Tropical Cyclone Analysis
Using Polar Orbiter Satellite Imagery

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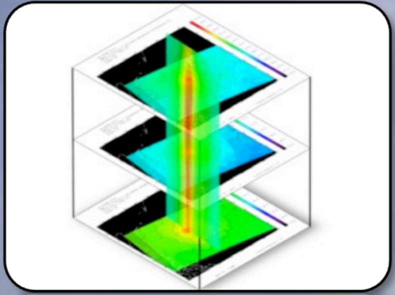
University of Wisconsin – CIMSS

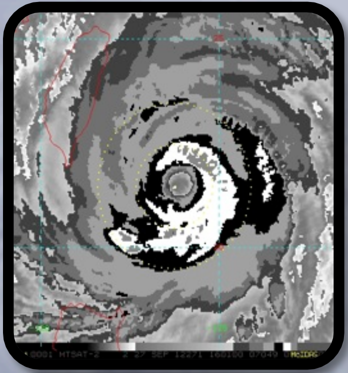
Direct Broadcast Workshop Miami, February 9-13, 2015

Microwave Sounders

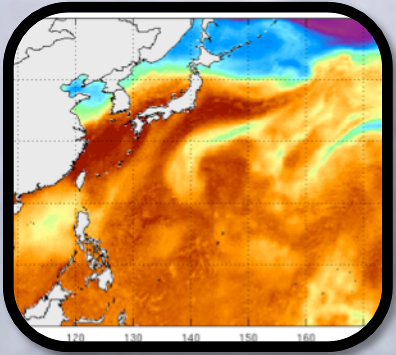
AMSU, SSMIS & ATMS



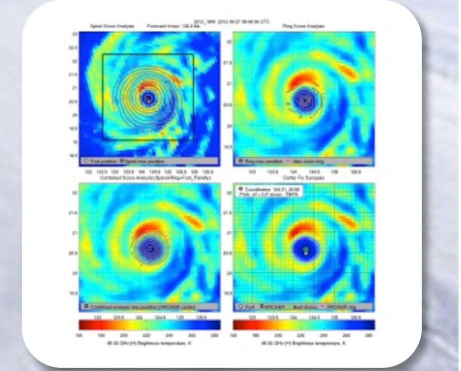
Dvorak



MIMIC-TPW



ARCHER



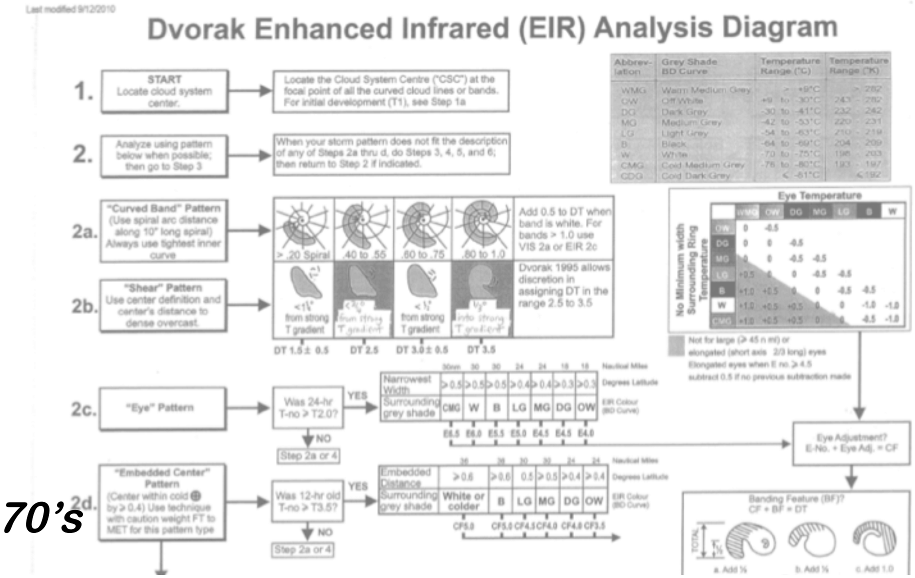
Super Typhoon Jelewat 2012

First …

How are Tropical Cyclones Analyzed?

Dvorak Technique

Vern Dvorak – circa late 1970's



Last modified 9/12/2010

Dvorak Enhanced Infrared (EIR) Analysis Diagram

1. **START** Locate cloud system center. → Locate the Cloud System Centre ("CSC") at the focal point of all the curved cloud lines or bands. For initial development (T1), see Step 1a

2. Analyze using pattern below when possible; then go to Step 3 → When your storm pattern does not fit the description of any of Steps 2a thru d, do Steps 3, 4, 5, and 6; then return to Step 2 if indicated.

2a. **"Curved Band" Pattern** (Use spiral arc distance along 10° long spiral) Always use tightest inner curve →

Add 0.5 to DT when band is white. For bands > 1.0 use VIS 2a or EIR 2c

2b. **"Shear" Pattern** Use center definition and center's distance to dense overcast. →

Dvorak 1995 allows discretion in assigning DT in the range 2.5 to 3.5

Abbrev-iation	Grey Shade BD Curve	Temperature Range (°C)	Temperature Range (°K)
WMG	Warm Medium Grey	> +9°C	> 282
OW	Off White	+9 to -30°C	243 - 282
DG	Dark Grey	-30 to -41°C	232 - 242
MG	Medium Grey	-42 to -53°C	220 - 231
LG	Light Grey	-54 to -63°C	210 - 219
B	Black	-64 to -69°C	204 - 209
W	White	-70 to -75°C	198 - 203
CMG	Cold Medium Grey	-76 to -80°C	193 - 197
CDG	Cold Dark Grey	≤ -81°C	≤ 192

Eye Temperature

No Minimum width Surrounding Ring Temperature

	WMG	OW	DG	MG	LG	B	W
OW	0	-0.5					
DG	0	0	-0.5				
MG	0	0	-0.5	-0.5			
LG	+0.5	0	0	-0.5	-0.5		
B	+1.0	+0.5	0	0	-0.5	-0.5	
W	+1.0	+0.5	+0.5	0	0	-1.0	-1.0
CMG	+1.0	+0.5	+0.5	0	0	-0.5	-1.0

▨ Not for large (≥ 45 n mi) or elongated (short axis 2/3 long) eyes
Elongated eyes when E no. ≥ 4.5
subtract 0.5 if no previous subtraction made

2c. **"Eye" Pattern** → Was 24-hr T-no ≥ T2.0? YES → ; NO → Step 2a or 4

Nautical Miles	30nm	30	30	24	24	18	18
Narrowest Width (Degrees Latitude)	> 0.5	> 0.5	> 0.5	> 0.4	> 0.4	> 0.3	> 0.3
Surrounding grey shade (EIR Colour (BD Curve))	CMG	W	B	LG	MG	DG	OW
	E6.5	E6.0	E5.5	E5.0	E4.5	E4.5	E4.0

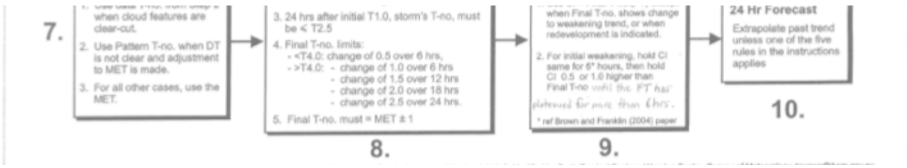
Eye Adjustment? E-No. + Eye Adj. = CF

2d. **"Embedded Center" Pattern** (Center within cold ⊕ by ≥ 0.4) Use technique with caution weight FT to MET for this pattern type → Was 12-hr old T-no ≥ T3.5? YES → ; NO → Step 2a or 4

Nautical Miles	36	36	30	30	24	24
Embedded Distance (Degrees Latitude)	≥ 0.6	≥ 0.6	0.5	≥ 0.5	≥ 0.4	≥ 0.4
Surrounding grey shade (EIR Colour (BD Curve))	White or colder	B	LG	MG	DG	OW
	CF5.0	CF5.0	CF4.5	CF4.0	CF4.0	CF3.5

Banding Feature (BF)? CF + BF = DT

"The Dvorak tropical cyclone (TC) intensity estimation technique has been the primary method of monitoring tropical systems for more than three decades. The technique has likely saved tens of thousands of lives in regions where over one billion people are directly affected by TCs (commonly called hurricanes, typhoons, or cyclones). The Dvorak technique's practical appeal and demonstrated skill in the face of tremendous dynamic complexity"
 - Velden et al 2006



7.
when cloud features are clear-cut.
2. Use Pattern T-no. when DT is not clear and adjustment to MET is made.
3. For all other cases, use the MET.

8.
3. 24 hrs after initial T1.0, storm's T-no, must be ≤ T2.5
4. Final T-no. limits:
  - <T4.0: change of 0.5 over 6 hrs,
  - >T4.0:
    - change of 1.0 over 6 hrs
    - change of 1.5 over 12 hrs
    - change of 2.0 over 18 hrs
    - change of 2.5 over 24 hrs.
5. Final T-no. must = MET ± 1

9.
when Final T-no. shows change to weakening trend, or when redevelopment is indicated.
2. For initial weakening, hold CI same for 6* hours, then hold CI 0.5 or 1.0 higher than Final T-no until the FT has plateaued for more than 6hrs.
* ref Brown and Franklin (2004) paper

10.
24 Hr Forecast
Extrapolate past trend unless one of the five rules in the instructions applies

Dvorak Technique

- Intensity is inferred from patterns and features
- 24 hour change requirement addresses diurnal changes unrelated to intensity
- TC position relative to convective features important for accurate intensity estimates
- Most accurate for estimating TC central pressure
- DT is most objective for eye scenes
- Method has stood the test of time however some changes can be made to improve estimates.

Dvorak Technique – Flow

Locate System

Estimate Intensity

Data T Number

1. Cloud system measurements

- Eye
- Curved Band
- Shear
- Covered center

Model Expected T Number

2. 24 hour changes

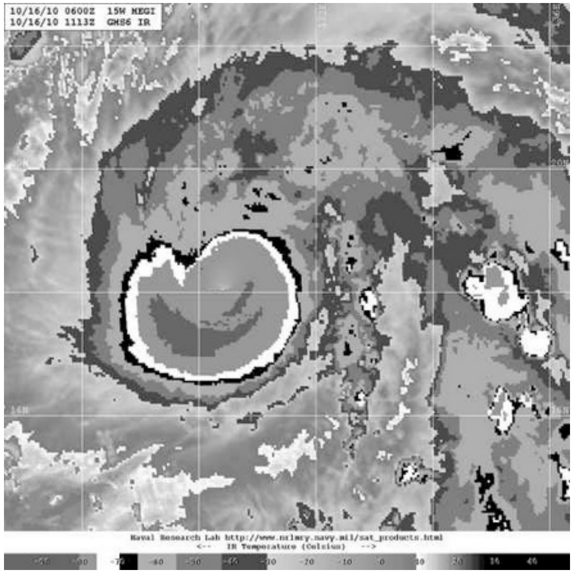
Pattern Adjusted Model T number

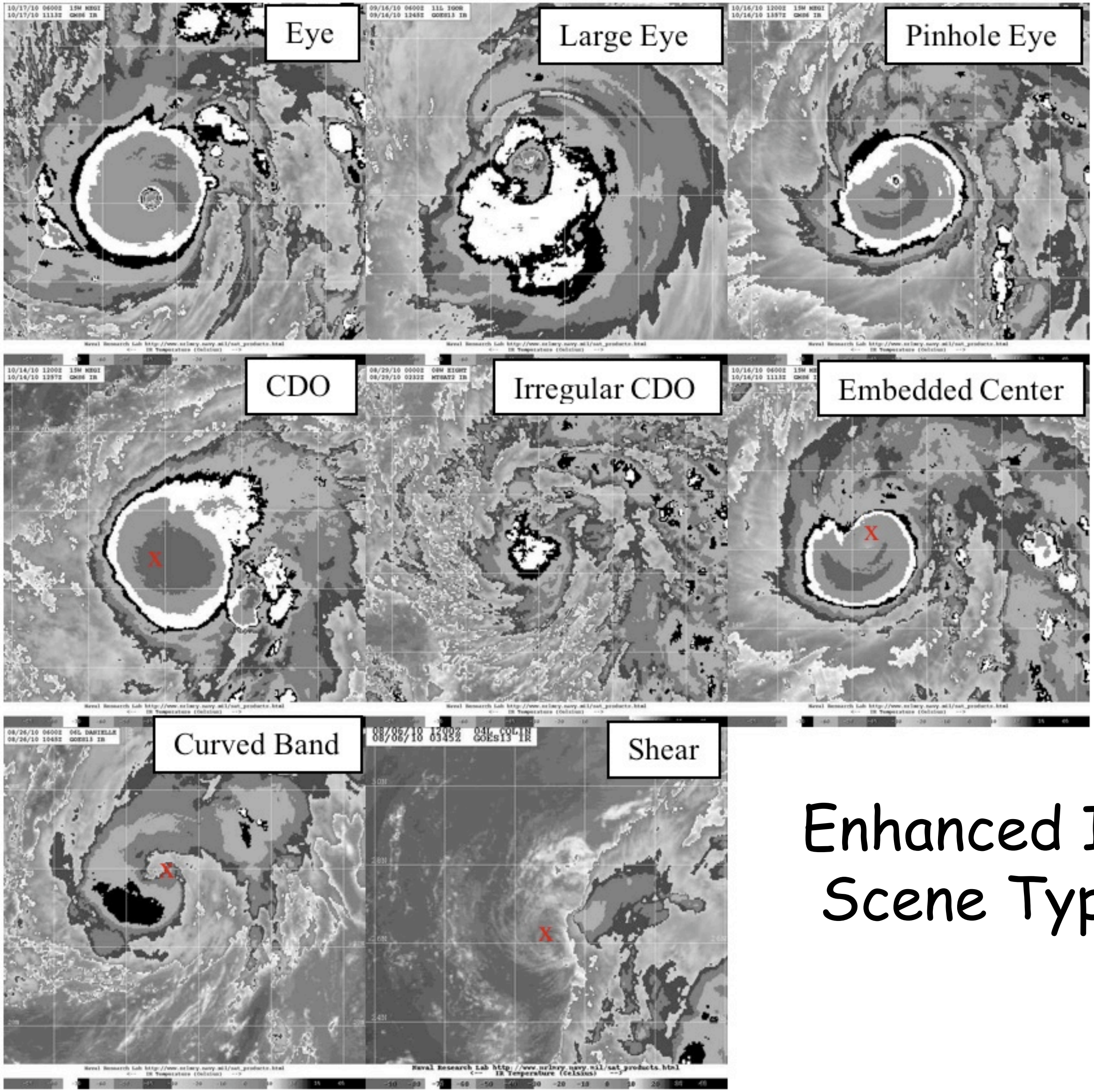
Pattern recognition

Choose best estimate

Apply constraints

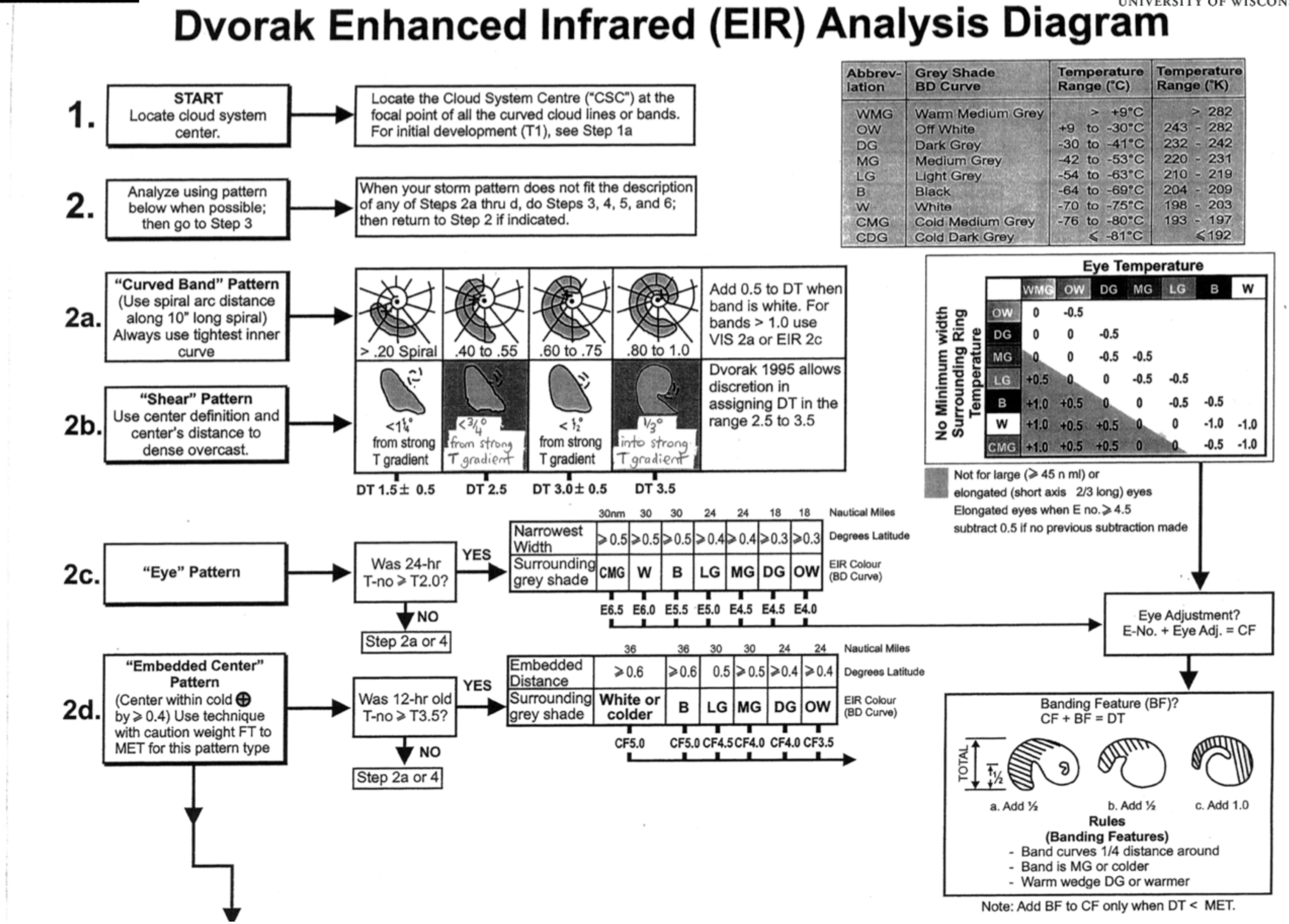
Final intensity





Enhanced IR Scene Types

Dvorak Technique



Dvorak Enhanced Infrared (EIR) Analysis Diagram

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2a. **"Curved Band" Pattern** (Use spiral arc distance along 10° long spiral) Always use tightest inner curve →

> .20 Spiral	.40 to .55	.60 to .75	.80 to 1.0	Add 0.5 to DT when band is white. For bands > 1.0 use VIS 2a or EIR 2c

2b. **"Shear" Pattern** Use center definition and center's distance to dense overcast. →

<1¼° from strong T gradient	<¾° from strong T gradient	< ½° from strong T gradient	⅓° into strong T gradient	Dvorak 1995 allows discretion in assigning DT in the range 2.5 to 3.5
DT 1.5 ± 0.5	DT 2.5	DT 3.0 ± 0.5	DT 3.5	

2c. **"Eye" Pattern** → Was 24-hr T-no ⩾ T2.0? NO → Step 2a or 4; YES →

	30nm	30	30	24	24	18	18	Nautical Miles
Narrowest Width	⩾0.5	⩾0.5	⩾0.5	⩾0.4	⩾0.4	⩾0.3	⩾0.3	Degrees Latitude
Surrounding grey shade	CMG	W	B	LG	MG	DG	OW	EIR Colour (BD Curve)
	E6.5	E6.0	E5.5	E5.0	E4.5	E4.5	E4.0	

→ Eye Adjustment? E-No. + Eye Adj. = CF

2d. **"Embedded Center" Pattern** (Center within cold ⊕ by ⩾ 0.4) Use technique with caution weight FT to MET for this pattern type → Was 12-hr old T-no ⩾ T3.5? NO → Step 2a or 4; YES →

	36	36	30	30	24	24	Nautical Miles
Embedded Distance	⩾0.6	⩾0.6	0.5	⩾0.5	⩾0.4	⩾0.4	Degrees Latitude
Surrounding grey shade	White or colder	B	LG	MG	DG	OW	EIR Colour (BD Curve)
	CF5.0	CF5.0	CF4.5	CF4.0	CF4.0	CF3.5	

Abbrev-iation	Grey Shade BD Curve	Temperature Range (°C)	Temperature Range (°K)
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Eye Temperature

No Minimum width Surrounding Ring Temperature	WMG	OW	DG	MG	LG	B	W
OW	0	-0.5					
DG	0	0	-0.5				
MG	0	0	-0.5	-0.5			
LG	+0.5	0	0	-0.5	-0.5		
B	+1.0	+0.5	0	0	-0.5	-0.5	
W	+1.0	+0.5	+0.5	0	0	-1.0	-1.0
CMG	+1.0	+0.5	+0.5	0	0	-0.5	-1.0

▨ Not for large (⩾ 45 n ml) or elongated (short axis 2/3 long) eyes

Elongated eyes when E no. ⩾ 4.5 subtract 0.5 if no previous subtraction made

Banding Feature (BF)?
CF + BF = DT

TOTAL

½

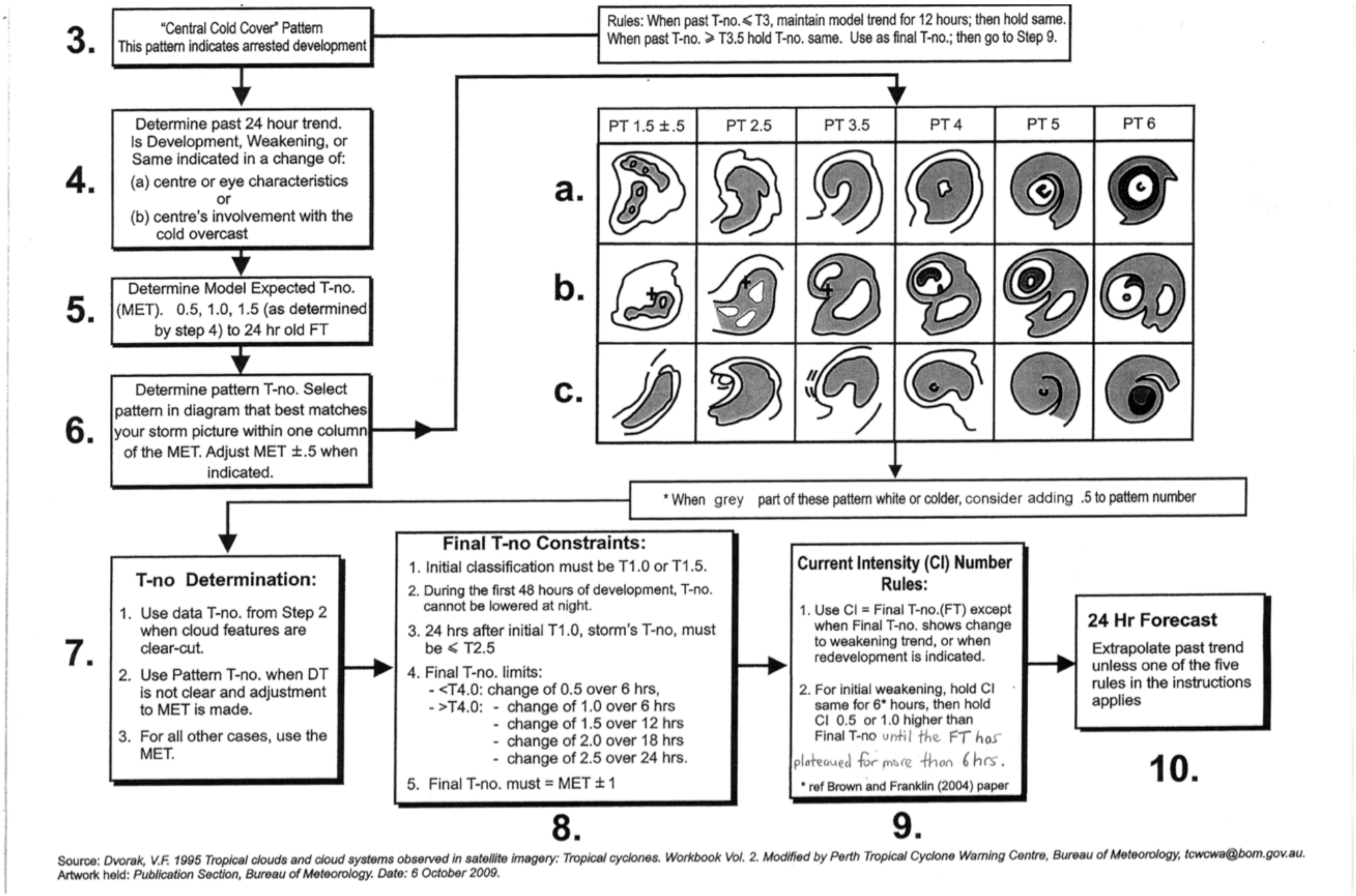
a. Add ½ b. Add ½ c. Add 1.0

Rules
(Banding Features)

- Band curves 1/4 distance around
- Band is MG or colder
- Warm wedge DG or warmer

Note: Add BF to CF only when DT < MET.

Dvorak Technique



3\. "Central Cold Cover" Pattern
This pattern indicates arrested development

Rules: When past T-no. ≤ T3, maintain model trend for 12 hours; then hold same. When past T-no. ≥ T3.5 hold T-no. same. Use as final T-no.; then go to Step 9.

4\. Determine past 24 hour trend. Is Development, Weakening, or Same indicated in a change of:
(a) centre or eye characteristics
or
(b) centre's involvement with the cold overcast

5\. Determine Model Expected T-no. (MET). 0.5, 1.0, 1.5 (as determined by step 4) to 24 hr old FT

6\. Determine pattern T-no. Select pattern in diagram that best matches your storm picture within one column of the MET. Adjust MET ±.5 when indicated.

* When grey part of these pattern white or colder, consider adding .5 to pattern number

7\. **T-no Determination:**

1. Use data T-no. from Step 2 when cloud features are clear-cut.
2. Use Pattern T-no. when DT is not clear and adjustment to MET is made.
3. For all other cases, use the MET.

8\. **Final T-no Constraints:**

1. Initial classification must be T1.0 or T1.5.
2. During the first 48 hours of development, T-no. cannot be lowered at night.
3. 24 hrs after initial T1.0, storm's T-no, must be ≤ T2.5
4. Final T-no. limits:
   - <T4.0: change of 0.5 over 6 hrs,
   - >T4.0:
     - change of 1.0 over 6 hrs
     - change of 1.5 over 12 hrs
     - change of 2.0 over 18 hrs
     - change of 2.5 over 24 hrs.
5. Final T-no. must = MET ± 1

9\. **Current Intensity (CI) Number Rules:**

1. Use CI = Final T-no.(FT) except when Final T-no. shows change to weakening trend, or when redevelopment is indicated.
2. For initial weakening, hold CI same for 6* hours, then hold CI 0.5 or 1.0 higher than Final T-no until the FT has plateaued for more than 6 hrs.

