1. Ocean Model Impact Tiger Team (OMITT)

Chair and co-chair

H.-S. Kim, *G. Halliwell*

Team

P. Black, *S. Chen*, *J. Cione*, J. Dong, *P. Fitzpatrick*, *G. Goni*, *B. Jaimes*, *S. Jayne*, B. Liu, *E. Sanabia*, *L. Shay*, B. Thomas, *J. Zhang*, L. Zhu,

A. Mehra and V. Tallapragada

Institutes

EMC, HRD/AOML, PhoD/AOML, USNA, MSU, NRL, U Miami, and WHOI

(work supported by multi-agency funding sources)

x: ad maius bonum

Wednesday November 8, 2017

HFIP Annual Meeting

2. Goal and Objectives

Background

Previously, ocean coupling often produced forecasts with equal or reduced skill compared to simpler or uncoupled models. This produces skepticism in the operational forecast community concerning the need to include state-of-the-art ocean coupling to operational prediction systems.

Goal

Address the benefit of adding various complexities of the ocean model under the hurricane atmospheric model through a careful assessment to observational data sets from multiple platforms to optimize TC-ocean interaction forecasts.

Coupled Model Systems

1) HWRF-POM
2) HWRF-HYCOM
3) HMON-HYCOM
4) COAMPS-TC/NCOM

Objectives

1) Prescribe SST – GDEM climatology, GFS, NCODA, and RTOFS SST;
2) Assess 1D and 3D dynamic ocean model coupling; and
3) Collaborate with experimental scientists to maximize the utility of various data sets for improved initial conditions in the ocean model, evaluate mixing parameters and surface wave impacts across the air-sea interface to reduce forecast errors.
   - ✓ Need temperature, salinity, and current observations to evaluate thermodynamical and dynamical balances
   - ✓ Turbulence measurements valuable for evaluation
   - ✓ Subsurface ocean observations are critically important
   - ✓ Surface wave observations are required to evaluate three-way coupling

3. Major Milestones 1

Operational

1. POM IC: RTOFS (HYCOM) analysis for EPac and CPac
2. HYCOM coupling
   a) to HWRF for 2017 WPac Typhoon and NIO Cyclone forecasts
   b) to HMON for 2017 EPac and CPac Hurricane forecasts
3. Implementation of new version HYCOM to HWRF and HMON (Oct 2017)
4. 1-way WW3 coupled HWRF-POM for 2017 NAtl Hurricane forecasts
5. COAMPS-TC coupled with NCOM for NHC & JWTC basins

Experimental (Stream2)

1. HWRF 3-way coupling:
   a) WW3 -POM for 2017 NAtl Hurricane forecasts (Liu et al.)
   b) WW3-HYCOM in progress (Kim et al.)
2. Ensemble:
   a) POM coupled HWRF ensemble for 2017 Natl Hurricane forecasts (Zhang et al.)
   b) HYCOM coupled HMON ensemble for 2017 NAtl Hurricane forecasts (Wang et al.)
3. COAMPS-TC with NCODA data assimilation;
   a) Targeted TC ocean guidance for 2017 EPac and NAtl forecasts;
   b) 3-way COAMPS-TC-NCOM-WW3 with wave data assimilation - in progress

Observation (leveraged by other funding sources)

1. IR SST (HRD), AXBT (HRD & USNA), AXCP (UM), AXCTDs (UM), APEX-EM (UM), ALAMO (USNA), Glider (NOAA/AOML).
2. Transition NOAA AXBTs data tank from *dcomdev* to *dcom*.
3. Currently look into other data format than JJVV (obsolete soon) for AF AXBTs.

Diagnostic graphic package

Sets of Python and MATLAB scripts – Ocean Parameters (suggested by OMITT diagnostic document, 2015).

4. Major Milestones 2

1. Ocean Impact Investigations:
   a) Real-case study for Gonzalo (Dong et al. Weather and Forecasting 2017)
   b) OSSE study for Isaac, Edouard, and Gonzalo (Halliwell et al. JGR 2017)
   c) New autonomous and Lagrangian ocean observations for Atlantic tropical cyclone studies and forecasts (Goni et al. TOS 2017)
   d) Real-case study for Blanca (Kim et al. in revision)
   e) Targeted ocean sampling guidance for tropical cyclones (Chen et al. JGR 2017)
   f) SST Sensitivity Study to Hurricane Edouard Prediction (Fitzpatrick et al.)
   g) Different forecast results between 2014 and 2016 HWRF for SST sensitivity runs
   h) Ideal Case Study with Coupled HWRF-1D and 3D HYCOM for Natl (Dong et al.)
   i) Ideal Case Study with Coupled HWRF-1D and 3D HYCOM for Bay of Bengal (Mohanty et al.)
   j) Observation analysis for Nate (Shay); forecast verification for Maria (Cione); forecast verification for Edouard (Zhang et al.)

