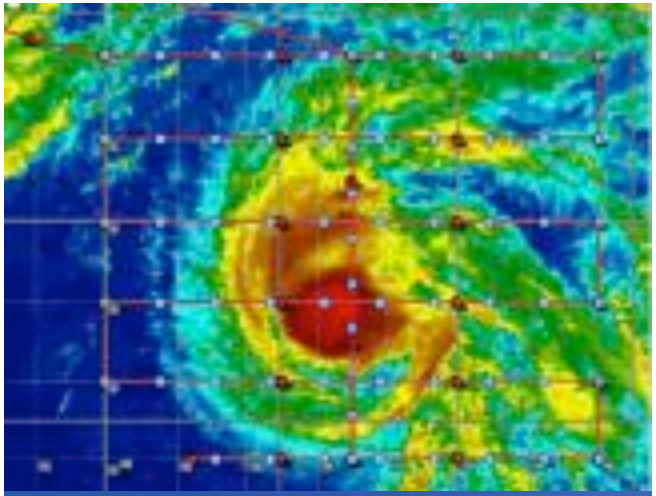
NASA's Hurricane and Severe Storm Sentinel (HS3): Results from the 2012-2013 Deployments



Scott Braun

Paul Newman

(NASA/GSFC)

Thanks to P. Black, M. Booth, A. Brammer, P. Colarco, J. Doyle, J. Dunion, J. Halverson, D. Hence, A. Juracic, S. Monette, M. Montgomery, E. Nowottnick, B. Rutherford, V. Tallapragada, C. Thorncroft, C. Velden

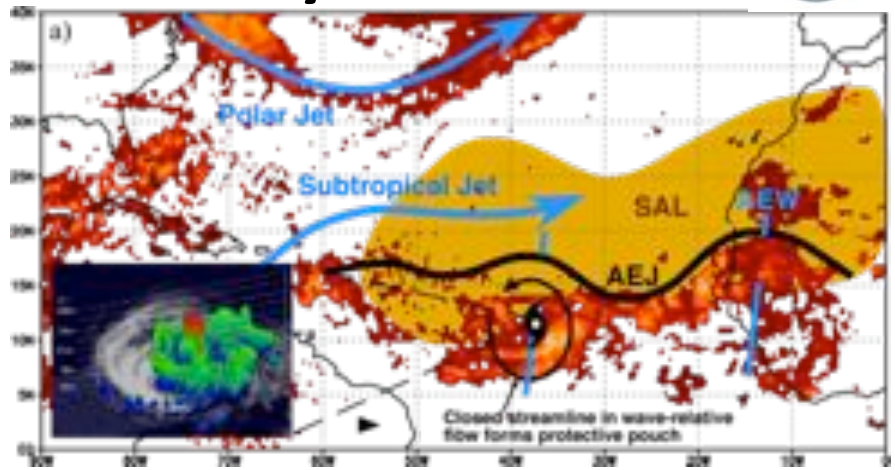
Presentation Overview

- HS3 background
- Outflow layer structure
- Hurricane Nadine evolution
- 2013 highlights

HS3 Summary

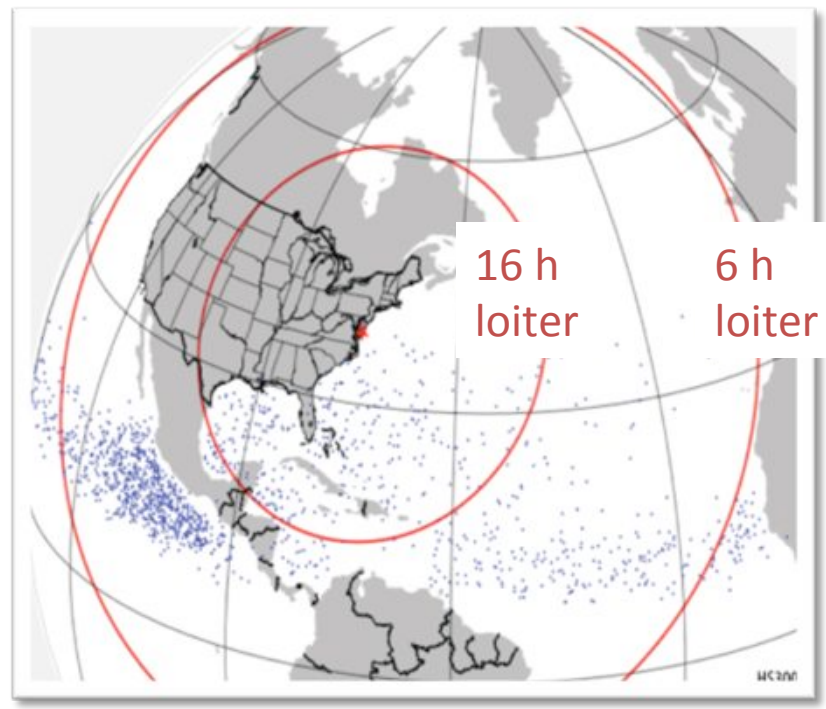
GOALS:

- What is the role of the Saharan Air Layer?
- What is the role of upper-level wind patterns?
- Are intense convective bursts key to formation/intensification?

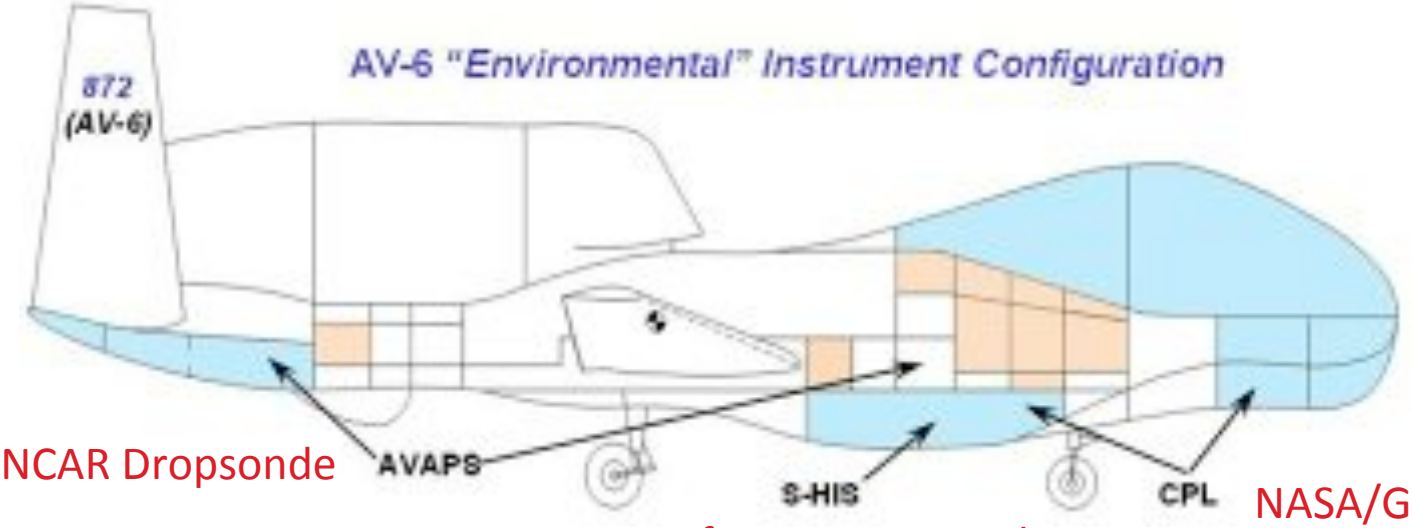


DEPLOYMENT DETAILS

- Two Global Hawks, one for the environment, one for inner-core measurements
- Deployed from Wallops, VA
- 5 week deployments



