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Construction of the marine earthquake and tsunami monitoring stations

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Earthquake Administration of Shanghai Municipality

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Shanghai Submarine Earthquake Monitoring and Tsunami Early warning Project

- Why to do?
- What to do?
- How to do?

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Why to do?

Tsunami Hazards From Potential Earthquake along China Coast

David A Yuen (University of Minnesota)

Yingchun Liu (South China Sea Institute of Oceanology, CAS) (Graduate University of CAS)

Erik Sevre (University of Minnesota)

Shuo M. wang (University of Minnesota)

Yaolin Shi (Graduate University of CAS)

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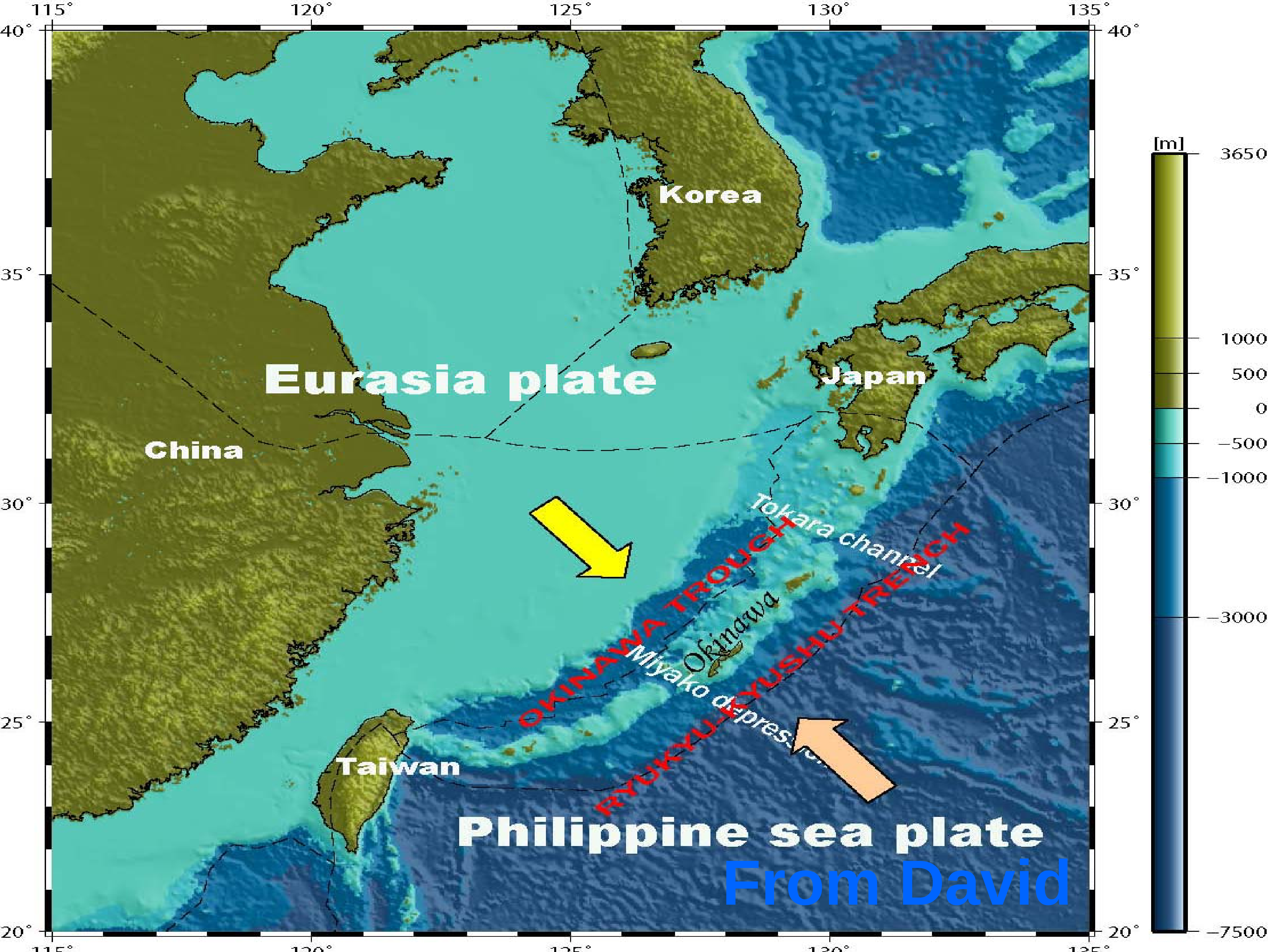
Conclusion(3)

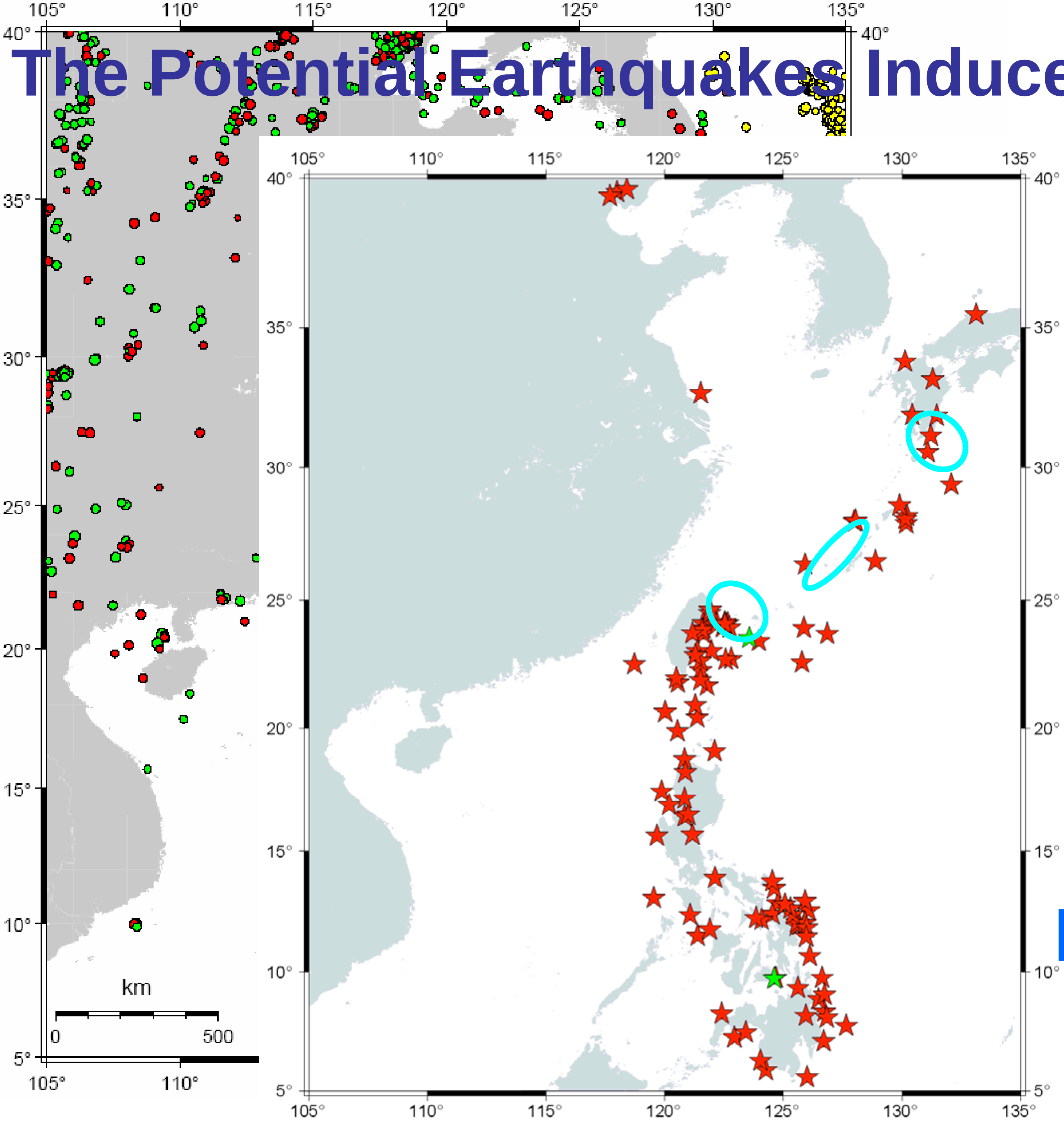
- **Our forecast is that there are 0.52 %probability for a 2m tsunami wave to hit Shanghai, 3.2 %for Wenzhou, and 7.2% for Keelung within the next 100 years.**
- **A 1-2m tsunami wave to hit Shanghai, there are 7.2%, the 0.5-1m is 13.15%.**

From David



115°
120°
125°
130°
135°
40°
35°
30°
25°
20°
Korea
Eurasia plate
Japan
China
Tokara channel
OKINAWA TROUGH
RYUKYU-KYUSHU TRENCH
Okinawa
Miyako depression
Taiwan
Philippine sea plate
From David
[m]
3650
1000
500
0
−500
−1000
−3000
−7500

