1ST INTERNATIONAL WORKSHOP ON
WAVES, STORM SURGES AND COASTAL HAZARDS
13/Sep/2017

New information on crossing waves of JMA

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Co-wroker:
Ayako Yamane (-Mar, 2017) and Tomoaki Sakuragi (Apr, 2017-)

Outline (summary)

- ✓ Information on “rough sea areas”, which may be challenging for navigation, was included in Wave Forecast Charts on March 7 March 2017.
- ✓ The new information indicates two conditions: 1) area of crossing wave and 2) area of rough waves by opposing current.
- ✓ Verification of the information is on-going with observed data by JMA Research Vessels, especially on wave components.
- ✓ Calculated wave components were fairly compared with observed wave components and seems reliable.

Contents

- Background
- Outline of new information
- Verification of wave components

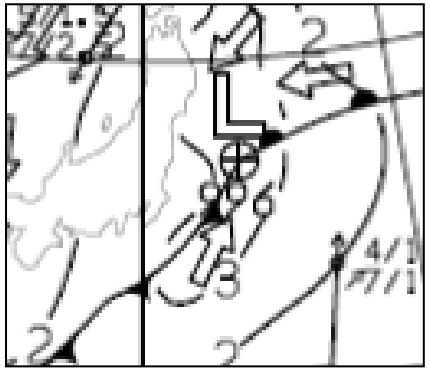
Motivation

Sea state gives strong influence to voyaging vessels. In usual, wave heights are commonly used to express sea state. However, complicated sea state is quite dangerous and tough for voyaging vessels and fishing activities.

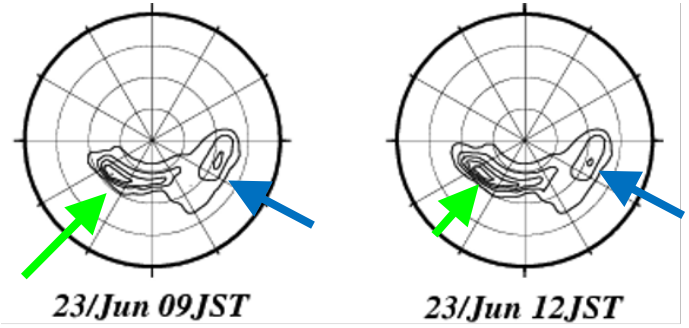
A fishing boat accident
(23 June 2008)
fishing boat of 135 gross tonnage overturned.
4 dead, 13 missing

- A low pressure system moved eastward and was located in the sea off Inubo-saki at 09JST on 23.
- Wave heights of 2 to 3 m were analyzed in the south of the low pressure center., although the wave height of **3m is not so dangerous** for fishing boats of 100 gross tonnages.
- Wave spectrum at the accident point indicates that there were several wave components. The sea could be rough, although it is circumstantial.

Location of the accident


Wave analysis chart (AWPN)

(00UTC on 23 June, 2008)



Wave spectra

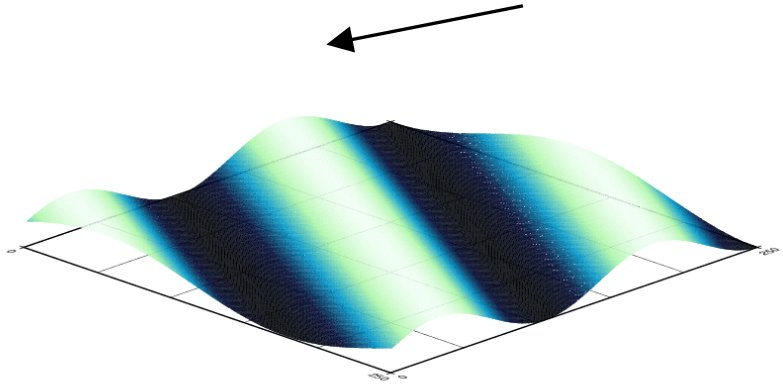
→ JMA developed some practical information on “rough sea area information”.

Sea state

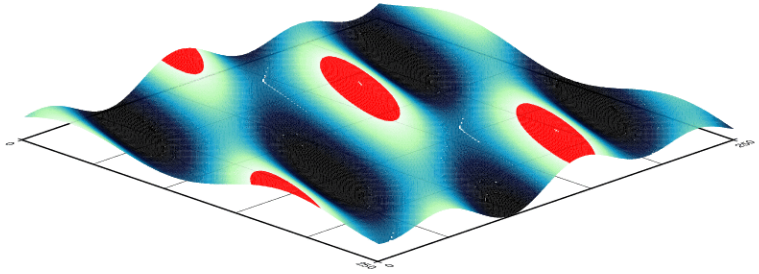
Douglas swell Scale	
degree	Description
0	No swell
1	Very Low (short or average and low wave)
2	Low (long and low wave)
3	Light (short and moderate wave)
4	Moderate (average and moderate wave)
5	Moderate rough (long and moderate wave)
6	Rough (short and high wave)
7	High (average and high wave)
8	Very high (long and high wave)
9	*Confused* (*wavelength and height indefinable*)

Crossing waves make sea state complicated.

Single wave



Crossing waves

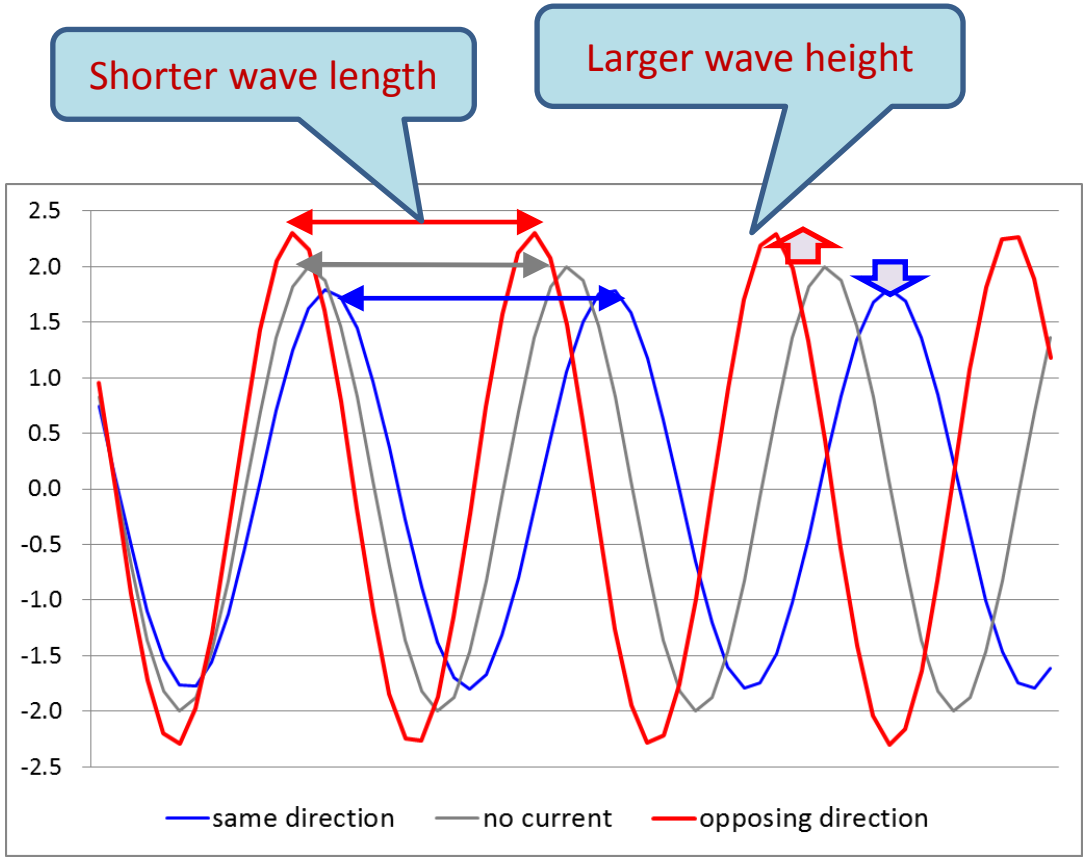


※Red:
Higher than the maximum level of single wave

Current effects to waves

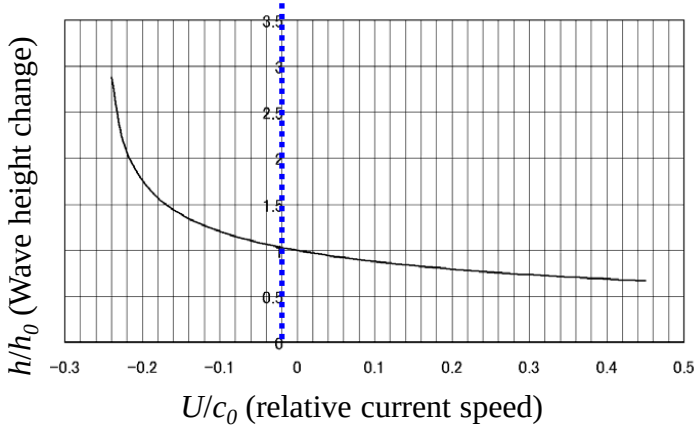
Opposing currents increase wave height and decrease wave length making wave steeper.

