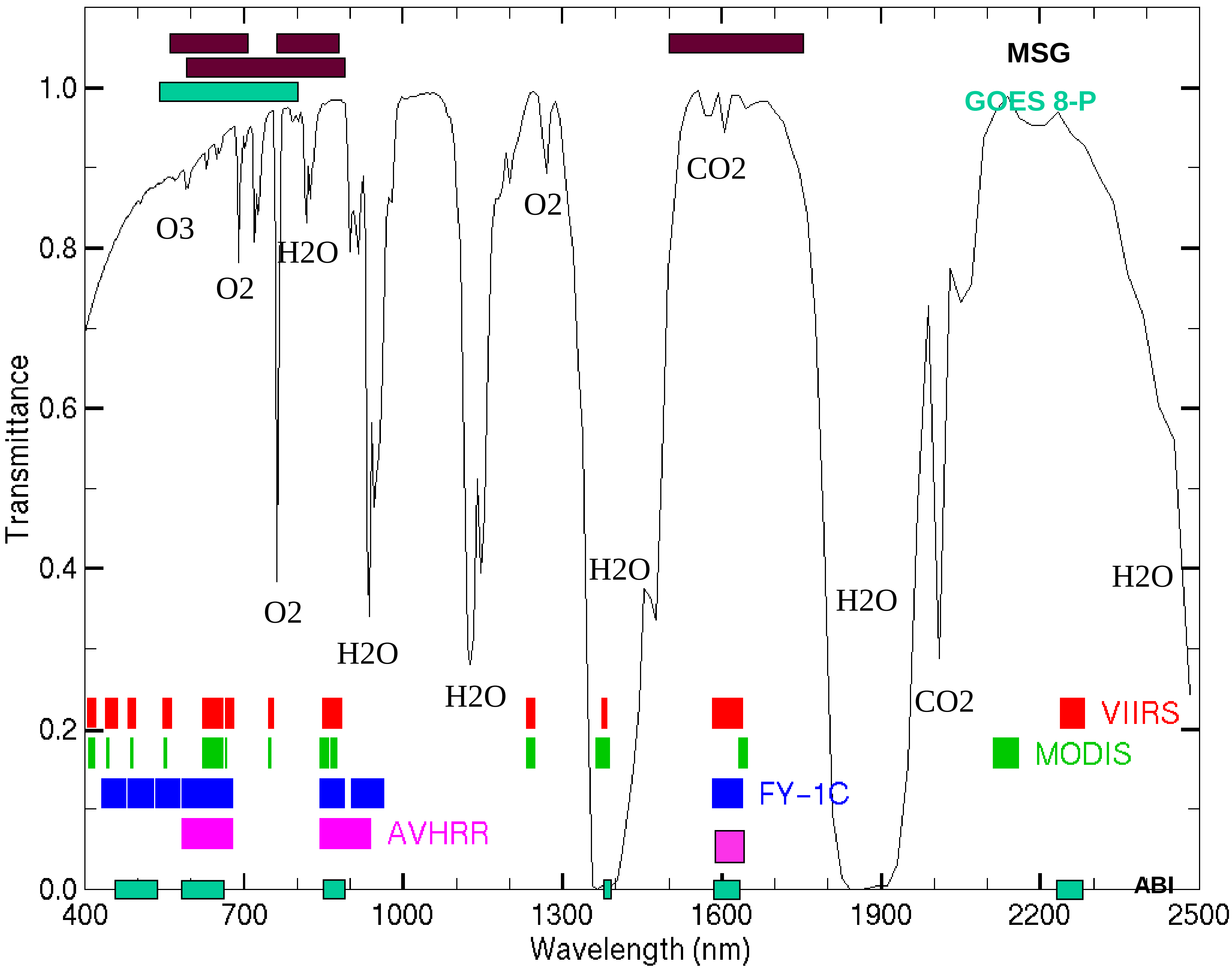
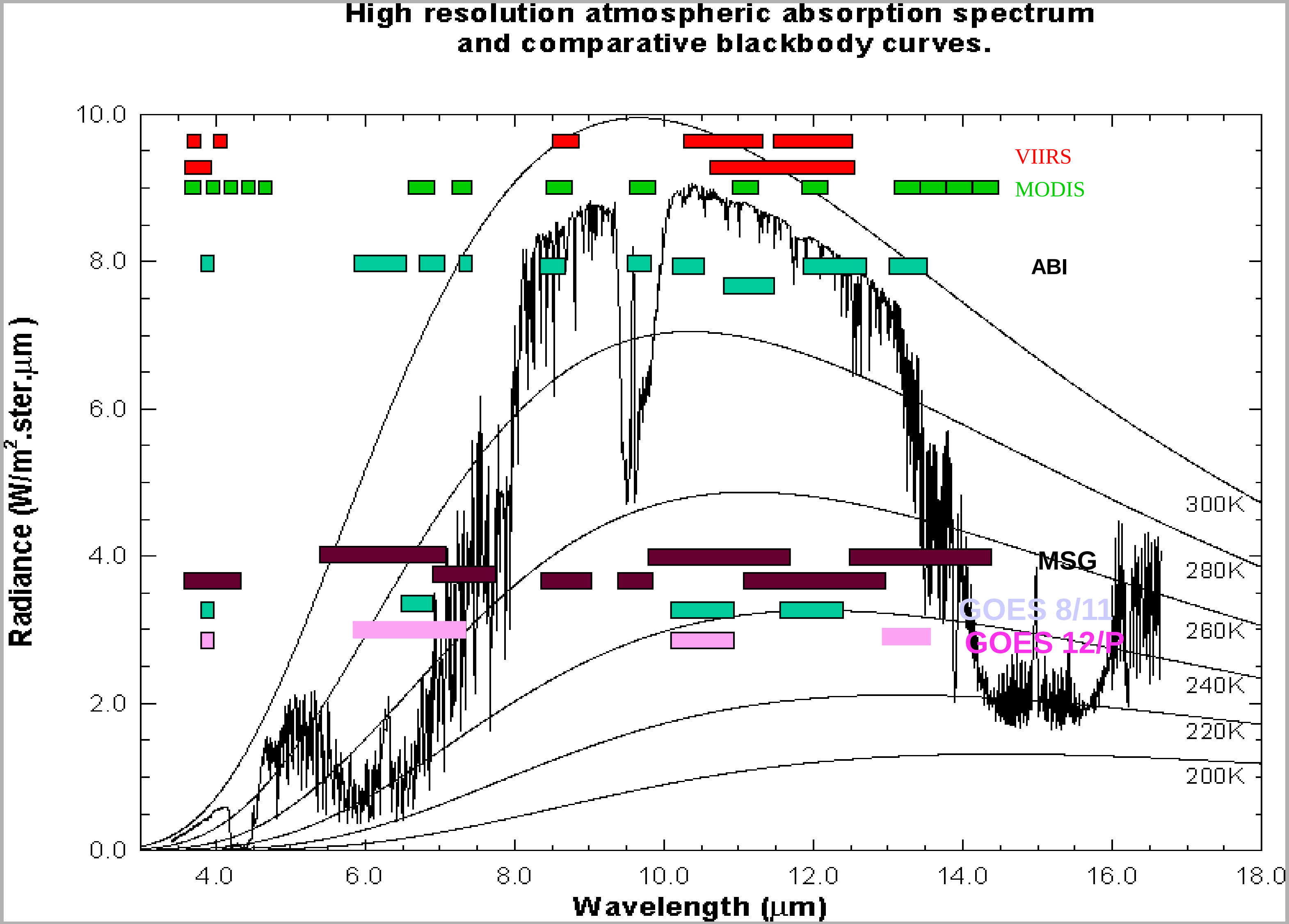
Spectral Bands And Their Applications

James F.W. Purdom

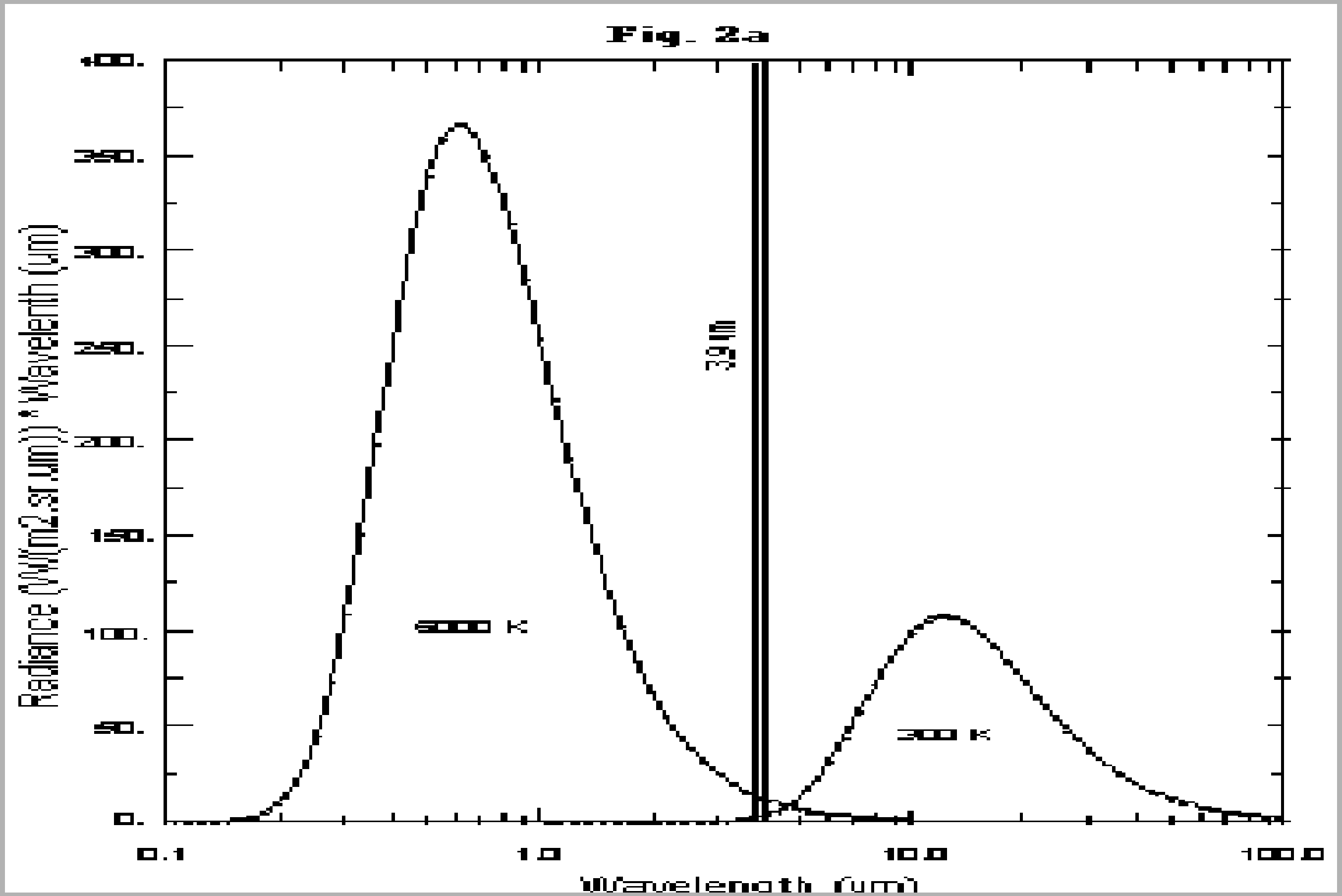
VIIRS, MODIS, FY-1C, AVHRR, ABI, GOES, MSG



Earth emitted spectra overlaid on Planck function envelopes



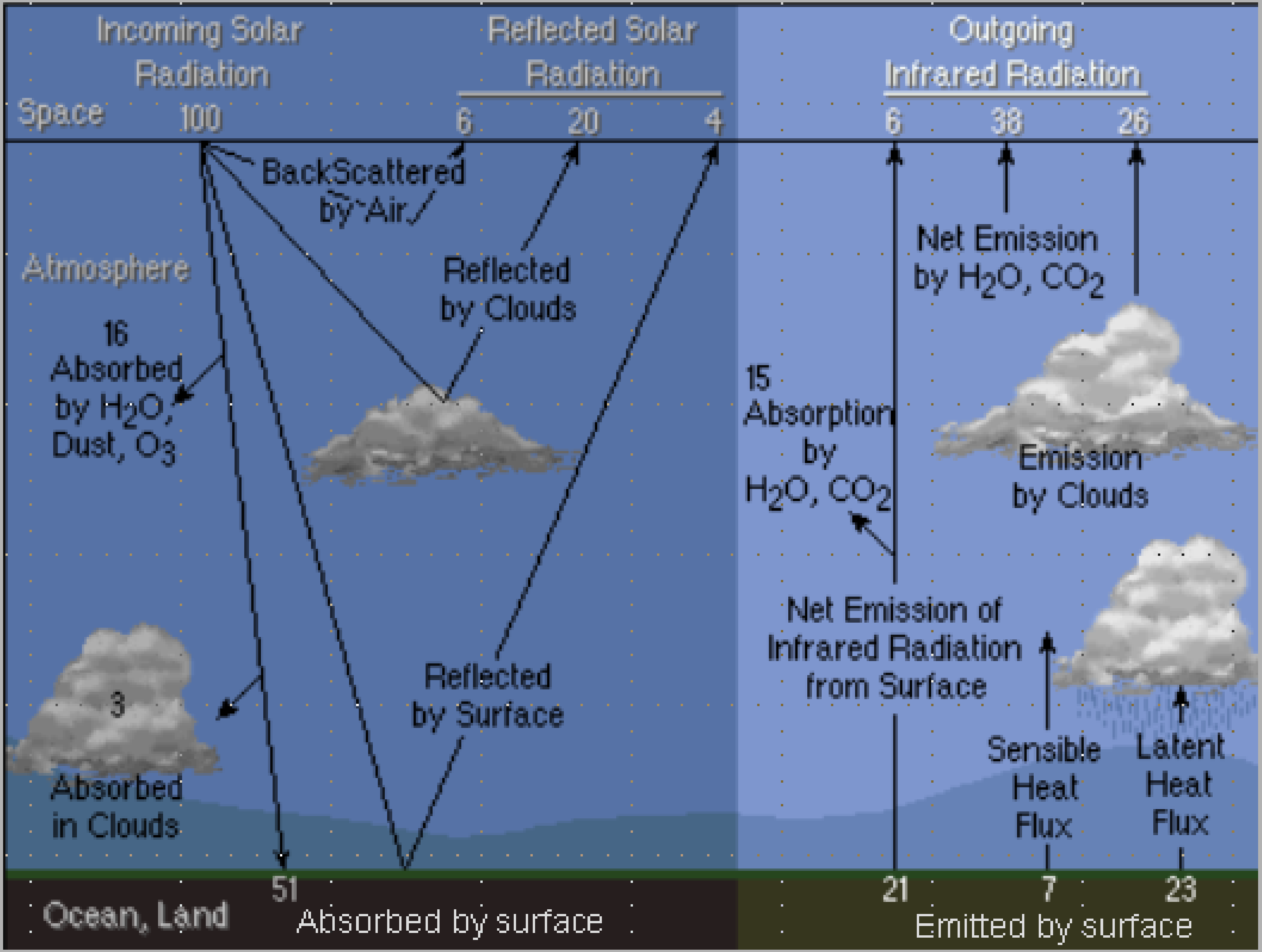
Radiance versus wavelength for blackbodies at 6000 K (sun) and 300 K (earth), notice 3.9 μm region



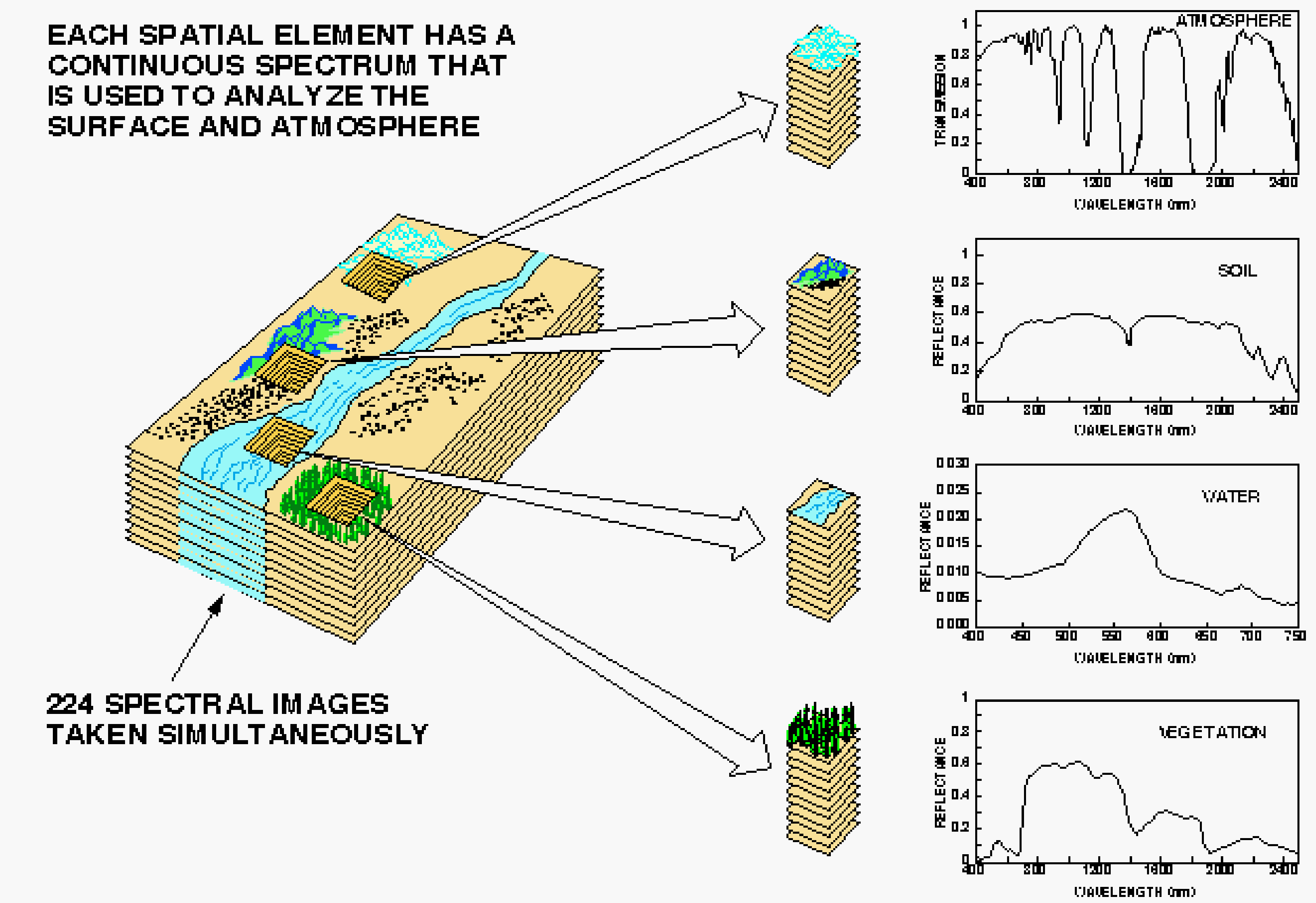
Today's satellites measure energy in spectral regions ranging from the visible portion of the electromagnetic spectrum to the far infrared and into the microwave region

At visible wavelengths, that energy is only reflected solar radiation; at far infrared wavelengths, that energy is only emitted terrestrial radiation. However for short wavelength infrared channels near 3.9 um energy measured by the satellite can be a mixture of reflected solar and earth emitted radiation during daytime.

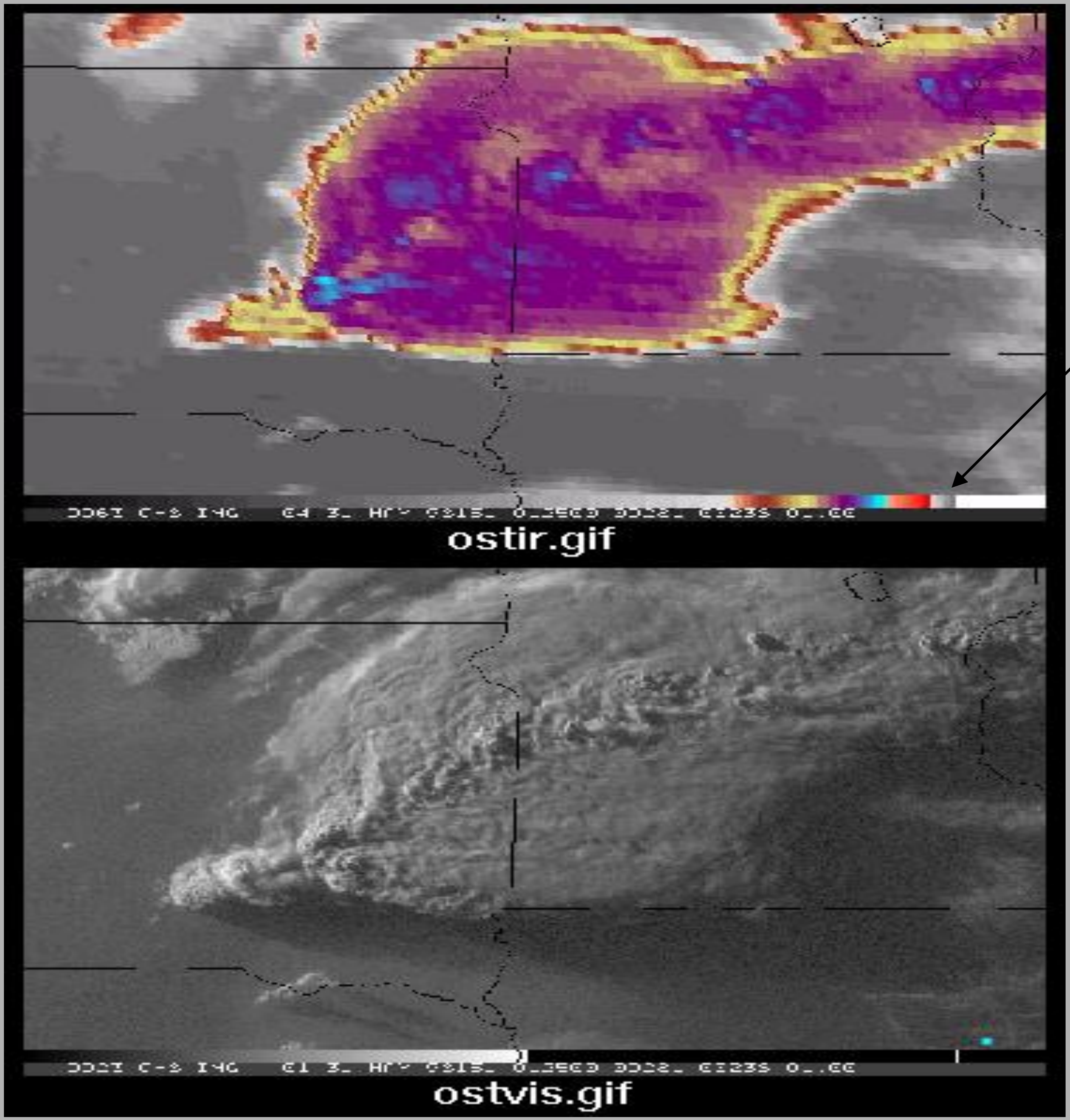
Surface and atmospheric properties effect what we view with a satellite sensor (solar left, emitted IR right)



Today we're digital
AND MULTISPECTRAL



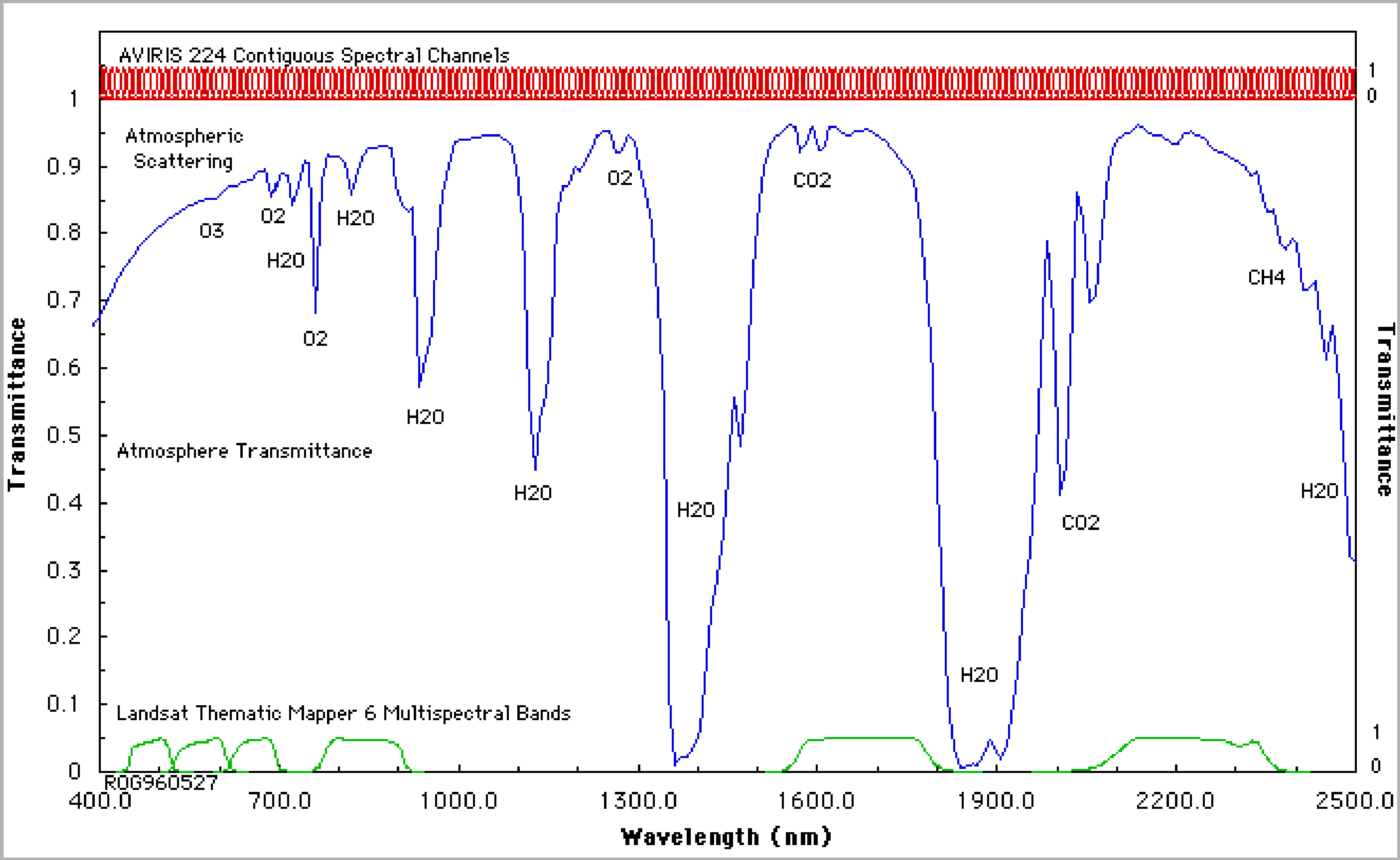
One advantage of digital data: Image Enhancement: Helping the eye detect

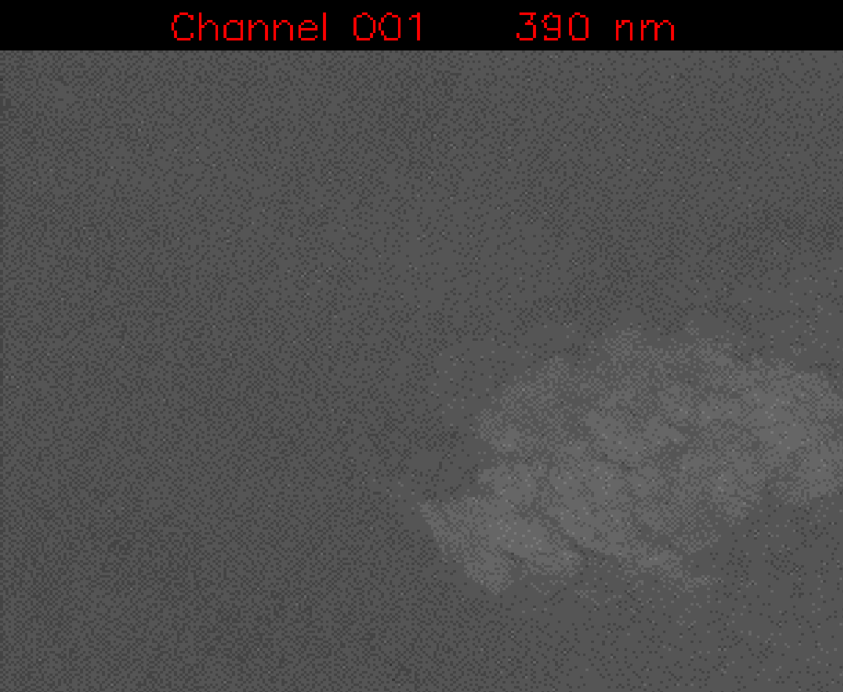


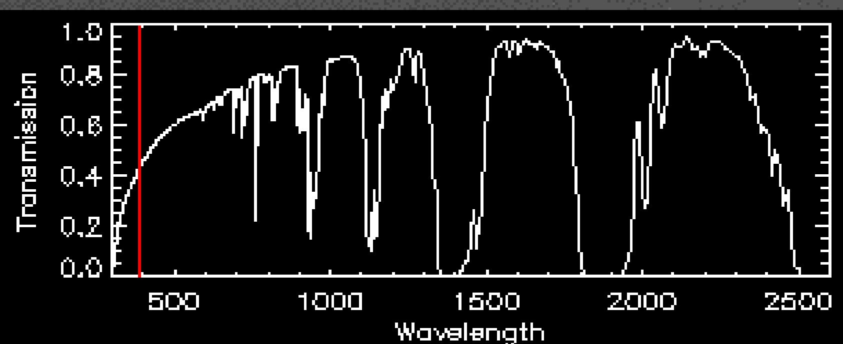
Color bar with warm on left and cold on right

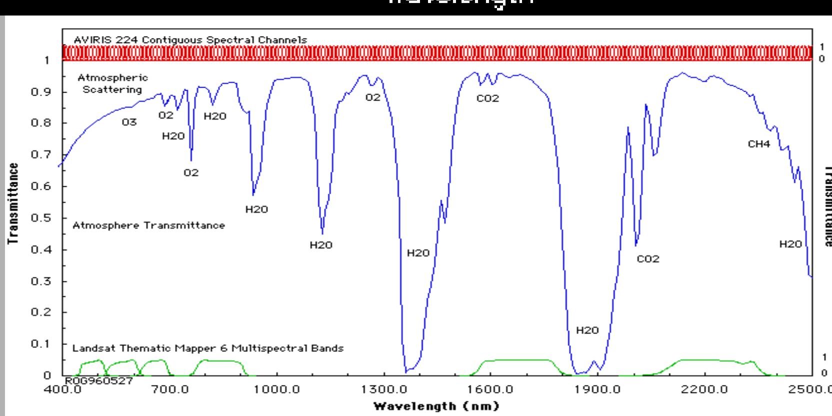
Overshooting thunderstorm tops and cloud top temperature

