The Improvement of JMA Operational Wave Models

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10th International Workshop on Wave Hindcasting and Forecasting and Coastal Hazard Symposium – 16/Nov/2007

Motivation and methodology

- Improve operational ocean wave prediction of JMA
  - Previous ocean wave model had clear bias.
- Decided to update ocean wave model.
  - MRI-III (Ueno and Kohno, 2004)
    - Introduced at the 8th Workshop by Mr. Kohno.

Summary of conclusions

- JMA has introduced the new MRI-III since 30 May 2007.
  - High spatial resolution
    - GWM : 1.25deg. → 0.5deg.
    - CWM : 0.1 deg. → 0.05deg.
  - Increase of spectral component (16 directions → 36 directions)
  - Improvements of physical treatment (Ueno and Kohno, 2004)
- New MRI-III has showed better performance.
  - Bias reduction (especially for swell estimation)
  - Better correspondence with observations
- A few issues were found.
  - Over estimation of wave height in particular case.
    - long fetch and duration period
    - rather moderate wind speed
  - Weak wave evolution in early stage.

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Introduction

- Wave Model Operation at JMA (Since 1977)
  - “MRI” series.
    - Developed at Meteorological Research Institute.
  - MRI-I (1977-1986.9)
    - First generation model.
  - MRI-II (1986.10-1998.4)
    - Second generation (Coupled Discrete) model.
  - MRI-III (1998.4-)
    - Third generation model.

MRI-III (Introduction cont.)

- MRI-III_1998 (1998.4-2007.5)
  - Good correspondence between wind and wave.
  - Strong dissipation about swell.
    - Bias correction scheme (2003.11-2007.5)
      - Applied wave height and period.
        - (No correction in spectral components)
- **(Improved) MRI-III (2007.5-)**
  - Ueno and Kohno, 2004

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Operations at JMA

- Numerical Model Operation
  - Operates 2 ocean wave models
    - GWM : Global Wave Model
    - CWM : Coastal Wave Model
  - Wind Input .. GSM and RSM
    - Operational weather models of JMA
      - GSM : Global Spectral Model
      - RSM : Regional Spectral Model

Current NWP models at NPD/JMA ***(Ref.)***

	Global Model (GSM)	Regional Model (RSM)	Typhoon Model (TYM)	Meso-scale Model (MSM)	One-week Ensemble
Objectives	Medium-range forecast	Short-range forecast	Typhoon forecast	Disaster reduction	One- week forecast
Forecast domain	Global	East Asia	Typhoon and its surrounding	Japan and its surrounding	Global
Grid size / Number of grids	0.5625 deg 640 x 320 (TL319)	20 km 325 x 257	24 km 271 x 271	5 km 721 x 577	1.125 deg 320 x 160 (TL159)
Vertical levels / Top	40 0.4 hPa	40 10 hPa	25 17.5 hPa	50 21,800m	40 0.4 hPa
Forecast hours (Initial time)	90 hours (00 UTC) 216 hours (12 UTC) 36 hours (06, 18 UTC)	51 hours (00, 12UTC)	84 hours (00, 06, 12, 18 UTC)	15 hours (00, 06, 12, 18UTC) 33 hours (03, 09, 15, 21 UTC)	9 days (12 UTC) 51 members
Analysis	4D-Var	4D-Var	Interpolated from Global Analysis	4D-Var	Global Analysis with ensemble perturbations

Operational Wave Models

- Model Improvements
  - Improvements of physical treatment.
    - In detail : See Ueno and Kohno, 2004
  - Increase of spatial resolution.
    - GWM: 1.25deg. → 0.5deg.
    - CWM: 0.1deg. → 0.05deg.
  - Increase of spectral components.
    - 16 directions → 36 directions

Global Wave Model (GWM)

Name		new GWM	previous GWM
Area	north-south	75N-75S	
	east-west	0E-180-0.5W (periodic boundary)	0E-180-1.25W (periodic boundary)
Horizontal resolution		**0.5deg.**	1.25deg.
Number of grids		720 x 301	288 x 121
Time step	advection	**10 minutes**	30 minutes
	source term	30 minutes	30 minutes
Calculated hours (Initial time)		84 hours(00UTC) 216 hours(12UTC)	84 hours(00UTC) 216 hours(12UTC)
Spectral component		**900 components** (25 frequencies x **36 directions**)	400 components (25 frequencies x 16 directions)
Wind field		Global Spectral Model (GSM)	
		Fujita's empirical formula and corresponding gradient wind for a typhoon	

Coastal Wave Model (CWM)

Name		new CWM	previous CWM
Area	north-south	50N-20N	55N-15N
	east-west	120E-150E	115E-155E
Horizontal resolution		**0.05deg.**	0.1deg.
Number of grids		601 x 601	400 x 400
Time step	advection	**1 minute**	5 minutes
	source term	**3 minutes**	5 minutes
Calculated hours (Initial time)		84 hours(00, 12UTC)	84 hours(00, 12UTC)
Spectral component		**900 components** (25 frequencies x **36 directions**)	400 components (25 frequencies x 16 directions)
Wind field		Regional Spectral Model (RSM) with the supplement of GSM	
		Fujita's empirical formula and corresponding gradient wind for a typhoon	
Boundary		Global Wave Model (GWM)	

Additional Updates

- On November 21…
  - New GSM starts in operation.
    - Current RSM is end ….
    - High Resolution
      - TL319 (0.5625deg.) → TL959 (0.1875deg.)
    - Operate 4 times a day (every 6 hours)
      - Up to 84 hours (216 hours; 12UTC Initial)
  - GWM and CWM begin to operate 4 times a day.
    - Start 84 hours forecast at 06, 18UTC (both GWM and CWM)
  - Wind input needs to be changed to new GSM.
    - GWM : current GSM → new GSM
    - CWM : RSM with current GSM → new GSM
    - Adjustment of parameters are needed.

