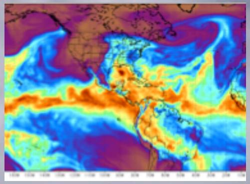
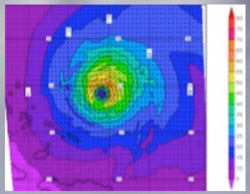
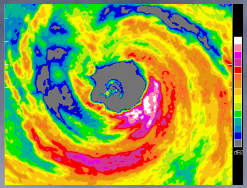
Optimizing observations and observing strategies to better evaluate and improve model physical processes

Can we improve TC forecasts through systematic evaluation, to document and understand model biases using observations?







Joseph J. Cione

AOML Program Review

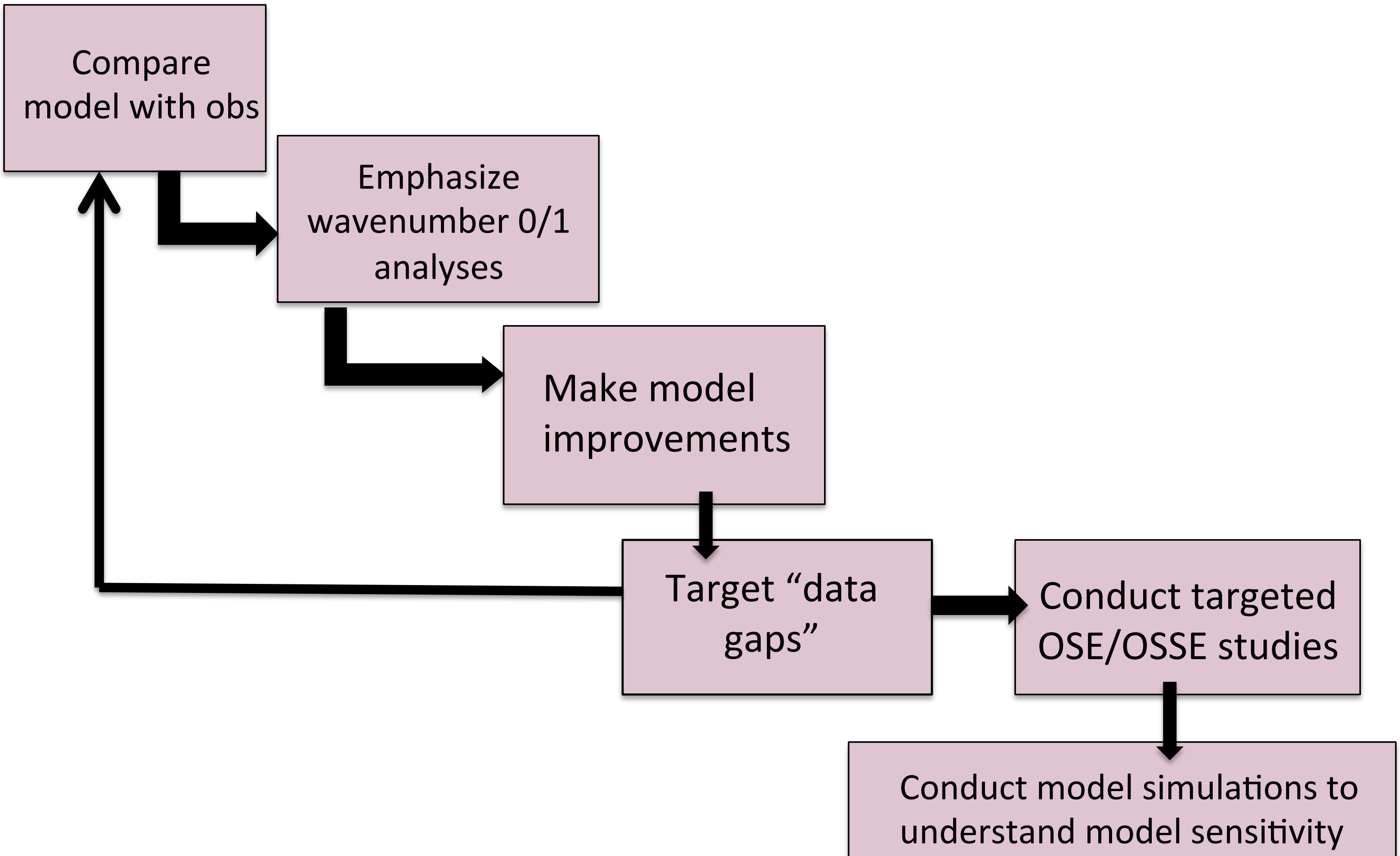
4-6 March 2013

Motivation

Overarching Objective…

Improve forecast performance through a systematic evaluation process, whereby model biases are documented, understood, & ultimately eliminated by implementing accurate, observation-based physical parameterizations.

