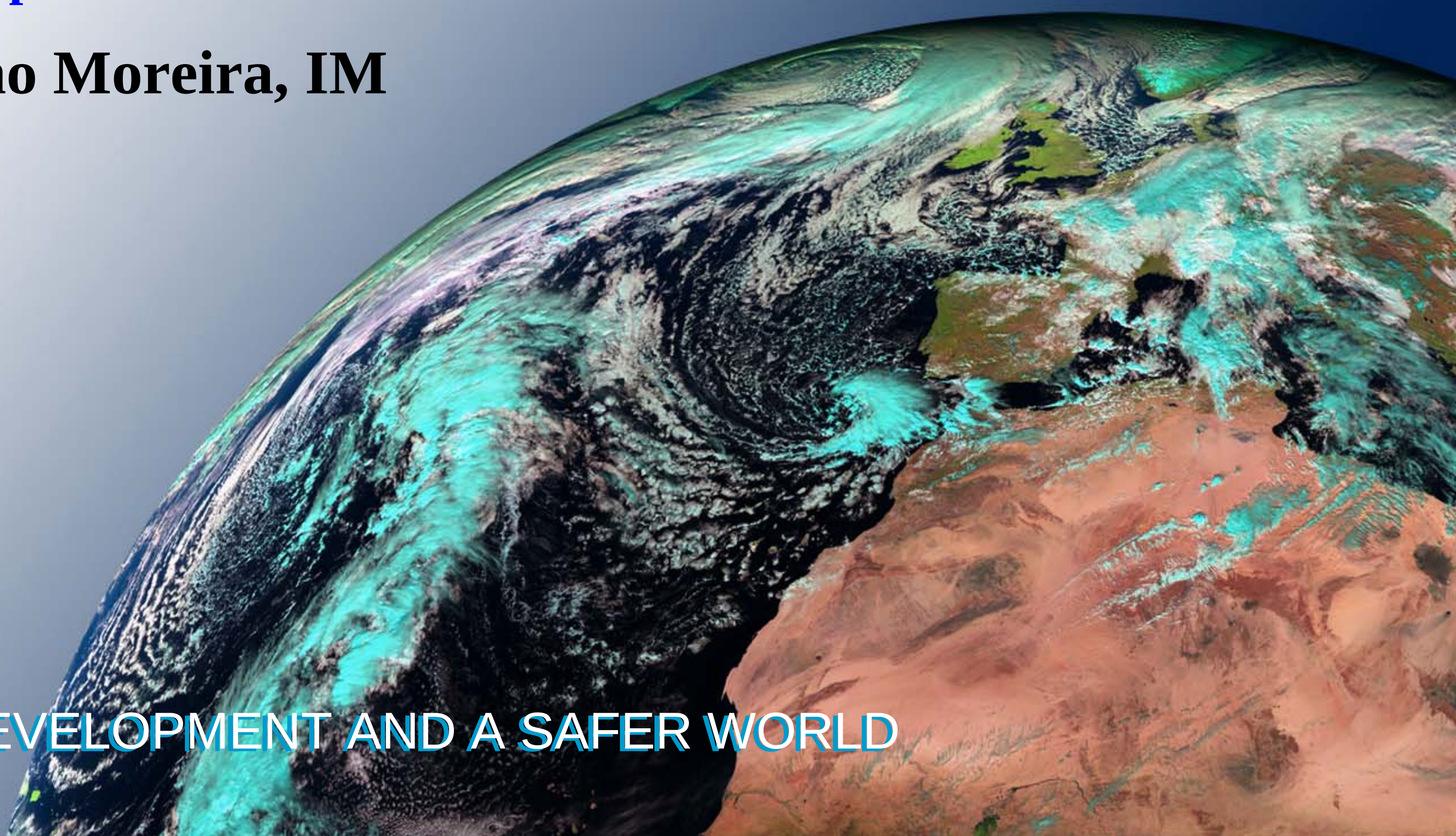
Satellite Image Interpretation and Applications

EUMETCAL/EUMETRAIN on-line course

Forest Fires

29 September 2011

Nuno Moreira, IM



MONITORING

WEATHER
CLIMATE
SEISMIC ACTIVITY

TO

A SUSTAINABLE DEVELOPMENT AND A SAFER WORLD

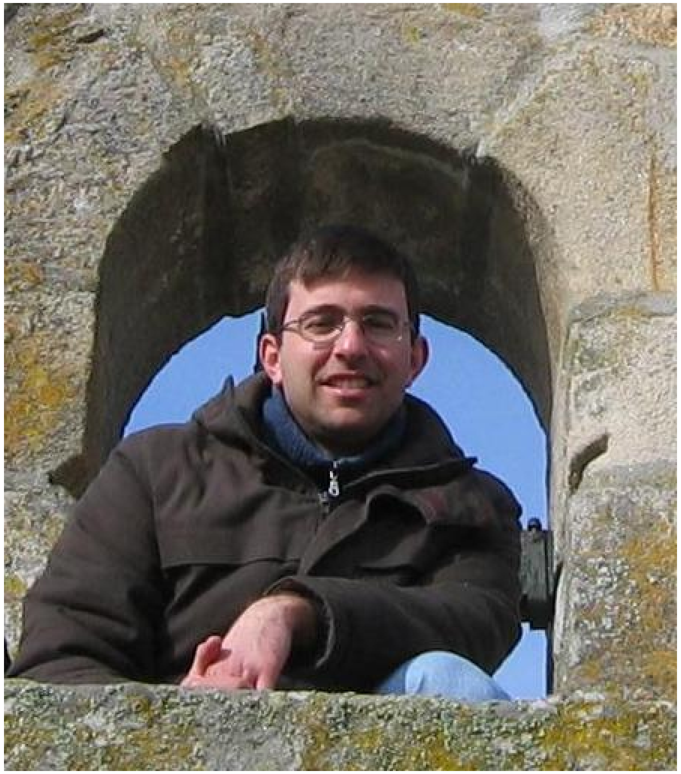
Outline

- Detection of Forest Fires Hot Spots

- Forest Fires Aerossol Detection

- Identification of Burnt Areas

- Fire Risk



Question ...

Q: How are **forest fires** and **fog** related ?

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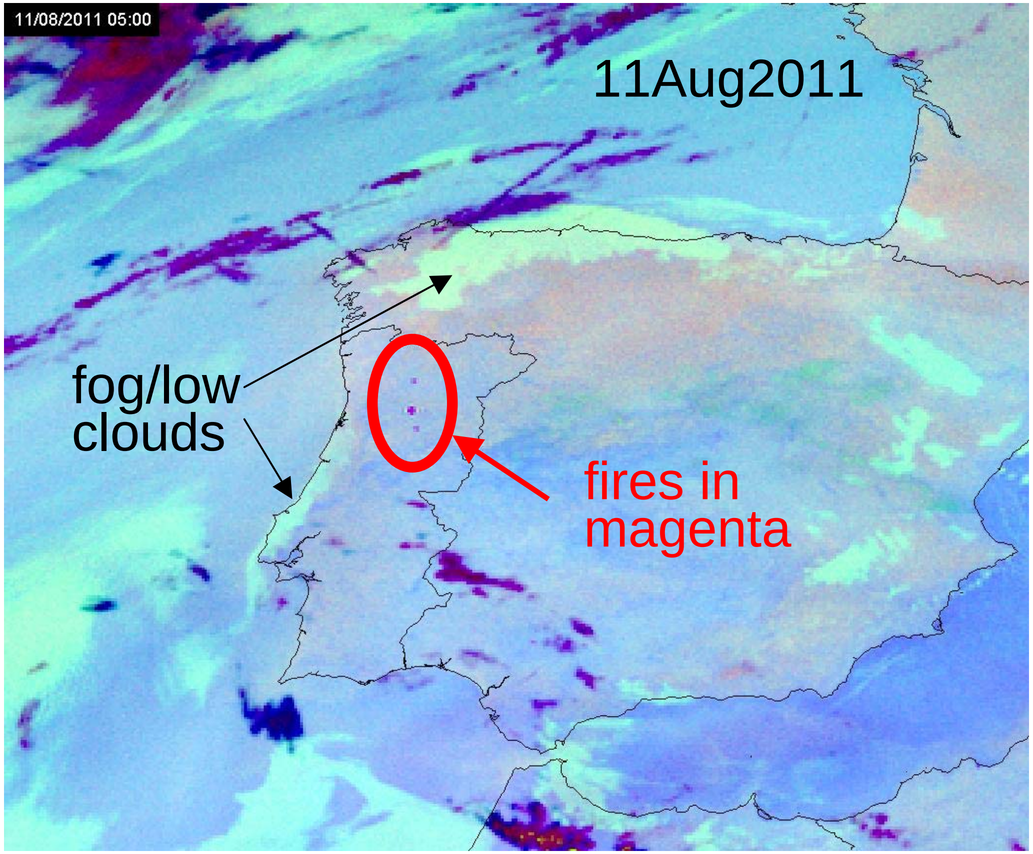
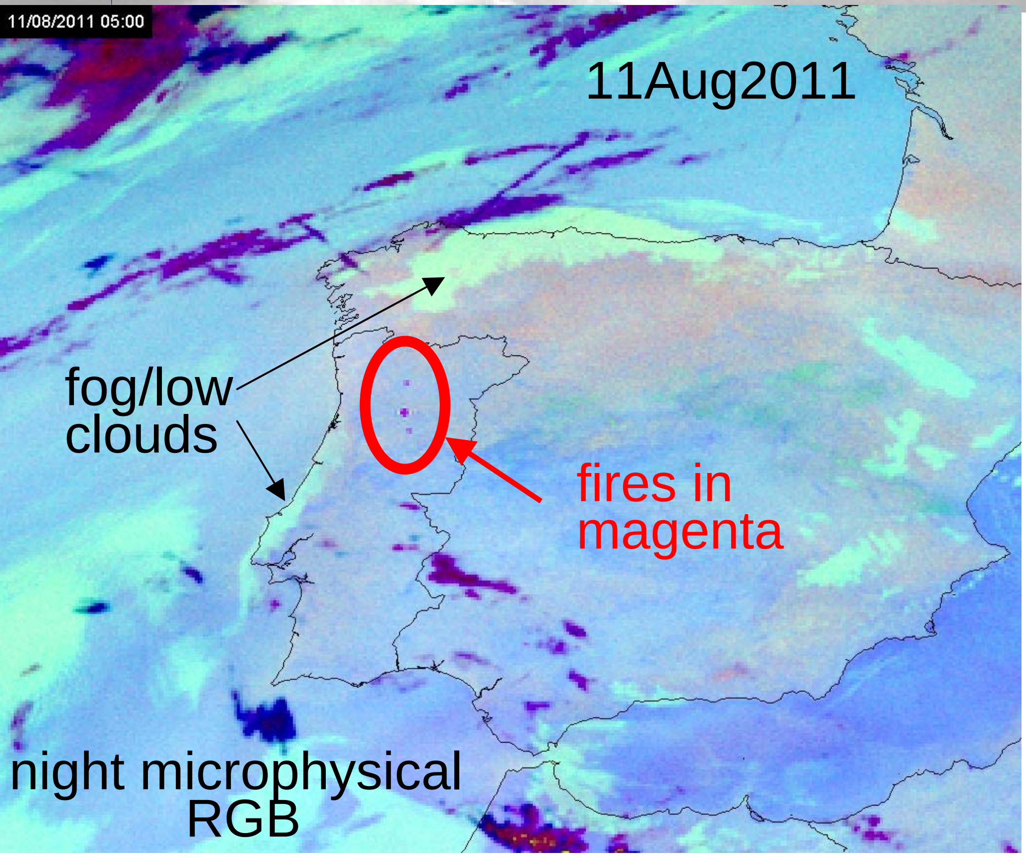
One possible answer...



A: They can be both detected using the night microphysical RGB

Now a more serious question ...



Q: Which channels are included in the night microphysical RGB ?

Use ✓ or ✗

Visible 0.6 micra	Visible 0.8 micra	High Res. Visible

Water Vapour 6.7 micra	Water Vapour 7.3 micra

Near IR 1.6 micra	IR 3.9 micra	IR 8.7 micra	IR 9.7 micra	IR 10.8 micra	IR 12.0 micra	IR 13.4 micra

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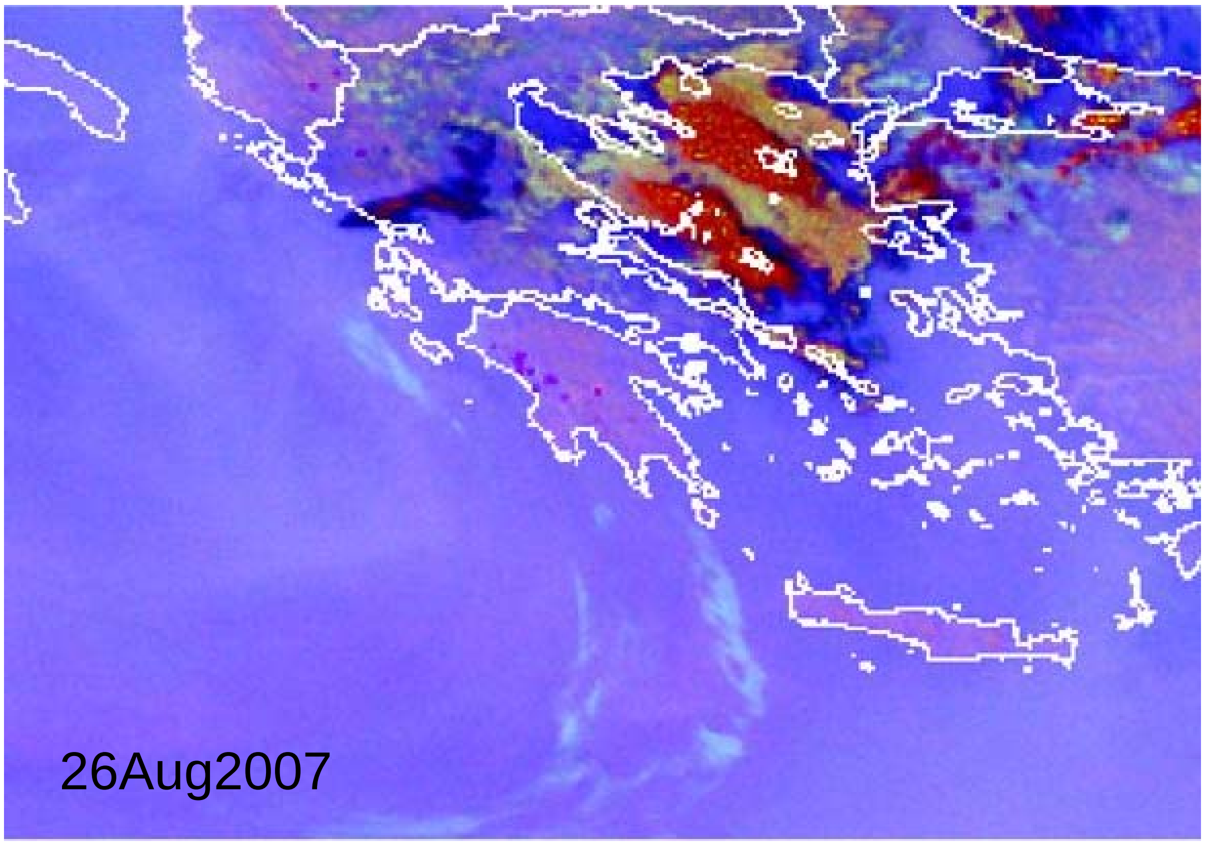
... and one recipe ...

Red	=	IR12.0 – IR10.8	-4 to +2K
Green	=	IR10.8 – IR3.9	0 to +10K
Blue	=	IR10.8	+243 to +293K



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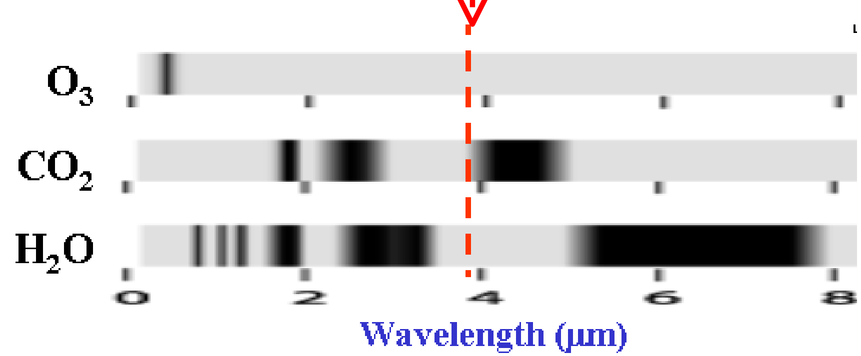
so ... the IR3.9 channel!

Channel no.		Characteristics of spectral band (μm)			Main gaseous absorber or window
		λ_{cen}	λ_{min}	λ_{max}	
1	VIS0.6	0.635	0.56	0.71	Window
2	VIS0.8	0.81	0.74	0.88	Window
3	NIR1.6	1.64	1.50	1.78	Window
4	IR3.9	3.90	3.48	4.36	Window
5	WV6.2	6.25	5.35	7.15	Water vapor
6	WV7.3	7.35	6.85	7.85	Water vapor
7	IR8.7	8.70	8.30	9.10	Window
8	IR9.7	9.66	9.38	9.94	Ozone
9	IR10.8	10.80	9.80	11.80	Window
10	IR12.0	12.00	11.00	13.00	Window
11	IR13.4	13.40	12.40	14.40	Carbon dioxide
12	HRV	Broadband (about 0.4 – 1.1)			Window/water vapor

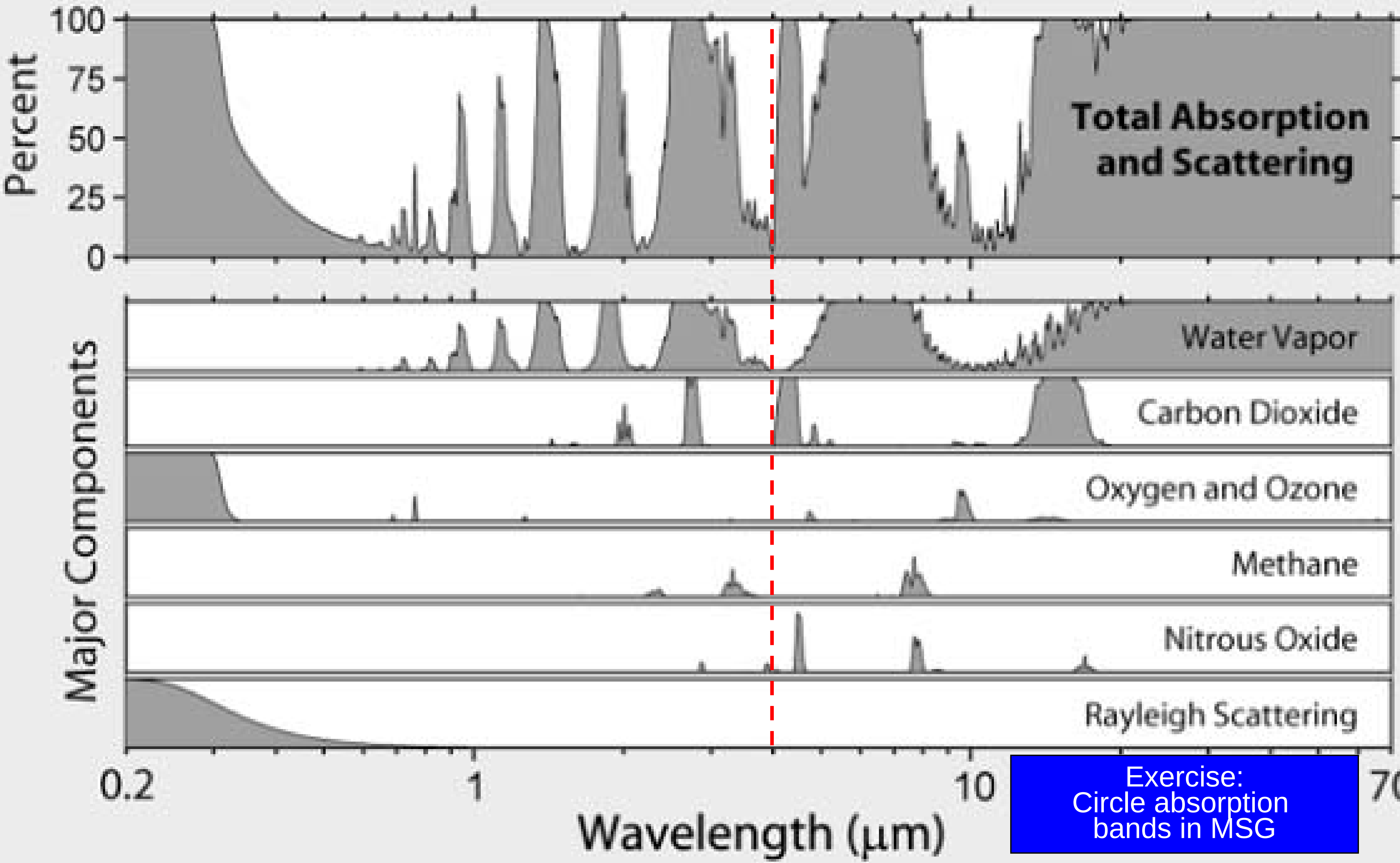
IR3.9 can be called a window channel, but is close to a CO_2 absorption band