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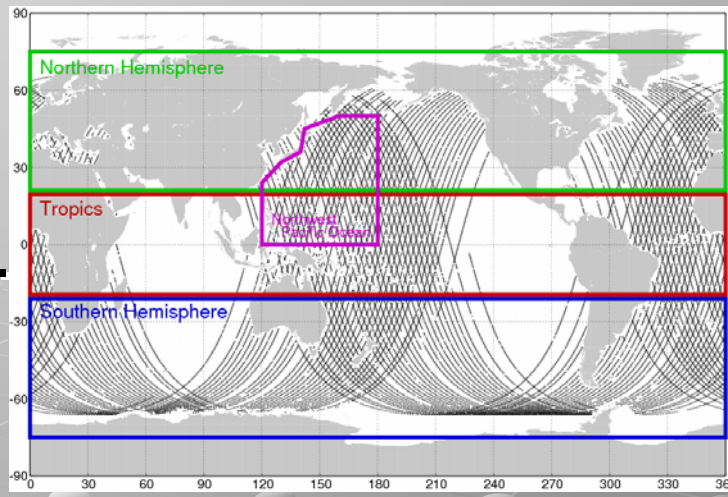
Performance



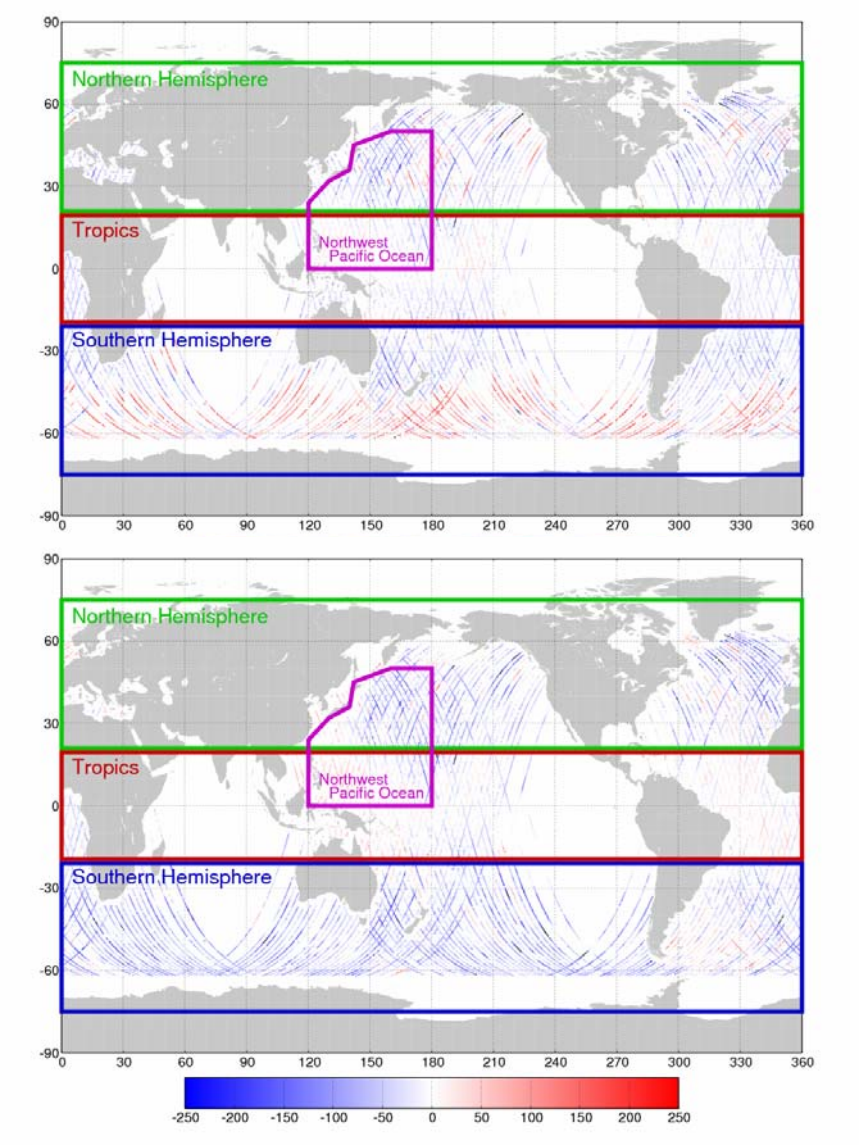
- Statistical performance of GWM.
  - Comparison with Radar Altimeter
    - In each area in March 2007.
      - Difference between GWM result of 12 hours forecast and JASON-1 radar altimeter.
        - Figure … Match-up data distribution.
  - Comparison with Manual Analysis (made at JMA)
    - In Northwestern Pacific Ocean in March 2007
      - Difference of average wave height between 12 hours forecast and manual analysis.
        - every 12 hours
  - Comparison with Buoy Observations
    - From 2002 to 2007
      - Difference between 24 hours forecast and Buoy observations.

