An ocean mixed layer model coupled with regional atmospheric data assimilation: a case of typhoon Soudelor (2015)

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([1]RIKEN R-CCS, [2]RIKEN iTHES in FY2017)

Apr. 17, 2018

RIKEN

R-CCS

Data Assimilation Team

Self introduction

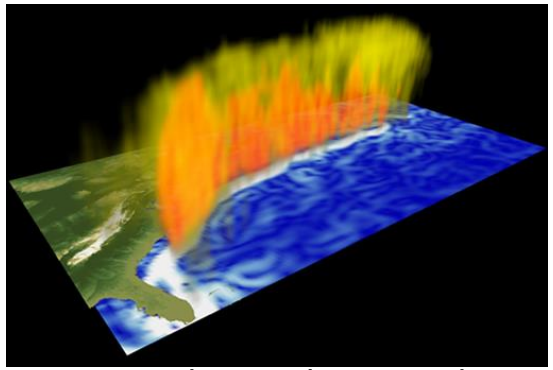
- Name: TAKATAMA, Kohei (高玉 孝平)
- History
  - Ph. D. @ Graduate School of Science, Hokkaido University
  - 2012~ International Pacific Research Center, University of Hawaii
  - 2017~ iTHES (FY2017) & AICS/R-CCS, RIKEN

Now!

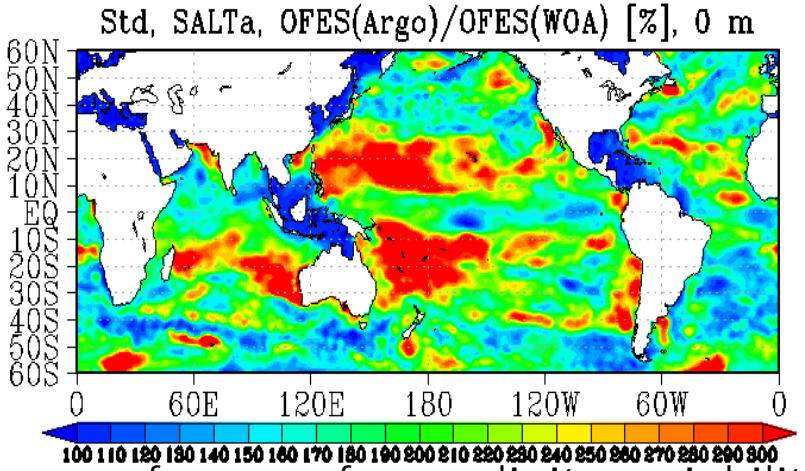
Air-Sea interaction over ocean current using RAMs.

Impact of obs. nudging in OGCMs.

Atmosphere-Ocean coupling with data assimilation.



Upward wind over the Gulf Stream
(Minobe et al. 2012)

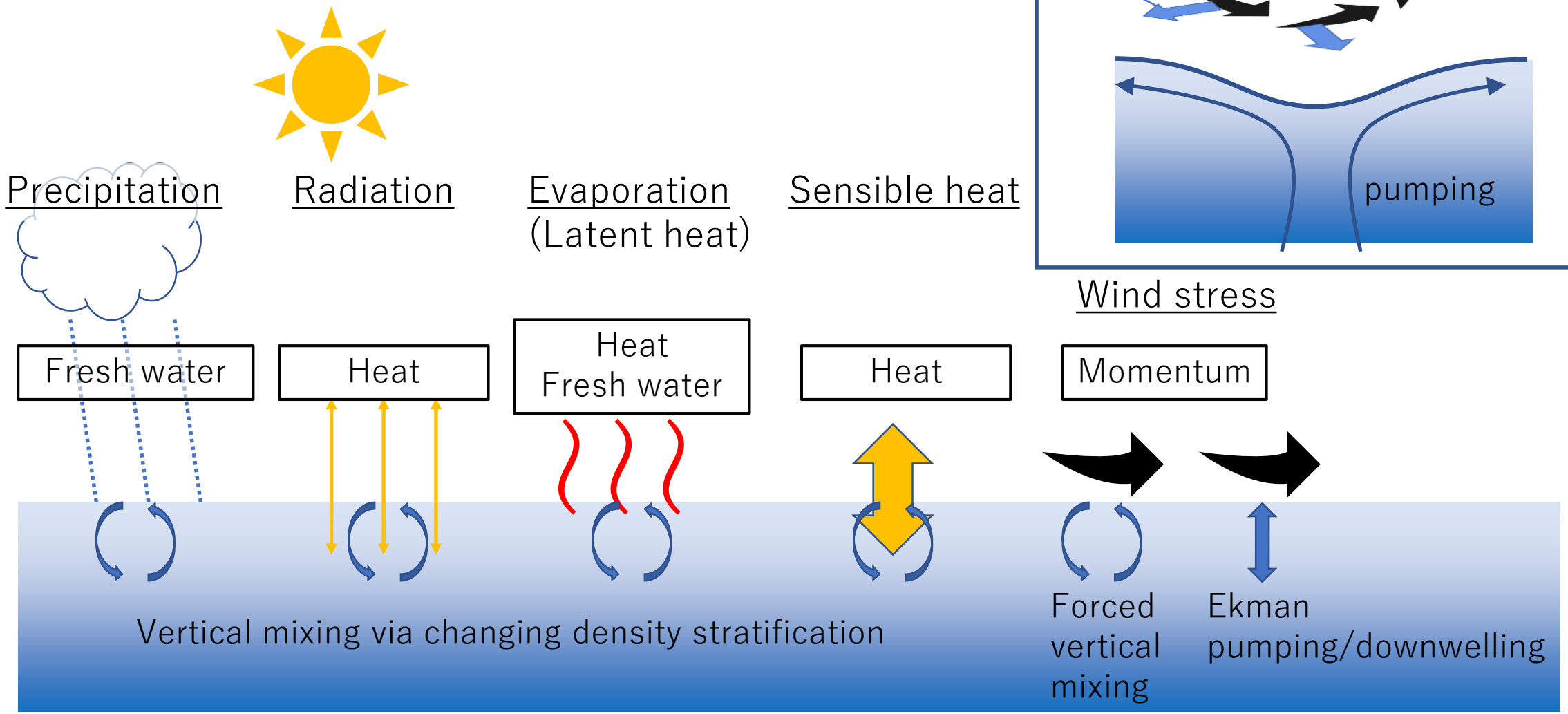


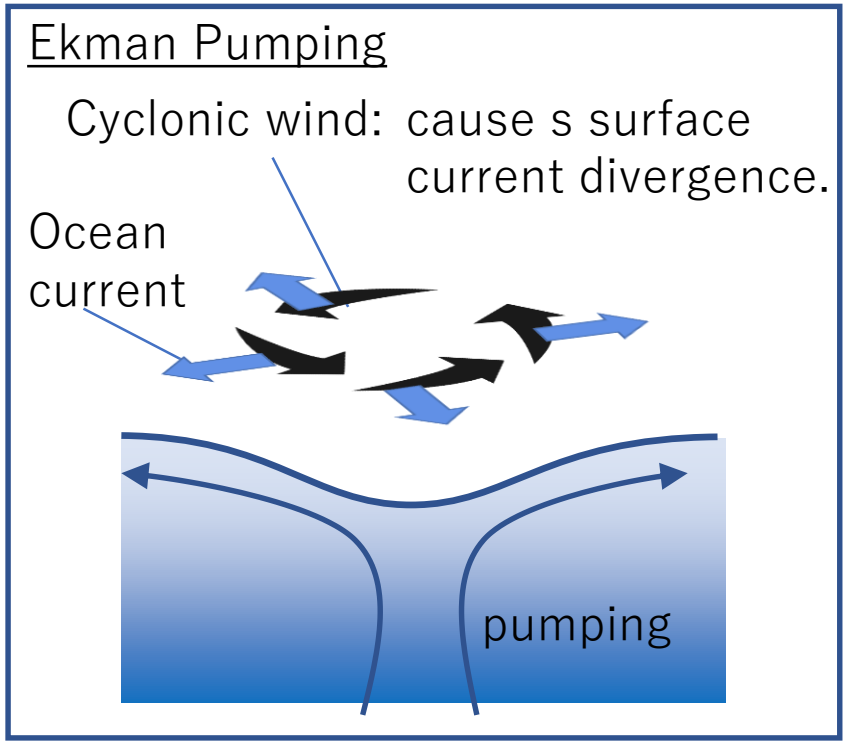
Change of sea surface salinity variability in OFES (Furue, Takatama et al. 2017)

- **Typhoon simulation**
- Coastal Ocean prediction

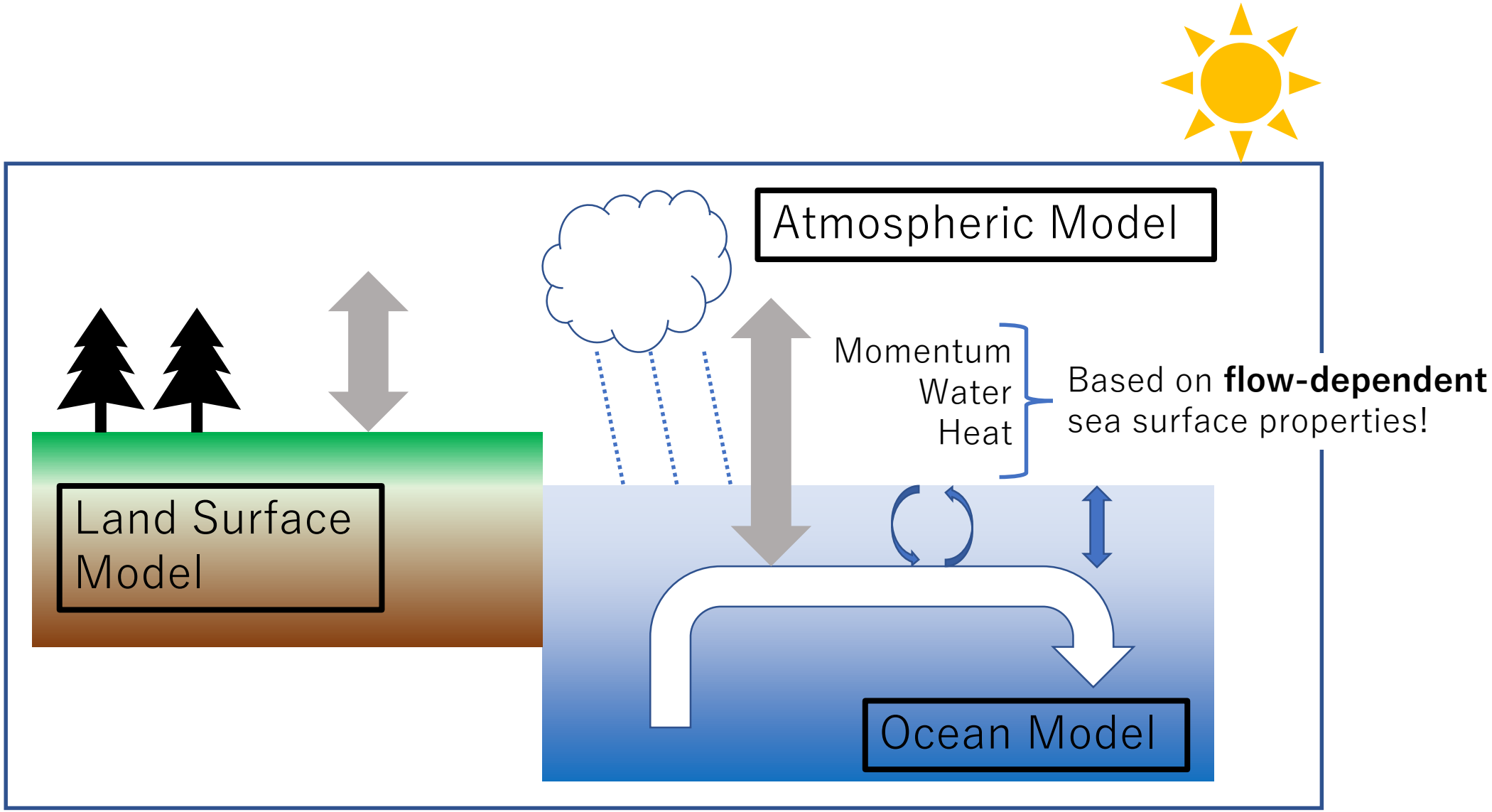
These are on going studies.
Any ideas & suggestions are welcome!

