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The quasi-operational 4D-Var ocean data assimilation/prediction system for the western North Pacific at JMA

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1. Introduction

JMA has a plan to introduce a new coastal ocean assimilation/prediction system (MOVE/MRI.COM-JPN) in 2020 . As a prototype of MOVE-JPN, MRI/JMA also developed a coastal prediction system for a limited area (MOVE-Seto) to be able to calculate with fewer computer resources. It consists of a MOVE-4DVAR covering the western North Pacific and a 2 km model covering western part of Japan around the Seto Inland Sea. This system, MOVE-Seto, has been quasi-operational since March 2016 at JMA. Our poster focuses on MOVE-4DVAR that consists in both MOVE-JPN and MOVE-Seto. MOVE-4DVAR is almost the same system described in Usui et al. (2017) for FORA-WNP30 (a reanalysis dataset). In the quasi-operational system, 10-days assimilation and subsequent 11-days prediction are executed in a daily basis, using the latest NWP model (GSM) as external forcing and near-real-time observations including satellite altimetry data.

2. Outline of MOVE/MRI.COM-WNP system

Model

MRI Community Ocean Model (MRI.COM version 2.4; Tsujino et al., 2010)

- Primitive equations with free surface, lat-lon coordinates and σ-z hybrid vertical coordinates
- **region**: 15°N-65°N, 117°E-160°W (Nested to North Pacific Model; MOVE-NP) (Fig. 1)
- **resolution**: 1/10°(lon.) x 1/10° (lat.) within 15°N-50°N, 117°E-160°E,1/6° (lon.) east of 160°E and 1/6° (lat.) poleward of 50°N
  54 vertical levels from 0.5 m at surface to 6000 m near the bottom
- **Atmospheric forcing** : the latest NWP model (GSM: 20km, 3 hourly data)

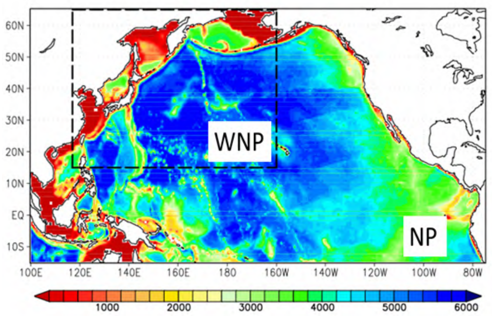

Fig. 1 Model domain for MOVE-NP and MOVE-WNP.

Data Assimilation scheme

MOVE (Multivariate Ocean Variational Estimation system)

- Move-4DVAR was developed as a natural extension of the present operational system in JMA base Multivariate 3DVAR scheme with vertical coupled Temperature-Salinity (T-S) EOF modal decomposition (Fujii et al., 2003). Amplitudes of the T-S EOF modes are employed as control variables.
- Assimilation window is 10 days. An initialization scheme of Incremental Analysis Updates (IAU) technique is used to correct the model fields with the analysis result. IAU period for forward model is set to 3 days (Fig. 2).

Observation data

- In situ T, S profiles (by ship, buoy and ARGO float) via GTS and other communication systems (e-mail, postal mail and facsimile from domestic organizations).
- Satellite altimetry data: near-real-time along-track sea level anomaly (SLA) data from CMEMS [Jason-2/3, AltiKa/Saral, Cryosat-2, HY-2A (until Jan.2016)]
- Sea surface temperature analysis (MGDSST: JMA-GHRSST product)

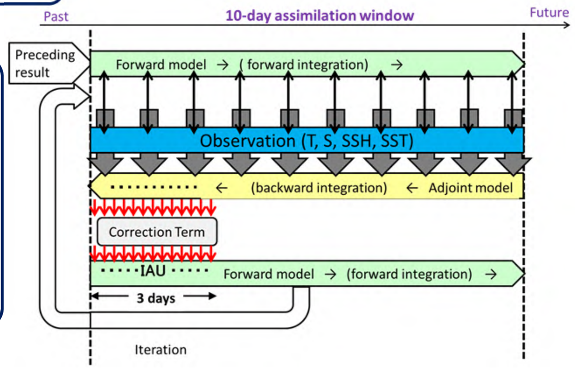

Fig. 2 Schematic of assimilation cycle for MOVE-4DVAR.

3. Comparison with observation data

- The validation results against in-situ data show that RMSE of subsurface temperatures for MOVE-4DVAR is significantly reduced in the region with large temperature variability such as the Japan Sea, Oyashio, Kuroshio, and Kuroshio Extension region compared to MOVE-3DVAR (the current operational 3D-var ocean assimilation system.) (Fig. 3-1).
- The positive bias is generally seen in the both systems (MOVE-4DVAR and MOVE-3DVAR). The bias of MOVE-4DVAR is somewhat larger south of 25°N, and this might lead the larger RMSE of MOVE-4DVAR in these areas (Fig. 3-2).
- An example of analysis at 22 Mar. 2016 (Fig. 4) shows that MOVE-4DVAR captures features of the Kuroshio path better than MOVE-3DVAR, especially a small perturbation south of Japan (arrows in Fig. 4).

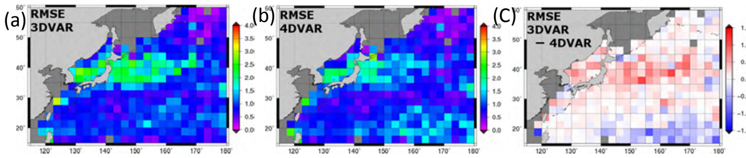

Fig.3-1 RMSE of daily 100m-depth temperatures against in-situ observations for 2014: (a) 3DVAR, (b) 4DVAR. (c) RMSE difference between 3DVAR and 4DVAR. Warmer (cooler) color indicates RMSE of 4DVAR is lower (larger) than that of 3DVAR.