Simple wave: Hw = 2m, Tp = 8sec (Cp=12.5m/s)
Modulation in the current U = ±1.0m/s



Wave height modifications by currents

$$\frac{h}{h_0} = \sqrt{\frac{2}{1+\frac{4U}{c_0}+\sqrt{1+\frac{4U}{c_0}}}} \qquad c_0 = \frac{gT}{2\pi} = 1.56T$$



h: modulated wave height,

h_0 : original wave height

U: relative current speed (to wave),

c_0: phase speed of wave

Contents

- Background
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- Verification of wave components

Ocean Wave Chart (FWPN)

Area of Crossing Waves

1. wave height ≧ 1.8 m
2. presence of comparable plural waves*
   Wave components (windsea and swell) are also plotted.

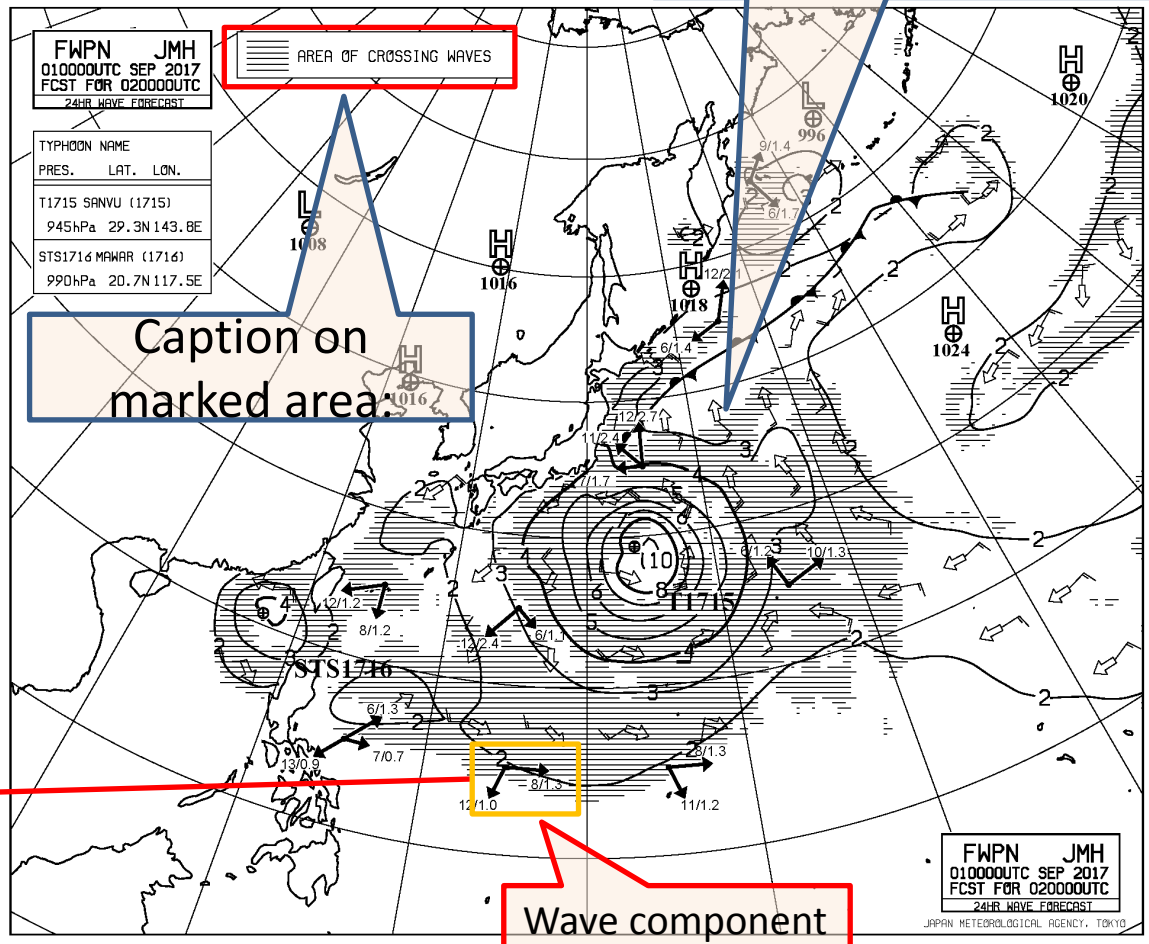
Areas of where plural waves are indicated by horizontal hatching.

*Definition of comparable waves

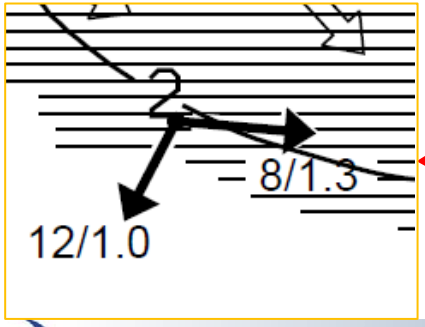
① $H_{w\_2} / H_{w\_1} > 0.6$

② $H_{w\_3} / H_{w\_1} > 0.45$

※ exclude the component direction angle is within 30 degree



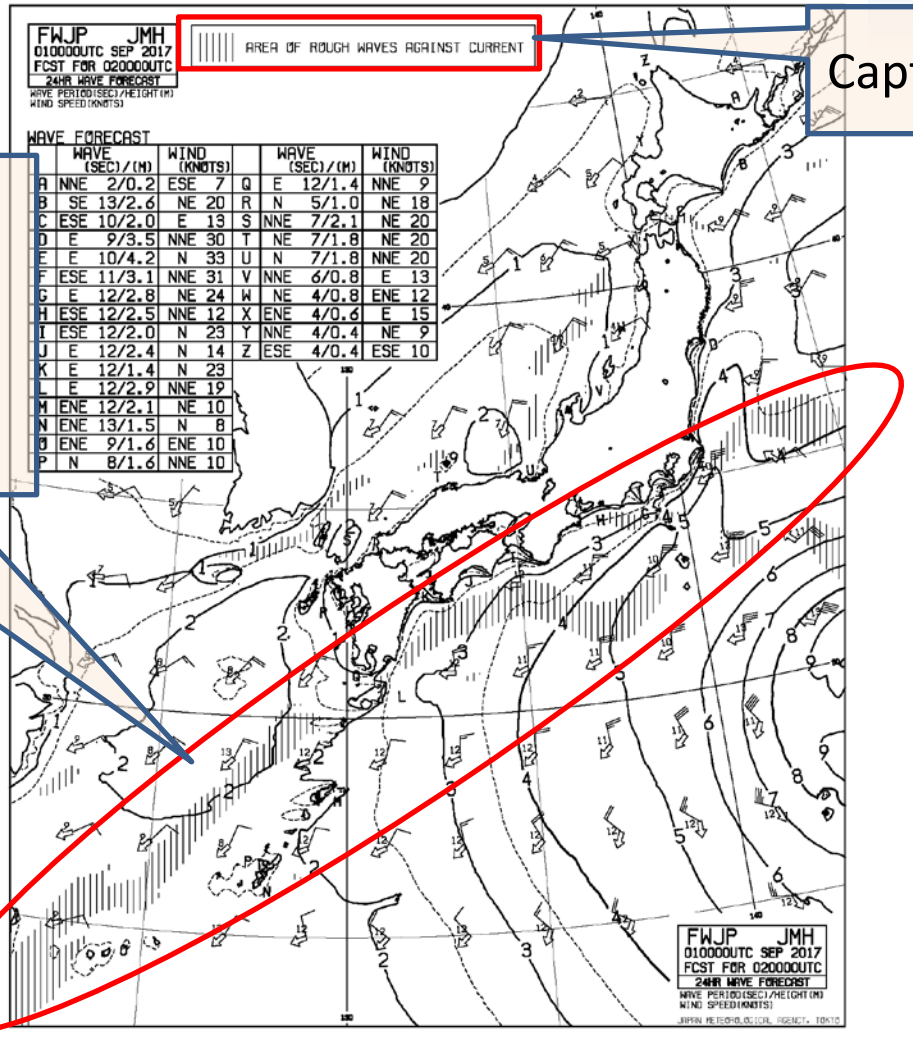
Each wave component
period (sec) / height (m)



