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

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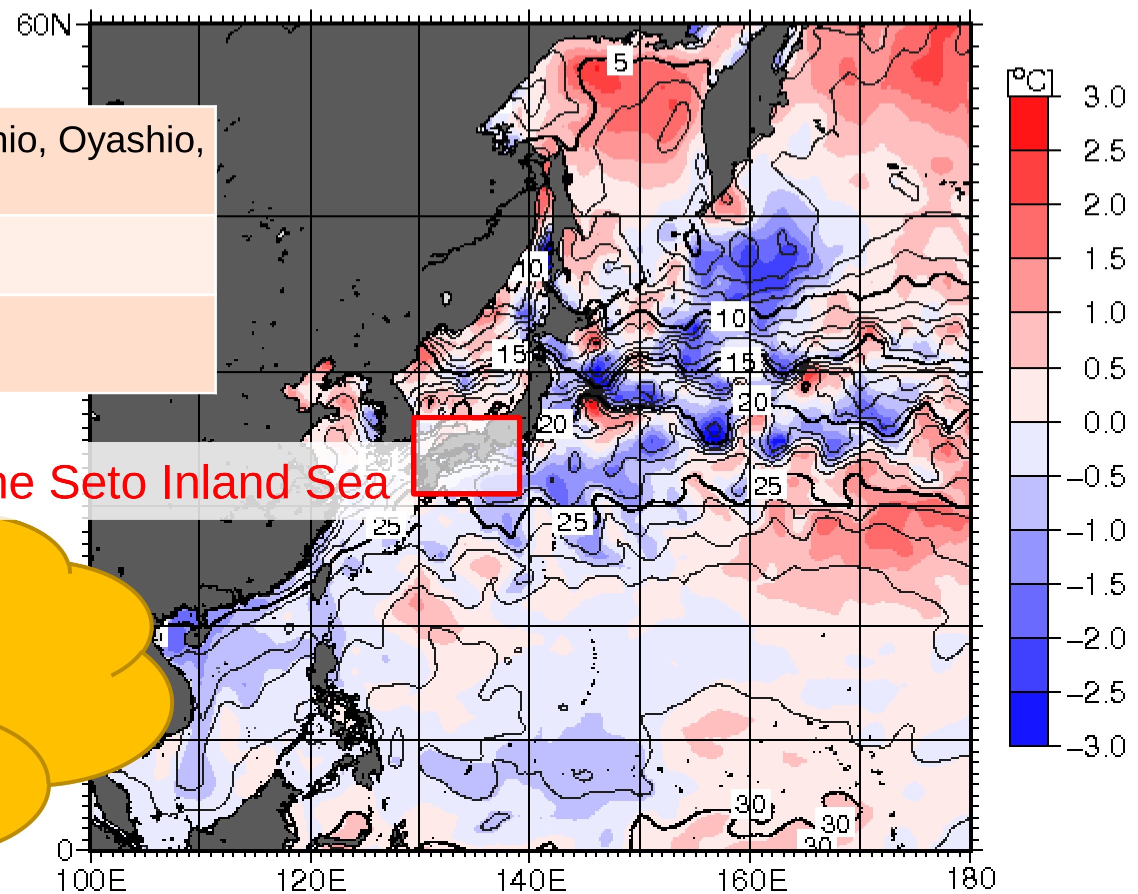
1. Introduction

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

SST anomaly forecast at Oct. 30, 2014

MOVE-WNP

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

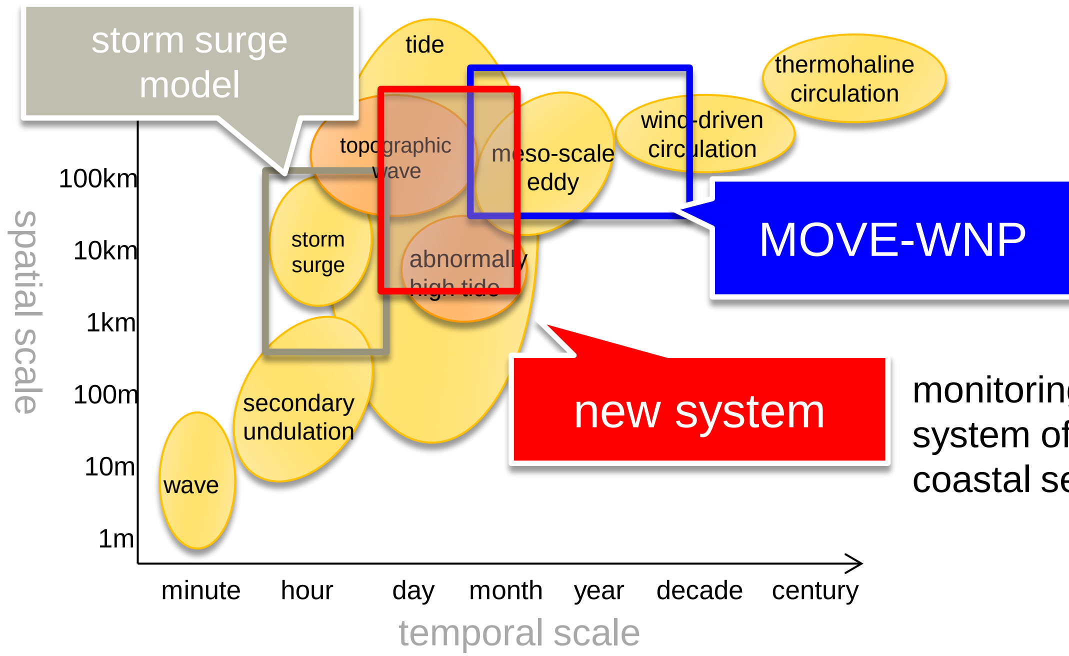


MOVE-WNP cannot meet demands for monitoring of coastal seas or coastal disaster prevention.

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

New system

the operational ocean models of JMA



monitoring and forecasting system of the Japanese coastal seas

Roadmap

2015- | several years later

the Seto Inland Sea → the whole coastal regions of Japan

System infrastructure

Coastal models

Data assimilation methods

Meteorological Research Institute

Today: introduce our Seto-Inland-Sea model, “Model Seto”

Seto-Inland-Sea model

Model Seto

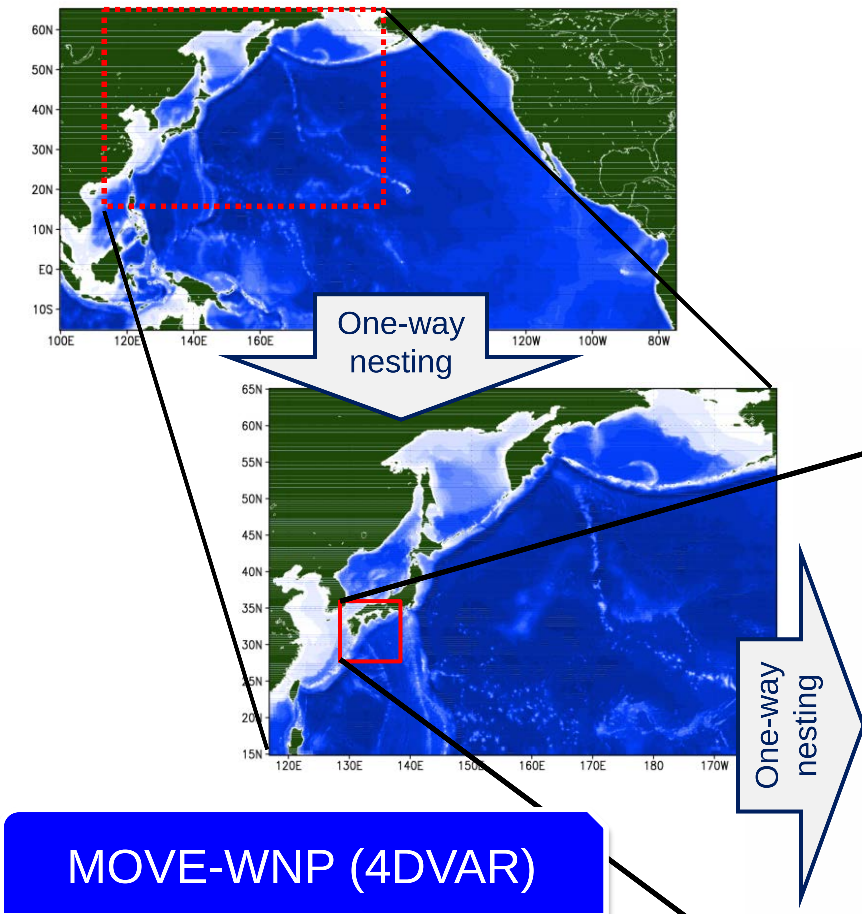
- **improved resolution**
  - downscale MOVE-WNP with a horizontal resolution of 2km
  - to represent coastal topographies and physical processes
- **schemes for coastal modeling**
  - Schemes suited for small-scale phenomena
    - high-precision advection scheme etc.
  - Specifications particular to coastal seas
    - river run-off
    - tidal mixing
- **general-purpose model**
  - A platform of research and services of coastal seas
  - to meet various requests

The purpose of my presentation is to give an overview of Model Seto.

