HWRF Surface Layer Thermodynamics Evaluation

Eric W. Uhlhorn and Joseph J. Cione

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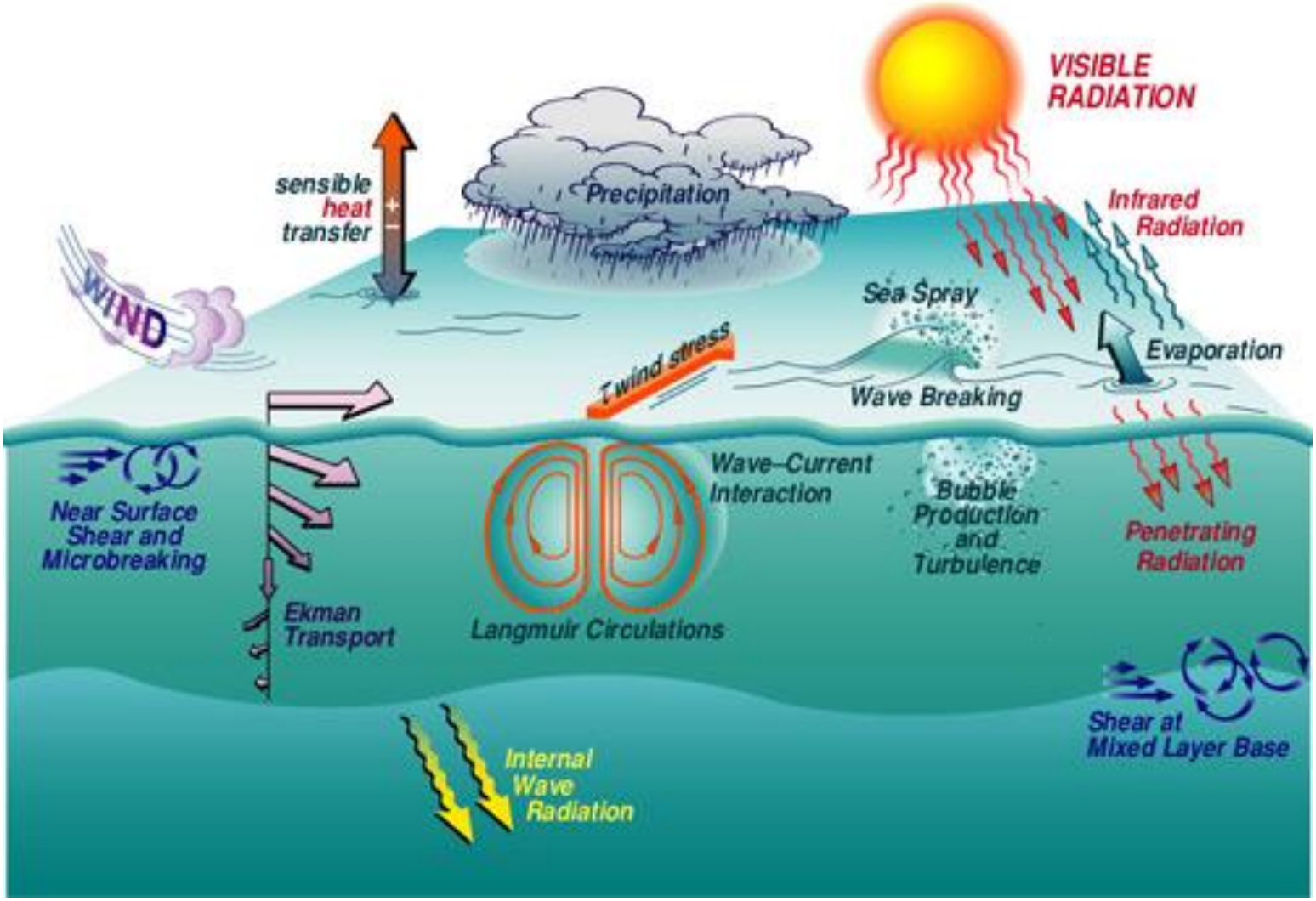
Special thanks….

- HRD HWRF modeling team
  - Gopal, Xuejin Zhang, Thiago Quirino, Vijay Tallapragada
- HFIP

Hurricane Air-Sea Interaction Physics



Evaluation of coupled air-sea thermodynamics

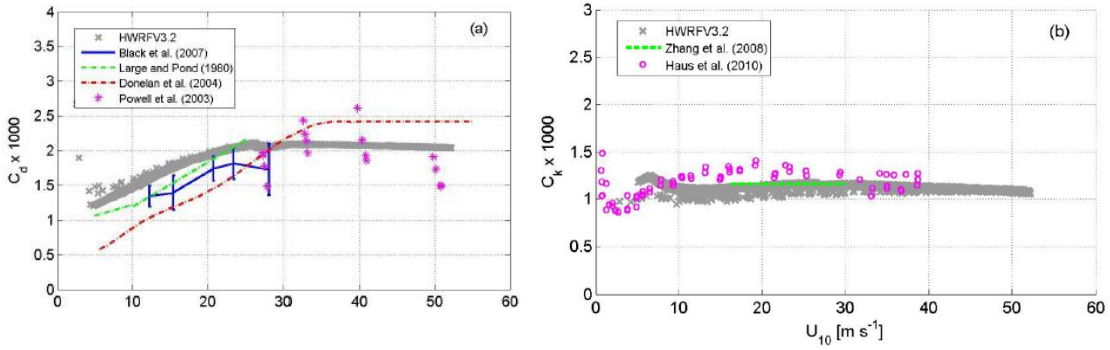
- Observations from Tropical Cyclone Buoy Database (TCBD; Cione et al. 2000, Cione and Uhlhorn 2003, Cione et al. in review)
- HWRF 2011 retrospective model runs
- GPS dropwinsonde database (Zhang et al. 2011, Zhang and Uhlhorn 2012, Zhang et al. in preparation)
- Consider observations in hurricanes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

