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The Development of JMA Wave Data Assimilation System

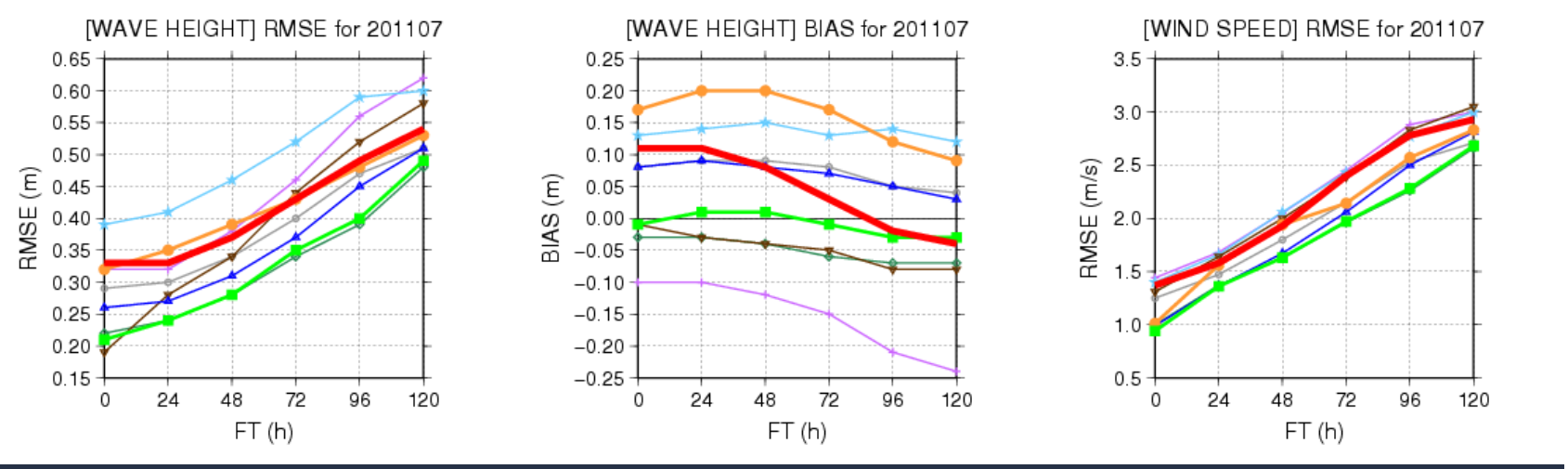
Nadao Kohno, Daisuke Miura, and Kumi Yoshita

Office of Marine Prediction, Global Environment and Marine Department, JMA
1-3-4, Ote-machi, Chiyoda, Tokyo 100-8122, Japan +81-3-3212-8341 (ext. 5139)

e-mail: nkono@met.kishou.go.jp

Motivation

Global wave model verification project (JCOMM) (July, 2011)



JMA wave model accuracy is not so good, especially at early forecast times.

The main reason is that wave observations are not incorporated in the wave models.

(The problem also seems to come from the JMA weather model…)

Improvement of initial condition is eagerly expected.

⇒ We developed a wave data assimilation system.

Method

(background)

- We developed the Objective Wave Analysis System (OWAS) and this system has been operationally used since December 1st, 2009.
- It analyzes wave heights by referring various observations.
- Since the OWAS results are supposed as the most reliable wave fields, initial condition is modified so as to fit with those analyses(wave heights).

(aim)

- By referring the wave height difference, wave spectra are modified by some way.
- It is desirable that windseas and swell are rectified respectively, if any.

Summary

- A wave data assimilation system has been developed . Wave data are not assimilated directly in this system. Instead, this system refers the analyzed wave heights of the JMA Objective Wave Analyses System (OWAS).
- In modification, windsea and swell parts are divided and modified respectively. The way of spectrum modification is based on the idea of the second generation wave models.
- The assimilation system showed good impacts. In verification tests, RSMEs were decreased by about 0.2 to 0.6m.
- The impact of assimilation was the largest in the Southern Hemisphere, where high waves exit and swell maintain the rectified information.
- The good impact of the assimilation system was confirmed, this system is going to be launched to the operation in the next year.

Analysis data (the OWAS products)

area	global area 75° S~75° N 180° W~0° ~180° E (cyclic)
grids	720 × 301
grid interval	0.5° × 0.5°
the first guess	Global Wave Model GPV (6hours forecast) *Coastal wave Model GPVs are used in the sea around Japan
analyzing method	Optimum Interpolation (OI) method
Observation data	Satellite (RA), buoy, ship, coastal recorders etc (Converted to 0.25 degree GPVs)
analysis time	4 times a day (00, 06, 12, and 18 UTC)

The outline of the OWAS was introduced in the 11th wave workshop.

The way of spectrum rectification

The OWAS product: wave height

The key value is the ratio of wave height between analysis and model

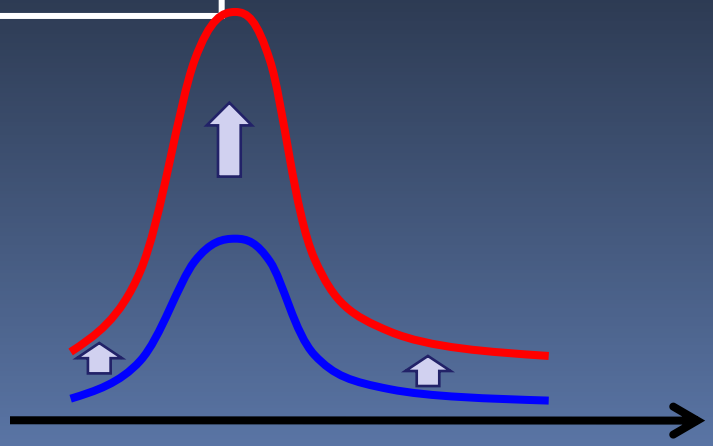
$$r = \frac{H_{w\_ana}}{H_{w\_mdl}} \qquad \left(r^2 = \frac{E_{ana}}{E_{mdl}} = \frac{E'}{E_{mdl}} \right)$$