* ref Brown and Franklin (2004) paper

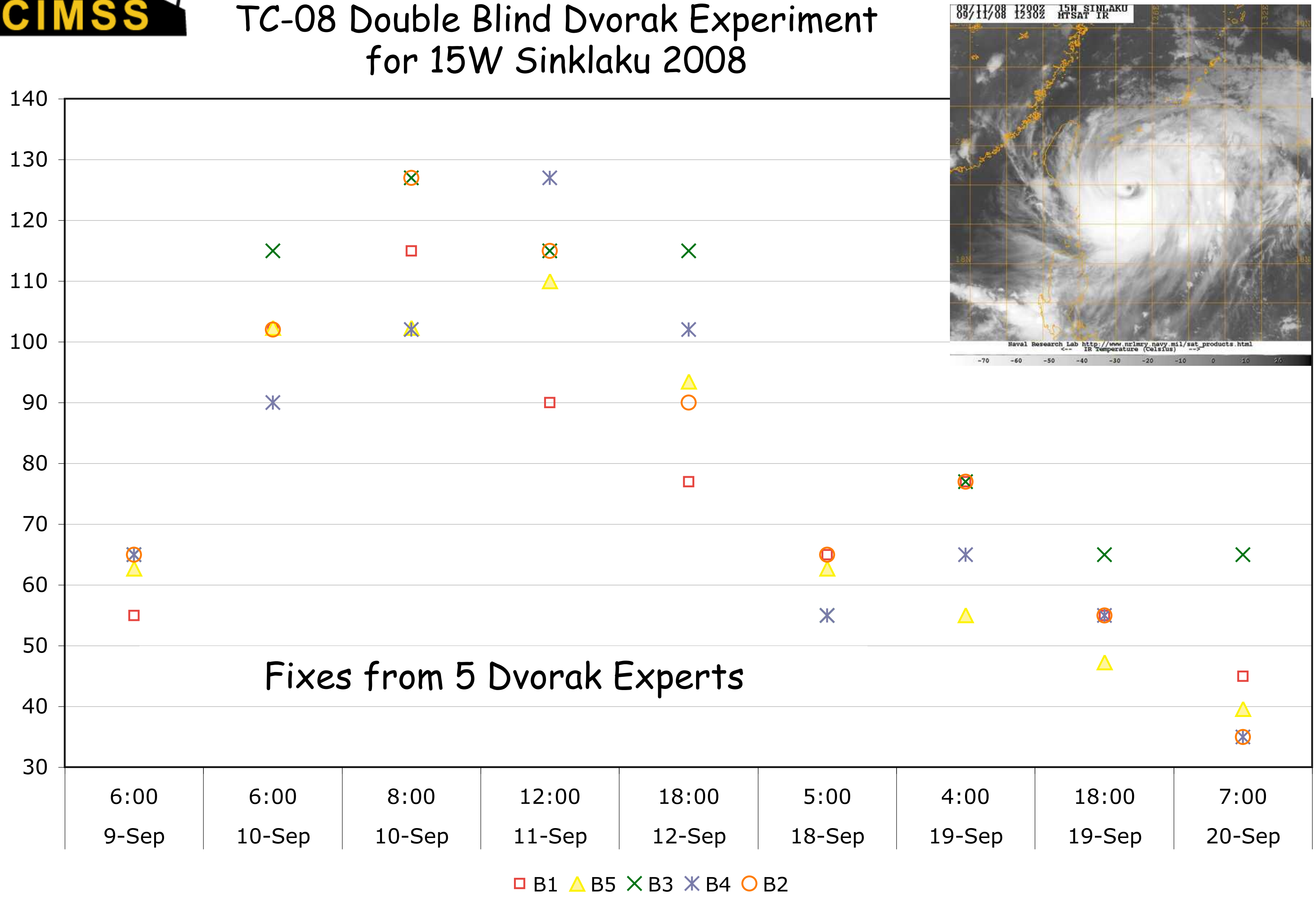
10\. **24 Hr Forecast**

Extrapolate past trend unless one of the five rules in the instructions applies

Source: *Dvorak, V.F. 1995 Tropical clouds and cloud systems observed in satellite imagery: Tropical cyclones. Workbook Vol. 2. Modified by Perth Tropical Cyclone Warning Centre, Bureau of Meteorology, tcwcwa@bom.gov.au.*
Artwork held: *Publication Section, Bureau of Meteorology. Date: 6 October 2009.*

Dvorak Technique – Estimate Variance

TC-08 Double Blind Dvorak Experiment for 15W Sinklaku 2008



Fixes from 5 Dvorak Experts

Dvorak Technique – Estimate Variance

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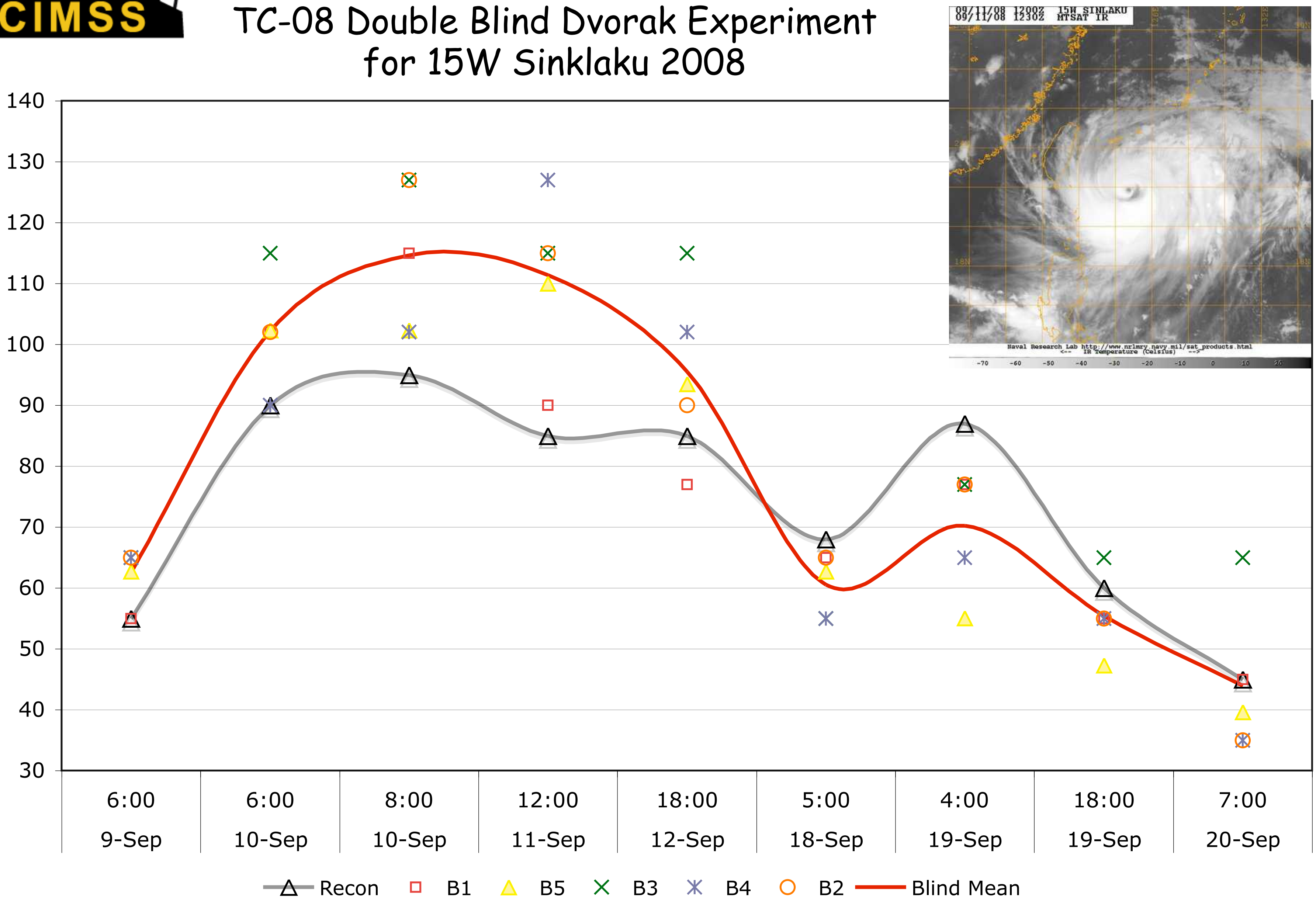
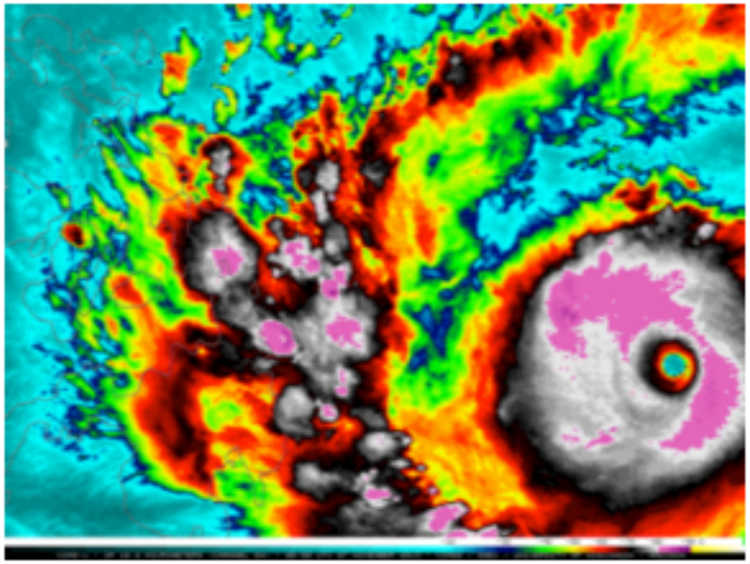
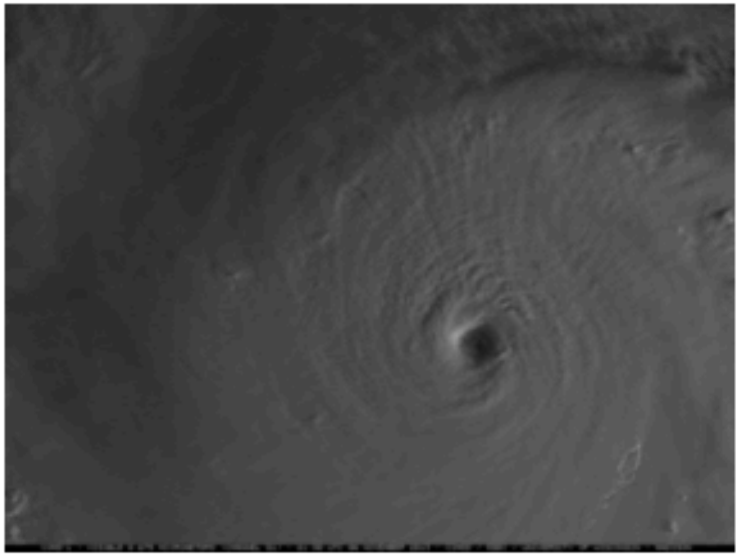
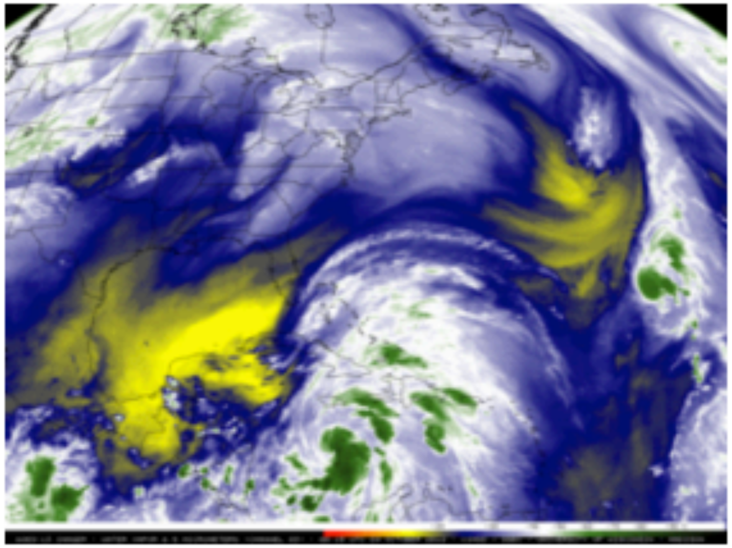


So Why Do We Need Polar Imagery?

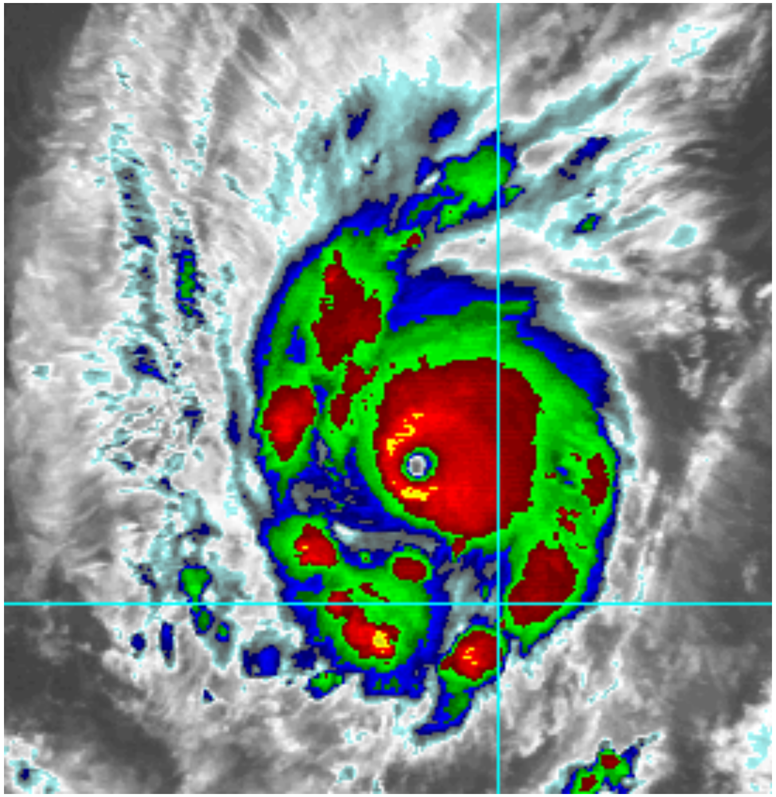




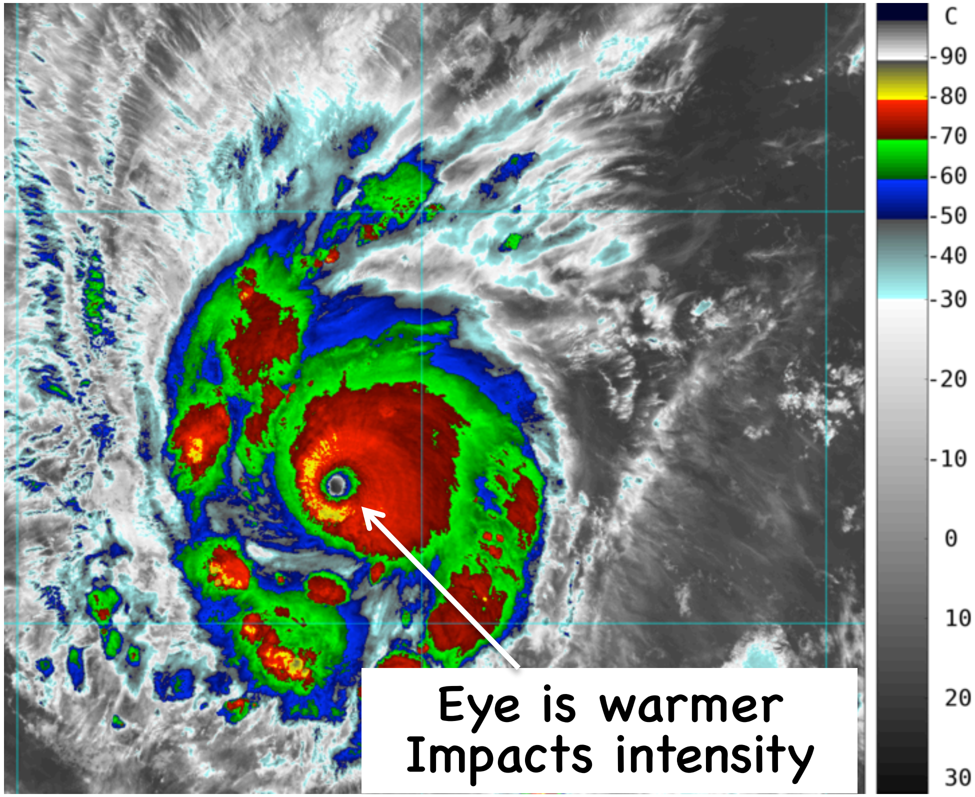


Why Do We Need Polar Imagery?

Better Resolution



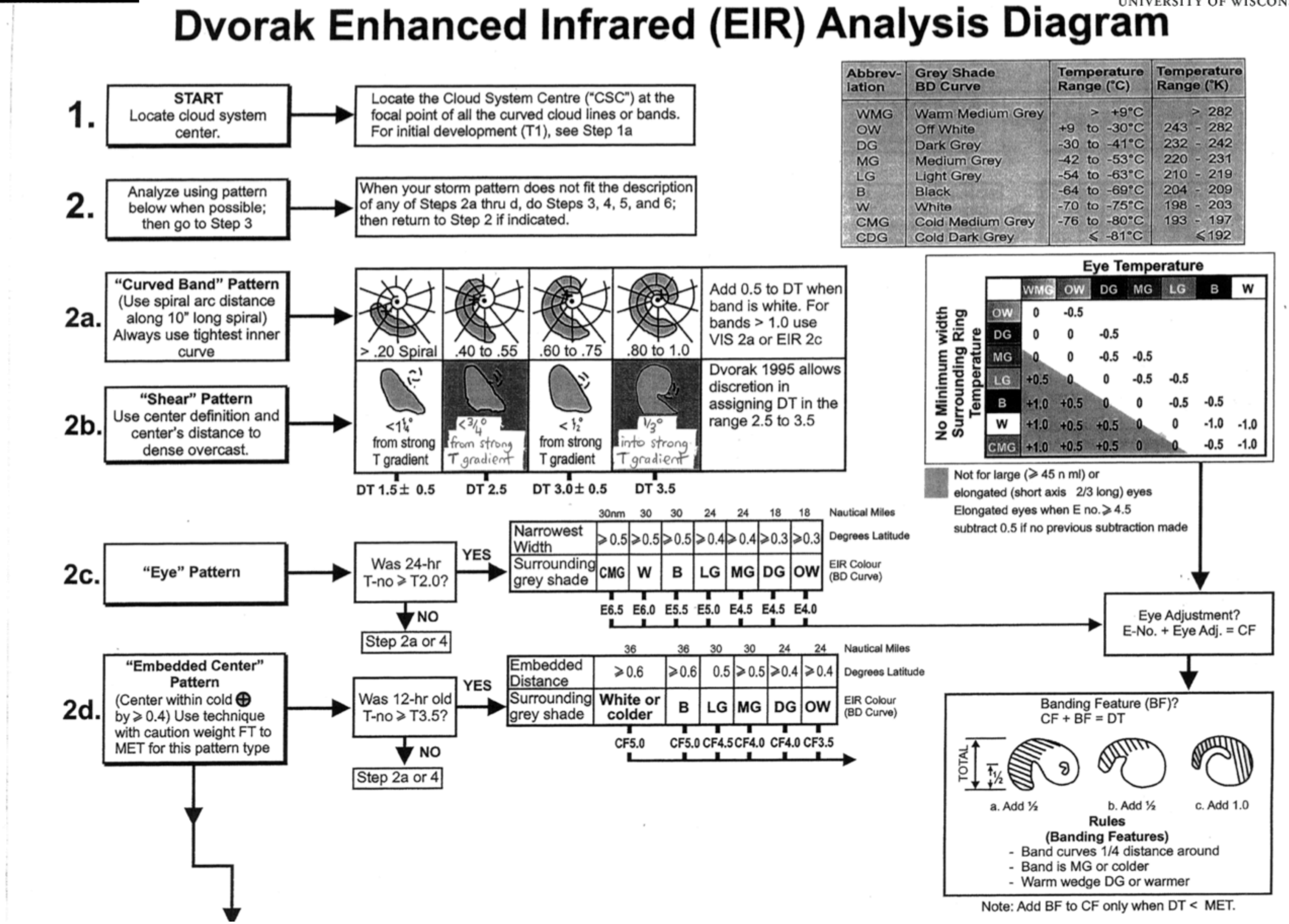
Geostationary 4 km



Eye is warmer
Impacts intensity

VIIRS 0.75 km

Dvorak Technique



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<1¼° from strong T gradient | <¾° from strong T gradient | <½° from strong T gradient | ⅓° into strong T gradient

Dvorak 1995 allows discretion in assigning DT in the range 2.5 to 3.5

DT 1.5 ± 0.5 | **DT 2.5** | **DT 3.0 ± 0.5** | **DT 3.5**

Eye Temperature

No Minimum width Surrounding Ring Temperature

	WMG	OW	DG	MG	LG	B	W
OW	0	-0.5					
DG	0	0	-0.5				
MG	0	0	-0.5	-0.5			
LG	+0.5	0	0	-0.5	-0.5		
B	+1.0	+0.5	0	0	-0.5	-0.5	
W	+1.0	+0.5	+0.5	0	0	-1.0	-1.0
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▨ Not for large (⩾ 45 n ml) or elongated (short axis 2/3 long) eyes

Elongated eyes when E no. ⩾ 4.5 subtract 0.5 if no previous subtraction made

2c. "Eye" Pattern → Was 24-hr T-no ⩾ T2.0? **YES** →

	30nm	30	30	24	24	18	18	Nautical Miles
Narrowest Width	⩾0.5	⩾0.5	⩾0.5	⩾0.4	⩾0.4	⩾0.3	⩾0.3	Degrees Latitude
Surrounding grey shade	CMG	W	B	LG	MG	DG	OW	EIR Colour (BD Curve)
	E6.5	E6.0	E5.5	E5.0	E4.5	E4.5	E4.0	

NO → Step 2a or 4

Eye Adjustment? E-No. + Eye Adj. = CF

2d. **"Embedded Center" Pattern** (Center within cold ⊕ by ⩾ 0.4) Use technique with caution weight FT to MET for this pattern type → Was 12-hr old T-no ⩾ T3.5? **YES** →

	36	36	30	30	24	24	Nautical Miles
Embedded Distance	⩾0.6	⩾0.6	0.5	⩾0.5	⩾0.4	⩾0.4	Degrees Latitude
Surrounding grey shade	**White or colder**	B	LG	MG	DG	OW	EIR Colour (BD Curve)
	CF5.0	CF5.0	CF4.5	CF4.0	CF4.0	CF3.5	

NO → Step 2a or 4

Banding Feature (BF)?
CF + BF = DT

a. Add ½ | b. Add ½ | c. Add 1.0

Rules
(Banding Features)

- Band curves 1/4 distance around
- Band is MG or colder
- Warm wedge DG or warmer

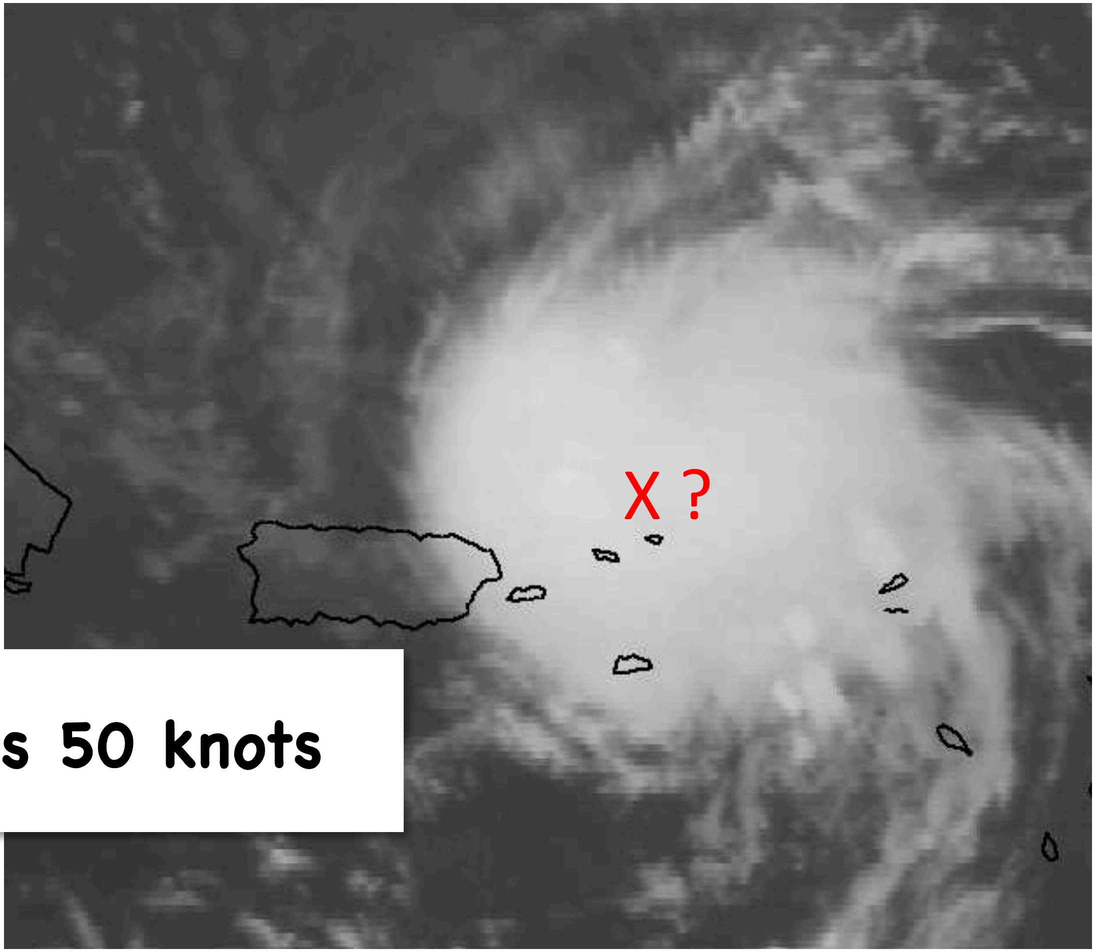
Note: Add BF to CF only when DT < MET.

Why Do We Need Polar Imagery?

Day Night Band

Where is the center?

Center location is KEY for estimating the intensity



If here intensity is 50 knots

GOES IR Image

Why Do We Need Polar Imagery?

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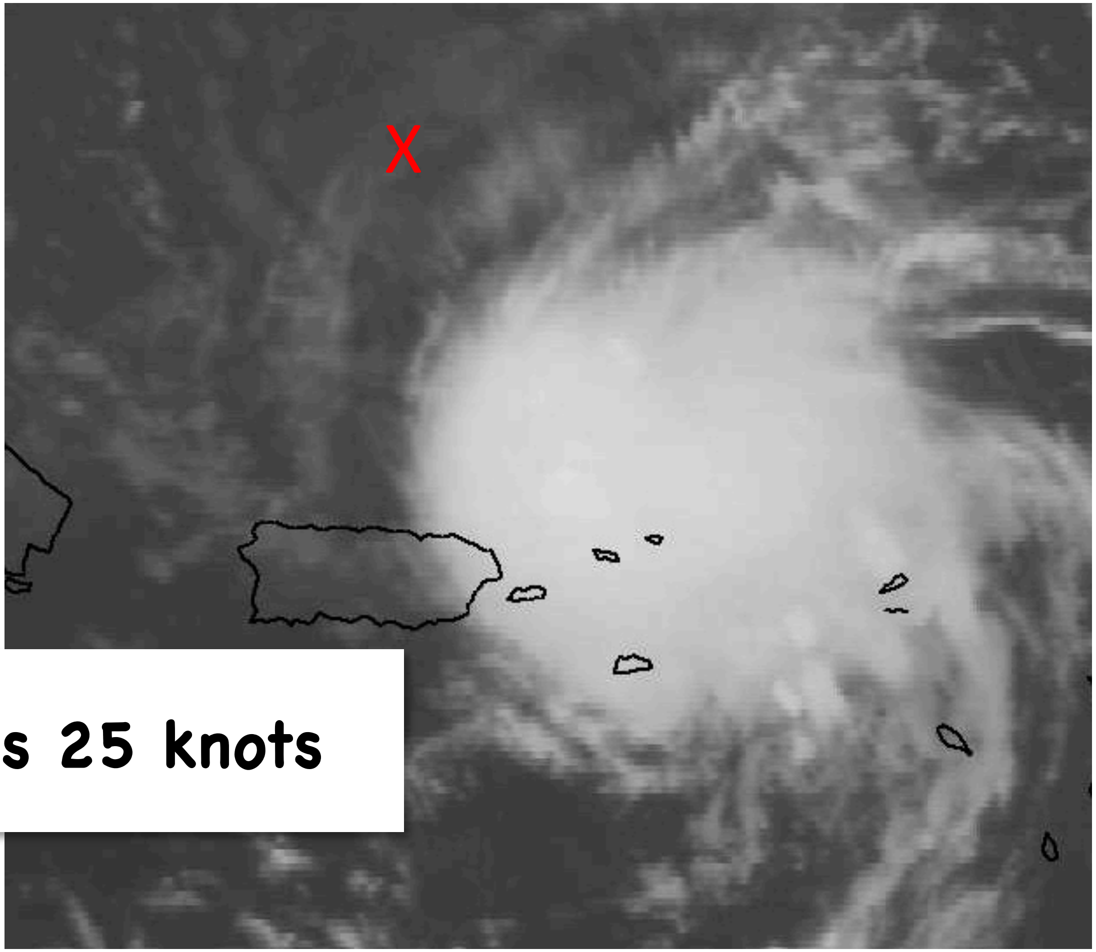
Center location is KEY for estimating the intensity



If here intensity is 25 knots

GOES IR Image

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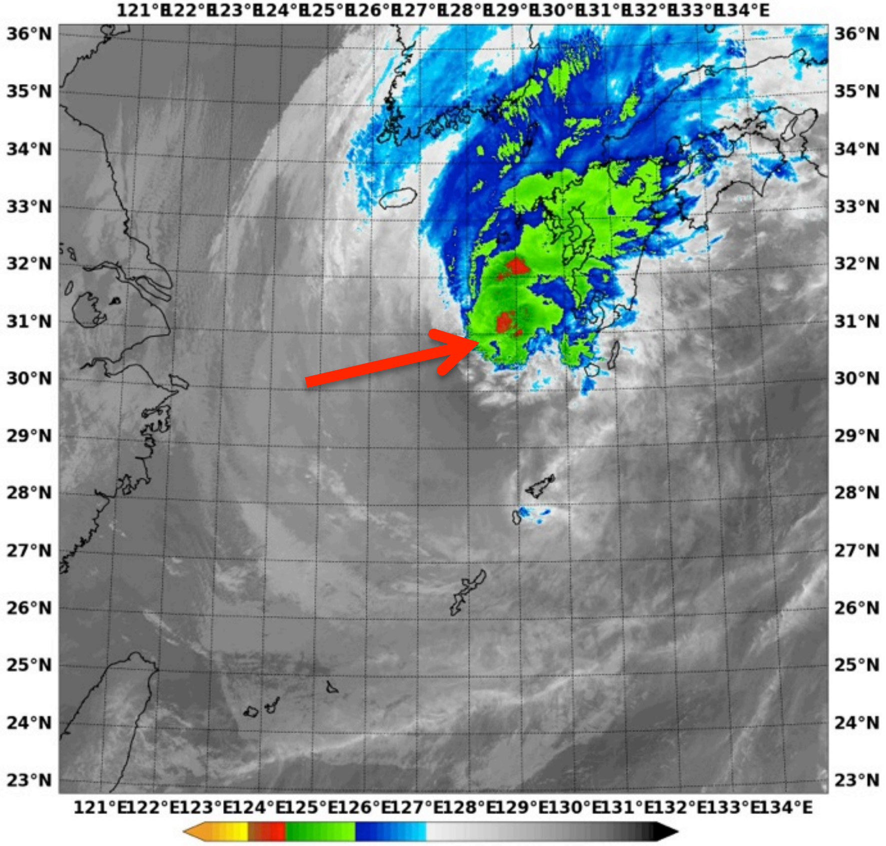
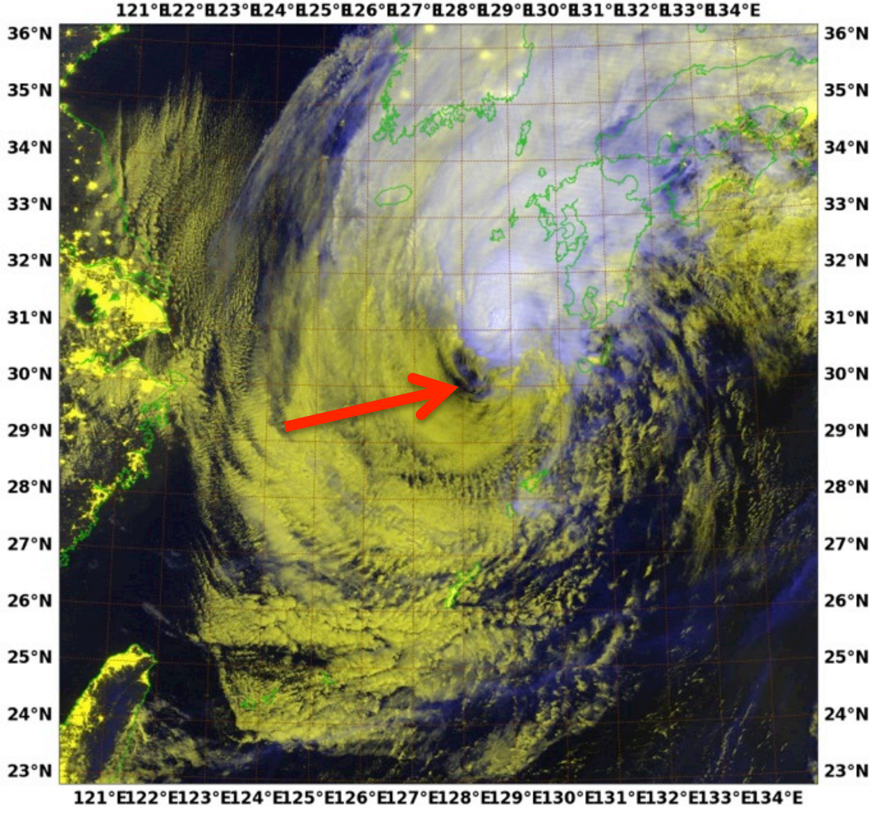
Day Night Band



NPP VIIRS Infrared 2014/10/12 17:02:47Z NRL-Monterey



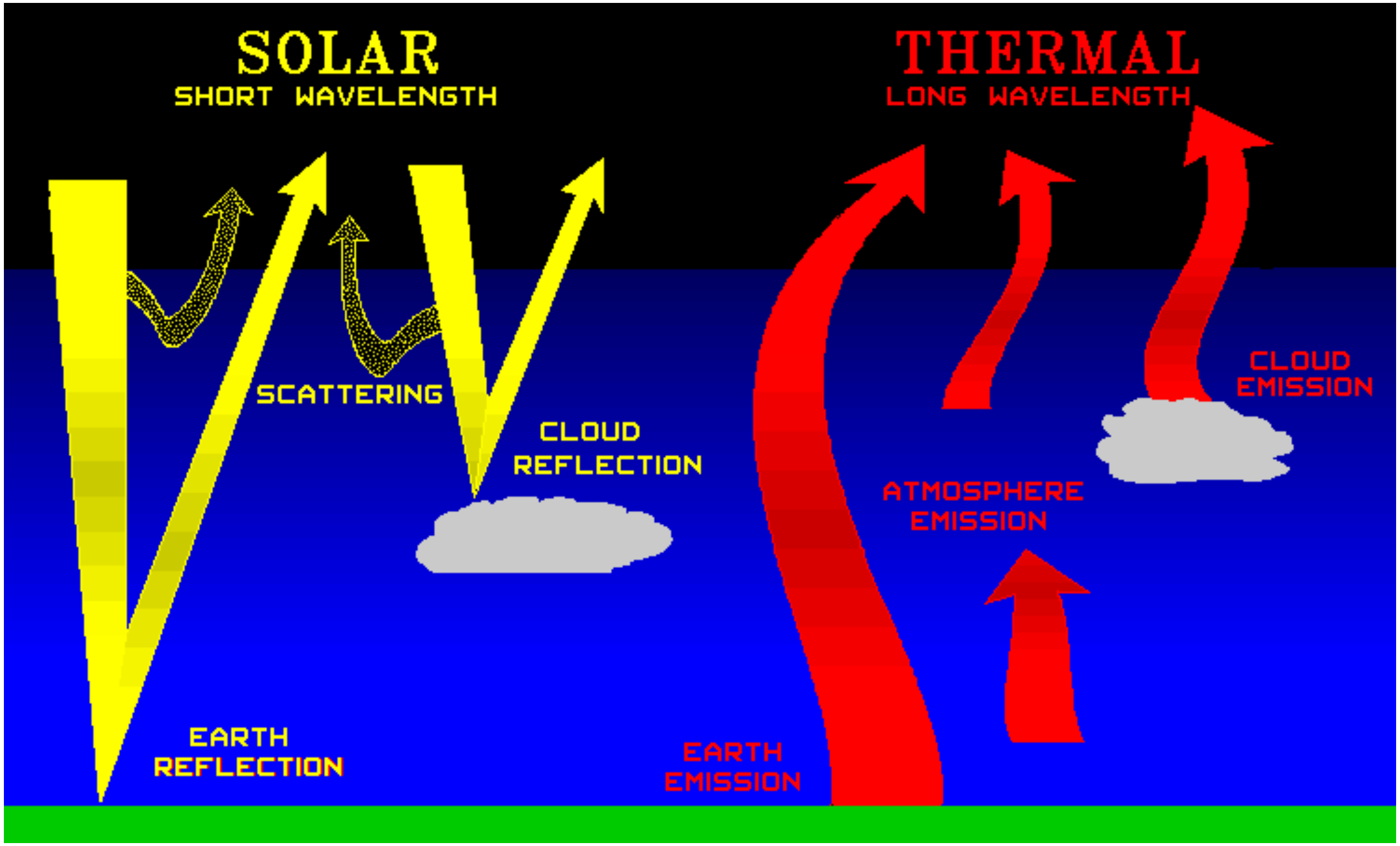
NPP VIIRS Lunar-Ref-IR 2014/10/12 17:02:47Z NRL-Monterey

Why Do We Need Polar Imagery?

