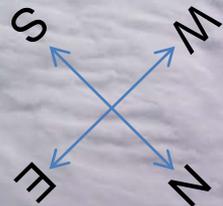
A satellite image of a tropical cyclone, showing a well-defined eye and spiral cloud bands over a dark ocean. The text is overlaid on the top half of the image.

# Application of NASA Field Observations, Satellite Measurements and High- Resolution WRF Simulations for Study of Physical and Dynamical Processes in Tropical Cyclones

G. M. McFarquhar, B. F. Jewett, S. W. Nesbitt, M. Gilmore, D. Harnos and  
R. Maliawco

University of Illinois at Urbana-Champaign

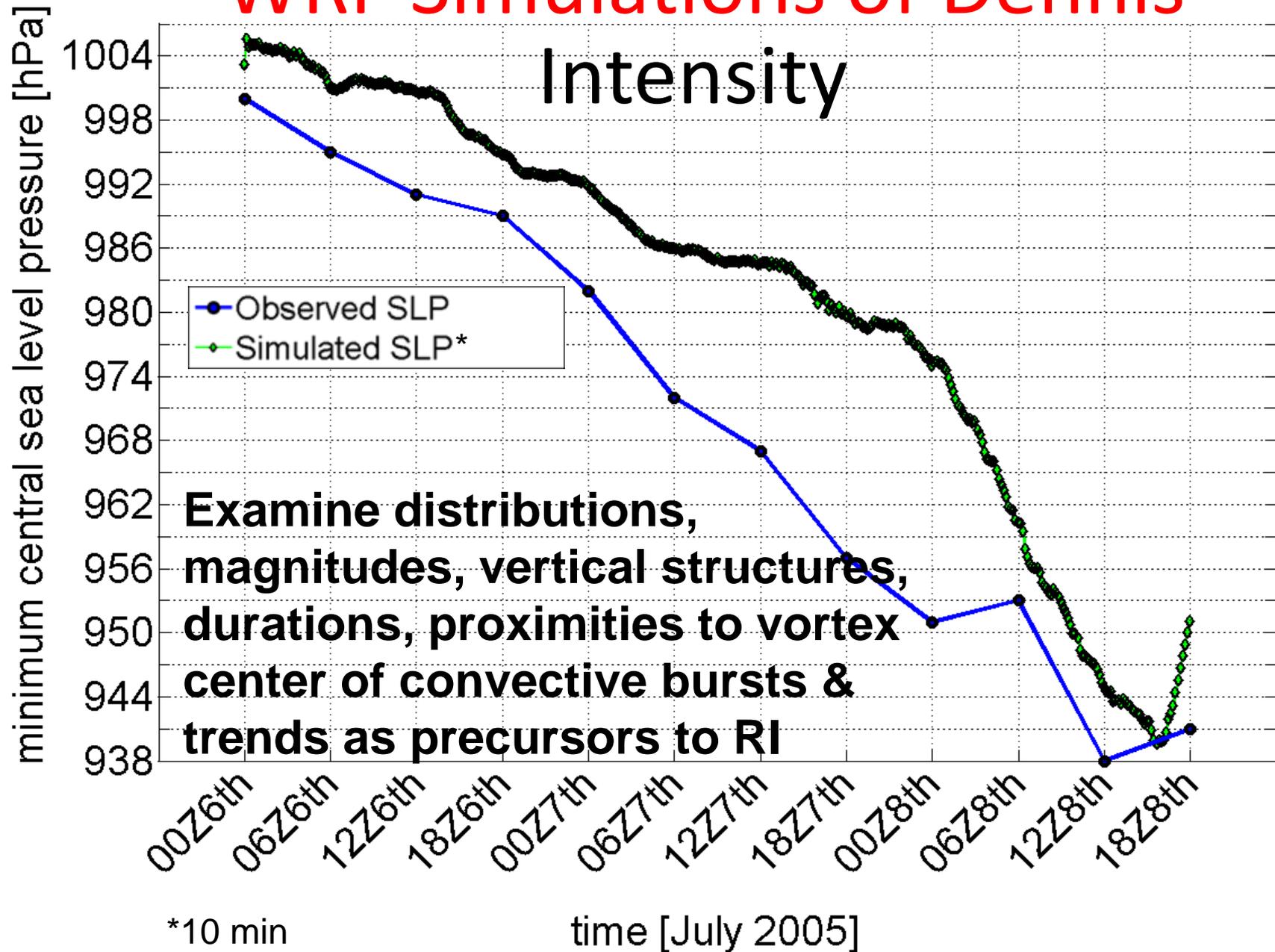
7 June 2011



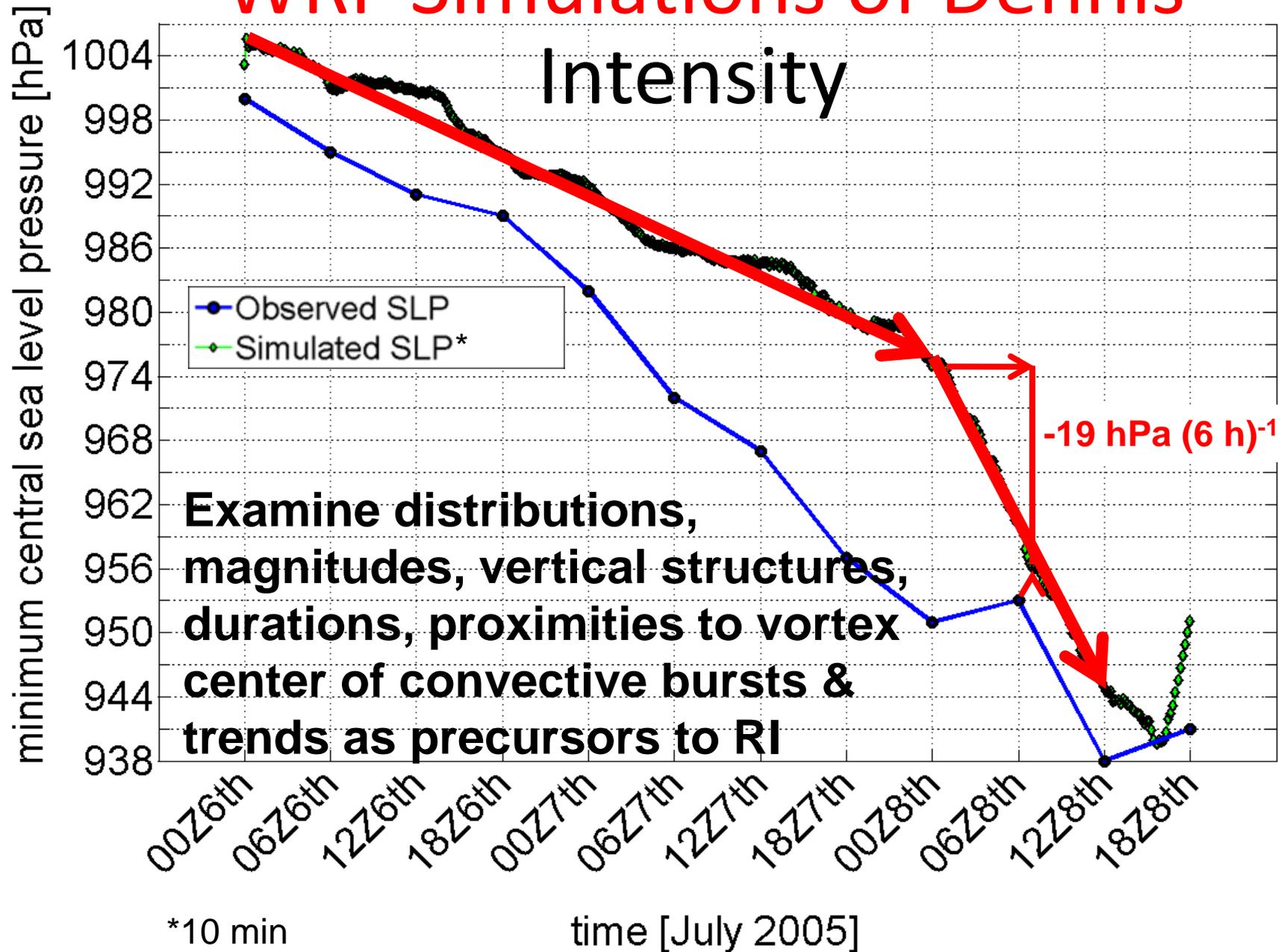
# Research Topics

1. Simulate Hurricane Dennis to examine mechanisms driving updraft and downdraft evolution.
2. Simulate how dust in SAL acting as CCN impacts TC intensity.
3. Construct comprehensive set of space borne microwave & radar data to examine role of varying TC morphology on rapid intensification.

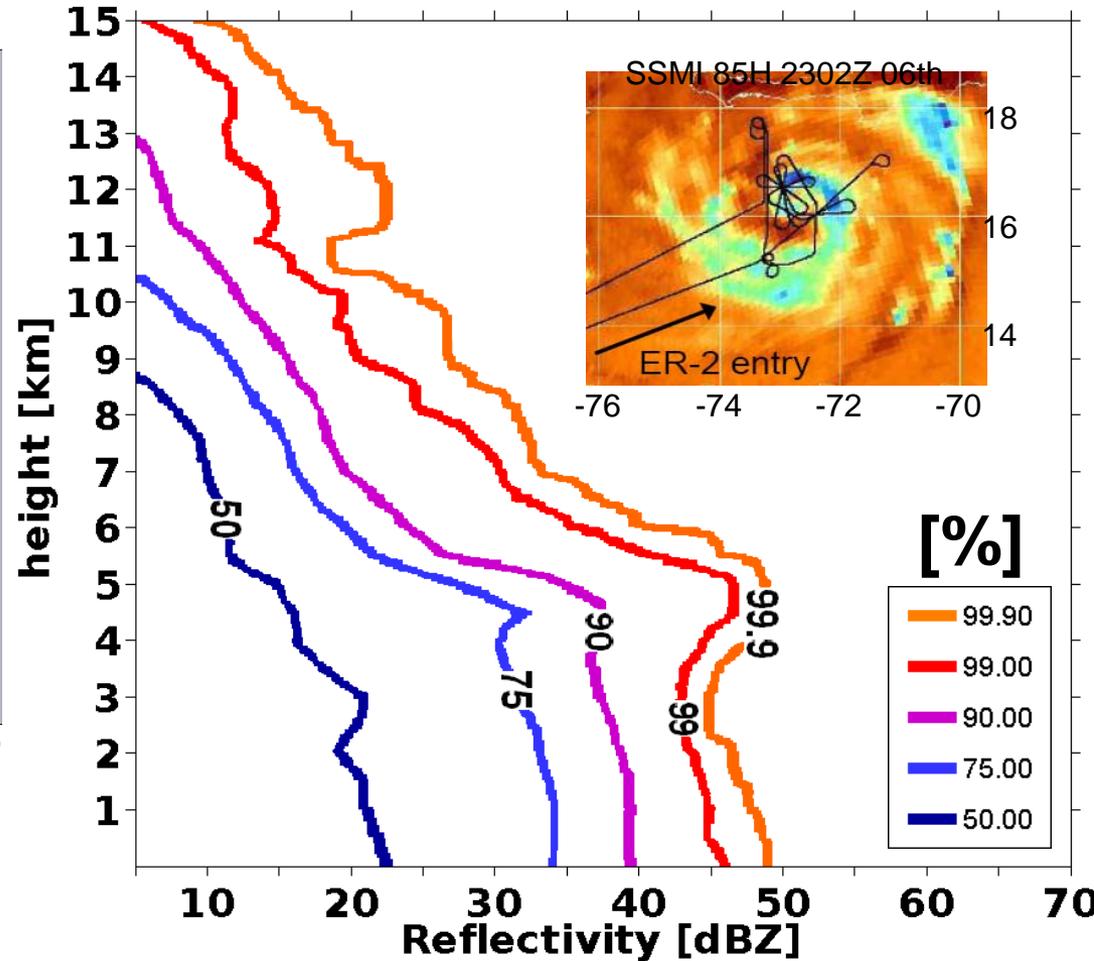
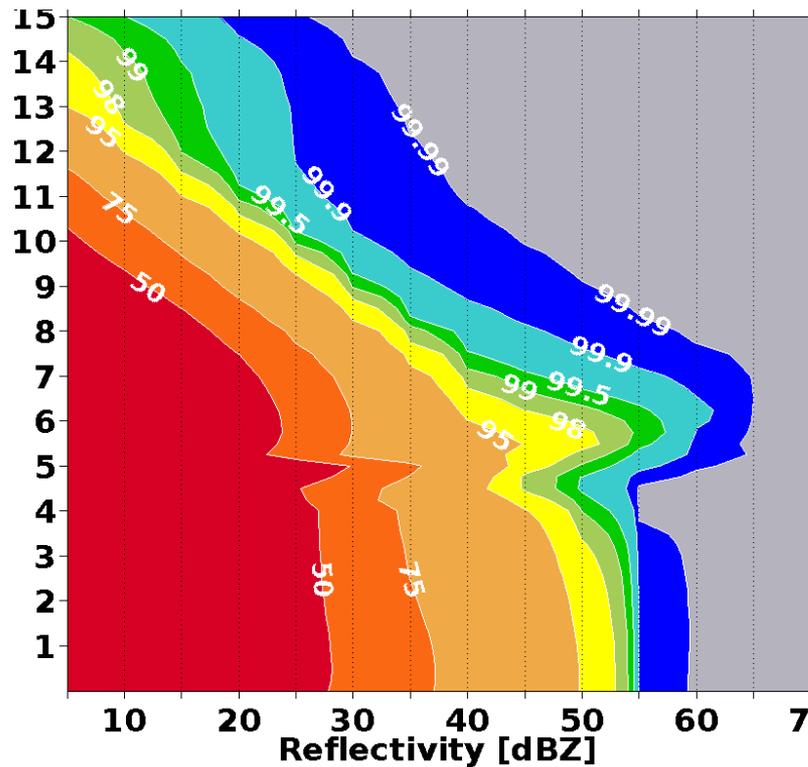
# WRF Simulations of Dennis