Model Evaluation & Improvement Methodology…



Project Stage I: Hurricane Air-Sea Interaction…

- Model physics evaluation & improvement is an iterative, multi-stage process

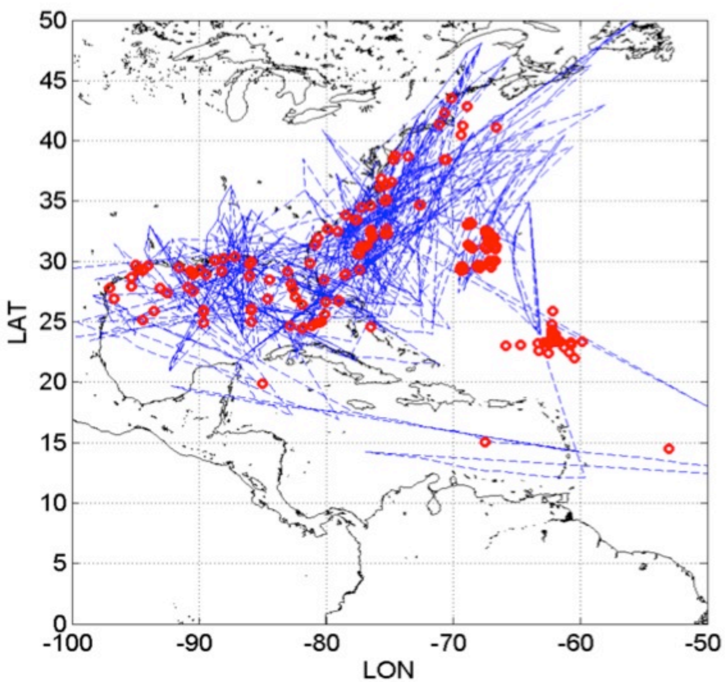
- 1st Stage:
  - In-depth model/observational comparison of the TC Air-Sea Environment

- Why ASI?
  - Critical region of the storm: Energy transfer from ocean to atmosphere
  - Existing ASI observations adequately describe wave numbers 0/1

- Therefore…
  - Properly-scaled ASI model analyses should provide an accurate assessment of ASI model performance (relative to the observations)

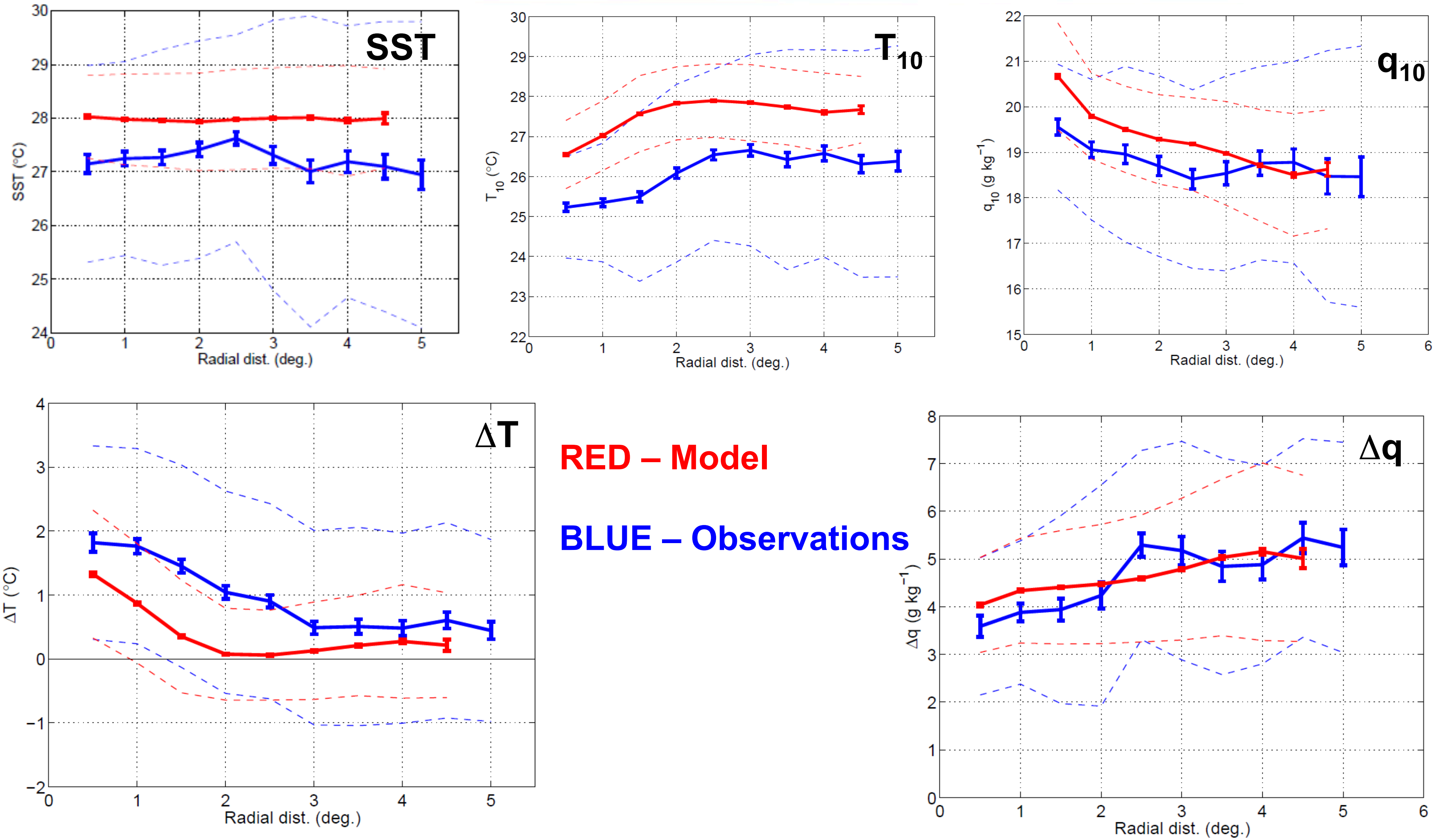
An evaluation of HWRF coupled air-sea thermodynamics…