Coastal Wave Chart (FWJP)

Area of Rough Waves Against the Current

- Areas with wave heights of 1 m and over amplified by 5%



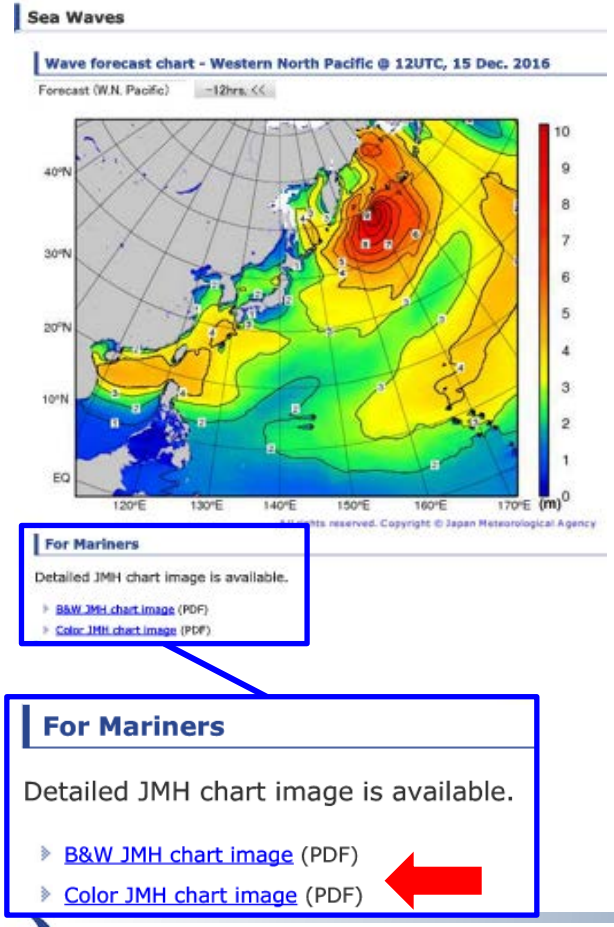
Caption on marked area

Areas with waves amplified opposing currents are indicated by vertical hatching

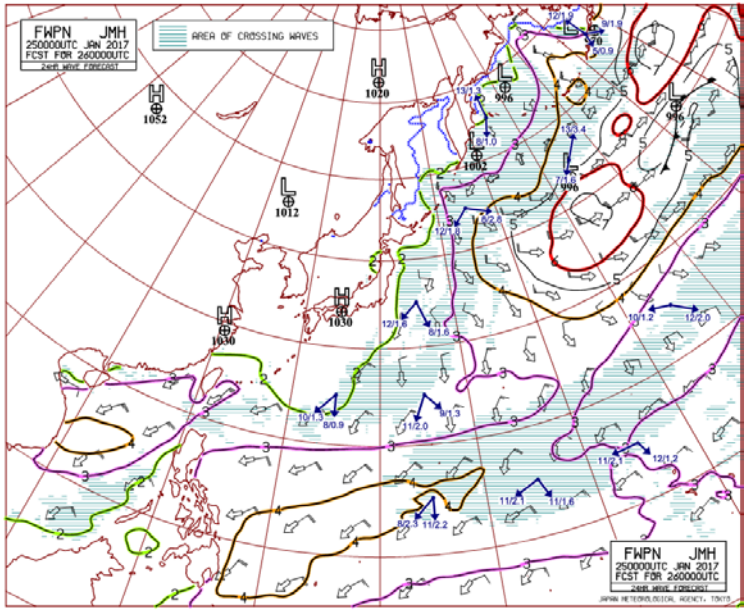
The websites for wave charts

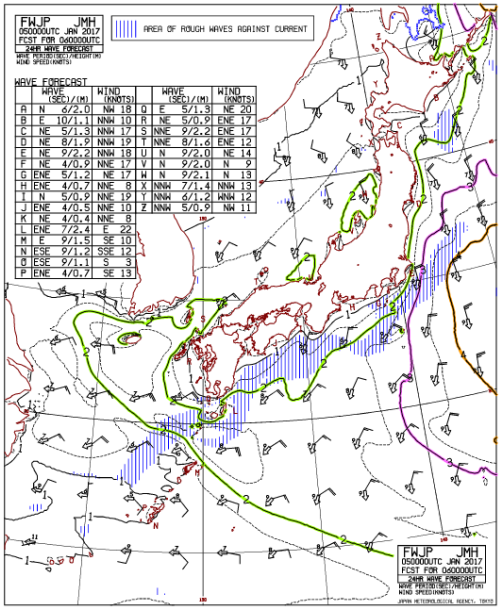
FWPN : http://www.data.jma.go.jp/gmd/waveinf/chart/fwpn.html
FWJP : http://www.data.jma.go.jp/gmd/waveinf/chart/fwjp.html

The colored wave charts, also added to the site, make it easier to distinguish the many items of information.



Colored wave charts





Contents

- Background
- Outline of new information
- Verification results

Evaluation of crossing wave condition

We started routine verification of wave components. Wave components are compared with observed data by JMA Research Vessels (Keifu-maru and Ryofu-maru, 1400t).

R/Vs observe wave components at 00UTC and reports the results.

We check wave conditions at observing point and compare observations with wave model 24 hours forecasts.

Results are shared with observers in R/V in real time basis and discuss about the results if necessary.

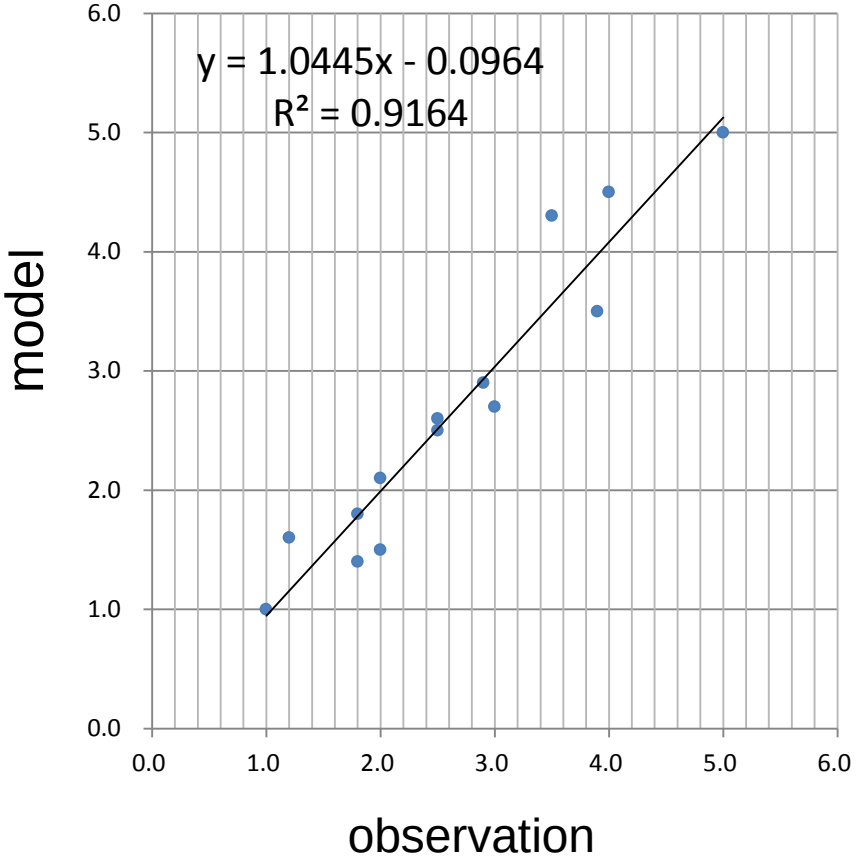
(We do not inform predicted data before the observation to avoid preconception.)

