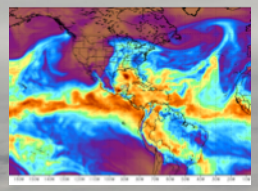
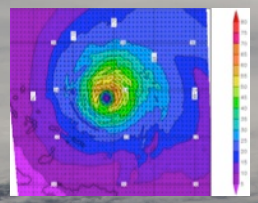
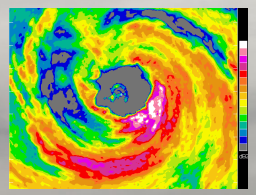
# NOAA's use of the Coyote UAS in Hurricane Edouard to enhance basic understanding and improve model physics

*Funding provided by The Disaster Relief Appropriations Act of 2013 (Sandy Supplemental)*

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**Intergovernmental Hurricane Conference**

**Jacksonville, FL March 4, 2015**

# NOAA's use of the Coyote UAS in Hurricane Edouard to enhance basic understanding and improve model physics

**Project Goal:**

To evaluate and assess the benefits of using observations from new and emerging technologies such as low altitude unmanned aircraft systems (UAS) in order to improve scientific understanding and enhance future predictions of tropical cyclone intensity change.

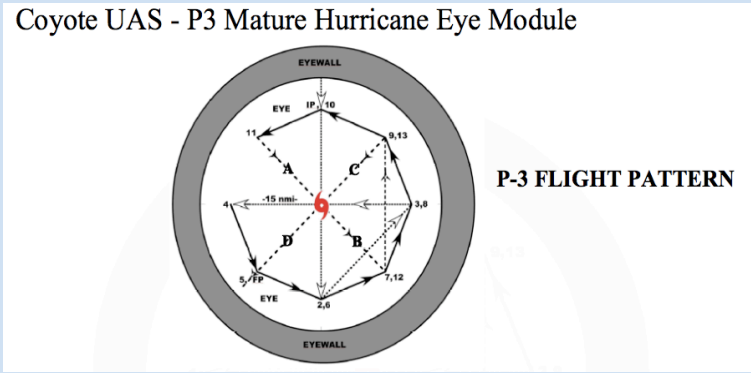
**Project Objectives:**

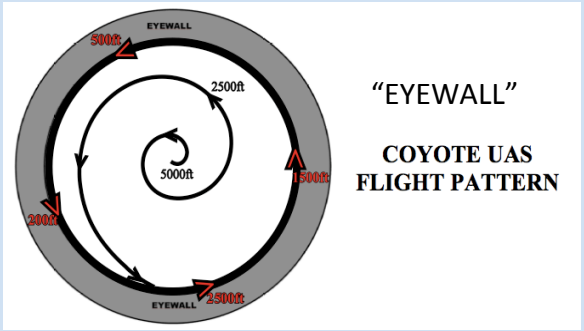
Enhance Observations in a Critical Data Void Region
*(Lower Atmospheric Boundary Layer)*

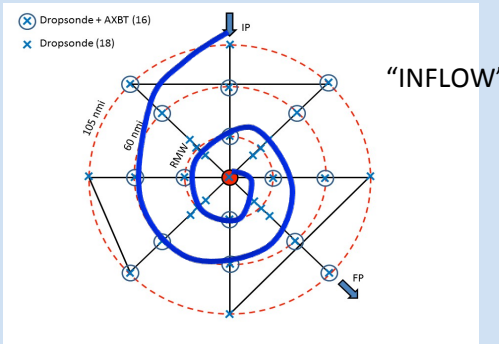
Evaluate Operational Hurricane Model Performance
*(Relative to UAS Observations)*

