From Concentric Eyewall to Annular Hurricane:

An Idealized Numerical Study with WRF model

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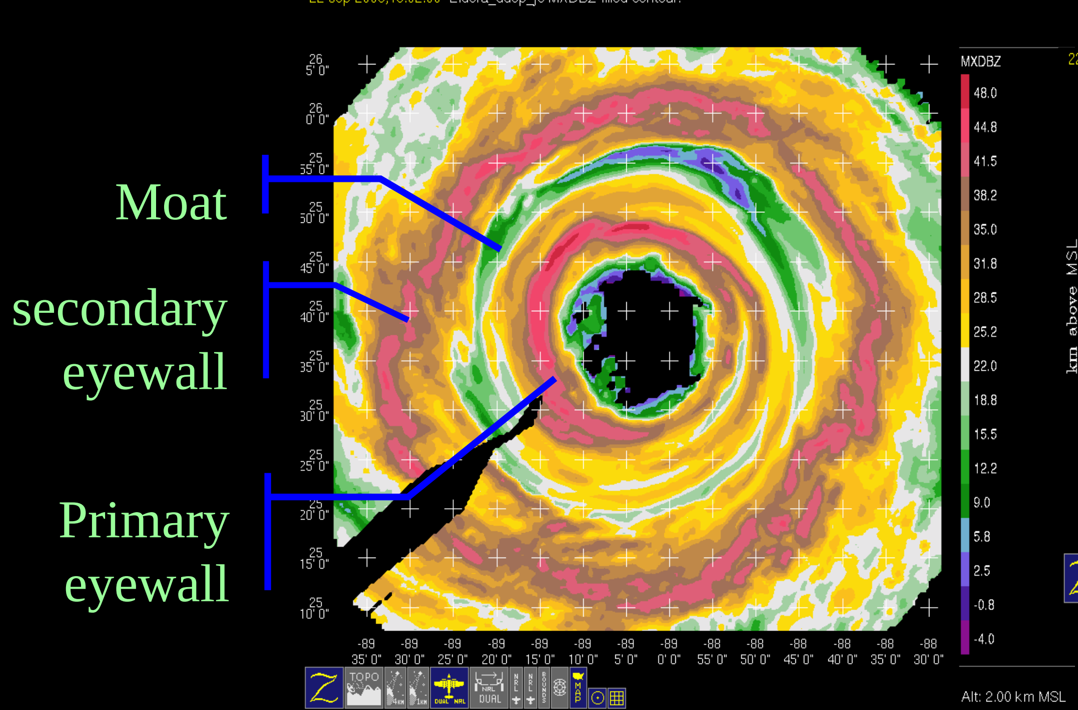
Outline

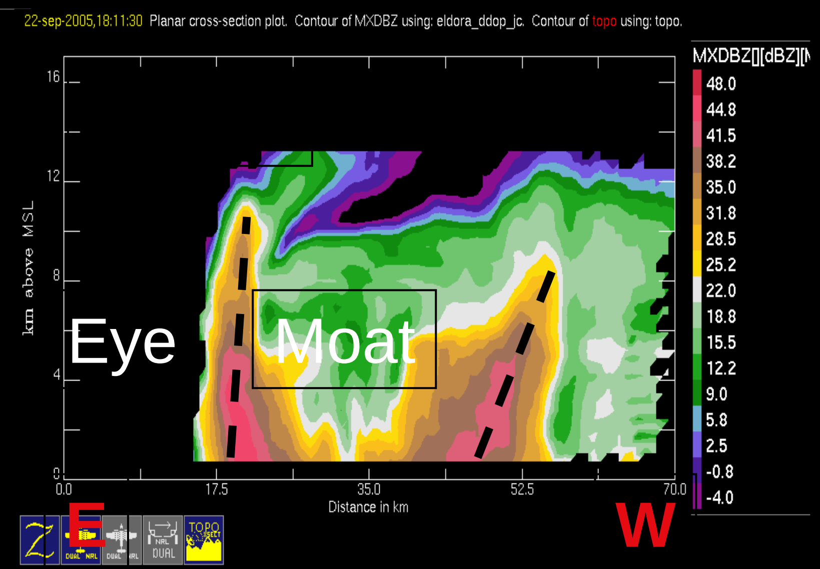
1. Introduction
   --Concentric eyewall
   --Annular hurricane
2. Experiment Design
3. Model Results
4. Summary and Discussion

Concentric eyewall

Willoughby et al (1982)

- Hurricane Rita (2005) Radar reflectivity (Houze and Smull 2008)





- Common in intense hurricanes
- Two convective rings with local tangential wind maximum
- Large intensity fluctuation during eyewall replacement
- Larger tilt of the outer eyewall

Concentric eyewall in numerical model

❑ MM5

Houze et al (2007)

--Hurricane Rita (2005)

❑ RAMS (Regional Atmospheric Modeling System)