Keifu-maru

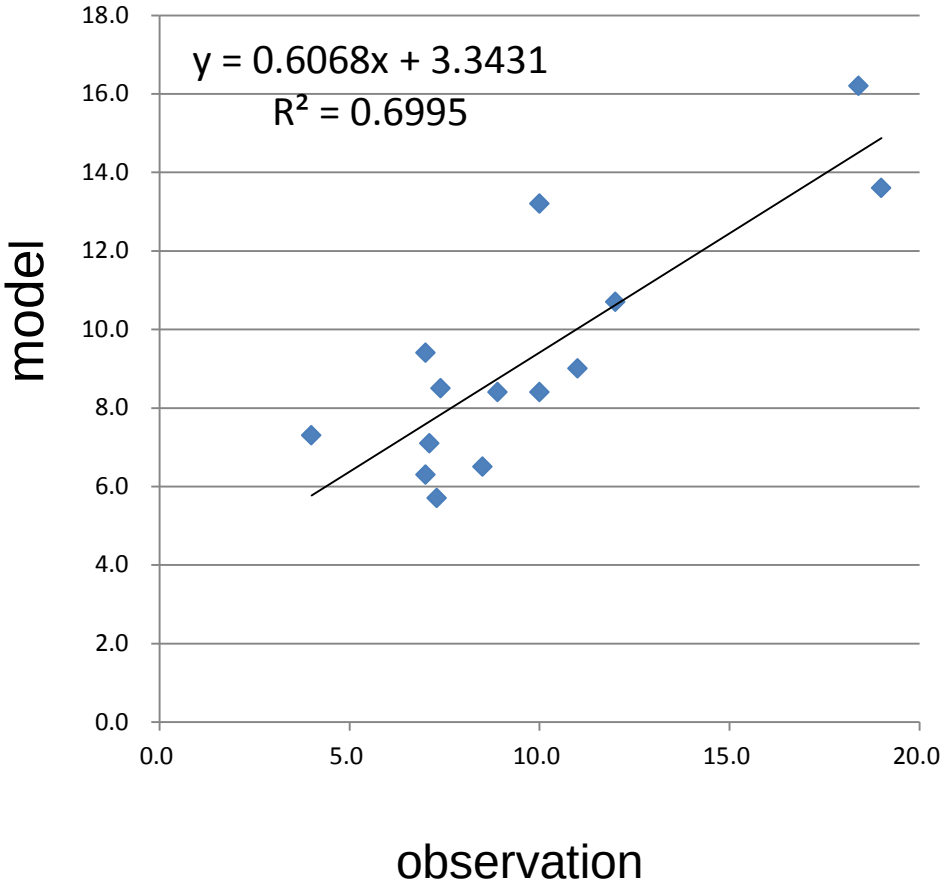
Ryofu-maru

Comparison with observations (Keifu-maru)

