The "Warm Rain" Ring Pattern and Tropical Cyclone Rapid Intensification

Haiyan Jiang[1], Margaret Kieper[1], and Edward J. Zipser[2]

[1]Florida International University

[2]University of Utah

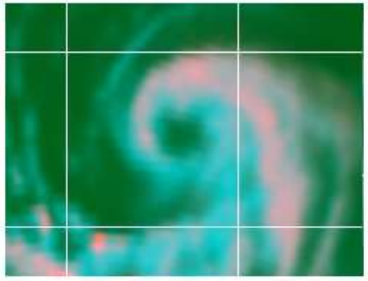
Background

- The "hot tower" **(Riehl and Malkus, 1958)** hypothesis assumes that the asymmetric deep convection in the inner core is vital for TC intensification & RI **(Kelley et al. 2004, 2005; Montgomery et al. 2006, Vigh and Schubert 2009).**
- However, it is found from 11+ years of TRMM data that statistically hot towers are neither necessary nor sufficient condition for RI, although the chance of RI increases slightly when one or more hot towers exist in the inner core **(Jiang 2012)**.
- In contrast, theoretical studies have shown that TCs intensify through the symmetric heating mechanism **(Ooyama 1969, Smith 1981, Shapiro and Willoughby 1982).**

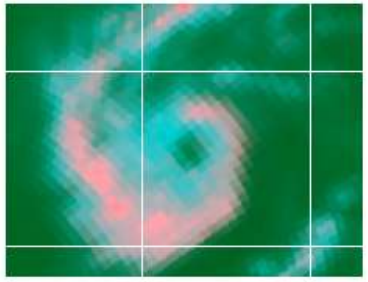
Kieper's Finding: 37 GHz cyan-color ring & RI

"Thick Ring" Pattern

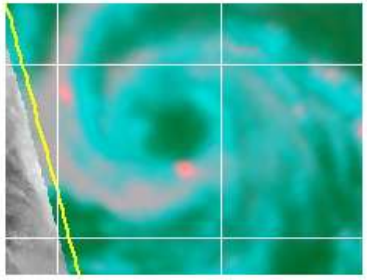
- appears in every rapidly-intensifying NATL hurricane in the study (covers 2003-2007 and does not address ERCs)
- shallow convective rainbands with a thick ring or plate appearance
- banding deep convection along the outer edge or migrating inward
- the initial appearance of the ring is always within six hours of the start of the 24h period of RI



