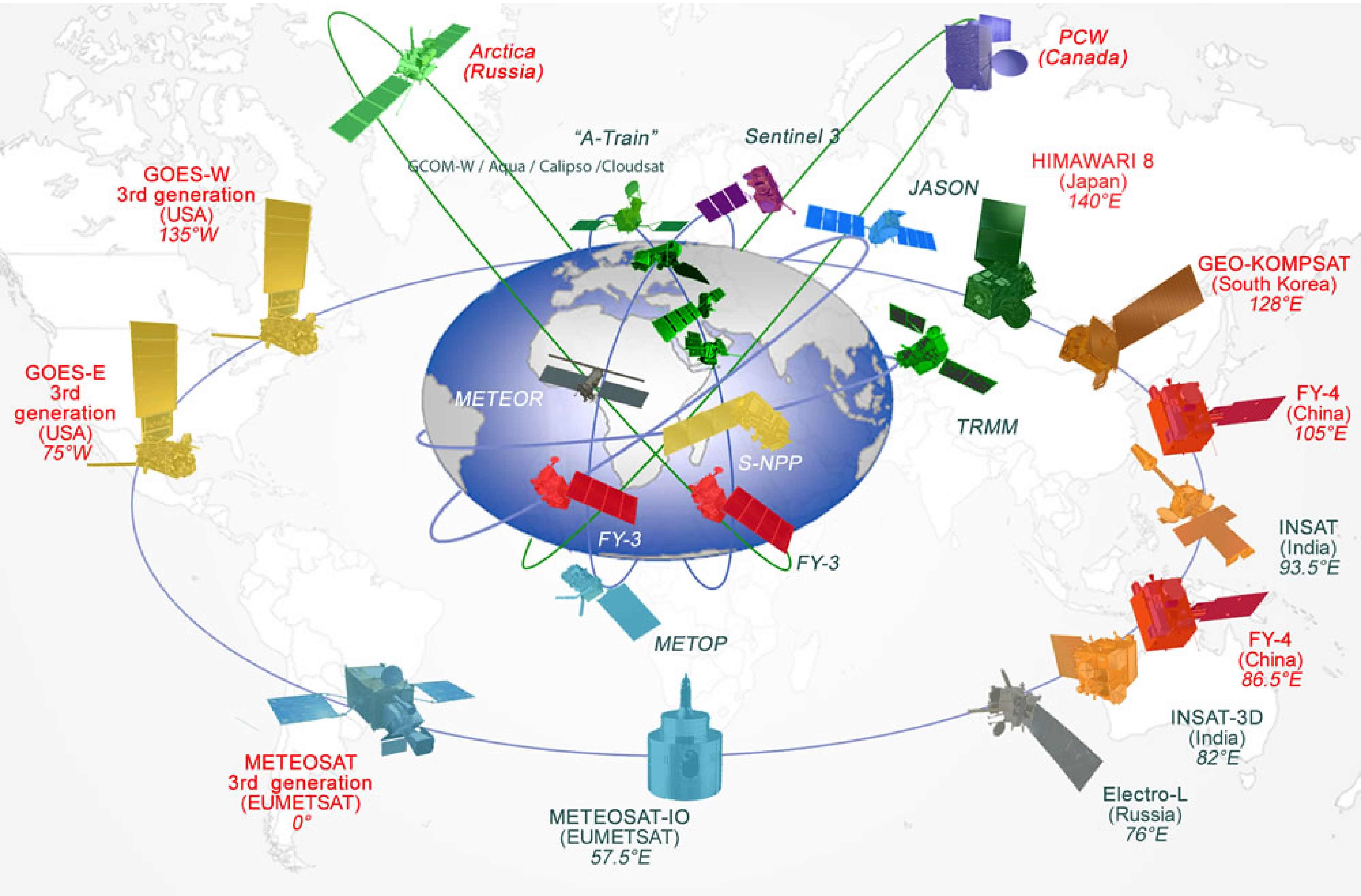
Prospects and expectation towards the era when the next generation geostationary meteorological satellites' global array will be in operation

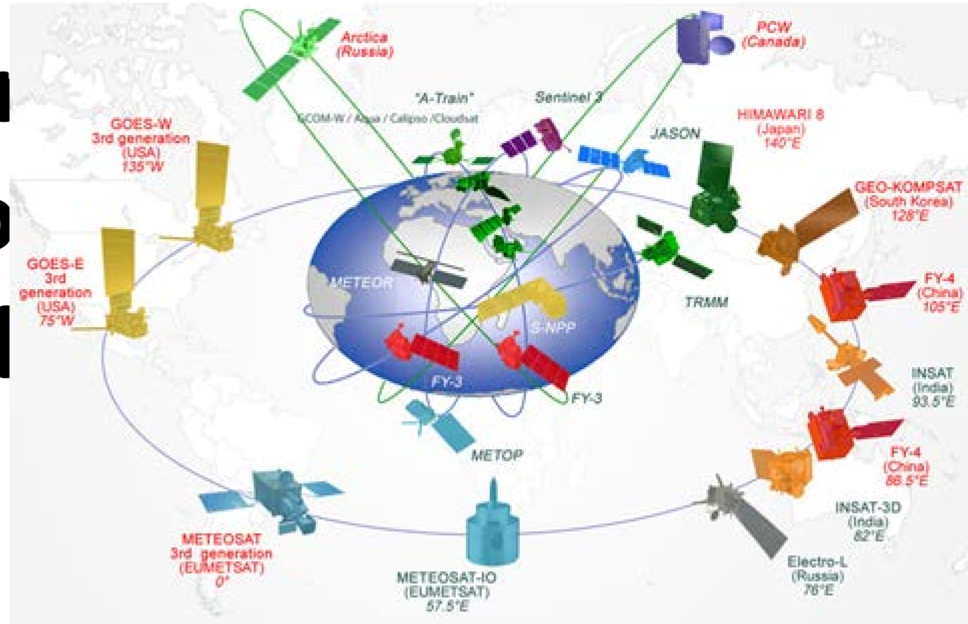
James F.W. Purdom, PhD
Chair, AOMSUC International Conference Steering Committee

20 minutes training, 15 minutes AOMSUC with questions



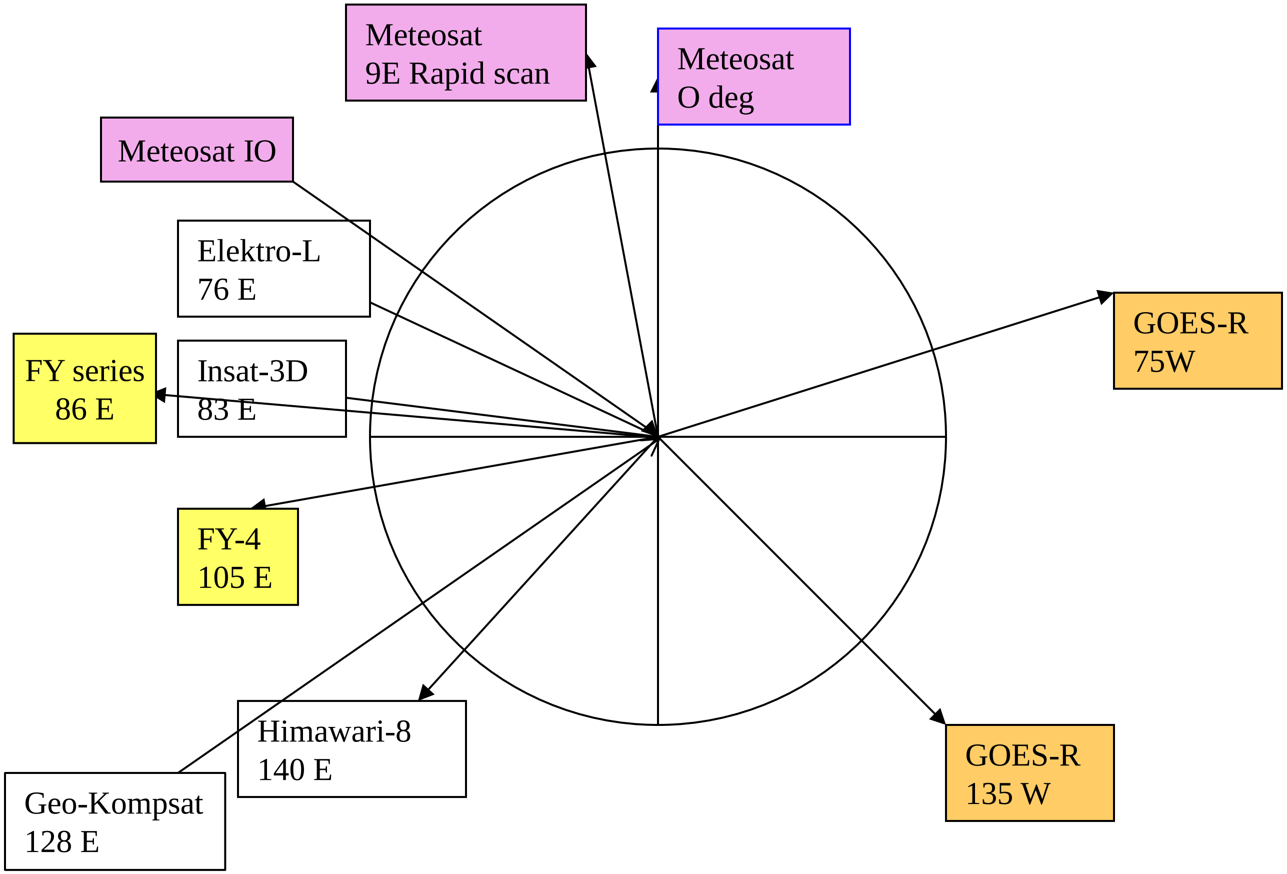
Arctica
(Russia)
PCW
(Canada)
"A-Train"
GCOM-W / Aqua / Calipso /Cloudsat
Sentinel 3
HIMAWARI 8
(Japan)
140°E
JASON
GOES-W
3rd generation
(USA)
135°W
GEO-KOMPSAT
(South Korea)
128°E
GOES-E
3rd
generation
(USA)
75°W
METEOR
FY-4
(China)
105°E
TRMM
S-NPP
INSAT
(India)
93.5°E
FY-3
FY-3
FY-4
(China)
86.5°E
METOP
INSAT-3D
(India)
82°E
METEOSAT
3rd generation
(EUMETSAT)
0°
Electro-L
(Russia)
76°E
METEOSAT-IO
(EUMETSAT)
57.5°E

Prospe… owards the e… eration geo… gical satel… be in



The space agencies are meeting the challenge of providing a rich and vibrant geostationary satellite constellation

Geostationary constellation of satellites anticipated in 2015-2020



Monitoring Weather, Climate and the Environment

By 2020 we should have experience at geostationary orbit with multi-spectral rapid scan imagery, hyper-spectral sounding, lightning mappers, Solar Environmental Monitoring, and be on the threshold of passive microwave

Next Generation of Geostationary imagers and sounders*

Satellite	Operator	Expected launch date	Longitude	Imager	Spectral channels	Spatial resolution	Temporal resolution (full disk)
Himawari-8	JMA	2014	140E	AHI	16	0.5-2km	10min
GOES-R	NOAA	2015	137W	ABI	16	0.5-2km	15min
Himawari-9	JMA	2016	140E	AHI	16	0.5-2km	10min
FY-4A	CMA	2017 , Oct.	86.5E	AGRI	14	1-4km	15min
Geo-KOMPSAT-2A	KMA	2017	128.2E	AMI	16	0.5-2km	10min
GOES-S	NOAA	2017	75W	ABI	16	0.5-2km	15min
MTG-I1	EUMETSAT	2019	9.5E	FCI	16	0.5-2km	10min
FY-4B	CMA	2019	105E	AGRI	15	0.5-2km	15min

FY-4A/B/C CMA hyperspectral sounder 16/16/8 1 hr or 3min

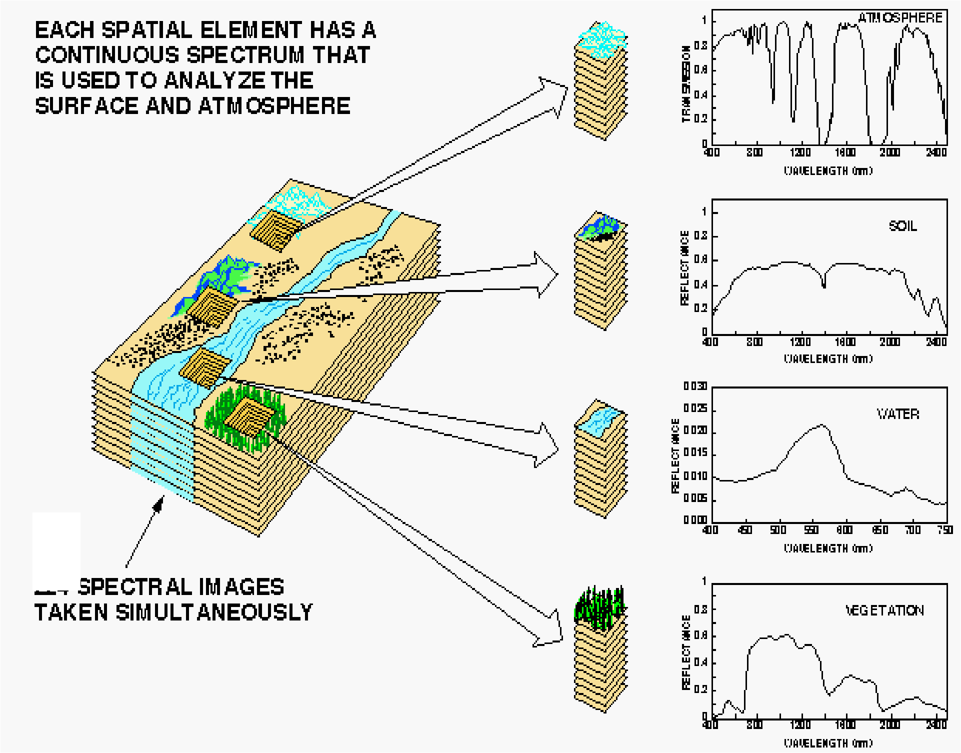
FY-4B CMA rapid scan imager 250 meter vis/1.6/2.2 & 2 km IR 1 minute or less

FY-4C CMA 2020 tbd AGRI 16 0.5-2km tbd

*** All capable of sampling limited areas in correspondingly shorter time intervals**

Recall that in satellite remote sensing, four basic parameters need to be addressed: all deal with resolution. The new generation geostationary satellites are a giant step forward in all four!!!

- temporal (how often)
- spatial (what size)
- spectral (what wavelengths and their width)
- radiometric (signal-to-noise)

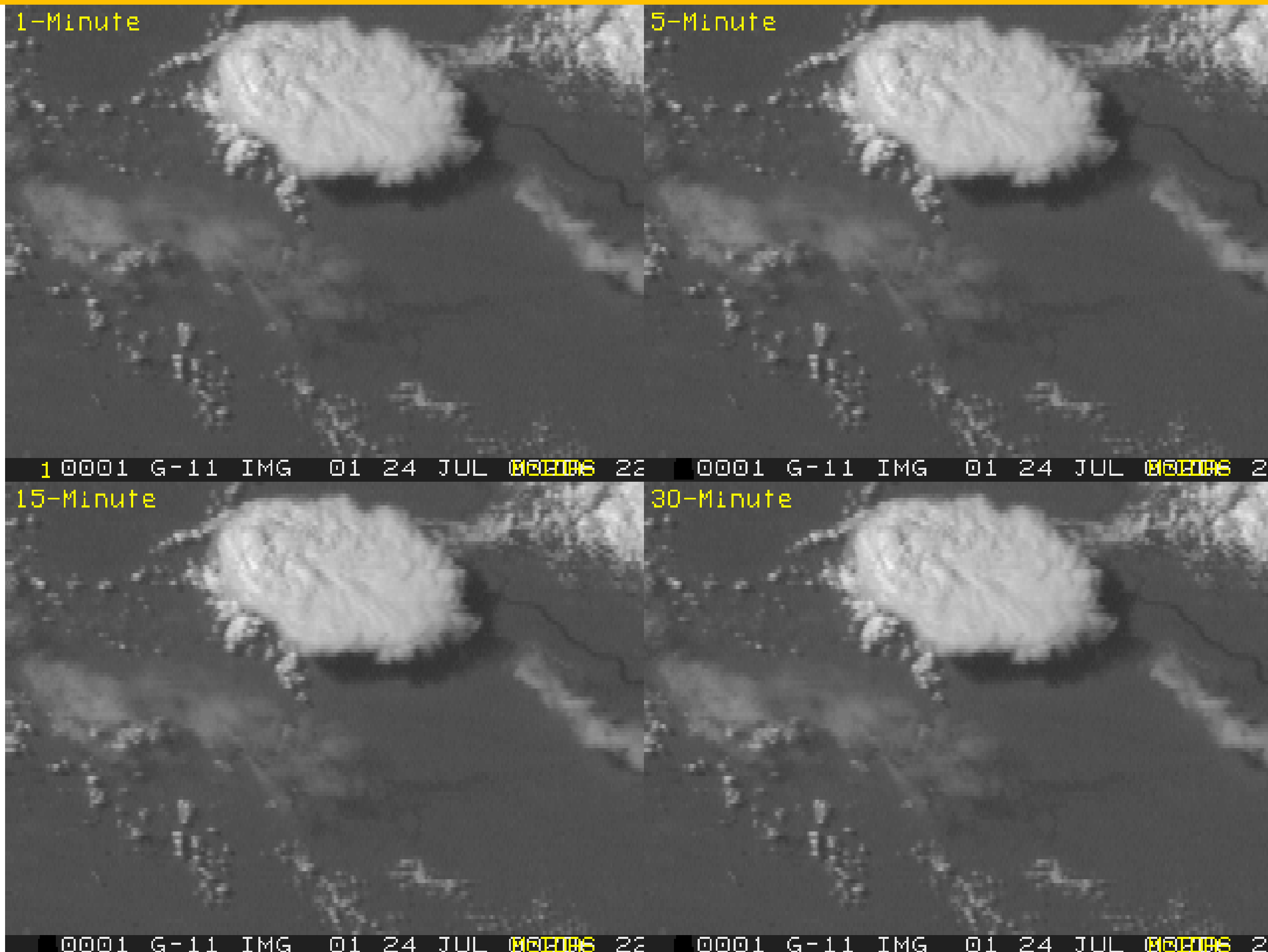


The spatial and temporal domains of the phenomena being observed drive the satellite systems' spectral needs as a function of space, time, and signal to noise.

Each spatial element has a continuous spectrum that may be used to analyze the surface and atmosphere

Temporal (2010 era)

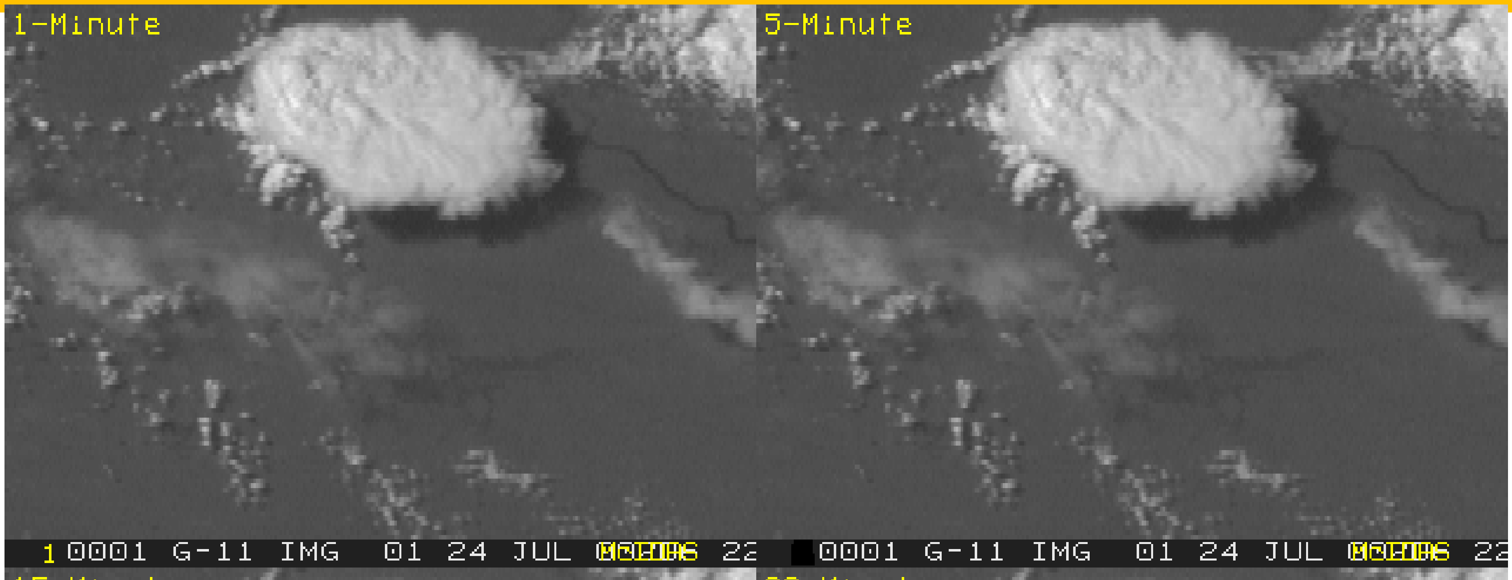
Comparison of animation sequences of severe thunderstorm over western Kansas. Movies at 30, 15, 5 and 1 minute intervals. While 5 minute interval imaging is routine for 2015s, special imaging like this is possible at 1 minute intervals or less.



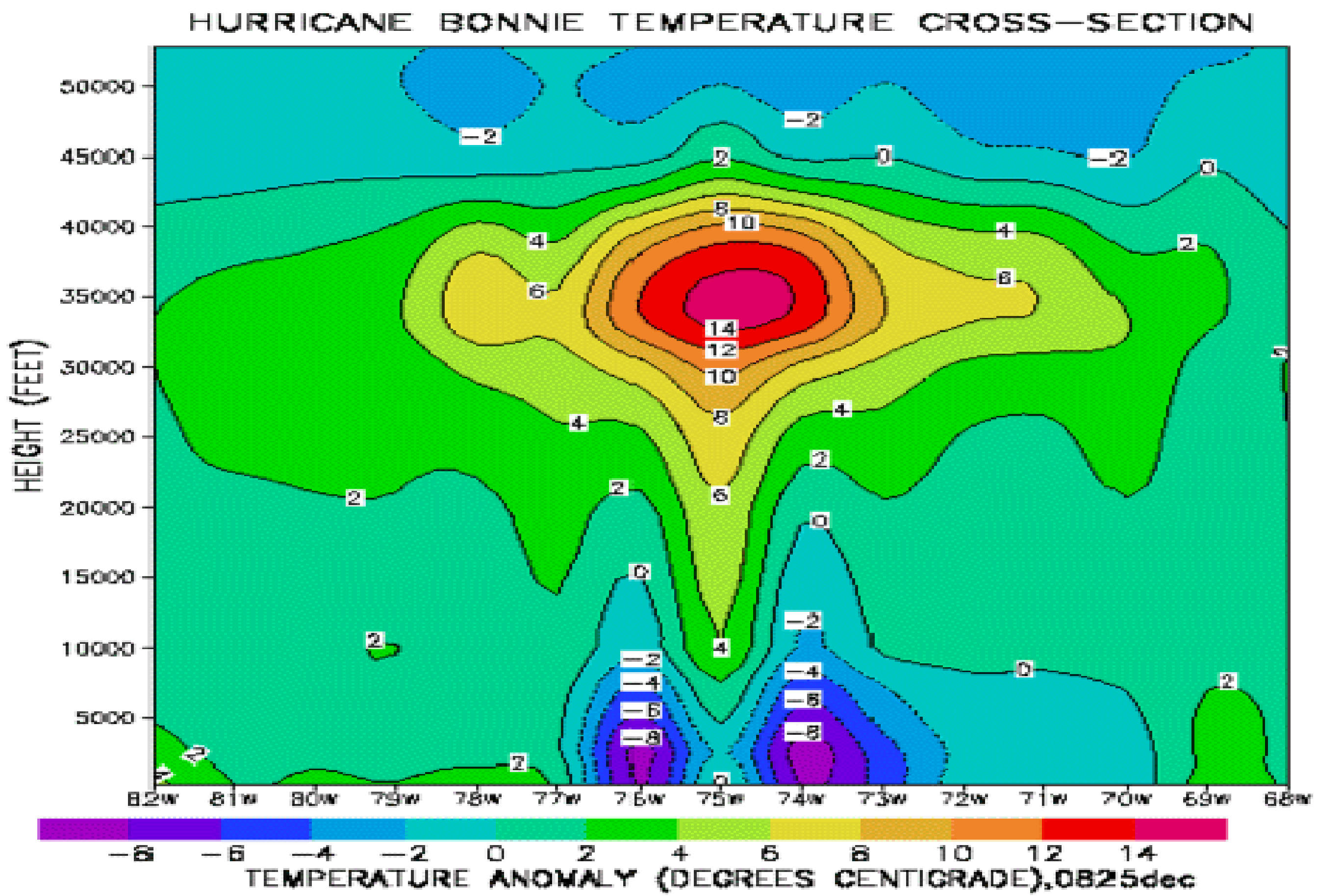
Temporal (2015 – 2020 era)

While 5-10 minute interval imaging is routine for 2015s, special imaging is possible at 1-3 minute intervals or less!!

*****Some may separate routine imaging and rapid scan. A 15 channel "routine" full disk imager with rapid scan from a 2000 x 2000 focal plane array with 250 meter resolution in the visible, 1.6 and 2.2 micron bands imaging at somewhere around every 6-12 seconds and a 2km IR every minute: a monumental move in the observing and analysis of convective development and evolution during the daylight hours. There is also the potential of fires at night using the 2.2 micron band.**

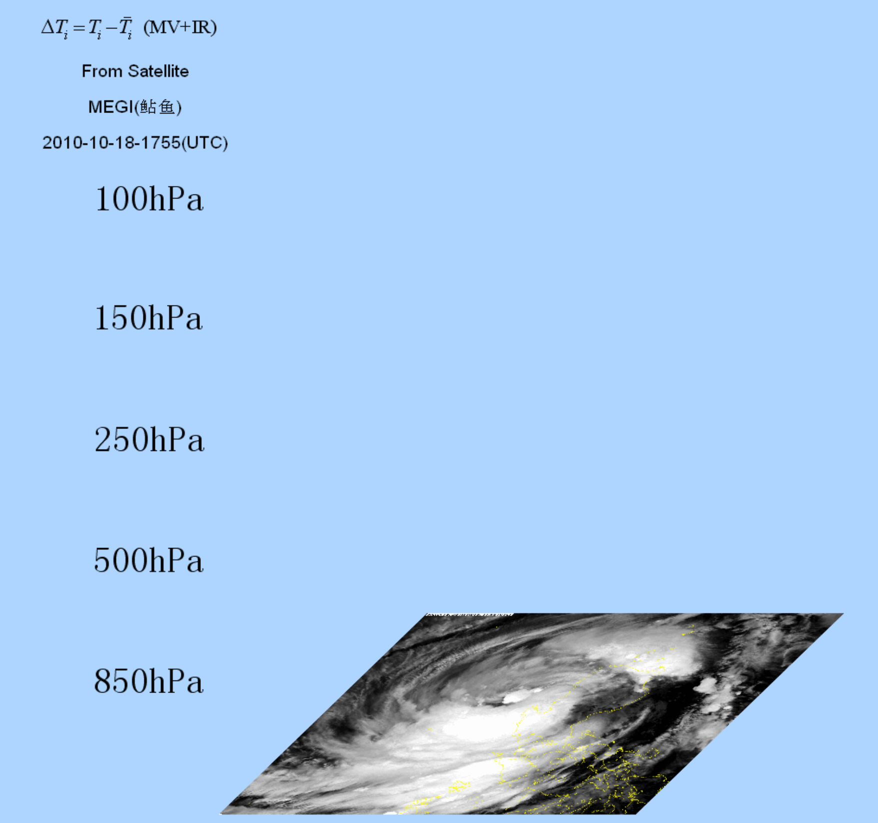


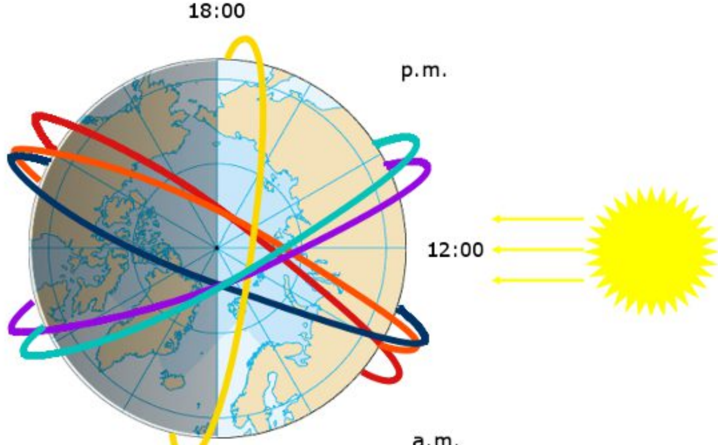
We utilize a composite satellite system: geostationary, polar and other

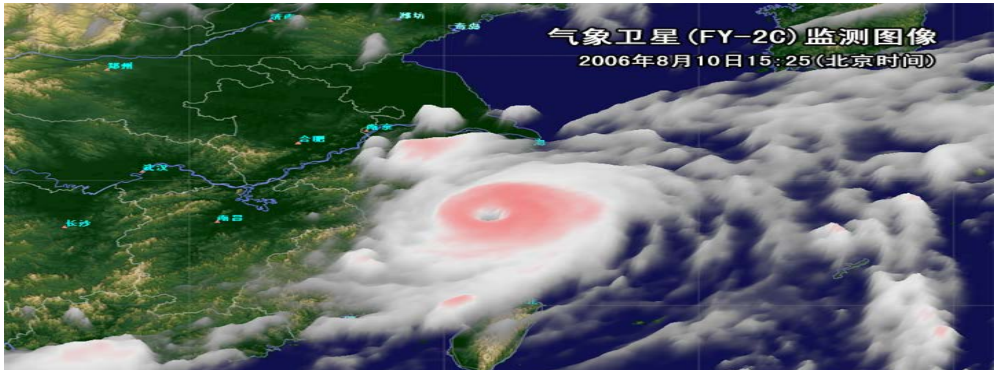


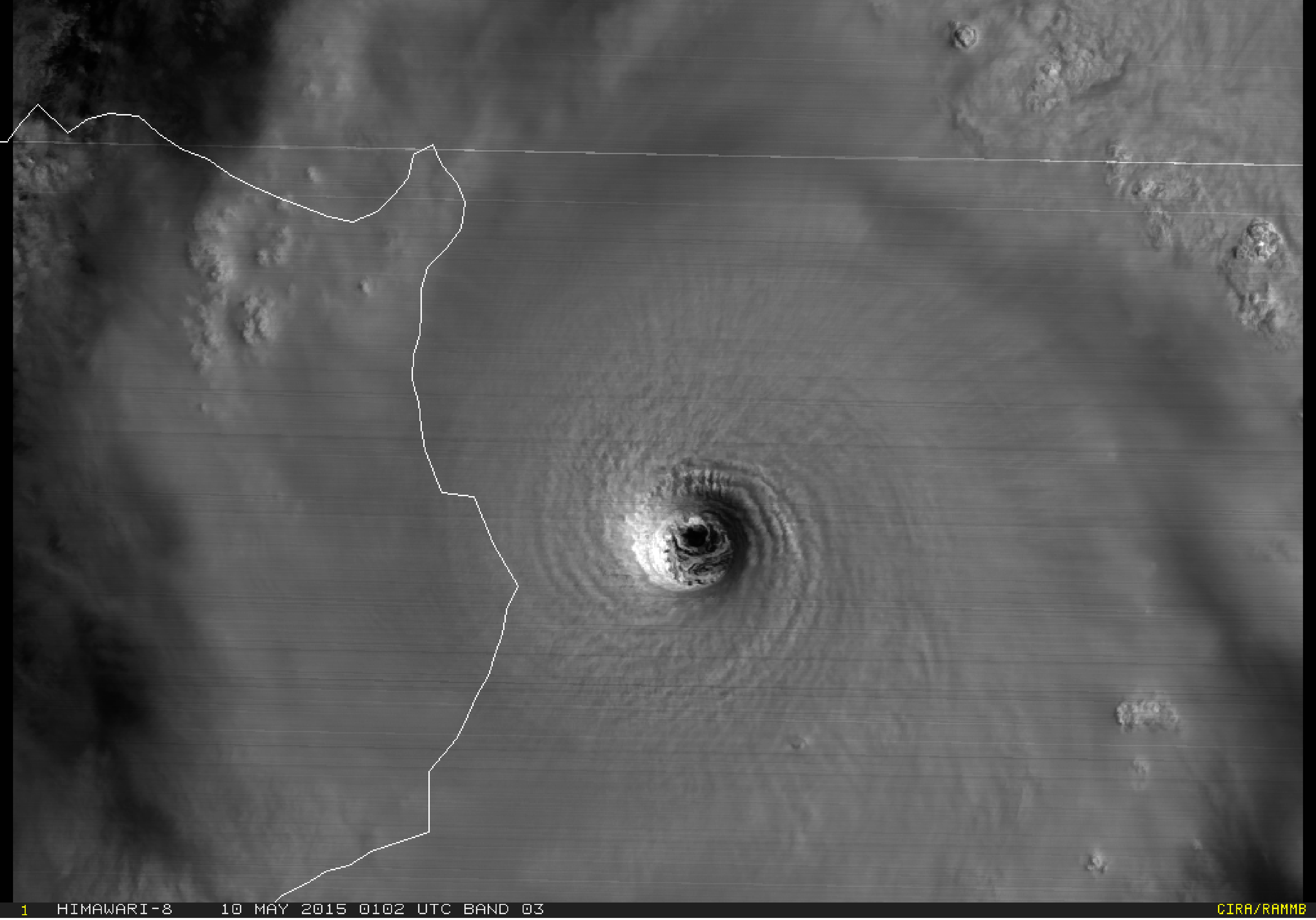
TC monitoring and warning Challenges

- **Biggest forecast challenge is rapid intensity change**
- Limited skill at even analyzing TC structure
- Frequent Monitoring the intensity change is Critical to timing and placement of watches/warnings
- **Can we anticipate by 2040 GEO or fleet LEO Microwave instruments**





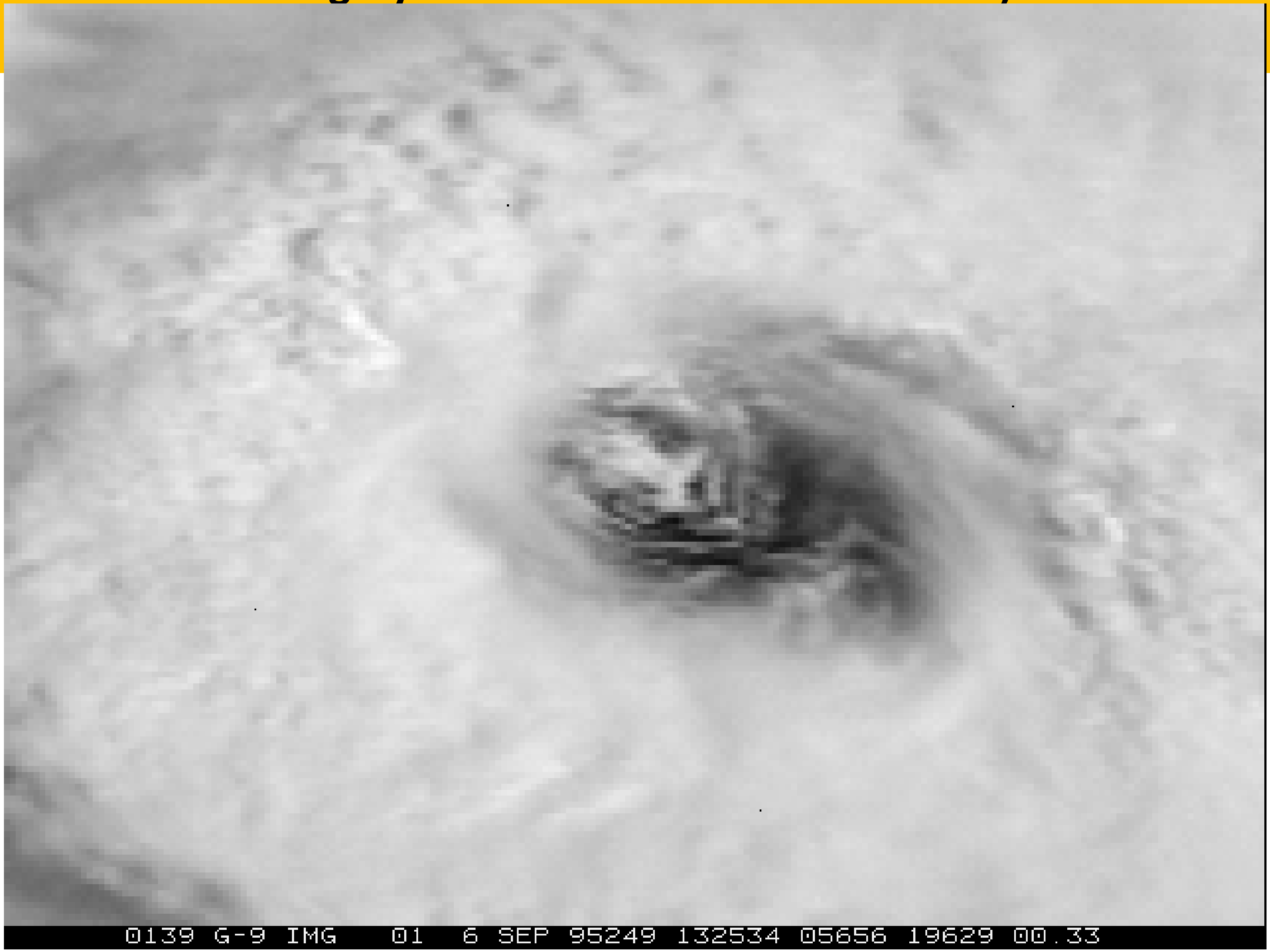




For the first time, we have 500 m VIS every 2.5 minutes

Temporal

The eye of hurricane Luis at one minute intervals (actual 1 km resolution visible imagery zoomed to 0.33 km resolution)



