# Operational Regional and Coastal Storm Surge/Tide Forecasting System in Republic of Korea


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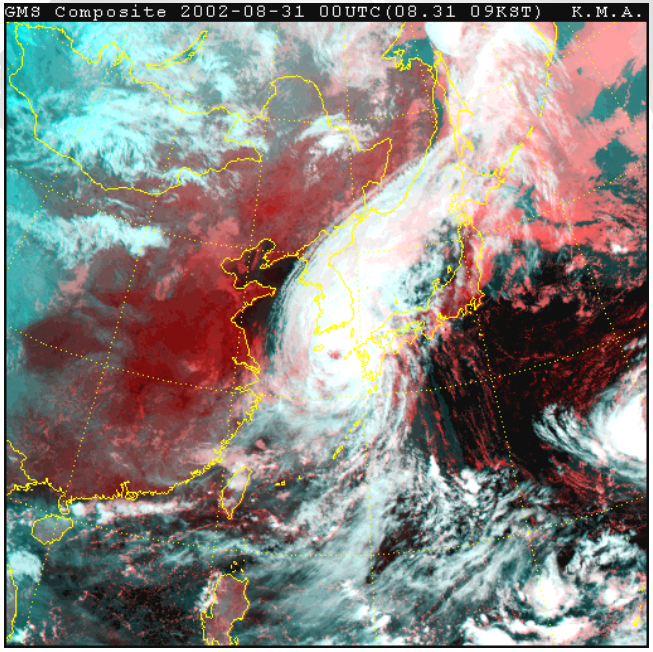
**KMA**

# Major Meteorological disasters in Korea

**Accumulated Damage (2001 ~ 2010)**

***GDP(2011) : 1,224TW**

| Disasters | Fatalities | Property Damage(BW) |
|---|---|---|
| Typhoon | 418 | 10,245 |
| Heavy Rain | 236 | 4,575 |
| Heavy Snow | 14 | 1,319 |
| Strong Wind | 12 | 39 |



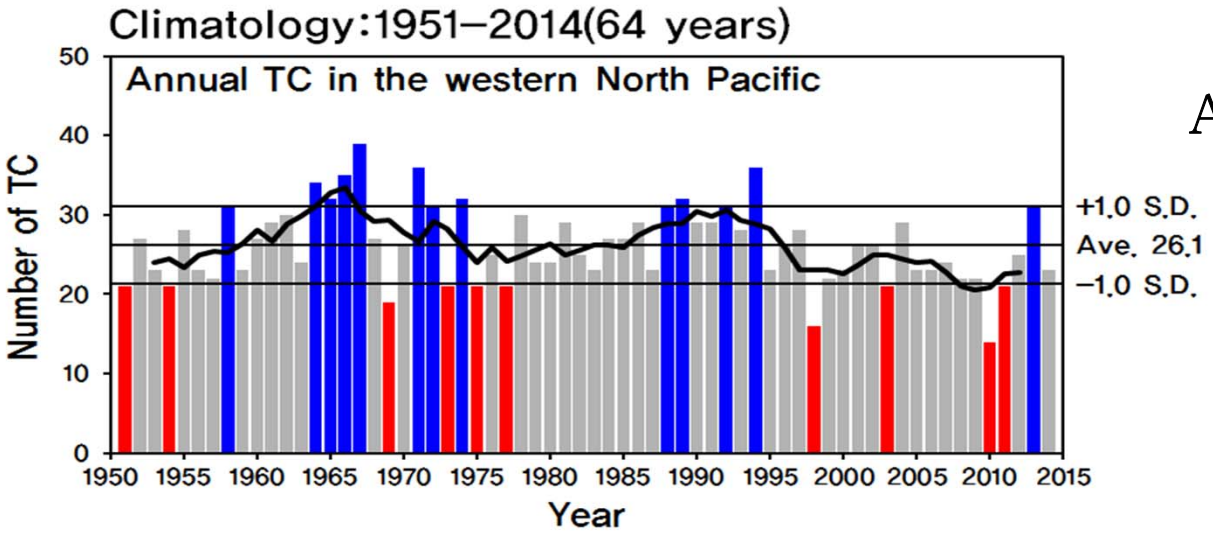

# Occurrence Frequency of Typhoon

**1951-2014**

| Month / Case | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 28 | 15 | 24 | 46 | 66 | 115 | 244 | 352 | 319 | 238 | 152 | 73 | 1672 |
| K | 0 | 0 | 0 | 0 | 2 | 17 | 58 | 75 | 47 | 7 | 0 | 0 | 206 |

A : Typhoon occurred in Northwestern Pacific Ocean

K : Typhoon effected on the Korean Peninsula



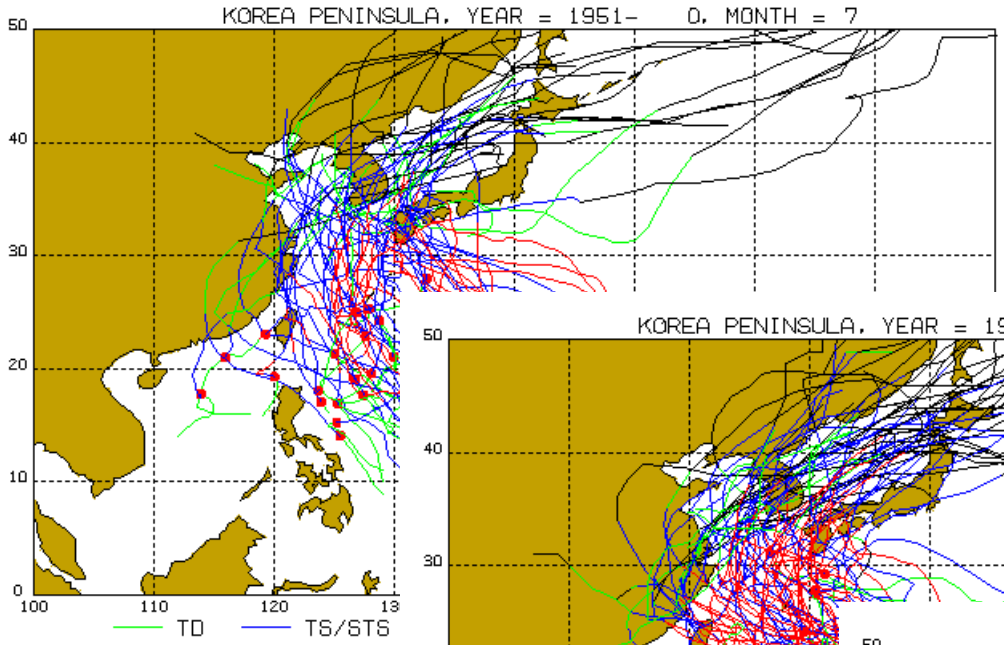

Average No. of Typhoon

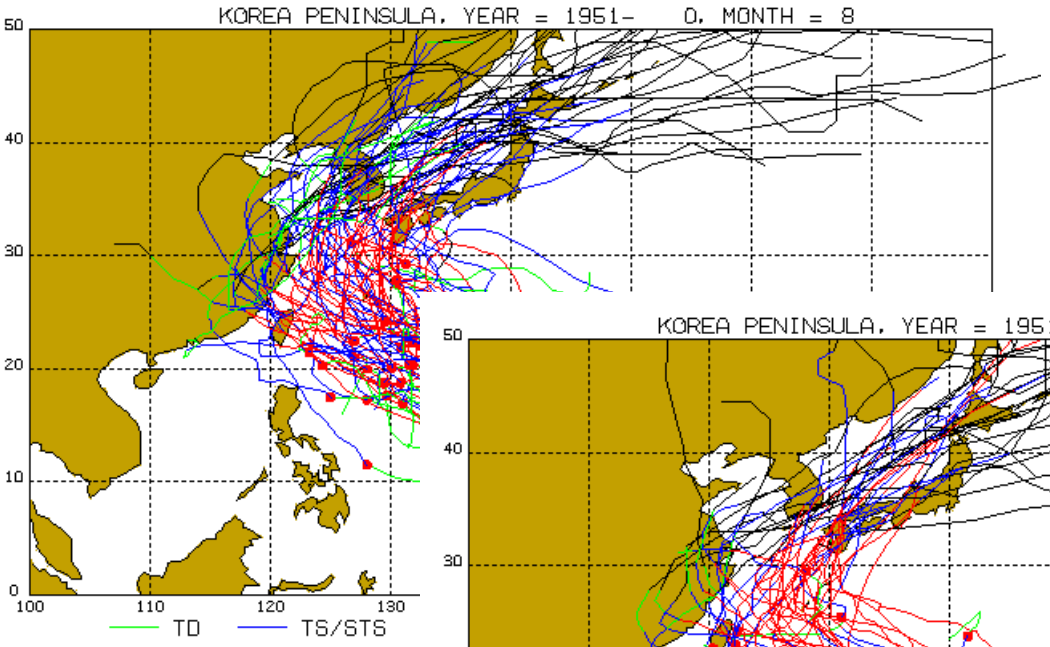
1951-2014 : 26.6

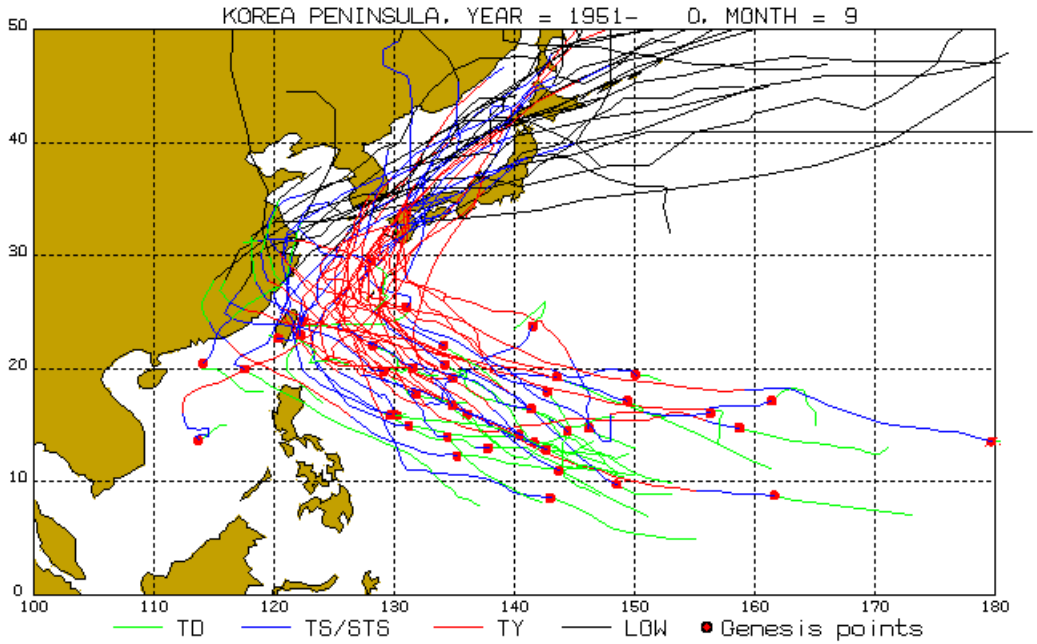
1985-2014 : 25.4

2005-2014 : 22.8

# Typhoon Tracks (Jul., Aug., Sep.)



# Typhoon Damages in Korea








# Observation

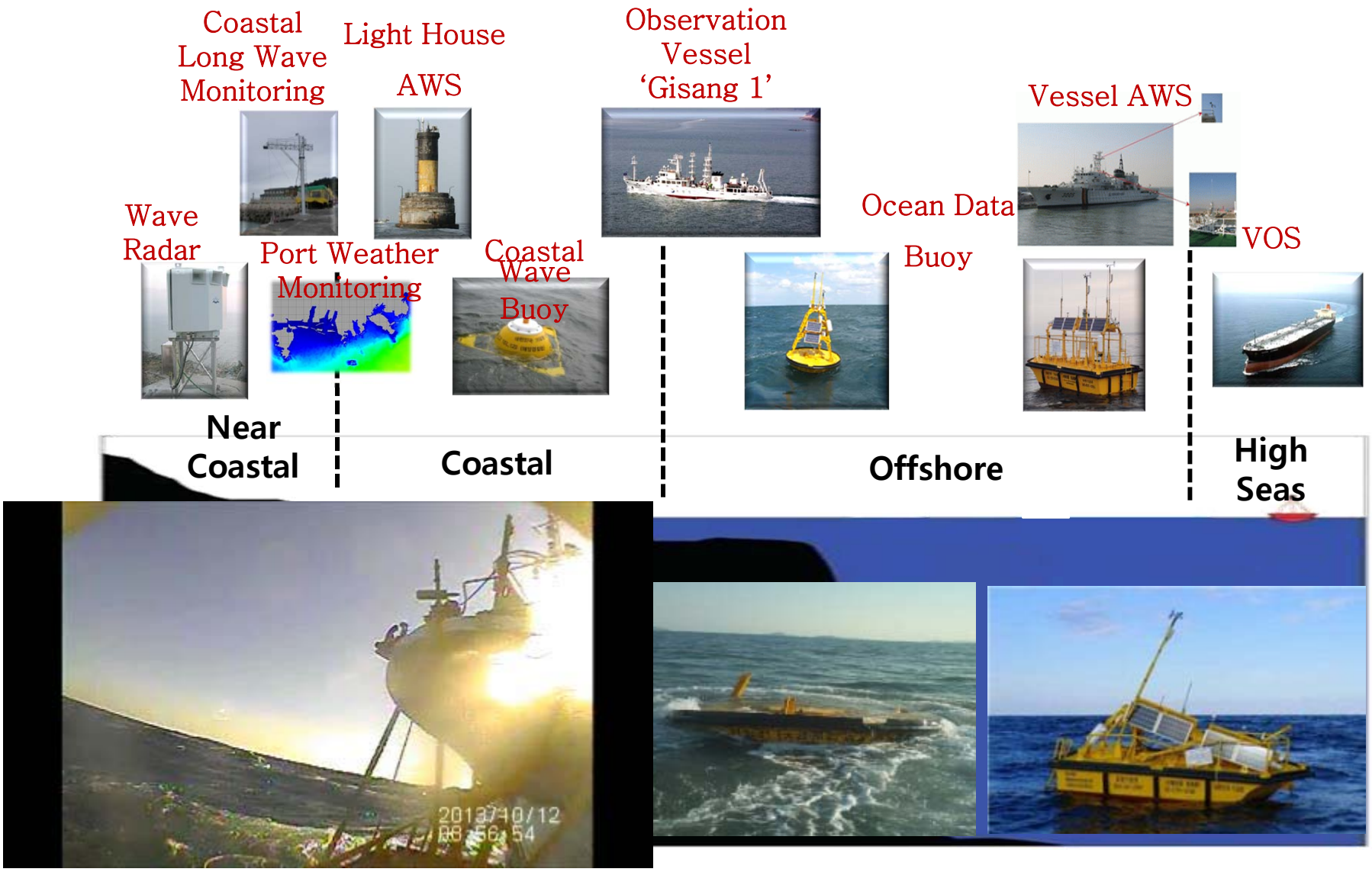
# Marine Observations Network (2015)