Microwave

Visible
(Solar Reflective Bands)

Infrared
(Emissive Bands)



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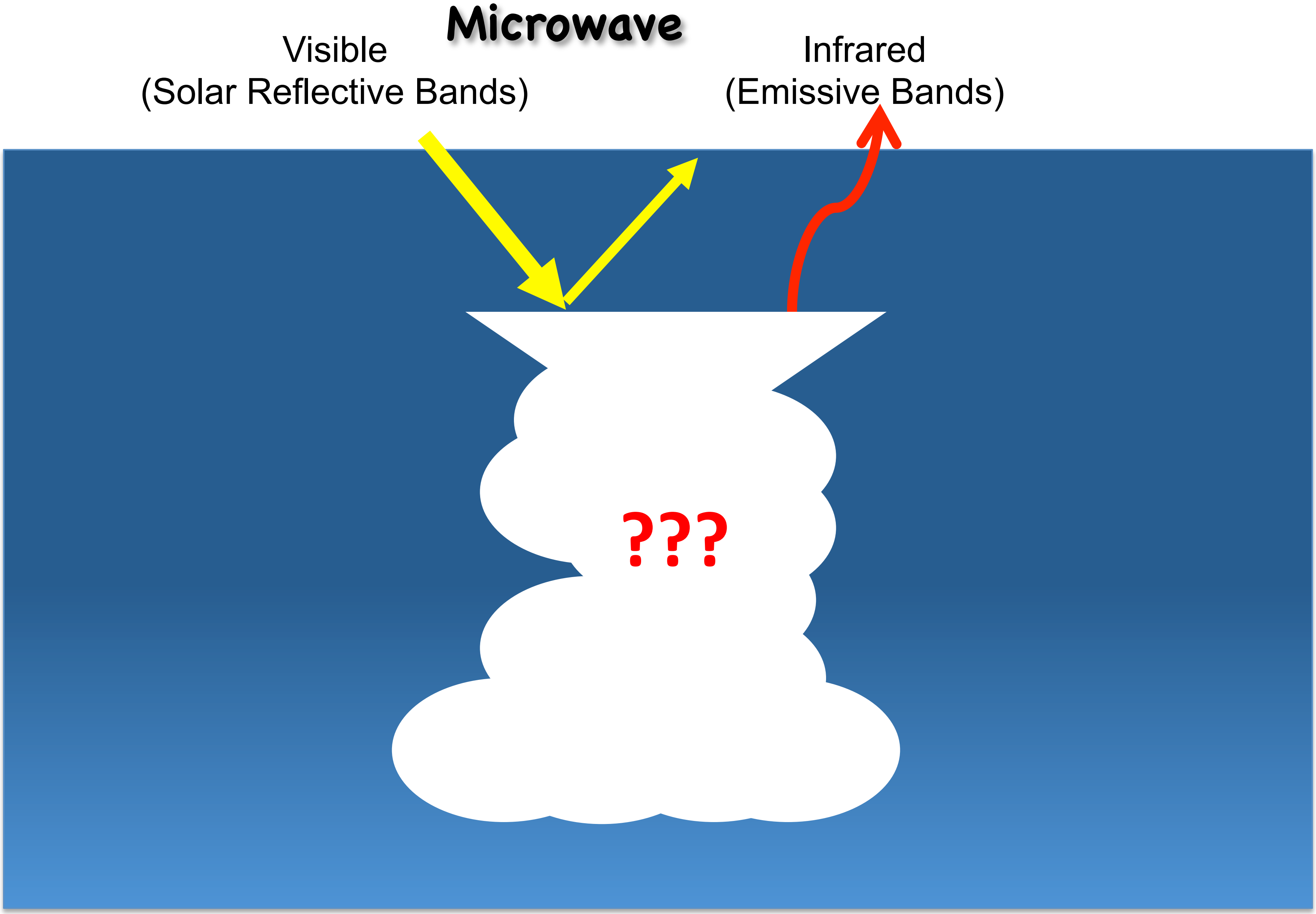
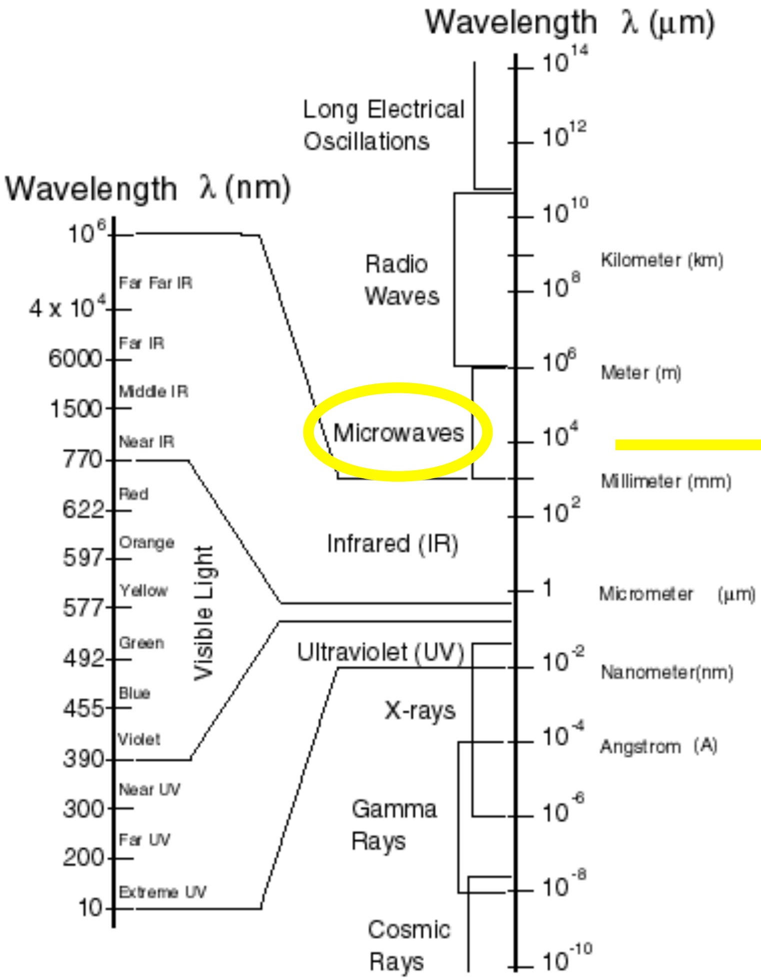


Microwave

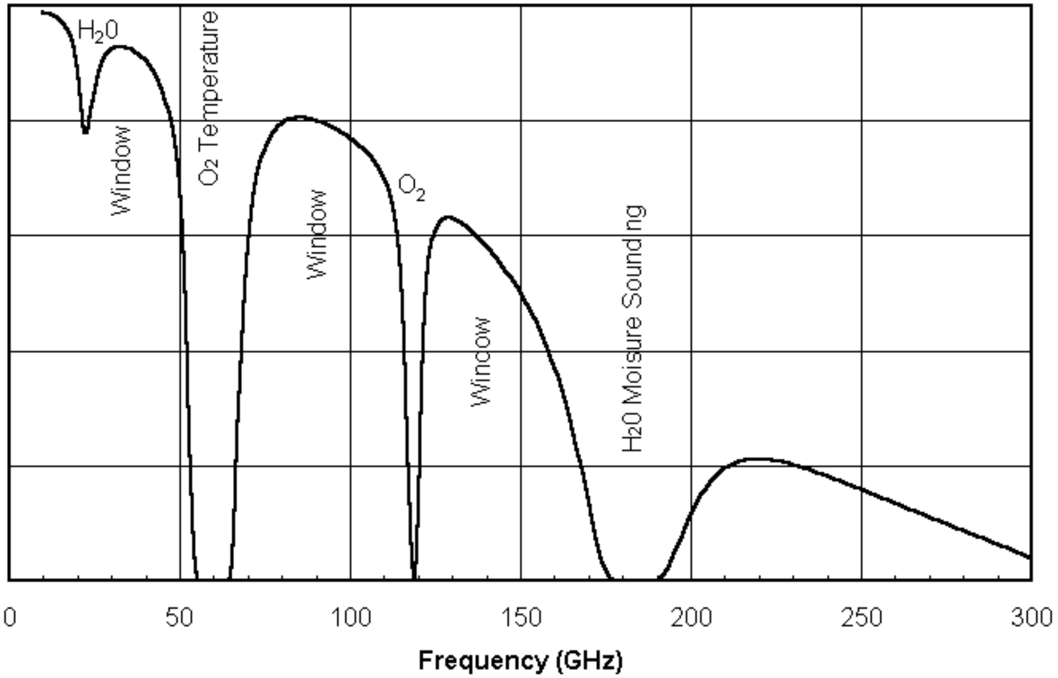
Visible
(Solar Reflective Bands)

Infrared
(Emissive Bands)

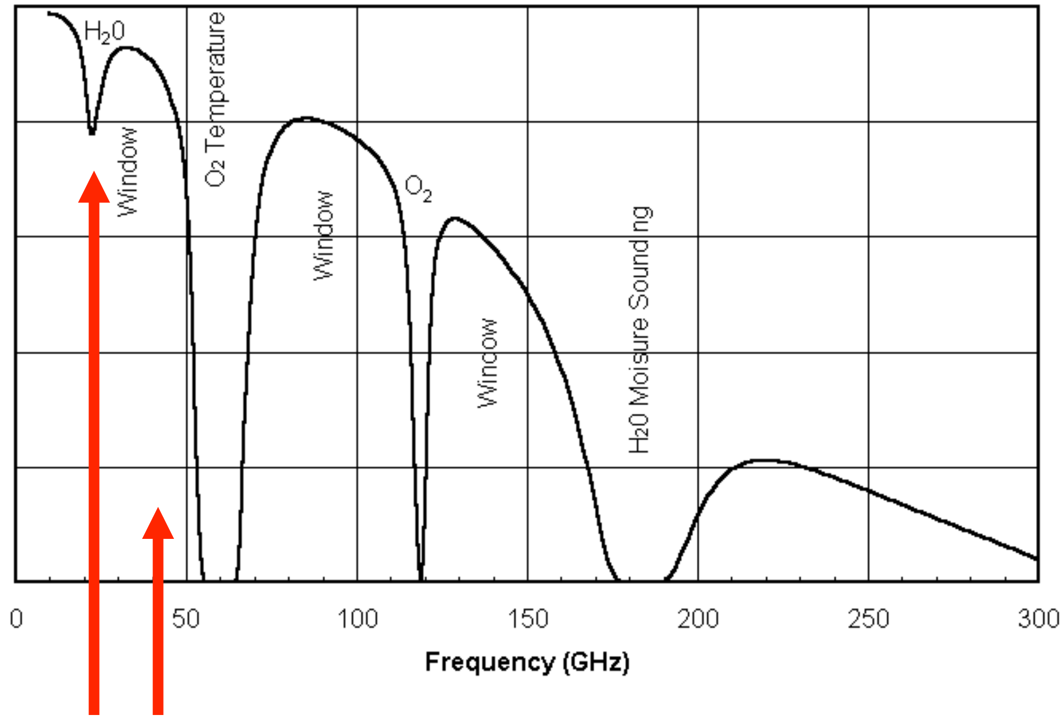
Frequencies and wavelengths of interest for MW analysis



Images courtesy CIRA/NESDIS



Microwave Imager Frequencies



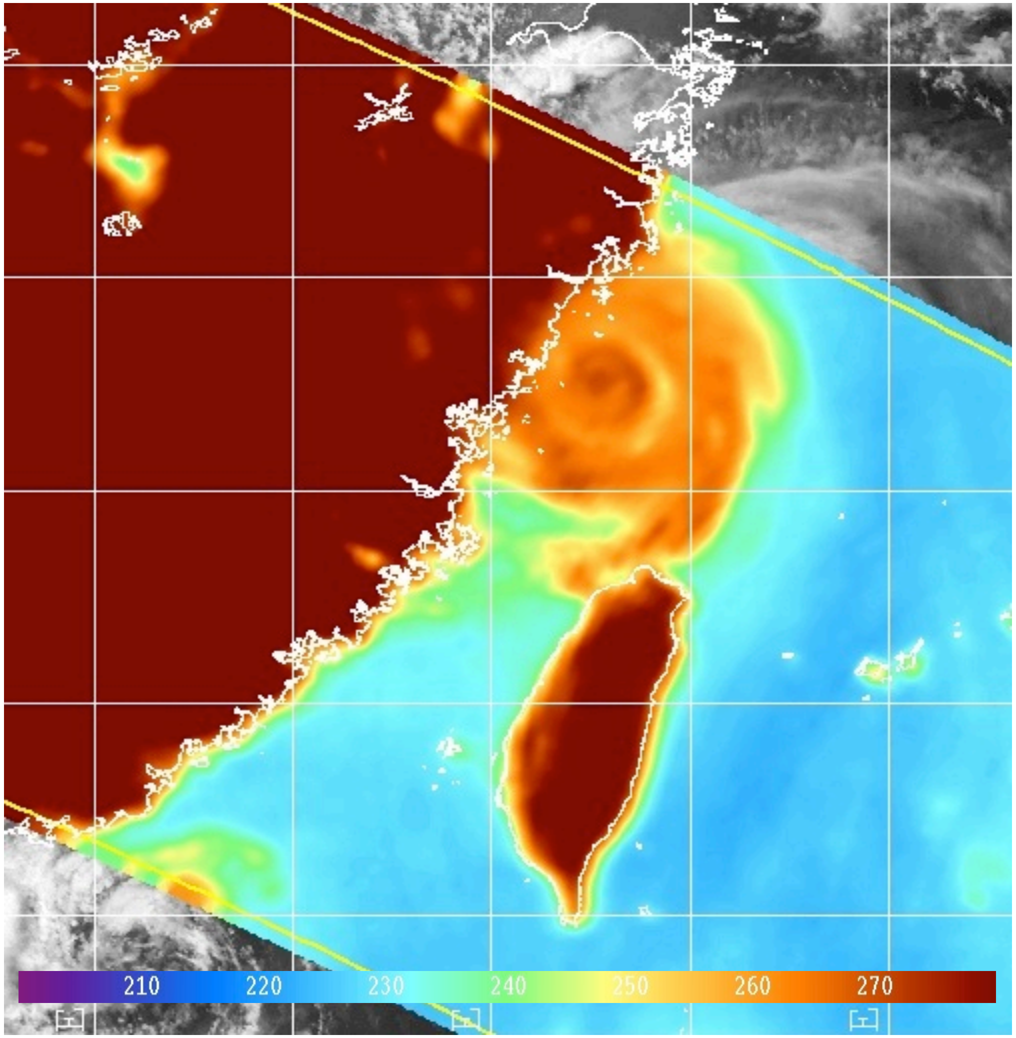
- 23 - 37 Ghz- Used to estimate CLW, land surface properties, snow cover/depth, and precipitation.
- TPW calculation takes advantage of small H2O absorption region

MW Sensors and Platforms

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

*TRMM orbit was boosted to higher altitude in 2001

MW Imager Frequencies: 37 Ghz



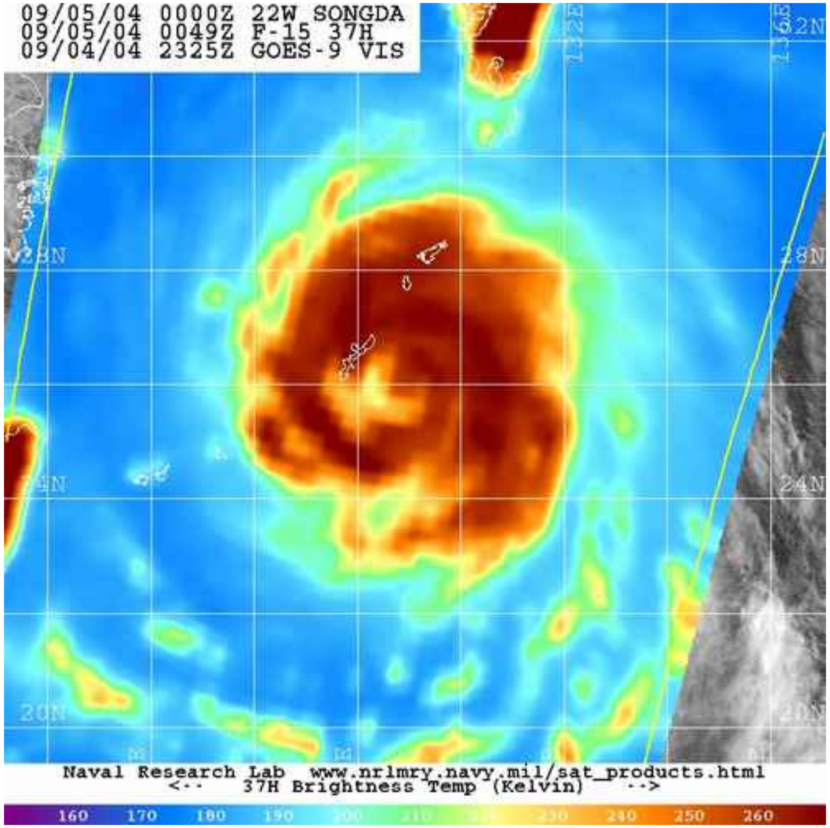
Naval Research Lab Monterey
www.nrlmry.navy.mil/tc_pages/tc_home.html

37 Ghz is strongly affected by liquid water content of the column. Warmer Tb's equate to larger concentrations of CLW revealing rainband structures.

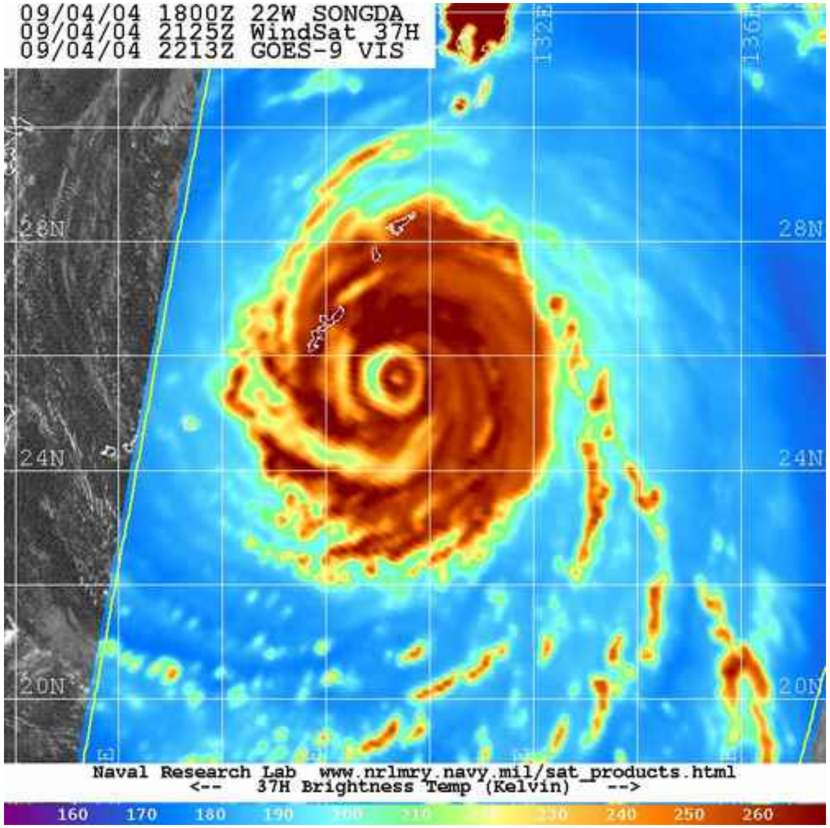
Images reveal TC structure below the freezing level

Magnitude of land surface emissions overwhelms moisture signal over land areas

MW Imager Frequencies: 37 Ghz

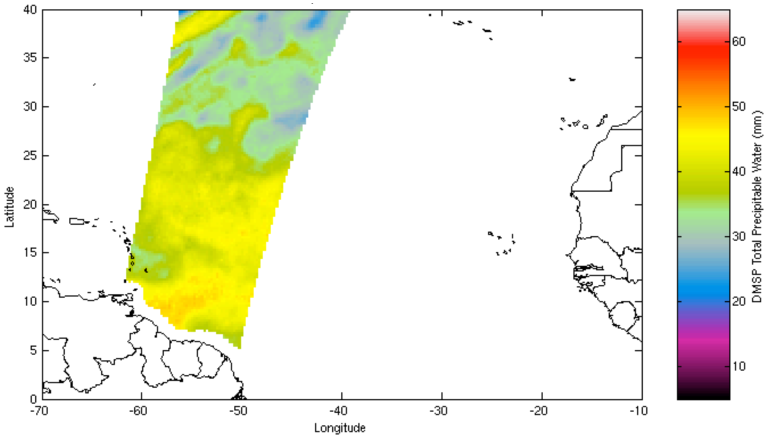


SSMI 37 Ghz

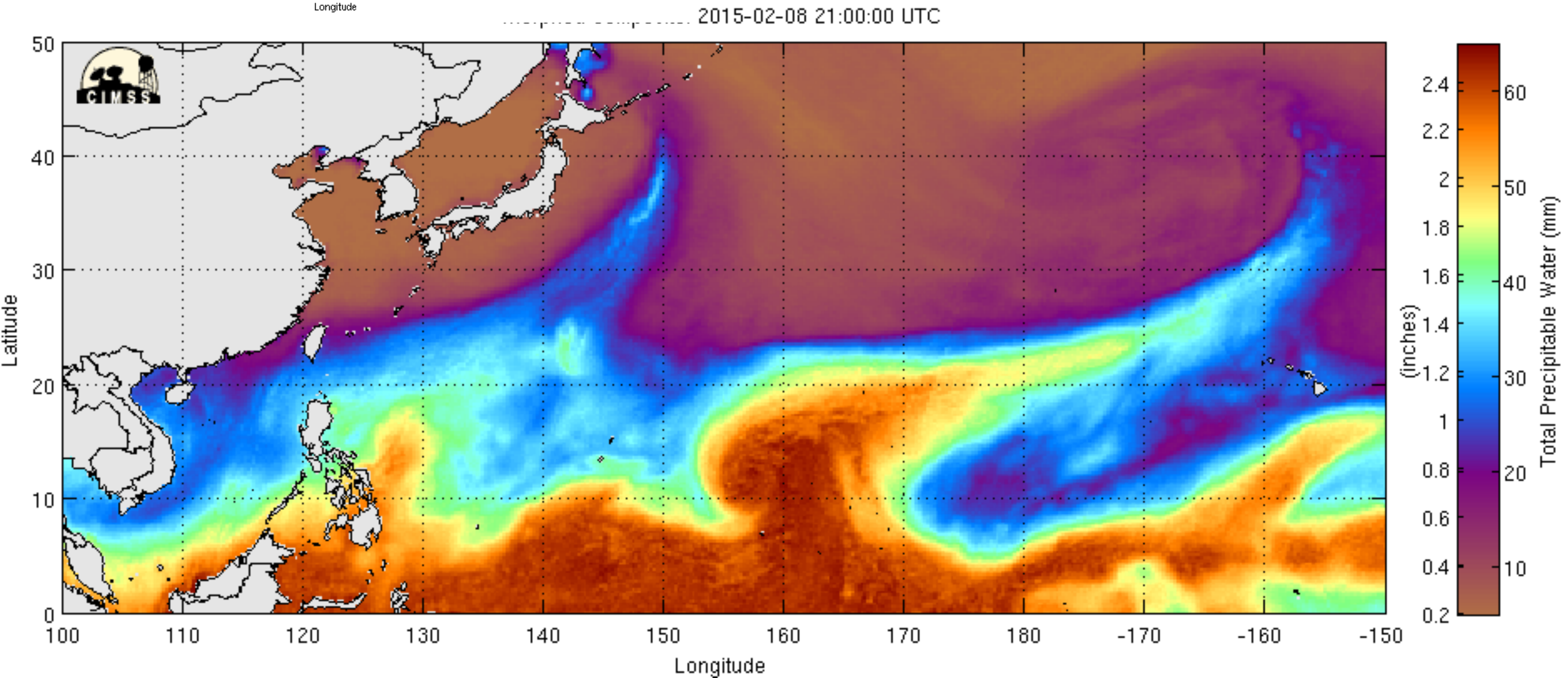


Coriolis WindSat 37 Ghz

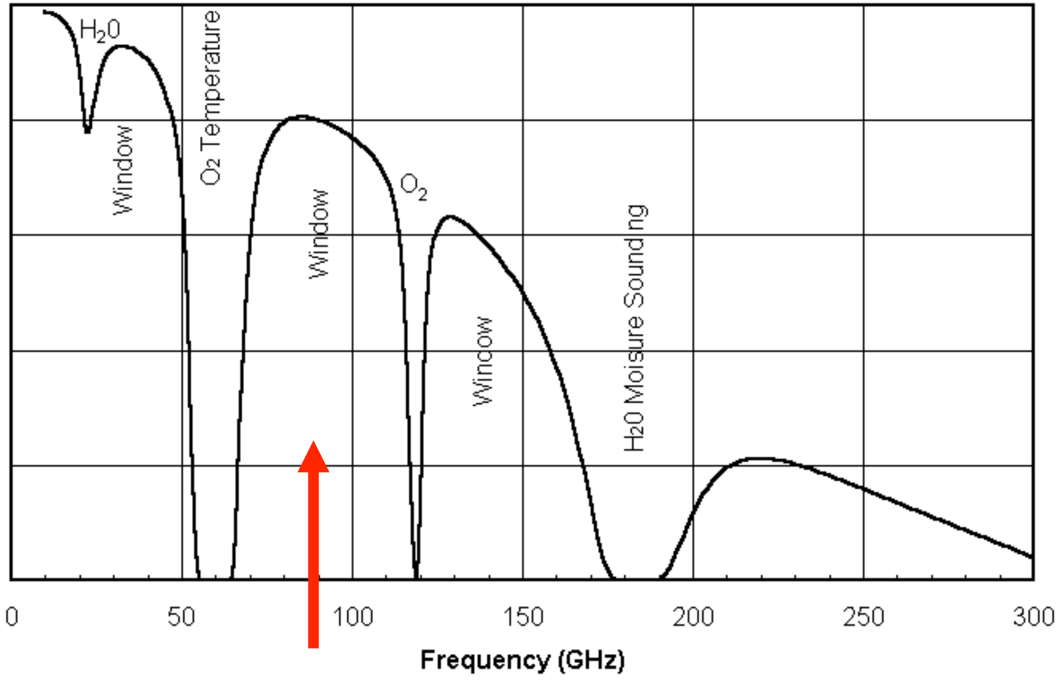
MW Imager Frequencies: 37 Ghz



MIMIC Total Precipitable Water

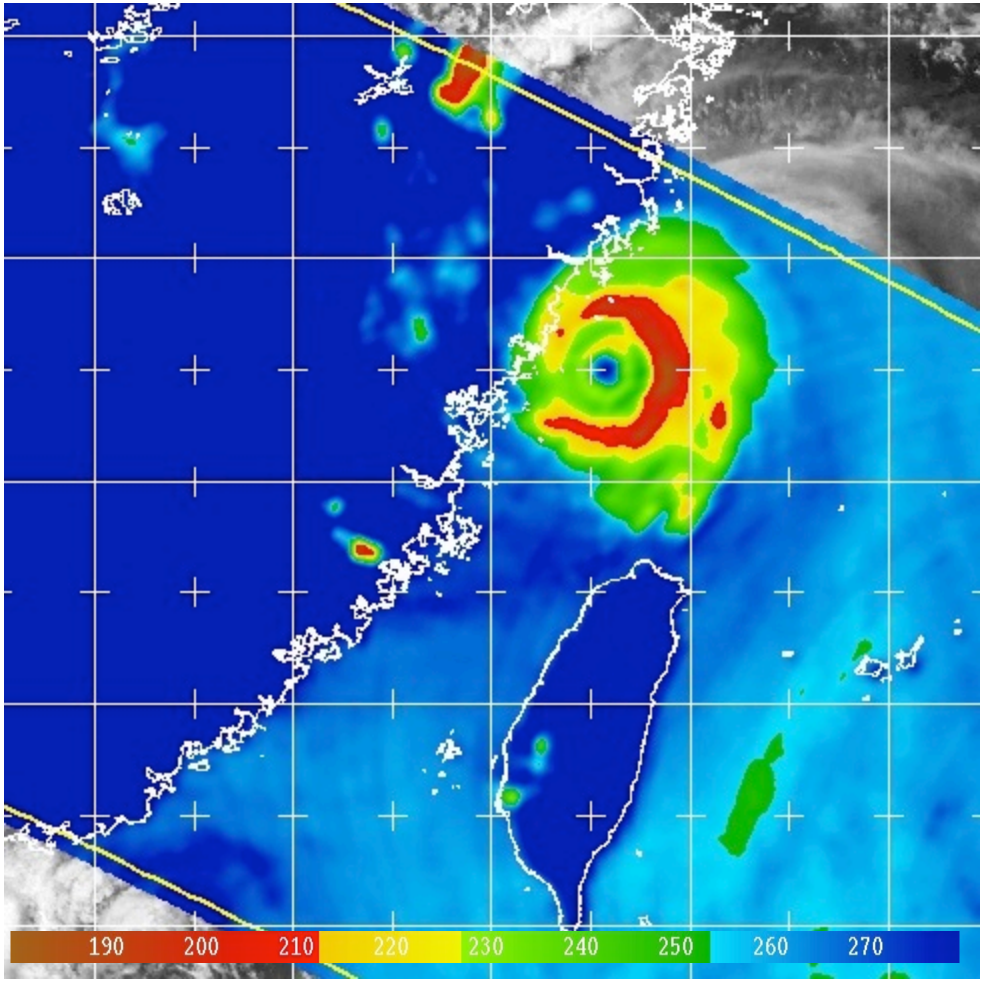


MW Imager Frequencies: 85-92 Ghz



- 85-92 Ghz- These frequencies are primarily impacted by scattering due to frozen hydrometeors.
- Used for evaluation of deep convective regions