- Observations from the Tropical Cyclone Buoy Database (Cione et al. 2000, 2003)



- Operational HWRF (retrospective model runs; 6 Hurricanes)

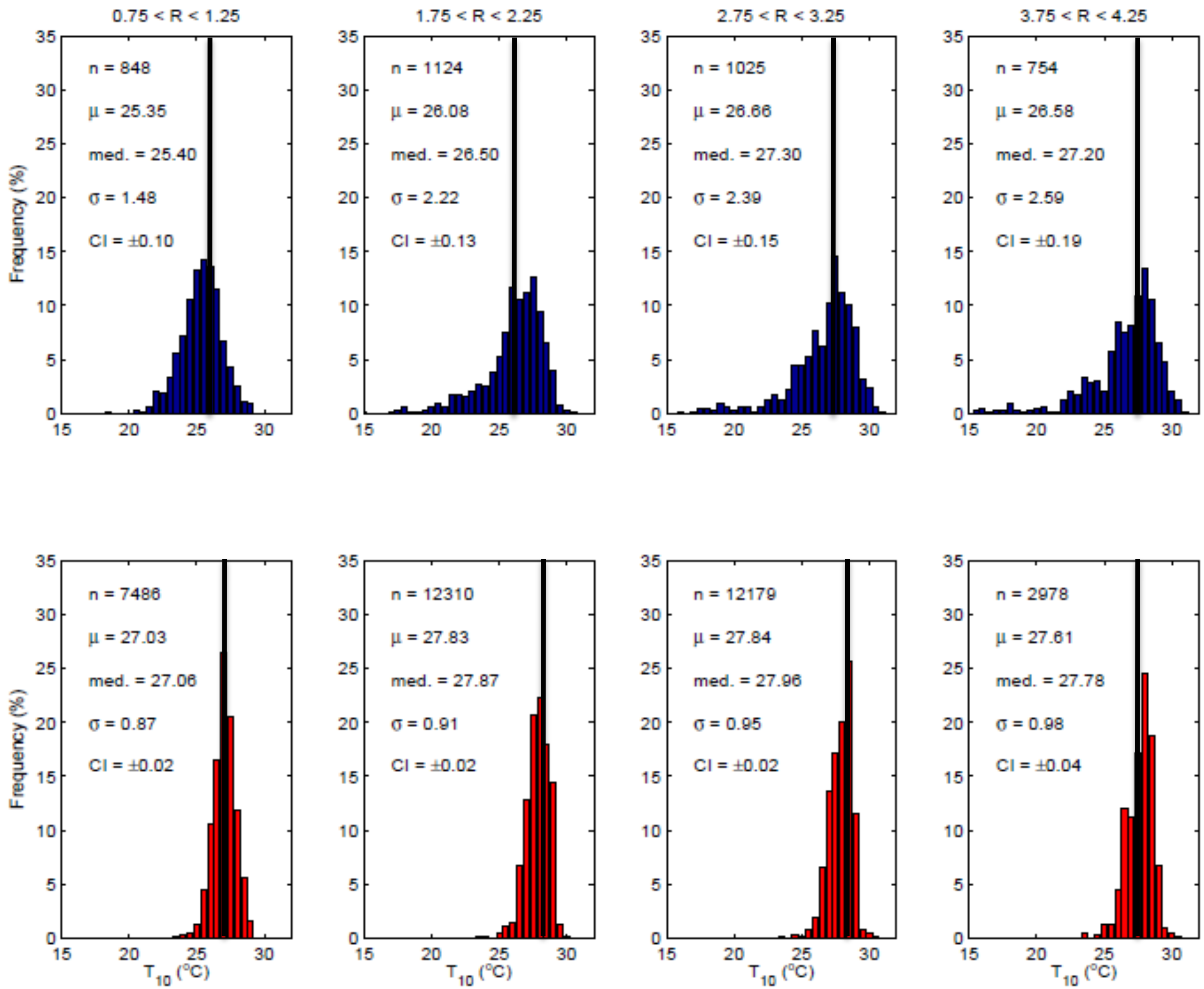
Model vs. Observations: Radial Distributions…



