

# Application of Coupled HWRF-HYCOM System for the Northwestern Pacific Typhoon Prediction

---

Hyun-Sook Kim  
[Hyun.sook.kim@noaa.gov](mailto:Hyun.sook.kim@noaa.gov)

Sam Trahan, Chanh Kieu, and Vijay Tallapragada

NOAA/NWS/NCEP/EMC

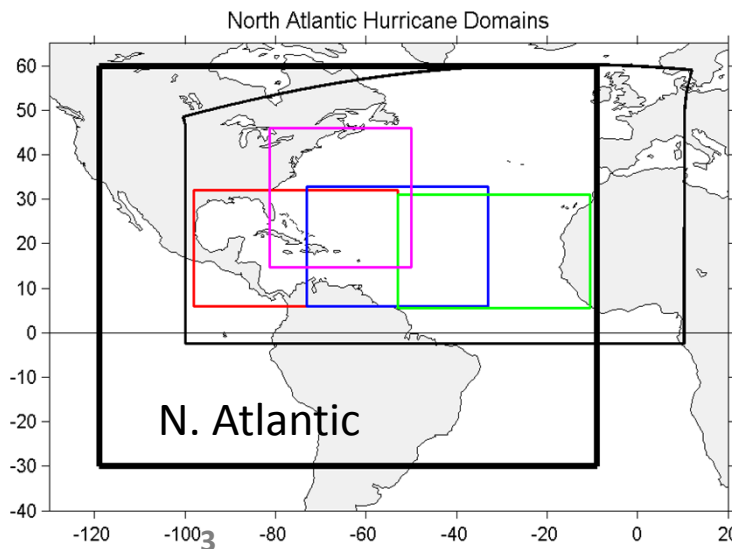
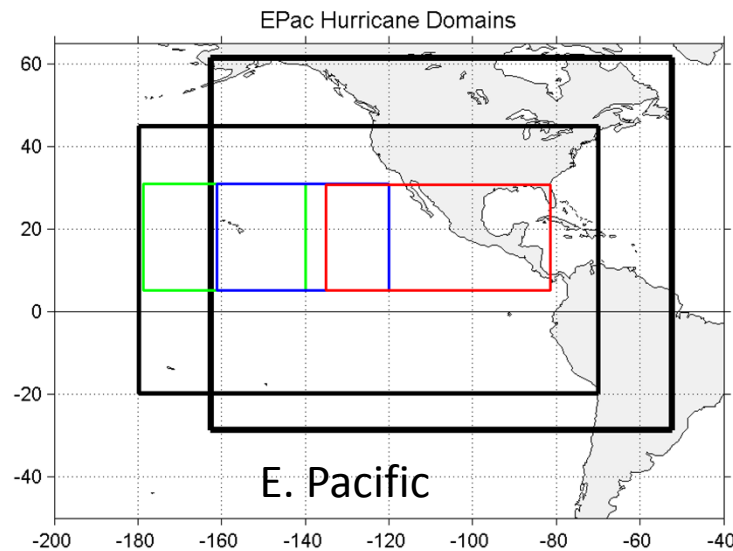
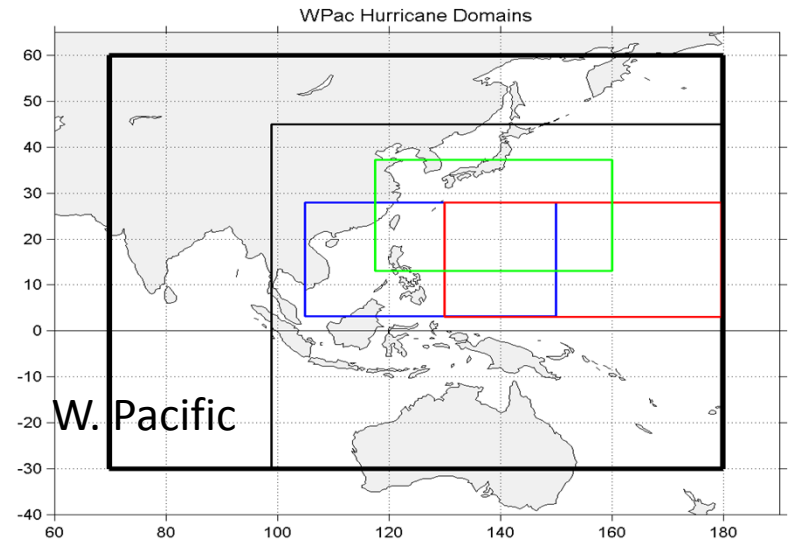
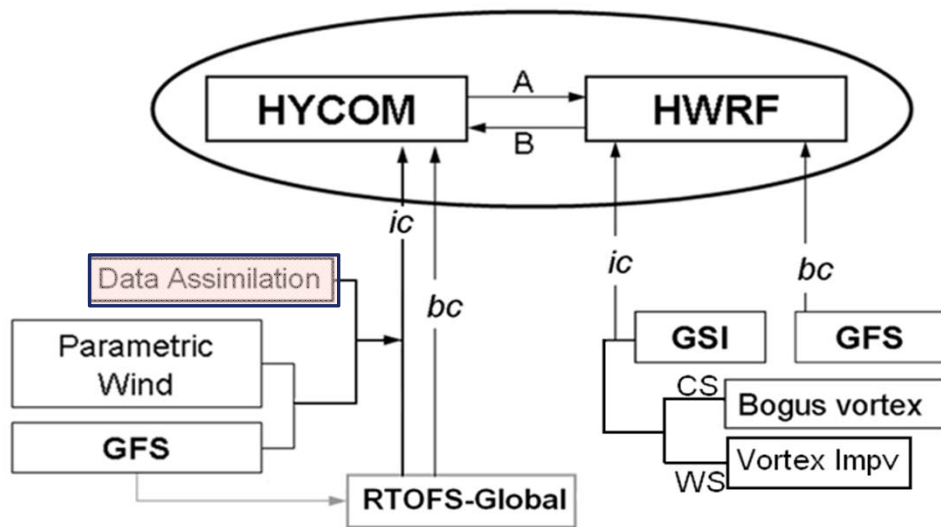