Payloads



NOAA/NCAR Dropsonde

U. Wisc. Interferometer sounder

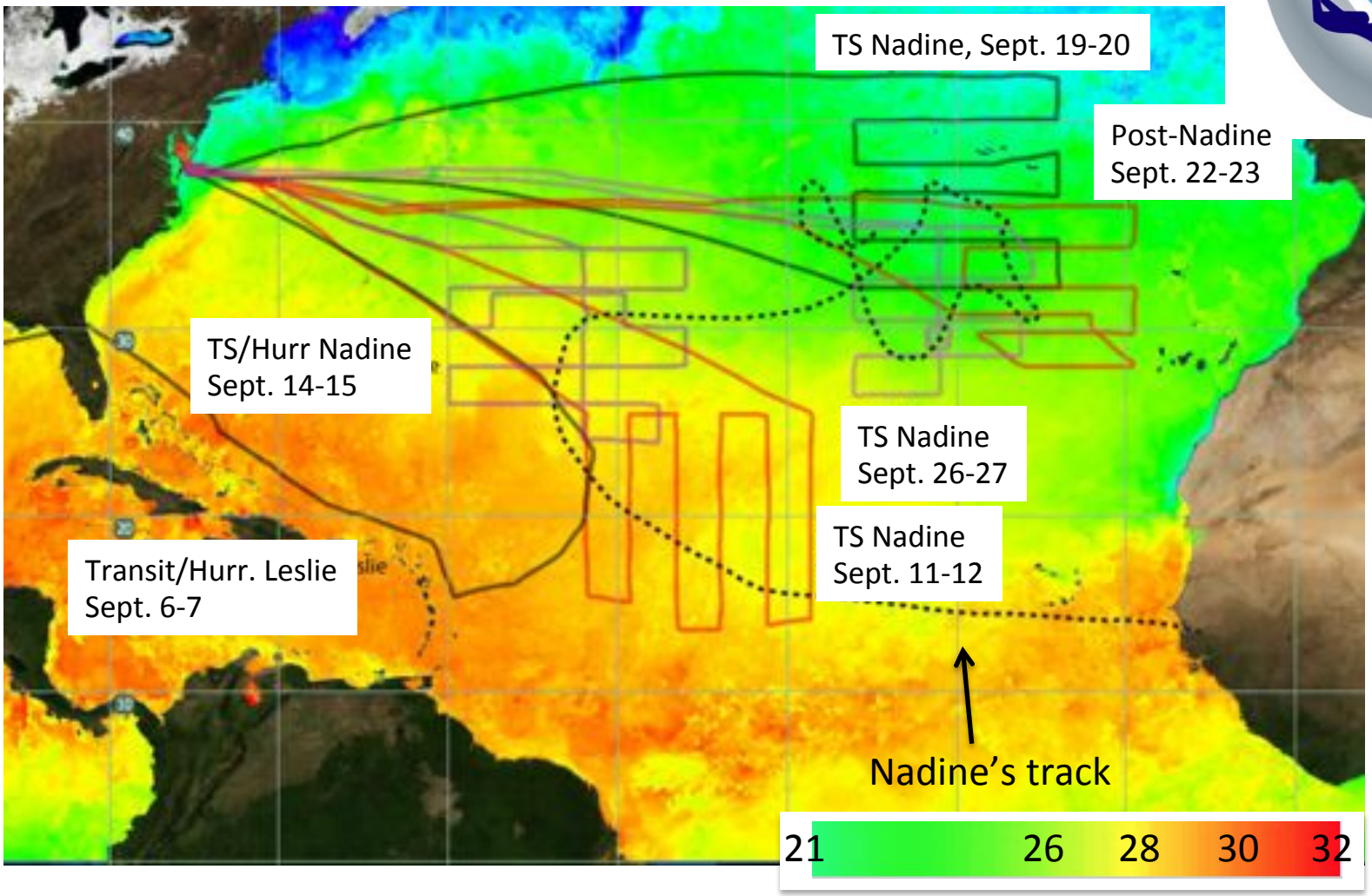
NASA/GSFC Cloud Physics Lidar

NASA/MSFC SFMR-type scanning radiometer

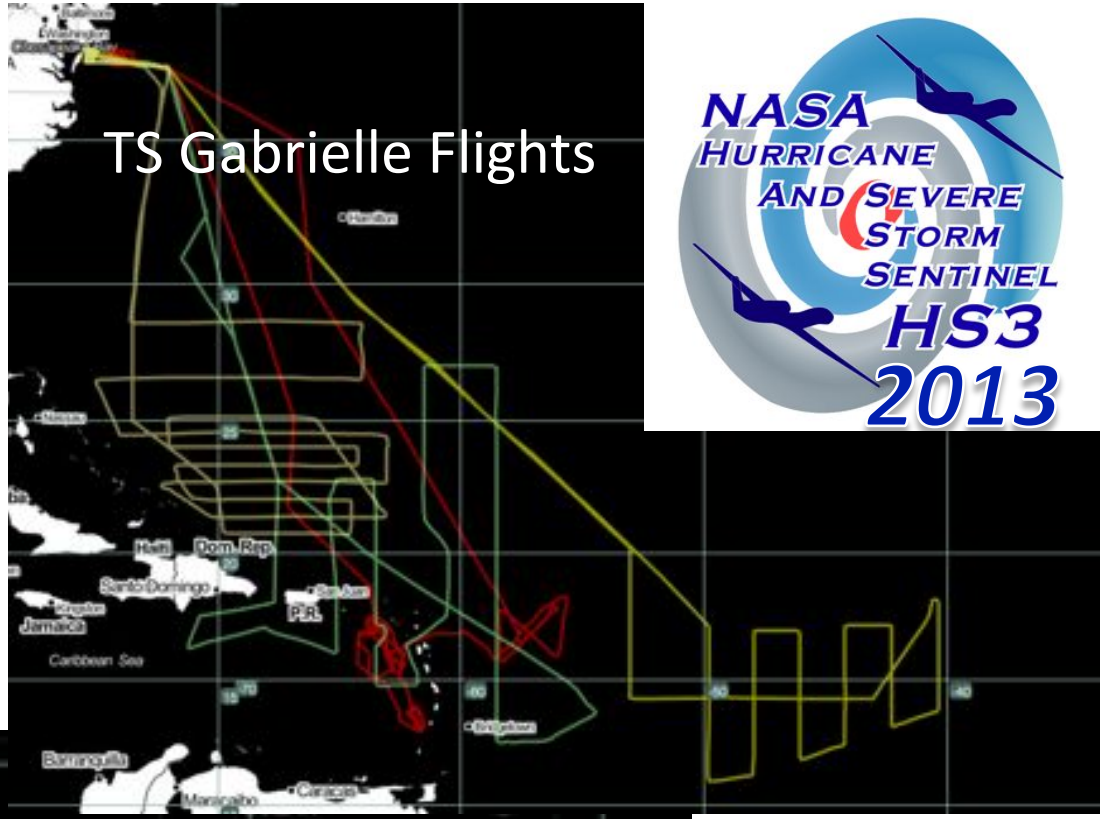
NASA/GSFC Doppler radar

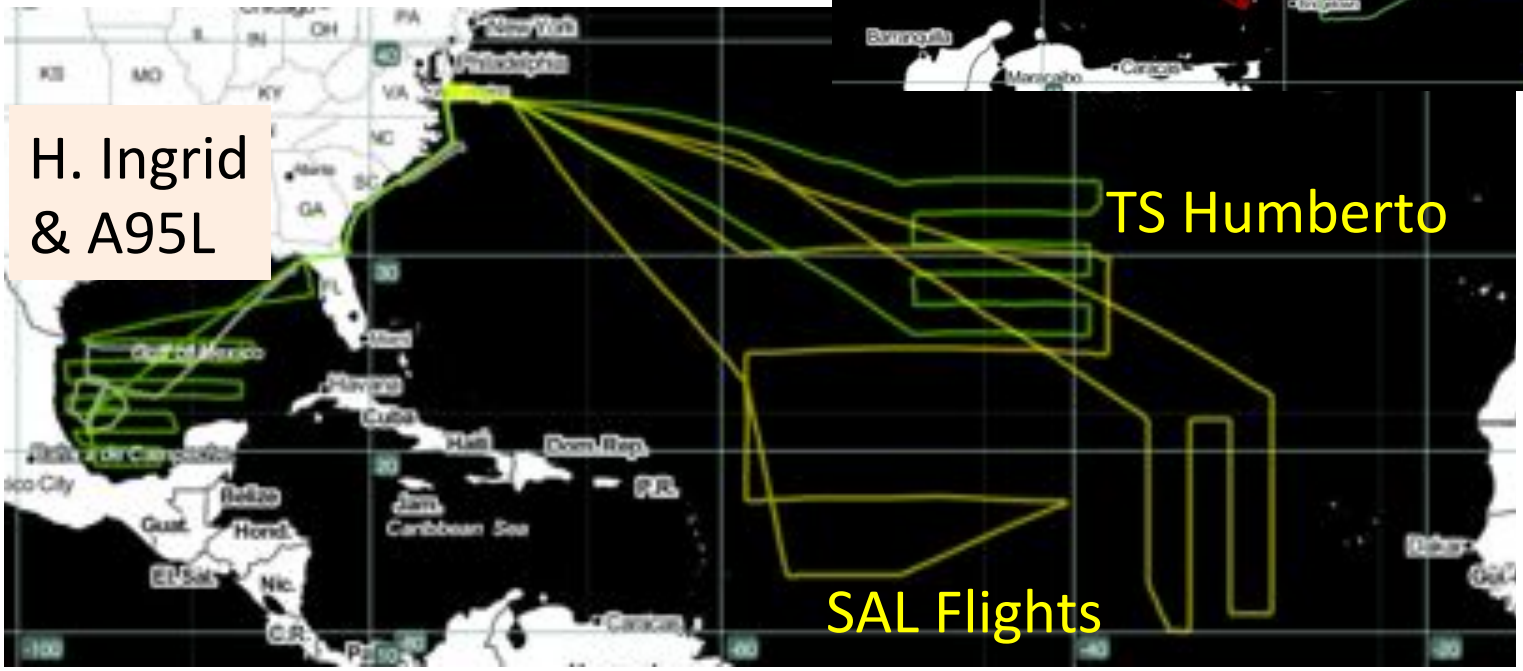
JPL microwave sounder

2012 HS3 Fight Tracks



2013 HS3 Fight Tracks





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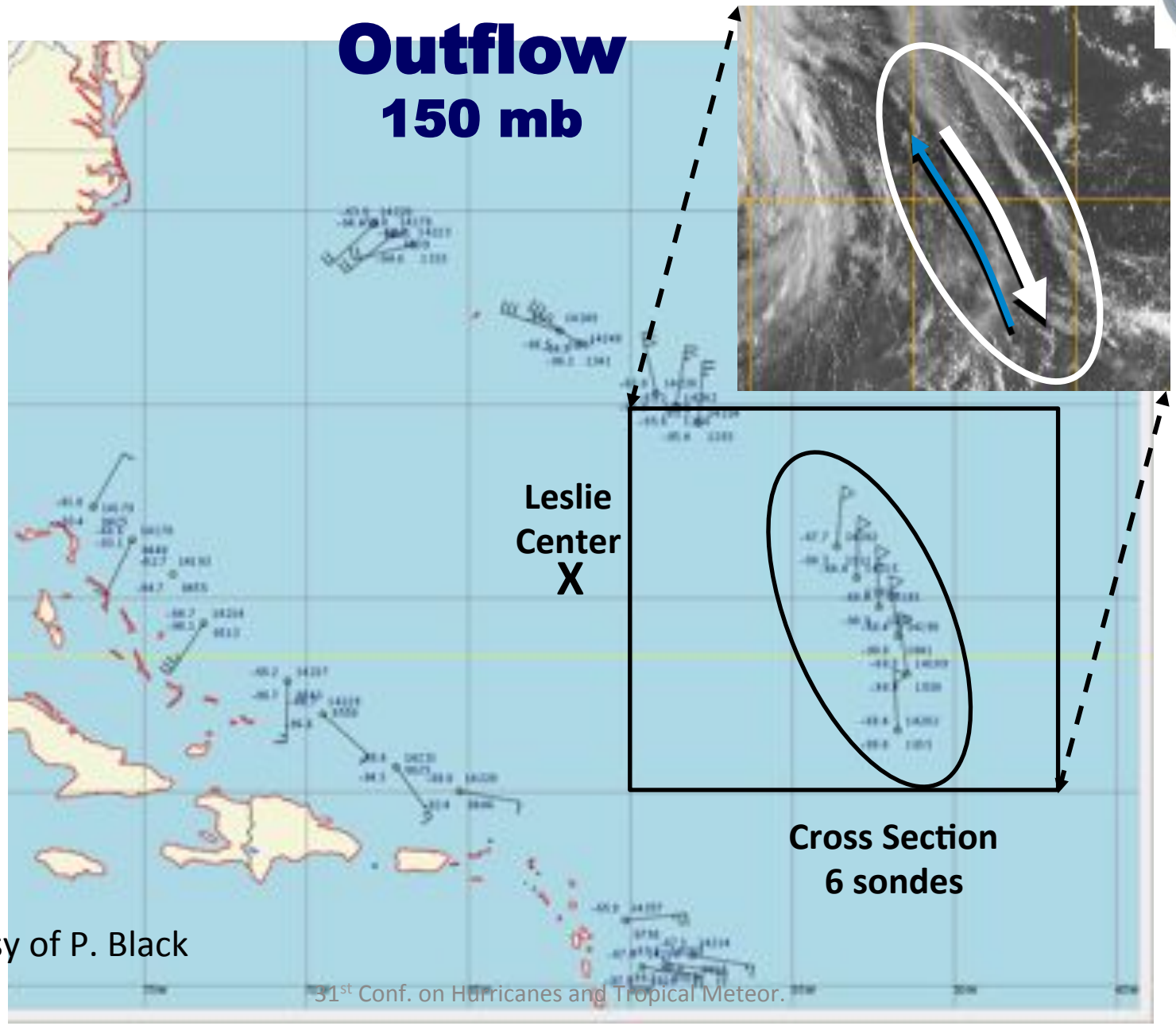
HS3 Observations of Leslie's Outflow

150 mb



Courtesy of P. Black

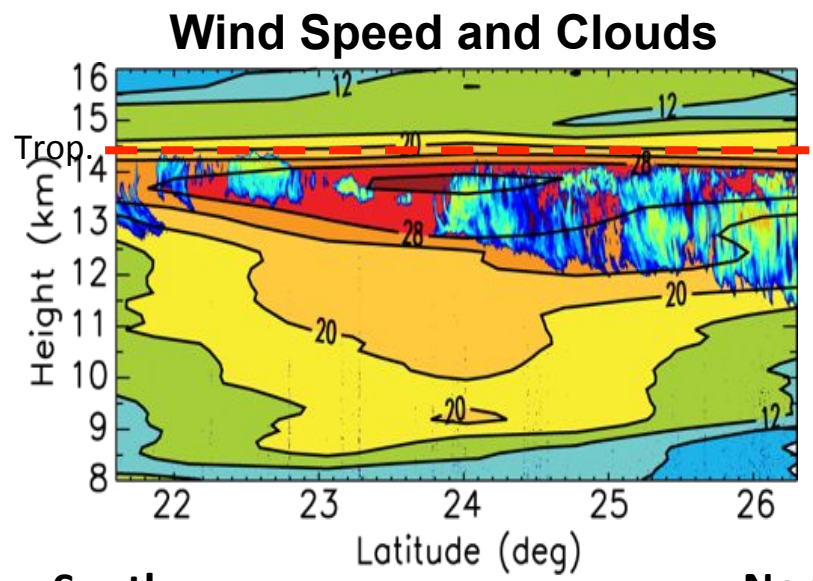
Structure of Tropical Cyclone Outflow

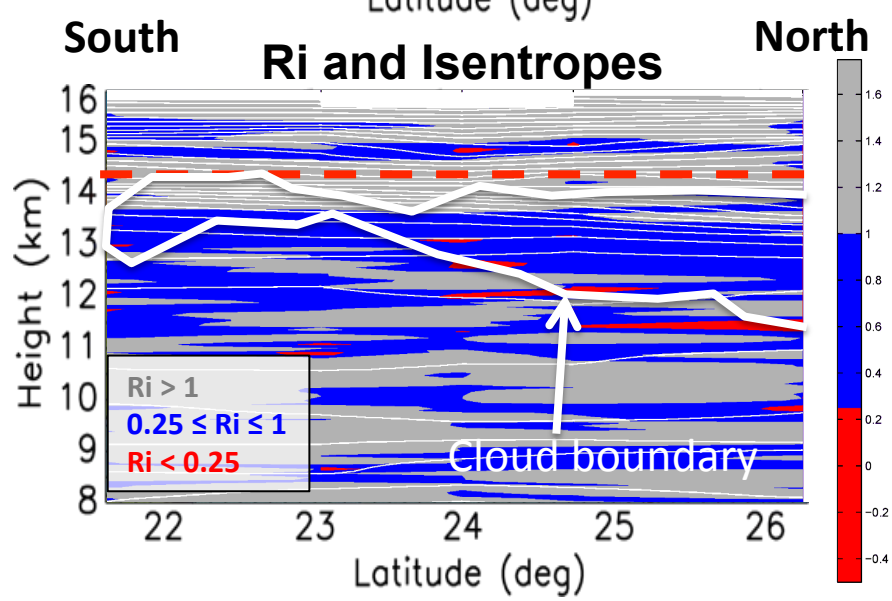
(Doyle talk, Session 8A)

- Goal: To characterize the TC outflow structure and evolution
- Dropsondes analyzed from the 6-7 Sept 2012 AV-6 ferry flight

  -6 sondes released in Leslie outflow
- Sondes show thin layer of outflow just below tropopause, with max. observed wind speed of 33 m s^{-1}.
- Along the shear layer at top of outflow, Ri<1.0. CPL and visible imagery suggests there is turbulent vertical mixing occurring.