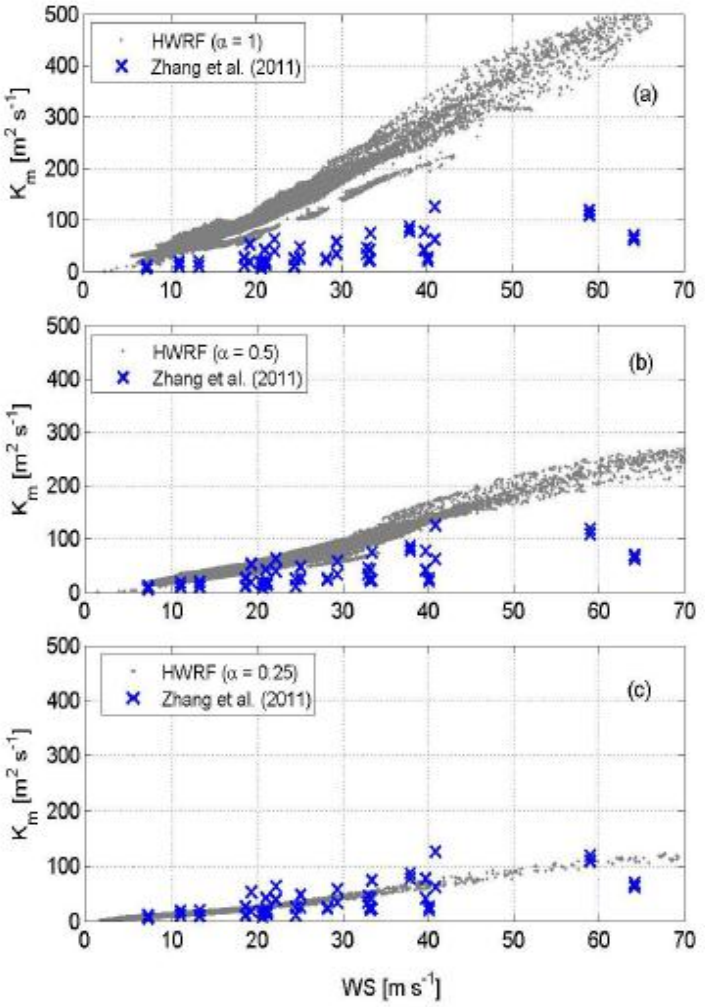
TC Buoy Observations

- 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

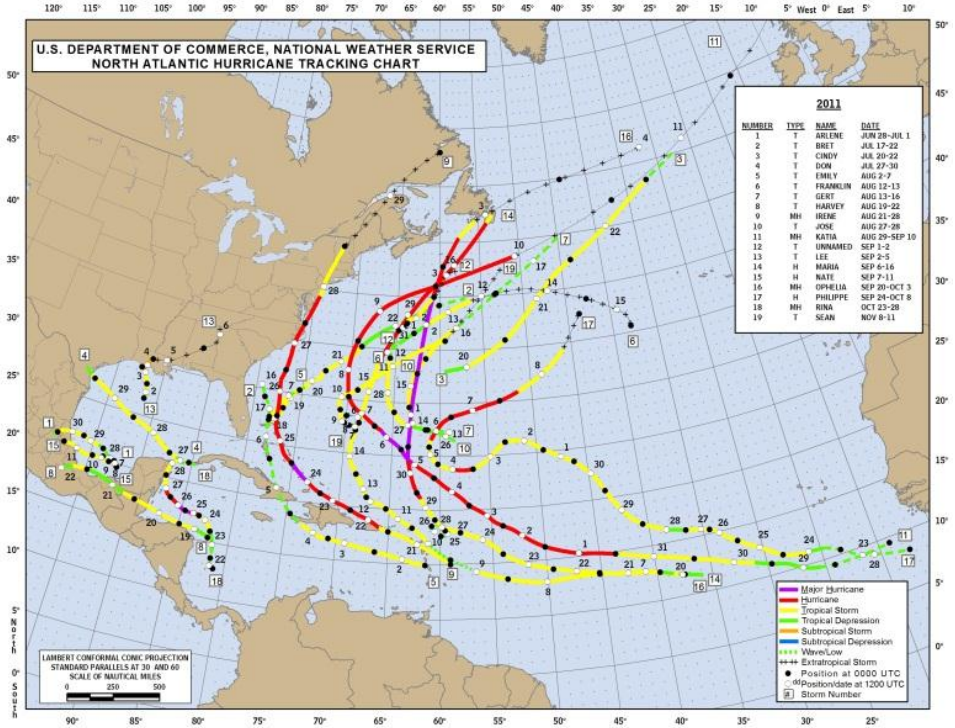




From Gopalakrisnan et al (JAS, in press)

2011 Season HWRF Retrospective Runs (cont.)

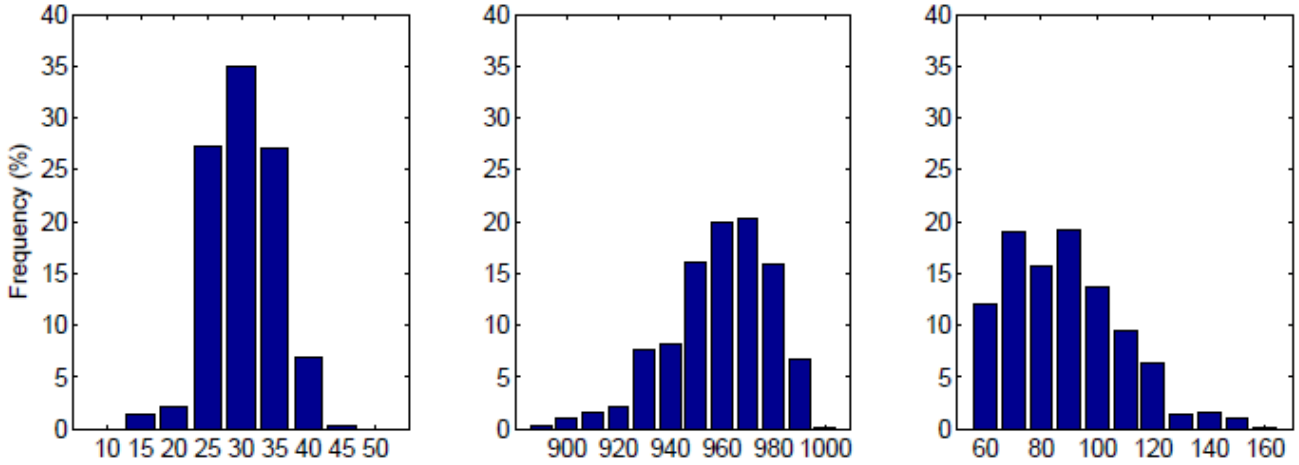
- Storms
  - Irene-09L (34 runs)
  - Katia-11L (46 runs)
  - Maria-14L (41 runs)
  - Ophelia-16L (48 runs)
  - Philippe-17L (60 runs)
  - Rina-18L (20 runs)