The Potential Earthquakes Induce Tsunamis



From David

ter depth <=30 Km

Linear and Nonlinear Shallow Water Equation

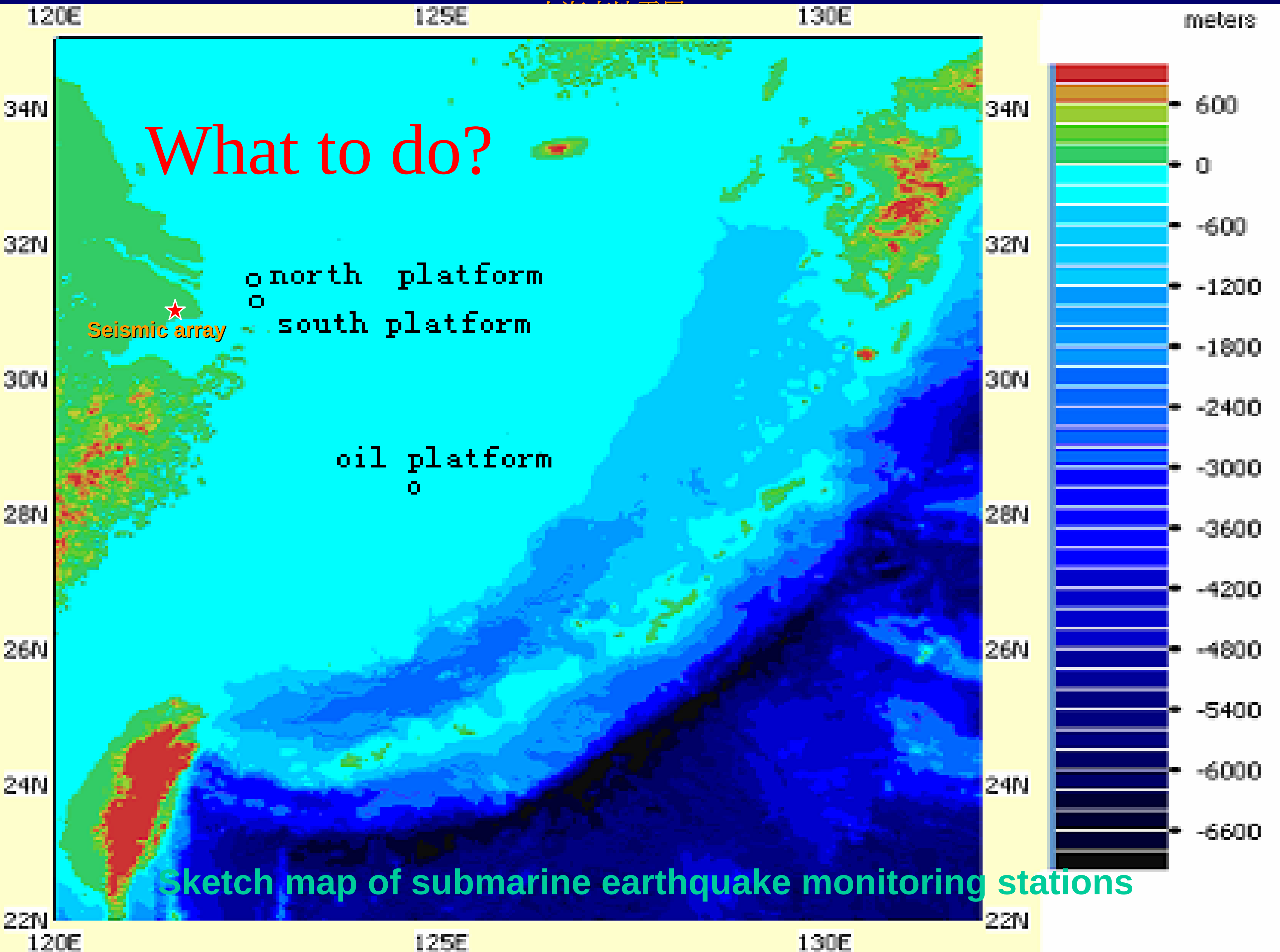
Linear Shallow Water Equation

$$\frac{\partial z}{\partial t} + \frac{\partial M}{\partial x} + \frac{\partial N}{\partial y} = 0$$
$$\frac{\partial M}{\partial t} + gD\frac{\partial \eta}{\partial x} = 0$$
$$\frac{\partial N}{\partial t} + gD\frac{\partial \eta}{\partial y} = 0$$

Nonlinear

$$\frac{\partial \eta}{\partial t} + \frac{\partial M}{\partial x} + \frac{\partial N}{\partial y} = 0$$
$$\frac{\partial M}{\partial t} + \frac{\partial}{\partial x}\left(\frac{M^2}{D}\right) + \frac{\partial}{\partial y}\left(\frac{MN}{D}\right) + gD\frac{\partial \eta}{\partial x} + \frac{\tau_x}{\rho} = 0$$
$$\frac{\partial N}{\partial t} + \frac{\partial}{\partial x}\left(\frac{MN}{D}\right) + \frac{\partial}{\partial y}\left(\frac{N^2}{D}\right) + gD\frac{\partial \eta}{\partial y} + \frac{\tau_y}{\rho} = 0$$

From David



Sketch map of submarine earthquake monitoring stations

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Shanghai Submarine Earthquake Monitoring and Tsunami Early warning Project

- Why to do?
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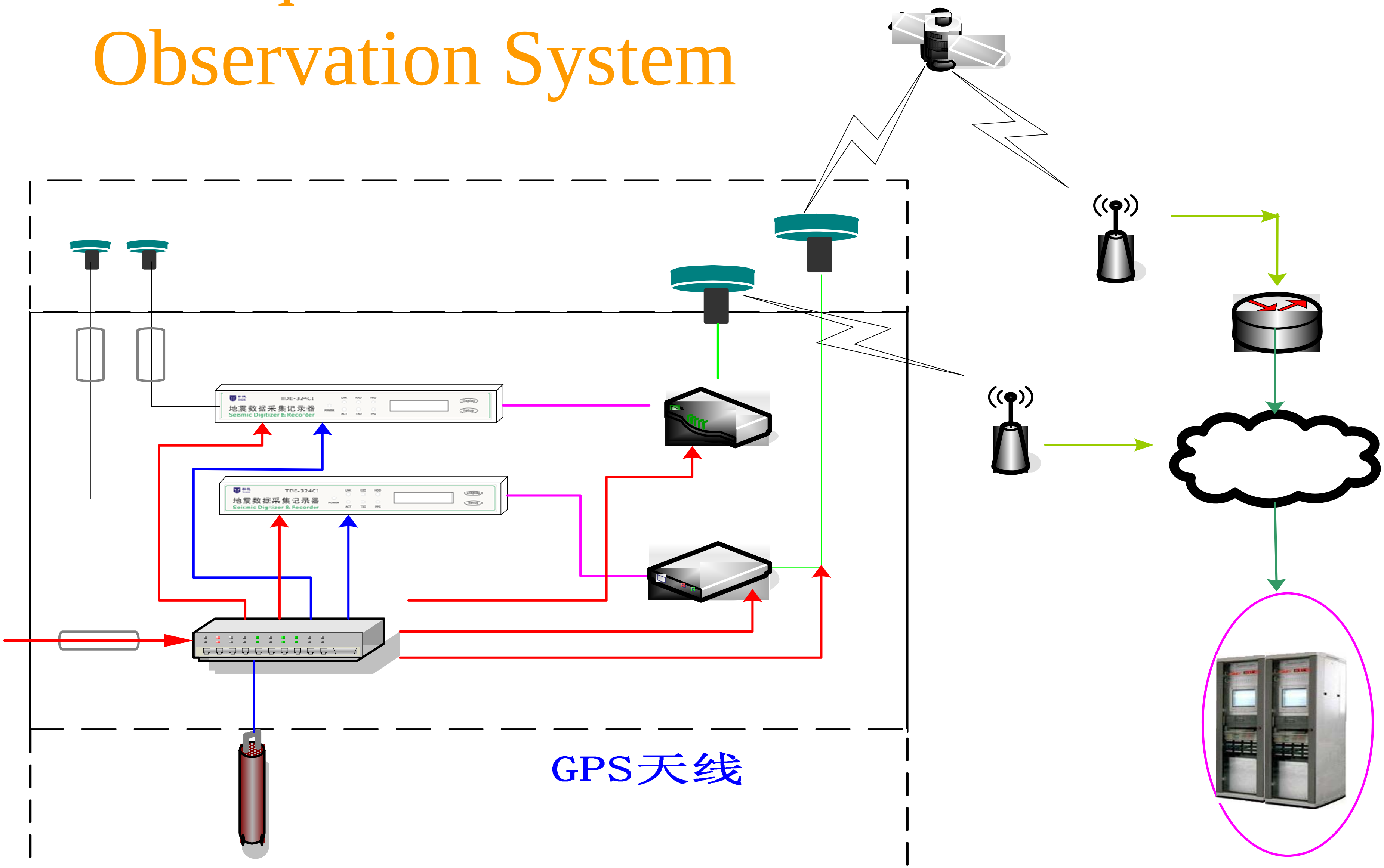
Shanghai Earthquake Tsunami Monitoring Project

exploration ship should sail into the location and bore the hole to put the seismometer into the hole.


2007 10 3

Sketch of Shanghai Earthquake Tsunami Observation System



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Shanghai Submarine Earthquake and Tsunami Monitoring Project

The tsunami observation instruments : TideGaugeRecorder-1050HT to monitor the tide & level of tsunami)

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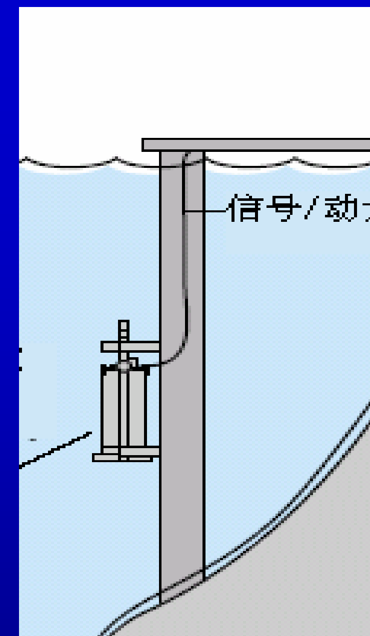
Shanghai Earthquake Tsunami Monitoring Project



The tsunami observation instruments : SBE26plus to monitor the wave and tide of tsunami). it's suitable to install it at the frame-staff of oil-platform station. By using the cable to connect it to the operation room of oil-platform station, and then transmit the record to the center of EASM

海啸是海洋长波,其数学模型有线性和非线性浅水长波方程，**Boussinesq**方程等。成熟的海啸传播模式是，越洋传播采用球坐标系下的线性浅水波方程并考虑了地球自转时的科氏力作用，近海海啸采用直角坐标系下的非线性浅水方程上底摩擦项，还有在模型中考虑涡粘项和频散项的。

非线性浅水波方程

$$\begin{cases} \dfrac{\partial \eta}{\partial t} + \nabla \bullet [(h+\eta)\vec{u}] = 0 \\ \dfrac{\partial \vec{u}}{\partial t} + (\vec{u} \bullet \nabla)\vec{u} + g\nabla\eta = 0 \end{cases}$$

Boussinesq方程

$$\begin{cases} \dfrac{\partial \eta}{\partial t} + \nabla \bullet [(h+\eta)\bar{\mathbf{u}}] = 0 \\ \dfrac{\partial \bar{\mathbf{u}}}{\partial t} + (\bar{\mathbf{u}} \bullet \nabla)\bar{\mathbf{u}} + g\nabla\eta = \dfrac{h}{2}\dfrac{\partial}{\partial t}\nabla[\nabla \bullet (h\bar{\mathbf{u}})] - \dfrac{h^2}{6}\dfrac{\partial}{\partial t}\nabla(\nabla \bullet \bar{\mathbf{u}}) \end{cases}$$

