HFIP

Ocean Model Impact Tiger Team (OMITT)

Chair and co-chair:

H.-S. Kim, G. Halliwell

Team:

L. Bernardet, P. Black, N. Bond, S. Chen, J. Cion, M. Cronin, J. Dong, I. Ginis, B. Jaimes, S. Jayne, B. Liu, E. Sanabia, G. Seroka, N. Shay, V. Tallapragada, B. Thomas, E. Uhlhorn, and L. Zhu

Institutions:

EMC, DTC, HRD/AOML, PhoD/AOML, PMEL, USNA, Navy, URI, UMiami, JISAO/UWashington, URutgers, and WHOI

Wednesday April 8, 2015

HFIP Biweekly Tele-Conference

Overview

1. Background and Goals
2. Approaches
3. Storms Proposed to Study
4. Brief Report on Activities and Progresses
5. Near Future Plans
6. Part II: Summary of Presentations

1. Background and Goals

Ocean Coupling in the Operational Prediction Systems

Background

- Observations identified
  - Shay et al. (2000) and Bosart et al. (2000) – Hurricane Opal (1995)
  - Scharroo et al. (2005) – Hurricane Katrina (2005)
  - Lin et al. (2009) – Typhoon Nargis (2008)

- But, limited Studies in the Operational Systems, especially the Importance of Ocean Model Complexity in the Systems.

Goals

Determine *the benefit of coupling ocean models of various complexity* to the hurricane atmospheric model, by assessing the impacts of the ocean components on the HWRF forecasts and the sensitivity of these impacts on air-sea interface, surface flux, and atmospheric parameters.

2. Approaches

Ocean Models and Complexity

1. <u>3D Ocean Coupling</u>
   - Operational: POM w/ HWRF
   - Experimental: HYCOM w/ HWRF, and NCOM w/ COAMPS-TC

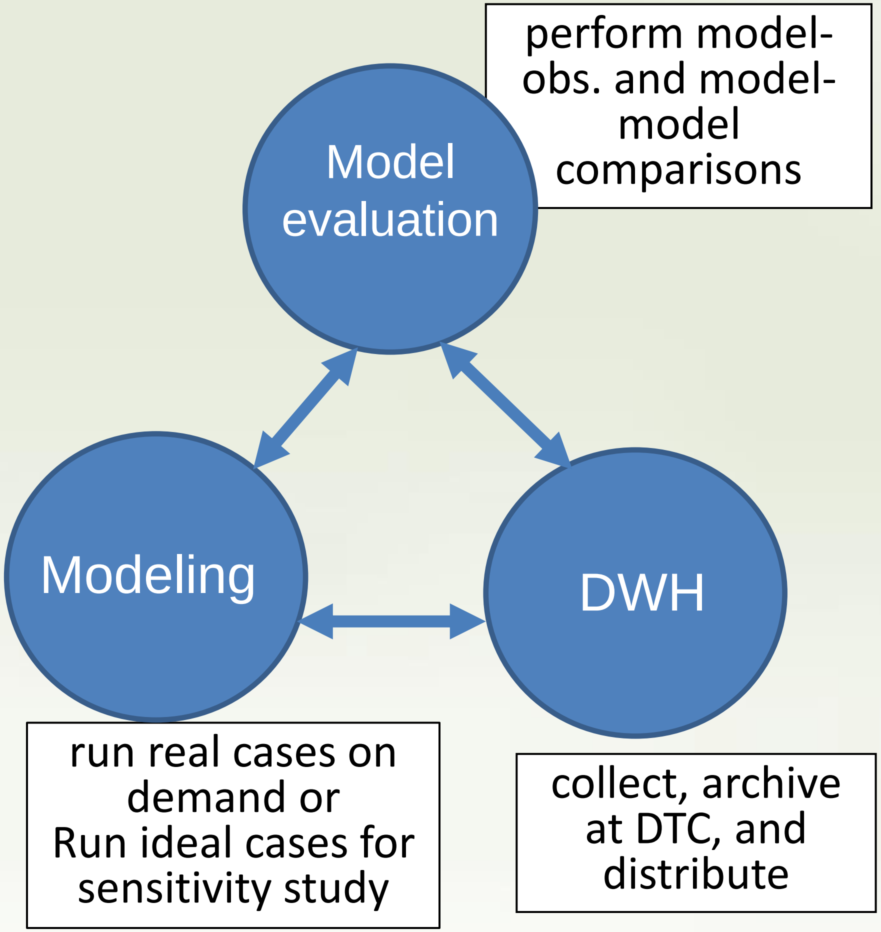
2. <u>1D Ocean Coupling</u>

   Mellor-Yamada and KPP

3. <u>Specified SST</u>

- Persistent SST from GFS (RTG), NCODA and RTOFS
- Update SST
  - GFS and (NCODA) – daily
  - RTOFS – hourly

Groups and Primary Tasks



3. Storms of interest (in red and pink fonts are priority)

#	Year	Storm (basin)	Lead	Period and area	Ocean data	Atm. Data
1	2014	**EDOUARD (ATL)**	Uhlhorn	9/12 18Z (pre) 9/15 18Z (in) 9/17 18Z (post) Area: 22-30N, 60-48W	AXBT, AXCP, AXCTD	dropsonde, Flight data (Coyote & H3)
2	2014	**Fengshen (WNP)**	Bond	7-9 Sep.	T, S, Currents	P, RH, Temp, Precip., Flux
3	2013	**Pabuk (WNP)**	Bond	23-26 Sep.	T, S, Currents	P, RH, Temp, Precip., Flux
4	2014	**JULIO (EPAC)**	Sanabia; Chen	Aug. 4-15	AXBT, ALAMO	dropsonde
5	2014	**ISELLE (EPAC)**	Sanabia; Chen	Aug. 4-15	AXBT, ALAMO	dropsonde
6	2014	**Gonzalo (ATL)**	Halliwell	Sep 12, 15 and 17	Seaglider	
7	2013	**Soulik (WNP)**	Kim	Aug. 8 – 10	Remote sensing SST&SSH	none
8	2013	**Haiyan (WNP)**	Kim	Nov. 5-10	Remote Sensing SST&SSH	none
9	2012	**ISAAC (ATL)**	Sanabia; Jaimes	8/16 (pre), 8/26-28 (in), 8/30 (post); area: GOM	AXBT, AXCP, (AX)CTD	dropsonde

4. Activities as of April 8

Bi-weekly Telecon since Jan. 14, 2015

1. Jan. 30, Benjamin James & N. Shay
   Observations of upwelling and downwelling induced by Hurricane Isaac (2012)
2. Feb. 12, Hyun-Sook Kim
   Made a set of MATLAB codes available through HWRF Contrib Repository
3. Feb. 13, Christina Holt and Ligia Bernardet
   a) HWRF Contrib Repository;
   b) Model and observation data sharing.
4. Feb. 27, Lin Zhu
   The simulation of 06L Edouard (2014) by operational HWRF (FY14).
5. Mar. 2–3 IHC, Presentation list on slide 6.
6. Mar. 13 – Discussion on the work plan and other pending items
8. Mar. 27, Beth Sanabia and P. Black
   2014 AXBT Demonstration Project: Operations Summary and Research Update.

blue font - see summary of their presentations in Part II

4. Activities as of April 8

Behind the scene

1. Final draft of OMITT work plan went out for review (Mar. 26, 2015)
2. 1D and 3D HYCOM coupling to HWRF (2015 version) for ideal case study was completed (J. Dong).
3. Experiments of stationary and moving storms using 1D HYCOM-HWRF were done (J. Dong).
4. A set of MALAB codes made available through DTC's HWRF contrib repository (H.-S. Kim)
5. Modification of the SHIPS code is in progress in order to extract from simulations and fill the TC parameter metrics (B Liu).
6. High frequency simulation outputs are being produced for Hurricane Edouard, for consistent and complete comparisons against observations (L. Zhu).
7. MPI-POM ("POM") simulations with different IC SST were conducted and comparisons of temperature simulations were performed against AXBTs (I. Ginis).
8. DTC – MATLAB diagnostic tools made available (L. Bernardet)

blue font - see summary of their presentations in Part II

Presentations related to OMITT

@ 69th Interdepartmental Hurricane Conference

- *Upper Ocean Observations in Hurricane Edouard. by* Uhlhorn et al.
- *Support for Users and Developers of the Hurricane WRF Model. by* Bernardet et al.
- *Kuroshio Extension Observatory (KEO) Measurements of the Upper-Ocean Response to Tropical Cyclones in the Western North Pacific. by* Bond et al.
- *2014 AXBT Demonstration Project: Operations Summary and Research Update. by* Sanabia and Black
- *Improving the Ocean Component of the Operational HWRF and GFDN/GFDN Hurricane Models. by* Ginis et al.
- *Advanced Operational Global Tropical Cyclones Forecasts from NOAA's High-Resolution HWRF Modeling System. by* Tallapragada
- *Proposed 2015 NCEP HWRF Hurricane Forecasting Model. by* Trahan et al.
- *Sensitivity of Ocean Sampling for Coupled COAMPS-TC Prediction. by* Chen et al.
- *NOAA's Use of the Coyote UAS in Hurricane Edouard to Enhance Basic Understanding and Improve Model Physics. by* Cion et al.
- *HFIP Ocean Model Impact Tiger Team (OMITT).* by Kim et al.

Underlined and in red font – summarized in Part II

5. Near Future Plans

1. Continue to work on Edouard - Comparisons between observations and simulations are in progress using re-runs (L. Zhu).
2. Simulation data for Iselle and Julio from operational and experimental will be available for additional analysis (H.-S. Kim and S. Chen).
3. Building ideal coupled systems will be completed (J. Dong and G. Halliwell).
4. TC parameters extracted from simulations will be made available through DTC HWRF Contrib Repository (B. Liu).
5. Building, collecting and assembling diagnostic tools are in progress.
6. Complete building tools and put in test in real-time (H.-S. Kim and B. Liu).

