NRL's Satellite Products & Support for JTWC

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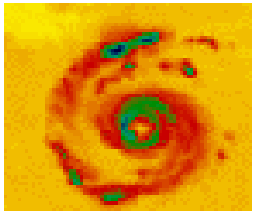
Sponsors:

Oceanographer of the Navy

Space and Naval Warfare Systems Command - SPAWAR PMW-155

Office of Naval Research

Risk-Benefit Assessment of Observing System Decision Alternatives : 18 June 2001



Tropical Cyclone Web Page

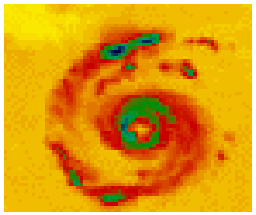
http://kauai.nrlmry.navy.mil/tc-bin/tc_home

Objective:

* **Demonstrate utility of passive microwave data for tropical cyclone monitoring:**
  - **location**
  - **structure-organization/intensity**
* **Provide coincident data sets for a given tropical system at one site.**
  - **multi-spectral satellite data.**
  - **track and forecast information.**

Approach:

* **Process global SSM/I, TMI and geostationary imagery (visible/IR) over "systems".**
* **Map all data sets to common grid and resolution.**
* **Fill in areas outside of passive microwave swath with coincident vis/IR data.**
* **Automate process and distribute via web page.**



Multi-Sensor Approach

* **Vital TC features often cloud obscured in Vis/IR imagery.**

* **Passive microwave data enables the analyst to view below most upper-level cloud decks:**

  - **Can map important rainband/eyewall features not evident in many vis/IR images.**

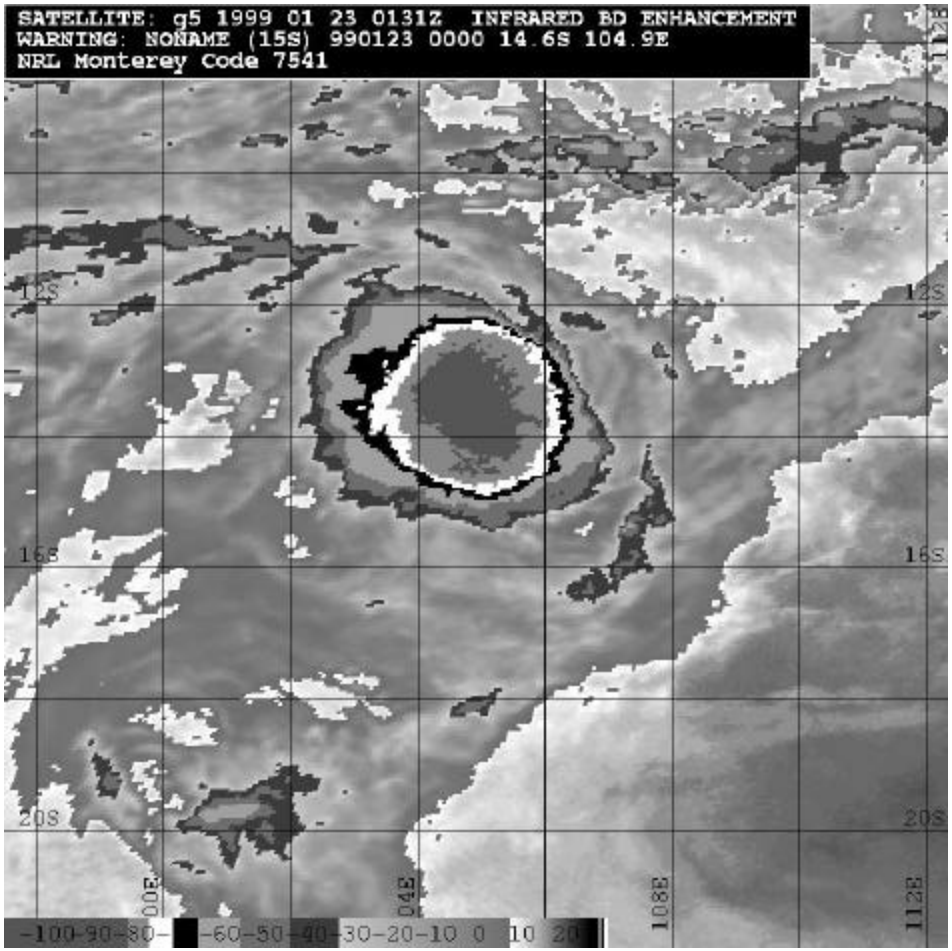
  - **Readily permits accurate eye/center locations.**

  - **Permits mapping exposed low-level centers.**

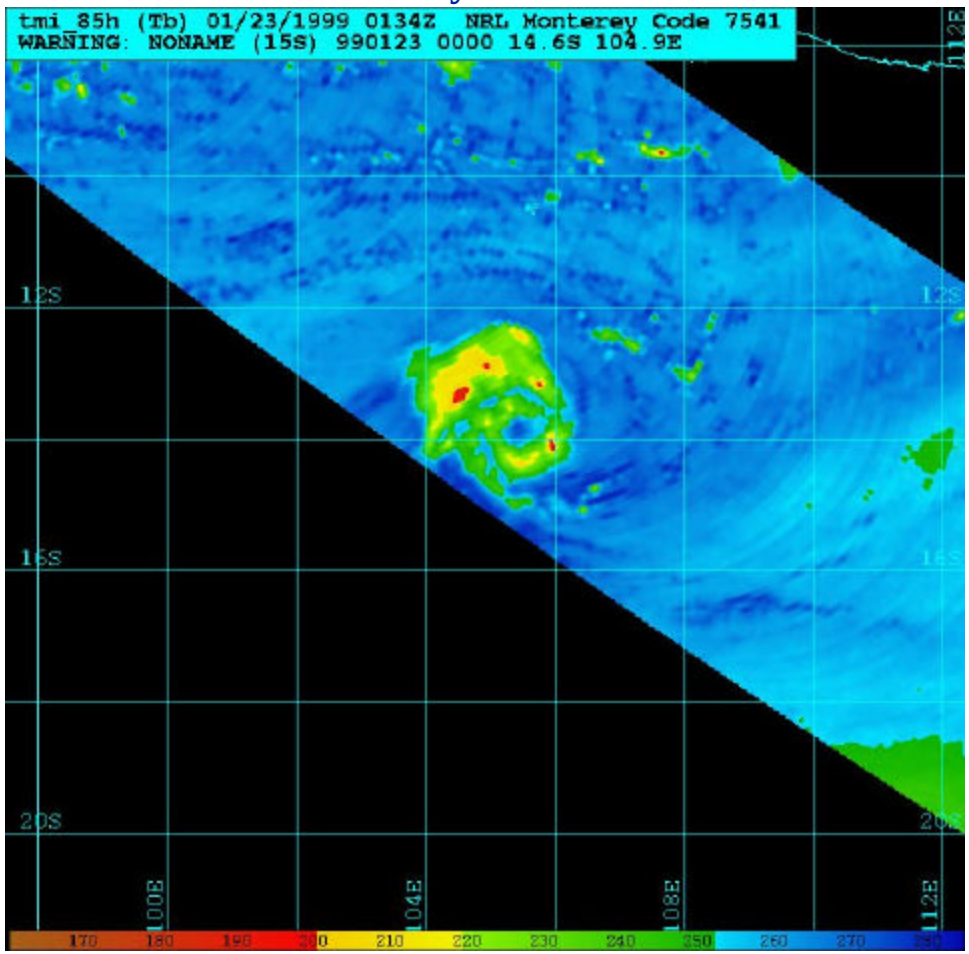
  - **Enables analyst to view structure changes with time.**

TRMM Microwave Imagery Relocated Tropical Cyclone Position - JTWC

Central Dense Overcast



Enclosed Eye with Bands



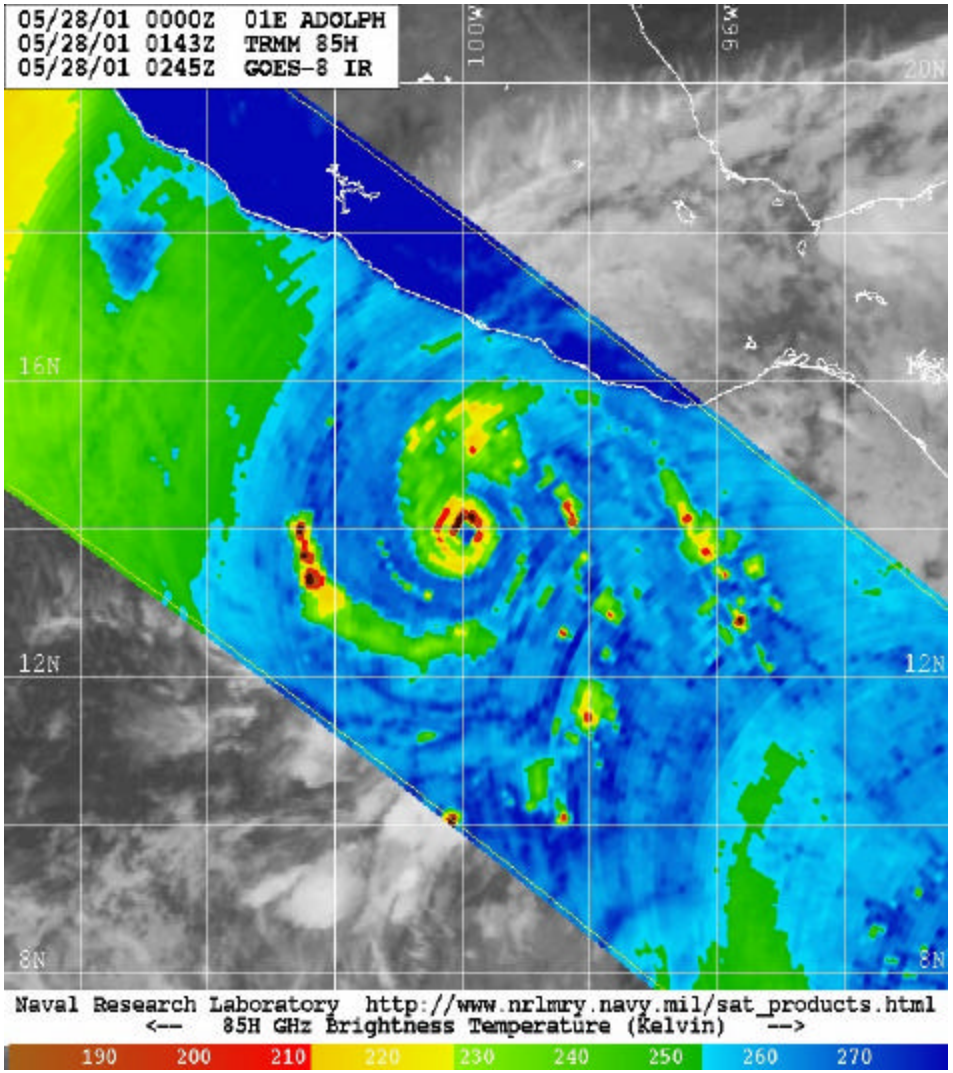
Dvorak IR Enhanced GMS-5 Image

TMI 85 GHz Image: 2 minutes after GMS-5 Image

TRMM data courtesy of NASA/GSFC

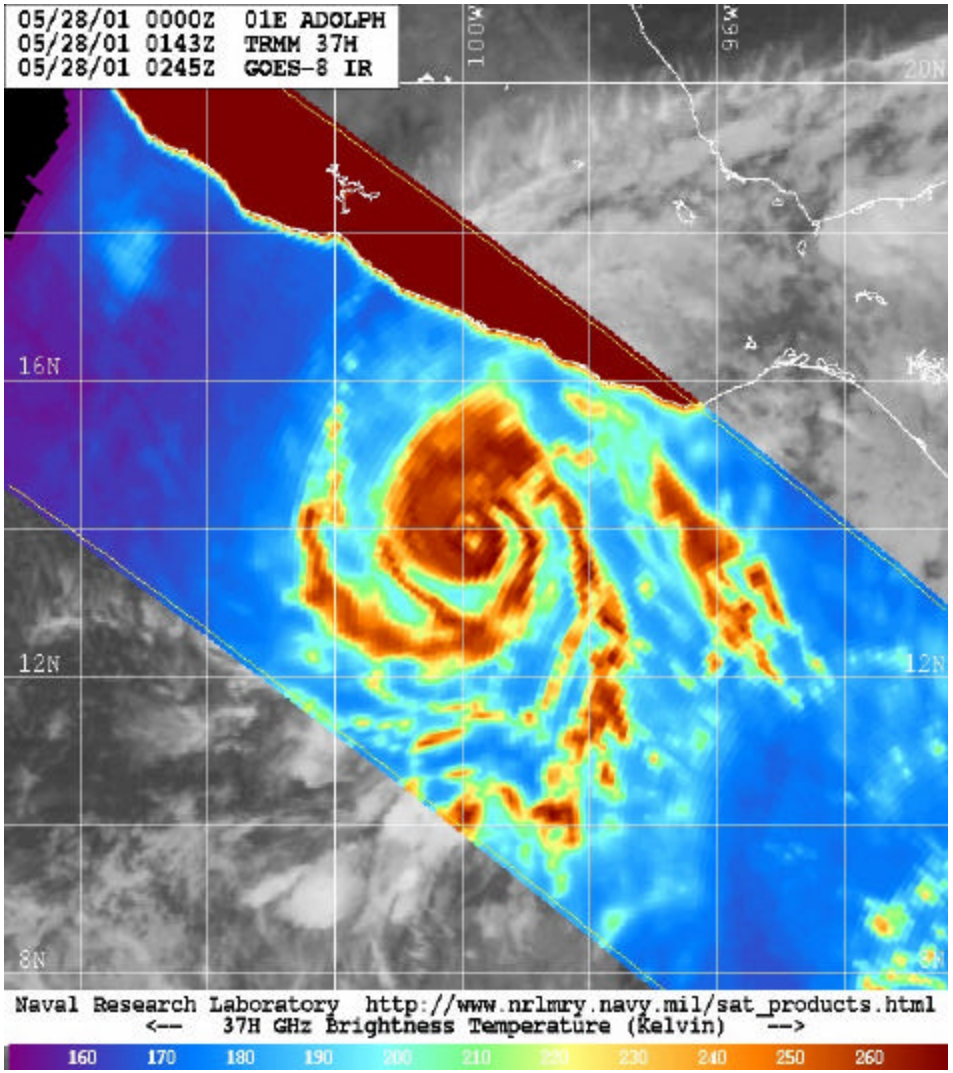
Scattering

- Scattering is caused by large frozen hydrometeors (graupel, hail, snowflakes).
- Energy from below is scattered away from the view of the satellite – very low brightness temperatures.
- Scattering is the dominant process at 85 GHz, also important at 37 GHz.



