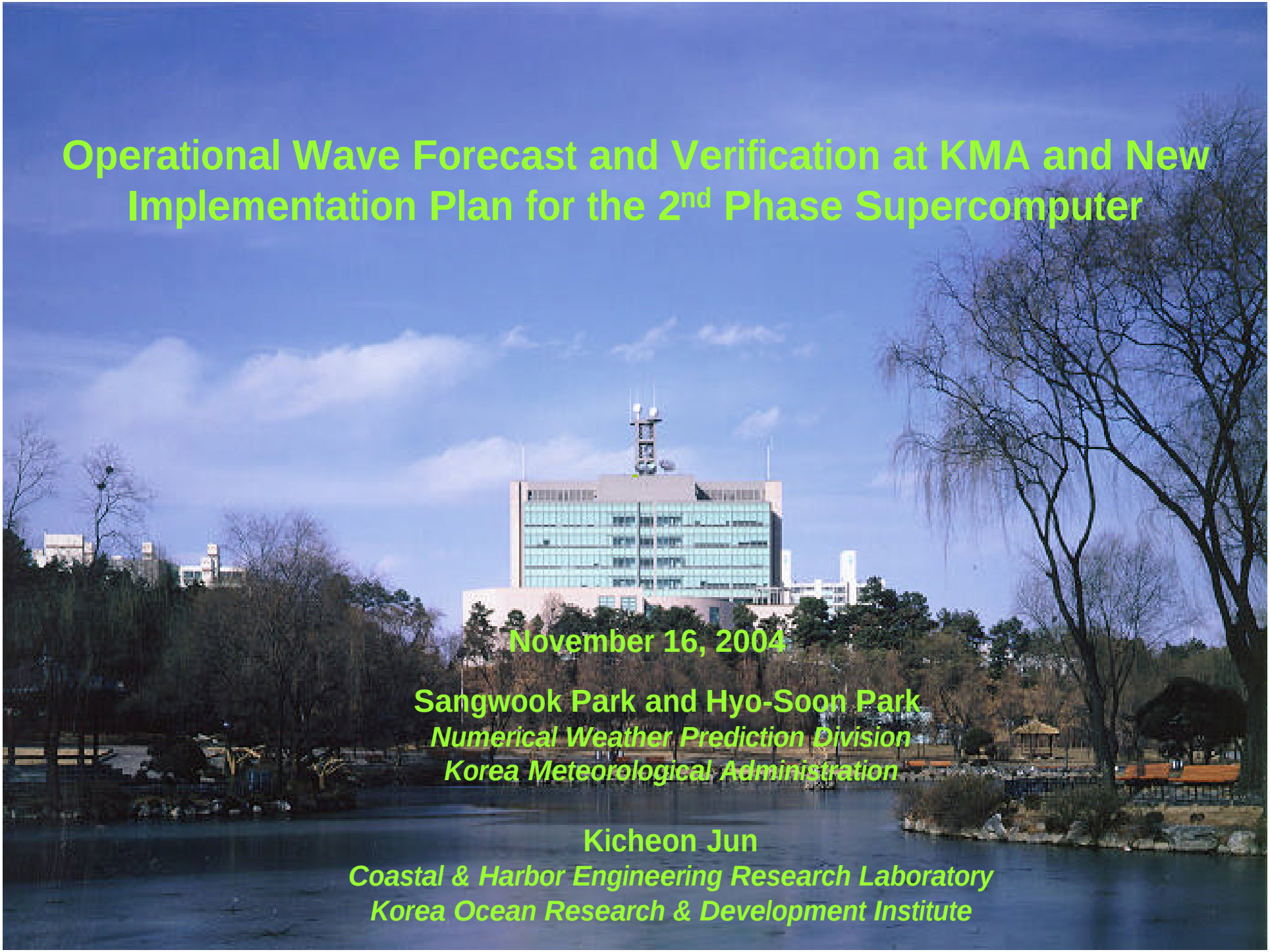

Operational Wave Forecast and Verification at KMA and New Implementation Plan for the 2nd Phase Supercomputer

November 16, 2004

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Numerical Weather Prediction Division
Korea Meteorological Administration

Kicheon Jun
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Korea Ocean Research & Development Institute

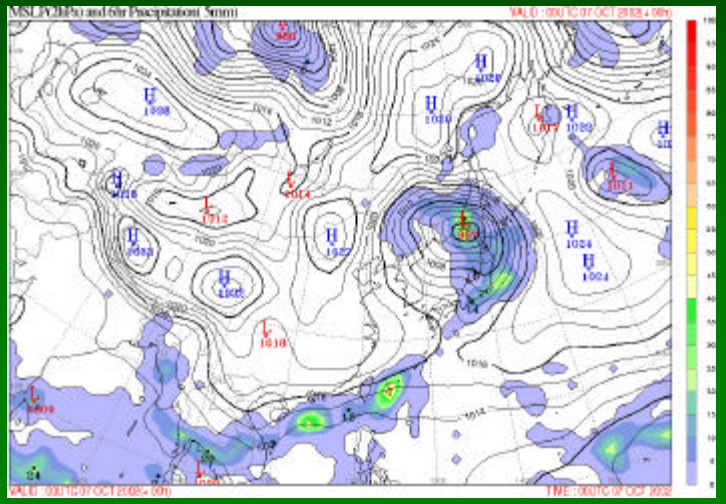
Numerical Weather Prediction

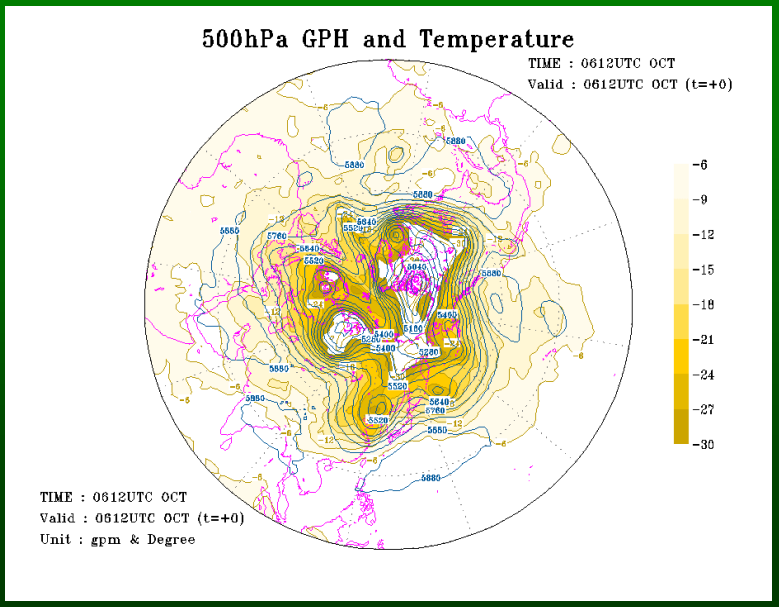
Model Description

Model	Resolution (layers)	Lead time (days)	Remark
GDAPS	110km (21)	10	Ensemble Prediction
	110km (21)	30	Monthly and seasonal outlooks
	55km (30)	3.5/10	Operation (SRF/MRF)
RDAPS	30/10/5km (33)	2/1/1	Triple Mesh
Typhoon Model (BATS)	1°×1° (Barotropic)	3	Typhoon Track
Wave Model (WAM)	1.25°×1.25°	10	Global
	0.25°× 0.25°	2	East Asia
Statistical Model	-	2-10	Max/Min Temp., PoP

GDAPS
(Global Data Assimilation and Prediction System)

	GDAPS (T213)	GDAPS (T106)
Governing equations	Primitive	Primitive
Resolution (km)/(layer)	55/30	110/21
Analysis	3DOI	3DOI
Convection	Kuo	Kuo
SST	Weekly	Weekly
Model Run per day	2	2

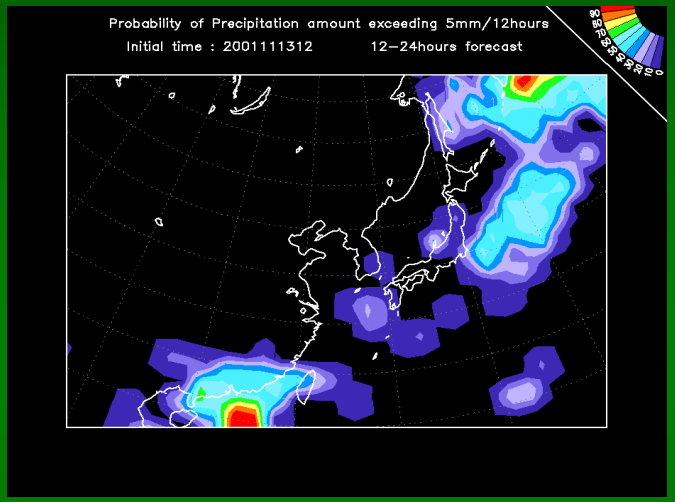


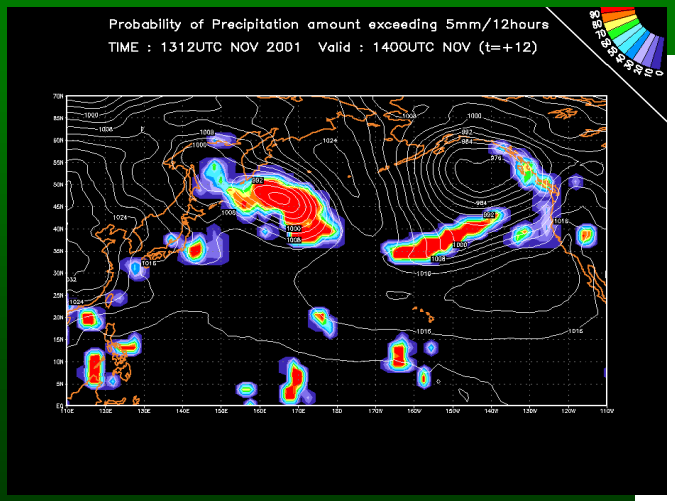


EPS
(Ensemble Prediction System)

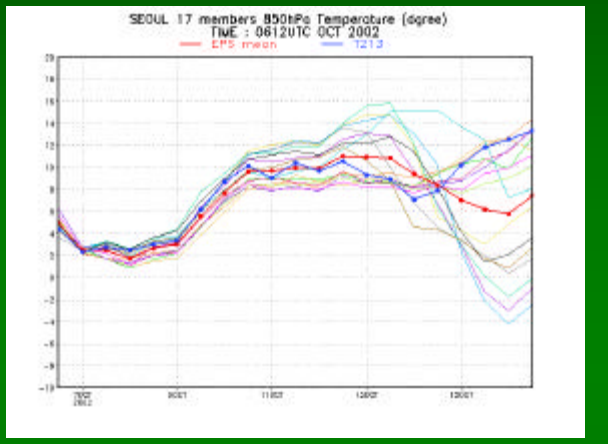
	EPS
Model	T106/L21
Member	17
Analysis	3DOI
Initial	BGM
SST	Weekly
Model Run per day	1 (12UTC)
Product	Mean, Spread

PoP

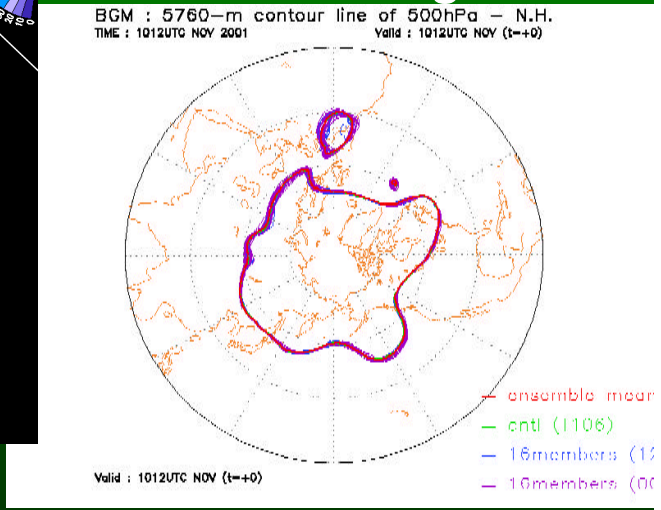




850 T at Seoul

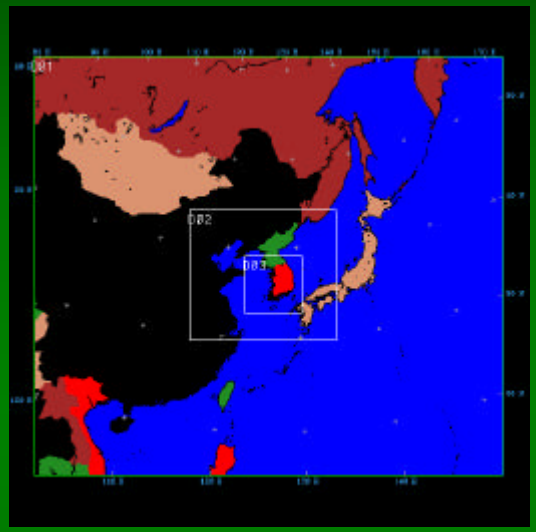


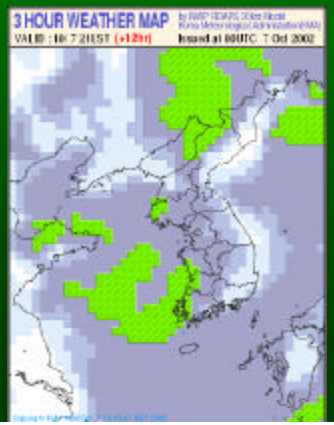
500 hPa height

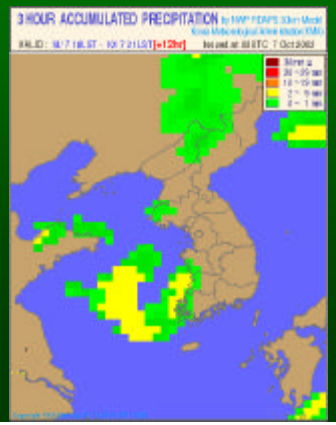


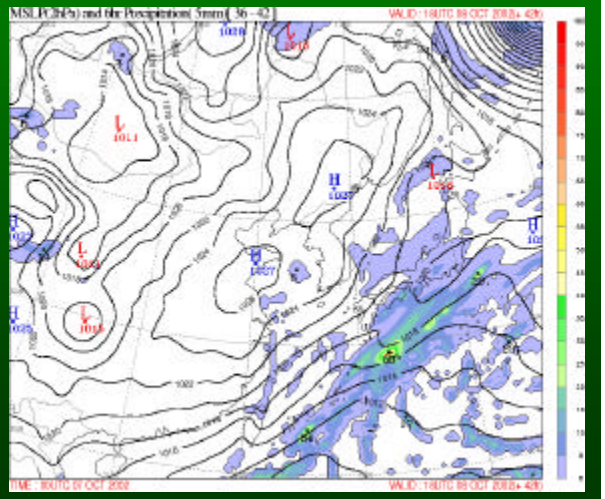
RDAPS
(Regional Data Assimilation and Prediction System)

	Regional Model	High Resolution Model	
Dynamics	Nonhydrostatic		
DX	30km	10km	5km
Dimension	171x191	160x178	141x141
Time steps	60	30	15
Vertical layers	33 / 50hPa	33 / 50hPa (model top)	
Forecast Time	48hrs	24hrs	
Initialization	FDDA (12hr)	1-way Interaction	
Lateral BC	Relaxation		
Explicit Moisture	Mixed Phase (water vapor, cloud, rain, ice, snow)		
Deep Convection	Kain-Fritch		None
PBL	Nonlocal Boundary Layer		
Ground Temp	5-layer Soil Model		
Radiation	Cloud Radiation		





