Microwave Imagery

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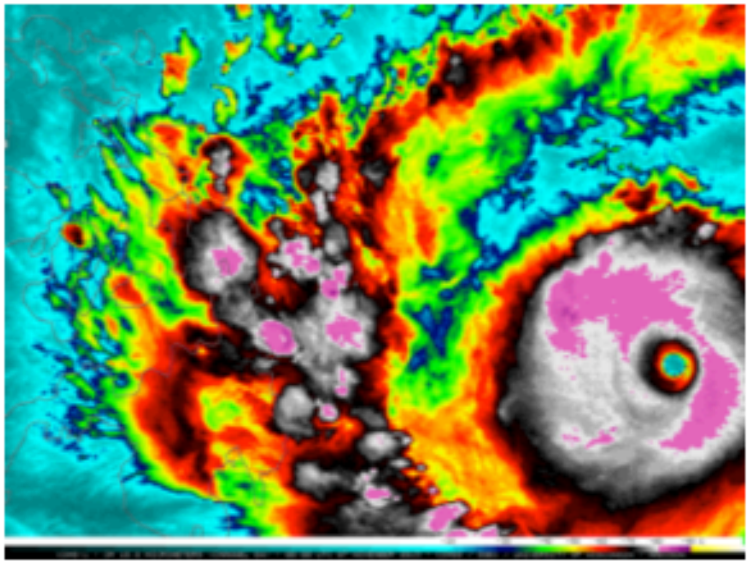
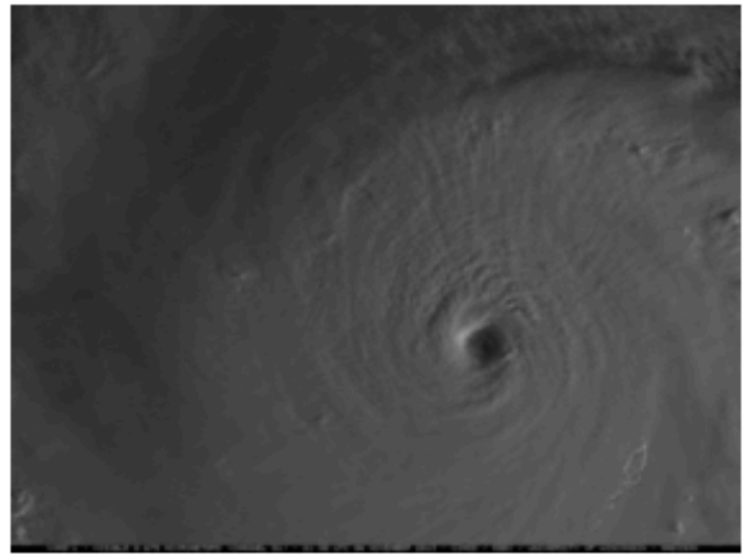
UW-Madison
CIMSS

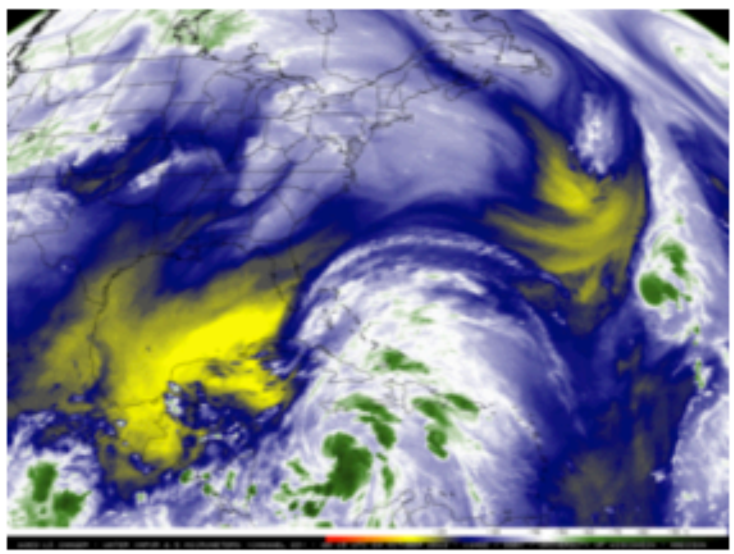
CIMSS

S FCDR of 37.0 GHz horizontally polarized brightness temperature DMSP F14 SSM/I 13 October 19

Why Do We Even Need Polar Imagery?



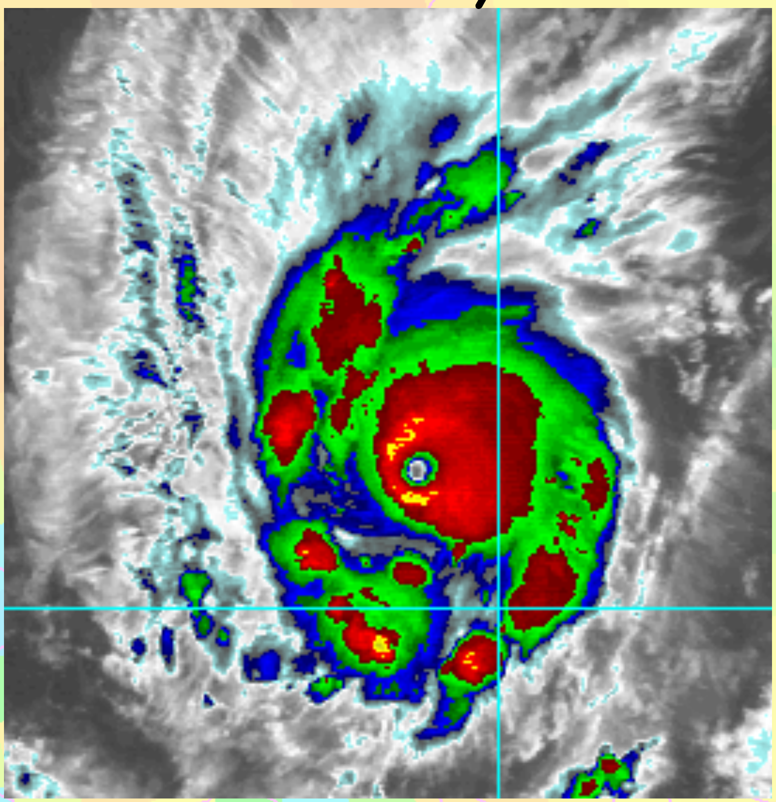




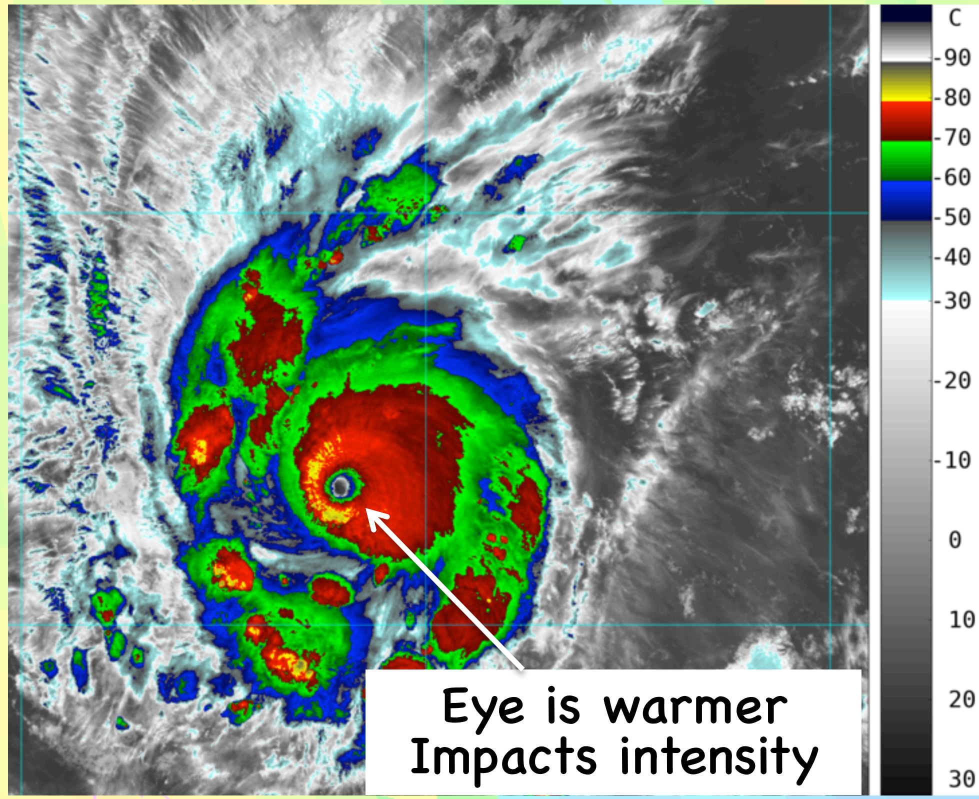
Why Do We Need Polar Imagery?

Better Resolution

Geostationary 4 km



VIIRS 0.75 km



Better Resolution is very important with microwave data because microwave is low-energy. As you move farther from the source, you need a bigger and bigger antenna to acquire the signal

FCDR of 37.0 GHz horizontally polarized brightness temperature DMSP F14 SSM/I 13 October 19

What is available from the Satellite ATMS on Suomi NPP / NOAA-20

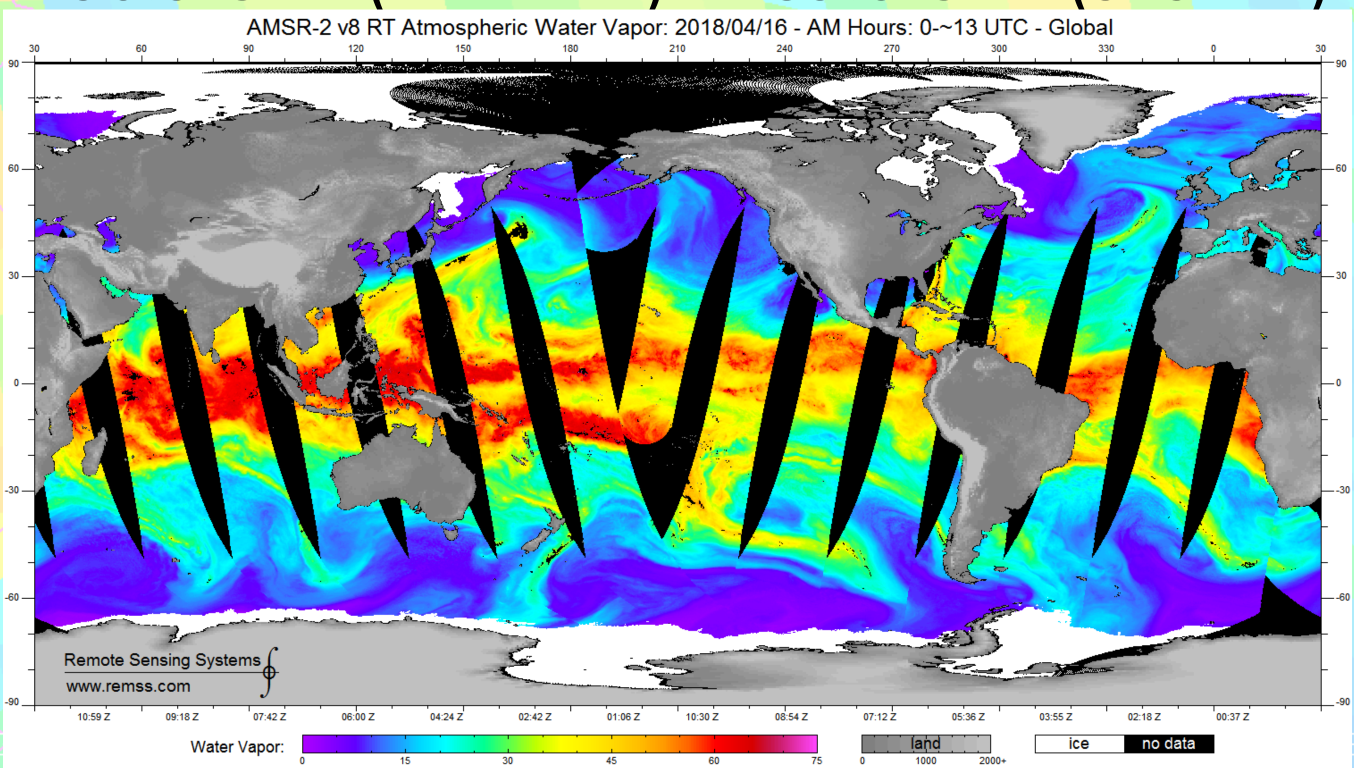
ATMS Channel Characteristics and Applications

Central Frequency (GHz)	Application	Footprint Size: Nadir View (km)	Footprint Size: Edge of Scan (km, Δy by Δx) Δy: Satellite's orbiting direction Δx: Perpendicular to satellite's orbiting direction
23.8 31.4	• Total precipitable water vapor • Precipitation • Integrated cloud liquid water • Integrated cloud ice water • Snow and ice cover characteristics (ice concentration, snow water equivalent) • Land surface temperature	75 x 75	142 x 323
50.3 51.76 52.8 88.2		32 x 32	60 x 137
53.6 – 57.29 (10 channels)	• Atmospheric temperature sounding	32 x 32	60 x 137
165.5 183.31 +/- 1 to 183.31 +/- 7 (5 channels)	• Atmospheric moisture sounding	16 x 16	30 x 68

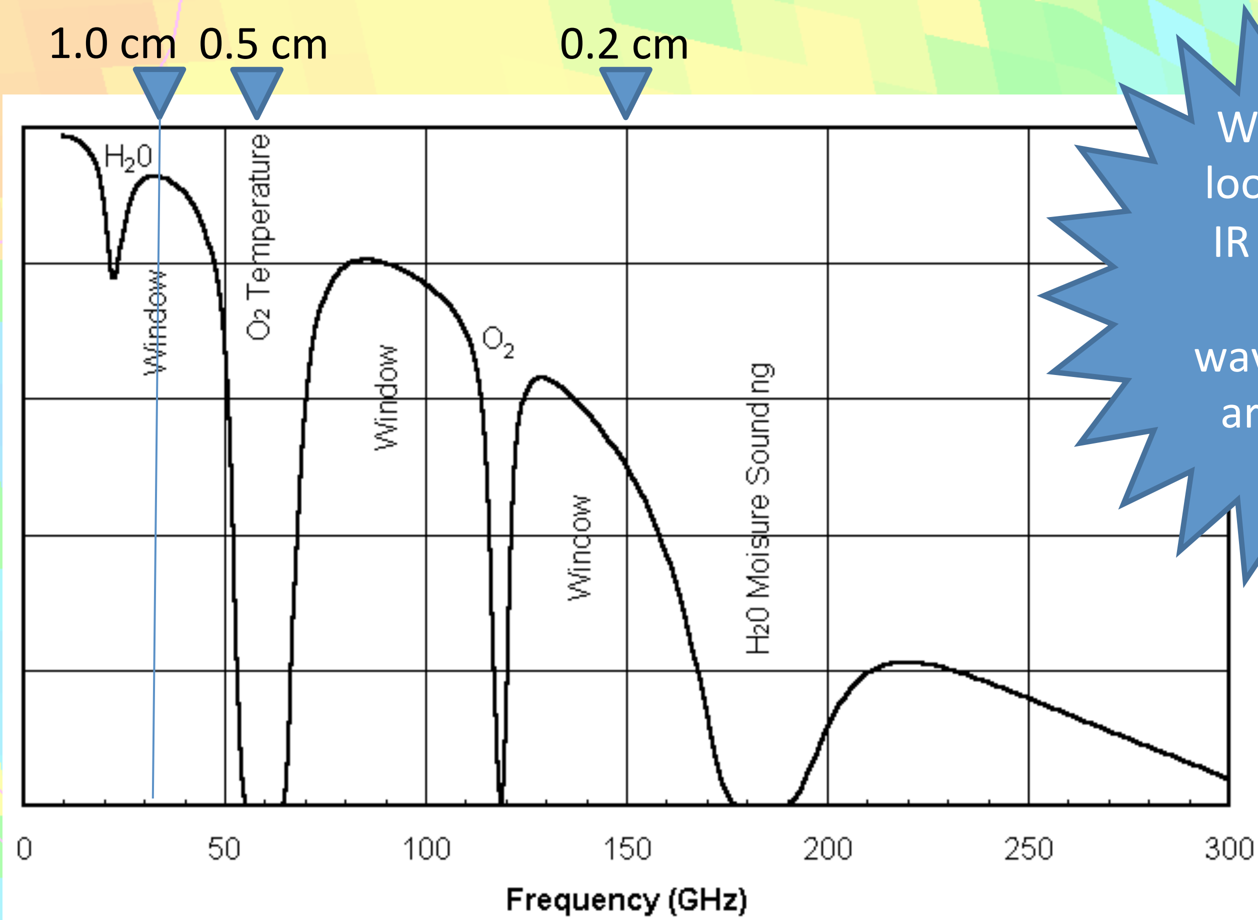
Note how resolution increases as Ghz increases

AMSR-2 on GCOM

- Similar to AMSR-E on Aqua (stopped in 2011)
- 0130/1330 Equatorial crossing
  - 36.5 Ghz (12x7 km) 89.0 Ghz (5x3 km)



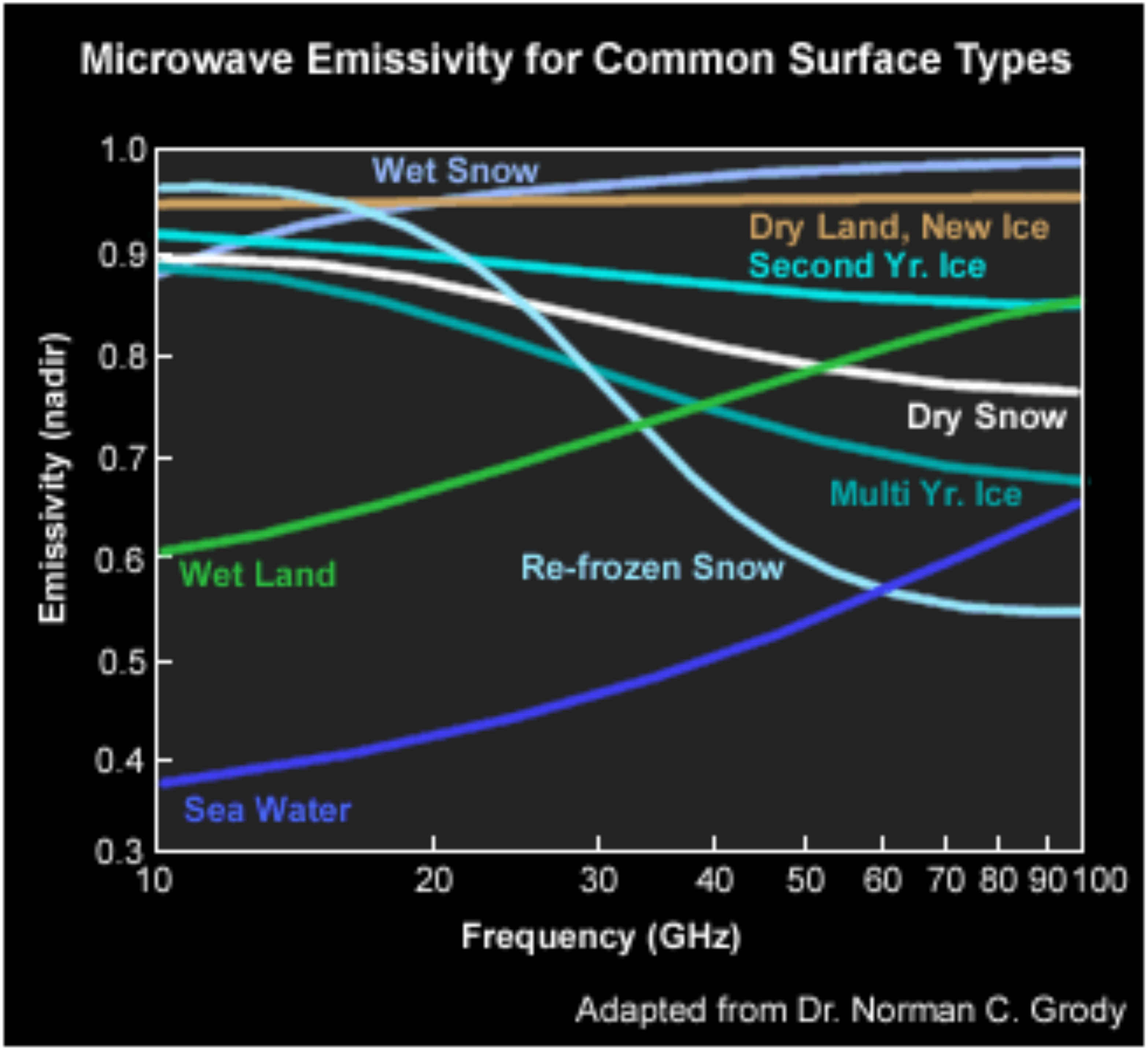
Microwave wavelengths and absorption bands



When you look at VIS/IR Spectra, short wavelengths are to the right!

wavelength increases   energy increases

Most Microwave Ovens. 2.45 GHz, Wavelength: 12.2 cm, ~ 5 inches – but that's liquid water absorption, not vapor


Microwave Emissivity for Common Surface Types
Emissivity (nadir)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
10
20
30
40
50
60
70
80
90
100
Frequency (GHz)
Wet Snow
Dry Land, New Ice
Second Yr. Ice
Dry Snow
Multi Yr. Ice
Wet Land
Re-frozen Snow
Sea Water
Adapted from Dr. Norman C. Grody

The impact of emissivity

- Scattering by large precipitation particles, especially by snowflakes above the freezing levels, causes 85 GHz brightness temperatures (Tb) to be low. Thus, convective rainbands tend to have very low Tb, often lower than 200 K. On the other hand, emission from low-level clouds and water vapor raises Tb as high as 280 K.
- Emission effects from the storm atmosphere often completely hide the view of the surface of the ocean from the satellite, but away from the storm, the low- emissivity surface of the ocean can be detected. In these regions the ocean Tb is relatively low, between 200 and 250 K.
- 85 Ghz: you see “cold” clouds against a warm sea background
- 31 Ghz: you see “warm” clouds against a cold sea background

$$R = \varepsilon \sigma T^4$$

Contrast!

