Preliminary Results from the AXBT Demonstration Project
in support of
Hurricane Coupled Modeling Products
and
Improvement in Guidance to NHC Hurricane Specialists

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Background

➤ The thermal structure of upper ocean is known to affect the tropical cyclone intensity

➤ Remote sensing of the ocean close to the TC is usually contaminated by clouds, but data can be obtained using Airborne eXpendable Bathy Thermographs (AXBT) or coastal buoy observations

➤ Near-real-time ocean observations beneath TCs have been shown to improve coupled model TC intensity forecasts in recent research field programs

➤ The 65th IHC Working Group approved an agenda item in March 2011 to permit AXBT operations on operational missions with the 53rd WRS on a no cost, not-to-interfere basis

➤ Goals
  – *2011:* Assimilate ocean observations beneath active TCs into coupled models in near-real-time
  – *Overall:* Assess value AXBT data add to coupled model forecasts of TC track and intensity in an operational setting

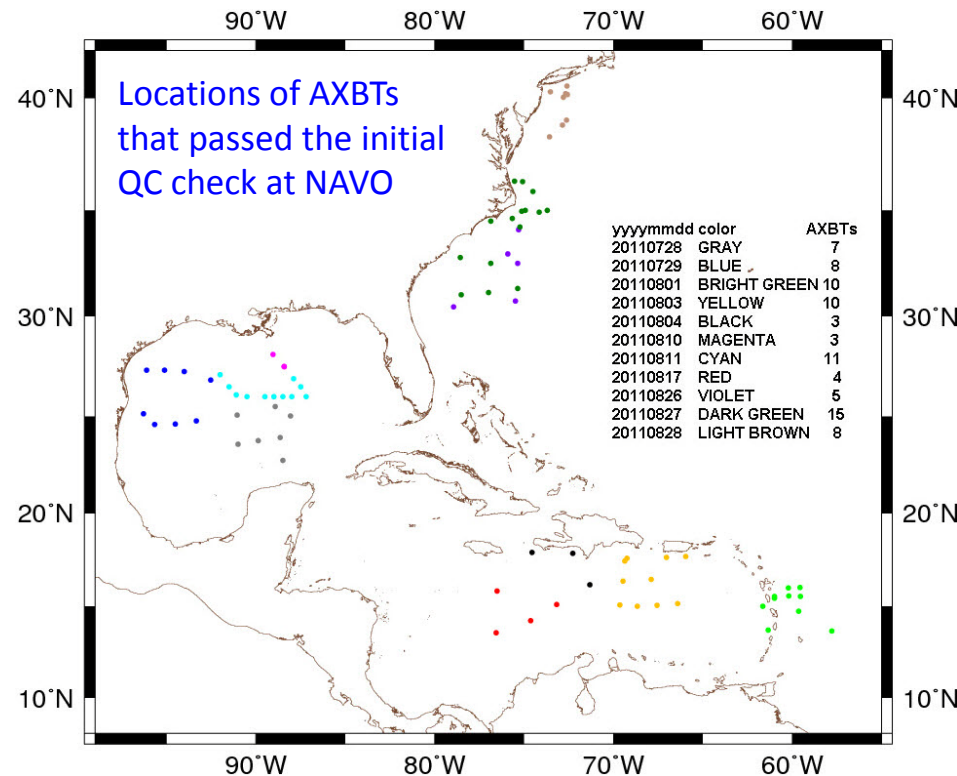Temperature Observations   03 Aug 11 12Z   6 km grid

Tropical Storm Emily
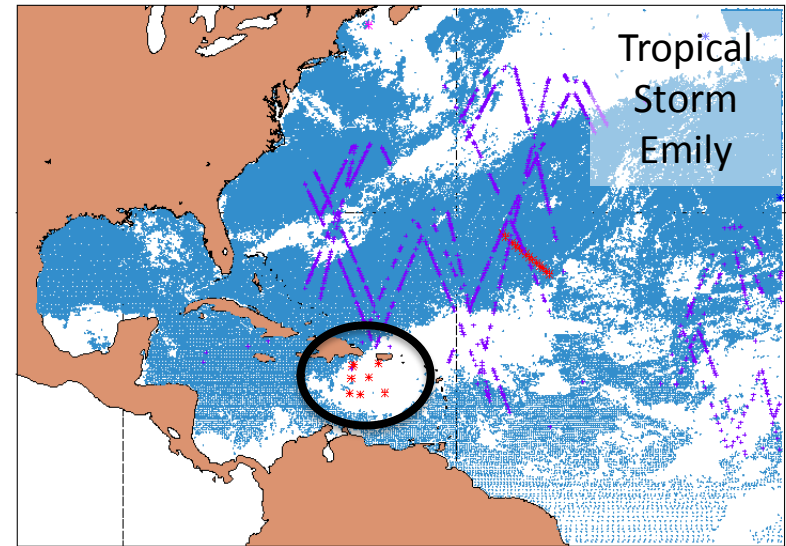
Temperature Observations   27 Aug 11 00Z   6 km grid
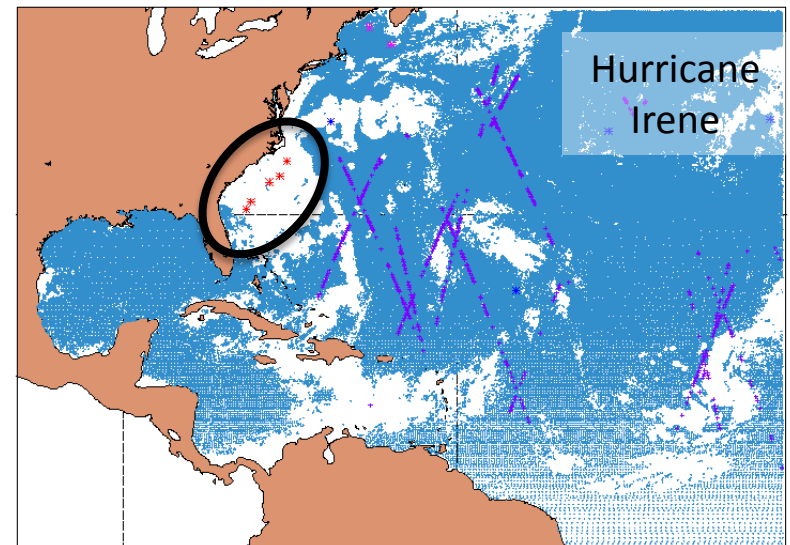
Hurricane Irene

Sea-surface observations in NAVO NCODA
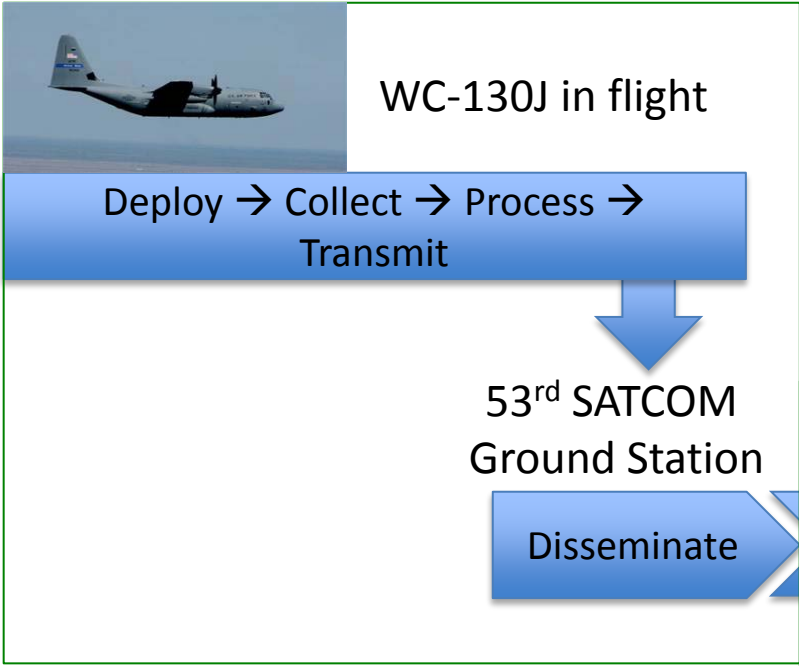(prior to NCOM / HYCOM and COAMPS)
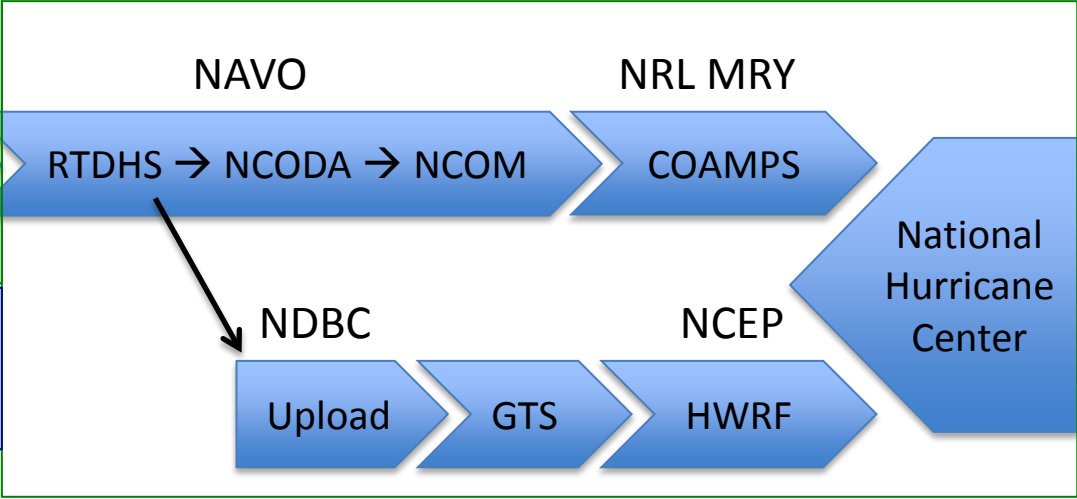
A Group Effort

2011 by the numbers

- **109** AXBTs deployed over **12** missions in **31** days:
  - Hurricane Irene (3 flights)
  - Tropical Storm Don (2 flights)
  - Tropical Storm Emily (3 flights)
  - Pre-TS Harvey (1 flight)
  - 2 training & 1 transit flights

- **85** AXBTs passed the initial QC check at NAVO (78%).

