Upgraded Numerical Wind Wave Prediction Systems at KMA and their Validation

- Current & Future NWP System at KMA
- Upgraded 2008 Wind Wave Prediction Systems
- Monthly Validation Statistics and Case Evaluation
- JCOMM Operational Global Wave Model Inter-comparison

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Korea Meteorological Administration

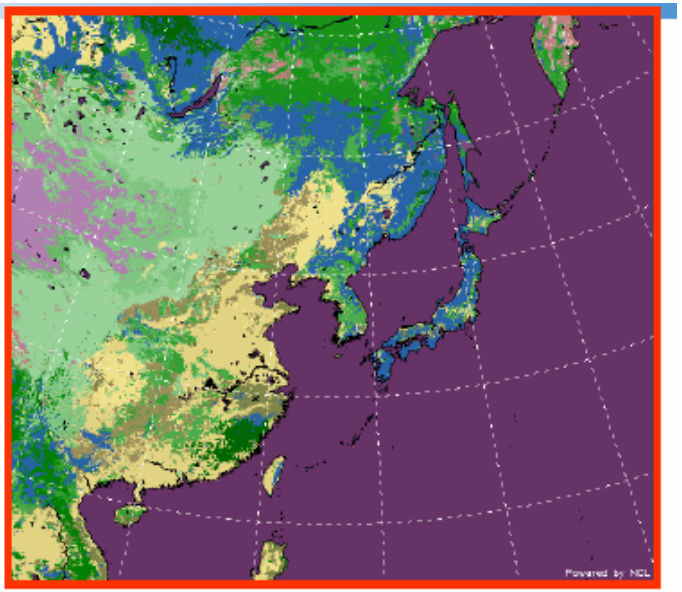
Cape Town, Oct. 13, 2008

Operational NWP Models at KMA

Model	Analysis	Resolution (Layers)	Lead time (Days)	Remark
Global Spectral Model (GDAPS) → Unified Model (UKMO)	3DVAR	T426 (30km, 40 levels)	10.5	
	3DVAR	T213 (55km, 40 levels)	10	32 Ensemble
	3DOI	T106 (110km, 21 levels)	90	Ensemble
Regional Model (RDAPS) & KWRF	3DOI/ 3DVAR	30/ 10/ 5km(33)	2.5	Triple Mesh
Typhoon Model (DBAR)	Bogus	20km (barotropic)	3	Typhoon Track
Wave Model (ReWAM,GoWAM) → Upgraded	n/a	0.25°	2.5	Asian
	n/a	1.25°× 1.25°	10.5	Global
Statistical Model		-	2.5	Temp, PoP

Summary of KWRF & RDAPS

- WRF Version 2.1.2
- WRFSI
- KWRF 10km(574x514x31)
- 48 Hours forecast
- U3VR 6 hour cycle
- DFI



Model Physics

	RDAPS	KWRF
Microphysics Scheme	Mixed Phase	WSM6
Radiation Scheme	Cloud radiation	Dudhia/RRTM
Cumulus parameterization	New Kain-Fritsch	New Kain-Fritsch
Land-Surface model	5-layer soil	Noah LSM
PBL Scheme	MRF PBL	YSU PBL

KWRF & RDAPS Sea Surface Wind Comparison

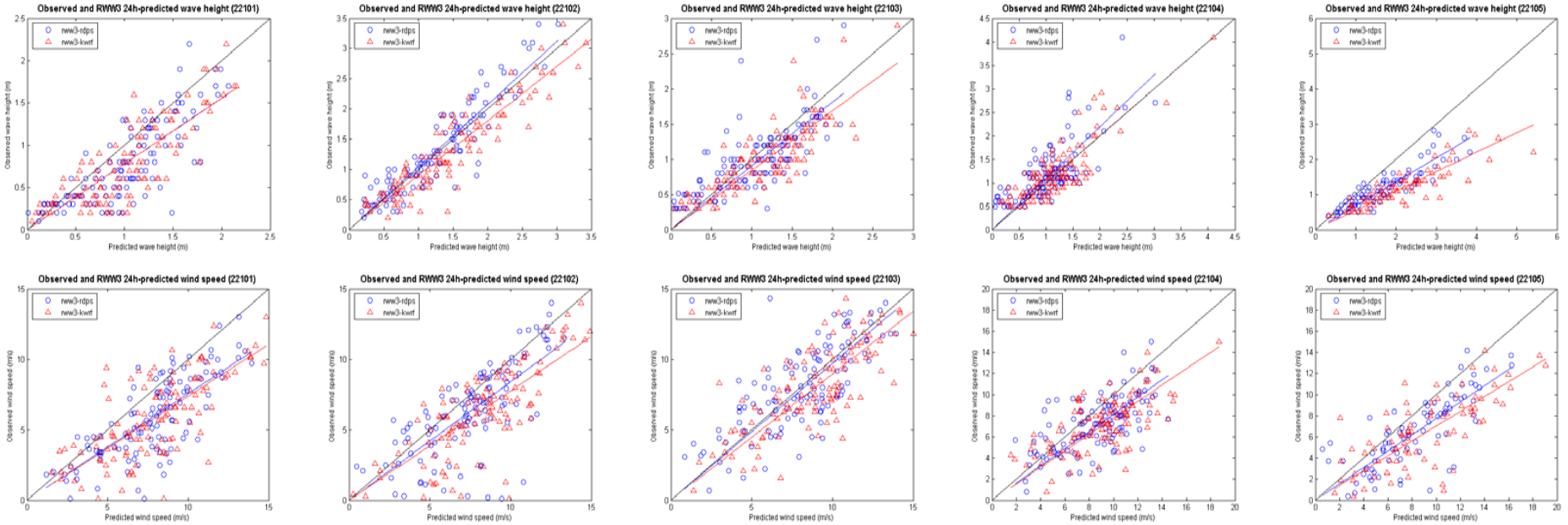


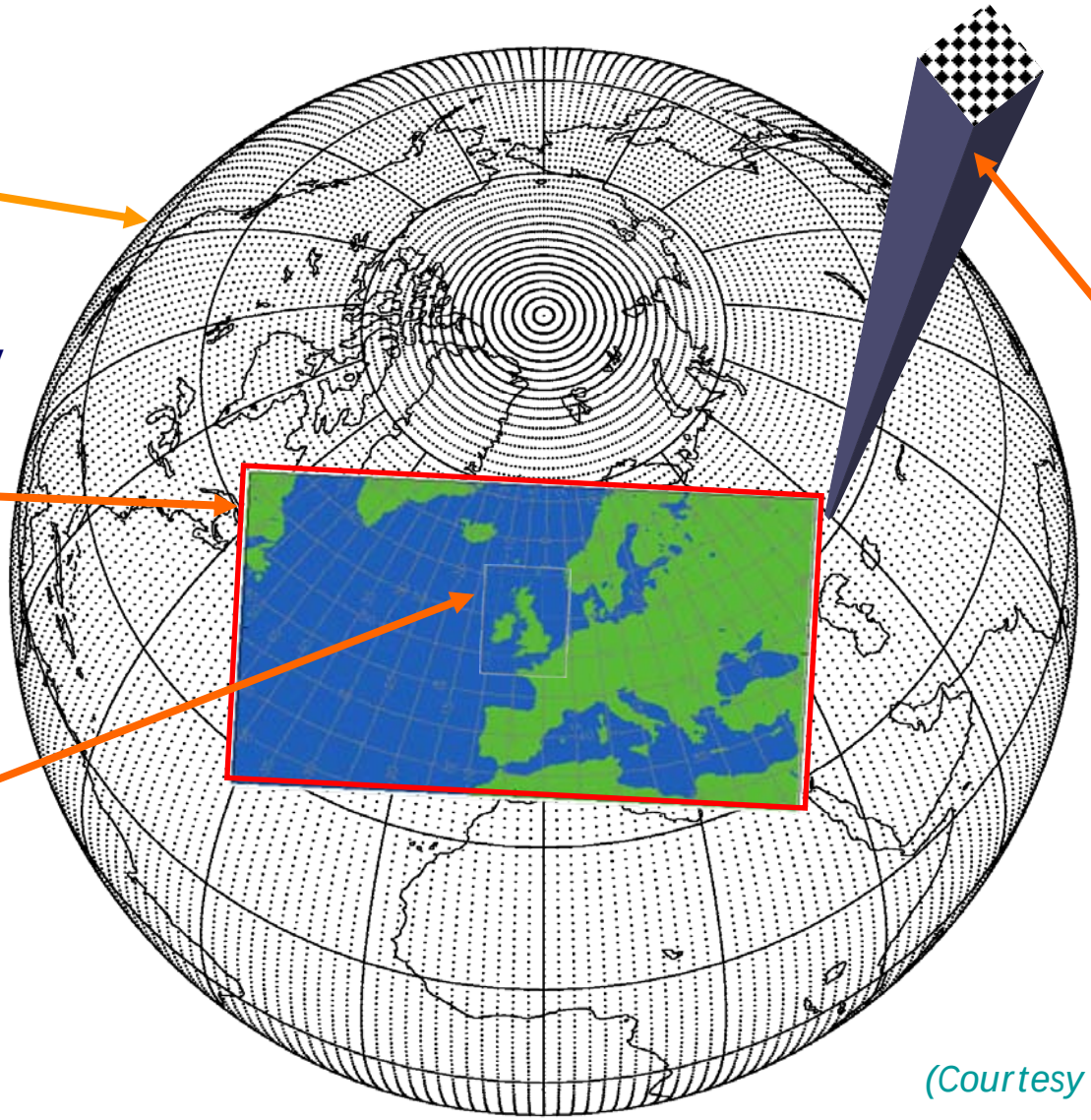
Fig. 1. Scatter plots of RWW3 predicted versus observed wave height (upper) and wind speed (lower) as well as line plots of regression between model and observed values from January to March 2008 for Deokjeok(22101), Chilbal(22102), Geomun(22103), Geoje(22104) and Donghae (22105) buoy stations. Blue circles and lines are for RWW3-RDPS and red triangles and lines are for RWW3-KWRF.

Operational NWP Models: 2007

Global
- 40Km
- 4DVAR
- 60 hour forecast twice/day
- 144 hour forecast twice/day
- +EPS 24member,90km

NAE
- 12Km 38 L
- 4DVAR
- 60 hour forecast
- 4 times per day
- +EPS 24member,24km

UK4
- 4km 38 L
- 3DVAR
- 36 hour forecast
- 4 times per day



50 levels (70L in Feb 08)

(Courtesy of S. Bell)

Wind Wave Prediction System Development at KMA

- 1987 - 1991 : Base research on the characteristics of ocean wave near Korean peninsula, (MRI/KMA: Meteorological Research Institute)
- 1992 : Operation of Far East Asia Model and 1st generation ocean wave model (DSA-5) with Cardone Model for the generation of sea surface winds
- 1996 : Operation of Regional Data Assimilation and Prediction System(RDAPS, 40km) and adaptation of wave model to corresponding horizontal resolution
- 1998 : Semi-operation of the 3rd generation wave model (WAM) with 0.5 degree resolution on CRAY-C90 for the replacement of DSA-5 model
- 1999 : Installation of NEC SX5-16A, Upgrade of RDAPS(MM4=>MM5), Operation of Regional (ReWAM : 0.25 deg) and Global (GoWAM: 1.25 deg) Wave Prediction System

- 2003 – 2005 : Coastal Wave Prediction System development in cooperation with Korea Ocean Research and Development Institute, Installation of Cray X1E (2005)
- 2006 – 2007 : Test Operation of high resolution ReWW3 (1/12deg) and Coastal Wave Prediction System (CoWW3, 1/120deg)
- 2008 3. : Operation of ReWW3 and CoWW3
- 2008 7. ~ : Test Operation of GoWW3 (0.5 deg)

- 2009 9. : Installation of 3rd supercomputer (~ 200 Tera Flops)
- 2010 10. : Operation of UM-N512L70 (Unified Model,~25km) based Wave Prediction System

