Recent updates of JMA's wave models and their products

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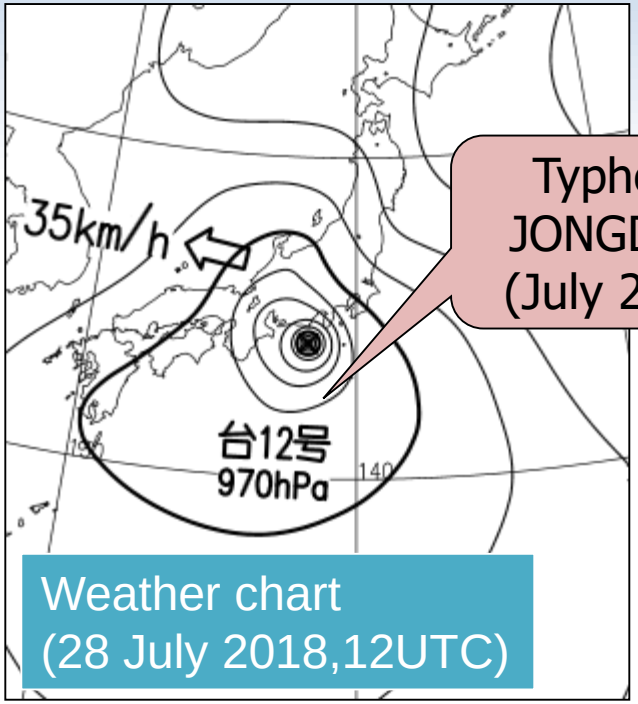
Global Environment and Marine Department

Japan Meteorological Agency (JMA)

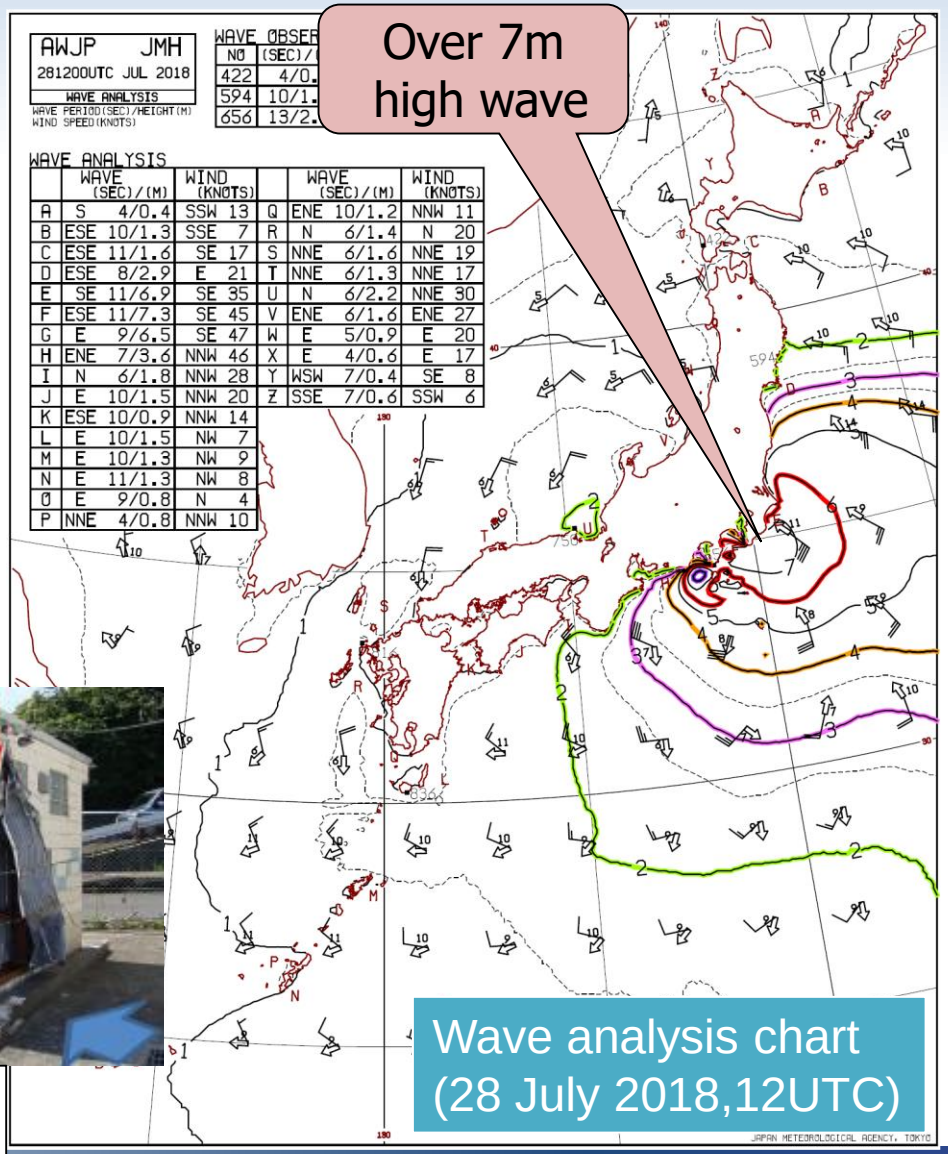
Disaster related to high waves (July. 2018)



Typhoon JONGDARI (July 2018)

Weather chart (28 July 2018,12UTC)

A house and a public restroom on the seaside were destroyed by high waves.



Over 7m high wave

Wave analysis chart (28 July 2018,12UTC)

Introduction

✓ Implementation of shallow water effects

Succeeded in improving the accuracy at shallow water areas in wave height.

✓ Probabilistic wave forecast products

For evaluating possibility of swell coming from far areas and their risk in coastal areas.

✓ Improvement plans

JMA plans to introduce higher resolution to

both deterministic models and ensembles in the coming years.

Table of Contents

- Implementation of shallow water effects
- Probabilistic wave forecast products
- Improvement plans

Operational wave models at JMA

	Global Wave Model (GWM)	Coastal Wave Model (CWM)	Wave Ensemble System (WENS)
model type	**MRI-III** (Third generation wave model)		
calculation area	global area 75° S～75° N 180° W～180° E	sea around japan 20° N～50° N 120° E～150° E	global area 75° S～75° N 180° W～180° E
grid resolution	0.5° × 0.5°	0.05° × 0.05°	1.25° × 1.25°
wave spectrum components	900 components （25 in frequency × 36 in direction） frequency：0.0375～0.3Hz；logarithmically divided direction：10 degree interval		

added Shallow Water Effects(SWEs)

Considered SWEs

◆Refraction

Changes in water depth (change in the velocity)
effect on wave height and direction.