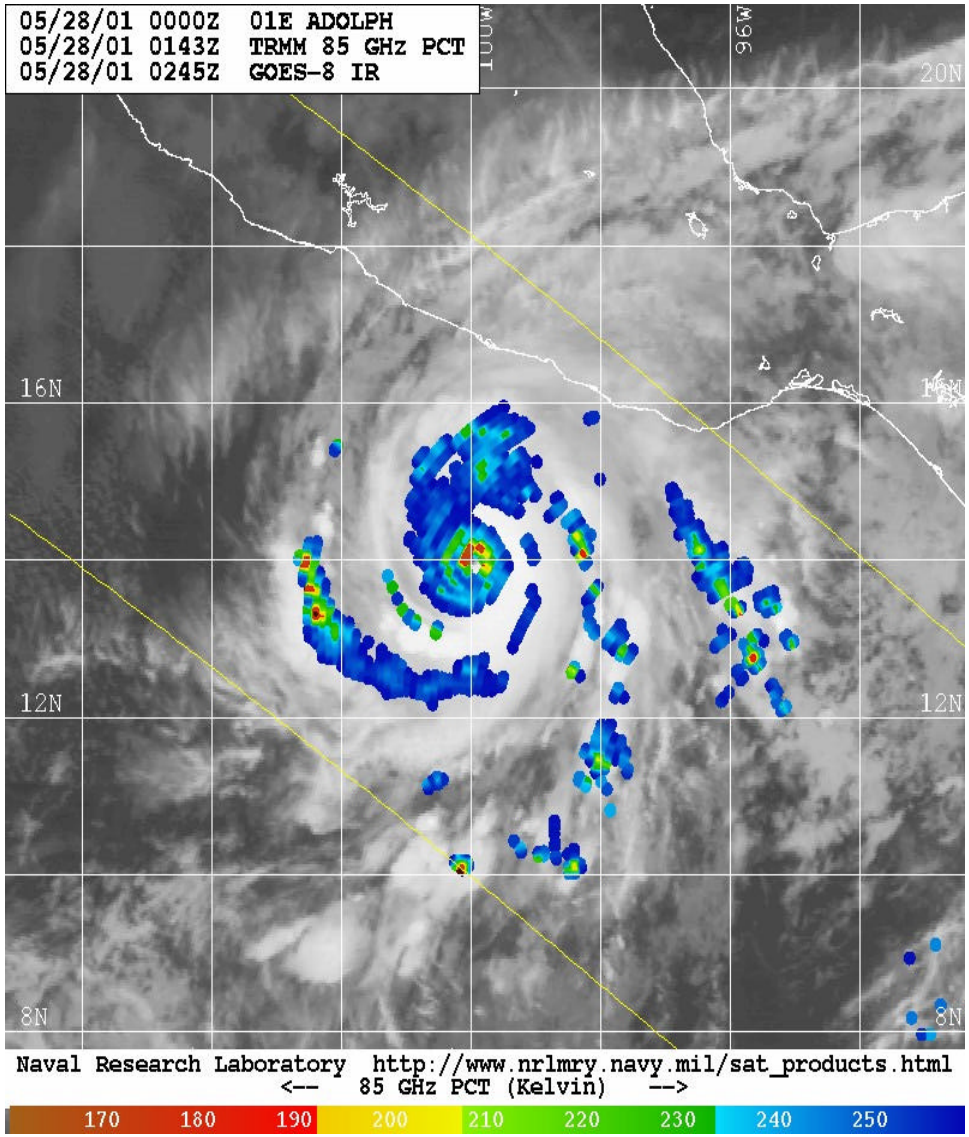
Emission

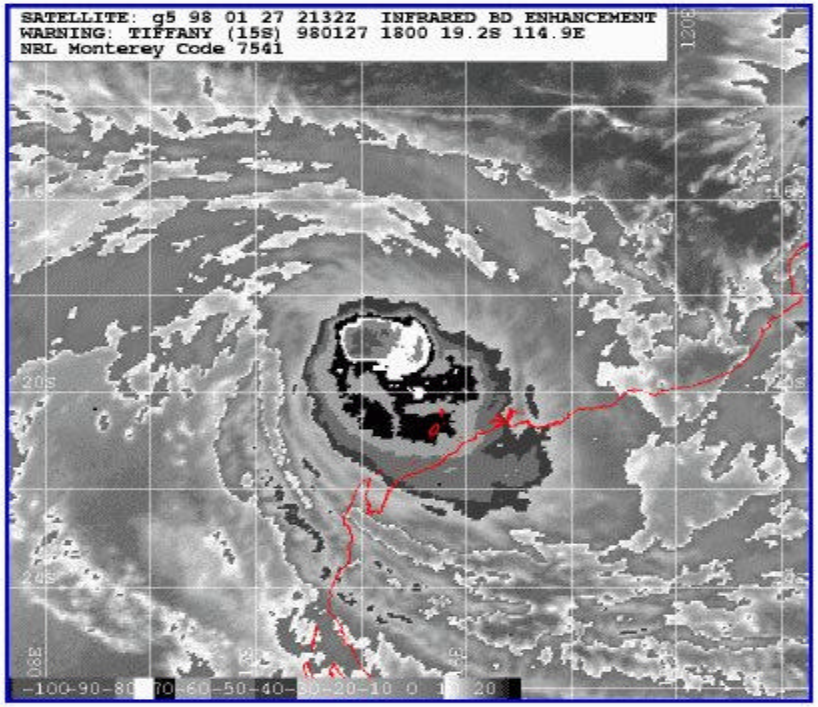
- Cloud water, vapor, & rain all emit microwave radiation.
- In the absence of clouds, vapor, & precipitation, the ocean surface is cold due to a low emissivity.
- Emission due to clouds, vapor, & precip causes warming compared to the ocean background.
- Emission effects (warming) appear on images of all frequencies.

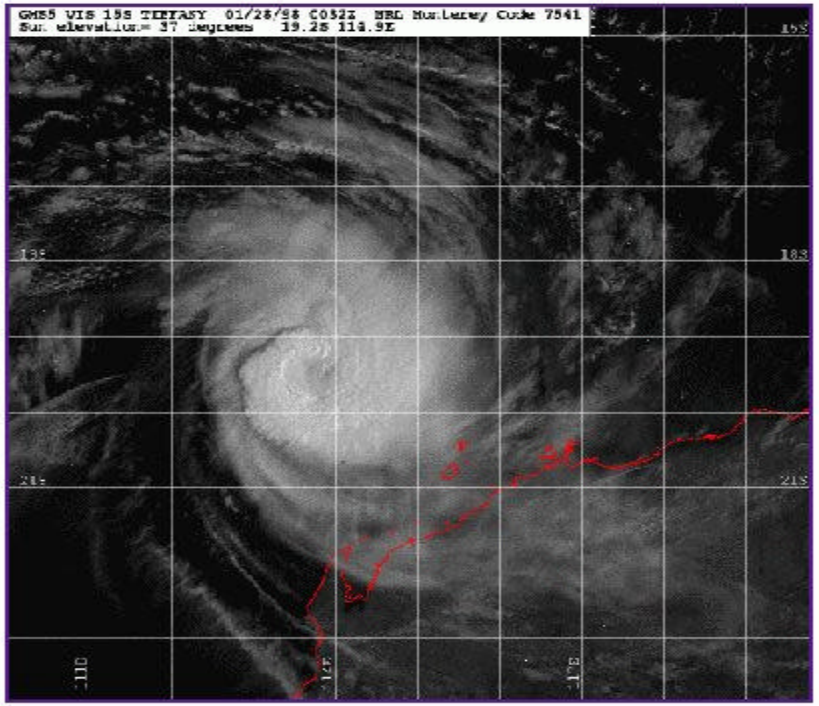


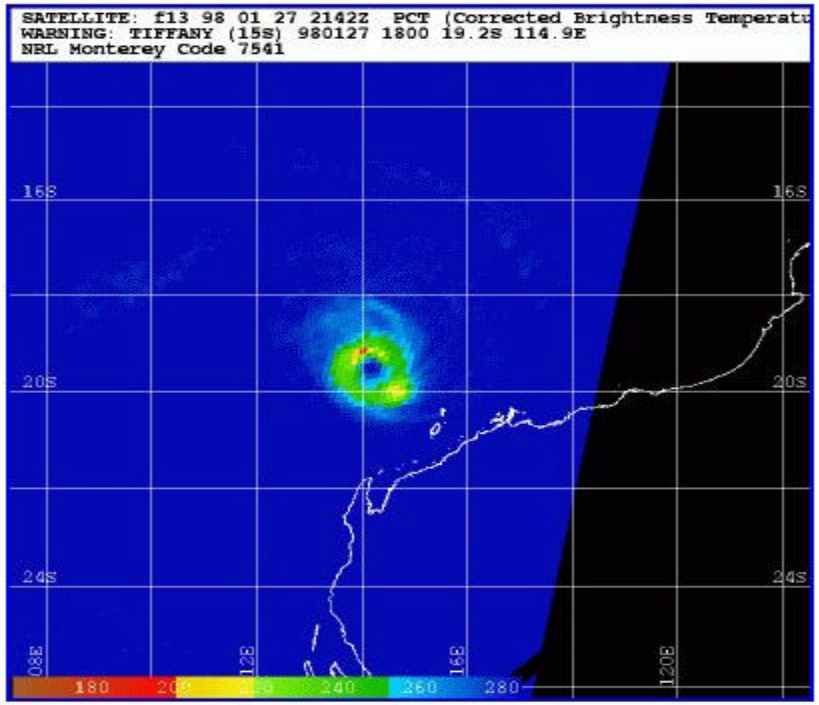
Polarization

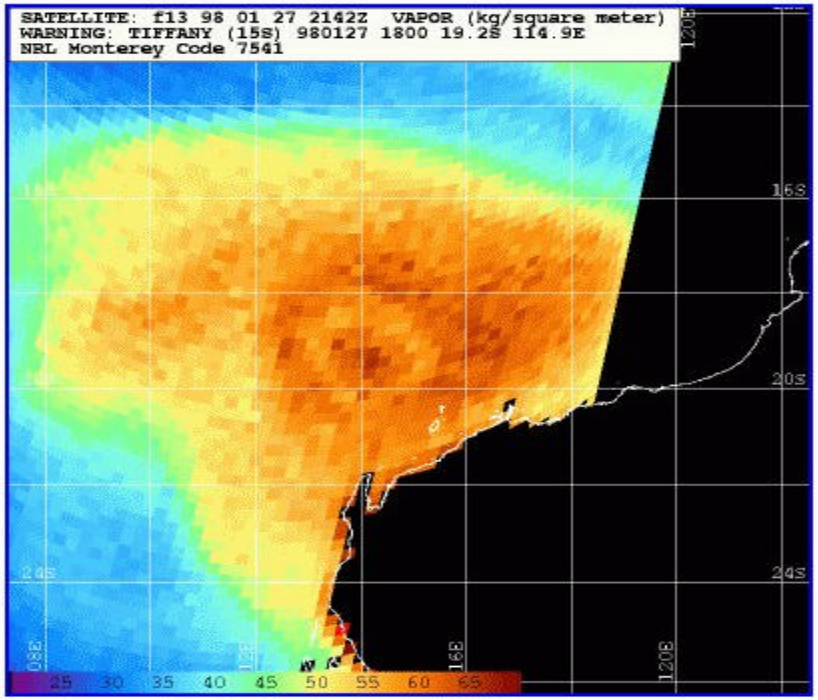
- Dual polarization (V & H) give two measurements of radiation.
- V & H measurements are different (polarized) over the cloud-free sea surface, but very similar over precip (unpolarized).
- V&H polarizations can be used to improve image quality for 37 and 85 GHz (polarization corrected temperature, PCT).

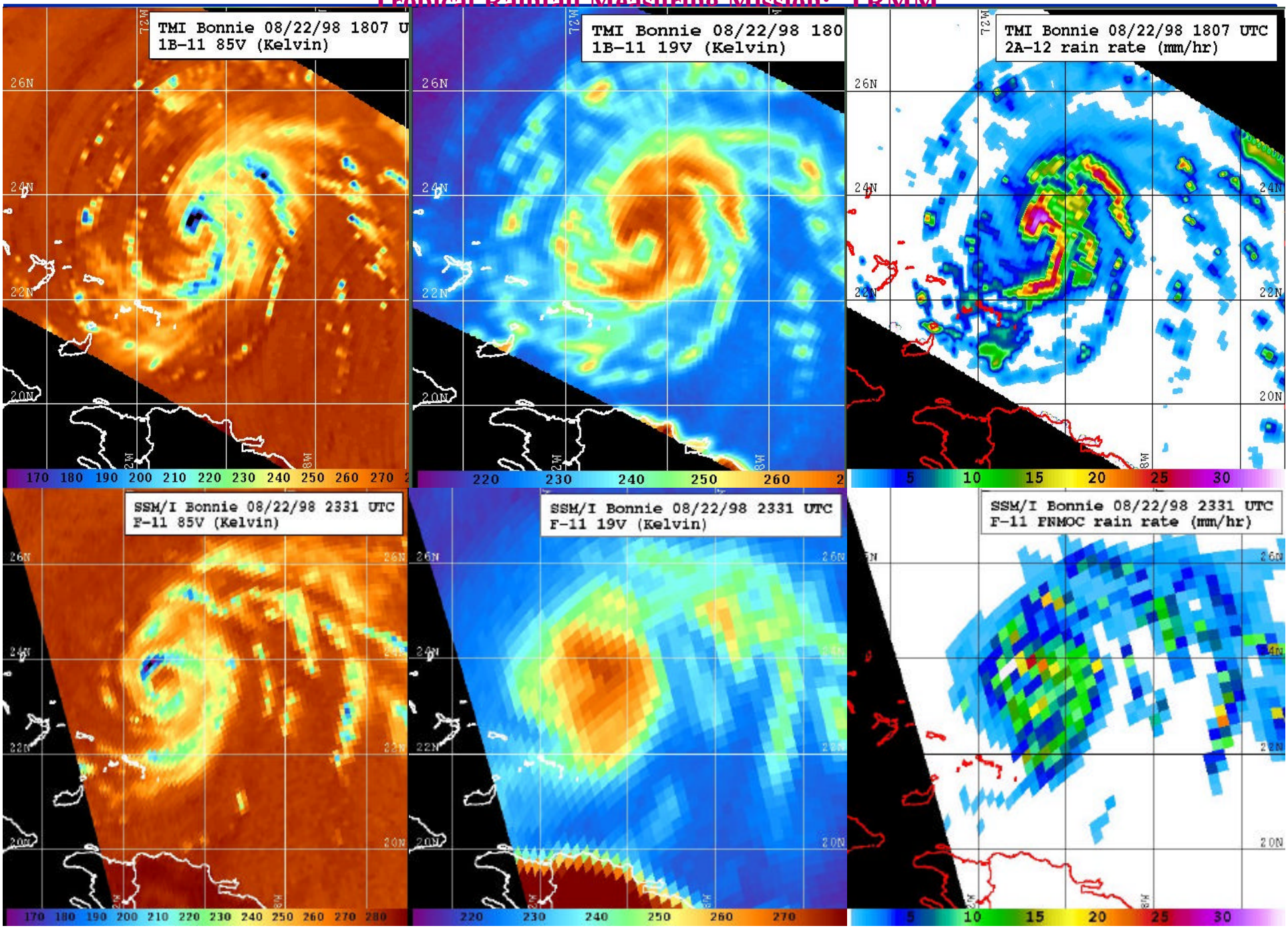



SATELLITE: g5 98 01 27 2132Z INFRARED BD ENHANCEMENT
WARNING: TIFFANY (15S) 980127 1800 19.2S 114.9E
NRL Monterey Code 7541


GMS5 VIS 15S TIFFANY 01/27/98 C052Z NRL Monterey Code 7541
Sun elevation= 37 Degrees 19.2S 114.9E


SATELLITE: f13 98 01 27 2142Z PCT (Corrected Brightness Temperatu
WARNING: TIFFANY (15S) 980127 1800 19.2S 114.9E
NRL Monterey Code 7541


SATELLITE: f13 98 01 27 2142Z VAPOR (kg/square meter)
WARNING: TIFFANY (15S) 980127 1800 19.2S 114.9E
NRL Monterey Code 7541


TMI Bonnie 08/22/98 1807 U
1B-11 85V (Kelvin)
TMI Bonnie 08/22/98 180
1B-11 19V (Kelvin)
TMI Bonnie 08/22/98 1807 UTC
2A-12 rain rate (mm/hr)
SSM/I Bonnie 08/22/98 2331 UTC
F-11 85V (Kelvin)
SSM/I Bonnie 08/22/98 2331 UTC
F-11 19V (Kelvin)
SSM/I Bonnie 08/22/98 2331 UTC
F-11 FNMOC rain rate (mm/hr)
26N
24N
22N
20N
72W
2W
8W
170 180 190 200 210 220 230 240 250 260 270
220 230 240 250 260
5 10 15 20 25 30
170 180 190 200 210 220 230 240 250 260 270 280
220 230 240 250 260 270

Tropical Cyclone Web Page

http://kauai.nrlmry.navy.mil/tc-bin/tc_home

2001 Storms

All | Active | Year

Atlantic

East Pacific

Central Pacific

West Pacific

Indian Ocean

Southern Hemisphere

- 92S.INVEST
- 91S.INVEST
- 90S.INVEST
- 06S.CHARLY

Disclaimer

NRL Monterey Marine Meteorology Division (Code 7500) Tropical Cyclone Page

Development Team

Display: Latest | Warn: Text Track ATCF | 1_km: Track&Image VIS IR Scatt | Info: General

SSMI Sectors:	VIS	IR	IR-BD	Multi-Sensor	85GHz-H	85GHz-H weak	PCT	Color	Rain	Wind	SSM/I Vapor			
TMI Sectors:	VIS	IR	IR-BD	Multi-Sensor	85Ghz-H	85Ghz-V	PCT	Color 85	Rain	Wind	Color 37	37GHz-V	37GHz-H	Liquid Water

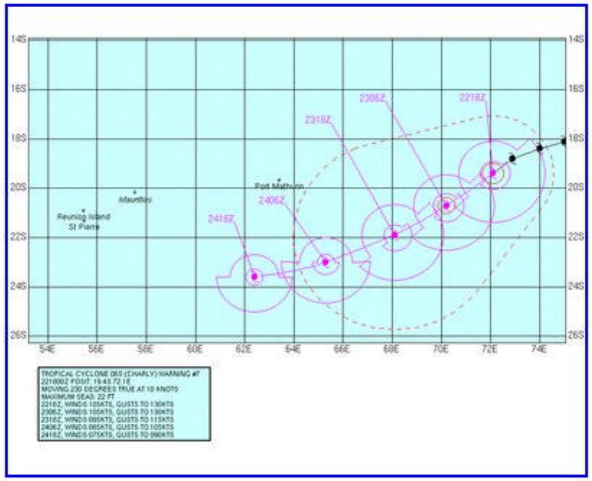
Latest	Upcoming Passes (more)	Current Time
SSMI: 01/22 1527Z	/01/23 01:52 quik 887.8	22:49:57 GMT
TRMM: 01/22 1903Z	/01/23 04:56 F-15 757.8	

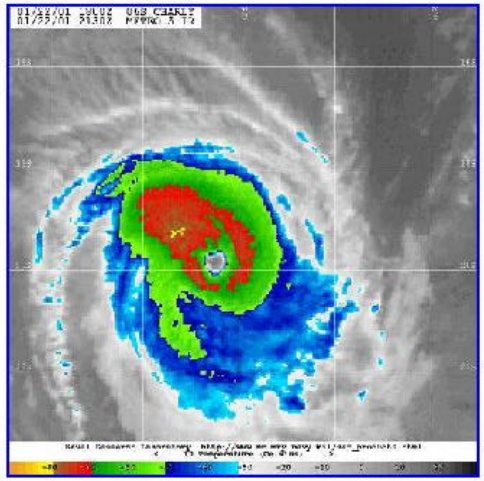
06S.CHARLY

Forecast by Joint Typhoon Warning Center/Naval Pacific Meteorology and Oceanography Center

Graphic by Naval Pacific Meteorology and Oceanography Center/Joint Typhoon Warning Center

1KM





(Click product for full sized image 19875 Bytes and 180707 Bytes.)