Operational Wind Wave Prediction Models

Global

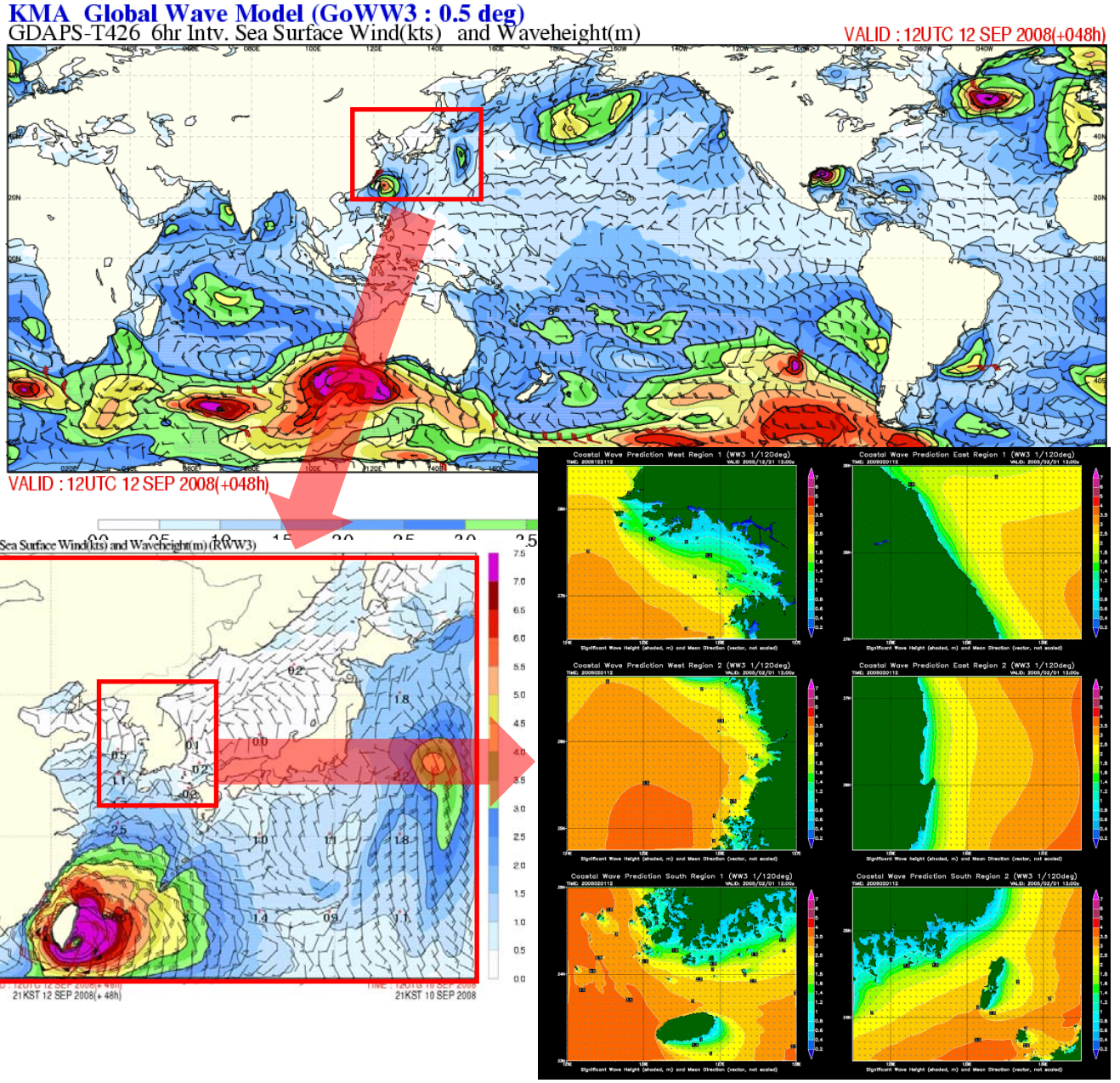
- 60Km (1/2°)
- 252 hour forecast twice/day

Regional

- 8Km (1/12°)
- 66 hour forecast twice/day

Coastal

- 1km (1/120°)
- 24 hour forecast twice/day
- 6 coastal domains



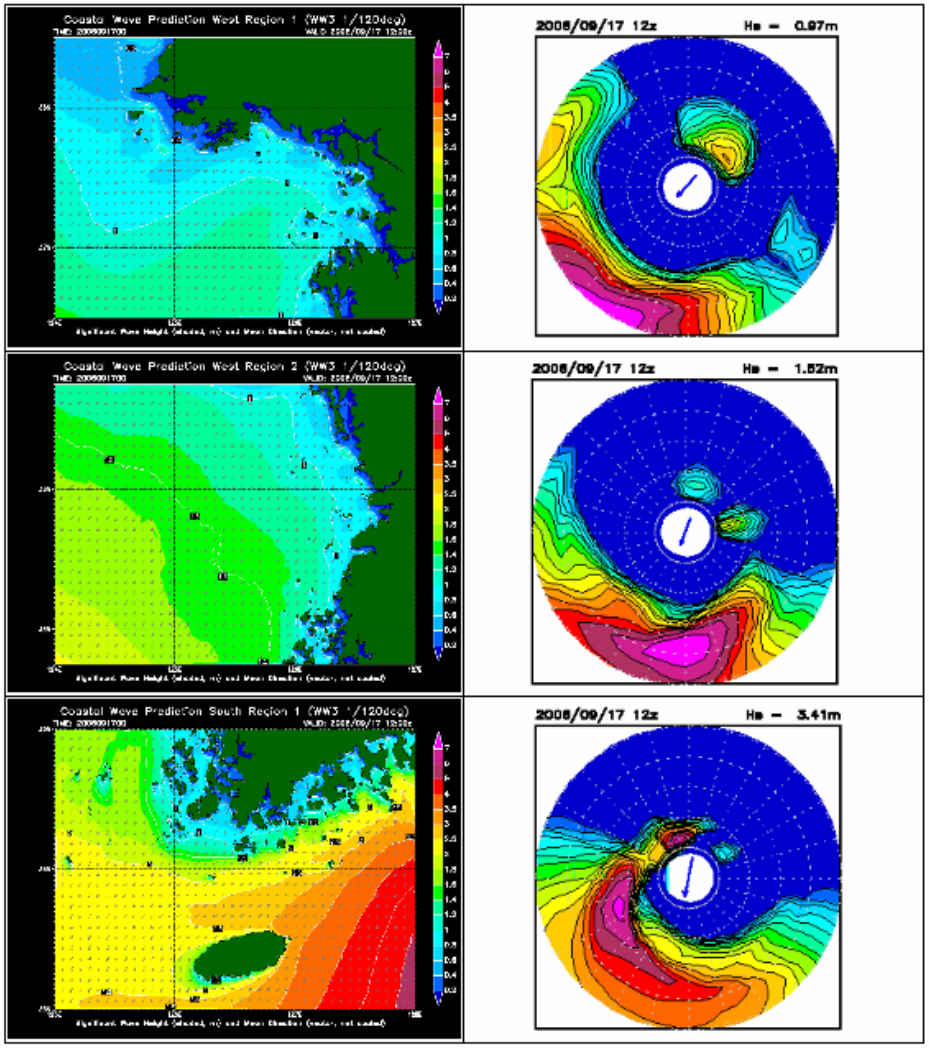


그림 4.2 서해중부(CoWW3-RGW1), 서해남부(CoWW3-RGW2), 남해서부(CoWW3-RGS1) 도메인의 유의파고, 파향 예상도 및 덕적도 브이, 칠발도 브이, 거문도 브이 지점에서의 스펙트럼 에너지 예상도

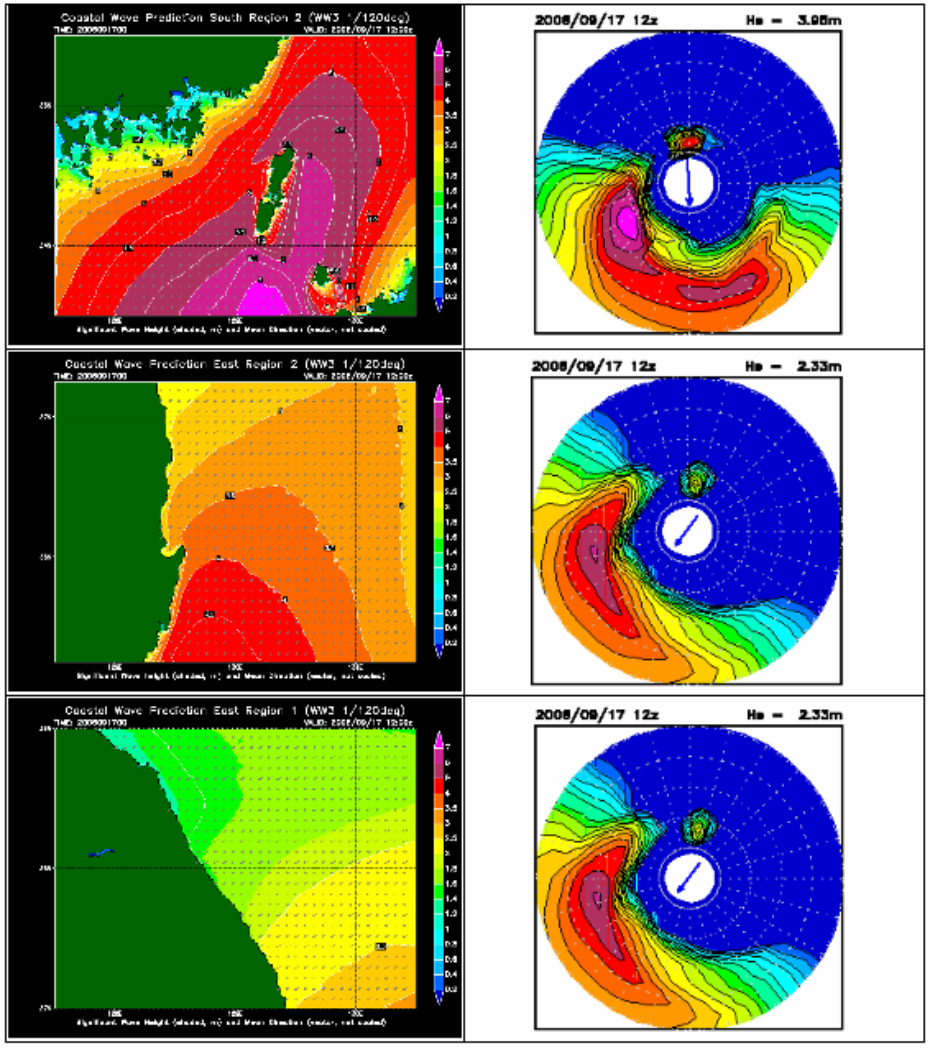


그림 4.3 남해동부(CoWW3-RGS2), 동해중부(CoWW3-RGE1), 동해남부(CoWW3-RGE2) 도메인의 유의파고, 파향 예상도 및 거제도 브이, 동해 브이 지점에서의 스펙트럼 에너지 예상도

	GoWW3	ReWW3	CoWW3	ReSTORM	CoSTORM*
Model Code	WAVEWATCH III Code (version 2.22)			POM Code (2D, Kantha)	
Model Coordinate	Spherical Coordinate			Spherical Coordinate	
Model Domain	70°S-70°N, 0°E-360°E	20°N-50°N, 115°E-150°E	RGW1:36.50°N-38.50°N,124.00°E-127.00°E RGW2:34.75°N-36.75°N,124.00°E-127.00°E RGS1:33.00°N-35.00°N,125.00°E-128.00°E RGS2:33.50°N-35.50°N,127.50°E-130.50°E RGE1:37.00°N-39.00°N,127.50°E-130.50°E RGE2:35.25°N-37.25°N,128.50°E-131.50°E	Same as ReWW3 area	Same as CoWW3 area
Spectral Resolution	25 Frequency 36 Direction		25 Frequency 36 Direction	N/A	
Spatial Resolution	0.5° (720×281)	1/12° (421x361)	1/120° (361×241)	1/12° (421×361)	1/120° (321×241)
ΔT	720sec	150sec	30sec	900sec	30sec
Prediction & Staring Time	256H (00,12UTC)	66H (00,12UTC)	24H (00,12UTC)	48H (00,12UTC)	
Initial & Boundary Data	-12H FCST	-12H FCST	-12H FCST/ ReWW3 Boundary Data	Warm Start	Warm Start ReSTORM Boundary Data
Input Forcing data	GDAPS Sea Surface Wind (0.5625 °)	RDAPS Sea Surface Wind (30km), KWRF Sea Surface Wind (10km)		RDAPS sea Surface Wind & Mean Sea Level Pressure	

※ **GDAPS**: Global Data Assimilation and Prediction System **RDAPS**: Regional Data Assimilation and Prediction System
KWRF: korea Weather and Forecasting model
GoWW3: Global WAVEWATCH III **ReWW3**: Regional WAVEWATCH III **CoWW3**: Coastal WAVEWATCH III
ReSTORM: Regional Storm Surge Model **CoSTORM**: Coastal Storm Surge Model

• The governing equation & source term parameterization

$$\frac{\partial E}{\partial t} + \nabla \bullet \left(\boldsymbol{c}_{\mathbf{g}} E \right) = S = S_{\text{in}} + S_{\text{nl}} + S_{\text{ds}} \qquad E = E(f,\theta,\boldsymbol{x},t) \qquad \boldsymbol{c}_{\mathbf{g}} = \boldsymbol{c}_{\mathbf{g}}(f,\theta)$$

- Initial Condition : hindcast or restart from previous run's spectra

- Wind Input :
  controls the quality of wave prediction
- Dissipation :
  bottom interaction and wave breaking