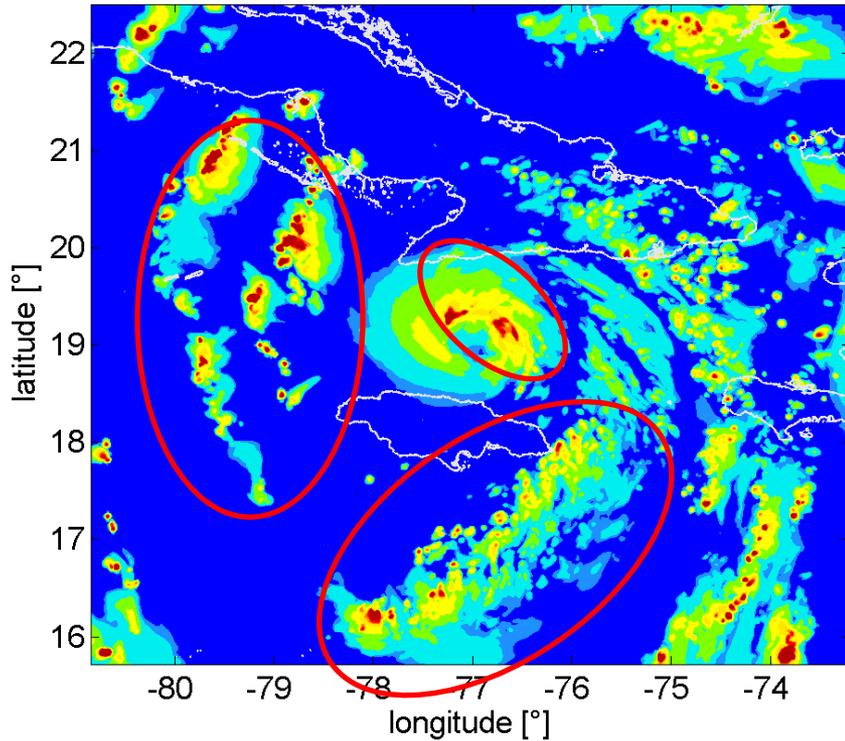
# WRF Simulations of Dennis



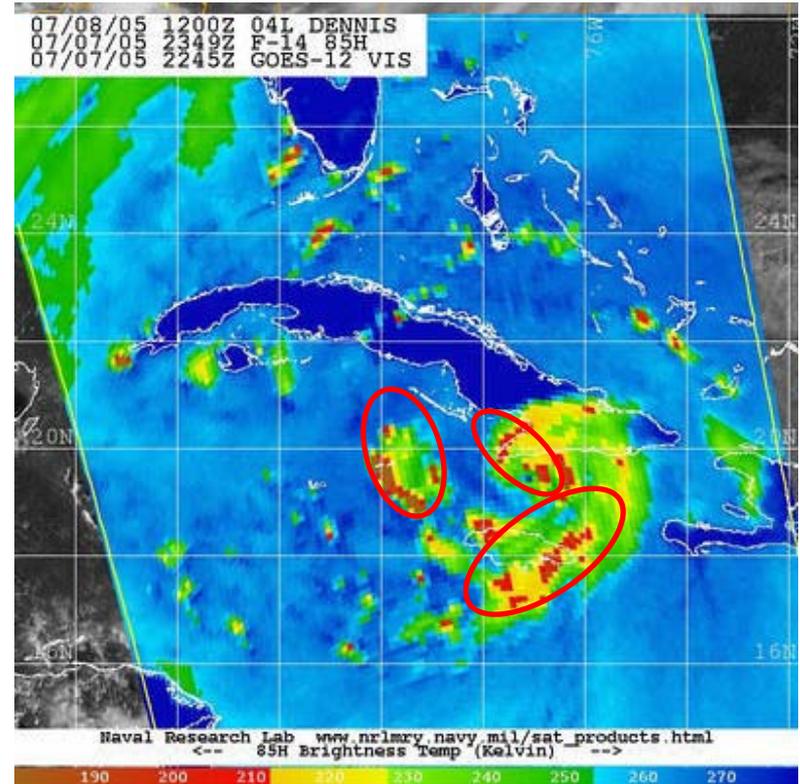
# CUMULATIVE CONTOURED FREQUENCY BY ALTITUDE DIAGRAM



# 2120Z 07<sup>th</sup> Column-Total GRAUPEL

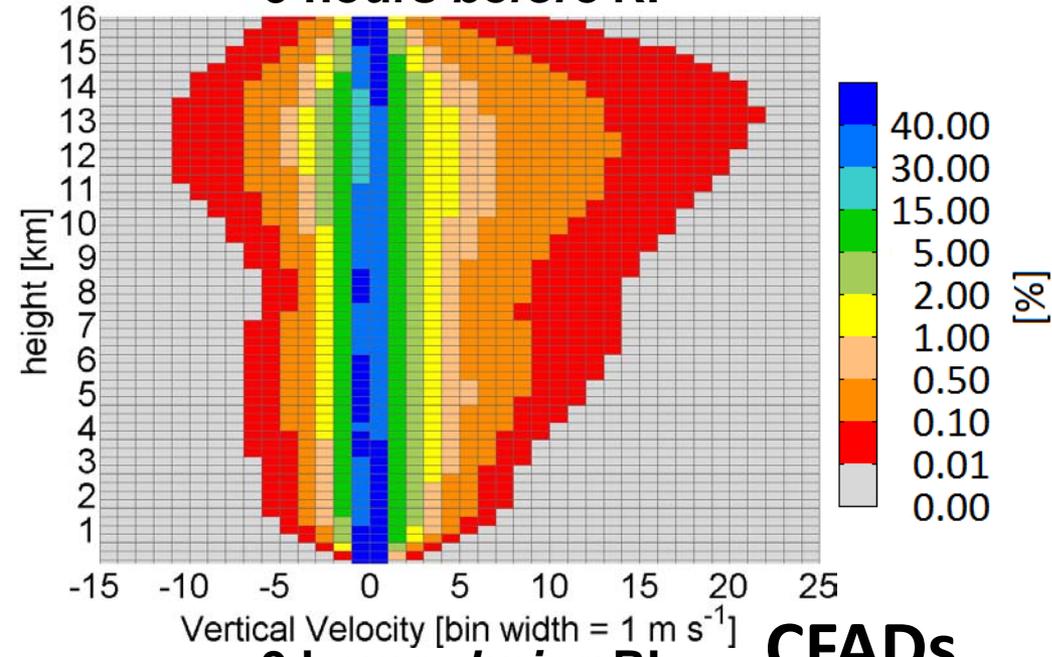


28.00  
22.00  
16.00  
11.00  
5.00  
1.20  
0.30  
0.04  
0.02  
[g kg<sup>-1</sup>]