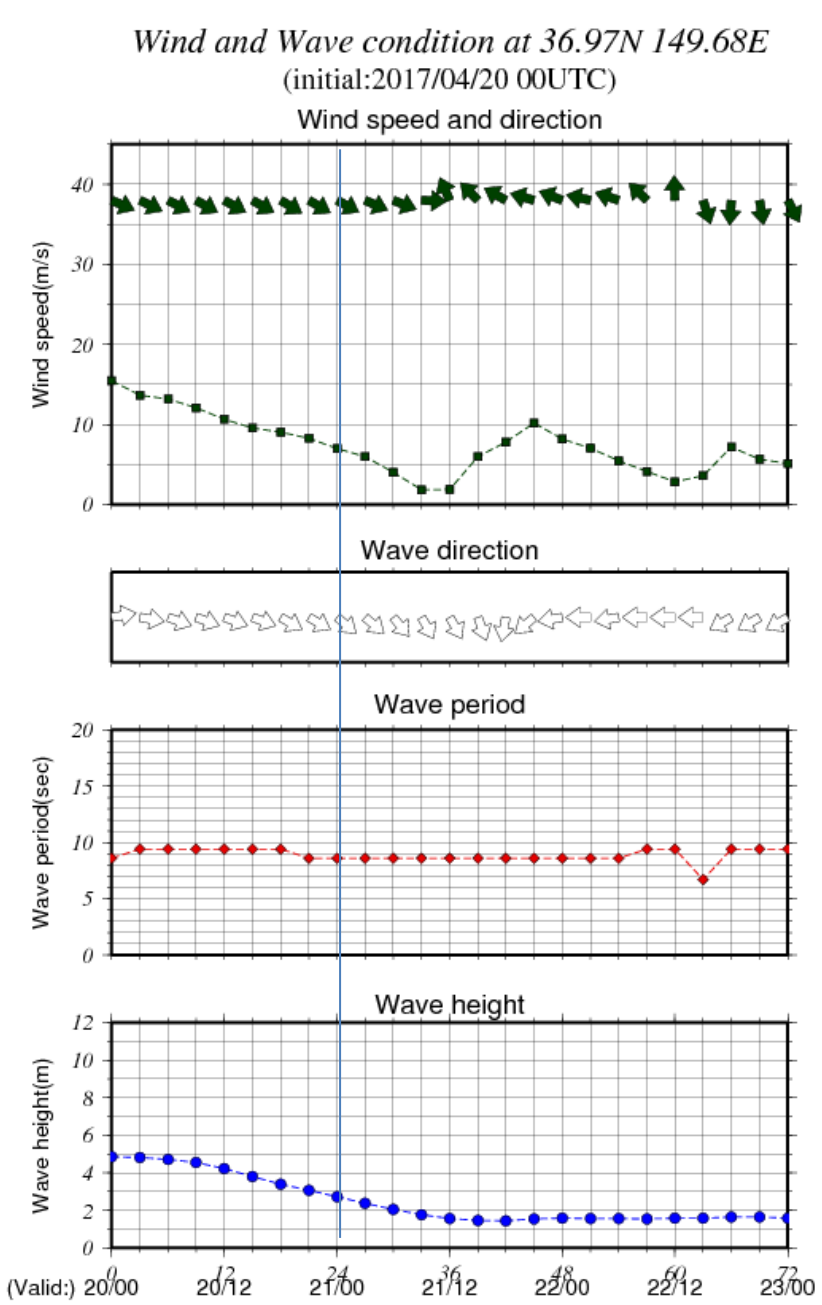
Significant (combined) Wave heights

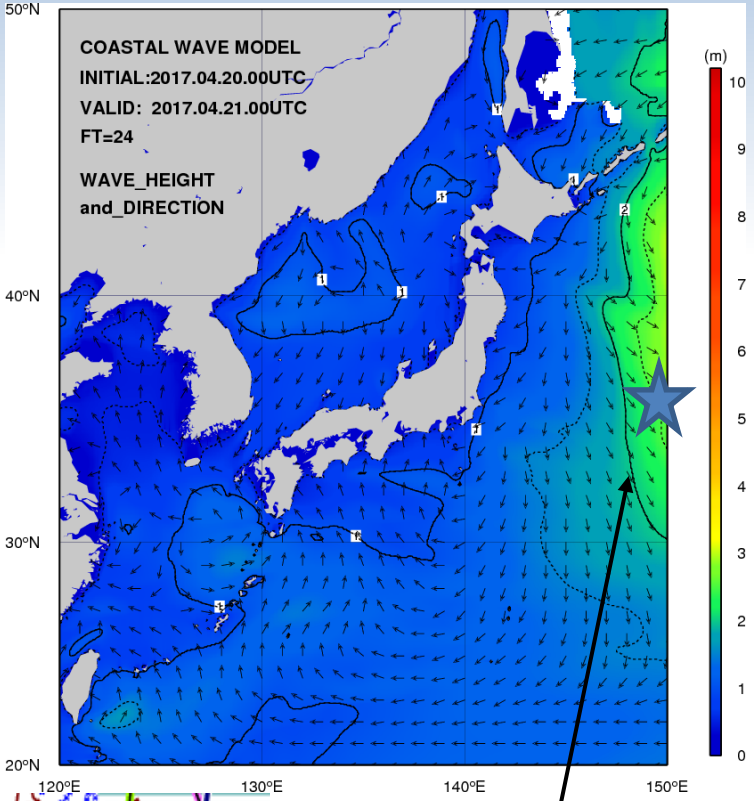


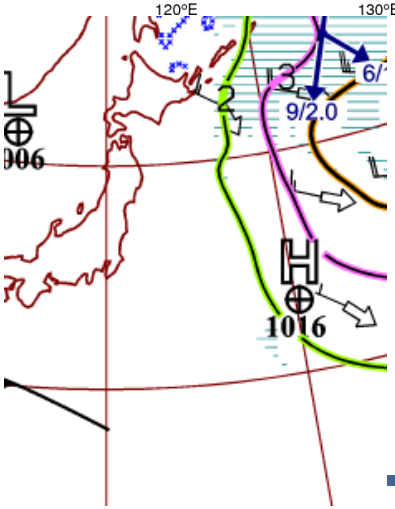
Surface winds



Results at 00UTC on Apr 21, 2017





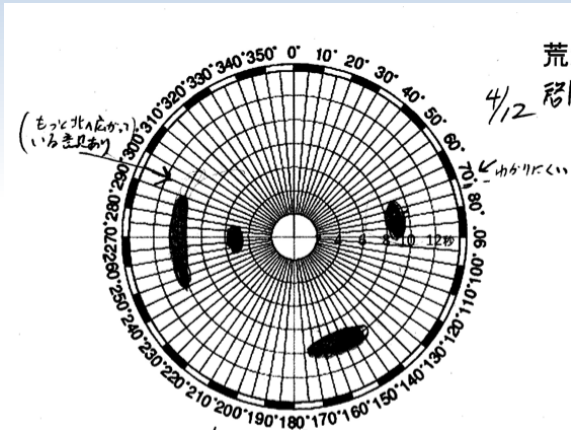


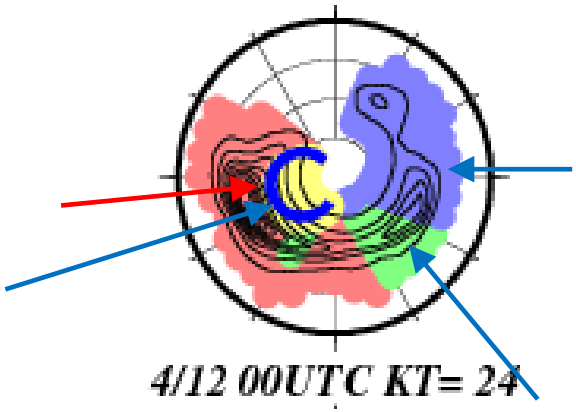
Keifu Maru

Result at 00UTC on Apr 12, 2017

Keifu Maru

	observation			Model*		
	speed (m/s)	Direction (deg)		speed (m/s)	Direction (deg)	
wind	7.4	270		8.5	256	
	Height (m)	Period (sec)	Dir. (deg)	Height (m)	Period (sec)	Dir. (deg)
wave	3.5			4.3	10.3	230
windsea	1.0	5.0		1.5	6.8	
Swell 1	2.5	10.0	250	3.3	11.8	250
Swell 2	1.5	10.0	150	1.4	10.1	150
Swell 3	1.0	9.0	80	1.1	11.0	90



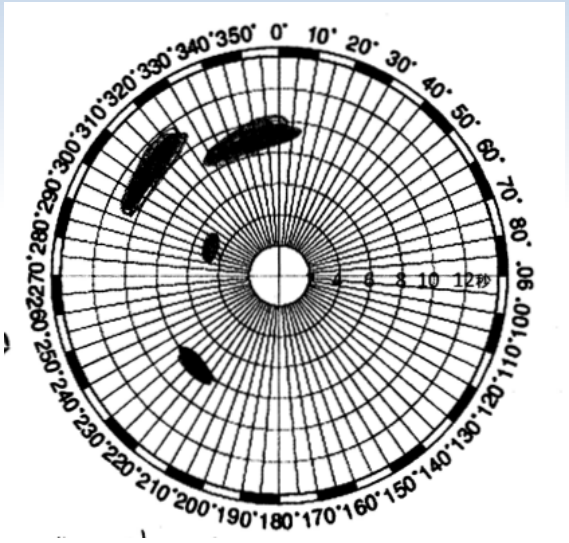


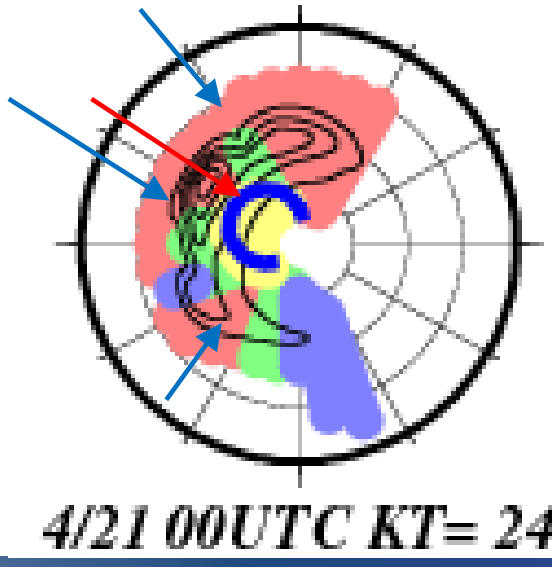
***CWM 24 hours forecast**
(Initial: 00UTC on Apr 11)

Result at 00UTC on Apr 21, 2017

Keifu Maru

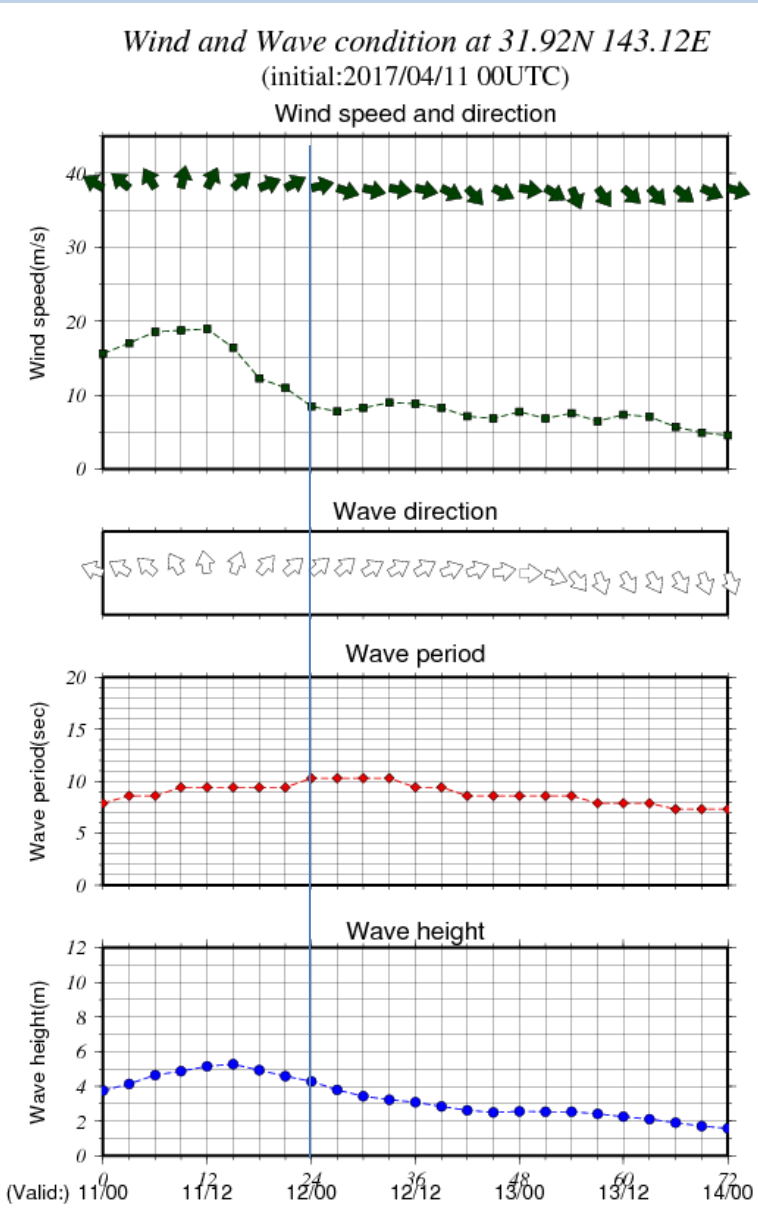
	observation			Model*		
	speed (m/s)	Direction (deg)		speed (m/s)	Direction (deg)	
wind	7.1	290		7.1	298	
	Height (m)	Period (sec)	Dir. (deg)	Height (m)	Period (sec)	Dir. (deg)
wave	3.0			2.7	8.6	310
windsea	1.0	4.0		0.9	5.8	
Swell 1	2.0	11.0	310	2.1	9.7	320
Swell 2	1.5	9.0	350	1.0	9.0	290
Swell 3	1.0	8.0	220	0.3	10.6	220