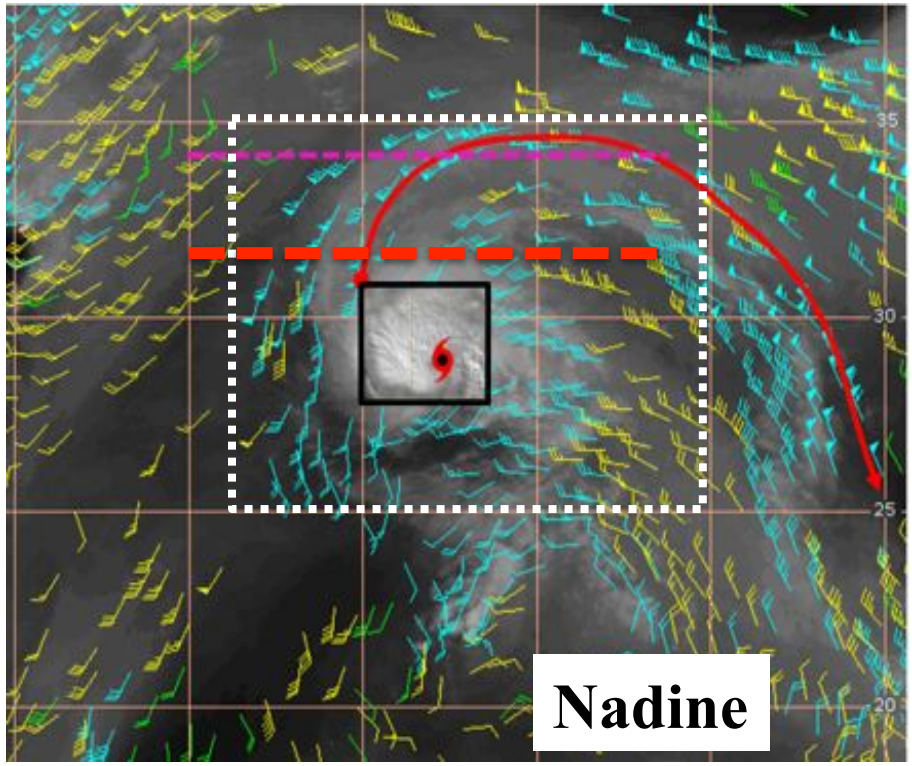
(From Doyle, P. Black, NRL; Braun GSFC)

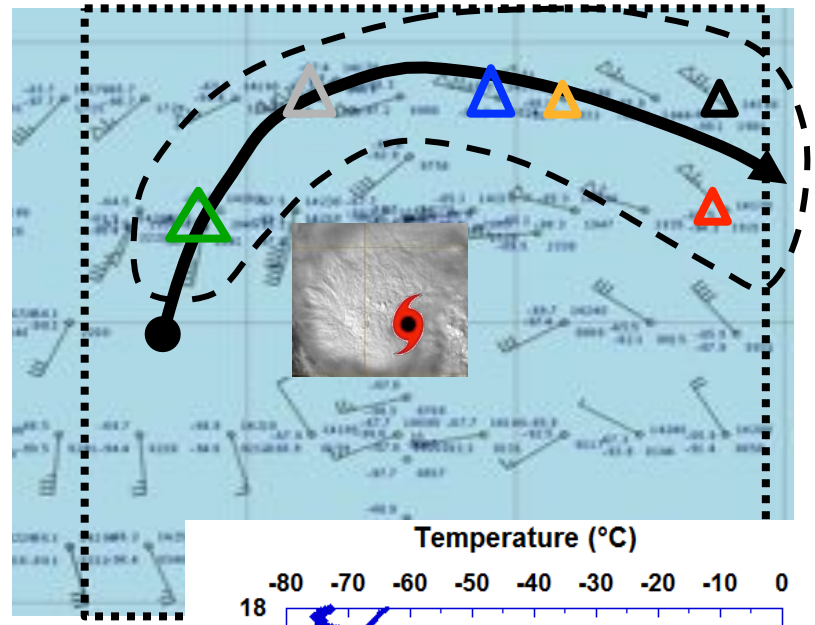


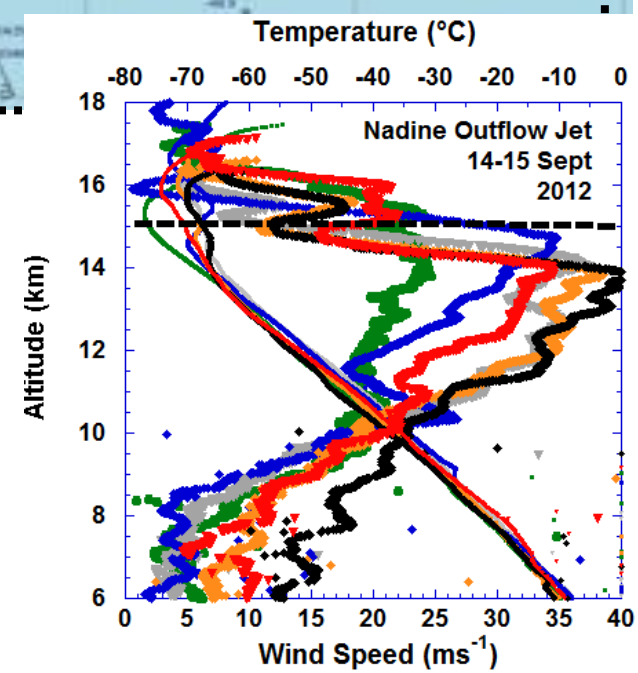


Structure of Nadine's (2012) Outflow

(P. Black talk, Session 8A)







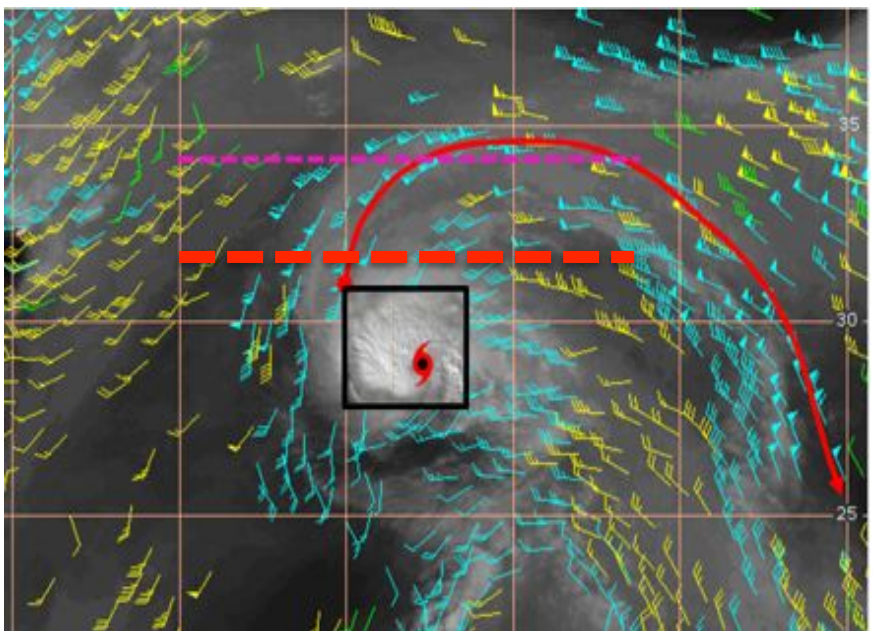
Outflow channel in Hurricane Nadine on 14-15 Sept at 1800 UTC. AMVs are shown by wind barbs, color-coded by level: blue 100-250 mb, yellow 250-350 mb and green 350-500 mb. Inner black square outlines MODIS 600-m resolution visible image of inner-core overshooting convection. Dotted box shows boundary of GH dropsonde observations shown in upper right along with solid black trajectory indicating the core of the outflow jet. Lower right shows six sonde profiles along the axis of the outflow jet indicated by triangles.

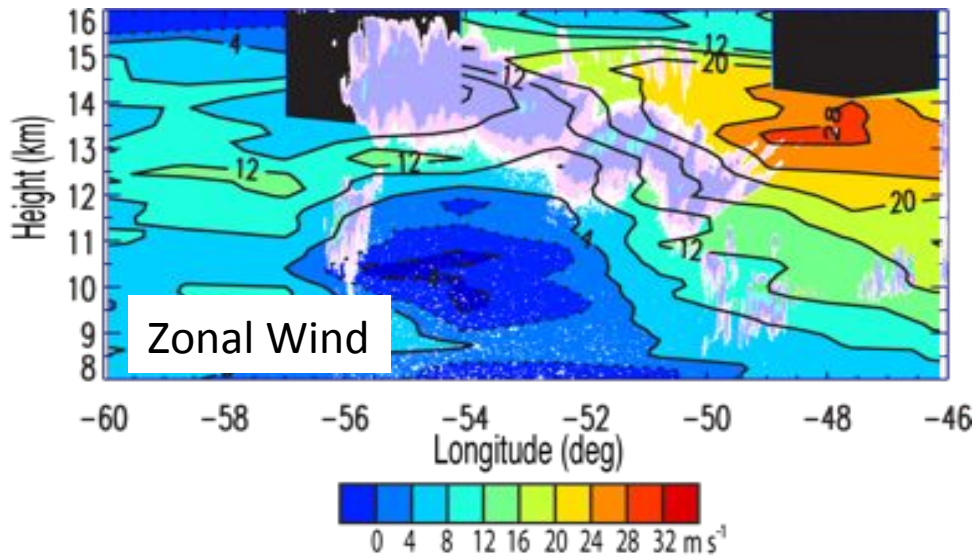
(From P. Black, NRL)

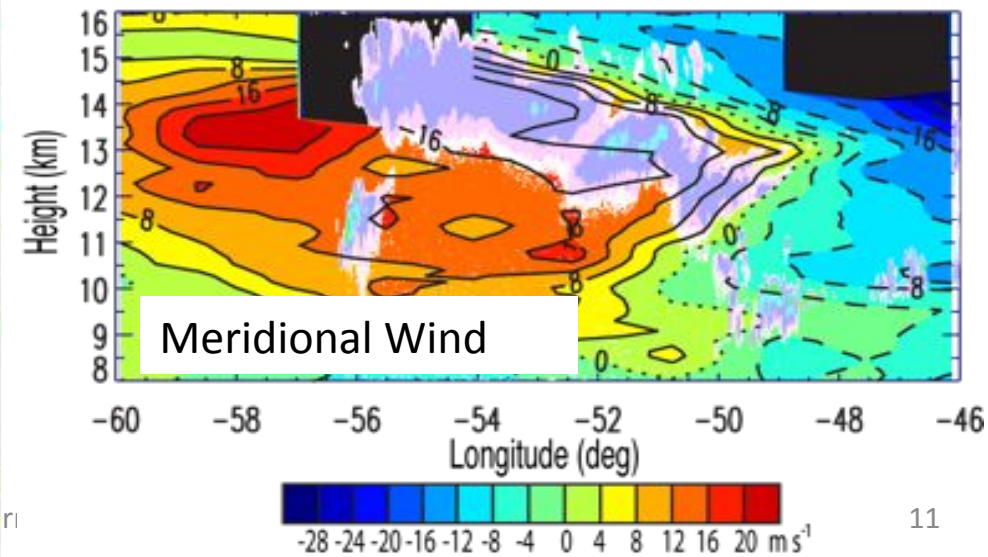
Flow Transitions in Nadine's Outflow Just North of the Storm Core

Sharp transition in U and V near top of cloud layer:

- U peaks near top, increases east of clouds
- V changes sharply from southerly to northerly above/ near cloud top







The TC Diurnal Cycle (Dunion talk, Session 15C)

TC Cirrus Canopy Thermodynamic Structure

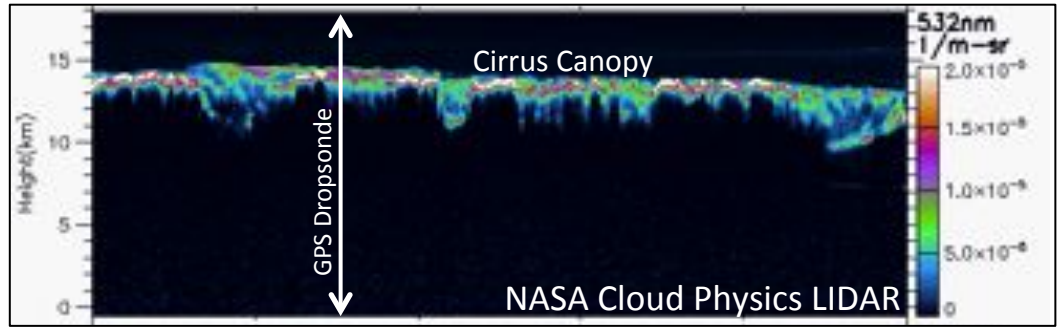
- Goal: Understand the impact of diurnal processes on the TC cirrus canopy;

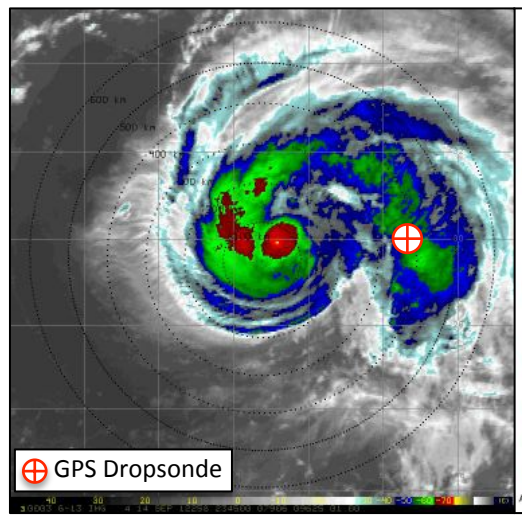
- Approach: Use Global Hawk-deployed GPS dropsondes to observe changes in the cirrus canopy temperature structure (near local sunset);

- Findings: A temperature inversion forms at the top of the cirrus canopy near the time of local sunset, creating a "double tropopause" structure. Possible linkages to the initiation of TC diurnal pulses observed in mature storms;

