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*

<table>
<thead>
<tr>
<th>Disasters</th>
<th>Fatalities</th>
<th>Property Damage (BW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typhoon</td>
<td>418</td>
<td>10,245</td>
</tr>
<tr>
<td>Heavy Rain</td>
<td>236</td>
<td>4,575</td>
</tr>
<tr>
<td>Heavy Snow</td>
<td>14</td>
<td>1,319</td>
</tr>
<tr>
<td>Strong Wind</td>
<td>12</td>
<td>39</td>
</tr>
</tbody>
</table>
### Occurrence Frequency of Typhoon

#### 1951-2014

<table>
<thead>
<tr>
<th>Month</th>
<th>Case</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td>28</td>
<td>15</td>
<td>24</td>
<td>46</td>
<td>66</td>
<td>115</td>
<td>244</td>
<td>352</td>
<td>319</td>
<td>238</td>
<td>152</td>
<td>73</td>
<td>1672</td>
</tr>
<tr>
<td>K</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>17</td>
<td>58</td>
<td>75</td>
<td>47</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>206</td>
</tr>
</tbody>
</table>

A: Typhoon occurred in Northwestern Pacific Ocean  
K: Typhoon effected on the Korean Peninsula

#### Climatology: 1951–2014 (64 years)

![Annual TC in the western North Pacific](chart)

**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

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)
Marine Observations Network (Temporal)

- **Coastal Wave Buoy**: 1 hour
- **Wave Radar**: 5 minutes
- **Coastal Long Wave Monitoring**: 0.5 sec
- **Observation Vessel ‘Gisang 1’**: 4-5 times/day
- **Vessel AWS**: 2 times/day
- **VOS**: 2 times/day
- **Vessel AWS**: 2 times/day
- **Drifting Buoy**: 0.5 sec
- **Ocean Data Buoy**: 5 minutes
- **VOS**: 2 times/day
- **Vessel AWS**: 2 times/day

Coastal, Offshore, High Sea
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
<table>
<thead>
<tr>
<th>Year</th>
<th>Instruments (total)</th>
</tr>
</thead>
</table>
| 2013 | Ocean Data Buoy(10)  
Light House AWS(9)  
Wave Radar(6)  
Coastal Wave Buoy(35)  
Long Wave Monitoring(17)  
Port Weather Monitoring(3)  
Vessel AWS(8)  
Research Vessel(1)  
Observation Station(1)  
Drifting Buoy (10) |
| 2014 | Ocean Data Buoy(10)  
Light House AWS(9)  
Wave Radar(6)  
Coastal Wave Buoy(39)  
Long Wave Monitoring(18)  
Port Weather Monitoring(4)  
Vessel AWS(10)  
Drifting Buoy (10) |
| 2017 | Ocean Data Buoy(13)  
Light House AWS(9)  
Wave Radar(6)  
Coastal Wave Buoy(56)  
Long Wave Monitoring(18)  
Port Weather Monitoring(11)  
Research Vessel(2)  
Observation Station(2)  
Vessel AWS(25)  
Drifting Buoy (410) |
Prediction
Super Computer in KMA

1st Supercomputer
NEC SX-5/28M2
1999.12 ~ 2005.11
Theoretical performance
0.2 TFlops

2nd Supercomputer
CRAY X1E 1024/MSP
2005.12 ~ 2010.11
Theoretical performance
18.5 TFlops

3rd Supercomputer
CRAY XE6 90,240 cores
2010.12 ~ 2015.12
Theoretical performance
758 TFlops

4th Supercomputer
CRAY XC40
2015.12 ~
Theoretical performance
2.9 Peta Fflops
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 (744x928 / top =39km)
- Target Length: 36hrs
- Initialization: 3DVAR
Wave/Storm Surges Forecasting System

Global, Regional UM
Sea Surface Wind & MSLP

Global, Regional Wave Model
(GWW3: 60km, RWW3: 8km)

Logical Depth DB

Regional Storm Surge Model
(RTSM : 8km)

Coastal Region
Sea Surface Wind Model

Bathymetry DB

Coastal Wave Model
(CWW3: 1km)

Bathymetry DB

Tide Model

Coastal Storm Surge Model
(CTSM : 1km)

Tide Coeff. DB
Operational Time Schedule

00 UTC

UM

3 Hr Intv Wind, Pressure

288H FCST
87H FCST

GWW3
RWW3, RTSM

12 H FCST - Initial First Guess

12 UTC

UM

3 Hr Intv Wind, Pressure

288H FCST
87H FCST

GWW3
RWW3, RTSM
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

Jean-Raymond Bidlot,
European Centre for Medium-range Weather Forecasts, jean.bidlot@ecmwf.int
2006 Typhoon EWINIAR
RTSM (Regional Tide/Storm Surges Model)

Storm surge
2003/09/09/00 (UTC)
2003/09/09/09 (KST)

- 2-D POM model
- 1/12° (8 km)
  
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

3HR Surge Height Forecast Chart
Regional Tide/Storm Surge Model (RTSM)
Korea Meteorological Administration
Storm Surges/ Tide Forecasting

30 coastal stations

Issued at 00UTC 01 Aug 2007
Valid : 09KST 01 Aug 2007 - 09KST 02 Aug 2007

Korea Meteorological Administration

Tide/Storm Surge Model (KSSM)

Korea Meteorological Administration
Model Verification

Western coast

Southern coast

Eastern coast

Tidal Stations

Incheon

Gunsan

Mokpo

Masan

Jeju

Wando

Busan

Mukho

Uleung

Korea

Tidal Stations

- SOKC
- MUKH
- HUPO
- POHA
- ULSN
- MASN
- BUSN

Tidal Stations

- INCH
- DAEH
- GONG
- CHUJ
- KOMU
- MOPO

Tidal Stations

- OBUK
- KTSM

Tidal Stations

- OBUK
- KTSM

Tidal Stations

- OBUK
- KTSM
Model Verification
# Model Verification

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

## BIAS and RMSE Graphs

- **BIAS 2005**
- **BIAS 2006**
- **BIAS 2007**

- **RMSE 2005**
- **RMSE 2006**
- **RMSE 2007**
Nesting Coastal Storm surges Model

<table>
<thead>
<tr>
<th>Model</th>
<th>2-D Ocean Circulation Model (POM 2D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate System</td>
<td>Spherical Coordinate</td>
</tr>
<tr>
<td>Model Domain</td>
<td>6 coastal areas</td>
</tr>
<tr>
<td>Horizontal Resolution</td>
<td>1/120 ° by 1/120 ° (361 × 241)</td>
</tr>
<tr>
<td>ΔT</td>
<td>60 sec</td>
</tr>
<tr>
<td>Input Data</td>
<td>E,U,V from Regional Model</td>
</tr>
<tr>
<td></td>
<td>RDAPS Wind and Pressure</td>
</tr>
</tbody>
</table>
Coastal Tide/Storm surges Model (CTSM)

Regional Model (8km)

Coastal Model (1km Resolution)

Boundary Condition
Typhoon Cases (Chanhom, 1509)
Typhoon Chanhom (1509)

MSLP & Sea Winds
Comparison of Storm Surge / Tide

Goheung

Geomundo
Verification

<table>
<thead>
<tr>
<th>Typhoon</th>
<th>Model</th>
<th>Bias(cm)</th>
<th>RMSE(cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chanhom (1509)</td>
<td>RTSM</td>
<td>5.74</td>
<td>10.64</td>
</tr>
<tr>
<td></td>
<td>CTSM</td>
<td>5.33</td>
<td>10.09</td>
</tr>
</tbody>
</table>
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