WAM-3	Komen (1984)
Tolman & Chalikov √	1996

- Non-Linear Interactions :
  most time consuming and energy transfer

Discrete Interaction Approx. √	Hasselmann
Webb-Resio-Tracy	Exact

- Propagation :
  includes shallow water effect & currents

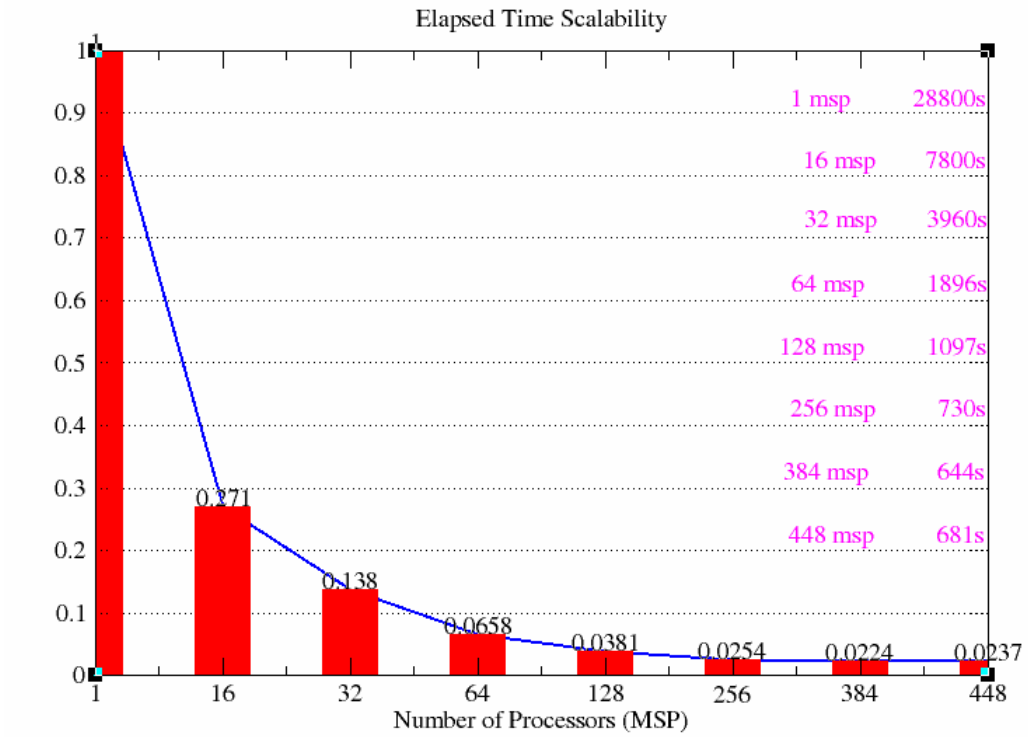
PR 1	1st order propagation
PR 2	Booij (1987) dispersion correc.
PR 3 √	Tolman (2002) averaging
PR 4	Tolman (2002) divergence

- Depth : shallow ($h < \lambda/4$) & deep
  JONSWAP bottom friction (Hasselmann)

- Effects of Boundaries, Coast Lines, and Islands :
  nested inside larger domain or zero energy flux along the boundaries

Scalability Test of WAVEWATCH-III

CPUs	Cray X1E	NCEP Linux
1	11.49	246.80
2	6.65	130.99
3	4.73	89.46
4	3.84	68.05
5	3.37	65.11
6	2.98	54.11
7	2.93	47.23
8	2.79	43.35
9	3.03	54.26
10	2.89	48.35
11	2.91	46.54
12	2.75	41.00
13	2.70	50.94
14	2.66	47.04
15	2.64	44.52
16	2.76	46.32



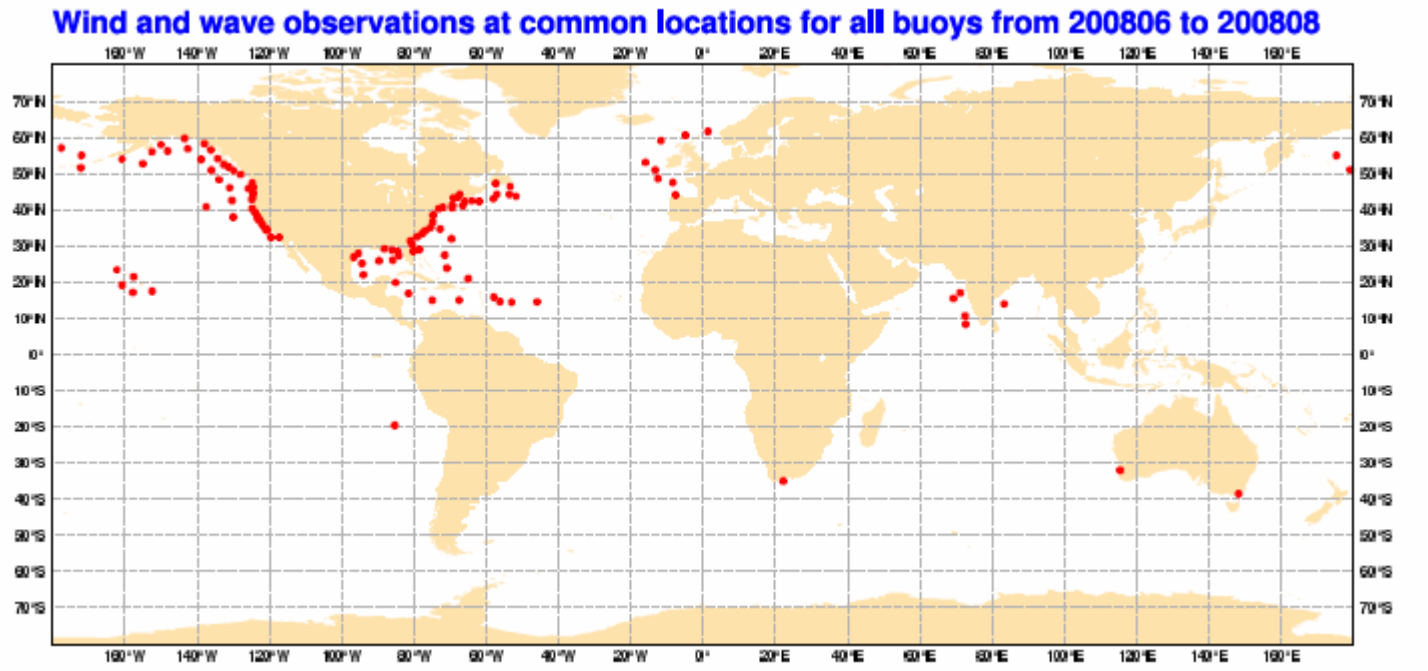
Scalability of 1/12deg ReWAM upon number of used processors

Comparison of WW-III test version computation in different platform
Cray X1E at KMA and Linux Cluster at NCEP

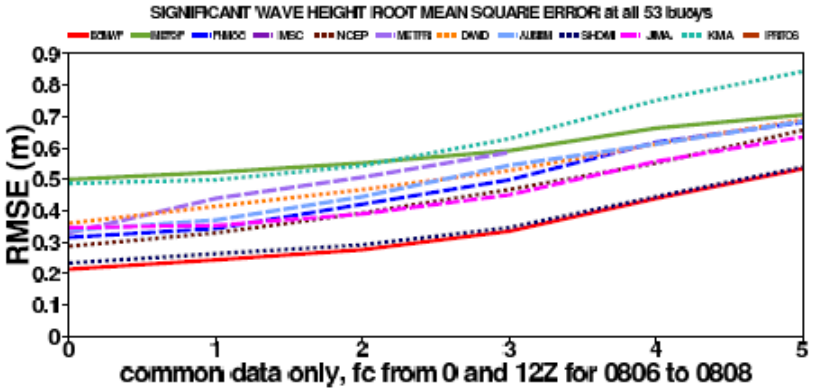
Intercomparison of operational wave forecasting systems against buoys: data from ECMWF, MetOffice, FNMOC, NCEP, MeteoFrance, DWD, BoM, SHOM, JMA and KMA
June 2008 to August 2008

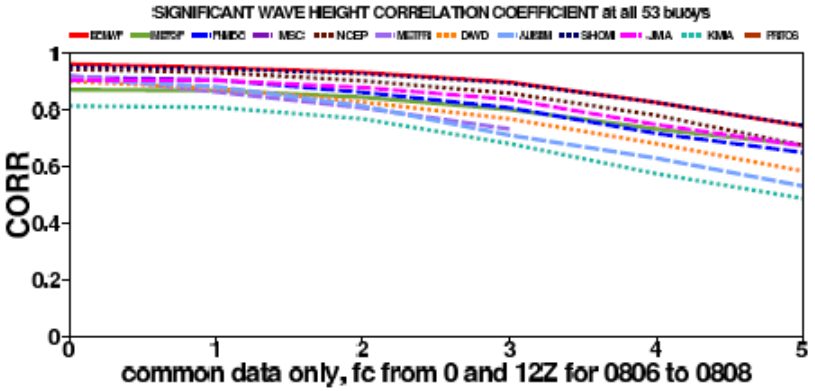
Jean-Raymond Bidlot, European Centre for Medium-range Weather Forecasts, jean.bidlot@ecmwf.int

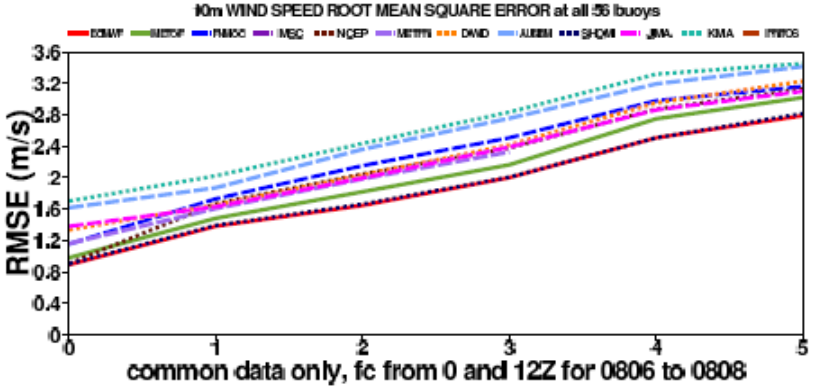
September 17, 2008

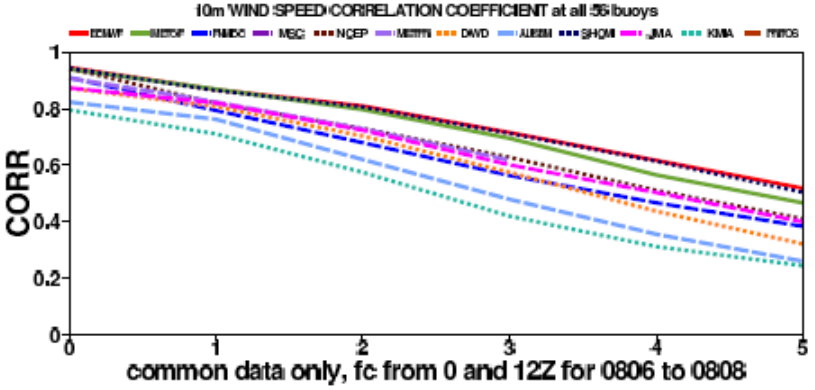


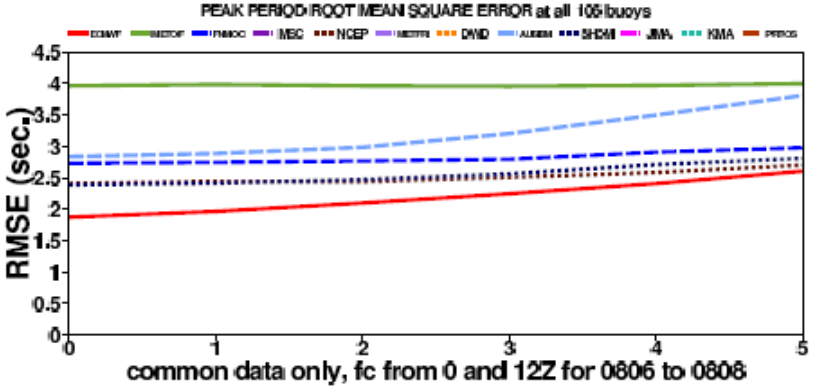
(Courtesy of J. Bidlot)



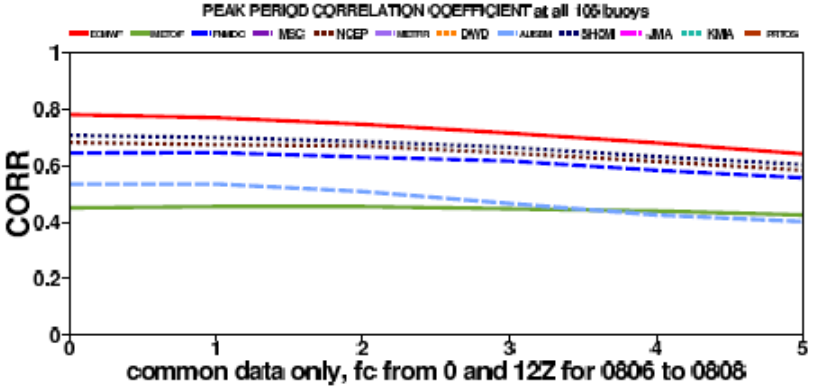






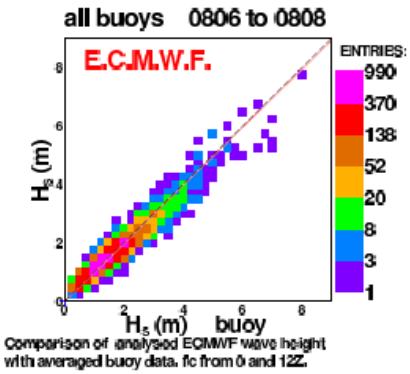


(a) R.M.S.E.

