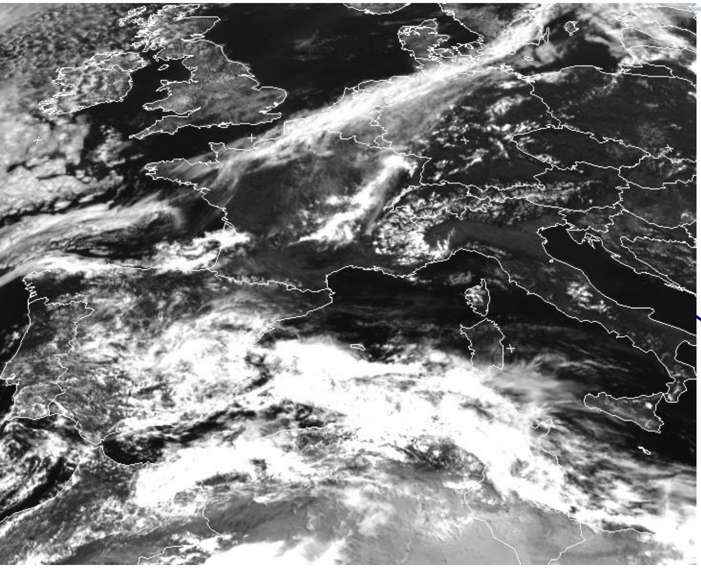


Index (2-1)/(2+1)
B (dry)= 25%
C (vegetated)= 40%

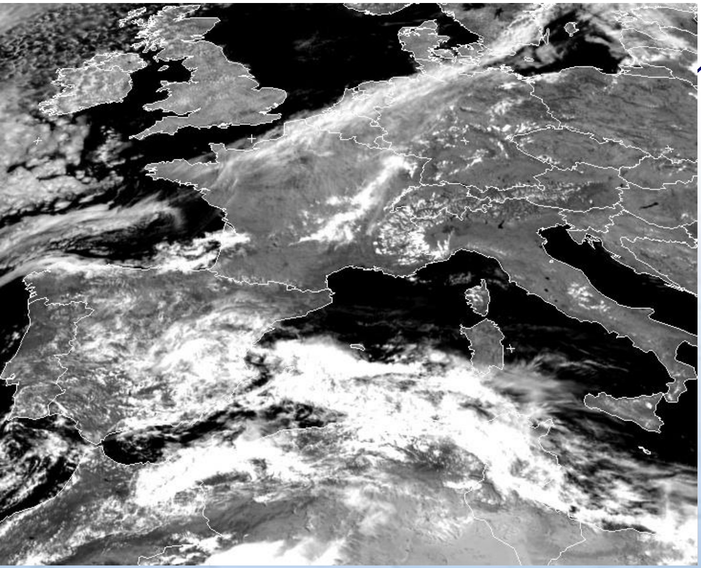
1.6µm reflects better than 0.8µm on dry ground, but worse in vegetated areas