Schmetz et al (2002)

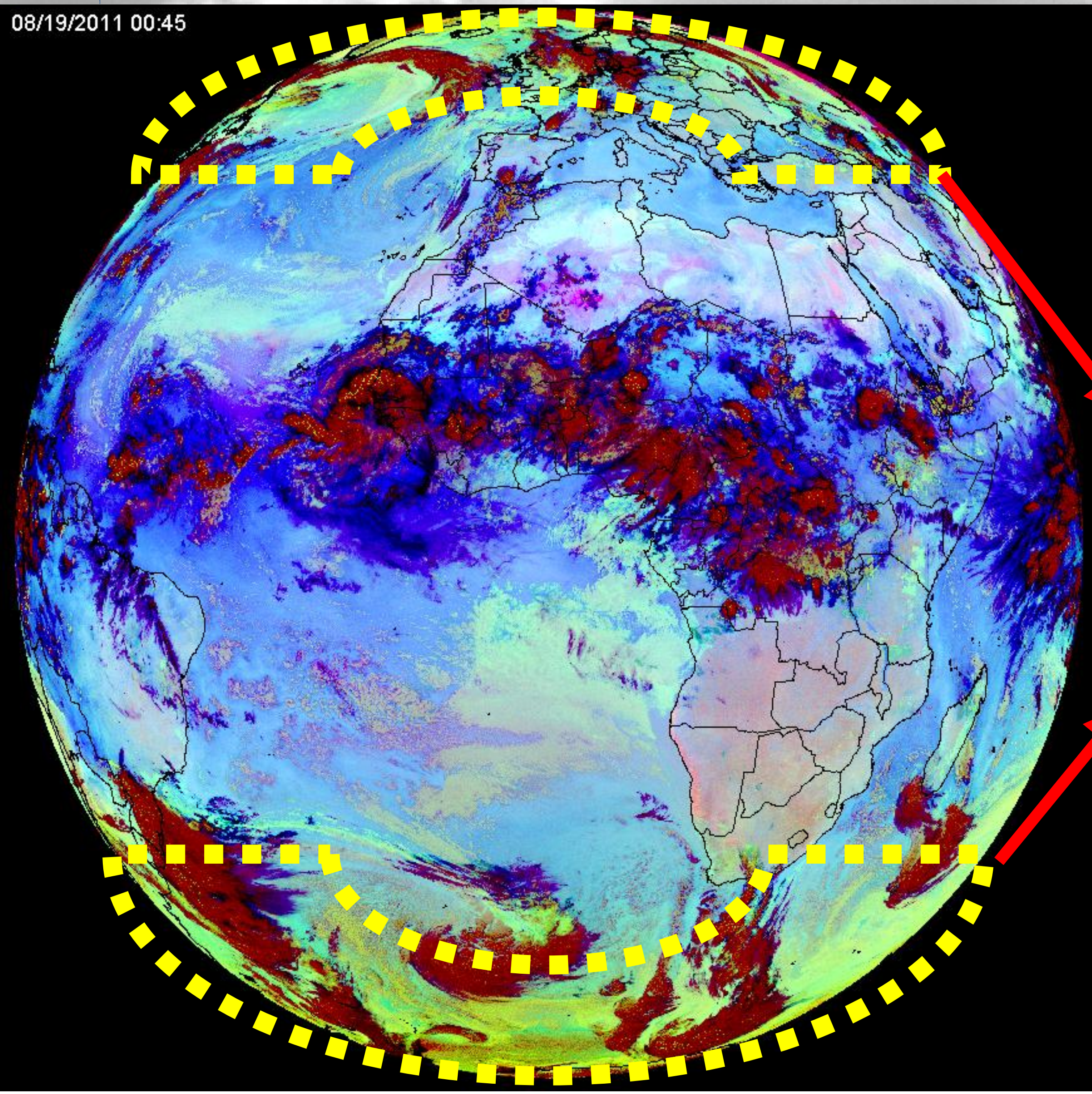
The IR3.9 channel and absorption bands

à frente do nosso tempo



Exercise:
Circle absorption bands in MSG

The IR3.9 channel and absorption bands



night microphysical RGB

Red	=	IR12.0 – IR10.8	-4 to +2K
Green	=	IR10.8 – IR3.9	0 to +10K
Blue	=	IR10.8	+243 to +293K

Limb cooling:

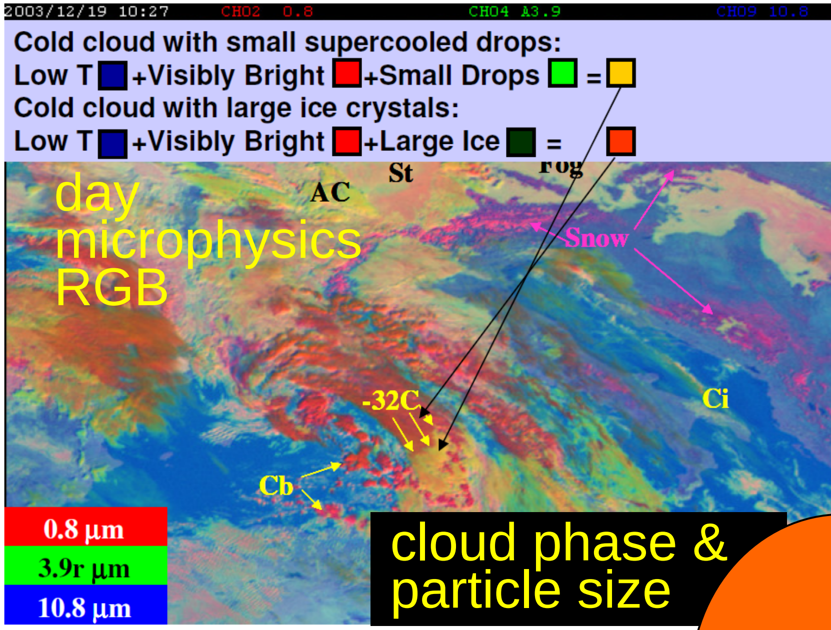
- In the edge of the globe view of a geostationary satellite (high incidence angles)

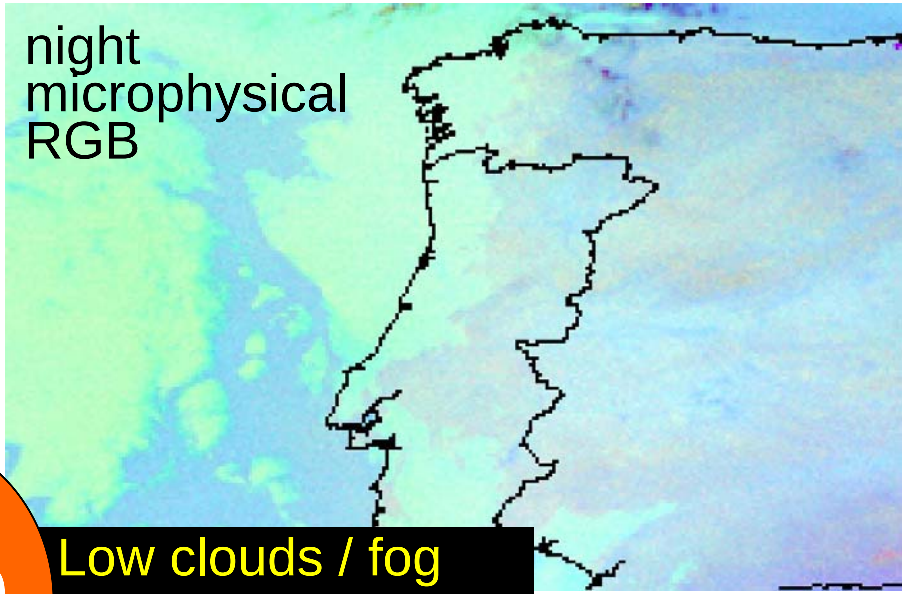
- Radiation travels longer distances in the atmosphere

- Significant absorption of 3.9 micra radiation due to existing CO_2

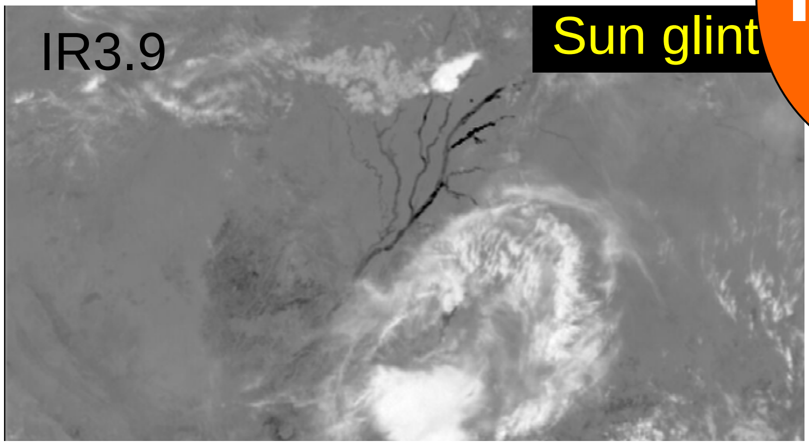
- Greener shades (only!) for high incidence angles

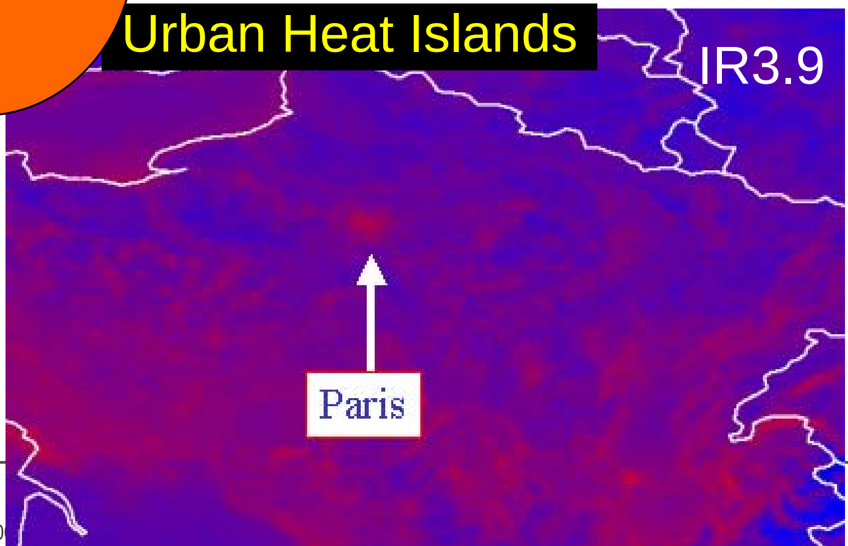
The “multi-task” IR3.9 channel



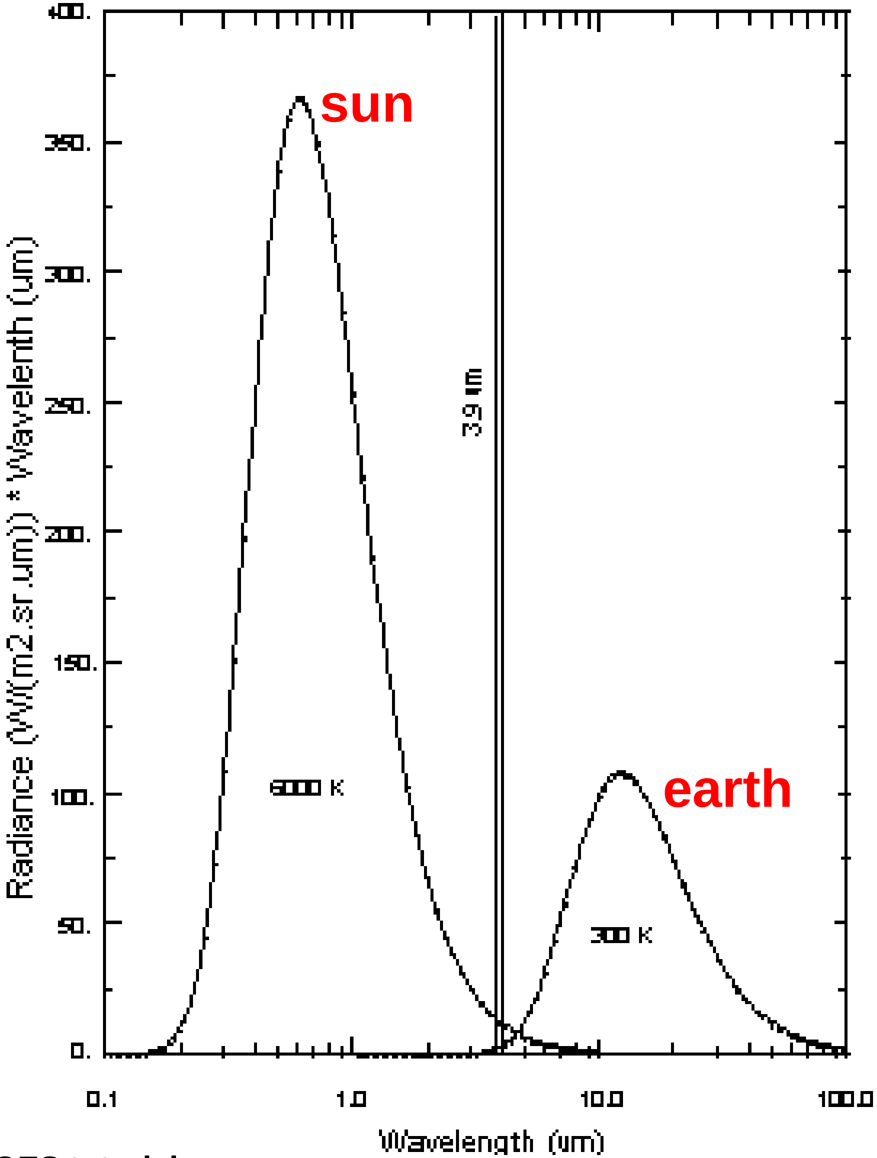


IR 3.9





The IR3.9 & Planck´s Law



Planck´s law:

"Variation with wavelength of black body monocromatic irradiance (radiant flux per area unit per wavelength) at specific temperatures"

Brightness temperature:

$$T_{B\lambda} = \frac{c_2}{\lambda \ln\left(\frac{c_1}{\lambda^5 B_\lambda} + 1\right)}$$

$$c_1 = 1.19 \times 10^{-8} Wm^{-2} ster^{-1} cm^{-4}$$

$$c_2 = 1.439\, Kelvin \times cm$$

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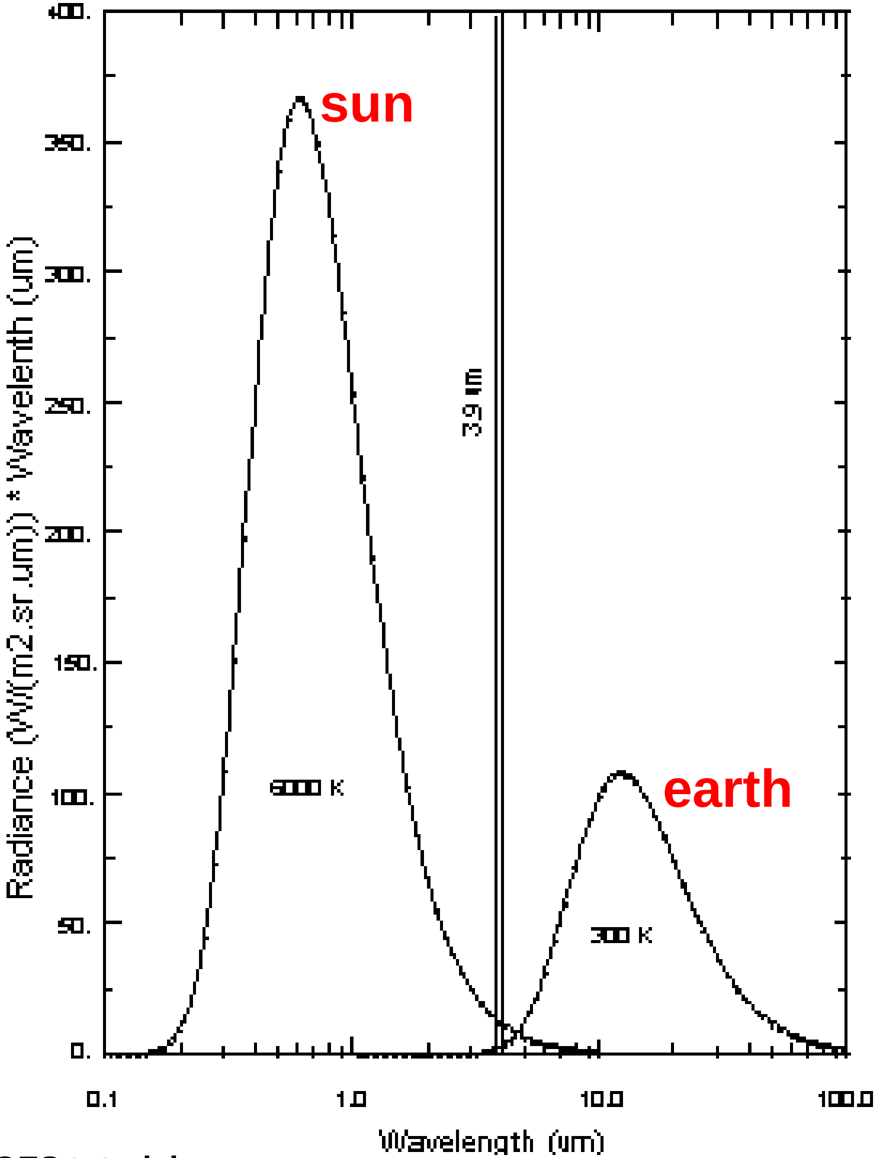
The IR3.9 & Planck´s Law



GOES tutorial

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Channel IR3.9 covers the spectrum of both solar and earth radiation

1 disadvantage: only during night we are sure IR3.9 signal is coming from the earth

