TRMM SATELLITE DATA — APPLICATIONS TO TROPICAL CYCLONE ANALYSIS AND FORECASTING

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TRMM Workshop. June 18-19, 2001. Boulder, CO.

TC FORECASTER's DILEMMA

- Lack of wind data over much of world's ocean areas
- Inability to accurately assess location and intensity of tropical cyclones (TC)
- Poor position estimate results in bad track forecast
- Poor model initialization results in unrealistic spinup/spindown of TCs
- Poor quantitative precipitation forecasts (QPF)

Satellite Wind and Rain Estimates

- Multiple Sensors (passive):
  - DMSP/SSMI - Defense Meteorological Satellite Program/Special Sensor Microwave Imager (U.S. Air Force)
  - TRMM - Tropical Rainfall Measuring Mission Microwave Imager (MI) (NASA)
- Multiple Sensors (active):
  - ERS-2 - European Remote-Sensing Satellite (5 GHz)
  - QuikSCAT - NASA Scatterometer (14 GHz)
  - TRMM Precipitation Radar (PR) (14 GHz) (NASA)

Satellite Surface Wind Detection

- Microwave (passive) - obtained from three frequencies: 19-, 22-, 37-GHz;
  - 19-GHz resolutions: 15 km for TRMM and 34 km for SSMI.
- Scatterometer (active) - microwave radar measures near-surface ocean backscattered energy generated by very small capillary waves
  - Resolutions: 25 km QuikSCAT and 50 km ERS-2

Strengths of Remote Wind Sensing

- Global near-surface wind estimates over remote oceanic areas
- Improves numerical model initialization
- Provides quantitative information on TC strength
- Provides quantitative information on the horizontal extent of TC-wind radii (e.g., 17 m s^{-1} and 25 m s^{-1} winds)

Limitations of Remote Wind Sampling

- Data coverage incomplete in time and space
- Data not in real-time (≤3 h old)
- Passive winds limited to ≤20 m s^{-1}; no wind direction available.
- Passive winds not available in presence of rain and/or sidelobes near coastlines.
- Scatterometer winds limited to ≤18 m s^{-1}; direction occasionally 180° out of phase; affected by heavy rain.

Benefits of TRMM

- TRMM in lower orbit than SSMI (350 km vs. 800 km) -> higher horizontal resolution (5 km vs. 10 km) -> more detail of features in eyewall
- TRMM PR is only satellite radar -> gives vertical and horizontal structure
- TRMM in low-inclination orbit (vs. polar orbit). Covers tropical latitudes better (1 in 8 orbits view a TC

Operational Use of TRMM Data

- 85- and 37-GHz channels "see" through clouds to depict low- and mid-level features and allow TC center location
- Qualitatively assess TC intensity by depicting eye obscured in VIS/IR imagery
- Qualitatively assess TC intensity trend by depicting eyewall changes
- TRMM MI/PR rainfall algorithms for QPF
- TRMM PR data has best horizontal resolution for depicting TC features

37-GHz Microwave Data

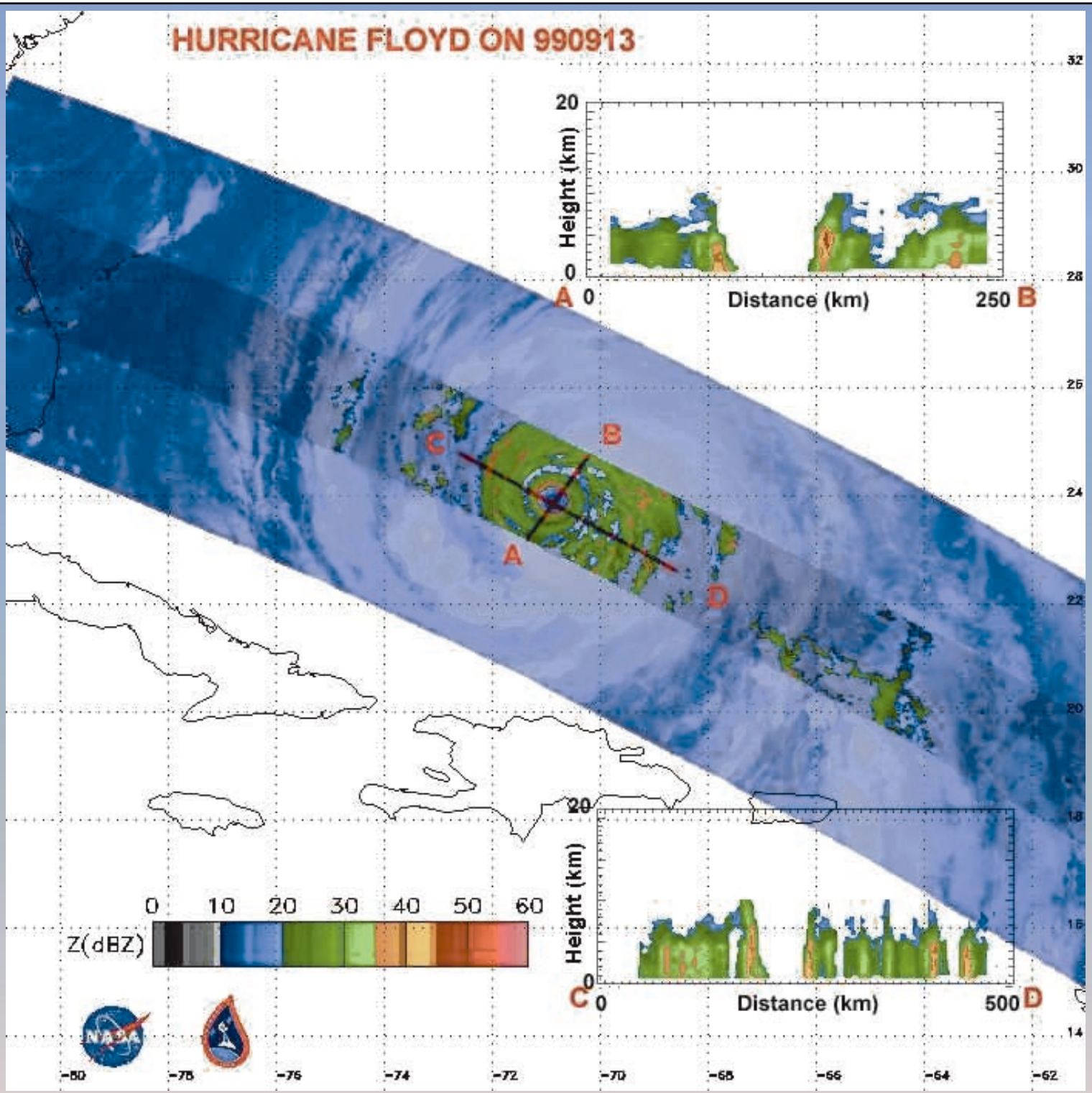
- Sensitive to rain.
- Insensitive to most ice precipitation particles that appear in and contaminate the 85-GHz data.
- Can depict lowest rainbands (≤1.5 km) within a TC (~13 km resolution).
- Shows spatial variations of rain intensity near center of the storm; such variations often do not appear in 85-GHz data because attenuation by ice in convective clouds.