1.6µm 🟥 B 🟨 C 🟩 **0.8µm**

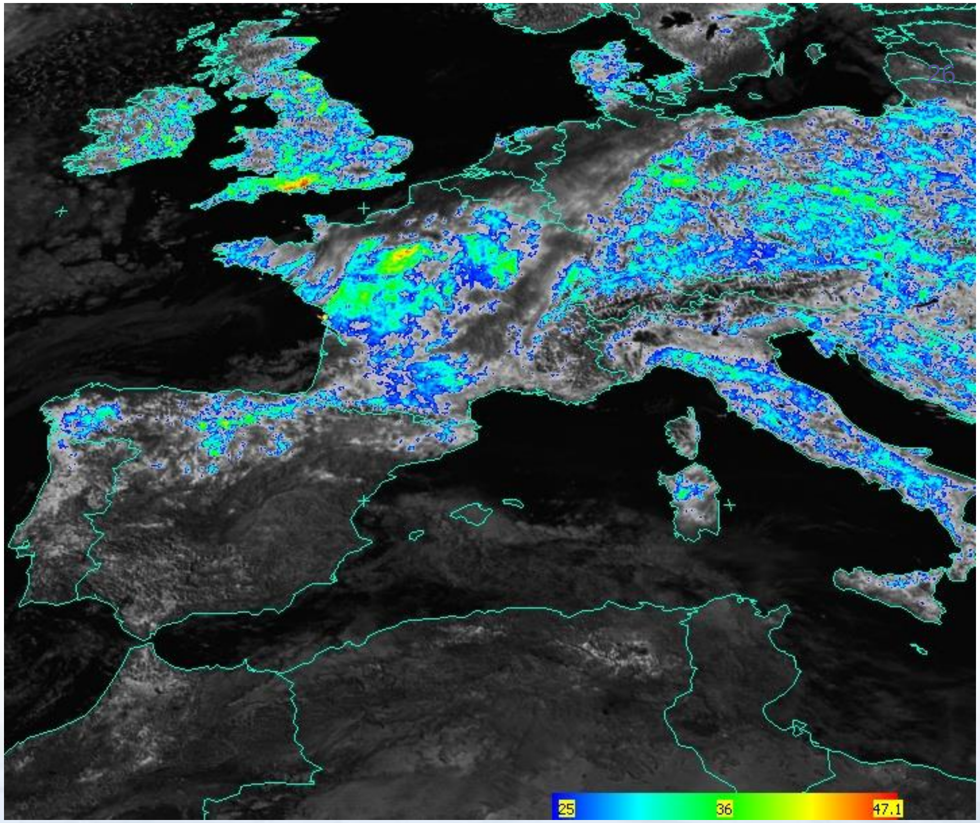
Solar channel differences over land



VIS0.6



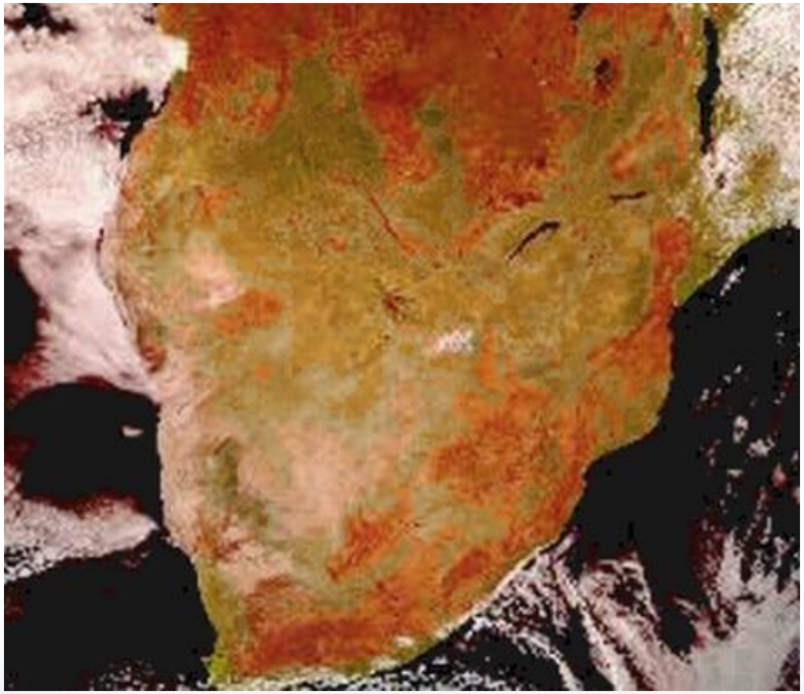
VIS0.8



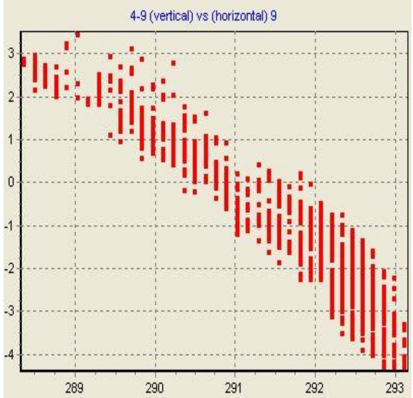
VIS0.8 – VIS0.6 Meteosat 2011-05-19 09:30 UTC

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

Suspicion and truth

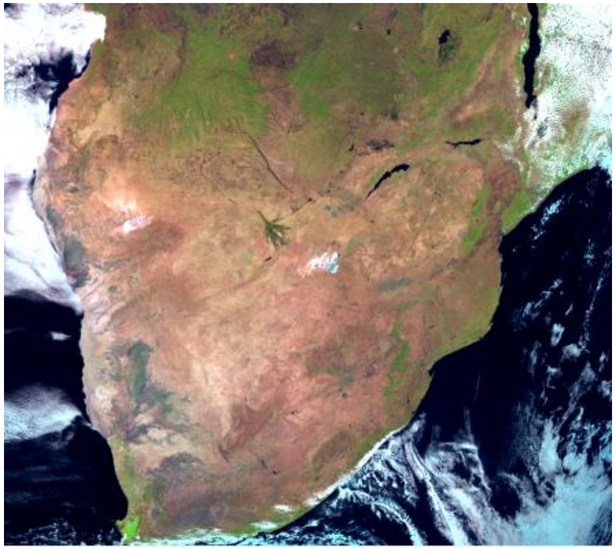


Hipothesis: “too dry”