1 advantage: at least during night we are sure IR3.9 signal is coming from the earth

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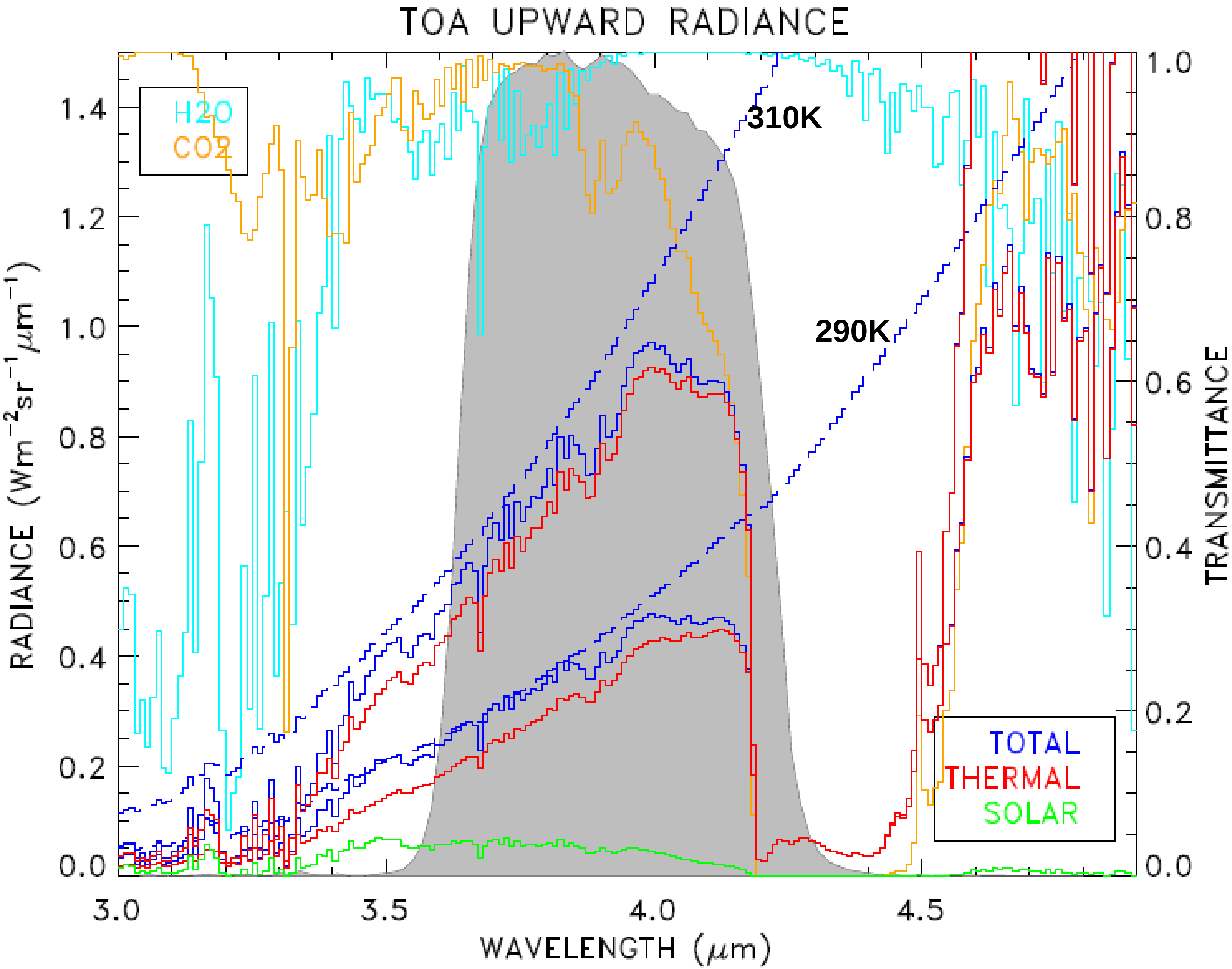
IR3.9 – the whole picture !

à frente do nosso tempo



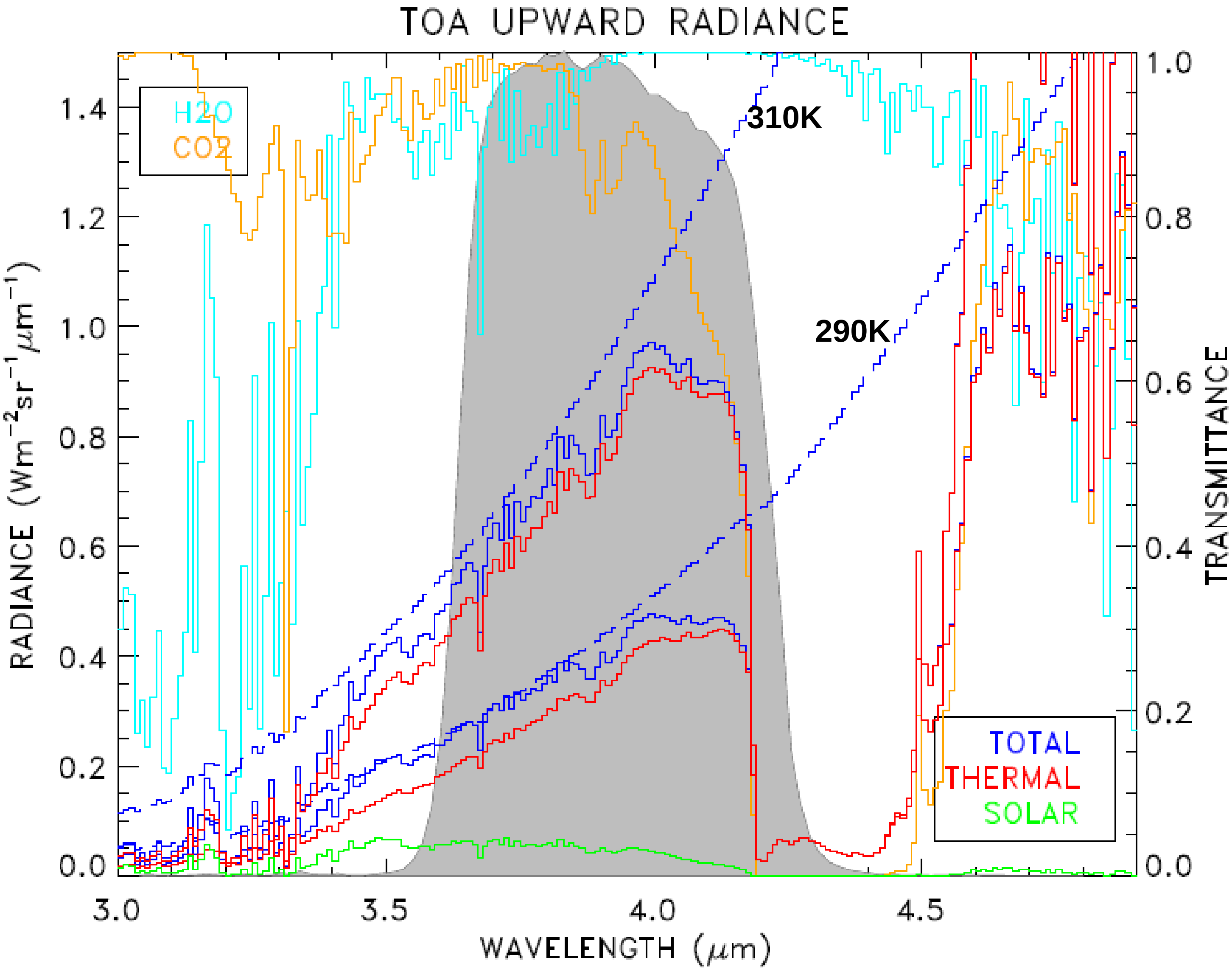
IR3.9 band in grey shade

H_2O Transmittance in Cyan

CO_2 Transmittance in Orange

Govaerts et al (2010)

IR3.9 – the whole picture !



Govaerts et al (2010)

IR3.9 band in grey shade

H_2O Transmittance in Cyan

CO_2 Transmittance in Orange

surface spectral total radiance in dashed blue

Top of Atmosphere spectral total radiance in solid blue

Thermal component in red

Solar component in green

Wien´s Law

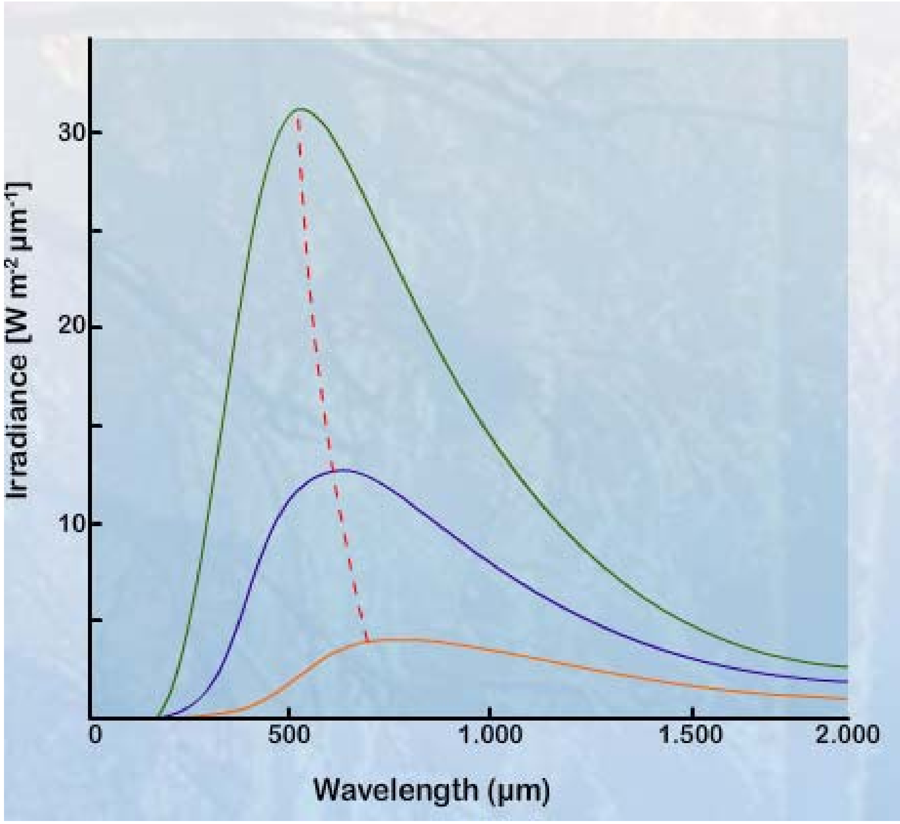
Wien´s law:

$$\lambda_m \times T = A$$

$$A = 2897\ \mu m\ K$$

T= Color temperature

λ_m = *Wavelength for the peak of Planck´s curve*



Wien´s law:
"The hotter an object is, the shorter the wavelength at which it will emit most of its radiation"

Wien´s Law

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$$\lambda_m \times T = A$$

$$A = 2897\ \mu m\ K$$

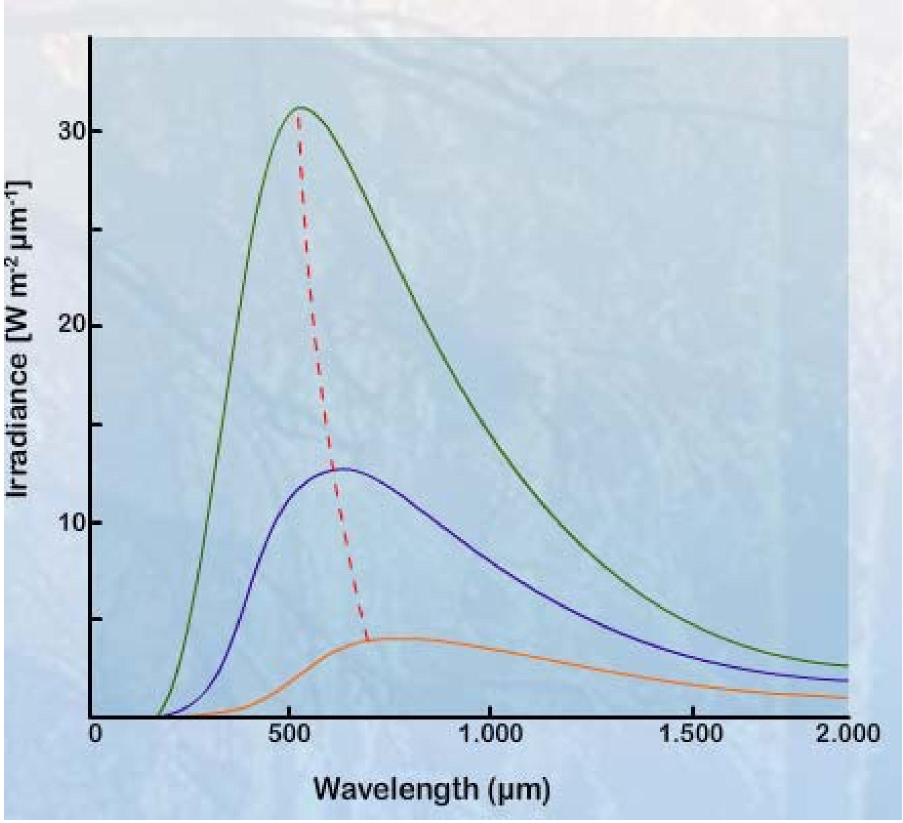
T= Color temperature

λ_m = Wavelength for the peak of Planck´s curve

Exercise:

Which is the color temperature (in ºC) of a body that has the irradiance peak at 3.9 micra ?

2/3 minutes



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Wien´s Law

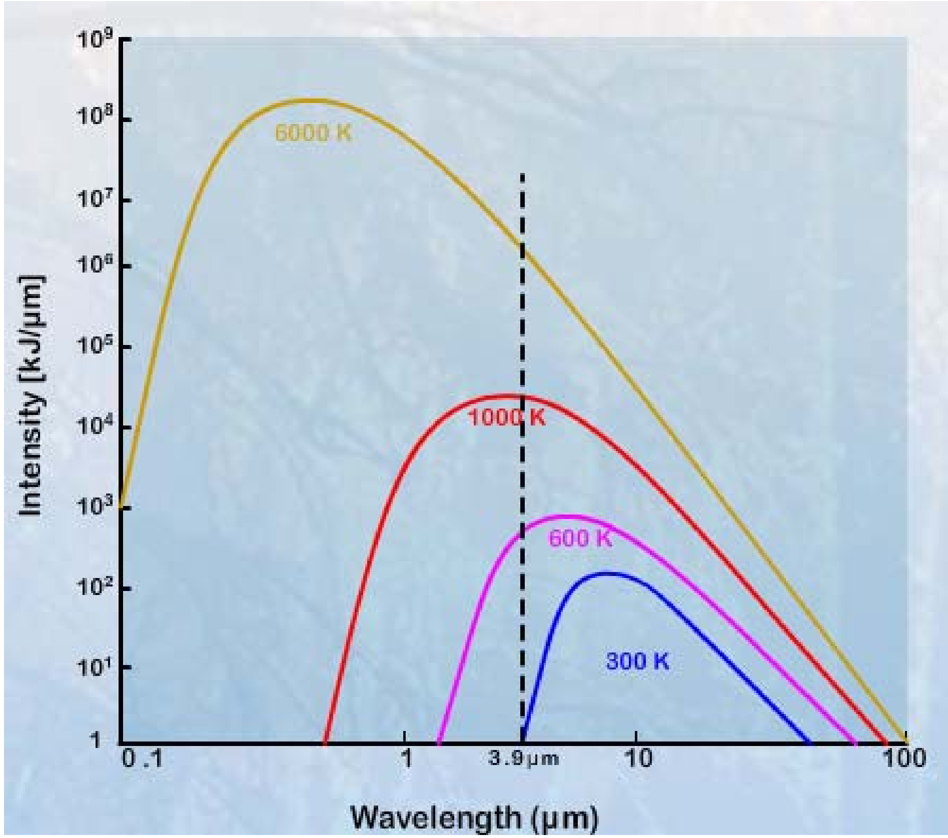
Exercise - resolution

Which is the color temperature (in ºC) of a body that has the irradiance peak at 3.9 micra ?

$$\lambda_m \times T = 2897\,\mu m\ K$$

$$\lambda_m = 3.9\,\mu m \Rightarrow T = \frac{2897}{3.9} = 742.8K$$

$$\therefore \quad T(°C) = 742.8 - 273.15 = 469.65°C$$



Wien´s Law & Fire temperature

Exercise - resolution

Which is the color temperature (in ºC) of a body that has the irradiance peak at 3.9 micra ?

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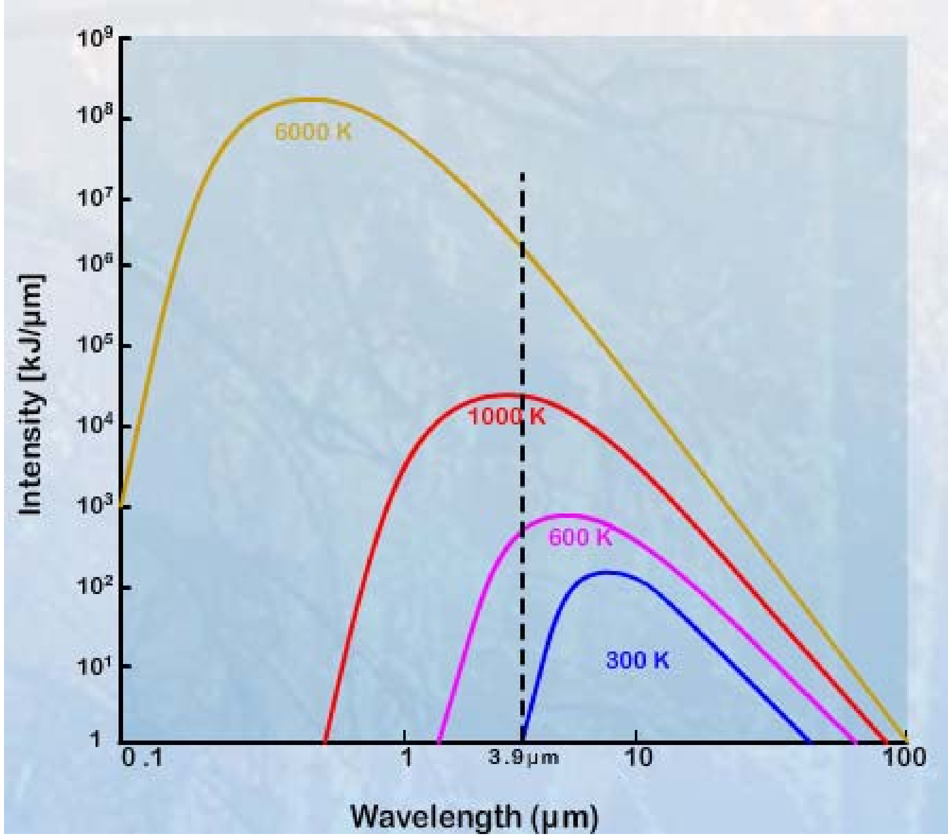


Question:

Which can be the temperature of a fire ? Write a number in the text chat ...