The visible to near infrared portion of the spectrum



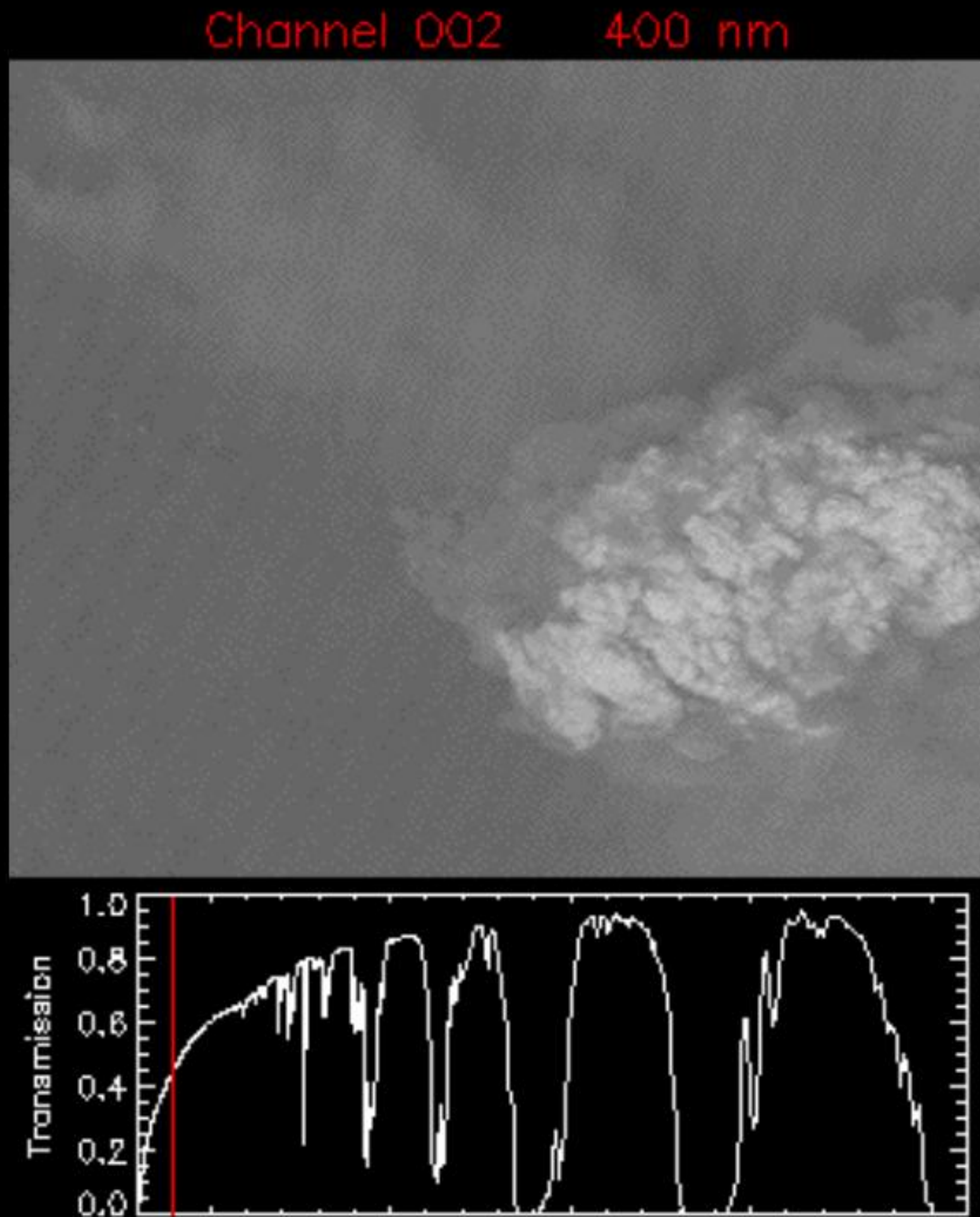




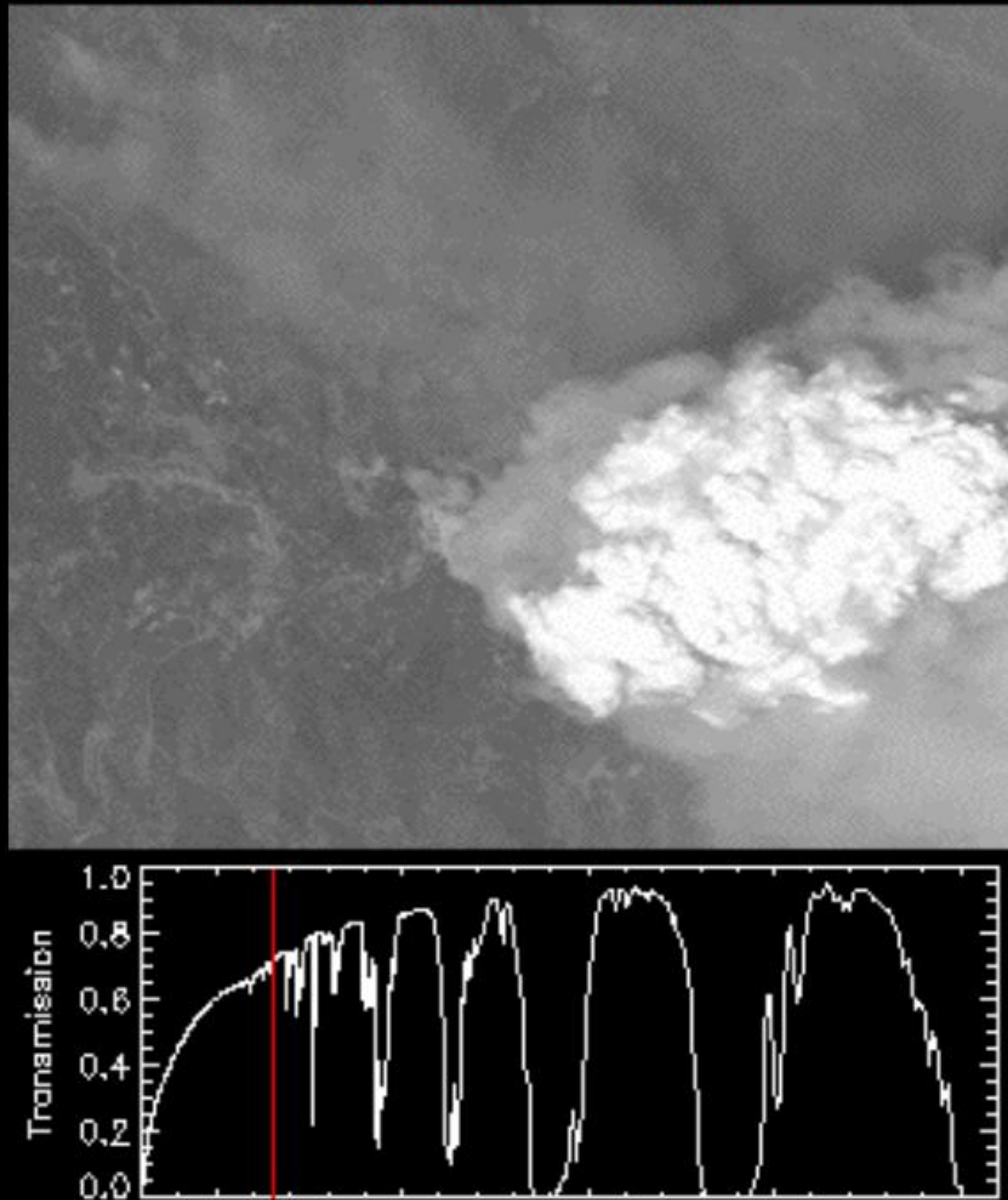


Click on picture to start and stop anima-tion

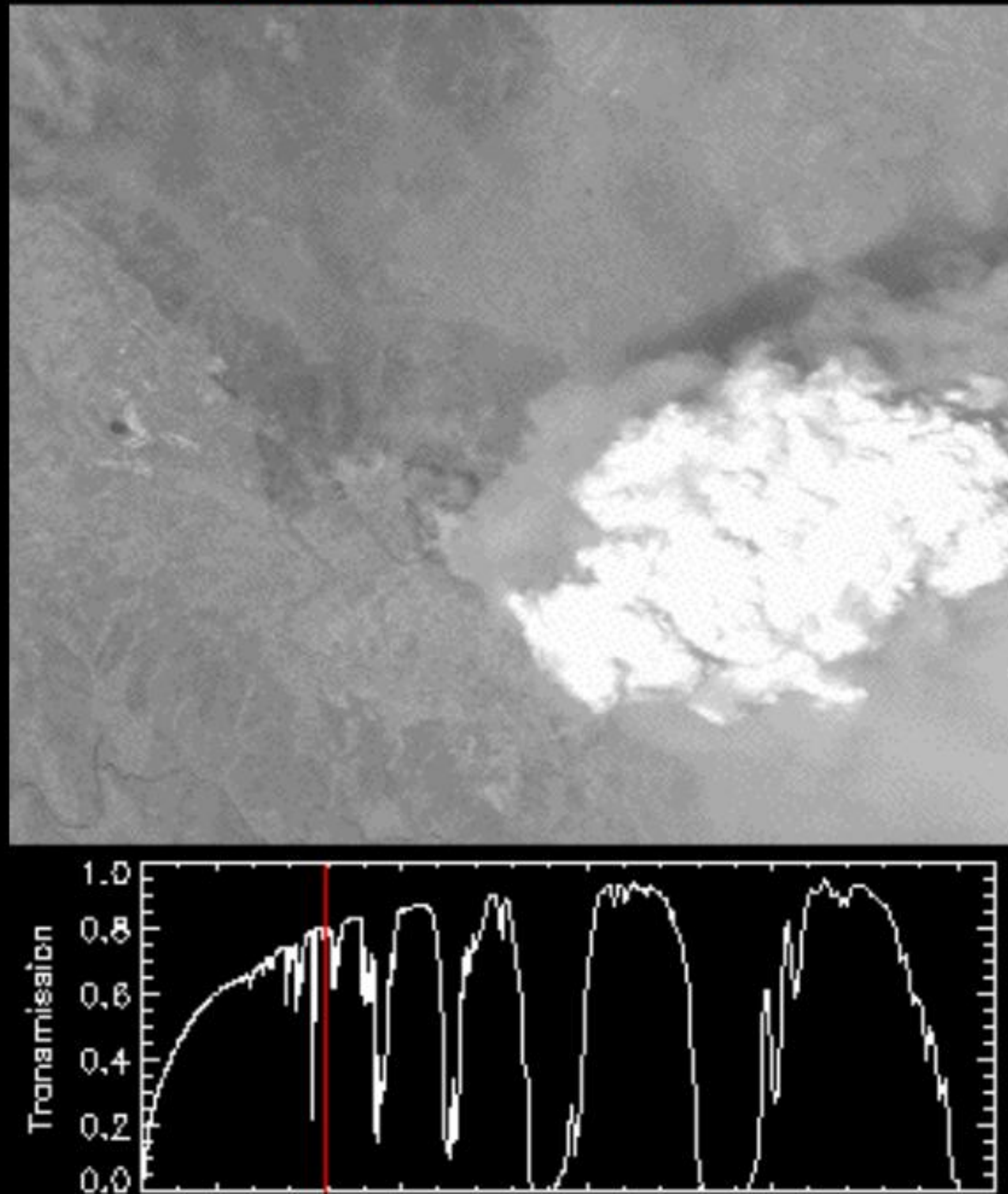
Spectral animation of a single AVIRIS scene reveals the power of being able to observe with high spectral resolution. Beginning at 400 nanometers ground features are difficult to discern, mainly due to molecular scattering which decreases at longer wavelengths. As we observe the scene at longer wavelengths, some features become distinct (land), while others become obscure (apparent decrease in smoke). Note the effect of the water vapor absorption regions on scene brightness. See also next slide.

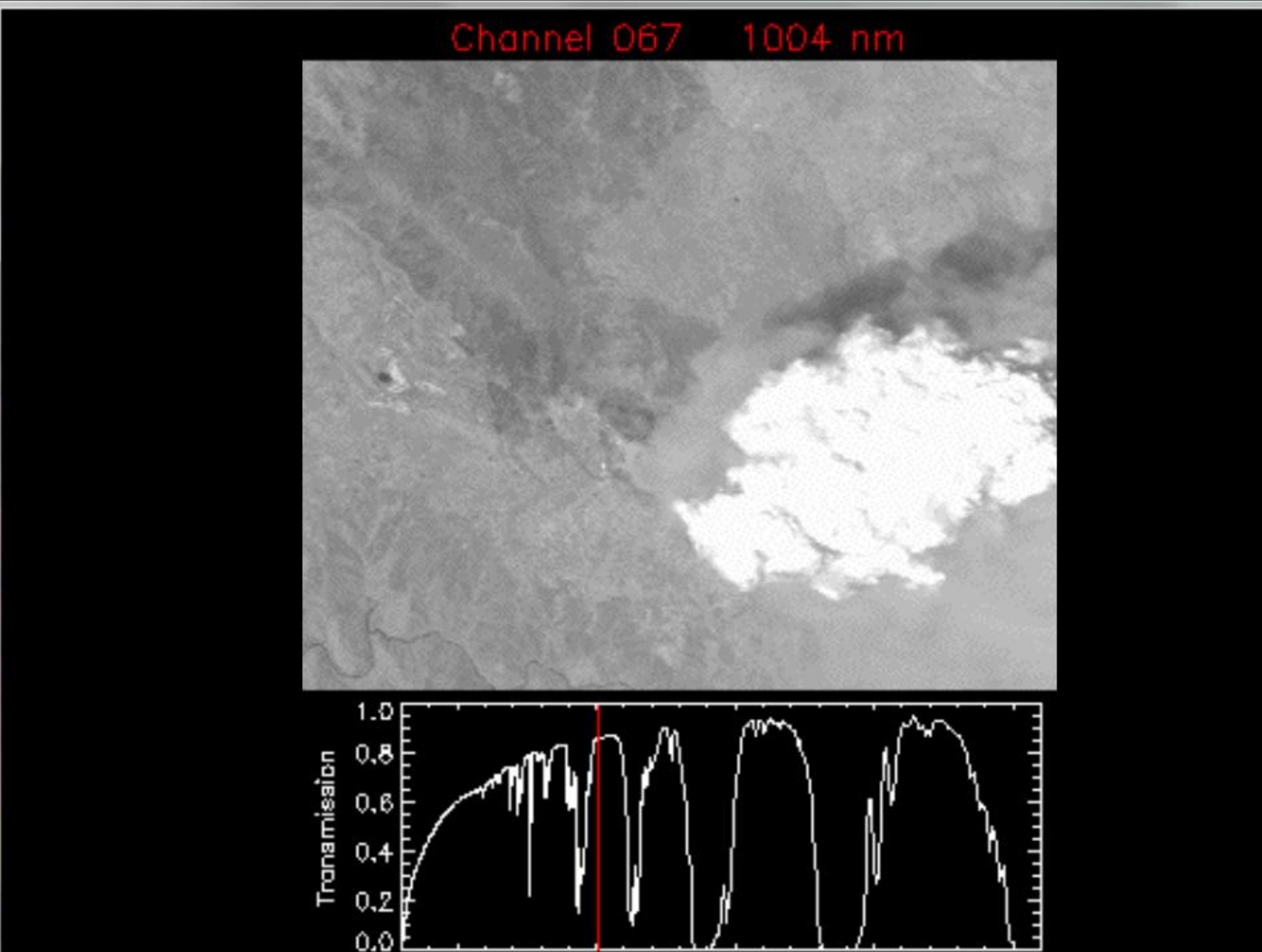

Channel 002 400 nm
Transmission
1.0
0.8
0.6
0.4
0.2
0.0

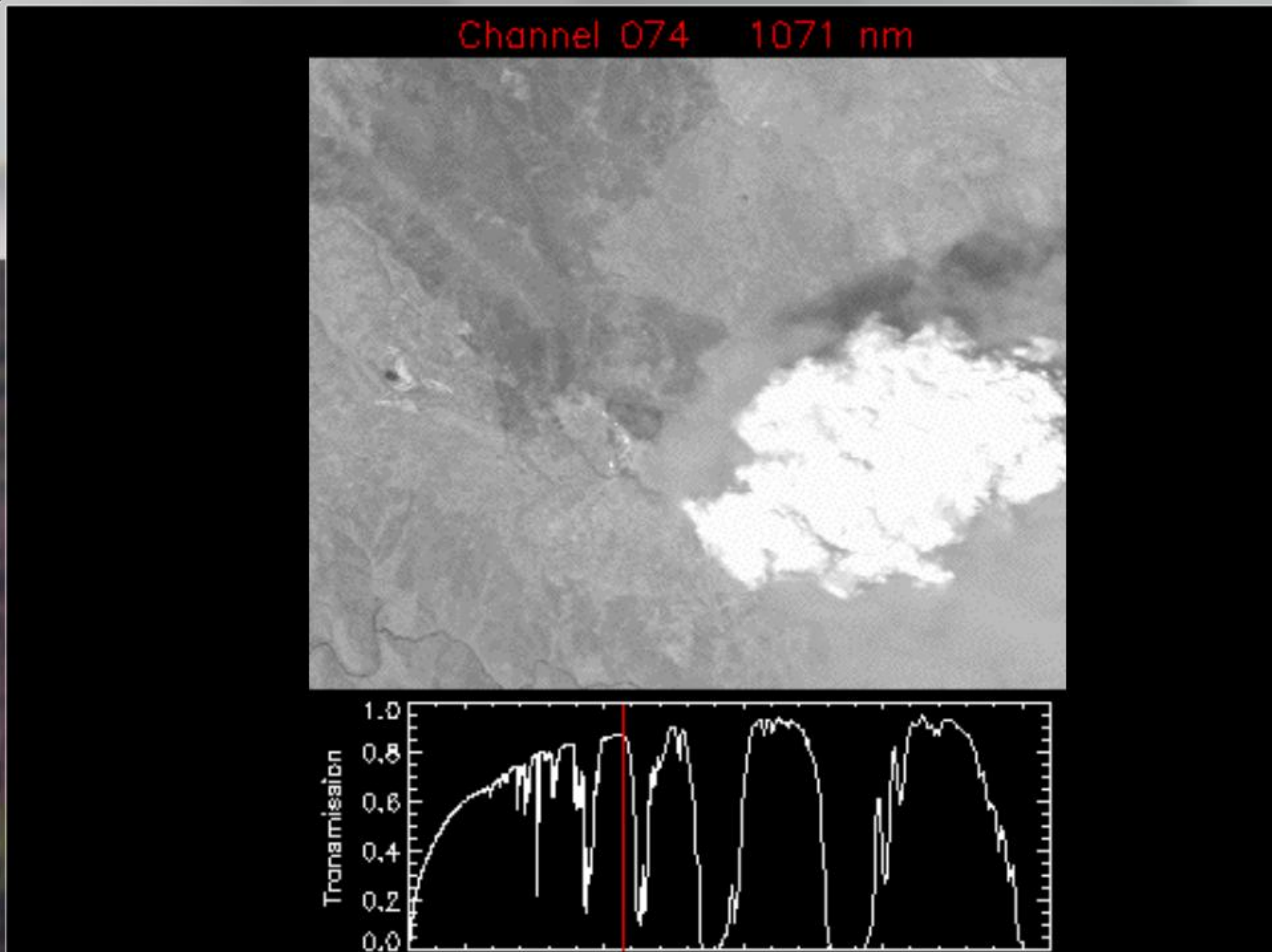
Channel 028   656 nm



Channel 045   792 nm

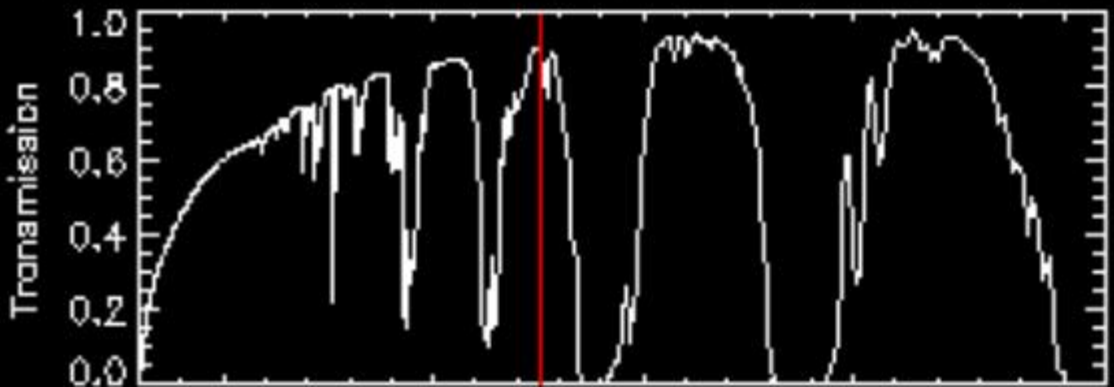



Channel 067 1004 nm
Transmission
1.0
0.8
0.6
0.4
0.2
0.0

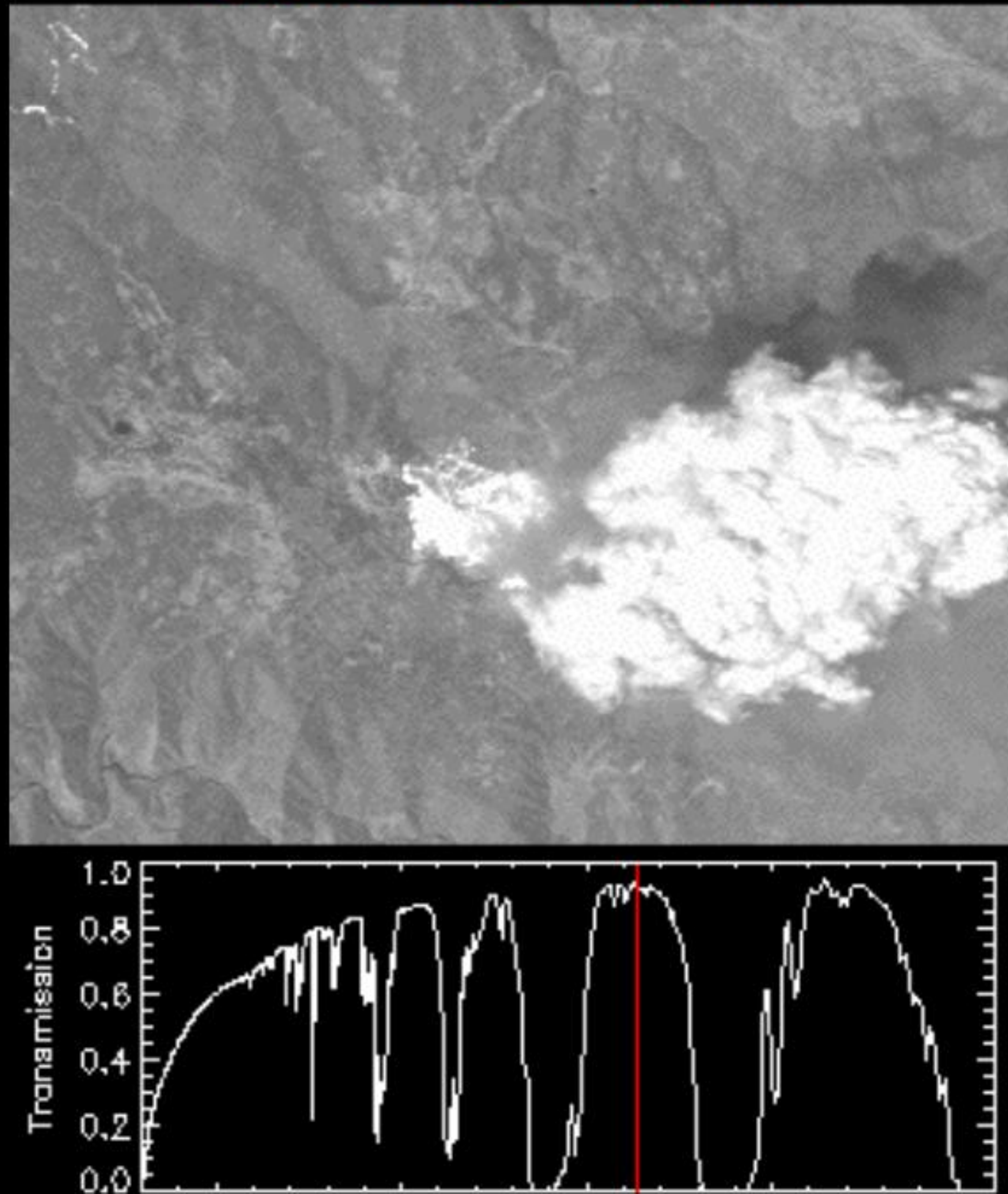


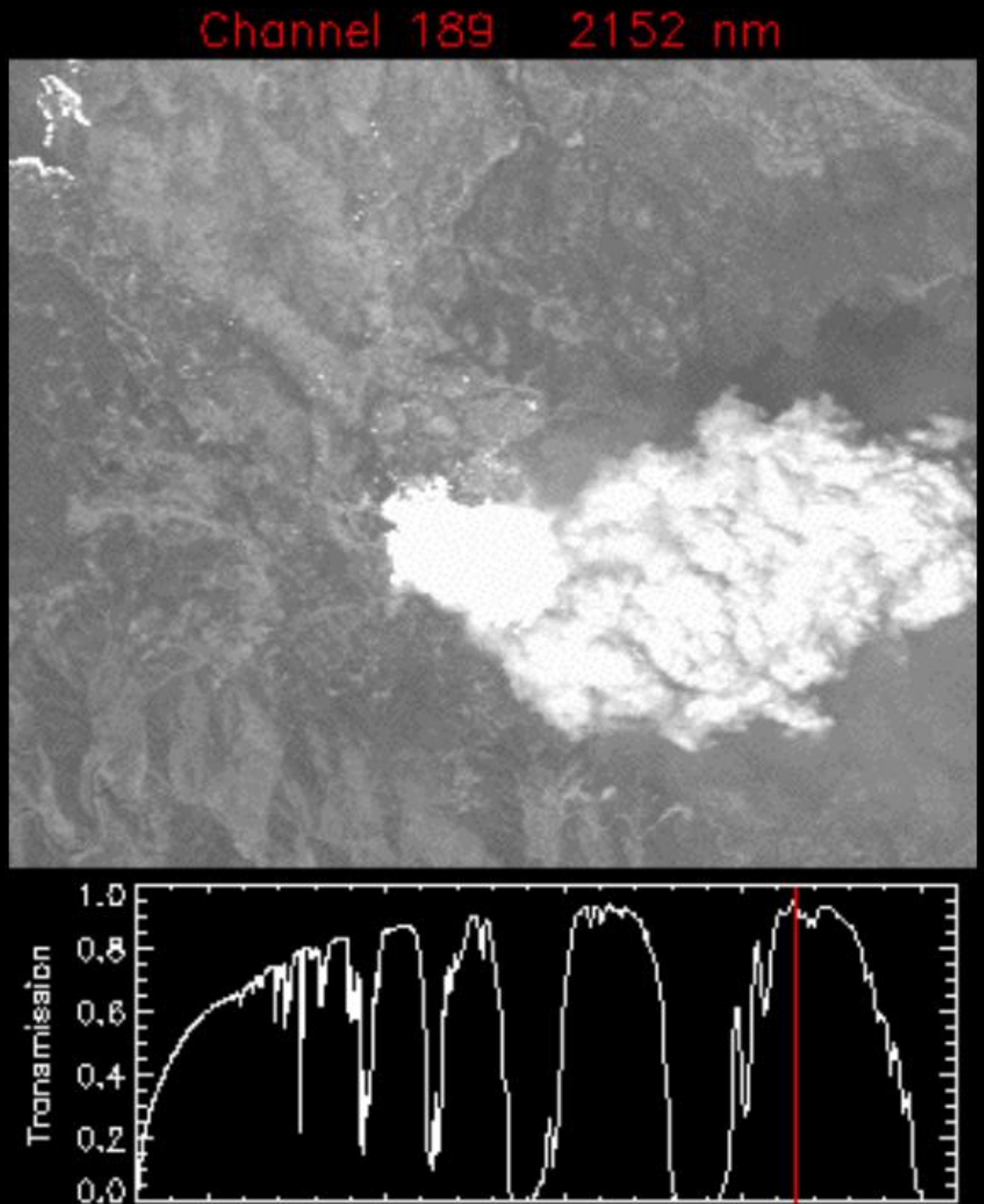
Channel 074 1071 nm
1.0
0.8
0.6
0.4
0.2
0.0
Transmission

