Ocean Model Impact Tiger Team (OMITT)

Chair and co-chair

H.-S. Kim, G. Halliwell

Team

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Institutions

EMC, NESDIS, DTC, HRD/AOML, PhoD/AOML, PMEL, USNA, NRL, URI, UM, JISAO/UW, and WHOI

Wednesday January 11, 2017
HFIP Annual Meeting

Overview

1. Review of Objectives
2. Activity summary
3. Progress
4. Future Plans

1. Objectives

- **Background**

The importance of the ocean on TC intensification has been observed, and many researches have demonstrated the ocean impact in various stages of a TC. However, **there are doubts of such roles of ocean model, especially for operational numerical guidance models**, because non-coupled model still has better skills than coupled.

- **Objective**

To investigate the very special subject in both real and ideal cases, having special attentions on **the impact of the complexity of the ocean model**, by assessing the impacts on the HWRF forecast and the sensitivity of these impacts on forecasting.

2. Activity Summary

1. Biweekly/monthly telecon among collborators w/ and w/o HFIP-funding from institutions - NOAA/JISAS (sandy), NOAA/AOML (sandy), NAVY, U. Mississippi, WHOI, and RSMAS
2. 2016 Ocean Sciences Meeting (February) – a session “Understanding Air-Sea Coupling in Tropical Cyclones for Improving Model Intensity Forecasts”
   a) 26 papers
3. 32nd Conference on Hurricanes and Tropical Meteorology (April)
4. Coyote UAS Summit (May) – Improving Operational HWRF (TC Coupled Models)
   a) Recommend concurrent atmospheric and oceanic profiling
   b) Data assimilation in a coupled sense

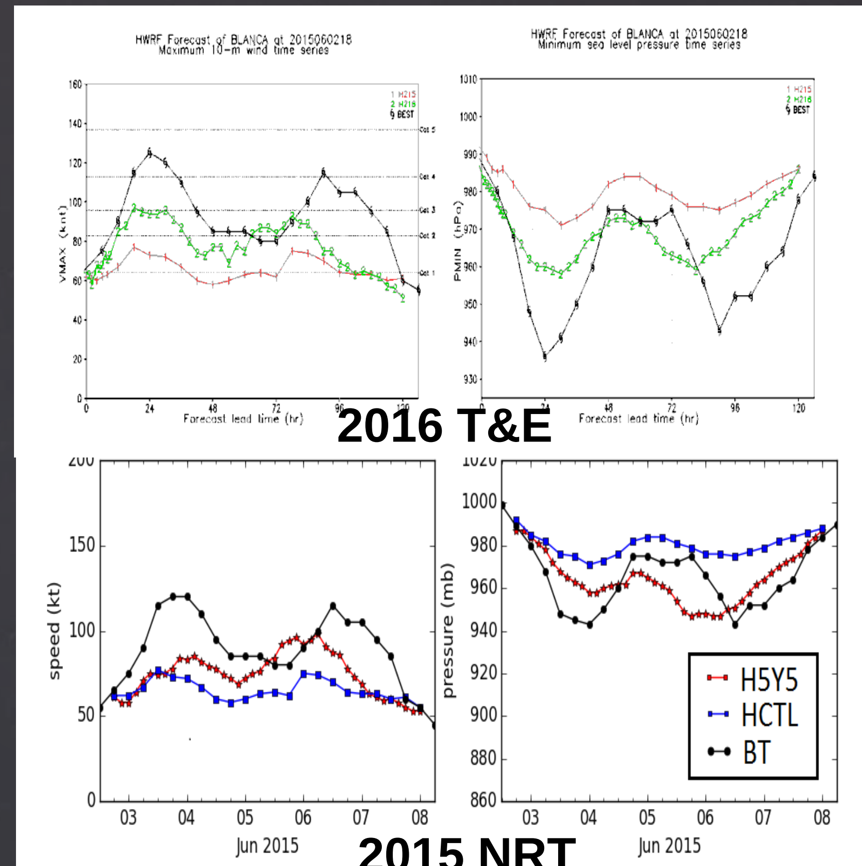
3. Progress

1. Stream-2 RT exercise w/ HWRF-HYCOM for 5 basins, including WPAC, NIO and SH in addition to NATL and EPAC.
2. Modeling and observation proposal for 3-way coupling to NOAA FY17 RTAP was under consideration for future funding.
3. Transition to Operation – 3-way coupling HWRF; for 2016 Operation, 1-way w/ WW3 coupling for NATL and EPAC; transitioned COAMPS-TC coupled to NCOM to FNMOC in 2016
4. Development of coupled HNMMB (NMMB-HYCOM)
5. Number of peer-review publications (table)

#	Storm (basin, year)	Relevant publication (year)
1	**Edouard (NATL, 2014)**	Halliwell et al. (2017); Fitzpatrick et al. (2017)
2	**Blanca (EPAC, 2015)**	Kim et al. (2017)
3	**Ignacio (EPAC, 2015)**	Sanabia and Jayne (2017)
4	**Gonzalo (NATL, 2014)**	Halliwell et al. (2017); Dong et al. (2016)
5	**Isaac (NATL, 2012)**	Jaimes and Shay (2015); Jaimes et al. (2016); Chen et al. (2017)

3a. Impacts of POM-RTOFS Initialization on H216 Performance for Blanca (2015) and storms (2014-2015)

- For Blanca,
  - using RTOFS for POM IC, H216 forecast is improved and is similar to H5Y5.
- For storms in 2014-2015,
  - Track is improved by <10%
  - Vmax skill is neutral but bias is significantly improved.