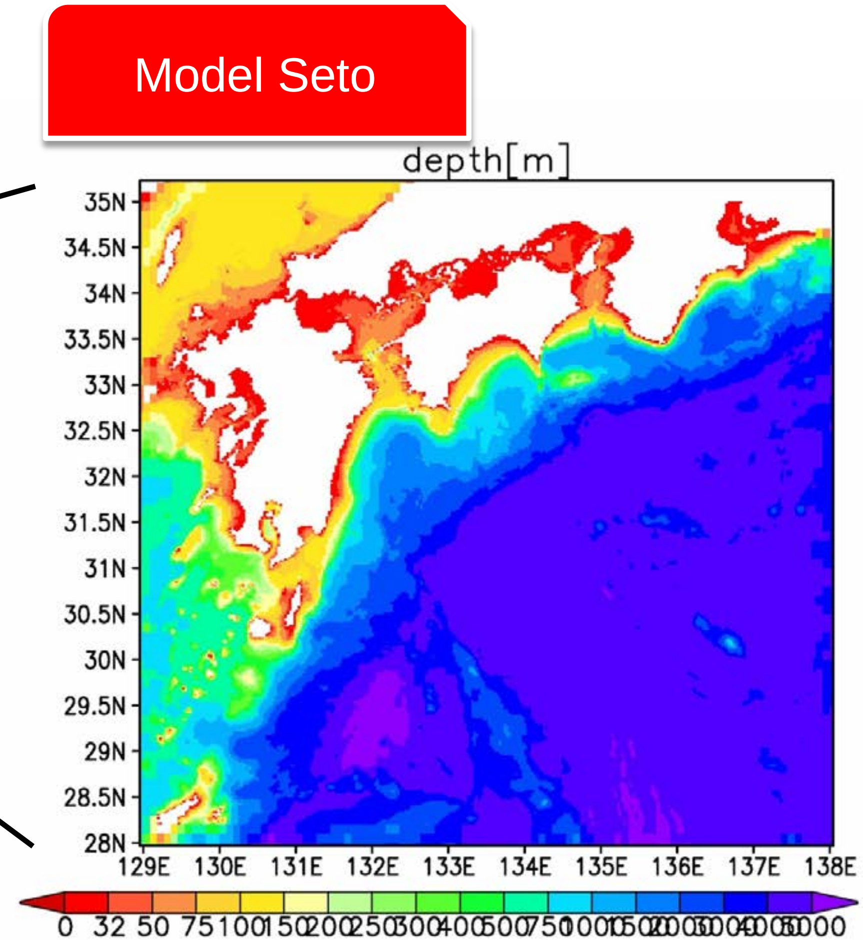
- 2: Model configurations
- 3: Results
- 4: Particular specifications
- 5: Brief introduction of the next version, “Model Japan”

2. Configurations of Model Seto

Model region



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

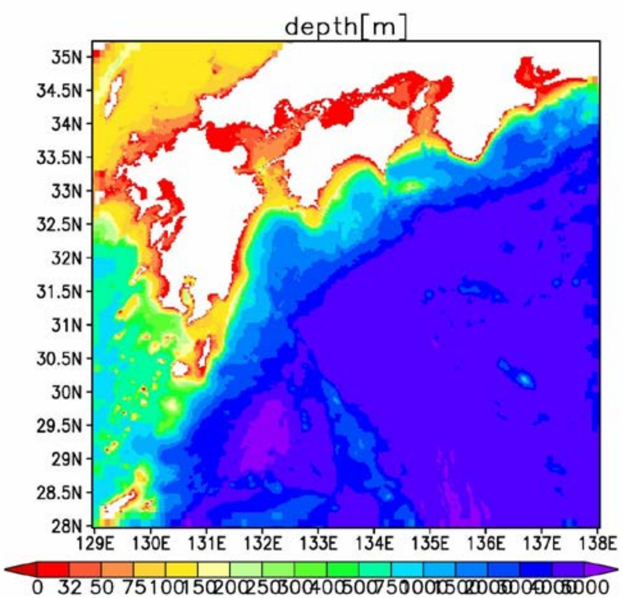


the same model as the current system

(data assimilation is changed from 3D-VAR to 4D-VAR)

Model configurations

Model Seto



lateral boundaries

MOVE-WNP (4DVAR)

re-analysis dataset

Numerical model	our own OGCM: MRI.COM Ver.3.2
coordinates	free-surface sigma-z, polar coordinates
horiz. resolution	about 2 km (1/33 degree *1/50 degree)
vertical resolution	4-600m (50 layers)
tracer advection	Second-order Moment closure (Prather 1986)
horiz. mixing	Smagrosinky 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

suited for small-scale

3 hourly, dx=5km

Test experiment

A test experiment to investigate model performance

Seto free run

nudging	spin up	3 years for analysis
	Sep 1, 2008	Jan 1, 2009 – Dec 31, 2011

free-running simulation (do not modify the model by data assimilation)