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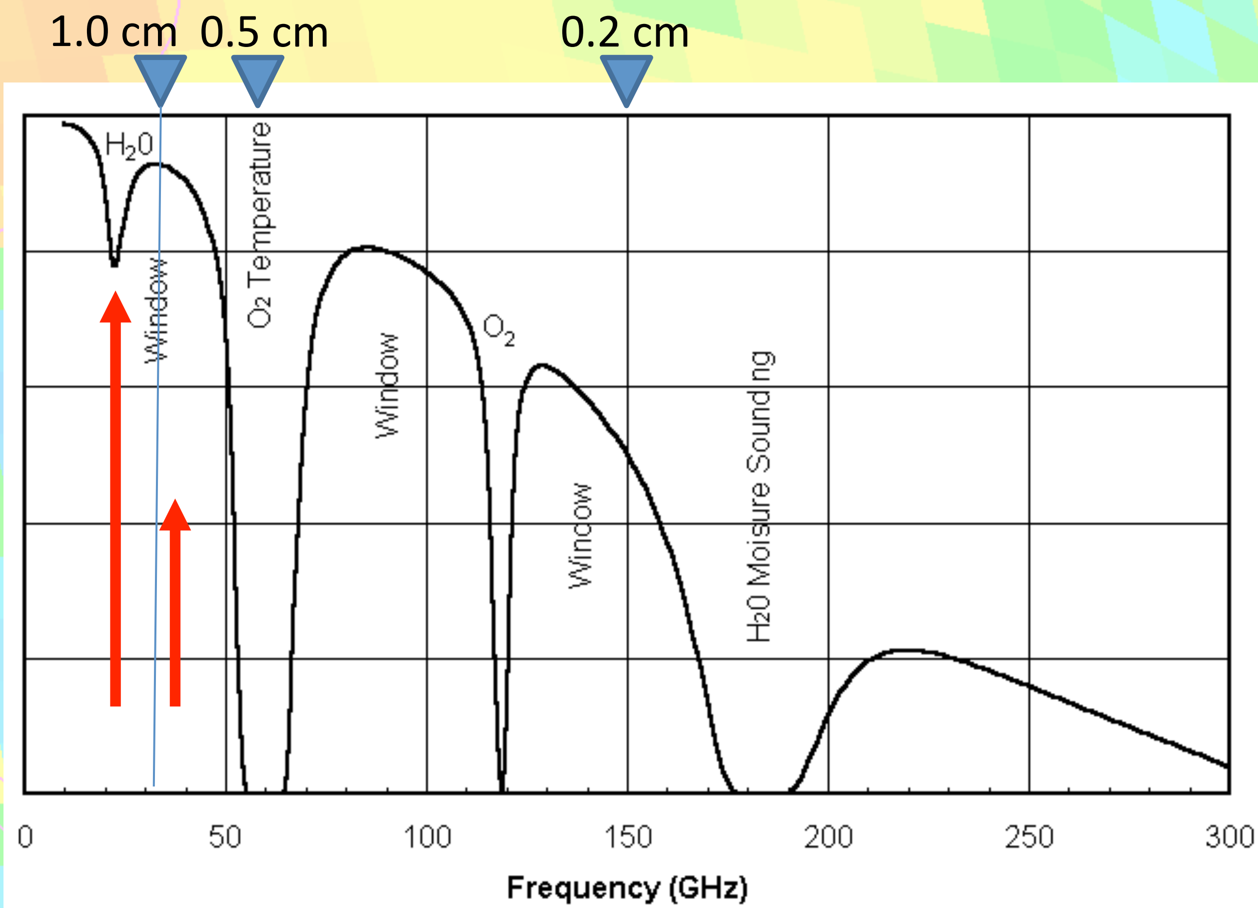
Note here: GHz larger: Resolution Smaller!

Platform	Frequency (Ghz)	Resolution (km)	Swath Width (km)
SSMI	37	25	1400
	85	12.5	
SSMIS	37	25	1700
	91	12.5	
TRMM*	37	12	878
	85	5	
AMSR-E	36	12	1600
	89	5	
WindSat	37	11	1025
AMSU	89	16	2345

Geostationary Satellites have no microwave sensors because the amount of energy available to be detected is too small

Microwave wavelengths



23 GHz: (weak) absorption by water
37 GHz: no absorption by water

Difference between the two: A function of TPW

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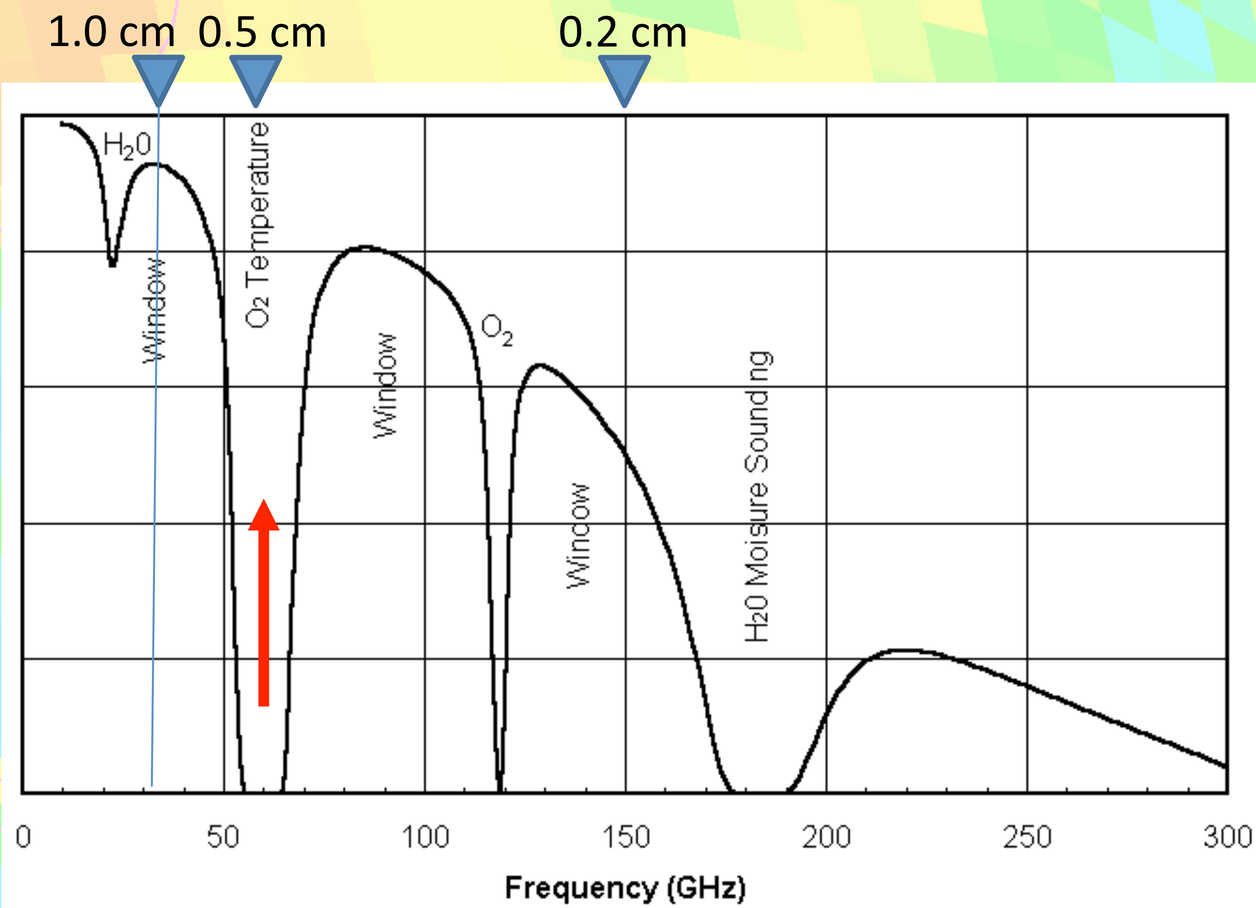
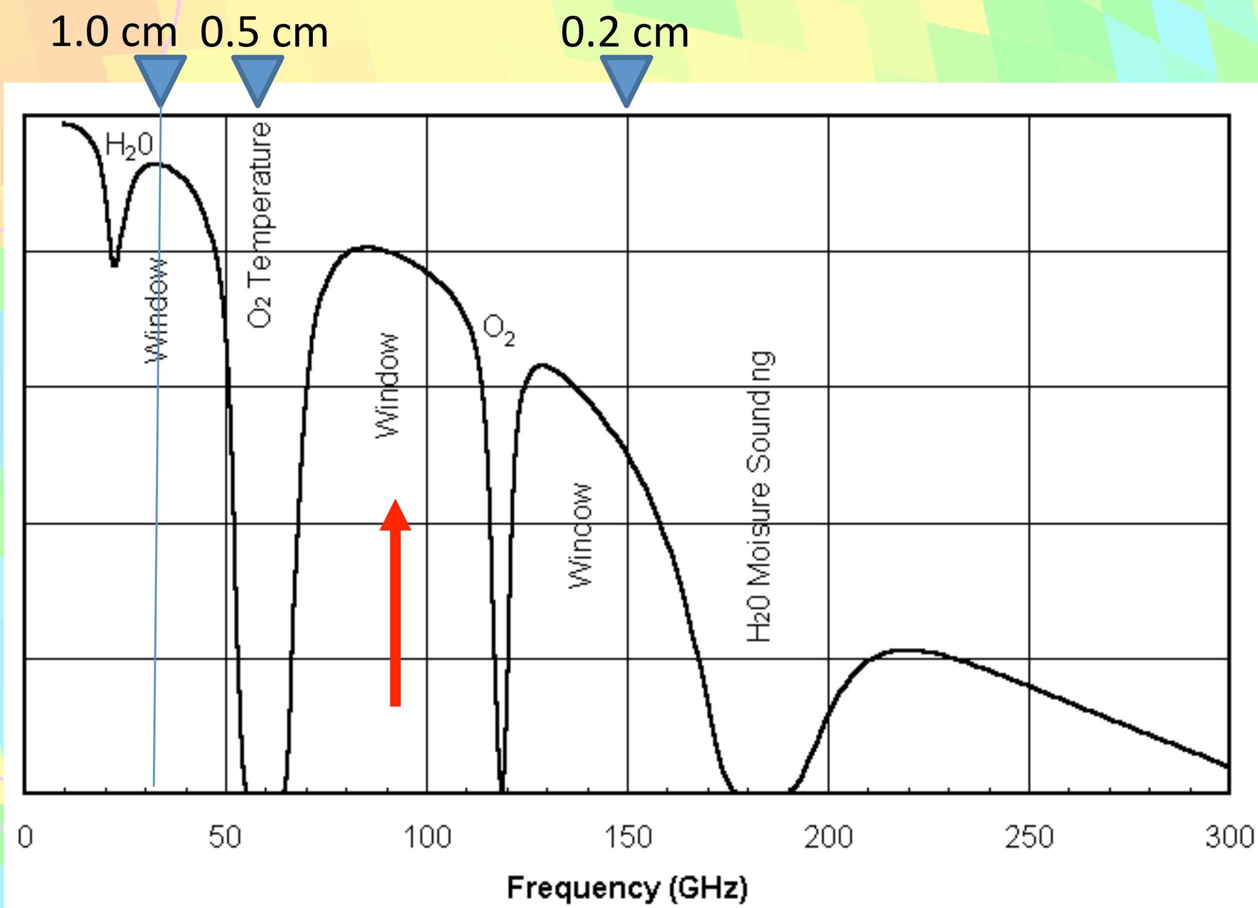
Microwave wavelengths



50-58 GHz: absorption by oxygen

Microwave data in this band are used to show vertical temperature profile information

Microwave wavelengths



85-92 GHz: scattering is important

Microwave data in this region is scattered mostly by frozen hydrometeors

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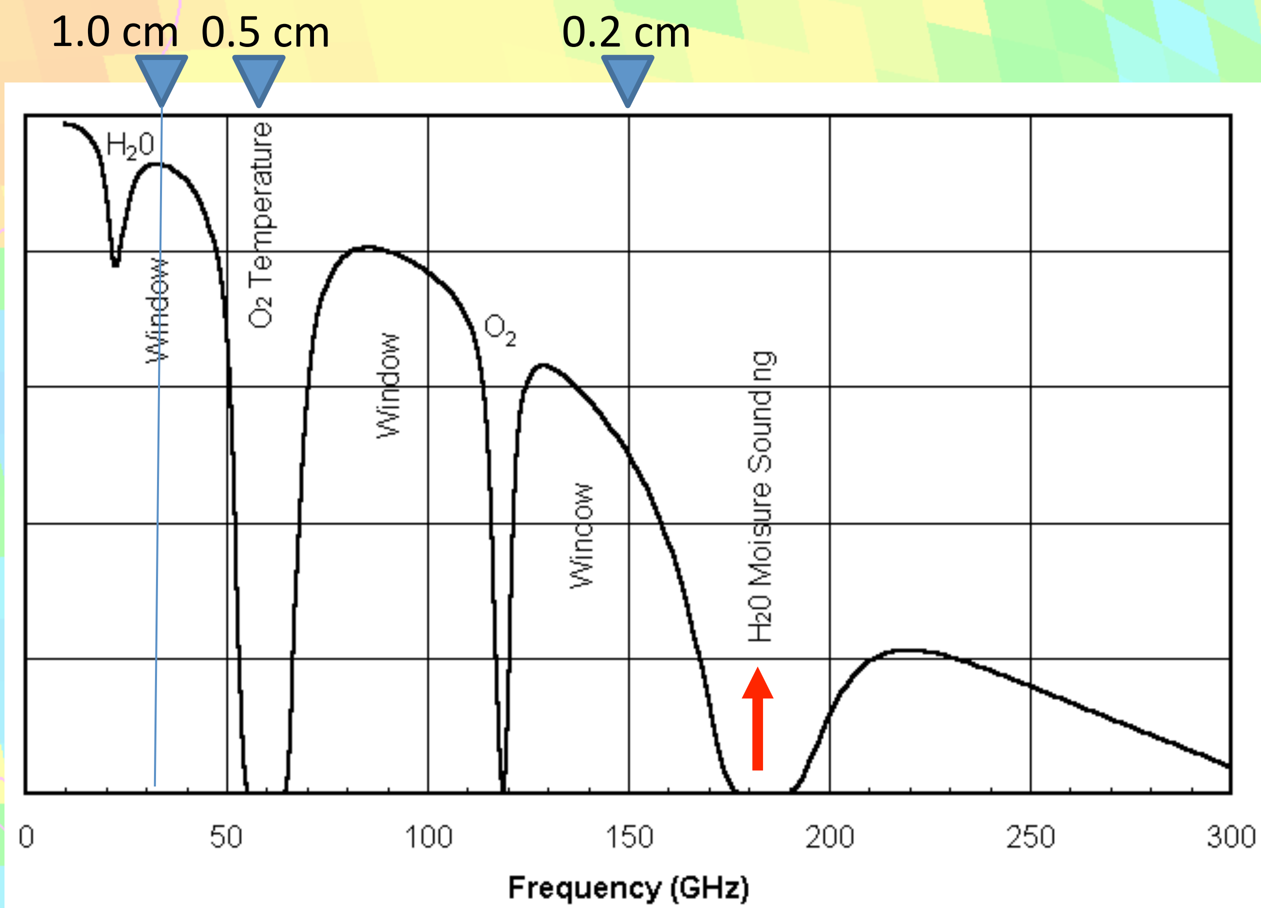
Microwave wavelengths



180-190 GHz

Microwave data in this region is gives water vapor information

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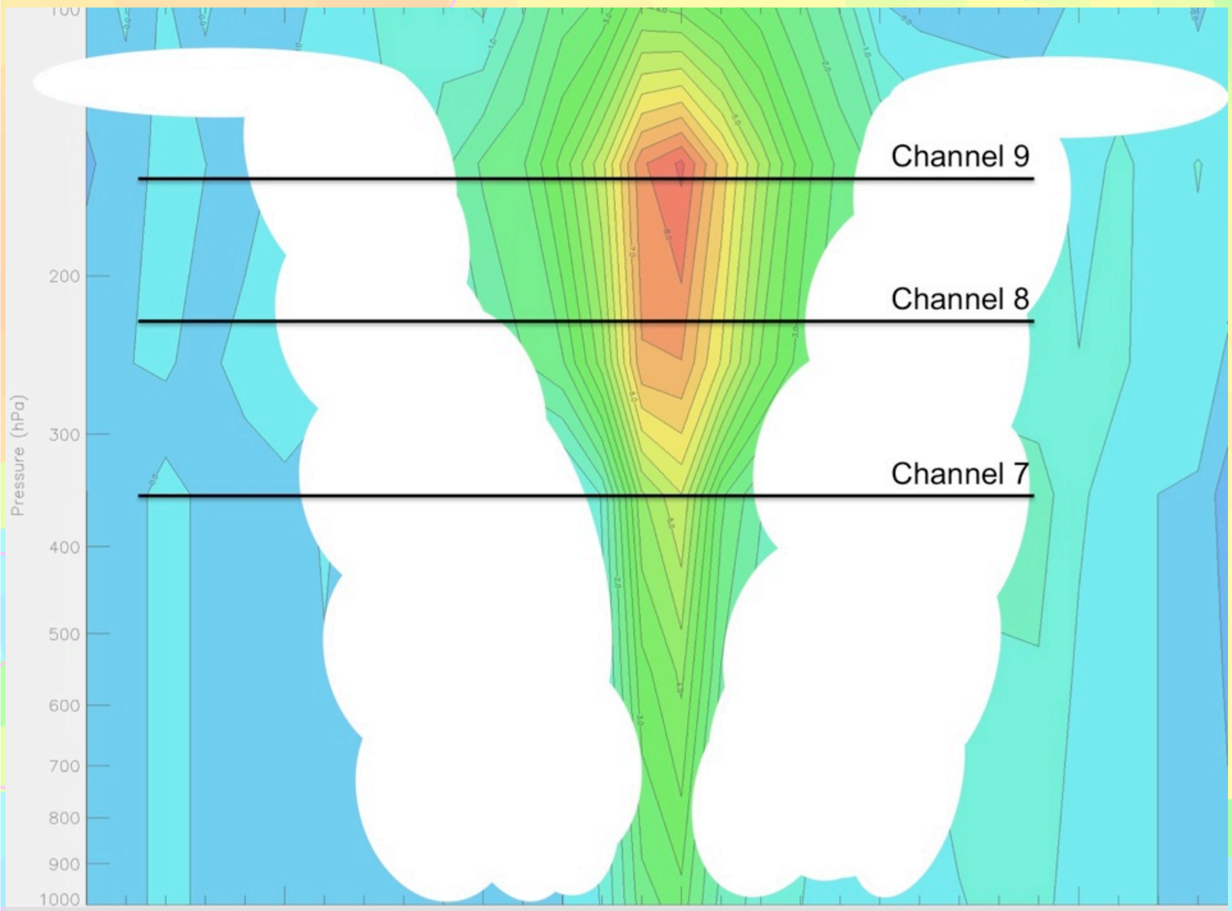
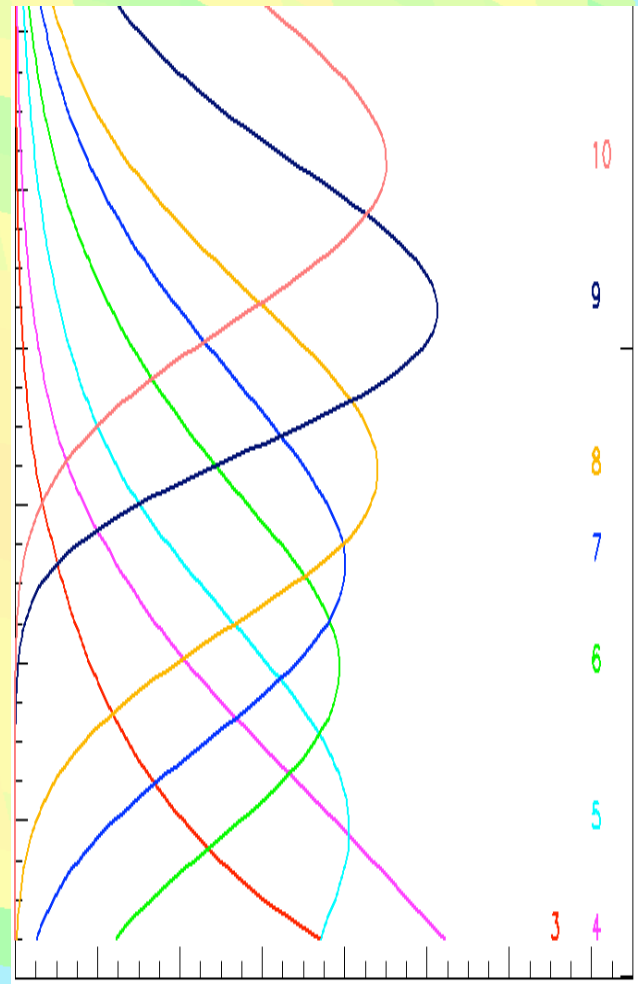
TC Intensity Analysis: Sounders

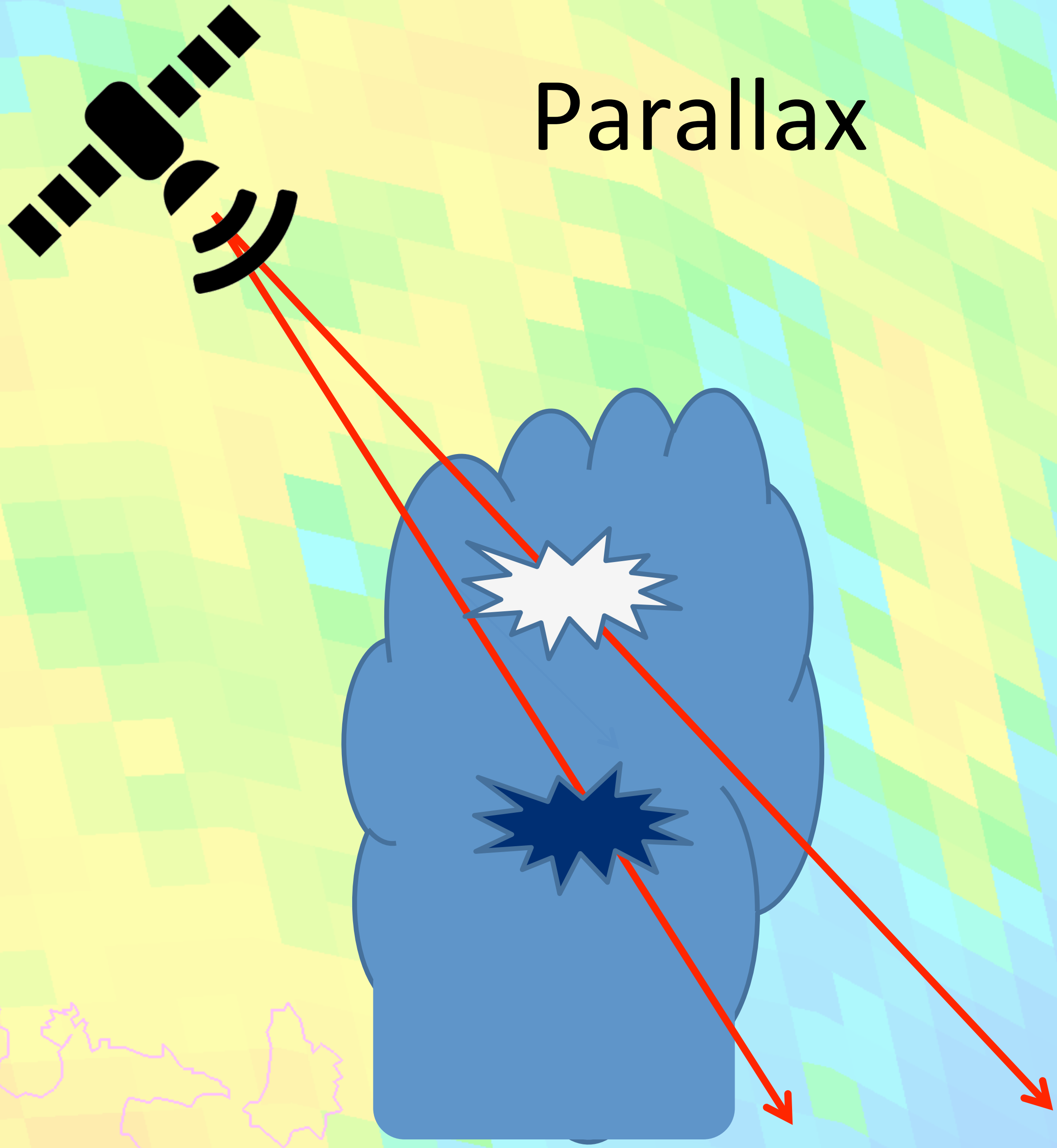
CIMSS ATMS Vertical Cross Section of Tb Anomaly for Typhoon Lekima