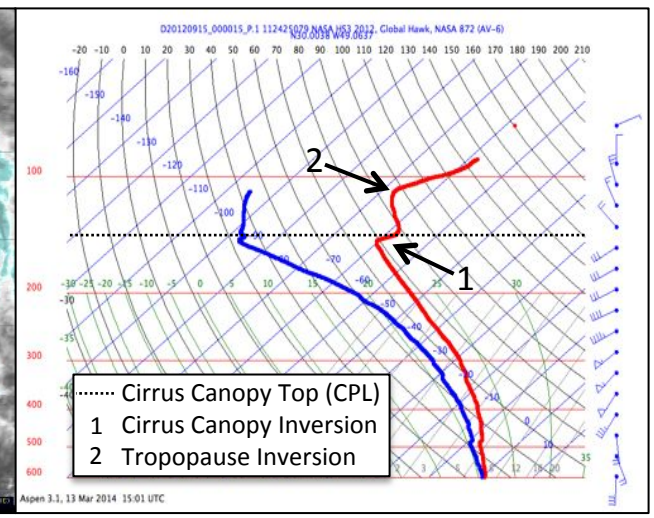
From J Dunion and C. Thorncroft

Hurricane Nadine: 15 Sep 2012





GOES-13 IR (11-µm)
14 Sep 2345 UTC
~2.5 hr after sunset



Global Hawk GPS Dropsonde
15 Sep 0000 UTC
~2.5 hr after sunset

Presentation Overview

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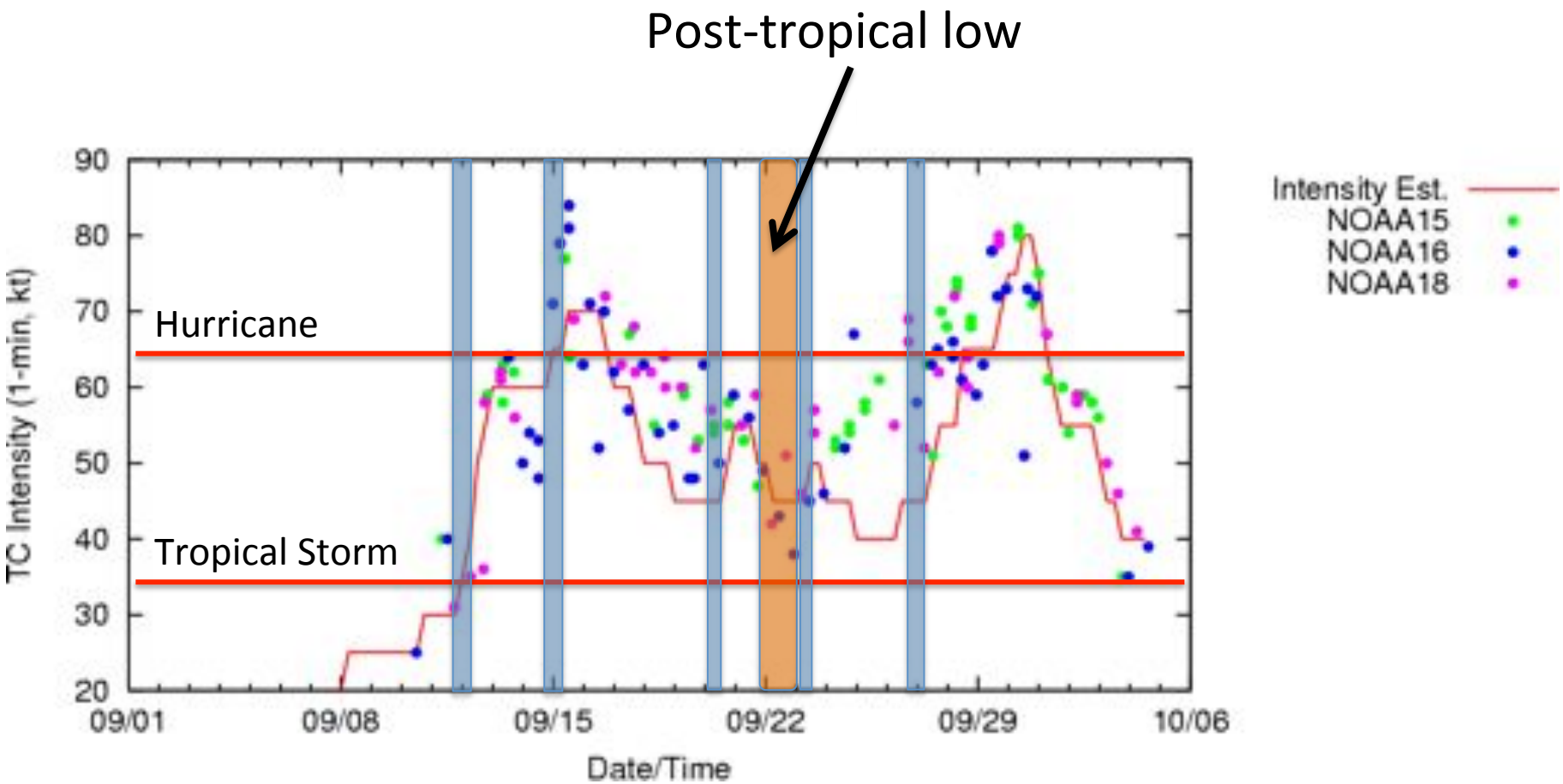
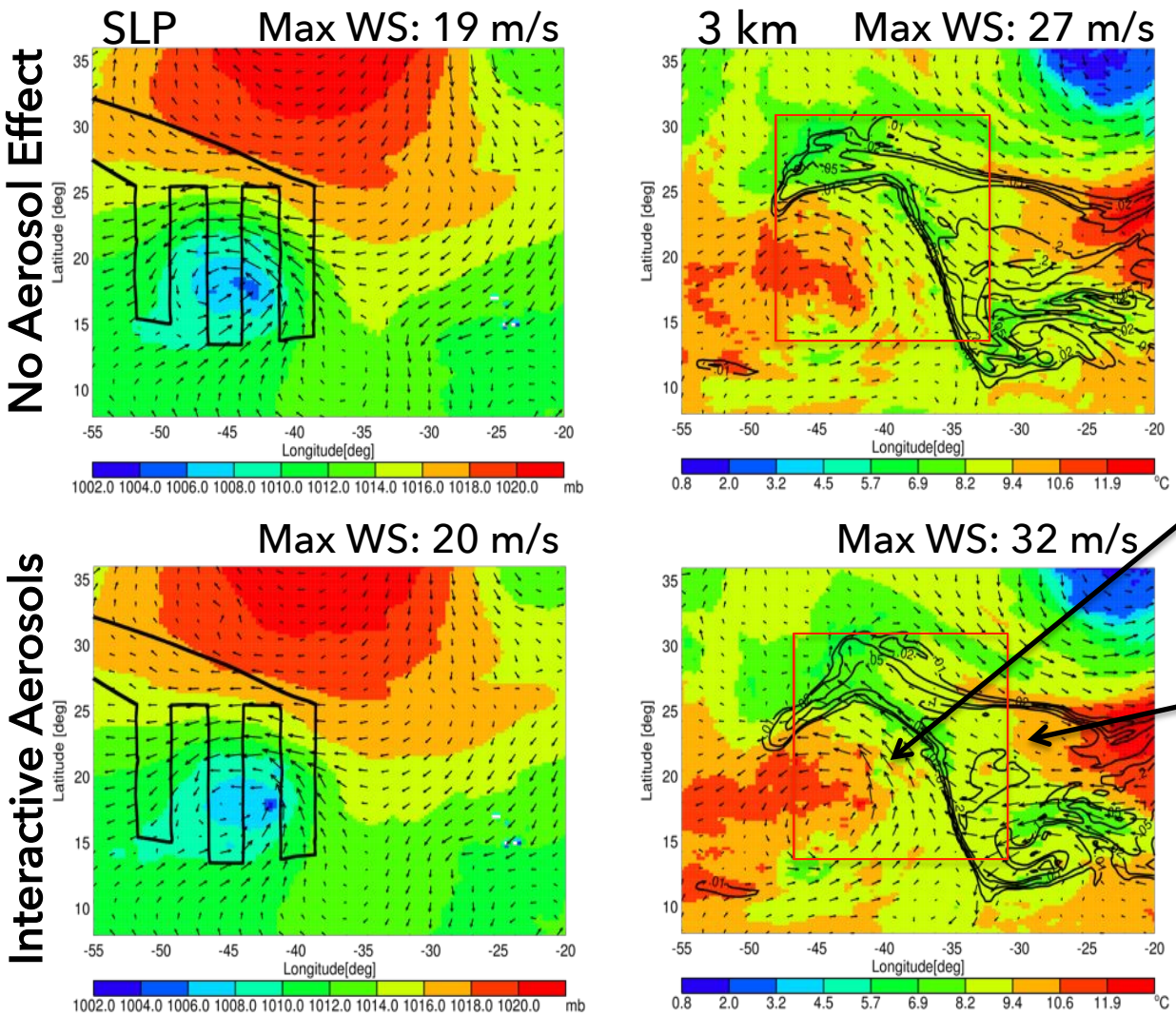
Flight Times As a Function of Nadine's Life Cycle



How do the radiative effects of dust aerosols impact a developing Nadine? (Nowottnick talk, session 9a)

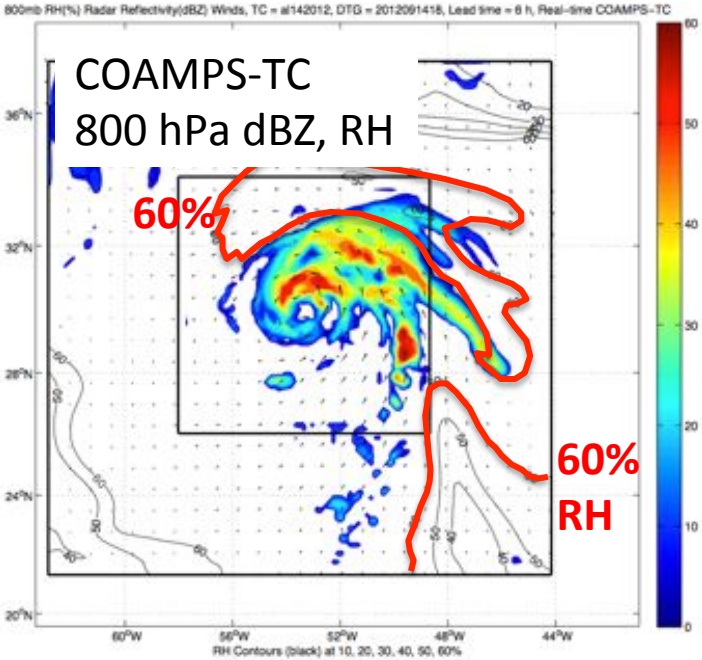
Aerosol Radiative Impacts on TS Nadine on 9/12/12 00z



Two GEOS-5 forecasts were made:
- One included aerosol radiative forcing
- One did not

When aerosol radiative effects are included we see:
– Greater wind speeds on the northeast side of pre-Nadine in close proximity to the dusty SAL.
- Slight warming within the dust layer due to absorbing by dust.

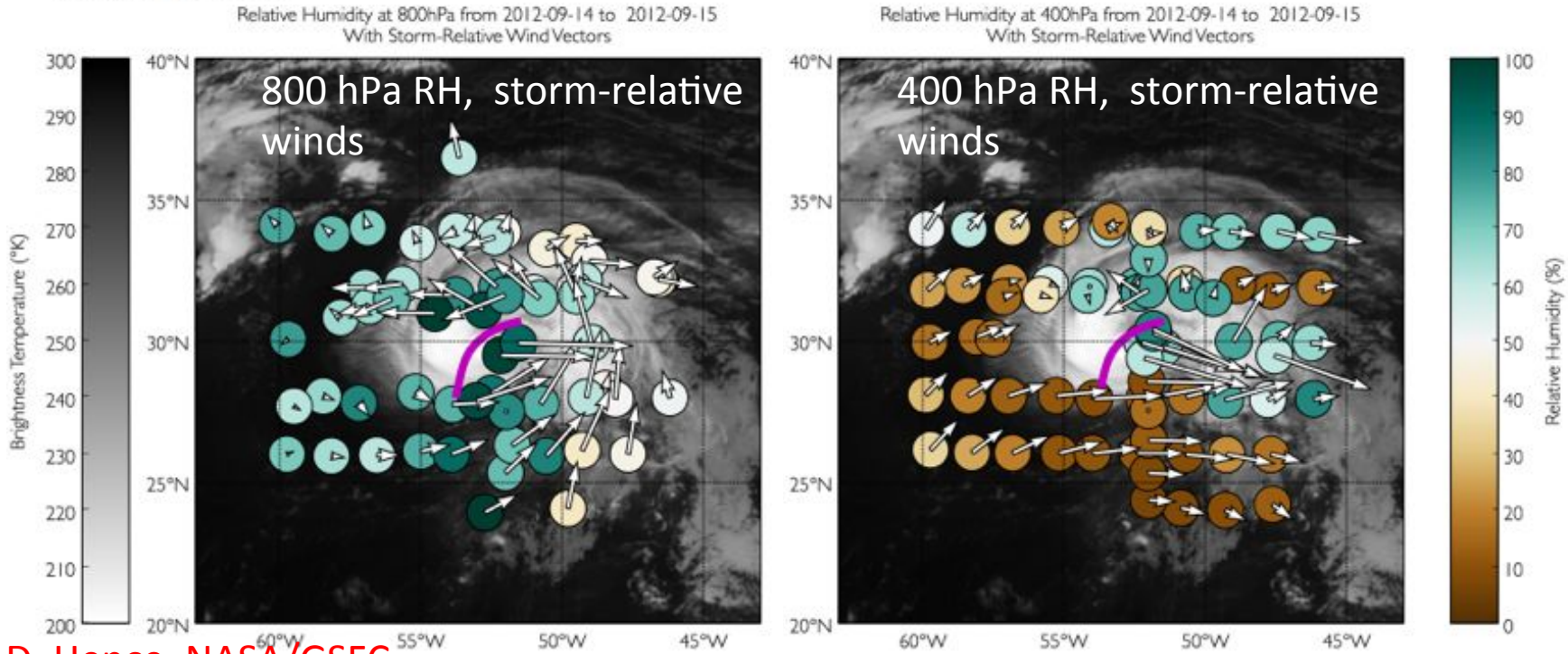
From Nowottnick & Colarco, NASA/GSFC



SAL, Shear and Nadine

(Hence talk, Session 8A)

