# High Definition Sounding System (HDSS) for atmospheric profiling: Validation and new TC observing strategy

Peter G. Black[1], Lee Harrison[2], Mark Beaubien[3], William Jeffries[3], Robert Bluth[4], Haflidi Jonsson[4], Andrew Penny[5] and Robert W. Smith[6]



[1]SAIC, Inc, Surveillance and Reconnaissance Solutions Division
[2]University at Albany, State University of New York, Atmospheric Sciences Research Center
[3]Yankee Environmental Systems, Inc.
[4]Naval Postgraduate School, Center for Interdisciplinary Remotely Piloted Aircraft Studies
[5]Naval Postgraduate School, Department of Meteorology and Physical Oceanography
[6]NASA/ Johnson Space Center, WB-57 Program Office, Ellington Field

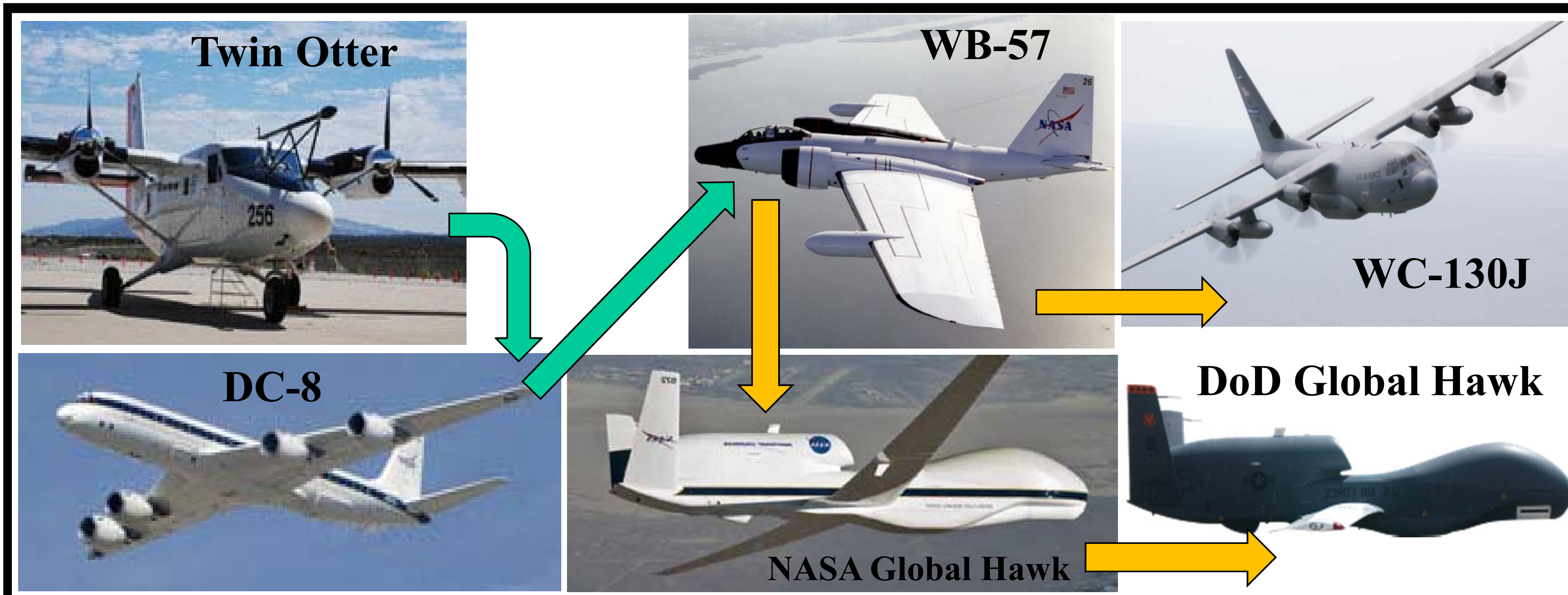
# High-Density Sounding System (HDSS): eXpendable Digital Dropsonde (XDD) + Automatic Deployment Dispenser (ADD)

- Motivation: Develop a new-generation atmospheric profiling system capable of high-altitude, multisonde ‘swarm’ XDD deployments sampling hurricane and high-impact weather outflow and inflow layers with loss-less, real-time data transmission.

- Goals: Validate initial XDD measurement accuracy of winds and Pressure, Temperature and Humidity (PTH) from:
    - 4-km altitude aircraft spiral descent and RD-94 aircraft dropsonde data,
    - 12-km altitude pressurized aircraft, dual fall-rate deployments at extended reception ranges,
    - 20-km altitude aircraft deployments concurrent with NWS radiosonde ascents

- Approach: Conduct test flights from:
    - CIRPAS Twin Otter aircraft on 24-25 June, 2011 off central California coast,
    - NASA DC-8 aircraft on 28-29 June, 2013 off Baja California coast and,
    - NASA WB-57 aircraft on 14-19 November, 2013 over the western Gulf of Mexico, off the Texas coast.

# HDSS Technology Investment Roadmap




**Accomplishments:**

- Twin Otter DEMO: CA Coast June, 2011
- DC-8 DEMO: Baja California June, 2013
- WB-57 DEMO: TX Gulf Coast November, 2013

**Plans:**

- NASA HS3 Atlantic Global Hawk
  ONR TCI Atlantic WB-57 2014
- Proposed NOAA SHOUT Atlantic
  UAV DEMO Global Hawk 2015
- Proposed NASA OUTFLOW
  Proposed ONR TCI
  WPAC TC Intensity
  Global Hawk 2016-17

