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Development of Tropical Cyclone Rainfall Climatology and Persistance (R-CLIPER) Model

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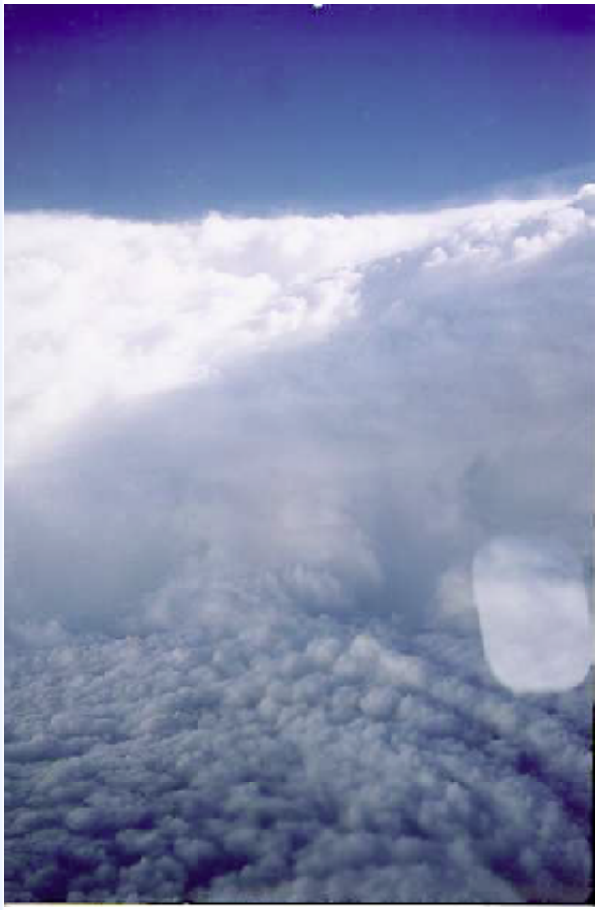
INTRODUCTION:

- Tropical cyclones (TC) pose significant quantitative precipitation forecast (QPF) problem as evidenced by tragic loss of life and property from rain in Hurricanes Mitch (1998), Floyd (1999), and TS Allison (2001).
- Over last 30 years majority of TC-related deaths are caused by flooding (Rappaport 2000).
- Threat of flooding is a function of rain rate (R) and duration, making storm size (D) and motion (Vs) critical parameters.
- Enhanced rainfall due to orographic forcing and/or interactions with mid-latitude frontal boundaries increase threat of flooding.

- QPF limited by complexity of precipitation processes and lack of microphysics data.
- Improved QPF, particularly in TCs, is a primary objectives of U. S. Weather Research Program (USWRP).



- w drafts are small (3 km), relatively weak (10%>±6.5 ms^{-1}; 1%>±10.5 ms^{-1}), with 3 times more updrafts than down.
- R cores are small (50% diameters >3.7 km) and short-lived (10% durations >8 min) covering only 10% of storm rain area. 90% of rain area is stratiform.
- Yet, stratiform rain makes up ~50% of total rain from TC.
- However, TC vortex structure dynamically constrains smaller scale circulations that confound better QPF.

- Over open water simplest TC QPF is a climatology and persistance (CLIPER) model that predicts peak storm total rain (R_{max}) as:

$$R_{max}=RDV_s^{-1}$$

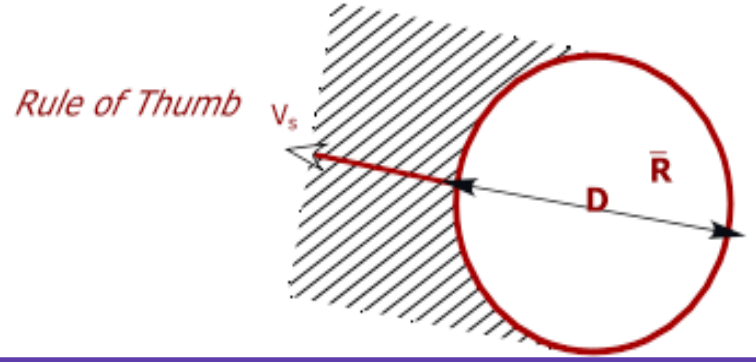
integral of R along line (D) with V_s.

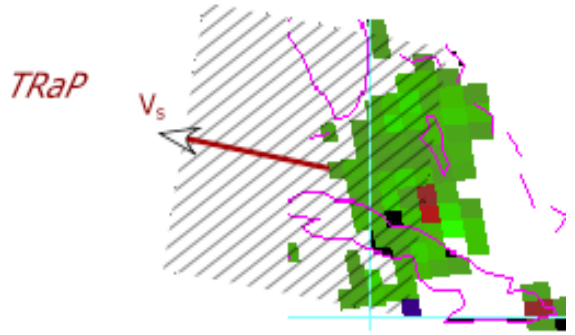
- Originated in late 1950s as Kraft's "rule of thumb" where:

$$R_{max}=130.8\ V_s^{-1}$$

where R_{max} in cm, V_s in m s^{-1}, and climatological R=0.98 cm h^{-1} and D=500 km.

- Tropical Rainfall Potential (TRaP) (Ferraro et al 1998) uses similar approach, but with satellite R-estimates projected along track
- Note these techniques have no adjustments for storm intensity, topography, or other parameters.





- Problem is sensitivity to assumptions of R, D, and V_s which come from TC climatology. Relatively good estimates of D and V_s climatology are available globally.

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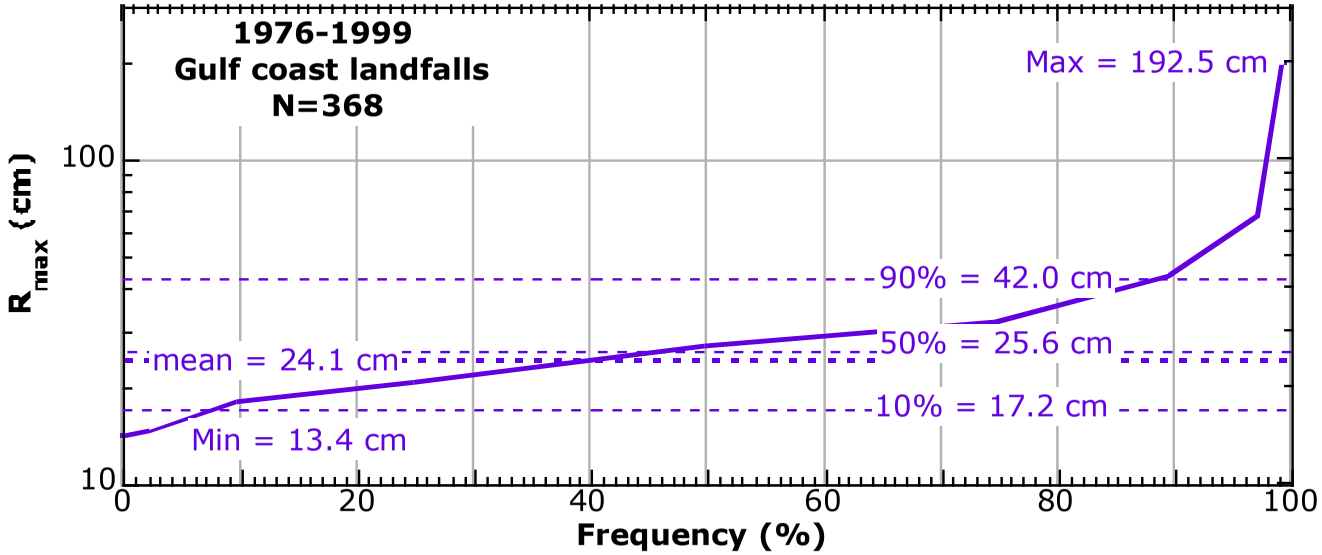
Sensitivity of R_{max} to V_s, holding $\bar{R}$ and D fixed for all Gulf landfalls 1976-1999