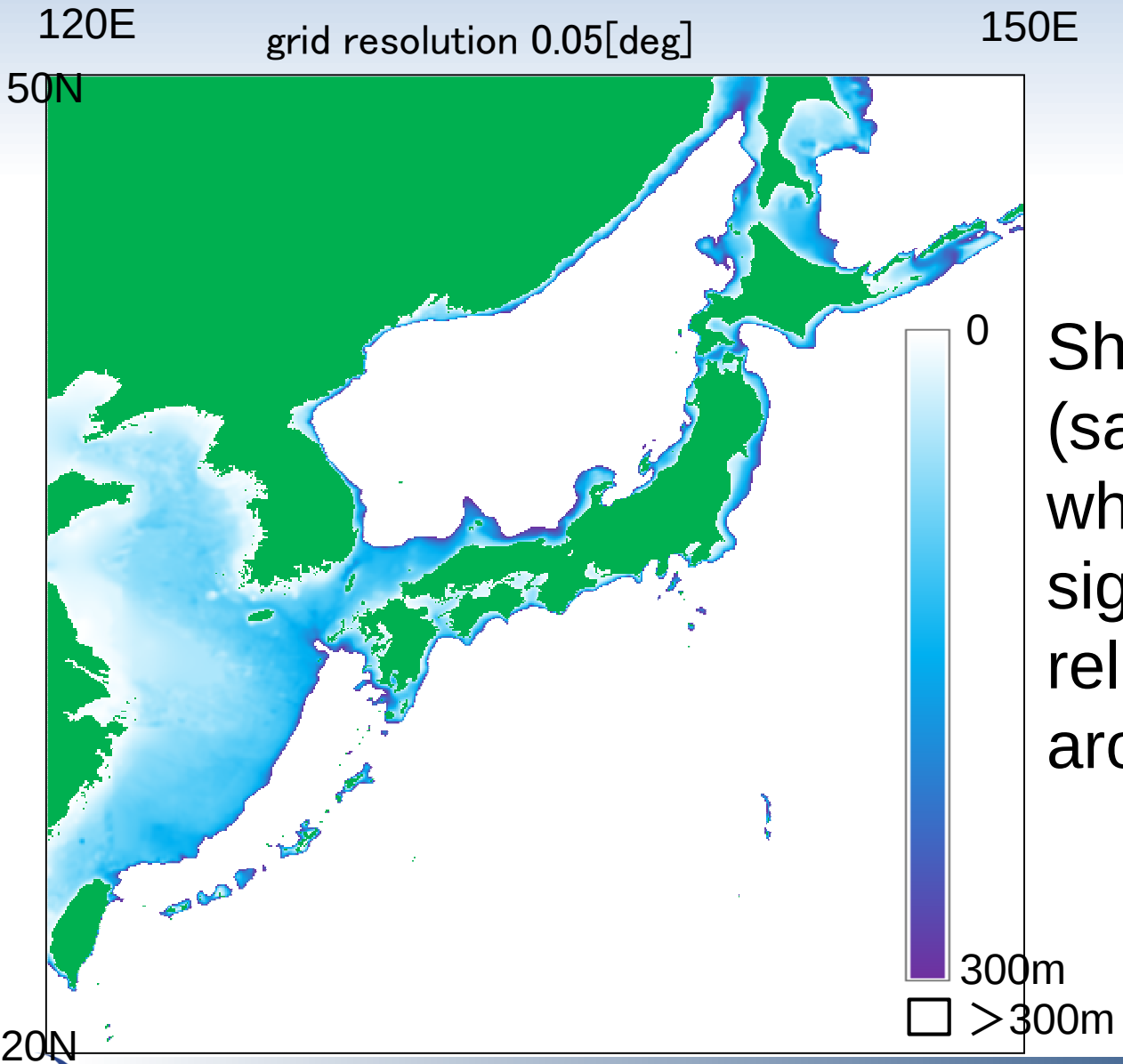
◆Energy dissipation by bottom friction

◆Non-linear energy transfer

Enhancement happens in shallow water area,
which leads to quick evolution.

The shallower the water depth and
the lower the frequency component,
the greater the enhancement.

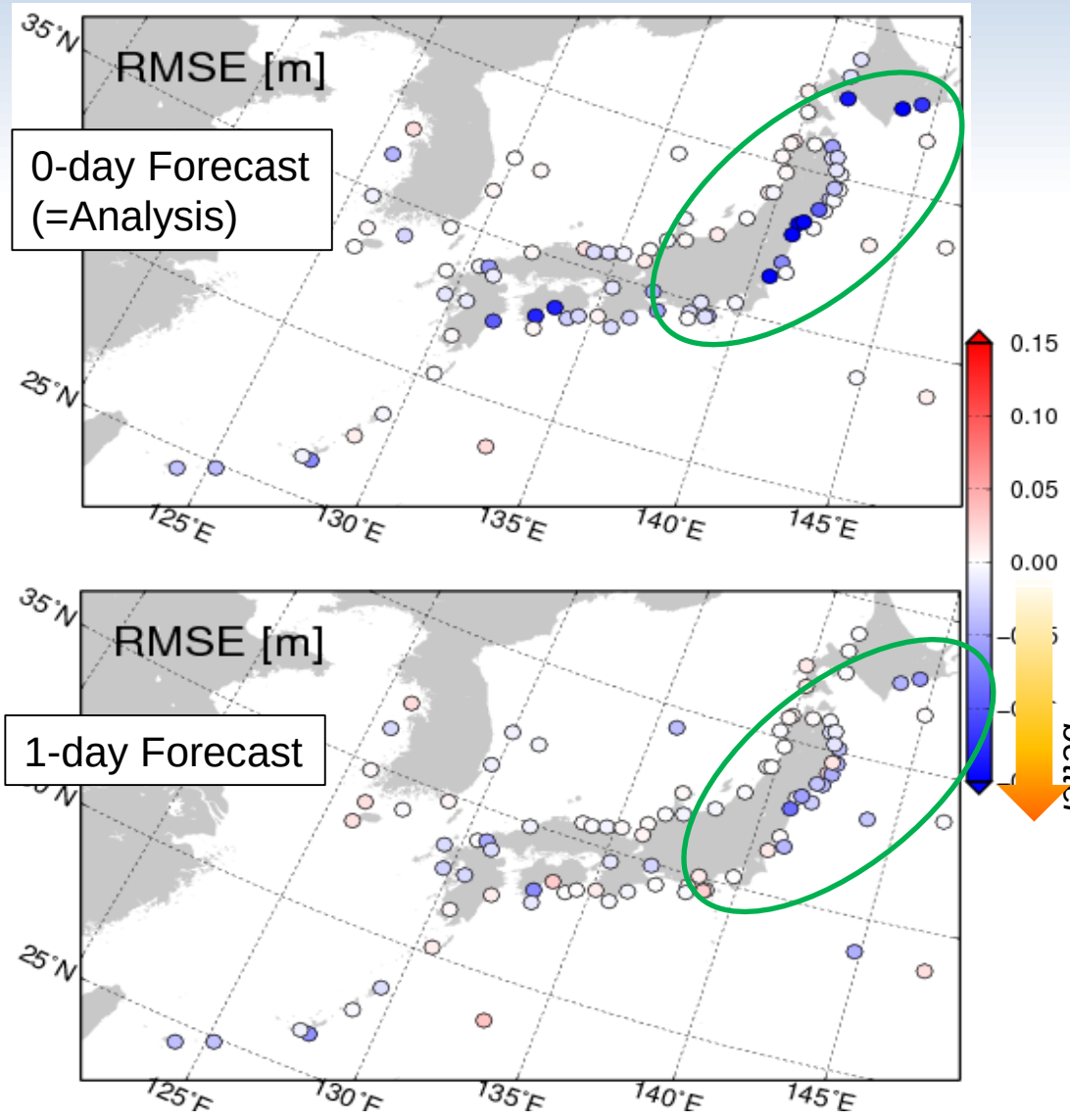
Water depth in Costal Wave Model



Shallow sea areas (say, depth < 100m), where SWEs are significant, are relatively narrow around Japan

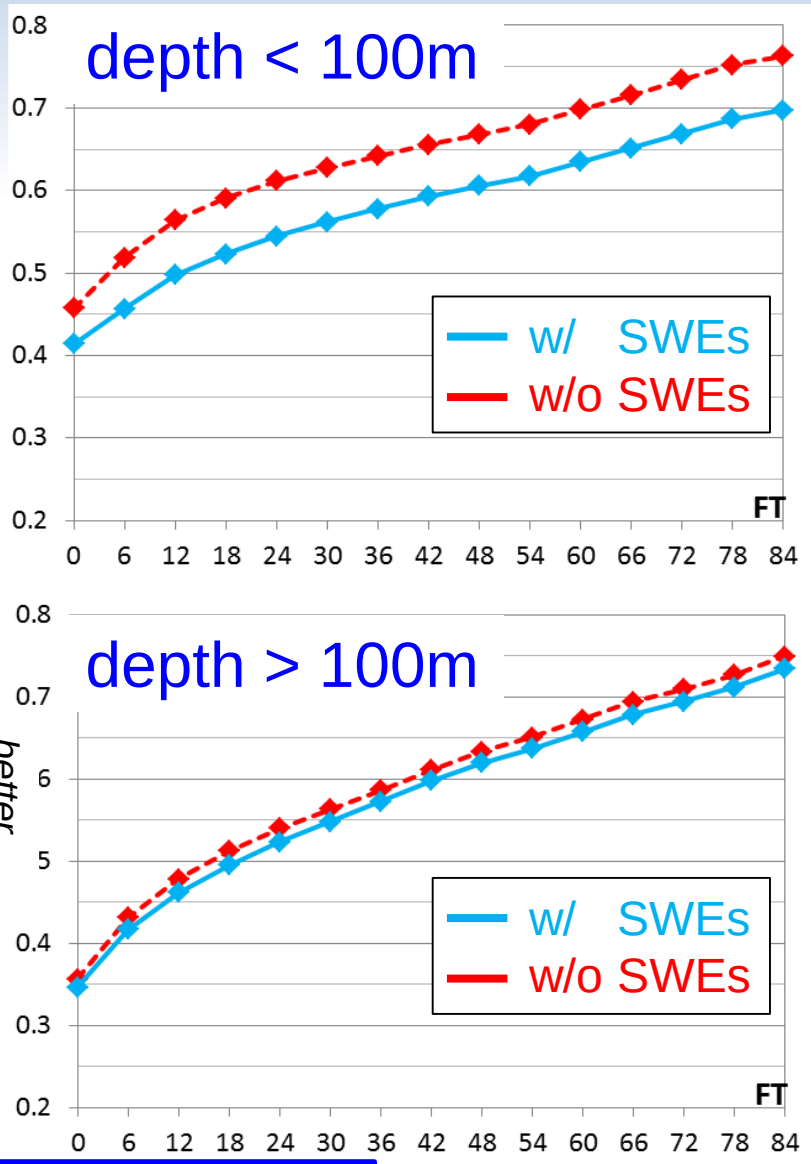
RMSE DIFF:w/SWEs – w/o SWEs

(V.S. Coastal buoys)



RMSE comparison

(V.S. Nothern Hemisphere buoys)



TERM:SUMMER(Jul-Sep.2016)