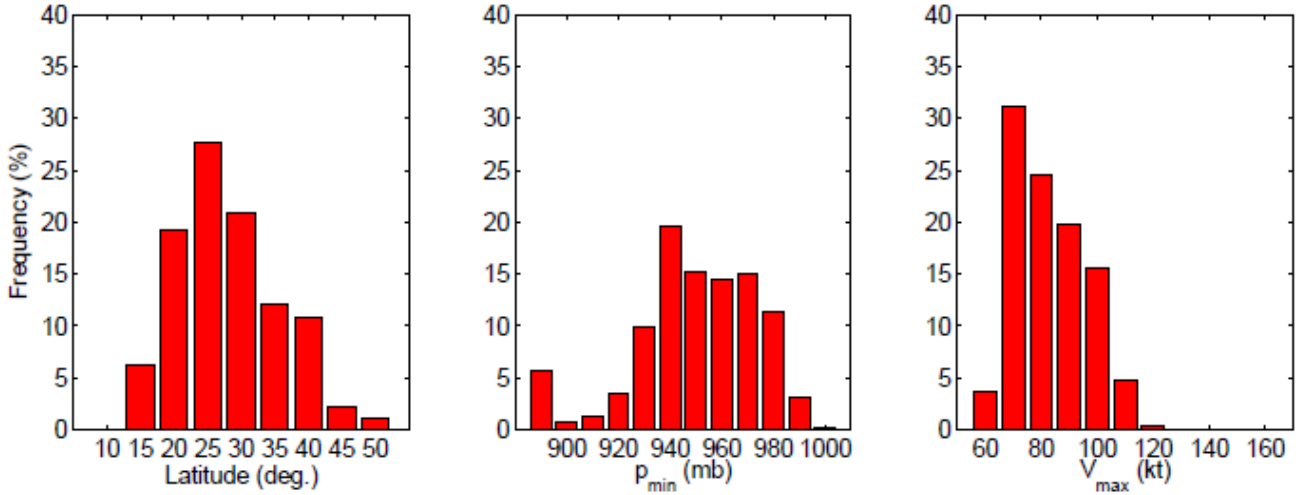
- Total 249 runs, 126 hr simulations, output every 3 hours

2011 HWRF & TCBD Storm Stats

TCBD

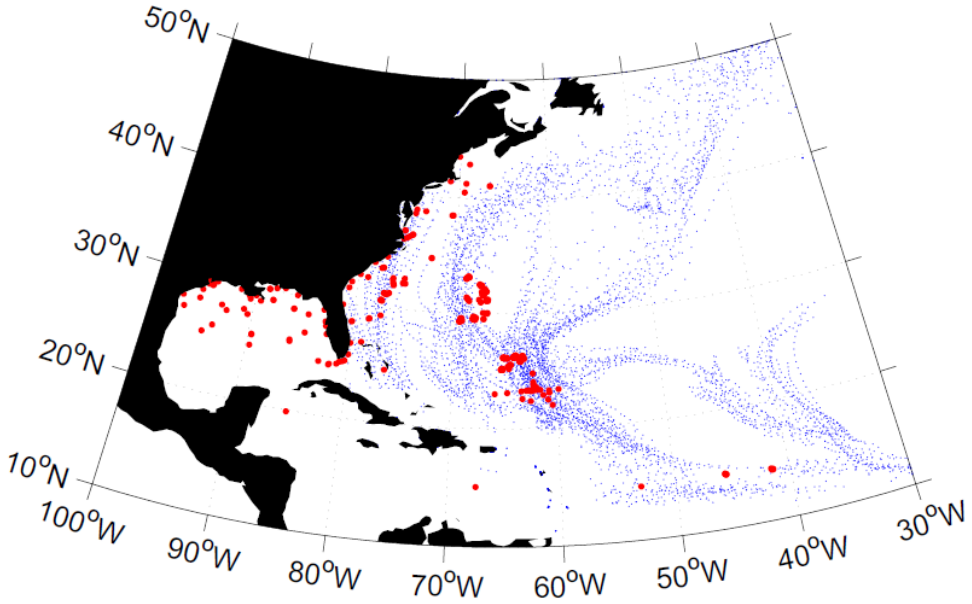


HWRF



Model Sampling Methodology

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



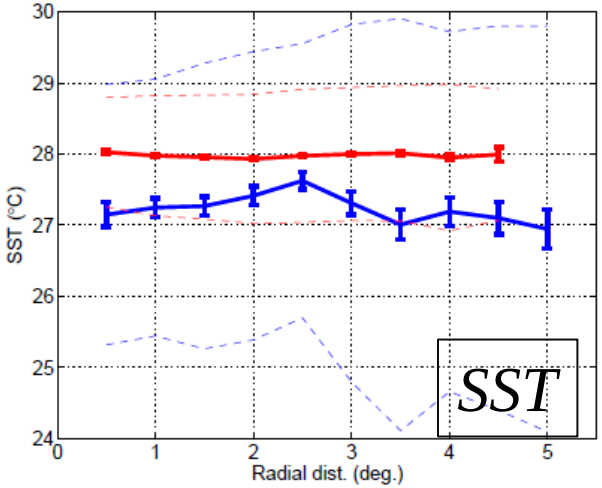
$$T_{10} = SST - \frac{Q_s}{\rho c_p C_h U_{10}}$$

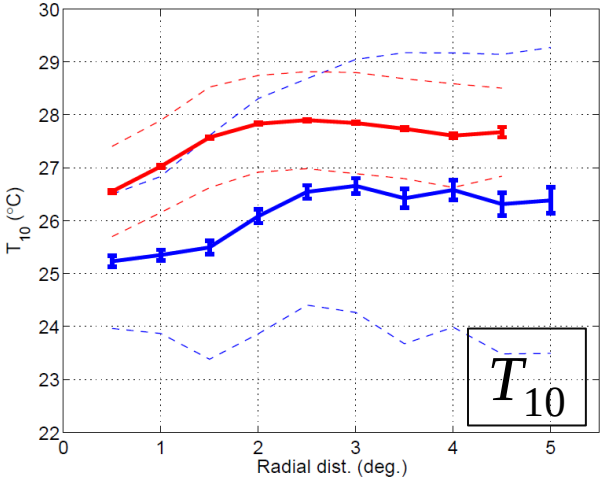
$$q_{10} = q_s(SST) - \frac{Q_l}{\rho L_v C_e U_{10}}$$