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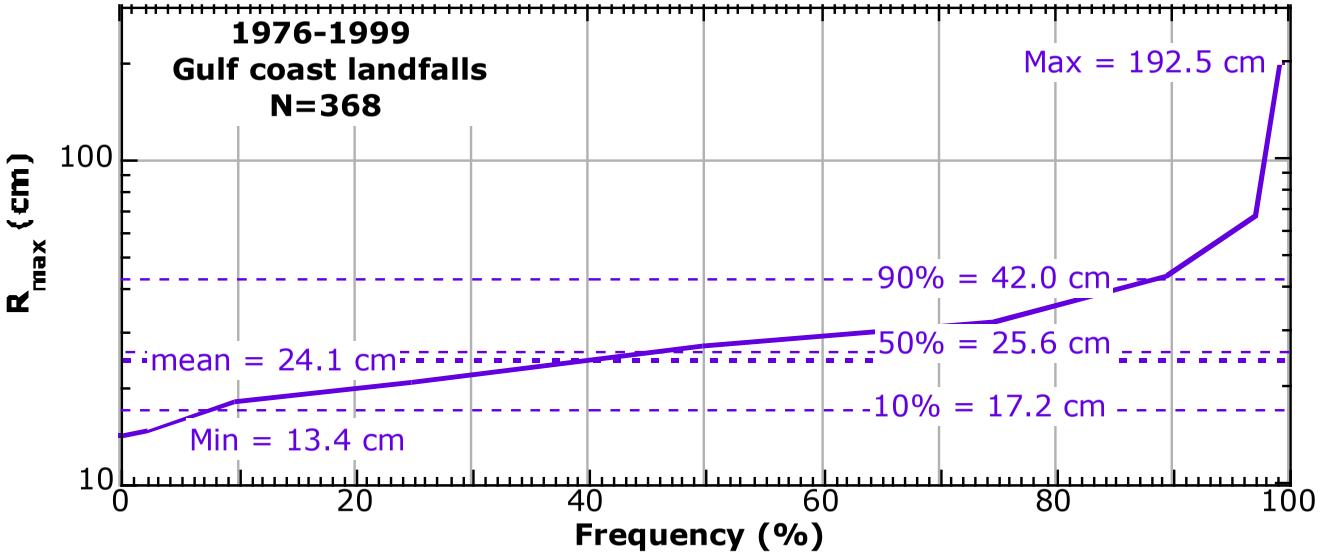

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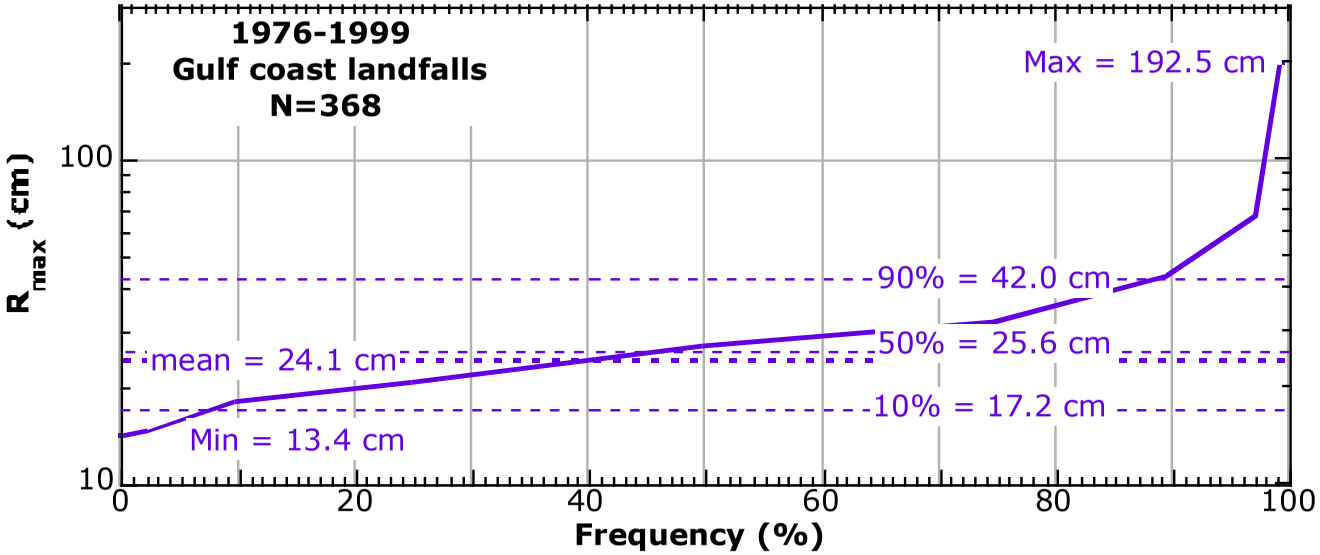

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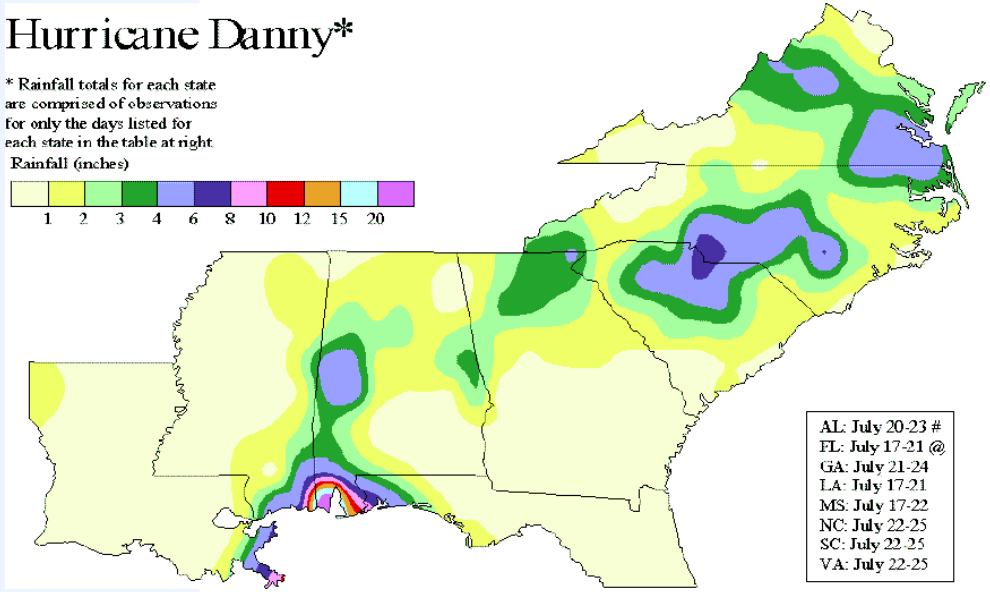
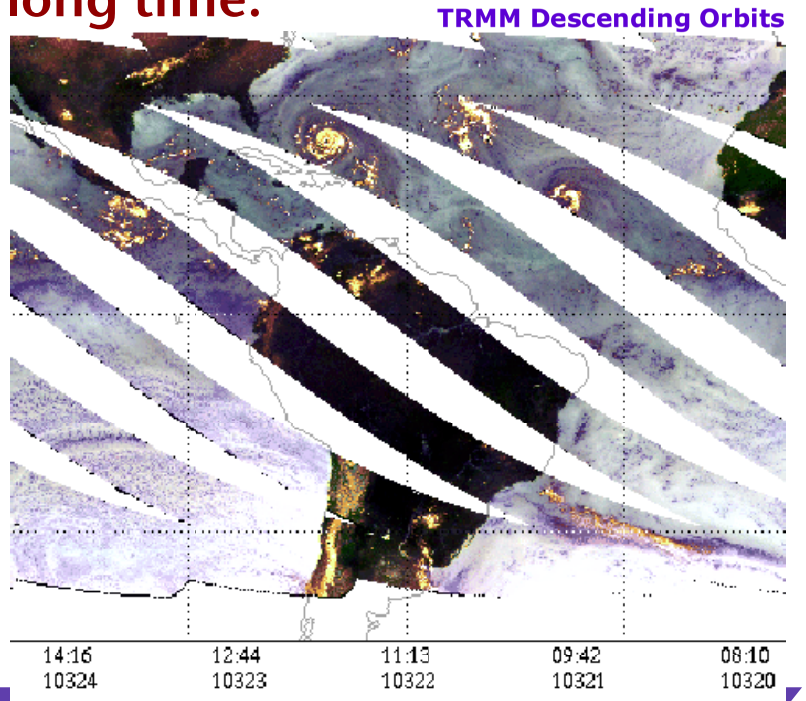
- Estimates of R distribution based on radar (WSR-88D) and satellite microwave remote sensors offer promising avenues to develop R climatology.