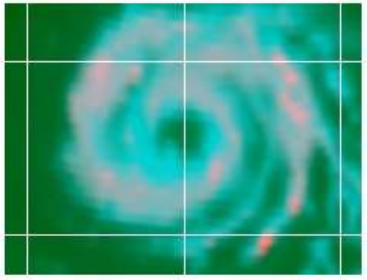
55 kt WindSat 09/04 2043Z 2004 Ivan



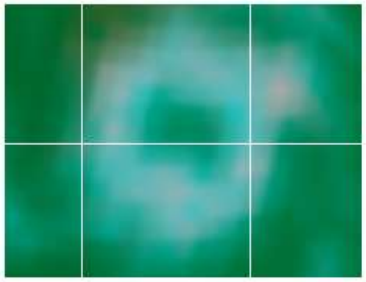
45 kt TRMM 08/14 1527Z 2004 Danielle



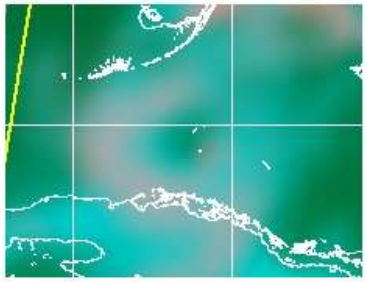
65 kt WindSat 09/16 2026Z 2006 Helene



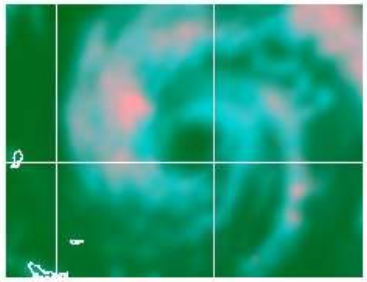
70 kt WindSat 09/13 1005Z 2006 Gordon



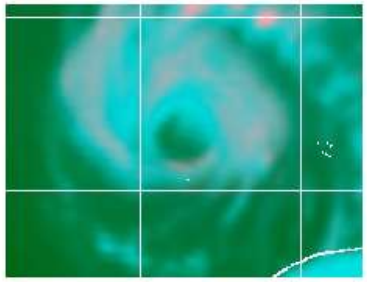
60 kt SSMI 09/07 0906Z 2003 Isabel



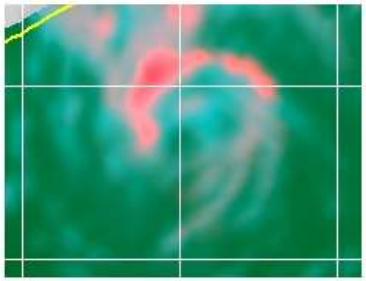
70 kt SSMIS 09/20 1323Z 2005 Rita



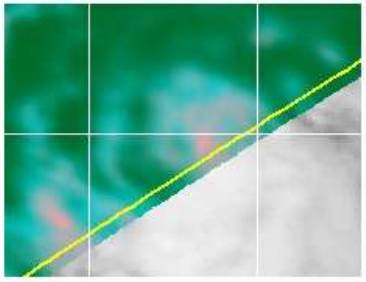
45 kt AMSR-E 09/19 1824Z 2004 Jeanne (2)



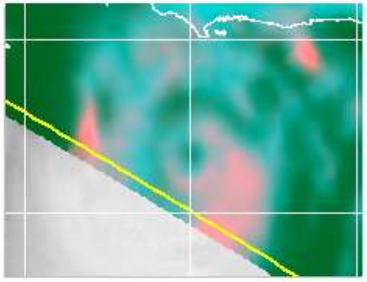
75 kt WindSat 07/18 2359Z 2005 Emily (2)



50 kt TRMM 09/09 2001Z 2006 Florence



70 kt TRMM 09/17 2317Z 2004 Karl



80 kt TRMM 07/07 0542Z 2005 Dennis

Figure Courtesy: NRL TC webpage, Margie Kieper

Forecast method developed:

The 37 GHz Ring RI Index (Kieper 2009)

- **A bright cyan (pink may be part of it) ring pattern** is identified from the microwave 37 GHz observations (NRL 37 GHz Color Product).
- Initial TC intensity is between 45 - 100 kt.
- The core of the TC is currently over water and is anticipated to remain over water for 24 hours.
- The SHIPS RI probability >= 20% (**environmental conditions are favorable**)

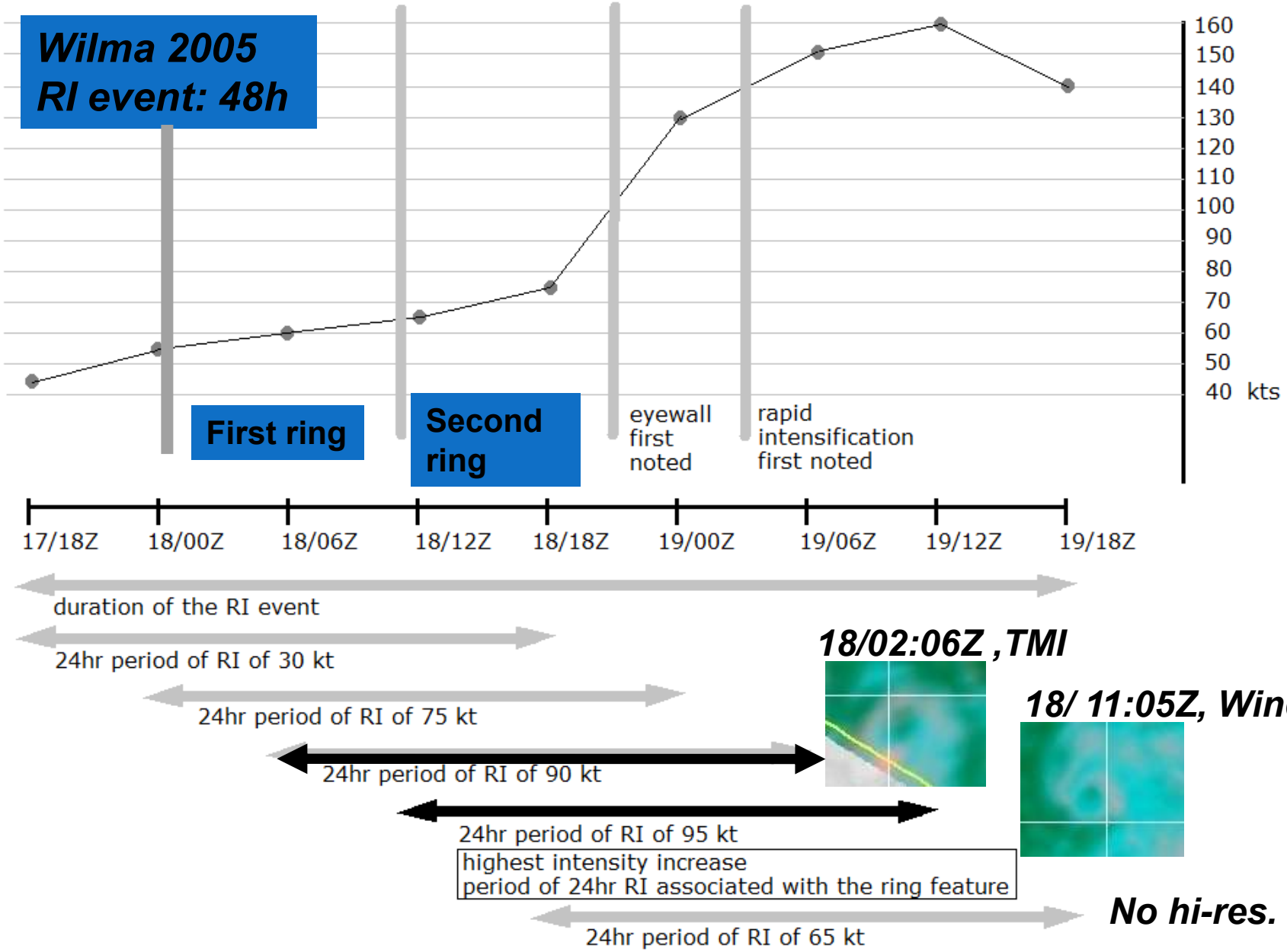
Recent results: RI event-based verification