8. On request, can provide assistance to coordinate the 2015 field observation.
9. Analyses for other storms including Typhoon Fengshen (2014) and Soulik (2013) (N. Bond and H.-S. Kim)
10. Additional work to complete analysis for Hurricane Isaac (2012) (E. Sanabia, B. Jaimes, S. Chen, H.-S. Kim and B. Liu).

6. PART II

Summary of Presentations

1. Estimates of Air-Sea Thermodynamic Fields and Fluxes For Edouard @69th IHC by E. Uhlhorn et al.
2. HWRF Forecasts for Hurricane Edouard (2014) @2/27 telecon by L. Zhu
3. Non-coupled HWRF Sensitivity to SST @69th IHC by H.-S. Kim and J. Dong
4. AXBT observations and SST cooling analysis @69th IHC and 3/27 telecon by E. Sanabia and P. Black
5. Improving the Ocean Component of the Operational HWRF and GFDN/GFDN Hurricane Models @69th IHC by I. Ginis et al.
6. Kuroshio Extension Observatory (KEO) Measurements of the Upper-Ocean Response to Tropical Cyclones in the Western North Pacific @69th IHC by N. Bond et al.

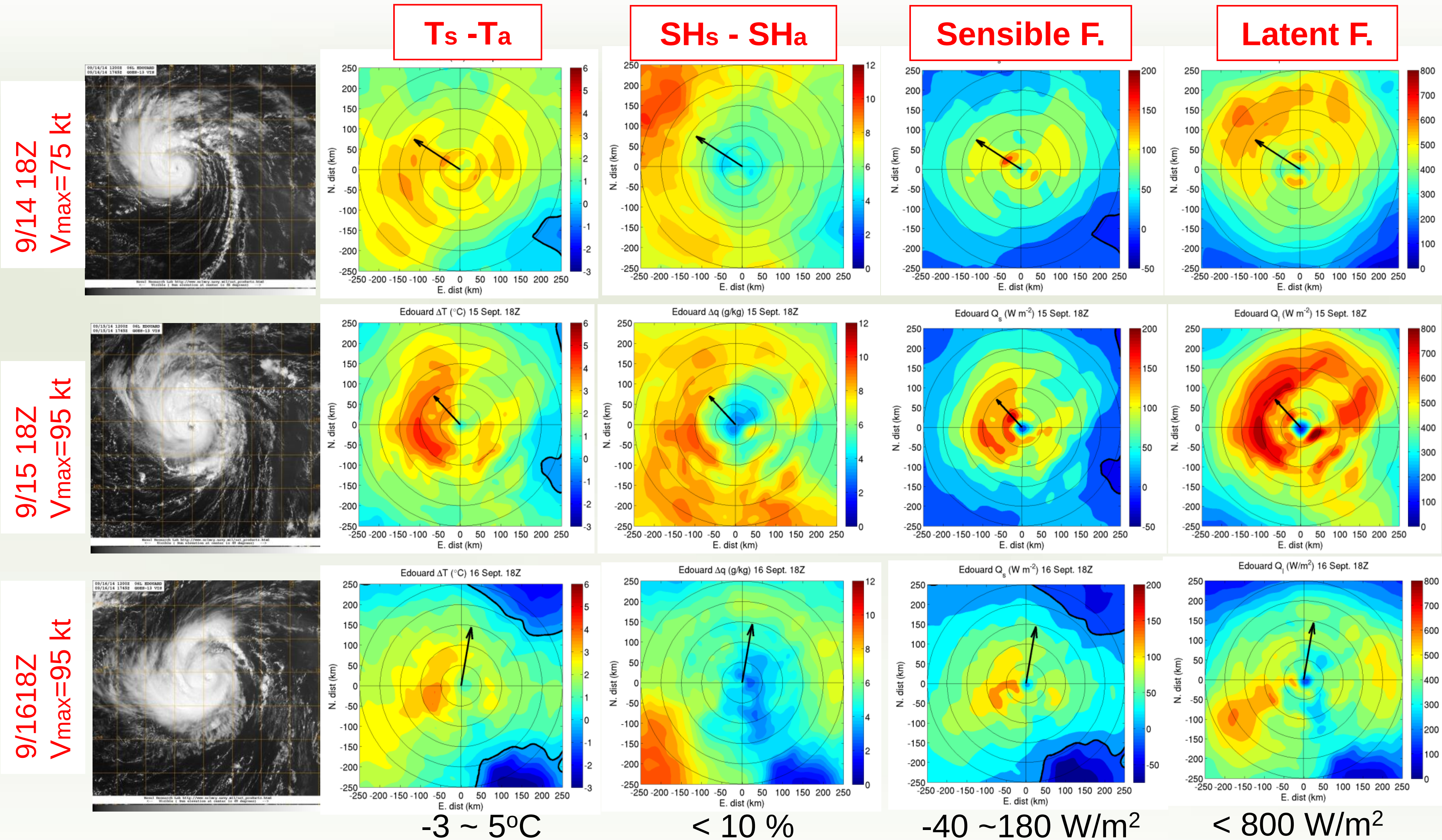
1. Estimates of Air-Sea Thermodynamic Fields and Fluxes at 69^{th} IHC by E. Uhlhorn et al.

1) SST cooling for the survey periods (9/14 - 9/16) was < -3.5^{o}C.
2) Mixed Layer Depth (MLD) deepening was < 30 m.
3) Air-sea temperature difference was ~5^{o}C for in-storm (95 kt 9/15 18Z), < 5^{o}C; 3.5^{o}C for pre- (75 kt 9/14 18Z) and post-storm (95 kt 9/16 18Z) periods.
4) Air-sea humidity difference was *O*(9 g/kg) outside the core for pre- and in-storm (left and front), and showed drier air in inner core and cold wake.
5) Cooling and drying toward the storm center are found.
6) Sensible heat fluxes changed from ~150 to ~200 W/m^2 for 1 day period (9/14 to 9/15), and a value at a weakening stage (9/16 18Z) was ~125 W/m^2. In cold wake, the heat flux was ~-70 W/m^2.
7) Latent heat fluxes varied from ~600 to 800 W/m^2 during the intensification stage (9/14 – 9/15). For the weakening stage, the flux was in order of less than 600 W/m^2, but the spatial coverage was less than one for 9/14.

Complementary graphics in slide 12.

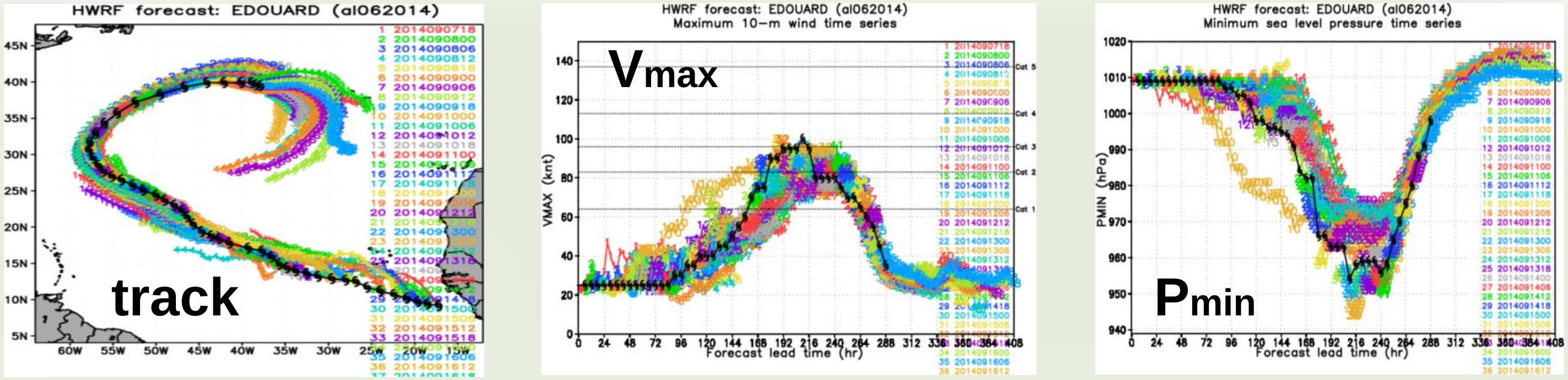
1. Estimates of Air-Sea Thermodynamic Fields and Fluxes at 69th IHC by E. Uhlhorn et al.

Summary Graphics

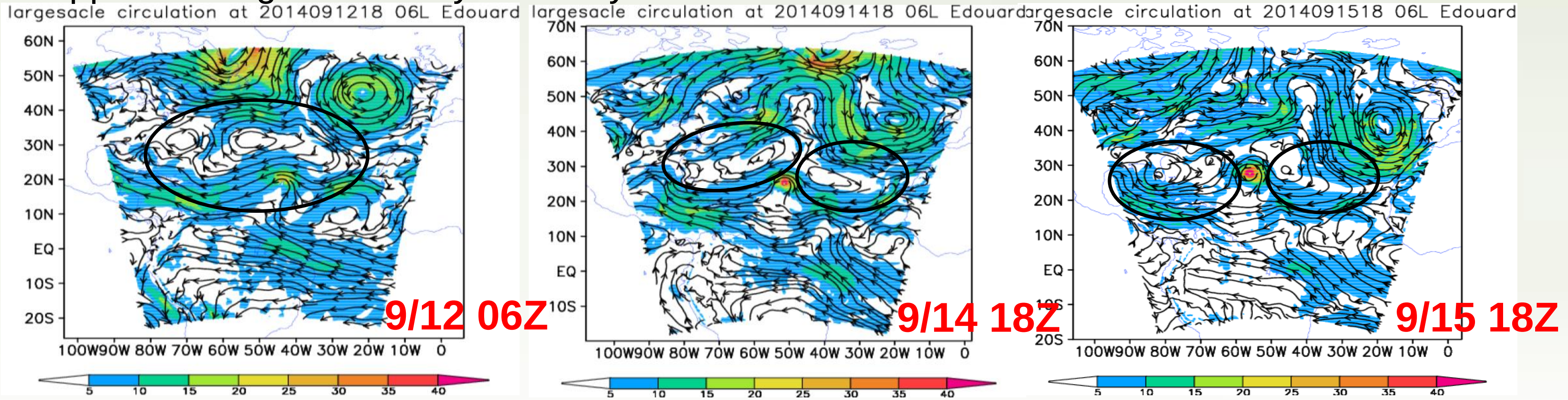


2. HWRF Forecasts for Hurricane Edouard (2014) at 2/27 telecon by L. Zhu

- Homogeneous verifications of a total of 33 cases show track error of < 120 nm, and intensity error of <~11 kt/11 hPa.



