HFIP Observations Team

Sim Aberson (NOAA/OAR) - co-lead
Nick Shay (UM/RSMAS - co-lead
Jim McFadden (NOAA/OMAO)
Paul Chang (NOAA/NESDIS)
Chris Fairall (NOAA/OAR)
Naomi Surgi (NOAA/NWS)
Mark DeMaria (NOAA/NESDIS)
Isaac Ginis (NOAA/OAR and URI)
Peter Black (SAIC at NRL)

08 November, 2009

Tasks

1. Conduct NOAA Hurricane Field Program with 700 flight h, 1500 dropwindsondes, 500 AXBT, and additional ocean observations in cooperation with MMS and other groups - AOC, AOML, UM/RSMAS

2. Work toward installation of Doppler radar on G-IV - AOC, AOML

3. Transmit new data types from P3s (Doppler, AXBT, AWRAP, 1-Hz flight-level, WSRA), including software development - AOML, EMC, NESDIS

4. Upgrade airborne radar system from RVP-5 to RVP-8 on one P-3 - AOC, AOML

5. Develop and populate a data warehouse for OSEs and verification - AOML, ESRL

6. Conduct OSEs with current data types - AOML

7. Attempt to obtain near-surface observations with low-altitude long-endurance aircraft (LALE) - AOML

8. Prepare to install instruments to obtain sea-spray and GPS surface data from NOAA P-3s - AOC, ESRL

9. Prepare to obtain in situ microphysical (sea spray and turbulence) measurements - ESRL

10. Increase bandwidth from NOAA aircraft for greater amounts of data transmission - AOC

11. Replace AXBT receivers on NOAA P3s - AOC, UM/RSMAS

12. Define data requirements from operational forecast and model centers - AOML, EMC

13. Develop and implement cross-platform dropwindsonde processing software for inner-core and environmental observations - AOML, NCAR (JHT)

1. Conduct NOAA Hurricane Field Program with 700 flight h, 1500 dropwindsondes, 500 AXBT, and additional ocean observations in cooperation with MMS and other groups - AOC, AOML, UM/RSMAS

1. Flight Hour and Expendables: $1,507,391

100/101.5 flight hours purchased/flown

$618.5K for dropsondes resulted in 900 sondes at combined old and new prices.

$150K for AXBT receivers deferred to FY10.

$290K for AXBT/AXCP and AXCTDs - 60 AXCPs for $98,312 ordered and received.

One AXBT Gulf survey mission flown in FY09.

FY09 totals were 67 flights, 372.2 h

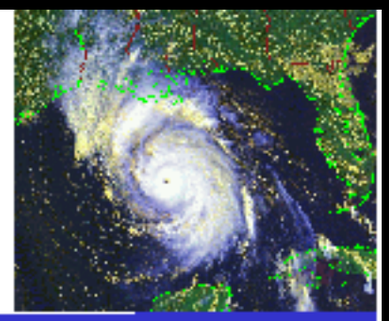
Summary

Date	A/C	T/O time	Flt ID	Mission	LPS	Radar	Dropsonde	Remarks	Summary
12 Aug	N43RF	?	090812I1	Ferry					
13 Aug	N49RF	?	090813N1	Ferry					
14 Aug	N49RF	20Z	090814N1	Salex/Ana	Dunion		Sellwood		N
15 Aug	N43RF	20Z	Canceled					Fuel line	
15 Aug	N49RF	20Z	090815N1	Salex/Ana	Aberson		Ananne		N
16 Aug	N43RF	08Z	Canceled					Fuel line	
16 Aug	N49RF	08Z	Canceled					Useless	
16 Aug	N43RF	20Z	090816I1	Ana	Black, M.	Black, B.	Annane		Y
18 Aug	N43RF	08Z	Canceled					Engine	
18 Aug	N49RF	08Z	090818N1	Bill	Dunion				N
18 Aug	N43RF	20Z	090818I1	Bill	Cione	Gamache	Annane		Y
18 Aug	N49RF	20Z	090818N2	Bill	Black, M.		Black, B.		Y
19 Aug	N43RF	08Z	090819I1	Bill	Rogers	Murillo	Sellwood		N
19 Aug	N49RF	08Z	090819N1	Bill	Dunion				N
19 Aug	N43RF	20Z	090819I2	Bill	Cione	Gamache	Annane		Y
19 Aug	N49RF	20Z	090819N2	Bill	Black, M.		Black, B.		N
20 Aug	N43RF	08Z	090820I1	Bill	Rogers	Murillo	Sellwood		N
20 Aug	N49RF	08Z	090820N1	Bill	Dunion				N
20 Aug	N43RF	20Z	090820I2	Bill	Black, M.	Gamache	Annane		Y
20 Aug	N49RF	1730Z	090820N2	Bill/NHC					
21 Aug	N49RF	1730Z	090821N1	Bill/NHC					

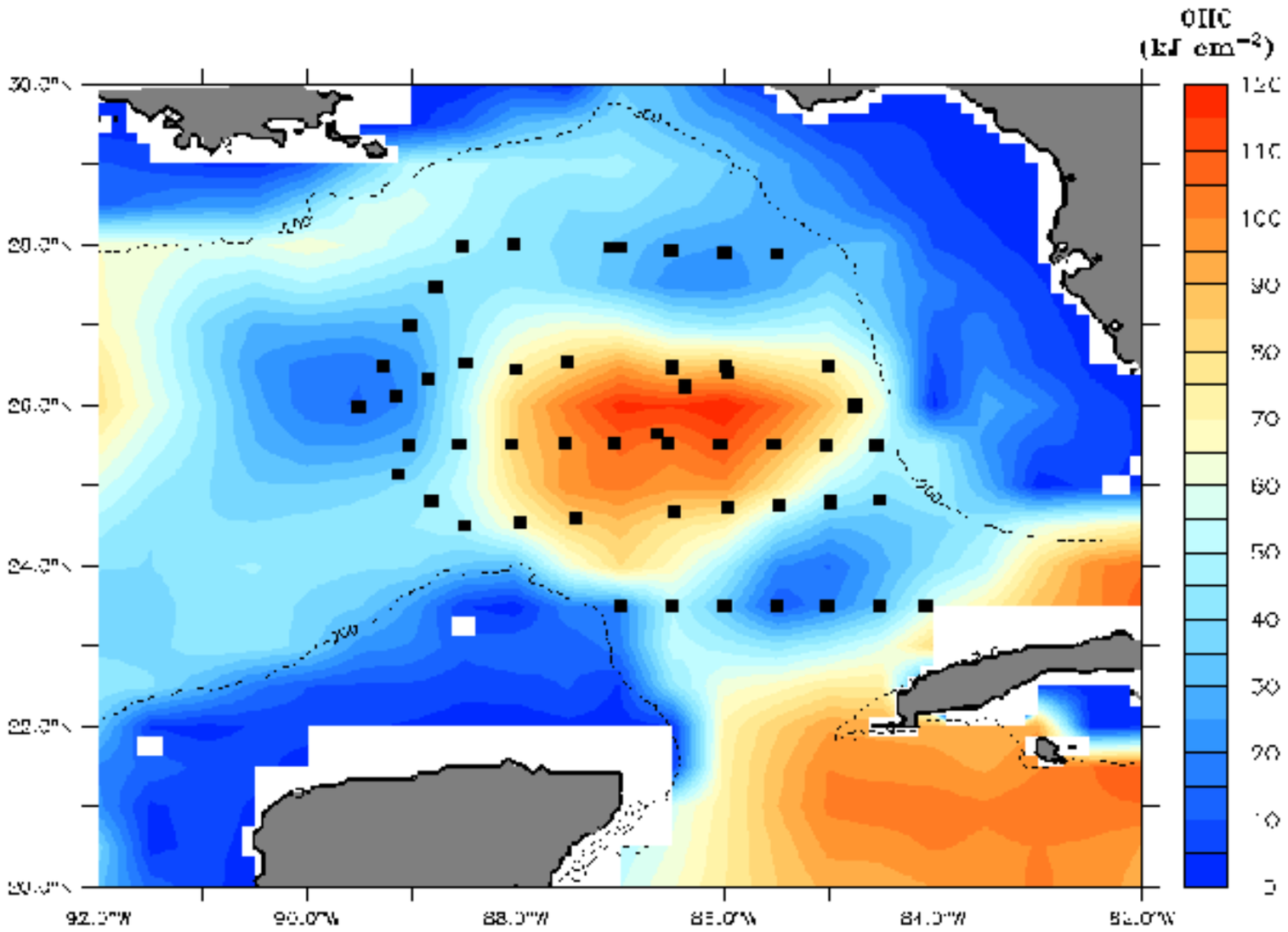
Summary

Flight ID	Mission	T/O	LPS
090825N1	Danny	20Z	Dunion
090825I1	Danny/cancelled	--	--
090826I1	Danny	08Z	Aberson
090826N1	Danny	1730Z	NHC
090826I2	Danny	20Z	Rogers
090827I1	Danny	08Z	Leighton
090827N1	Danny	1730Z	NHC
090827I2	Danny	20Z	Rogers
090828I1	Danny	08Z	Leighton
090920I1	Coyote Test	13Z	Cione
090821I1	SFMR Rain	15Z	Uhlhorn

Pre Hurricane Season Experiment July 09 and Summary of Procurements with HFIP $$.

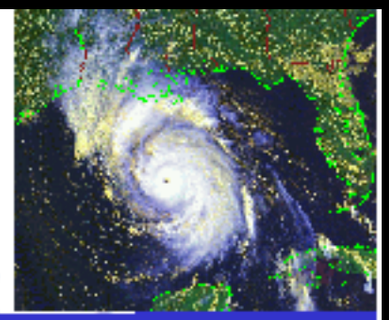


- 60 AXBTs were deployed in mesoscale features.
- Success rate: 91% .
- New RX units (Mark 10a/21a) will be ordered in new fiscal year (Lockheed Martin)
- Delivery of Channel 12 AXCP (LM) expected.
- AXBT order (800- m) either through Ultra Electronics or Sparton both in Canada (Working with J. Roles at AOC) will be ordered in new FY.
- No engineer support for RSMAS.



Oceanic Heat Content from NHC/RSMAS Altimetry
Analysis : 16 July 2009

NOAA Aircraft profiling over MMS Moorings Deployed for Loop Current Dynamics Study During



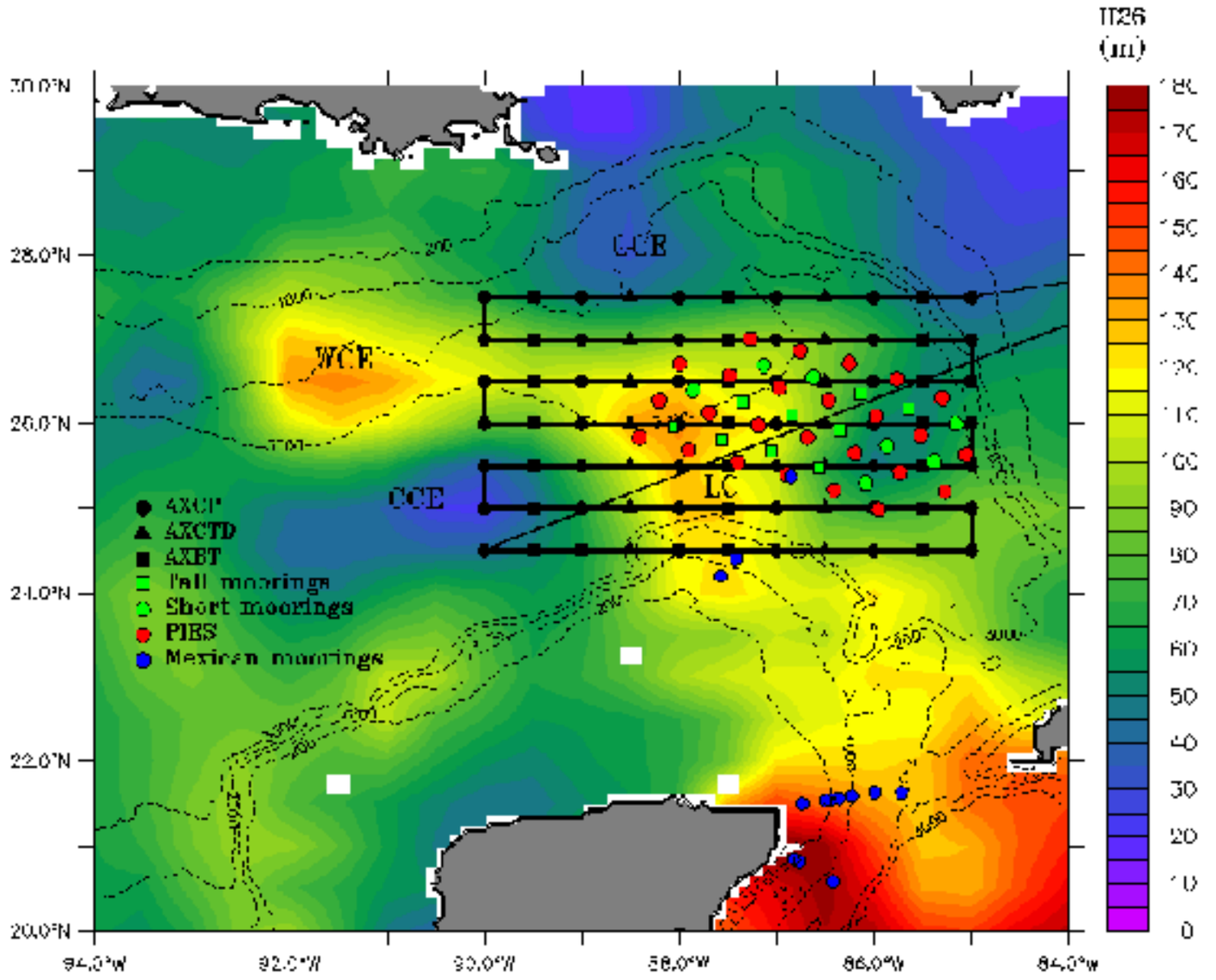
Goal: To observe and understand the LC response to the near-surface TC wind structure .