Wave model: directional spectrum

The simplest modification

All spectrum components are rectified monotonously with this ratio

$$F(f,\theta)' = r^2 F(f,\theta)$$



The way of spectrum rectification

1. Extraction of windsea component.

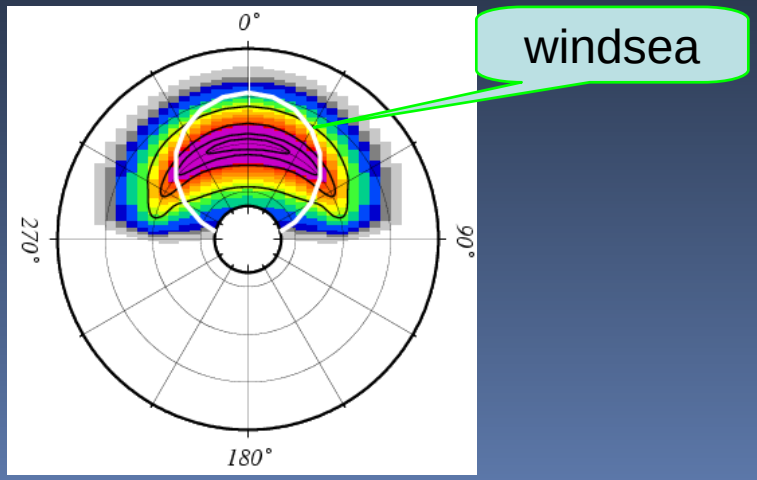
Windsea part $F_{sea}(f, \theta)$ is defined as

$$F_{sea}(f_w, \theta); \quad f_w > \frac{f_{cr}}{\cos\theta} \quad \left(|\theta| < \frac{\pi}{2}\right)$$

The threshold is

$$f_{cr} = 0.75 \cdot f_p = 0.75 \cdot \frac{0.13\,g}{u_{10}}$$

Where u_{10} is wind speed,



A simplified way of the second generation (CH) TOHOKU wave model (Toba et al., 1985).

2. Windsea rectification

Wind sea components are replaced with JONSWAP spectrum with the peak frequency f_p', where f_p' is determined from the model f_p supposing Toba's power low:

$$\left(\frac{f_p'}{f_p}\right)^3 = \left(\frac{H_{wsea}'}{H_{wsea}}\right)^2 = r^2$$

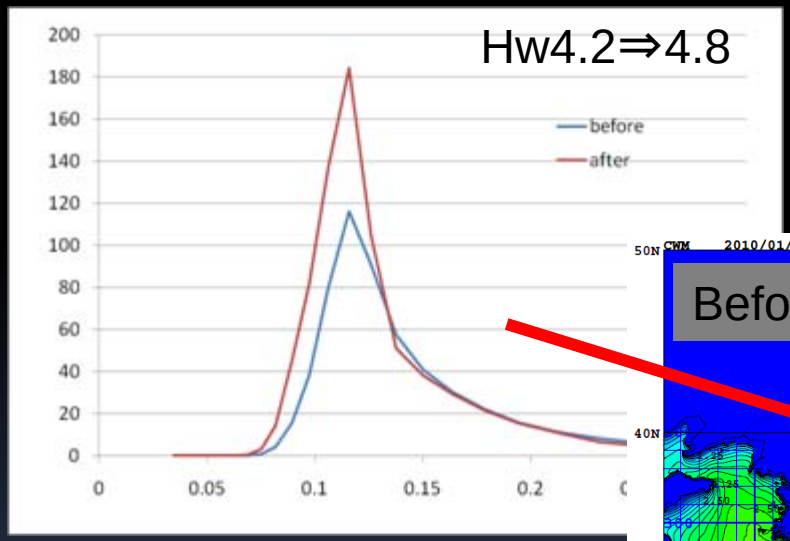
3. Swell rectification

We have no information on swell components. Therefore, swell components are simply modified with the energy difference.