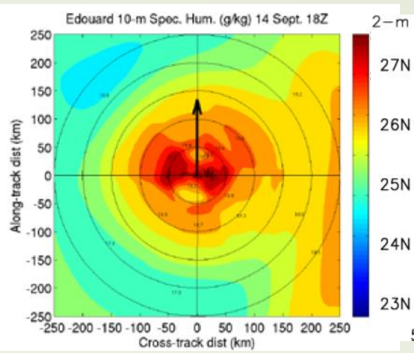
- The large scale environment simulations suggest that the subtropical high pressure was divided into two high pressure systems as Edouard situated between the systems and appeared to gain intensity relatively fast.



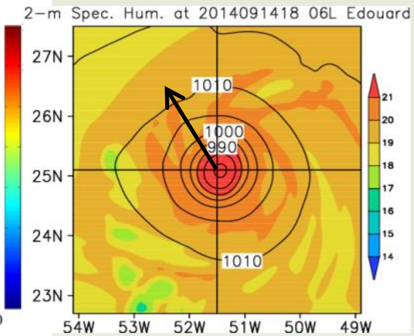
(Quantitative) Comparisons with Observations

1) Specific Humidity (g/kg) – Model values are similar, but having uniform distribution in inner core.

obs

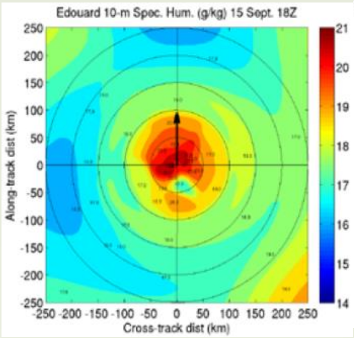


HWRF

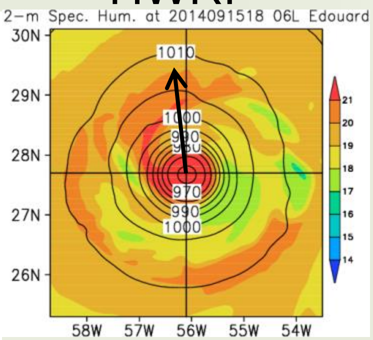


9/14 18Z

obs



HWRF



9/15 18Z

Pre-storm survey (9/24 18Z)

1) Values – similar w/ 21 g/kg max.
2) Patterns
- obs: two local peaks at left and right of the storm.
- model constant values within RMW.

In-storm survey (9/15 18Z)

1) Values – similar w/ 21 g/kg max.
2) Patterns
- obs: located the front quardrants
- model: uniform and constant in inner core

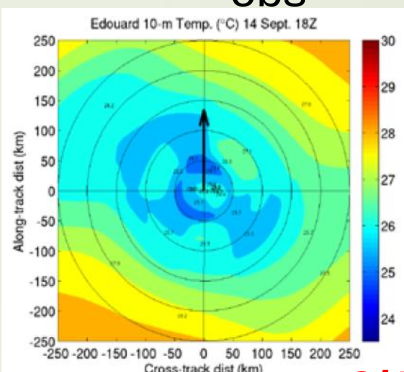
Note: Heights and the model orientation are different.
Consistent estimations are in progress (see Near Future Plans)

2. HWRF Forecasts for Hurricane Edouard (2014) @2/27 telecon by L. Zhu

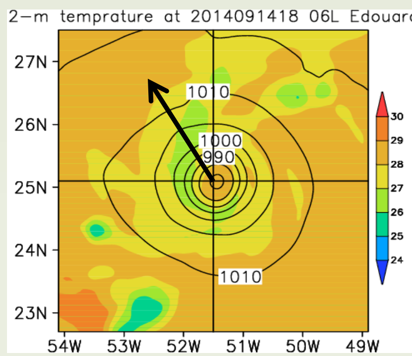
(Quantitative) Comparisons with Observations

2) Surface temperature – In general, model is warmer by <3^{o}C.

obs

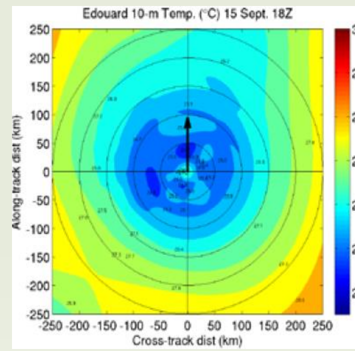


HWRF

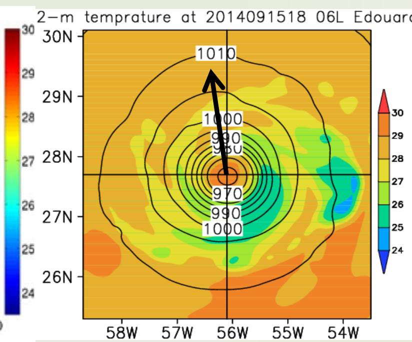


9/14 18Z

obs



HWRF



9/15 18Z

Pre-storm survey (9/24 18Z)

1) Values: model is warmer.
- obs: ~25–27^{o}C
- model: ~26–28^{o}C

2) Patterns: a relatively cold band around the core
- obs: 26^{o}C outside the core
- model: 27-28^{o}C outside the core

In-storm survey (9/15 18Z)

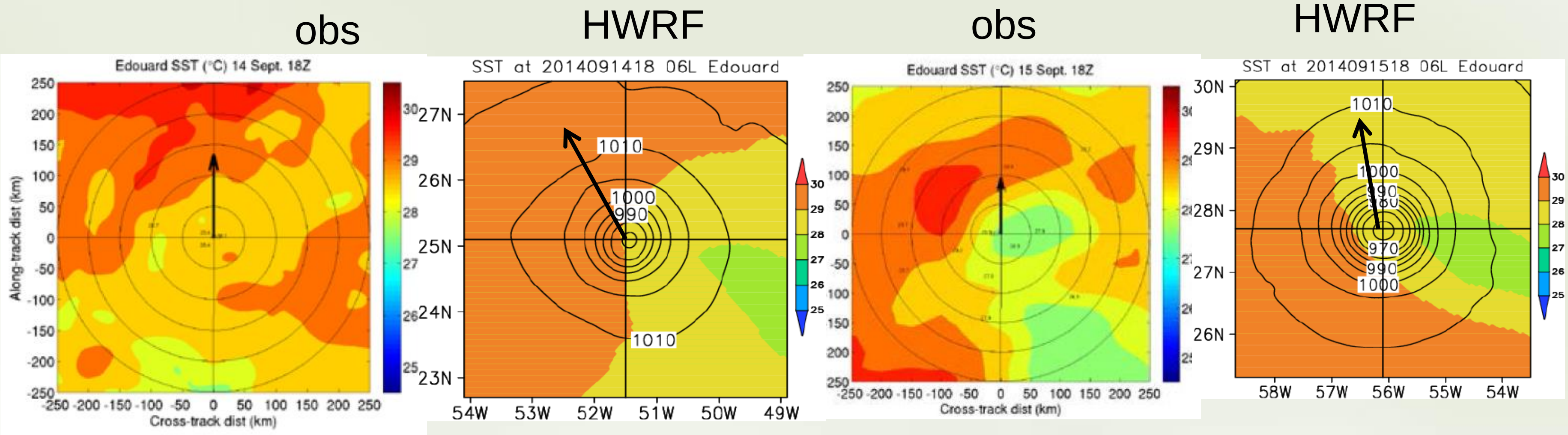
1) Values: model is warmer.
- obs: 26^{o}C (core)
- model: 29^{o}C (core)

2) Patterns:
- obs: 24-25^{o}C surrounding
- model: 25^{o}C behind the storm; >27^{o}C ahead.

2. HWRF Forecasts for Hurricane Edouard (2014) @2/27 telecon by L. Zhu

(Quantitative) Comparisons with Observations

3) Sea Surface Temperature – model is cooler for pre-storm, and warmer for in-storm, having smooth field and missing small scale variability.