- **8** SOPs developed for data collection, processing, dissemination, and archiving
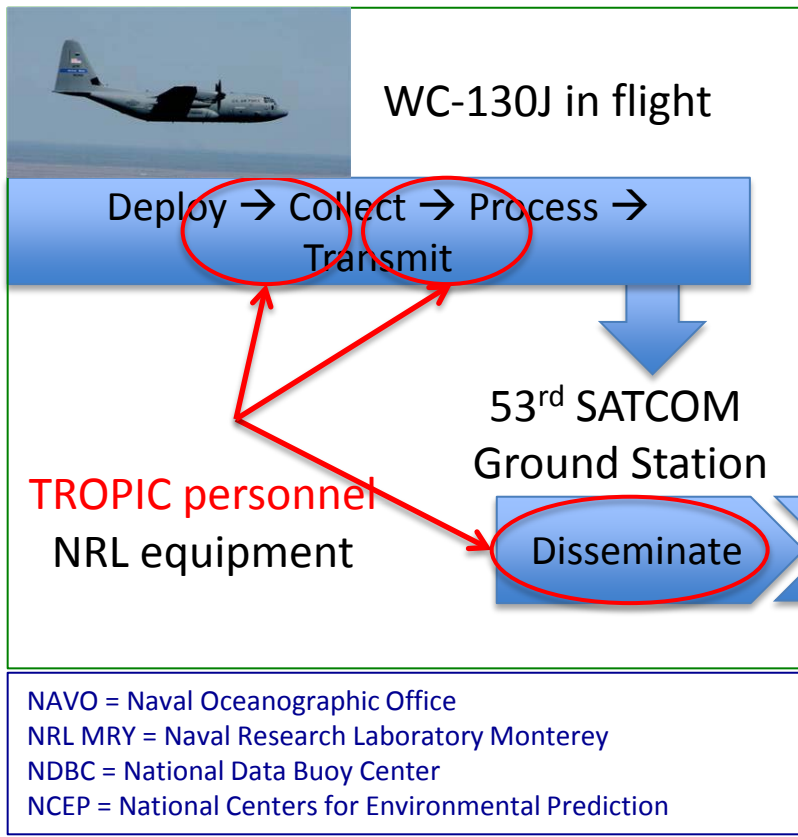
Locations of AXBTs that passed the initial QC check at NAVO

yyyymmdd	color	AXBTs
20110728	GRAY	7
20110729	BLUE	8
20110801	BRIGHT GREEN	10
20110803	YELLOW	10
20110804	BLACK	3
20110810	MAGENTA	3
20110811	CYAN	11
20110817	RED	4
20110826	VIOLET	5
20110827	DARK GREEN	15
20110828	LIGHT BROWN	8

AXBT Data Path

WC-130J in flight

Deploy → Collect → Process → Transmit

53rd SATCOM Ground Station

Disseminate

NAVO

RTDHS → NCODA → NCOM

NRL MRY

COAMPS

National Hurricane Center

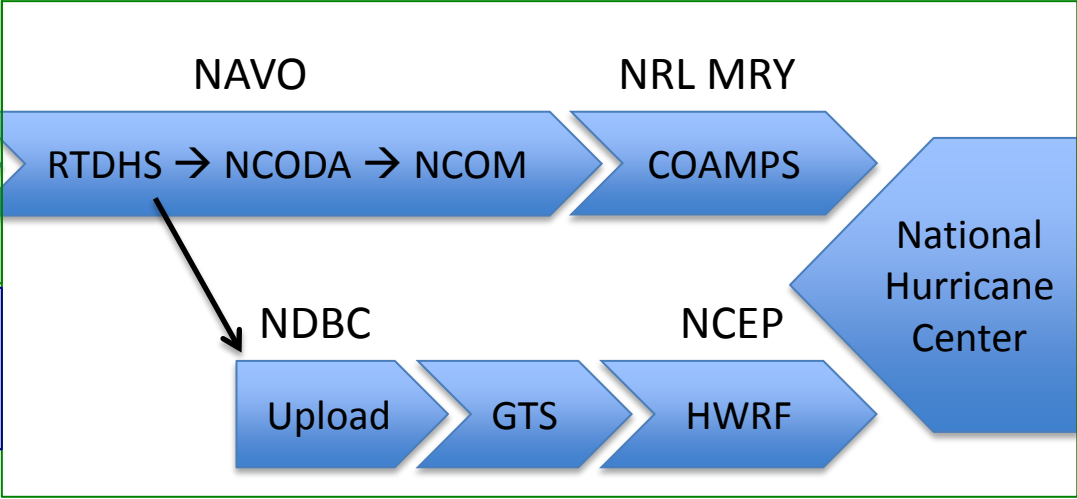NDBC

Upload

GTS

NCEP

HWRF

NAVO = Naval Oceanographic Office
NRL MRY = Naval Research Laboratory Monterey
NDBC = National Data Buoy Center
NCEP = National Centers for Environmental Prediction

TROPIC Field Phase

1. **Goal:** Get the ocean data from the aircraft into the coupled models in as near real time as possible.
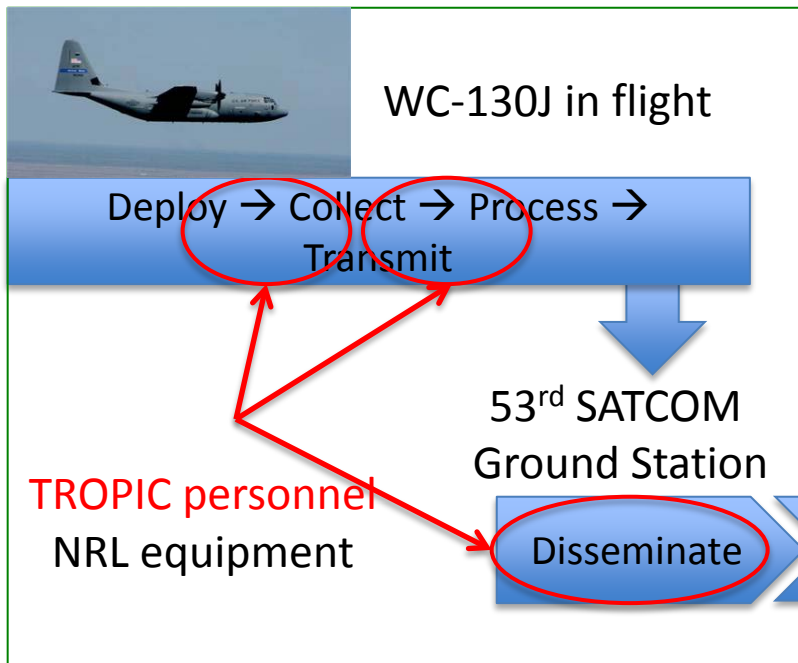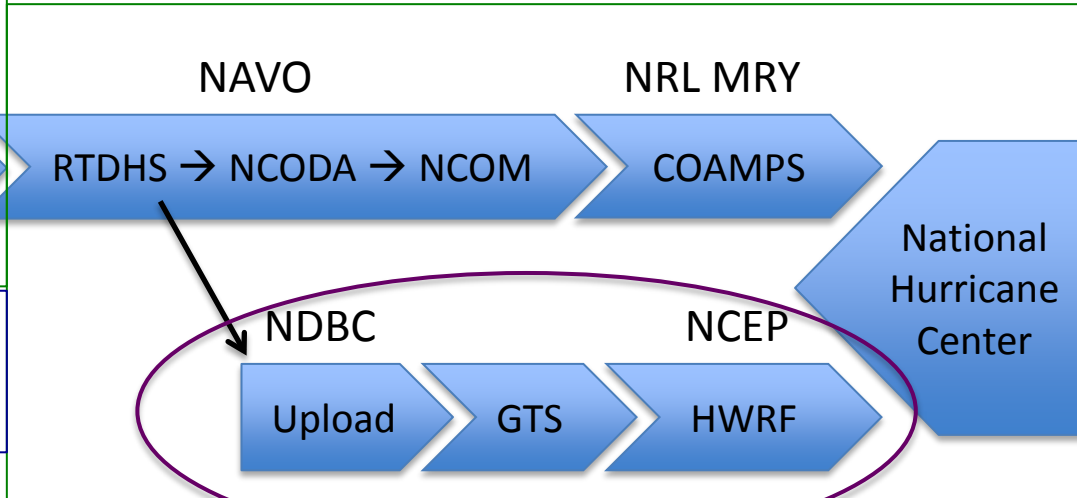
AXBT Data Path