# Motivations

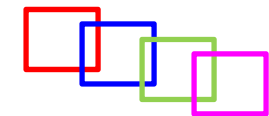
- NRT exercises for the Atlantic and EPac Hurricane forecasts since 2009 prove the concept of coupled HWRF-HYCOM Typhoon prediction.
  - HYCOM coupling improves intensity error by a maximum of 13.8% and reduces positive bias with operational HWRF (2009) by as much as 43.9% (Kim et al. 2014).
- 1/12-degree Global RTOFS runs daily in NCEP since October 2010.
  - This provides geographically un-limited regions for coupled TC modeling.
- Experimental Operational HWRF Support for JTWC
  - Presently with no-ocean coupling since 2012.
  - Parallel runs at EMC with HYCOM coupling since 2012.

# Coupled HWRF-HYCOM System

Coupled hurricane modeling with regional ocean components  
(future HYCOM application, since 2009)



Current:



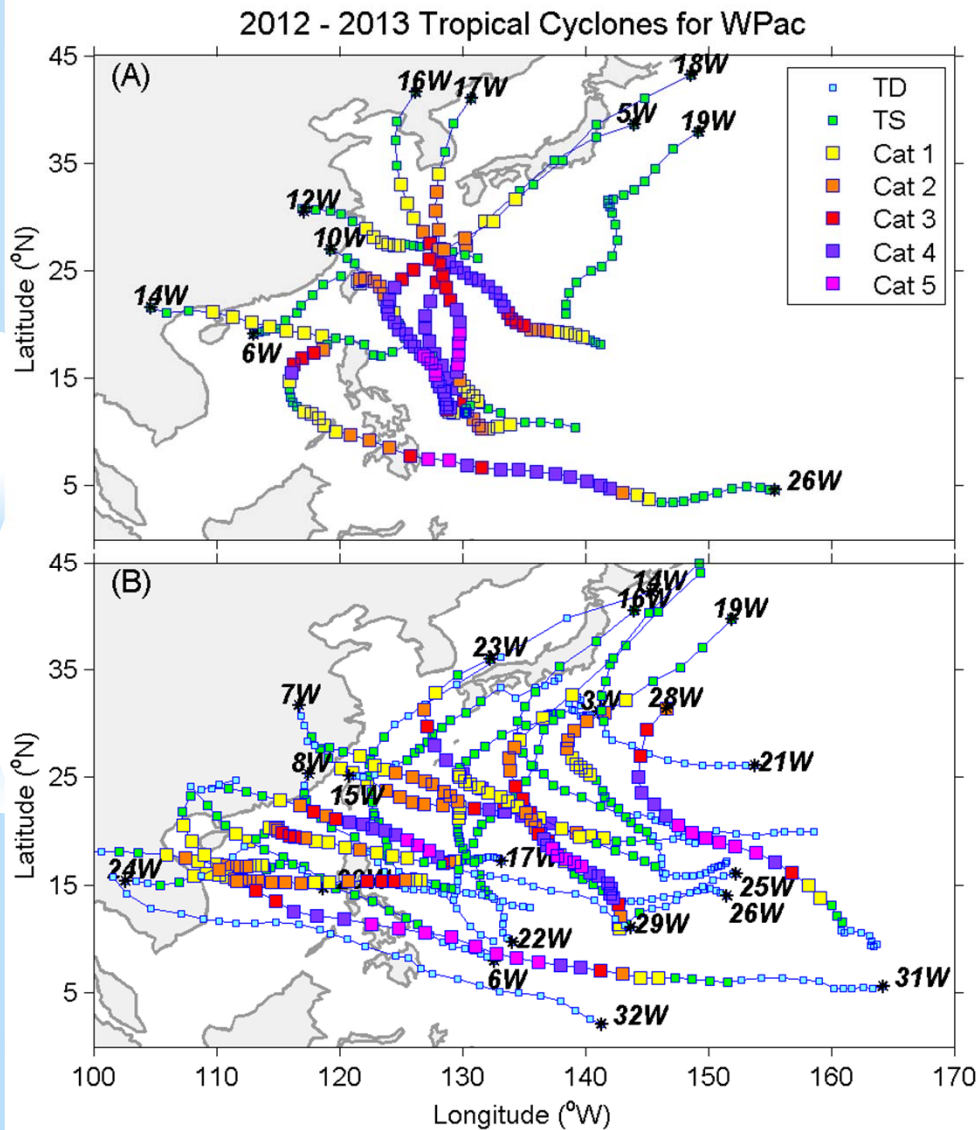
Future - basin



HWRF parent



## Storms included in the study



### 2012:

Guchol 05W (ST4); Talim 06W (TS);  
 Saola 10W (T2); Haikui 12W (T1);  
 Kai-Tak 14W (T1); Tembin 15W (T4);  
 Bolaven 16W (ST4); Sanba 17W (ST5);  
 Jelawat 18W (ST5); Ewiniar 19W (TS);  
 Bopha 26W (ST5)