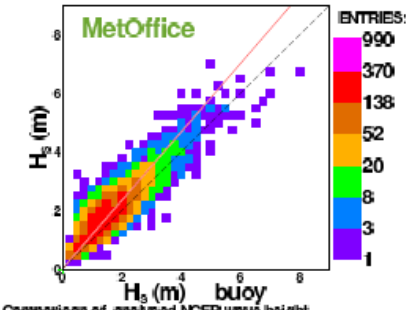


(b) Correlation Coefficient

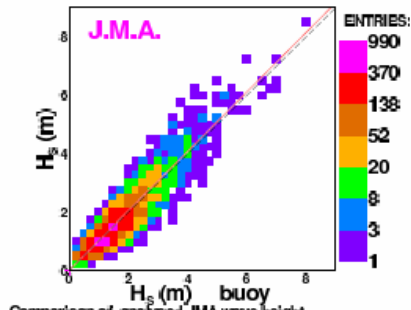
(Courtesy of J. Bidlot)



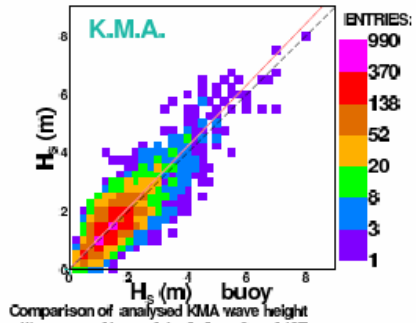
Comparison of analysed ECMWF wave height with averaged buoy data. fc from 0 and 12Z.



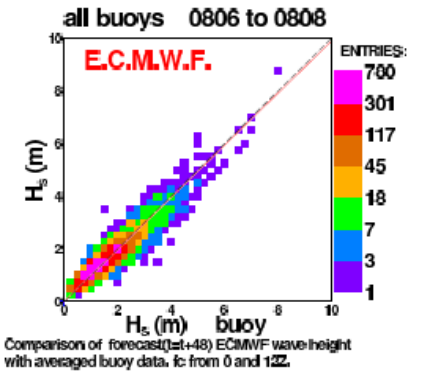
Comparison of analysed NCEP wave height



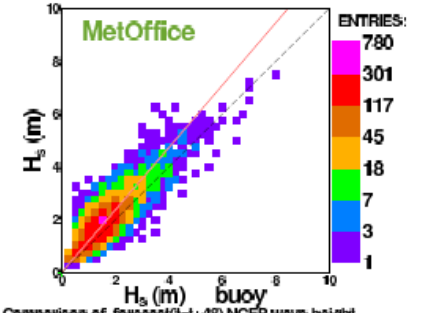
Comparison of analysed JMA wave height with averaged buoy data. fc from 0 and 12Z.



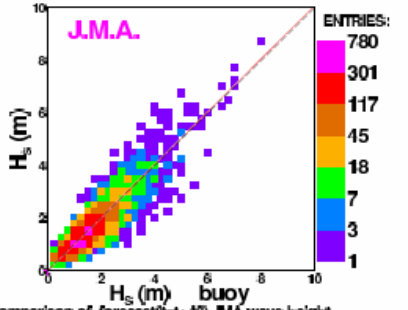
Comparison of analysed KMA wave height with averaged buoy data. fc from 0 and 12Z.



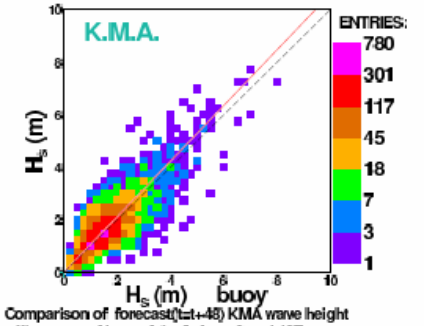
Comparison of forecast(t=t+48) ECMWF wave height with averaged buoy data. fc from 0 and 12Z.



Comparison of forecast(t=t+48) NCEP wave height



Comparison of forecast(t=t+48) JMA wave height with averaged buoy data. fc from 0 and 12Z.



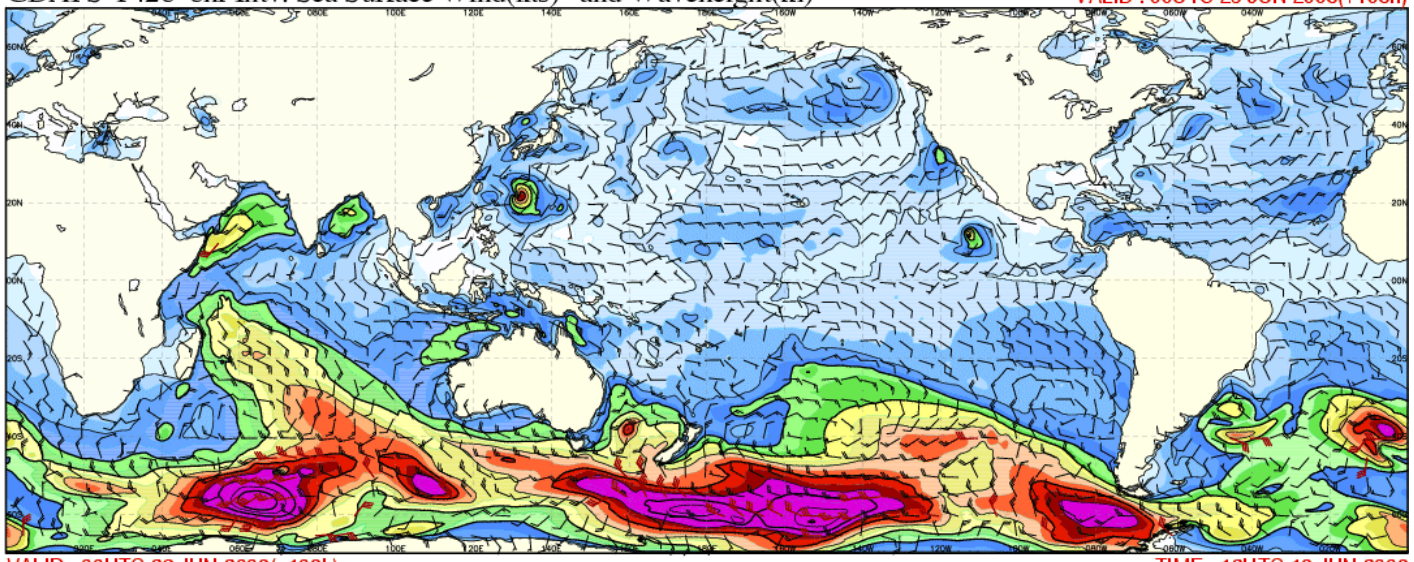
Comparison of forecast(t=t+48) KMA wave height with averaged buoy data. fc from 0 and 12Z.

(Courtesy of J. Bidlot)

KMA Global Wave Model (GoWW3 : 0.5 deg)

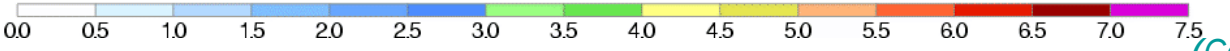
GDAPS-T426 6hr Intv. Sea Surface Wind(kts) and Waveheight(m)

VALID : 00UTC 23 JUN 2008(+108h)



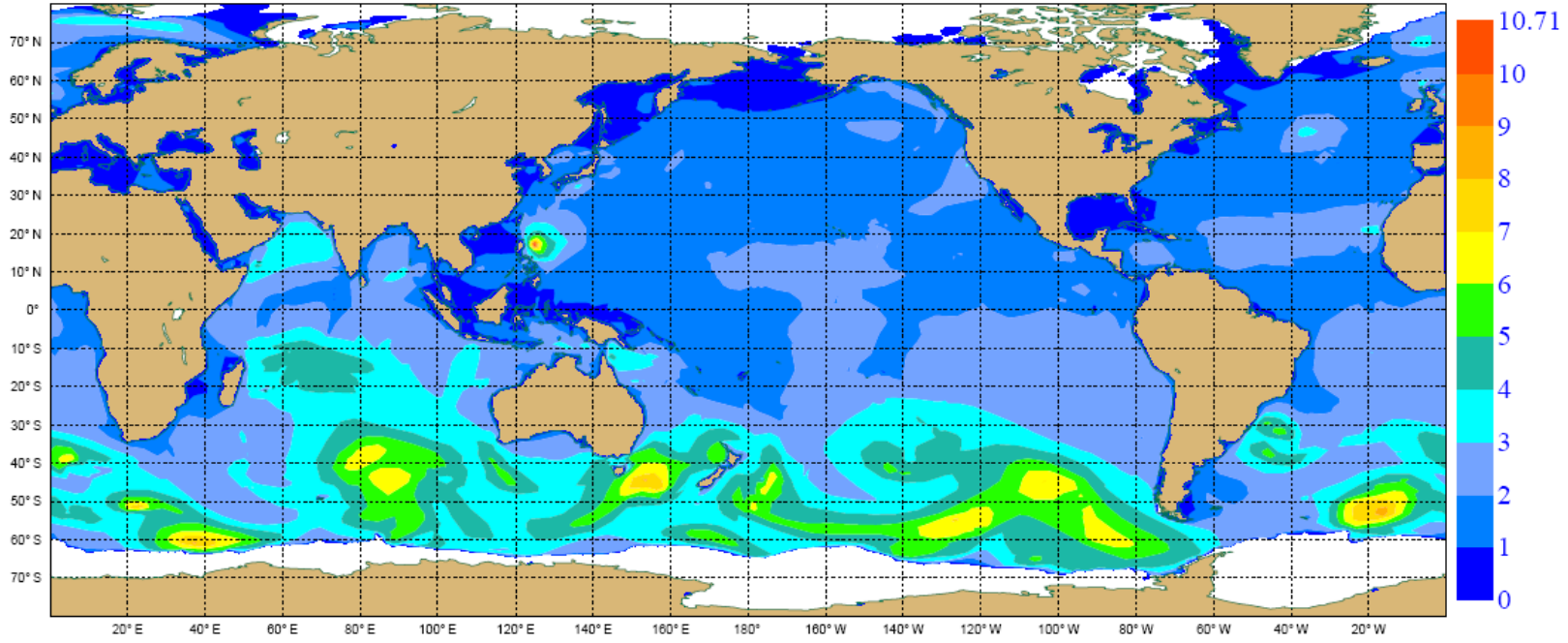
VALID : 00UTC 23 JUN 2008(+108h)