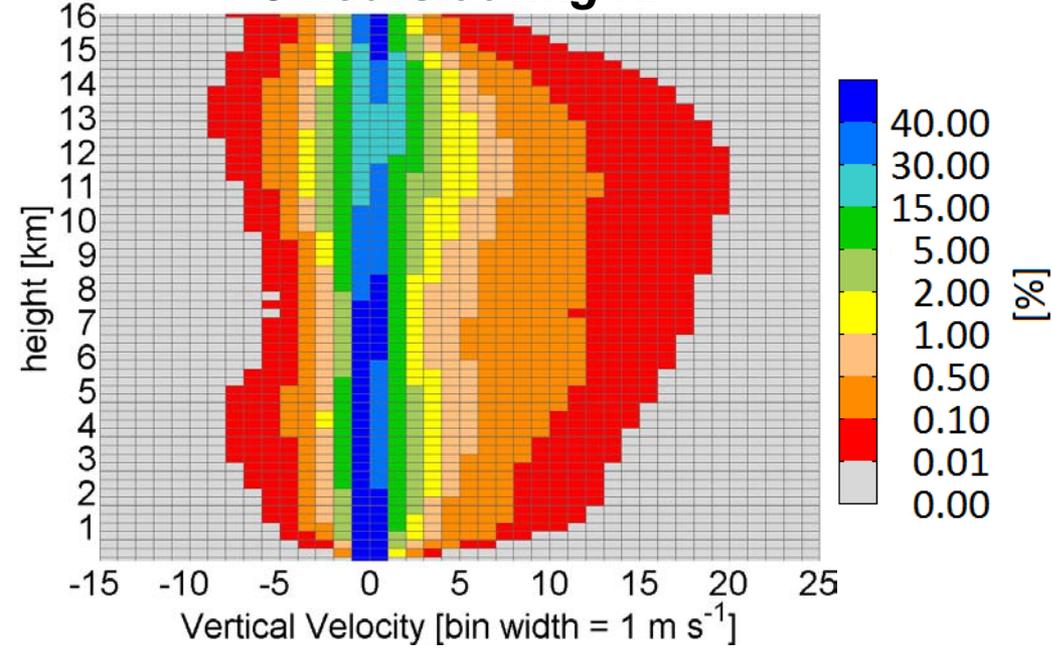


**9 hours *before* RI**



**Cumulative  
CFADs within  
75 km before &  
during RI**

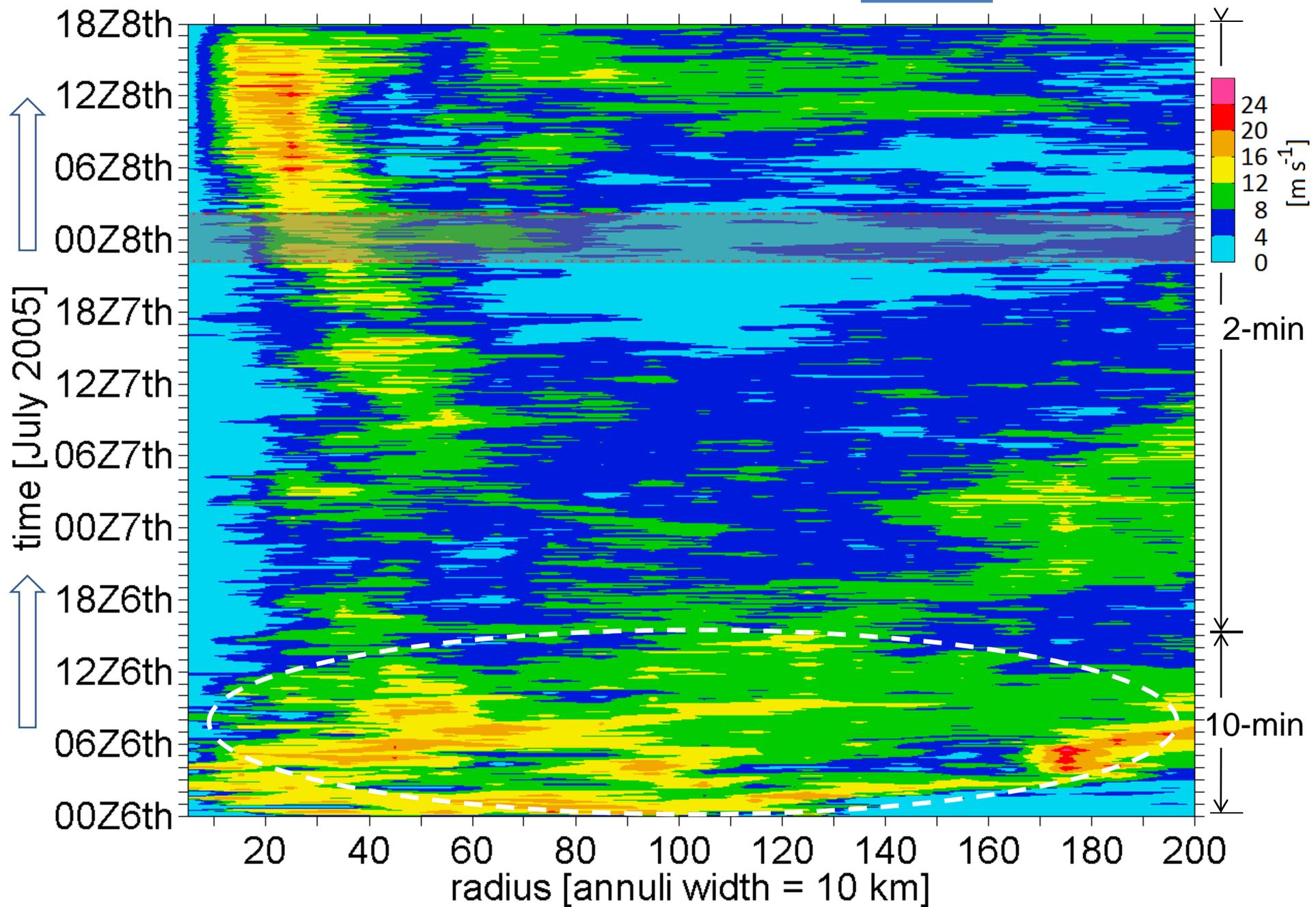
**9 hours *during* RI**



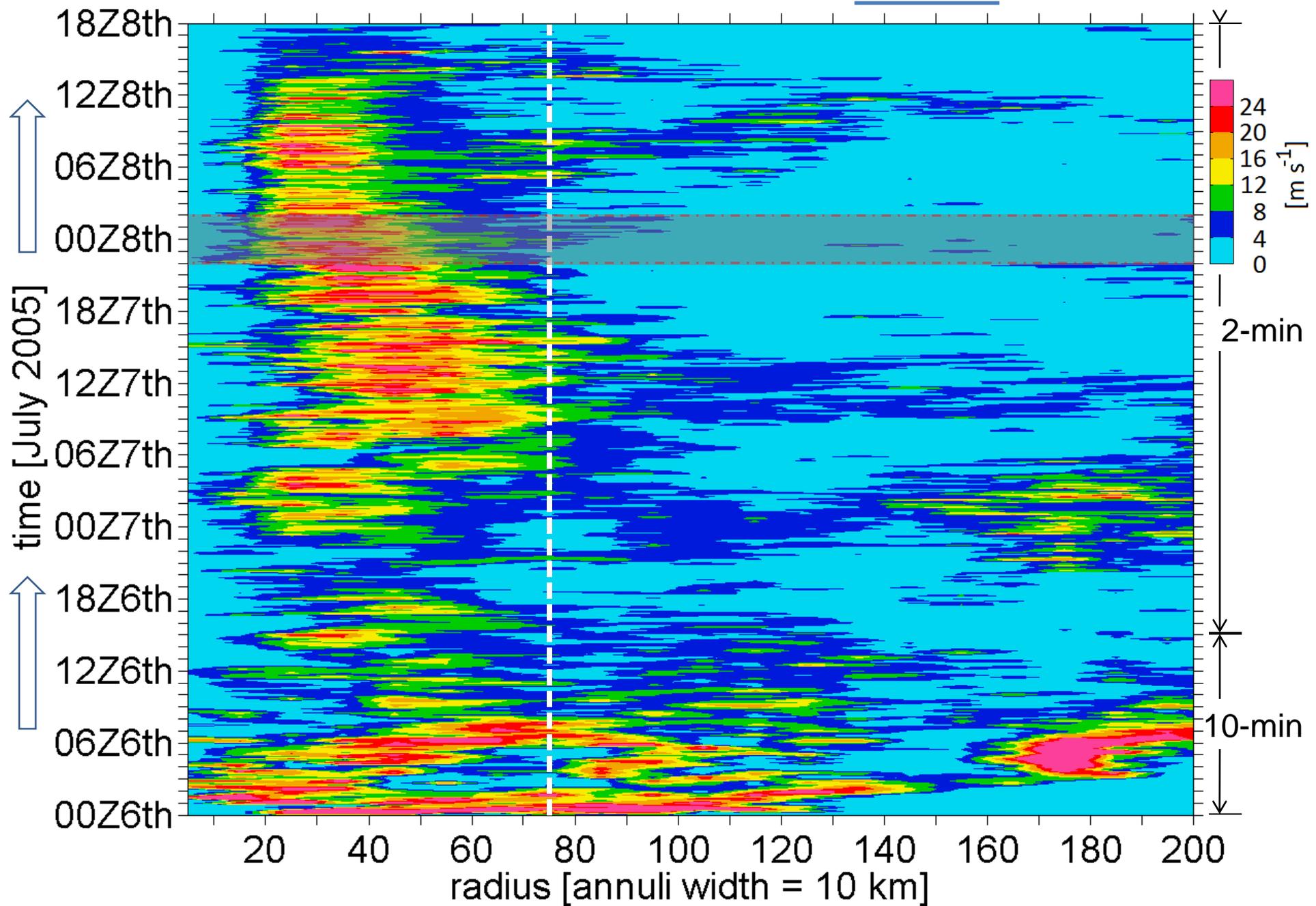
**CFADs**

**Distribution  
broader before  
RI for  $z > 11$  km,  
but broader  
after RI for  $z < 6$   
km**

99.9th Percentile VERTICAL VELOCITY at  $z = 6.00$  km

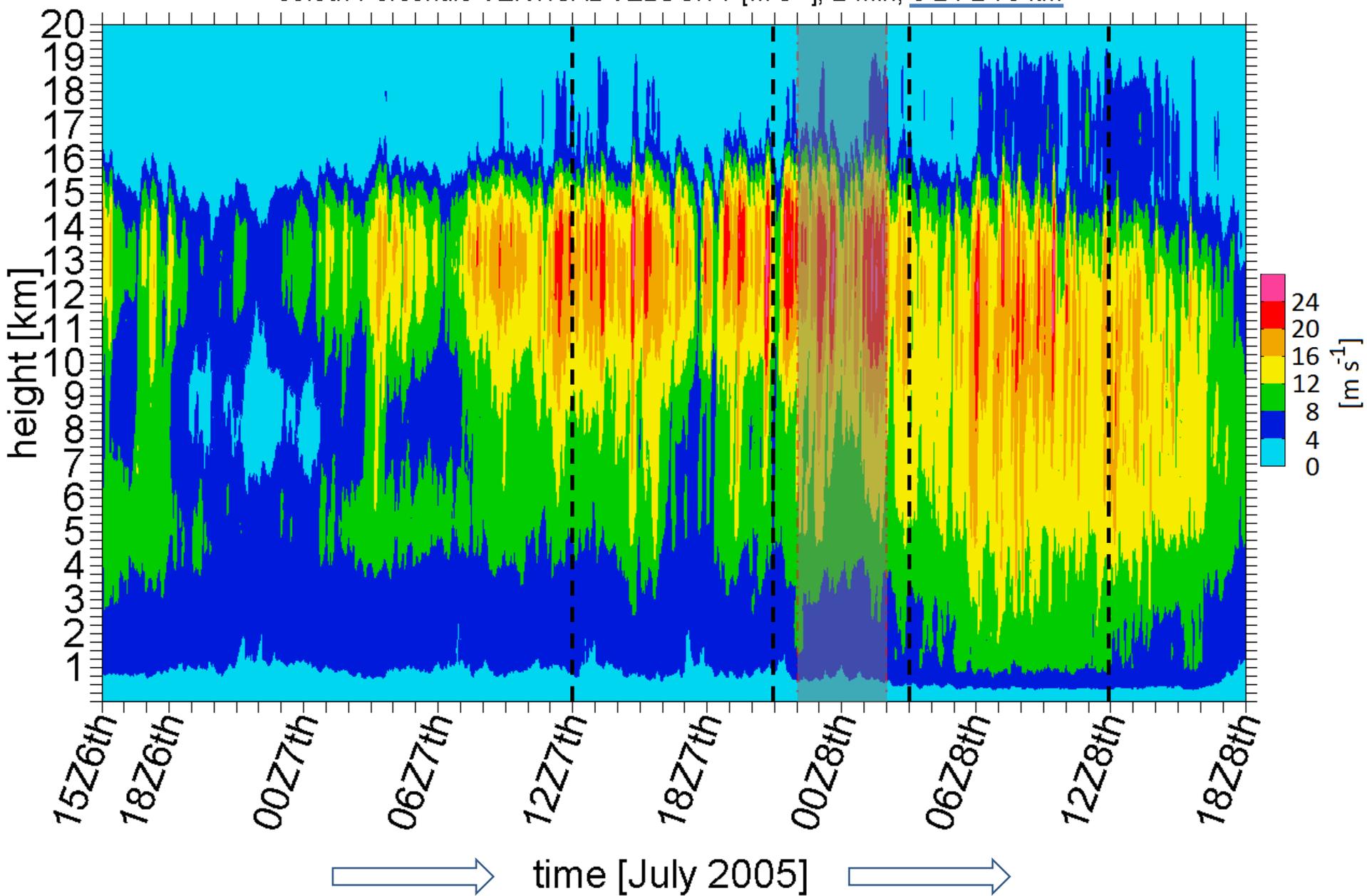


99.9th Percentile VERTICAL VELOCITY at z = 14.00 km



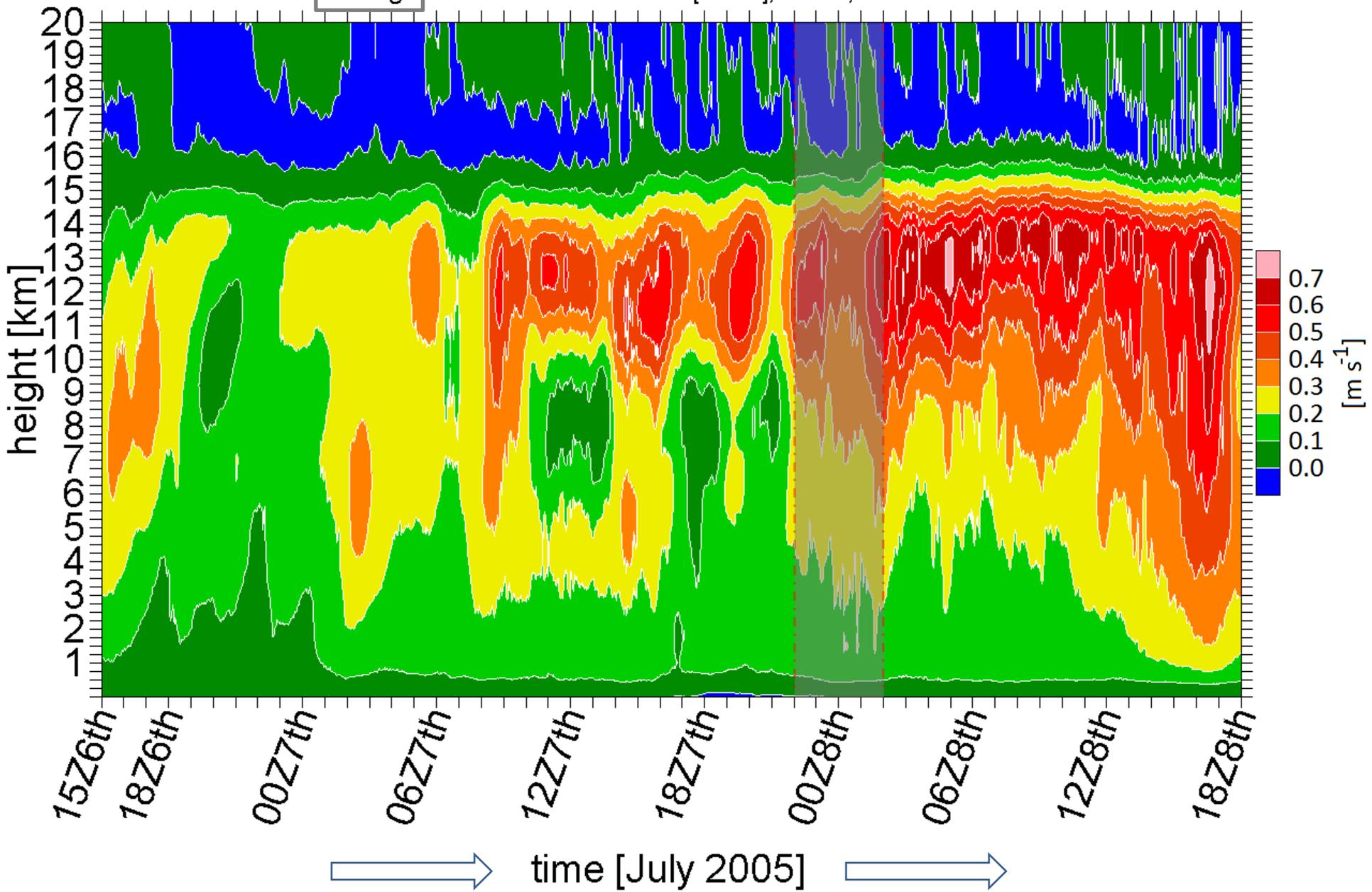


99.9th Percentile VERTICAL VELOCITY [ $\text{m s}^{-1}$ ]; 2-min;  $0 \leq r \leq 75 \text{ km}$





Average VERTICAL VELOCITY [ $\text{m s}^{-1}$ ]; 2-min;  $0 \leq r \leq 75 \text{ km}$