11 storms =

**2TS+2T1+1T2+1T4+2ST4+3ST5**

### 2013:

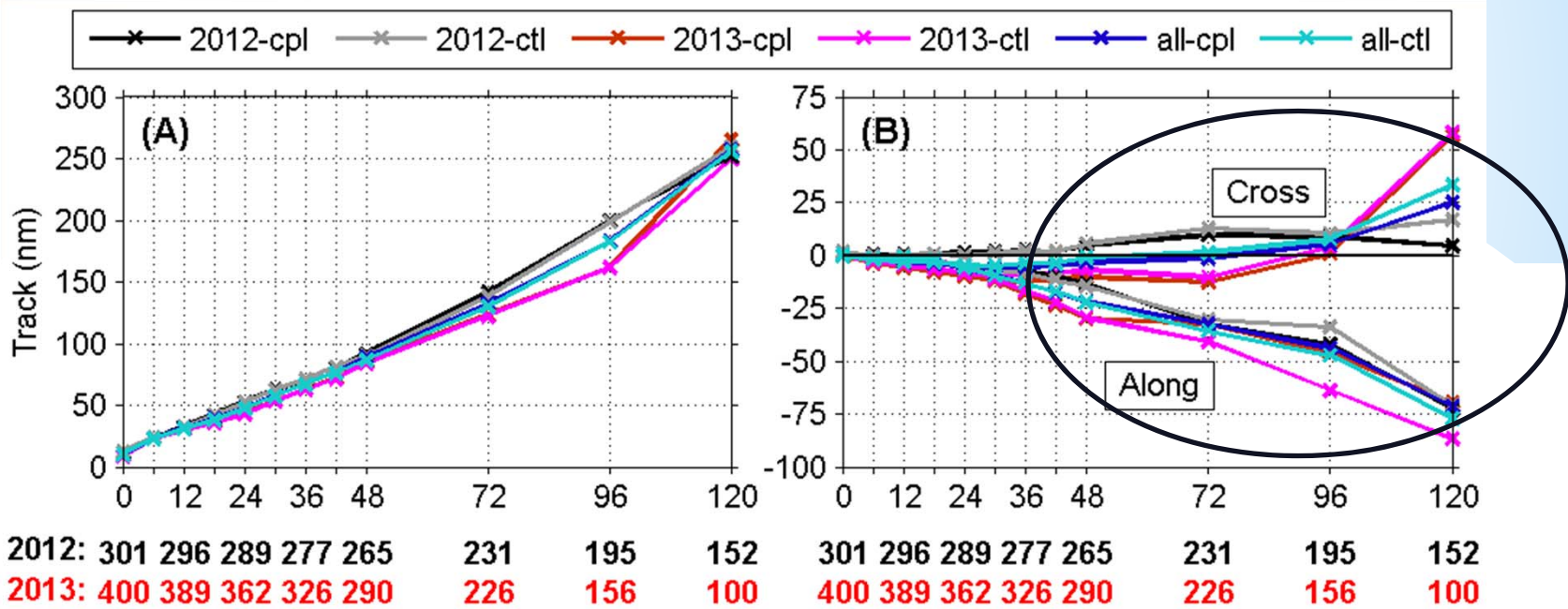
Yagi 03W (TS); Rumbia 06W (T1);  
 Soulik 07W (ST4); Cimaron 08W (TS);  
 Kong-Rey 14W (TS); Toraji 15W (TS);  
 Man-Yi 16W (TS); Usagi 17W (ST5);  
 Pabuk 19W (T2); Wutip 20W (T2);  
 Sepat 21W (TS); Fitow 22W (T2);  
 Danas 23W (ST4); Nari 24W (T3);  
 Wipha 25W (T4); Francisco 26W (ST5);  
 Lekima 28W (ST5); Krosa 29W (T3);  
 Haiyan 31W (ST5); Podul 32W (TD)

20 storms =

**1TD+6TS+1T1+3T2+2T3+1T4+2ST4+5ST5**

# Typhoon Forecasts for the 2012 and 2013 season HWRF-HYCOM (cpl) vs. HWRF (ctl)

## Track Verification (701 cases)



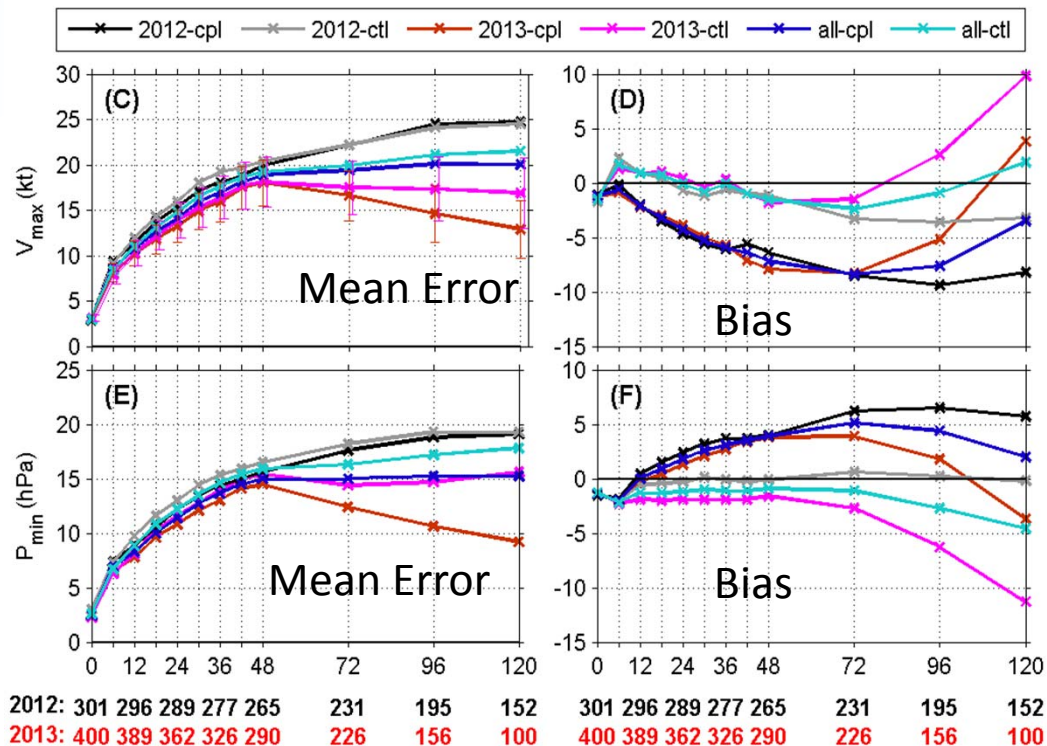
- The differences in TC track between Coupled (**cpl**) and persistent SST (**ctl**) forecasts are very small.
- Analysis of the individual components suggests that the tracks have a southeast/westward bias, but having ocean coupled corrects this bias. A similar correction are reported in Khain and Ginis (1991) and Bender et al. (1993).