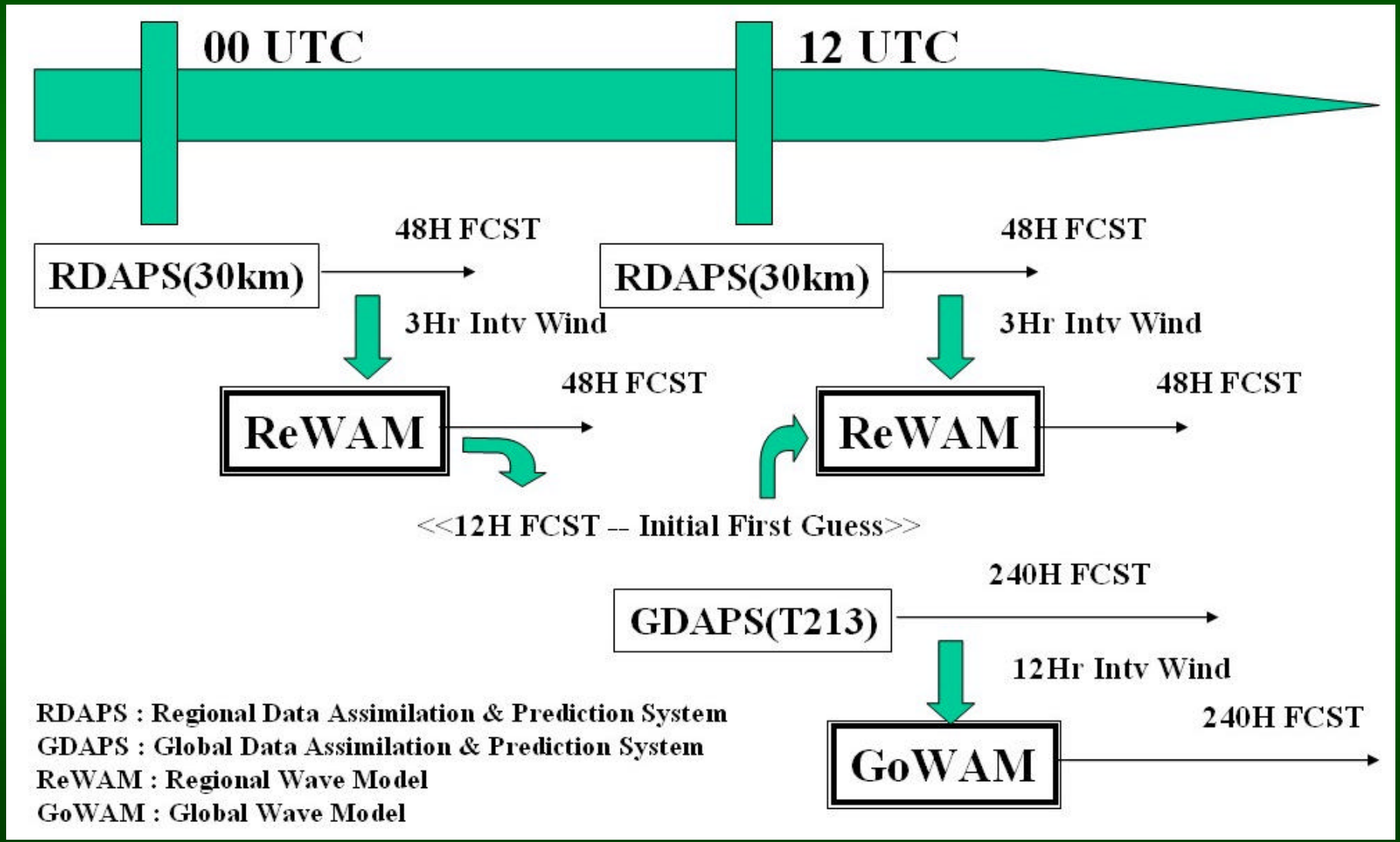


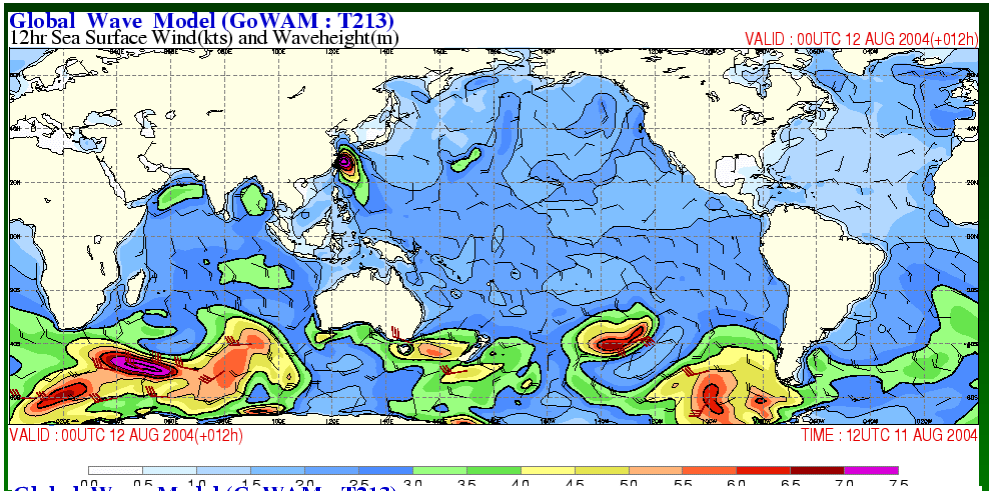


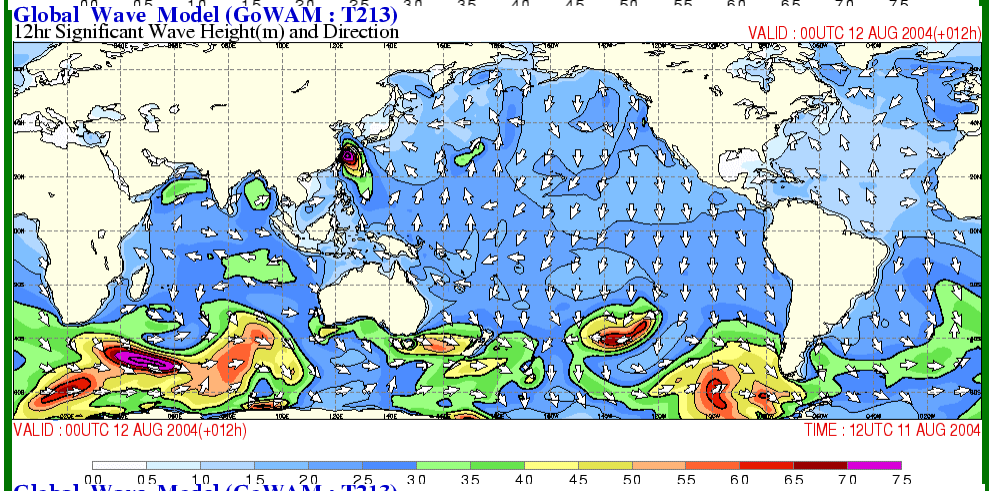
Operatioanl Wave Model Specification

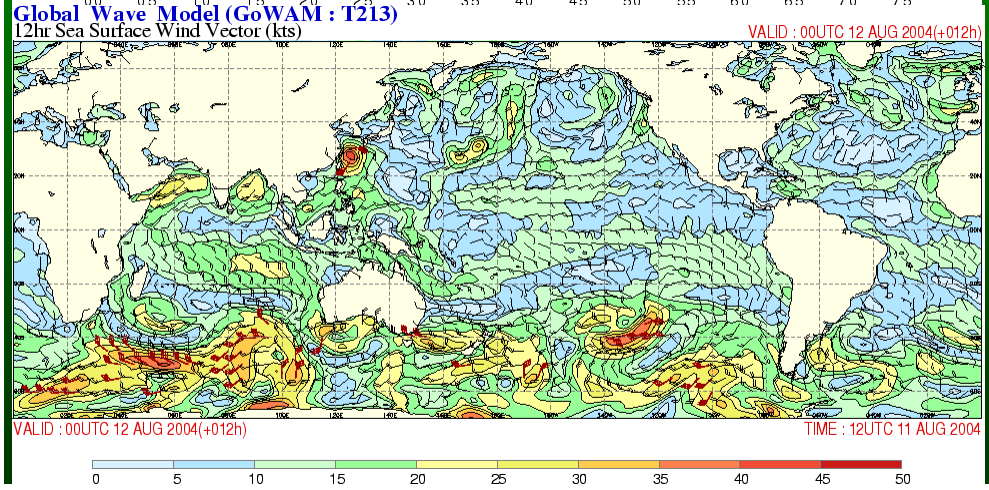
	GoWAM	ReWAM
Source Code	WAM model cycle 4	WAM model cycle 4
Coordinate	Spherical coordinate	Spherical coordinate
Spatial Domain	70°S-70°N	20°N-50°N, 115°E-150°E
Spatial Resolution (Dim.)	1.25° (288 by 113)	0.25° (141 by 121)
Spectral Resolution	25 frequency 24 direction	25 frequency 24 direction
Integration Time Step	720 second	360 second
Lead Time	240 hour (12UTC)	48 hour (00/12UTC)
Elapsed Time	12 minute	2.5 minute
Initial Condition	Previous 24 hour forecast	Previous 12 hour forecast
Sea Surface Wind Input	GDAPS 12-hour interval	RDAPS 3-hour interval

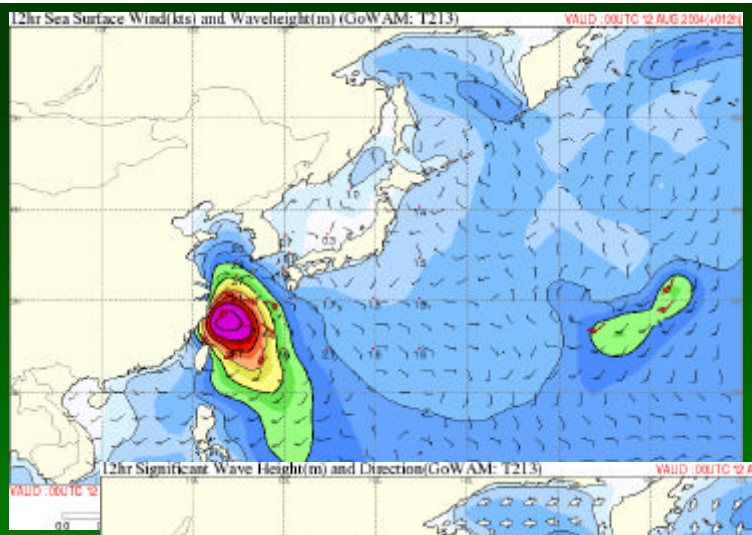
Wave Model Job Scheduling

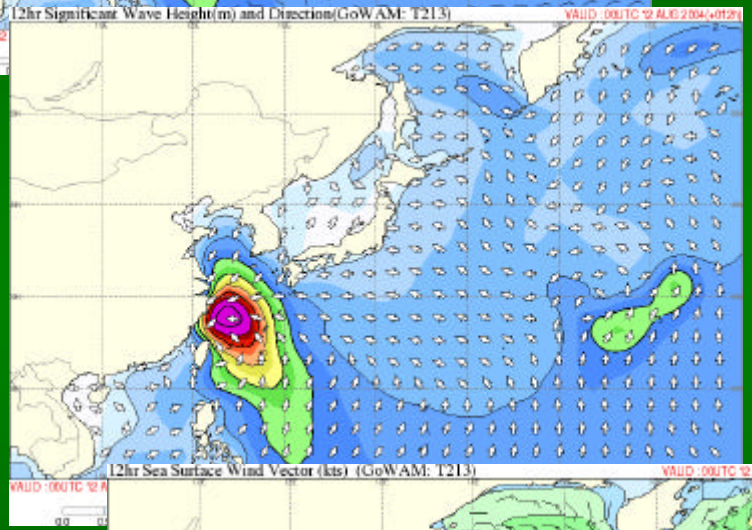


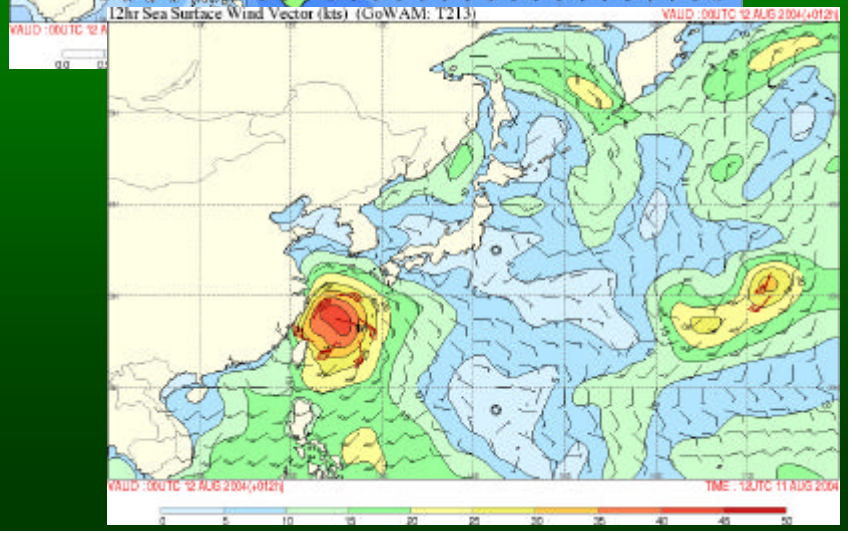

Global Wave Model (GoWAM : T213)
12hr Sea Surface Wind(kts) and Waveheight(m)
VALID : 00UTC 12 AUG 2004(+012h)
VALID : 00UTC 12 AUG 2004(+012h)
TIME : 12UTC 11 AUG 2004
0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5

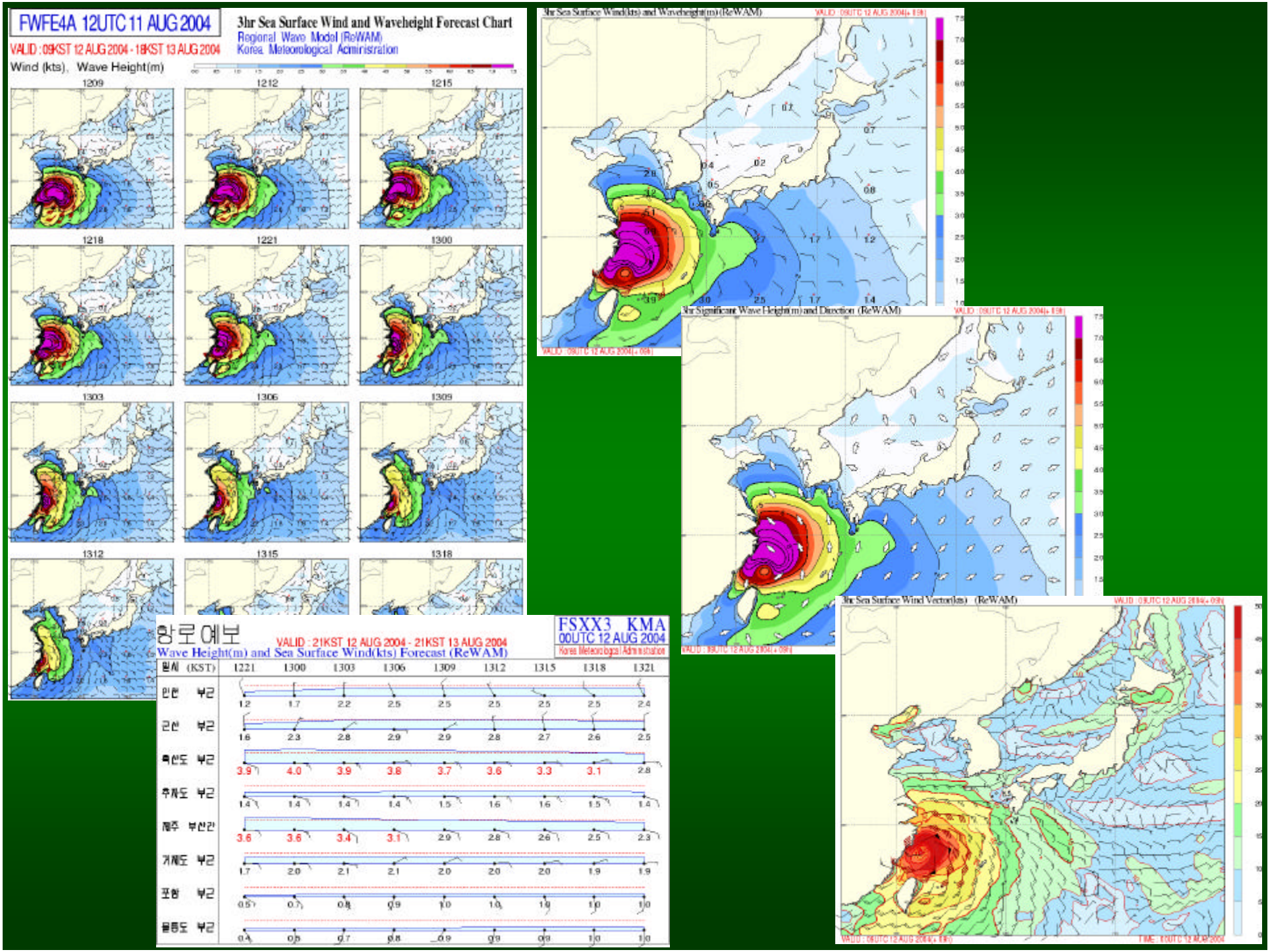

Global Wave Model (GoWAM : T213)
12hr Significant Wave Height(m) and Direction
VALID : 00UTC 12 AUG 2004(+012h)
VALID : 00UTC 12 AUG 2004(+012h)
TIME : 12UTC 11 AUG 2004
0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5


Global Wave Model (GoWAM : T213)
12hr Sea Surface Wind Vector (kts)
VALID : 00UTC 12 AUG 2004(+012h)
VALID : 00UTC 12 AUG 2004(+012h)
TIME : 12UTC 11 AUG 2004
0 5 10 15 20 25 30 35 40 45 50


12hr Sea Surface Wind(kts) and Waveheight(m) (GoWAM: T213)

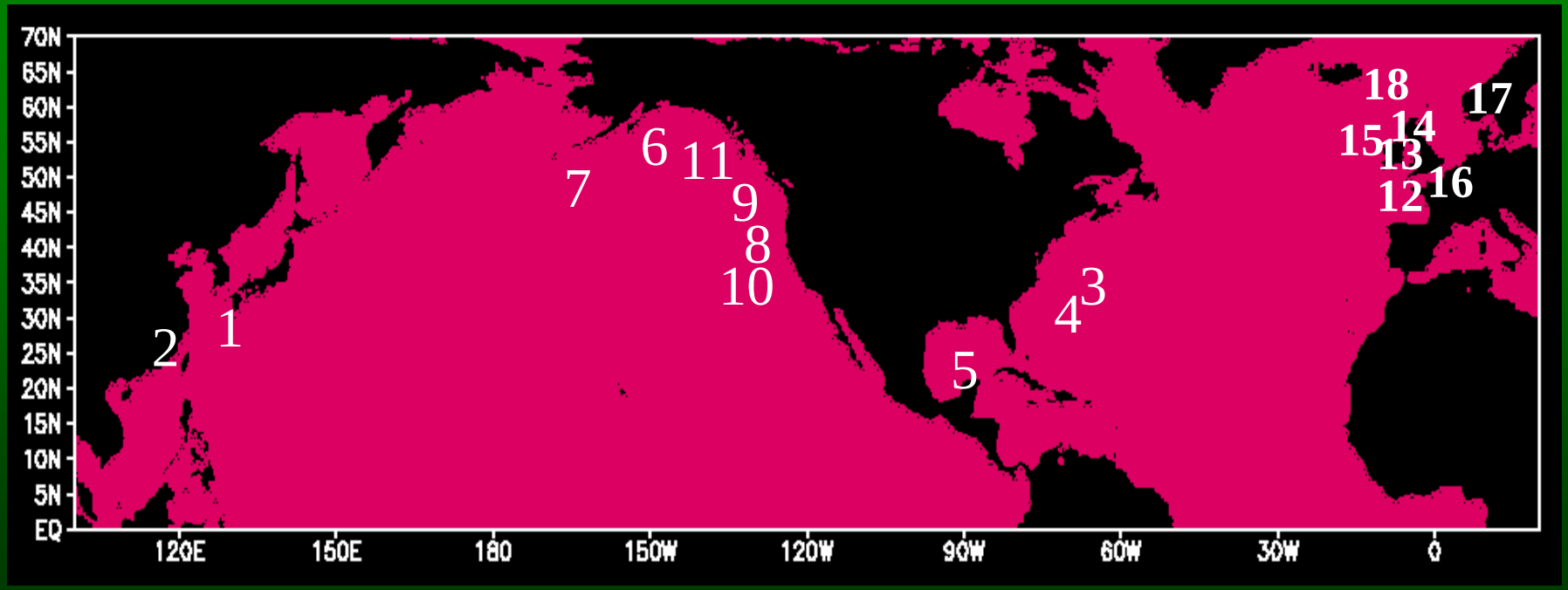

12hr Significant Wave Height(m) and Direction(GoWAM: T213)


12hr Sea Surface Wind Vector (kts) (GoWAM: T213)

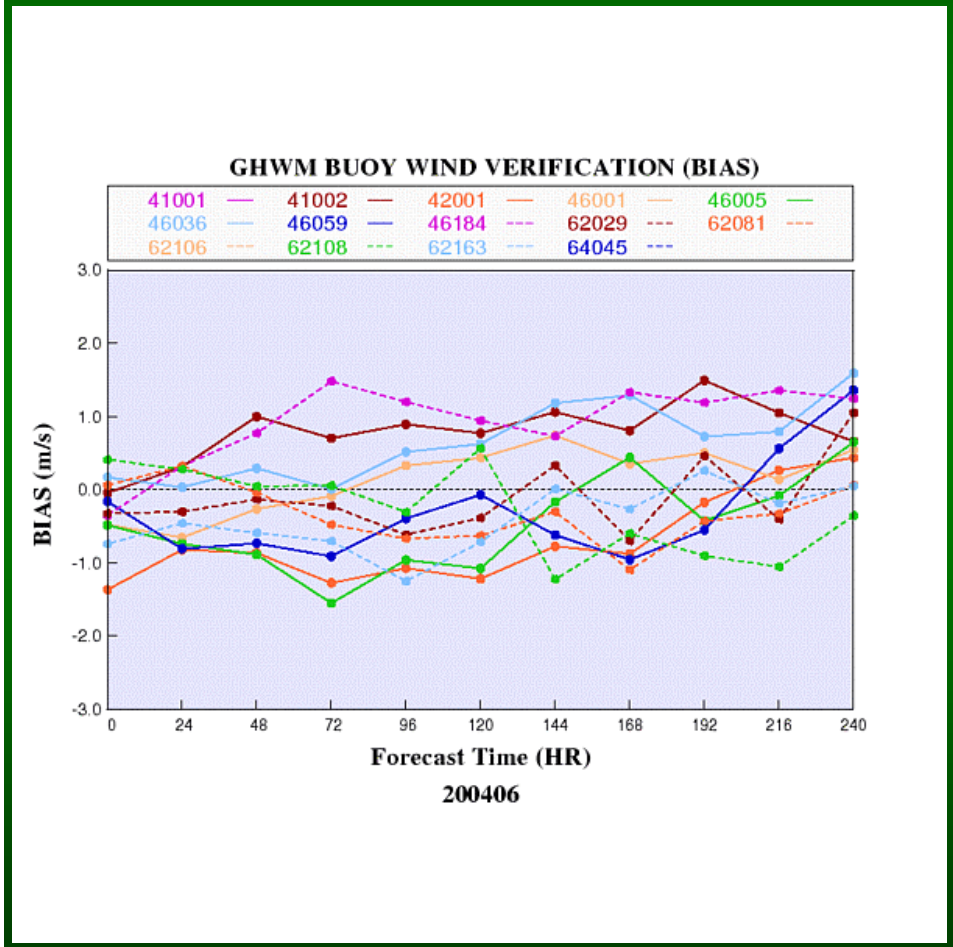

FWFE4A 12UTC 11 AUG 2004
VALID : 09KST 12 AUG 2004 - 18KST 13 AUG 2004
3hr Sea Surface Wind and Waveheight Forecast Chart
Regional Wave Model (ReWAM)
Korea Meteorological Administration
Wind (kts), Wave Height(m)
1209
1212
1215
1218
1221
1300
1303
1306
1309
1312
1315
1318
3hr Sea Surface Wind(kts) and Waveheight(m) (ReWAM)
3hr Significant Wave Height(m) and Direction (ReWAM)
3hr Sea Surface Wind Vector(kts) (ReWAM)
왕로예보
VALID : 21KST 12 AUG 2004 - 21KST 13 AUG 2004
Wave Height(m) and Sea Surface Wind(kts) Forecast (ReWAM)
FSXX3 KMA
00UTC 12 AUG 2004
Korea Meteorological Administration
발시 (KST)
1221
1300
1303
1306
1309
1312
1315
1318
1321
인천 부근
군산 부근
흑산도 부근
추자도 부근
제주 부산간
거제도 부근
포항 부근
울릉도 부근