Specific objectives are:

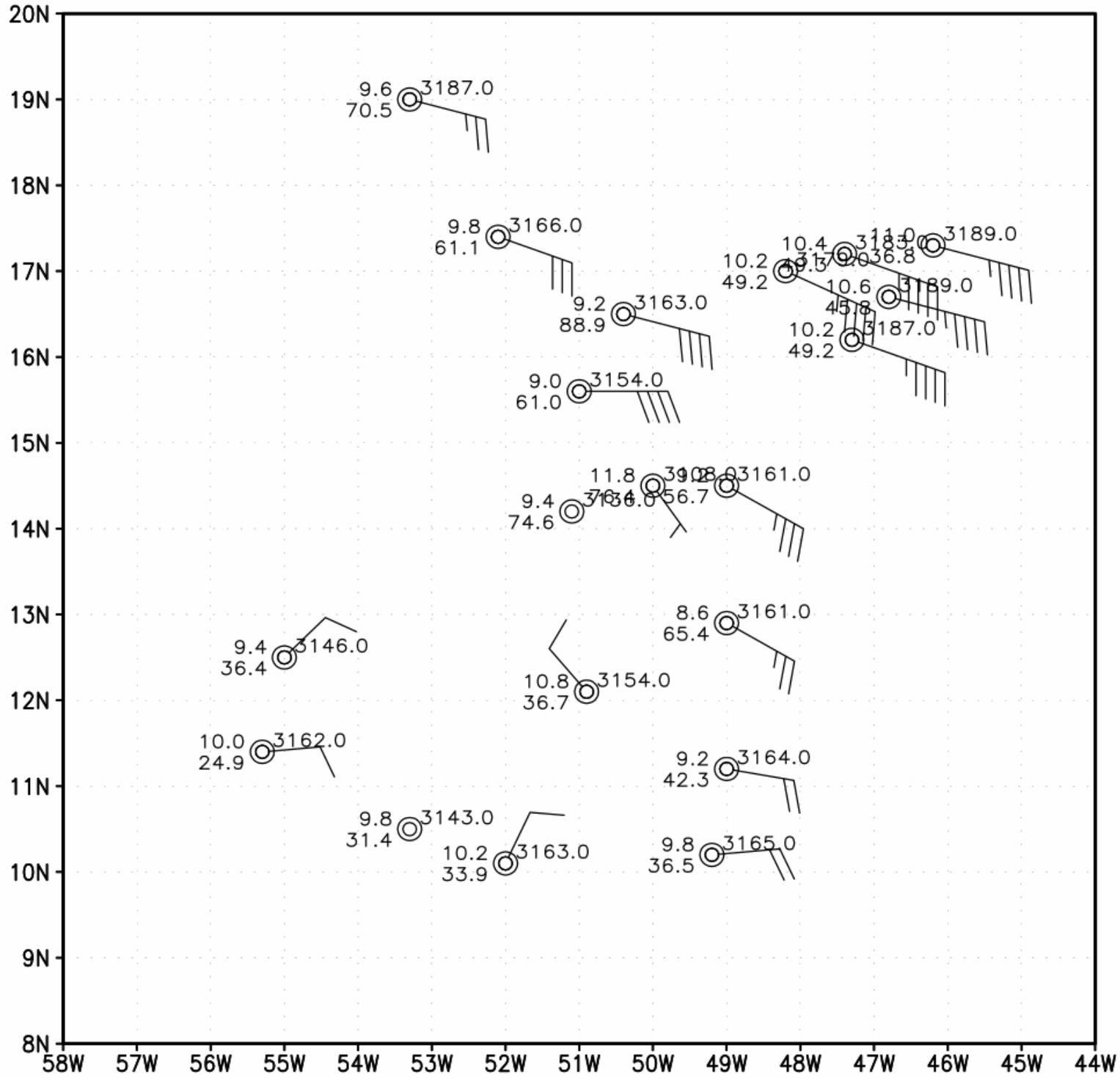
1. Determine the oceanic response of the LC to TC forcing; and,

2. Influence of the LC response on the TC's boundary layer and Intensity change.

In situ measurements will be used to improve our understanding of the eddy shedding process in models such as HYCOM.