- **OPPORTUNITY:**
  - Develop R climatology in TCs regionally and globally
  - Develop methodology to validate model forecasts.
- **DATA and METHOD:**
  - Instantaneous R-estimates from TRMM Microwave Imager (TMI) and Precipitation Radar (PR). Strength is global coverage with single instrument.
  - Hourly R-estimates from gauges. Strength is high temporal resolution over long time.





GOAL:

- Improve understanding of tropical cyclone (TC) rainfall (R) by developing a rain climatology of TCs, globally,
- Develop a methodology to improve forecasting of TC rain distributions.

DATA:

- R estimates from TMI version 5 for 245 storms from December 1997 to December 2000, globally, yielding 2121 events (observations), in TCs ranging from TD to category 5 intensity.

1998-2000 TMI events by Intensity

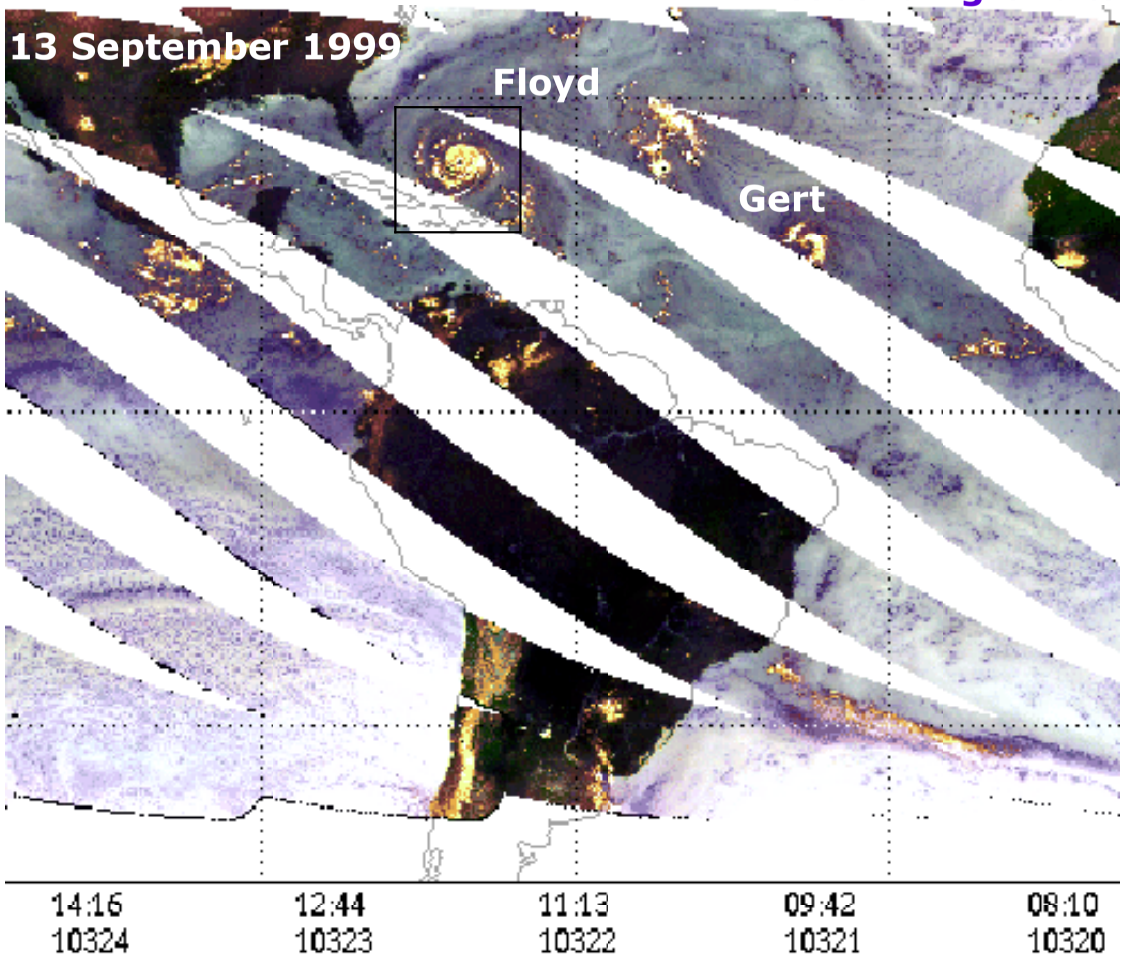
Storm Intensity	Events	%
TD/TS	1361	64
Category 1-2	548	26
Category 3-5	212	10
Total	**2121**	

- 560,000 hourly rain gauge estimates in 46 landfalling hurricanes in the U. S. from 1948-2000

METHOD (continued):

- TMI passive microwave radiometer at 10.7, 19.4, 21.3, 37, and 85.5 GHz over a 758.5 km swath with ~5 km resolution. Surface rain (R, mm h^{-1}) estimates from TB.

TRMM Descending Orbits



Analysis domain:
- storm-centered
- 50 10-km wide annuli
- 4 quadrants

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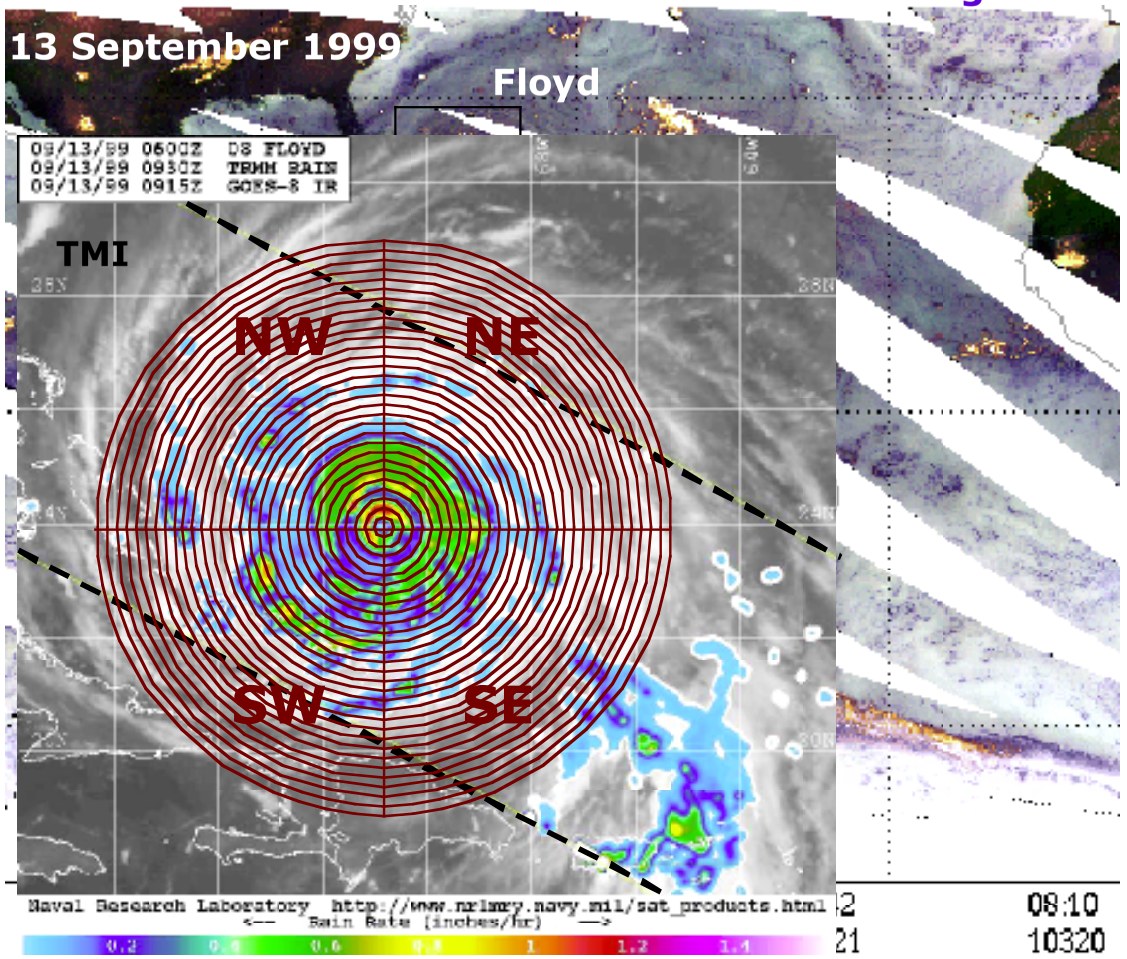