Fire temperature

Forest fire flame temperatures range from 600K to 1500 K

The most expected temperature during active phases: 1000 K

IR3.9

NIR1.6

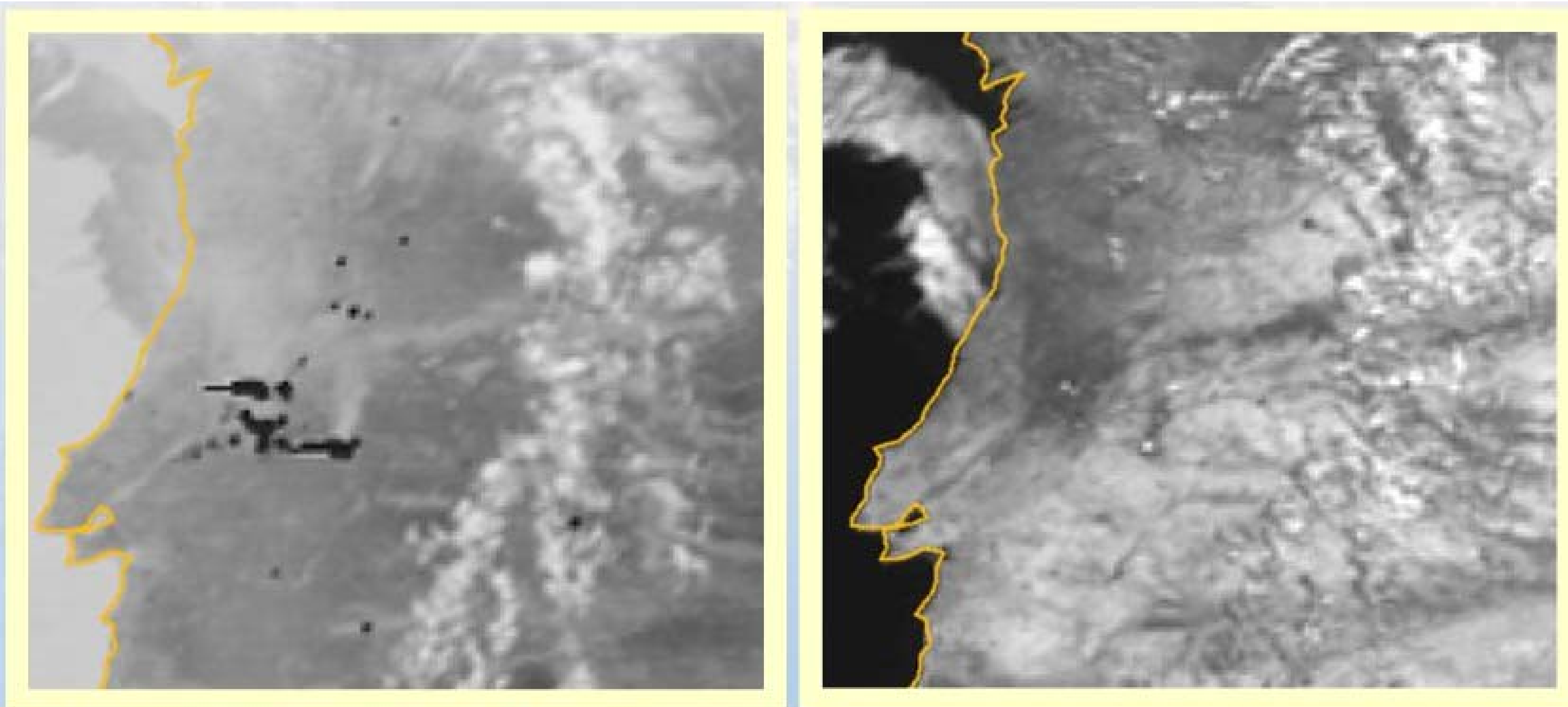


Fig 5.9 - Left image: Meteosat 8 IR3.9 - 3 August 2003 12:00 UTC (inverted grey scale - hot spots as darker pixels). Right image: Meteosat 8 NIR1.6 for the same instant (non-inverted grey scale - hot spots as white pixels). Source: MSG Interpretation guide

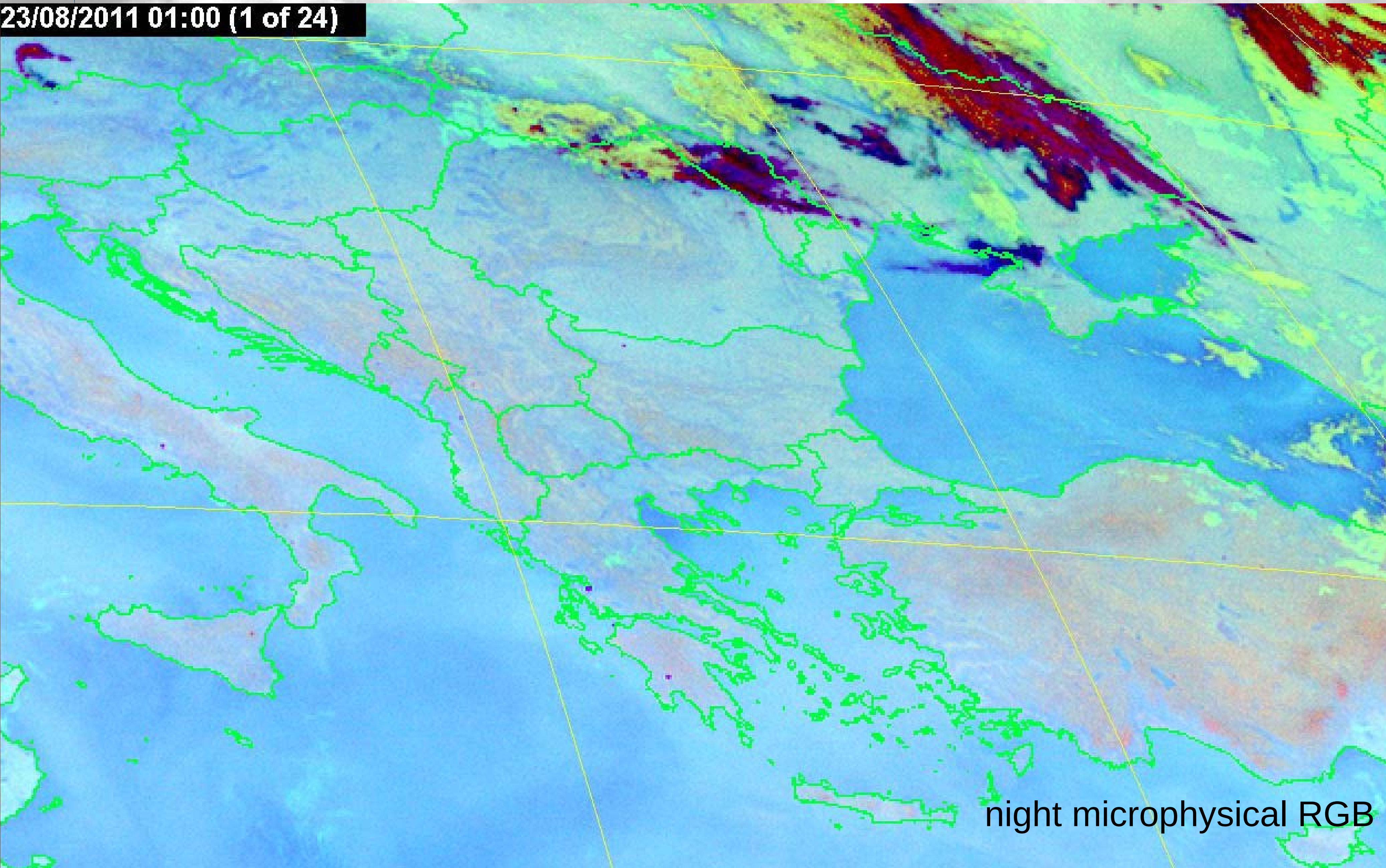
From Wien´s law:

1.6 micra is the wavelength at which a black body at ***1537 K*** has the emission peak

>> emited radiation component of NIR1.6 <<

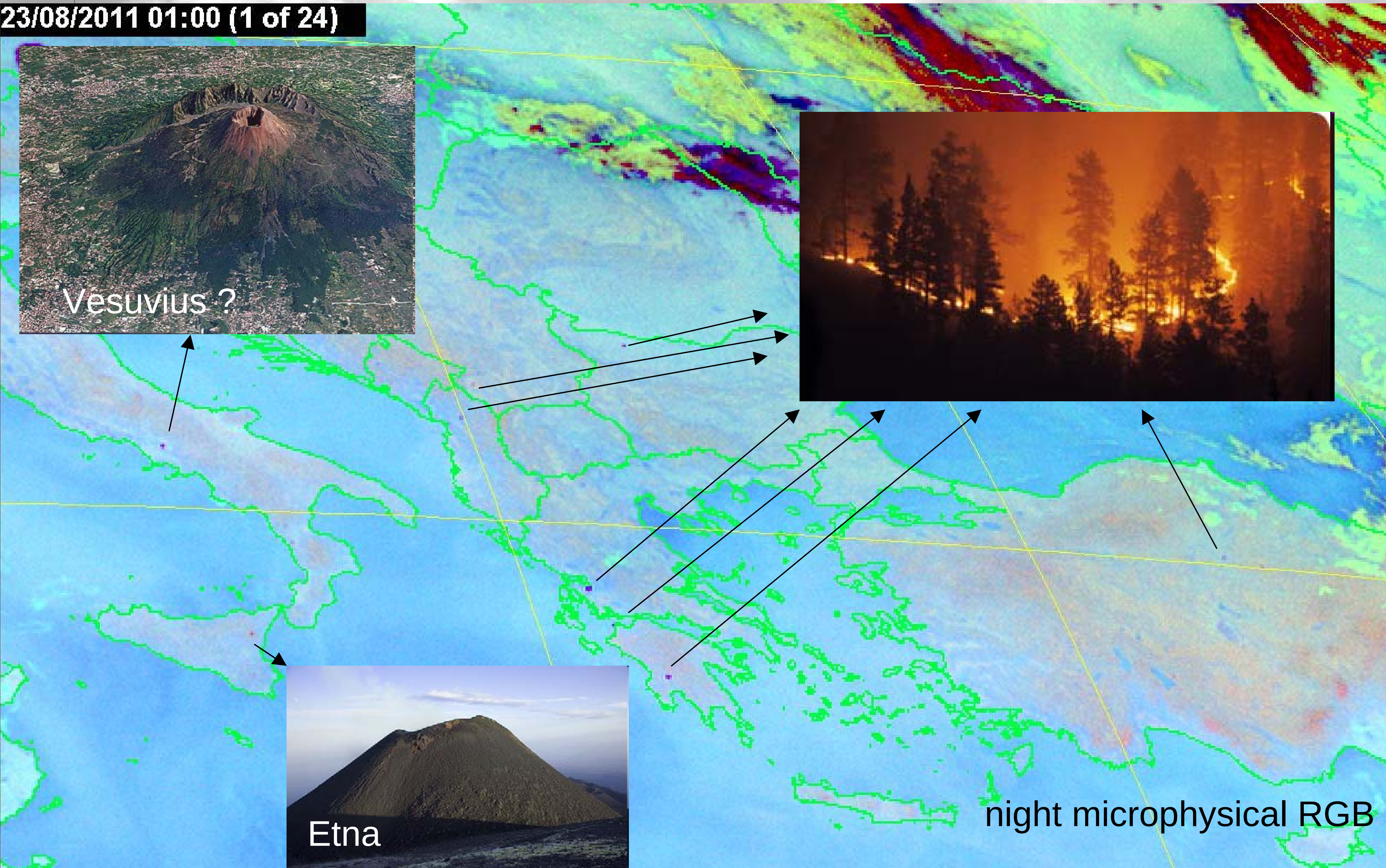
à frente do nosso tempo

Where do you suspect of forest fires?



à frente do nosso tempo

Where do you suspect of forest fires?



IR10.8 and IR3.9

Question:

And could IR10.8 alone also be used to detect fires ?

Temperature Responsivity

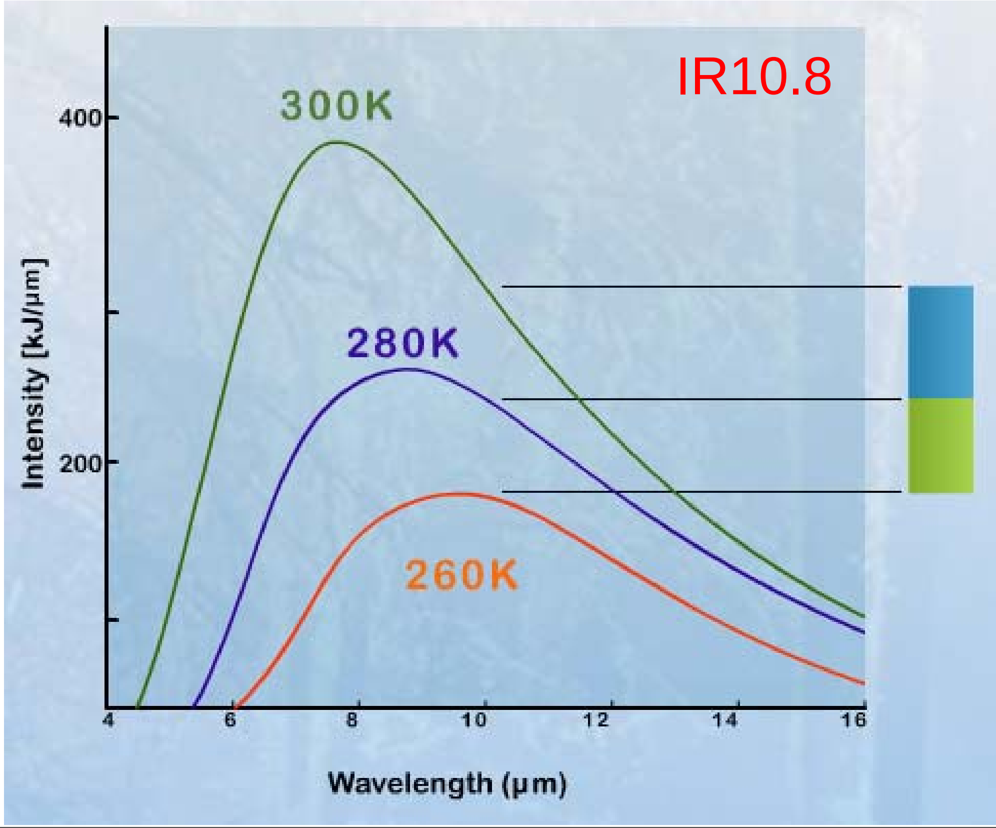
Question:

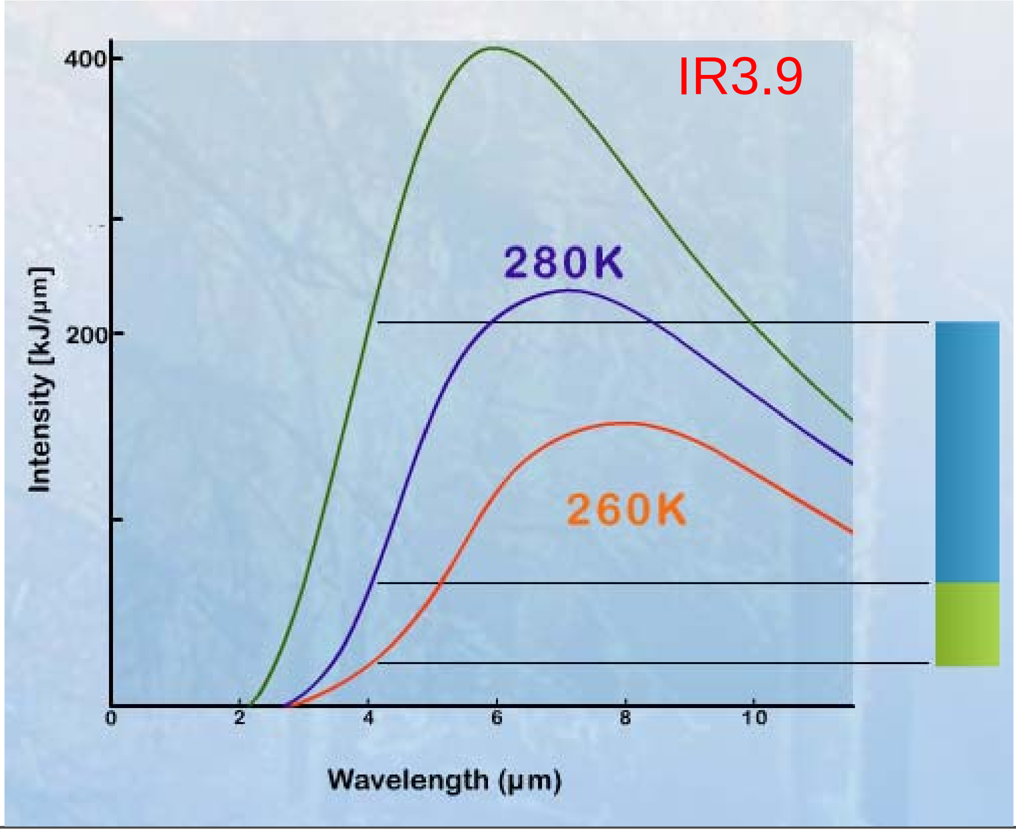
And could IR10.8 alone also be used to detect fires ?

Answer:

Not really...