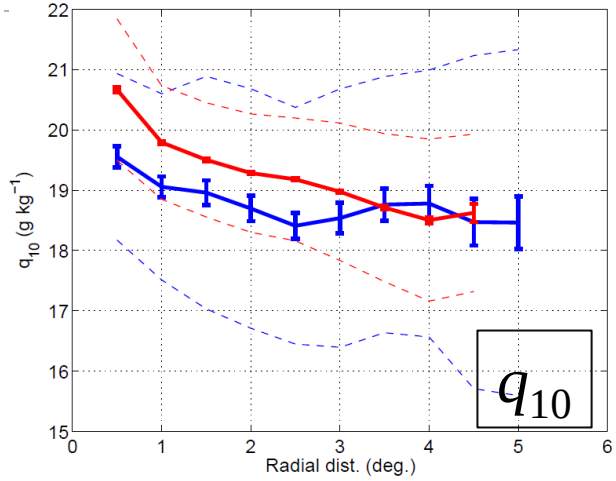
$$C_h = C_e = C_k$$

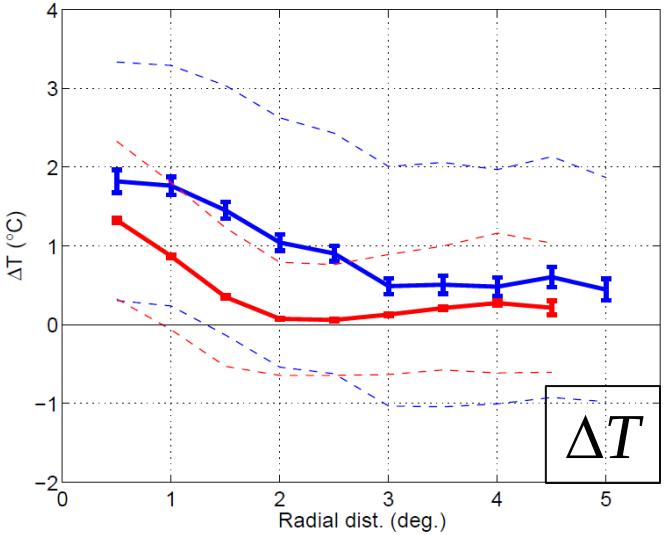
- Compute T_{10}, q_{10} from output model fields
- Sample model at TCBD buoy locations falling within model grid as cyclones translate/evolve
- Compute statistical distributions and compare with observations

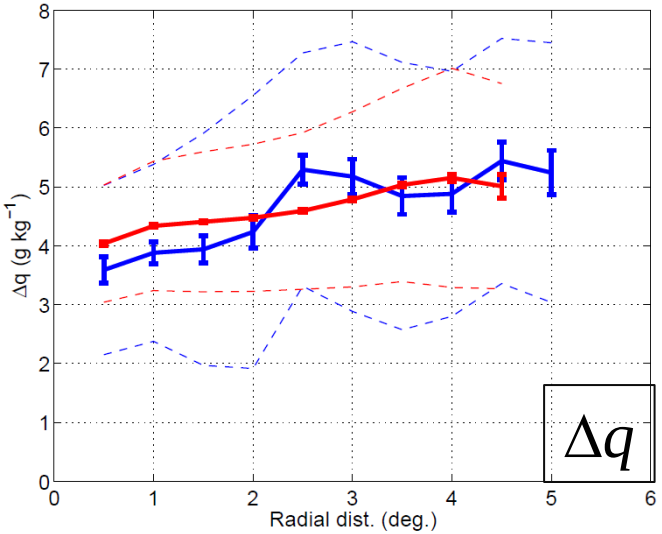
Radial Distributions of Observed and HWRF Surface Layer