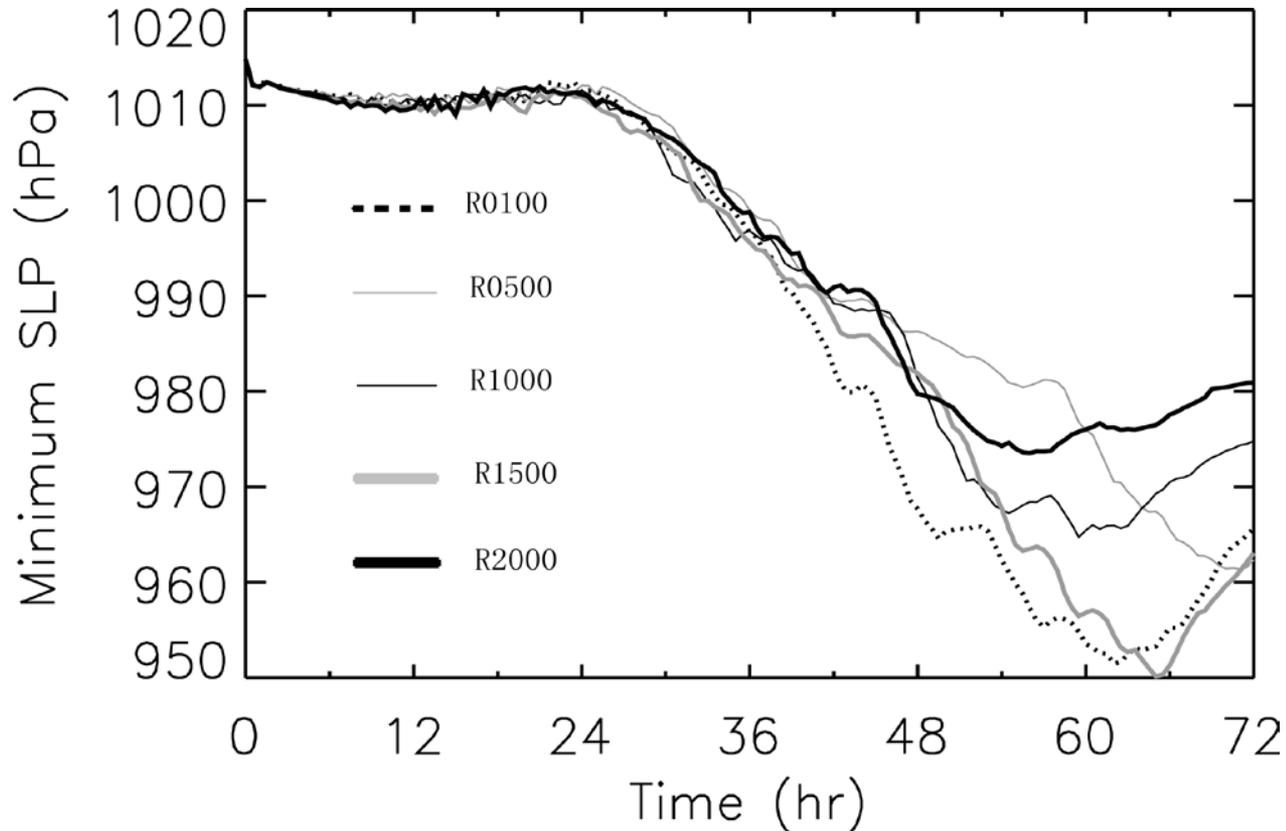




# Dennis Conclusions

- Outlier (e.g., 99.9<sup>th</sup> percentile) w better indicators of RI than averages
  - Precursor to RI *at upper levels* (e.g., 14 km)
  - Continual broadening and convergence toward TC center
- Outlier (e.g., 99.9<sup>th</sup> percentile) w *at lower levels* (e.g., 6 km), however, increase only *after* onset of and *during* RI
- Precursor w have *unnoticeable* impact on latent heating
  - Vertical structure
  - Thresholds for definition

# SAL Aerosol Influence on TCs

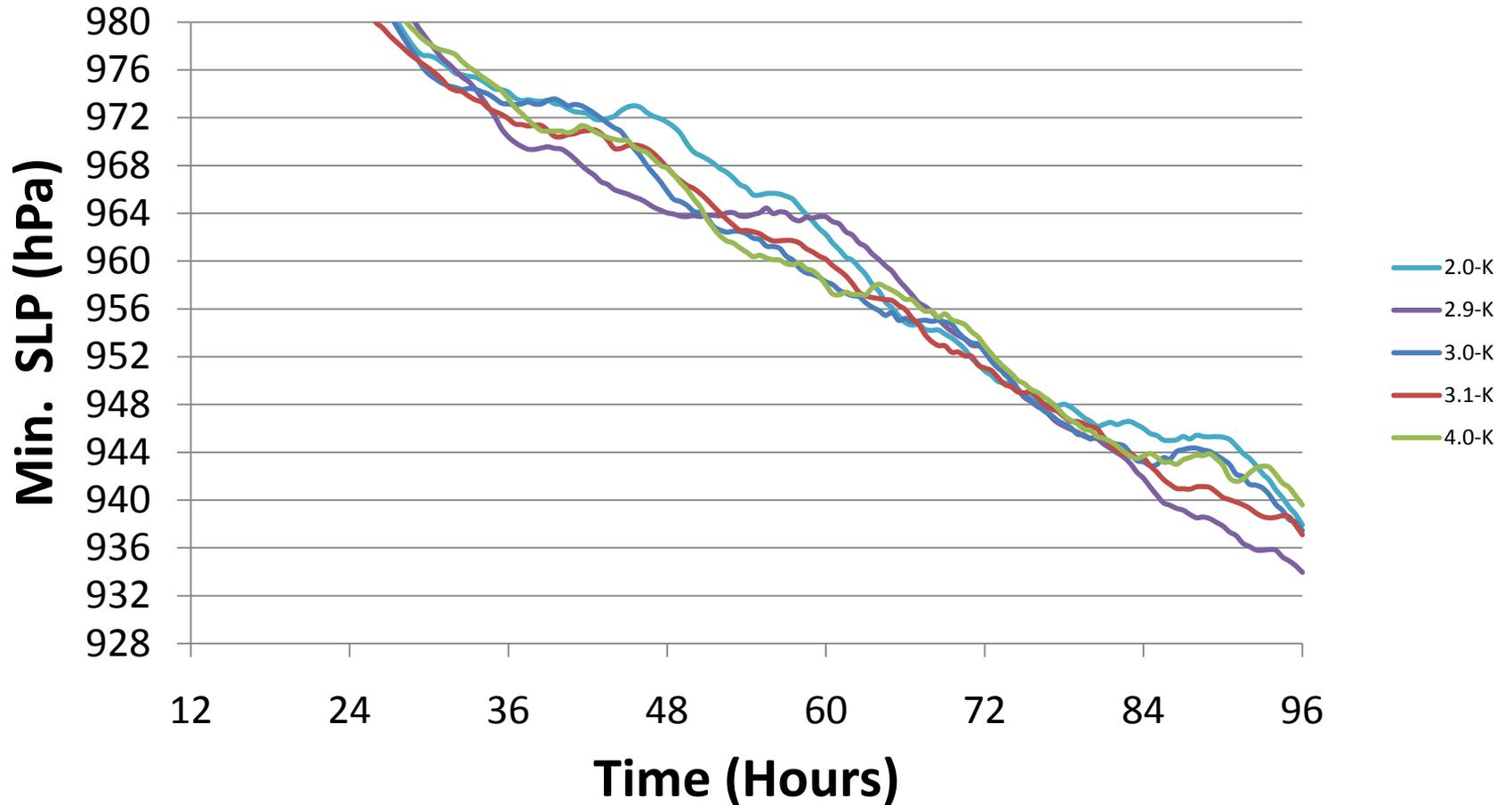


- Zhang et al. (2007, 2009) suggested TCs sensitive to variations in CCN concentration
  - TC intensity exhibited non-monotonic response to increases in CCN concentration

