E-p21

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Development of a high-resolution coastal forecasting system with a 4DVAR assimilation scheme

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Introduction

- JMA/MRI has developed a coastal forecasting system (**MOVE/MRI.COM-Seto**), which consists of a 10km analysis model with four-dimensional variational (4DVAR) analysis scheme (**MOVE-4DVAR**) and a 2km coastal model**.**
- MOVE-4DVAR was developed as a natural extension of the present operational system in JMA based on 3DVAR using T-S coupled EOF modes (Fujii and Kamachi 2003).
- Since 4DVAR extracts information about the time evolution of the state, it is expected that 4DVAR improves short-term variability.
- This study investigates the impact of the 4DVAR scheme on short-term variations of the Kuroshio path south of Japan and related sea-level variability at the southern coast of Japan.

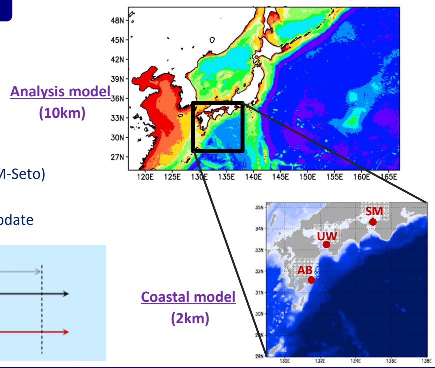
Configuration of MOVE/MRI.COM-Seto

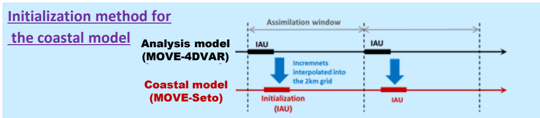
☐ Analysis model (MOVE-4DVAR)

- Western North Pacific (MRI.COM-WNP; 15°-65°N, 117°-200°E)
- **10km** resolution, 54 levels
- **4DVAR** analysis scheme

☐ Coastal model (MOVE-Seto)

- Covering western part of the Japanese coastal region (MRI.COM-Seto)
- **2km** resolution, 51 levels
- Initialized with 10-km analysis results by Incremental Analysis Update





MOVE-4DVAR assimilation scheme

☐ 4DVAR analysis scheme

- Estimate T and S fields
- Use of vertical T-S EOF for the BG error covariance (Fujii&Kamachi 2003)
- Initialization with Incremental Analysis Update
- Assimilated observations:
  - + T and S profiles
  - + Altimeter-derived SSH anomaly
  - + Gridded SST

（Cost function）

$$J(\mathbf{z}) = \frac{1}{2}\mathbf{z}^T\mathbf{B}^{-1}\mathbf{z} + \frac{1}{2}\left[\mathbf{Hx}(\mathbf{z}) - \mathbf{y}^{\mathrm{TS}}\right]^T \mathbf{R}^{-1}\left[\mathbf{Hx}(\mathbf{z}) - \mathbf{y}^{\mathrm{TS}}\right] + \frac{1}{2\sigma_h^2}\left[\mathcal{H}_{\mathrm{SSH}}(\mathbf{x}(\mathbf{z})) - \mathbf{y}^{\mathrm{SSH}}\right]^T\left[\mathcal{H}_{\mathrm{SSH}}(\mathbf{x}(\mathbf{z})) - \mathbf{y}^{\mathrm{SSH}}\right]$$

（Gradient）

$$\nabla J(\mathbf{z}) = \mathbf{B}^{-1}\mathbf{z} + \mathbf{G}^T\left[\mathbf{M}^*\mathbf{H}^T\mathbf{R}^{-1}\{\mathbf{Hx}(\mathbf{z}) - \mathbf{y}^{\mathrm{TS}}\} + \frac{1}{\sigma_h^2}\mathbf{M}^*\mathbf{H}^*_{\mathrm{SSH}}\{\mathcal{H}_{\mathrm{SSH}}(\mathbf{x}(\mathbf{z})) - \mathbf{y}^{\mathrm{SSH}}\}\right]$$

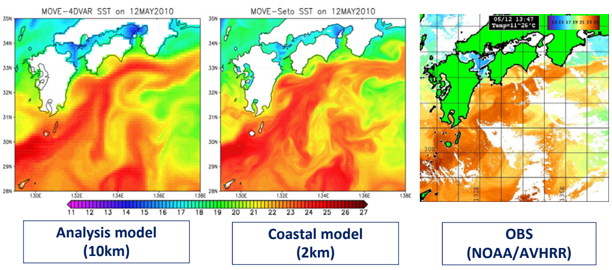
- Model operator $\mathbf{x}(\mathbf{z}) = \mathcal{M}(\mathbf{x}_0(\mathbf{z}))$
- Relation between control variable z and initial TS field $\mathbf{x}_0$: $\mathbf{x}_0 = \mathbf{x}_0^b + \mathbf{Gz}$ $(\mathbf{G} \equiv \mathbf{SU\Lambda})$