WC-130J in flight

Deploy → Collect → Process → Transmit

53rd SATCOM Ground Station

TROPIC personnel
NRL equipment

Disseminate

NAVO

RTDHS → NCODA → NCOM

NRL MRY

COAMPS
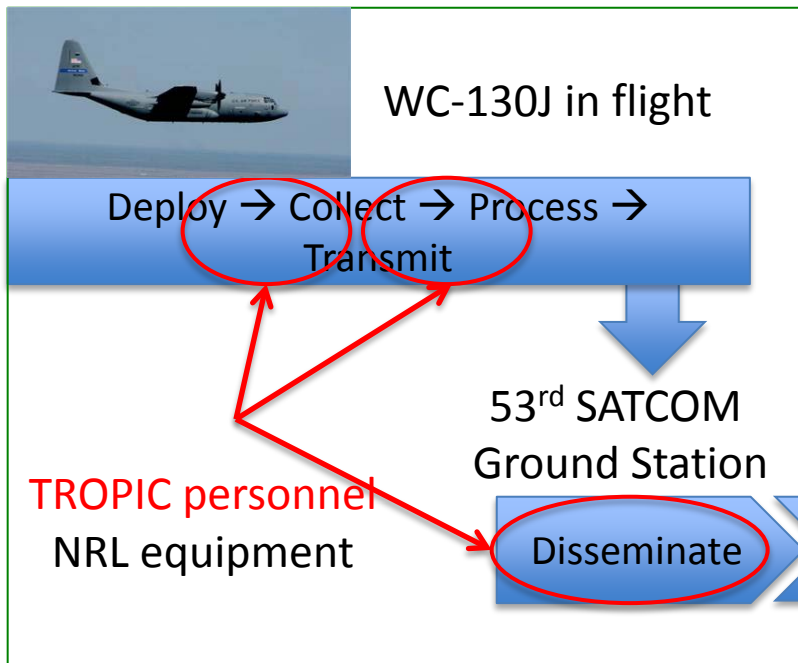
National Hurricane Center

NDBC

Upload

GTS

NCEP

HWRF

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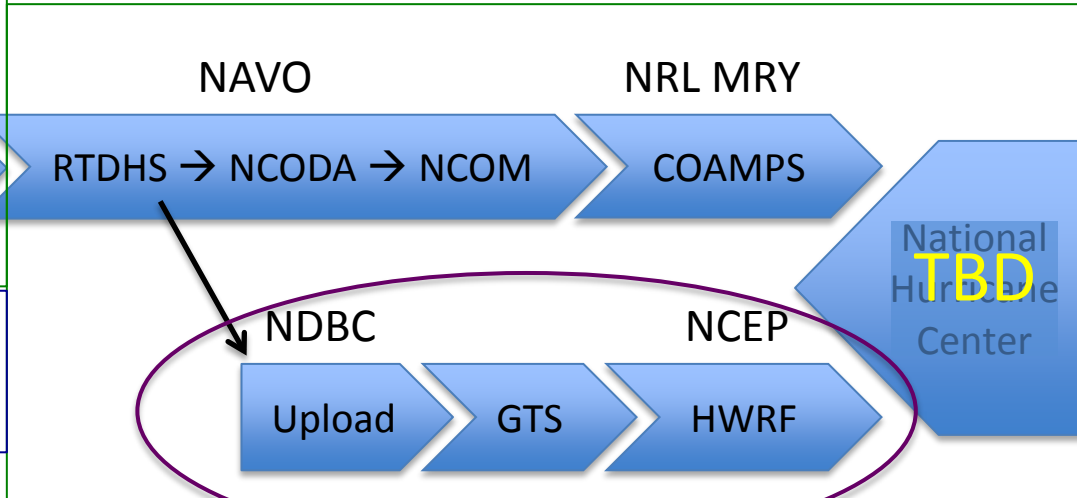NCEP = National Centers for Environmental Prediction

TROPIC Field Phase

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2. **TROPIC Personnel:** Collect, process, disseminate

AXBT Data Path

WC-130J in flight

Deploy → Collect → Process → Transmit

53rd SATCOM Ground Station

TROPIC personnel

NRL equipment

Disseminate

NAVO

RTDHS → NCODA → NCOM

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NDBC

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Upload > GTS > HWRF

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1st ever upload of ocean observations to HWRF (archived)

TROPIC Field Phase

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3. **Coordination:** 53rd WRS, CARCAH, NAVO, NDBC, NRL MRY, NCEP

AXBT Data Path

WC-130J in flight

Deploy → Collect → Process → Transmit

53rd SATCOM Ground Station

TROPIC personnel

NRL equipment

Disseminate

NAVO

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TBD

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TROPIC Field Phase

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# Model vs. Observed Thermal Structure

- 53rd WRS Weather training flight 11 Aug 2011 *(1454-1815 UTC)*
- 13 AXBTs deployed about every ½ degree (~6 minutes)
  - *First AXBT: 1547 UTC 11 Aug 11*
  - *Last AXBT: 1712 UTC 11 Aug 11*
- IASNFS (Intra-Americas Sea Nowcast/Forecast System)
  - Regional model: Gulf of Mexico, Caribbean and Straits of Florida
  - 6-km horizontal resolution 40 vertical levels
  - Initial and boundary conditions are forced by NOGAPS and the Global NCOM
  - MODIS for Data Assimilation (AXBT data are *NOT* included)
 - IASNFS model data courtesy of Dr. Dong-Shan Ko (NRL Stennis)

IASNFS OHC Analysis 00 UTC 11 August 2011
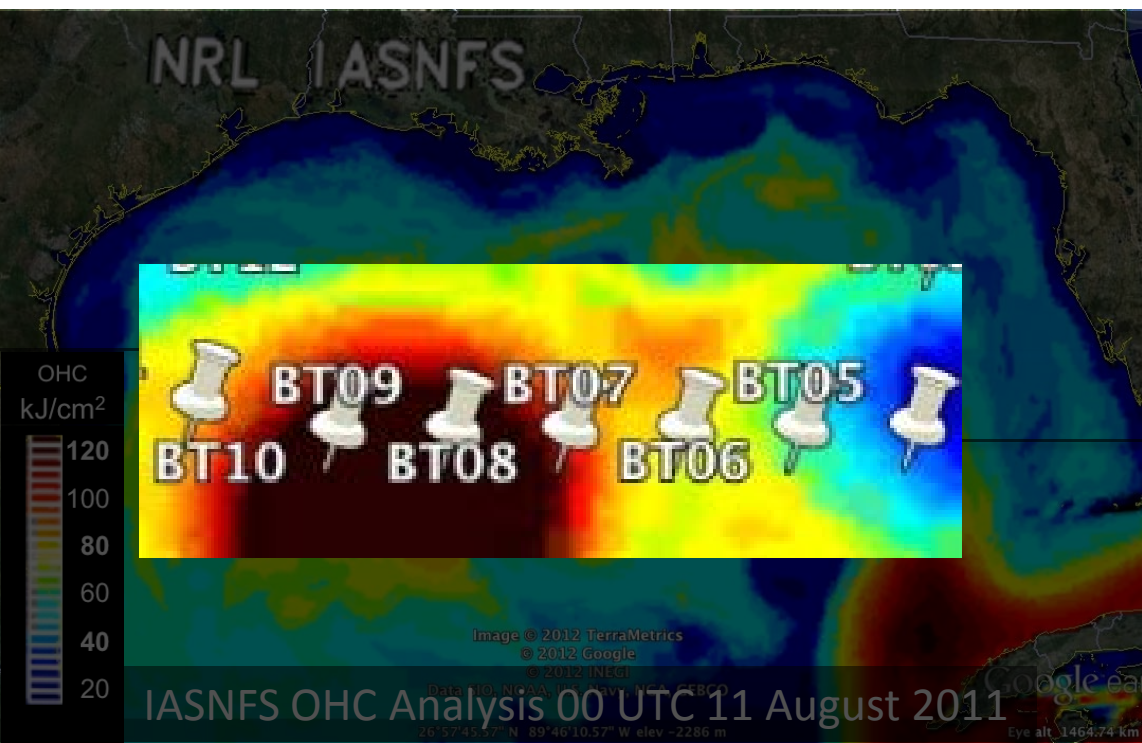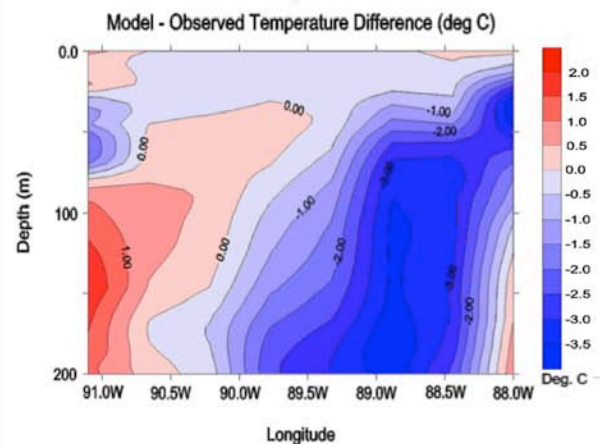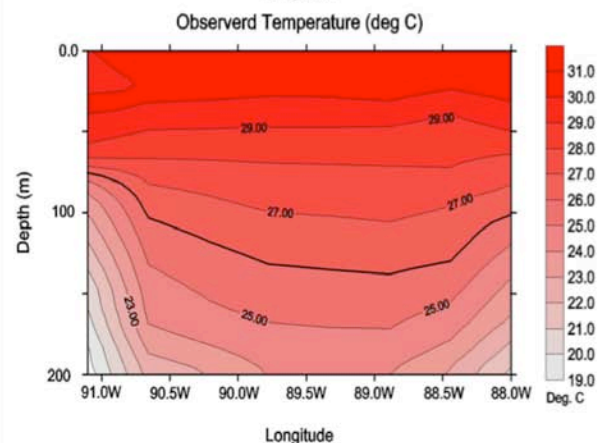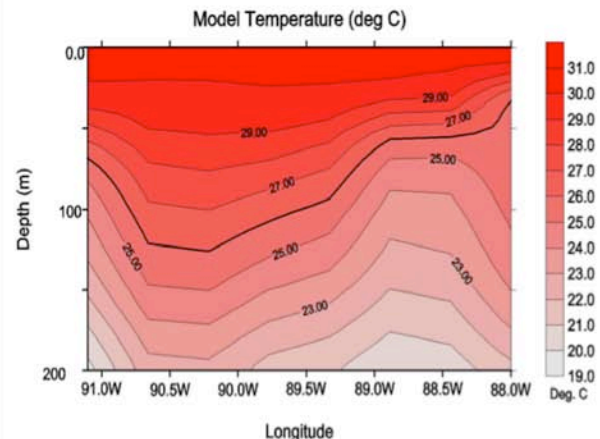
AXBT Impacts at 100m in HYCOM

- Weather training flight 11 Aug 2011 *(1454-1815 UTC)*

- 13 AXBTs deployed about every ½ degree (~6 minutes of flight time)
  - *First AXBT: 1547 UTC 11 Aug 11*
  - *Last AXBT: 1712 UTC 11 Aug 11*

- HYCOM (HYbrid Coordinate Ocean Model)
  - Variable horizontal and vertical resolutions
  - 1-km horizontal resolution in the Gulf of Mexico,
  - NCODA for Data Assimilation (AXBT data *ARE* included)

- All but one of the profiles collected on 11 Aug were used in the real-time, HYCOM 18 UTC 11 August 2011 analysis.
  - The rejected profile did not sample to 300 m depth
  - This depth is a tunable analysis parameter which has subsequently been adjusted to permit shallow drops into the DA system

- **Primary Impact: strengthen and correct the position of the warm core loop current eddy in the central Gulf.**

- But no TC forecast here…

Temperature Analyzed Increment (C)   100 M Depth
11 Aug 11 18Z Tau 000   1 km grid

<-3 -2 -1 0 1 2 3>
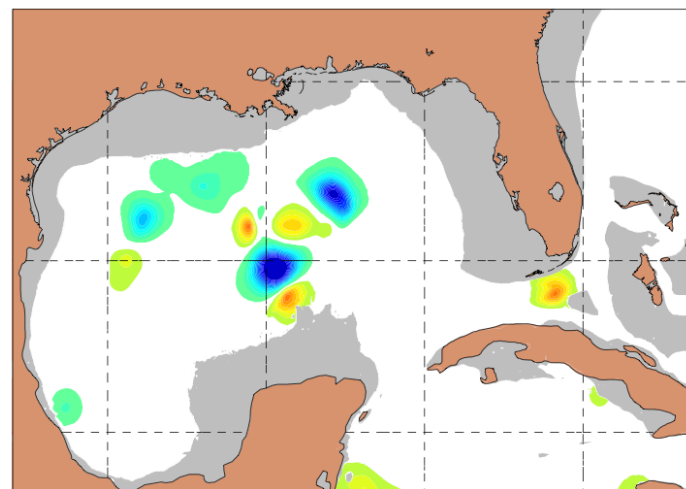
Temperature (C)   100 M Depth
11 Aug 11 18Z Tau 000   1 km grid