# Typhoon Forecasts for the 2012 and 2013 seasons HWRF-HYCOM (cpl) vs. HWRF (ctl)

## Intensity verification (701 cases)

$V_{max}$



$P_{min}$

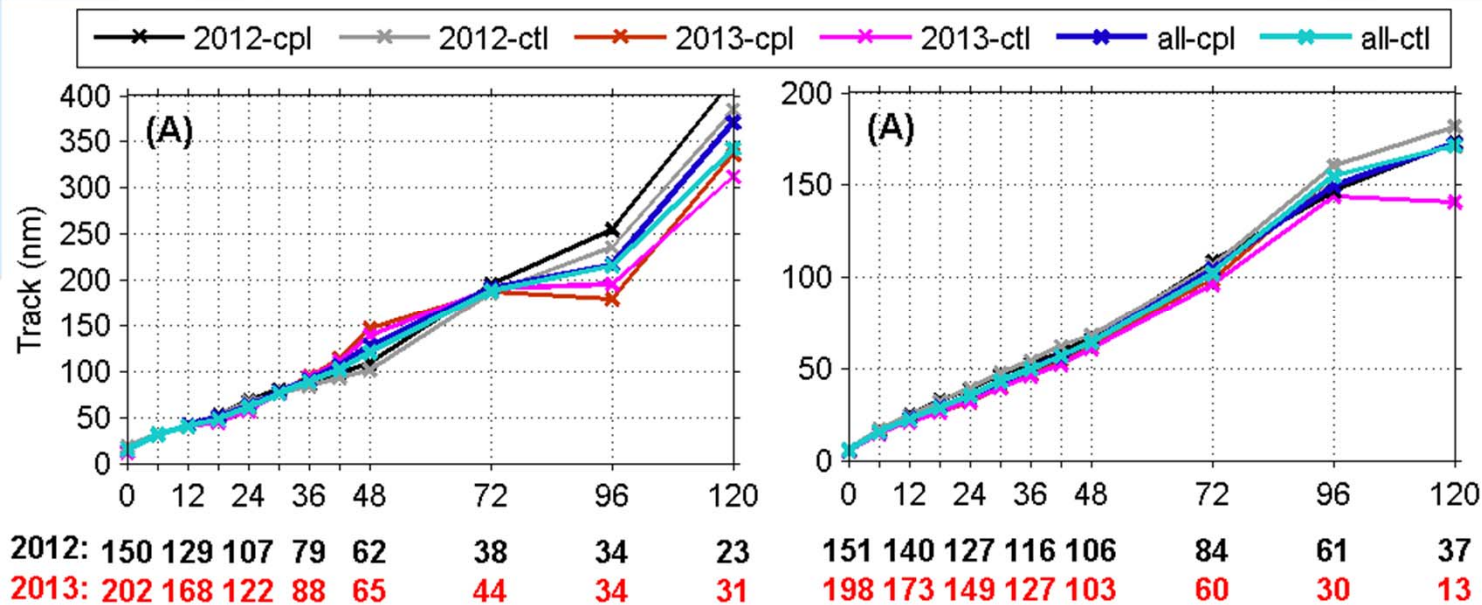
- HWRF-HYCOM (**cpl**) shows smaller error especially later forecast hours, cf non-coupled (**ctl**), e.g. a maximum 25% reduction for the 2013 season (red).
- Mostly, negative bias in  $V_{max}$  (< 9 kt), and positive  $P_{min}$  (< 6 hPa).

## Weak ( $\leq TS$ ) and Strong Storms ( $\geq$ Cat. 1):

### Track Verification – Absolute Error

**Weak: 352 = 150 + 202**

**Strong: 349 = 151 + 198**



- 68 to 84% larger for weak (< 450 nm) than strong storms (< 180 nm).
- CTL (noncoupled) run for 2012 has better skill at the lead hours longer than 72 h.
- Both CPL and CTL perform better for the 2013 weak storms, relatively, but they are still worse than for the strong storms.

