Impact of air-sea interaction on TC forecast: A case study of typhoon Fanapi (2010)

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Introduction

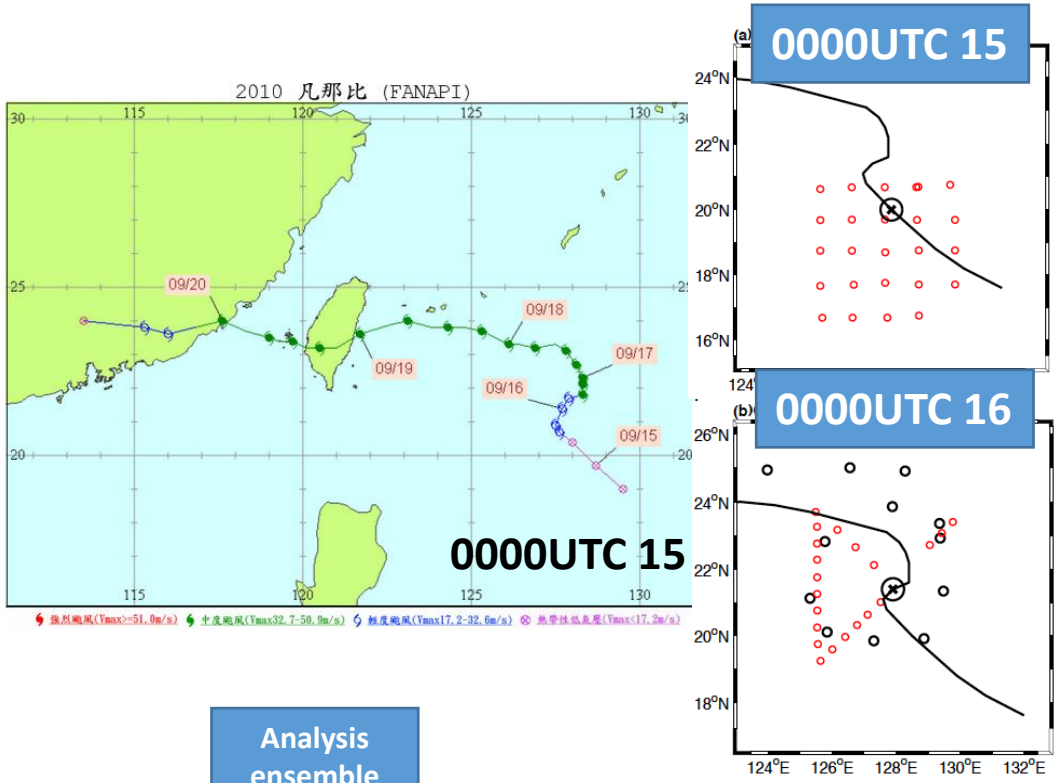
- Air-sea interaction plays an important role in TC development
  - Ocean provides energy for TC
  - The TC-induced cold wake acts as a break to prevent over-intensification
- The TC-ocean coupled effect becomes more essential when there are ocean eddies
- The air-sea interaction is generally believed to have larger impact on TC intensity, but less impact on TC track
- In the eddy-rich WNP, few studies have focus on the TC ensemble prediction using a high-resolution coupled model.

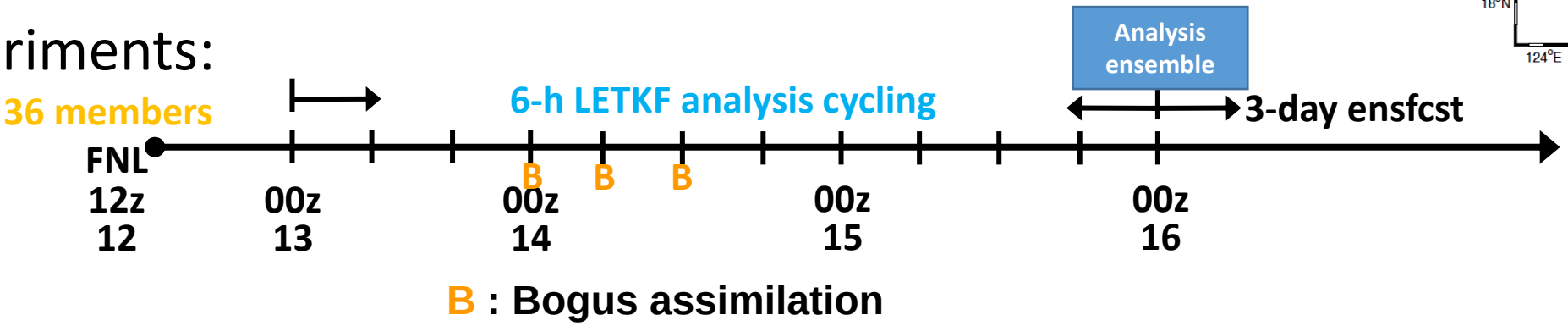
Investigate the TC-ocean interaction in typhoon Fanapi (2010) using high-resolution coupled ensemble forecast

Experiment setup

WRF-LETKF DA system (Yang et al. 2013, Lin et al. 2016)

- Advanced Research WRF (ARW) V3.6.1
  - ✓Nested domain 12/4/1.33(no DA) km, 36 layers
- Observations:
  - ✓sound, ground station, airep, buoy, AMV, JTWC's MSLP, dropsonde (ITOP), synthetic wind profile (to spin-up vortex)
- Experiments:





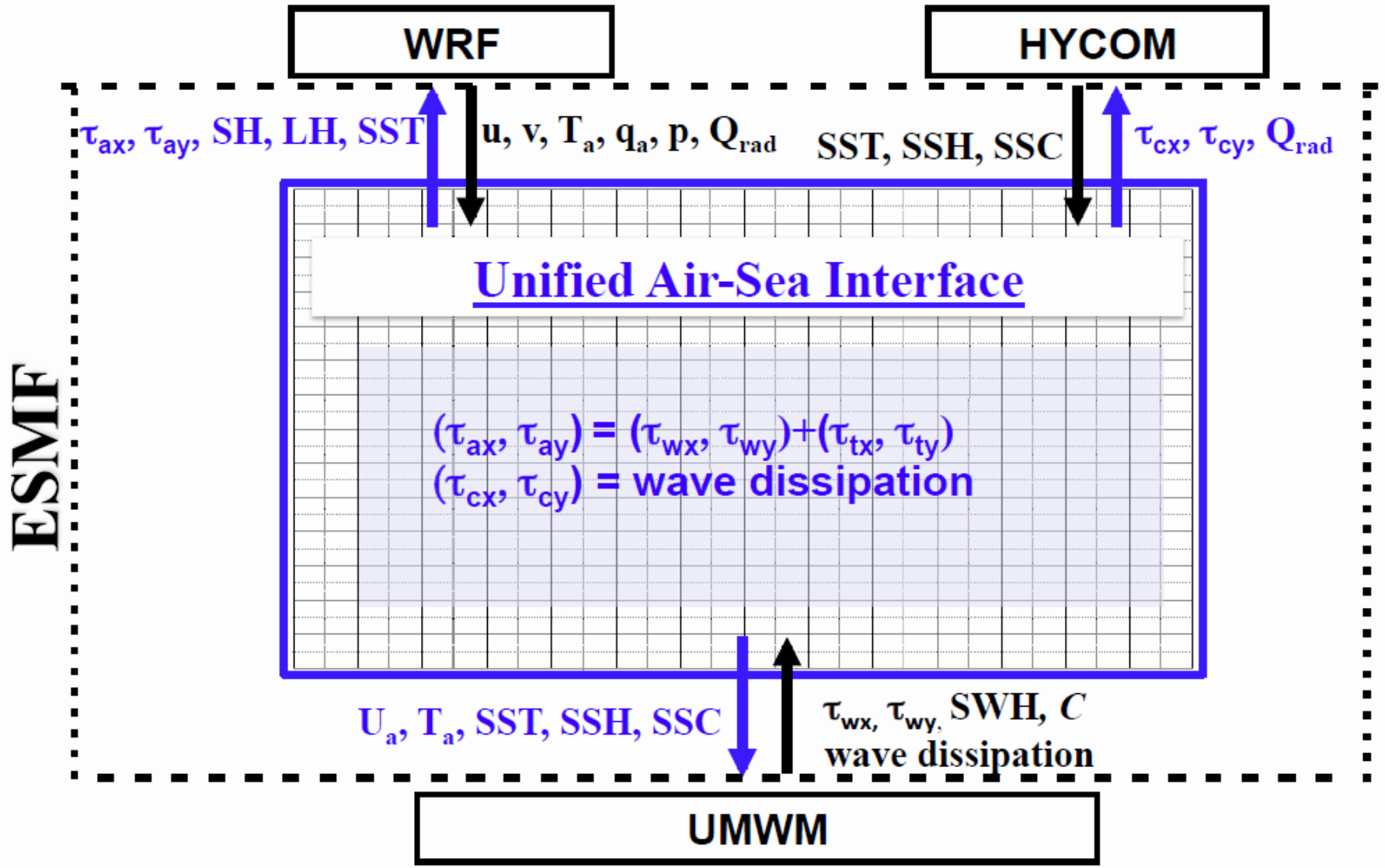
B : Bogus assimilation

3-day ensemble forecast UA: WRF only

AO: UMCM (WRF + HYCOM 4km res.)

IC: HYCOM global anal.

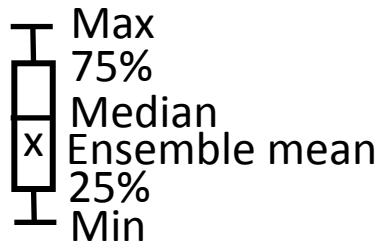
University of Miami Coupled Model (UMCM)

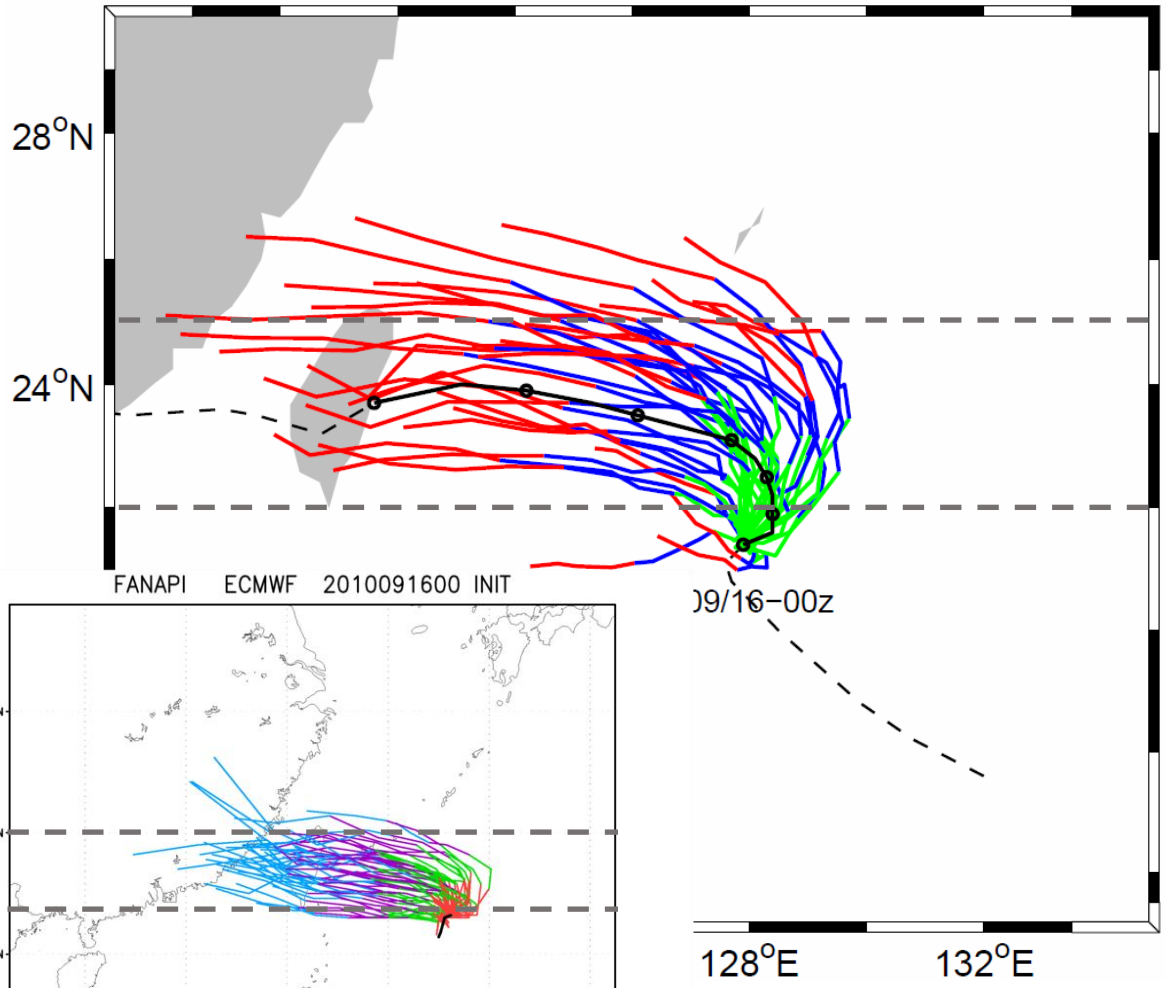


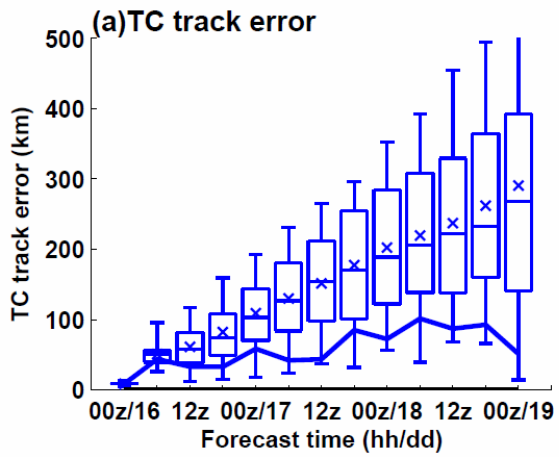
University of Miami Wave Model (Donelan et al. 2012)