**Future Technology Transfer**

**Operational Tropical Cyclone Reconnaissance**

- DoD/NOAA Global Hawk
- Air Force WC-130J

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# HDSS Validation Platforms

**Migration from Navy CIRPAS Twin Otter 2011**

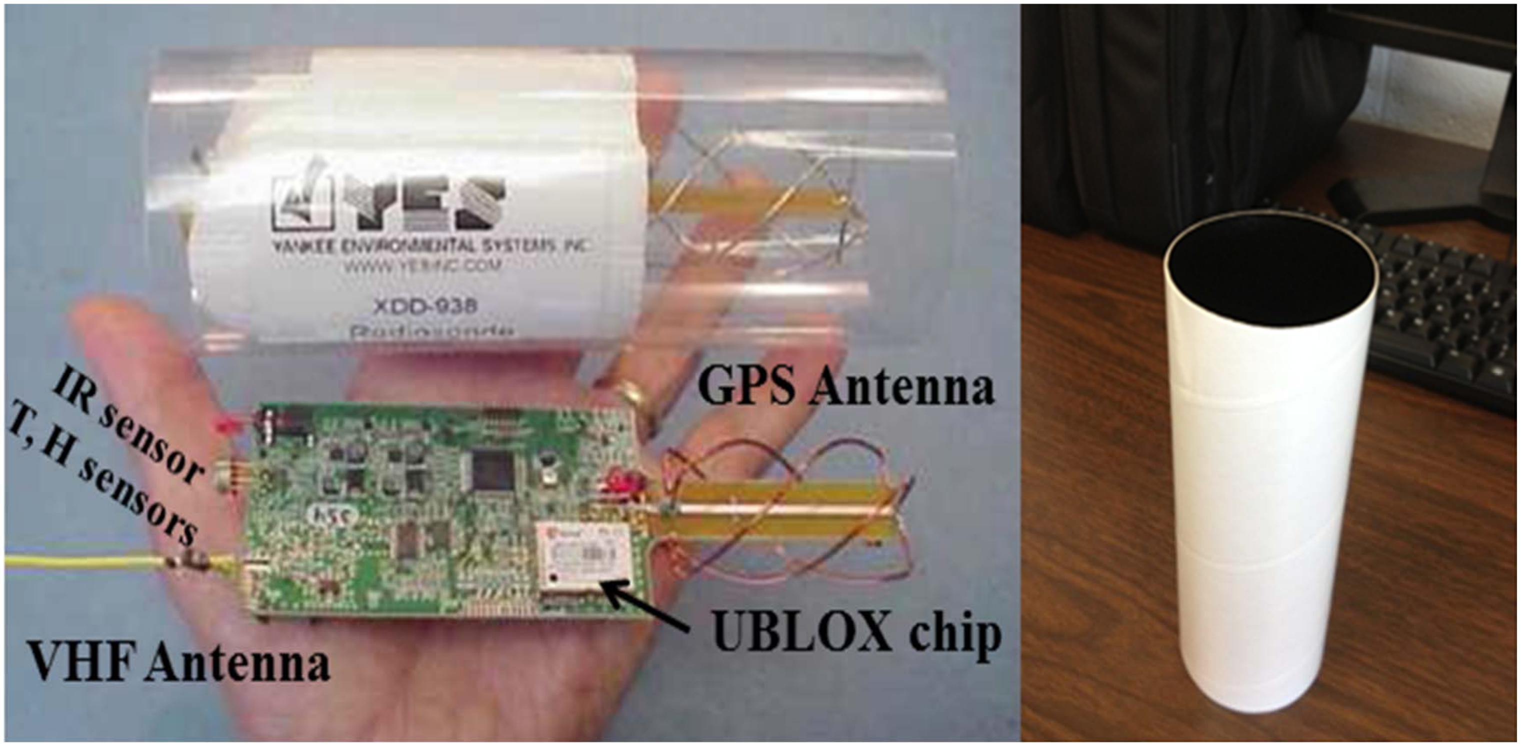
**To NASA JSC WB-57 2013**


**CIRPAS Twin Otter and Motley Crew**

## A-Alpha

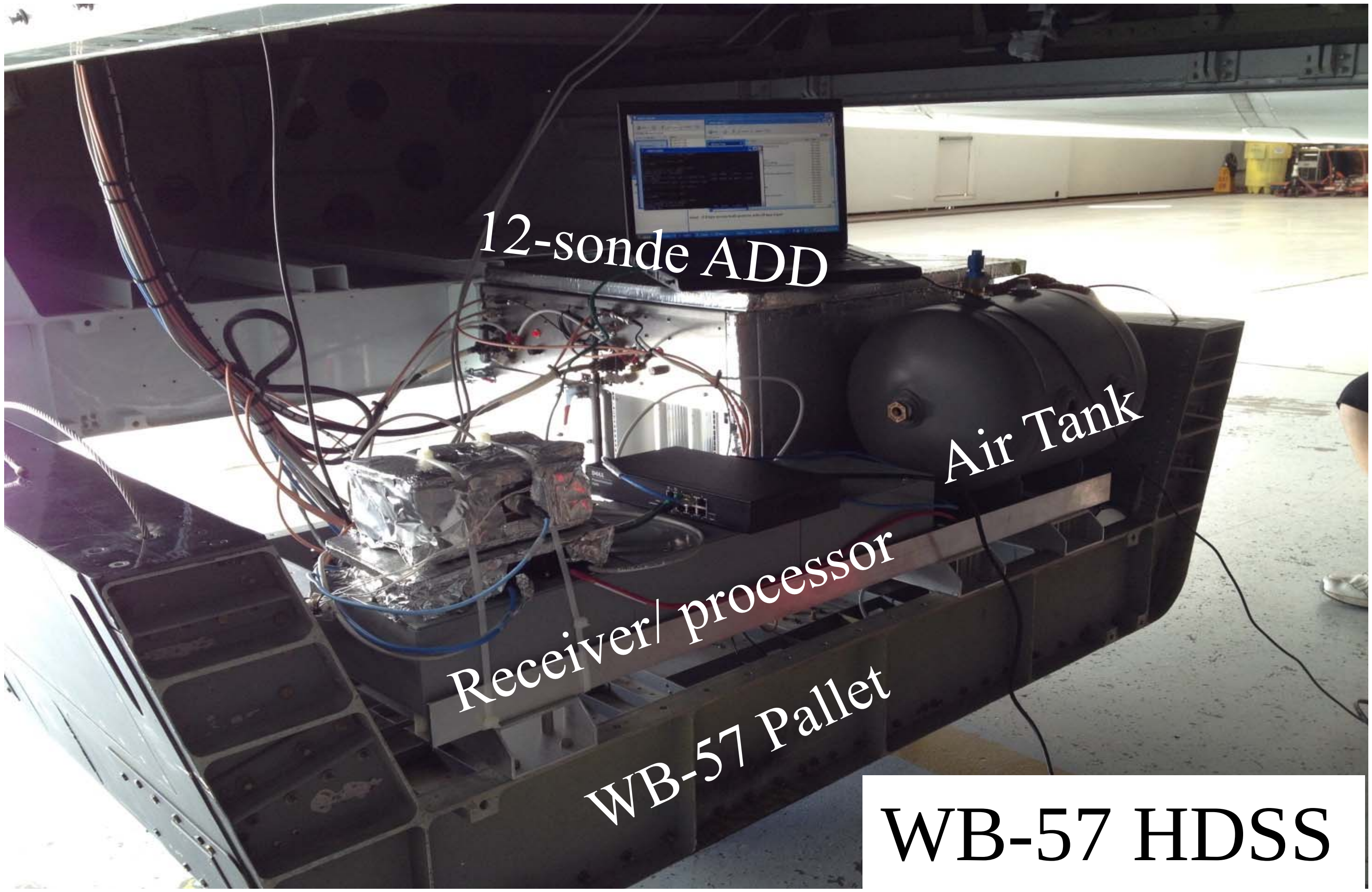
**NASA JSC WB-57 and Crew**

## Ω-OMEGA




**XDD (wt: 58g, size: 17.8H x 6.6D cm) with printed circuit board, GPS and VHF antenna and sensor location (lower-left). Modified XDD (right) with black/white cardboard cylinder to minimize radiation effects.**


**HDSS as configured on the CIRPAS Twin Otter for 24-25 June, 2011 California Coast flights. Receiver/ processor mounted on rack to the left of the door.**




**HDSS as configured on NASA WB-57. Pallet is suspended below the aircraft by cables for instrument installation. Pallet is raised and secured to fuselage for flight**