Table of Contents

- Implementation of shallow water effects
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- Improvement Plans

Operational wave models at JMA

NOW FOCUS ON

	Global Wave Model (GWM)	Coastal Wave Model (CWM)	Wave Ensemble System (WENS)
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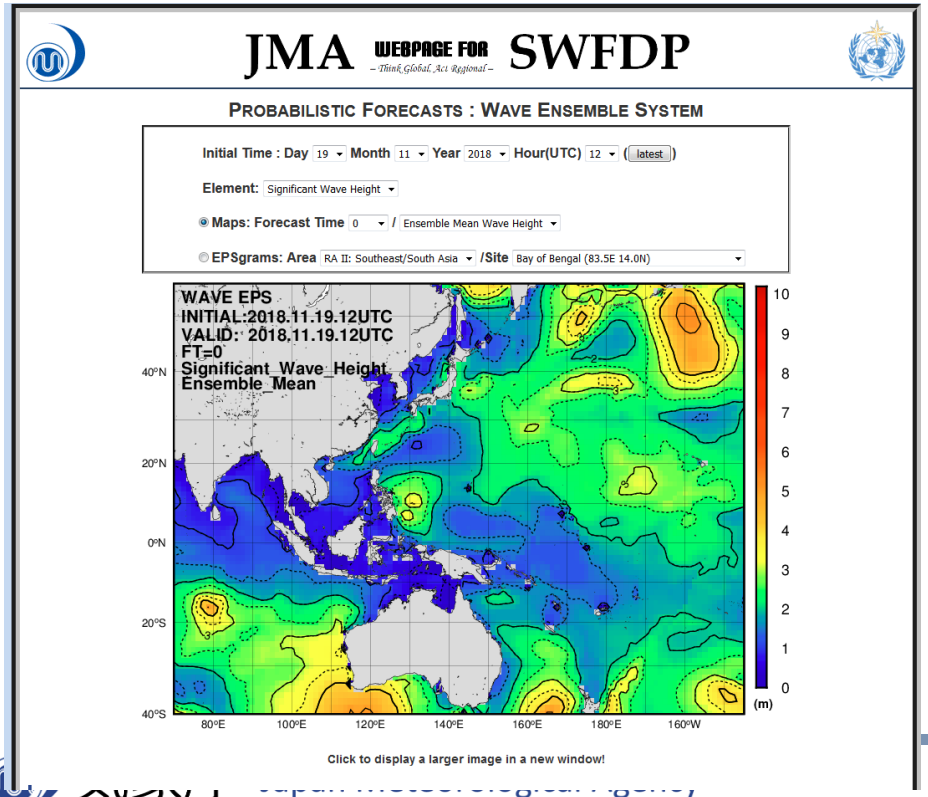
Forced by Global Ensemble Prediction System
(40km grid, 27 members)

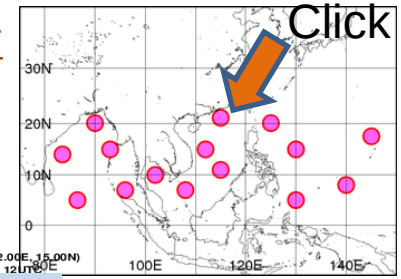
Products of WENS

- JMA started operating the Wave ENsemble System (WENS) in June 2016.
- WENS products are available at SWFDP web site since 2017.
- Products on wave period are added in 2018.

Probabilistic forecast maps

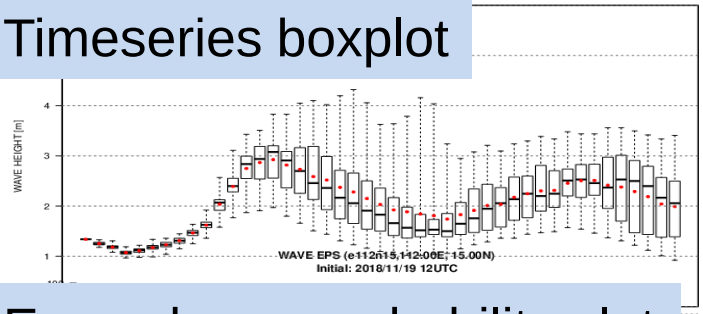


EPSgrams at stations

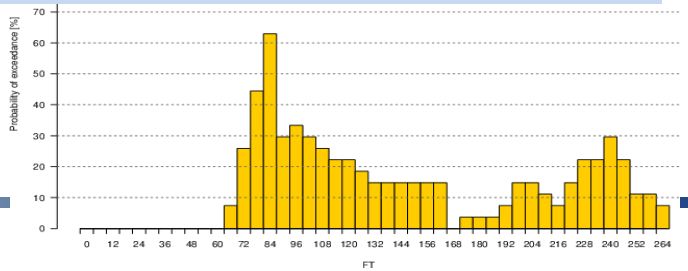


appear

Timeseries boxplot



Exceedance probability plot



WMO Severe Weather Forecasting Demonstration Project (SWFDP)

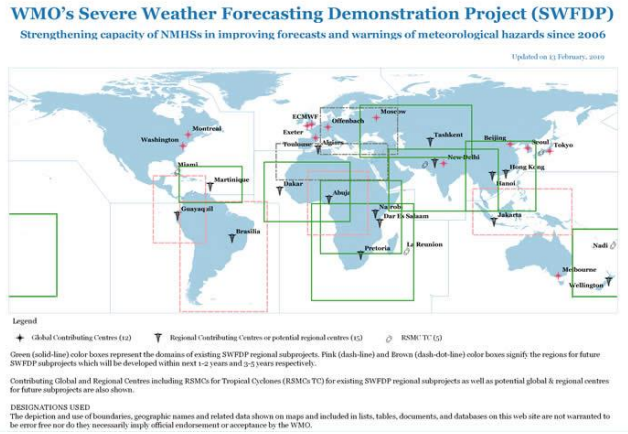
◆ Purpose

- ✓ To strengthen capacity in National Meteorological and Hydrological Services (NMHSs)
- ✓ To deliver improved forecasts and warnings of severe weather to save lives, livelihoods and property.

◆ Role of JMA

- ✓ As a global centre, JMA contributes to SWFDP regional subprojects:
  - ➢ South Pacific Islands (RA-V)
  - ➢ Southeast Asia
  - ➢ Bay of Bengal
  - ➢ Central Asia (RA-II)

by providing NWP information etc. through its SWFDP web.

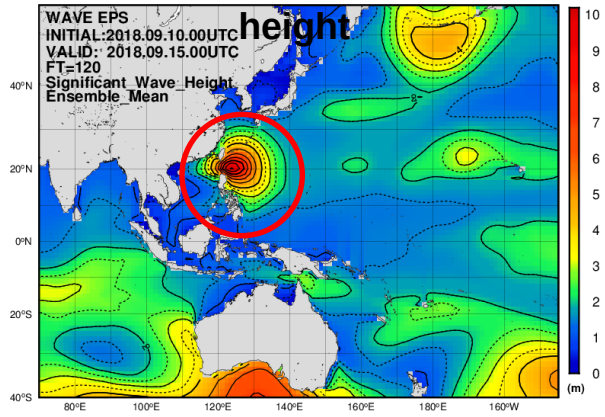


Map products (significant wave height)

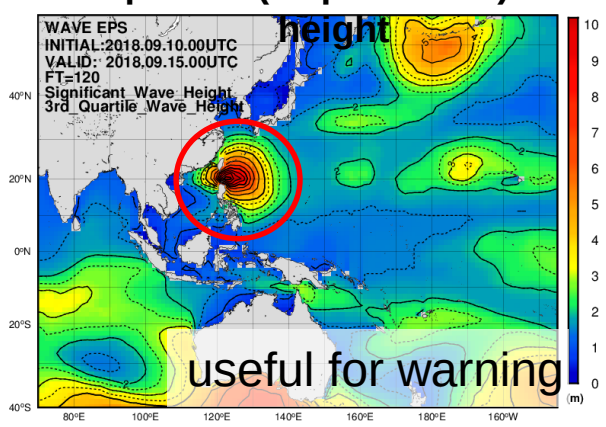
Case 1: Typhoon Mangkhut (T1822)

Results of 5-day forecast (Initial: 00UTC on Sep/10/2018)