85-GHz Microwave Data

- Deep convection (red) distinguished from low-level clouds and warm rain (blue-green).
- Blue-green regions traces non-precipitating low-level cyclonic circulation.
- Deep convection characterized by ice precipitation above freezing-level (>4.5 km) and used to detect mid-level eye formation.
- If red areas increase (decrease) in size and more (less) organized over time, means a TC is getting stronger (weaker).
- Compare to 37-GHz or radar to assess eye tilt.

TRMM Precipitation Radar (PR) for Rain Data

- Radar transmits at 14-GHz frequency
- 5-km horizontal resolution at surface
- 250 m vertical resolution;
- 215 km swath width is ~1/4 size of passive radiometer swath width
- rainfall rate in mm h^{-1} based on 5 km thick cloud layer and 0.5 km “bright” band


HURRICANE FLOYD ON 990913
Height (km)
20
0
A
0
Distance (km)
250
B
C
B
A
D
Height (km)
20
0
C
0
Distance (km)
500
D
0
10
20
30
40
50
60
Z(dBZ)
32
30
28
26
24
22
20
18
16
14
-80
-78
-76
-74
-72
-70
-68
-66
-64
-62

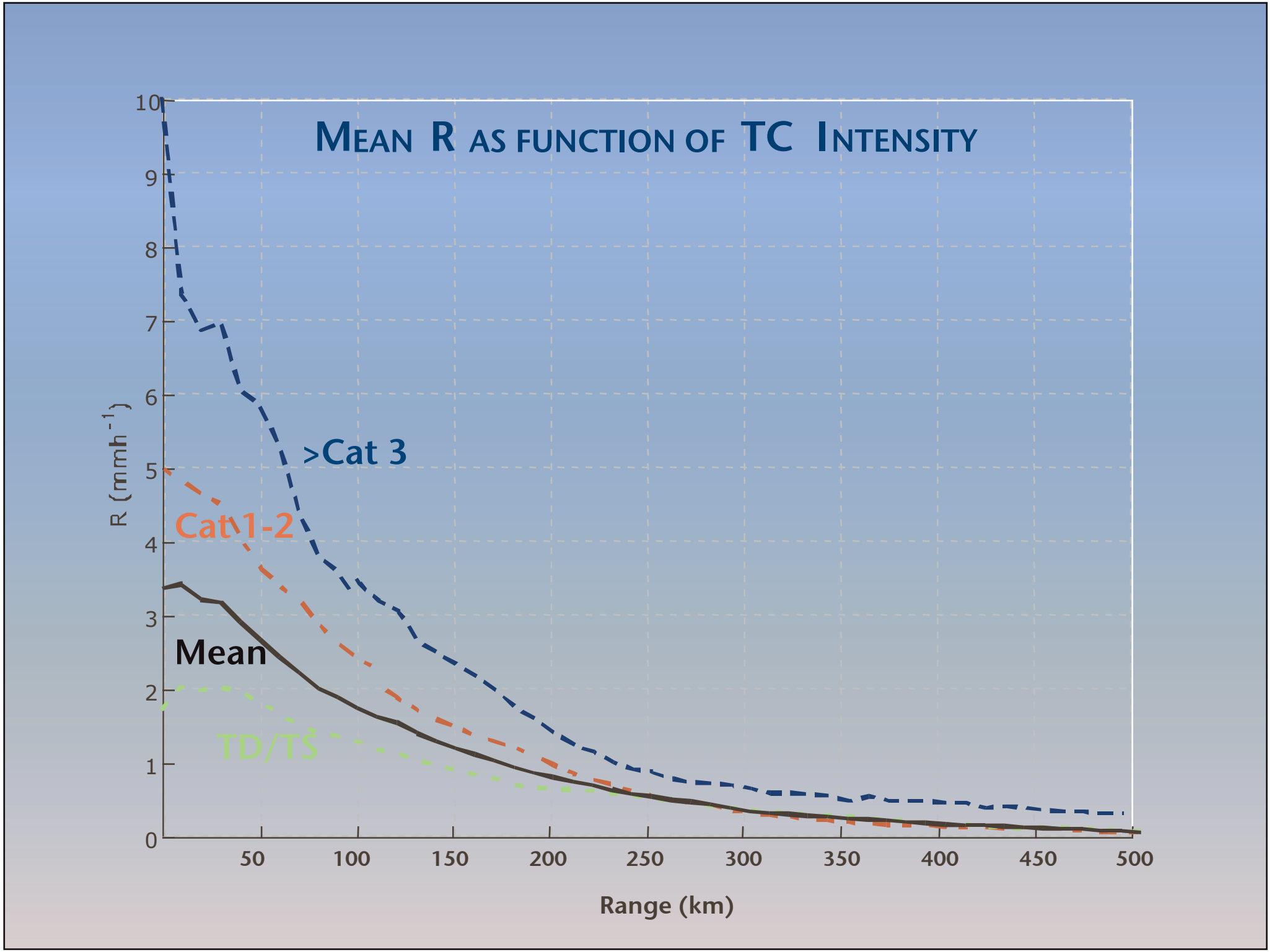
Develop TC Rain Climatology

Goal:

- Improve understanding of TC rainfall by developing global TC rain climatology
- Develop methodology to validate model forecasts of TC rain.

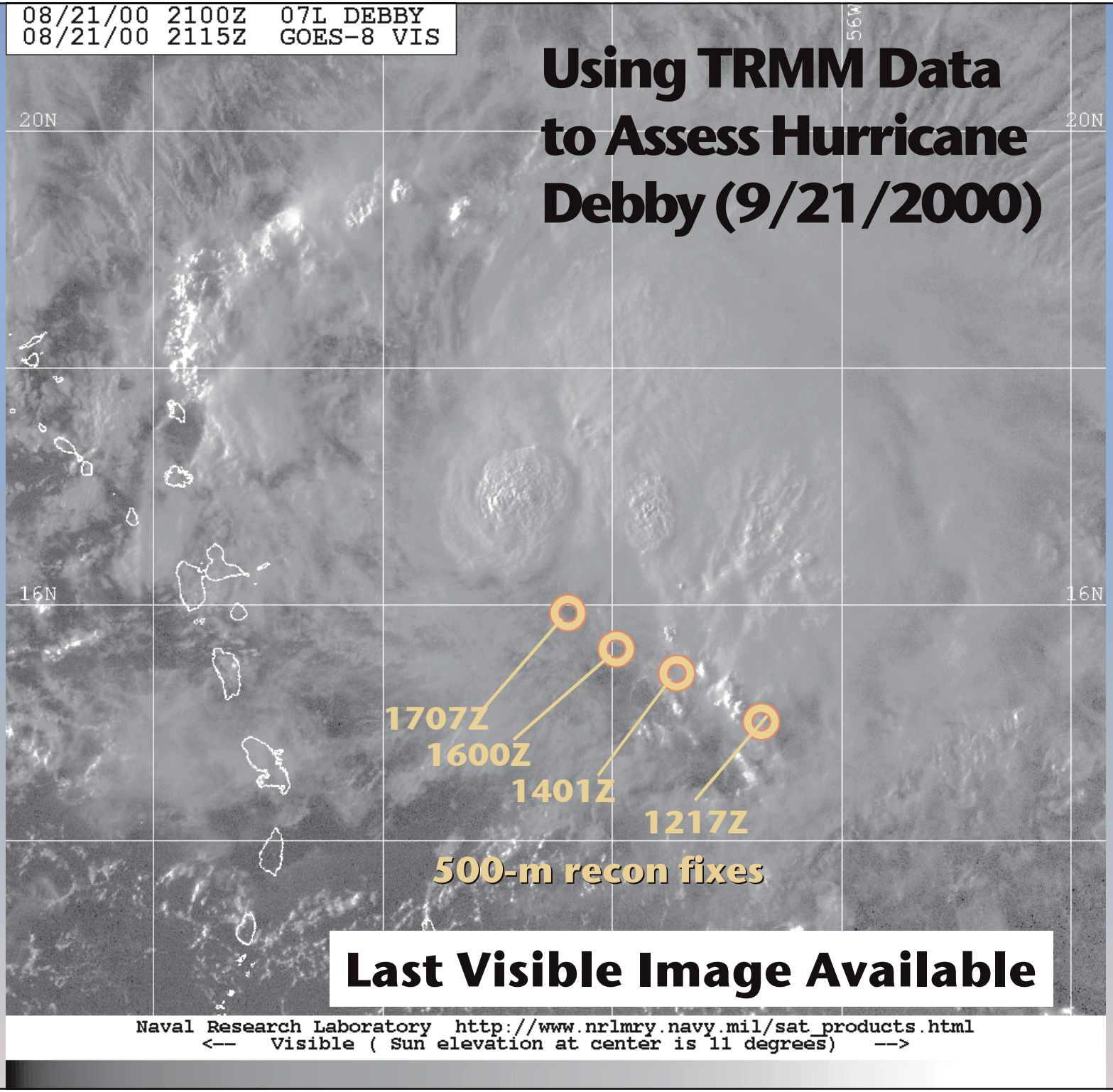
DATA and METHOD:

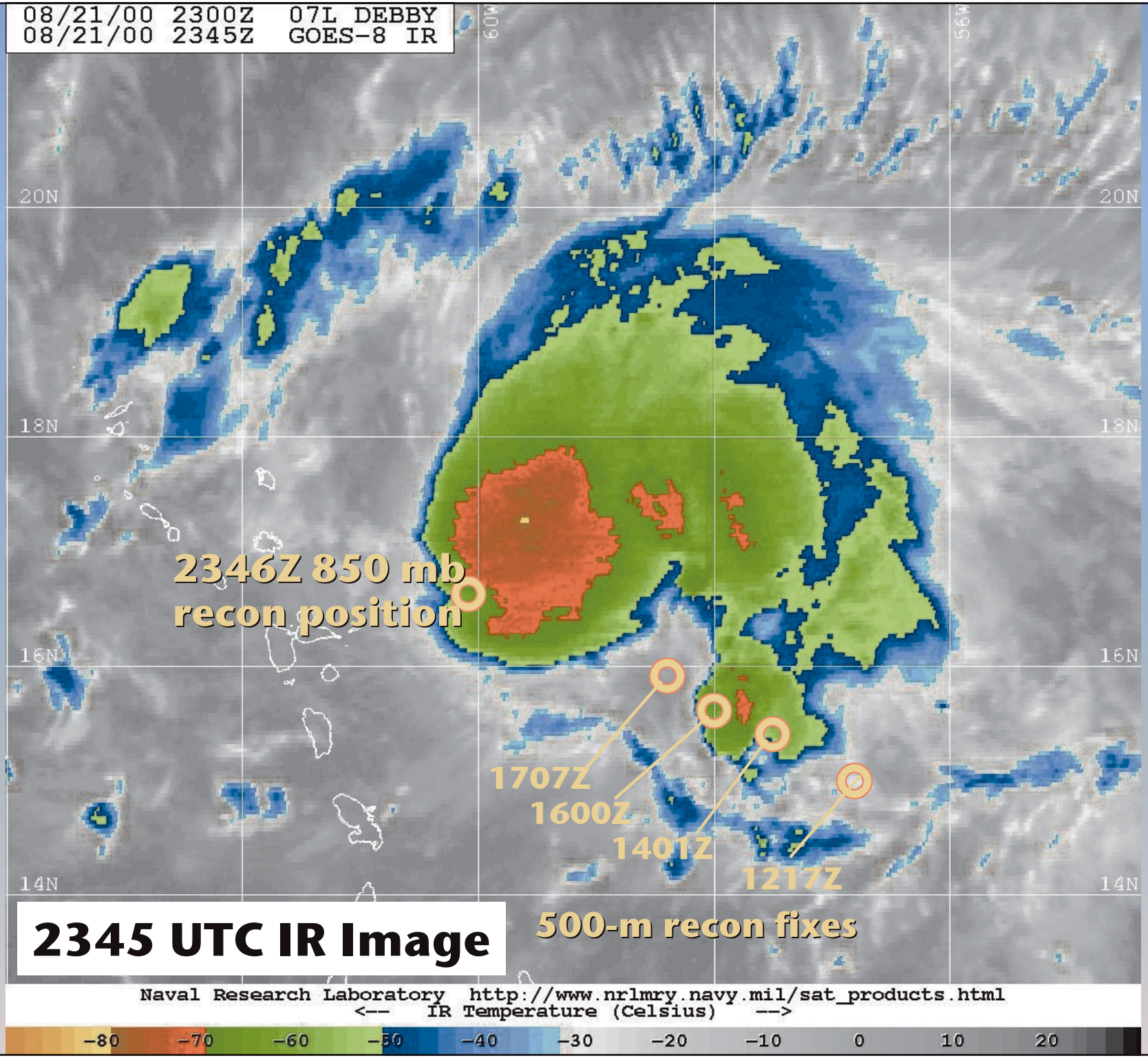
- R estimates from TRMM MI and PR.
- 193 storms from December 1997 to December 1999, yielding >1800 events, from storm to category 4 hurricane.