(Local) Air-Sea interaction

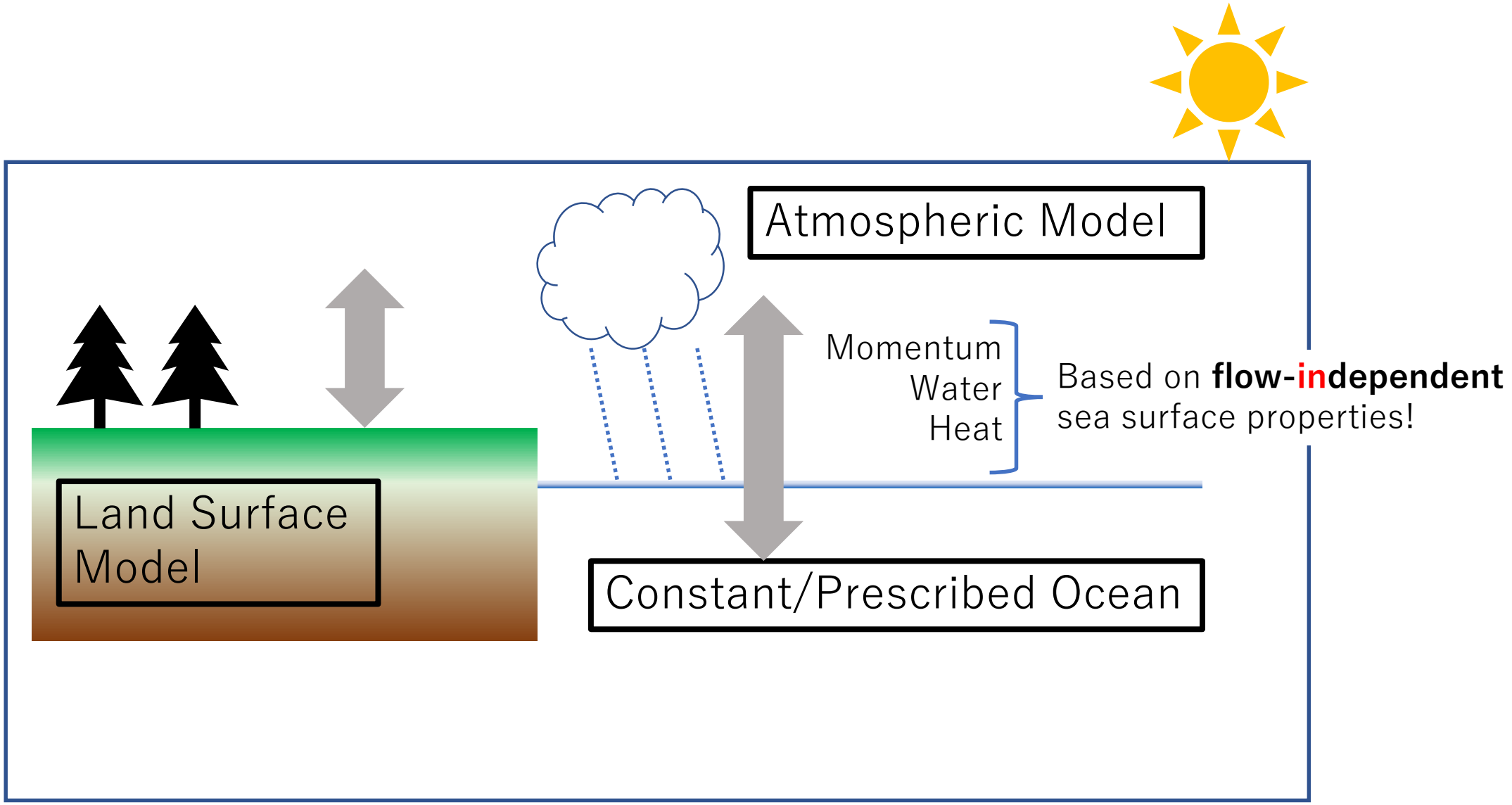




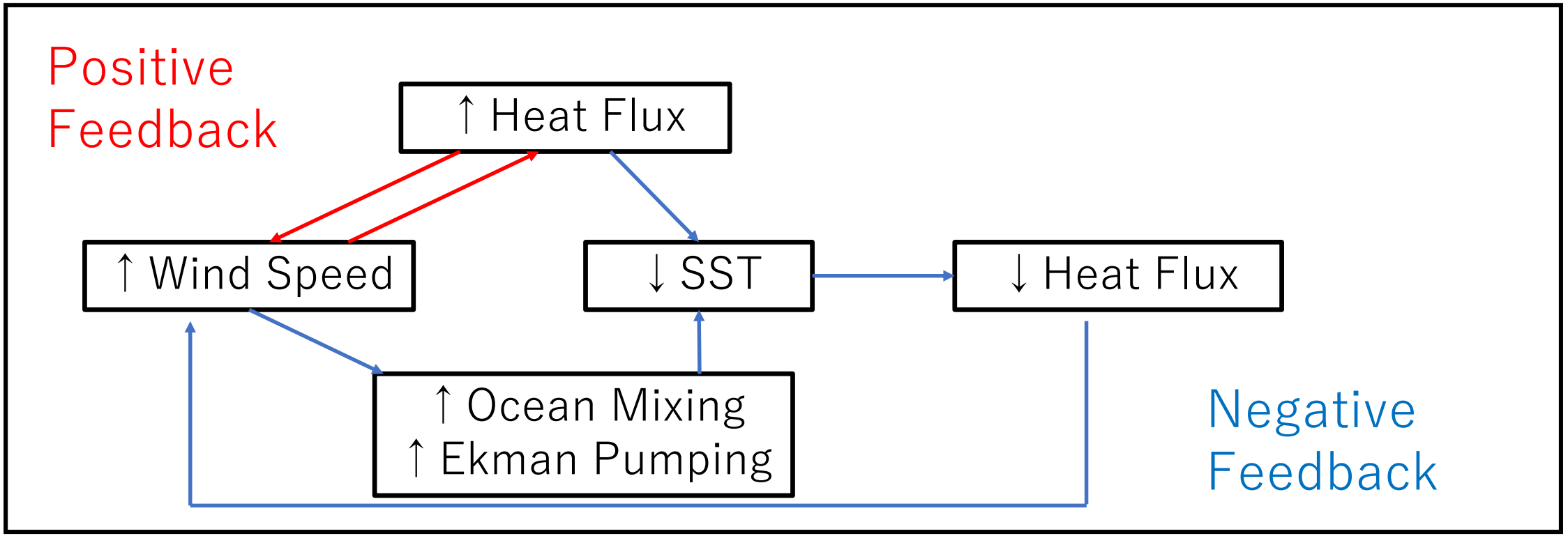
Atmosphere-Ocean coupling system



Typical atmospheric experiments

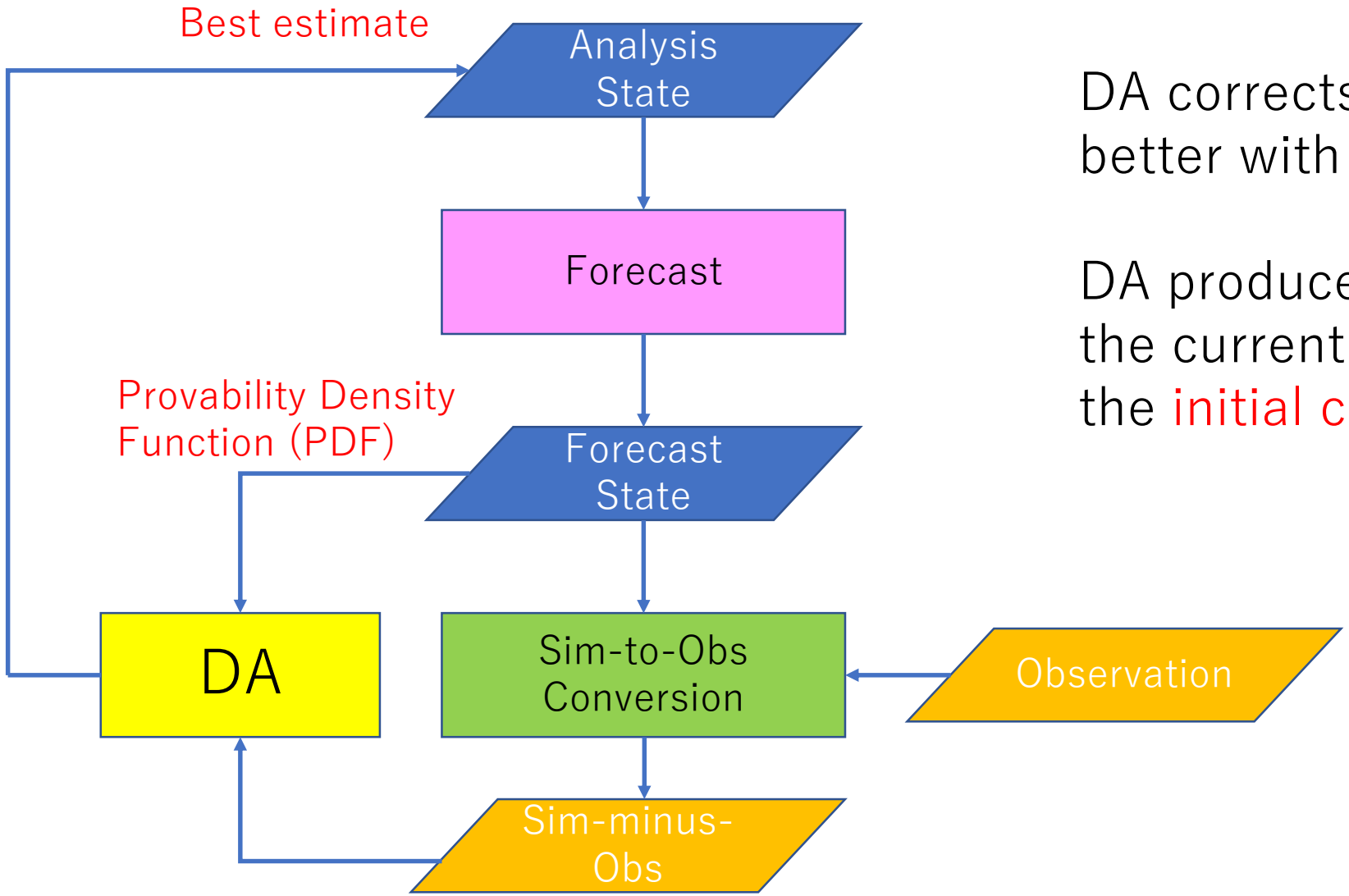


Air-sea interaction of Typhoon



There is no negative feedback loop
in the typical atmospheric experiments.

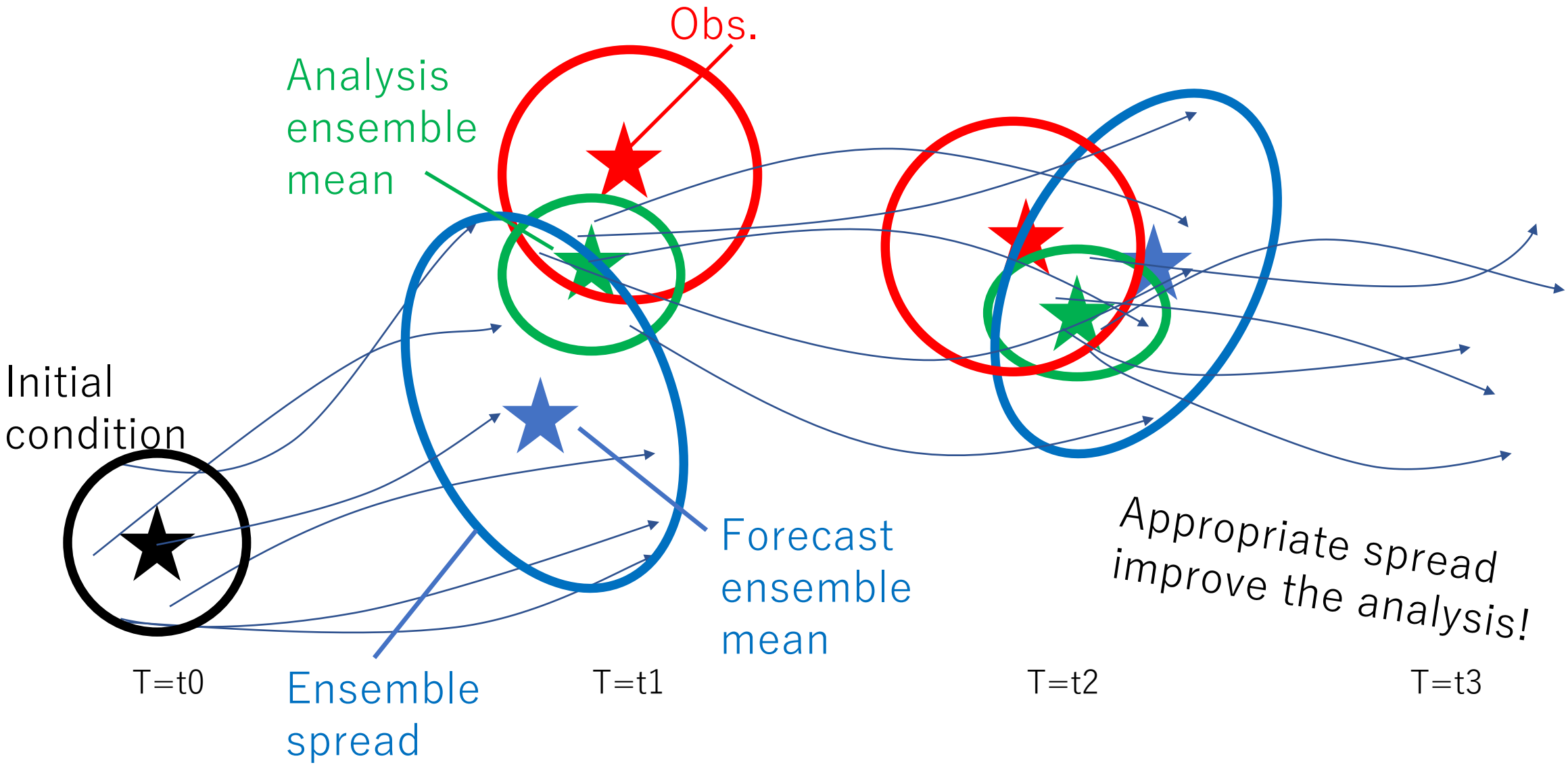
Data assimilation workflow



DA corrects forecast fields to fit better with observation.

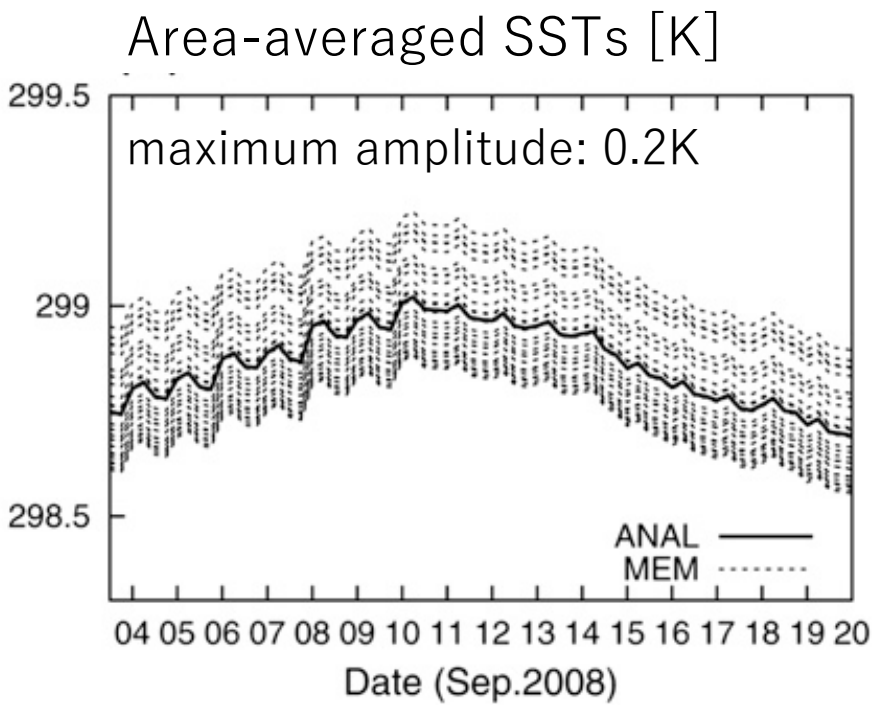
DA produces the best estimate of the current state, which is used as the initial condition.

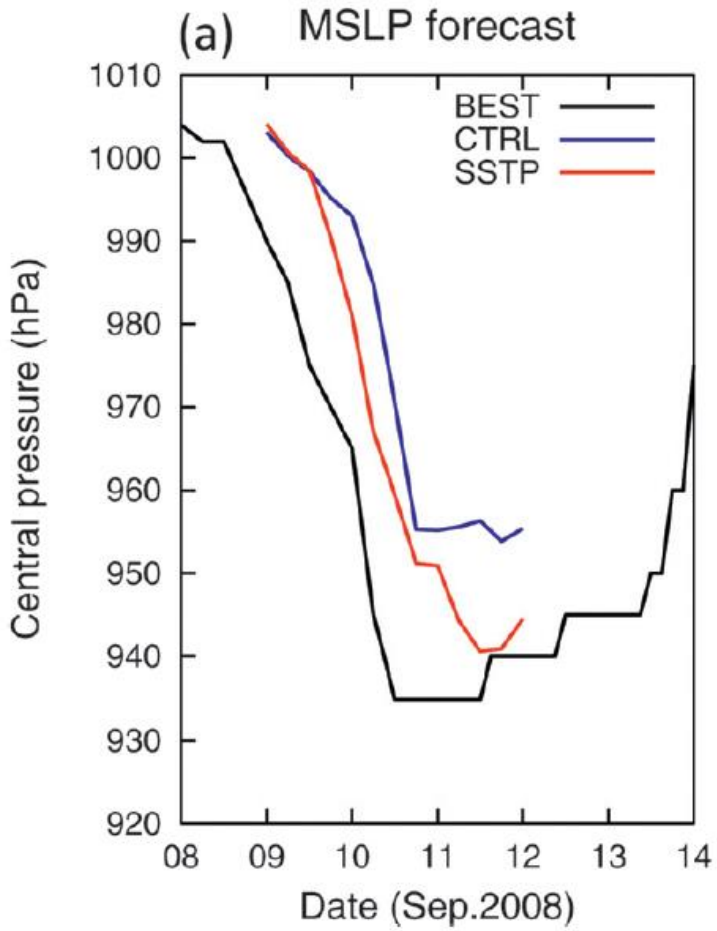
Evolution of PDF/spread in Ensemble Kalman Filter

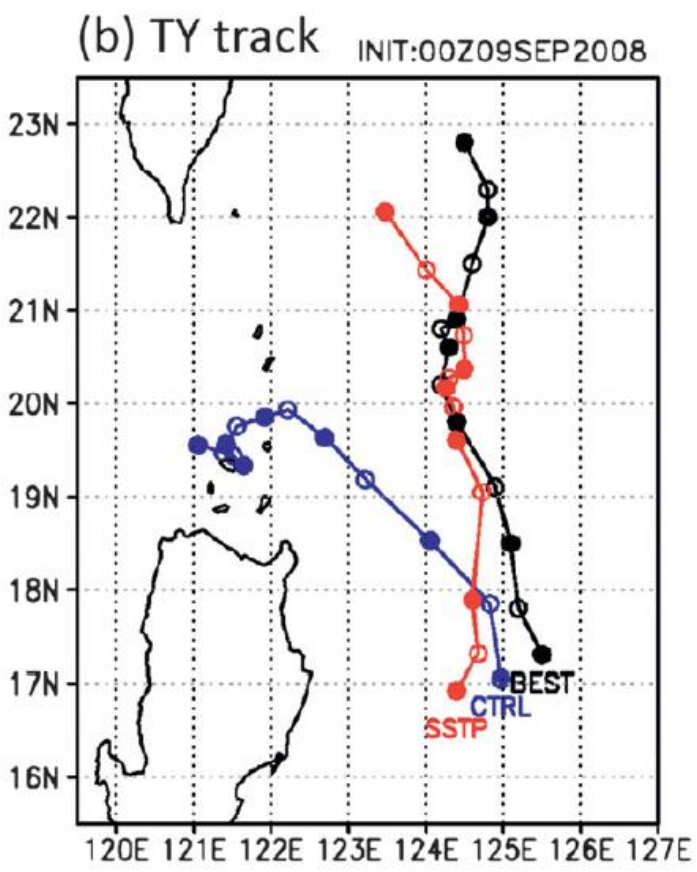


Role of SST perturbation in atmospheric DA

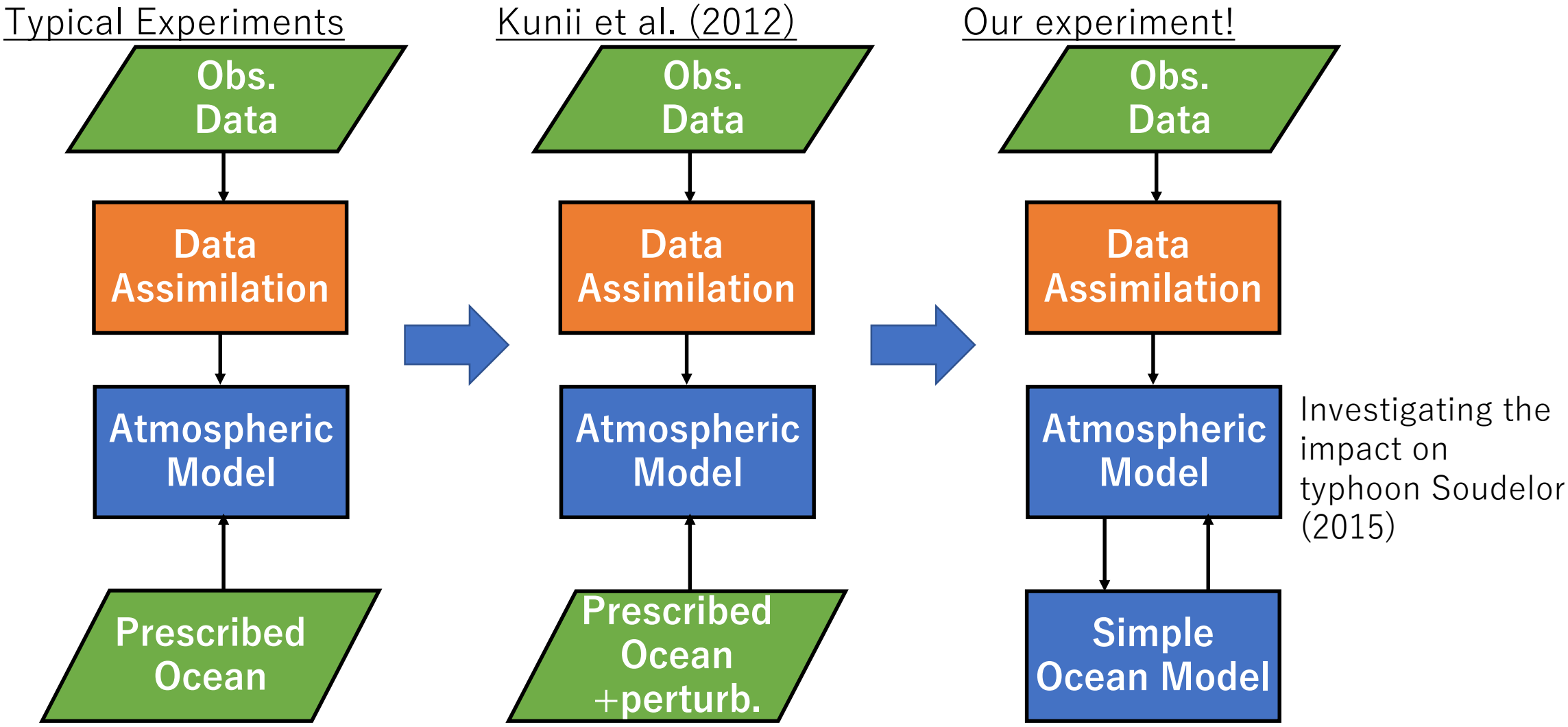
Even **flow-independent artificial SST perturbations (spread)** improved analysis and forecast of typhoon Sinlaku (2008).
Kunii et al. (2012)





