Correlating convective bursts in tropical cyclones with rapid intensification using TRMM Precipitation Radar reflectivity profiles

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MOTIVATION

One of the greatest challenges in tropical cyclone forecasting is anticipating rapid intensification (RI), defined here as a 30 kt or greater increase in one-minute average winds in a period of 24 h or less. There have been several studies linking convective bursts (CBs) in tropical cyclones to RI, but RI does not occur every time there is a CB. Many of these studies theorize that CBs are a precursor to RI, but it is not clear to what extent RI is governed by external factors (e.g., vertical shear, sea-surface temperature) or internal processes (e.g., CB structure). In this study possible differences in the structure of CBs and their role in RI is investigated by comparing vertical profiles of reflectivity from the TRMM Precipitation Radar (PR) for CB cases that undergo RI compared with those CB cases that do not undergo RI. Vertical profiles of reflectivity can serve as a proxy for vertical motion within a CB, allowing for comparisons of the structure of CBs within each of these datasets.

METHODOLOGY

-GOES IR imagery of TCs in the Atlantic between 1998 and 2005 were analyzed to look for convective bursts. A burst is defined as a half-degree by half-degree or larger area of <-70° C cloud tops that persists for at least three hours using GOES IR. The center of the CB must be within 200 km of the center of the storm.

-Storms that contained CBs were divided into two datasets:

- 1. Storms that underwent RI within 24 hours after the CB
- 2. Storms that did not undergo RI

-Once these cases were established, TRMM PR reflectivity data was obtained by downloading reflectivity files from the NASA website and using a Matlab algorithm to obtain swaths of reflectivity.

- This algorithm also sorted precipitation type in convective and stratiform.
- This analysis is only performed for the convective precipitation, which made up 11.3% of all precipitation for the RI cases and 11.5% for the non-RI cases

-In addition to the CB criteria for inclusion, each case had to meet the PR criteria for inclusion, which includes:

- The center of the TC had to be within 300 km of the center of the PR swath.
- Most of the CB must be in the PR swath
- The CB must also correlate with an area of precipitation within the PR swath.

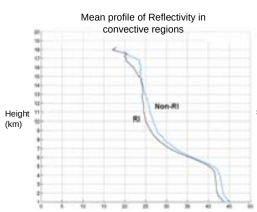
-The vertical profiles of reflectivity were then analyzed, which is shown in the results section.

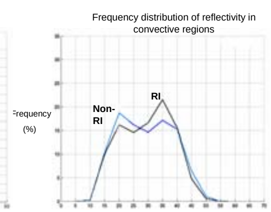
RESULTS

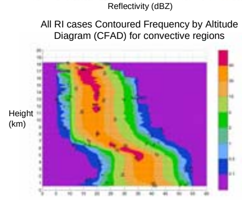
Comparisons of RI vs. non-RI not involving TRMM PR:

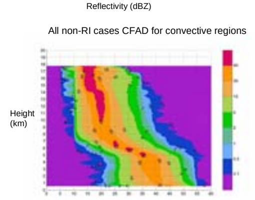
1. **% of area with cloud tops <-60C within 200 km of center**:
RI: mean: 50% st. dev: 26% - **non-RI**: mean: 34% st. dev: 15%
2. **Wind shear**:
RI: mean: 10 kt st. dev: 4 kt - **non-RI**: mean: 20 kt st. dev: 9 kt
3. **standard deviation in brightness temp (measure of symmetry)**:
RI: 12.44 - **non-RI**: 22.89

TRMM PR results - All cases







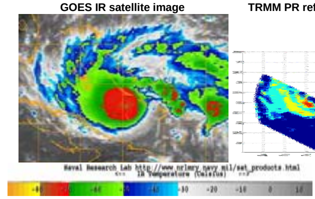


•The slope of mean reflectivity with height is more vertical for the RI cases in the middle to upper troposphere.

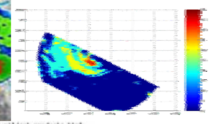
•The slope of the line representing the highest 15% of dBZ was more vertical for the RI cases than the non RI cases.

•The slope of the right 15% line is 0.5 (0.8) dBZ/km between 8-13 km for the RI (Non-RI) cases.

SATELLITE EXAMPLE



The red color represents the convective burst (the area of cloud tops that are colder than -70° C) in Tropical Storm Rita (2005).



A snapshot of the TRMM PR swath of reflectivity taken at the same time as the IR image on the left (latitudes are aligned).

In both figures, Tropical Storm Rita is at an intensity of 58 kt, 14 hours before the commencement of a period of RI. In the IR satellite image, the center of the convective burst is near 23N, 76W, the same location with the highest reflectivity shown on the PR swath.

RESULTS

Differences between the RI dataset and the non-RI dataset:

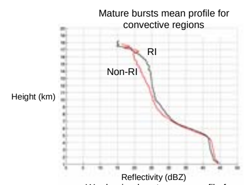
•There were 12 RI cases and 15 non-RI cases used.