Numeric analysis

Confirmation **or** refusal through statistical **analysis**



Correction of the **display** technique that generated the wrong assumption

The two images are identical, just differently **enhanced or processed**

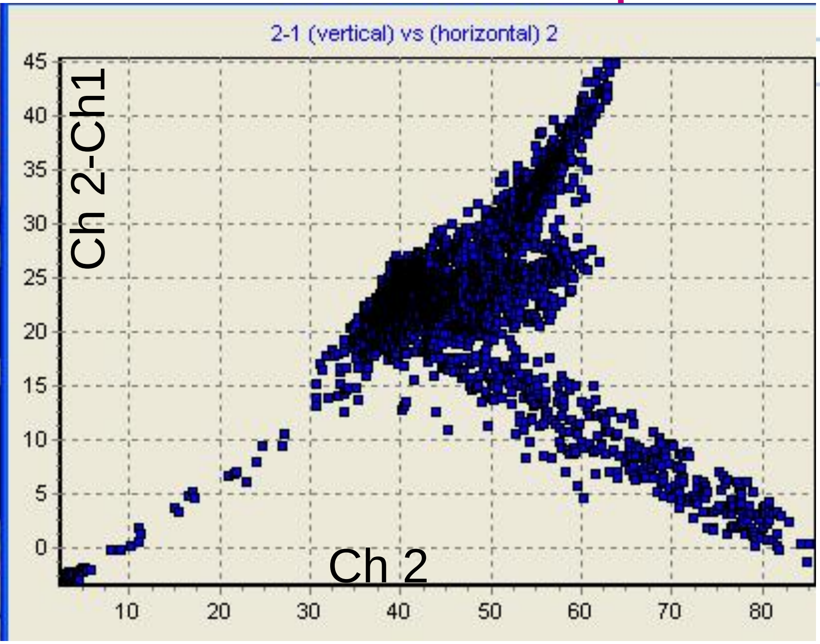
France, 10March 17April 24May

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

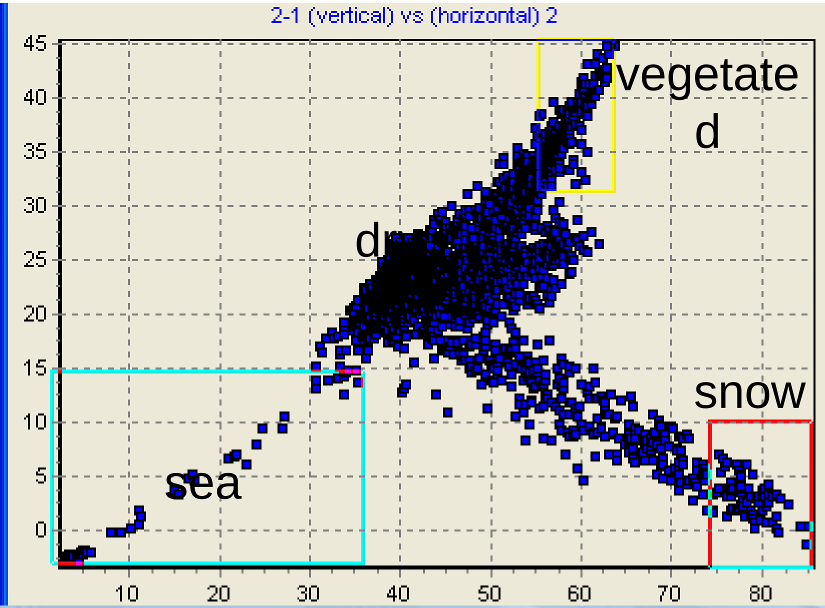
Spain 6April 22May 2010

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

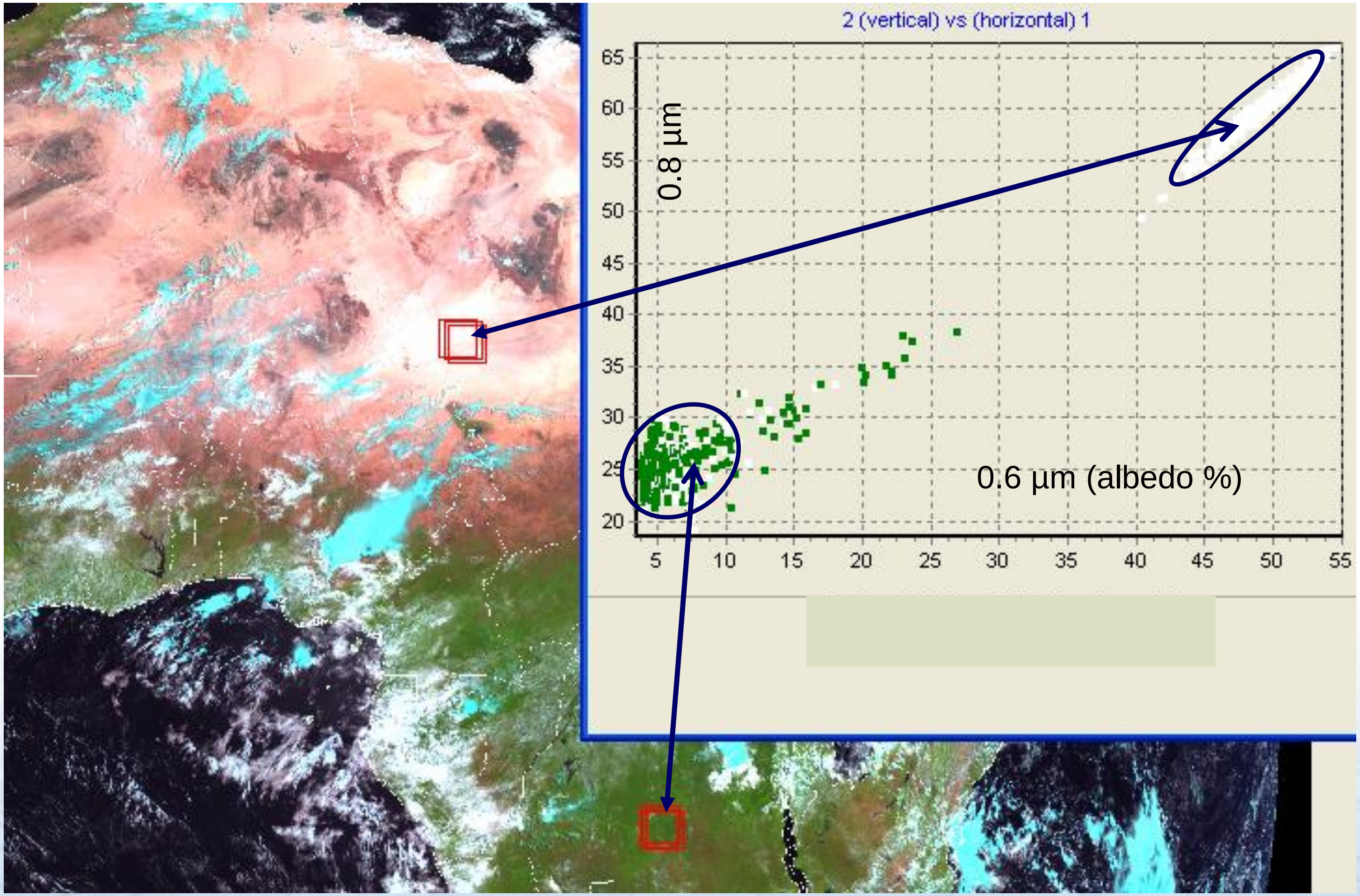
Meteosat-9
RGB Natural
colours
2008-04-06
12UTC



Where are the growing vegetation pixels on the graph?