Pre-storm survey (9/24 18Z)

1) Values:
- obs: ~28–30°C
- model: ~27–29°C

2) Patterns: relatively warm ahead of and cold water behind the storm.
- obs: > 29°C
- model: ~29°C

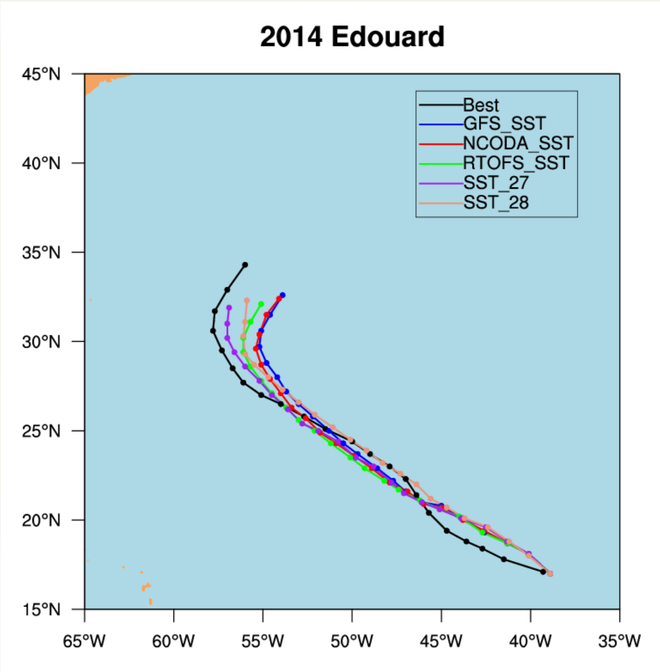
In-storm survey (9/15 18Z)

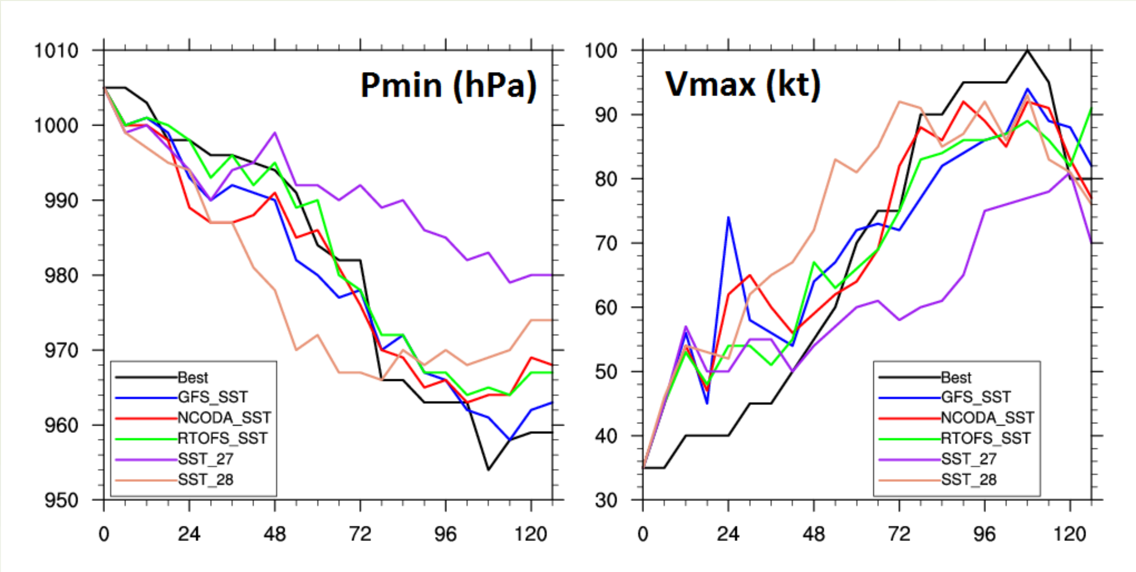
1) Values: 27-29°C.
- obs: more variations
- model: relatively uniform at 28°C

2) Patterns: warmer on left-front and cold water on rear-right, but more variations w/ obs.

3. Non-coupled HWRF Sensitivity to SST @69th IHC (H.-S. Kim and J. Dong)

Preliminary Results for Experiment 1
Non-coupled HWRF using persistent SST (spatially uniform vs. varying)





<u>Track – a similar bias pattern:</u>
northward for 0-30 hrs, southwestward for 36-66 hrs, and eastward for 72-120 hrs.

Except 28°C SST's track is excellent for 36-60 hrs.

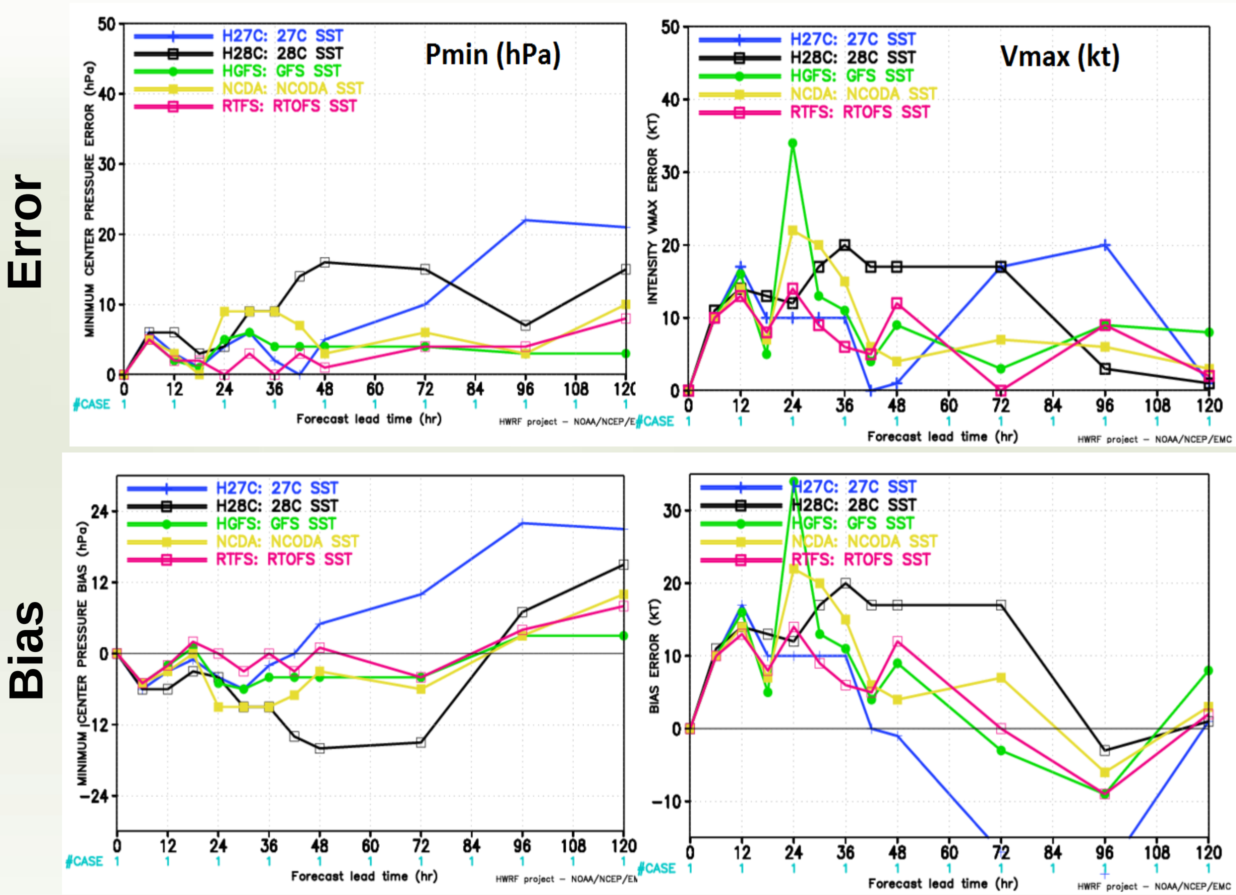
<u>Intensity – two groups:</u>

- **Large difference** between constant SSTs.
- **Less differences** among spatially varying SST.

➢ Constant SST results in under-prediction for 27°C and over-prediction for 28°C.

➢ All GFS, NCODA and RTOFS SST show a similar forecasts.

3. Non-coupled HWRF Sensitivity to SST @69th IHC (H.-S. Kim and J. Dong)



Note: different color codes from the previous slide.

1. **Constant SST** – large error at later lead times; and the same for bias to negative in Pmin for 28°C and positive for 27°C, and opposite for Vmax.

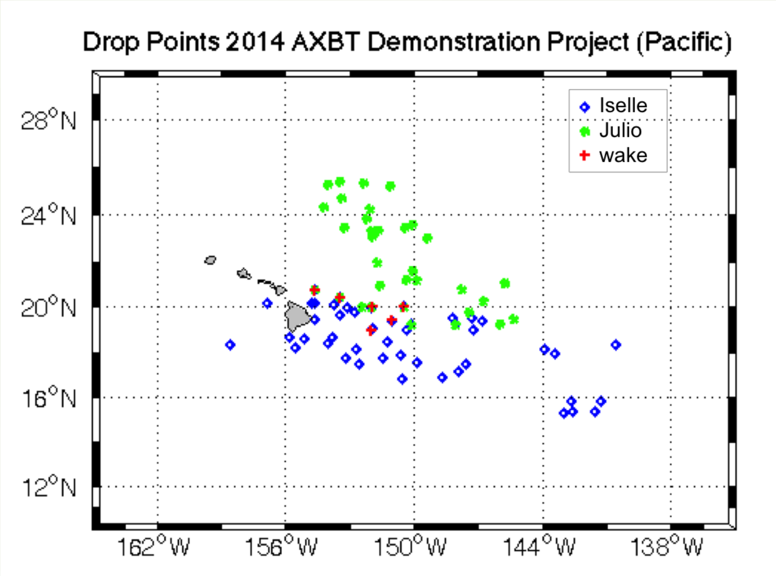
2. **RTOFS** (pink) – less spin-up/down; overall small error and bias at later lead times, cf others.

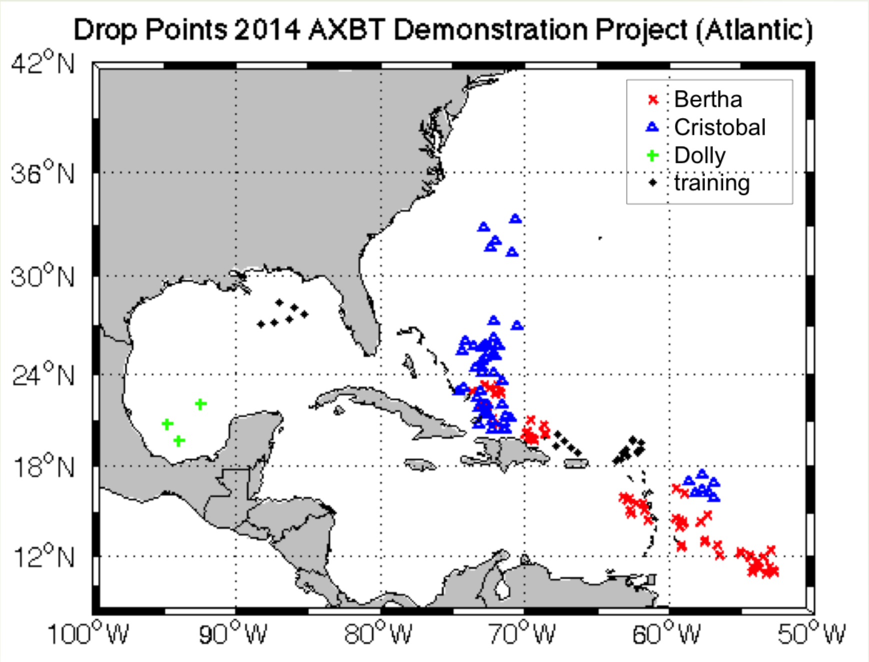
3. **NCODA** (yellow) – relatively large bias and errors, starting from 24-hr and persistent.