ATMS Weighting Functions for channels 3-10

Parallax



Important Underlying Assumption

Satellite Navigation assumes clear skies

Receiving information from a specific angle, navigation places it on the land

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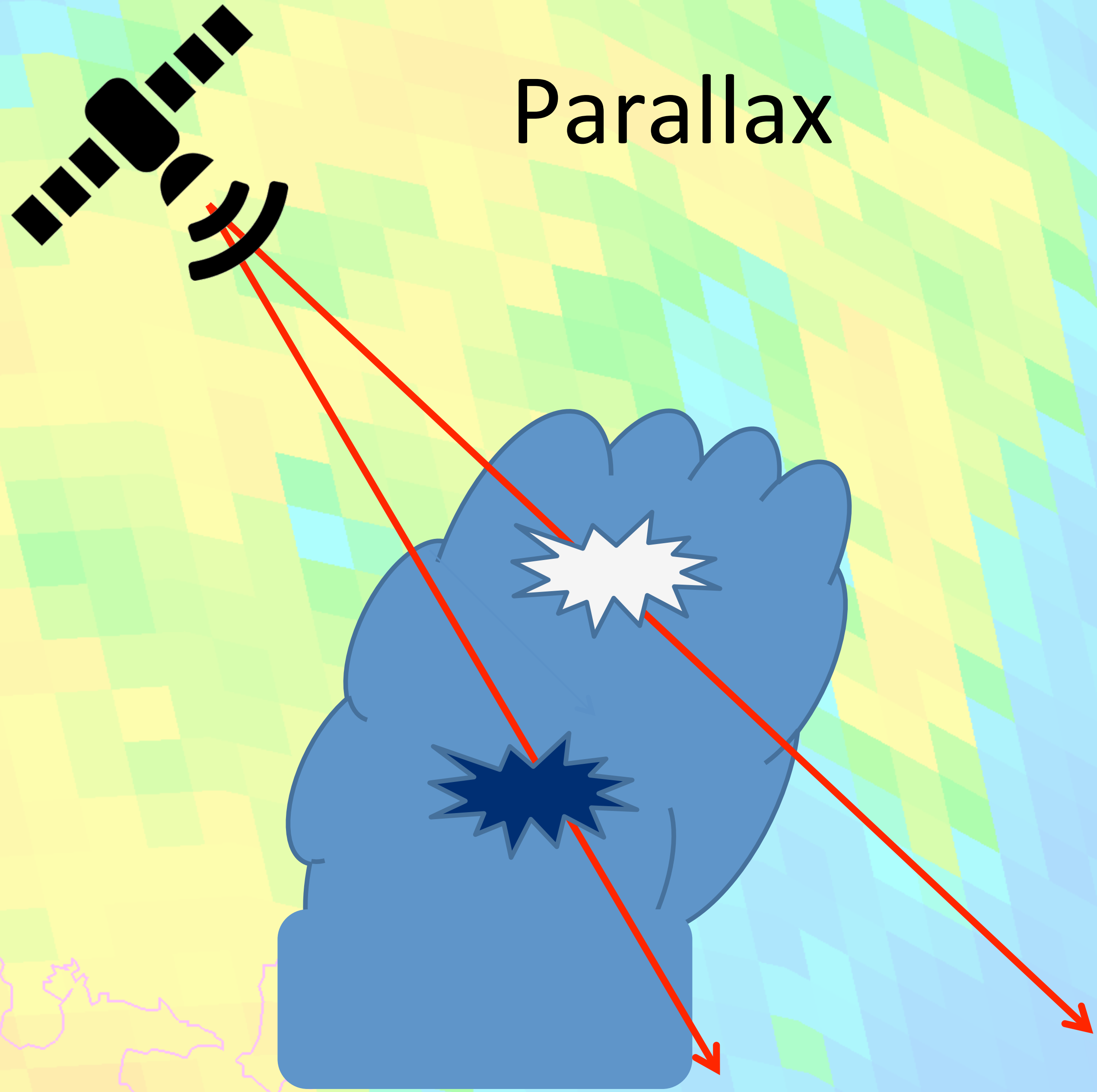
Parallax



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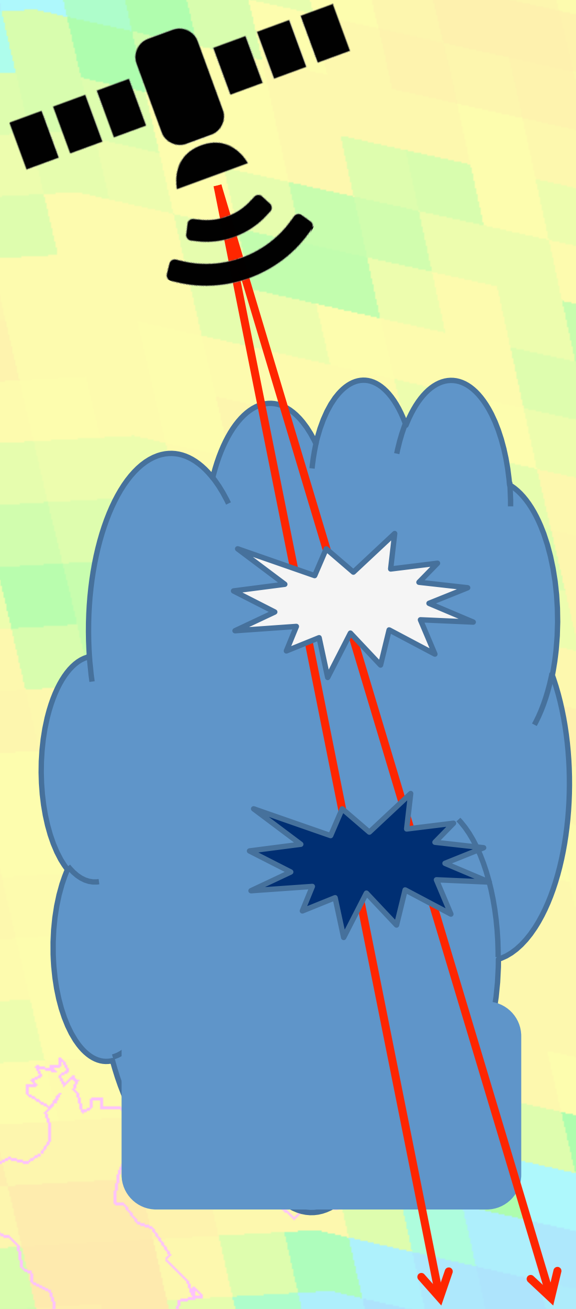
Sheared away from Nadir

Parallax



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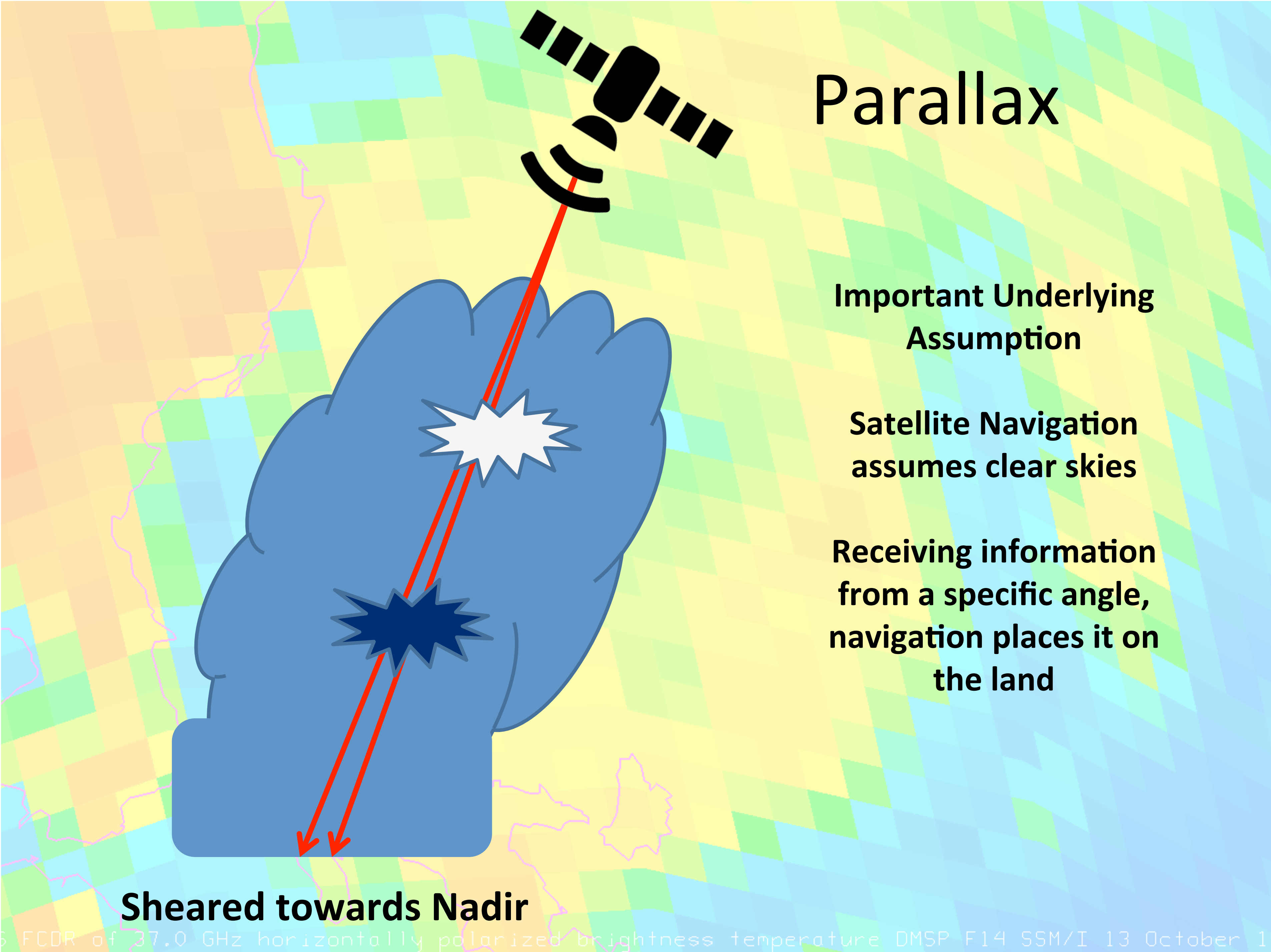
Parallax
Important Underlying Assumption
Satellite Navigation assumes clear skies
Receiving information from a specific angle, navigation places it on the land
Sheared towards Nadir
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37 GHz Microwave Data

- Energy leaves the surface, some absorption by rain drops, but little scattering. More of the emitted energy from the surface/lower part of the cloud is detected by satellite: Warmer Brightness Temperatures
- **You see more of the warm rains at 37 GHz**
- Less energy, so lower resolution than 89 GHz
- Smaller parallax error because you're detecting lower in the cloud
- **Use 37 GHz to find centers** – because at 89 GHz you might have more parallax error
- Parallax Error: Or Effects of Shear tilting the storm?

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89 GHz Microwave Data

- Energy leaves the surface, and it's absorbed by water droplets, and scattered by cloud droplets and large ice crystals. Not a lot of the surface emissions makes it to the satellite – because of scattering in the cloud: Cool brightness temperature
- You see more of the ice precipitation in the cloud because the warm rain signal is scattered out
- Typically highest resolution
- Higher Parallax error at 89 GHz because you are seeing higher in the cloud

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“Poor Man’s Radar”

- Cirrus Canopies obscure infrared information – but cirrus canopies are transparent to 85 GHz energy. 85 GHz imagery can reveal the lower structure of the storms. You get views of tropical cyclones from space that used to be available only from coastal radars and aircraft penetrations.

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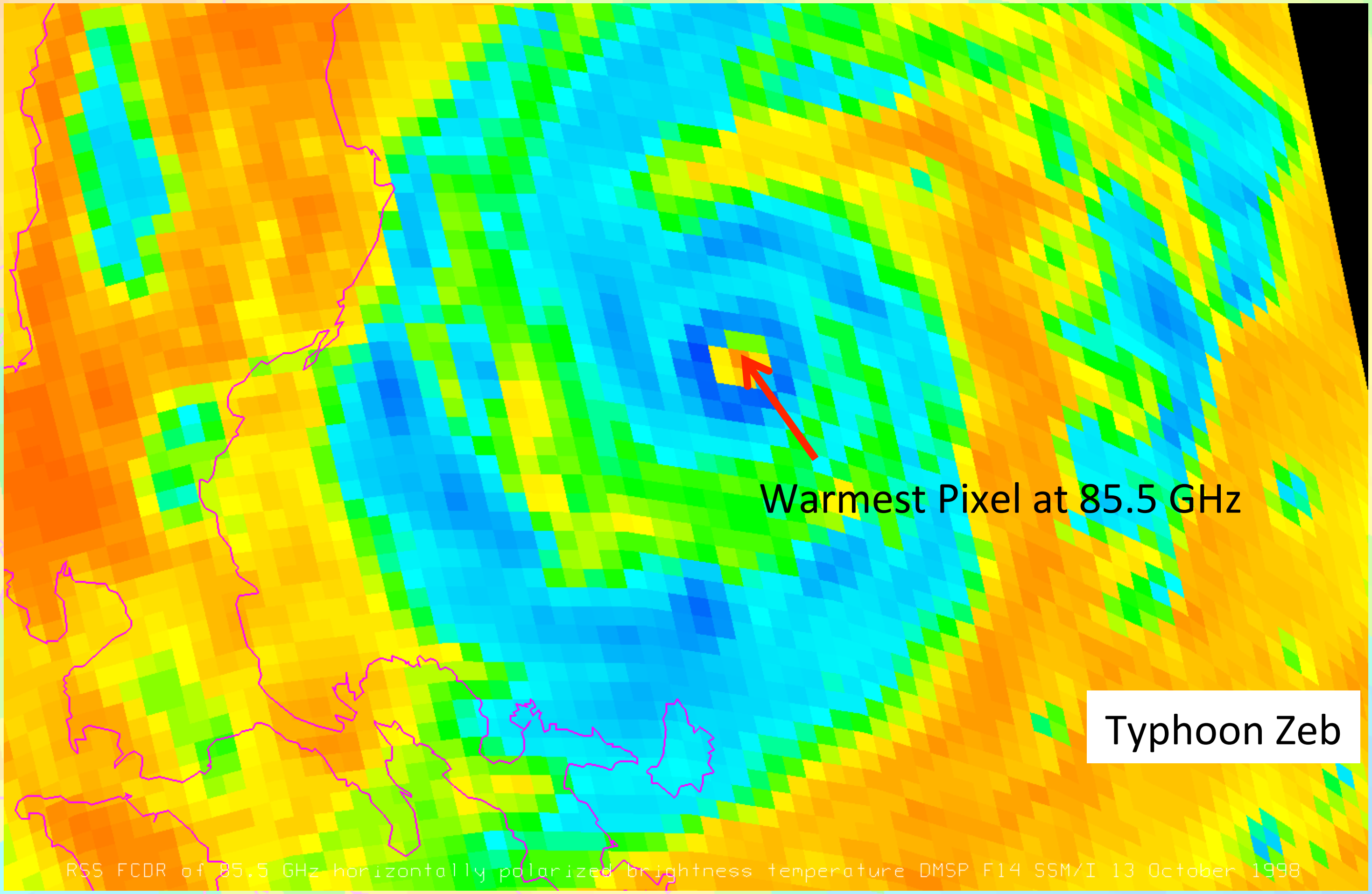
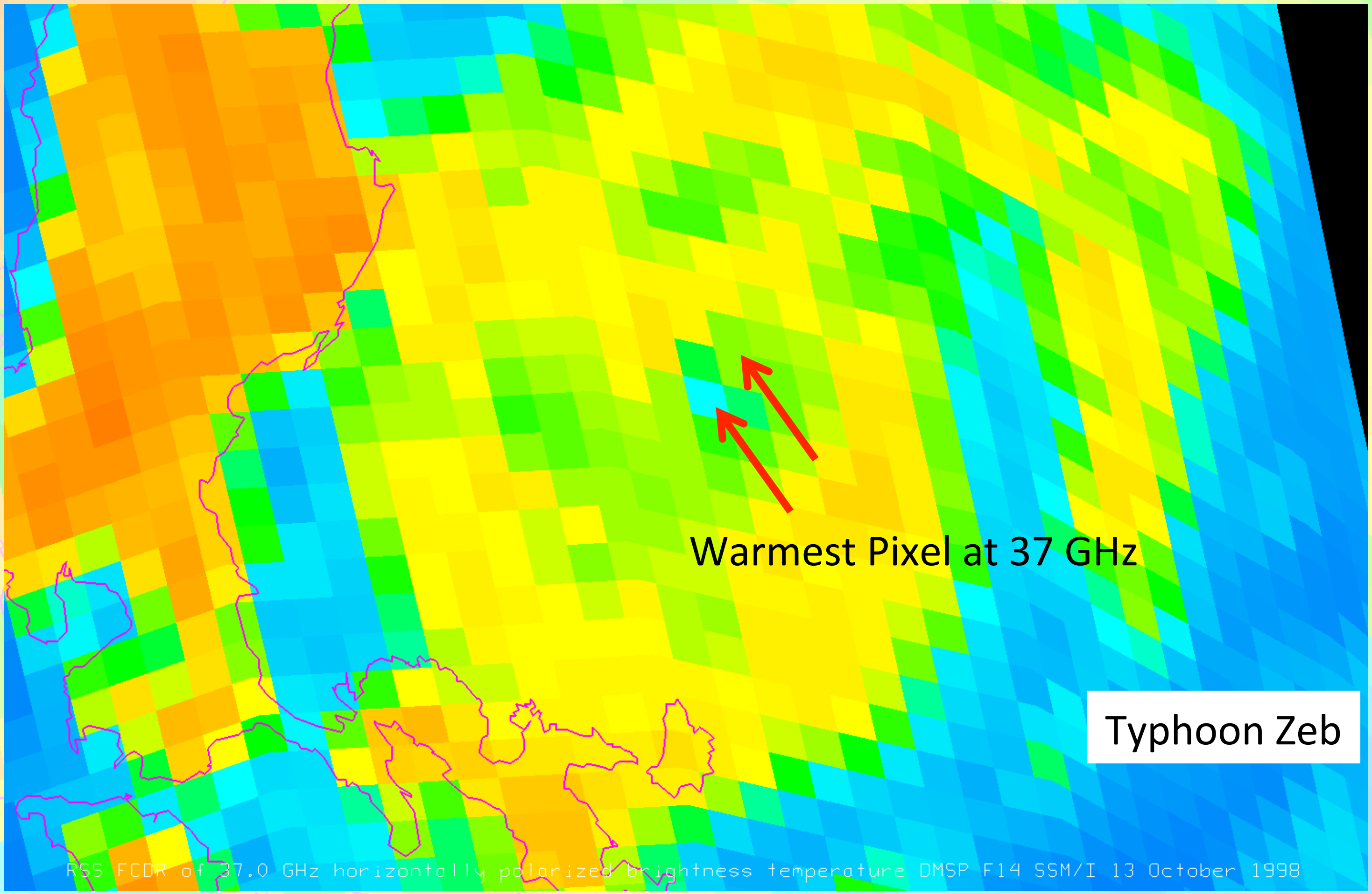
F14 (DMSP) 13 Oct 1998 85.5 GHz



Where is the storm center?

F14 (DMSP) 13 Oct 1998 37.0 GHz



What about 37 Ghz

- Images of 37 GHz are valuable for two main reasons: First, this frequency is sensitive to low-level rain, not large ice particles in convection aloft. It is insensitive to most of the precipitation-sized ice particles that appear on 85 GHz images. Thus, 37 GHz can provide images of the lowest rainbands within a storm.
- Secondly, 37 GHz images show the spatial variations in rain magnitude near the center of the storm. Such variations often do not appear on images of 85 GHz because this frequency "washes out" over heavy rain clouds.

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NRL Training and webpages that are useful!

- https://www.nrlmry.navy.mil/training-bin/training.cgi
  - (Tropical Cyclones -> TRMM -> Tmi_37v)
  - (Tropical Cyclones -> SSMI -> 85h)
- https://www.nrlmry.navy.mil/tc_pages/tc_home.html