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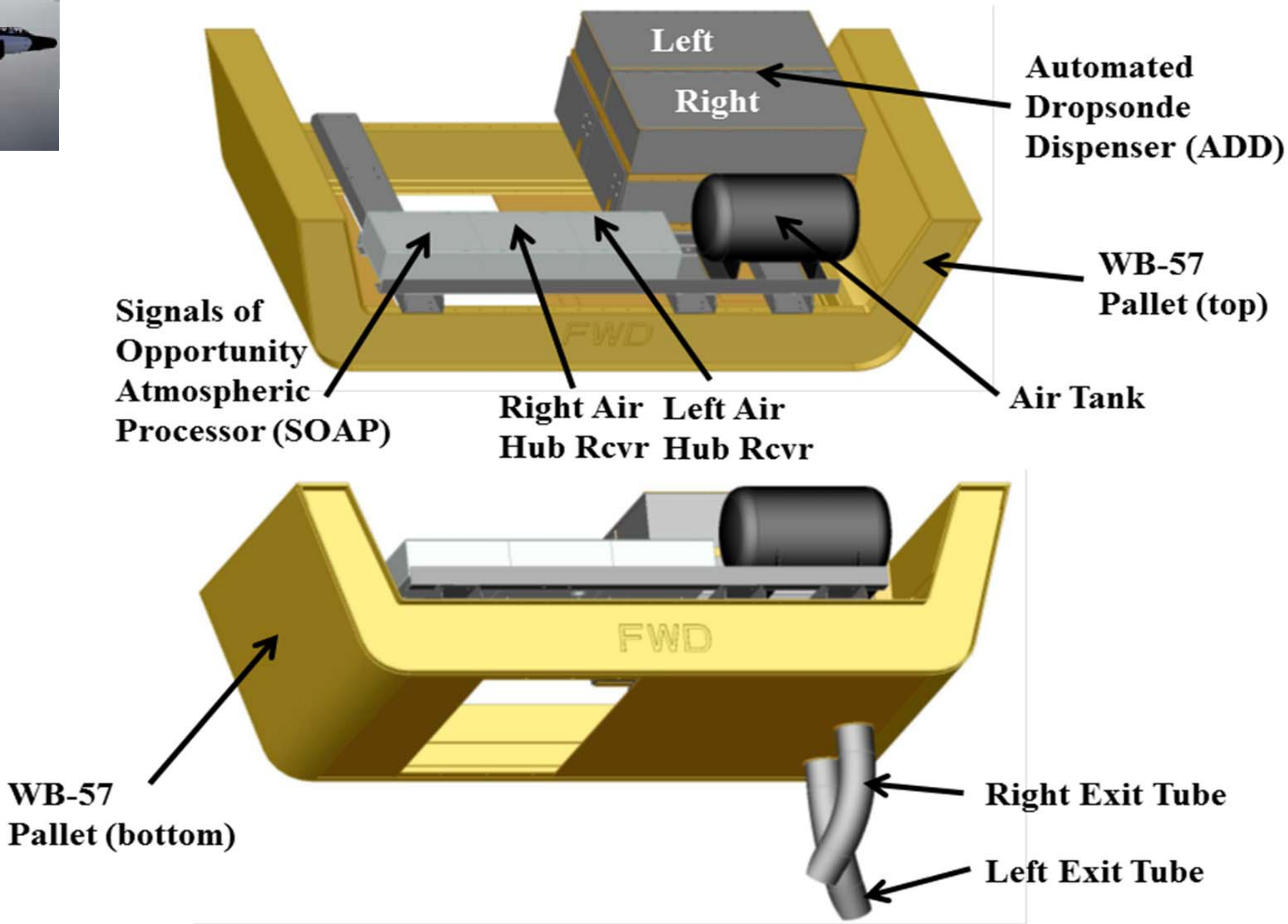
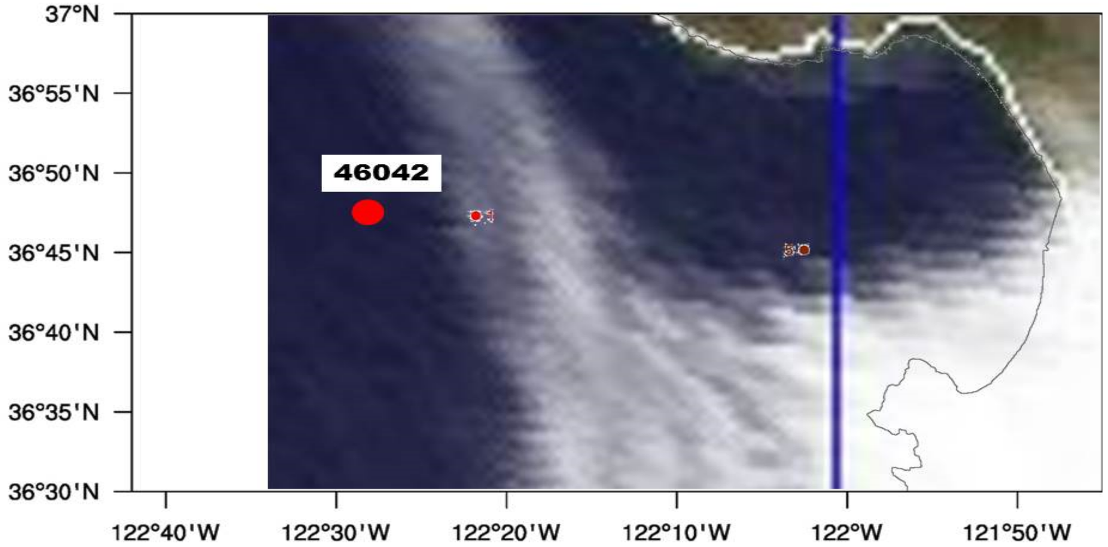
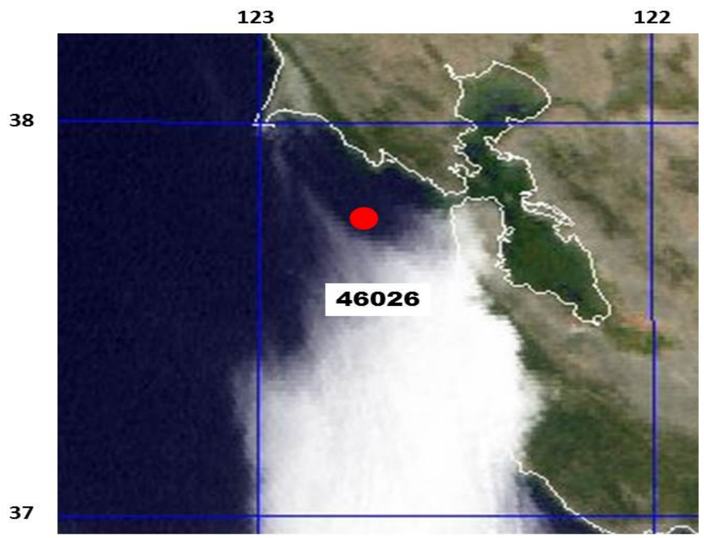



HDSS as configured for WB-57 showing top and bottom perspectives.




**Location of Twin Otter XDD deployments, spiral-descent flights and visible cloud cover over NDBC buoy 46042 off Monterey Bay on 24 June, 2011 (left) and over NDBC buoy 46026 off San Francisco Bay on 25 June, 2011 (right).**