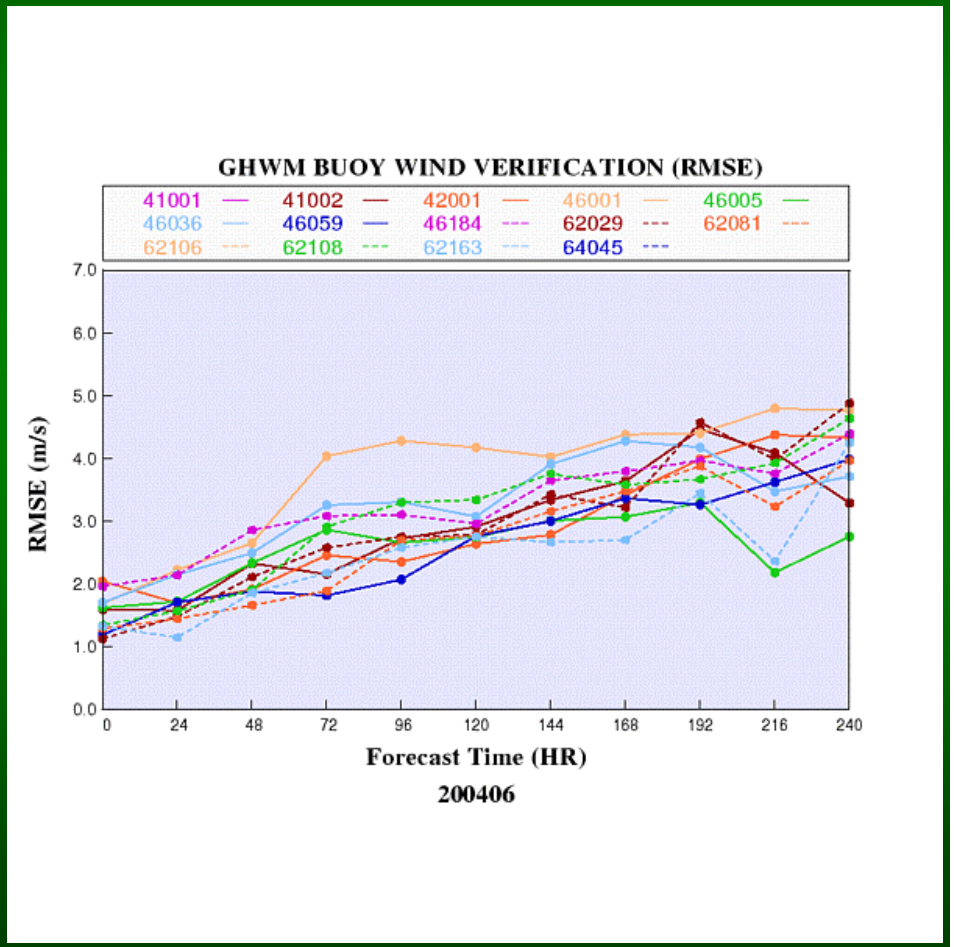
Buoy Locations

1. 21004 Japan South-East Coast
2. 22001 East China Sea shelf break
3. 41001 US East Coast
4. 41002 US South-East Coast
5. 42001 Gulf of Mexico
6. 46001 Gulf of Alaska
7. 46003 Aleutian Peninsula
8. 46005 US North-West Coast
9. 46036 US North-West Coast
10. 46059 US West Coast
11. 46144 Canada West Coast
12. 62029 UK Celtic Sea shelf break
13. 62081 UK East Atlantic
14. 62106 UK North-East Atlantic
15. 62108 UK East Atlantic
16. 62163 UK Celtic Sea shelf break
17. 63111 North Sea shelf break
18. 64045 UK North-East Atlantic

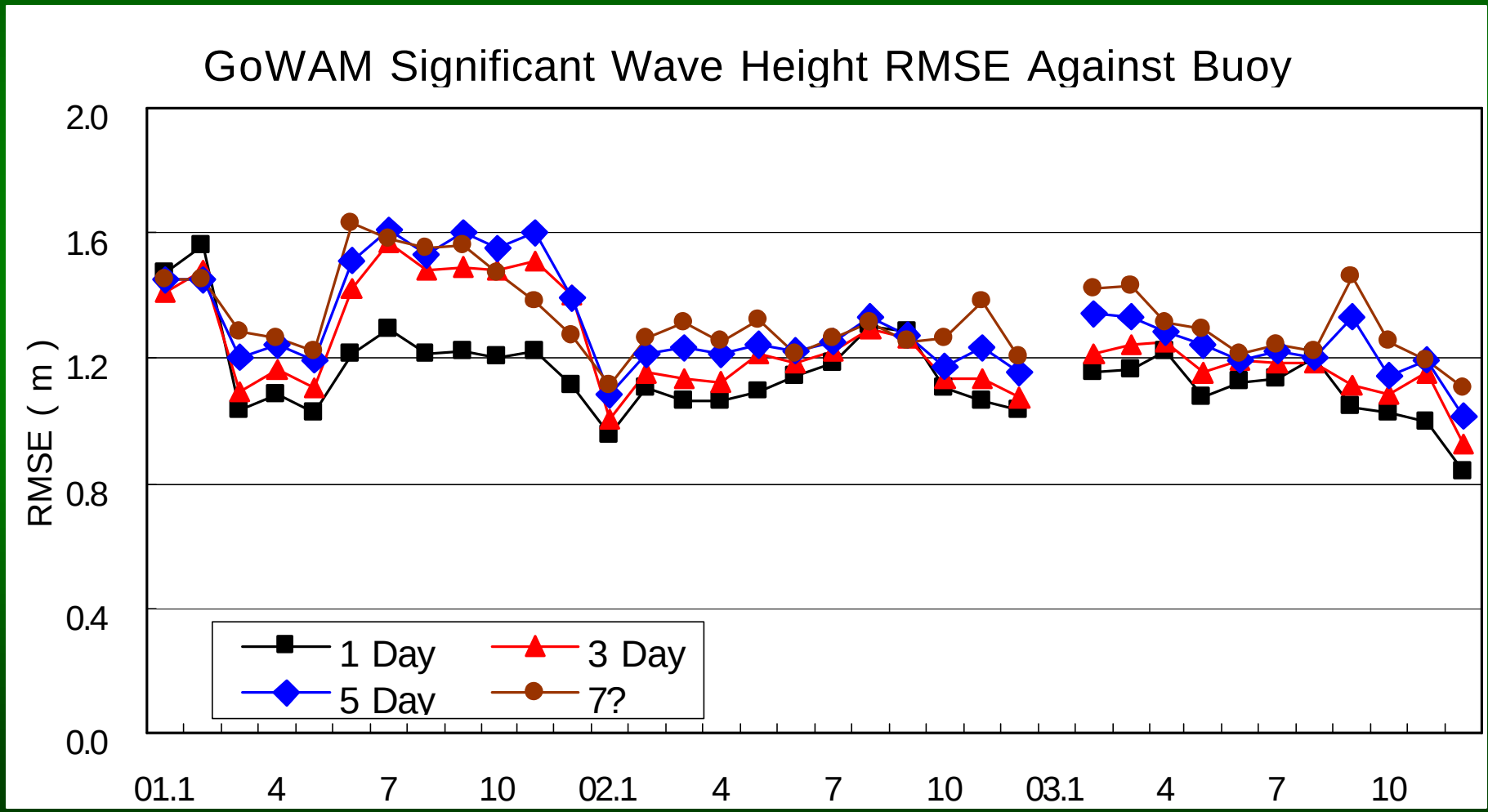


GoWAM Wind Verification against Buoy

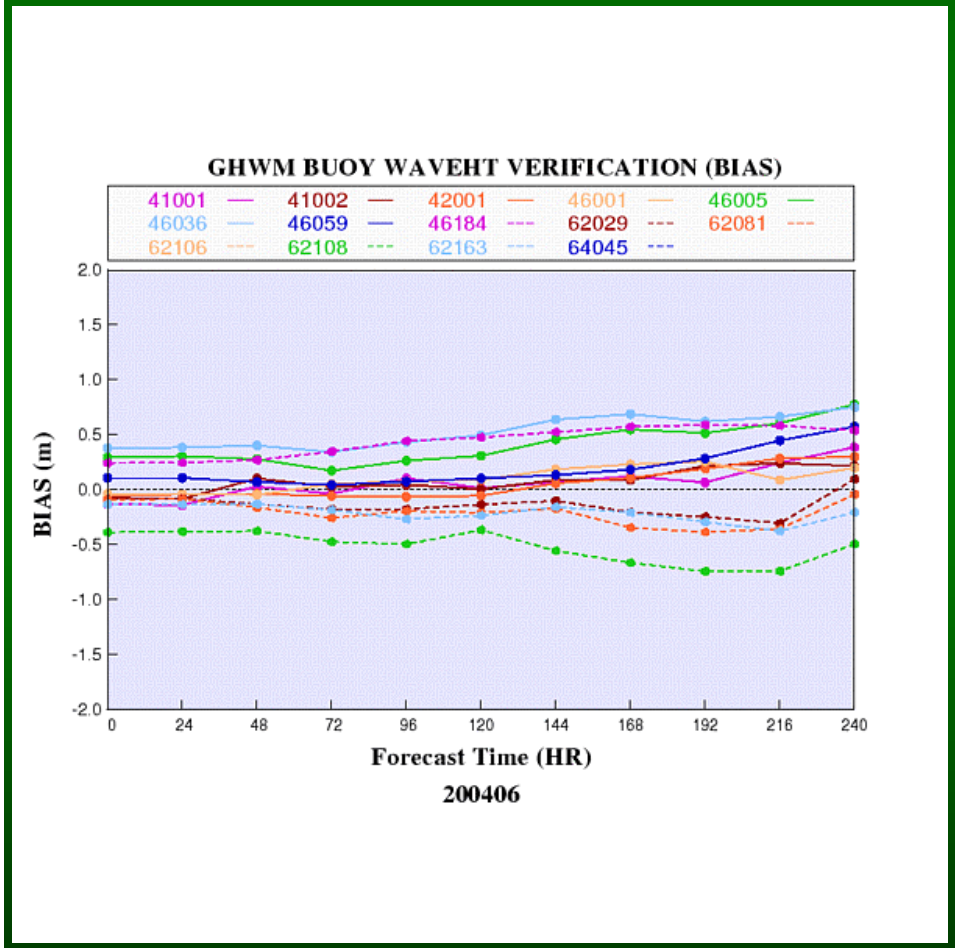


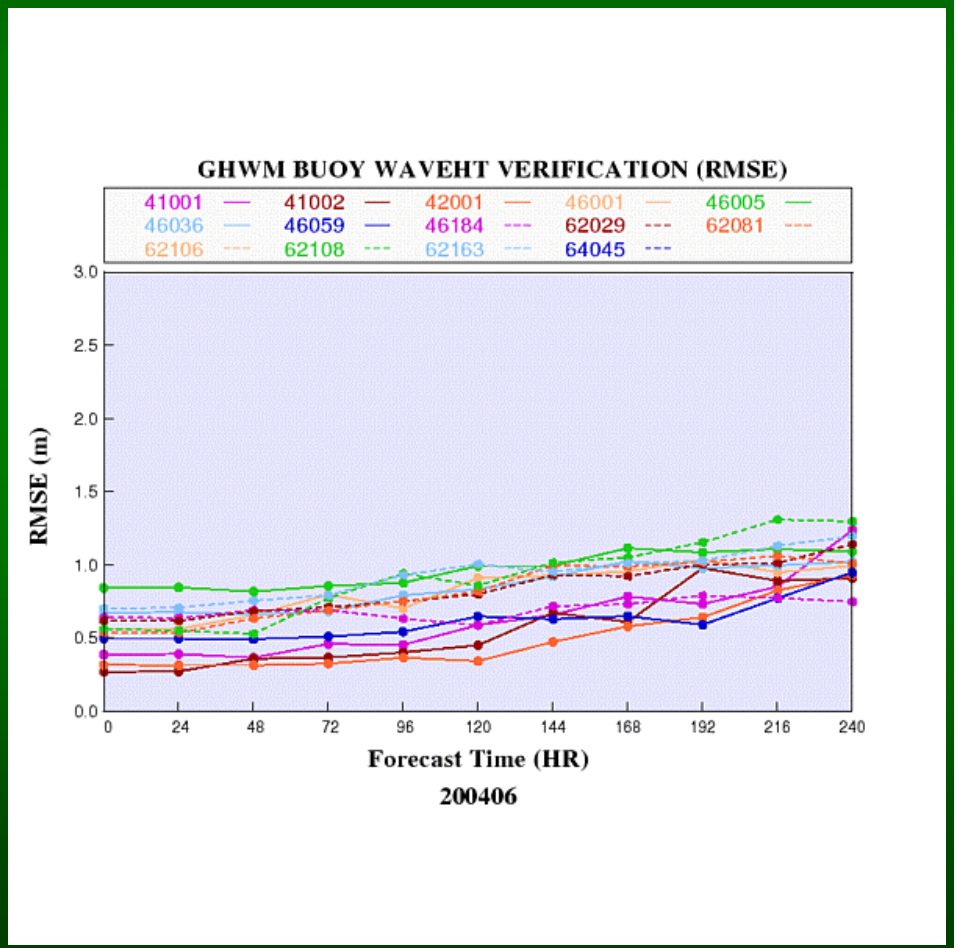


GoWAM Wave Height Verification against Buoy



GoWAM Wave Height Verification against Buoy





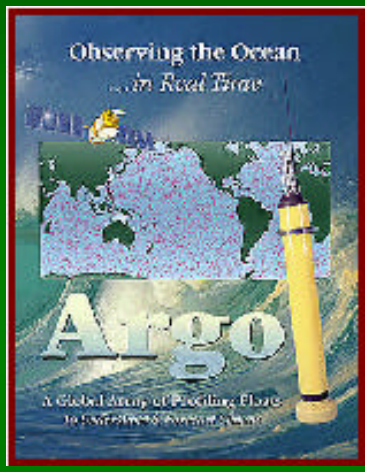
Marine Observation

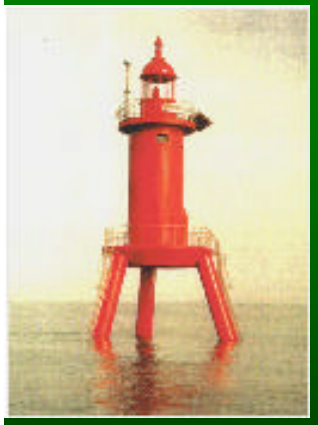
- **Marine observations**
  - Observing ship (1)
  - Ocean buoys (5)
  - Lighthouse AWSs (2)

3m discus buoy

3m NOMAD buoy

Gisang 2000





Lighthouse + AWS(surface)

Meteorological Observation Network

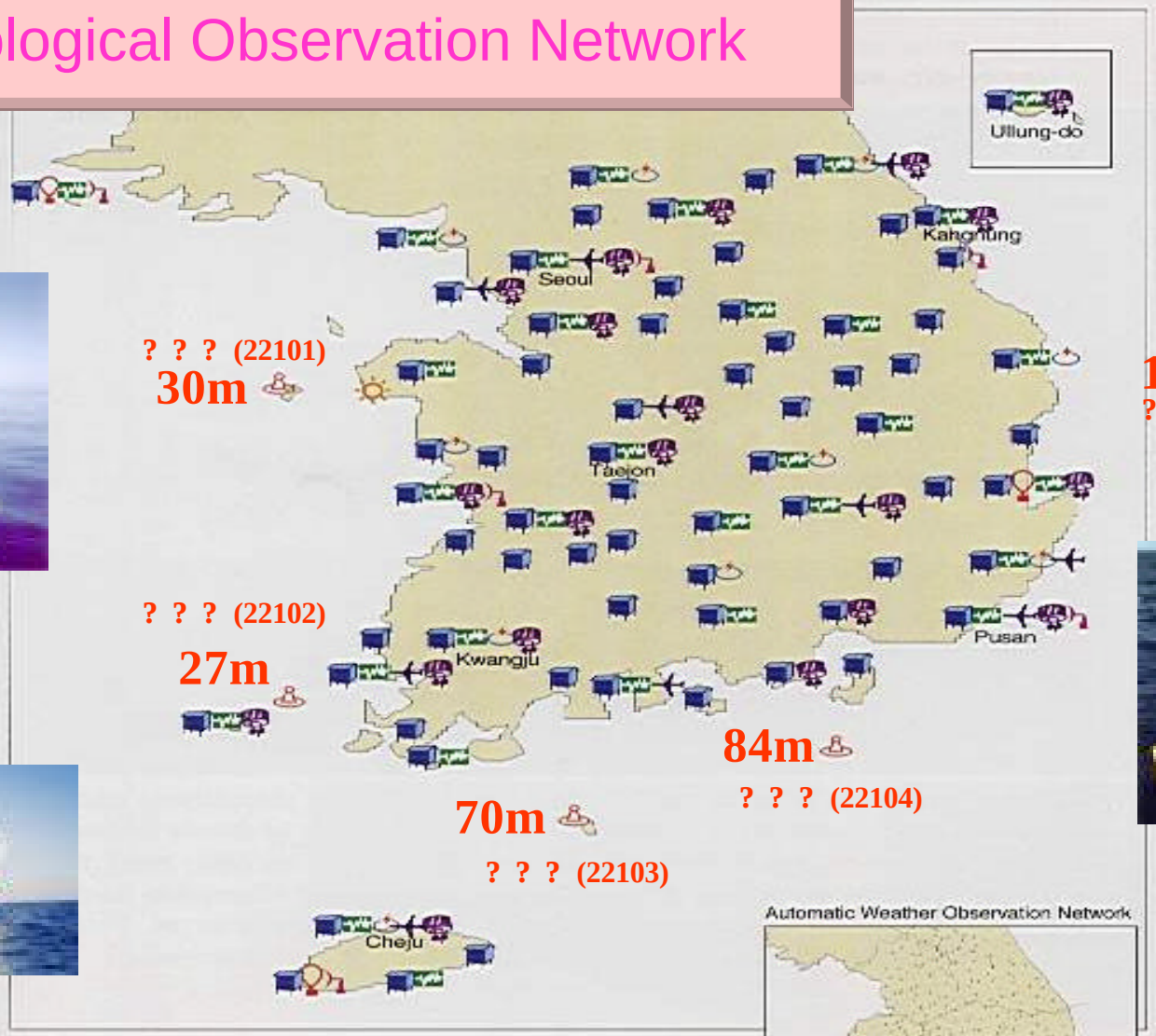
? ? ? (22101)
30m

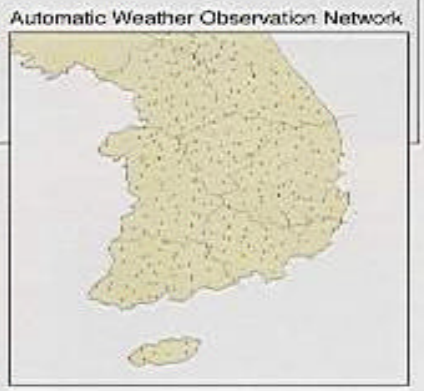
? ? ? (22102)
27m

70m
? ? ? (22103)

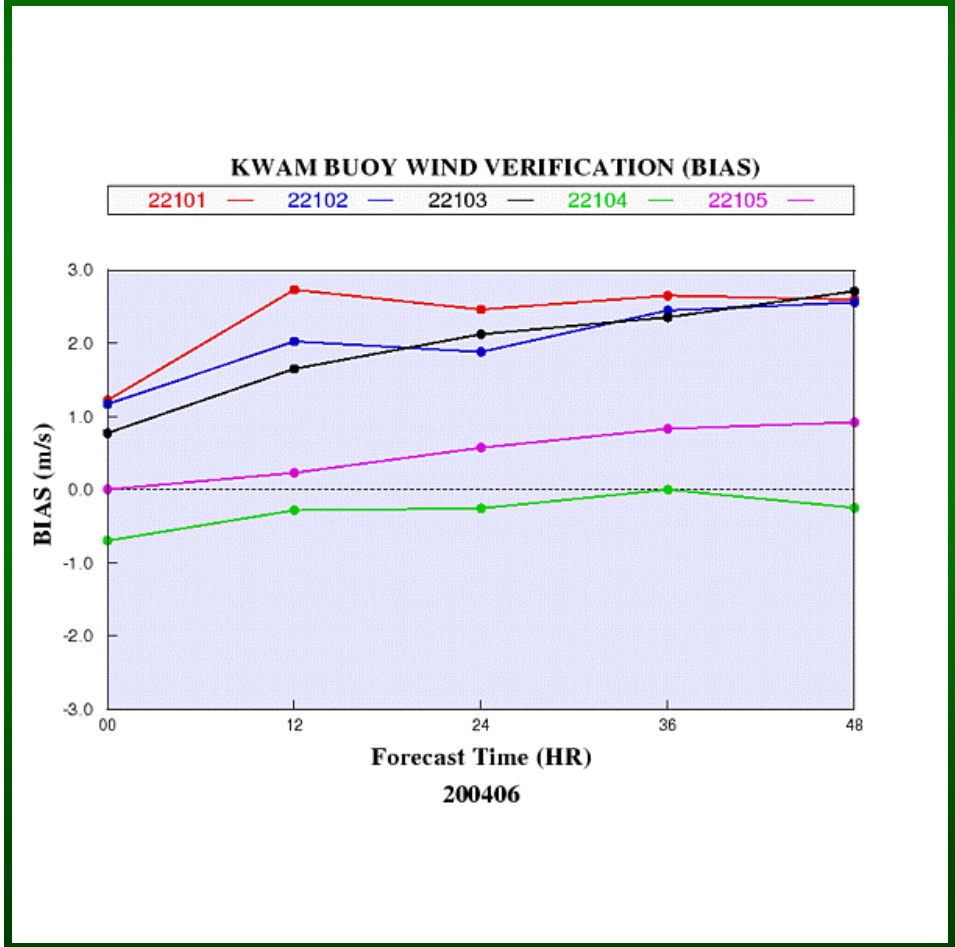
84m
? ? ? (22104)