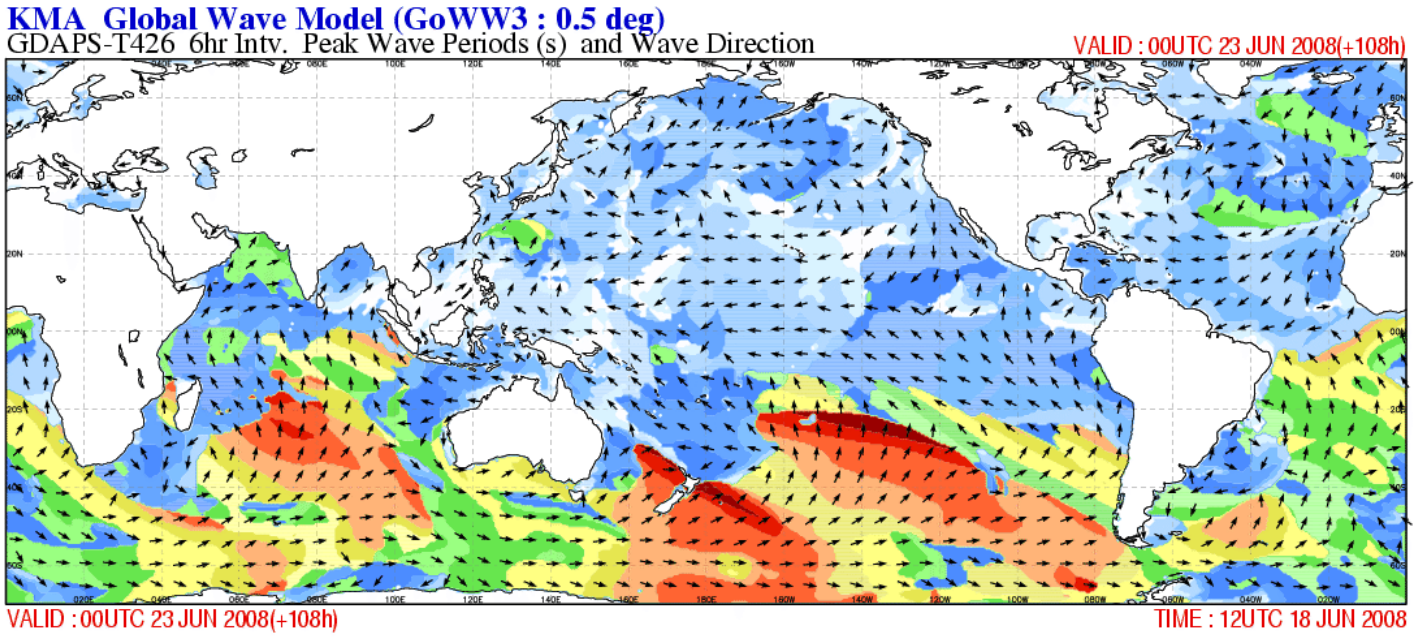
TIME : 12UTC 18 JUN 2008



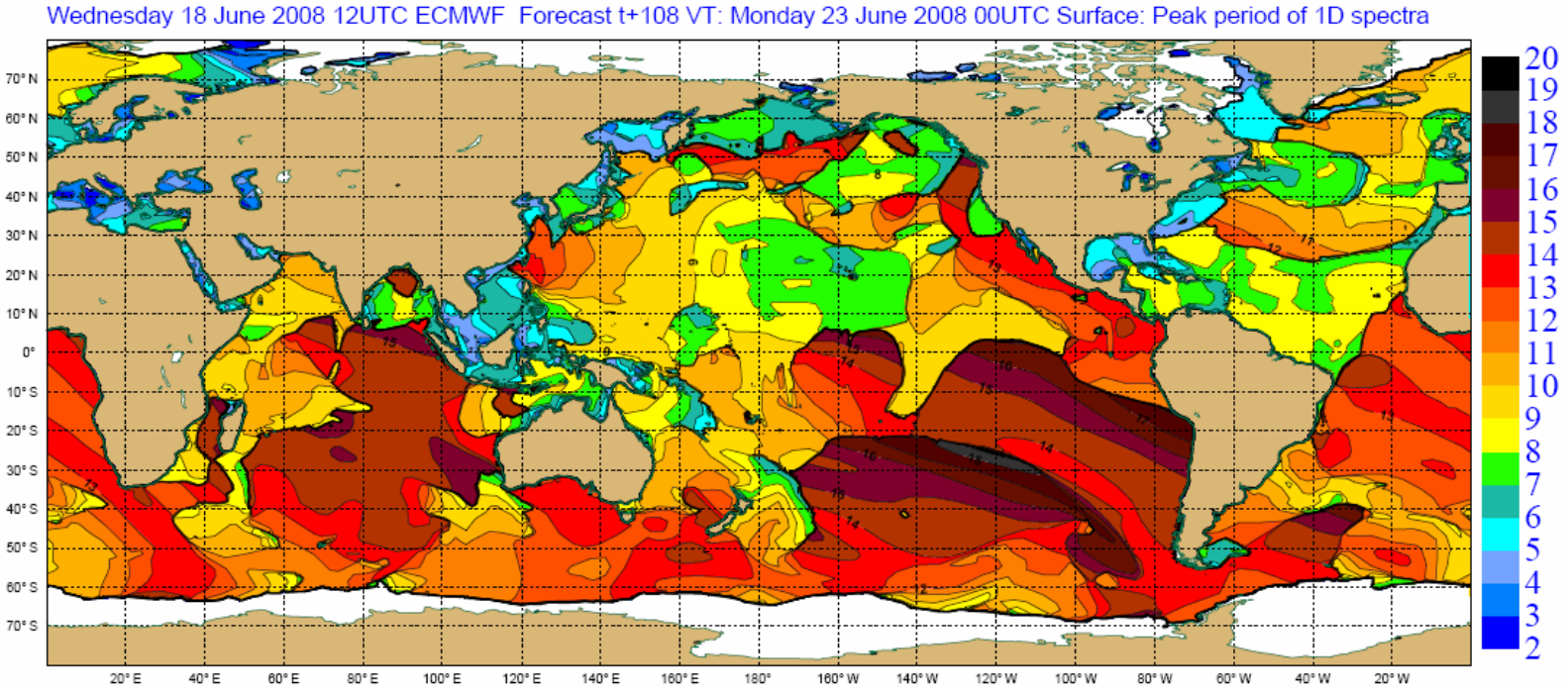
(Courtesy of J. Bidlot)

Wednesday 18 June 2008 12UTC ECMWF Forecast t+108 VT: Monday 23 June 2008 00UTC Surface: Significant wave height (Exp: 0001)

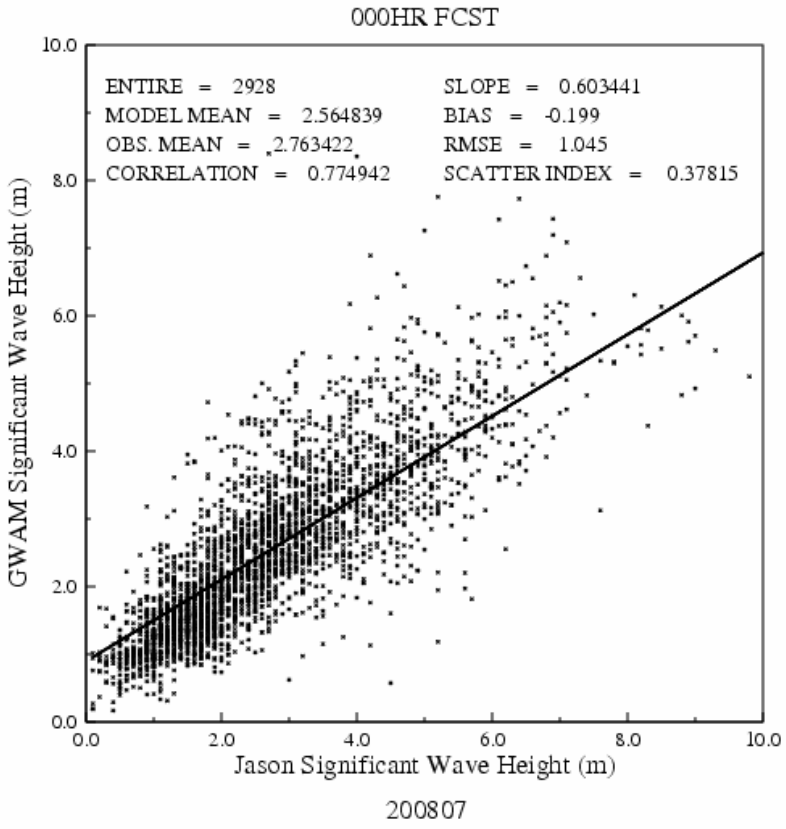


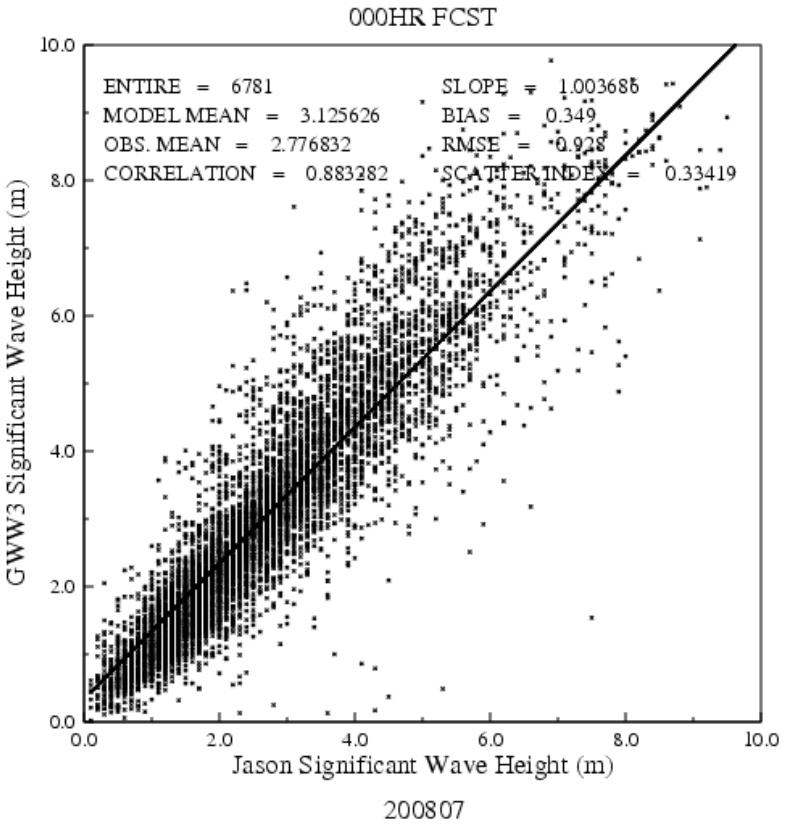


(Courtesy of J. Bidlot)



- **Comparison of GoWAM(1.25) & GoWW3(0.5) against Jason Significant Wave Height**





No. 11 Typhoon NARI

KMA | 2007.9.16 19:00

ANALYSIS	Present Position	Minimum Surface Pressure(hPa) Maximum Sustained Wind (m/s)	Radius of 15 m/s (km)	Moving Direction and Speed(km/h)
ANALYSIS 1800 UTC 16 Sep.	34.4 N, 127.4 E	980, 27 (97km/h)	160 (NW 140)	NNE, 25
FORECAST 0000 UTC 17 Sep.	35.9 N, 128.1 E	990, 23 (83km/h)	120 (NW 100)	NNE, 30
FORECAST 0600 UTC 17 Sep.	37.3 N, 129.3 E	995, 19 (68km/h)	100 (NW 80)	NE, 32
FORECAST 1800 UTC 17 Sep.	39.6 N, 132.9 E	1002		ENE, 33

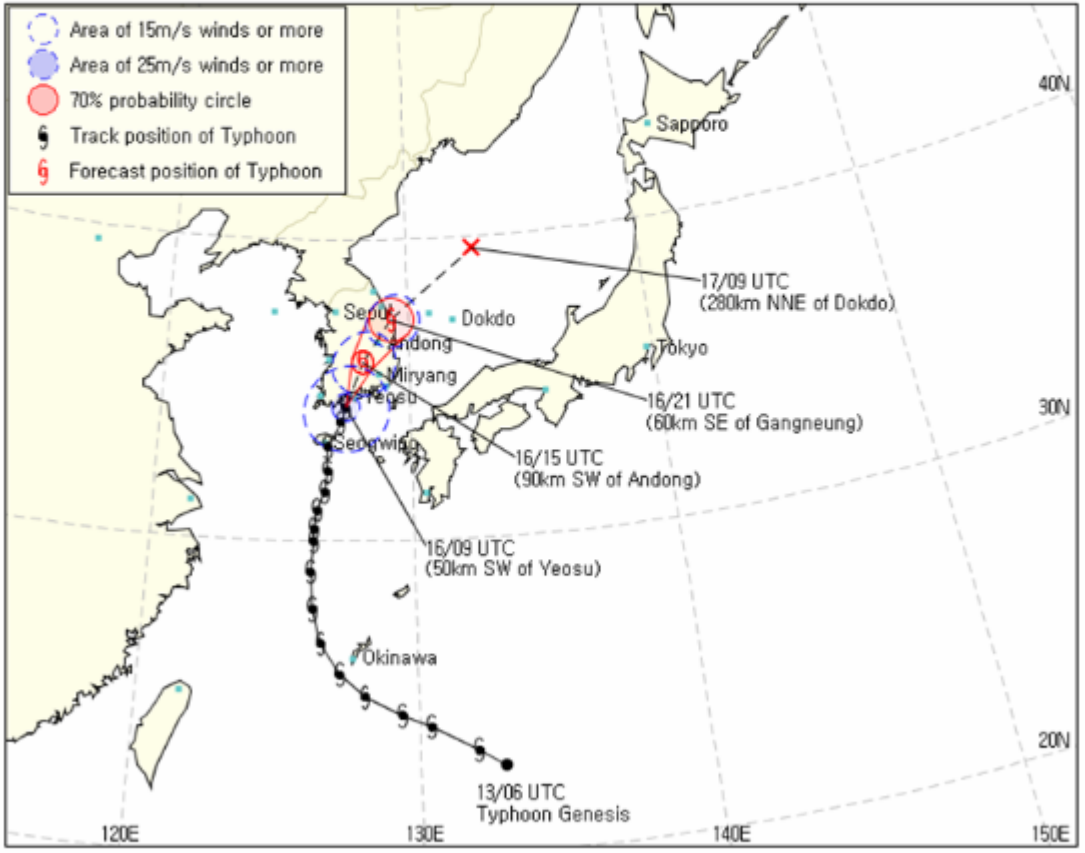


그림 4.8 2007년 11호 태풍 나리(Nari) 경로도

- The 11th Typhoon of the year 2007 - 'NARI' was chosen for comparing with spectral wave model results. Left figure shows the best track of 'NARI'

- Just before landing, the 'NARI' passed over 'Geomundo' buoy. The highest wind (SSE, 27.1 m/s) , significant wave height (SW, 9.8m), and maximum wave height (SW, 13.7m) were recorded on Sept. 16th 1600KST. Approximately 5 hours later, the 'Geojaedo' buoy, which located on the East from 'NARI' best track, recorded the highest significant wave height (SW, 4.9m) and maximum wave height (SW, 7.8m).