## Observation Network

**Ocean Data Buoys : 17**
**Coastal Wave Buoys : 48**
**Long Wave Monitoring : 18**
**Wave Radars : 6**
**Ports Weather Station : 2**
**Lighthouse AWS : 9**
**Vessel AWS : 10**
**Marine Obs. Station : 1**

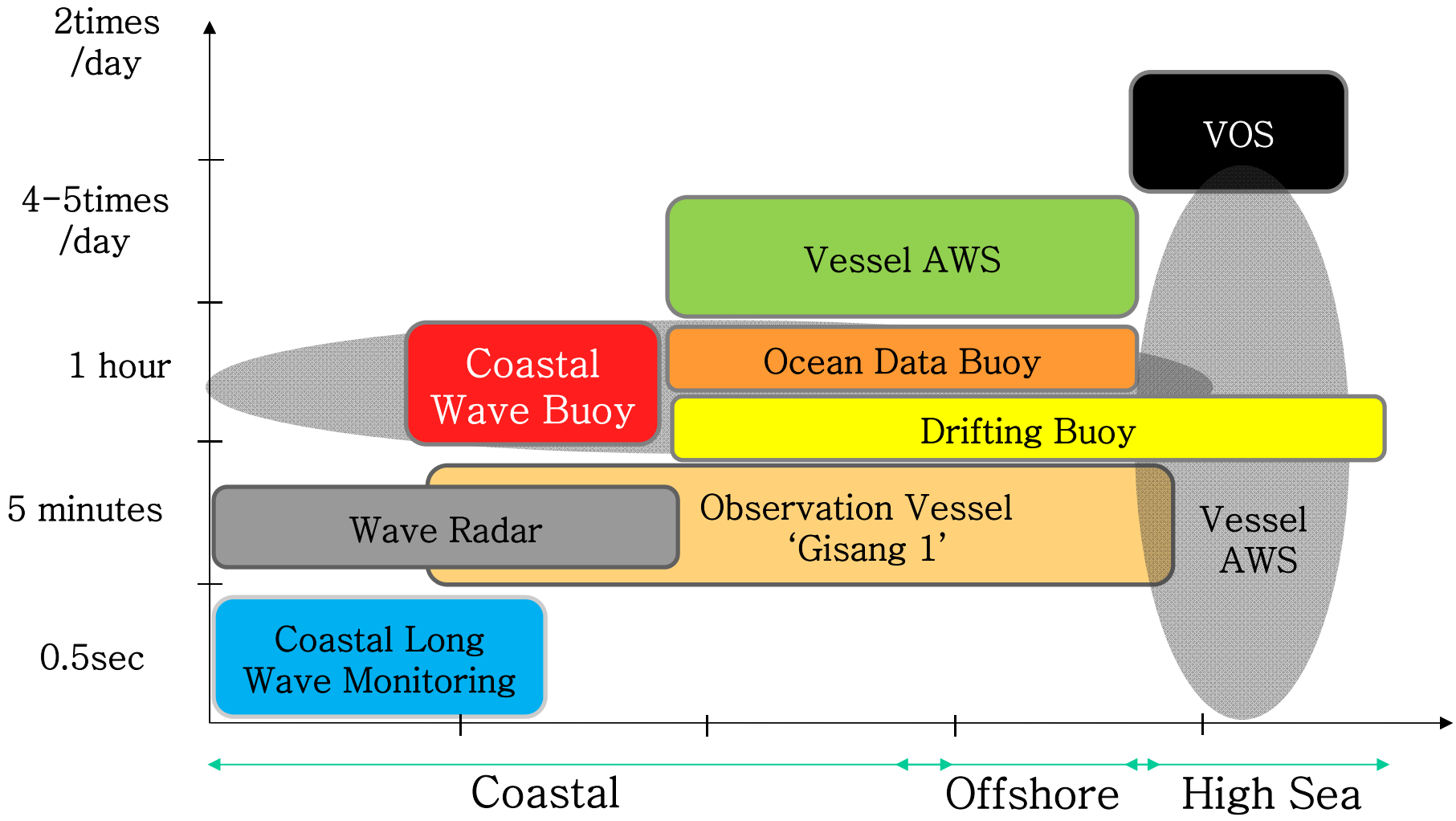

## Observation Vessel (500 tons)

# Marine Observations Network(Spatial)



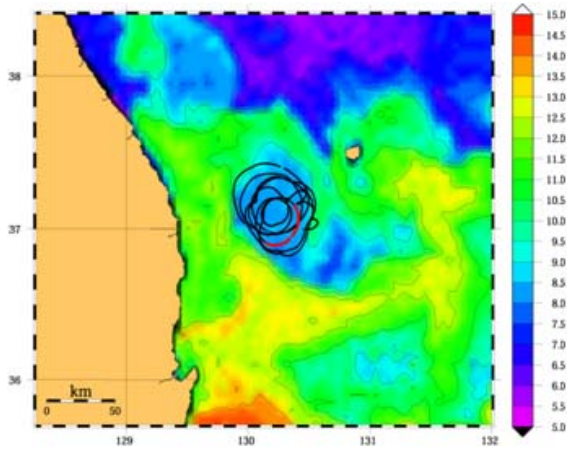

Black Box Image on Ocean Data Buoy

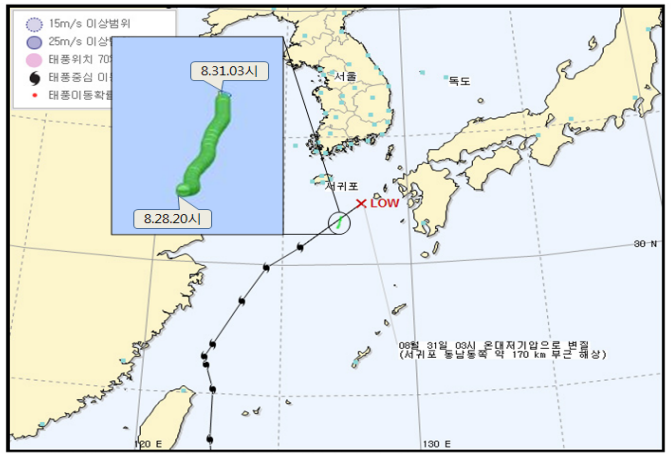
# Marine Observations Network(Temporal)

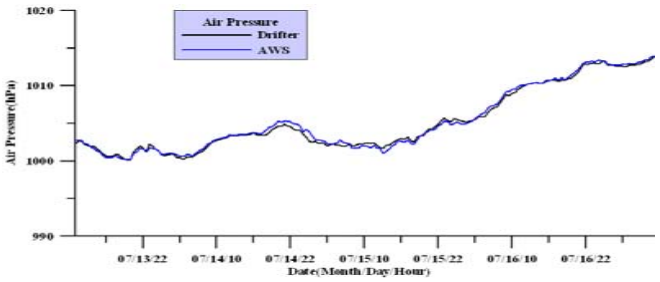


# Drifting Buoy (Offshore)

- ❖ Lagrangian observation
- ❖ GPS, Satellite Communication
- ❖ Observation : Position, Temperature,  Pressure, Wave



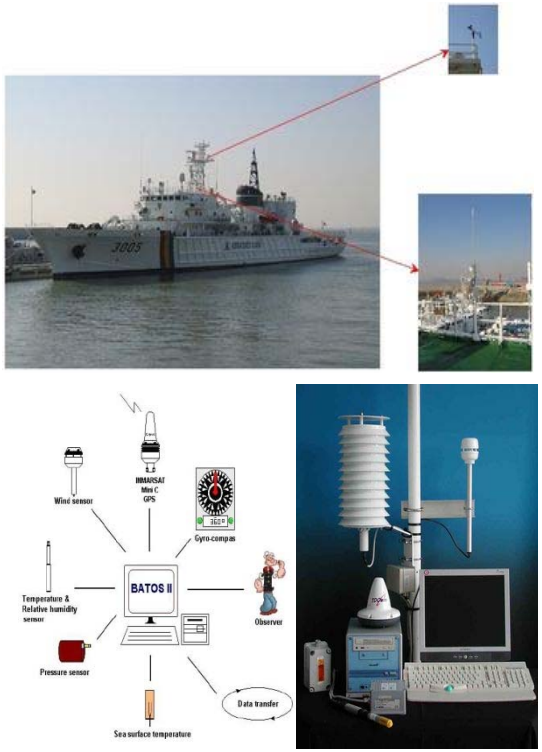




<Comparison of Pressure between AWS and buoy >


# Vessel AWS (High Seas)

❖ **AWS on Vessel of Government and Passenger Ship**

## 1 Government Ship



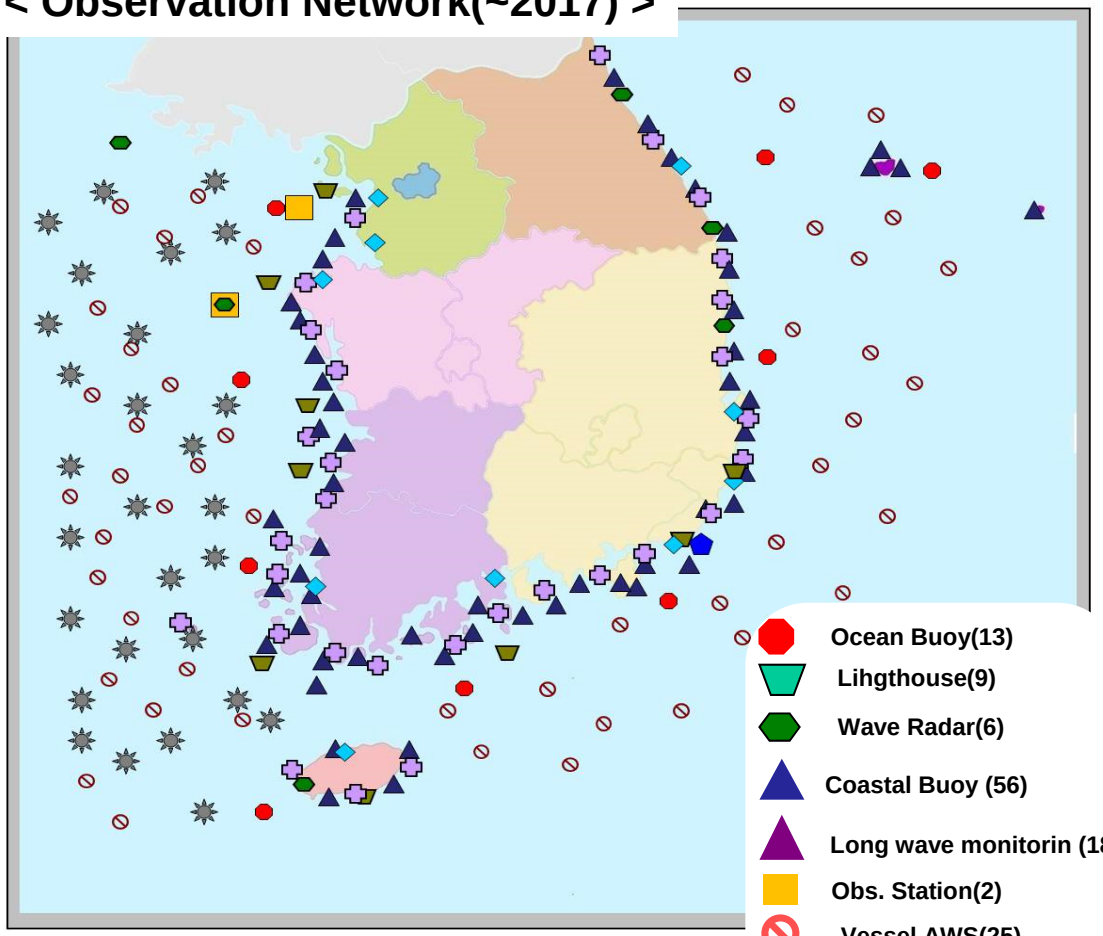

## 2 VOS (Volunteer Observing Ship)


## 3 Passenger Ship

# Strategic Extension of Marine Observation Network

| Year | Instruments(total) |
|---|---|
| 2013 | Ocean Data Buoy(10)<br>Light House AWS(9)<br>Wave Radar(6)<br>Coastal Wave Buoy(35)<br>Long Wave Monitoring(17)<br>Port Weather Monitoring(3)<br>Vessel AWS(8)<br>Research Vessel(1)<br>Observation Station(1)<br>Drifting Buoy (10) |
| 2014 | Ocean Data Buoy(10)<br>Light House AWS(9)<br>Wave Radar(6)<br>Coastal Wave Buoy(39)<br>Long Wave Monitoring(18)<br>Port Weather Monitoring(4)<br>Vessel AWS(10)<br>Drifting Buoy (10) |
| 2017 | Ocean Data Buoy(13)<br>Light House AWS(9)<br>Wave Radar(6)<br>Coastal Wave Buoy(56)<br>Long Wave Monitoring(18)<br>Port Weather Monitoring(11)<br>Research Vessel(2)<br>Observation Station(2)<br>Vessel AWS(25)<br>Drifting Buoy (410) |