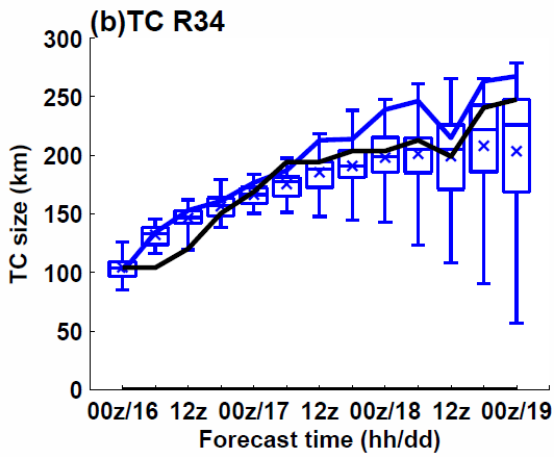
Chen et al. (2013)

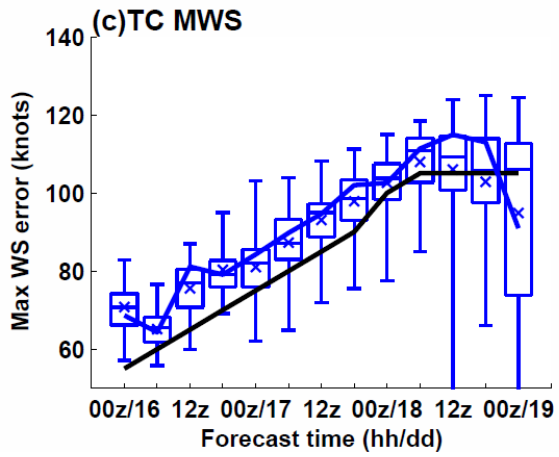
Uncoupled (UA) forecast result

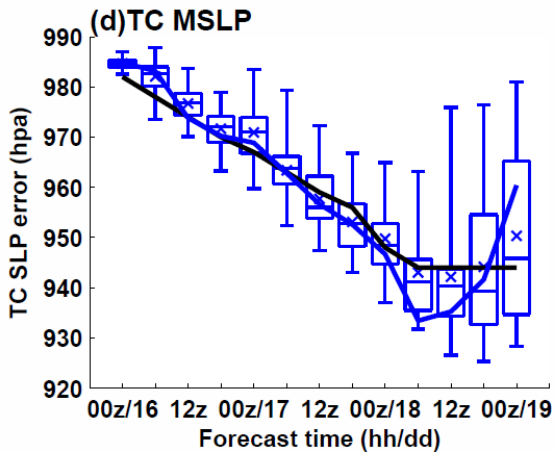








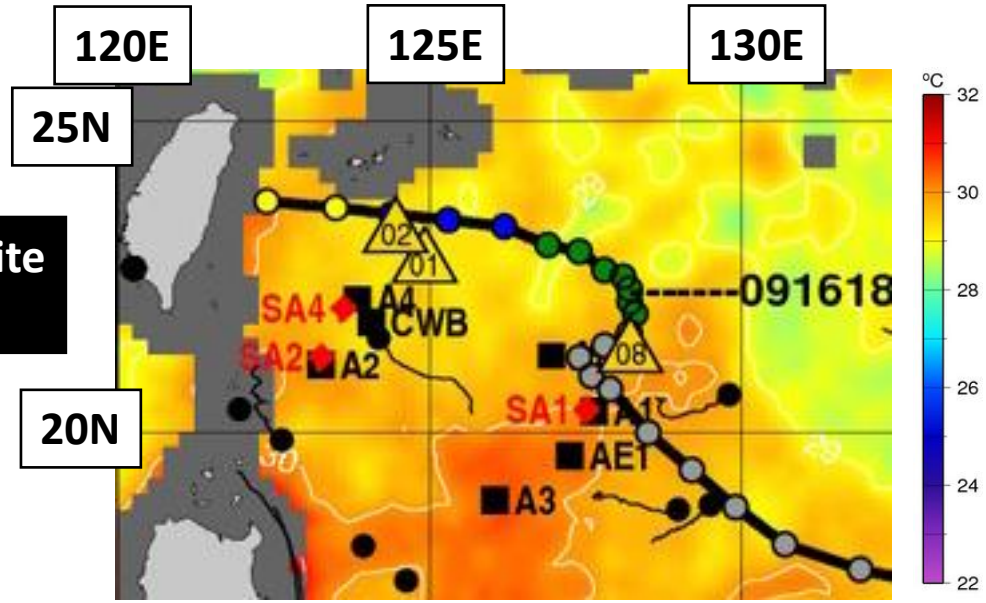




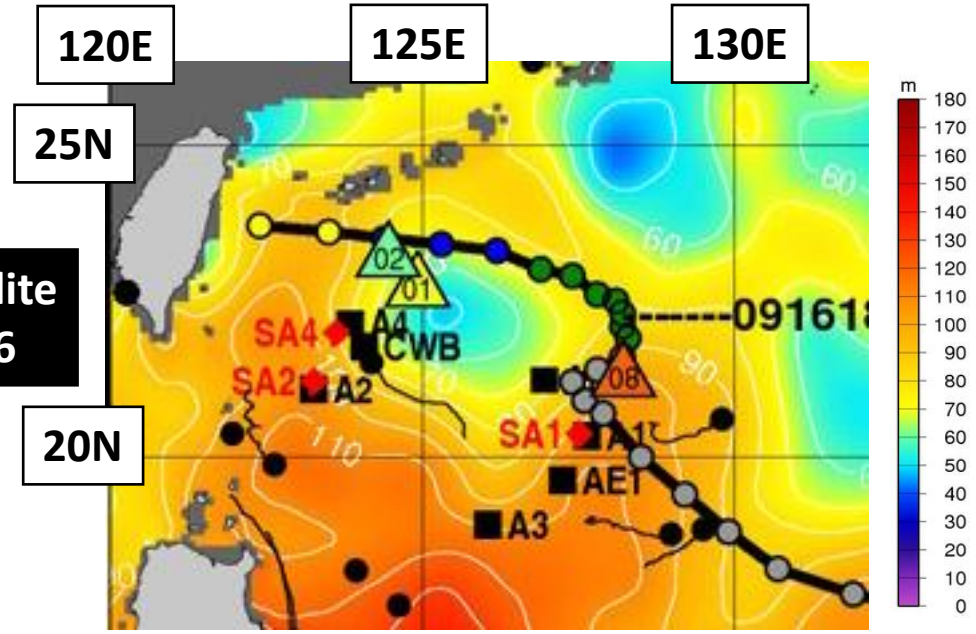
5~10 knots higher

HYCOM IC at 0000UTC 16 Sep. 2010

Satellite SST

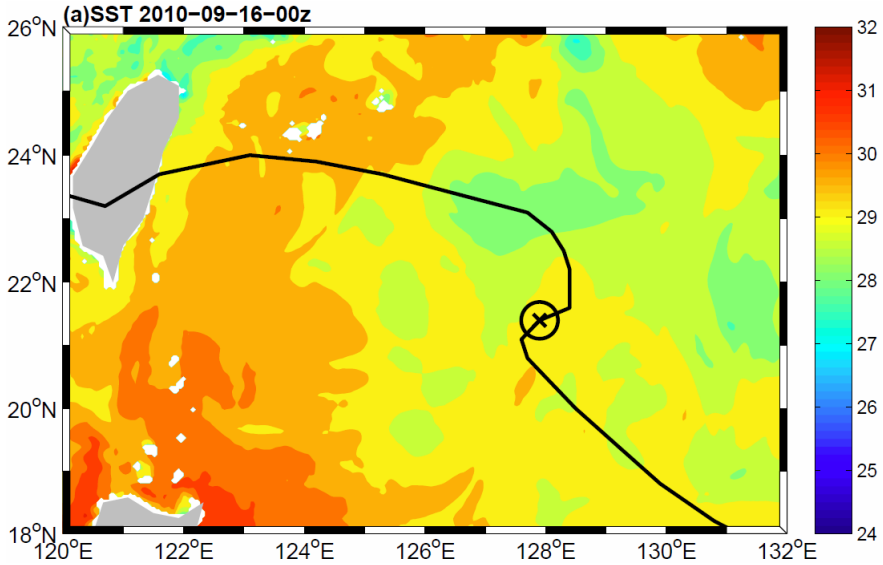


Satellite D26

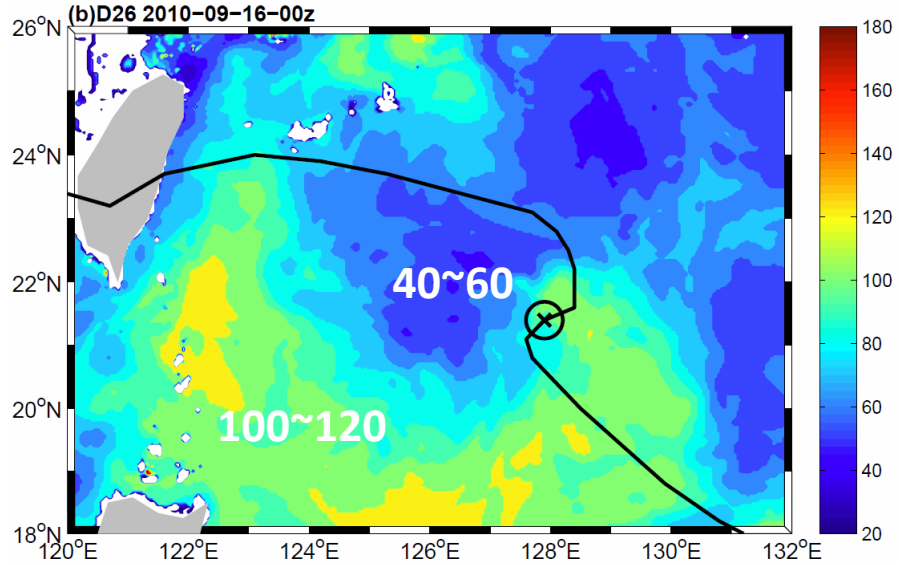


NTU product.
From ITOP web.

