Coupled Ocean-Wave Model Team (Team 8) Report

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Team 8 Outline

1. Operational development at NCEP
2. COAMPS-TC coupling (NRL-MRY)
3. NOAA/ESRL sea spray flux parameterizations (ESRL and URI)
4. Sensitivity of SST cooling to ocean model resolution (URI)
5. Sensitivity of HWRF intensity forecasts to ocean coupling (AOML/PhOD and AOML/HRD)

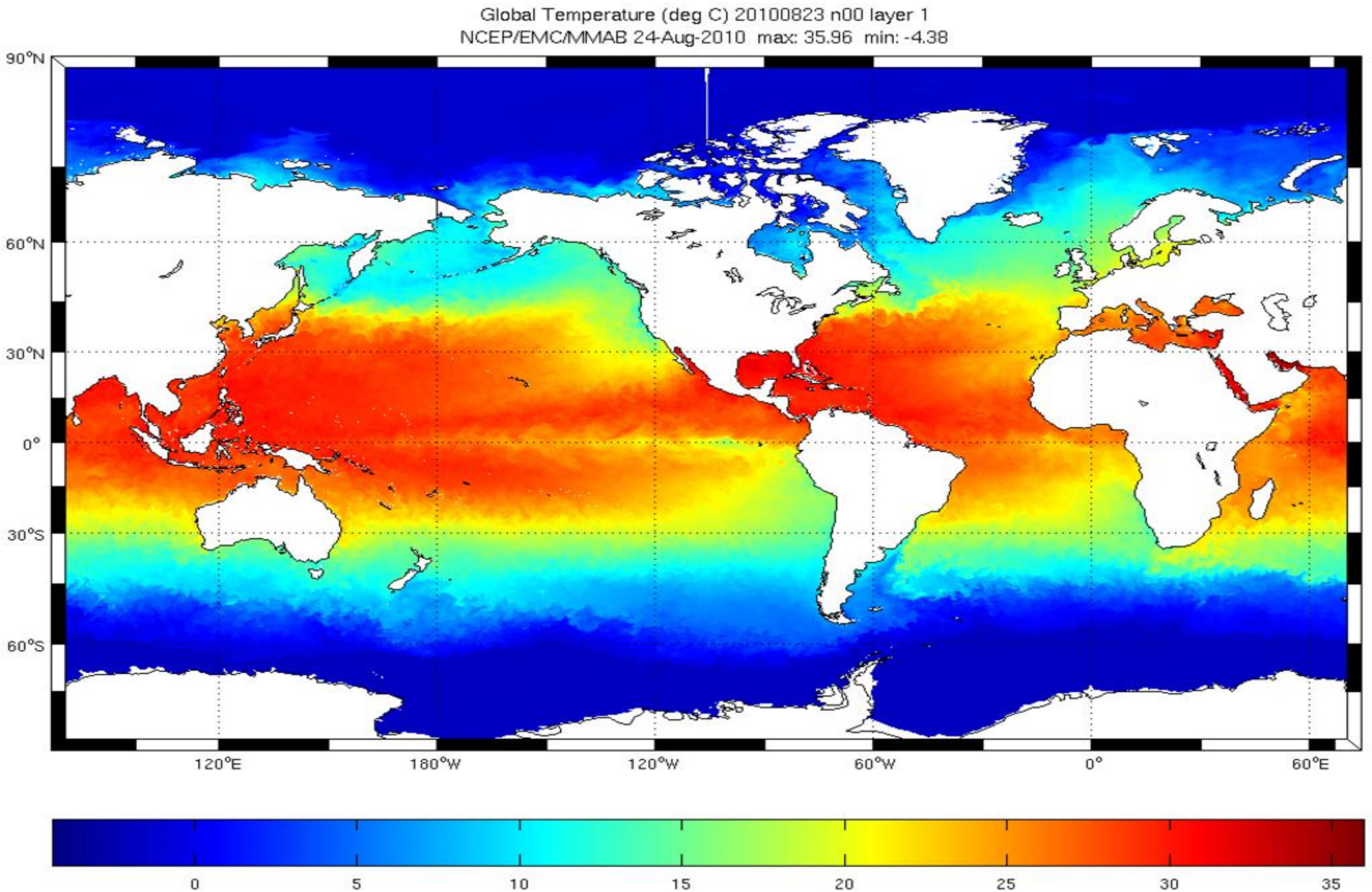
Operational Development at NCEP

1. RTOFS-Global HYCOM transitioned into operations
2. Coupler design consideration for HYCOM-HWRF (HyHWRF)
3. Real time parallel results of HyHWRF

RTOFS-Global

- Global 1/12 degree HYCOM model implemented operationally 10/26/2011.
    - Partnership with U. S. Navy. NCODA initialization provided daily by Navy.
  - Application for hurricane modeling (HFIP)
    - Simplified ocean model initialization anywhere in the world.
    - Ocean heat content products

1/12 Degree Global Domain



Coupler considerations

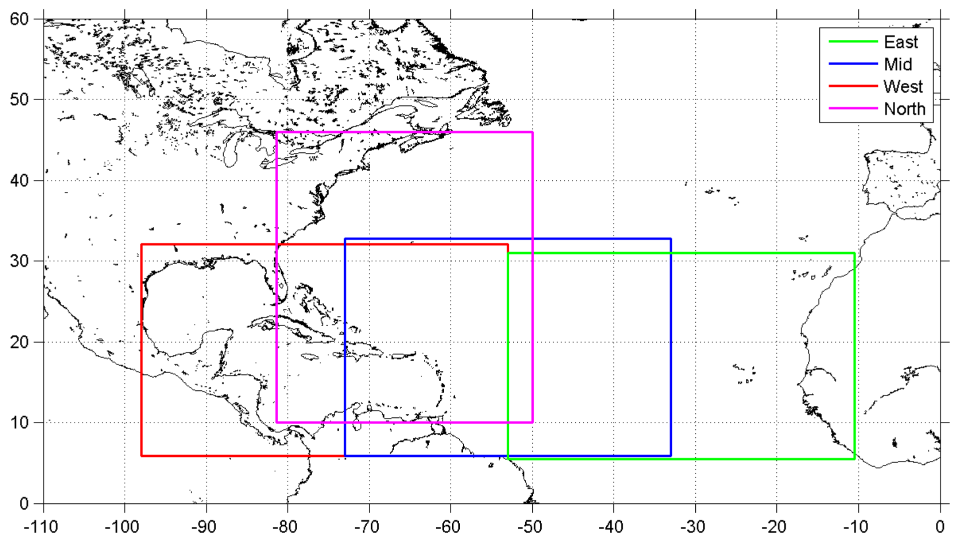
- Simple view of coupling:
  - Couple the models and improvement immediately realized
- Reality:
  - Three HWRF configurations require different optimization
    - Uncoupled (no ocean response, e.g. E.Pac) .
    - Coupled to POM (weak ocean response, e.g. Atlantic).
    - Coupled to HYCOM (strong ocean response)
  - GFS forcing used for global HYCOM is drastically different from surface fluxes produced by HyHWRF
    - Causes rapid upper-ocean T drift at start of forecasts
    - Correcting this problem requires extensive modification and tuning of WRF and HYCOM

1. New HyHWRF using 1/12-degree Global HYCOM

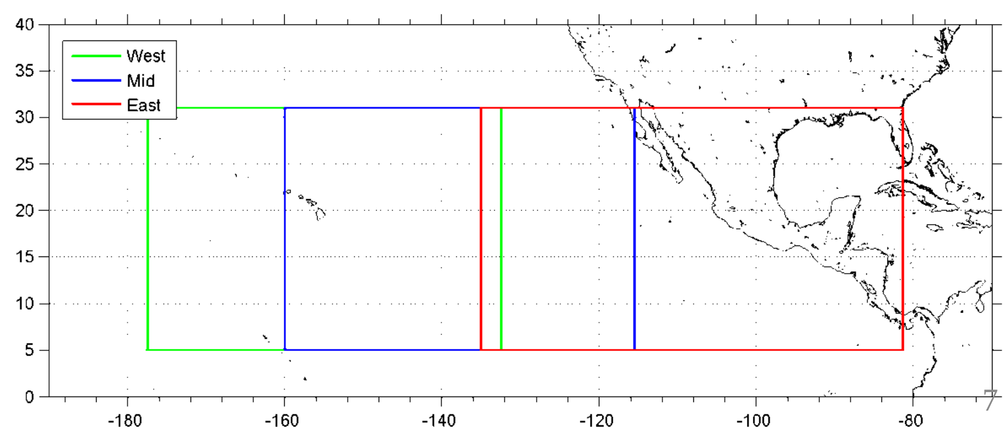
Accomplished/In-Progress, including

A. Hurricane subdomain configurations in Atlantic and Pacific Basins
B. Data Assimilation used in HyHWRF to improve initialization provided by global RTOFS HYCOM (adapt 3D VAR method from global RTOFS)
C. Effort to utilize ESMF capability in HYCOM for future coupler