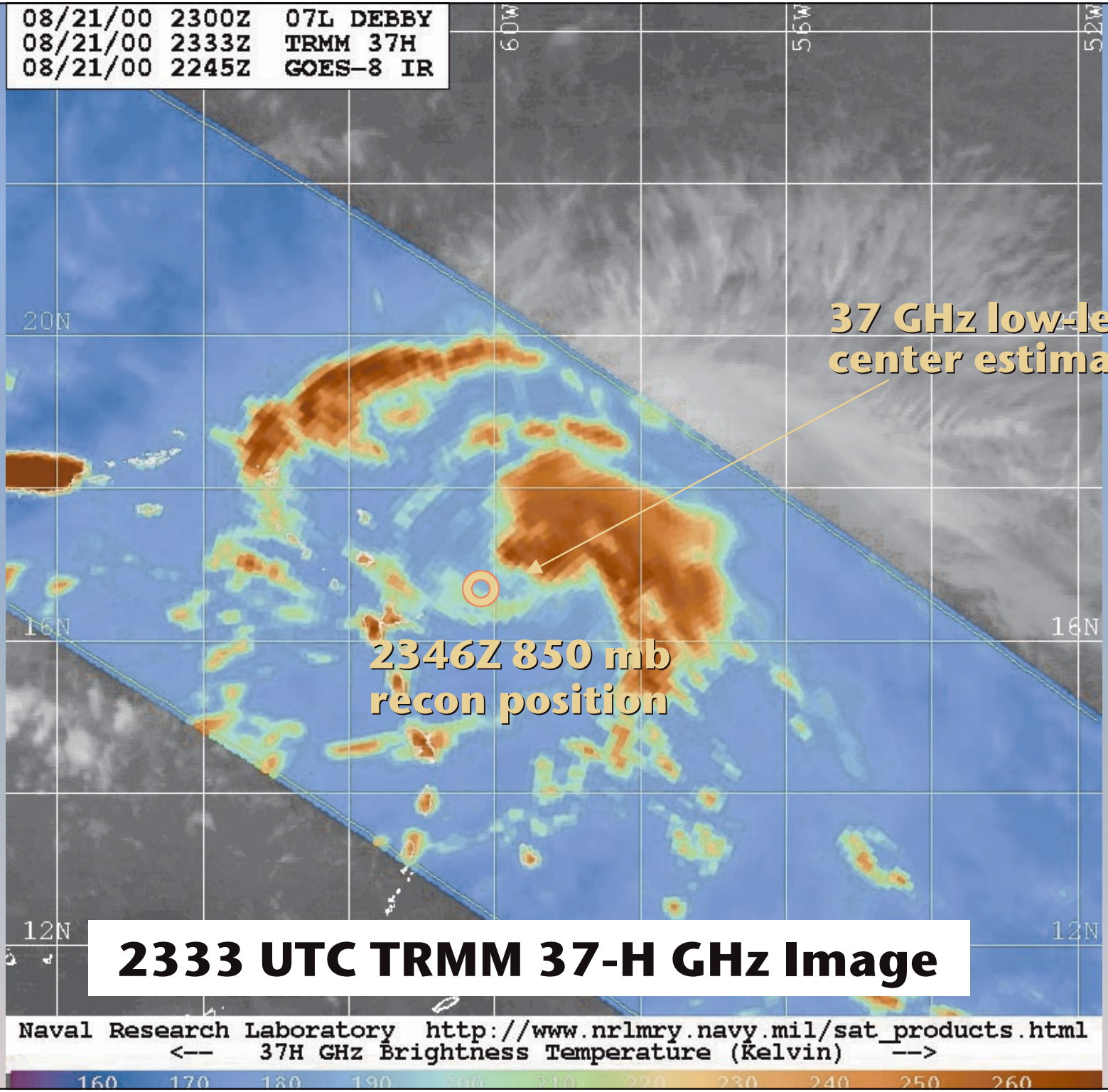

MEAN R AS FUNCTION OF TC INTENSITY
R (mmh-1)
10
9
8
7
6
5
4
3
2
1
0
>Cat 3
Cat 1-2
Mean
TD/TS
50
100
150
200
250
300
350
400
450
500
Range (km)

Unique to TPC/NHC

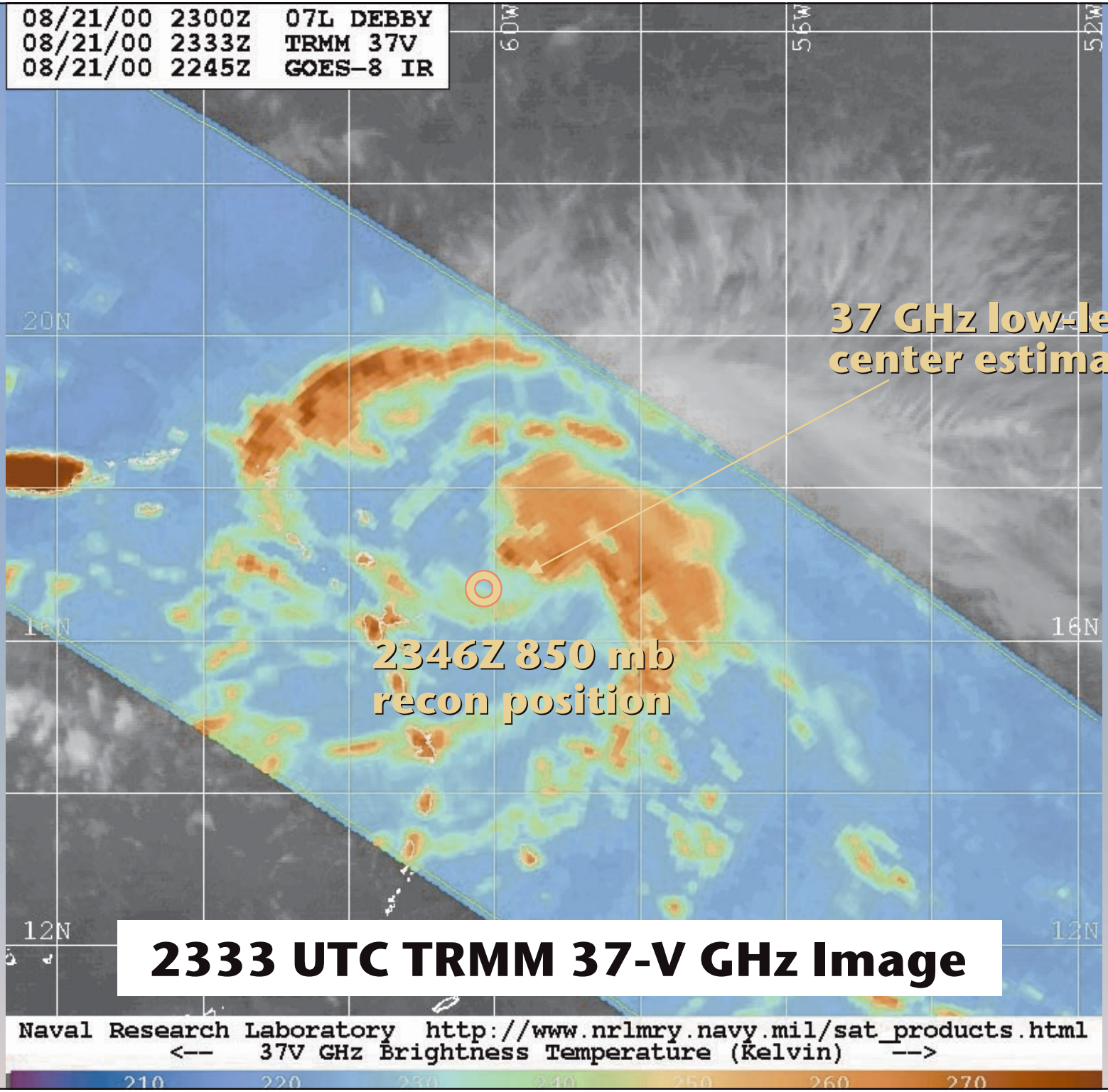
- TRMM data available operationally only since late 1999 season.
- Operational aircraft reconnaissance available in Atlantic (ATL) basin
- Main use in fixing TCs without clear eye when aircraft are unavailable (E of 50°W or East Pacific basin-EPAC)
- See example for Hurricane Debby (2000)