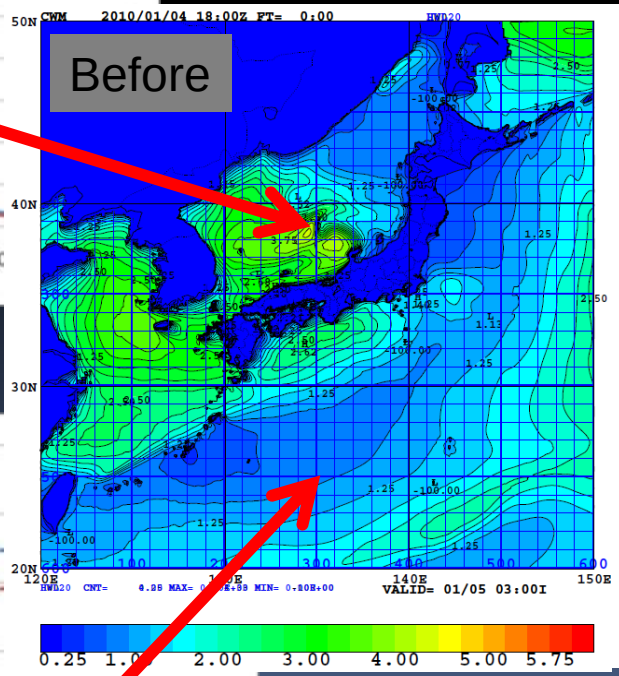
4. Total modification

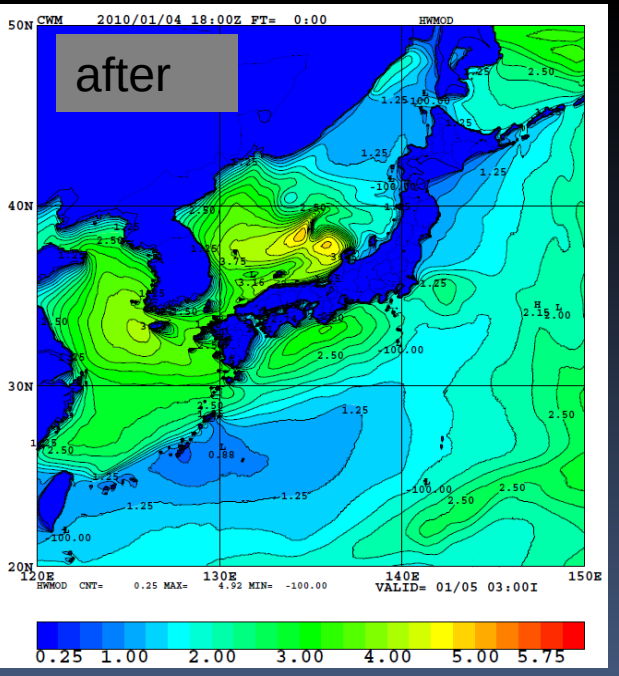
Finally, wave energy is modified so that wave height becomes analysis

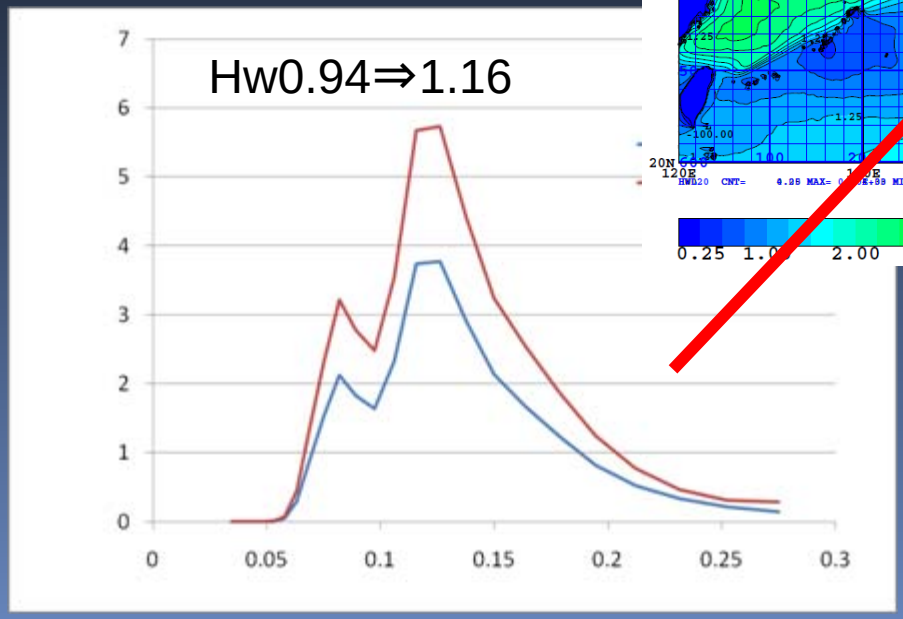
◆Examples of rectification



←Windsea dominant
The peak frequency is slightly shifted to lower frequency.







←<u>Swell dominant</u>
There is no change in spectrum profile

The assimilation cycle

- Wave models/OWAS run 4times a day (6 hourly)
- Available wave data at Initial in real time base are usually limited. However, appended data will be available a few hours later.
- Assimilation is carried out at the start time of hindcast (FT=-6) with appended data again.
- Then assimilation is also carried out at initial time (FT=0).

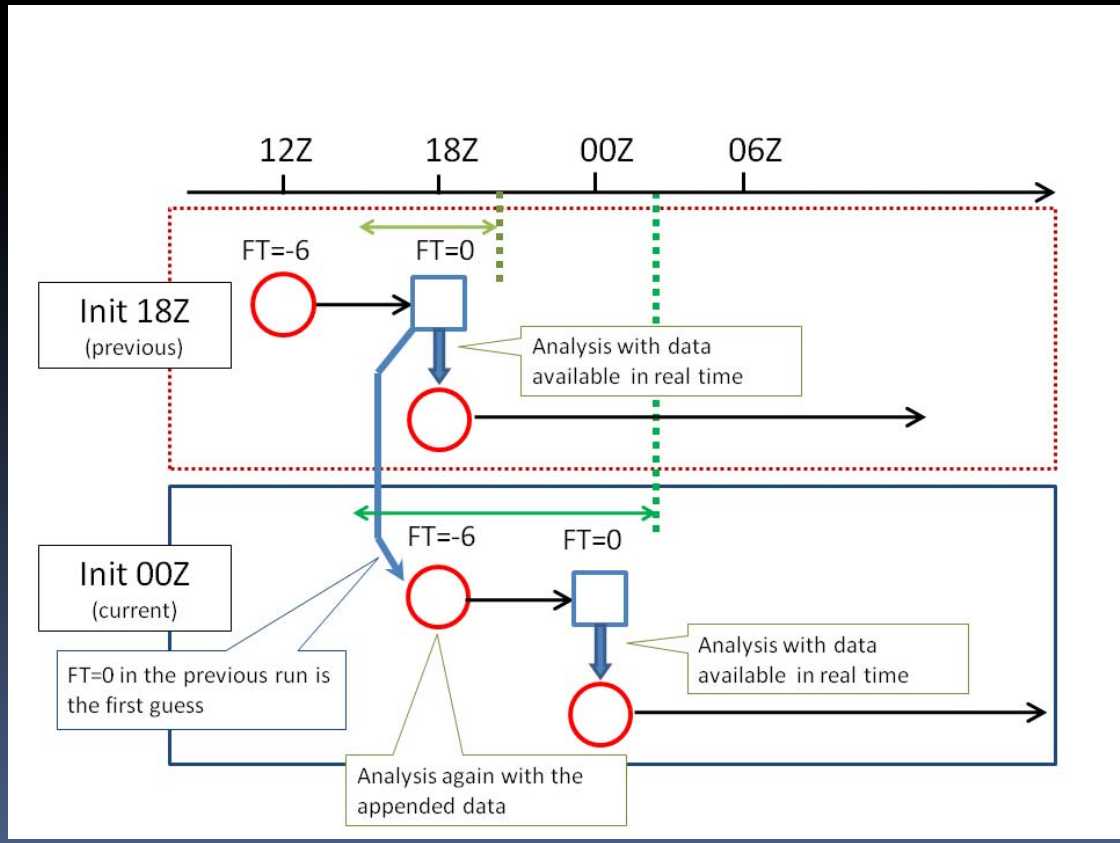


Image of assimilation cycle

Verification tests

- The global calculations
  - Winter: January 1-31, 2010
  - Summer: August 1-20, 2009
  - Autumn: October 1-31, 2009
- The regional calculation
  - Winter: January 1-20, 2010