080914n 700 mb

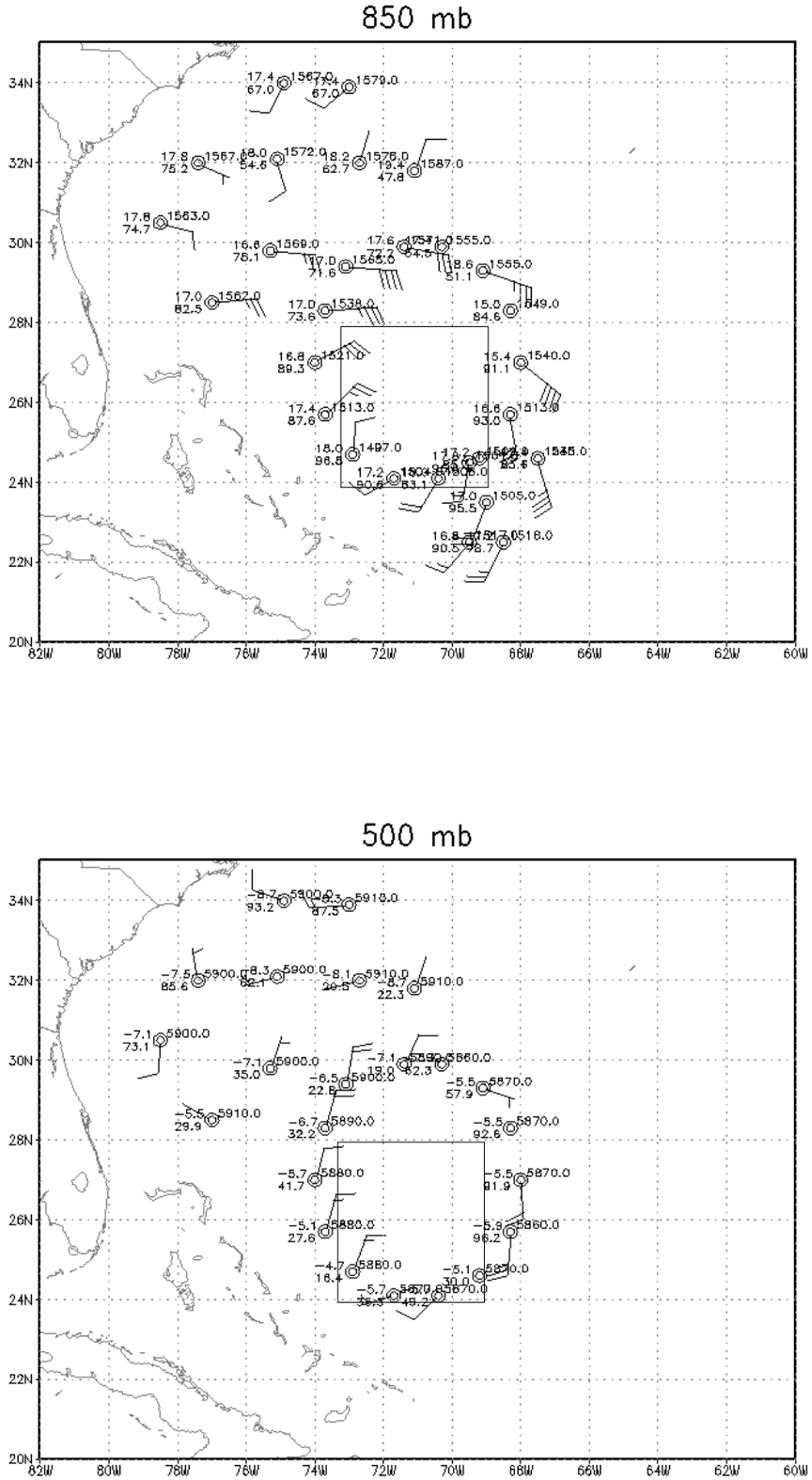


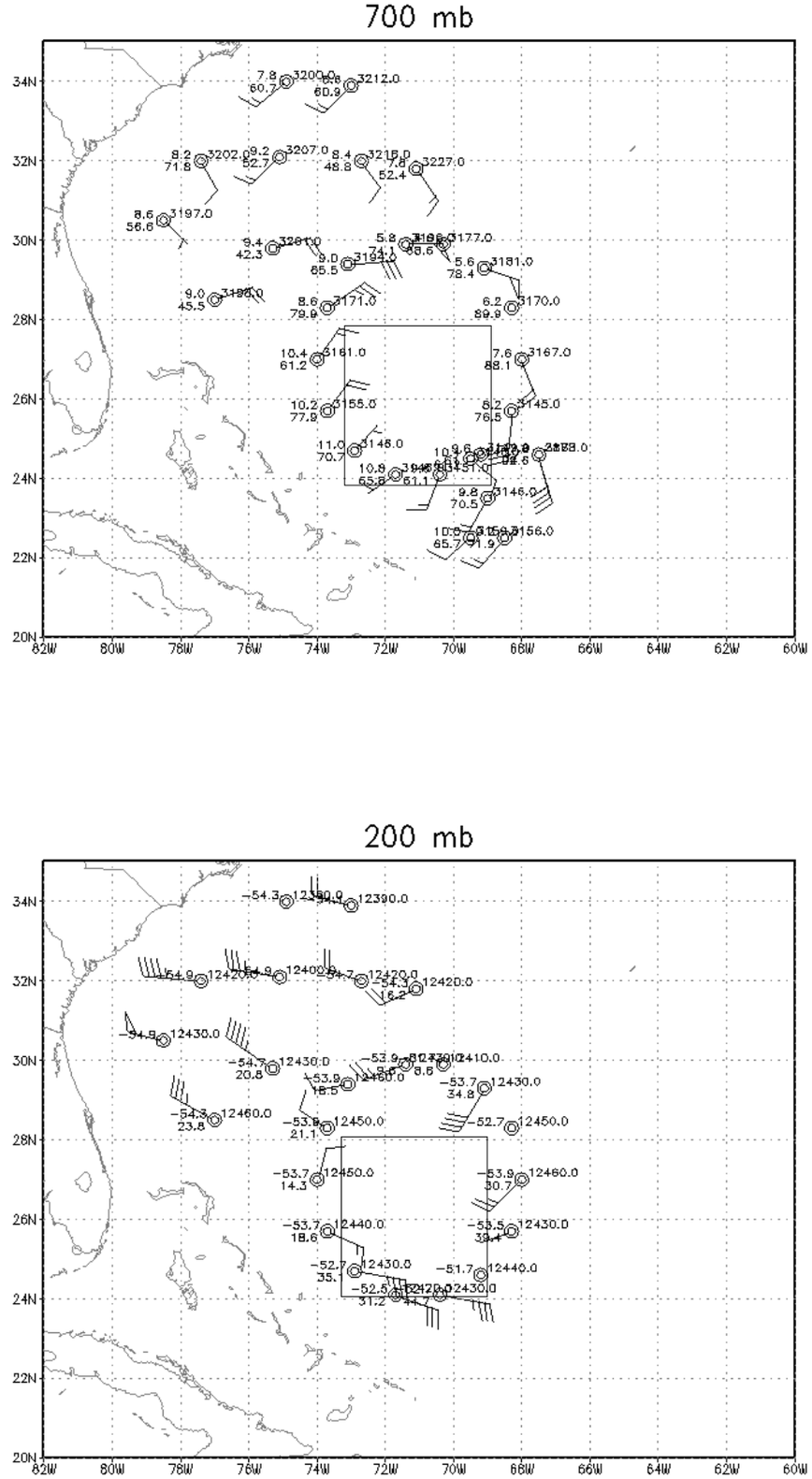
GrADS: COLA/IGES

2009-09-02-16:18

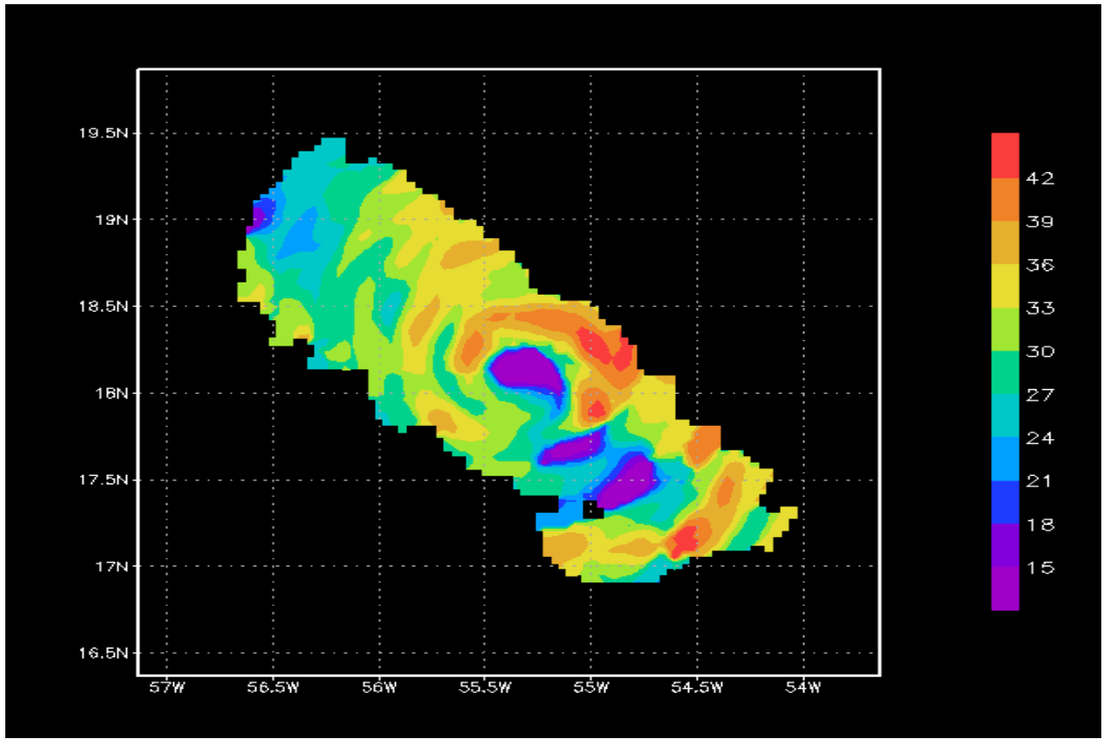
090826N1 Environmental-scale observations

centered on 00 UTC Aug. 27



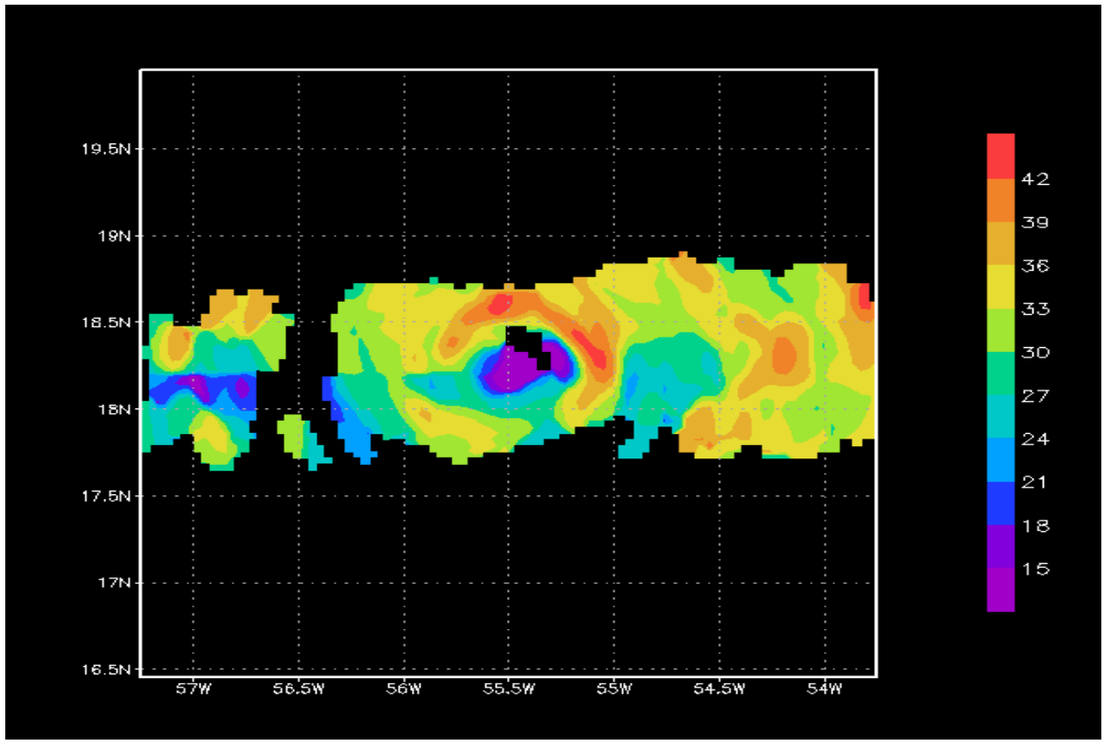


1039Z Aug 19



(a)

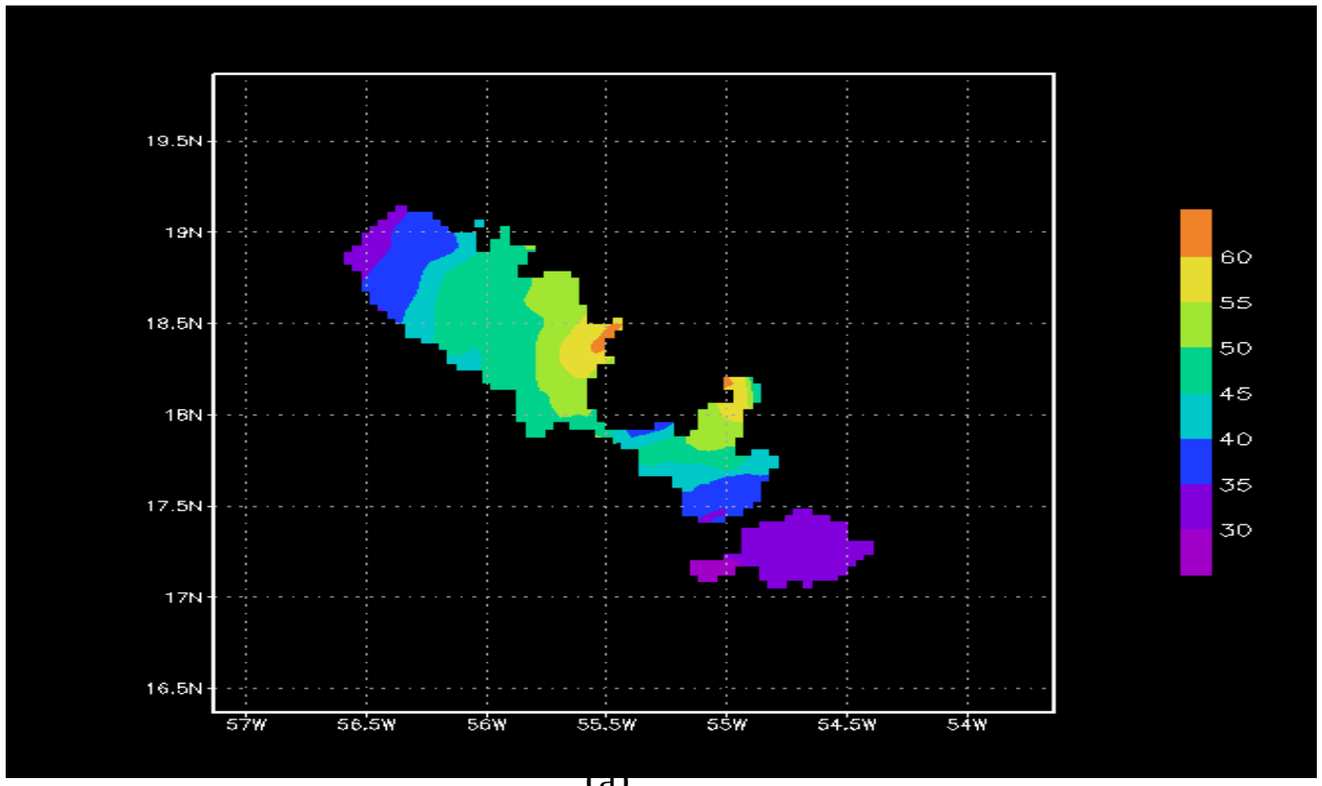
1141Z Aug 19



(b)

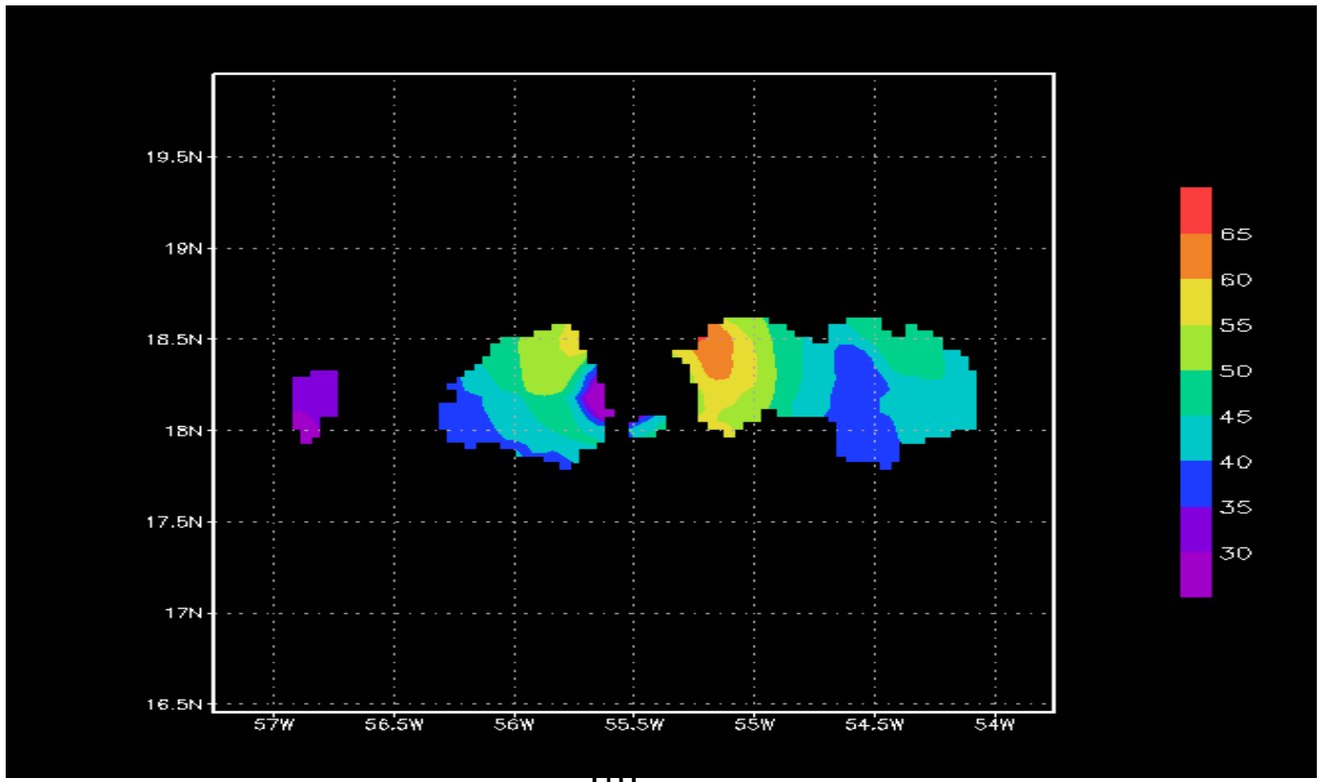
Figure 4. Reflectivity (dBZ) measured from tail Doppler radar at 3 km altitude for radar legs centered at (a) 1039 UTC and (b) 1141 UTC August 19.