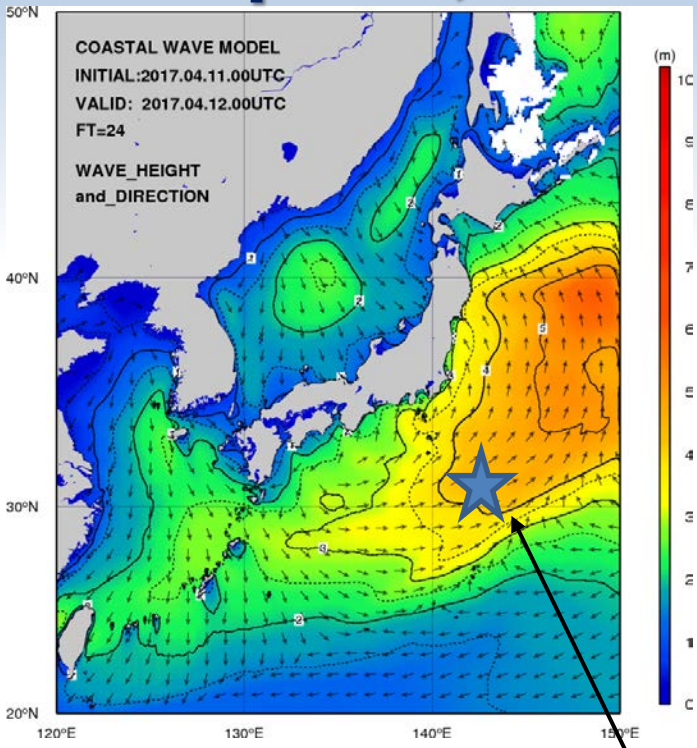


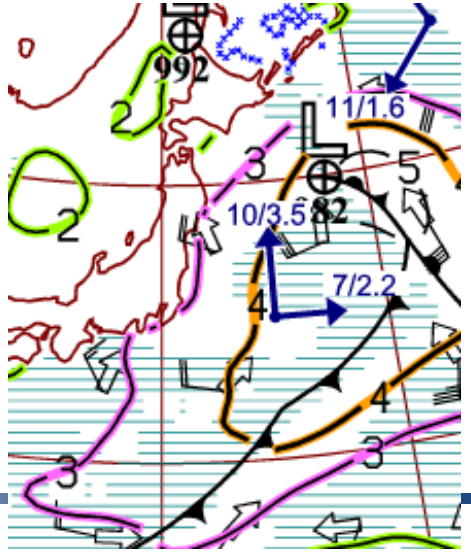


***CWM 24 hours forecast**
(Initial: 00UTC on Apr 20)

Results at 00UTC on Apr 12, 2017







Keifu Maru

Visualization of sea state

It turned out that observers sometimes feel difficult to determine wave components. Besides, many navigation officers gave us comments that wave spectra are difficult to interpret sea state.

Therefore, we tried to create sea image so that the user can easily understand the real conditions. Once we create sea state images (including water motion data), we may analyze those data too.

First, we checked the performance with ideal windsea and swell.

Method:

We simulated ideal windsea and swell with the following assumption:

- Initial: static state
- Windsea is generated by 20 m/s wind for 72 hours
- After 72 hours, wave propagates under 0m/s wind as swell

Then, calculated spectra were converted to water motion, and seastate images were created.

We analyzed the water motion with zero-up cross method and get statistical wave values.

Visualization of sea state

Surface water motion is estimated from wave spectra.

$$F(f,\theta) \rightarrow \eta(x,y)$$

F:2D spectrum η: water level

In general, progressive wave in 2d horizon is expressed as,

$$\eta(x,y,t) = a\cos\left(k_x \cos\theta_x + k_y \sin\theta_y - \omega t + \varepsilon\right)$$

a: amplitude $k=2\pi/L$: wave number
$\theta=(\theta_x, \theta_y)$: wave direction
$\omega = 2\pi/T$: angular frequency ε: phase

For deep water, $\omega^2=gk$

The real water may be expressed with summation of waves:

$$\eta(x,y,t) = \sum_{n=0}^{\infty} a_n \cos\left\{\frac{\omega_n^{\,2}}{g}\left(\cos\theta_{nx} + \sin\theta_{ny}\right) - \omega_n t + \varepsilon_n\right\}$$

Wave spectrum $F(f, \theta)$

$$\frac{1}{2}a_n^{\,2} = F(\omega,\theta)d\omega d\theta$$

Therefore amplitude of each wave can be

$$a_n = \sqrt{2F(\omega,\theta)d\omega d\theta}$$

When current exist, angular frequency and amplitude are replaced to

$$\omega' = \omega + \mathbf{k}\cdot\mathbf{U}$$

$$a' = a\sqrt{\frac{2}{1+4U/c_0+\sqrt{1+4U/c_0}}}$$

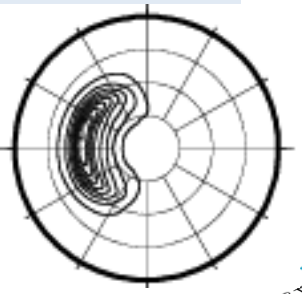
Note:
Non-linear effect or time evolution are not considered.

Sea state

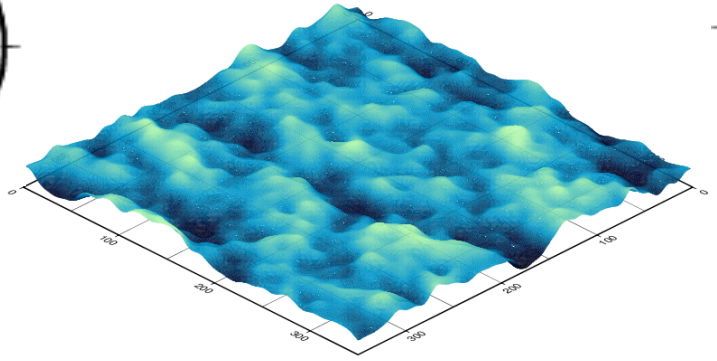
Tp(sec) / Hw(m)

(windsea)

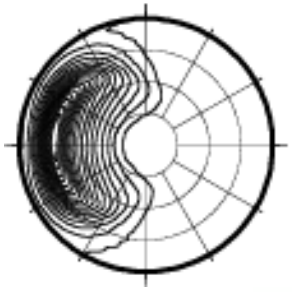
12 hours



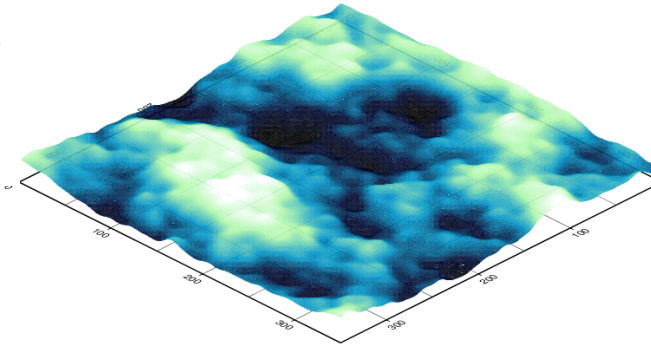
8.4/4.6



48 hours

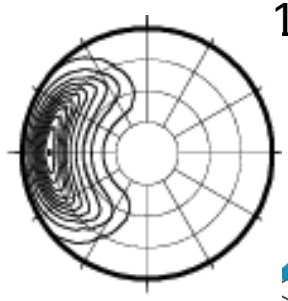


13.0/7.8

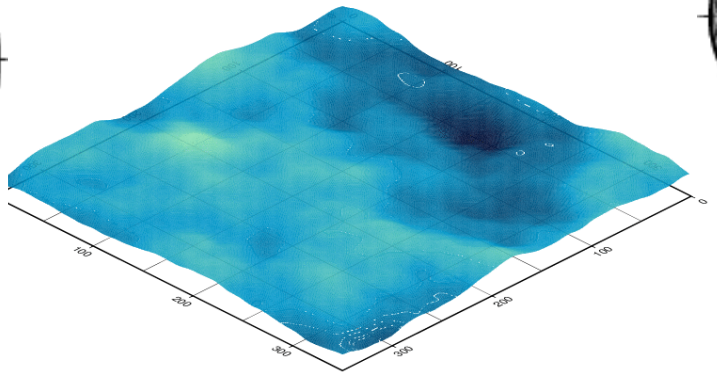


(swell)