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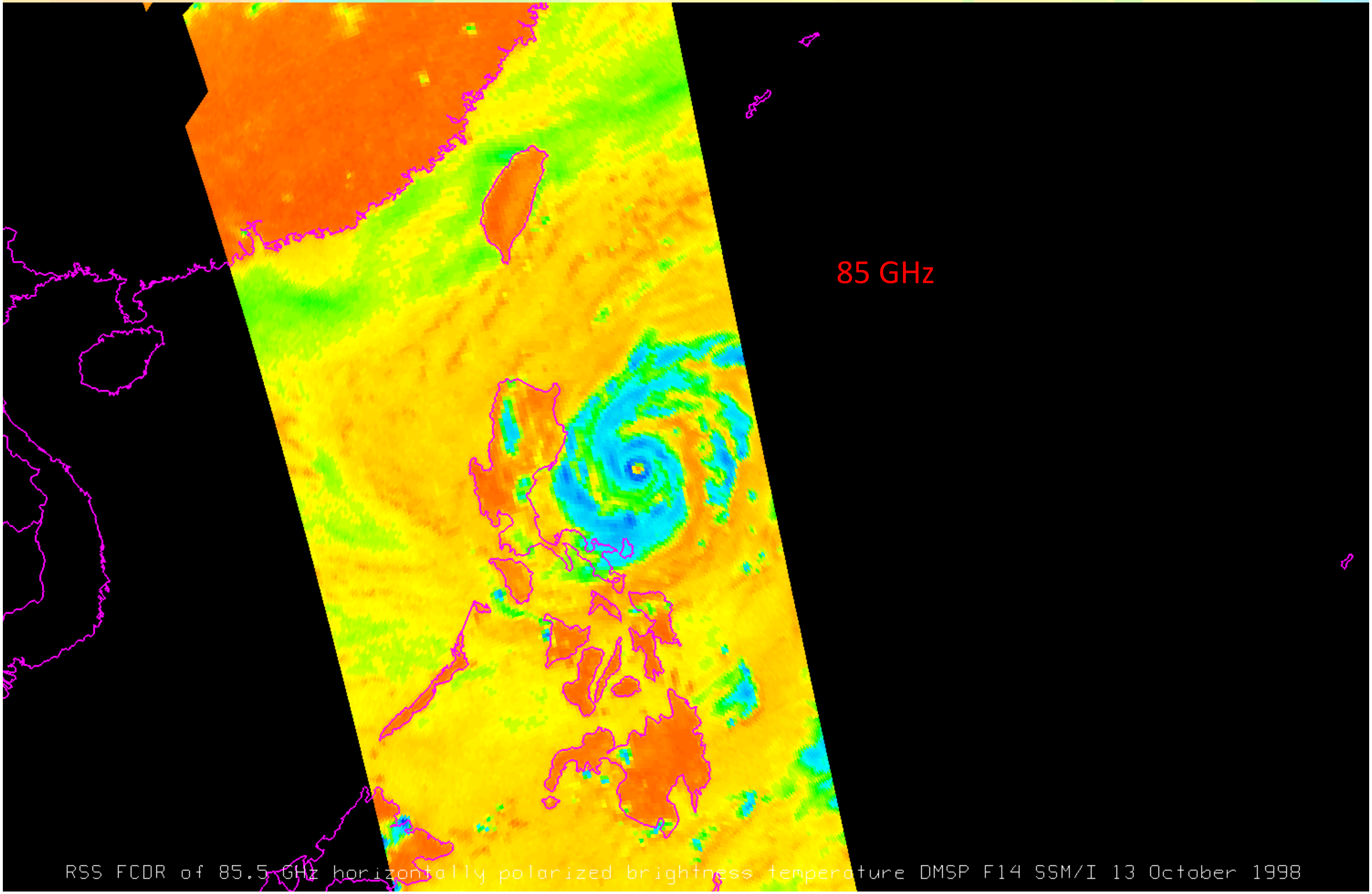
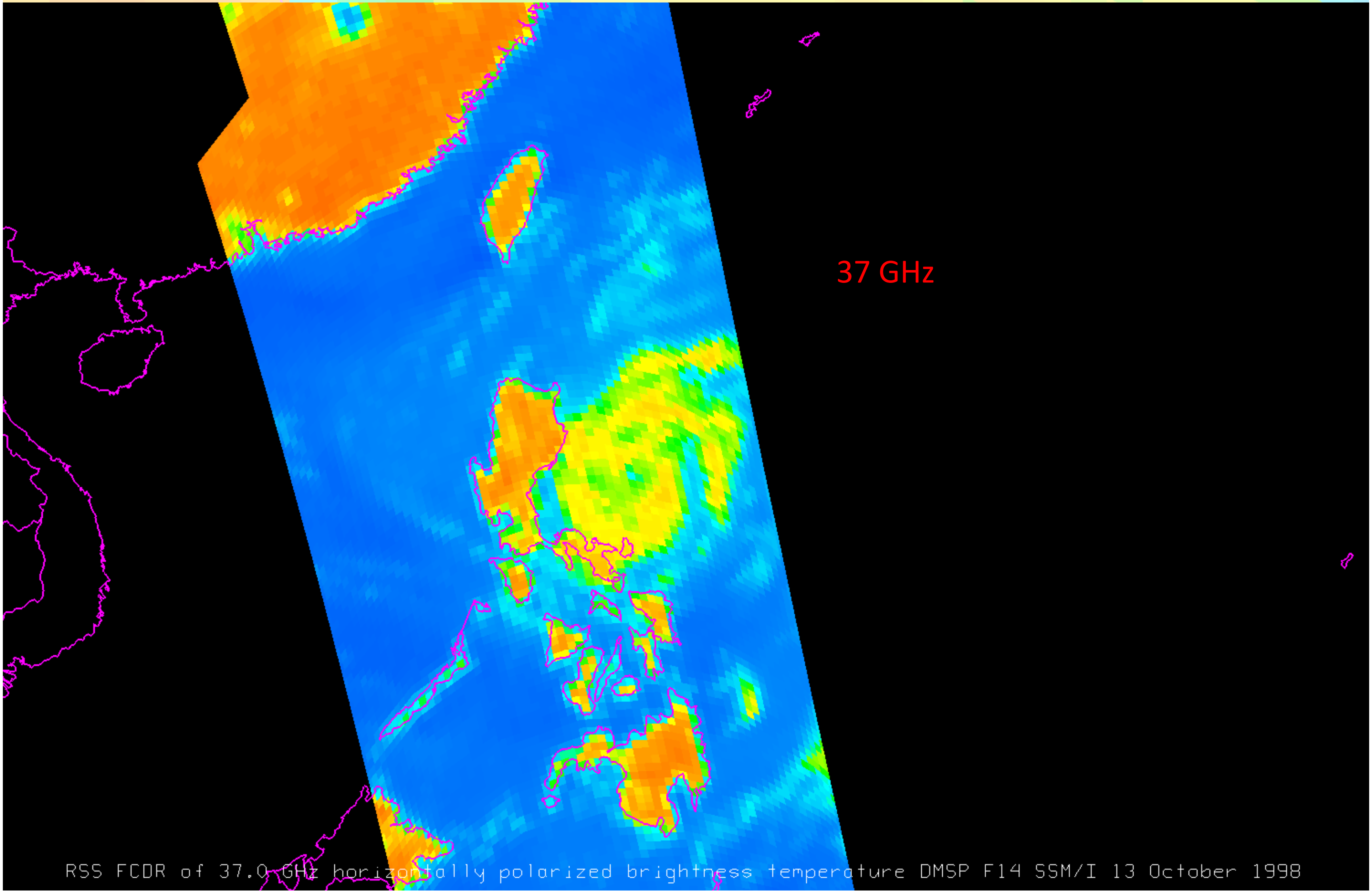
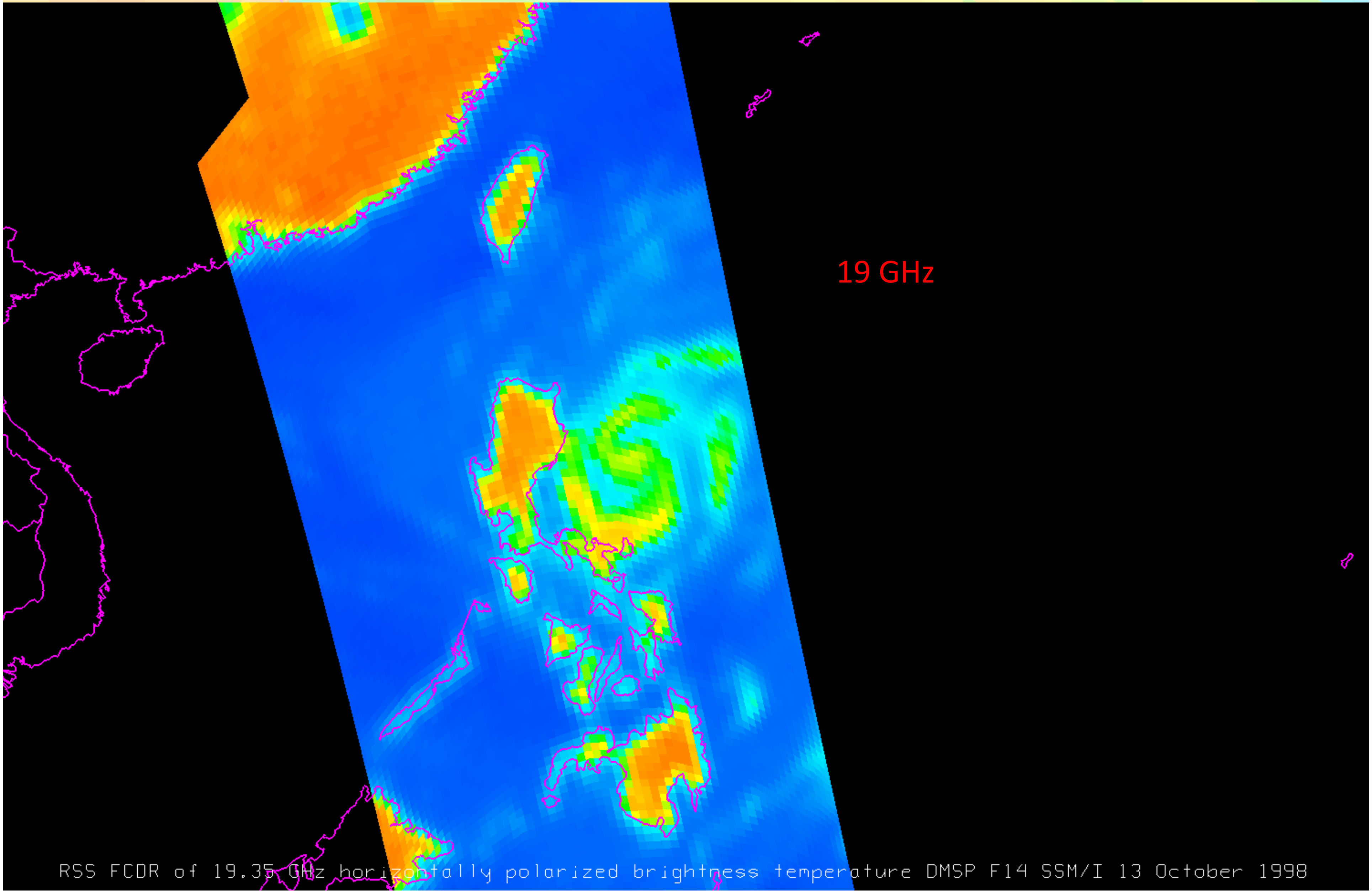
Typhoon Zeb 13 October 1998



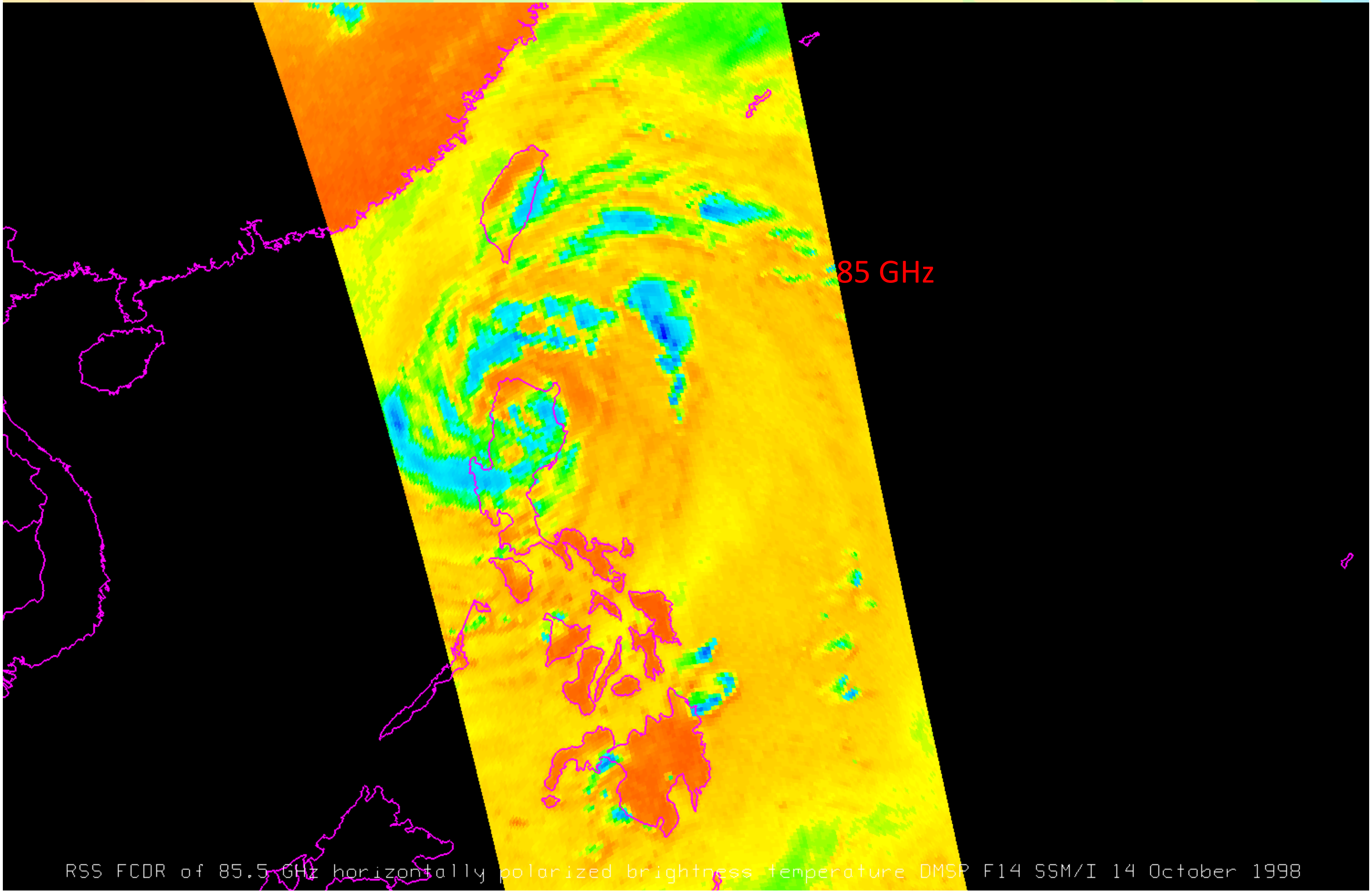
Typhoon Zeb 13 October 1998



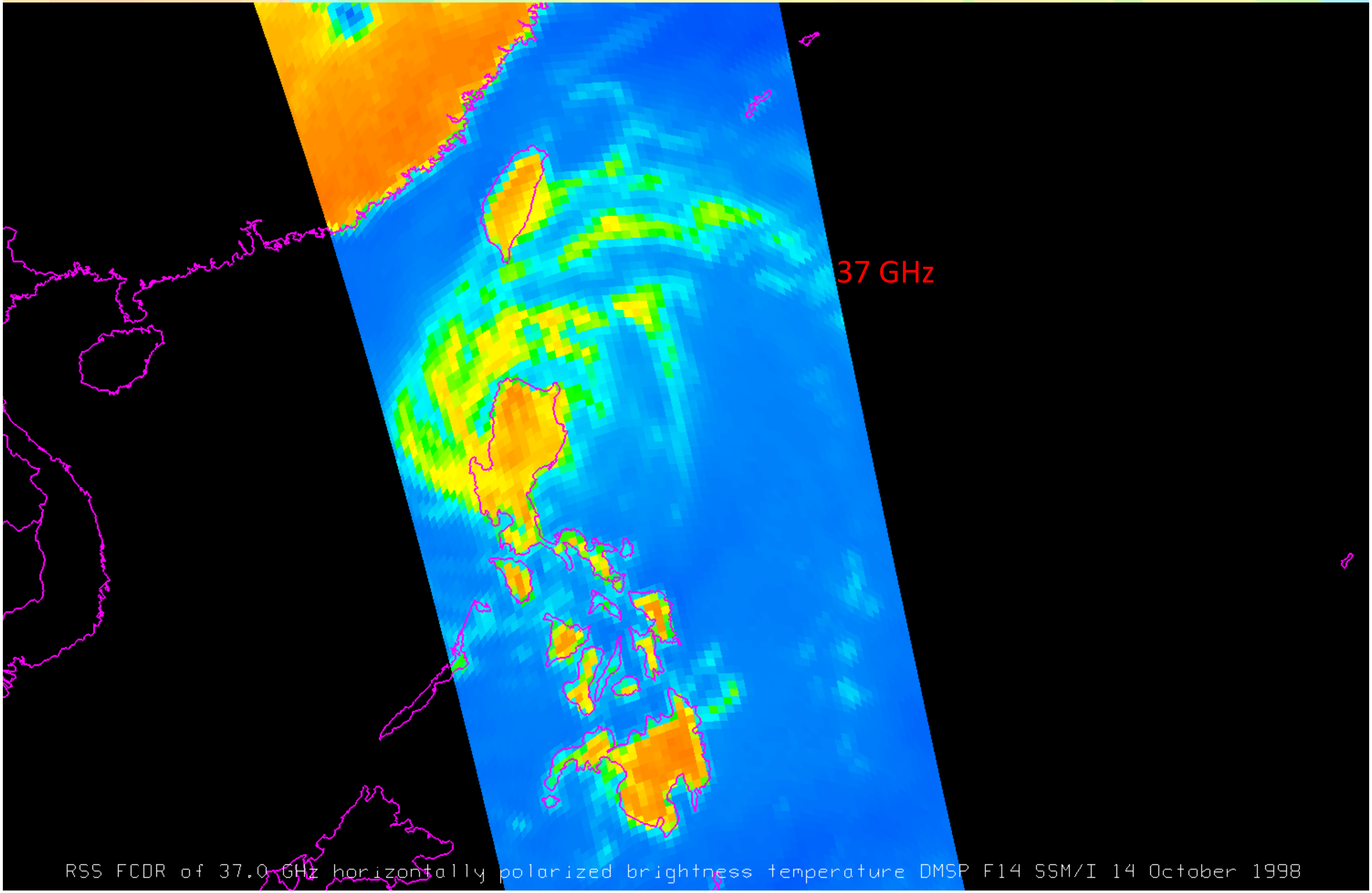
Typhoon Zeb 13 October 1998



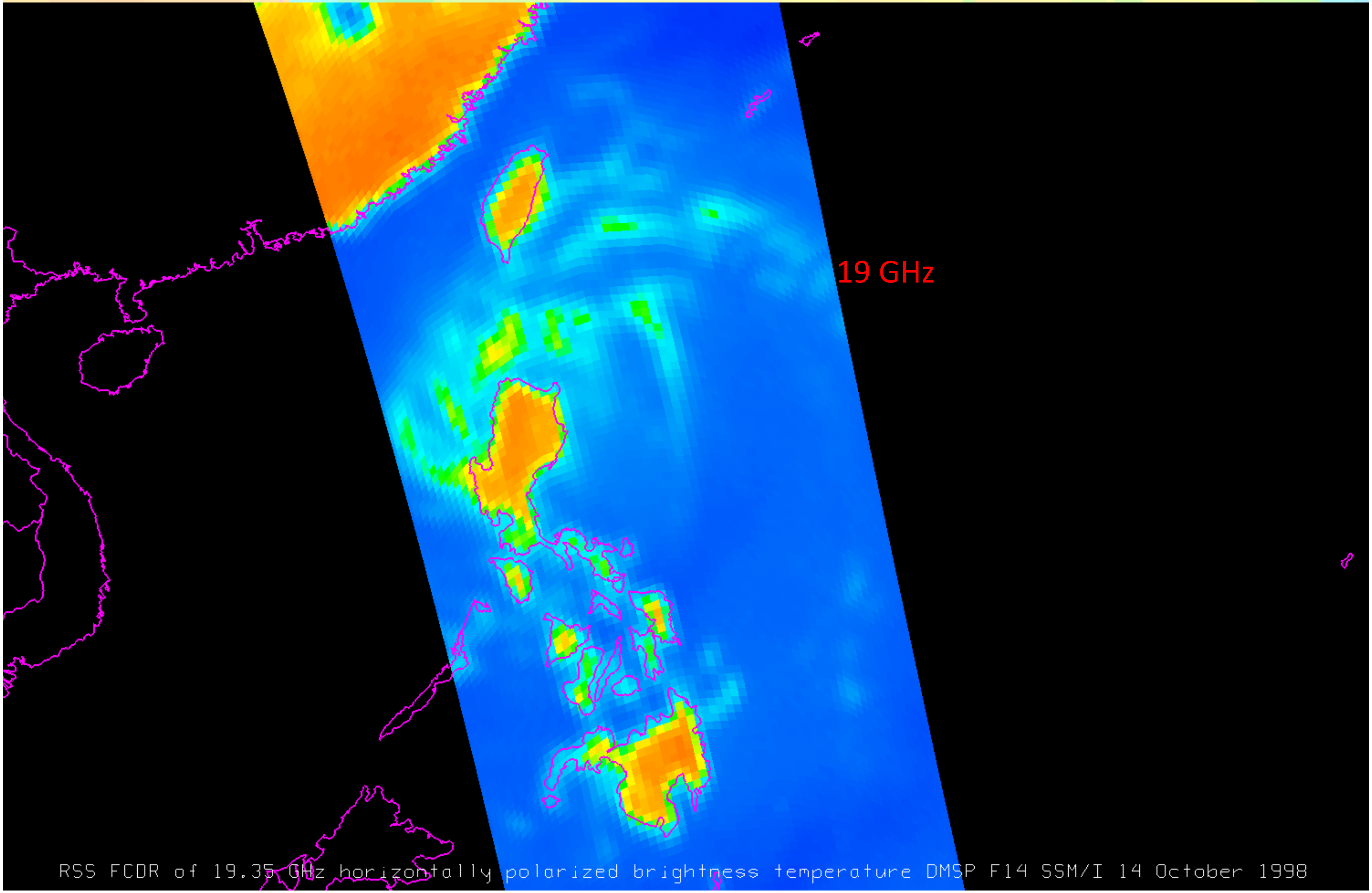
Typhoon Zeb 14 October 1998



Typhoon Zeb 14 October 1998



Typhoon Zeb 14 October 1998



Rain Rate

- An OSPO-generated product derived from Polar Orbiters, available on the web
  - Satellites used: NOAA-18, NOAA-19, Metop-A, DMSP F16, F17, F18
    - Different sensors on different satellites
    - Values of Rain Rate vary – one satellite might be ‘wetter’ than another, etc.

- Stitched together into a mosaic
  - “Histogram-corrected”
    - Create a histogram of 5 days’ of data from each satellite
    - Adjust distributions to diminish inter-satellite differences
    - Different processing over Land and over Water

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Rain Rate

- Low emissivity of ocean allows rain drop emission – larger than the ocean – to show up (as opposed to over higher emissive lands)

- Scattering increases as GHz increases – because the wavelength is decreasing and there's a particle size control to the amount of scattering

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Rain Rate

- An OSPO-generated product derived from Polar Orbiters
  - – 12-hour composites are created hourly
    - A Polar orbiter will have about 7 orbits in those 12 hours
    - Most recent observation is used at each point
  - – Instruments used: SSMI/S, MHS, AMSU/B
  - – DMSP, Metop-A/-B, NOAA-18+, pre-NOAA-18
  - – Does not use ATMS (on NPP/NOAA-20)
- Data are available on-line

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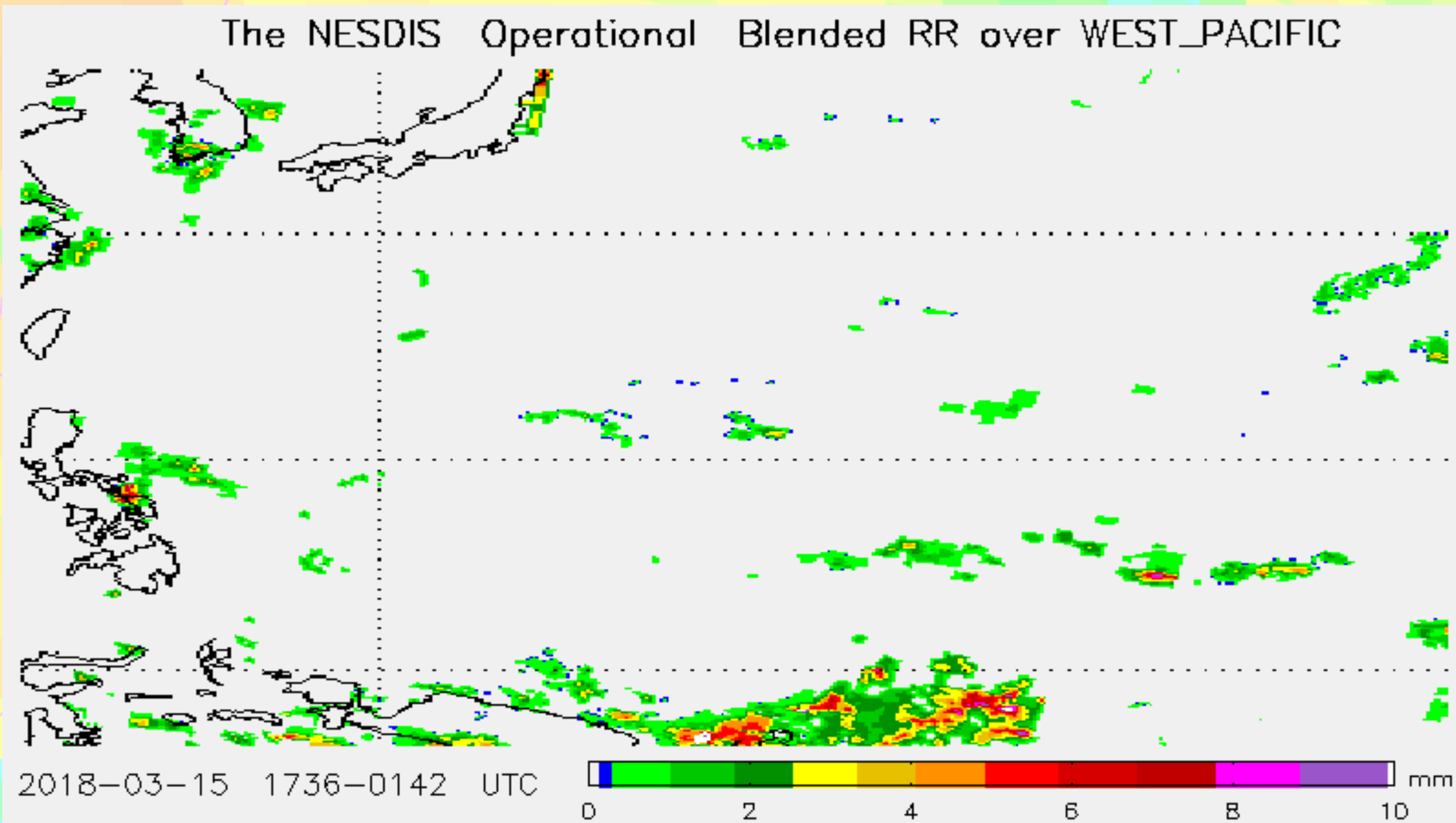
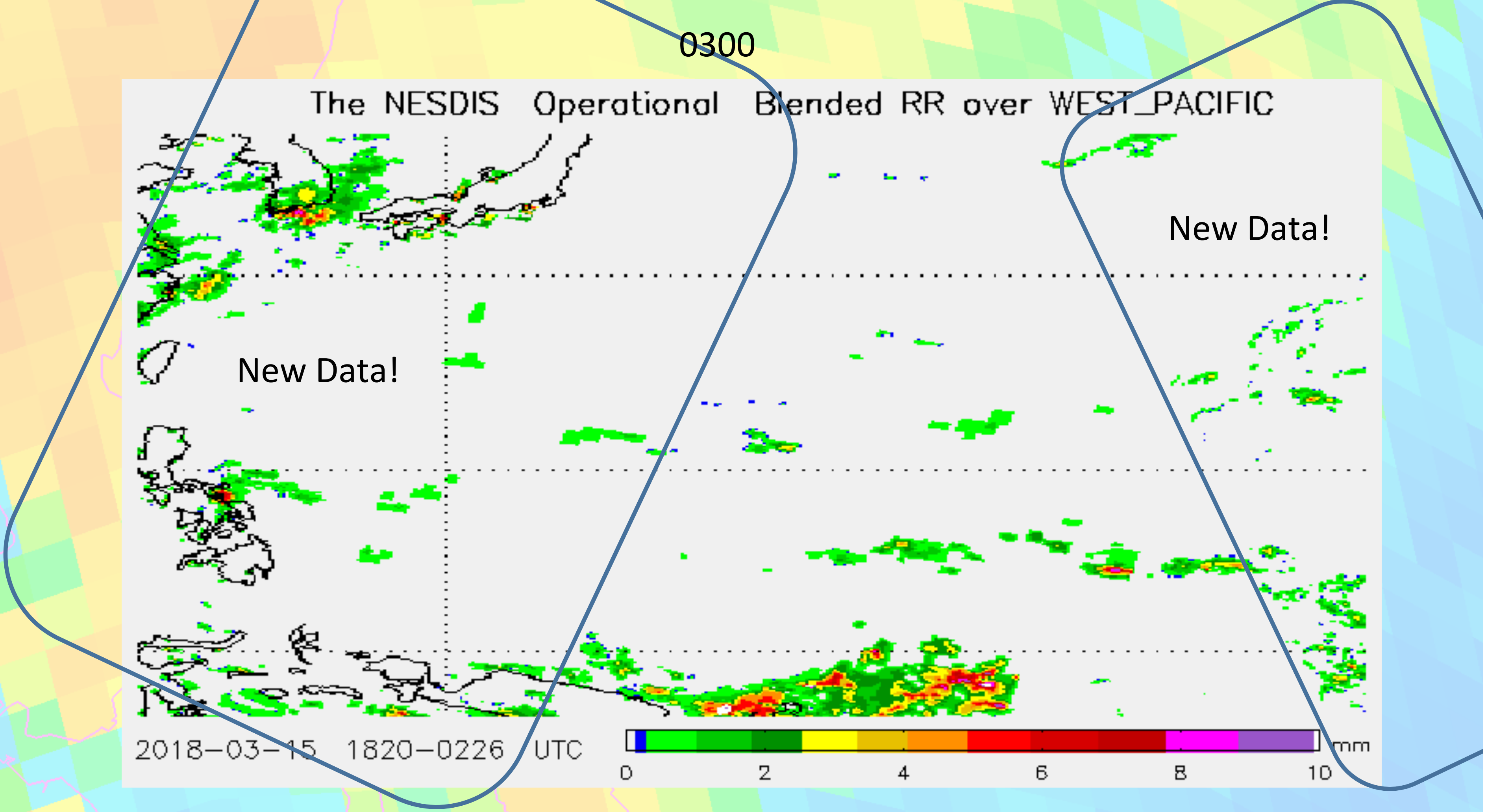
Blended Rain Rate