Atlantic



E. Pacific



Also Western Pacific for Typhoons

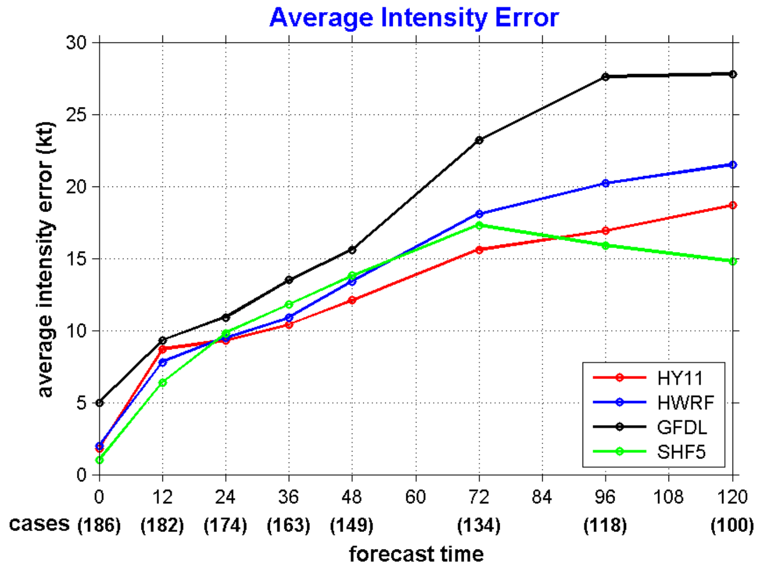
2011 Real-Time Tests of HyHWRF

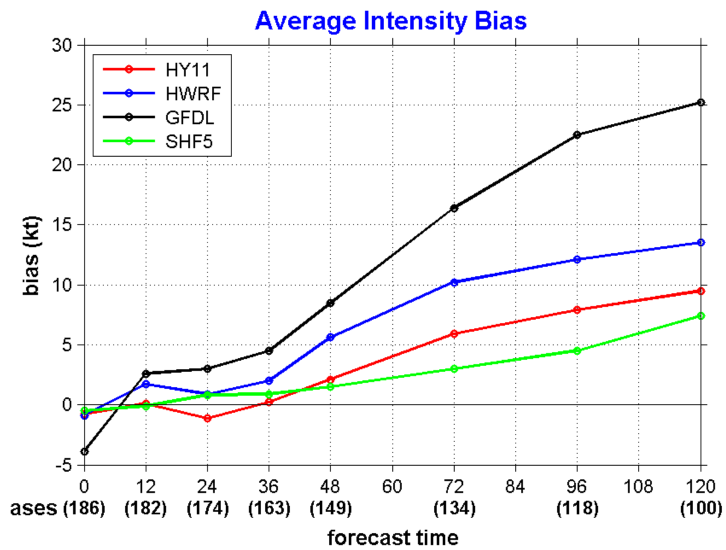
➢**Summary of run results**:

- For 6 tropical cyclones (186 cases)
    - HyHWRF shows improvement in intensity error and bias (< ~5 kt)
    - HyHWRF track forecast is highly comparable to HWRF.

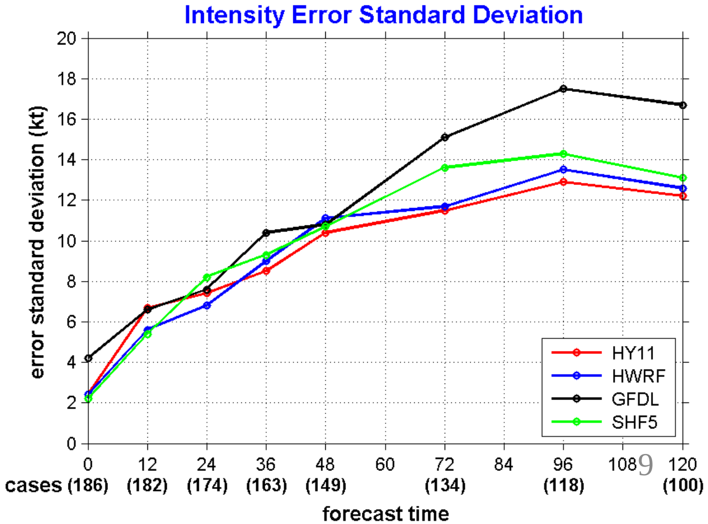
Intensity Forecast for 6 TCs (186 cases): Gert07L, Irene09L, Katia12L, Maria14L, Ophelia16L, and Philippe17L

HY11=HyHWRF2011; HWRF=operational HWRF



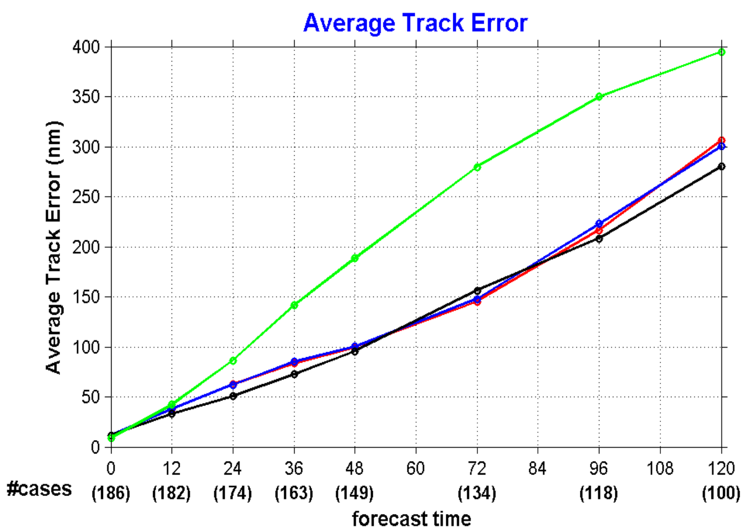


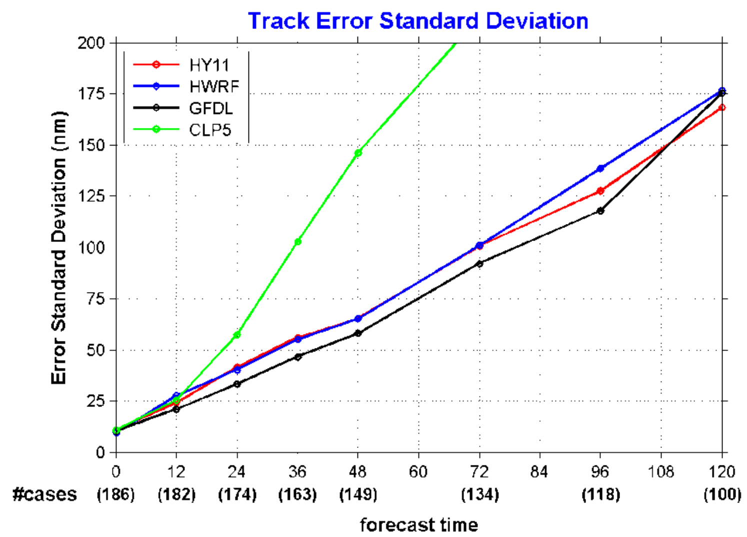
- HyHWRF average intensity error and bias are the best among participant models, except degradation at 12h in average error and negative bias at 24h.
- HyHWRF standard deviation is consistently the smallest, except 12 and 24 h.



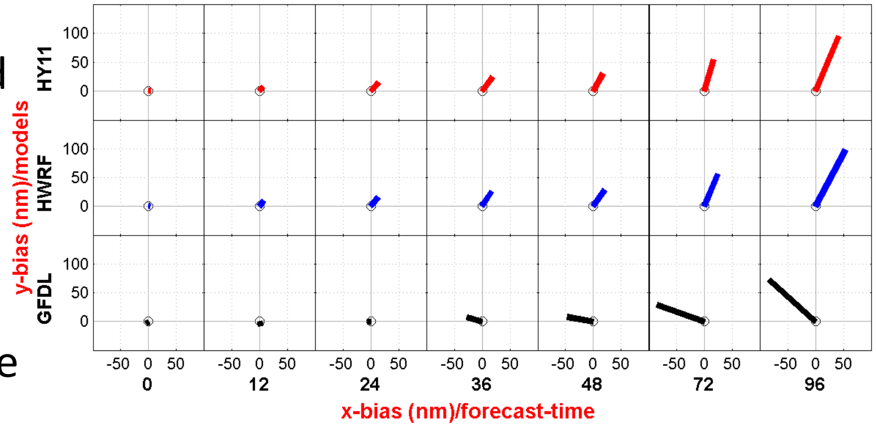
<u>**Track Forecast for 6 TCs (186 cases):**</u> Gert07L, Irene09L, Katia12L, Maria14L, Ophelia16L, and Philippe17L

HY11=HyHWRF2011; HWRF=operational HWRF





- HyHWRF exhibits comparable performance with HWRF for average track error and standard deviation (STD), except STD outperformance at 96 -120 h. GFDL shows mixed comparison but the best STD.
- HyHWRF track bias is the same northeastward as HWRF, but the bias magnitude is better than the HWRF. GFDL shows west/northwestward bias.