4. **GFS** (green) – comparatively better performed than NCODA, except abnormal peak in bias around 24 hr.

Preliminary Results ➔ Best w/ RTOFS SST
➔ Worse w/ constant SST

Deployment Activity during the 2014 Season





42 flights with 53rd WRS

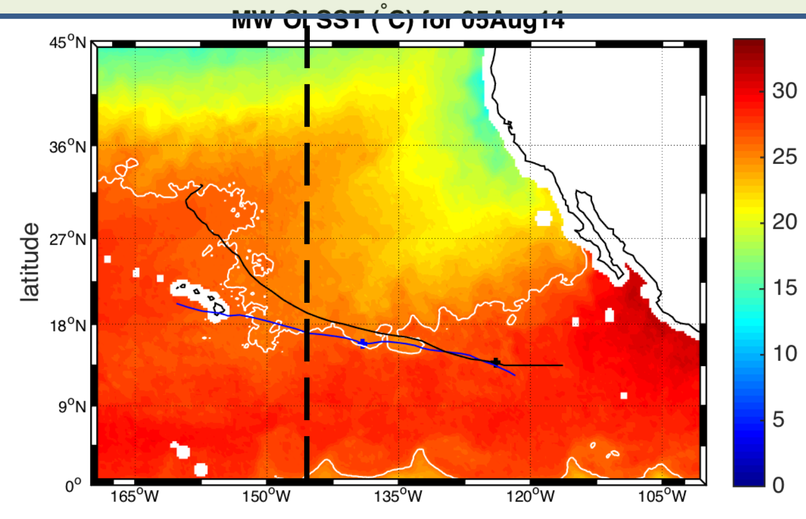
- Hurricane Bertha (5)
- Hurricane Iselle (7)
- Hurricane Julio (5)
- Hurricane Cristobal (10)
- Other invests (2)
- Transits/Training (13)

- 20 July – 15 September 2014
- 6 personnel
  - 3 Midshipmen, 2 Officers, 1 NCO
- 257 AXBTs deployed

Hurricane Iselle

Storm-Track SSTs

- Method: SST anomalies
  - SSTs at each TC center locations averaged over the 15-day period
  - Departures from the average shaded



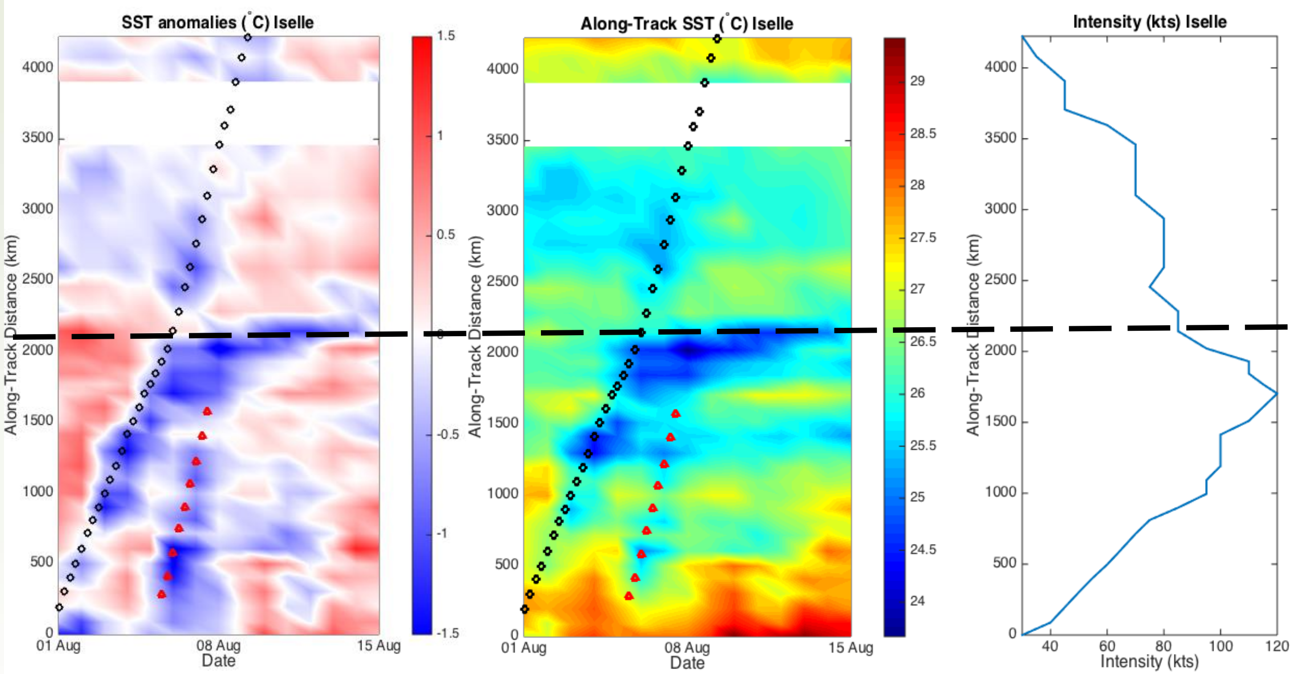
Iselle

1) Cooling most evident during intensification and maximum intensity

2) Cooling *greater* when storm speed is *slower;*

➢ Speed increased at 2000 km (west of 140W)

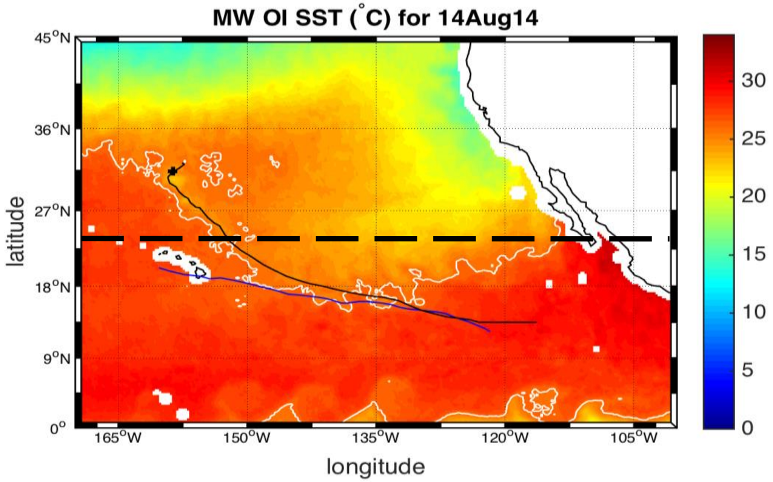
3) Post-TC warming followed by subsequent cooling as Julio crossed wake



4. AXBT observations and SST cooling analysis @69th IHC and 3/27 telecon
by E. Sanabia and P. Black

Hurricane Julio
Storm-Track SSTs

- Julio: Along-Track SSTs
  - Progression from warm-cool-warm (pre-storm) SSTs
  - Strong cooling concurrent with brief reintensification