cyan – presented in this talk

Green – included in the talk, but

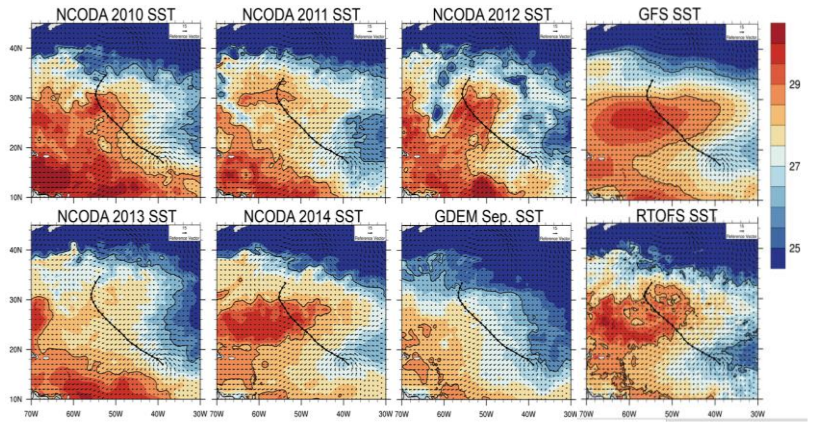
2. Attending national conferences and meetings:
   a) 2017 AGU fall meeting – Glider observation for Gonzalo (2014) (Goni et al.)
   b) 2018 AMS annual meeting (3 presentations , including OMITT (Kim et al.))
   c) 2018 AMS TC conference (6 presentations, including OMITT (Kim et al.))
   d) Ocean Science 2018 (5 presentations)

5. An analysis of Hurricane Edouard SST sensitivity runs by HWRF in a low-shear environment (Fitzpatrick et al.)

Model: 2016 HWRF w/ non ocean coupling

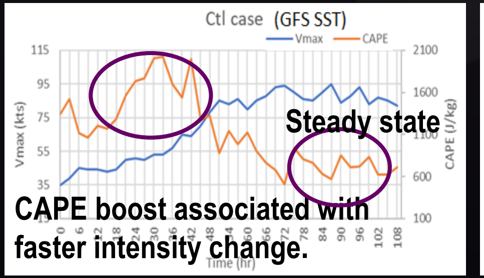
SST: NCODA (2010-2014), GDEM, GFS and RTOFS

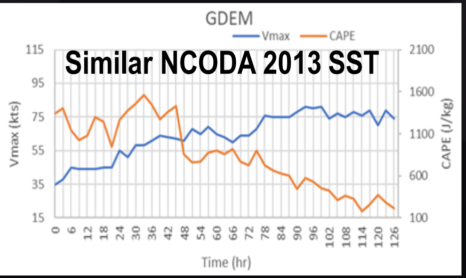
1) Time series analysis for shear<14 m/s
2) Relationship analysis to V_{max} and 24-hr intensity change
3) Maximum Potential Intensity applications?



Findings:

1) Time series analysis





2) Relationship analysis to V_{max} and 24-hr intensity change

dVmax	linear regression	variance
SST	-0.28	7.6
PW	0.02	0.0
heat flux	-0.46	21.4
latent flux	-0.51	25.7
CAPE	0.70	49.4
DPT	-0.04	0.1
RH	0.00	0.0
shear	-0.44	19.5

Vmax	linear regression	variance
SST	0.78	60.9
PW	0.27	7.2
heat flux	0.85	71.6
latent flux	0.88	77.5
CAPE	-0.63	39.1
DPT	-0.11	1.2
RH	-0.61	37.1
shear	0.10	1.0

Future Plan:

3) MPI applications?

A large HWRF SST-sensitivity database could elucidate steady-state and MPI functionality with surface fluxes via empirical application:

e.g. assume general *sigmoidal* relationship

$$V_{max}(H) = \frac{\varepsilon\, MPI}{1+e^{-(H-A)/B}} = \frac{\varepsilon\, MPI}{1+\frac{e^{A/B}}{e^{H/B}}}$$

where *H* is sensible heat flux, ε is an environmental inhibitor (ε =1 is MPI conditions), and A, B are empirically-derived constants.

