Using TCSP Observations to Evaluate Model Simulations of Hurricane Dennis (2005)

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1. Motivation

- Hurricane intensity forecasts have shown minimal improvement in last 20 years (Franklin 2007)
- Many factors limit our understanding of hurricanes. Methods of improving understanding include:
  - Incorporating more detailed representation of microphysics in numerical models
  - Quantifying temporal and spatial distribution of latent heating and how it impacts hurricane evolution

This study uses TCSP airborne radar and radiometer data to evaluate the performance of a numerical model with advanced microphysics for simulating cloud fields of Hurricane Dennis (2005) at 3 different stages of evolution: Tropical depression, tropical storm, and cat. 1 hurricane after Cuban landfall

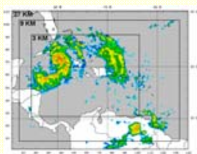


Fig 1. Model grid layout

2. Simulation Overview

- The Advanced Research Weather Research and Forecasting (WRF-ARW) model, version 2.2 is used with the following options:
- NCEP GFS initial, boundary data
- Simulation times: 00Z 4 July, 2005 to 00Z 10 July, 2005.
- Three grids: dx = 27, 9, and 3 km. Nests placed July 5, 00Z or July 5, 12Z
- Vertical levels: 54
- Cumulus parameterization: Kain-Fritch, outer grid only
- Explicit microphysics: Thompson (2006) with 2007 updates

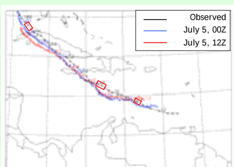


Fig 2. Observed and modeled hurricane tracks

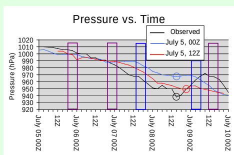


Fig 3. Observed and modeled min. central pressure. Purple boxes: TCSP observation times. Blue boxes: simulation times used for comparison (focusing on July 5, 00Z case). Circles: Cuban landfall.

3. Simulated and Observed Reflectivity

Statistically compare observed and modeled Z using contoured frequency by altitude diagrams (CFADs) (Yuter and Houze 1995) at 2 different stages of development

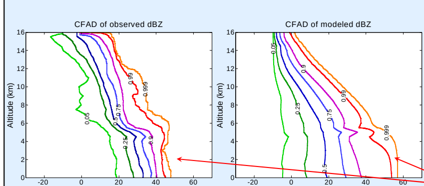


Fig 4. CFAD of dBZ from EDOP (left) and model (right) for comparison at tropical storm stage

Model over-predicts largest dBZ compared to ER-2 Doppler radar (EDOP)

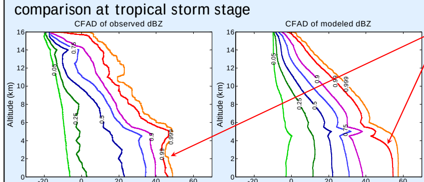


Fig 5. Same as fig. 4, but for comparison at category 1 stage

- Model fails to capture differences seen in observed dBZ for observations made at 2 different intensities → Model does not capture changes in hydrometeor fields

4. Simulated and Observed T_b

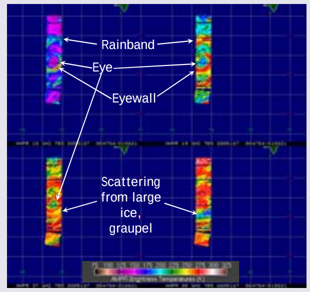
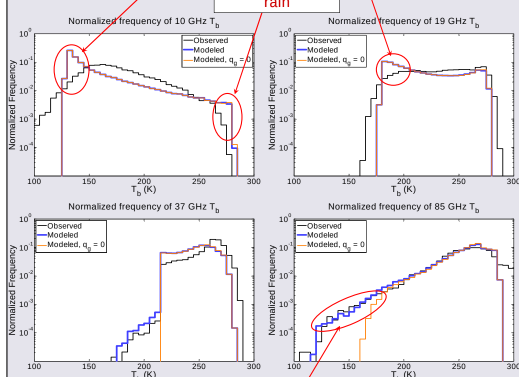


Fig 6. AMPR T_b with features of hurricane structure

- T_b computed from modeled fields using Kummerow radiative transfer model
- Additional calculation (q_g = 0) removes graupel contribution to T_b to determine if over-prediction of graupel noted in previous studies (e.g. McFarquhar et al. 2006) exists
- Clear pixels removed from observed and modeled T_b data using mask based on Hood et al. (2006) classification

Clear pixels not removed by mask

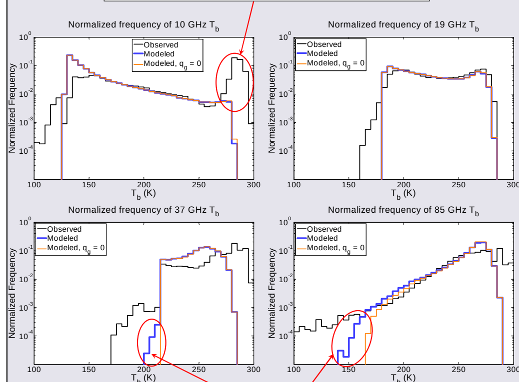
Model over-predicts heavy rain



Model exhibits enhanced scattering caused primarily by graupel

Fig 7. Normalized frequency histograms of and T_b at 10, 19, 37 and 85 GHz for observation (black), model (blue) and model with graupel effects removed (red) for comparison at tropical storm stage

Model under-predicts heavy rain



Model under-predicts graupel

Fig 8. Same as fig. 7, but for comparison at category 1 stage

- To extent presence of supercooled water does not affect interpretation of data, over-prediction of rain and graupel noted in past studies not present at later, more intense stages.

5. T_b Sensitivity to N_0

- Kummerow radiative transfer model assumes fixed intercept parameter (N_0) for snow, graupel
- N_0 dependent on mixing ratio in Thompson microphysics
- Lack of variable N_0 can affect model/observed comparison
- Range of N_0 chosen to match ranges expected in modeled fields

Higher N_{0gr} → less scattering

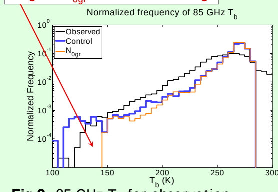


Fig 9. 85 GHz T_b for observation, control ($N_{0gr} = 8x10^6$), and sensitivity test ($N_{0gr} = 8x10^8$)

Higher N_{0sn} → higher frequency of high T_b

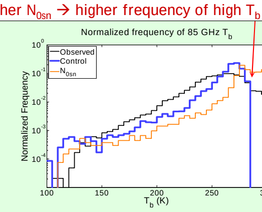


Fig 10. Same as figure 7, but for snow control ($N_{0sn} = 1.6x10^7$) and sensitivity ($N_{0sn} = 1.6x10^5$)

6. Summary

- TCSP ER-2 measurements were compared to simulated reflectivity, Tb to assess WRF results for 2 stages of Dennis (tropical storm and cat. 1 hurricane)
- Over-prediction of graupel, rain not noted for later observation of Dennis (cat. 1 hurricane)
- Model fields change little between tropical storm and cat.1 stages, unlike observations
- Analysis tools for model data need to be consistent with model assumptions

7. Future Work

- Conduct 1 km simulations utilizing moving nest
- Incorporate highly-detailed microphysical parameterization (Straka Gilmore 2008)
- Compare modeled, EDOP wind fields
- Introduce variable N_0 into Kummerow RT Model for consistency with microphysics
- Improve reflectivity algorithm to improve comparison with EDOP

8. References

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9. Acknowledgements

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