The parent model for comparison

MOVE-WNP 4DVAR re-analysis

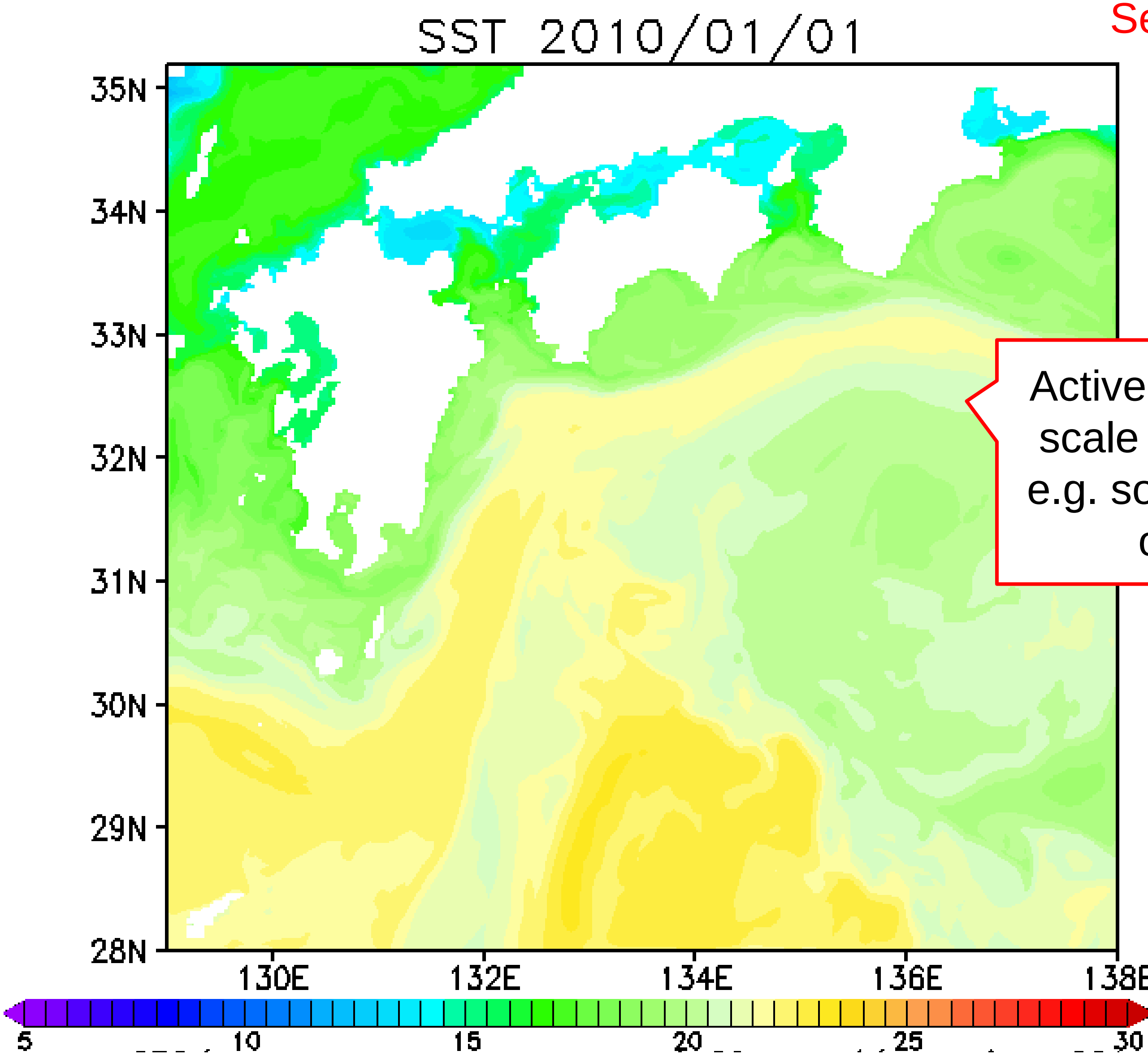
Observation datasets

- 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

Seto free run



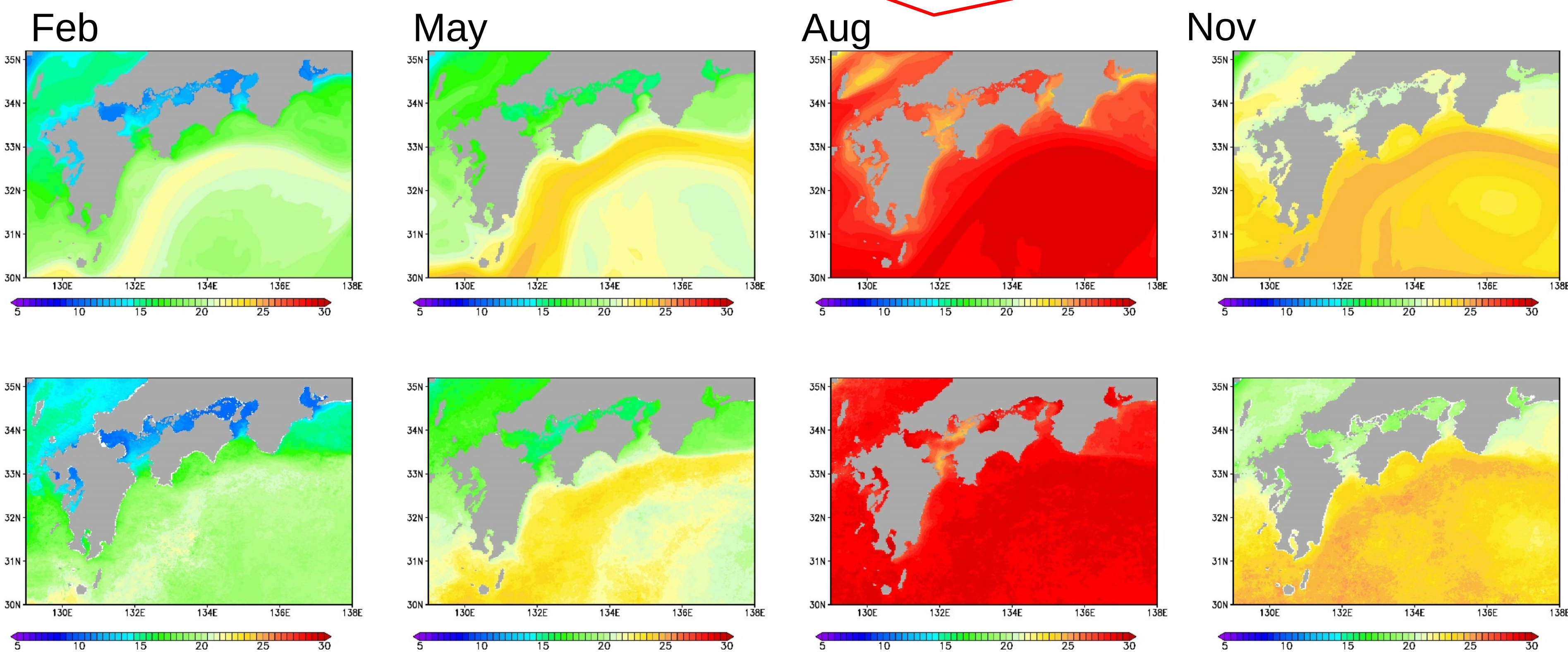
Active motion with a scale of 10-100 km e.g. southern coasts of Japan ☺

Seasonal evolution of SST

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

Monthly SST (2010)

Seto free run



Satellite Obs.

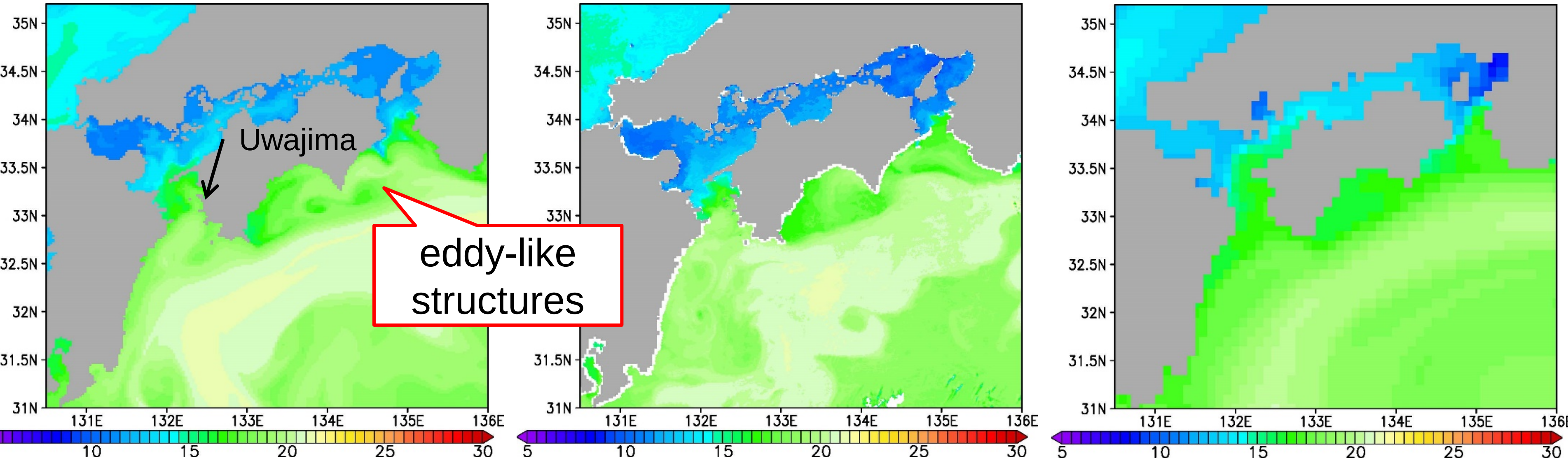
SST Snapshot

SST snapshot on Mar 1, 2011.

Seto free run
dx = 2km
free run

Satellite Obs.

