Predictability of warm core eddies released from Kuroshio Extension in 2024 based on an ice-ocean coupled data assimilation forecast system

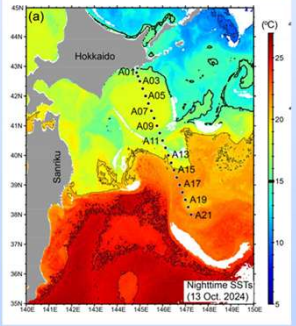
*Takuya Nakanowatari[1], Shoko Abe[1], Taira Nagai[1], Ryu Saiki[1], Hiroshi Kuroda[1], Takeshi Okunishi[1], Takashi Setou[1], Daisuke Hasegawa[1], Hikaru Homma[1], Joji Oida[1], Shigeho Kakehi[1], Taiki Fuji[1], an Satoshi Suyama[1]

1: Japan Fisheries Research and Education Agency, 2: Hokkaido University, Institute of Low Temperature Science

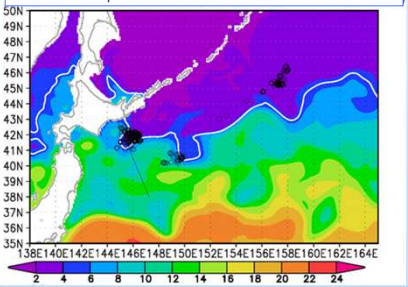


1. Relationship between warm core eddy and fishery ground in KOC

Spatial Distribution of Sea Surface Temperature observed by the Himawari-9 Meteorological Satellite on October 13, 2024



Spatial Distributions of the 100-m Water Temperature from FRA-ROMSII Nowcasts and Pacific Saury Fishing Grounds in September 2025



Kuroda et al. (2025)

- In recent years, with extreme weather phenomena such as global warming and marine heatwaves are occurring with increasing frequency, the importance of using numerical models to assess the current state of the marine environment and generate forecasts has grown.
- In 2024, an extremely strong warm core eddy (WCE) was detached from the Kuroshio Extension (Kuroda et al., 2025), and affected fishery ground for commercial pelagic fishes such as Pacific saury.
- In this study, we evaluated prediction skill of WCE in 2024/2025 by employing new operational ocean forecast system based on an ice-ocean coupled model with 3DVAR data assimilation.

2. Data assimilation system based on an ice-ocean coupled model (iROMS-3Dvar)

An ice ocean coupled model in NW-Pacific (iROMS-NWP)

Region : 16–64°N, 115°E–160°W

Horizontal resolution : 1/10°

Vertical resolution : 48 layer (S-coordinate, θ=5, b=0 ; high resolution near surface)

Model topography : ETOPO5

Tidal mixing process

3-D distribution of vertical diffusive coefficient derived from energy dissipation of internal wave (St. Laurent et al. 2002)

Sea ice model

Dynamical deformation process with EVP rheology (Hunke and Dukowicz, 1997)

2 category thermodynamic model with one layer ice and snow (Mellor and Kantha, 1989)

River discharge

Daily mean river runoff data of JRA55do (Tsujino et al., 2018)

Data assimilation（3Dvar）

EOF-based method（Fujii and Kamachi, 2003）

Assimilation data are temperature and salinity (Sea surface height is transformed into baroclinic component with temperature and salinity based on dnamical height)

Assimilation window

7days（Initial condition is every Tuesday 12:00）

The increment of assimilated fields are added to model based on IAU method（Incremental Analysis Update）

Before 3Dvar calculation, model fields are modified with WOA climatology（Miyazawa et al. 2010）

Assimilation data

Quality controlled in-situ T-S profiles

GTSPP additional T-S profiles from local government fisheries research stations, FRA (Glider, UCTD, and XCTD)

SST

NOAA AVHRR OISST (Reynolds et al. 2002), OSTIA (UKMO, 2007)

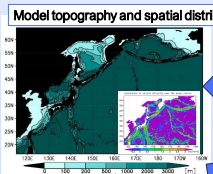
Sea surface height

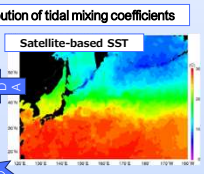
CMEMS daily mean SSHA

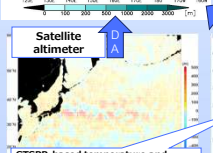
Pacific: daily 1/4 degree

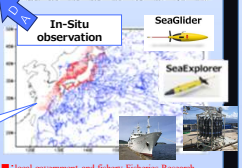
Japan Sea: Along-track

Model topography and spatial distribution of tidal mixing coefficients





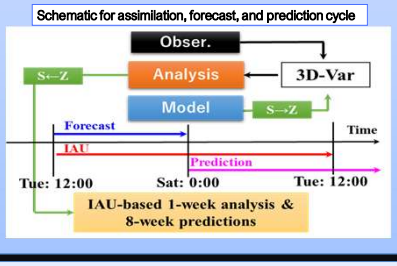




GTSPP-based temperature and salinity (T-S) profiles, together with additional observations from gliders operated by FRA and local governments, are assimilated in near real time.