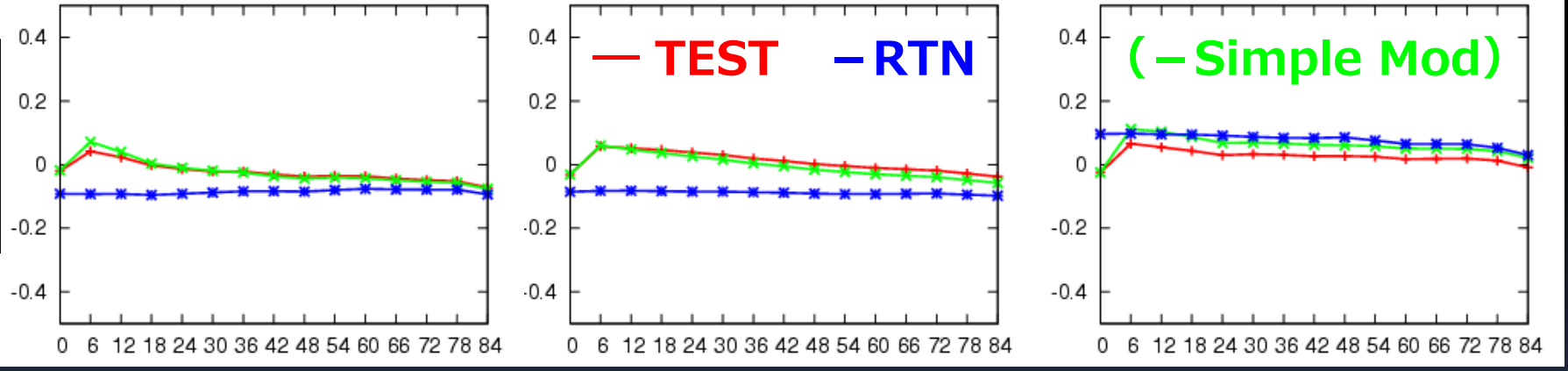
The calculated results were compared with observed data.
(Observed data: satellite (RA), buoys, and ships)

- TEST : assimilated results
- RTN : results of routine model (no assimilation)

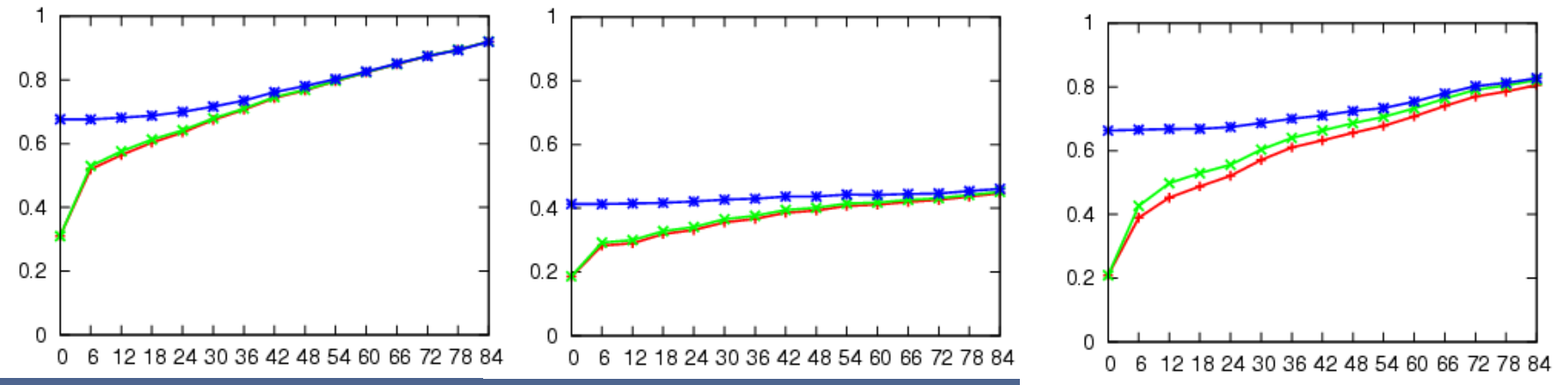
The global calculation result (January, 1-31, 2010)

Northern Hemisphere | Tropics | Southern Hemisphere

BIAS



RMSE



- The assimilation impact is preserved up to 72 hours forecasts
- The assimilation impact is large in the SH (swell maintain information, high waves exist)
- The bias becomes to change in early forecast times (problem of spin-up)
- The developed scheme gets the better results than the simple modification