Radial-binned distributions…T_{10}

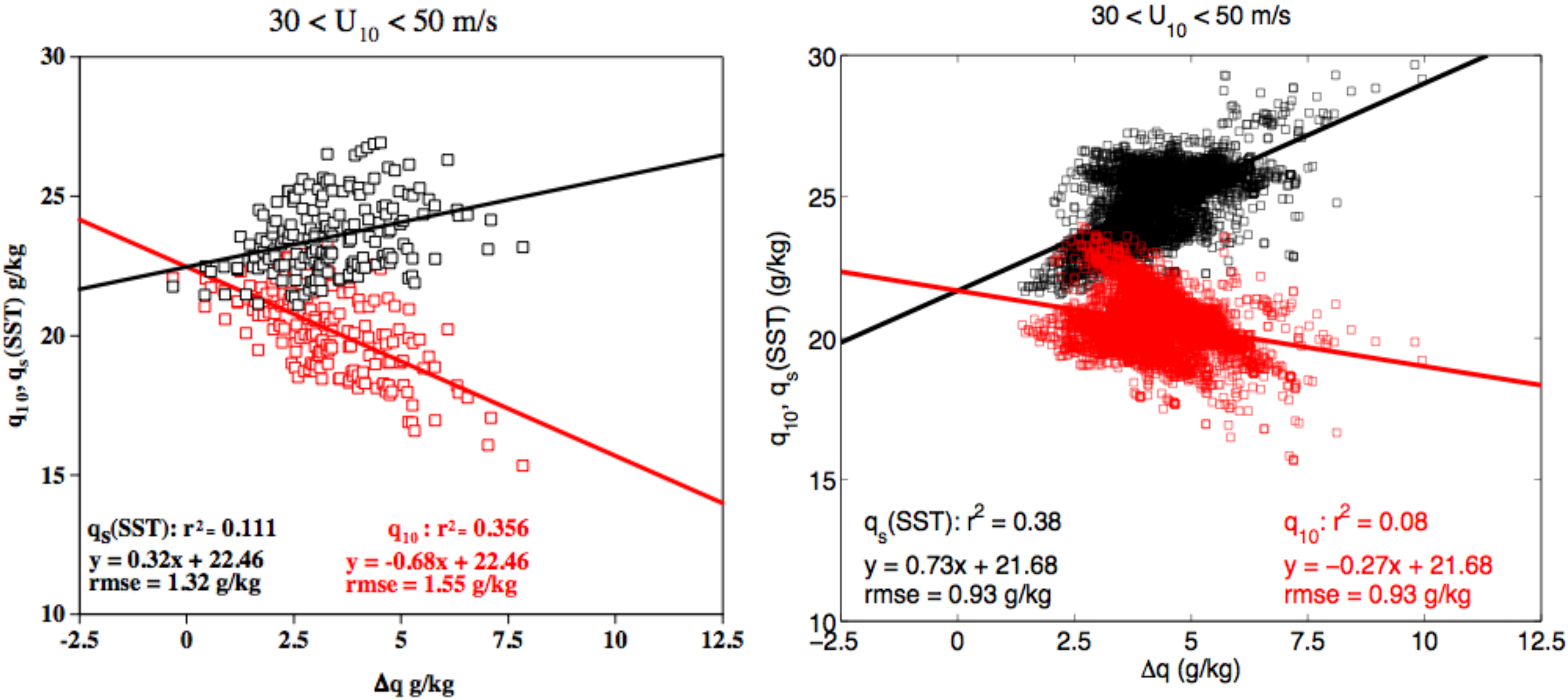
Observations T_{10}

Model T_{10}

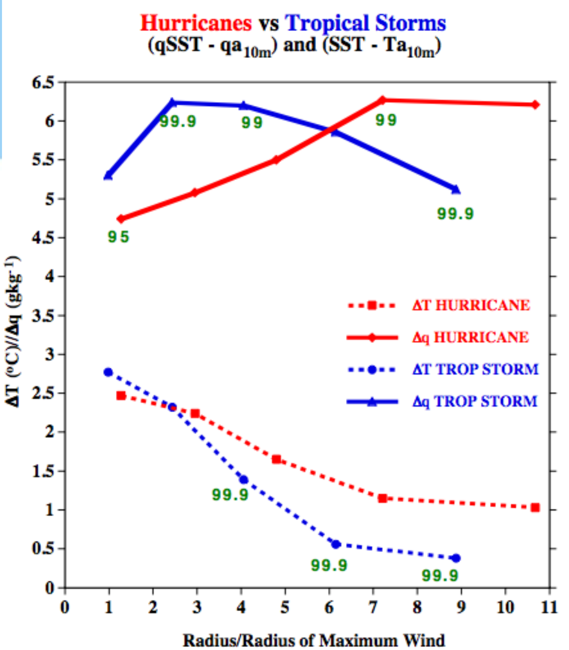


What is the dominant thermodynamic factor impacting TC surface moisture flux? Ocean q_s(SST)..orAtmosphere (q_{10})