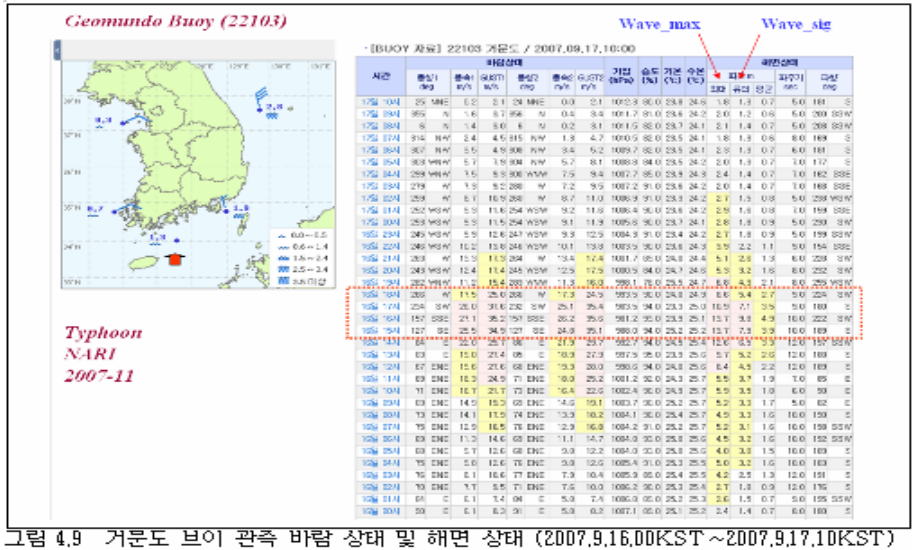


그림 4.9 거문도 브이 관측 바람 상태 및 해면 상태 (2007.9.16.00KST ~2007.9.17.10KST)

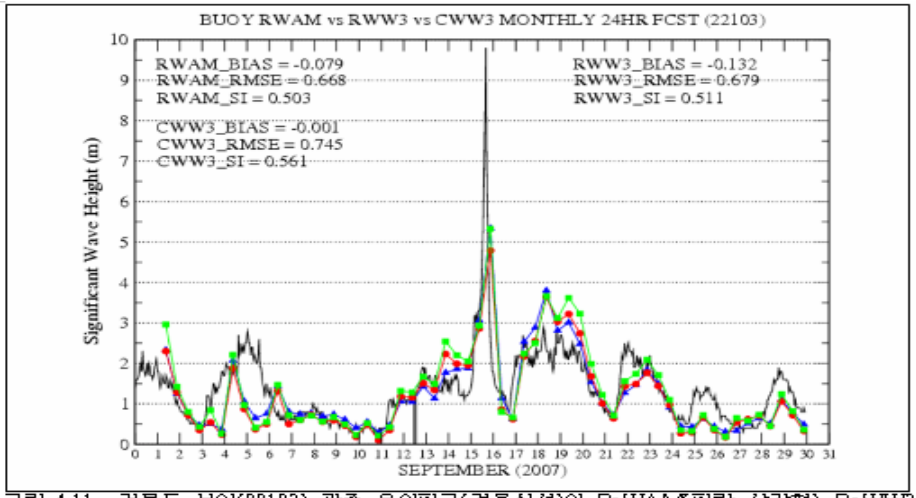


그림 4.11 거문도 브이(22103) 관측 유의파고(검은실선)와 ReWAM(파란 삼각형), ReWW3 (붉은 원형), CoWW3(녹색원형) 24시간 예상 유의파고 시계열

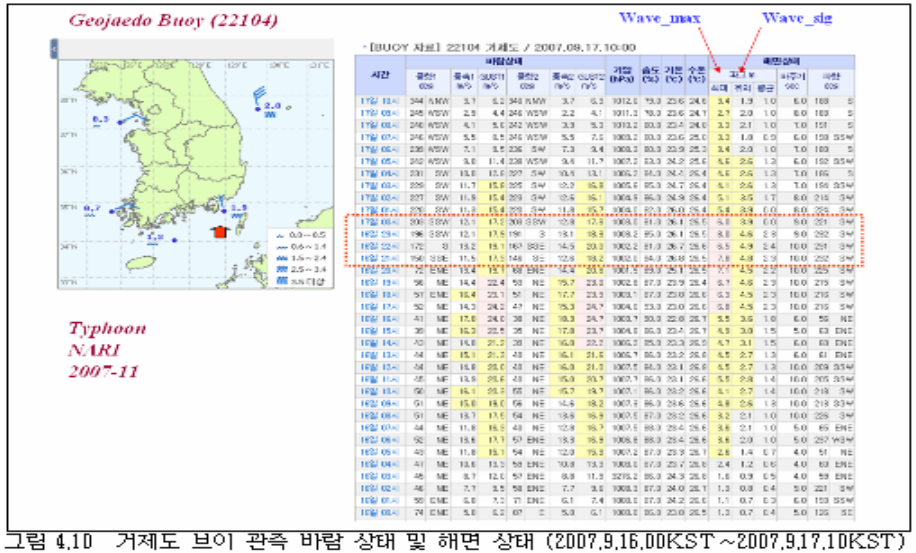


그림 4.10 거제도 브이 관측 바람 상태 및 해면 상태 (2007.9.16.00KST ~2007.9.17.10KST)

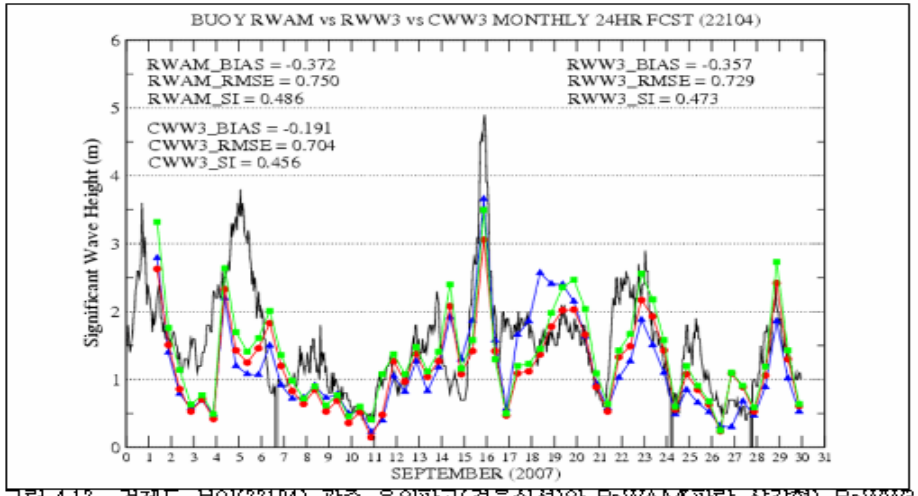


그림 4.12 거제도 브이(22104) 관측 유의파고(검은실선)와 ReWAM(파란 삼각형), ReWW3 (붉은 원형), CoWW3(녹색원형) 24시간 예상 유의파고 시계열

Time series and monthly validation statistics of September 2007 are shown for two buoy's observed significant wave height (black line) against model's 24 hour forecast. The underestimation in spectral wave model prediction for NARI case is clear. This discrepancy is mainly caused by underestimated sea surface wind forecast

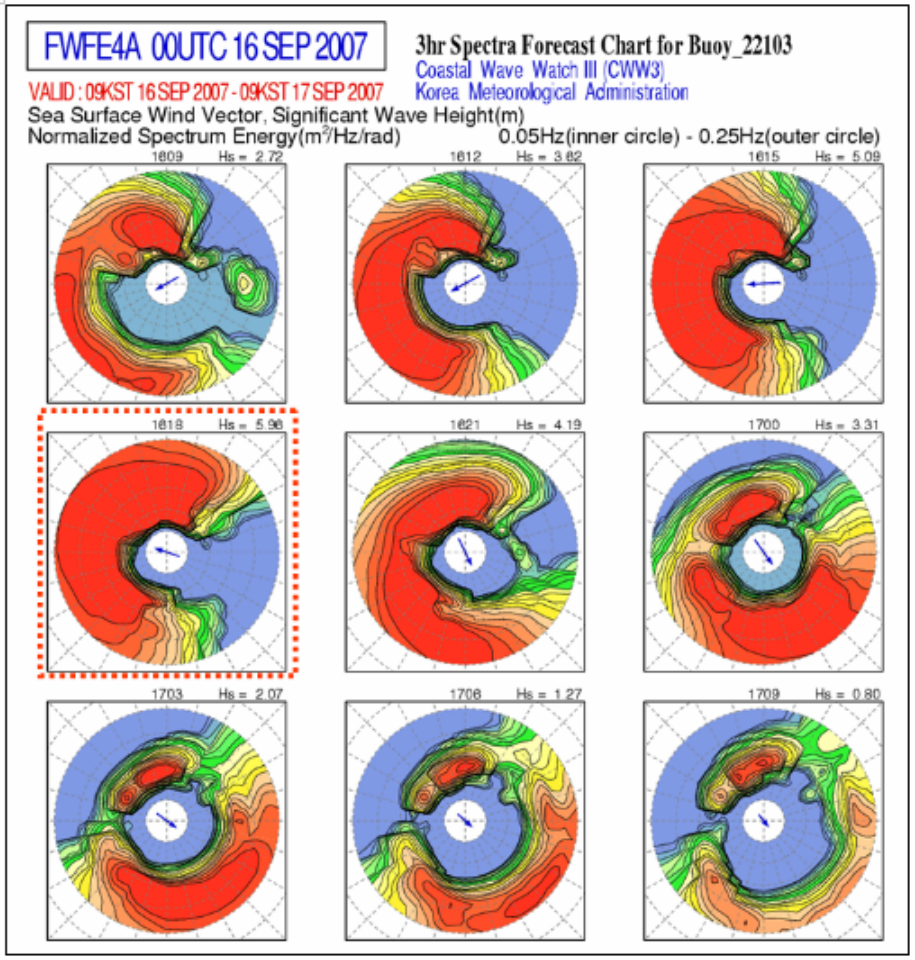


그림 4.13 거문도 브이 지점 CoWW3-RGS1 모델 3시간 간격 스펙트럼 에너지 예상도

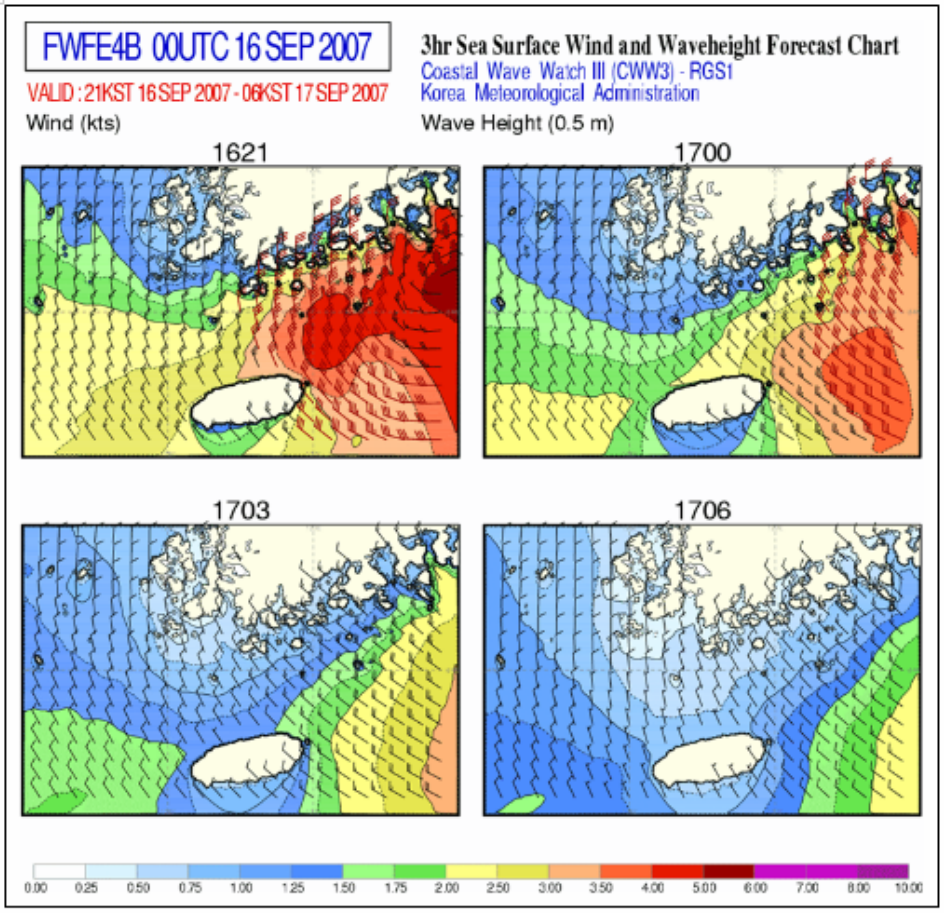


그림 4.14 CoWW3-RGS1 모델의 3시간 간격 해상풍 및 유의파고 예상도

The point wave model spectra derived from KMA's operational Coastal Wave Prediction System(CoWW3) corresponding to Geomundo buoy location are shown. The concentric circles representing frequencies linearly increasing from 0.05 Hz (20 sec; inner circle) to 0.25 Hz (4 sec; outer circle) in 0.05 Hz interval. The isopleths of wave energy are in normalized units of m2/Hz/rad in the direction to which waves are traveling. The northward moving long wave (with period over 10 sec) is persistent, while the short wave rotate counterclockwise following the typhoon's wind fields.