Temperature Responsivity



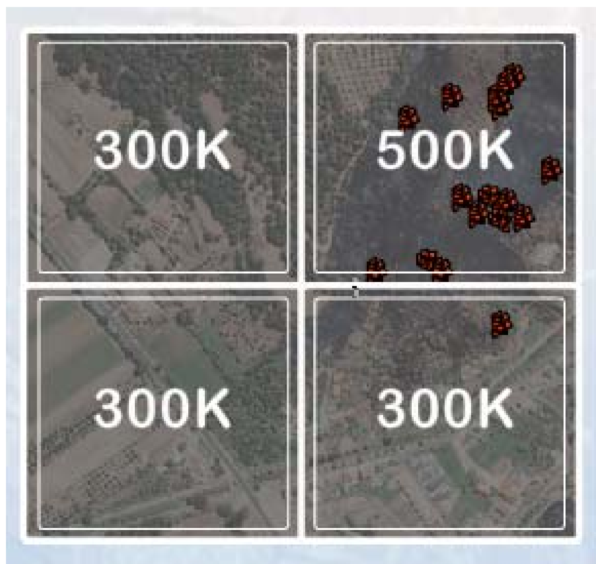


Sub-Pixel Response

"The measured radiance in a pixel is the average of individual radiances in the sub-pixels"

1 pixel

4 sub-pixels



Rayleigh-Jeans approximation:

$$B = T^{a/\lambda}$$

radiance

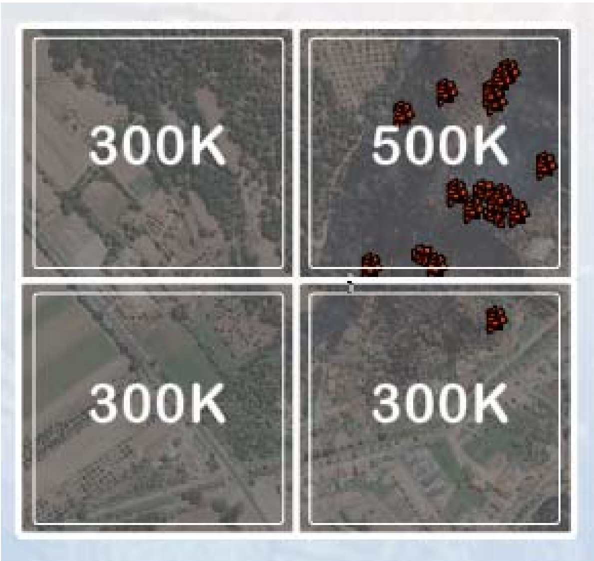
constant

temperature

wavelength

Sub-Pixel Response

4 sub-pixels



Which will be the pixel brightness temperature in IR10.8 and IR3.9 ?

$$B = T^{\alpha/\lambda}$$

$$IR10.8 \Rightarrow \frac{\alpha}{\lambda} = 4.8$$

$$IR3.9 \Rightarrow \frac{\alpha}{\lambda} = 13.4$$

Averaging radiances ✓
or
Averaging temperatures? ✗

IR10.8

$$B = T^{4.8}$$

$$B = \frac{B1 + B2 + B3 + B4}{4}$$

$$T = B^{1/4.8}$$

$$T = 392\ K$$

IR3.9

$$B = T^{13.6}$$

$$B = \frac{B1 + B2 + B3 + B4}{4}$$

$$T = B^{1/13.6}$$

$$T = 451\ K$$

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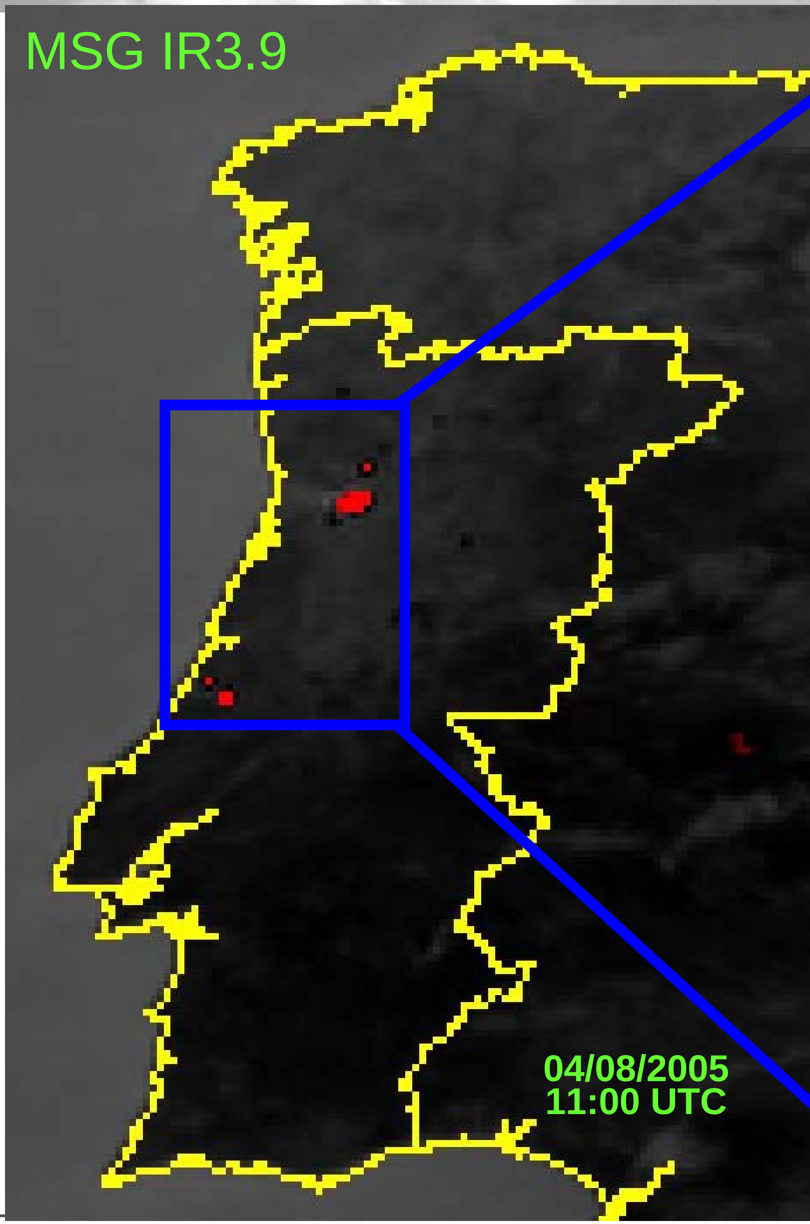
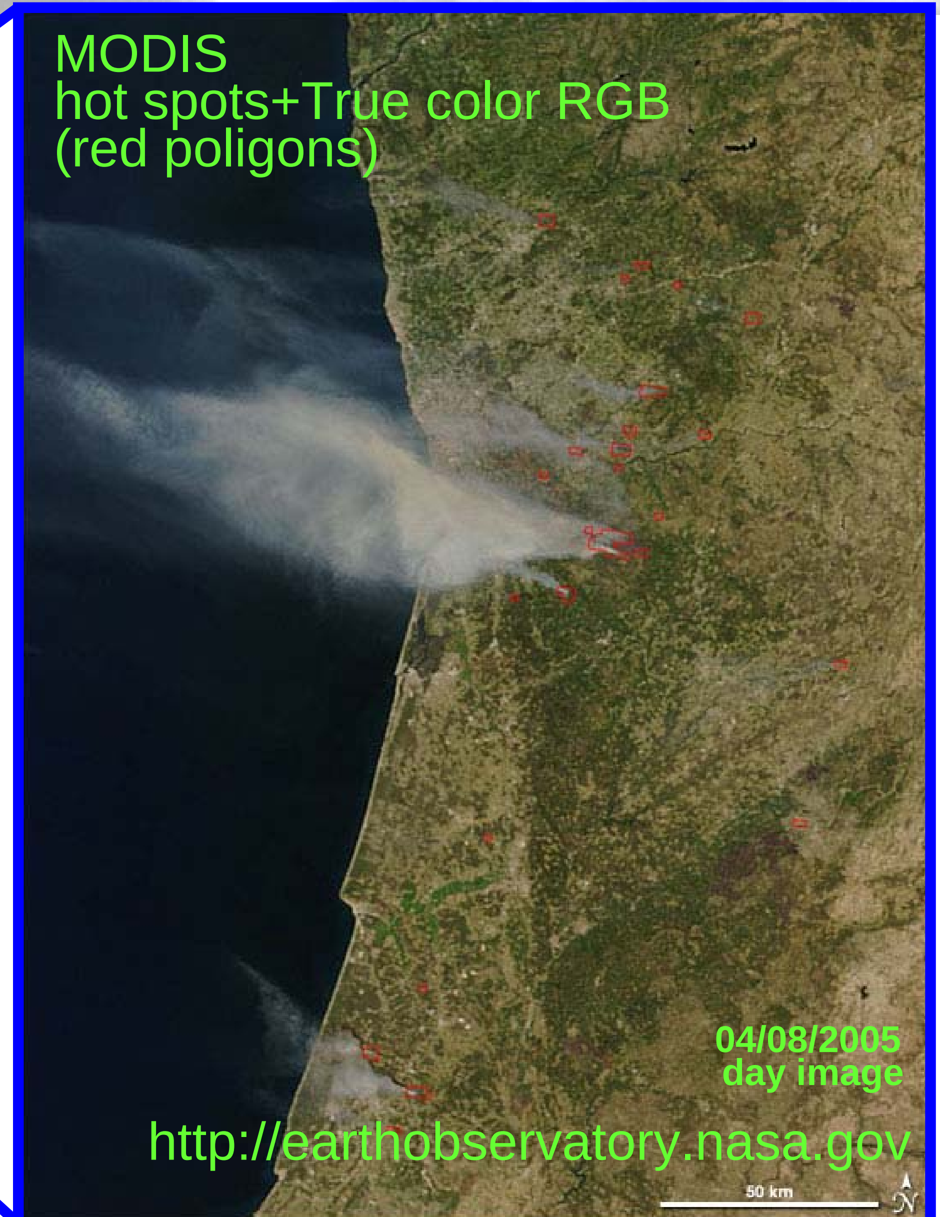
Pixel size - Geostationary versus Polar satellites

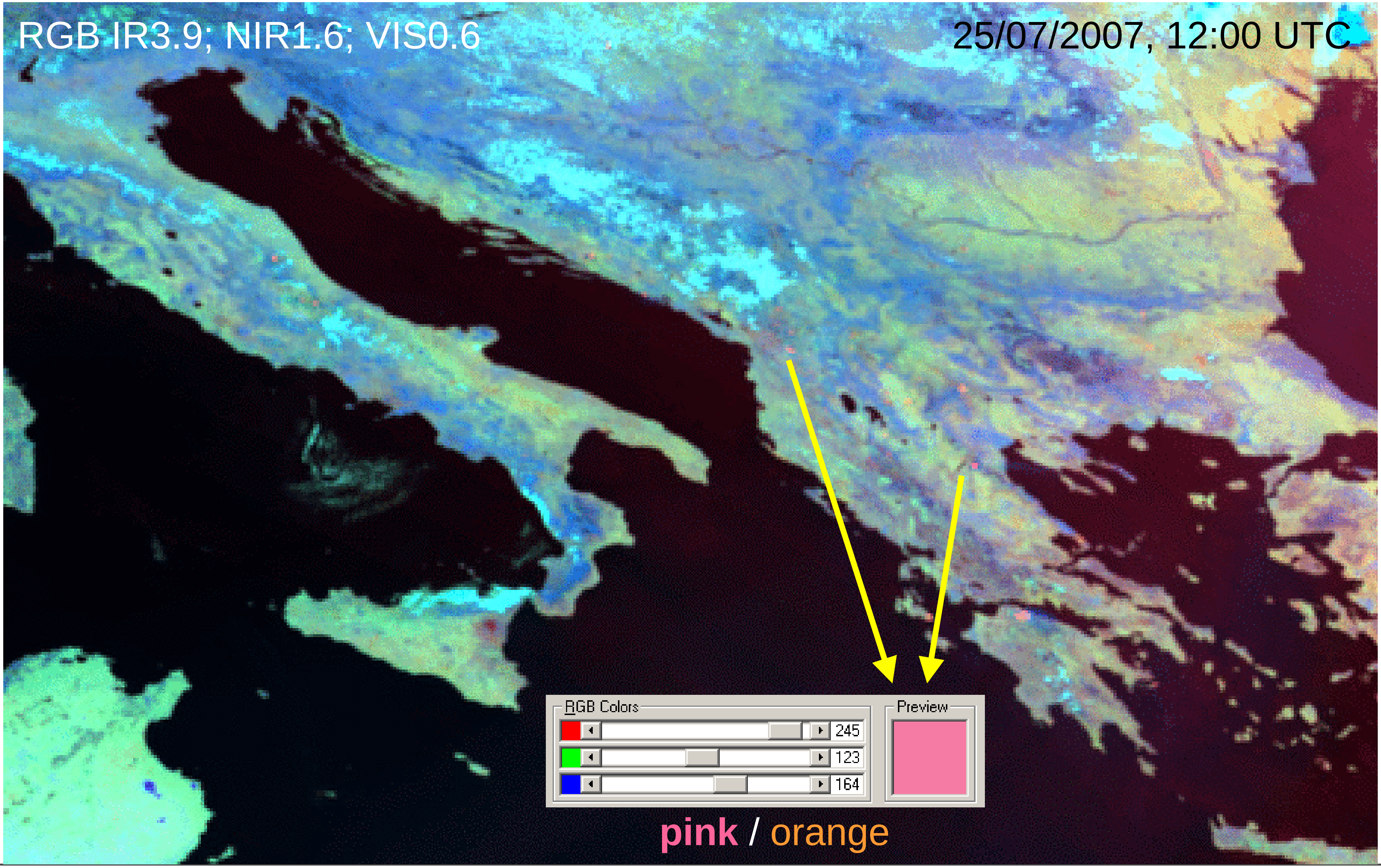
à frente do nosso tempo





Forest fires during the day ... also with RGB´s

à frente do nosso tempo



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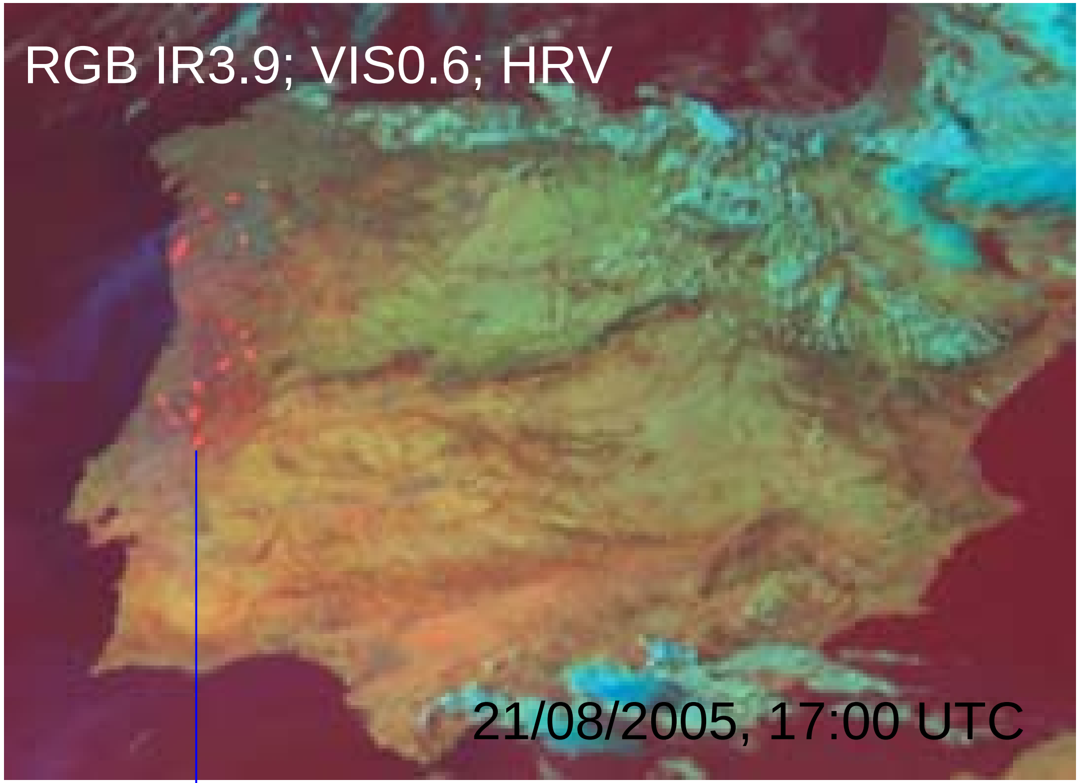

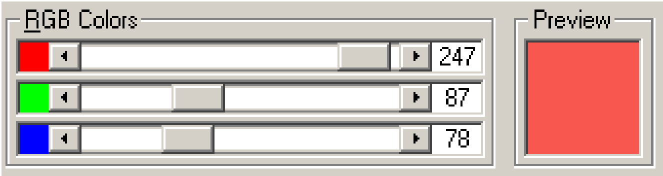

Forest fires all day ... with objective products

à frente do nosso tempo

LSA SAF

LAND SURFACE ANALYSIS SATELLITE APPLICATIONS FACILITY

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Home

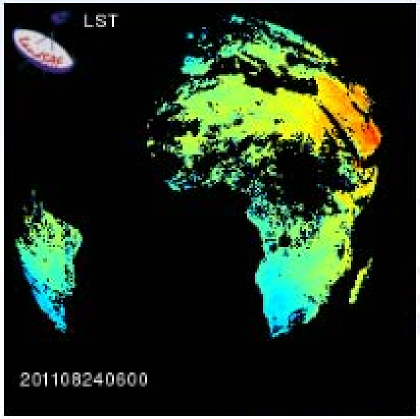
The scope of Land Surface Analysis Satellite Applications Facility (LSA SAF) is to increase benefit from EUMETSAT Satellite (MSG and EPS) data related to:

- Land
- Land-Atmosphere interaction
- Biospheric Applications

The LSA SAF performs:

- R&D Programs.
- Operational Activities
  - Generation
  - Archiving
  - Dissemination

of land surface related products.



See colour legends...

Latest News:

- Warning LSA SAF database maintenace see more...
- Important VCS intervention see more...
- Important LSA SAF outage see more...
- Important IM Archive system maintenance. see more...
- Important IM Archive system maintenance. see more...
- Information LSA SAF Outage see more...

Caption

Internal	Develop.	Demo.	Pre-Operat.	Operat.

Product Development Status:

MSG/SEVIRI based products
Wild Fires
Fire Radiative Power - PIXEL
Fire Radiative Power - GRID
Fire Risk Map
Fire Detection and Monitoring
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
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
MetOp/AVHRR based products
Land Surface Temperature
EPS - Land Surface Temperature
Down-welling Surface Fluxes
Down-welling Surface Long-wave Radiation Flux

3 main types of fire products

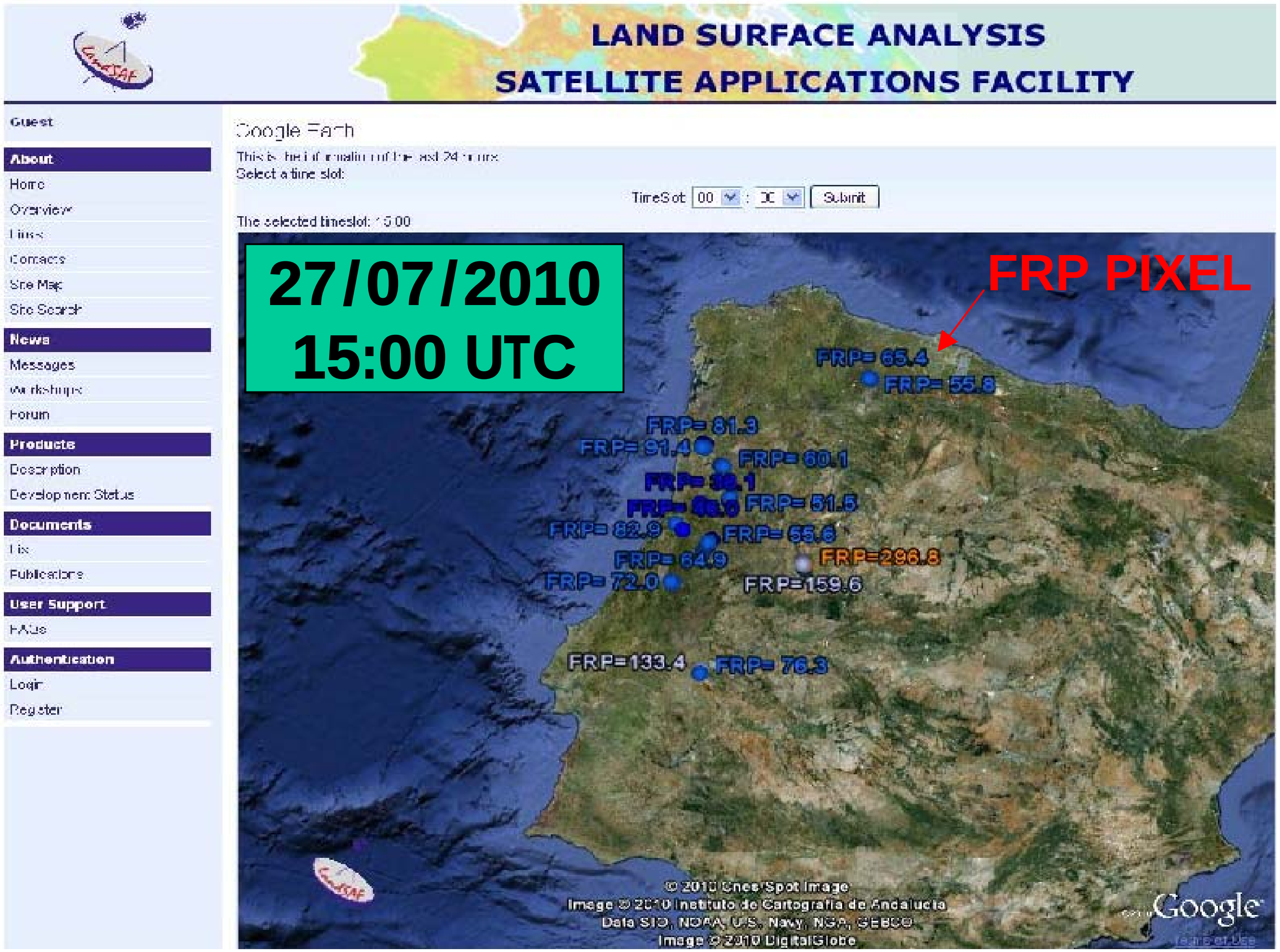
1 product in 2 modes (pixel/grid)

2 products already operational

2 products pre-operational

http://landsaf.meteo.pt/

LandSAF - Fire Radiative Power - Pixel (MegaWatt)



FRP:
Amount of radiant energy liberated per unit time during a vegetation fire.