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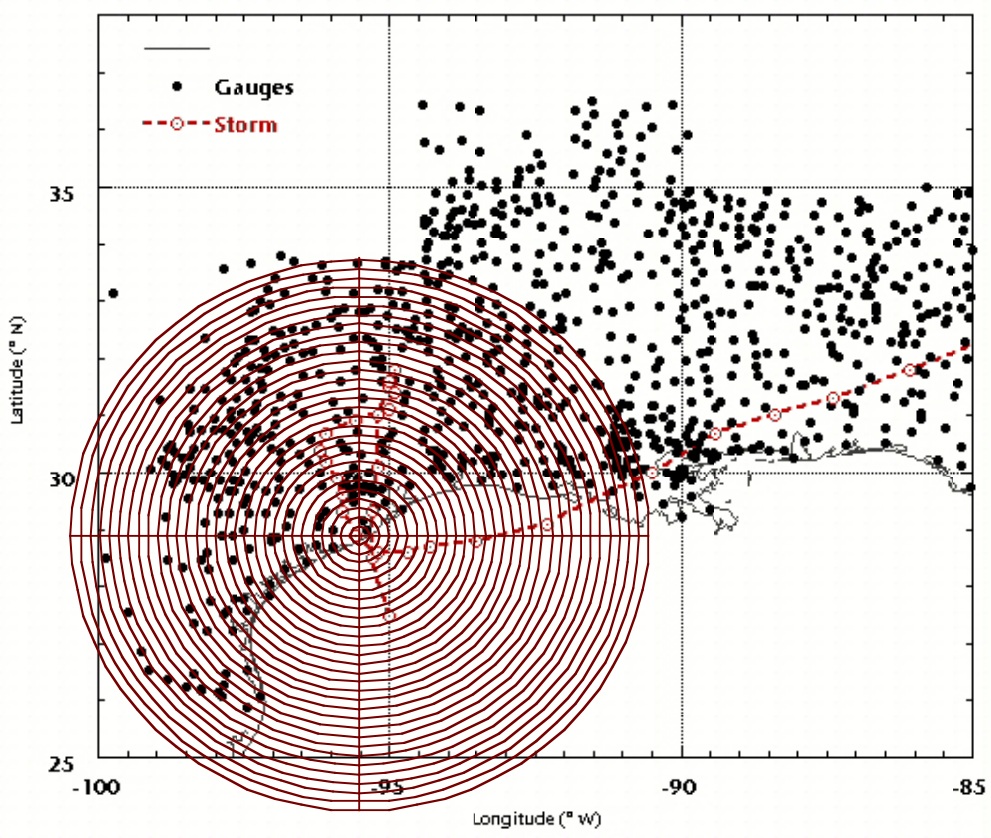

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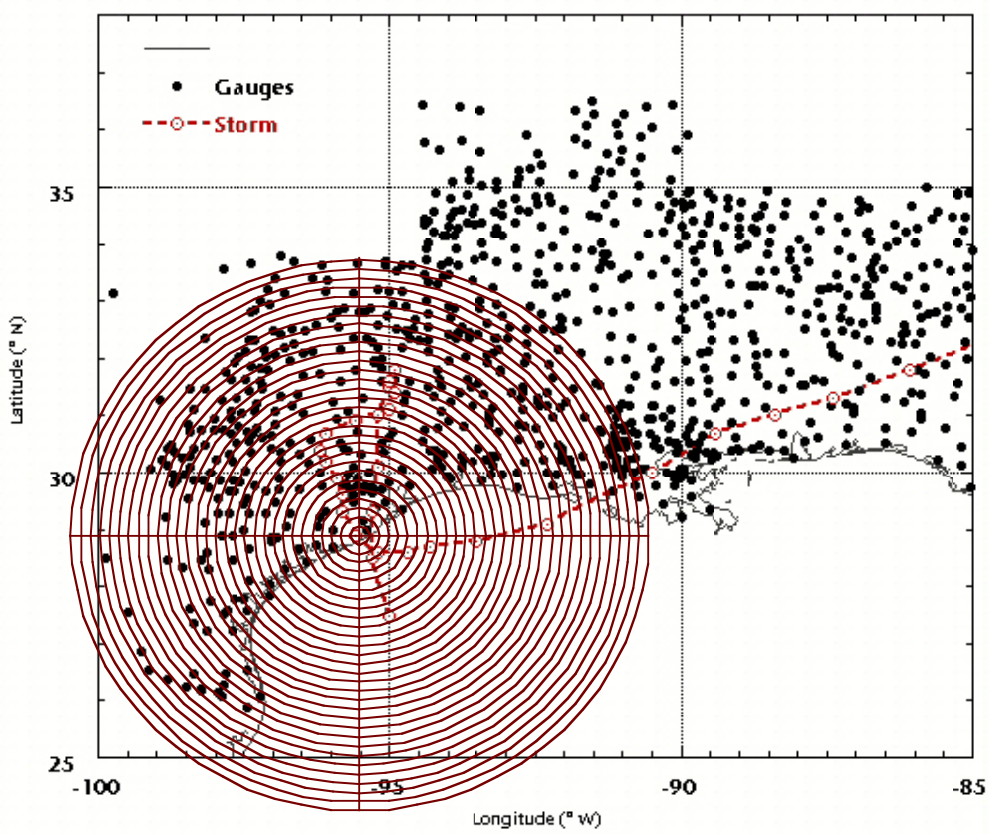