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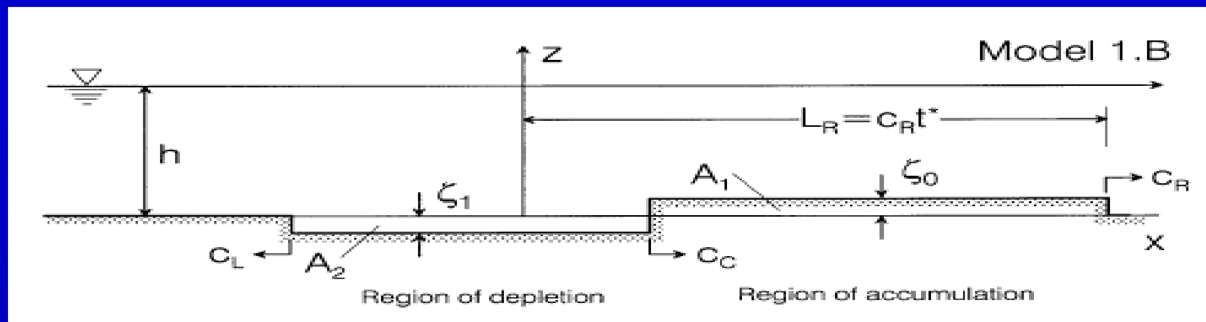
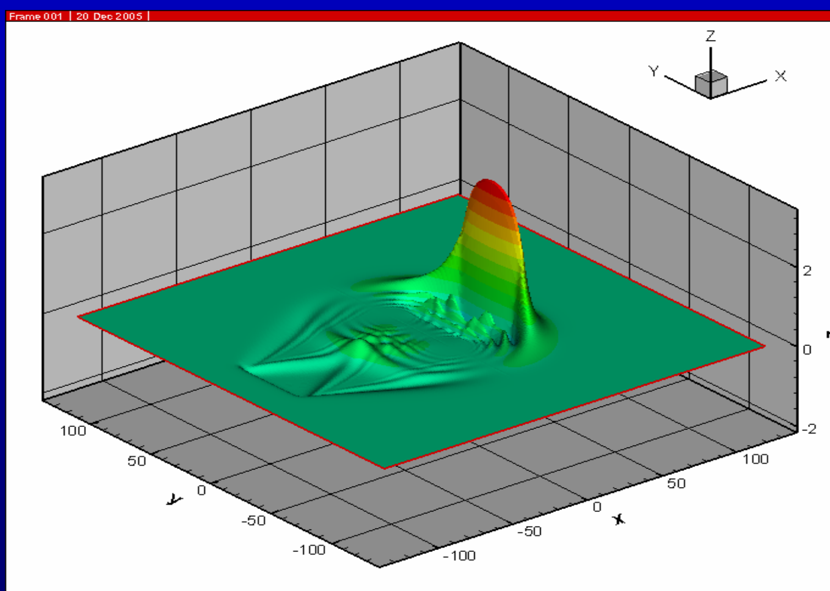
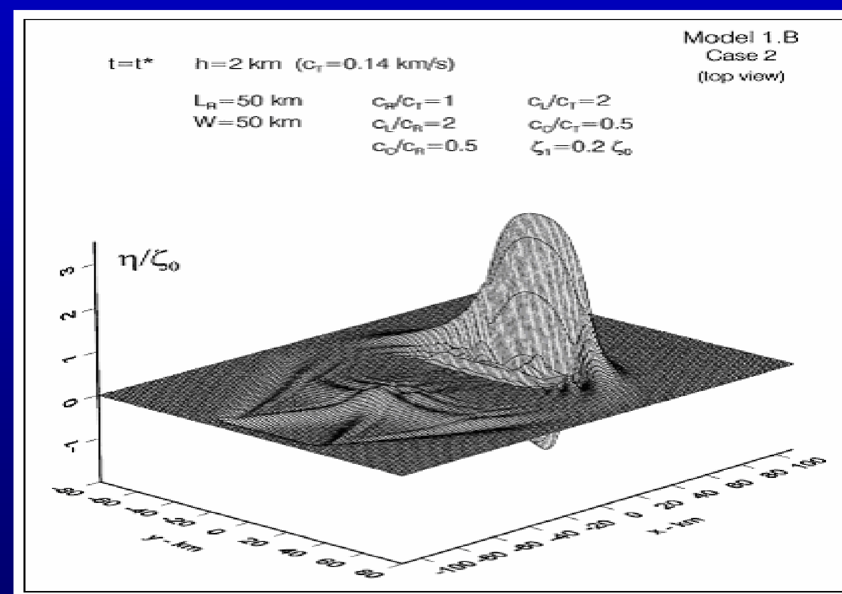
Numerical Analysis of Nonlinear Equation of Tsunami Propagation





Calculation result (Zhu et al) for model 1.B



Calculation result (Trifunac et al) for model 1.B

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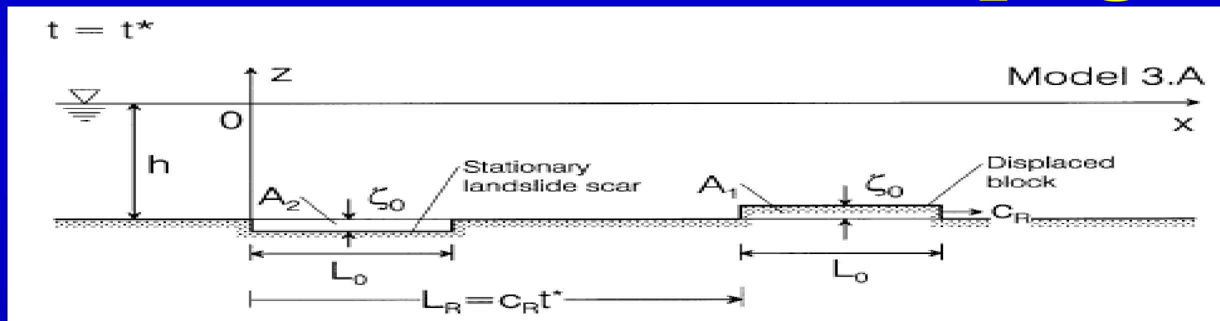
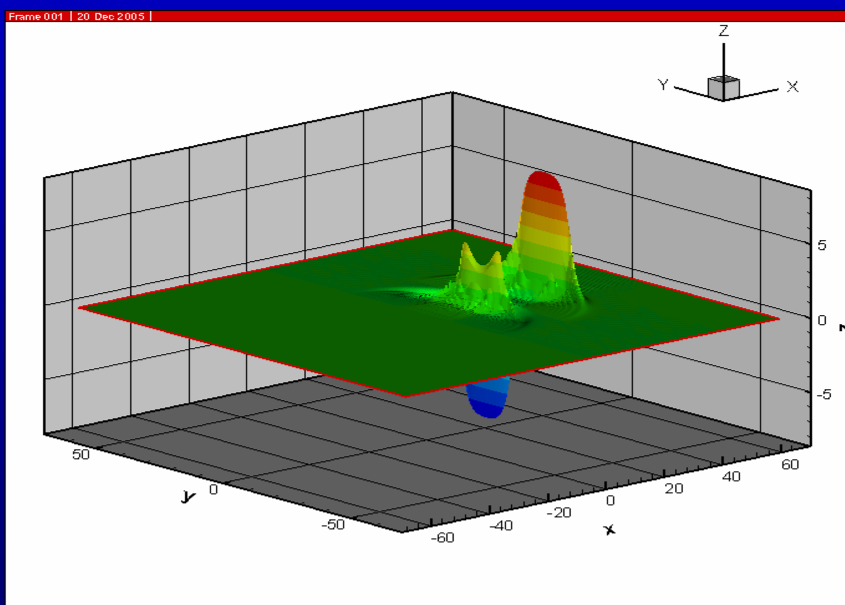
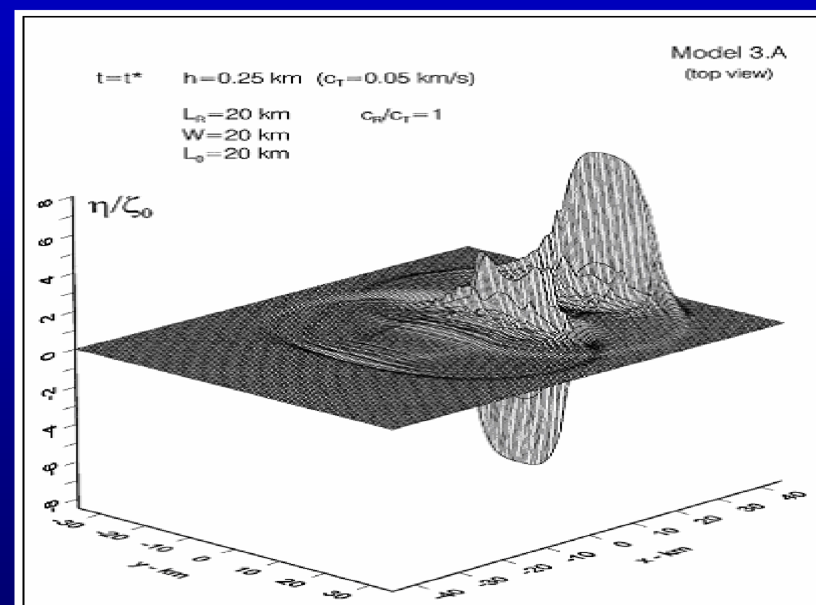
Numerical Analysis of Nonlinear Equation of Tsunami Propagation