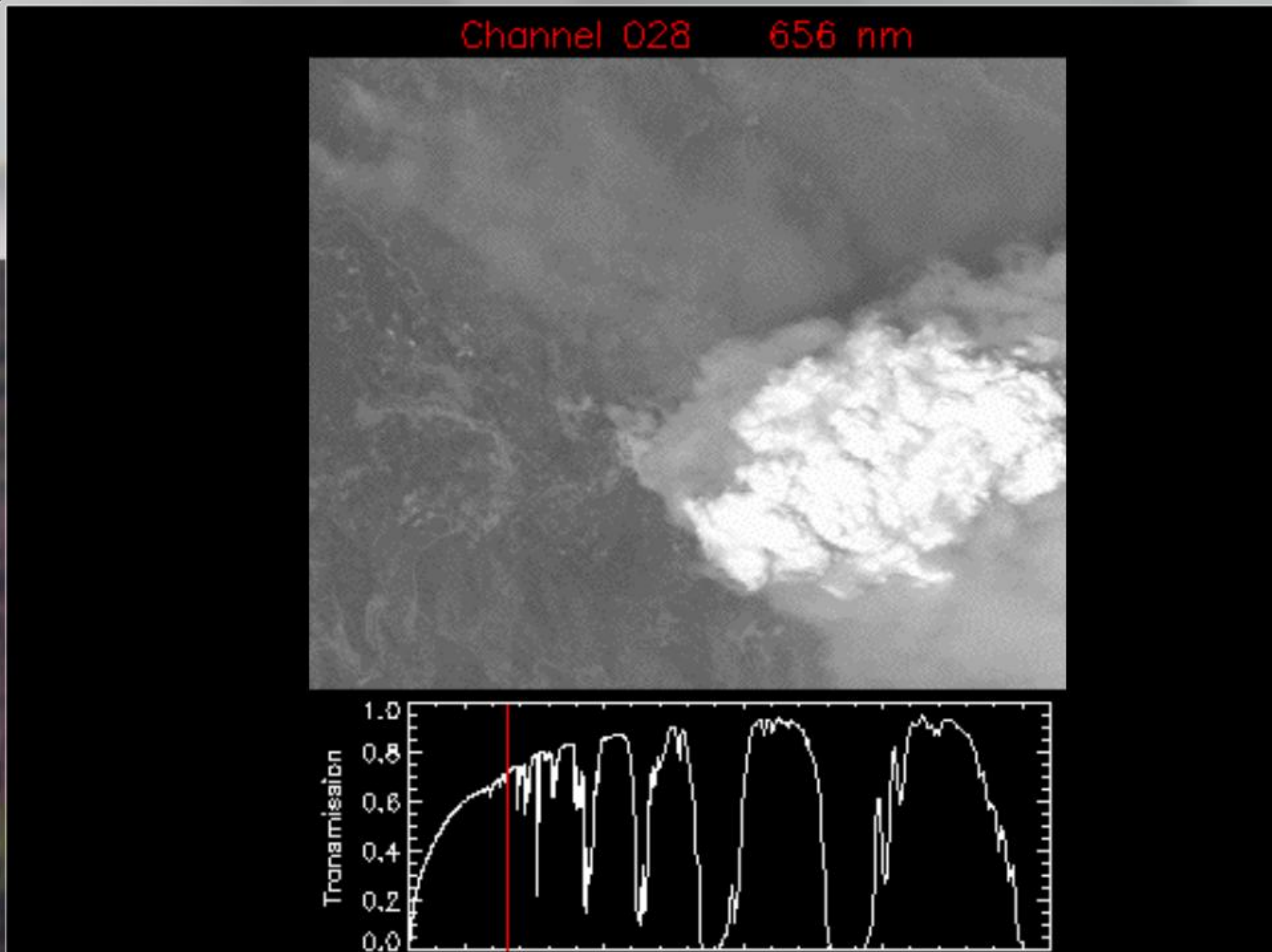
Channel 093   1253 nm

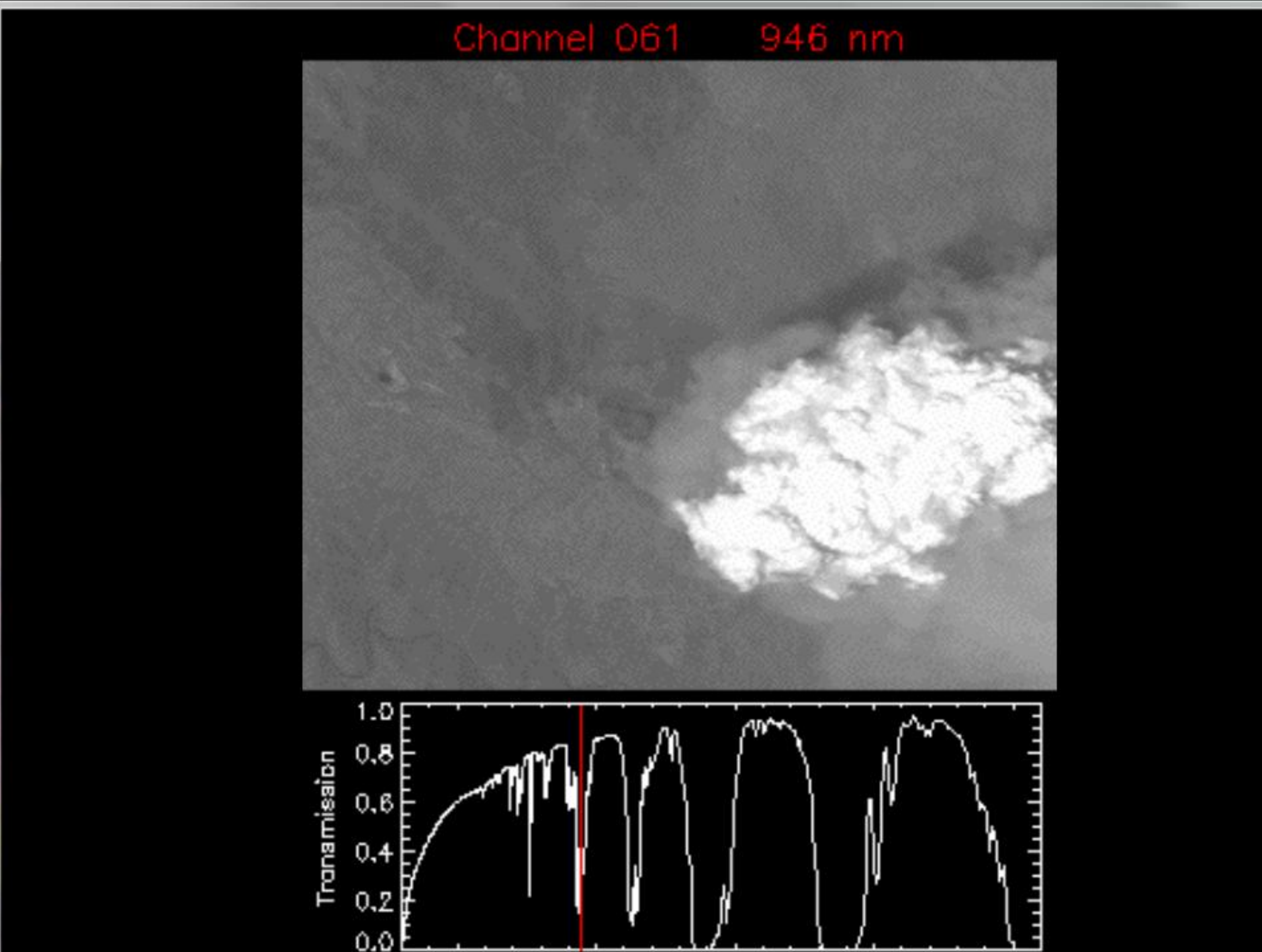


Channel 135 1640 nm

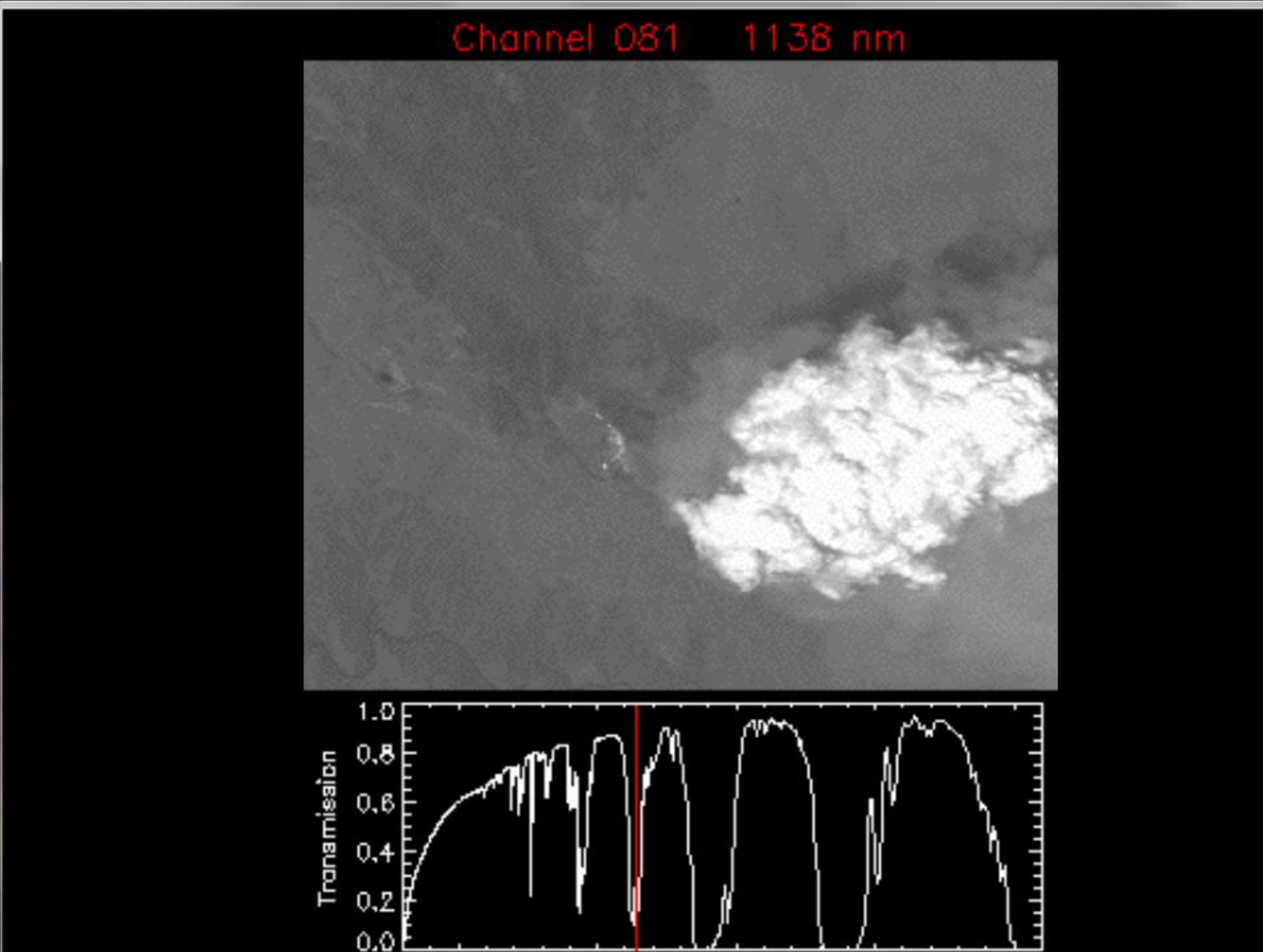


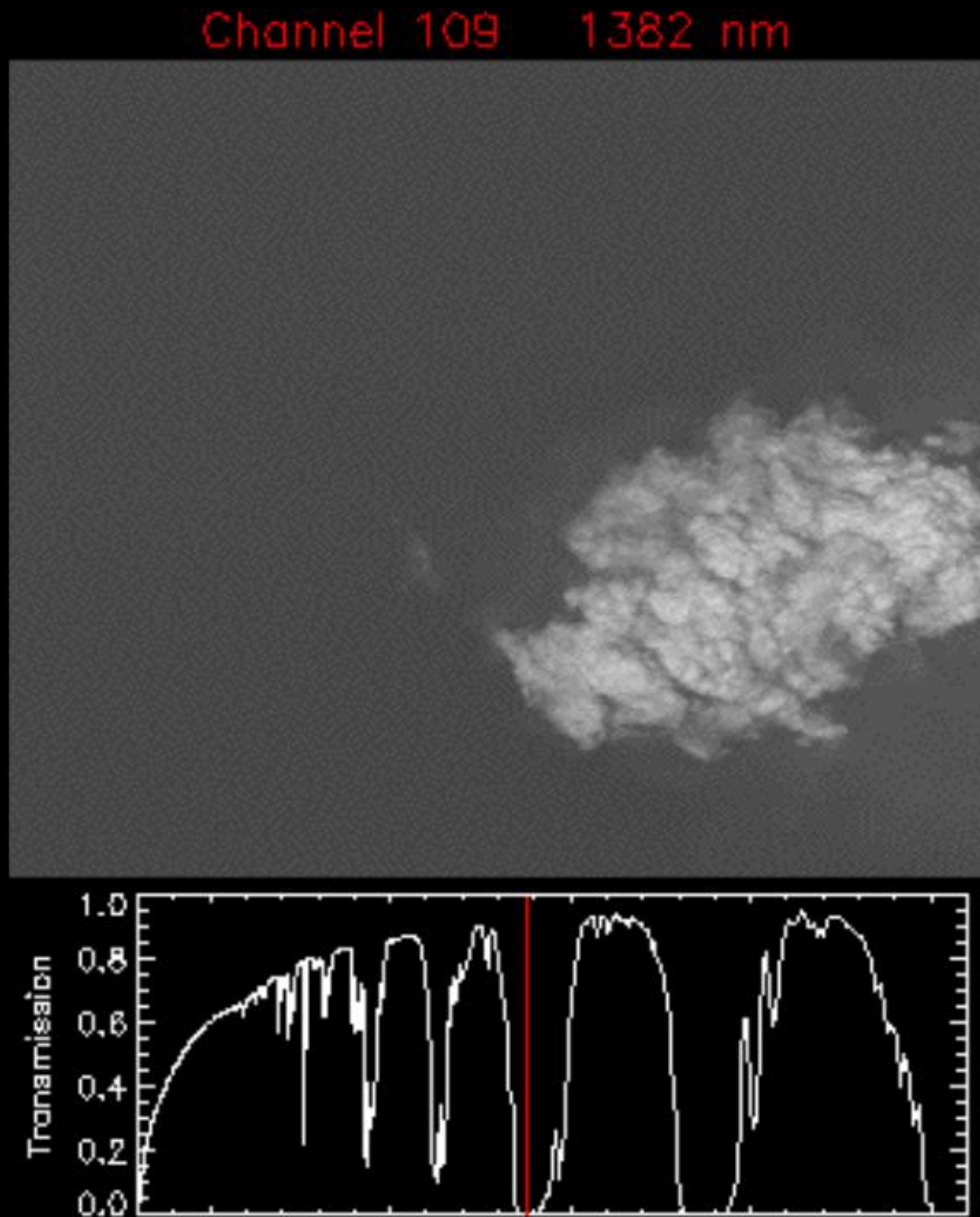

Channel 189 2152 nm
1.0
0.8
0.6
0.4
0.2
0.0
Transmission

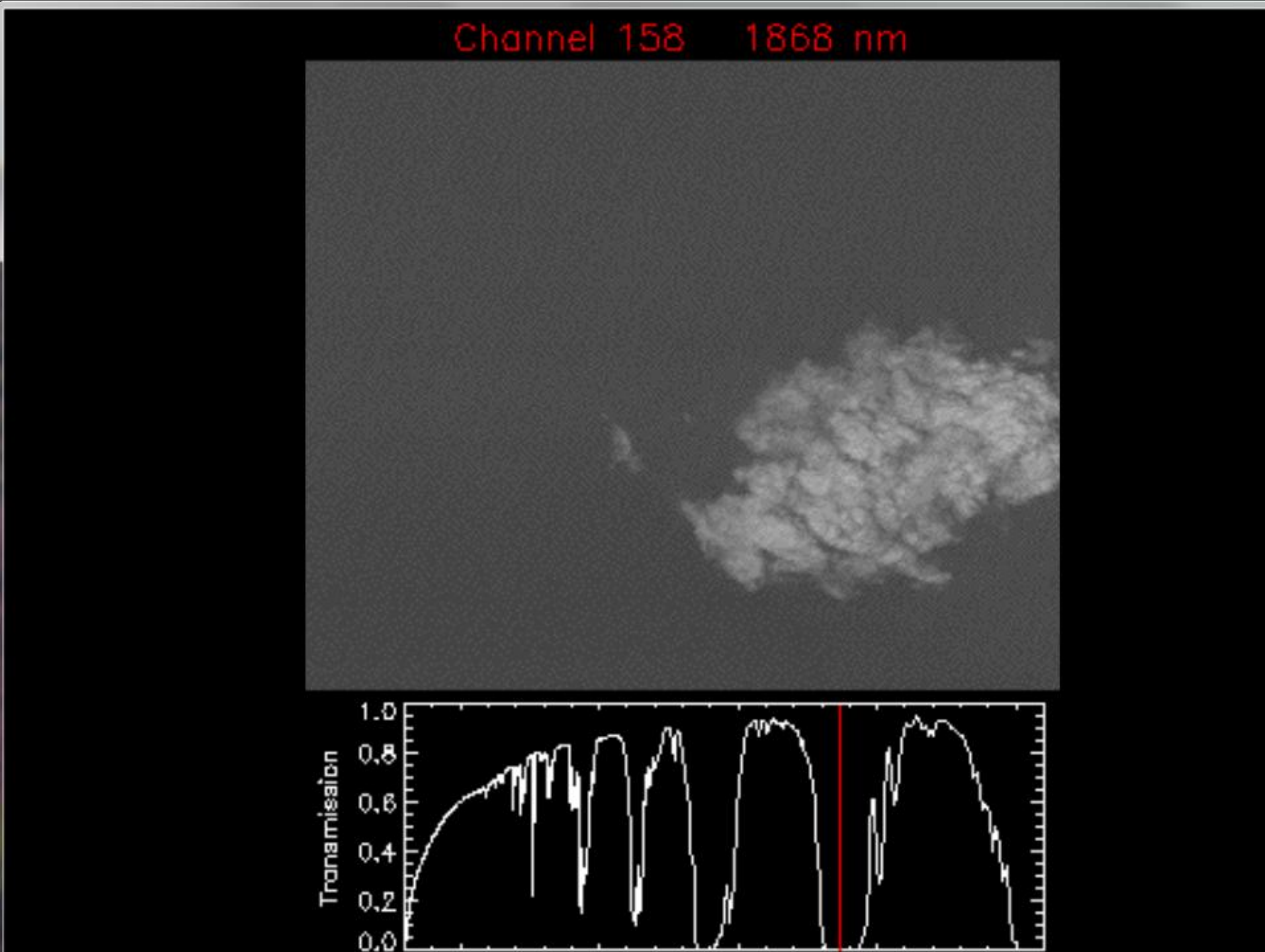

Channel 028 656 nm
Transmission
1.0
0.8
0.6
0.4
0.2
0.0



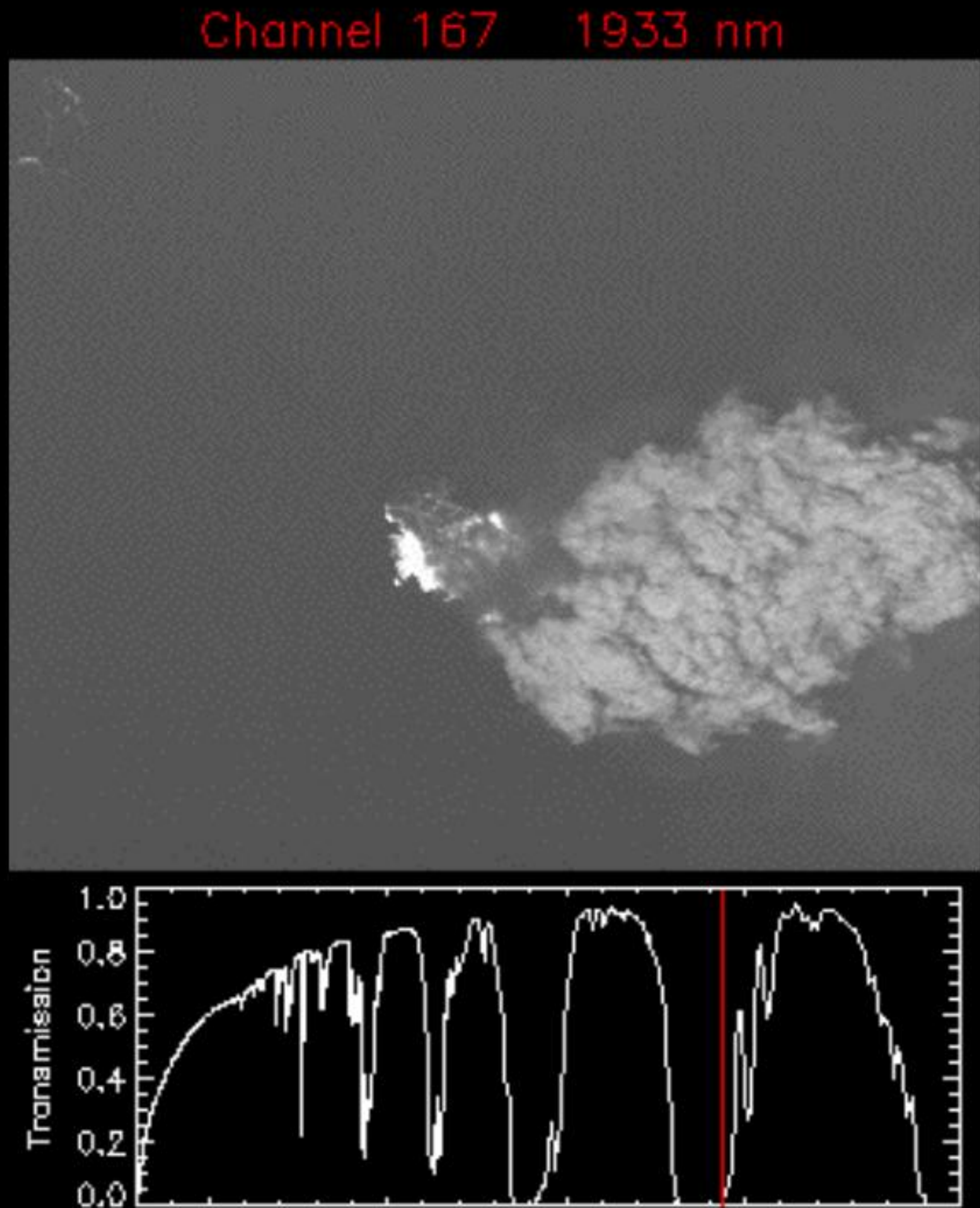
Channel 061 946 nm
Transmission
1.0
0.8
0.6
0.4
0.2
0.0

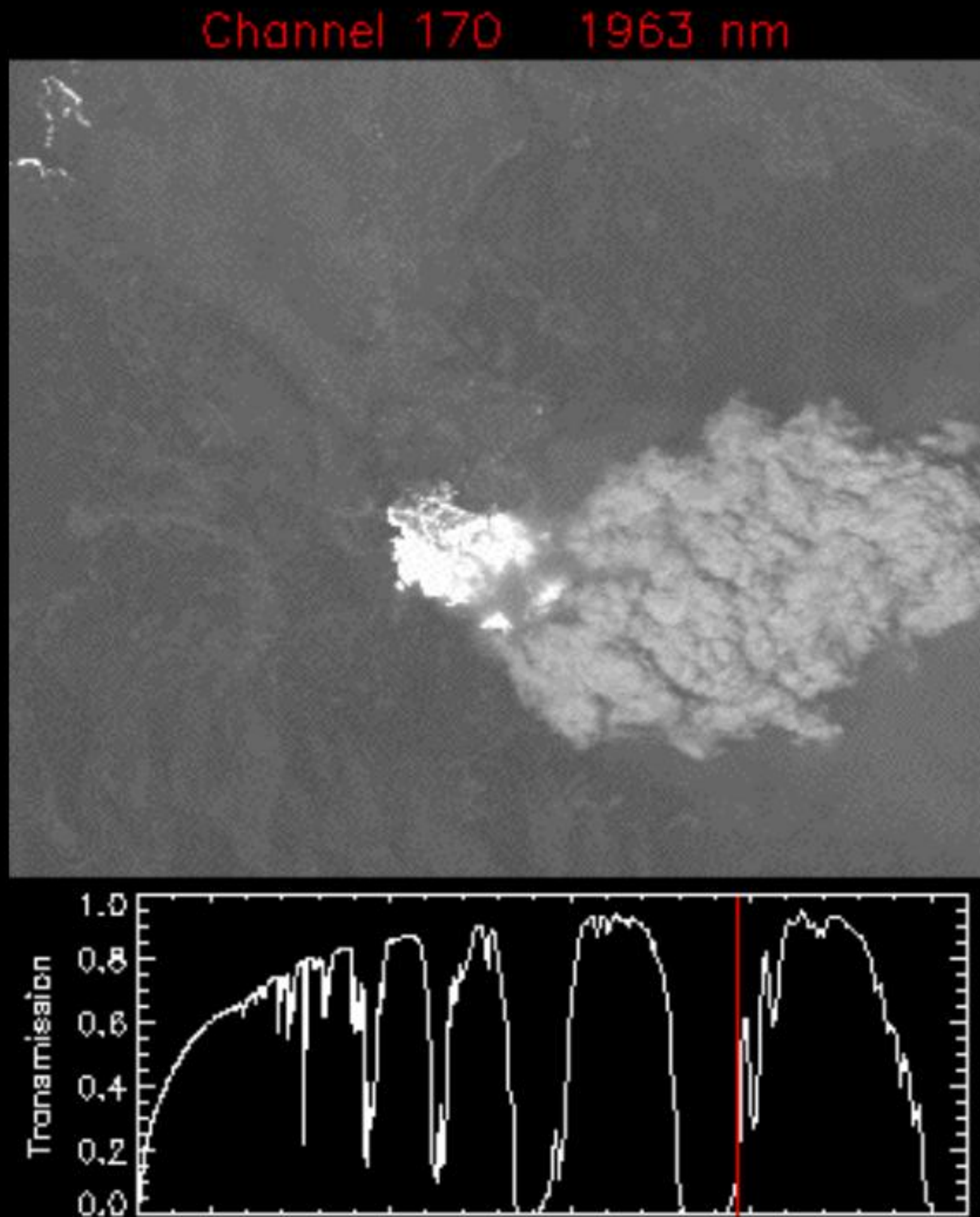

Channel 081 1138 nm
Transmission
1.0
0.8
0.6
0.4
0.2
0.0


Channel 109 1382 nm
Transmission
1.0
0.8
0.6
0.4
0.2
0.0



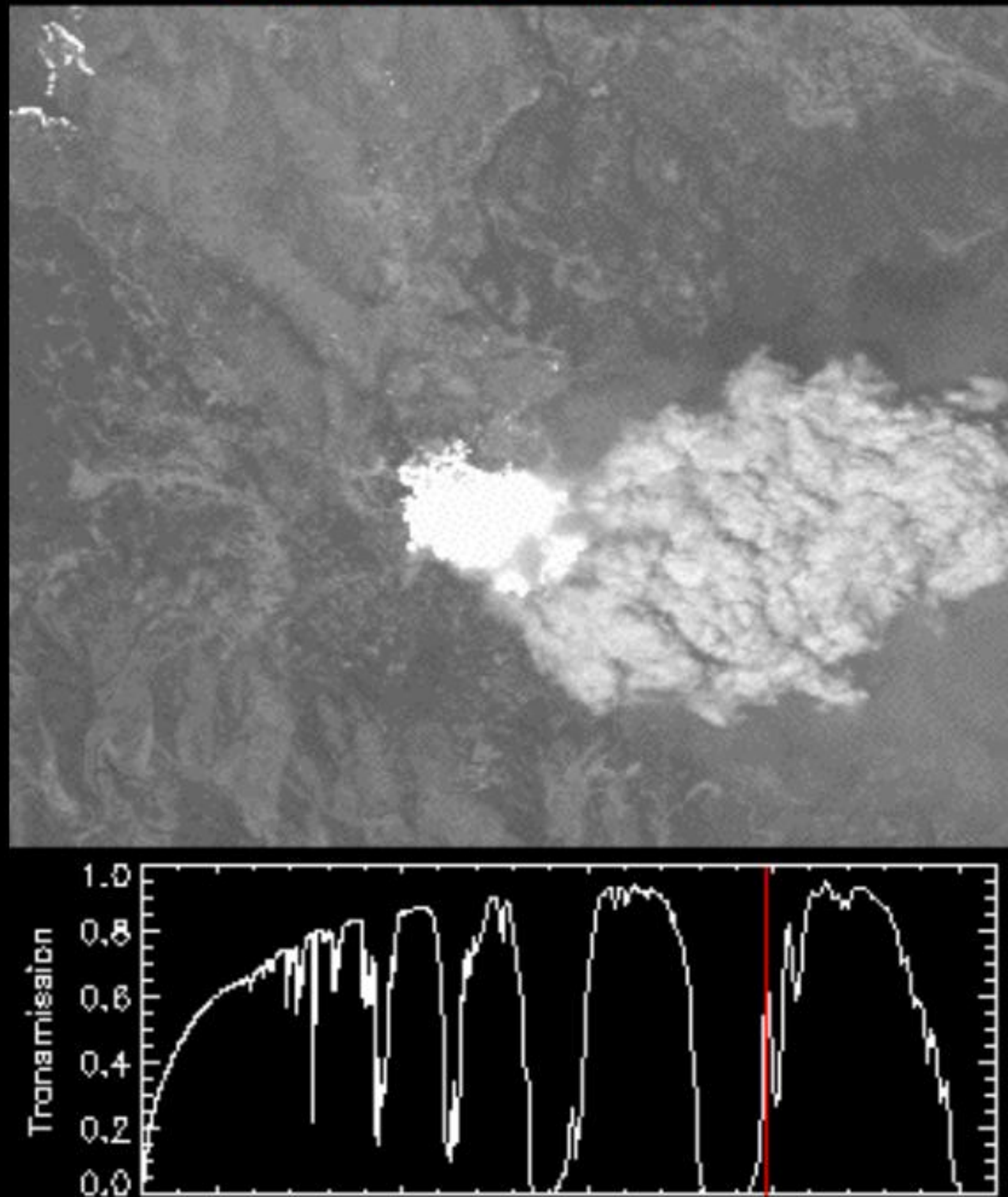
Channel 158 1868 nm
Transmission
1.0
0.8
0.6
0.4
0.2
0.0

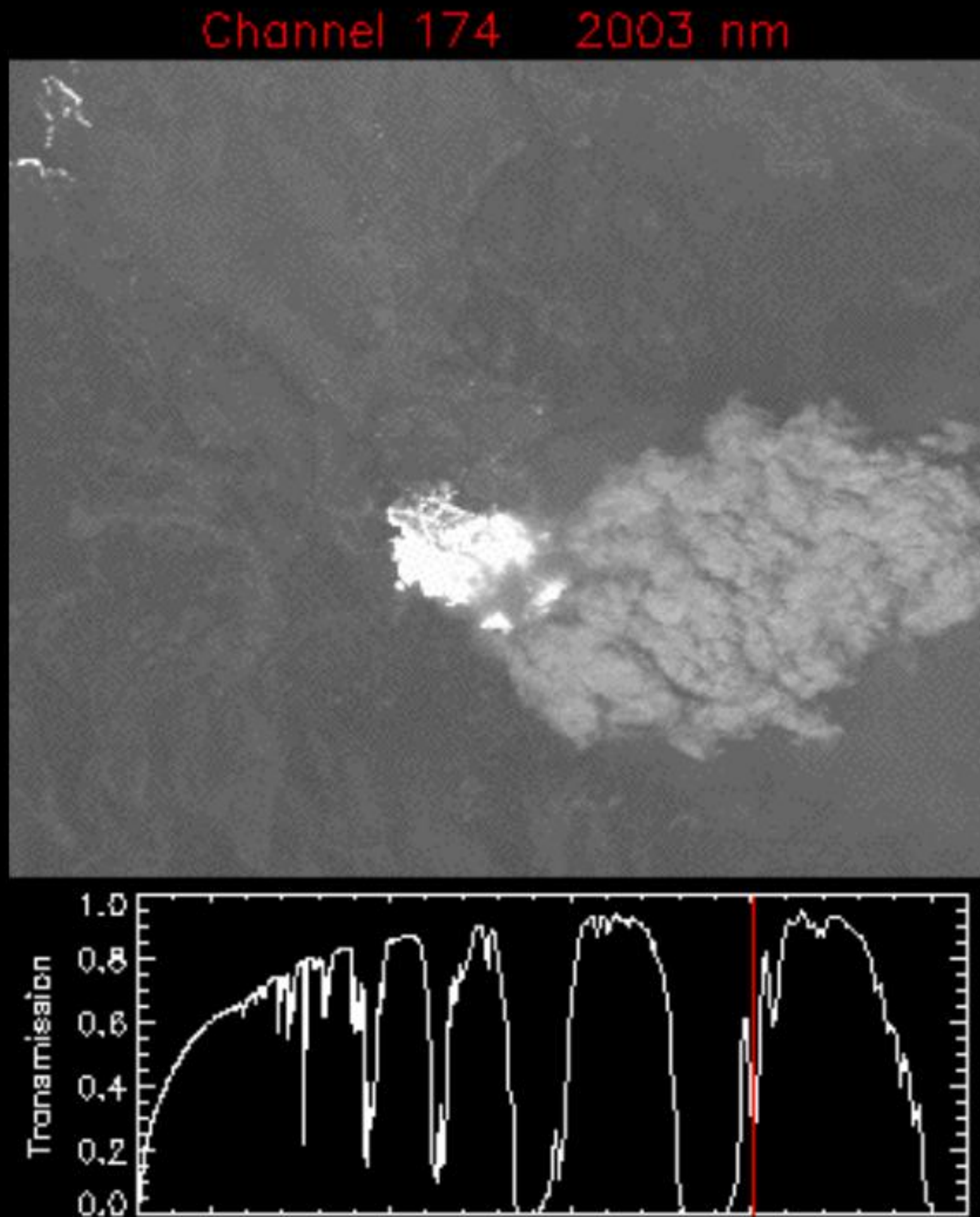

Channel 167 1933 nm
Transmission
1.0
0.8
0.6
0.4
0.2
0.0



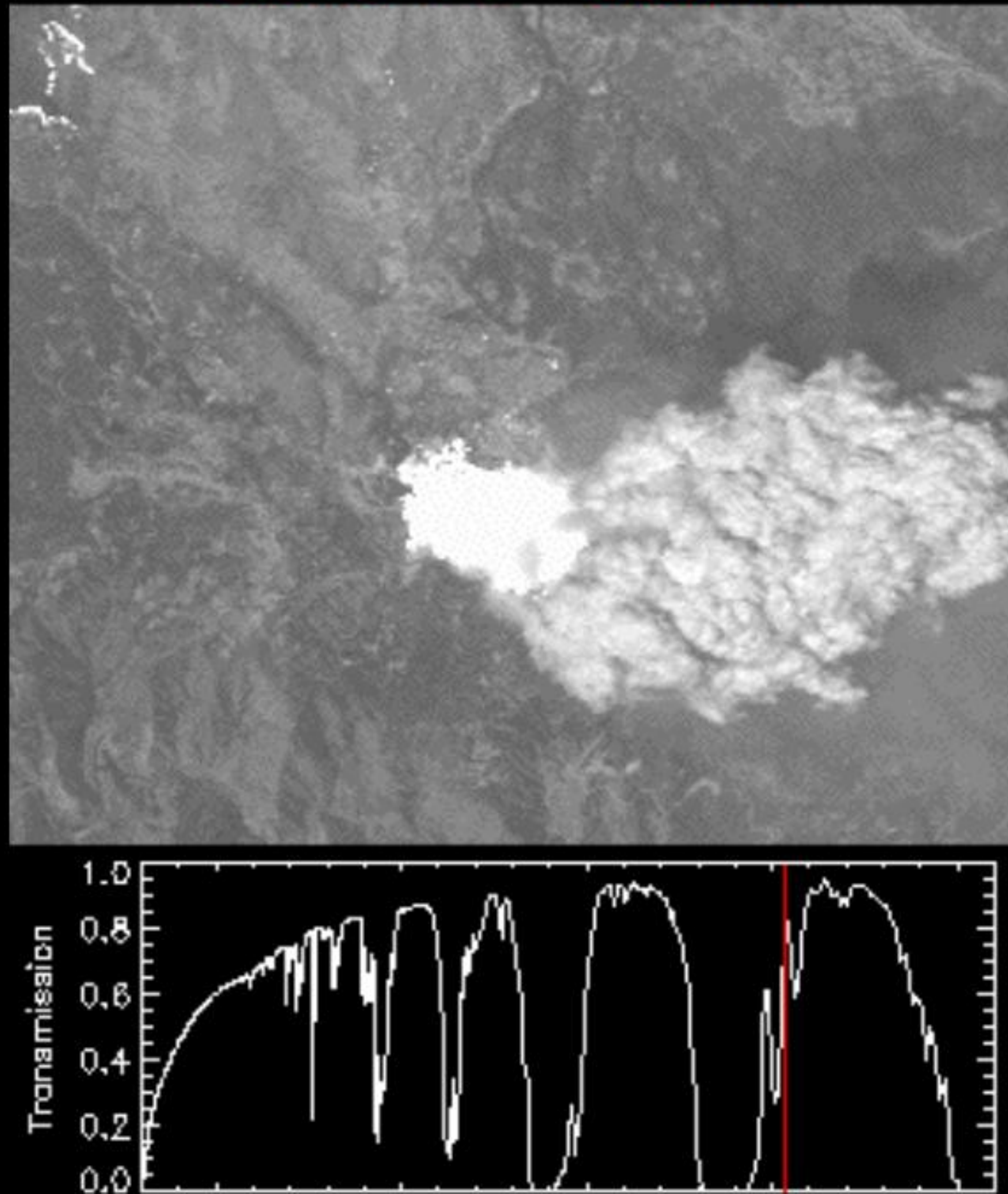
Channel 170 1963 nm
Transmission
1.0
0.8
0.6
0.4
0.2
0.0