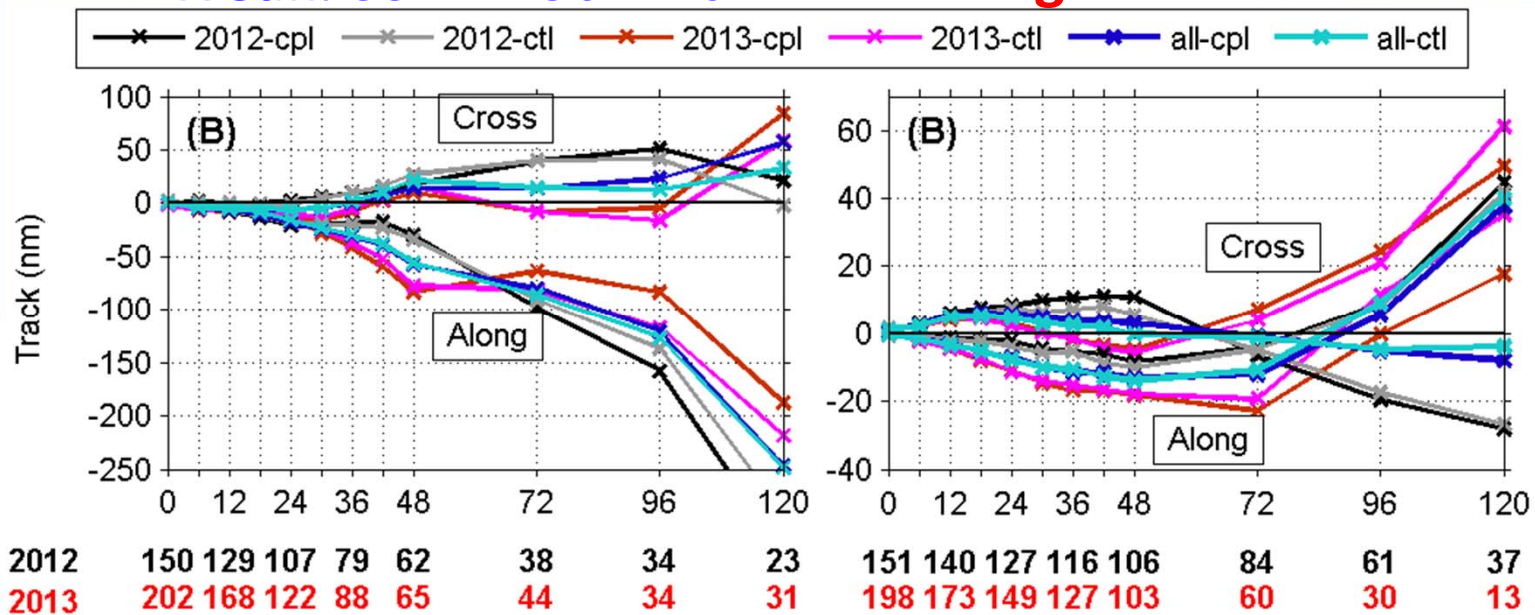
**HWRF has more accurate track forecasts for strong storms, compared to weak storms.**

# Weak ( $\leq$ TS) and Strong Storms ( $\geq$ Cat. 1):

## Track Verification - Bias

**Weak: 352 = 150 + 202**

**Strong: 349 = 151 + 198**



- Appears the weak storms governs the track bias for combined season, due to large bias, especially along track (> 250 nm for the 2012);
- Southeast for 2012 and southwestward bias for 2013.

- Bias changes onwards from 60 hr – from southeast to northwest for 2012; and from southwest to northeast for 2013.
- This is primarily due to substantial change in the along track bias (from -350 to 60 nm) – from slower for weak to faster for strong storms.

