Vertical Velocity and Microphysical Distributions Related to Rapid Intensification of Hurricane Dennis (2005)

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NASA Earth and Space Science Fellowship

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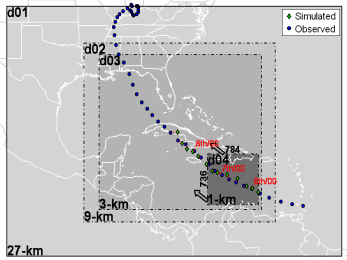
MOTIVATION

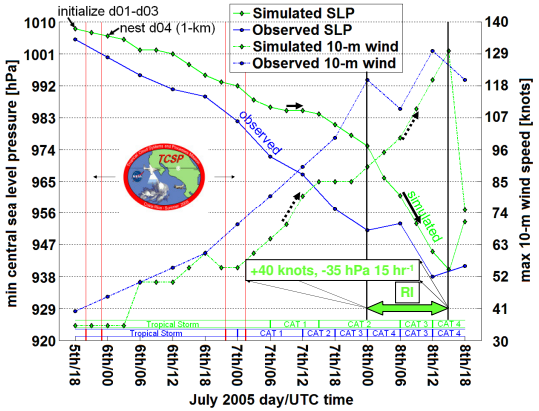
- Critical need for improved understanding and forecasting of tropical cyclone rapid intensification (RI)
- Key lifecycle observations of Hurricane Dennis (2005) from NASA Tropical Cloud Systems and Processes (TCSP) campaign for evaluation of numerical models and parameterization schemes
- Prior research (Price et al. 2009, *Nature Geosci.)* documenting peak lightning as a 24-hour precursor to RI of Hurricane Dennis (2005)
- Reliance of this correlation on localized, intense updrafts (i.e., convective bursts)
- Disagreement, for unknown reasons, how the breadth of vertical velocity distributions, and thus structure of convective bursts, varies with height between previous studies (McFarquhar et al. 2006, *JAS*; Rogers et al. 2007, *JAS*)
- Limited understanding of the timing, 3-D structure, and the relation of convective bursts to distributions of latent heat, and – ultimately – their impacts on the RI of Hurricane Dennis (2005)

WRFV3.0.1-ARW CONFIGURATION



- 1-km d04 vortex-following
- 55 vertical levels
- GFDL/GFS initial & BCs
- d01-d03 u,v analysis nudging, non-PBL
- Thompson microphysics
- Kain-Fritsch convective parameterization on d01
- Yonsei PBL scheme w/ Cd & Ck TC modifications
- Dudhia SW; RRTM LW

INTENSIFICATION



- Observed central pressure drop of 31 hPa 24 hr^{-1} preceding 00Z 08th not reproduced well (i.e., -17 hPa 24 hr^{-1}) in simulation
- Observed wind speed increase, however, simulated fairly well (e.g., +25 knots v. simulated +30 knots from 00Z to 15Z 07th)
- Most pronounced, persistent, and rapid deepening *and* acceleration of wind speed after 00Z 08th, consistent with observations

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  - NOAA/AOML/HRD (for P-3 LF composite radar accessed via http://www.aoml.noaa.gov/hrd/Storm_pages/dennis2005/)
  - Greg Thompson, NCAR (for Z derivation consistent with WRFV3.0.1 microphysics parameterization scheme)
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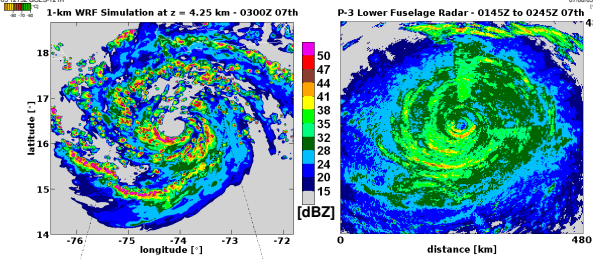
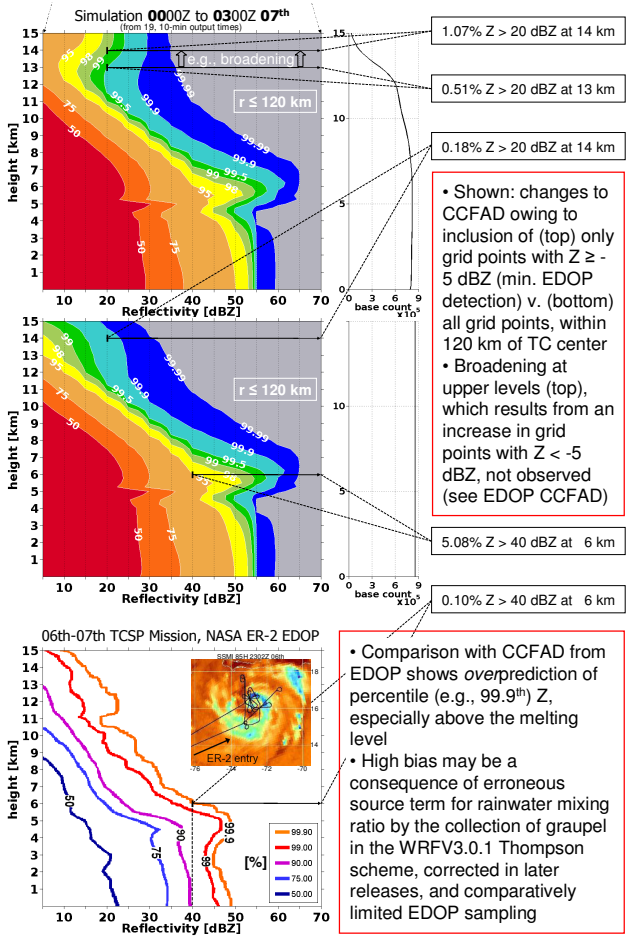
  - Joe Turk, NRL (for overlay of 06th-07th EDOP flight path on SSMI 85H imagery accessed via http://www.jcsda.noaa.gov/JCSDASeminars2007past.php)