<15   20   25   30>
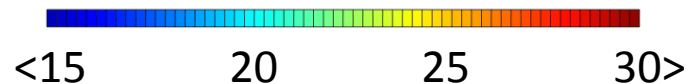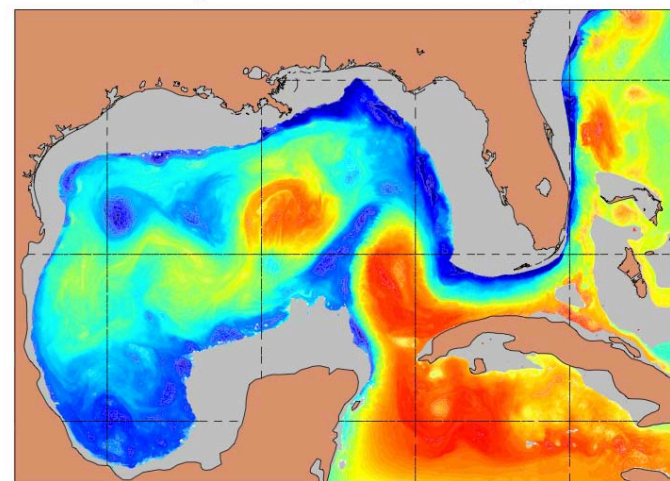
Operational flights
AXBT drop locations

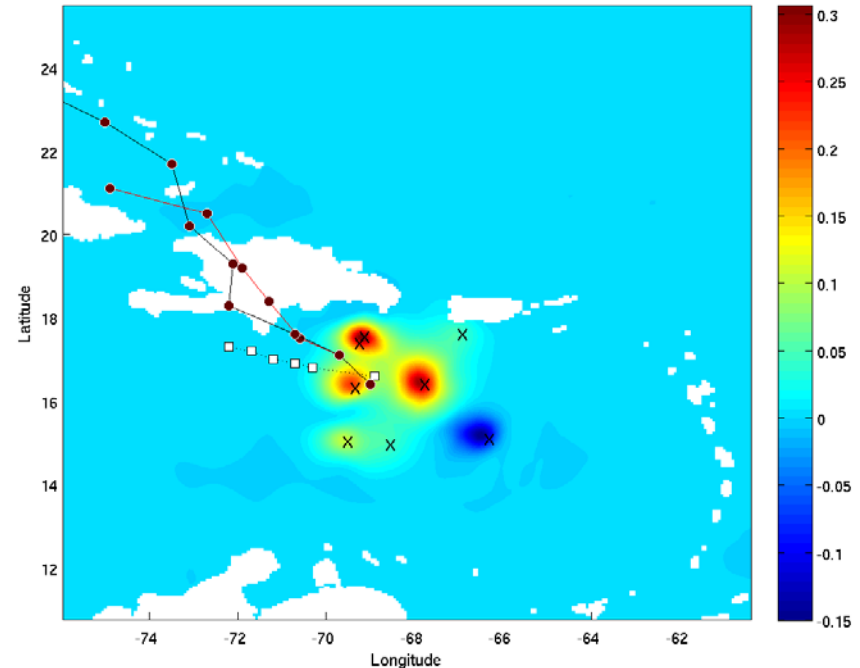Tropical Storm Emily
03 August 2011

AXBT 06
JJVV Message

JJVV 03081 0741/ 716360 069460 88888
51099 00291 00291 00291 14291 19289
57289 66287 72284 80278 99901
08270 30265 39261 56256 73242
83234 90228 93224 99902 00222
14216 33206 36202 51194 59190
69185 73183 80181 99903 15163
26162 36157 48154 56152 88140
99904 00138 06134 26133 42129
48126 65123 99905 04115 31108
48105 74099 99906 11092 65089
87084 99907 11080 97066 99908
48065 AF306

AXBT 06
Profile
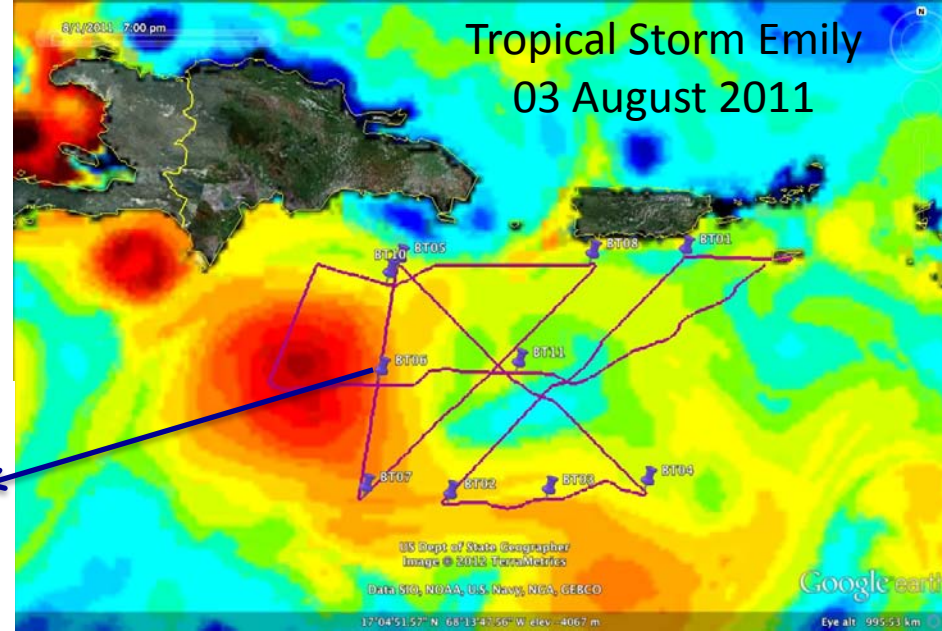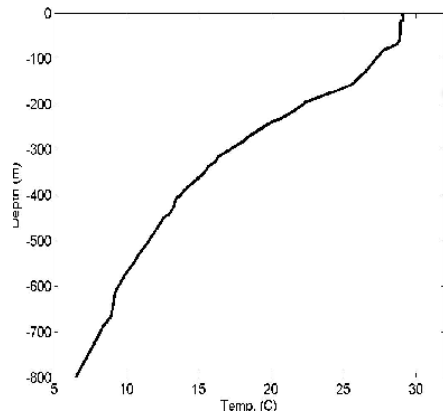
- Varied spatial distribution
  - Radius of influence
- Profile data format
  - "Significant" levels only
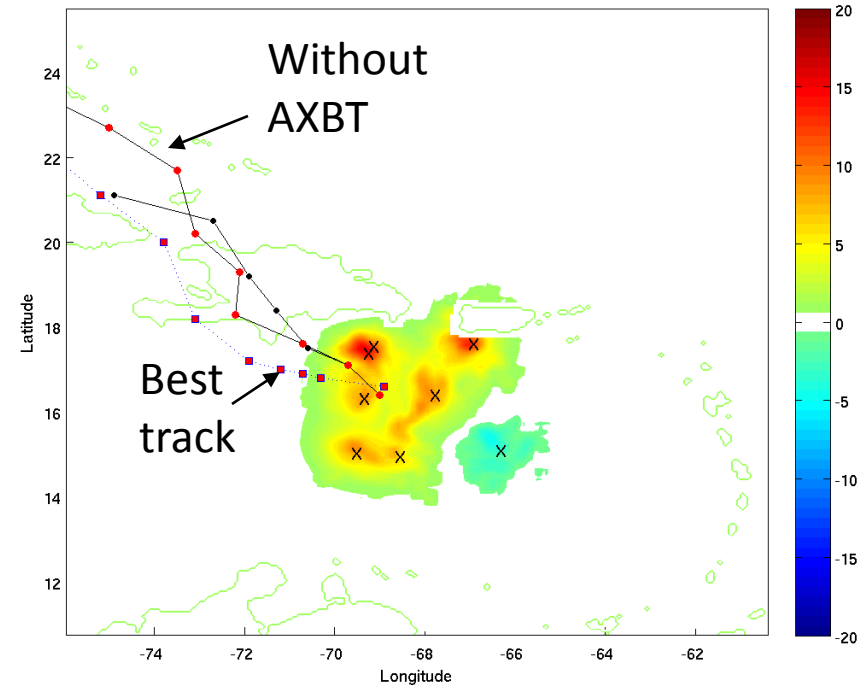 - Discussion ongoing regarding optimal vertical resolution

Sea Surface Temperature Difference(C), 2011080312

AXBT Impact Study – Tropical Storm Emily

Ocean Heat Content (2011080312)