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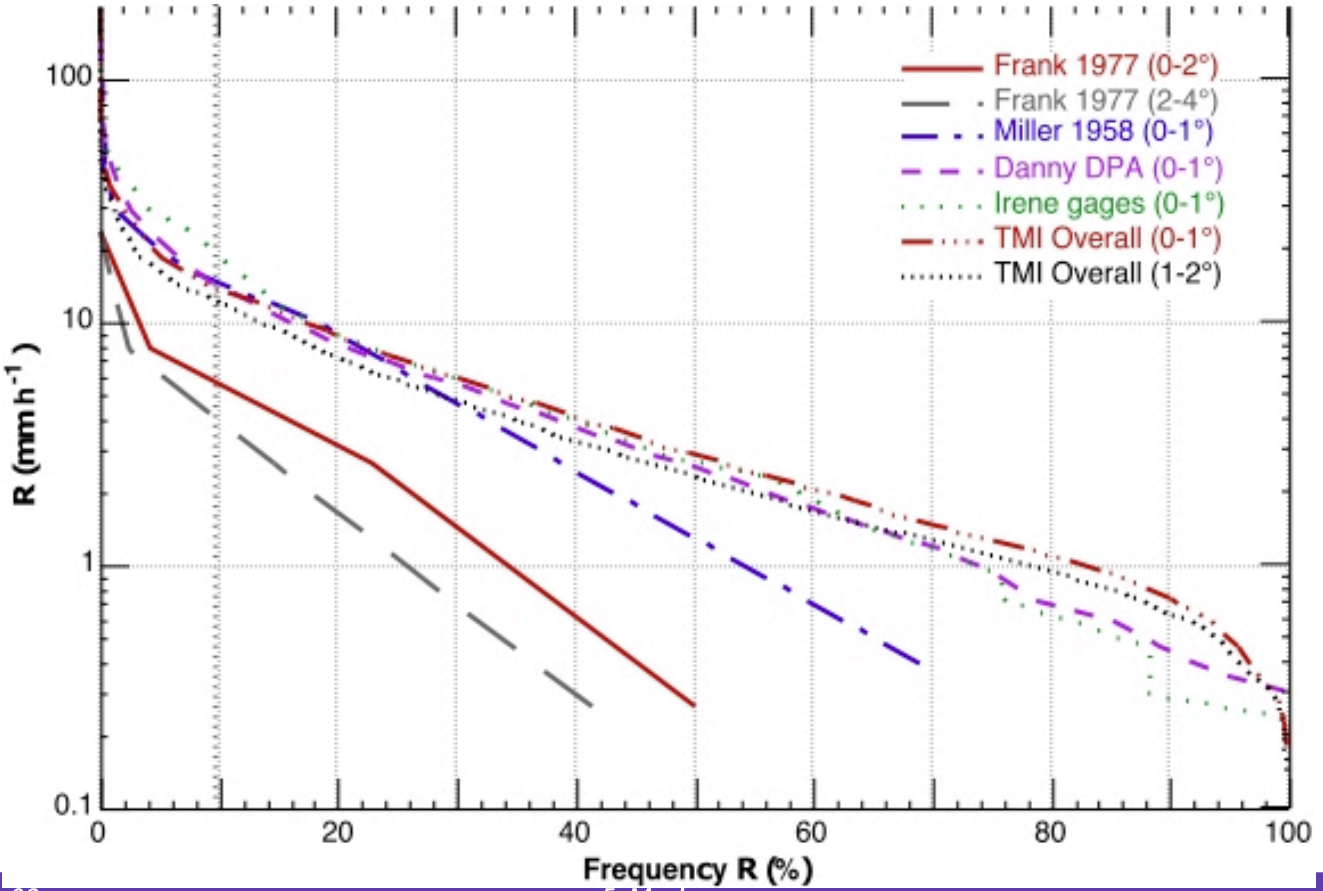
- Distribution of R examined as a function of intensity.
- PDF of R computed for 10 km radial bands in 1 dBR (10 $\log_{10}$R) steps from 0.3-300 mm h^{-1} (-5 to 25 dBR).
- Stratified by intensity and motion, to compare to radar and model estimates.

RESULTS:

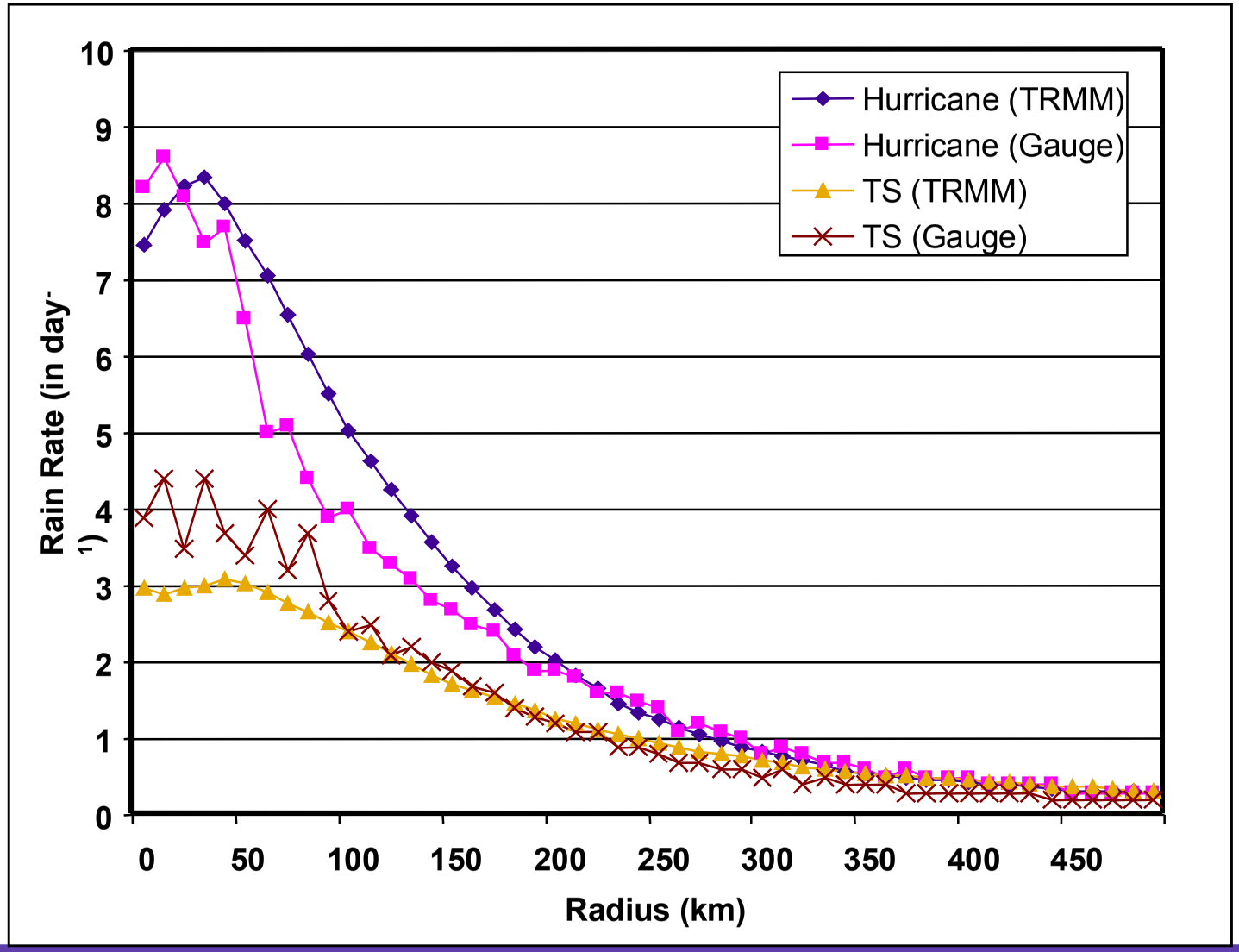
- Comparison of TMI and gauge to TC R probability distributions by Miller (1958) and Frank (1977) shows fairly good agreement.
- Comparison of TMI with recent WSR-88D and recent gauge estimates shows very good agreement.



R-CLIPER Model

(Rain Gauge vs TMI Version)

(Rain gauge data for storms within 6 h of landfall)

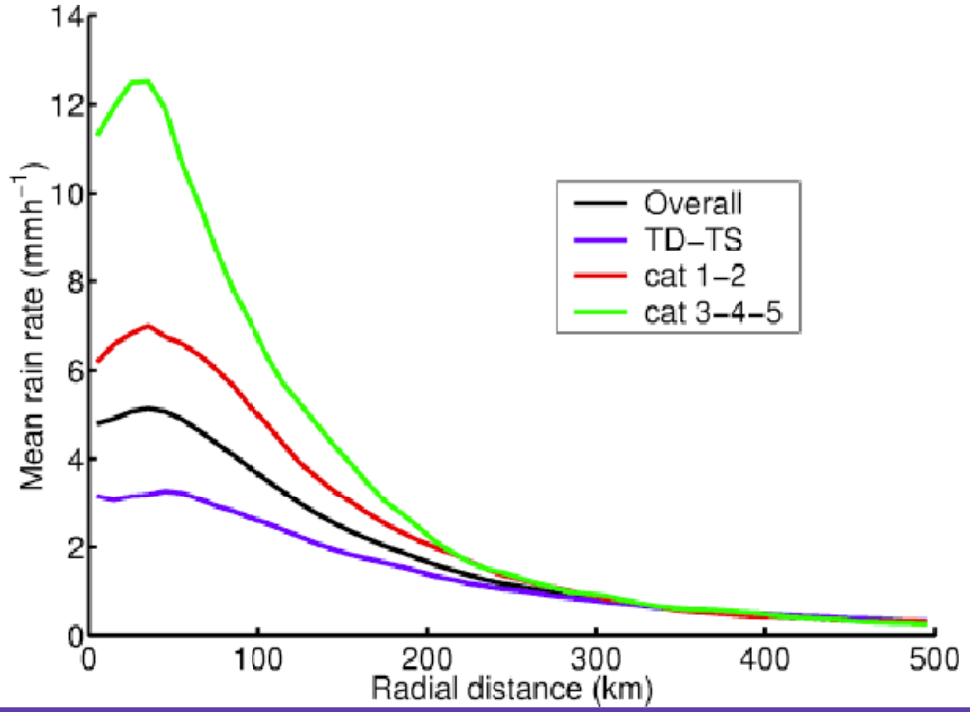


R-CLIPER Generalization using TMI Data

- Gauge data insufficient to stratify by intensity
  - Gauge R-CLIPER forecasts depend only on track
- Use TRMM data to determine rain rate versus intensity
  - Replace gauge R with TRMM R.
  - TRMM R-CLIPER depend on track and intensity.