1039Z Aug 19



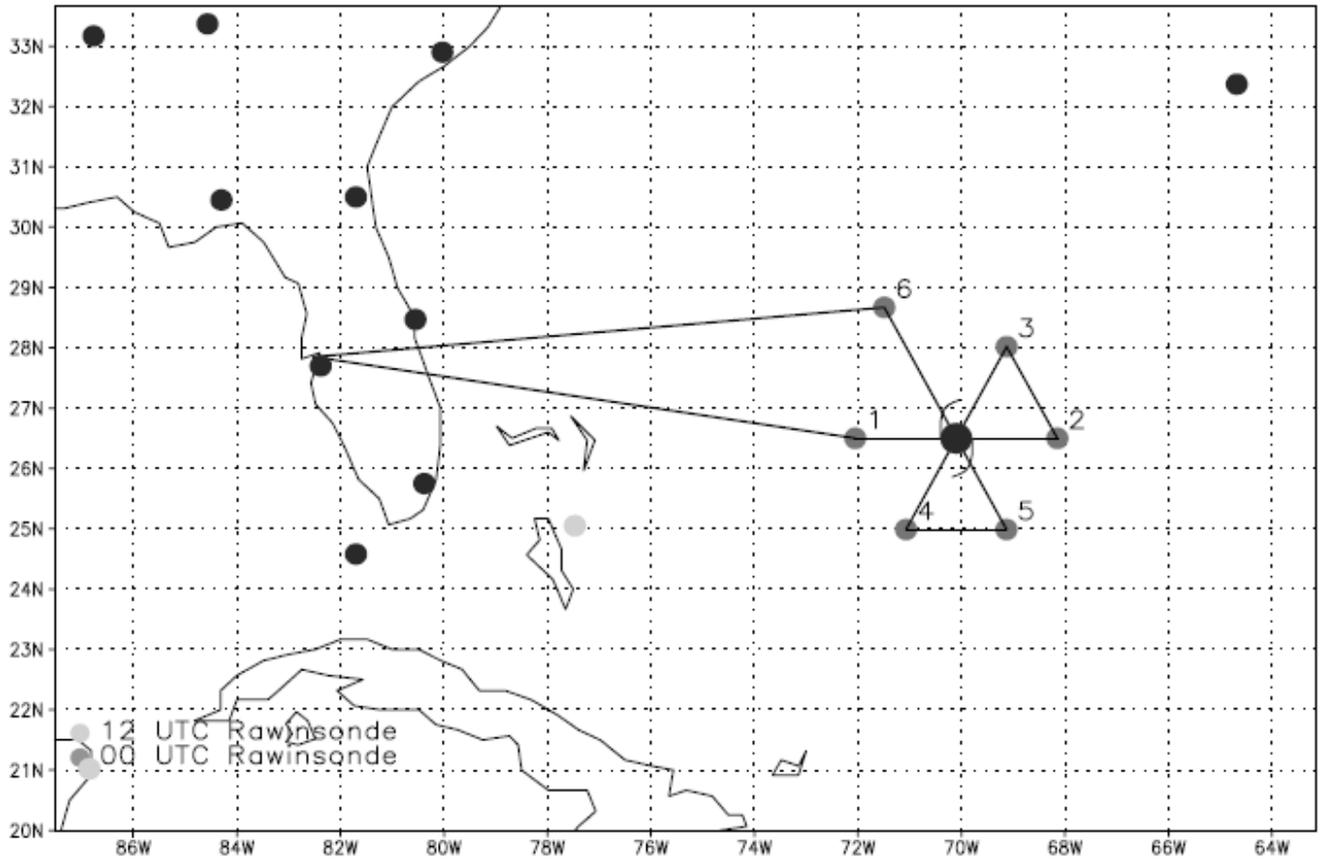
(a)

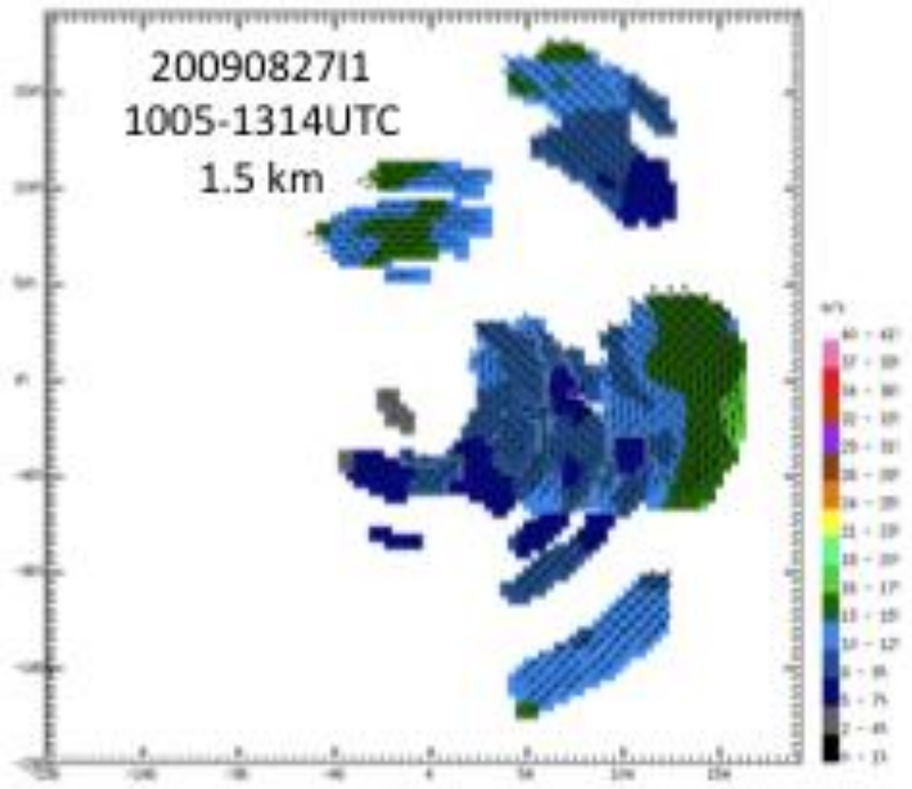
1141Z Aug 19

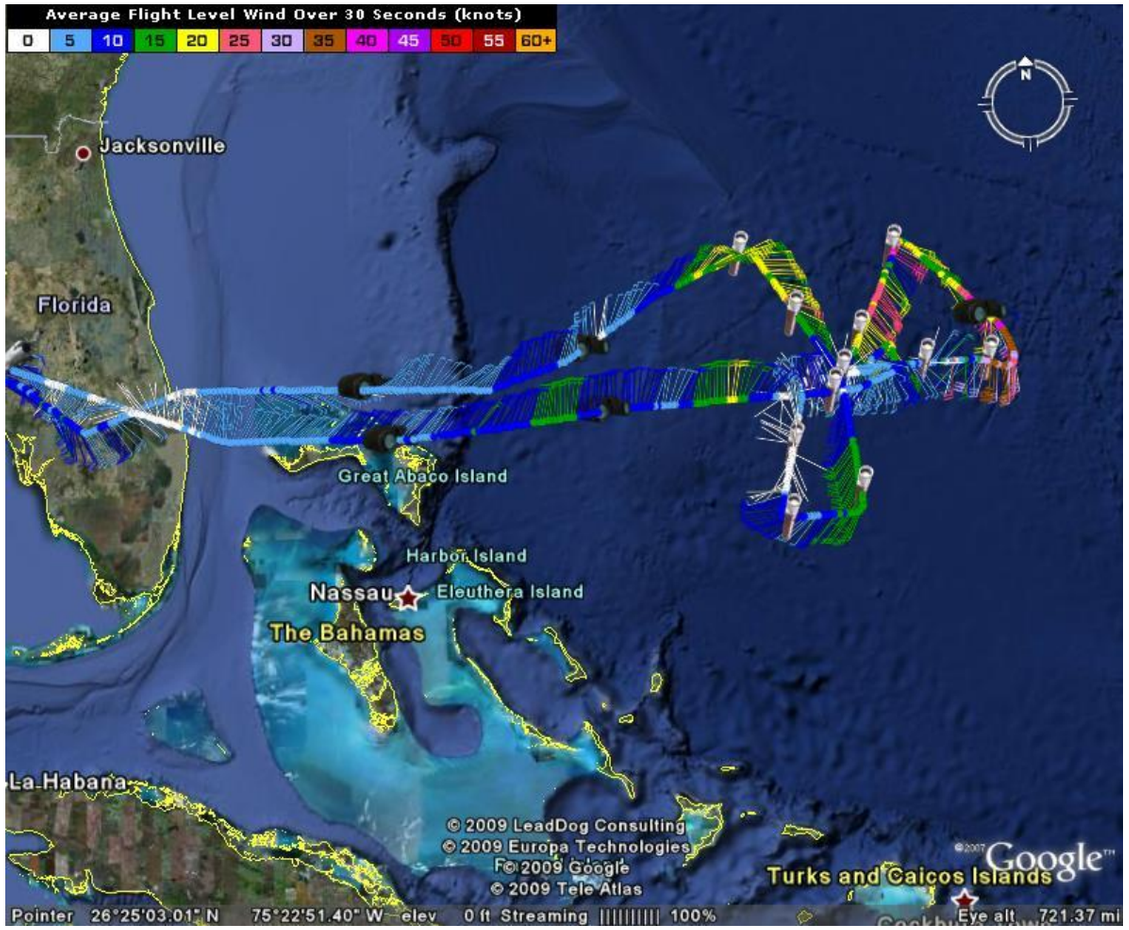


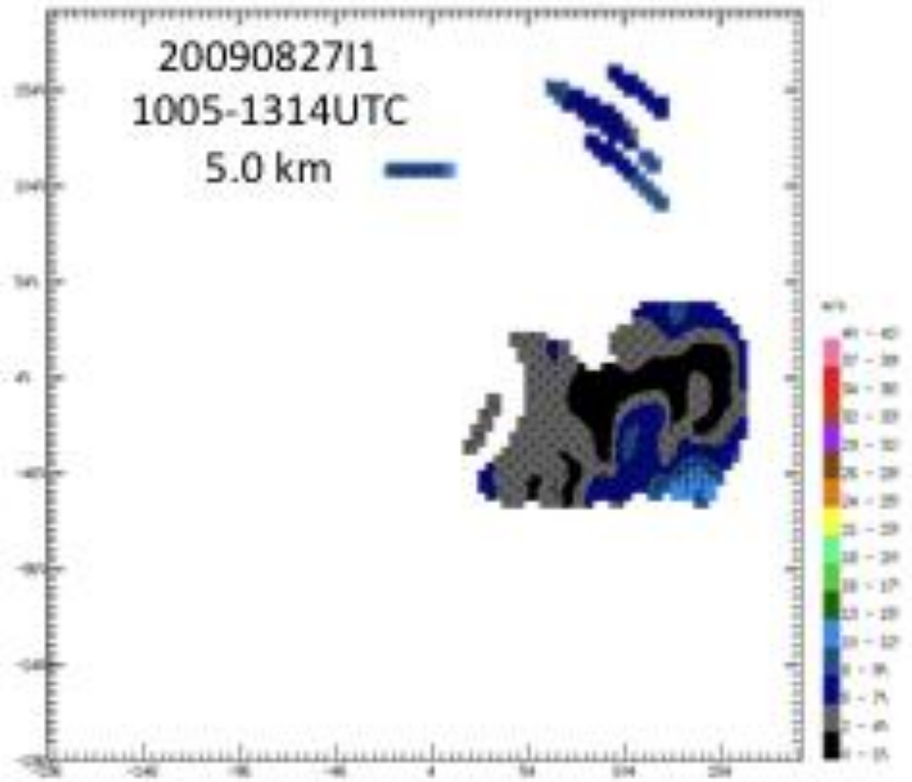
(b)

Figure 6. Wind speed (m/s) measured from tail Doppler radar at 1 km altitude for radar legs centered at (a) 1039 UTC and (b) 1141 UTC August 19.


33N
32N
31N
30N
29N
28N
27N
26N
25N
24N
23N
22N
21N
20N
86W
84W
82W
80W
78W
76W
74W
72W
70W
68W
66W
64W
1
2
3
4
5
6
12 UTC Rawinsonde
00 UTC Rawinsonde


2009082711
1005-1314UTC
1.5 km


Average Flight Level Wind Over 30 Seconds (knots)
0 5 10 15 20 25 30 35 40 45 50 55 60+
Jacksonville
Florida
Great Abaco Island
Harbor Island
Nassau
Eleuthera Island
The Bahamas
La Habana
Turks and Caicos Islands
© 2009 LeadDog Consulting
© 2009 Europa Technologies
© 2009 Google
© 2009 Tele Atlas
Google
Pointer 26°25'03.01" N 75°22'51.40" W elev 0 ft Streaming 100%
Eye alt 721.37 mi


2009082711
1005-1314UTC
5.0 km

2. Work toward installation of Doppler radar on G-IV - AOC, AOML

1. G-IV TDR Installation:

   Factory ground acceptance tests completed in early October.

   G-IV inducted for TDR installation on 16 October 2009

   FAA and Scientific acceptance tests to be completed prior to WSR-10.

3. Transmit new data types from P3s (Doppler, AXBT, AWRAP, 1-Hz flight-level, WSRA), including software development - AOML, EMC, NESDIS

The only item funded from this task was $60K for:

Deliverable: Tail doppler radar (TDR) data from N42 and N43 made available in real-time at NWS/NCEP Central Operations (NCO).

Funding went directly to AOC to implement a modification to an existing contract

Original plan was to start effort in Spring 2009 for implementation and testing during the FY09 hurricane season.

Funds arrived at AOC at end of 3rd quarter and contract award was in late August to Remote Sensing Solutions, Inc.

Code developed and validated that parses and processes the John Gamache TDR radial files, creates UDP packet payloads (compressed), reads and decompresses payload data after transmission and writes output profile data to file. In addition to the radial velocity contained in the John Gamache files, the code was designed to include reflectivity and spectral width profiles in future when these data become available.