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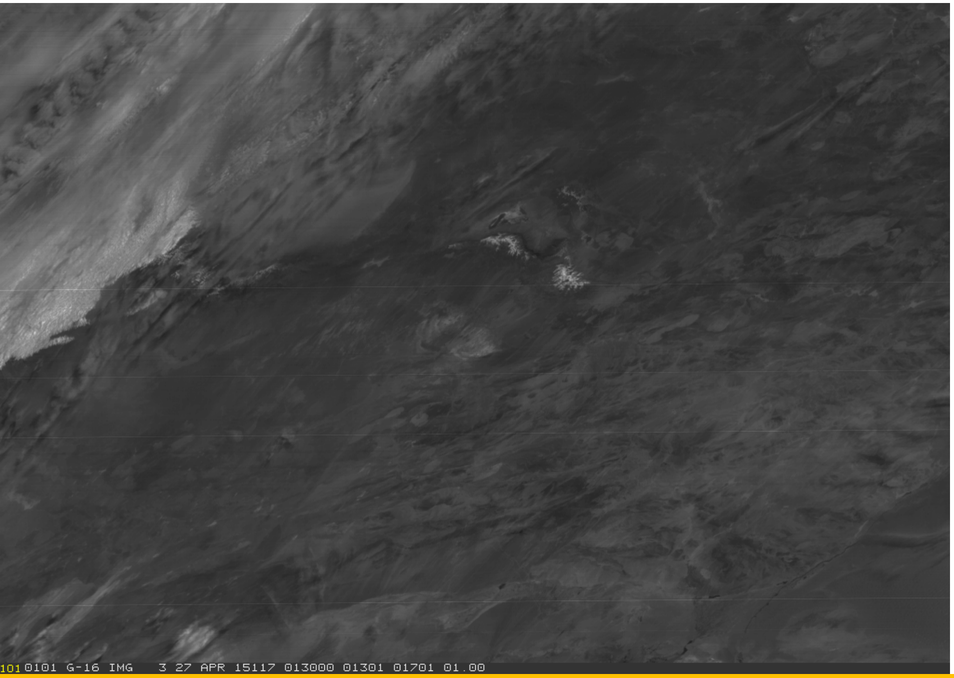
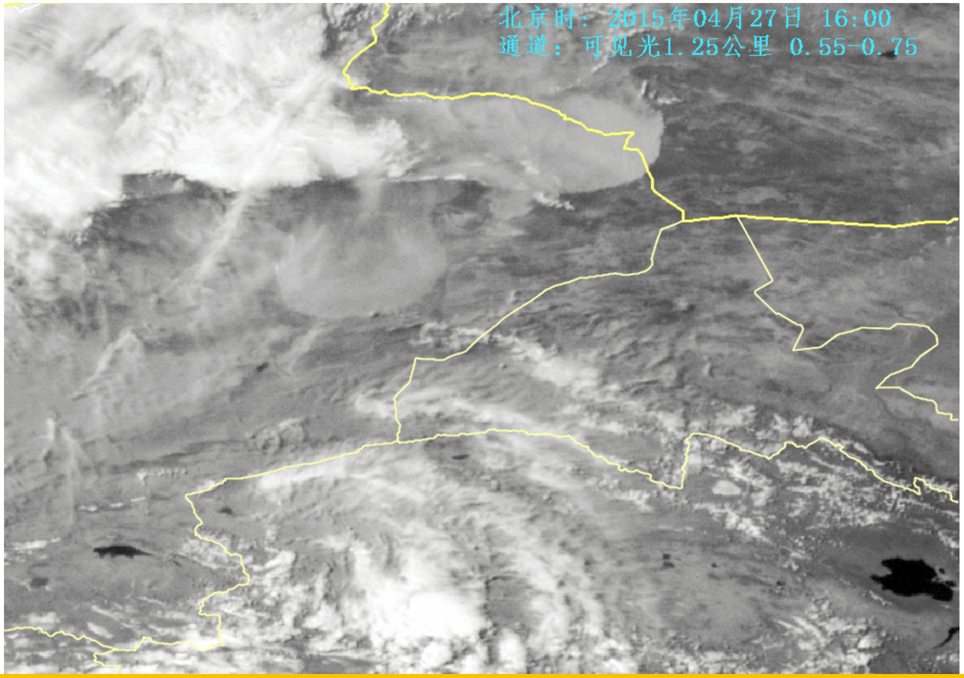
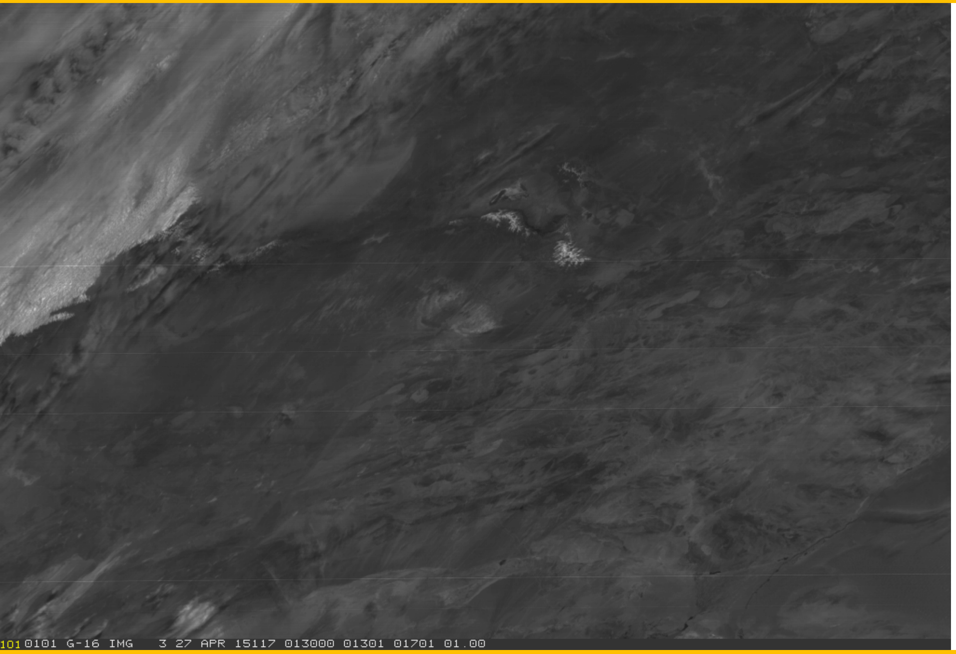


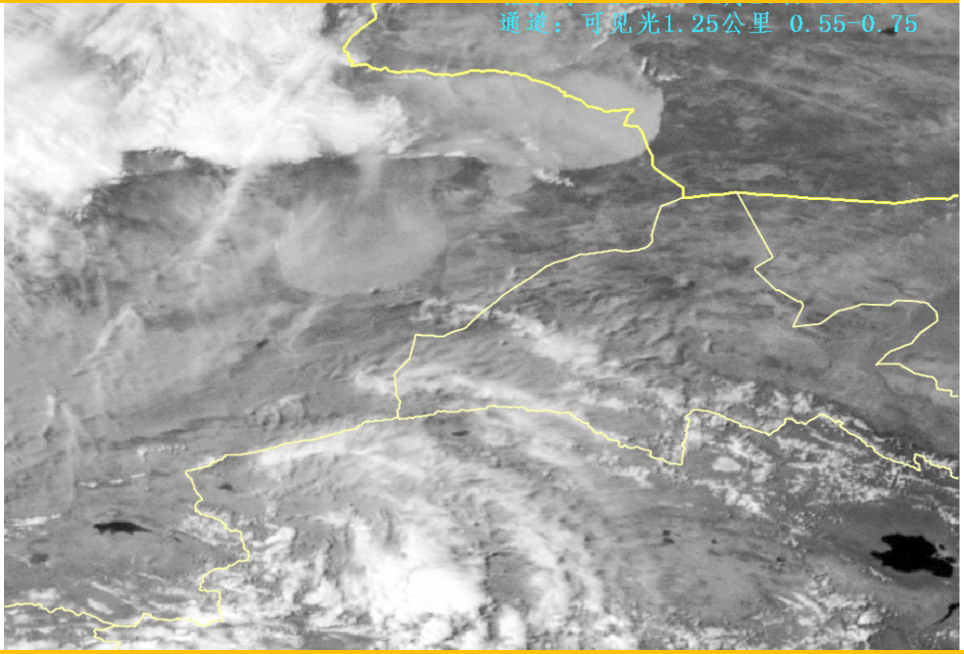


Animations from Himawari-8 (left) at its routine 10 minute interval viewing and FY-2 (right) in a 3 minute rapid scanning mode, both showing exceptional detail of a dust storm on April 27, 2015.

Temporal (2015 – 2020 era)

Can you see the difference in viewing angles between Himawari and FY-2? This has advantages when viewing clouds and doing cloud motion vectors. Over Asia/Oceania great opportunities!!





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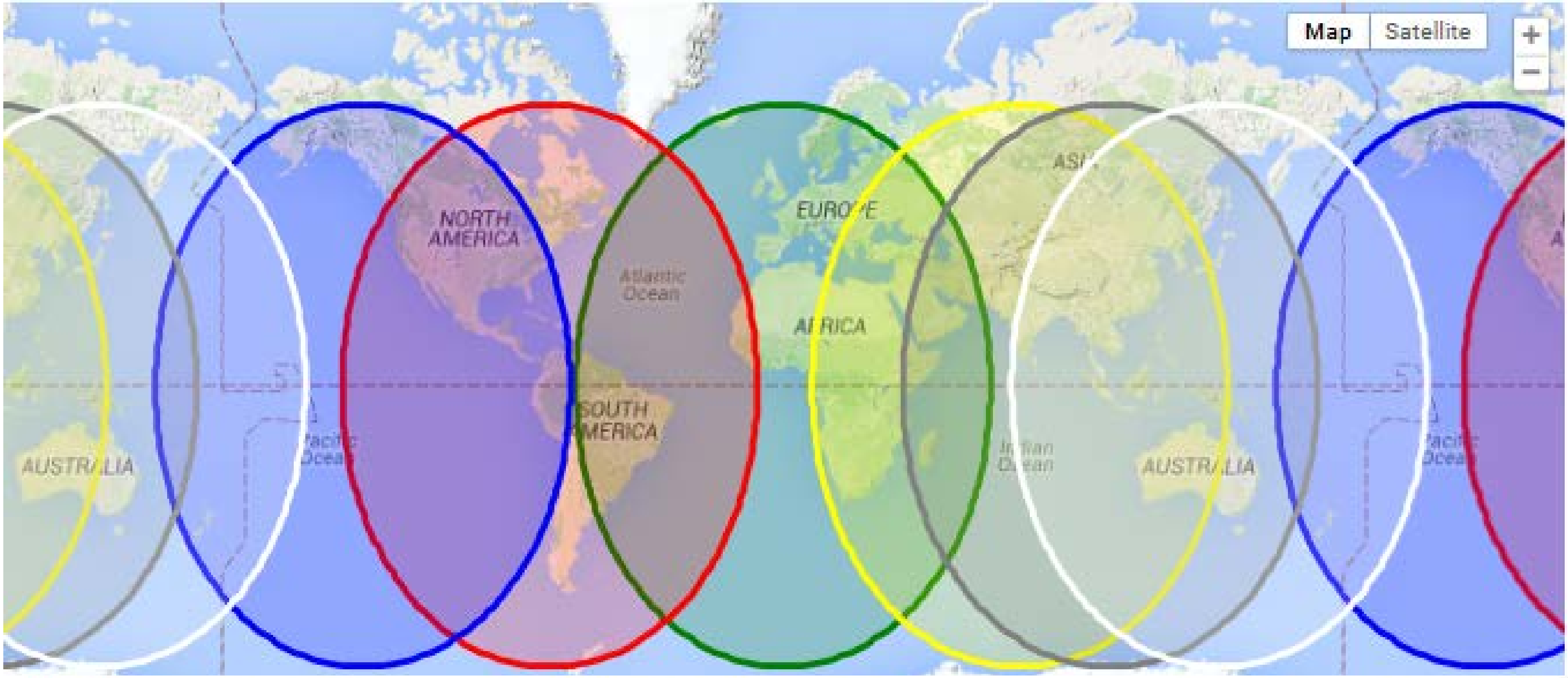

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Update on Accurate Cloud Motion and Heights Using Time Adjusted Stereo

G. Garrett Campbell 2, James F.W. Purdom 1,2 and Carol E. Vaughn 2

Third International Wind Workshop, June 1996

- Asynchronous stereo and motion analysis
  - Uses stereographic techniques, but does not require time synchronization between the different satellites (may also include polar orbiters).

  - The inclusion of many measurements improves the accuracy of the height and the motion.

  - Cloud optical properties like emissivity may also be derived given the geometric height of the cloud.

With satellite remote sensing, there are four basic questions that need to be addressed

- They all deal with resolution:
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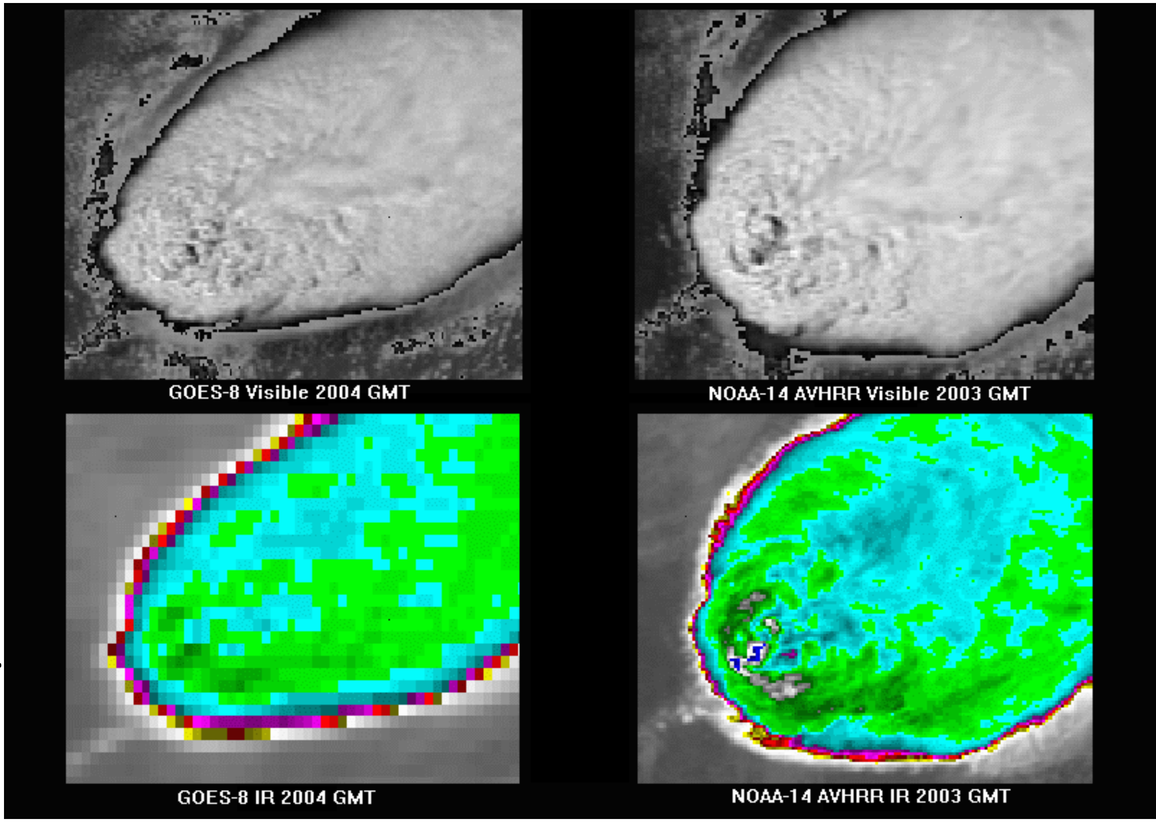
  - spectral (what wavelengths and their width)
  - radiometric (signal-to-noise)

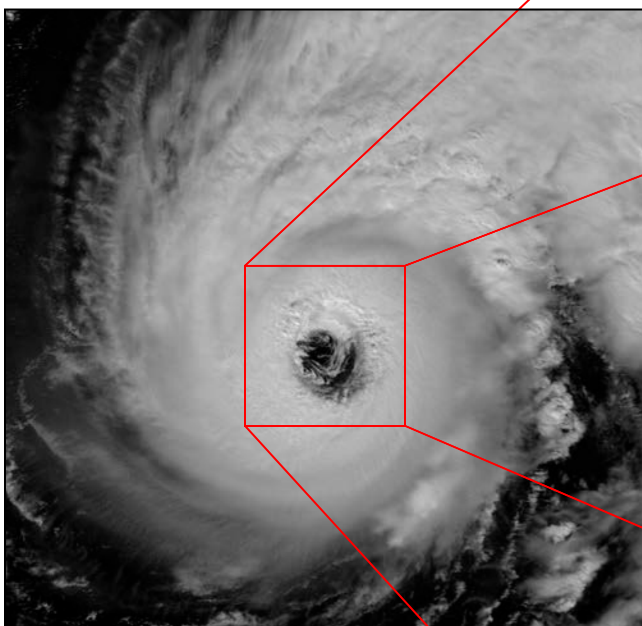


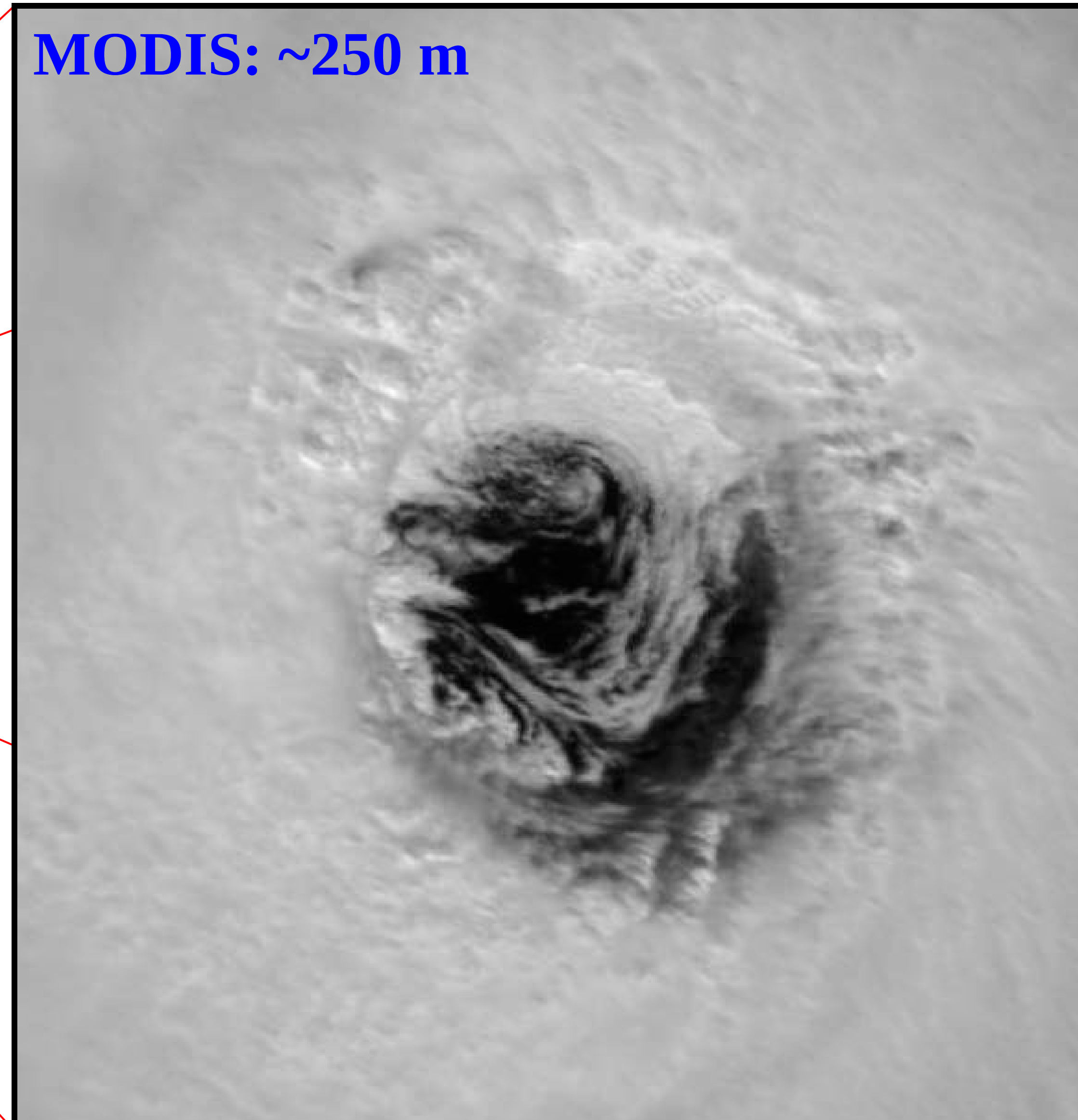
GOES and AVHRR 1 km Vis (top)
GOES 4 km IR, AVHRR 1 km IR (bottom)

1 Km to 250 m

Hurricane Erin

09/09/01 ~1530 Z





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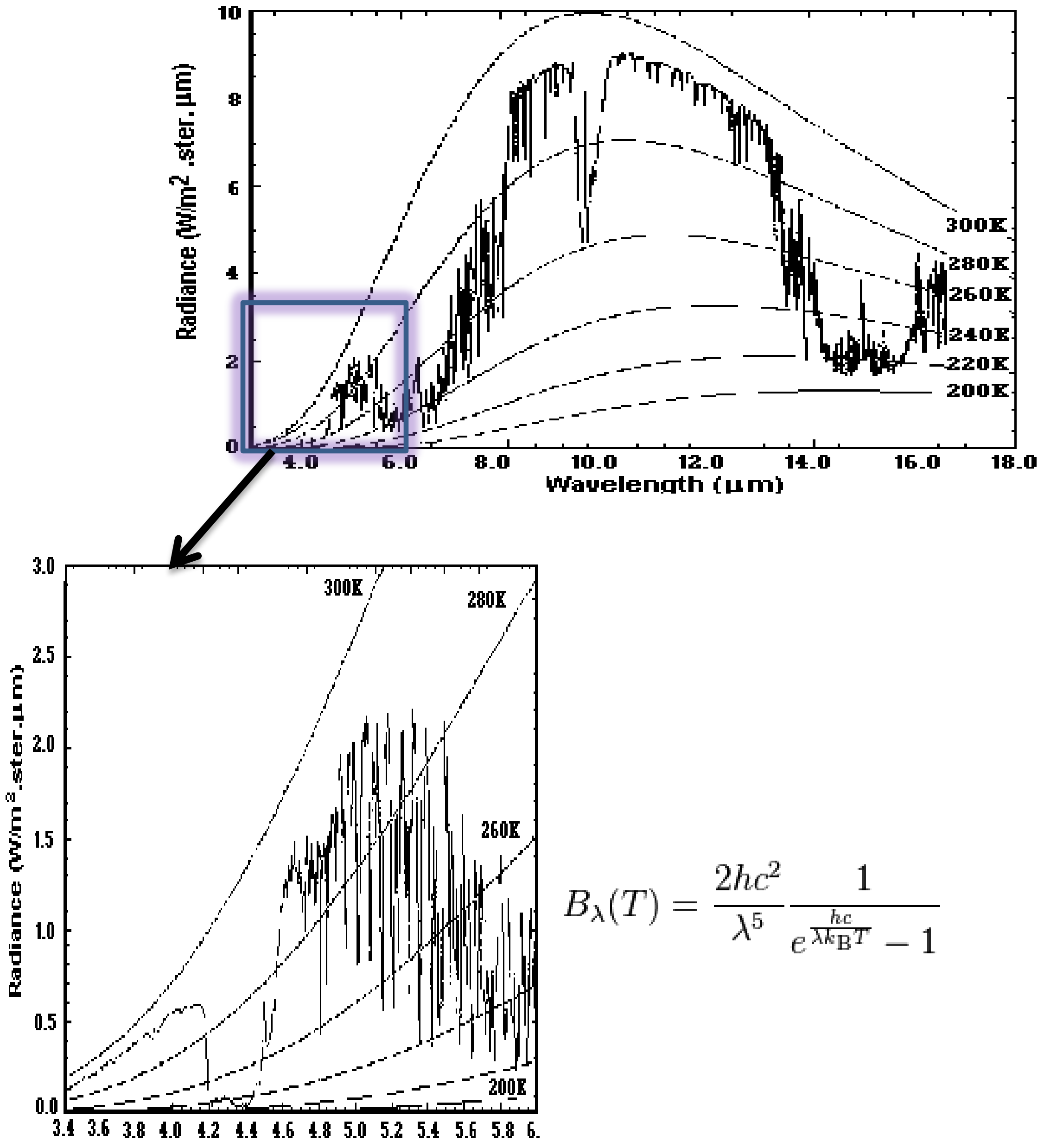
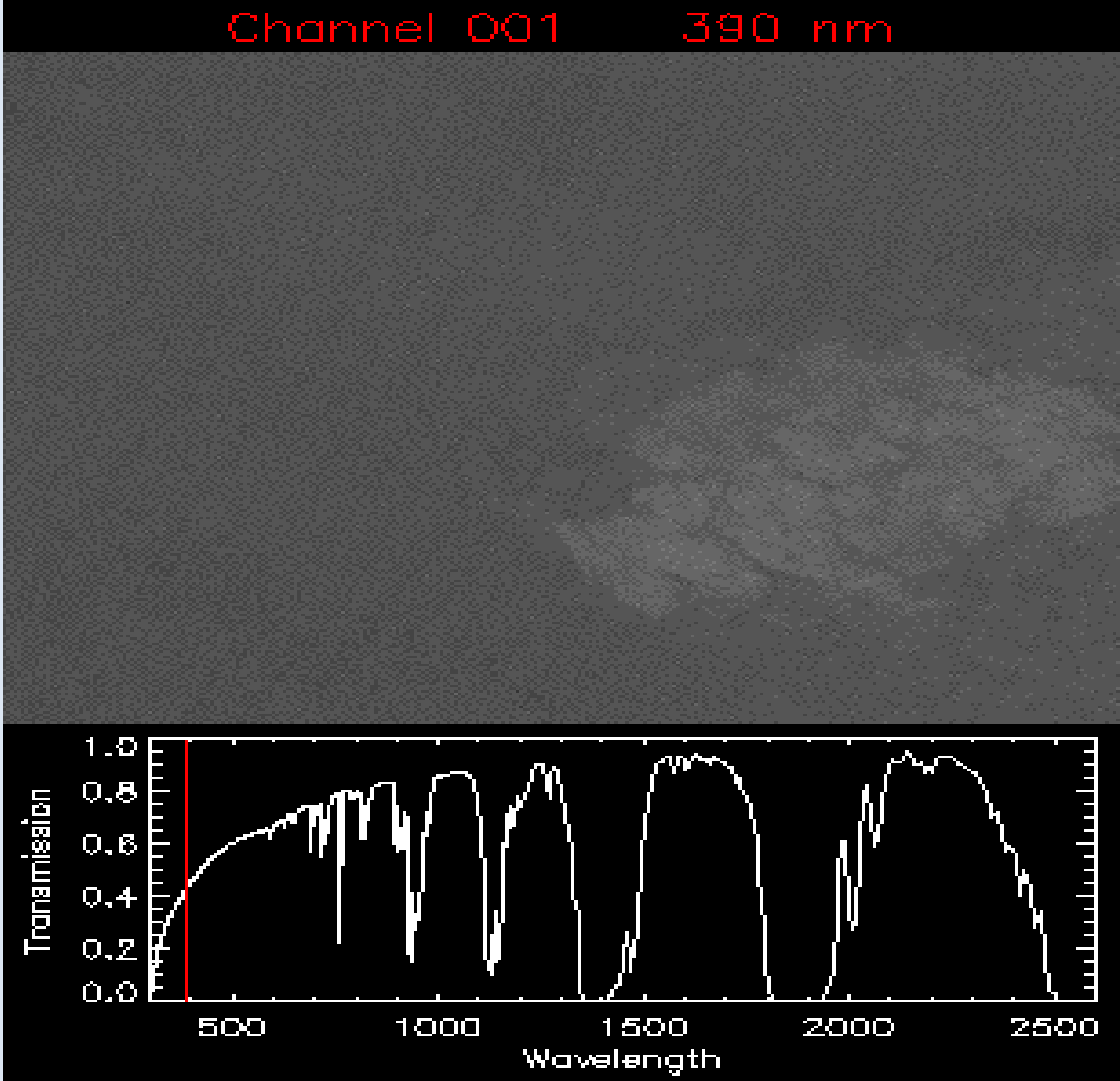
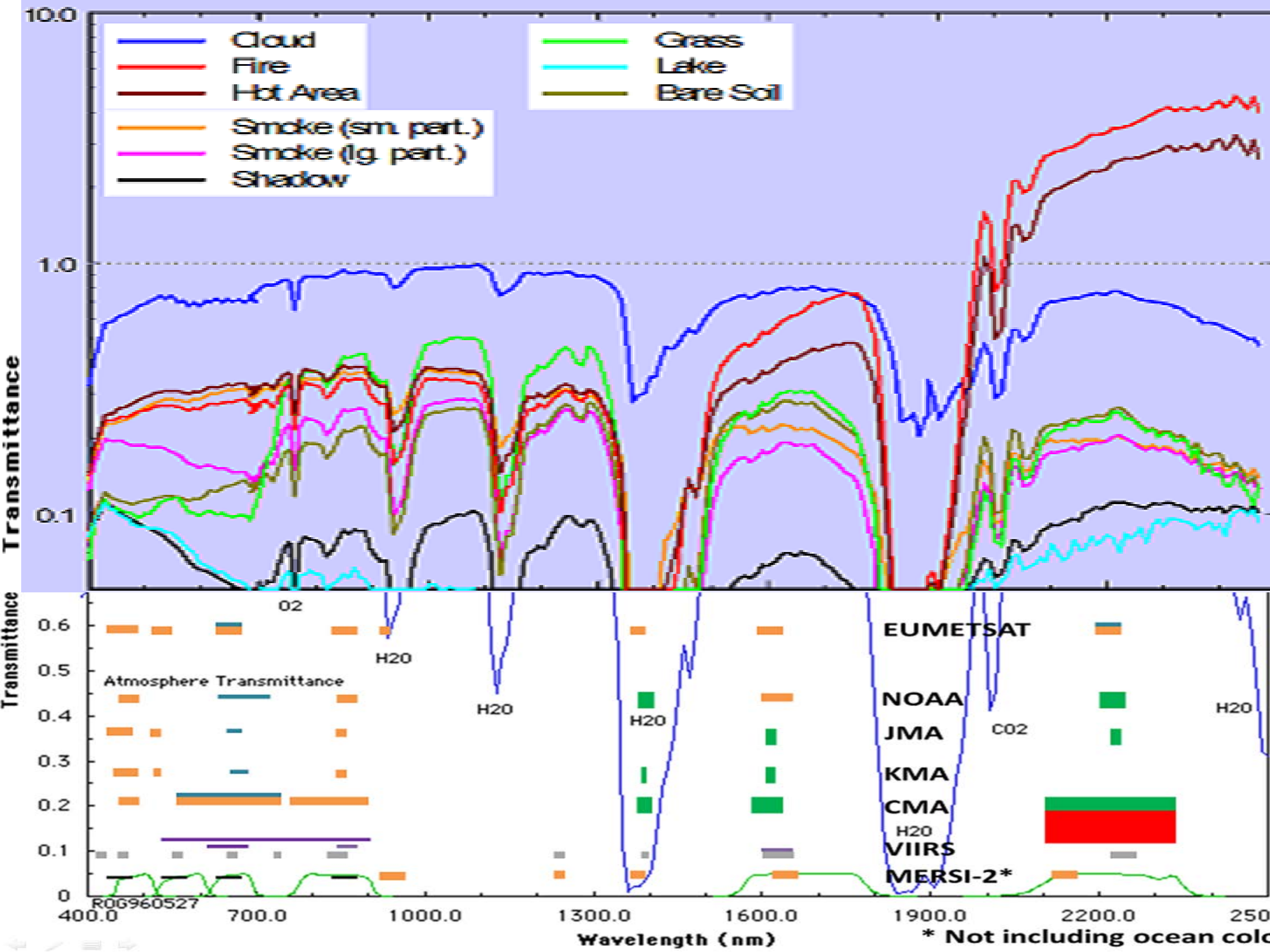


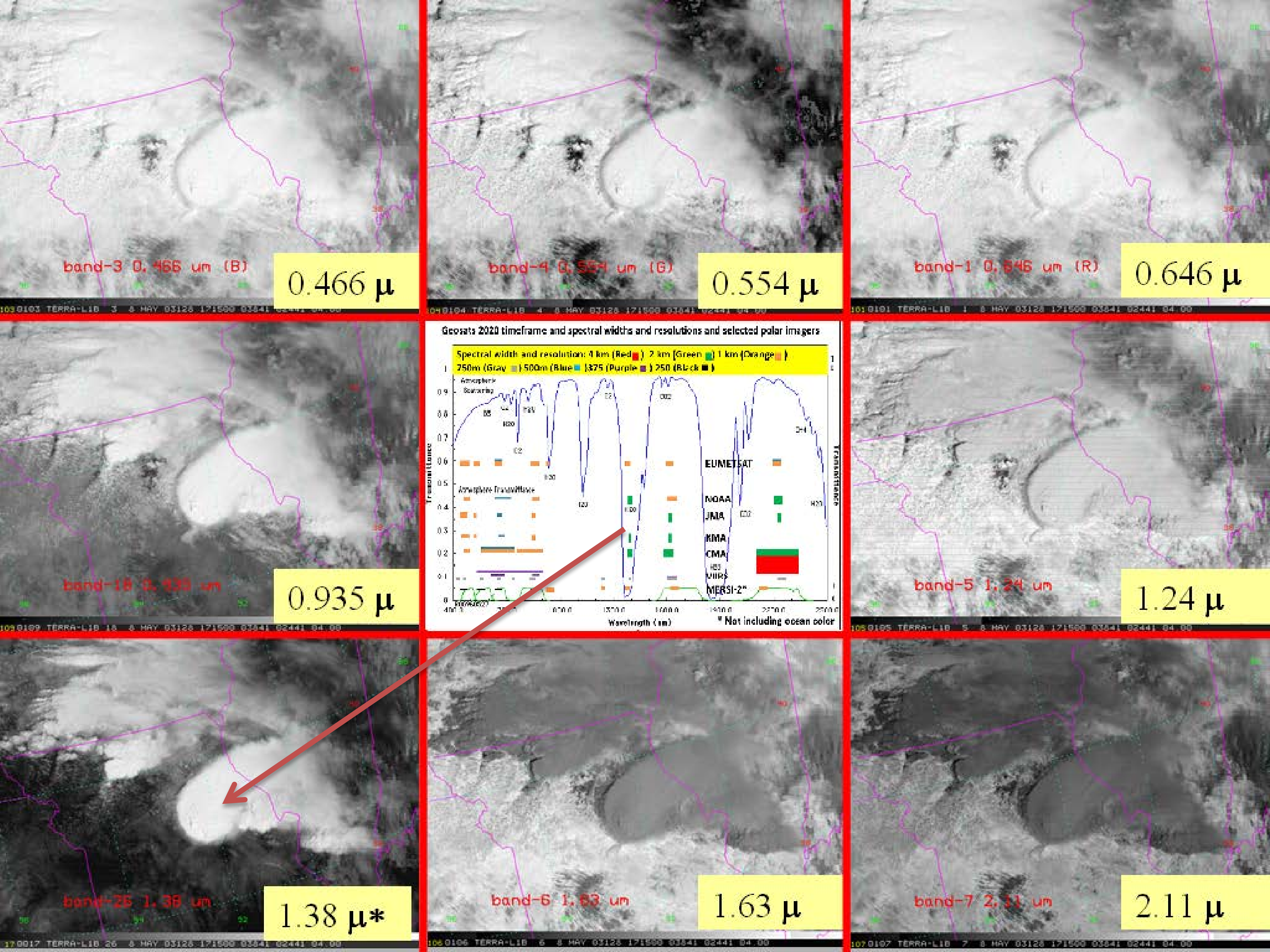
$$B_\lambda(T) = \frac{2hc^2}{\lambda^5}\frac{1}{e^{\frac{hc}{\lambda k_B T}} - 1}$$

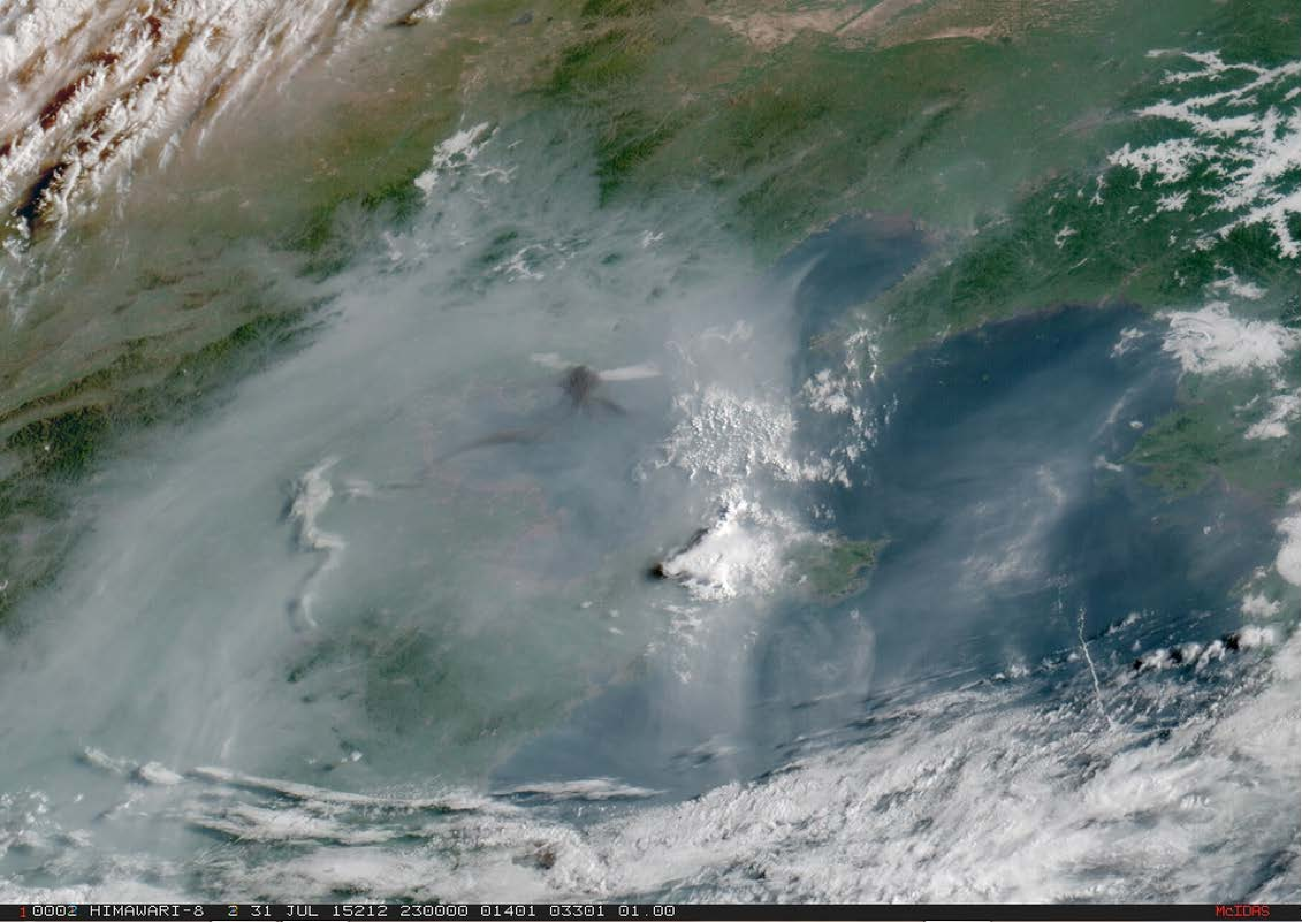
Animation of the spectrum from 0.4 µm to 2.5 µm. Notice how as we move to longer wavelengths the cloud becomes more distinct, the fire becomes apparent and the haze and smoke go away. Also note H**2**0's absorption effect.