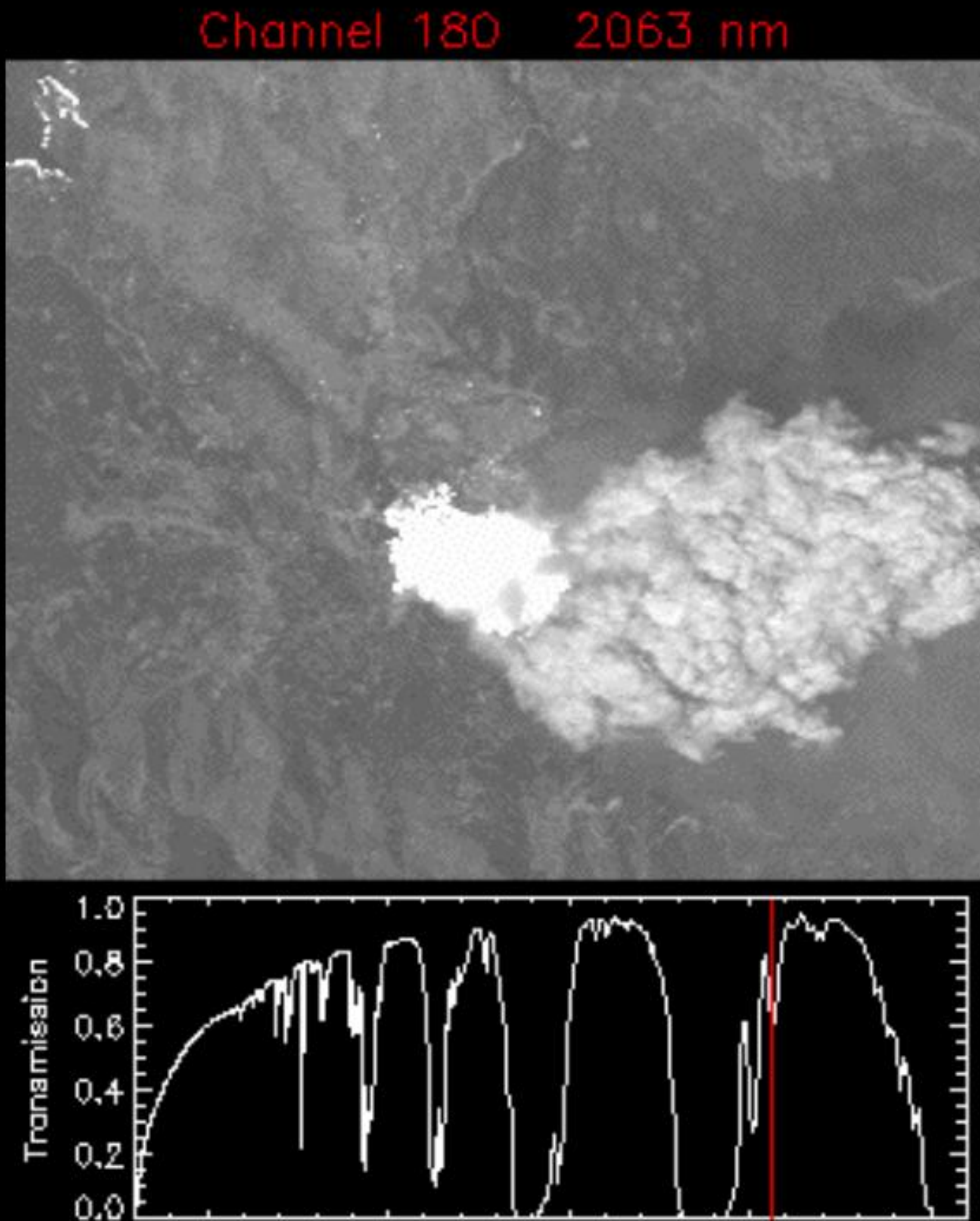
Channel 172 1983 nm

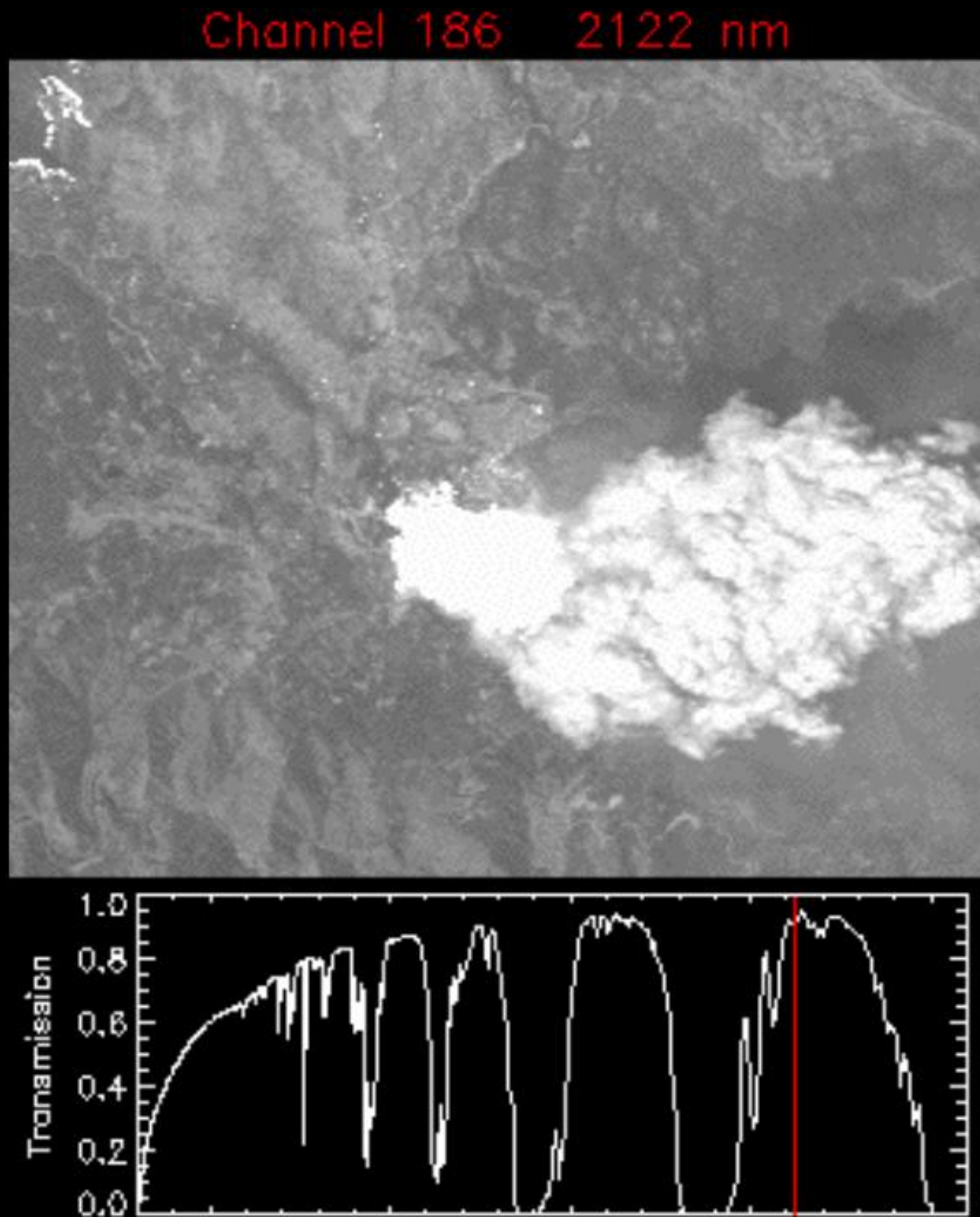



Channel 174 2003 nm
Transmission
1.0
0.8
0.6
0.4
0.2
0.0

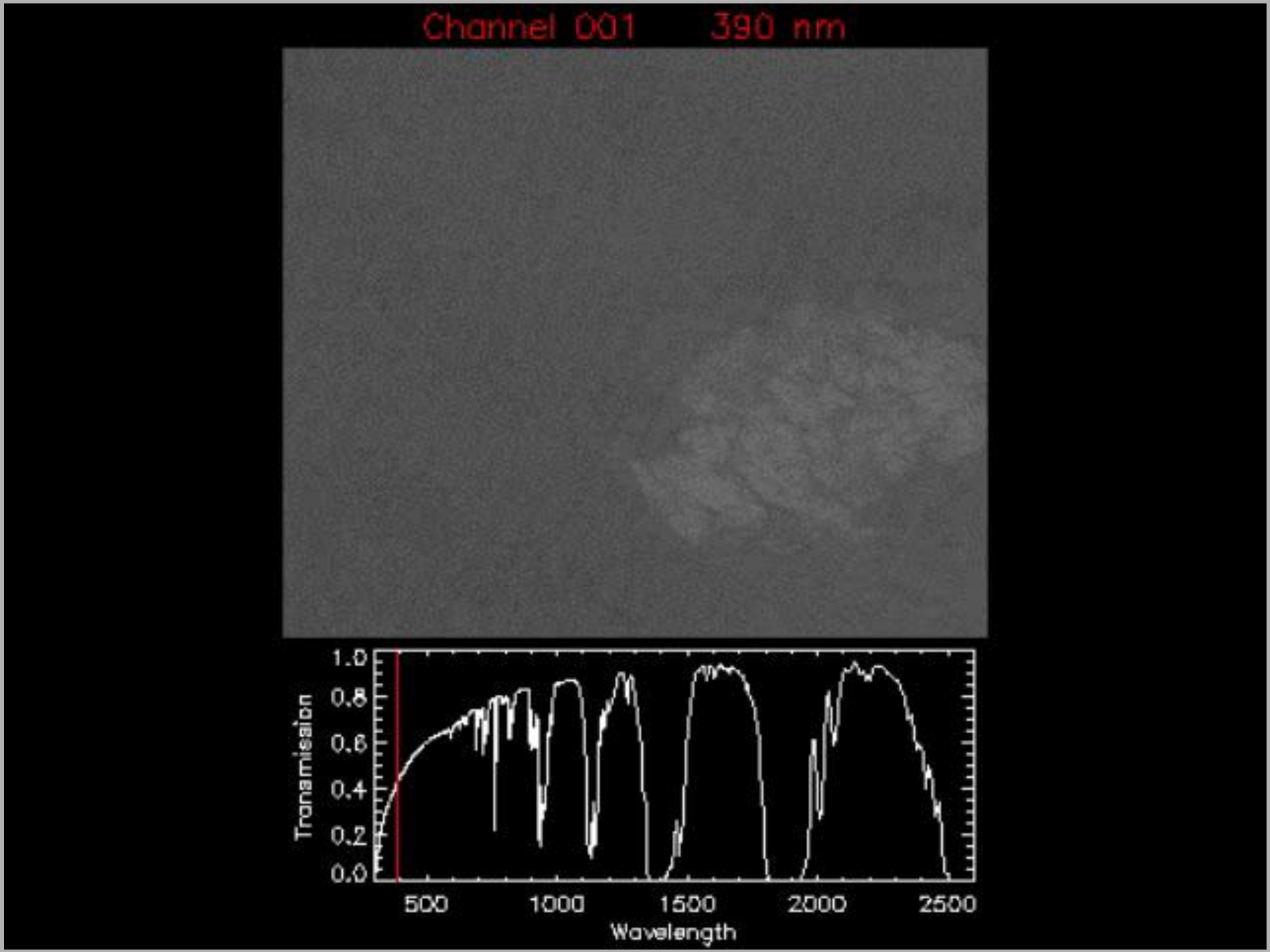
Channel 177 2033 nm



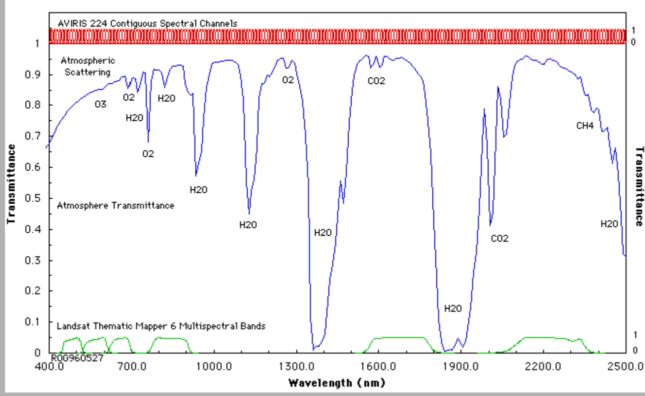

Channel 180 2063 nm
Transmission
1.0
0.8
0.6
0.4
0.2
0.0

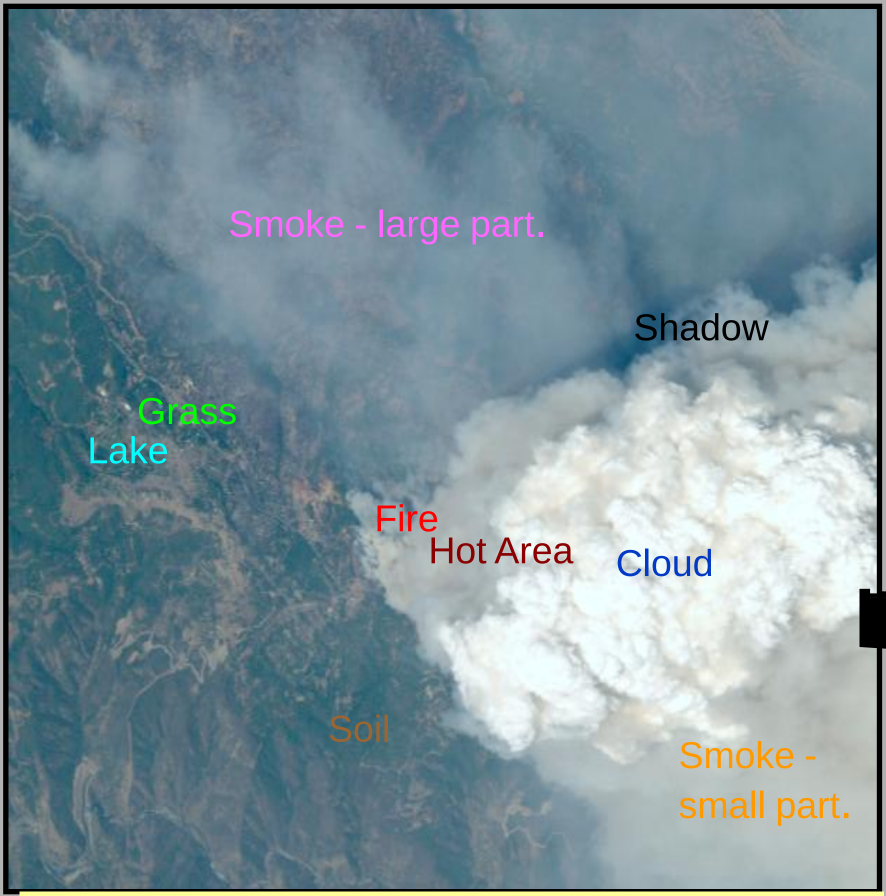


Channel 186 2122 nm
1.0
0.8
0.6
0.4
0.2
0.0
Transmission

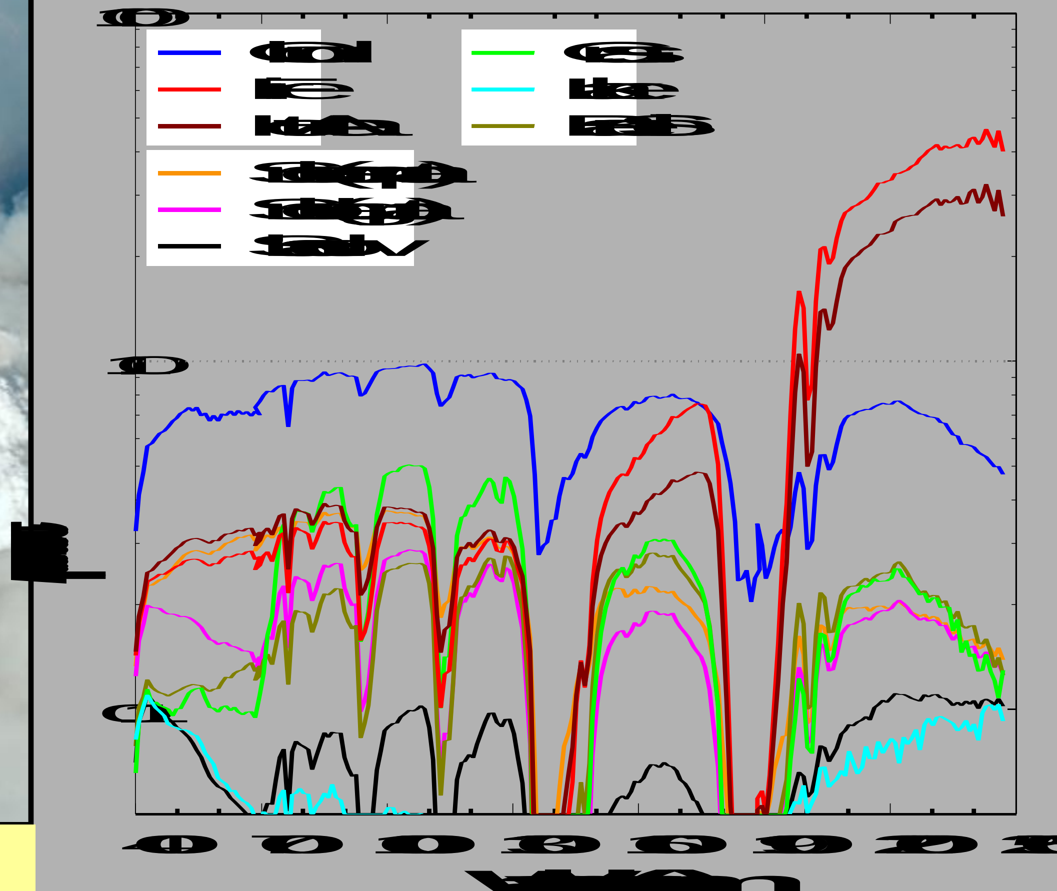

Channel 001 390 nm
Transmission
1.0
0.8
0.6
0.4
0.2
0.0
500
1000
1500
2000
2500
Wavelength

AVIRIS Spectral Information from the Scene Depicting Cloud, Smoke and Active Burn Areas





AVIRIS Image - Linden CA 20-Aug-1992
224 Spectral Bands: 0.4 - 2.5 μm
Pixel: 20m x 20m Scene: 10km x 10km



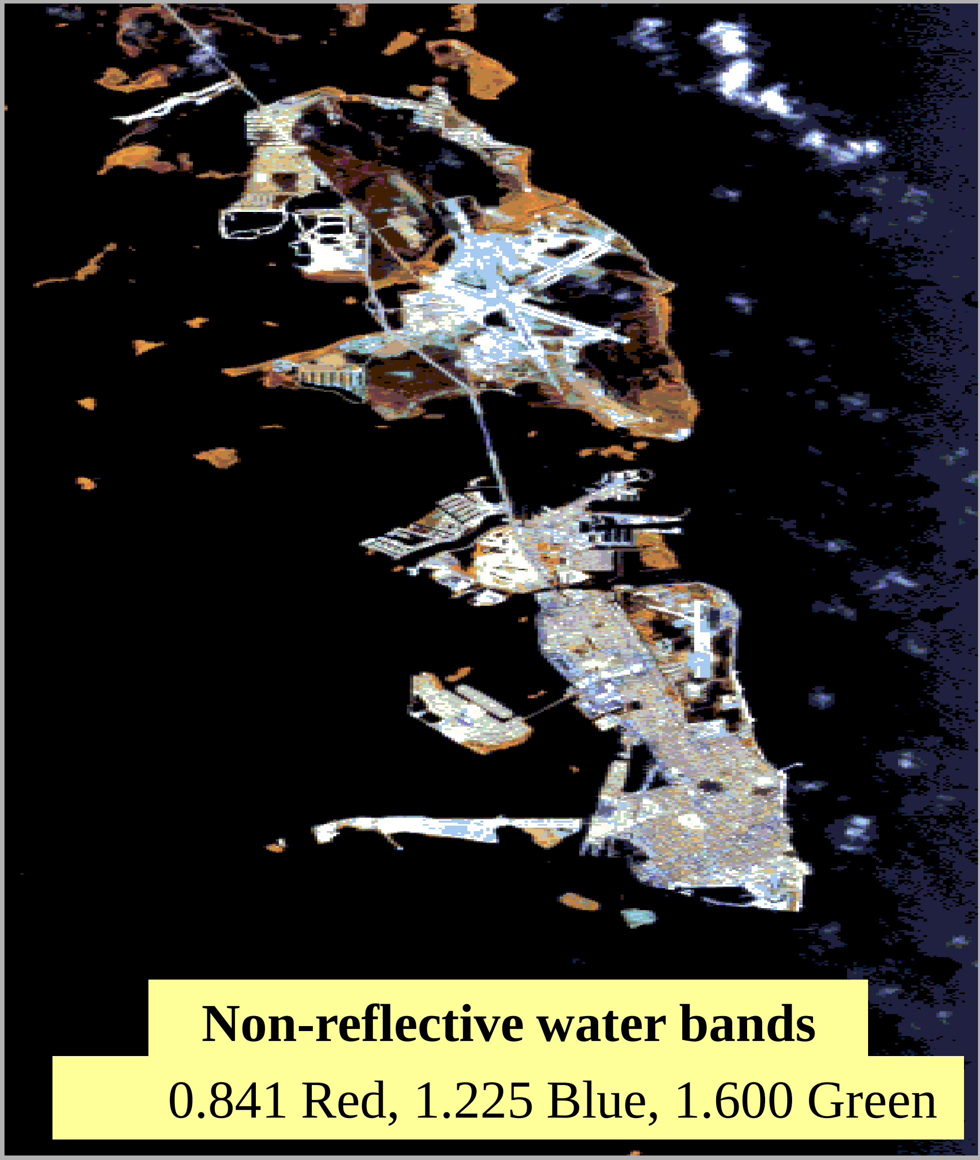
Spectral Signatures of Selected Pixels

Below, the same scene viewed with different visible to near infrared wavelength combinations

“true color”

0.646 Red, 0.547 Blue, 0.449 Green

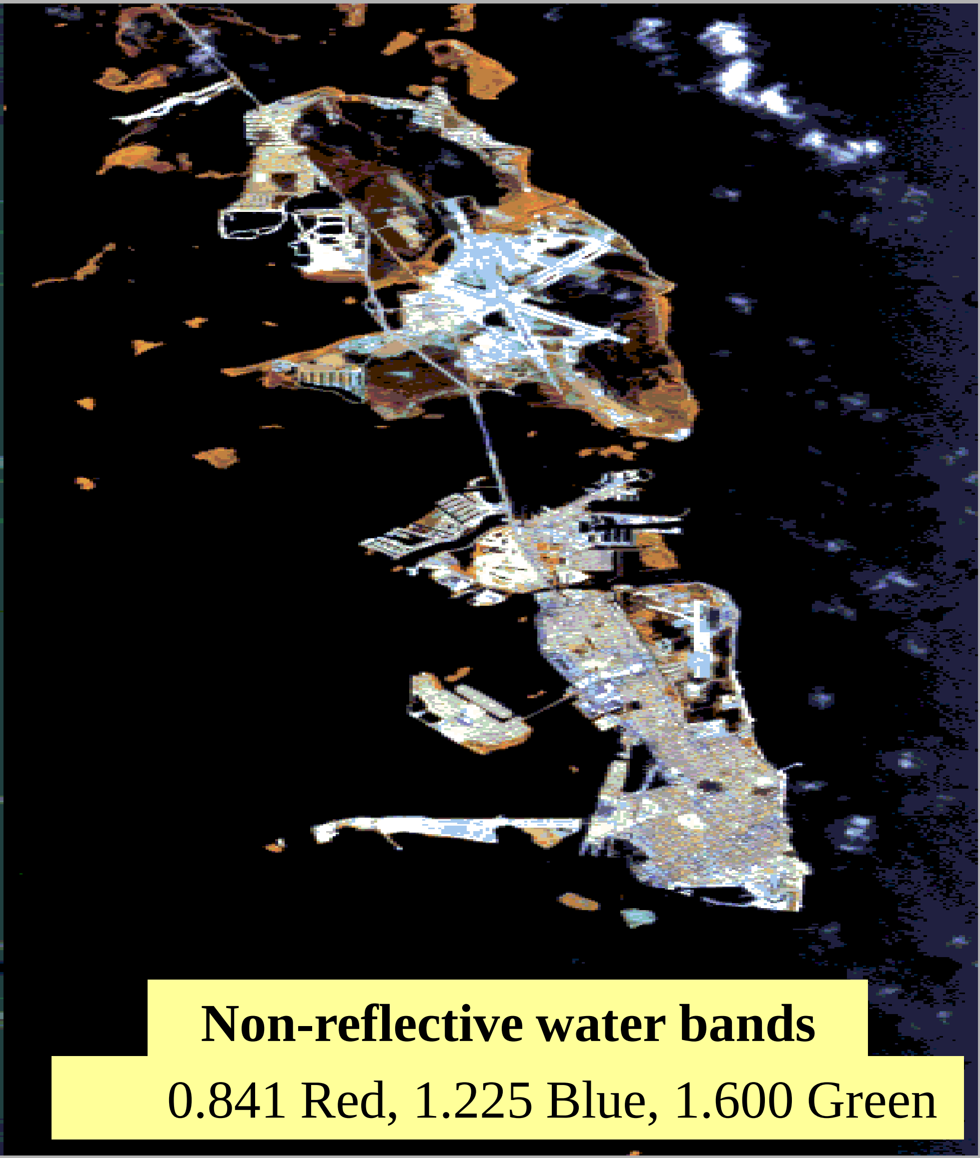
Below, the same scene viewed with different visible to near infrared wavelength combinations



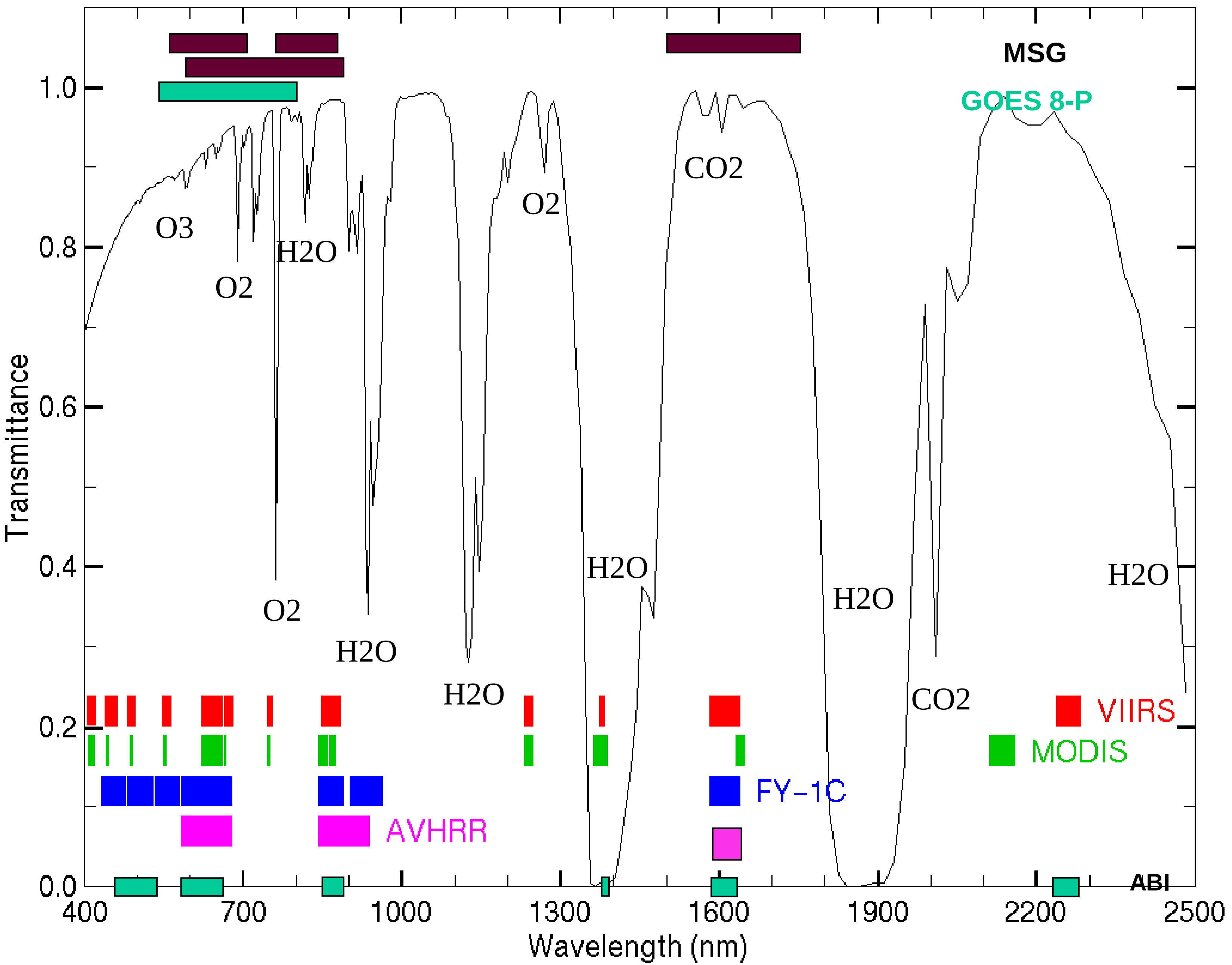
Non-reflective water bands

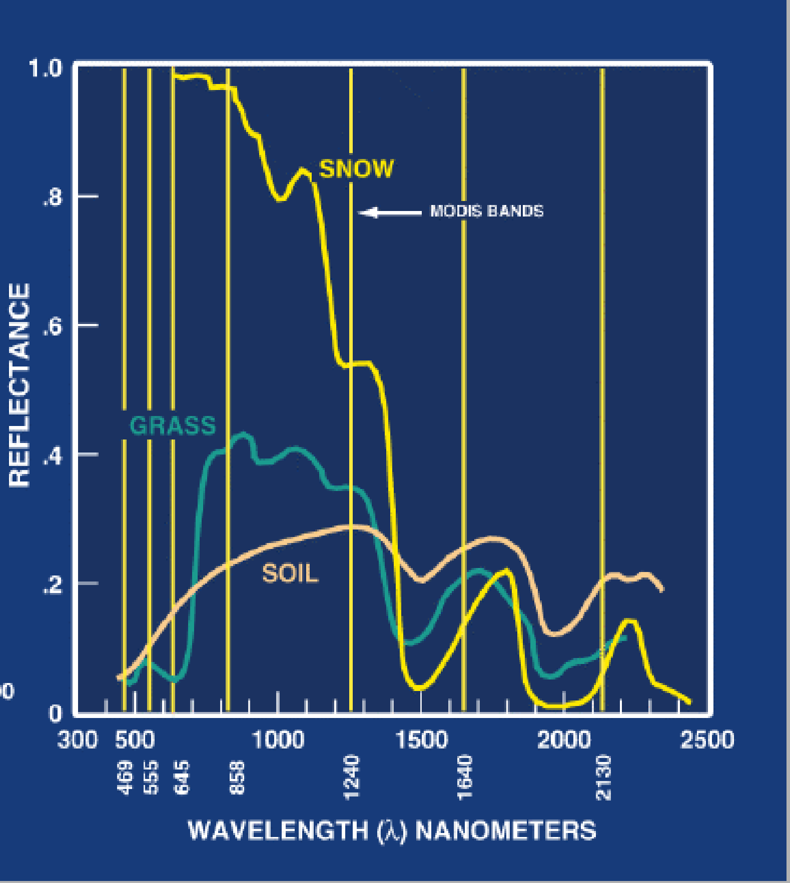
0.841 Red, 1.225 Blue, 1.600 Green

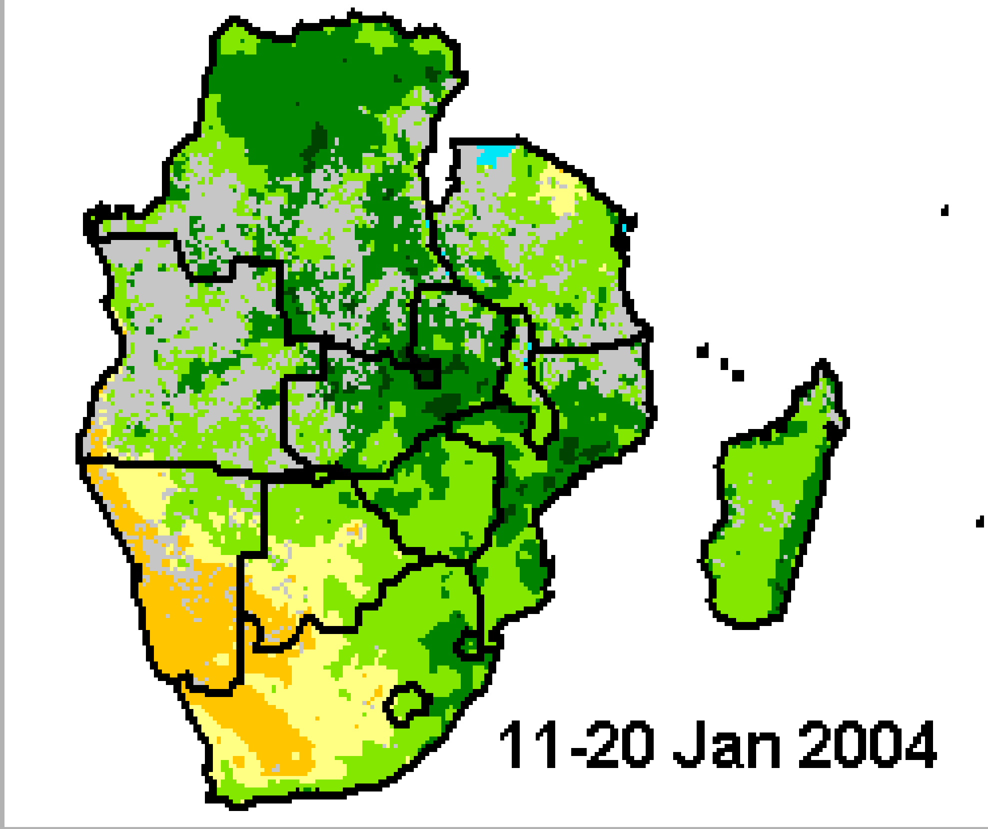
Below, the same scene viewed with different visible to near infrared wavelength combinations



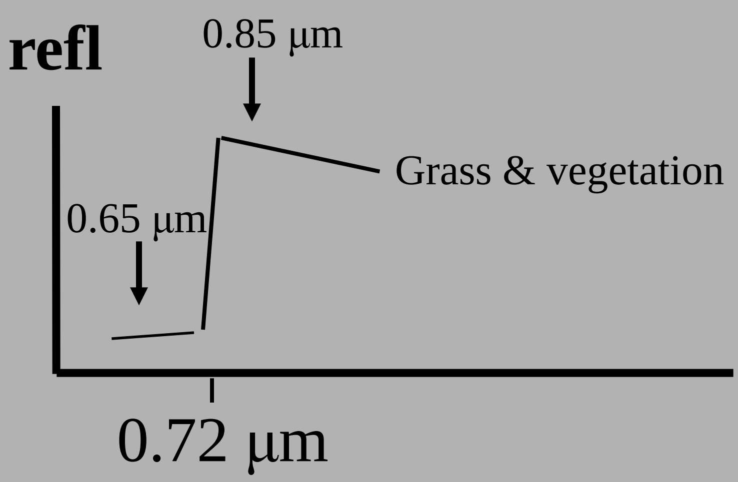
VIIRS, MODIS, FY-1C, AVHRR, ABI, GOES, MSG