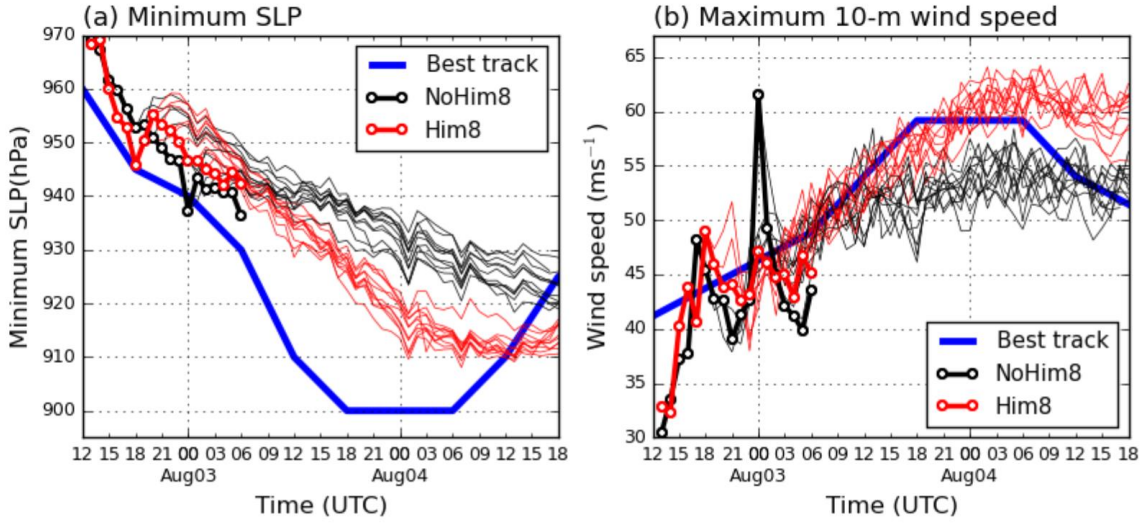


Purpose of this study

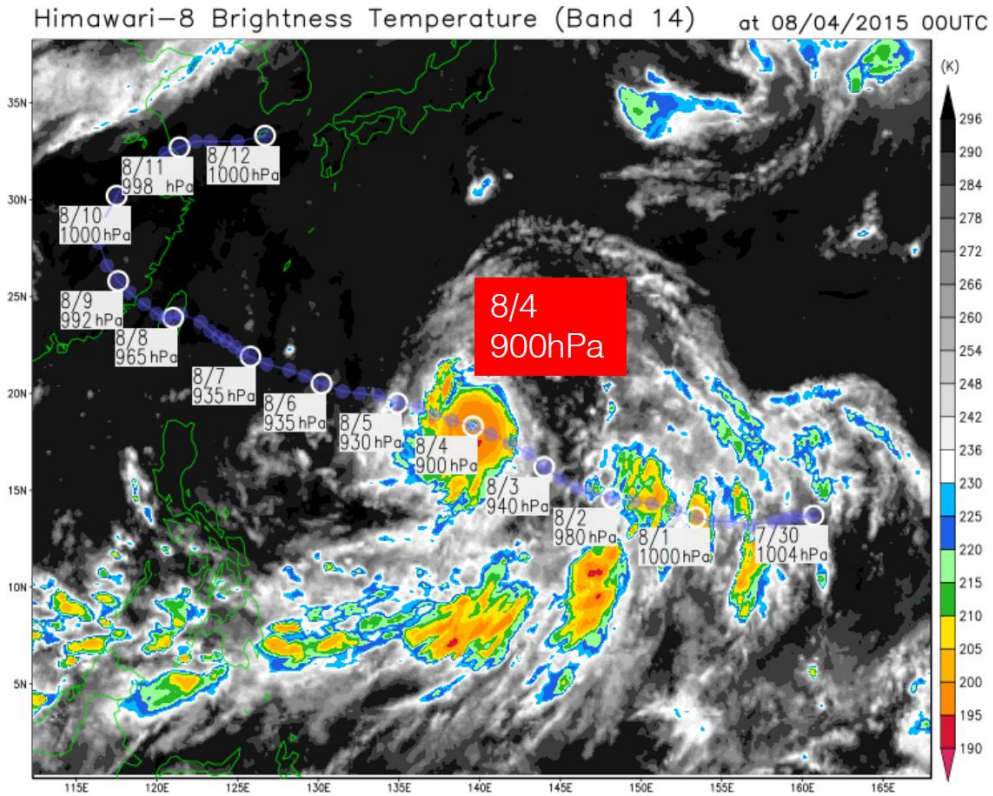


Typhoon Soudelor (2015)

- **Typhoon Soudelor** was the strongest tropical cyclone in the 2015 Pacific.
- There have been some simulation studies focusing on this typhoon.



Honda et al. (2017)



Ocean Mixed Layer Model: PWP model

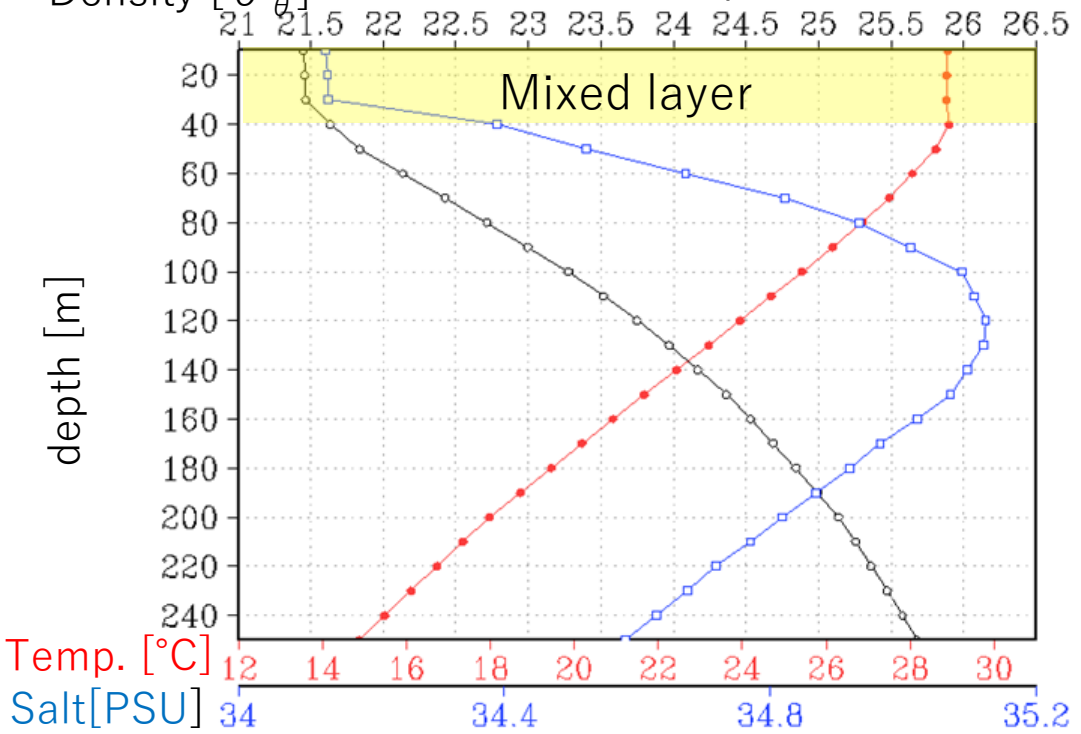
(Price, Weller, and Pinkel 1986)

- One of the most simplest **mixed layer model**.
  - Vertically 1-D model without turbulence.
  - No Ekman pumping.
- Density and wind induced current control vertical mixing.
  - Static instability
    - $S_I = \frac{\partial \rho}{\partial z} \geq 0$
  - Bulk mixed layer instability
    - $R_B = \frac{g \Delta \rho h}{\rho_0 (\Delta V)^2} \geq 0.65$
  - Shear flow instability
    - $R_G = \frac{g \partial \rho / \partial z}{\rho_0 (\partial V / \partial Z)^2} \geq 0.25$

Mixed layer bottom (h):

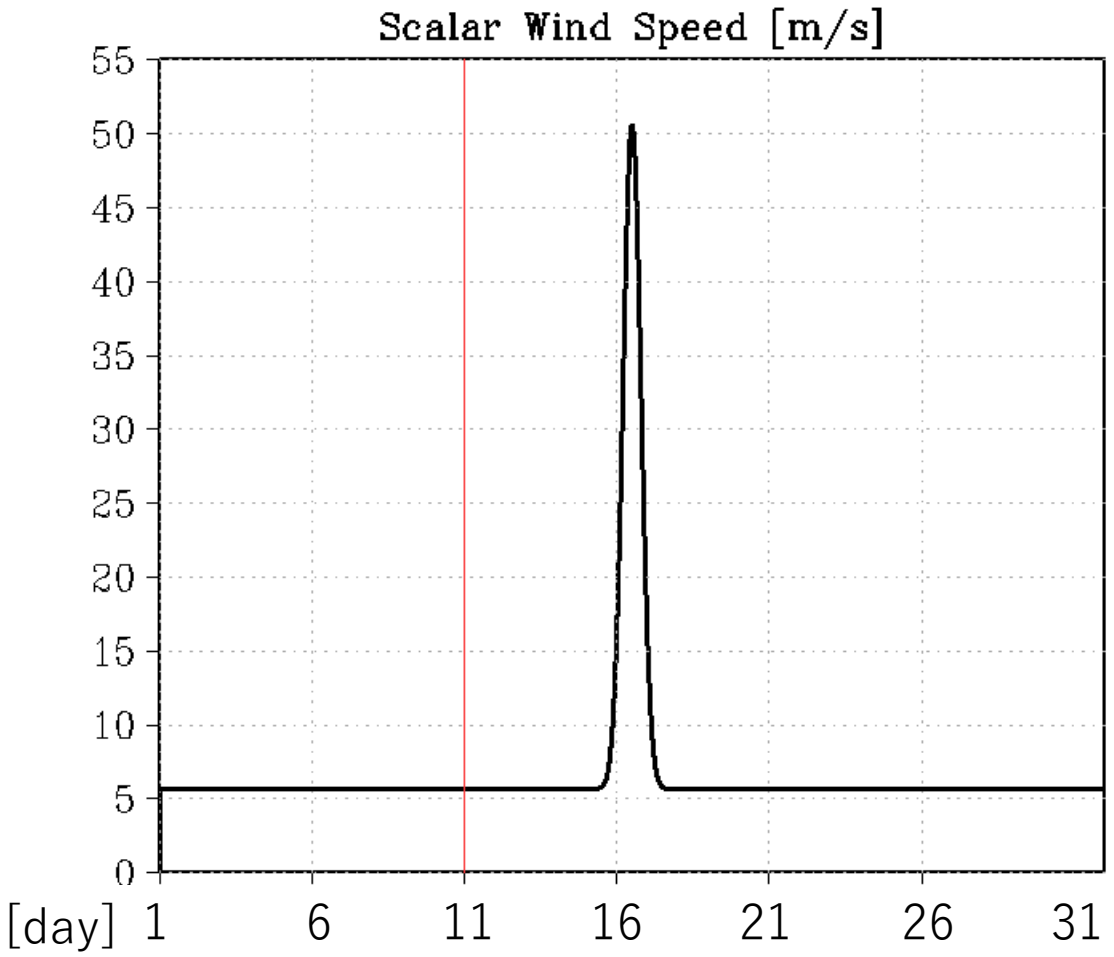
the top depth of $\frac{\partial \rho}{\partial z} > 1.0 \times 10^{-3} kg/m^3/m$

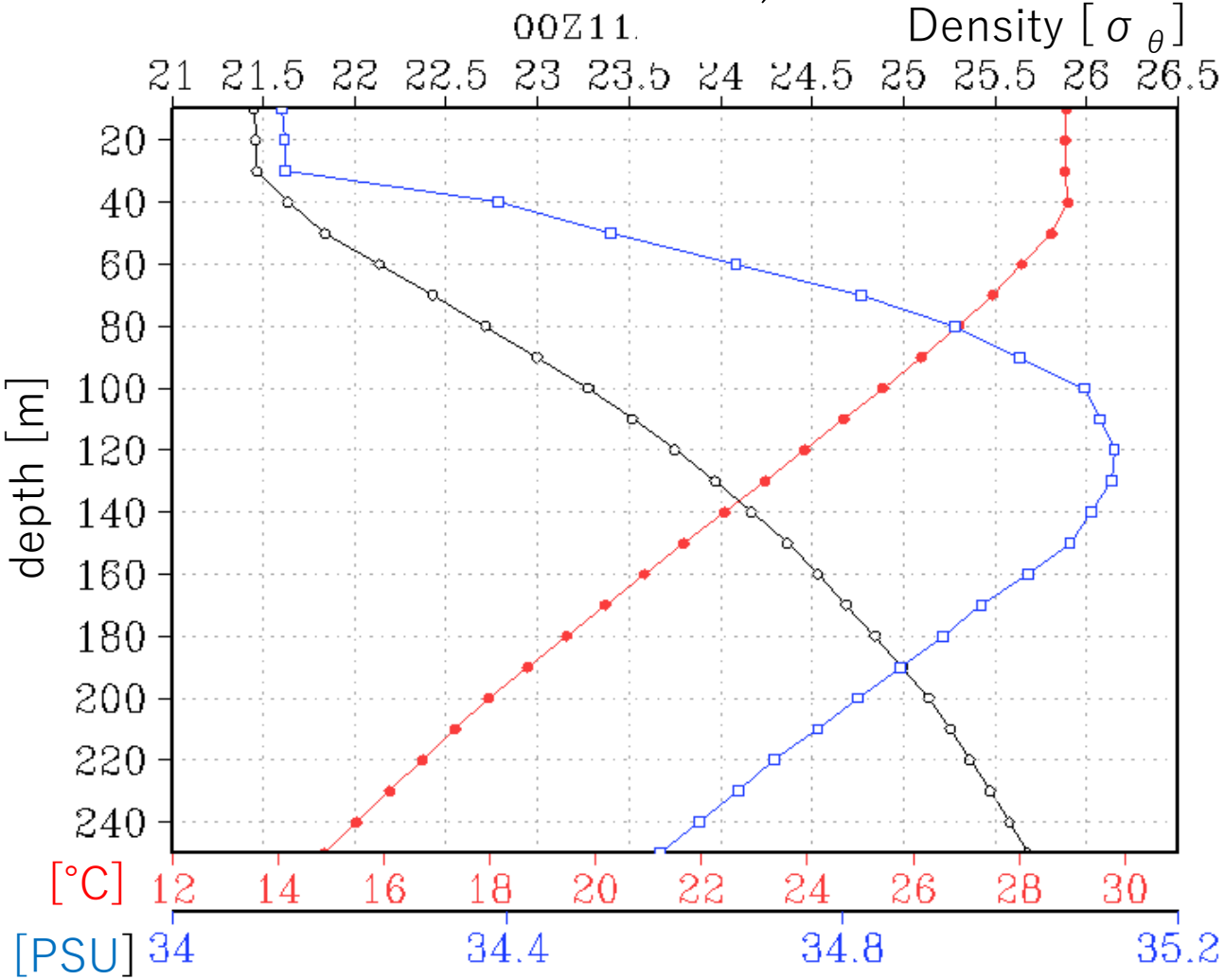
Typical ocean profile in the summer subtropical Pacific



Example of PWP model

(Ideal situation for the western subtropical North Pacific in summer season)





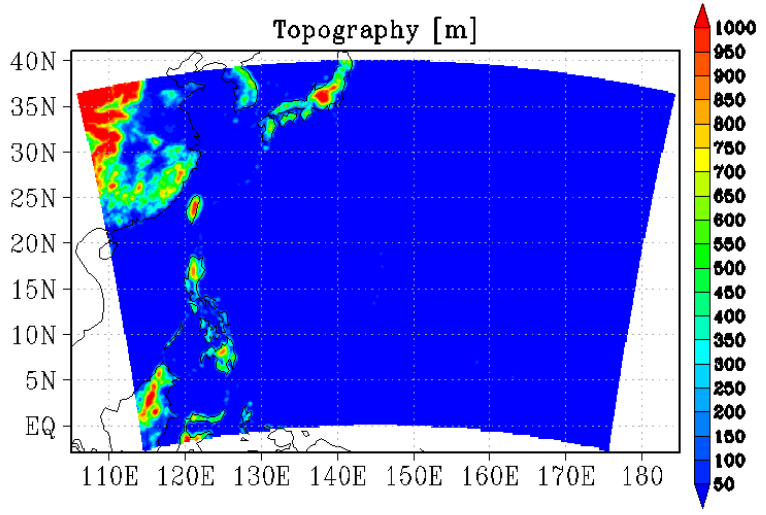
Strong wind causes:

- **surface temperature->small**
- surface salinity -> large
- surface density -> large

Experimental setting for FREE runs

Atmospheric setting

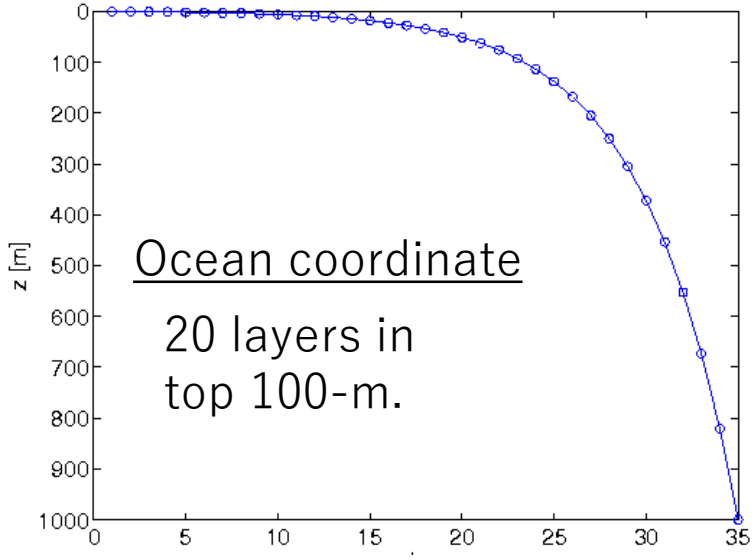
Model	SCALE-RM v5.2.5
Initial/Boundary cond.	NCEP-GFS (6 hr)
Period	Jul. 24 — Aug. 9, 2015
Resolution	15 km, 36 layers