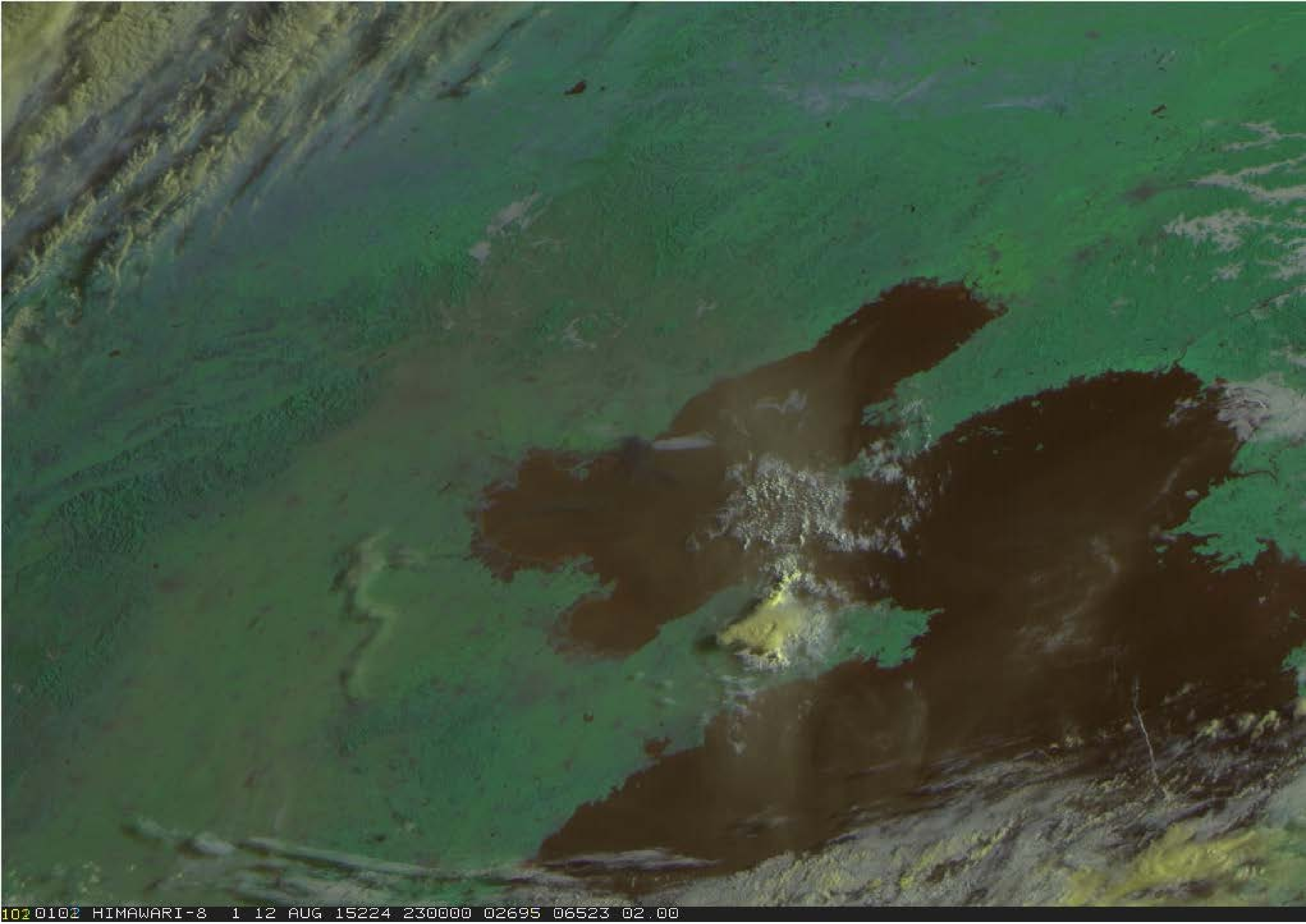


Cloud
Fire
Hot Area
Smoke (sm. part.)
Smoke (lg. part.)
Shadow
Grass
Lake
Bare Soil
Transmittance
10.0
1.0
0.1
O2
H2O
H2O
H2O
H2O
CO2
H2O
H2O
Atmosphere Transmittance
EUMETSAT
NOAA
JMA
KMA
CMA
VIIRS
MERSI-2*
0.6
0.5
0.4
0.3
0.2
0.1
0
R0G960527
400.0
700.0
1000.0
1300.0
1600.0
1900.0
2200.0
Wavelength (nm)
* Not including ocean colo


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
Geosats 2020 timeframe and spectral widths and resolutions and selected polar imagers
Spectral width and resolution: 4 km (Red) 2 km (Green) 1 km (Orange)
250m (Gray) 500m (Blue) 375 (Purple) 250 (Black)
Atmospheric Scattering
Atmosphere Transmittance
EUMETSAT
NOAA
JMA
KMA
CMA
VIIRS
MERSI-2*
Wavelength (nm)
* Not including ocean color
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

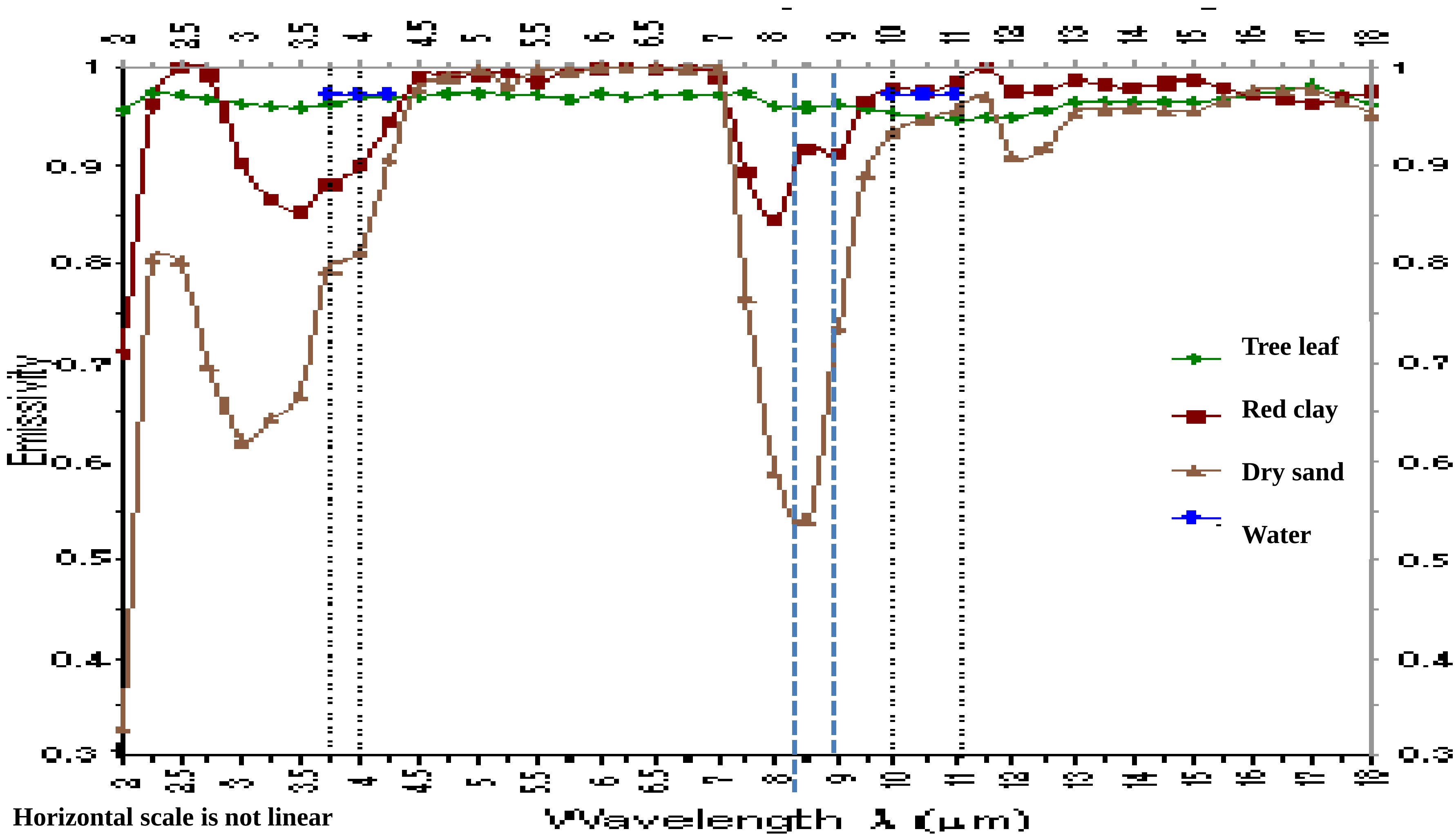


True color image over Bohai Bay, Tianjin, Beijing and North East China – note smog obscuring land

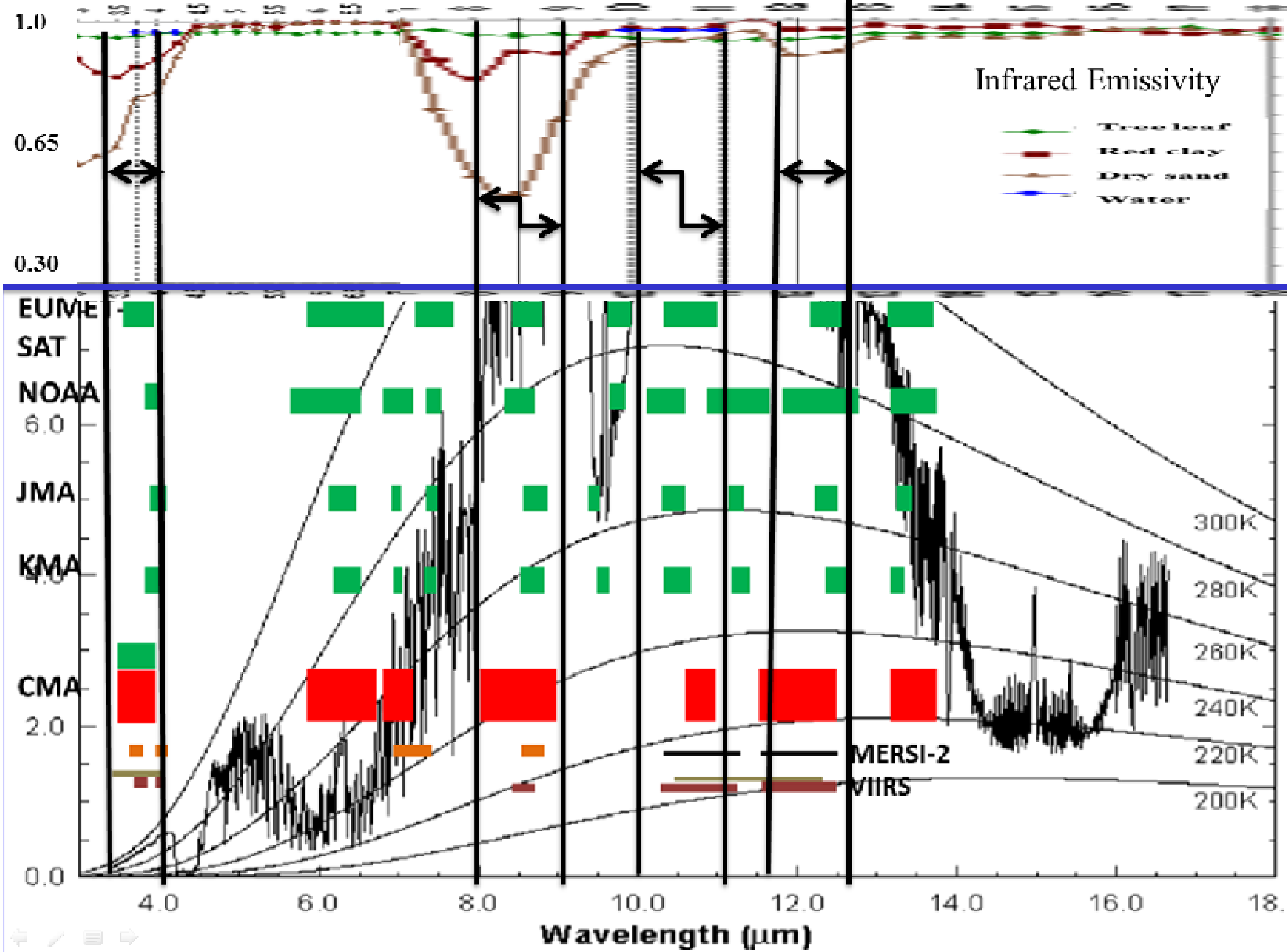


Three channel composite (.74, .86, 1.2) image over Bohai Bay, etc. made to show water/no smog

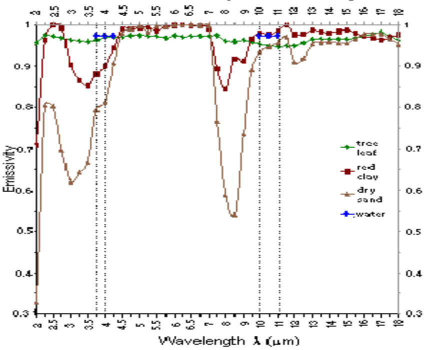
Infrared emissivity versus wavelength for different surfaces



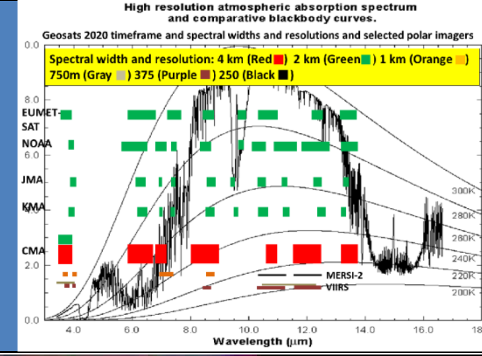
Horizontal scale is not linear

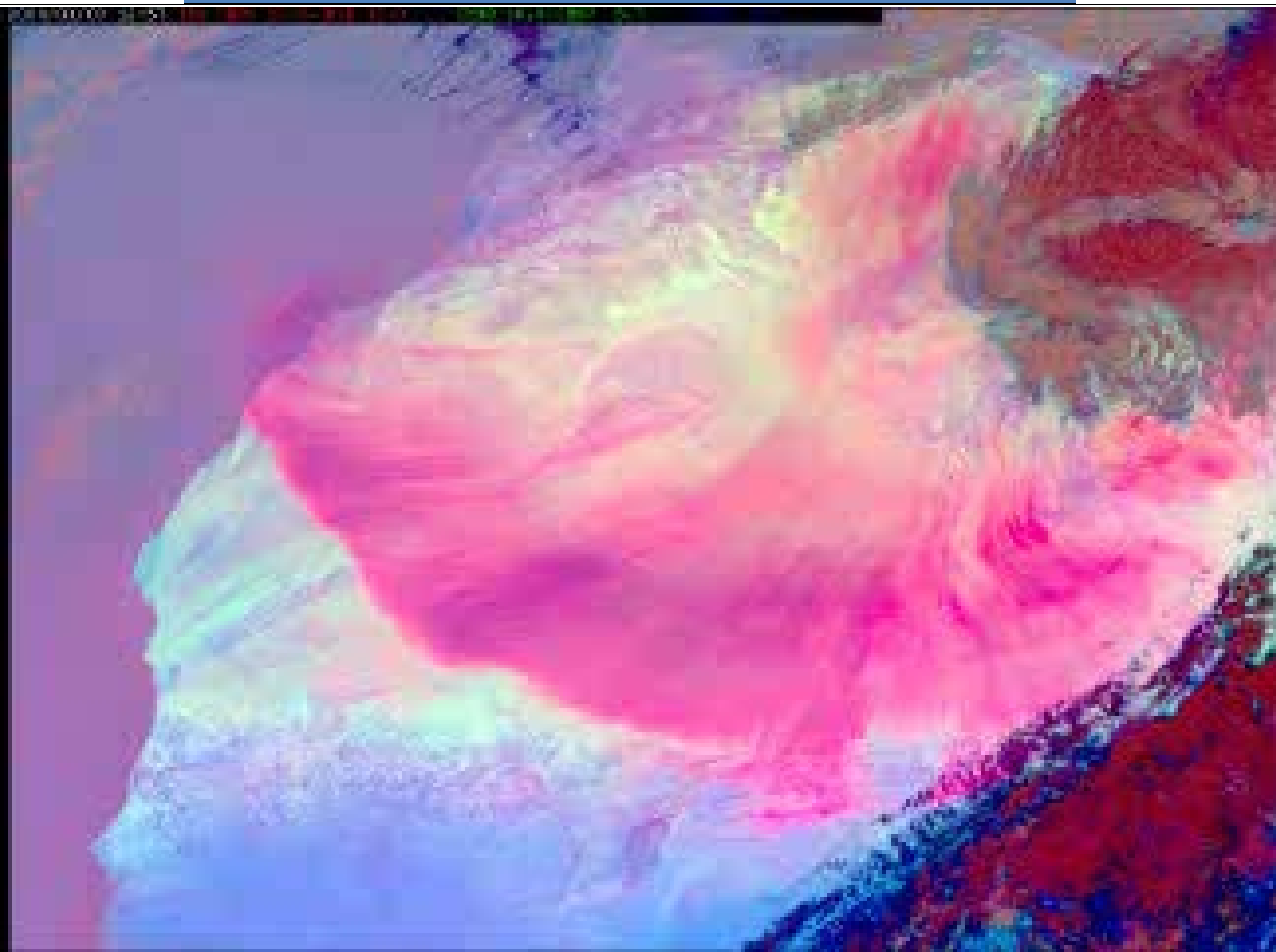


Infrared Emissivity
Tree leaf
Red clay
Dry sand
Water
1.0
0.65
0.30
EUMET-SAT
NOAA
JMA
KMA
CMA
MERSI-2
VIIRS
300K
280K
260K
240K
220K
200K
6.0
2.0
0.0
4.0
8.0
10.0
12.0
14.0
16.0
Wavelength (μm)



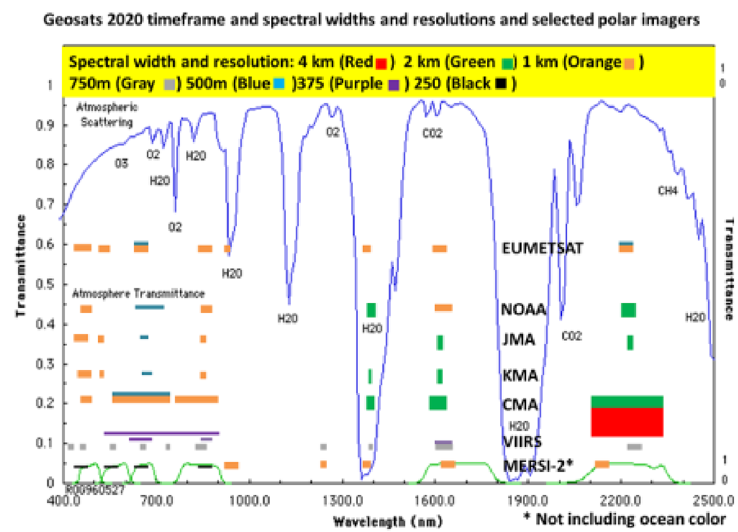
Dust storm night
Filling the gaps between
4 hourly polar
(10.8, 10.8 - 8.6, 10.8 - 12)

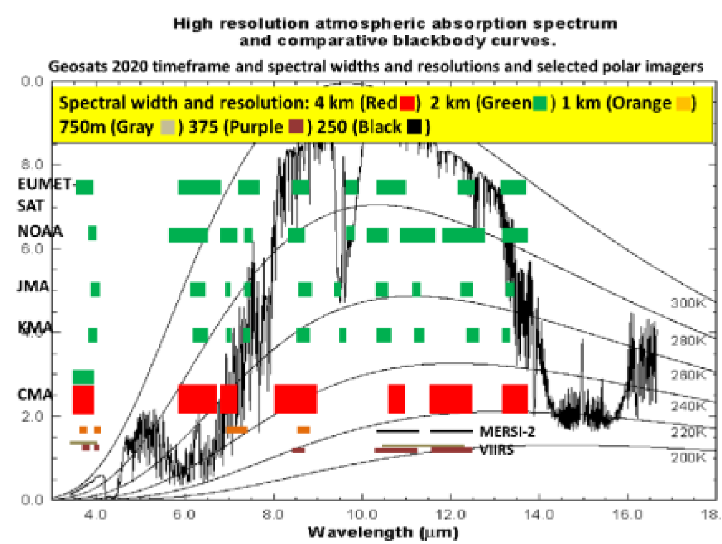




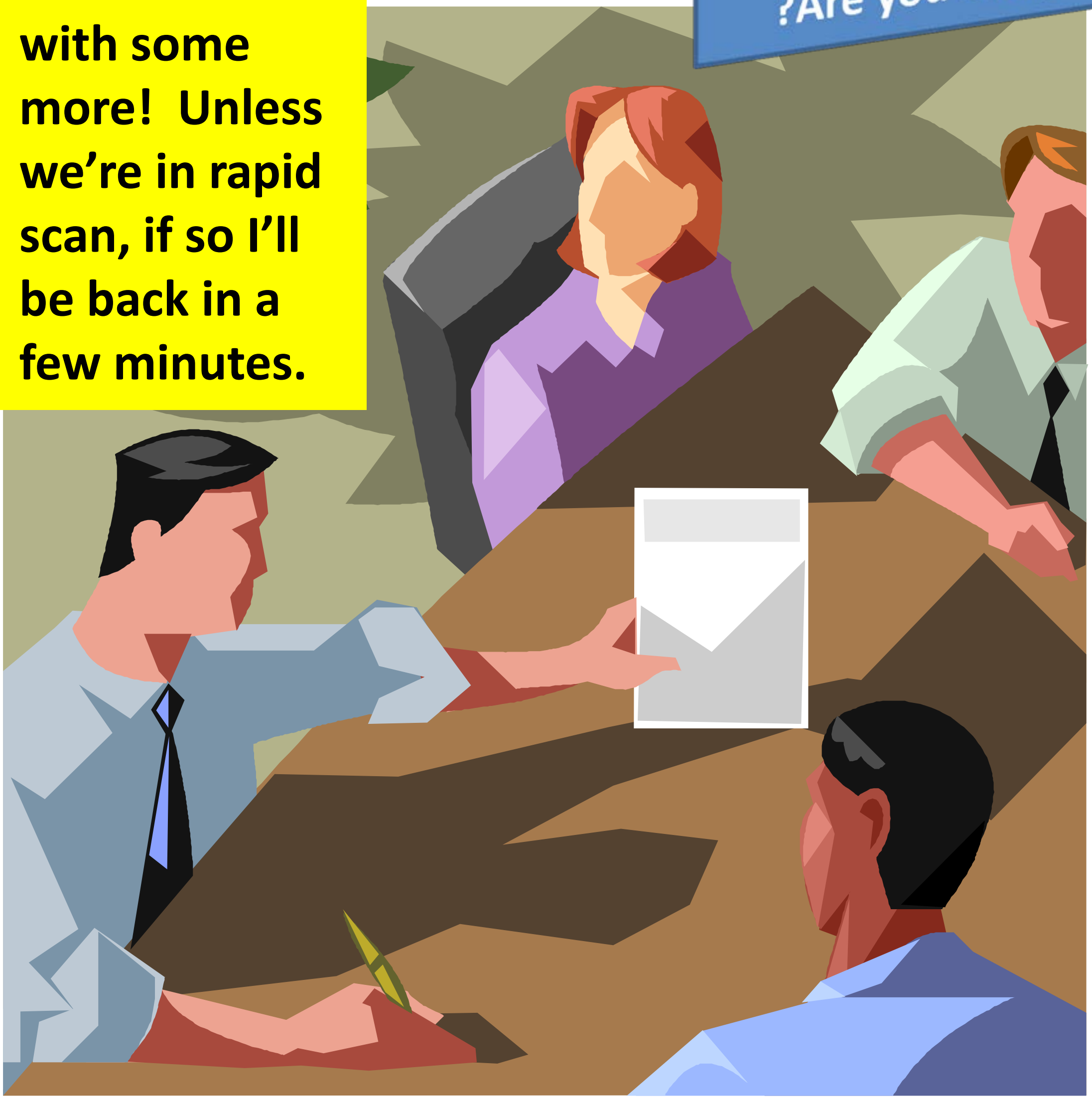
65,535 ways to “combine” 16 channels

- Single channel 16
- 2 channels per image 120
- 3 channels per image 560
- 4 channels per image 1820
- 5 channels per image 4368
- 6 channels per image 8008
- 7 channels per image 11440
- 8 channels per image 12870
- 9 channels per image 11440
- **********
- 15 channels per image 16
- 16 channels 1





Great News!! I’ve got 65,535 down to 560 – I’ll be back in 10 minutes with some more! Unless we’re in rapid scan, if so I’ll be back in a few minutes.



?Are you crazy?

I’ve got an idea!!! Let’s do something to simplify things.

The Problem and a Solution

- **Multi-spectral (satellite) imagery has spectral bands that contain more redundant information, than difference information, about the scene being viewed**.
- It would be nice if each spectral band/image contained information separate from the other spectral bands/images. But this is not the case in the real world.
- There is a transformation technique for multi-spectral imagery that can separate the variables and interpret the imagery.

Why transform imagery?

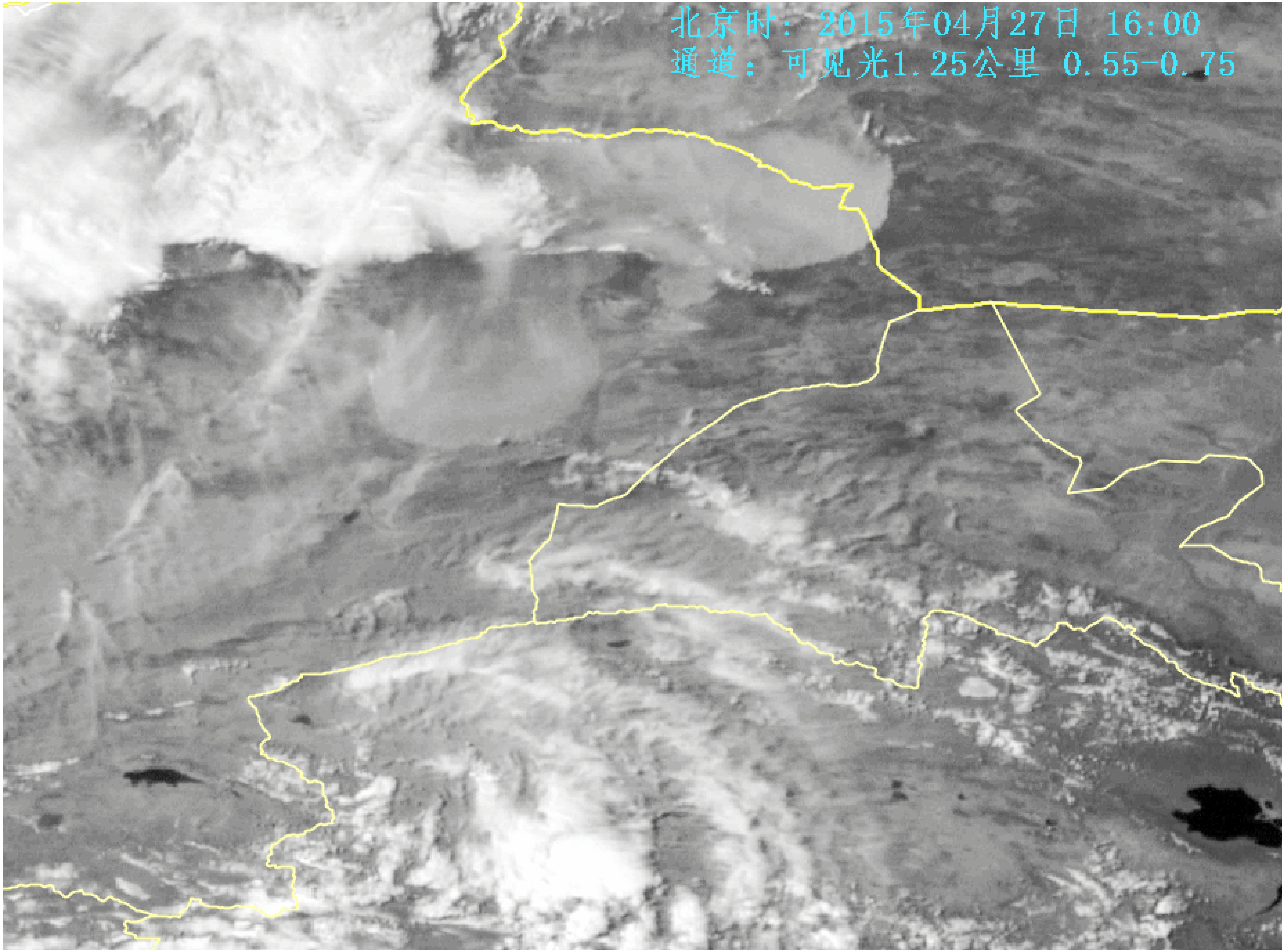
- To <u>**simplify**</u> **multi-spectral imagery** by reducing redundancy to obtain the independent information.
- A new set of images that are <u>**optimal combinations**</u> **of the original spectral-band images** for extracting the <u>variance</u> in the available imagery.
- **Uncover important** <u>**image combinations**</u> for detection of <u>**atmospheric and surface features**</u> in multi-spectral imagery.

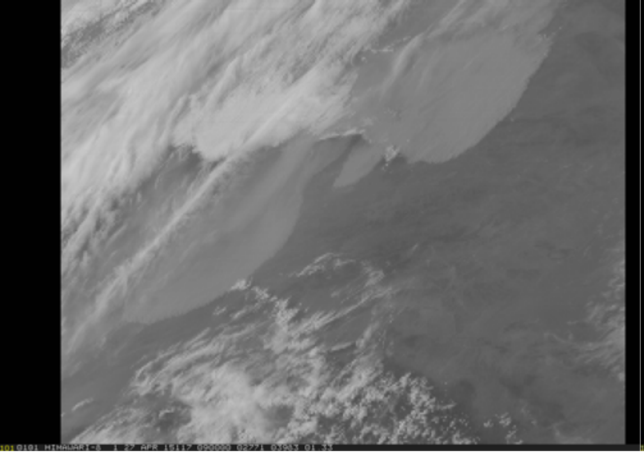
Features of Principal Component Imagery (PCI)

- Puts common/redundant information into first PCIs
- Puts difference information into higher-ordered PCIs.
- Reduces the number of independent variables to a minimum.
- Can reduce noise by relegating noise to highest-order PCIs.

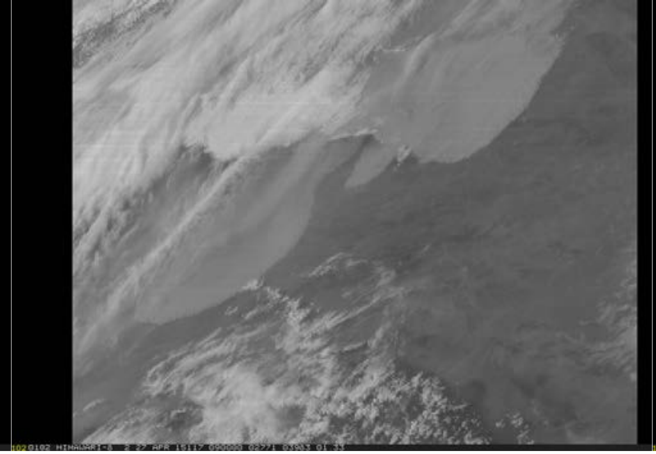

I guess we don't need everything then. Let's let the meteoro-logical event help narrow the imagery and products we use.
There's hope out there somewhere!
I've got an idea!!! We already have some pretty nice imagery combinations – let's look into this Principal Component thing and sharpen them up plus create some new and useful products!

http://rammb.cira.colostate.edu/templates/loop_directory.asp?data_folder=dev/lindsey/loops/27apr15_abi_truecolor2&image_width=1020&i

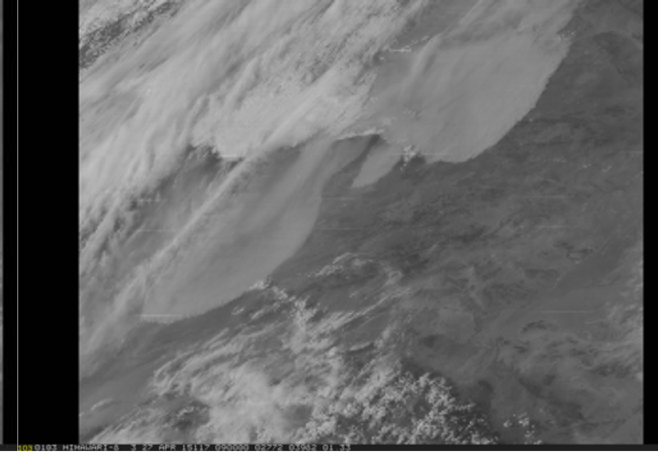

北京时: 2015年04月27日 16:00
通道: 可见光1.25公里 0.55-0.75



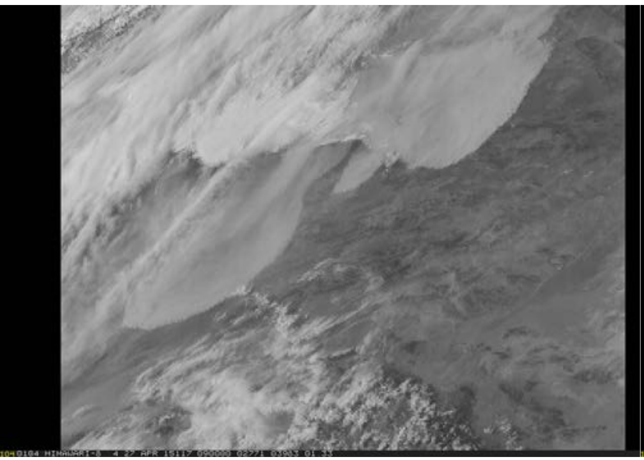
0.455



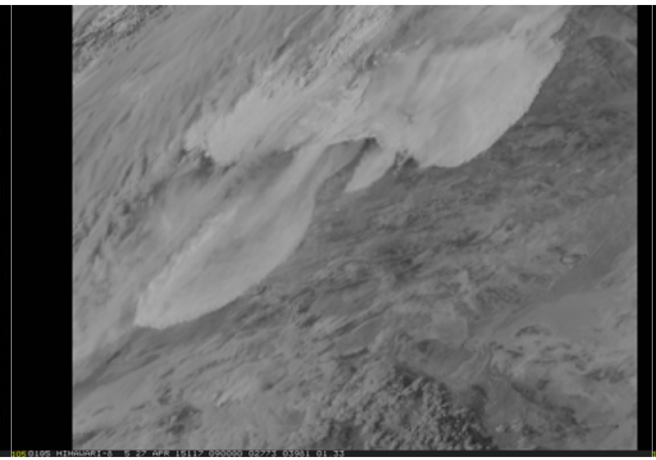
0.510



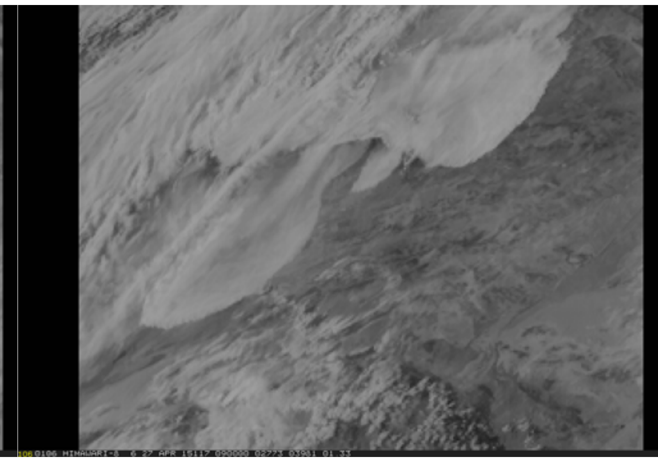
0.645



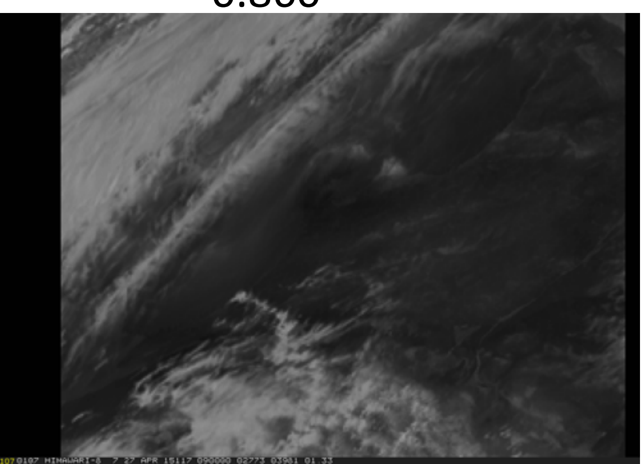
0.860



1.61

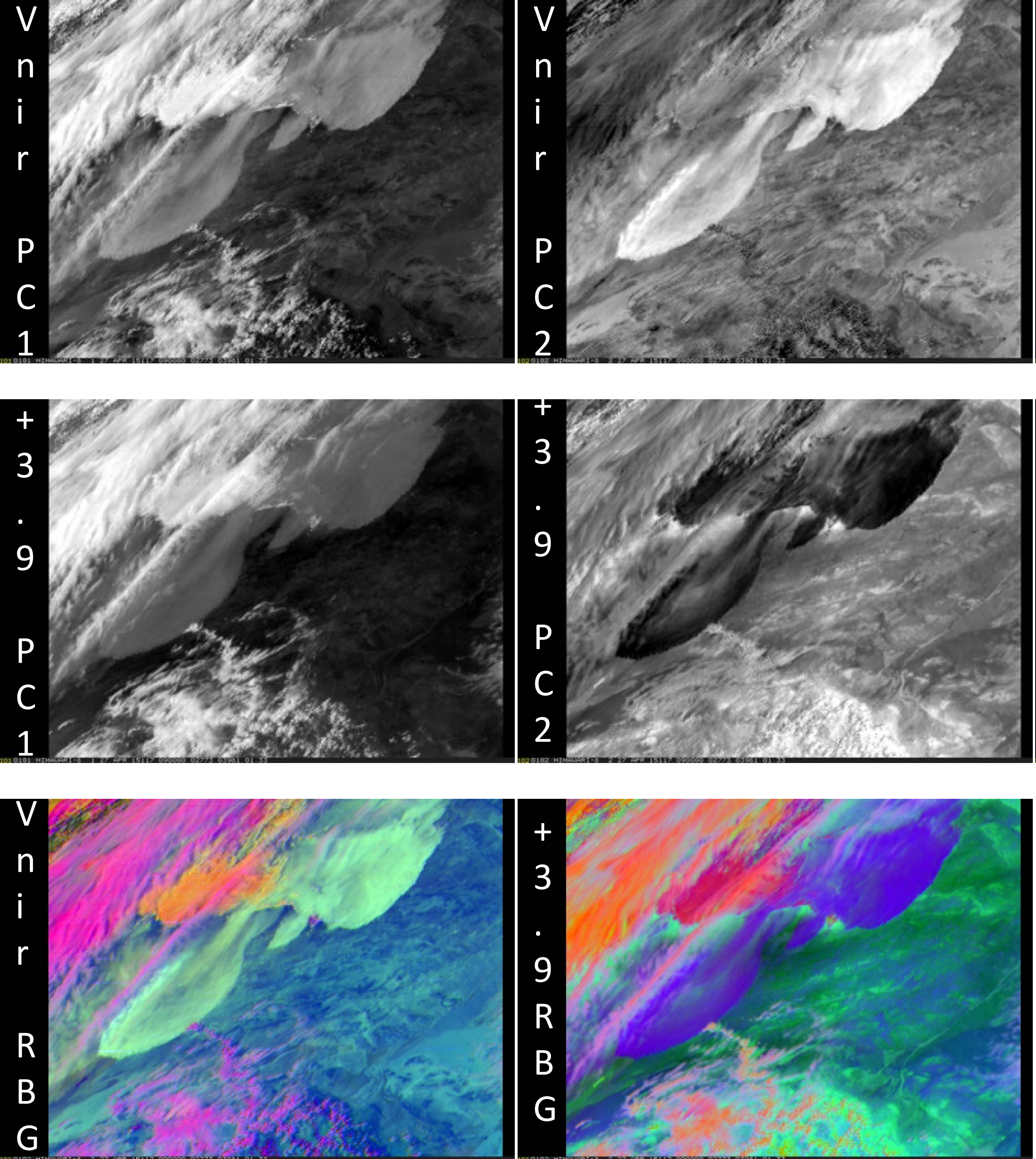


2.26



3.85

From 27 April 2015. Going from left to right, top to bottom. Himawari visible and near IR channels plus the 3.85 micron channel on the bottom left. Channel wavelength in microns.