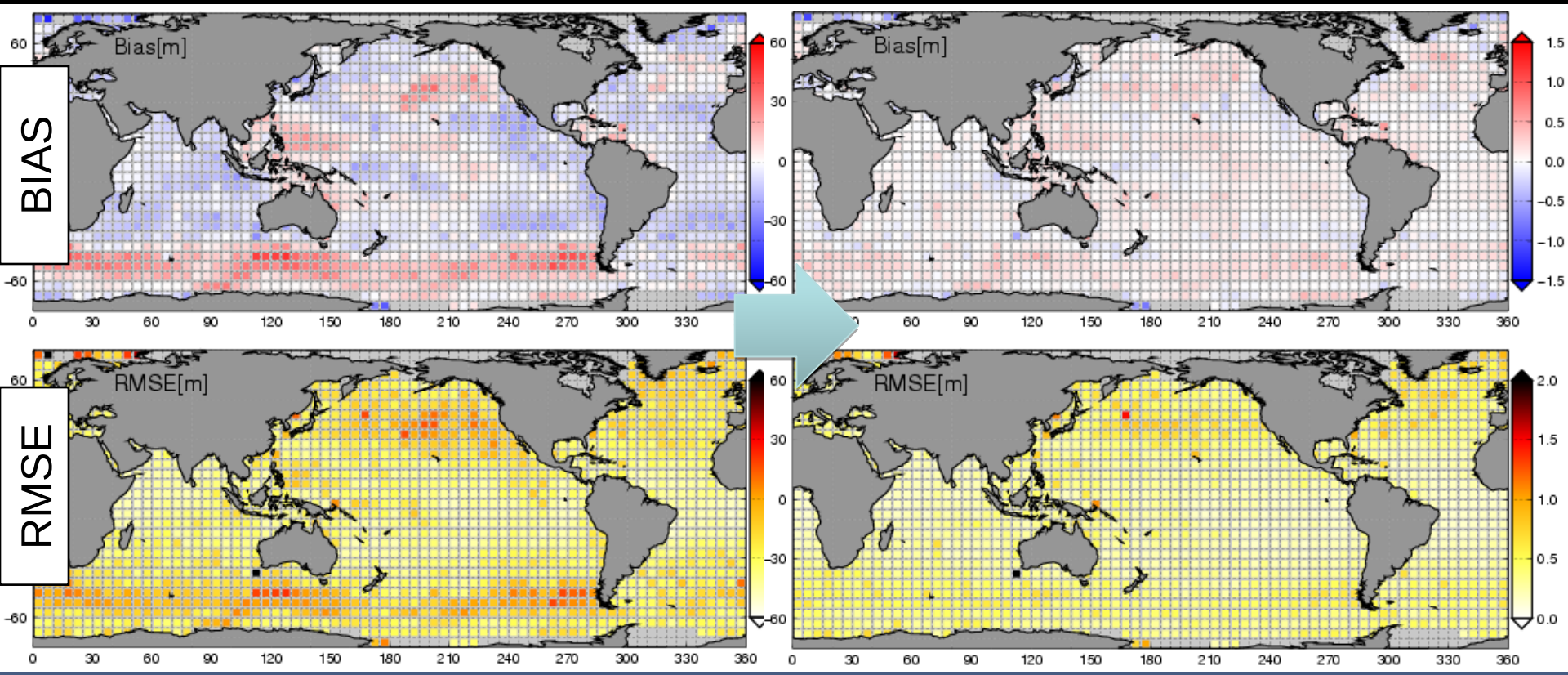
The scores at 6 hours forecast

RTN

TEST

BIAS

RMSE



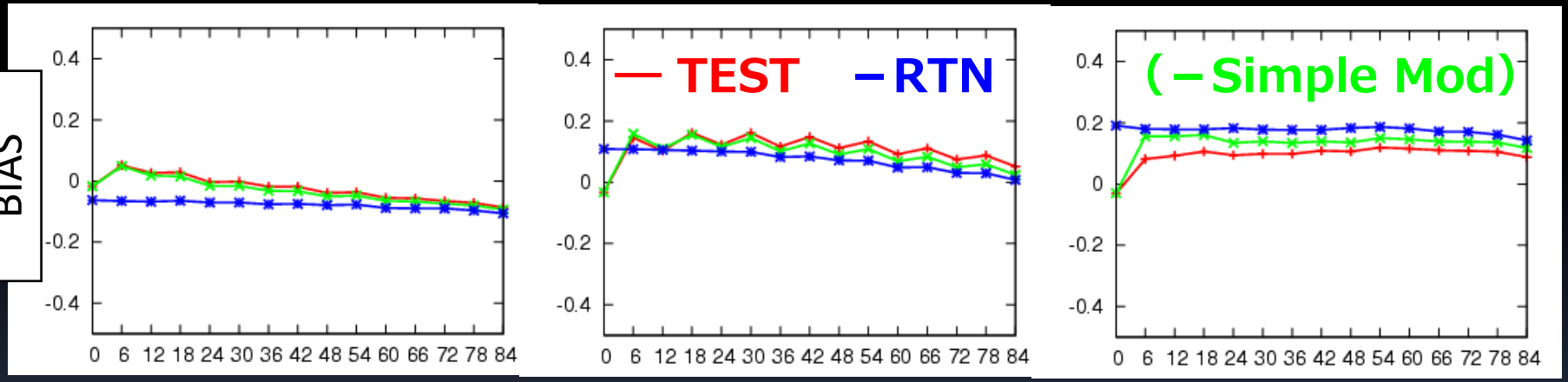
・The bias of RTN is large and has local dependency, but that of the assimilated run becomes homogeneous.

・The RMSE of the assimilated run becomes smaller as the removal of bias.

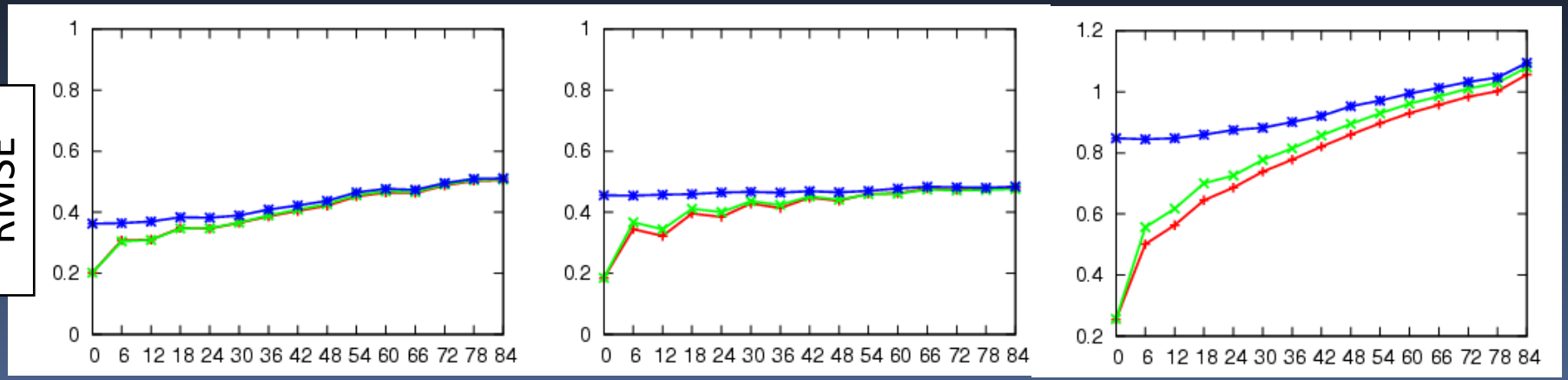
The global calculation result (August, 1-20, 2009)

