Impact of in situ and satellite data assimilation on ocean circulation prediction system in Northwest Pacific

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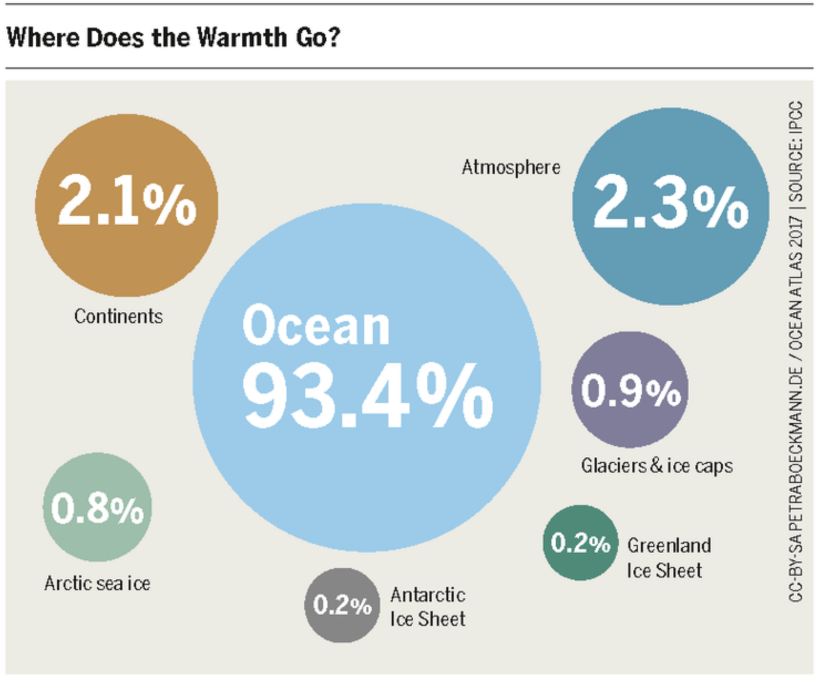
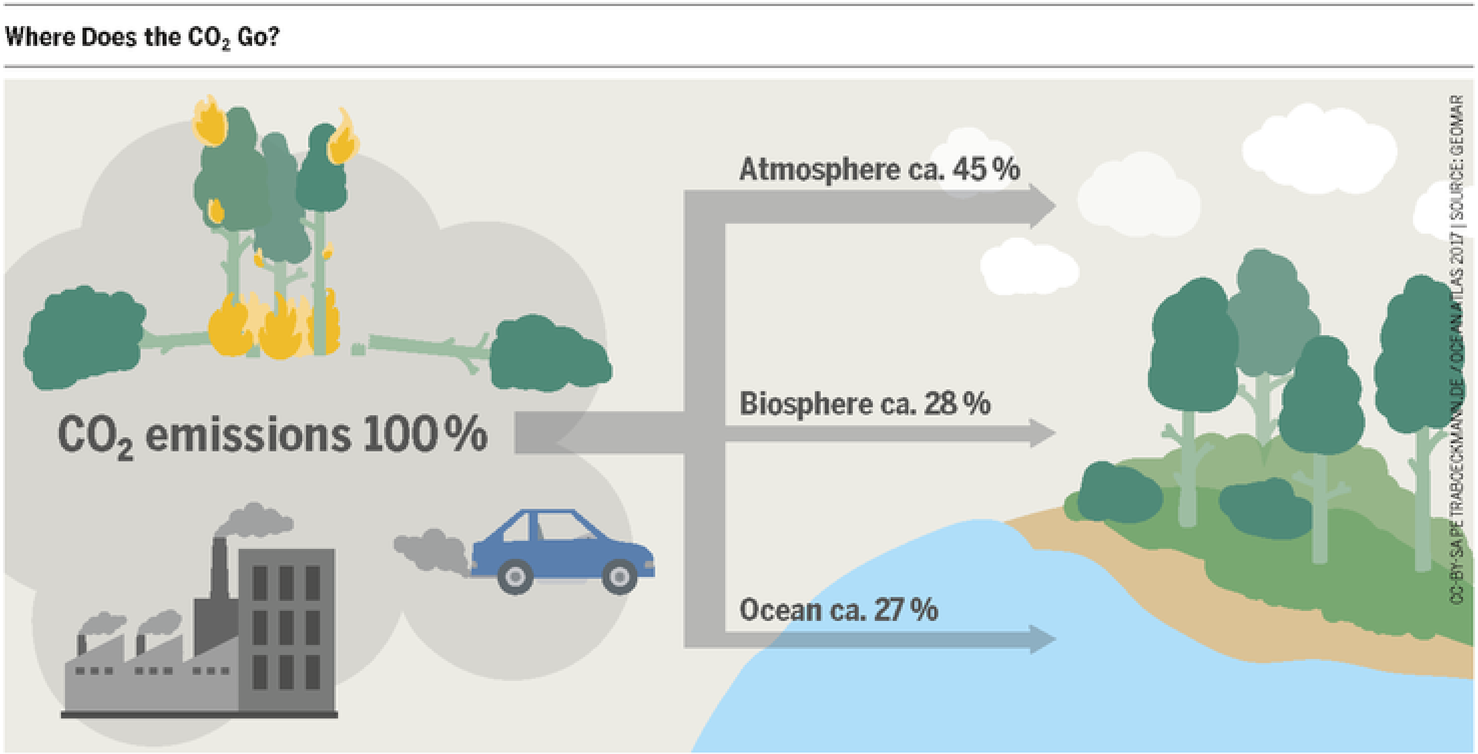
SynObs Kickoff 2022

Motivation

Where is the heat generated by the Greenhouse effect?



The ocean absorbs the lion's share of the additional warmth resulting from human CO_2 emissions, which supplements the natural greenhouse effect.

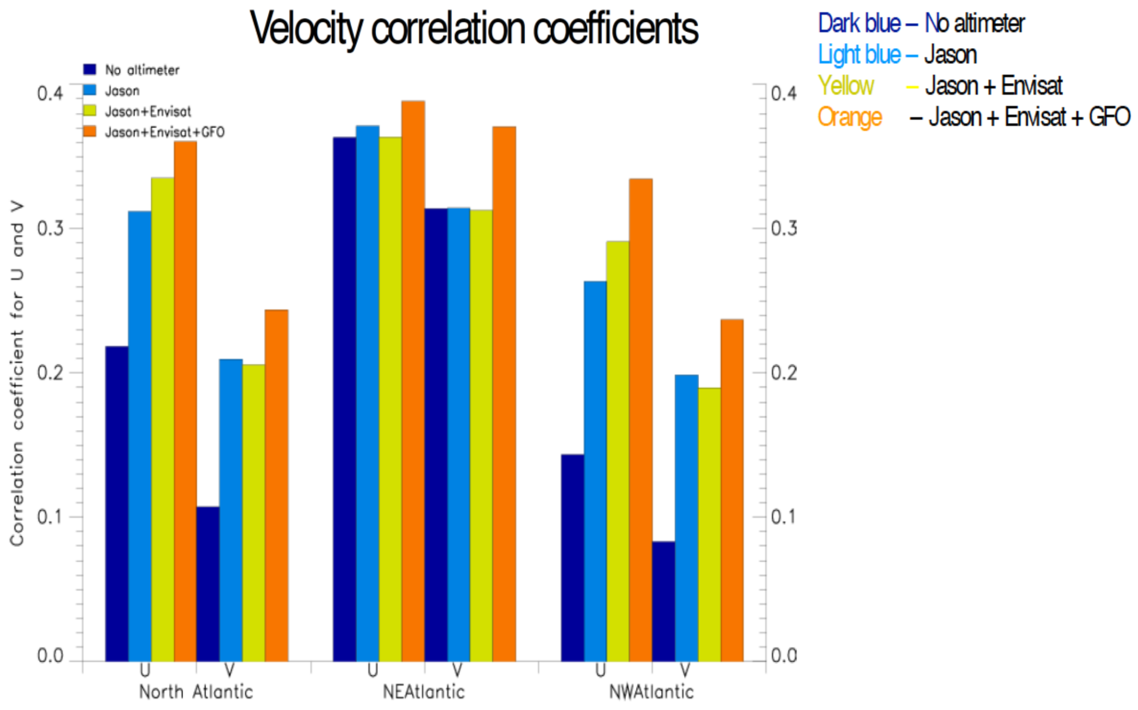


The CO_2 produced by people (i.e., in addition to natural emissions) is distributed as shown.