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


## Flight patterns



# First air-deployed UAS mission into a hurricane (a major one at that)

**When: 1432Z September 16th 2014**

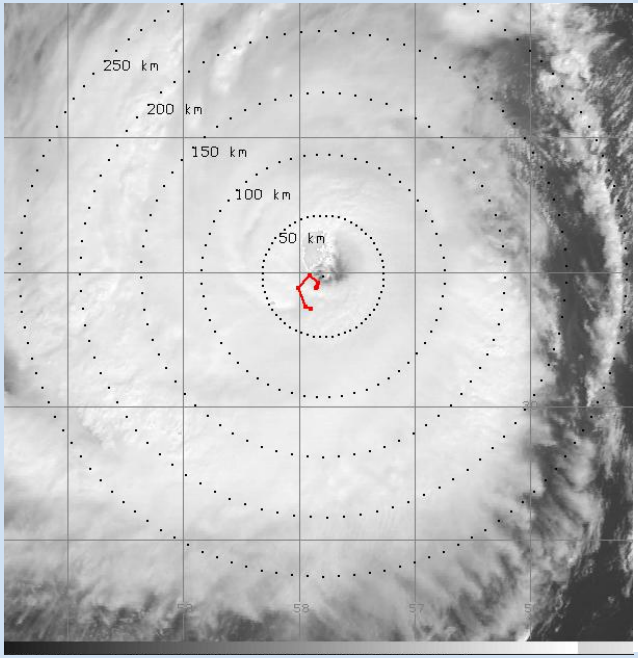
**Where: Deployed into Major Hurricane Edouard's eye (then eyewall)**

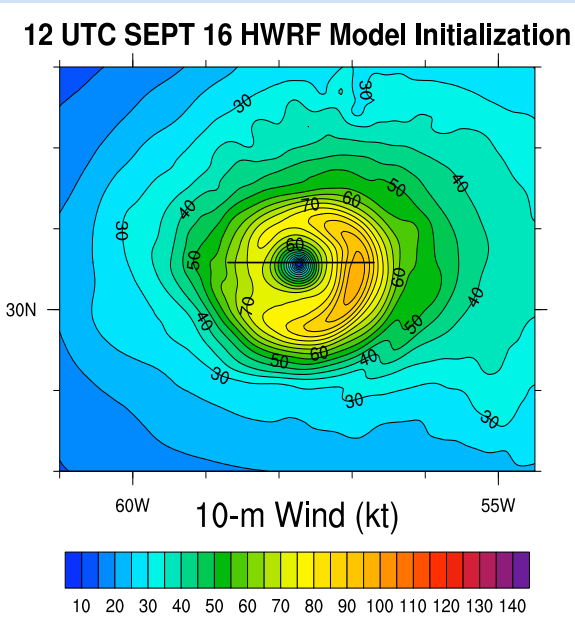
**Deployment aircraft: NOAA WP-3D Orion (42)**

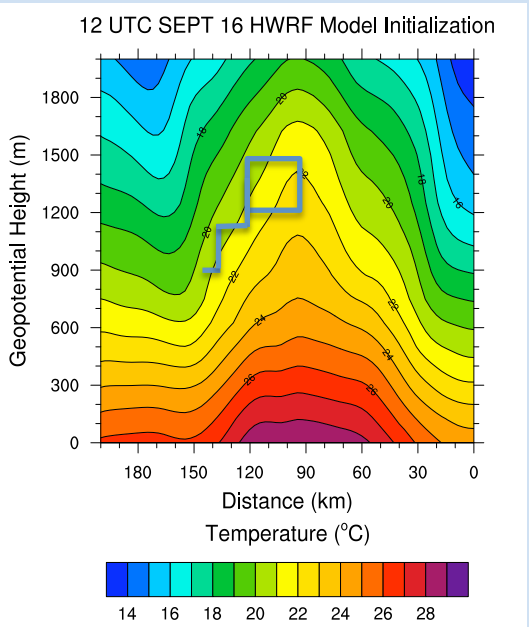
**UAS flight duration: 28 minutes**

**Minimum Altitude: 896m**

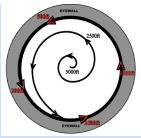
**Maximum Wind Speed: 100kt @971m (in SW eyewall) Platform record!**