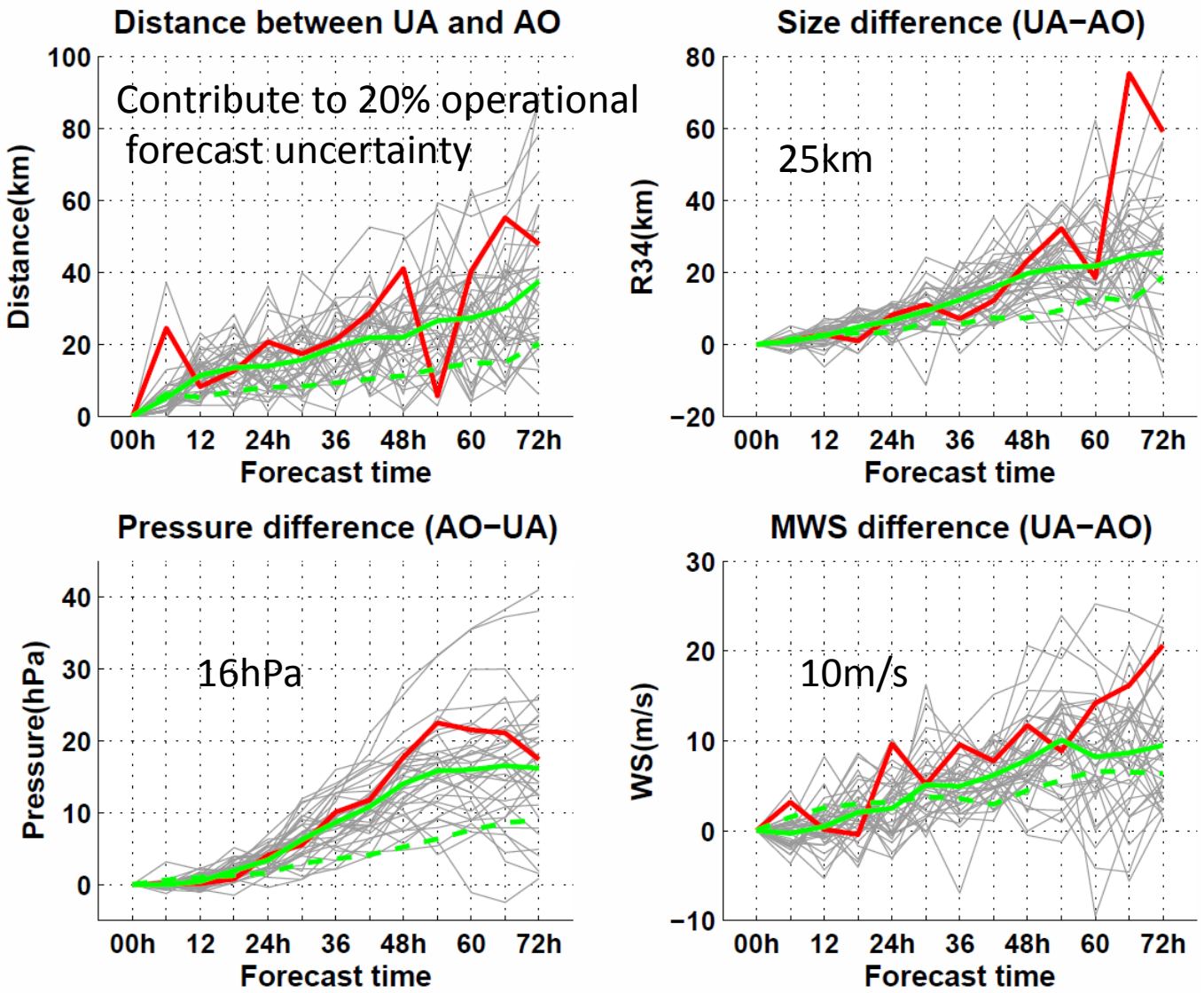
HYCOM SST



HYCOM D26



Difference between UA & AO

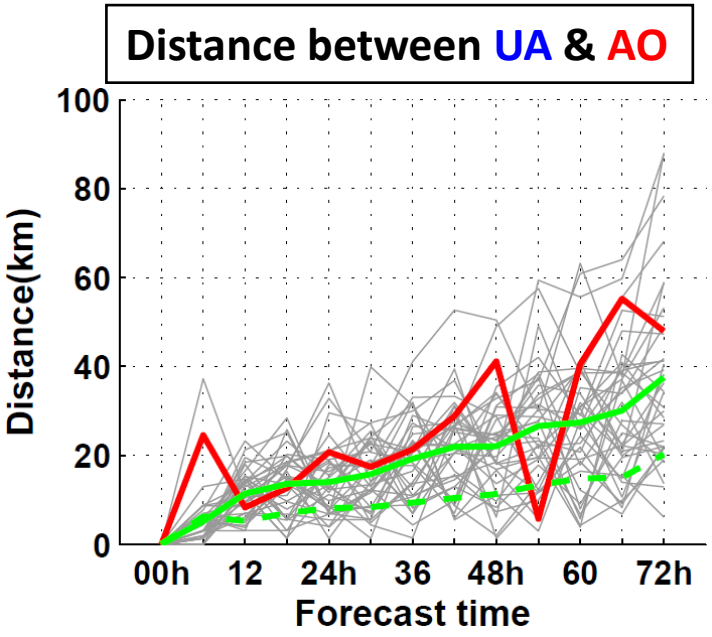


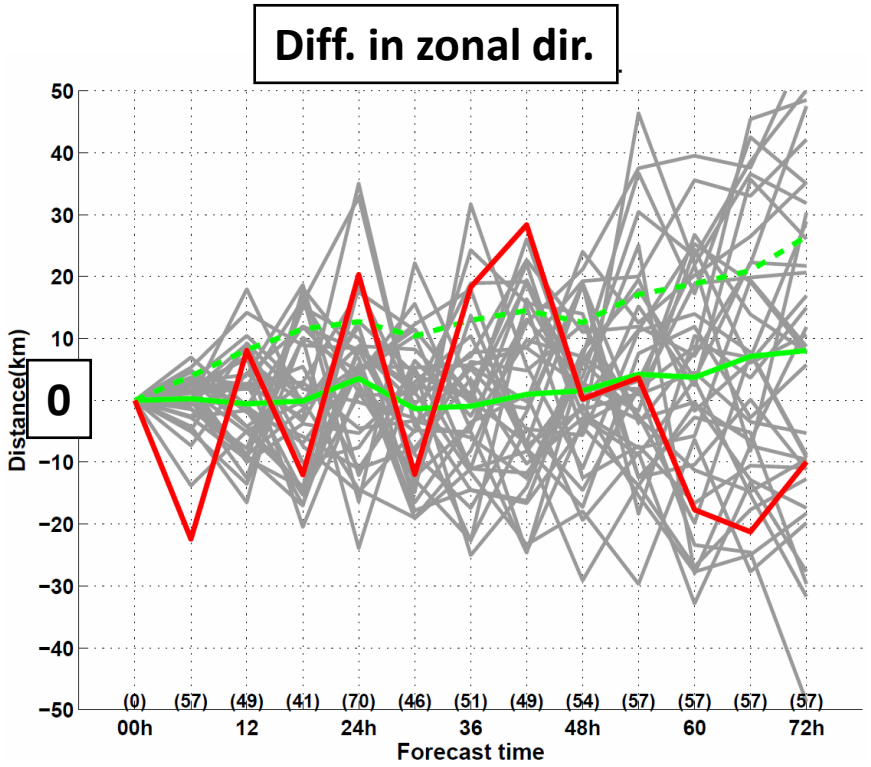
Ensemble members
Diff. in mean forecast
Ens. forecast mean (solid)
Ensemble spread (dashed)

