Storm Surge Prediction in Vietnam

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Geographic and climate effect

- Large and Complicate Tide
- Typhoon (June-November)
- North-East Monsoon (November-March)
- South-East Monsoon (June-October)
Typhoon in Vietnam

- There are about 10-12 typhoons and 5-6 affect to land.

Storm distribution in South China Sea

Storm numbers monthly attacking Vietnam coast in 53 years
Track of typhoon in 2013

Total: 13 typhoons
Strong Haiyan typhoon

Track

Pressure variation

Land fall the coast at Vietnam at low tide
- No inundation
Damage due to typhoon

Both Typhoon № 10 and № 11 (2013): 25 people die, loss 1,800 billions VND (90 million USD)
7 death and 43 injury during Sonting (2012) typhoon affect, with maximum wind speed up to 47m/s, central pressure of 945 hPa. Loss 75000 billion VND (375 million USD)

Television tower was collapsed by high wind force

Honla breakwater was broken by high wave (up to 5m)
Inundation due to high tide and heavy rain at Doson in Typhoon №4
High Vulnerable storm surge (abundant typhoon + shallow water)

Less Vulnerable storm surge (rare typhoon + deep water)

Less Vulnerable storm surge (shallow water + rare typhoon)

Number of Typhoon

Typhoon and storm surge in Vietnam
### Storm surge in Vietnam coastal

**Table 1: Storms and surges along Vietnam coast**

<table>
<thead>
<tr>
<th>Latitude (N)</th>
<th>Number of storms</th>
<th>P%</th>
<th>Annual average number</th>
<th>Observed maximum surge (m)</th>
<th>Expected maximum surge (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>21-22 North Cửa Ông</td>
<td>29</td>
<td>12.04</td>
<td>0.74</td>
<td>2.2</td>
<td>2.6</td>
</tr>
<tr>
<td>20-21 Cửa Ông - Cửa Đại</td>
<td>39</td>
<td>16.19</td>
<td>1.00</td>
<td>2.2</td>
<td>3.0</td>
</tr>
<tr>
<td>19-20 Cửa Đại - Cửa Quăn</td>
<td>34</td>
<td>14.11</td>
<td>0.87</td>
<td>3.0</td>
<td>4.0</td>
</tr>
<tr>
<td>18-19 Cửa Vân - Đê Ngang</td>
<td>29</td>
<td>12.04</td>
<td>0.74</td>
<td>3.4</td>
<td>4.0</td>
</tr>
<tr>
<td>17-18 Đê Ngang - Cửa Tùng</td>
<td>16</td>
<td>6.64</td>
<td>0.41</td>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td>16-17 Cửa Tùng - Đà Nẵng</td>
<td>9</td>
<td>3.73</td>
<td>0.23</td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td>15-16 Đà Nẵng - Quang Ngãi</td>
<td>23</td>
<td>9.54</td>
<td>0.59</td>
<td>1.4</td>
<td>1.6</td>
</tr>
<tr>
<td>14-15 Quảng Ngãi - Bình Định</td>
<td>23</td>
<td>9.54</td>
<td>0.59</td>
<td>1.0</td>
<td>1.2</td>
</tr>
<tr>
<td>13-14 Bình Định - Phú Yên</td>
<td>11</td>
<td>4.56</td>
<td>0.28</td>
<td>0.8</td>
<td>1.0</td>
</tr>
<tr>
<td>12-13 Phú Yên - Khánh Hòa</td>
<td>9</td>
<td>3.73</td>
<td>0.23</td>
<td>0.8</td>
<td>1.0</td>
</tr>
<tr>
<td>11-12 Ninh Thuận - Bình Thuận</td>
<td>10</td>
<td>4.13</td>
<td>0.26</td>
<td>1.0</td>
<td>1.2</td>
</tr>
<tr>
<td>10-11 Bình Thuận - Bến Tre</td>
<td>4</td>
<td>1.66</td>
<td>0.10</td>
<td>1.8</td>
<td>2.0</td>
</tr>
<tr>
<td>9-10 Bến Tre - Bạc Liêu</td>
<td>3</td>
<td>1.24</td>
<td>0.08</td>
<td>2.0</td>
<td>2.4</td>
</tr>
<tr>
<td>8-9 Bạc Liêu - Cà Mau</td>
<td>2</td>
<td>0.83</td>
<td>0.06</td>
<td>2.0</td>
<td>2.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>241</strong></td>
<td><strong>100</strong></td>
<td><strong>6.18</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 5-4. Magnitude of maximum storm surge along the coast.**

Storms and surges along Vietnam coast
storm surge in 2013

Typhoon No 2 (land fall at high tide, surge height: 0.7m - inundation)

Typhoon No 10-Wutip (strong-Surge height: 1.3m at low tide)

In 2013: 13 typhoons.