08/21/00 2100Z 07L DEBBY
08/21/00 2115Z GOES-8 VIS
Using TRMM Data to Assess Hurricane Debby (9/21/2000)
20N
16N
56W
1707Z
1600Z
1401Z
1217Z
500-m recon fixes
Last Visible Image Available
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
<-- Visible (Sun elevation at center is 11 degrees) -->

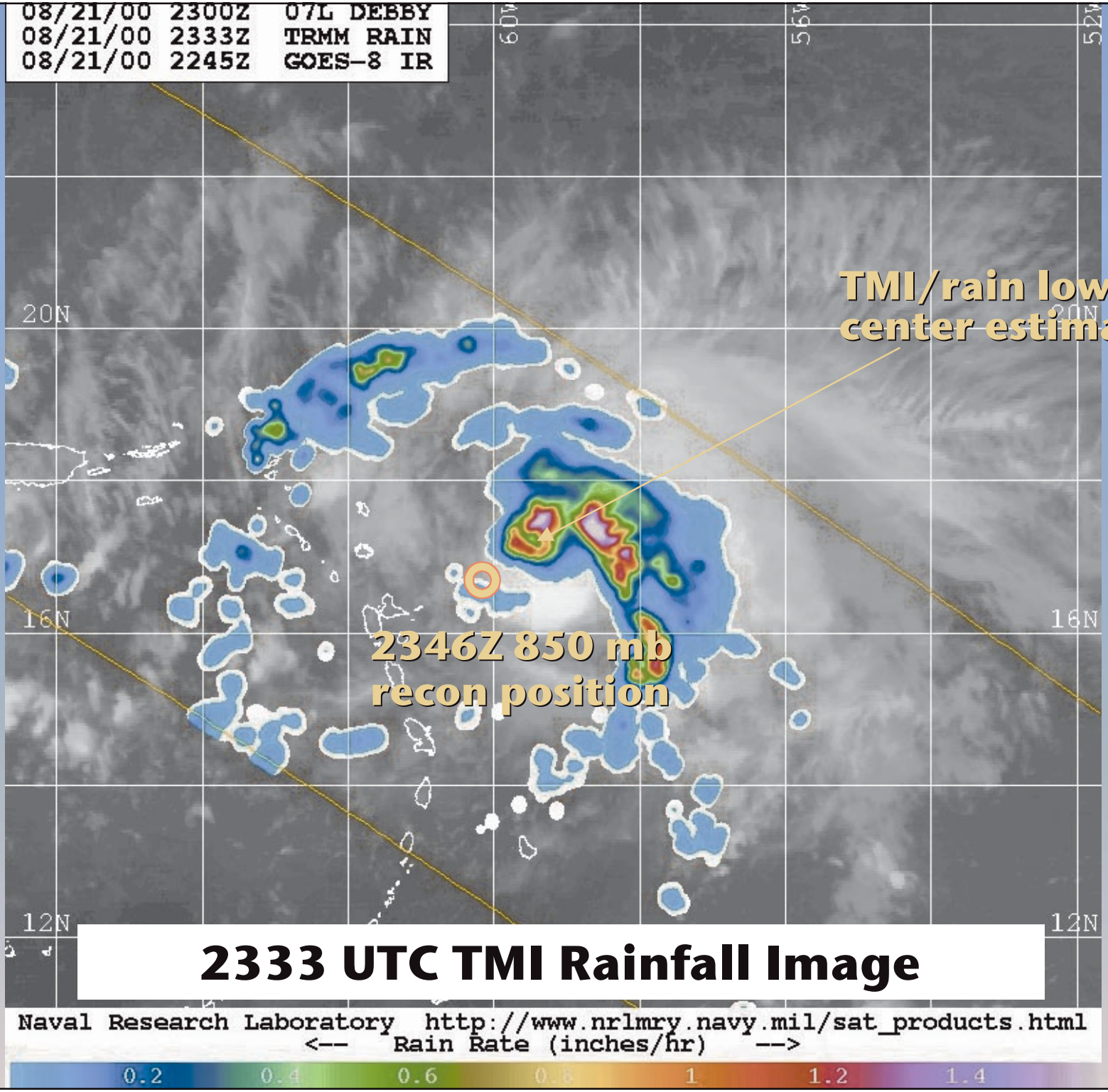

08/21/00 2300Z 07L DEBBY
08/21/00 2345Z GOES-8 IR
60W
56W
20N
18N
16N
14N
2346Z 850 mb
recon position
1707Z
1600Z
1401Z
1217Z
500-m recon fixes
2345 UTC IR Image
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
<-- IR Temperature (Celsius) -->
-80 -70 -60 -50 -40 -30 -20 -10 0 10 20