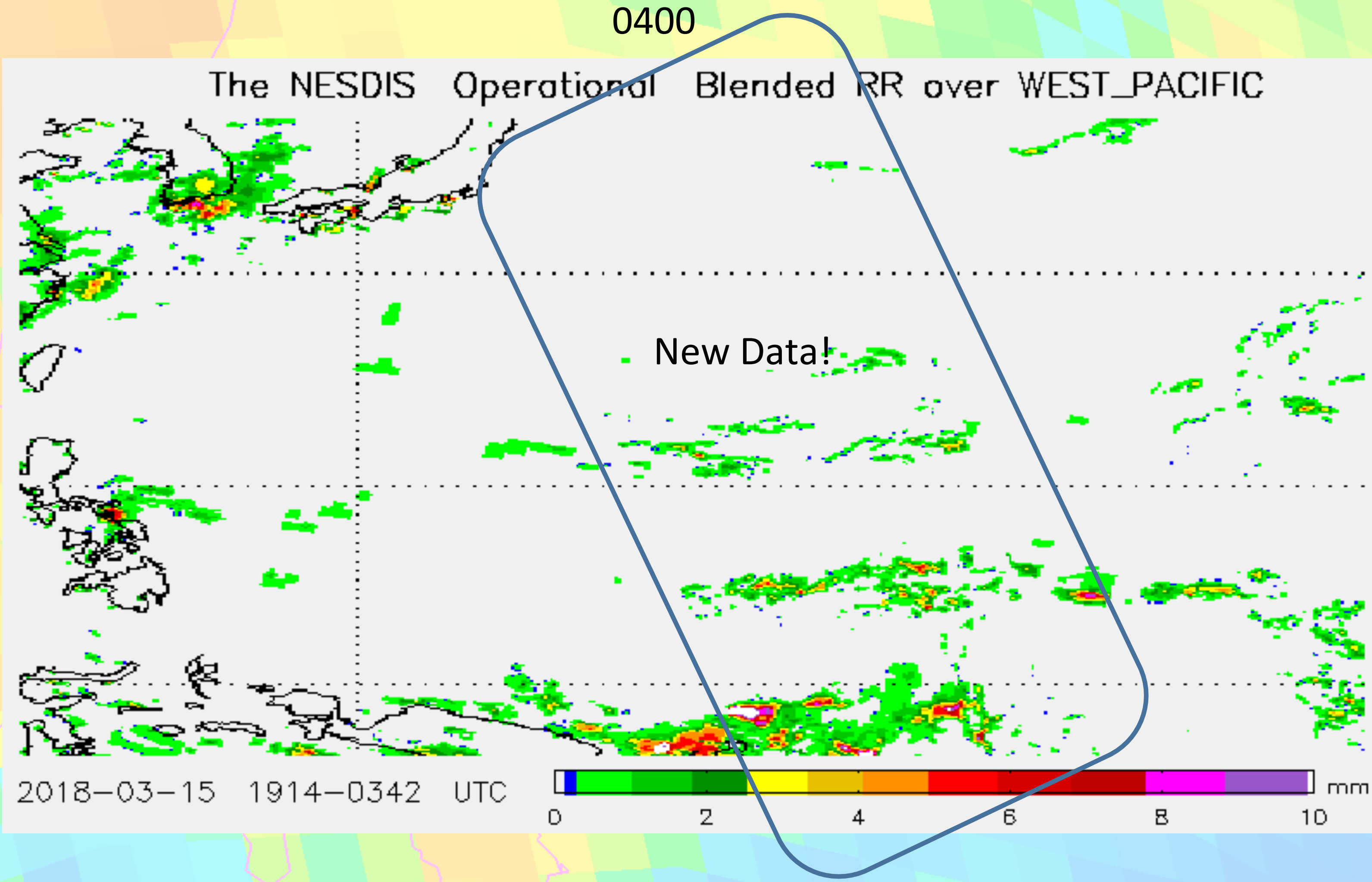
0200



Blended Rain Rate



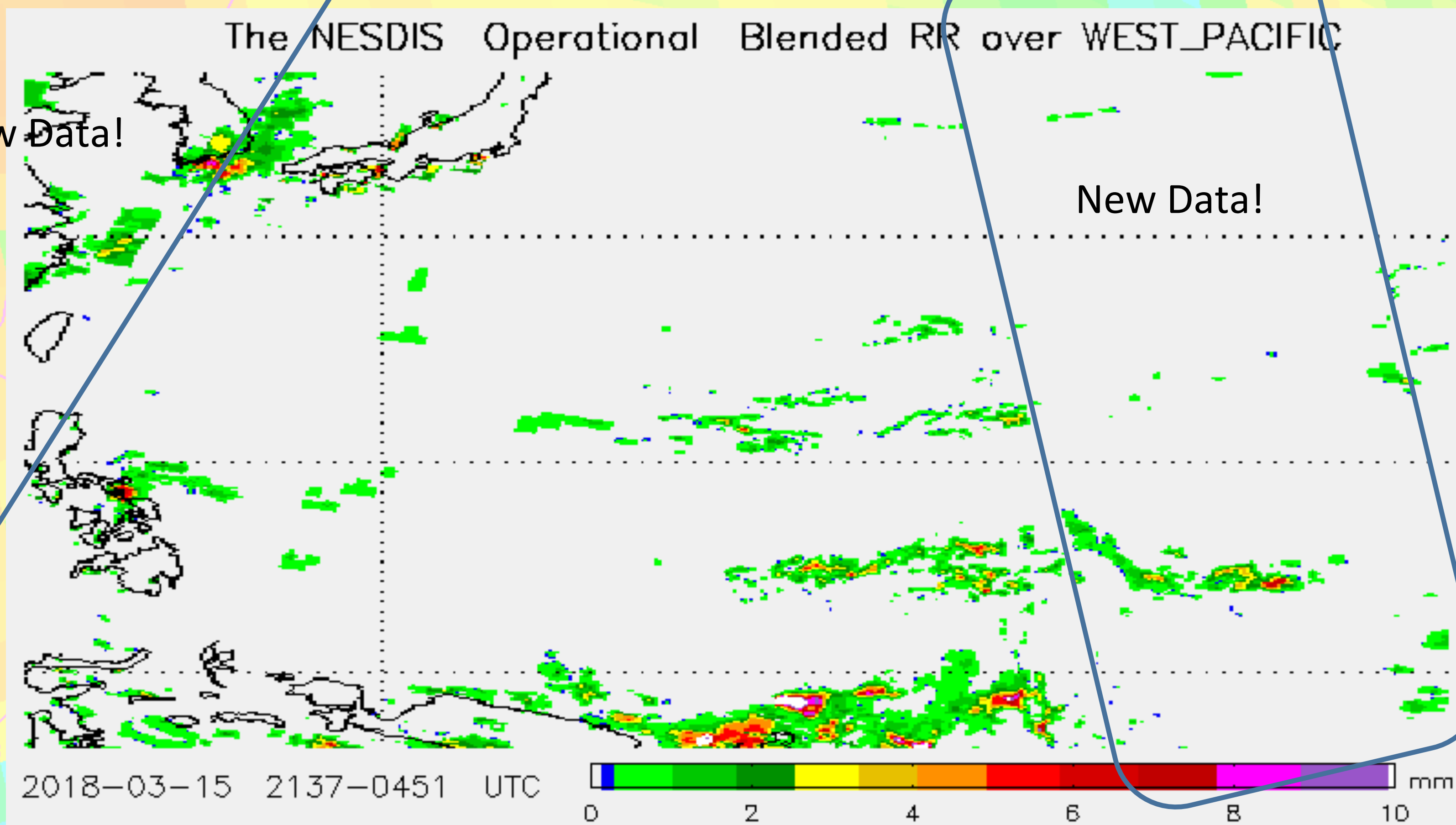
Blended Rain Rate



Blended Rain Rate

0500

New Data!



New Data!

MIRS

- [Operational Microwave Integrated Retrieval System](http://www.ospo.noaa.gov/Products/atmosphere/mirs/index.html)
  - Uses data from ATMS, AMSU-A, MHS, SSMI/S
    - Thus: Uses the Blended Rainrate instruments plus ATMS
  - A variety of products are generated from each satellite
  - Data are shown at Global Scale
  - Website link goes to:
  - http://www.ospo.noaa.gov/Products/atmosphere/mirs/index.html

Products

Brightness Temperature
Total Precipitable Water
Rain Rate
Snowfall Rate
Cloud Liquid Water
Ice Water Path
Snow Water Equivalent
Snow Cover
Sea Ice
Land Surface Temperature
Land Surface Emissivity
Surface Type
Temperature Profiles
Moisture Profiles

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What do you see in your AWIPS?

- Infrared and Visible imagery
  - VIIRS wavelengths are similar to AHI (and ABI if you ever transfer stateside)
- Microwave imagery
  - Especially useful for rainfall and Tropical Cyclone Structure
- I particularly like the ability to compare microwave and IR/VIS imagery from NPP
  - ATMS and VIIRS both on NPP and NOAA-20

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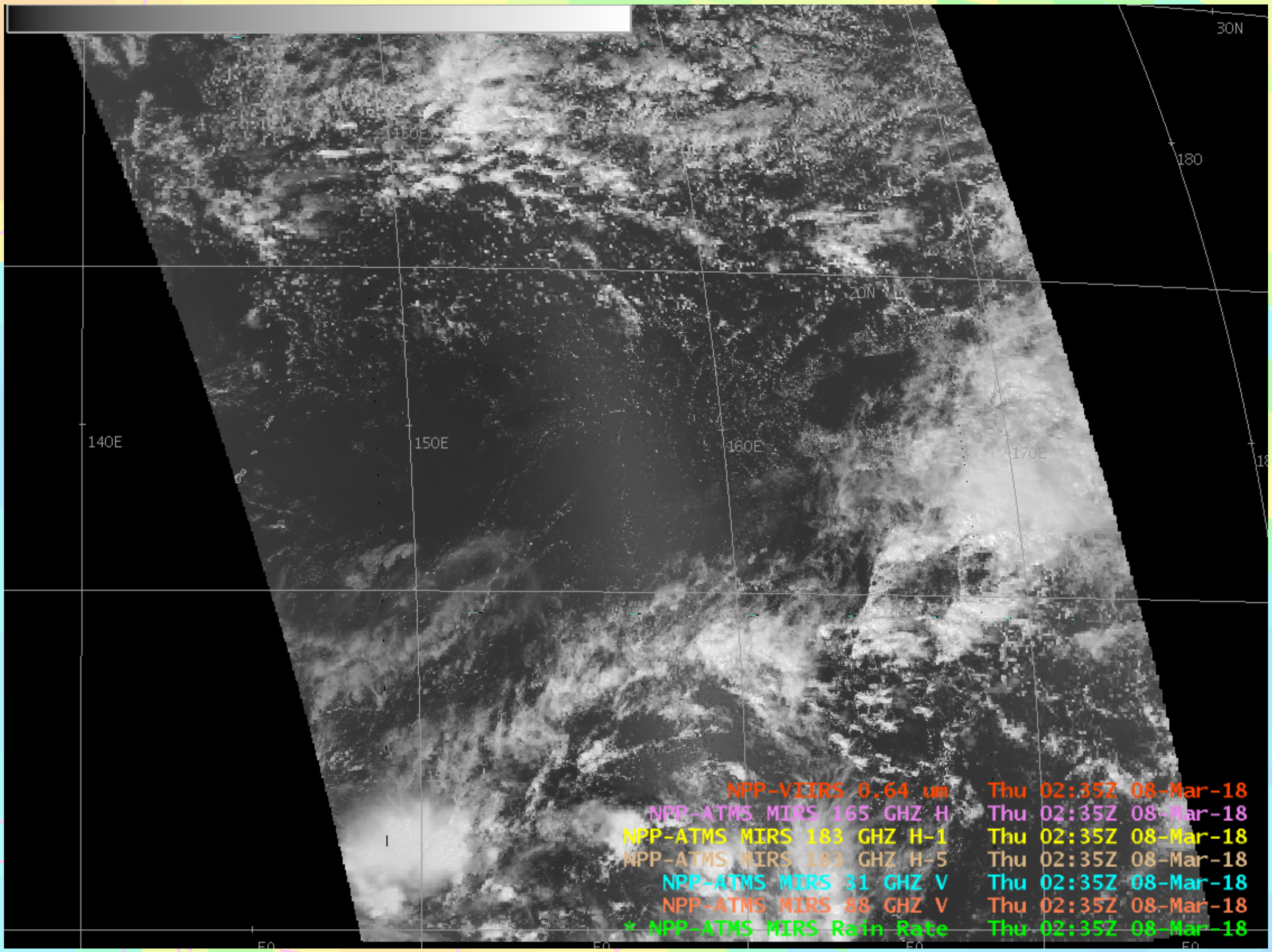
VIIRS Visible (0.64 μm) (I01)



Where is the heavy rain?

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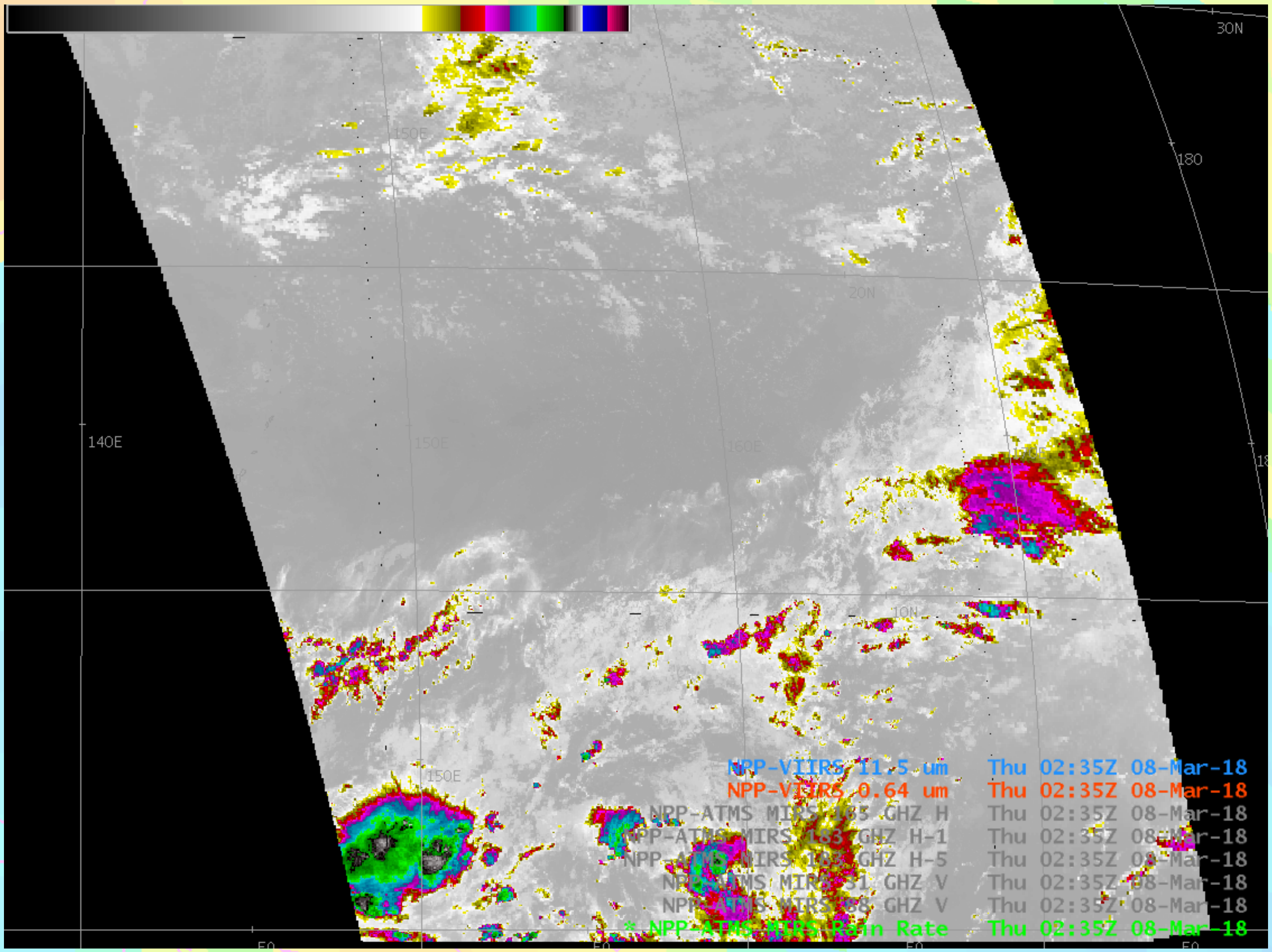
VIIRS Visible (11.5 μm) (I05)



Where is the heavy rain?

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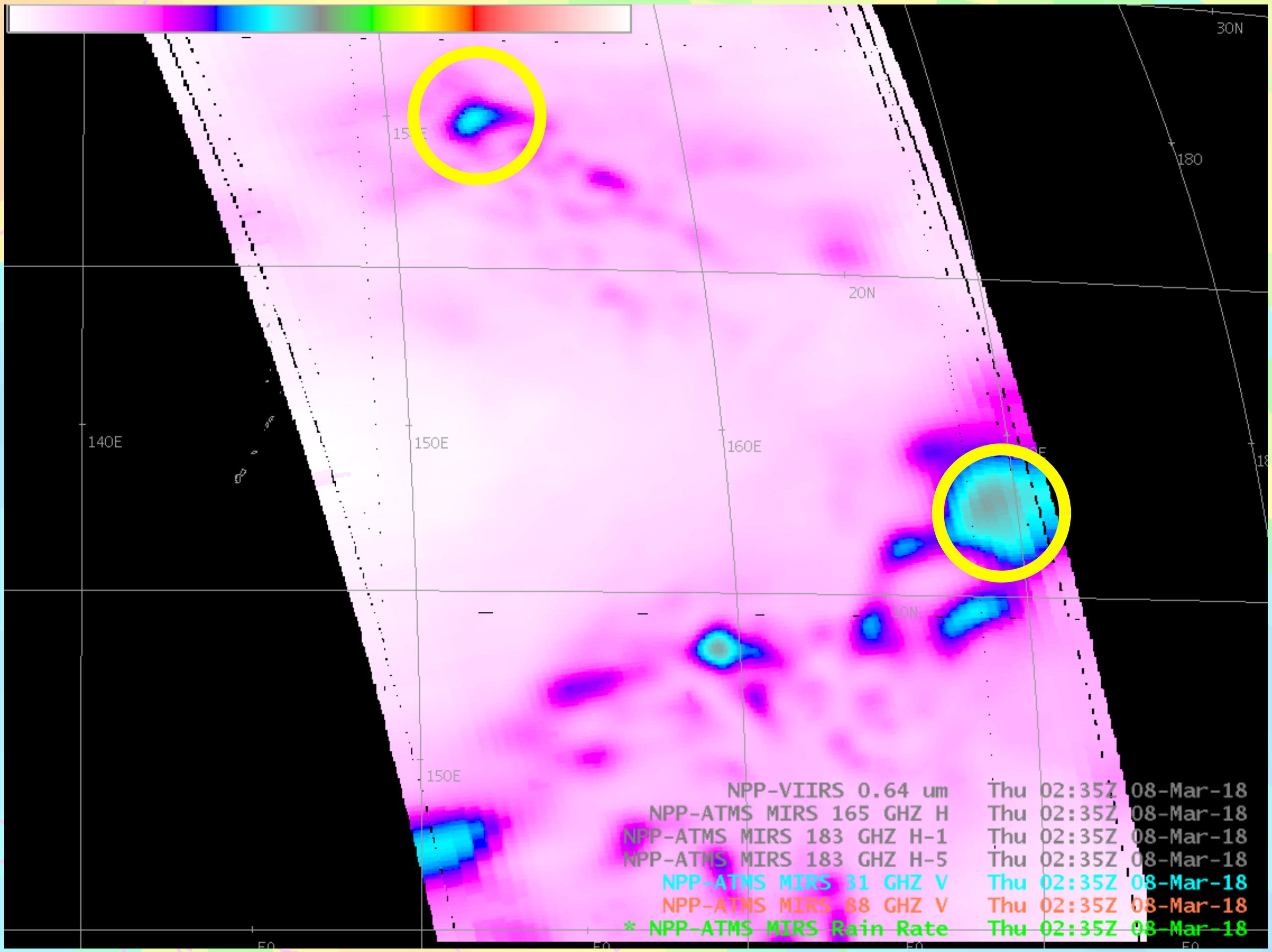
ATMS 31 Ghz