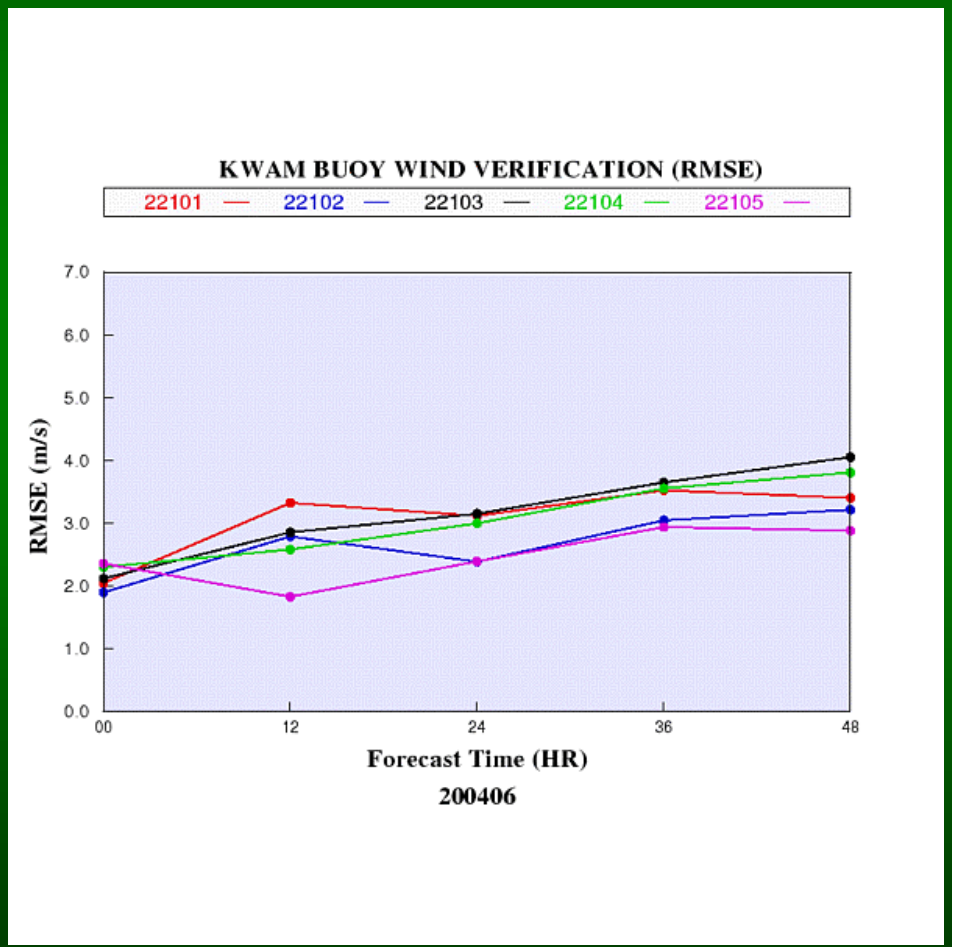
1500m
? ? (22105)



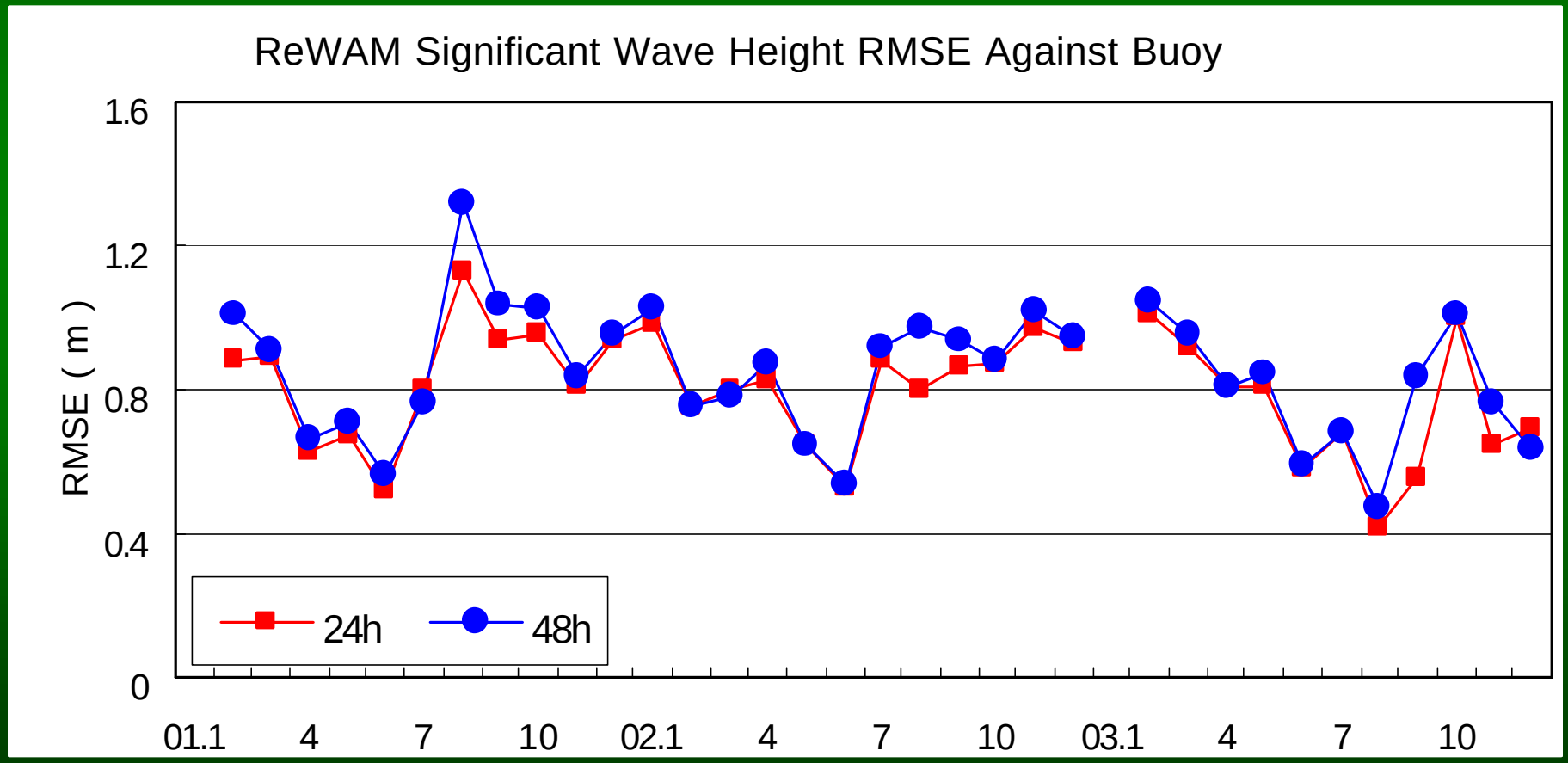


ReWAM Wind Verification against Buoy

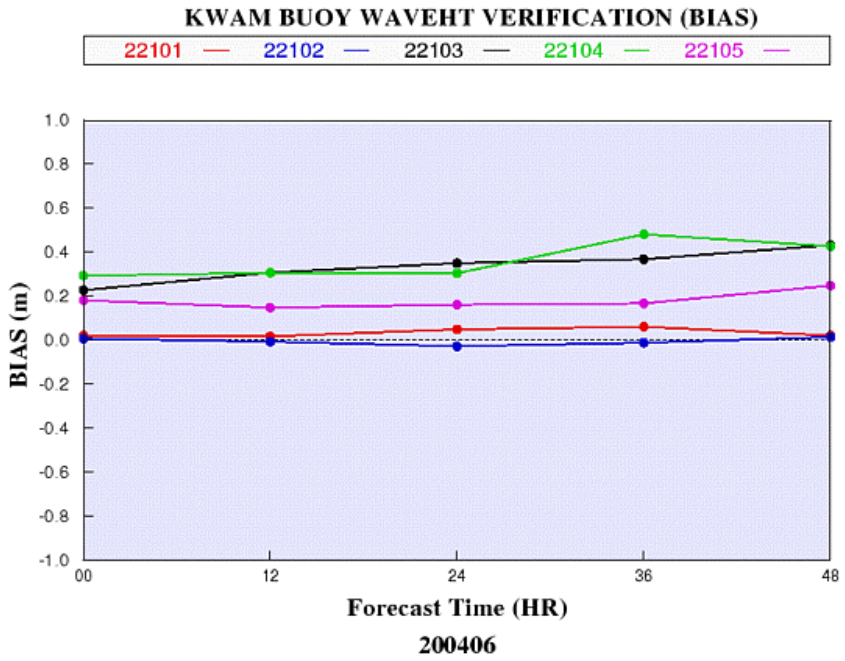


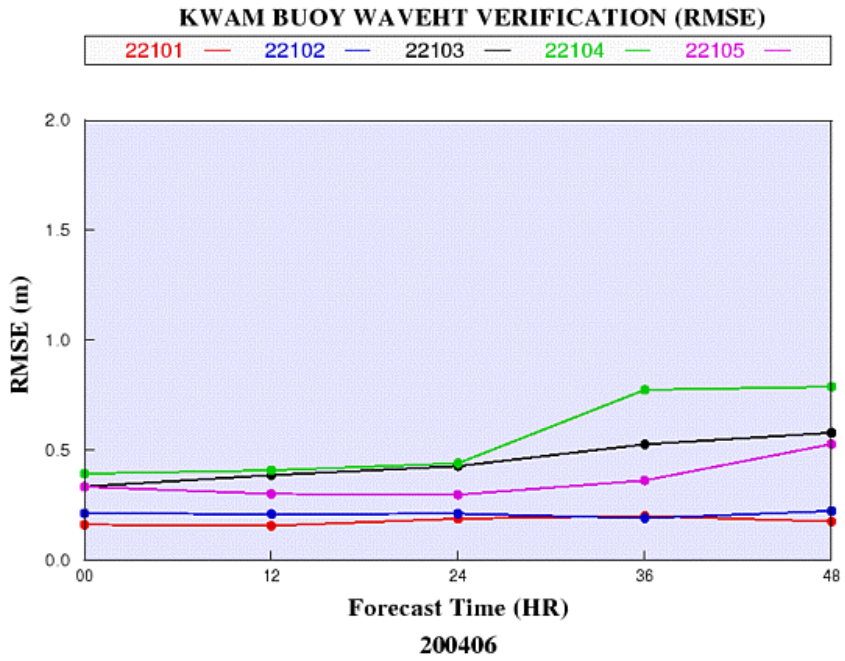


ReWAM Wave Height Verification against Buoy

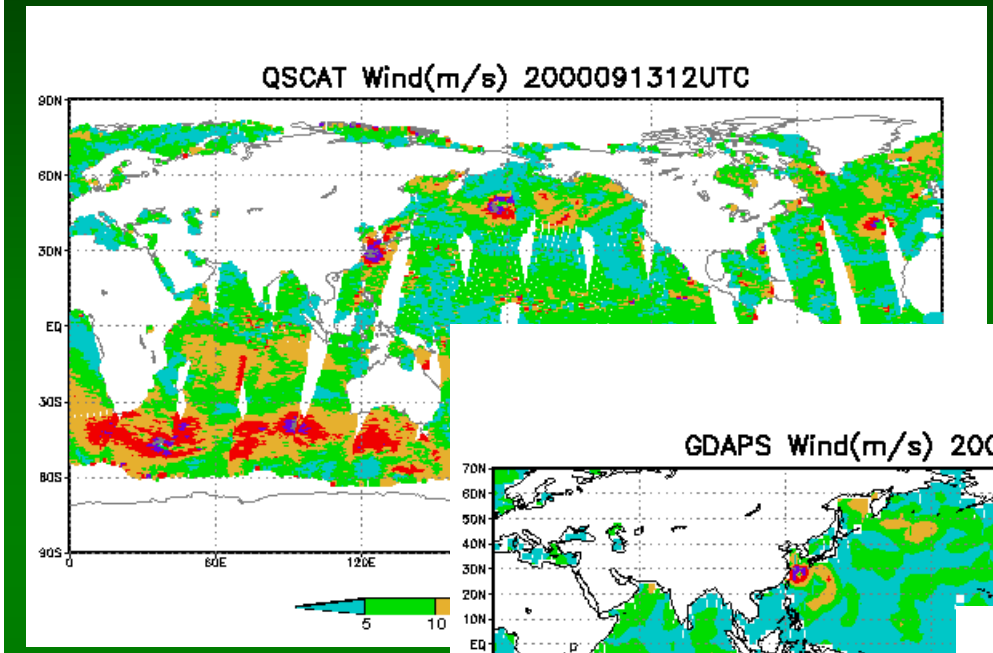


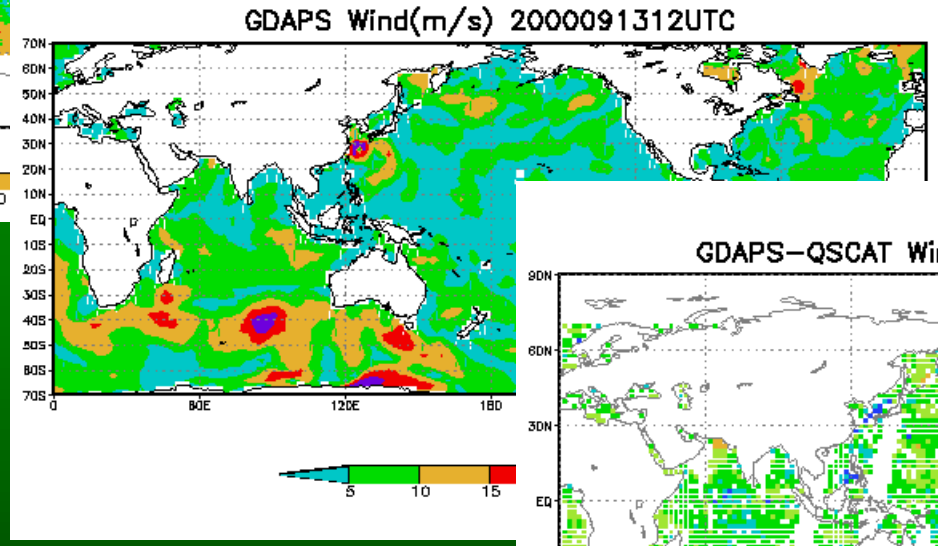
ReWAM Wave Height Verification against Buoy

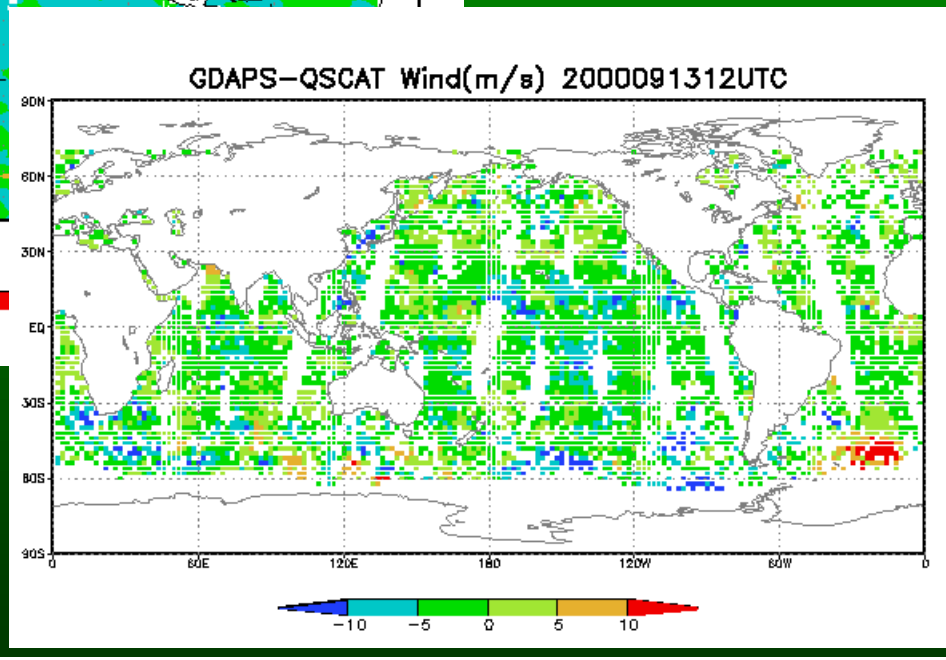




GoWAM Wind Verification against QuikSCAT



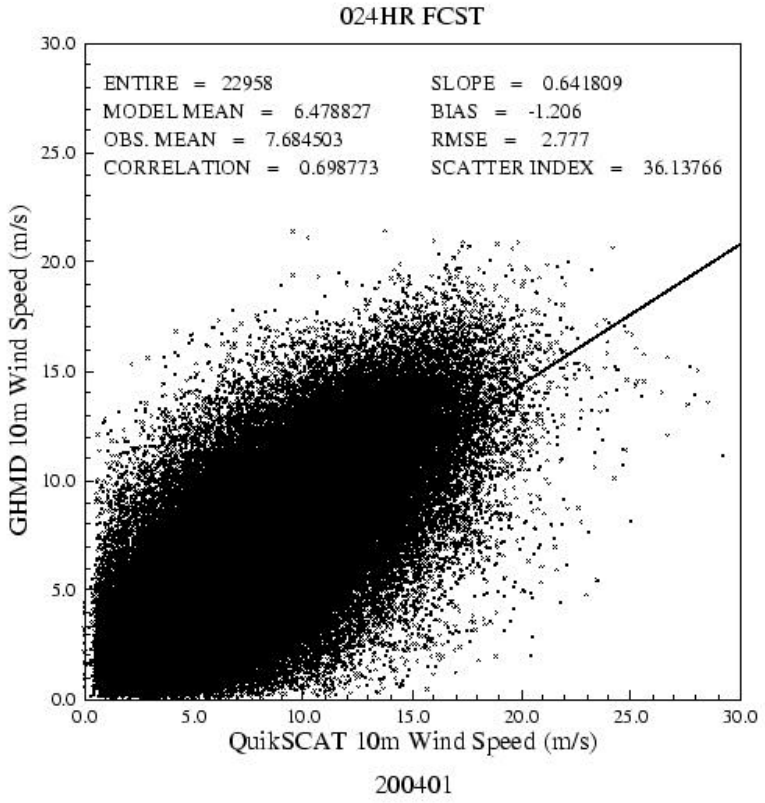


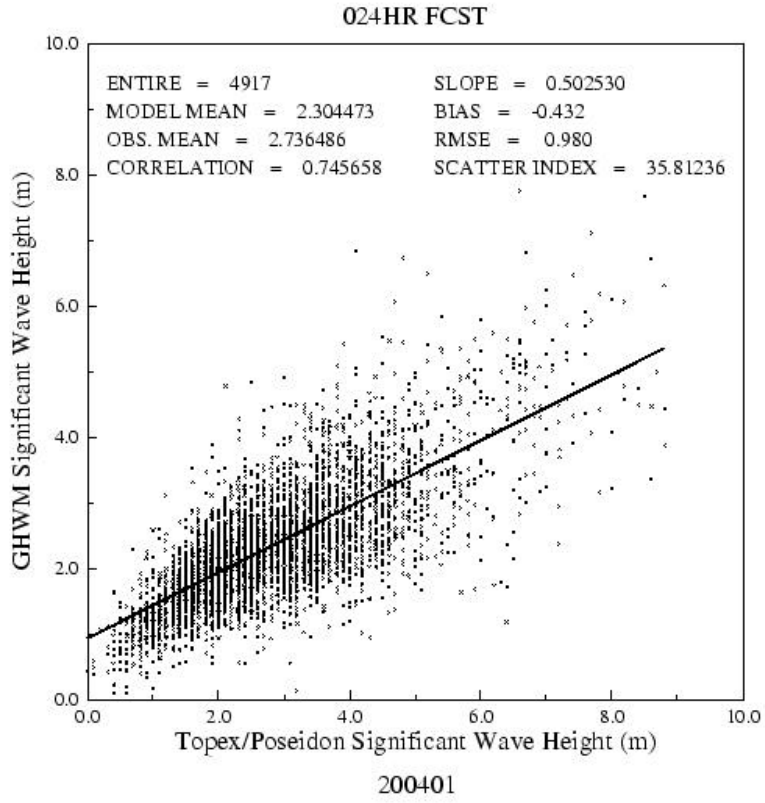


GoWAM Wind/Wave Height Verification against Satellite

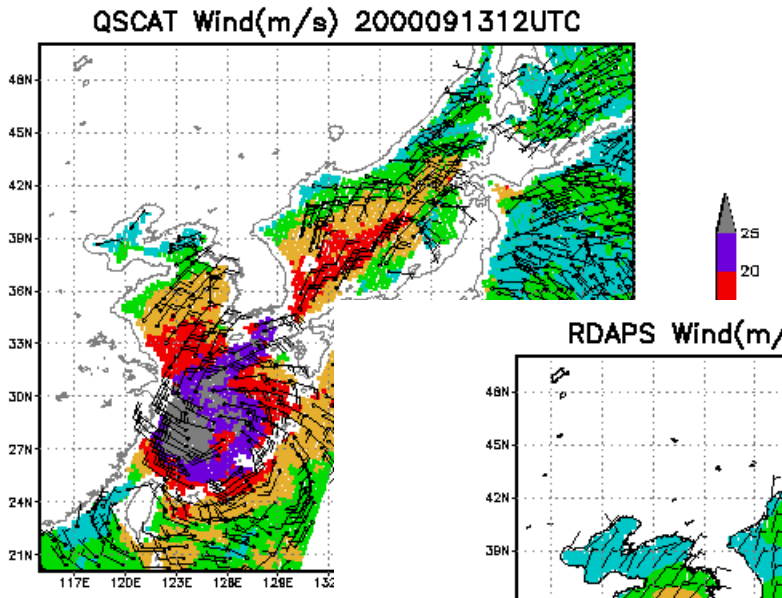
- **Annual GoWAM monthy error statistics for 24-hour forecast year 2003**

