Topic 1: Tropical Cyclone Structure and Intensity Change

Topic 1.2: Inner-core Impacts

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Here we are referring to inner core structure only:

1. Structure and structural changes in the inner core that lead to intensity change;
2. Structural changes in the inner core that may or may not lead to/impact intensity change, but are simply structural changes.
We covered: peer-reviewed (major) work from 2006-2010

We left out: (covered by other rapporteur reports)
  • direct environmental forcing on inner-core changes
  • boundary layer and air-sea interactions
  • genesis and structural/intensity changes during “genesis”

Note: difficult to draw the line
may be overlap with other reports
maybe something got left out as a result...
Structure of this presentation

A. Factors that impact “normal” intensification
B. Factors that impact “rapid” intensification
C. Structure changes – no impact on intensity
D. Summary and Future Directions
A. Garden-Variety Intensification

Summary of factors that affect “normal” intensification

1. Impact on the primary circulation
2. Barotropic Instability
3. Intense asymmetric convection and helicity
4. Re-intensification after landfall
The primary circulation – idealised vortices - heating

- The efficiency of the heating increases with increasing intensity.
- Increases rapidly at an intensity of 35 - 40 m s\(^{-1}\).

Sensitivity to location of heating:
- **Outside RMW** - inefficient
- **Inside RMW** - extremely efficient

(Vigh and Schubert 2009) (Pendergrass and Willoughby 2009)
2 Barotropic instability - idealised

Diabatic heating in the eye wall generates a ring of high potential vorticity (PV) with strong gradients at the edges. The ring becomes barotropically unstable and breaks down into mesovortices that eventually rearrange the PV into a monopole at the center of the eye.

- Thin rings likely to break down into long-lived mesovortices before further merging into the monopole.
- Thick rings reached monopole state more slowly

170 simulations:

Most likely end state was monopole of PV in center.

- End state - increase in intensity

(Hendricks et al. 2009) 

(Rozoff et al. 2009)
3 Intense asymmetric convection and helicity

**Weak/developing TCs**

![Image of a hurricane with radar data]

- Extreme helicity in the BL of TCs in high environmental vertical wind shear:
  - Development of super-cell-like asymmetric convection
  - Maintain TC intensity against shear

**Mature TCs**

- **On the other hand ...**

  - Poor organisation of even very intense “hot tower” convection can lead to weakening of a strong/mature TC

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(Molinari and Vollaro 2008; 2010)

(Cecil 2010)
Simulations showed that redevelopment of eye and eyewall features were supported by large heat fluxes from hot, wet sandy soil (Emanuel et al. 2008)
B. Rapid Intensification

Summary of factors that affect “rapid” intensity

1. Eye-eyewall mixing
2. Intense convection
3. Eyewall contraction
1 Eye-eyewall mixing

**Absolute Vorticity**
Storm-relative asymmetric wind vectors

![Absolute Vorticity Diagram](image)

**“Super Intensity”**

Turning off the coefficient of heat exchange turns off the super-intensity mechanism...

Prevents the build up of high $\theta_e$ air in the eye.

(Bryan and Rotunno 2009)


Mesovortices in the eye wall $\rightarrow$ eye-to-eyewall boundary layer flow of high $\theta_e$ air. Helps to maintain or intensify the convection in the eye wall.

(Braun et al. 2006; Cram et al. 2007)
Convection

Simulation of Hurricane Dennis (2005):

Presents a more traditional view that convection contributes to the overall mass flux.

- The greater the mass flux within a small radius of the center (a.k.a. organisation), the greater the intensification - RI

(Rogers 2010)
C. Inner core structure

Summary of factors that affect inner core structure

1. Eye formation
2. Secondary eyewall formation – moat regions
3. Tropical cyclone spiral bands
4. Hub clouds
5. Slope of the radius of maximum winds
Eye formation was a feature of strongly diabatic vortices.

(Wirth and Dunkerton 2009)
Hub cloud formation is a function of eye size

- small eye - uniform distribution of subsidence across the eye.
- large eye - twice the subsidence on the edges than in the middle

(Schubert et al. 2007)
**Common Theme** running throughout this presentation and throughout the report is that processes associated with deep convection are important for inner-core intensity and structure change.

Two factors:

The level of maturity of the TC; and

The *nature* of the convection - "very intense and hot", or "deep but ordinary" - *and its organisation* - symmetric or asymmetric and inside or outside the eyewall - appears to be important for the type of response of the inner core:
**Summary**

**Weak TC:**
Convection deep/hot and well organised → normal intensification
Convection hot and asymmetric → maintain against a detrimental environment

**Strong/Mature TC:**
Convection hot and asymmetric → weakening
Convection deep/hot and becoming more organised → RI
Convection deep/hot and symmetric (mesovortices) → SI

**There is a consistent pattern developing here for both observations and simulations**
Understanding the role of convection and convective organisation in any type of intensity change, whether intensification and weakening or rapid intensification. Some of the processes that need to be understood include, but are not limited to:

- the physical characteristics of the eye-eyewall boundary layer in developing very intense (hot tower) eyewall convection;
- secondary eyewall formation;
- formation and changing structure of the eye;
- the triggers for, and impacts of intense asymmetric convection;
- the impacts of organisation of convection around the eyewall.

Future Directions ... Research in
Thankyou !!!