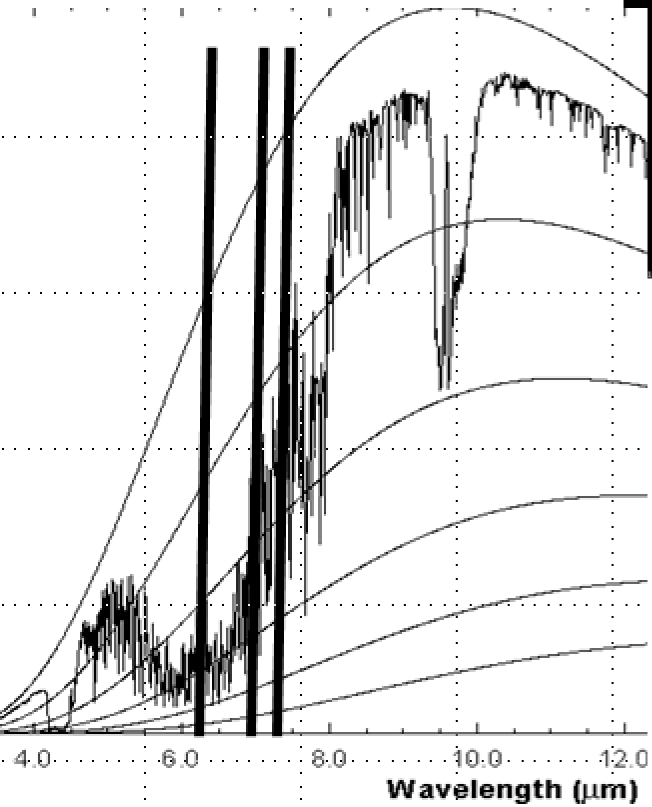
Top: PC's 1,2,3 of Visible and Near IR
Middle: PC's 1,2,3 of Visible, near IR and 3.9 microns
Bottom left RBG from PC's 1,2,3 of Vnir; Middle RBG of PC's 1,2,3 of Vnir and 3.9

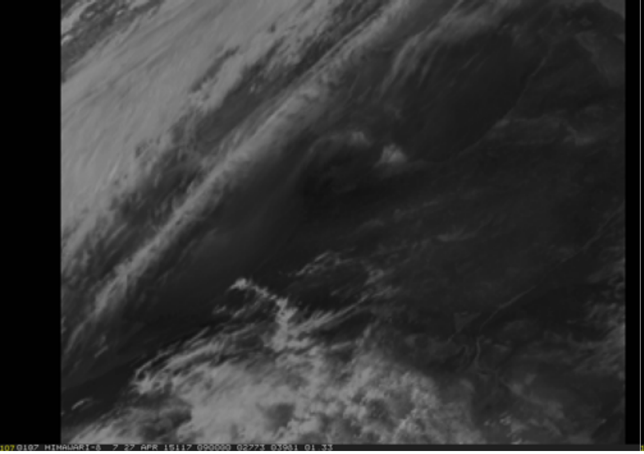
Himawari Water infrared water vapor sensitive channels from 27 April 2015. Wavelength in microns. These are not used in the development of the Principal Components for this case.

6.25

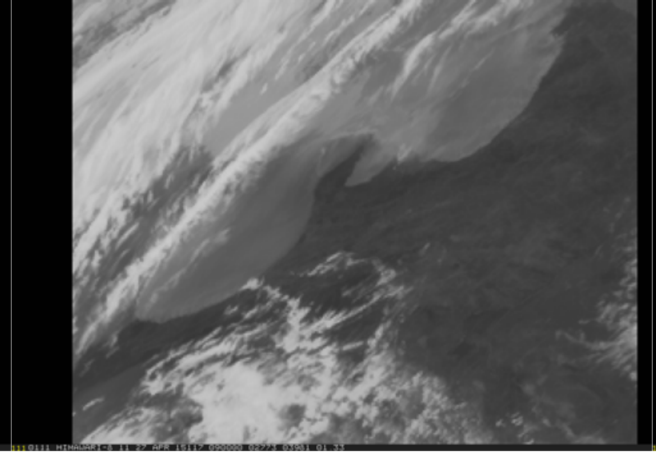
6.95

7.35

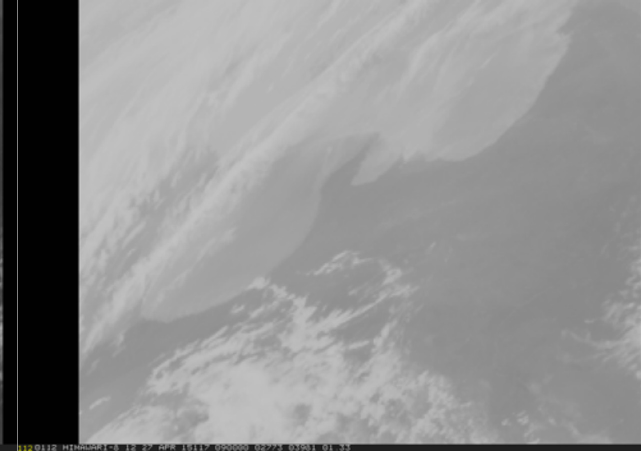




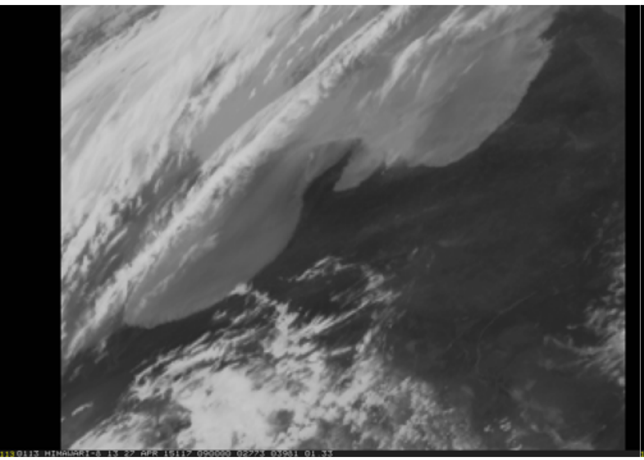
3.85



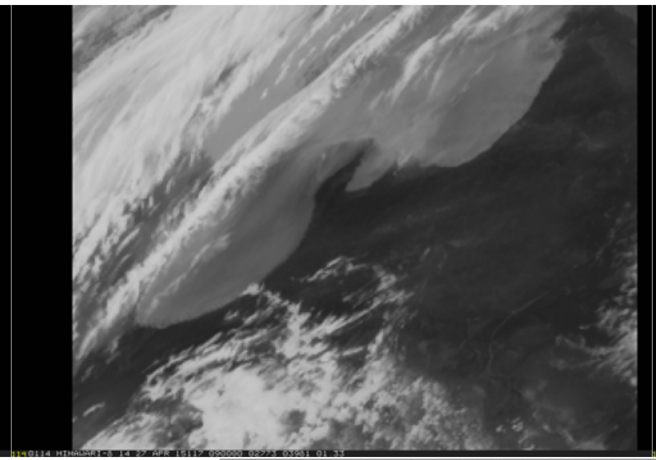
8.60



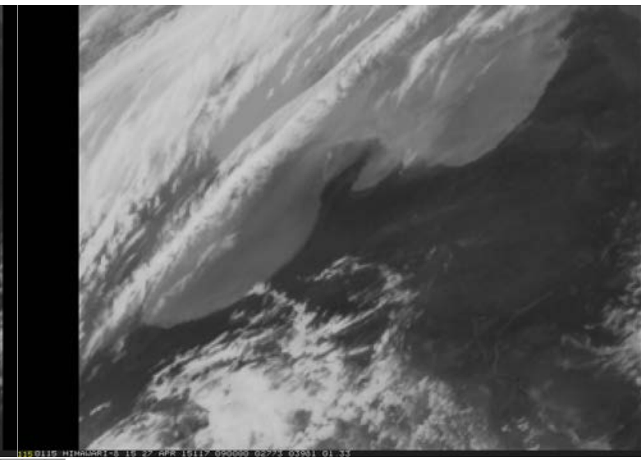
9.63



10.45

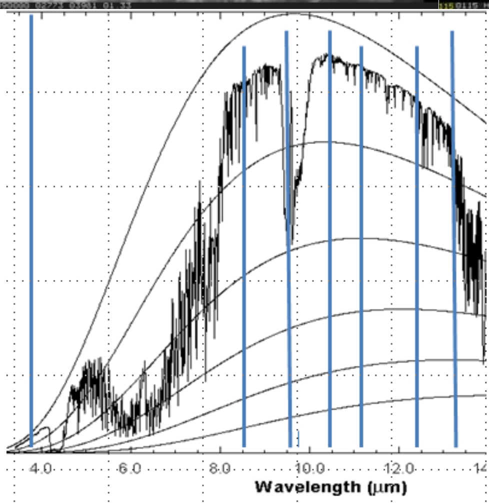


11.20

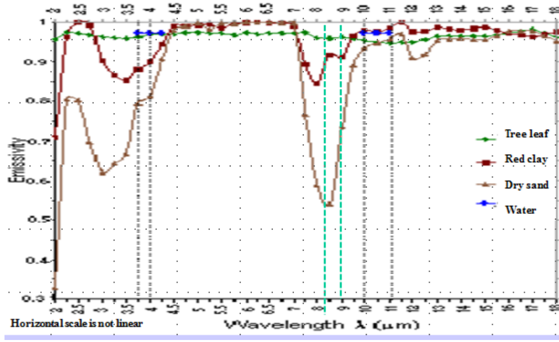


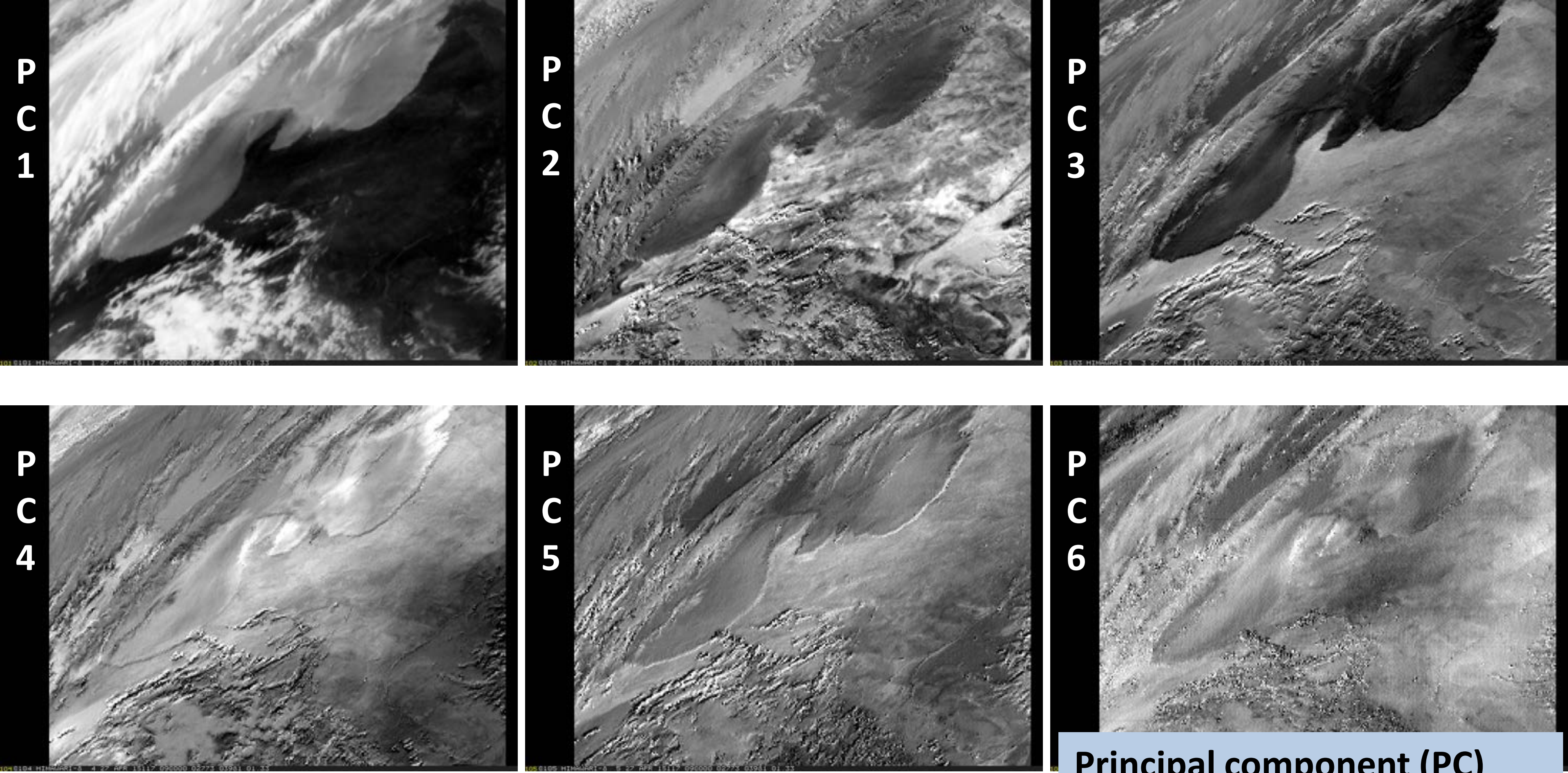
12.35

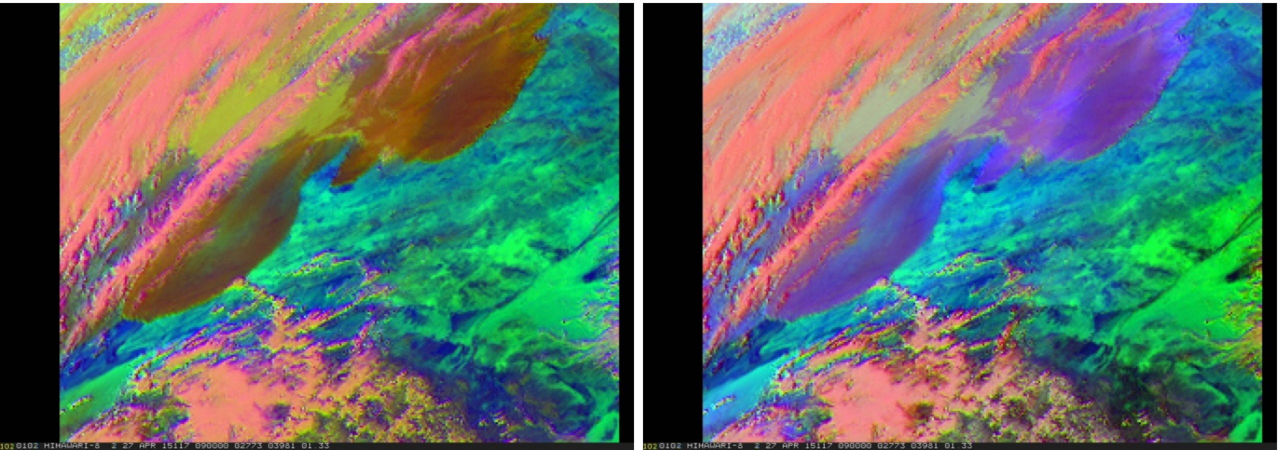
13.30



Himawari IR channels for 27 April 2015 case.

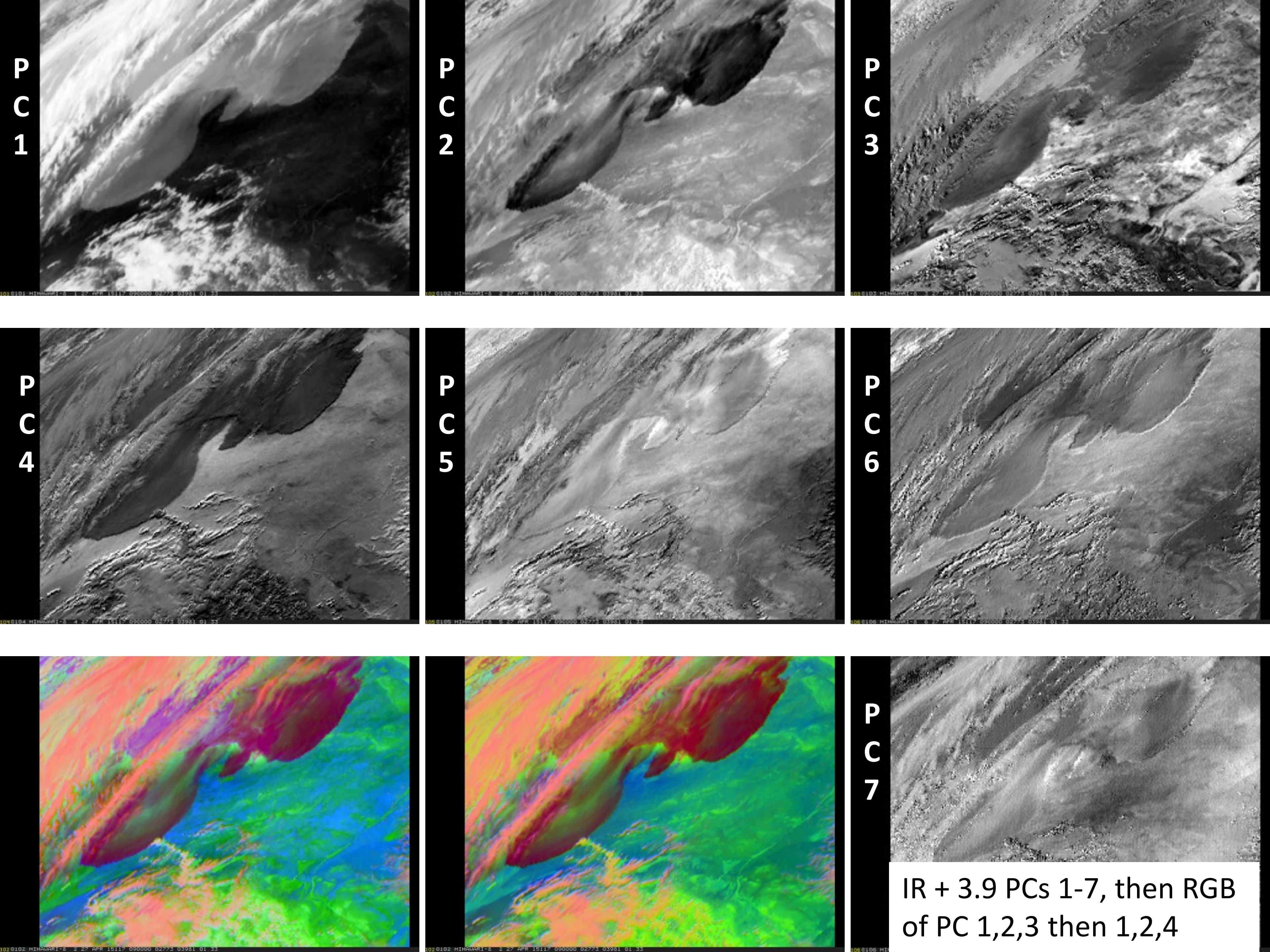






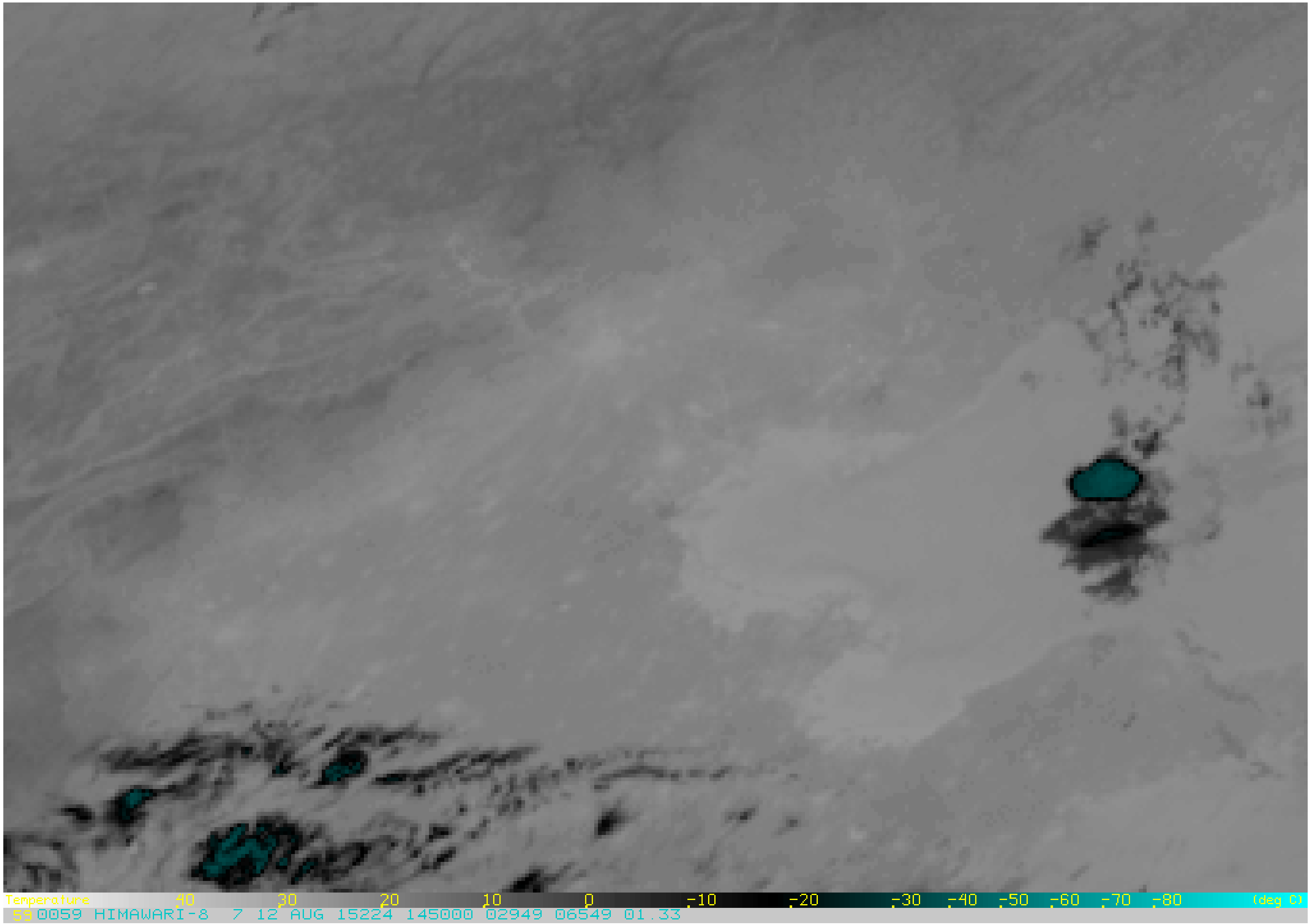
Principal component (PC) images from pure IR channels only (i.e. 3.9 microns not used and no water vapor channels).

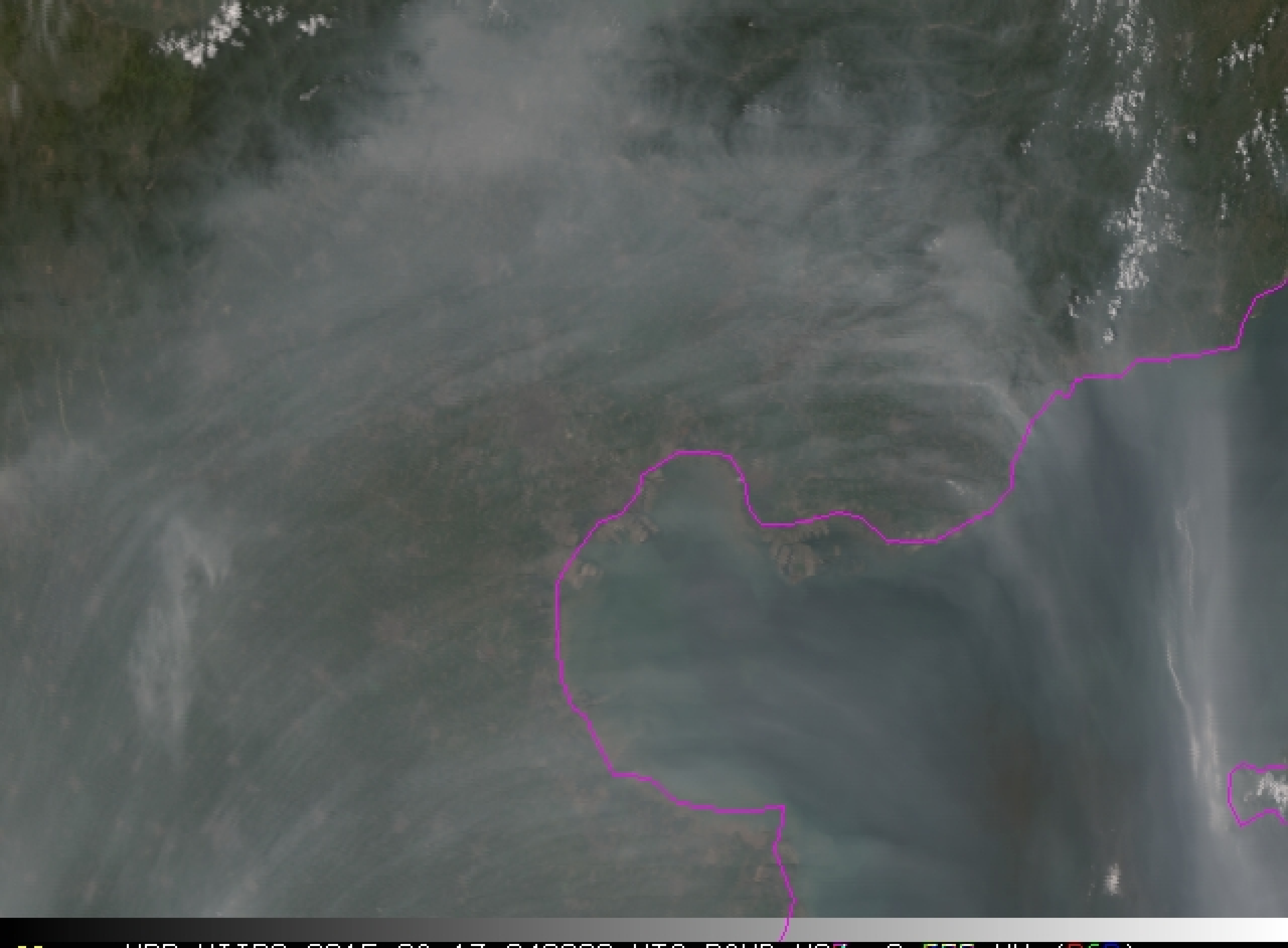
Upper left to lower right: PC images 1-6 and RGB of PC 1,2,3 then PC 1,2,4



IR + 3.9 PCs 1-7, then RGB of PC 1,2,3 then 1,2,4


INNER MONGOLIA
JILIN
LIAONING
Beijing
北京
North Korea
Sea of Jap
HEBEI
Tianjin
天津
Seoul
서울
SHANXI
SHAANXI
SHANDONG
South Korea
Xi'an
西安
Hiroshima
広島
Busan
부산
HENAN
Fukuoka
福岡
JIANGSU
Nanyang
南阳
Shanghai
上海
Wuhan
武汉
HUBEI
ANHUI
Hangzhou
杭州
East China Sea

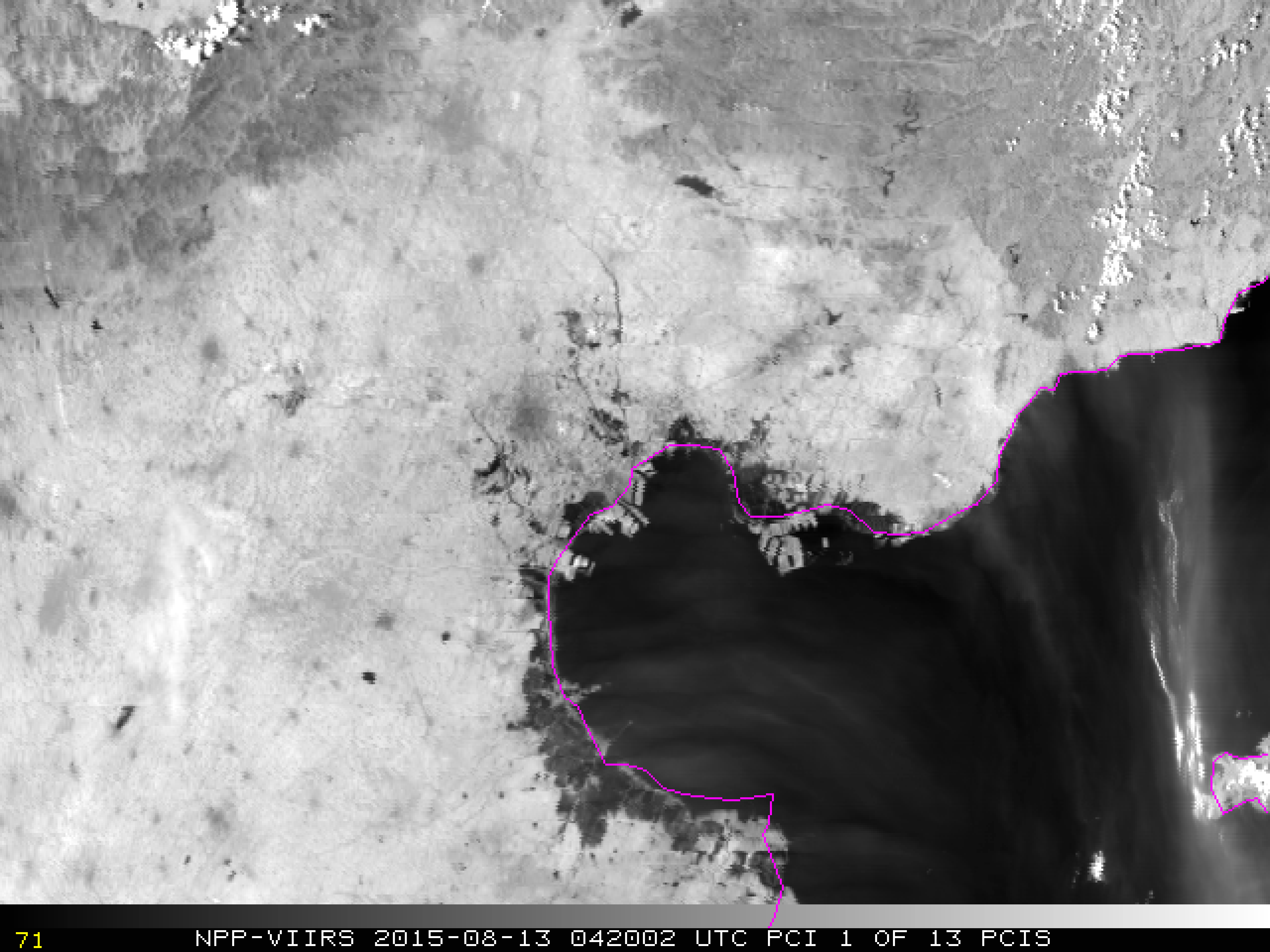

Temperature
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
(deg C)
59 0059 HIMAWARI-8 7 12 AUG 15224 145000 02949 06549 01.33

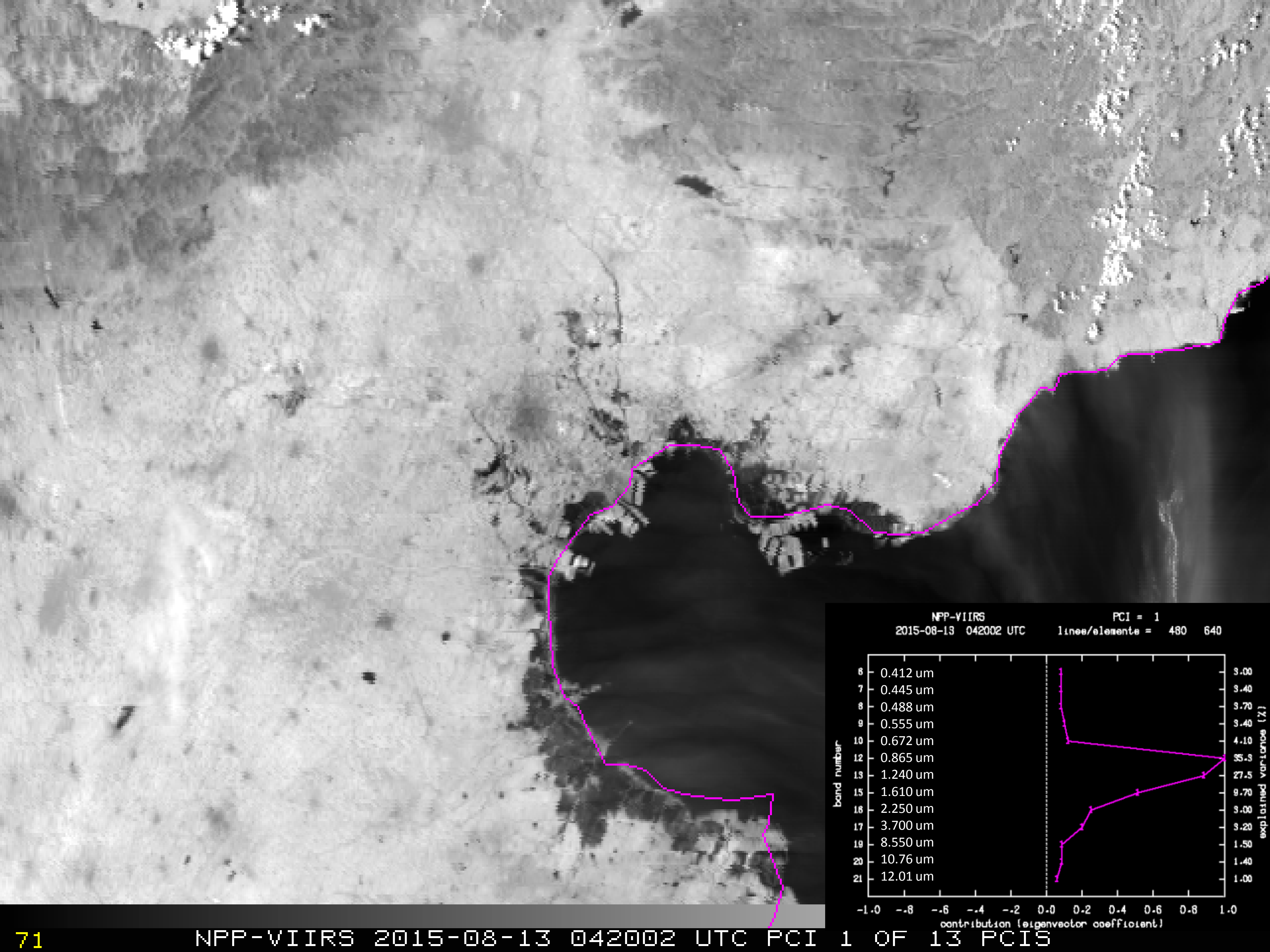


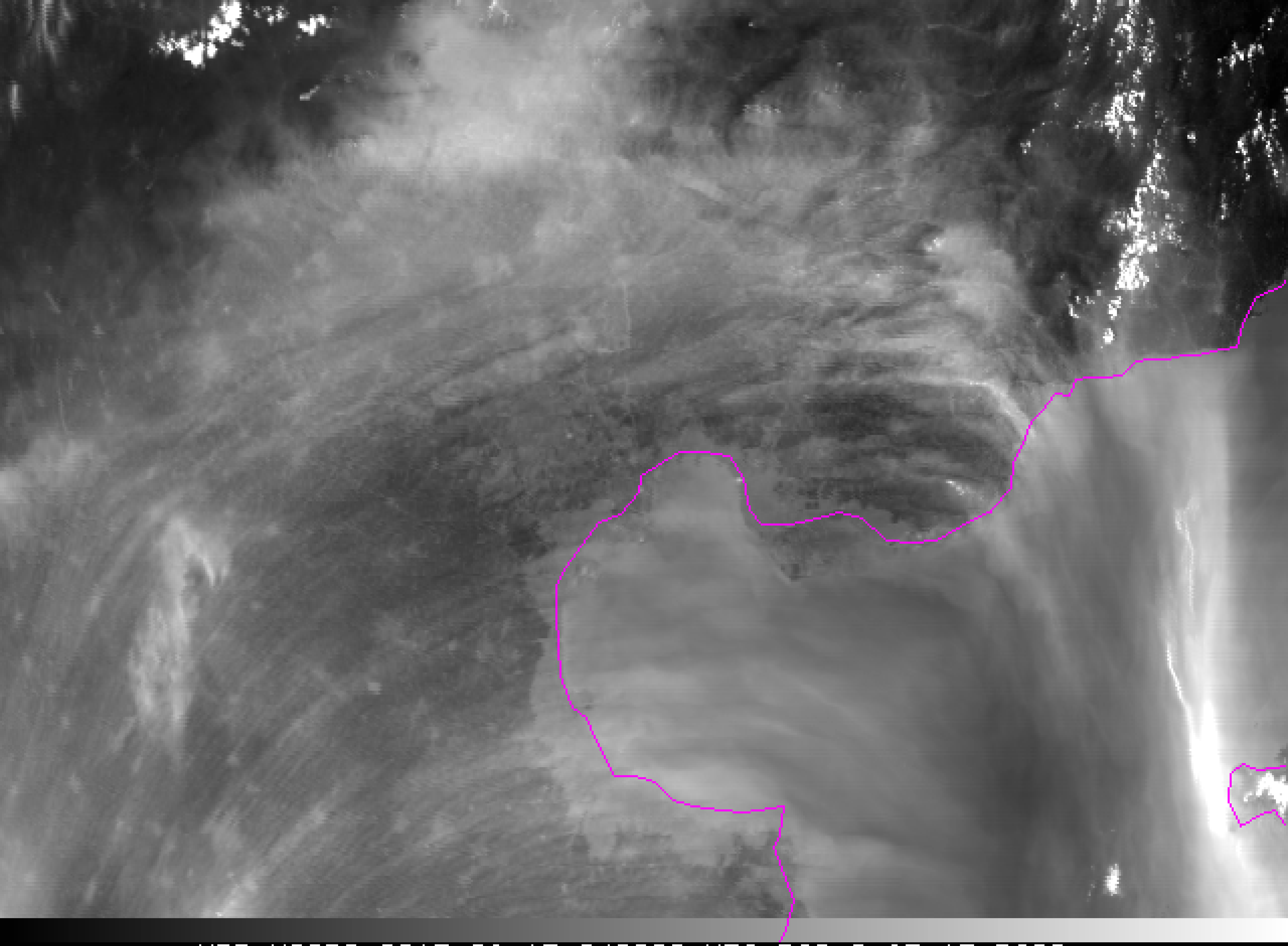
68 NPP-VIIRS 2015-08-13 042002 UTC BAND M04 0.555 UM (RGB)