There will be a signal here where low-level clouds are full of water

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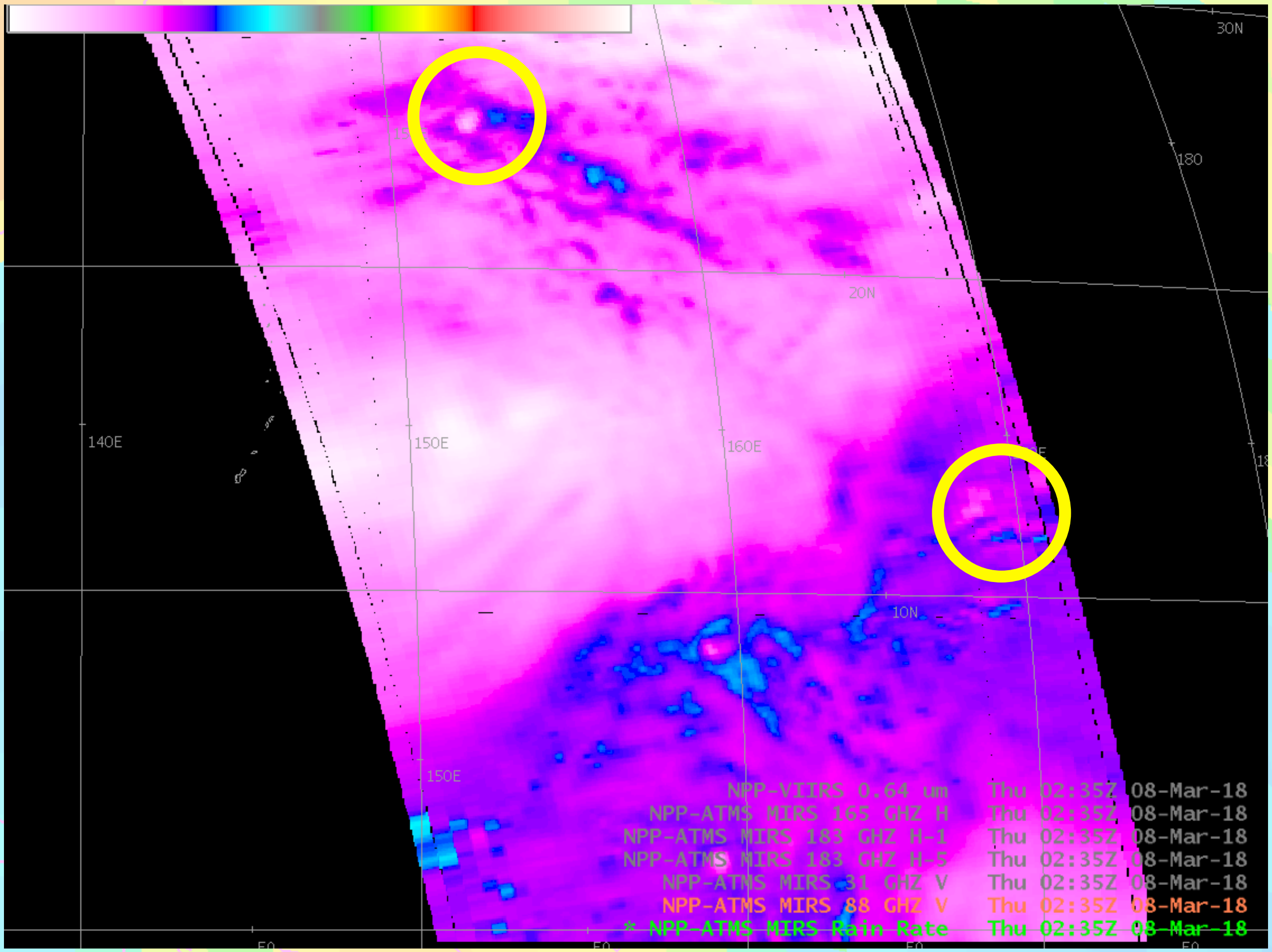
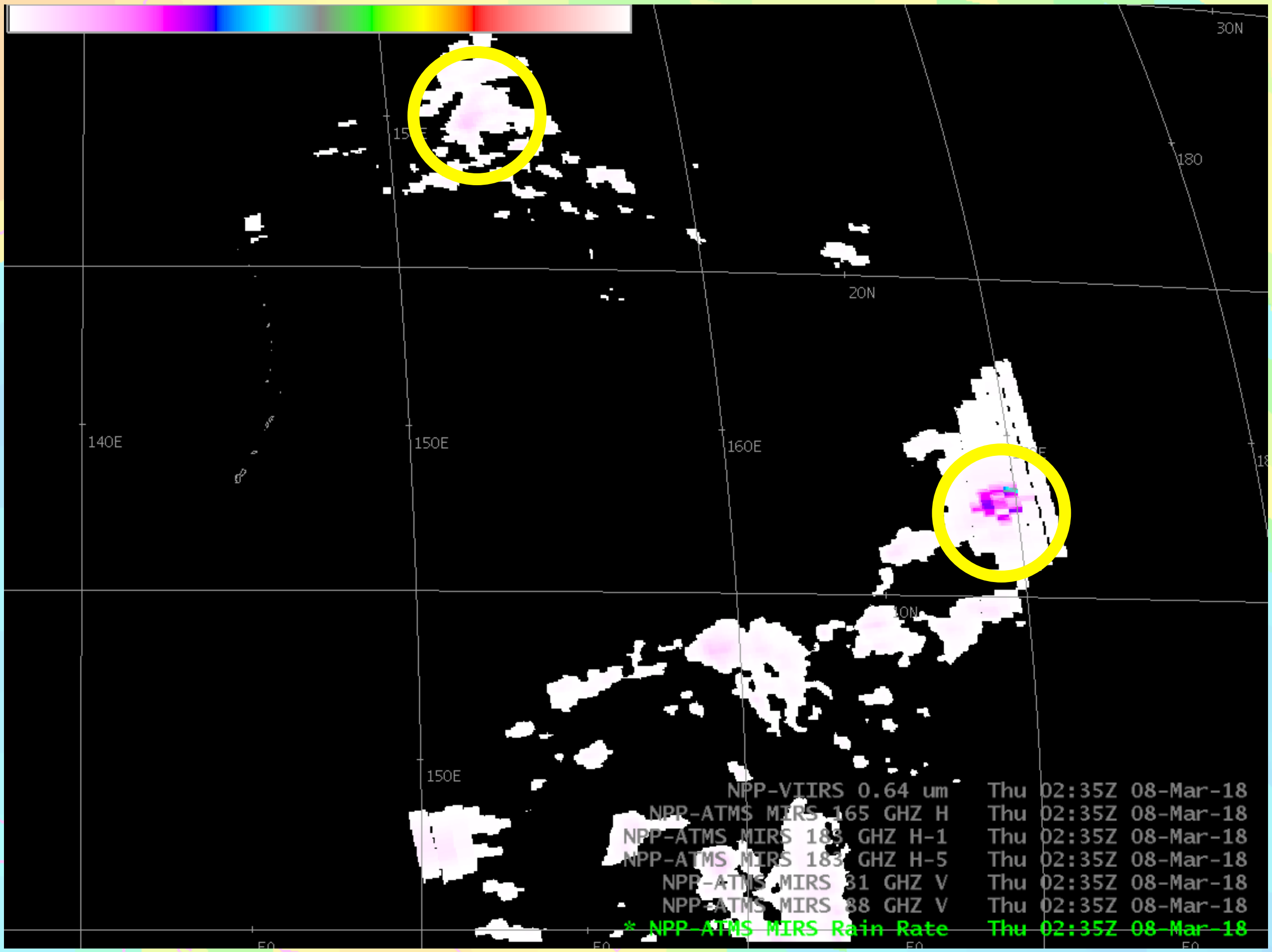
ATMS 88 Ghz



There will be a signal here where cirrus clouds scatter information
Note the lack of signal where low-level water is present!

MIRS Rain Rate



Where is the rain falling now? This is a microwave only product

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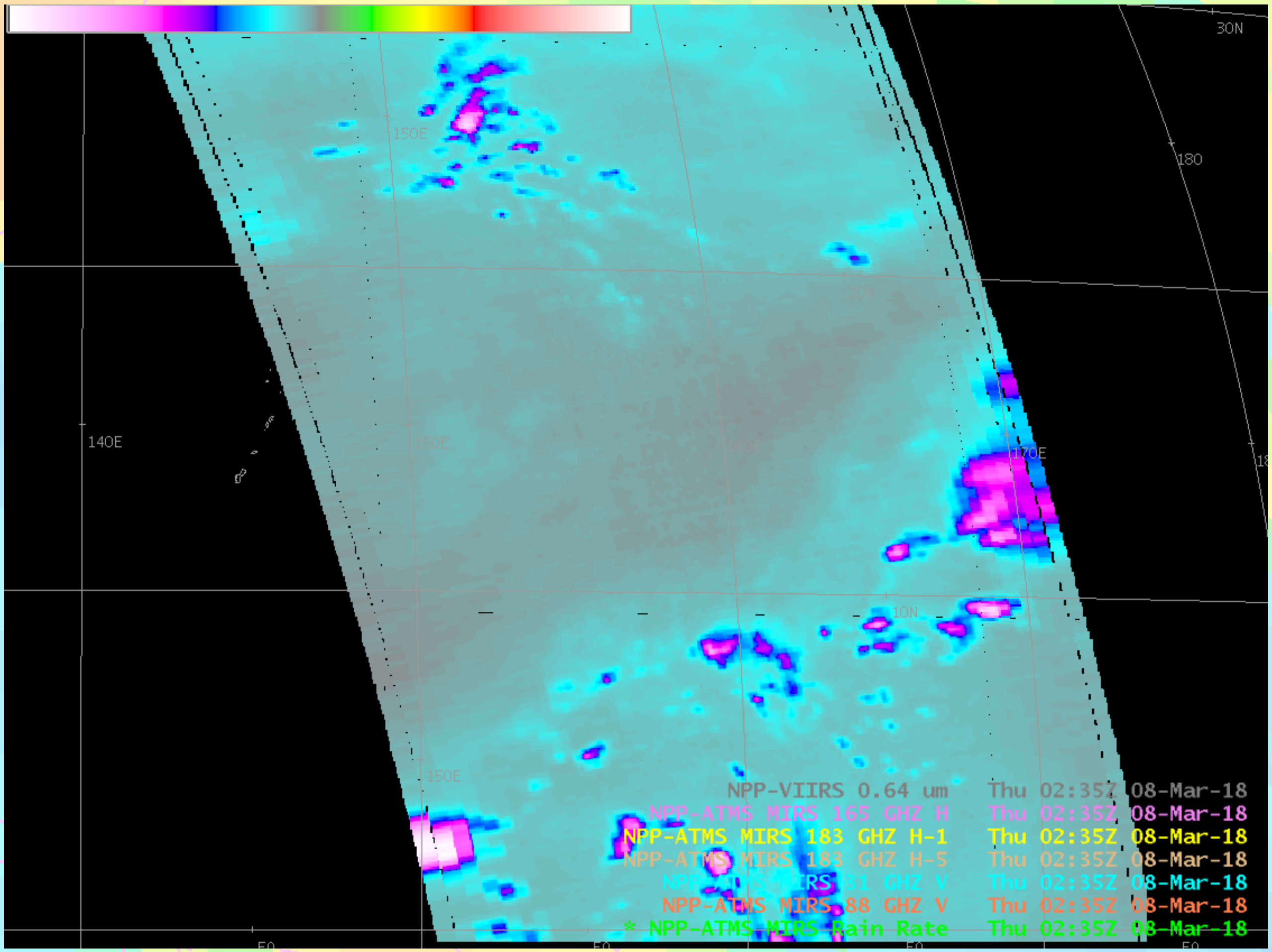
165 Ghz



Frequencies exceeding 150 Ghz are used in temperature soundings

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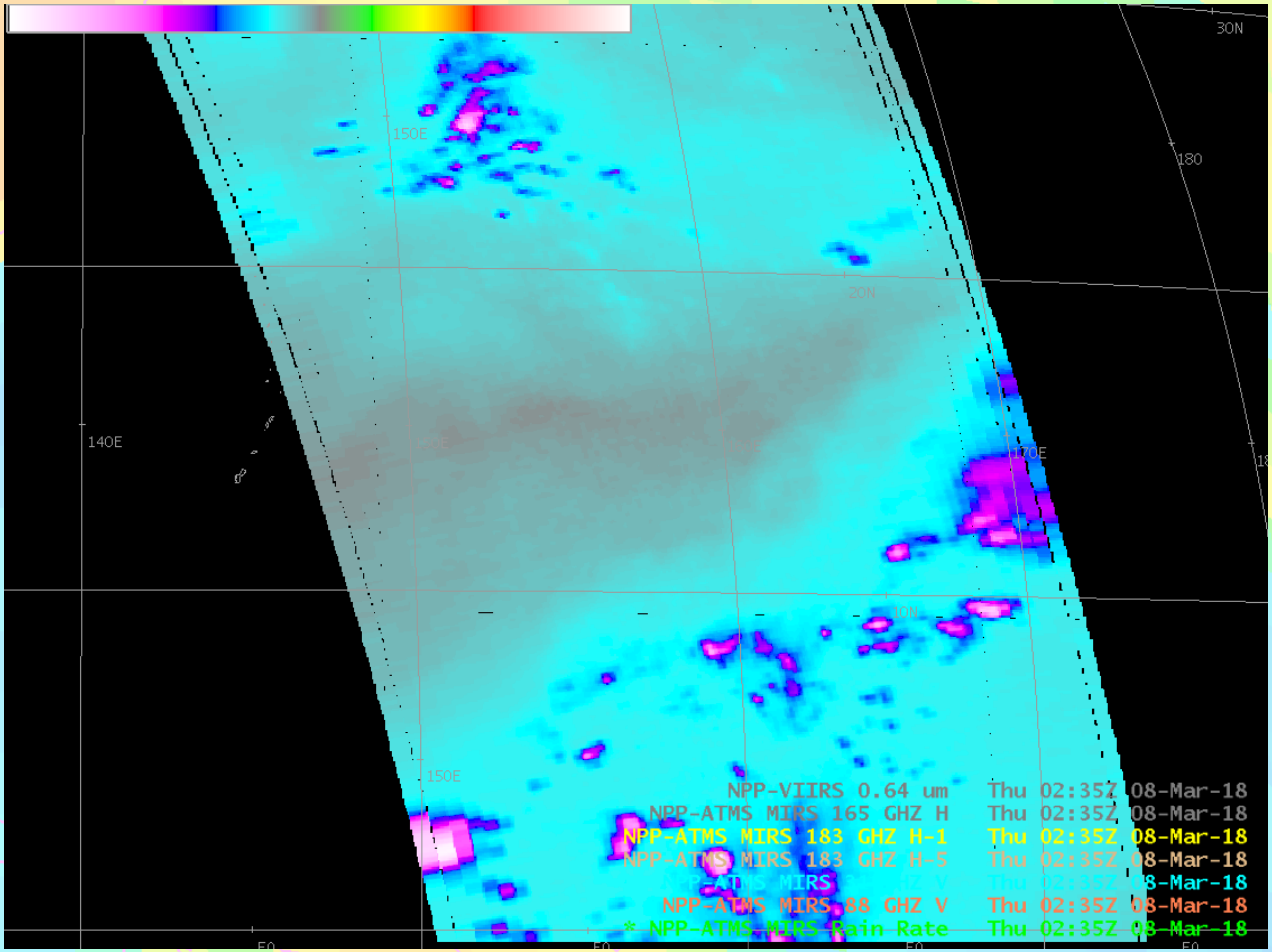
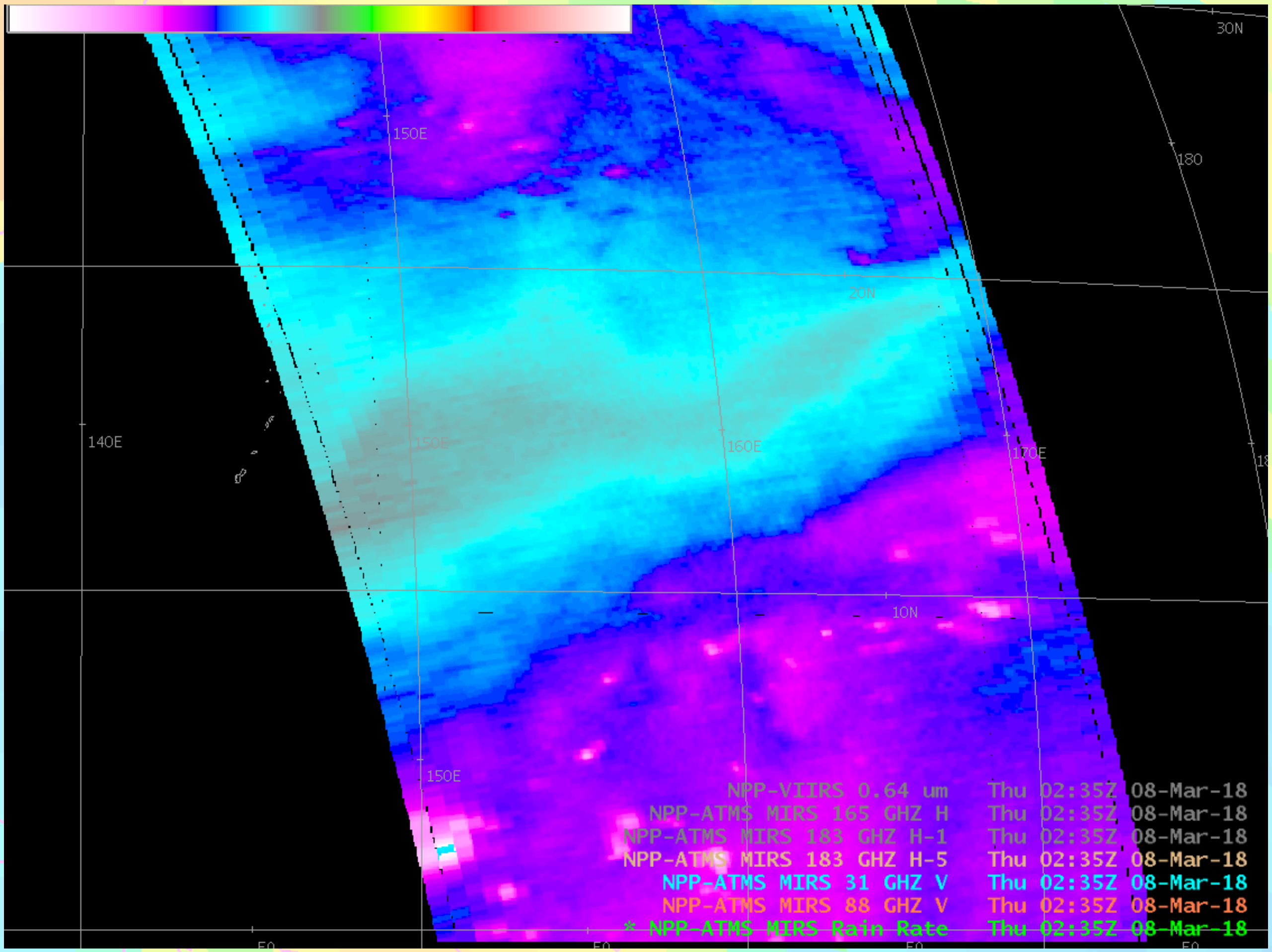
183 Ghz

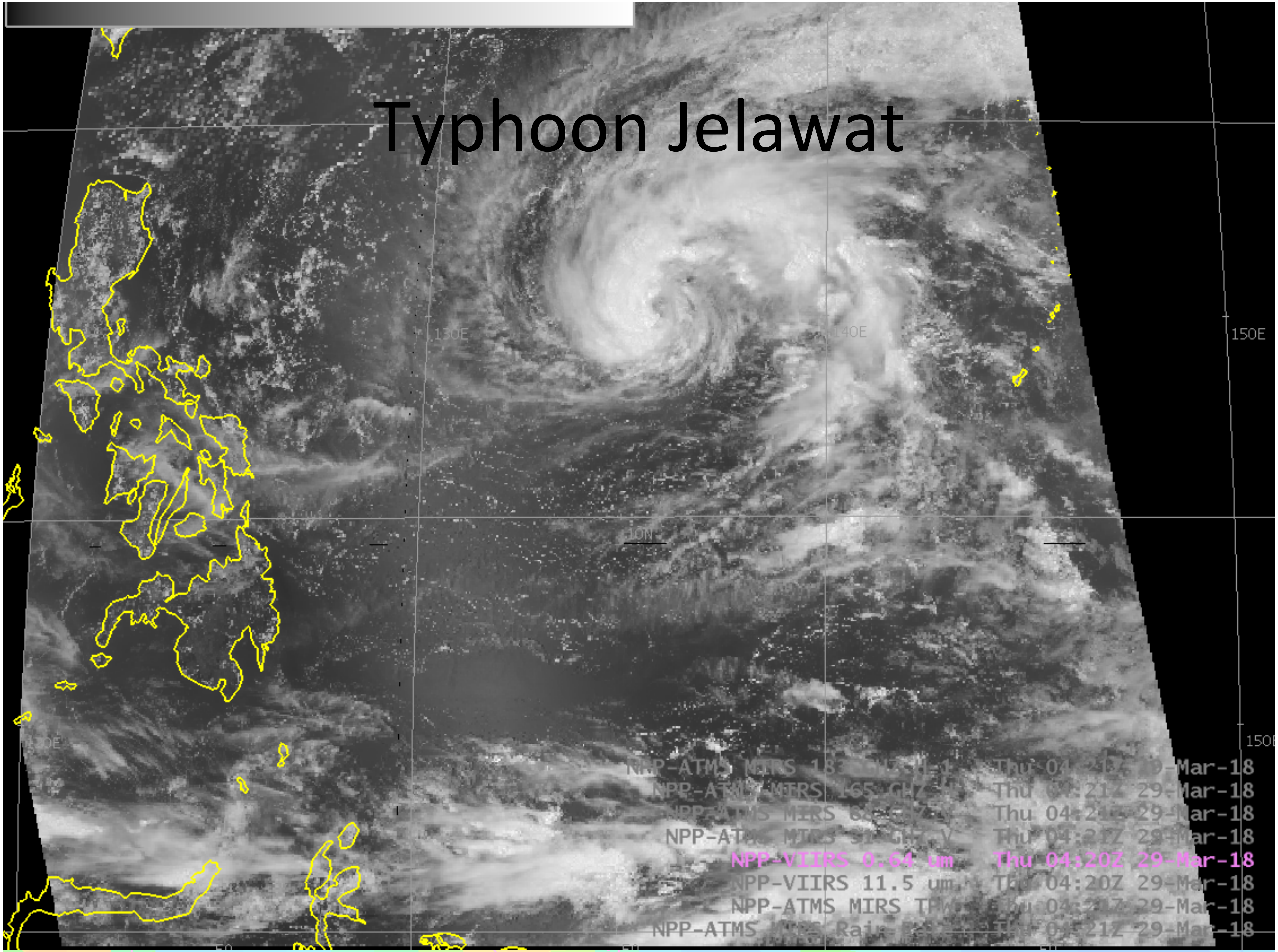

30N
180
150E
20N
140E
170E
10N
150E
NPP-VIIRS 0.64 um Thu 02:35Z 08-Mar-18
NPP-ATMS MIRS 165 GHZ H Thu 02:35Z 08-Mar-18
NPP-ATMS MIRS 183 GHZ H-1 Thu 02:35Z 08-Mar-18
NPP-ATMS MIRS 183 GHZ H-5 Thu 02:35Z 08-Mar-18
NPP-ATMS MIRS 88 GHZ V Thu 02:35Z 08-Mar-18
* NPP-ATMS MIRS Rain Rate Thu 02:35Z 08-Mar-18