- Track difference:
  40 km after 72h, **20** km std.
- Size difference:
  25 km after 72h, **20** km std.
- MSLP difference:
  16 hPa after 72h, **10** hPa std.
- MWS difference:
  10 m/s after 72h, **8** m/s std.

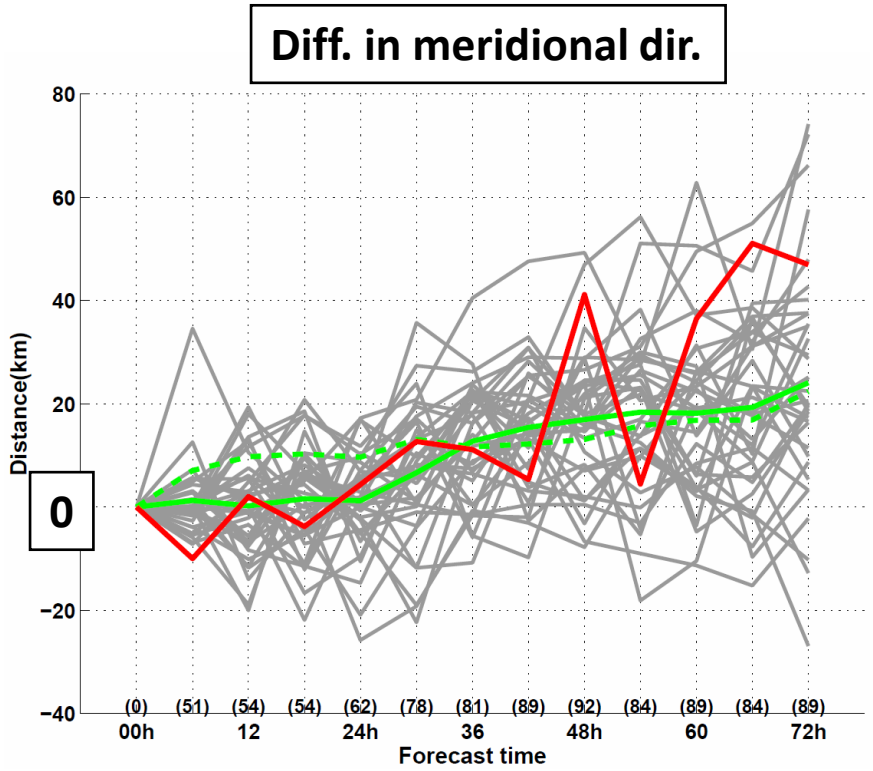
TCs become too weak!!