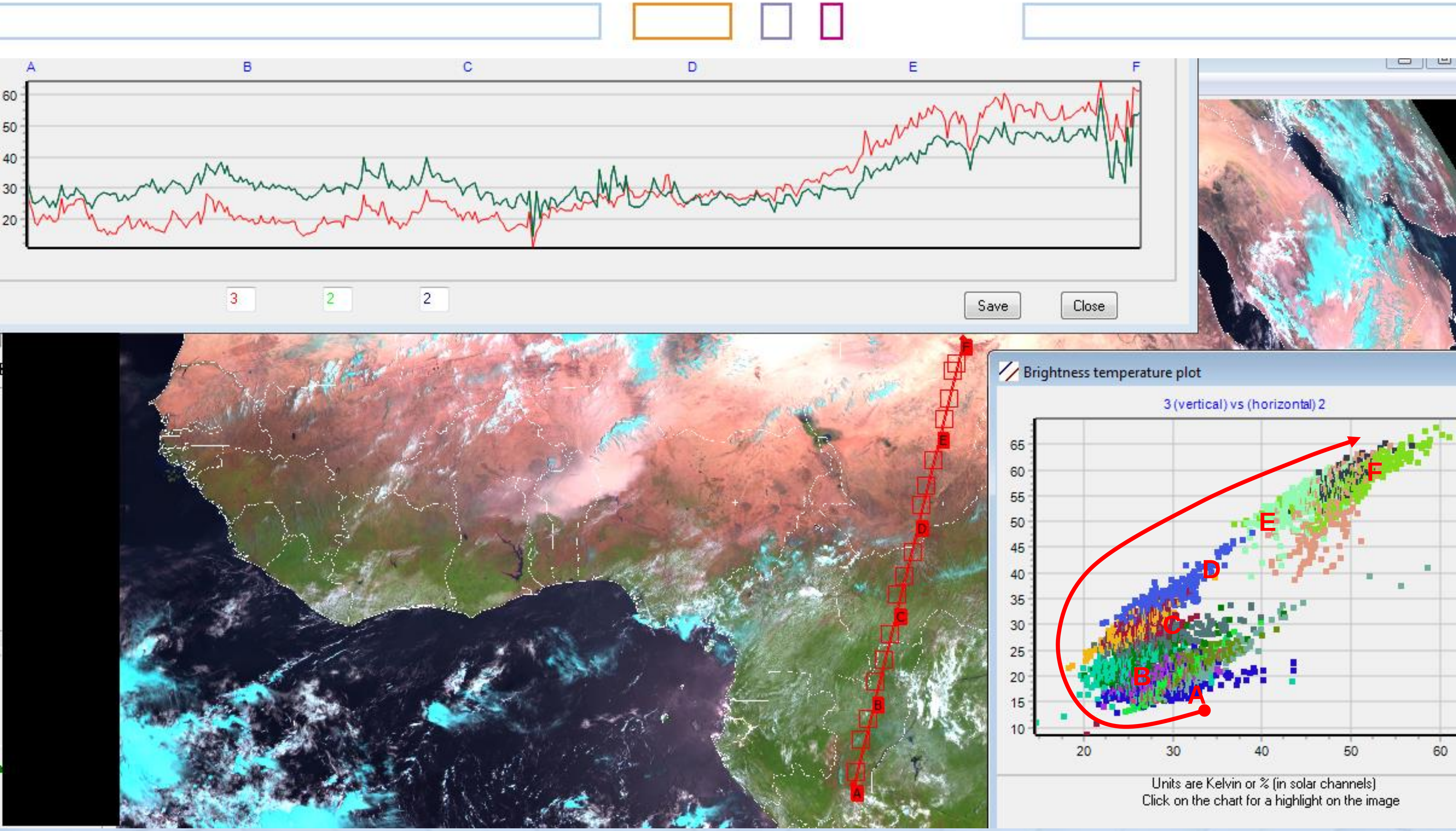


Desert and tropical forest in the solar channels



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

Comparison of 1.6µm and 0.8µm channels

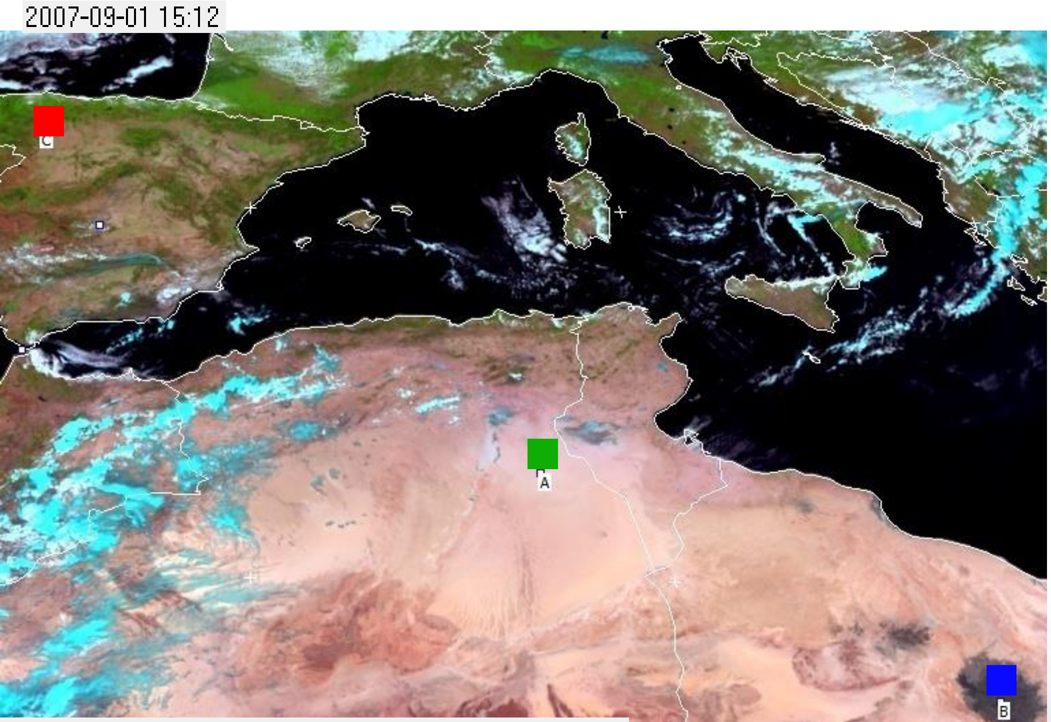


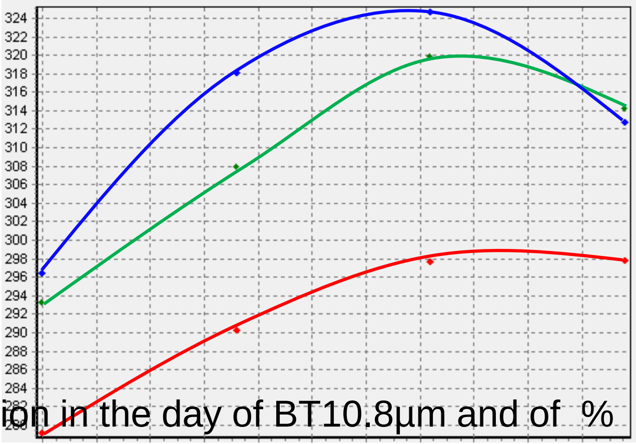
Brightness temperature plot

3 (vertical) vs (horizontal) 2

Units are Kelvin or % (in solar channels)
Click on the chart for a highlight on the image

Channel reflectivities on soil



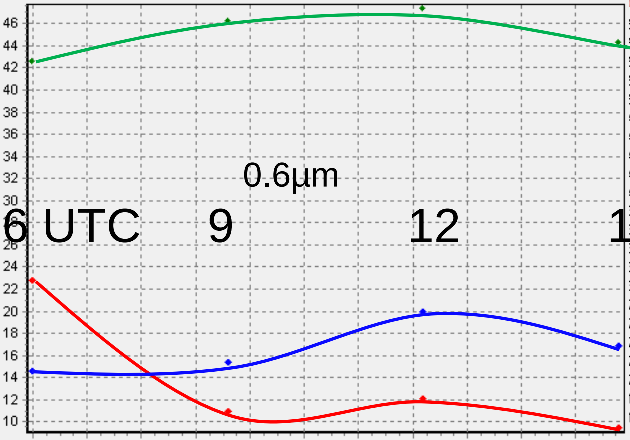


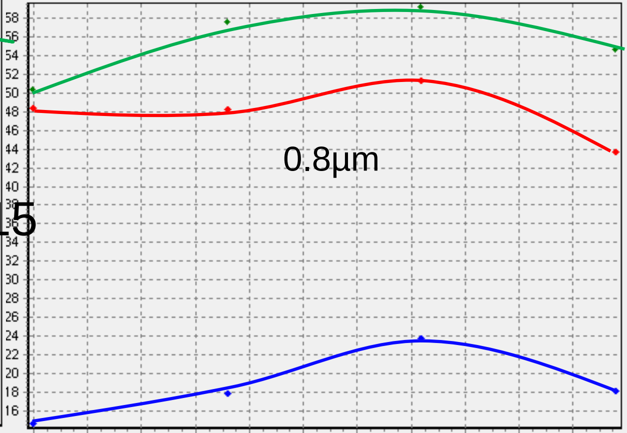
Evolution in the day of BT10.8µm and of % reflectivity at Meteosat channels 1,2 and 3:

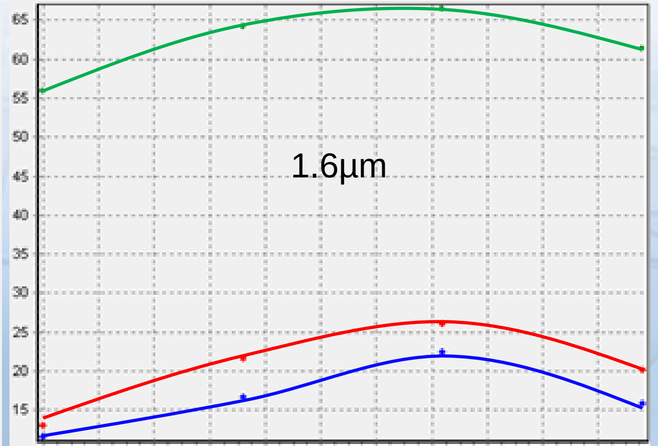
-Simple reflectivity formula shows directionality in reflection for

Sun-sat 90, 47, 15, 47

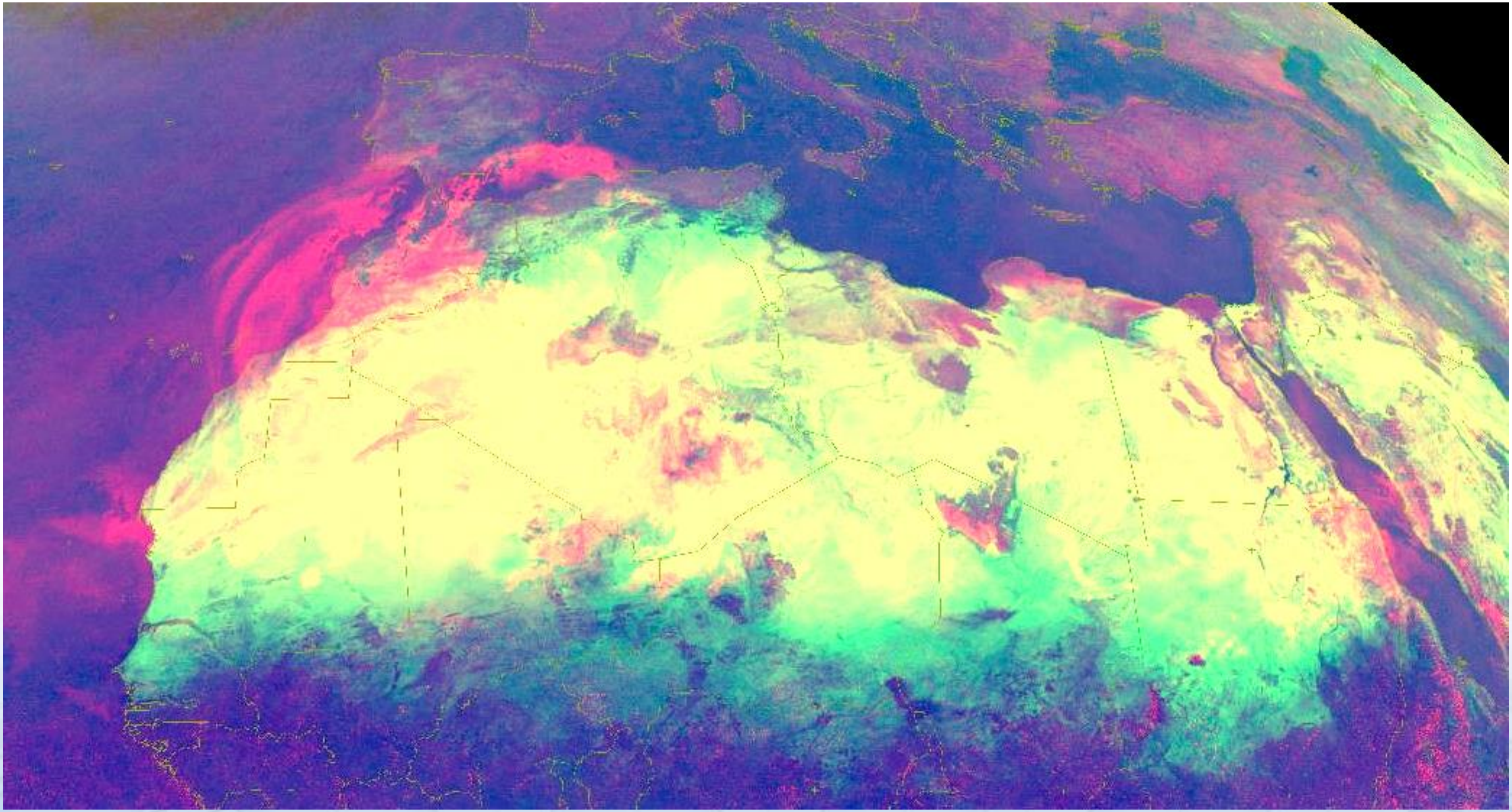
Solar: 77,41, 26, 54







Maximum of infrared composite: dust presence



20June- 19July 2015

Maximum of infrared channel (3.9µm): soil conductivity

20June- 19July 2015

Sand and rock areas discriminated by conductivity

Thin cloud, emissivity, conductivity

IR max imagery:

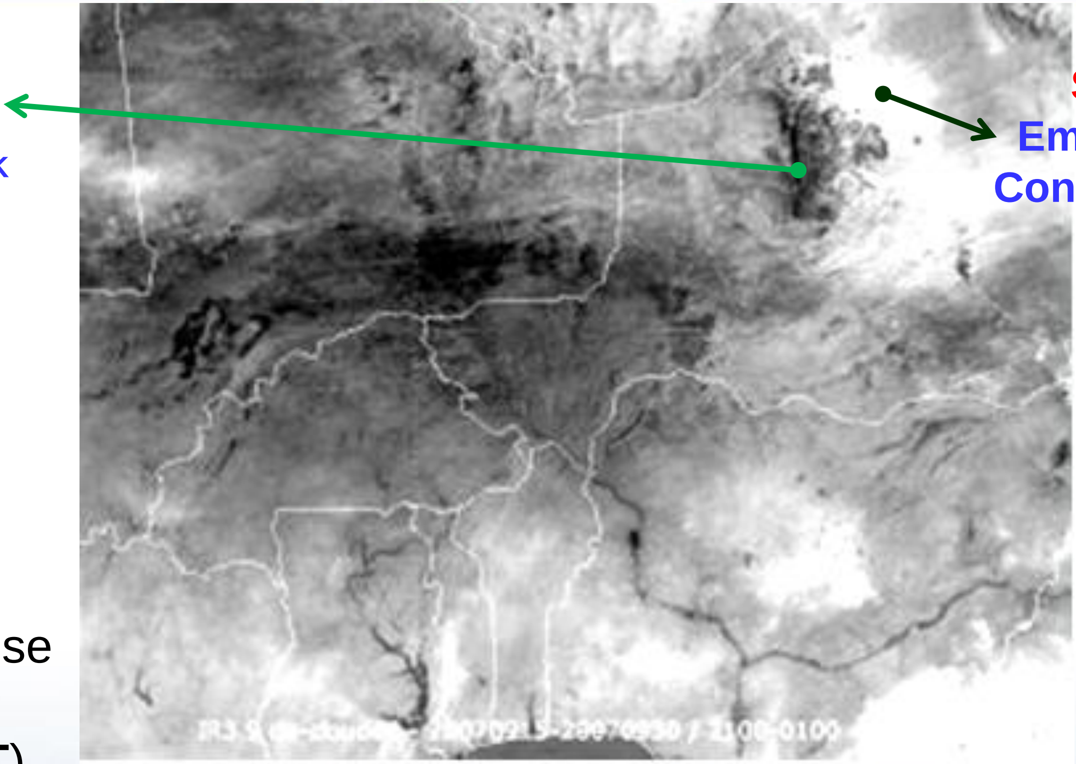
-Indication of soil emissivity-**conductivity** (i.e. separates rock from sand).

-Water and soil **humidity** raise the emissivity (higher brightness temperatures, **BT**)

-Removes cloud in long image series

-Sunglint-affected under 4 µm (water surfaces, reservoirs)

Rock
Emiss:0.9
Conduct: 2.0 W/m/K

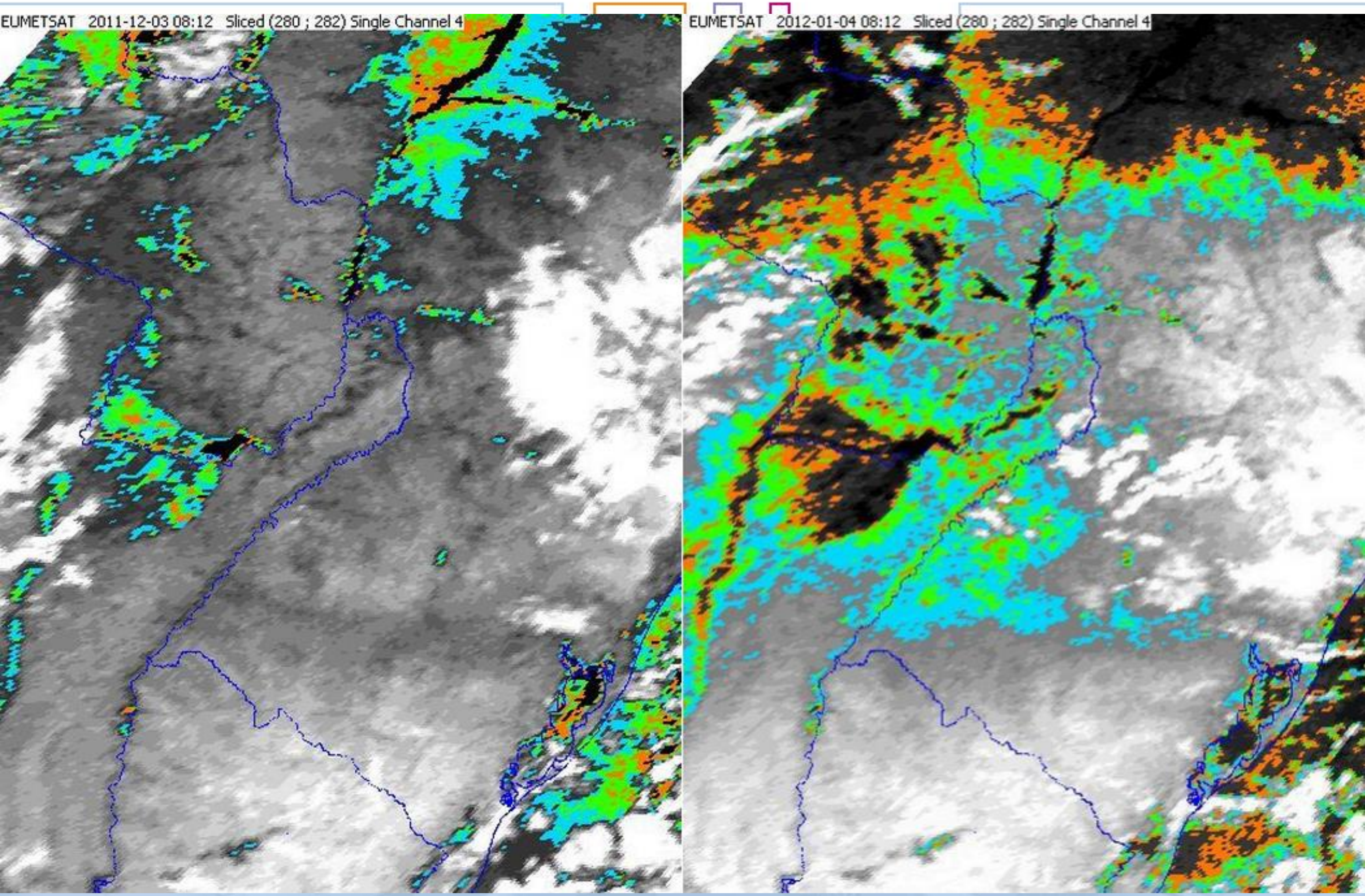


Sand
Emiss: 0.7
Conduct: 0.1

Met-9, 15-30 September 2007, 21:00-01:00 UTC
Channel 04 (IR3.9) max brightness temperature
Range: 288 K (white) to 298 K (black)

Warm water surfaces, rocky grounds and fires show in de-clouded images (maximum value in several days)
Sand is less emissive and cools off faster than rocky ground, which has texture