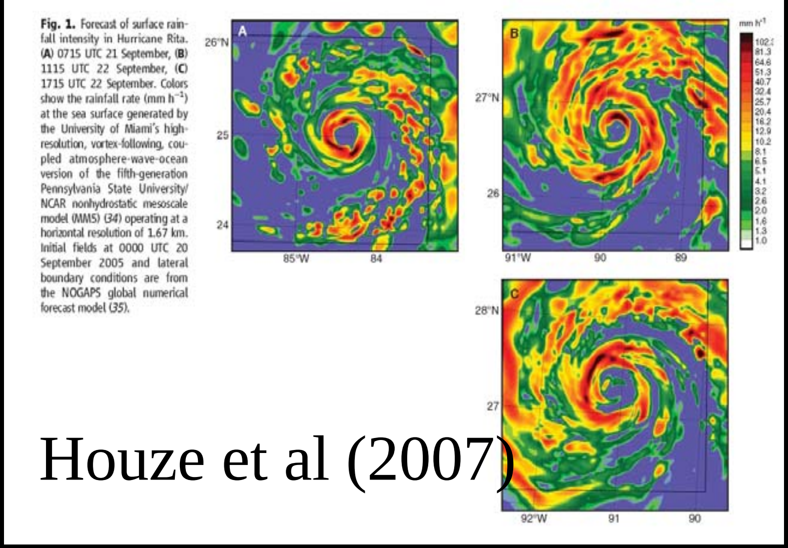
Terwey and Montgomery (2008)

--Idealized numerical study

❑ TCM4

Wang (2006)

--Idealized numerical study



Houze et al (2007)

❑ WRF?

Corbosiero et al (2008): no eyewall replacement and intensity fluctuation

Annular Hurricanes

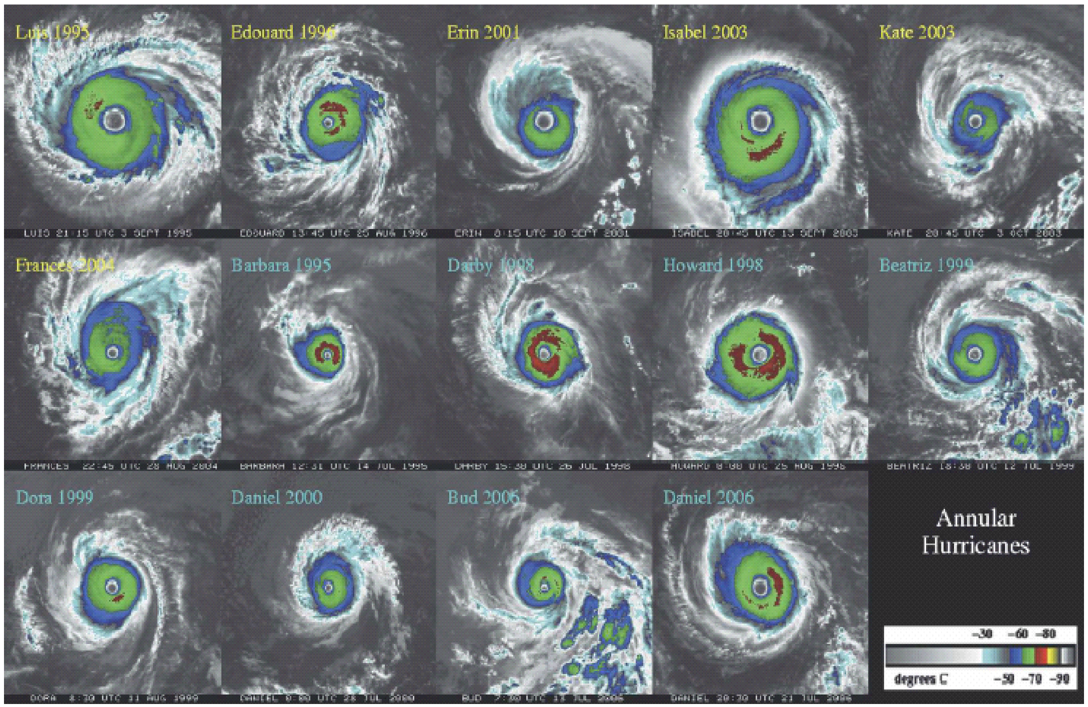


FIG. 2. Color-enhanced GOES IR satellite imagery of the 14 annular hurricane cases at or near peak visual annular characteristics. Storm names, dates, and times are given at the bottom of each individual image panel. In addition, storm names and years are listed in the upper left of each image panel with North Atlantic and eastern–central North Pacific storm names indicated by yellow and cyan text, respectively.

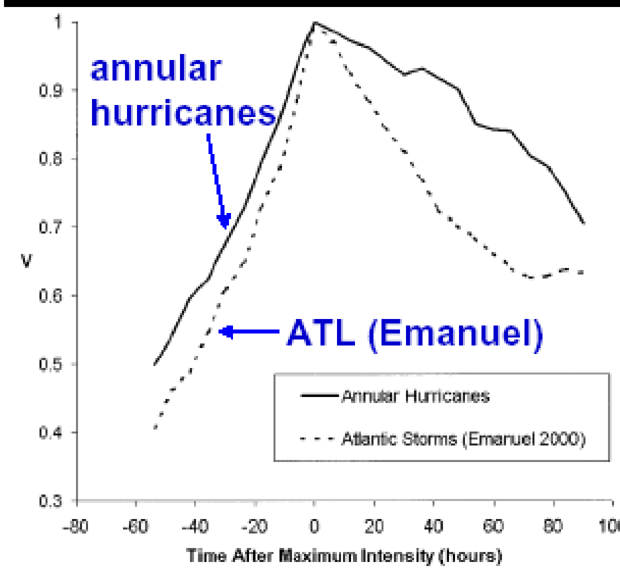
"Doughnut", "truck tire"