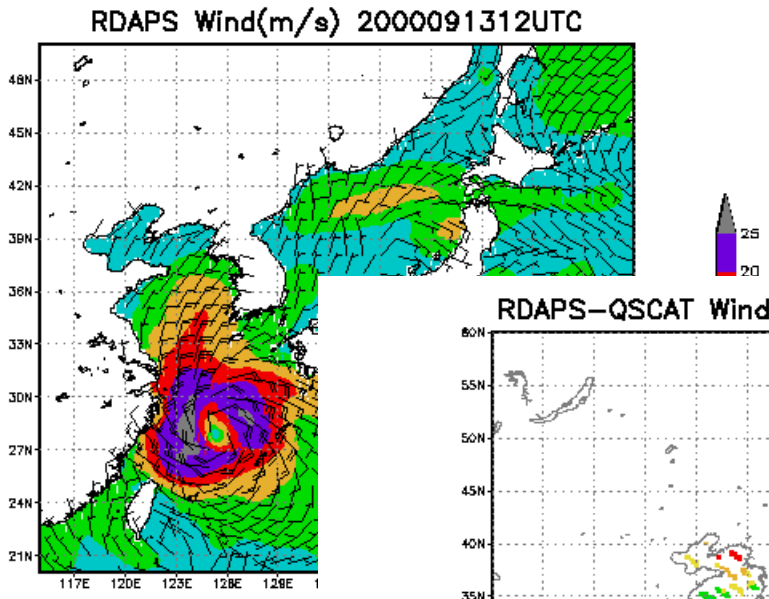
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
bias	-0.391	-0.524	-0.534	-0.556	-0.421	-0.456	-0.452	-0.507	-0.452	-0.431	-0.273	-0.248
rmse	1.004	1.155	1.167	1.221	1.079	1.123	1.136	1.206	1.049	1.020	0.995	0.840
corr	0.735	0.695	0.698	0.656	0.749	0.702	0.790	0.614	0.762	0.691	0.675	0.733

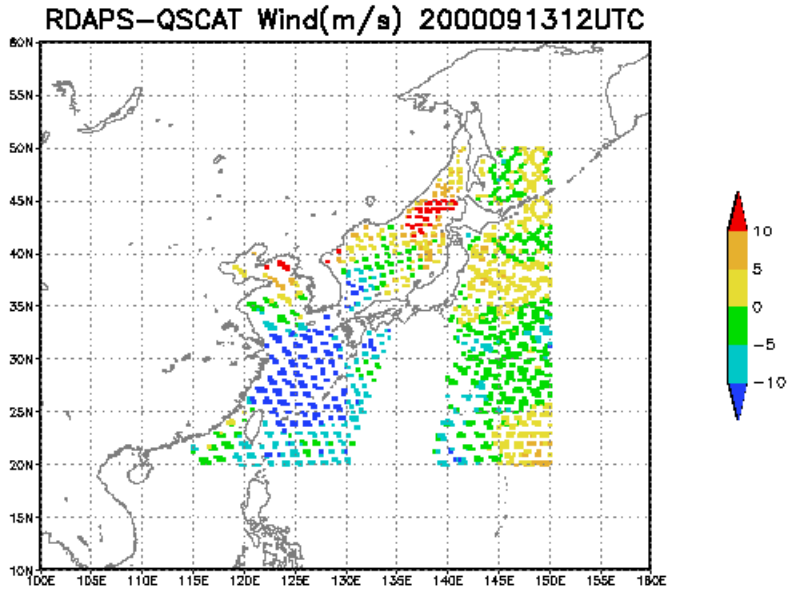




ReWAM Wind Verification against QuikSCAT



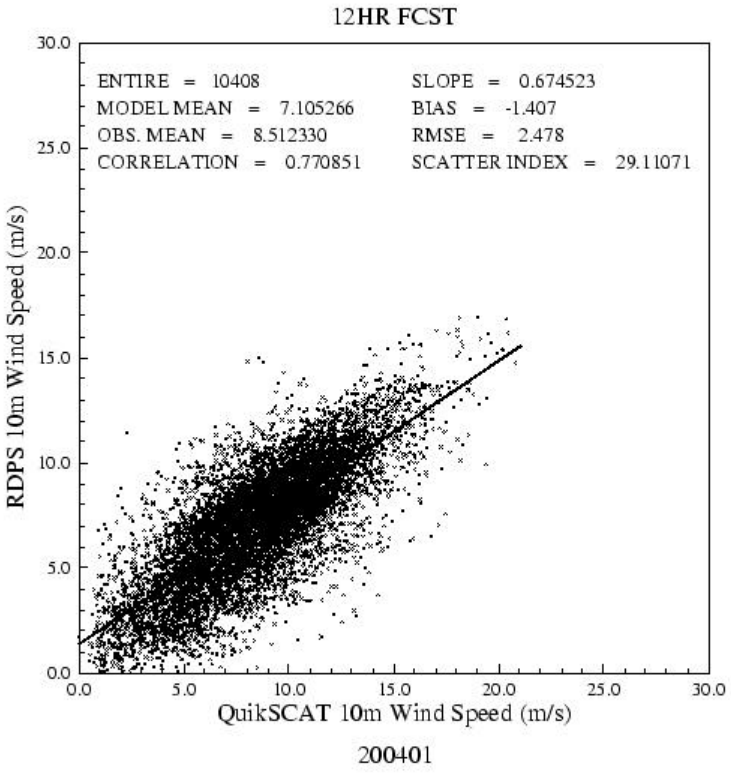


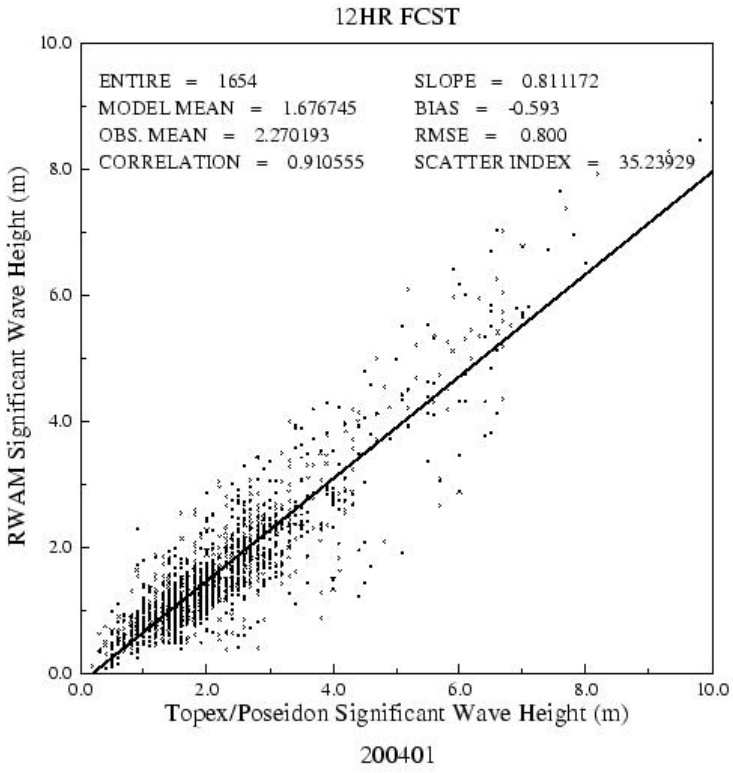


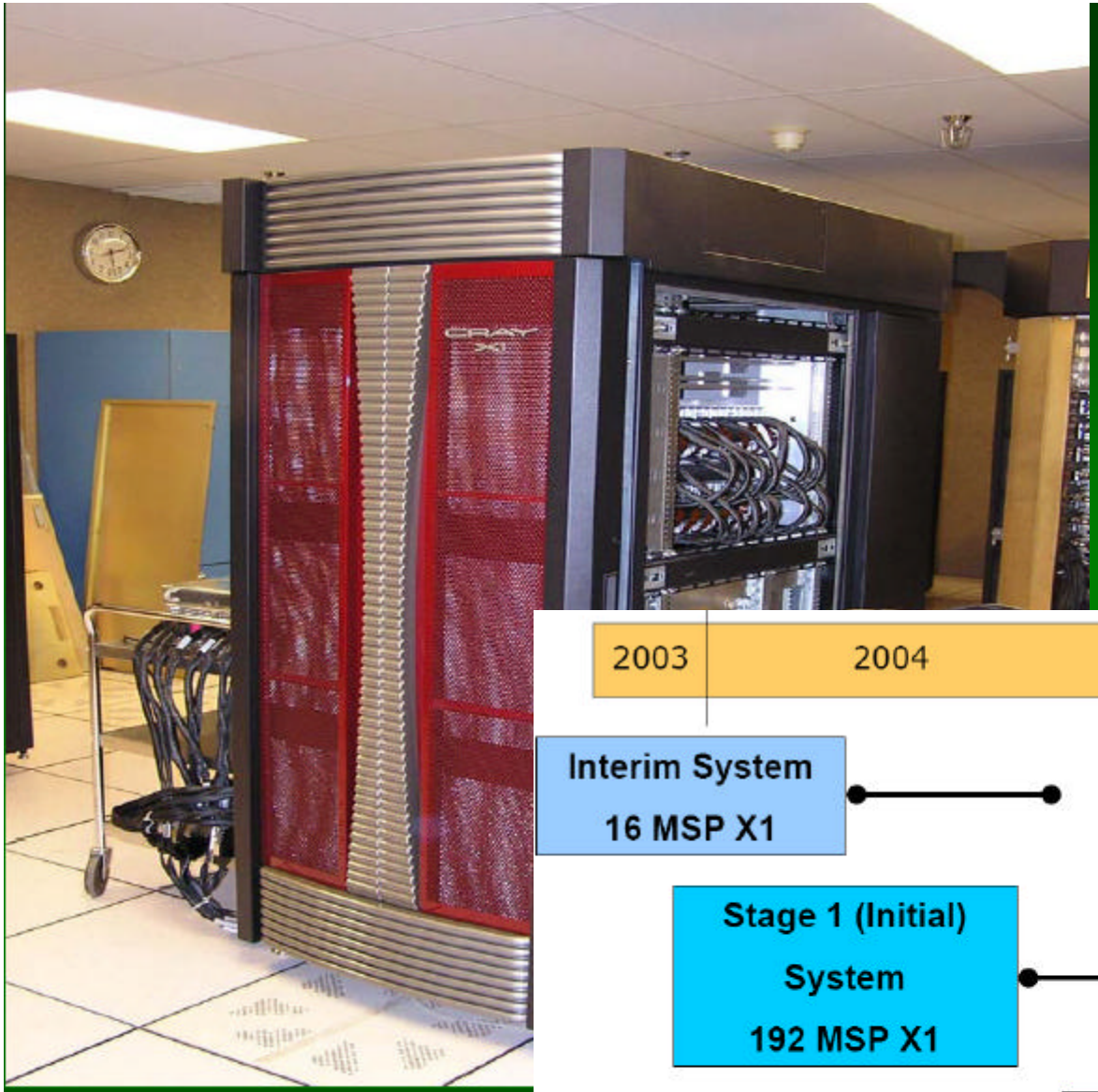
ReWAM Wind/Wave Height Verification against Satellite

- **Annual ReWAM monthy error statistics for 12-hour forecast year 2003**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
bias	-0.727	-0.691	-0.616	-0.472	-0.445	-0.214	-0.382	-0.206	-0.295	-0.841	-0.499	-0.572
rmse	0.890	1.006	0.944	0.822	0.806	0.553	0.688	0.440	0.544	1.023	0.626	0.740
corr	0.884	0.757	0.775	0.686	0.685	0.715	0.606	0.671	0.775	0.755	0.879	0.824







2003 2004 2005

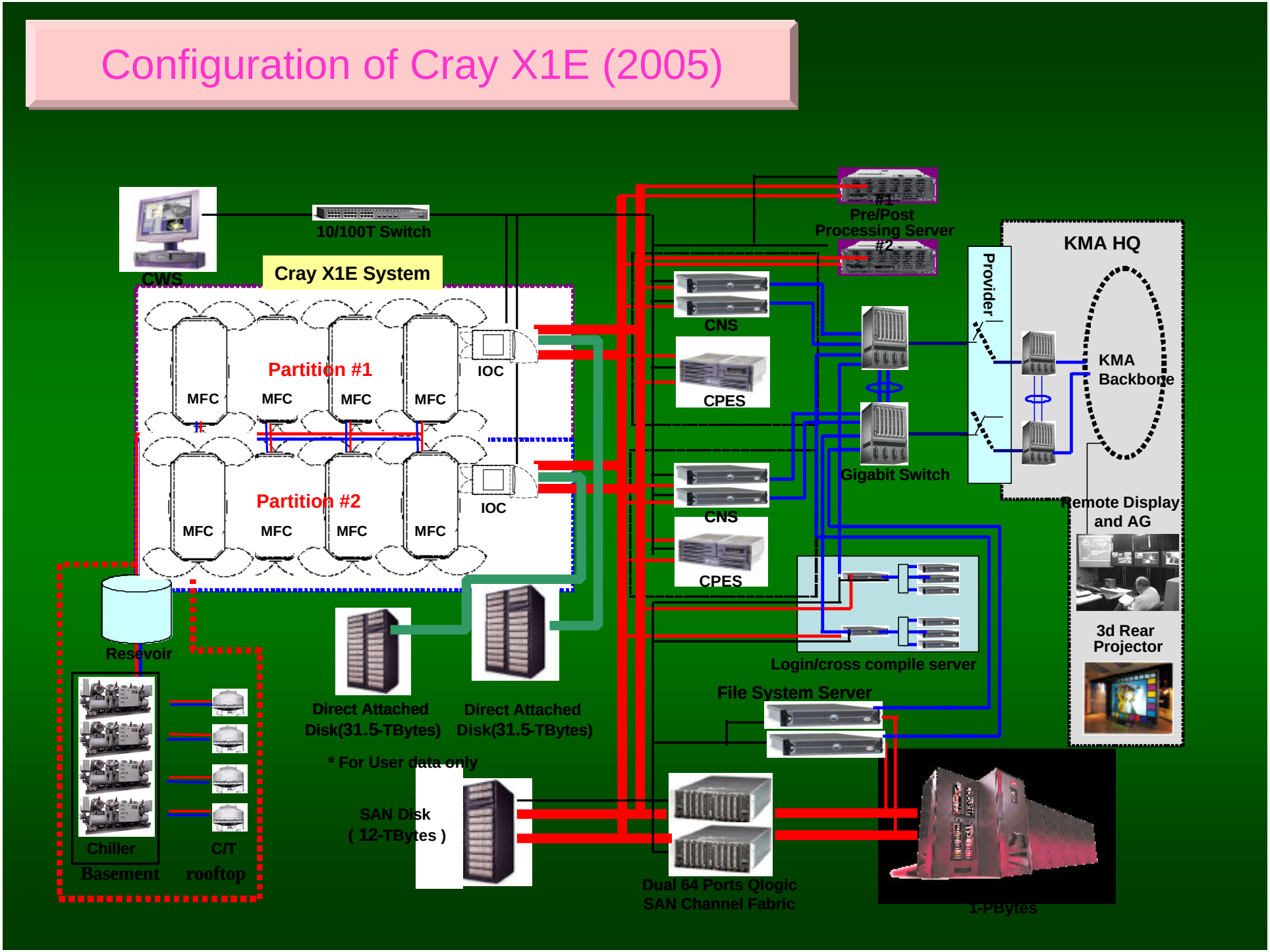
Interim System
16 MSP X1

Stage 1 (Initial)
System
192 MSP X1

Stage 2 (Final)
System
960 MSP X1E

Training

Configuration of Cray X1E (2005)



Specification

Items			The first proposal	
			Initial system (2004)	Final system (2005)
Model name			X1-3/192-L	X1E-8/960-L
Main System	The number of cabinets		3	7.5
	Nodes	System	1	4
		Computing	47	236
	CPUs	System	4	16
		Computing	188	944
	Single CPU performance		12.8Gflops	19.2Gflops
	1 CPU Sustained performance		3.38 Gflops	4.63Gflops
	Total Sustained Gflops		635.44 Gflops	4,370.72 Gflops
	Total memory size		760 Gbytes	3776 Gbytes

Newly Devised Wave Prediction System

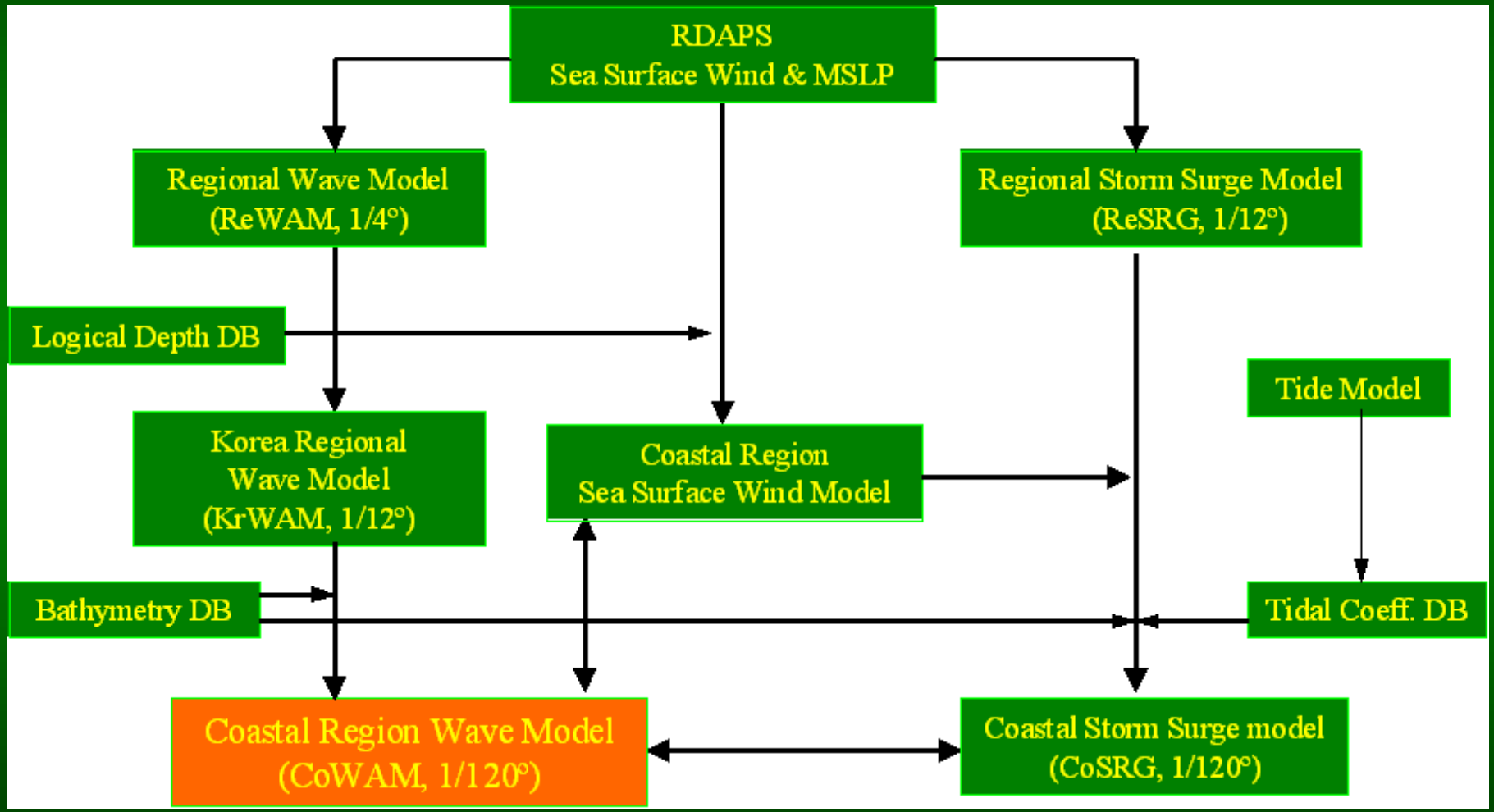
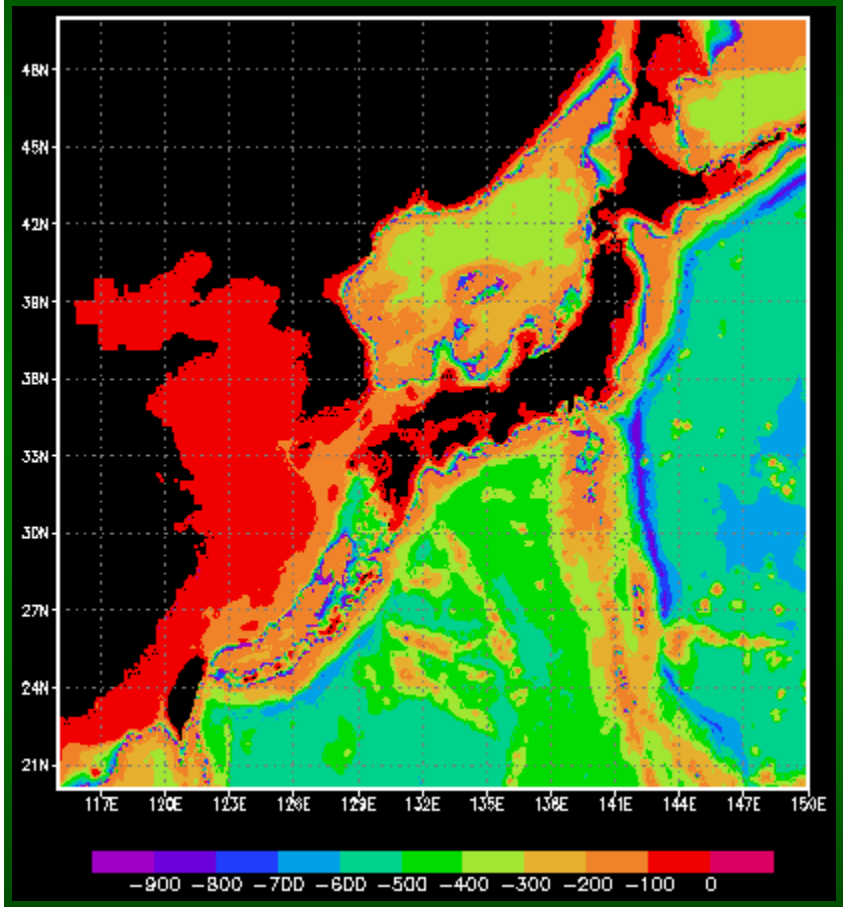