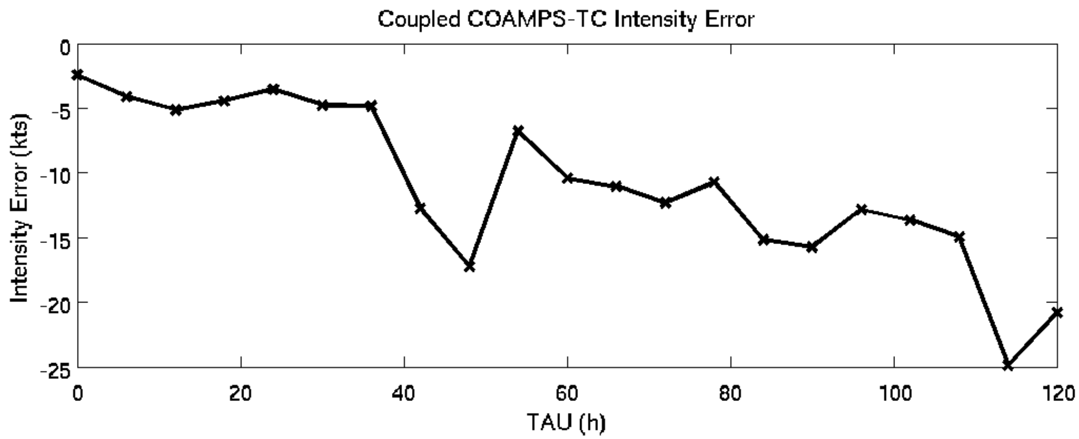
Coupled COAMPS-TC at NRL-MRY

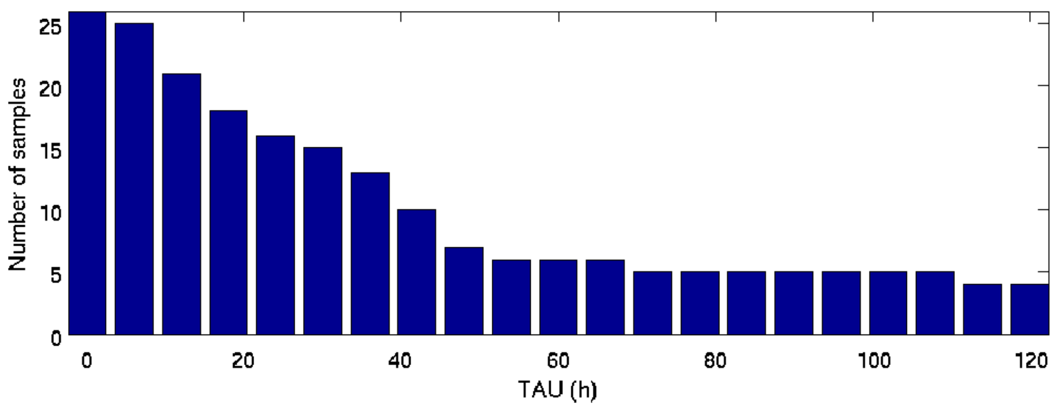
Progress

- Merged new atmospheric physics including microphysics, cumulus, PBL, and sea spray from uncoupled COAMPS-TC
- Performed near-real time air-ocean coupling tests with the updated new atmospheric physics in the Atlantic basin
- Performed XBT assimilation impact studies
- Performed air-ocean-wave coupled tests on selected tropical cyclones

Coupled COAMPS-TC Homogenous Intensity Error

(09L, 12L, 14L, 16L, 17L)





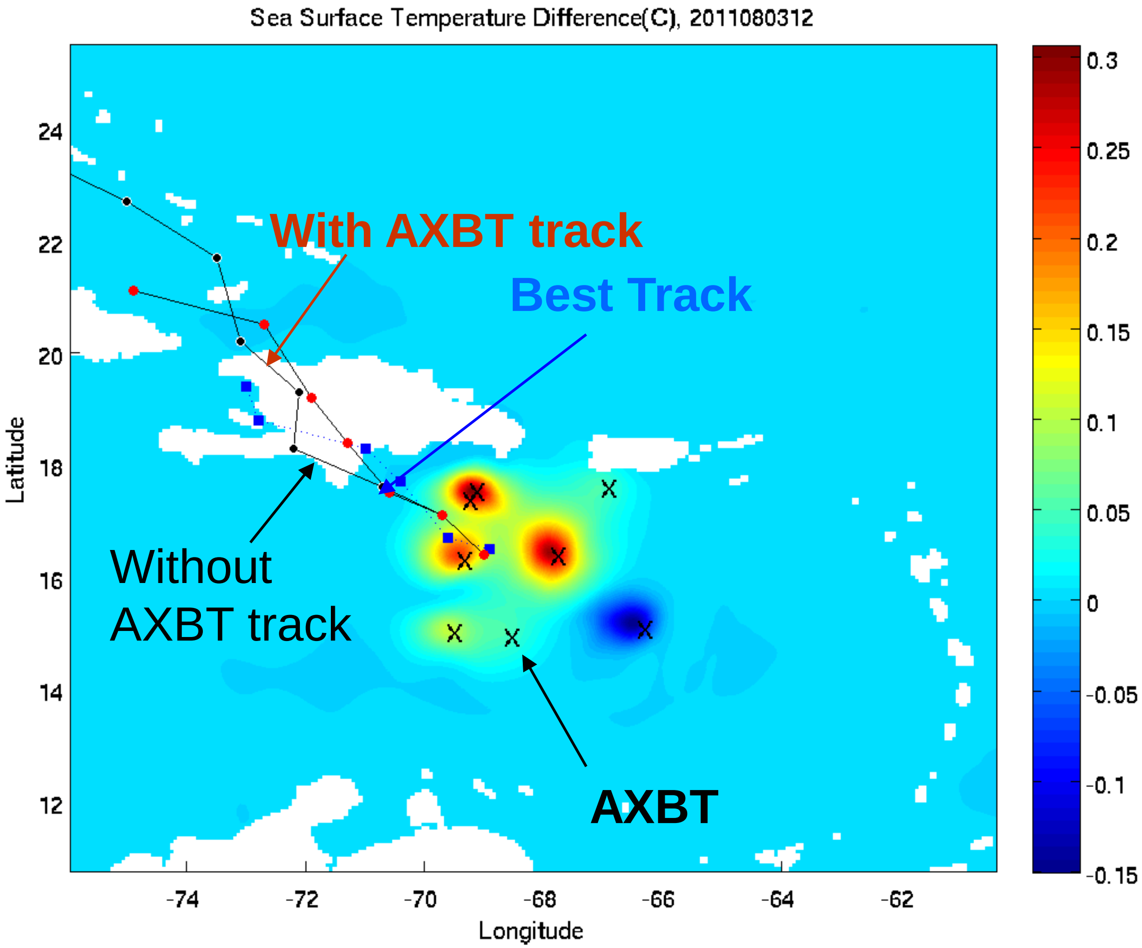
Coupled COAMPS-TC has an averaged (27 samples) negative intensity bias, suggesting:

•Higher horizontal resolution may be needed for the coupled COAMPS-TC

or

•Further adjustment of new atmospheric physics for 5 km coupled COAMPS-TC is needed