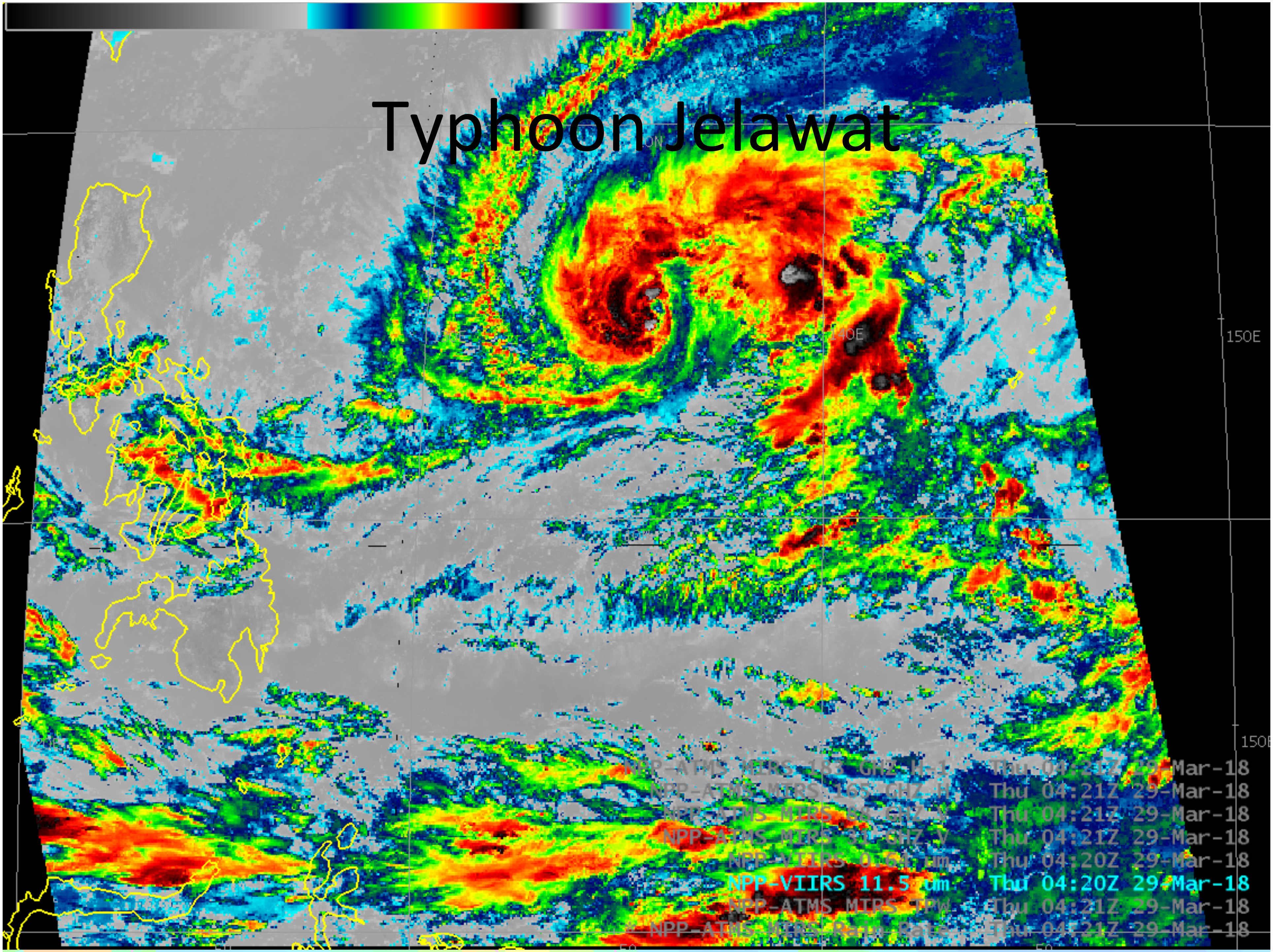
183 Ghz



FCDR of 37.0 GHz horizontally polarized brightness temperature DMSP F14 SSM/I 13 October 19

Typhoon Jelawat



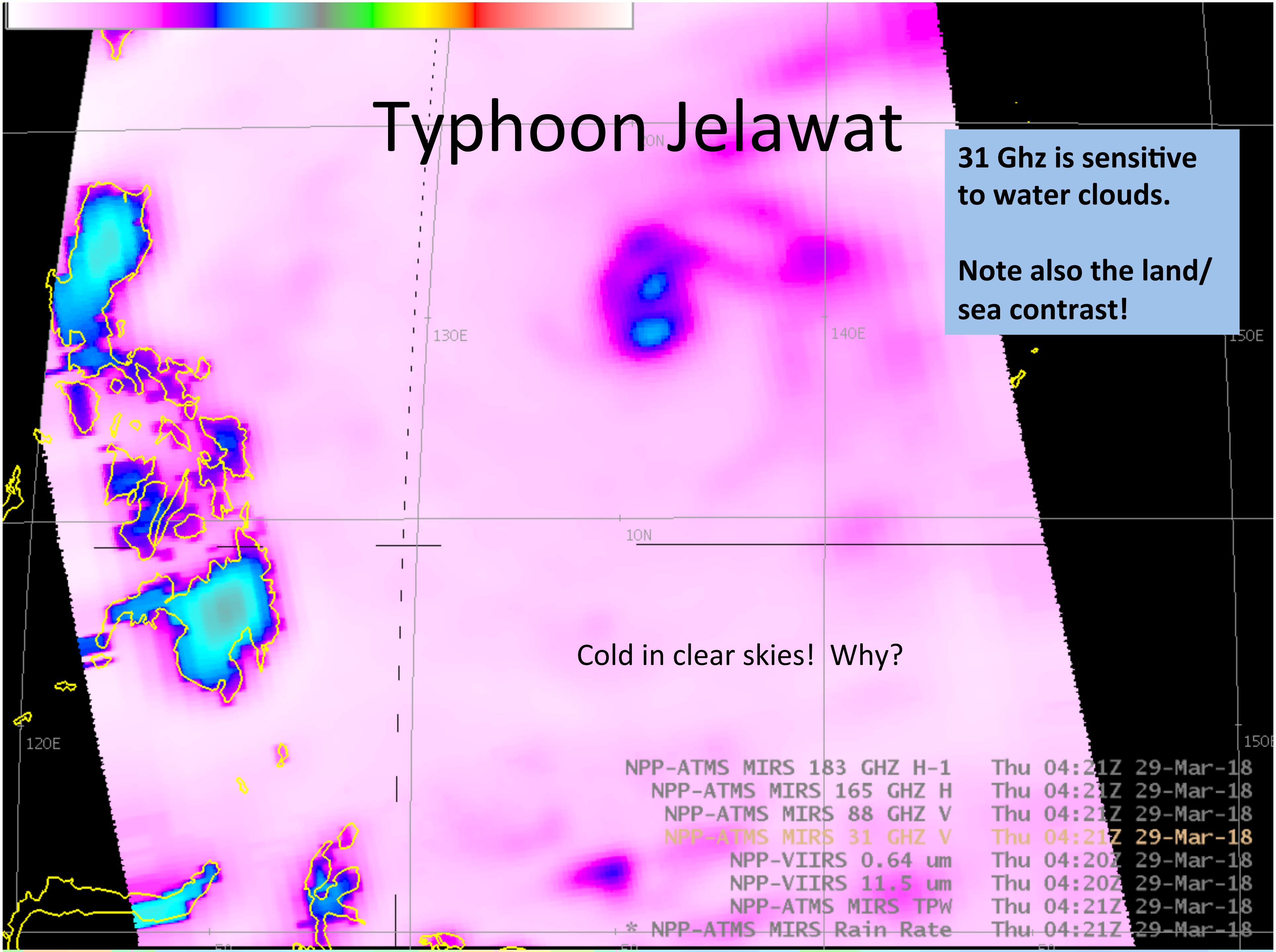

Typhoon Jelawat
140E
150E
NPP-VIIRS 11.5 um Thu 04:20Z 29-Mar-18

Typhoon Jelawat

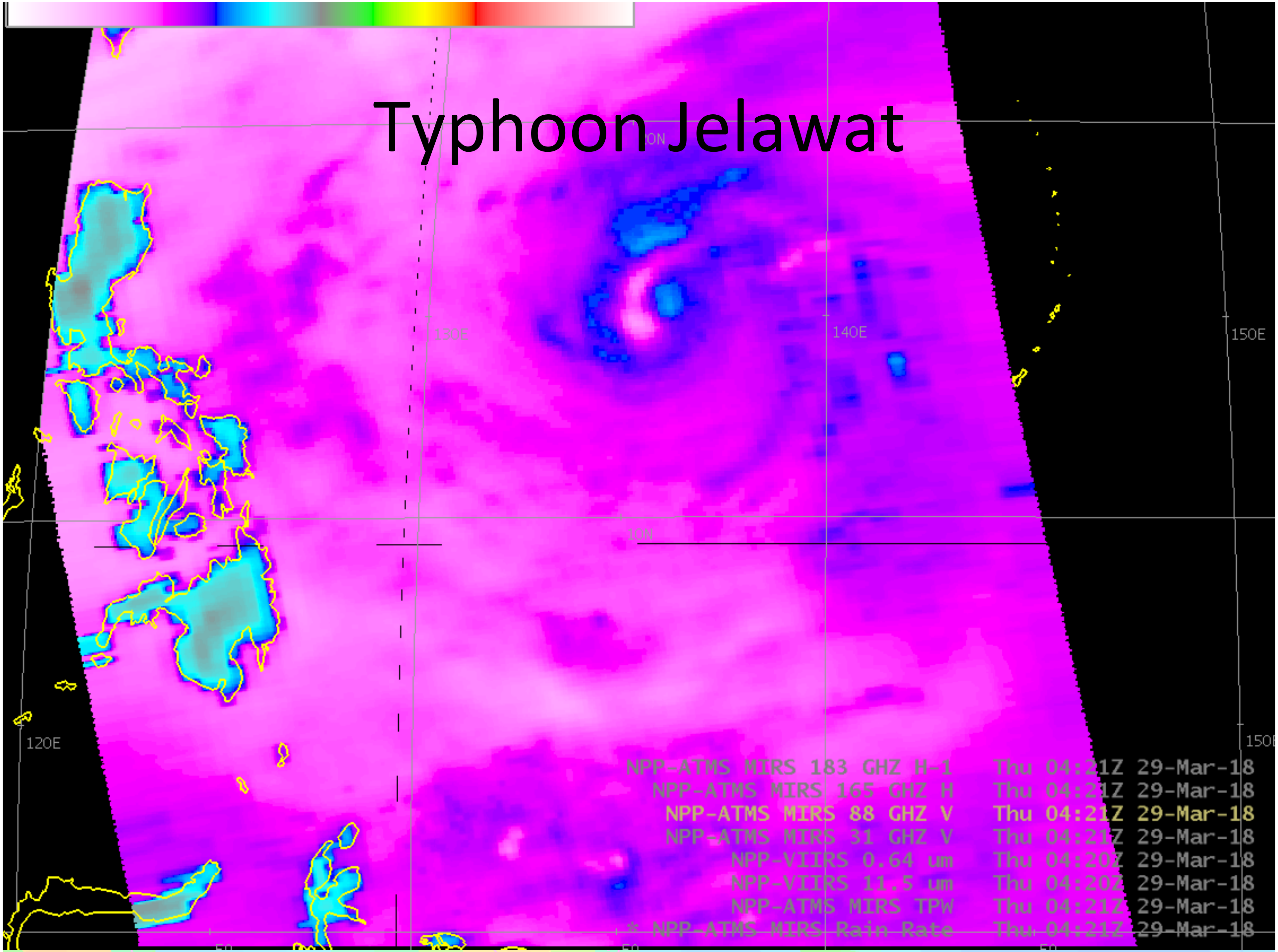
31 Ghz is sensitive to water clouds.

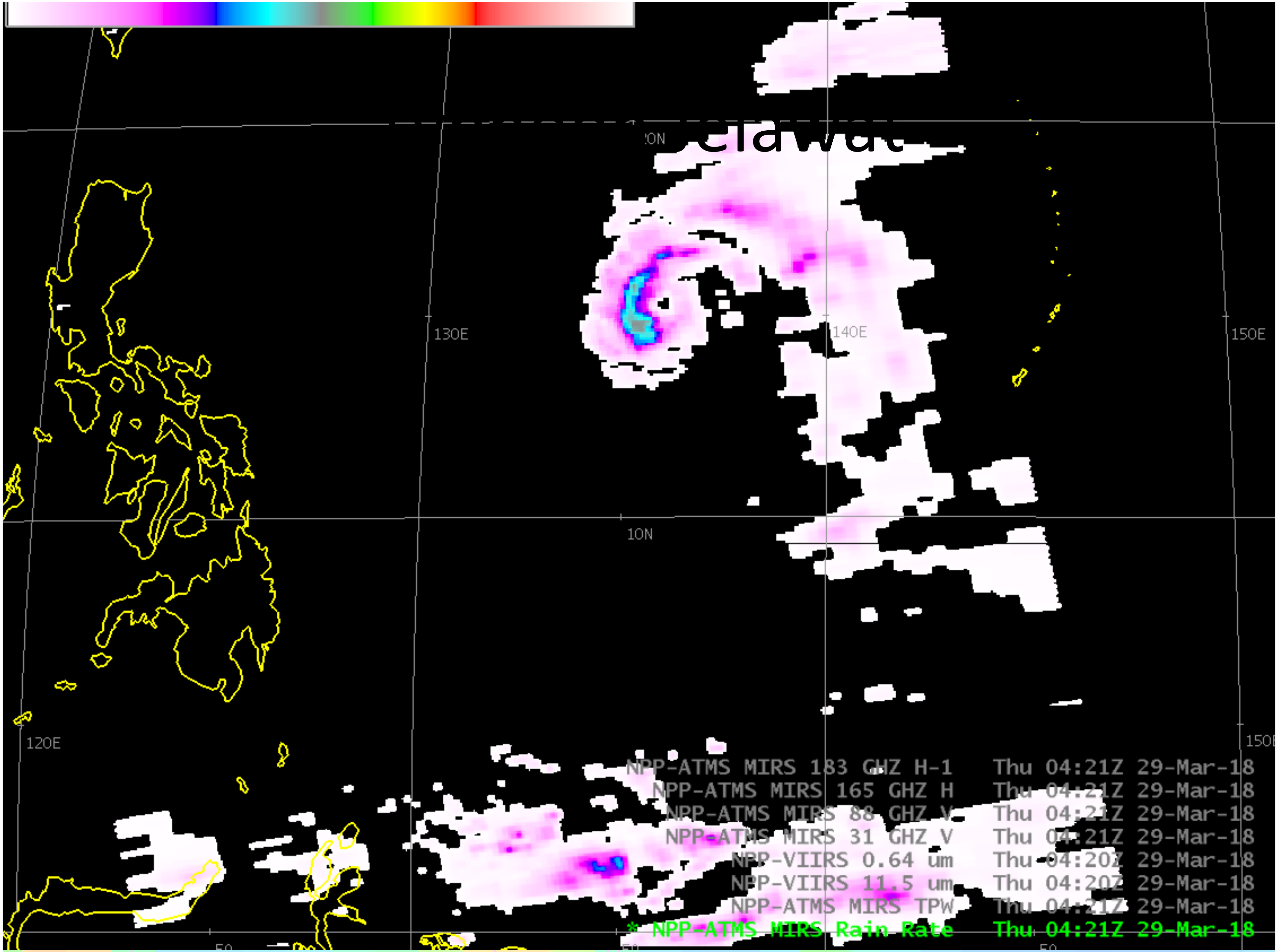
Note also the land/ sea contrast!

Cold in clear skies! Why?

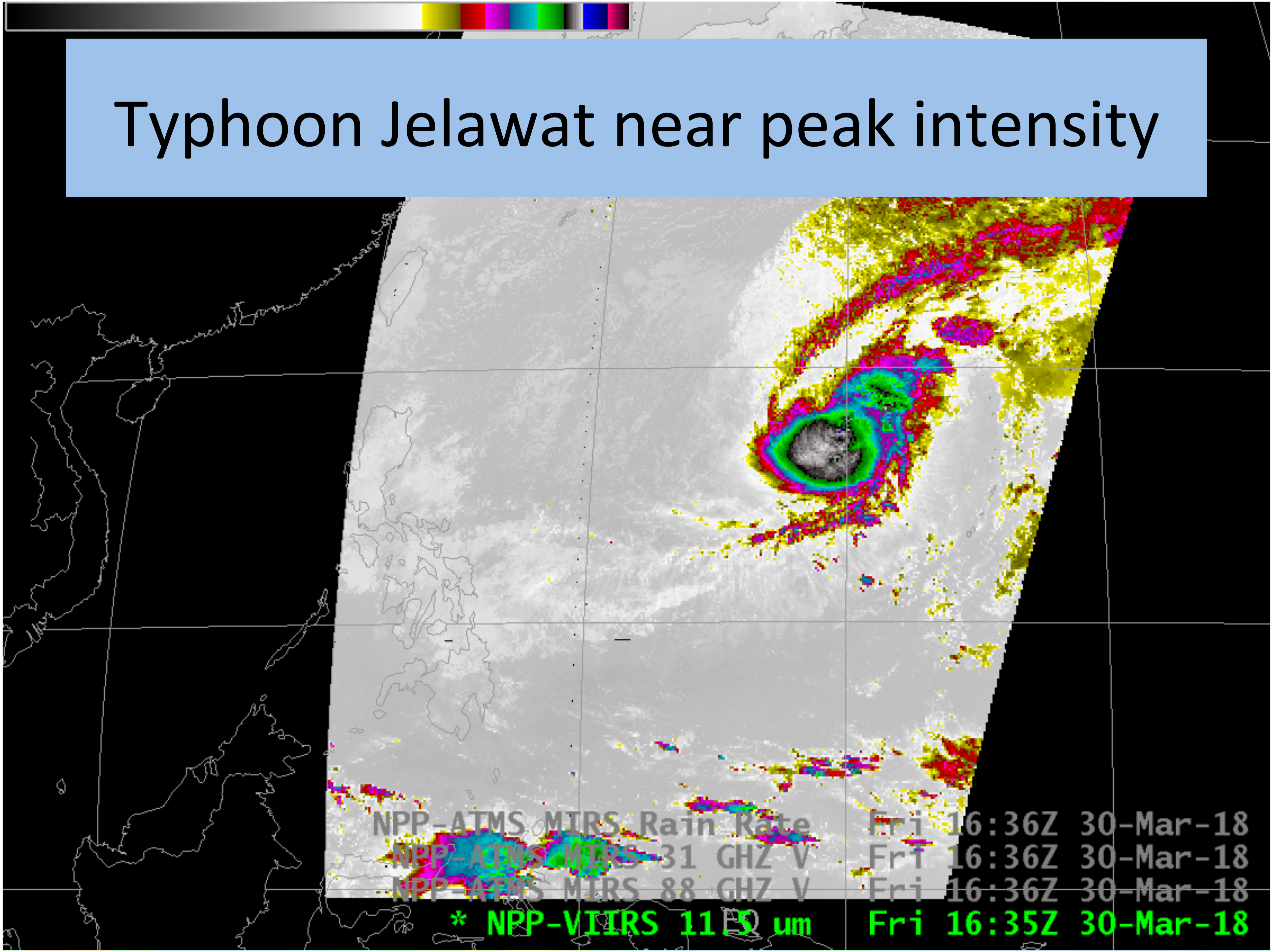


Typhoon Jelawat

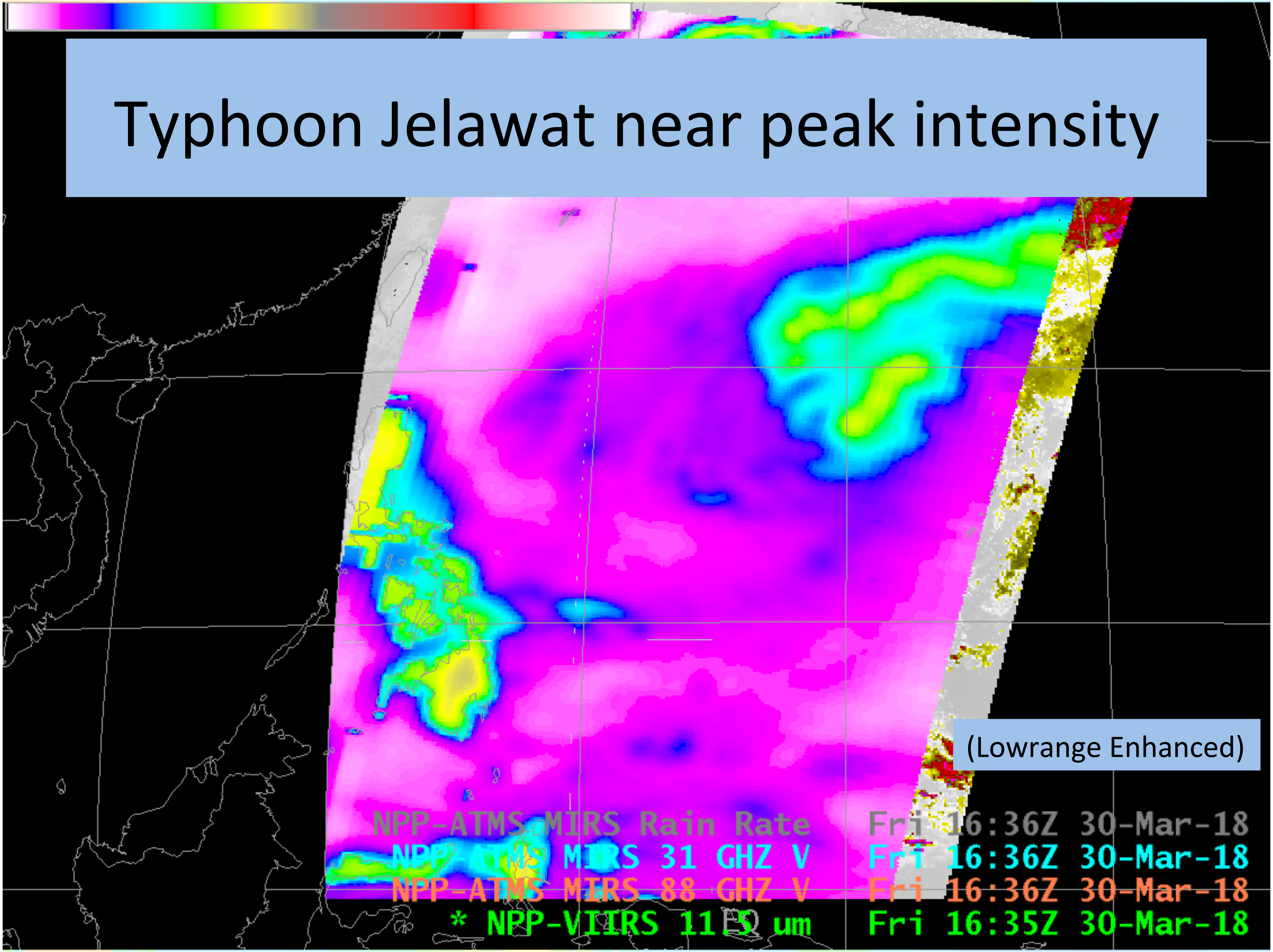



20N
130E
140E
150E
10N
120E
NPP-ATMS MIRS 183 GHZ H-1 Thu 04:21Z 29-Mar-18
NPP-ATMS MIRS 165 GHZ H Thu 04:21Z 29-Mar-18
NPP-ATMS MIRS 88 GHZ V Thu 04:21Z 29-Mar-18
NPP-ATMS MIRS 31 GHZ V Thu 04:21Z 29-Mar-18
NPP-VIIRS 0.64 um Thu 04:20Z 29-Mar-18
NPP-VIIRS 11.5 um Thu 04:20Z 29-Mar-18
NPP-ATMS MIRS TPW Thu 04:21Z 29-Mar-18
* NPP-ATMS MIRS Rain Rate Thu 04:21Z 29-Mar-18