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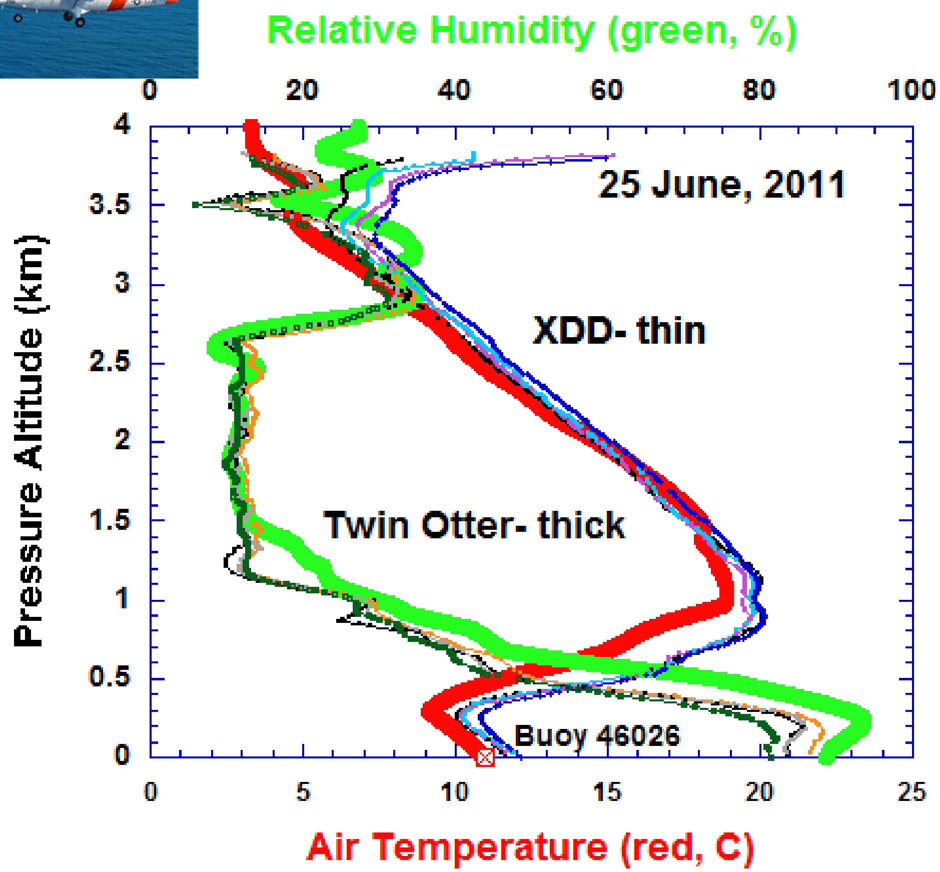
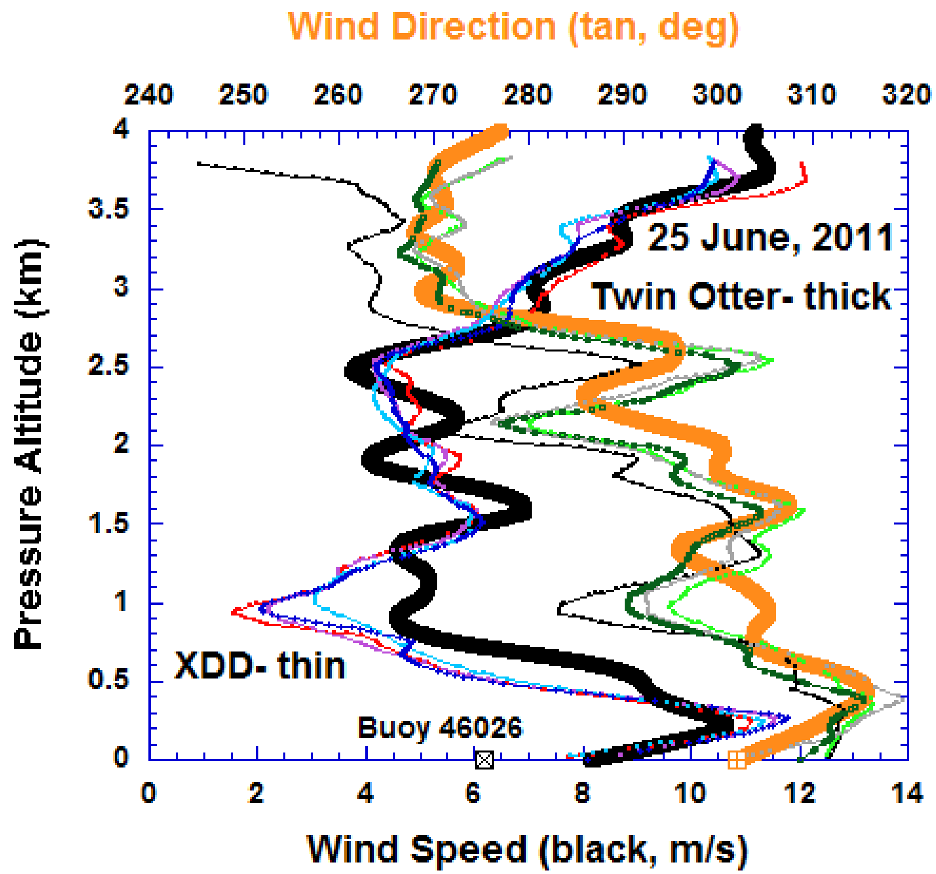
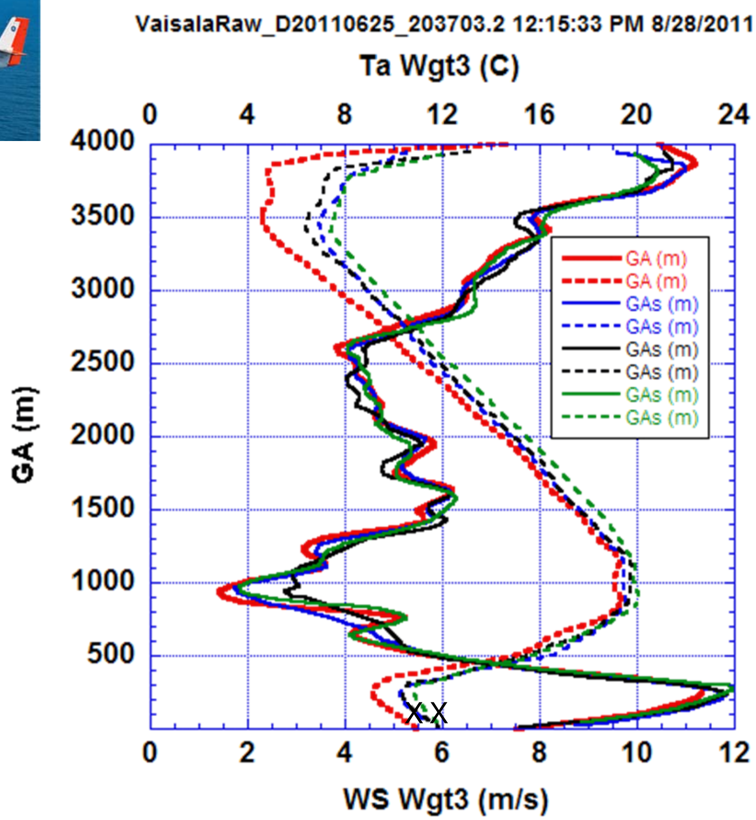
# 8-sec Interval XDD Deployments

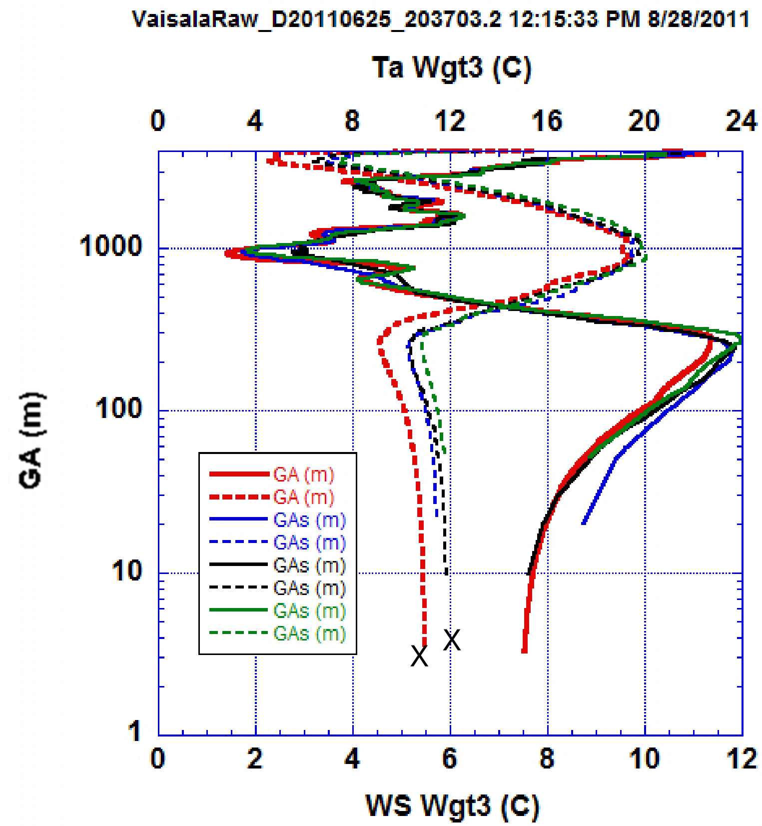


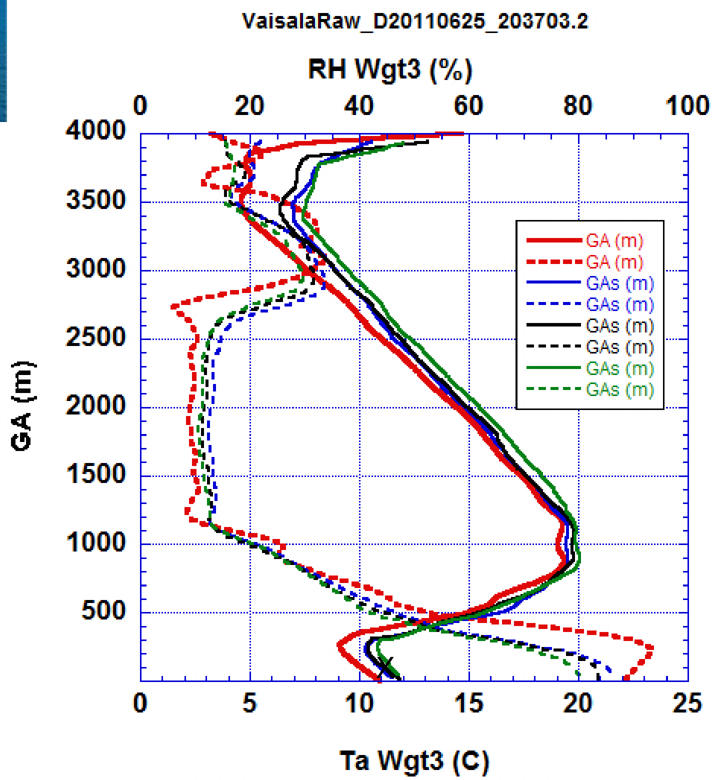

**Multiple XDD air temperature and humidity profiles are in good agreement with each other. Relative to Twin Otter, XDD obs suggest slow response time and warm, dry bias.**