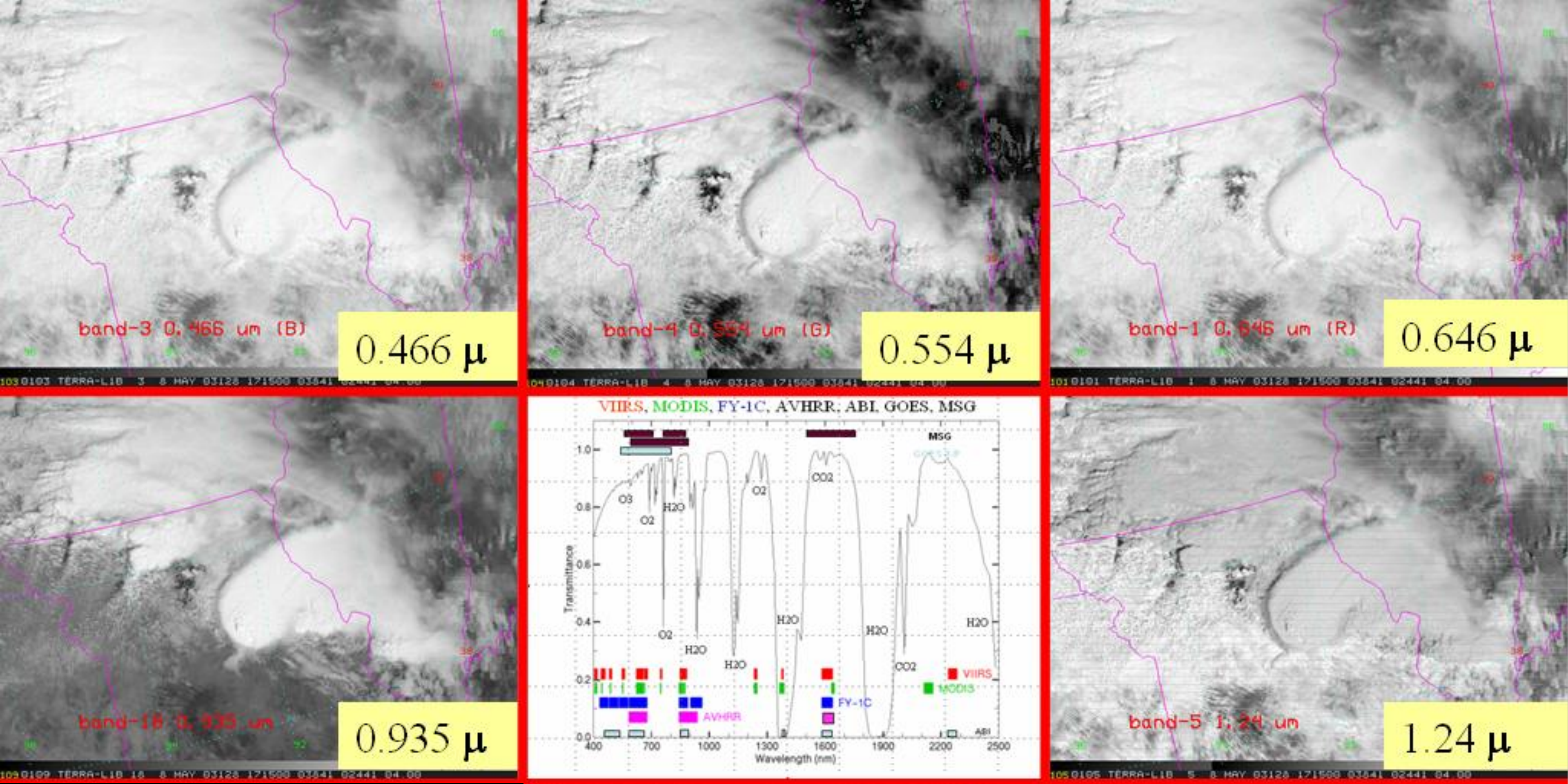




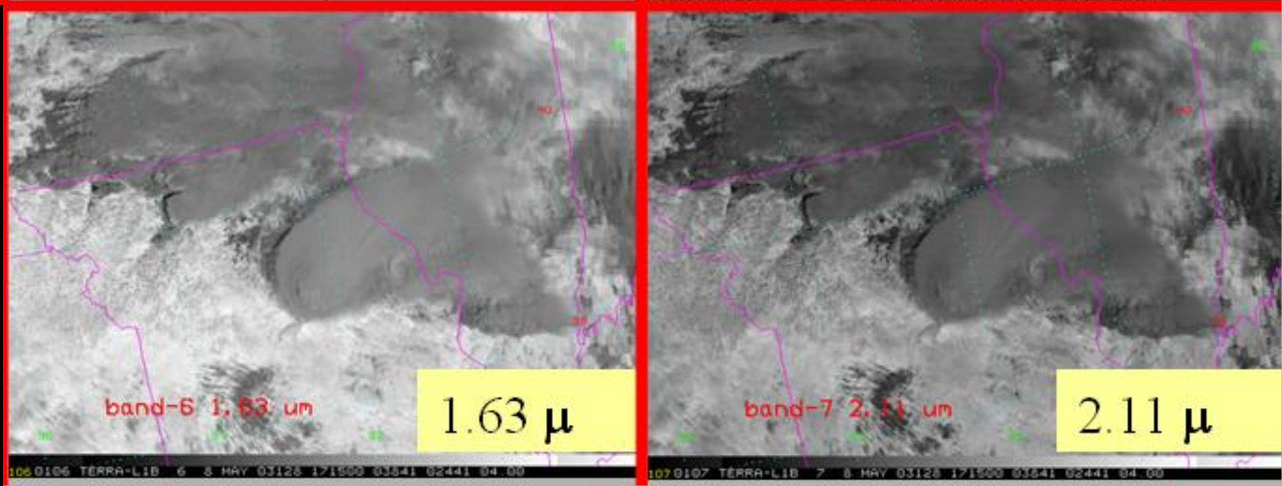
e.g. reflection from grass and vegetation

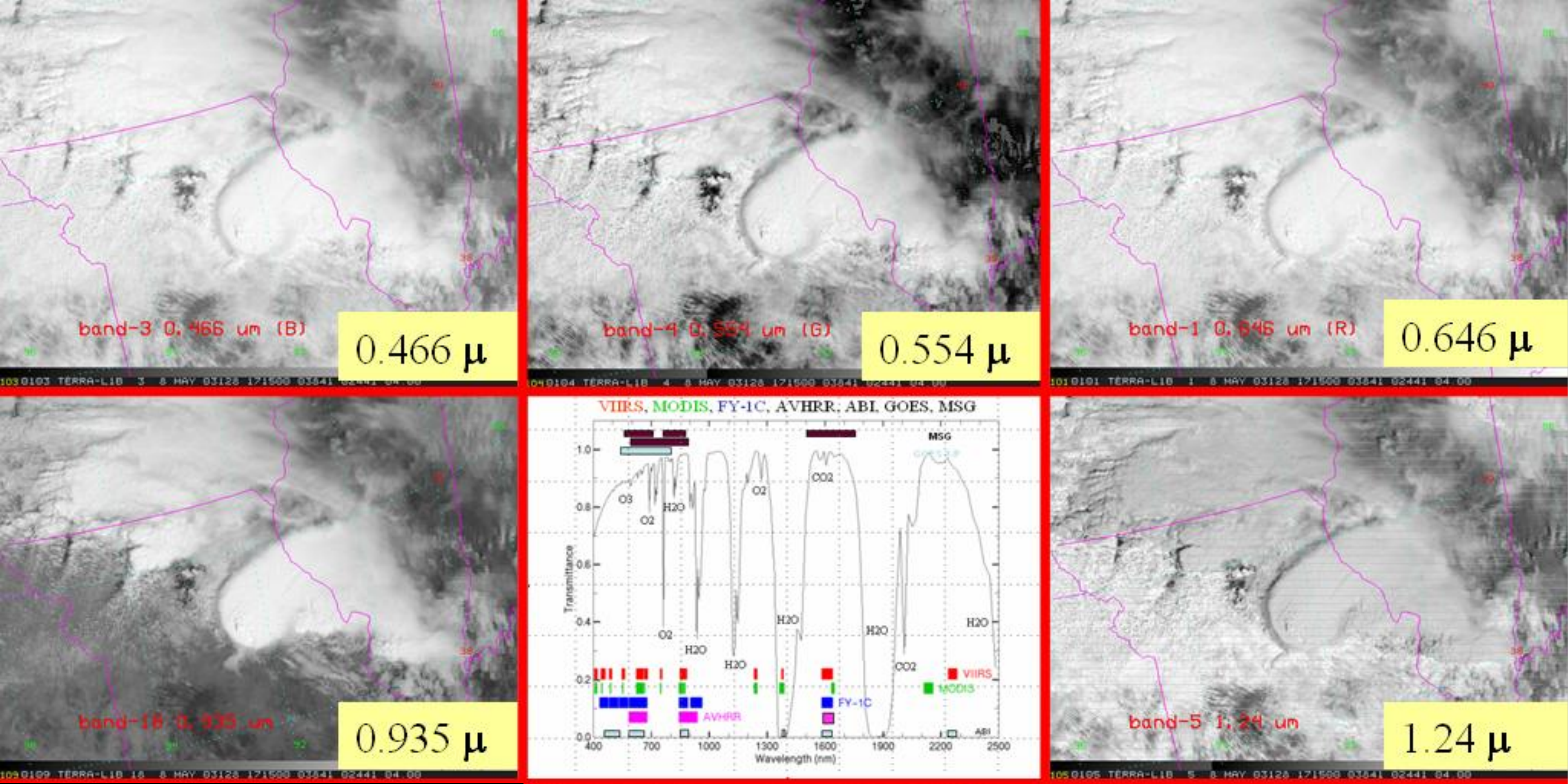


If 0.65 µm and 0.85 µm channels see the same reflectance then surface viewed is not vegetation;
if 0.85 µm sees considerably higher reflectance than 0.65 µm then surface might be vegetation

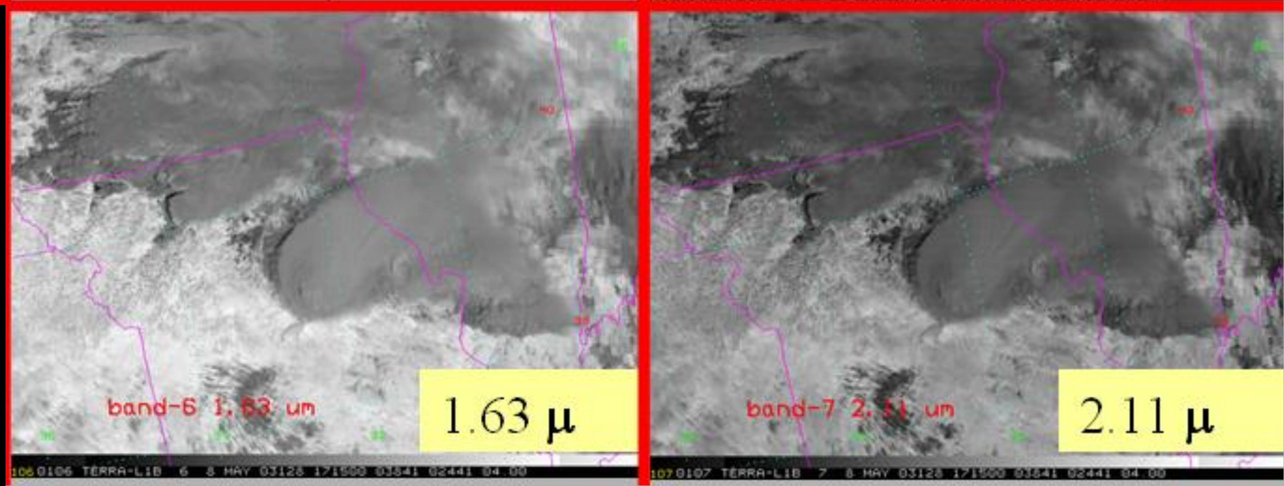


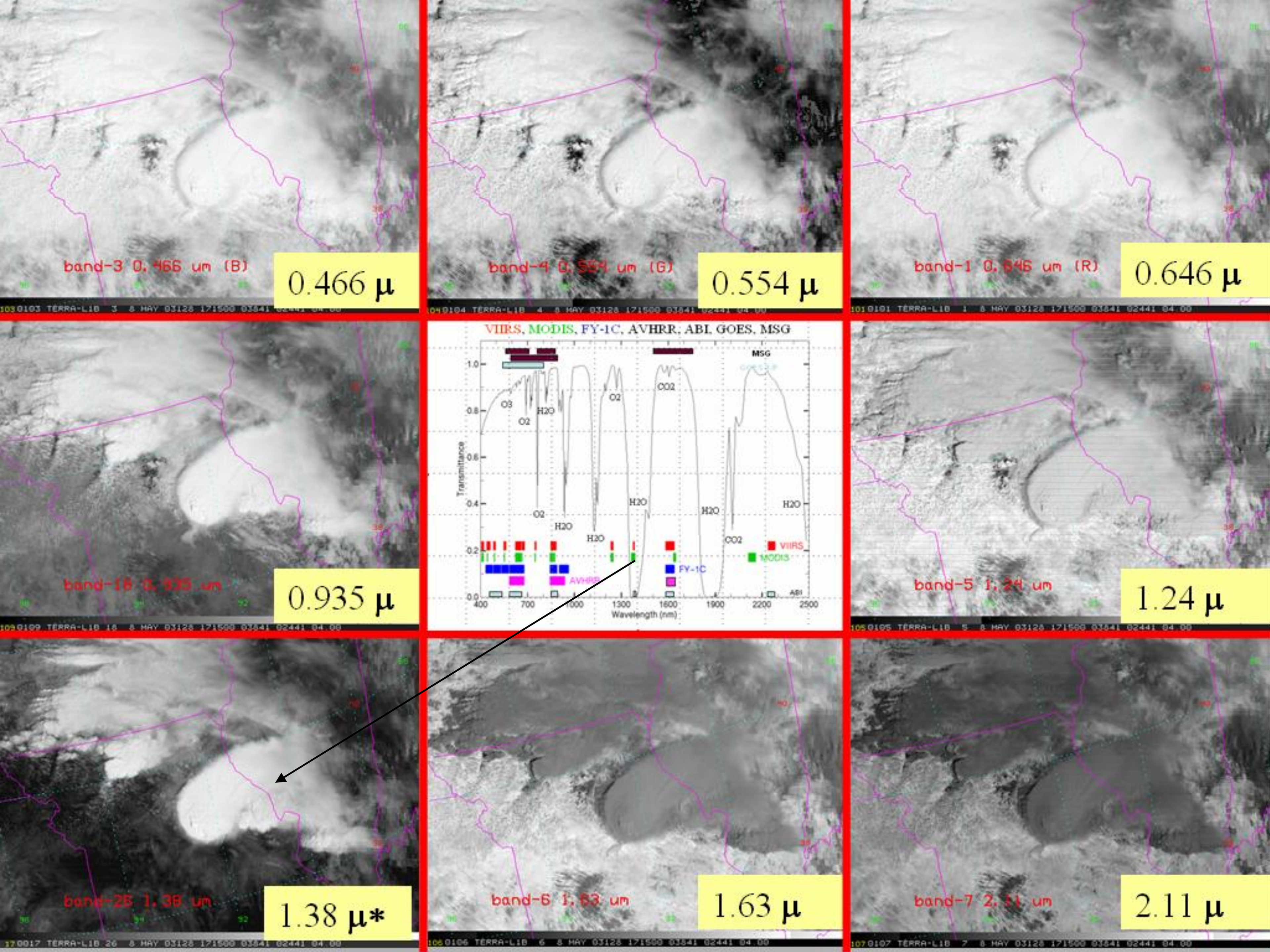
Daytime view of low cloud (water) and a thunderstorm anvil (ice) in different MODIS reflective channels

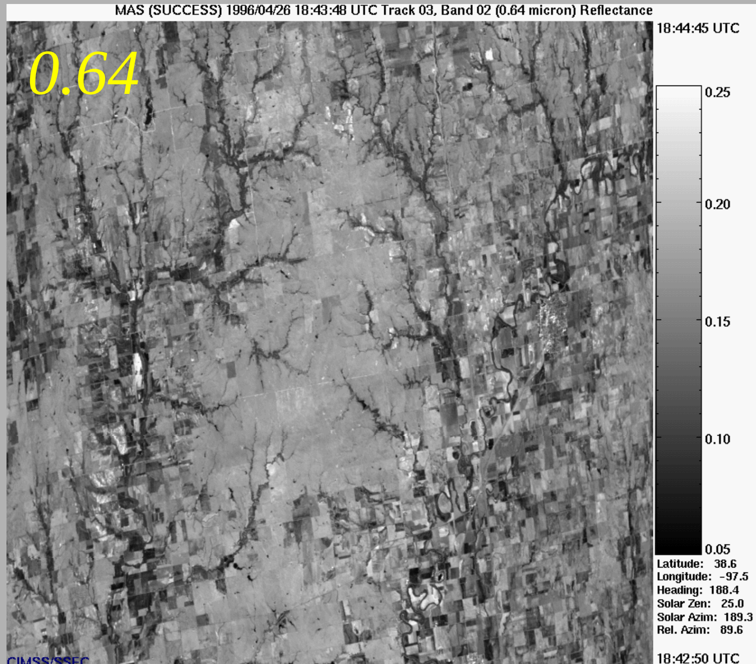


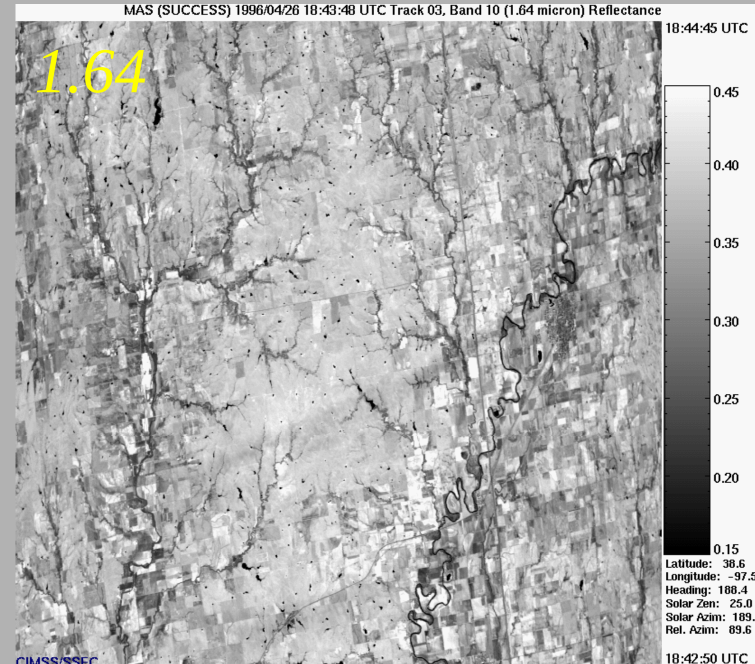


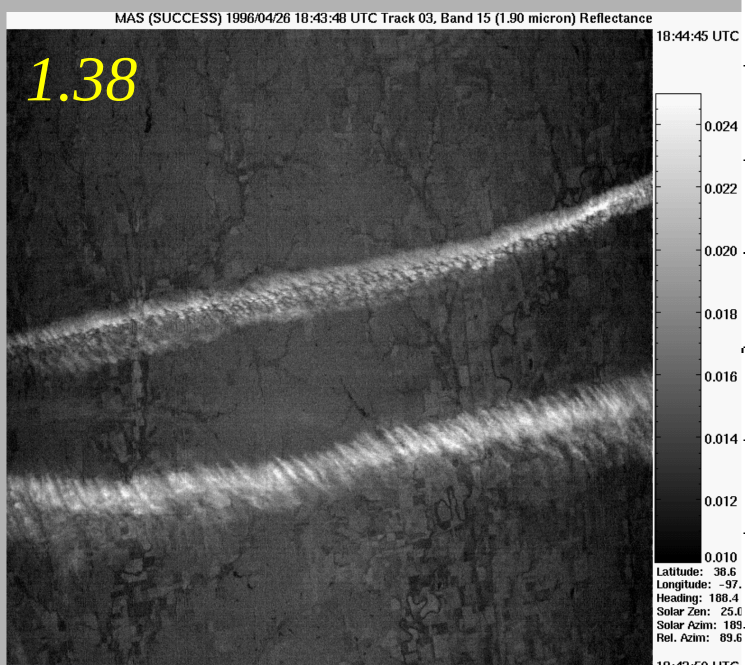
Now for a look at the reflection from the 1.38 micron MODIS channel in the center of a water vapor absorption region

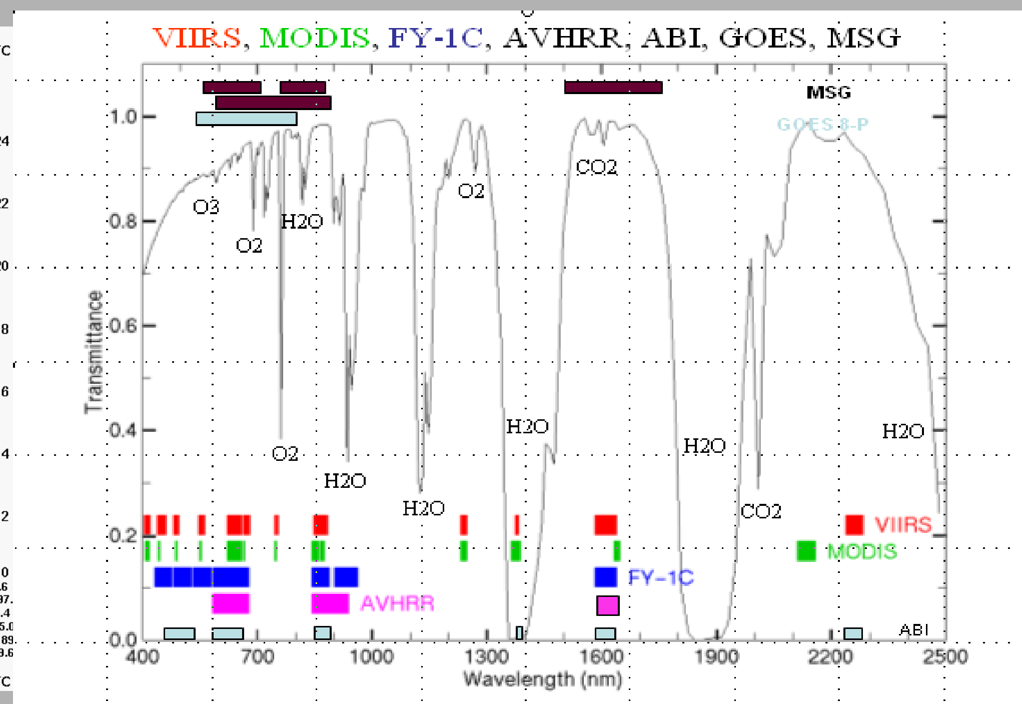



band-3 0.466 um (B)
0.466 μ
band-4 0.554 um (G)
0.554 μ
band-1 0.646 um (R)
0.646 μ
VIIRS, MODIS, FY-1C, AVHRR, ABI, GOES, MSG
MSG
O3
O2
H2O
O2
CO2
H2O
CO2
VIIRS
MODIS
FY-1C
AVHRR
ABI
Transmittance
Wavelength (nm)
band-18 0.935 um
0.935 μ
band-5 1.24 um
1.24 μ
band-26 1.38 um
1.38 μ*
band-6 1.63 um
1.63 μ
band-7 2.11 um
2.11 μ

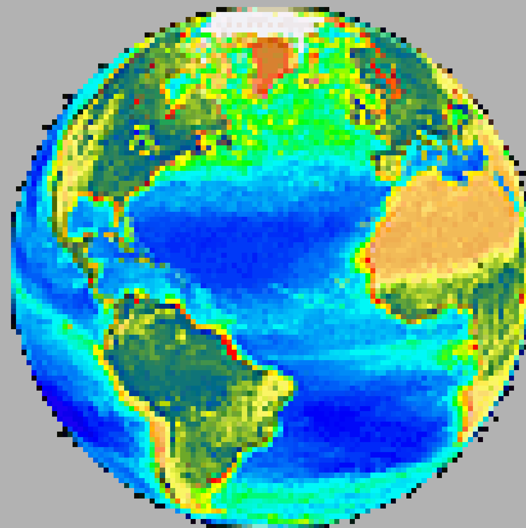

MAS (SUCCESS) 1996/04/26 18:43:48 UTC Track 03, Band 02 (0.64 micron) Reflectance
0.64
18:44:45 UTC
0.25
0.20
0.15
0.10
0.05
Latitude: 38.6
Longitude: -97.5
Heading: 188.4
Solar Zen: 25.0
Solar Azim: 189.3
Rel. Azim: 89.6
18:42:50 UTC
CIMSS/SSEC


MAS (SUCCESS) 1996/04/26 18:43:48 UTC Track 03, Band 10 (1.64 micron) Reflectance
1.64
18:44:45 UTC
0.45
0.40
0.35
0.30
0.25
0.20
0.15
Latitude: 38.6
Longitude: -97.5
Heading: 188.4
Solar Zen: 25.0
Solar Azim: 189.3
Rel. Azim: 89.6
18:42:50 UTC
CIMSS/SSEC


MAS (SUCCESS) 1996/04/26 18:43:48 UTC Track 03, Band 15 (1.90 micron) Reflectance
1.38
18:44:45 UTC
0.024
0.022
0.020
0.018
0.016
0.014
0.012
0.010
Latitude: 38.6
Heading: 188.4
Rel. Azim: 89.6
18:42:50 UTC
CIMSS/SSEC

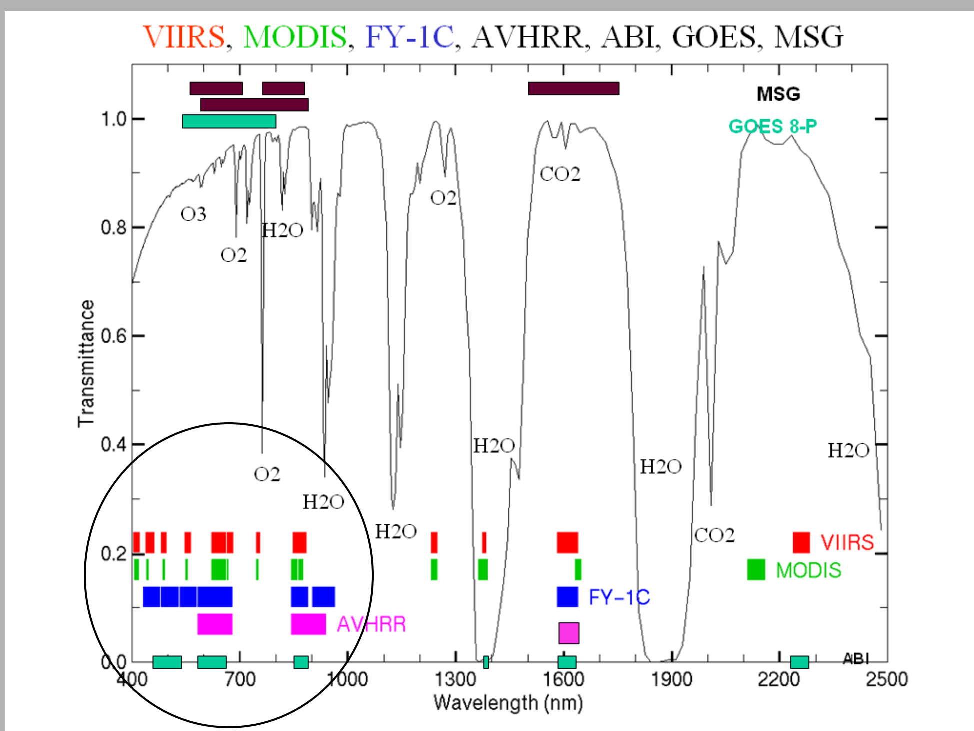

VIIRS, MODIS, FY-1C, AVHRR, ABI, GOES, MSG
MSG
GOES 8-P
O3
O2
H2O
O2
O2
H2O
H2O
CO2
H2O
H2O
CO2
H2O
VIIRS
MODIS
FY-1C
AVHRR
ABI
Transmittance
0.0
0.2
0.4
0.6
0.8
1.0
400
700
1000
1300
1600
1900
2200
2500
Wavelength (nm)

Ocean Color: As illustrated by SeaWifs



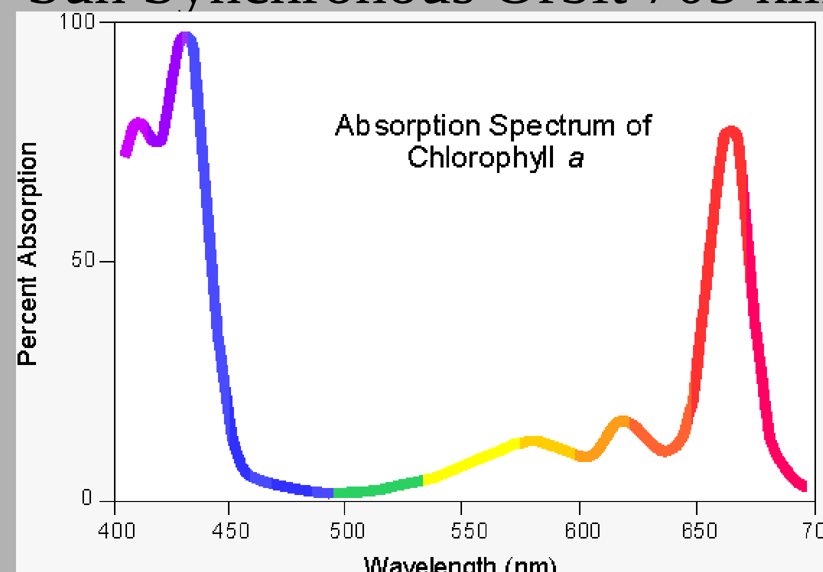
Instrument Bands

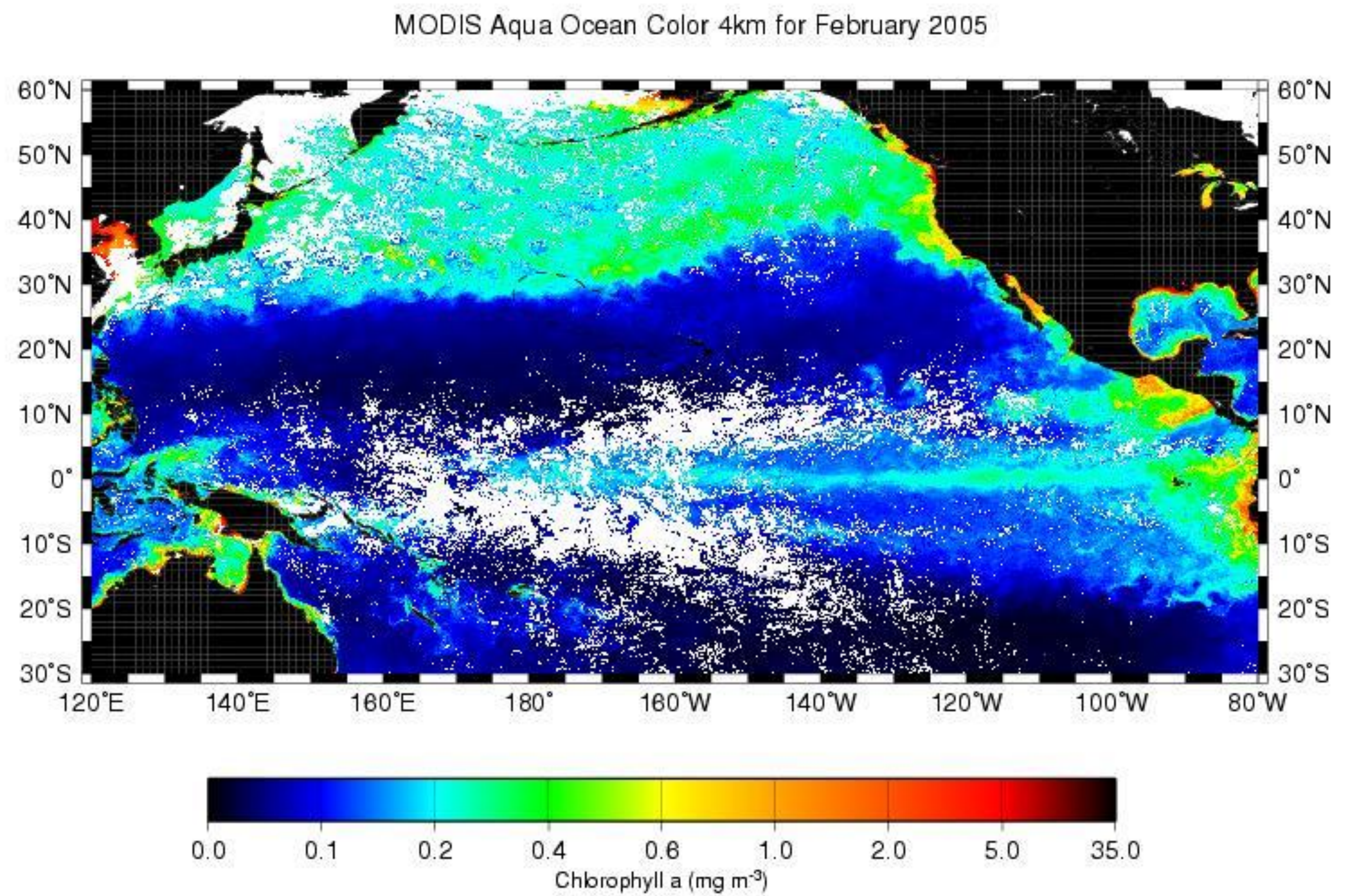
402-422 nm
433-453 nm
480-500 nm
500-520 nm
545-565 nm
660-680 nm
745-785 nm
845-885 nm



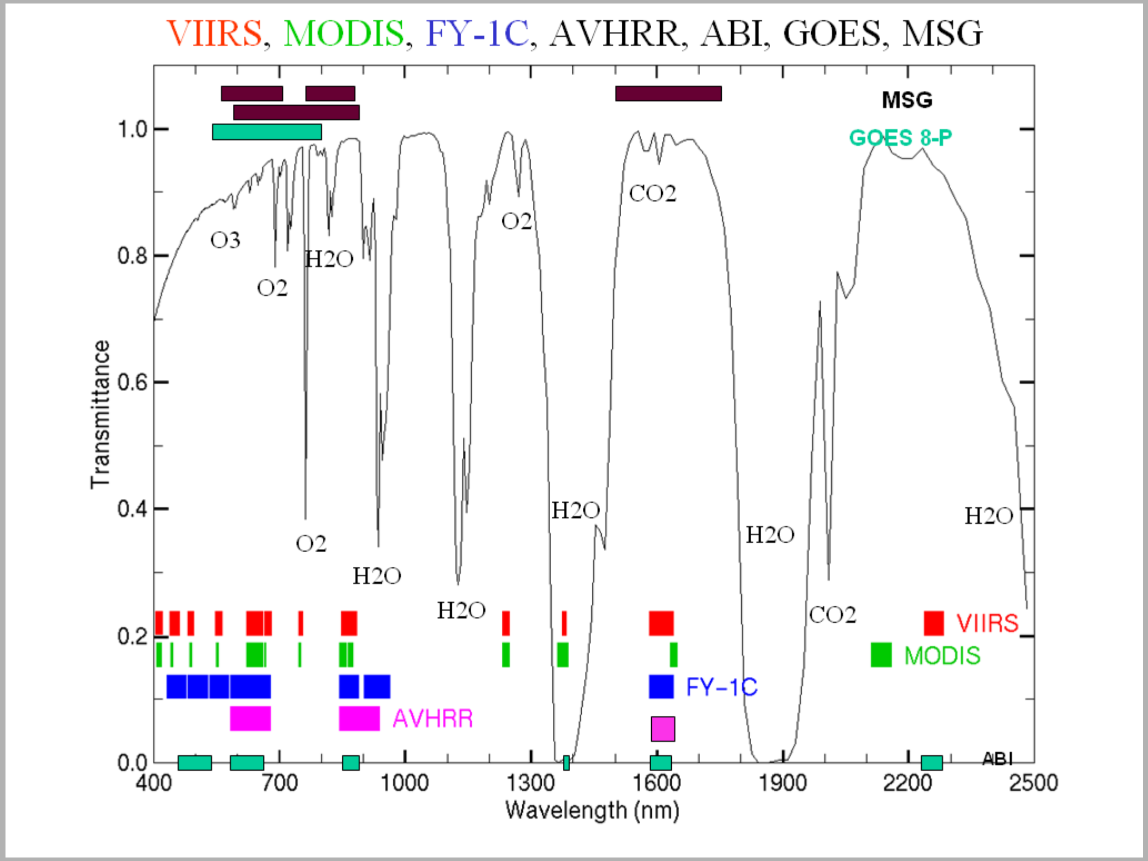
Mission Characteristics

Sun Synchronous Orbit 705 km



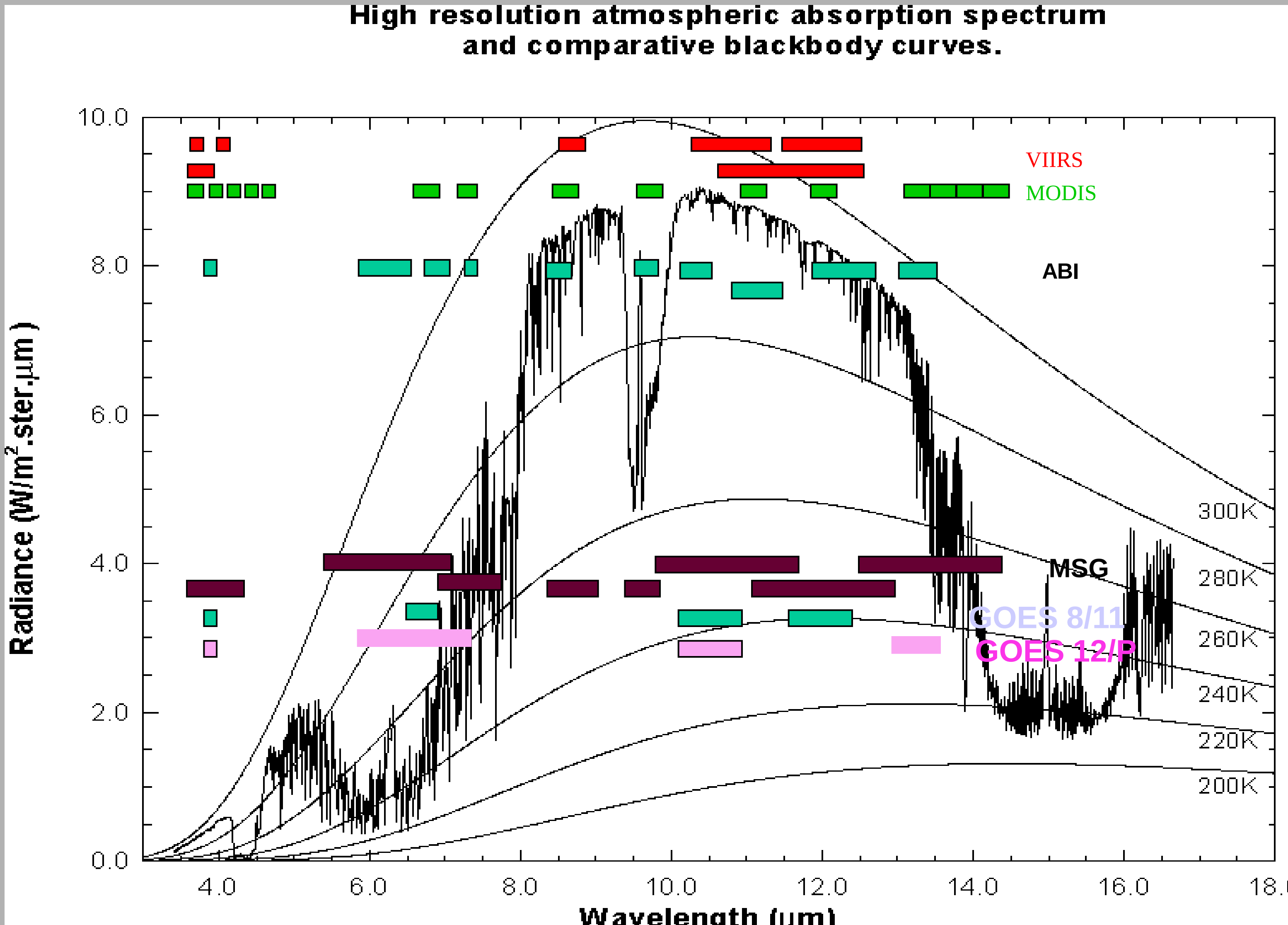


Ocean color product from MODIS showing the abundance of chlorophyll a across part of the Pacific Ocean.