- TMI, AMSR-E, Windsat, SSM/I, SSMIS: 2003-2007 Atlantic TCs
- Each RI event is defined as the whole RI period for each storm's each intensifying period: *more than one RI events for each storm is possible; usually includes several 24-h overlapping RI periods*
- Only use the first ring to forecast each RI event

# of total RI events	28
# of total events with a cyan ring	23 (82%)
# of correct forecasts	21
# of false alarms	2
Probability of detection (POD)	75%
False Alarm Ratio (FAR)	9%

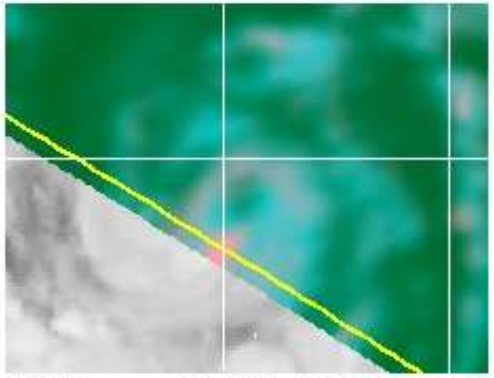
Kieper and Jiang (2012, GRL, in revision)

Wilma 2005 Case: ring is associate with the highest intensity increase



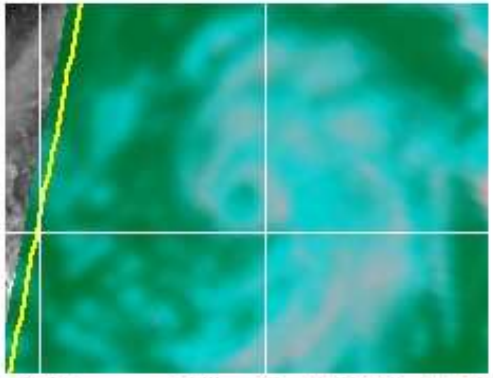
Part of the figure is from Kieper and Jiang (2012, GRL, in revision)