Features

a) large eye,
b) thick eyewall,
c) Relatively fewer rainbands,
d) high intensity (~108 knots)

Knaff et al 2003, 2008

Composite time series of TC intensity change (normalized by peak intensity)



Formation of annular hurricane

Knaff et al (2003) :

Typical environment conditions:

1)Weak easterly or southeasterly vertical shear easterly flow

2)Rrelative cold temperatures at 200 hPa

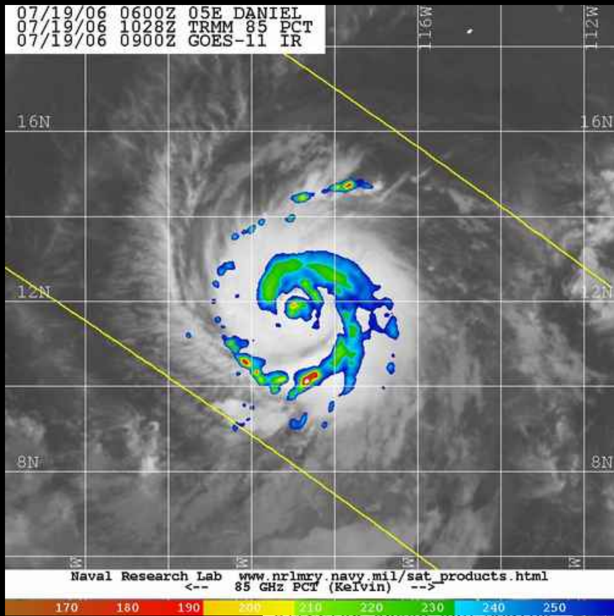
3) 25.4-28.5 SST

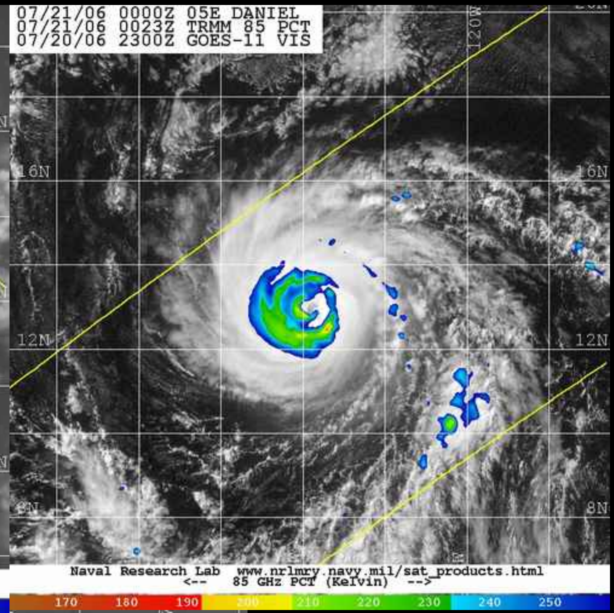
4) A lack of 200 hPa relative eddy flux convergence due to environmental interaction

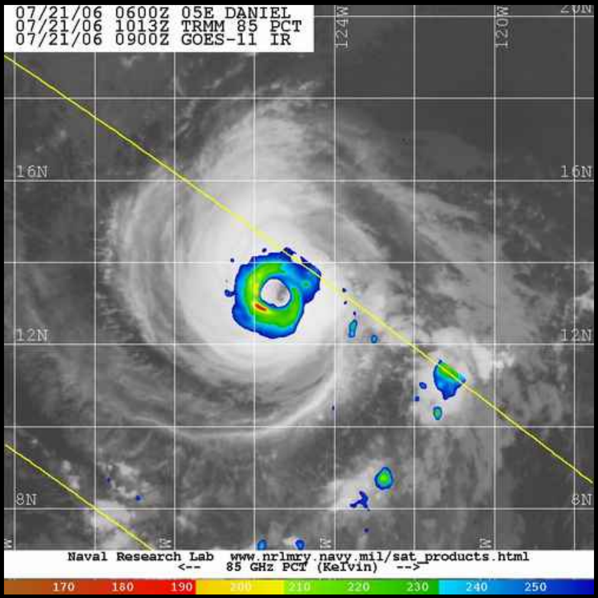
Wang (2008):

A result of several cycles of inward contraction of the inner spiral rainband

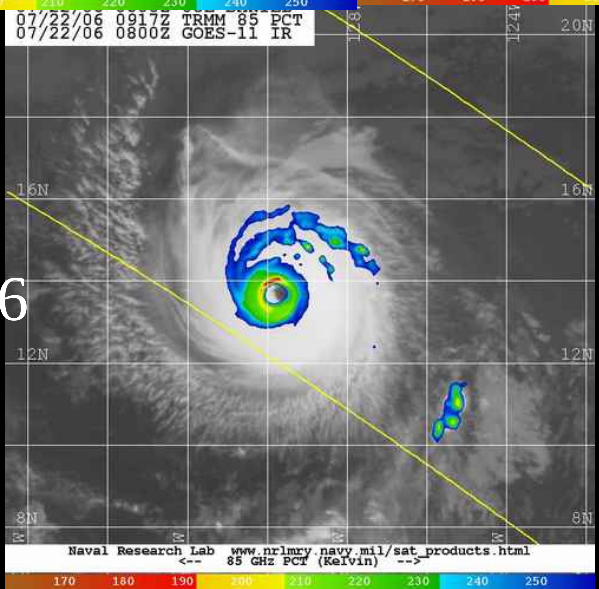
From Concentric eyewall to annular hurricane