Designed standardized file format for TOC TDR files, wrote application to produce these files from TDR data and provided to NCO for validation.

Data flow connectivity has been tested between P-3s, AOC provided ground server, and NWS/TOC. This included implementation of a connection “heartbeat” between ground server and aircraft.

Full end-to-end data flow validation (P-3 to TOC) can be tested during the NESDIS Ocean Winds winter experiment.

AXBT data flow to the TOC will be implemented assuming HRD modification of AXBT processing code to run in real-time

Doppler radial superobs were transmitted in realtime from each flight. These were assimilated by Fuqing Zhang’s group using WRF-ARW. Two sets were transmitted in Ana, 13 in Bill and 13 in Danny.

4. Upgrade airborne radar system from RVP-5 to RVP-8 on one P-3 - AOC, AOML

AOC is awaiting installation of G-IV radar before P-3 upgrades. Upgrade to be completed before 2010 season.

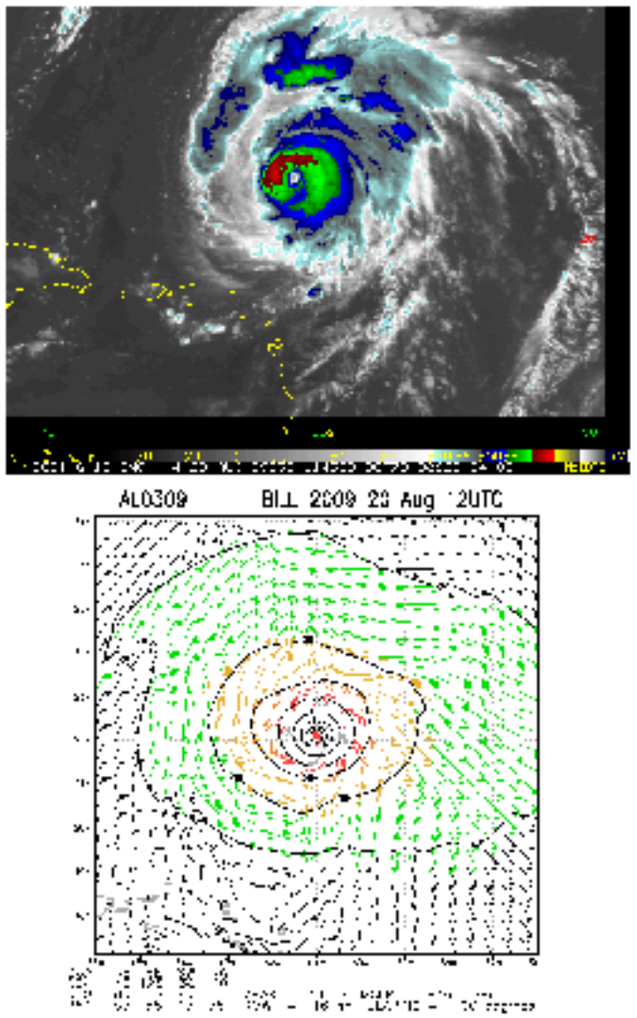
AOML is waiting to test software on the new systems.

5. Develop and populate a data warehouse for OSEs and verification - AOML, ESRL

http://www.aoml.noaa.gov/hrd/data_sub/hurr.html

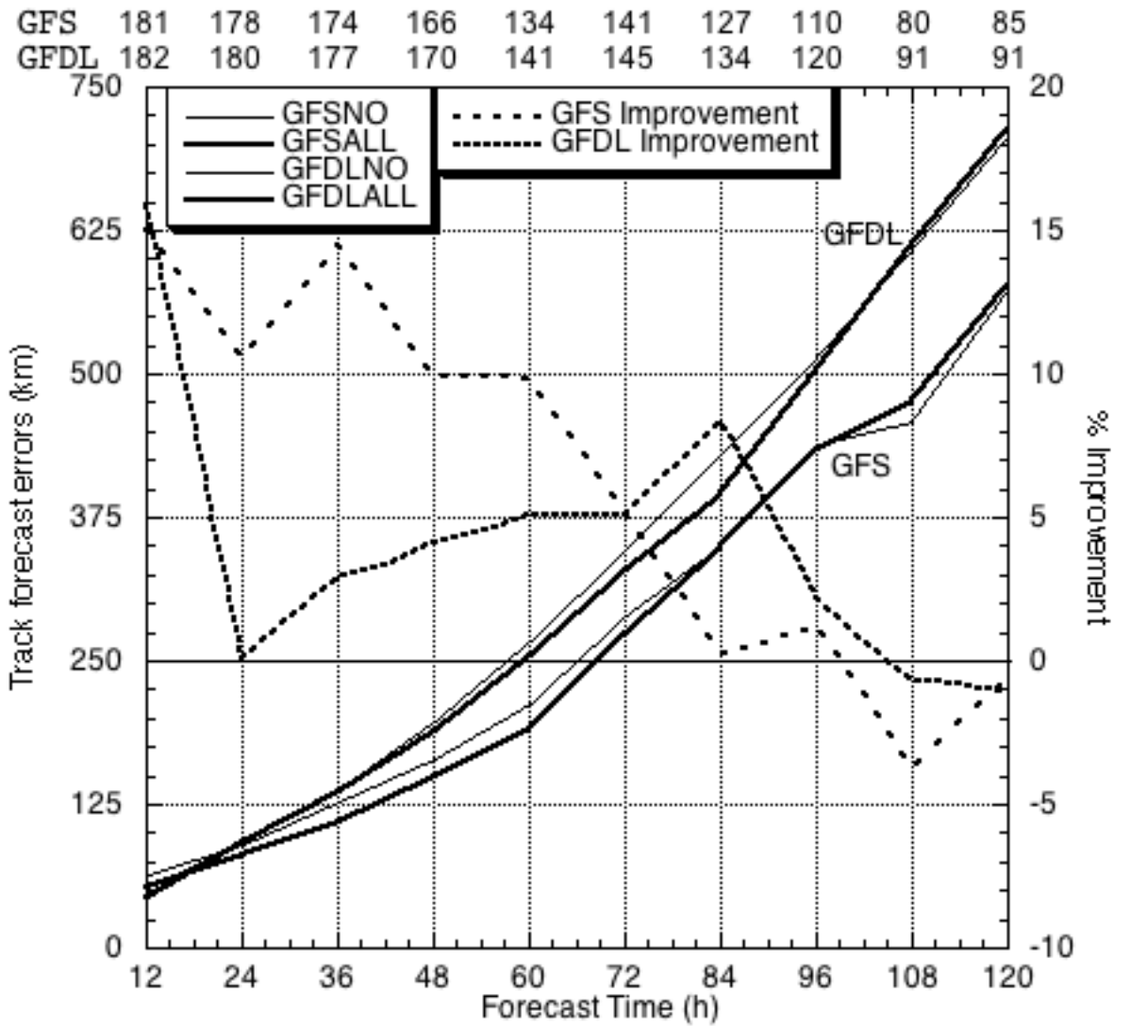
NESDIS/CIRA Contributions to HFIP Observations Team

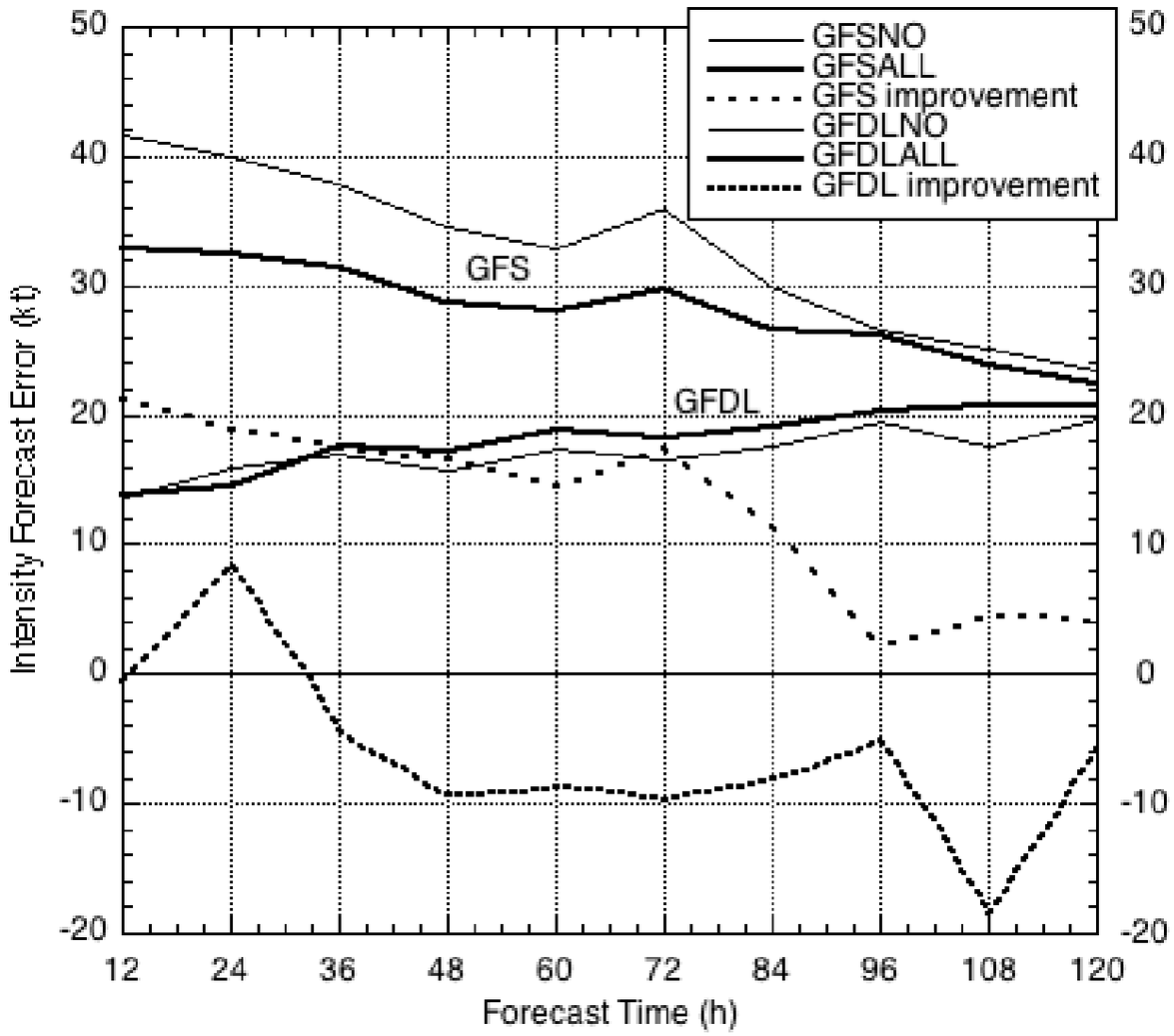
- Quick- look satellite products for 2008- 2009 global tropical cyclones available from
  http://rammb.cira.colostate.edu/products/tc_realtime
- Digital data available upon request
- Storm- centered vis, IR imagery
- Satellite- based surface wind analyses (every 6 hr)
  - Combines, geo, microwave and scatterometer
- Ocean Heat Content
- Additional satellite products



Sample IR image and satellite surface wind analysis for Hurricane Bill at 12 UTC on 20 Aug 2009

6. Conduct OSEs with current data types - AOML





7. Attempt to obtain near-surface observations with low-altitude long-endurance aircraft (LALE)

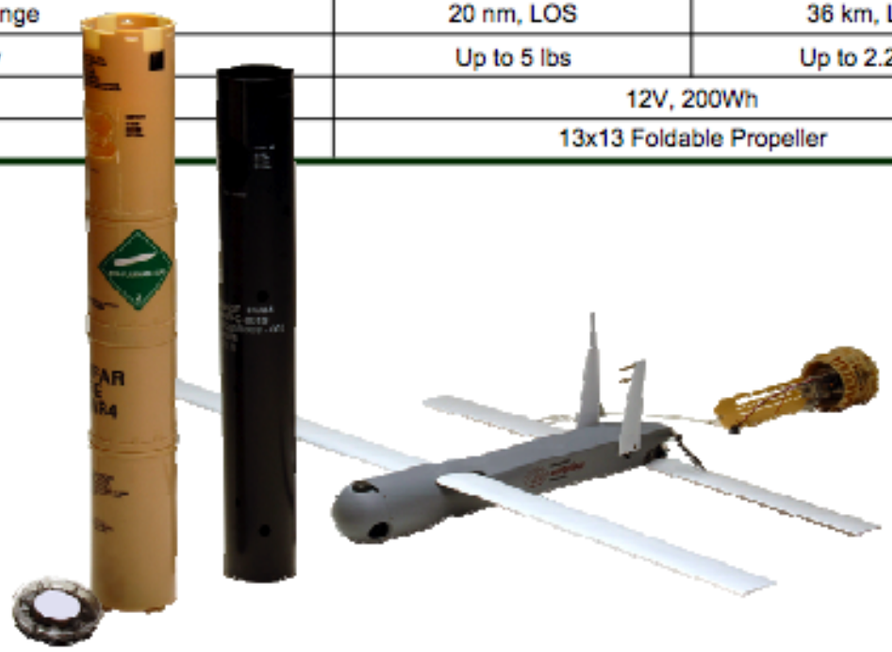
Joseph J. Cione NOAA/AOML/HRD
Eric Uhlhorn NOAA/AOML/HRD
Nancy Ash NOAA/AOC