Motivation

- Since SST is an important ocean variable that connects many processes such as the air-sea exchange of energy and the formation of water mass in the upper ocean, the SST observations have been widely used in ocean data assimilation. (e.g., Tang et al., 2004, Zhou et al., 2021).

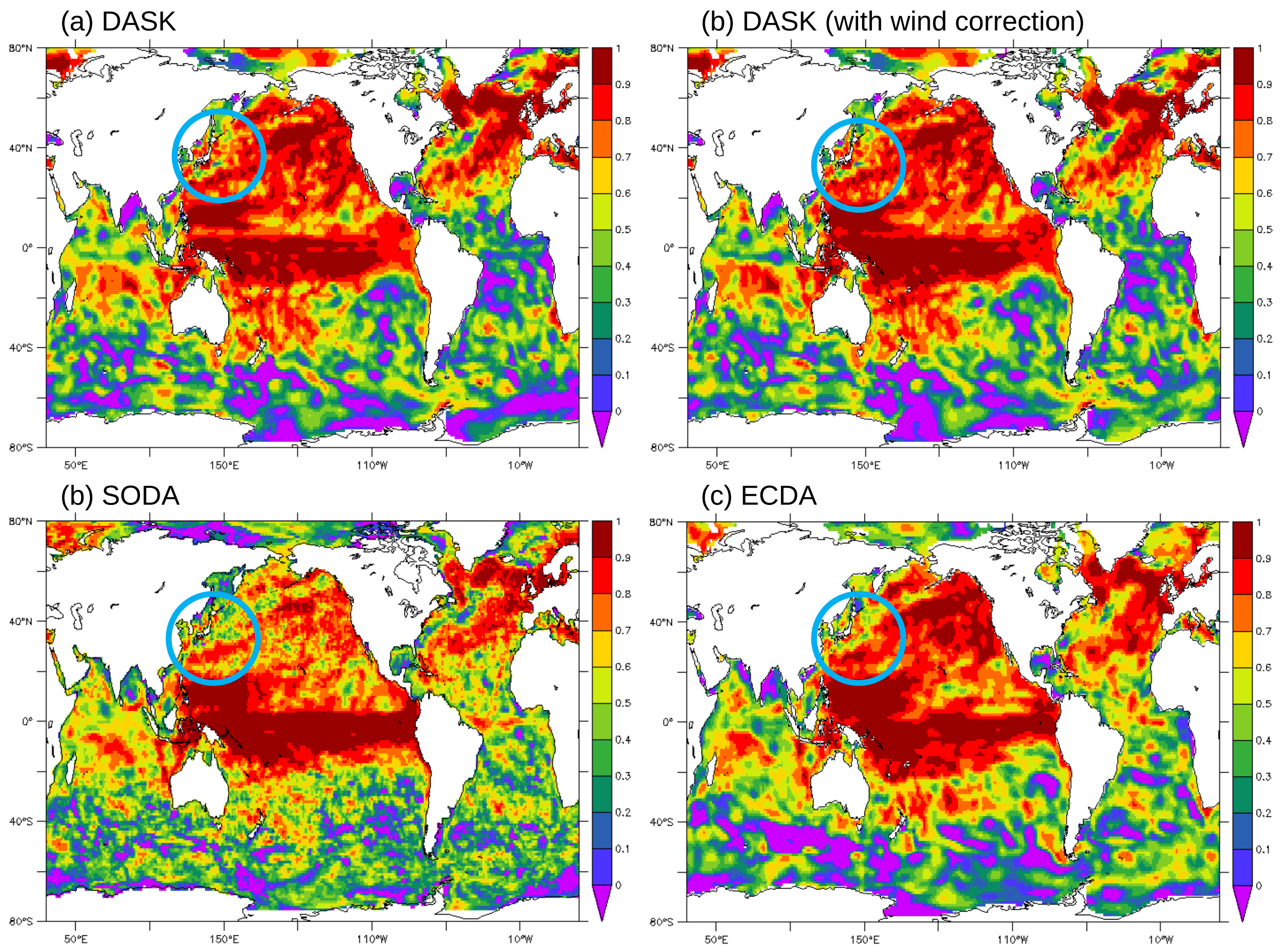
- The assimilation of in-situ T/S profiles improves the density of sea water, especially assimilation of temperature directly affects ocean heat content.



- The assimilation of SSH improves the performance of subsurface structure as well as ocean surface current.

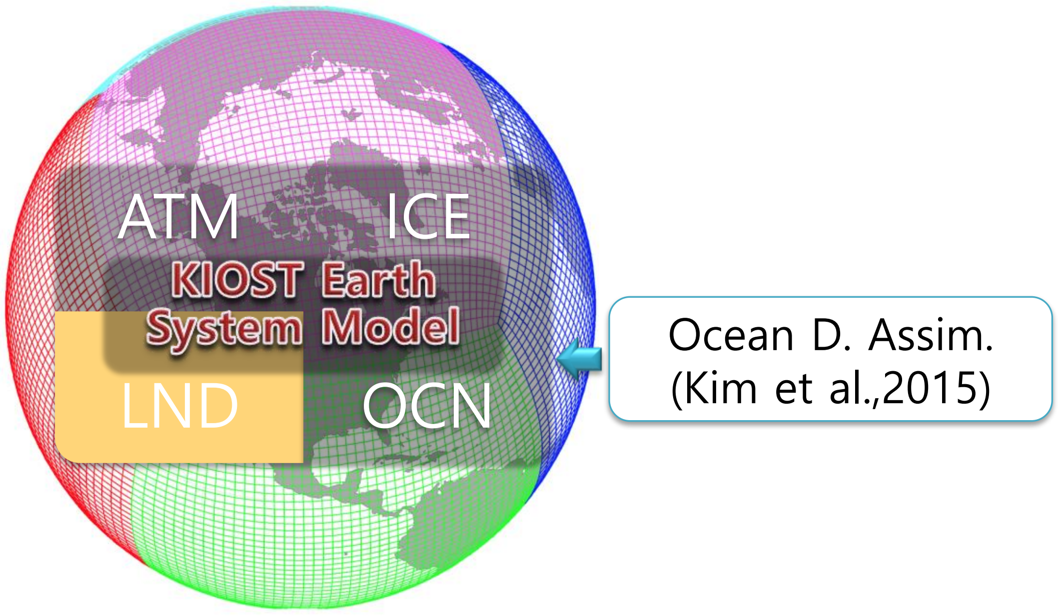
Motivation

Ocean Heat Content Correlation



Kim et al. (2015)