Satellite - Tropical Cyclone Overpass Predictor

06S.CHARLY Satellite Passes			
Date	Time	Sat	CPA (km)
2001/01/24	17:14:43	F-15	271.8
2001/01/24	18:11:59	tmm	402.5
2001/01/25	01:01:25	quik	1260.5
2001/01/25	01:36:25	F-13	84.5
2001/01/25	02:40:59	quik	1261.1
2001/01/25	03:59:10	F-14	224.2
2001/01/25	04:29:52	F-15	650.6
2001/01/25	10:31:27	tmm	225.3
2001/01/25	13:51:01	quik	743.8
2001/01/25	14:07:50	F-13	123.2
2001/01/25	16:30:25	F-14	179.1
2001/01/25	16:59:19	tmm	123.2
2001/01/25	17:00:31	F-15	633.6

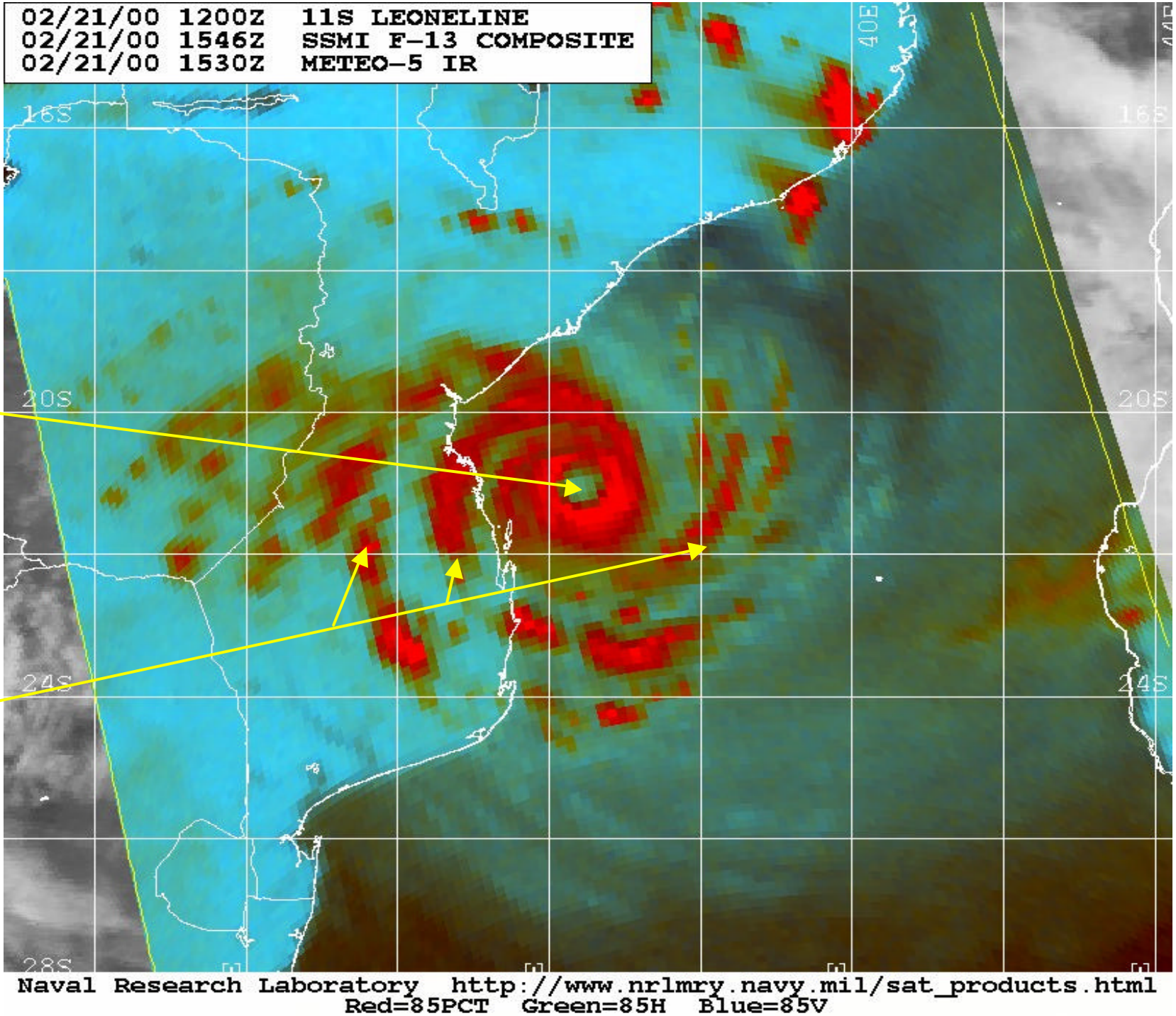
Year/Month/Day

Closest Point of Approach between storm and satellite nadir track

Time (Z)