6. Hurricane Edouard SST sensitivity runs by HWRF (Dong et al.)

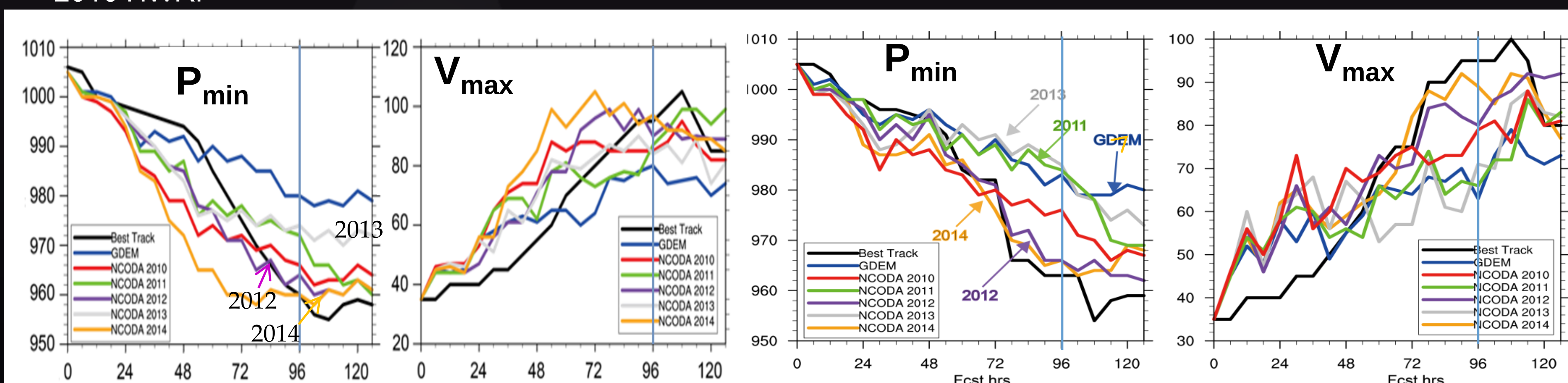
Additional Complexity

Differences in forecast between 2014 and 2016 version of HWRF

There are distinct storm-response patterns with 2014 HWRF, but not with 2016 HWRF

2016 HWRF

2014 HWRF



Moving target – How can we work around?

7. Field Observations (2017)

TC Name	Instruments	PI	NPTS	GTS	Dates of data	storm stage pre	in	post
Harvey	Glider	G. Goni	3	yes & RT	July 2017-	yes	yes	yes
Jose	Glider	G. Goni	3	yes & RT	July 2017-	yes	yes	yes
Irma	AXBT	E. Sanabia	90				yes	
	ALAMO	E. Sanabia	8					
	AXBT	J. Zhang	8			yes		
	Glider	G. Goni	3	yes & RT	July 2017-	yes	yes	yes
Maria	AXBT	J. Cione	50		Sep 22-24, 2017			
	IR SST	J. Cione	40-50					
	Glider	G. Goni		yes & RT	July 2017-	yes	yes	yes
Nate	AXBT	L. K. Shay	87			yes	yes	yes
	APEX-EM	L. K. Shay	5 Floats		May 2017-	yes	yes	yes
	AXCP	L. K. Shay	40			yes	yes	yes
	AXCTD	L. K. Shay	10			yes	yes	yes

Specific Plans (by PIs):

1. Glider (Goni et al.): verification of HWRF and HMON (future) forecasts
2. IR SST, Coyote and AXBTS (Cione et al.), focusing on air-sea interaction (extended work done by Zhang for Edouard, 2017)
3. Expendable array and APEX-EM Floats (Shay and Jaimes): Mutual responses
4. AXBTs and ALAMO (Sanabia, Jayne and Chen): Verification of COAMPS-TC forecasts, ocean observations impact experiments

Team approach: coordinate observational analysis, model initialization evaluation, and model performance evaluation with respect to intensity.

8. Future Plans

Near Future Activity

1. Continue analyses for Edouard (2014), Blanca (2015) and Bay of Bengal toward publications
2. Do ocean model impact analyses for upcoming HWRF, HMON T&E, and COAMPS-TC
3. Observational data analysis (by PIs) for Nate (2017), Maria (2017), Irma (2017), Edouard (2014) and Gonzalo (2014) (note: a postdoc at AOML/PhoD)
4. Continue collaboration with India
5. AXBT data RT transfer to GTS
6. Closely collaborate with observational community to assess and potentially design an pilot ocean observing system for TC studies and forecast.