Comparison with Rader Altimeter

- Statics and Bias distribution (March 2007)

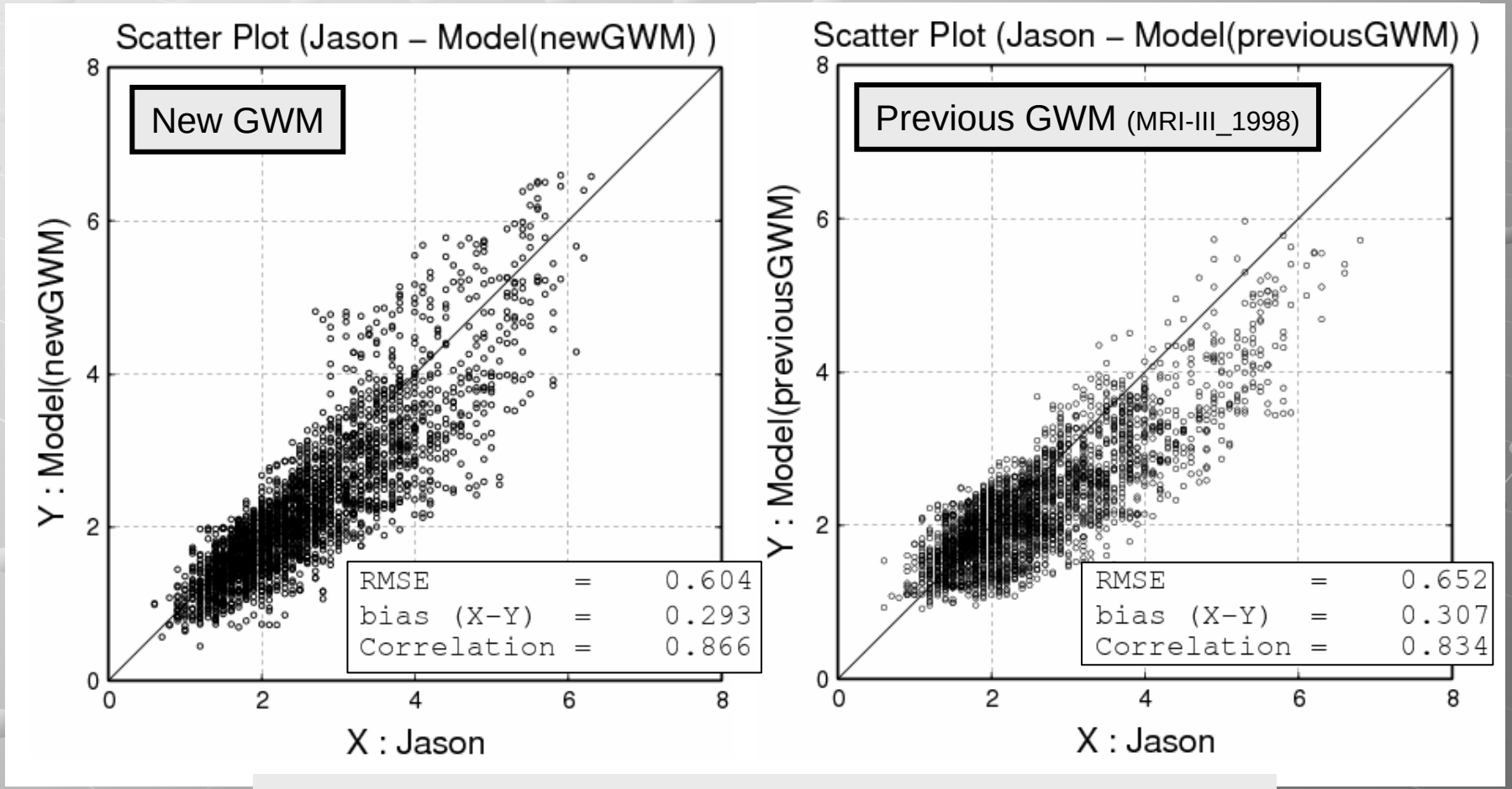
new GWM			
Region	data num.	bias [m]	RMSE [m]
Global	25637	-0.130	0.750
N.H.(75-20N)	6328	-0.408	0.786
Tropics(20N-20S)	6458	-0.212	0.401
S.H. (75-20S)	12851	-0.044	0.857

previous GWM (MRI-III_1998)			
Region	data num.	bias [m]	RMSE [m]
Global	25557	-0.463	0.777
N.H.(75-20N)	6093	-0.468	0.787
Tropics(20N-20S)	6414	-0.082	0.408



Comparison with Rader Altimeter

- Scatter plot in Northwestern Pacific Ocean.