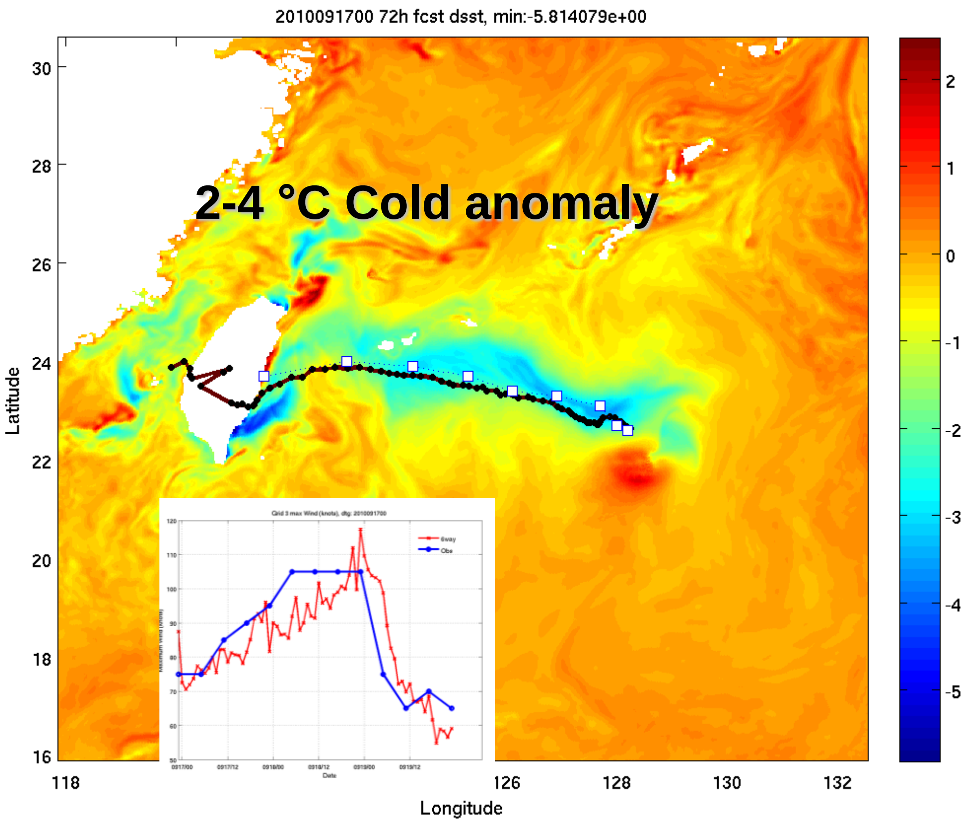
AXBT Impact Study – Hurricane Emily



- AXBT assimilation run has a warmer SST than the run without the AXBT
- Slight track difference after 12h
- AXBT assimilation run has a landfall location close to the observation

Air-Ocean-Wave Coupled COAMPS-TC

High-Resolution Coupled COAMPS Simulations of Typhoon Fanapi (2010)



Atmosphere: 27, 9, and 3 km

Ocean: 9 and 3 km

Wave: 1/6 degree

Model spin-up from 2010090800

12 h update cycle

- **COAMPS forecast of Fanapi intensity is promising**
- **Model is 6 hr too slow due to adjustment to the unbalanced TC bogus vortex in the first 12 h**

ESRL Air-Sea Coupled Modeling

in collaboration with URI

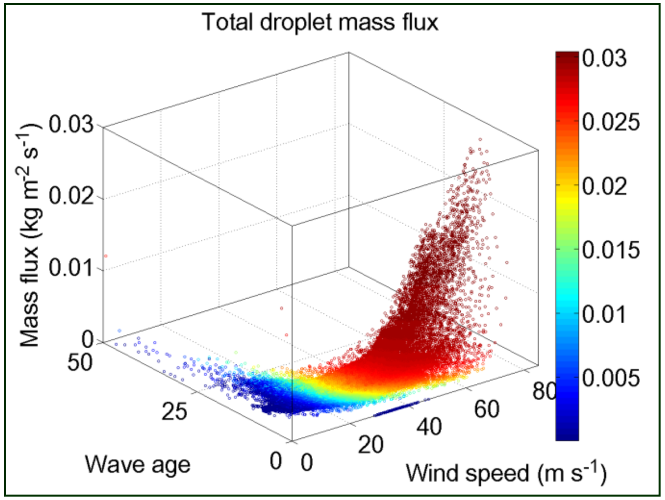
Task:

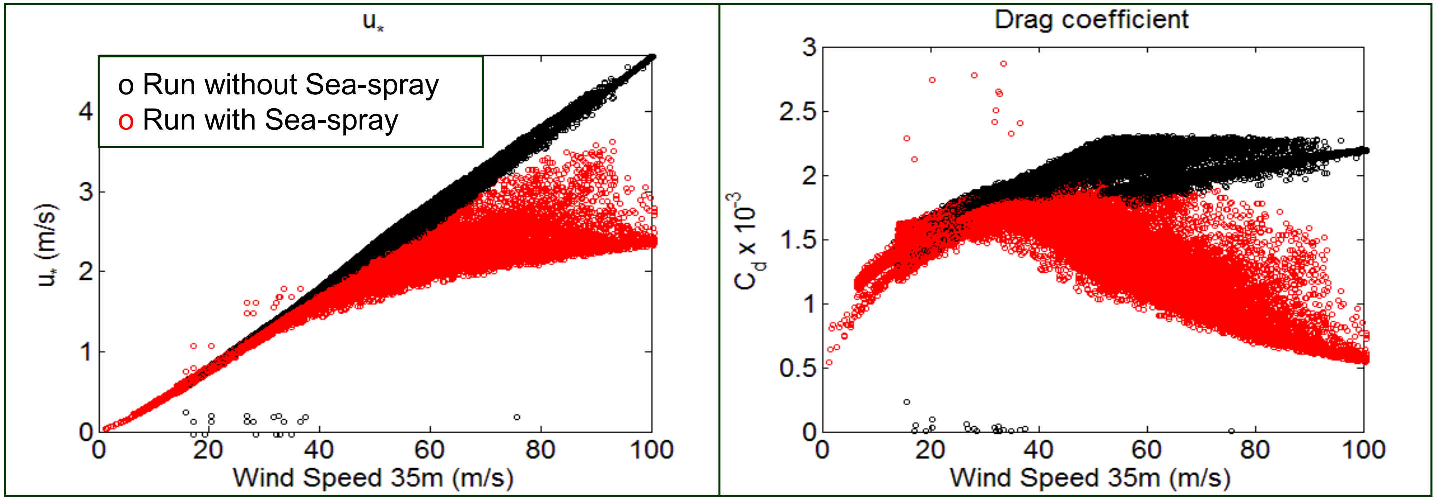
In collaboration with the URI group, we have implemented and tested the NOAA/ESRL sea spray parameterization scheme in the GFDL coupled atmosphere-wave-ocean hurricane model for an idealized case. The scheme predicts that the overall impact of sea-spray droplets on the mean winds depends on the wind speed at the level of sea-spray generation.

Results:

As the wind speed increases, the droplet size increases and the overall wind speed in the surface layer above the level of sea-spray generation increases, indicating that the increase of droplet size due to the increase of wind speed enhances the vertical mixing. This is consistent with observations and results from previous numerical model simulations of the microphysical characteristics of sea spray in the atmospheric boundary layer.

Testing the ESRL Sea-Spray Scheme in the Coupled GFDL Hurricane Model





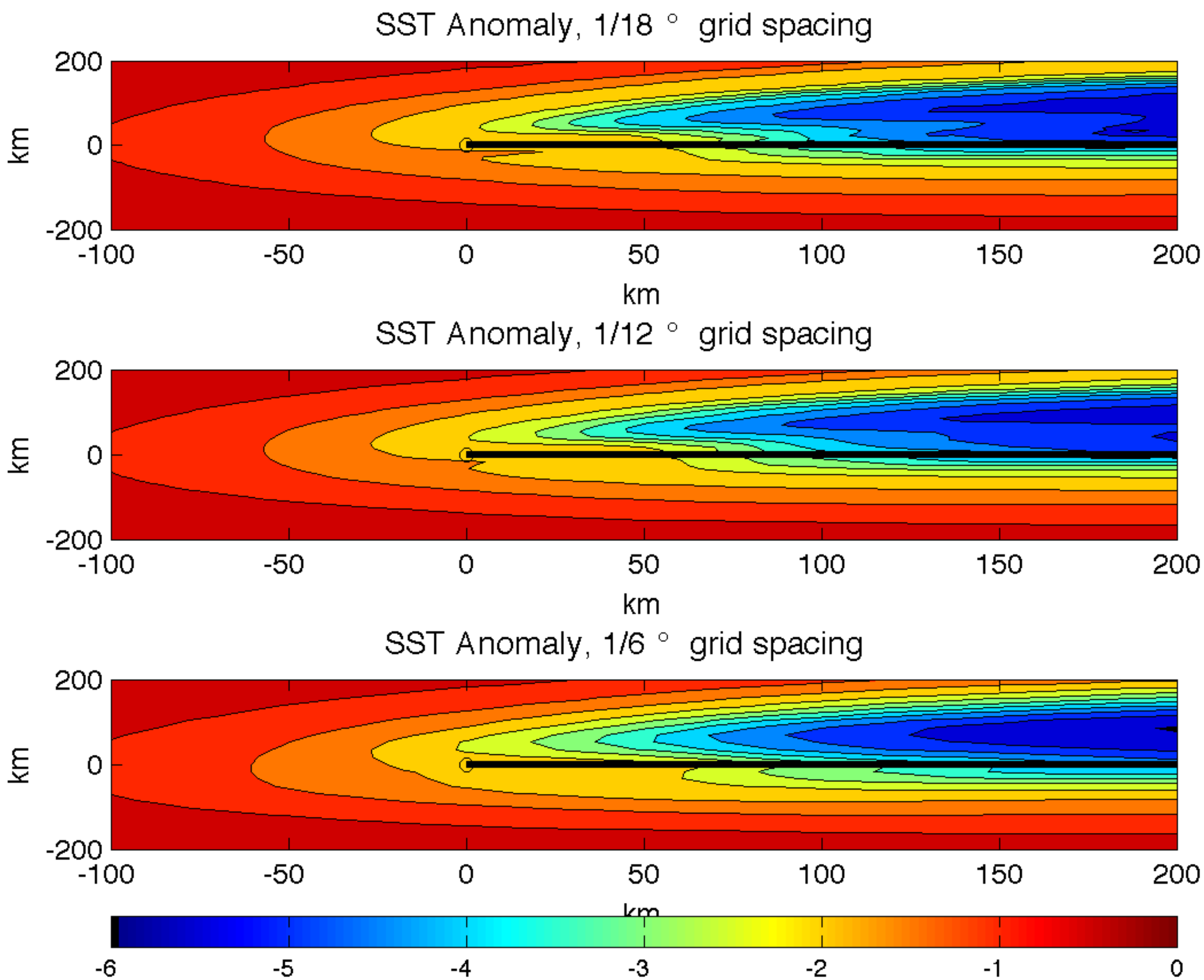
What is the optimal horizontal resolution for the ocean model?