Northern Hemisphere | Tropics | Southern Hemisphere

BIAS

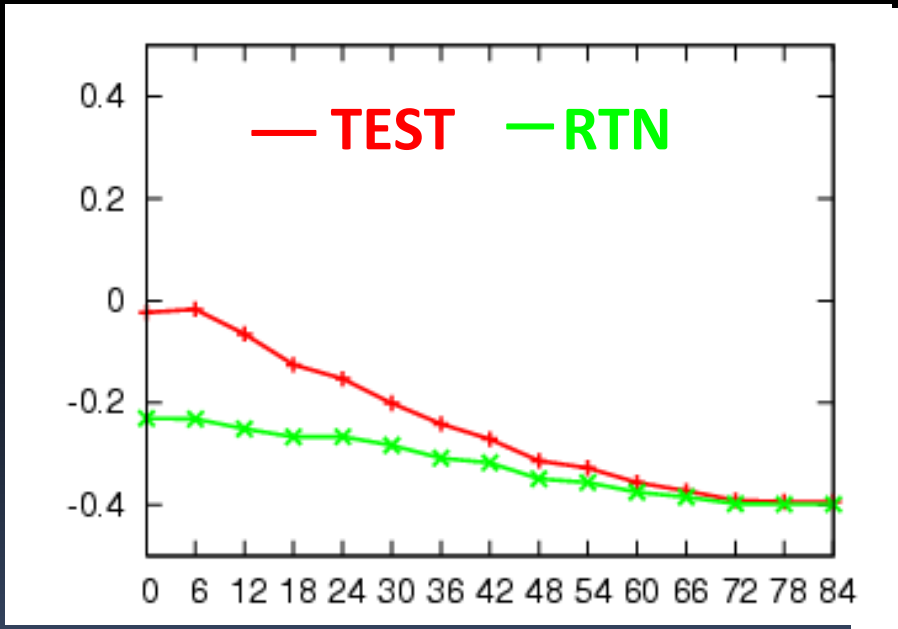


RMSE

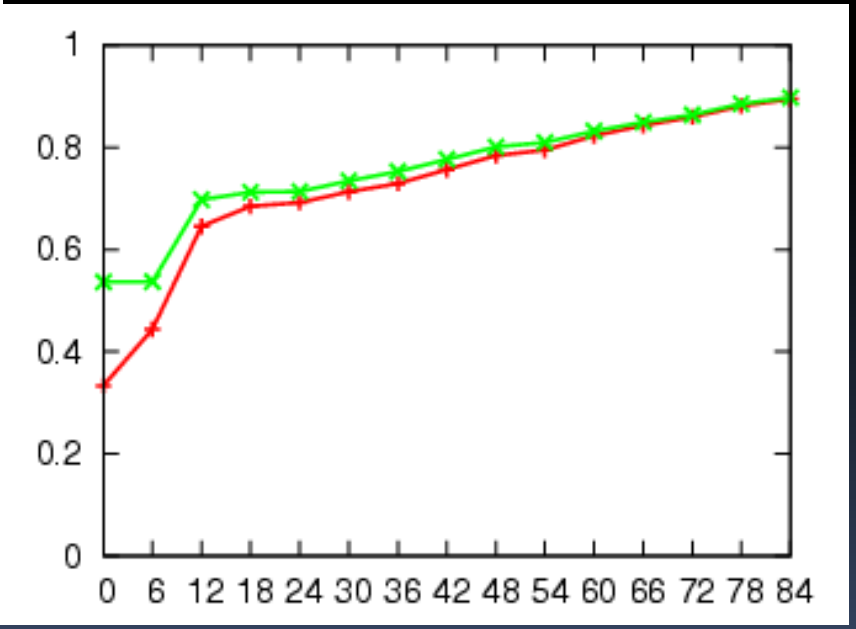


The regional calculation results (Jan. 1-20, 2010)