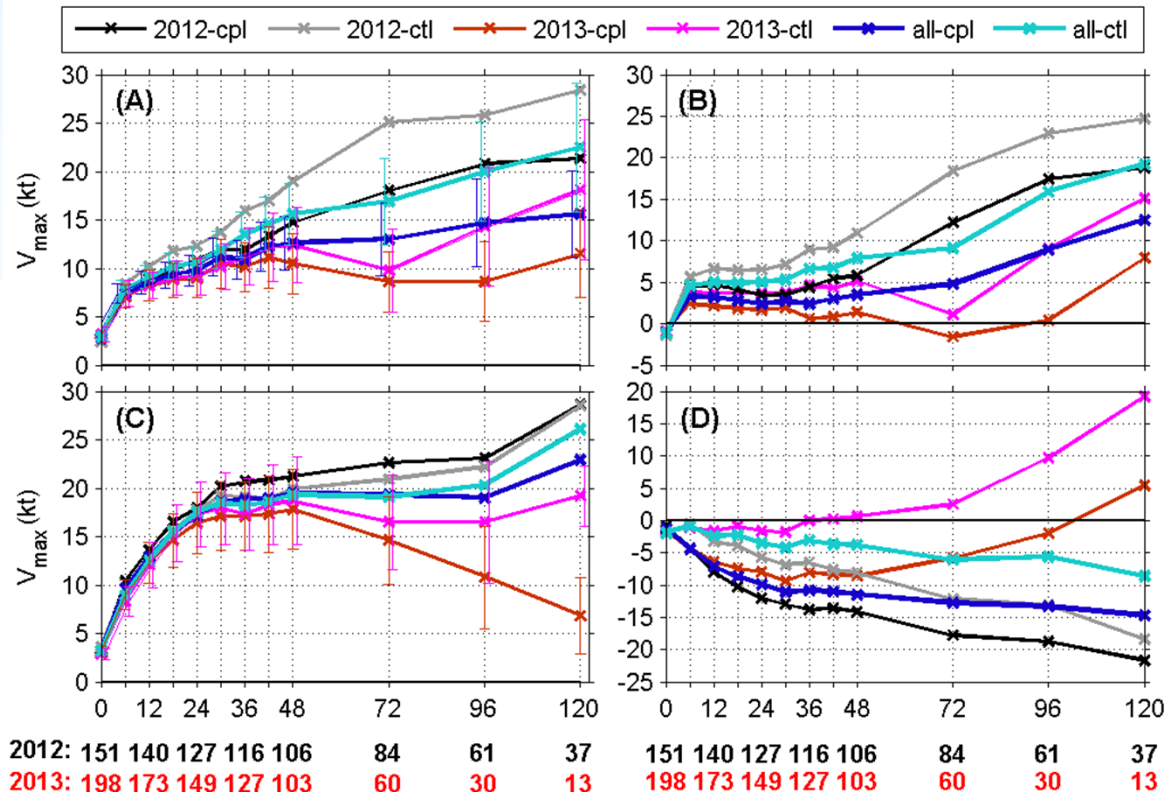


## Weak ( $\leq TS$ ) and Strong Storms ( $\geq$ Cat. 1):

### V<sub>max</sub> Verification – Absolute Error (left) & Bias (right)

Weak: 352

Strong: 349

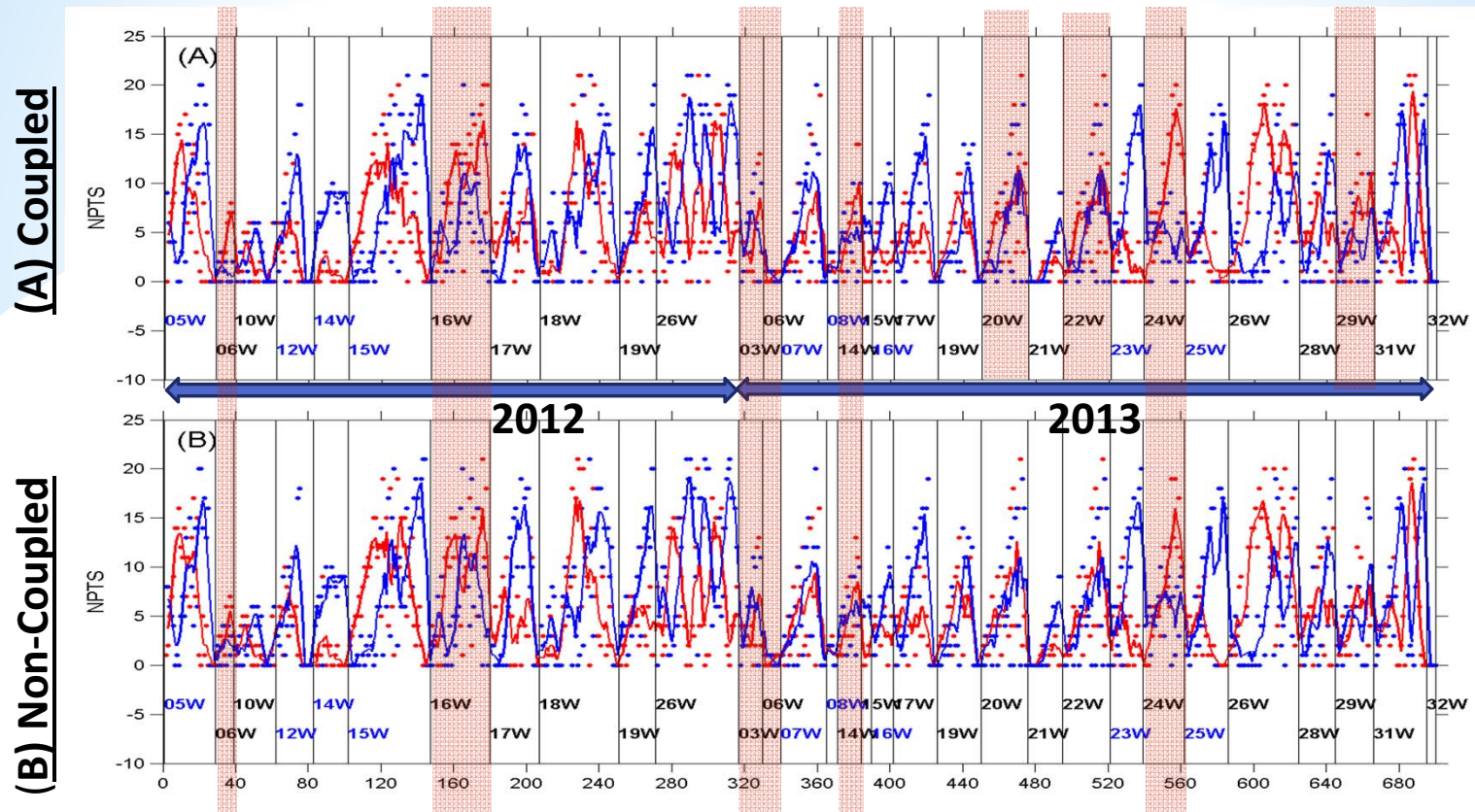


**Both coupled and non-coupled HWRF both over-predict weak storms intensity, except coupled-run for 2013; and under-predict strong storms intensity.**

- HYCOM coupling makes improvement in the forecast error for both weak and strong storms; makes significant improvement for weak storms than strong storms by less than 7 kt; the greatest improvement is for strong storms in 2013 by as much as ~10 kt.
- The coupling brings positive V<sub>max</sub> bias for weak storm and positive/negative bias for strong storms to negative by less than 15 kt (2013).

# 1. Storm Translation Speed $U_t$ Estimates:

Relative to the Best Track estimate – faster (red) and slower (blue) in number of counts. Lines are 5-pt (24-h) running average.



- **Coupled and noncoupled runs underestimate  $U_t$ , except 6 storms (shaded):** Tamlin 06W (2012), Bolaven 16W (2012), Yagi 03W (2013), Rumbia 06W (2013), Kong-Rey 14W (2013), and Nari 24 W (2013).
- **Coupled runs have more cases of over-estimate  $U_t$ :** In addition, Wutip 20W (2013), Fitow 22W (2013), and Krosa 29W (2013).
- **Appears more cases of over-estimates  $U_t$  for 2013 with coupled runs.**