(Idealized experiments with the Princeton Ocean Model)

1/18°

1/12°

1/6°



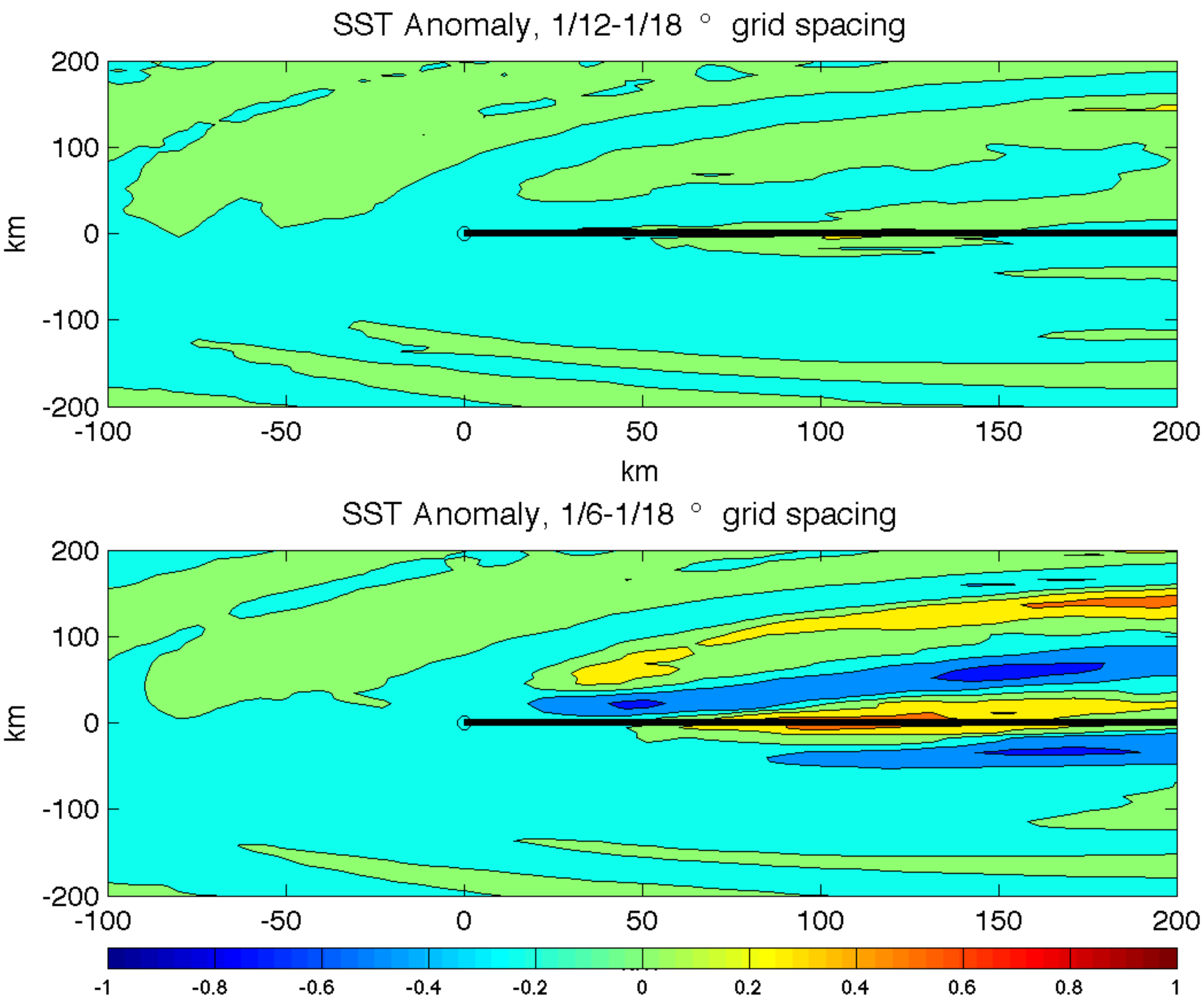
Hurricane:
R_m=55 km,
V_m=55 m/s
U_T=5 m/s

Kaufman, Ginis, Yablonsky (URI)

SST Differences
Between 1/6º, 1/12º, 1/18º Resolutions

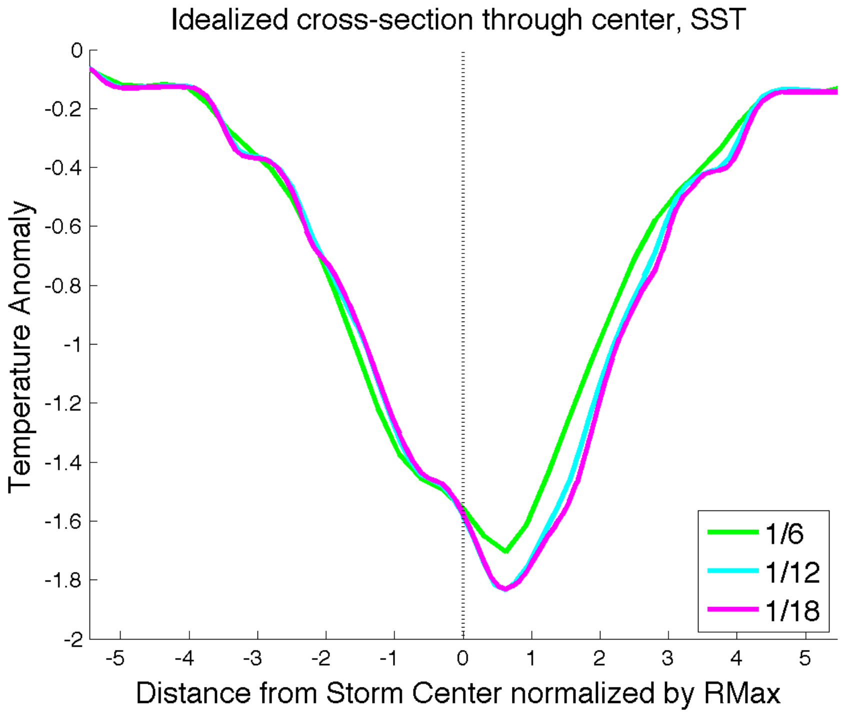
SST(1/12º)
-
SST(1/18º)

SST(1/6º)
-
SST(1/18º)