Observations *Model*

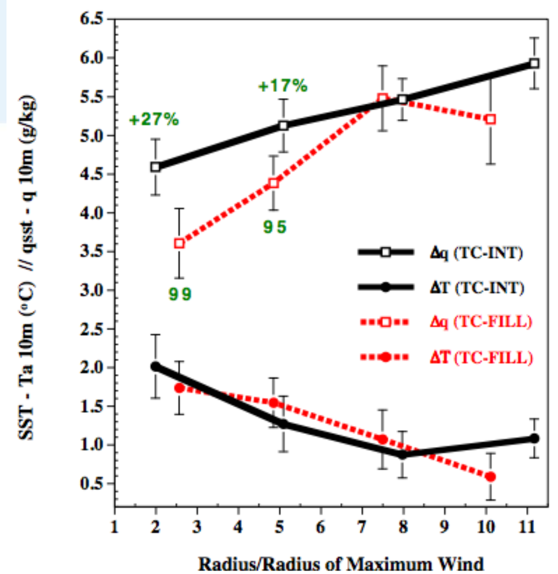


Intensification vs.. Weakening

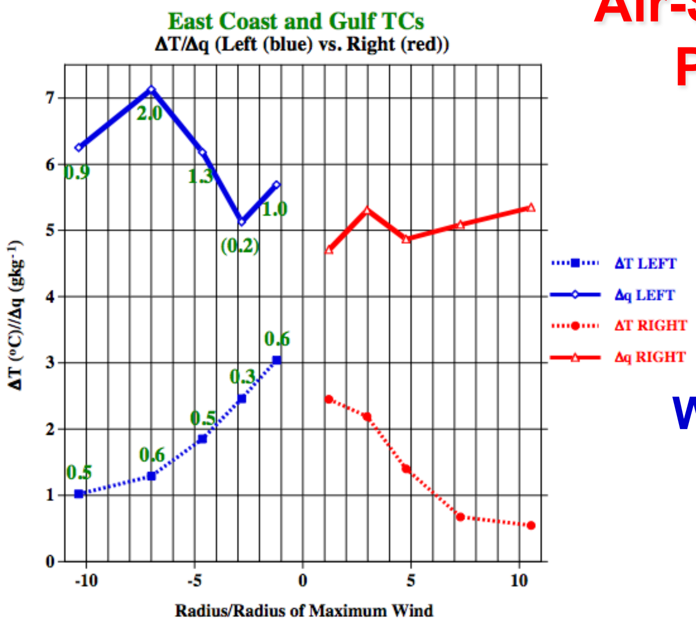


Wave Number 0

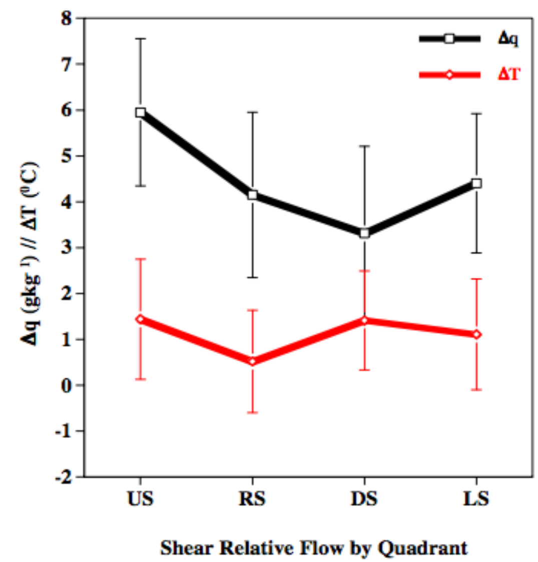
axi-symmetric
ΔT/Δq structure



Additional Model-Obs Air-Sea Evaluation Possibilities



All Hurricanes; SST≥ 26°C; Lat < 38.5°N
qsst - qa_{10m}(Δq) and SST - Ta_{10m}(ΔT)
as a function of of shear relative flow



Wave Number 1

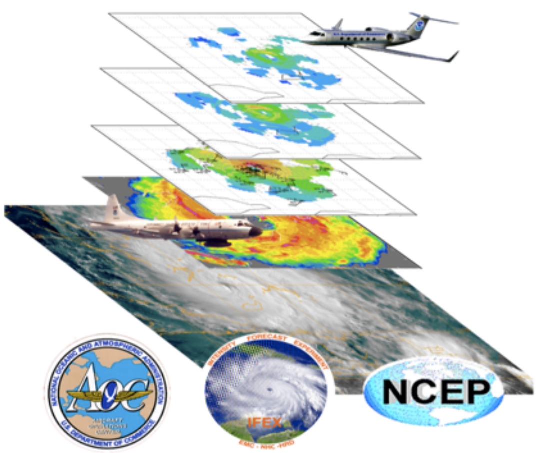
Asymmetric
ΔT/Δq structure

Manned & Unmanned Aircraft Observing Strategies for Model Physics Evaluation

Mission Description

The ideal experiment consists of coordinated three-plane missions designed to observe several mechanisms responsible for modulating hurricane boundary layer heat and moisture:

- Air-sea energy exchange
- Transport from convective downdrafts
- Entrainment at the boundary layer top
- Lateral transport from the environment
- Ocean response



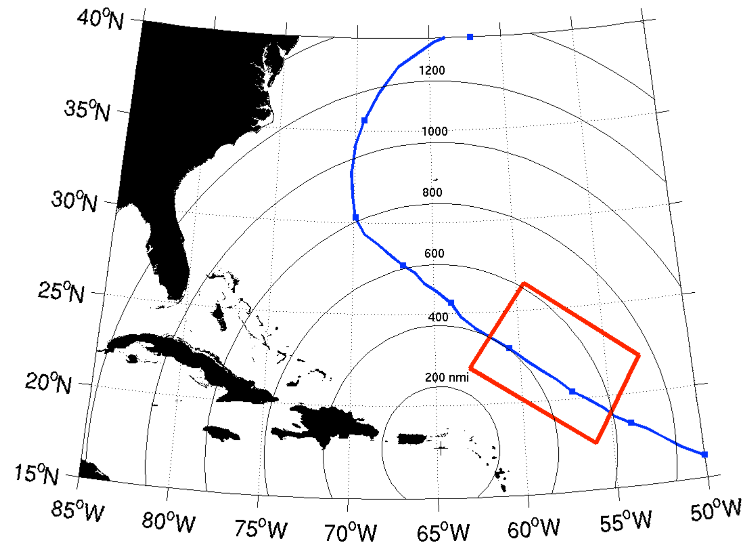
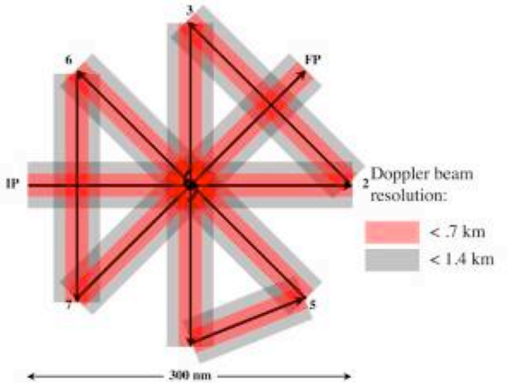
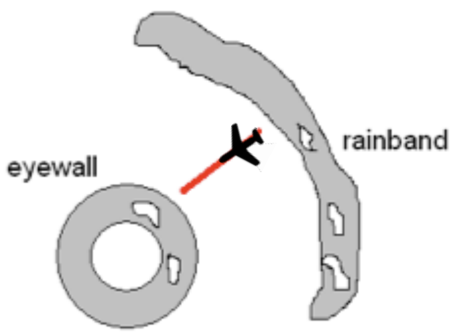


Figure 1. Storm track (blue), and observation region (red box), optimally suited for multi-aircraft experiment. Range rings are 200 nmi relative to forward operating base at STX (TISX). Track marks are spaced every 24 hrs.

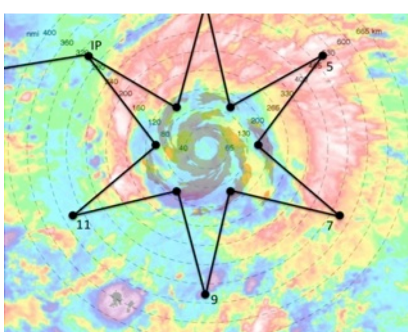
Plan: Establish a multi-aircraft experimental design in geographical areas with limited operational requirements over a 24h refresh cycle



One NOAA P3 → Captures the core, storm scale circulation (e.g. Current TDR mission profiles)

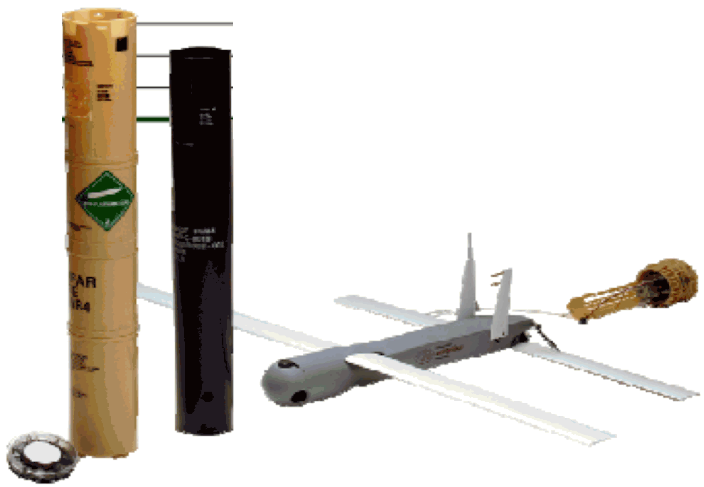


2nd NOAA P3 → Responsible for sampling predetermined areas of interest outside the immediate TC high wind inner core (e.g. Entrainment flux module)