BIAS



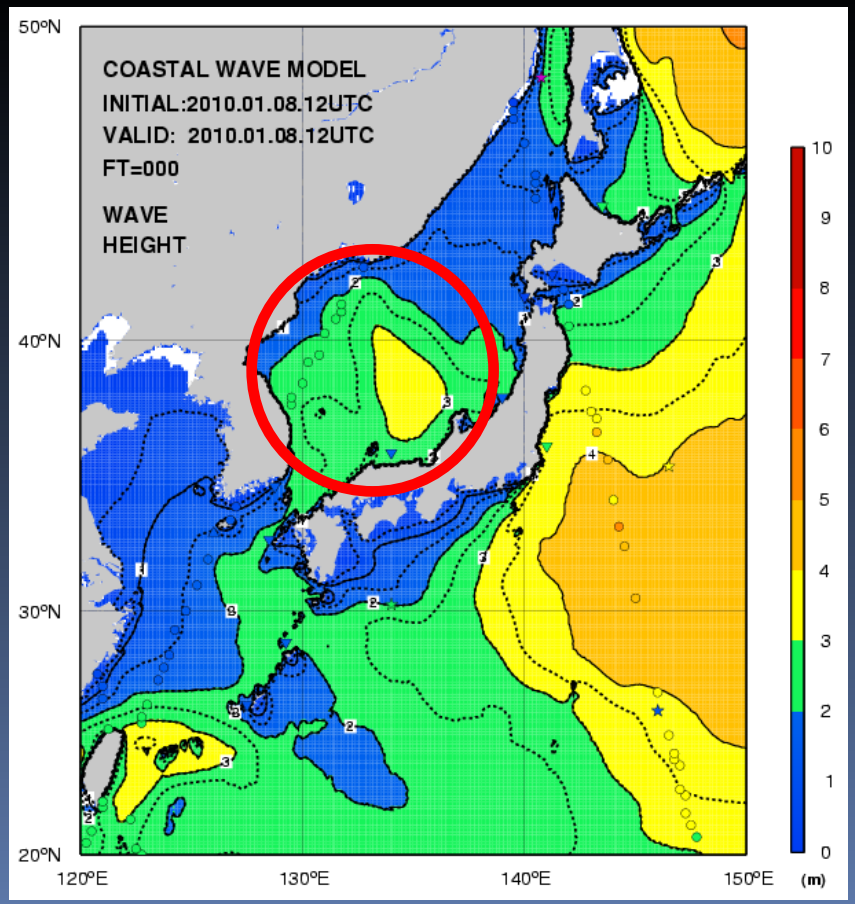
RMSE



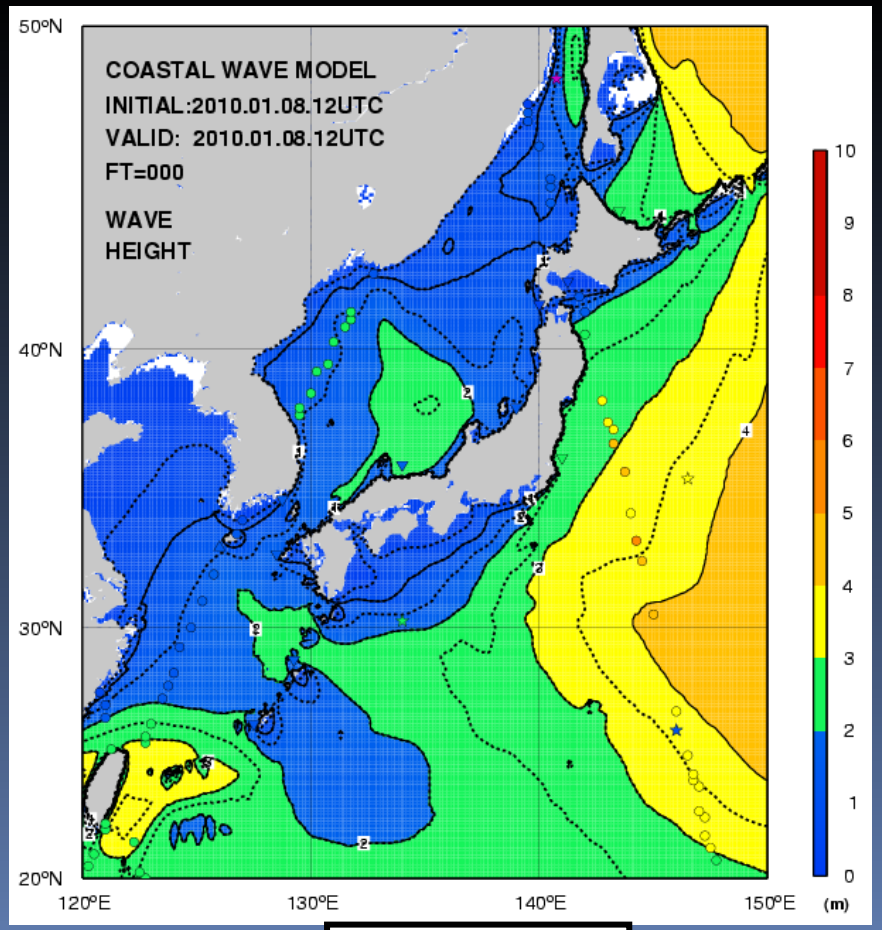
・The impact is detectable but much smaller than the global results and quickly disappears.
・Not so effective as the global model