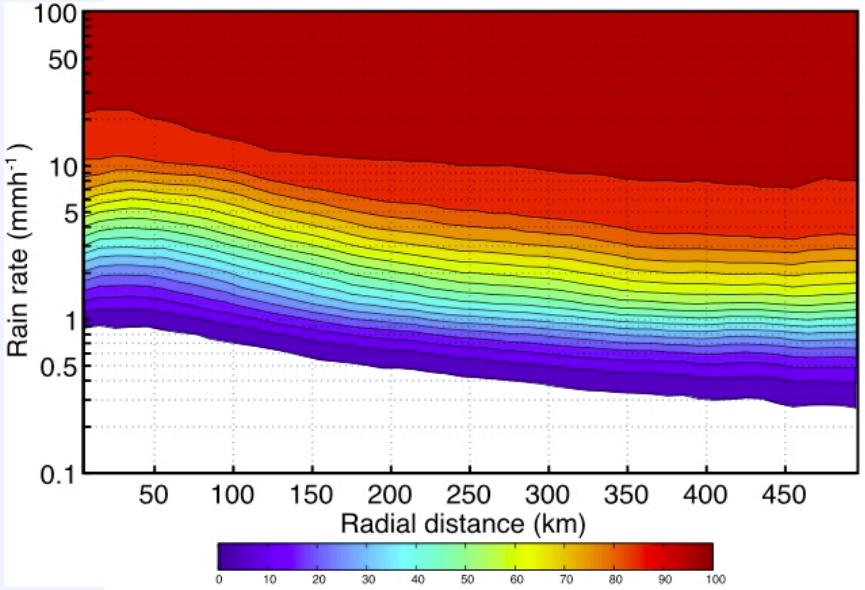
TMI R-CLIPER

- Radial distribution of R realistic, with peak ~3.9 mm h^{-1} at 50 km and a drop below 1 mm h^{-1} by 350 km.
- R near center increases with intensity from 3 mm h^{-1} for TD/TS, to 7.2 mm h^{-1} for hurricanes, to 12.5 mm h^{-1} for major hurricanes.
- Radius of maximum R decreases with storm intensity from 60 km for storms, to 45 km for hurricanes, to 28 km for major hurricanes.

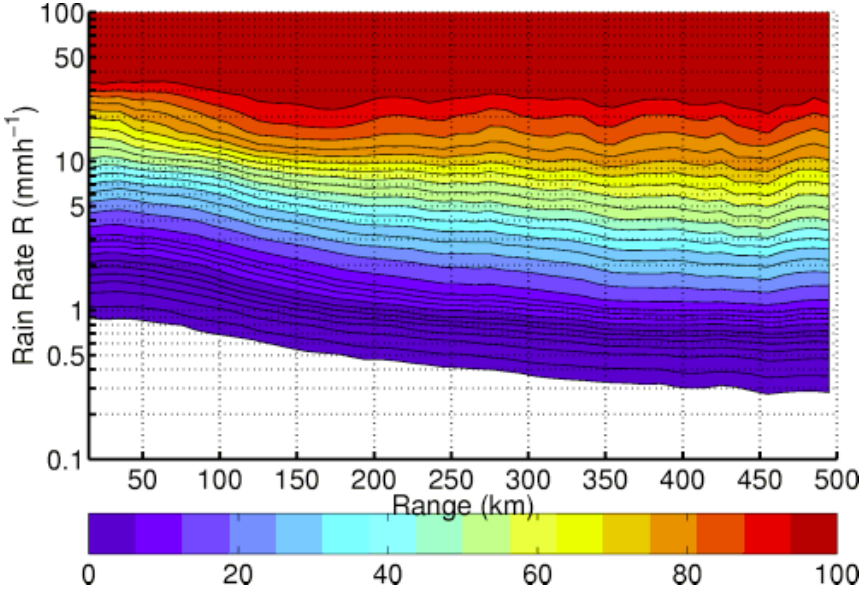


TMI R-CLIPER

- TMI has added benefit of providing P(R) with uniform spread over 500 km indicating that R>20 mm h^{-1} occurs at all ranges.
- Largest probability of R>10 mm h^{-1} occurs at ranges <100 km. Most probable R >100 km is 1 mm h^{-1}.
- RP(R) shows contribution to total R flux at ground. Indicates that R>10 mm h^{-1} contributes most to flux <250 km, >300 km majority of flux from R<5 mm h^{-1}.