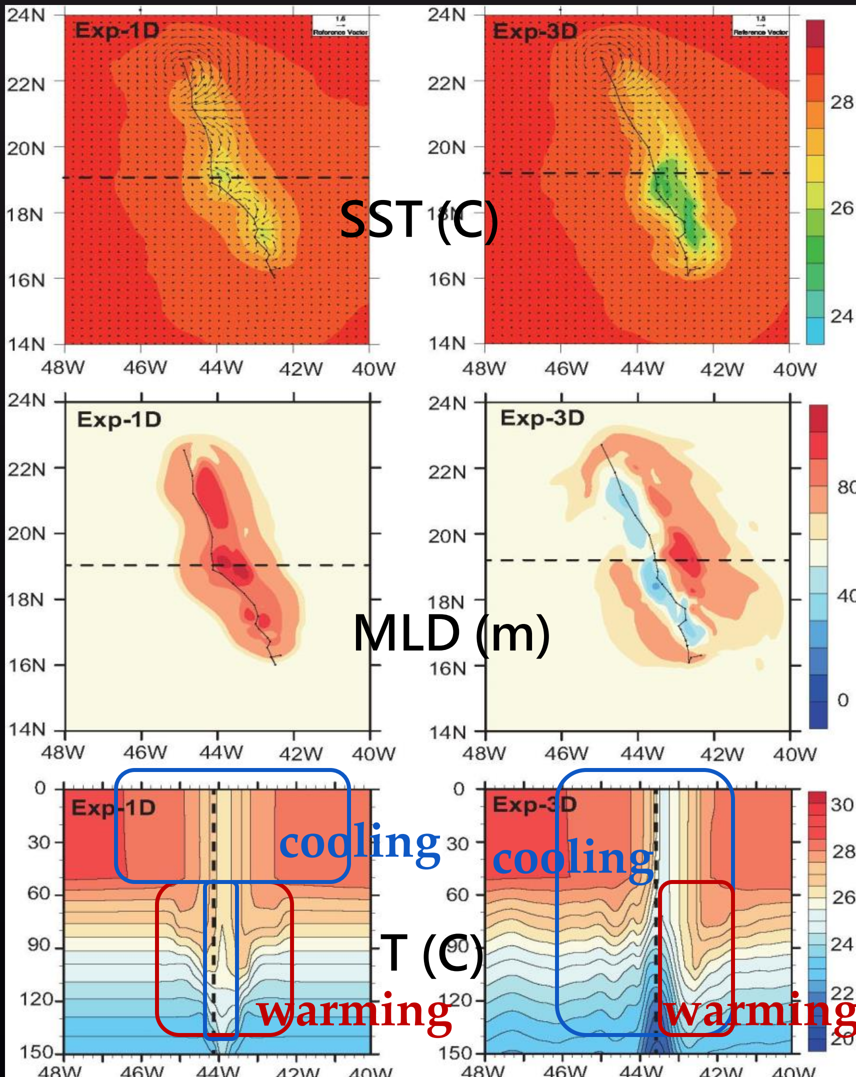
Improvement of the ocean component (EMC & NRL)

1. Validation with observations in collaboration with observation PIs.
2. Complete 3-way coupling, including implementation of non-linear currents-waves interaction and mixing (Stokes drift, Langmuir mixing) in ocean components
3. Implement DA to the HYCOM ocean component
4. Complete 3-way coupling, including the wave DA for COAMPS-TC

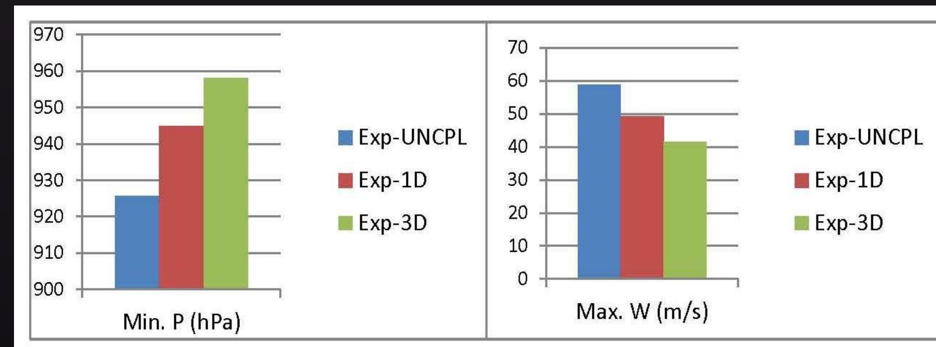
7. Ideal-Case Study for Hurricane Edouard (Dong et al.)

1D vs. 3D HYCOM-HWRF

A moving vortex at 4 m/s & GDEM3 climatology IC



at 36 h



3D coupling, compared to 1D:

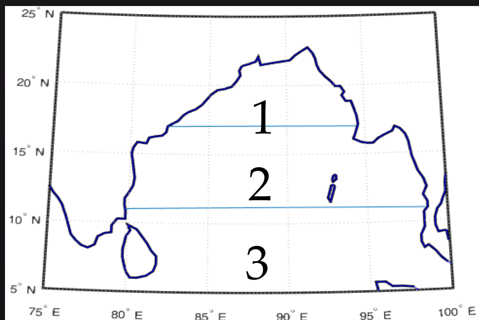
1. SST cooling is more significant and consistent through the upper layer (whereas, 1D coupling exhibits a bi-modal pattern of cooling above MLD and warming below MLD).
2. Inertial wave is less significant, and
3. MLD is shallower on the left and deeper on the right side of the storm, having relatively large variation in space.

Future work:

1. Comparisons against observations (in-situ: AXBTs, XCTDs; remote-sensing: SST, SSH)

8. Ocean Coupling Impact on Bay of Bengal Intensity Forecasts (Mohanty/Halliwell et al.)

Domain

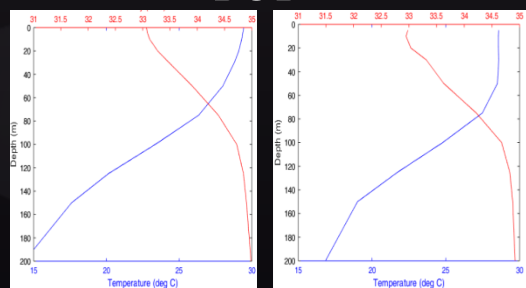


Configuration

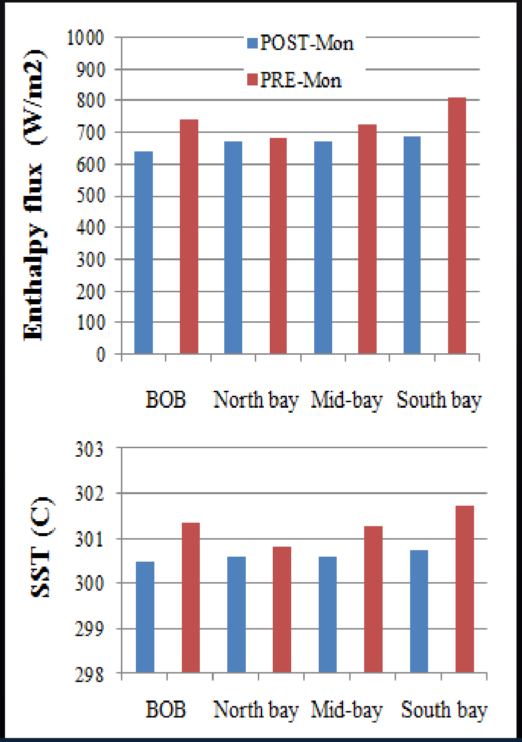
- Identical atmospheric initializations (ideal vortex)
- Ideal horizontally homogeneous ocean using climatological T-S profiles representative of pre- and post monsoon for:
  - whole bay (BOB), north bay (1), mid-bay (2), and south bay (3)

BOB

Pre-monsoon



Post-monsoon

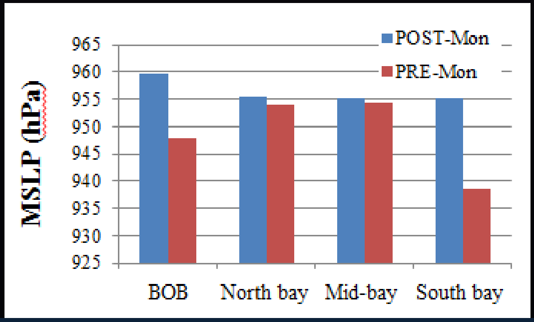


Discussion and Conclusion:

a) Pre-monsoon storms stronger than post-monsoon storms in BOB and south bay cases.

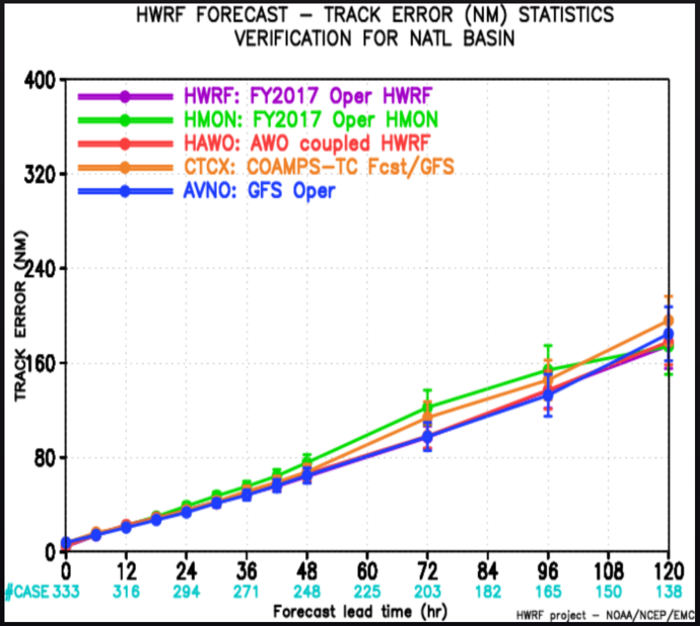
b) SST averaged over the same area is less-closely related to intensity.

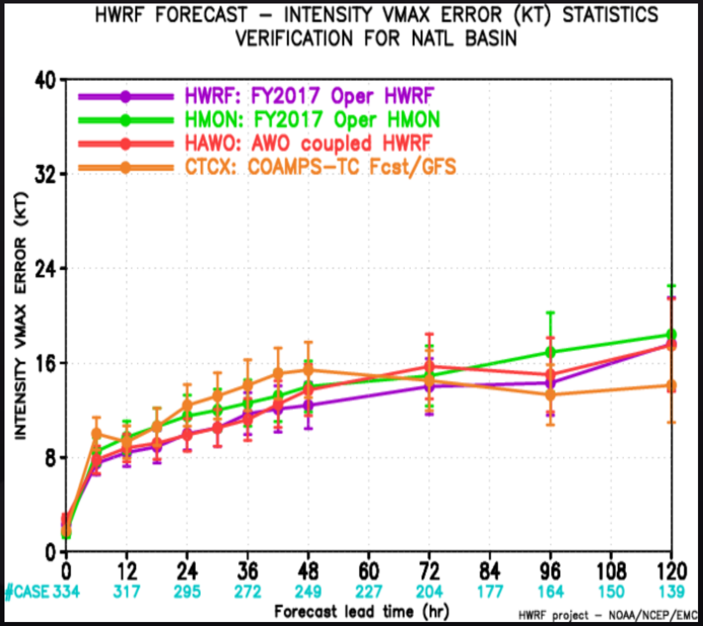
c) Enthalpy flux averaged over inner-core is closely related to intensity → the most accurate predictor intensity.