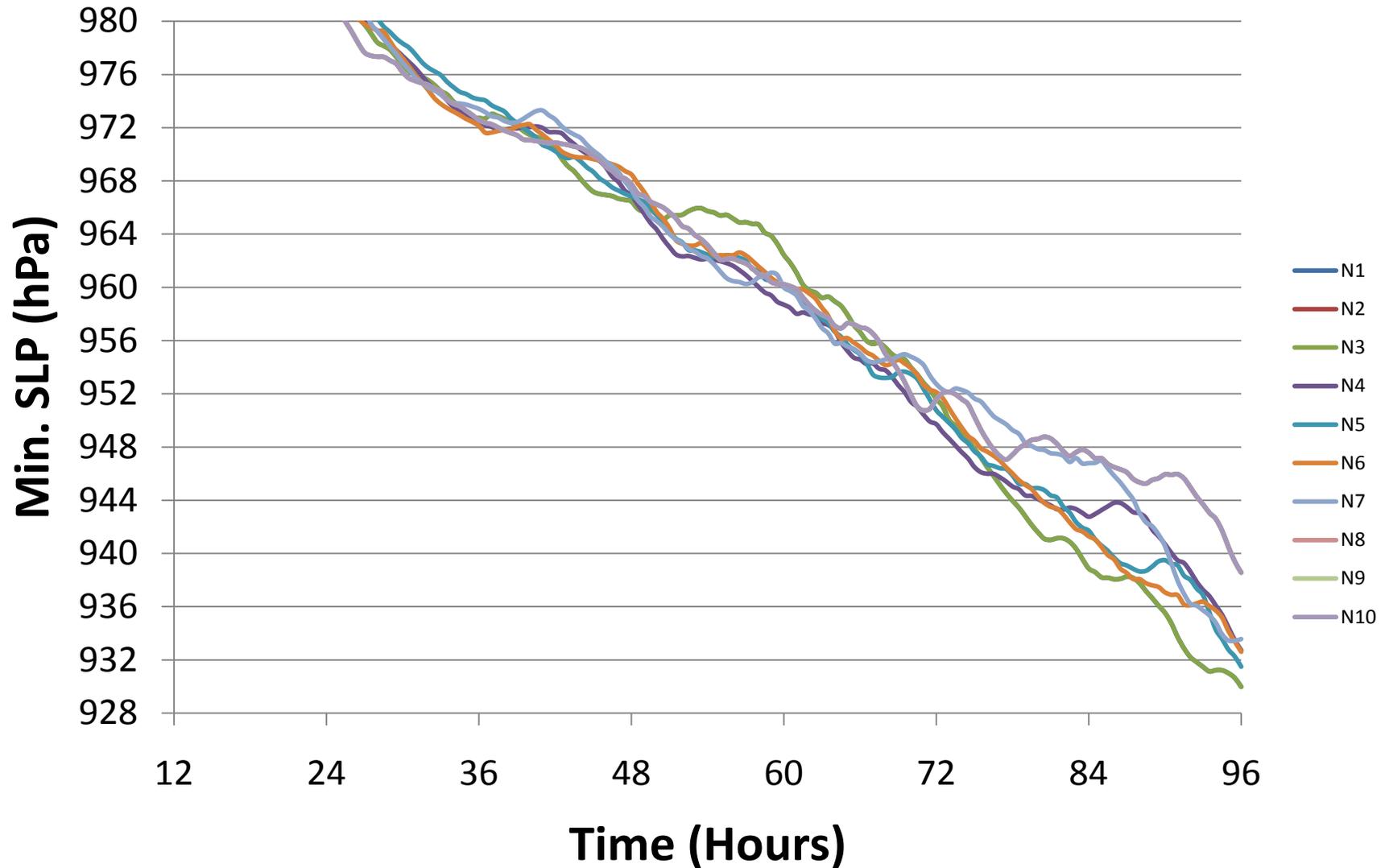
# Idealized RAMS 6.0 Simulations

- Vary initial vortex properties to understand context of TC dependence on CCN
- 40 vertical levels, inner grid spacing of 2km
- Vary initial bubble temperature by  $\pm 0.1$  K or  $\pm 1.0$  K
- Examine effects of running simulations on different nodes of local Linux cluster

# Temperature Perturbation Simulations on (Same Node)



# Simulations with Identical Initial Conditions (Different Nodes)



# SAL Study Conclusions

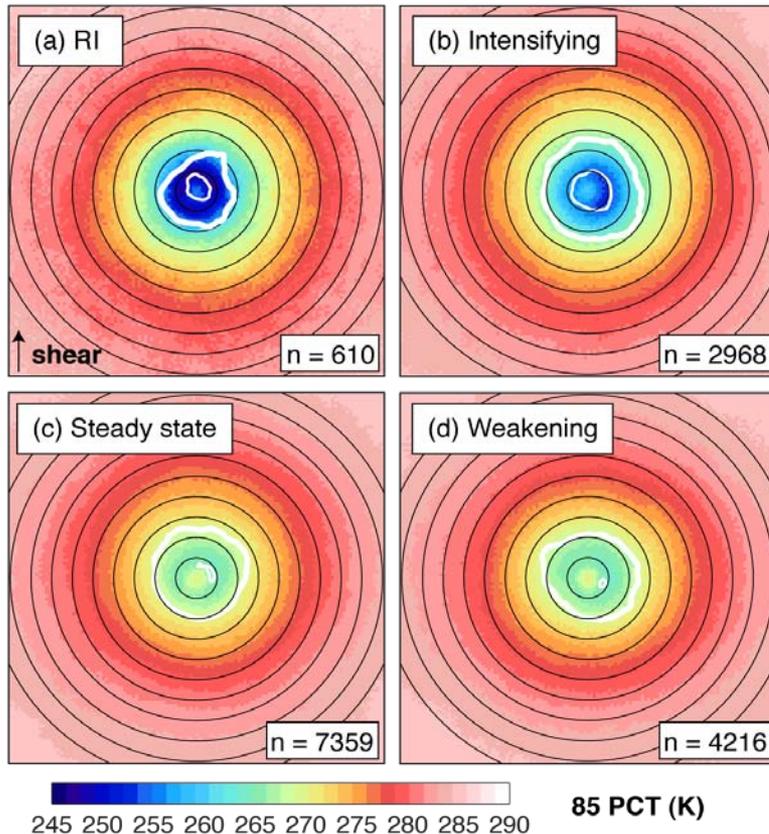
- Sensitivity to changes in ICs  $\leq$  that due to running on different computational nodes
- Computational differences eliminated by running on single node  $\rightarrow$  identical architectures needed for sensitivity results
- Future work will determine sensitivity to varying CCN in context of variations in ICs in other fields via ensemble series of simulations
- Sensitivity of location & timing of perturbations to ICs will be determined

# Remote sensing studies of dynamical & microphysical processes in tropical cyclone intensification

*(Stephen W. Nesbitt and Daniel S. Harnos)*

- Key Questions:
  - What are the critical precursors to TC intensification?
  - How can we increase understanding and anticipation of these precursors?
- To evaluate: 85 GHz passive microwave data
  - Sensitive to ice scatter from convective precipitation
  - Database constructed of every TC overpass from SSM/I (1987-2008) and TMI (1997-2008) globally
  - Relatively high resolution (downscaled to 8 km, 15x13 at worst in native resolution)

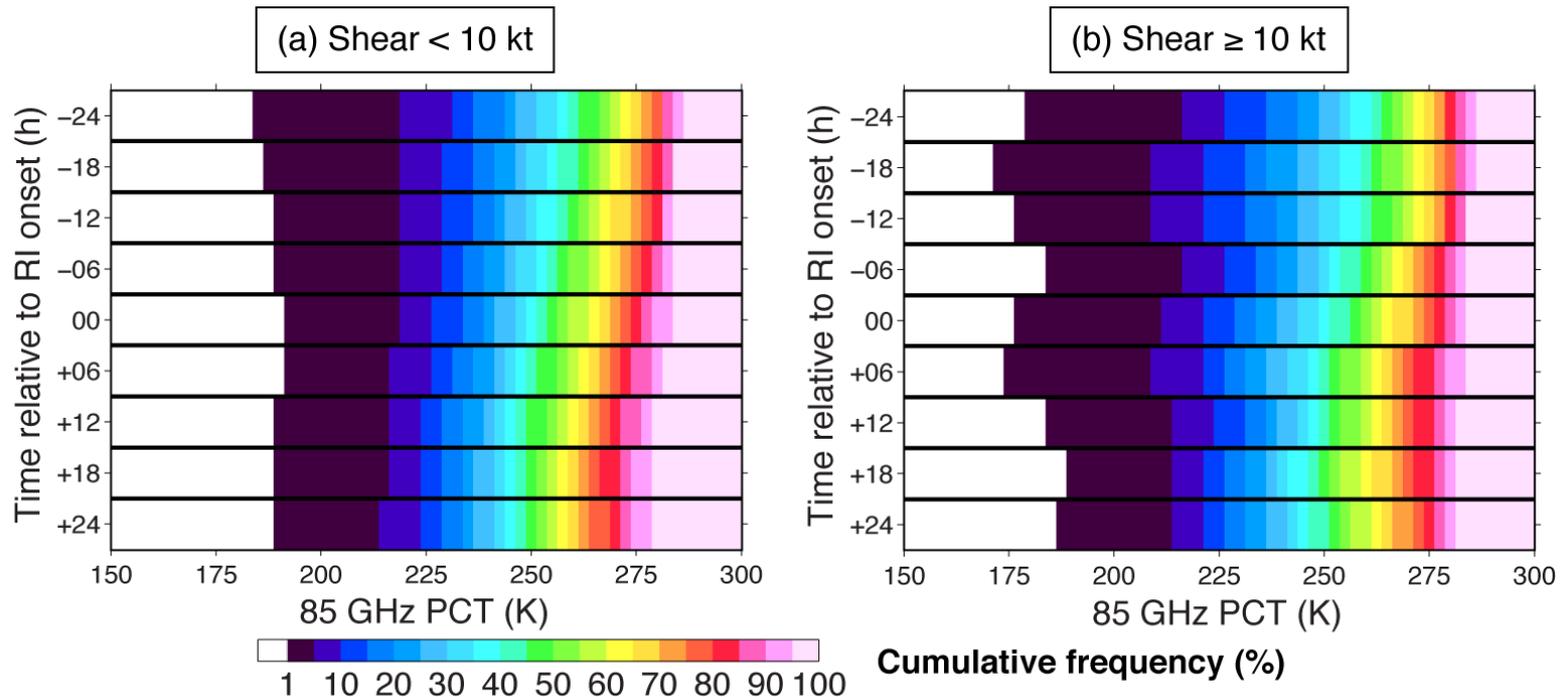
# Composite analysis reveals RI systems are fundamentally different



Harnos, D. S. and S. W. Nesbitt (2011),.

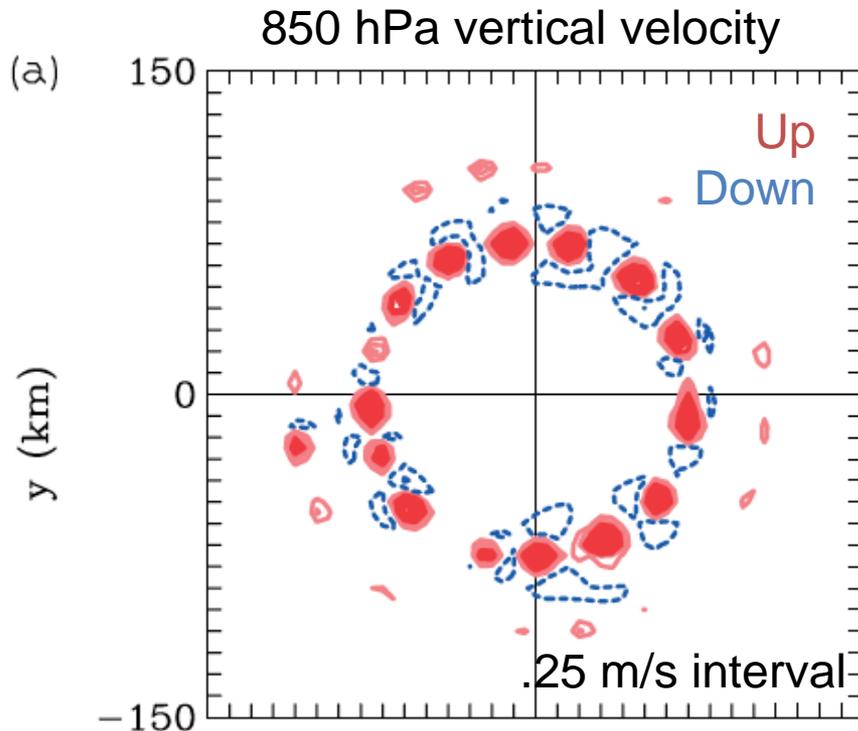
- Enhanced convective signature for RI systems versus other intensification statuses.
- Convection appears largely axisymmetric
- Highest variability constrained to interior of this axisymmetric feature
  - Secondary mode of RI possible, with axisymmetric mode being dominant?