DASK Climate Reanalysis by applying weakly coupled Data Assimilation



Motivation

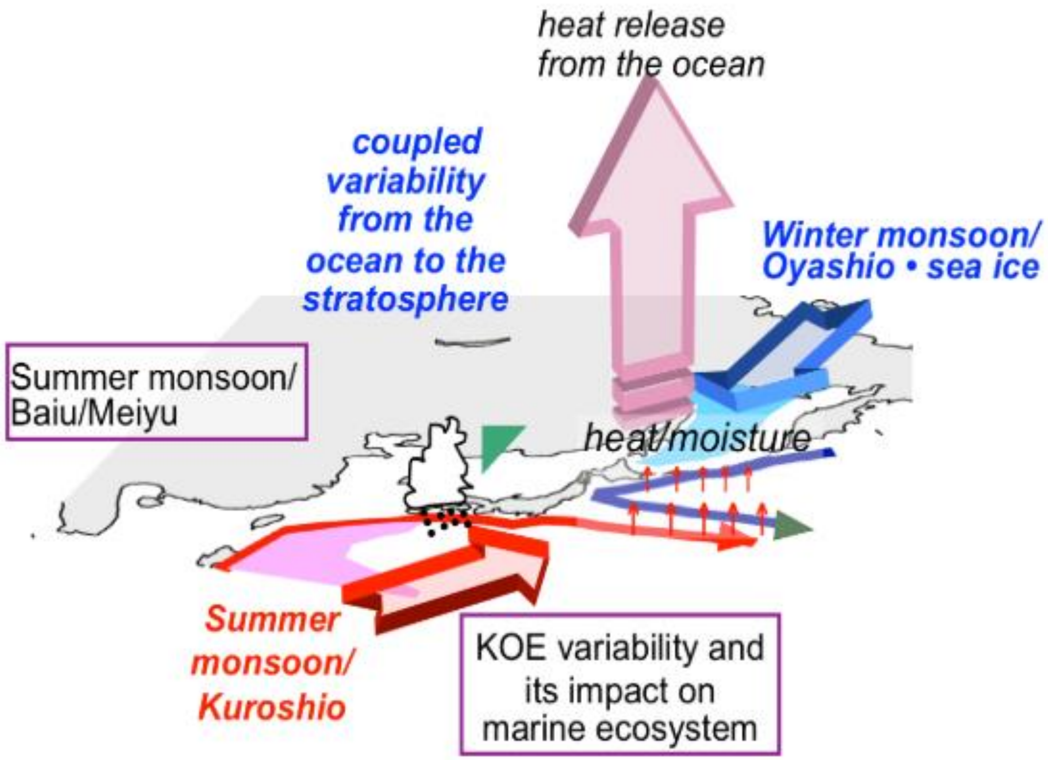
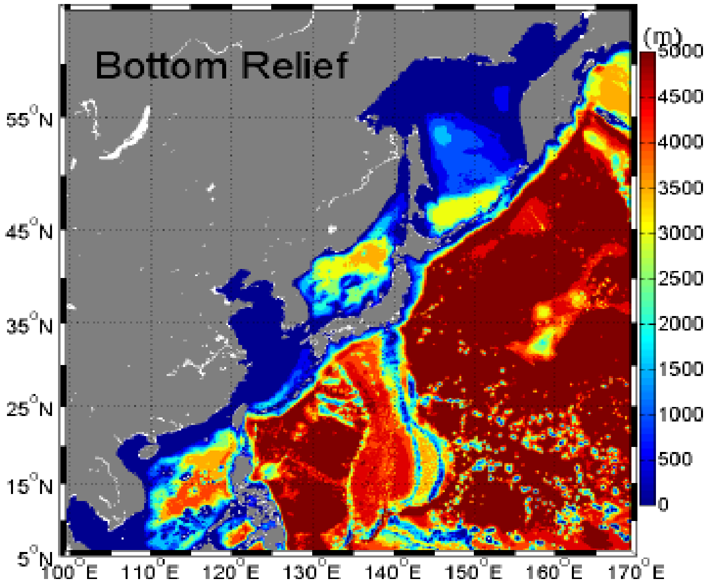


Fig. 2 : "Hot Spot in Climate System" : Air-Sea Interaction under the East-Asian Monsoon.

From http://www.atmos.rcast.u-tokyo.ac.jp/hotspot/eng/organization/a03_8.html

Ocean prediction model

- System title : KOOS-OPEM (Ocean Predictability Experiment for Marine environment)
- Based model : GFDL-MOM5
- Domain : 5-63˚N, 99-170 ˚E (Northwestern Pacific)
- Resolution : 1/24 ˚x 1/24 ˚ (Arakawa B-grid) & 51 layers (z-star coordinate system)



▪ **Model domain and Bottom Relief**

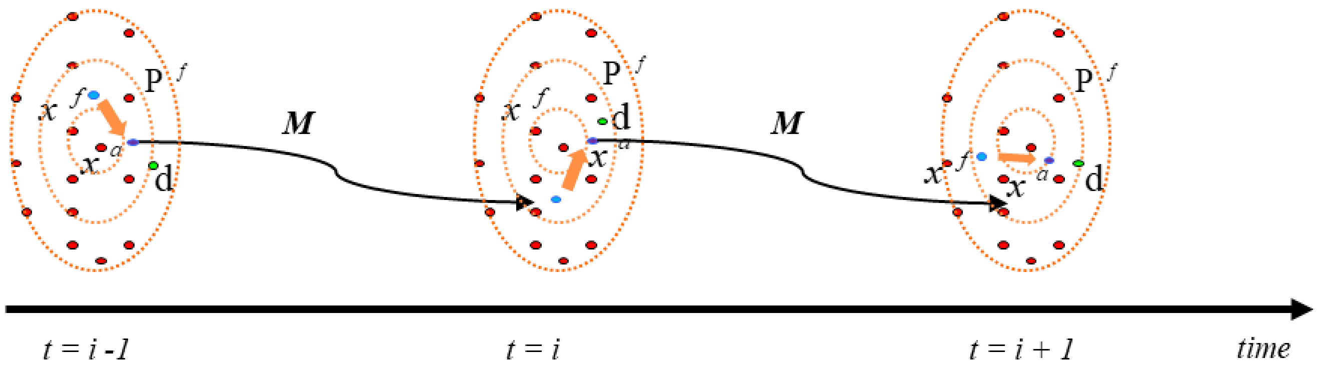
Table 1. Summary of Open boundary condition and surface forcing field

	Data source	Variables	Temporal resolution
Open boundary condition	GLORYS12V1	Temperature, Salinity Sea Surface Height (SSH) Velocity (Zonal, Meridional)	Daily
Surface forcing field	ERA5	Air temperature Wind velocity Air pressure Total cloud cover Specific Humidity Runoff	6-Hourly
		Net solar radiation Net thermal radiation Total precipitation Snow fall	3-Hourly

Data assimilation system

- Method : Ensemble Optimal Interpolation (Kim et al., 2015)
- Altimetry assimilation system : Cooper and Haines (1996, CH96)
- The number of ensemble members : 50
- Horizontal de-correlation length scale : 150km
- Vertical de-correlation length scale : 50m