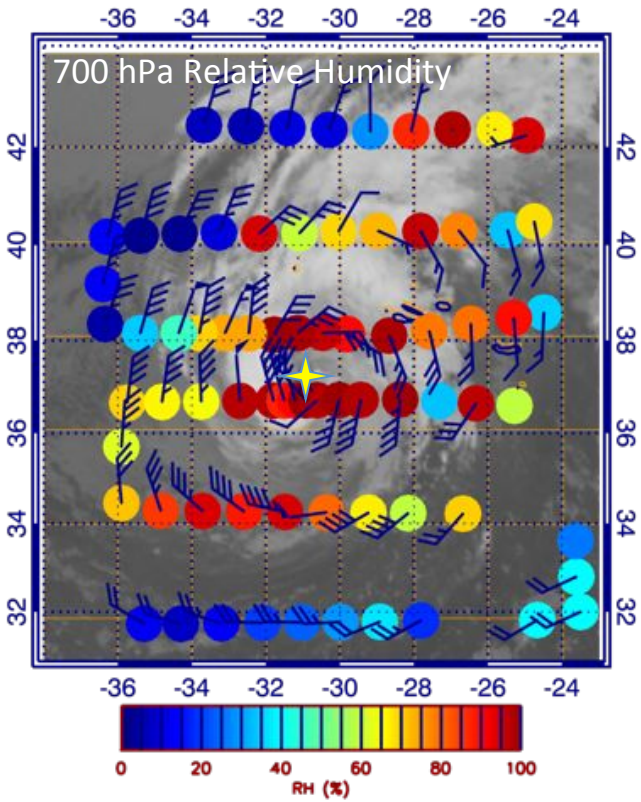
- Analysis with aircraft and satellite observations and model output
- Complex interaction between dry air to west, SAL, and Nadine's circulation
- Minimal penetration of SAL into storm center

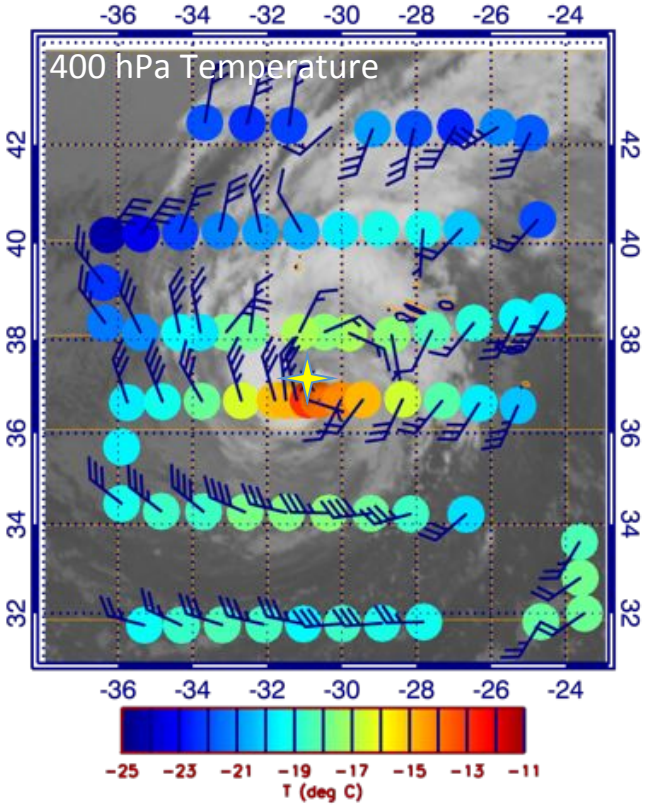


From D. Hence, NASA/GSFC

Nadine Survives Despite Adverse Conditions (Sept 19-20)

- Despite strong vertical shear (~25-30 kt between 850-200 hPa) and low SSTs (~22°C), Nadine survives
- Dropsondes reveal warm core structure near center through most of the troposphere
- NHC uses HS3 observations, among others, to maintain Nadine as a tropical storm



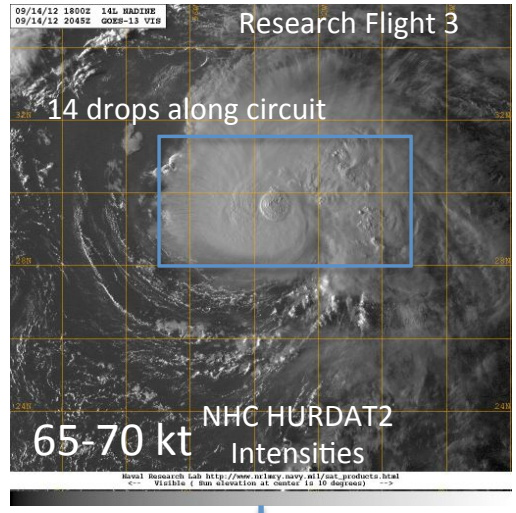


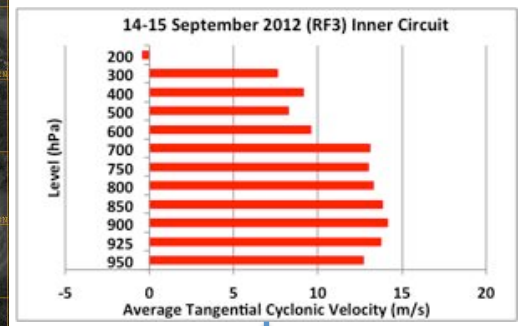
Investigating Nadine's resilience: quantifying wind structure change

Calculating the change in circulation helps quantify growth of circulation and storm resilience

- Goal: Determine the vertical structure and time evolution of circulation using actual data.
- Methodology: Average tangential velocity determined from a simple average of circulation about a circuit's perimeter.
- While the maximum wind intensity of Nadine decreased between these two flights, the areal extent of the circulation increased, as hinted in satellite imagery as well as depicted in the increase of tangential velocity at all levels up to 400 hPa.

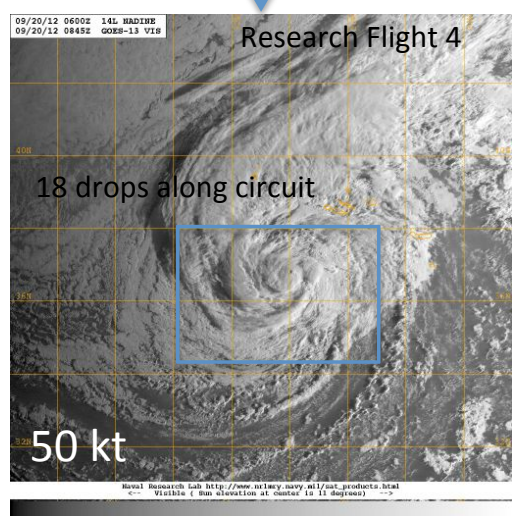
From Boothe, Montgomery, NPS

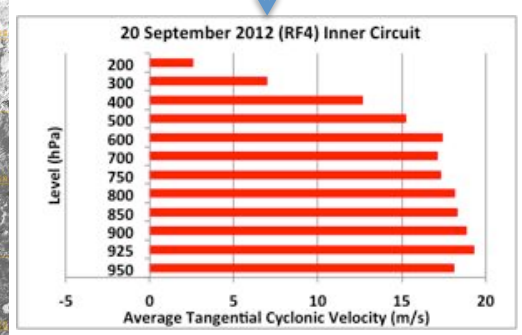




Increase of ~5 m/s at all levels up to 400 hPa

About 5 days





overy of High θe

r warmer

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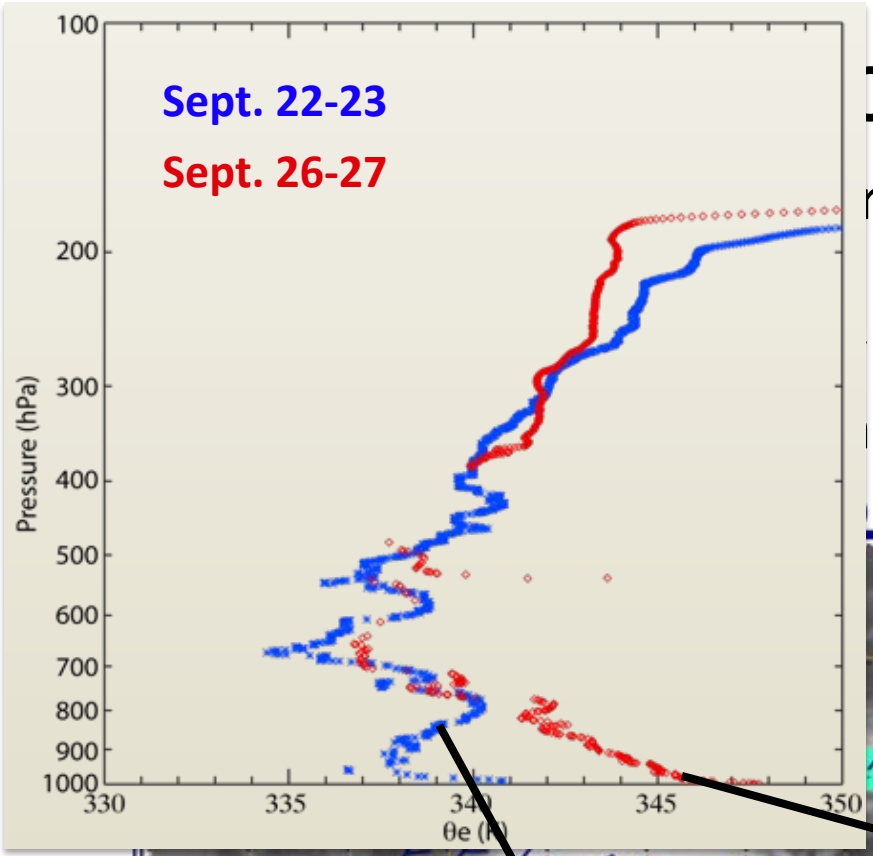
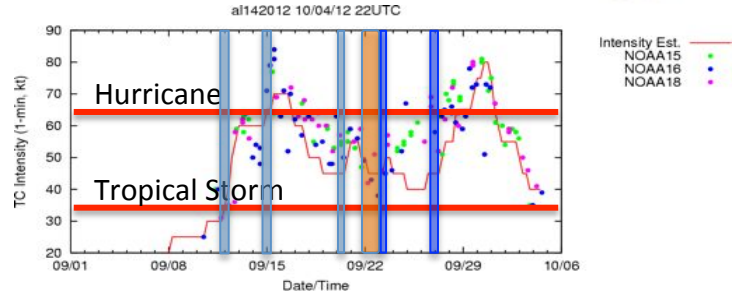
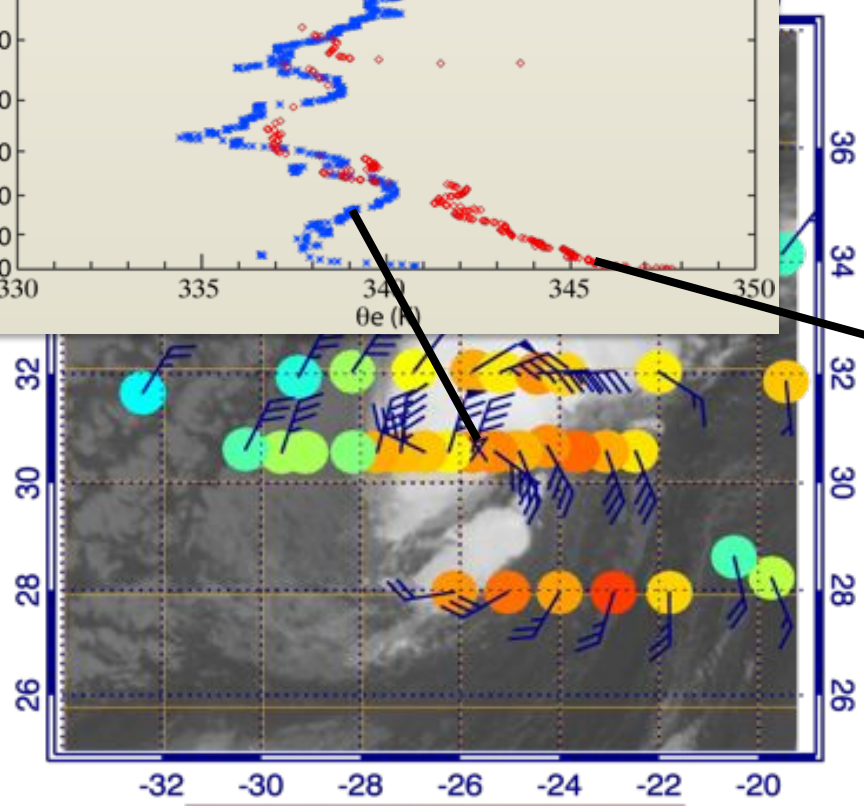
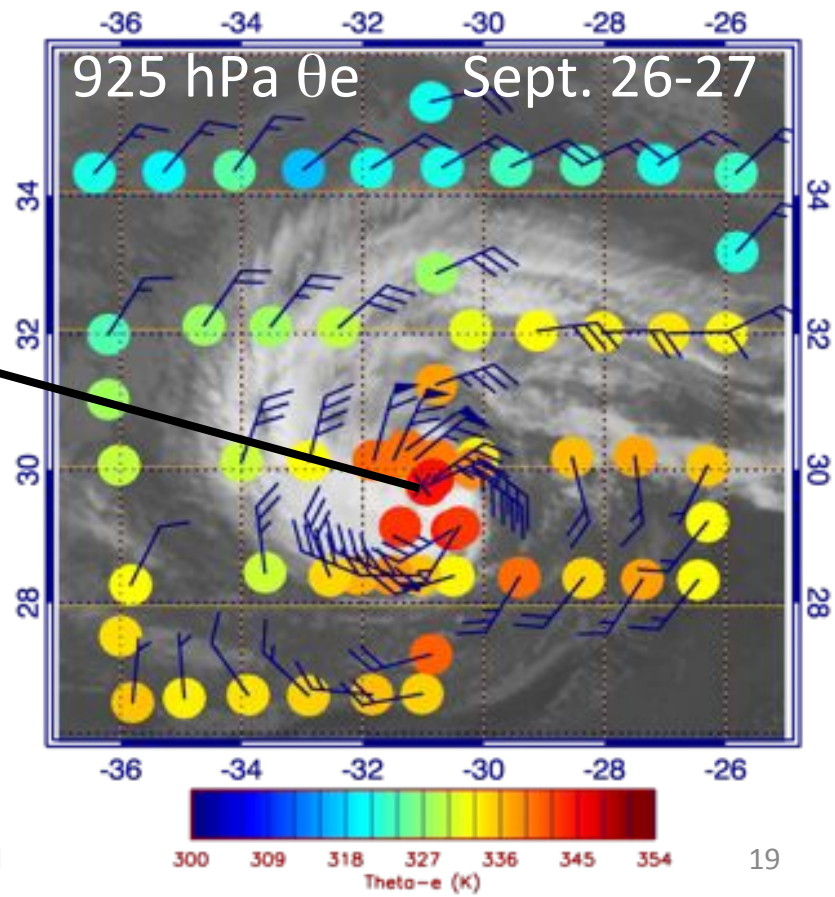
nd 26-27