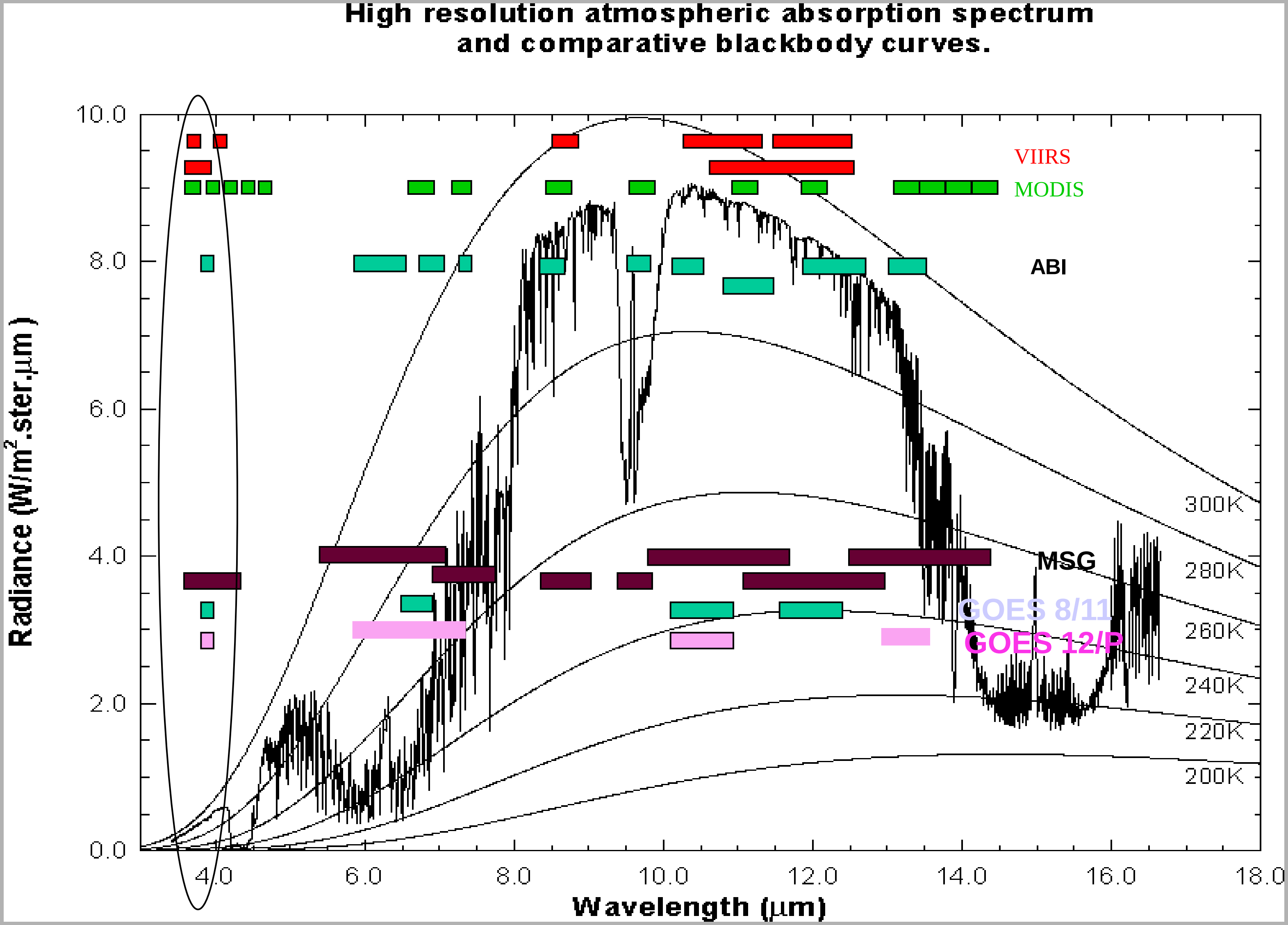


One might ask "why the various satellite imager channel widths and spectral locations?" The answers are complex, but basically relate back to four basic resolutions (spatial, spectral, temporal and s/n) and specifically the tradeoff between desired spectral resolutions versus the practicality of spatial resolution versus obtaining a high enough signal to noise ratio so that the instrument's data may be used to describe the feature of interest to a desired accuracy level

Earth emitted spectra overlaid on Planck function envelopes

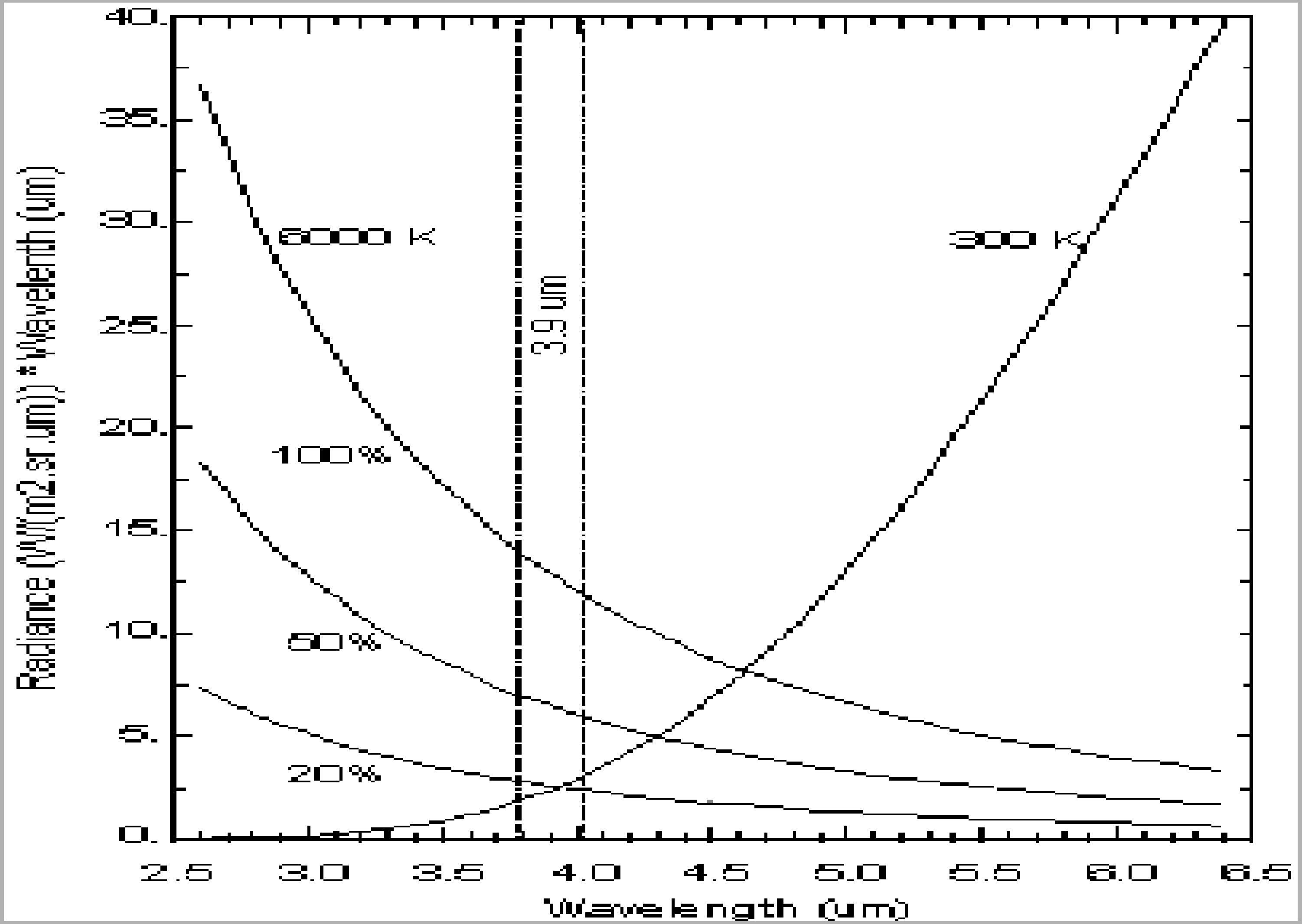


Earth emitted spectra overlaid on Planck function envelopes



The special area in the vicinity of 3 and 4 microns

A close-up view around 3.9 mm, with radiance at 100%, 50% and 20% for the 6000 K source

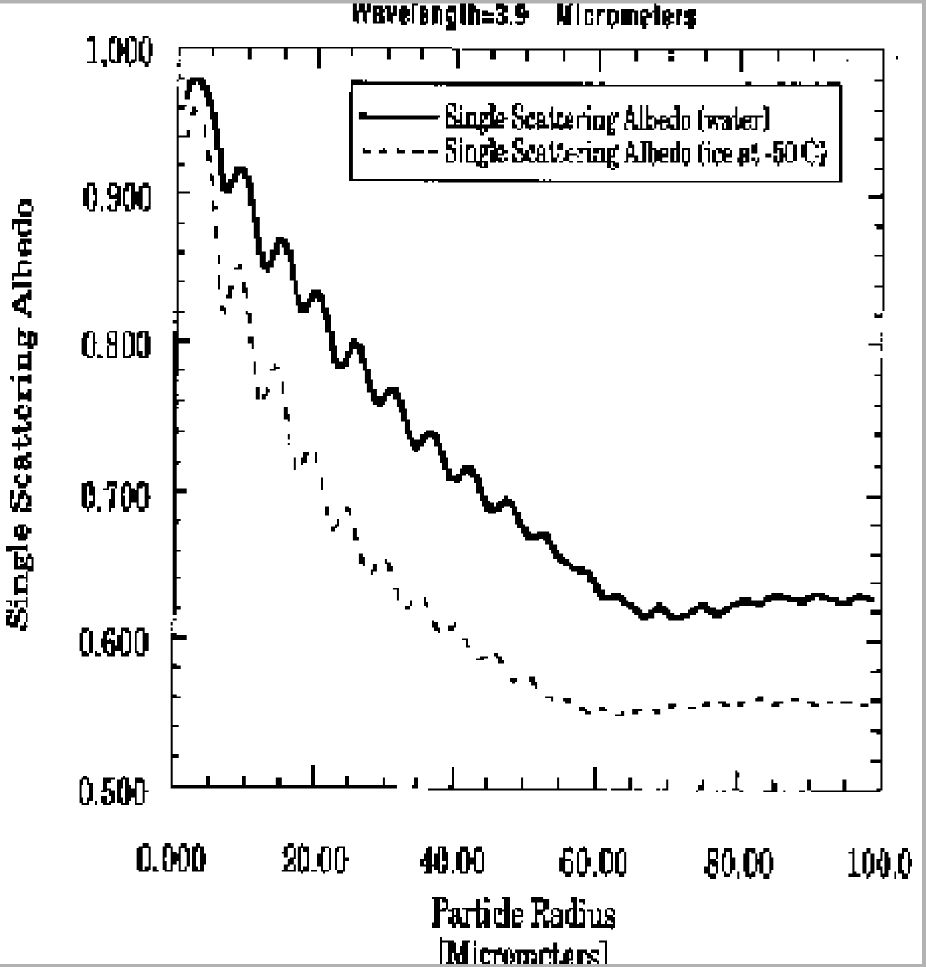


The special area between 3 and 4 microns

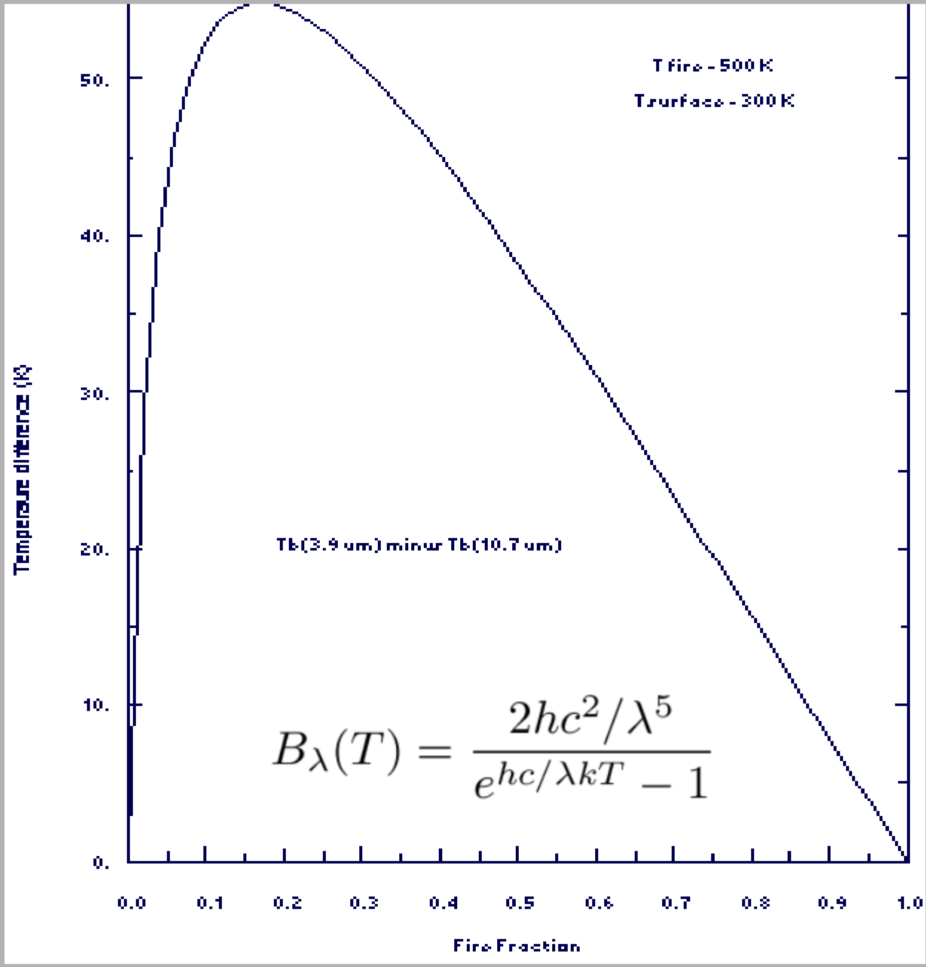
3.7 - 3.9 um Channel Imagery Applications (with other channels)

- Night-time Fog, Stratus & Cirrus
- Super-cooled Clouds
- Fog, Ice & Water Clouds Over Snow
- Winter Storms
- Land- and Sea-surface Temperatures
- Thin Cirrus & Multi-layered Clouds
- Urban Heat "Islands"
- Fire Detection
- Sun Glint
- Cumulus Bands at Night
- Convective Cloud Phases
- Volcanic Ash Cloud Monitoring

Spectral Awareness, cloud phase and non-linear aspects of thermal response

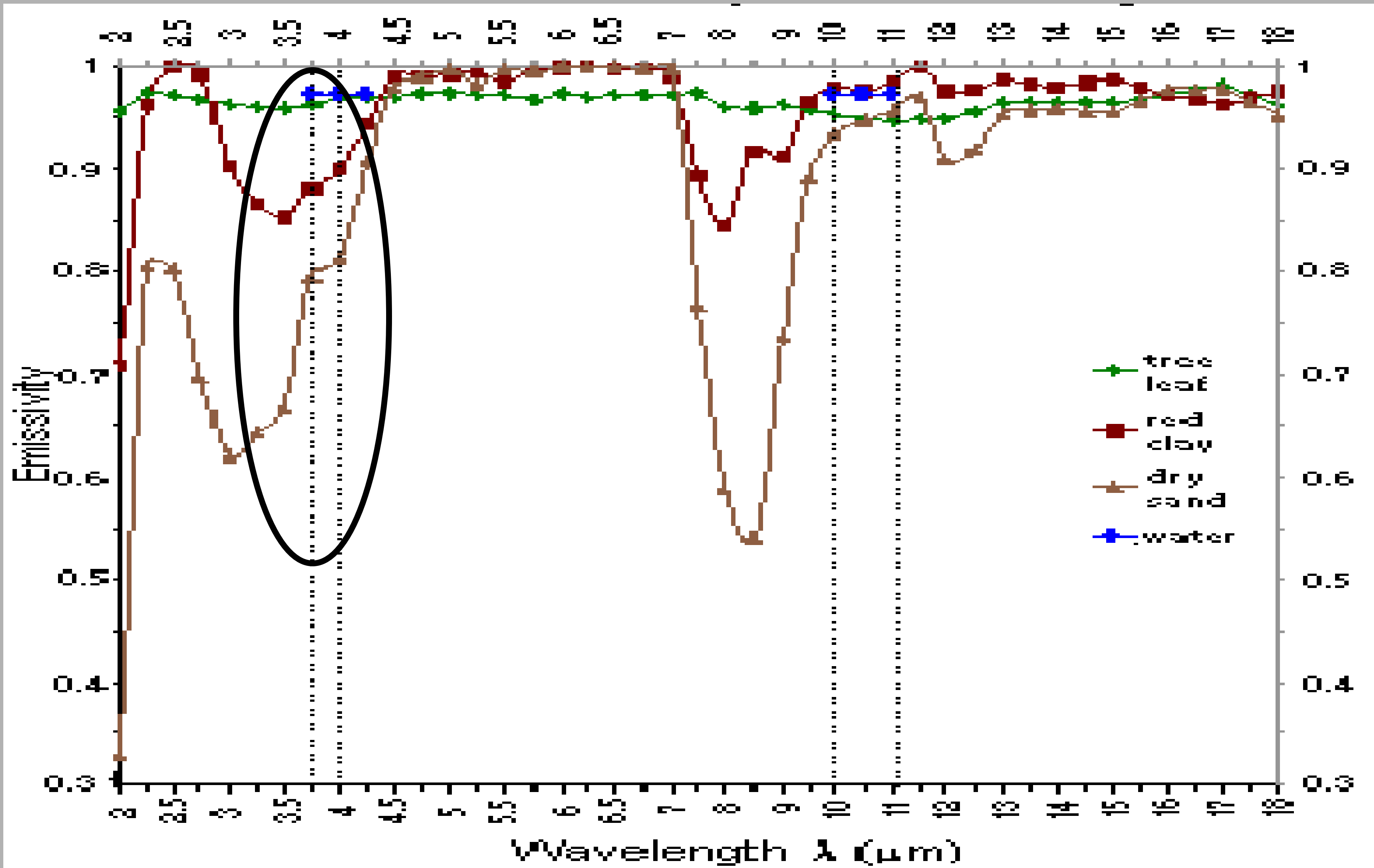


Scattering from water versus ice particles at 3.9 microns

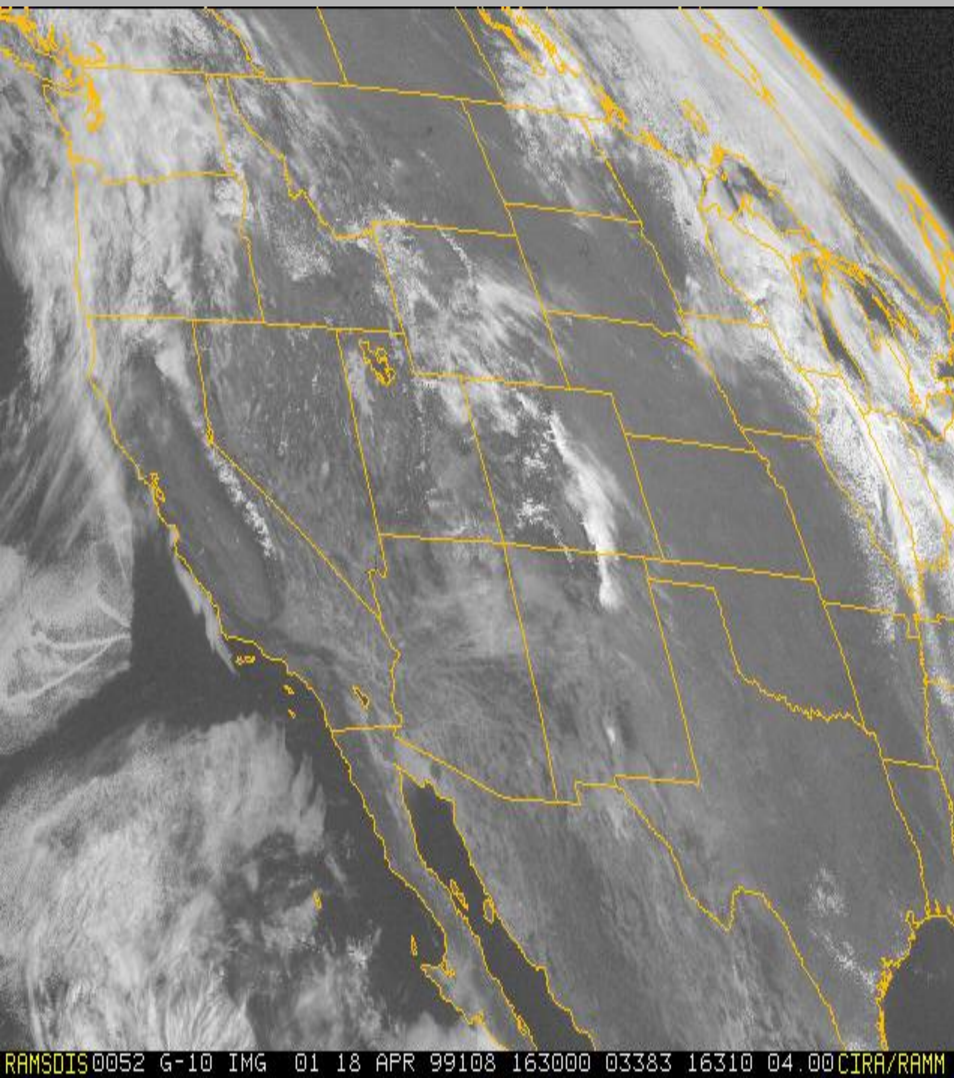


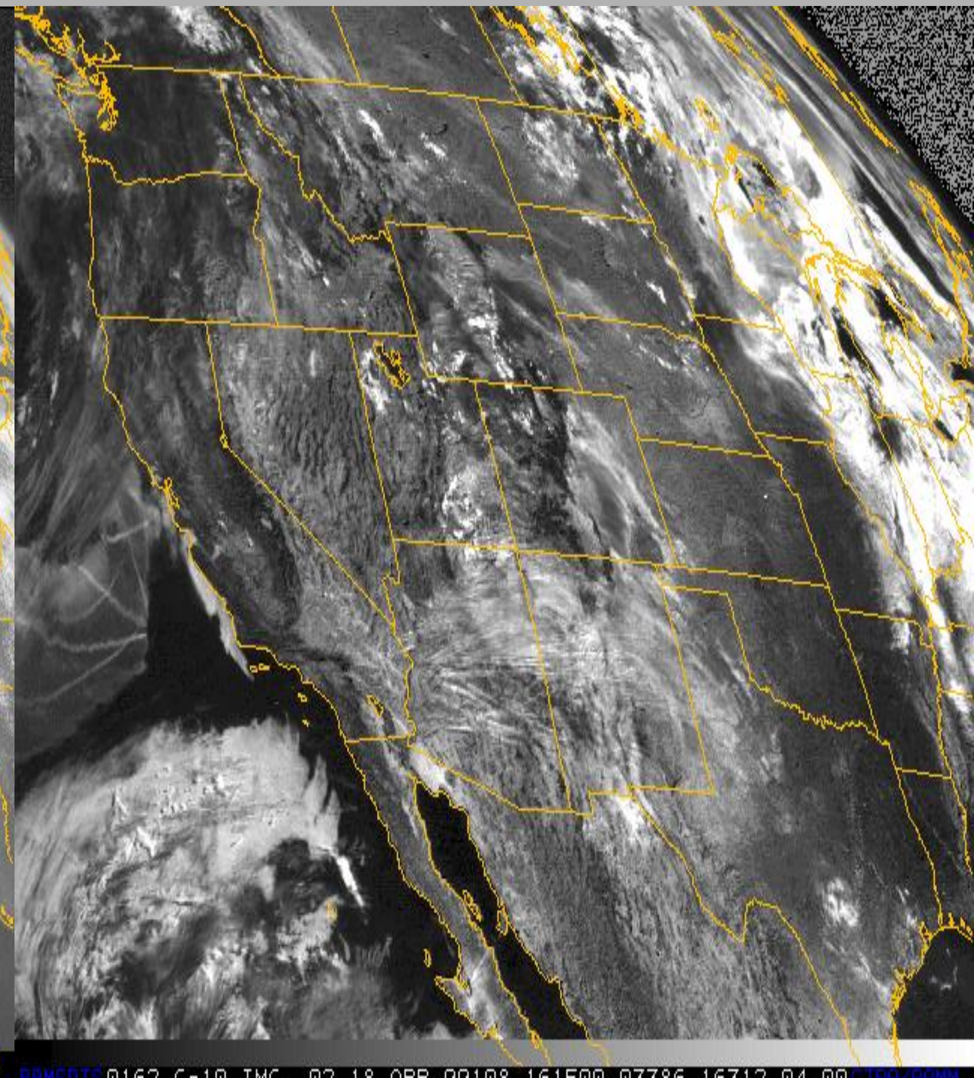
Response of 3.9 vs. 10.7 microns to Temperature variability in a FOV

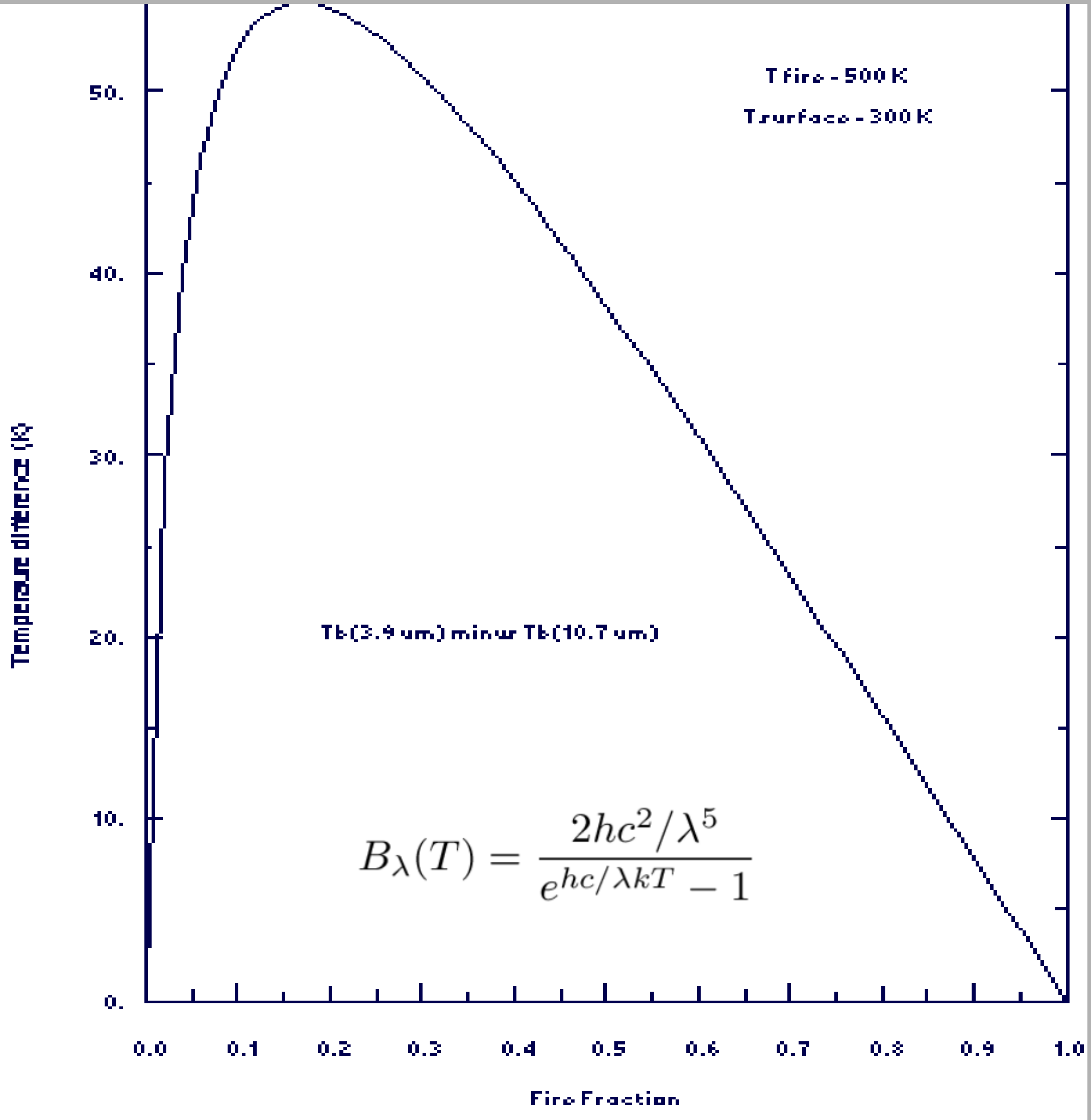
Spectral Awareness, surface characteristics



Display and analysis of imagery at short 3.9 microns.
Visible loop (left) and 3.9 micron reflective component loop (right) from GOES-West (aspect ratio not 1:1)
Click on images to start and stop animations.