Ocean setting

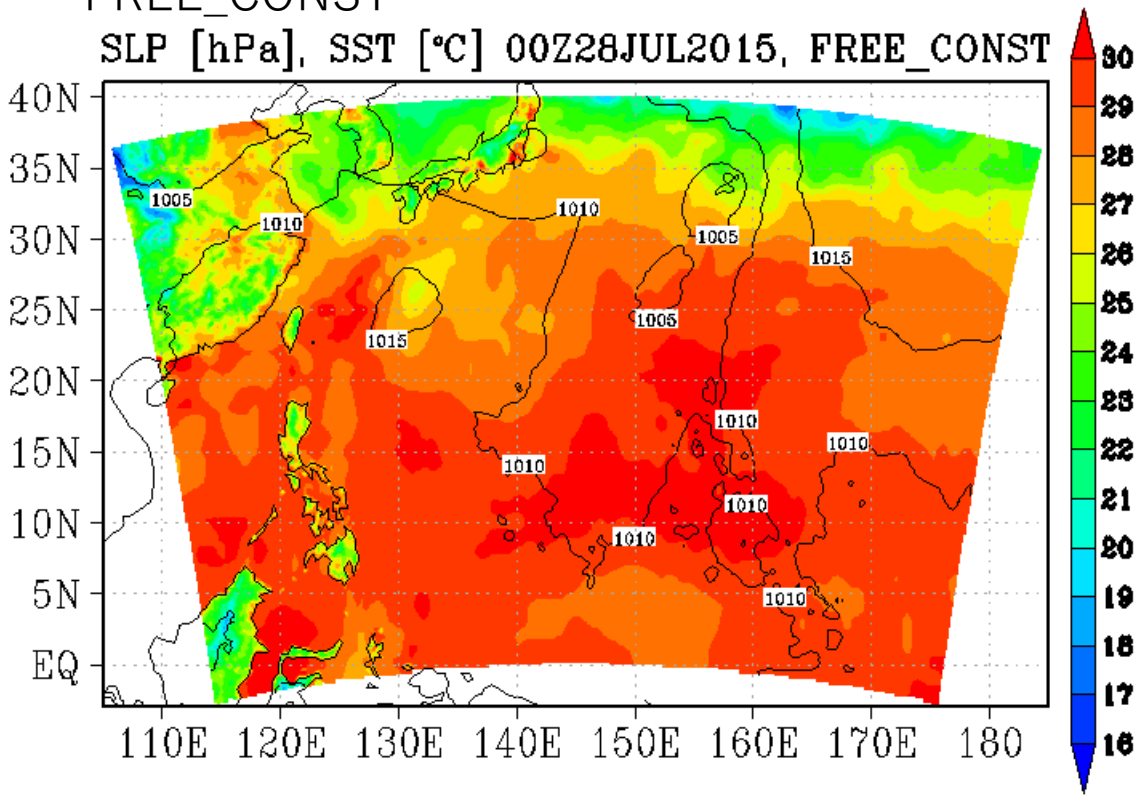
Exp. Name	FREE_CONST	FREE_PWP
Ocean model	Given (NCEP-GFS)	PWP model

NCEP-GFS for initial surface.
WOA13 (monthly climatology) for ocean interior
35 layer, up to 1000-m depth.

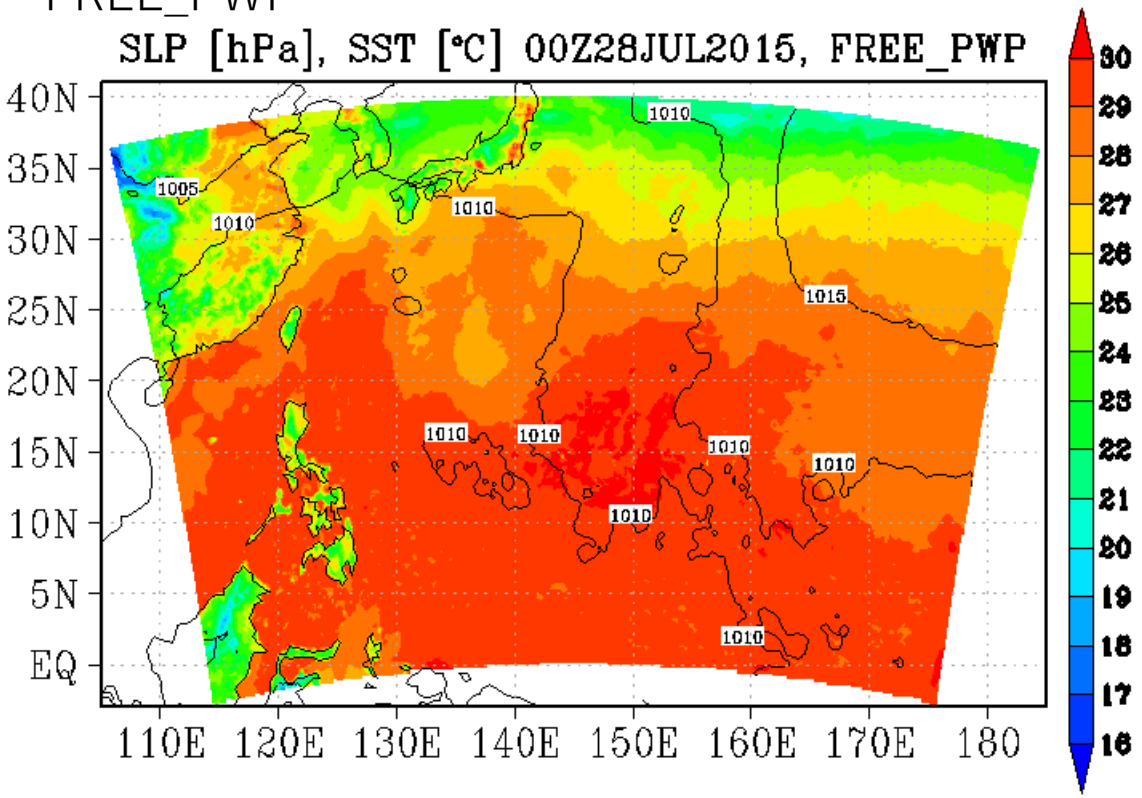


SLPs and SSTs in FREE runs

FREE_CONST



FREE_PWP

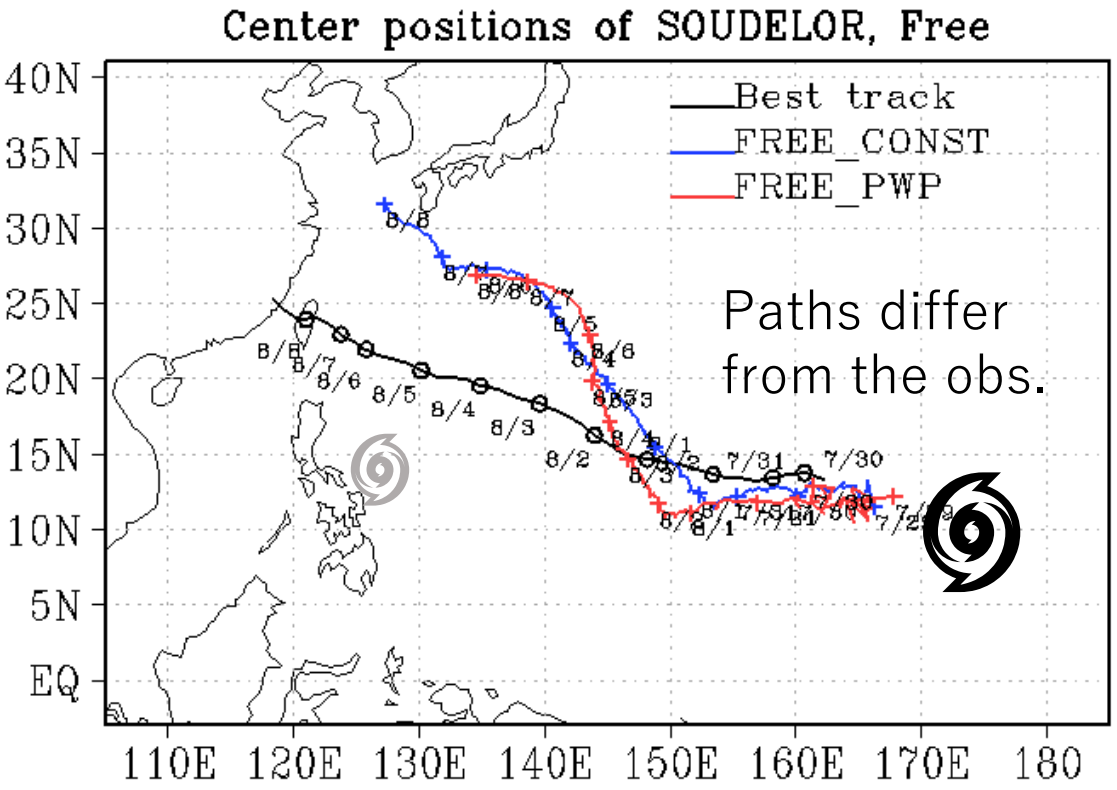


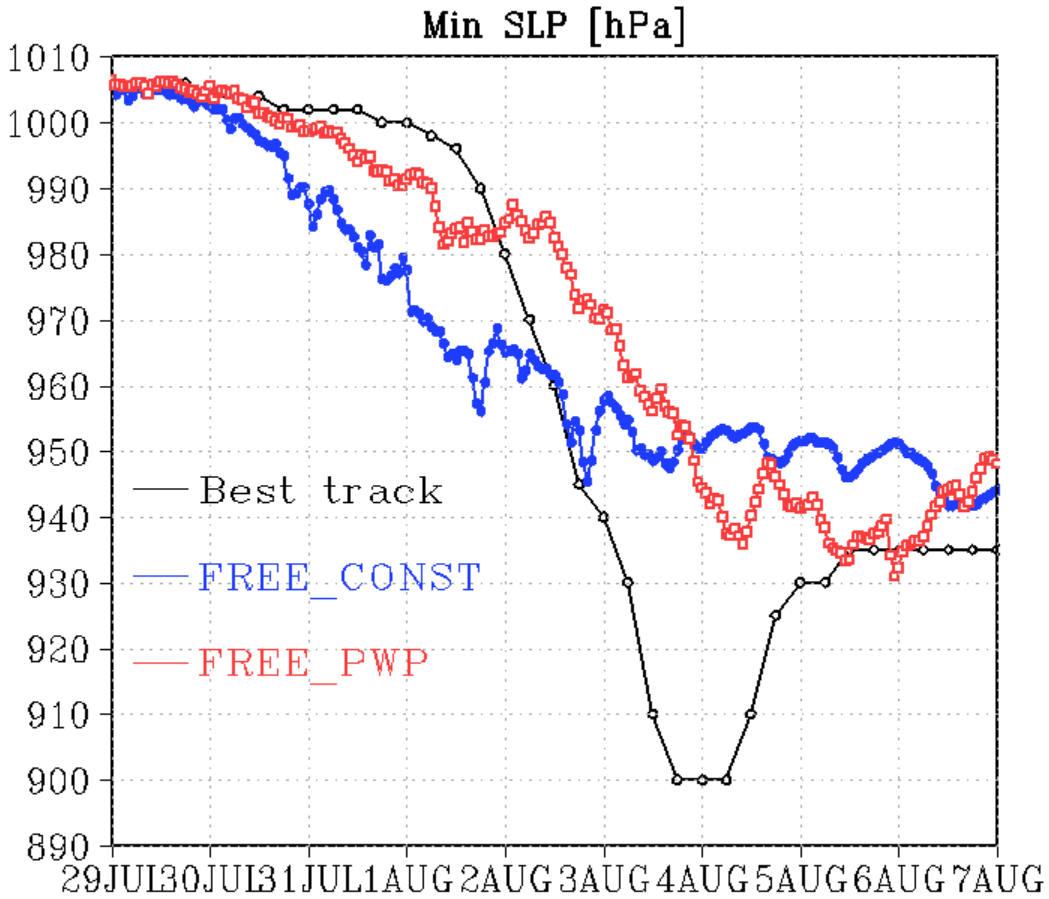
Typhoon Soudelor is generated in both runs.

SST changes slowly.
No diurnal cycle & interaction.

Good diurnal cycle and interaction.

Paths and min. SLPs in FREE runs





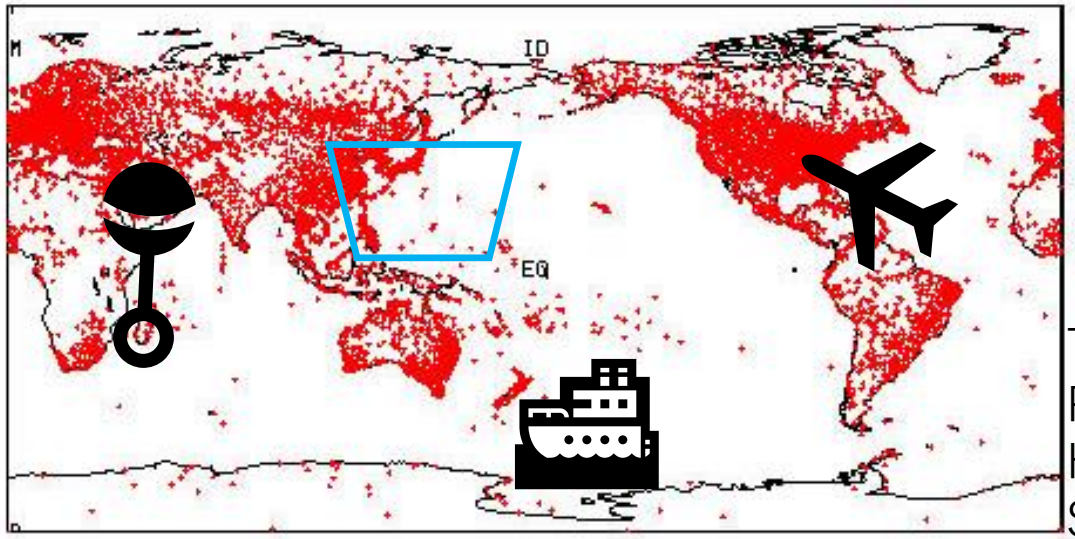
The minimum SLP in FREE_PWP is **smaller** than that in FREE_CONST.

Experimental setting for ANA & FCST runs

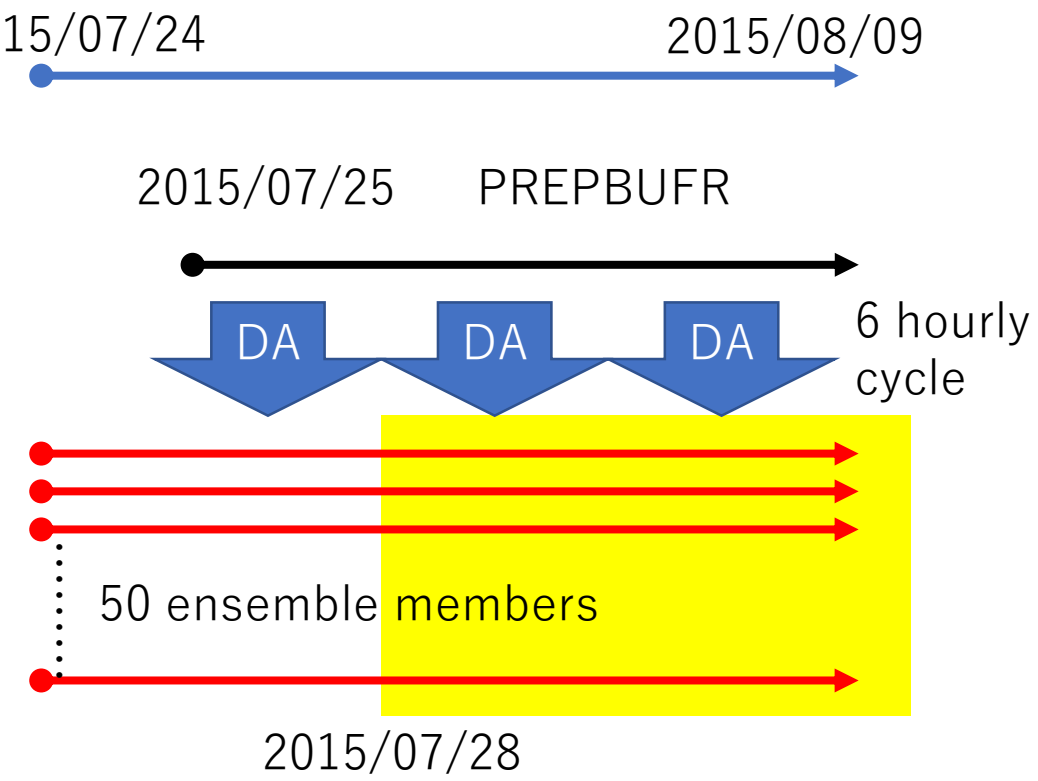
Model	SCALE-LETKF (Lien et al. 2017)
Observation	**PREPBUFR**
OCEAN	Constant
	PWP
	Constant but with perturbation