An example of modification
Initial:12UTC on 8 Jan. 2010

FT=0



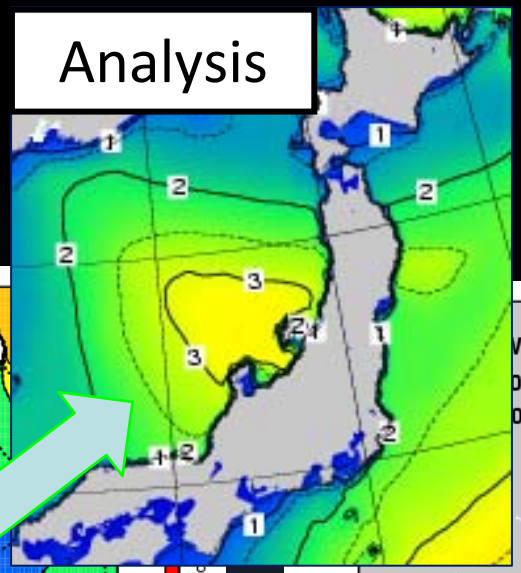
TEST

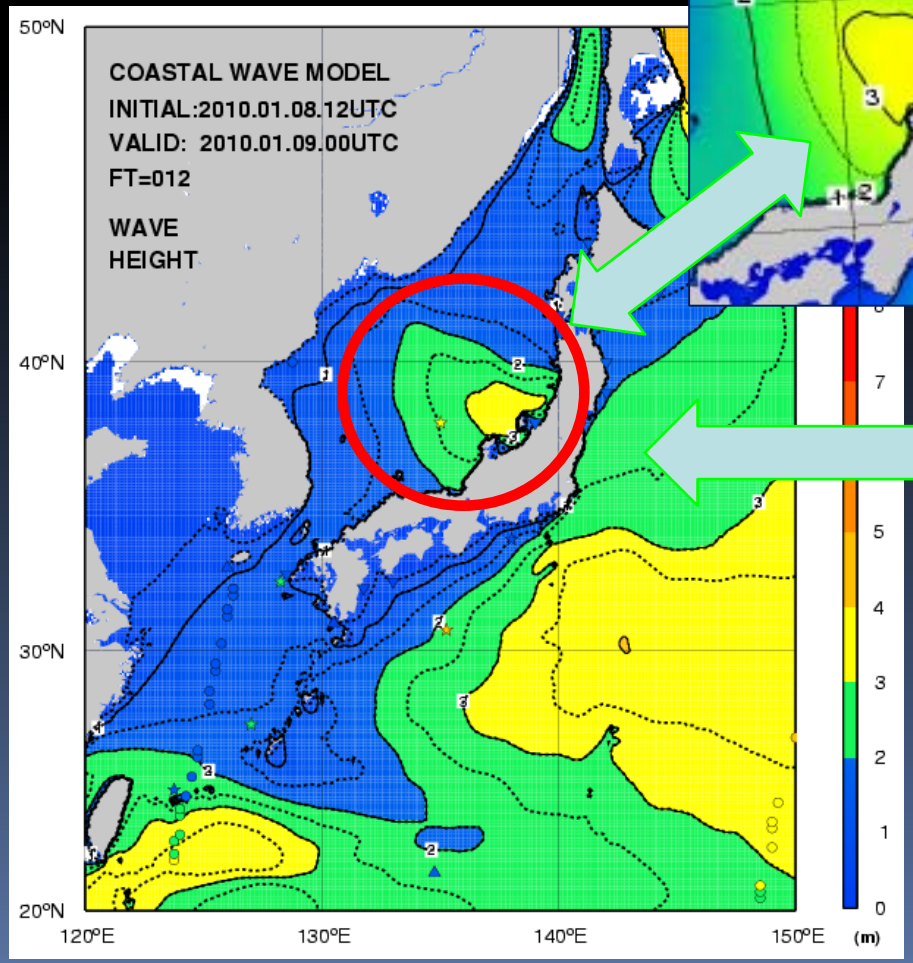


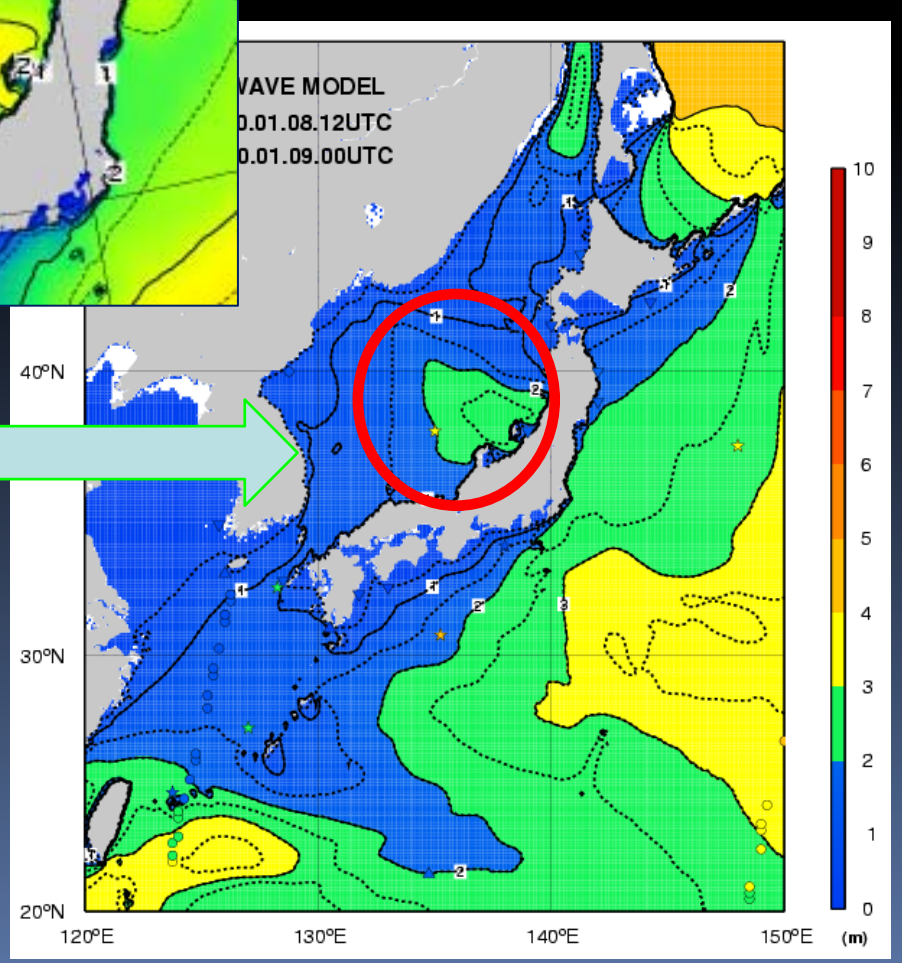
RTN

FT=12

Analysis







TEST

RTN

Summary

- In our system, windsea and swell parts are partitioned and modified respectively. Windsea spectra are modified supposing the JONSWAP spectrum profile. The peak frequency is determined by considering Toba's power law. As for swell spectrum modification, we monotonously rectify their energy by the wave height difference.
- The assimilation system showed good improvement of accuracy in all tests. In verification tests, assimilation system decreased RSME by about 0.2 to 0.6m.
- The assimilation impact is apparent and maintained longer in global calculations. The reason may be that swell preserve the information. Also, there is much possibility for large rectification because high waves usually exist in global area.

Further developments

- This system uses results of the OWAS. The statistic RMSE of the OWAS is about 0.4m and it should be improved. We have a plan to further develop the OWAS, by introducing the 3D-VAR method instead of the OI method.
- In the assimilation system, no observed wave spectrum is used. However, that information is crucial, especially to modify model spectra in detail. We would like to consider a way to utilize wave spectrum observations.

Thank you!