	Atmos. Ver.	Ocean Model	IC
H216	2016	POM	RTOFS
H215/HCTL	2015	POM	GDEM
H5Y5	2015	HYCOM	RTOFS

3b. Stream 2 for the 2016 season

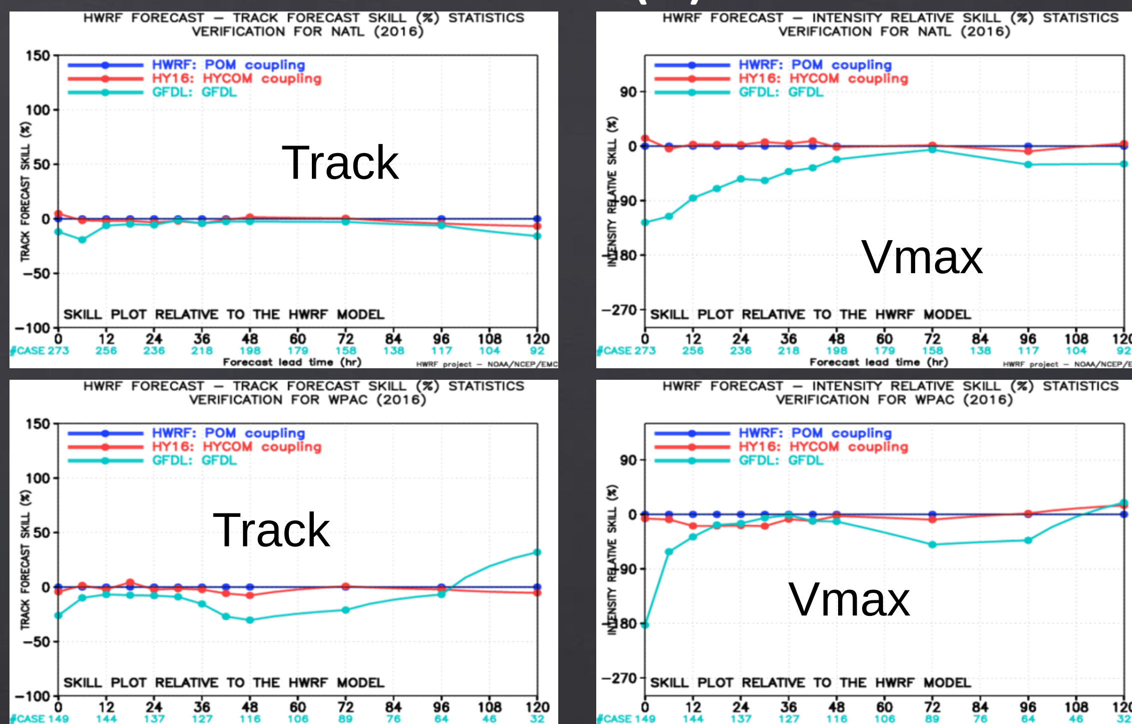
- <u>Experimental HWRF, coupled to HYCOM;</u>
- <u>Experimental COAMPS-TC coupled to NCOM</u>
- Operational HWRF, coupled to POM

- Operational and Experimental HWRF are comparative for 3 basins – NATL, EPAC and WPAC. ➔ Statistically little difference between POM and HYCOM
- Significant differences between HWRF and GFDL ➔ the atmospheric is major control factor (Operational GFDL, coupled to POM)

Forecast Skill (%)

NATL

WPAC



3c. 2016 Field Plan

CDR E. R. Sanabia, Jun 24

- AF WC-130
  - phase 1: 15 July – 17 August 2016, for training flights and storm missions
  - phase 2: 18 August – 31 October 2016, for storm missions only
  - Instruments: AXBTs (< 480 total), ALAMO (30) + 2 CTDs

N. Shay, July 21

- In LC/WCE Experiment**, as part of TC-Ocean Interaction Experiment in GoM,** module includes:
  - Expendable profiler surveys w/ AXBTs, AXCPs, AXCTDs, GPS Sondes from P-3 aircraft;
  - Coordinated float/drifter and AXBT deployment by From AF WC-130.

3d. Sample Studies

1. *Impact of Ocean Model Initialization on Upper-Ocean Cooling and Intensity Predictions for Hurricane Blanca (2015)* by G. Halliwell et al. (Jun. 2016)
2. *Ocean Response Study – Patricia (2015)* by N. Shay et al. (Dec. 2016)
3. *Ocean Mixed Layer and SST Response During Hurricane Isaac (2012)* by B. Jaimes et al. (Mar. 2016)
4. *Kuroshio Extension Observatory (KEO) Measurements of the Upper-Ocean Response to Tropical Cyclones in the Western North Pacific* by N. Bond et al. (Dec. 2016)
5. *Glider data assimilation for Hurricane Gonzalo Track and Intensity Forecast* by J. Dong et al. (2016)
6. *Sea State Dependent Air-Sea Fluxes in Coupled HWRF-POM-WWIII* by Meixner et al. (Jan. 2017)
7. *Optimal Ocean Sampling for Tropical Cyclone* by Chen et al. (Jan. 2017)

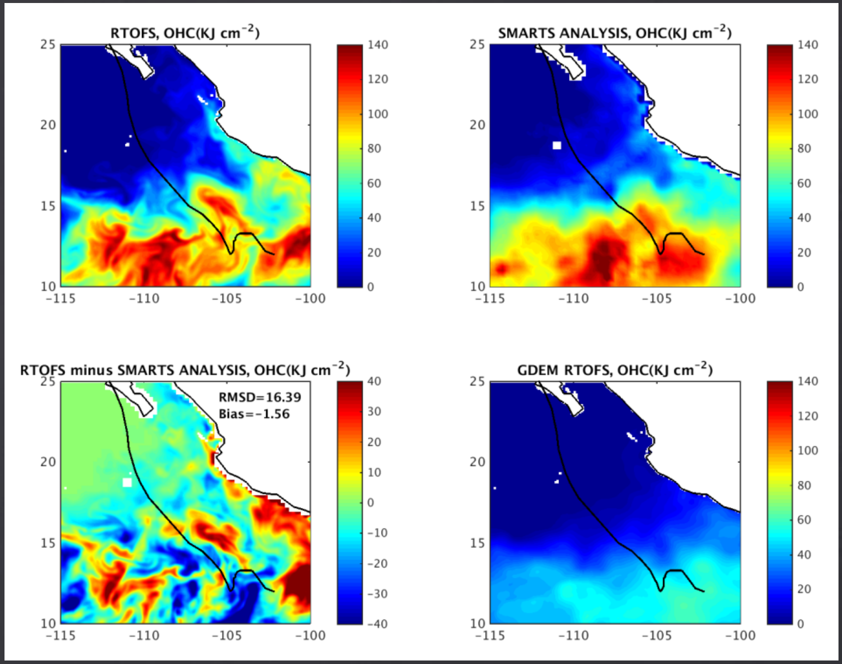
3d.1. Impact of Ocean Model Initialization on Upper-Ocean Cooling and Intensity Predictions for Hurricane Blanca (2015)

G. Halliwell et al. (Jun, 2016)

➤ Findings:

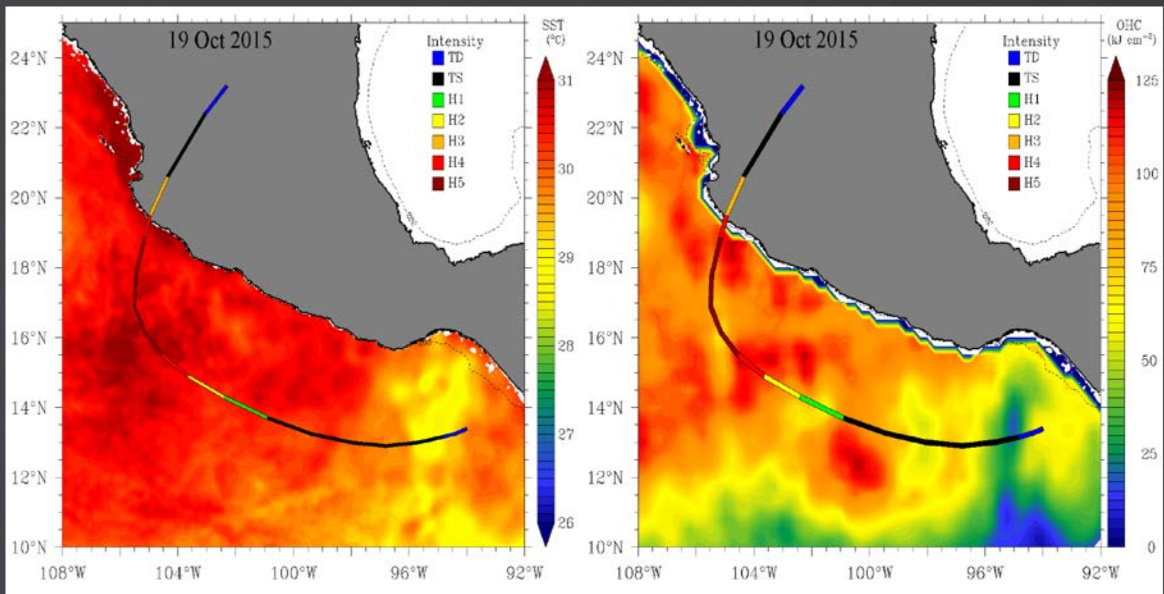
1. Ocean model initialization has a large influence on intensity.
    - GDEM fcst. reaches cat 1
    - RTOFS fcst. reaches cat 3
2. RTOFS represents the anomalously warm ocean during 2015 which reduces the tendency to underestimate intensity; Storm-induced SST cooling is ~3C less over a smaller area.
3. However, significant errors still exist in the magnitude and timing of predicted intensity changes.
4. Comparison to observations of SSH and OHC suggest that HYCOM predicted a realistic ocean response during the time that Blanca was nearly stationary.

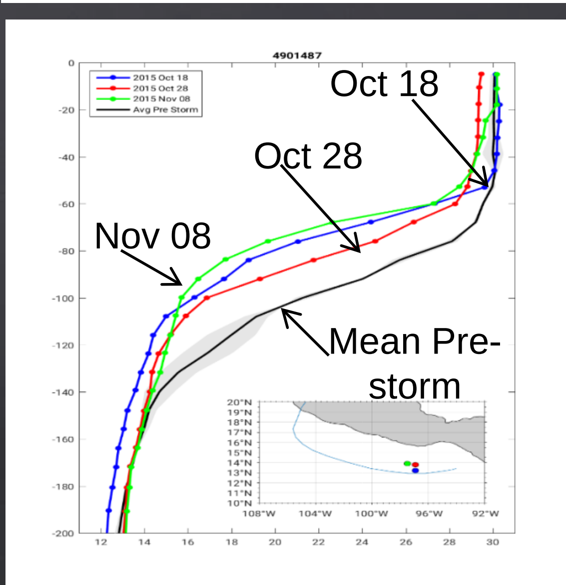
OHC Pre-Storm Ocean Conditions, 1 June 2015

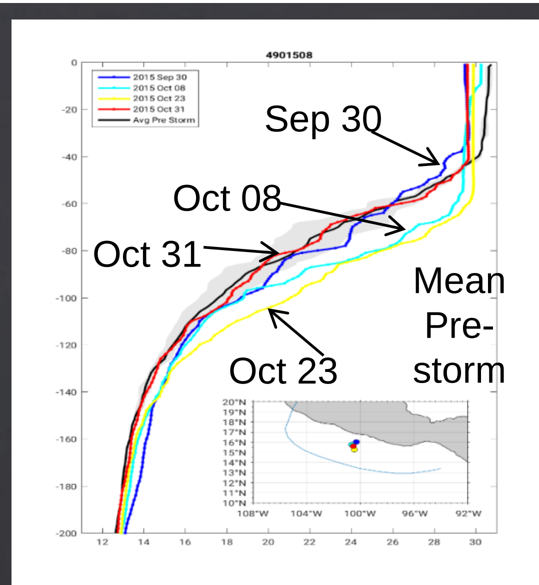


3d.2. Ocean Response Study – Patricia (2015)