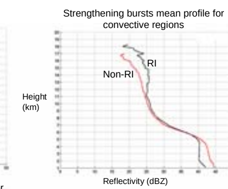
•The TCs for the RI cases averaged having a maximum sustained wind speed of 62 kt and the non-RI cases averaged 47 kt.

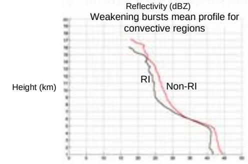
•The center of the convective burst for the RI cases averaged 61 km from the center of the TC, and the non-RI cases averaged 116 km from the center of the storm, which implies more symmetry in the RI cases.

•The center of the PR swath averaged being 123 km from the center of the TC for the RI cases and 84 km for the non-RI cases, which implies that the non-RI cases sampled the storm (and most likely the CB) better.

Cases stratified by burst stage

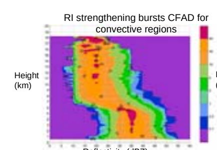


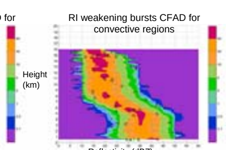


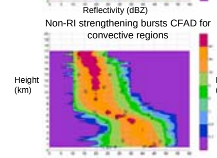


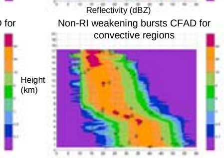
Slopes of mean dBZ

		RI	no RI
mature	5-8 km	-4.1	-4.2
	8-13 km	-0.8	-1
str	5-8 km	-3.9	-4.3
	8-13 km	-0.5	-0.8
weak	5-8 km	-4.2	-4
	8-13 km	-0.7	-0.8







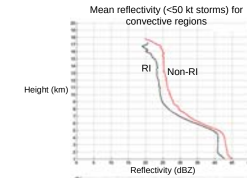


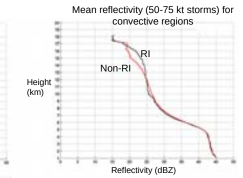
• For all of the burst stages, the mean reflectivity of the RI cases has a more vertical slope than the mean reflectivity of the non-RI cases in the middle to upper levels of the troposphere. This could mean that upward motions are stronger for the RI cases.

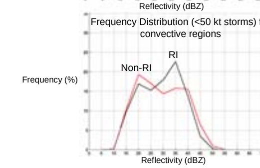
• When comparing the burst stages, strengthening bursts have the largest difference in slope between RI and non-RI in the middle to upper levels of the troposphere, while weakening bursts have almost no difference.

RESULTS

Cases stratified by storm intensity

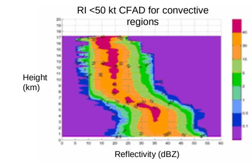


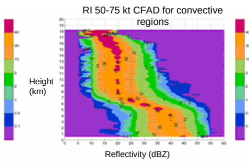


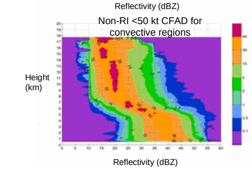


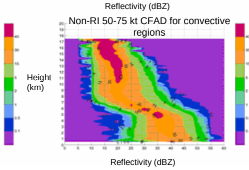
Slopes of mean dBZ

		RI	no RI
<50 kt	5-8 km	-4.3	-3.8
	8-13 km	-0.6	-0.9
50-75 kt	5-8 km	-4.2	-4.1
	8-13 km	-0.8	-1









• Again, the slopes of reflectivity are more vertical for the RI cases in the middle to upper levels of the troposphere.

• The diagram with the most positive slope in that layer is the 50-75 kt RI cases, and the diagram with the most negative slope is the <50 kt non-RI cases.

CONCLUSIONS

- Most RI cases have a more vertical slope of mean reflectivity in the middle to upper levels of the troposphere, which could mean that the CBs in the RI cases had a higher upward vertical velocity in that layer.
- The RI cases did not have higher reflectivity on average than the non-RI cases; however, the mature and strengthening bursts did show a slightly higher reflectivity for the RI cases over the non-RI cases.
- For the entire integrated column, most RI cases displayed a higher frequency of 35 dBZ reflectivity and most non-RI cases displayed a higher frequency of 20 dBZ reflectivity.
- The centers of the convective bursts are closer to the centers of the storms for the RI cases, which implies that storms about to undergo RI are more symmetric than storms that are not about to undergo RI.
- To confirm the symmetry argument, the TCs that are about to undergo RI have a higher percentage of colder cloud tops within 200 km of the center and have lower wind shear environments. Also, the standard deviation of brightness temperature was greater for the non-RI cases.
- The sample size may not be large enough to prove statistical significance (statistical tests still need to be performed).
- It is possible that environmental factors such as wind shear and SST play a larger role in rapid intensification than the convective burst itself.

FUTURE WORK

- Include more storms in sample; expand to other basins
- Test for statistical significance
- Analyze stratiform precipitation differences
- Look at SST, RH, and other parameters
- Compare TRMM with aircraft, high-resolution simulations where applicable
- Work with new or proposed platforms that will provide measurements of vertical velocities (e.g., NEXRAD in space)