2005 Wilma



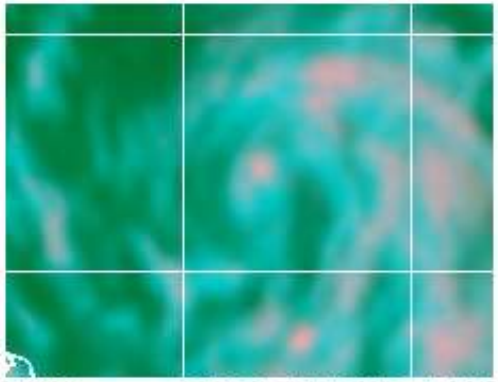
55 kt TRMM 10/18 0206Z

plate ring, banding convection on edge of ring



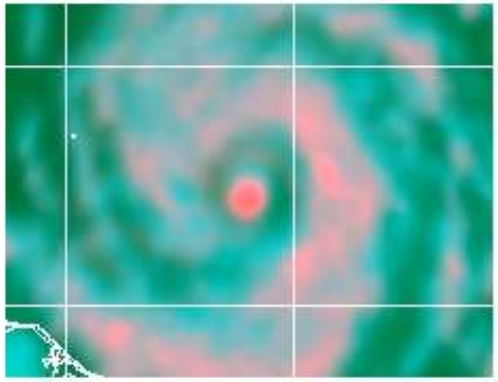
65 kt WindSat 10/18 1105Z

improved symmetry, inner diameter of ring decreasing



75 kt AMSR-E 10/18 1857Z

diameter decreasing rapidly, convection migrating inward



150 kt AMSR-E 10/19 0709Z

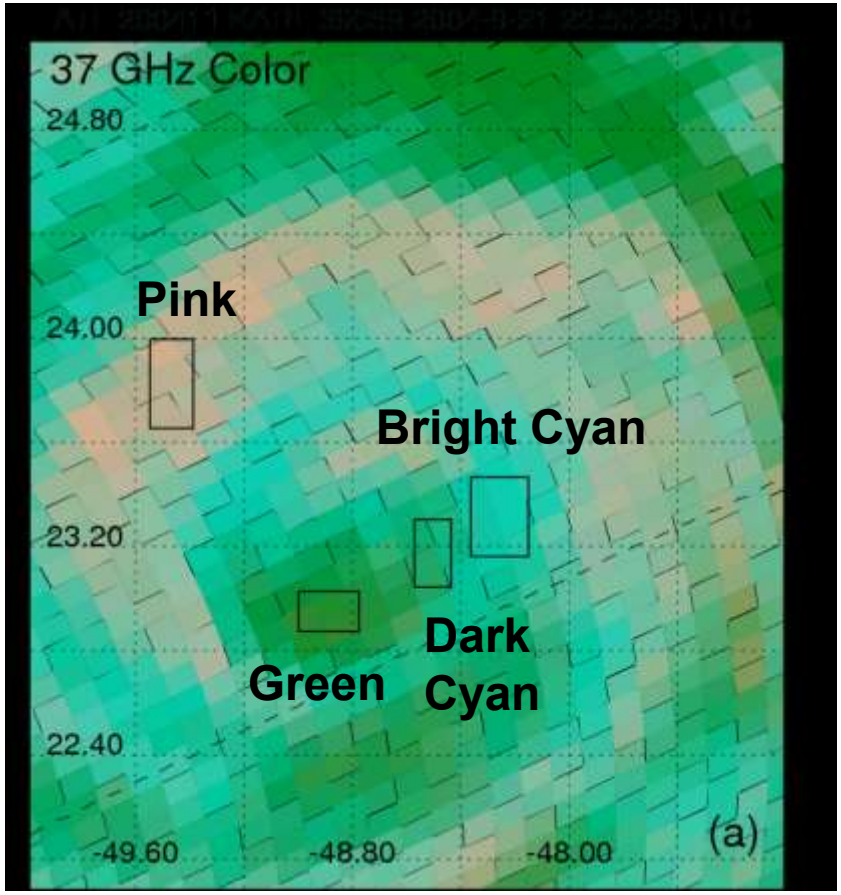
complete convective eyewall, decrease in ring diameter

Figure Courtesy: NRL TC webpage, Margie Kieper

What is in the cyan ring?

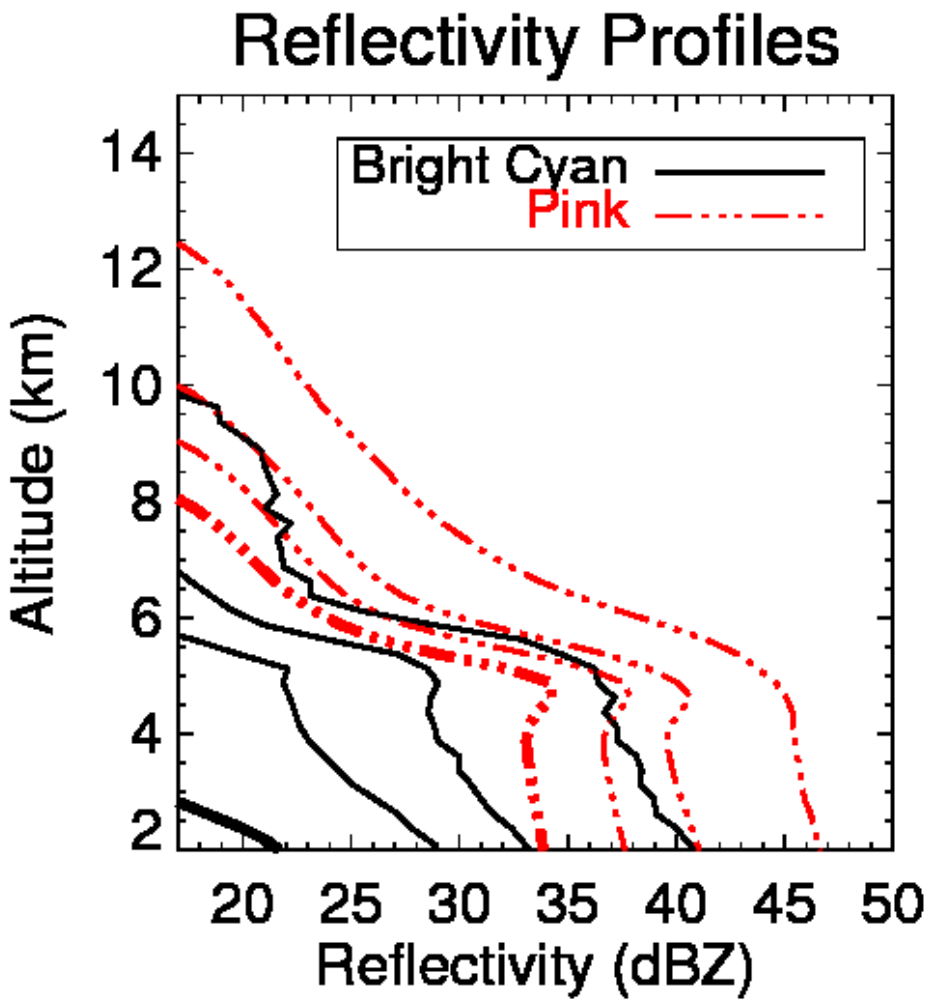
- The NRL 37 GHz color product: 1) combines 37 GHz Polarization Corrected brightness Temperature (PCT), 37 GHz vertically and horizontally polarized TB's; 2) no quantitative information; 3) pink→ deep convection, cyan→low level clouds, green→ sea surface (Lee et al. 2002).