Ocean Heat Content (kJ/cm**2), 2011080312 with AXBT

With AXBT

AXBTs
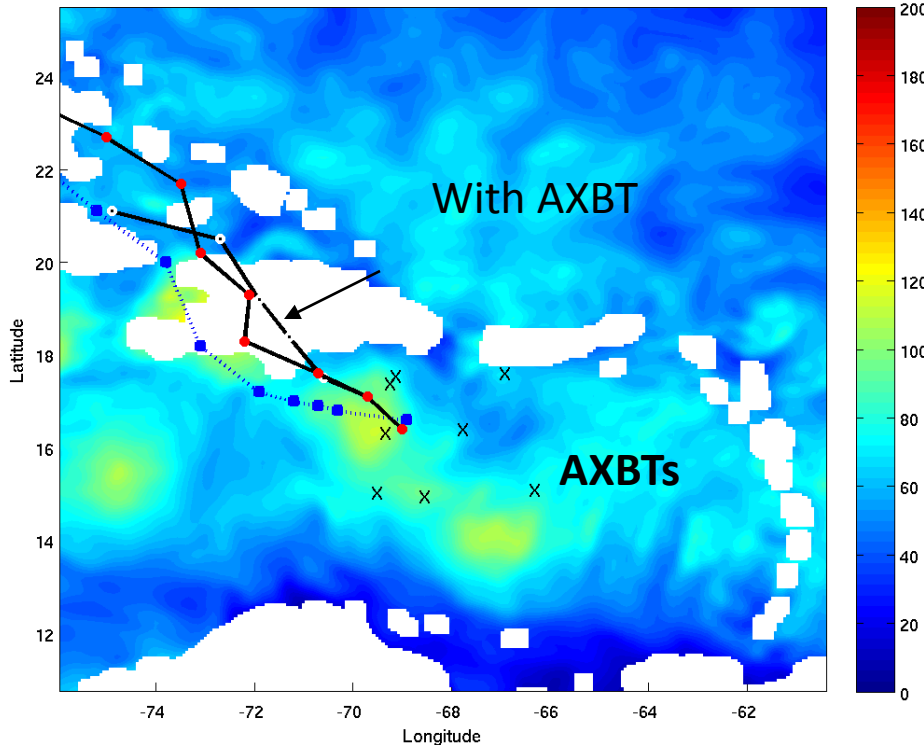
OHC difference

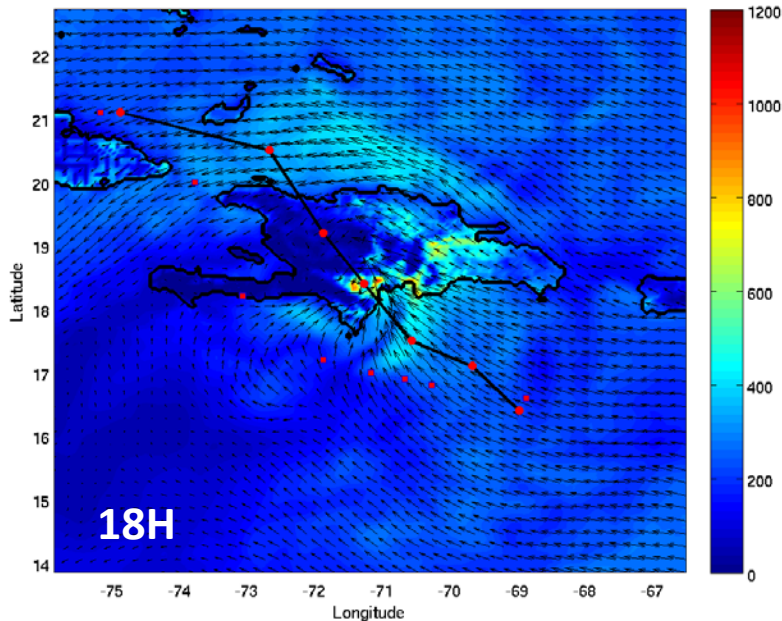Ocean Heat Content Difference (kJ/cm**2), 2011080312

Without AXBT

Best track

➢ **Assimilation of AXBT data increased the model initial OHC by as large as 19 kJ/cm², which results in initially 0.3°C warmer SST north of the model cyclone center**
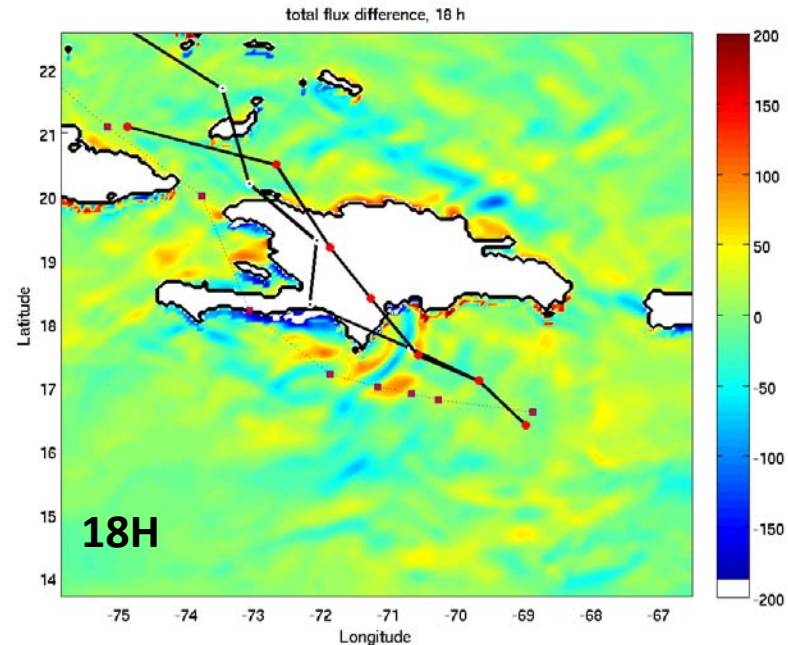
AXBT Impact Study – Tropical Storm Emily

Sensible+Latent flux (with abxt)

Total flux difference

➢ **The AXBT assimilation has a larger total flux prior to model landfall time**

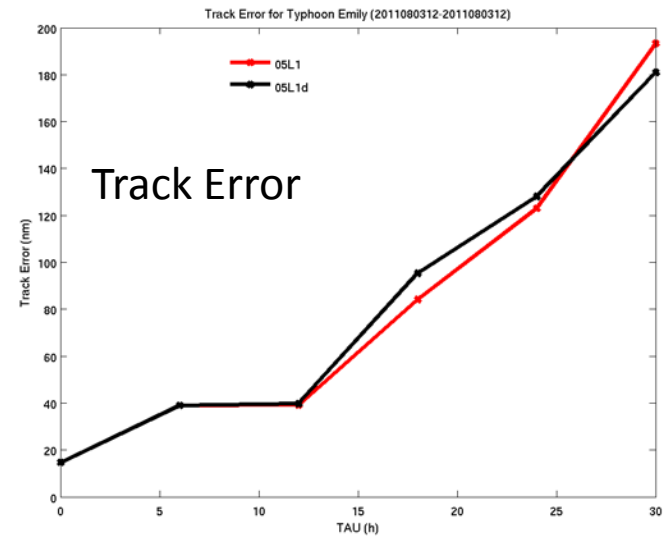➢ **Weaker ocean cold wake with the AXBT assimilation**

With AXBT

Intensity Error for Typhoon Emily (2011080312-2011080312)

Intensity Error

05L1
05L1d

Track Error for Typhoon Emily (2011080312-2011080312)

Track Error

05L1
05L1d

➢ **Intensity a wash…**

➢ **Track starts differ slightly after 18h**

Initial SST Difference (2011082700)

Sea Surface Temperature Difference(C), 2011082700
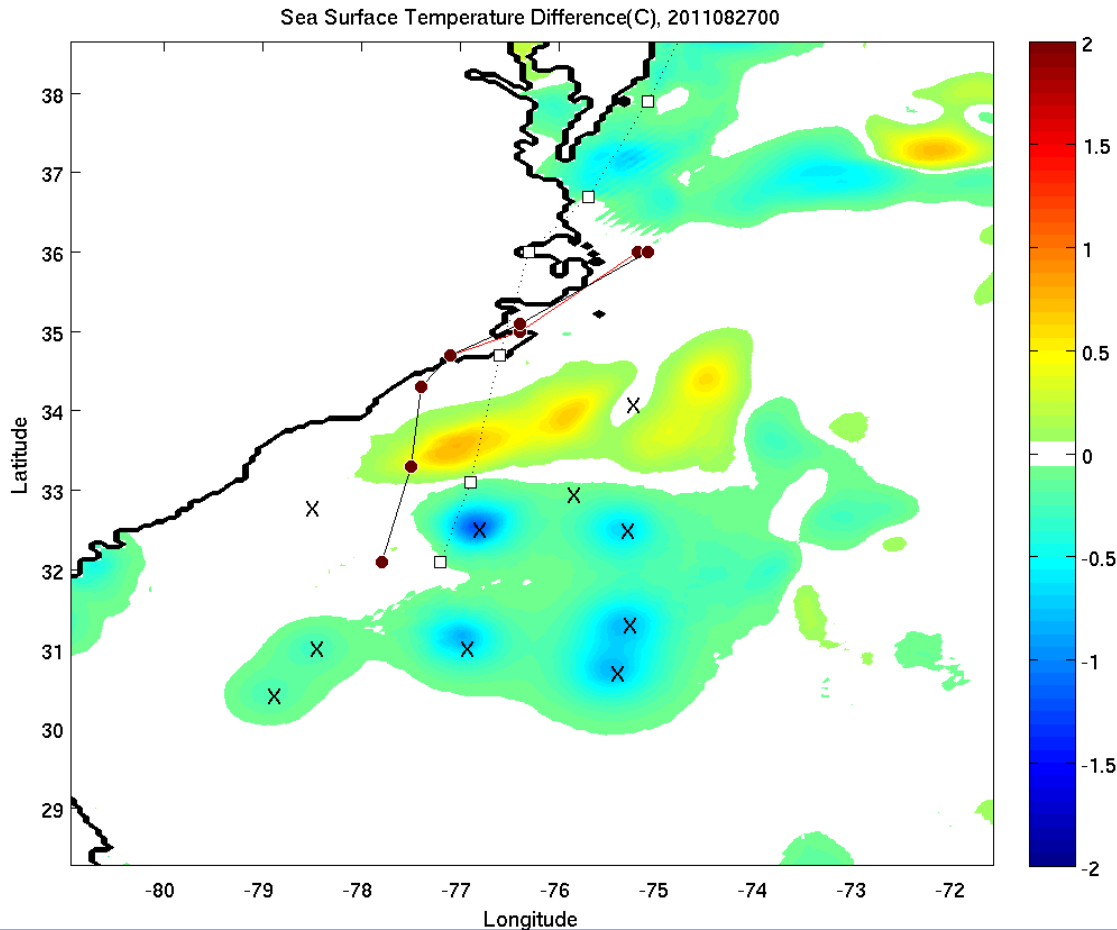
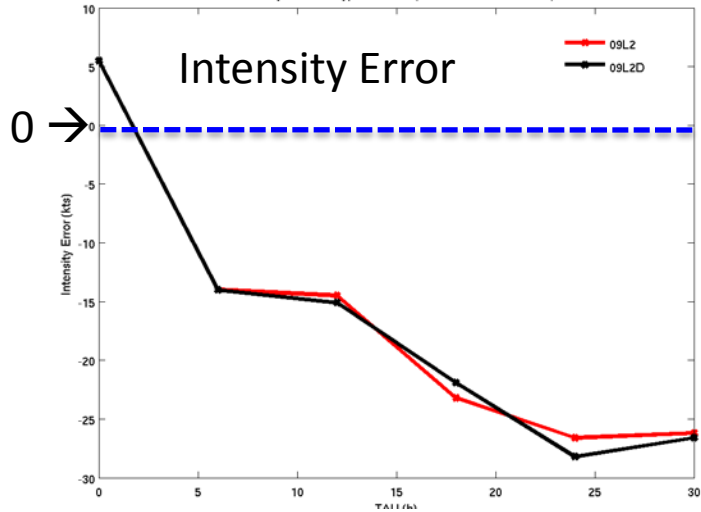Assimilation of AXBT improved the Gulf Stream cross-shore horizontal sea temperature gradient