■:local government and fishery Fisheries Research Station, FRA, etc
■:Others (JMA, University JAMSTEC, Japan Coast Guard)

Schematic for assimilation, forecast, and prediction cycle



3. Reforecast experiments for 2024 and 2025



Assimilation With JRA55 / No-assimilation with JRA55 / No-assimilation with CFS



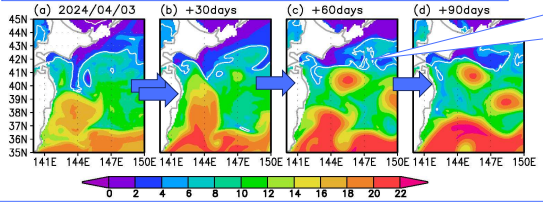
Assimilation & JRA55 / No-assimilation & JRA55 / No-assimilation & CFS / No-assimilation with In-situ / Assimilation with Glider

- Prediction skill is evaluated in the assumption that the analysis of iROMS-3dvar is truth value (perfect model).
- In reforecast experments, we used 6-hourly JRA55 reanalysis data (Kobayashi et al., 2014) and NCEP Climate Forecast System ver.2 (NCEP-CFS ver.2, Saha et al., 2011) data as the atmospheric boundary conditions.
- In the case for 2025 reforecast experiment, we evaluated the impact of In-situ observation of the model initialization on the prediction skill.

【Acknowledgement】This study is supported by a stock assessment project and the research program and Fisheries Resources Research center grand-funded research project of the Japan Fisheries Research and Education Agency and JSPS KAKENHI (22H05203, 26K07200).

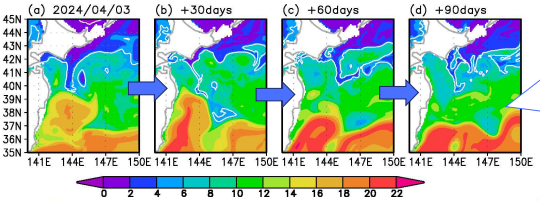
4. WCE is separated from KE in spring 2024

Daily mean analysis temperature at 100m depth from

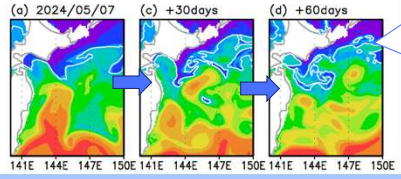


- WCE was separated from KE in early June, 2025

Predicted daily mean temperature at 100m depth (Reforecast 1)



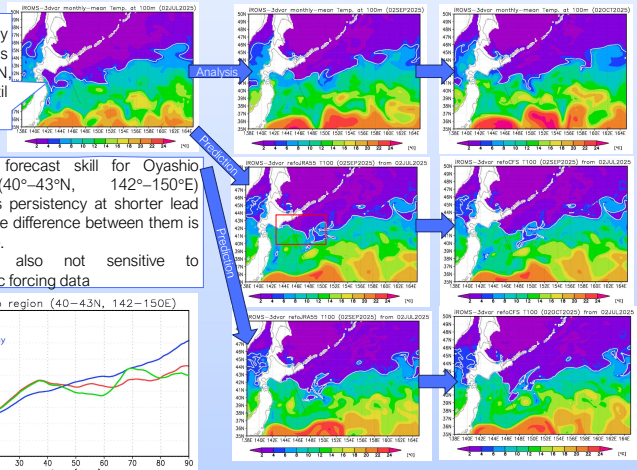
- The separation of WCE is not skillfully predicted from early April.



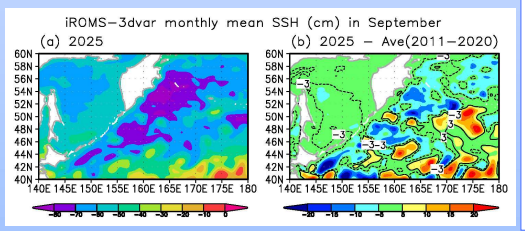
- The separation of WCE is well predicted from early May.

5. WCE persists in the offshore of Hokkaido Is. in autumn 2025

- WCE in early July persists around 42°N, 144°E until October

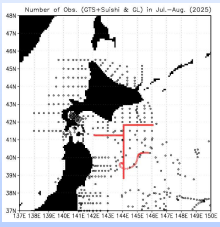


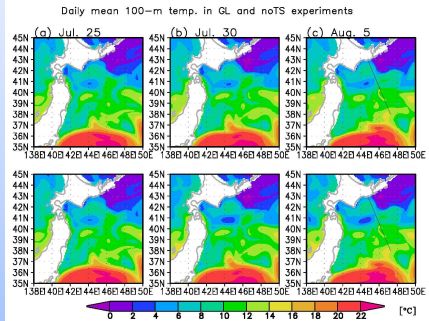
- Dynamical forecast skill for Oyashio region (40°–43°N, 142°–150°E) overwhelms persistency at shorter lead time, but the difference between them is not so large.
- RMSE is also not sensitive to atmospheric forcing data



- In September 2025, the cyclonic circulation in the western subarctic North Pacific and the Sea of Okhotsk is relatively strong compared with previous 10 years.
- The location of WCE is likely to be controlled by both wind-driven circulation which blocks the northeastward movement of WCE

6. Impact of in-situ observation in KOC region on prediction skill





- In the case for GL & UCTD data assimilations, cold water intrusion of Oyashio water around 41°N, 145°E is remarkable in July 30.

7. Summary

Using data assimilation system based on an ice-ocean coupled model (iROMS-3dvar), we valuated the prediction skill of WCEs in the KOC region found during 2024 to 2025.

The separation of WCE in 2024 is skillfully predicted at the lead time of only 1 month, but the lead time of the prediction skill for the location of WCE in 2025 is 2 or 3month ahead.

This is likely related to the strength of cyclonic circulation in the western subarctic North Pacific and the Sea of Okhotsk, suggesting that the baroclinic circulation system in the Sea of Okhotsk may have played an important role in the KOC during summer and autumn 2025.