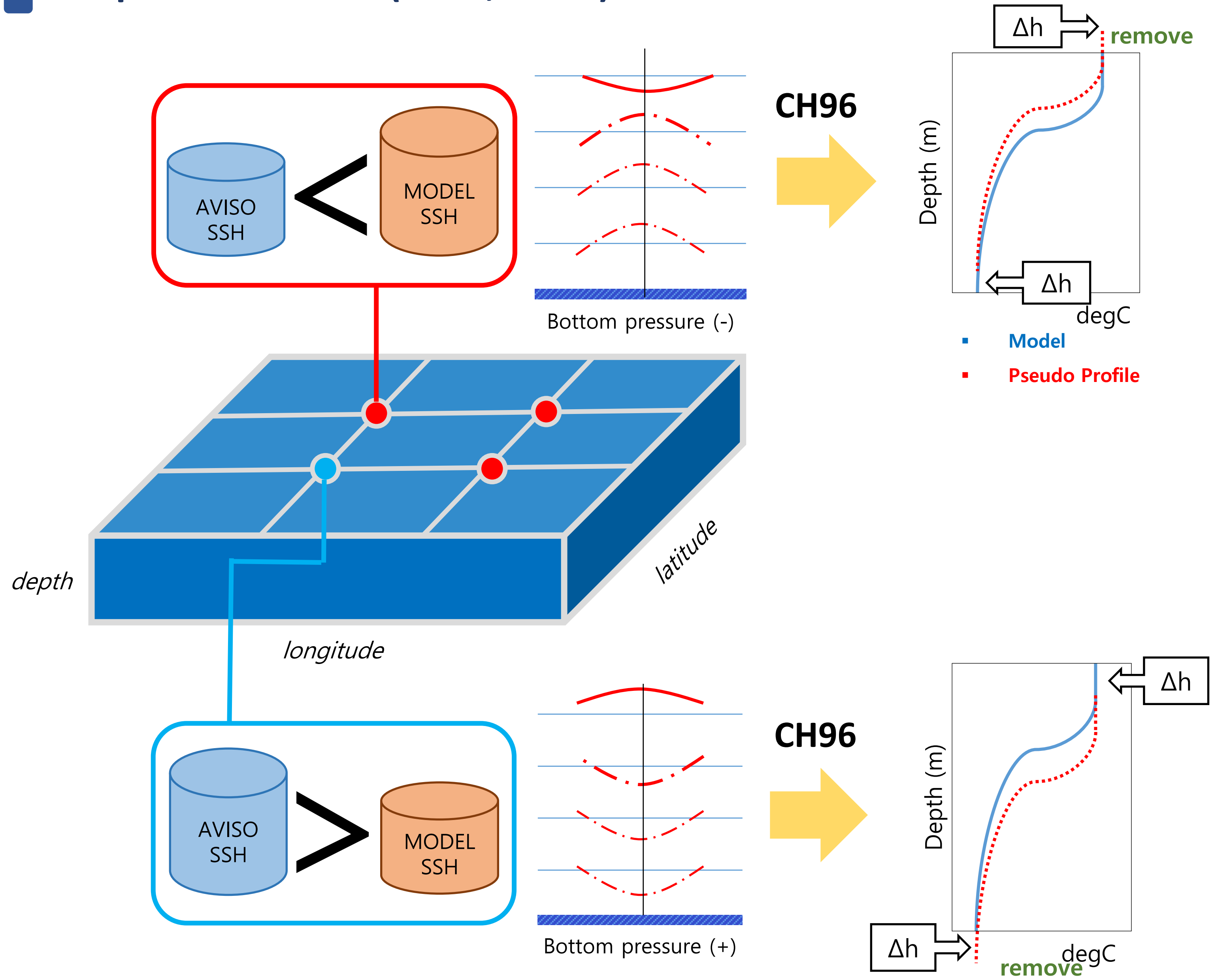
$$\psi^a = \psi^f + K\,(d - H\,\psi^f)$$



Where ;

- ψ^a = *Analysis fields*
- ψ^f = *Simulated fields*
- K = *Kalman gain*
- d = *Observations*
- H = *Spatial operator converting from the model data to observations*

Cooper and Haines (1996, CH96)



A) Assuming bottom pressure conservation

B) Conservation of Potential vorticity

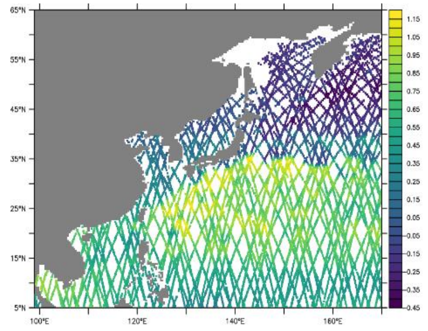
Bottom constraint

$$g \int_0^{-H} \Delta\rho \, dz = \Delta Ps$$

$$\Delta Ps = \rho_0 g \Delta\eta$$

$$\Delta h = \frac{\Delta Ps}{g[\rho_0 - \rho(-H)]}$$

✓ Creates a "Pseudo profile" using "Δh" and the "model's profile" at the specific grid points



Experiment setup and observation

Table 2. Summary of the sensitivity experiment

	Control variables	Experiment period
CTR	-	1 year (1993.01.01.~1993.12.31.)
EXP01	SST	
EXP02	SST, T/S profiles	
EXP03	SST, T/S profiles (+KODC)	
EXP04	SST, T/S profiles, SSH	
EXP05	SST, T/S profiles (+KODC), SSH	

Table 3. Summary of observations and errors

Observed variables	Data	Observation error	Assimilation window
in situ profiles	KODC (only temperature) WOD 2018	0.3˚C 0.025 psu	7 days
Sea Surface Temperature (SST)	OISST	1˚C	1 day
Sea Surface Height (SSH)	Along-track altimeter products (50km subsample)	0.9˚C 0.075 psu	1 day

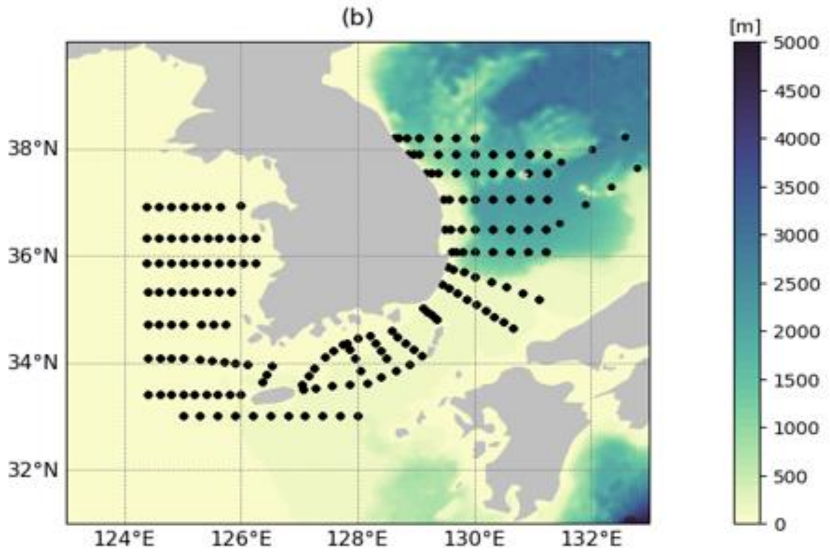


Figure 1. (a) Horizontal distribution of KODC observation stations used in this study.

Validation data set

Table 4. Summary of validation data

Variables	Data
T/S profiles	KODC WOD 2018
SSH	CMEMS-GLOBAL OCEAN GRIDDED L4 SEA SURFACE HEIGHTS AND DERIVED VARIABLES REPROCESSED (1993-ONGOING)

Table 5. The metrics used to assess the assimilation performance

Metrics	Equation
Root mean square error (RMSE)	$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(m_i - o_i)^2}$
Impact of data assimilation (IOA)	$IOA = \frac{RMSE_{CTR} - RMSE_{EXP}}{RMSE_{CTR}} \times 100$