Very small initial SST difference along the model forecast track
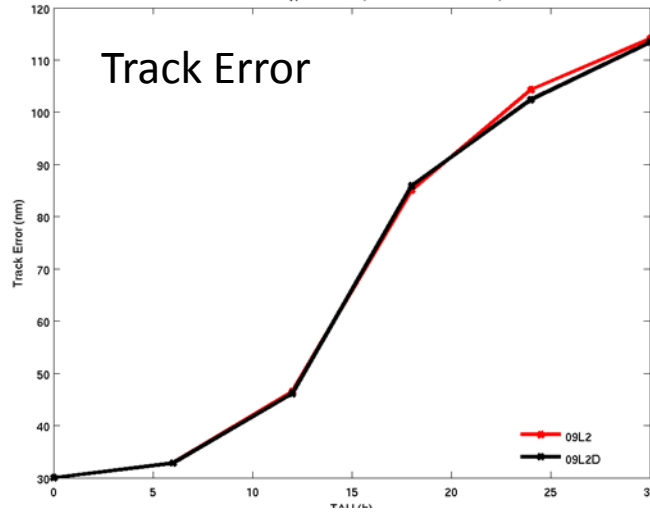
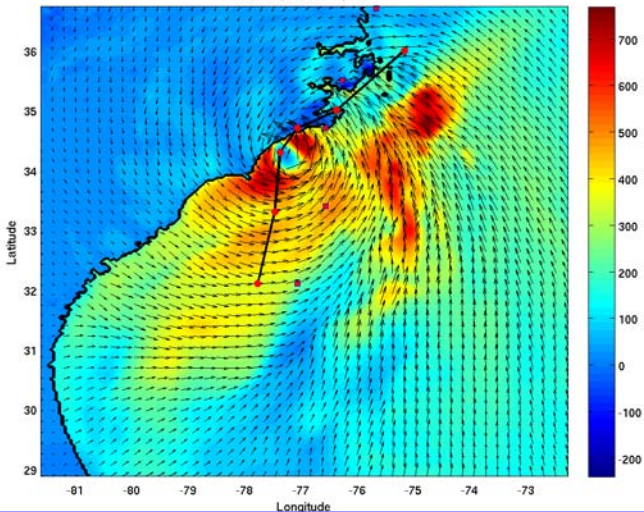Little impact on track forecast

2011082700

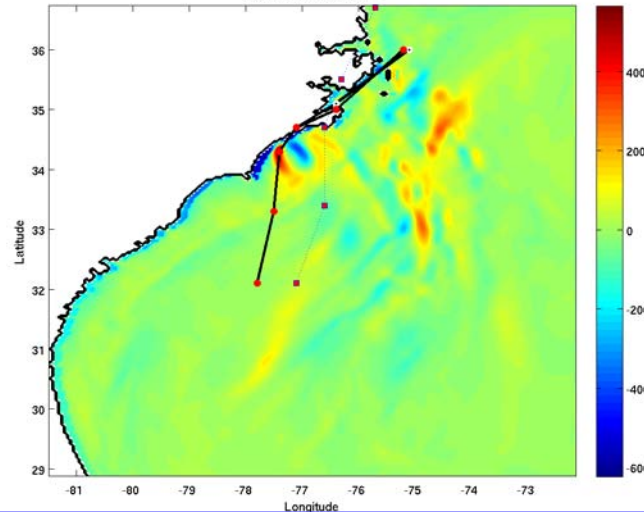➢**Very little track and intensity difference**

➢**Possibly due to model initial TC position was located in the area with little SST/OHC difference**

AXBT Impact Study – Hurricane Irene
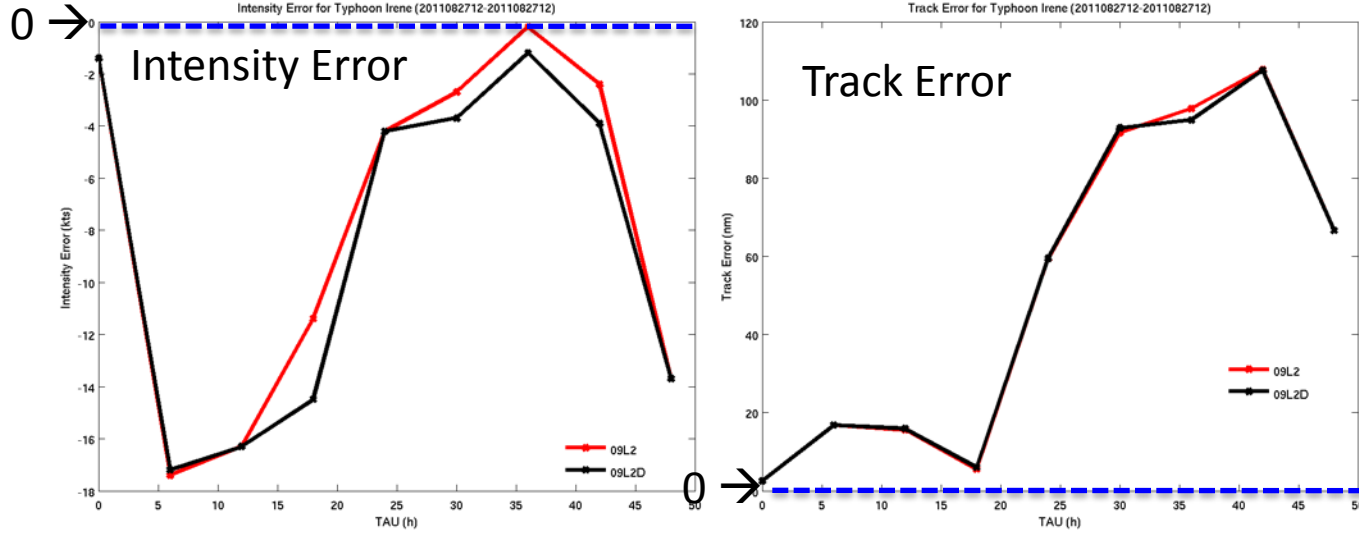

Intensity Error

Track Error

2011082712 run

➤ 2 knots smaller intensity error with the AXBT assimilation run

➤ No track difference

Courtesy: Sue Chen, NRL Monterey
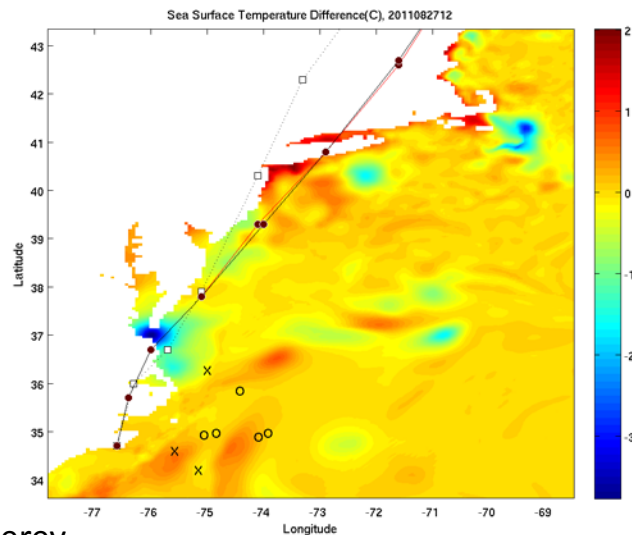
Summary of preliminary model analyses

➤ The impact of improved upper-ocean initial conditions by special AXBT observations to tropical cyclone forecast was tested in the air-ocean coupled COAMPS

➤ A total of 85 AXBTS were used in 2011 real-time coupled COAMPS-TC demonstration and 24 AXBTS were used in Emily and Irene forecasts

➤ Preliminary results showed including the AXBT observation had a small impact on COAMPS Emily and Irene forecasts.

Current Operations: Topics and Challenges

- **Equipment**
  - Re-design of AXBT launcher
  - Availability of modified launchers
- **Data & Data Path**
  - Standardize Quality Control
  - Standardize Archive Procedures
  - Resolution
    - Horizontal: appropriate radius of influence
    - Vertical: "mandatory" and significant levels?
  - Timing
    - NAVO: Real-Time Data Handling System
      - 2-hr binning
      - 2200 "black hole"
    - COAMPS-TC: scheduling model runs
  - Assimilation
    - The analysis rejected profiles if the sample:
      - did not reach at least 300m or
      - half the water column depth
    - Tunable, but time-consuming
- **Sampling strategy**
  - Model sensitivity to observation position
 - Real-time tracking of ocean features and aircraft position