Satellite ID:
F- 13, 14, 15
TRMM
QuikSCAT, ERS-2

TRMM 85 GHz Composite



Eye & Eyewall

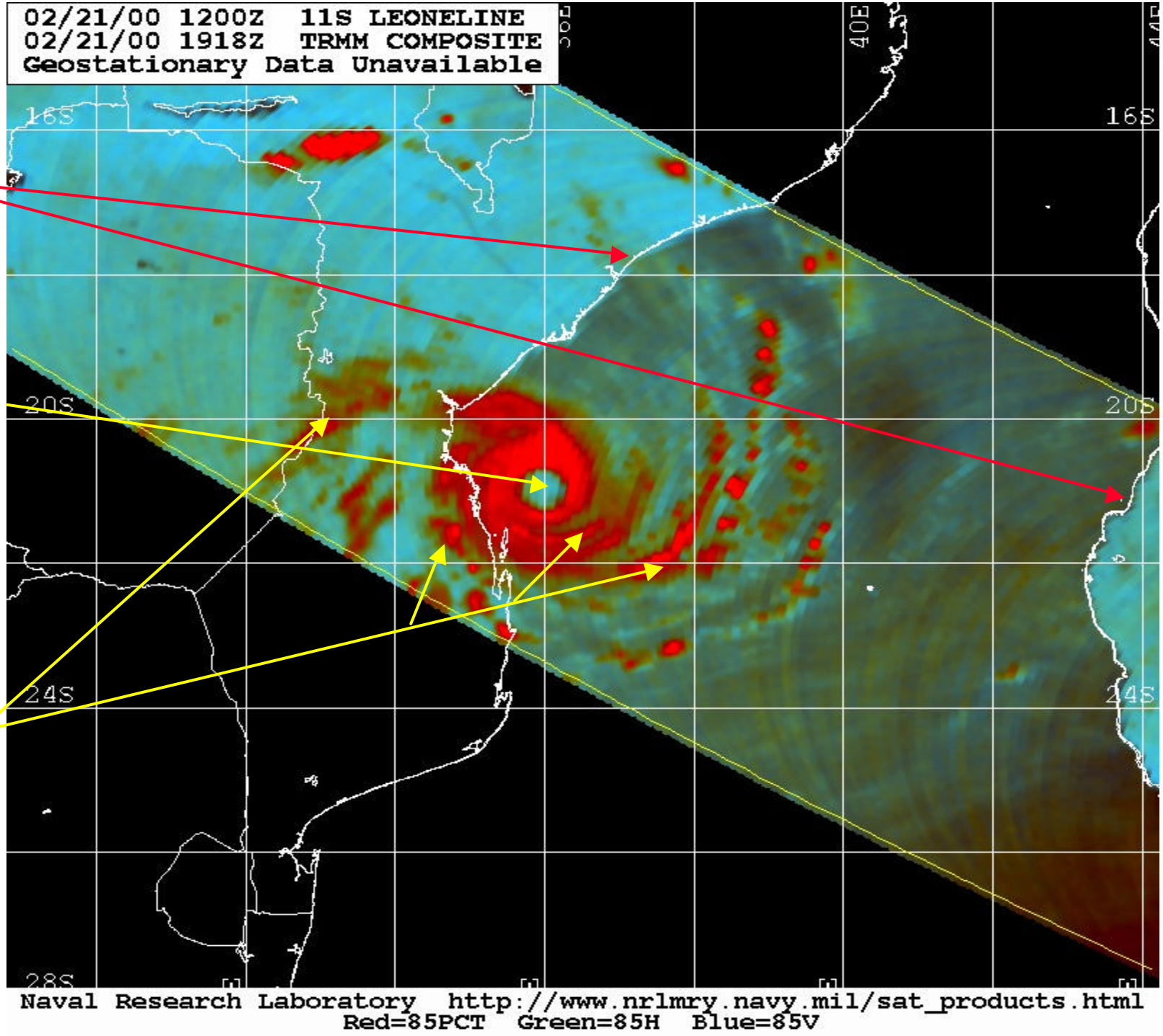
Rainbands

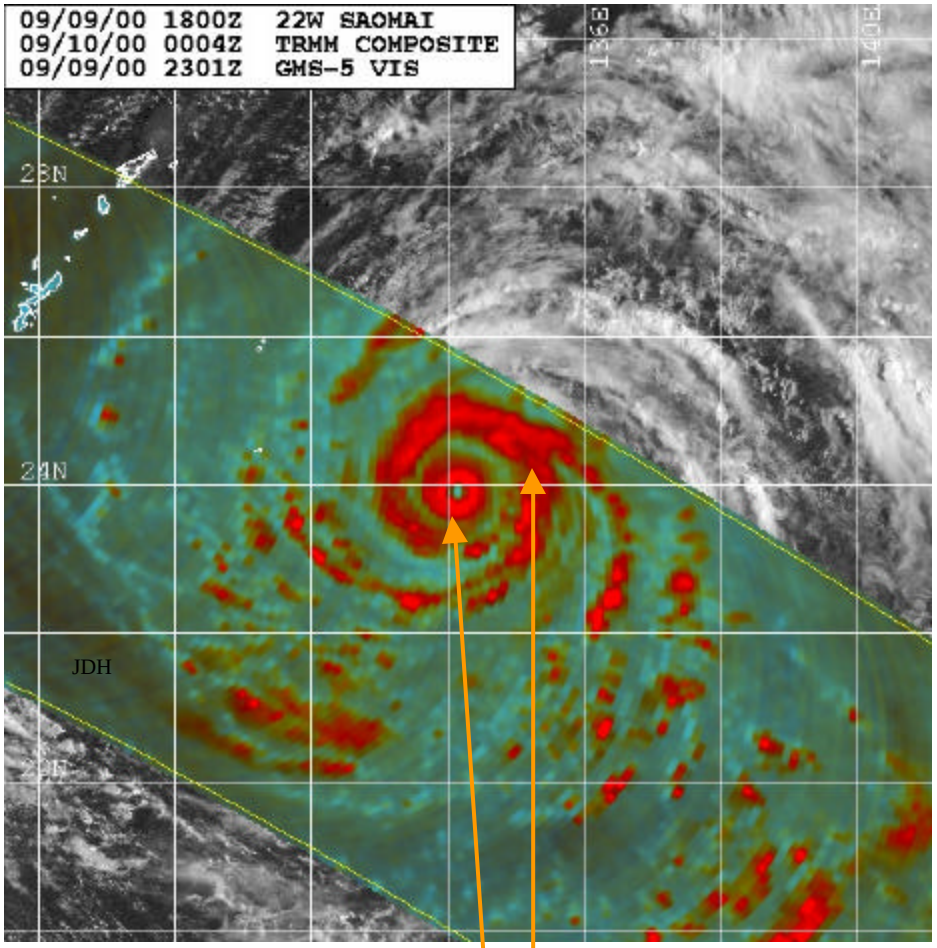
TRMM 85 GHz Composite

Accurate Geolocation

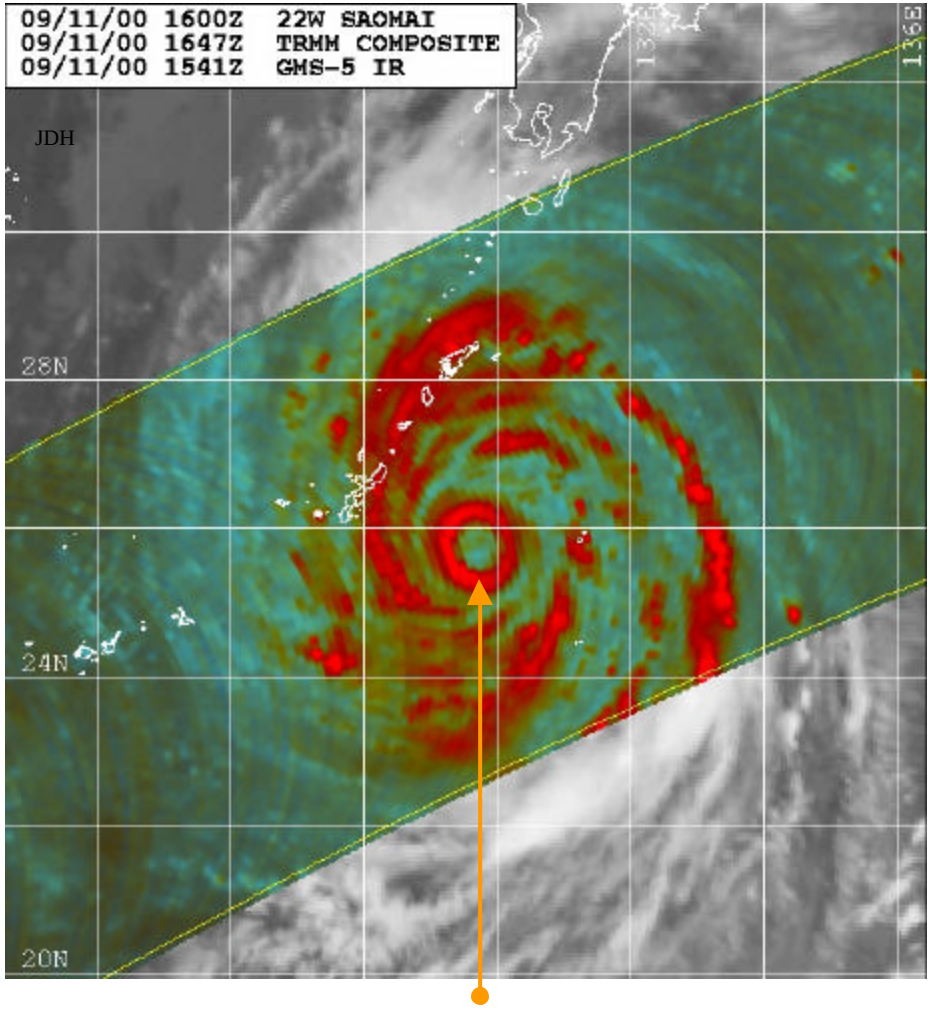
Eye & Eyewall

Rainbands

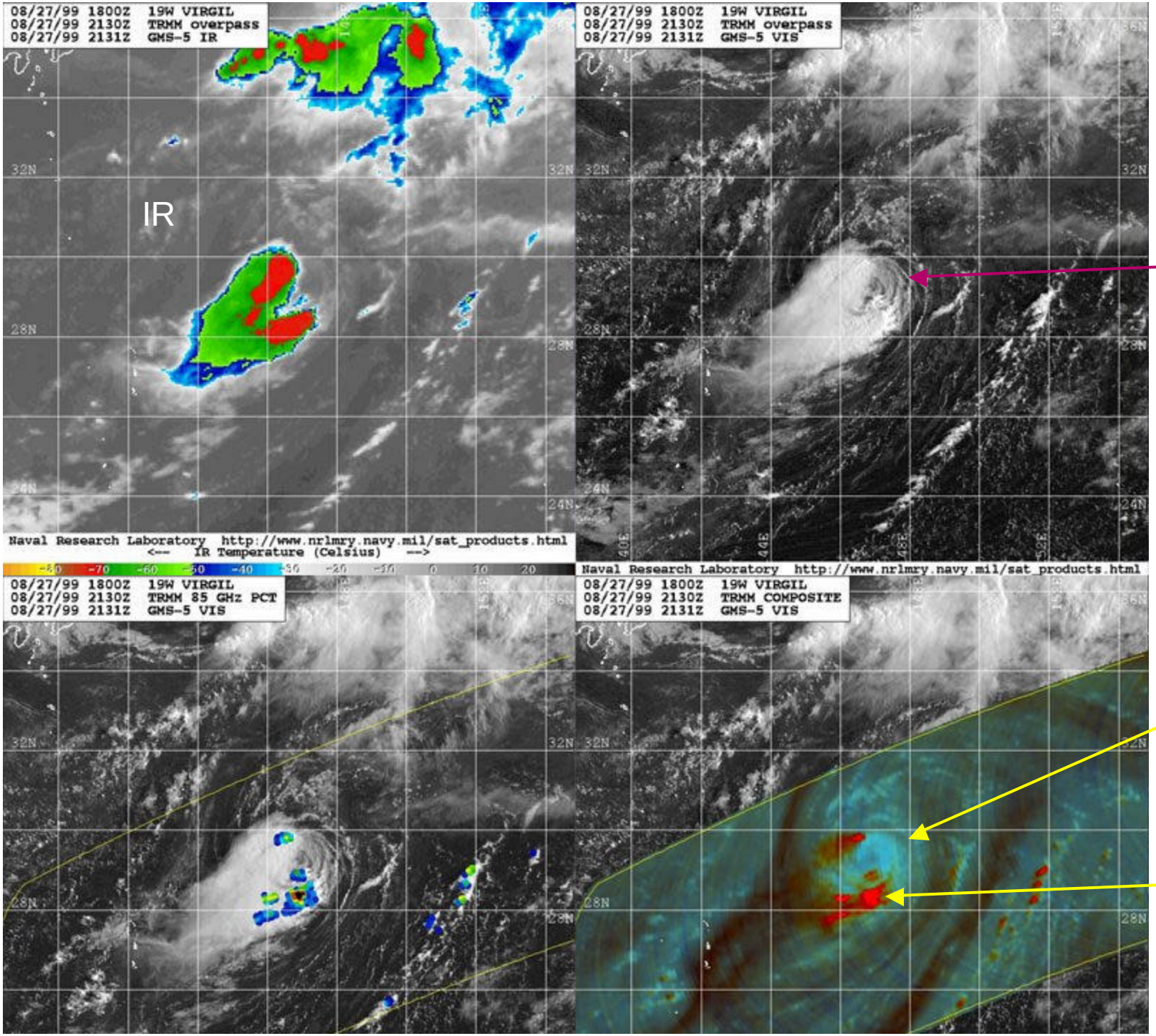




Small, Intense Eye With Secondary Eyewall Developing



Small Inner Eye Replaced by Larger, Outer Eyewall (Eyewall Replacement Cycle)