< Observation Network(~2017) >





# Prediction

# Super Computer in KMA

**NEC SX-5/28M2**
1999.12 ~ 2005.11
Theoretical performance
**0.2 TFlops**

1st Supercomputer

×90

**CRAY X1E 1024/MSP**
2005.12 ~ 2010.11
Theoretical performance
**18.5 TFlops**

2nd Supercomputer

×41

**CRAY XE6 90,240 cores**
2010.12 ~ 2015.12
Theoretical performance
**758 TFlops**

3rd Supercomputer


×10

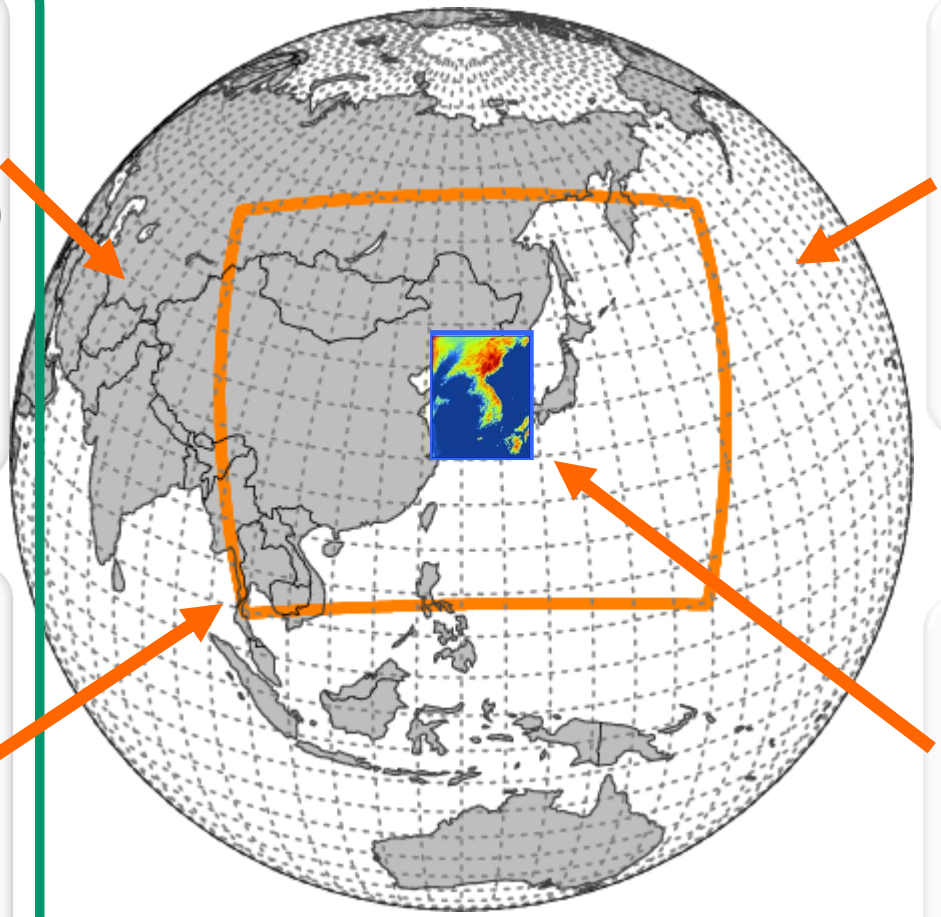
**CRAY XC40**
2015.12 ~
Theoretical performance
**2.9 Peta Fflops**

4th Supercomputer

# NWP model based on Unified Model (UM)

## Global(UM)
- Resolution
  **N512L70**
  (~25km / top = 80km)
- Target Length
  288hrs (00/12UTC)
  87hrs (06/18UTC)
- Initialization : **4DVAR**

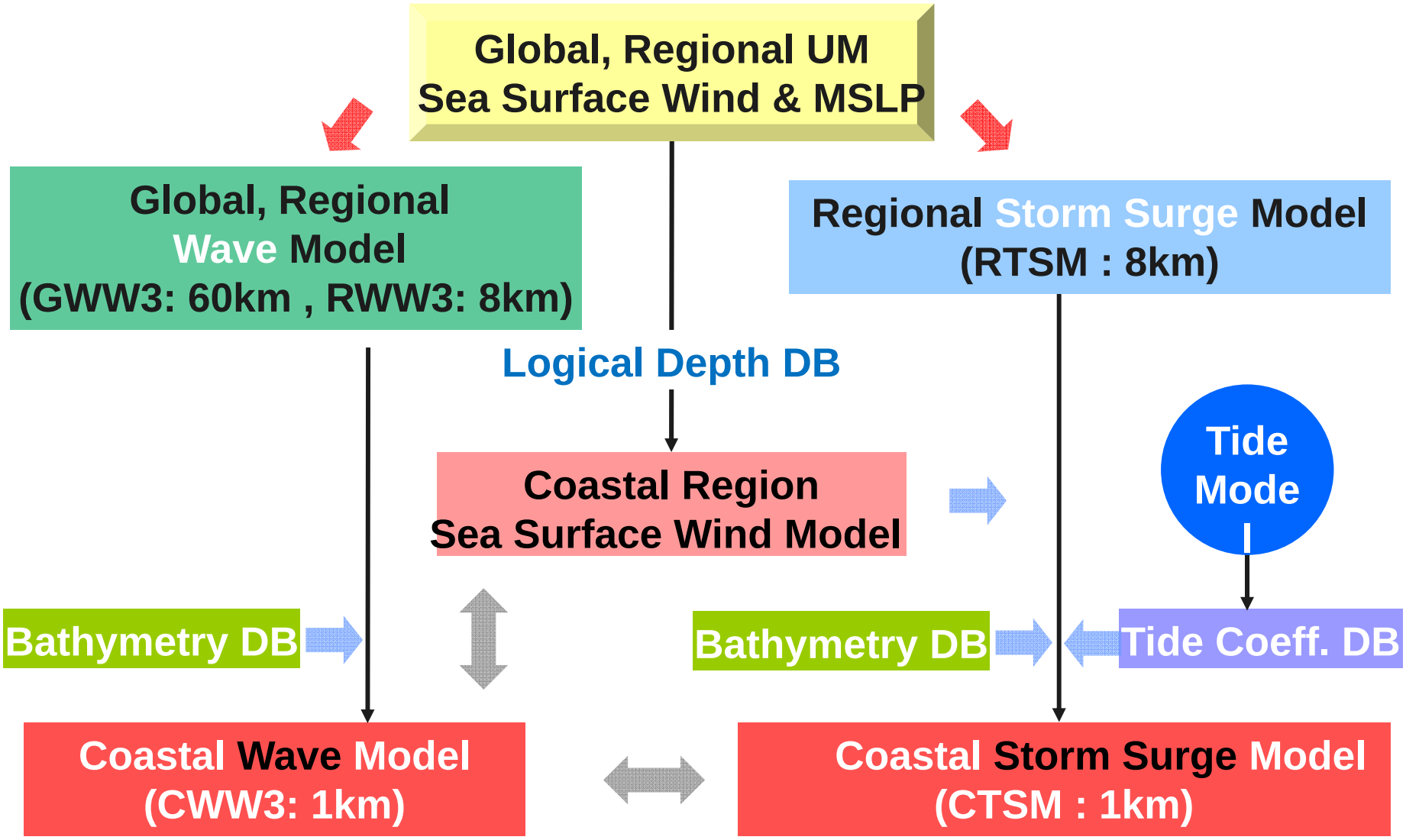
## Regional(UM)
- Resolution
  **12kmL70**
  (0.11°x0.11° / top=80km)
- Target Length
  87hrs (6 hourly)
- Initialization : **4DVAR**



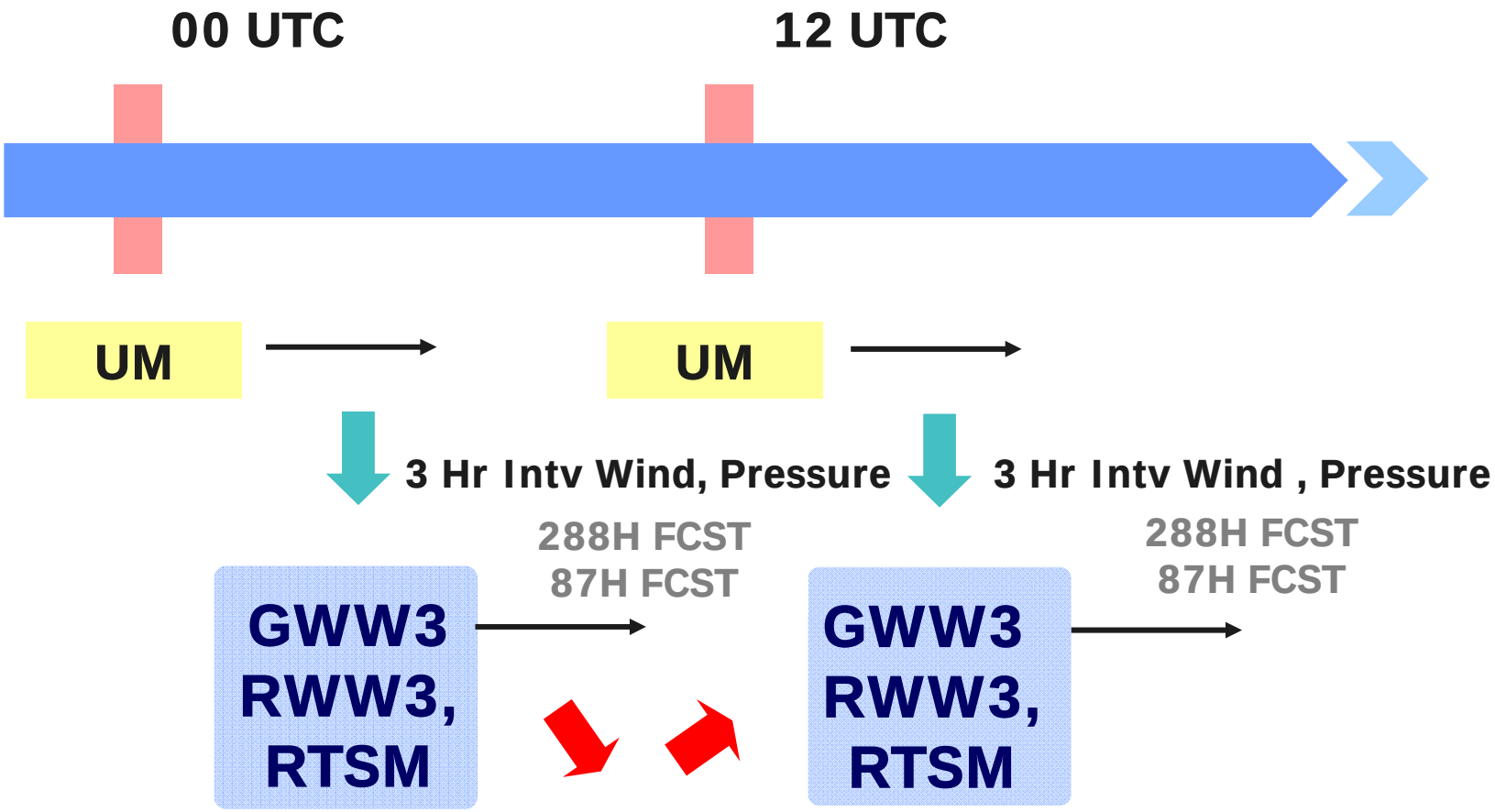
## Global EPS
- Resolution
  **N320L70**
  (~40km/ top =80km)
- Target Length
  240hrs
- IC : GDAPS
- # of Members : 24

## Local (HIW)
- Resolution
  **1.5kmL70**
  (744×928 / top =39km)
- Target Length
  36hrs
- Initialization : **3DVAR**

# Wave/Storm Surges Forecasting System



# Operational Time Schedule



# Operational Wind Wave Prediction Models

## Global

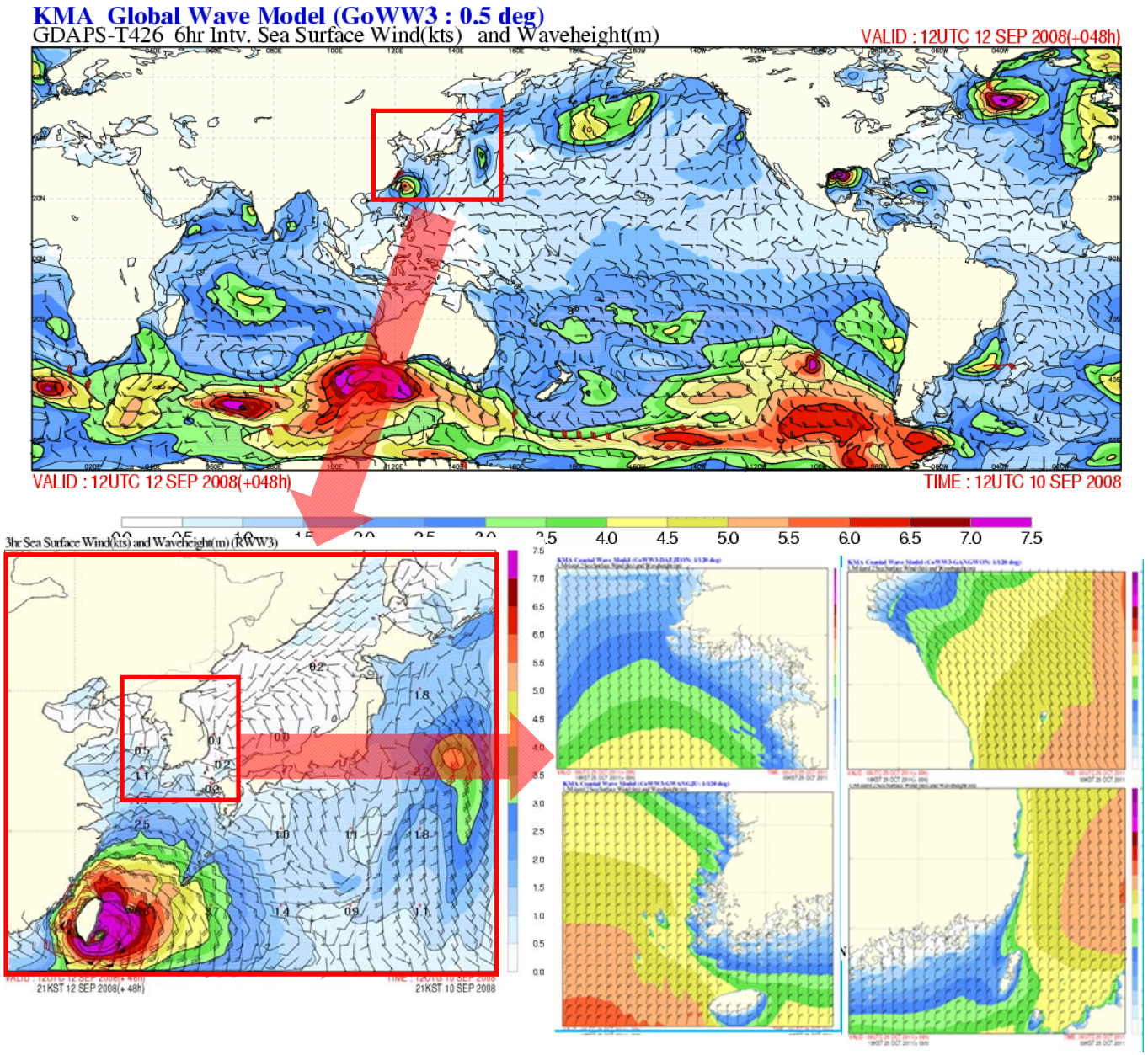
- 60Km (1/2°)
- 288 hour forecast twice/day