Ensemble mean wave height

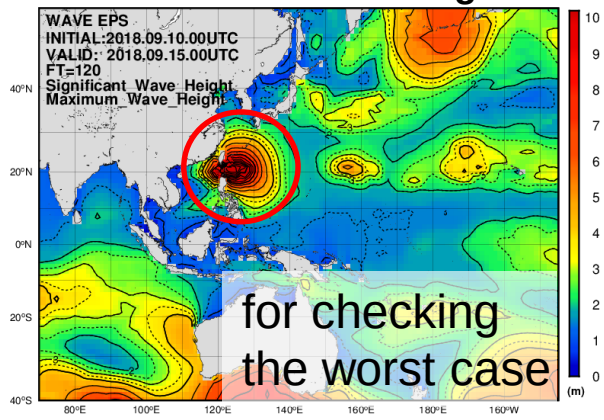


3rd quartile (75 percentile) wave height



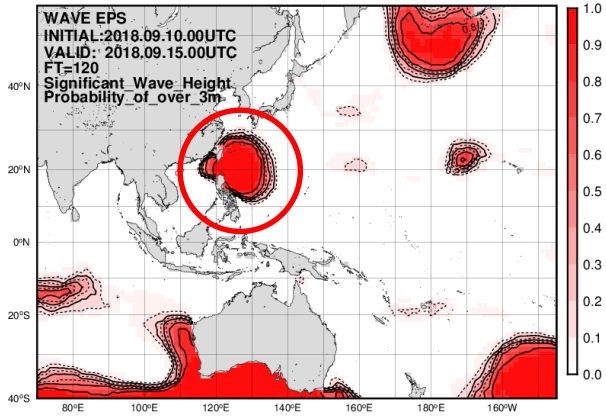
useful for warning

Maximum wave height

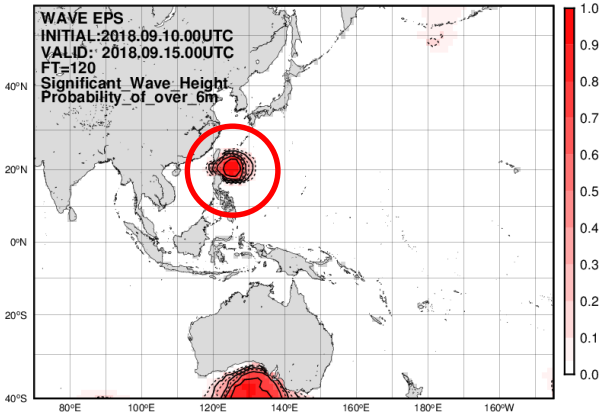


for checking the worst case

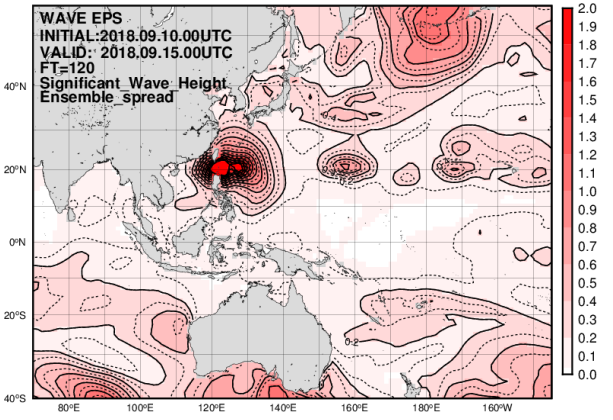
Probability of Hw > 3m



Probability of Hw > 6m



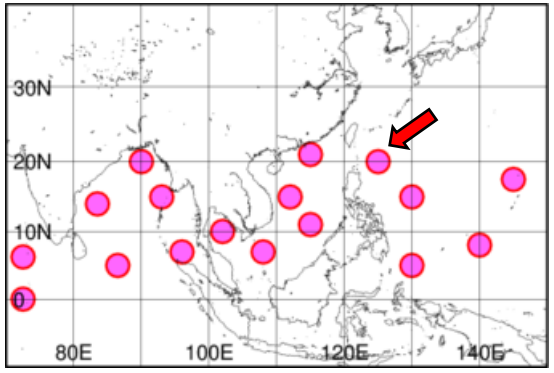
Ensemble spread



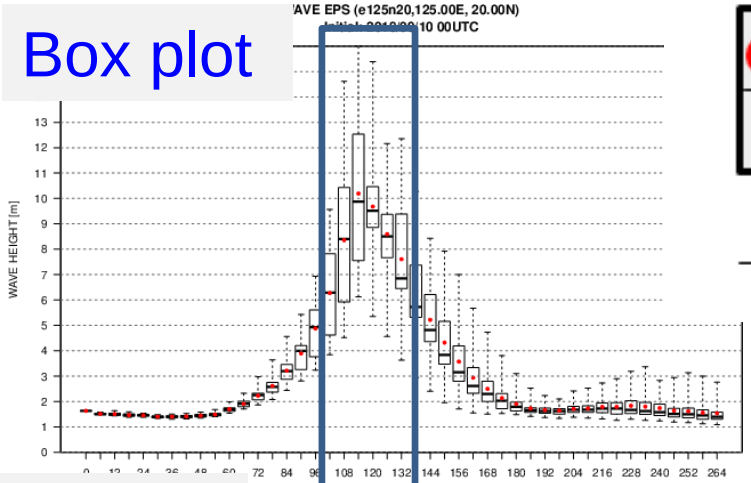
EPSgrams at stations (significant wave height)

Case 1: Typhoon Mangkhut (T1822)

Time series (Initial: 00UTC on Sep/10/2018)



Box plot



Maximum

The 3rd quartile

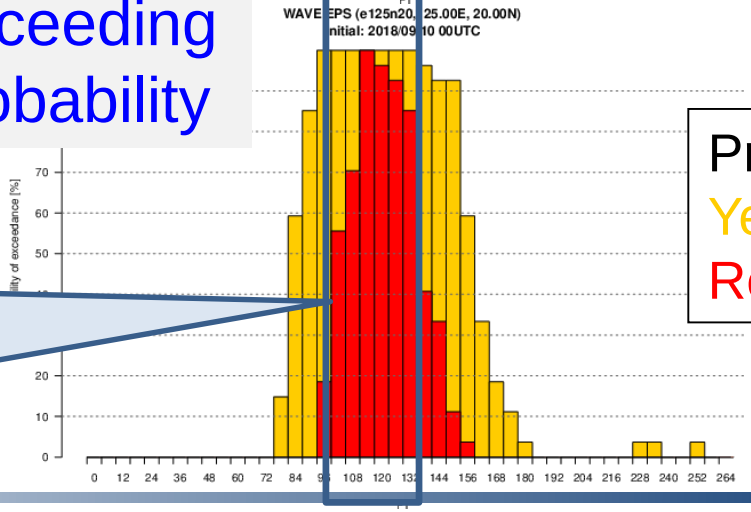
Mean

Median

The 1st quartile

Minimum

Exceeding probability



Wave heights larger than 6m were predicted by many members.

Probability

Yellow: Hw > 3m

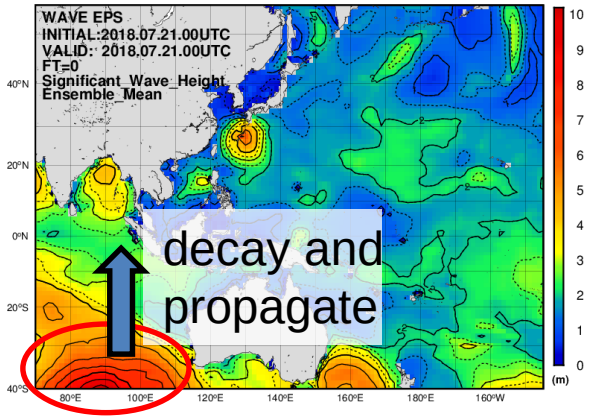
Red: Hw > 6m

Probabilistic forecast maps (peak wave period)

Case 2: the swell from the Southern Ocean

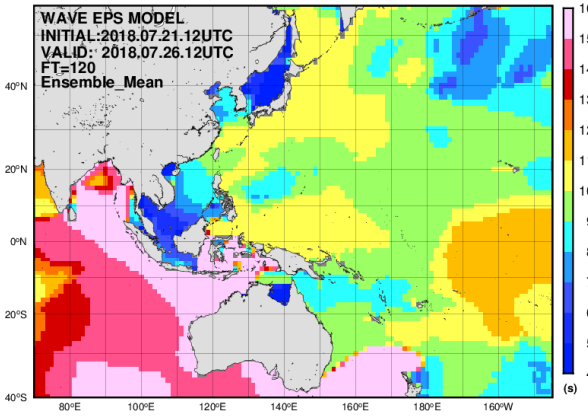
Results of 5-day forecast (Initial: 12UTC on Jul/21/2018)

Significant wave height (FT=0)