Calculation result (Zhu et al) for model 3.A

Calculation result (Trifunac et al) for model 3.A

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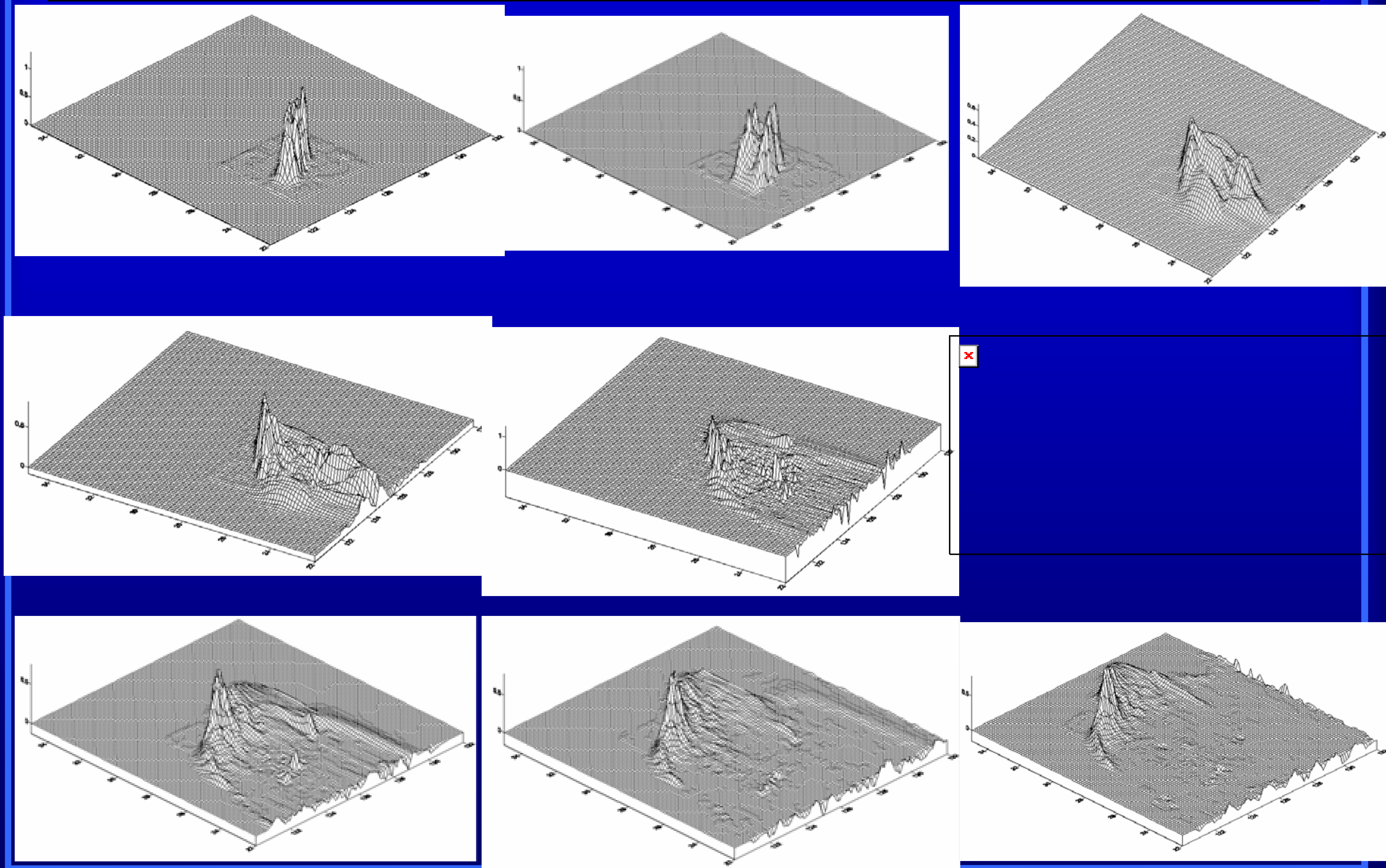
Its analytical solution:

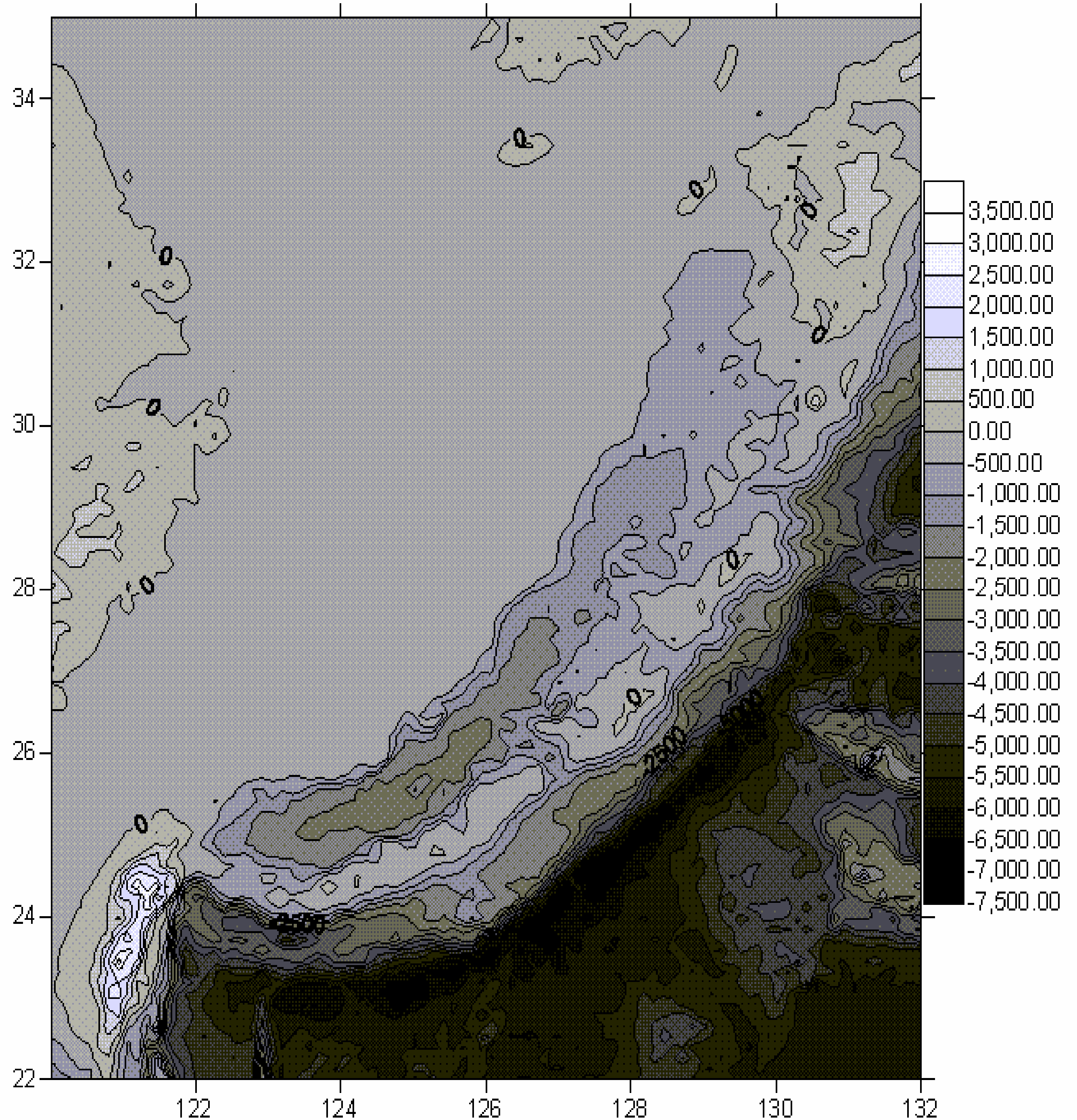
$$D_i(\vec{x},t) = \int_{-\infty}^{+\infty} d\tau \iint_{\Sigma} [D_j(\vec{\xi},t)] c_{jkpq} \upsilon_k G_{ip,q}(\vec{x},t;\vec{\xi},\tau) d\Sigma(\vec{\xi})$$

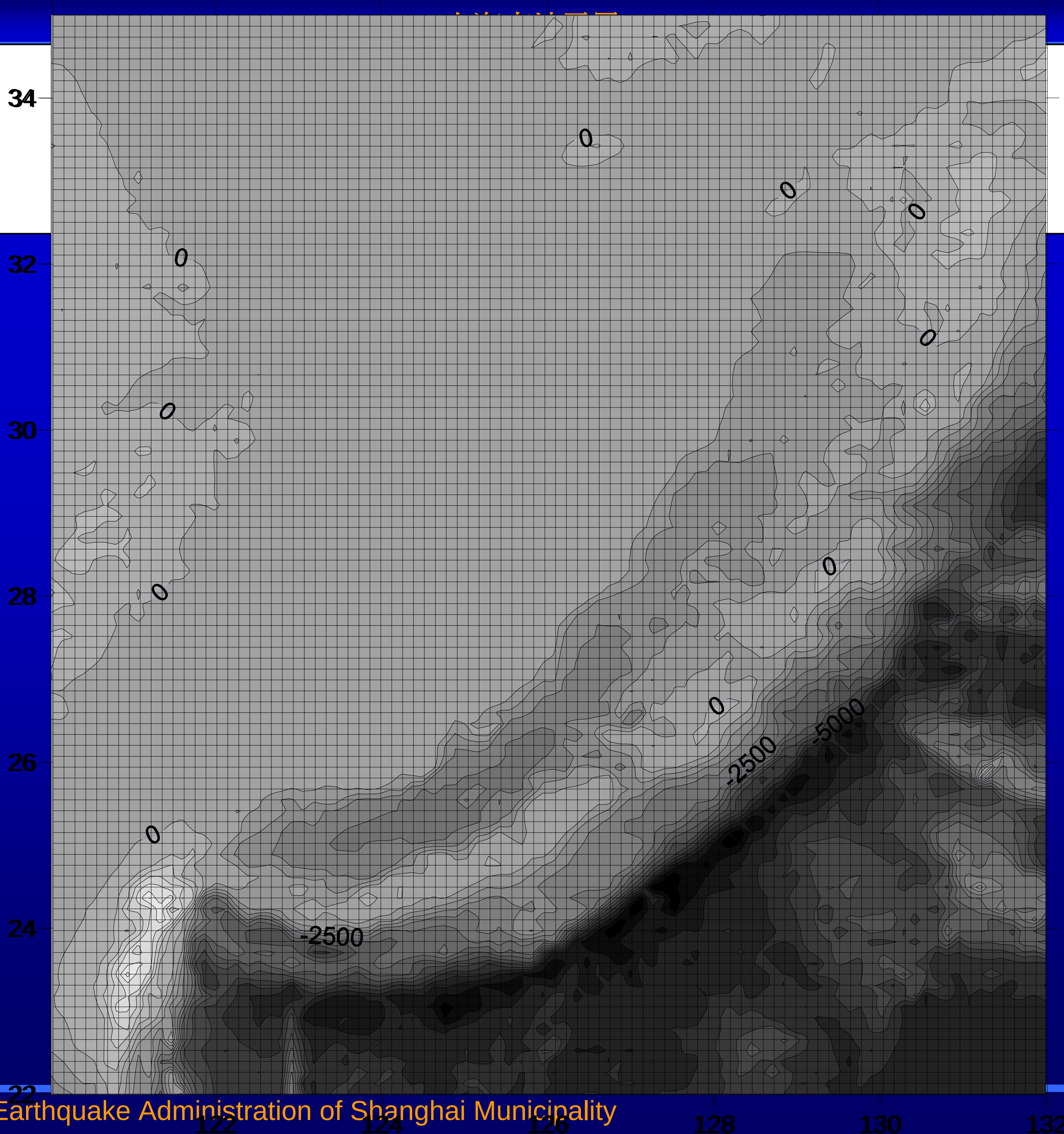
Where, $D_i(\vec{x},t)$ the seafloor uplift displacement, $D_j(\vec{\xi},t)$ the earthquake dislocation, υ_k the dislocation area normal $\vec{n}$ cosine, $G_{ip,q}(\vec{x},t;\vec{\xi},\tau)$ the green function derivative of vector from $\vec{\xi}$ to $\vec{x}$.

