HWRF Surface Layer Thermodynamics Evaluation

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- HRD HWRF modeling team
  - Gopal, Xuejin Zhang, Thiago Quirino, Vijay Tallapragada
- HFIP
Hurricane Air-Sea Interaction Physics
Evaluation of coupled air-sea thermodynamics

- Observations from Tropical Cyclone Buoy Database (TCBD; Cione et al. 2000, Cione and Uhlhorn 2003, Cione et al. in review)
- HWRF 2011 retrospective model runs
- GPS dropwinsonde database (Zhang et al. 2011, Zhang and Uhlhorn 2012, Zhang et al. in preparation)
- Consider observations in hurricanes only
- Radially between 0.5 (no eye) and 6 RMWs
TC Buoy Observations

- Cione et al. 2000, 2003
- Temperature and humidity reported hourly
- Winds (10-min mean) reported every 10 mins.
- Obs. adjusted to 10-m level
- Winds converted to 1-min mean
2011 Season HWRF Retrospective Runs

- Configuration
  - 3 km inner nest
  - Coupled to ocean (POM)
  - Modified $C_k$, $C_d$ (CBLAST & others)
  - Modified diffusion (Zhang et al. 2011)
  - Operational in 2012

From Gopalakrishnan et al (JAS, in press)
2011 Season HWRF Retrospective Runs (cont.)

- Storms
  - Irene-09L (34 runs)
  - Katia-11L (46 runs)
  - Maria-14L (41 runs)
  - Ophelia-16L (48 runs)
  - Philippe-17L (60 runs)
  - Rina-18L (20 runs)

- Total 249 runs, 126 hr simulations, output every 3 hours
2011 HWRF & TCBD Storm Stats

TCBD

HWRF

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Fields of \( SST \), latent \( (Q_l) \) and sensible \( (Q_s) \) heat fluxes, and 10-m winds \( (U_{10}) \) are provided as model output.

\[
T_{10} = SST - \frac{Q_s}{\rho c_p C_h U_{10}}
\]

\[
q_{10} = q_s (SST) - \frac{Q_l}{\rho L_v C_e U_{10}}
\]

\[
C_h = C_e = C_k
\]

- Compute \( T_{10}, q_{10} \) from output model fields
- Sample model at TCBD buoy locations falling within model grid as cyclones translate/evolve
- Compute statistical distributions and compare with observations
Radial Distributions of Observed and HWRF Surface Layer SST, $T_{10}$, and $q_{10}$.
Observed vs. Simulated SST Variability

TCBD

HWRF

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GPS Dropwindsonde Database

- 10 m winds, temperature, humidity, NO SST
- Ongoing (labor-intensive) effort to add co-located AXBT SSTs to sonde profiles

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Empirical Probability Distributions

- Cumulative probability (%) vs. 10 m Wind speed (m/s)
- Cumulative probability (%) vs. 10 m Relative humidity (%)
- Cumulative probability (%) vs. 10 m Temperature (°C)
- Cumulative probability (%) vs. 10 m Dewpt. Temp. (°C)

- Sonde (n = 1168)
- TCBD (n = 1603)
Observed Temperature and Moisture

Relative Humidity

Temperature and Dewpoint

Observed (TCBD+Sondes)

- Sonde
- TCBD
- Combined Bin Avg

10 m Temperature T
10 m Dewpoint Td
10 m Wind speed U_{10} (m/s)
HWRF Evaluation

Graphs showing the relationship between 10 m temperature, dewpoint temperature, and relative humidity with 10 m wind speed, comparing HWRF, TCBD Obs., and Sonde Obs. data.
**TCBD Obs.**
- $q_{10}$ better correlated with $\Delta q$ than $q_s$
- Both de-correlate slightly with increased wind, but $q_{10}$ remains more highly correlated

**HWRF**
- $q_s$ better correlated with $\Delta q$ than $q_{10}$
- $q_{10}$ shows almost no relationship to $\Delta q$ at high winds
Summary

- A comprehensive evaluation of air-sea thermodynamic properties of the operational coupled HWRF has been performed.
- Results indicate:
  - HWRF atmosphere near-surface is typically warmer and more moist than observed
  - HWRF surface layer significantly lower relative humidity
    - Gradual tendency toward saturation as wind speed increases (max ~97% at 60 m/s)
    - Obs show far more rapid trend toward saturation (>95% at 30 m/s, max ~97-98% at 40 m/s)
  - POM-simulated SST cools significantly less than observed in response to TC forcing
Questions

- How to eliminate warm SST bias?
  - URI colleagues have indicated wind stress is reduced 25% in operational version for 2012
  - Comprehensive observation-based evaluation of operational coupled POM needed

- How to cool/dry the surface layer?
  - Fluxes and exchange coefficient modifications
  - Spray (cools but moistens)
  - Precipitation-induced downdraft transport
  - Entrainment/shallow convection

- Is HWRF overly-sensitive to the ocean?
  - Coupled-model simulations have shown changes to the ocean coupling can have large impact on simulated intensity
  - Extensive coupled-modeling efforts have not led to significant improvements to intensity prediction