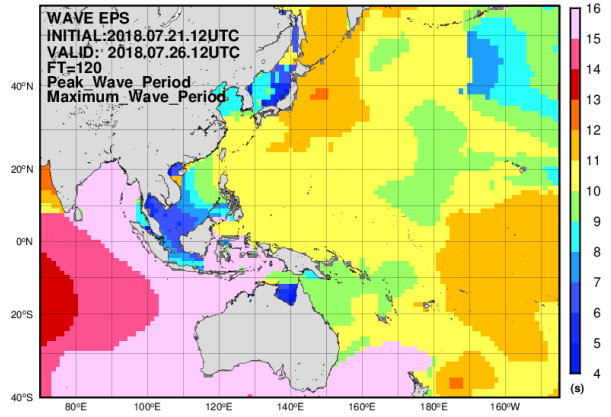


Severe storm on 40S

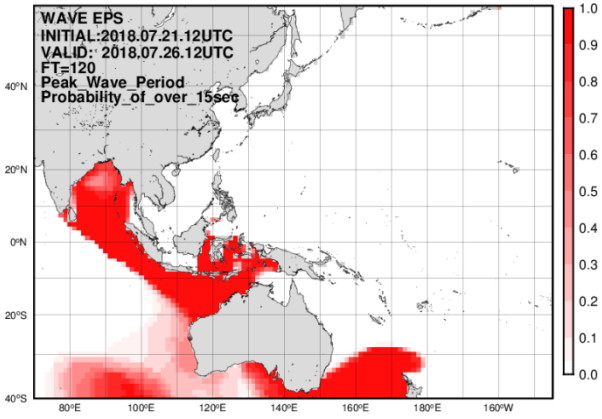
Mean wave period



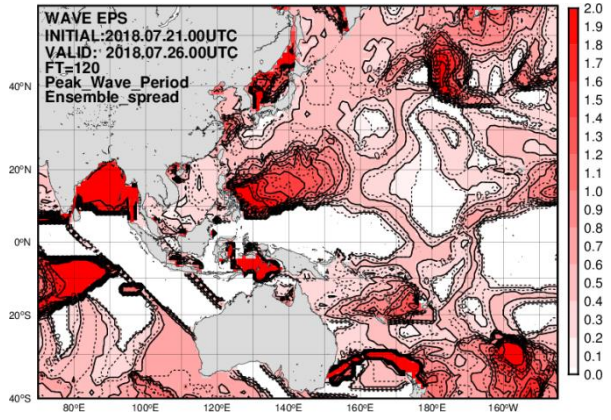
Maximum wave period



Probability of Pw > 15s



Ensemble spread

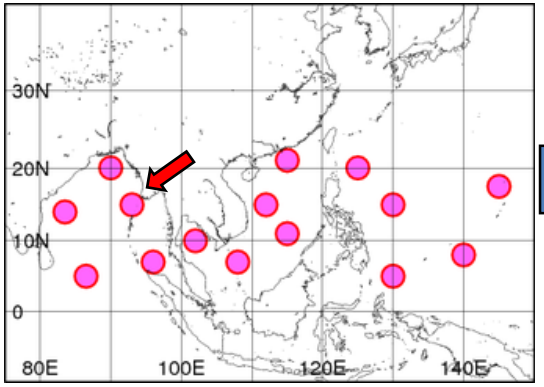


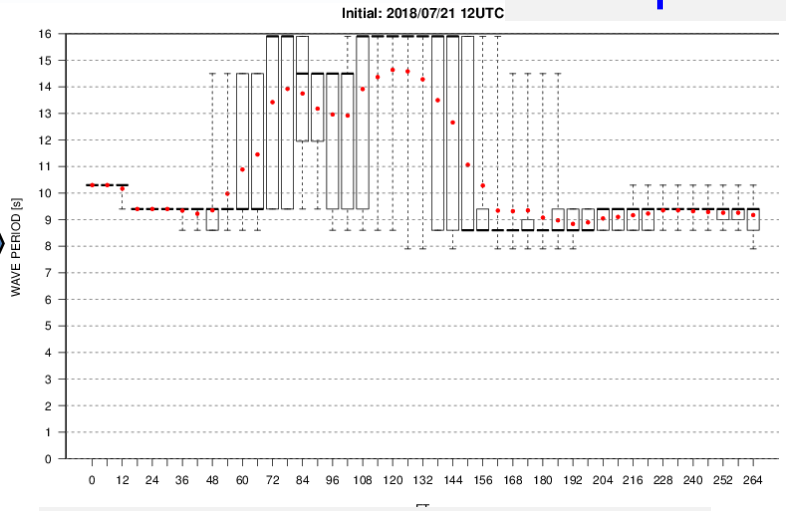
EPSgrams at stations (peak wave period)

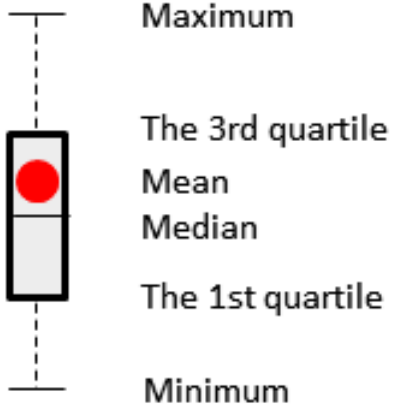
Case 2: the swell from the Southern Ocean

Time series (Initial: 12UTC on Jul/07/2018)

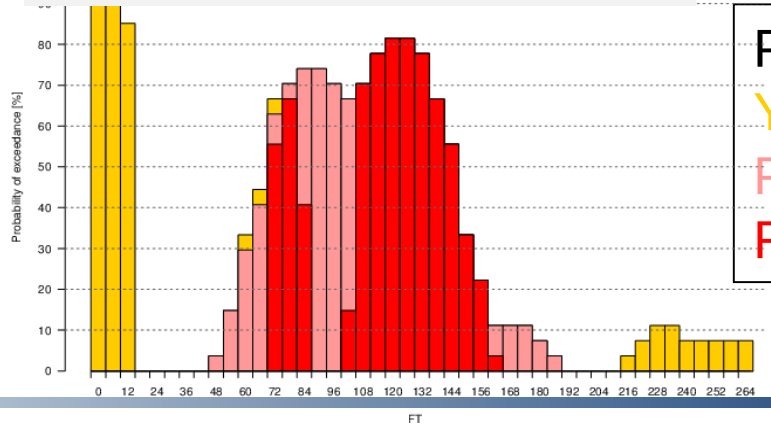
Box plot







Exceeding probability



Probability
Yellow: Pw > 10s
Pink: Pw > 12s
Red: Pw > 15s

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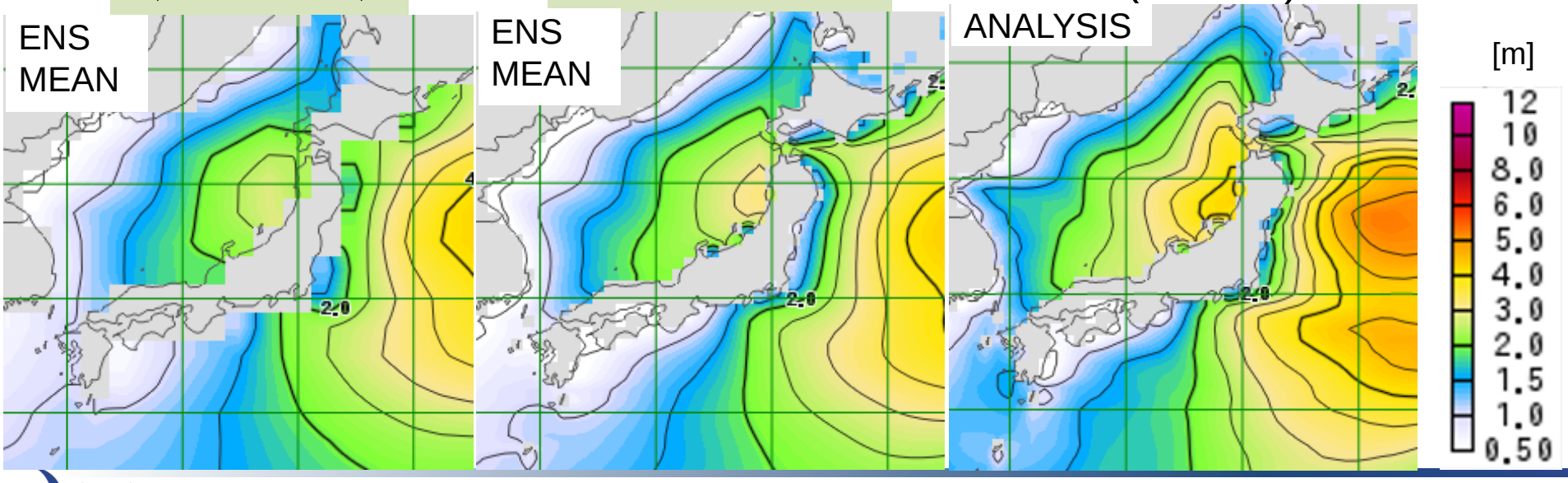
Wave ENsemble System

Next year, we will improve the resolution of the wave prediction system from 1.25x1.25 to 0.5x0.5 and introduce the shallow water effect as the deterministic models.