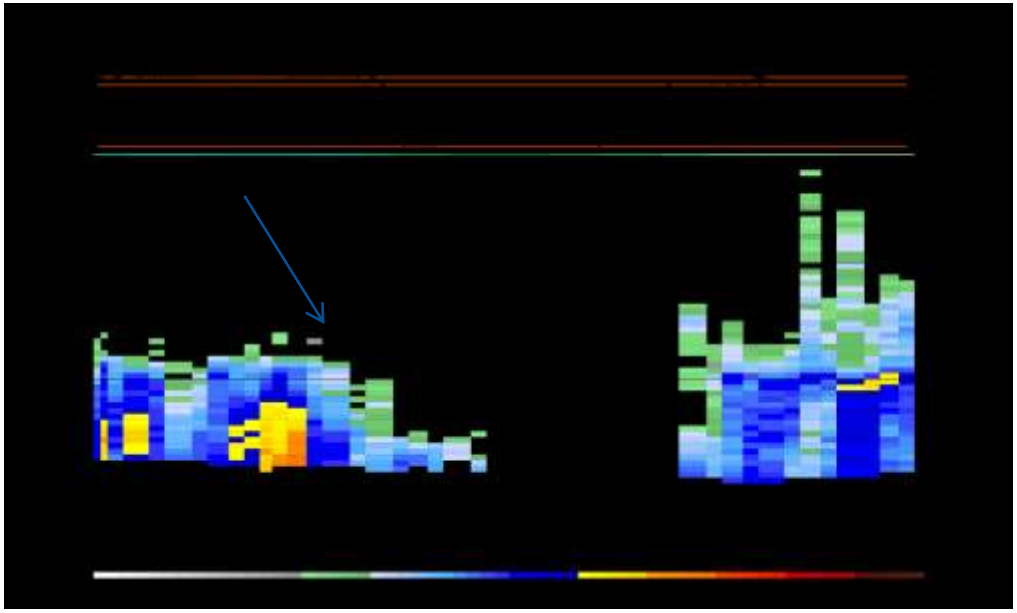
- **Method:** Using 1998-2009 TRMM TC observations over the Atlantic from the TRMM Tropical Cyclone Precipitation Feature (TCPF) database (http://tcpf.fiu.edu; Jiang et al. 2011, JAMC).
- Study the convective and rainfall properties in the cyan vs. pink region in the ring feature