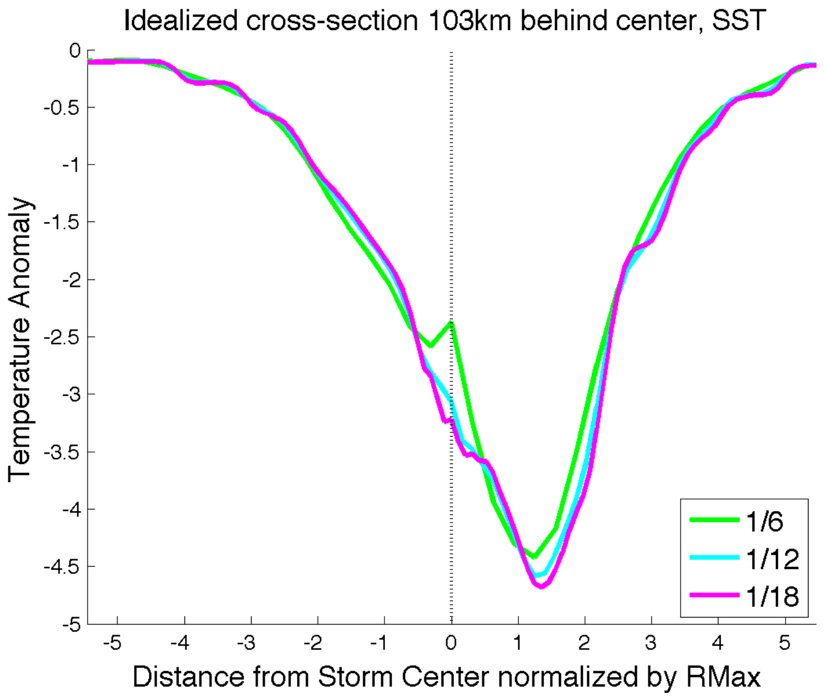


SST Cross-track Profiles

Through center



103 km behind center



Conclusions:

1. SST cooling within hurricane core in the 1/12^o and 1/18^o runs is larger (but not much) than in 1/6^o run

2. The 1/12^o and 1/18^o results are very similar

Sensitivity of HWRF V3.2 to the Ocean

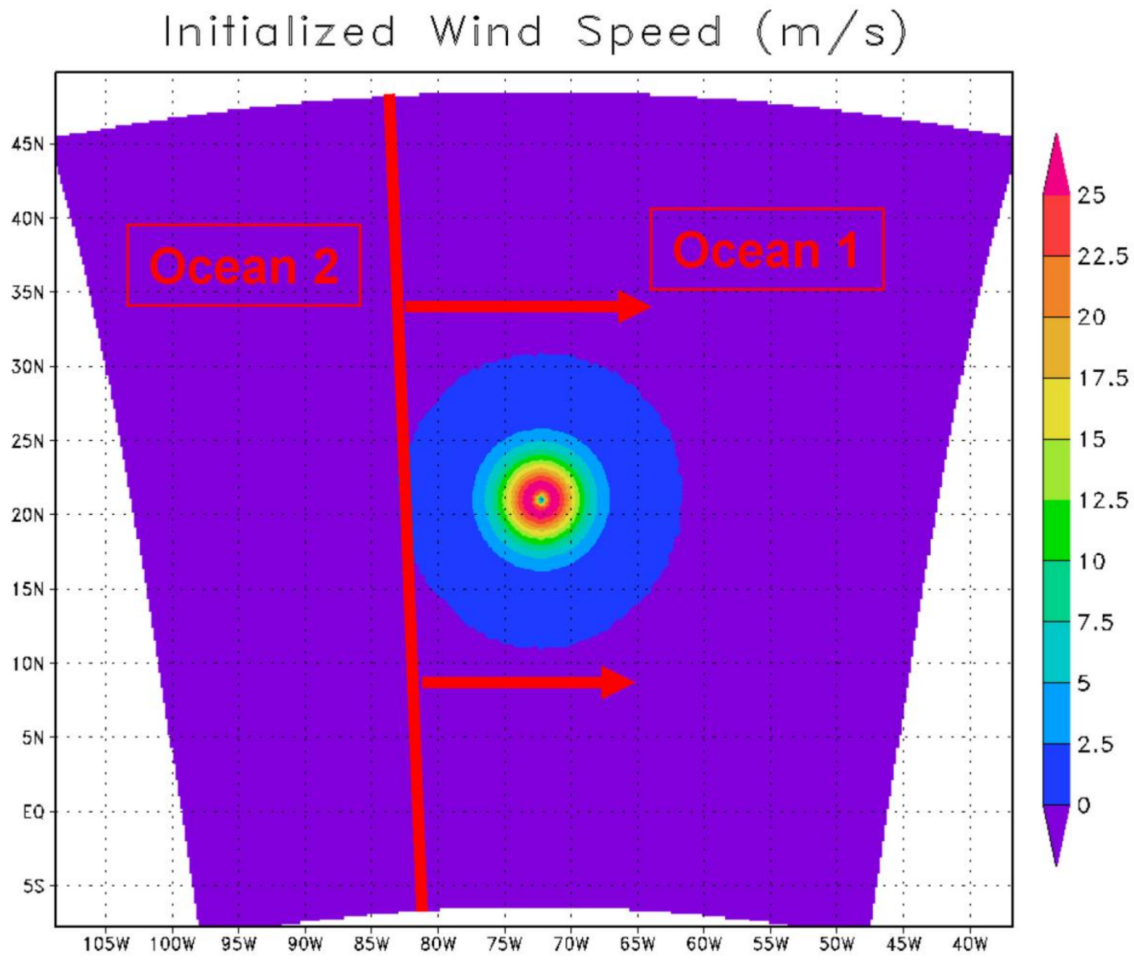
- Problem: poor quantitative understanding of the sensitivity of forecast intensity to changing ocean conditions in coupled forecast models (when/where is the ocean important?)
- Questions:
  - What is the dependence of quasi-equilibrium storm intensity on ocean heat content?
  - How is forecast intensity affected by changing ocean heat content and SST cooling rate?
    - Quantify the magnitude and time scale of the intensity response
  - How do storm parameters affect these results?
    - Storm size and translation speed
- Approach: Perform idealized HWRF V3.2 study minimizing impact of atmospheric processes that affect intensity
  - Magnitude and pattern of SST cooling is the dominant large-scale process affecting intensity

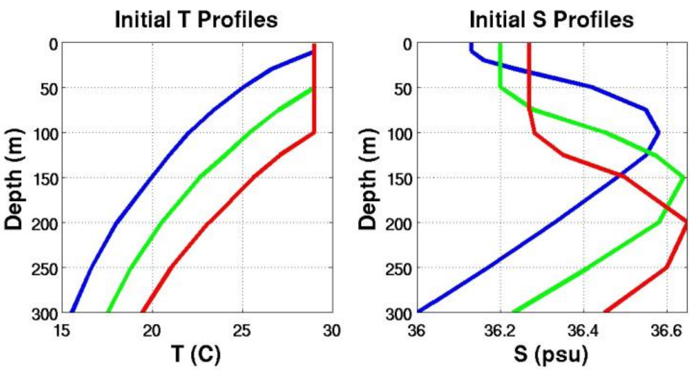
Idealized Study

- NOAA/HRD HWRF Version 3.2, 27-9-3 resolution
- Idealized atmosphere
  - Background is horizontally uniform and at rest
  - Initialized with a weak axisymmetric vortex highly favorable for intensification
  - Resulting storm remains approximately stationary
- Idealized Ocean
  - Embed one-dimensional mixing models extracted from HYCOM into HWRF 3.2
  - Initialized using specified ocean profiles
  - Ocean is bodily advected eastward past the storm to mimic storm translation
    - Use of uniform Trade Winds to control storm speed failed

Ocean Model Initialization

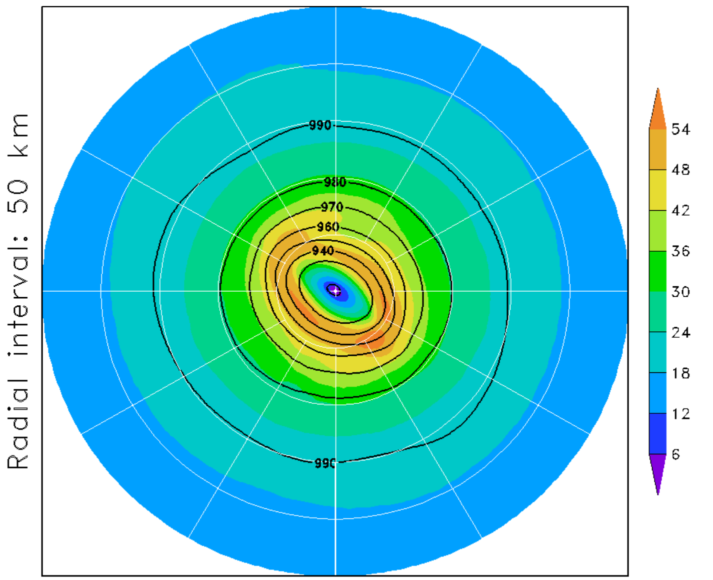
Initialized with either a homogeneous ocean (ocean 1 = ocean 2) or a dual ocean (ocean 1 ≠ ocean 2)