In general, we regard the seafloor vertical displacement as the initial surface displacement. This formula can be regarded as the initial calculation condition of tsunami.

依次200s 1000s 3000s 4000s 8000s 10000s 12000s 18000s 24000s

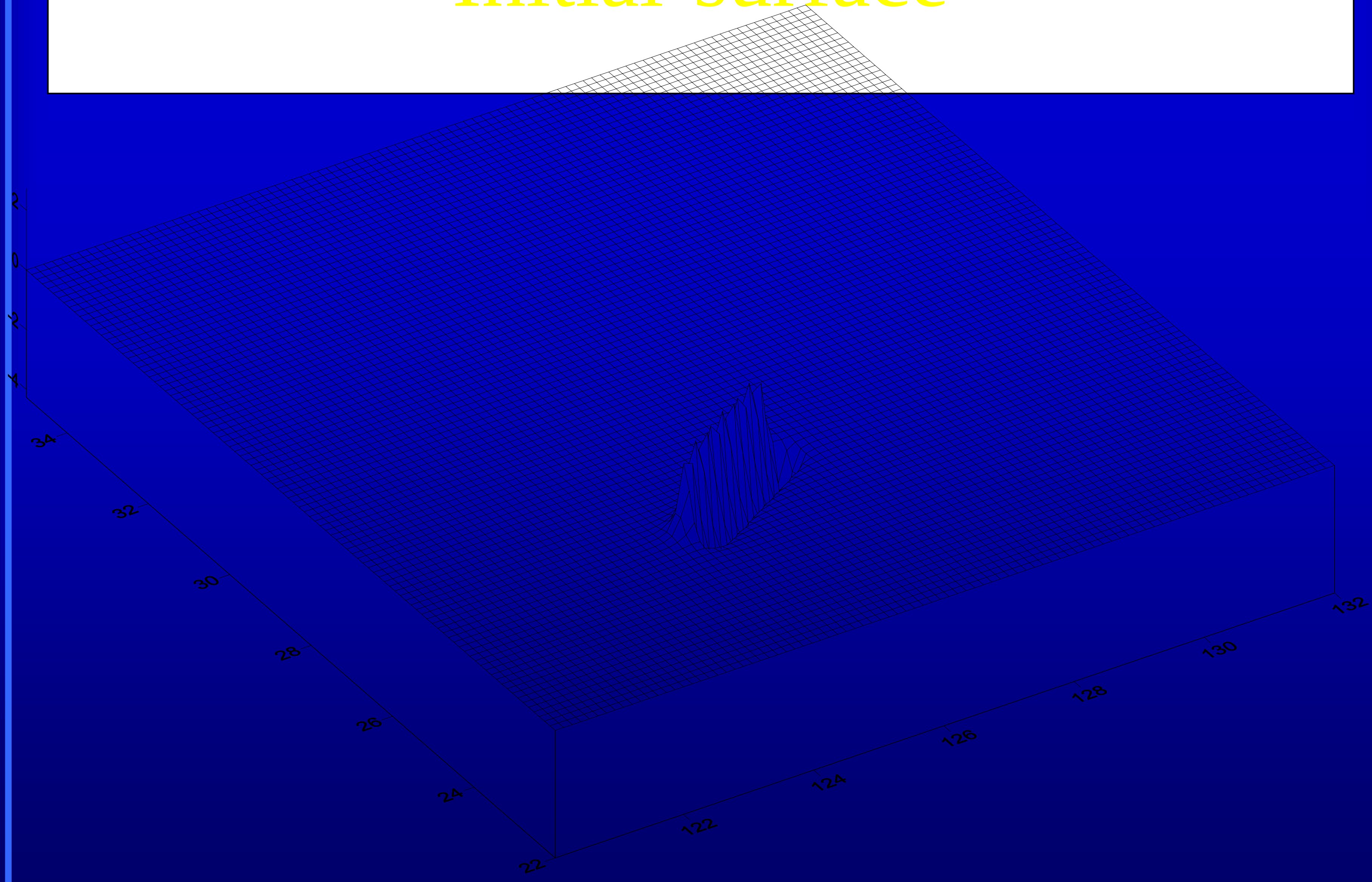



34
32
30
28
26
24
22
122
124
126
128
130
132
0
2500
3,500.00
3,000.00
2,500.00
2,000.00
1,500.00
1,000.00
500.00
0.00
-500.00
-1,000.00
-1,500.00
-2,000.00
-2,500.00
-3,000.00
-3,500.00
-4,000.00
-4,500.00
-5,000.00
-5,500.00
-6,000.00
-6,500.00
-7,000.00
-7,500.00