Now operating
（1.25x1.25）

Higher resolution
（0.5x0.5）

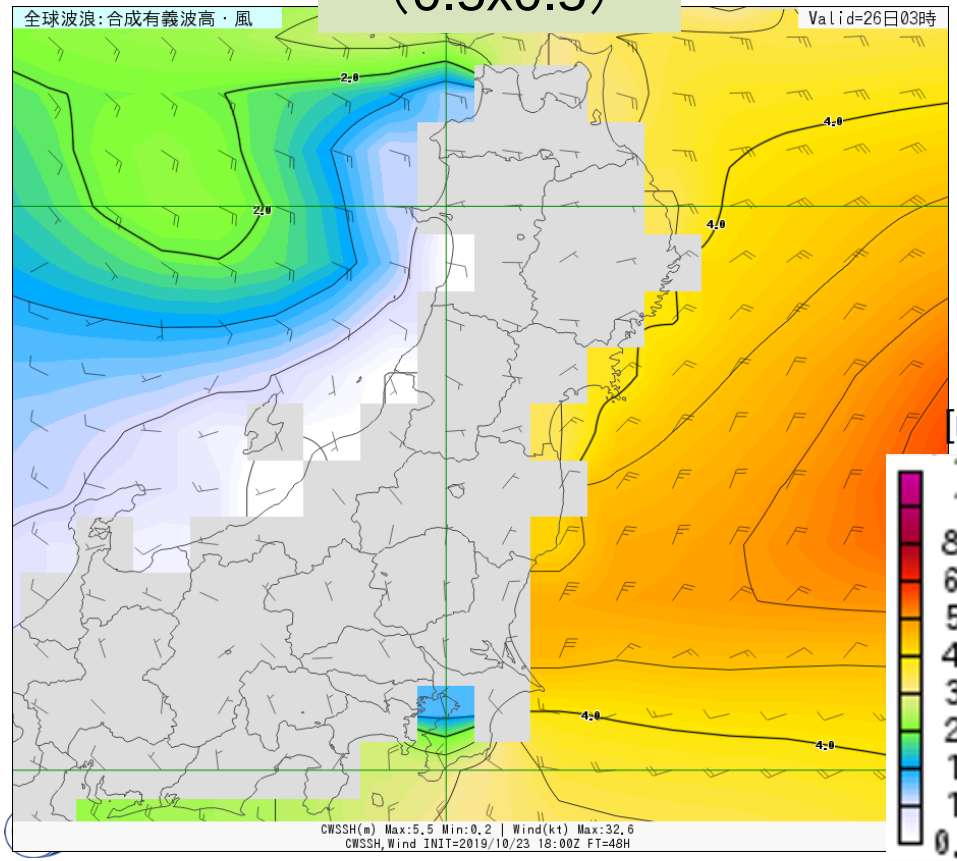
Global Wave Model
(0.5x0.5)



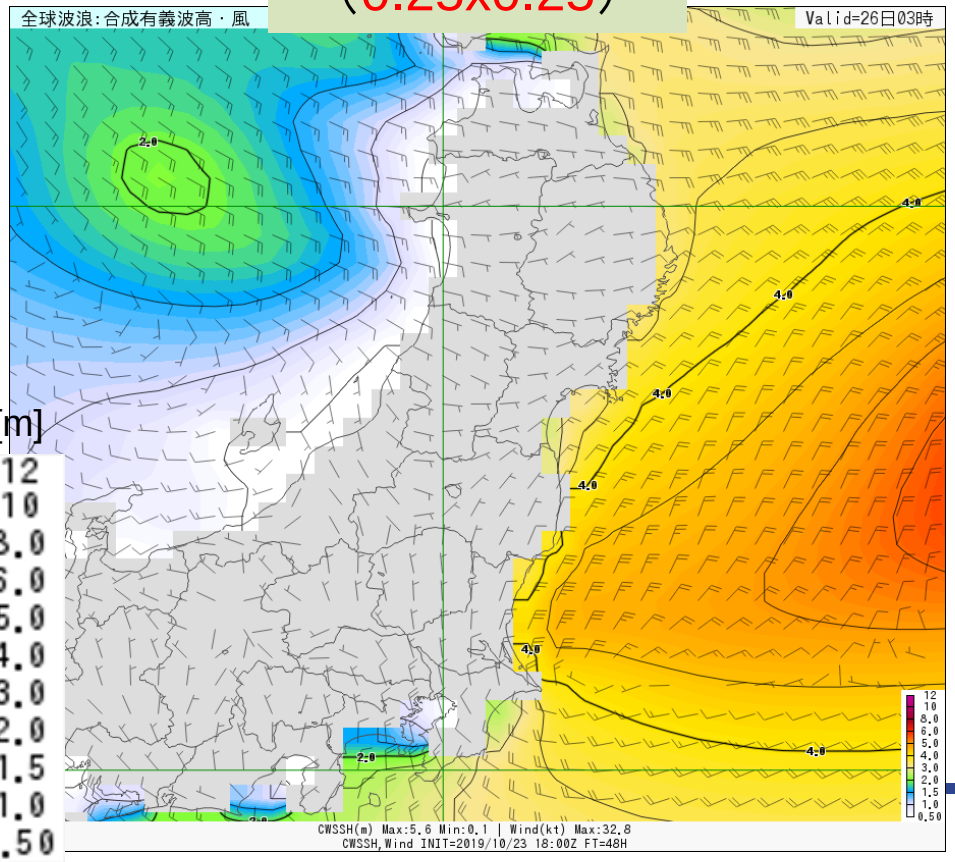
Global Wave Model

We plan to improve the resolution of the wave model in a few years.

Now operating
（0.5x0.5）



Higher resolution
（0.25x0.25）



Summary

✓ Implementation of shallow water effects

The accuracy at shallow water areas is improved.

✓ Probabilistic wave forecast products

JMA contributes to WMO SWFDP as one of global centres by providing probabilistic wave forecast products.

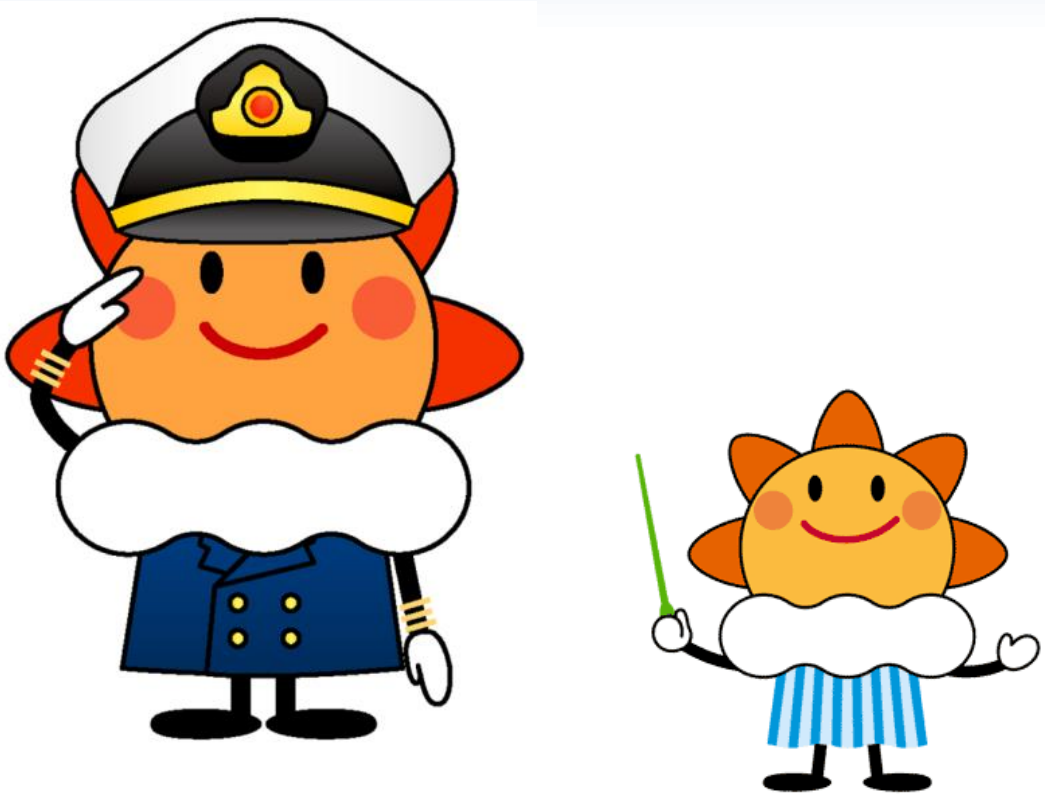
Probabilistic products on wave period are added.

It is useful for estimating the effects of swell.

✓ Plans on increasing resolution

- Global Wave Model
  - 0.5x0.5 → 0.25x0.25 [deg]
- Wave Ensemble System
  - 1.25x1.25 → 0.5x0.5 [deg]
  - with shallow water effects implementation

Thank you for your attention



JMA mascot “*Harerun*”

Operational wave models at JMA

	Global Wave Model (GWM)	Coastal Wave Model (CWM)	Wave Ensemble System (WENS)
forcing (wind)	Global Spectral Model GSM (20km grid) + typhoon bogusing (~ 72 hours)		Global Ensemble Prediction System (GEPS) 40km grid **27 members**
operation	4 times / day (00, 06, 12, 18 UTC)		2 times / day (00, 12 UTC)
forecast time	264 hours (12UTC) 132 hours	132 hours	264 hours

Shallow water effects

Advection term

$$\frac{\partial E(f,\theta;\mathbf{x},t)}{\partial t} + \nabla\cdot\left\{C_g(f,\theta;\mathbf{x})\cdot E(f,\theta;\mathbf{x},t)\right\} + \frac{\partial}{\partial\theta}\left(C_g(f,\theta;\mathbf{x})\cdot\nabla\theta\right)E(f,\theta;\mathbf{x},t) = 0$$

Shoaling

Variation of the group velocity.