Impact of HS3 Dropsondes on COAMPS-TC Forecasts of Hurricane Nadine (2012)

(Doyle talk, Session 8A)

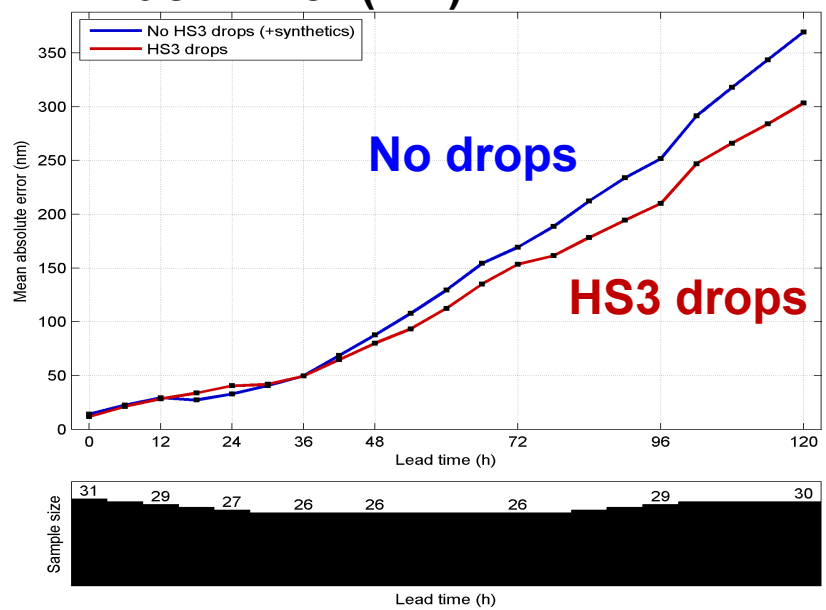
- Goal: To assess the impact of HS3 obs. on forecasts of Nadine

- Dropsonde impact experiments performed for 19-27 Sep. (3 flights)
  - -Red, with HS3 drops
  - -Blue, no drops with synthetics

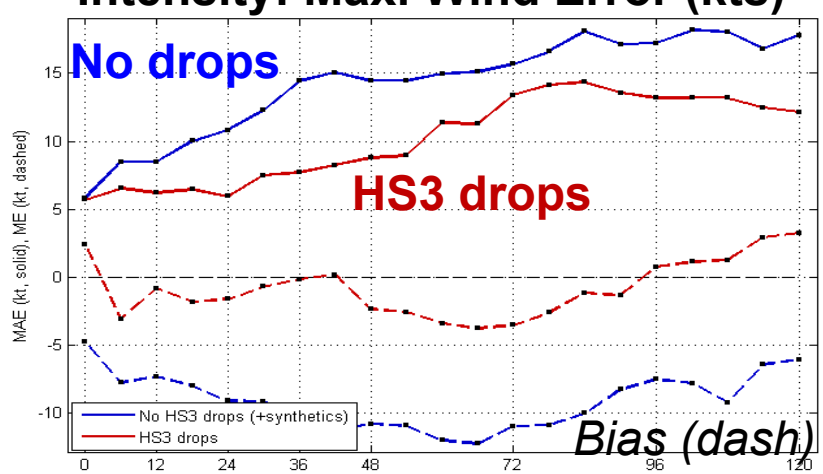
- COAMPS-TC Intensity and Track skill are improved greatly through assimilation of HS3 Drops.

(From Doyle, NRL)

Track Error (nm)



Intensity: Max. Wind Error (kts)

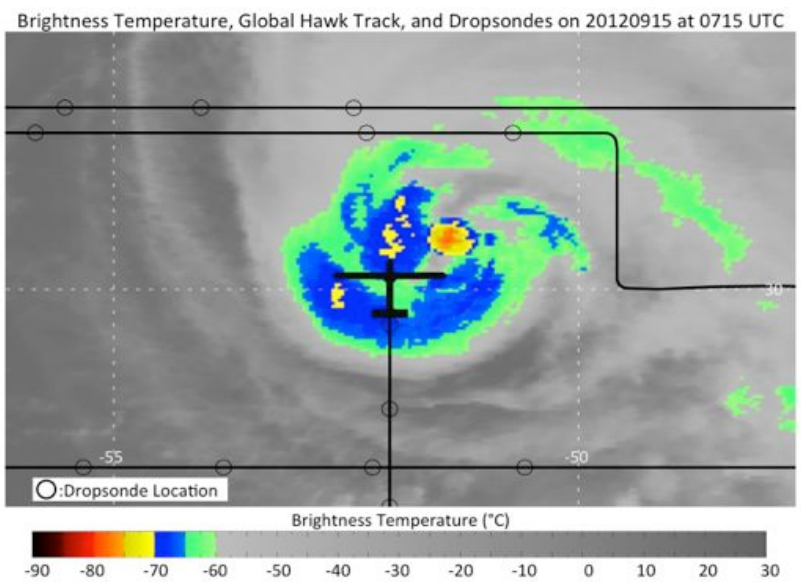


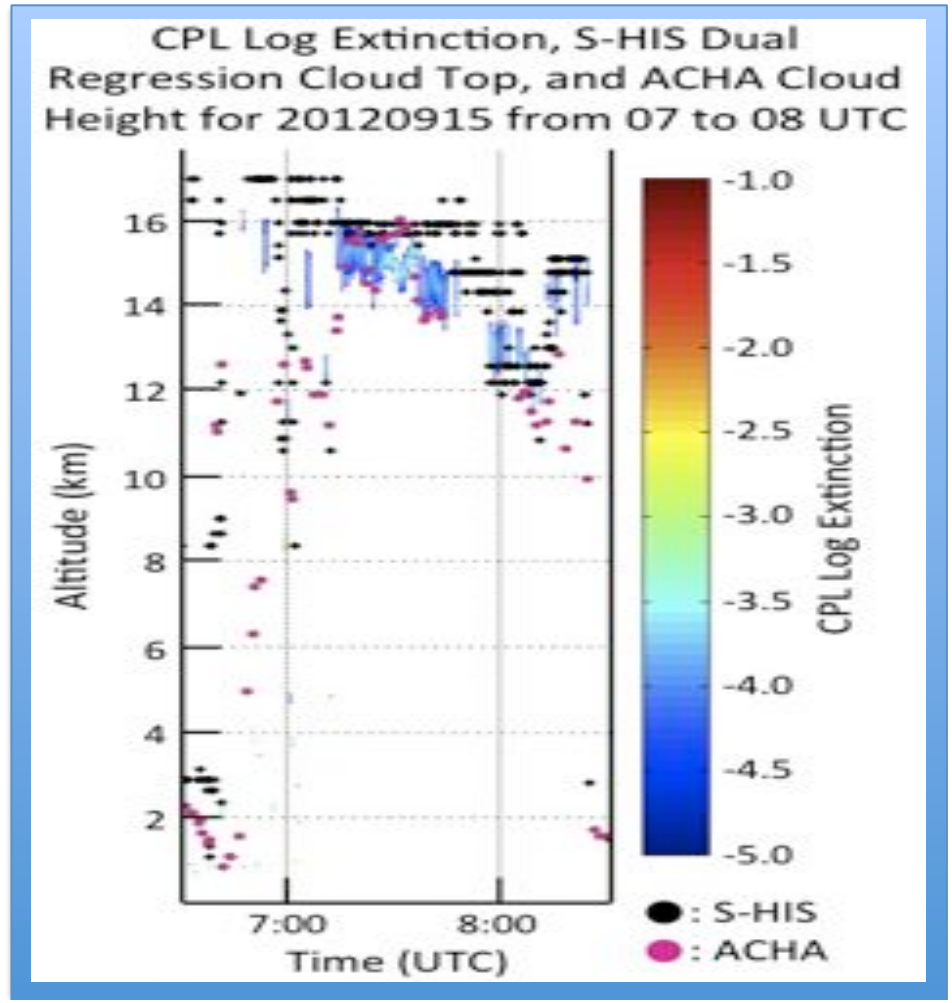
Validation of Satellite-Derived Cloud Top Heights in Tropical Cyclones using HS3 Observations

PIs: Christopher Velden and Sarah Monette – Univ. Wisconsin-CIMSS

(Talk in Session 9A)

- Goal: Utilize HS3 over-flight measurements of TCs to assess the quality of cloud height estimates derived from latest NESDIS satellite algorithm (ACHA).
- Compare satellite estimates with collocated CPL and S-HIS measurements