VIIRS Channels Used in 12 August 2015 Tianjin Analysis

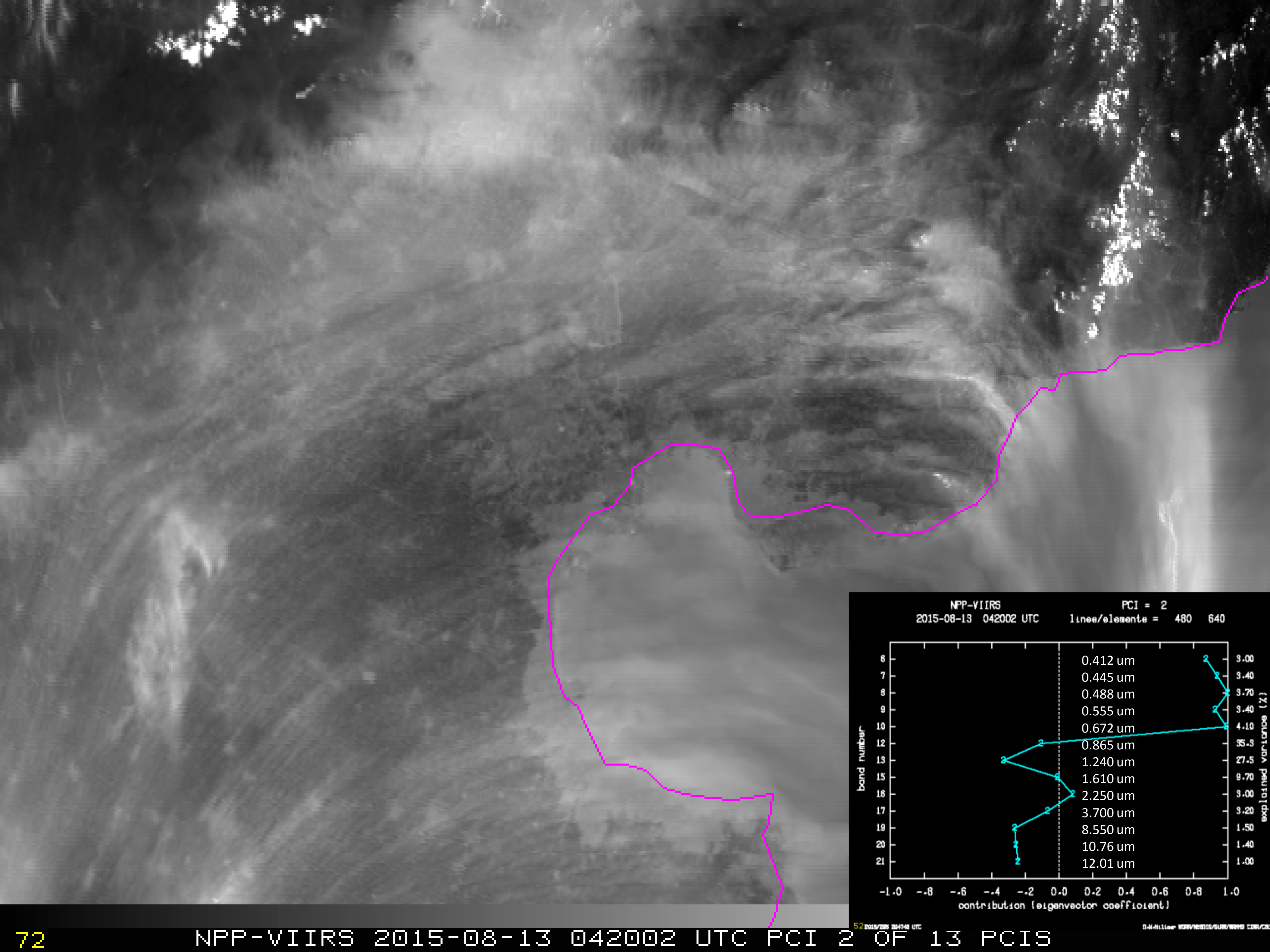
VIIRS Band	McIDAS Band	Central Wavelength	
6	M01	0.412 um	
7	M02	0.445 um	
8	M03	0.488 um	
9	M04	0.555 um	
10	M05	0.672 um	
~~11~~	~~M06~~	~~0.746 um~~	not used bad striping
12	M07	0.865 um	
13	M08	1.240 um	
~~14~~	~~M09~~	~~1.378 um~~	not used very noisy
15	M10	1.610 um	
16	M11	2.250 um	
17	M12	3.700 um	
~~18~~	~~M13~~	~~4.050 um~~	not used no data
19	M14	8.550 um	
20	M15	10.763 um	
21	M16	12.013 um	

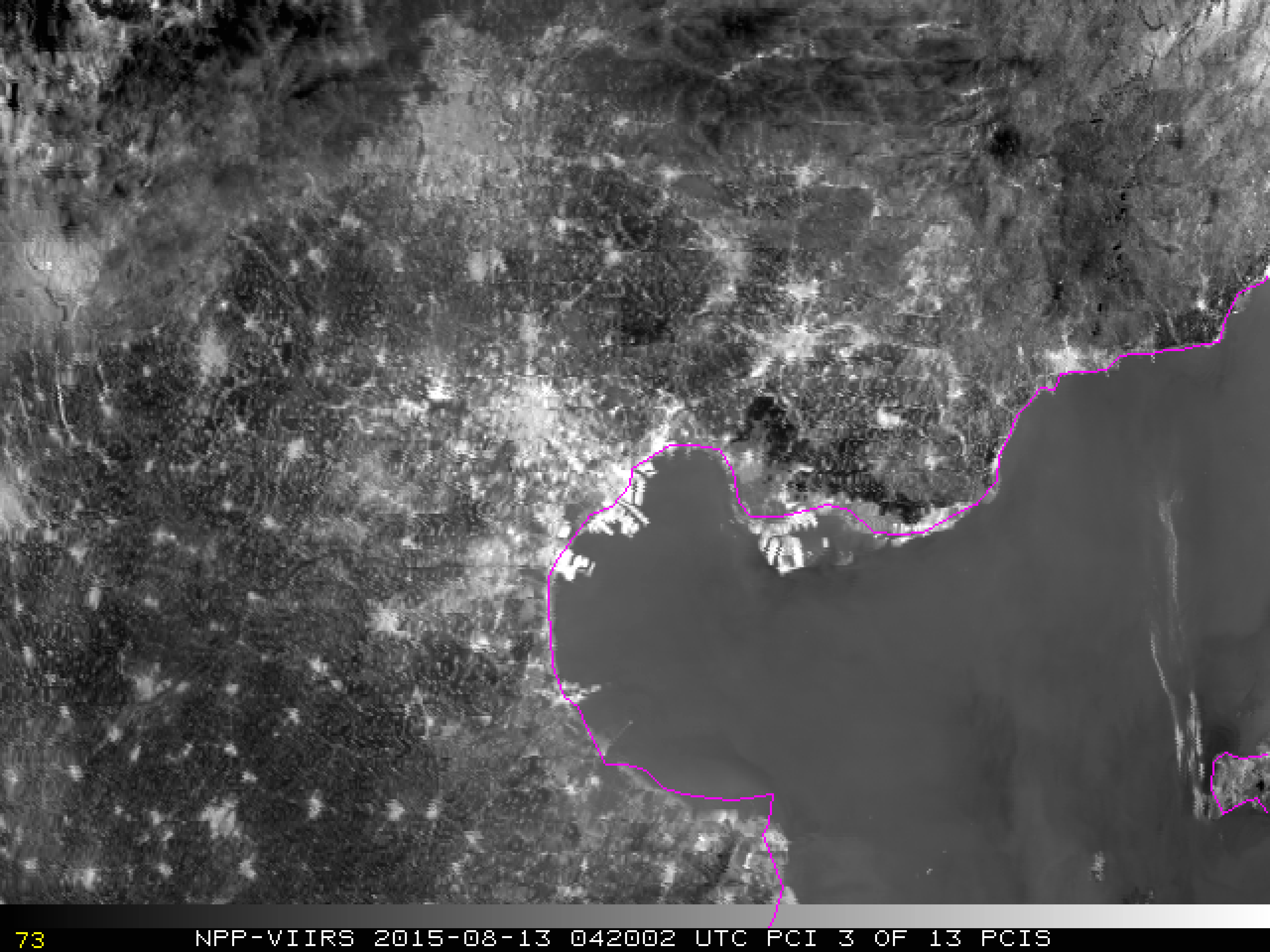

71
NPP-VIIRS 2015-08-13 042002 UTC PCI 1 OF 13 PCIS

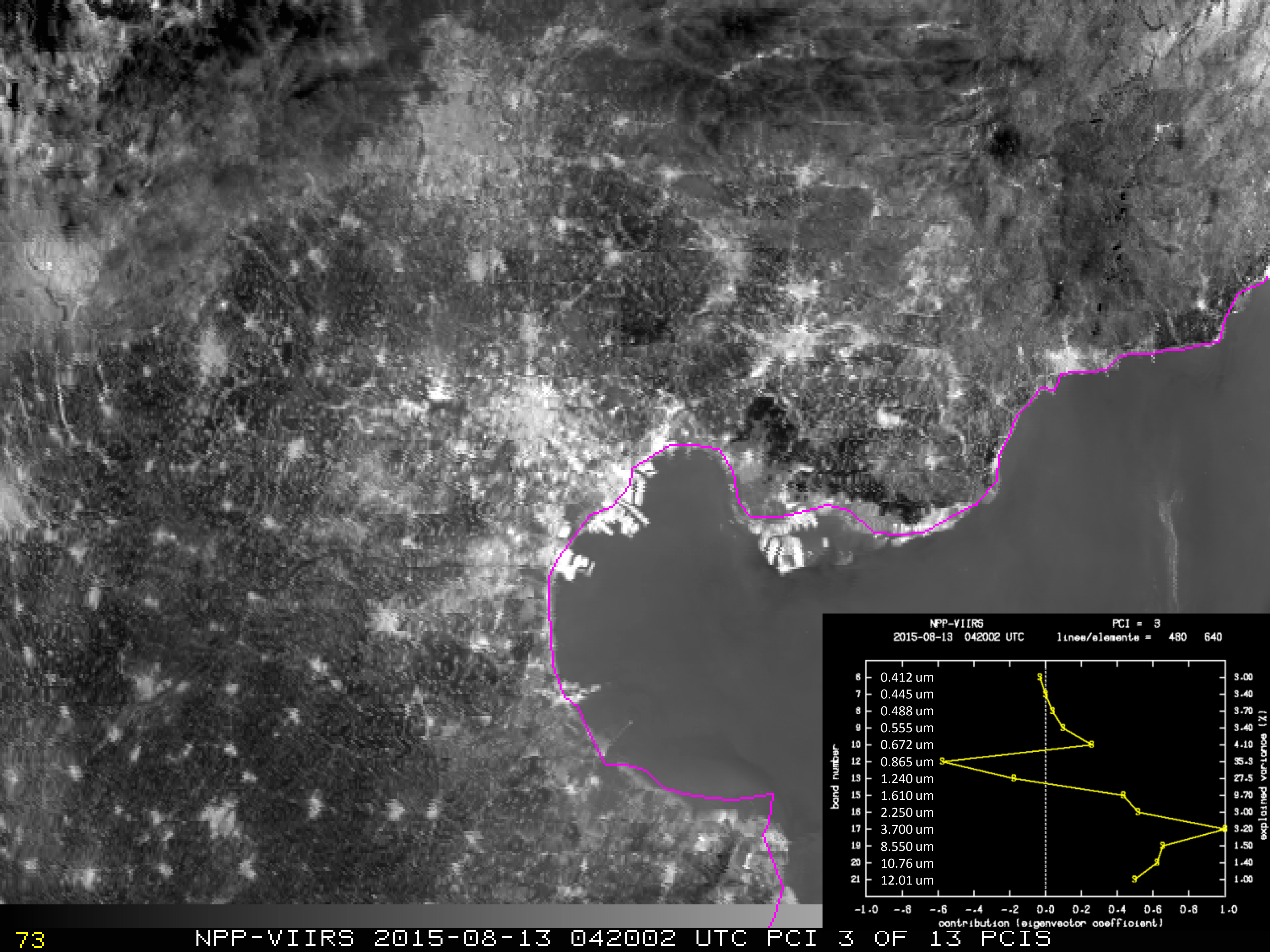

NPP-VIIRS
2015-08-13 042002 UTC
PCI = 1
lines/elements = 480 640
band number
6 0.412 um
7 0.445 um
8 0.488 um
9 0.555 um
10 0.672 um
12 0.865 um
13 1.240 um
15 1.610 um
16 2.250 um
17 3.700 um
19 8.550 um
20 10.76 um
21 12.01 um
3.00
3.40
3.70
3.40
4.10
35.3
27.5
9.70
3.00
3.20
1.50
1.40
1.00
explained variance (%)
-1.0 -.8 -.6 -.4 -.2 0.0 0.2 0.4 0.6 0.8 1.0
contribution (eigenvector coefficient)
71
NPP-VIIRS 2015-08-13 042002 UTC PCI 1 OF 13 PCIS

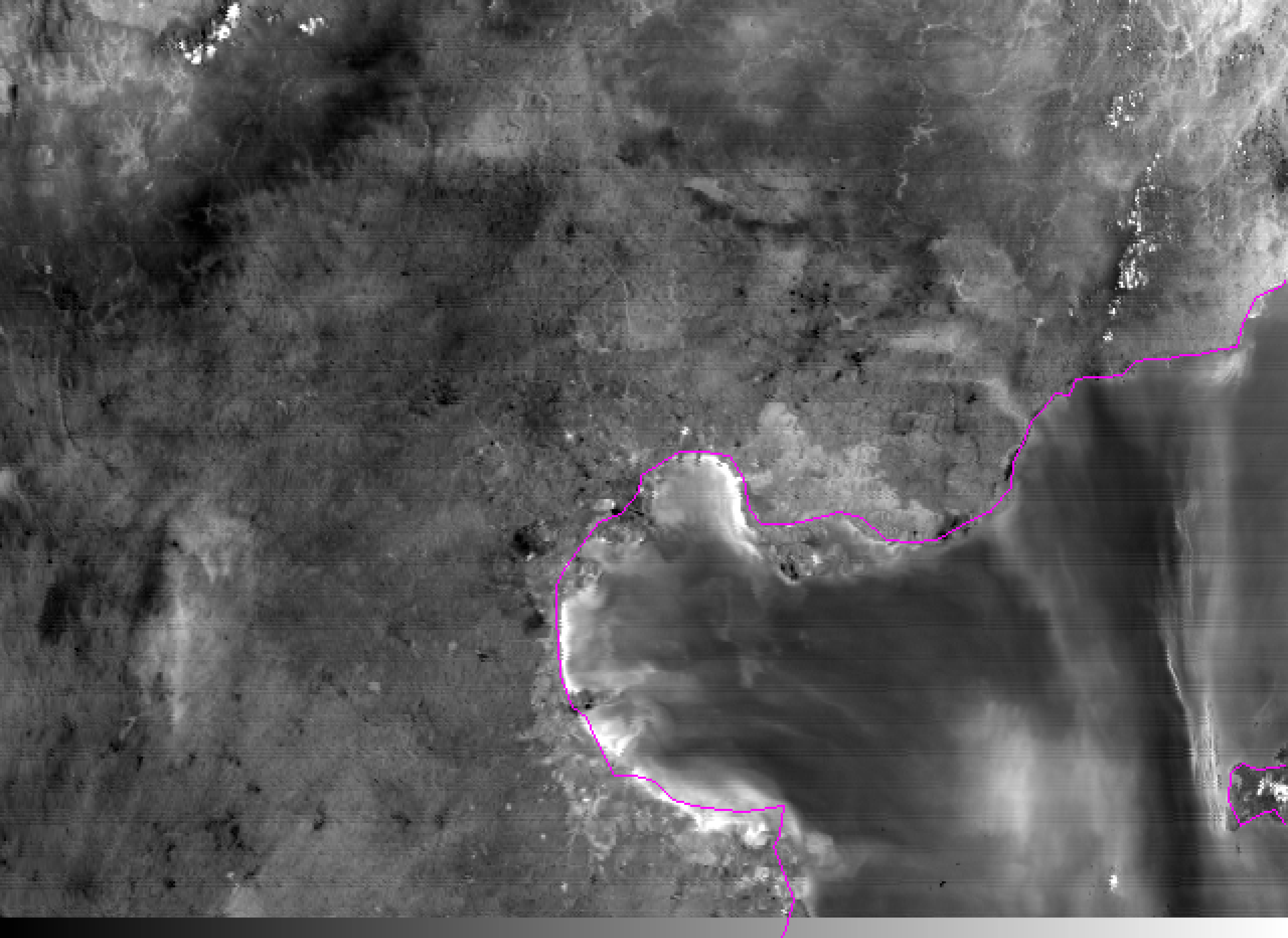


72 NPP-VIIRS 2015-08-13 042002 UTC PCI 2 OF 13 PCIS

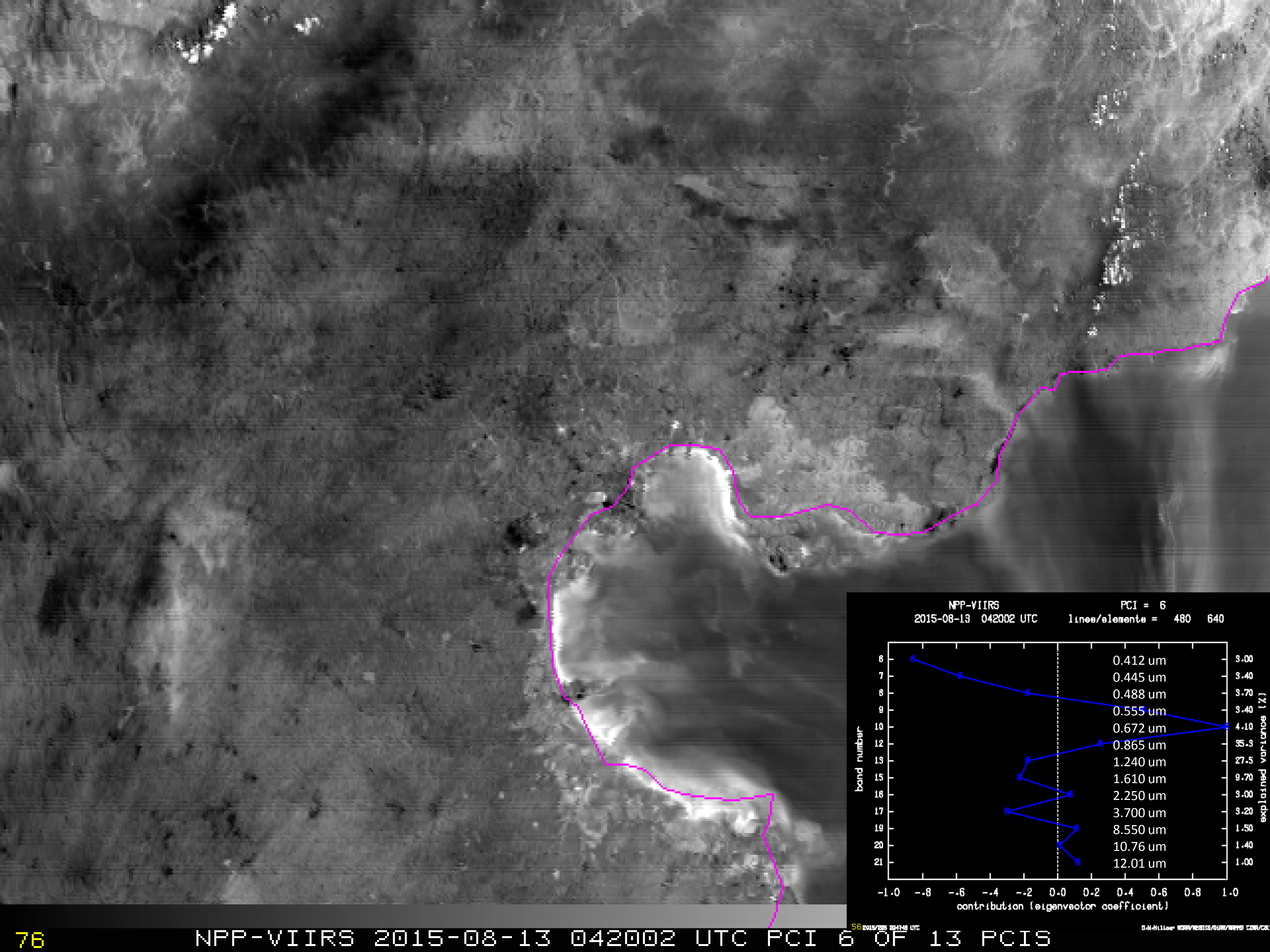

NPP-VIIRS
2015-08-13 042002 UTC
PCI = 2
lines/elements = 480 640
0.412 um
0.445 um
0.488 um
0.555 um
0.672 um
0.865 um
1.240 um
1.610 um
2.250 um
3.700 um
8.550 um
10.76 um
12.01 um
band number
explained variance (%)
contribution (eigenvector coefficient)
72
NPP-VIIRS 2015-08-13 042002 UTC PCI 2 OF 13 PCIS

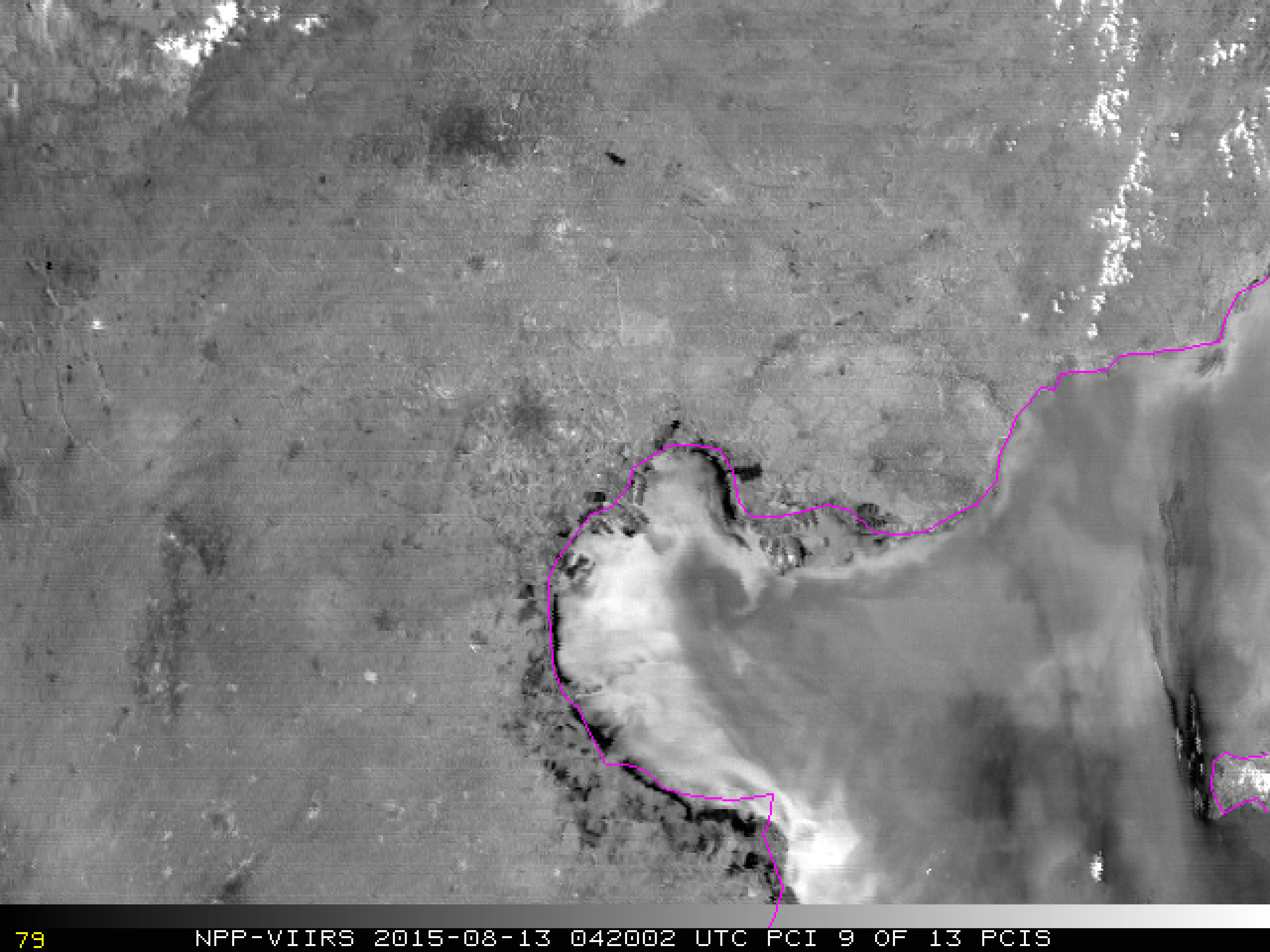

73
NPP-VIIRS 2015-08-13 042002 UTC PCI 3 OF 13 PCIS

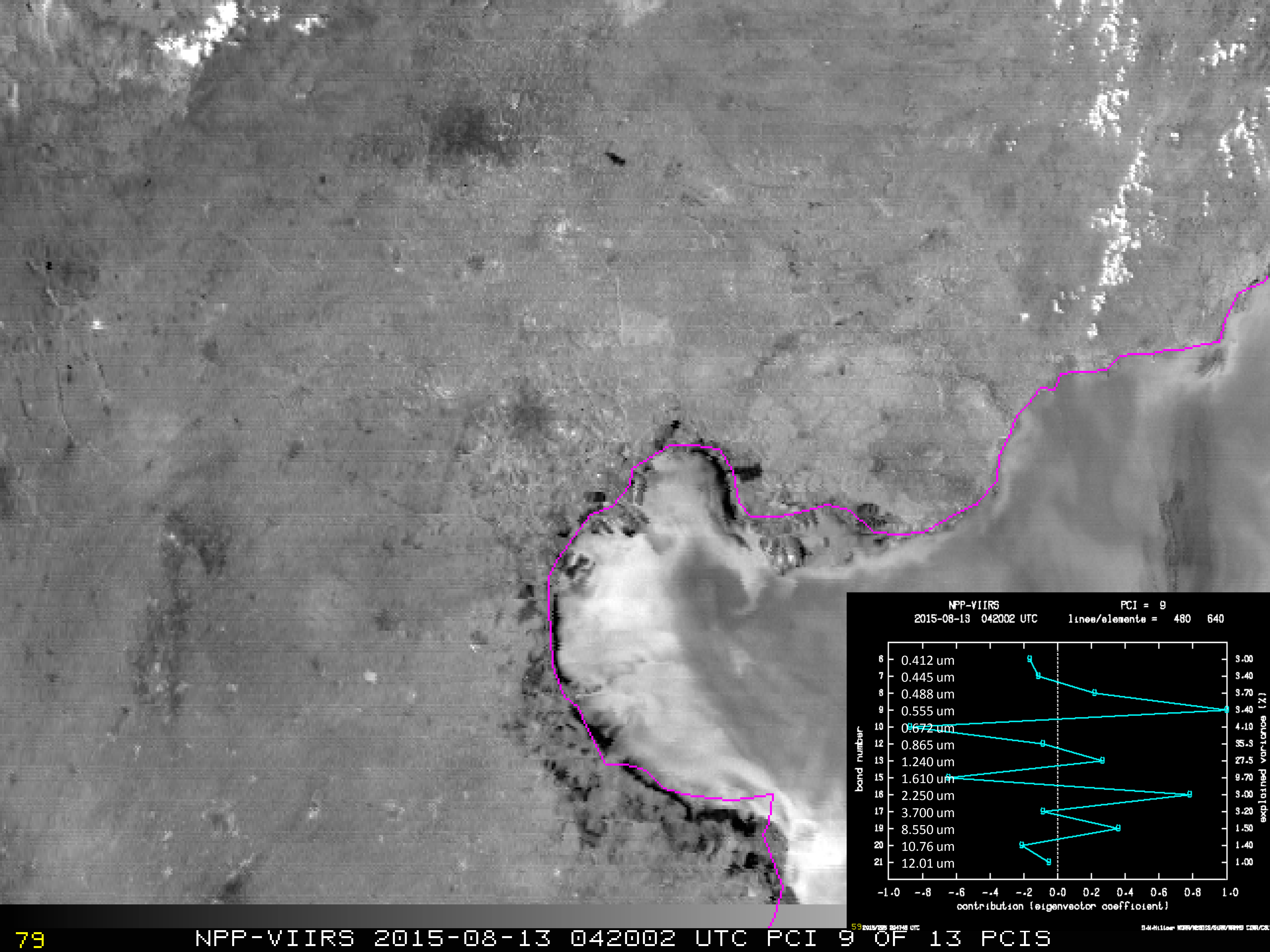

NPP-VIIRS
2015-08-13 042002 UTC
PCI = 3
lines/elements = 480 640
6 0.412 um
7 0.445 um
8 0.488 um
9 0.555 um
10 0.672 um
12 0.865 um
13 1.240 um
15 1.610 um
16 2.250 um
17 3.700 um
19 8.550 um
20 10.76 um
21 12.01 um
band number
3.00
3.40
3.70
3.40
4.10
35.3
27.5
9.70
3.00
3.20
1.50
1.40
1.00
explained variance (%)
-1.0 -.8 -.6 -.4 -.2 0.0 0.2 0.4 0.6 0.8 1.0
contribution (eigenvector coefficient)
73
NPP-VIIRS 2015-08-13 042002 UTC PCI 3 OF 13 PCIS

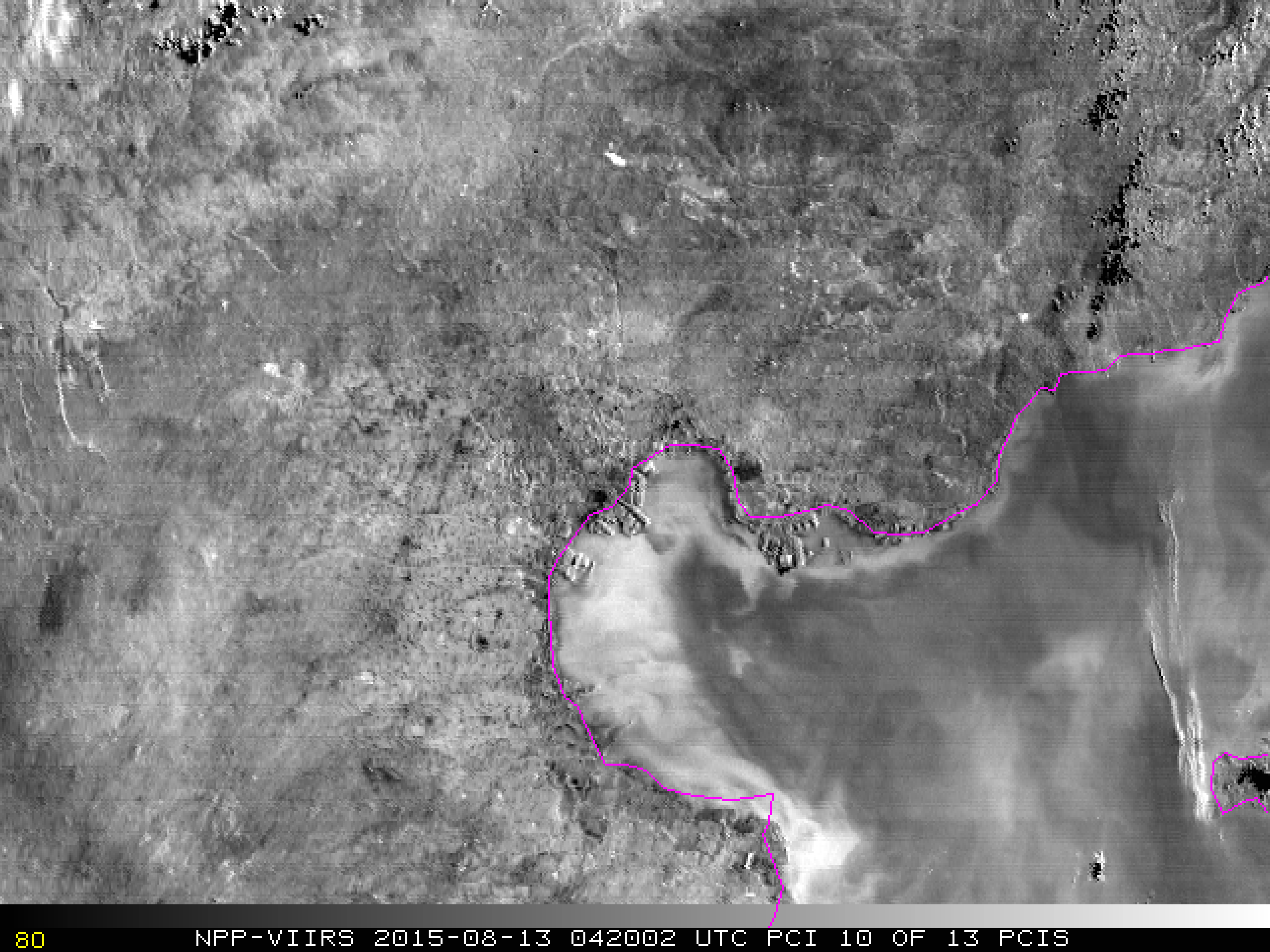


76 NPP-VIIRS 2015-08-13 042002 UTC PCI 6 OF 13 PCIS

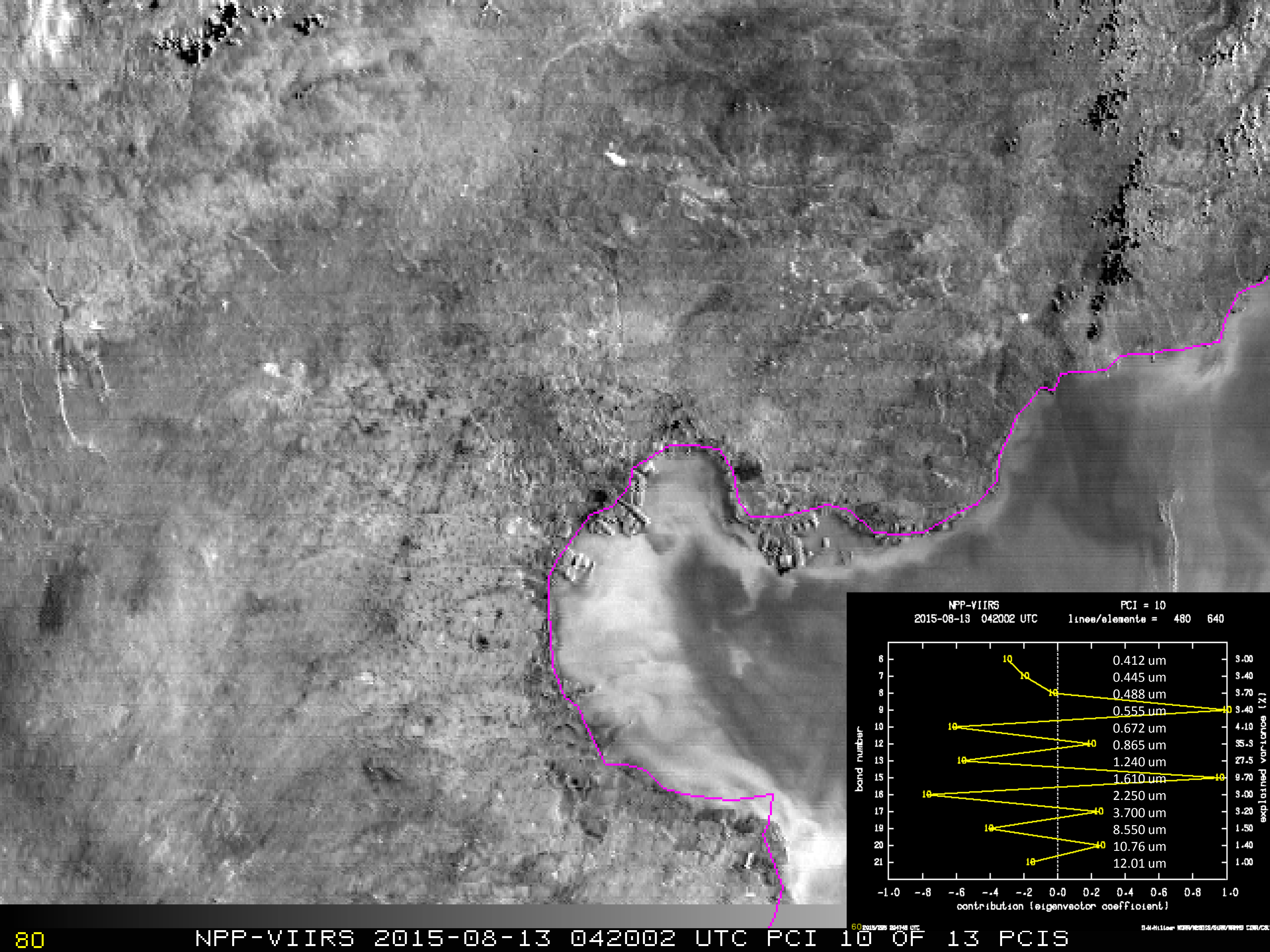

NPP-VIIRS
2015-08-13 042002 UTC
PCI = 6
lines/elements = 480 640
band number
6
7
8
9
10
12
13
15
16
17
19
20
21
0.412 um
0.445 um
0.488 um
0.555 um
0.672 um
0.865 um
1.240 um
1.610 um
2.250 um
3.700 um
8.550 um
10.76 um
12.01 um
explained variance (%)
-1.0 -.8 -.6 -.4 -.2 0.0 0.2 0.4 0.6 0.8 1.0
contribution (eigenvector coefficient)
76 NPP-VIIRS 2015-08-13 042002 UTC PCI 6 OF 13 PCIS