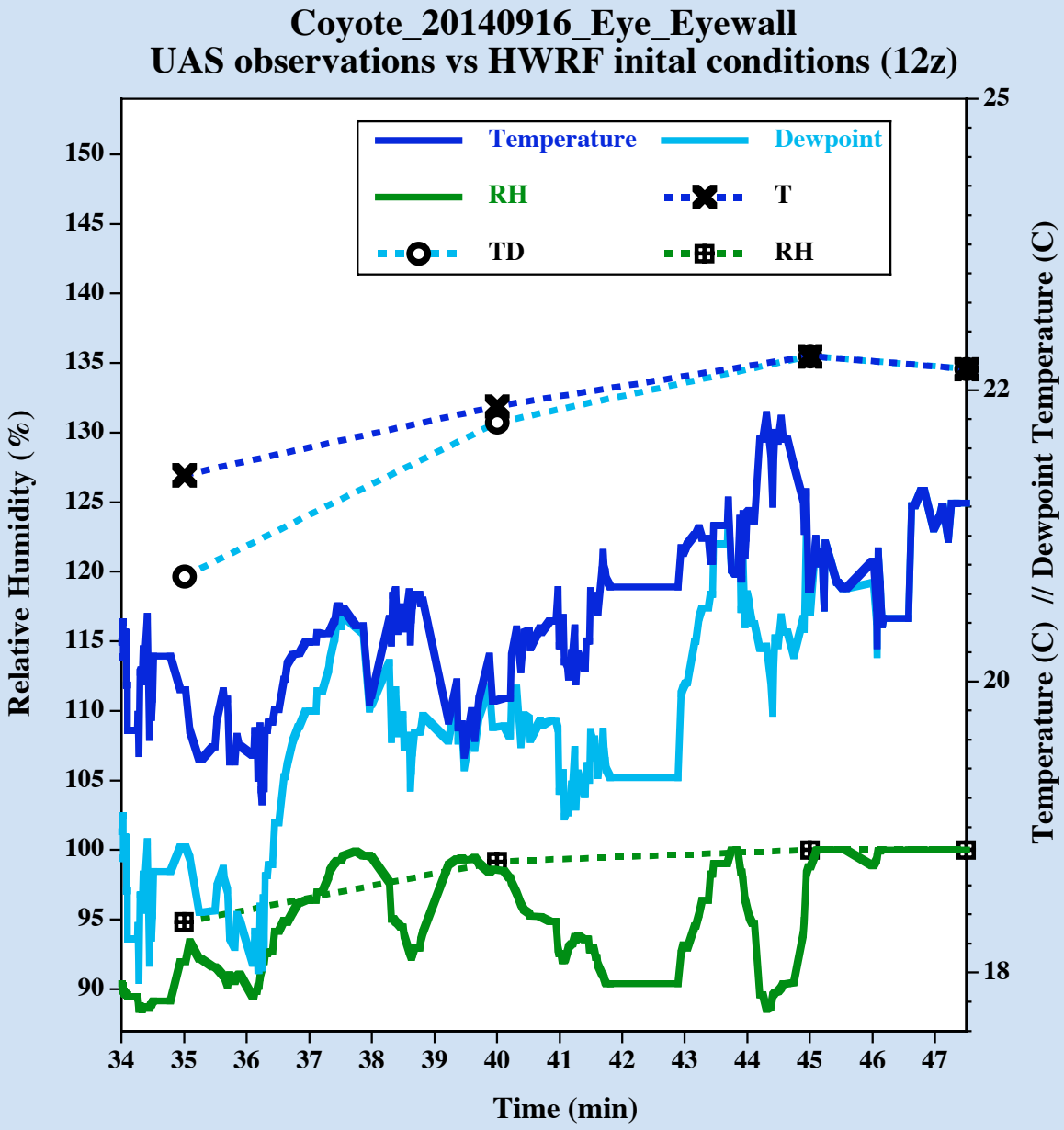




**Eye/Eyewall Experiment**



COYOTE UAS FLIGHT PATTERN




solid lines – UAS

dashed lines - HWRF

- At flight level (900-1200m), the modeled temperature and moisture at the initial forecast time are too high relative to Coyote UAS observations. (RH “correct” though!)