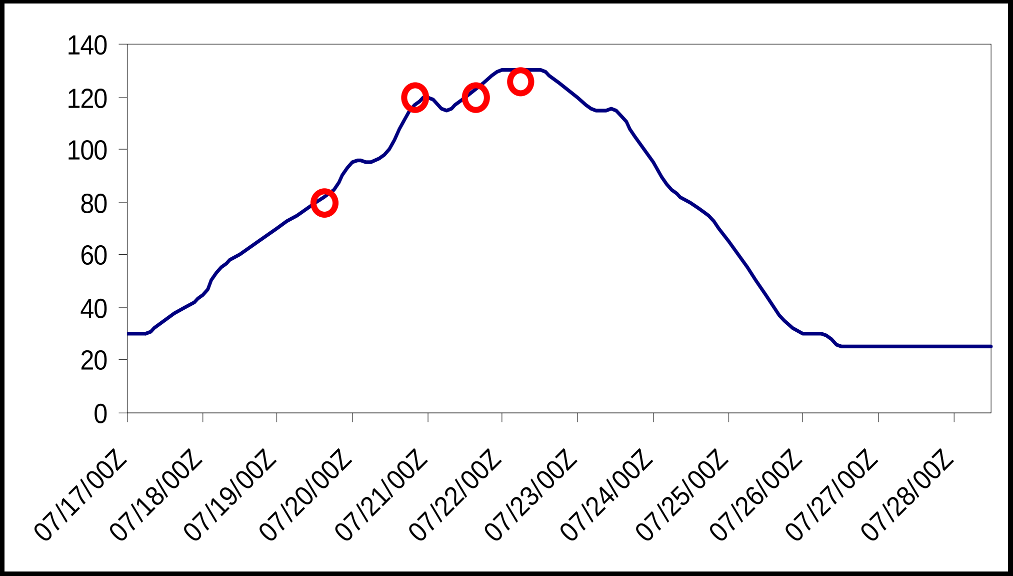






EP
Hurricane
Daniel 2006



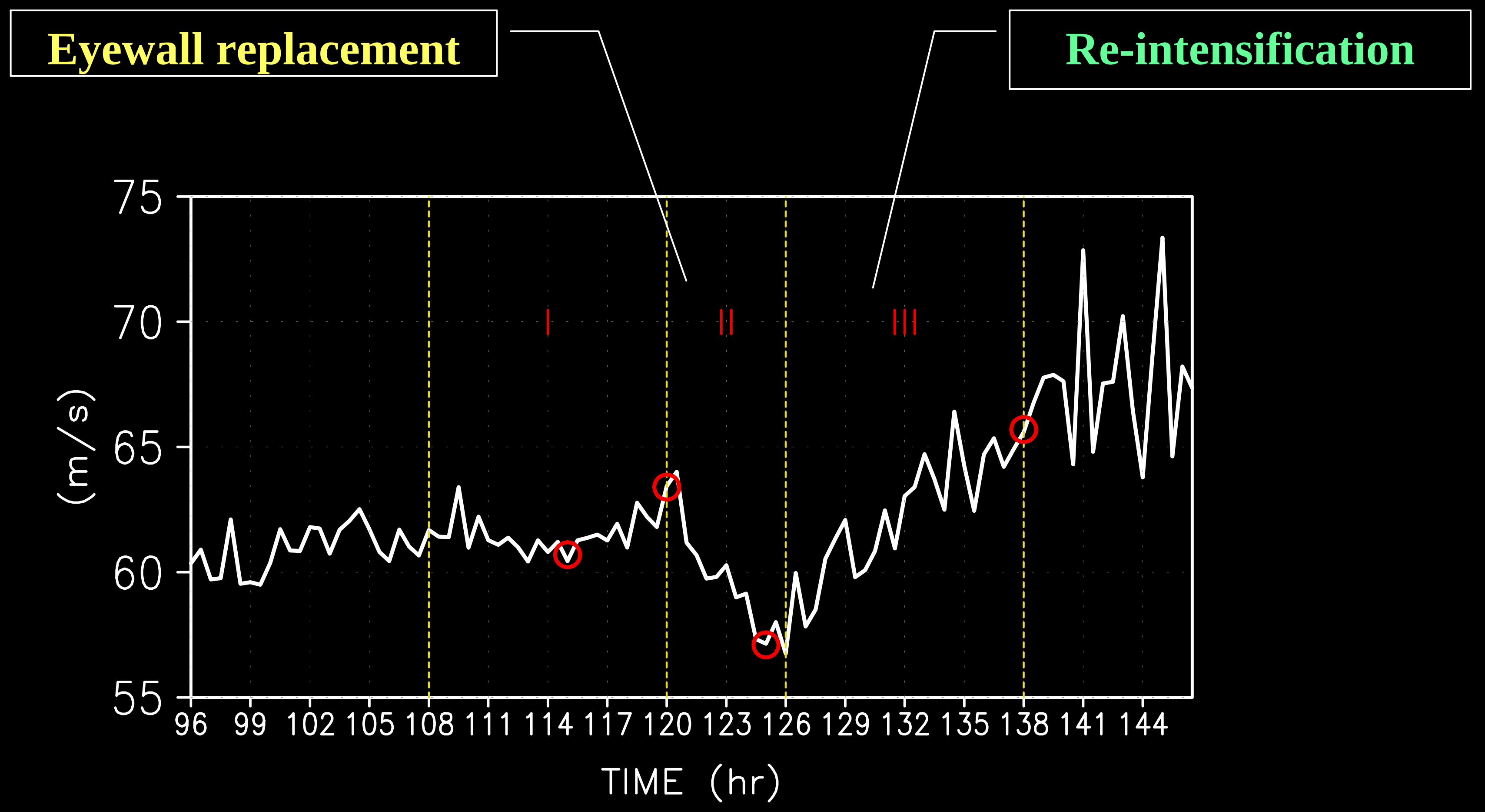


Experiment design

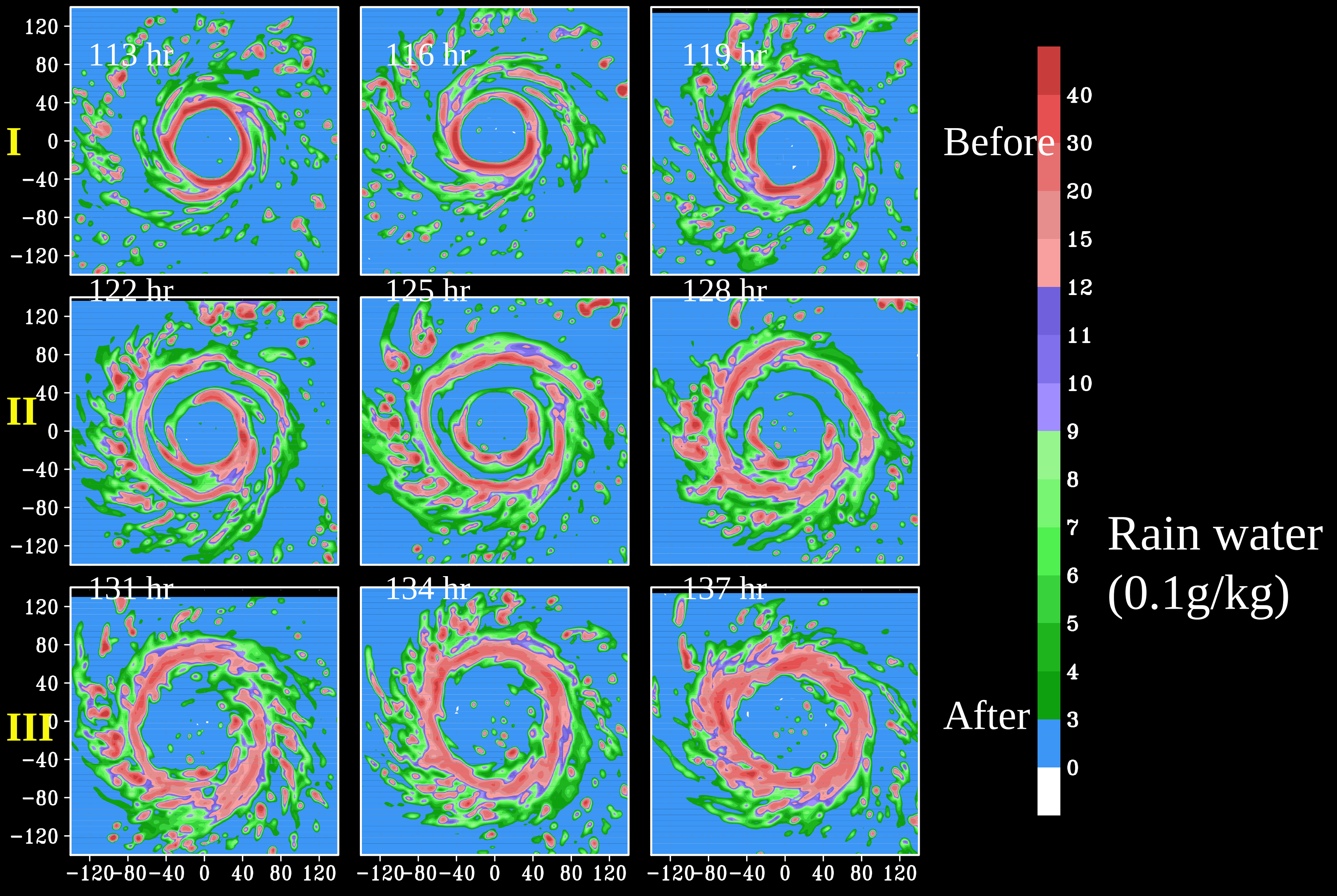
- WRF-ARW model
- 4 domains (2km 6km 18km 54km)
- Microphysics scheme: Lin et al (1983)
- No cumulus scheme for fine domains
- f –plane
- SST=29^{o}C
- Rest environment
- Initial disturbances:

  A weak vortex with maximum tangential wind 15m/s

Time series of hurricane intensity



Formation of concentic eyewall and AH



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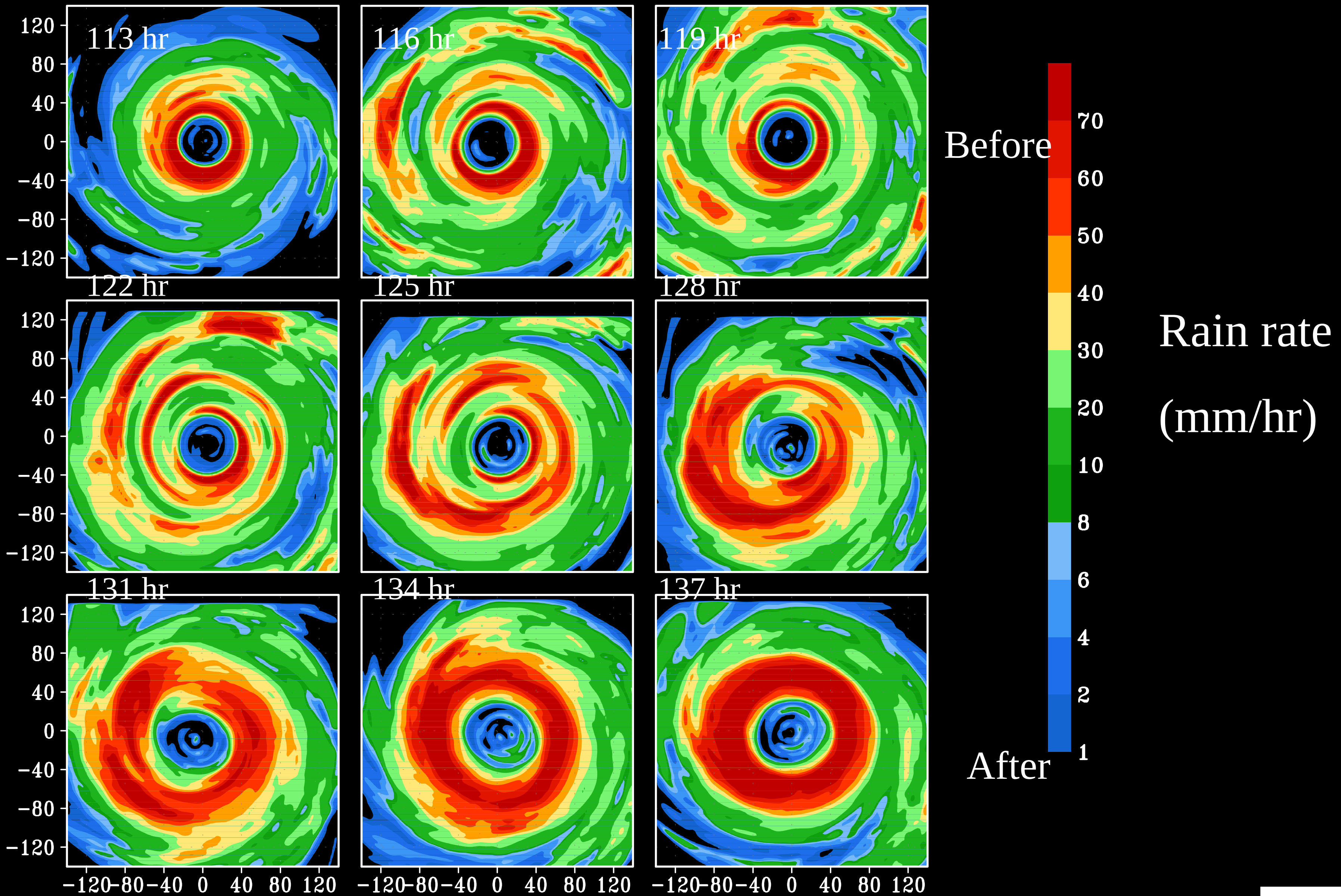
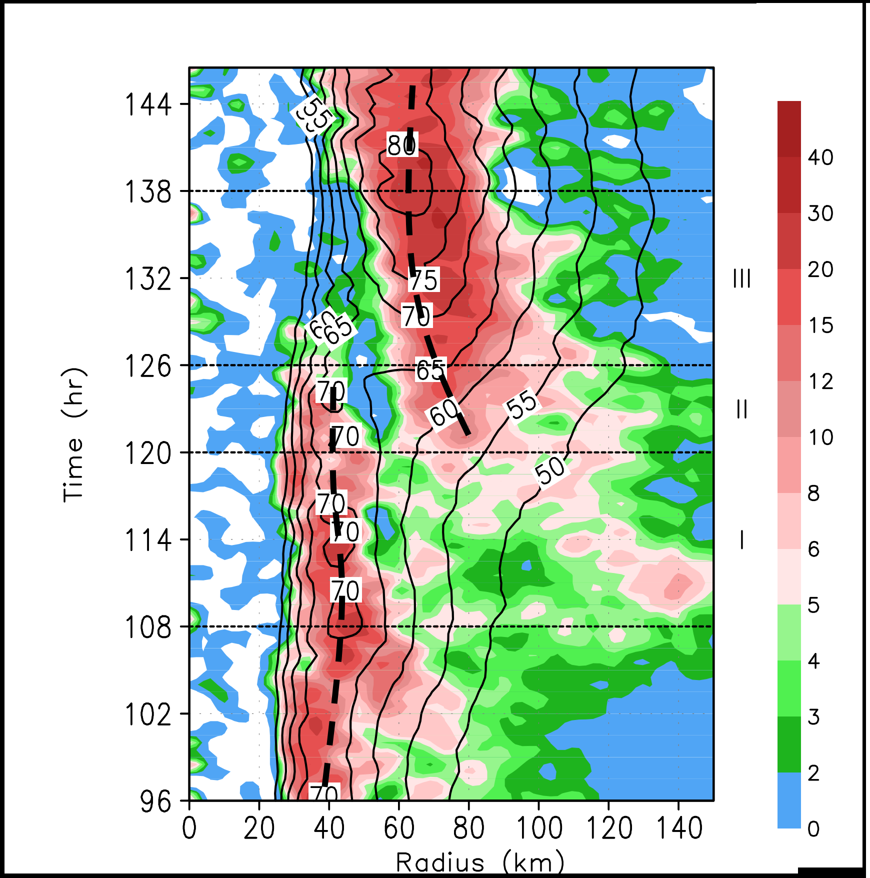