EVALUATION: REFLECTIVITY



- Rainband and developing eyewall reflectivity (Z) derived from simulation biased high compared with observed Z
- Need statistical analysis to assess generality of this statement

- CUMULATIVE CONTOURED FREQUENCY BY ALTITUDE DIAGRAM
- CCFAD - variation with height of cumulative frequency distributions (i.e., % ≤ given value)

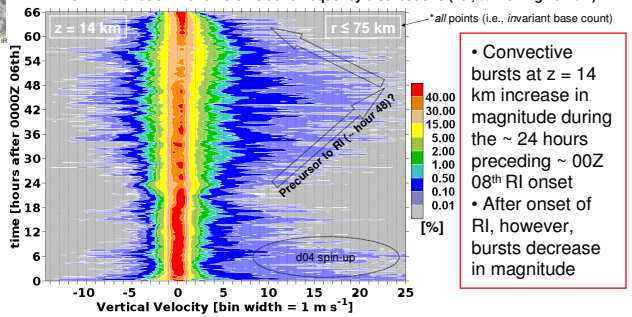


- Shown: changes to CCFAD owing to inclusion of (top) only grid points with Z ≥ -5 dBZ (min. EDOP detection) v. (bottom) all grid points, within 120 km of TC center
- Broadening at upper levels (top), which results from an increase in grid points with Z < -5 dBZ, not observed (see EDOP CCFAD)

- Comparison with CCFAD from EDOP shows *over*prediction of percentile (e.g., 99.9th) Z, especially above the melting level
- High bias may be a consequence of erroneous source term for rainwater mixing ratio by the collection of graupel in the WRFV3.0.1 Thompson scheme, corrected in later releases, and comparatively limited EDOP sampling

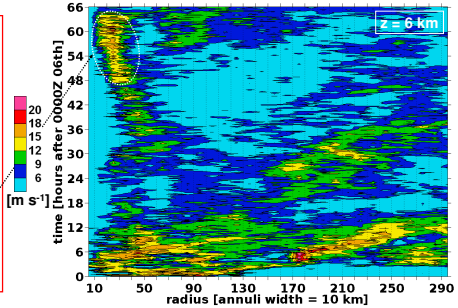
EVOLUTION: VERTICAL VELOCITY

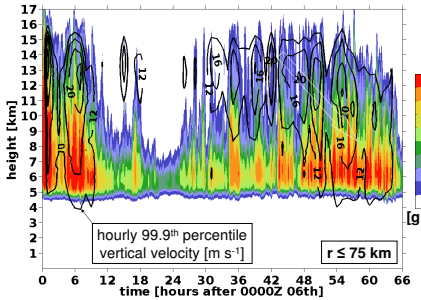
- CONTOURED FREQUENCY BY TIME DIAGRAM
- CFTD - variation with time of relative frequency distributions (i.e., % within given bin)



- Convective bursts at z = 14 km increase in magnitude during the ~ 24 hours preceding ~ 00Z 08th RI onset
- After onset of RI, however, bursts decrease in magnitude

- 99.9th percentile (relative to *all* points within annuli) vertical velocity at z = 6 km changes little *preceding* RI…
- But increases *during* RI, opposite of trend at z = 14 km





- 99.9th percentile graupel mixing ratio increases during RI
- Corresponds to shift in trend from upper-level to lower-level increase in 99.9th percentile vertical velocity at onset of RI noted above

CONCLUSIONS

- Percentiles computed from model-derived Z are biased high, especially above the melting level.
- Restricting CCFAD to grid points with Z ≥ -5 dBZ results in upper-level broadening, and thus could (assuming infrequent collocation of Z < -5 dBZ and intense updrafts) explain the discrepancy between CFADs of McFarquhar et al. (2006) and Rogers et al. (2007).
- Continual broadening of simulated vertical velocity distribution tail (i.e., enhancement of convective bursts) occurs at upper levels (e.g., 14 km) during the ~ 24 hours *prior to* RI and narrowing thereafter.
- However, the 99.9th percentile vertical velocity at lower levels (e.g., 6 km) increases only *after* the onset of and *during* RI.
- These lower-level convective bursts increase graupel *after* the onset of RI and may increase lightning contrary to the finding of a 24-hour lag by Price et al. (2009).
- Further analysis of the timing and location of convective bursts, with emphasis on 4-D latent heat distributions resulting from hydrometeor conversions, is in progress.