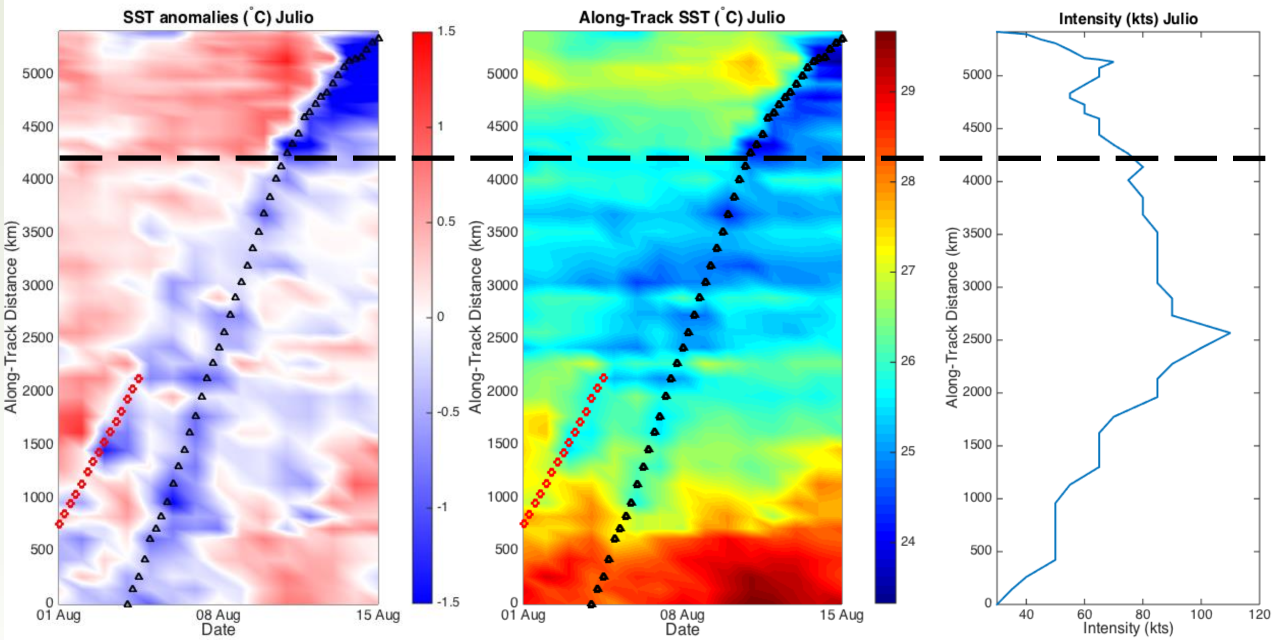
Julio

1) Cooling most evident at end life cycle

2) Cooling *greater* when storm speed is *slower;*

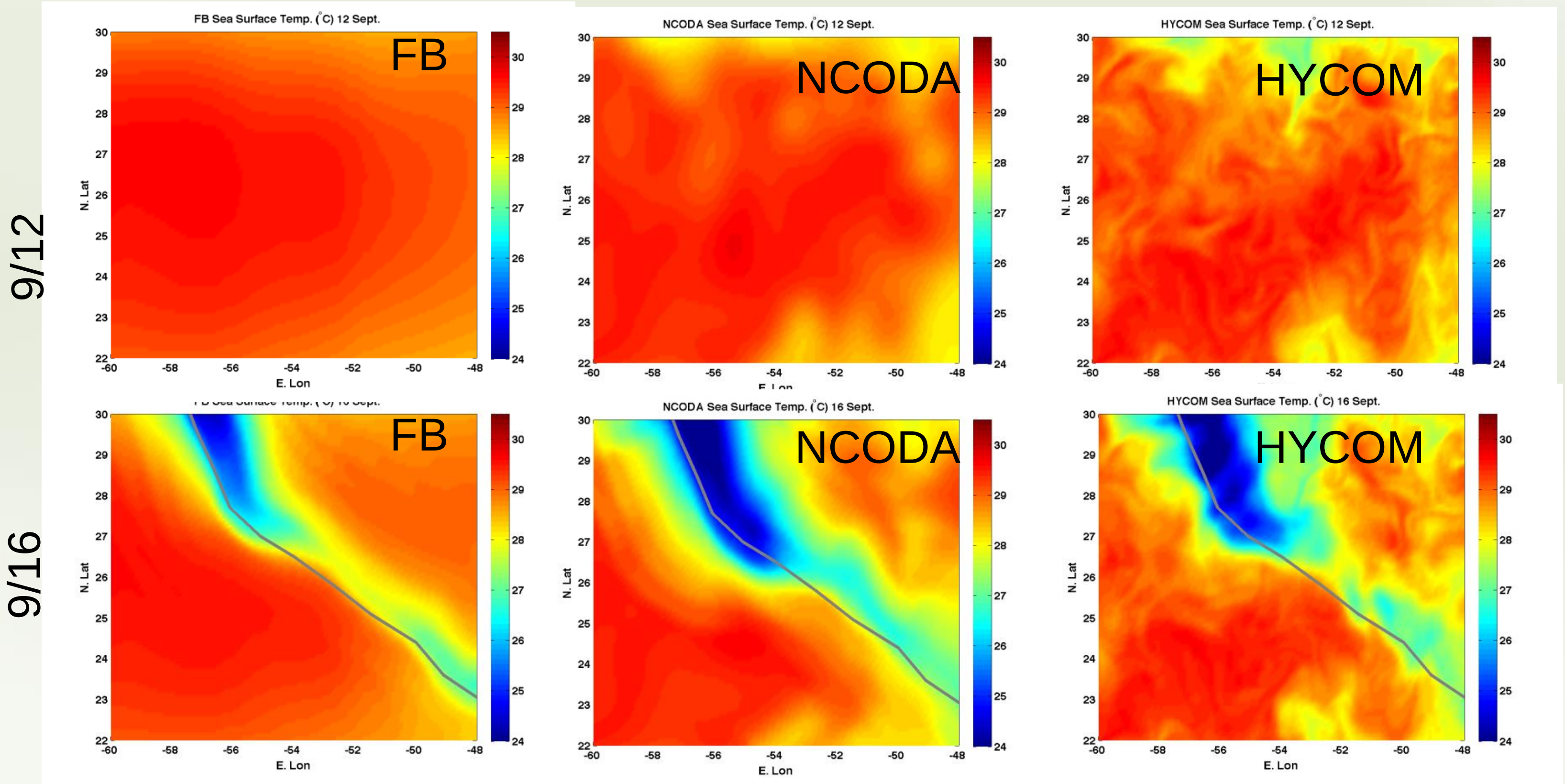
➢ Speed decreased at 2000 km (north of 25N)

3) Early cooling appears largely consistent and may have been enhanced due to passage of Iselle.



5. Improving the Ocean Component of the Operational HWRF and GFDN/GFDN Hurricane Models @69th IHC by I. Ginis et al.

MPI-POM forced with HWIND (one-way)
Ocean Initialization Options: Hurricane Edouard (2014)



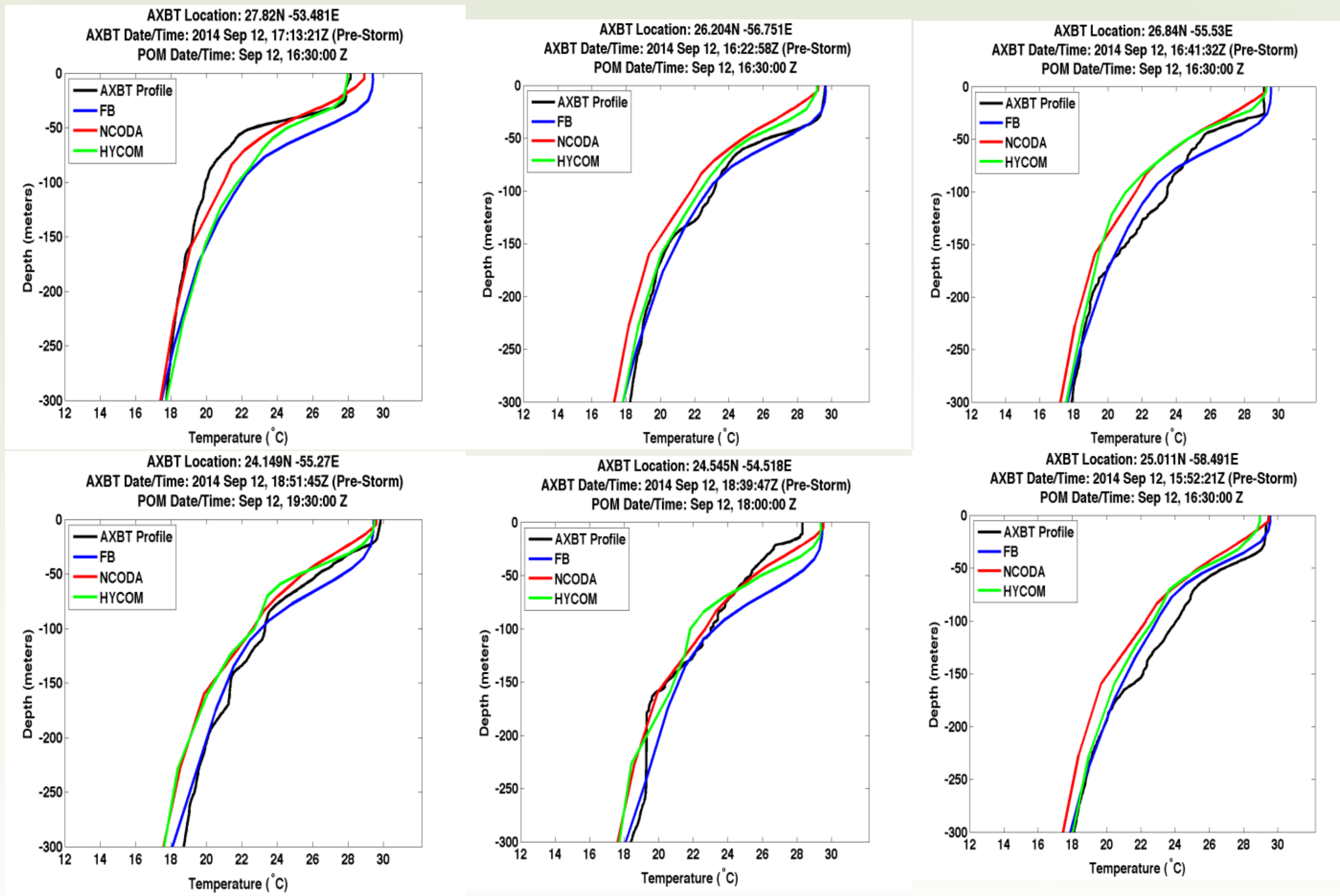
- SST Cooling is stronger for NCODA and HYCOM.
- HYCOM retains small scale variability.
- NCODA cooling takes place sooner than the other two.

5. Improving the Ocean Component of the Operational HWRF and GFDN/GFDN Hurricane Models @69th IHC by I. Ginis et al.

Evaluation of Ocean Initialization Options:

Comparison with AXBTs for pre-Storm –
warmer SST and deeper MLD for FB;
warm SST and less definitive/shallower MLD for NCODA;

9/12 (pre-storm)