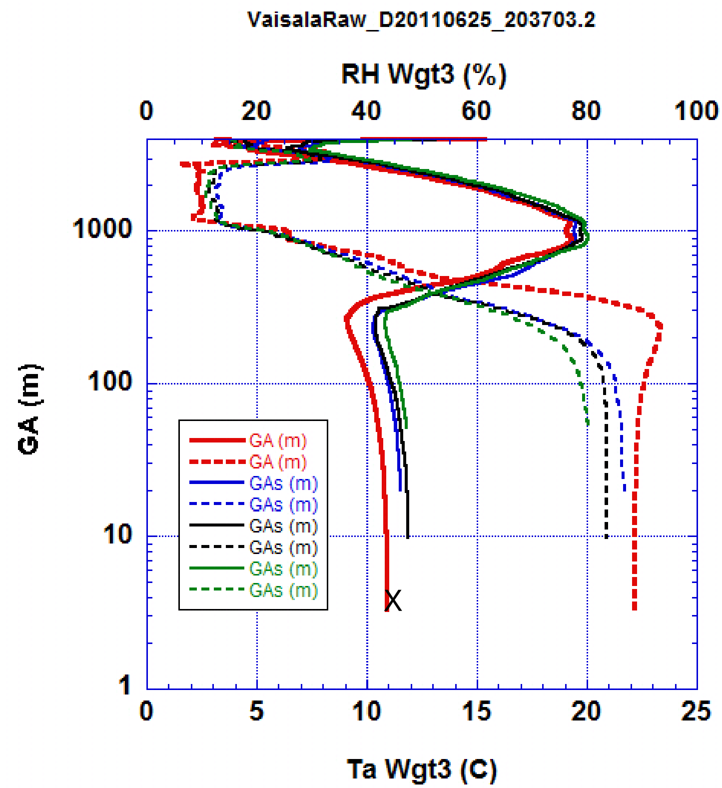
**Multiple XDD wind speed and direction profiles are in good agreement with each other. Small-scale wind fluctuations agree well with Twin Otter, especially low-level wind maximum.**



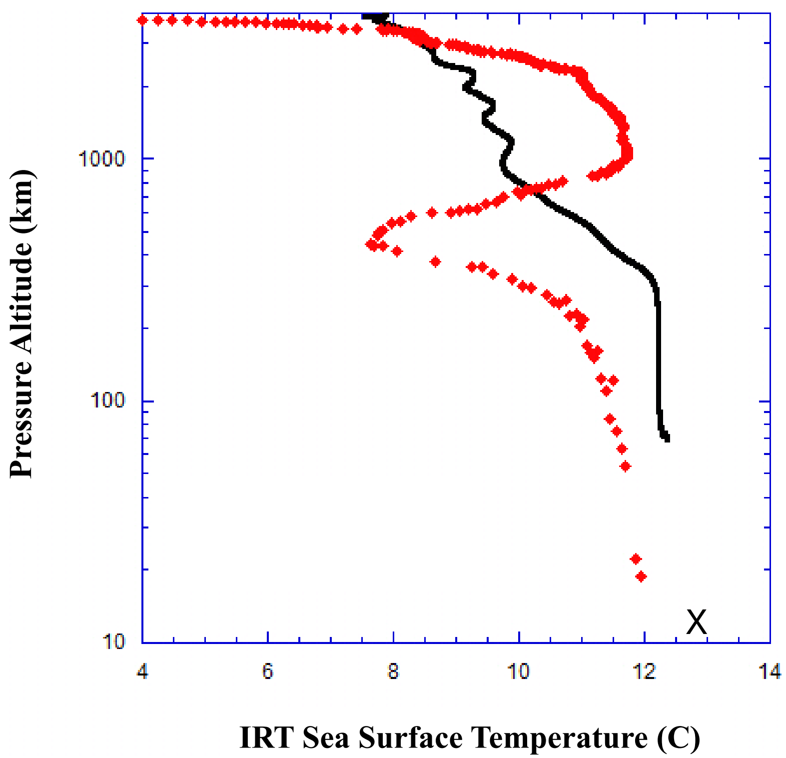



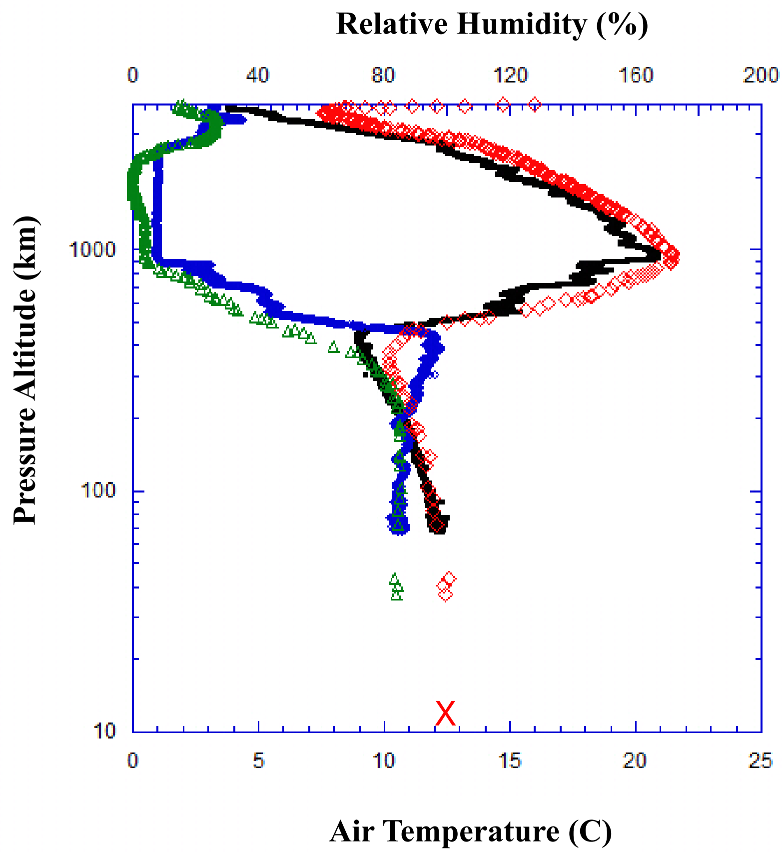

Comparison from CIRPAS Twin Otter aircraft between YES XDD and Vaisala RD94 dropsonde observations of wind speed (solid), WS and air temperature (dashed), Ta – flight 2, 25 June 2011: linear geopotential height coordinates on the left, log coordinates, emphasizing boundary layer detail, on the right. Vaisala data is in red , YES data in blue, black and green. X is data from NDBC buoy 46026.