Track difference in zonal and meridional direction





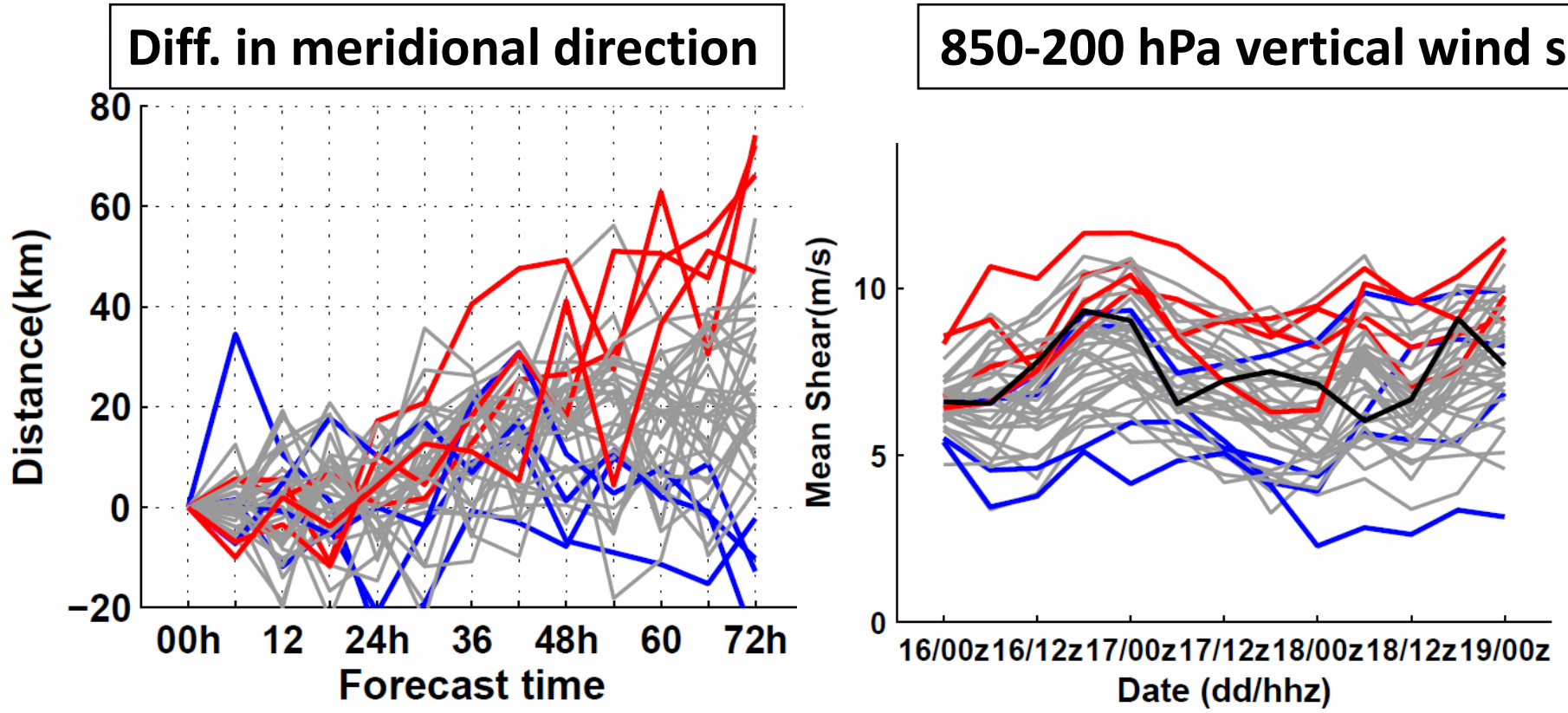
No significant bias in zonal dir.



23 km northward bias in 3 day forecast

Ensemble members
Diff. in mean forecast
Ens. forecast mean (solid)
Ensemble spread (dashed)

Large displacement VS. **Small** displacement

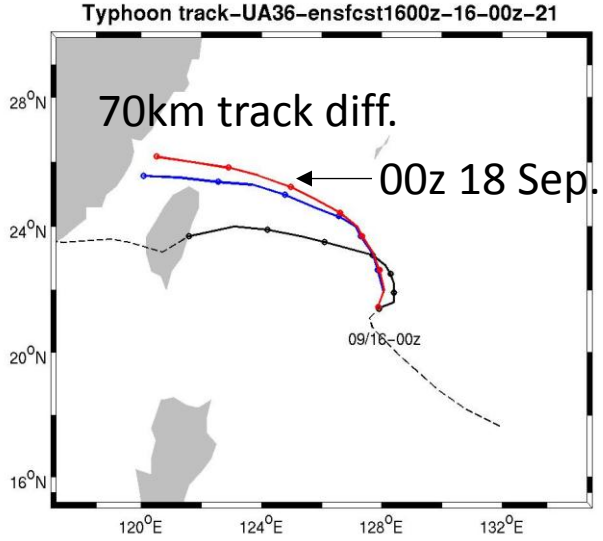


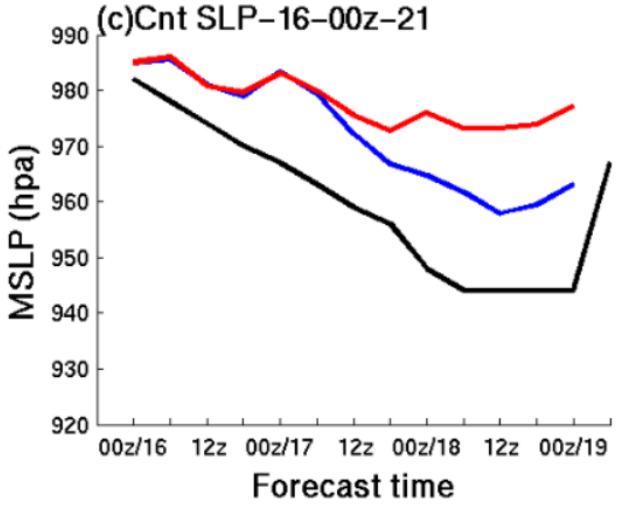
Why does the track ensemble from AO deflect to the north?

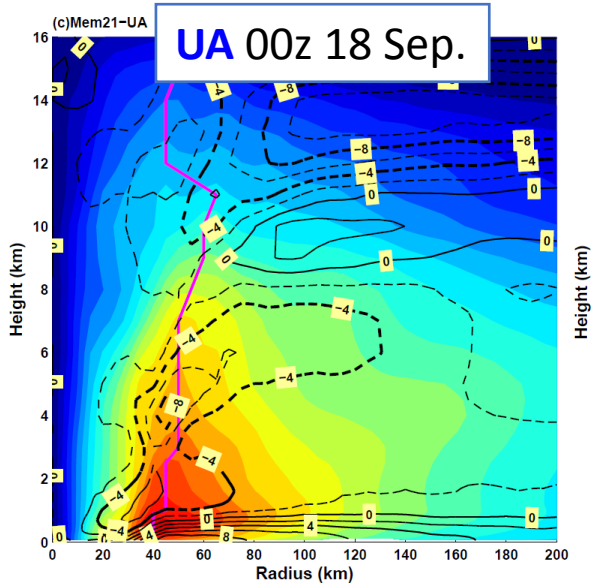
Characteristics of the TCs with larger northward track deflection after coupled with ocean.