N. Shay et al. (Dec. 2016)



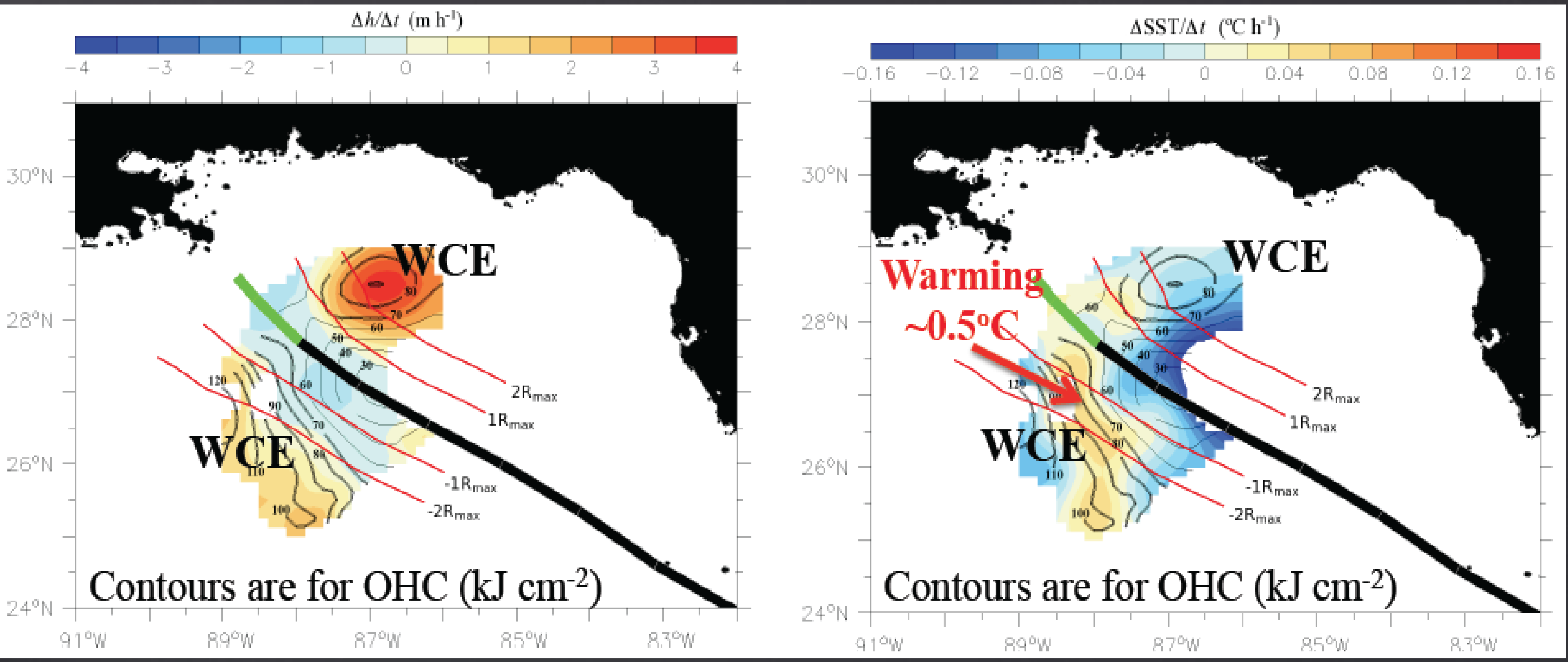




- Pre-Patricia SST (left) and OHC (right) relative to the Track on 19 Oct 2015. These OHC levels were a factor of 2 times higher due to the 2015 El Nino (Rogers et al., BAMS, 2017).
- ARGO Floats (4901487 and 4901508) underneath and on the right side of the track (see inserts) prior to explosive deepening-pre-storm OHC values were consistent with satellite derived values.

3d3. Ocean Mixed Layer and SST Response During Hurricane Isaac (2012)

B. Jaimes et al. (2016)

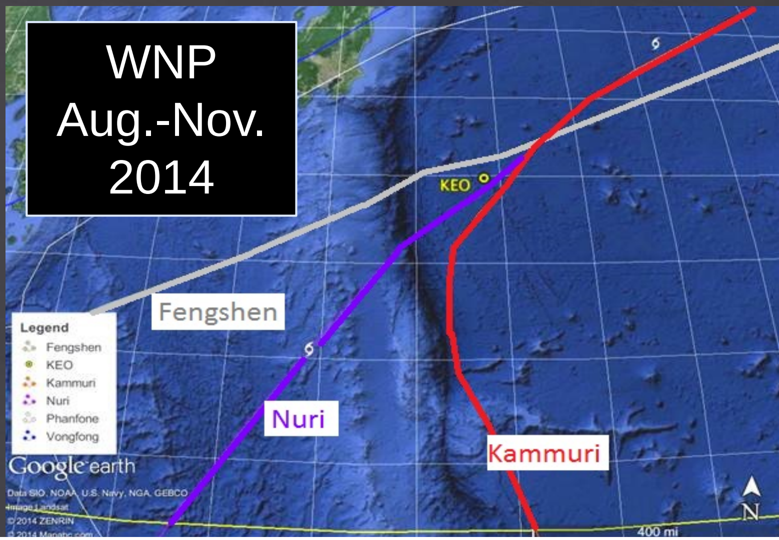


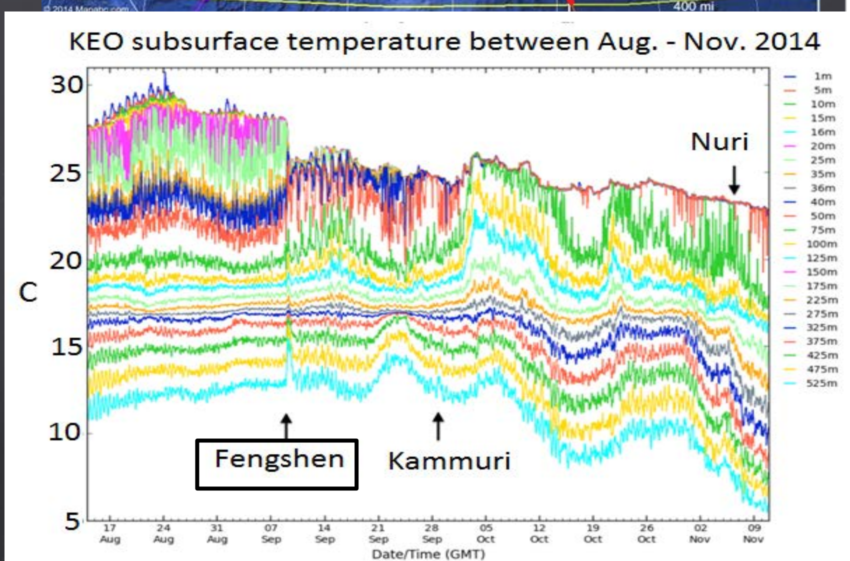
In- storm (12 h interval) Ocean Mixed layer (OML) deepening; h is OML depth.

In- storm (12 h interval) sea surface cooling; SST: sea surface temperature.