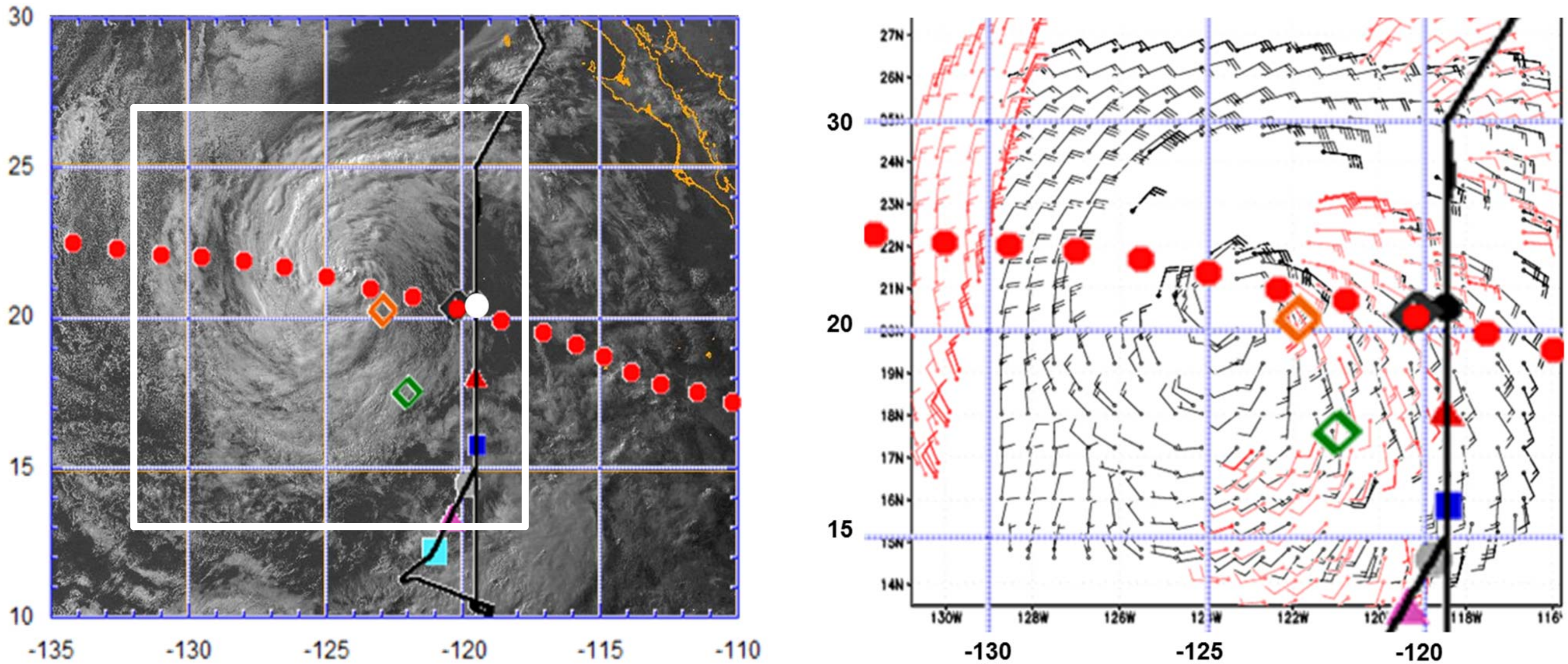




Comparison from CIRPAS Twin Otter aircraft between YES XDD and Vaisala RD94 dropsonde observations of air temperature (solid), Ta, and relative humidity (dashed), RH-flight 2, 25June 2011: linear geopotential height coordinates on the left, log coordinates, emphasizing boundary layer detail, on the right. Vaisala data is in red, YES data in blue, black and green. X is data from NDBC buoy 46026.

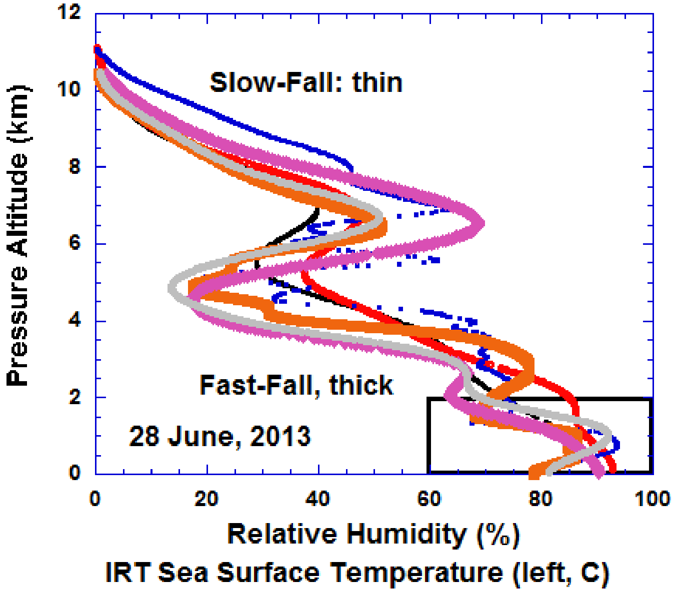


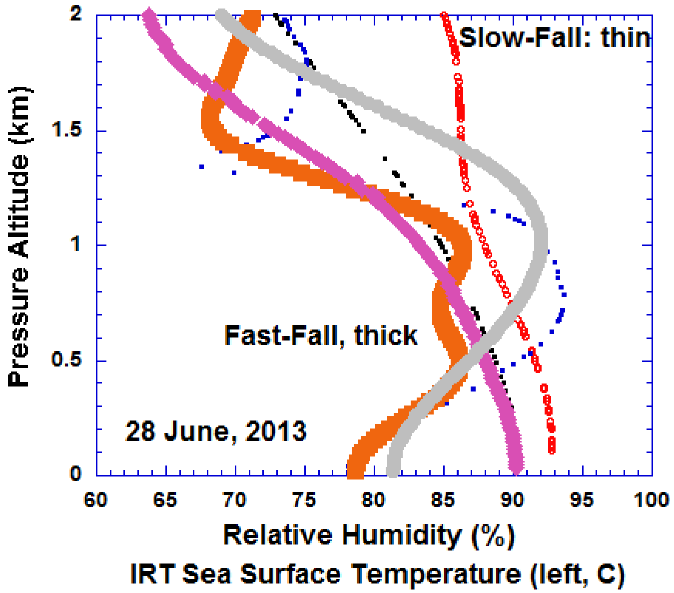



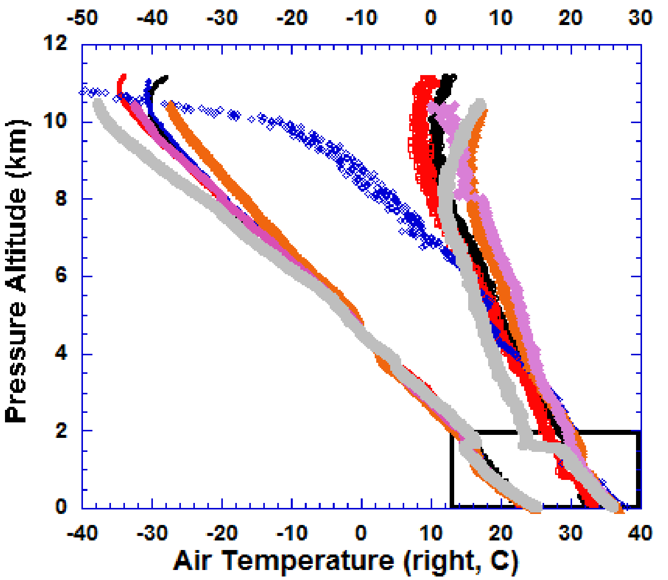

**Log height presentation of Twin Otter- observed InfRared (IR) SSTs in the marine boundary layer (red diamonds, left) compared to XDD IR SST observations and buoy SST observations at the surface (left). Marine boundary layer temperature and humidity profiles (right) from an XDD profile and Twin Otter spiral descent also agree very well. Red diamonds and green triangles are Twin Otter observations.**

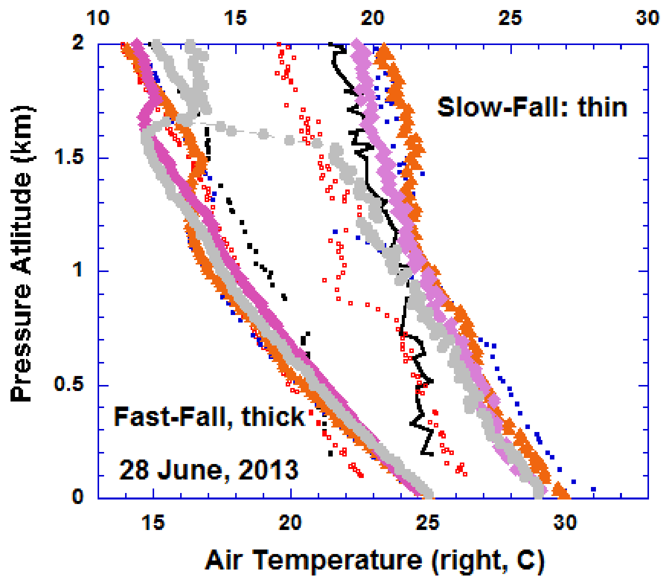



**Satlelite visible image of a decaying Hurricane Cosme in the Eastern Pacific west of Baja showing the DC-8 flight track in black with colored symbols indicating XDD launch positions as the aircraft flew from south to north with the first 3 being slow-falls and the last 3 fast-falls. ARGOS drifting buoy locations are shown by the diamonds and red dots indicate Cosme's track. White square indicates the domain of O-SCAT and ASCAT surface winds shown in the right panel.**