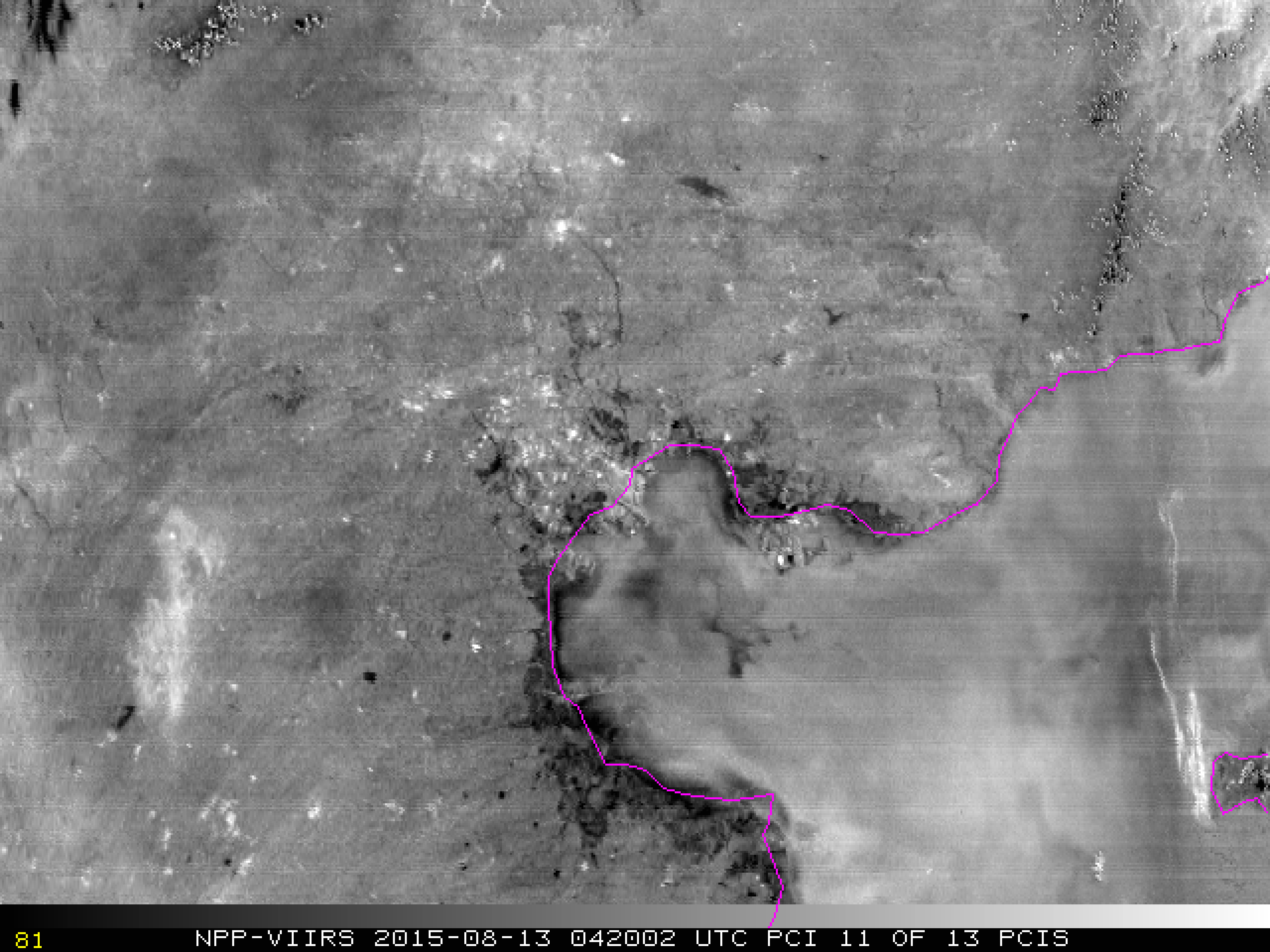

79
NPP-VIIRS 2015-08-13 042002 UTC PCI 9 OF 13 PCIS

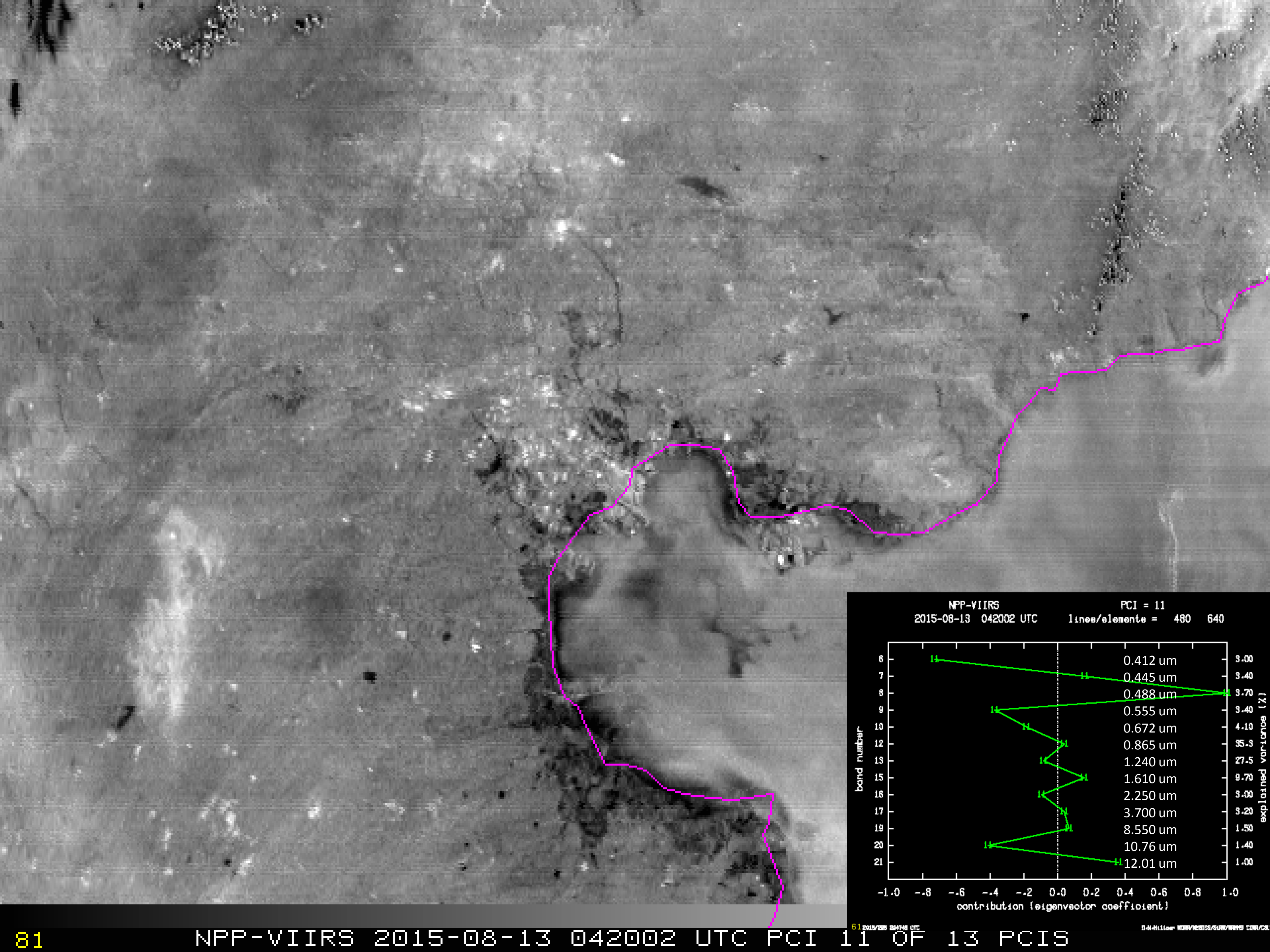

NPP-VIIRS
2015-08-13 042002 UTC
PCI = 9
lines/elements = 480 640
6 0.412 um
7 0.445 um
8 0.488 um
9 0.555 um
10 0.672 um
12 0.865 um
13 1.240 um
15 1.610 um
16 2.250 um
17 3.700 um
19 8.550 um
20 10.76 um
21 12.01 um
band number
explained variance (%)
-1.0 -.8 -.6 -.4 -.2 0.0 0.2 0.4 0.6 0.8 1.0
contribution (eigenvector coefficient)
79
NPP-VIIRS 2015-08-13 042002 UTC PCI 9 OF 13 PCIS

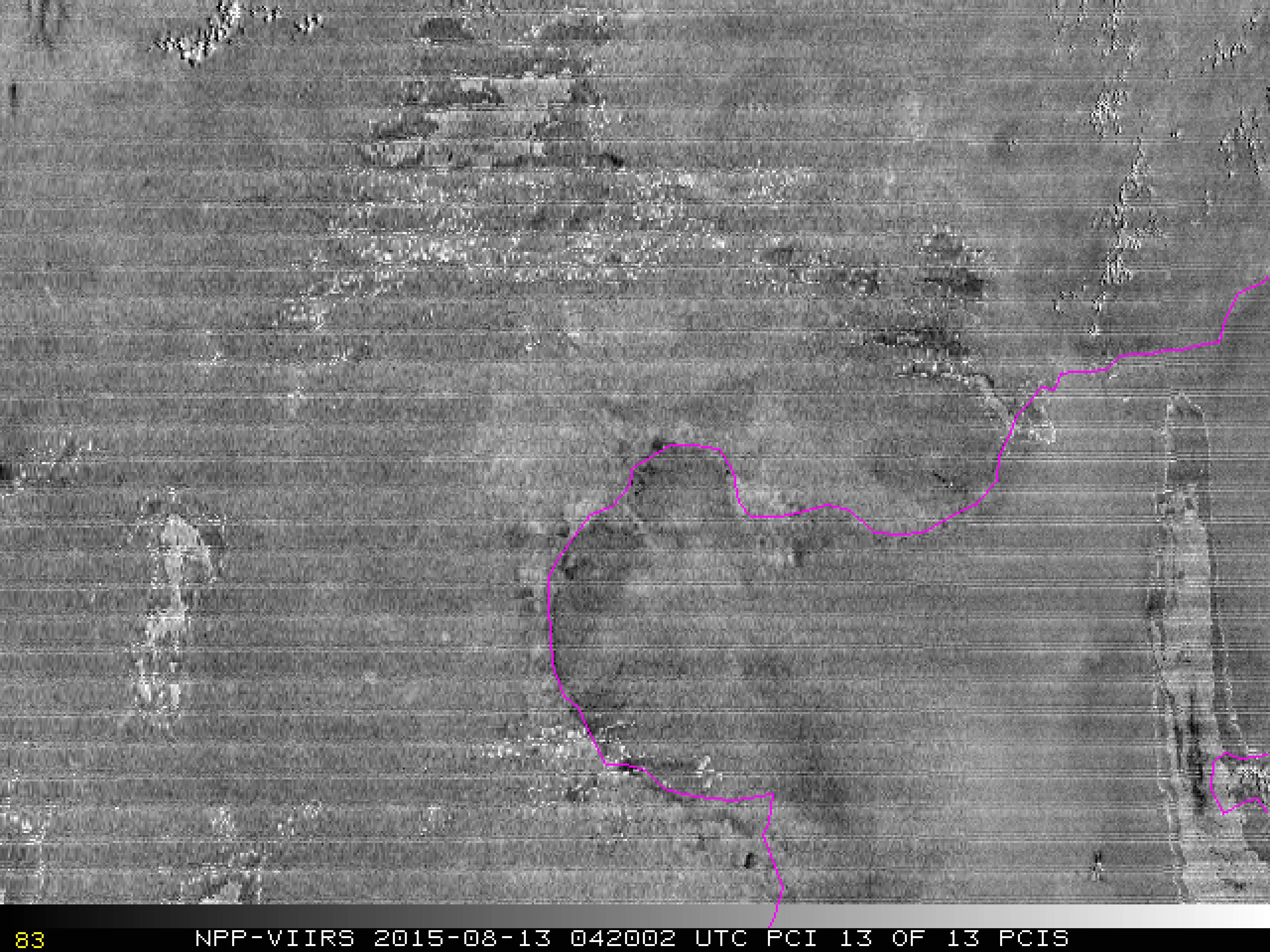


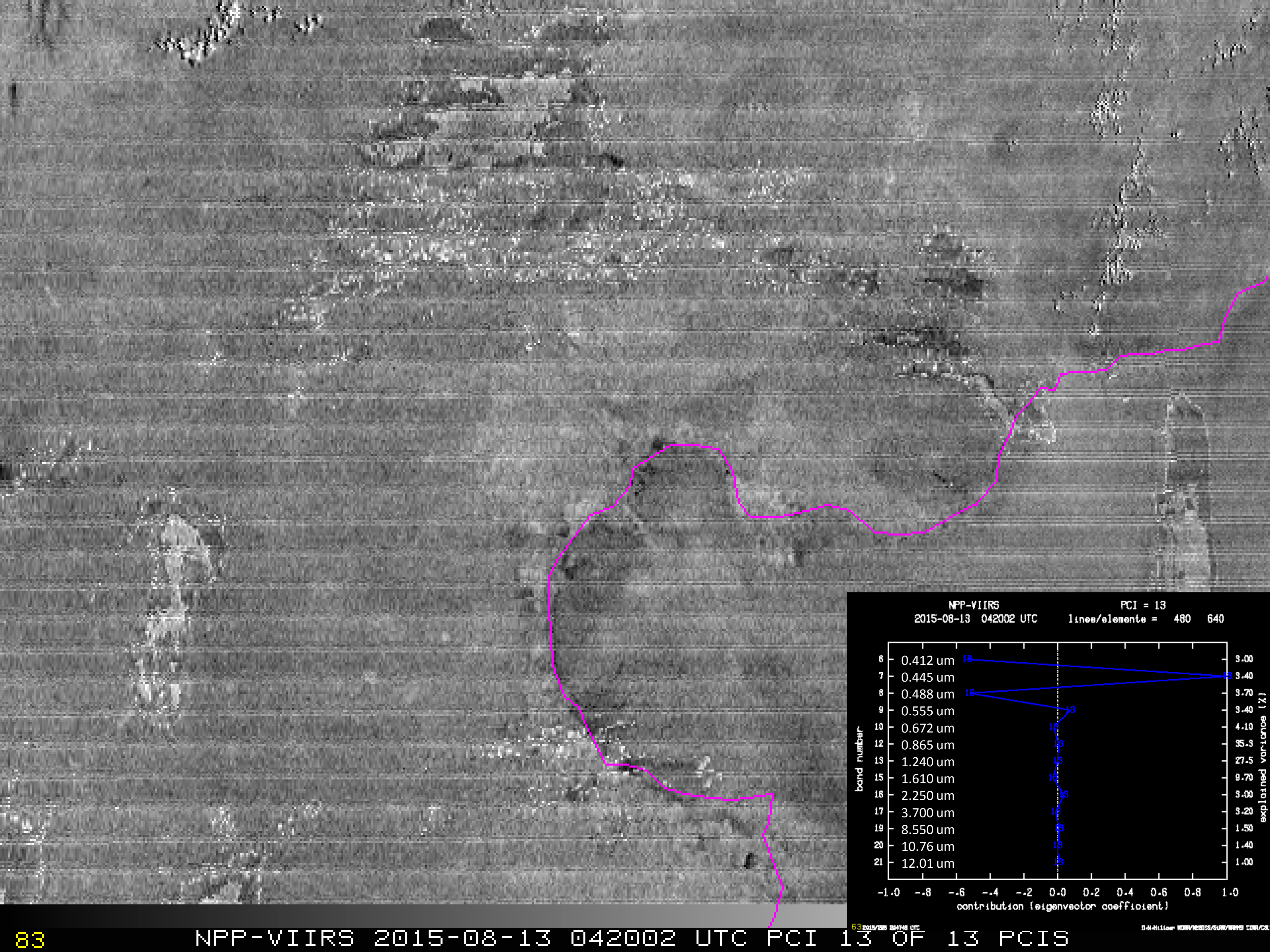
80
NPP-VIIRS 2015-08-13 042002 UTC PCI 10 OF 13 PCIS

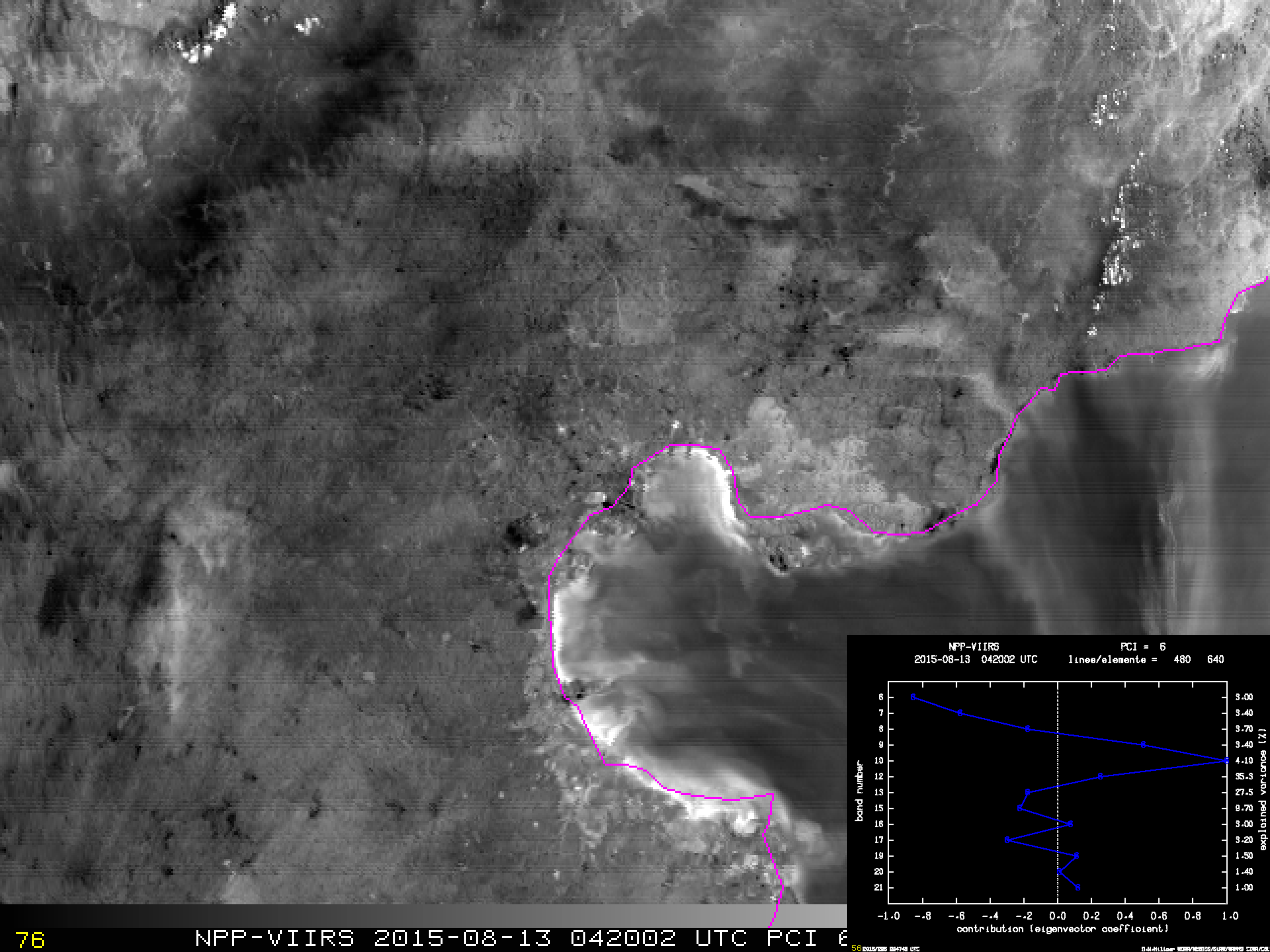

NPP-VIIRS
2015-08-13 042002 UTC
PCI = 10
lines/elements = 480 640
band number
explained variance (%)
0.412 um
0.445 um
0.488 um
0.555 um
0.672 um
0.865 um
1.240 um
1.610 um
2.250 um
3.700 um
8.550 um
10.76 um
12.01 um
contribution (eigenvector coefficient)
80
NPP-VIIRS 2015-08-13 042002 UTC PCI 10 OF 13 PCIS

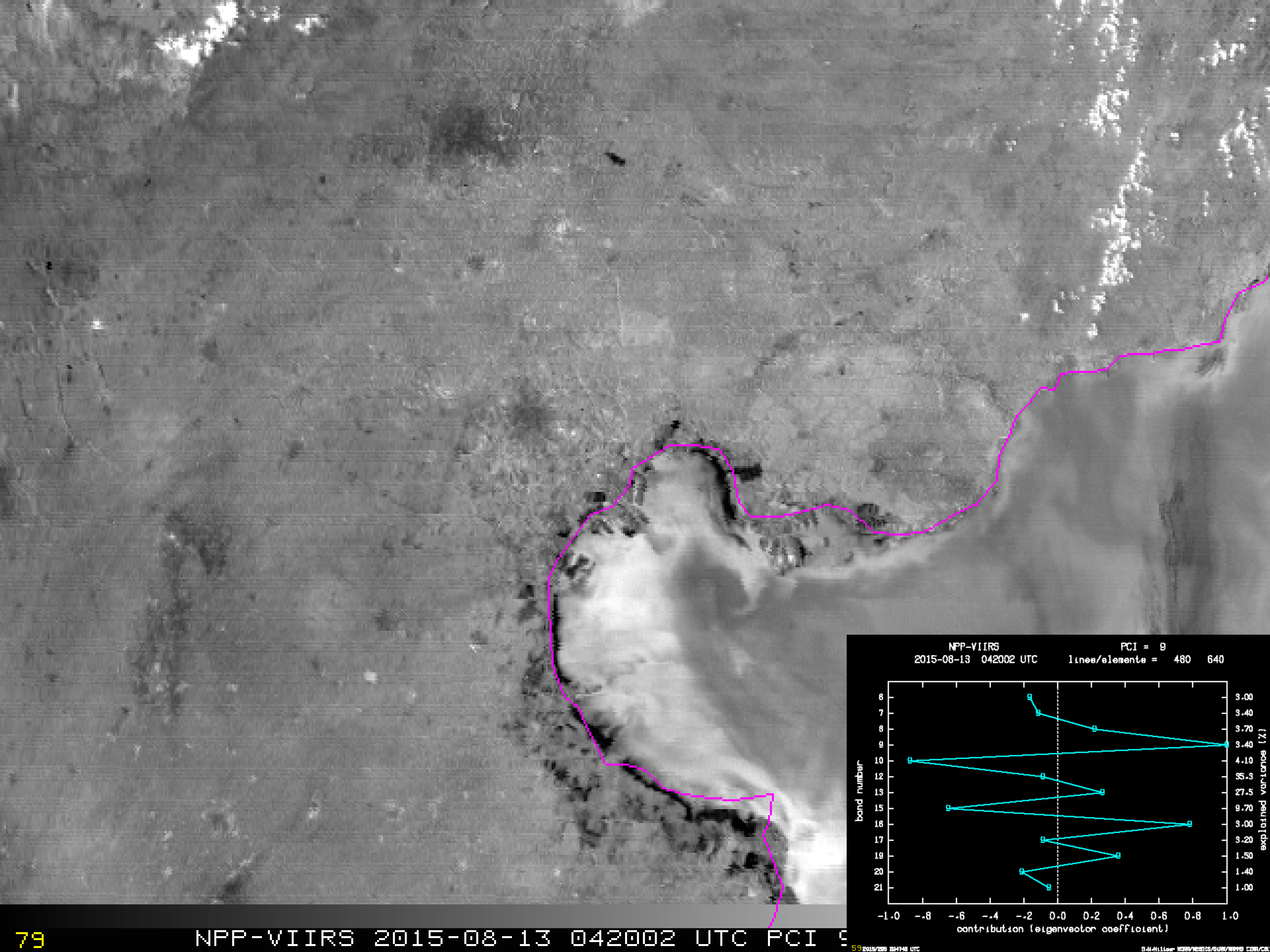

81
NPP-VIIRS 2015-08-13 042002 UTC PCI 11 OF 13 PCIS

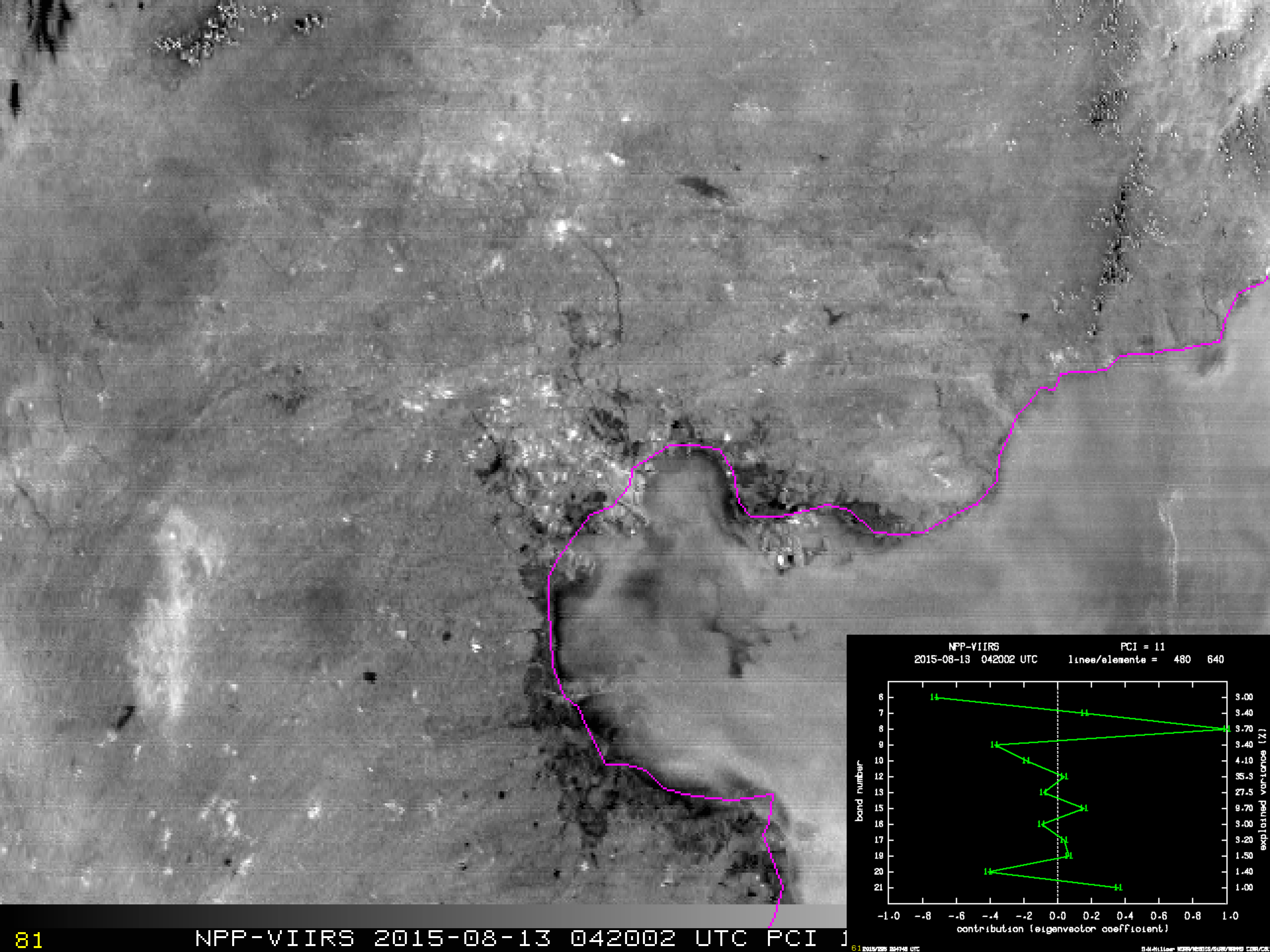

NPP-VIIRS
2015-08-13 042002 UTC
PCI = 11
lines/elements = 480 640
0.412 um
0.445 um
0.488 um
0.555 um
0.672 um
0.865 um
1.240 um
1.610 um
2.250 um
3.700 um
8.550 um
10.76 um
12.01 um
band number
explained variance (%)
contribution (eigenvector coefficient)
81
NPP-VIIRS 2015-08-13 042002 UTC PCI 11 OF 13 PCIS


83
NPP-VIIRS 2015-08-13 042002 UTC PCI 13 OF 13 PCIS

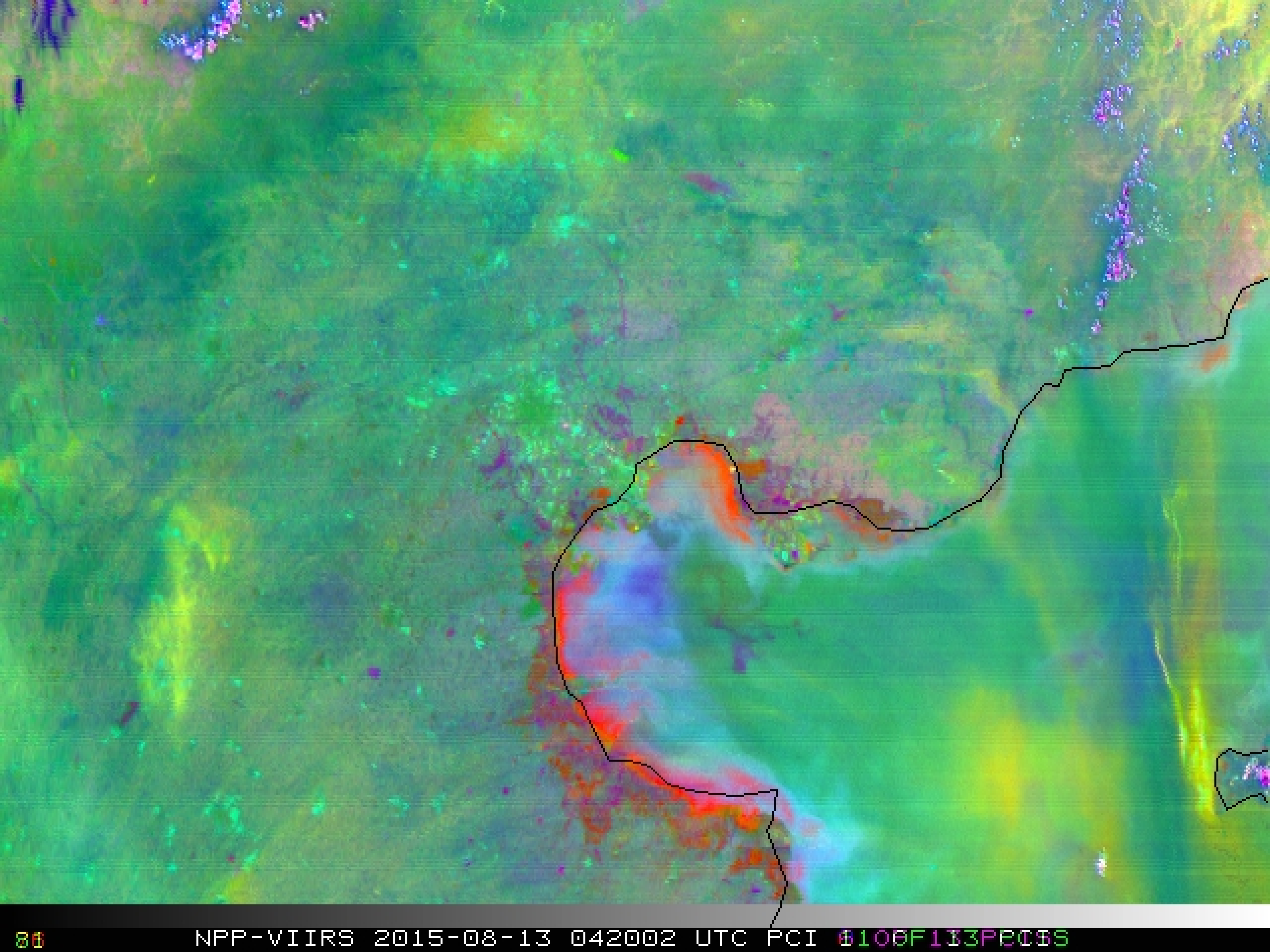

NPP-VIIRS
2015-08-13 042002 UTC
PCI = 13
lines/elements = 480 640
band number
6 0.412 um
7 0.445 um
8 0.488 um
9 0.555 um
10 0.672 um
12 0.865 um
13 1.240 um
15 1.610 um
16 2.250 um
17 3.700 um
19 8.550 um
20 10.76 um
21 12.01 um
3.00
3.40
3.70
3.40
4.10
35.3
27.5
9.70
3.00
3.20
1.50
1.40
1.00
explained variance (%)
-1.0 -.8 -.6 -.4 -.2 0.0 0.2 0.4 0.6 0.8 1.0
contribution (eigenvector coefficient)
83 NPP-VIIRS 2015-08-13 042002 UTC PCI 13 OF 13 PCIS

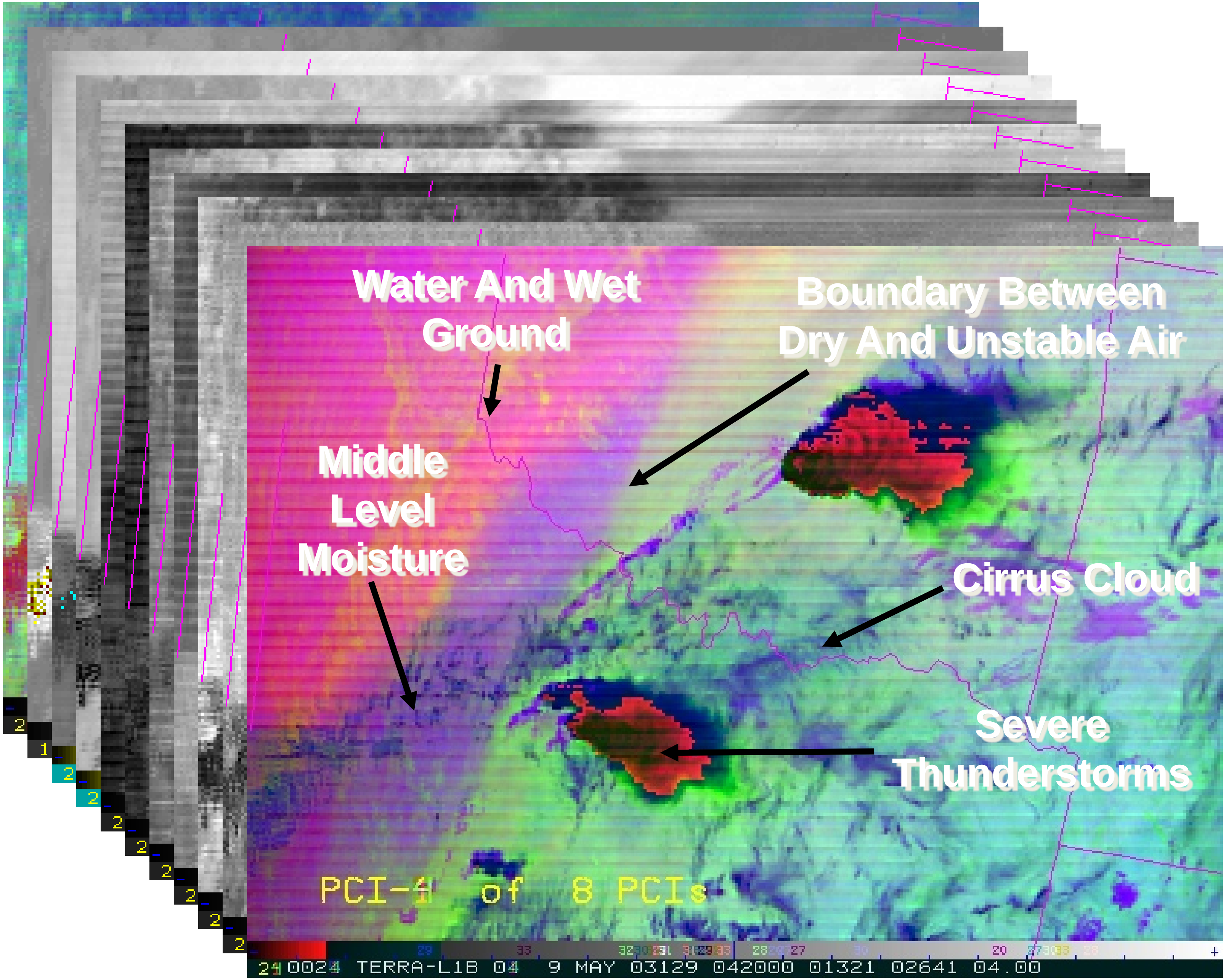

NPP-VIIRS
2015-08-13 042002 UTC
PCI = 6
lines/elements = 480 640
band number
6
7
8
9
10
12
13
15
16
17
19
20
21
explained variance (%)
3.00
3.40
3.70
3.40
4.10
35.3
27.5
9.70
3.00
3.20
1.50
1.40
1.00
-1.0 -.8 -.6 -.4 -.2 0.0 0.2 0.4 0.6 0.8 1.0
contribution (eigenvector coefficient)
76
NPP-VIIRS 2015-08-13 042002 UTC PCI 6


NPP-VIIRS
2015-08-13 042002 UTC
PCI = 9
lines/elements = 480 640
band number
6
7
8
9
10
12
13
15
16
17
19
20
21
explained variance (%)
3.00
3.40
3.70
3.40
4.10
35.3
27.5
9.70
3.00
3.20
1.50
1.40
1.00
-1.0 -.8 -.6 -.4 -.2 0.0 0.2 0.4 0.6 0.8 1.0
contribution (eigenvector coefficient)
79
NPP-VIIRS 2015-08-13 042002 UTC PCI 9



NPP-VIIRS
PCI = 11
2015-08-13 042002 UTC
lines/elements = 480 640
band number
6
7
8
9
10
12
13
15
16
17
19
20
21
explained variance (%)
3.00
3.40
3.70
3.40
4.10
35.3
27.5
9.70
3.00
3.20
1.50
1.40
1.00
-1.0 -.8 -.6 -.4 -.2 0.0 0.2 0.4 0.6 0.8 1.0
contribution (eigenvector coefficient)
81
NPP-VIIRS 2015-08-13 042002 UTC PCI 1


NPP-VIIRS 2015-08-13 042002 UTC PCI



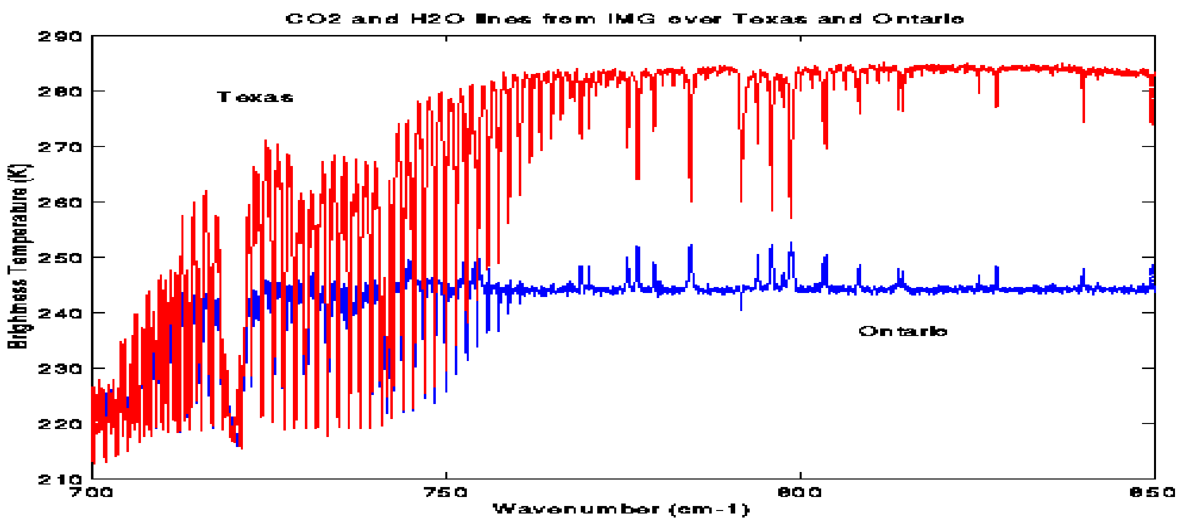
New products based on mathematical analysis of multi-channel images – every 5 minutes or less!