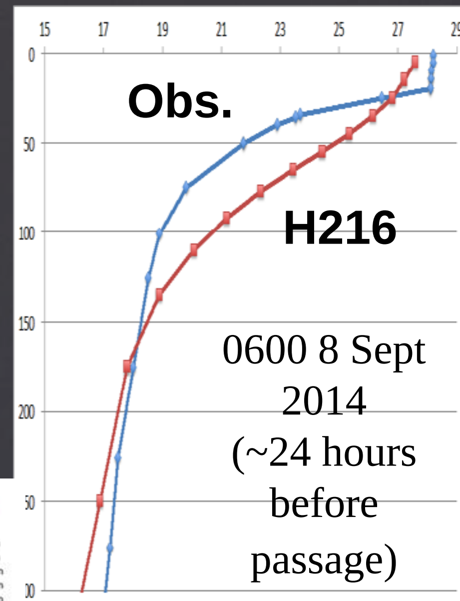
3d.4. Kuroshio Extension Observatory (KEO) Measurements of the Upper-Ocean Response to Tropical Cyclones in the Western North Pacific

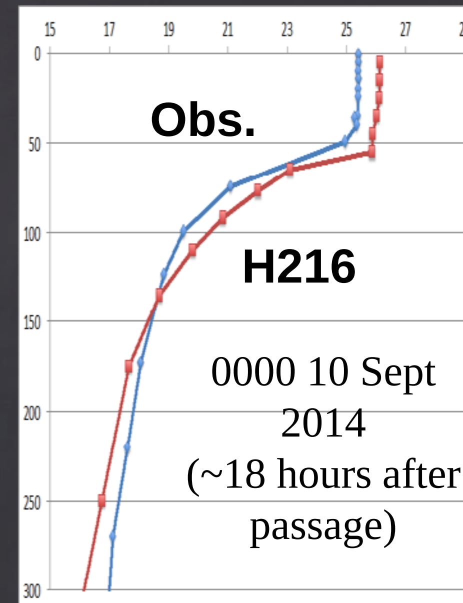
N. Bond et al. (Dec. 2016)





Typhoon Fengshen





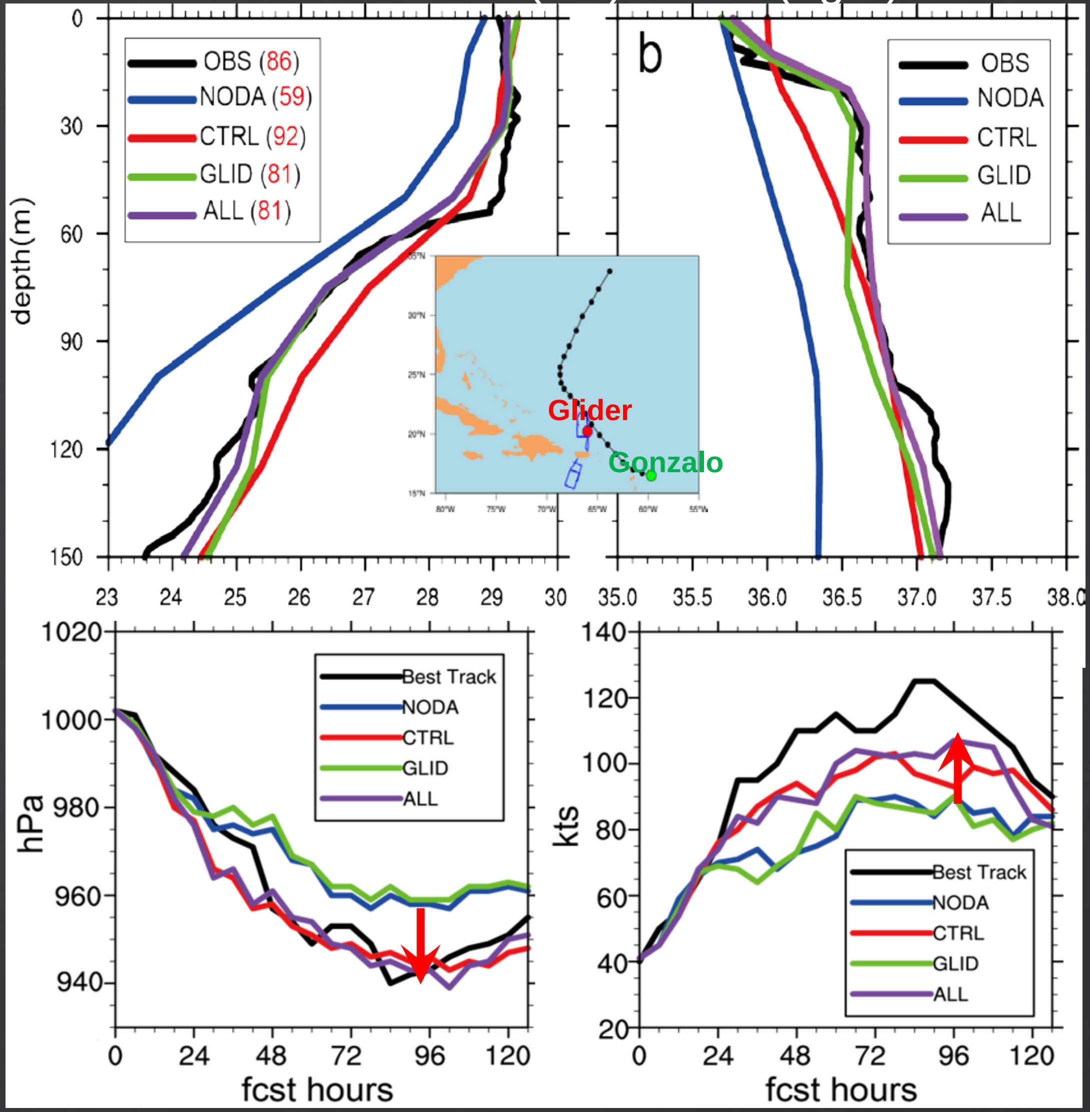
- Findings:
  1. Model upper layer is less stratified and warmer below mixed layer.
  2. H216 simulates less storm-induced cooling by *O*(1.5C).
  3. H216 simulates stronger shear driven mixing.

3d.5. Glider data assimilation for Hurricane Gonzalo Track and Intensity Forecast

J. Dong et al. (2016)

Pre-Storm T (left) and S (right)

- Findings:
  1. Improve ICs, e.g. >1C SST, and MLD base stability.
  2. Reduce ocean both T and S forecast error.