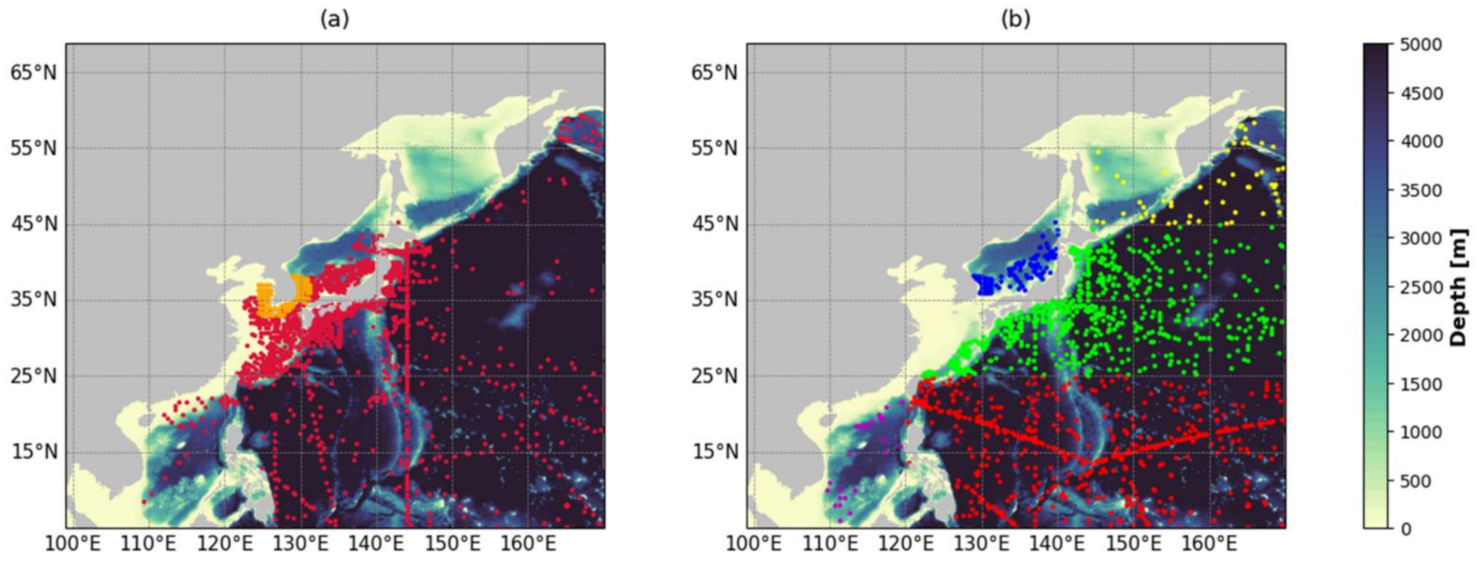
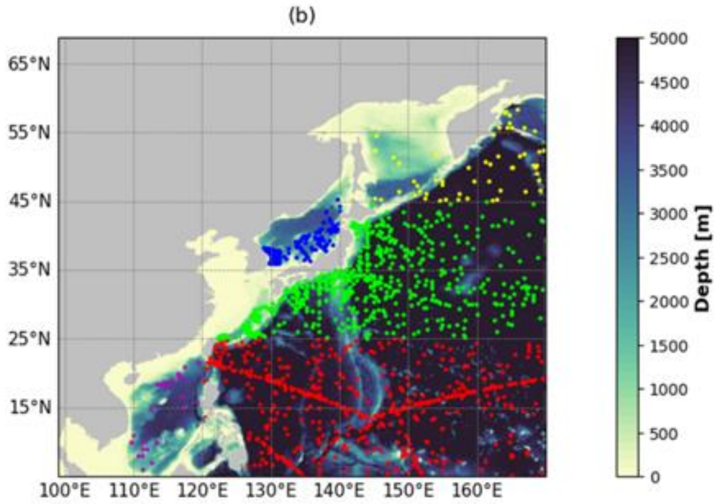
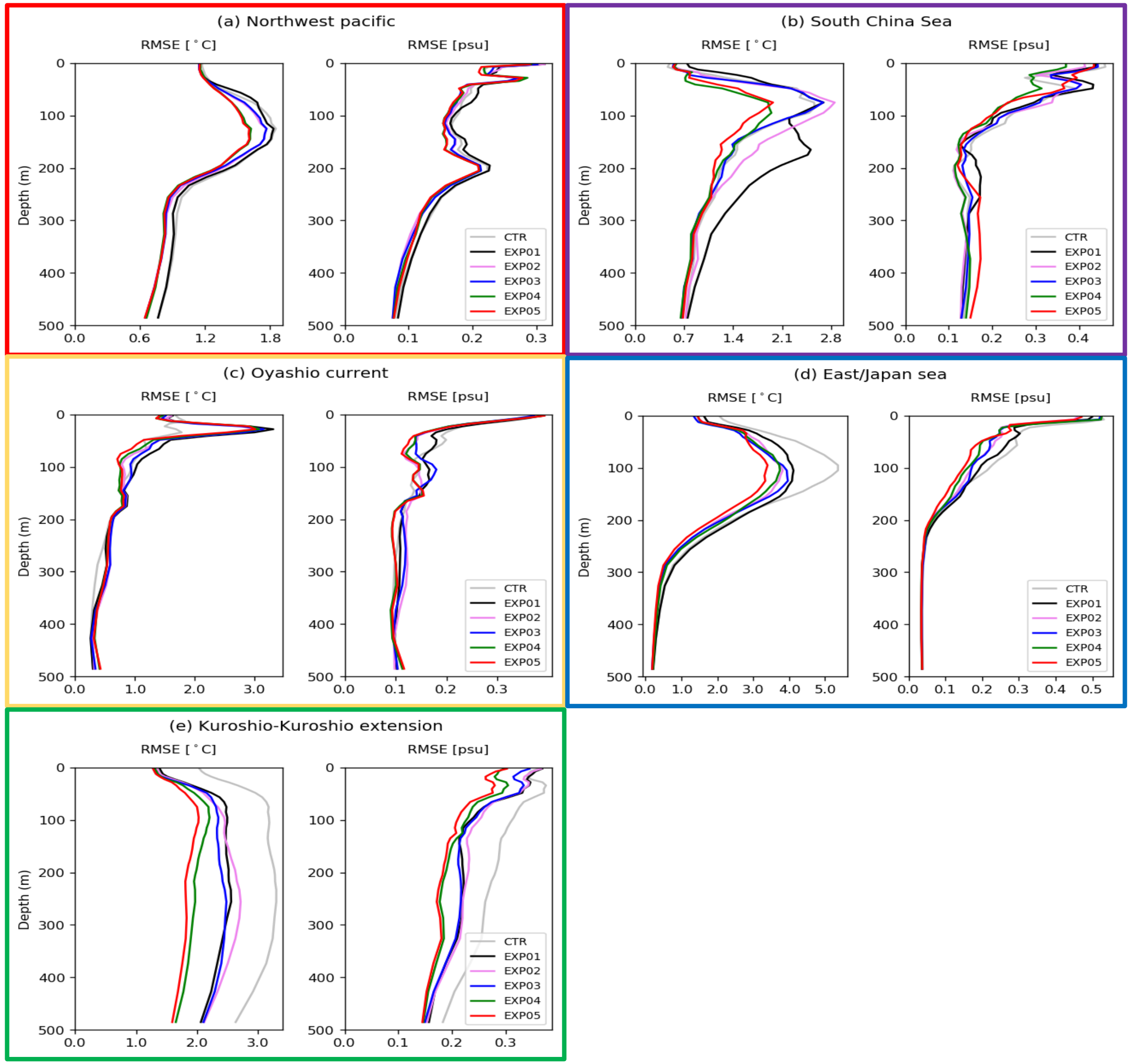


Figure 2. The distribution of in-situ temperature profile used in data assimilation and validation. (A) temperature profile used in data assimilation in February. (B) temperature profile used in validation.