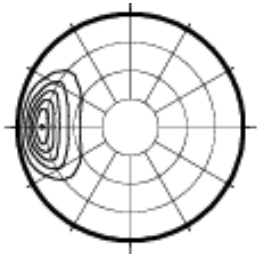
96 hours



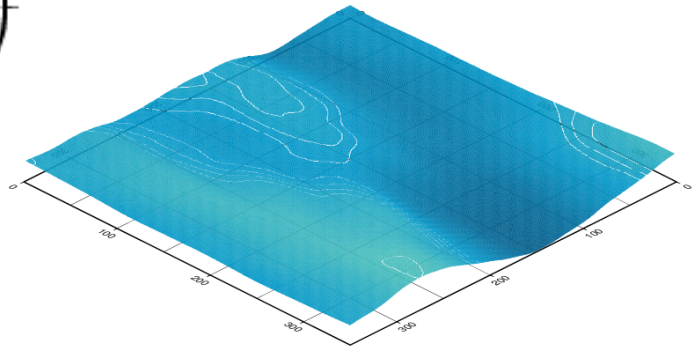
14.2/3.5



144 hours

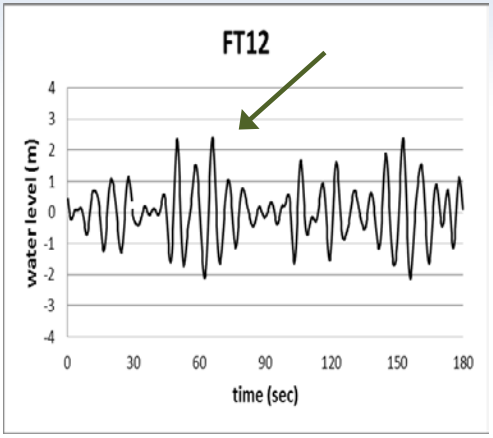


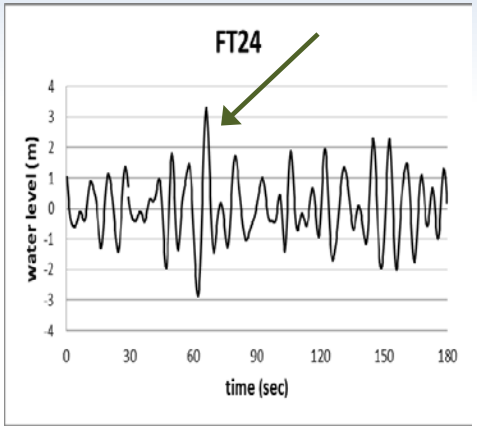
14.2/1.4

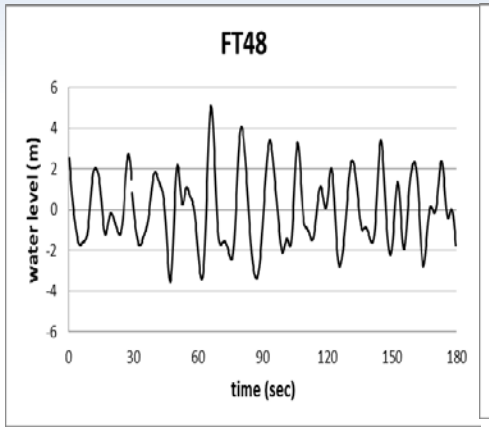


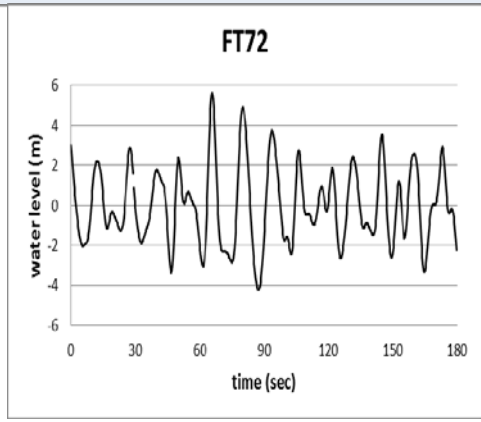
Calculated surface water motion (at middle point)