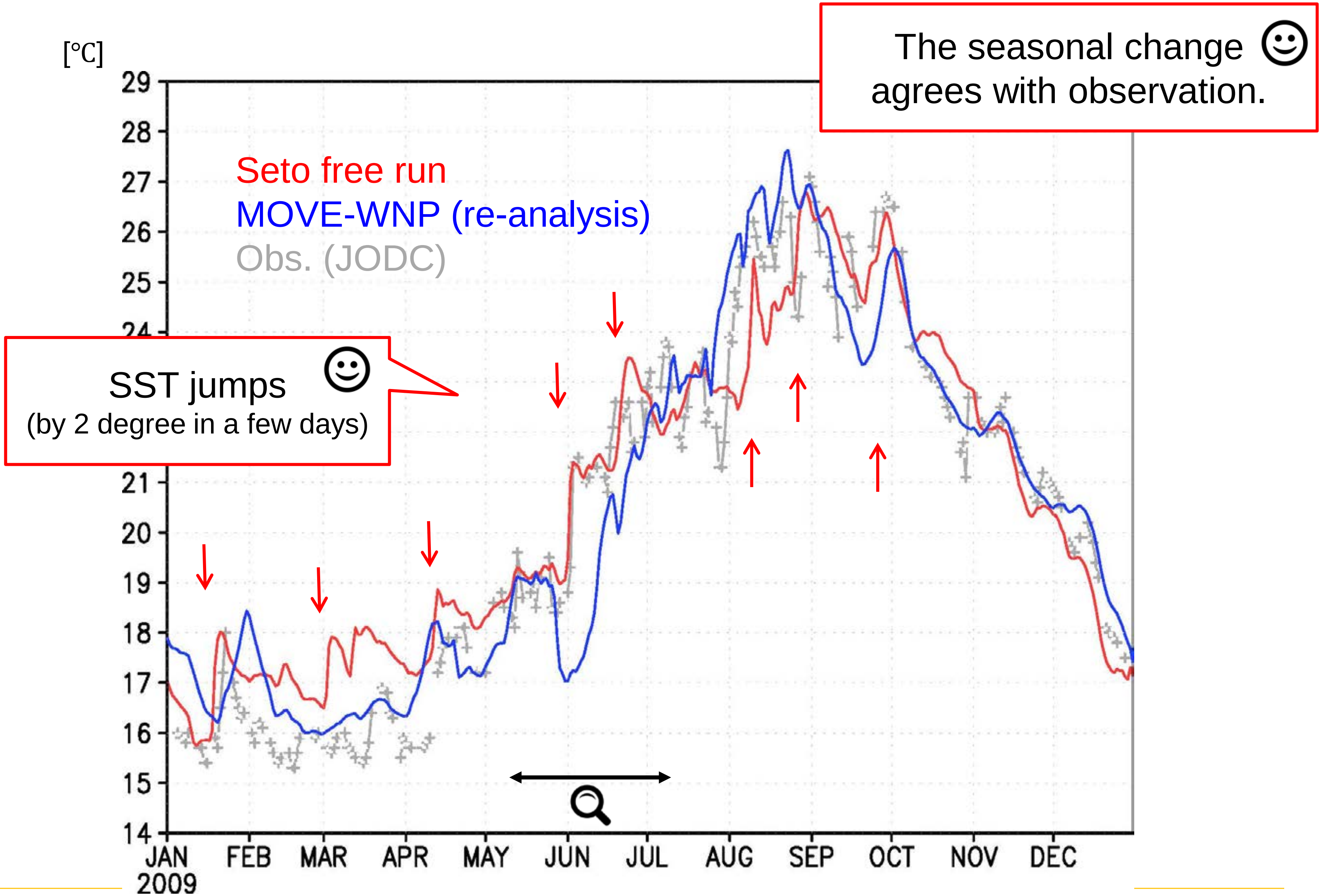
MOVE-WNP
dx = 10km
assimilation



various scales of structures (10–100 km)

no small-scale structures

SST variation at Uwajima

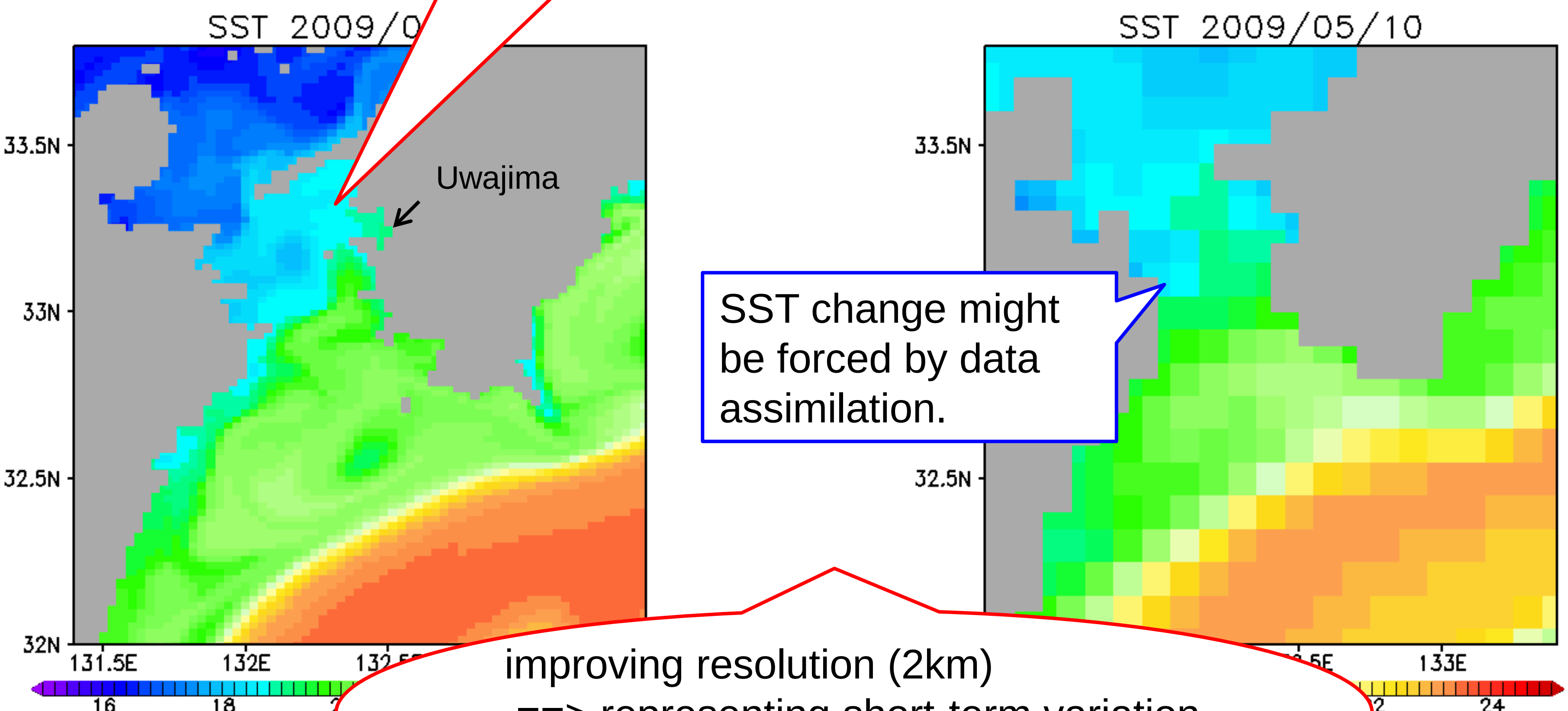


Kuroshio-water intrusion

Seto free run
dx = 2km
free run

Kuroshio-water intrusion with a scale of 10 km induces SST jumps.