FCST only

PREPBUFR observation points



Temperature, Pressure, Height, Humidity, SST, SLP, Wind

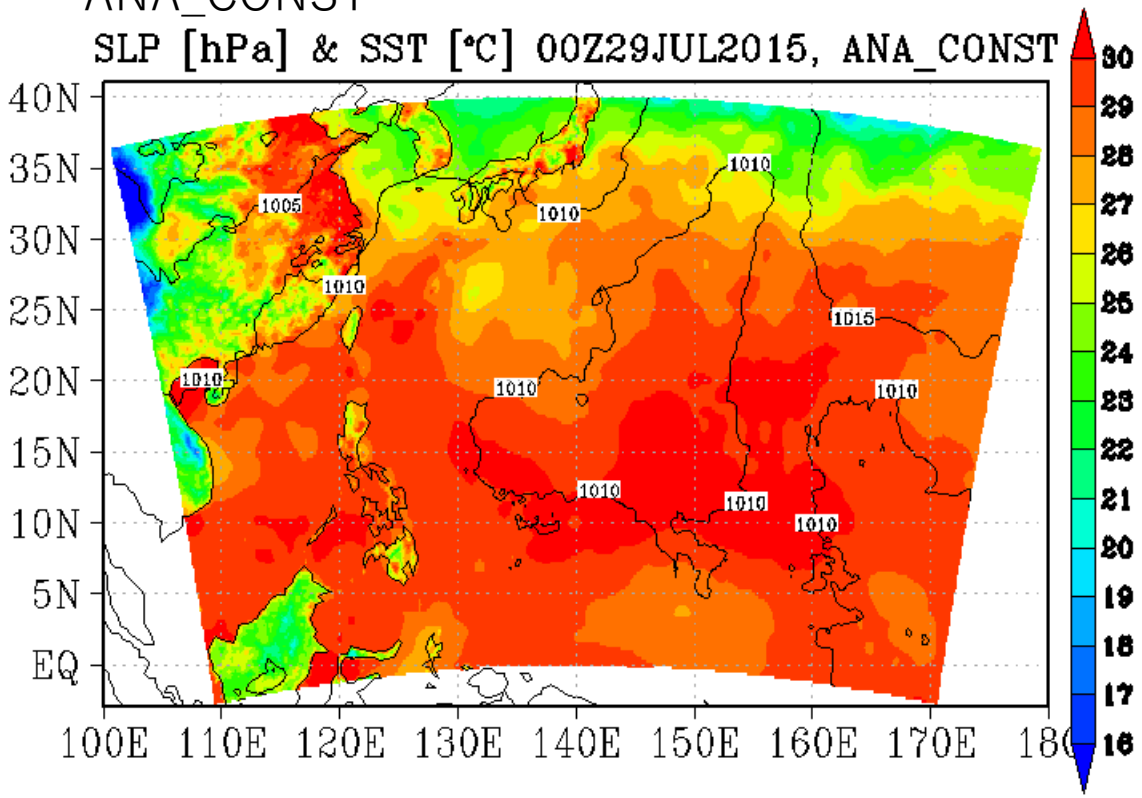


For analyzing and forecasting

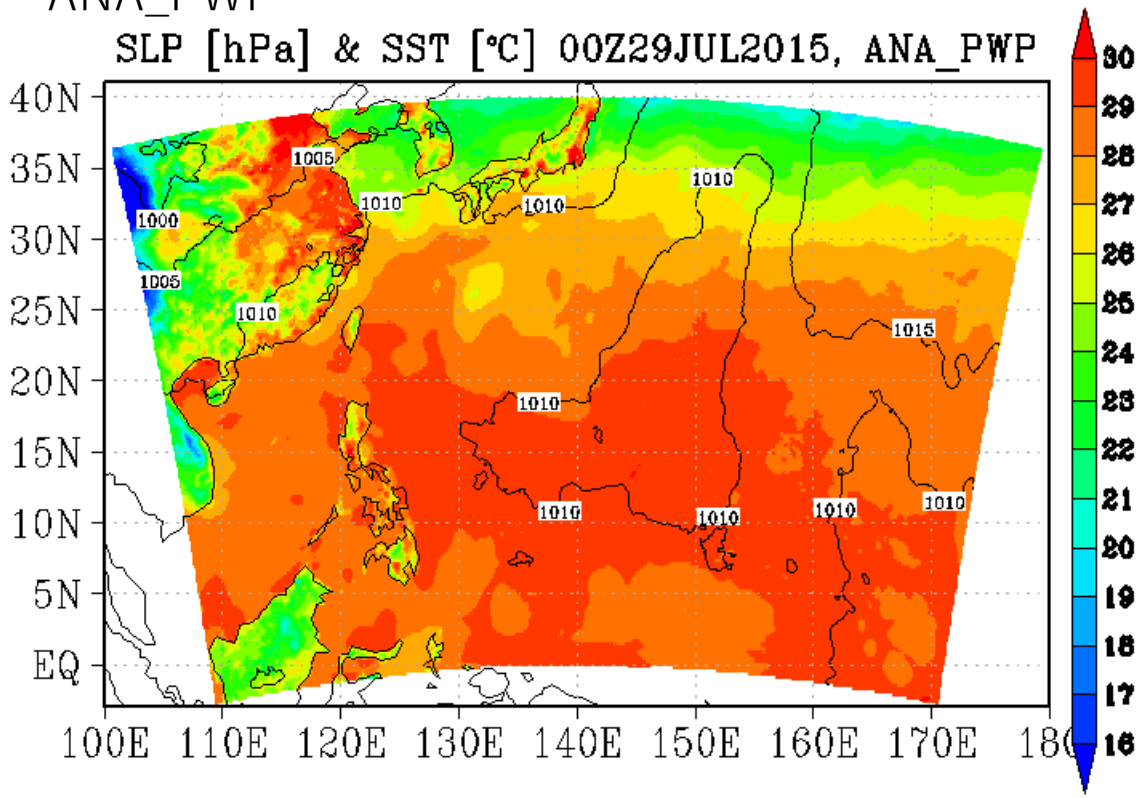
(classified as Typhoon at 18:00 July 29)

SLPs and SSTs in ANA runs

ANA_CONST

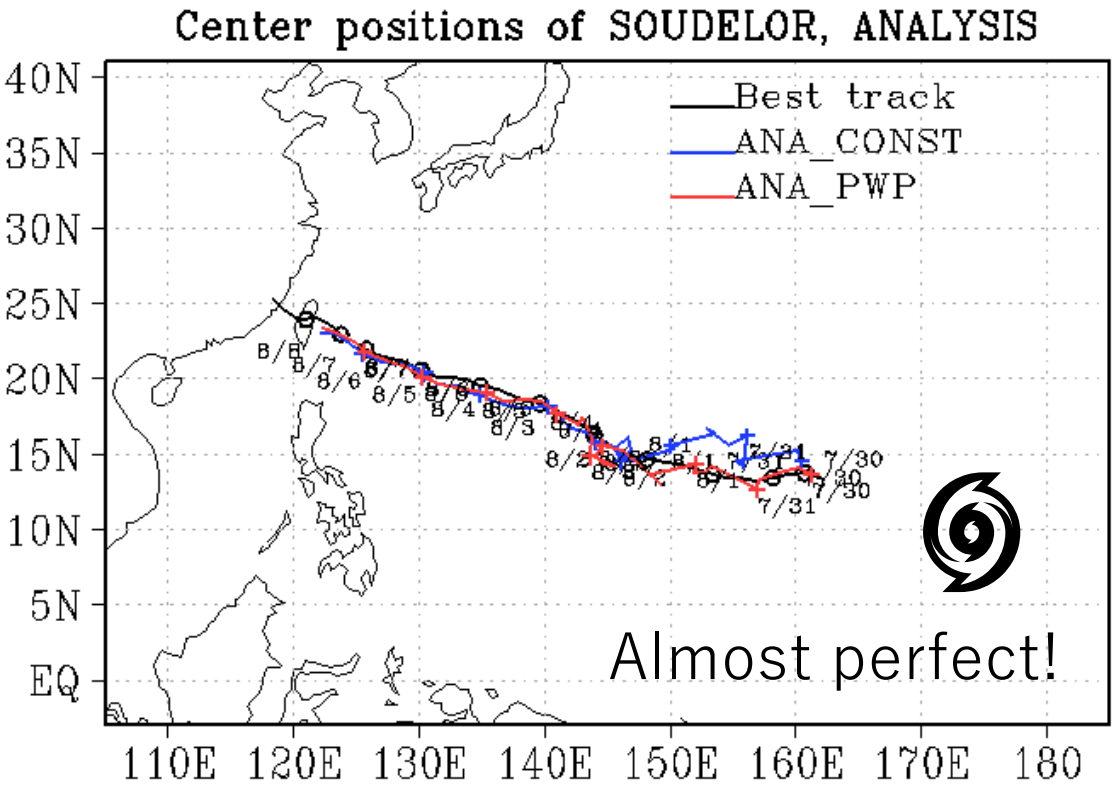


ANA_PWP

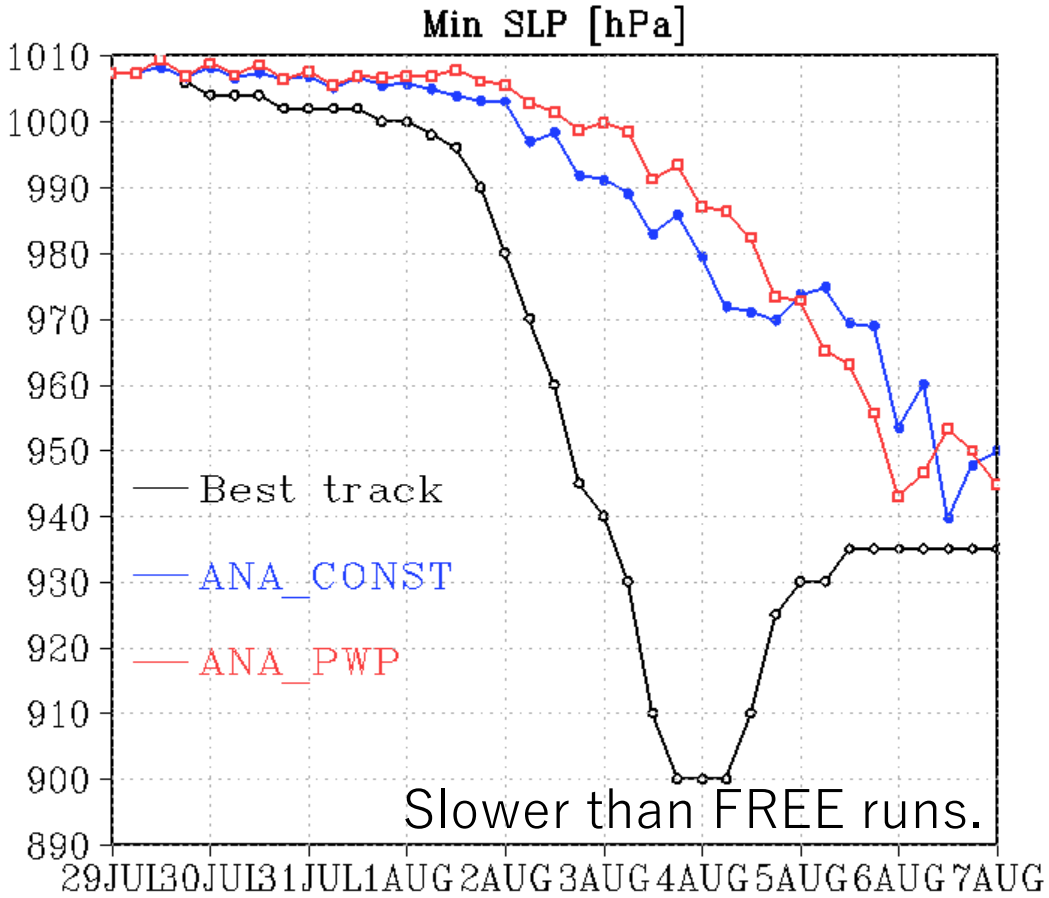


SLPs are very similar…

Paths and min. SLPs in ANA runs

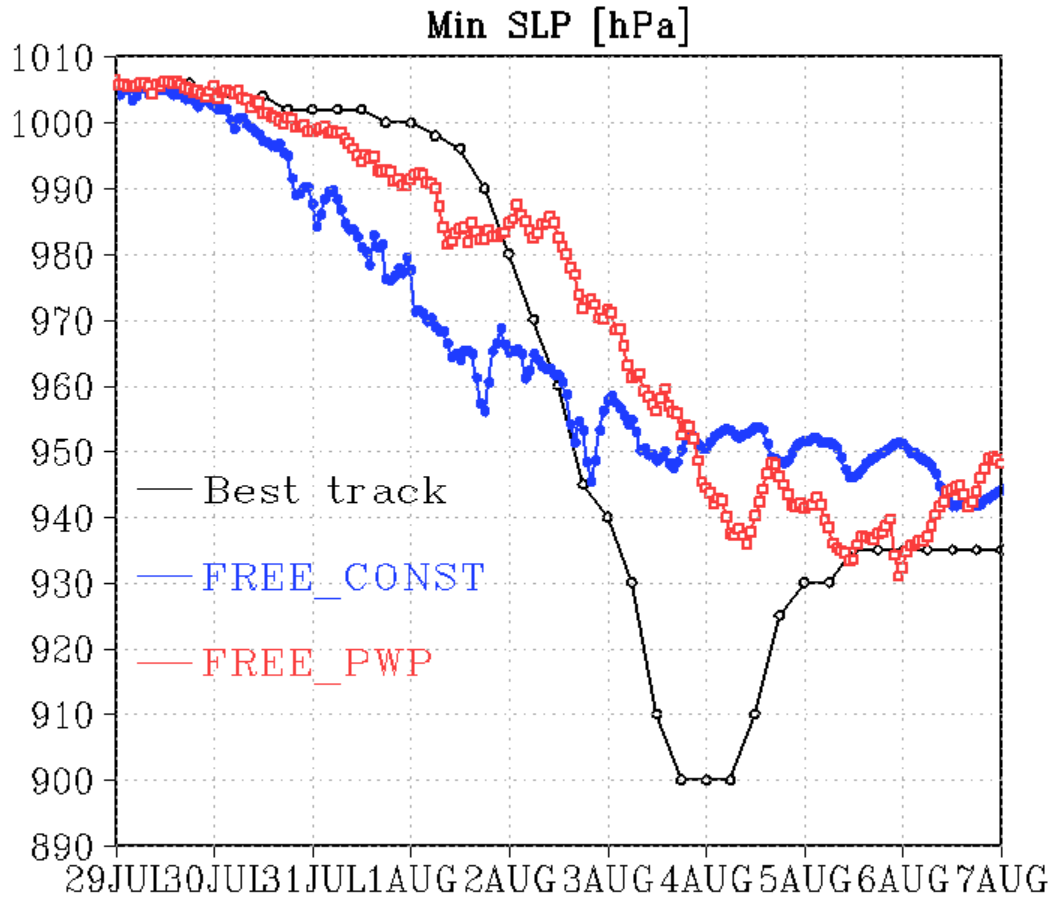


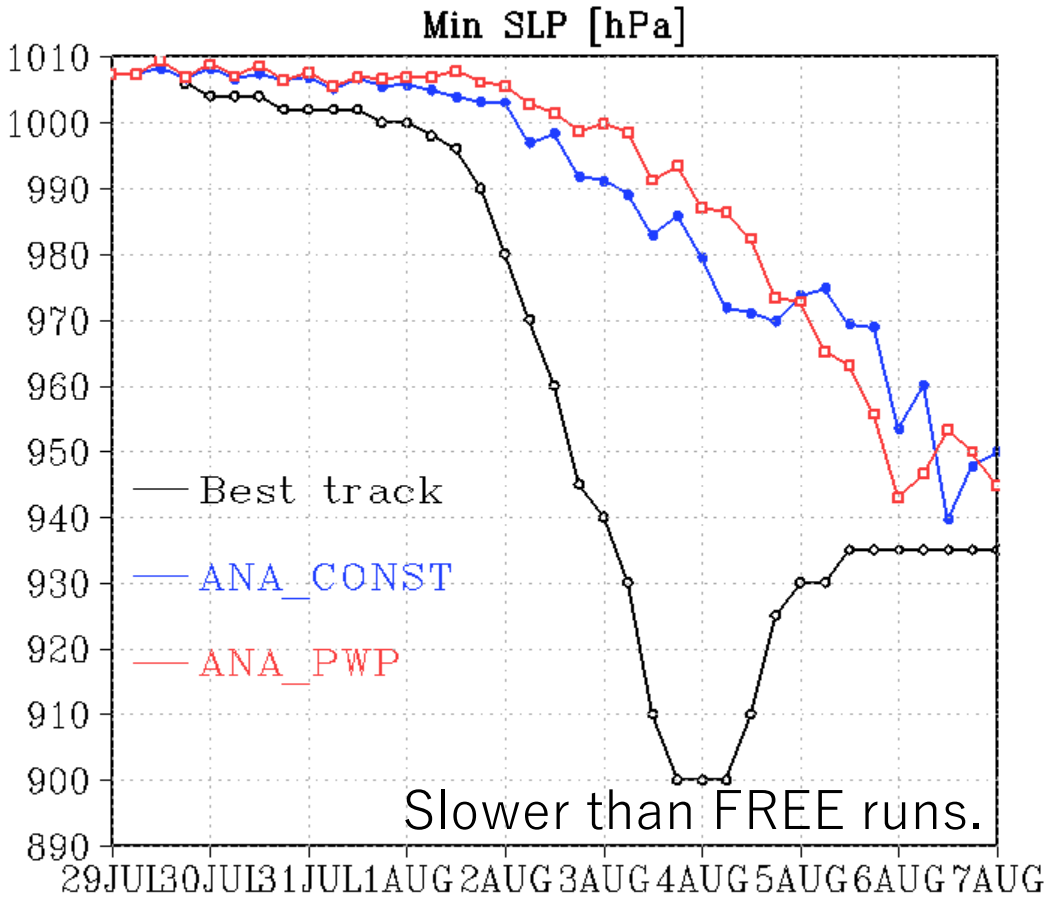
Almost perfect!