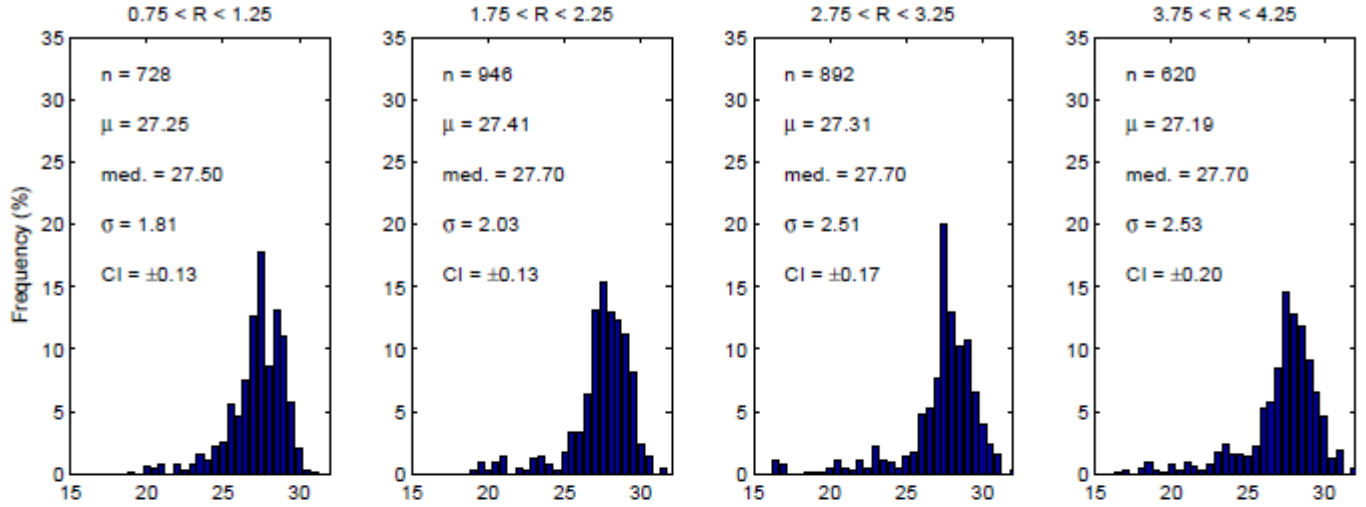




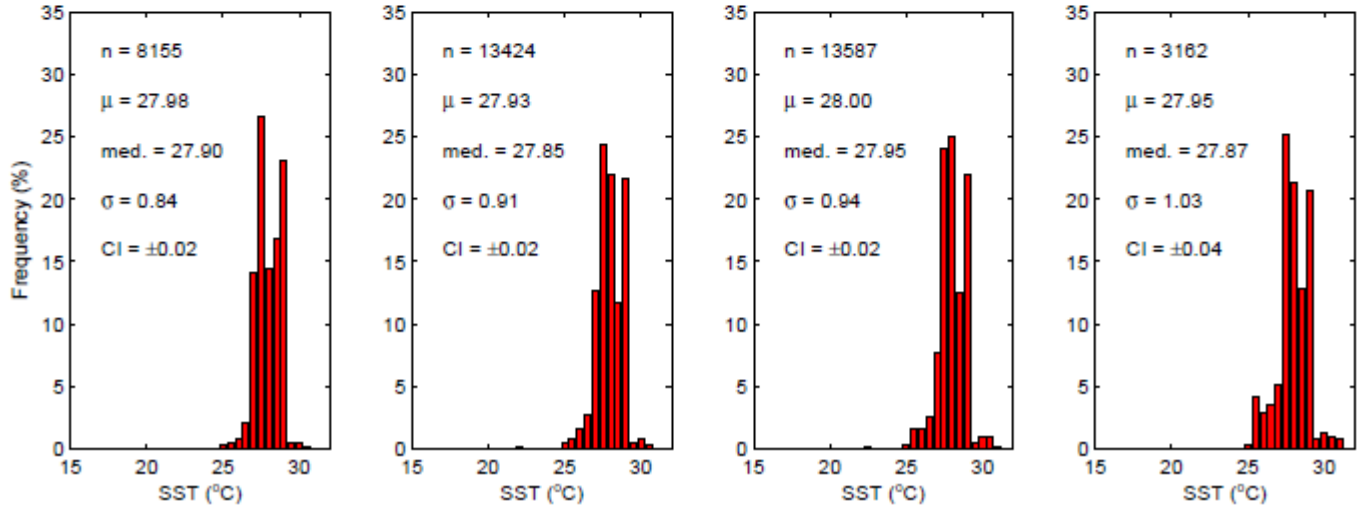


Observed vs. Simulated SST Variability

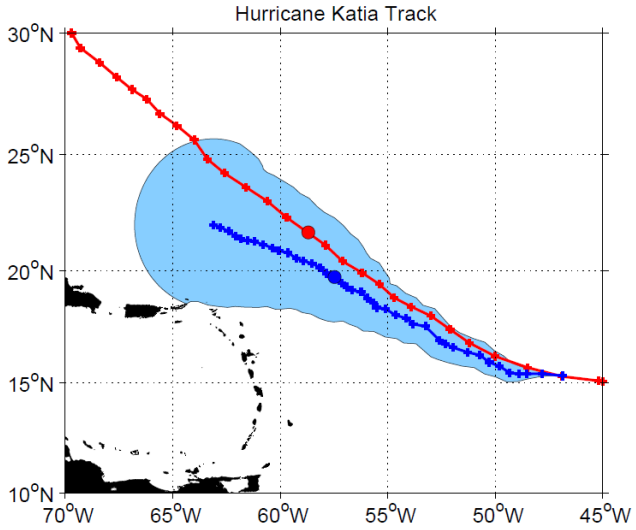
TCBD

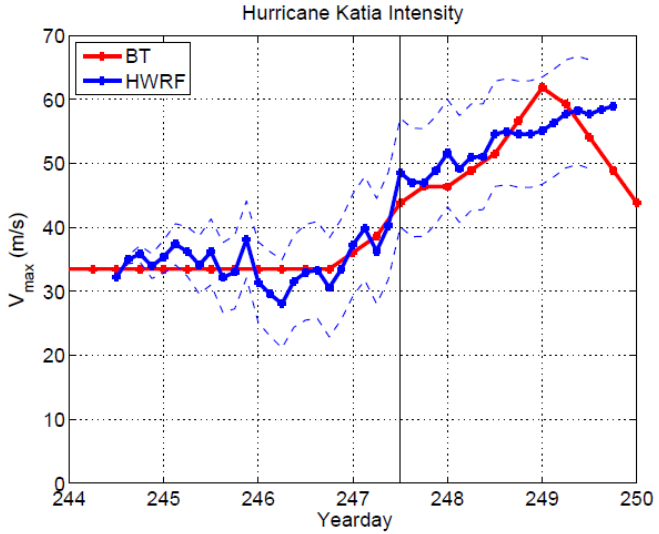


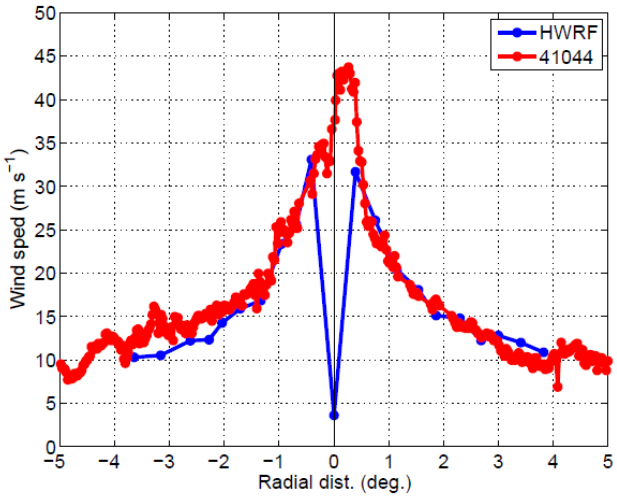
HWRF

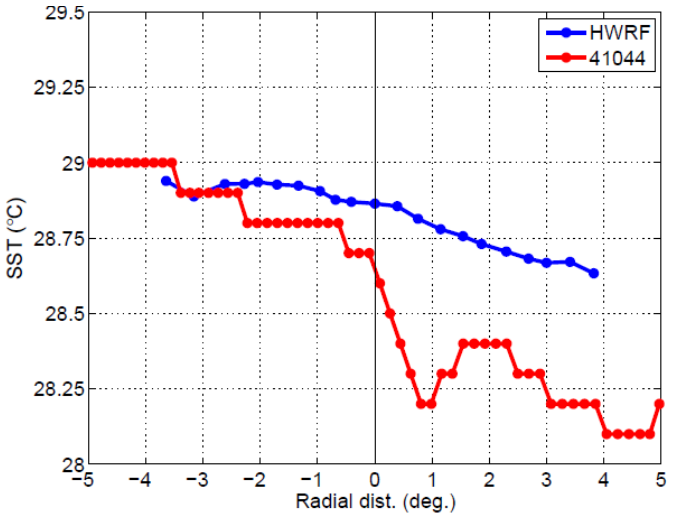


Hurricane Katia Buoy “Intercept”