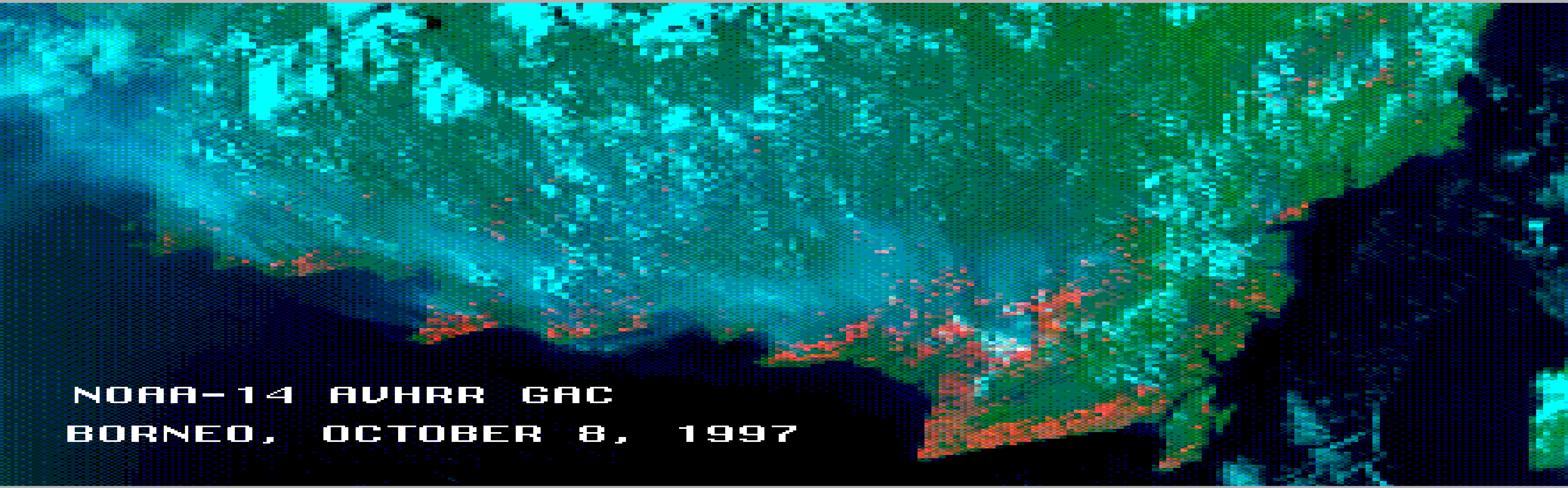


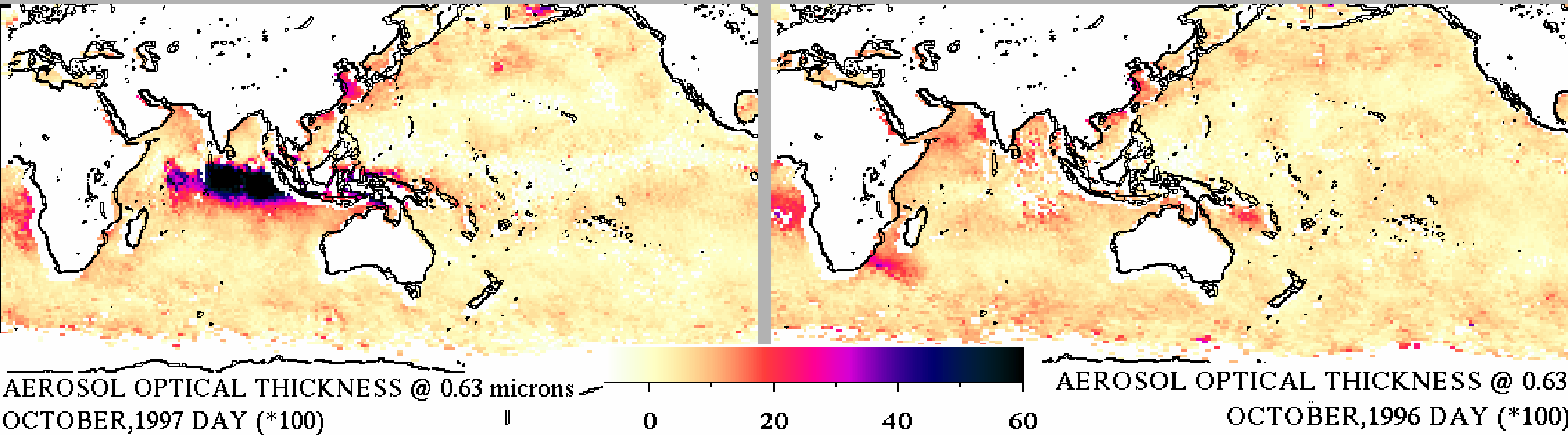




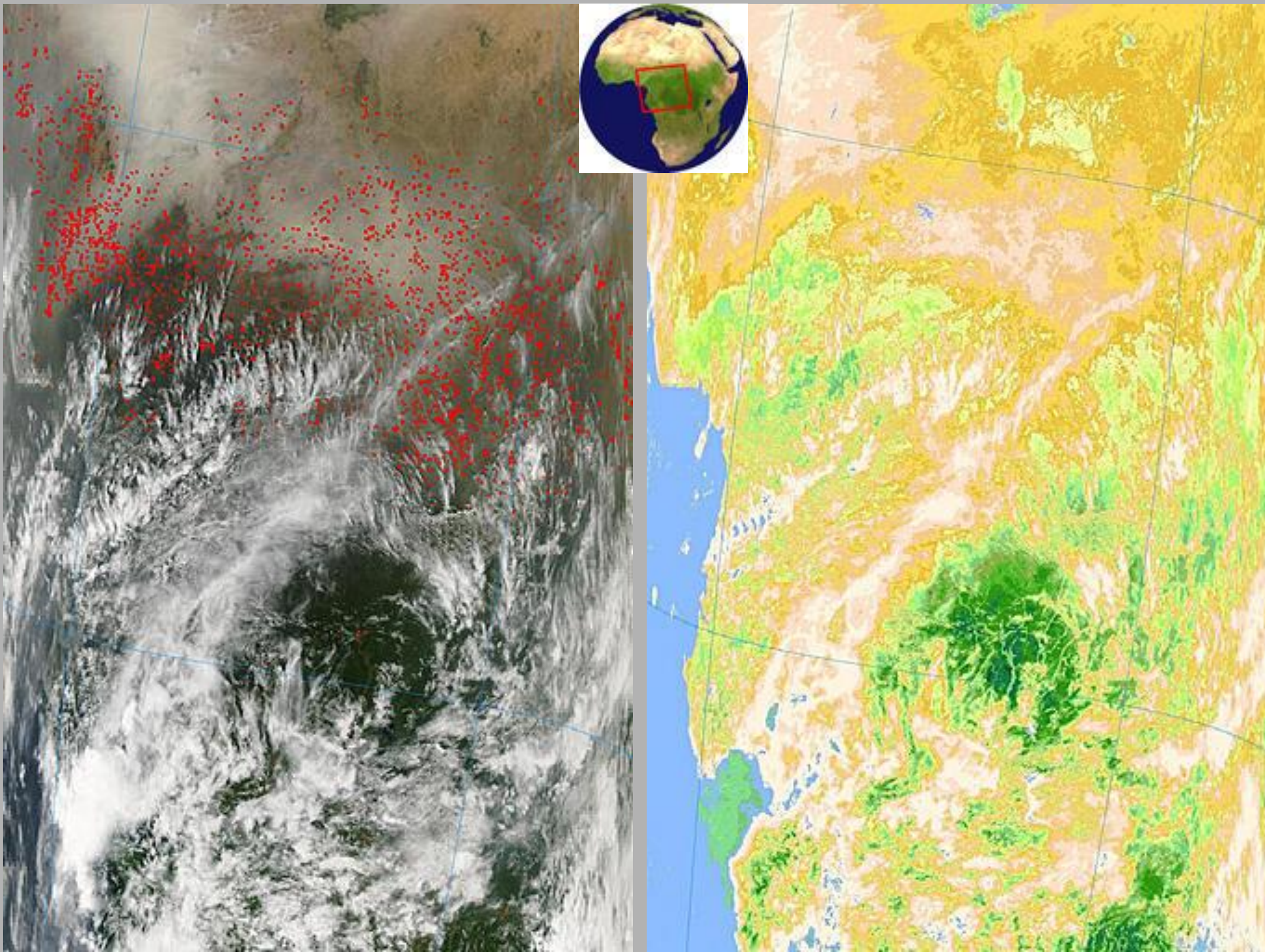
On the left is an example of the difference in temperature measured at 3.9 and 10.7 microns for a partially filled field of view (FOV) for nighttime when there is no solar reflection. In this example, the hot-area is at 500 K and the remainder of the pixel is at 300 K.

Fires detected on October 8, 1997, using AVHRR over Borneo, and aerosols over region in mid-October 1996 versus mid-October 1997

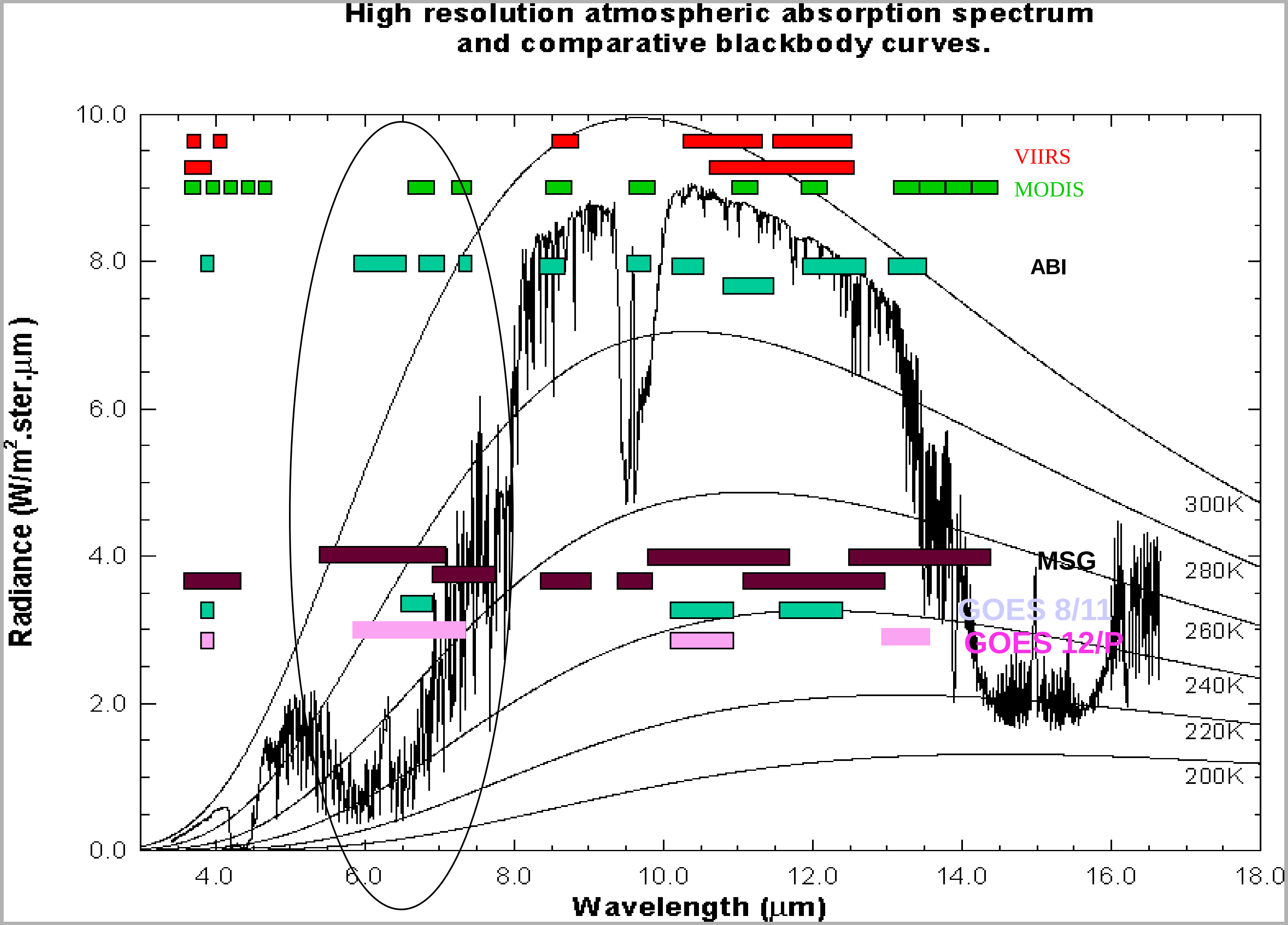




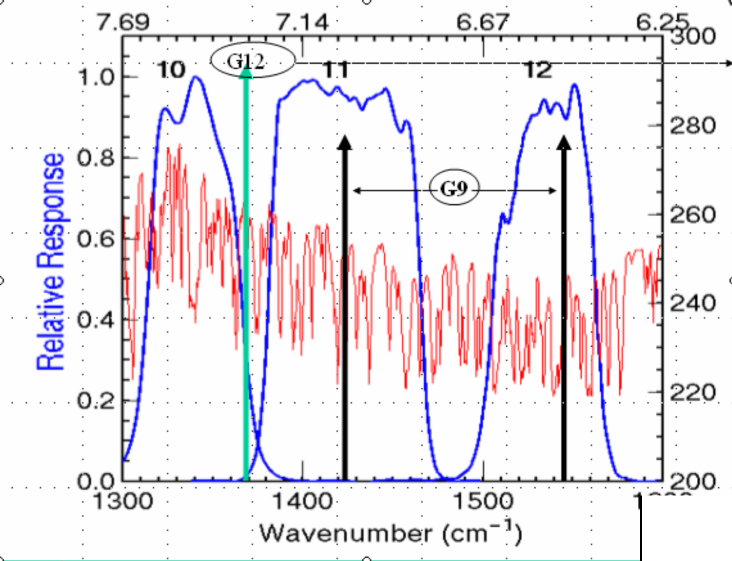
Fires detected by MODIS over Africa (left) and NDVI (right)



Earth emitted spectra overlaid on Planck function envelopes

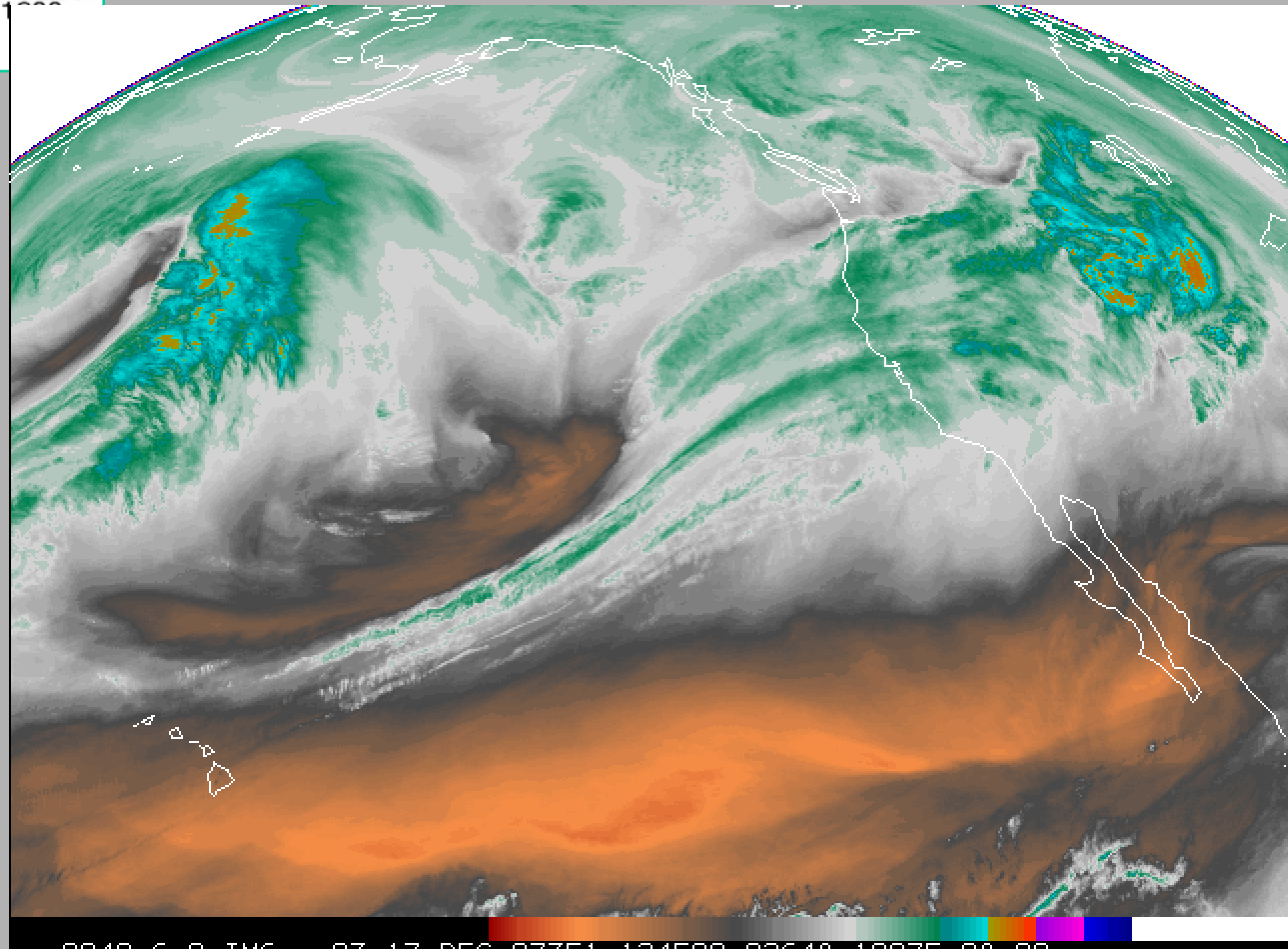


The strong water vapor absorption region

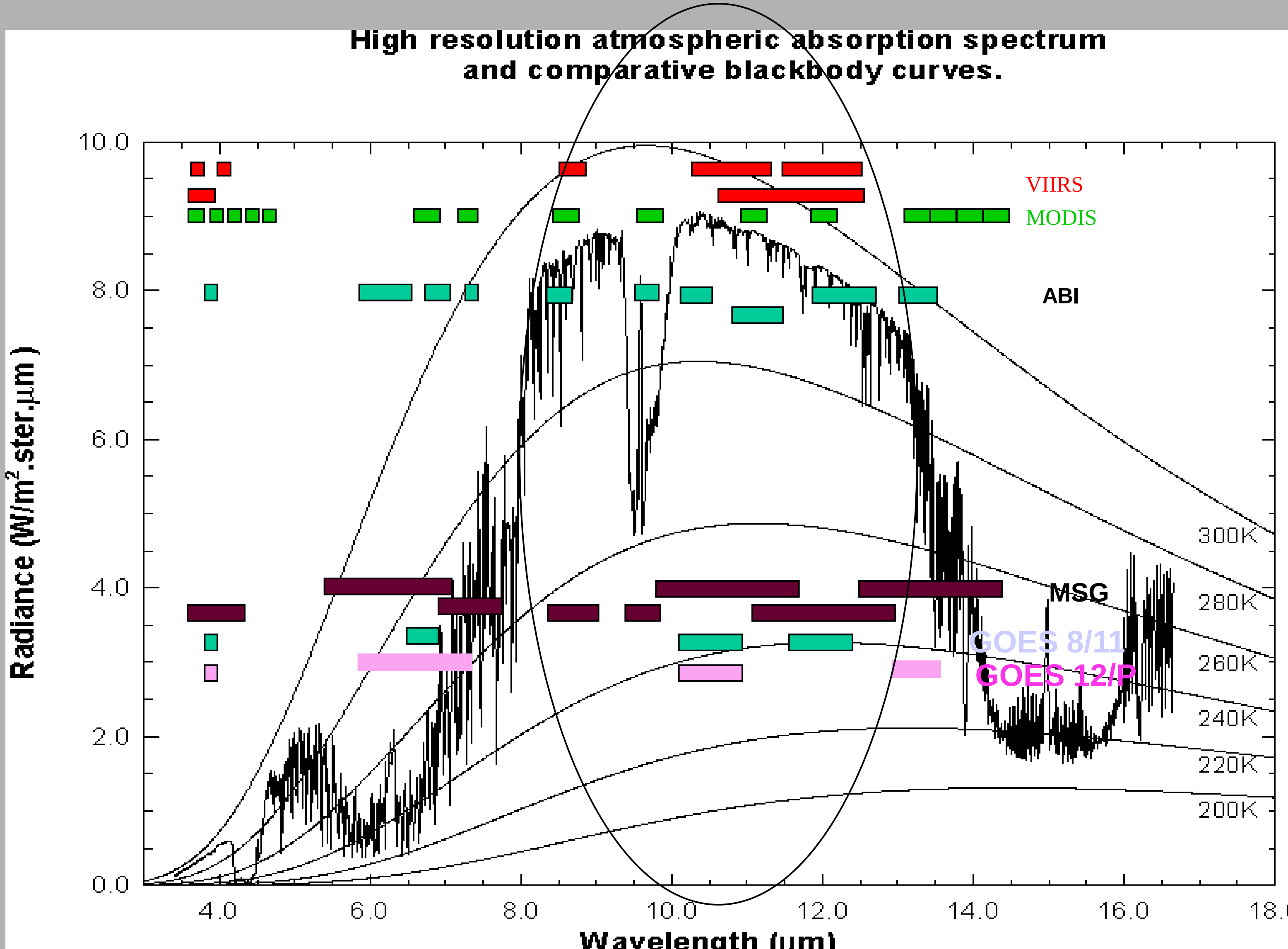


GOES-9 6.7 micron infrared (water vapor channel) movie loop: a broadband channel that extends from 6.47 to 7.02 microns

With GOES-12 the broadband water vapor channel spectral rage was increased to span the interval 5.8 to 7.3 microns

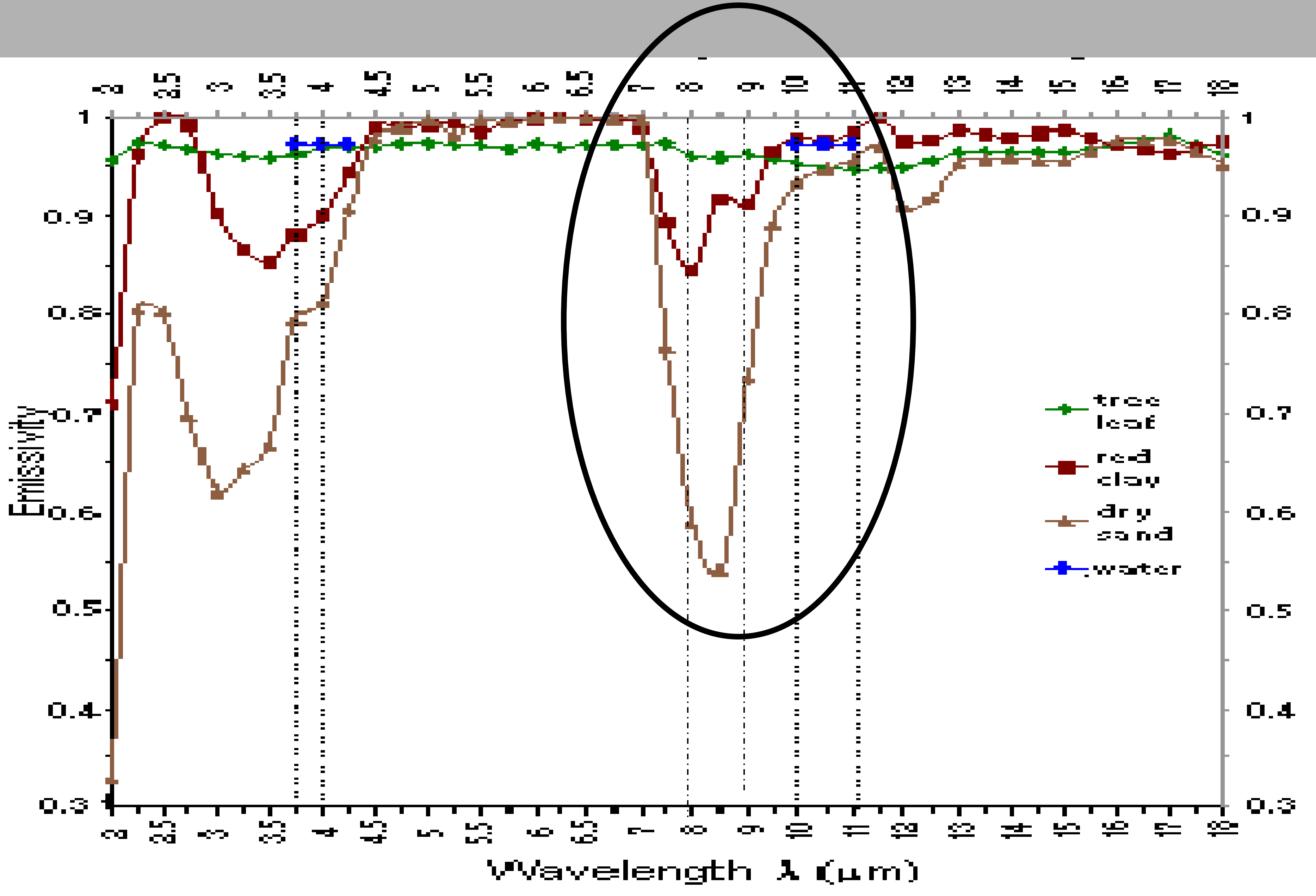


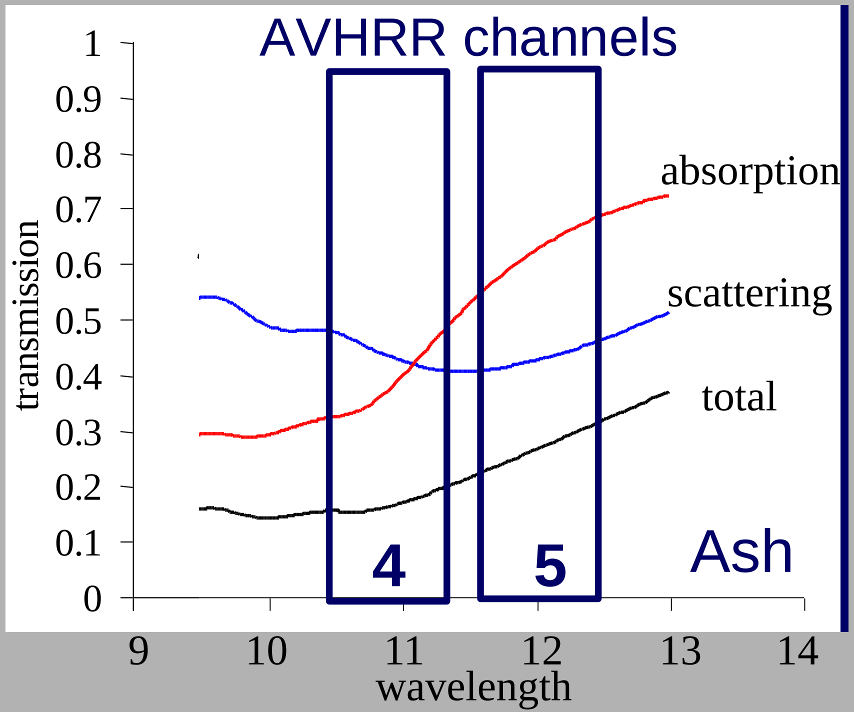
Earth emitted spectra overlaid on Planck function envelopes



The infrared window regions and ozone absorption area

Spectral Awareness, surface characteristics

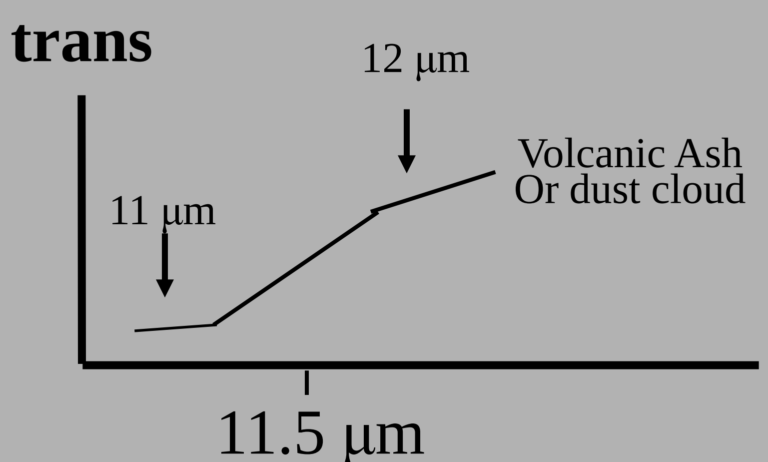




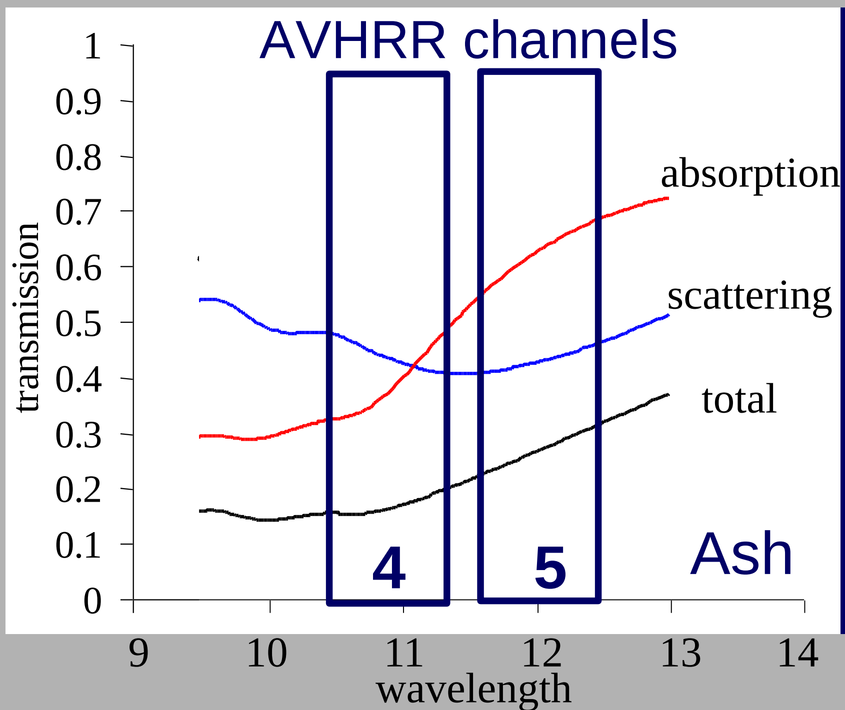
Investigating with Multi-spectral Infrared Combinations

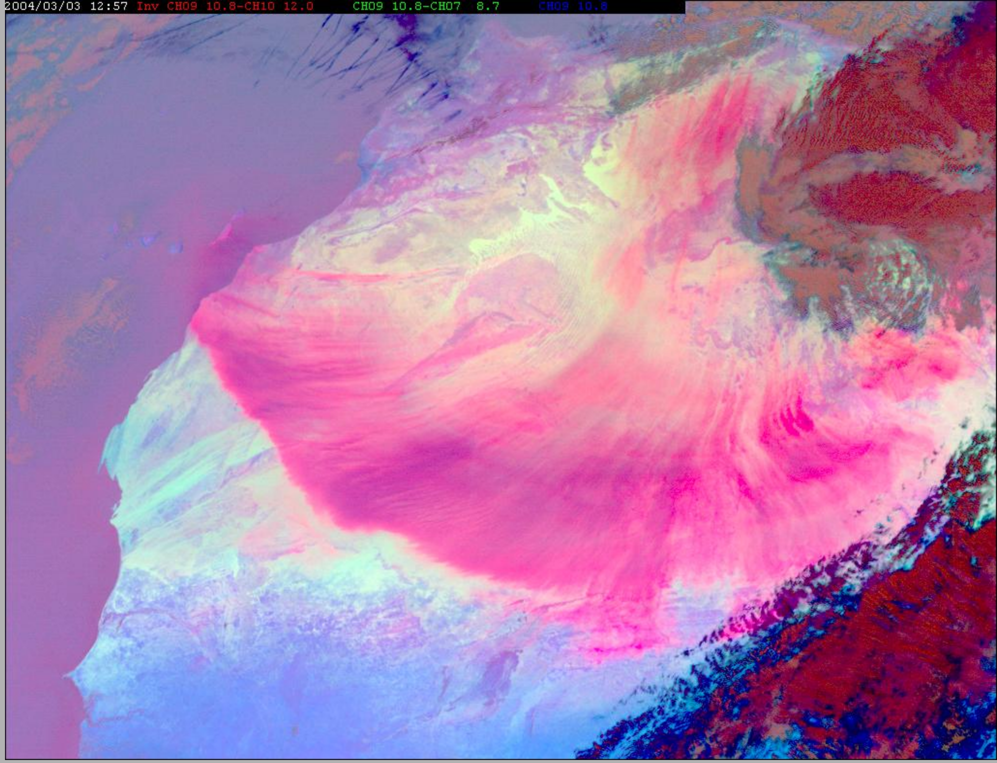
Given the spectral response of a surface or atmospheric feature select a part of the spectrum where the absorption changes with wavelength

e.g. transmission through dust cloud or volcanic ash

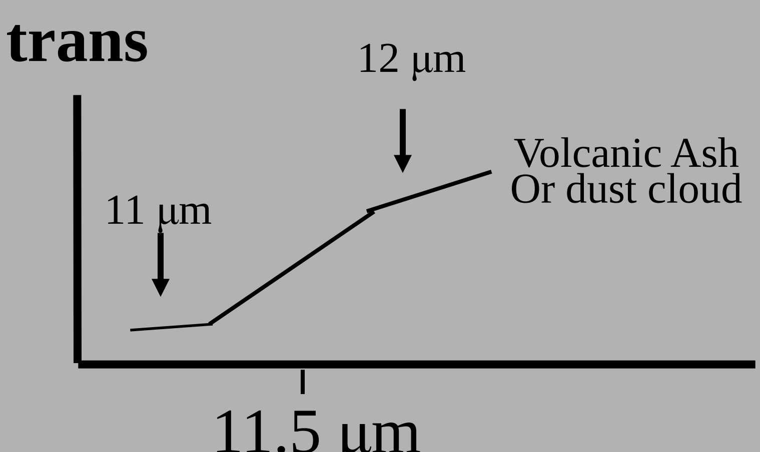


If 12 µm sees considerably higher BT than 11 µm then the atmosphere probably contains dust or volcanic ash; if 11 µm sees the same or higher BT than 12 µm the atmosphere viewed does not contain dust cloud or volcanic ash.