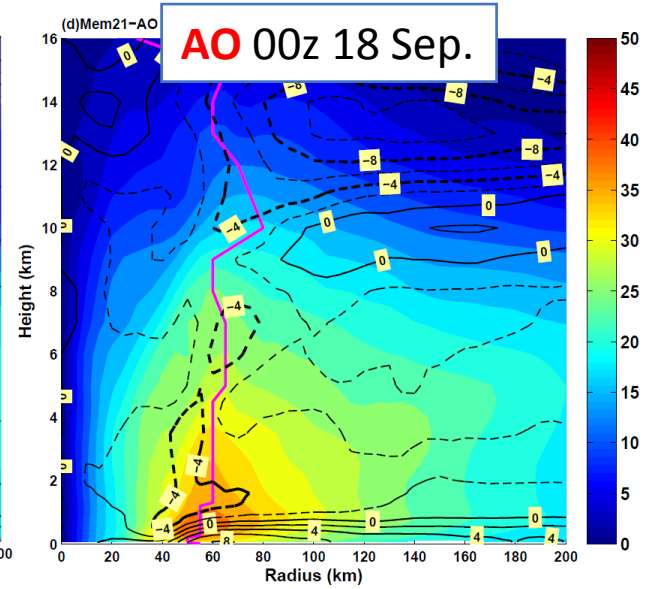
- Large vertical shear in the environment
- Fast moving speed
- Smaller size and weaker intensity

Why AO deflect to the north? (1) height of TC development

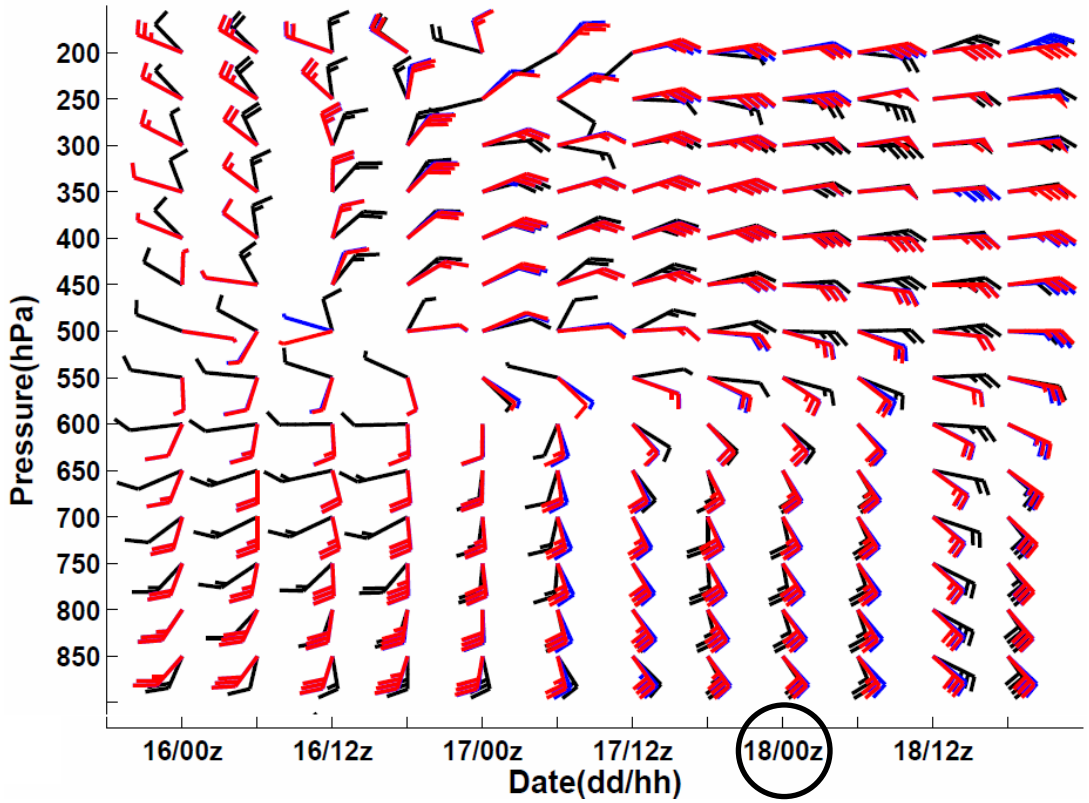








Environmental flow – Mem21

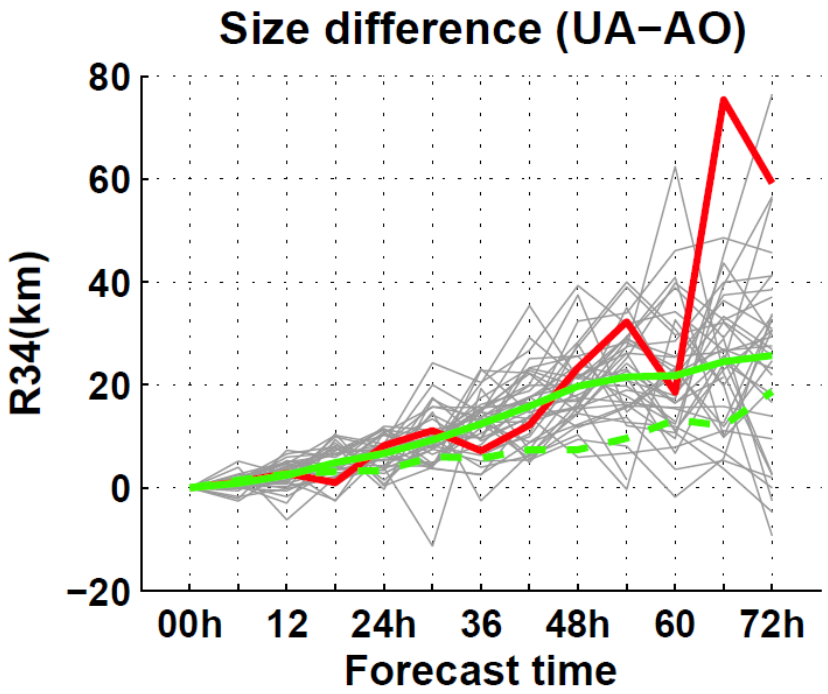


Small difference between **UA** and **AO** in environmental flow

Why AO deflect to the north? (2) beta effect

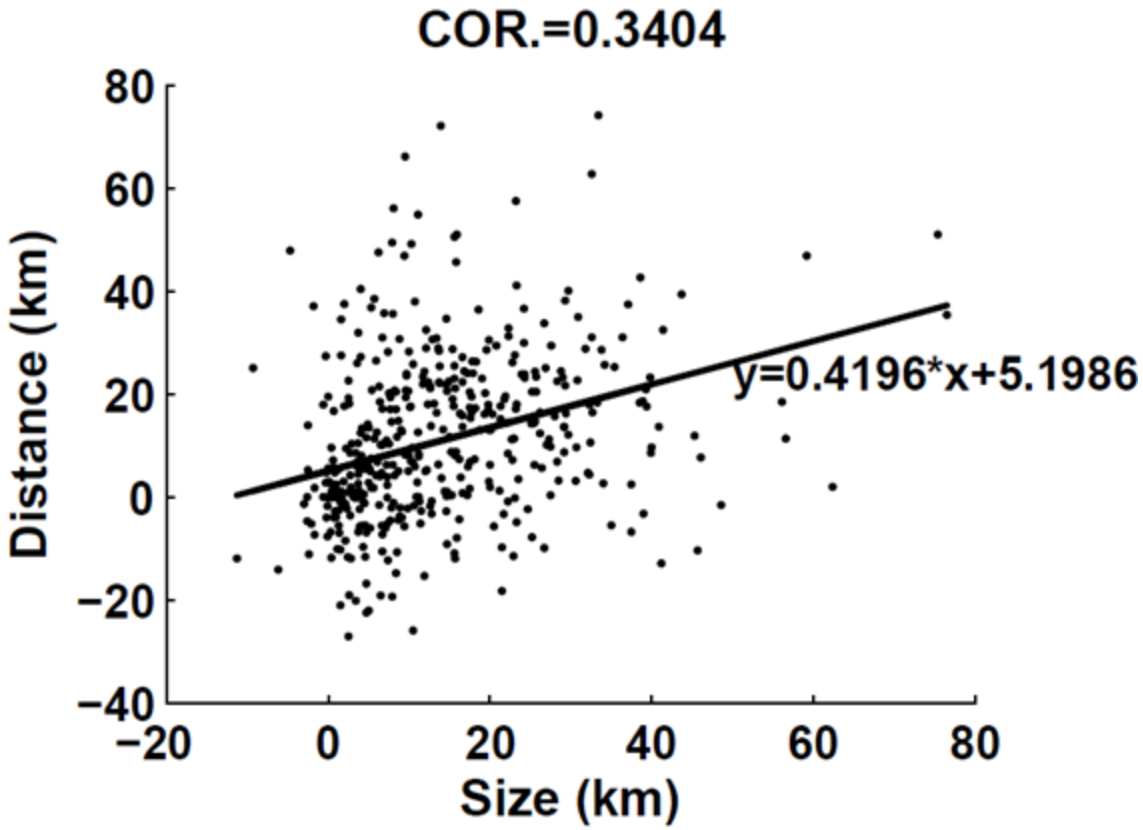
Bender et al. (1993): Air-sea interaction has weaken the TC at all radius that will alters the orientation of beta gyres and thus affects the beta drift.