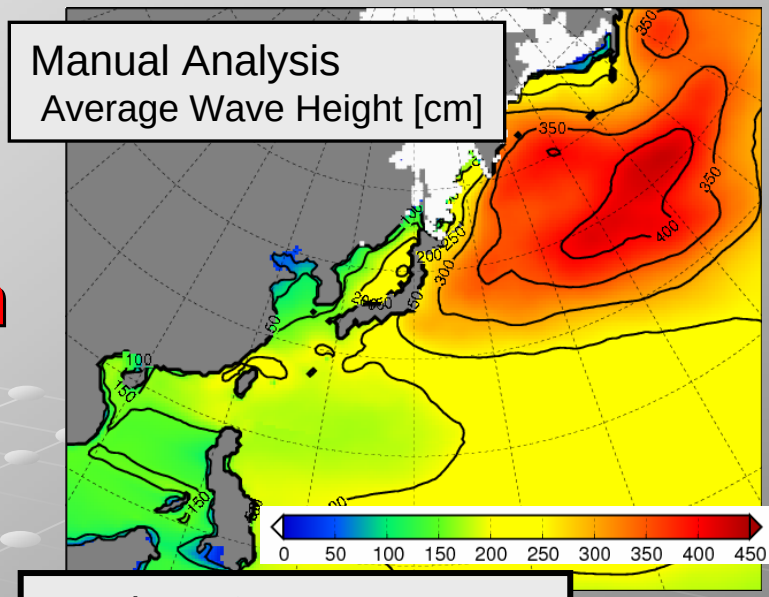


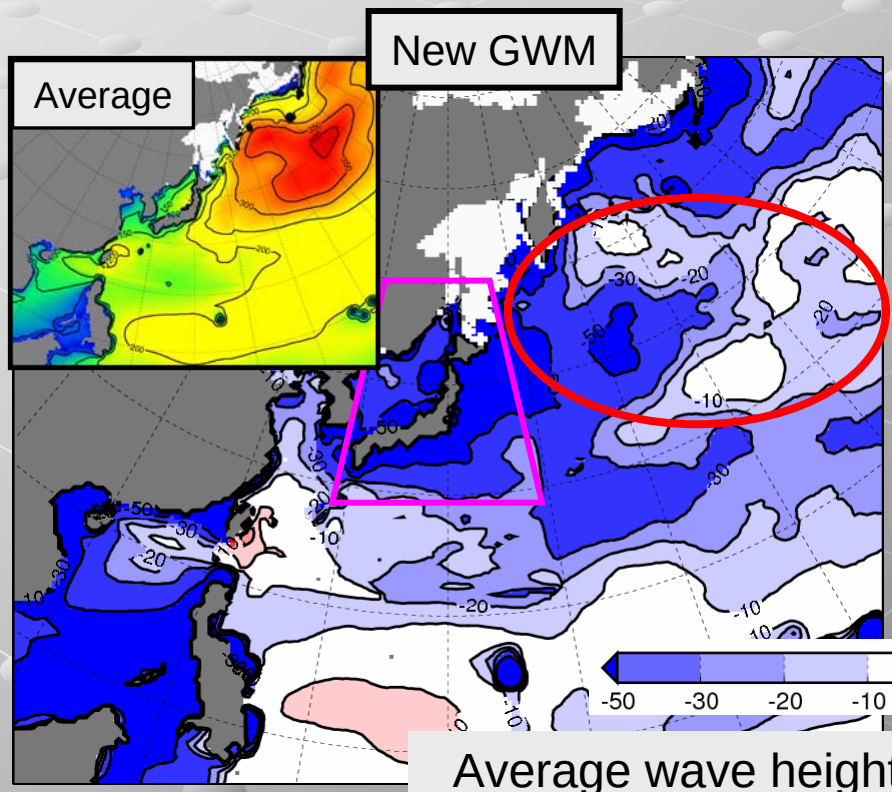
Scatter plots of wave height between JASON-1 radar altimeter and 12 hours forecast in March 2007.

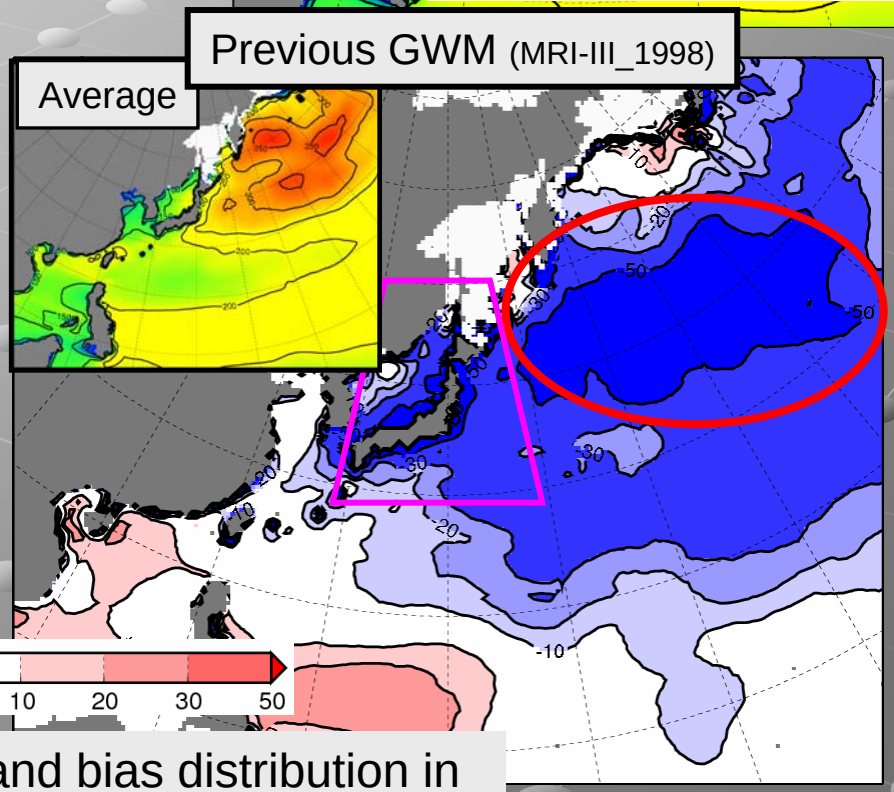
Comparison

with Manual Analysis

- **Improvement of swell estimation in open ocean.**
- Increase of negative bias around Japan.
  - Problems about initial wave evolution.