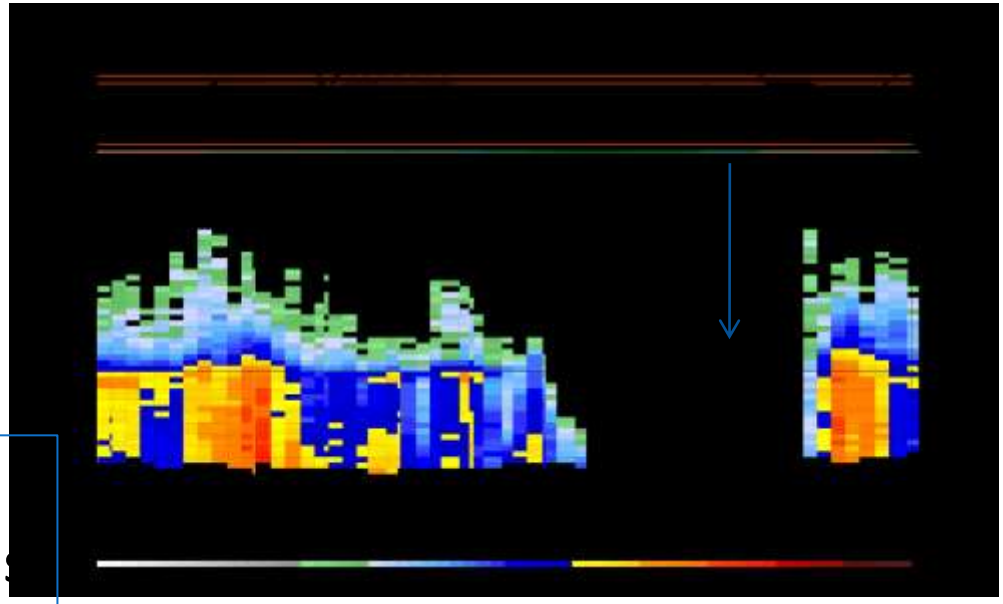


50%, 75%, 90%, and 99% of Radar Reflectivity Profiles

Vertical Cross Sections of Danielle 2004 case

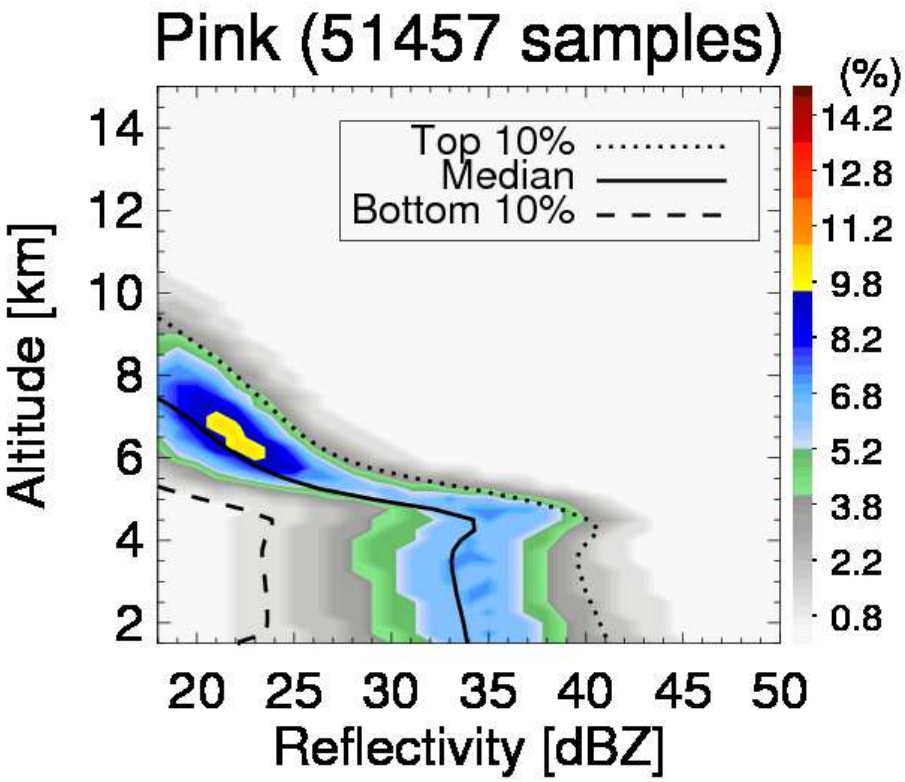


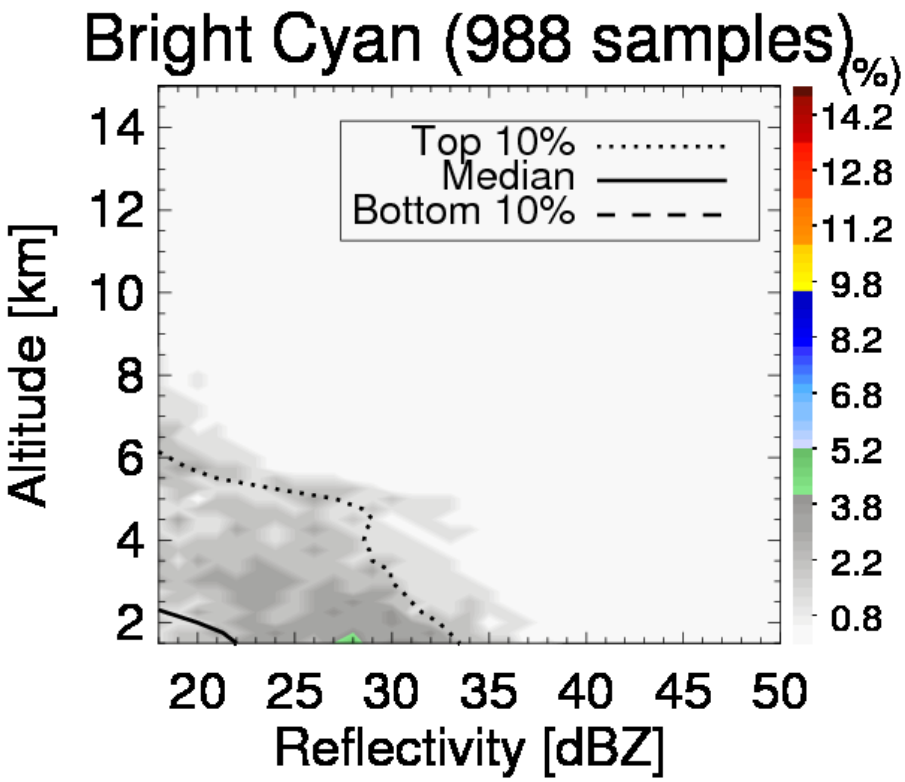