MOVE-WNP
dx = 10km
assimilation

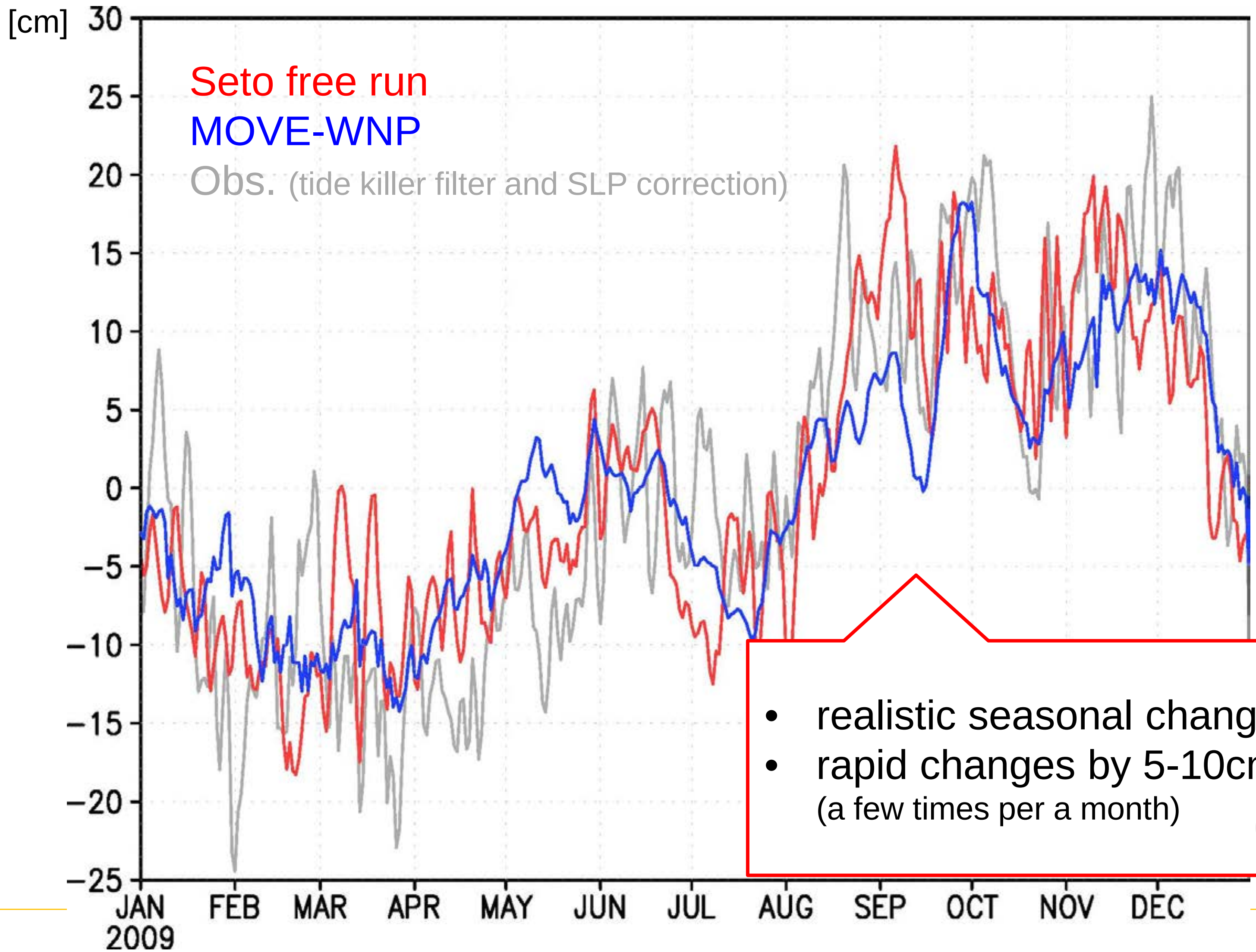


SST change might be forced by data assimilation.

improving resolution (2km)
==> representing short-term variation
(a few days)

SSH variation at Uwajima

SSH anomaly
(departure from averages)



- realistic seasonal change
- rapid changes by 5-10cm
  (a few times per a month) ☺

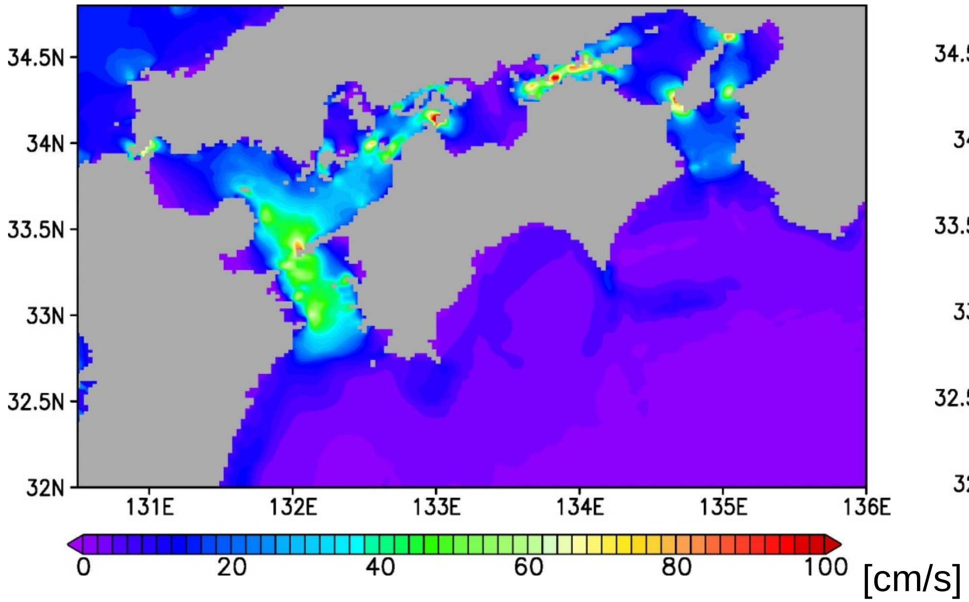
4. Particular specifications

Tidal mixing parameterization

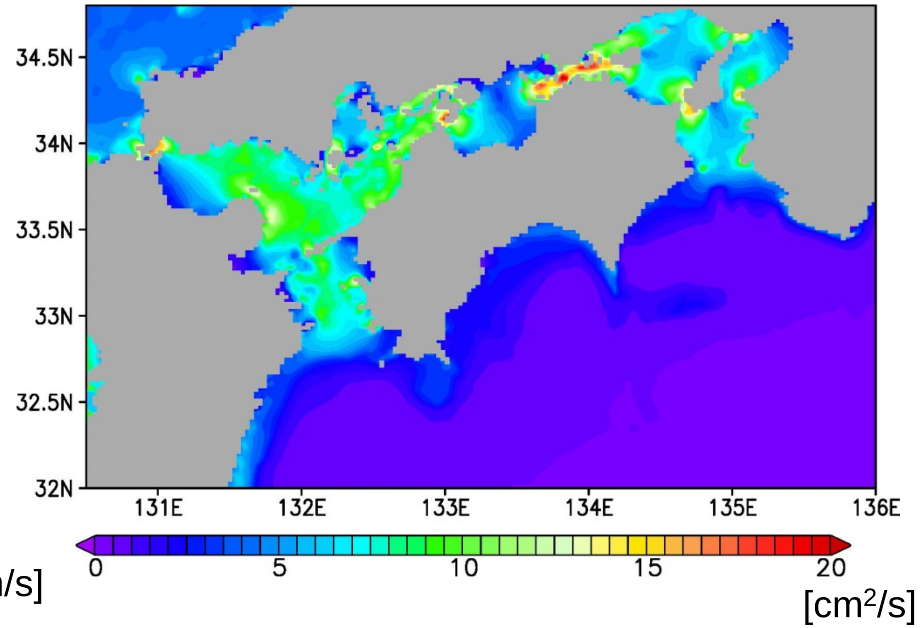
Model Seto implements a tidal mixing parameterization to compensate for lack of tides.