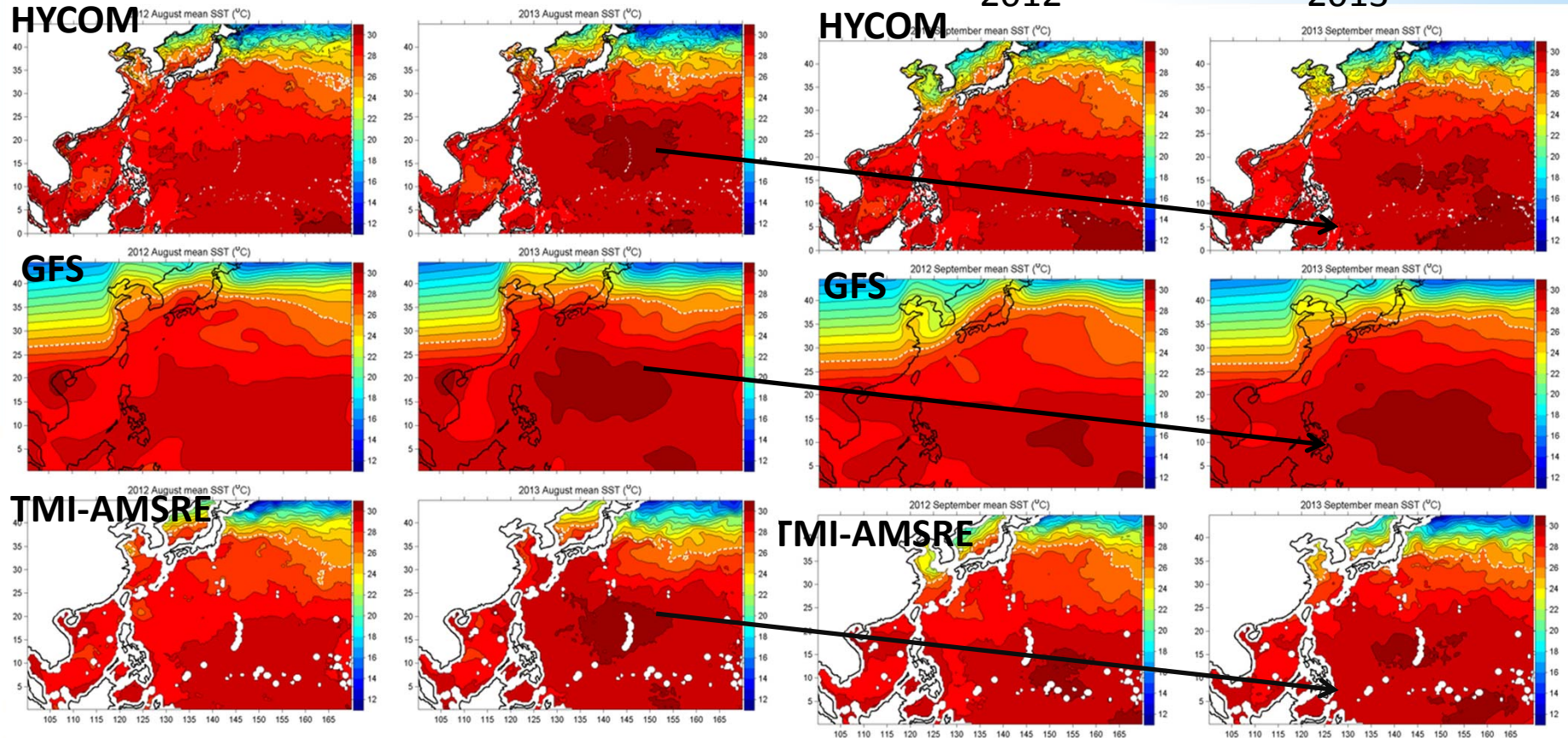
## 2. Comparison of SST for Coupled and Non-coupled

August  
2012

2013

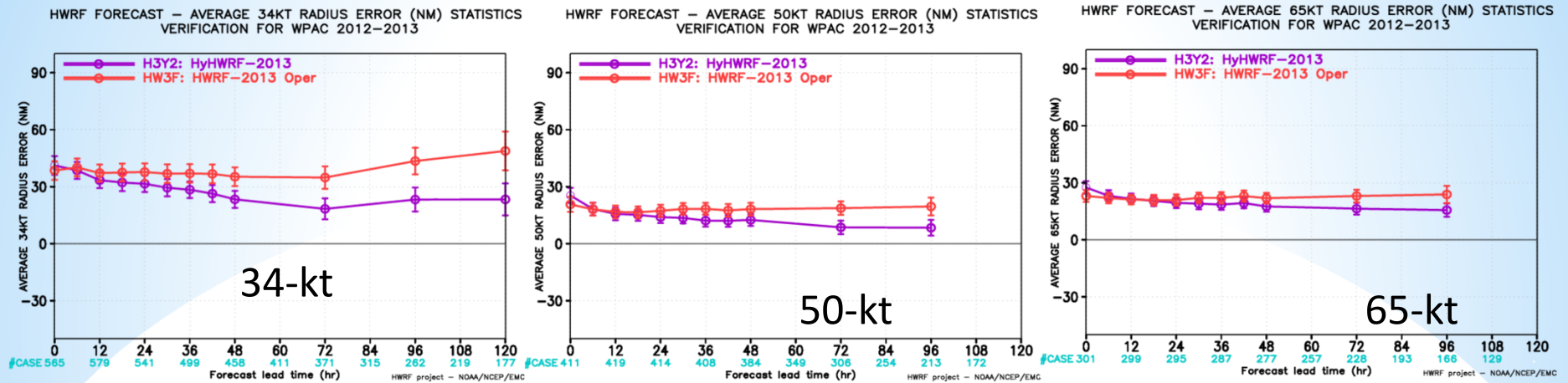
September  
2012

2013



1. HYCOM SST is very similar to MW observed Data.
2. Warmer Summer in 2013 than 2012, similarly observed for all three data set, by having the warm pool extended further north.
3. The body of warm water of GFS continues to expand from August to September, and the GFS SST is at least 0.5°C warmer than HYCOM SST and MW SST.

### 3. Storm Size:



#### Both Coupled (purple) and non-coupled/control (red):

- Both the model overestimate storm size by less than 50 nm (34-kt threshold).
- The best estimates are for the 50-kt threshold.