3/5-yr Outlook

| Year	Duration	Data Collection Focus	Modeling Focus
2011	1 month (Jul-Aug)	Launcher, QC, Timing	Data Path, Assimilation
2012	2 months (Aug-Sep)	Launcher, QC, Drop Totals and Patterns, Tasking Order Development	Data Impact Study (COAMPS) Assimilation in near-real-time (HWRF)
2013	2 months (Aug-Sep)	Tasking Order Development, Automation	Assimilation in near-real-time
2014	2 months (Aug-Sep)	Automation / Transition?	Real-time runs
2015	2 months (Aug-Sep)	Transition?	Real-time runs
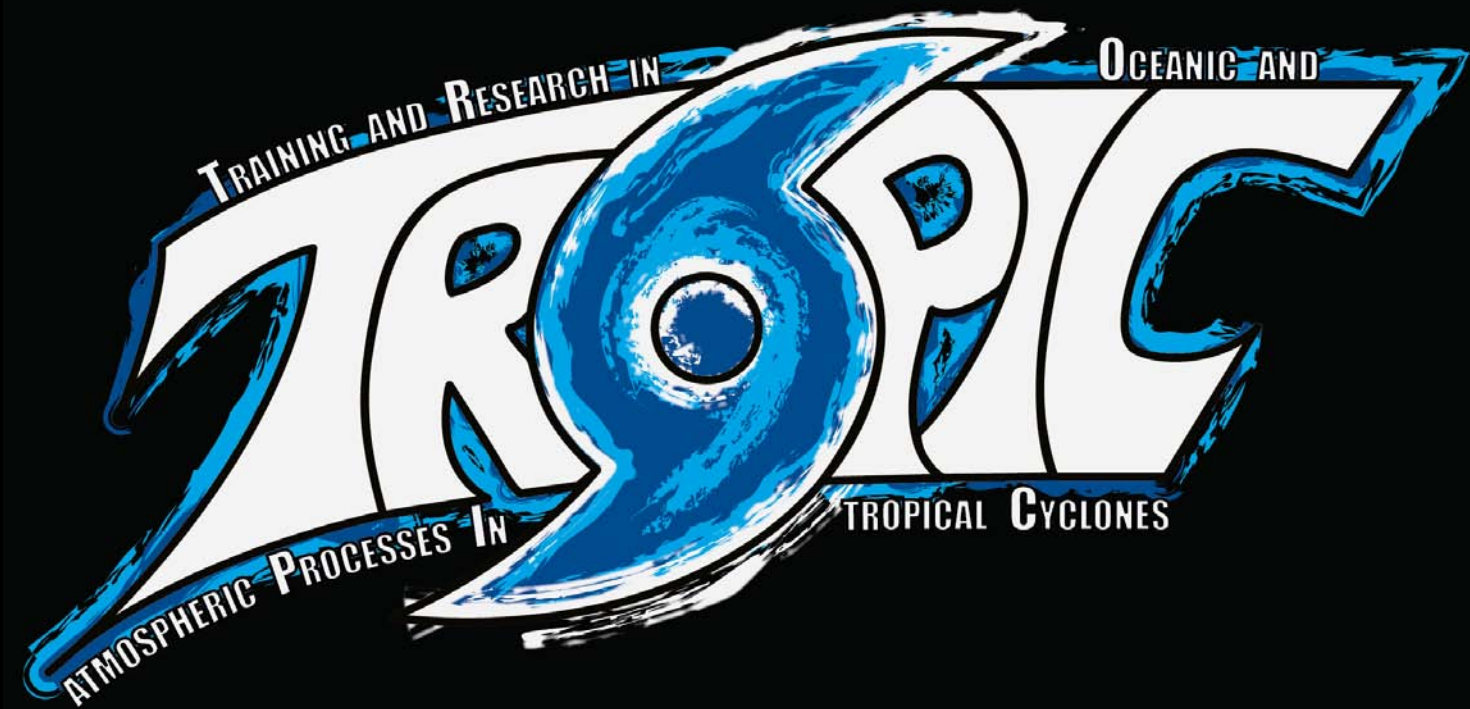
QUESTIONS?

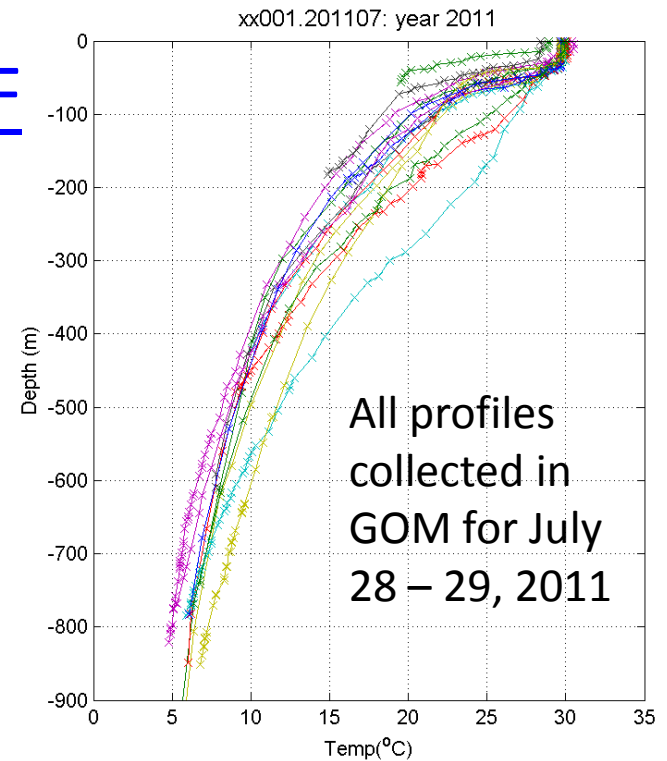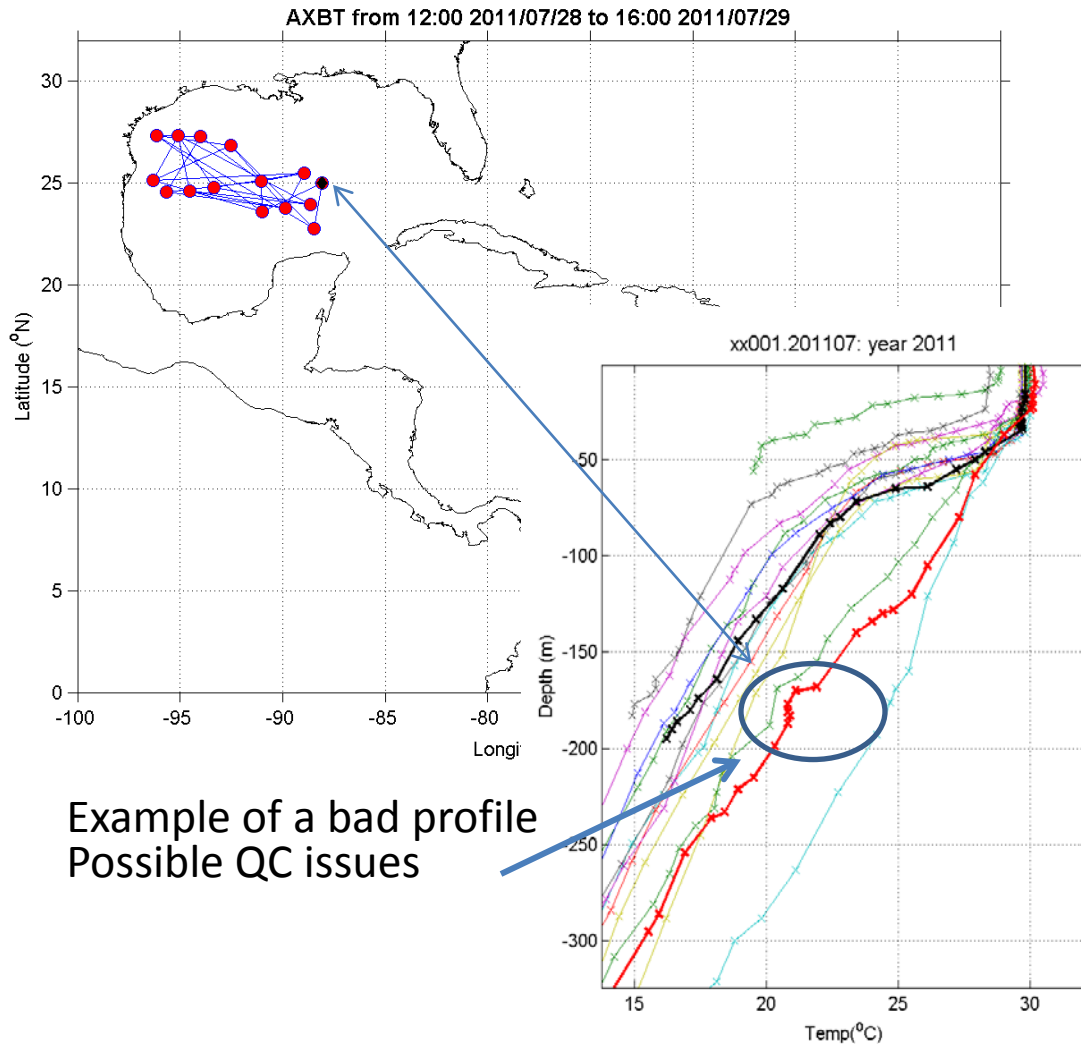# Air-Ocean-Wave Coupled COAMPS Data Assimilation System
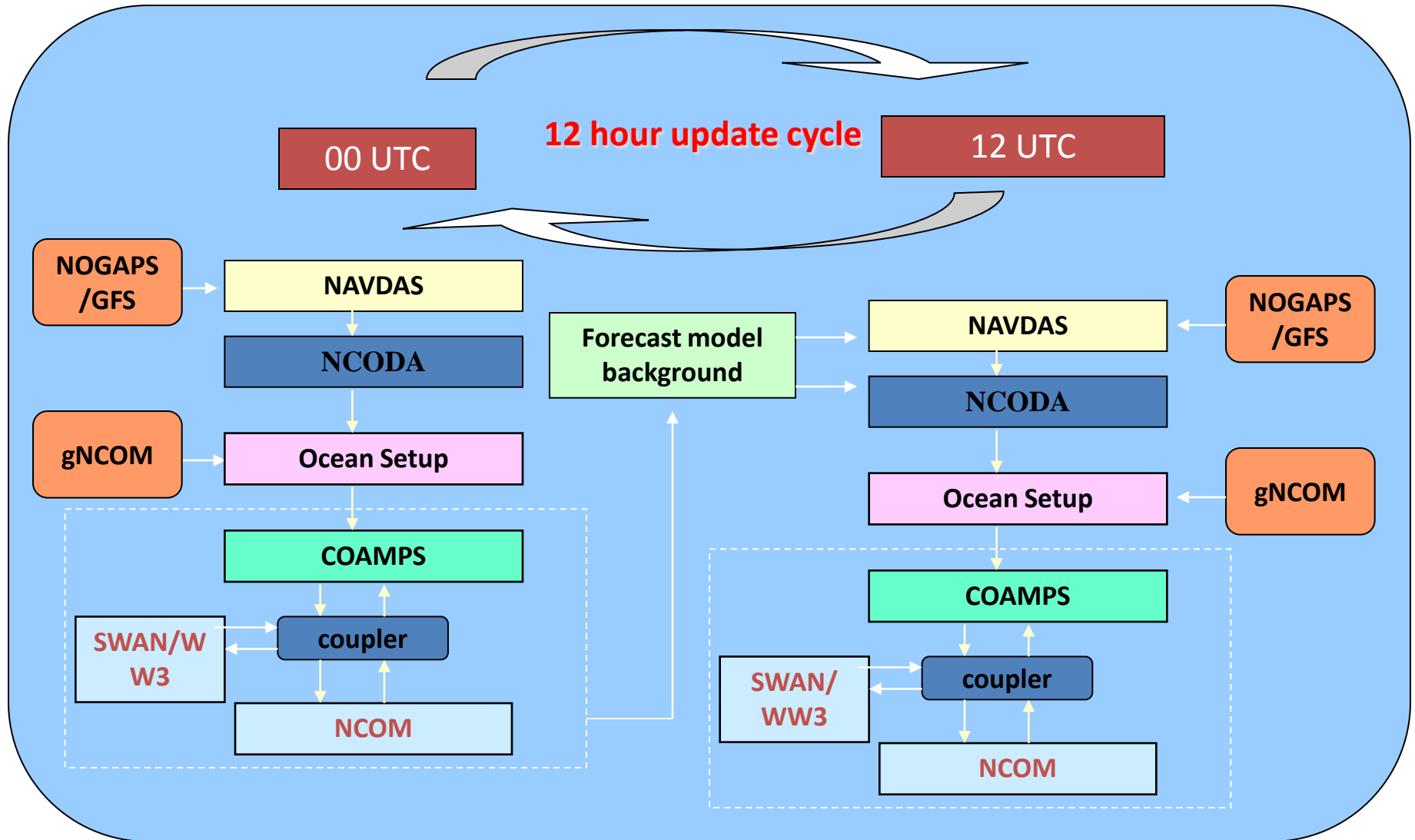
Coupled COAMPS-TC Air-Sea Interface Physics
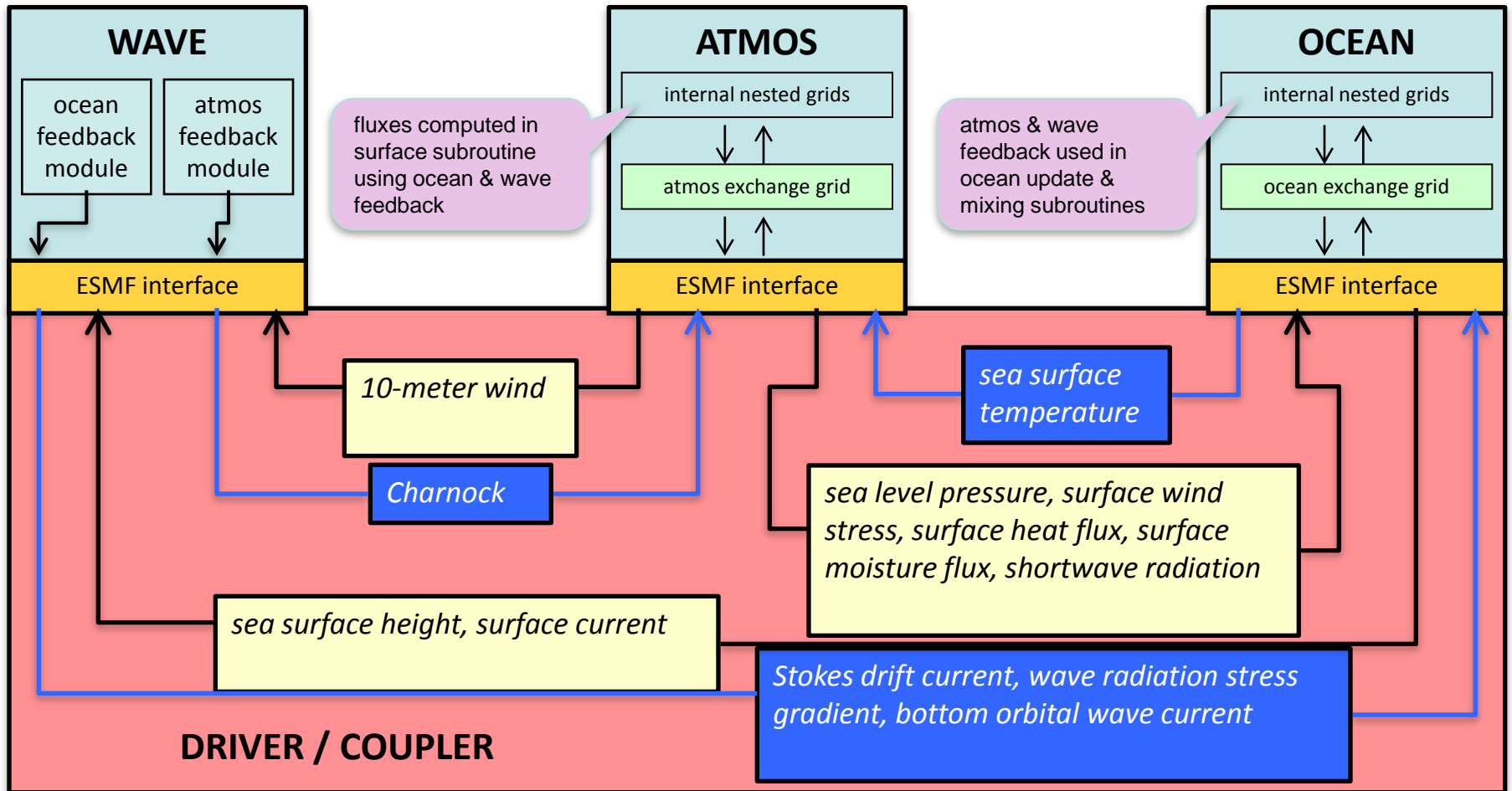
Wave model is not used for this study