MW Imager Frequencies: 85-92 Ghz

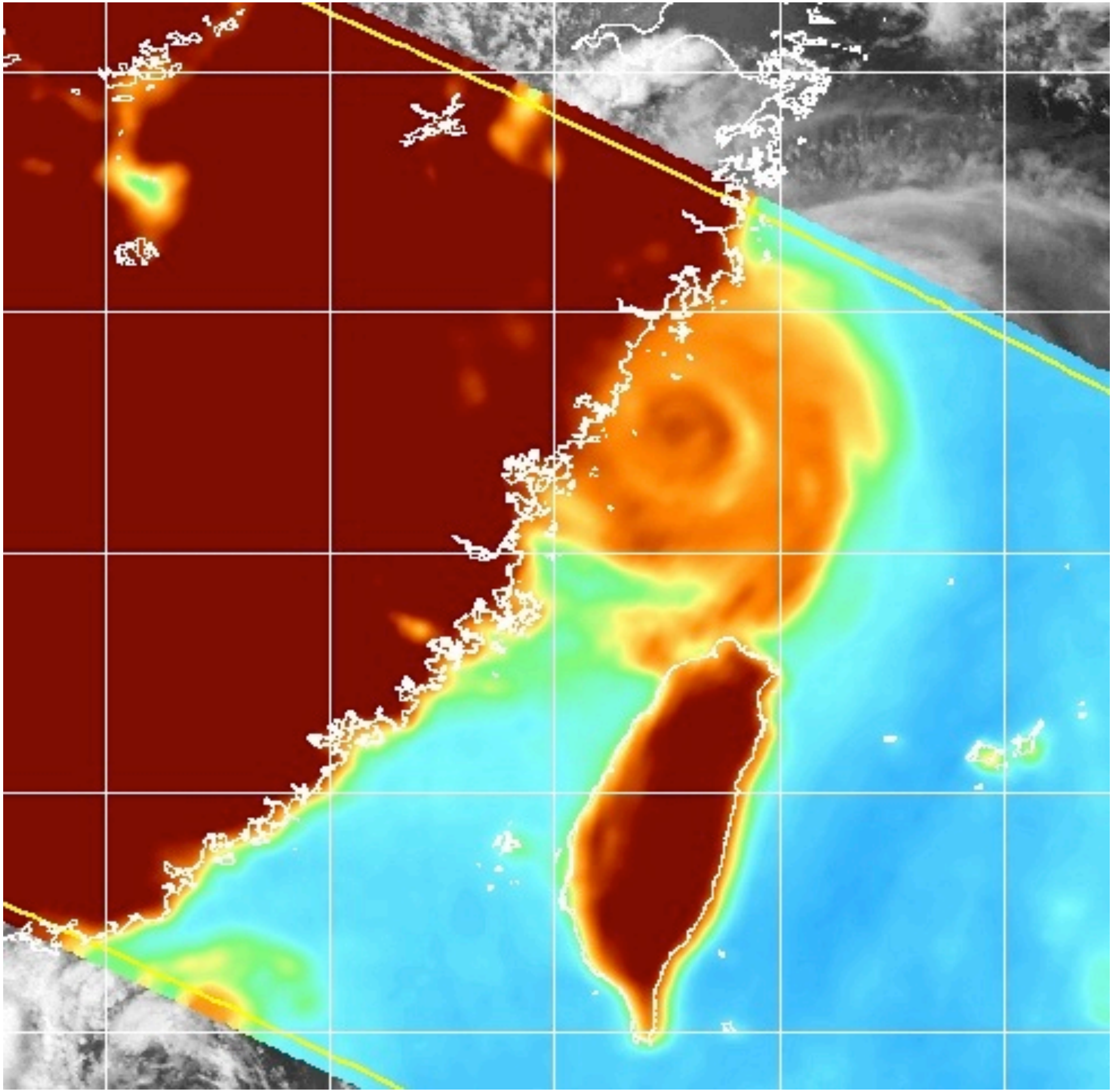


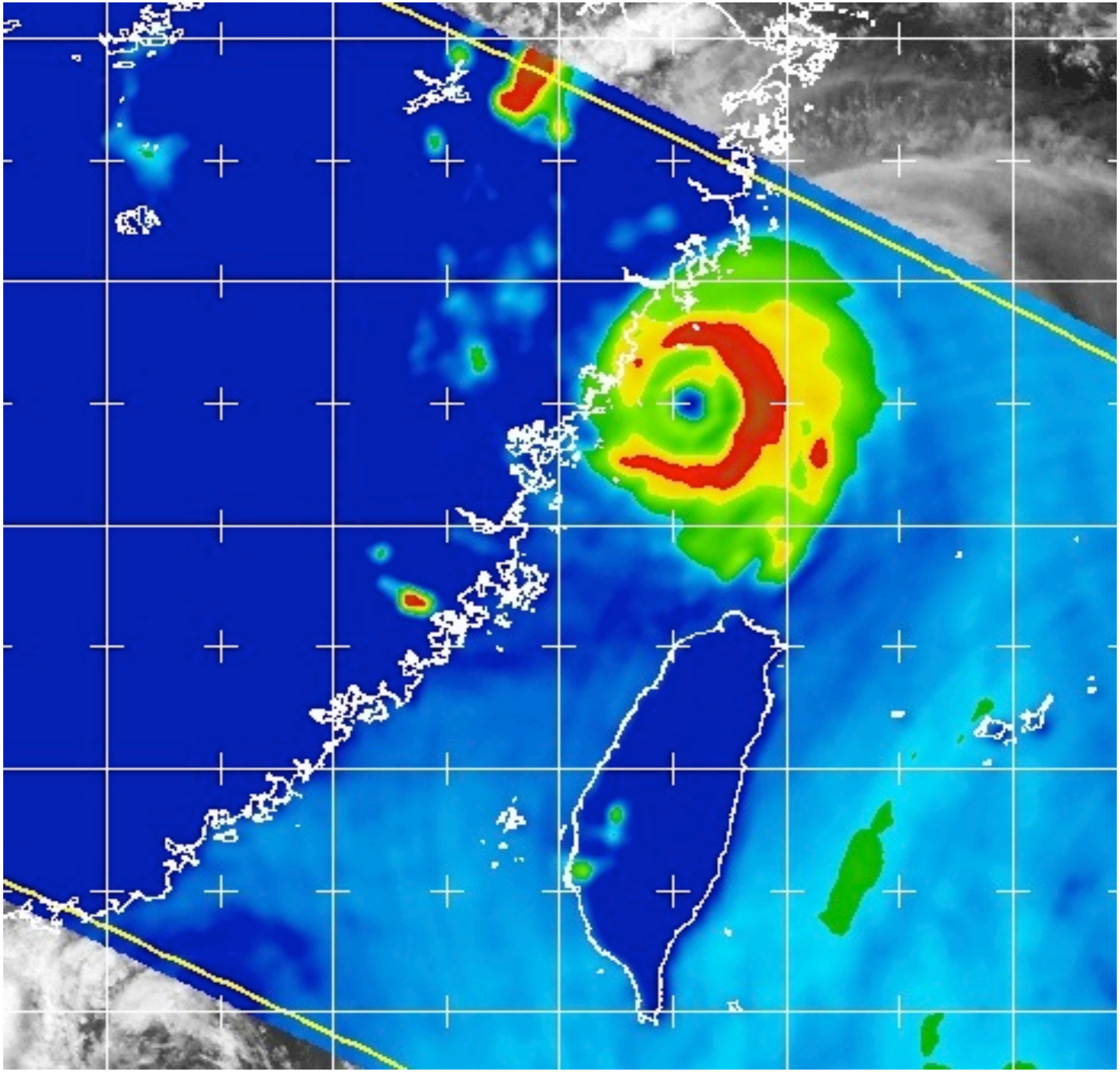
Naval Research Lab Monterey
www.nrlmry.navy.mil/tc_pages/tc_home.html

85-92 Ghz is strongly attenuated by frozen hydrometeors. The result is that convection will appear cold

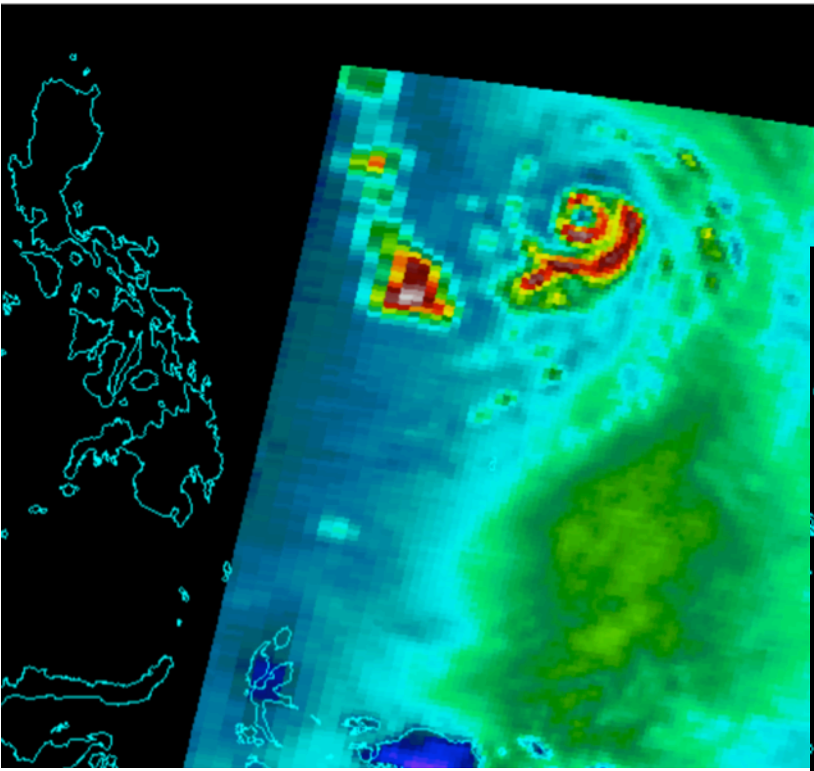
Images reveal TC structure above the freezing level

Smaller difference in emission of mw energy between ocean and land permit depiction of cloud features over land.

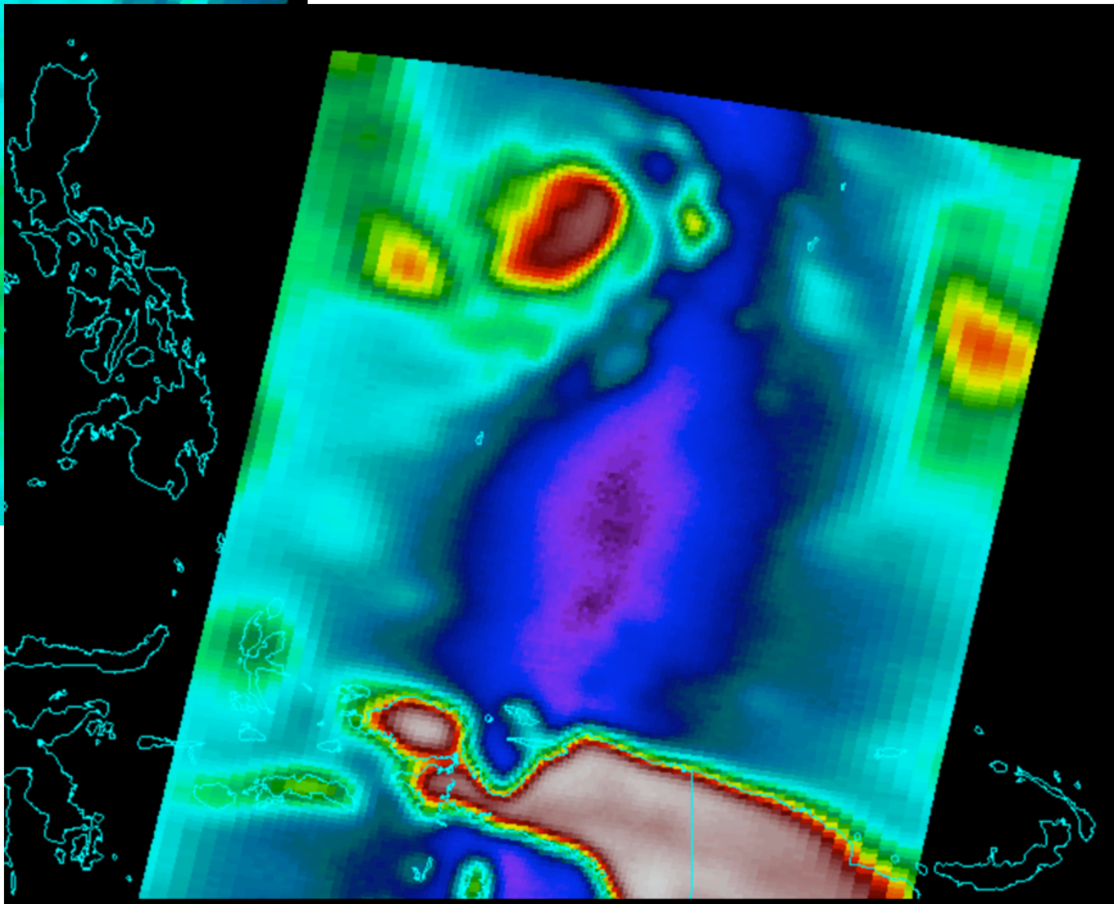


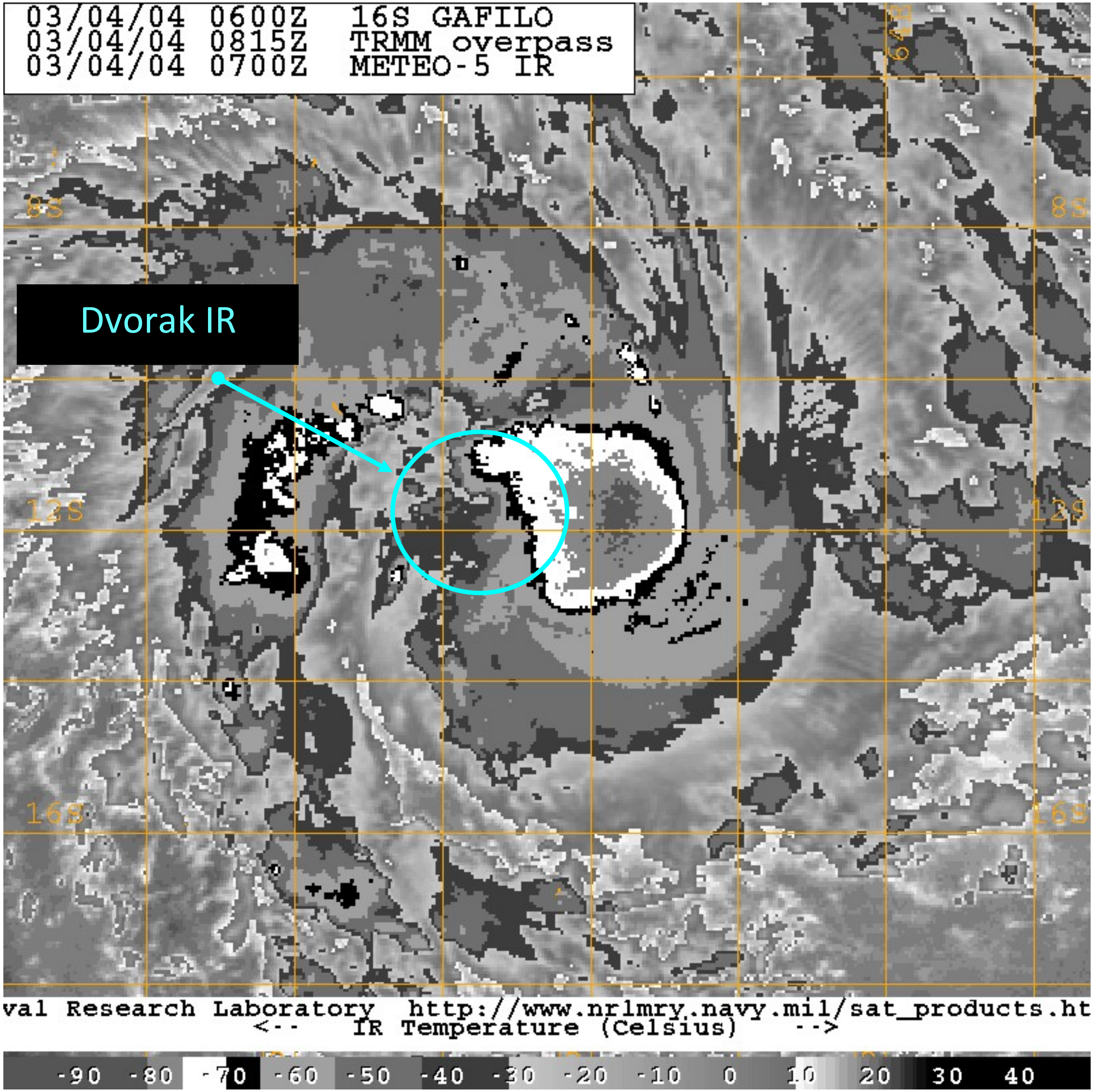


89 GHz
"Cold" Precipitation
Against Warmer
Ocean Background

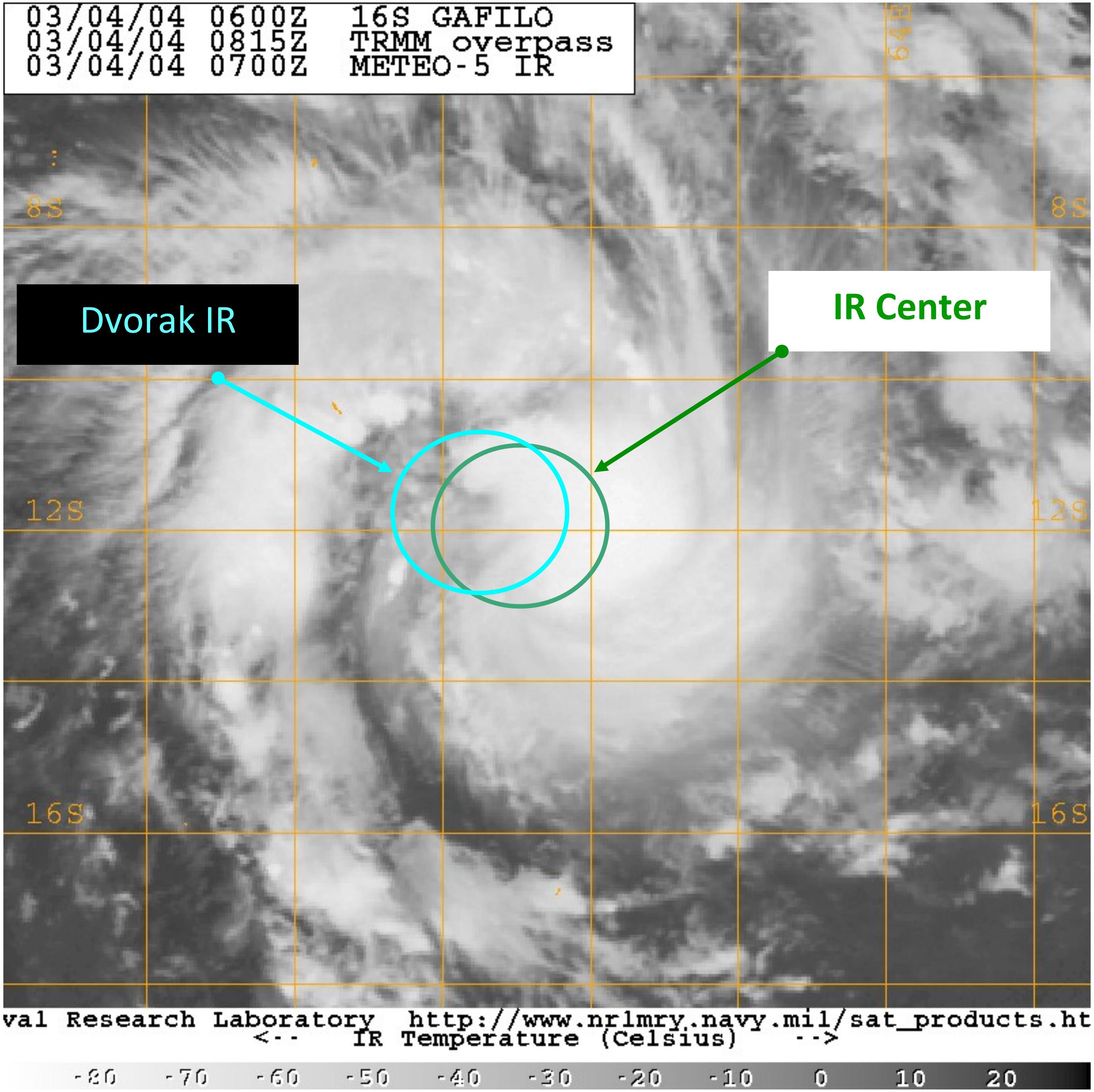


36 GHz
"Warm" Precipitation
Against Colder
Ocean Background



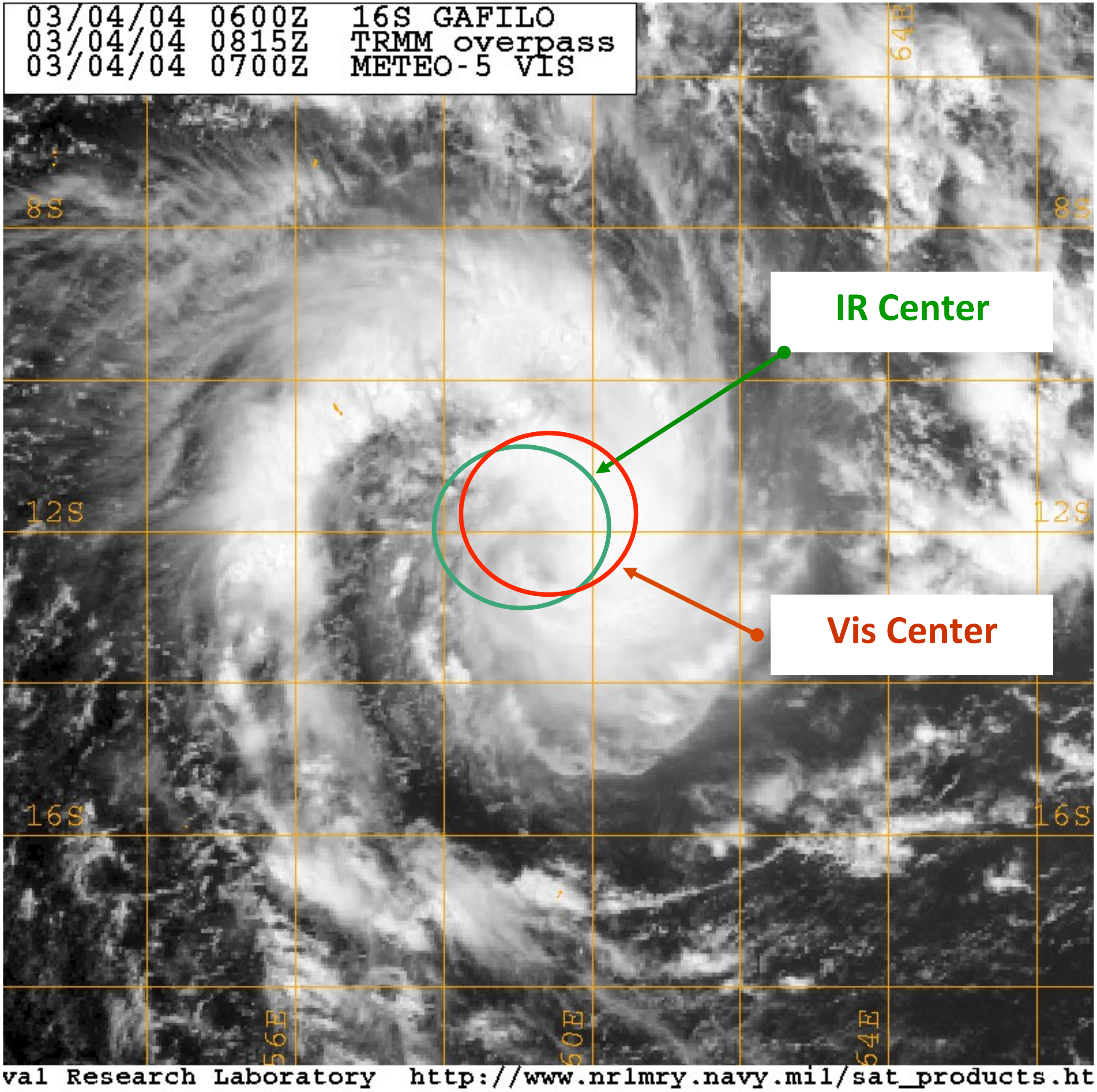

03/04/04 0600Z 16S GAFILO
03/04/04 0815Z TRMM overpass
03/04/04 0700Z METEO-5 IR
64E
8S
8S
12S
12S
16S
16S
val Research Laboratory http://www.nrlmry.navy.mil/sat_products.ht
<-- IR Temperature (Celsius) -->
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40