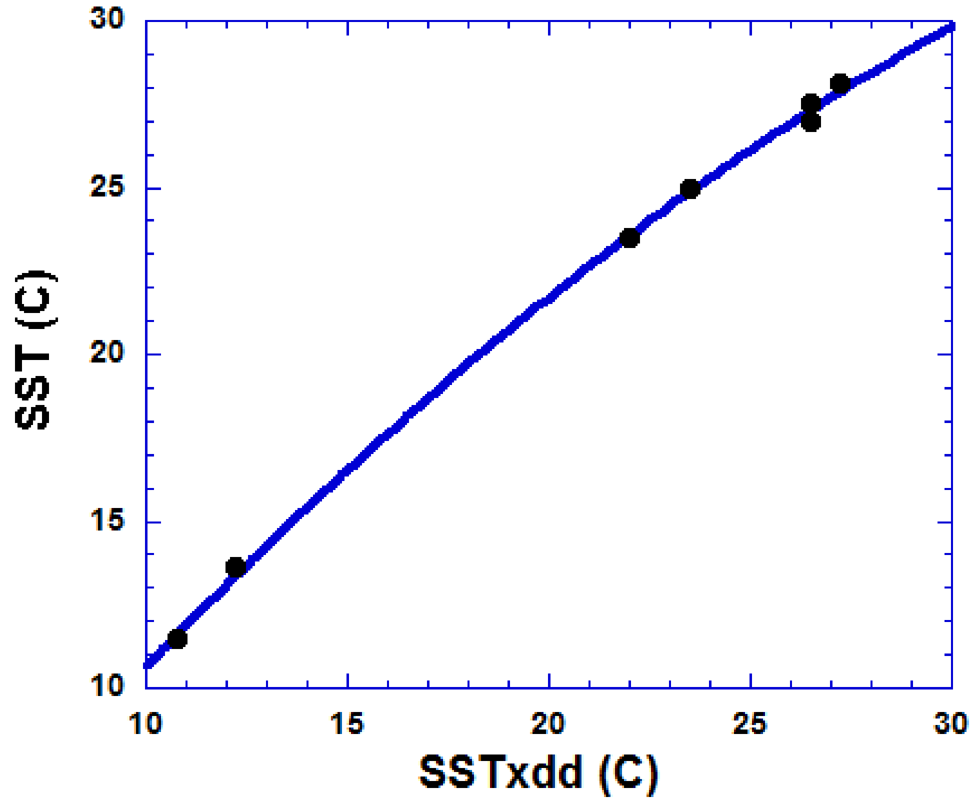


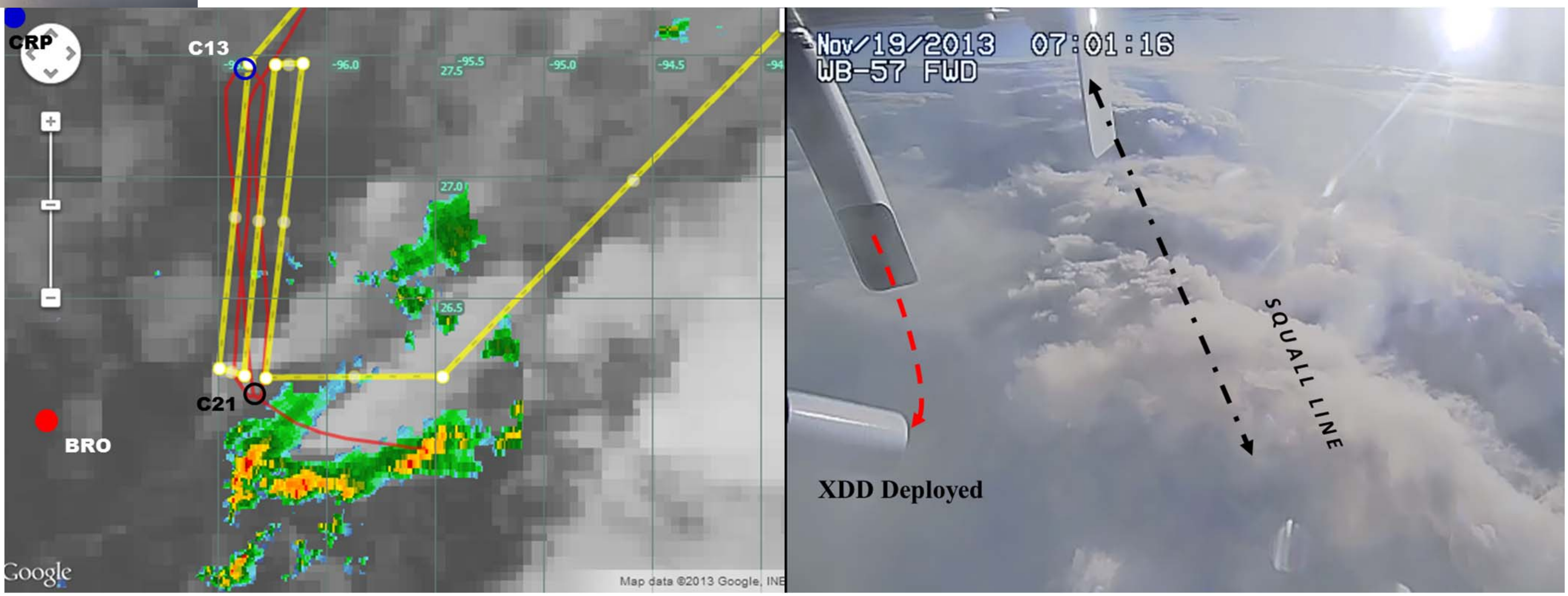




**Fast-Fall sondes tend to agree better with each other, while Slow-Fall sondes tend to be more erratic.**




**XDD SST observations compared to buoy and satellite image SSTs from Twin Otter, DC-8 and WB-57 deployments off the California coast, off Baja California and in the western Gulf of Mexico , respectively, indicates that the XDD exhibits only a small cool bias on the order of 0.5 – 1.0 C.**