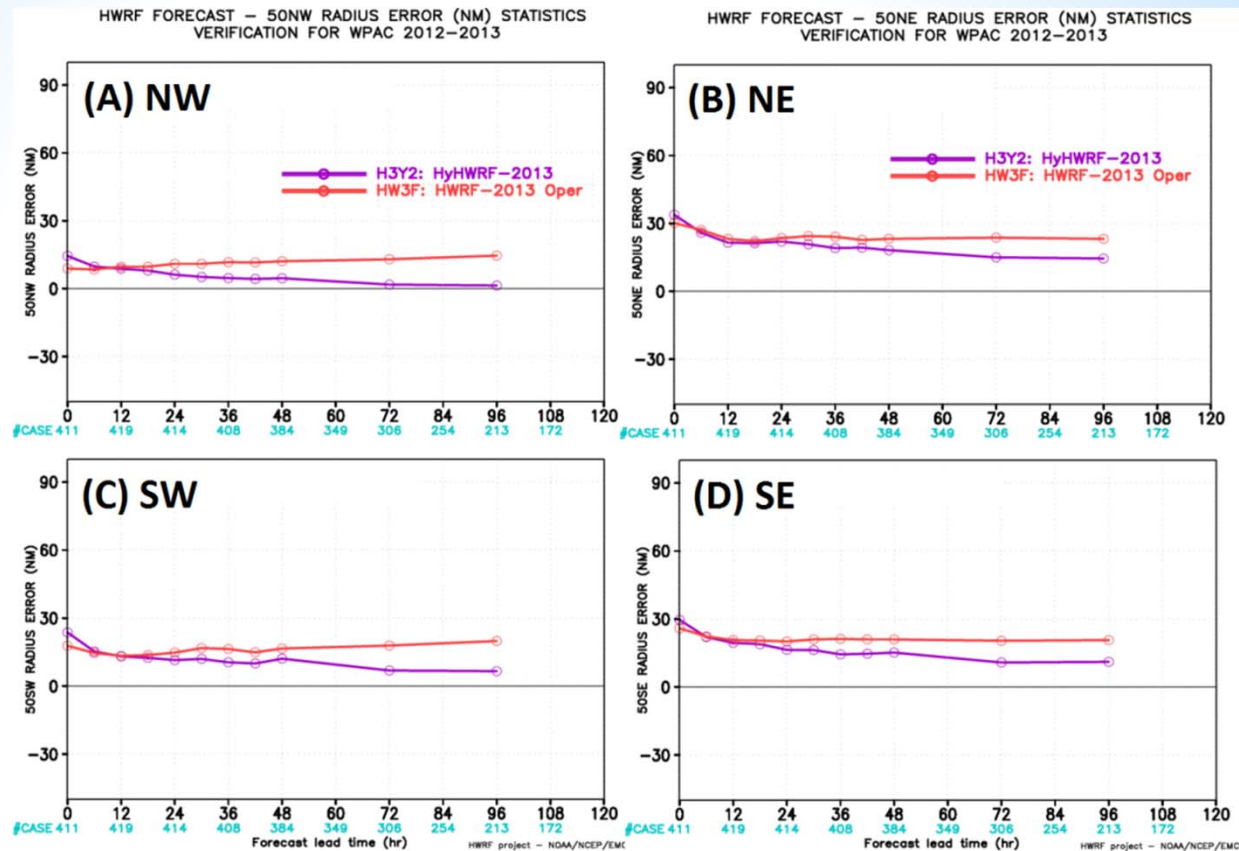
#### Between Coupled (purple) and non-coupled/control (red):

- Coupled model performs better for all thresholds.
- The best simulations is for the 50-kt threshold, but
- The largest improvement over control runs is for weak storms (by ~50%).
- The size forecasts of coupled model contracts with time by as much as 50% (50-kt) and for all the threshold.

## 4. Storm Pattern:

Example:  
50-kt

Cpl ----  
Ctl ----



- Coupled model (purple) predicts the storm size better than the control runs (red) for all quadrants, by showing smaller errors except  $t=0$ .
- The best simulation in size is for the northwest (NW) quadrant.
- The size errors of the coupled runs improve with forecast lead times, compared to control runs whose errors is constant or becomes constant for lead hours after 6-12 h.



# Summary

(coupled) HWRF-HYCOM compared to (non-coupled) HWRF:

1. ***Little difference*** in the track forecasts, but ***coupled runs correct the southeast/southwestward bias*** of control runs.
2. Both models show ***better track forecast for strong storms*** than weak storms. For weak storms, they over-estimate track, particularly in ***along track component (slower translation speed)***. While the track bias for weak storms is consistently southeast/west-ward, one for strong storms switches directions: from SE to NW for 2012, and from SW to NE for 2013.
3. Both models have ***positive intensity for weak storms*** and ***negative intensity bias for strong storms***.
4. ***HYCOM monthly SST*** and anomaly/variations are ***similar to observed TMI-AMSRE OI*** data; but warmer ***GFS SST in both near and far fields (by 0.5°C)***, compared to HYCOM SST and MW SST.
5. ***Smaller storm size*** on average; ***Contracting*** with time (less than 5%); and ***Asymmetric*** flux pattern.
6. Both the models ***under-estimate storm speeds***; but HYCOM coupling produces relatively faster storm, compared to non-coupled.
7. ***HYCOM coupling provides lower surface enthalpy*** (less than average of 26%) .

## Discussions

(coupled) HWRF-HYCOM compared to (non-coupled) HWRF:

1. HYCOM SST cooler than GFS in both near and far fields.
2. Faster storm translation speed, relative to non-coupled.
3. Smaller storm size on average, and contracting with time (less than 50%).
4. Asymmetric pattern of the flux field.
5. Lower surface enthalpy (less than 45% for Soulik 07W, e.g.).

*These are recipes for intensity under-prediction !!!*

### Maximum Potential Intensity (MPI)

Emanuel (2003)

$$V_{\max}^2 \propto \frac{(T_1 - T_2)}{C_d T_2} F_h$$

$T_1 = \text{SST};$

$T_2 = \text{outflow temperature};$

$C_d = \text{drag coefficient}; \text{ and}$

$F_h = (\text{LHT} + \text{SHT}) \text{ the surface flux of enthalpy.}$

### Re-considered are:

1. *Sub-grid parameterization in both the atmospheric and oceanic components;*
  2. *Optimizing air-sea flux parameters to two-way coupling system, e.g.  $C_d$  &  $C_h$ .*
- and more ...*