Coyote UAS Test Flight 090920I1

- **Coyote Flight 9/20/2009 Into Warning Area 174 (NW of Key West)**
- **Mission Plan: Launch, command & control Coyote using NOAA P-3 aircraft**
- Three Coyote UAS were brought onboard the manned aircraft. The plan was to deploy two UAS with the third to at as a back up.
- Science team members. Cione, Uhlhorn, Lorsolo (HRD); Ash (AOC); Corcoran, Osbrink (BAE Systems)
- Mission Synopsis: Takeoff: 930am local out of MacDill Air Force Base
- ~1030am: First Coyote deployed. Parachute malfunction resulted in fast fall. First UAS test release was unsuccessful.
- Coyote 2: BAE had problems with initialization. Effort aborted.
- ~1230pm: Began initializing Coyote #3.
- Third (and final) Coyote UAS launch was a success. Release time ~1pm local
- Operational plan: Fly UAS within a 3mi x 3 mi 'box pattern'. Coyote deployed from P-3 @10,000ft . Before activating the UAS' (electric) motor remotely, the Coyote was required to establish 5,000 ft separation with 43. After several minutes of controlled glide descent, the Coyote was fully operational @5000ft. Coyote continued descent to 1,000ft. The remainder of the flight consisted of repeated ascending and descending controlled soundings between 600-1000ft. The last 5-10 minutes of the flight included control stair-step descent from ~600ft UAS down to ~64ft.
- 4 GPS sondes were released during the 50-minute UAS test flight. The last drop occurred as the UAS was at ~100ft altitude. 5000 ft vertical/3-5min horizontal separation was maintained. The P-3 conducted 'multiple spirals' centered on the Coyote 3mi x 3mi boxed flight plan below. (Planned) 'lost comms' checks worked as expected.
- **Other issues/lessons learned:**
- BAE's difficulty in attaining timely UAS pre-flight initialization. Not a straightforward process. It was however the 1st time BAE operated/worked with the P-3/AOC personnel.
- Weaker than expected P-3/UAS in-flight communications. This, despite 3-5mi/5000kft minimal separation in clear air. After speaking with BAE engineers, they are confident gain can be greatly improved with a stronger antenna/receiver system. BAE says they already have a fix for this and expect no issues going forward.
- Short battery life. The 50minute duration will be dramatically increased once a shorter pre-flight routine is established. Reducing/eliminating 'up soundings' would also increase duration. BAE

Coyote Specifications

Parameter	Value (U.S.)	Value (Metric)
Maximum Gross Takeoff Weight (MGTW)	14 lbs	6.4 kg
Nominal Mission Takeoff Weight (NMTW)	12 lbs	5.4 kg
Nominal Mission Endurance	1.5 Hours	
Motor	Brushless Electric Motor	
Airspeed (Cruise @ NMTW)	50 kts	93 kph
Airspeed (Dash - level flight @ NMTW)	75 kts	140kph
Airspeed (Max. Endurance @ NMTW)	45 kts	83kph
Airspeed (Stall @ NMTW)	38 kts	70kph
Airspeed (VNE @ NMTW)	100 kts	185kph
Navigation	GPS	
Service Ceiling	25,000 feet	7,610 meters
Payload (EO)	Sony FCB-IX10A EO Camera	
Payload (IR)	BAE SCC500, Uncooled IR	
Command and Control Radio (C2)	Up to 2 Watt, Discrete/Frequency Agile, Military Band / ISM Band Radio Modem (TX/RX)	
Command and Control Radio Range	20 nm, Line of Sight (LOS)	36 km, Line of Sight (LOS)
Video Transmitter	2 Watt (optional 5W), S-Band FM Video TX With Optional 19.2kbps Data Carrier	
Video Transmission Frequency Range	2.20-2.39 GHz	
Video System Range	20 nm, LOS	36 km, LOS
Payload Capacity	Up to 5 lbs	Up to 2.25 kg
Onboard Power	12V, 200Wh	
Propulsion	13x13 Foldable Propeller	



advanced ceramics research

3292 East Hemisphere Loop • Tucson, Arizona 85706
T: 520.573.6300 • F: 520.573.2057 • www.acrtucson.com

050620

A New (and improved) Concept of Operations for Low Altitude Hurricane Missions

….using the Coyote UAS

- **Fill existing critical low altitude data void in hurricanes**

Safely provide continuous observations of T,P,V, q below 200ft

Enhance future observational capabilities (via payload development)

- **Ensure safety**

No need for low level manned flight in hurricanes (i.e. below 5000ft)

Operations fall within NOAA's existing comprehensive ORM

Onboard P-3 command and control maximizes efficient communication

- **Fully integrate with NOAA's existing research, operational & manned aircraft assets**

Leverage existing NOAA resources (AOC, HRD, NHC, EMC, HFIP)

- **Complement existing NOAA-P3 onboard systems & observational tools**

Utilize existing P-3 AXBT deployment system

Utilize existing P-3 communication systems

Complement existing P-3 GPS AXBT/dropsonde observational systems

- **Minimize cost (vs. traditional deploy/launch/recover TC LALE conop)**

No forward deployment costs/teams required

No pre-mission site survey missions required

No complicated ground-to-plane communications required

- **Minimize mission and air-space regulatory risk:**

No ingress and egress

8. Prepare to install instruments to obtain sea-spray and GPS surface data from NOAA P-3s - AOC, ESRL

9. Prepare to obtain in situ microphysical (sea spray and turbulence) measurements - ESRL

1. <u>Sea-spray (salinity) and GPS-bistatic probes</u>:

   Salinity probe installed and computer software generation complete. Ready for next mission on N43RF.

   Bi-static GPS probe installed and has been used to collect two sets of data. Analysis of data by ESRL ongoing.

Bistatic GPS Reflection

V. Zavorotny & C. Fairall (ESRL), D. Akos (University Colorado)

*Reflection intensity - surface roughness

*Reflection phase/timing – surface elevation (Surge)

*Receiver deployed 2 flights Hurricane Ike

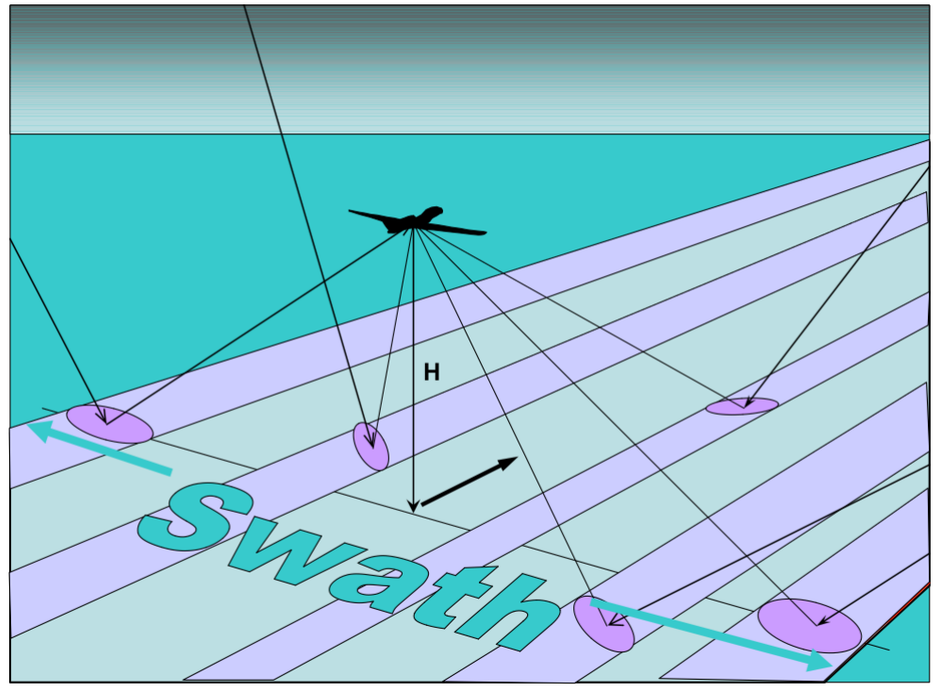
- Raw mulitchannel time series recorded
- Preliminary processing shows **surface roughness** features

*Altimetry (surge) application

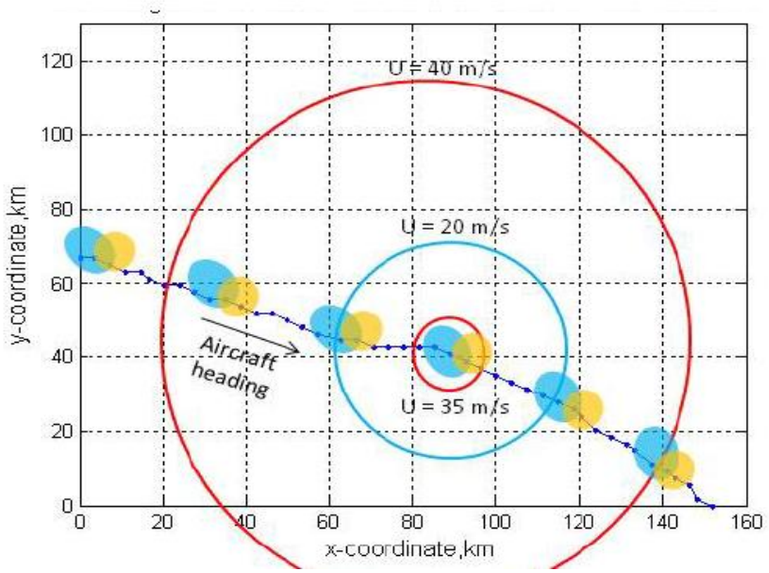
- Requires longer pulse signals
- New antenna for extra signals purchased
- Fall 09 and/or Spring 10 deployment planned

*Exploring applications on G-IV

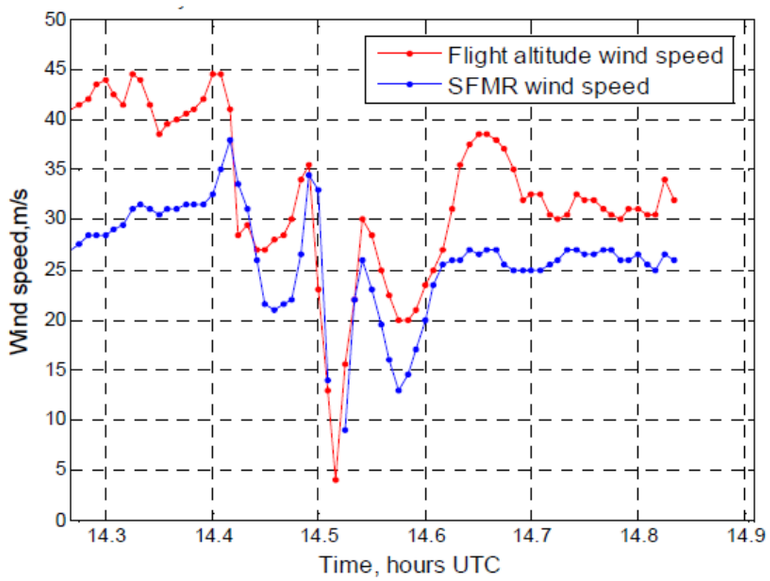
- Intensity mode gives good signal in lower winds
- Possible superior performance in far-field surveys



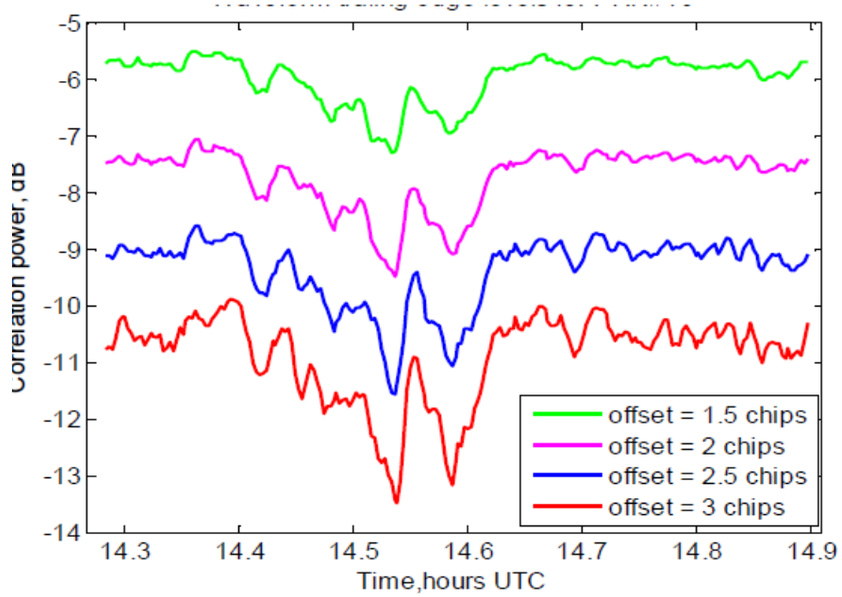
Concept sketch showing reflections from different GPS Satellites