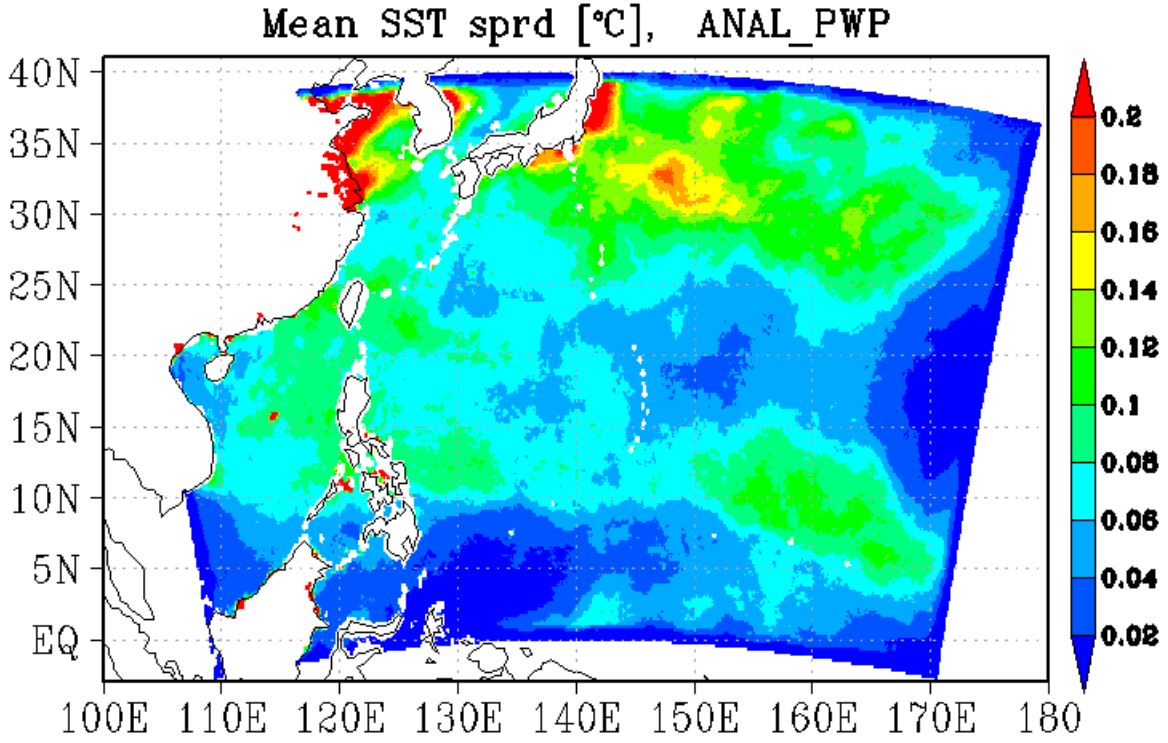
Slower than FREE runs.

Paths and min. SLPs in ANA runs

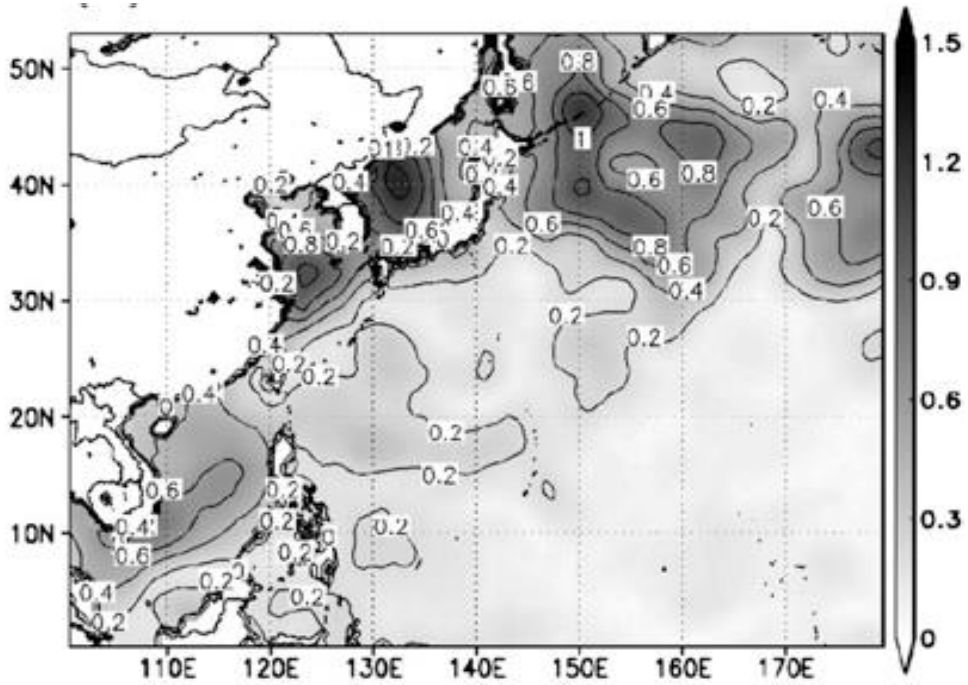




SST spreads in ANA_PWP

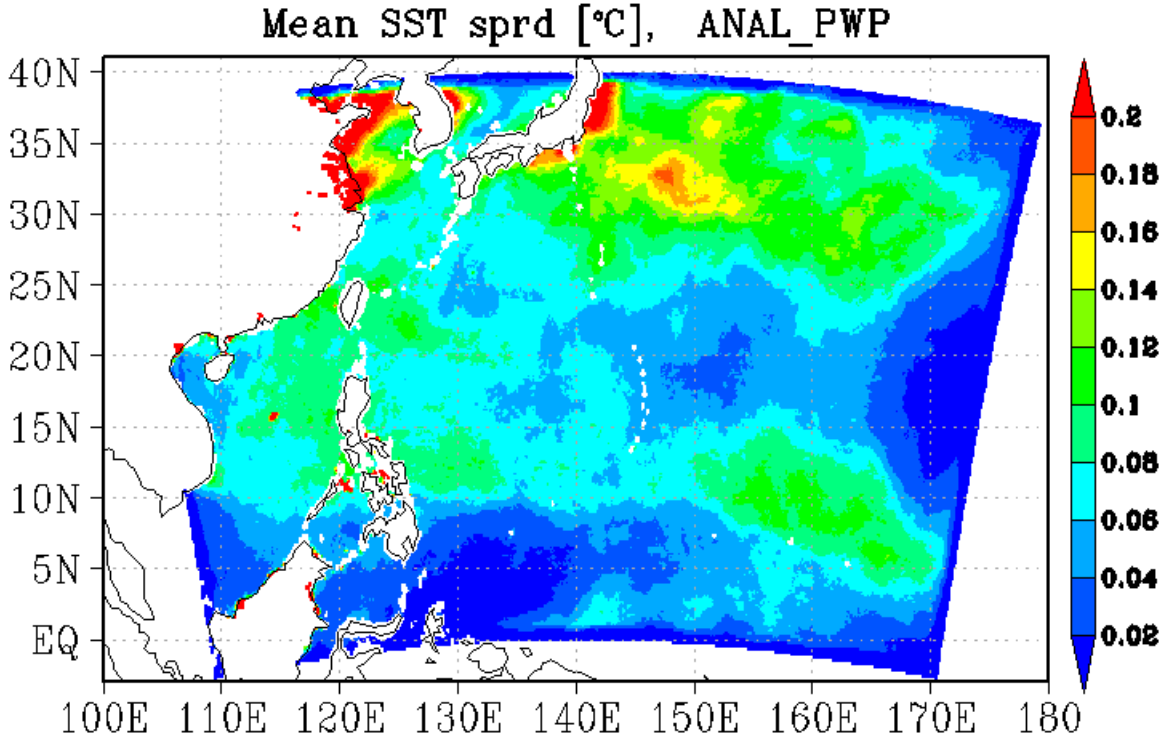


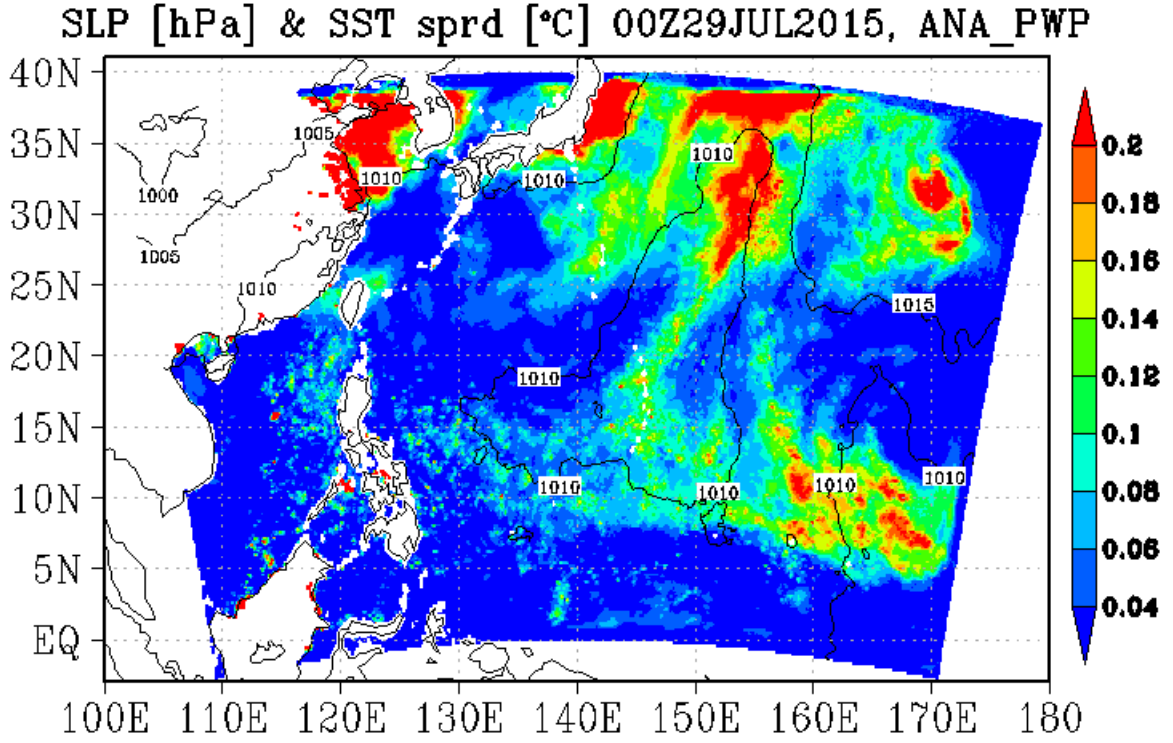
Mean SST spreads (Kunii et al. 2012)



Spreads is smaller than those in Kunii et al. (2012).

SST spreads in ANA_PWP



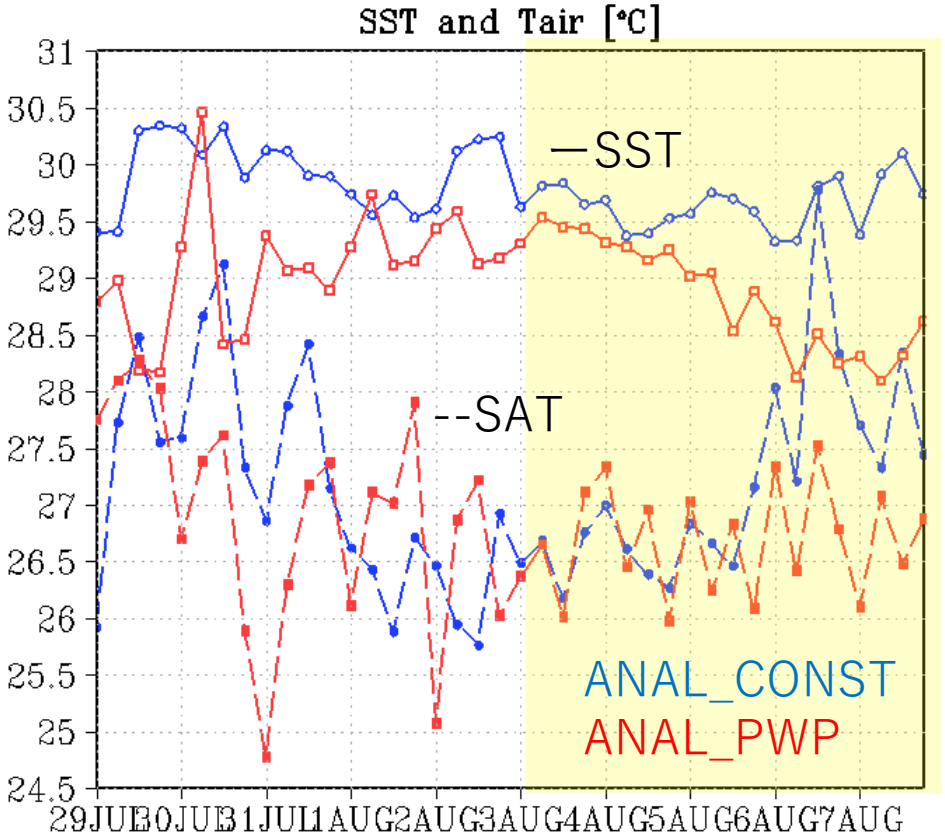


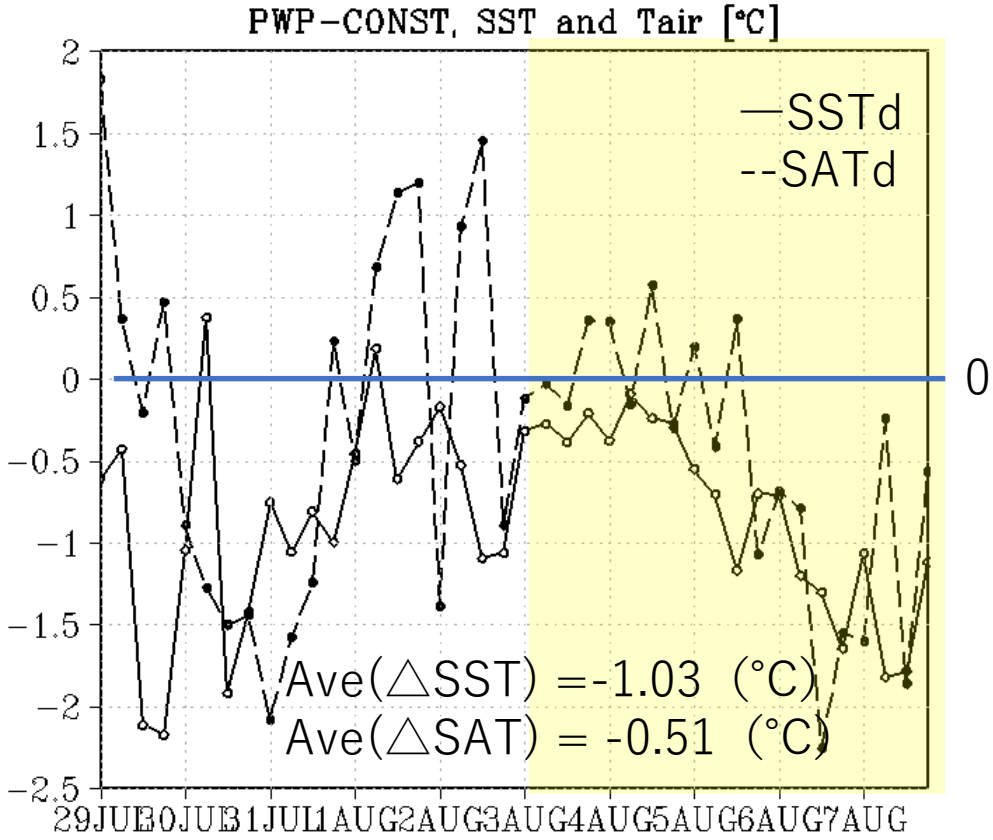
Spreads is smaller than those in Kunii et al. (2012).

Large diurnal cycle.
Large spread just under the typhoon.
Small spread around the typhoon.

SSTs and SATs along the path in ANA runs

(Surface Air Temperature)

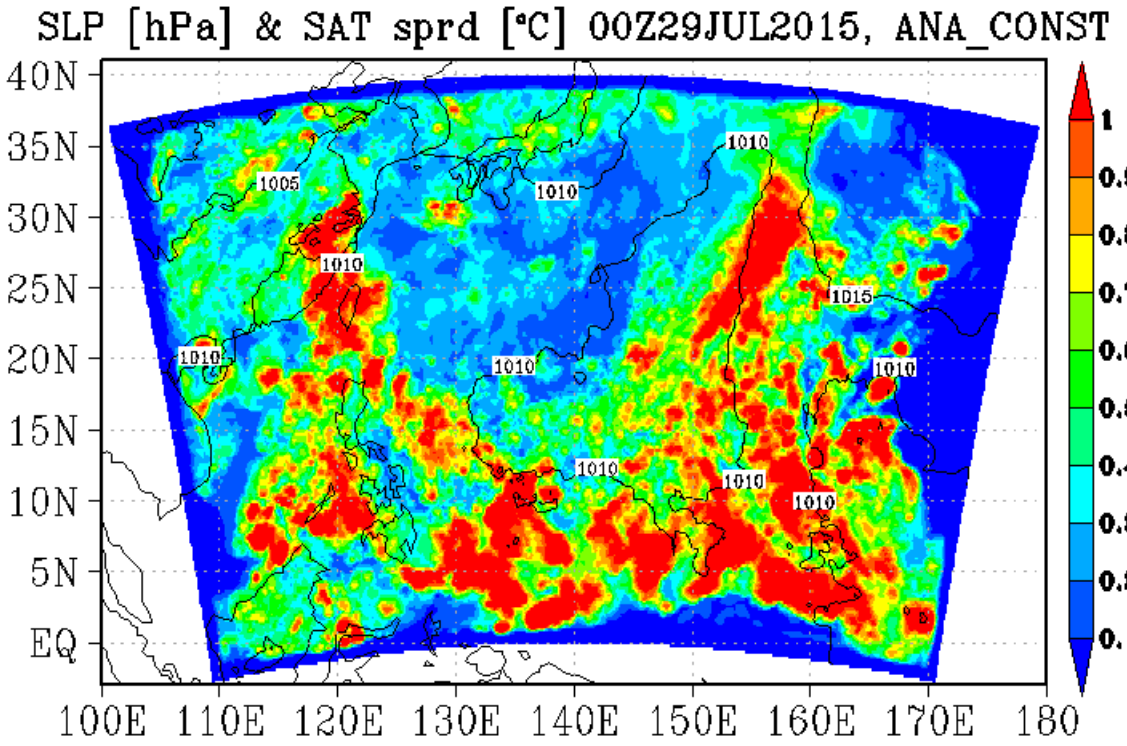


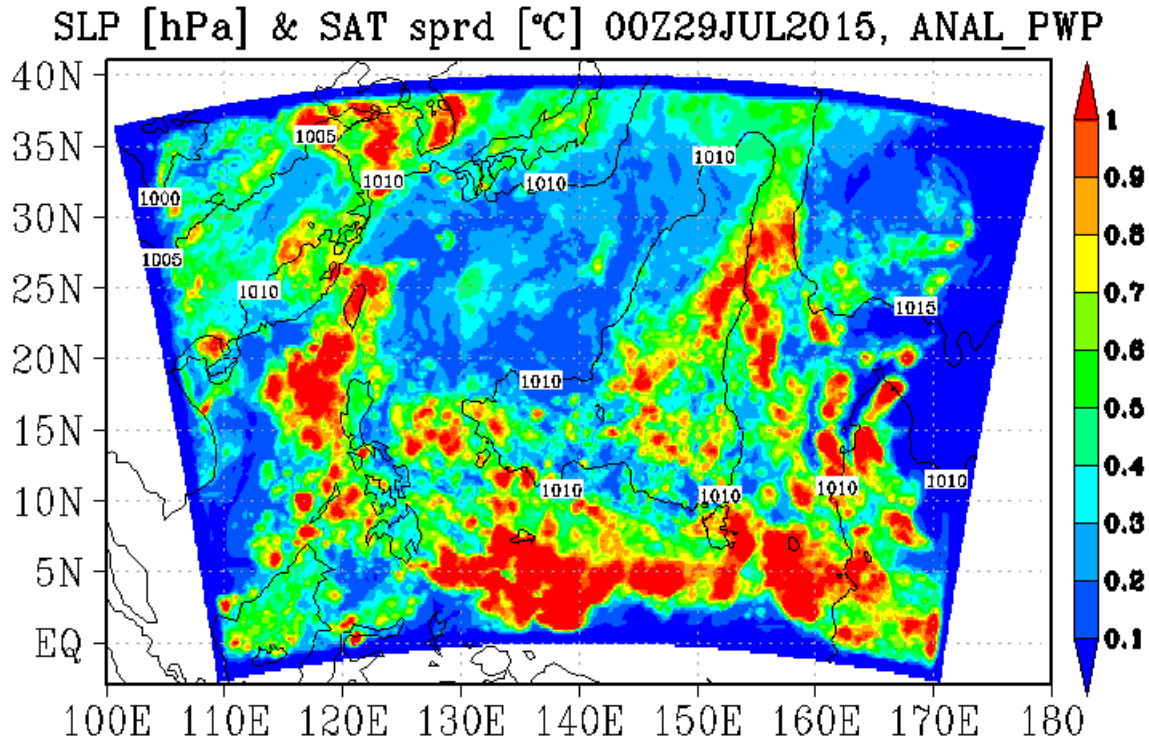


SST: CONST: Nearly constant
PWP: Decrease
SAT: CONST: Increase
PWP: Nearly constant

SST & SAT in ANA_PWP is **smaller** than those in ANA_CONST.