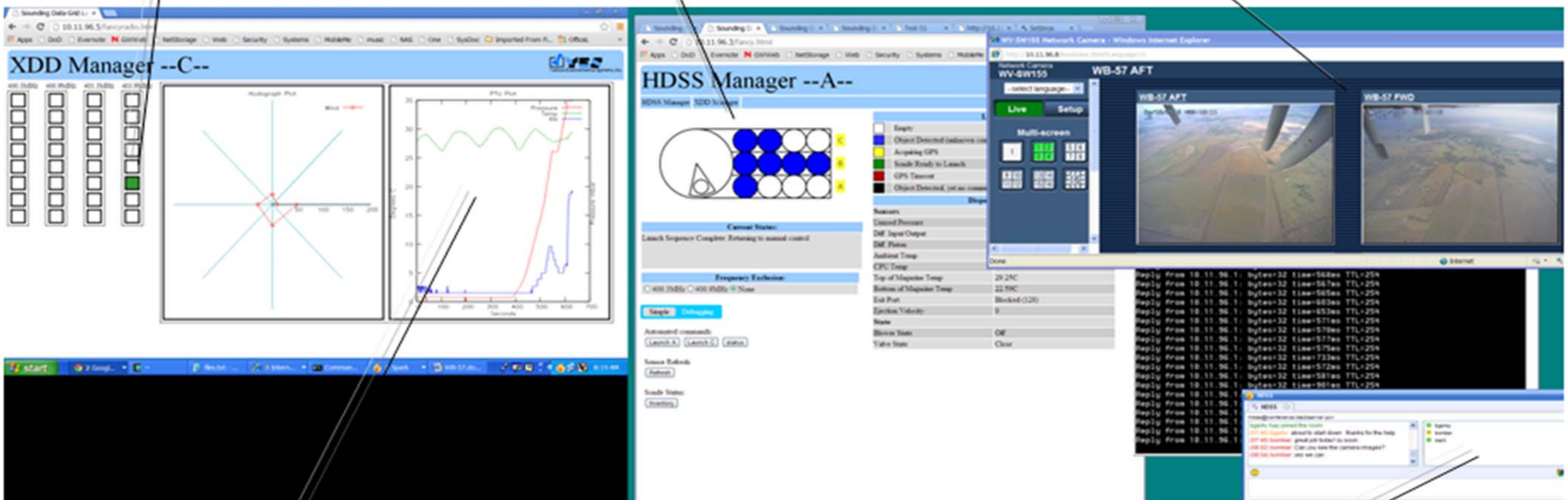



**Planned flight track in yellow (left panel) and actual flight track in red showing race-track pattern between Brownsville (BRO) and Corpus Christi radiosonde stations and about 80 km offshore. Flight track included a segment over and along a pre-frontal squall line shown by the BRO radar and IR satellite image (1-hr earlier than radar image). Forward-facing, belly camera on the WB-57 shows the squall line spreading out ahead of the aircraft while deploying an XDD into the weather. The dashed-dot line In the image in the right panel indicates the orientation of the squall line seen in the radar image in the left panel.**

XDD telemetry active

ADD Control showing magazine status

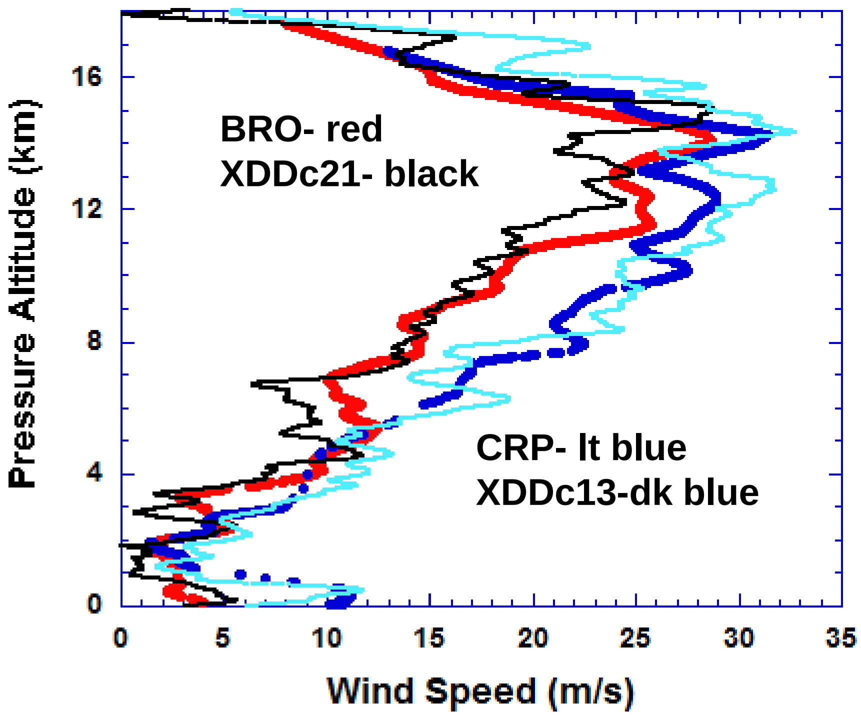
Aft and Forward real time camera views

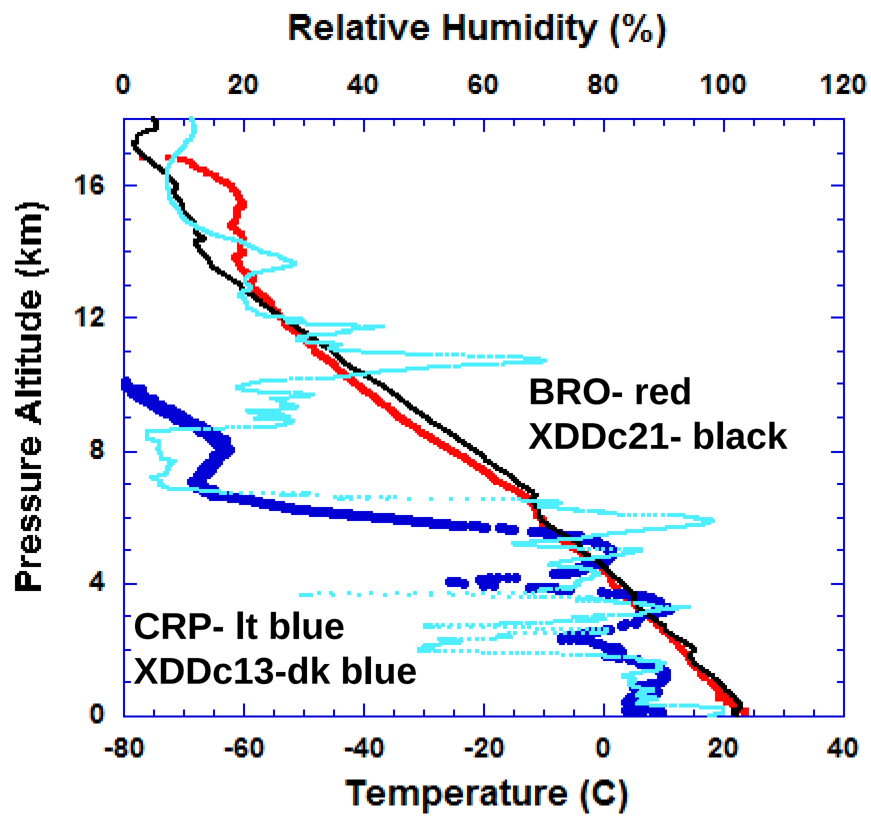



Real Time Raw PTU data

Chat window to WB-57 backseater; ping satcom

HDSS display monitor




**Excellent XDD wind speed comparisons with NWS radiosonde winds at Brownsville and Corpus Christi showing excellent resolution of upper subtropical jet structure along the frontal zone advancing over the Gulf of Mexico, as well as details of low-level jet structure behind the frontal zone. Temperature measurements show excellent comparisons, while humidities fail above 8 km, dropping to 0% while radiosonde observes approximately 20%.**

# Summary

- XDD’s measure atmospheric profiles of pressure, temperature, relative humidity and wind speed/ direction in good agreement with research aircraft spiral descents, conventional RD-94 drospondes, National Weather Service radiosondes and NDBC moored buoys.
- Especially good wind comparisons were observed at relatively fine spacial scale.
- Humidity and temperature measurements suffer a 5% dry bias and 1 deg cool bias with slower response than aircraft and RD-94s. Humidity fails above 8 km when air temperatures are below -30C, similar to RD-94 humidity’s which fail above 12 km when air temperatures drop below -40C.
- Multiple sonde launches at 5- to 8-sec intervals were demonstrated from Twin Otter and up to 10 sondes in the air simultaneously from the WB-57.
- XDD’s measure IR-derived Sea Surface Temperature (SST) in agreement with NDBC moored buoy SSTs,  ARGOS drifting buoy SSTs and satellite-derived SSTs with only a cool bias of 0.5-1.0 C.
- Fast-Fall XDDs in ballistic mode provide more accurate and less noisy observations than slow-fall XDDs in spiral-dive mode.
- Sondes function equally well in unpressurized (Twin Otter, WB-57) and pressurized (DC-8) environments from altitudes of 4-, 12- and 20-km.

# Future Plans

- Improve thermodynamic sensor performance.
- Demonstrate multiple sonde deployments for larger sonde arrays on order of 15-20 sondes
- Improve HDSS real time performance from WB-57 air frame.
- Migrate HDSS to other airframes such as NASA Global Hawk and Air Force WC-130J for potential use in operational reconnaissance.