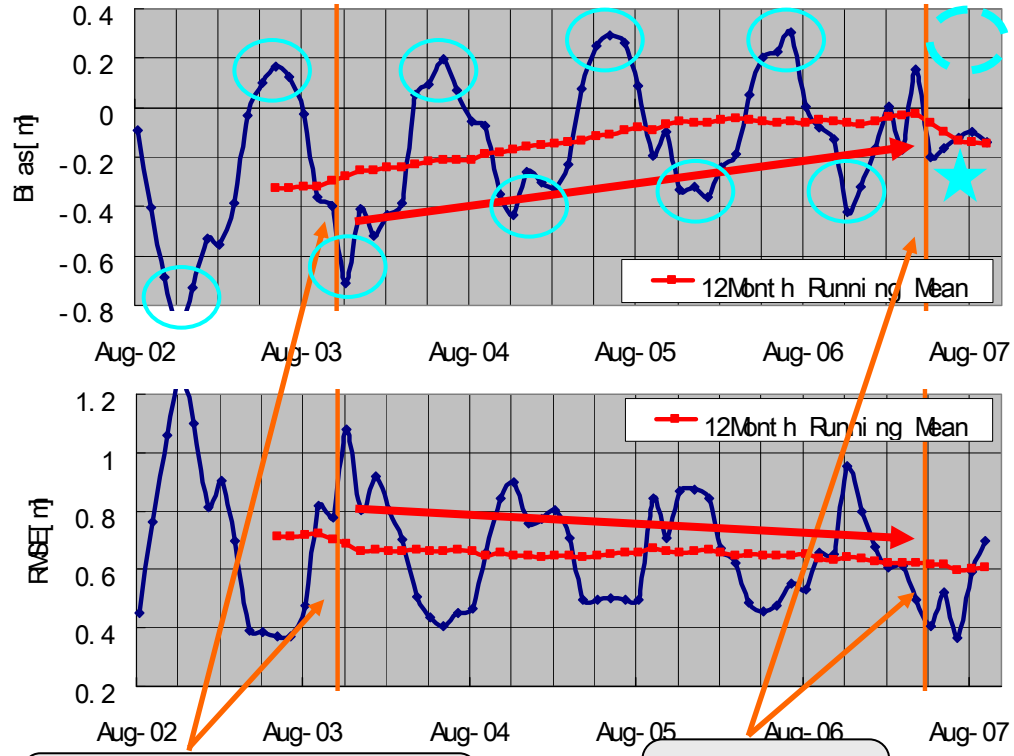


-50 -30 -20 -10 10 20 30 50

Average wave height and bias distribution in the Northwest Pacific Ocean in March 2007.

Comparison with Buoy Observations

- Difference between operational GWM result of 24 hours forecast and Buoy observations in the North Pacific Ocean from 2002 to 2007.



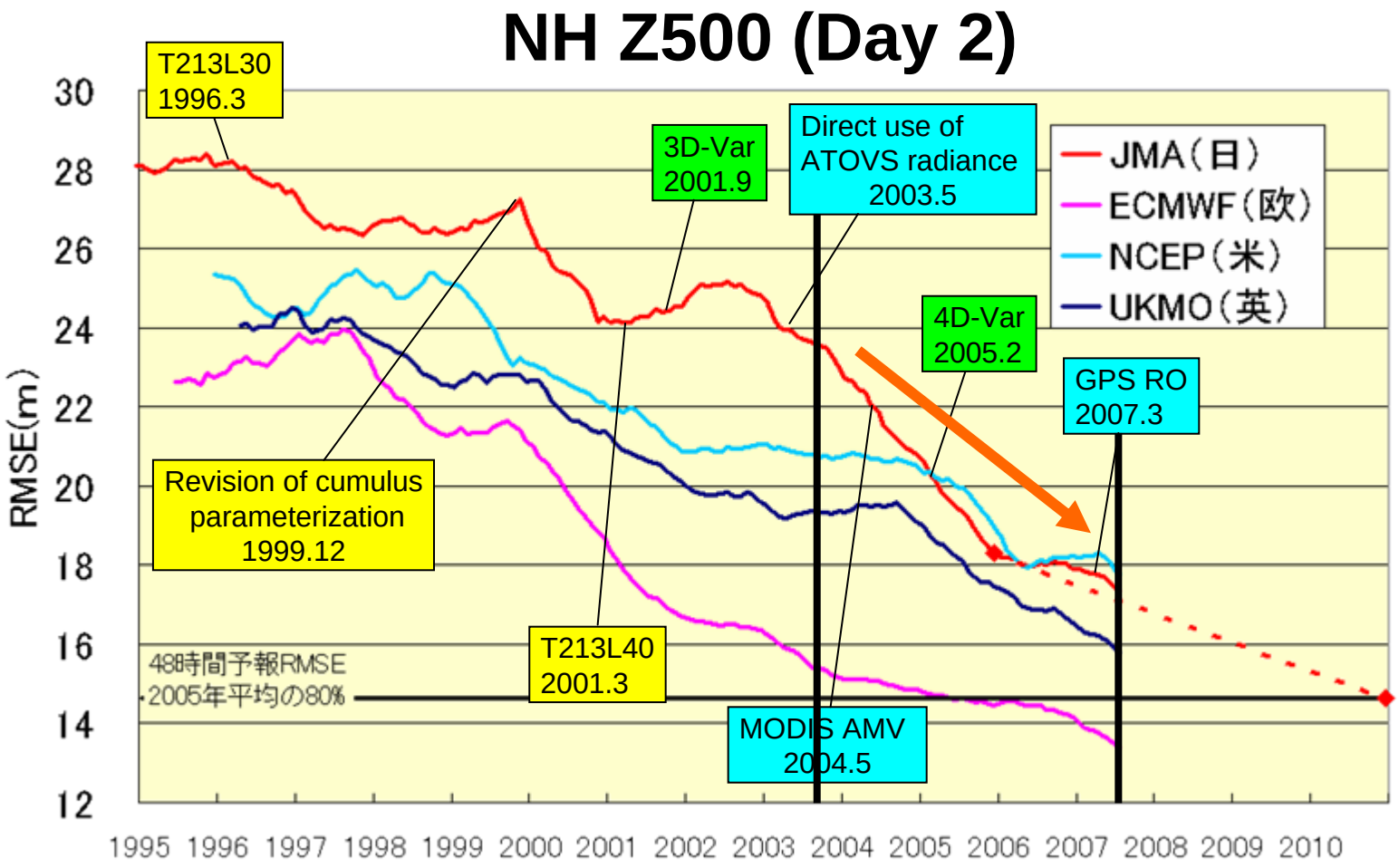
November, 2003
Introduced bias correction scheme