## Regional

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

## Coastal

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



# Intercomparison of Operational Wind Wave

## Intercomparison of operational wave forecasting systems against buoy data: time series of statistics data from ECMWF, MetOffice, FNMOC, NCEP, MeteoFrance, DWD, BoM, SHOM, JMA and KMA

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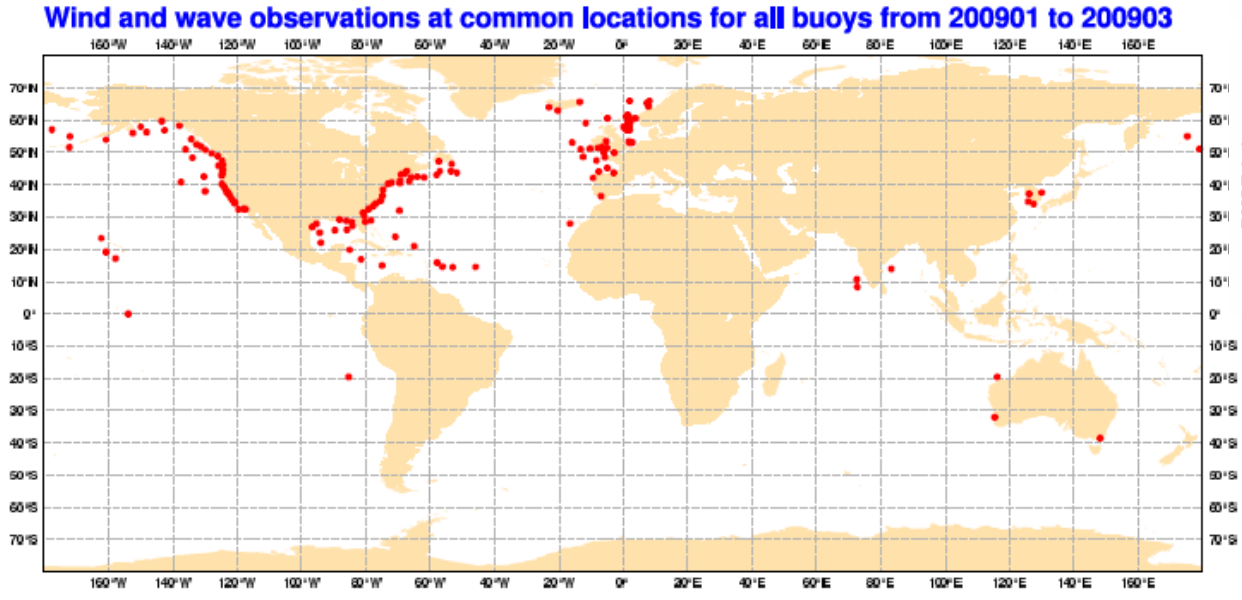
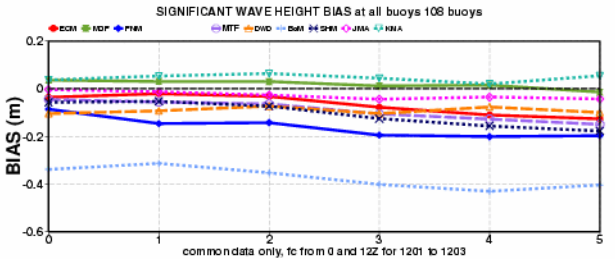
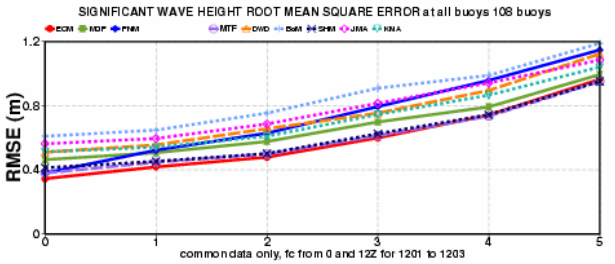
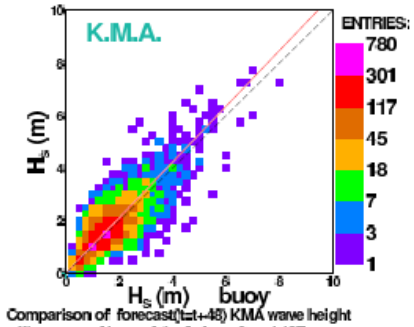
European Centre for Medium-range Weather Forecasts,
jean.bidlot@ecmwf.int

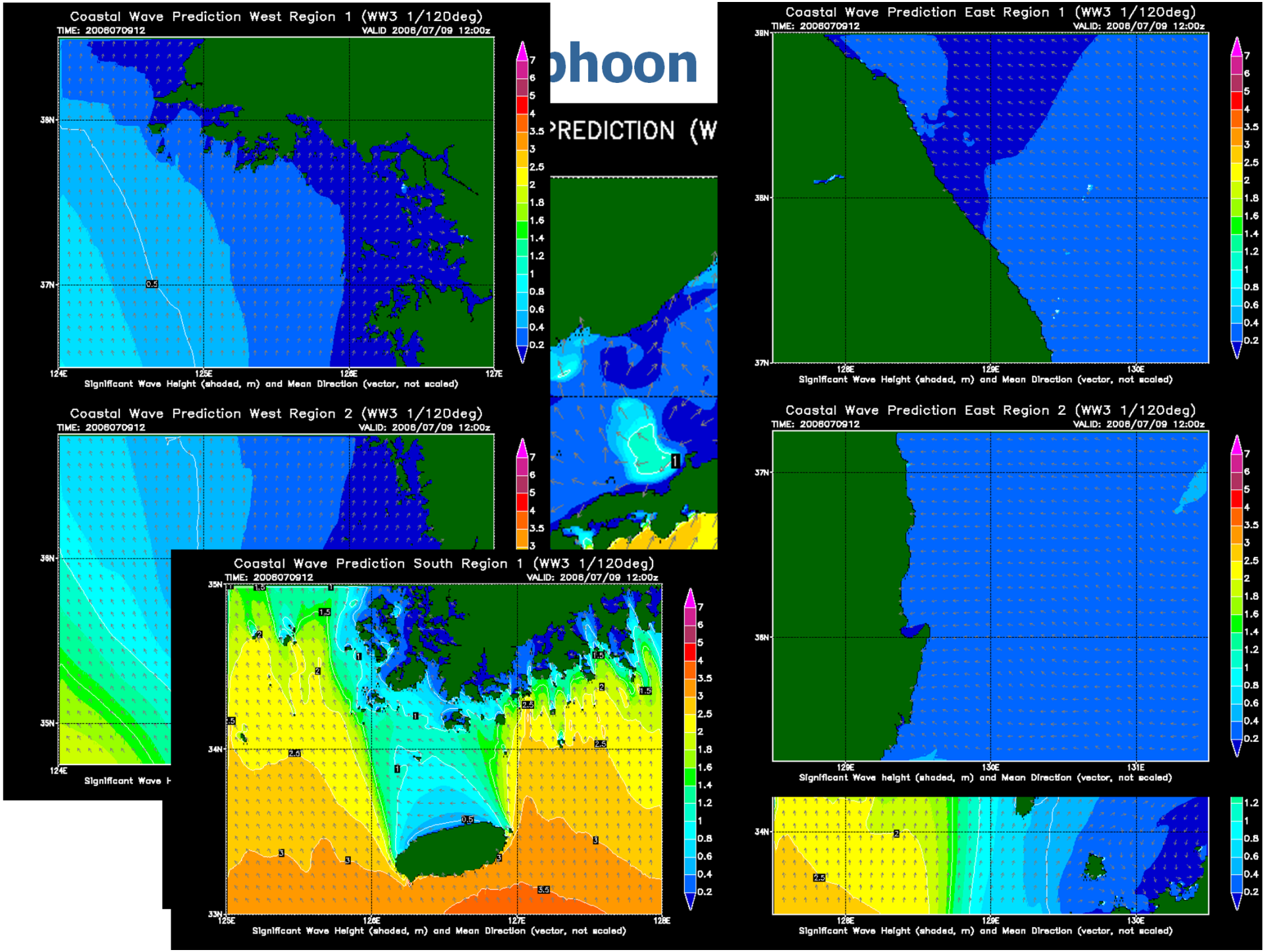


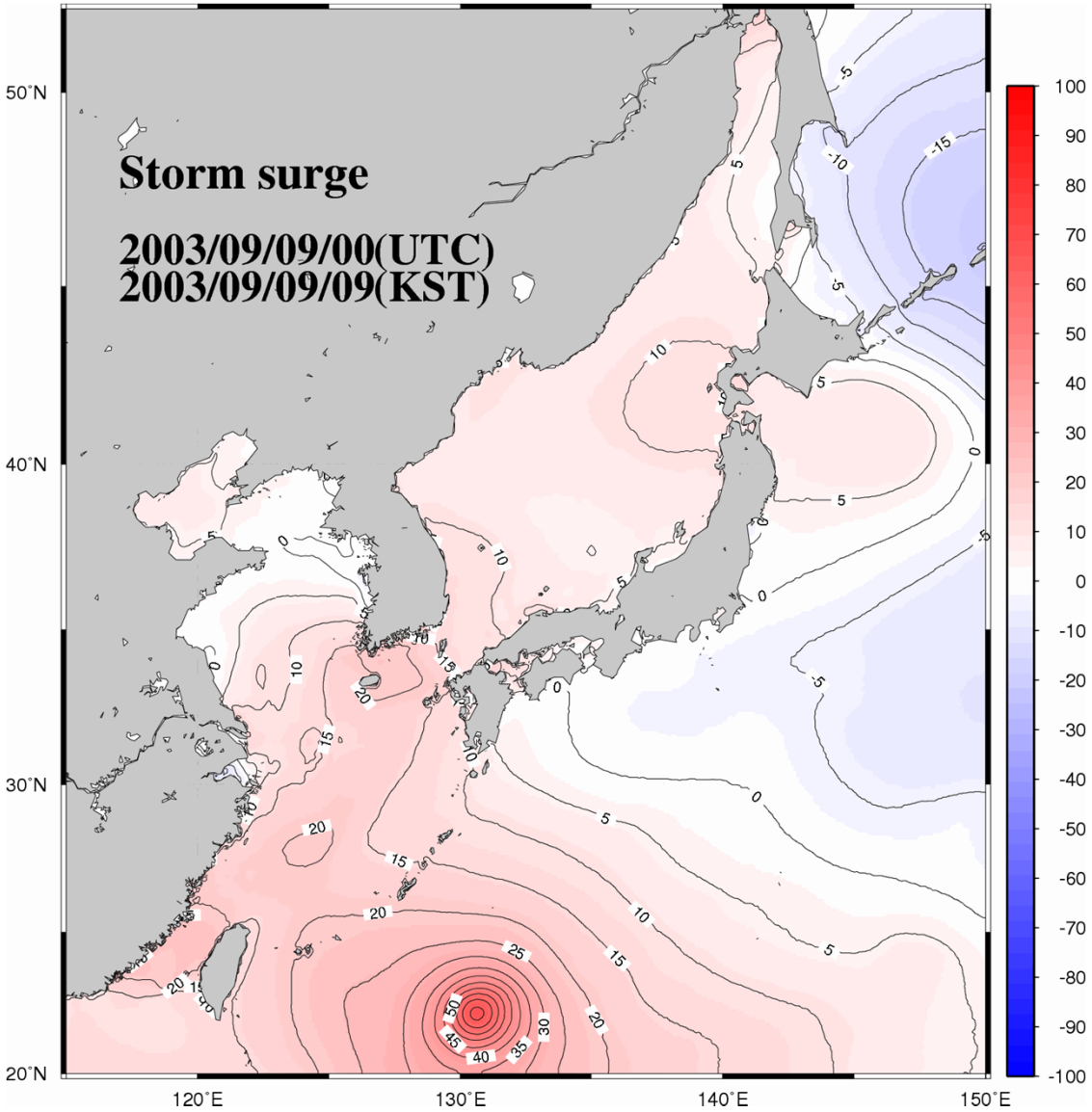




Comparison of forecast(t=t+48) KMA wave height with averaged buoy data. fc from 0 and 12Z.