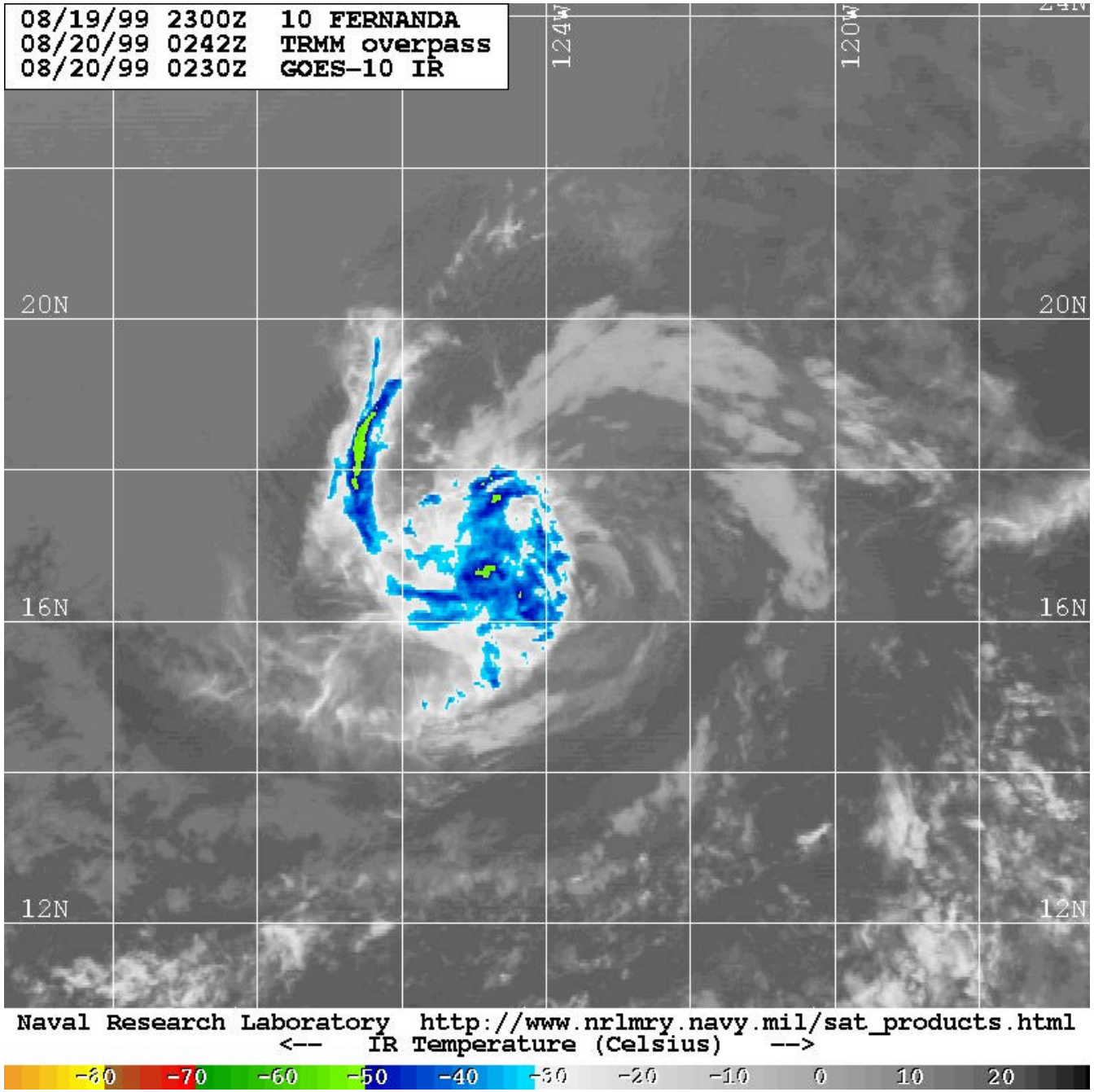
19W Virgil Multi-Spectral Views

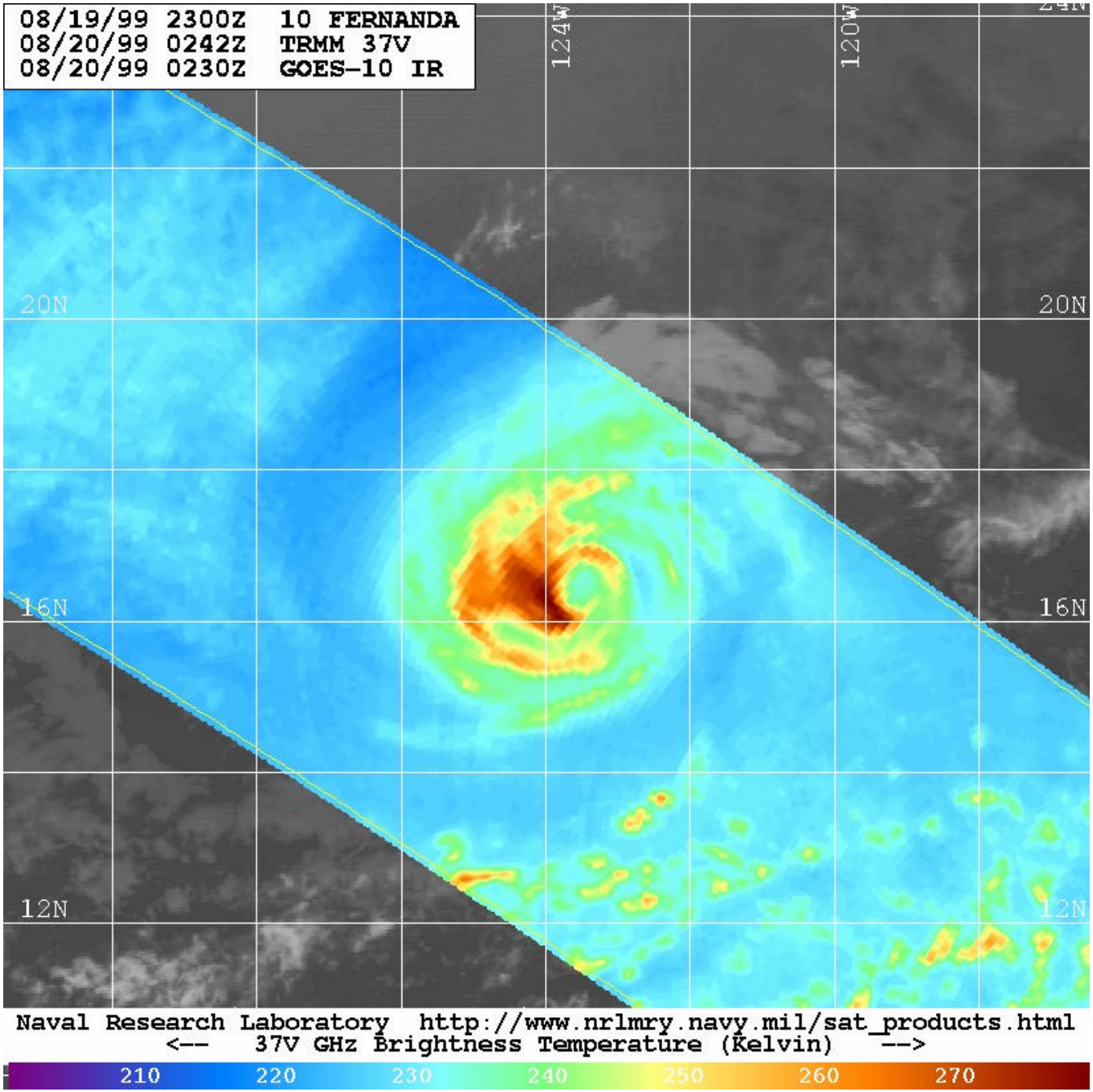
Visible

Exposed Low-Level Circulation

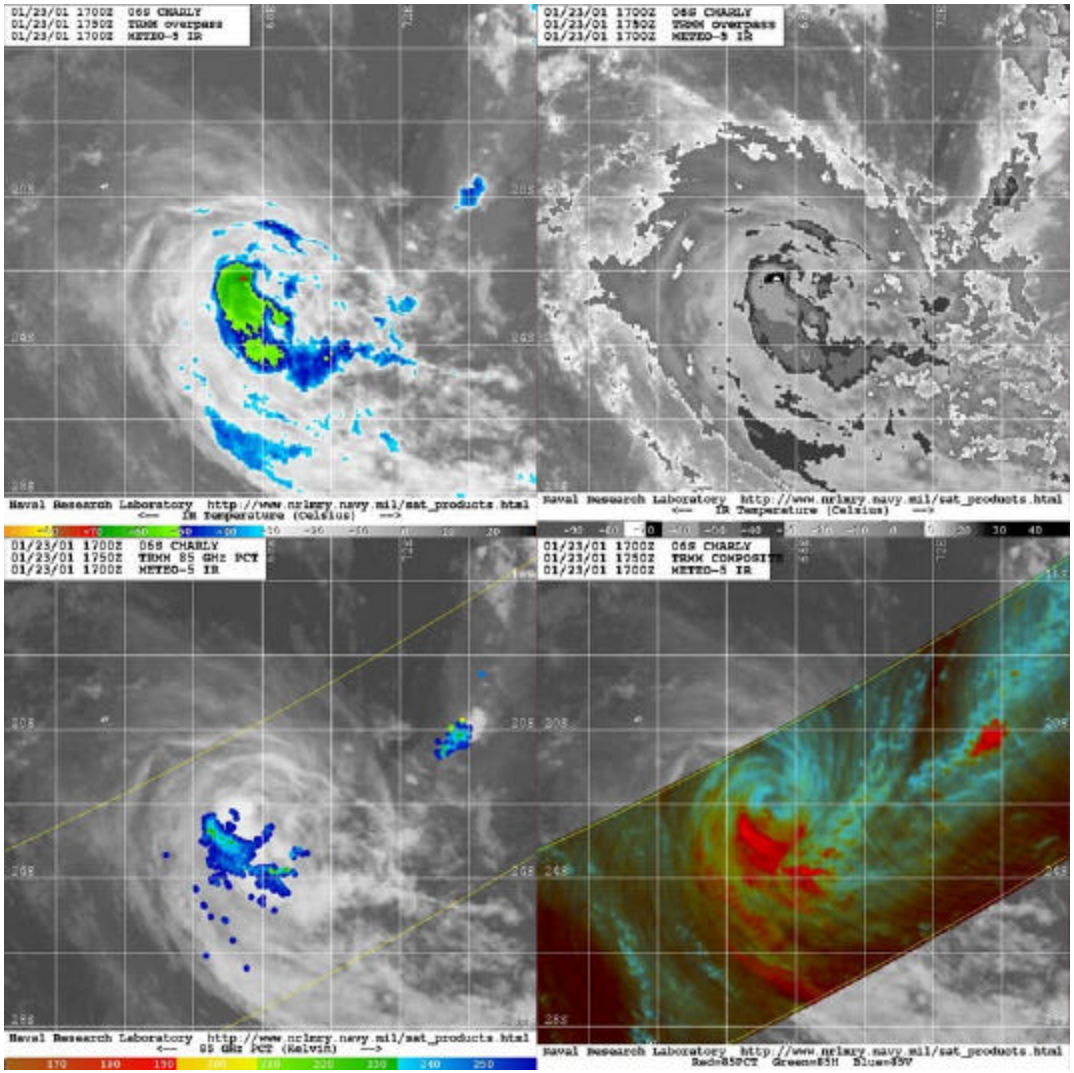
Exposed Low-Level Circulation

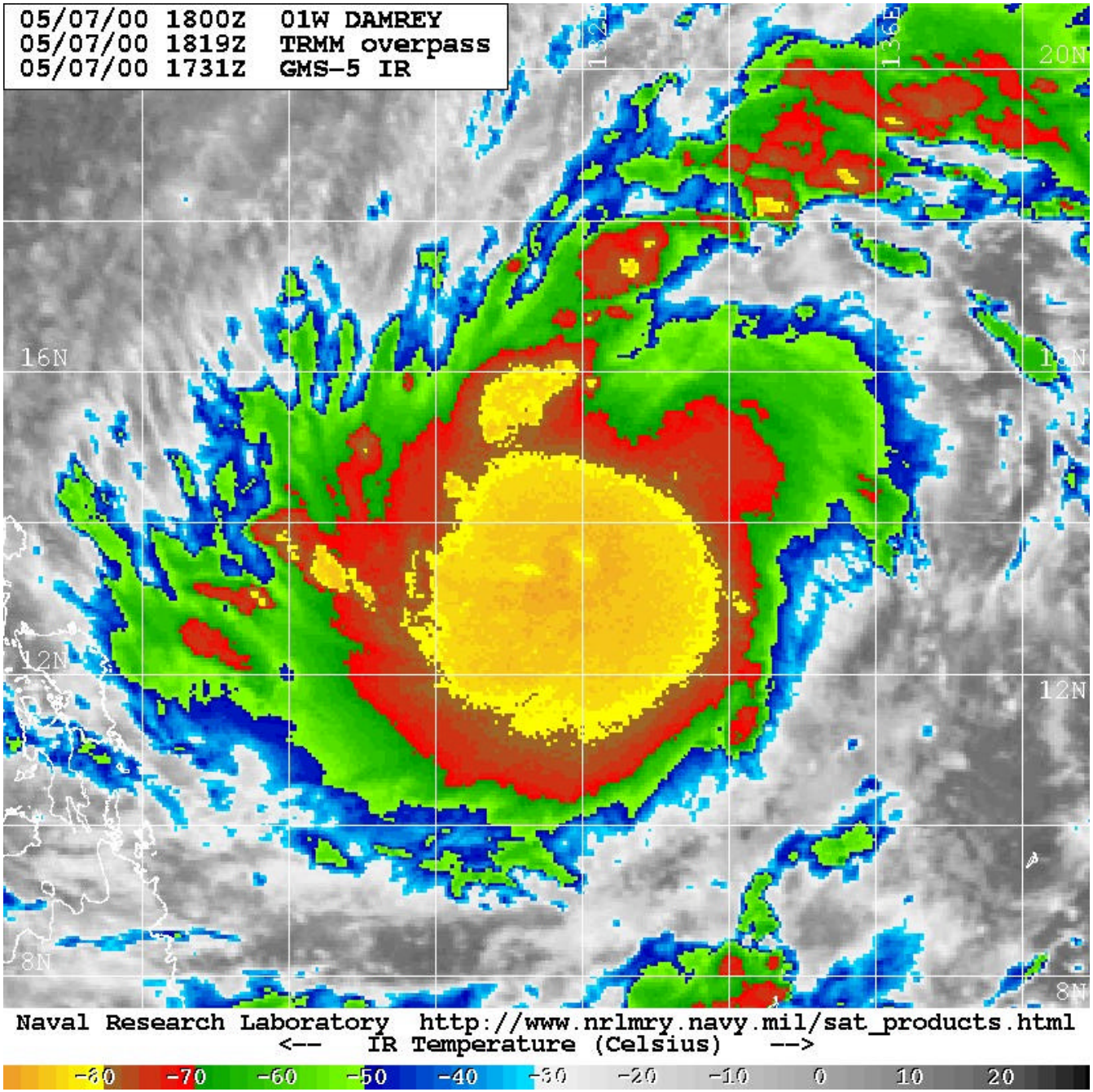
Sheared Convection

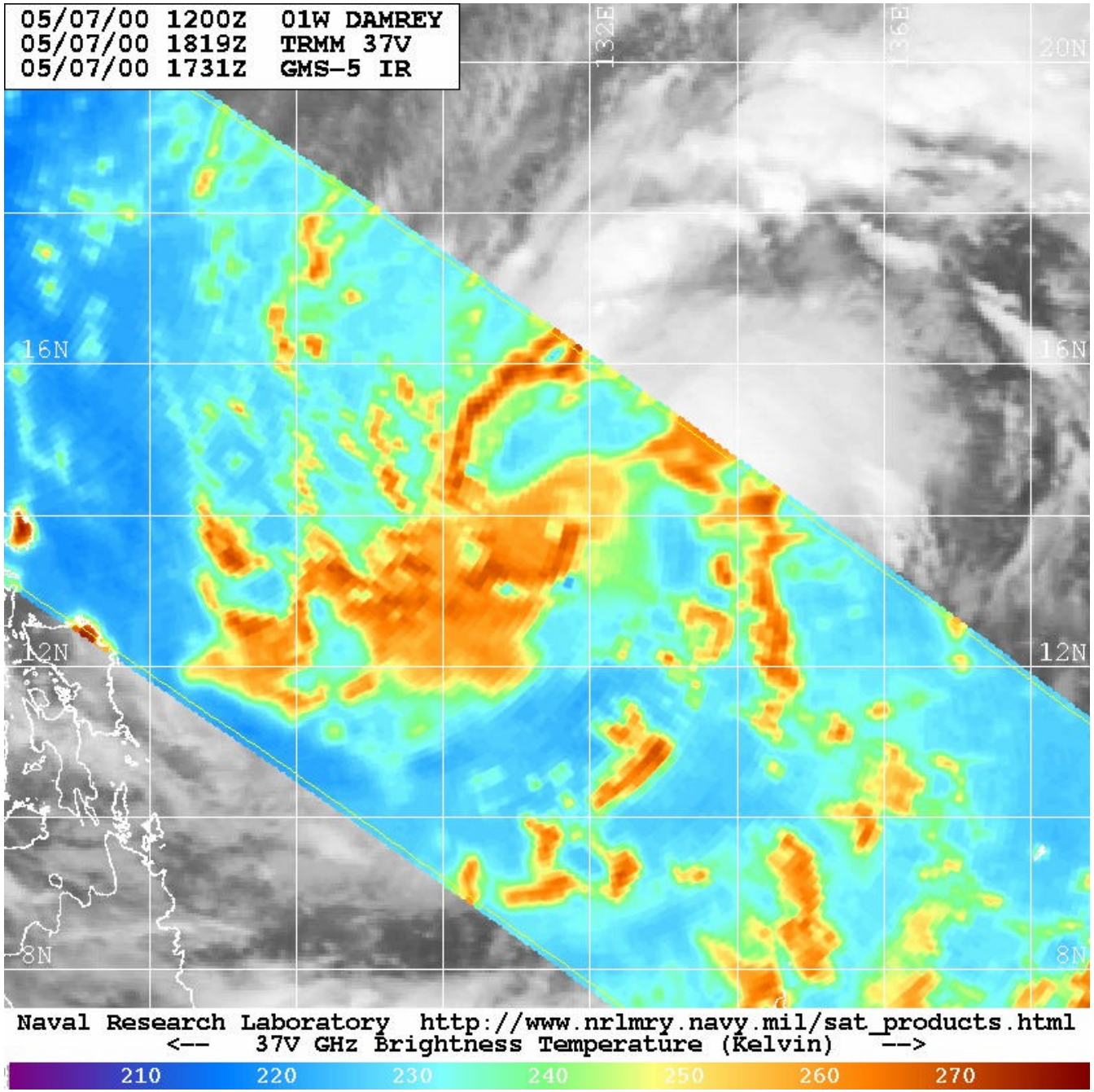

08/19/99 2300Z 10 FERNANDA
08/20/99 0242Z TRMM overpass
08/20/99 0230Z GOES-10 IR
124W
120W
20N
16N
12N
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
<-- IR Temperature (Celsius) -->
-80 -70 -60 -50 -40 -30 -20 -10 0 10 20

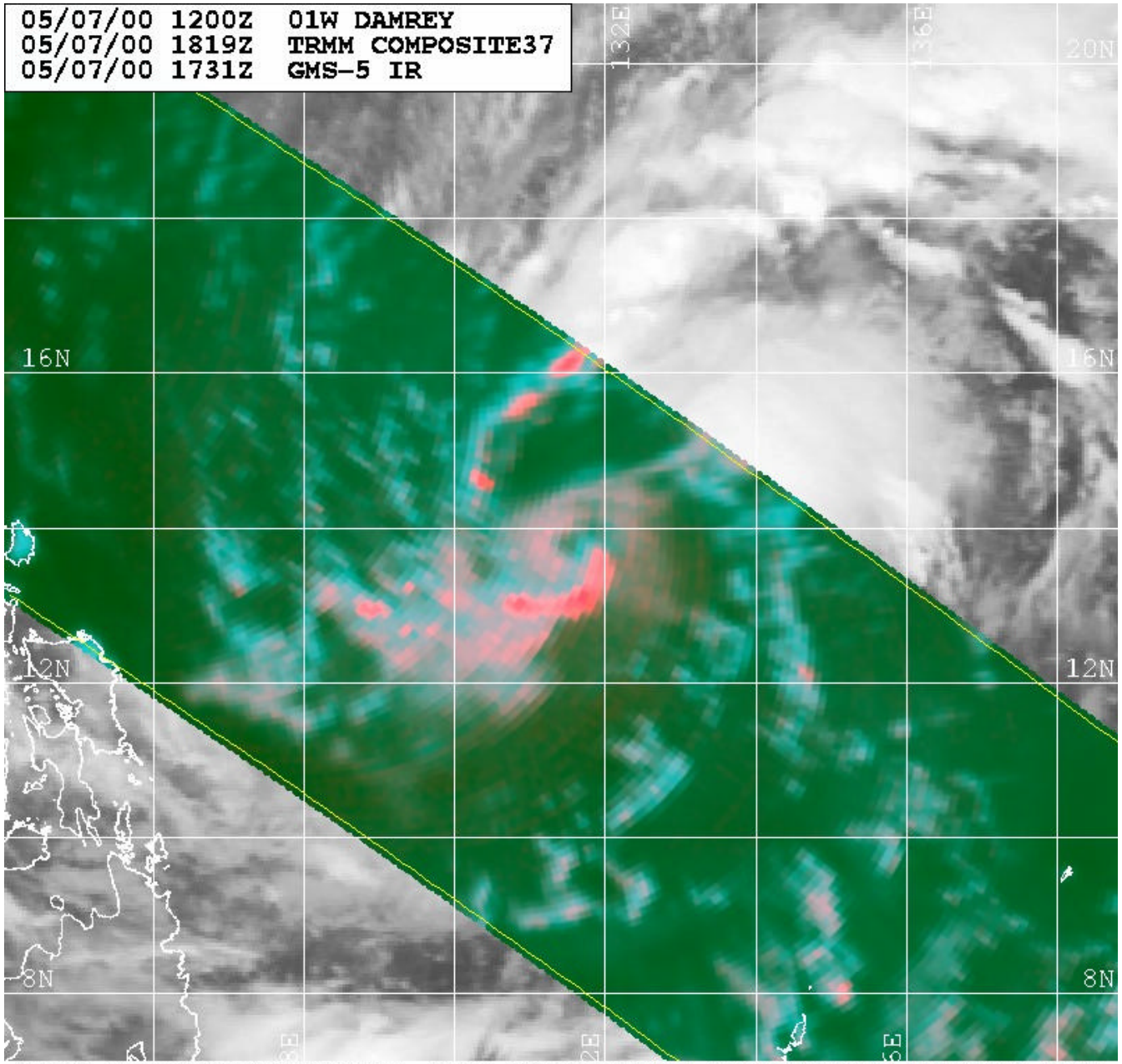

08/19/99 2300Z 10 FERNANDA
08/20/99 0242Z TRMM 37V
08/20/99 0230Z GOES-10 IR
124W
120W
20N
16N
12N
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
<-- 37V GHz Brightness Temperature (Kelvin) -->
210 220 230 240 250 260 270

Shear Exposed Via Passive Microwave (TMI)

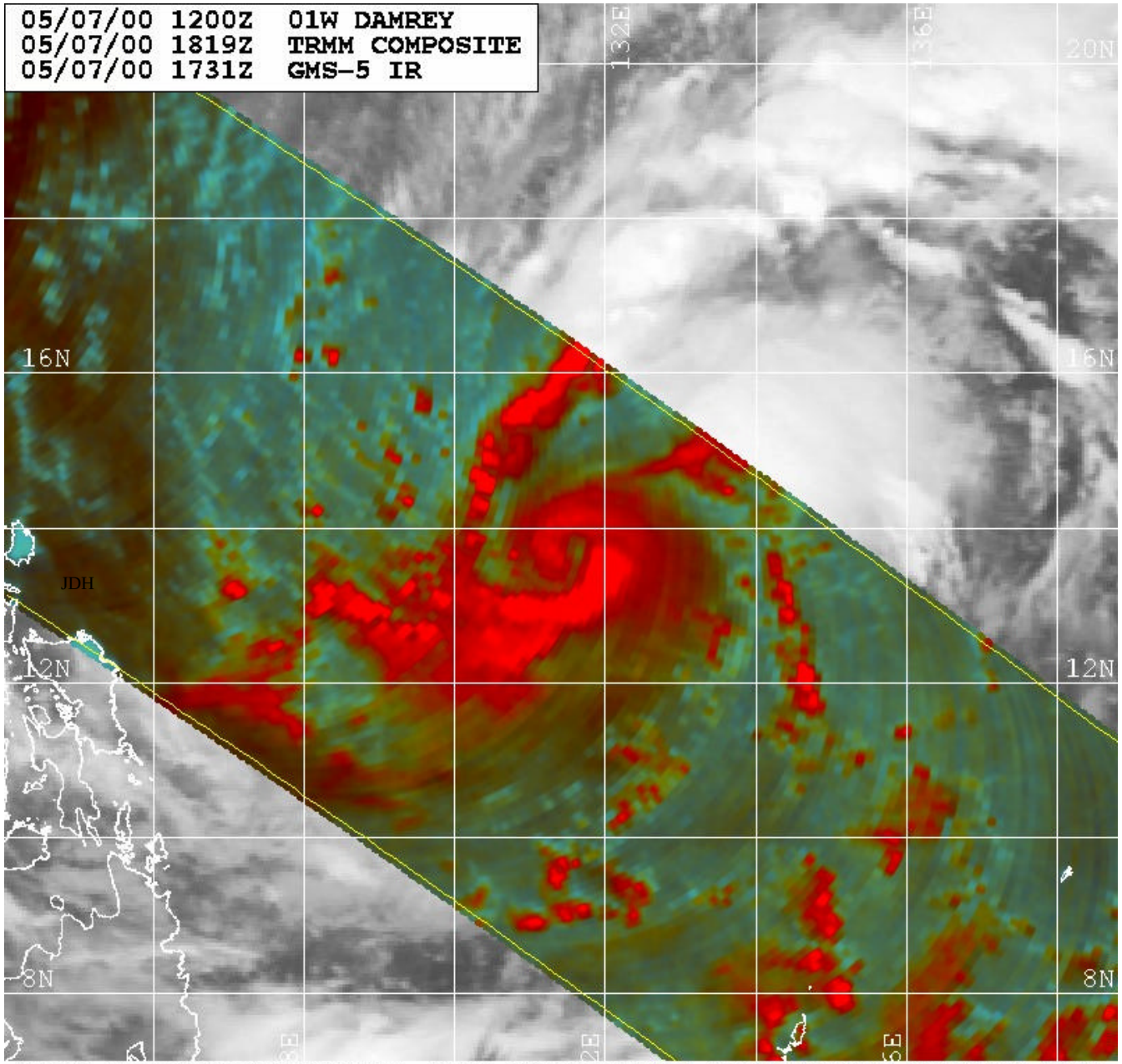



05/07/00 1800Z 01W DAMREY
05/07/00 1819Z TRMM overpass
05/07/00 1731Z GMS-5 IR
132E
136E
20N
16N
12N
8N
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
<-- IR Temperature (Celsius) -->
-80 -70 -60 -50 -40 -30 -20 -10 0 10 20


05/07/00 1200Z 01W DAMREY
05/07/00 1819Z TRMM 37V
05/07/00 1731Z GMS-5 IR
132E
136E
20N
16N
16N
12N
12N
8N
8N
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
<-- 37V GHz Brightness Temperature (Kelvin) -->
210
220
230
240
250
260
270


05/07/00 1200Z 01W DAMREY
05/07/00 1819Z TRMM COMPOSITE37
05/07/00 1731Z GMS-5 IR
132E
136E
20N
16N
16N
12N
12N
8N
8N
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
Red=37PCP Green=37H Blue=37V