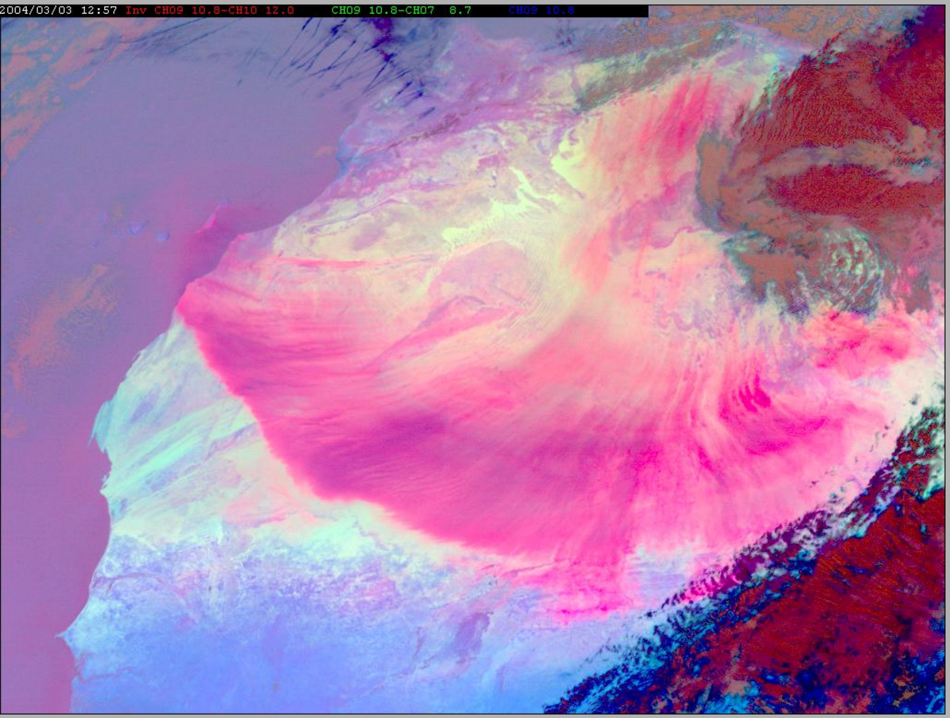


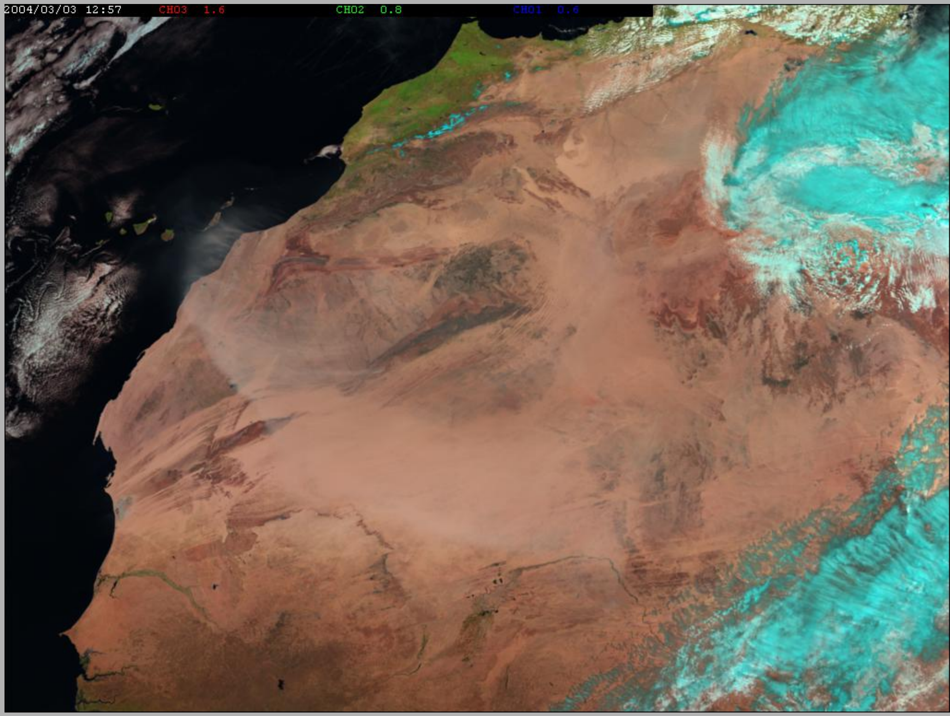
METEOSAT movie of large dust storm over Africa



If 12 μm sees considerably higher BT than 11 μm then the atmosphere probably contains dust (as above) or volcanic ash; if 11 μm sees the same or higher BT than 12 μm the atmosphere viewed does not contain dust cloud or volcanic ash;

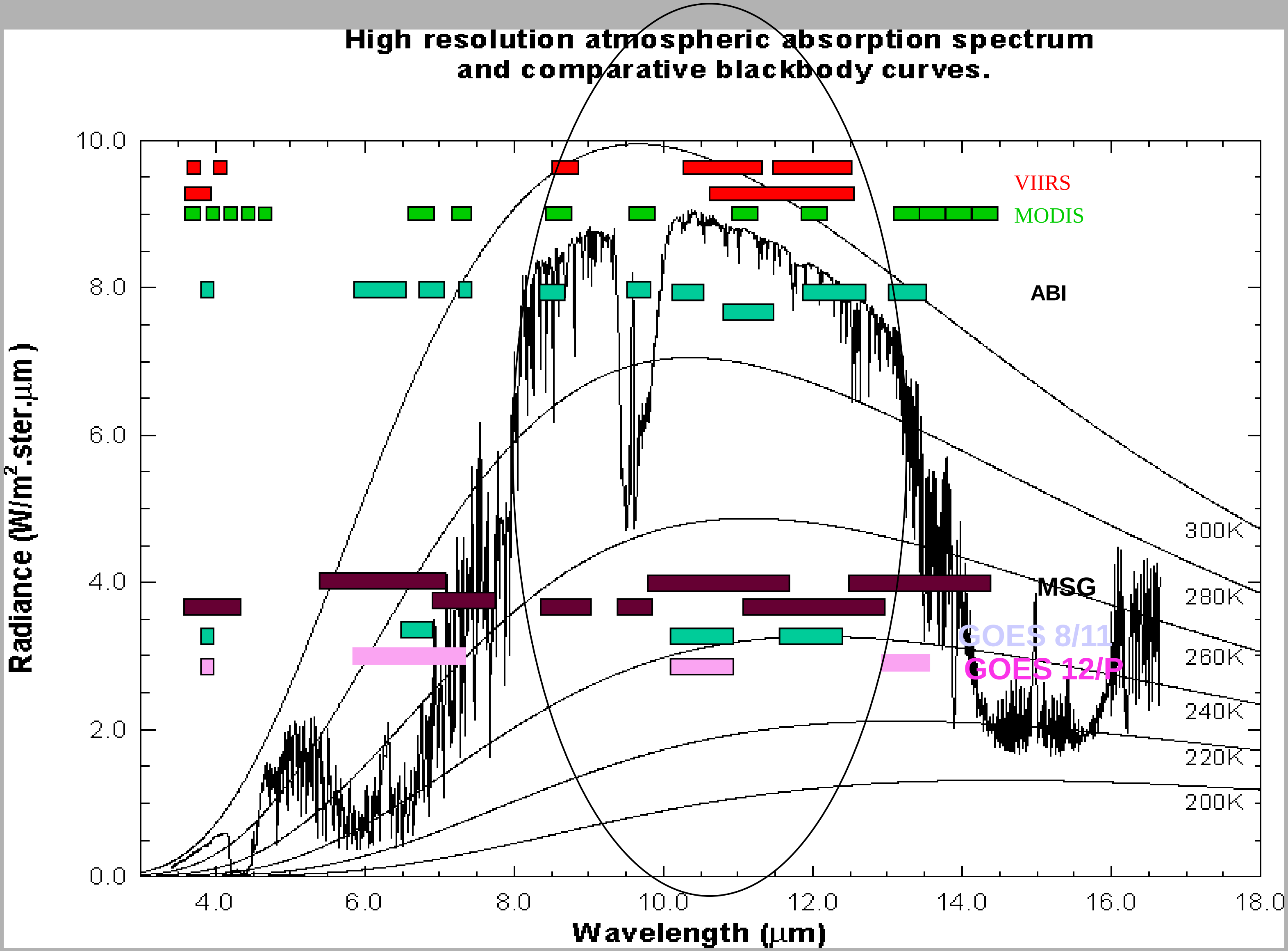
METEOSAT-8 (MSG) detection of large dust storm over Africa using visible to near IR (right) and IR (left) channel combinations



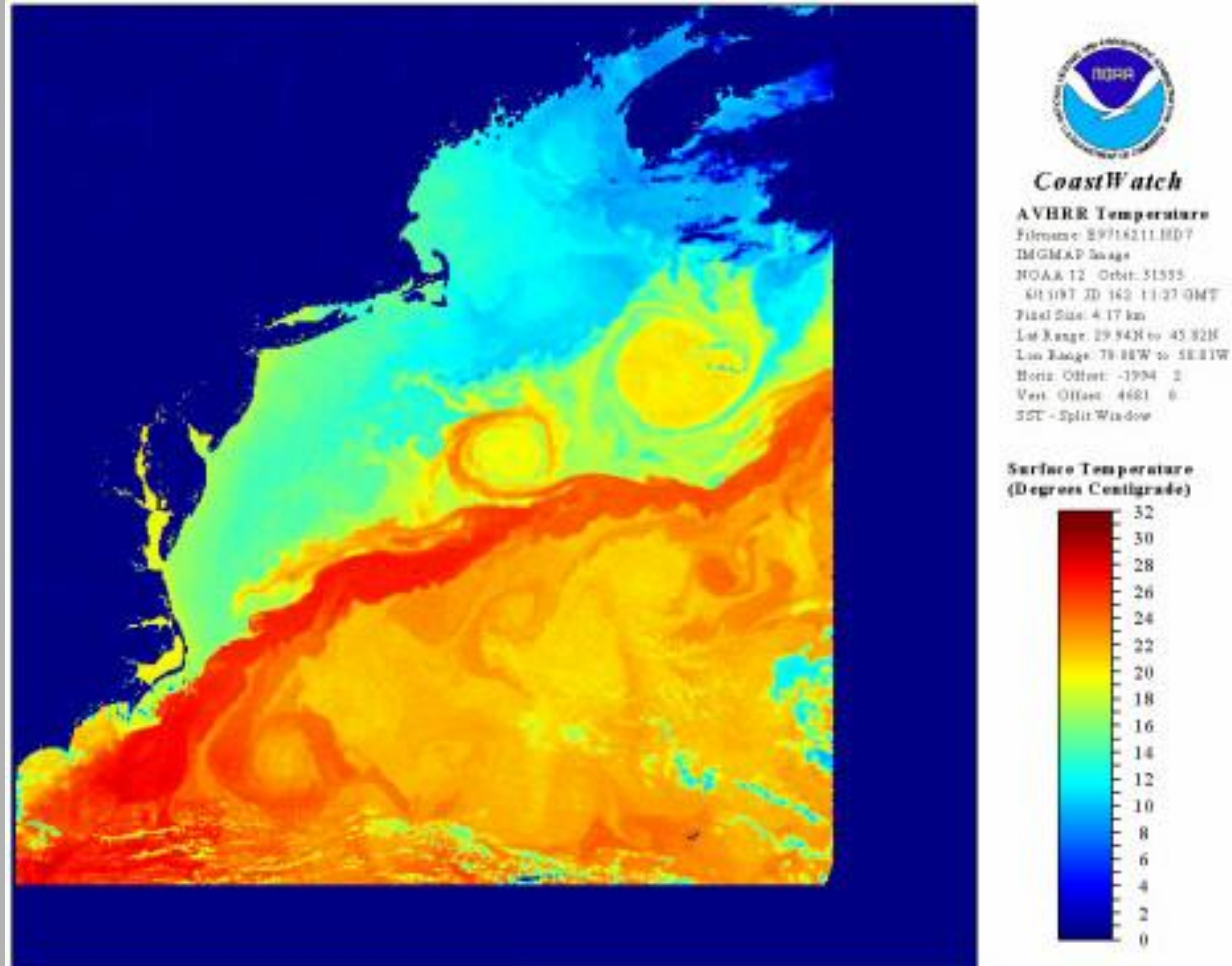


False color images from MSG channels. Left: 12.0-10.8 (R), 10.8-8.7 (G), 10.7 (B). Right: 1.6 (R), 0.8 (G), 0.6 (B). Click on either image to view animation.

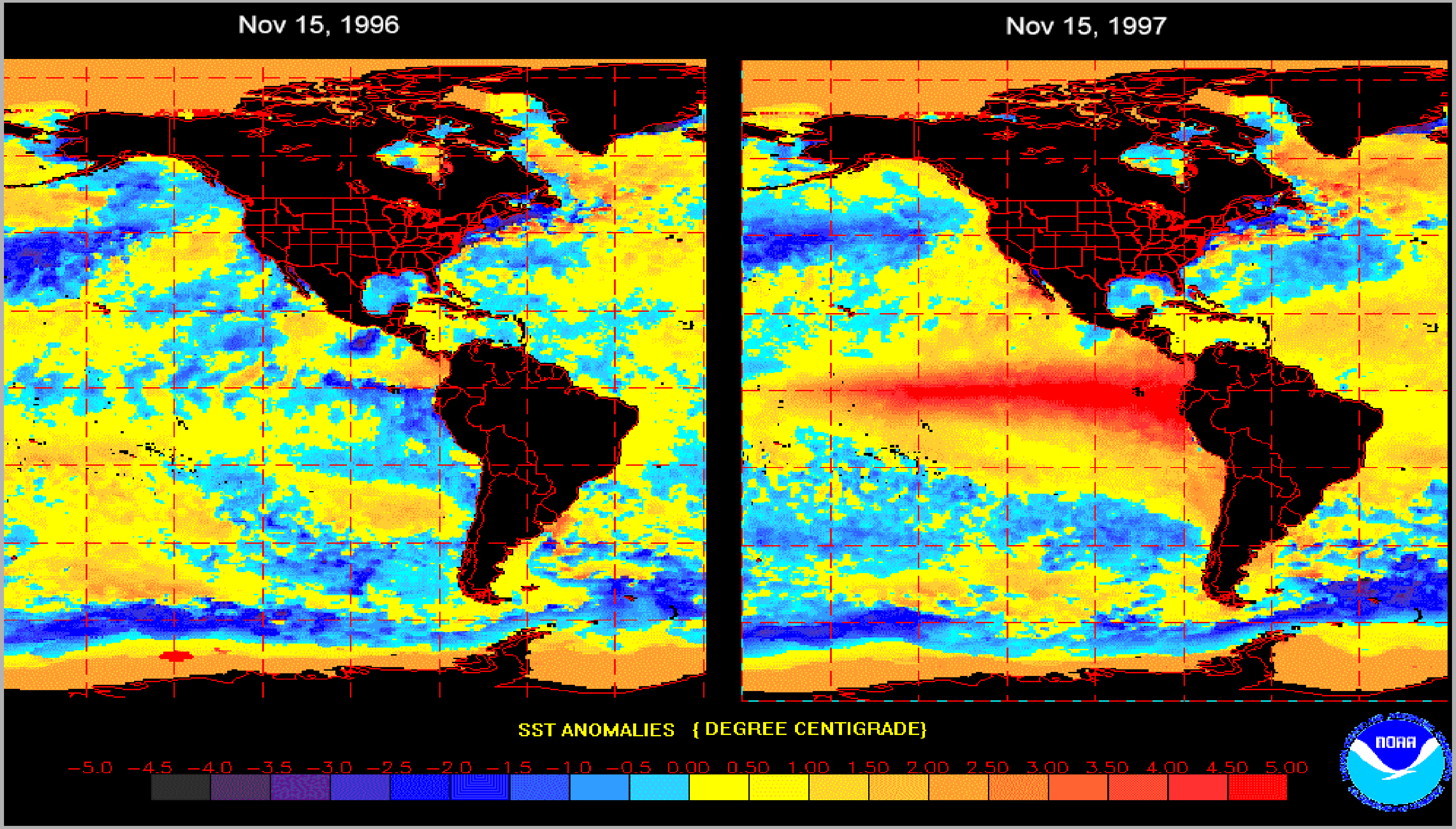
Earth emitted spectra overlaid on Planck function envelopes



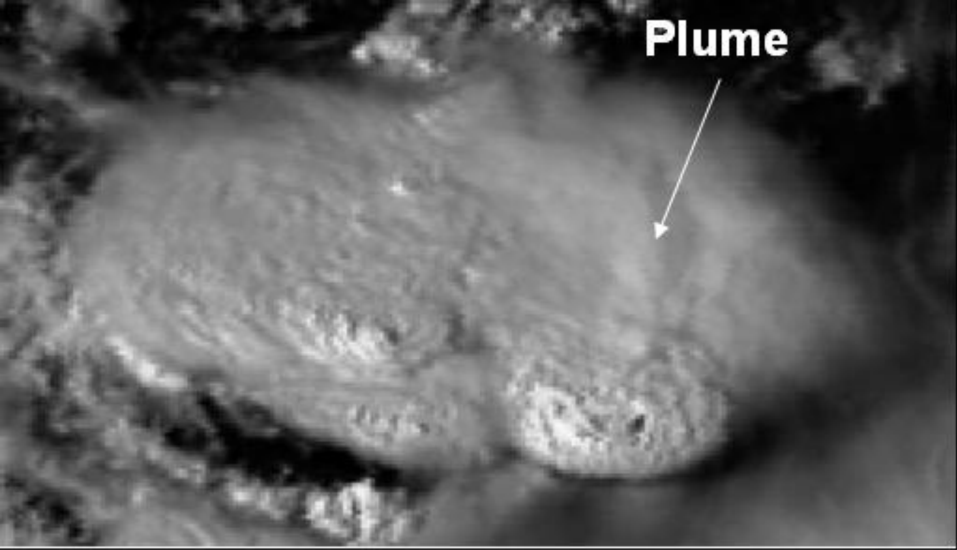
The infrared window regions and ozone absorption area



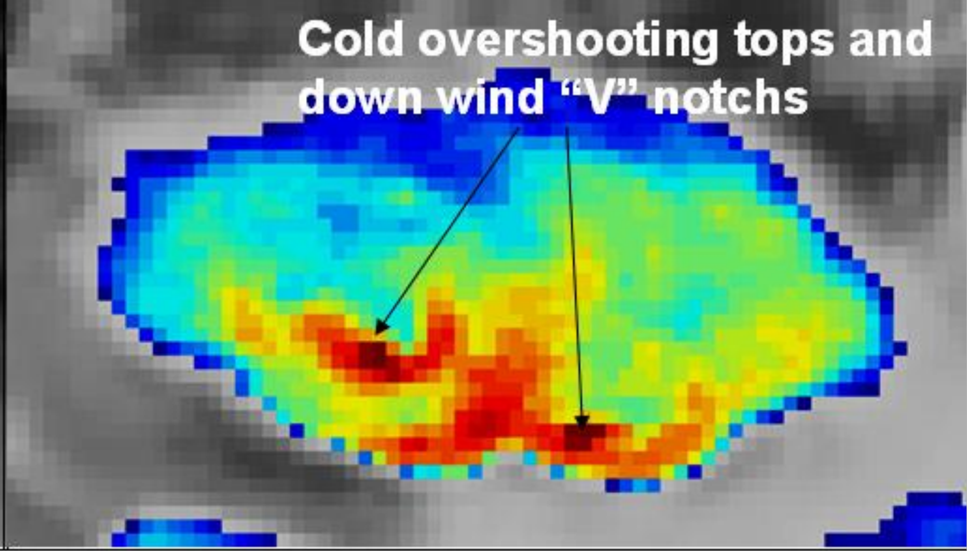
AVHRR Sea surface Temperature product produced by CoastWatch. This picture is over he Atlantic Ocean off of the East Coast of the United States. Notice the strong temperature gradient across the boundary of the Gulf Stream and warm eddies that have broken off and migrated into the colder waters.



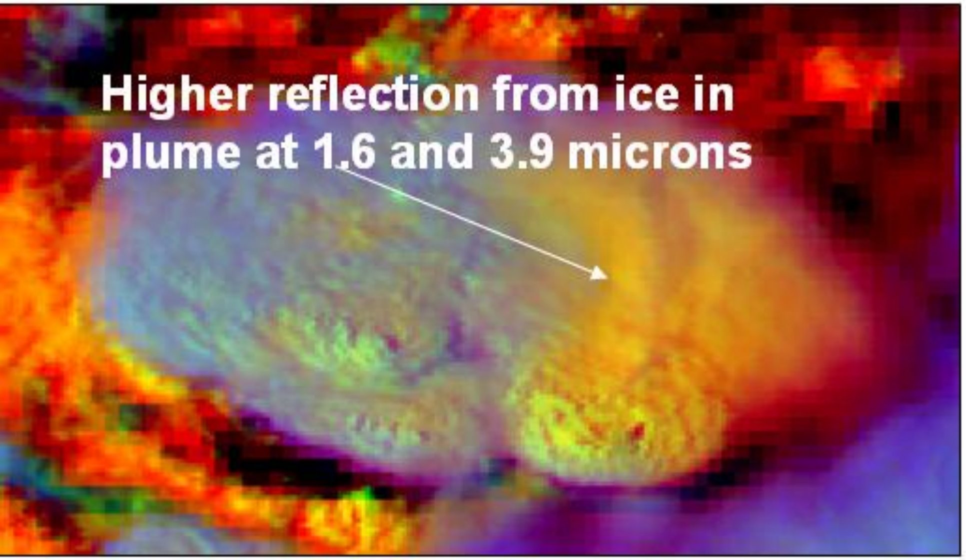
AVHRR Sea Surface temperature Anomalies (Deg. C)
November 1996 vs November 1997



MSG High Resolution Visible (HRV)



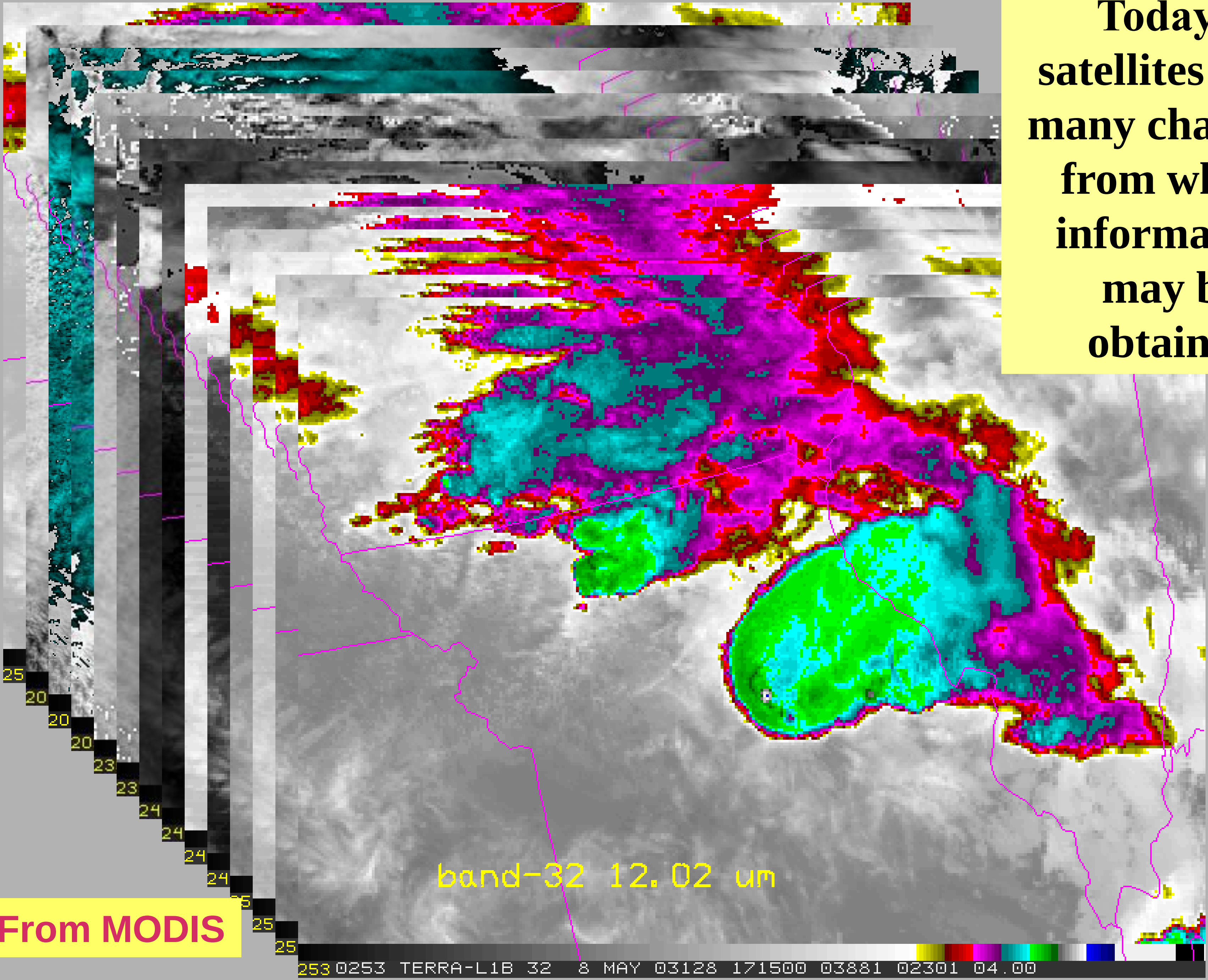
MSG Enhanced 10.7 micron IR



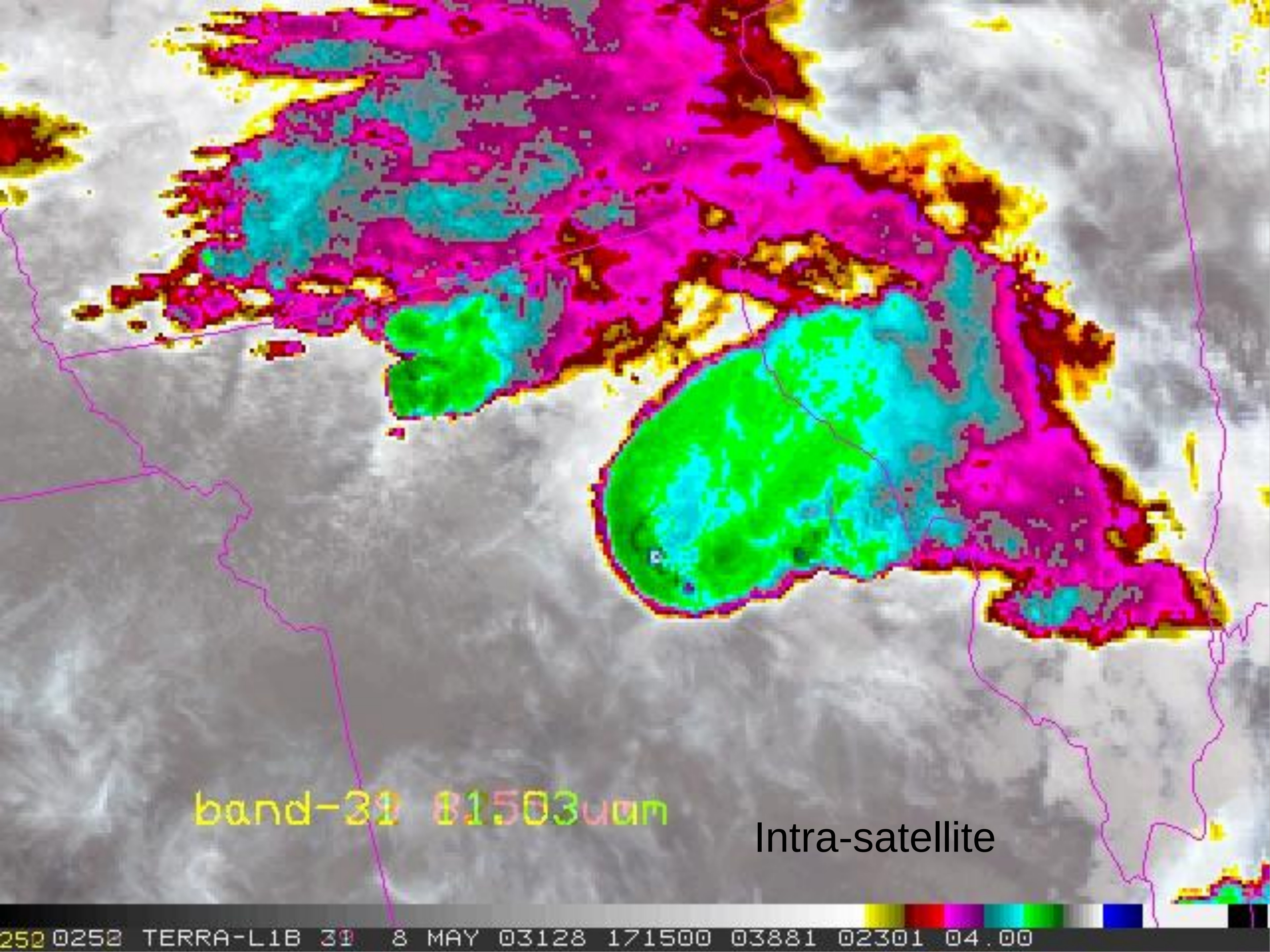
MSG 3 channel color image using HRV, 1.6 and 3.9 micron channel data

Figure 27: Thunderstorm tops over Europe from MSG on 29 July 2005 at 14:30 UTC. This case, presented by Martin Sevtak at the EUMETSAT Users' Conference showed higher reflection from ice in the plume at thunderstorm top in 1.6 and 3.9 microns, likely due to smaller cloud particle size and related to updraft characteristics. Cold over-shooting top and "V" notches are clearly shown in the 10.7 channel image, as are the plume brighter reflection from the right-most storm.

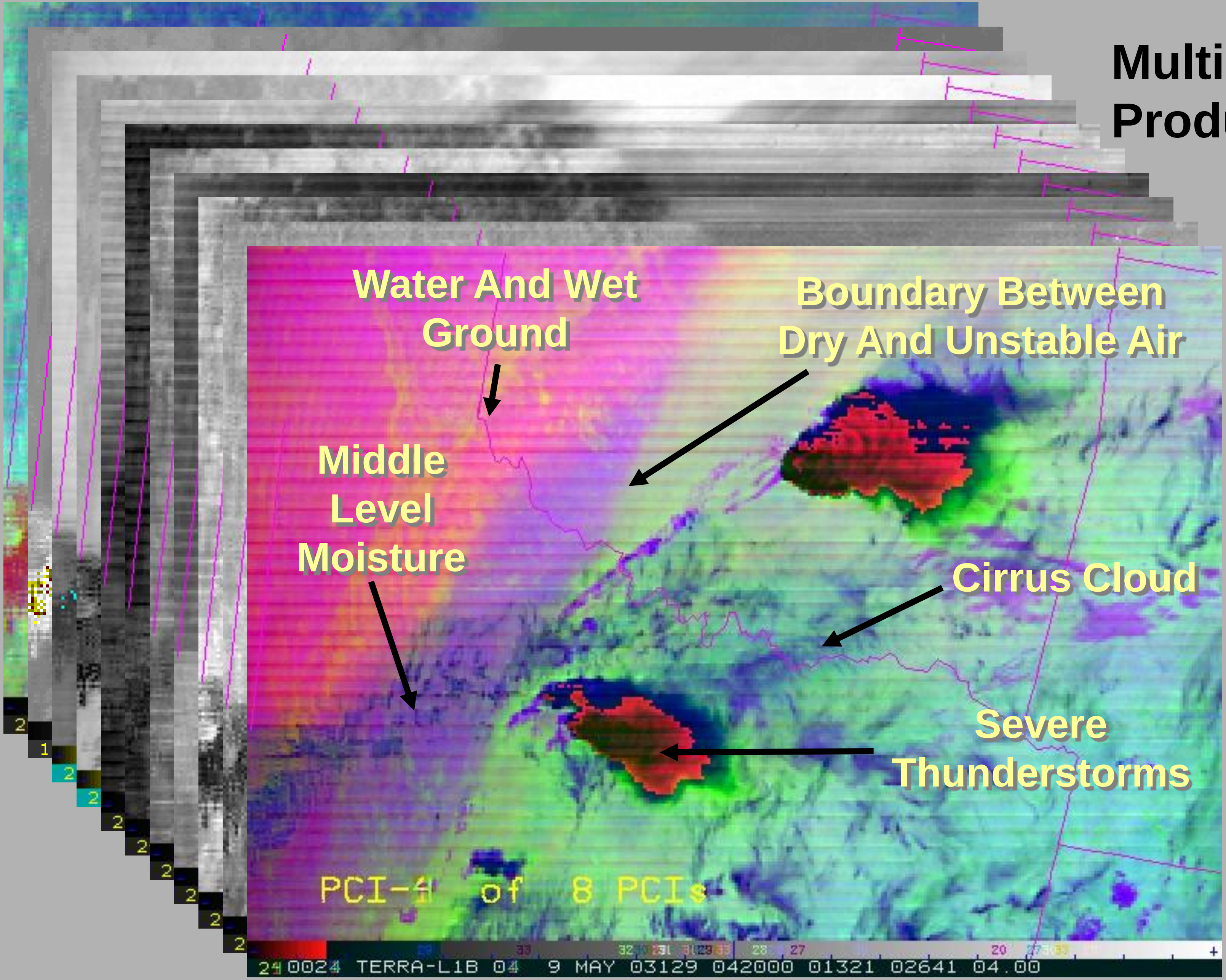
Today's satellites have many channels from which information may be obtained



From MODIS


band-31
Intra-satellite
0252 0252 TERRA-L1B 31 8 MAY 03128 171500 03881 02301 04.00

Multi-channel Product



Products based on mathematical analysis of multi-channel images – we can do now with MODIS and MSG!

Conclusions

- Understand the difference visible, near infrared and infrared radiation (channels)
  - Understand the influence of surface and atmospheric properties on what we view with a satellite sensor
- Understand the basic underlying principals behind channel selection and the factors that influence channel selection
- Understand what information can be obtained using the various satellite channels available from operational and research satellites
- Understand how to interpret data from various channels individually and in combination with other channels
- Understand the difference between multi-spectral and hyper-spectral data