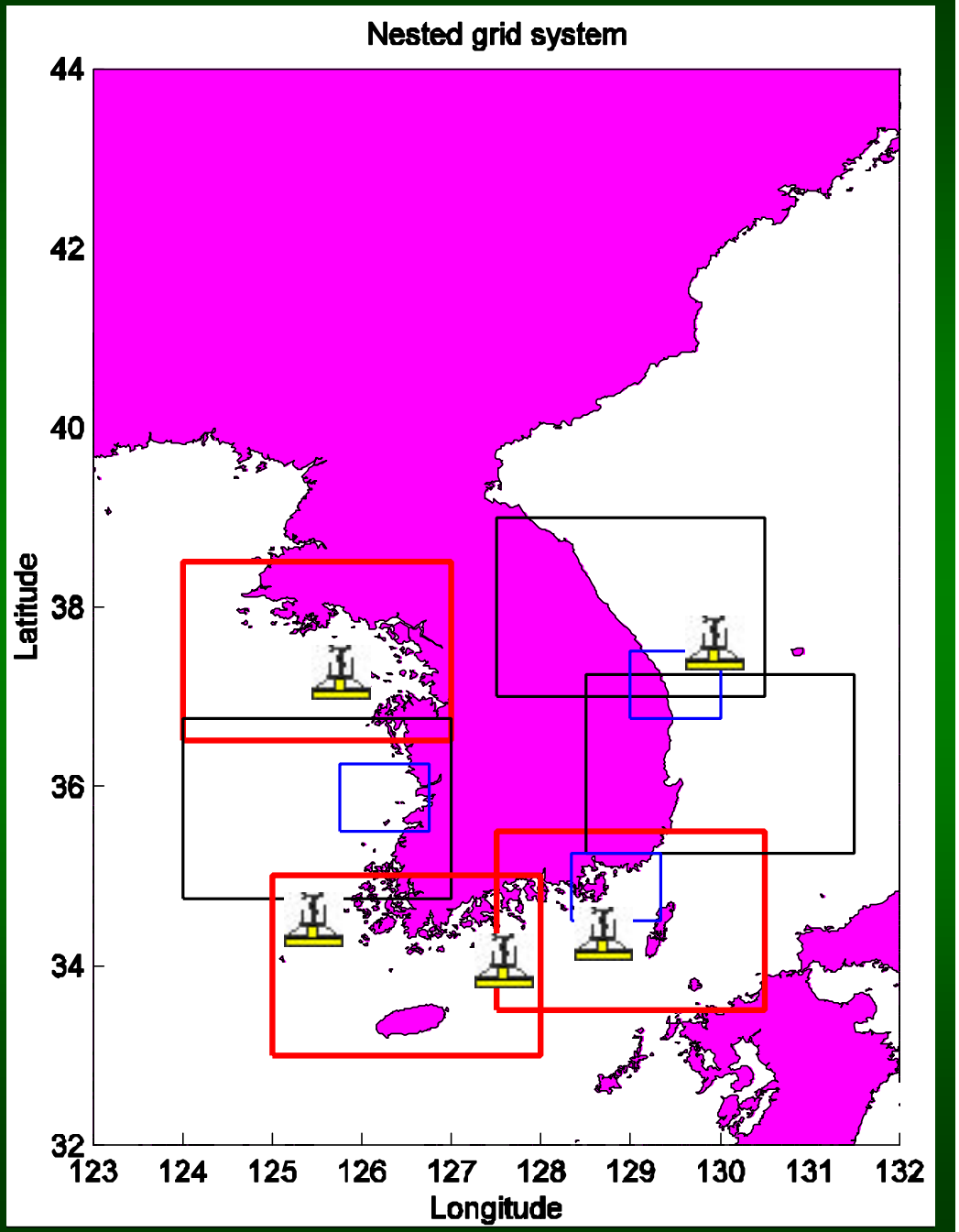
Table 1. Numerical Wave Prediction System in KMA (* experimental stage)

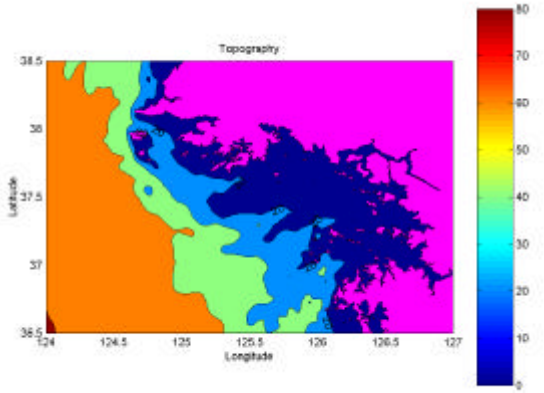
	GoWAM	ReWAM	KrWAM*	CoWAM*	ReSRG*	CoSRG*
Model Code	3rd Generation Wave Model (WAM) Code			SWAN Code	Storm Surge Model Code	
Model Coordinate	Spherical Coordinate				Spherical Coordinate	
Model Domain	70°S-70°N, 0°E-360°E	20°N-50°N, 115°E-150°E	32°N-44°N, 123°E-132°E	BUS:34.50°N-35.25°N,128.33°E-129.33°E DON:36.75°N-37.50°N,129.00°E-130.00°E GUN:35.50°N-36.25°N,125.75°E-126.75°E	Same as ReWAM area	Same as CoWAM area
Spectral Resolution	25 Frequency 24 Direction			25 Frequency 24 Direction	N/A	
Spatial Resolution	1.25° (288×113)	1/4° (141×121)	1/12° (109×145)	1/120° (121×91)	1/12° (421×361)	1/120° (121×91)
? T	720sec	360sec	240sec	60sec	900sec	120sec
Prediction & Staring Time	240H (12UTC)	48H (00,12UTC)			48H (00,12UTC)	
Initial & Boundary Data	-24H FCST	-12H FCST	-12H FCST/ ReWAM Boundary Data	-12H FCST/ KrWAM Boundary Data	Cold Start	Cold Start ReSRG Boundary Data
Input Forcing data	GDAPS Sea Surface Wind	RDAPS Sea Surface wind			RDAPS sea Surface Wind & Mean Sea Level Pressure	

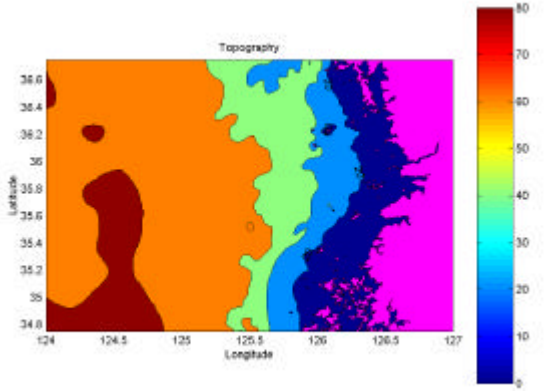
? **GoWAM**: Global Wave Model
ReWAM: Regional Wave Model
KrWAM: Korea region Wave Model
CoWAM: Coastal region Wave Model
ReSRG: Regional Storm Surge Model
CoSRG: Coastal Storm Surge Model
SWAN: Simulating Wave Nearshore