Earthquake Administration of Shanghai Municipality

Initial-surface



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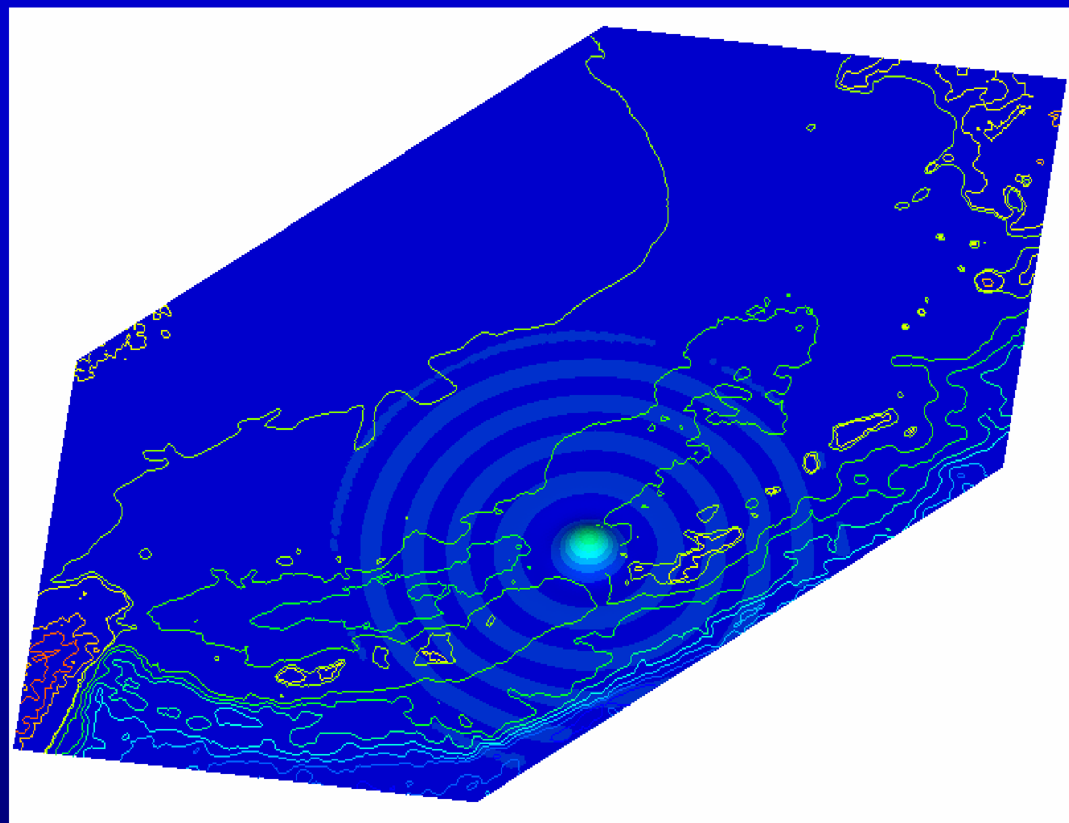
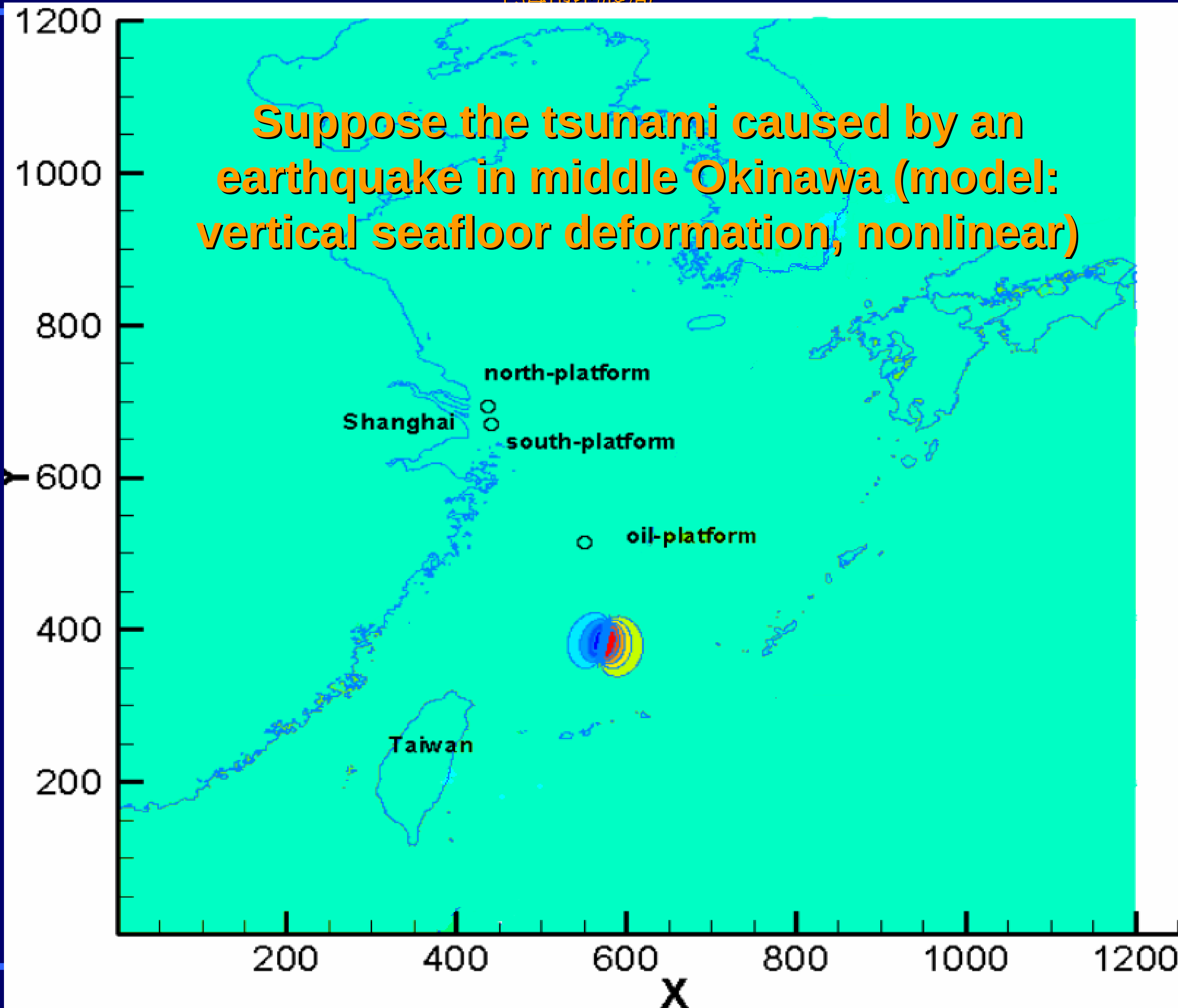
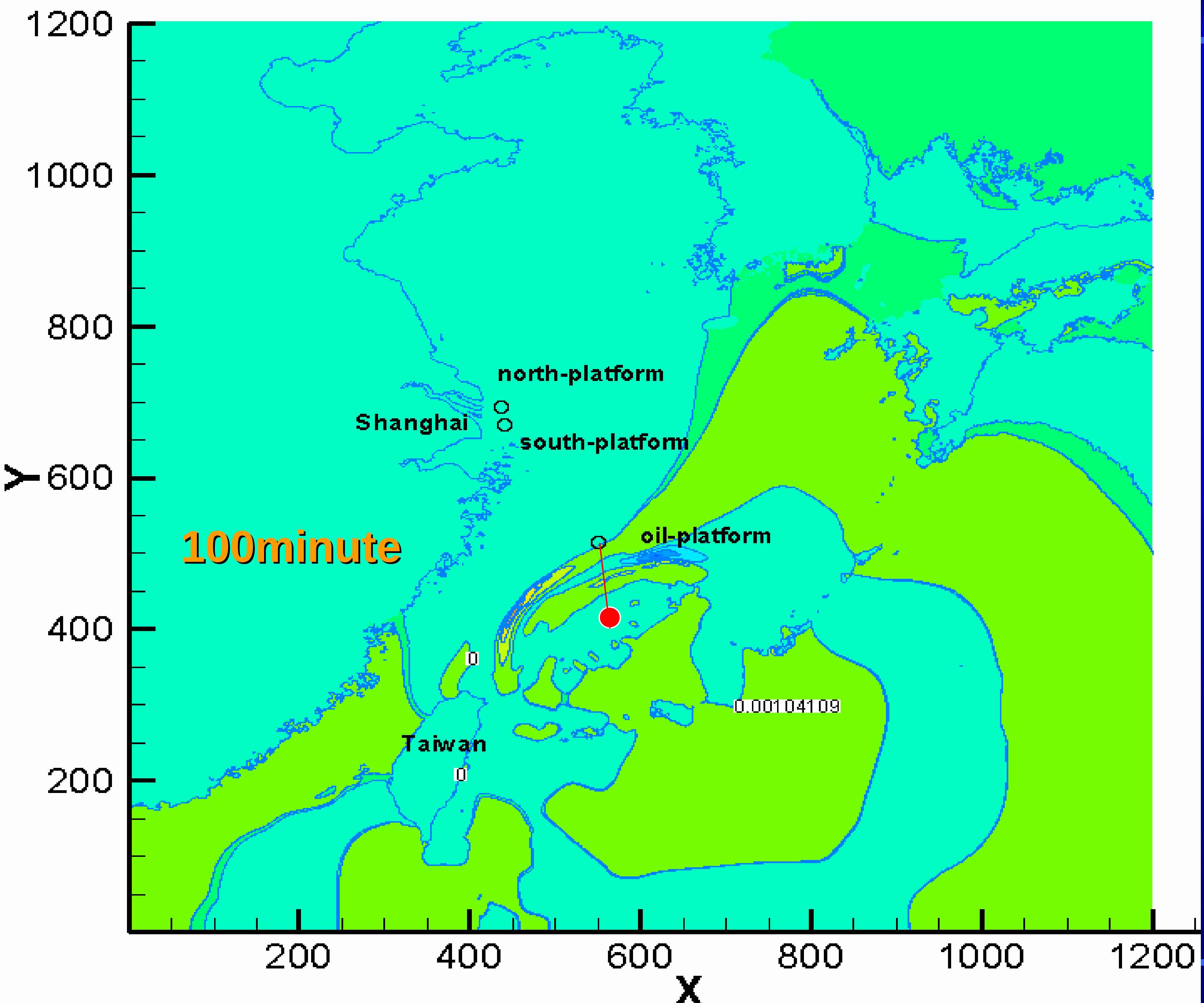
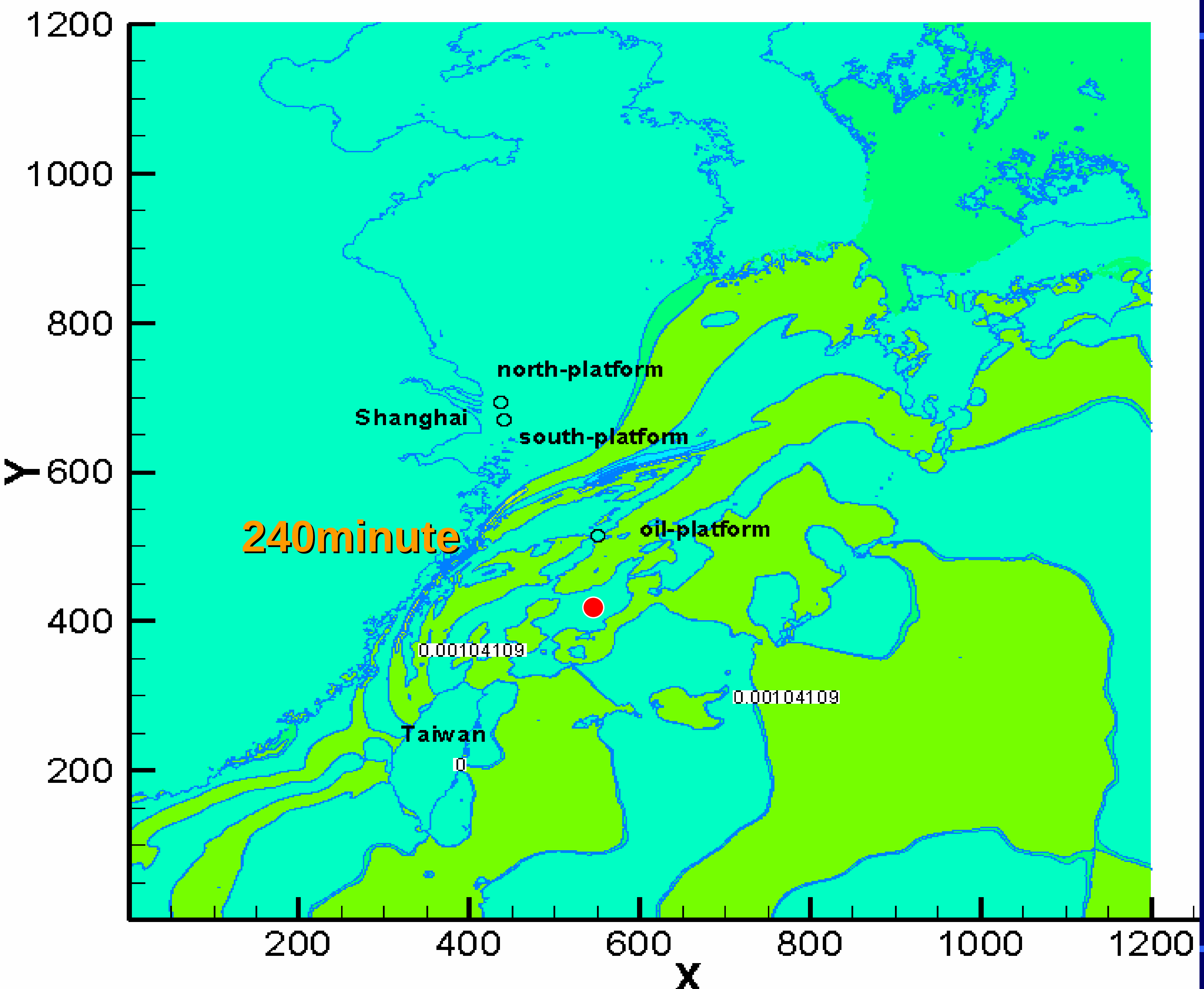