Dvorak IR



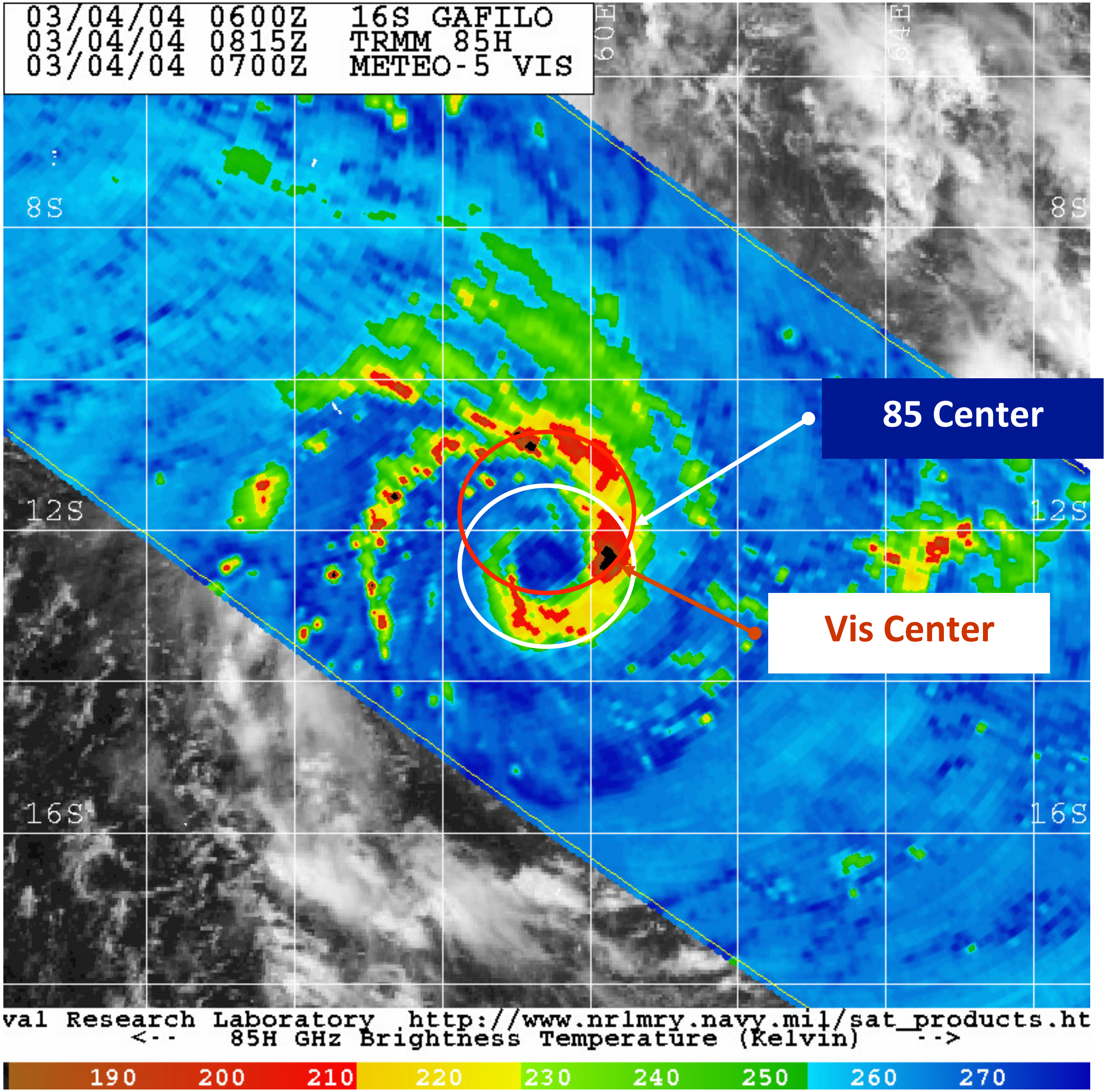
Dvorak IR

IR Center



IR Center

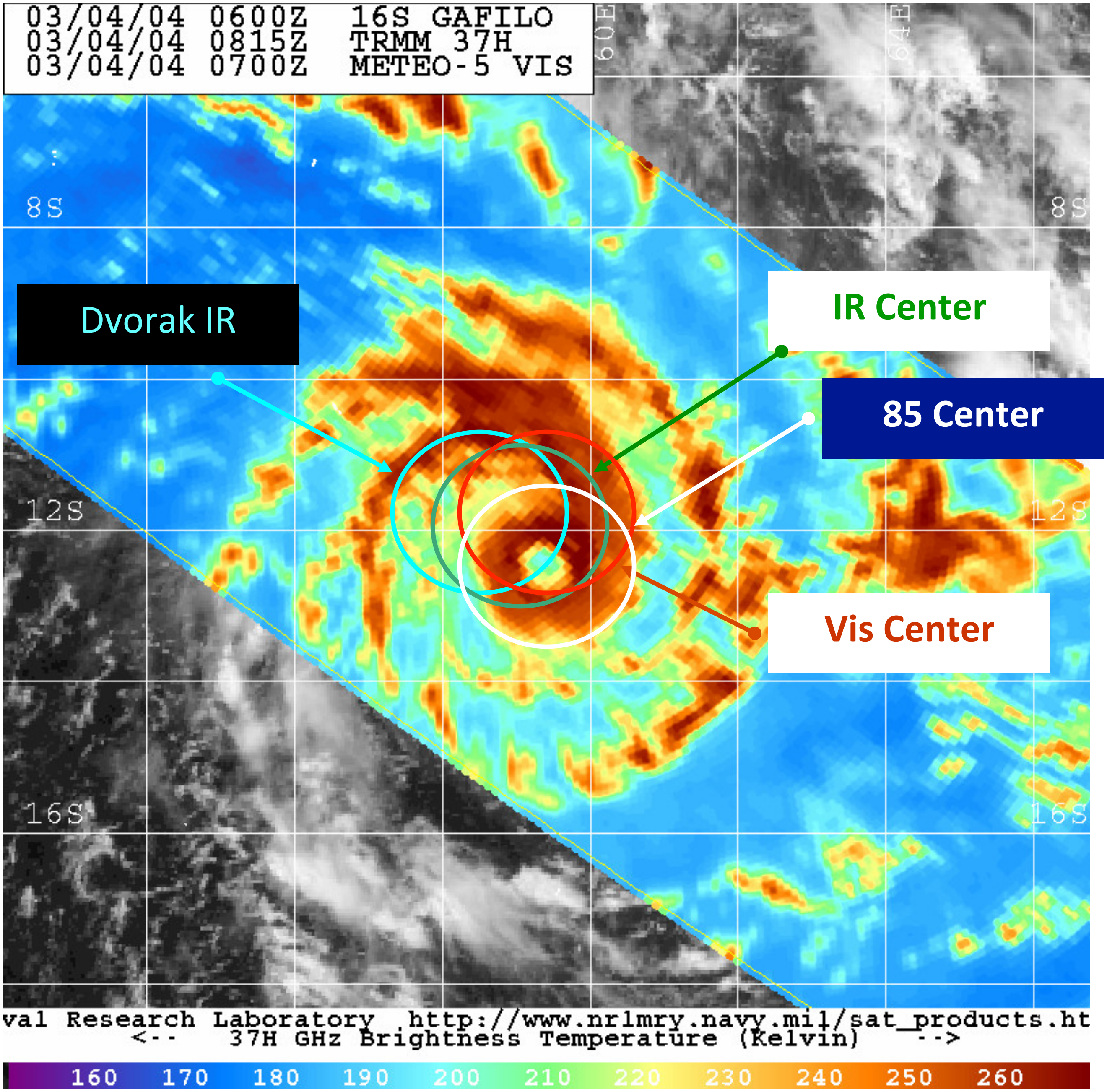
Vis Center



85 Center

Vis Center

Tropical Cyclone Center Positioning Quandary



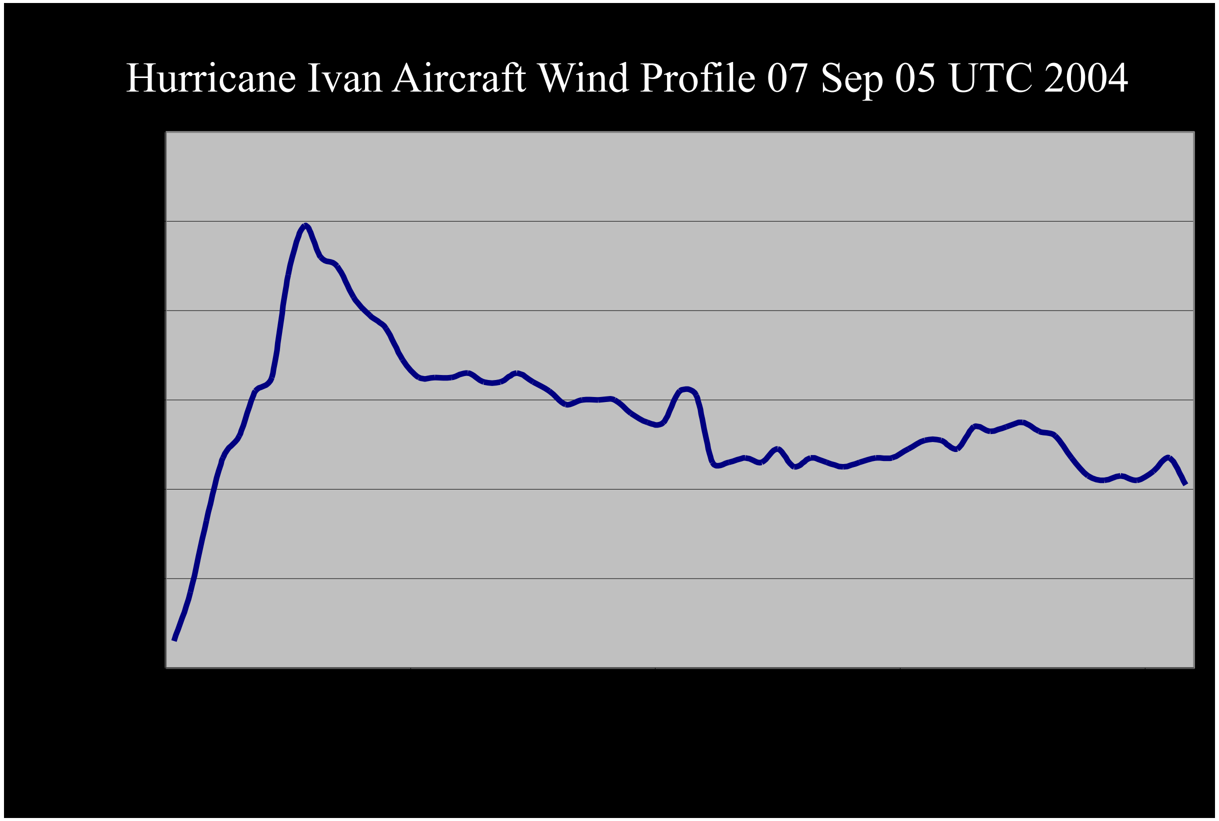
Dvorak IR

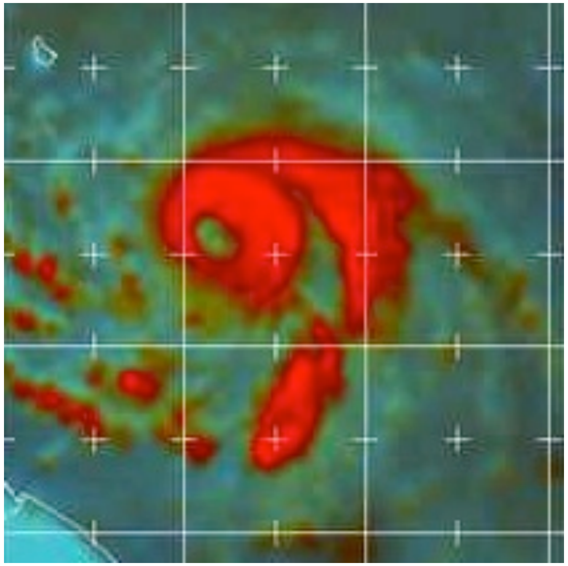
IR Center

85 Center

Vis Center

TC Structure: Hurricane Ivan 2004

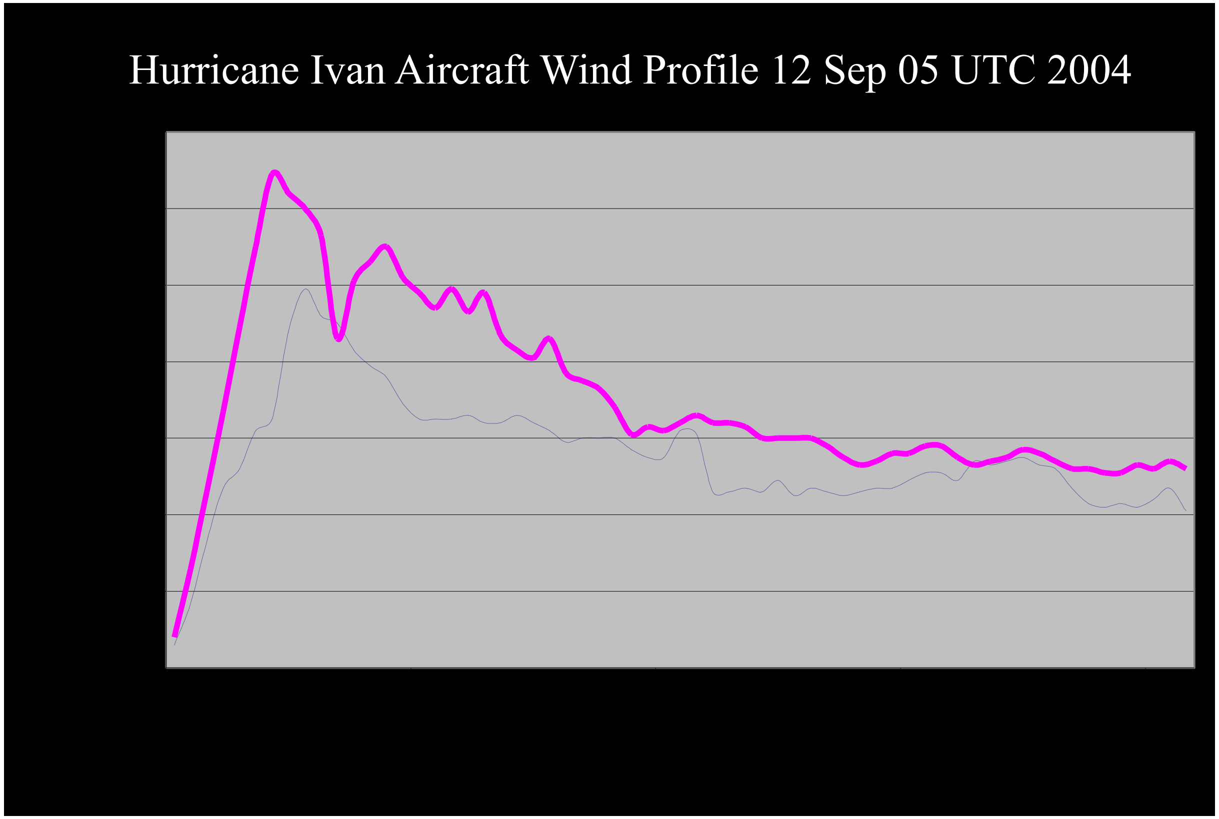


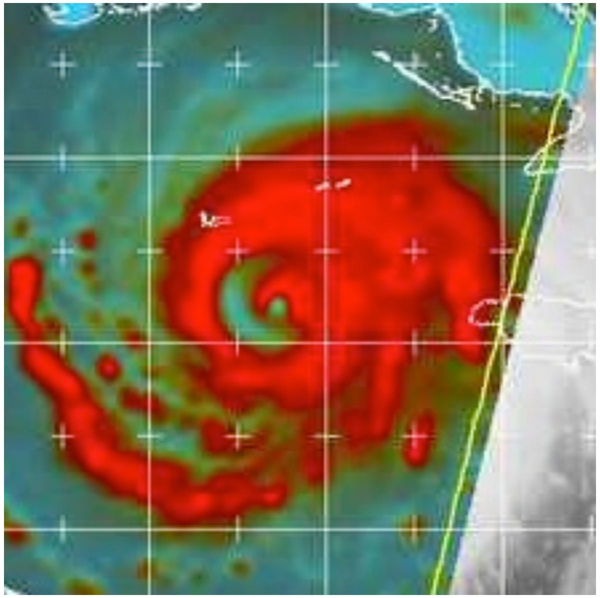


7 Sep 0530 UTC AMSR-E 89 Ghz

- Single thick eyewall typical of developing/intensifying TC
- Wind profile displays rapid wind peak with rapid decrease in wind speed outside of eyewall then more gradual decrease

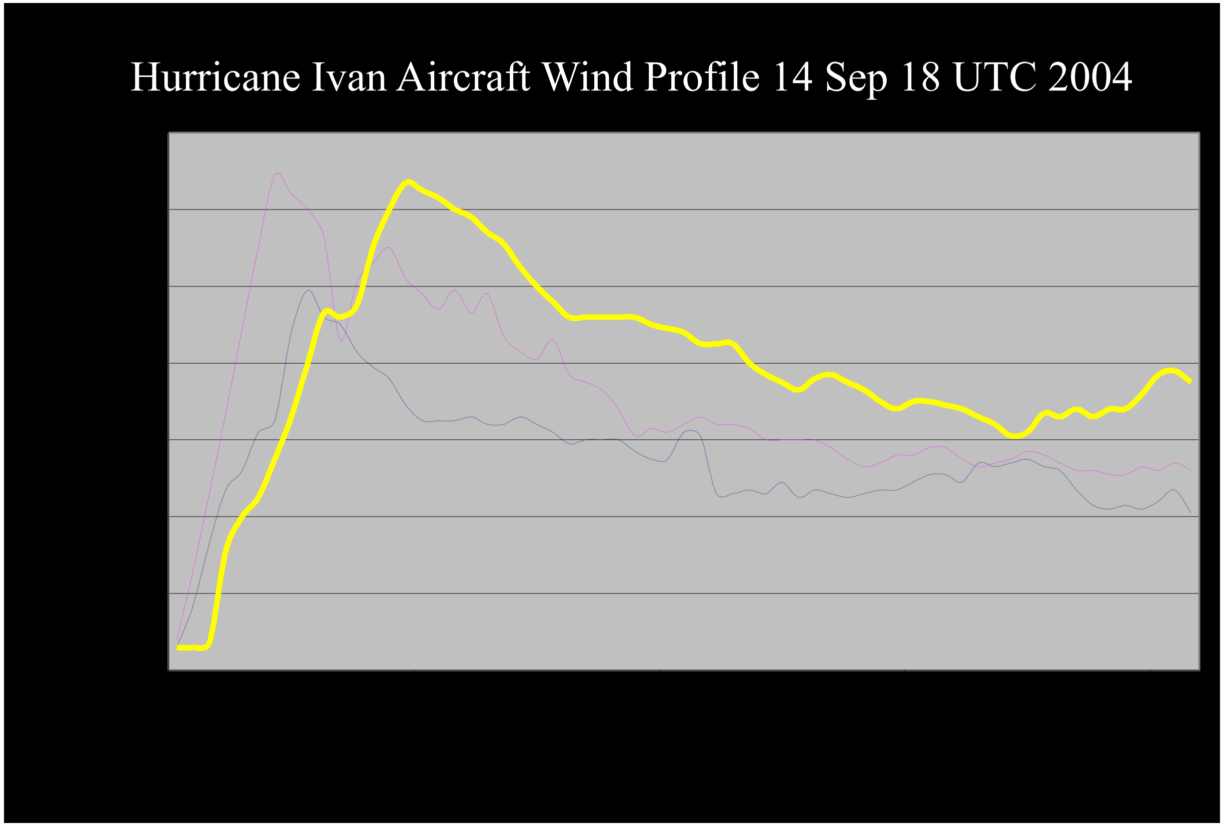
TC Structure: Hurricane Ivan 2004

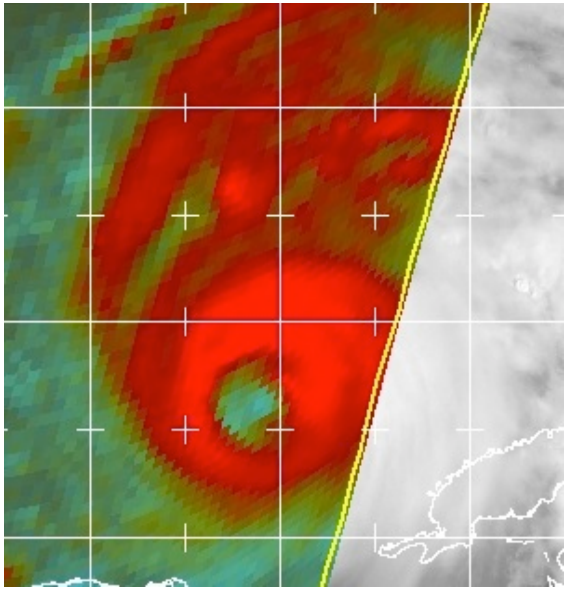

Hurricane Ivan Aircraft Wind Profile 12 Sep 05 UTC 2004


12 Sep 0730 UTC AMSR-E 91 Ghz

- RMW moves inward toward center as eyewall contracts
- Wind profile displays 2 maxima with secondary eyewall at 20 nm. Intensification halted?
- Wind field has expanded and winds are stronger throughout

TC Structure: Hurricane Ivan 2004

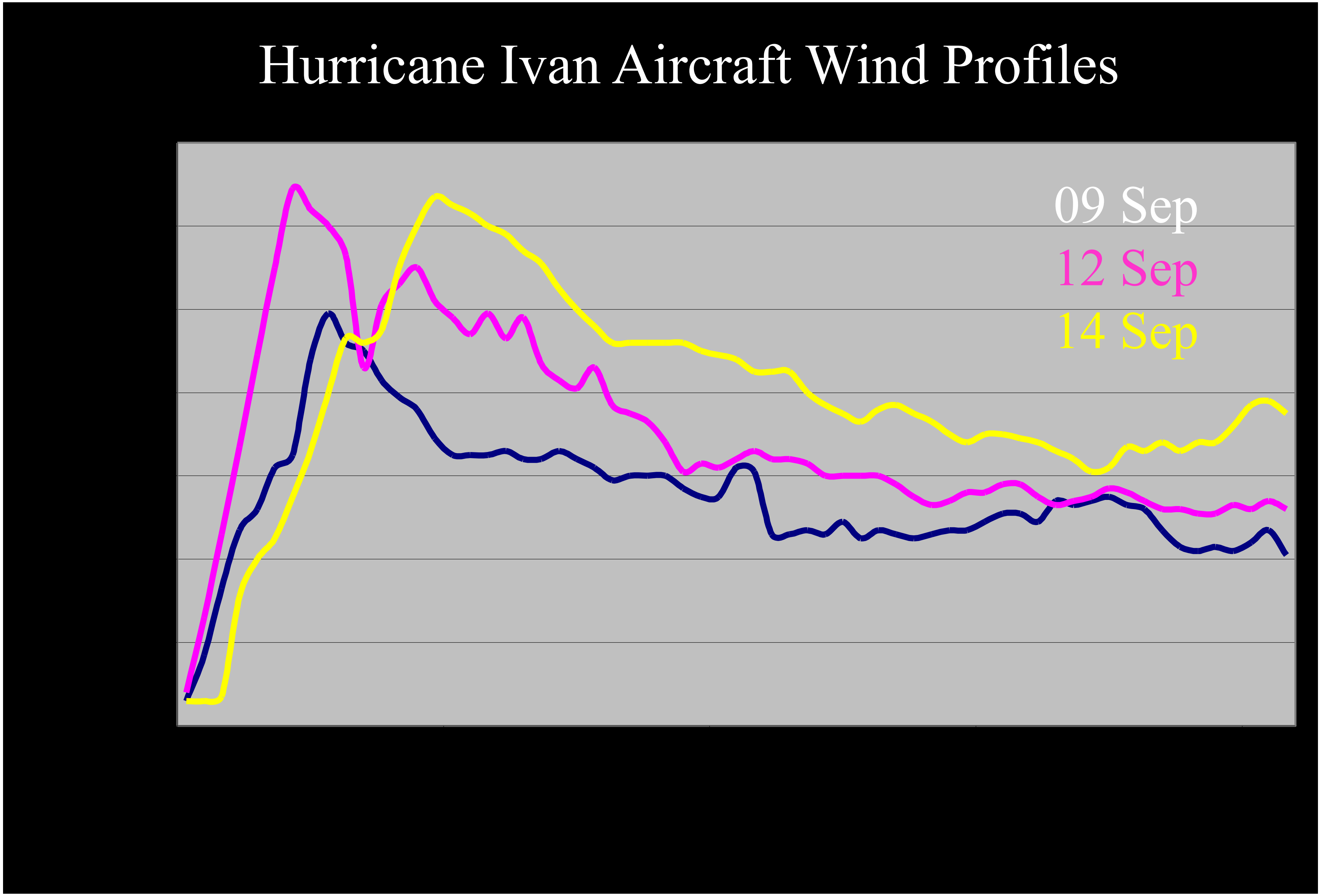




14 Sep 1528 UTC SSMI 85 Ghz

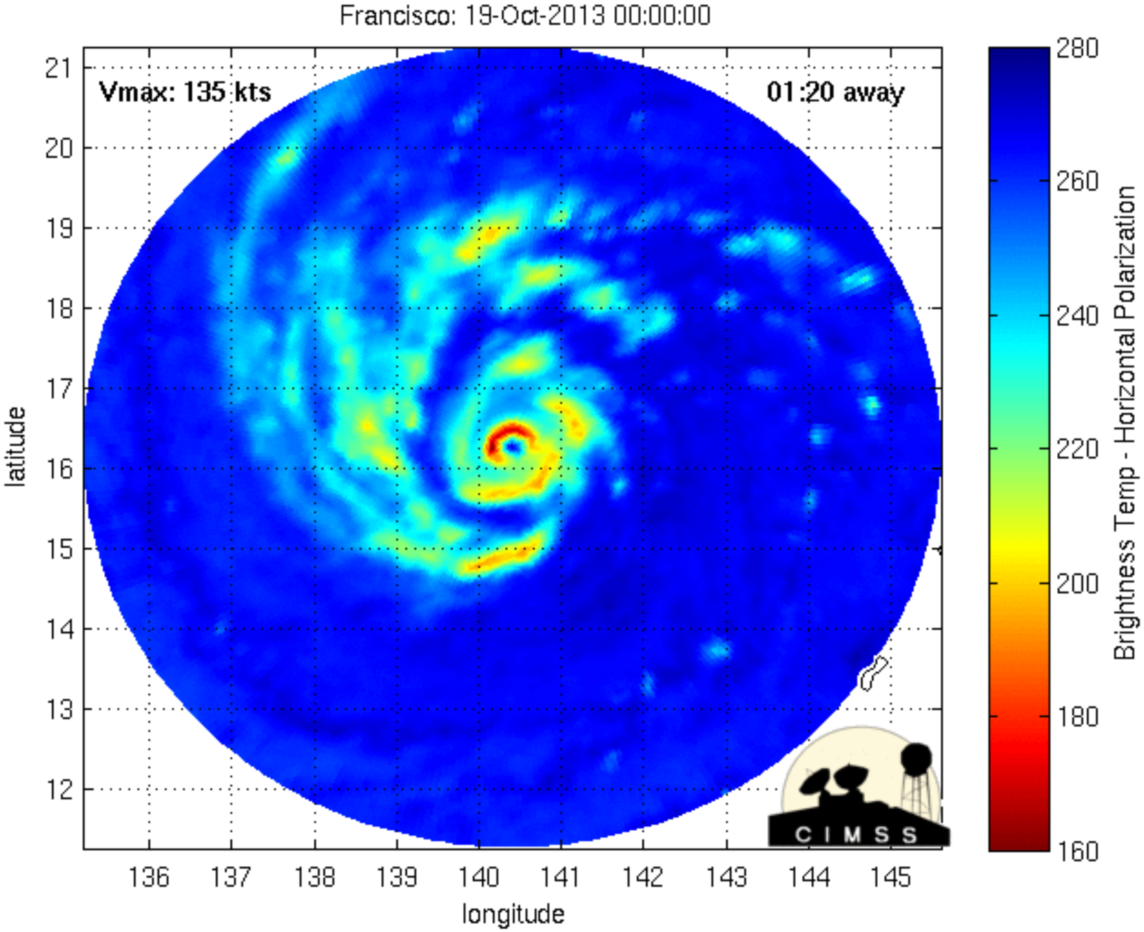
- Inner eye has dissipated and is replaced by larger outer eyewall indicated by single peak in wind profile
- Intensification resumes?
- Expansion of outer wind field continues