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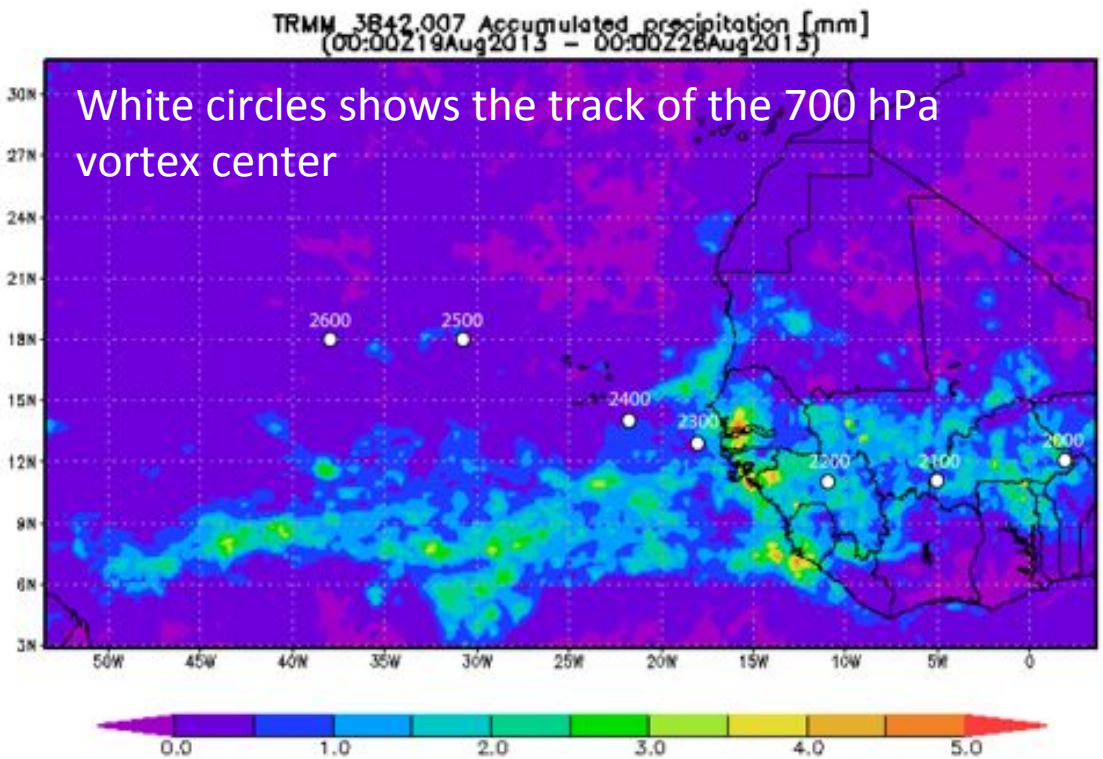
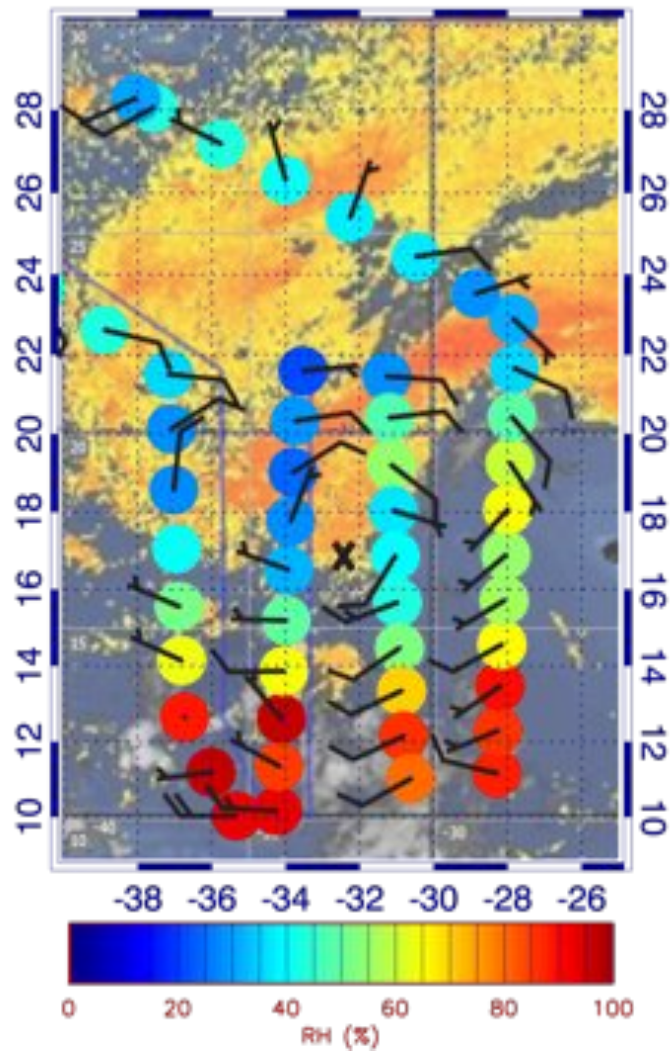
SAL Structure on Aug. 24-25

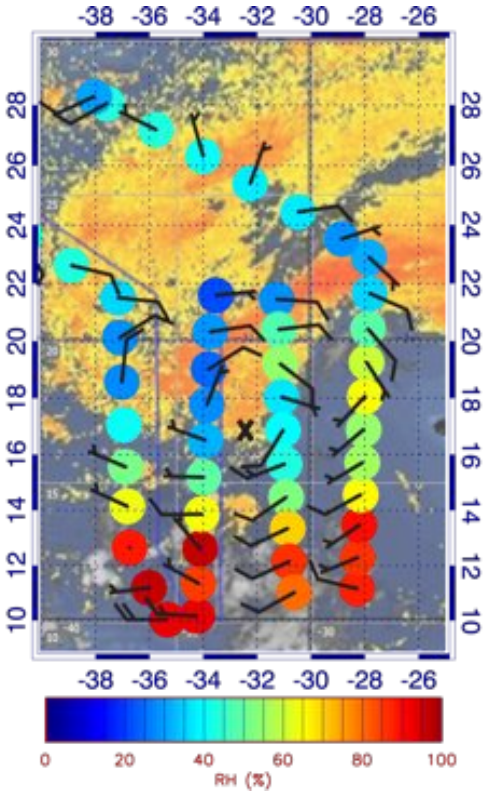
- TRMM data (below) shows the movement of the circulation center well north of the ITCZ

- Dropsonde data (right) shows a well defined circulation center in the wave-relative flow with dry SAL air wrapping around the southern side of the wave



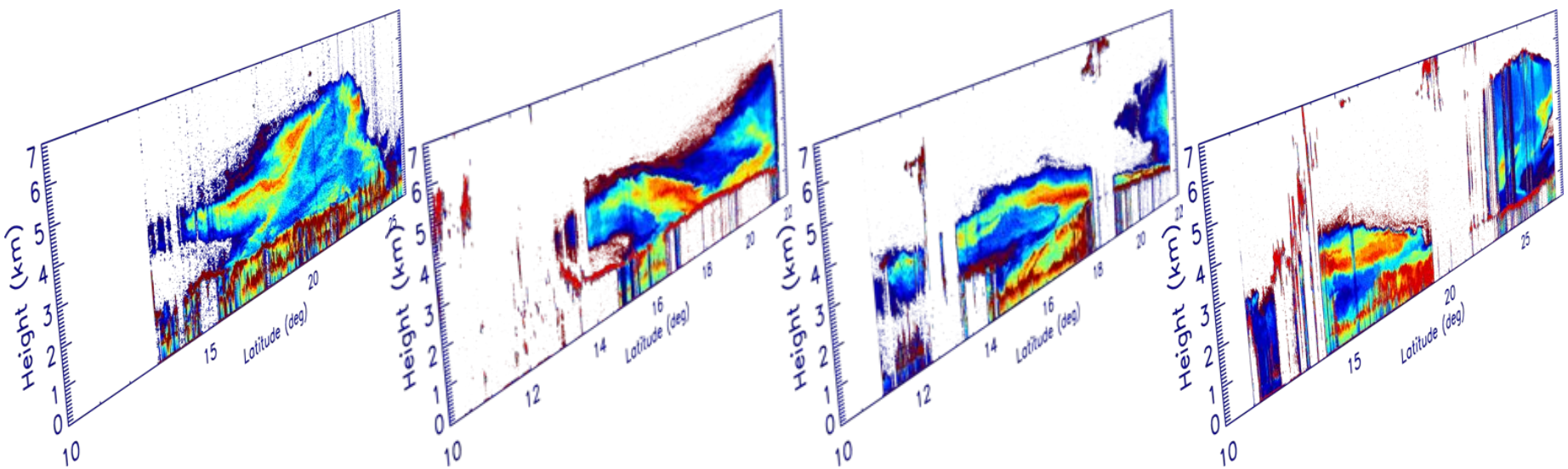
800 hPa relative humidity and wave-relative winds



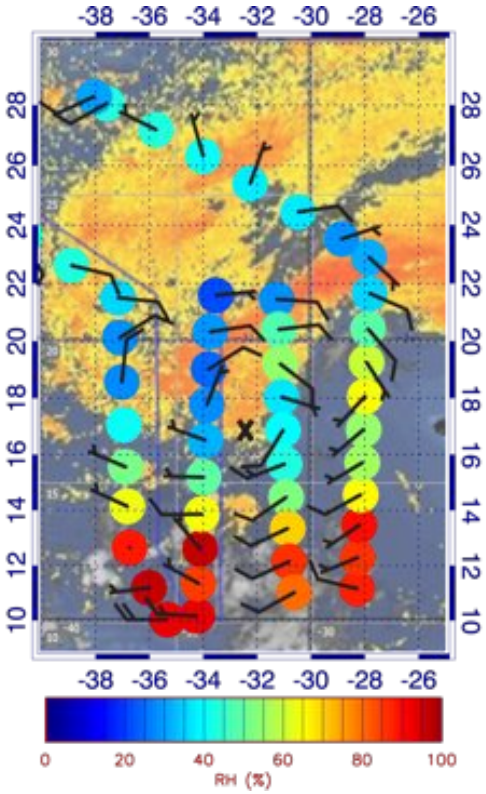


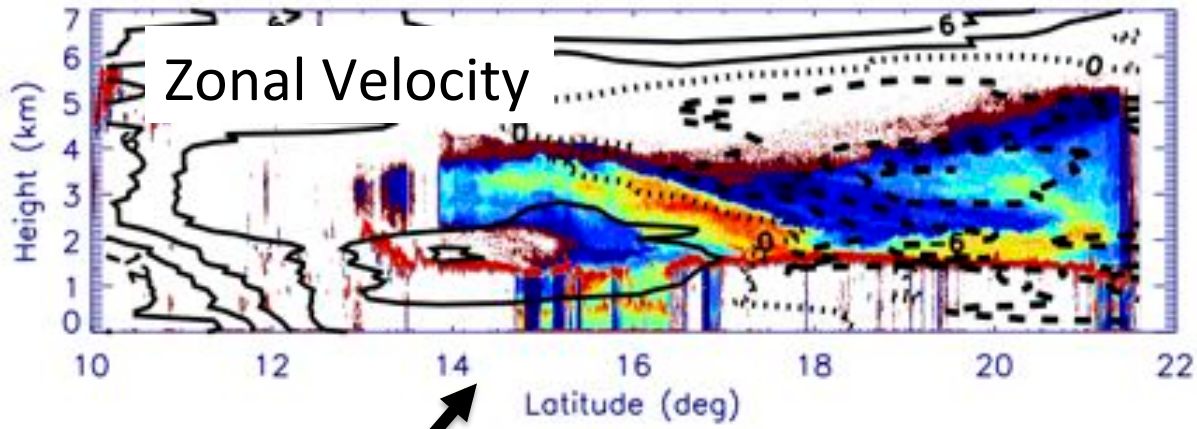
SAL Structure on Aug. 24-25

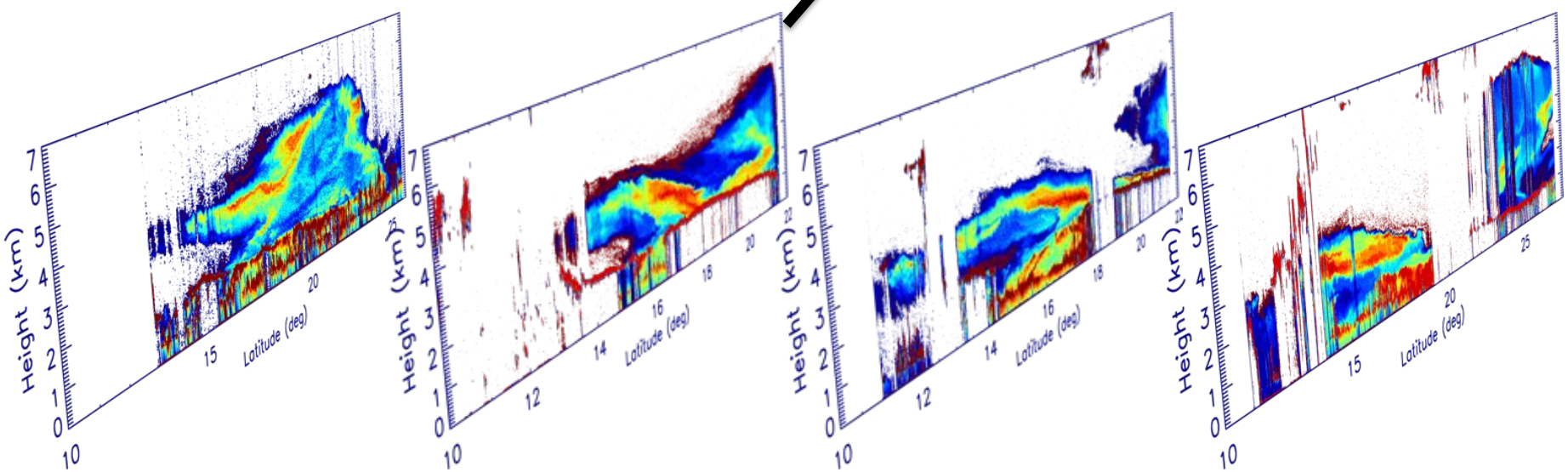
- Cross sections from west to east (below)
- Deep region of dust to the west gradually splits into two regions
- Southern region of dust extends farther south than suggested in GOES SAL product