P-3 Track Hurricane Ike. Small colored circles show GPS footprints from 2 satellites



Flight-level and SFMR near-surface winds from P-3 flight track



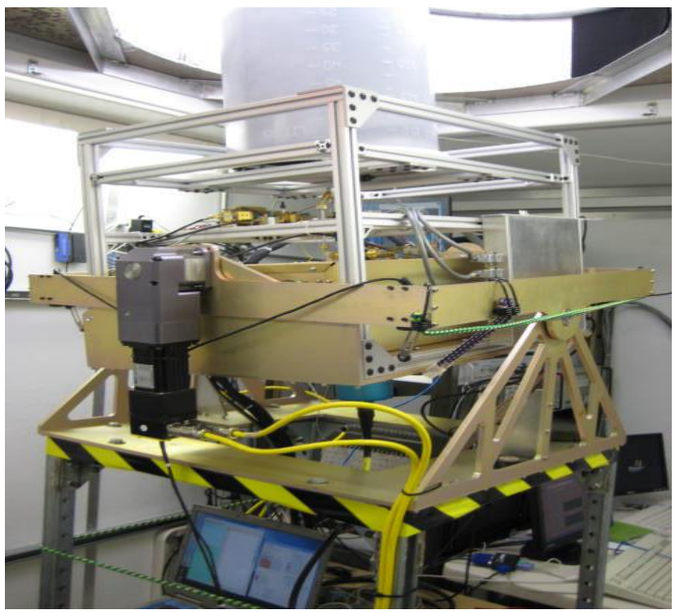
GPS reflection correlation power at different delays corresponding to the Hurricane Ike flight track

W-Band (94 – GHz) Doppler Radar for P-3

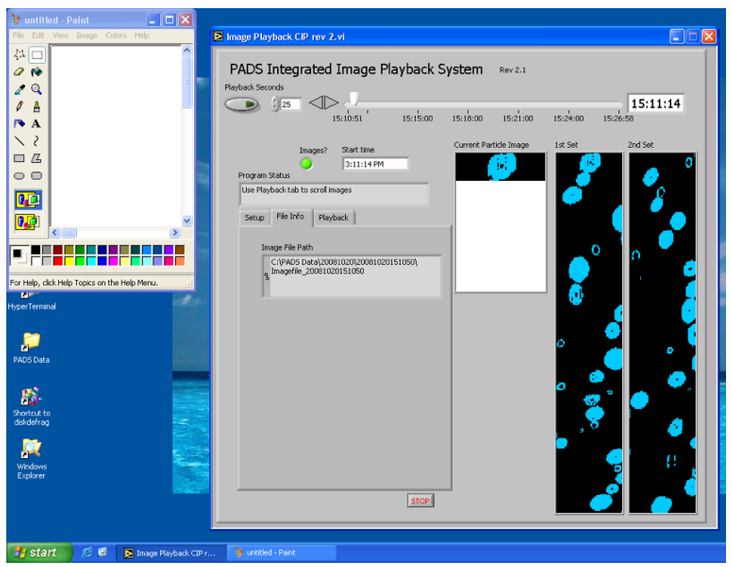
Sea Spray & Cloud Microphysics: Ship-based Field Tests November 2008

C. Fairall & K. Moran (ESRL)

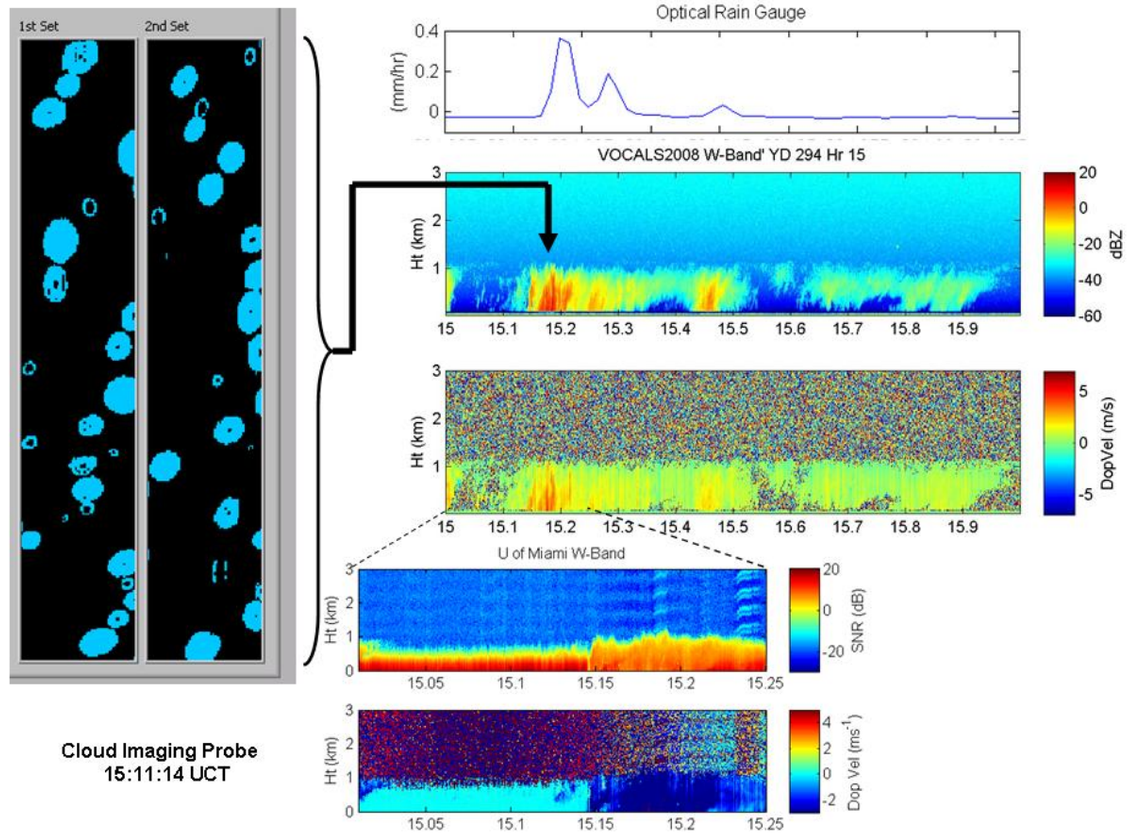
- Radar construction completed August 2008
- Field deployed on shipboard Oct-Nov 2008 and June 2009
- Sensitivity in full Doppler mode = -36 dBZ at a range of 1 km
- Typical sea spray drops: 0 to +15 dBZ
- Processing of Doppler time series yields in-cloud turbulence profiles
  - Velocity variance, TKE dissipation, velocity skewness (not shown but available)
- Processing of Doppler spectra
  - Cloud and Sea Spray microphysics (Frisch et al. 1995/1996)



Radar deployed in motion stabilizer on NOAA *Ship Ron Brown* VOCALS2008 field program



CIP Drizzle droplet spectrum coincident with radar return. Droplets shown are about 0.3 mm Diameter



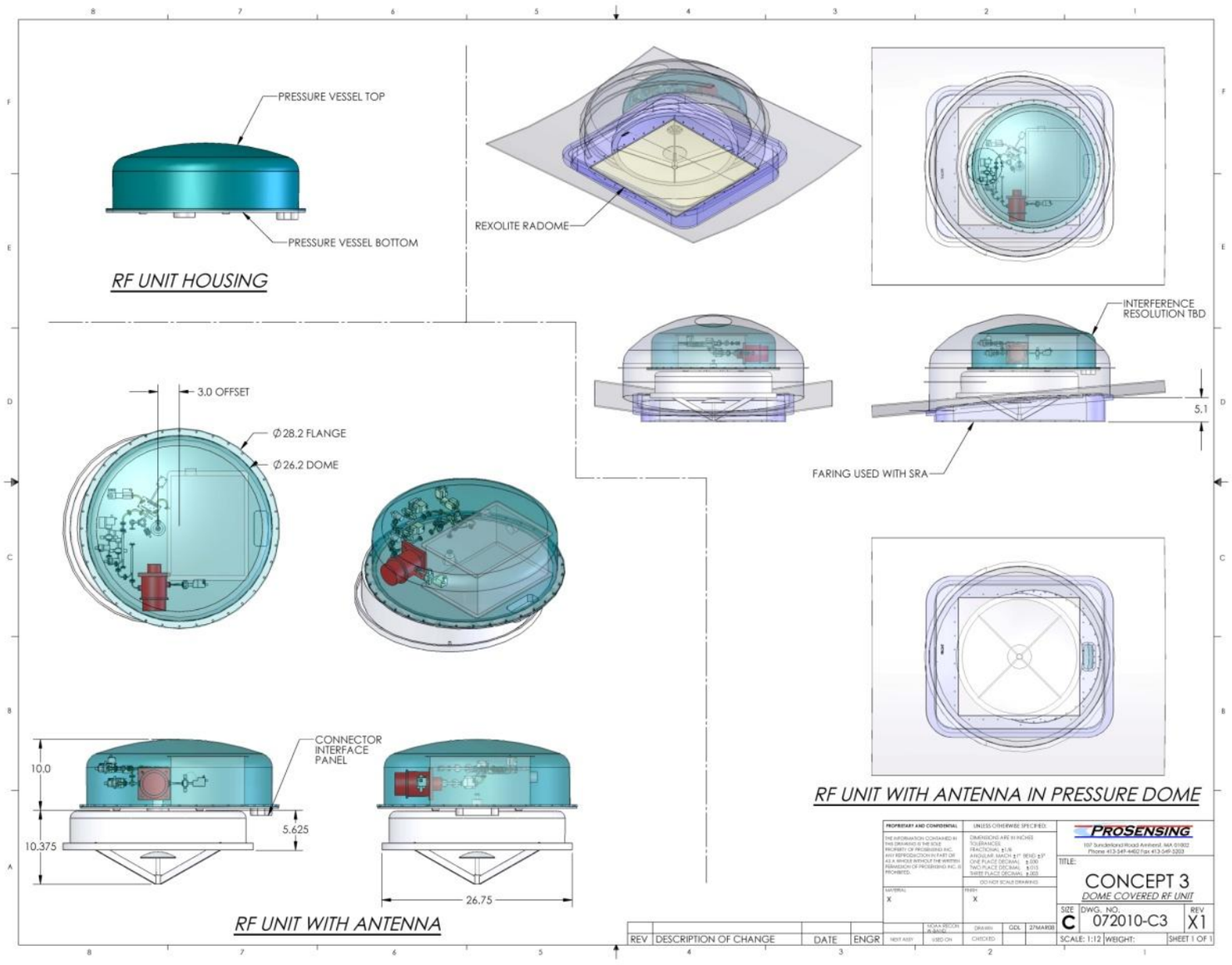
1-hr Time height cross section of backscatter intensity from light drizzle (~.3 mm/hr) during VOCALS2008 featuring Sea Spray sized droplets

W-Band (94 – GHz) Doppler Radar for P-3

Sea Spray & Cloud Microphysics: Preparations for P-3 Installation

C. Fairall & K. Moran (ESRL)

- Contract let to ProSensing Inc
  - Design new layout for RF sections
  - Repackage for P-3 pressure cell
  - Coordinate planning for installation
- Radar dissembled and shipped to ProSensing
- Receiver/calibration upgraded
- Operating characteristics re-spec'd for Sea Spray mission