Refraction

Variation of the propagation direction

✓ **Shoaling**

Considering variation of the group velocity with the change of water depth.

✓ **Refraction**

Considering variation of the propagation direction and wave height due to the change of the propagation velocity with the change of water depth.

Shallow water effects

Source term

Non-linear energy transfer S_{nl} ・・・ energy exchange between spectral components

In shallow water area, S_{nl} is intensified.

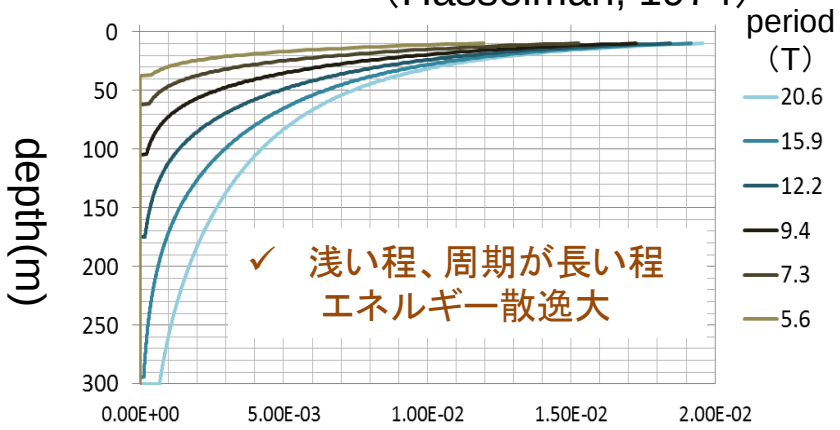
$$S_{nl\_shallow} = r_s \cdot S_{nl\_deep} \qquad r_s = 1.0 + 5.5\left(\frac{1.0}{\bar{k}} - \frac{5.0}{6.0}\right)\exp\left(-1.25\bar{k}\right) \qquad k: \text{Wavenumber}$$

bottom friction S_{btm} ・・・ energy dissipation due to ocean bottom friction

$$S_{btm} = -\frac{0.038}{g^2} \cdot \frac{(2\pi f)^2}{\sinh^2(kd)} \cdot E(f,\theta)$$