Suppose a tsunami caused by an earthquake in middle Okinawa Trough

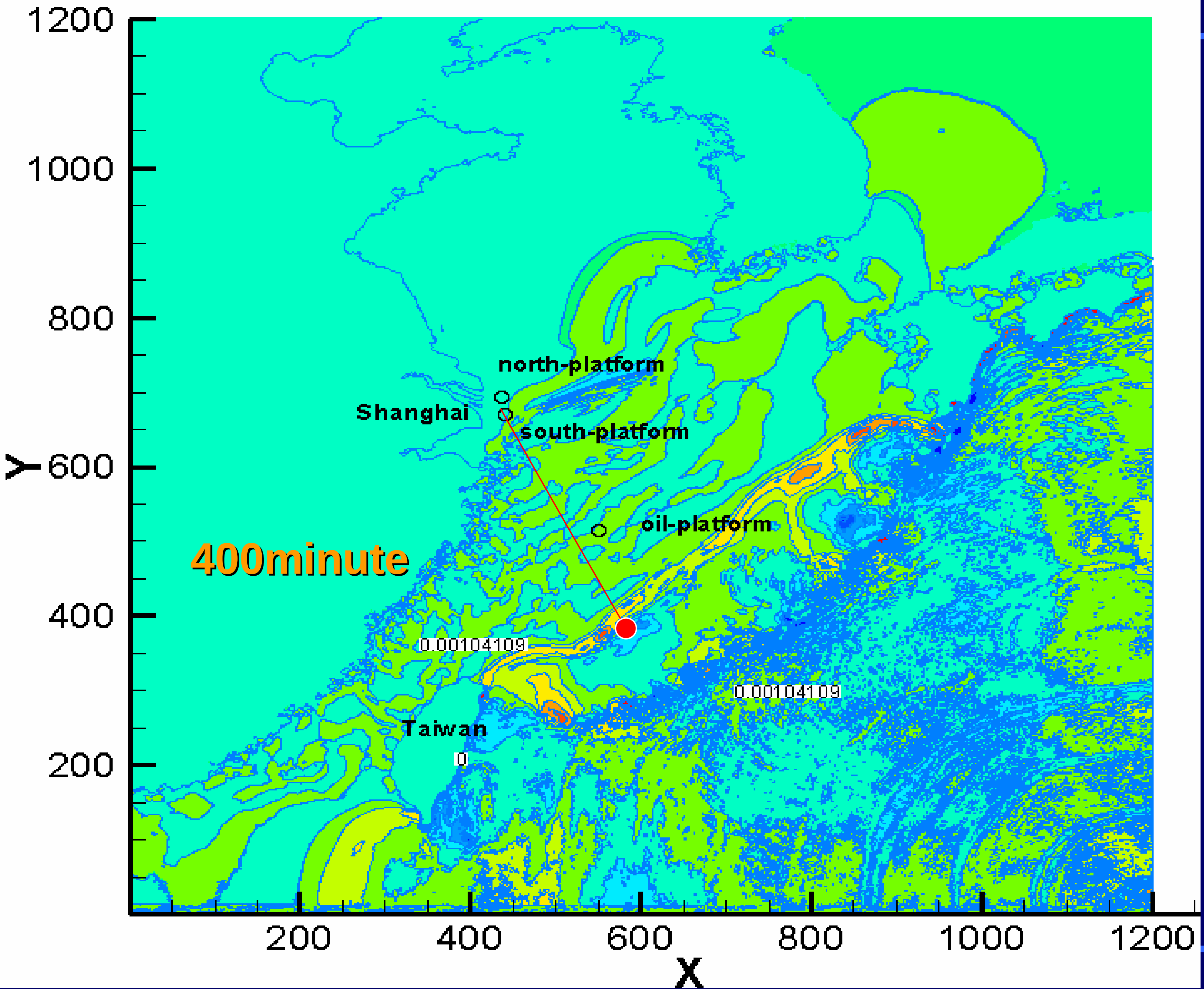
Suppose the tsunami caused by an earthquake in middle Okinawa (model: vertical seafloor deformation, nonlinear)



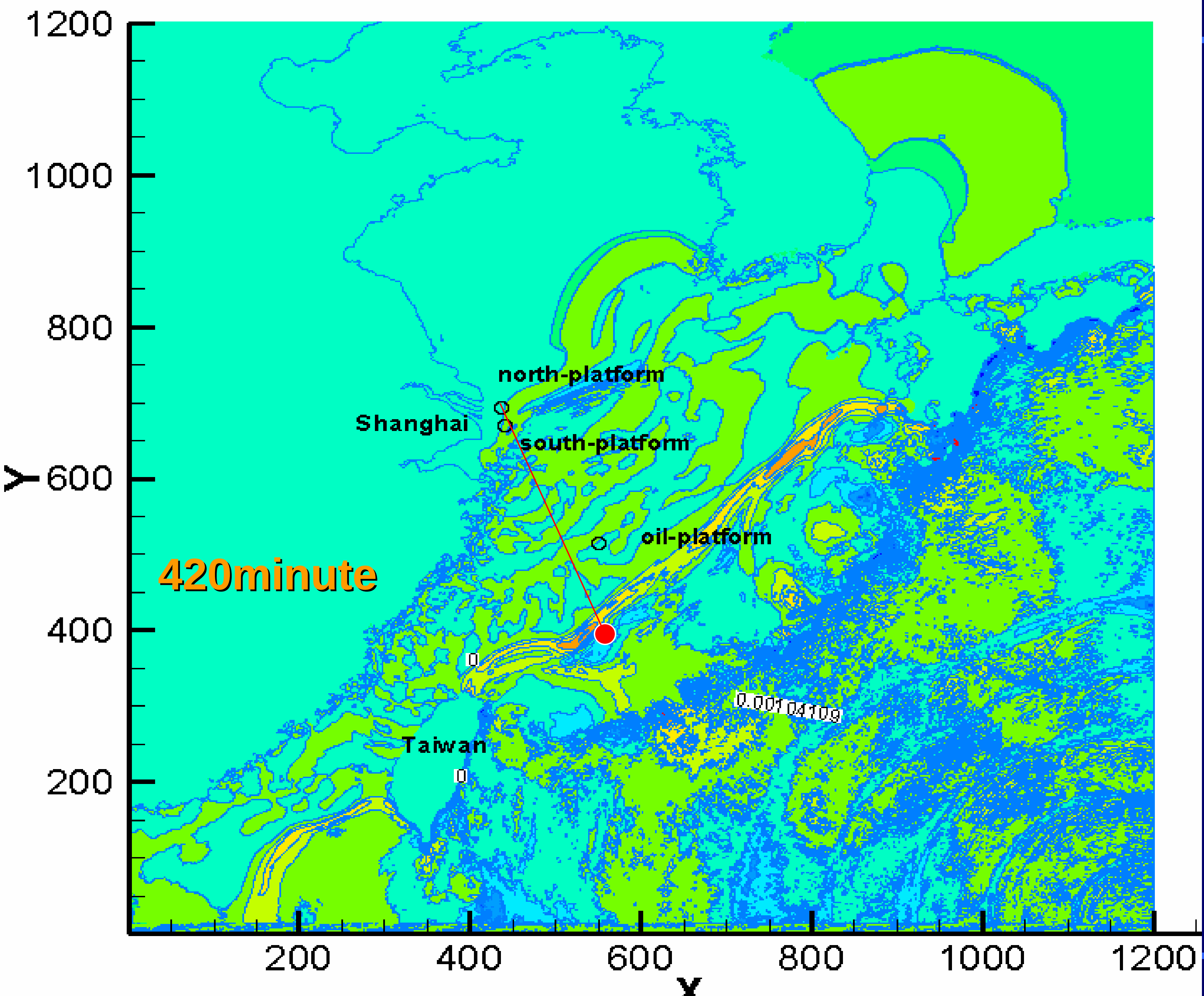

1200
1000
800
600
400
200
Y
200
400
600
800
1000
1200
X
north-platform
Shanghai
south-platform
oil-platform
100minute
0
0.00104109
Taiwan
0

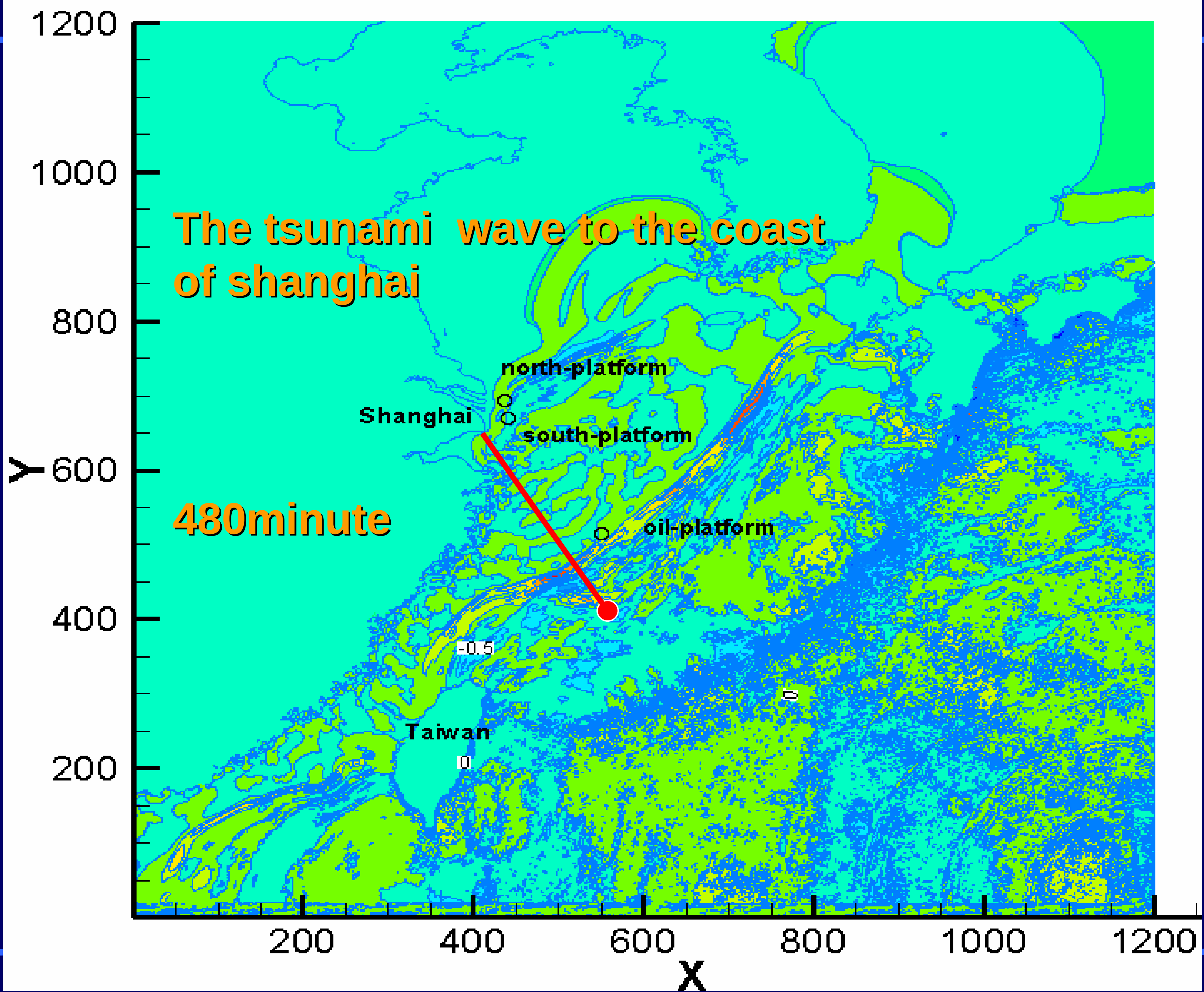


1200
1000
800
600
400
200
Y
200
400
600
800
1000
1200
X
north-platform
Shanghai
south-platform
240minute
oil-platform
0.00104109
0.00104109
Taiwan
0