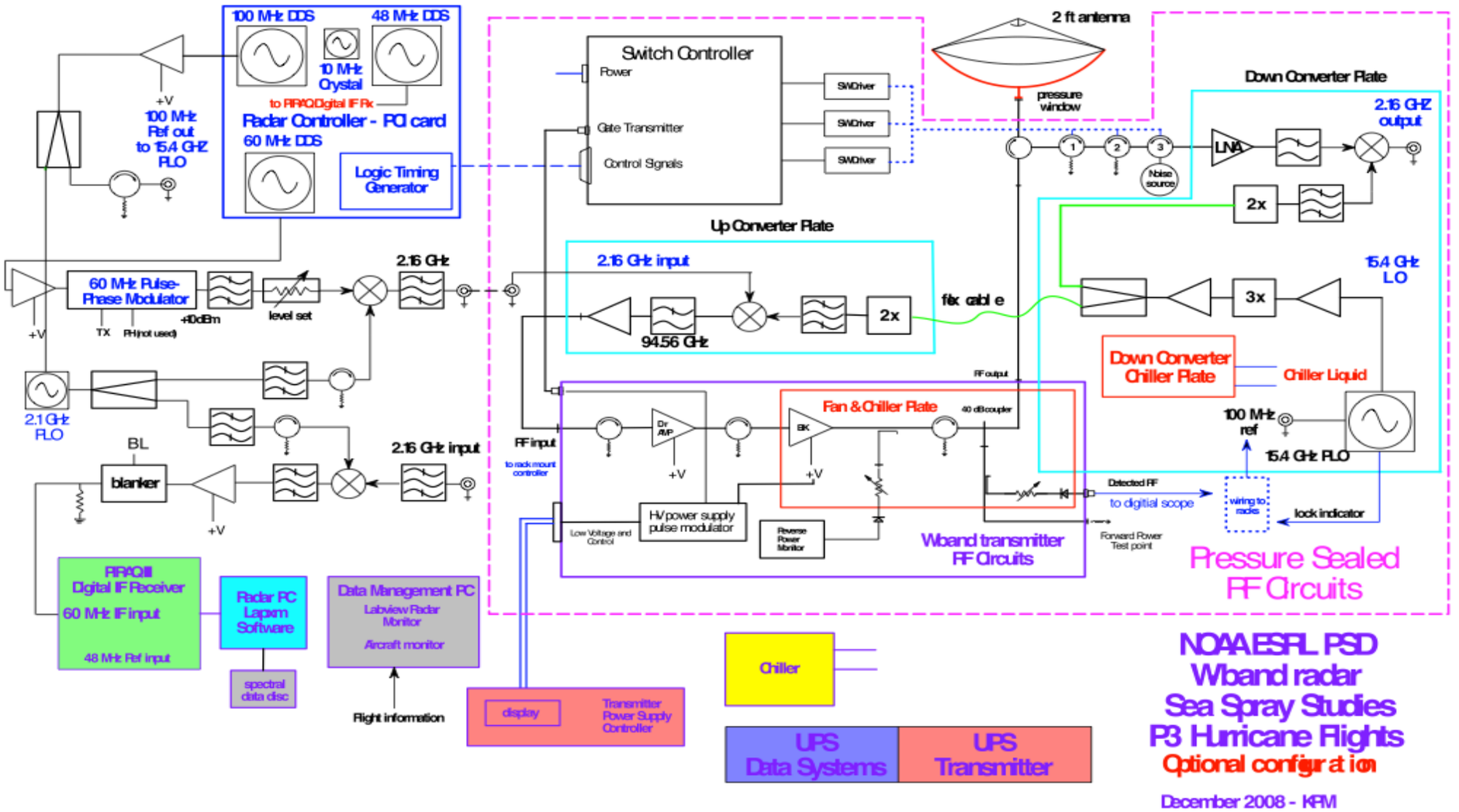
Operating characteristics for ESRL W-band airborne Doppler radar.									
Frequency	Peak/Avg Power	PRF_{MAX}	Antenna	Range Cell Size	Number of Range Cells	Velocity Resolution	Signal Processing	Data Archive	Sensitivity
94.56 GHz	1200/1 W	10 KHz	24 in Cassegrain	10-m	200	6.2 cms^{-1}	Average FFT; 0.2 s dwell time	Avg. Spectra	-30 dBz (R = 1km)

W-Band (94 – GHz) Doppler Radar for P-3

Sea Spray & Cloud Microphysics: Preparations for P-3 Installation

C. Fairall & K. Moran (ESRL)

- Contract let to ProSensing Inc
  - Design new layout for RF sections
  - Repackage for P-3 pressure cel
  - Coordinate planning for installation
- Radar dissembled and shipped to ProSensing
- Receiver/calibration upgraded
- Operating characteristics re-spec'd for Sea Spray mission



Operating characteristics for ESRL W-band airborne Doppler radar.									
Frequency	Peak/Avg Power	PRF $_{MAX}$	Antenna	Range Cell Size	Number of Range Cells	Velocity Resolution	Signal Processing	Data Archive	Sensitivity
94.56 GHz	1200/1 W	10 KHz	24 in Cassegrain	**10-m**	200	6.2 cms^{-1}	Average FFT; **0.2 s dwell time**	Avg. Spectra	-30 dBz (R = 1km)

Extreme Turbulence (ET) Probe
R. Eckman ARL

- FY09 first year of OAR funding
- Goal: upgrade & test probes for extended marine deployments
- Upgraded probes use Linux single board computer. 12 W total power
- Two upgraded probes deployed: 560 m pier in Duck, NC and Tennessee Reef in Florida Keys
- Probes still deployed and functioning with some data gaps mainly due to site power issues

10. Increase bandwidth from NOAA aircraft for greater amounts of data transmission - AOC

1. Increased SATCOM bandwidth:

   IMMARSAT equipment to upgrade SATCOM to broadband due in December 2009.

   To be installed early 2010.

11. Replace AXBT receivers on NOAA P3s - AOC, UM/RSMAS

New RX units (Mark 10a/21a) will be ordered in new fiscal year (Lockheed Martin), acquisition completed in 2010.

AXCPs have been delivered to AOC.

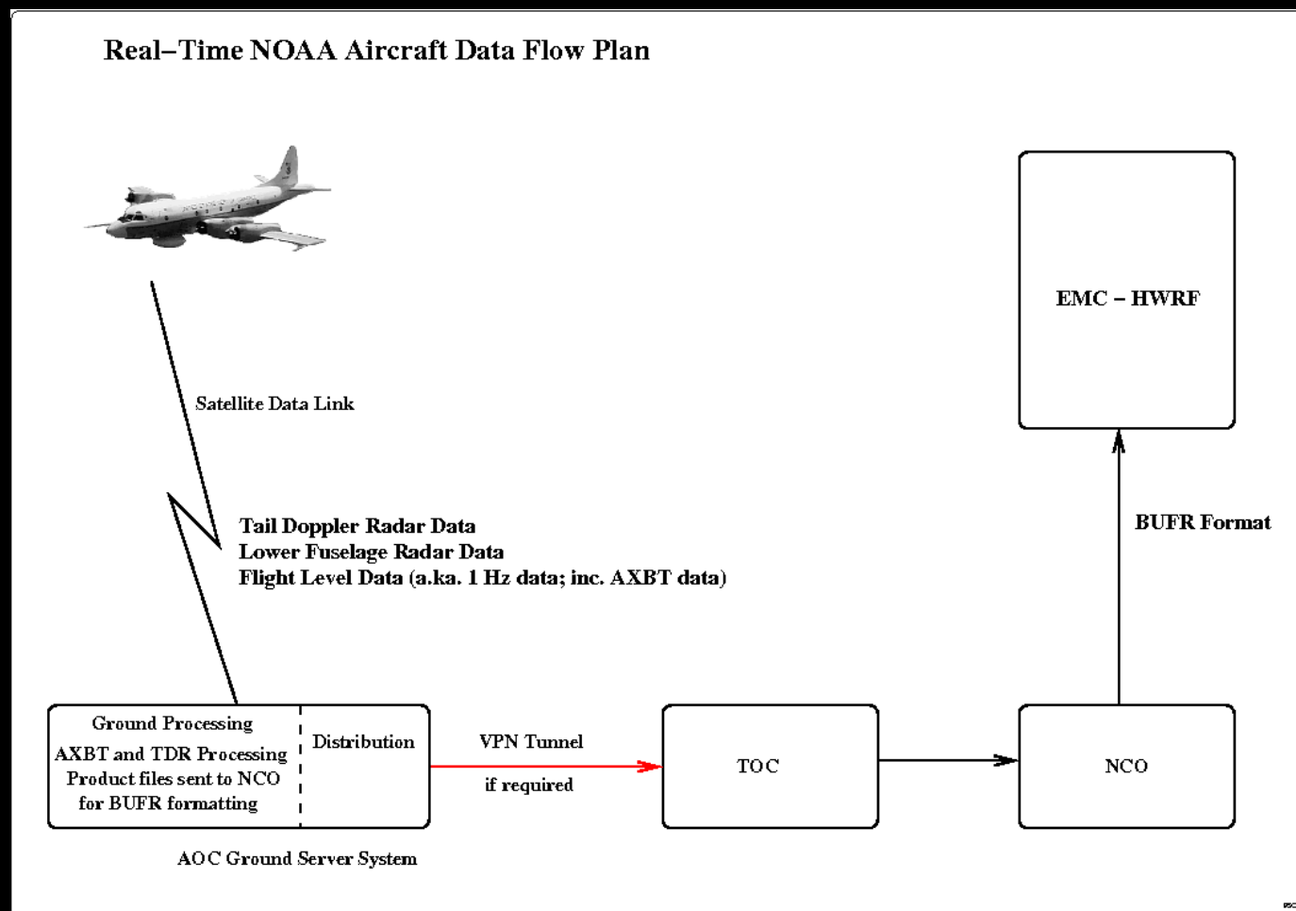
No engineer support for RSMAS.

12. Define data requirements from operational forecast and model centers - AOML, EMC

Real-Time Data (RTD) working group established in November 2008

Goals: To define and execute the formal pathways/procedures to flow data from the NOAA aircraft into NCO for operational utilization by NWS

Key members: Michelle Mainelli (NCO), Jim Carswell (RSS), Sean McMillan and John Hill (AOC), Paul Chang (NESDIS) and Dan Starosta (TOC)



Task Progress/Status

The working group focused on radar and AXBT data.

Meetings with HRD (John Gamache/Eric Uhlhorn) and EMC personnel.

FY09 funding went directly to AOC to modify an existing contract with RSS.

Original plan was to start in Spring 2009 for implementation and testing during the FY09 hurricane season.

Funds arrived at AOC at end of 3rd quarter, contract awarded late August to RSS.

Code has been written and validated to parse the radar data and create UDP packet payloads (compressed). In addition to the radial velocity, hooks for reflectivity and spectral width have also been developed for future expansion.

Developed and tested standardized file format for TOC ingest.

Data flow connectivity has been tested between P-3s, AOC-provided ground server, and NWS/TOC. This included implementation of a connection “heartbeat.”

Full end-to-end data flow validation (P-3 to TOC) can be tested during the NESDIS Ocean Winds winter experiment scheduled for early 2010.

AXBT data flow to the TOC will be implemented after modification of the AXBT processing software.

13. Develop and implement cross-platform dropwindsonde processing software for inner-core and environmental observations - AOML, NCAR (JHT)

ASPEN has been converted to multi-platform graphics package and a beta version will be available soon.

NCAR is in the process of hiring a software engineer to continue the project.

We should have a full Linux, Windows, Unix, and MAC version of ASPEN by year's end. A prototype system withenhanced capabilities will be available by early next summer, at the latest.

AOC HFIP Activities FY10

P-3 Radar Upgrades :

Upgrade on N42RF to be completed by mid-June 2010.

Upgrade on N43RF to be completed by August 2010 following CalNex.

Tail flat-plate antennae for both P-3s being acquired. Delivery date in approximately one year (Nov. 2010)

Sea Spray and GPS-bistatic probes :

W-band (94-GHz) Doppler radar for sea spray and cloud microphysics planned for 3rd P-3.

Bi-static GPS probe installed and has been used to collect two sets of data. Analysis of data by ESRL ongoing.

AOC HFIP Activities FY10

Increased SATCOM bandwidth :

IMMARSAT equipment to upgrade SATCOM to broadband due in December 2009.

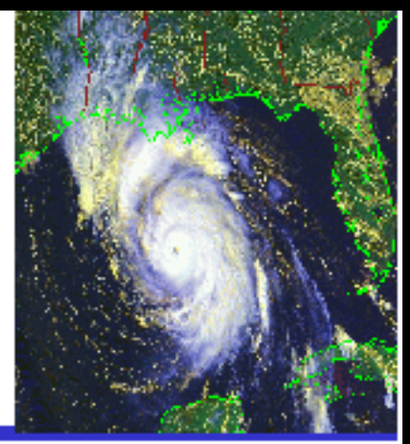
To be installed early 2010.

Purchase new AXBT receivers :

Receiver selection being made.

Acquisition to be completed in 2010.

Ocean-Atmosphere Plans



Provide a higher resolution, objectively mapped, sea surface height fields (anomaly and total), isotherm depths and OHC at ¼ degree for HFIP community for diagnostics and modeling teams (subject to NOAA NESDIS funding).

Procure, install and test new ocean data acquisition system for NOAA WP-3Ds working with AOC (RSMAS Engineer remains unfunded). Order deep AXBTs (800 m vintage).

Conduct MMS Loop Current Dynamics Study program during a hurricane with NOAA IFEX and in collaboration with NASA GRIP (Genesis and Rapid Intensification Program) in the Gulf of Mexico basin.

Process ocean data (and combine with moored data) and estimate air-sea fluxes during hurricane passage following Shay and Uhlhorn (MWR, 2008).

Work with modelers in determining ocean model performance using developed metrics (Taylor diagrams, statistical analyses, etc) following Halliwell et al. (MWR, 2009).

Assess boundary layer structures from oceanic and atmospheric measurements.

Milestones

- FY10
  - –Test fly Wband radar P-3 (pending slot availability)
  - –Complete field tests ET probe
  - –Fly old GPS system G-4; new system P-3
- FY11
  - –Fly Wband radar P-3 in hurricane (pending slot availability)
  - –Field ET probe in Pacific cyclone study
  - –Fly new GPS system P-3/G-4 hurricanes; submit paper on results