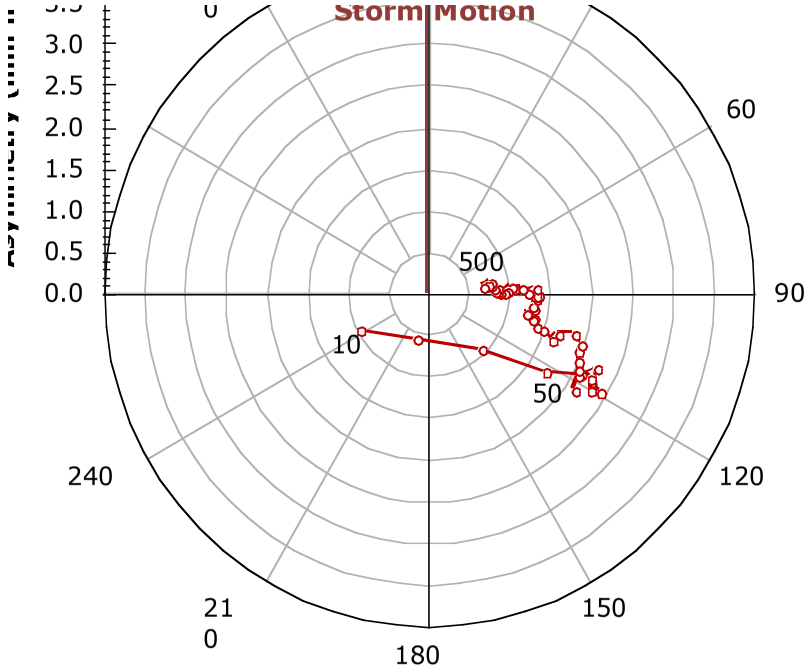
Cumulative PDF of occurence



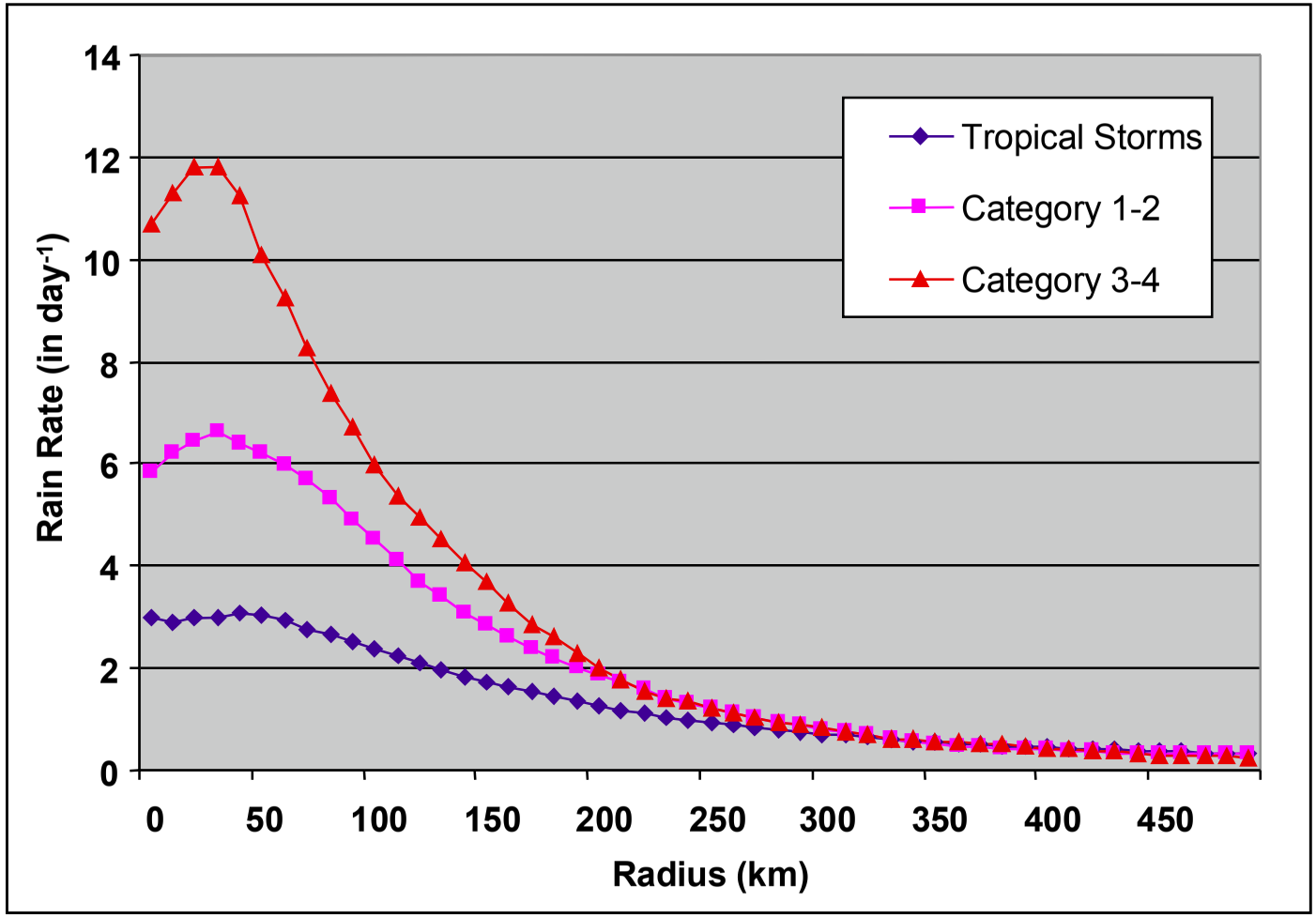
Cumulative PDF of rain flux

TMI R-CLIPER

- Also can produce asymmetry.
- Major asymmetry just outside range of maximum R. Magnitude of R asymmetry is 50% of maximum R.
- Over all basins and intensities, major asymmetry to the right of track, and slightly to the rear.