11. 3-way coupling HWRF (HWRF-POM-WW3)

Track and Intensity Performance for 2017 North Atlantic Storms (333 cases)





1. Track forecasts for HAWO (red) are as good as HWRF (purple) and AVNO (blue).
2. Intensity forecasts are mixed: Better than HMON (green) for the entire forecast period, but mixed skill between CTCX (orange) and HWRF (purple). Particularly wrt HWRF, degradation exists between 48-96 h, showing higher intensity errors (not statistically significant).
3. Impact on track: little
4. Impact on intensity: mixed
5. Impact on the storm structure (not shown): Smaller sizes than HWRF and Best Track.

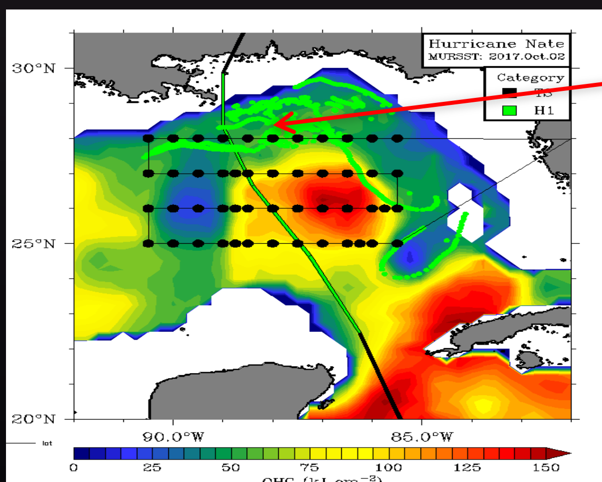
12. Observations in the Gulf of Mexico

Pre-storm ocean grid (dots) of expendables (AXBTs, AXCTDs, AXCPs) deployed from NOAA WP-3D, w/ OHC (**color**), Nate's track and APEX-EM sampling sites (**green**) just north of the Loop Current sponsored by Gulf od Mexico Research Institute (GoMRI).

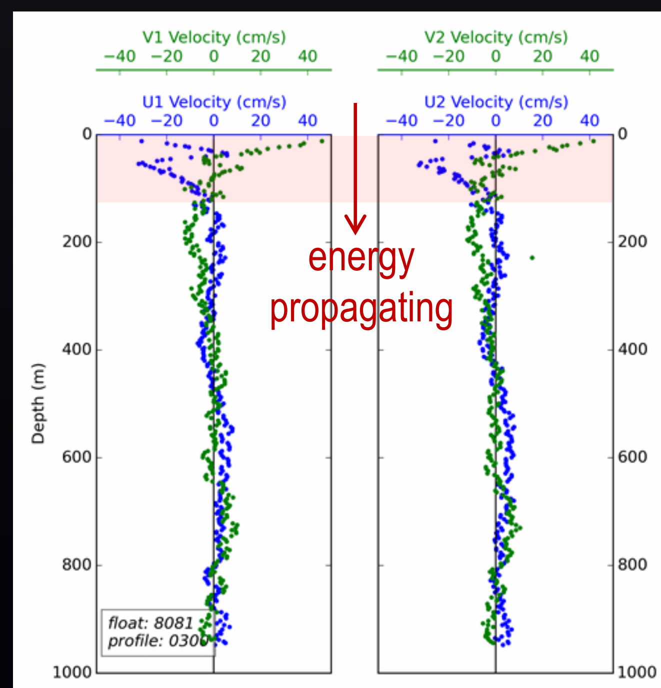
APEX-EM Float (GoMRI project): Current Response to Nate