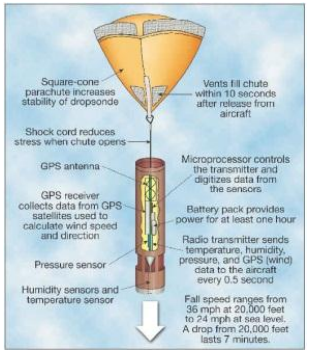


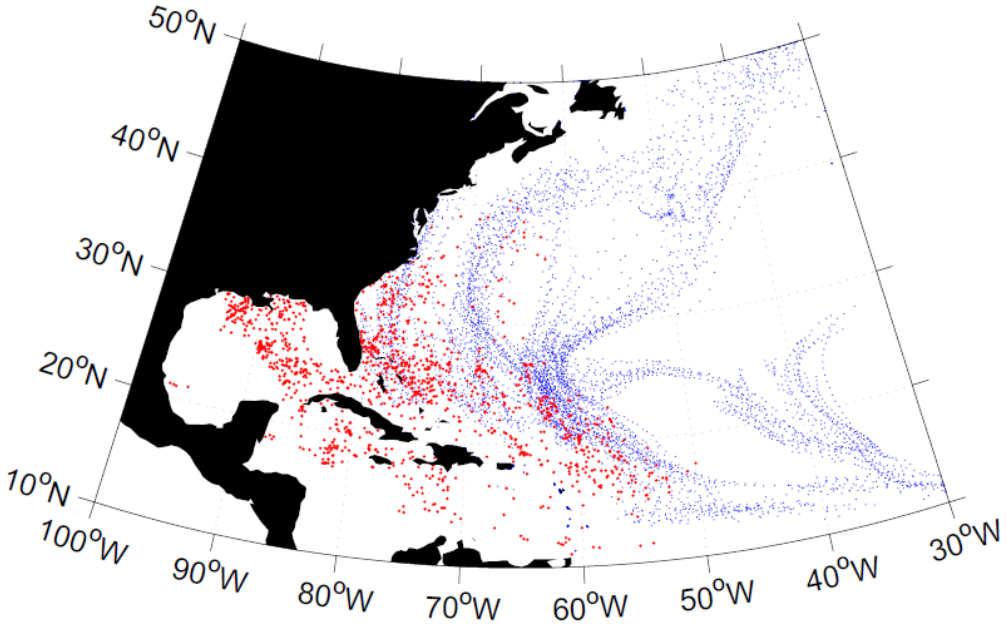


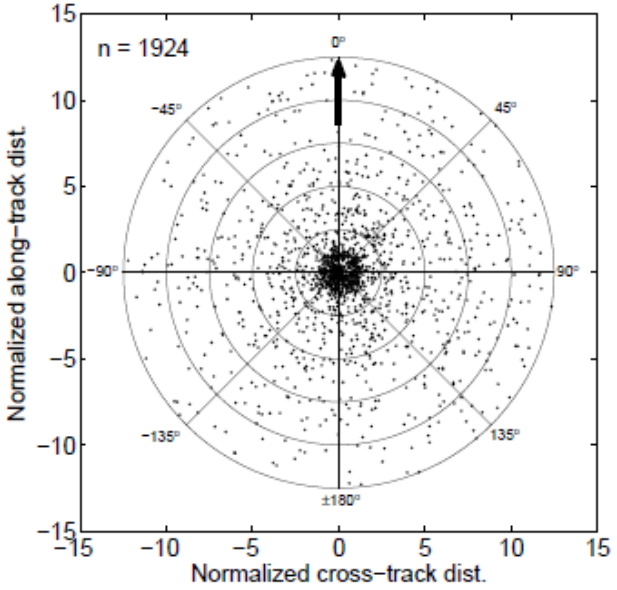


GPS Dropwindsonde Database

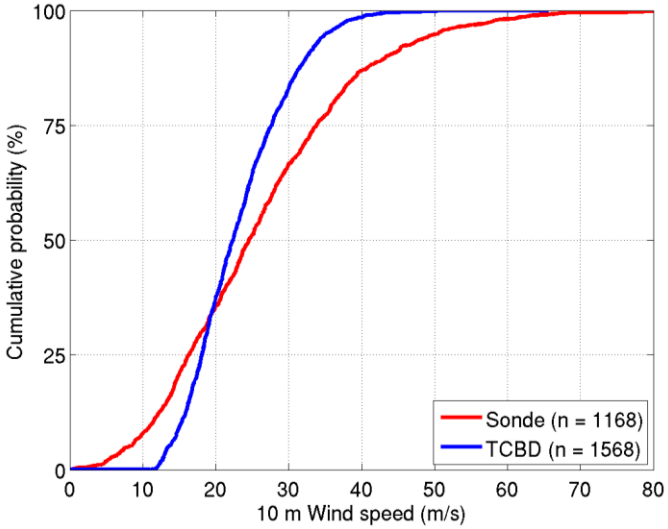
- 10 m winds, temperature, humidity, *NO* SST
- Ongoing (labor-intensive) effort
  to add co-located AXBT
  SSTs to sonde profiles

