Development of a Seto-Inland-Sea model toward operational monitoring and forecasting

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Japan Meteorological Agency, JMA, is monitoring and forecasting the Western North Pacific ocean operationally using a data assimilation system, “MOVE-WNP”.

MOVE-WNP targets:
- open ocean: Kuroshio, Oyashio, meso-scale eddies
- prediction: 1 month
- horiz. resolution: 10km (1/10 degree)

MOVE-WNP cannot meet demands for monitoring of coastal seas or coastal disaster prevention.

SST anomaly forecast at Oct. 30, 2014

http://www.data.jma.go.jp/gmd/kaiyou/data/db/kaikyo/ocean/forecast/month.html
New system

the operational ocean models of JMA

Meteorological Research Institute

Roadmap
2015- several years later
the Seto Inland Sea the whole coastal regions of Japan

System infrastructure
Coastal models Data assimilation methods

Today: introduce our Seto-Inland-Sea model, “Model Seto”
The purpose of my presentation is to give an overview of **Model Seto**.

- 2: Model configurations
- 3: Results
- 4: Particular specifications
- 5: Brief introduction of the next version, “**Model Japan**”
2. Configurations of Model Seto
Model region

The resolution (2km) is 5 times as fine as MOVE-WNP.

MOVE-WNP (4DVAR)

the same model as the current system (data assimilation is changed from 3D-VAR to 4D-VAR)
Model configurations

**Numerical model**: our own OGCM: MRI.COM Ver.3.2

**Coordinates**: free-surface sigma-z, polar coordinates

**Horizontal resolution**: about 2 km (1/33 degree * 1/50 degree)

**Vertical resolution**: 4-600m (50 layers)

**Tracer advection**: Second-order Moment closure (Prather 1986)

**Horizontal mixing**: Smagorsinsky bi-harmonic scheme

**Vertical mixing**: Noh and Kim (1999)

**Tides**: tidal mixing parameterization (Lee et al. 2006)

**Lateral boundaries**: re-analysis dataset of MOVE-WNP 4DVAR

**Downscaling**: off-line one-way nesting

**Atmospheric forcing**: JMA operational datasets (GSM+MSM)

**River run-off**: daily observation of 28 major rivers

**Time step interval**: 2.5 minutes

**Others**: restore sea surface salinity to climatology with 29.2 day

**Model Seto**: suited for small-scale

**MOVE-WNP (4DVAR)**: 3 hourly, dx=5km

*Images of geographical maps showing depth and lateral boundaries.*
A test experiment to investigate model performance

Seto free run

- Sept 1, 2008
- Jan 1, 2009
- Dec 31, 2011
- 3 years for analysis
- spin up
- nudging
- free-running simulation (do not modify the model by data assimilation)

The parent model for comparison

- MOVE-WNP 4DVAR re-analysis

Observation datasets

- Satellite sea surface temperature (SST) (MODIS: JAXA/Tokai Univ.)
- SST time series at a coastal site (JODC)
- sea surface height (SSH) by tide gauge (JMA)
3. Results
SST in Model Seto

Active motion with a scale of 10-100 km e.g. southern coasts of Japan

Seto free run
Seasonal evolution of SST

Monthly SST (2010)
Seto free run

realistic seasonal evolution of the ocean states, owing to our model tuning and good performance of MOVE-WNP (used for lateral boundaries)
SST Snapshot

SST snapshot on Mar 1, 2011.

Seto free run
dx = 2km
free run

Satellite Obs.

MOVE-WNP
dx = 10km
assimilation

various scales of structures
(10–100 km)

no small-scale structures
The seasonal change agreements with observation.

SST jumps (by 2 degree in a few days)
Kuroshio-water intrusion with a scale of 10 km induces SST jumps.

IMPROVING RESOLUTION (2km) => representing short-term variation (a few days)

SST change might be forced by data assimilation.

Seto free run

dx = 2km
free run

MOVE-WNP

dx = 10km
assimilation
SSH variation at Uwajima

SSH anomaly
(departure from averages)

- realistic seasonal change
- rapid changes by 5-10cm
  (a few times per a month)
4. Particular specifications
Tidal mixing parameterization

Model Seto implements a tidal mixing parameterization to compensate for lack of tides.

Mean speed of the tidal currents $\rightarrow$ background vertical diffusivity

Lee et al. (2006)
(assume fixed stratification)

output of Model Japan with 8 tidal constituents

value at sea surface
Impact of tidal mixing

SST in Sep 2011
Seto free run

- too low

low SST and a tidal front

Case w/o tidal mixing

- no fronts

Satellite Obs.
Usage of river runoff obs.

- River runoff affects the ocean state in the Seto Inland Sea. (Kobashi and Fujiwara 2003 in Japanese)
- suggesting that it is important to use an accurate dataset of river runoff.

Seto free run
data: daily observation of 28 major rivers
(1994-2003 mean)

A case using a low-resolution data
data: 1-degree monthly runoff in the CORE dataset

The values are converted to rainfall in the model grid.
Impact of river runoff

Sea surface salinity in Sep 2011
Seto free run

Case with a low-resolution river runoff dataset

Salinity near the coasts depends on river runoff strongly. An accurate dataset is important.

reflects river mouths
5. Model Japan (next ver.)
Overview of Model Japan

- expands Model Seto to the whole coastal regions of Japan
  - Same numerical model (MRI.COM)
  - Same horizontal resolution (about 2km)
- uses up-to-date schemes
  - new turbulence closure (GLS)
  - implementation of explicit tidal forcing (Sakamoto et al. 2013, OS)
  - on-line two-way nesting of 3 models
    - Global – WNP – Model Japan
Results: tides

- Model Japan can reproduce tides and other ocean processes simultaneously.
- Tides are dominant in SSH variation at the coasts of Japan.

Tides would affect the ocean state strongly.
Results: SST

1-year free running simulation
SST (25-hour mean)

Various scales of motion appear seamlessly.
(Pacific ocean – marginal seas – coastal regions)

We are developing Model Japan to be a platform of coastal oceanography research / public services in future.
6. Conclusion
Conclusion

- We have developed an operational coastal model of the Seto Inland Sea, Japan, “Model Seto”.
  - features:
    - fine horizontal resolution (about 2 km)
    - schemes for small-scale phenomena
    - specifications particular to coastal seas (e.g. tidal mixing, river runoff)
  - performance:
    - realistic seasonal evolution of the ocean state
    - coastal processes with a scale of 10 km
    - short-term variation (a few to ten days)

- Japan Meteorological Agency will start operating the monitoring and forecasting system using Model Seto in 2015.
  - The data assimilation method will be also updated to 4DVAR.

- We are developing the next version, “Model Japan”.
  - to be a platform of research, disaster prevention, fisheries, etc.
  - regional impacts of climate change