NOAA GIV → Primarily responsible for capturing the tropical cyclone's surrounding larger scale environment

Coyote UAS: A new tool to help us better understand, initialize & evaluate…



advanced ceramics research

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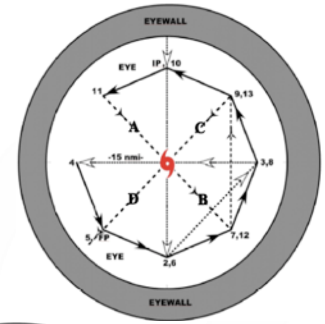
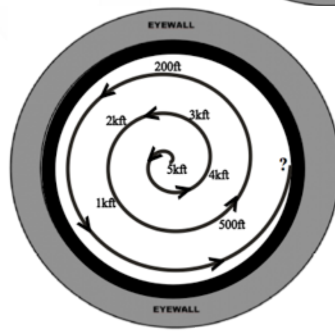
Flight patterns

Coyote UAS - P3 Mature Hurricane Eye Module

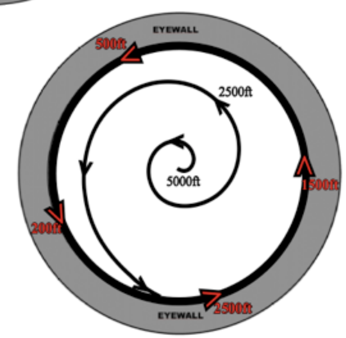


P-3 FLIGHT PATTERN



"EYE"

COYOTE UAS FLIGHT PATTERN



"EYEWALL"

COYOTE UAS FLIGHT PATTERN

Small Unmanned Aircraft Vehicle Experiment (SUAVE)

Part of IFEX Goal 2: Develop new measurement technologies

SUAVE objectives:

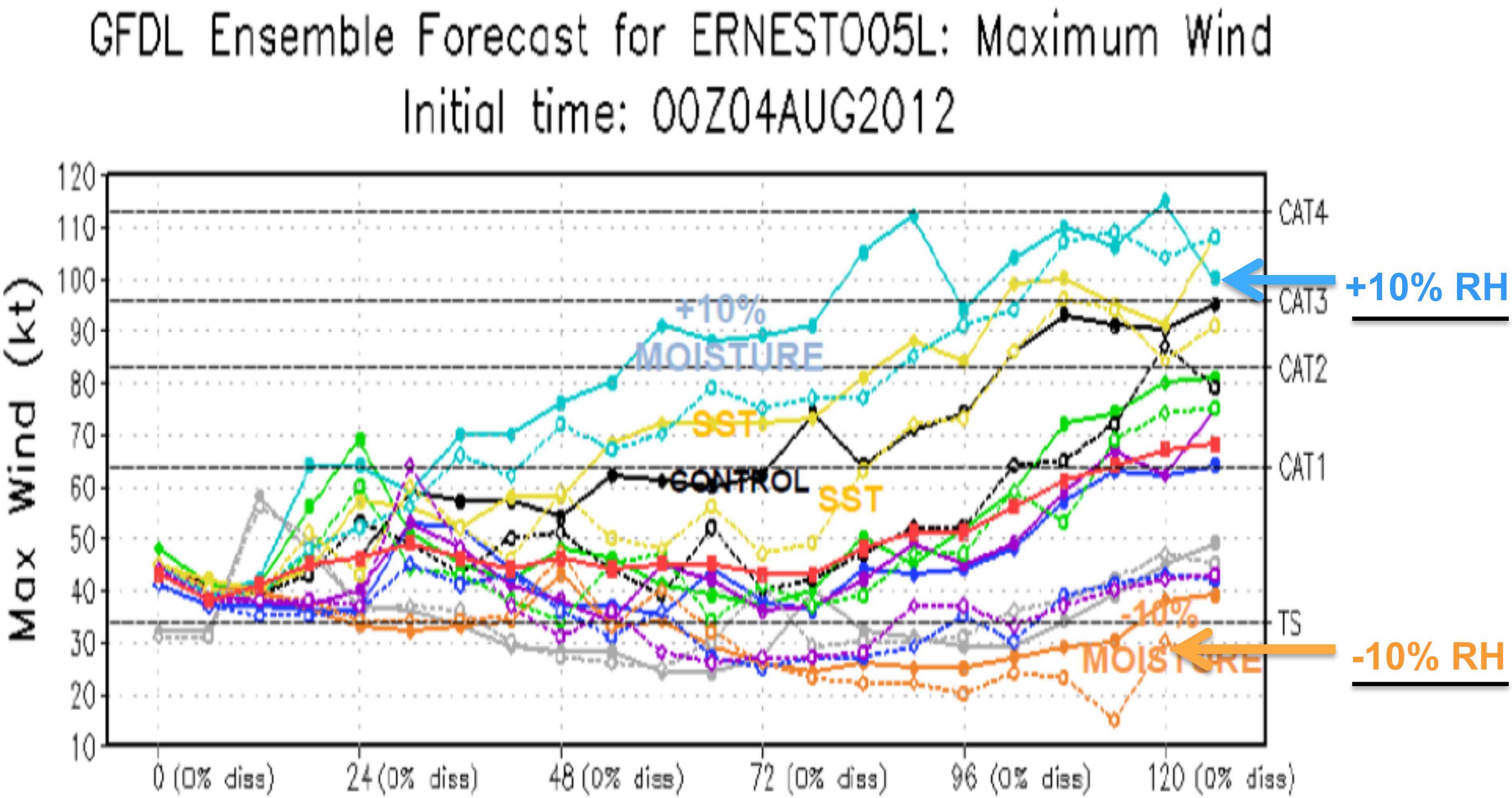
- Improve understanding of TC near-surface energy transfer process
  - Ocean/Atmosphere T/q/M exchange processes
  - Investigate eye/eyewall T/q/M exchange processes
  - **Dramatically enhance existing sparse thermodynamic coverage (esp. moisture) within the TC boundary layer**