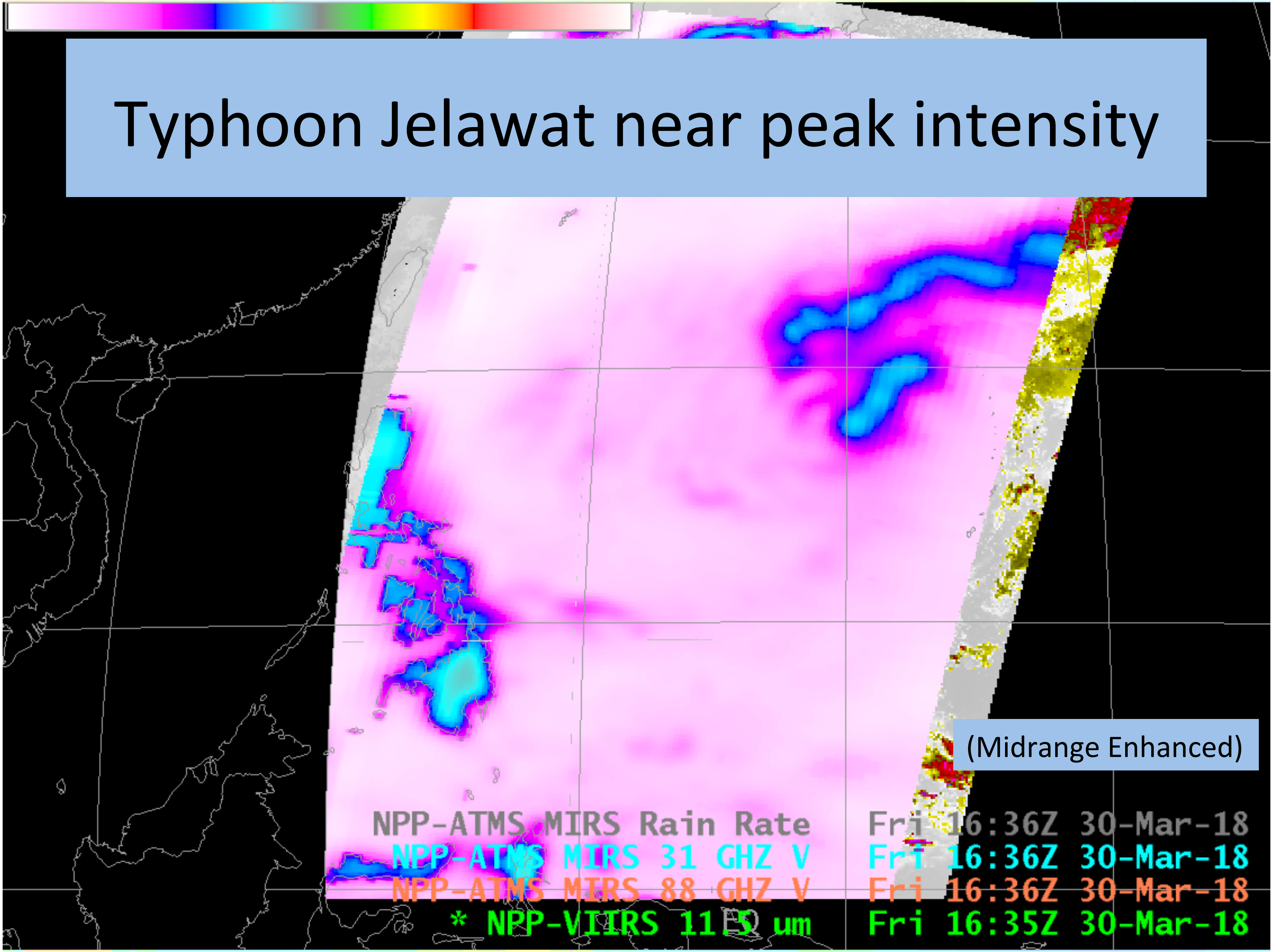
Typhoon Jelawat near peak intensity

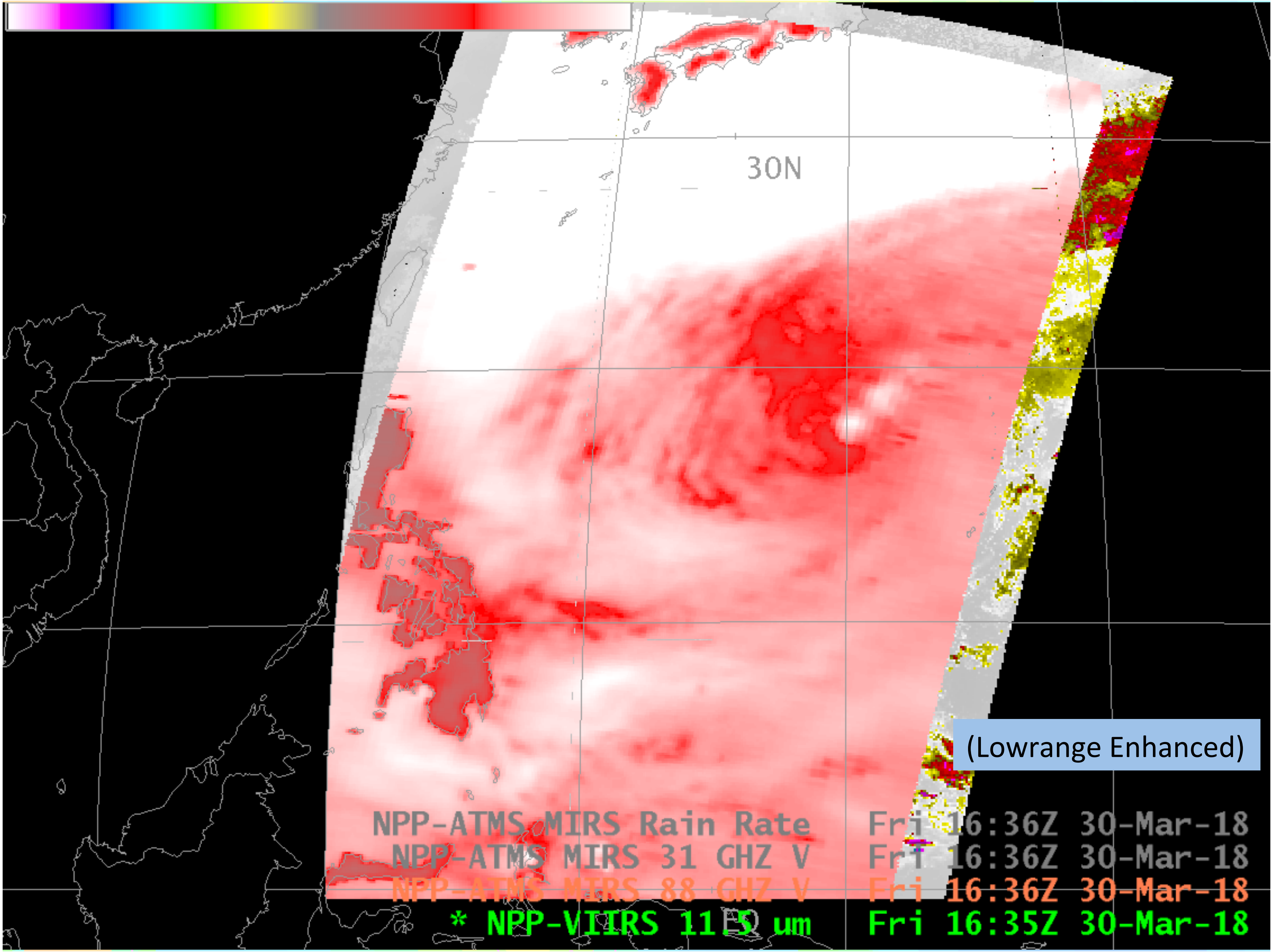


Typhoon Jelawat near peak intensity

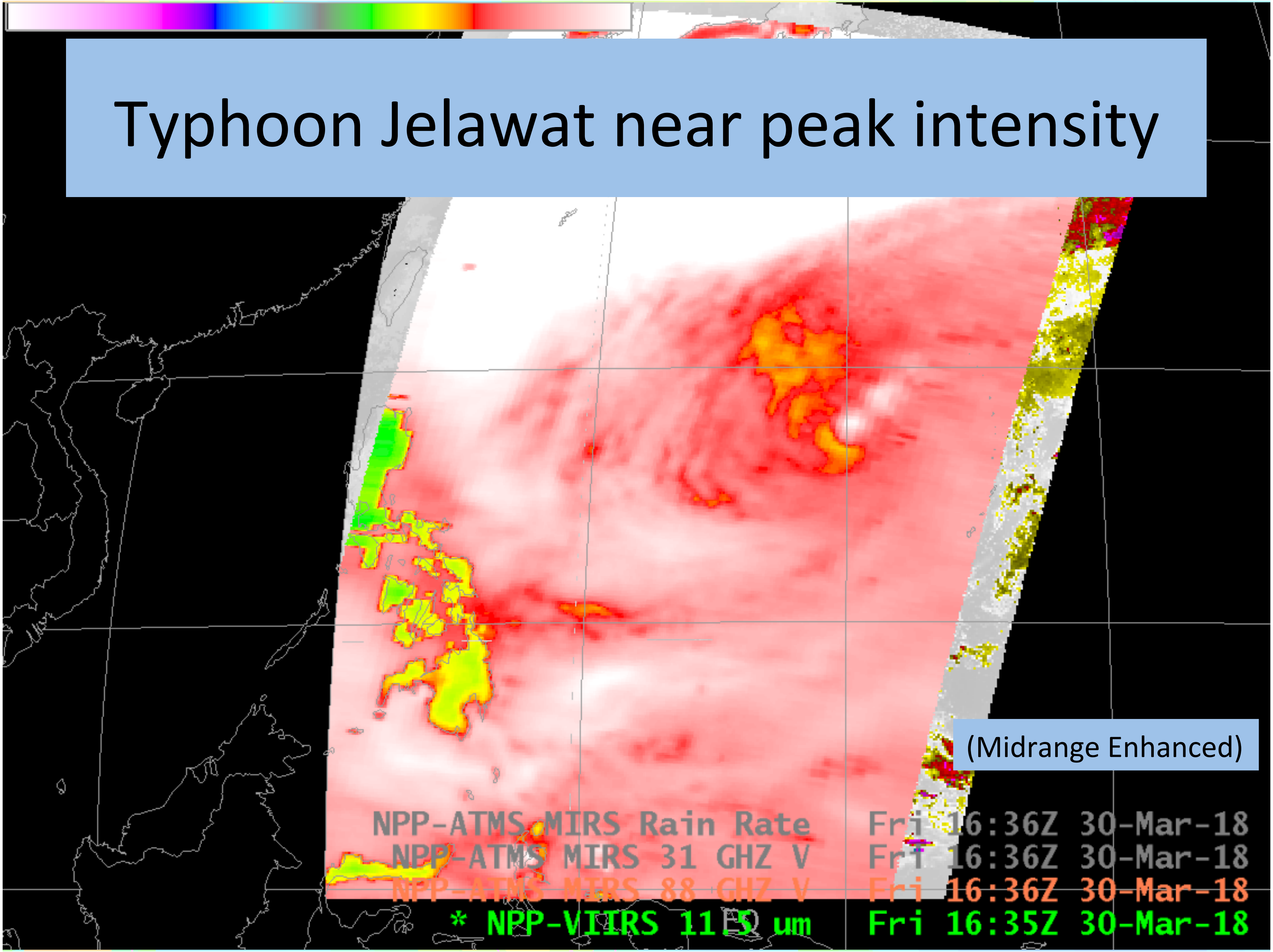


Typhoon Jelawat near peak intensity

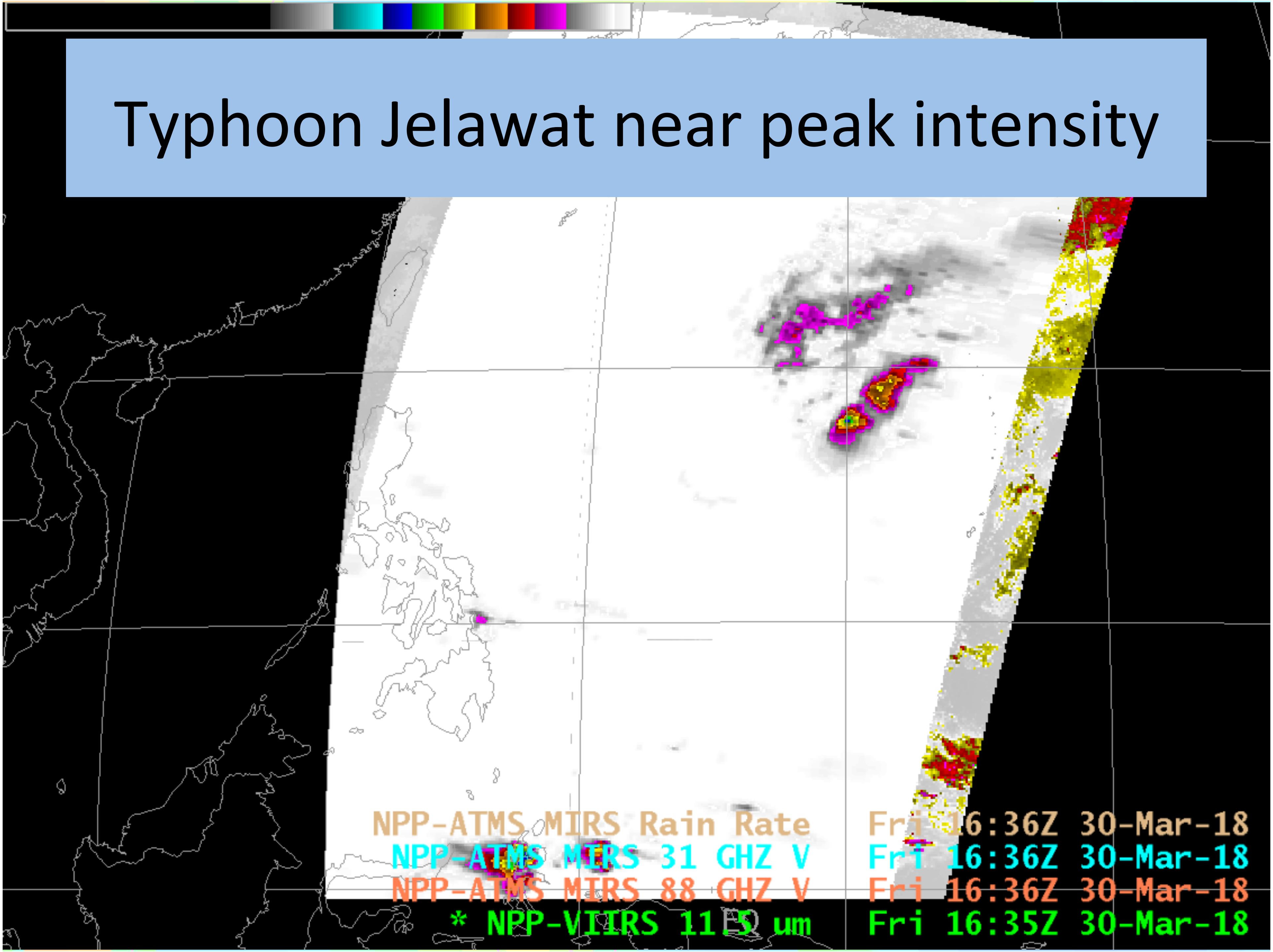



30N
(Lowrange Enhanced)
NPP-ATMS MIRS Rain Rate Fri 16:36Z 30-Mar-18
NPP-ATMS MIRS 31 GHZ V Fri 16:36Z 30-Mar-18
NPP-ATMS MIRS 88 GHZ V Fri 16:36Z 30-Mar-18
* NPP-VIIRS 11.5 um Fri 16:35Z 30-Mar-18

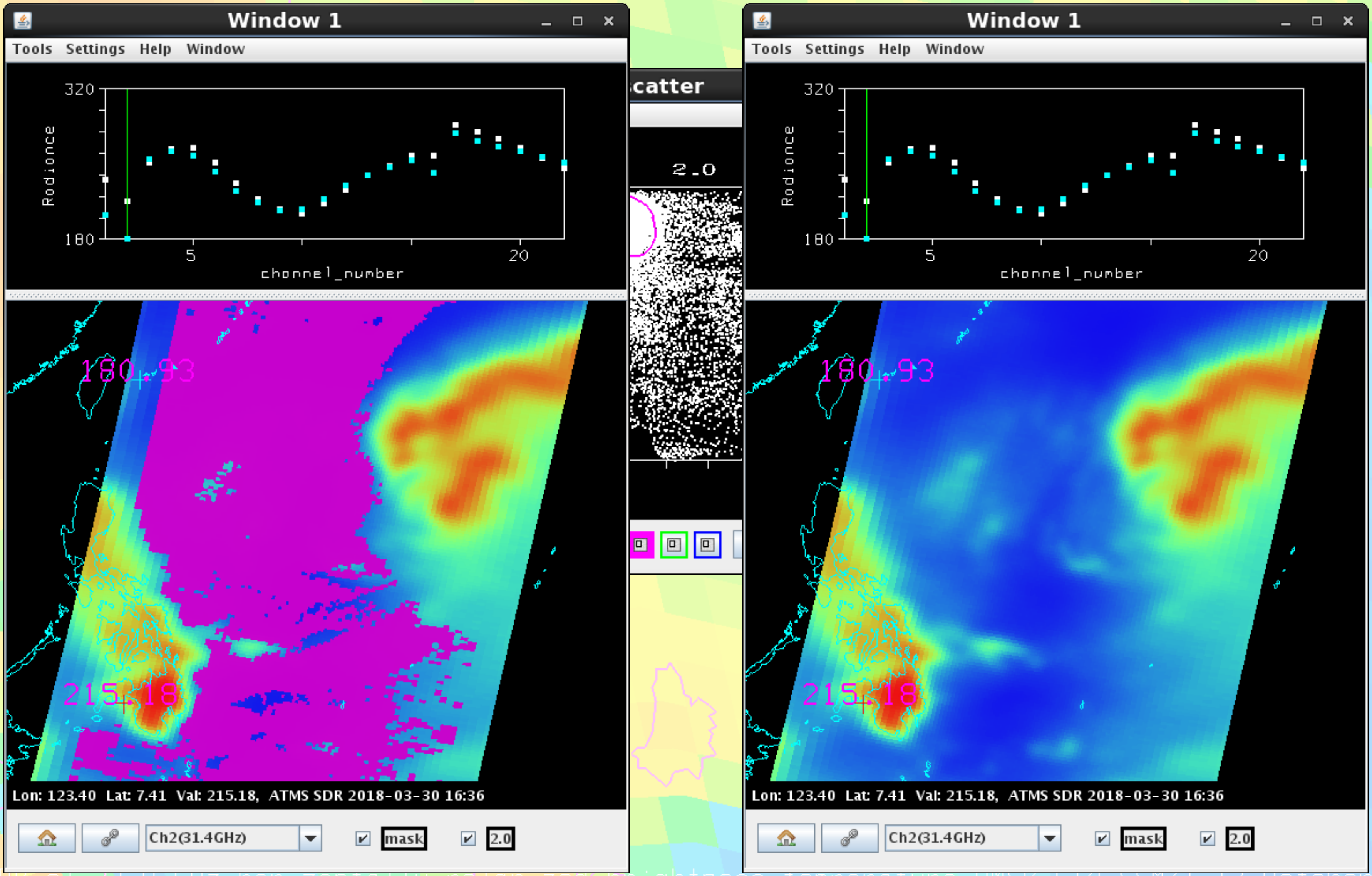
Typhoon Jelawat near peak intensity



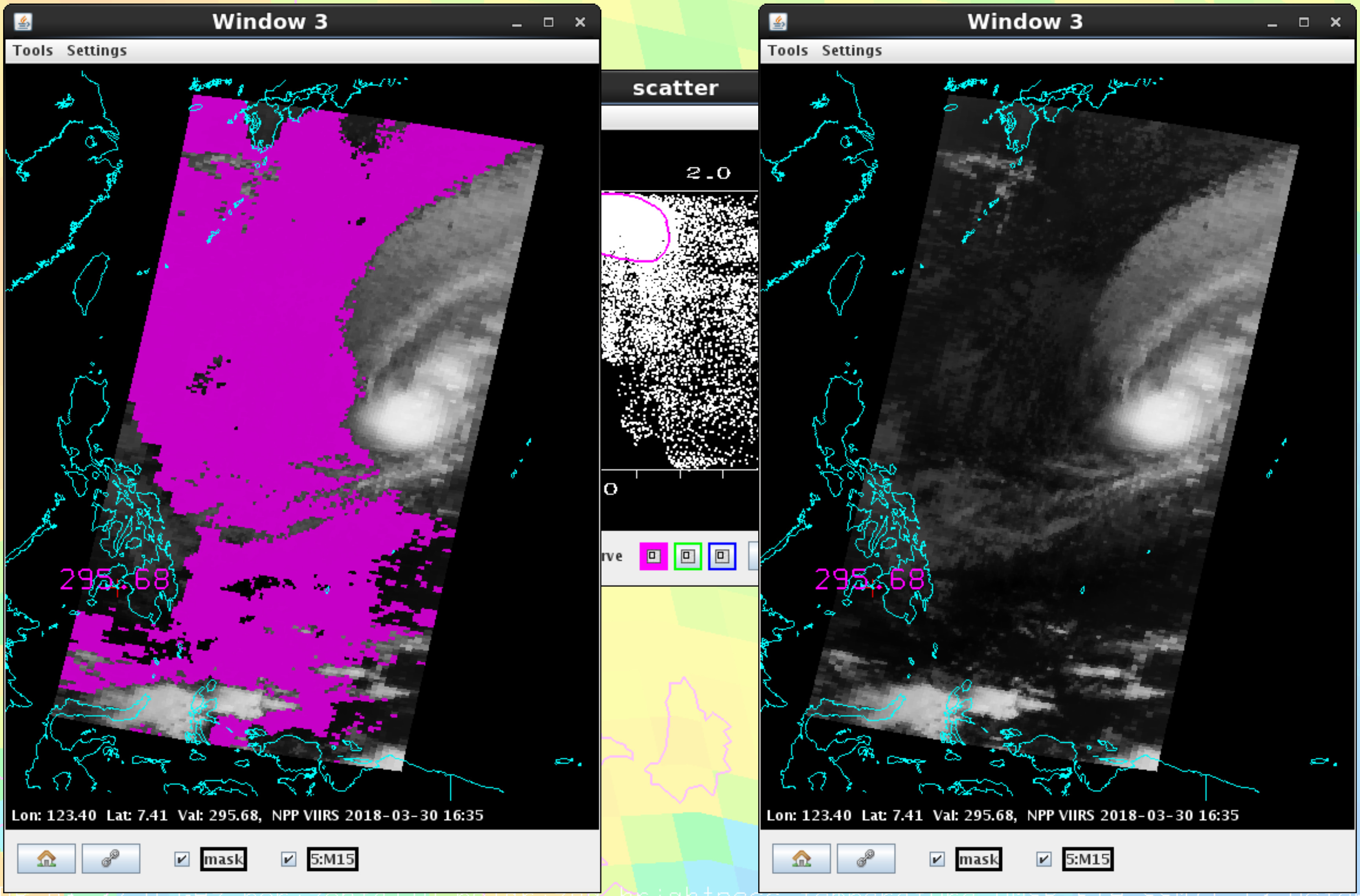
Typhoon Jelawat near peak intensity



Compare ATMS and VIIRS



Compare ATMS and VIIRS



Conclusions

- Microwave data gives important information in regions of clouds
- Important precipitation-related products can be generated by microwave channel combinations
  - Total Precipitable Water
  - Rain Rate
- Emissivity properties of the surface cause different brightness temperatures than what you might expect given IR temperatures.

S FCDR of 37.0 GHz horizontally polarized brightness temperature DMSP F14 SSM/I 13 October 19