RMSE of temperature/salinity profiles



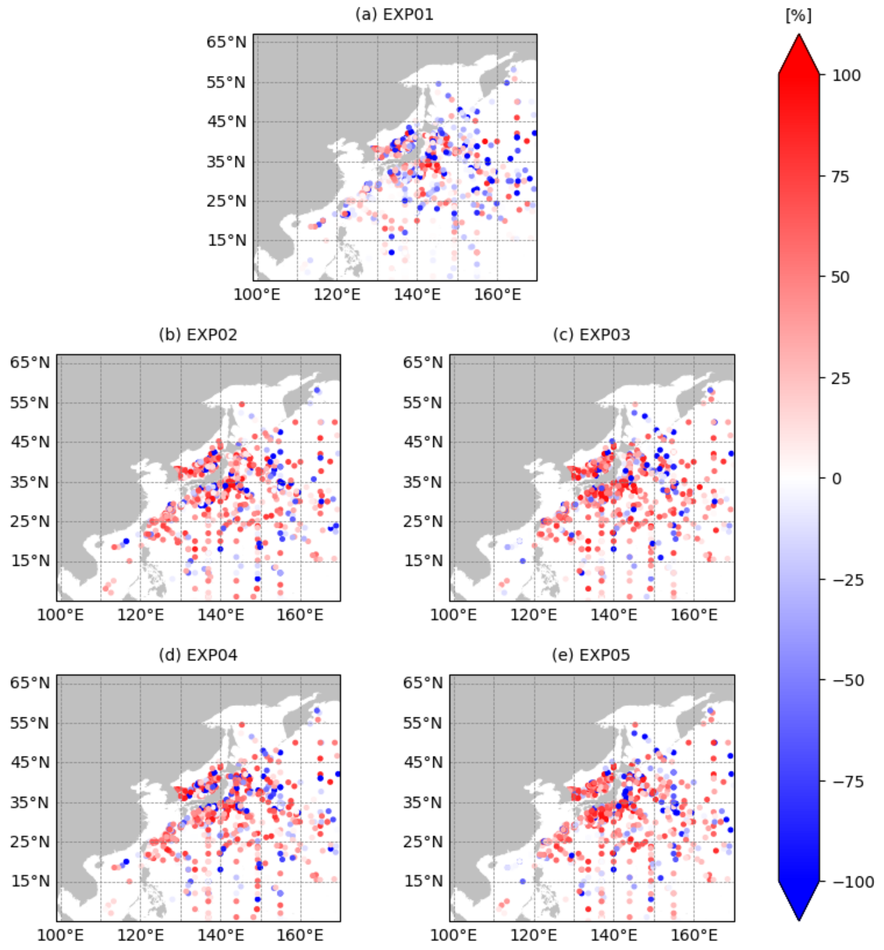
	Control variables	Experiment period
CTR	-	
EXP01	SST	
EXP02	SST, T/S profiles	1 year
EXP03	SST, T/S profiles (+KODC)	(1993.01.01.~1993.12.31.)
EXP04	SST, T/S profiles, SSH	
EXP05	SST, T/S profiles (+KODC), SSH	

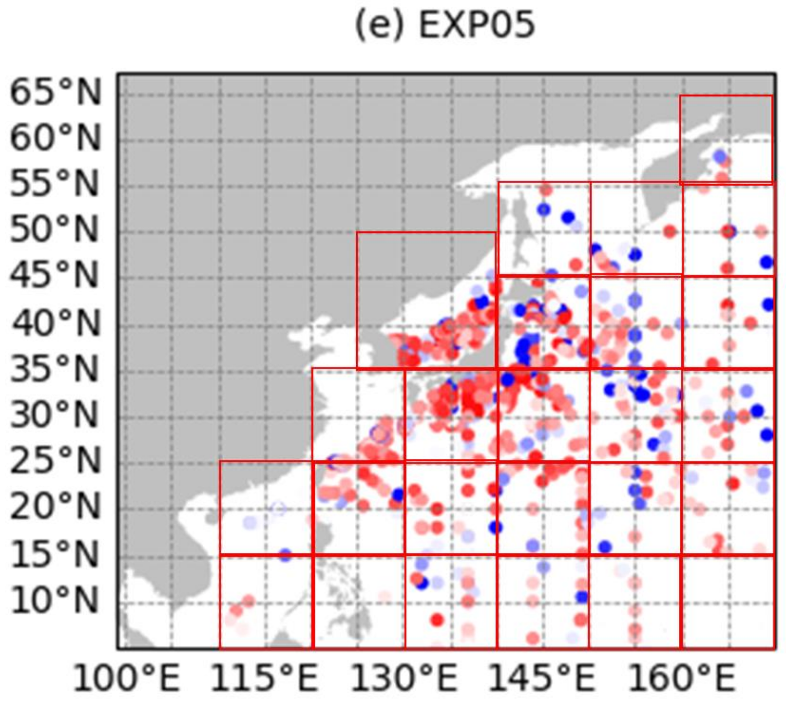


- ✓ The assimilation of satellite altimetry data improve the temperature/salinity structure in most regions.
- ✓ The assimilation of KODC data improves the temperature/salinity structure in Kuroshio extension as well as East/Japan sea.

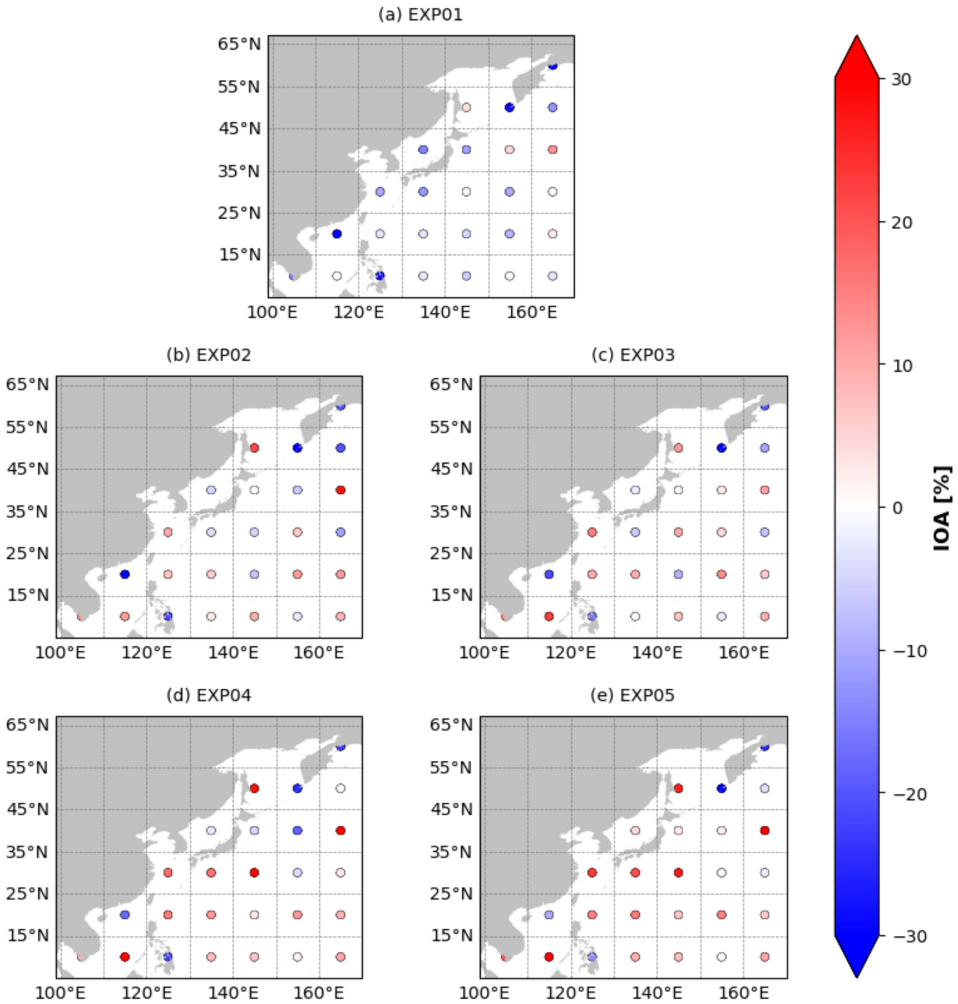
IOA of subsurface temperature/salinity (100~500m)