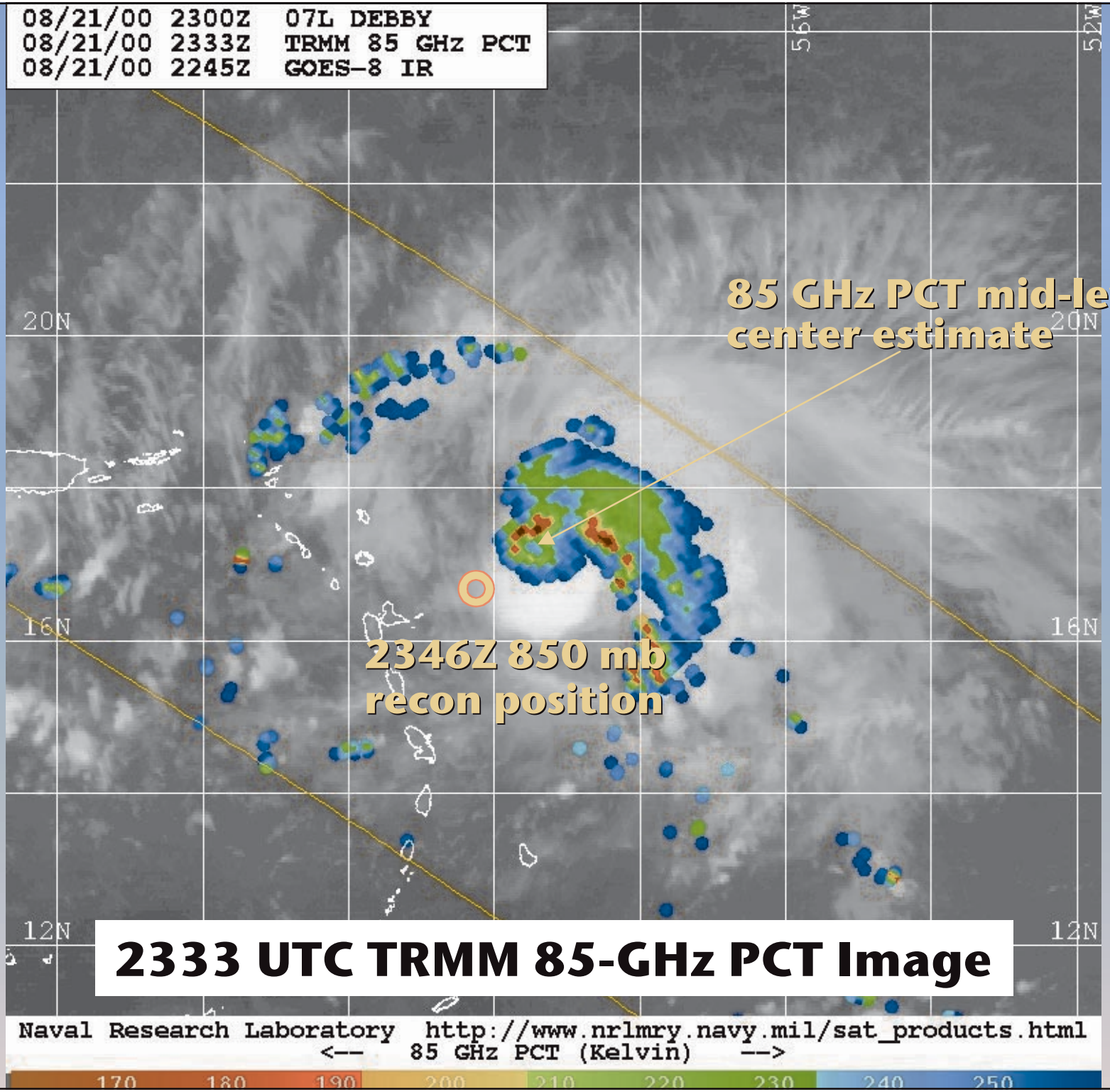


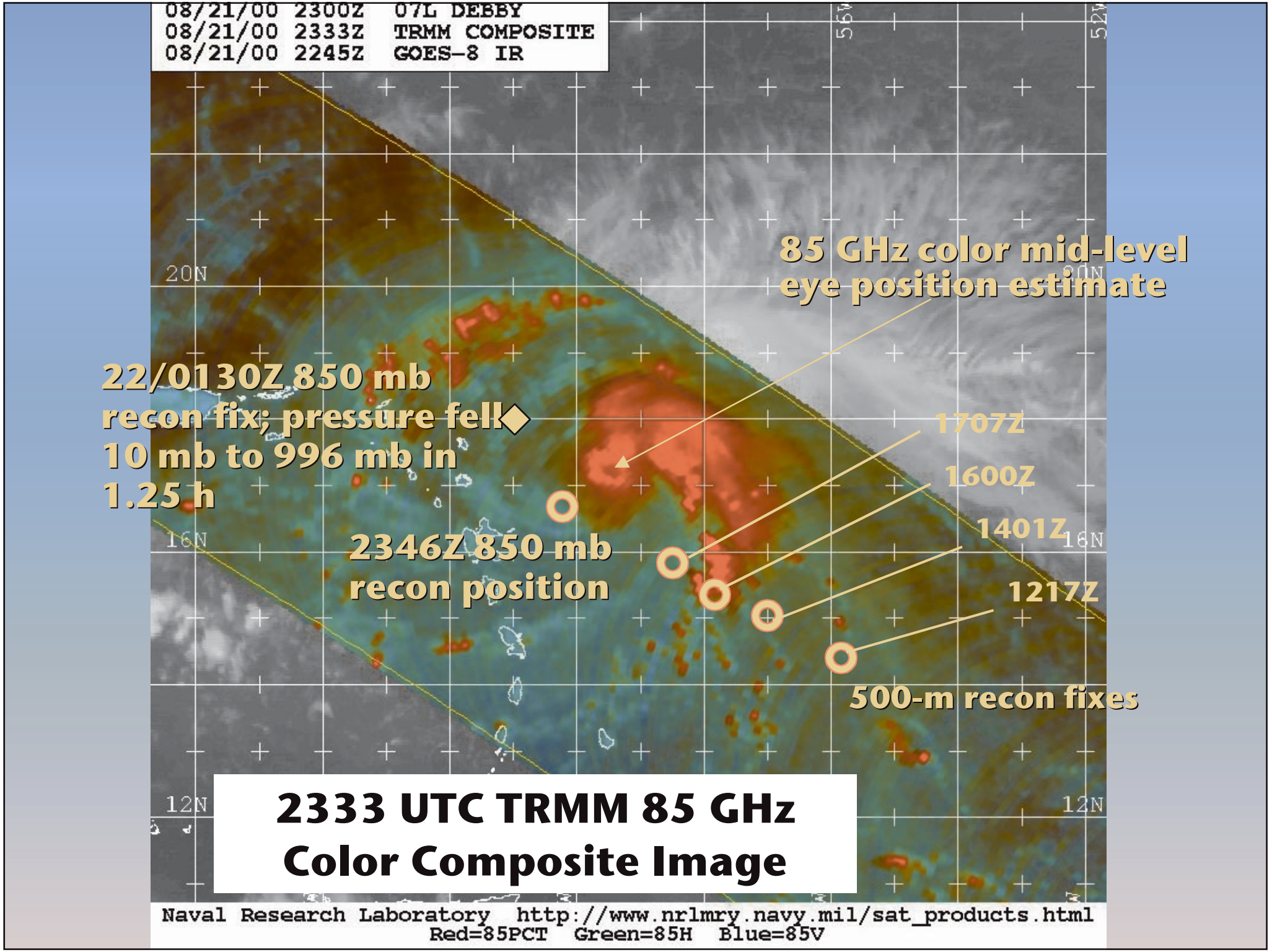
2333 UTC TRMM 37-H GHz Image



2333 UTC TRMM 37-V GHz Image


08/21/00 2300Z 07L DEBBY
08/21/00 2333Z TRMM RAIN
08/21/00 2245Z GOES-8 IR
60W
56W
52W
20N
16N
12N
TMI/rain low-level
center estimate
2346Z 850 mb
recon position
2333 UTC TMI Rainfall Image
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
<-- Rain Rate (inches/hr) -->
0.2
0.4
0.6
0.8
1
1.2
1.4


08/21/00 2300Z 07L DEBBY
08/21/00 2333Z TRMM 85 GHz PCT
08/21/00 2245Z GOES-8 IR
56W
52W
20N
16N
12N
85 GHz PCT mid-level center estimate
2346Z 850 mb recon position
2333 UTC TRMM 85-GHz PCT Image
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
<-- 85 GHz PCT (Kelvin) -->
170 180 190 200 210 220 230 240 250



2333 UTC TRMM 85 GHz Color Composite Image

Ensuing TPC/NHC Discussion

ZCZC MIATCDAT2 ALL
TTAA00 KNHC DDHHMM
TROPICAL STORM DEBBY DISCUSSION NUMBER 7
NATIONAL WEATHER SERVICE MIAMI FL
5 AM EDT MON AUG 21 2000

THE CENTER OF DEBBY IS STILL HARD TO LOCATE. RECENT SATELLITE FIXES NUDGE THE SYSTEM A LITTLE FURTHER WEST THAN THE PREVIOUS PACKAGE...