$\mathbf{z}$	: Amplitude of TS-EOF modes (control variable)
$\mathbf{x}$	: Analysis (T and S)
$\mathbf{y}$	: Observation
$\mathbf{S}$	: Diagonal matrix composed of standard errors of background field
$\mathbf{U}$	: Matrix composed of T-S EOF modes
$\mathbf{\Lambda}$	: Diagonal matrix composed of singular values of T-S EOF modes
$\mathbf{B}$	: Horizontal correlation matrix of background filed

Assimilation experiment

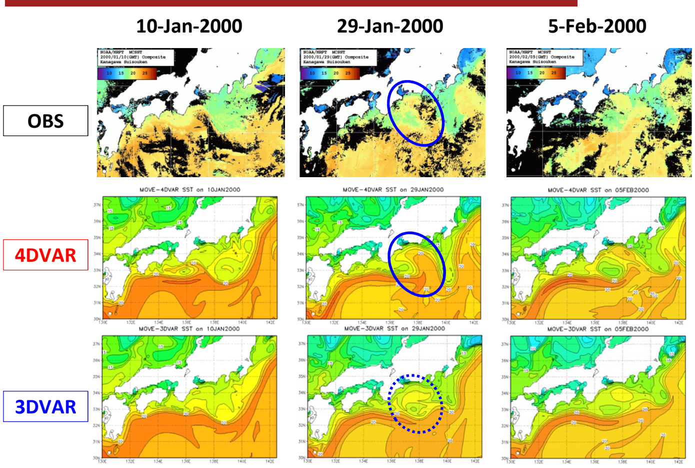
- 10-day assimilation window
- 3-day IAU for the forecast model initialization
- 3DVAR experiment was also conducted for comparison

SST snapshot



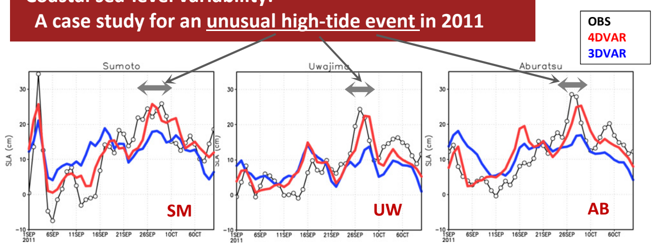
Comparison of SST snapshot fields on 12 May 2010.

Improvement of short-term mesoscale variability by 4DVAR

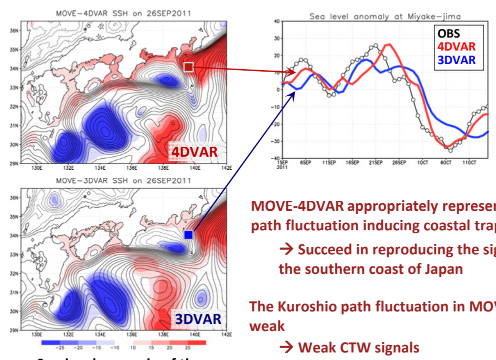


Intrusion of warm Kuroshio water caused by a disturbance propagating along the Kuroshio in the late January to the early February 2000.

Coastal sea-level variability: A case study for an unusual high-tide event in 2011



Sea-level anomalies at (left) Sumoto, (middle) Uwajima, and (right) Aburatsu in Sep-Oct 2011



Sea-level anomaly of the analysis model on 26Sep2011

Sea-level anomaly at Miyake-jima in Sep-Oct 2011

MOVE-4DVAR appropriately represents a short-term Kuroshio path fluctuation inducing coastal trapped waves (CTWs)

→ Succeed in reproducing the significant sea-level rise at the southern coast of Japan

The Kuroshio path fluctuation in MOVE-3DVAR is somewhat weak

→ Weak CTW signals

→ Poor reproduction of the sea-level rise at the southern coast of Japan

Summary

- We have developed a coastal forecasting system named MOVE/MRI.COM-Seto, which consists of a 10km analysis model with 4DVAR and a 2km coastal model.
- The 4DVAR scheme fairly improves short-term mesoscale variability compared with 3DVAR.
- The appropriate representation of short-term Kuroshio fluctuations by 4DVAR leads to significant improvement in sea-level variability at the southern coast of Japan.