# Record duration Coyote UAS mission!

## Thermodynamic and kinematic radial profile within the boundary layer of Hurricane Edouard

**When: 1507Z September 17th 2014**

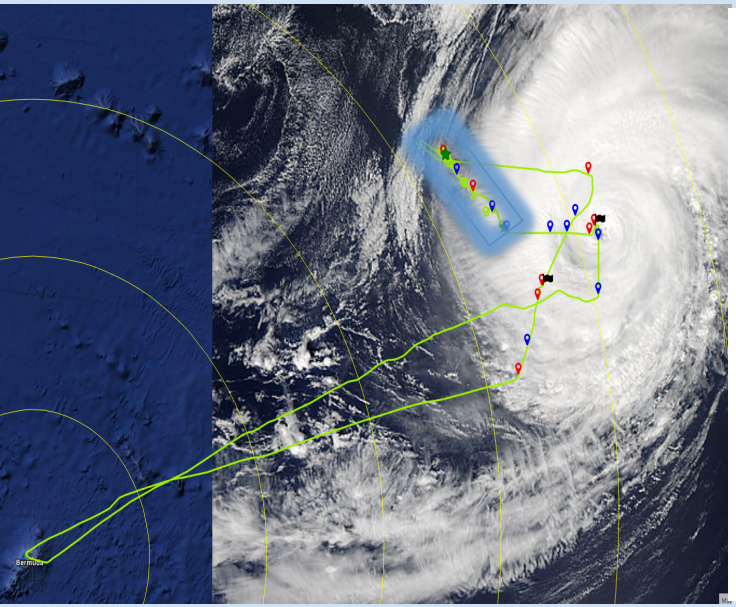
**Where: Deployed along Hurricane Edouard boundary layer inflow channel**

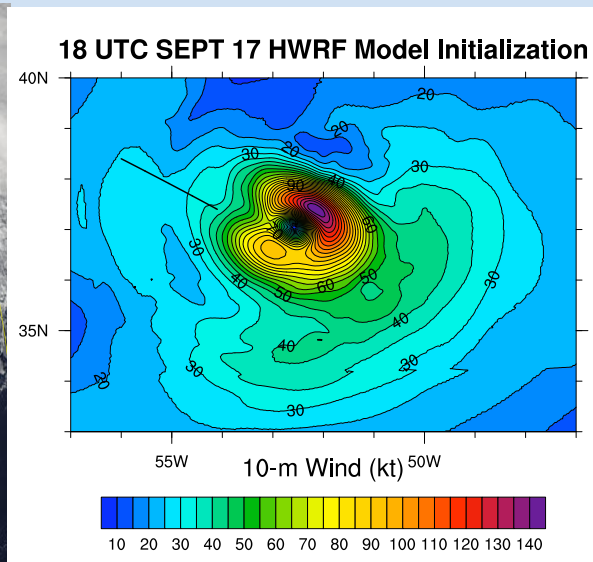
**Deployment aircraft: NOAA WP-3D Orion (42)**

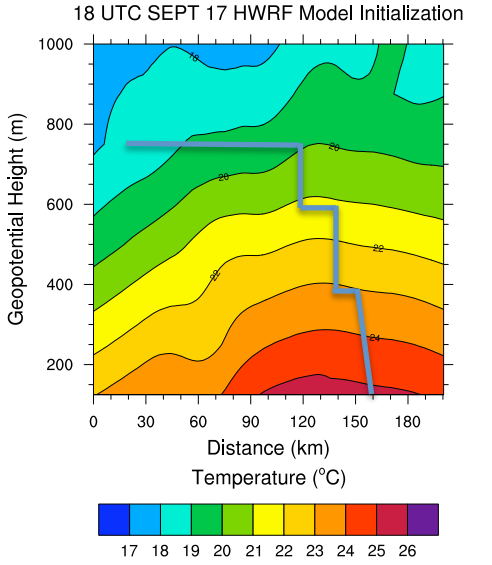
**UAS flight duration: 68 minutes (platform record!)**