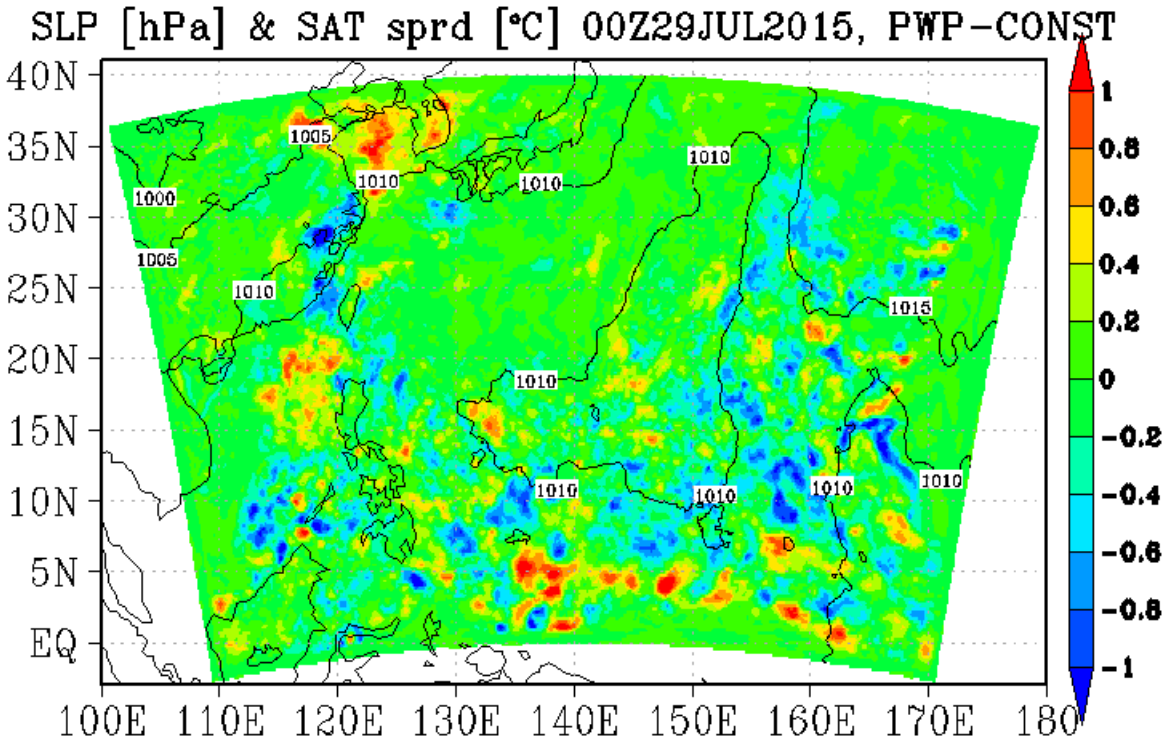
SAT spreads (1/2)



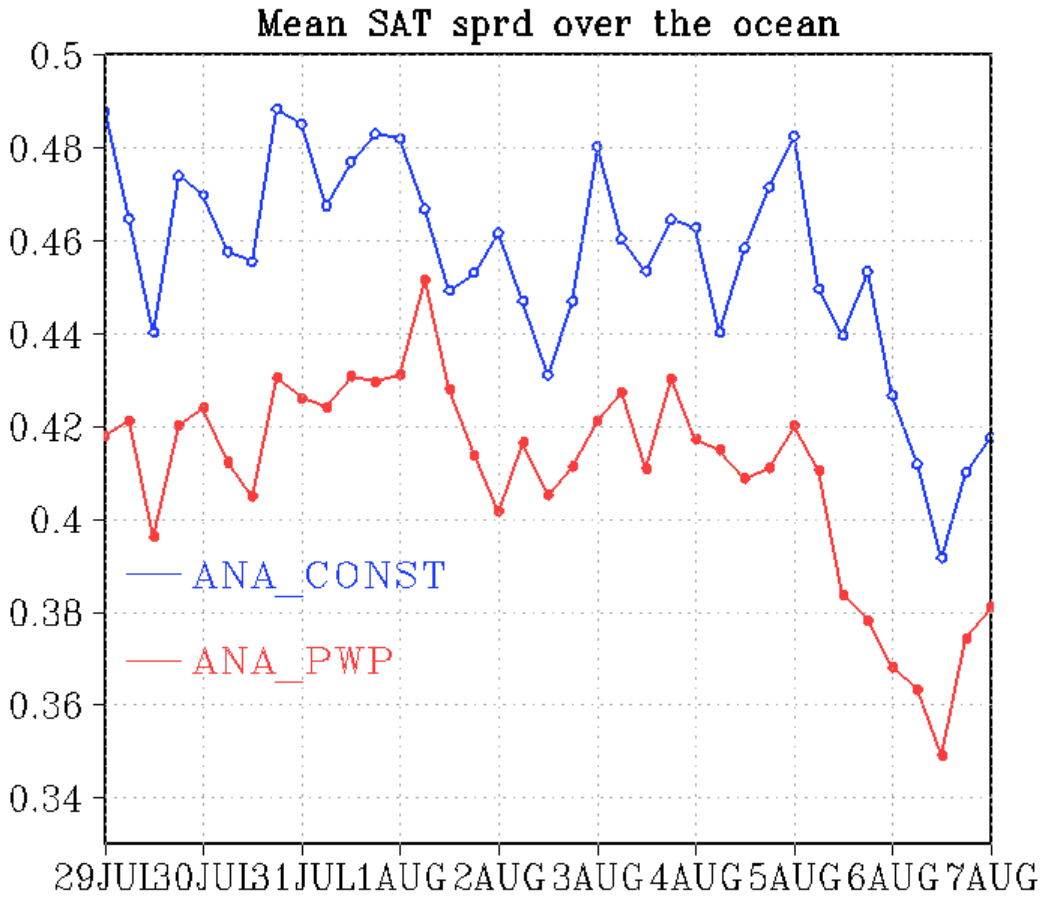


- 5 times larger than SST spreads.
- Large spread just under the typhoon.

SAT spreads (2/2)



Spread around the typhoon in ANA_PWP tend to be smaller than that in ANA_CONST.

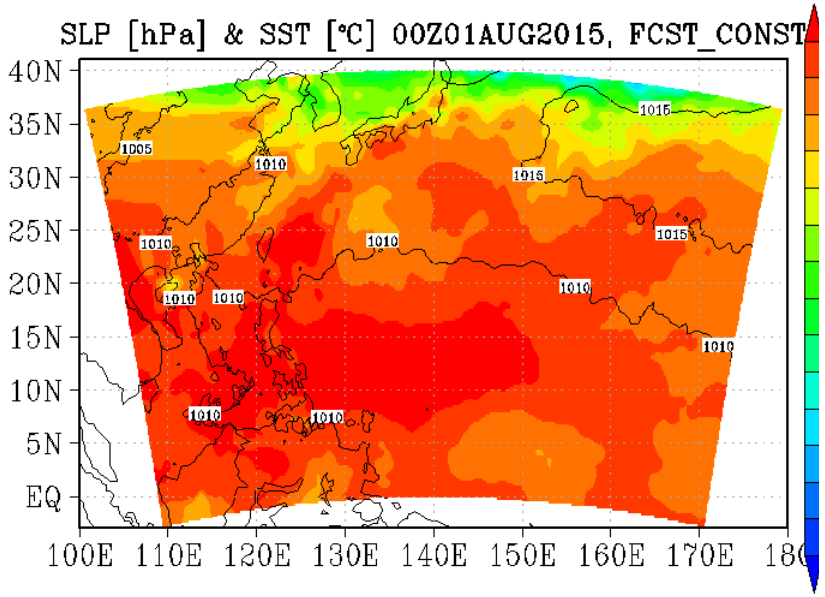


Mean spreads in ANA_PWP is generally smaller than that in ANA_CONST.

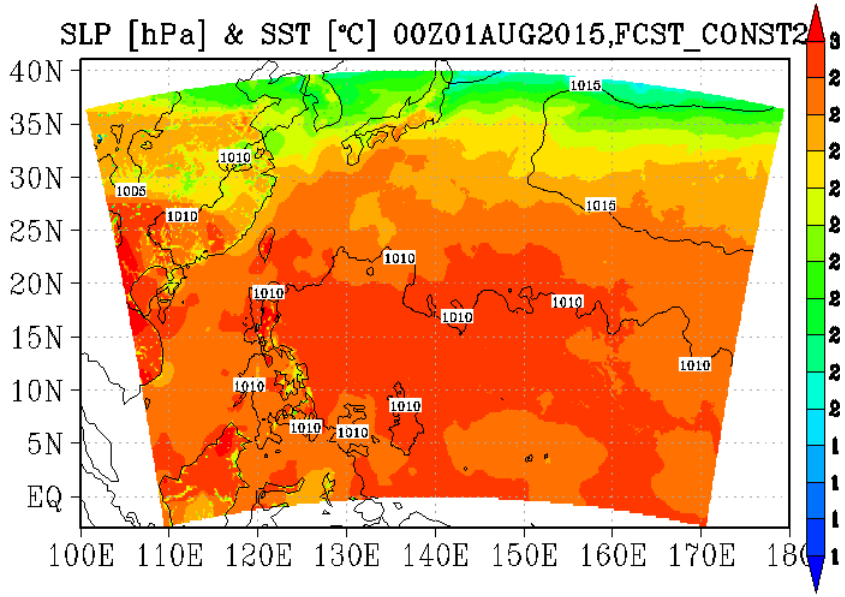
Negative feedback by PWP model shrinks the ensemble spreads!

SLPs and SSTs in FCST runs (20150801~)

FCST_CONST

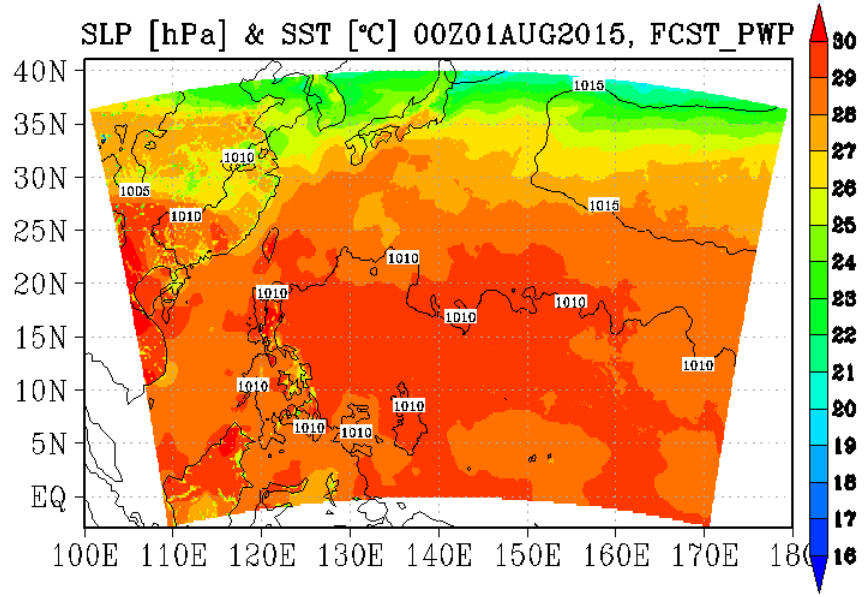


FCST_CONST2



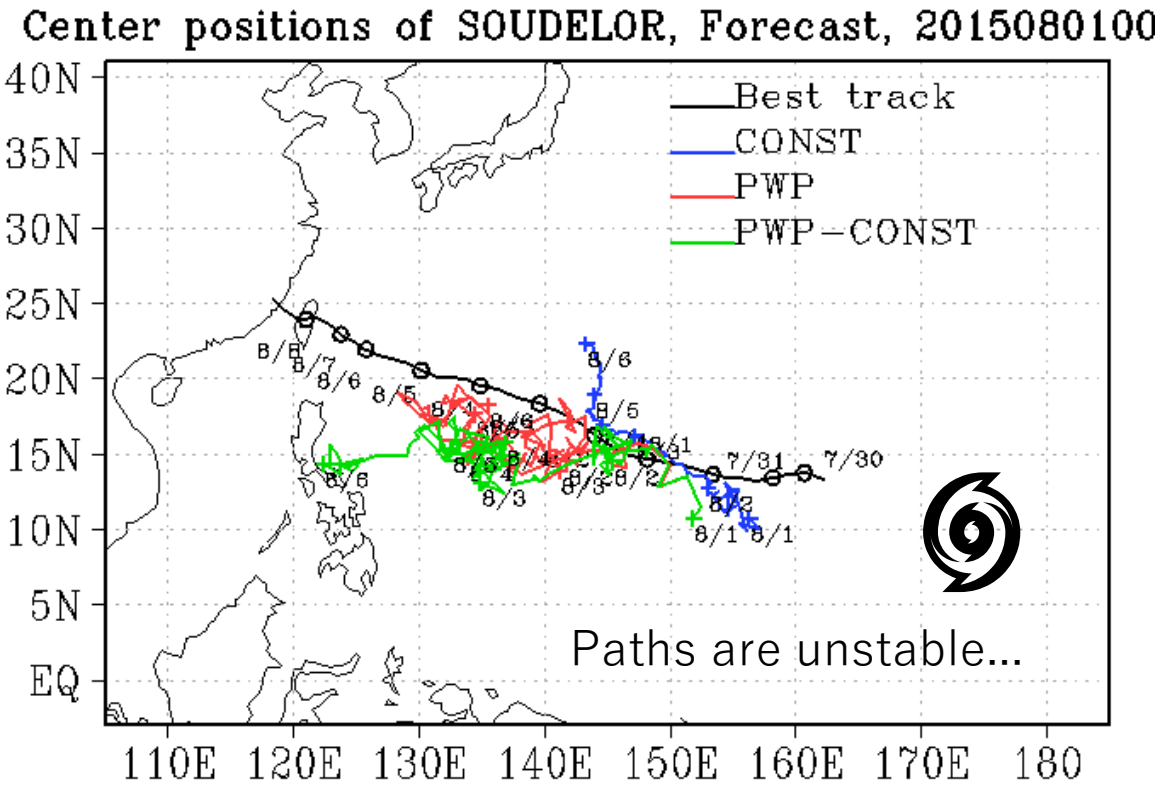
Constant SSTs,
but have ensemble perturbations

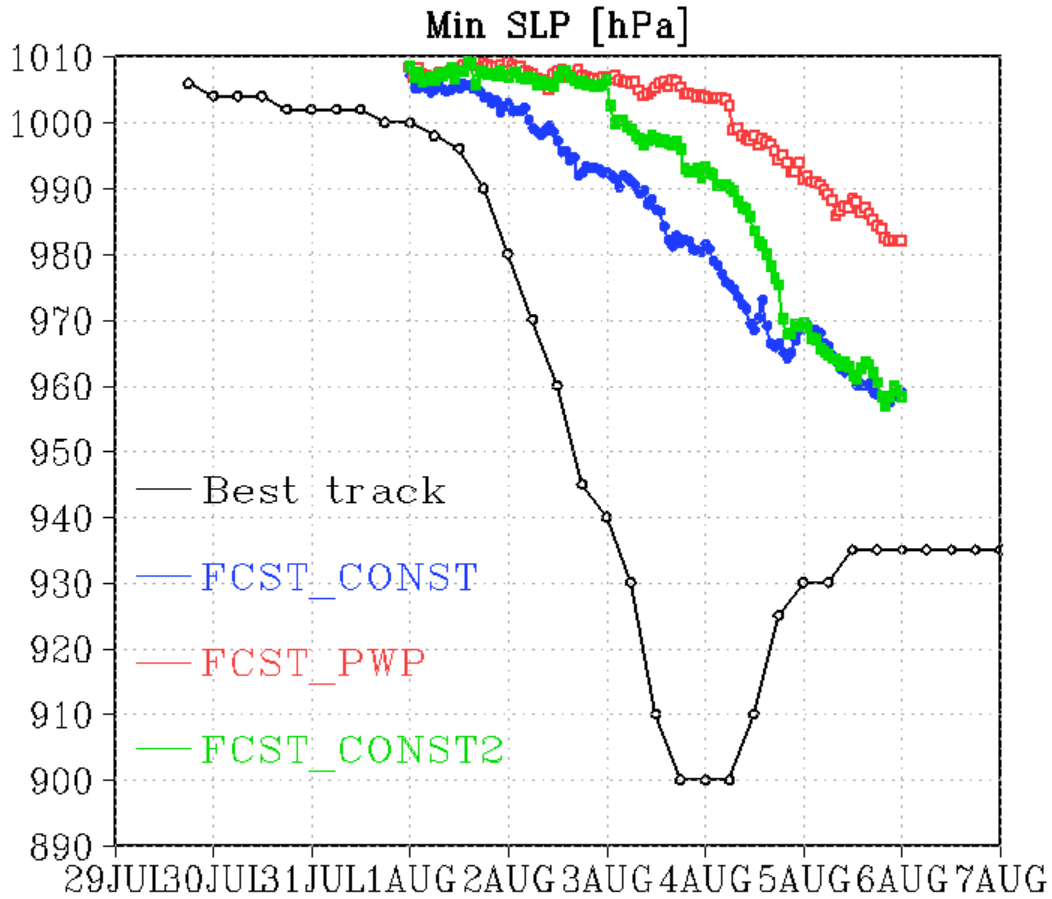
FCST_PWP



Time-dependent SST even in
the forecast experiment!