85 GHz Product



TRMM EVALUATION

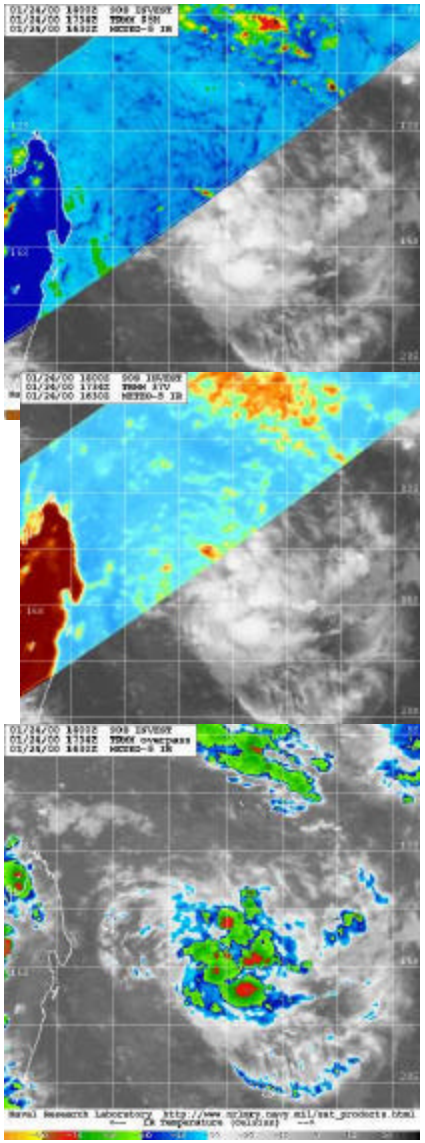
EARLY SIGNS OF RAPID DEVELOPMENT

TC 08S (CONNIE)---- Max Wind 120 KT

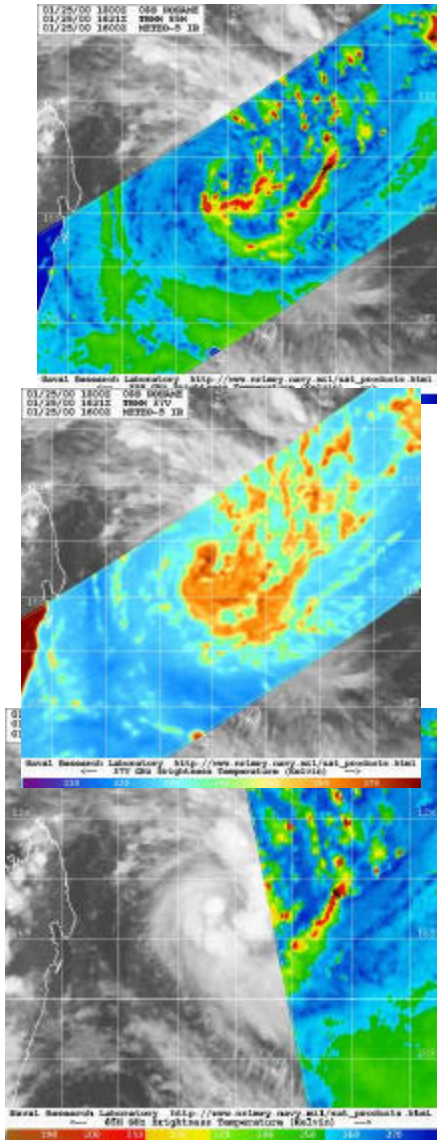
TRMM 85h

TRMM 37v

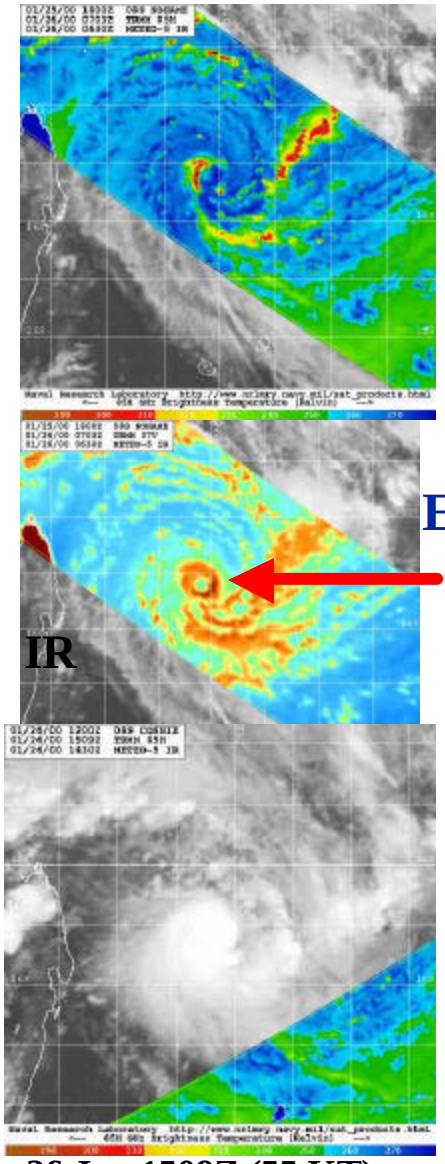
IR



24 Jan 1731Z (25KT)

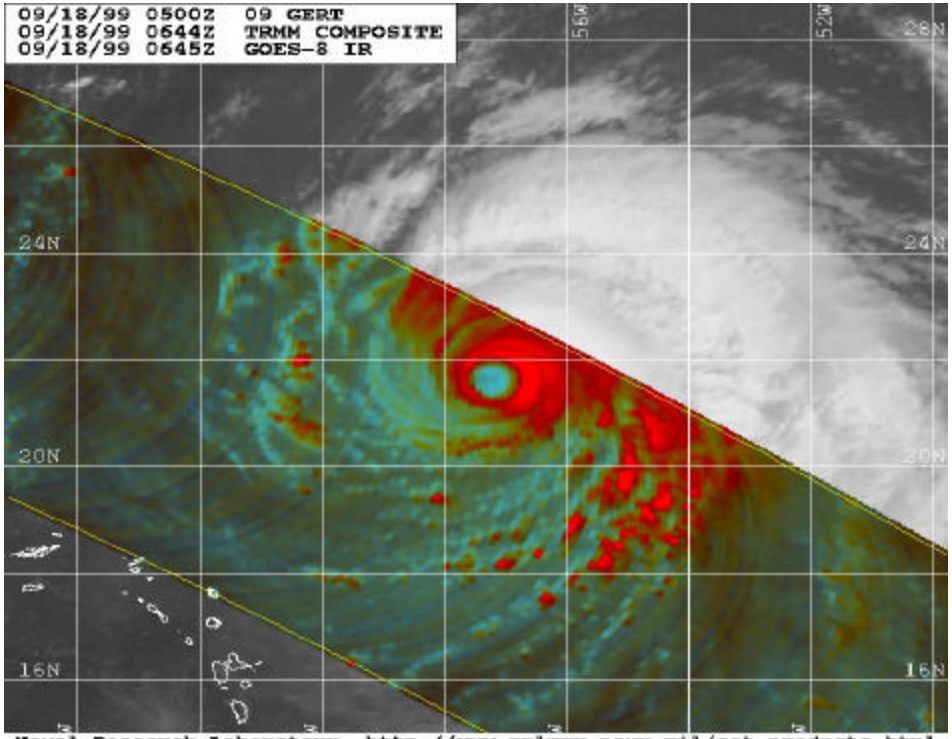


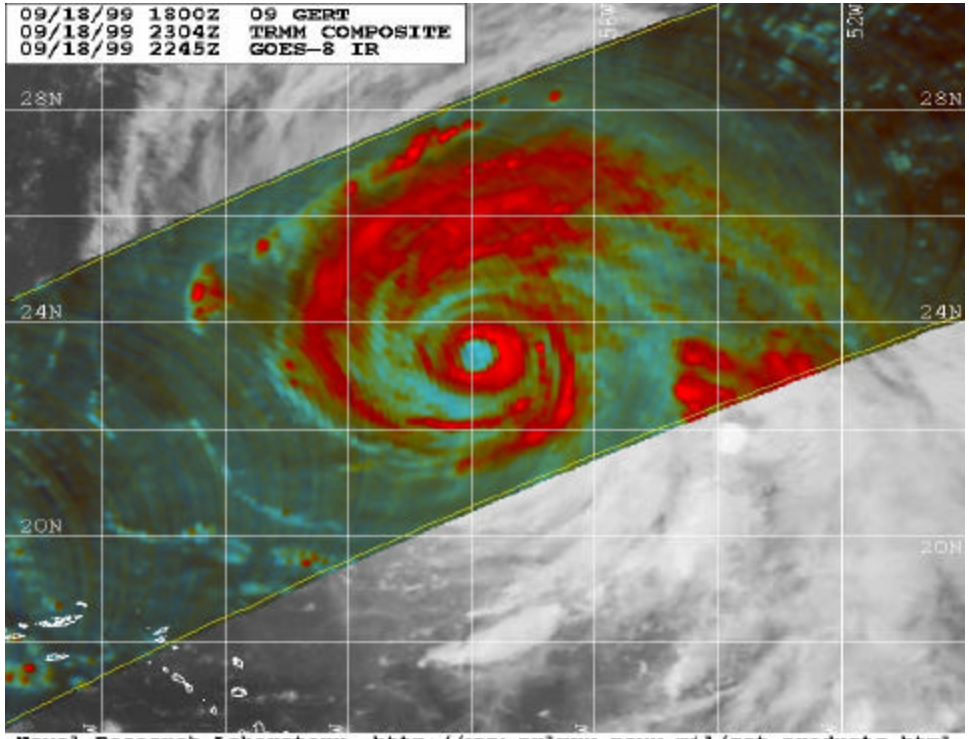
25 Jan 1621Z (35KT)

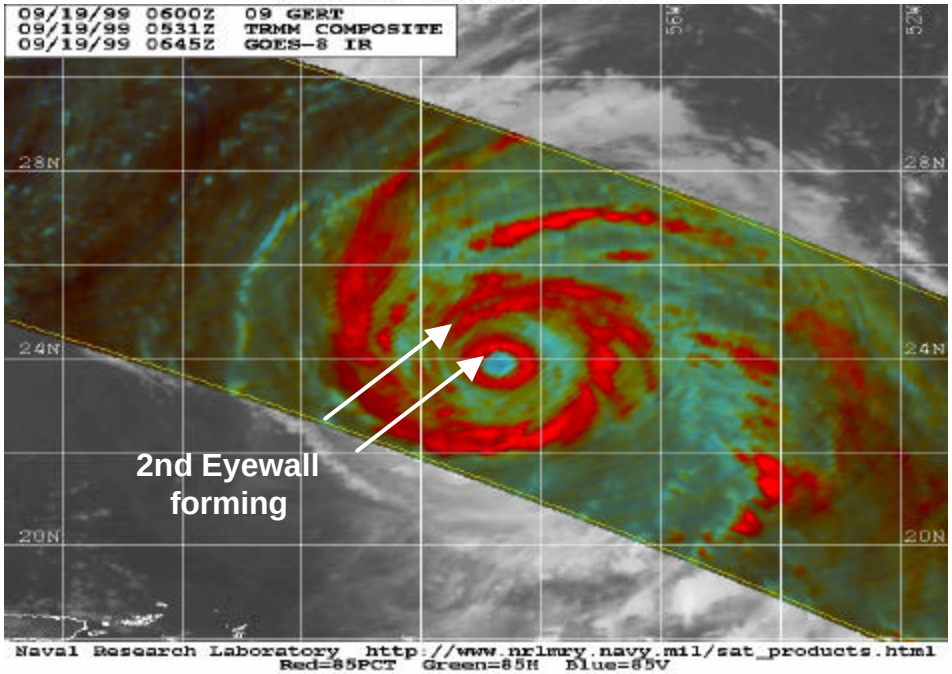


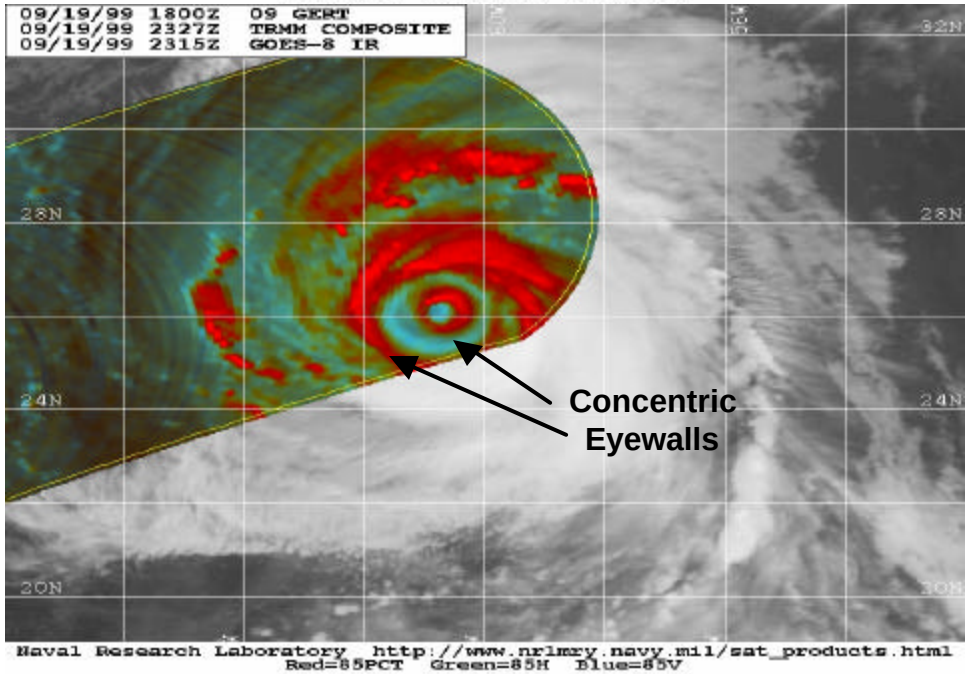
EARLY
37v
EYE

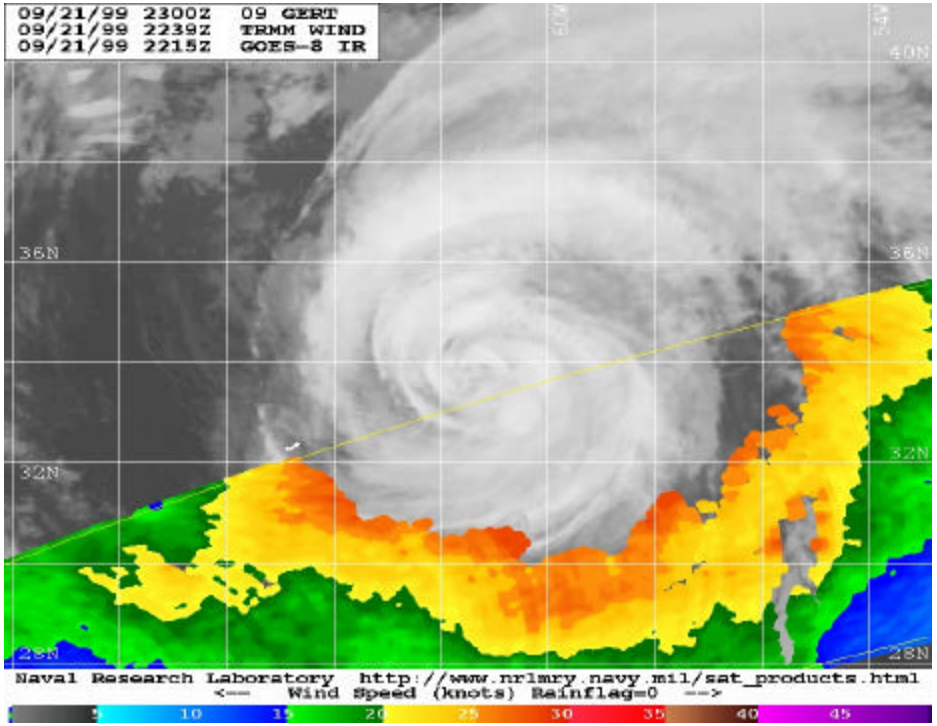
26 Jan 1509Z (55 KT)