TC Structure: Hurricane Ivan 2004



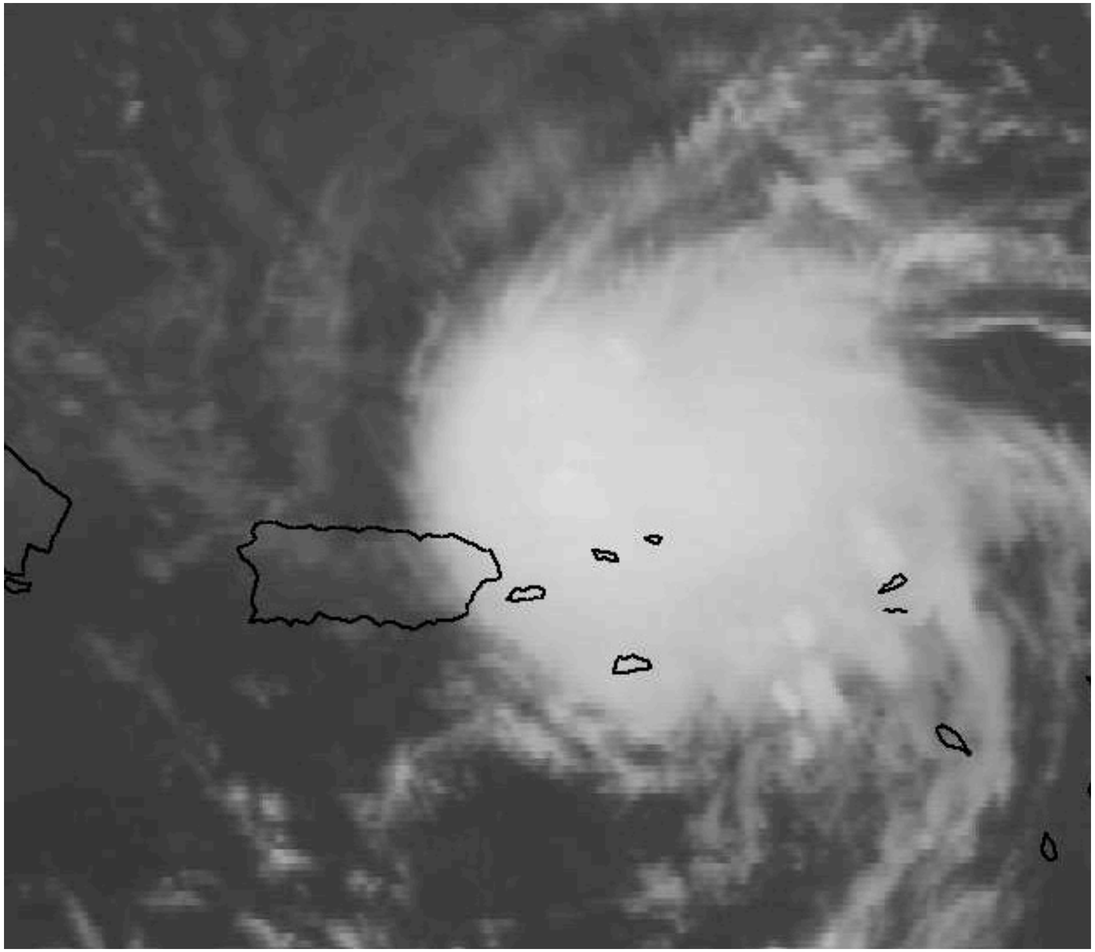
Animation of 85-92 Ghz

MIMIC-TC animation

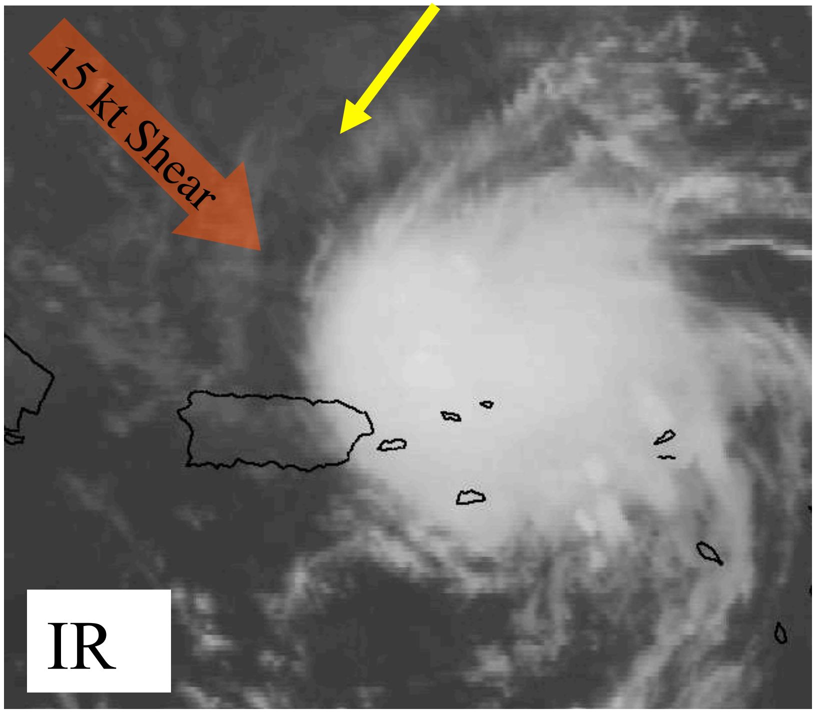


http://tropic.ssec.wisc.edu/real-time/mimic-tc/tc.shtml

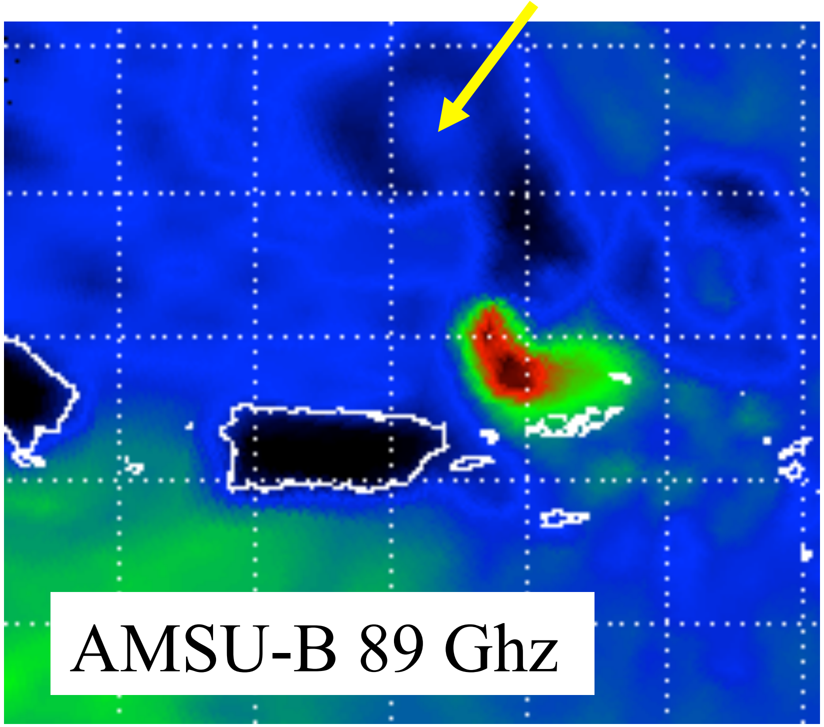
TC Center Estimation Using MW



TC Center Estimation Using MW



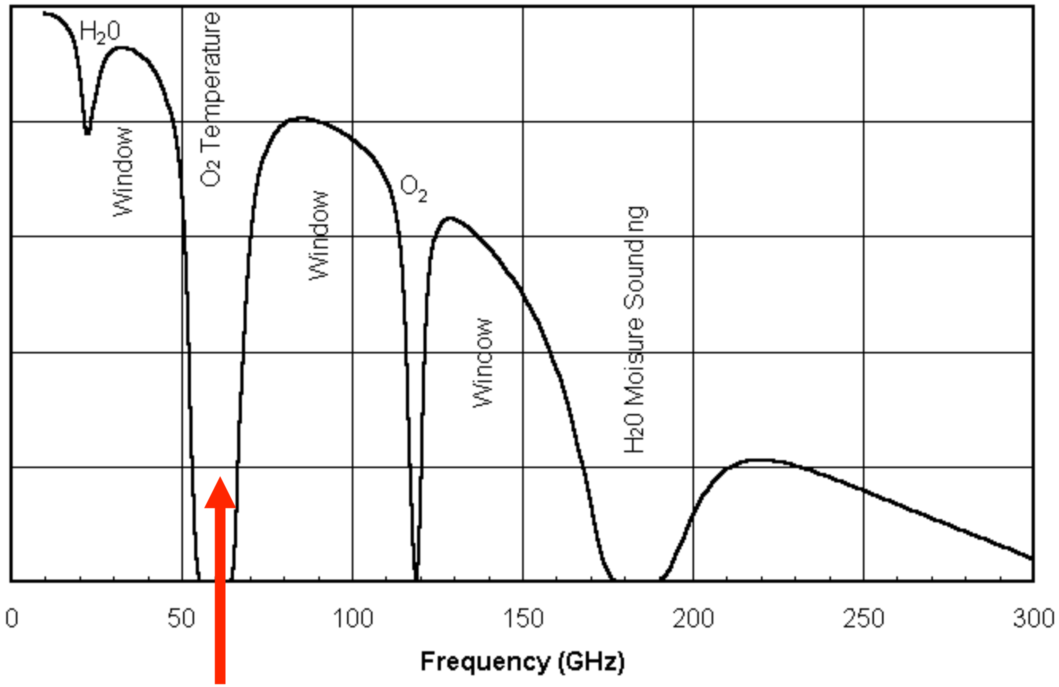
Center



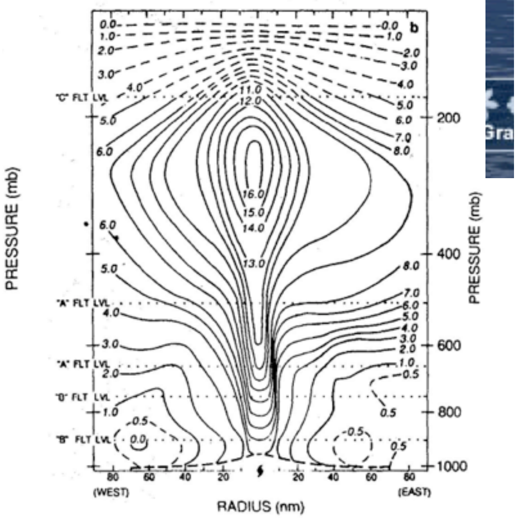
Center

89 GHz image indicates center is well NW of convection in this sheared storm. Significant intensification is unlikely

MW Sounder Frequencies: ~55 Ghz



- 50-58 Ghz- Microwave temperature sounders make use of the O2 absorption band in this freq band.
- Used to produce estimates of temperatures at different layers of the atmosphere



Hawkins and Rabsam 1968
Hurricane Hilda 1964

JANUARY 2006 HALVERSON ET AL.

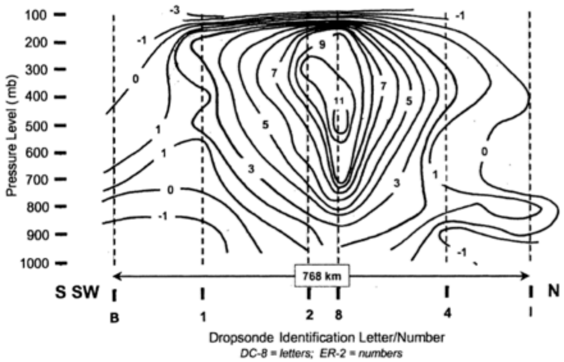
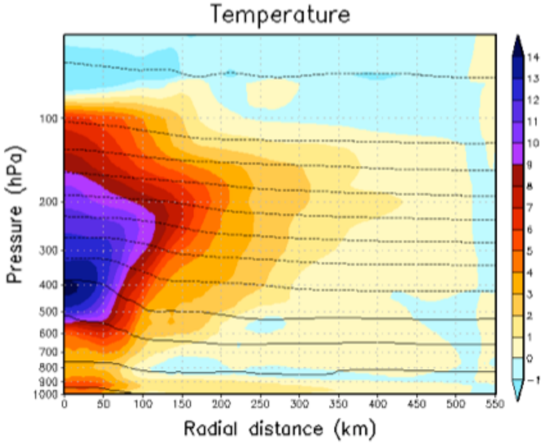


FIG. 6. Cross section through Erin's core showing temperature perturbation. Analysis was mac compositing dropsondes along/nearby the dashed line shown in Fig. 1. The vertical slide is oriented southwest to northeast. Maximum perturbation temperature of +11°C and distance scale are sh Initial release times of dropsondes are 1629, 1648, 1704, 1750, 1928, and 1936 UTC for B, 1, 2, 4, 8 I, respectively.

Halverson 2006
Hurricane Erin 2001

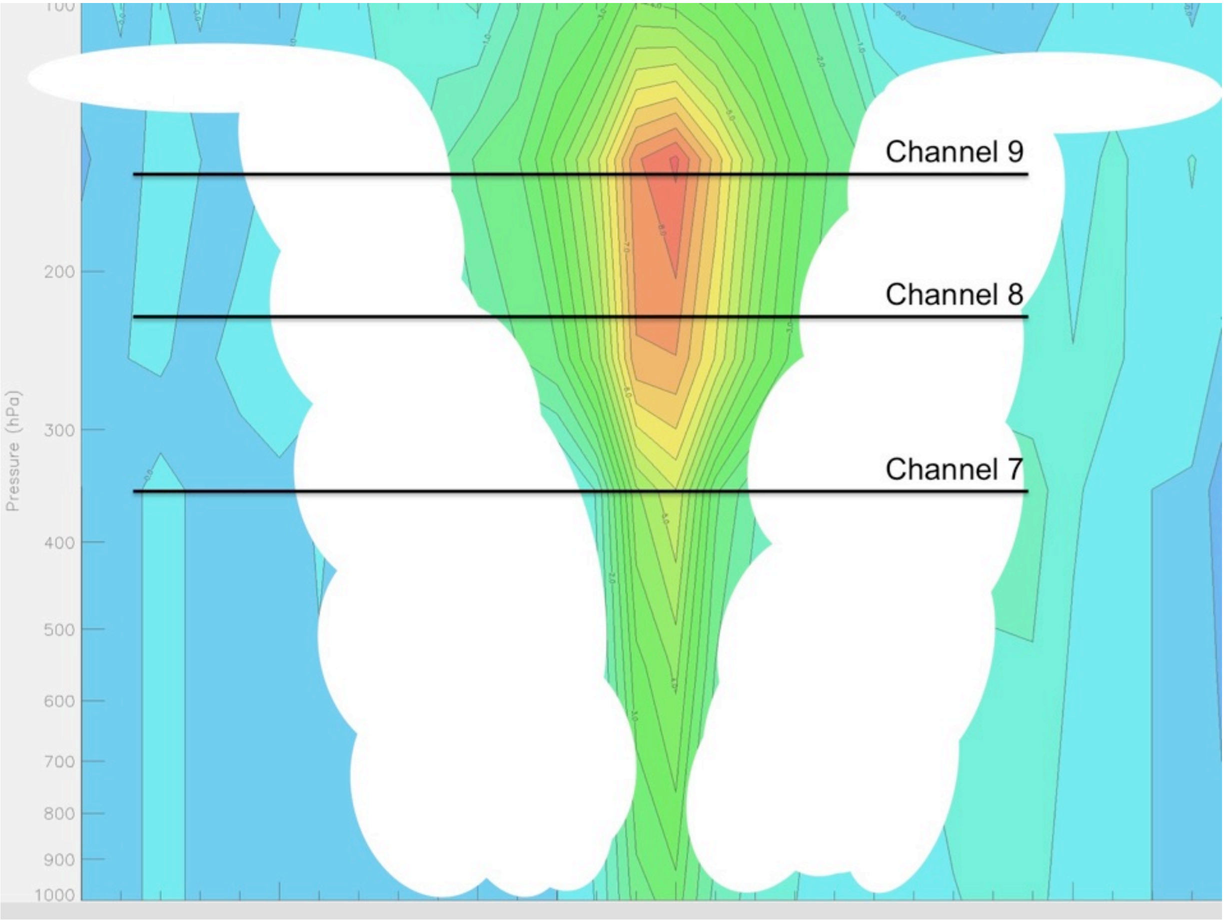


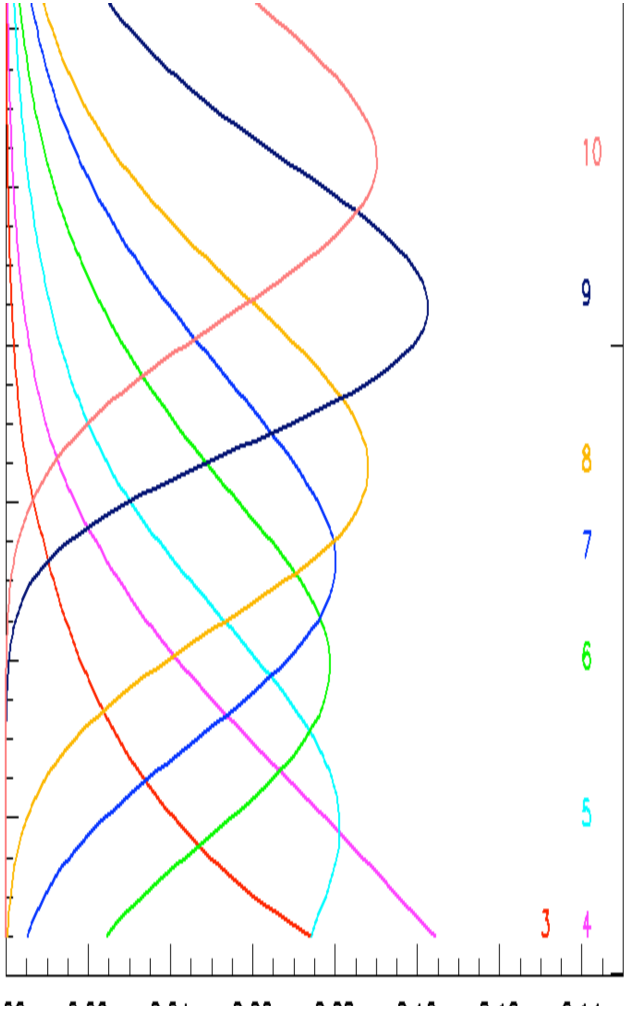
HALONG 11w, d23, Azimuthally averaged, 2014080506, 66 h FCST
Temperature deviation (shaded), Min=−4.07007, Max=14.2156 °C
Temperature (contour), Min=−78.4161, Max=33.388 °C

HWRF
Typhoon Halong 2014

TC Intensity Analysis: Sounders

CIMSS ATMS Vertical Cross Section of Tb Anomaly for Typhoon Lekima

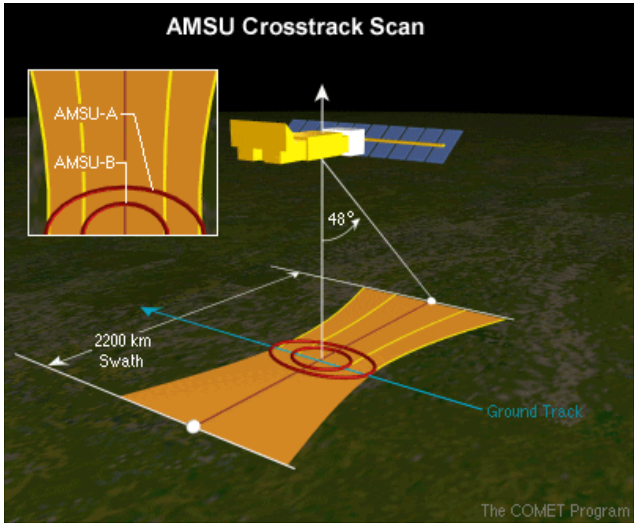




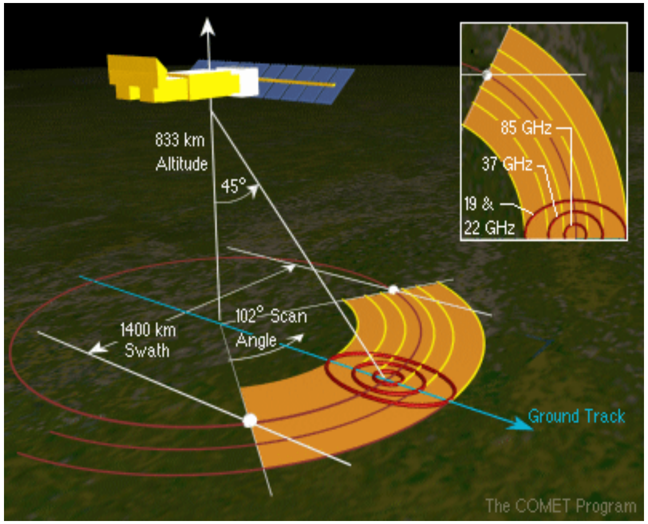
ATMS Weighting Functions
for channels 3-10

TC Intensity Analysis: Sounders

AMSU/ATMS - CROSSTRACK



SSMIS - CONICAL



- Flown aboard NOAA 15-19, METOP A/B, Aqua, FY Series, S-NPP (ATMS)
- 2 Instruments: AMSU-A (temperature) AMSU-B/MHS (moisture. ATMS 1 instrument)
- Primary channels of interest are AMSU-A 5-8 and channel 16 on AMSU-B
- Data must be limb-corrected
- 48 km at nadir increasing to > 80 km at limb

Special Sensor Microwave Imager/Sounder

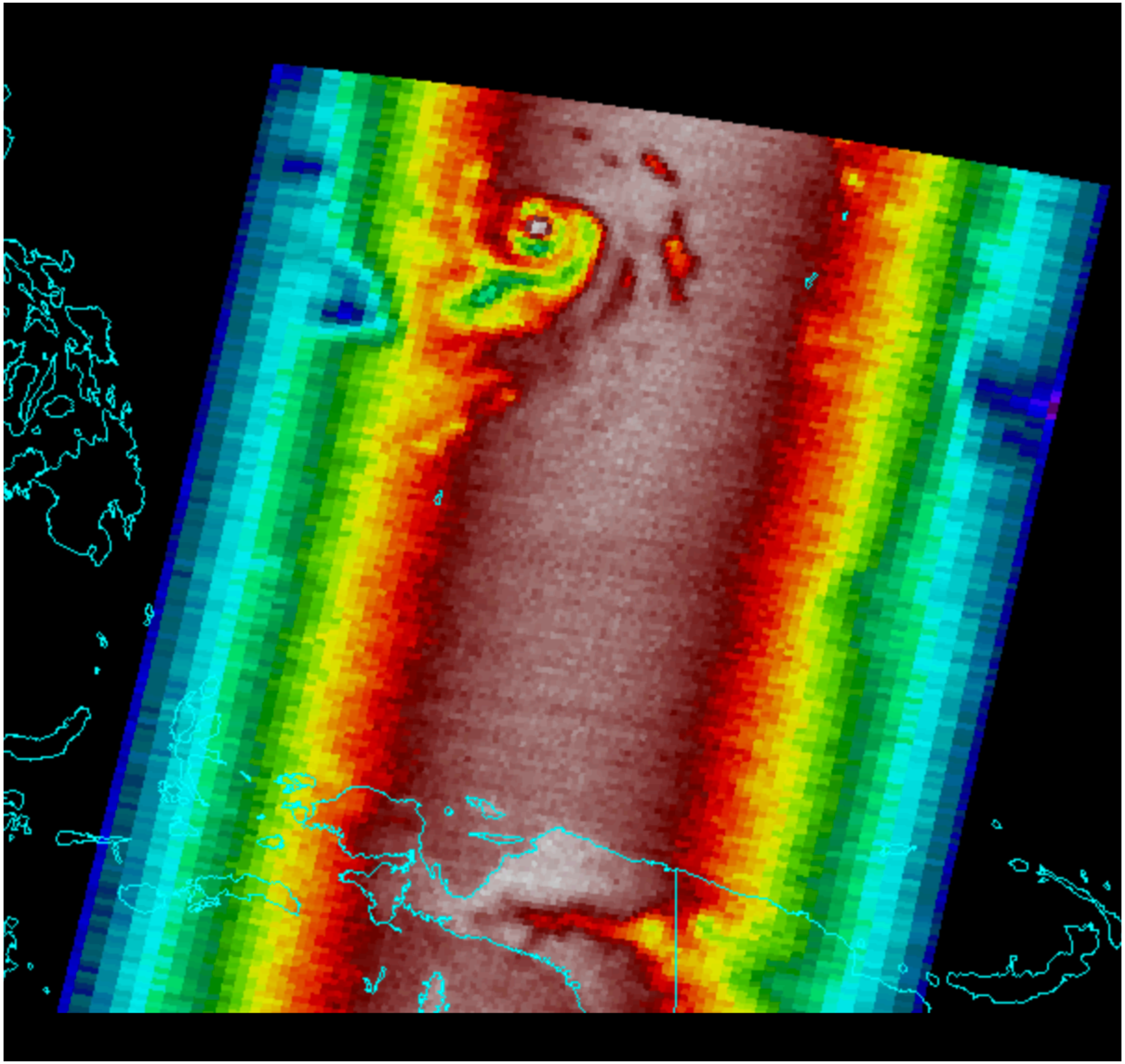
- Flown aboard F16-19
- Primary channels of interest are channels 3-5 (sounder) and channel 17-18 (imager)
- 37.5 km resolution

Cross-track Scanning Effects

S-NPP ATMS

Scan angle cold bias caused by increased optical path for larger scan angles

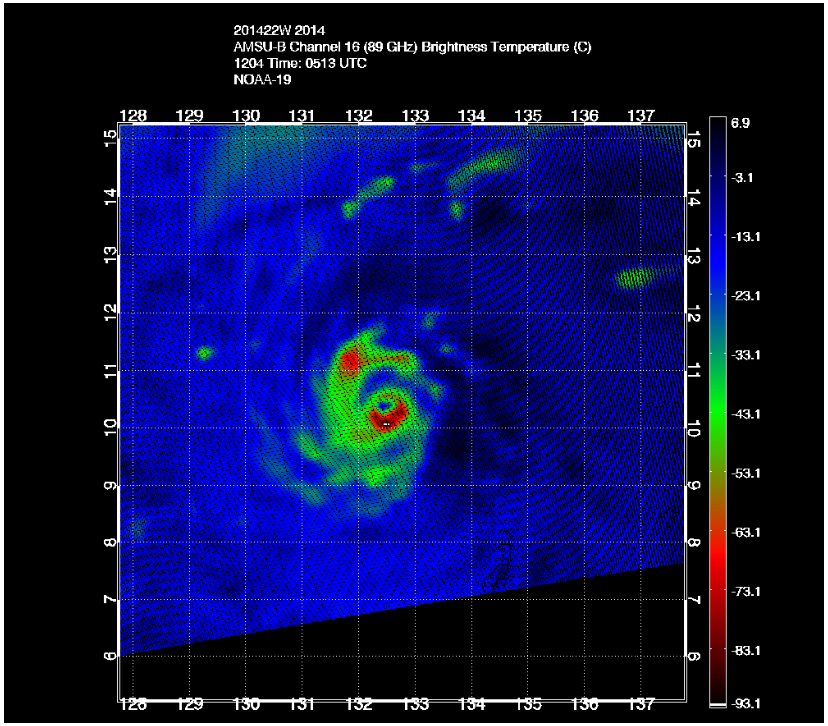
ATMS CH6

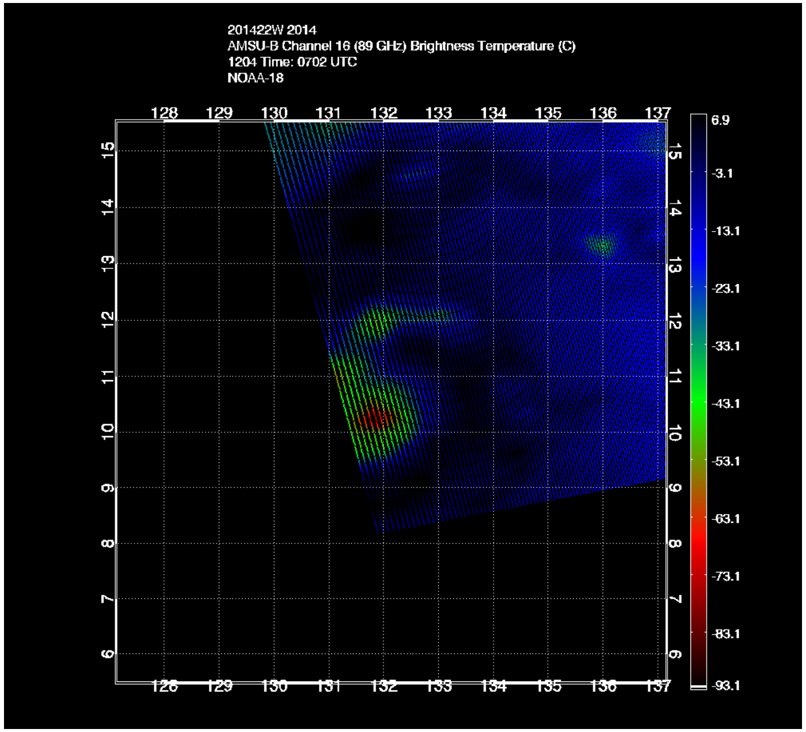


Cross-track Scanning Effects

Cross-track scanning resolution degradation and impact on TC analysis

AMSU/ATMS 89 Ghz Imagery

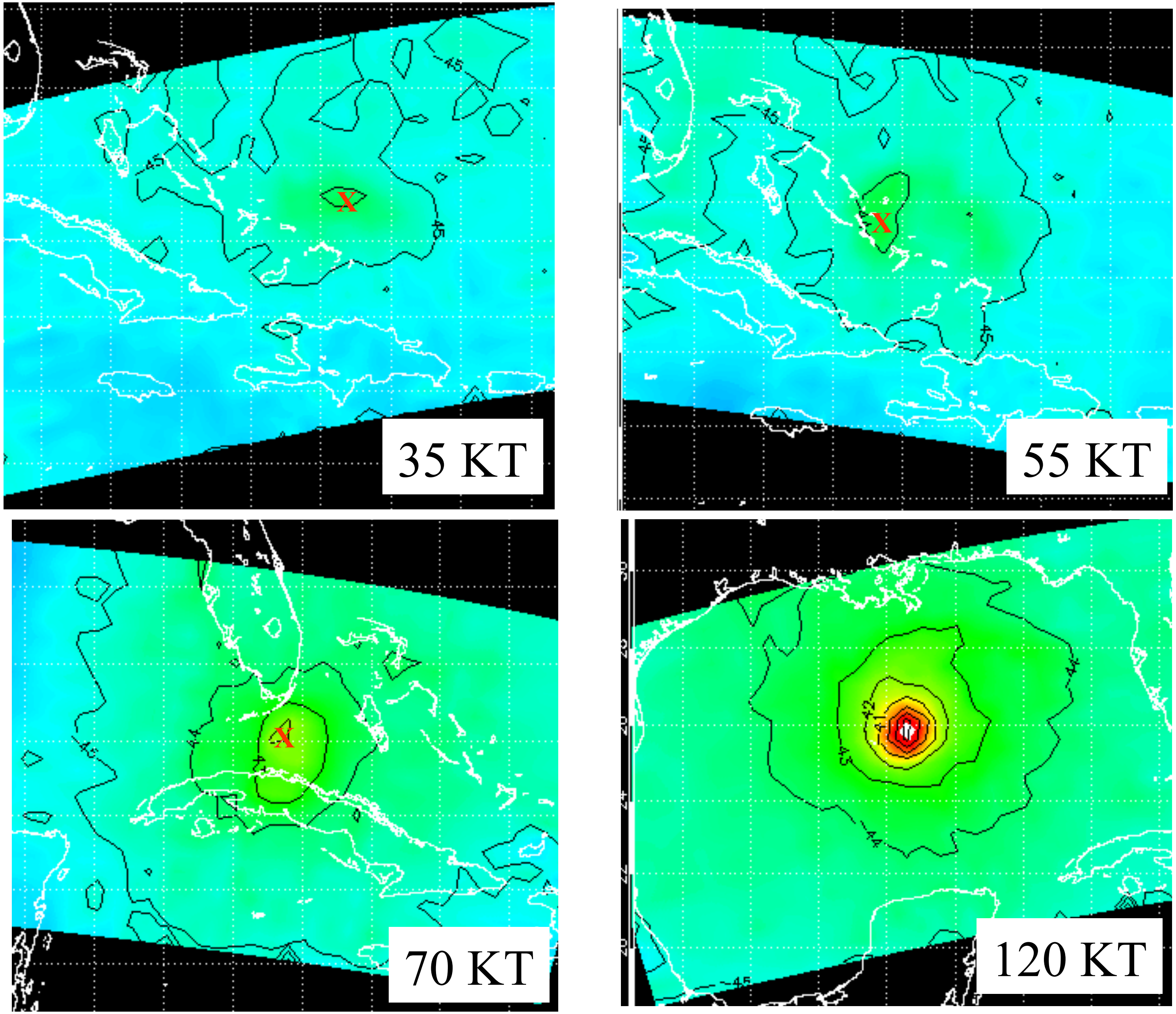




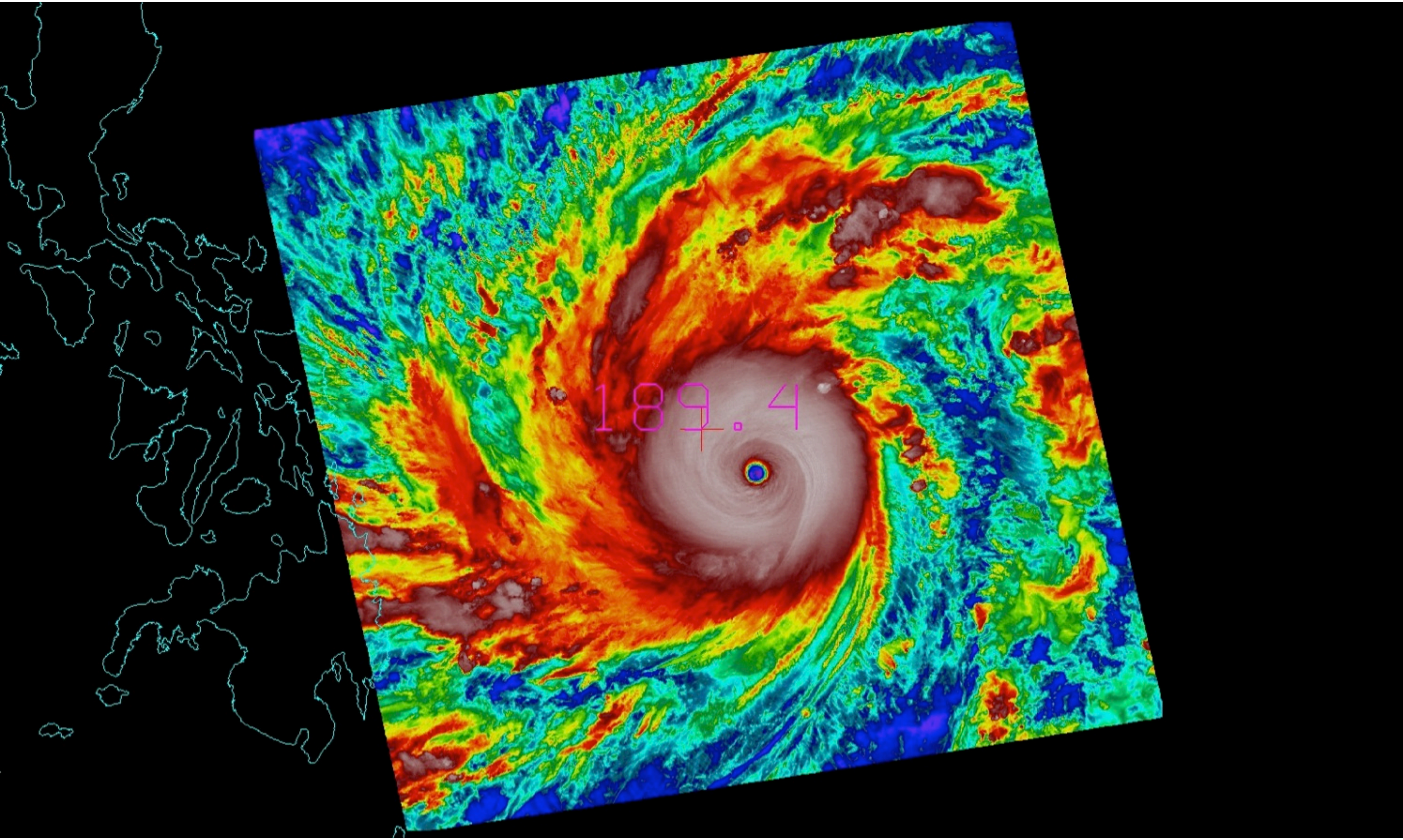
TC Structure

- Evaluation of TC structure is critical for intensity forecasts
- MW imagery often reveals eyewall formation well before visible/IR imagery
- Secondary eyewall development and Eyewall Replacement Cycles (ERC’s) modulate intensity for strongest storms
- MW images can help locate center in sheared and developing storms
- Radius of gale/storm force winds can be estimated from QuickScat, WindSat and AMSU imagery