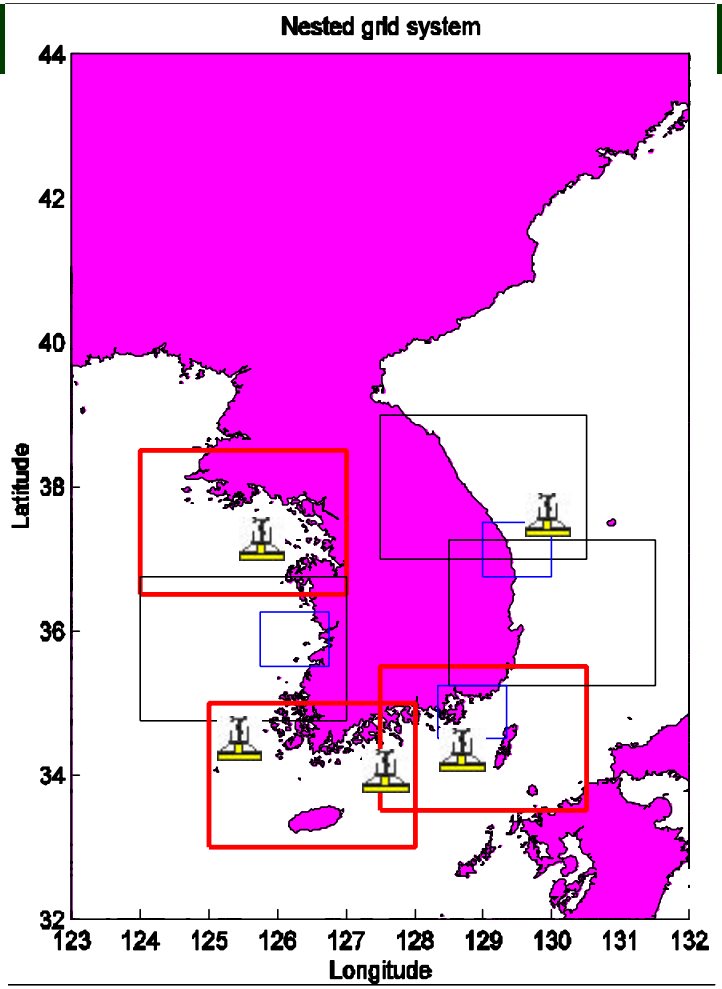
Coastal Model Domain

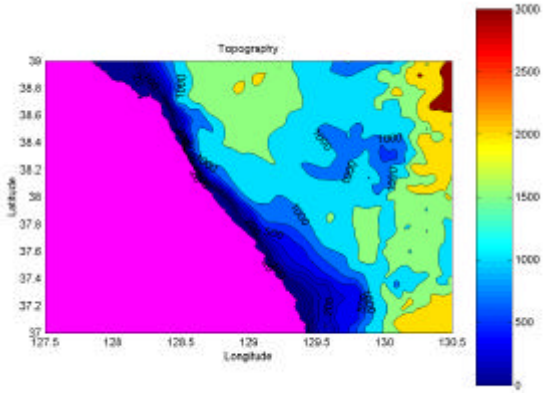


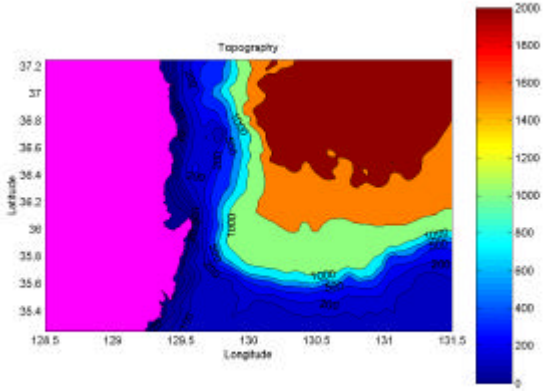


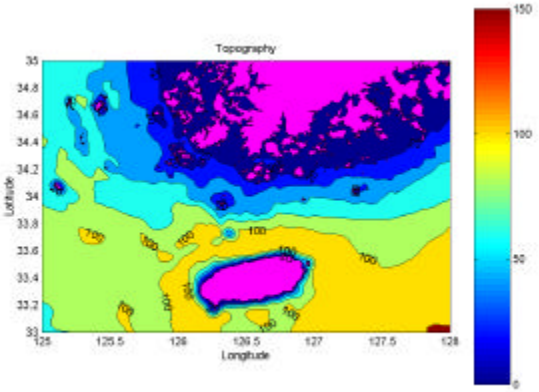

Topography
Latitude
Longitude

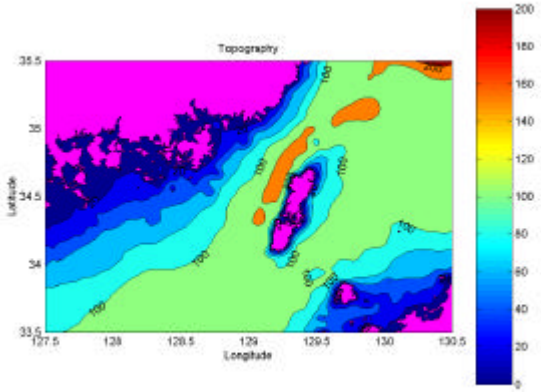

Topography
Latitude
Longitude

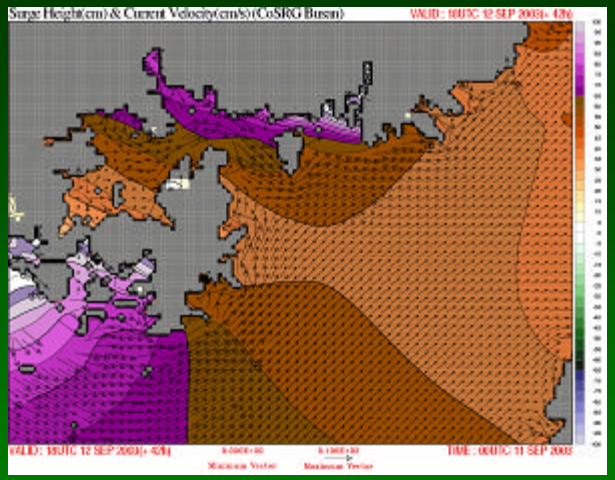

Nested grid system
Latitude
Longitude

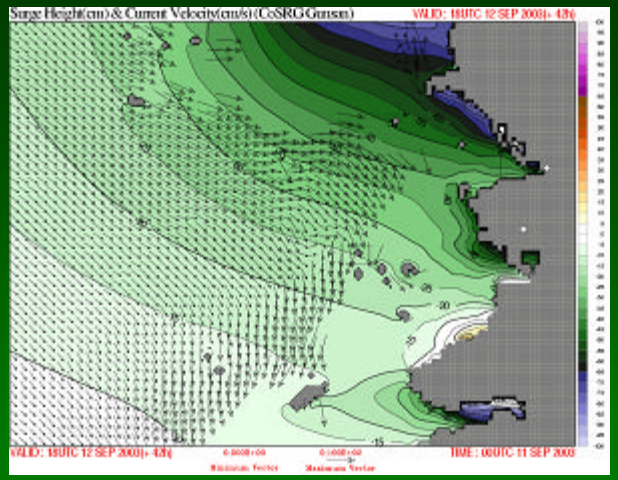

Topography
Latitude
Longitude

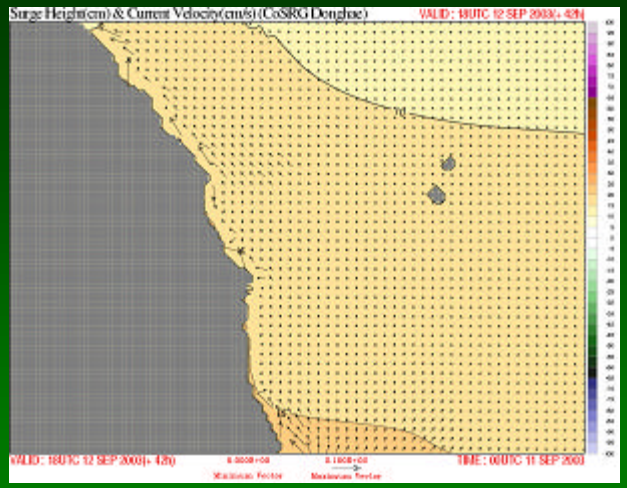

Topography
Latitude
Longitude

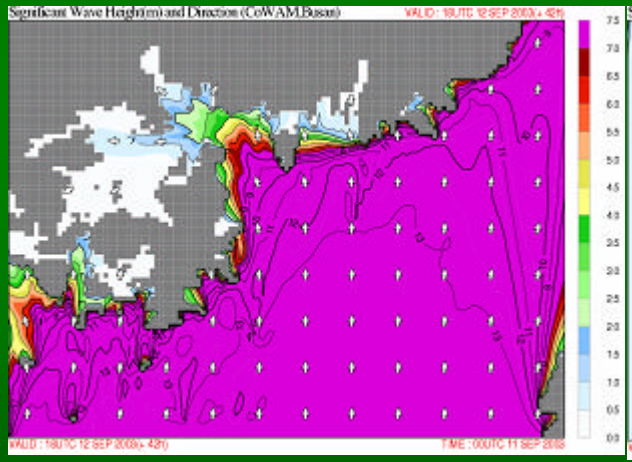

Topography
Latitude
Longitude

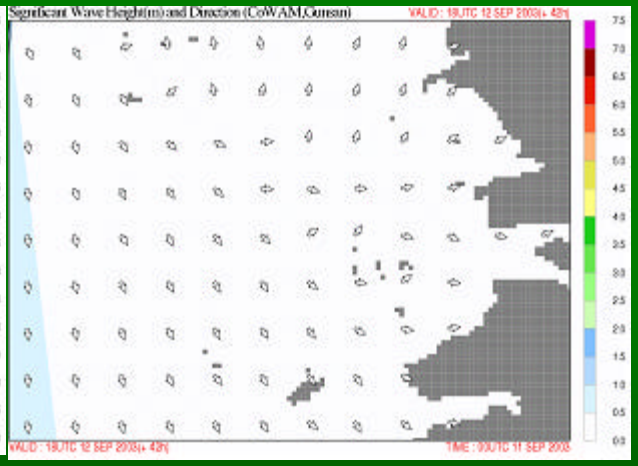

Topography
Latitude
Longitude

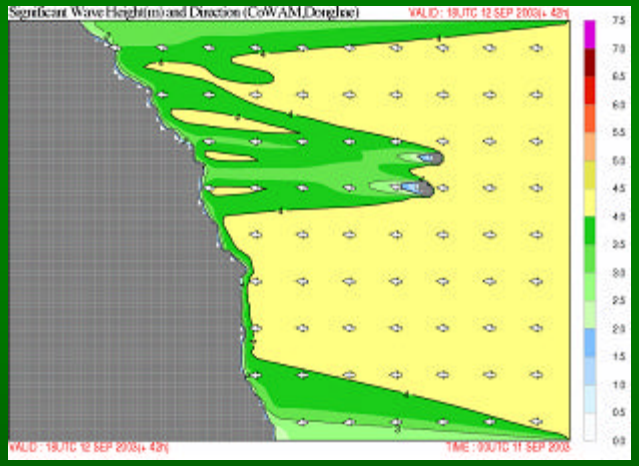




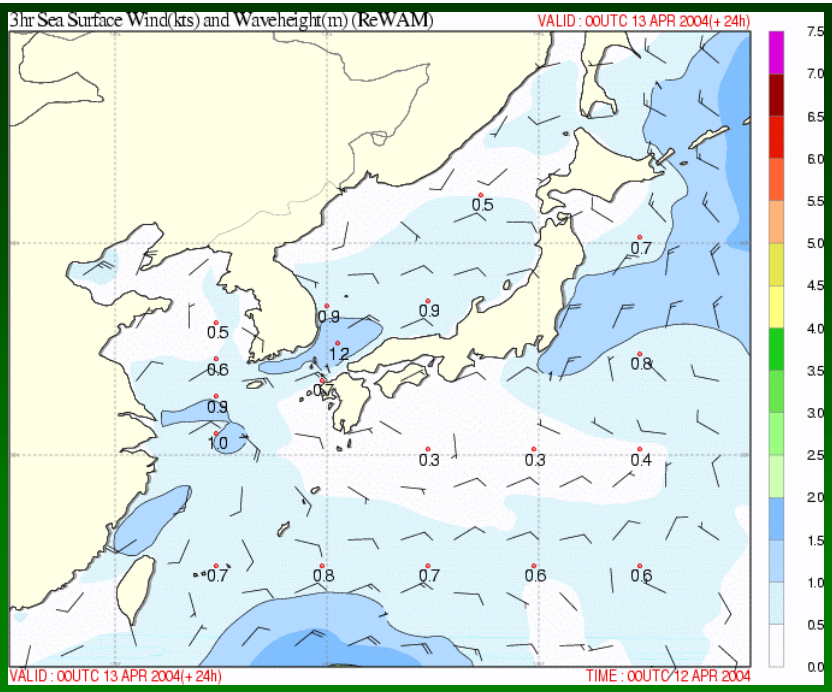


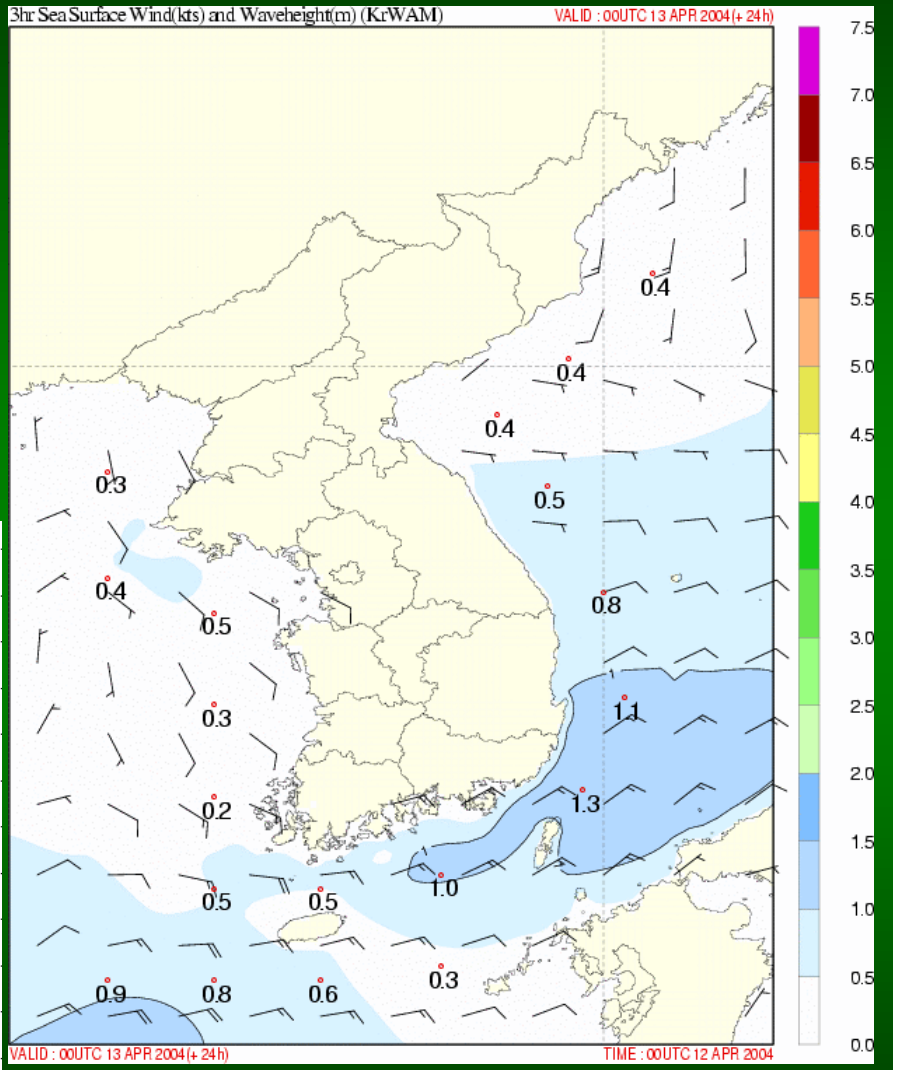


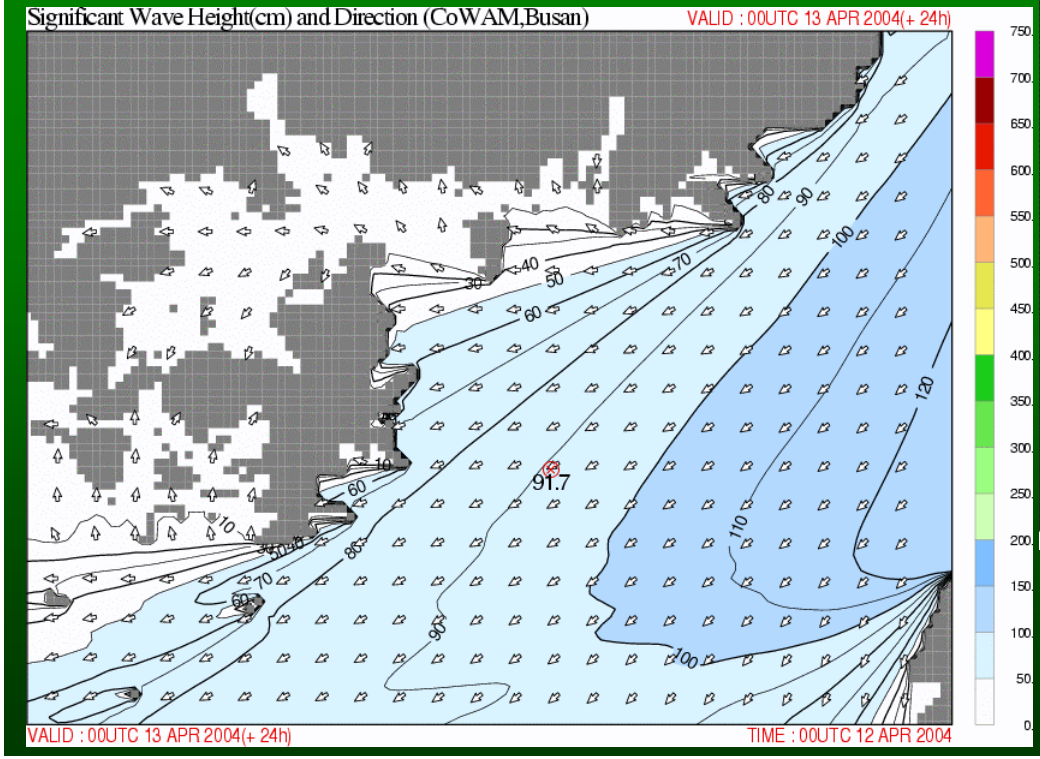


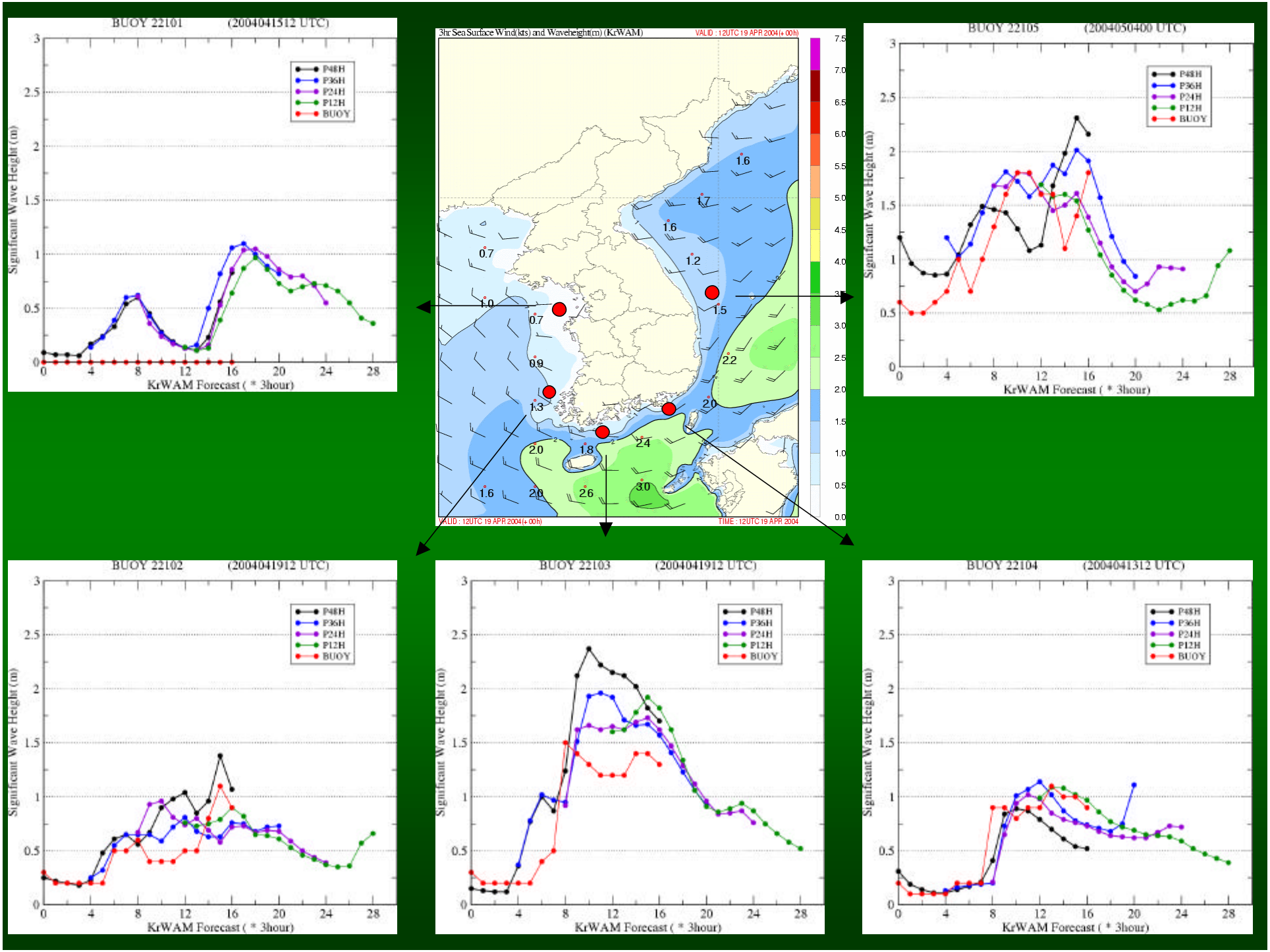


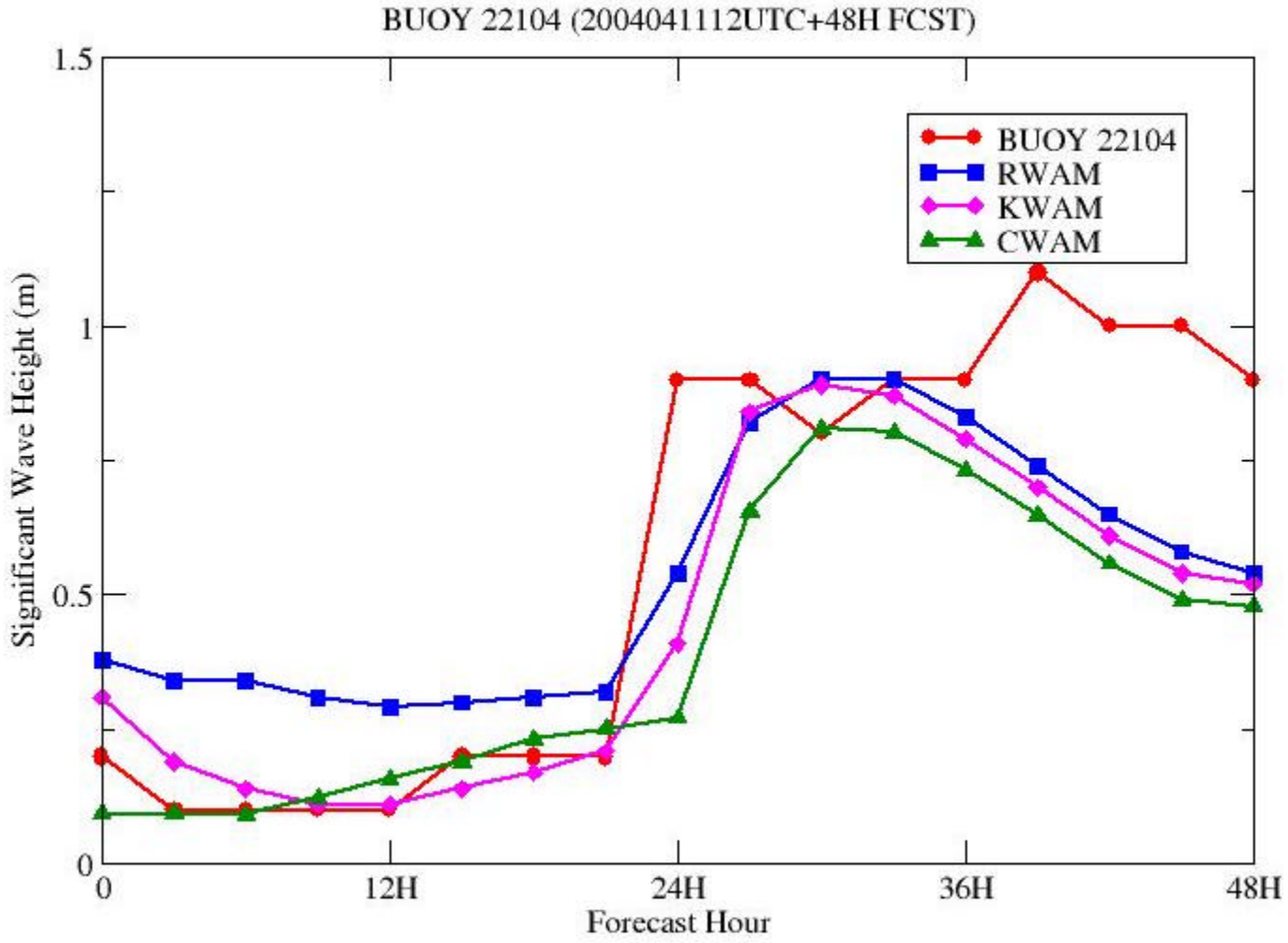
Coastal surge height and current velocity for Busan, Gusan, and Donghae domain (upper panel from left to right), and coastal significant wave height and direction for the same domain area (lower panel from left to right) of Sept. 11, 2003 case.

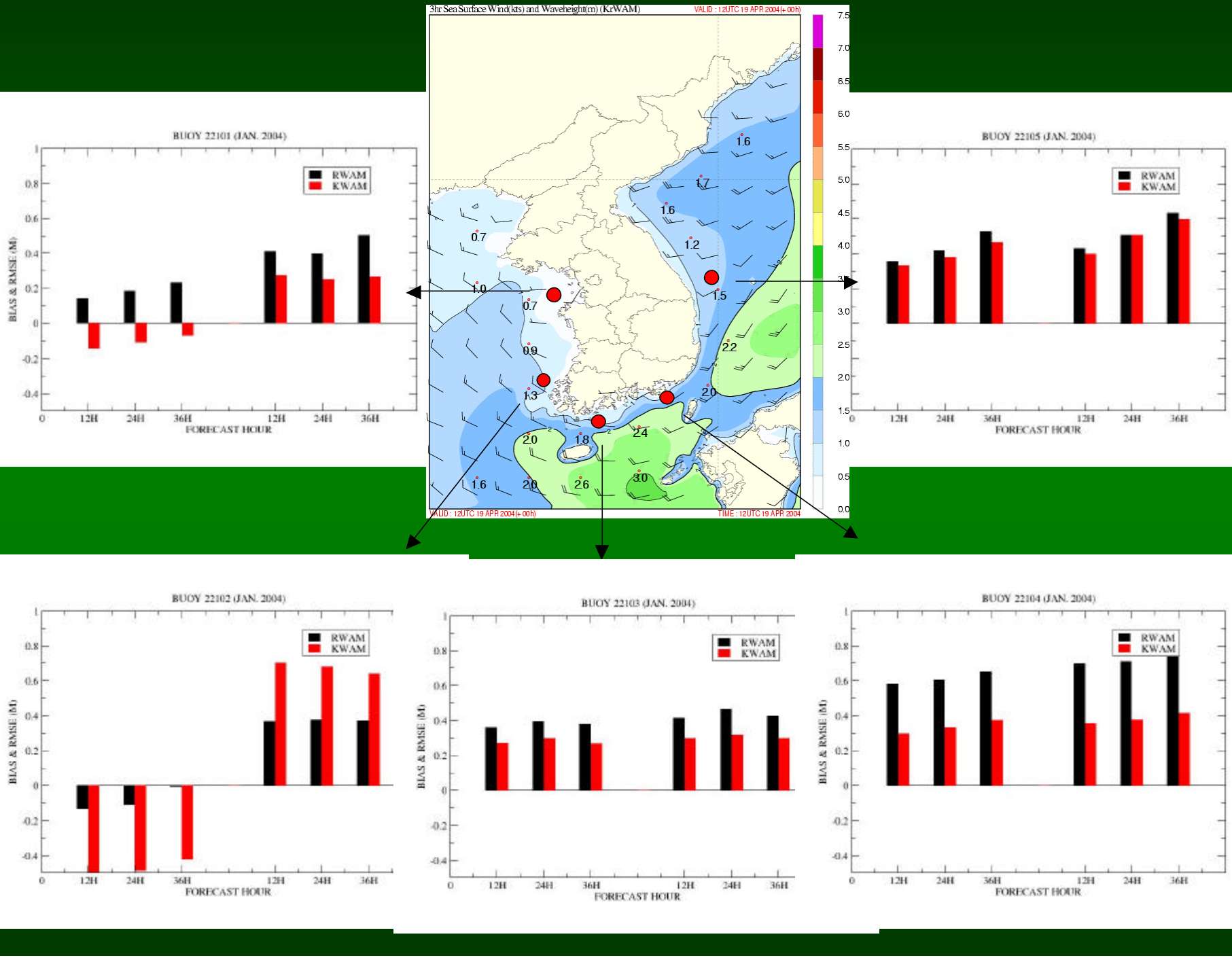

3hr Sea Surface Wind(kts) and Waveheight(m) (ReWAM)
VALID : 00UTC 13 APR 2004(+ 24h)
VALID : 00UTC 13 APR 2004(+ 24h)
TIME : 00UTC 12 APR 2004


3hr Sea Surface Wind(kts) and Waveheight(m) (KrWAM)
VALID : 00UTC 13 APR 2004(+ 24h)
VALID : 00UTC 13 APR 2004(+ 24h)
TIME : 00UTC 12 APR 2004

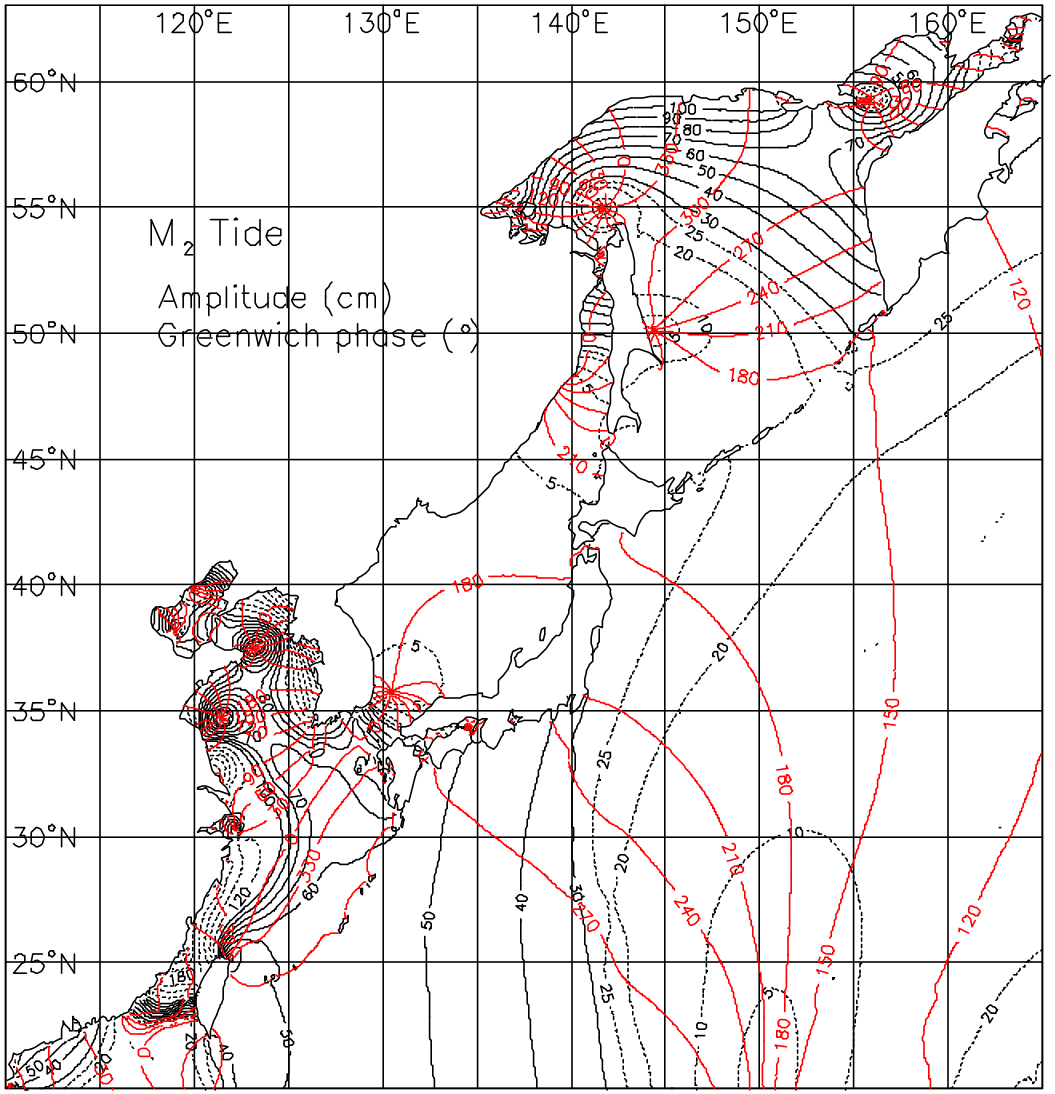

Significant Wave Height(cm) and Direction (CoWAM,Busan)
VALID : 00UTC 13 APR 2004(+ 24h)
VALID : 00UTC 13 APR 2004(+ 24h)
TIME : 00UTC 12 APR 2004