$$IOA = \frac{RMSE_{CTR} - RMSE_{EXP}}{RMSE_{CTR}} \times 100$$

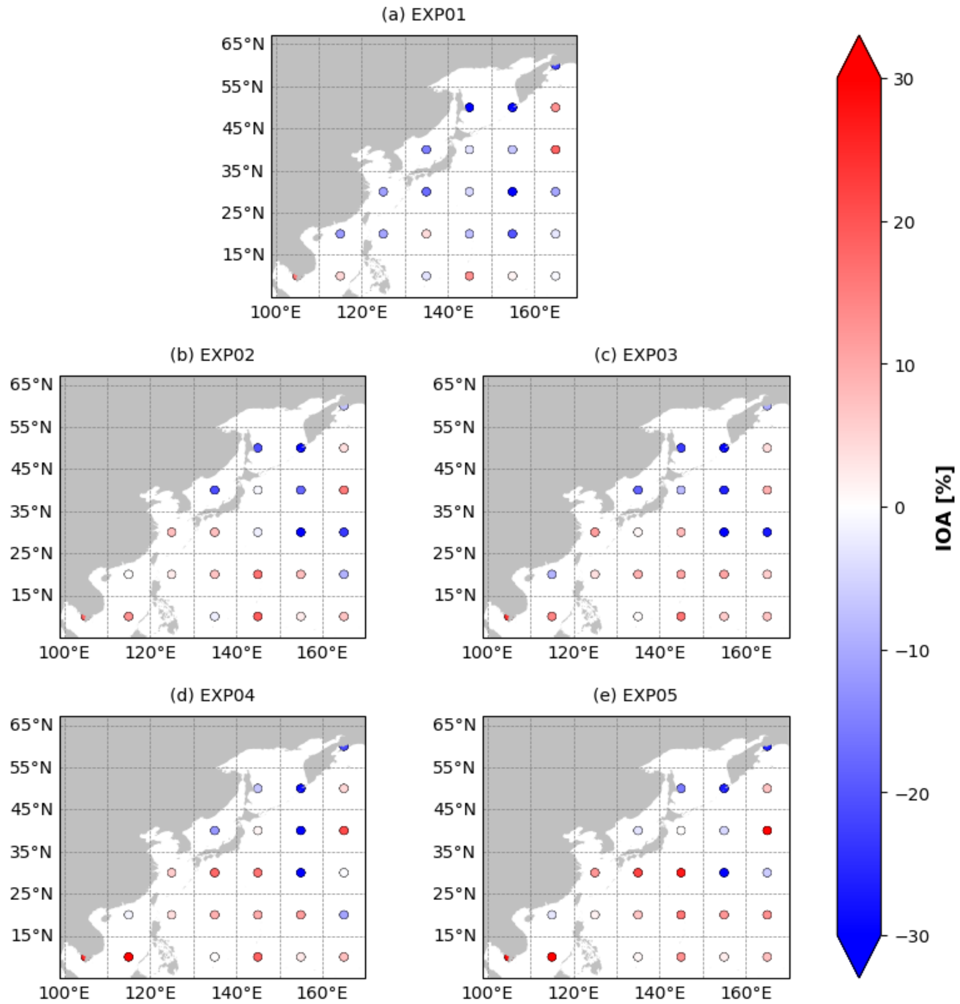




IOA of subsurface temperature/salinity (100~500m)