Current TRMM R-CLIPER

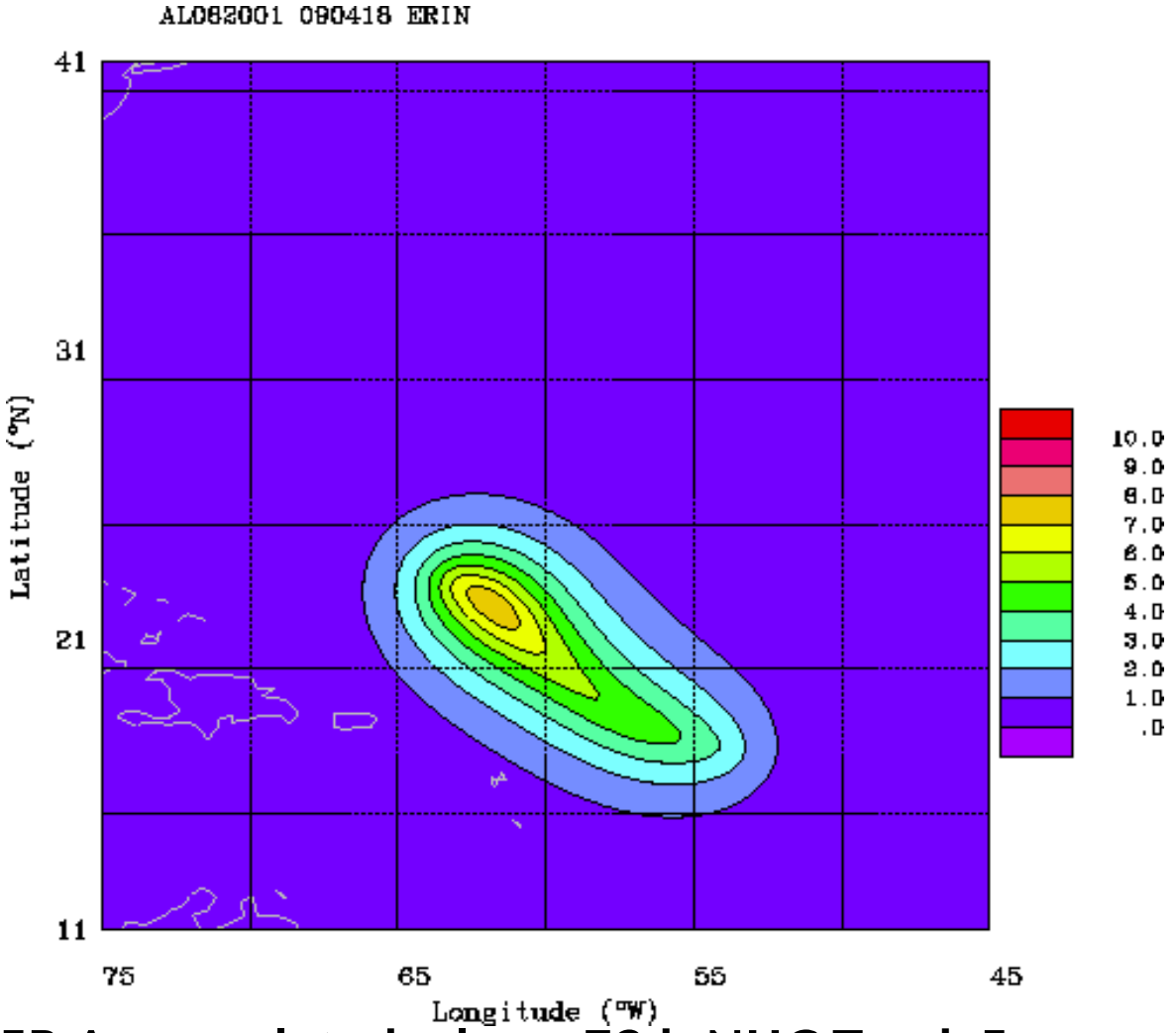


Functional Form: $R(r) = (R_0) + (R_m - R_0)(r/r_m)$ $r<r_m$

$= R_m \exp(-(r-r_m)/r_e)$ $r>r_m$

Free parameters R_0, R_m, r_m, r_e are functions of max winds

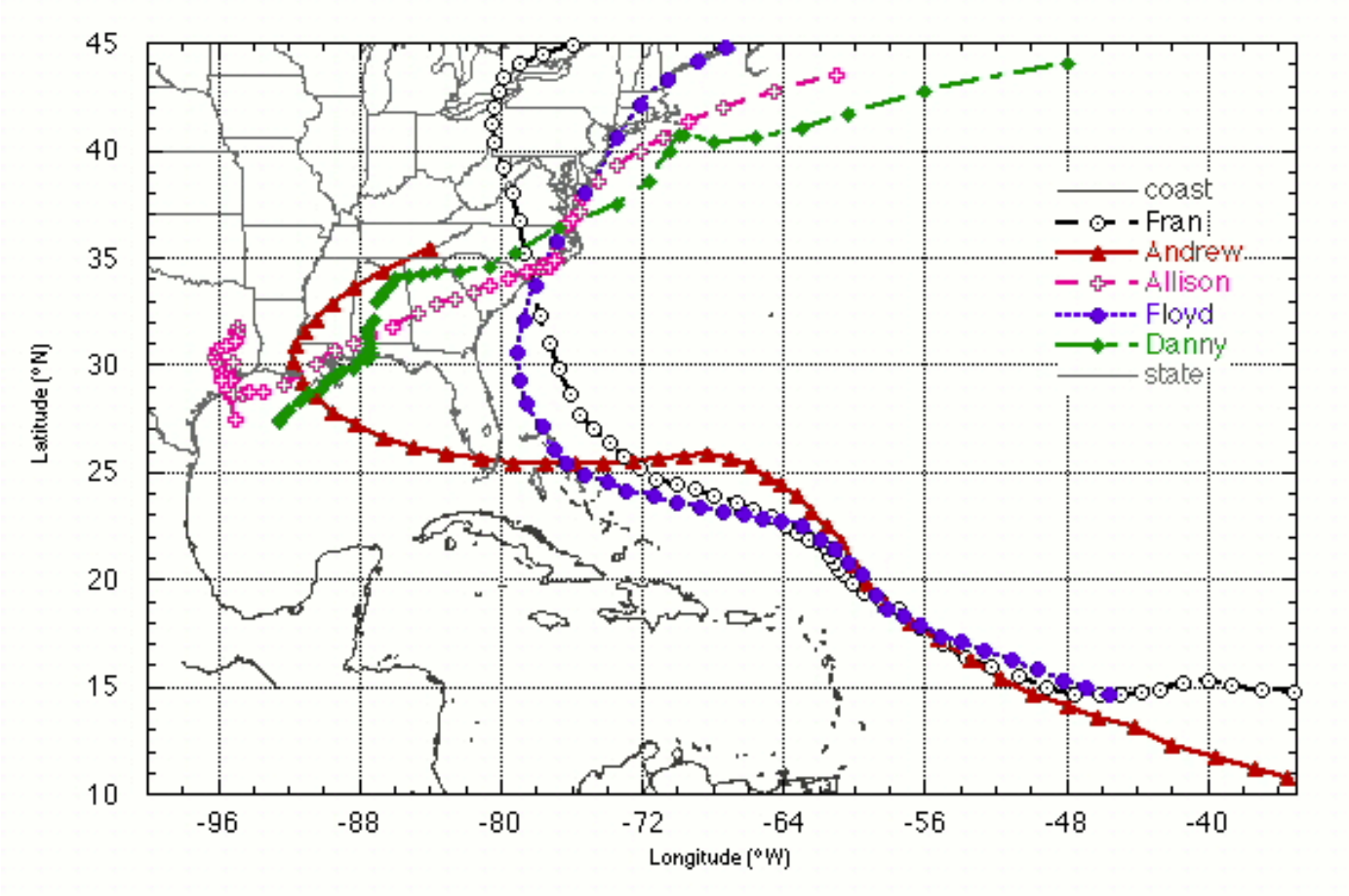
R-CLIPER Forecast for Erin 2001



R-CLIPER Accumulated along 72 h NHC Track Forecast for Erin (4 Sept. 2001 18 UTC)

DIAGNOSTICS

- Plans call for diagnostics run on 5 cases.
- Validate storm total rainfall and 24-h total rain.

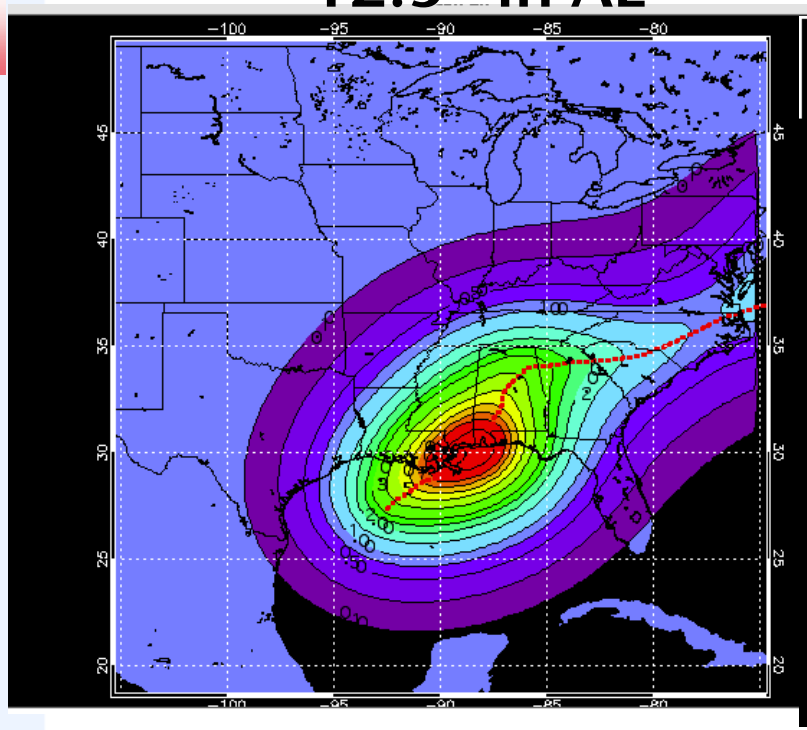


R-CLIPER for Andrew 1992 and Danny 1997

(Position and Intensity from Best Track)

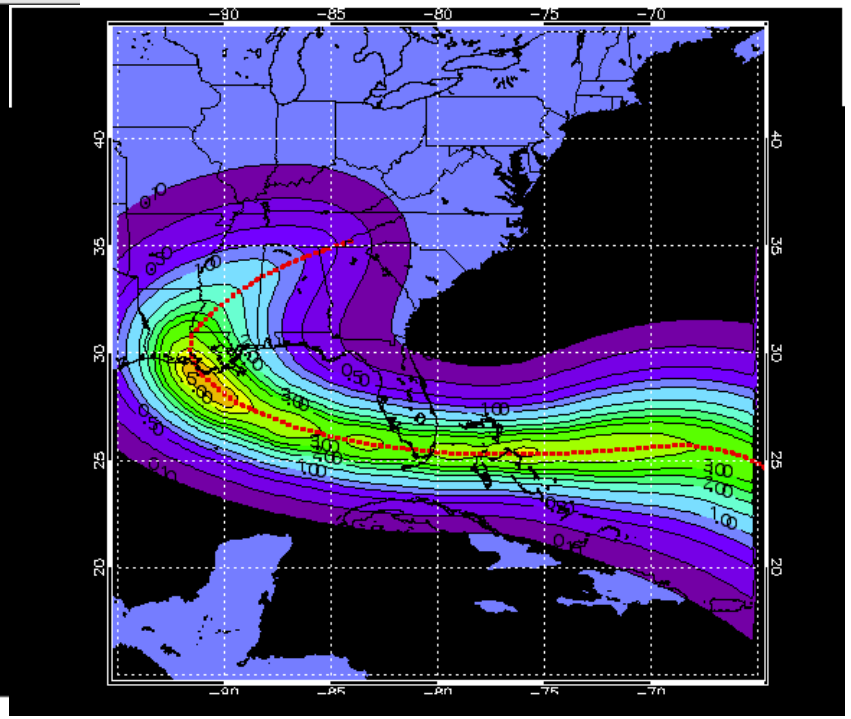
Peak storm total rain

12.3” in AL



Danny

7.0” in LA



Andrew

Where Do We Go From Here?

- R-CLIPER will provide a benchmark for evaluation of other more-general QPF techniques.
- Evaluate the R-CLIPER forecasts run on a number of past storms to provide some statistics on model performance and to develop different data products useful to hurricane specialists.
- Compare R-CLIPER forecasts with 6-h areal average rainfall amounts on a 1°X1° grid, which is what HPC uses.