mean speed of the tidal currents → background vertical diffusivity

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



output of Model Japan with 8 tidal constituents



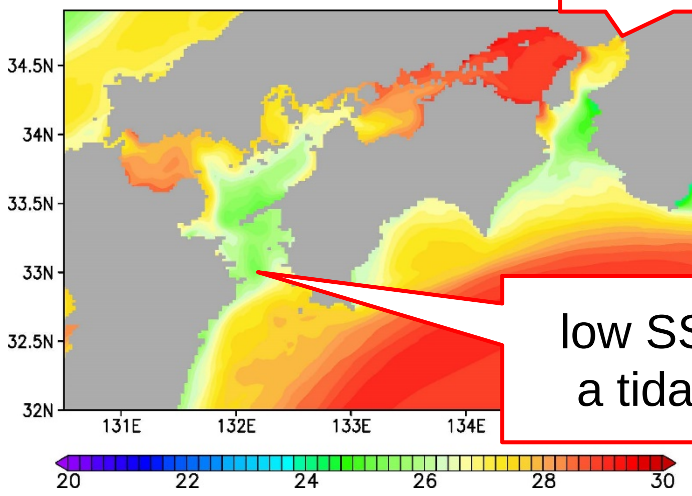
value at sea surface

Impact of tidal mixing

SST in Sep 2011

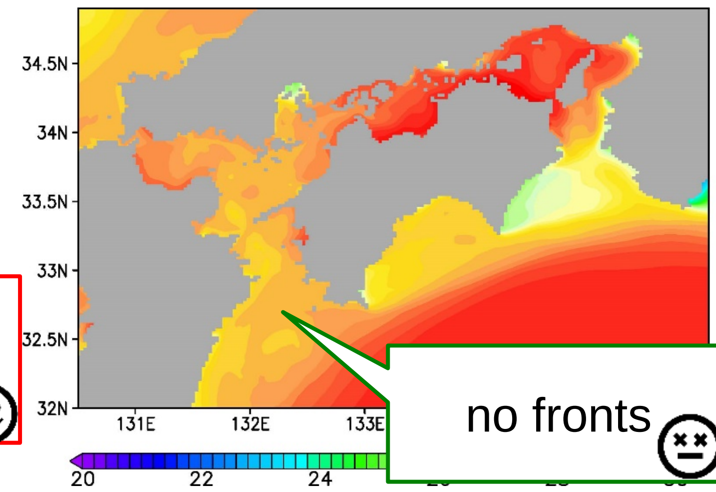
Seto free run

too low



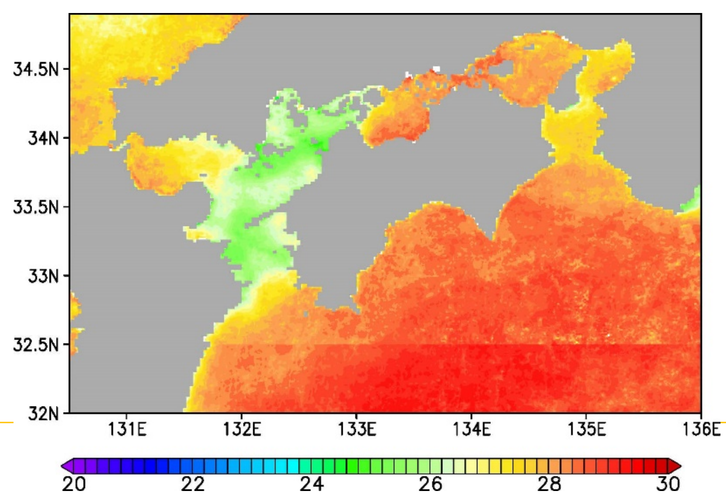
low SST and
a tidal front

Case w/o tidal mixing



no fronts

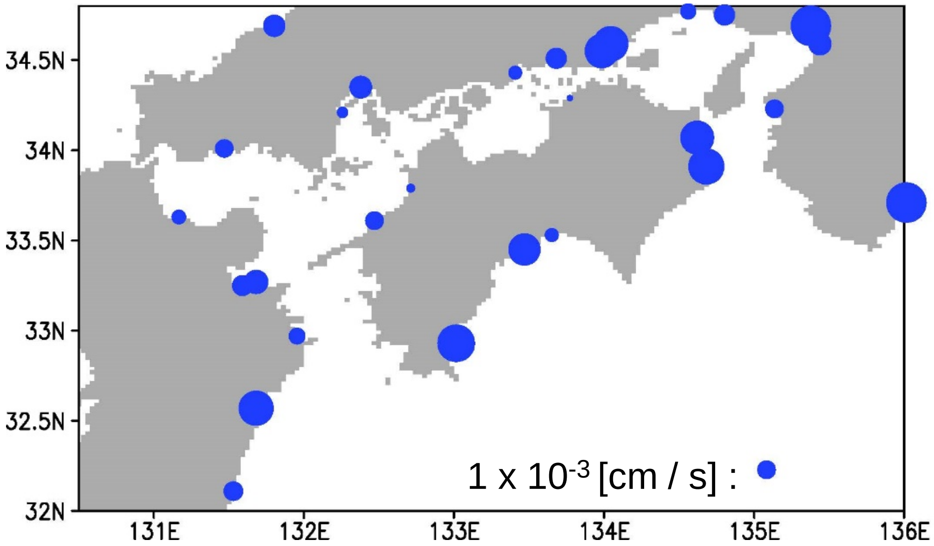
Satellite Obs.



Usage of river runoff obs.

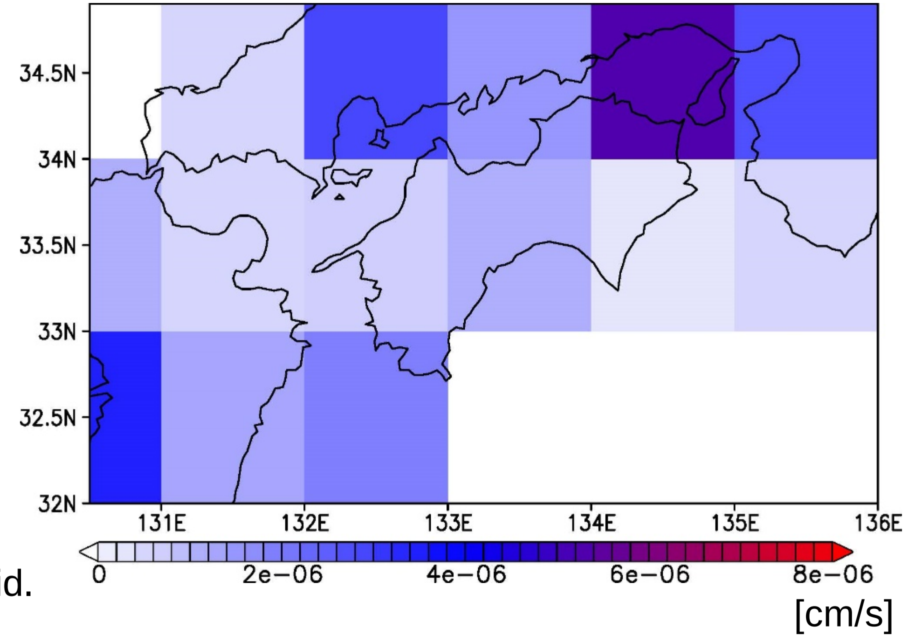
- River runoff affects the ocean state in the Seto Inland Sea.
  (Kobashi and Fujiwara 2003 in Japanese)
  - suggesting that it is important to use an accurate dataset of river runoff.

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



The values are converted to rainfall in the model grid.