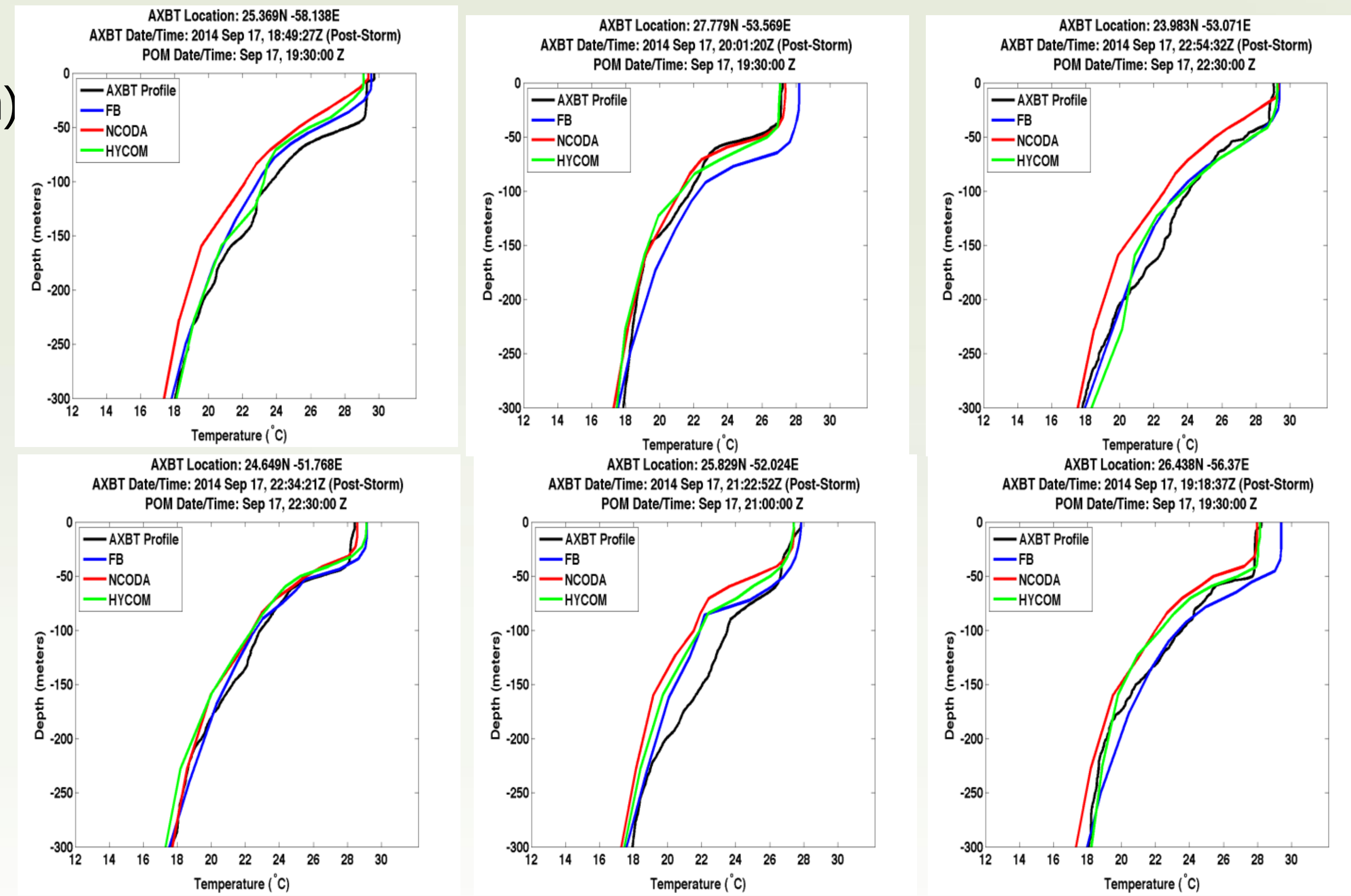


5. Improving the Ocean Component of the Operational HWRF and GFDN/GFDN Hurricane Models @69th IHC by I. Ginis et al.

Evaluation of Ocean Initialization Options:

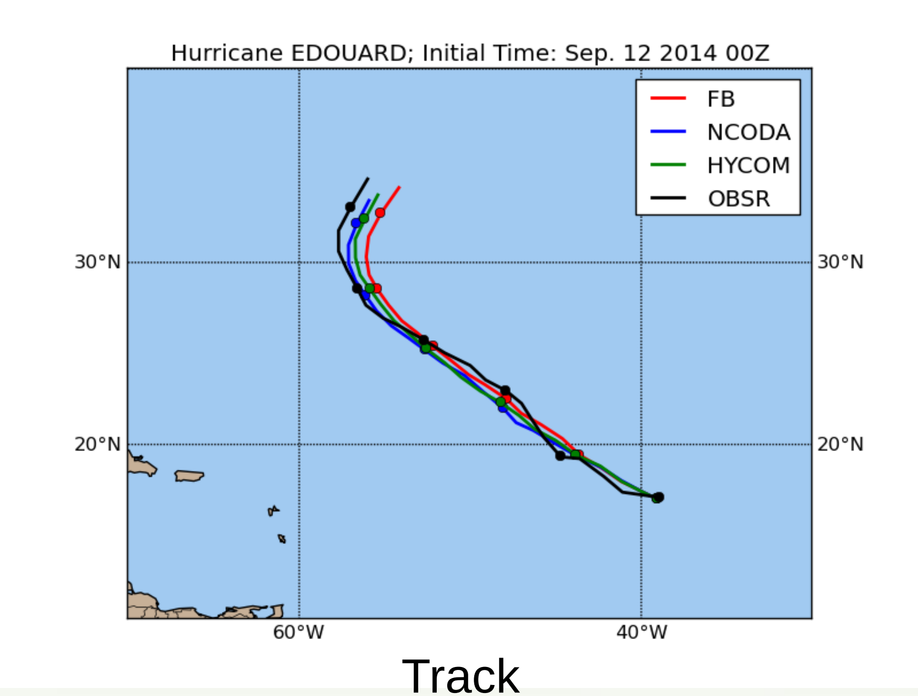
Comparison with AXBTs for post-storm – warmer SST and agreeable MLD for FB; agreeable SST and shallower MLD for NCODA; agreeable SST and MLD for HYCOM.

9/17 (post-storm)

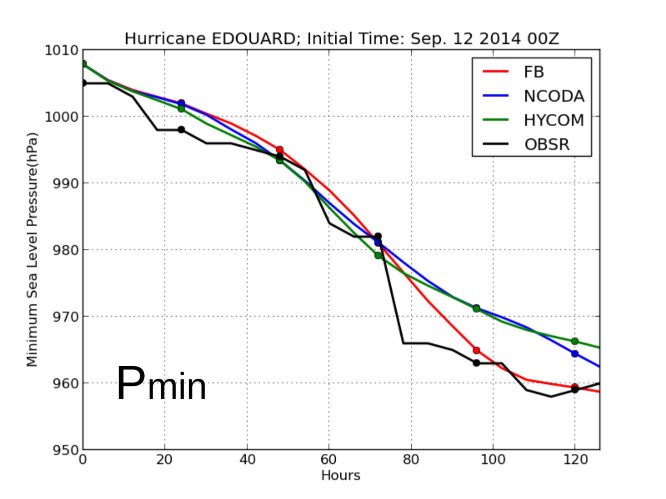


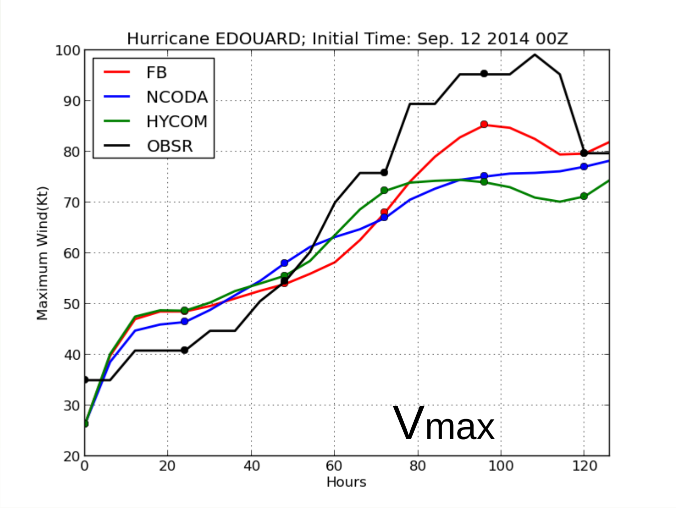
5. Improving the Ocean Component of the Operational HWRF and GFDN/GFDN Hurricane Models @69th IHC by I. Ginis et al.

Impact on Hurricane Forecasting w/ GFDL Hurricane Model
IC=2014/9/12 00Z



Track

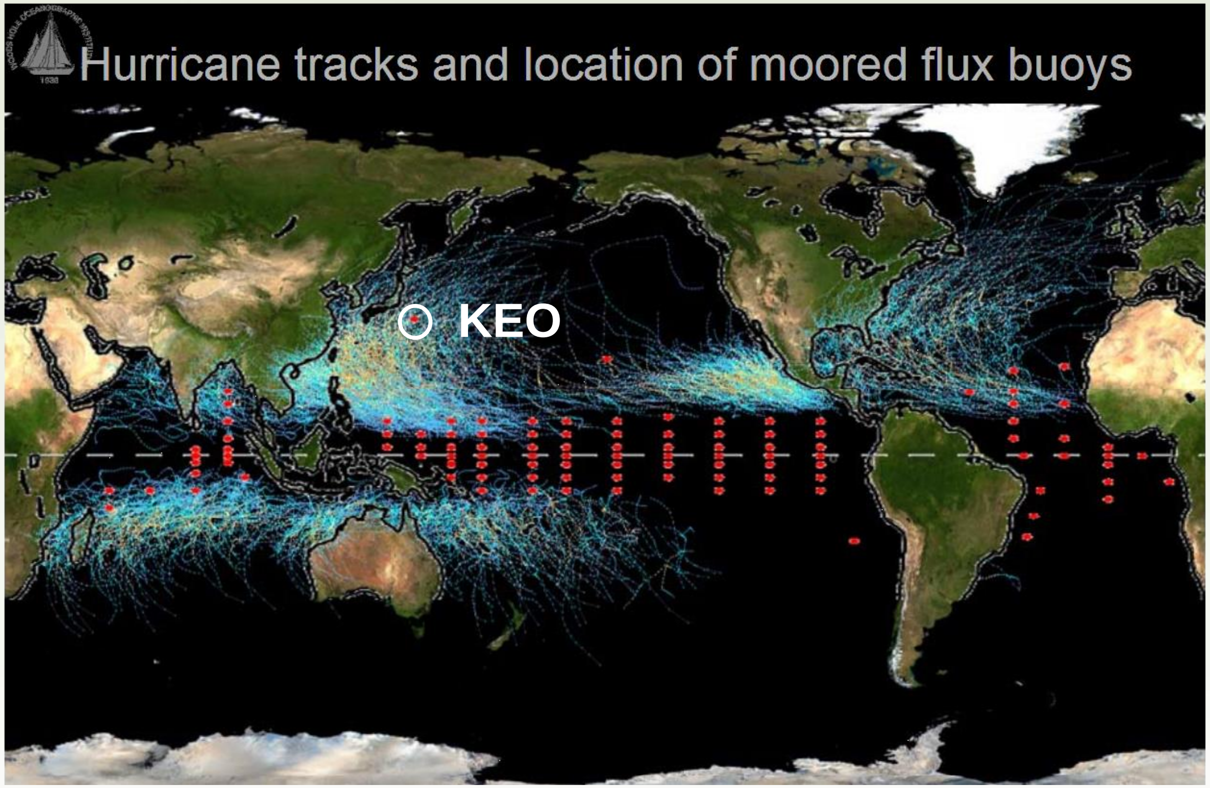




- Track forecast using FB is worse (eastward bias) than NCODA and HYCOM.
- Vmax forecast is sensitive to IC SST, having FB showing better intensity forecast.