May, 2007
New MRI-III

Wave Works

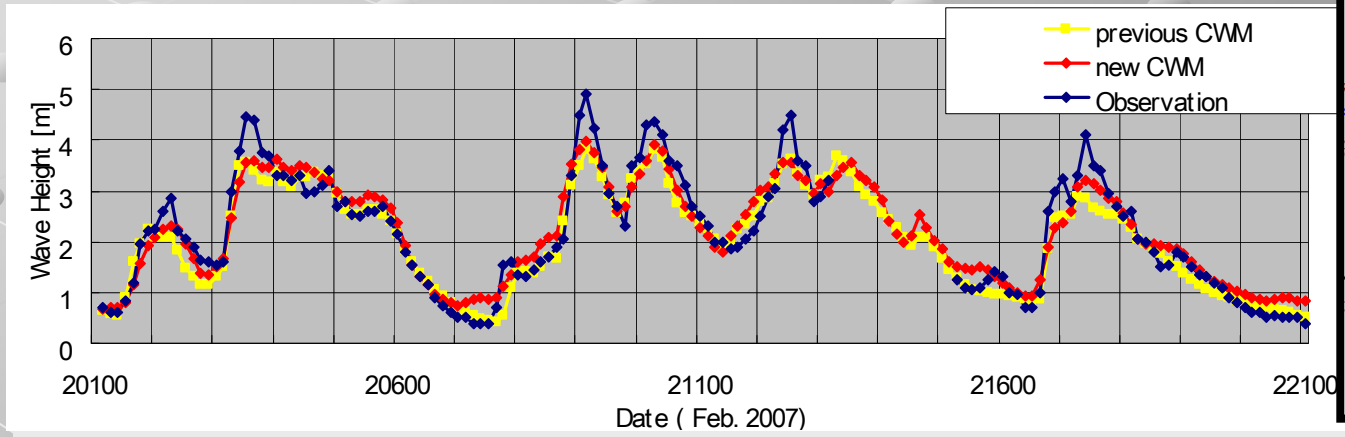
- Improvement from 2003 through May 2007
  - Corresponds to the improvement of GSM.
- ★ Has the negative bias became worse?
  - Prev. GWM
    - Positive bias … summer
    - Negative bias … winter
  - New GWM
    - Bias characteristic has changed.

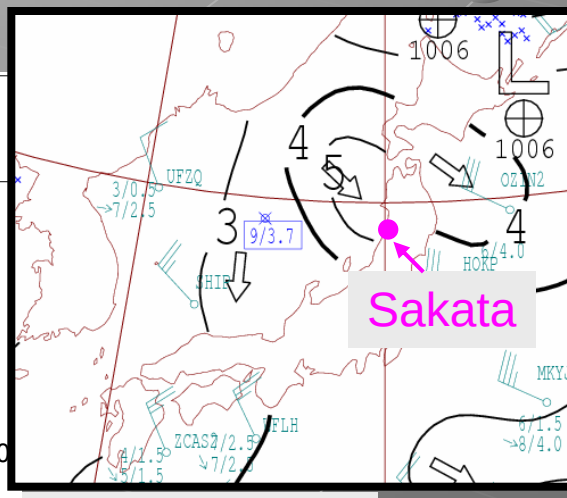
Performance of GSM (1) *(Ref.)*



Performance of CWM

- Main objective of CWM
  - Accurate estimation for windseas that reached coast.
    - Case … High waves against Japan Sea coast by winter monsoons.
- Parameter tuning for CWM
  - Hindcast experiments were carried out.





Comparison of wave height between model results and observations of the wave recorder at Sakata.

Data From : NOWPHAS (Nationalwide Ocean Wave information network for Ports and HArbourS).
… Japanese nationwide coastal wave data observed by the associated agencies of the Ports and Harbours Bureau of MLIT (Ministry of Land, Infrastructure and Transport) and analyzed by Port and Airport Research Institute.