Paths and min. SLPs in ANA runs





No improvement by PWP model...

Conclusions

- PWP model has been implemented into SCALE-LETKF.
  - Flow-dependent SST can be used even in forecast.

- PWP model does **not improve the analysis/forecast** of the Typhoon Soudelor (2015) with the current setting.
  - PWP model **weakens the intensification** as expected.
  - PWP model **decreases the atmospheric ensemble spread**, although the artificial SST perturbations just increase the spread.

Plans

- Reviewing the experimental setting.
  - More high-resolution experiment with nested domain.
  - Parameters for DA.
- Development of fully coupled atmosphere-ocean DA system.
  - More realistic physics, such as Ekman pumping.
  - Estimating accurate spread in the coupling system.

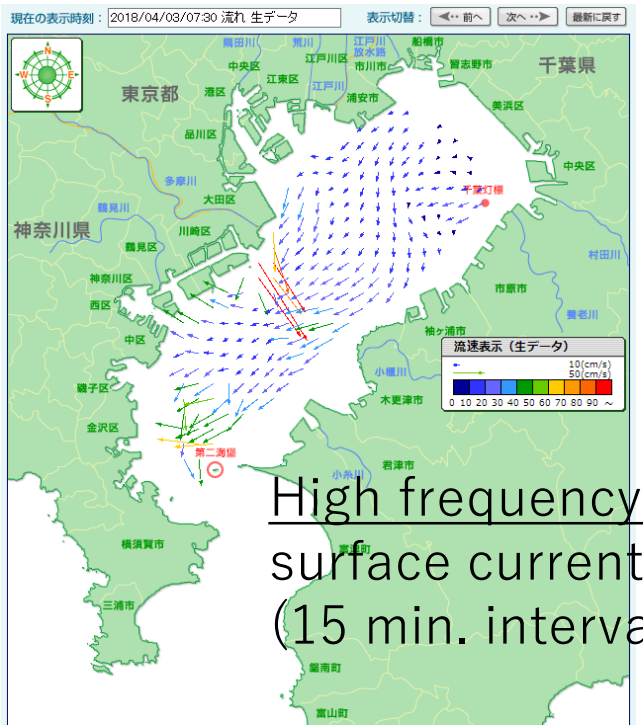
Related to the second topic,
we have developed a **coastal ocean prediction system**.

Development of a coastal ocean prediction system

- **Goal**: Predicting red-tide a few days ago or earlier.
- **Method**: Building a coastal ocean prediction DA system.
- **Target**: Tokyo Bay

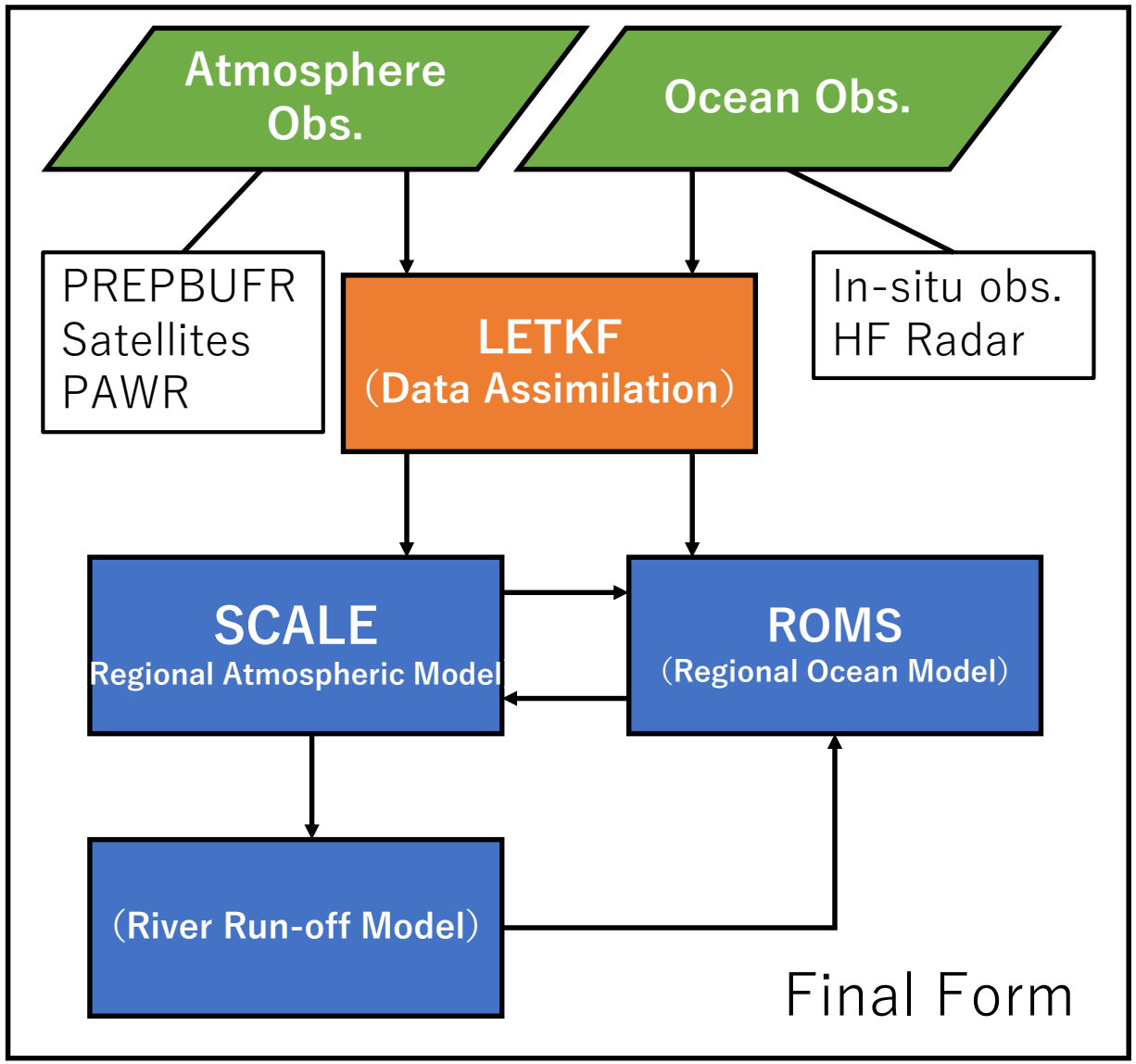
In-situ observations
(1 hourly)
Atmospheric
Temperature, Wind
Oceanic
Temperature, Current,
Salinity, Turbidity,
Chlorophyll

(*Tokyo Bay Environmental Information Center*)

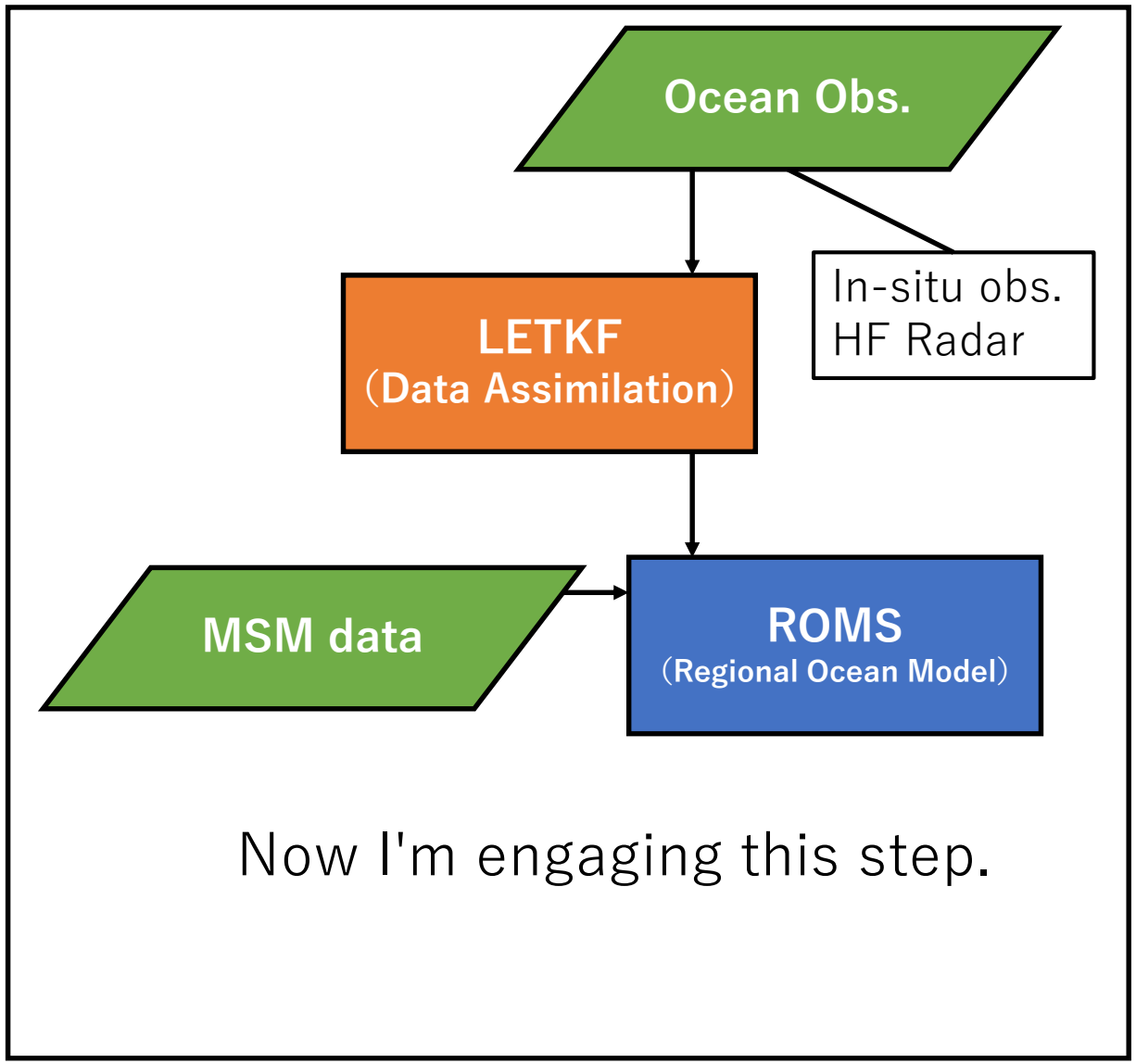


High frequency radar
surface current
(15 min. interval)

Coastal Ocean Prediction System

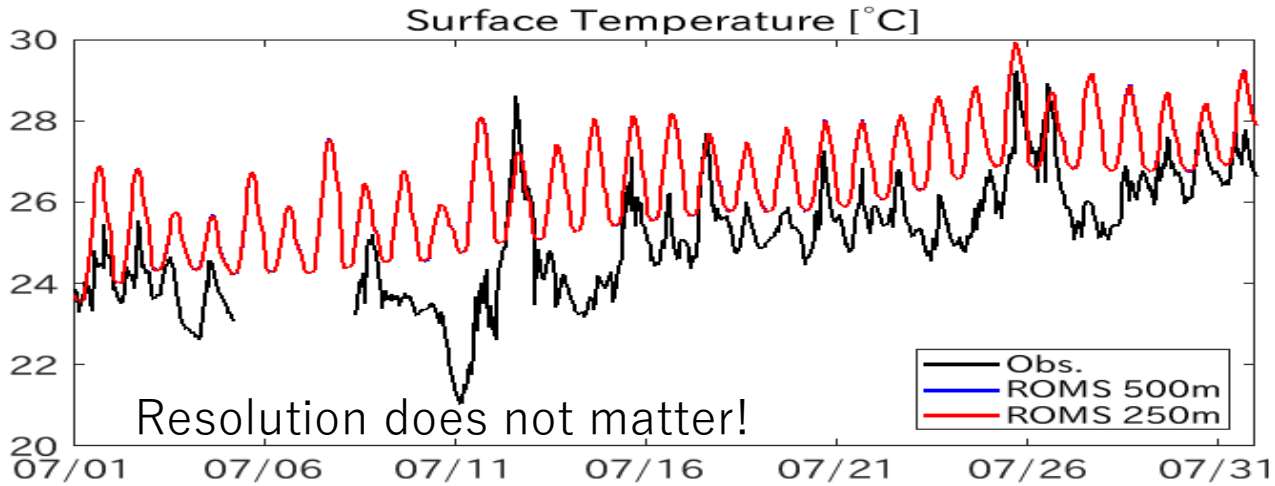


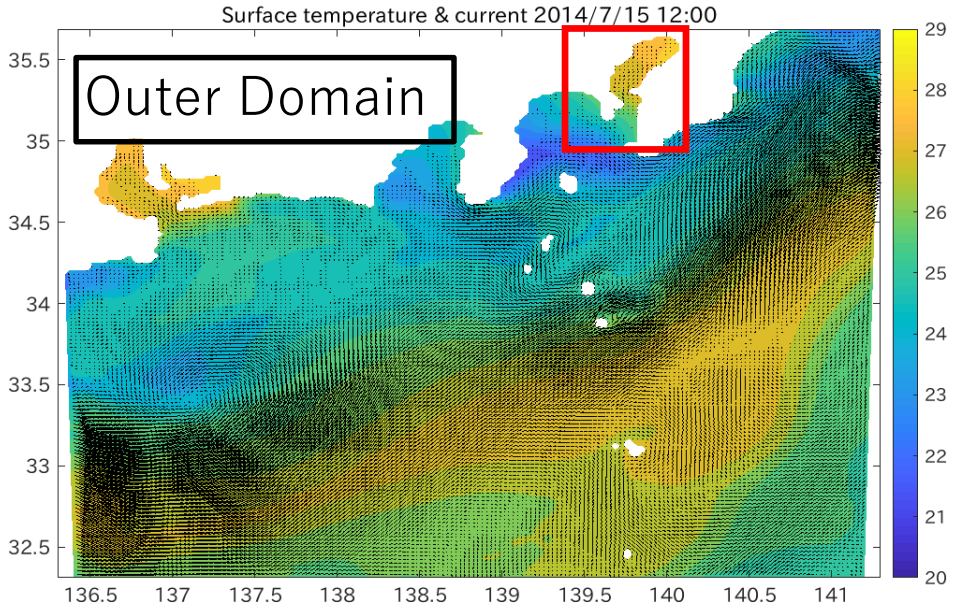
Coastal Ocean Prediction System

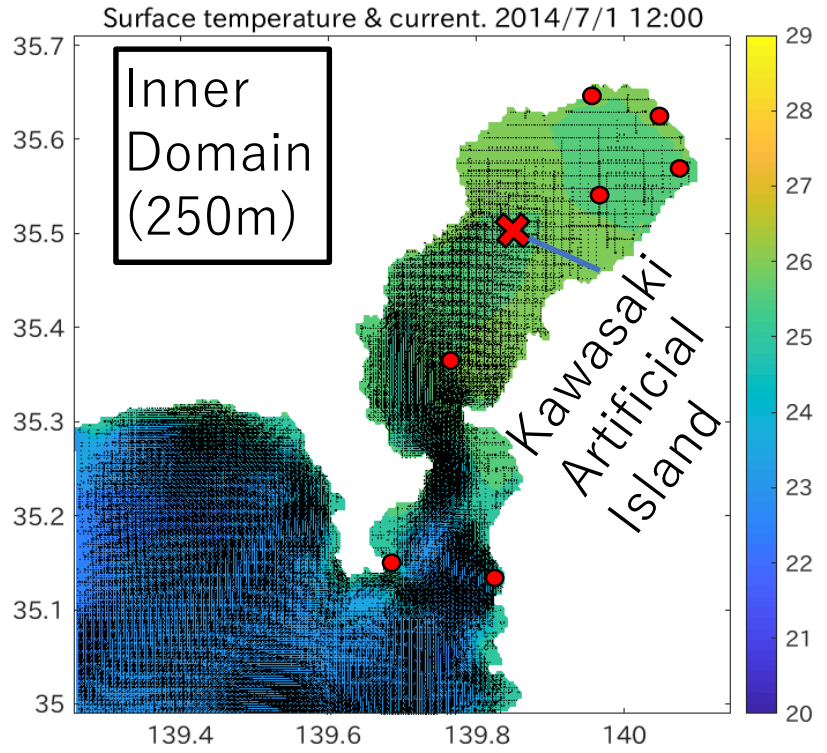


Results from FREE ocean runs

- Model: **ROMS**
- Initial/Boundary cond.: **FORA-WNP30** (0.1°, JAMSTEC's reanalysis)
- Atmosphere: **MSM** (5 km, JMA's forecast)
- Topography: **JEGG-500** (500 m, JODC)
- Domain: Outer-2.5 km, Inner-500 m or 250 m







There is enough room for improvement by the new system.

Thank you!