# RI signal occurs in means, not extremes



- Both high and low shear cases see intensification signal in 25-80<sup>th</sup> percentiles from 6 hours before RI through 18 hours after
- Overall vigor greater for high shear, although limited by sample size.

# Future Work



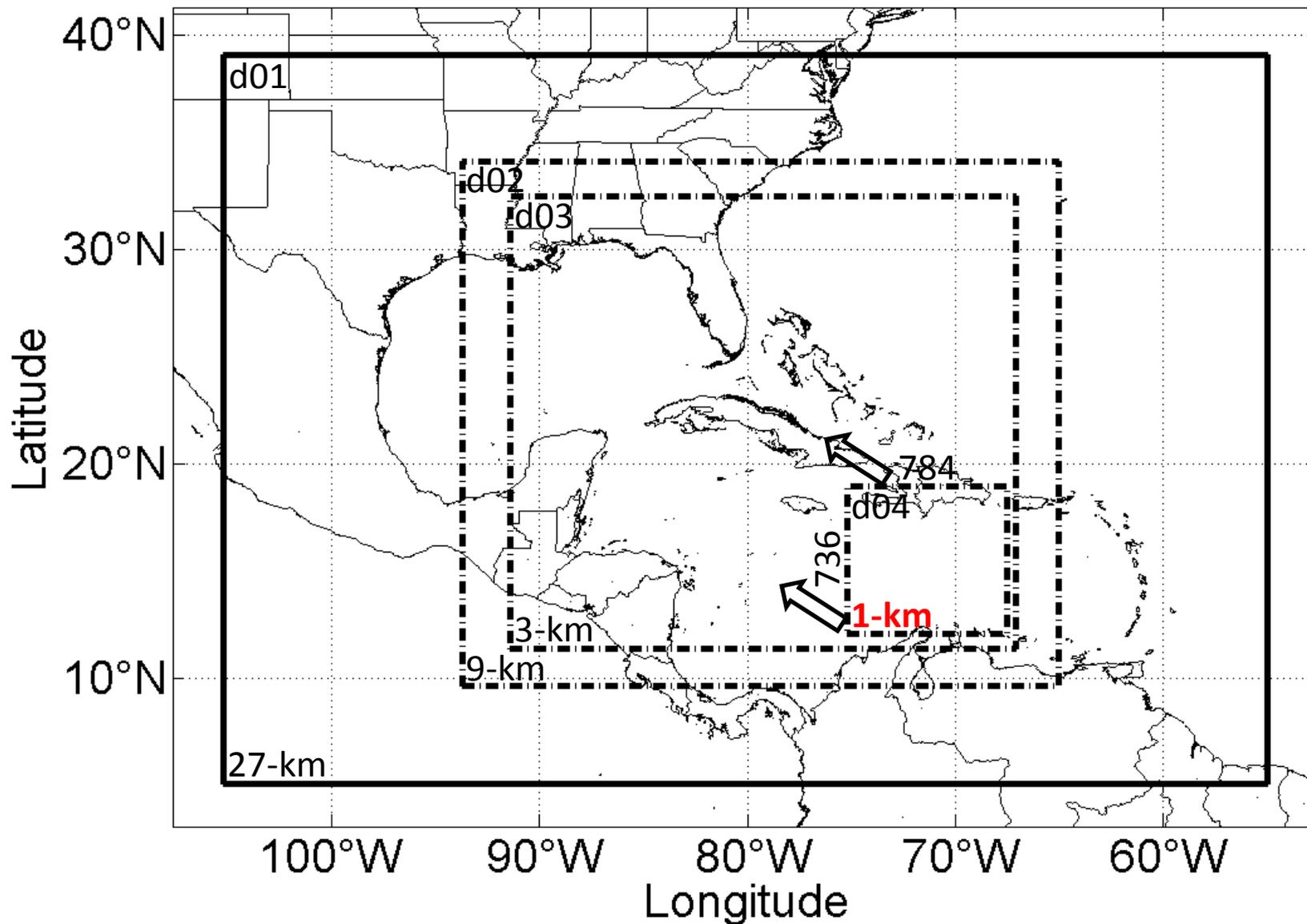
Nguyen, et al. (2008) – Q. J. R. Meteorological Soc.

- Is axisymmetry valid?
- Alternative non-convective hypothesis have been proposed (Haiyan Jiang, FIU)
- High resolution WRF simulations ongoing to determine precipitation processes taking place.
- Collaboration with Steve Durden and Simone Tanelli (NASA – Ames) comparing APR-2 data of the RI of Earl and Karl to WRF simulations

*Harnos, D. S. and S. W. Nesbitt (2011), Convective structure in rapidly intensifying tropical cyclones as depicted by passive microwave measurements, Geophys. Res. Lett., 38, L07805, doi:10.1029/2011GL047010.*

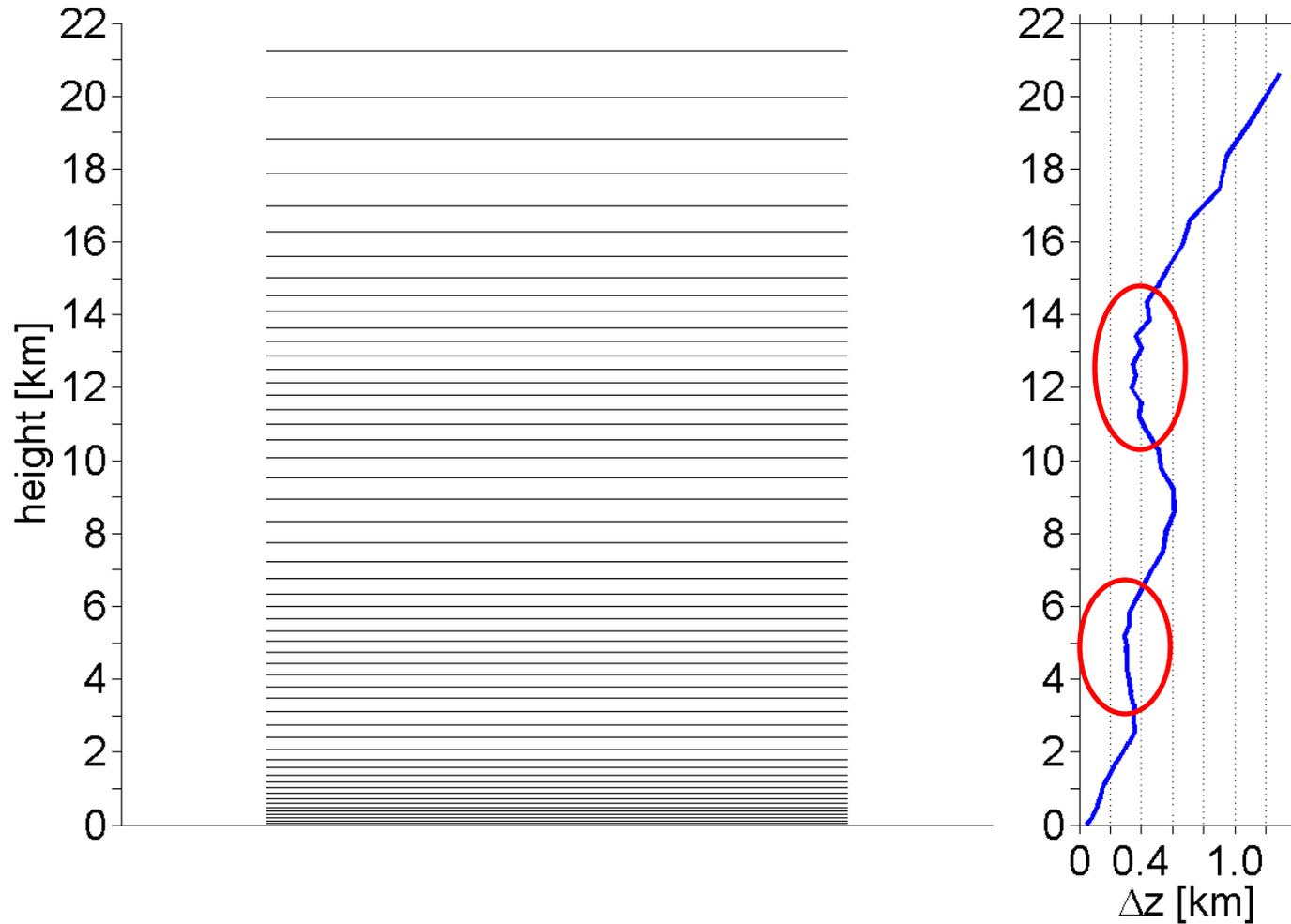
# WRF Configuration

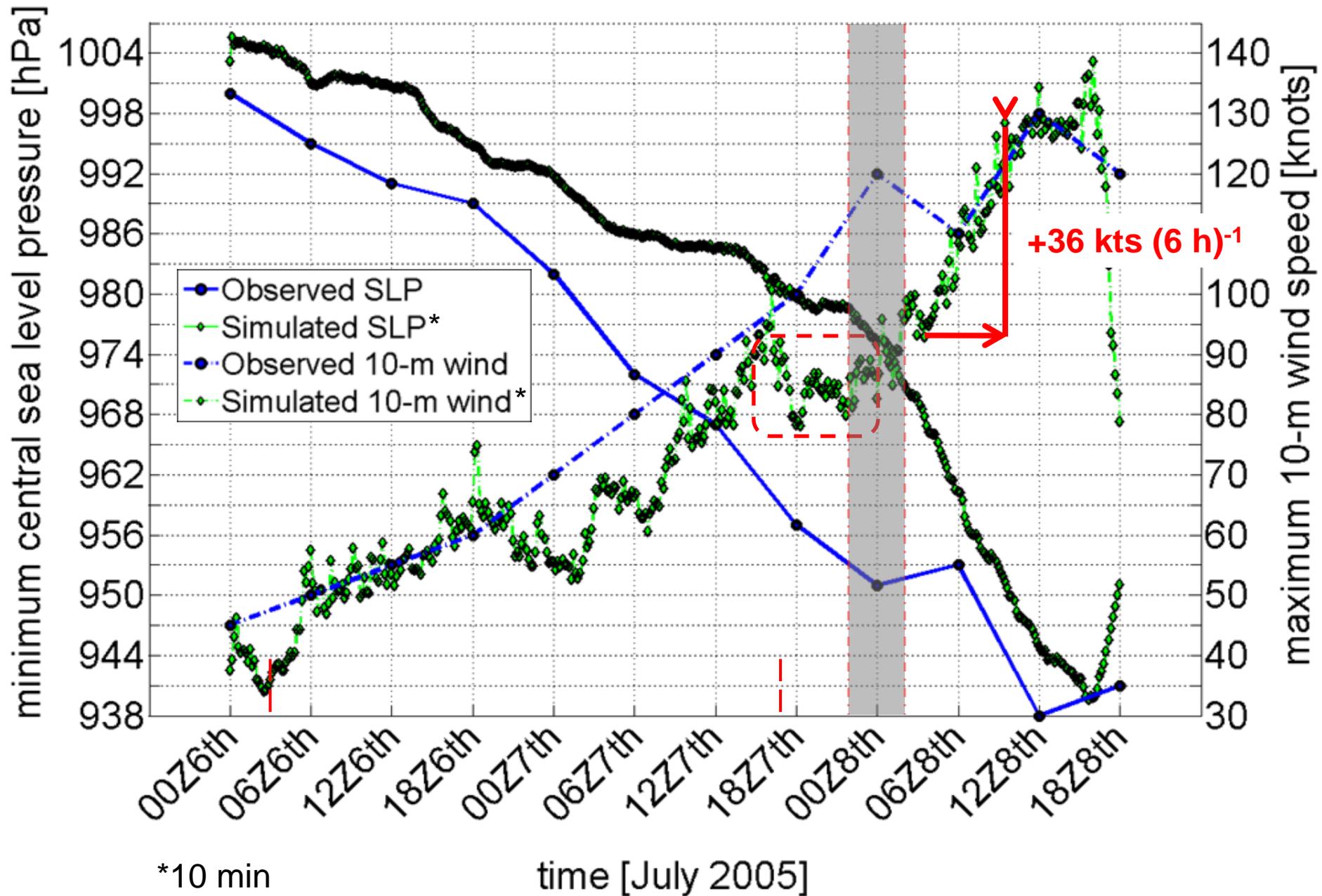
Horizontal...