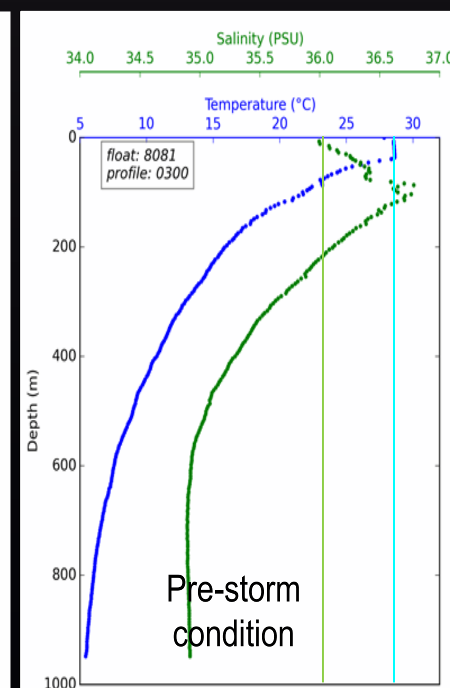
Measures

T, S, U, V, Dissolved Oxygen, Chlorophyll fluorescence, Backscatter, and CDOM



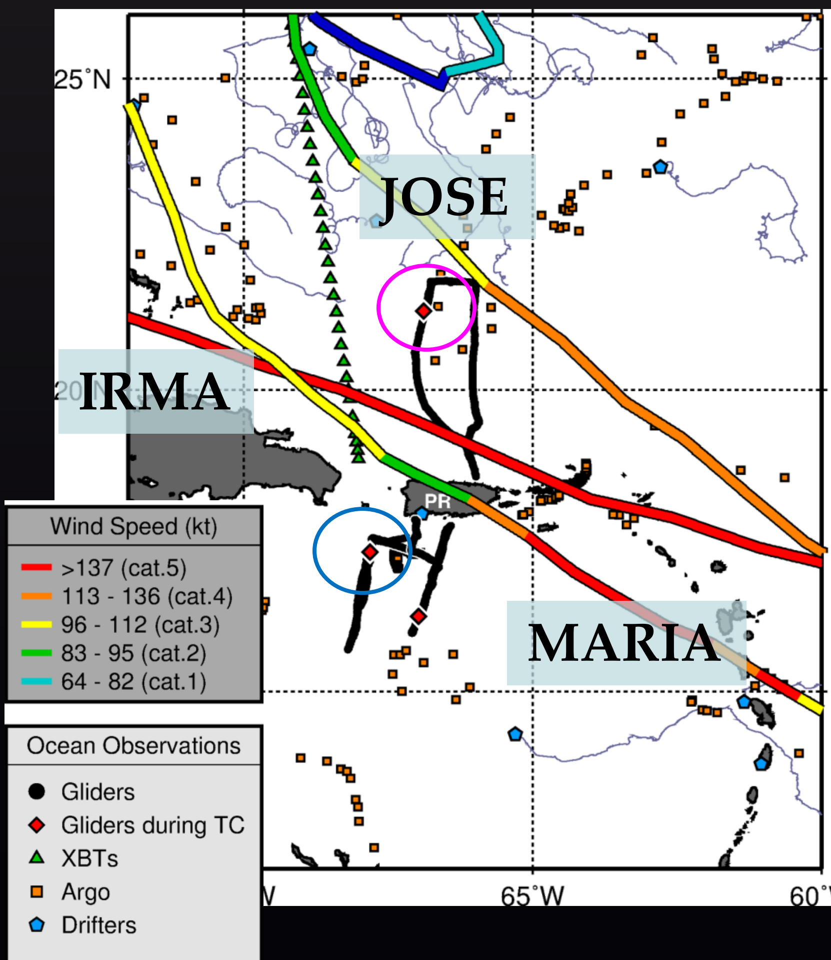
Evolving Ocean Currents and T/S profiles from this float (8081) ~ 2 Rmax from Nate's center.





13. NOAA/AOML/PhOD – CARICOOS Hurricane Underwater Gliders (G. Goni)

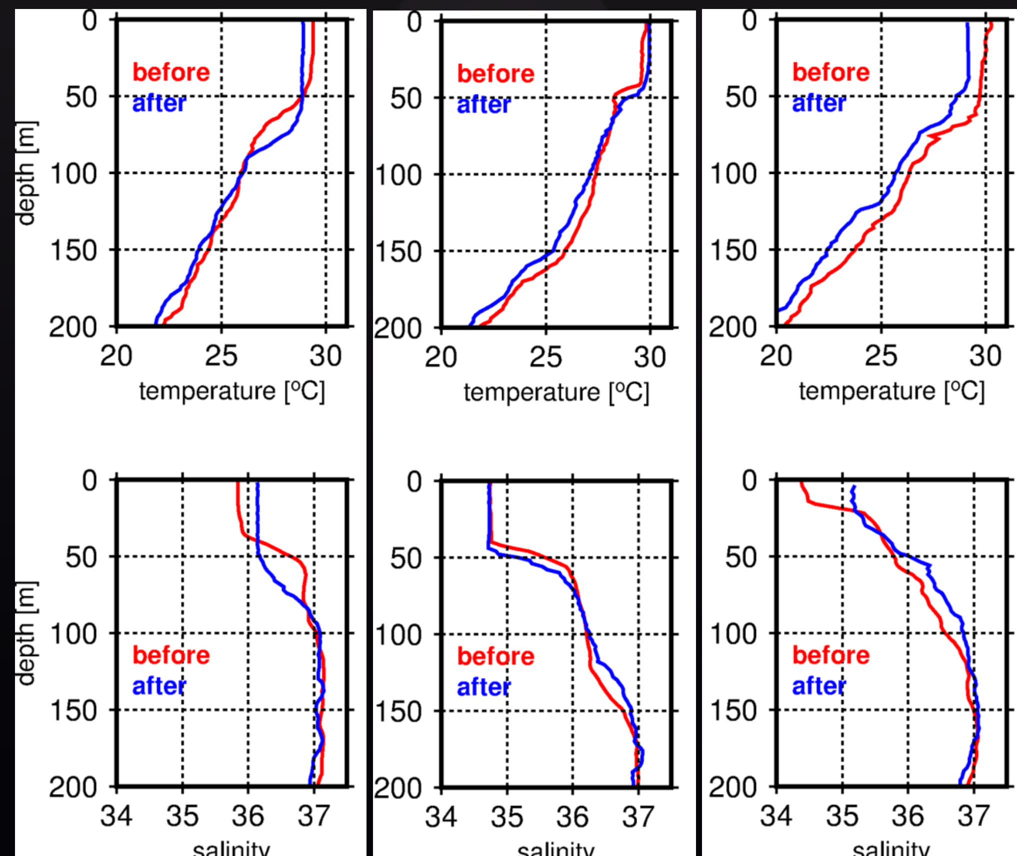
2017 Hurricane Season Underwater Gliders Ocean Observations