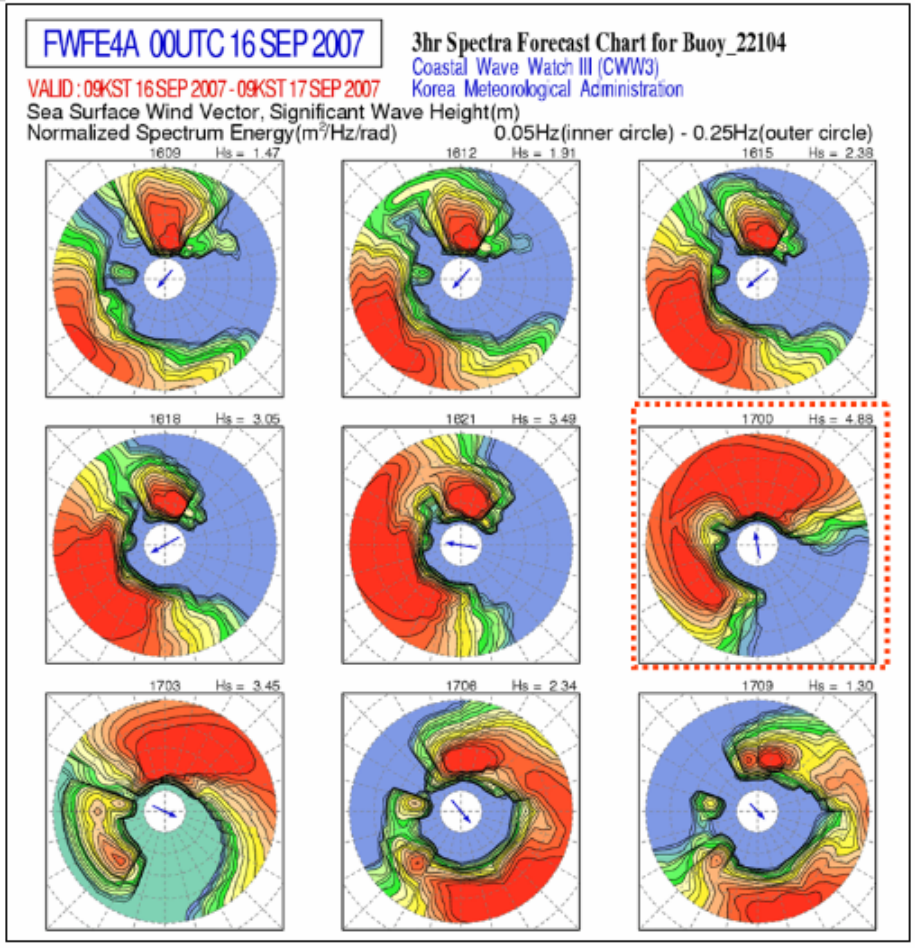


그림 4.15 거제도 브이 지점 CoWW3-RGS2 모델 3시간 간격 스펙트럼 에너지 예상도

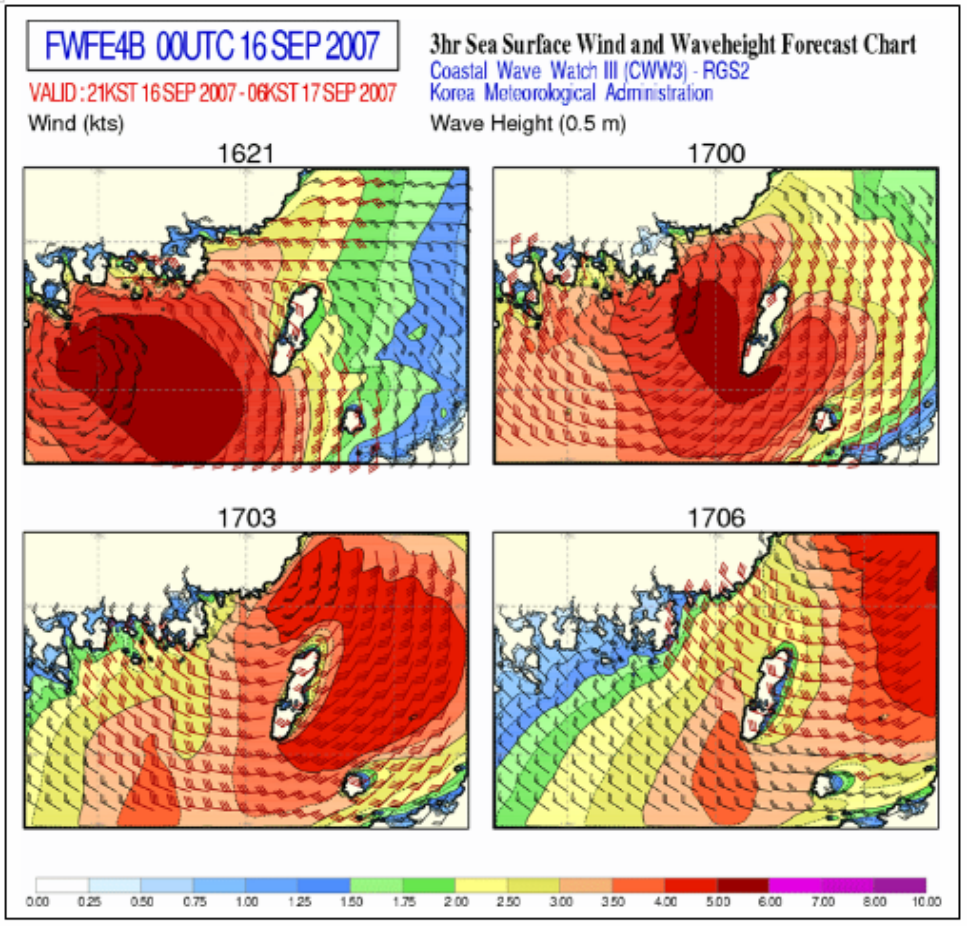
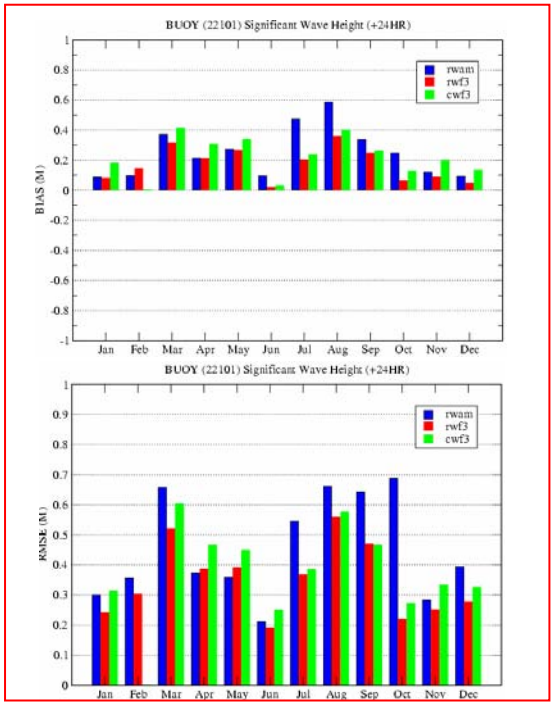
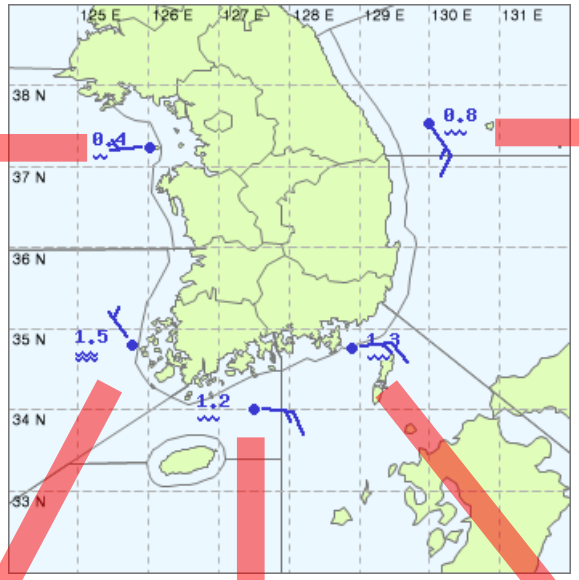
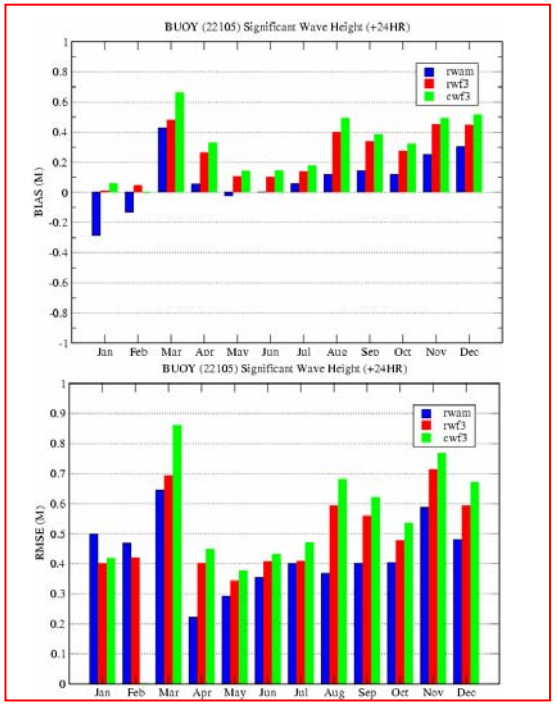


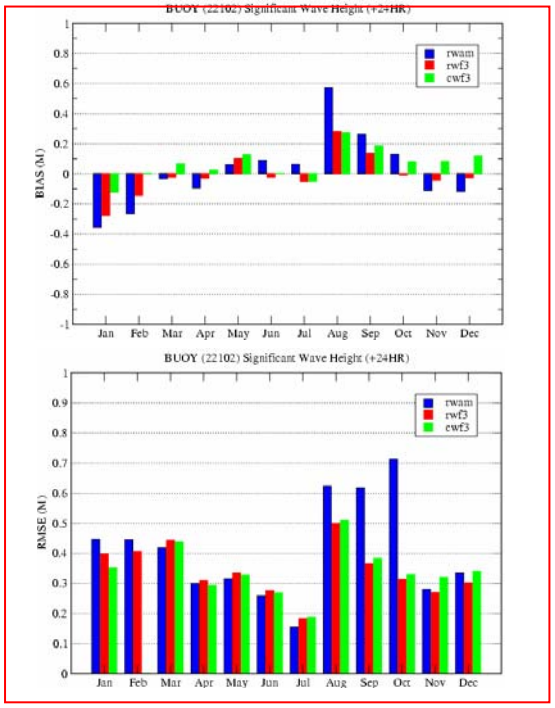
그림 4.16 CoWW3-RGS1 모델의 3시간 간격 해상풍 및 유의파고 예상도

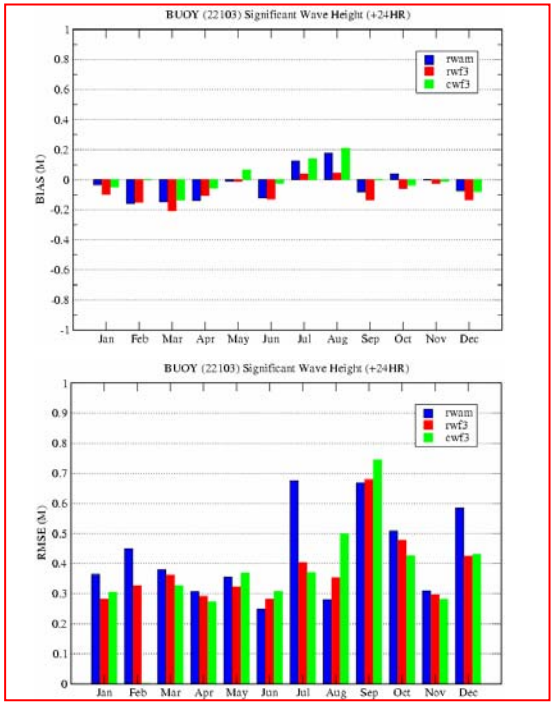
The point wave model spectra derived from KMA's operational Coastal Wave Prediction System(CoWW3) corresponding to Geojaedo buoy (right) location are shown. The concentric circles representing frequencies linearly increasing from 0.05 Hz (20 sec; inner circle) to 0.25 Hz (4 sec; outer circle) in 0.05 Hz interval. The isopleths of wave energy are in normalized units of m2/Hz/rad in the direction to which waves are traveling. The northward moving long wave (with period over 10 sec) is persistent, while the short wave rotate counterclockwise following the typhoon's wind fields.