# WRF Configuration

Vertical...

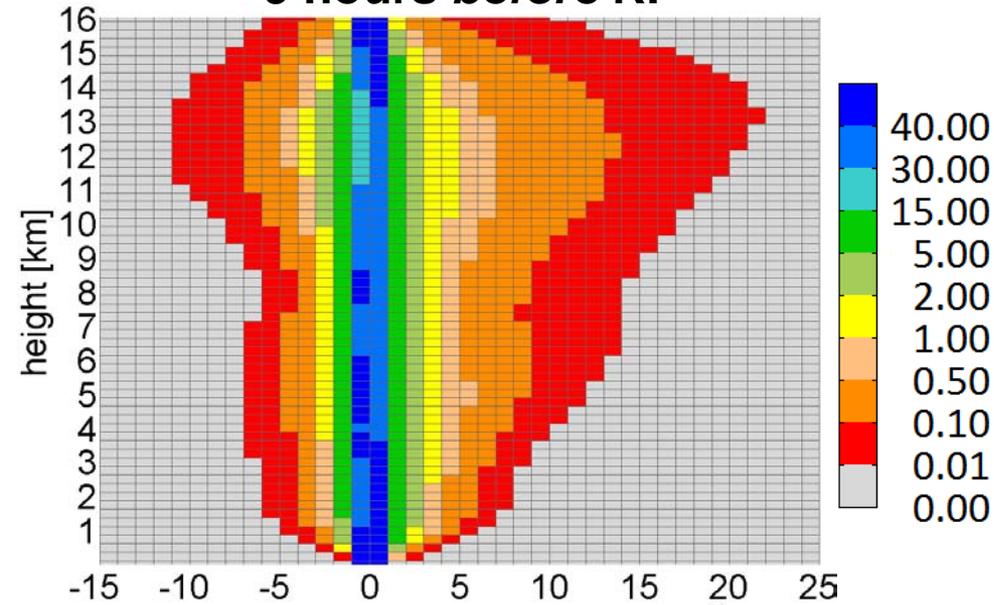




\*10 min

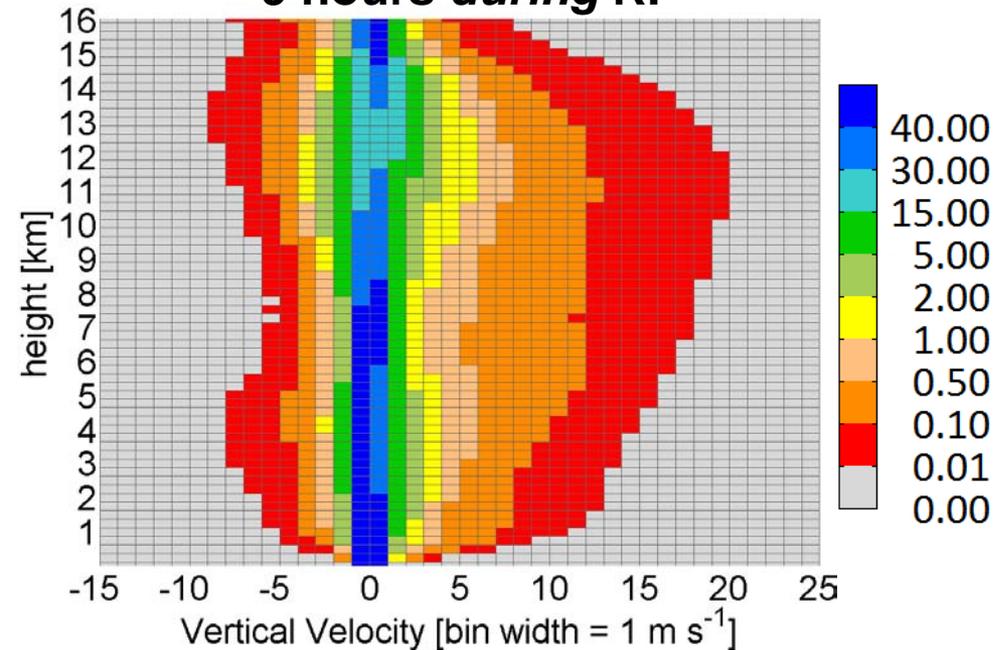
time [July 2005]