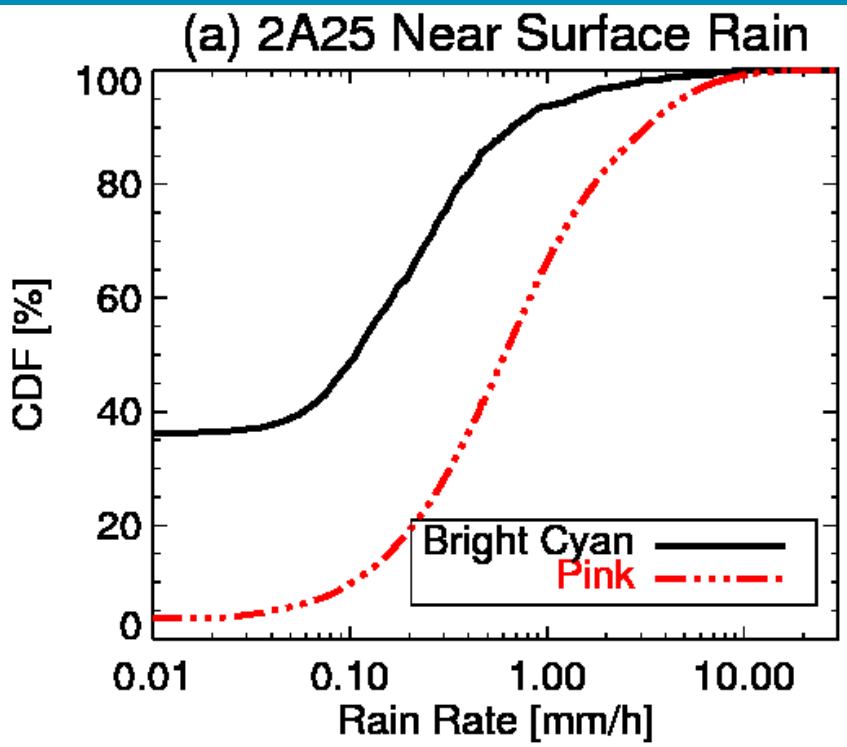


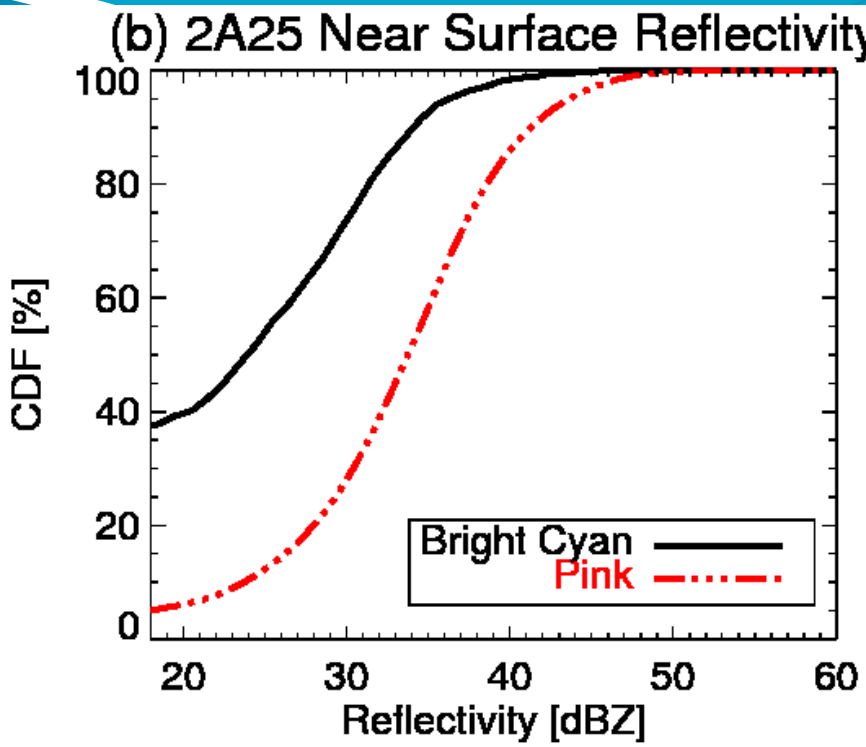
- The cyan profile slopes downward substantially; About 50% of cyan pixels can not be seen by the TRMM PR.