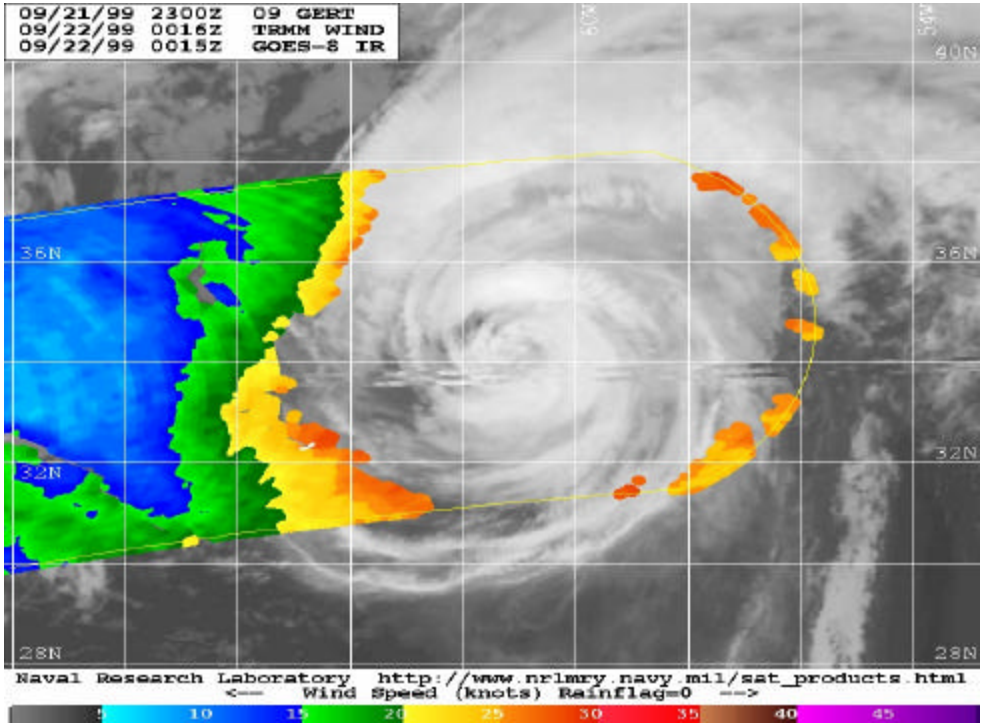

09/18/99 0500Z 09 GERT
09/18/99 0644Z TRMM COMPOSITE
09/18/99 0645Z GOES-8 IR
28N
24N
20N
16N
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
Red=85PCT Green=85H Blue=85V

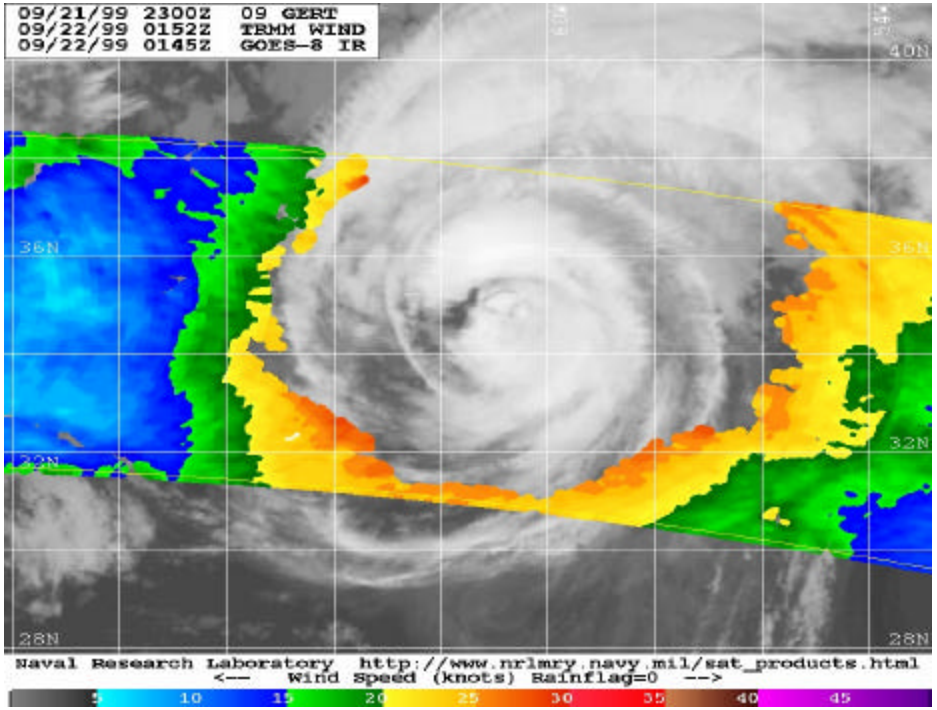

09/18/99 1800Z 09 GERT
09/18/99 2304Z TRMM COMPOSITE
09/18/99 2245Z GOES-8 IR
28N
24N
20N
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
Red=85PCT Green=85H Blue=85V

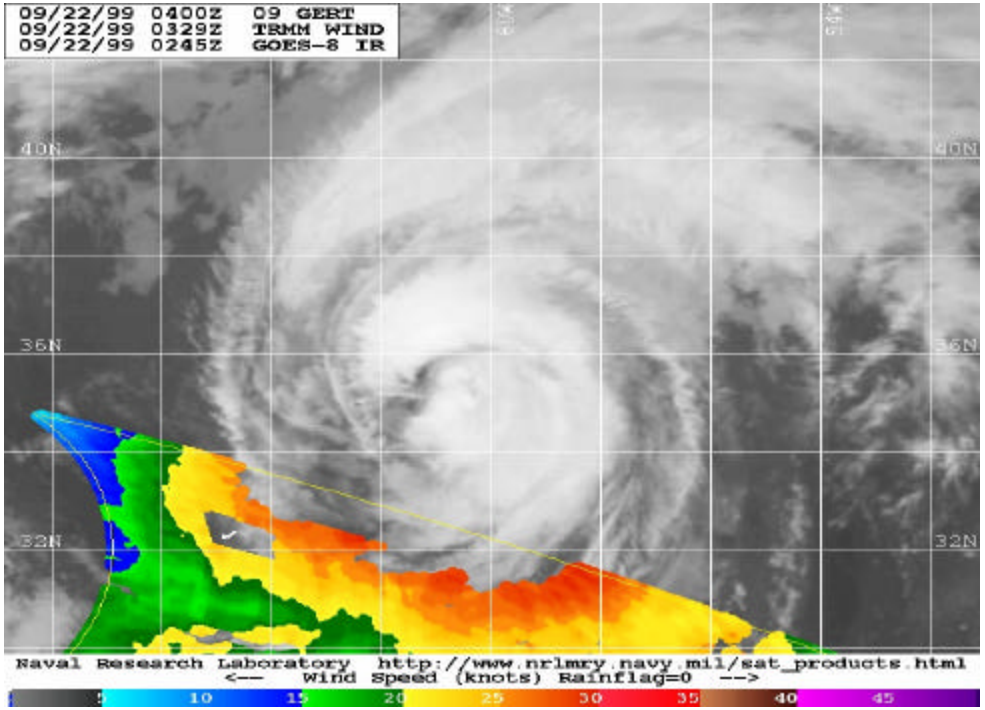

09/19/99 0600Z 09 GERT
09/19/99 0531Z TRMM COMPOSITE
09/19/99 0645Z GOES-8 IR
2nd Eyewall forming
28N
24N
20N
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
Red=85PCT Green=85H Blue=85V


09/19/99 1800Z 09 GERT
09/19/99 2327Z TRMM COMPOSITE
09/19/99 2315Z GOES-8 IR
Concentric Eyewalls
28N
24N
20N
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
Red=85PCT Green=85H Blue=85V


09/21/99 2300Z 09 GERT
09/21/99 2239Z TRMM WIND
09/21/99 2215Z GOES-8 IR
40N
36N
32N
28N
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
<-- Wind Speed (knots) Rainflag=0 -->
10 15 20 25 30 35 40 45


09/21/99 2300Z 09 GERT
09/22/99 0016Z TRMM WIND
09/22/99 0015Z GOES-8 IR
40N
36N
32N
28N
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
<-- Wind Speed (knots) Rainflag=0 -->
10 15 20 25 30 35 40 45


09/21/99 2300Z 09 GERT
09/22/99 0152Z TRMM WIND
09/22/99 0145Z GOES-8 IR
40N
36N
32N
28N
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
<-- Wind Speed (knots) Rainflag=0 -->
10 15 20 25 30 35 40 45


09/22/99 0400Z 09 GERT
09/22/99 0329Z TRMM WIND
09/22/99 0245Z GOES-8 IR
40N
36N
32N
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
<-- Wind Speed (knots) Rainflag=0 -->
10 15 20 25 30 35 40 45

TC Warning Center Utilization of SSM/I & TRMM Data

Fiji RSMC: TC 13P (Paula)

"Gentlemen, I wish to commend you on managing and maintaining this most invaluable site as far as tropical cyclone forecasting/warning is concerned in the Southwest Pacific basin."

JMA, TOKYO RSMC: NRL-MRY TC Web Page

"The homepage has been providing us with invaluable information on evolving tropical cyclones in both conducting operations of TC analysis and forecasting and making posterior analyses for the Best Track data at RSMC Tokyo-Typhoon Center."

JTWC Remarks: Tropical Cyclone 05P

"A 091651Z **TRMM pass indicated virtually all of the convection displaced to the southeast of the LLCC. Vertical shear appears to be affecting the system more than 6 hours ago**…"

NHC Hurricane Gert Discussion #34

"**Microwave data indicate that Gert underwent an eyewall replacement cycle** earlier today and this may explain why it appeared weaker at that time."..

NHC Tropical Storm Jose Discussion #27

"**A TRMM overpass from the NRL Homepage at 0517Z showed that the low-level center of Jose was better engaged with the deep convection. This would suggest some strengthening** and indeed satellite classification from TAFB was up to 65 kt"..

Perth Australia, Manager Forecasting Operations (Gus Foley):

"It's (the web page) excellent and we at the Perth Tropical Cyclone Warning Center use it constantly, particularly to gain access to SSM/I and TRMM imagery. We have had a number of sheared or suspect systems this season located well away from ships, buoys, and radar and the 85 GHz imagery has helped enormously in centre location in these situations…. It seems to me that your site is a great practical example of international cooperation for the global good, and it is appreciated."

Online Training about NRL SSM/I & TRMM Products

- Interpretation of channel images (85 & 37 GHz) and geophysical parameters (wind speed and rainrate).
- Uses examples identical in format to those on the NRL-MRY TC website.
- Written for users, not academics.
- Employed by NHC for training new forecasters and international visitors.
- Will consider requests for new training on satellite products.
- Training button is on NRL Satellite Webpage.

Tropical Cyclone Web Page

http://kauai.nrlmry.navy.mil/tc-bin/tc_home

Summary and Future Plans

- **Tutorials online for TC passive microwave products.**
- **Added grids to 85 GHz color products.**
- **37 GHz TRMM color product included.**
- **Scatterometer wind vector overlays implemented.**
- **Transitioned transmission of digital passive microwave products (TDF) to FNMOC operationally.**
- **Transitioning TC web page capability to FNMOC in Spring (June).**
- **Adding AMSU-B 89 GHz imagery next.**
- **Adding SSM/IS products when cal/val effort gives the “ok”..**

Capturing Rapidly-Evolving Rain Events

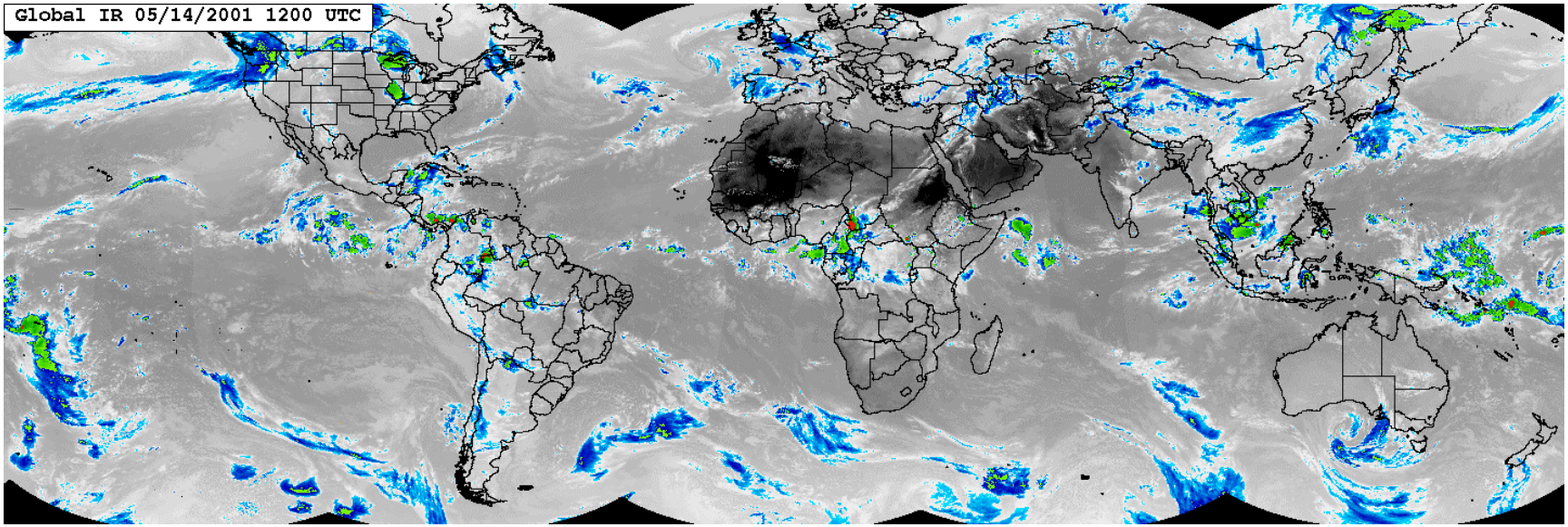
Basic Principle and Methodology

- GEO: rapid-update, fine-scale, IR-based
- LEO: infrequent time-update, coarse scale, microwave-based
- Accumulate regional probability-matched histograms of time/space-coincident IR and rain measurements, dynamically

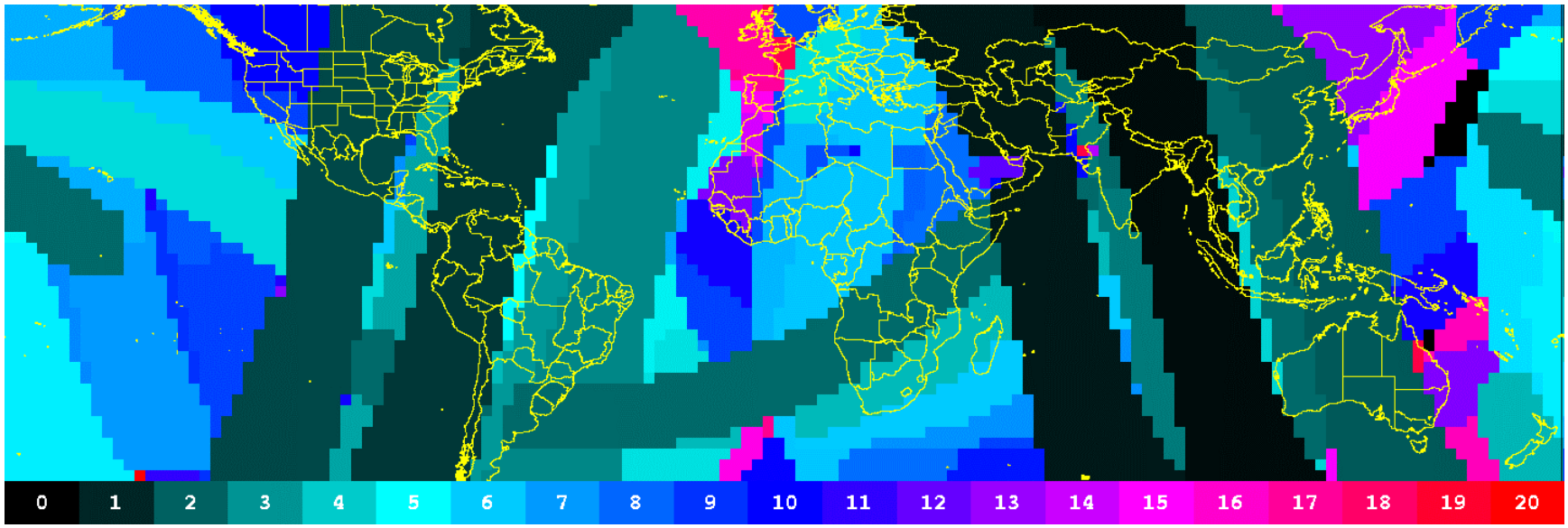
Limitations

- The limited number of MW-based satellite sensors
- At shorter time scales, the temporal information is nearly all from the IR
- Time gaps between successive microwave overpasses relative to the time scale of the storm evolution
- Orographically-based events
- Artifacts in the microwave data (snow, poor geolocation, etc.)

