Necessary Conditions for Rapid Intensification as Derived from 11 Years of TRMM Tropical Cyclone Precipitation Feature (TCPF)

Haoyian Jiang (haoyian.jiang@fiu.edu) and Ellen M. Ramirez, Florida International University, University of Utah

Motivation
- However, no comprehensive comparisons have been made to distinguish the relative importance of total rainfall and deep convection in the inner core to TC intensity change, especially rapid intensification (RI).

Objectives of This Study
- What’s the necessary condition for RI in terms of inner core properties? Is especially intense convection, such as how towers, necessary? Sufficient?
- Quantitative comparison of rainfall and convective properties derived from one single satellite platform – TRMM in terms of their relationships to TC intensity changes: Rapidly Intensifying (RI), Slowly Intensifying (SI), Neutral (N), and Weakening (W).
- Convective properties: radar dBZ profile, 85/37 GHz PCT (Spencer et al. 1989, Cecil et al. 2002), and lightning.
- Rainfall properties: rain rate, raining area, volumetric rain.

Data
- Collected TRMM observations (PR, TMI, LIS, & VIRS) in TCs between 1998-2008; only considering observations over ocean.
- Three sub-regions are subjectively separated, i.e., inner core (IC), inner rainband (IB), and outer rainband (OB) by following Cecil et al. (2002).
- Only parameters within the inner core region are analyzed (except for the lightning analysis).

Passive Microwave Convective Properties: 85/37 GHz PCTs

CFADS of Maximum Radar Reflectivity
- RI storms do not necessarily have the strongest convection in the inner core.
- Necessary conditions for RI: min 85 PCT < ~235K; min 37 GHz PCT < ~275K.
- The distribution is highly concentrated around the median profile for RI storms, but spreads out for other intensity change categories.
- About 50% of RI storms have hot towers (defined as 20 dBZ height > ~14 km) in the inner core, while the other 50% do not. Other categories have lower % of hot towers.

Top 10%, Median, and Bottom 10% of Vertical Profiles of Maximum Radar Reflectivity
- The largest distinction is the bottom 10th percentile, where RI storms have much stronger dBZ profiles than SI, N, and W storms.

TRMM Radar Rainfall Properties
- RI storms always have the largest raining area & volumetric rain in the inner core, followed by SI, W, and N storms.
- Rain rate in the inner core is not well related to TC intensity change.
- Necessary conditions for RI: inner core raining area > ~4,000 km²; volumetric rain > ~5,000 mm/h km²; rain rate > ~2 mm/h.

Summary
- RI storms do not necessarily have stronger convective intensity in the inner core than storms in other intensity change stages. Extremely intense convection (e.g., hot towers) is neither necessary nor sufficient condition for RI, although % of hot towers is the highest in RI storms.
- Instead, this study found that larger raining area and volumetric rain in the inner core are necessary conditions for RI. Moderate convective intensity is also a necessary condition.
- Symmetric, well-organized inner core precipitation structure is the key for RI.
- Total lightning (including in-cloud, intra-cloud, and cloud-to-ground) activities in the inner core (outer rainband) has a negative (positive) relationship with storm intensity change.

Acknowledgements: This work is partially from Ellen Ramirez’s MS thesis, Thanks to Ed Zipser and Dow Cecil for guidance and discussions. This research is supported by the NASA HSRP program - Kenichi Kato (NSF’s Office of Science).

Box and Whisker Plots of Reflectivity Parameters
- Necessary conditions for RI:
  1. Max. near sfc dBZ > ~40 dBZ (~20-25 dBZ for SI, N, W storms)
  2. Max. 20 dBZ height > ~8 km (~2-4 km for SI, N, W storms)
  3. Max. 30 dBZ height > ~6 km (> 0 km for SI, N, W storms)
  4. Max. 40 dBZ height > ~4 km (> 0 km for SI, N, W storms)

Consistent with the Warm Rain Ring Feature Associated with RI
- RI storms have the lowest % of TC orbits having at least one flash in the inner core, while the weakening storms have the highest %.
- RI storms have the highest % of TC orbits with lightning in the outer rainband region, while the weakening storms have the lowest %.

Flash Density (per Raining Area)

% of TC Orbits with Lightning