9 hours *before* RI

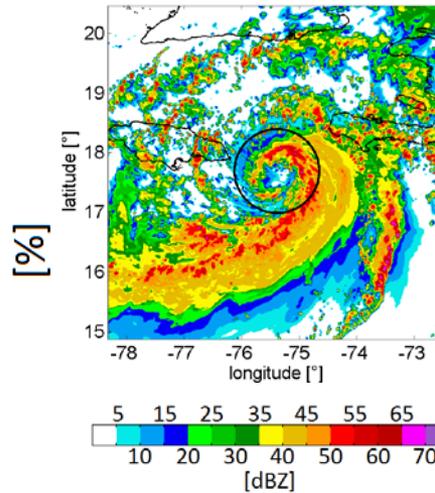


**CFADs**

9 hours *during* RI

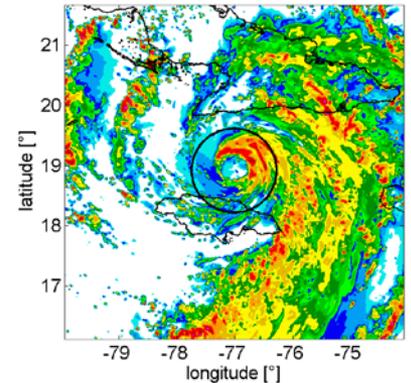


1200Z 07 July 2005

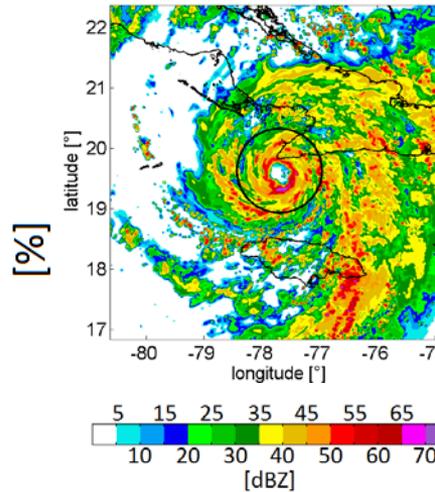


Column  
Max  
Reflectivity

2100Z 07 July 2005

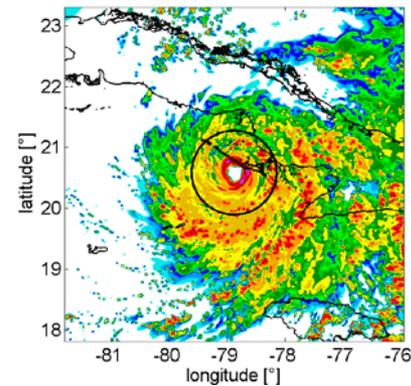


0300Z 08 July 2005

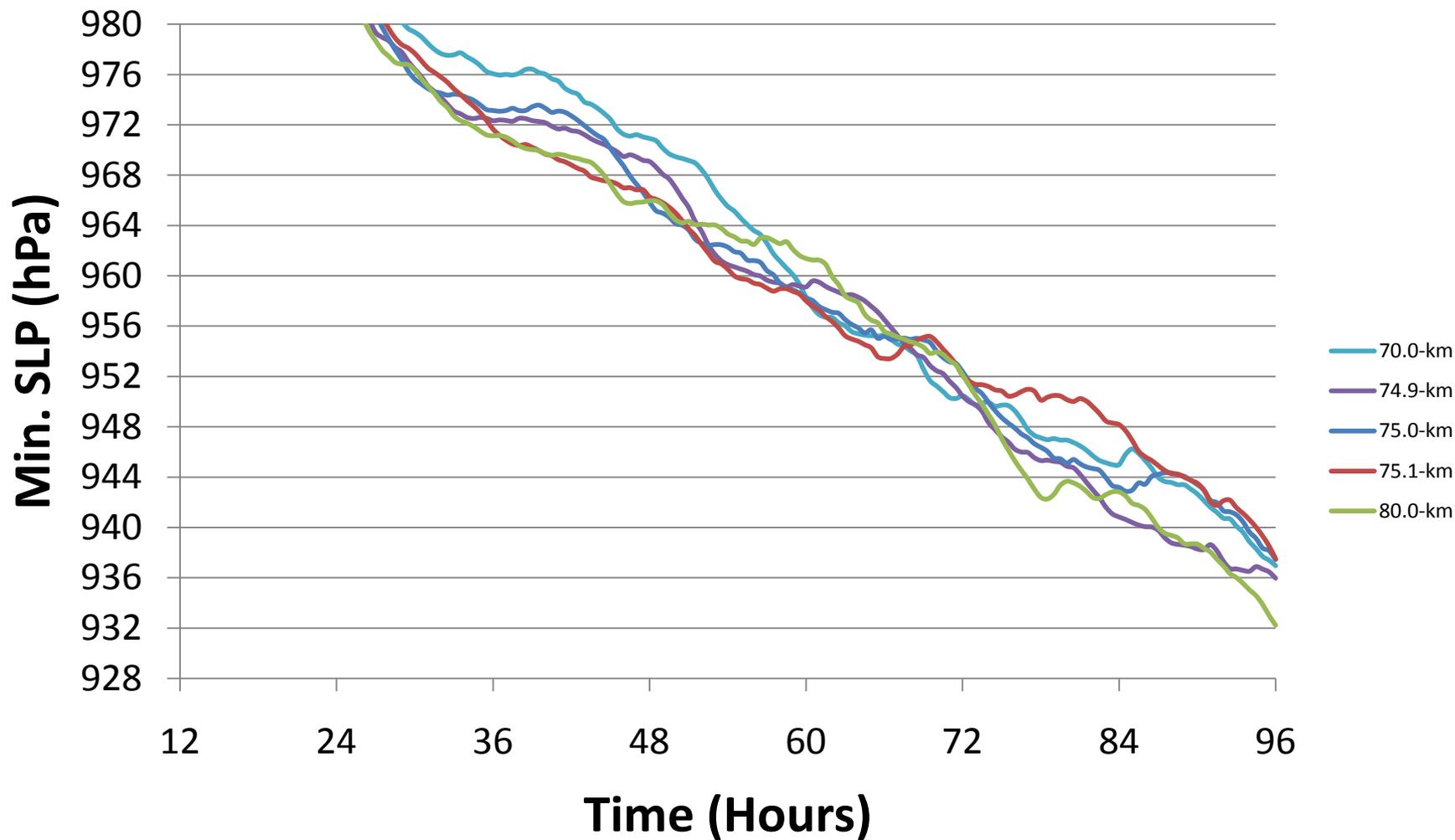


Column  
Max  
Reflectivity

1200Z 08 July 2005

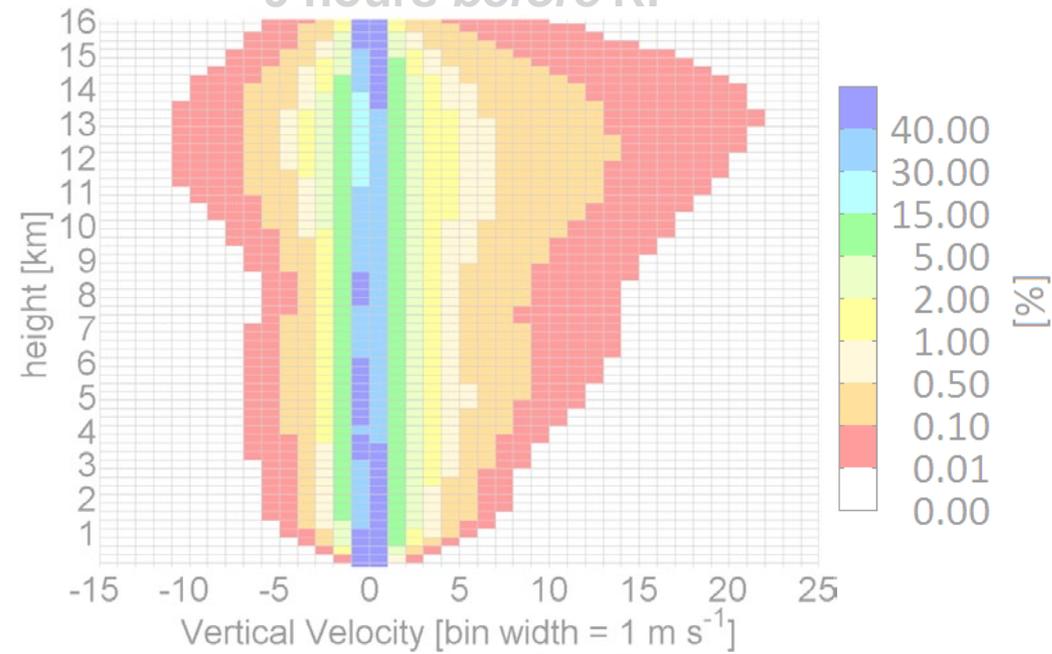


# RMW Perturbation Simulations (Same Node)

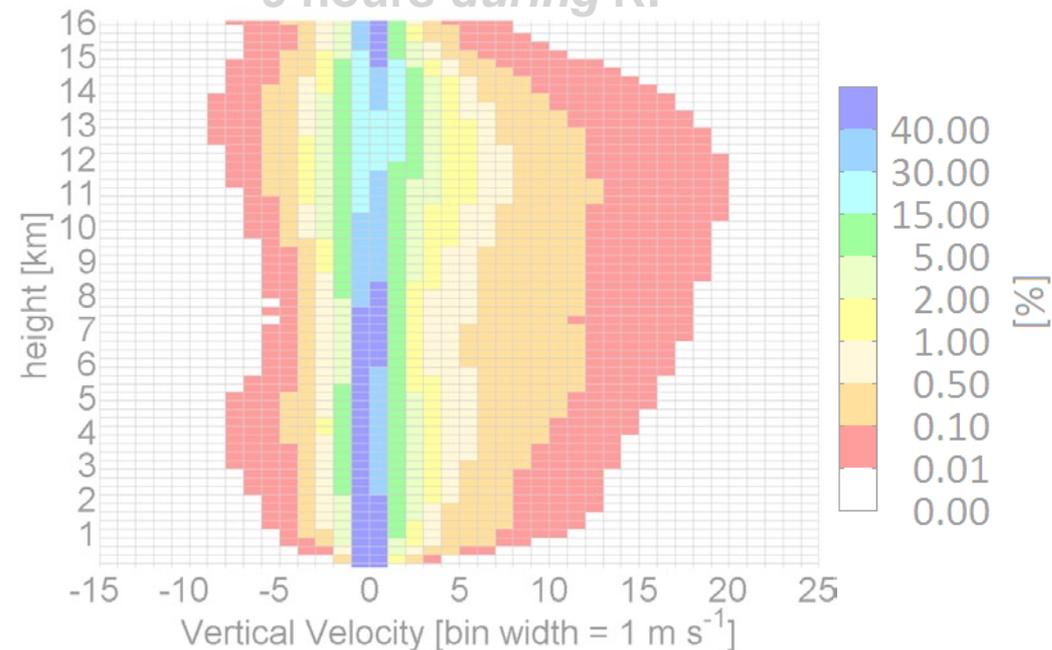




9 hours *before* RI

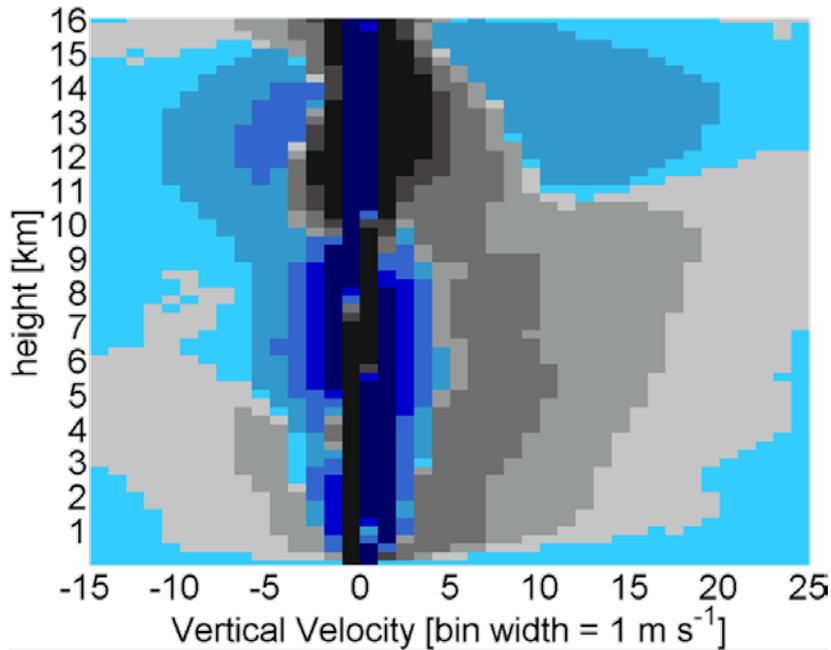
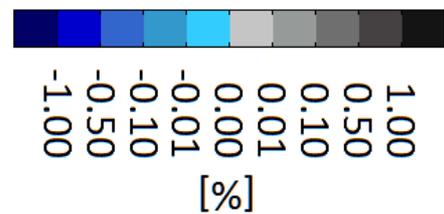


9 hours *during* RI



## CFAD Difference

*during* - *before* RI



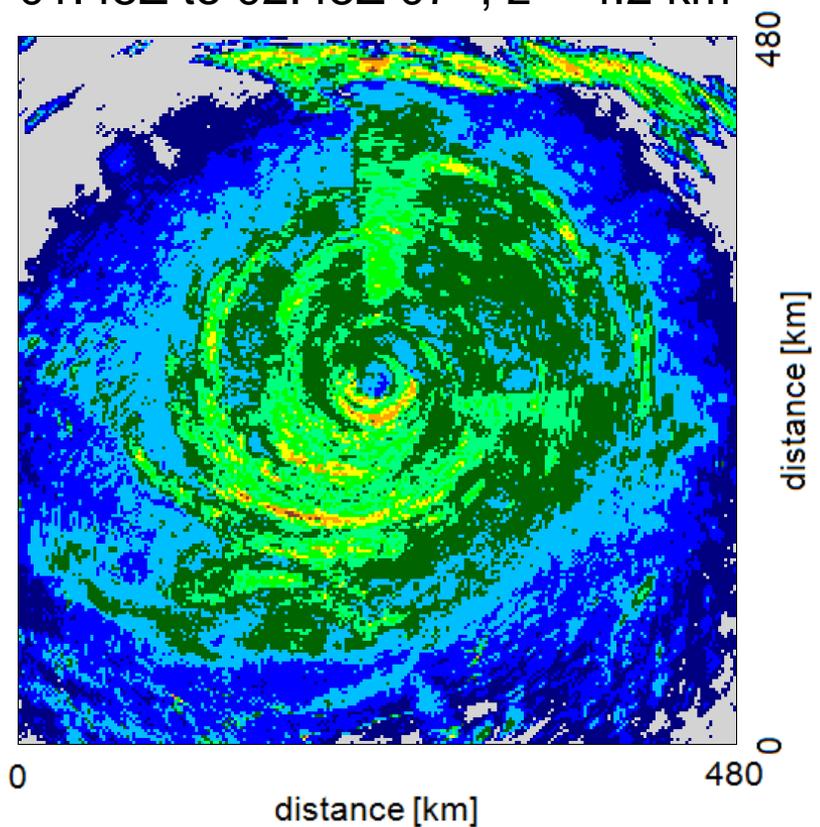
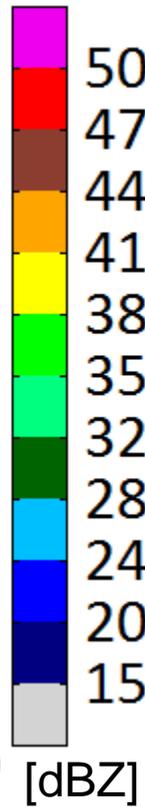
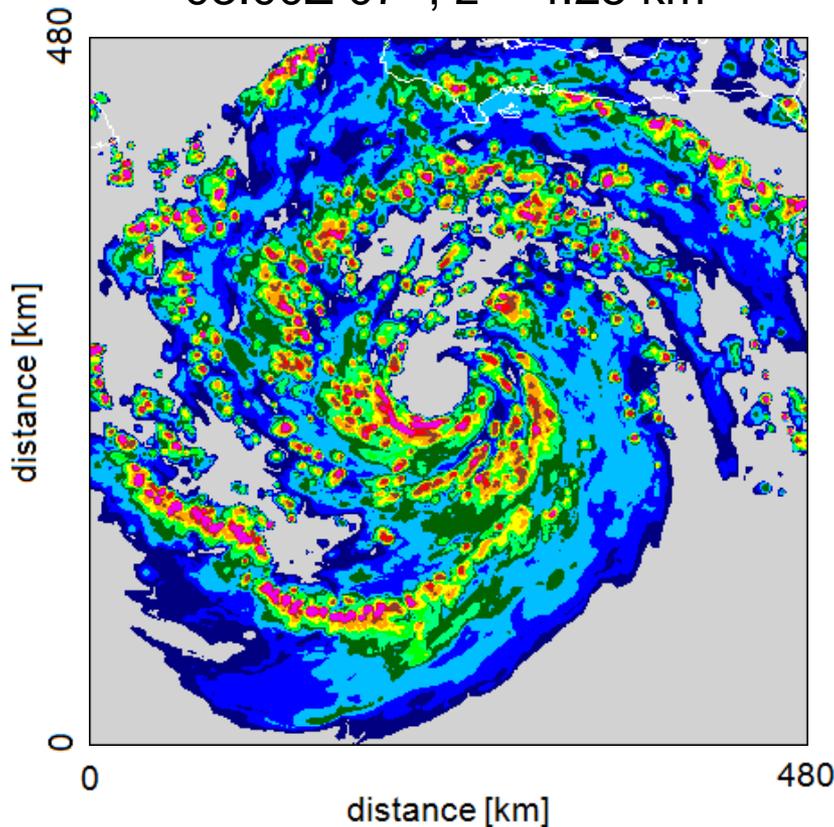
# Reflectivity Comparison

Simulation

NOAA P-3 Radar

03:00Z 07<sup>th</sup>; z = 4.25 km

01:45Z to 02:45Z 07<sup>th</sup>; z = 4.2 km



# WRF Simulations of Dennis

Examine distributions, magnitudes, vertical structures, durations, proximities to vortex center of convective bursts & trends as precursors to RI