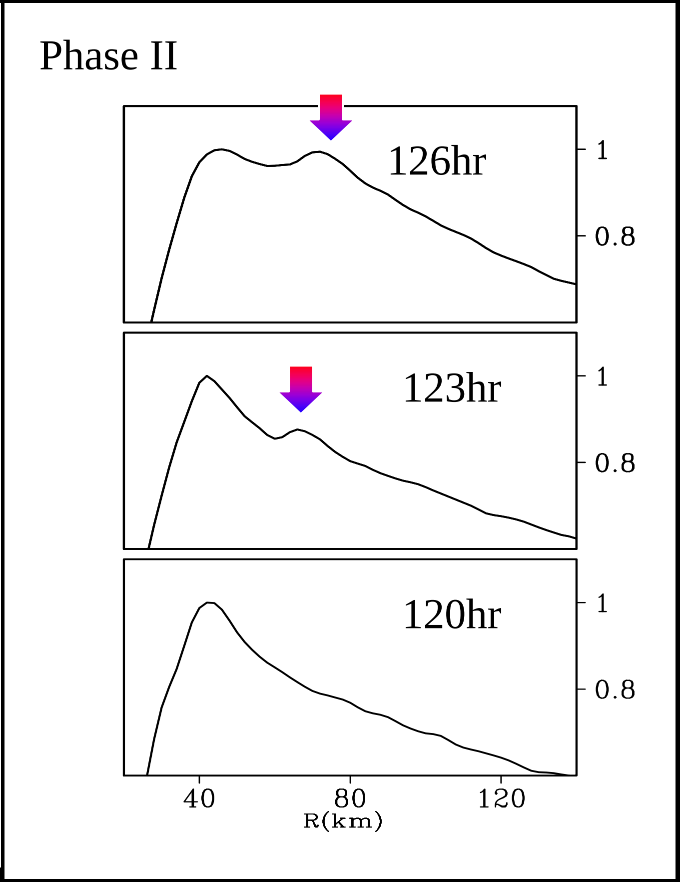
Symmetric structure

Shading: W (1cm/s) in 500hPa

Contour: Vt (m/s) in 700hPa



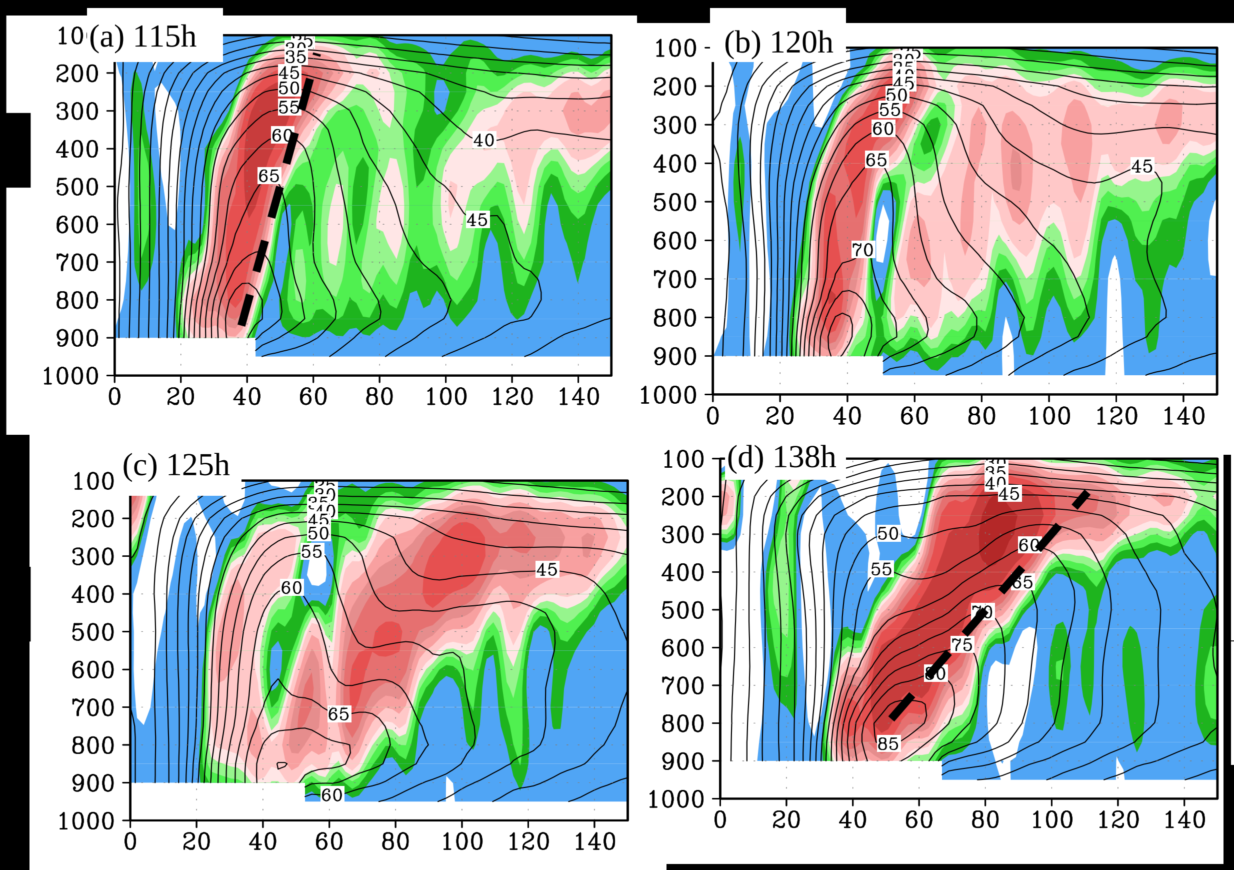
Vt (m/s) in 700hPa normalized by the maximum wind