Forecast Comparisons

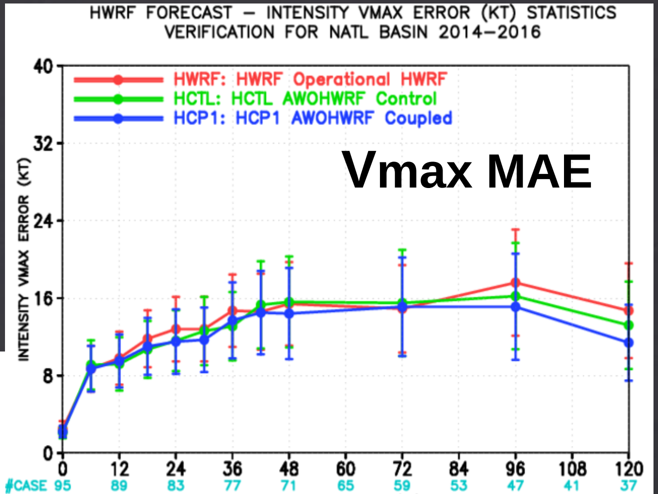
3d.6. Sea State Dependent Air-Sea Fluxes in Coupled HWRF-POM-WWIII

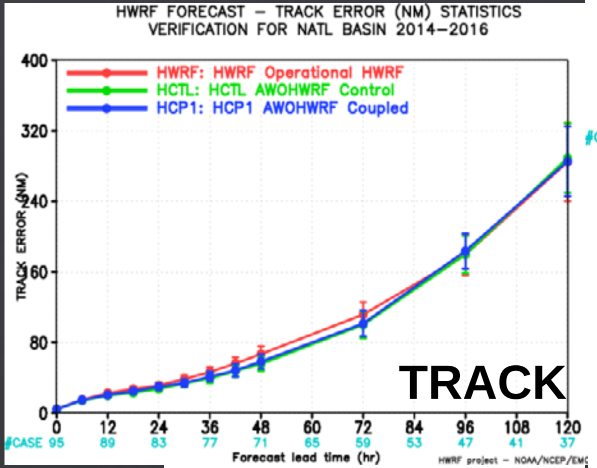
Meixner et al.

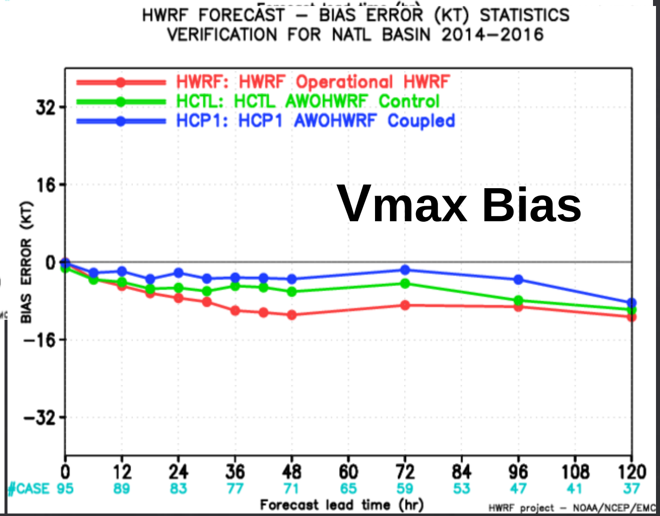
Verification of 3-way coupling runs for Arthur (2014), Edouard (2014) and Matthew (2016)

- Findings:

1. Improvement of the storm size and intensity
2. Reduction in both the ocean surface currents and SST







Operational HWRF
Control (HCTL)
Coupled (HCP1)

3d.7. Optimal Ocean Sampling for Tropical Cyclone

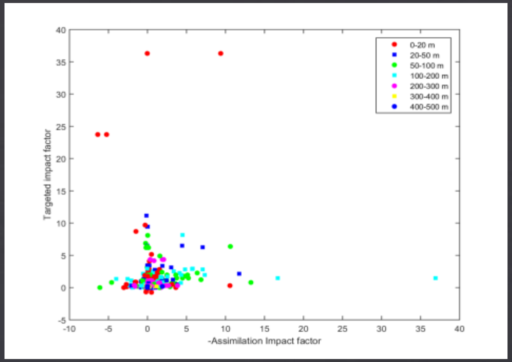
Chen et al. 2017

Targeted AXBT and ALAMO sampling for Isaac (2012), Hilda (2015) and Matthew (2016)

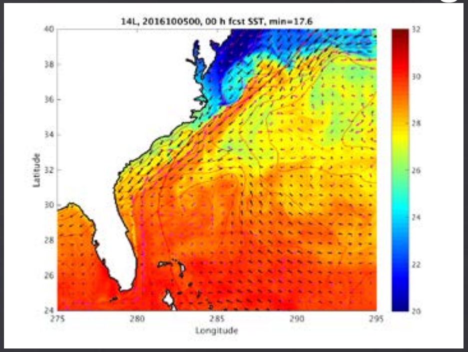
- Findings:

1. High ~0.6 mean linear correlation between targeted and verifying impacts to reduce the COAMPS-TC coupled with NCOM ocean sea temperature forecast from the ocean surface down to 500 m
2. largest positive impacts in reducing the TC model forecast errors are sensitive to the initial pre-storm ocean conditions, storm-induced ocean cold wake, and model track errors.

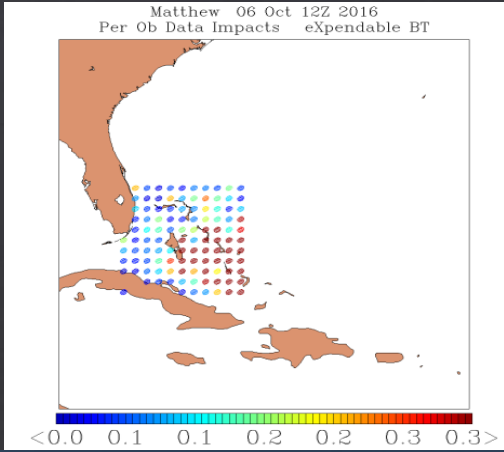
Targeted & verifying impacts

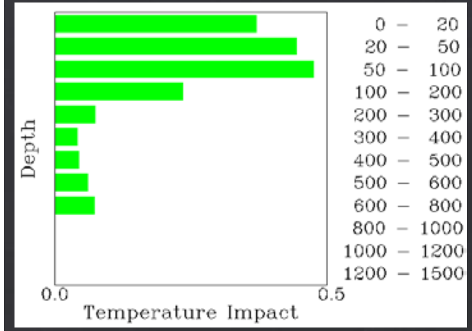


3-4 °C Wake cooling



Targeted impact map for Hurricane Matthew (12Z Oct 6)