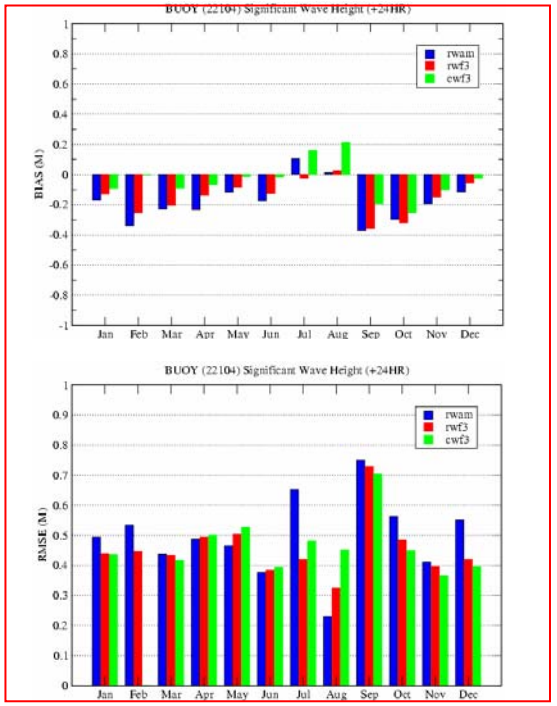

BUOY (22101) Significant Wave Height (+24HR)
BIAS (M)
rwam
rwf3
cwf3
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
BUOY (22101) Significant Wave Height (+24HR)
RMSE (M)
rwam
rwf3
cwf3
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


125 E
126 E
127 E
128 E
129 E
130 E
131 E
38 N
37 N
36 N
35 N
34 N
33 N
0.4
0.8
1.5
1.3
1.2


BUOY (22105) Significant Wave Height (+24HR)
BIAS (M)
rwam
rwf3
cwf3
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
BUOY (22105) Significant Wave Height (+24HR)
RMSE (M)
rwam
rwf3
cwf3
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


BUOY (22102) Significant Wave Height (+24HR)
BIAS (M)
rwam
rwf3
cwf3
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
BUOY (22102) Significant Wave Height (+24HR)
RMSE (M)
rwam
rwf3
cwf3
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


BUOY (22103) Significant Wave Height (+24HR)
BIAS (M)
rwam
rwf3
cwf3
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
BUOY (22103) Significant Wave Height (+24HR)
RMSE (M)
rwam
rwf3
cwf3
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


BUOY (22104) Significant Wave Height (+24HR)
BIAS (M)
rwam
rwf3
cwf3
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
BUOY (22104) Significant Wave Height (+24HR)
RMSE (M)
rwam
rwf3
cwf3
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

• *Research plan for 2008-2009*

Objective: Sensitivity test of sea surface wind forecasts from the UM on the global, regional, and coastal operational ocean wind wave prediction at KMA

- Installation of an interface module for ingesting the sea surface wind forecasts from UM-global and UM-regional onto wave models
- Construction of parallel run frame for global and regional wave prediction system to conduct sensitivity test of sea surface wind forecasts from the UM-global and UM-regional

• *Outline plan for 2010-2012*

- Parallel run of GoWW3 with UM-global and ReWW3, CoWW3 with UM-regional sea surface wind and their performance evaluation
- Application of sea surface wind generated by the UM-based very high-resolution model to CoWW3
- The feasibility study on synchronous coupling between GoWW3 and UM-global and their impact assessment
- Trapped-Fetch Wave Model (Al MacAfee, MSC) application to tropical cyclone

• Two New Moored Buoy (Nomad-Type) at KMA

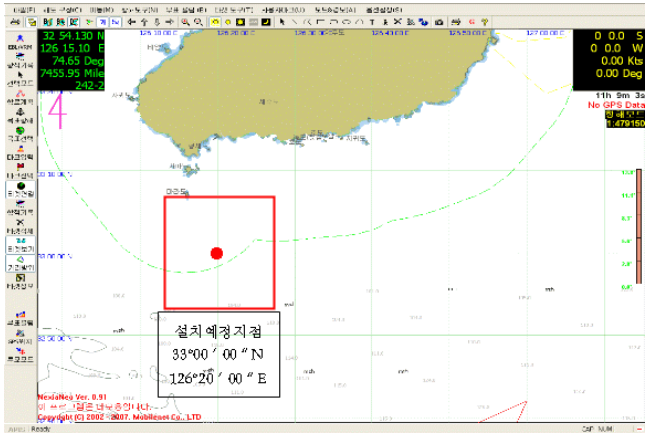
INFORMATION ON NON-DRIFTING BUOY(MOORED)

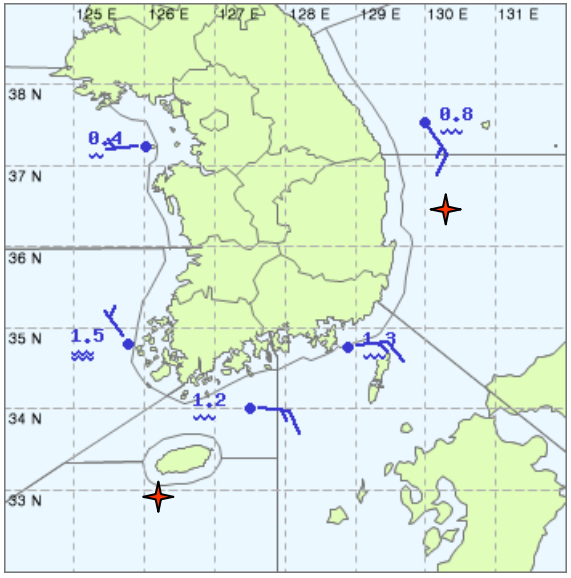
Country: Republic of KOREA Date: July 15, 2008

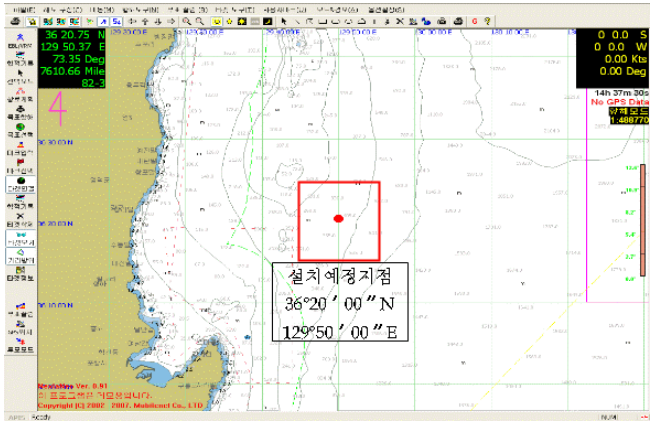
IDENTIFIER		ODAS		LOCATION		VARIABLES MEASURED												Trans Means	CORRE FORM	Data Avail-ability	Status	COMMENTS
WMO	OTHER (spec)	Type	Hull	POSITION	DATE	Air Temp	Air Press	Press Tend	Humi-dity	Wind (DD,FF)	Wave (PP,HH)	Wave Spectra	SST	S/Surf Temp	Salini-ty	Curr-ent	Others (spec)					
22106	Pohang	M	06 N	36° 20′N 129° 50′E	10/08	24	24		24	24	24		24					O		G	O	
22107	Jeju	M	06 N	33° 00′N 126° 20′E	10/08	24	24		24	24	24		24					O		G	O	

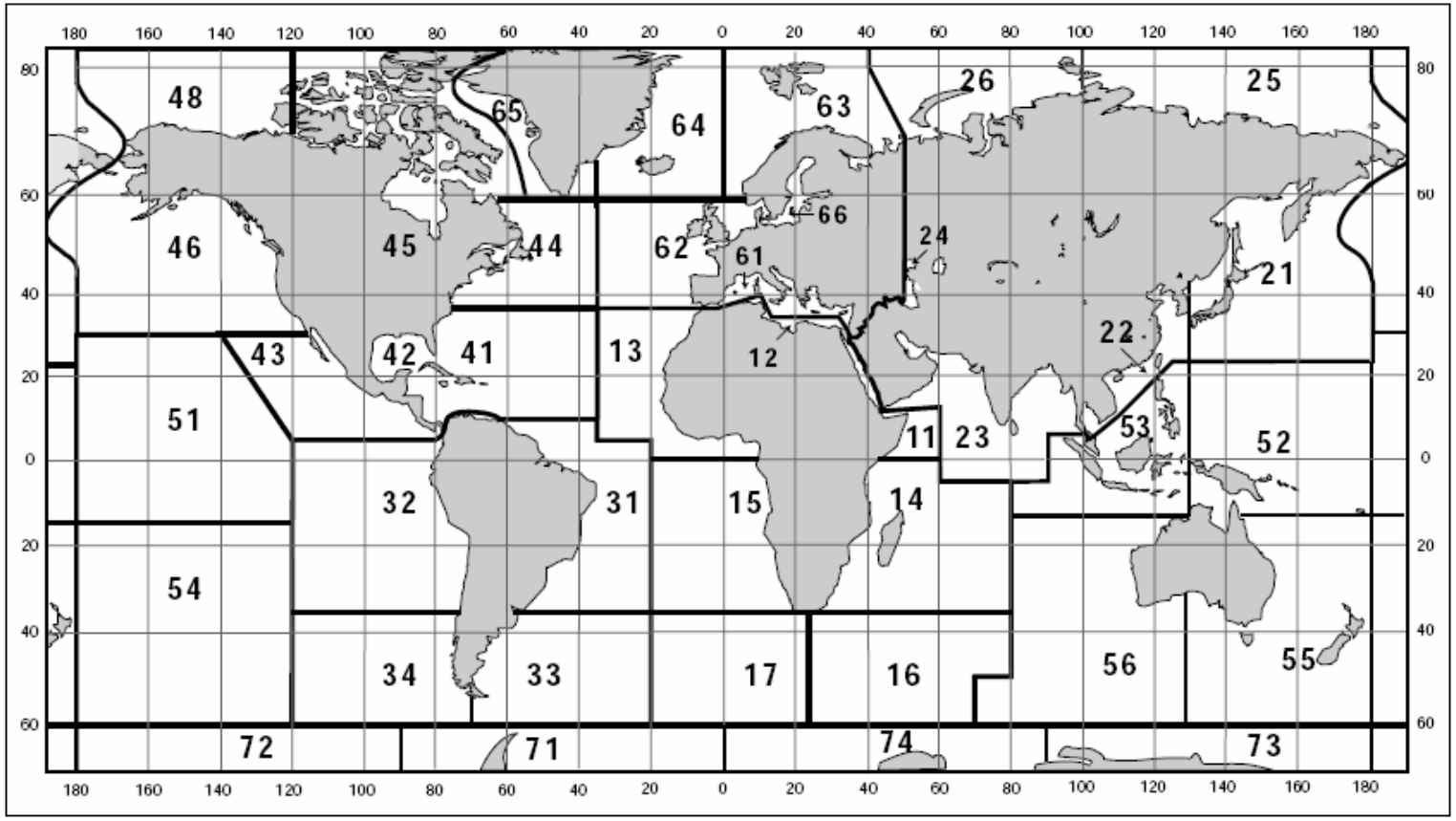
※Operated by the Korea Meteorological Administration(KMA)

(Courtesy of T. Kim)









22001 - 22010	Japan
22011 - 22025	USA
22026 - 22040	USA
22041 - 22070	China
22071 - 22085	USA
22086 - 22100	USA
22101 - 22107	Republic of Korea
22108 - 22112	USA

⇔ 53456 – 53463 Republic of Korea

※ DBCP23-Doc-9-3-secretariats-report