  Provide new (continuous) TCBL observations for use in Model evaluation:
  - Compare/contrast/validate w/coincident, instantaneous TC BL observations
  - Compare UAS BL fields w/existing numerical BL structure

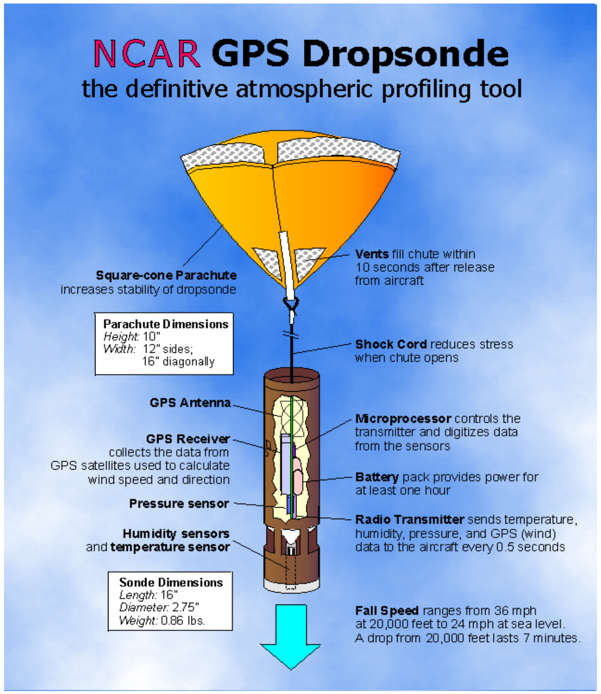
Potential Operational Benefits:

1. Use UAS data to improve the accuracy of model initialization, parameterizations, physics (and ultimately) operational performance
2. Unique -continuous- measurements of V_{10} in the eyewall (better Vmax?)
3. Early detection of rapid intensity change (→ 'loitering' in the eye)

Model Extreme Sensitivity to Small Differences in Inner-Core Moisture as it relates to Hurricane Intensity



GPS Dropsonde Modifications…A partnership with AOC and NCAR…



NEW: GPS Dropsondes -with- SST

- Air-sea coupling with every drop
- Large chute -> + vertical resolution

UASPO/AOML/ESRL Collaboration: Integrated METOC payload for small UAS

2014 NOAA SBIR:

"UAS-Borne Atmospheric and SST Sensing"

– Proposed Goal:

- Use emerging observing technologies (UAS, miniaturized sensors and payloads) to capture critical kinematic & thermodynamic observations within the hurricane boundary layer & air-sea environment.

Summary

- **It's time to think of "model evaluation" in a more fundamental way...**
    - True model evaluation is *not*...
        - Model vs. Best Track
        - Forecast A vs. Forecast B
        - Model X vs. Model Y
    - Instead...How well are we simulating reality (physical fields, processes)?
    - How often do we get the right answer (forecast) for the wrong reason?
    - Where are the model biases, what physical processes are causing them?
    - Where are the (model sensitive) data gaps and how can we best fill them?
    - ***HRD is well-positioned to help answer each of these questions***
- **In a world of limited resources we need to....**
    - Identify the low hanging fruit (and grab it!)
    - Maintain realistic goals:
        - Target evaluation and improvements linked to wave number 0 (mean) and wave number 1 (asymmetric) structure and phenomenon...