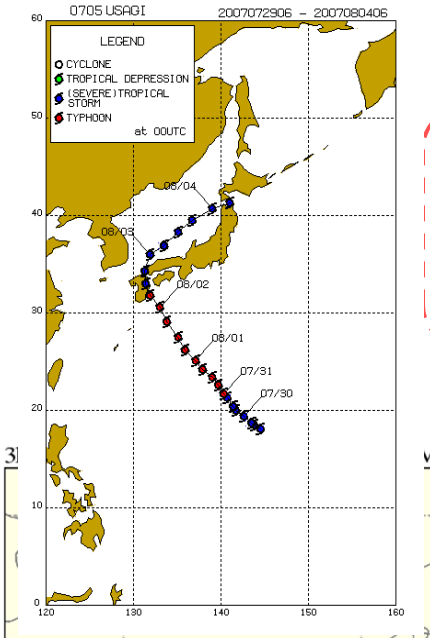

Coastal Wave Prediction West Region 1 (WW3 1/120deg)
TIME: 2006070912
VALID 2006/07/09 12:00z
Significant Wave Height (shaded, m) and Mean Direction (vector, not scaled)
Coastal Wave Prediction West Region 2 (WW3 1/120deg)
TIME: 2006070912
VALID: 2006/07/09 12:00z
Coastal Wave Prediction South Region 1 (WW3 1/120deg)
TIME: 2006070912
VALID: 2006/07/09 12:00z
Significant Wave Height (shaded, m) and Mean Direction (vector, not scaled)
Coastal Wave Prediction East Region 1 (WW3 1/120deg)
TIME: 2006070912
VALID: 2006/07/09 12:00z
Significant Wave Height (shaded, m) and Mean Direction (vector, not scaled)
Coastal Wave Prediction East Region 2 (WW3 1/120deg)
TIME: 2006070912
VALID: 2006/07/09 12:00z
Significant Wave Height (shaded, m) and Mean Direction (vector, not scaled)

# RTSM (Regional Tide/Storm Surges Model)

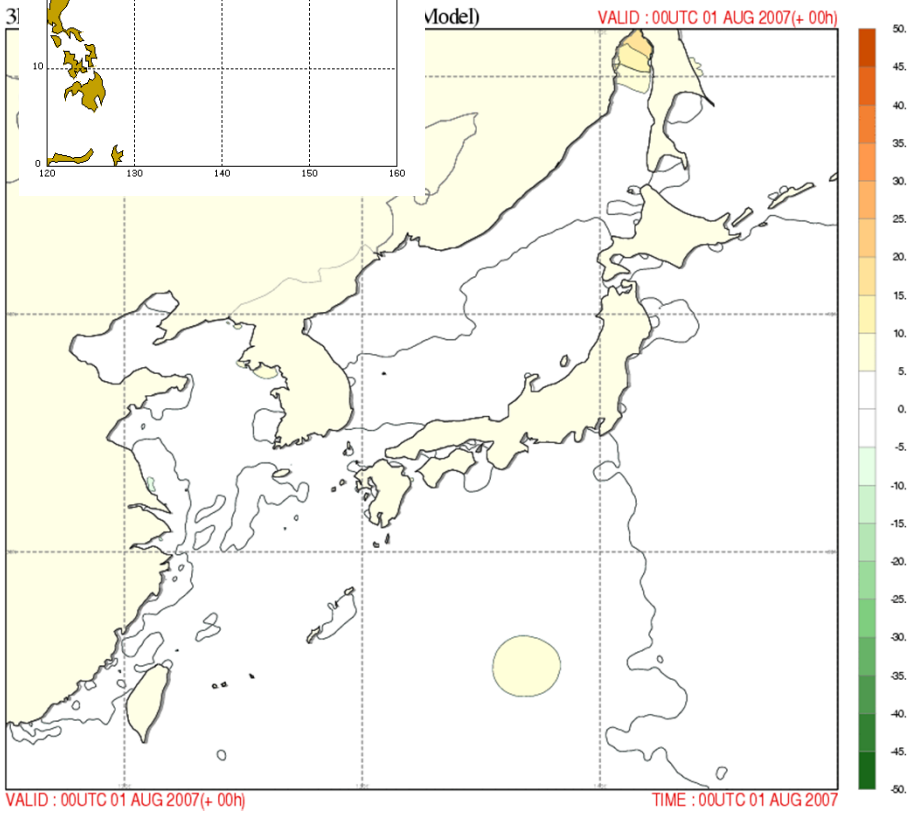


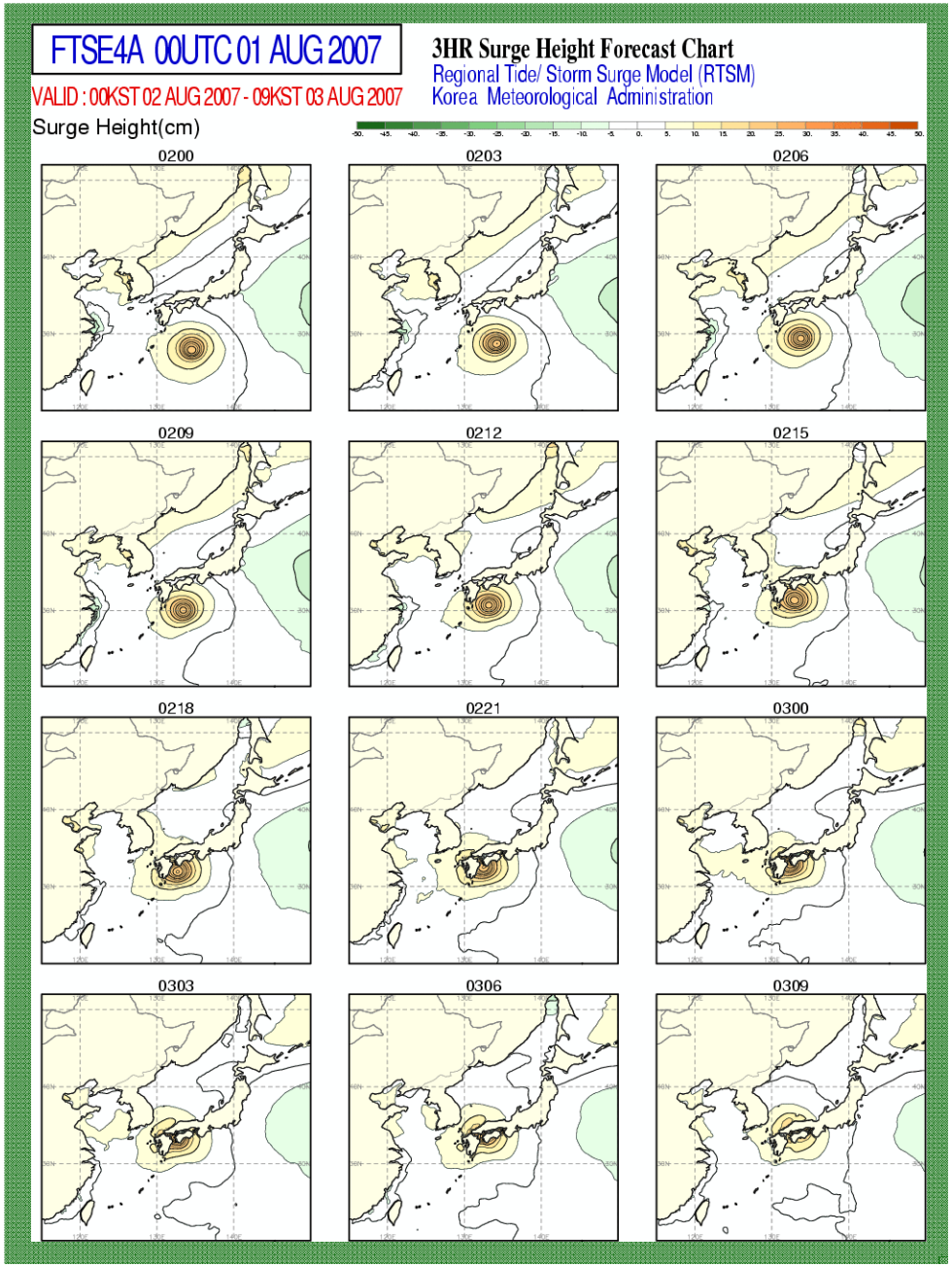

- ✓ *2-D **POM** model*
- ✓ *1/12° (8km) Regional Storm Surge Model*
- ✓ *Considering tide, sea wind, pressure*
- ✓ *Calculating the height of Tidal elevation and storm surge*
- ✓ *operating from June 2006*