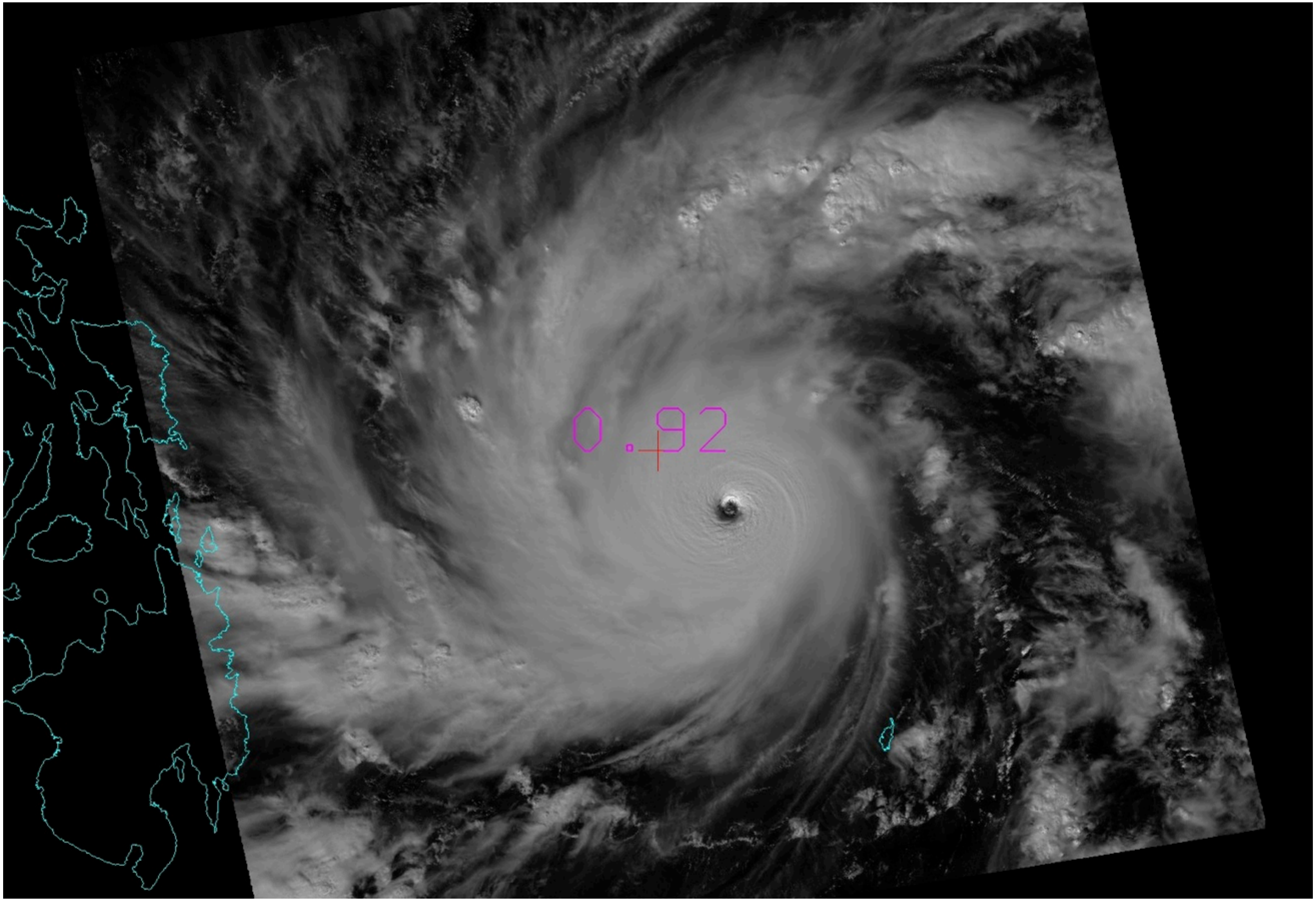
AMSU Channel 7 Tb's Rita September 18-21



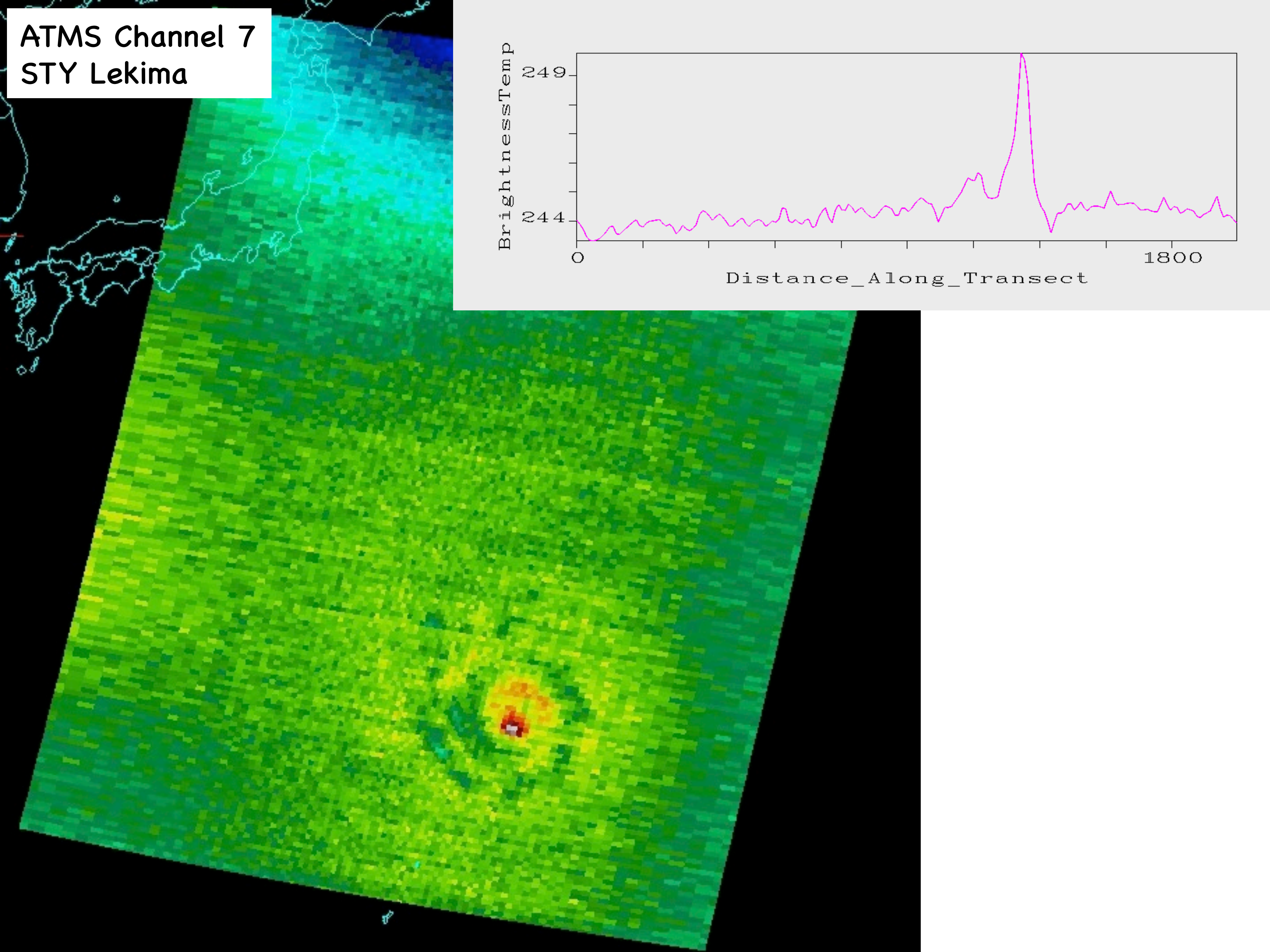
Super Typhoon Lekima 2014



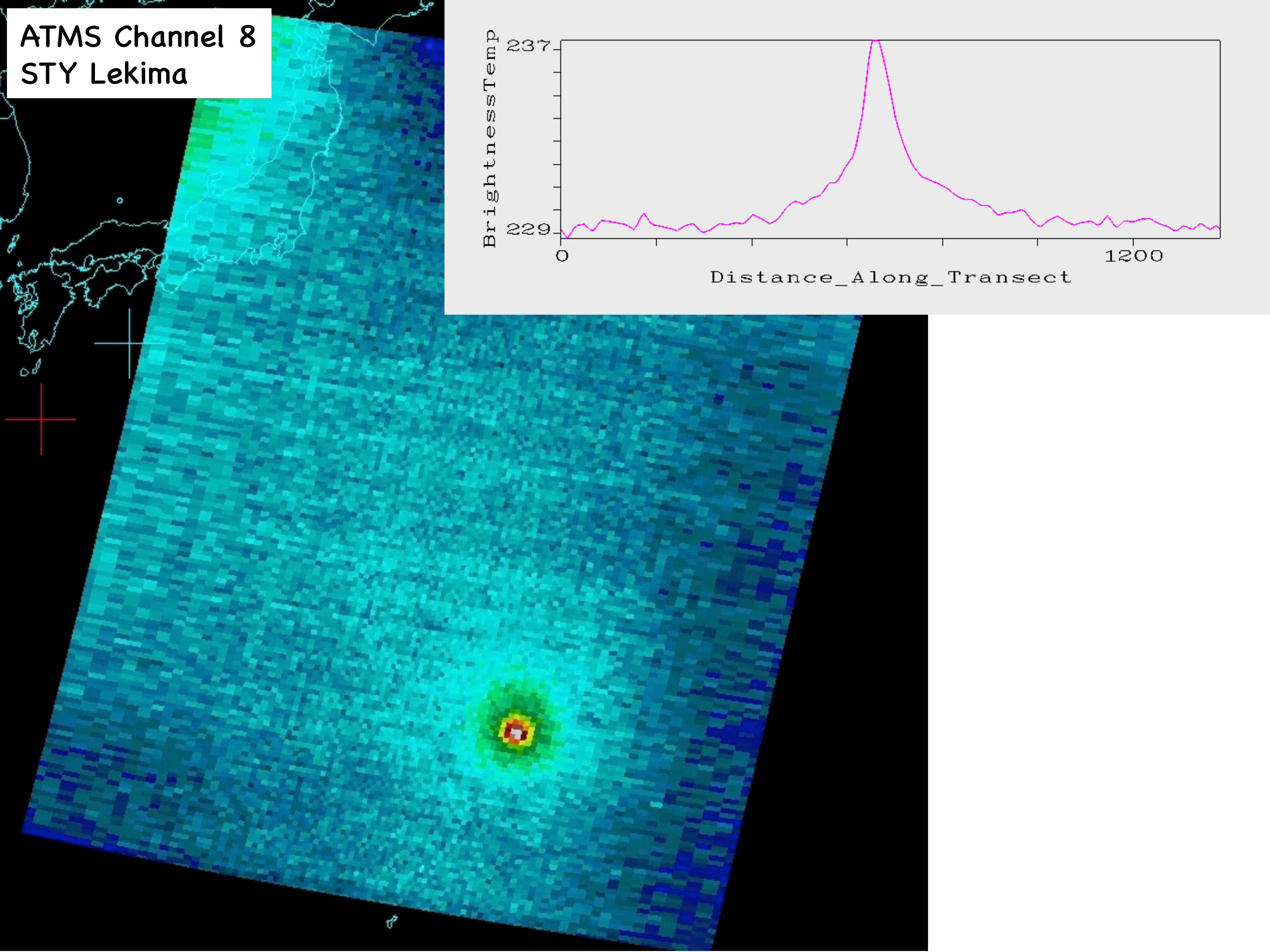
Super Typhoon Lekima 2014



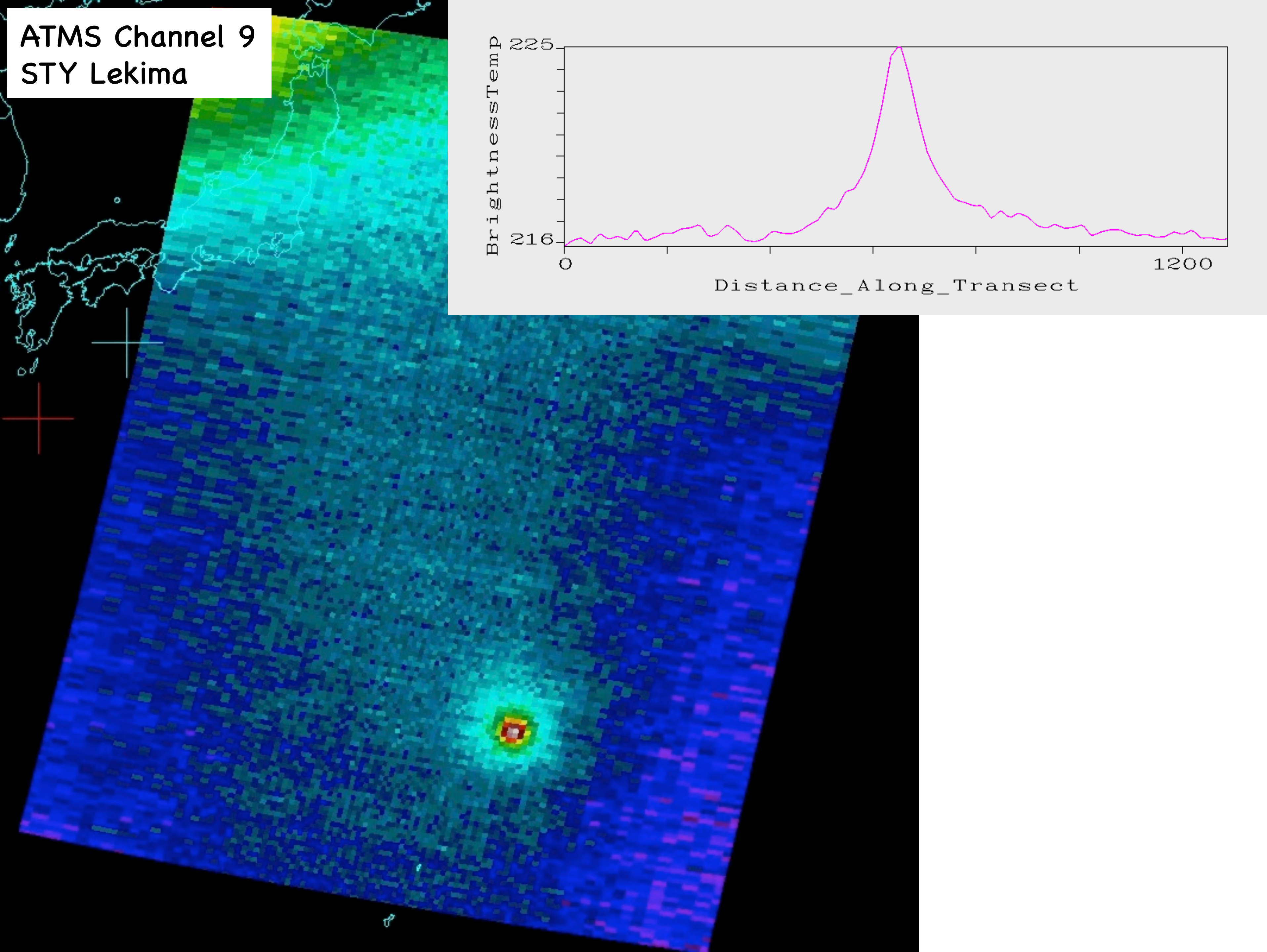
ATMS Channel 7
STY Lekima



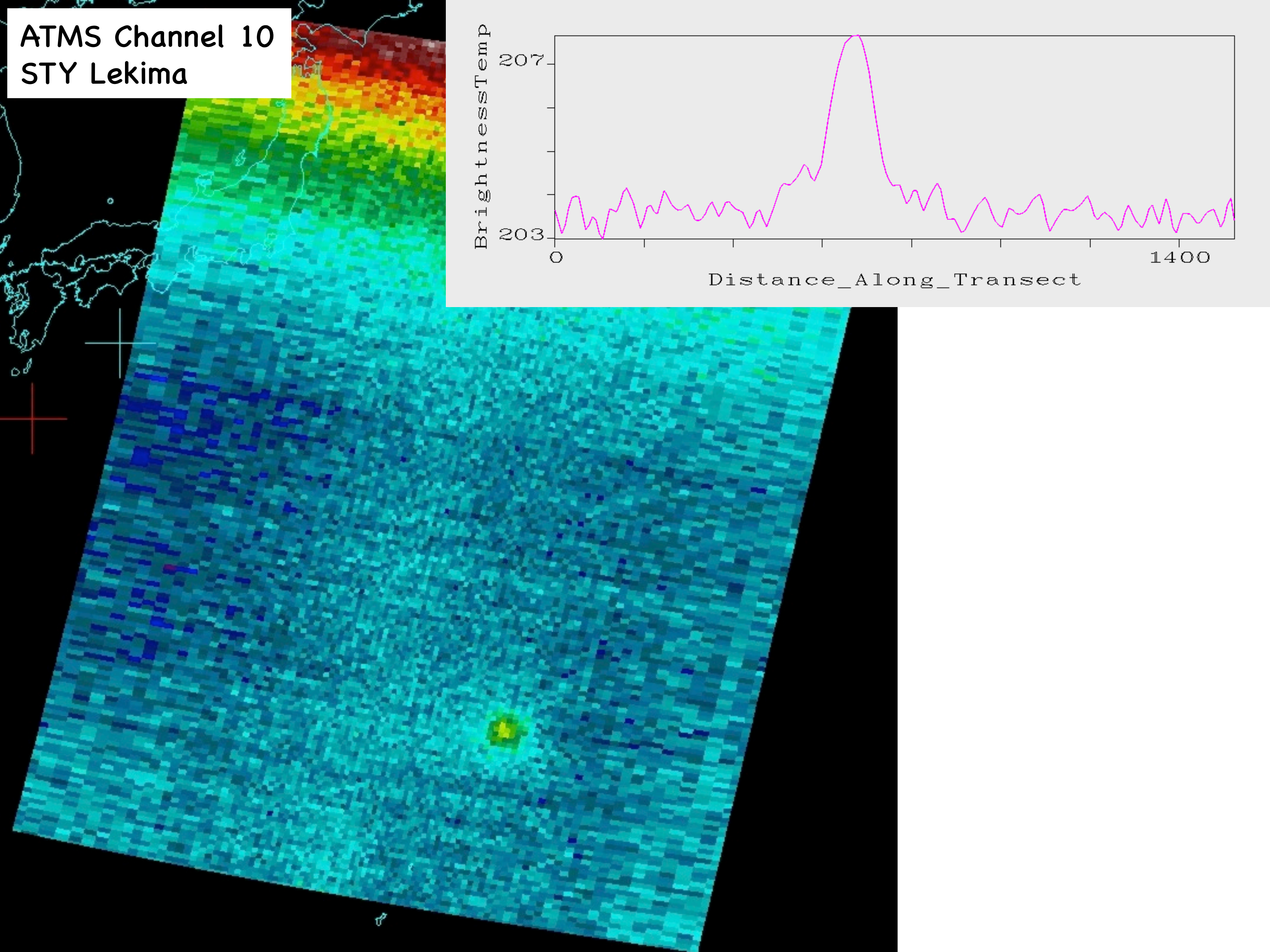
ATMS Channel 8
STY Lekima



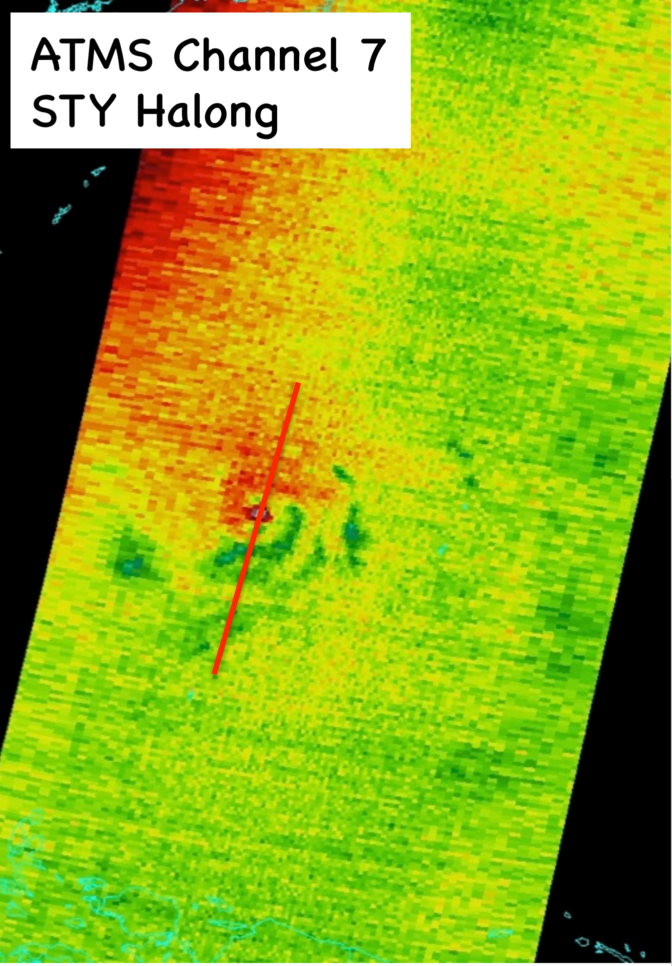
ATMS Channel 9
STY Lekima

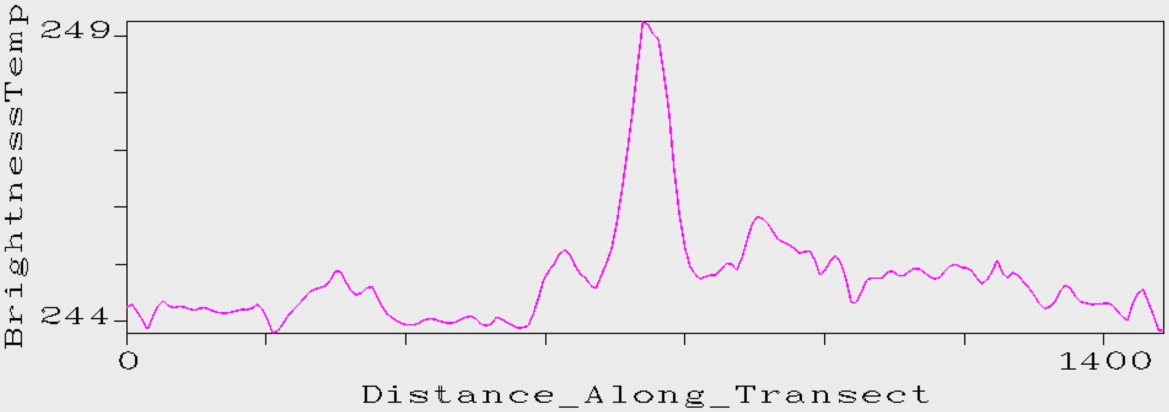


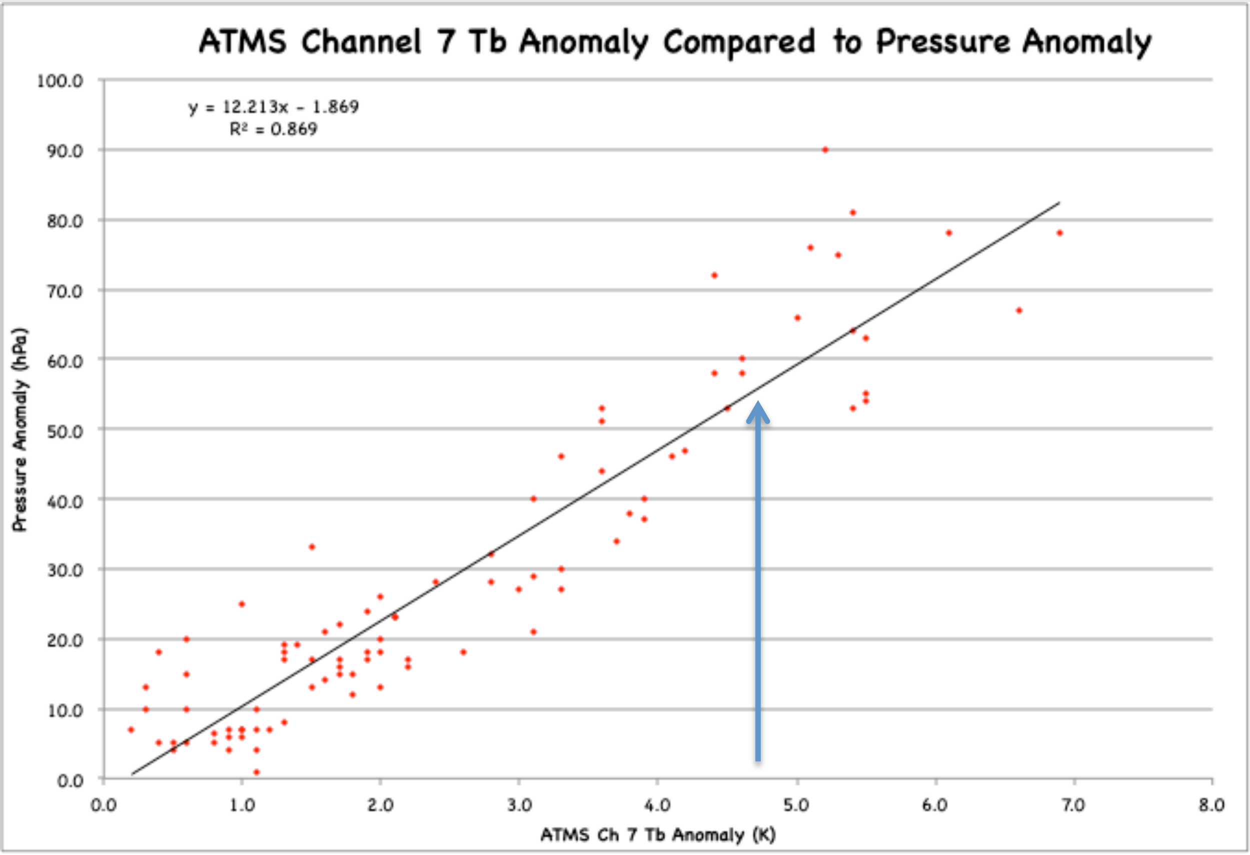
ATMS Channel 10
STY Lekima



ATMS Channel 7
STY Halong



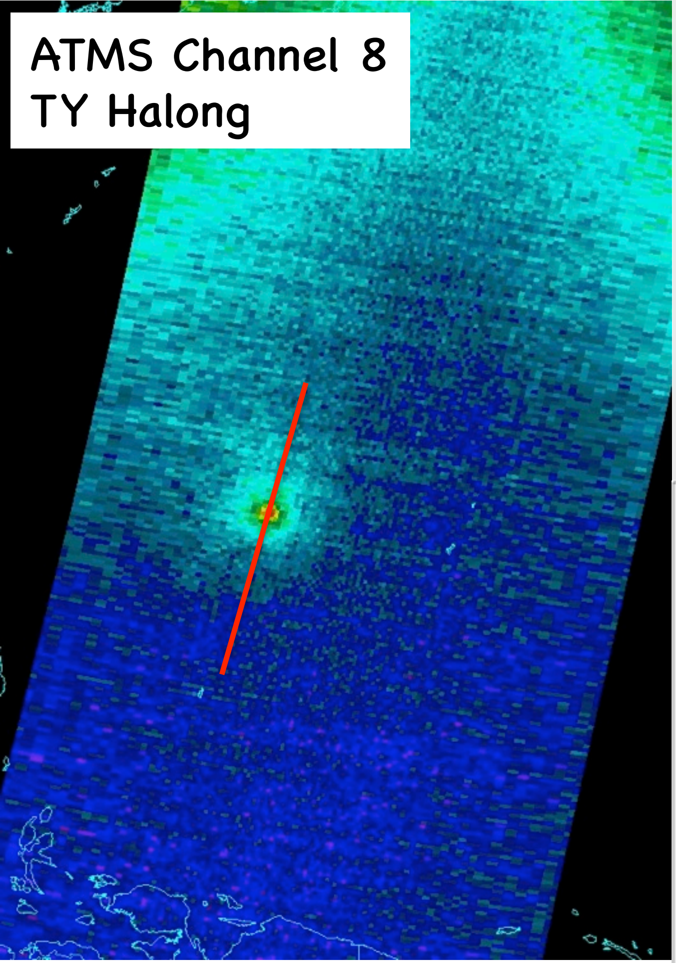


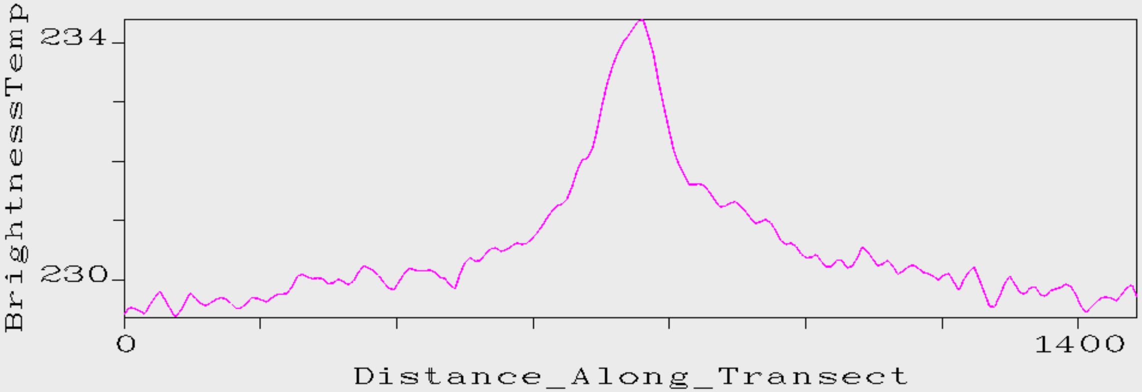

ATMS Channel 7 Tb Anomaly Compared to Pressure Anomaly

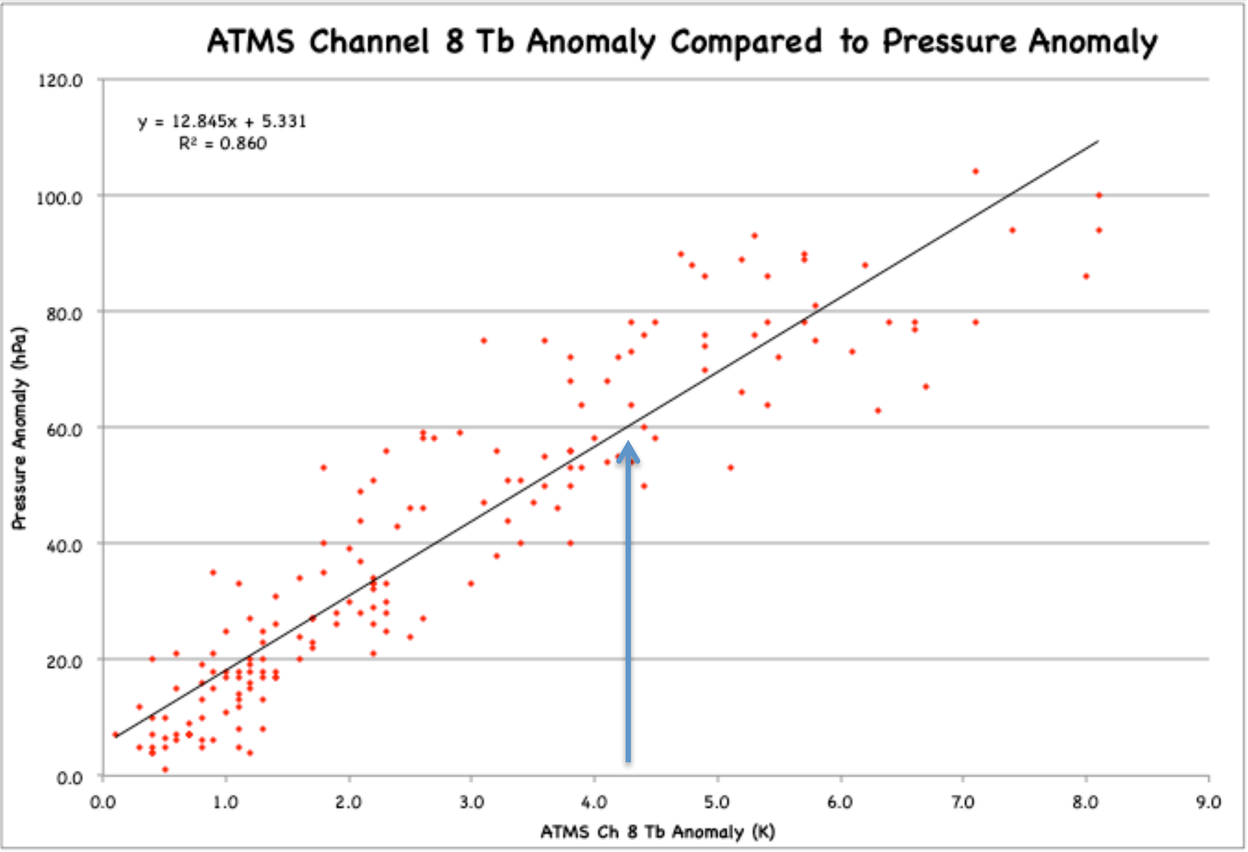
Pressure Anomaly of ~ 57 hPa
Environmental Pressure = 1007