Channel 3.9µm before-after flooding, on consecutive nights



Solar: cloud influence. MIN image

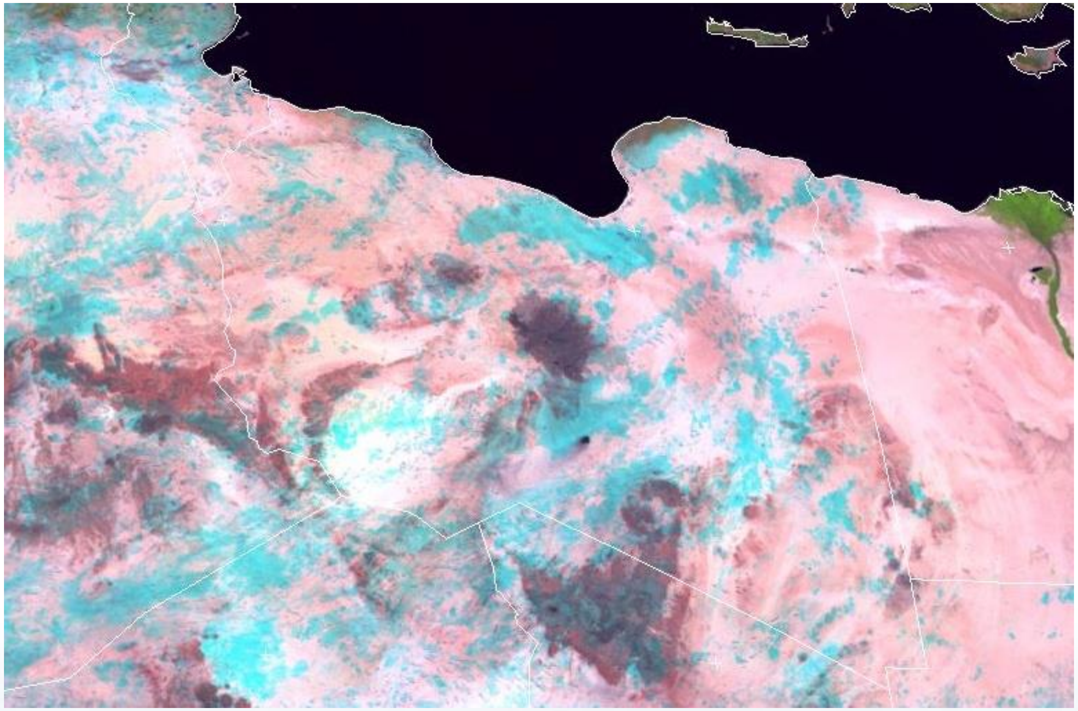
Solar min imagery:

-On **dry** surfaces, 1.6µm albedo is very high, so icy cloud (lower albedo) hides it.

-Lowest albedo at solar channels indicates **vegetation** maxima.

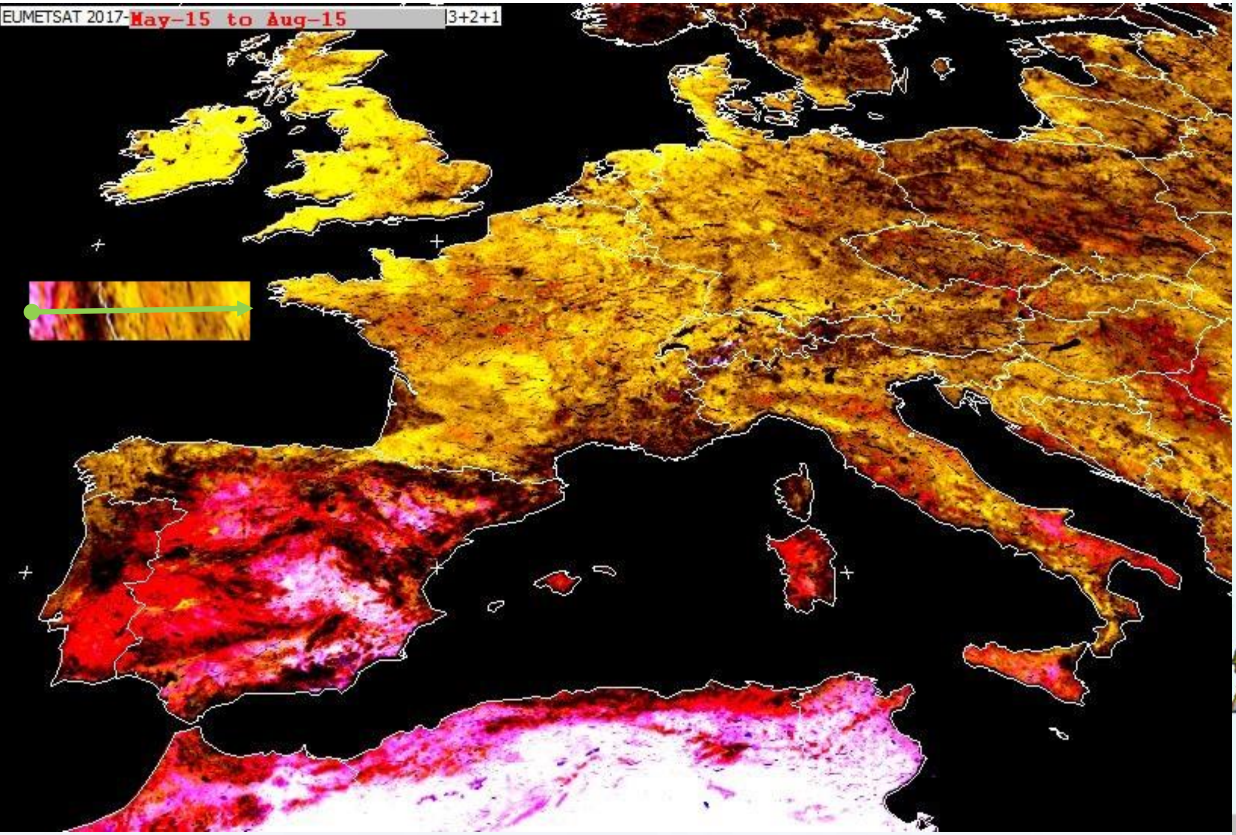
-Over water, low surface albedos prevail and are shown black.