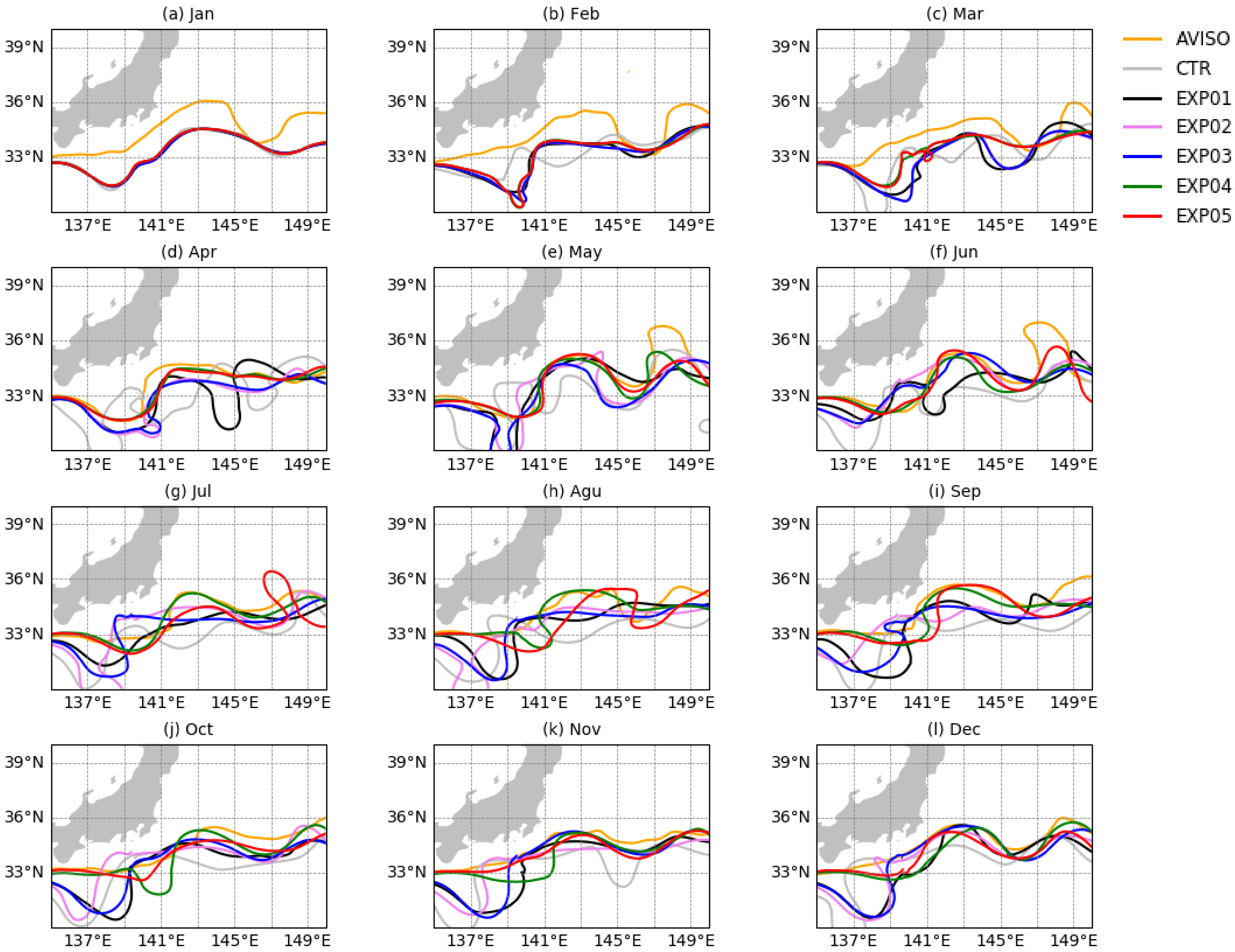
▪ Temperature



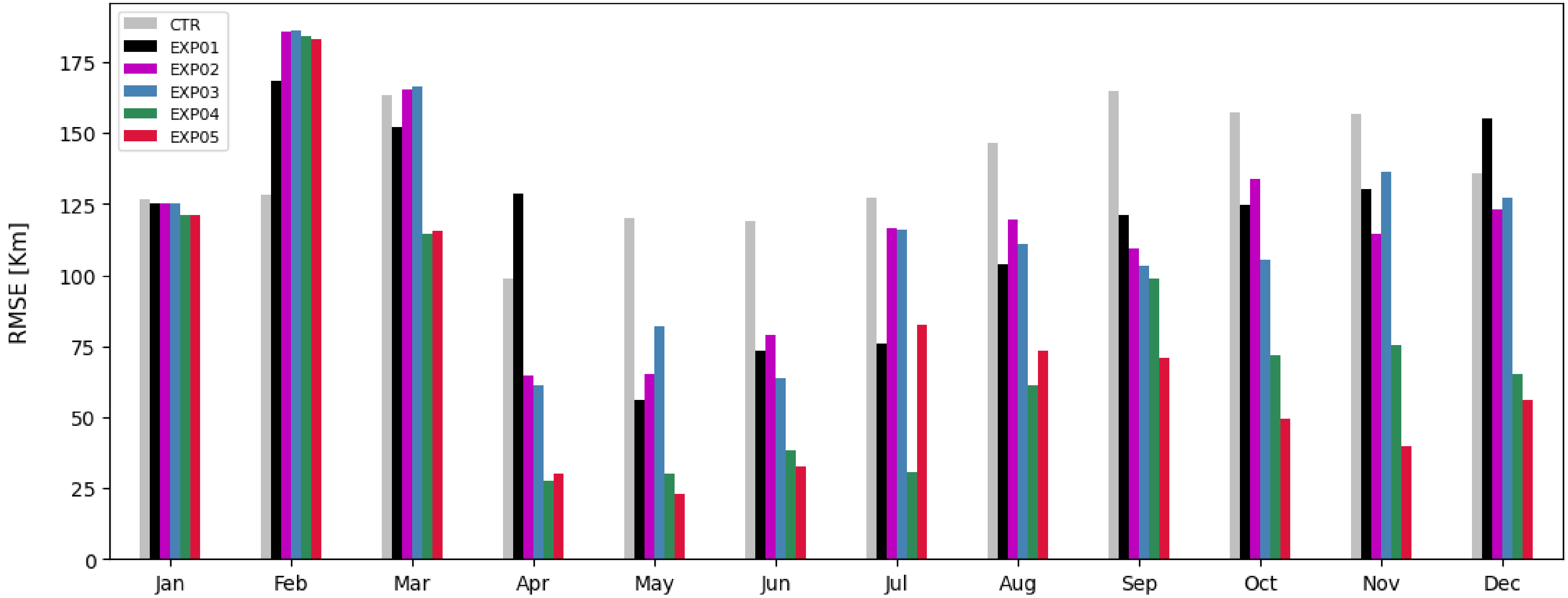
▪ Salinity

✓ The assimilation of KODC data improves the subsurface of temperature/salinity in Kuroshio-Kuroshio extension.

Representation of Kuroshio axis



RMSE for latitude of Kuroshio axis

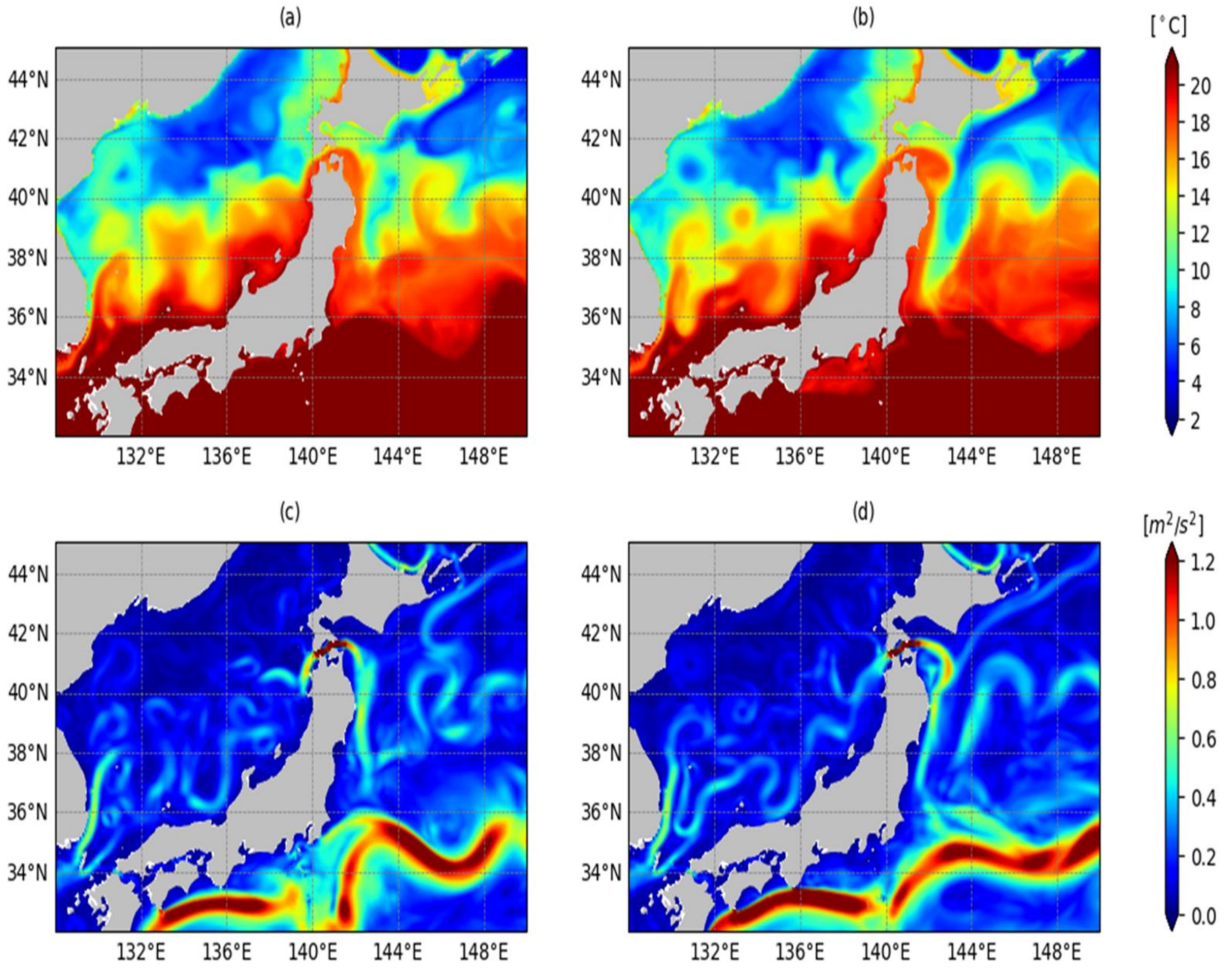


✓ The assimilation of satellite altimetry data and KODC data improve representation of Kuroshio axis

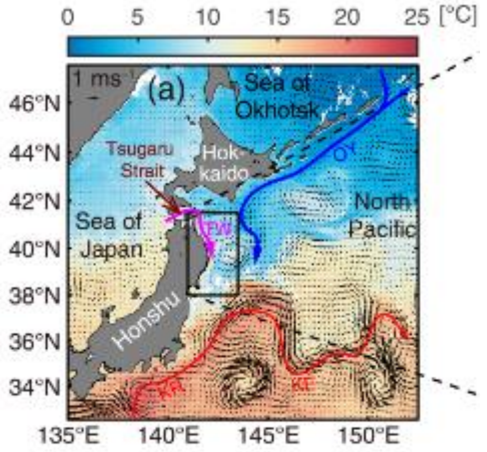
The monthly mean temperature and current speed

Temperature

Current speed



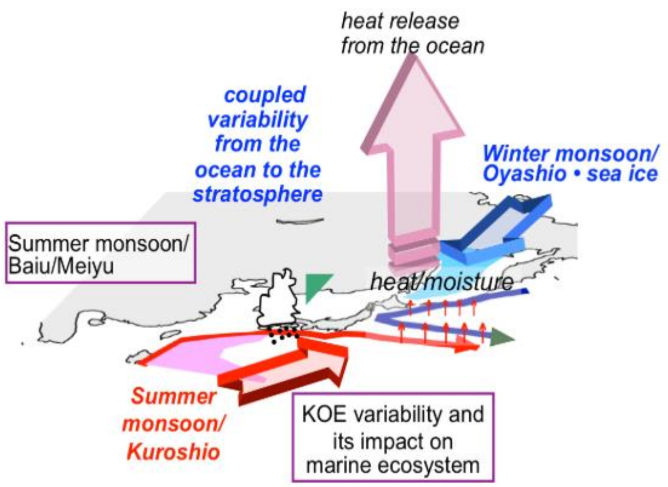
EXP04 EXP05



(Itoh et al. 2022)

Summary

- **The assimilation of SSH improves the subsurface temperature and salinity in most areas.**
- **The assimilation of KODC profile data improves the surface and subsurface features in the Kuroshio - Kuroshio Extension area as well as in Korean marginal seas.**
- **In particular, KODC profiles have contributed to improving representation of Kuroshio axis.**
- **It is important to predict the Kuroshio-Kuroshio Extension more accurately because the Kuroshio Extension system is an important component of the global climate system, particularly in the North Pacific basin.**
- **This study suggests that greater attention should be paid to the role of the regional ocean observing networks to improve the ocean and climate prediction skills in the open ocean such as Pacific as well as the region.**



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Thank you

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Q & A

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