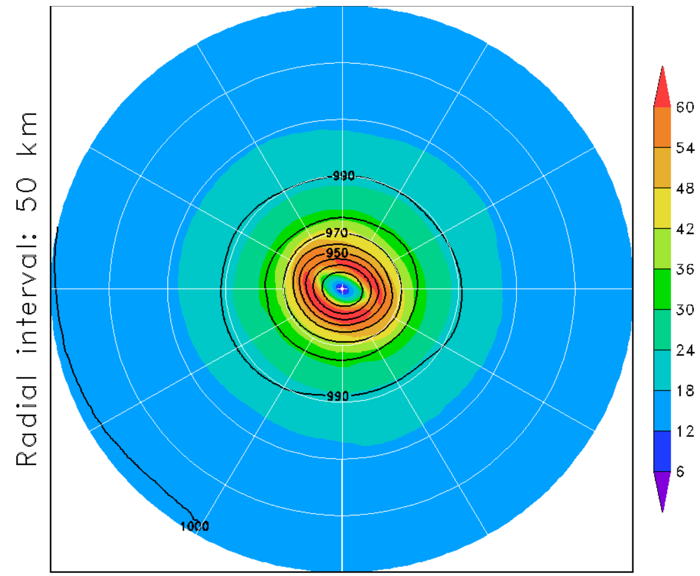


Initial Profiles:
Cool Ocean (OHC=25)
Warm Ocean (OHC=85)
Hot Ocean (OHC=148)

Large Storm



Medium Storm

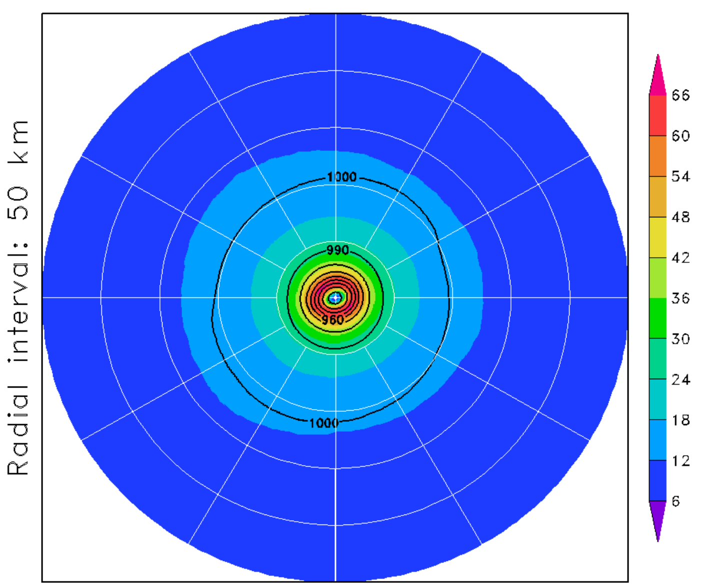


Uncoupled
3 storm sizes

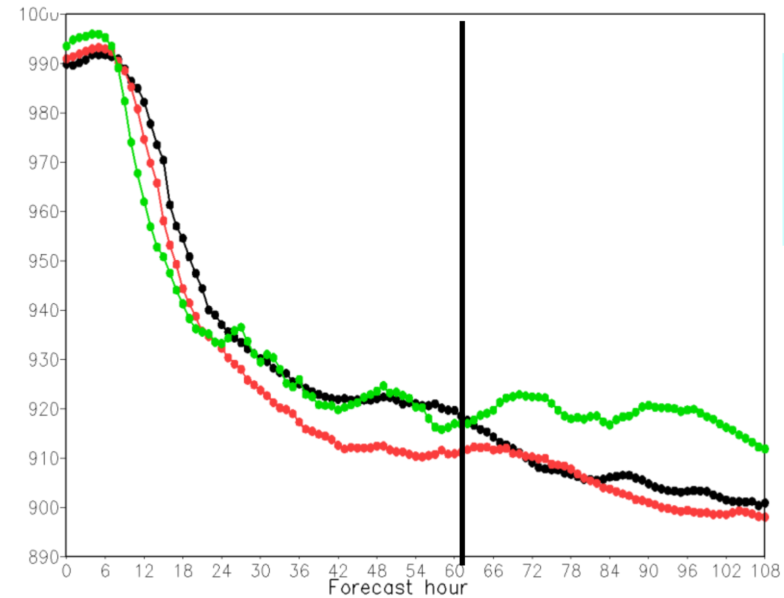
(forecast hour 60)

Wind speed (color)
MSLP (contours)

Small Storm

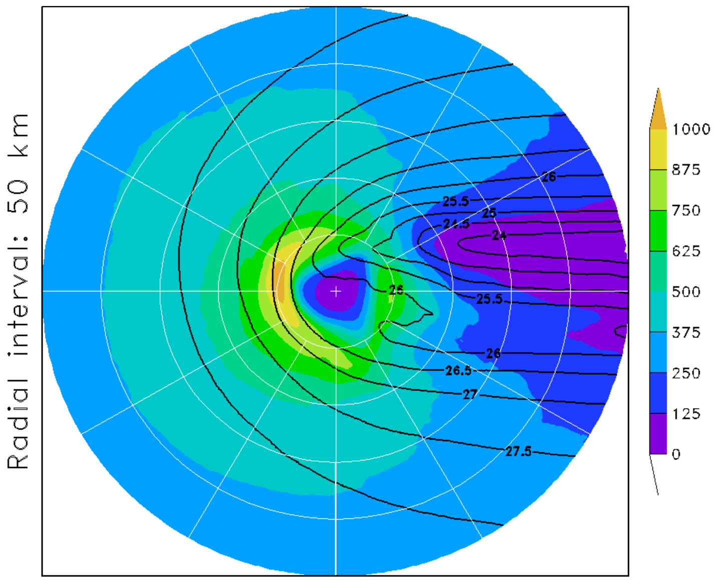


Minimum MSLP

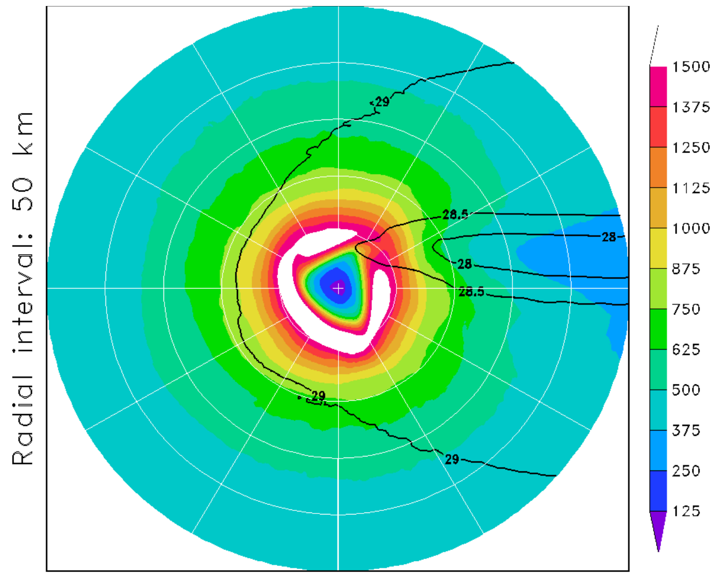


Large storm
Medium storm
Small storm

Cool Ocean



Hot Ocean



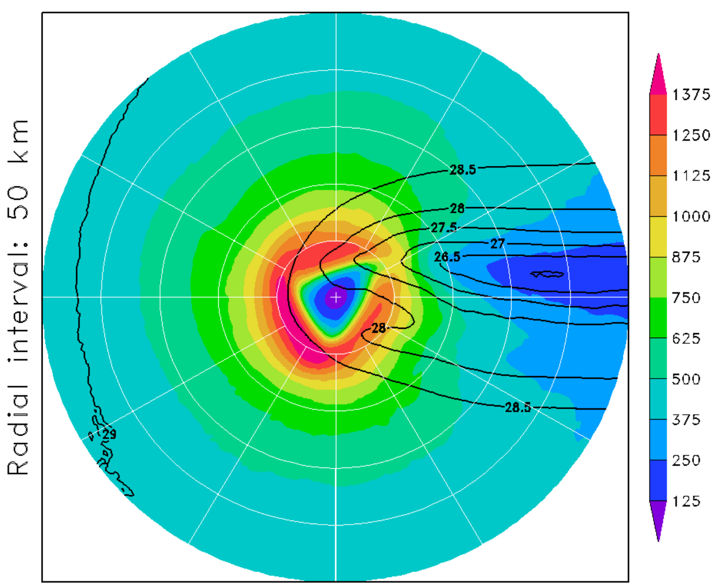
Ocean Heat Content

(forecast hour 60)