-Sunglint **removed** at min image



Meteosat-10 20 July – 17 Aug 2015: MIN solar RGB at midday

Drought as a fire risk indicator



SIMPLIFIED GEOLOGICAL MAP OF BRITAIN AND WESTERN EUROPE.
This generalised map is modified after Kirkaldy (1967), and is not necessarily

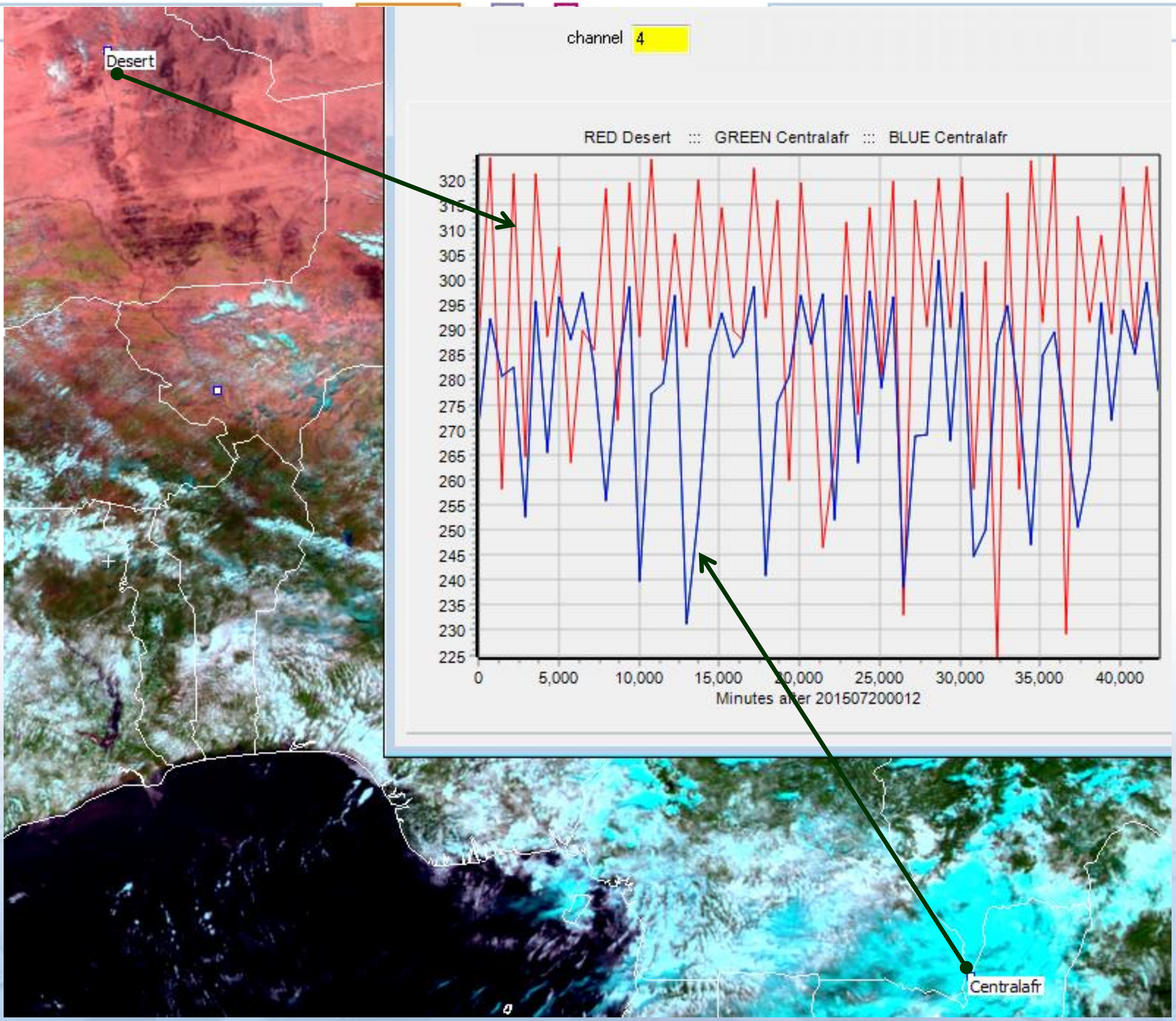
c3: sandy

Dry + Vegetation = Fire risk
Algorithm based on RGB=(min_in_period(max_on_pixel(c3,c2))
min_in_period(c2)
min_in_period(c1))
Fire risk areas in brown or red.

c1: dry

c2: growing

Midday-midnight oscillation: dry and humid ground + cloud



Skin layer entropy: connection between drought and fire risk

Hypothesis, TBC on imagery:

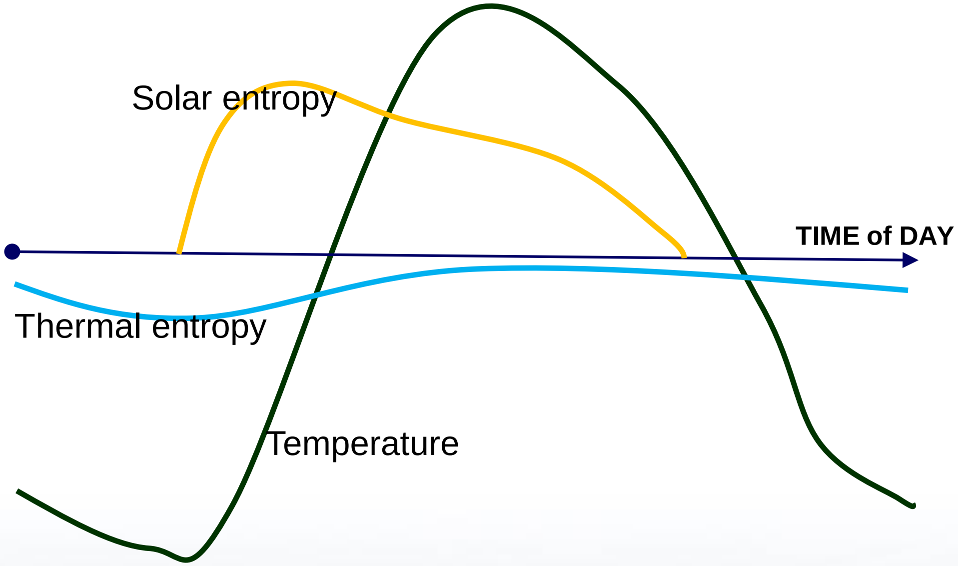
“Skin layer entropy peaks lead to **fires**, and shows a high correlation with fires”

There is a slow **conductive** term between surface and depth, which regulates the surface temperature and moderates the entropy changes.

Fast components are solar and thermal radiation.

Problem: No simple evaluation of the solar energy with **cloud**

Ground **temperature** and emissivity estimated from BT10.8µm and BT12µm



Solar entropy = cos θ * solar contant / soil temperature

Thermal entropy = emissivity * σ * temperature^3

Conclusions

- Solar channels at 0.6µm and 0.8µm are designed to measure vegetation growth

- Channel 1.6µm in Meteosat is a detection tool for dry sandy areas, and is used, concurrently with 0.6 and 0.8µm, for monitoring fractional cover of vegetation

- LSA SAF offers an excellent palette of vegetation products on a regular operational schedule. A library of **case** analyses with satellite imagery is being built. Please **contribute!**

- Studies relating accumulated **heat in soil** and fire onset expect your **cooperation**!

THANK YOU FOR YOUR ATTENTION!

EUMETSAT