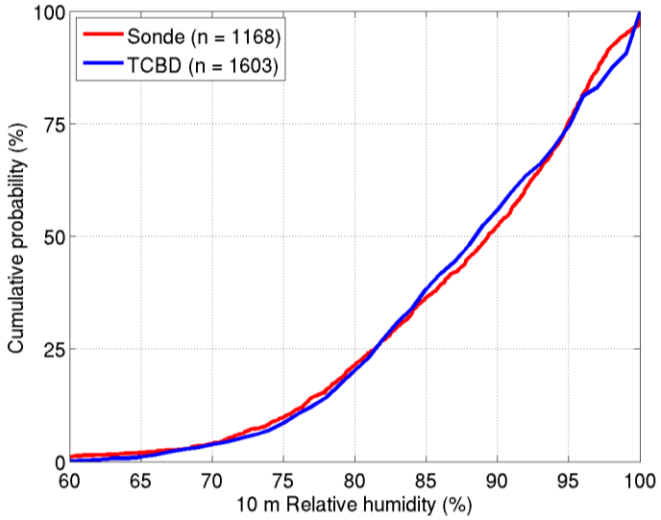


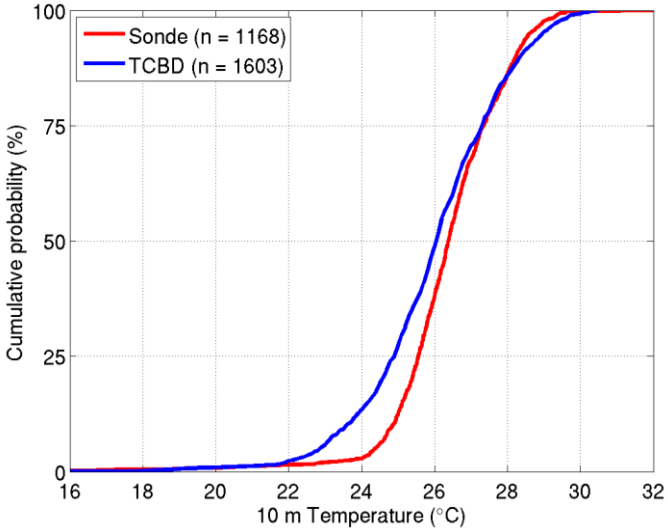


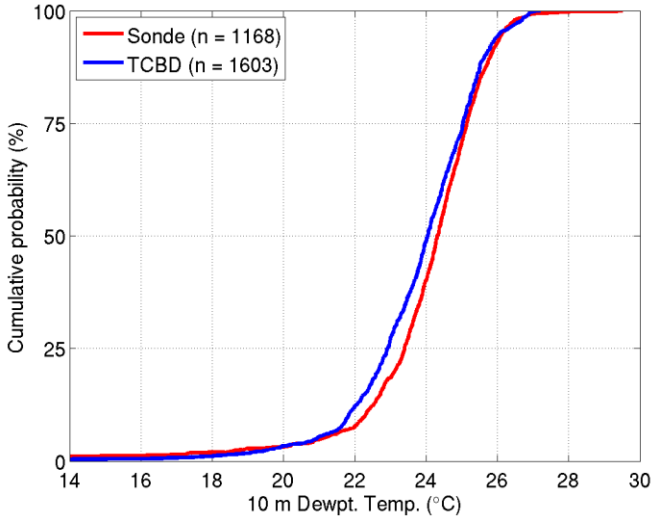


Empirical Probability Distributions



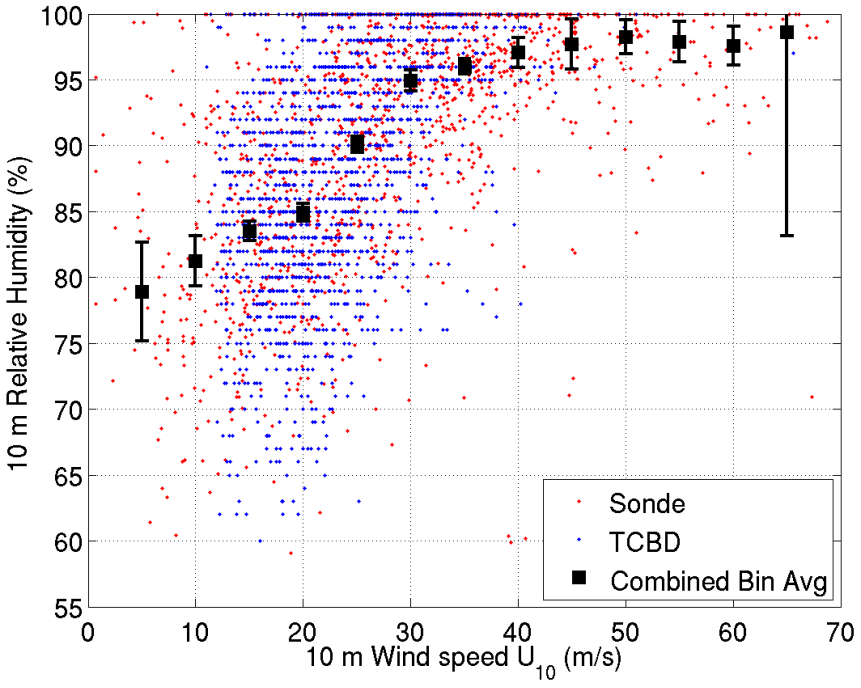




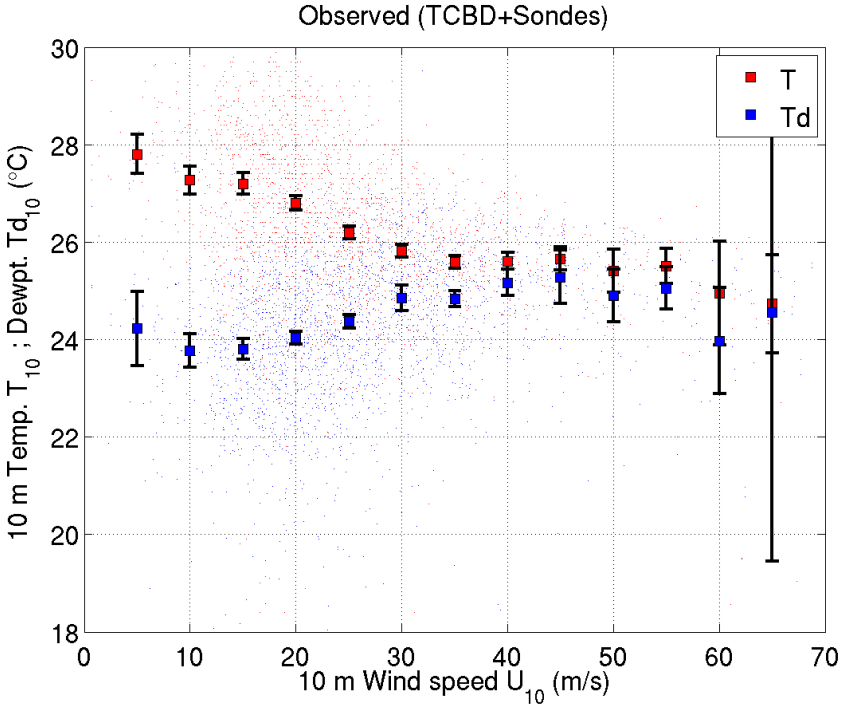


Observed Temperature and Moisture

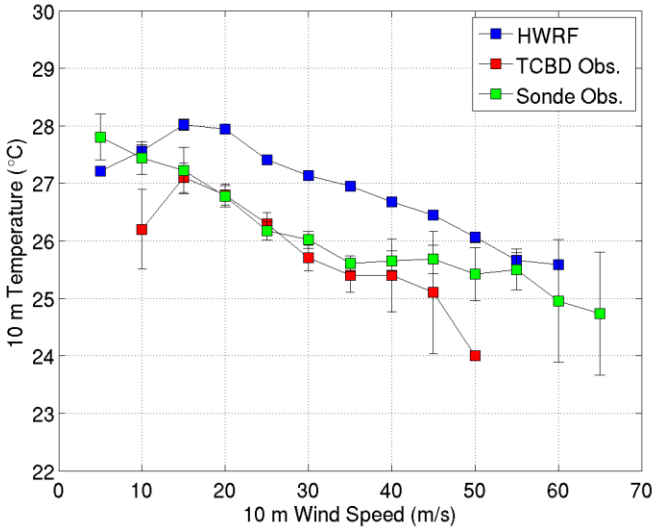
Relative Humidity

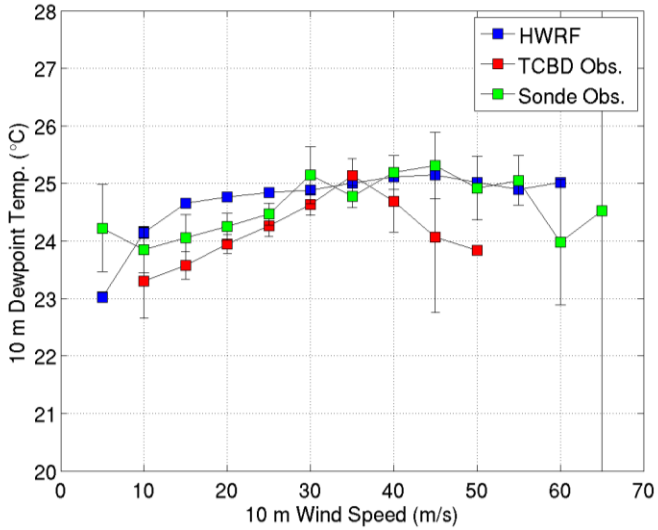


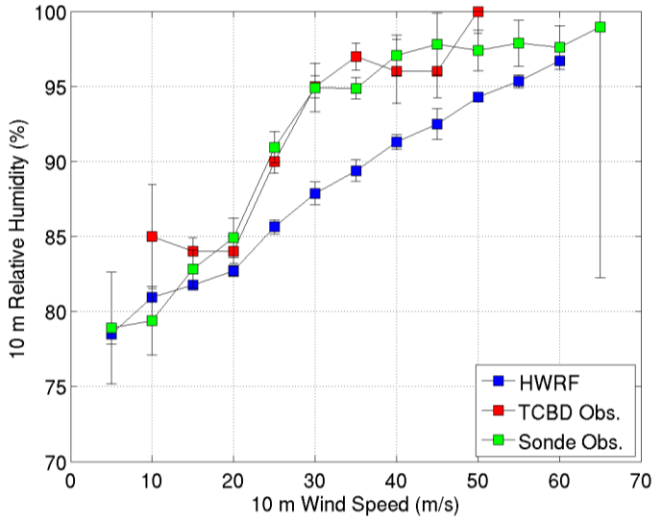
Temperature and Dewpoint