# Storm Surges Forecasting



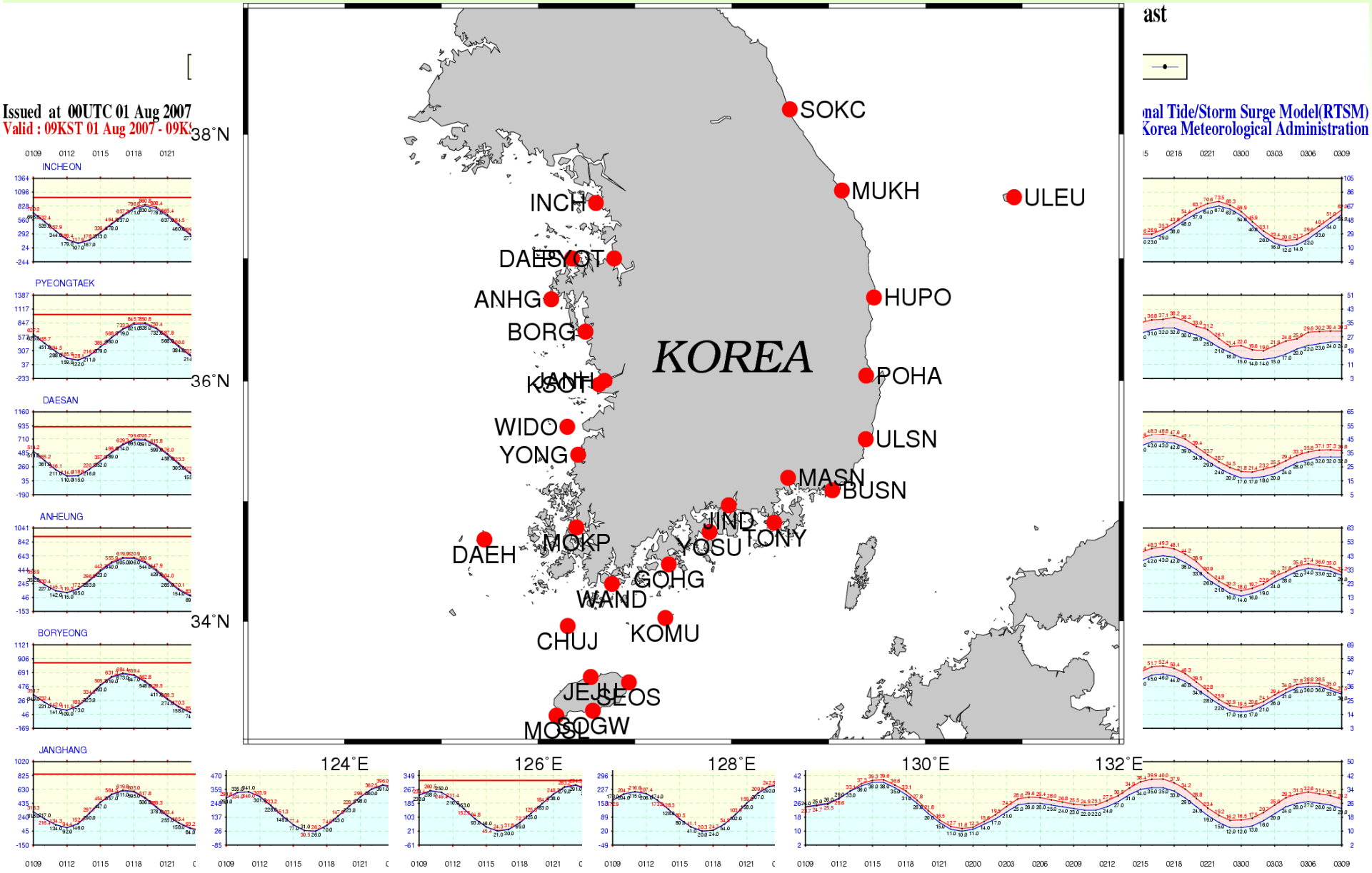

**Typhoon USAGI**



# Storm Surges/Tide Forecasting

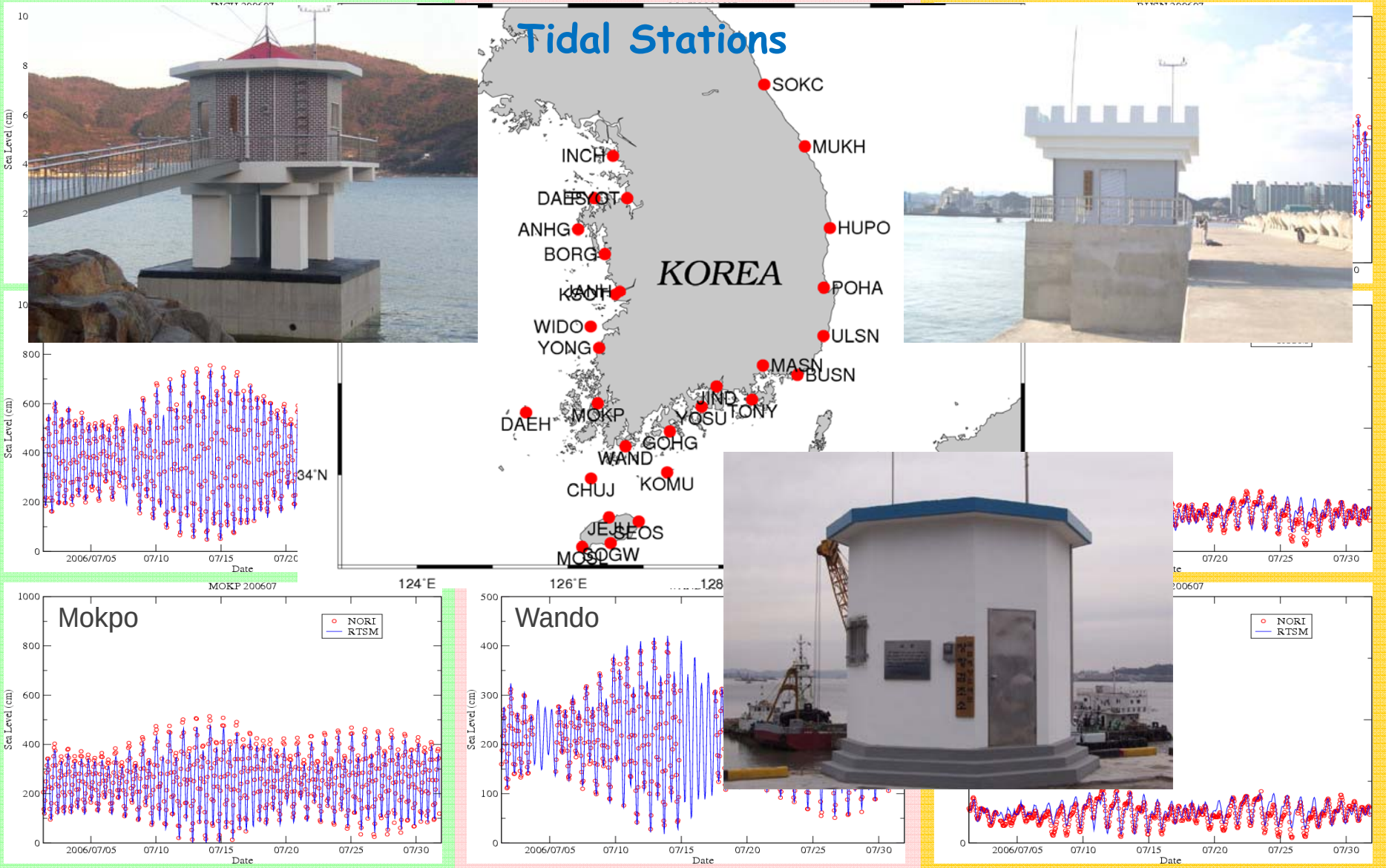
30 coastal stations



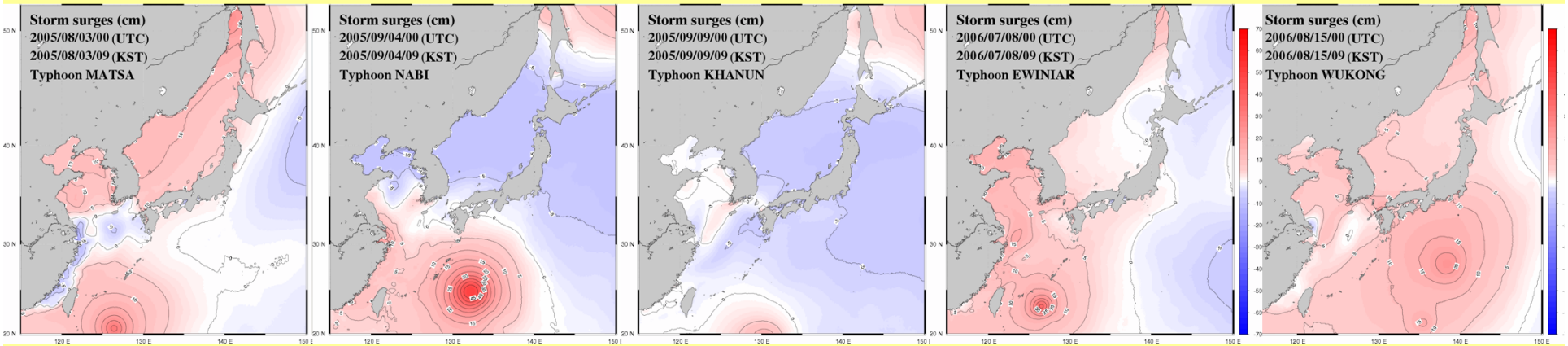
# Model Verification

o Obs, - Mod

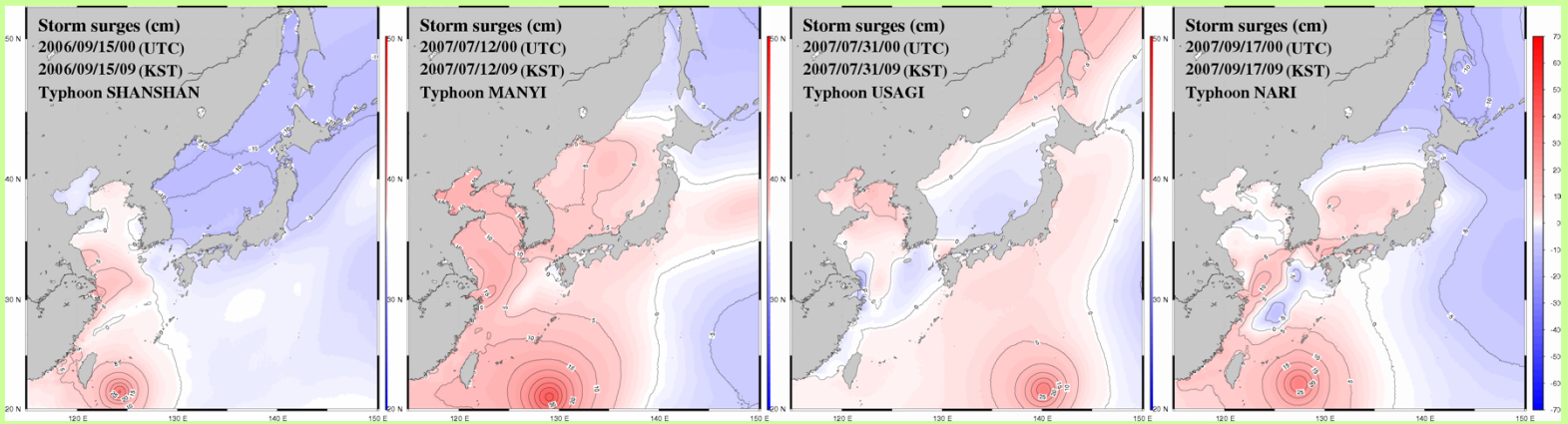
Western coast | Southern coast | Eastern coast



# Model Verification



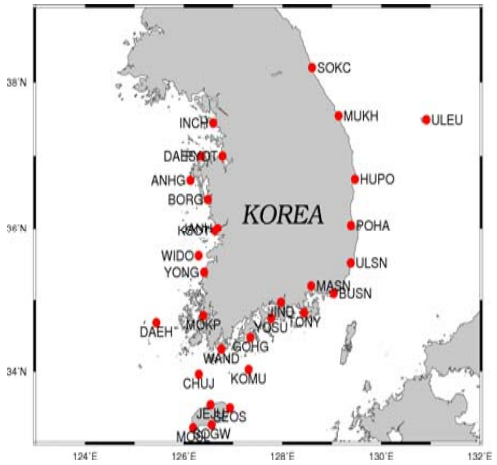

MATSA (0509) NABI (0514) KHANUN (0515) EWINIAR (0603) WUKONG (0610)



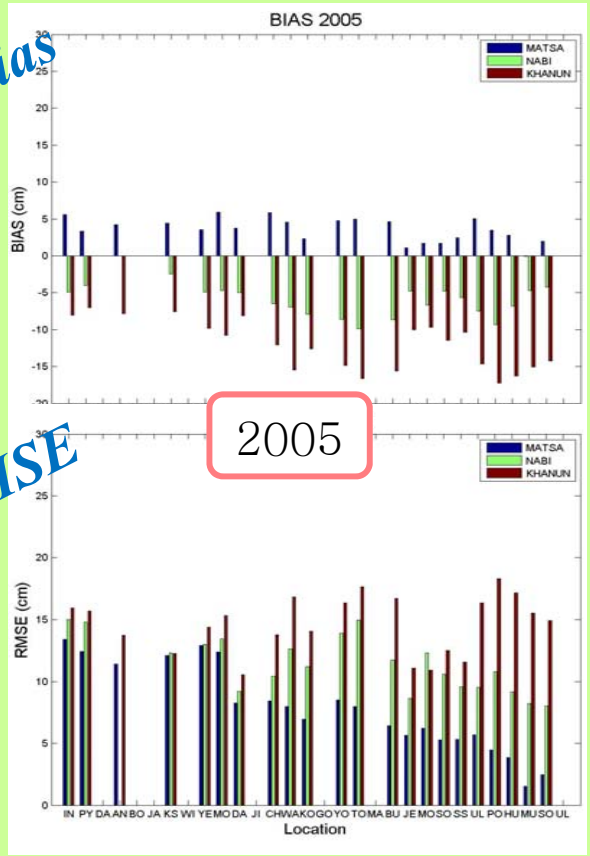

SHANSHAN (0613) MANYI (0704) USAGI (0705) NARI (0711)

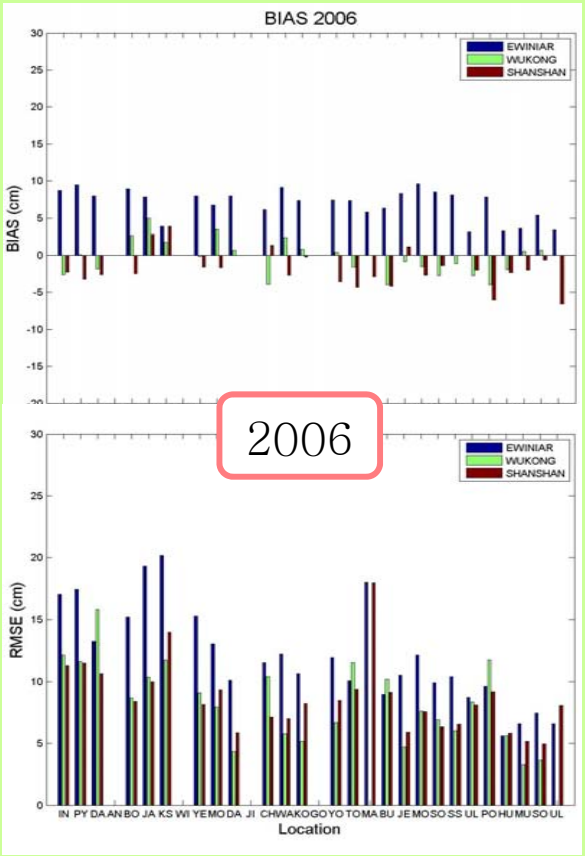
# Model Verification

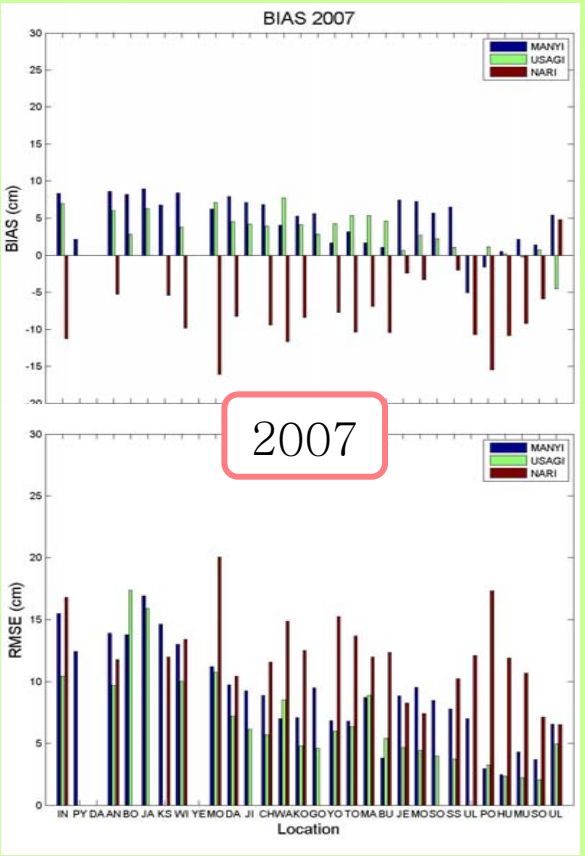
| | MATSA (0509) | NABI (0514) | KHANUN (0515) | EWINIAR(0603) | WUKONG (0610) |
|---|---|---|---|---|---|
| BIAS (cm) | 3.54 | -6.14 | -12.06 | 6.92 | 0.79 |
| RMSE (cm) | 7.72 | 11.41 | 14.61 | 12.00 | 9.07 |
| | SHAN HAN (0613) | MANYI (0704) | USAGI (0705) | NARI (0711) | Avg. |
| BIAS (cm) | -1.76 | 4.69 | 3.34 | -7.99 | 3.86 (+)/- 6.99 (-) |
| RMSE (cm) | 8.63 | 8.95 | 6.78 | 12.19 | 10.15 |




Bias




RMSE

2005

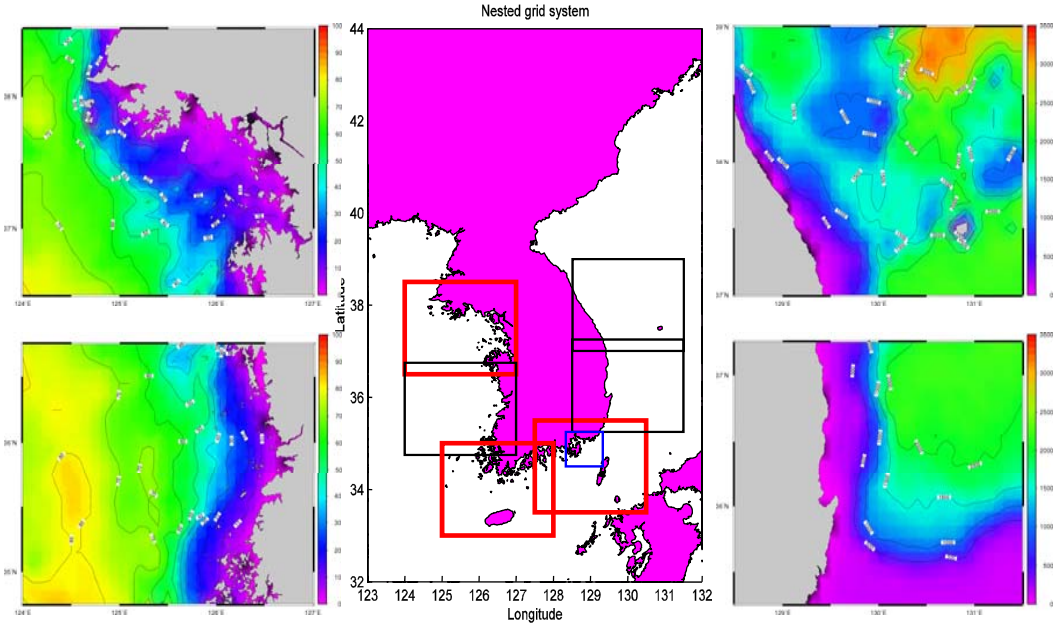



2006

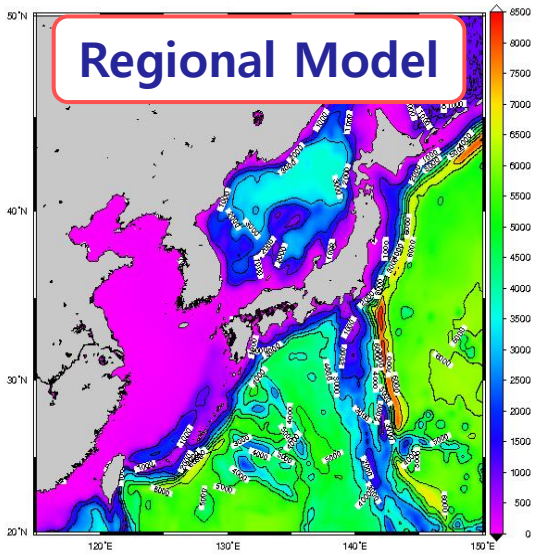


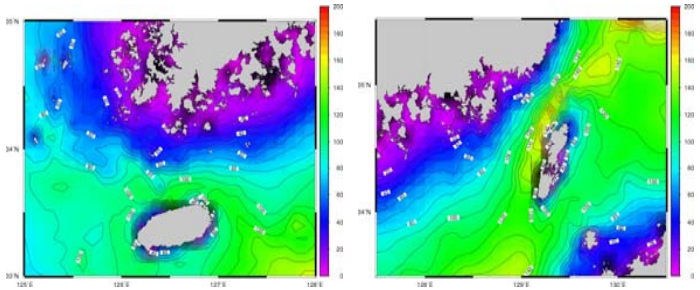

2007

# Nesting Coastal Storm surges Model




B.C.