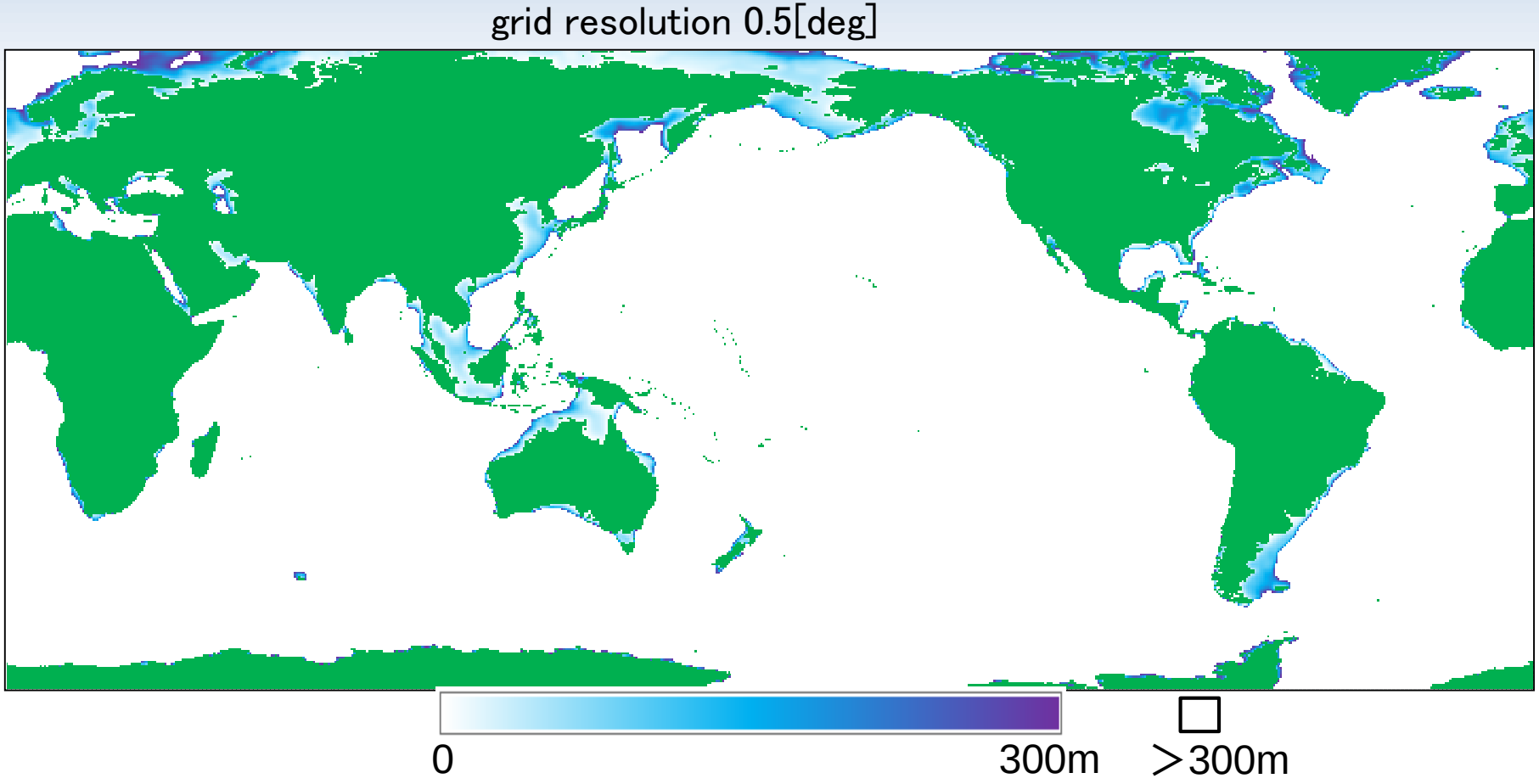
k: Wavenumber　d: Depth

（Hasselman, 1974）



bottom friction in the model

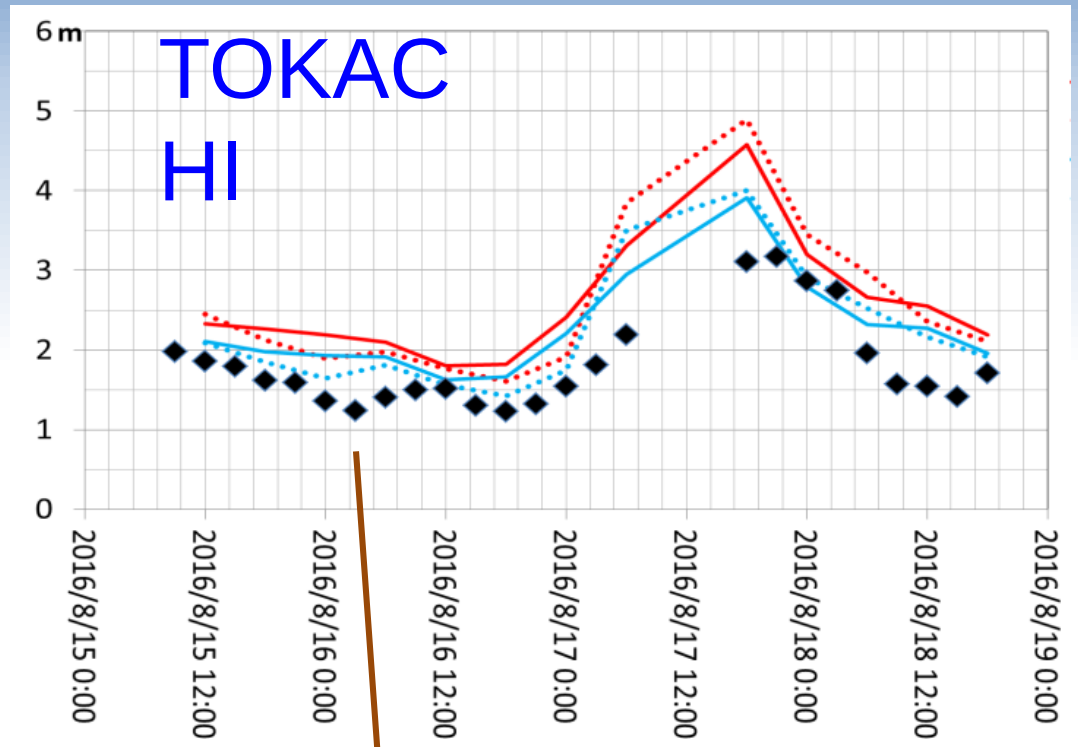
Water depth in Global Wave Model

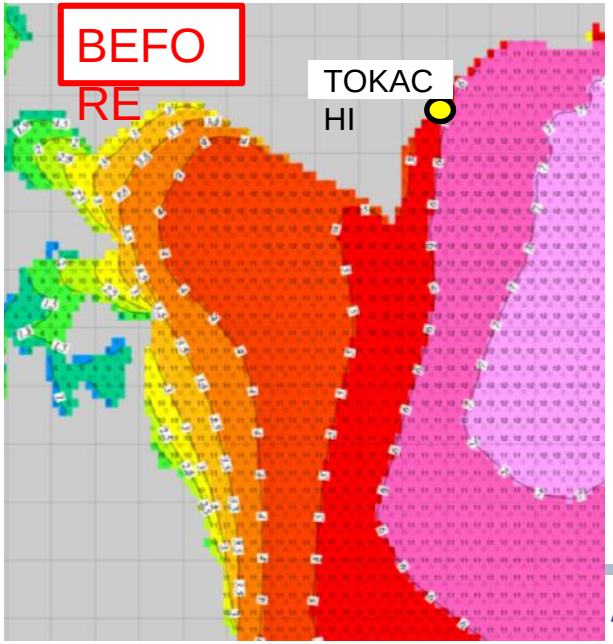


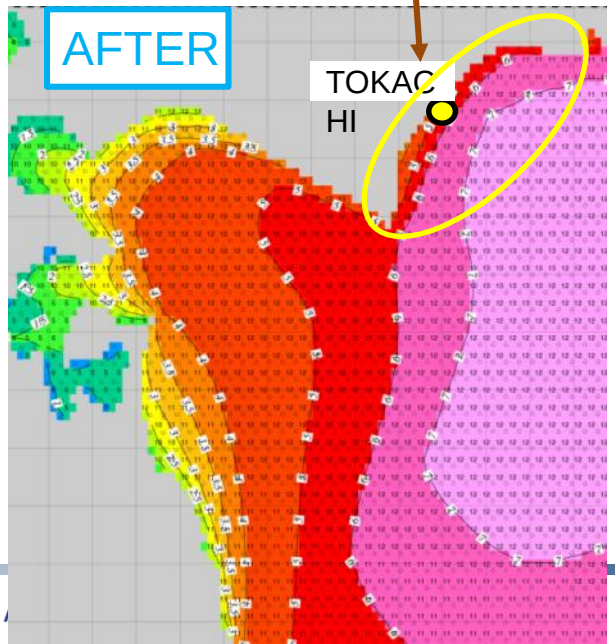
Around Japan

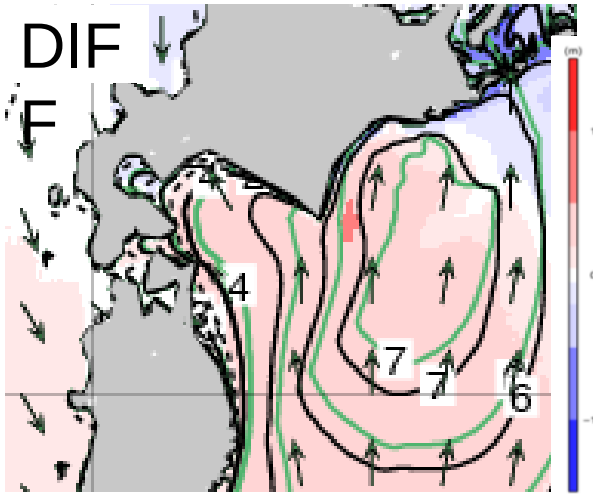
Observation
BEFORE(Lat
BEFORE(-24h)
AFTER(Latest
AFTER(-24h)

INIT:2016.08.17 00UTC
FT=12h

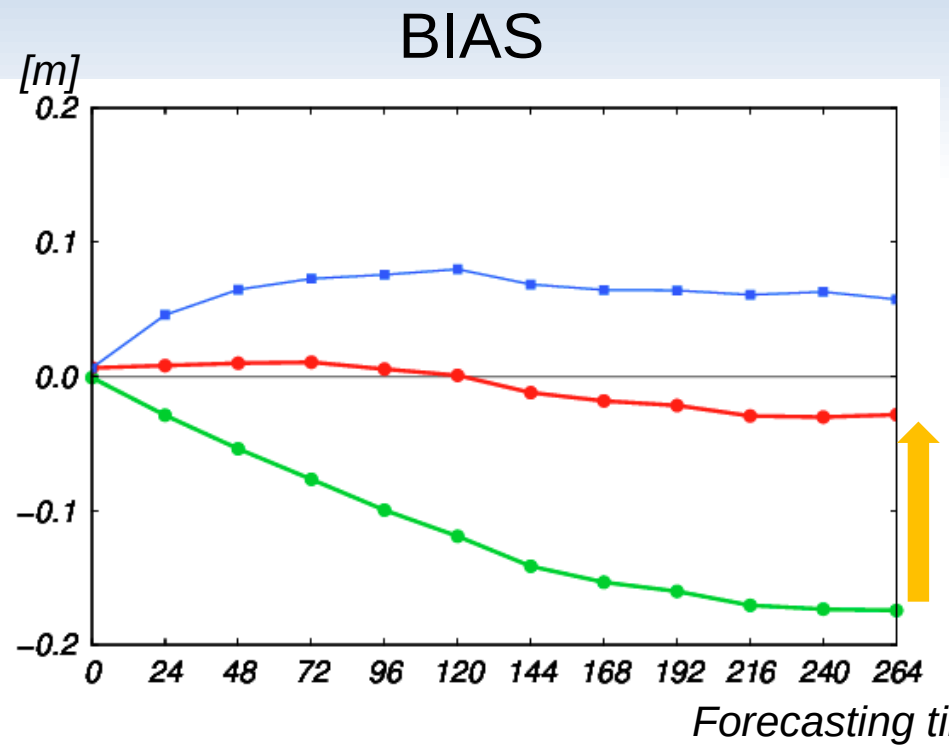


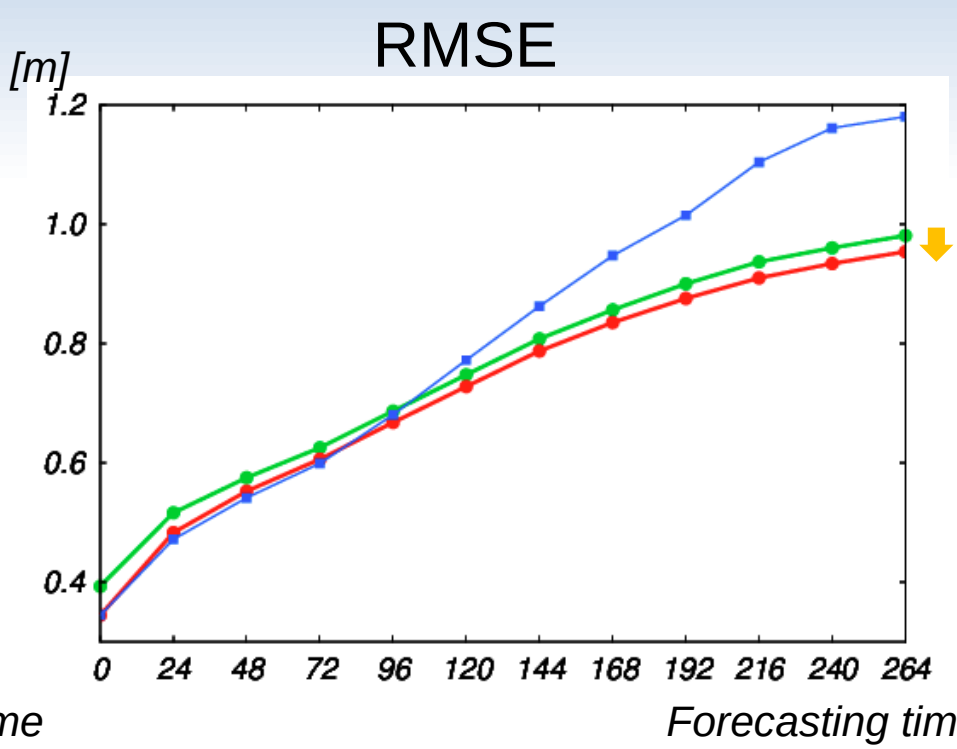






Verification for WENS updates





Verification on wave height with satellites (global)
EPS: MEAN 2017.04 to 2019.03

WENS(new released)
WENS(now operating)
GWM(deterministic model)

Verification for WENS updates

SUMMER（J,A,S,O）　　WINTER（D,J,F,M）

BIAS

RMSE