AND NIGHTTIME MULTISPECTRAL IMAGERY HINTS THAT IT MIGHT EVEN BE SOUTH OF 15N. IN VIEW OF THIS UNCERTAINTY...THIS PACKAGE CONTAINS A LOT OF CONTINUITY AND EXTRAPOLATION. SOME RE-LOCATION MAY BE NECESSARY IN THE NEXT PACKAGE.

THE INITIAL MOTION IS ESTIMATED TO BE 285/16. ... NOTE THAT SOME ADJUSTMENT OF THE INITIAL INTENSITY IS POSSIBLE AFTER AN AIR FORCE RESERVE HURRICANE HUNTER ARRIVES AT 12Z.

FORECASTER BEVEN

TPC/NHC TRMM Usage

- Every system in ATL and EPAC had at least 1 TRMM TC fix (>5% of the 715 advisories issued). Total: 37 TCs; 16% TD; 50% TS; 34% HUR
- 11 TCs in ATL and EPAC had at least 1 forecast package/position modified by TRMM data (note: more modified by SSMI data because there are 3 DMSP satellites).

SUMMARY

- TRMM/TMI 85- and 37-GHz microwave channels "see" through thick clouds to permit depiction of low- and mid-level clouds and assist in TC center identification
- TRMM data enables qualitative assessment of TC strength by depiction of an "obscured" eye
- TRMM data enables a qualitative assessment of TC intensity trend by analyzing eyewall patterns
- TRMM MI and PR provide good quantitative TC rain estimates