4. Future Plans

Near Future Activity

- Continue analyses for Edouard (2014) and Blanca (2015) toward publications
- Complete Ideal Case Studies for Edouard and Blanca, by including seasonal variability in ICs ➔ publication
- Do HYCOM/POM impact analyses for upcoming HWRF T&E
- HYCOM impact analyses for HNMMB T&E
- NCODA assimilation impact on COAMPS-TC track and intensity study

Improvement of the ocean component

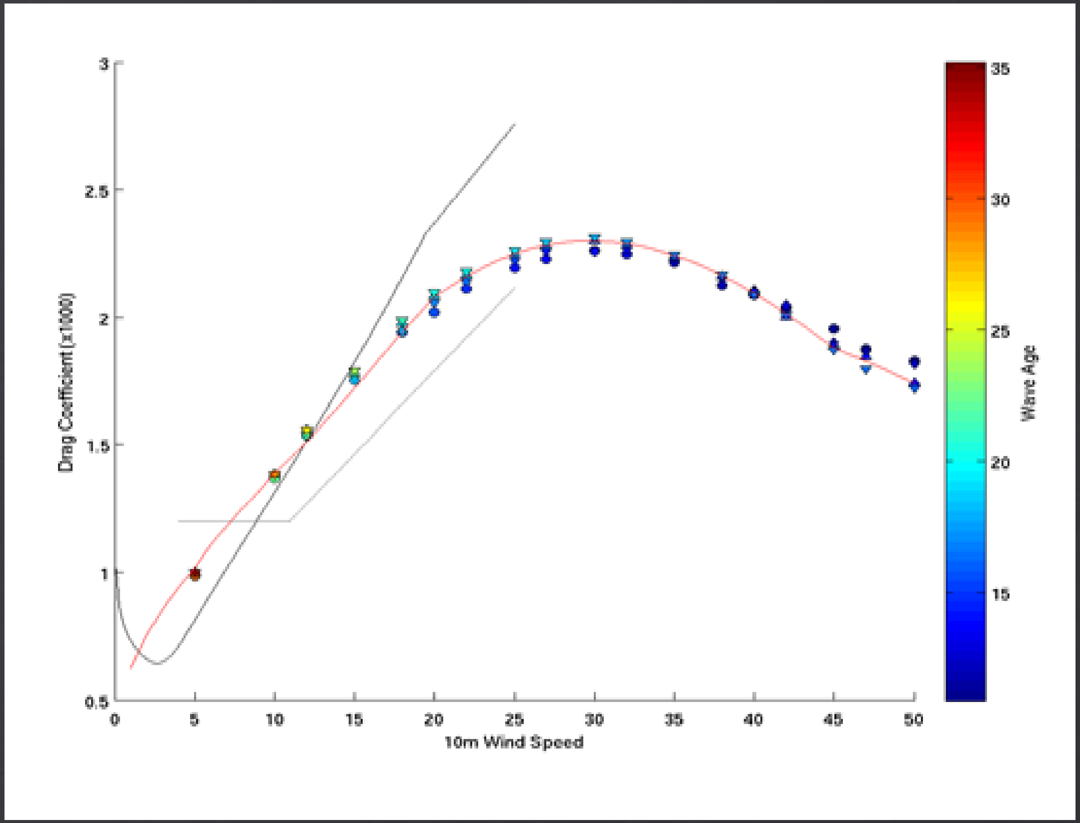
- Complete 3-way coupling, including implementation of non-linear currents-waves interaction (Stokes drift, Langmuir mixing) in the HYCOM ocean component; COAMPS-TC-NCOM 3-way coupling with WW3
- Implement Data Assimilation (DA) to the HYCOM ocean component
- Implement coupled DA
- Ocean OSE/OSSE evaluation of observations to improve initialization

3i. Sea State Dependent Air-Sea Fluxes in Coupled HWRF-POM-WWIII

Meixner et al.

Sea State Dependent Drag Coefficient

Fetch limited experiment to determine tail level parameters to match 2016 HWRF drag coefficient (redline), superimposed on Large & Pond (grey) and COARE 3.5 (black).



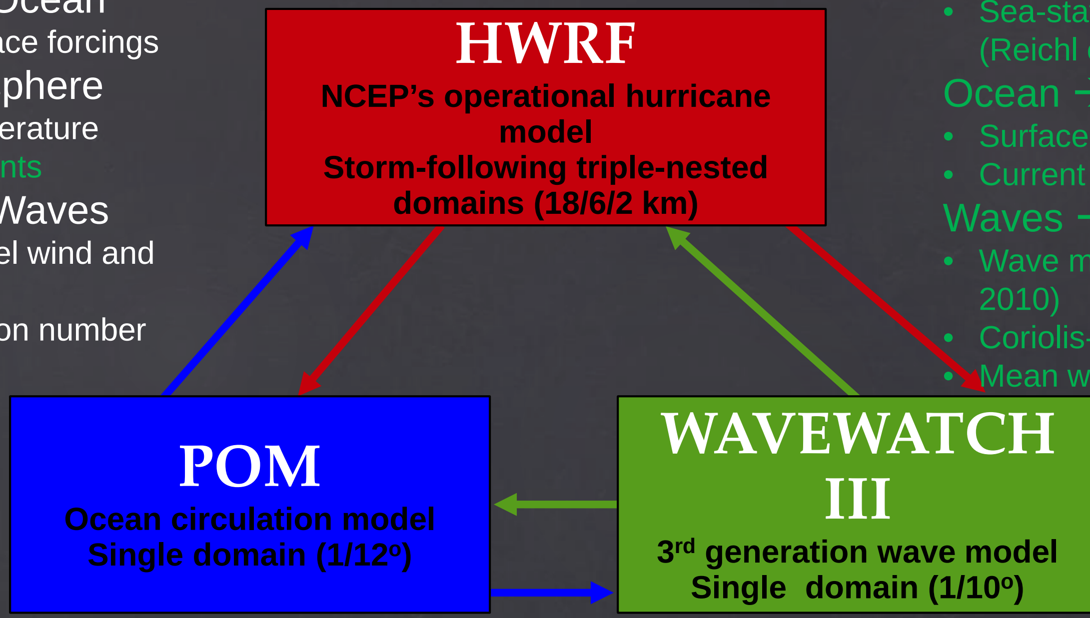
3i. Sea State Dependent Air-Sea Fluxes in Coupled HWRF-POM-WWIII

Meixner et al.