HWRF Evaluation







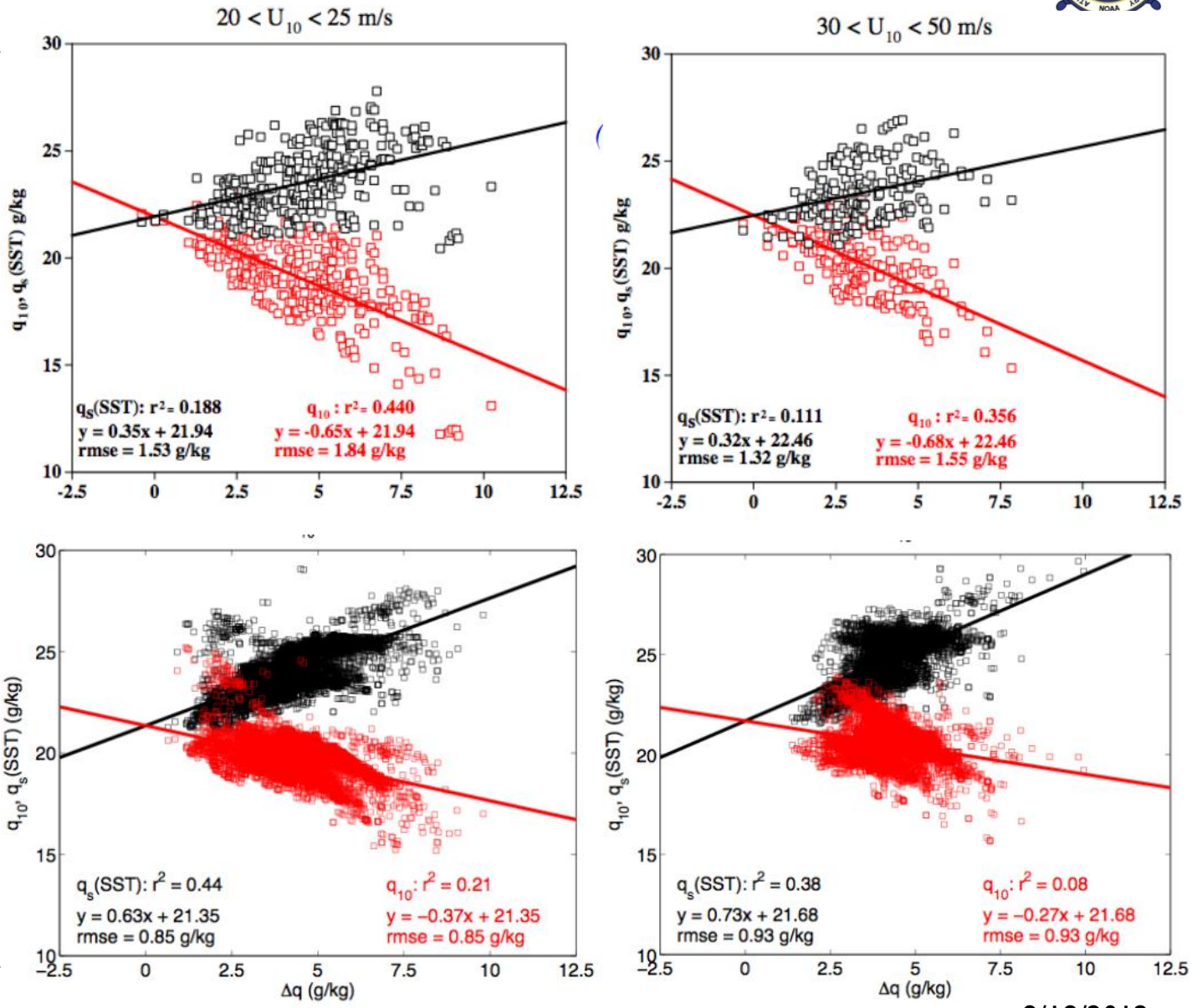
Controls on Moisture Flux

TCBD Obs.

- q_{10} better correlated with Δq than q_s
- Both de-correlate slightly with increased wind, but q_{10} remains more highly correlated

HWRF

- q_s better correlated with Δq than q_{10}
- q_{10} shows almost no relationship to to Δq 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 significant 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