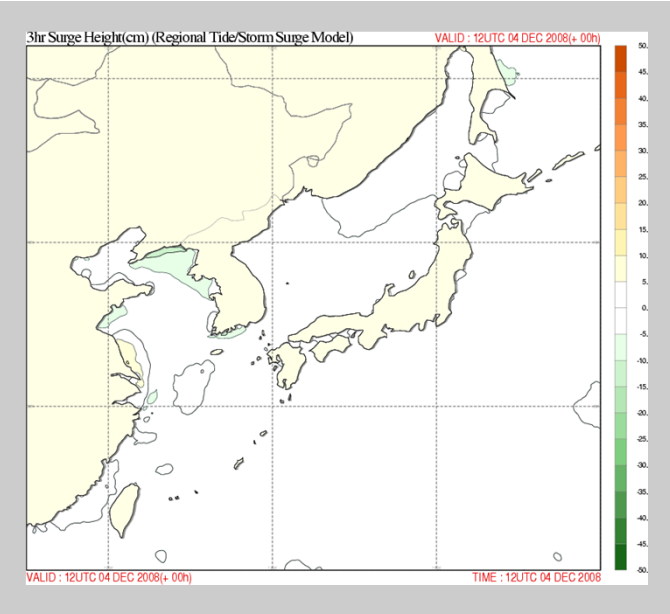


| | |
|---|---|
| Model | 2-D Ocean Circulation Model (POM 2D) |
| Coordinate System | Spherical Coordinate |
| Model Domain | 6 coastal areas |
| Horizontal Resolution | 1/120 ° by 1/120 ° (361 ×241) |
| ΔT | 60 sec |
| Input Data | E,U,V from Regional Model RDAPS Wind and Pressure |

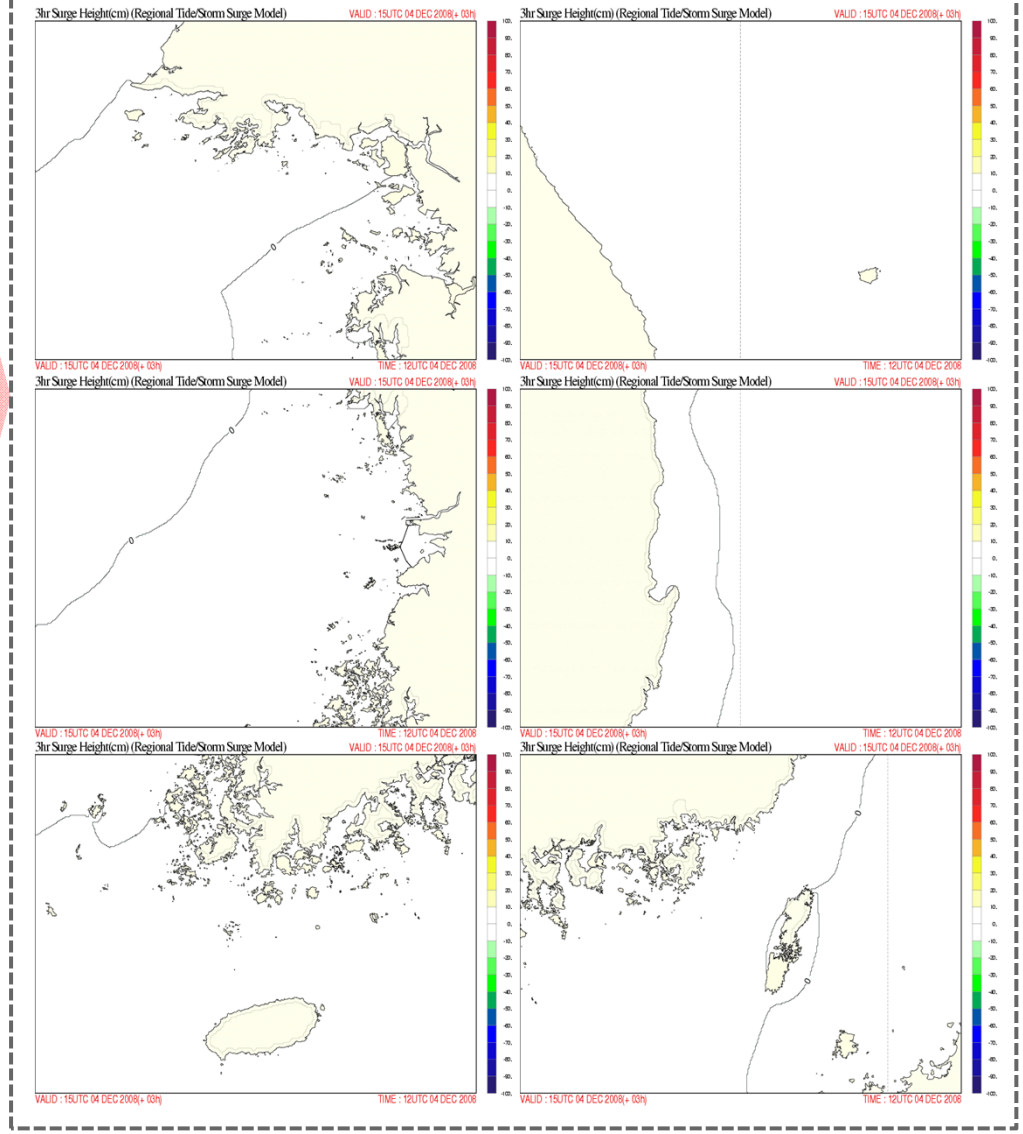
# Coastal Tide/Storm surges Model(CTSM)

## Regional Model (8km)

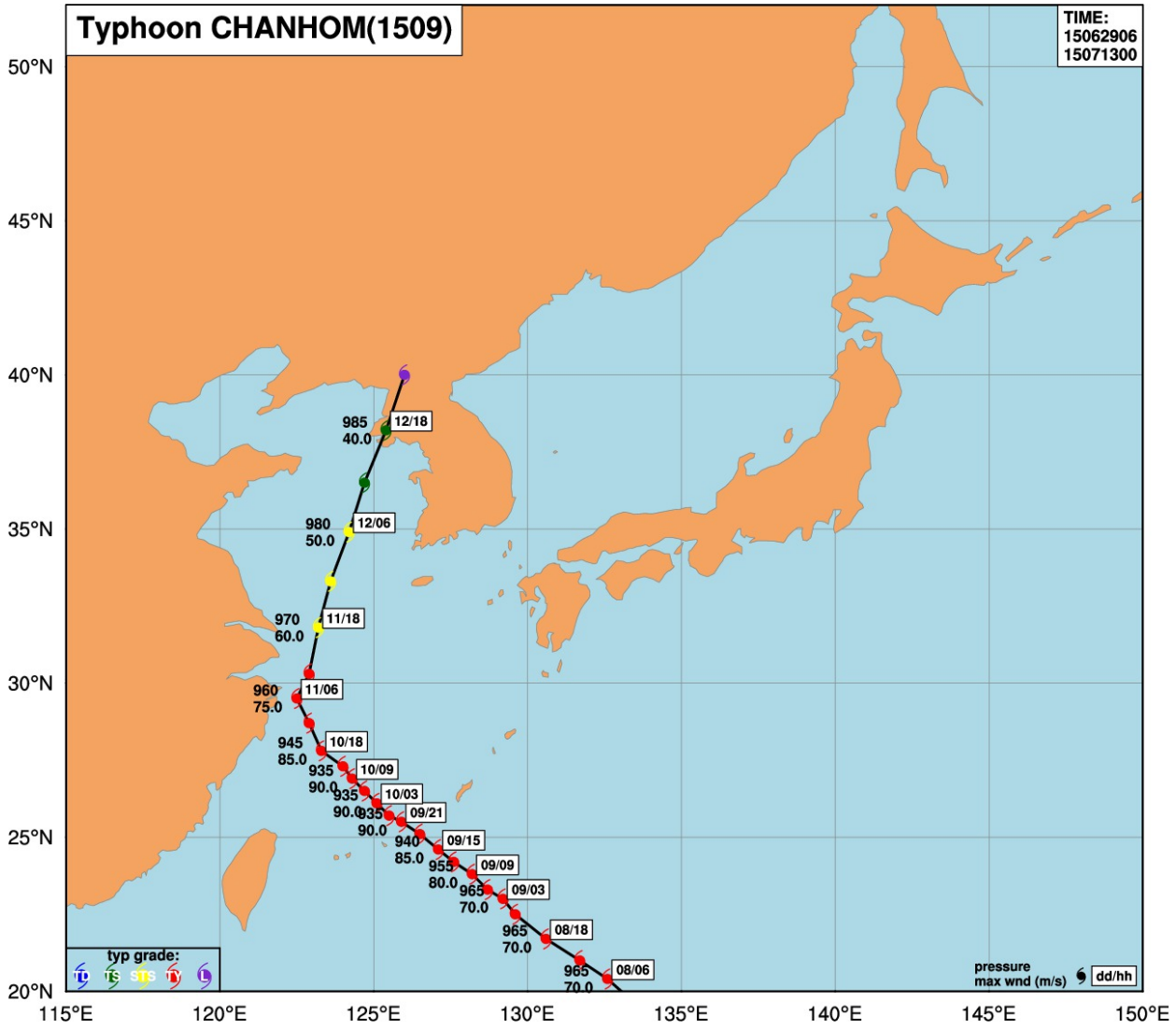



Boundary Condition

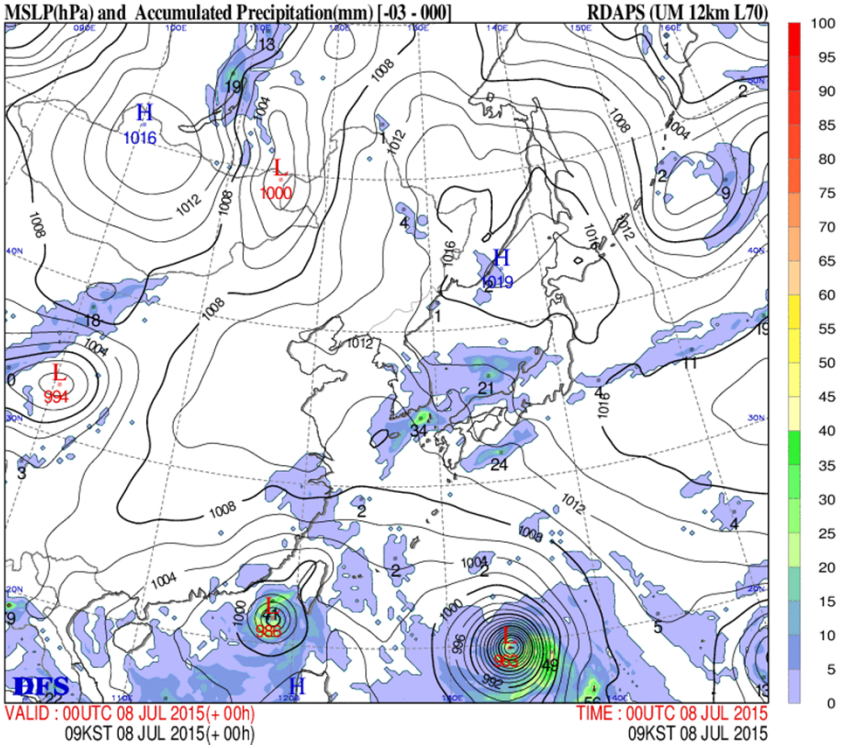
## Coastal Model (1km Resolution)