North glider during **Irma**

North glider during **Jose**

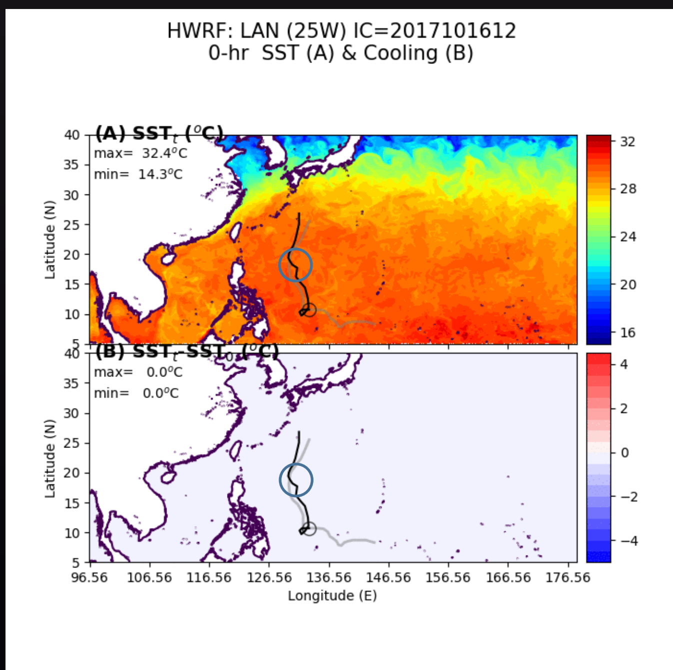
South glider during **Maria**



14. Diagnostic graphic package (H.-S. Kim)

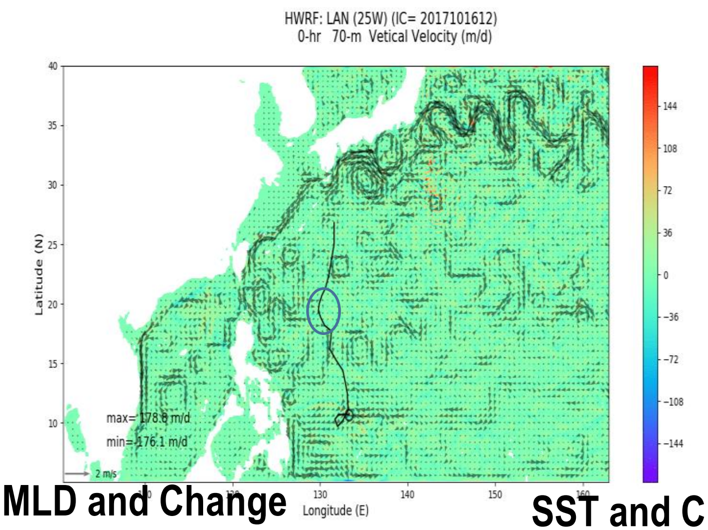
Oceanic diagnostic parameters suggested in an OMITT report of Hurricane Coupled Model Evaluation and Inter-Comparison Project (2014).

- Covers SST, SST cooling, MLD and MLD change in time, OHC and OHC change in time, ocean currents U/V/W at different depths, for the ocean domain and storm footprint scale.

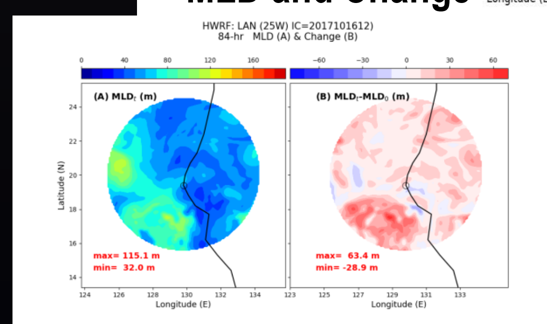


Large SST cooling due to shallow MLD associated with a Cold Eddy at **O**

70-m U/V (vectors) and W (shade)



MLD and Change



SST and Change