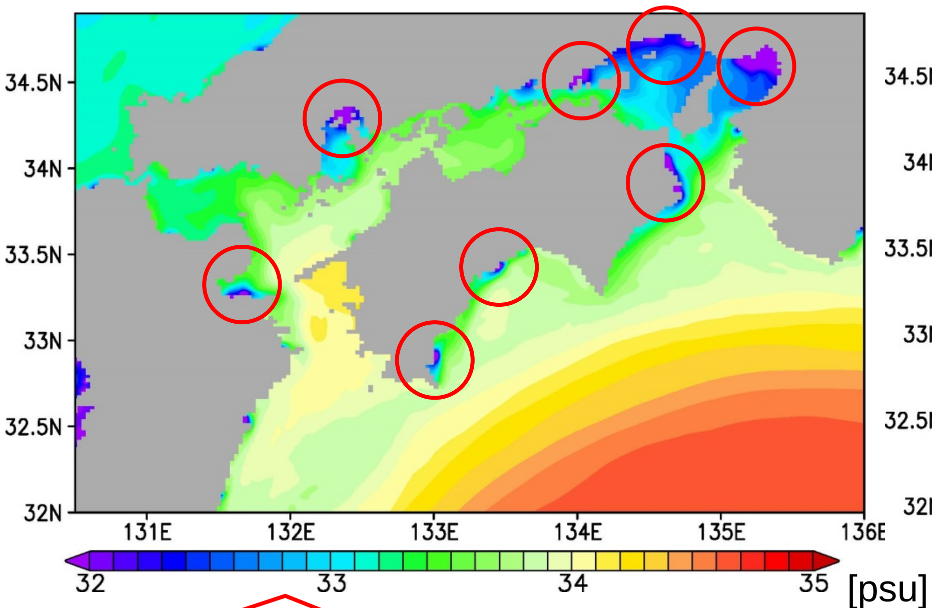
A case using a low-resolution data
data: 1-degree monthly runoff in the CORE dataset



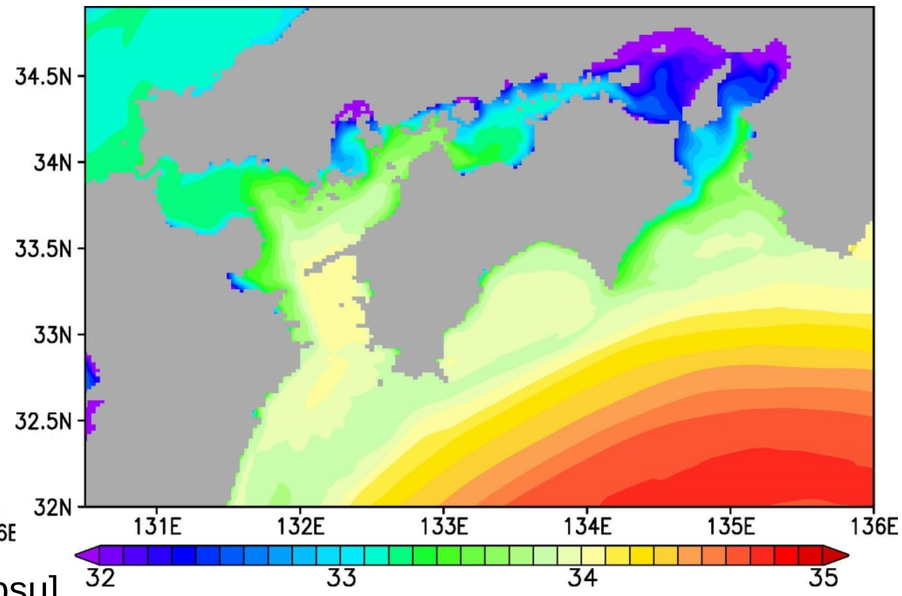
Impact of river runoff

Sea surface salinity in Sep 2011

Seto free run

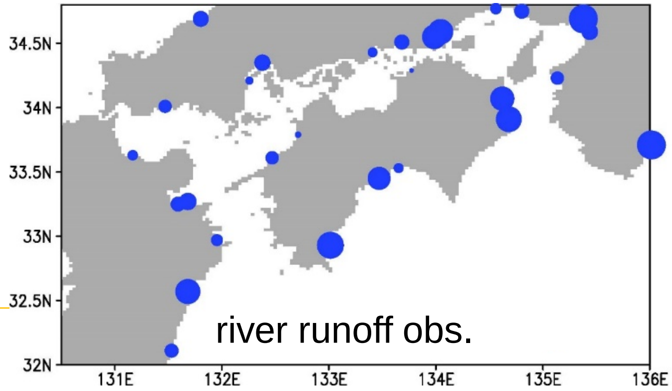


Case with a low-resolution river runoff dataset



reflects river mouths

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

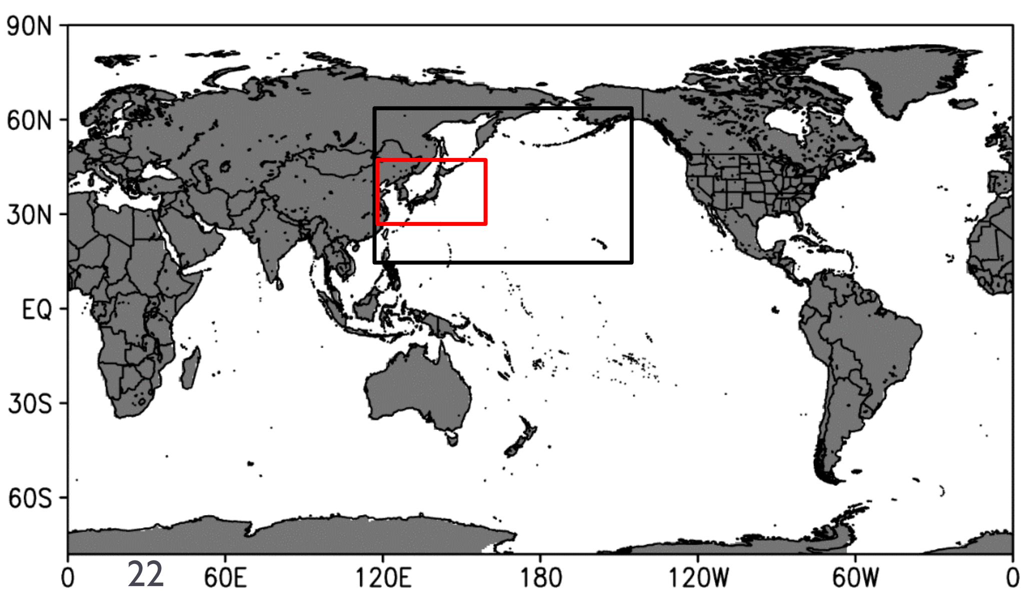


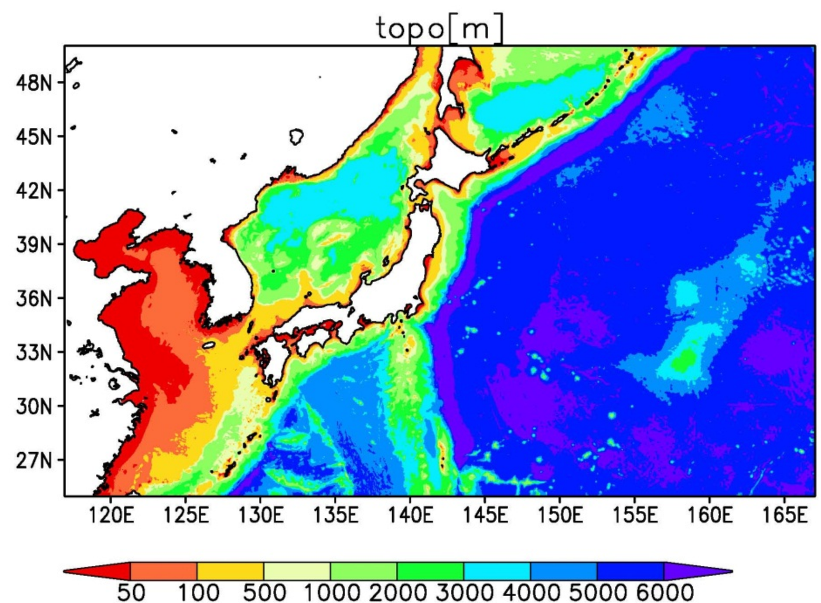
5. Model Japan (next ver.)