6. Kuroshio Extension Observatory (KEO) Measurements of the Upper-Ocean Response to Tropical Cyclones in the Western North Pacific @69th IHC by N. Bond et al.

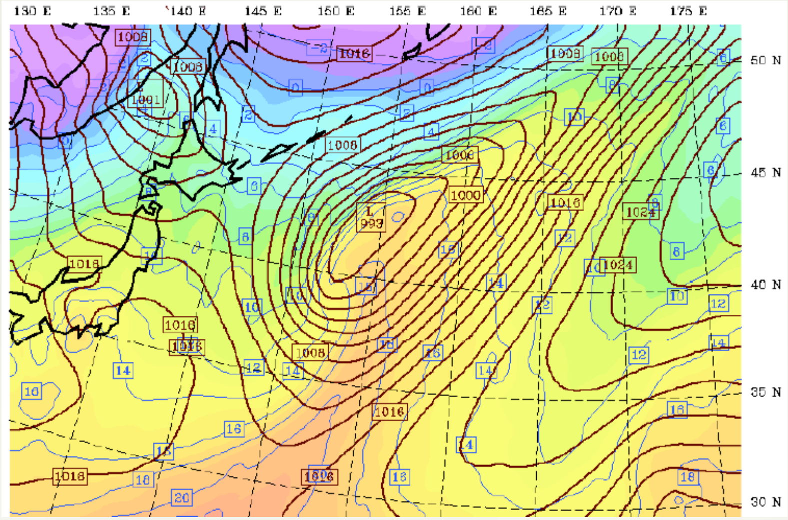
- **BACKGROUND:**
- PMEL Kuroshio Extension Observatory (KEO) moored buoy deployed off the coast of Japan since 2004.
- Routinely in the path of mature tropical cyclones beginning extra-tropical transition.



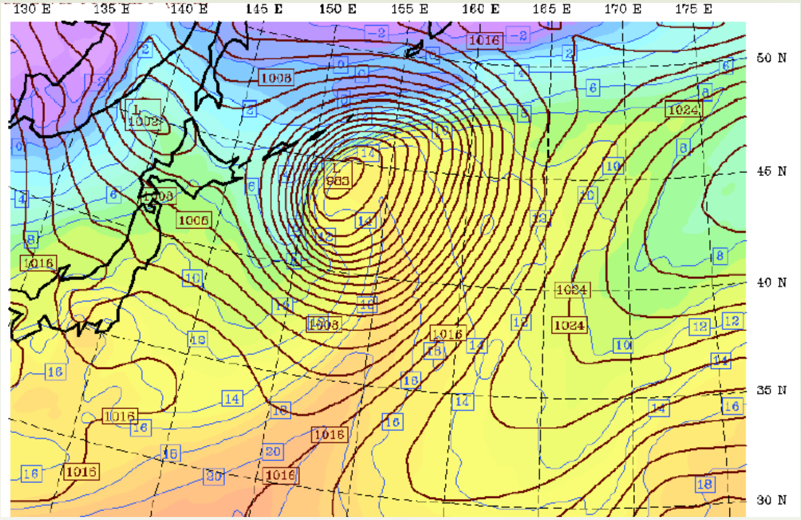
6. Kuroshio Extension Observatory (KEO) Measurements of the Upper-Ocean Response to Tropical Cyclones in the Western North Pacific @69th IHC by N. Bond et al.

Past Numerical Experiment (Bond et al. 2010)

WRF simulations of the extra-tropical transition of Typhoon Tokage with imposed SST perturbations revealed that the ocean can impact storms.



Control

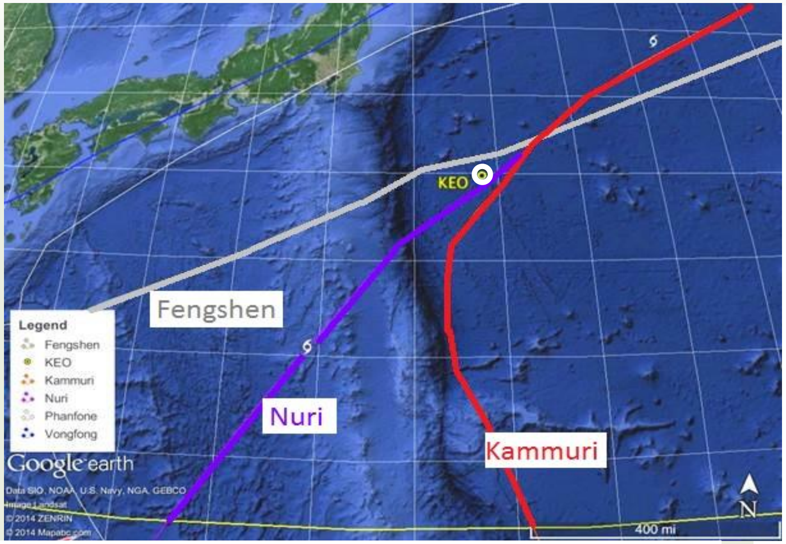


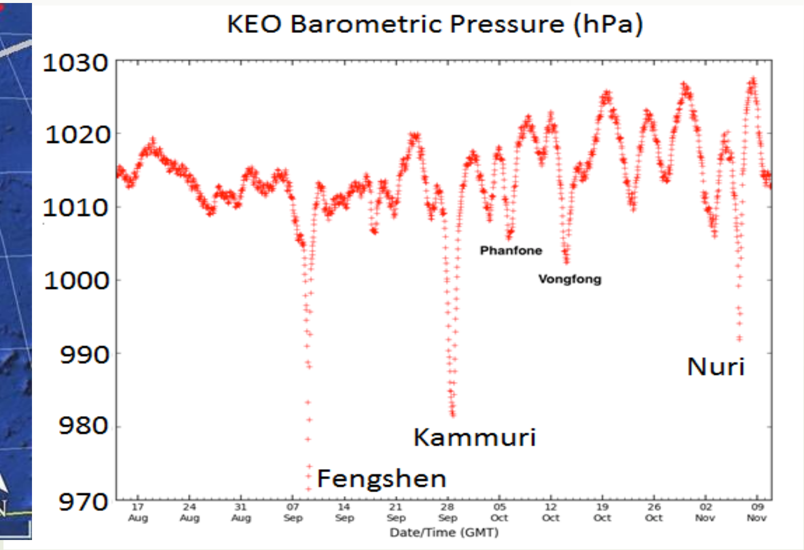
Cold Perturbation (1-1.5^{o}C) between 30-40 N extending east of Japan

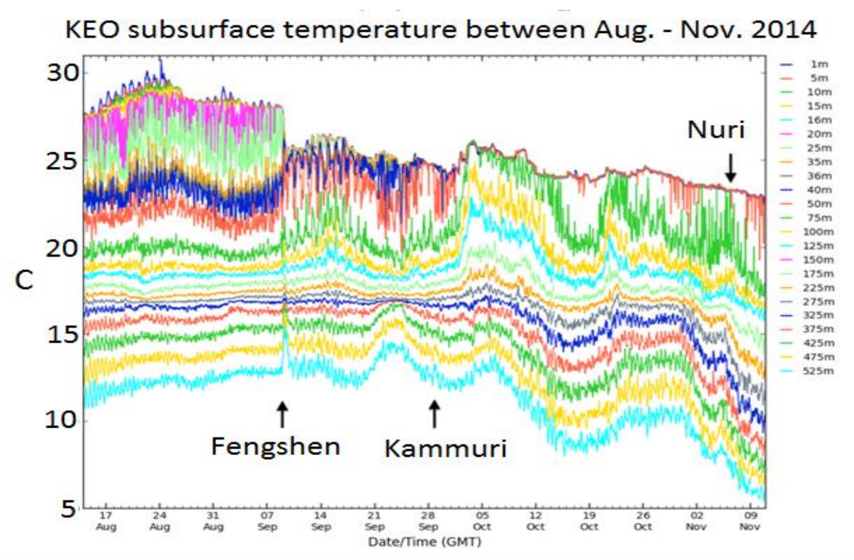
- Warm SST perturbation – slightly weaker cyclone ~2 d after transition.
- Cold SST perturbation – stronger cyclone by 10 hPa P_{min}.

6. Kuroshio Extension Observatory (KEO) Measurements of the Upper-Ocean Response to Tropical Cyclones in the Western North Pacific @69th IHC by N. Bond et al.

WNP
Aug.-Nov.
2014







Fengshen

Pre

- MLD ~20 m
- SST ~ 27.5-28°C

During

- Strong mixing – MLD ~35 m
- SST loss – *O*(3°C)

Post

- Mixing continued, MLD ~40 m↓
- SST ~24-25°C
- After Kammuri, MLD ~50 m & 25°C SST↓

6. Kuroshio Extension Observatory (KEO) Measurements of the Upper-Ocean Response to Tropical Cyclones in the Western North Pacific @69th IHC
by N. Bond et al.

Typhoon Fengshen (2014) caused a rapid drop in near-surface temperatures, warming beneath the ML, and strong near-inertial currents,