**Minimum (controlled) Altitude: 400m**

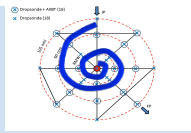
**Maximum Wind Speed: 53kt @6m**



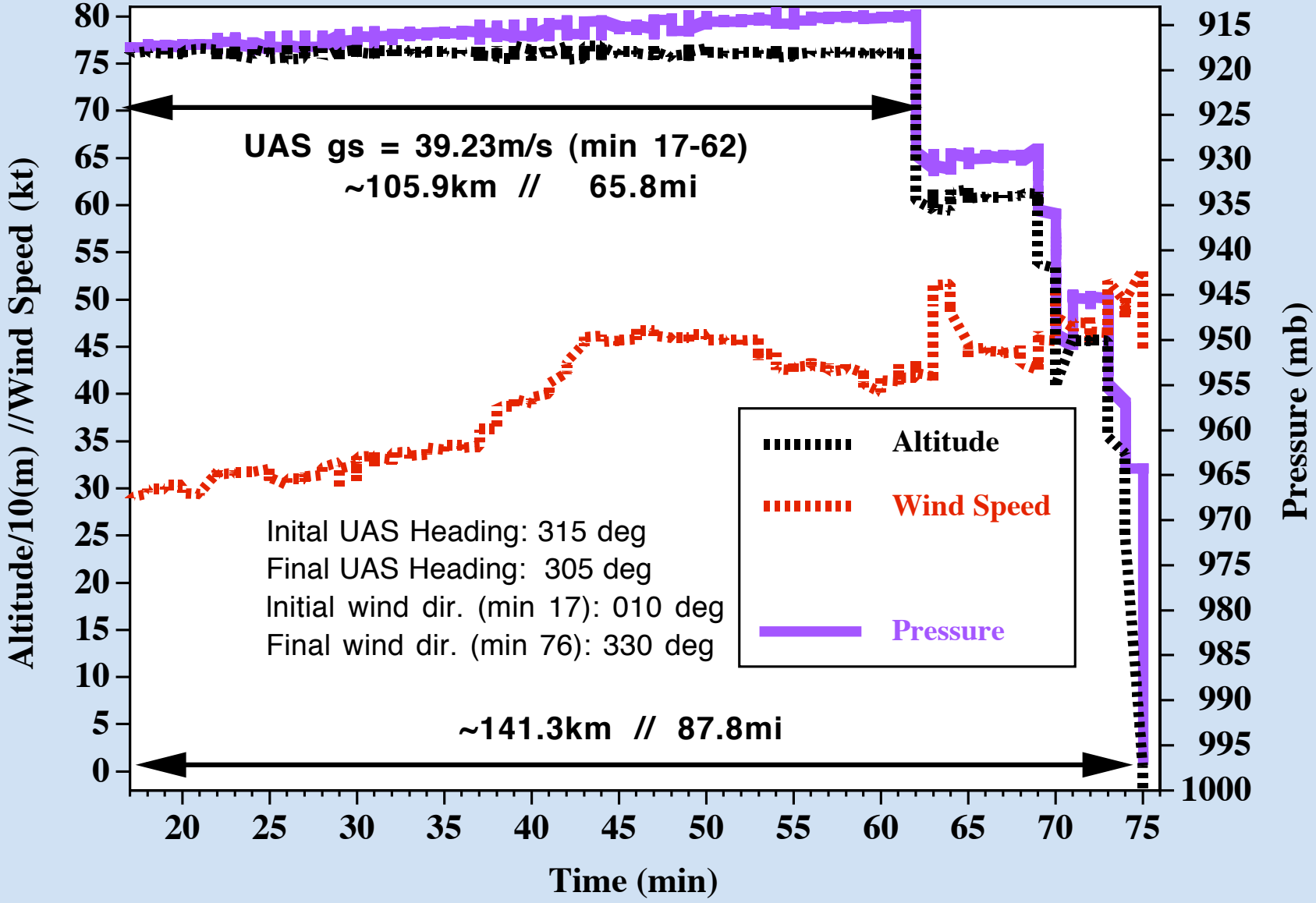



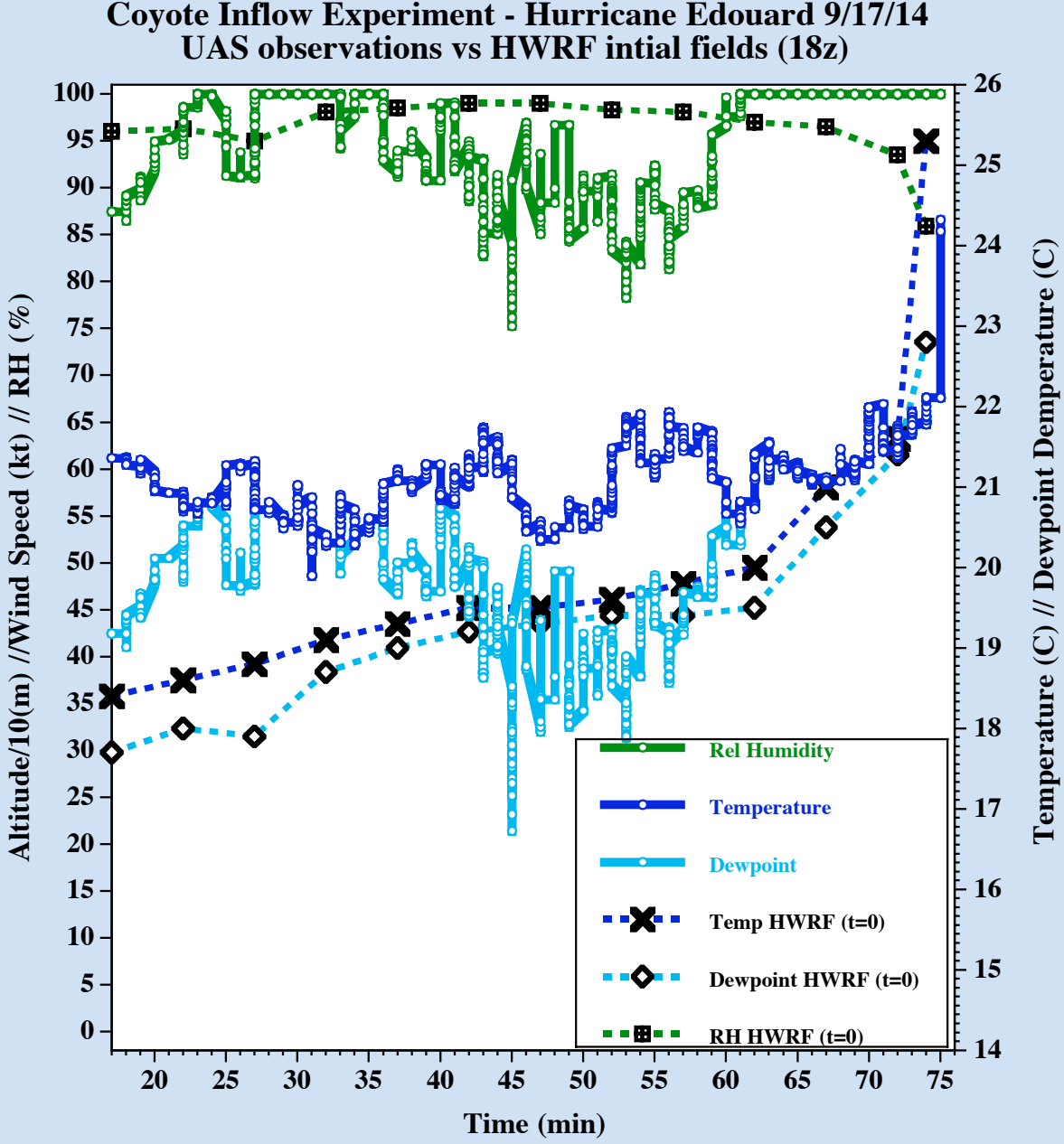