Operational Results & Status: HWRF

July 28 – 29, 2011

AXBT from 12:00 2011/07/28 to 16:00 2011/07/29

xx001.201107: year 2011

Example of a bad profile
Possible QC issues

xx001.201107: year 2011

All profiles collected in GOM for July 28 – 29, 2011

Data: Timing and Quality

- Most data not received in near real time in 2011.

- Currently able to receive and decode in real time.

- Data quality occasionally questionable.

- Need to improve QC system.

Input from Hyung-Sook Kim, EMC

# Operational Results & Status: HWRF

August 1 – 28, 2011

AXBT from 17:00 2011/08/01 to 12:00 2011/08/28
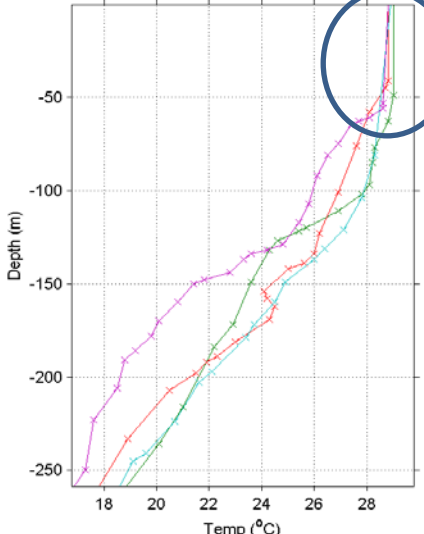
Aug. 10 - 11

Aug. 26 - 28

Aug. 1 - 4
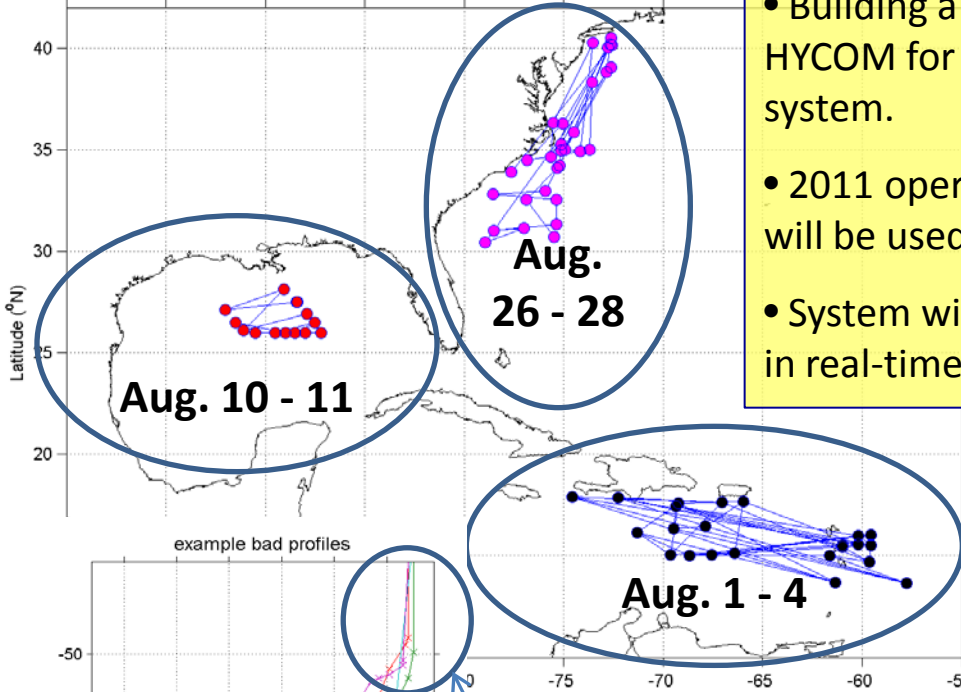
Assimilation

- Building a DA framework in HYCOM for the HWRF coupled system.

- 2011 operational AXBT data will be used to test this system.

- System will run in test mode in real-time next season.

xx001.201108: year 2011

All samples for August, 2011

Emily (5L)
Irene (09L)
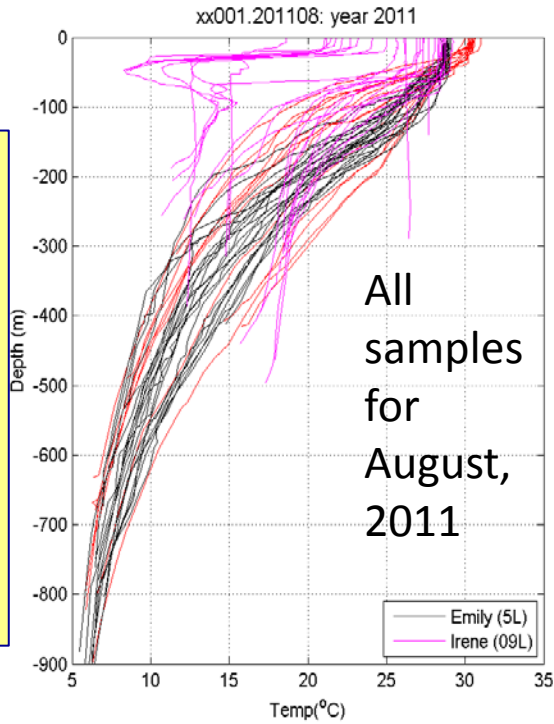
example bad profiles

1. Coarse sampling issue for some profiles during Emily and Irene

2. Temp. inversion. Real (?)

AXBT profiles for Irene (09L)

Input from Hyung-Sook Kim, EMC

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