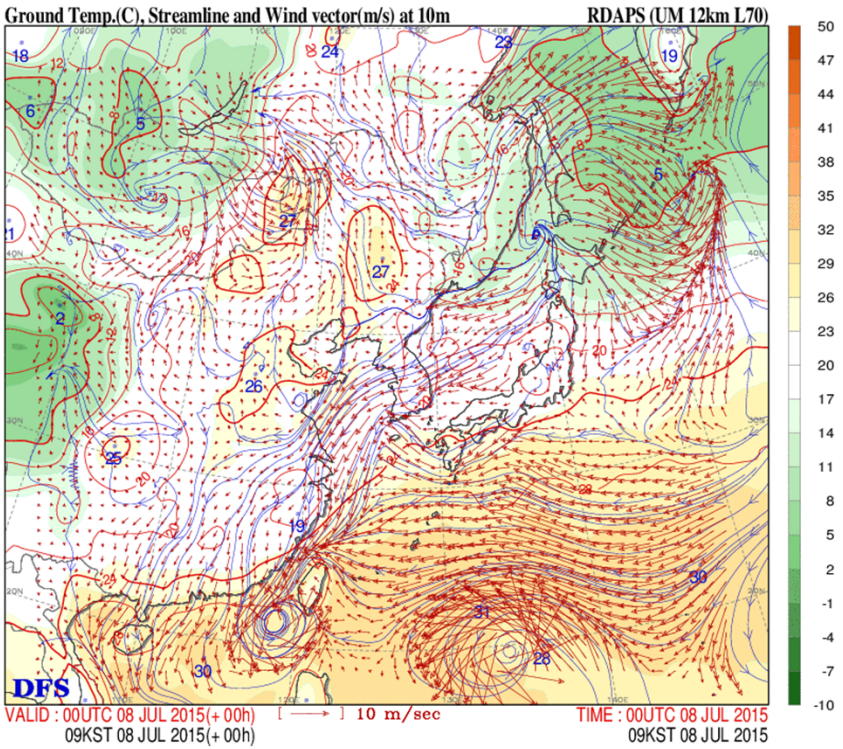


# Typhoon Cases (Chanhom, 1509)



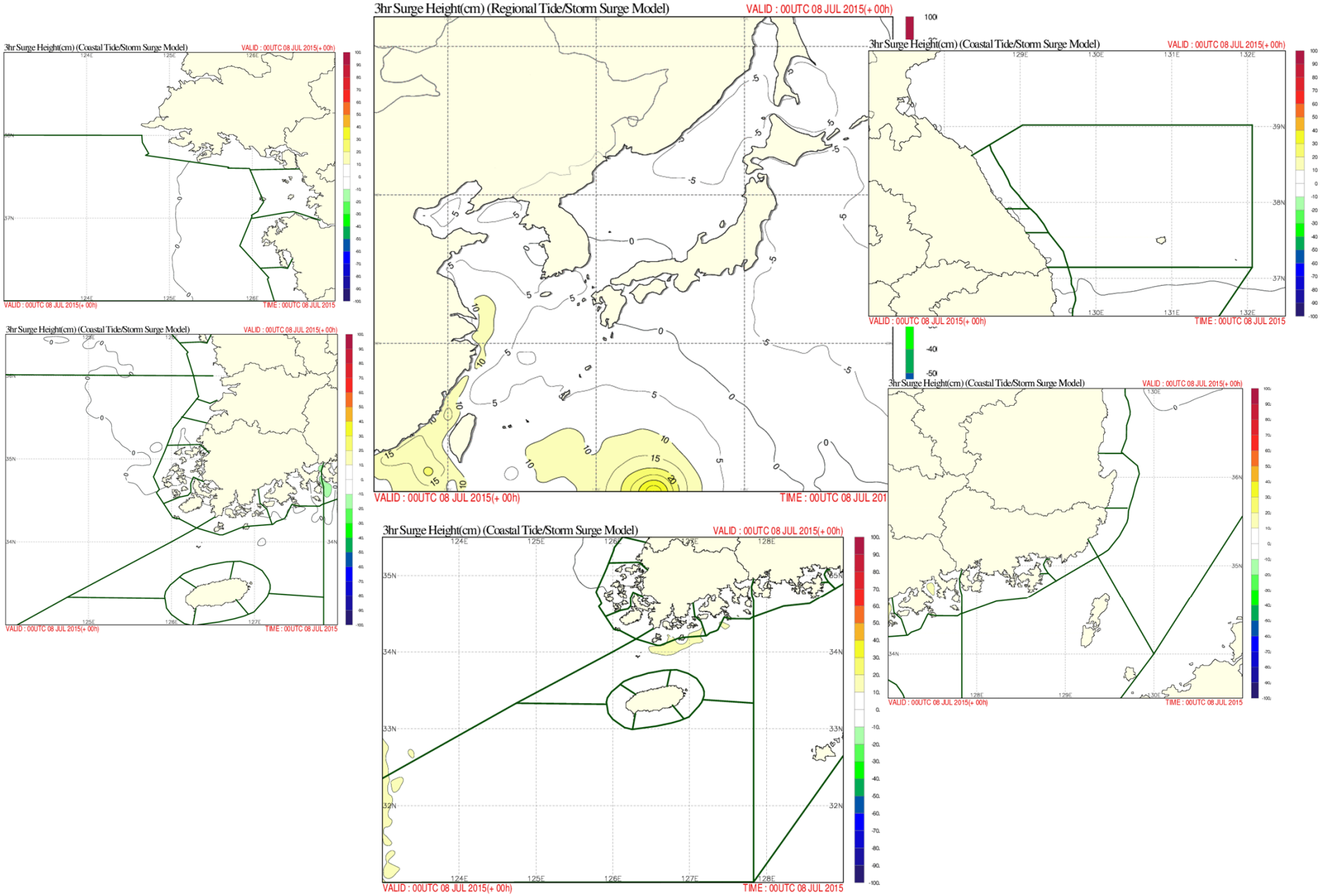
# Typhoon Chanhom(1509)



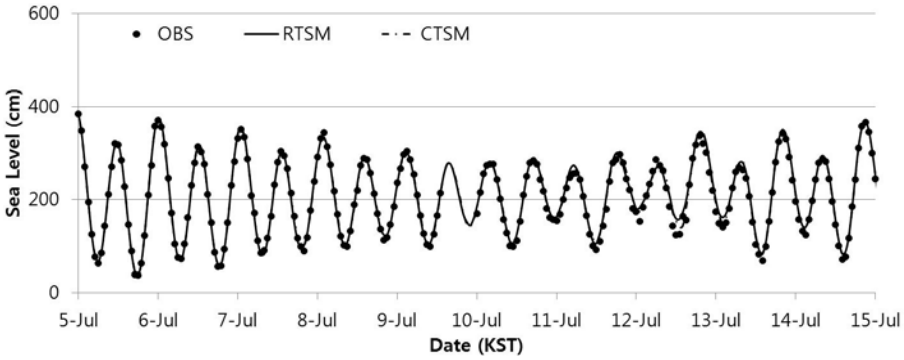



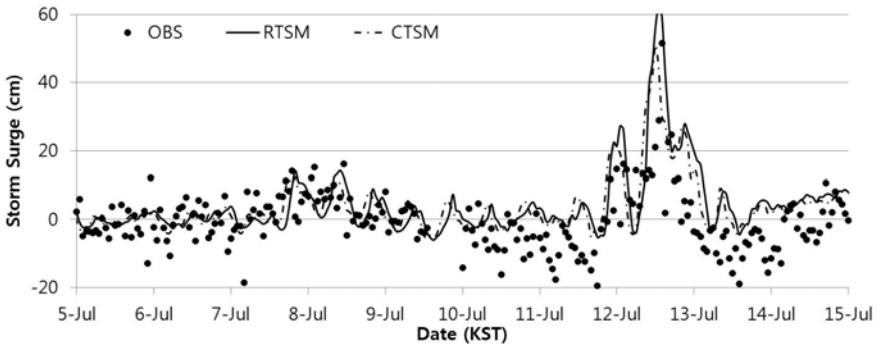

## MSLP & Sea Winds

# RTSM & CTSM

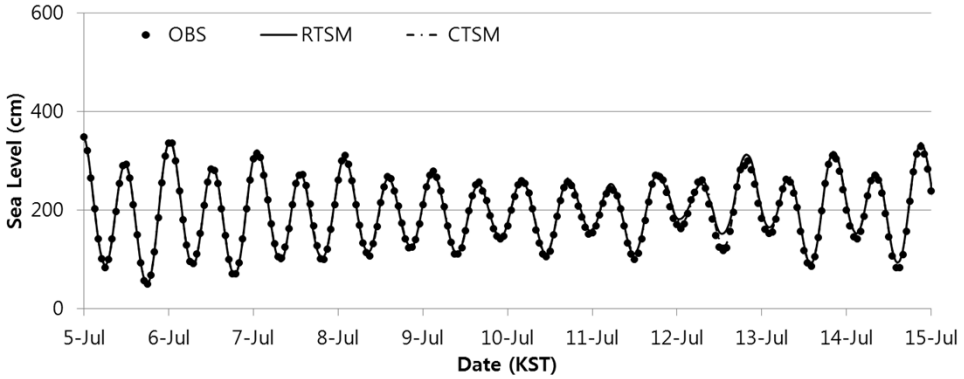

3hr Surge Height(cm) (Regional Tide/Storm Surge Model)
VALID : 00UTC 08 JUL 2015(+ 00h)
TIME : 00UTC 08 JUL 201
3hr Surge Height(cm) (Coastal Tide/Storm Surge Model)
VALID : 00UTC 08 JUL 2015(+ 00h)
TIME : 00UTC 08 JUL 2015

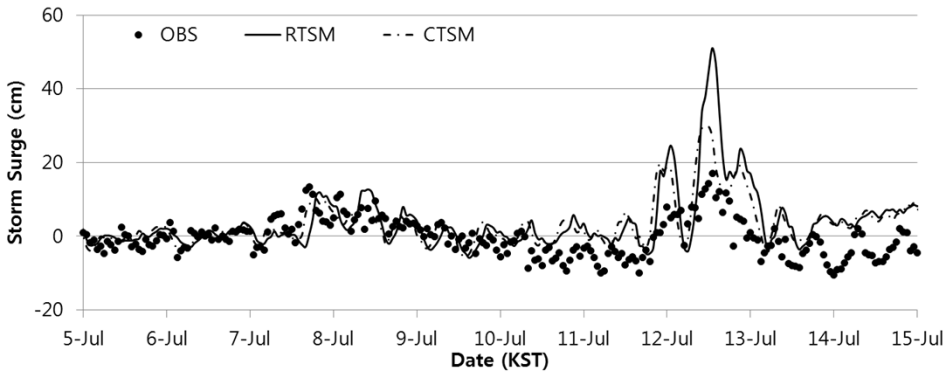
# Comparison of Storm Surge / Tide



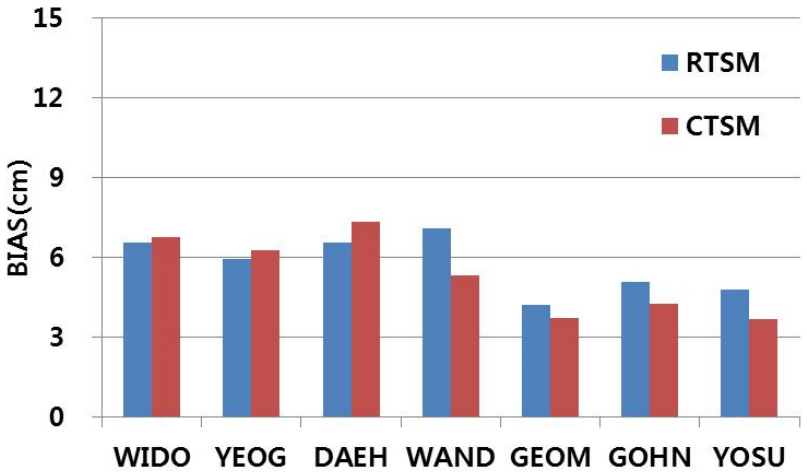

Goheung

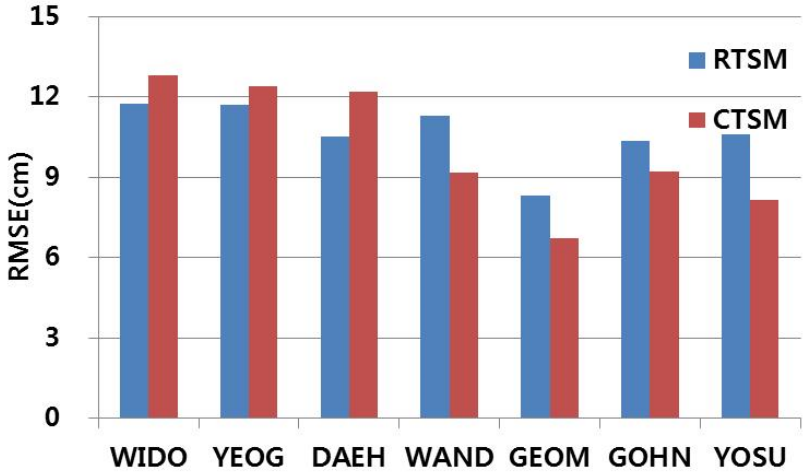


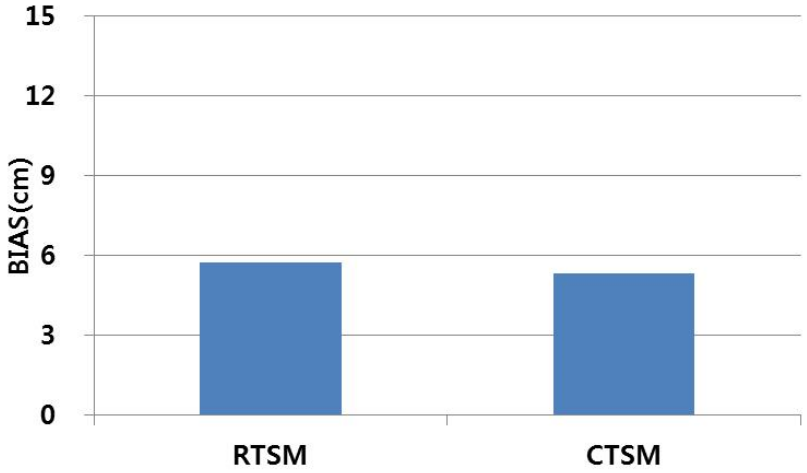




Geomundo

# Verification





| Typhoon | Model | Bias(cm) | RMSE(cm) |
|---|---|---|---|
| Chanhom (1509) | RTSM | 5.74 | 10.64 |
| | CTSM | 5.33 | 10.09 |

# Summary

- Examine the storm surge with nine typhoon (2005-2007) by comparing Operational Regional Storm surge model results and observation from 30 stations

  - Total Averaged RMSE : 10.2 cm
  - Maximum positive bias : 6.92cm, Negative bias : -12.06 cm

- Developing Operational Regional (8km) and Coastal (1km) Storm surge model

  - High resolution coastal storm surge model show a little better agreement with the observed storm surge along the complex coastline of Korea