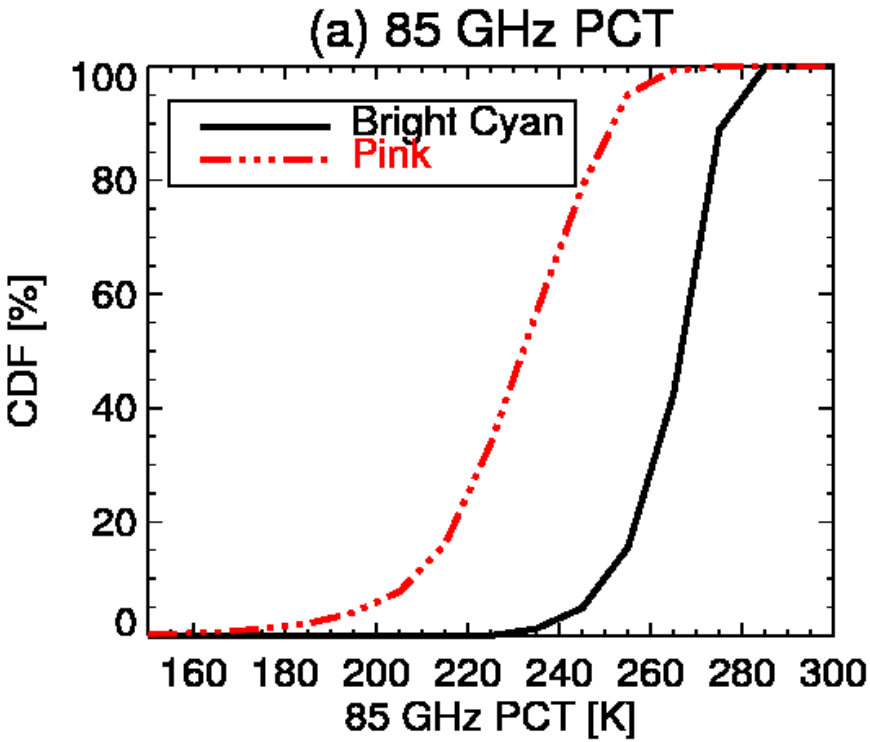
CFADs of Radar Reflectivity






(a) 2A25 Near Surface Rain
CDF [%]
Rain Rate [mm/h]
0.01
0.10
1.00
10.00
0
20
40
60
80
100
Bright Cyan
Pink


(b) 2A25 Near Surface Reflectivity
CDF [%]
Reflectivity [dBZ]
20
30
40
50
60
0
20
40
60
80
100
Bright Cyan
Pink


(a) 85 GHz PCT
CDF [%]
85 GHz PCT [K]
160
180
200
220
240
260
280
300
0
20
40
60
80
100
Bright Cyan
Pink

Summary

- High POD and low FAR can be achieved by using the 37 GHz ring RI index on top of the SHIPS RI index.
- The ring is associated with about 80-90% RI events, and about 70% of rings are associated with the highest intensity increase period. These percentages could be higher if we have continuous 37 GHz microwave observations.
- The 37 GHz channel contains unique information for low-level clouds or warm rain with LWP < 2mm (Weng and Grody 1994).
- In the cyan-color ring, there are mainly light/warm rains as seen by the TRMM radar. There could be some very light rain & low-level clouds with high LWP that couldn't be seen by the PR.
- In the future work, we'll examine the latent heating profiles in the cyan ring.

Publications

- Jiang, H., T. Yuan, E. Zipser, and J. Kaplan, 2012: An objective rapid intensification index derived from the 37 GHz microwave ring pattern around the tropical cyclone center. *Wea. Forecasting*, to be submitted.

- Yuan T., and H. Jiang, 2012: Forecasting rapid intensification of tropical cyclones in the Western North Pacific using TRMM 37 GHz microwave observations. *Wea. Forecasting*, to be submitted.

- Kieper, M., and H. Jiang, 2012: Predicting tropical cyclone rapid intensification using the 37 GHz ring pattern identified from passive microwave measurements. *Geophys. Res. Lett.*, in revision.

- Jiang, H., 2012: The relationship between tropical cyclone intensity change and the strength of inner core convection. *Mon. Wea. Rev*., **140**, 1164-1176.

- Jiang, H., C. Liu, and E. J. Zipser, 2011: A TRMM-based Tropical Cyclone Cloud and Precipitation Feature Database. *J. Appl. Meteor. Climatol.*, **50**,1255-1274.

Thanks!