1200
1000
800
Y 600
400
200
200
400
600
800
1000
1200
X
north-platform
Shanghai
south-platform
oil-platform
400minute
0.00104109
0.00104109
Taiwan
0


420minute
north-platform
Shanghai
south-platform
oil-platform
Taiwan
0
0
0.00104109
1200
1000
800
600
400
200
Y
200
400
600
800
1000
1200
X



The tsunami wave to the coast of shanghai
480minute
north-platform
Shanghai
south-platform
oil-platform
-0.5
Taiwan
0
1200
1000
800
600
400
200
Y
200
400
600
800
1000
1200
X

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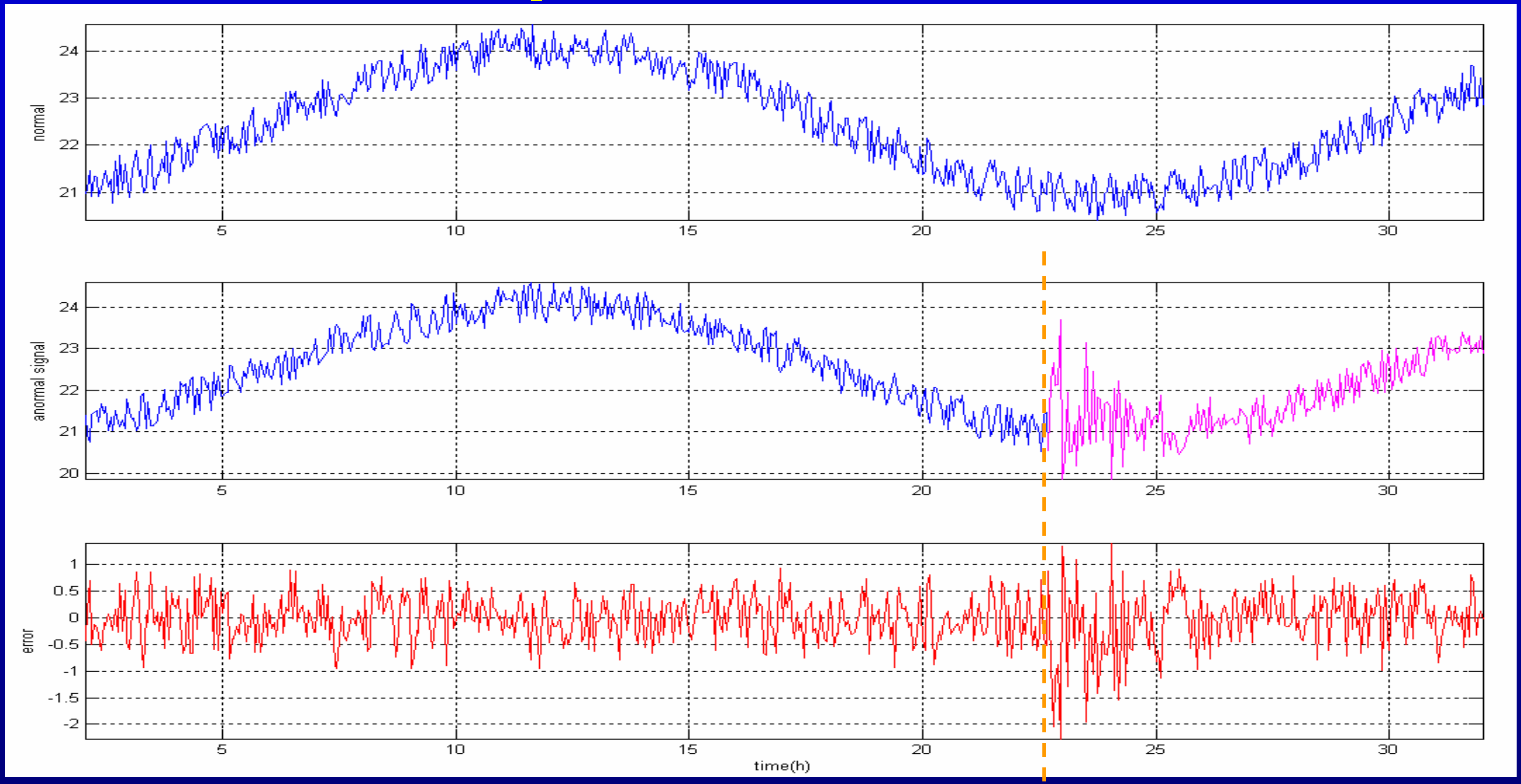
If all three stations receive the abnormal tides at the time calculated by the above slides, then the system determines the earthquake-tsunami occurrence.



Supposed tsunami data curve; Normal signal (above); Tsunami coming (middle); Difference of them (below)

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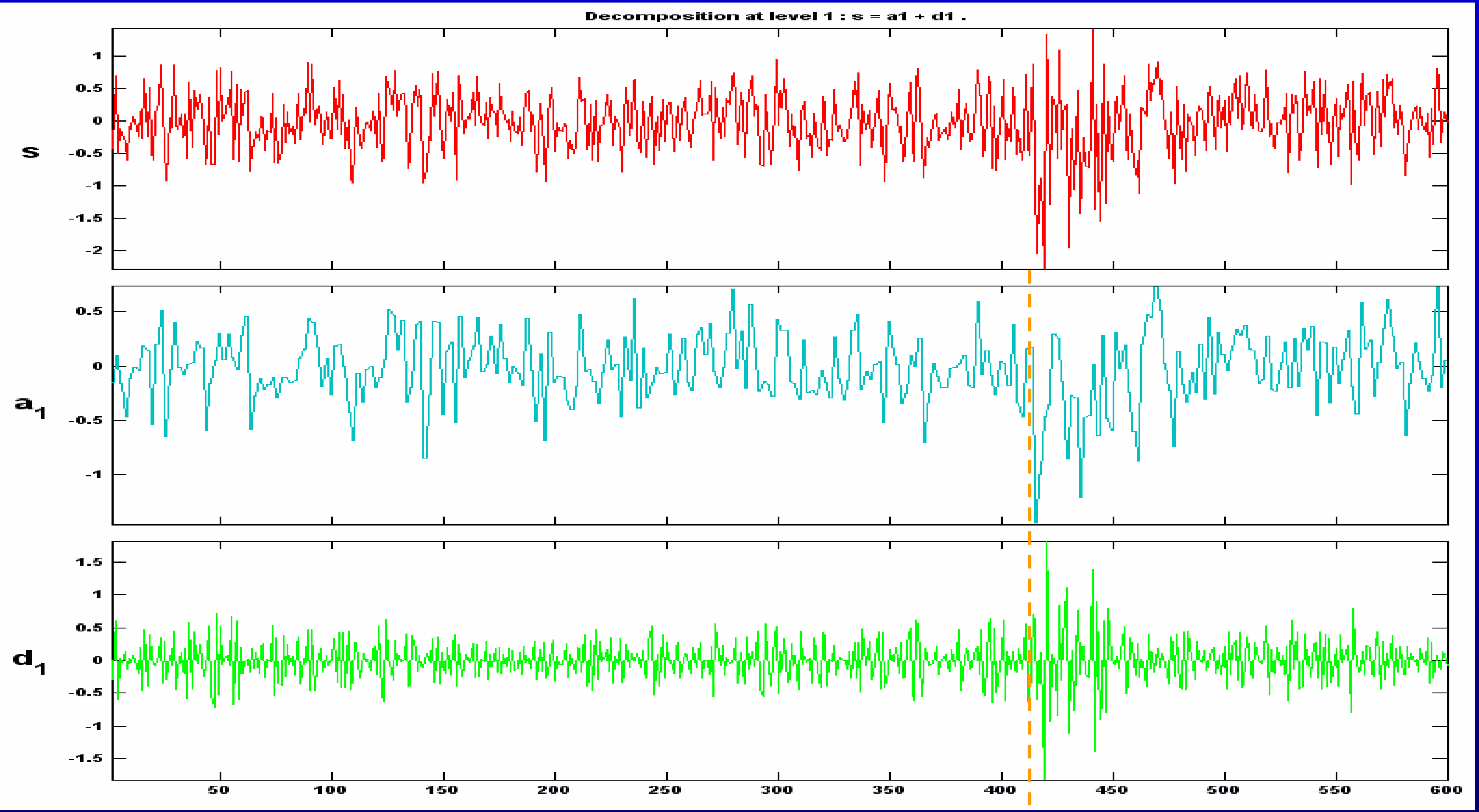

The wavelet analysis of errors; Errors (Difference of them in fig,above); The low frequent component of decomposition (middle); The high frequent component of decomposition (below)

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Shanghai Submarine Earthquake Monitoring and Tsunami Early warning Project

- Unsolved problem

If a tsunami is going to attack Shanghai and all three stations receive the abnormal tides at the exactly calculated time, we have no idea how much the abnormal gauge needed.

Also, we have no practical data from this area to compare with modeling data, but this is very important for us to give a tsunami early warning correctly.

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Next step

We plan to install various marine geophysical, hydrologic, meteorological instruments, so as to develop the ocean bottom seismic stations into the comprehensive marine science observation platforms

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Thank you