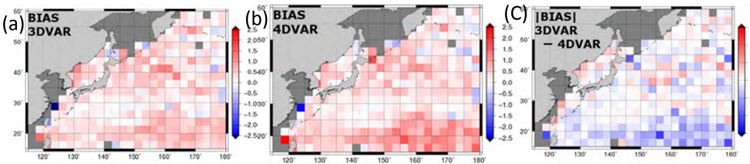

Fig.3-2 Bias of daily 100m-depth temperatures against in-situ observations for 2014: (a) 3DVAR, (b) 4DVAR. (c) Difference of absolute value of bias between 3DVAR and 4DVAR. Warmer (cooler) color indicates absolute value of bias for 4DVAR is lower (larger) than that of 3DVAR.

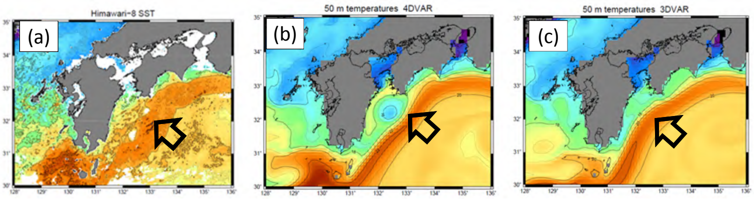

Fig. 4 Comparison of the representation of the Kuroshio path at 22 Mar. 2016.
(a) SST observations derived from HIMAWARI-8. 50m-depth temperature analysis of (b) 4DVAR and (3) 3DVAR at 22th March 2016 south of Japan.

References:

[1] Fujii et al., 2003: Three-dimensional analysis of temperature and salinity in the equatorial Pacific using avariational method with vertical coupled temperature–salinity EOF modes. *Journal of Geophysical Research: Oceans (1978–2012)* ,108(C9).

[2] Tsujino et al., 2010: Reference manual for the Meteorological Research Institute Community Ocean Model (MRI.COM) version 3. *Technical Reports of the Meteorological Research Institute*, 59, 273 pp.

[3] Usui et al., 2017: Four-dimensional variational ocean reanalysis: a 30-year high-resolution dataset in the western North Pacific (FORA-WNP30), *J. Oceanogr.*, 73(2), 205-233.

4. Improvement of SLA assimilation scheme

- We consider that the positive biases of MOVE-3DVAR and MOVE-4DVAR are attributed to the current method for SLA assimilation.

Current Cost Function $J = J_b + J_{TS} + \frac{1}{2\sigma_{SSH}{}^2}\left[Dyn(T,S) - (\eta'_{obs} + \overline{Dyn})\right]^2$

$\boldsymbol{J_b}$: background term, $\boldsymbol{J_{TS}}$: observation term related T and S $\boldsymbol{\sigma_{ssh}}$: observational error of SLA ,
$\boldsymbol{\eta'_{obs}}$: Altimeter-derived SLA, ***Dyn (T, S)*** : sea surface dynamic height (SDH) of model, $\boldsymbol{\overline{Dyn}}$: mean SDH

$\eta'_{obs} = \eta'_{dyn} + \eta'_{bt} + \eta'_{mass}$

η'_{dyn}: SDH
η'_{bt}: ocean water mass variation by wind stress
η'_{mass}: ocean water mass variation by net surface water flux

- η'_{bt} and η'_{mass} components of observed SLA possibly contribute to analysis errors or biases of subsurface temperatures and salinity.

New Cost Function $J = J_b + J_{TS} + \frac{1}{2\sigma_{SSH}{}^2}\left[Dyn(T,S) - (\eta'_{obs} - \eta'_{bt} - \eta'_{mass} + \overline{Dyn})\right]^2$

- Adding monthly η'_{mass} (Fig. 5) contributes the decrease of positive subsurface temperature biases by 0.2 ~ 0.3℃ on an average for the area 15-45°N, 140°E-120°W.

◎Estimation method of monthly η'_{mass}
(averaged value for MOVE-NP region)

$$\eta'_{mass} \sim \frac{1}{A}\iint \left[\underset{\uparrow}{\eta'_{obs}} - (\underset{\uparrow}{Dyn(T,S)} - \overline{Dyn})\right] dxdy$$

Altimeter-SLA

SDH derived from monthly mean 3DVAR analysis (T, S) assimilated only in-situ data.

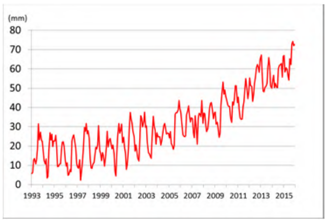

Fig. 5 Time series of monthly η'_{mass} from 1993 to 2015.

- 5-day climatology (1993-2012) of η'_{bt} component is estimated from the bottom pressure anomalies of the model(MOVE-NP) (fig. 6).

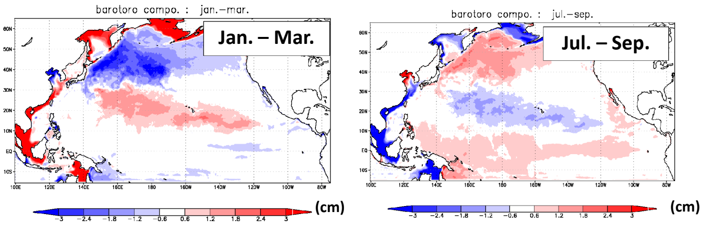

Fig. 6 Climatological η'_{bt} map for (left) Jan. – Mar. and (right) Jul. – Sep.