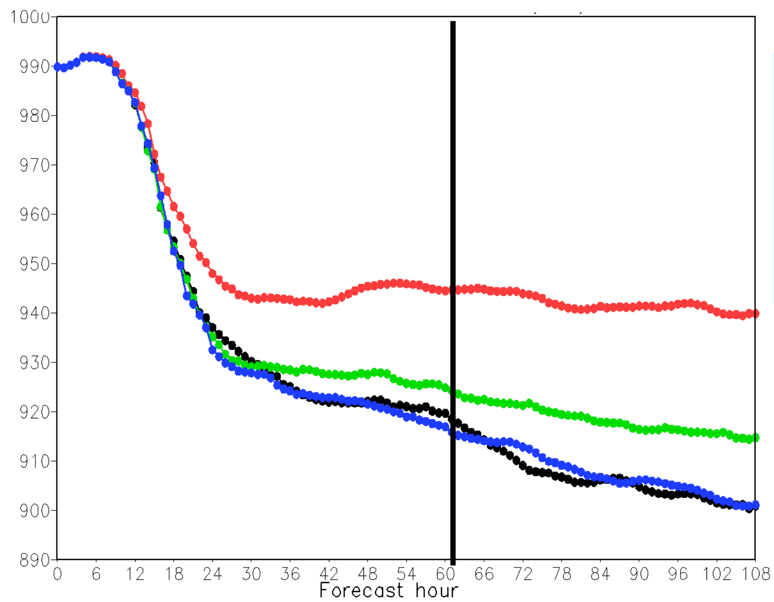
Enthalpy flux (color)

SST (contours)

Warm Ocean



Minimum MSLP



Uncoupled

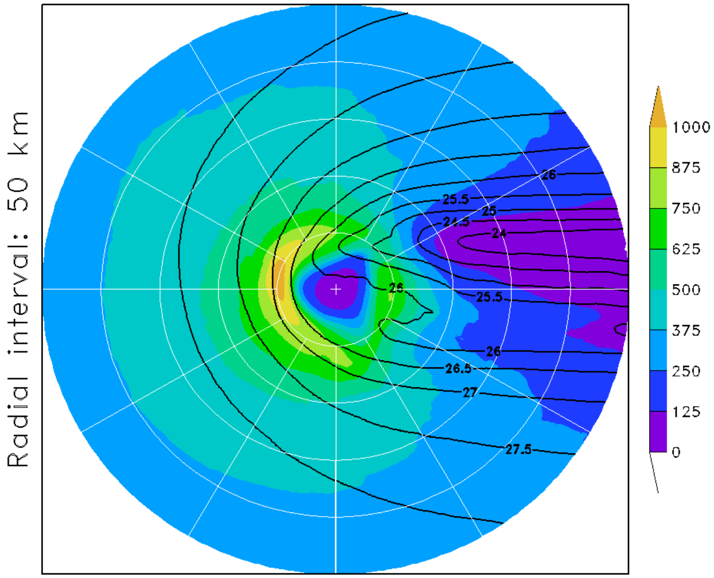
Cool ocean

Warm ocean

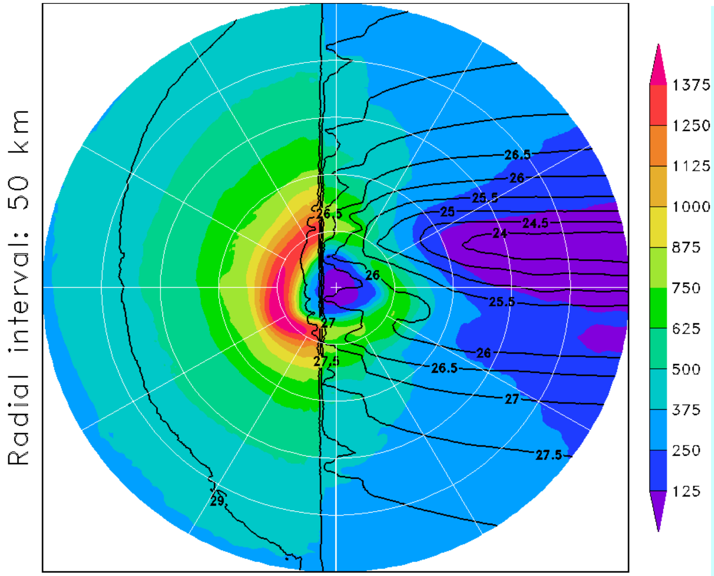
Hot ocean

Large storm
4 m/s speed

Cool Ocean



Cool → Warm Ocean

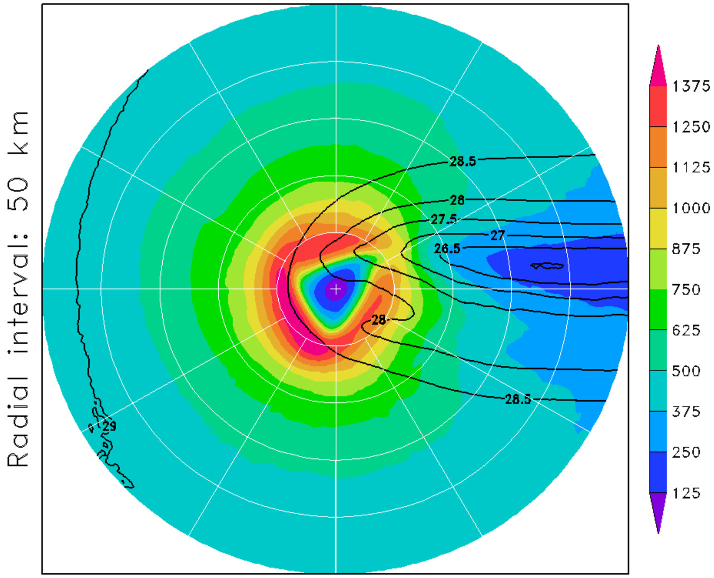


Changing Ocean Heat Content

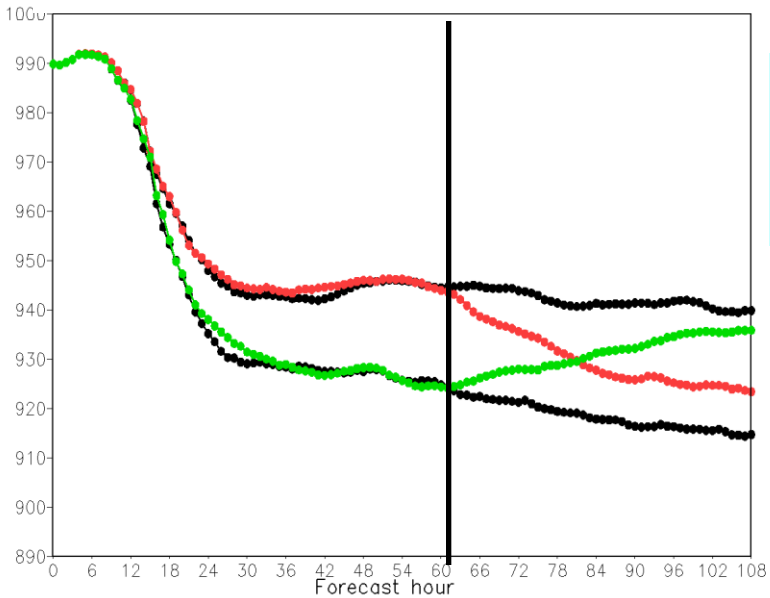
(forecast hour 60)

Enthalpy flux (color)
SST (contours)

Warm Ocean



Minimum MSLP



Large storm
Medium storm
Small storm

Large storm
4 m/s speed

Limitations of 1-D Ocean Models

- Significant limitations of 1-D models, even in a horizontally uniform ocean
  - Does not properly reproduce near-inertial wave response
    - Local pure inertial current response produced by 1-D model remains trapped in the OML, overestimating shear and entrainment
  - Does not account for wind-driven upwelling
    - Very important for slow and near-stationary storms (e.g. Yablonsky and Ginis, 2009)
    - Also running idealized experiments where w(z) is diagnosed from continuity eq. at each grid point and used to estimate upwelling contribution to SST change

Final Comments

- Idealized study described here will be extended to Hy-HWRF (3-D ocean)
- Similar idealized studies should be performed with other coupled forecast models
- Realistic ocean coupling studies need to be performed as soon as possible (all models)
  - Thorough scientific analysis of how ocean coupling (changes in the pattern and rate of SST cooling and enthalpy flux) affects storm intensity
  - Need high-quality upper-ocean observations beneath storms to evaluate the SST cooling patterns predicted by forecast models