FRP is related to the rate at which the fuel biomass is being consumed (Wooster et al., 2005).

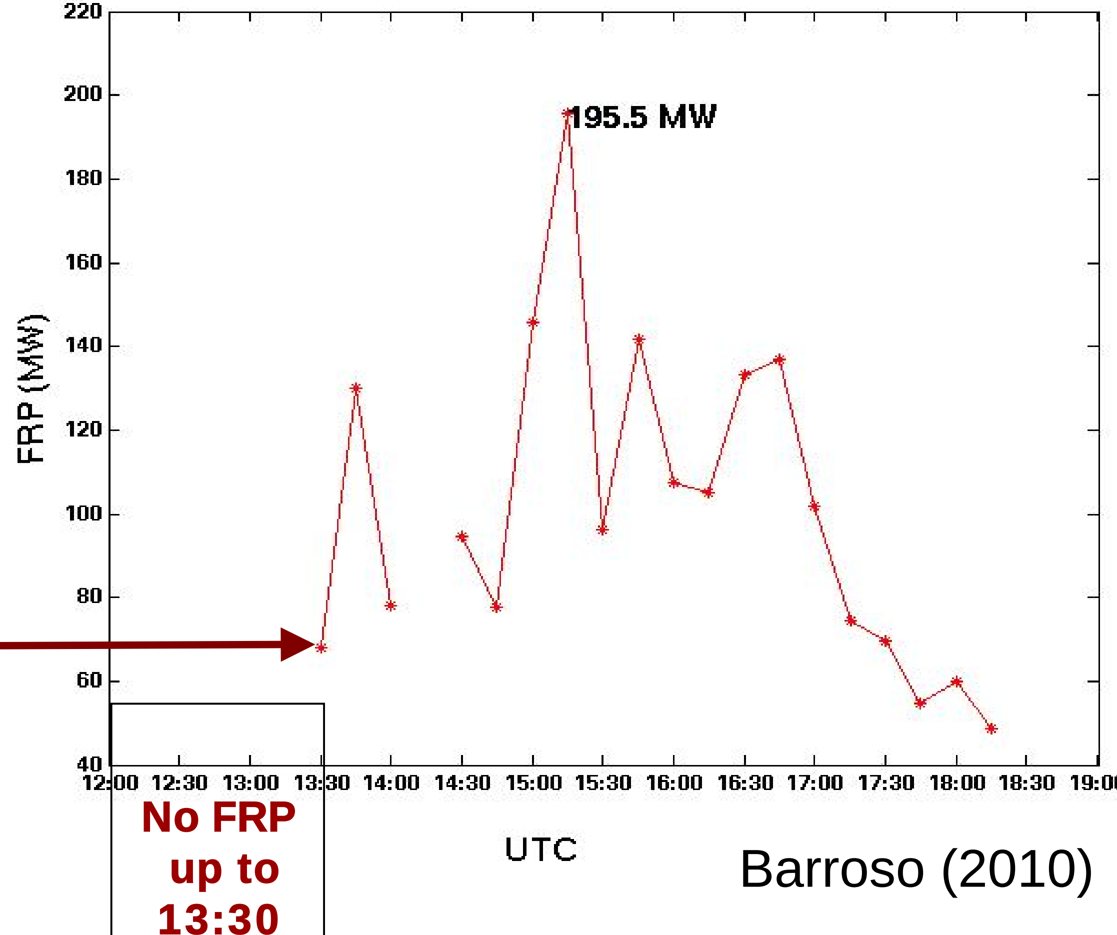
FRP GRID : hourly averaged FRP measure for each 5.0º grid cell (level 3 product still pre-operational)

LandSAF - Fire Radiative Power - Pixel (MegaWatt)

- Fire in a tire factory
- The warning given at 13:26 UTC;

At the 13:30 UTC slot, ~70MW of measured radiant energy output from the fire!

Temporal evolution of FRP(MW)
16 August 2010 (12:00– 19:00 UTC)

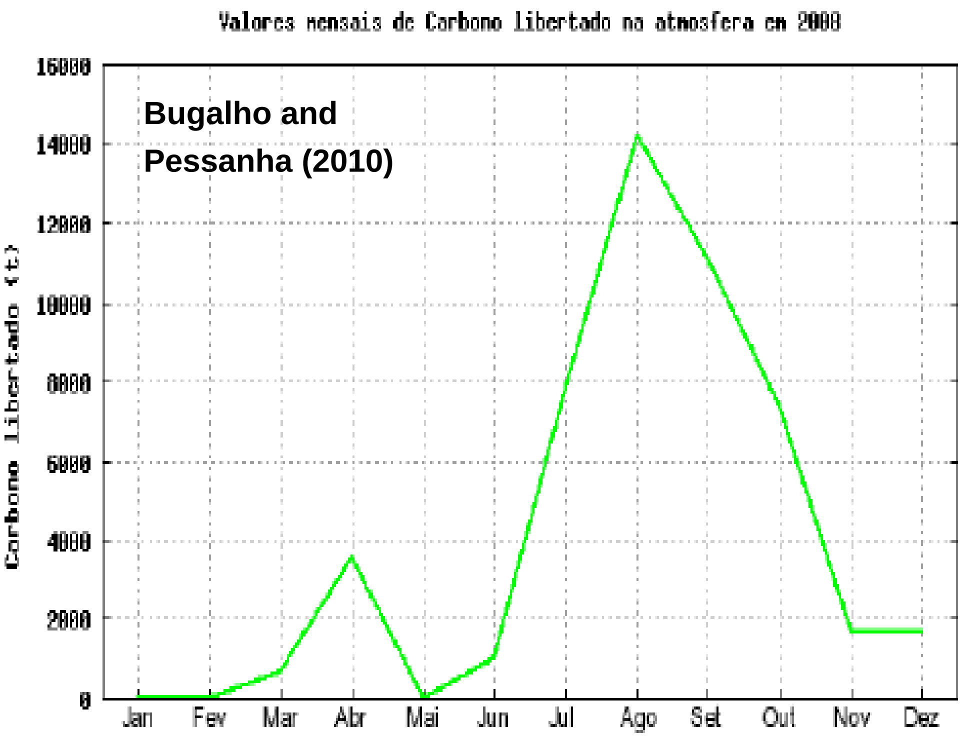


Barroso (2010)

LandSAF - Fire Radiative Power - Pixel (MegaWatt)

FRP can be used to obtain other estimates in near-real time:

- **Fire Radiative Energy <> Total Fuel Mass Combusted for the lifetime of a fire**
- **Emission of trace gases species (example below for Carbon emission in tons)**

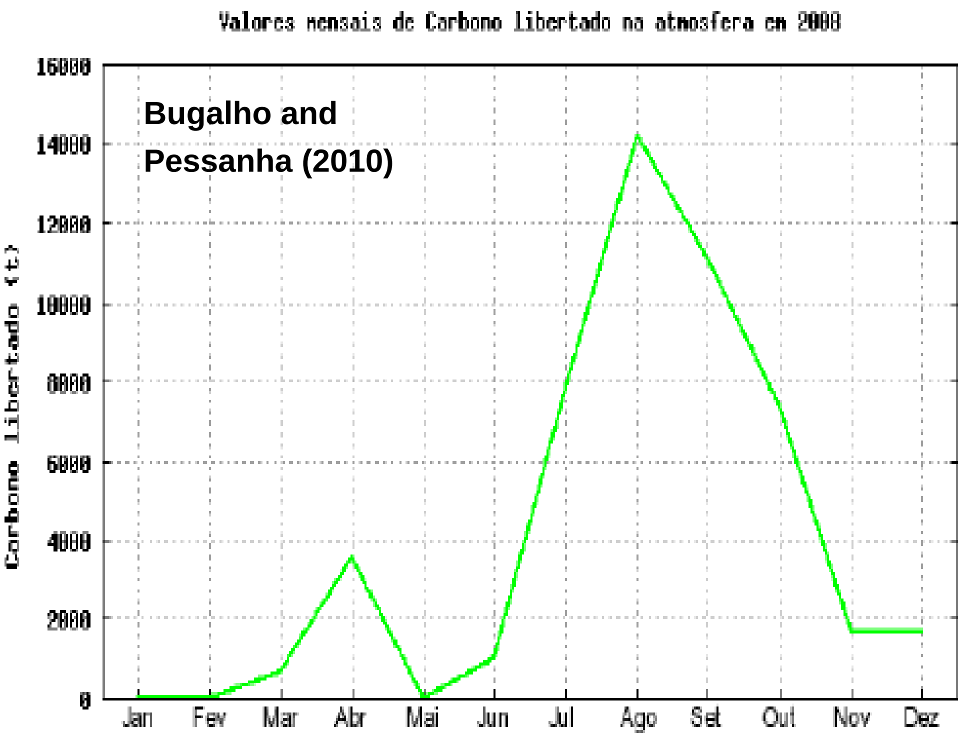


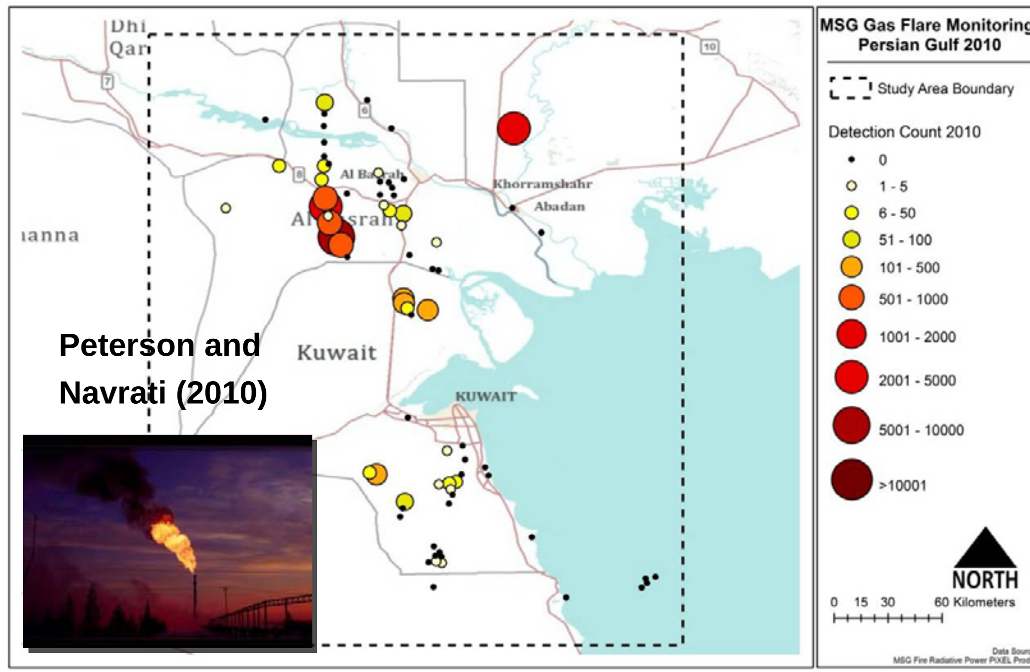
LandSAF - Fire Radiative Power - Pixel (MegaWatt)

à frente do nosso tempo

FRP can be used to obtain other estimates in near-real time:

- **Fire Radiative Energy <> Total Fuel Mass Combusted for the lifetime of a fire**
- **Emission of trace gases species (example below for Carbon emission in tons)**
- **Monitoring of gas flares**





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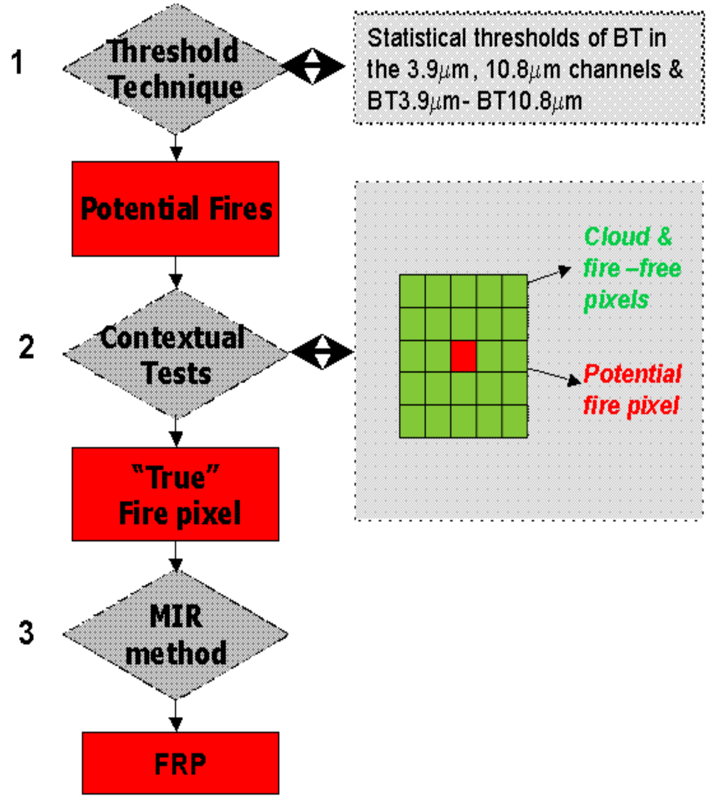
LandSAF – FRP / Fire Detection & Monitoring

FRP is calculated for pixels of potential fire



Potential Fire detection based on following criteria:

- BT (IR3.9) > dynamic threshold (space&time dependant)
- BTD (IR3.9-IR10.8) > dynamic threshold (space&time dependant)
- Exclusion of sun-glint pixels

Fire Detection & Monitoring (FDM):

- Still pre-operational

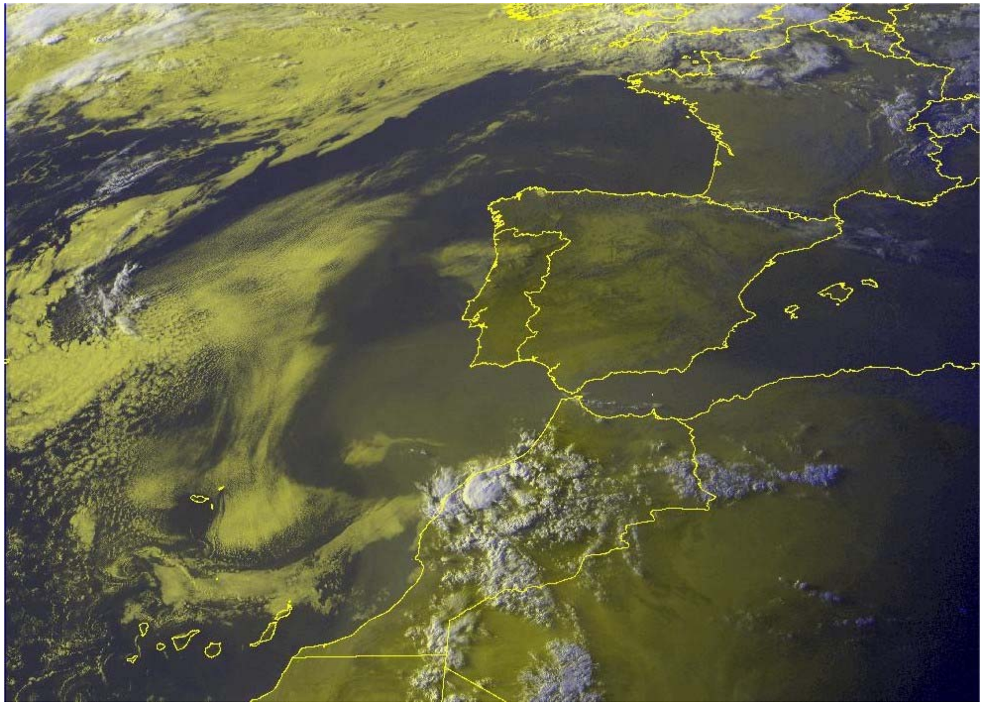
- Finer detection of hot-spots

Forest Fires Aerossol Detection

Fire smoke in High Resolution Visible RGB

à frente do nosso tempo

04/08/2005 – 17 UTC



26/07/2010 – 18 UTC

Colour	Ch (micra)	Range (K)	Contrast (gama)
R	HRV	**0 ... 100**	1.7
G	HRV	**0 ... 100**	1.7
B	10.8 (inverted)	**+203 ... +323**	1.0

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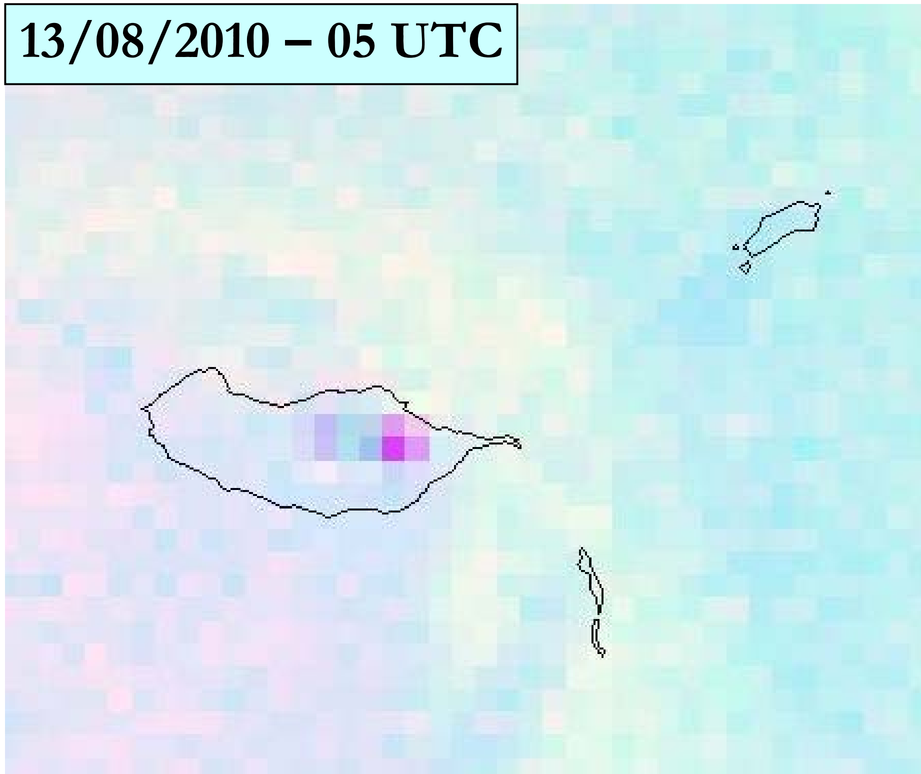
Fire smoke in High Resolution Visible RGB

Night Fire RGB [~ Night Microphysical RGB]