Let’s take a quick look at hyperspectral sounding

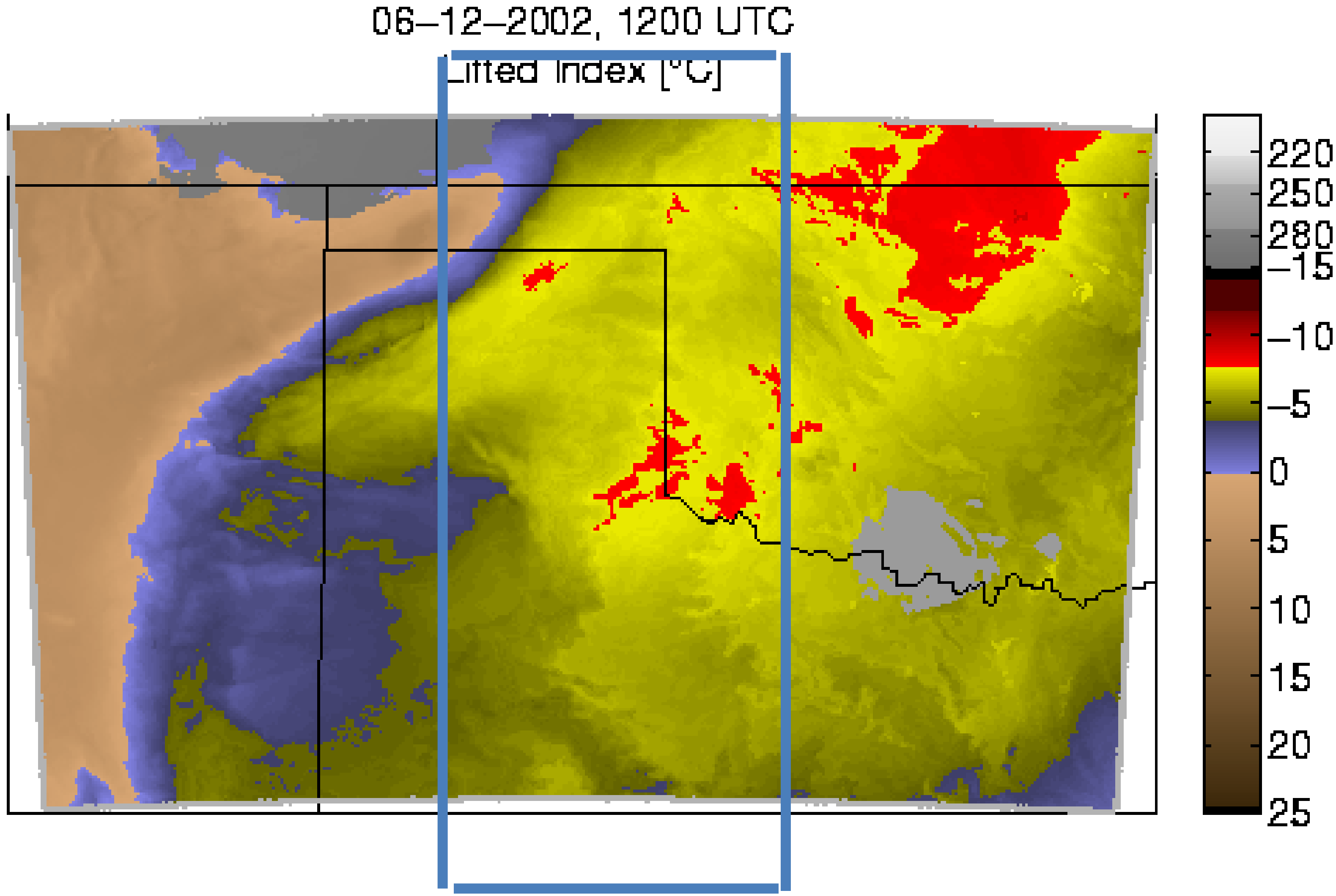
IMG demonstrates interferometer capability to detect low level inversions: example over Ontario with inversion (absorption line BTs warmer) and Texas without (abs line BTs colder)

Spikes up - Heating with height

Spikes down - Cooling with height



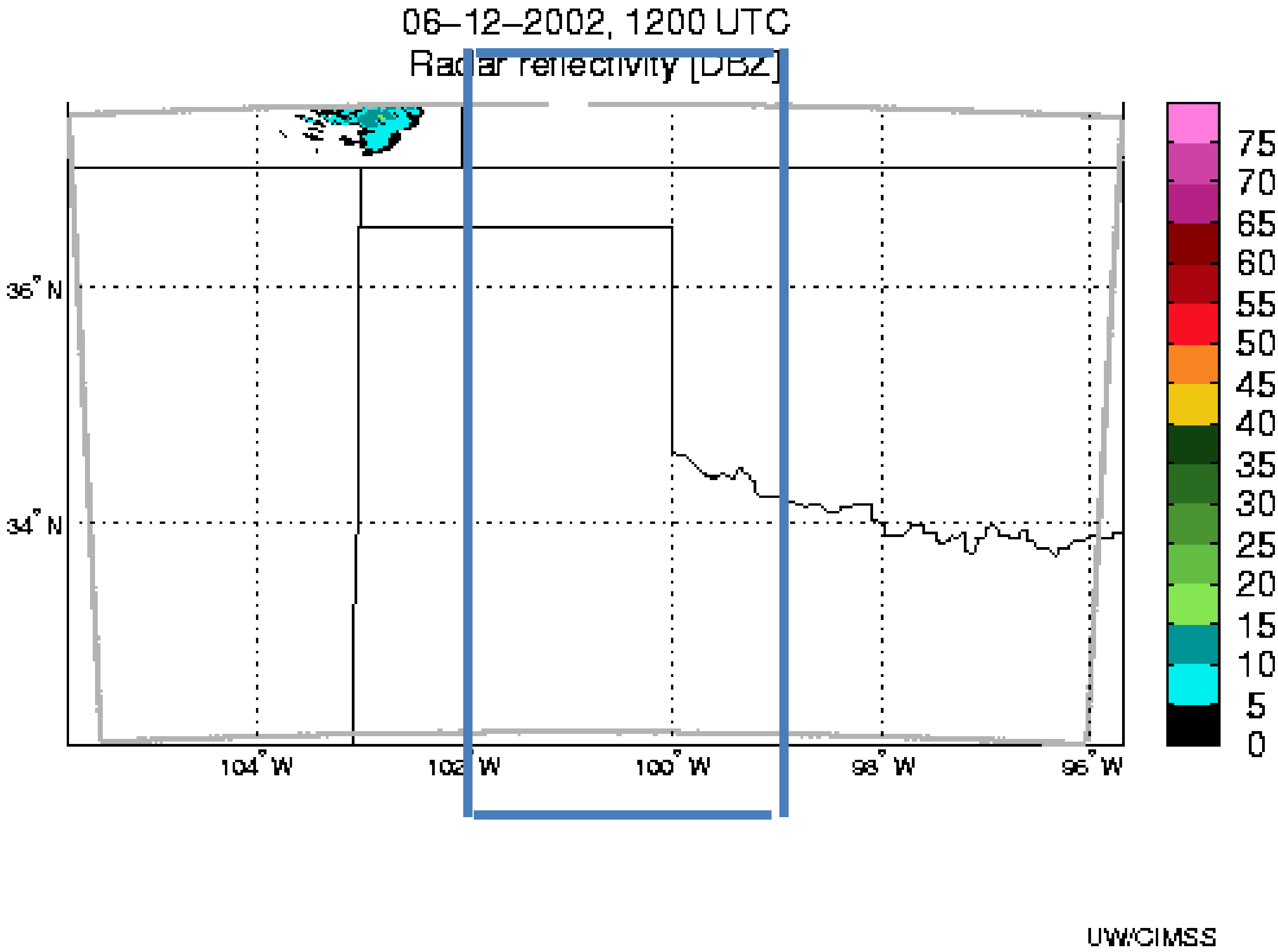
Mode B GIIRS Derived LI



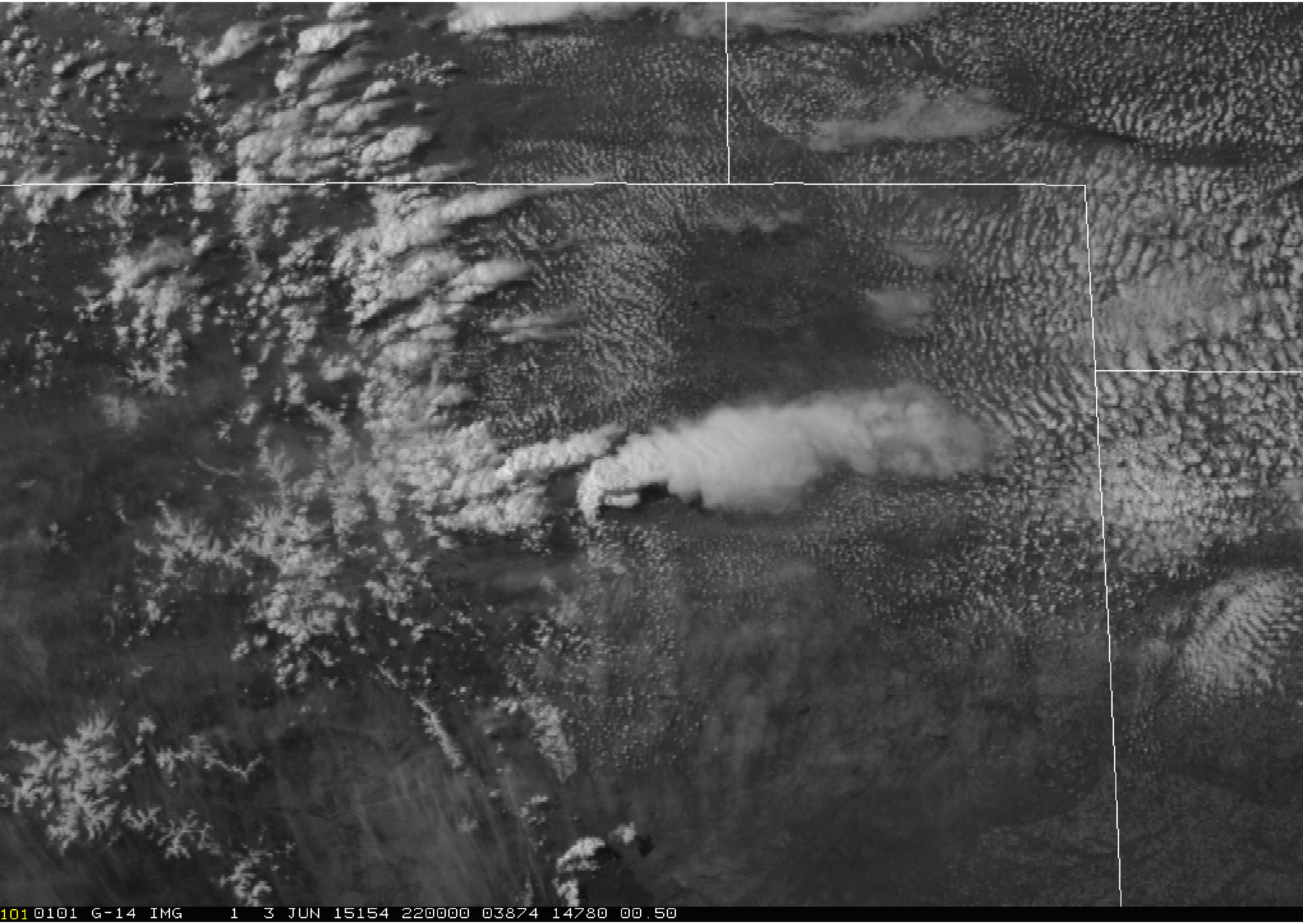
GIIRS in (Mode A) hourly coverage with weather dictated target or (Mode B) in 2 minute coverage (about 300 by 600 km) over an event area (to be fixed for the duration of the event).

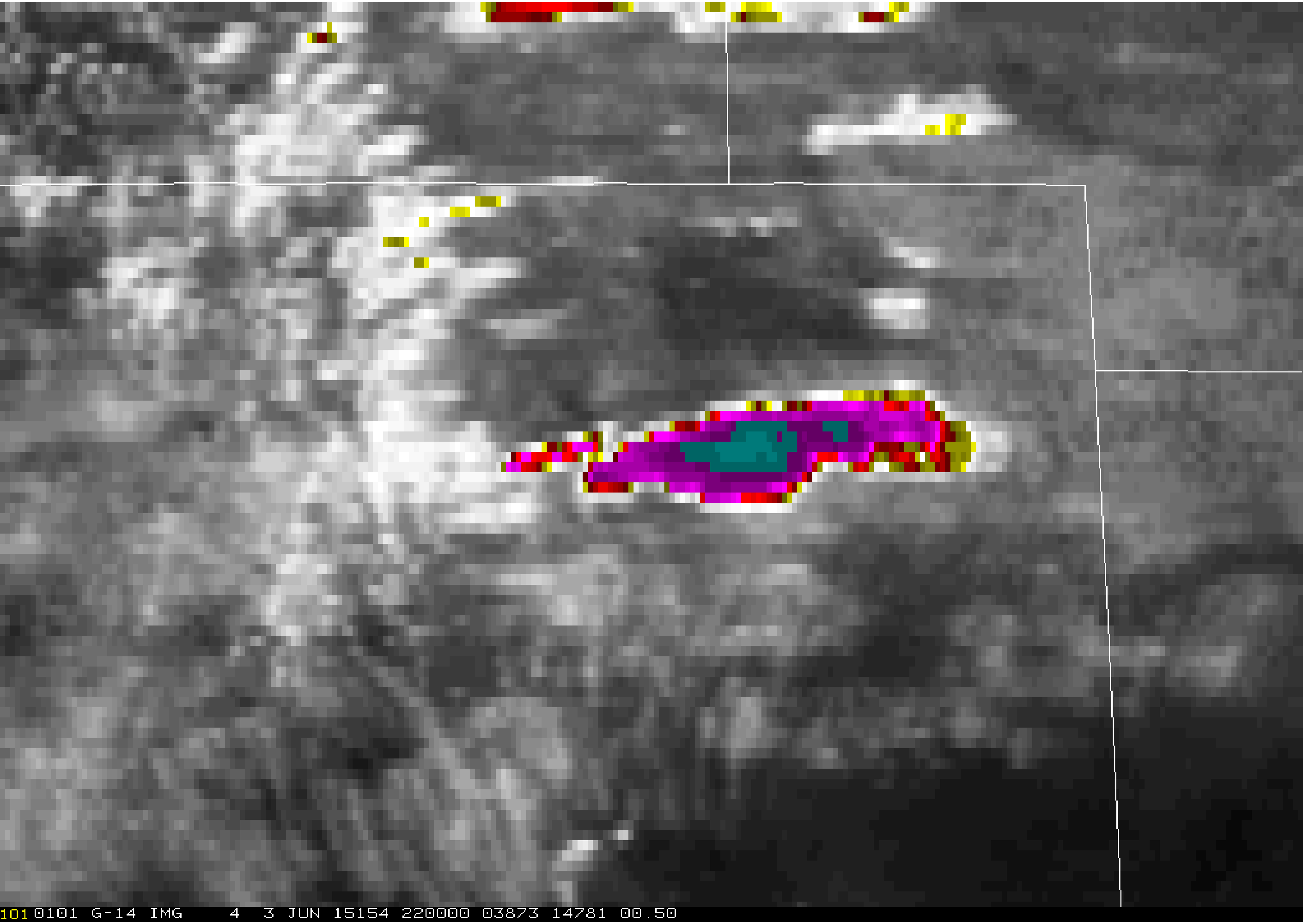
UW/CIMSS

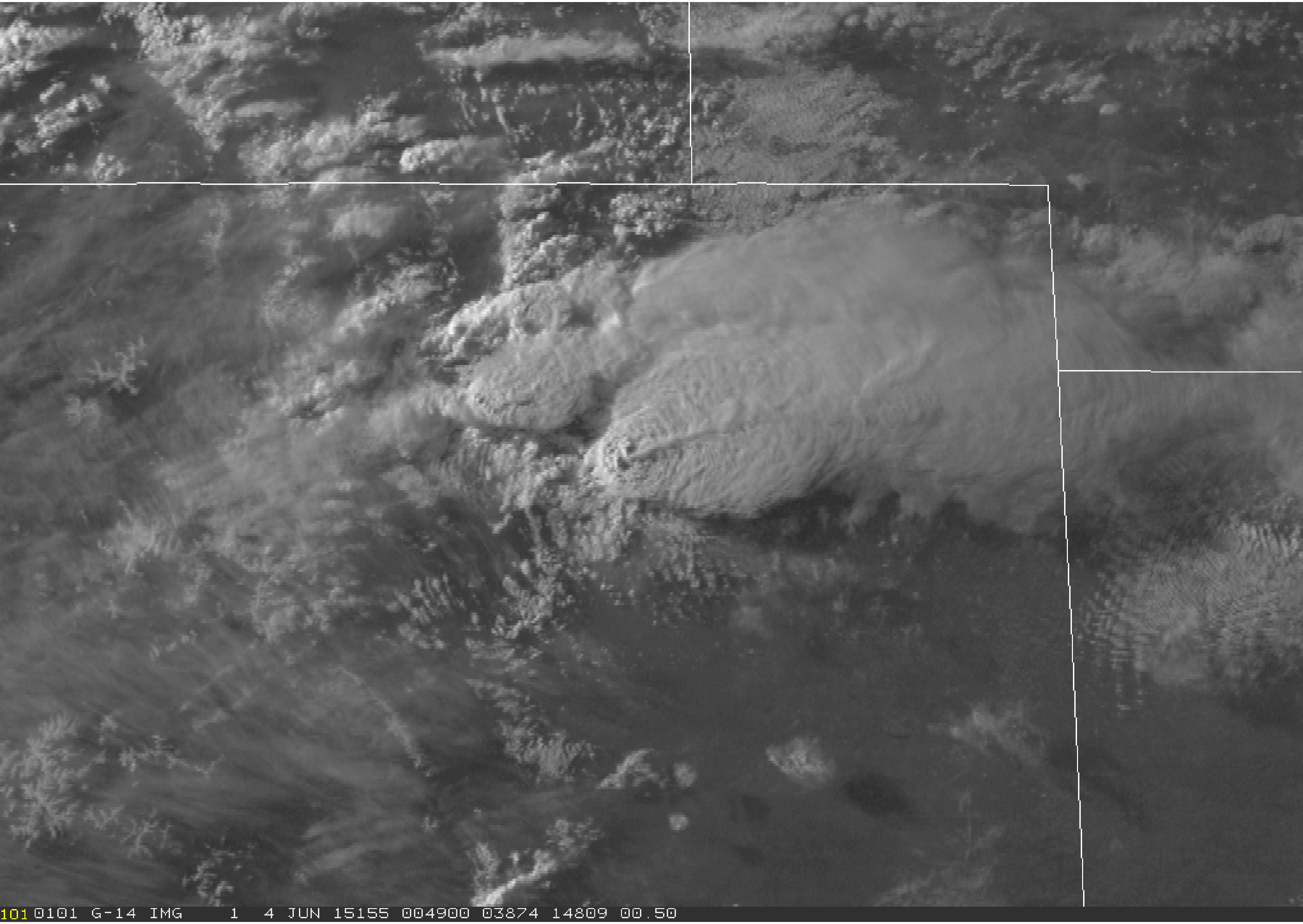
Radar

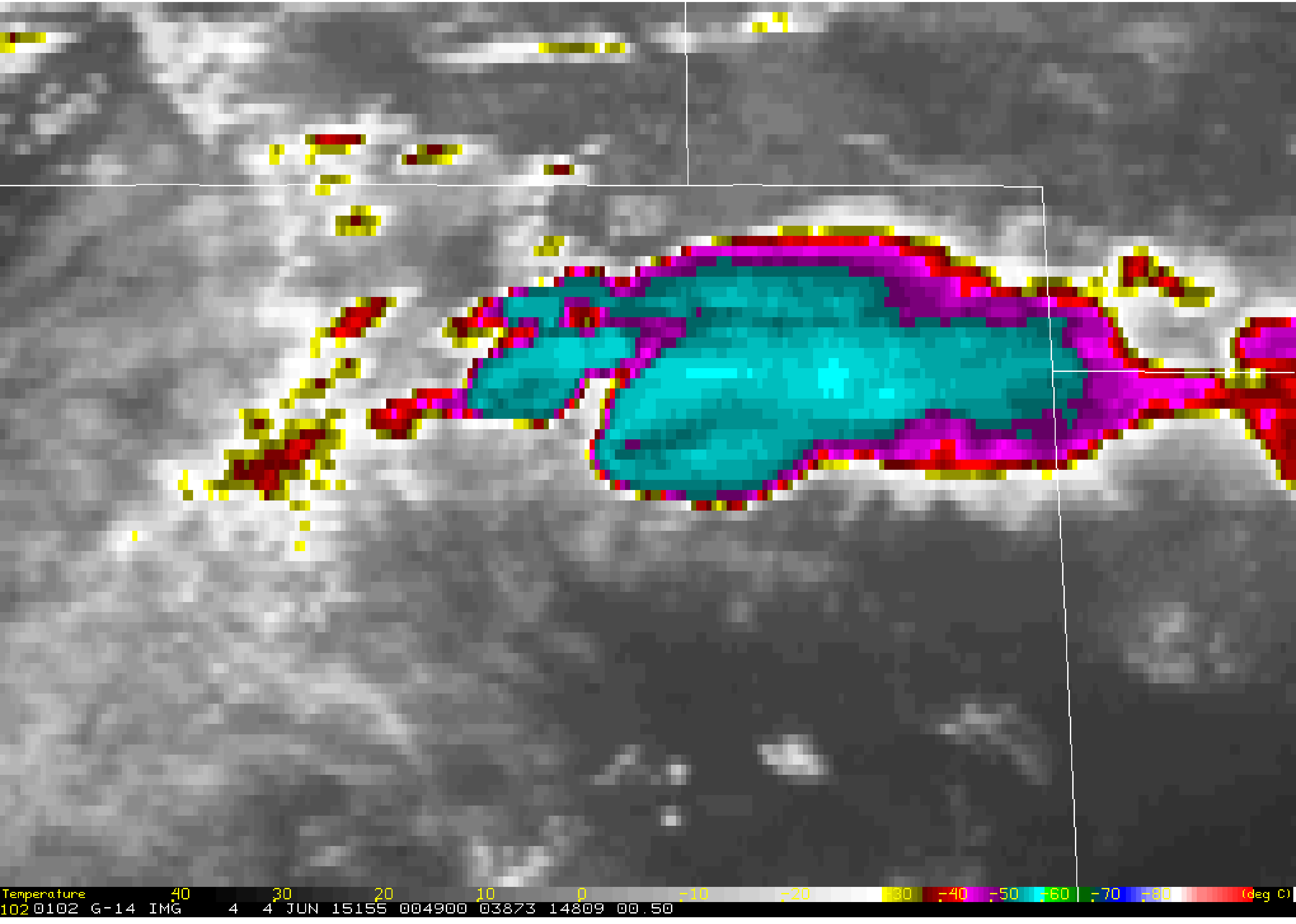


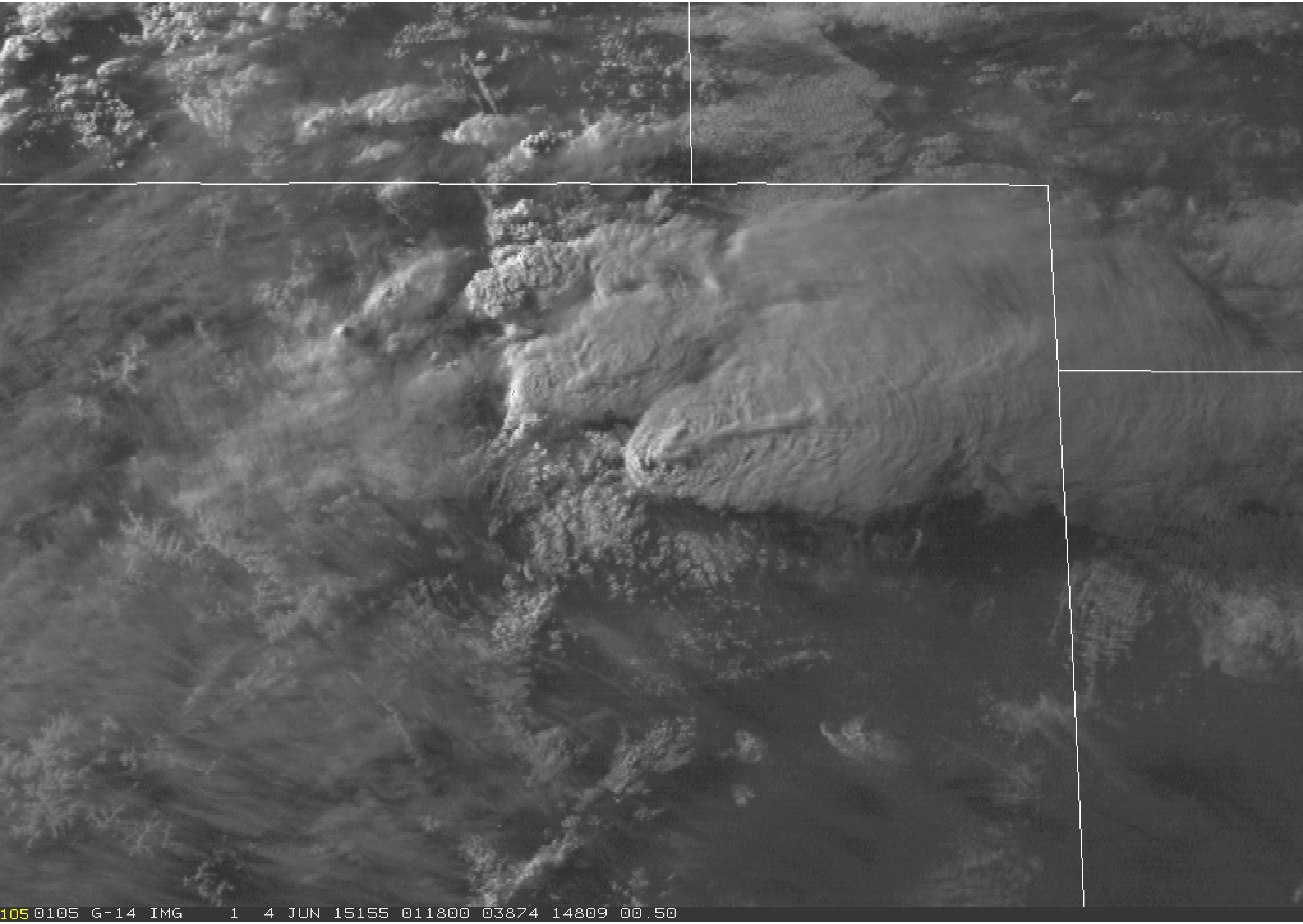
06–12–2002, 1200 UTC
Radar reflectivity [DBZ]
36° N
34° N
104° W
102° W
100° W
98° W
96° W
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
UW/CIMSS


101 0101 G-14 IMG 1 3 JUN 15154 220000 03874 14780 00.50


101 0101 G-14 IMG 4 3 JUN 15154 220000 03873 14781 00.50


101 0101 G-14 IMG 1 4 JUN 15155 004900 03874 14809 00.50


Temperature 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 (deg C)
102 0102 G-14 IMG 4 4 JUN 15155 004900 03873 14809 00.50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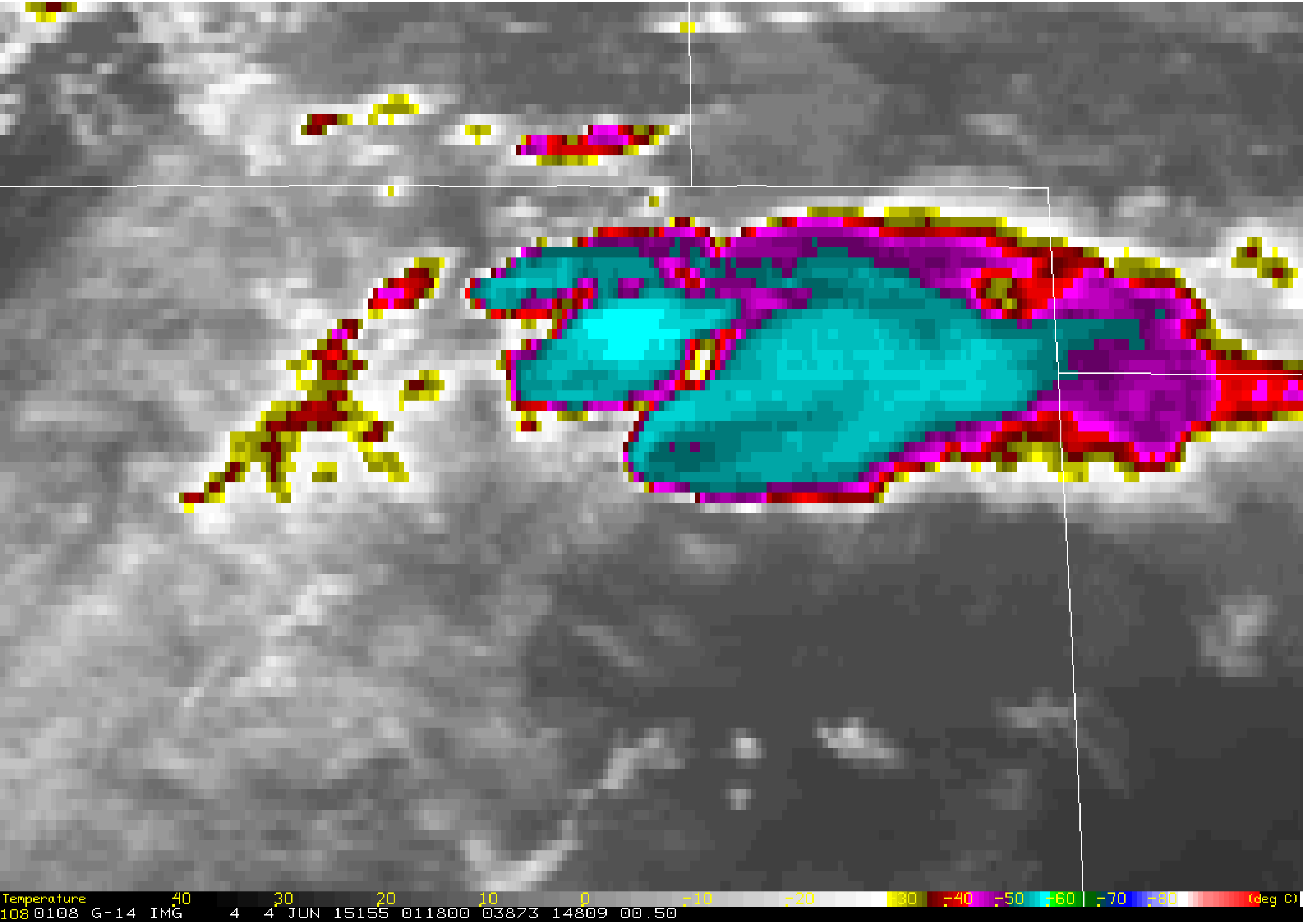
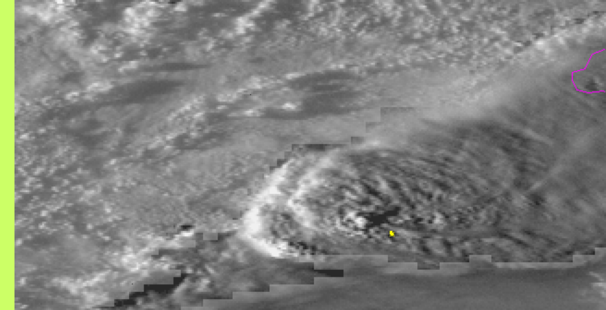
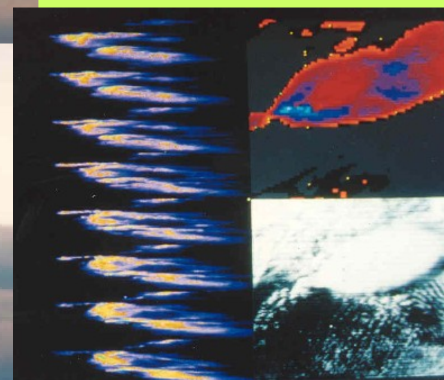
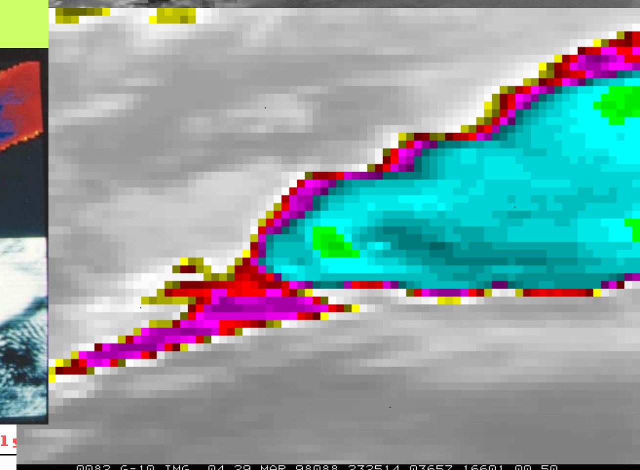

Temperature 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 (deg C)
108 0108 G-14 IMG 4 4 JUN 15155 011800 03873 14809 00.50

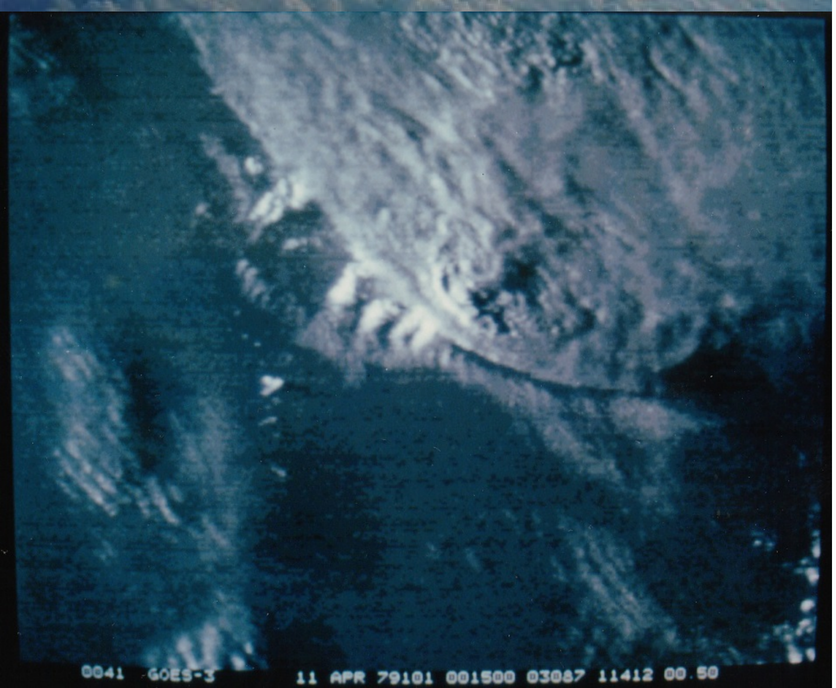
Overshooting Tops

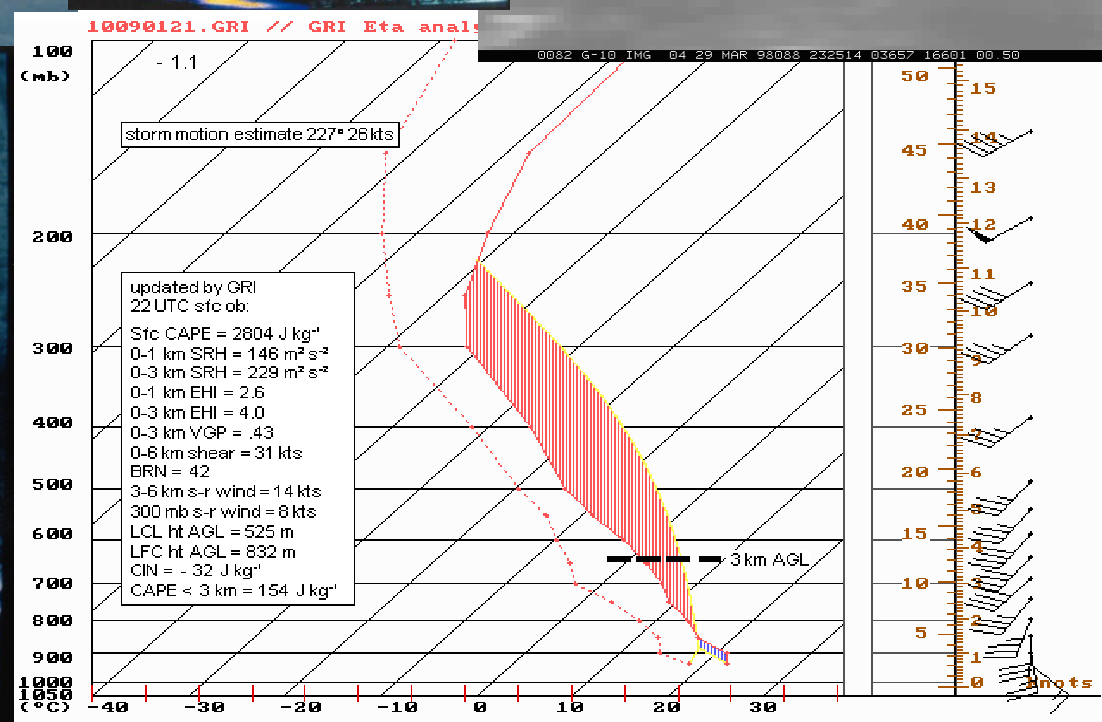
What do they mean?