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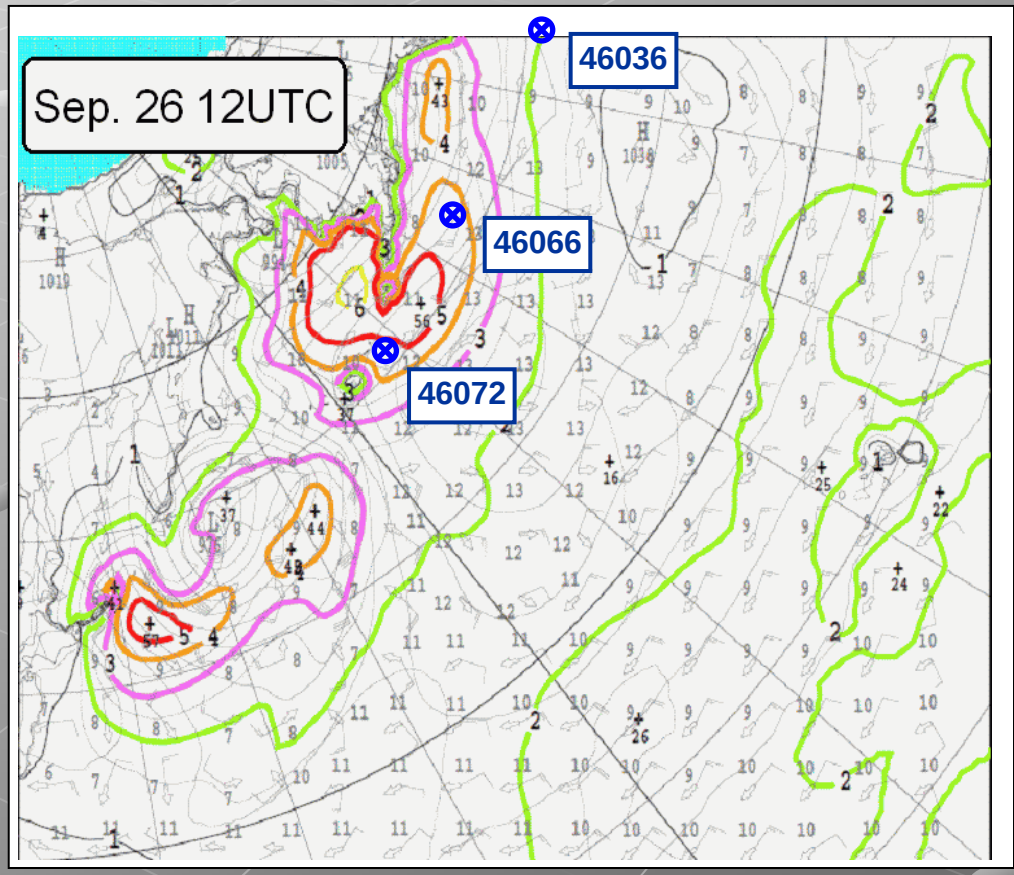
Discussion

- A few problems were found through operational use.
  - Over estimation of wave heights in particular case.
    - It happens …
      - In the area with enough fetch.
      - In the time when duration is long and wind speed is rather moderate.
  - Weak wave evolution in early stage.