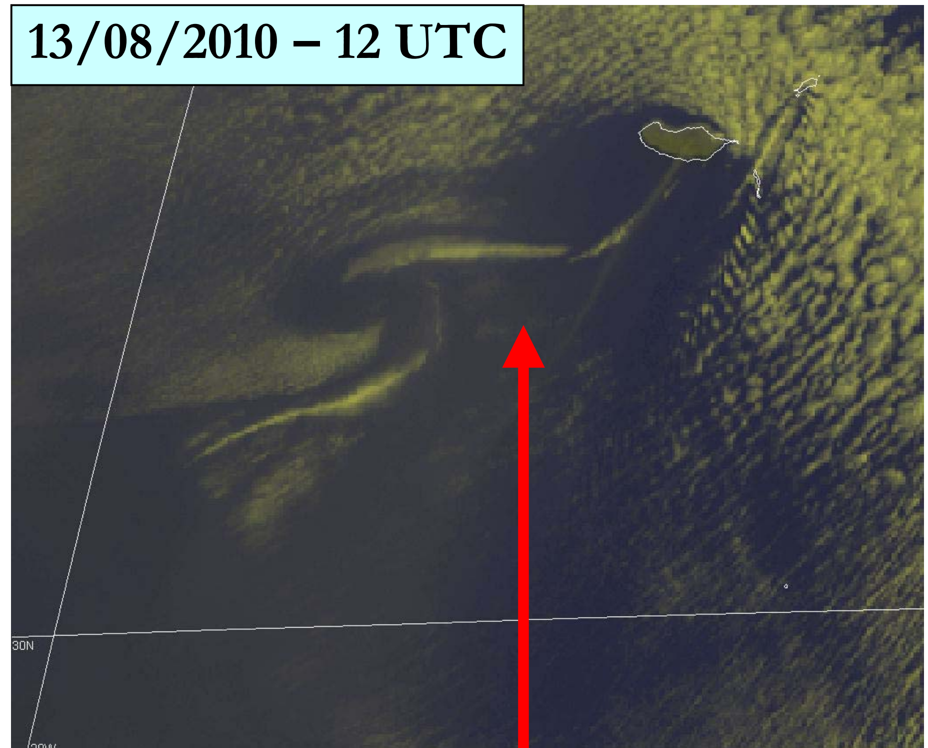
13/08/2010 – 05 UTC



Colour	Ch (micra)	Range (K)	Contrast (gama)
R	12.0-10.8	**-4 ... 0**	1.0
G	10.8-3.9	**-15 ... +6**	2.0
B	10.8	**+223 ... +293**	1.0

Colour	Ch (micra)	Range (K)	Contrast (gama)
R	HRV	**0 ... 100**	1.7
G	HRV	**0 ... 100**	1.7
B	10.8 (inverted)	**+203 ... +323**	1.0

13/08/2010 – 12 UTC



smoke and
Von Karman vortices clouds

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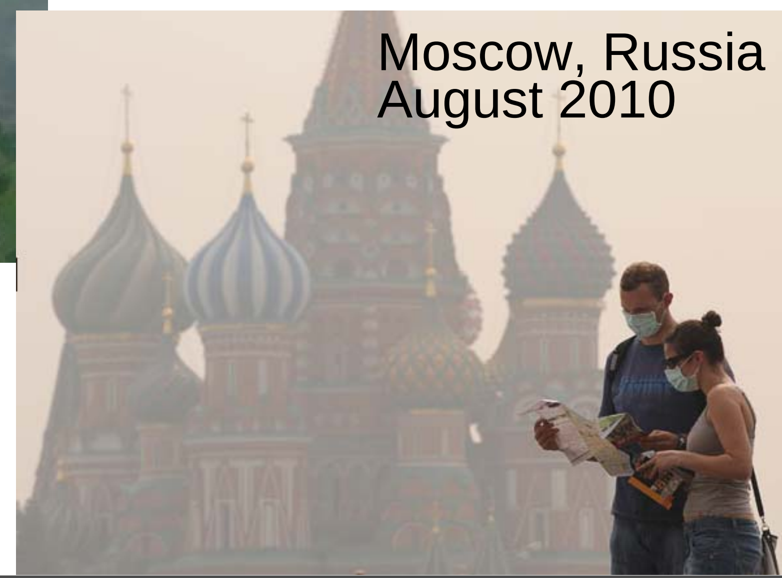
Fire smoke in MODIS True color RGB

hot spots
in red

exercise:

where do you think
there in **NO smoke?**



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Fire smoke in MODIS True color RGB

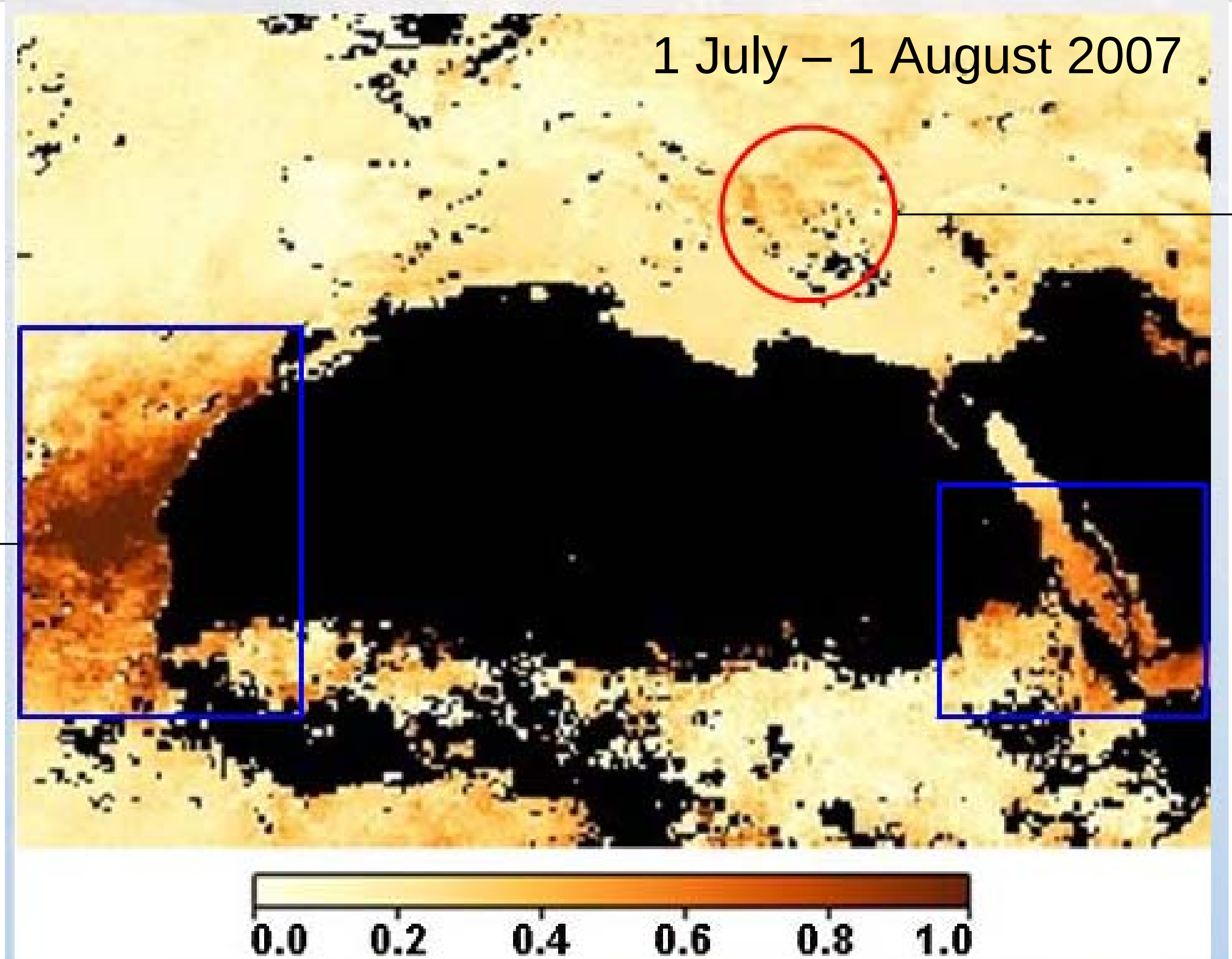
MODIS 19 Aug 2010,western Canada

Figure 2. MODIS image of western Canada and northwestern US, August 19th, 2010. Image courtesy NOAA and Steve Taylor, Canadian Forest Service.

Figure 10. Visibility is reduced to several blocks in downtown Edmonton on the afternoon of August 19, 2010. Photo courtesy Alberta Environment.

The Canadian Smoke Newsletter, 2011

MODIS Aerossol Optical Thickness



most likely from forest fires

most likely from desert dust

Aerossol Optical Thickness obtained from:

7 channels between 0.47 and 2.13 micra (over ocean)

3 channels - 0.47, 0.66 and 2.13 micra (over land)

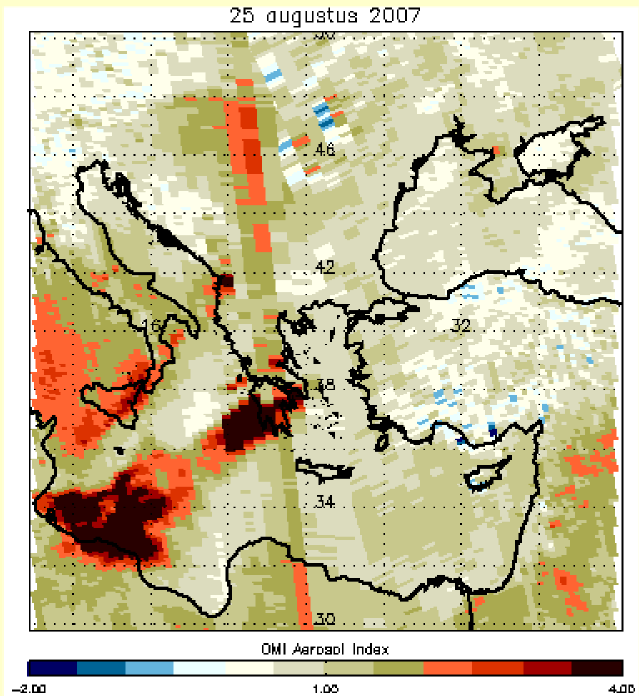
à frente do nosso tempo

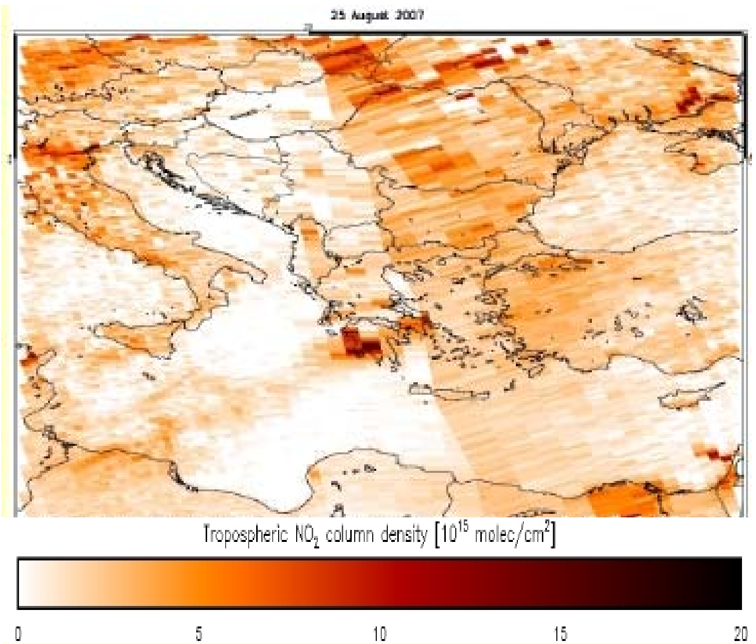
Other ways of detecting forest fire aerossols

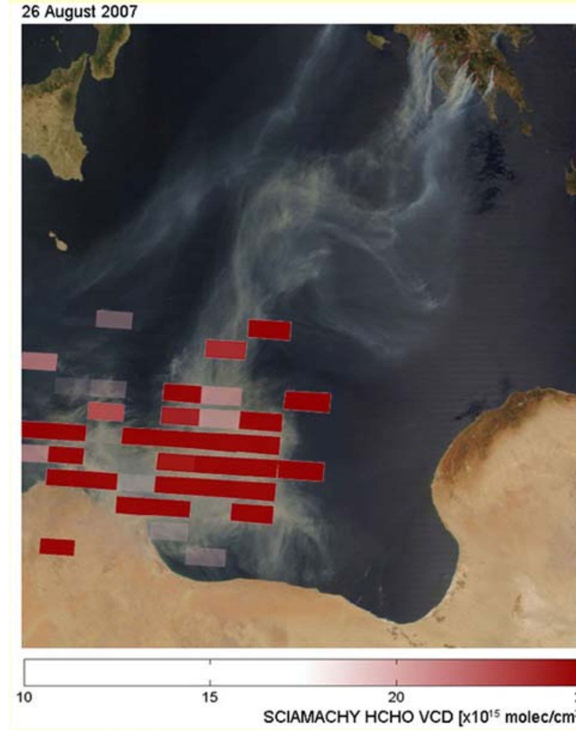
Tropospheric NO2 column density

Ozone Monitoring Instrument (OMI)

AURA







Aerossol Index

Ozone Monitoring Instrument (OMI)

AURA

Formaldehyde Concentration

Schiamachy

ENVISAT

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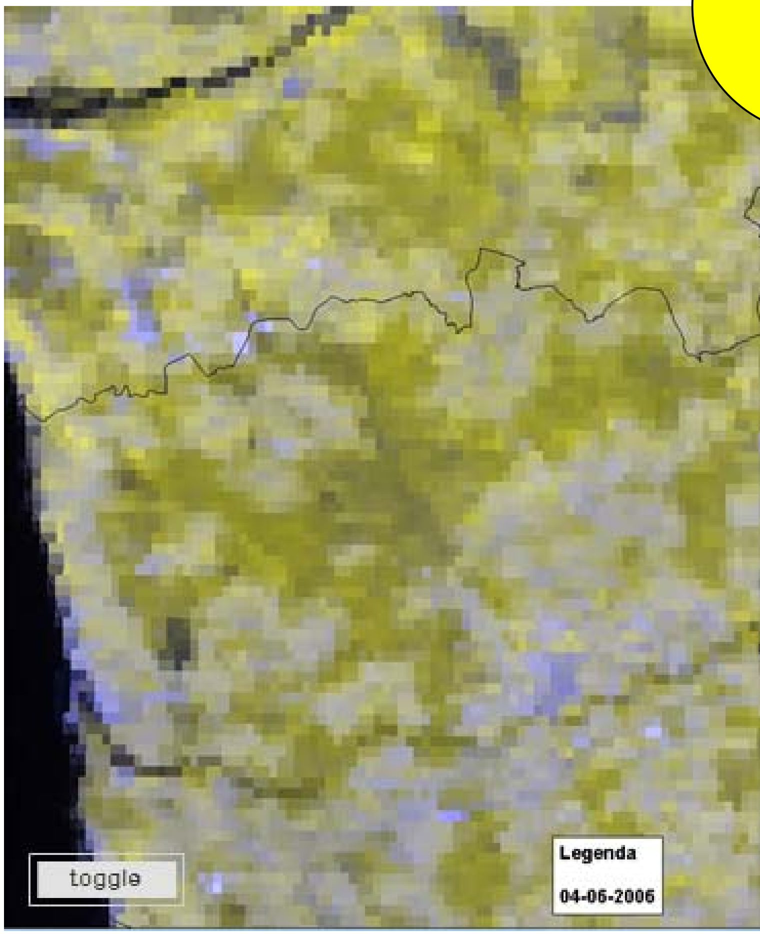
Burnt Areas

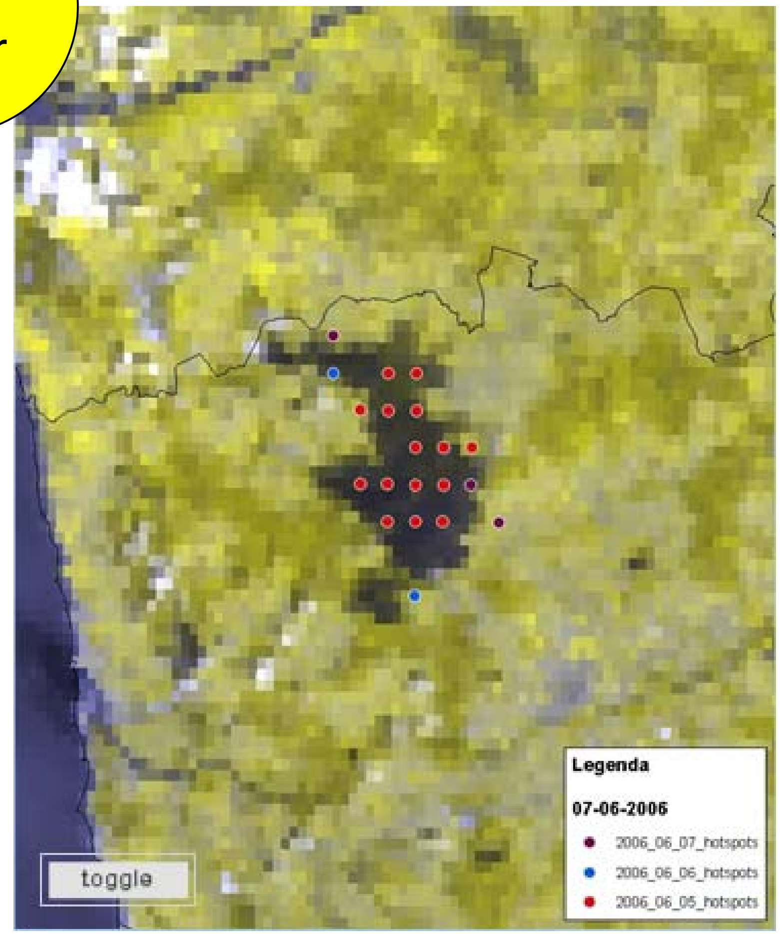
Burnt areas ... the after math ...

04/06/2006

Modis true color

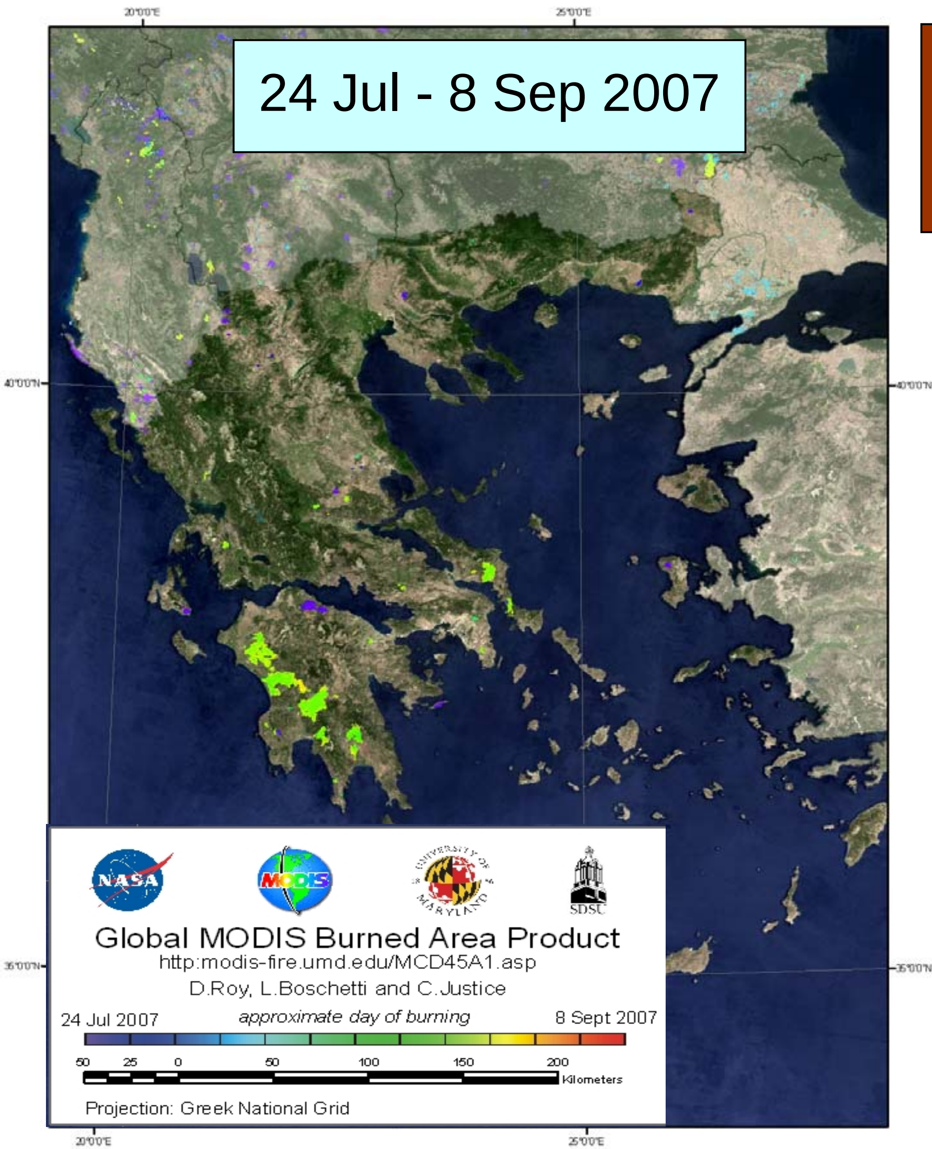
07/06/2006





Café and Tavares (2008)

Burnt areas ... the after math ...