Three generated high surge on coast

Typhoon No 11-Nari (strong-Surge height: 1.5m at low tide)
Storm surge prediction in Vietnam
SuWAT (Surge Wave and Tide) Model-Operational Model

Two dimensional long wave equations + Swan model

\[
\frac{\partial \eta}{\partial t} + \frac{\partial M}{\partial x} + \frac{\partial N}{\partial y} = 0
\]

\[
\frac{\partial M}{\partial t} + \frac{\partial}{\partial x} \left( \frac{M^2}{d} \right) + \frac{\partial}{\partial y} \left( \frac{MN}{d} \right) + gd \frac{\partial \eta}{\partial x} = fN - \frac{1}{\rho_w} d \frac{\partial P}{\partial x} + \frac{1}{\rho_w} (\tau_s^x - \tau_b^x + F_x) + A_h \left( \frac{\partial^2 M}{\partial x^2} + \frac{\partial^2 M}{\partial y^2} \right)
\]

\[
\frac{\partial N}{\partial t} + \frac{\partial}{\partial x} \left( \frac{NM}{d} \right) + \frac{\partial}{\partial y} \left( \frac{N^2}{d} \right) + gd \frac{\partial \eta}{\partial y} = -fM - \frac{1}{\rho_w} d \frac{\partial P}{\partial y} + \frac{1}{\rho_w} (\tau_s^y - \tau_b^y + F_y) + A_h \left( \frac{\partial^2 N}{\partial x^2} + \frac{\partial^2 N}{\partial y^2} \right)
\]

Open boundary condition: NAO.99b, NAO.99Jb models-
Storm surge prediction in Vietnam

- Wind and Pressure Model:

+ Typhoon Model: Empirical model

\[
P(r) = P_\infty - \frac{P_\infty - P_c}{\sqrt{1 + (r/r_0)^2}} \quad \text{(Fujita)}
\]

\[
V = \begin{pmatrix} v_x \\ v_y \end{pmatrix} = c_1 \begin{pmatrix} -V_g (\sin \alpha \cdot \cos \theta + \cos \alpha \cdot \sin \theta) \\ V_g (\cos \alpha \cdot \cos \theta - \sin \alpha \cdot \sin \theta) \end{pmatrix} + c_2 \begin{pmatrix} v_{tx} \\ v_{ty} \end{pmatrix} e^{-\frac{\pi r}{500}}
\]

+ NWP: WRF
Structure of SuWAT Model in Vietnam
Verifying the SuWAT Model on Tide on April 2014
Effect of wave on Storm surge

Variation of storm surge at Danang Station

Track of Xangsena typhoon (9/2006) land fall at Danang (middle of Vietnam)

Effect of tide is insignificant, but wave significant
Effect of tide and storm surge on wave height

(a) Without consider wave

(b) With wave

Maximum storm surge
Effect of tide and storm surge on wave height

(a) Without consider wave

(b) With wave

Maximum significant wave height
Effect of tide and storm surge on wave height

Time variation of Hsig. at shallow and deep water point
- Model setup by: Norwegian Meteorological Institute under the project “Strengthen the early warning system” at National Centre for Hydrometeorological Forecasting of Vietnam (NCHMF)

-Meteorological Model:

+ WRF
+ Resolution: 15km.
+ Boundary: GSM-JMA GFS-NCEP

Computational domain and bathymetry
Some Preliminary Results

Case 1: Xangxane typhoon 2006

Track of Xangxena typhoon (9/2006) land fall at Danang (middle of Vietnam)

Wind and pressure at the time typhoon land fall – WRF model
Distribution of surge height at the time typhoon Xangxane (9/2009) land fall – ROMS Mode Results
Verifying the model with OBS data for typhoon Xangxane (9/2006)

Cuviet: river station
Danang: Sea station

Flooding due heavy rain

Time Variation of Storm Surge at Cuviet (above) and Danang (below) Stations
Case 2: Ketsena typhoon (9/2009)

Track of Ketsena typhoon (9/2009) land fall at Danang (middle of Vietnam)
Distribution of surge height at the time typhoon Xangxane (9/2006) land fall -ROMS Mode Results
Verifying the model with OBS data for typhoon Ketsena (9/2009)

In this case: SuWAT using Empirical typhoon Model (Fujita Model)

Time Variation of Storm Surge at Cuaviet (above) and Danang (below) Stations
Case 3: Kalmaegi typhoon 2014

Track of Xangsena typhoon (9/2006) land fall at Danang (middle of Vietnam)

The surge generated after typhoon landfall and reached to 12 hours (look right figure). This is due to South-West monsoon.
Suge and wave after typhoon Kalmaegi Land fall 12 hour

Surge + high tide + wave generated inundation at Haiphong coast
Distribution of surge height at the time Kalmaegi typhoon 9/2014 land fall 3 and 6 hour - ROMS Mode Results.
Verifying the model with OBS data for typhoon Kalmaegi (9/2014)

Time Variation of Storm surge at Hondau Station
Time variation at Hondau station during typhoon Kalmaegi (9/2014)
Conclusion and future work

1. ROMS model can simulate good agreement surge not only in the case of typhoon, but strong wind.
2. Operation surge in monsoon (wind and airpressure variation)
3. Coastal inundation due to storm tide.
4. Asiimilation for HF radar (wave and surface current)
Surface ocean current in South China sea and the coast of Vietnam – Result from observation and analyze

In winter (Dec.-Jan.)
- Strong surface current in SW direction

In summer (Jun-Aug.)
- Strong surface current in NE direction
Upwelling in SW monsoon

Observation station for investigation upwelling
Thank You - Questions and Discussion?