BUOY 22101 (2004041512 UTC)
BUOY 22105 (2004050400 UTC)
3hr Sea Surface Wind(kts) and Waveheight(cm) (KrWAM)
VALID : 12UTC 19 APR 2004 (+ 00h)
TIME : 12UTC 19 APR 2004
BUOY 22102 (2004041912 UTC)
BUOY 22103 (2004041912 UTC)
BUOY 22104 (2004041312 UTC)
P48H
P36H
P24H
P12H
BUOY
Significant Wave Height (m)
KrWAM Forecast (* 3hour)

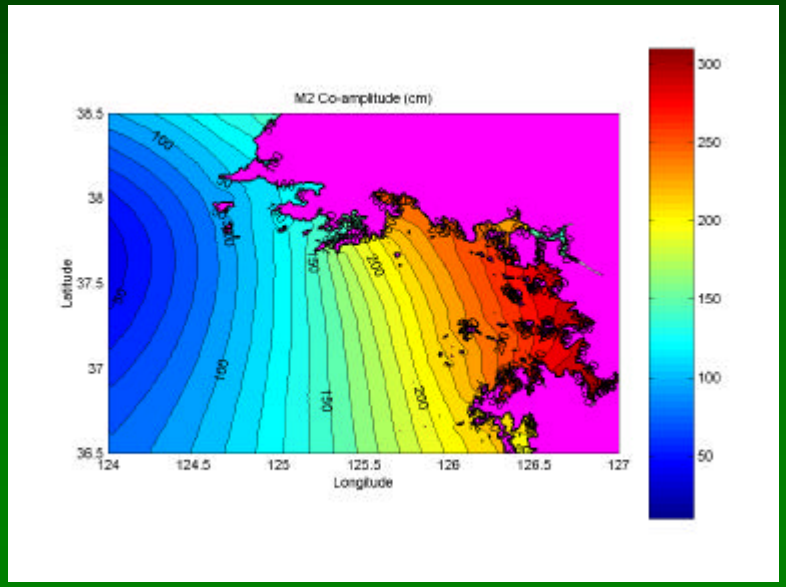

BUOY 22104 (2004041112UTC+48H FCST)
BUOY 22104
RWAM
KWAM
CWAM
Significant Wave Height (m)
1.5
1
0.5
0
0
12H
24H
36H
48H
Forecast Hour

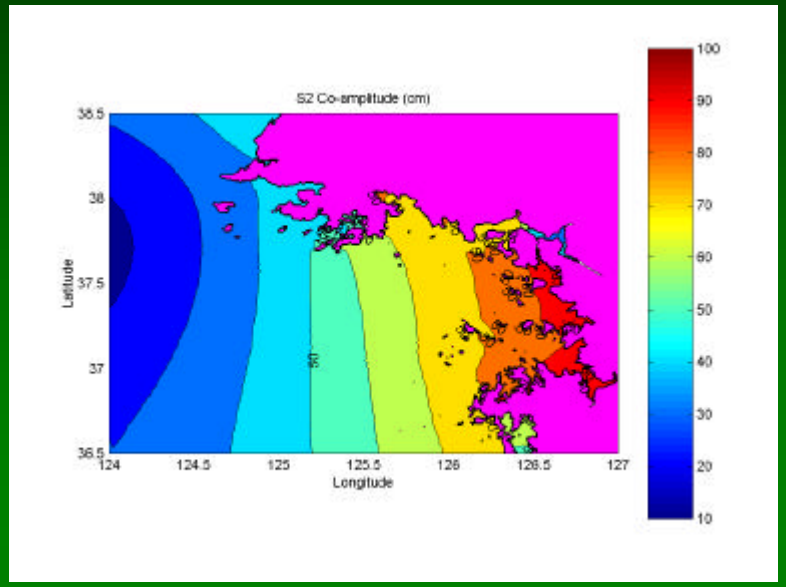

3hr Sea Surface Wind(kts) and Waveheight(m) (KrWAM)
VALID : 12UTC 19 APR 2004 (+ 00h)
VALID : 12UTC 19 APR 2004 (+ 00h)
TIME : 12UTC 19 APR 2004
1.6
1.7
1.6
0.7
1.2
1.0
1.5
0.7
2.2
0.9
1.3
2.0
2.0
1.8
2.4
1.6
2.0
2.6
3.0
BUOY 22101 (JAN. 2004)
BUOY 22105 (JAN. 2004)
BUOY 22102 (JAN. 2004)
BUOY 22103 (JAN. 2004)
BUOY 22104 (JAN. 2004)
RWAM
KWAM
BIAS & RMSE (M)
FORECAST HOUR
0
12H
24H
36H

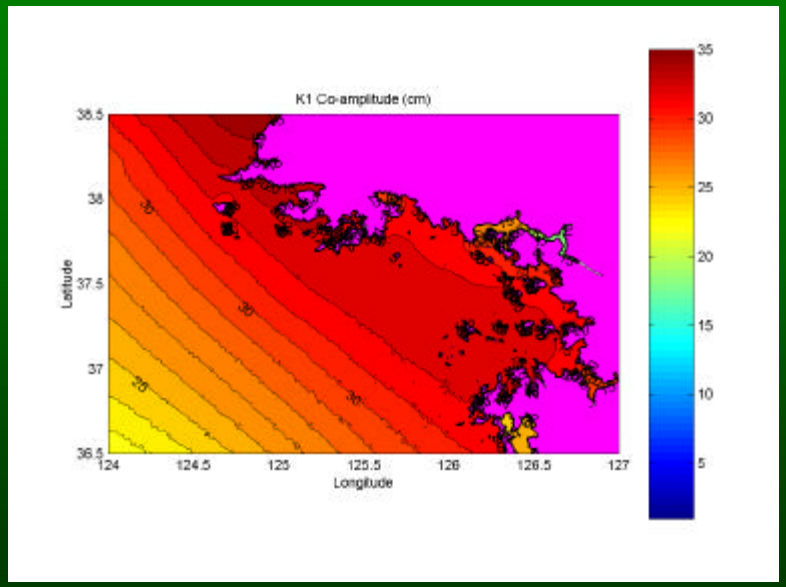
M2 tide amplitude and phase

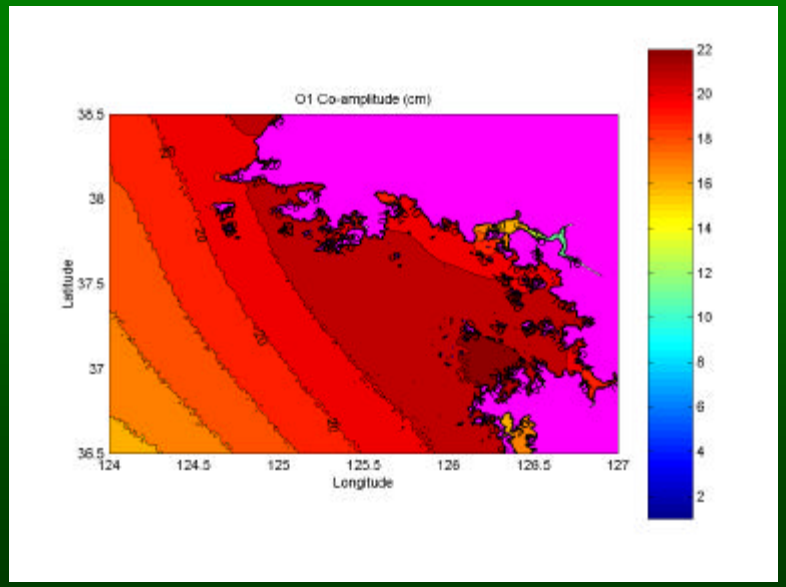


1/120° M2,K1,S2,O1 co-amplitude (cm)

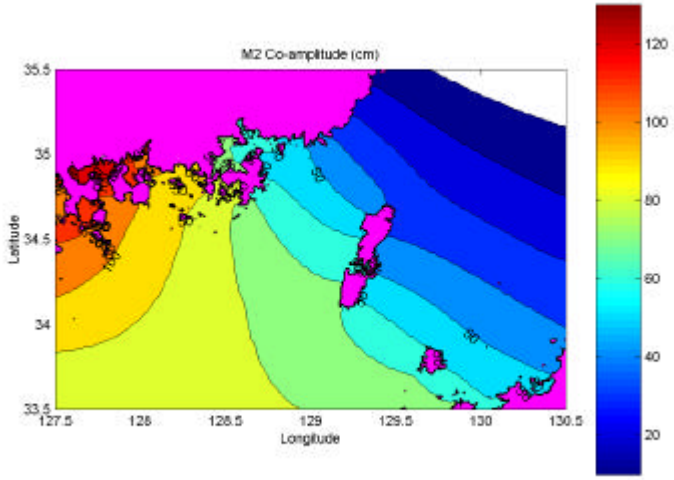


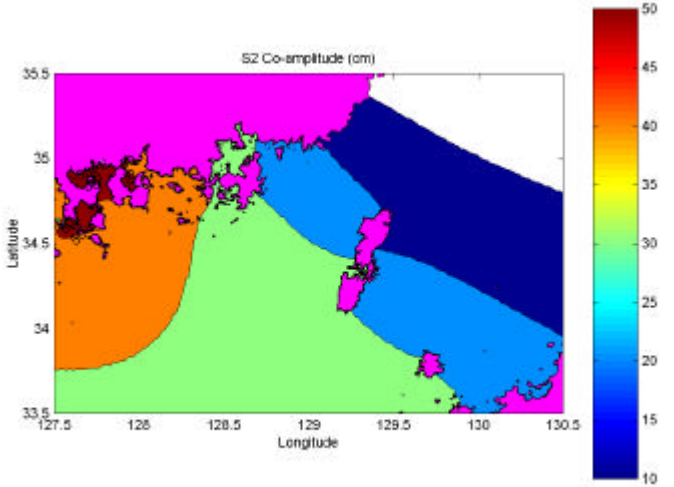


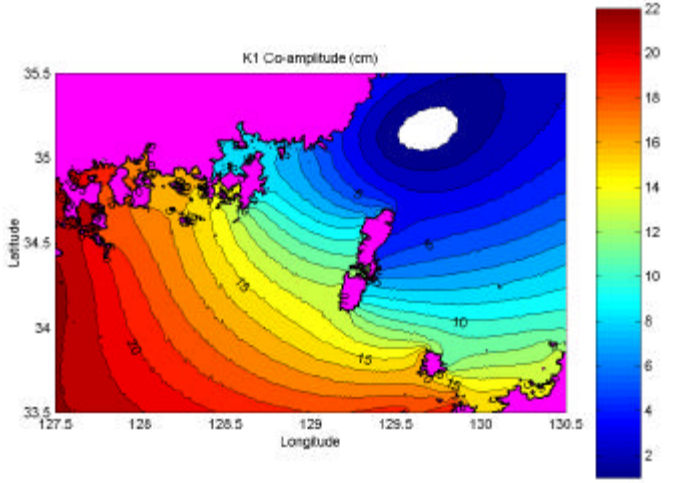


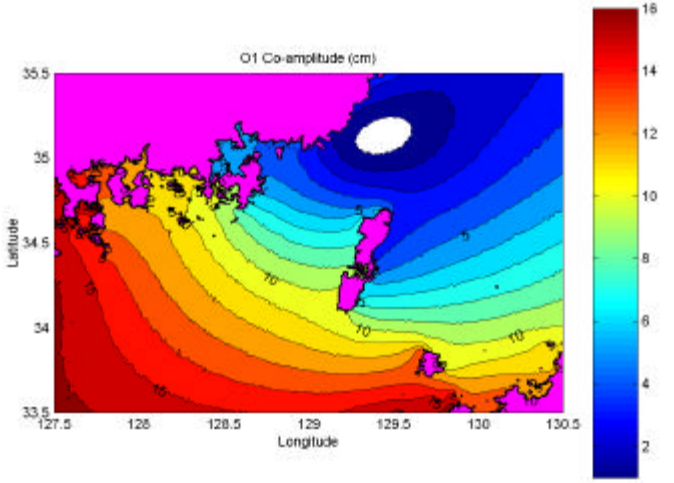


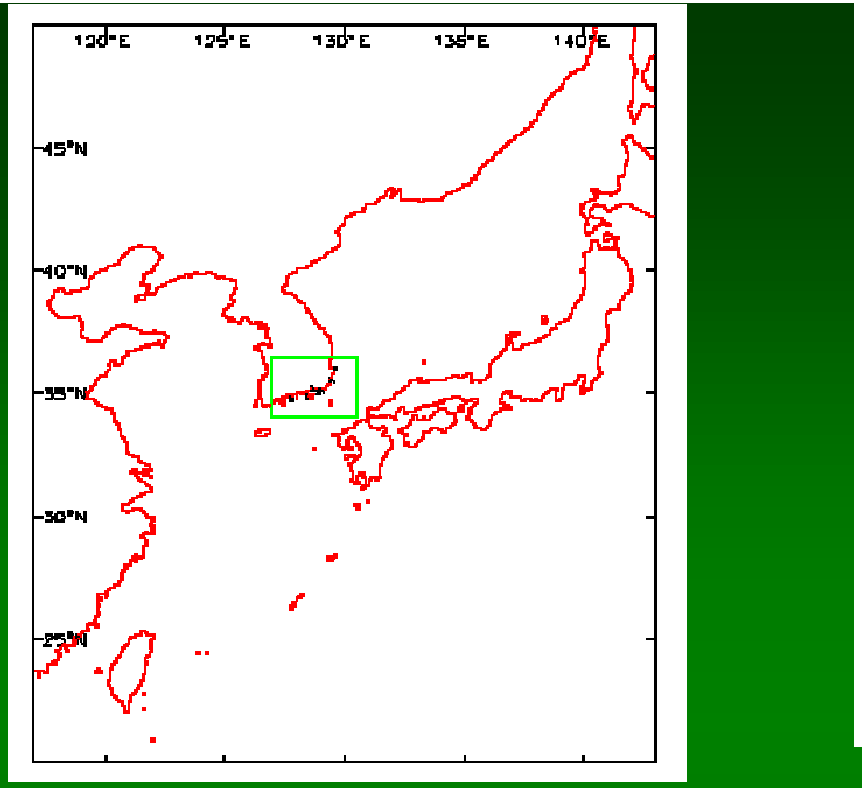
1/120^{o} M2,K1,S2,O1 co-amplitude (cm)

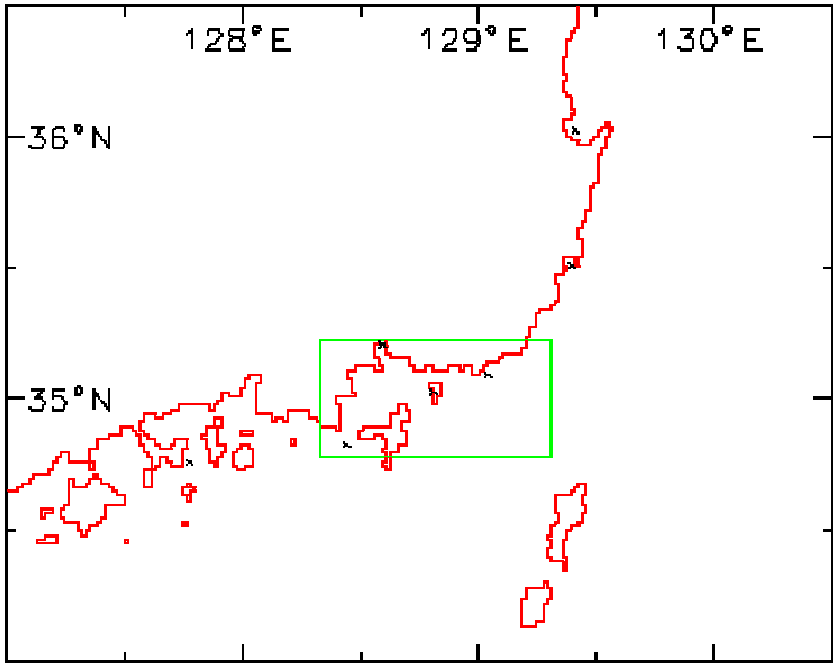


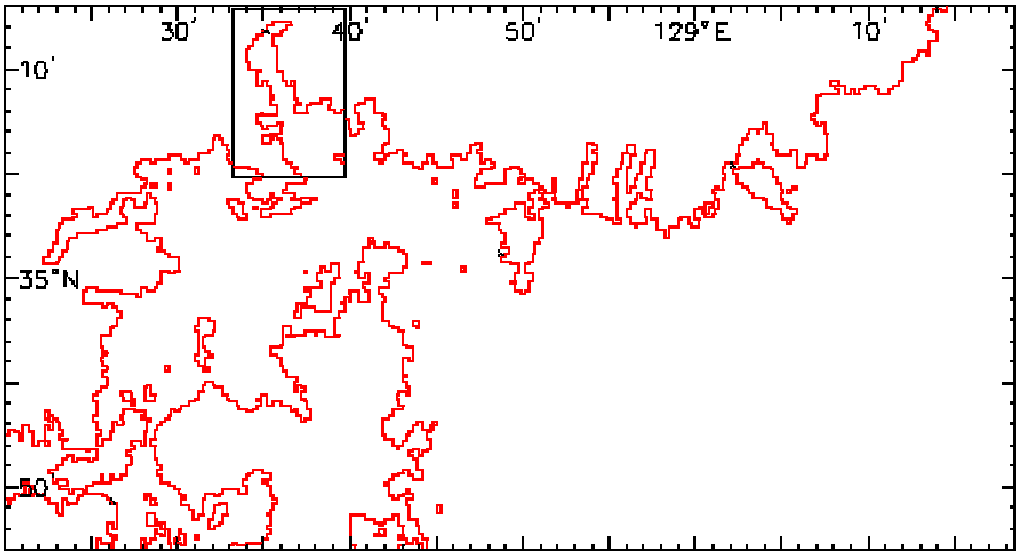


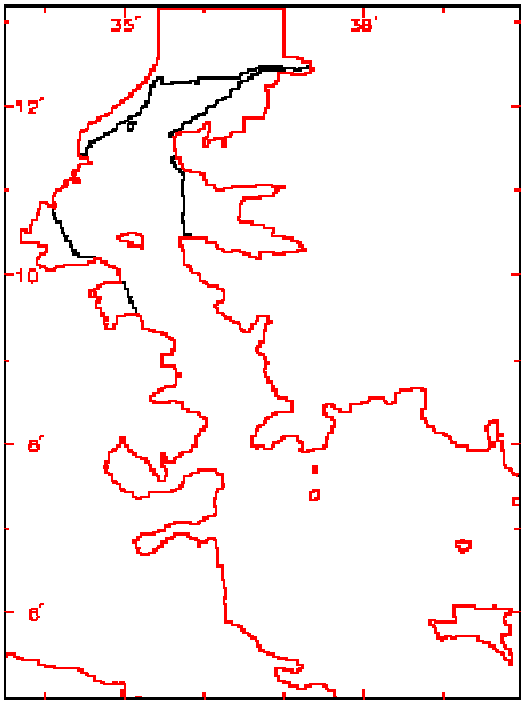





120°E
125°E
130°E
135°E
140°E
45°N
40°N
35°N
30°N
25°N


128°E
129°E
130°E
36°N
35°N


30'
40'
50'
129°E
10'
10'
35°N
50'


35'
38'
12'
10'
8'
6'

TRANSITION of Wave Prediction System with New CRAY X1E

- Migration of wave source code from WAM to WWIII for GoWAM & ReWAM
- Spatial resolution increase (GoWAM: 1.25°? 1/2°, ReWAM:1/4°? 1/12°)
- Introducing Coastal Wave Model (CoWAM:1/120°, SWAN code)
- 12 hour hindcast window with analyzed wind and assimilation wave parameter (wave height & period)
- Post-process data archive with GRIB packing

Thank You