Modis

Burnt area product

Fire Risk

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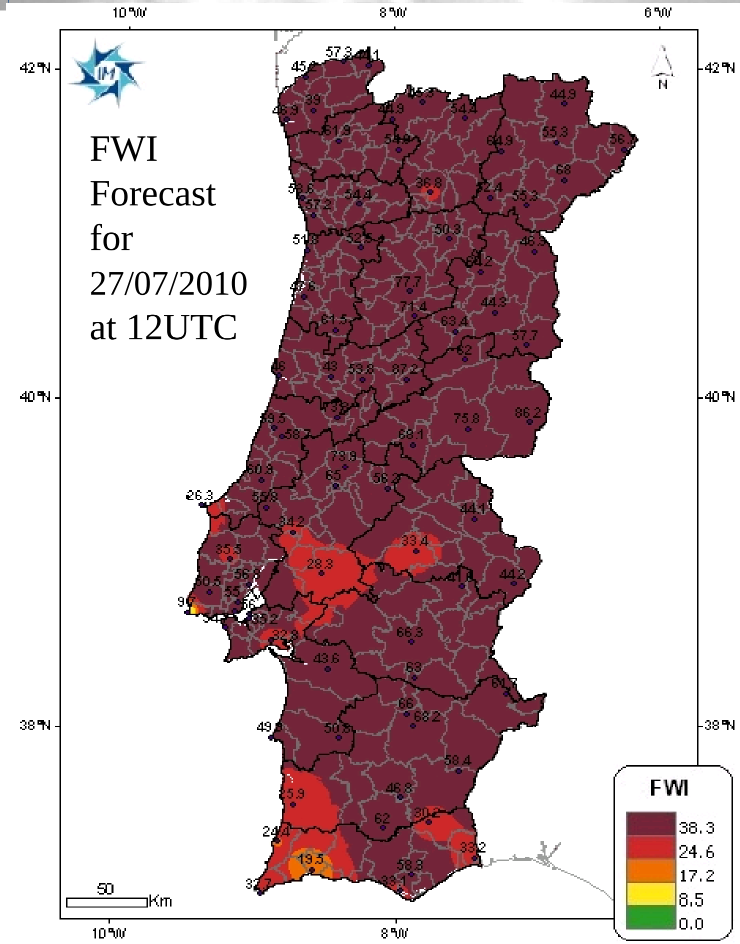
Fire Weather Index – AWS Observation & Model Forecast

à frente do nosso tempo



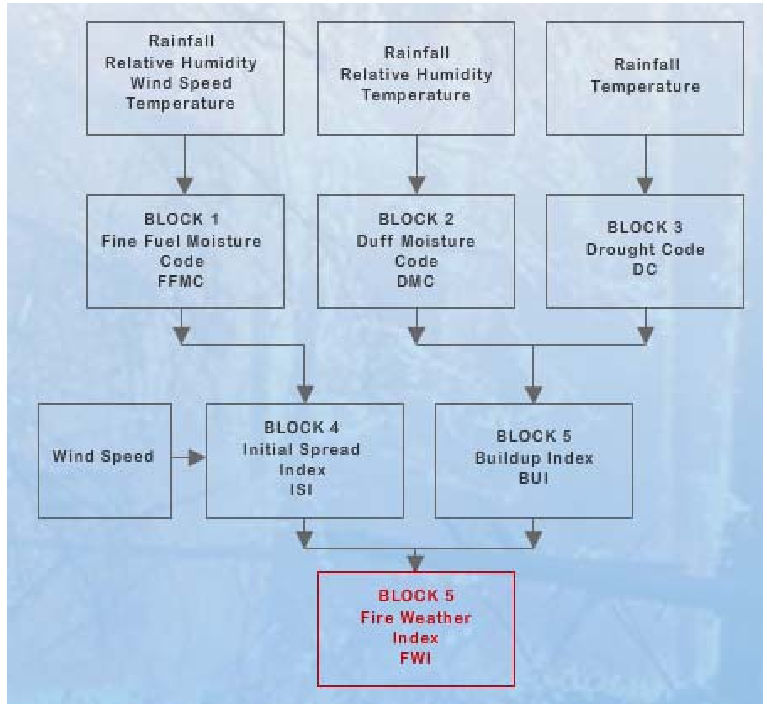


Fig 3.14 – Block diagram of the Canadian Fire Weather Index (Van Wagner, 1987).

http://www.zamg.ac.at/eumetrain/

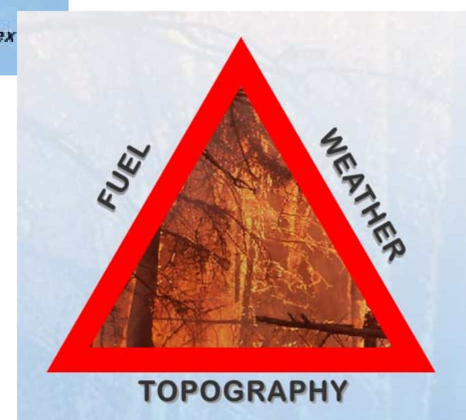


Fig 3.1 - Triangle of fire. Fire hazards are influenced by fuel, weather and topography

- Map of FWI observations for 85 AWS
- 24h and 48h **forecasts from Aladin model**
- 12 UTC run

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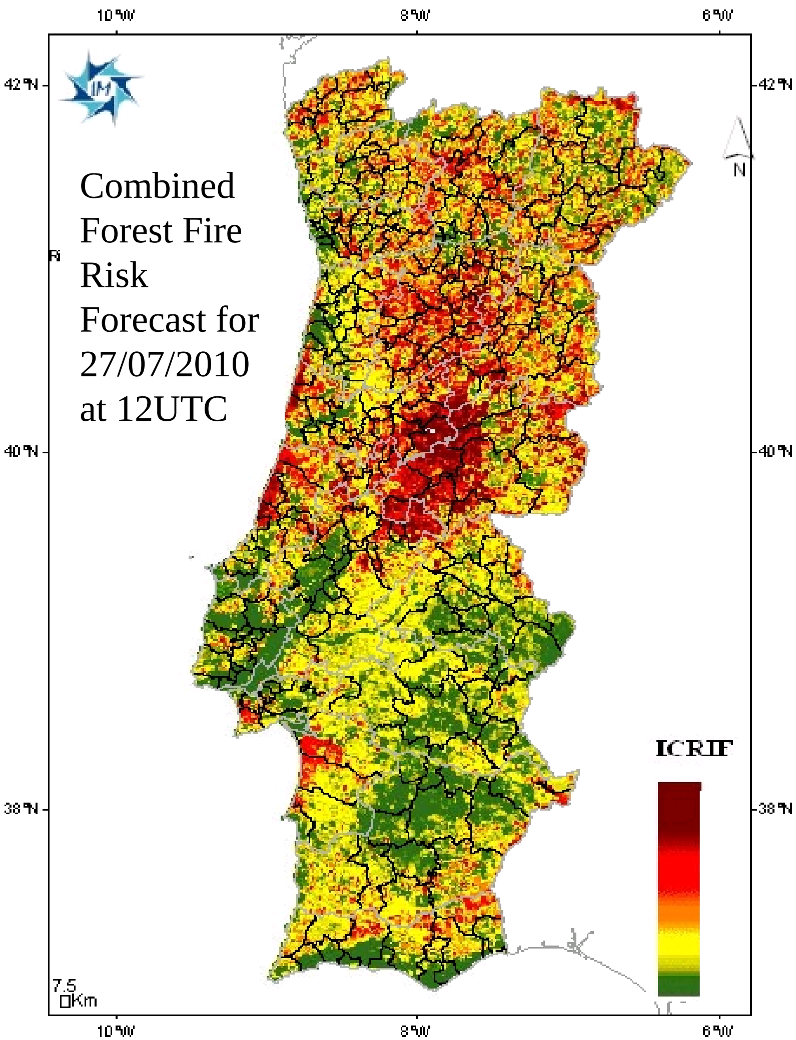
Combined Forest Fire Risk (ICRIF)

à frente do nosso tempo

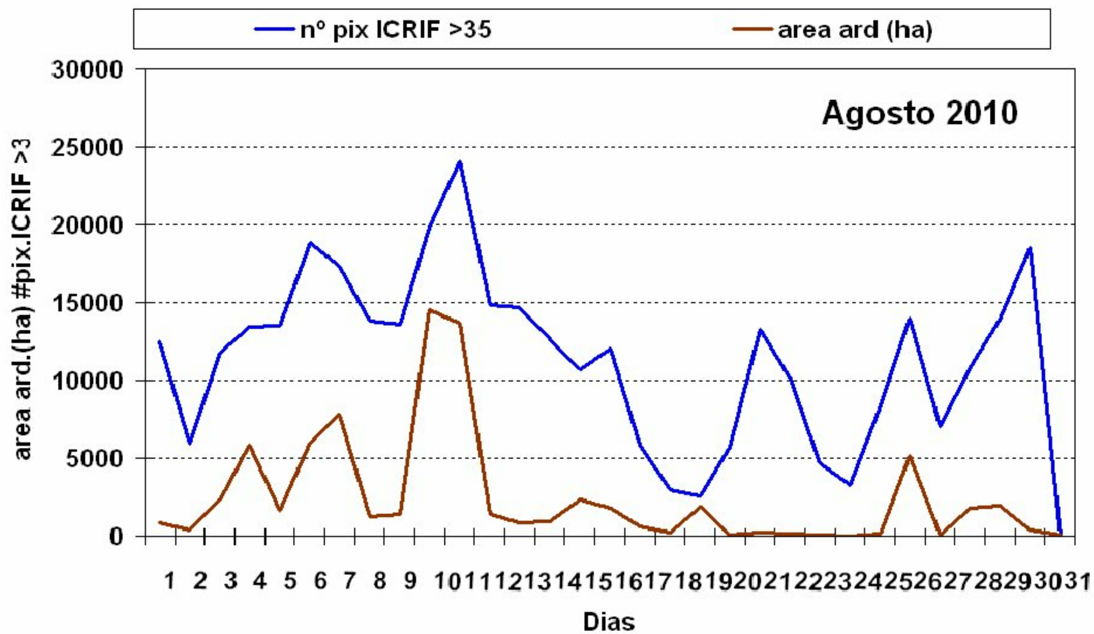


Bugalho and Pessanha (2007)

Combined Forest Fire Risk (ICRIF):

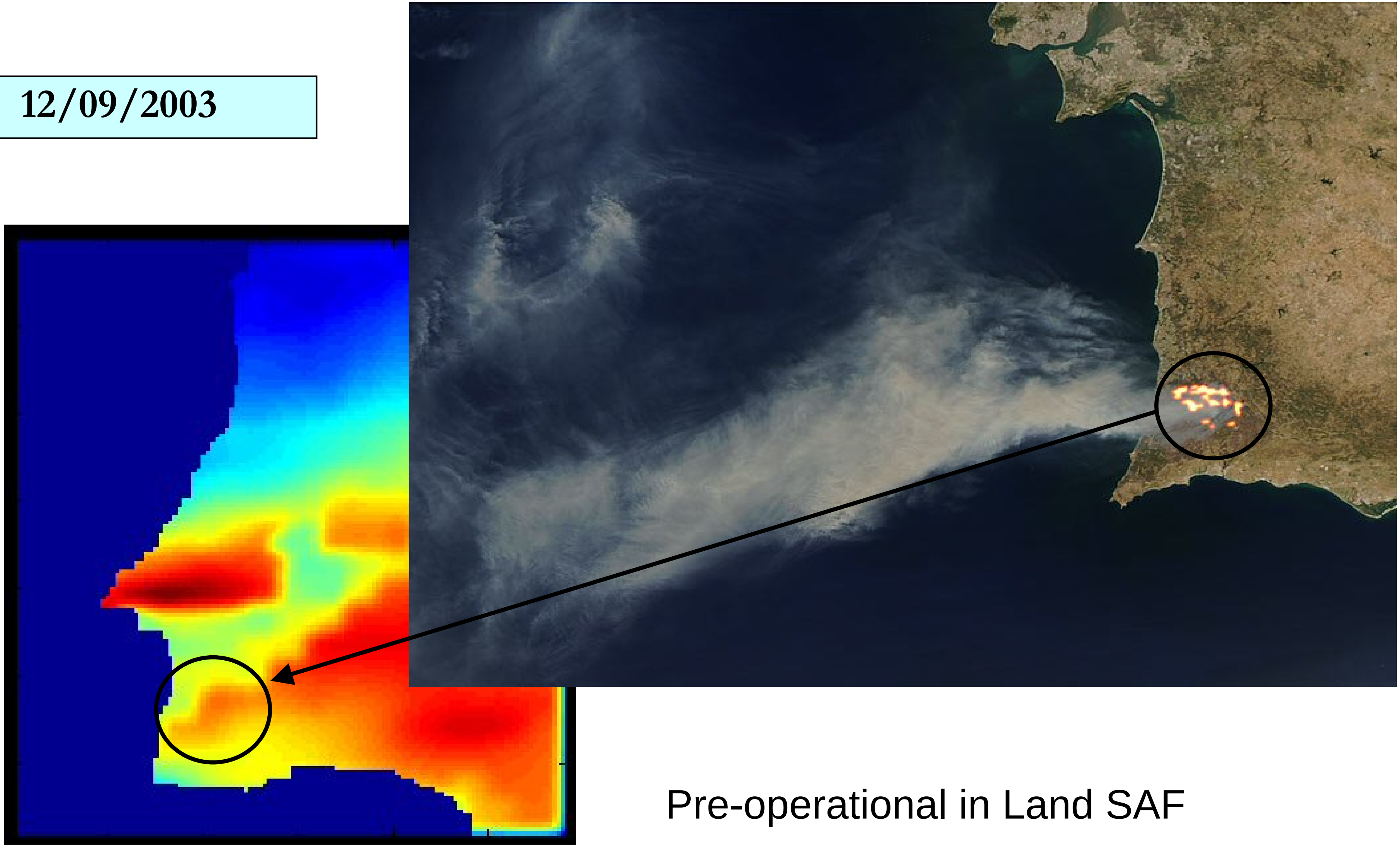
FWI + Land Cover + NOAA NDVI

NDVI = Normalized Difference Vegetation Index



Fire Risk Monitoring

12/09/2003



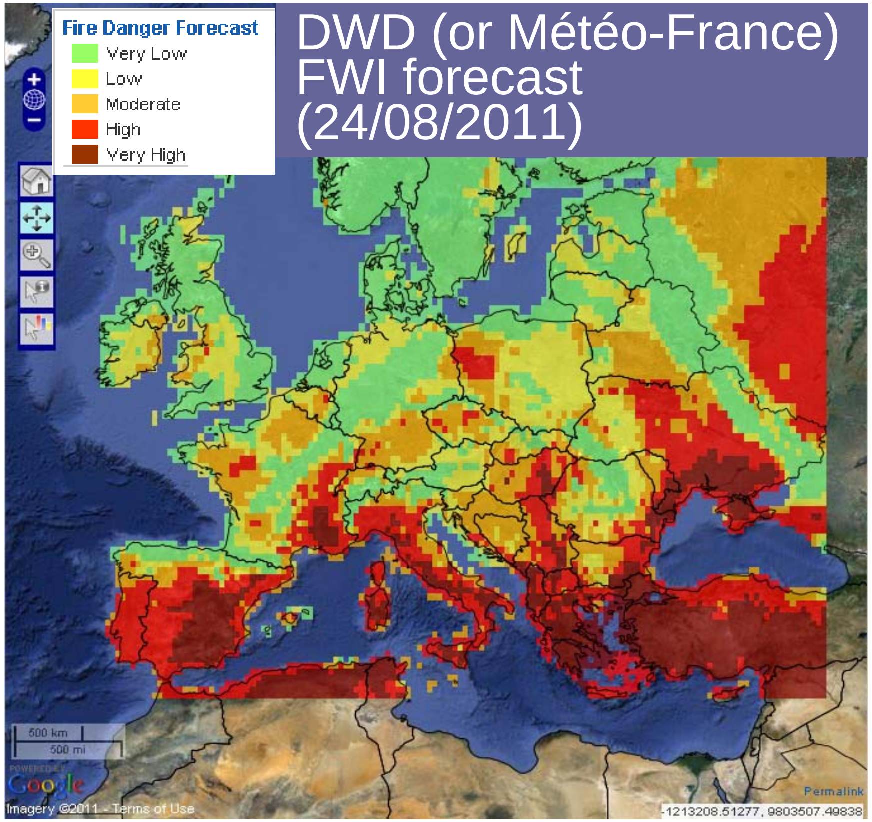
Pre-operational in Land SAF

Courtesy: C. Camara

European Forest Fire Information System (EFFIS)
Fire Risk, Hotspots & Burnt Areas

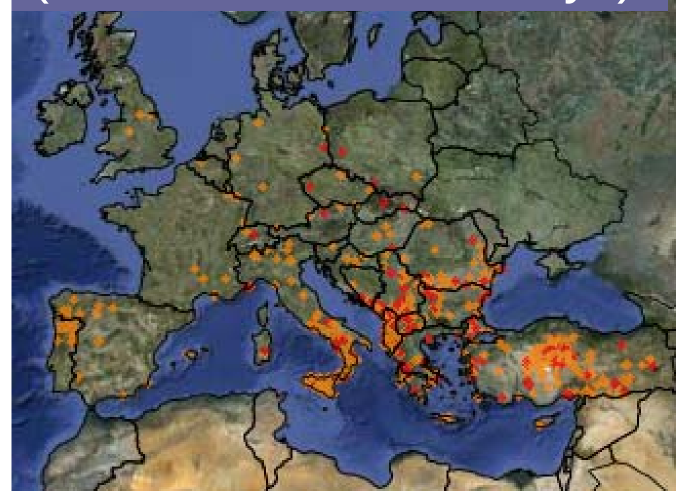
à frente do nosso tempo

DWD (or Météo-France) FWI forecast (24/08/2011)



Burnt areas (24/08/2011 - last 7 days)

Hot spots (24/08/2011 - last 7 days)



http://effis.jrc.ec.europa.eu/current-situation

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European Forest Fire Information System: http://effis.jrc.ec.europa.eu/current-situation

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à frente do nosso tempo

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