**Inflow Experiment**



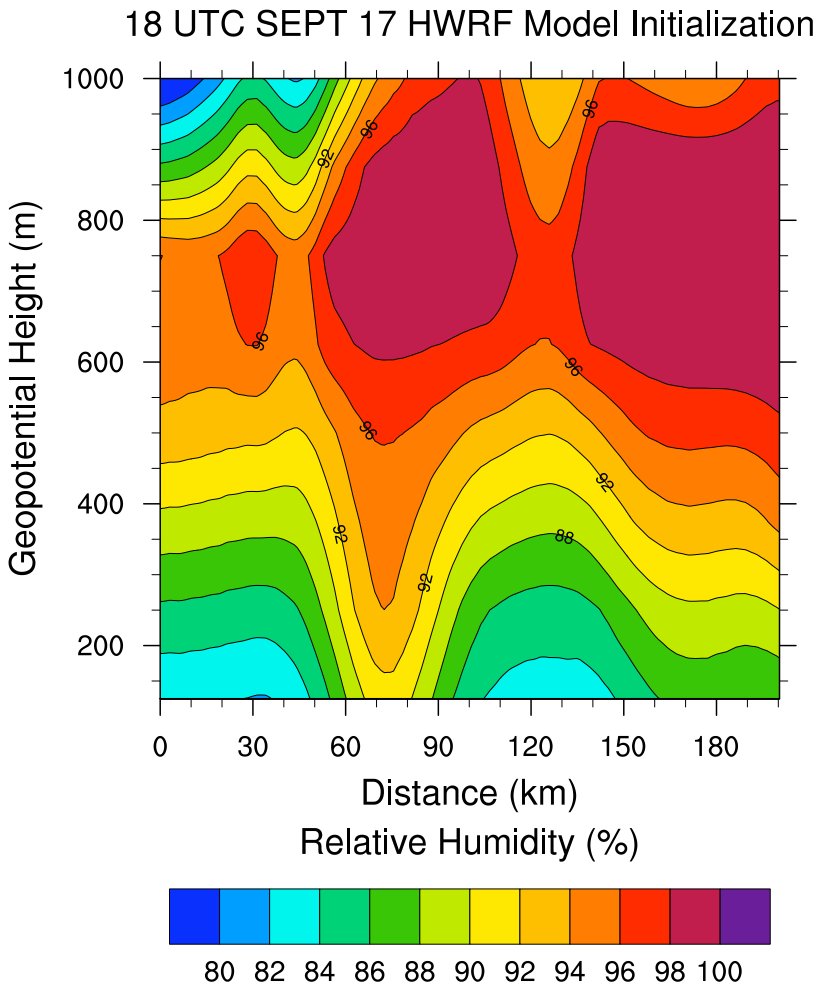
# Coyote Inflow Experiment - Hurricane Edouard 9/17/14