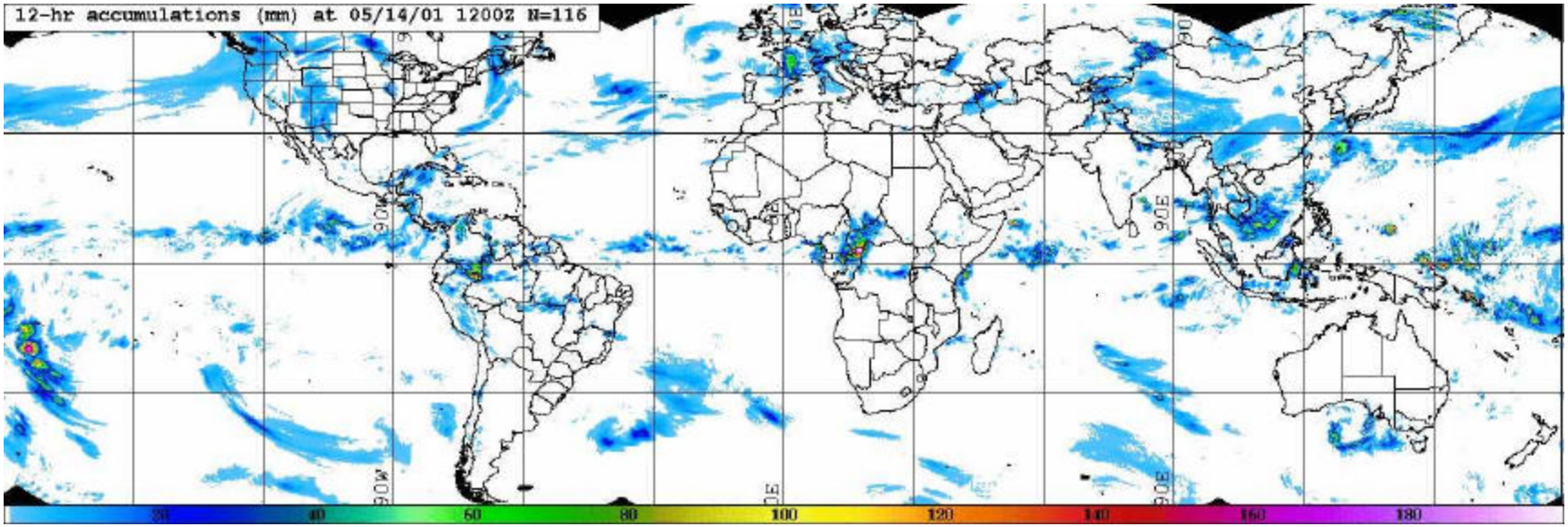
Global geostationary IR composite at 2001/05/14 1200 UTC



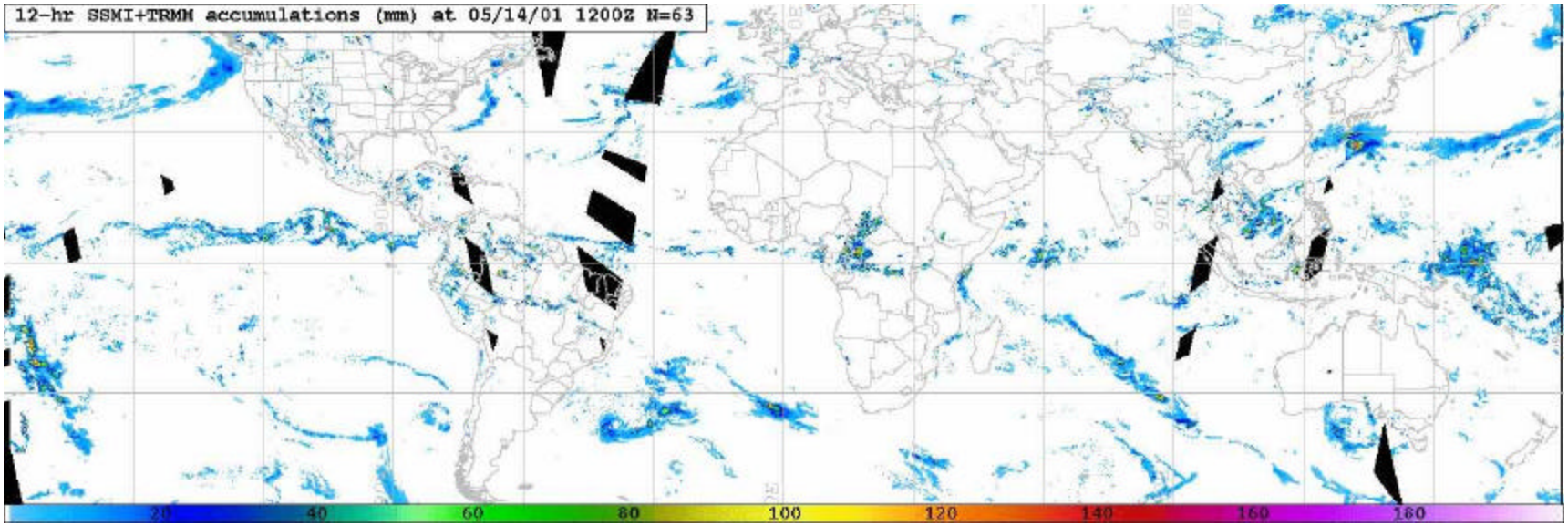
How many hours ago did the last microwave-based update occur? (F-13/14/15, TMI)



12-hour accumulations at 2001/05/14 1200 UTC – **blended technique**



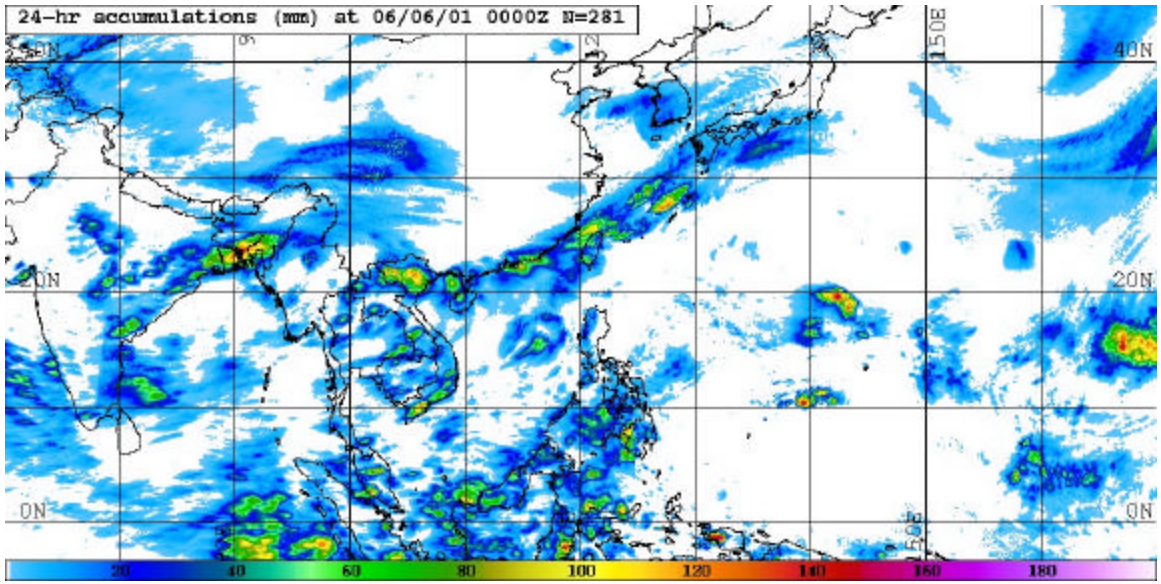
12-hour accumulations at 2001/05/14 1200 UTC – **microwave only** (F-13/14/15, TMI)



Heavy Flooding in Bangladesh 5-6 June 2001

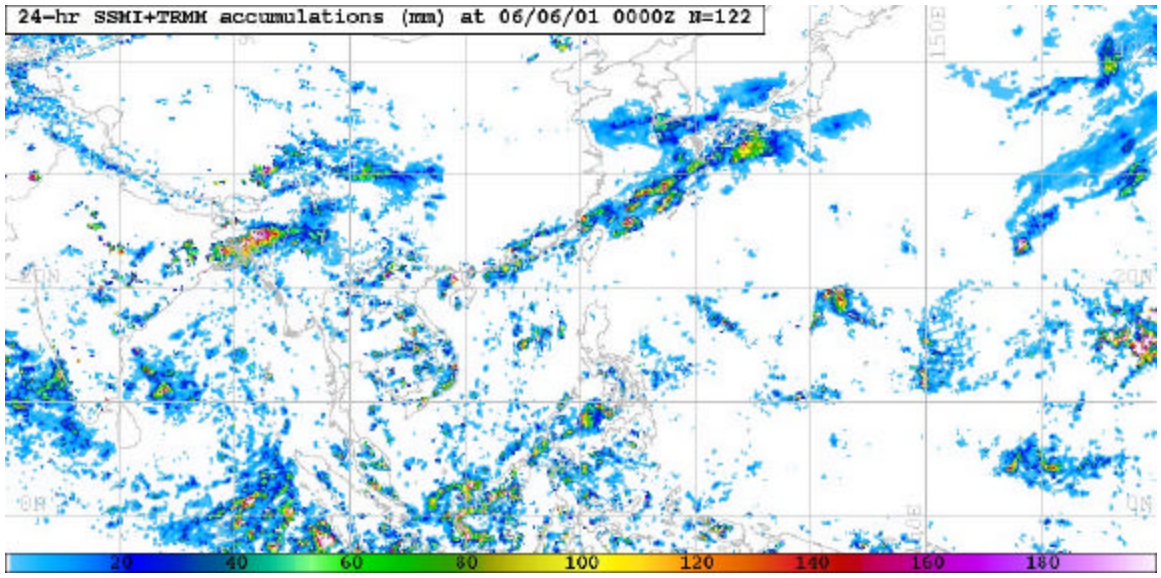
From local Geosats:
Meteosat-5 (47 updates/24 hrs)
GMS-5 (26 updates/24 hrs)

Adjusted by recent overpasses from any of SSMI F-13/14/15 and the TRMM TMI



From low-Earth orbiters:
24-hour accumulation of SSMI F-13/14/15 and one TMI

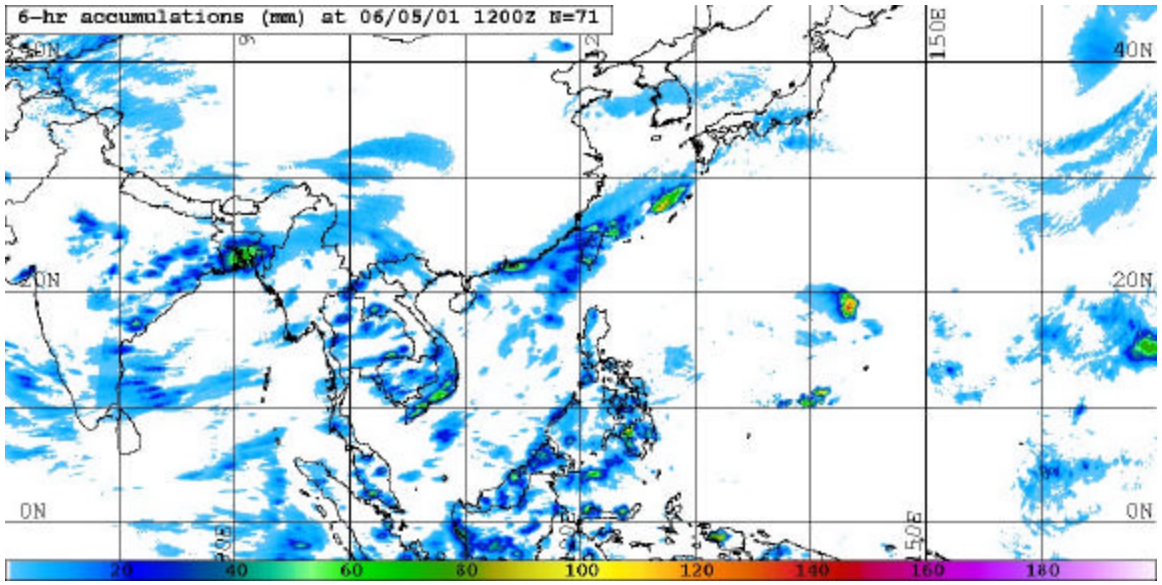
Looks like continuous coverage, but there were limited passes over the Indian Ocean…..



Heavy Flooding in Bangladesh 6-hr time scale

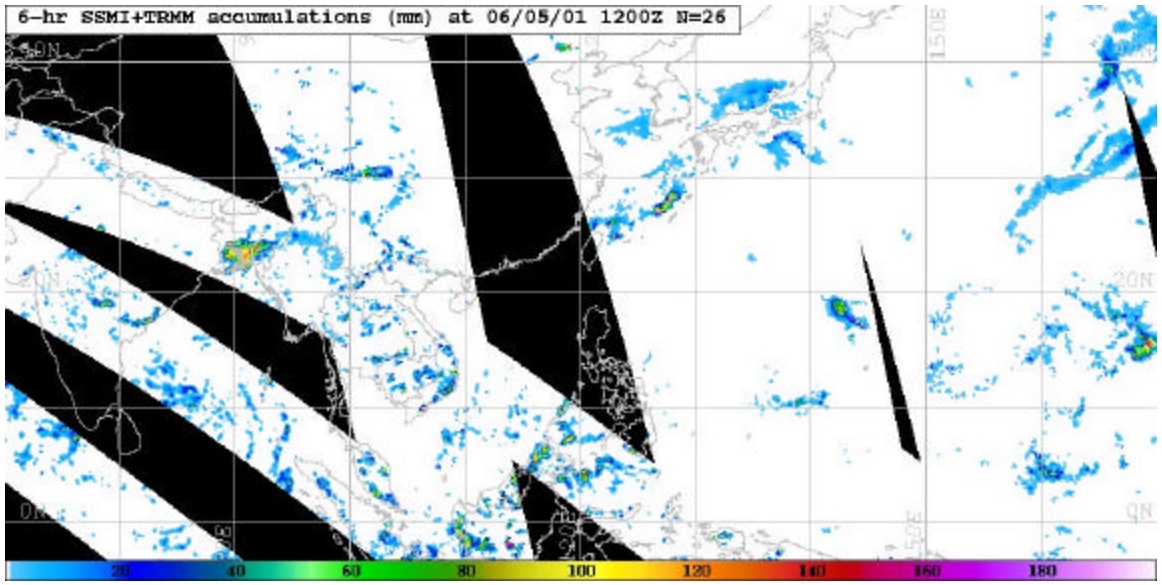
From local Geosats:
Meteosat-5 (13 updates/6 hrs)
GMS-5 (7 updates/6 hrs)

Adjusted by recent overpasses from any of SSMI F-13/14/15 and the TRMM TMI



From low-Earth orbiters:
6-hour accumulation of SSMI F-13/14/15 and one TMI

Only one TMI pass over northeastern India and the Bay of Bengal



Rainrate Science and Product Collaboration Globally

TMI is a key component of the near real-time global rain analysis developed and produced by NRL Monterey

Coordination with NOAA-NESDIS: Ongoing assessment and validation of satellite-based rainfall techniques

Coordination with BMRC for TC coastal rainfall, also validation with Australian national gauge network

Coordination with KMA and Seoul National University for validation against the Korean AWS dense raingauge network

Technique implemented experimentally at NESDIS, KMA, EUMETSAT and under development in the EURAINSAT (European Commission) project

SOUTHCOM use of datasets for South America heavy rain events

FSU superensemble forecasting model, real-time use

NASA-GSFC (GLDAS model), AFWA, Naval Postgraduate School

NOGAPS model verification