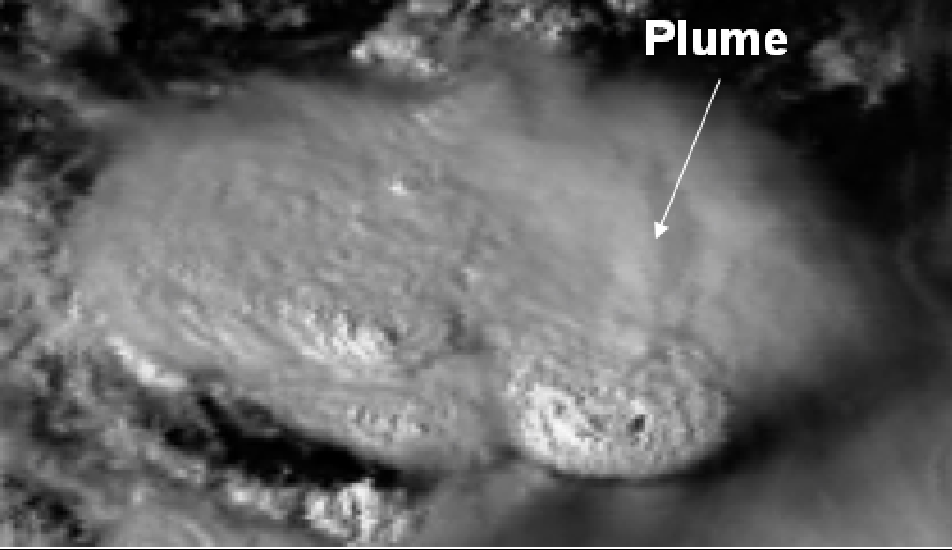




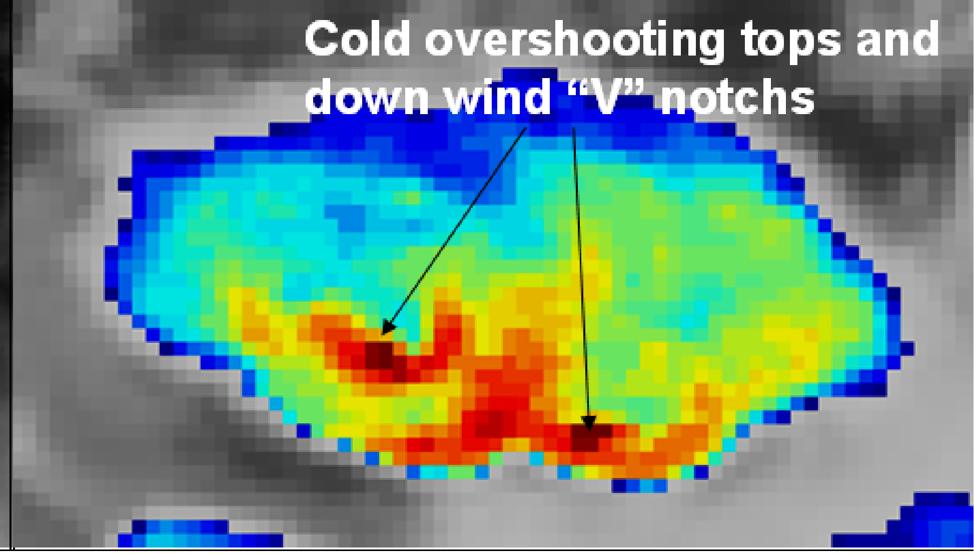




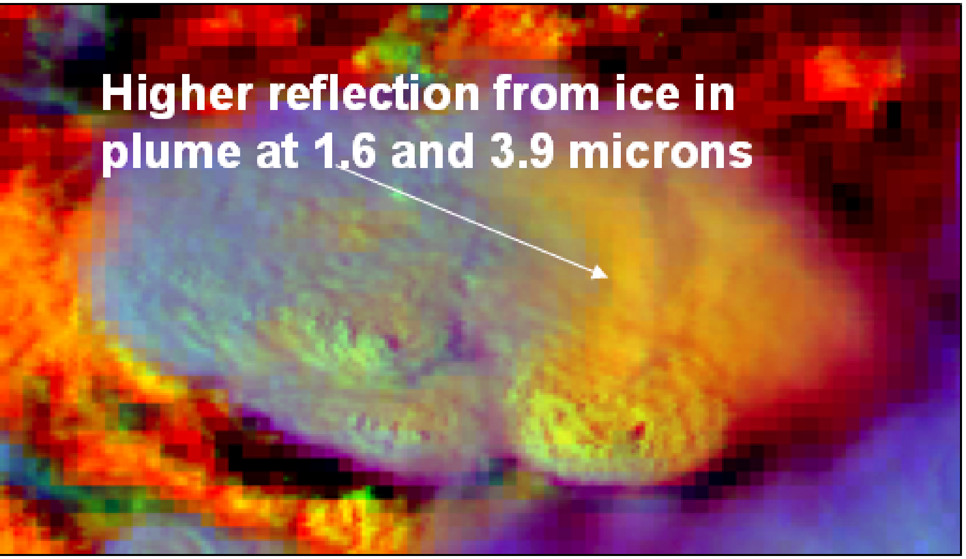




MSG High Resolution Visible (HRV)

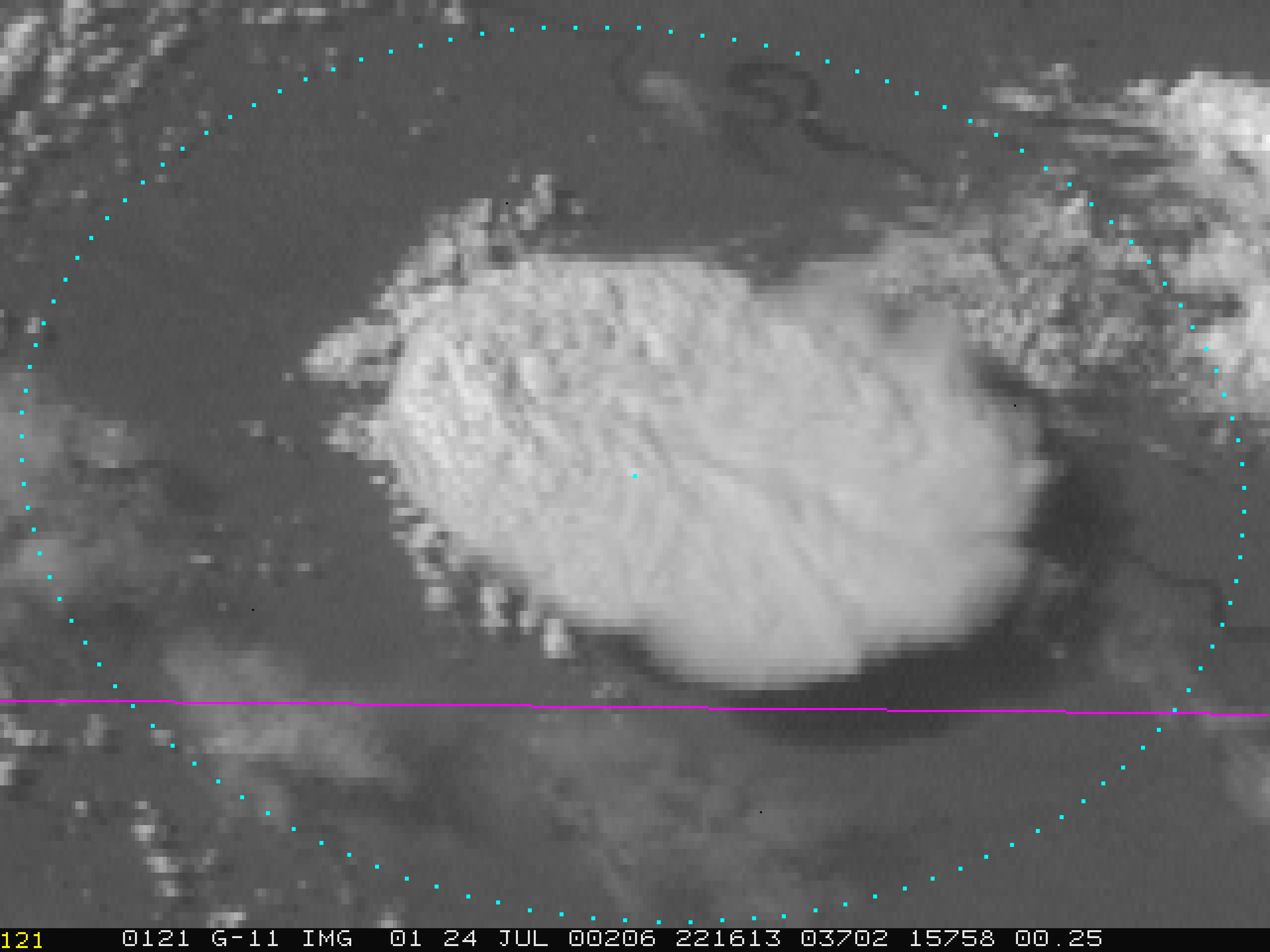


MSG Enhanced 10.7 micron IR



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.


121
0121 G-11 IMG 01 24 JUL 00206 221613 03702 15758 00.25

CONCLUSIONS

Prospects and expectation are great as the next generation geostationary meteorological satellites' global array becomes operational

These satellites are part of a high resolution digital age and serve a variety of user communities including: meteorology, climate, ocean, ecology, land and environmental

Capabilities of geostationary satellites in the global array are converging on 16 channel high spectral resolution imagers; all have rapid scanning as a part of their routine operation; some will have lightning mappers and some have hyperspectral sounders

There is going to be a tremendous increase in data volume which will lead to inconceivable advance in products and their utilization which will present us (the community) with opportunities and challenges

In realizing the opportunities and challenges we improve the way we do business; we will focus on:

*national and international partnerships including focused satellite applications facilities, and international science teams

*continuing to foster strong cooperation between international users such as exists today with NWP, and the WMO international working groups that focus on satellite calibration, precipitation, winds, soundings, etc.

*training for full utilization with strong involvement of the WMO/CGMS Virtual Laboratory for Satellite Data Utilization

Conclusion

- **We are entering an era of unprecedented opportunities in satellite meteorology**
- **Opportunity awaits those who choose to take advantage of it – time is too precious to waste – the job at hand is too big for any one Nation to take on alone. Form strategic Asia/Oceania partnerships for exploitation based on the EUMETSAT SAF model and the NESDIS CIRA/CIMSS model**
- **Questions?**

Thank you for your attention

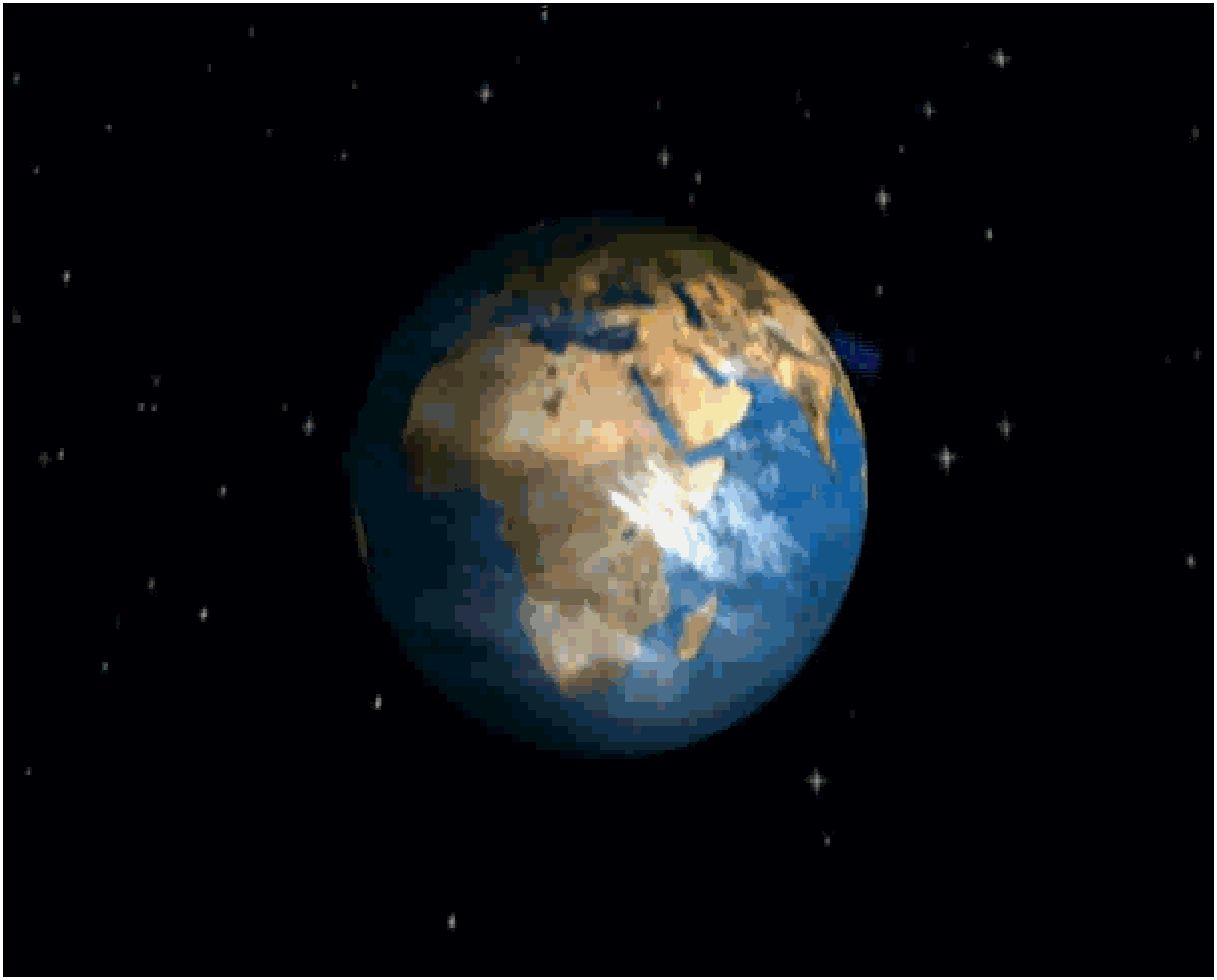
Orbits

- The mainstay orbits for meteorological and environmental applications
    - **Sun synchronous Polar orbits**
    - **Geostationary orbits**
- Other orbits and specialized applications
    - **Pro-grade orbits**
    - **Constellations and formation flying**

Sun synchronous Polar orbits

Twice-a-day global coverage from each satellite.

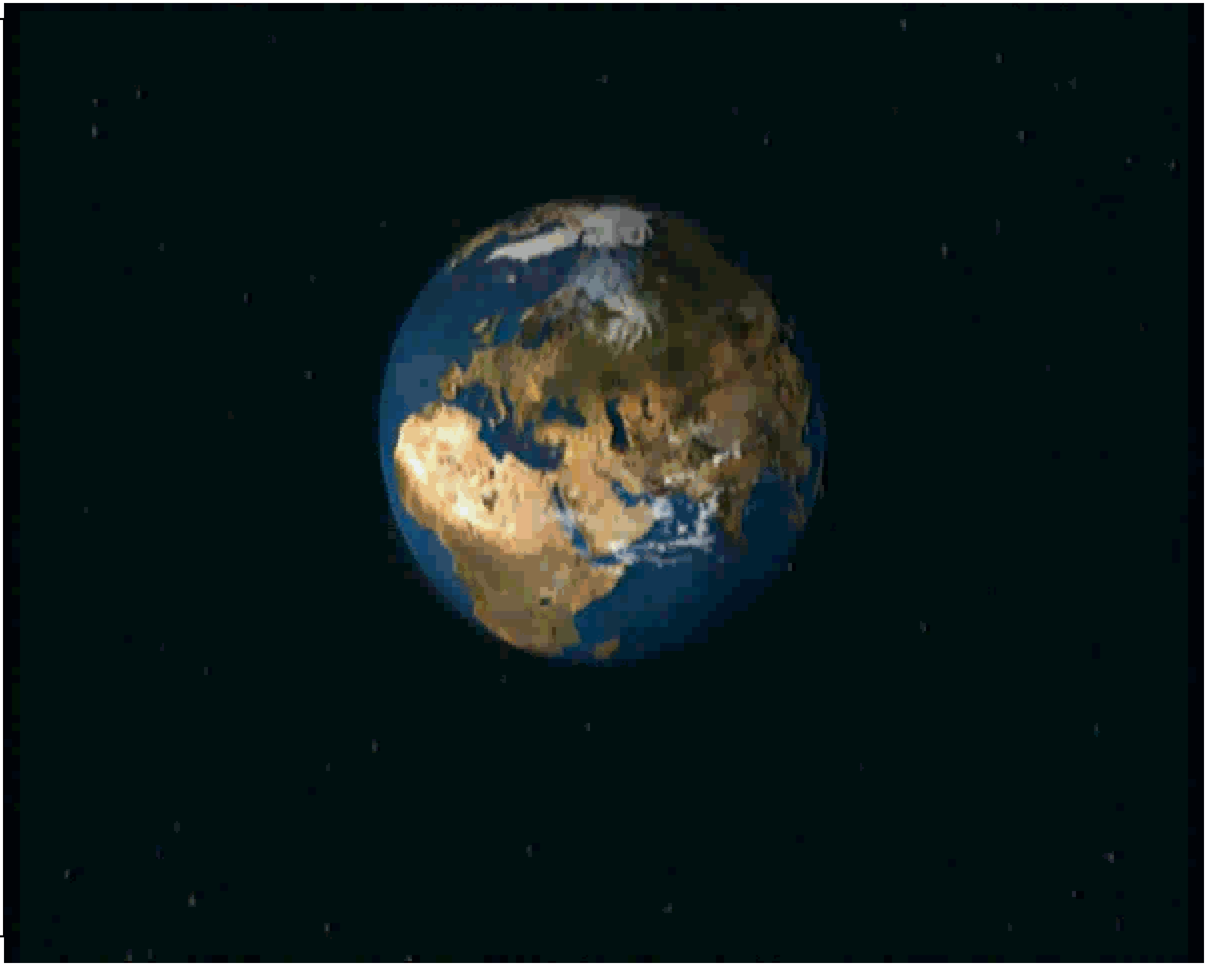
They provide global coverage of selected phenomena using visible, infrared and microwave imagers and infrared and microwave sounders.



Orbital altitudes near 850 km, orbital periods of around 101 min

Geostationary orbits

Geostationary orbits are used for observing the development and evolution of weather phenomena in the tropics and middle latitudes that change on relatively short time scales: their data are used mainly for nowcasting and the determination of atmospheric motion vectors



Orbital altitude of approximately 36,000 km, orbital periods of 24 hours makes the satellite appear stationary above a fixed point above the equator

Comparison of geostationary (Geo) and low earth orbiting (Leo) satellite capabilities

Geo	Leo
observes process itself (motion and targets of opportunity)	observes effects of process
repeat coverage in minutes ($\Delta t \leq 15$ minutes)	repeat coverage twice daily ($\Delta t = 12$ hours)
near full earth disk	global coverage
best viewing of tropics & mid-latitudes	best viewing of poles
same viewing angle	varying viewing angle
differing solar illumination	same solar illumination
multispectral imager (generally lower resolution)	multispectral imager (generally higher resolution)
IR only sounder (8 km resolution)	IR and microwave sounder (1, 17, 50 km resolution)
filter radiometer	filter radiometer, interferometer, and grating spectrometer
diffraction more than leo	diffraction less than geo

The Future of Environmental Satellite Monitoring: Challenges of Metamorphosis

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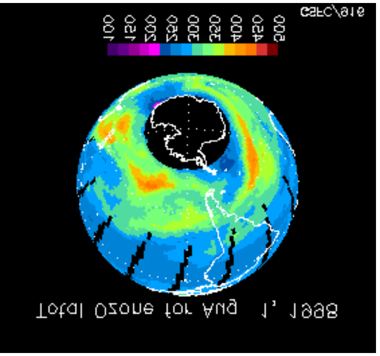
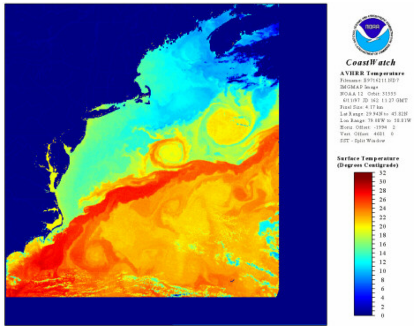
CIRA
Colorado State University, Fort Collins, CO 80523

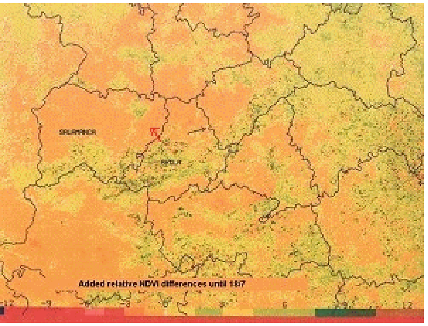
Meteorological



Climate

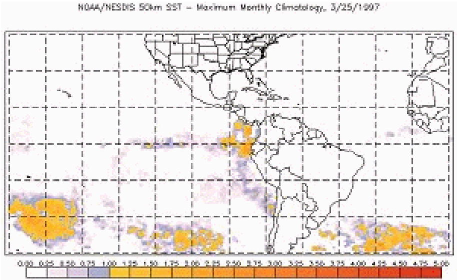
Ocean



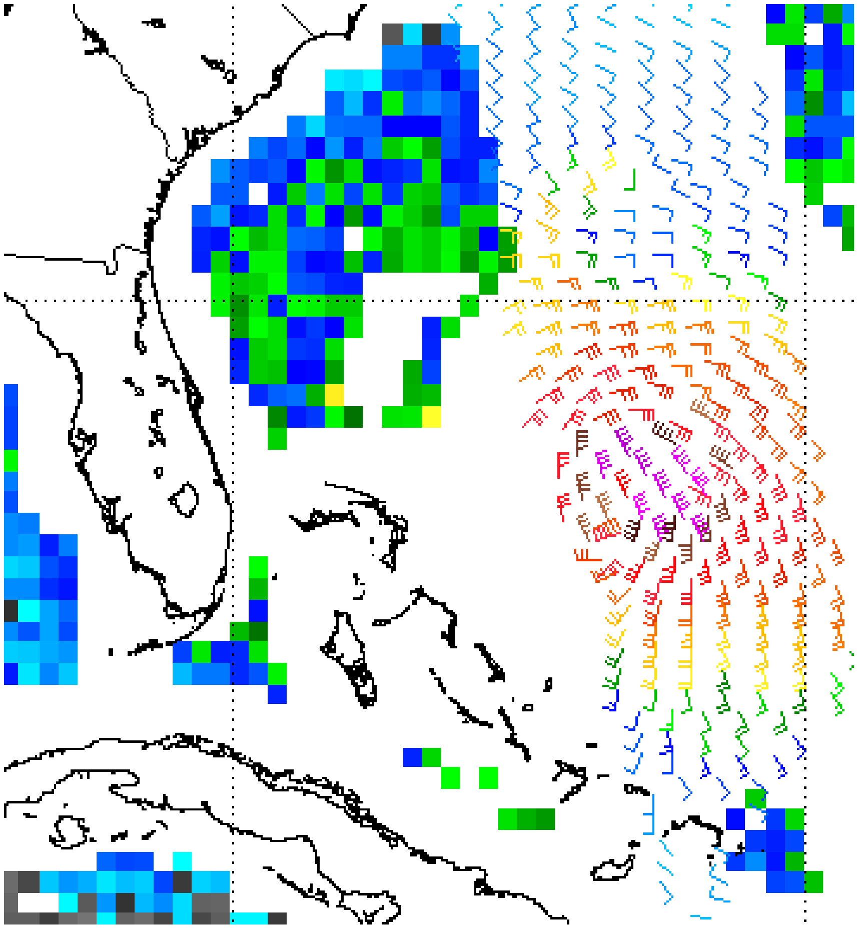


Land

Ecological



We utilize a composite satellite system: geostationary, polar and other



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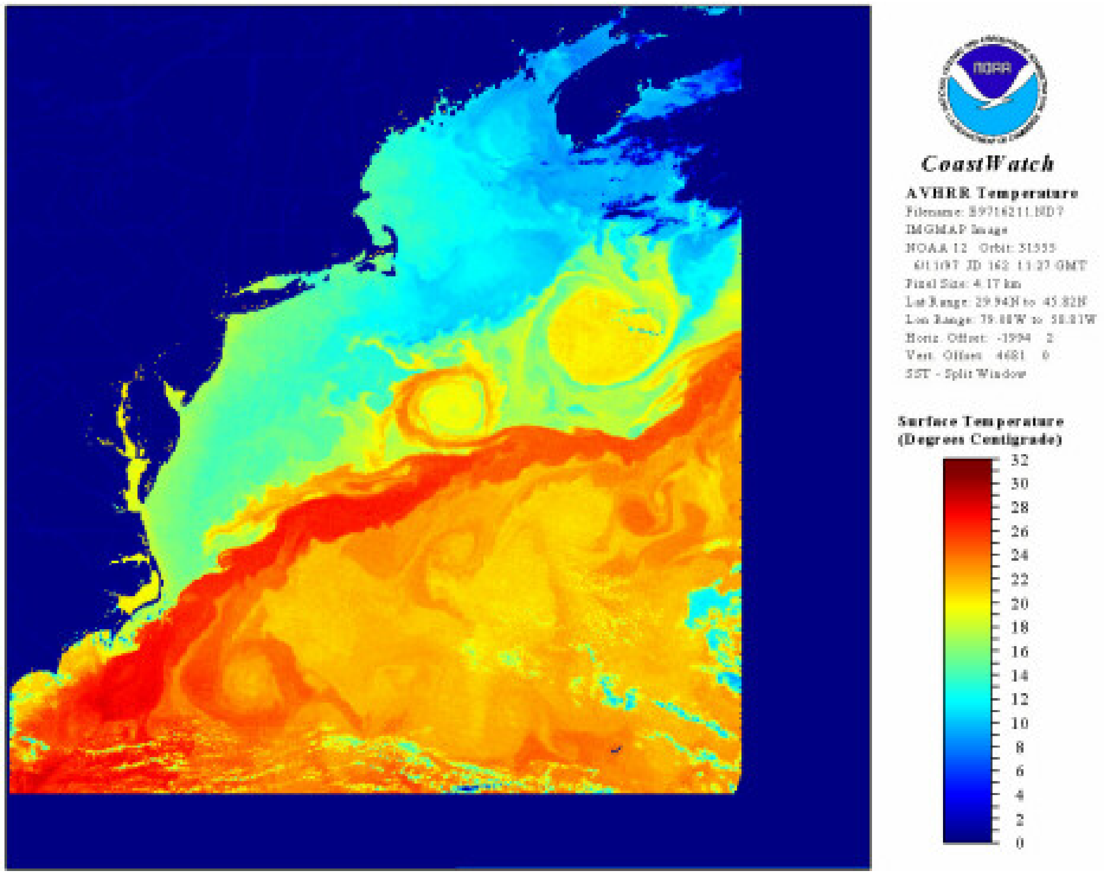

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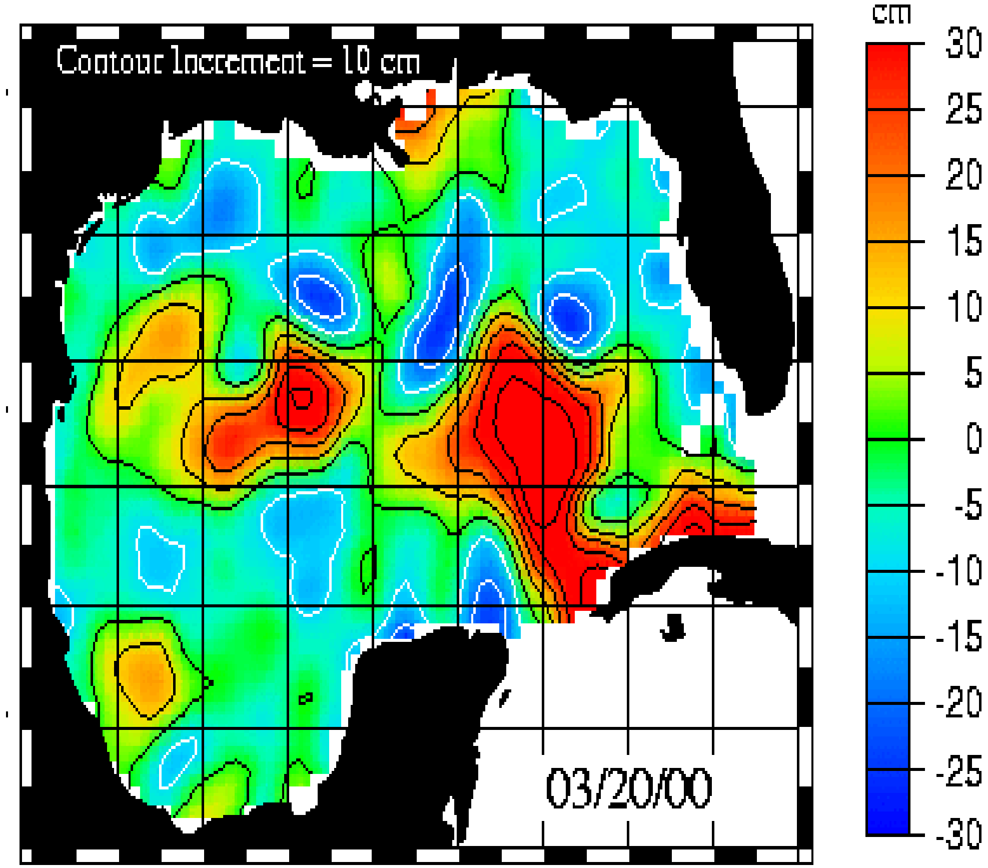

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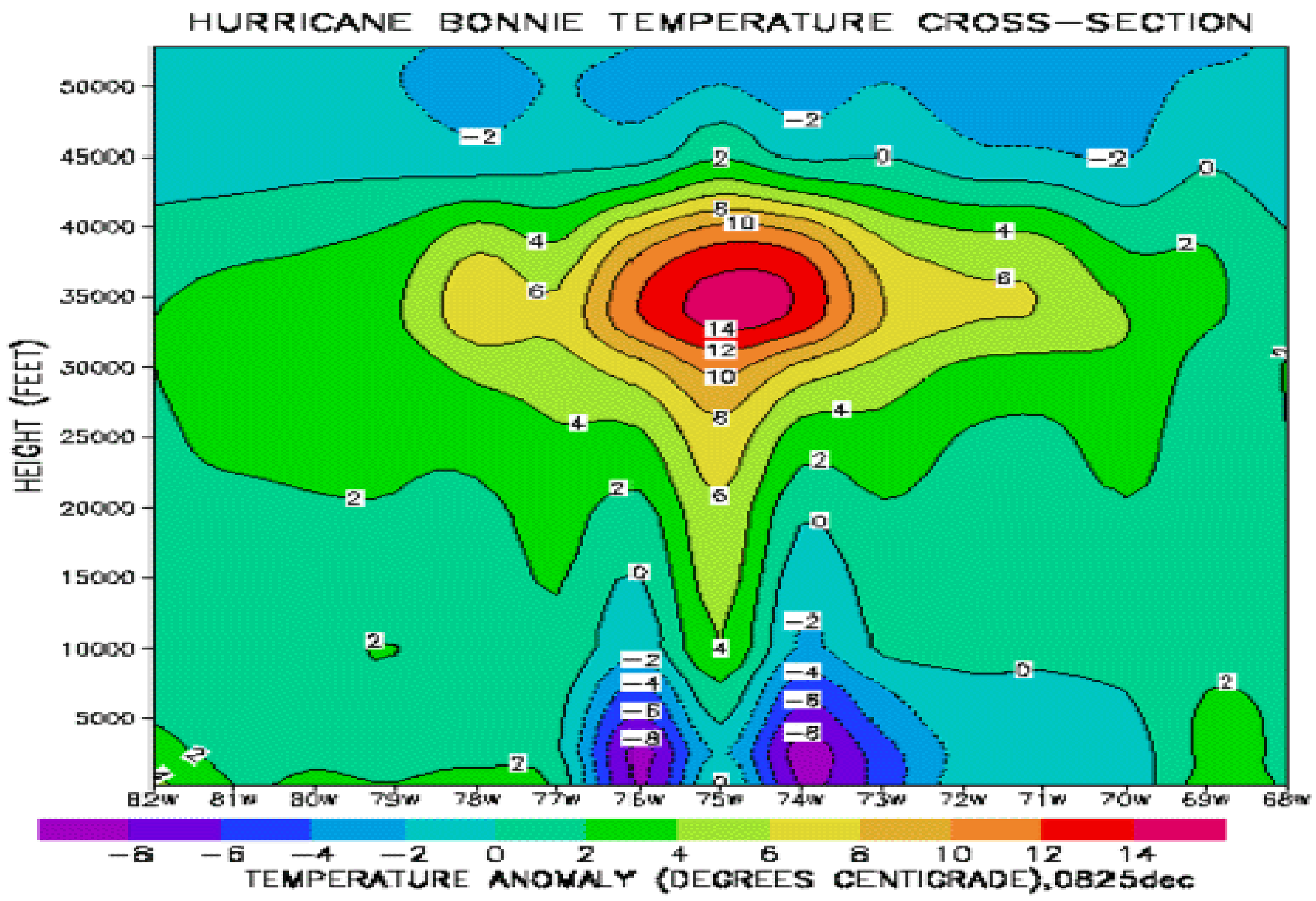
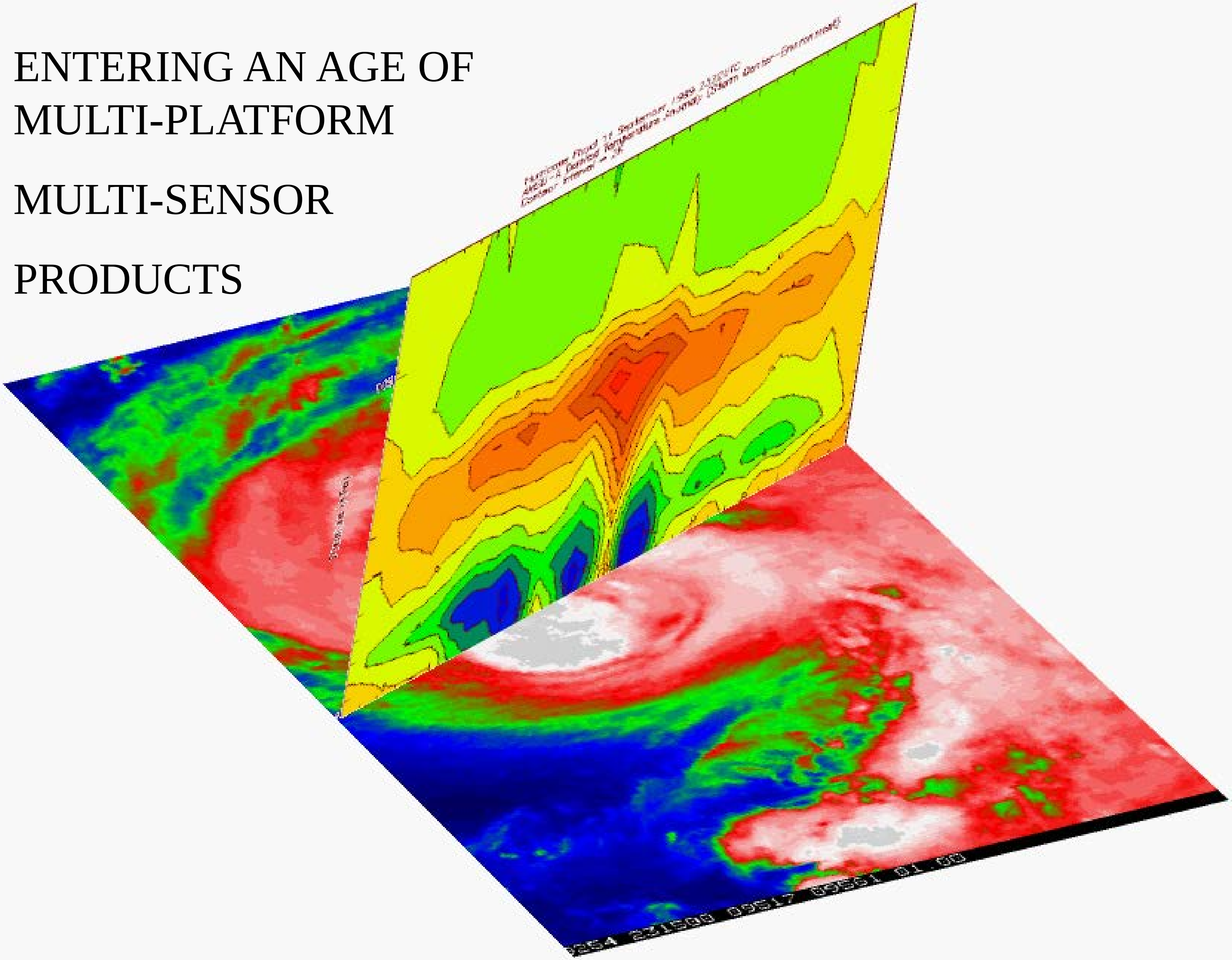


ENTERING AN AGE OF
MULTI-PLATFORM

MULTI-SENSOR

PRODUCTS



3 hourly polar

- 3 hourly microwave