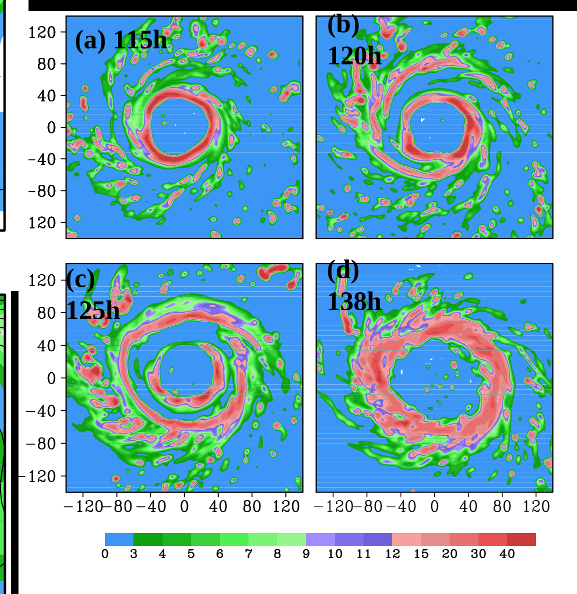


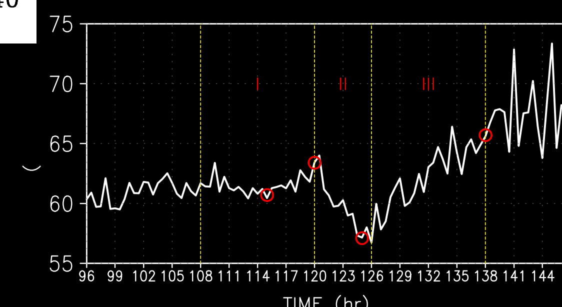
Vertical structure

(hPa)

(hPa)







Symmetric W (1cm/s) and Vt (m/s)

Summary and Discussion

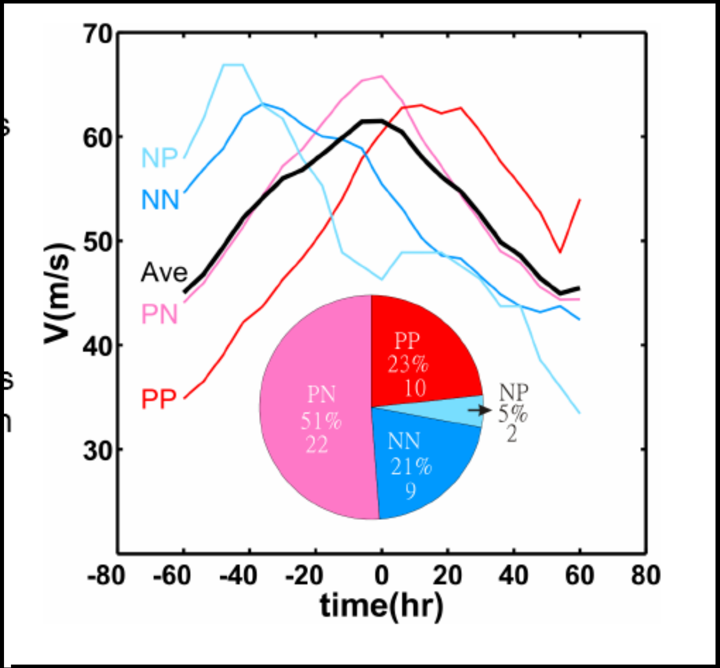
1) The WRF model successfully produce the concentric eyewall, the eyewall replacement and accompanied intensity change

2) The replacement process is quite fast (about 6hr) and the intensity does not have dramatic fluctuation (8-10 m/s) during the eyewall replacement

3) Concentric eyewall is a route to the formation of an annular hurricane

Average: -5m/s in 10hrs

P: increase; N: decrease



Composite time series of the intensity change before and after the concentric eyewall (Kuo et al 2007)

Thank you