windsea

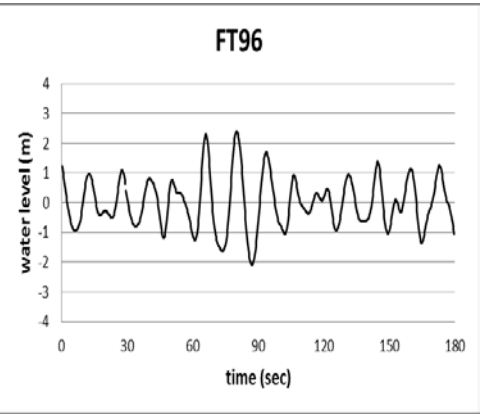


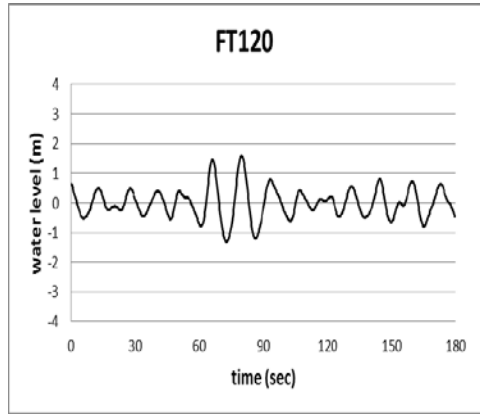


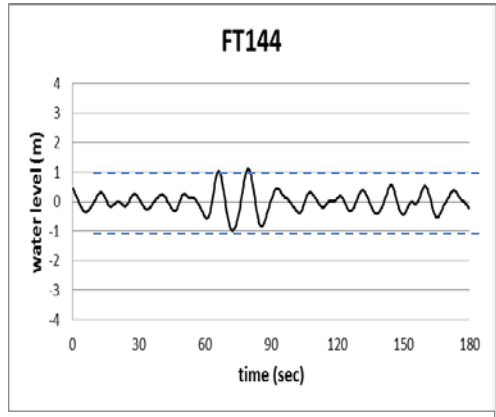


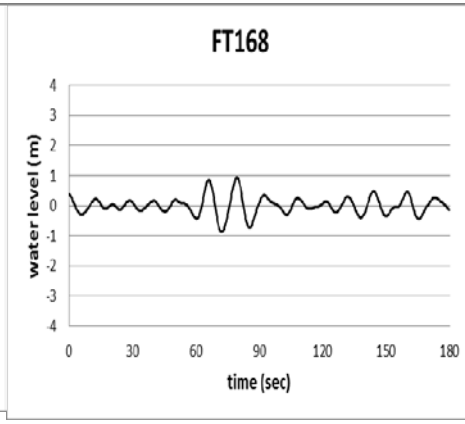


swell



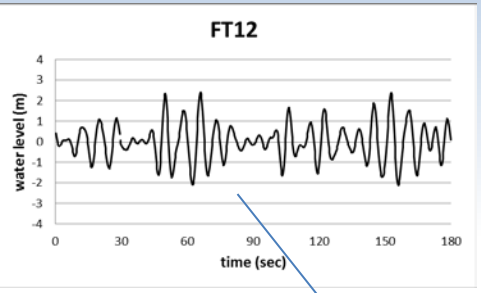


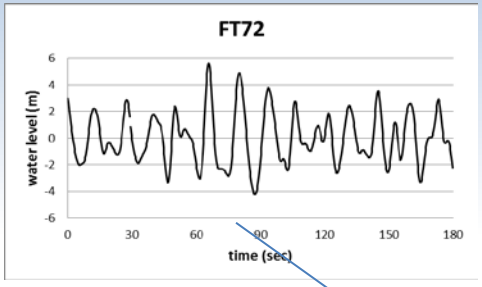




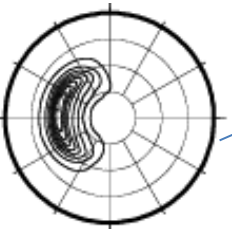
Wave values comparison

windsea

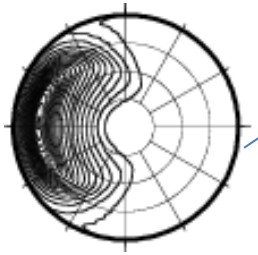




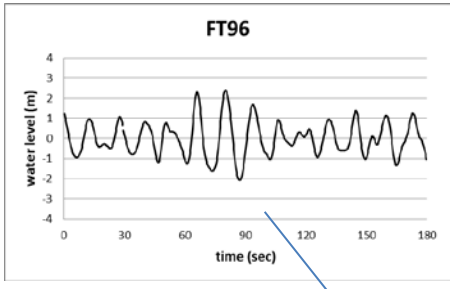
11.0/3.7
8.3/4.5

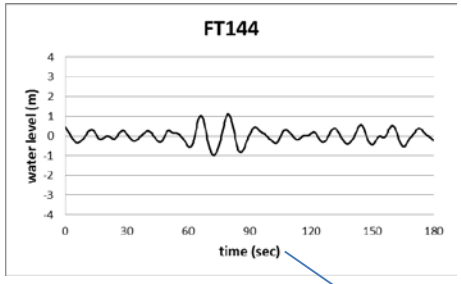


13.2/7.6
12.3/8.4

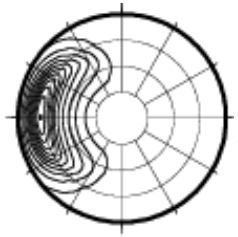


swell

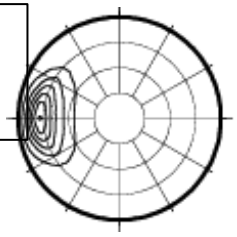




13.5/3.4
13.6/3.5



13.0/1.5
14.0/1.4

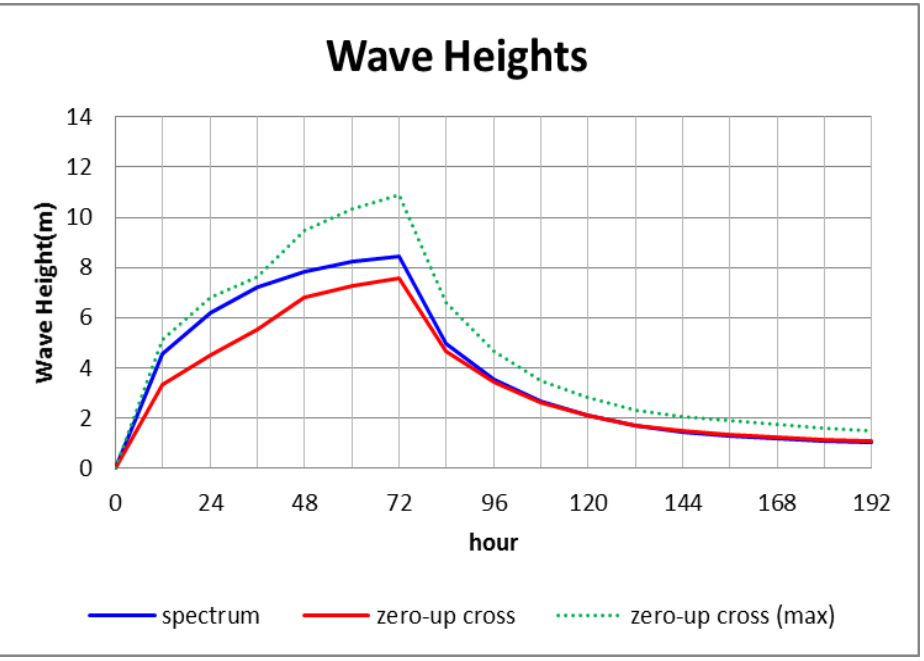


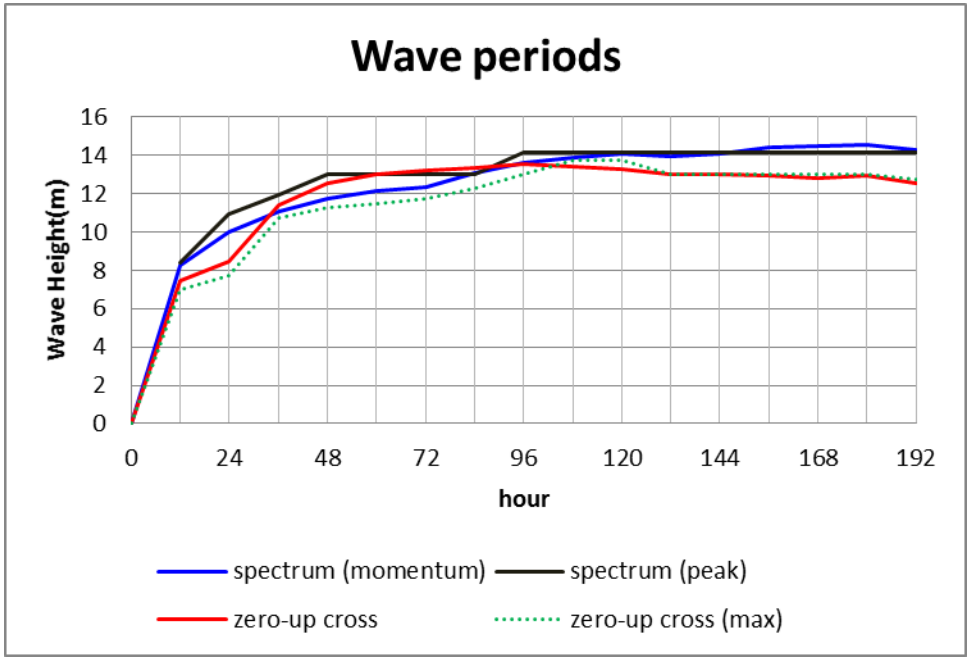
The values in boxes:
(upper)
Tp / Hw derived from zero-up cross
(lower)
Tp / Hw derived from spectra

- ✓ There are some discrepancy between values in the case of windsea.
- ✓ In general, wave values derived from both ways seems similar, especially in the case of swell.

Statistical analysis

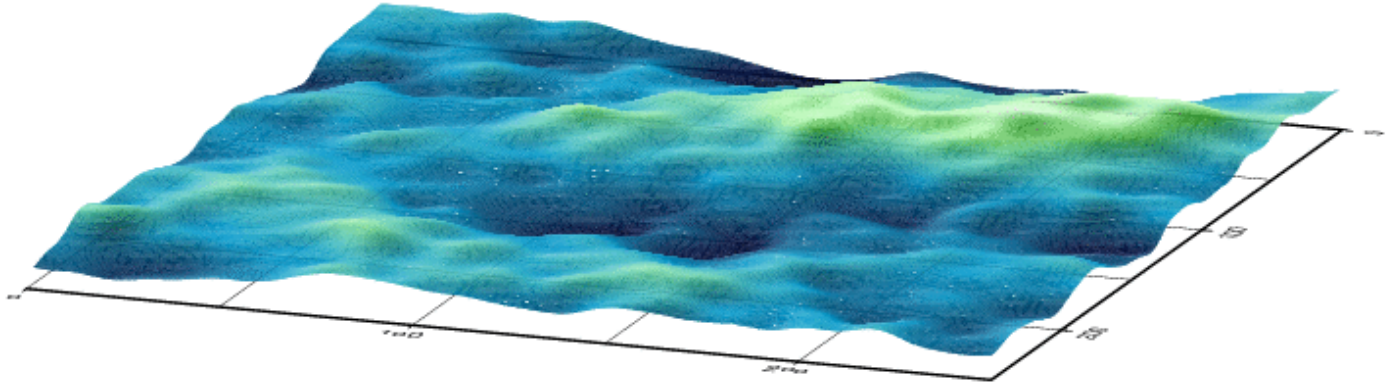
- ✓ Windsea heights by zero-up cross method were systematically underestimated, and thus we may need to modify the way for windsea.
- ✓ On the contrary, swell heights by zero-up cross method showed good agreement with wave values by spectra.
- ✓ Wave periods also are in good agreement.





Direct Comparidon

(Wave condition at 00UTC on Apr 12, 2017)



Summary

- JMA started issuing rough sea information on march 7 2017. The information is included to wave forecast charts which are directly provided to mariners via radio facsimile / JMA web site.
- Verification of the information also started. Calculated wave components were fairly compared with observed wave components and seems reliable.
- We tried to visualize sea state and to evaluate each wave motions. Wave values determined by zero-up cross method basically showed good agreement with those by spectra, although windsea was underestimated.
- There may be room for improvement in the way but we would like to use the calculated water motion, for objective evaluation.
- We have a plan to start providing wave components in near future.
- Non-linear effects will be considered in future, for freak wave prediction.

Thank You for attention!

The JMA Mascot “*Harerun*”

(The word “hare” means fine weather in Japanese.)