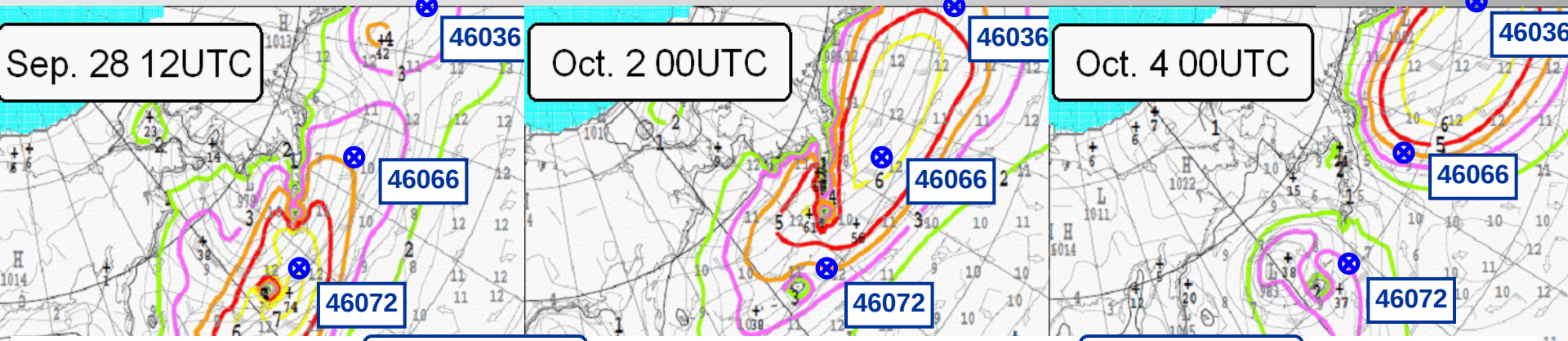
Case of over estimation

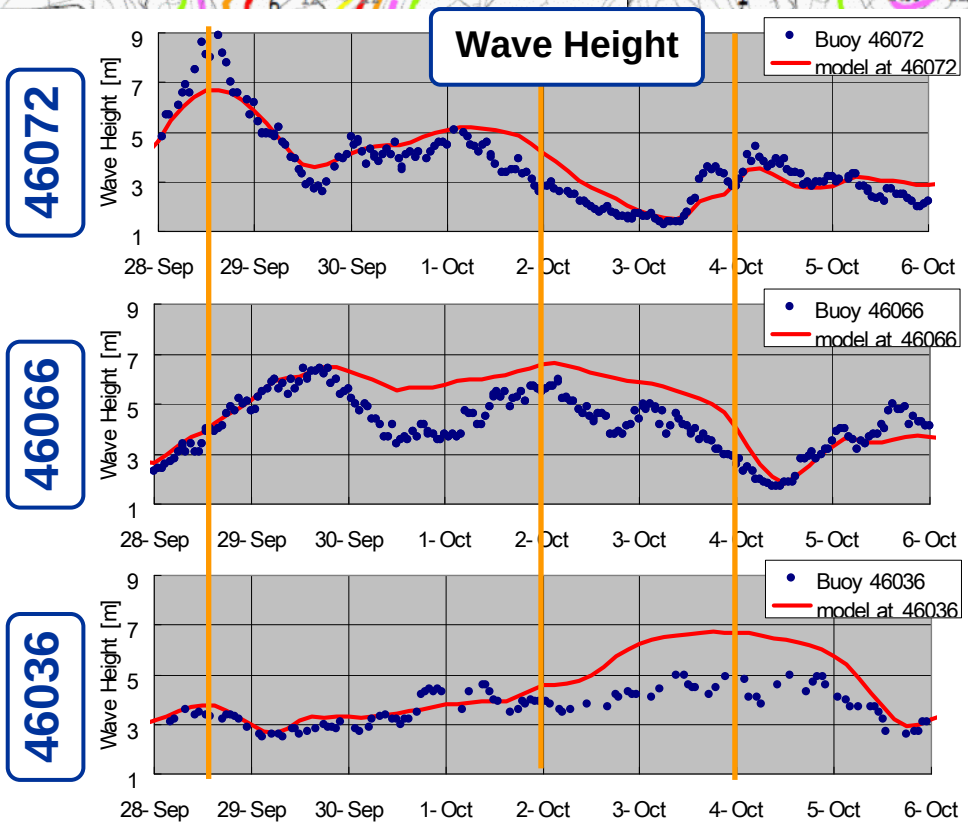
- In the Sea around Aleutian Islands.
  - From September 26 to October 5.

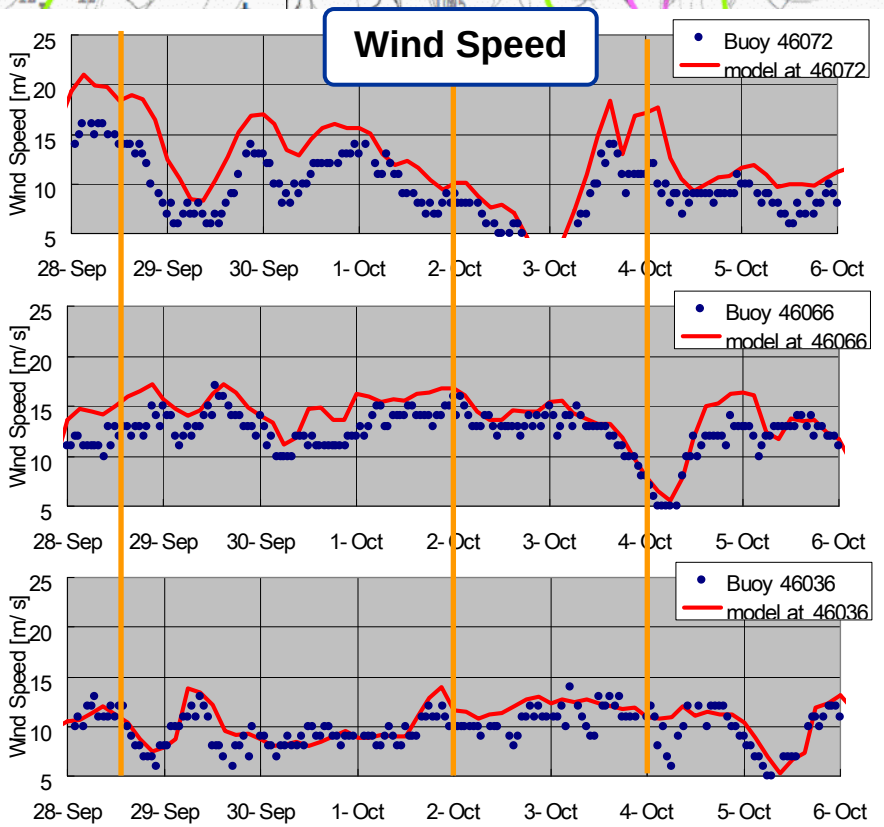
- Data comparison between Buoy and Hindcast of GWM.
  - At 46072 … upstream
  - At 46066 … midstream
  - At 46036 … downstream



Comparison between Buoy and Hindcast







Discussion (cont.)

- To solve these problems …
  - Further adjustment of wave coefficients to the new weather model is necessary.
  - We need to research about dissipation term.
  - We have a plan to develop a data assimilation system in model cycle.

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    - rather moderate wind speed
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Future Plans (Summary cont.)

- Increase of Model Operation.
  - twice/day → 4times/day (every 6hours)
    - From 21 November 2007. (Next Wednesday)
- Adjustment of wave coefficients to the new GSM.
  - Balance between evolution and dissipation.
- Update of the model description.
  - Research about dissipation term.
- Development of a data assimilation system.

The End.