MSLP = 950 hPa

ATMS Channel 8
TY Halong



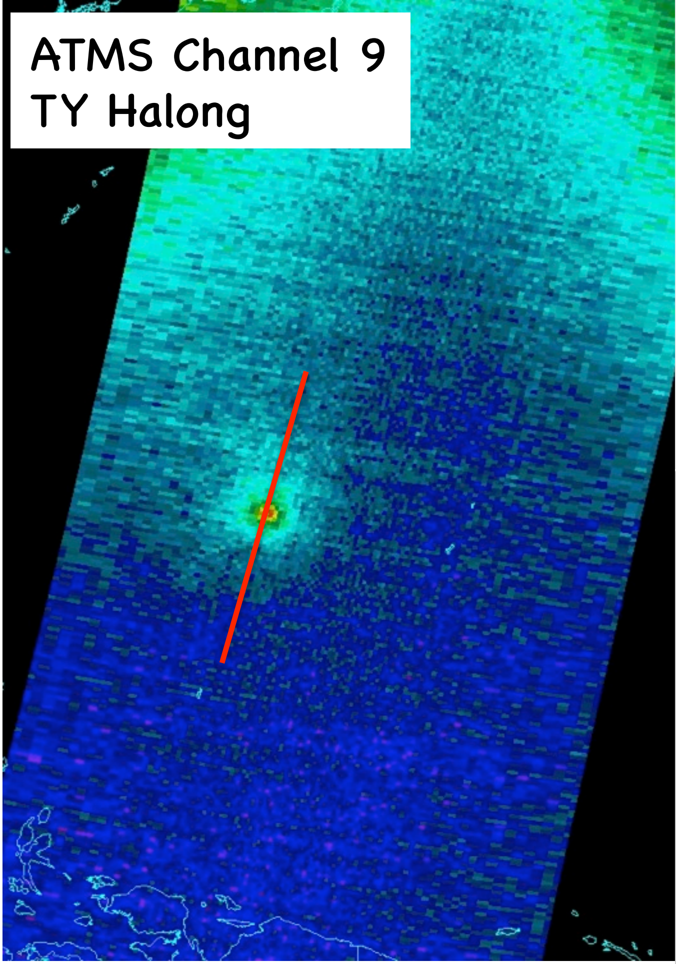


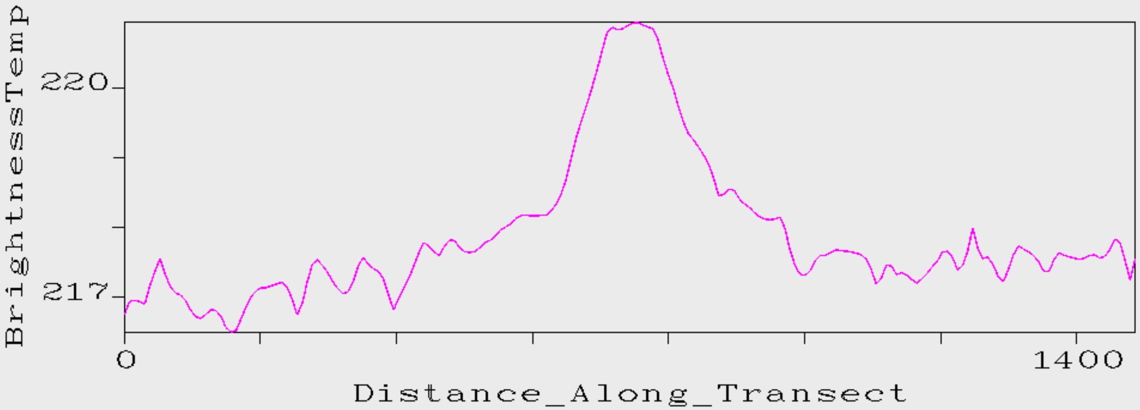

ATMS Channel 8 Tb Anomaly Compared to Pressure Anomaly

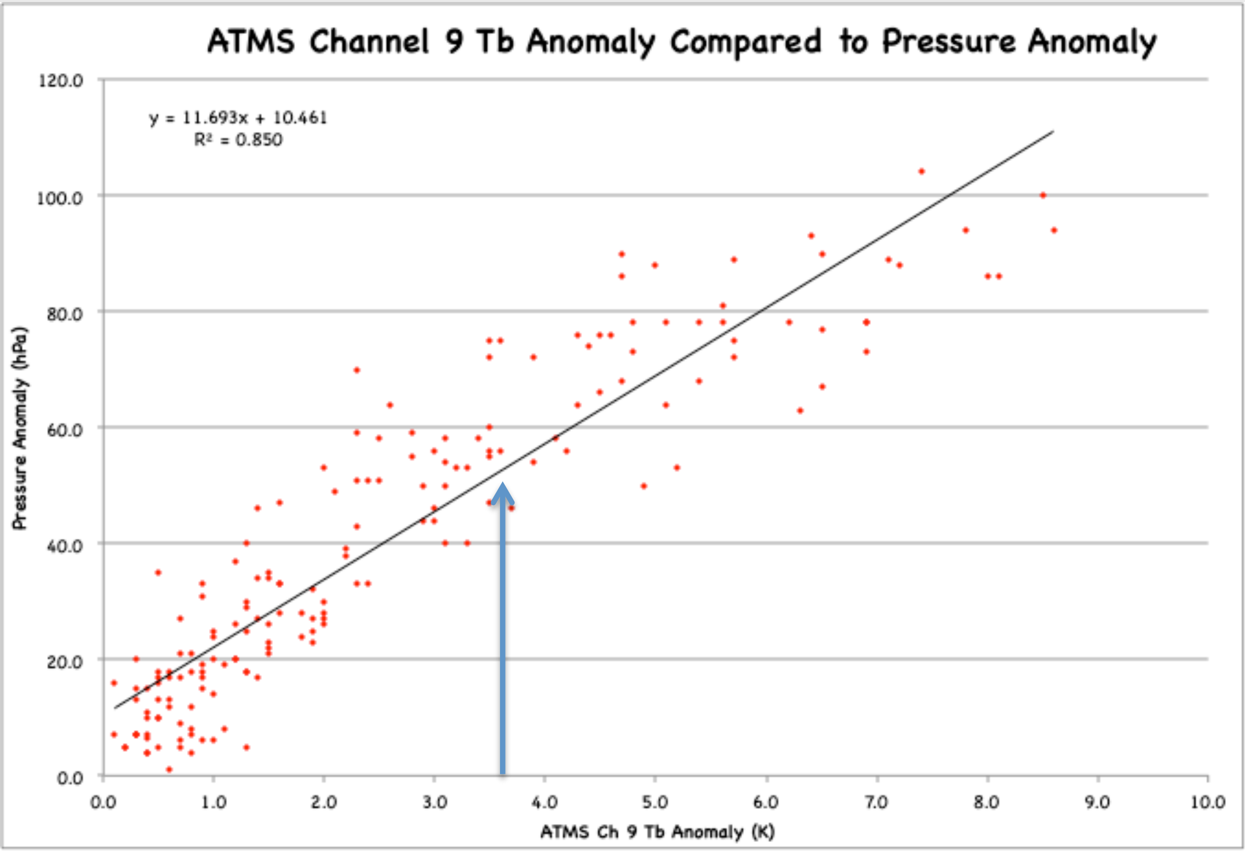
Pressure Anomaly of ~ 59 hPa
Environmental Pressure = 1007

MSLP = 947 hPa

ATMS Channel 9
TY Halong

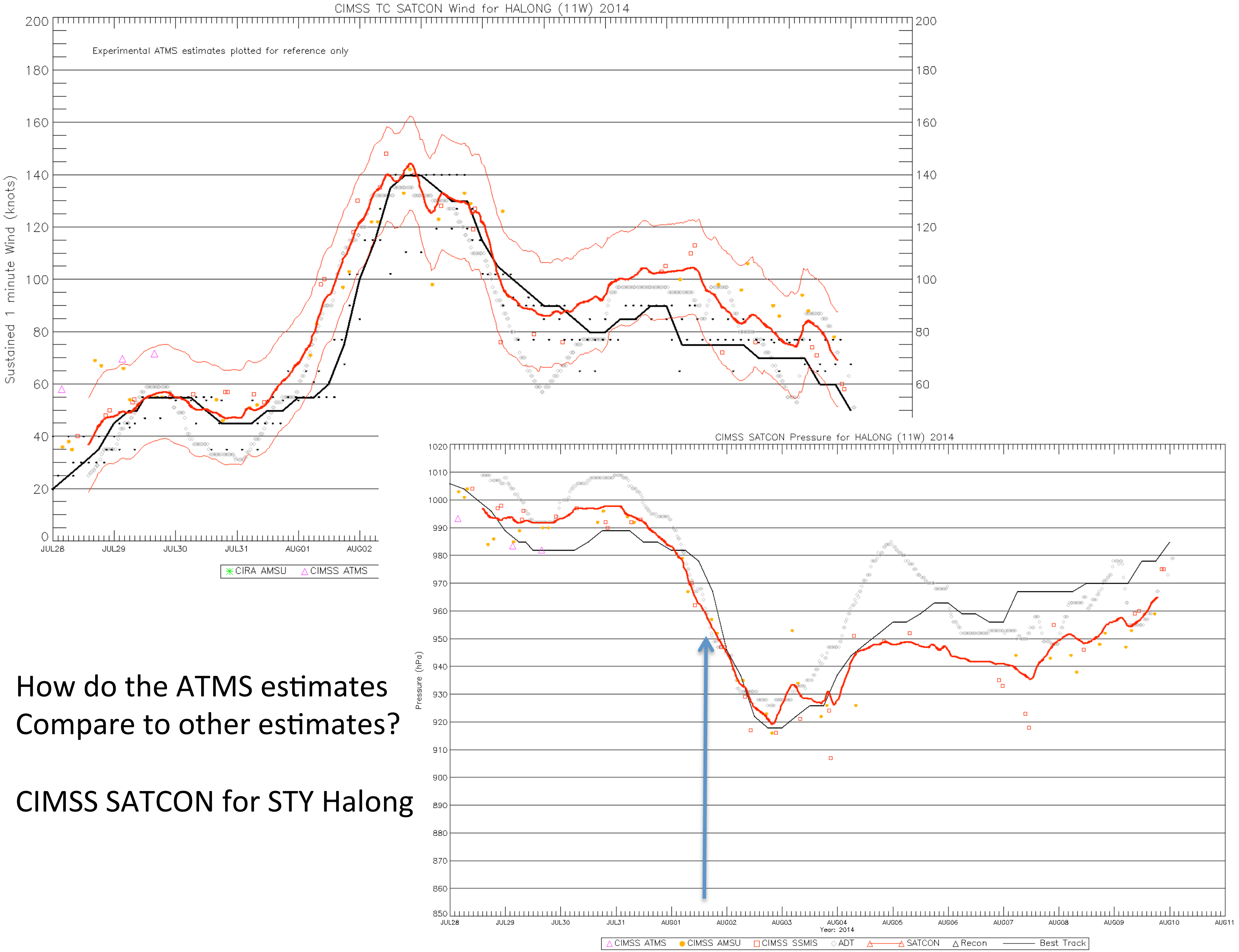





ATMS Channel 9 Tb Anomaly Compared to Pressure Anomaly

Pressure Anomaly of ~ 54 hPa
Environmental Pressure = 1007

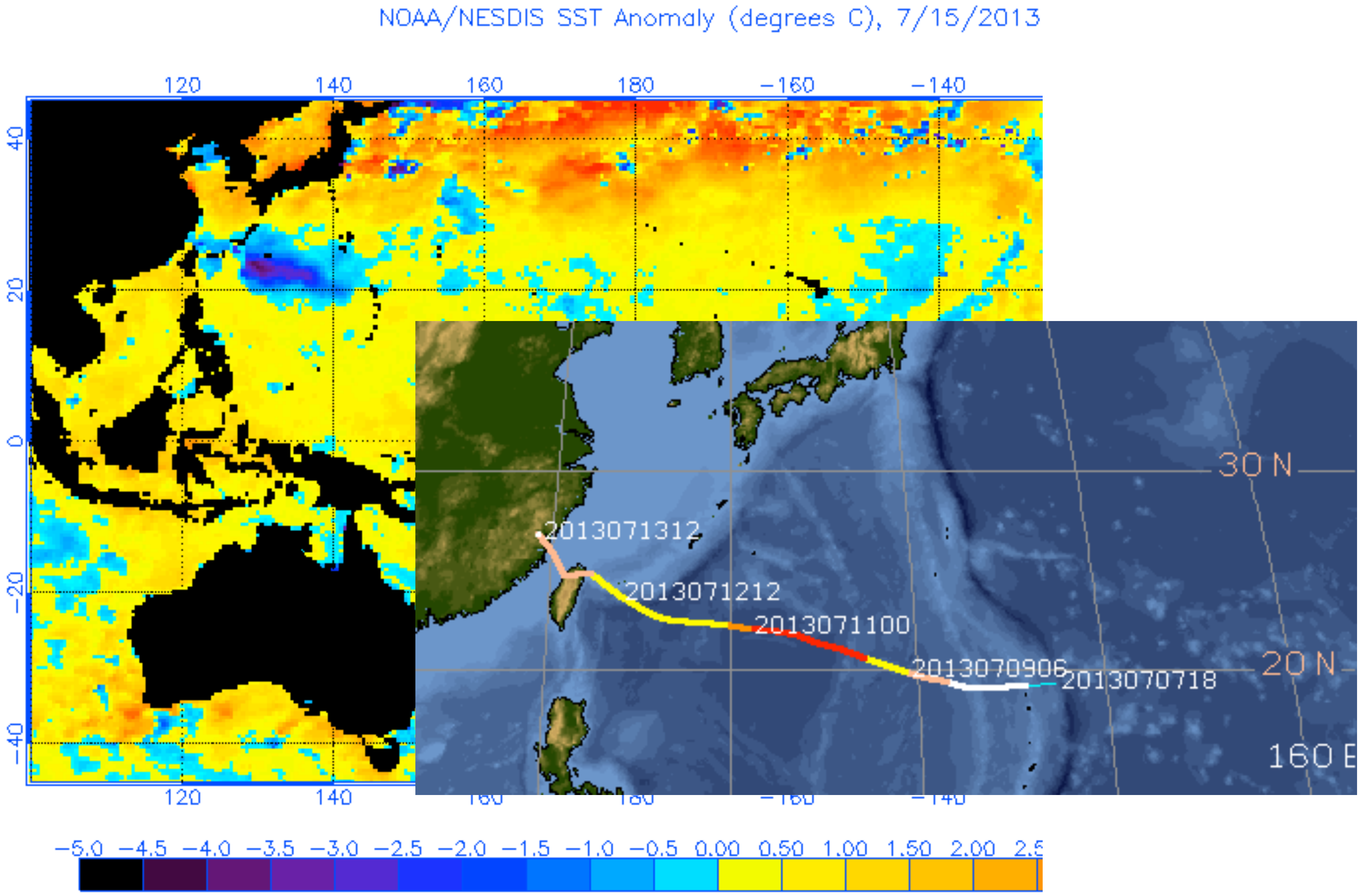
MSLP = 953 hPa

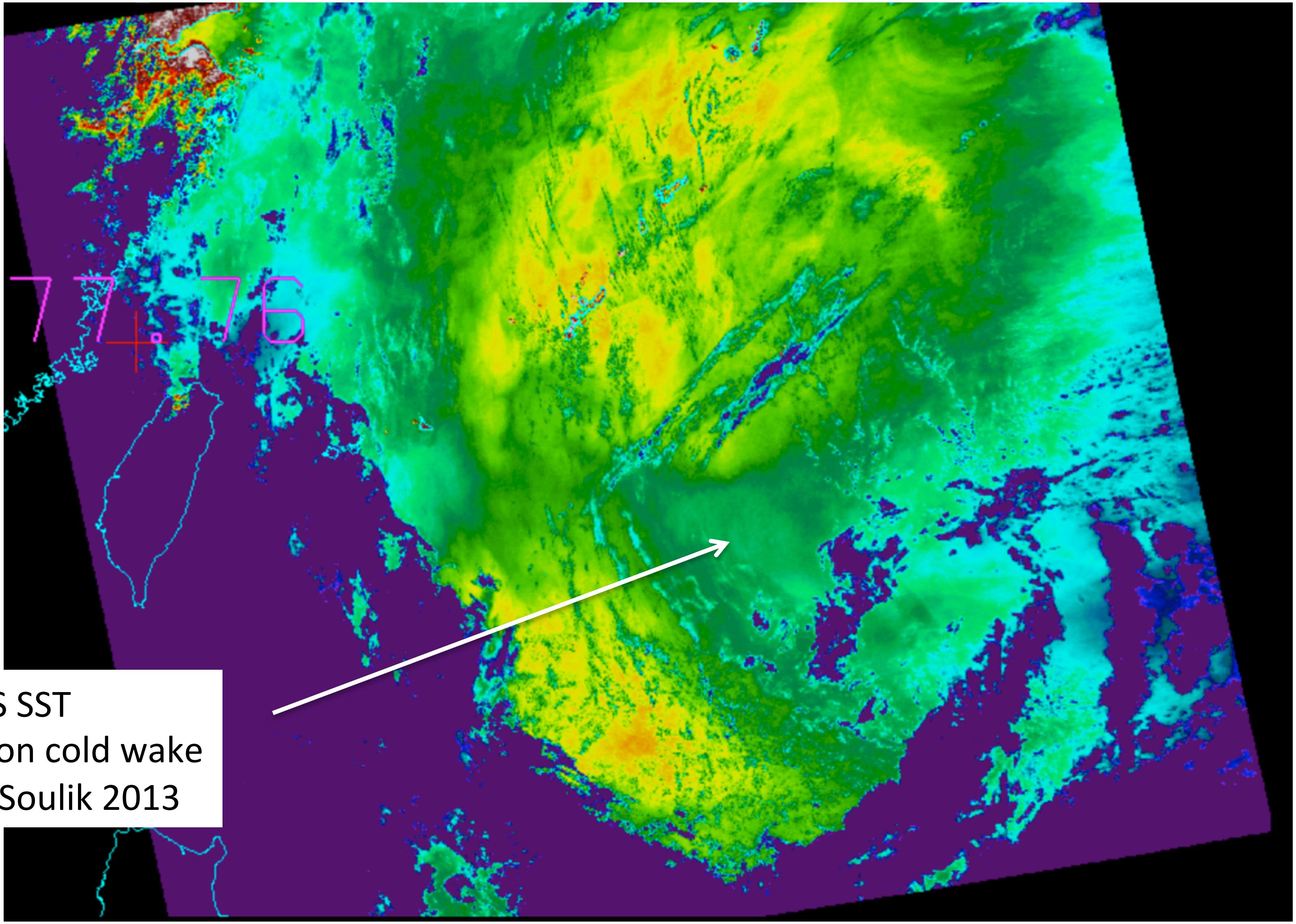


How do the ATMS estimates Compare to other estimates?

CIMSS SATCON for STY Halong

Typhoon Soulik 2013

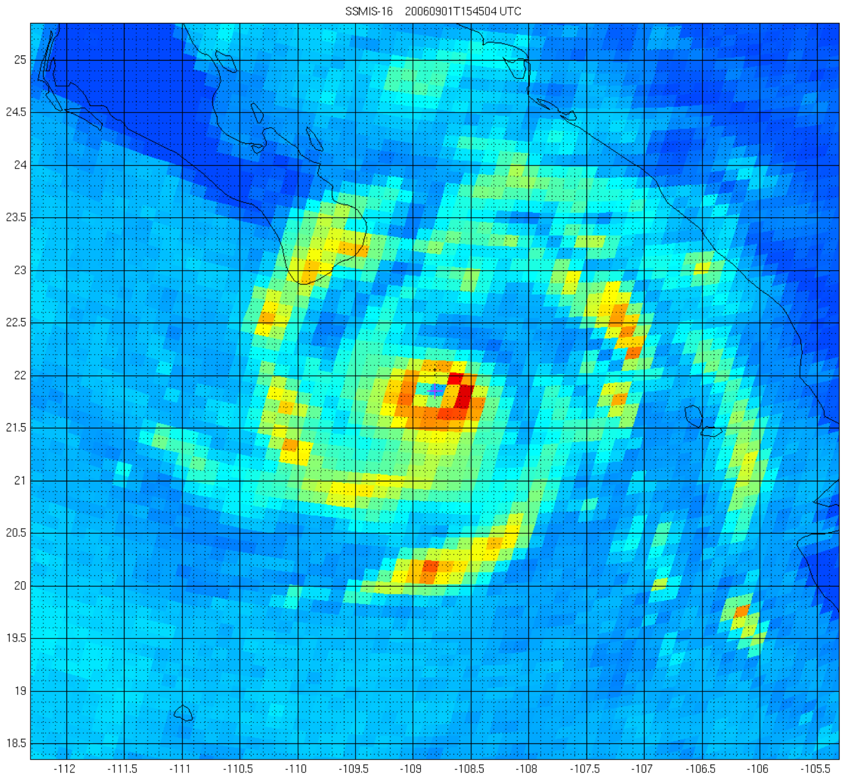




MODIS SST
Typhoon cold wake
for TY Soulik 2013

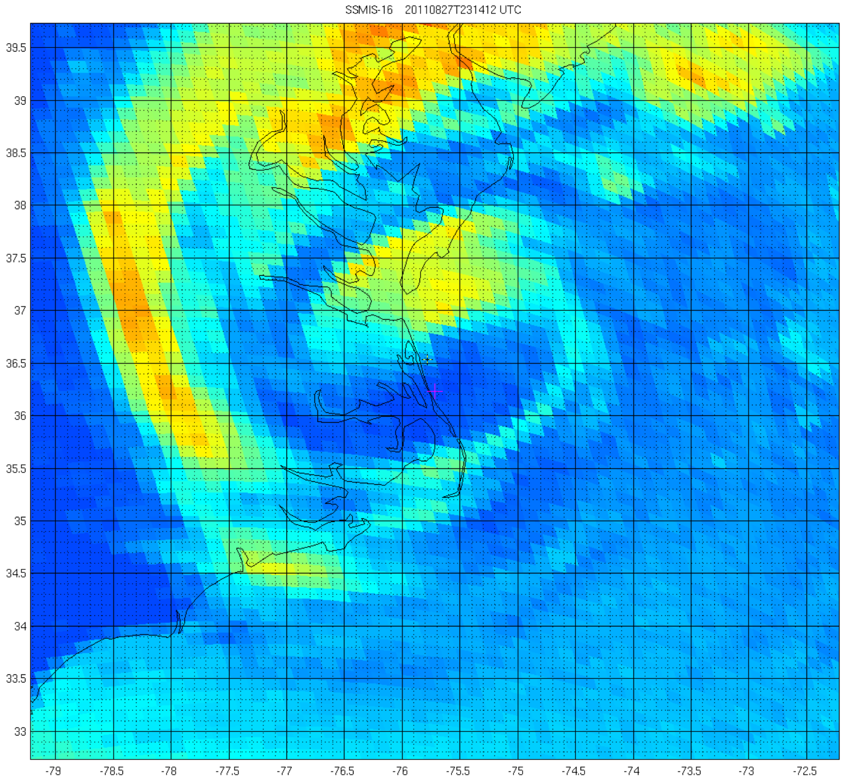
85-92 Ghz in Objective Intensity Estimates

Same MSLP for these 2 storms but different MSW



Compact wind field. More efficient momentum transfer in eyewall

ACRHER Score = 85

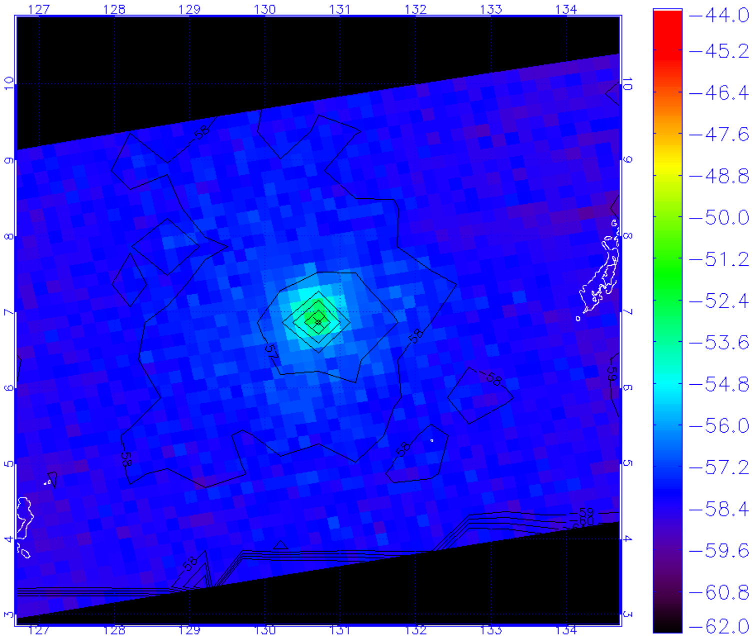


Expanding wind field. Less efficient momentum transfer with weaker convection

ACRHER Score = 10

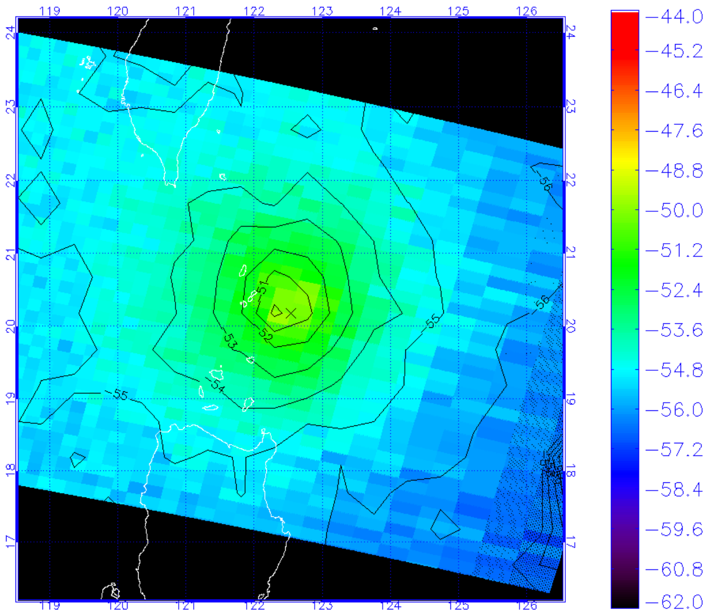
ATMS Sounder

Same MSLP for these 2 storms but different MSW


201226W BOPHA
SNPP–ATMS Channel 9 (55.5GHz) Tb (C)
1203 0437

Max Tb: –52.7410 C Contour Interval = 1C

Compact wind field. More efficient momentum transfer in eyewall


201317W USAGI
SNPP–ATMS Channel 9 (55.5GHz) Tb (C)
0920 1757

Max Tb: –49.7790 C Contour Interval = 1C

Expanding wind field. Less efficient momentum transfer with weaker convection