Westward tracks turn more to the north.

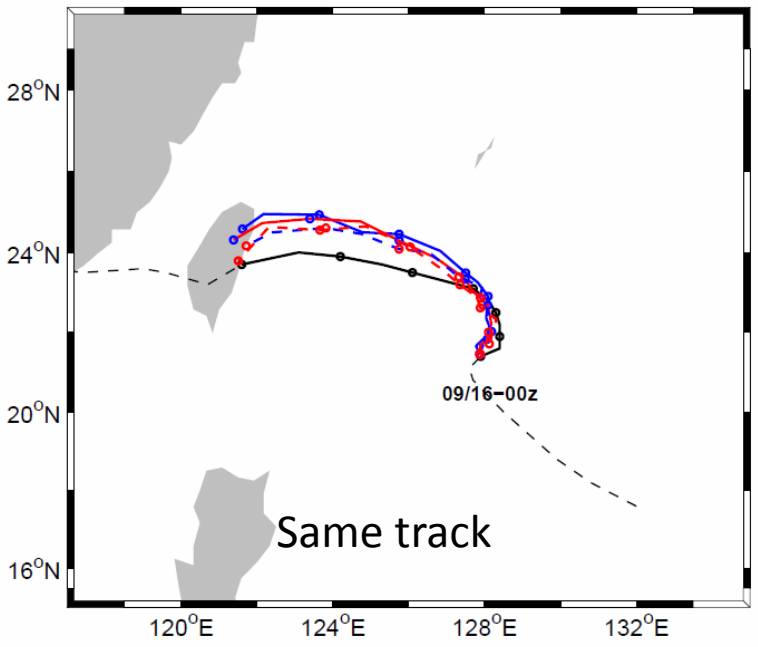


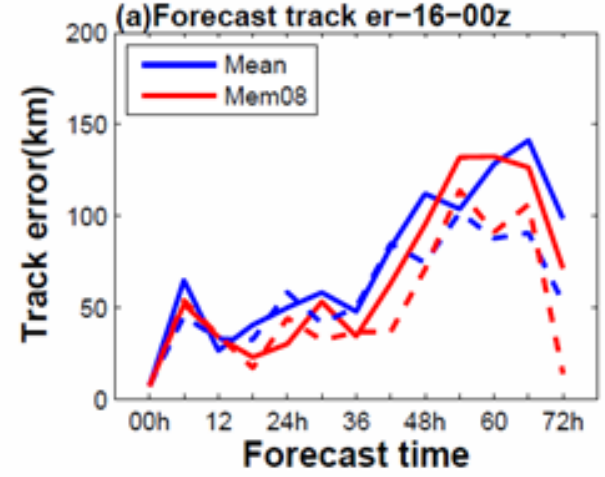
After coupled with ocean, TC become smaller

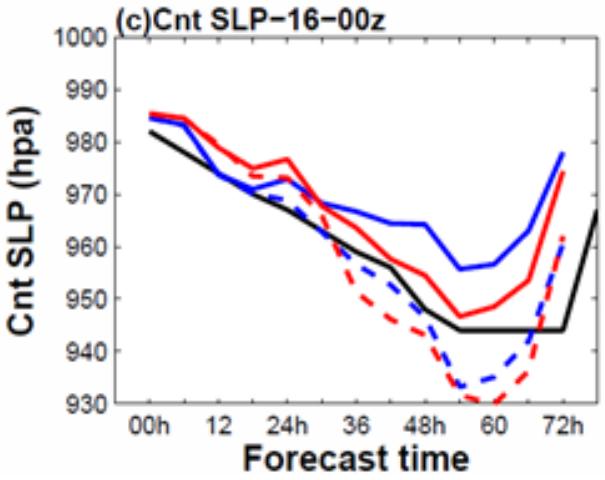
Size change VS meridional displacement

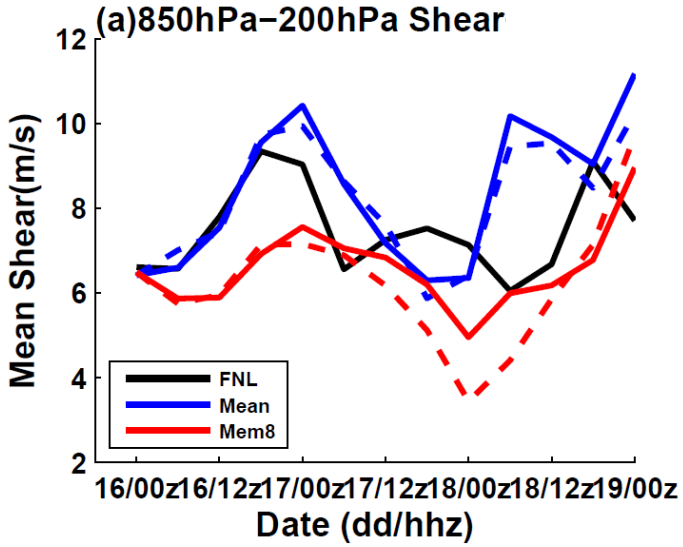


Coupled effect increases intensity variability in TC simulation









With ocean coupled, MSLP become 10 hPa different

Summary

- As pointed out in previous studies, the TC-ocean coupled effect has a strong impact on TC development.(TC become smaller, weaker and more asymmetry)
- Results show that the coupled effect can modulate the TC track. (contribute to 20% operational forecast uncertainty)
  - (1) Interaction between TC and environmental flow; (2) Beta effect
- Impact of air-sea interaction on TC development：
  - ☐Ocean provides energy for TC
  - ☐The TC-induced cold wake acts as a break to prevent over-intensification
  - ☐Modulate how TC interacts with its environment

Ocean direct effect

Ocean indirect effect

- The coupled effect seems to degrade the performance of TC intensity forecast. However, the atmosphere-ocean conditions are not well coupled initially: over-intensified TC (from uncoupled model) + cold eddy!

A more balanced coupled states should be constructed through coupled DA!!

Thank you!!