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

Model Japan

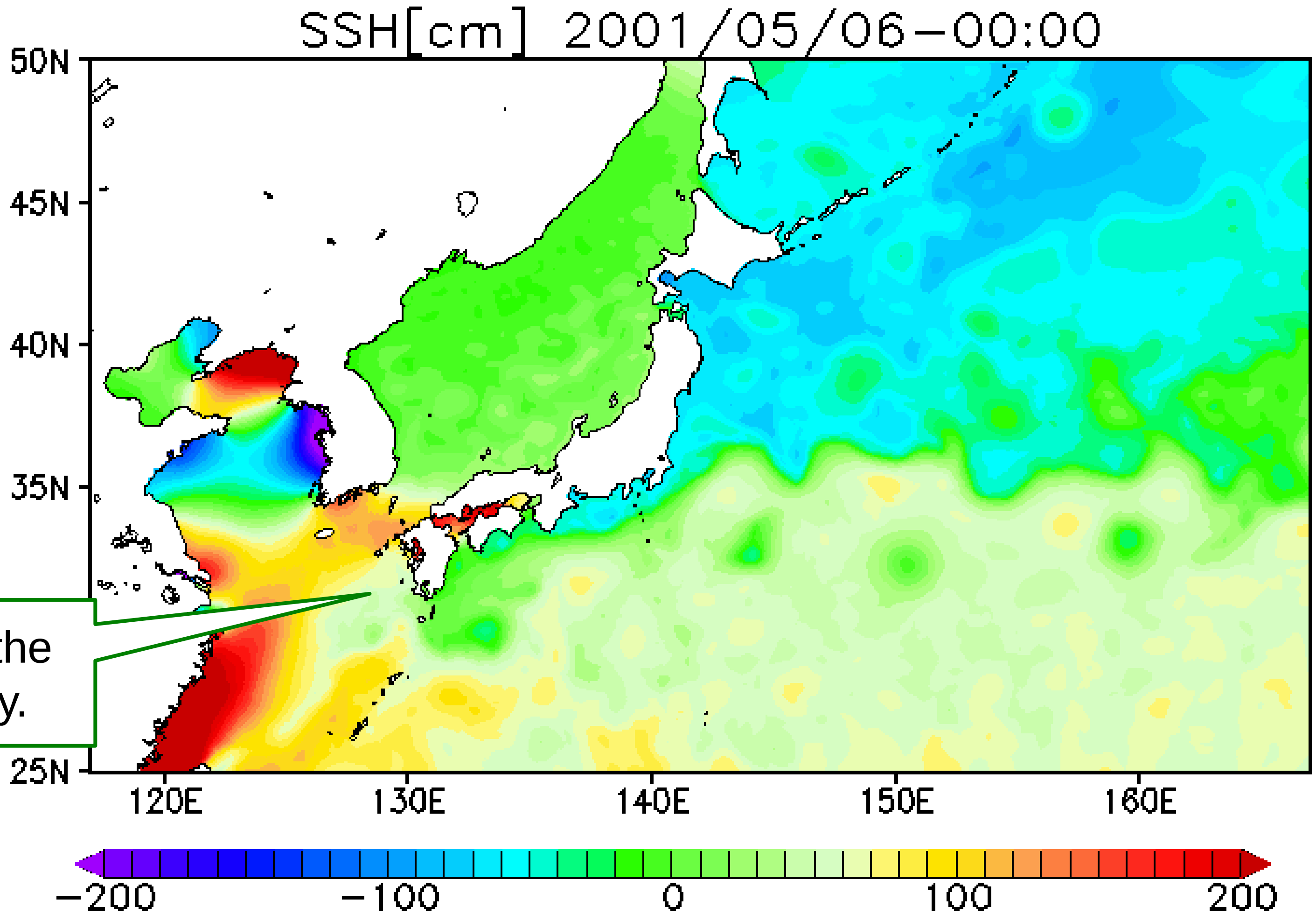




Results: tides

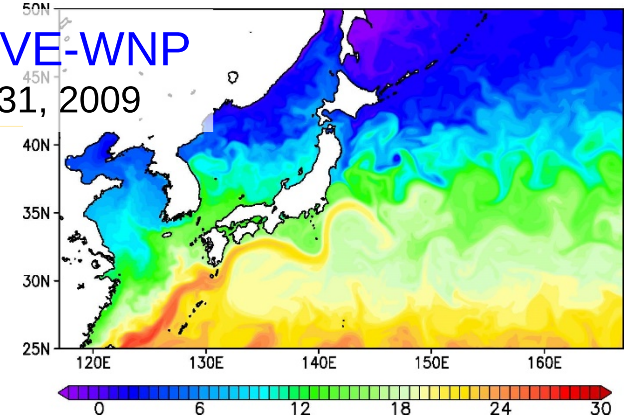
- Model Japan can reproduce tides and other ocean processes simultaneously.
  - Tides are dominant in SSH variation at the coasts of Japan.

SSH

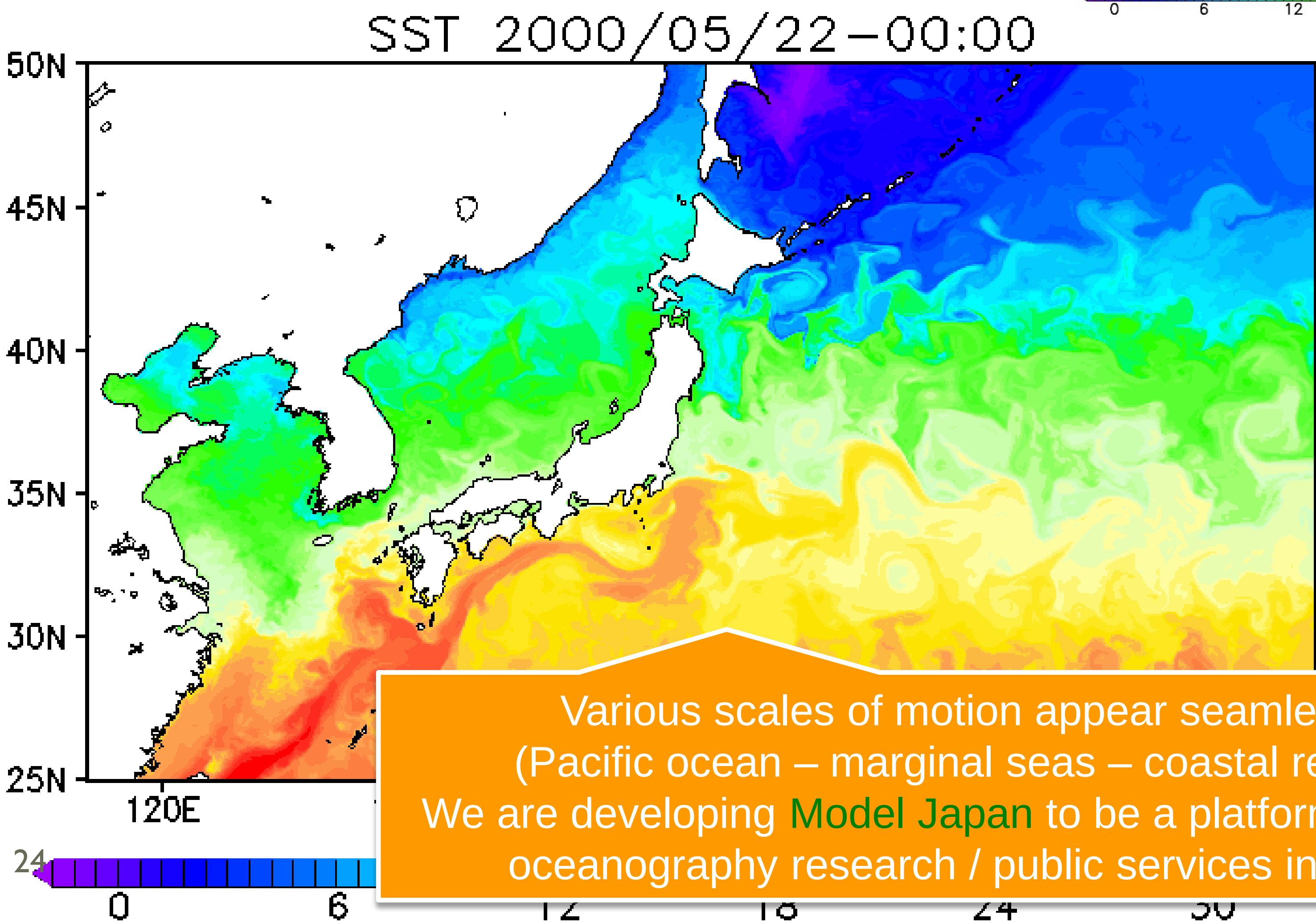


Tides would affect the ocean state strongly.

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