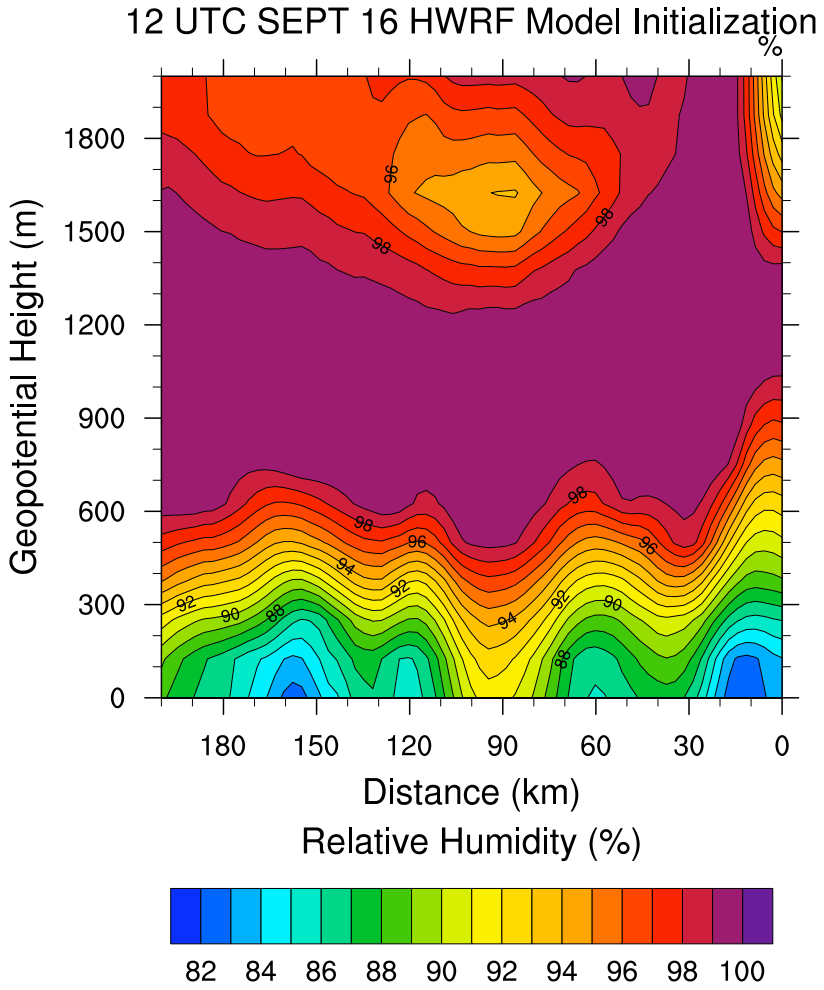



- On average, the modeled temperature and moisture at the initial forecast time are lower (cooler and drier) relative to Coyote UAS observations at flight level (750m). Near the surface, HWRF Ta is ~ 1C too warm and Td is ~1.5C too dry. → ***HWRF BL too unstable and Sfc RH too low (85%), fluxes too high?***

## HWRF Relative Humidity Initial Conditions:
### *Valid for the Coyote UAS September 16th Eye/Eyewall Experiment*




## HWRF Relative Humidity Initial Conditions:
### *Valid for the Coyote UAS September 17th Inflow Experiment*




- **Based on Edouard observations from UAS, GPS dropsonde and analyses shown in Cione et al. (2000), (2013) and Cione (2015), the modeled near surface RH is simply too low (80-85%). Values should be 95-100% in the eyewall and 90-95% within the inflow region outside the core. These conditions will result in erroneously high values of modeled surface latent heat flux (assuming other factors to be equal).**

# Summary

- Historic Coyote UAS Missions into the boundary layer of Hurricane Edouard were successfully conducted (September 16-17, 2014).
- A 13 lb., 5 ft. wingspan aircraft *can* survive within a turbulent hurricane environment.
- Data collected by the UAS were used to evaluate the performance of operational hurricane models.
  - UAS thermodynamic and wind data compare well with GPS dropsonde measurements (for both Coyote UAS experiments)
  - ***Eye:*** 900-1200m Model Ta/Td too warm/moist
  - ***Inflow:*** 750m Model Ta/Td too cool/dry; ***0-750m too unstable***
  - ***Both:*** Flight level RH were "correct" (for the wrong reason); Sfc Ta too warm ~(1-2C); Sfc Td too dry ~(1-2C)
    - ***→ Sfc RH too low (10-15%)-→ Sfc fluxes too high (all other factors equal)***

# Next Steps for 2015?

*Orange= request submitted; Green= accomplished; Blue= planned and/or in progress*

- **Acquire resources for additional Coyote UAS and operational support for 2015**
  - *NOAA UASPO budget request for additional support in 2015 is currently under review*
- **Resolve/Incorporate critical 'lessons learned' issues from Edouard Missions**
  - **Improve communications between UAS and P-3. Increase range via P3/UAS antenna optimization, UAS signal amplification and utilization of 350mHz signal frequency (vs. 900Mhz).** ***UPDATE: 2/20/15*** *10X increase in P3/Coyote UAS range (60nmi) achieved during P3/Coyote UAS Avon Park, FL test. 100nmi possible in open ocean TC environment*
  - **Improve "systems awareness" by enhancing UAS/P3 real-time data visualization capabilities. Update 2/20/15 As part of the NOAA/Raytheon/NCAR visit to AOC during 2/17-2/20/15, this task has been successfully completed.**
  - **Upgrade/improve existing UAS payload package. Incorporate higher response sensors, optimize existing payload physical configuration, and add a new IR sensor for SST mapping in 2015.**
  - **Standardize an appropriate UAS "operational launch sequence" to be used on the P3. This will be tested during the planned P3/Coyote UAS clear air test currently set for June/July '15 in Florida.**
- **Make Coyote UAS data available in near-real time to operational centers**
  - *Work directly with NHC to design an experimental module for Coyote operations in 2015.*
  - *Send low level Coyote UAS wind speed and direction data to the NHC in near-real time.*