Atmosphere → Ocean
- Atmospheric surface forcings

Ocean → Atmosphere
- Sea surface temperature
- Sea surface currents

Atmosphere → Waves
- Lowest model level wind and height
- Stability Richardson number



Waves → Atmosphere
- Sea-state -dependent drag coefficient (Reichl et al 2014)

Ocean → Waves
- Surface current
- Current at depth

Waves → Ocean
- Wave modified wind stress (Fan et al 2010)
- Coriolis-Stokes drift forcing
- Mean wave length (for current field)

Three-way coupled atmosphere-wave-ocean HWRF system. The coupling processes in black are in currently operational HWRF and the control experiment, whereas the coupling processes in green are additional coupling processes considered in the coupled experiment.

3i. Sea State Dependent Air-Sea Fluxes in Coupled HWRF-POM-WWIII

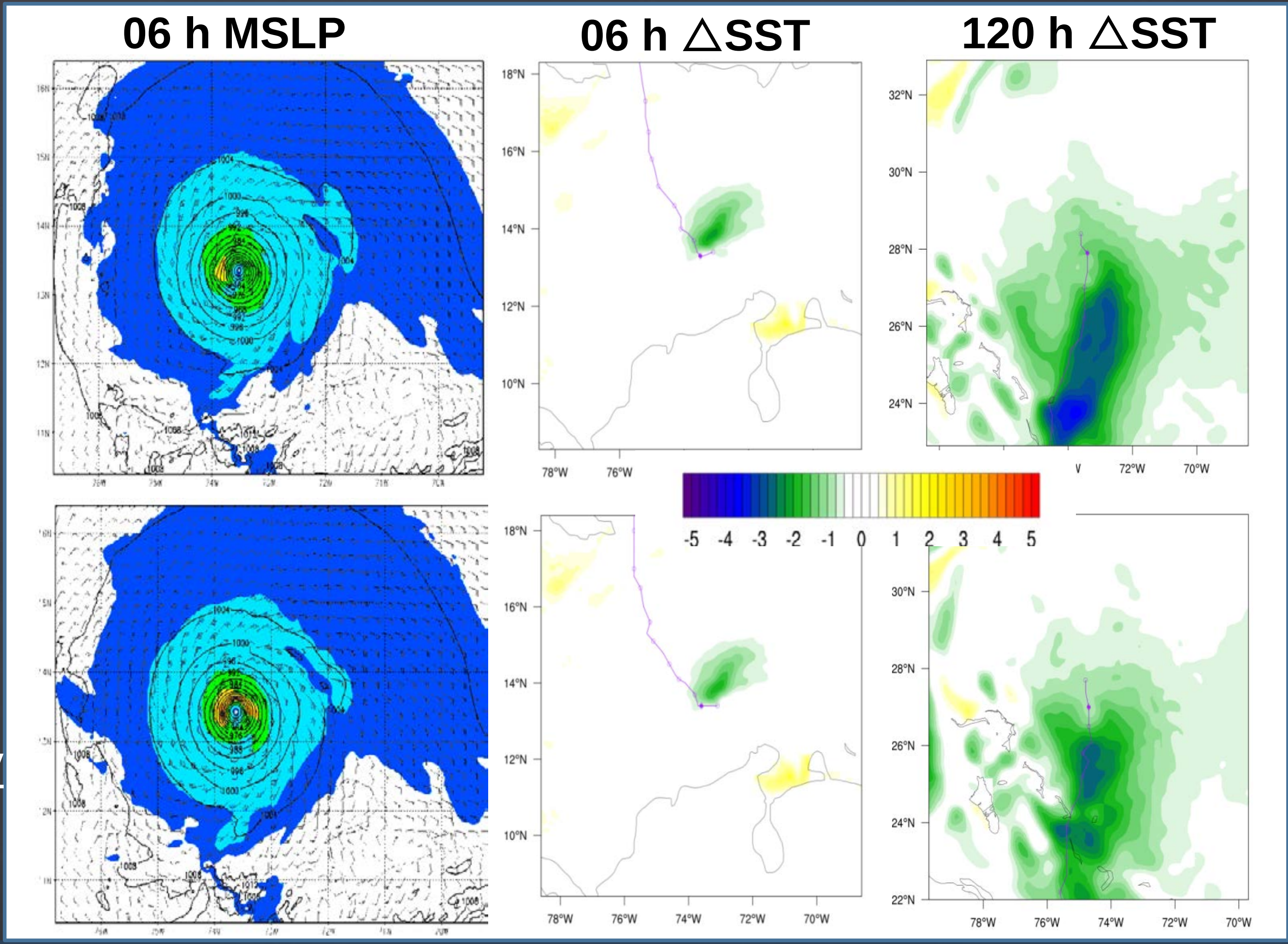
Meixner et al.

control

➤ Findings:

1. Improvement of the storm size and intensity
2. Reduction in both the ocean surface currents and SST

3-way



COAMPS-TC HFIP-OMITT

Sue Chen, NRL

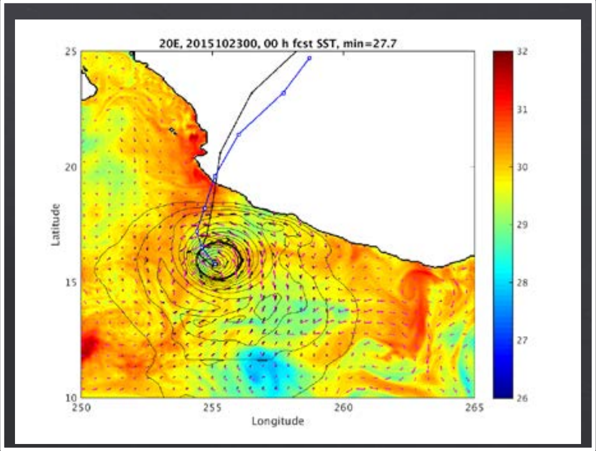
Progress:

- Transitioned the COAMPS-TC coupled to 3D ocean model NCOM (5 km), which is operational at FNMOC in 2016 for all ocean basins
- Improved the mean track and intensity forecast skills
- Completed the development and evaluation of optimal target ocean observation tool in NCODA

Future Plans:

- Continue the development of COAMPS-TC-NCOM coupling with WaveWatch III
- Continue the research on air-sea stress and targeted ocean & wave observations

Patricia 2015102100
max wake SST cooling -3.7 °C



- **Largest TC-ocean observation impacts to reduce NCOM sea temperature forecast errors are in the wake region**