SAL Structure on Aug. 24-25



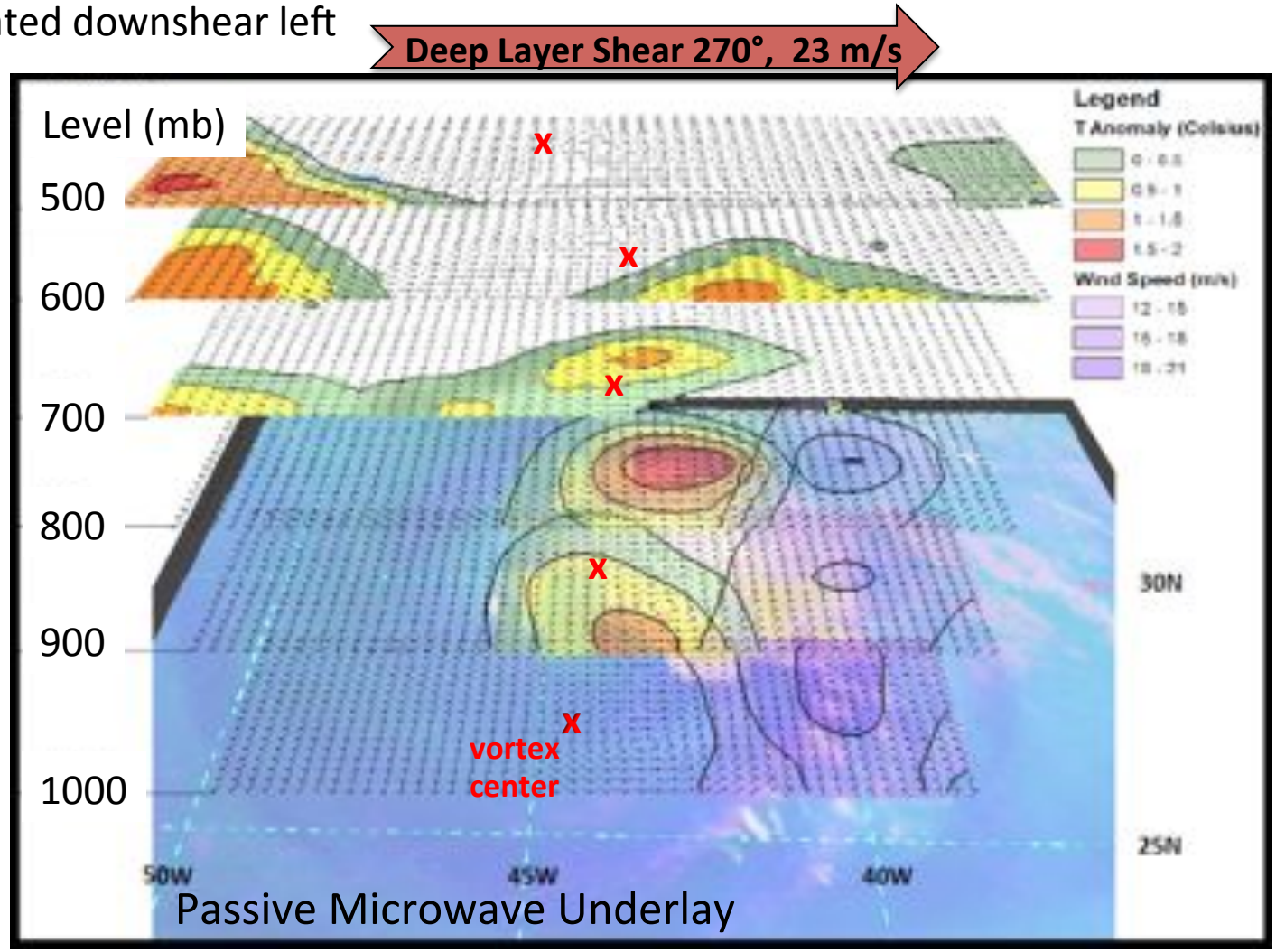




Dropsonde Analysis of TS Humerto's 3D Thermal and Wind Structure (Sept. 17, 2013)

Jeffrey B. Halverson, Alex Martin (UMBC)

- Highly asymmetric structure w/ 21 m/s wind max creating convergent zone in NE quad
- Deep convection located downshear left
- Warm anomaly in low levels, to right of center, likely subsidence-driven
- Kinematic, rain & thermal fields consistent with a shear-forced, wave number 1 asymmetry

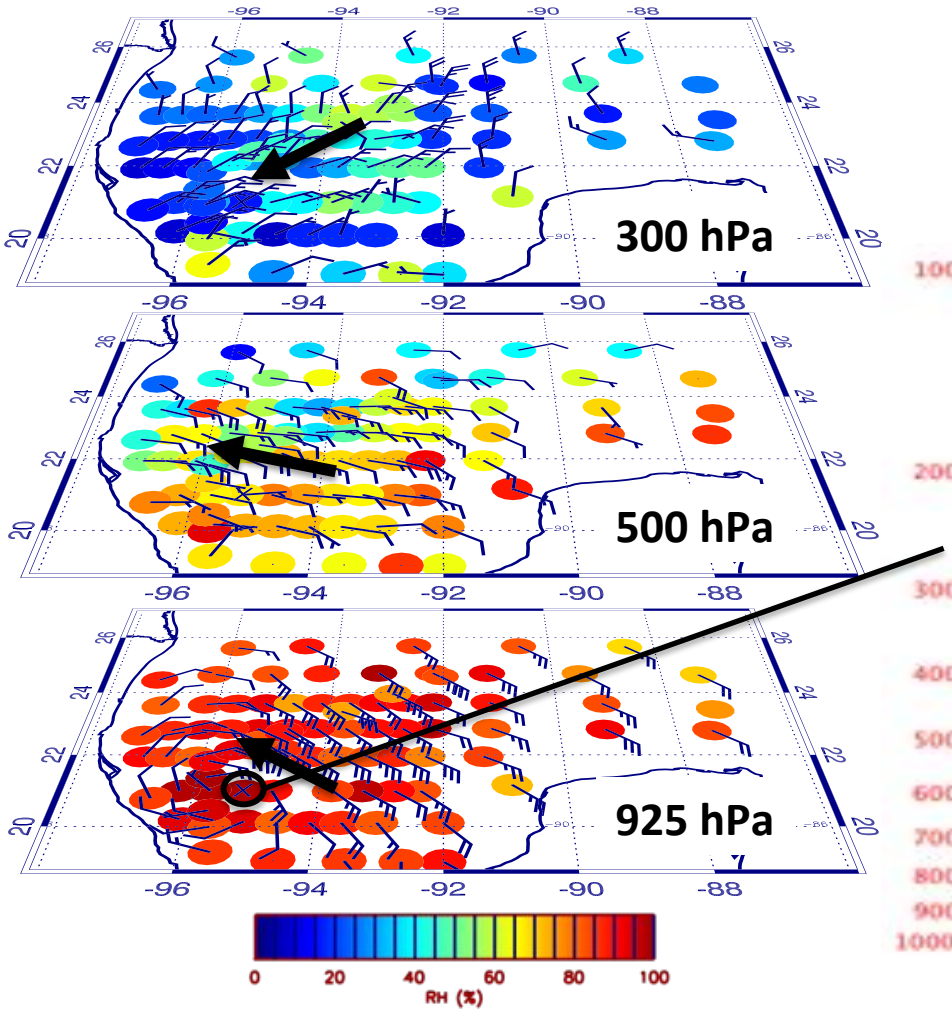


What Killed Invest 95L?

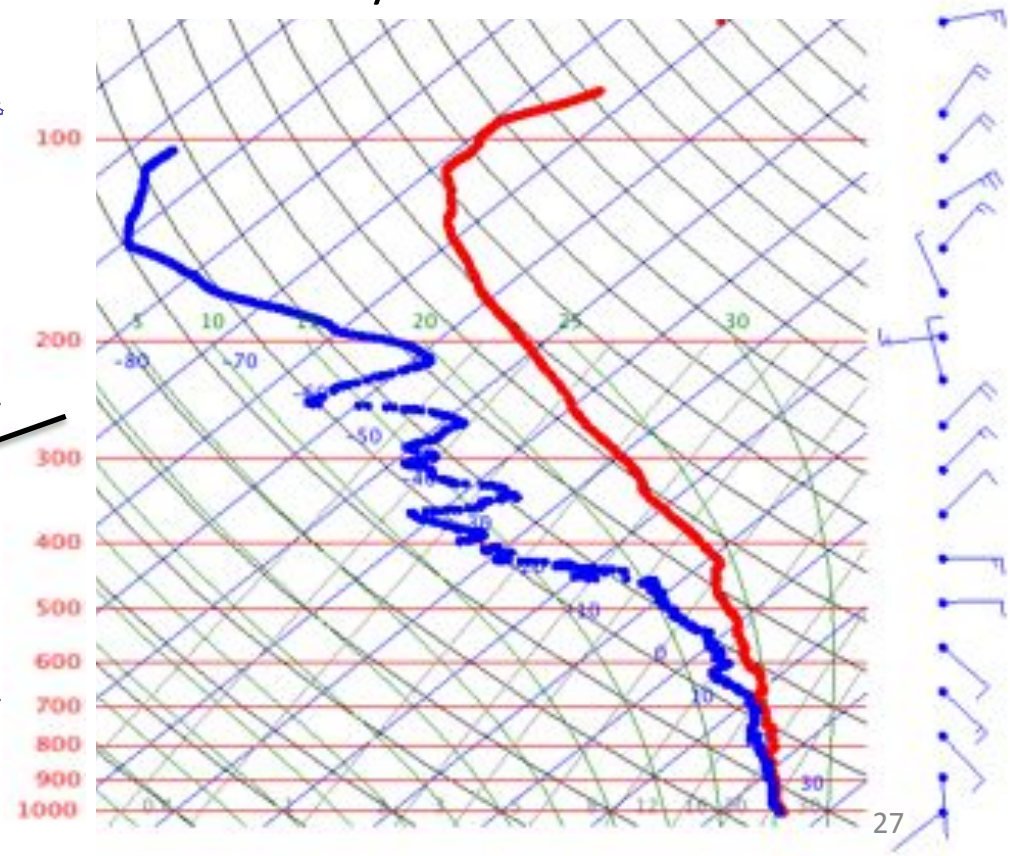
See related poster by Fritz and Wang, Thursday

19-20 September 2013

Relative Humidity and Wind Barbs



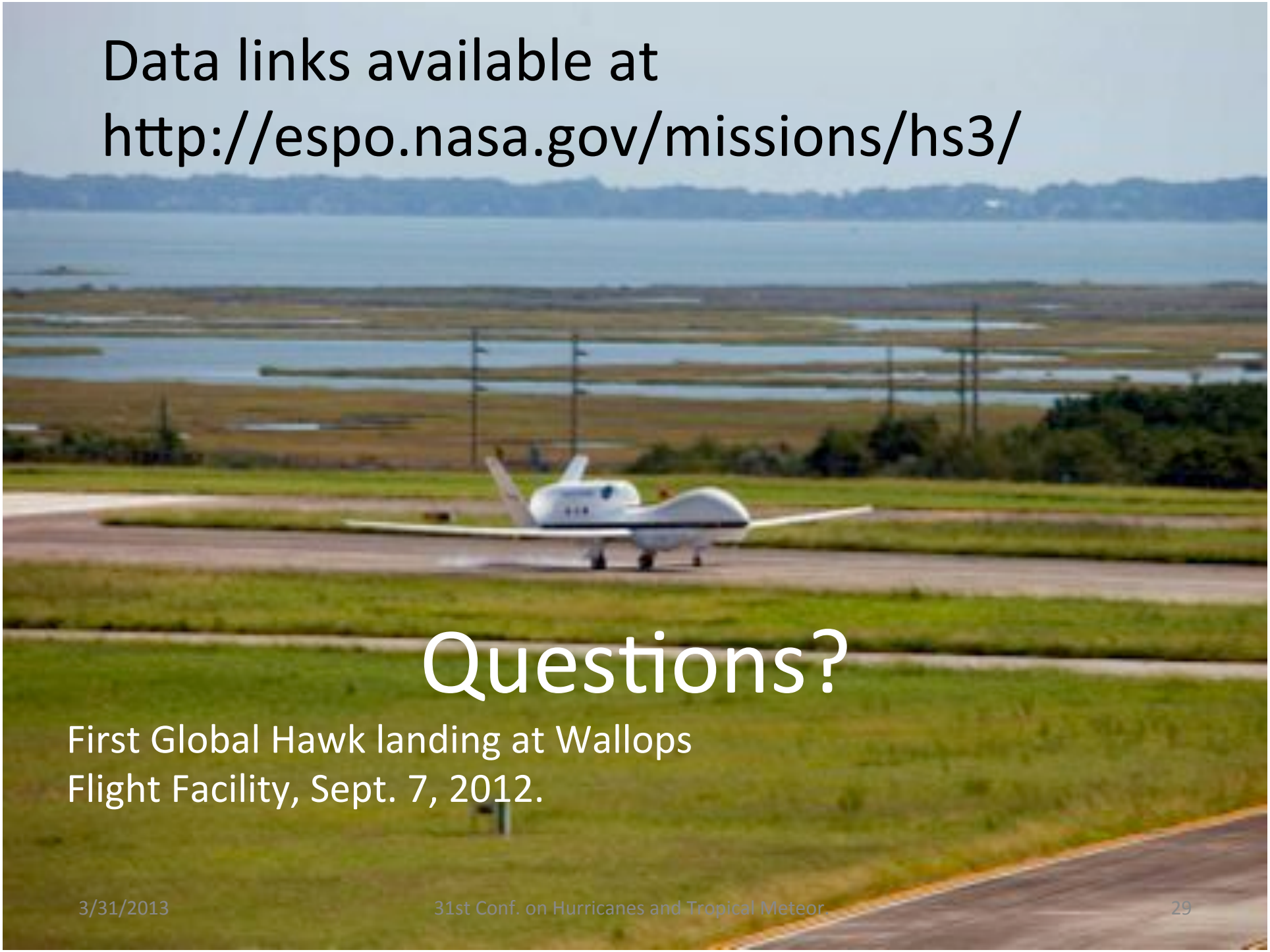
- NHC forecasted 70% chance of development, but failed to form
- Lots of dry air at mid-upper levels
- Dropsonde data suggests multiple subsidence layer aloft



The 2014 HS3 Campaign

- Science Operations Period ~AUG 26-SEPT 29
- Originally planned 4 weeks, NOAA funding extension of operations
  - 5th week of aircraft/science operations
  - Up to 5 flights (3 environmental, 2 over storm)
  - Contributing mission scientists to participate at Wallops Island

Data links available at
http://espo.nasa.gov/missions/hs3/



Questions?

First Global Hawk landing at Wallops Flight Facility, Sept. 7, 2012.