# This event was documented by multiple literatures with multiple languages

1. 《淡水廳志》:「同治六年，冬十一月，地大震。......二十三日，**雞籠頭、金包里沿海，山傾地裂，海水暴漲**，屋宇傾壞，溺數百人」

2. 《字林西報》:「**棕櫚島和基隆島之間的海面上有湮霧。海港內的水湧向海外，致使遠至閻王岩的地方有幾秒鐘成為無水地帶**，所有的東西都被退去的海水捲走了，然後海水又形成兩個大浪湧回，將舢板和上面的人淹沒，並把帆船擱淺在基隆對岸。海水也不像往常那樣清澈，而是變得又黃又渾。大量的魚被沖到岸上。海水退出港口時，有一個男人從一條帆船上下來，但是在他到達岸上之前，就被回湧的海水淹沒了。無數的煤船傾覆沈沒。一條深埋在沙中多年的舊帆船沖上了岸」

3. 《1881年通商各關貿易報告》:「1867年地震發生在12月18日，海水從基隆港傾瀉而出，留下了一個乾涸的泊位，但不幾秒鐘，帶著兩個浪頭的海水又洶湧而回，淹沒了舢板和人口。**基隆、金包里及巴其那等城鎮部份泡為廢墟。淡水遭到嚴重破壞，好幾百人死亡**」

4. 《同治年間於金包里附近之地變》「初時，南邊的硫磺山發出如雷的聲響，聲音由南向北傳遞，繼而地面開始左右劇烈搖晃，約五分鐘後，海面開始暴退，三十分鐘後，海底約裸露四、五町之多，一個鐘頭後，**海水暴漲，發生海嘯。磺港、水尾港附近皆受波及，海水暴升兩丈高，金包里街、八斗子均被海水淹沒**」

5. From Far Formosa和The Island of Formosa中亦有描述到當日地震和海嘯之情境，但無更近一步之較具體之海嘯物理現象描述。

# Historical records

- 1867 December
- Earthquakes
- Smoke observed
- Tsunami
  - 6~7m tsunami height
  - seabed exposed
- Tsunami impact at Jinshan and Keelung
- Hundreds death toll

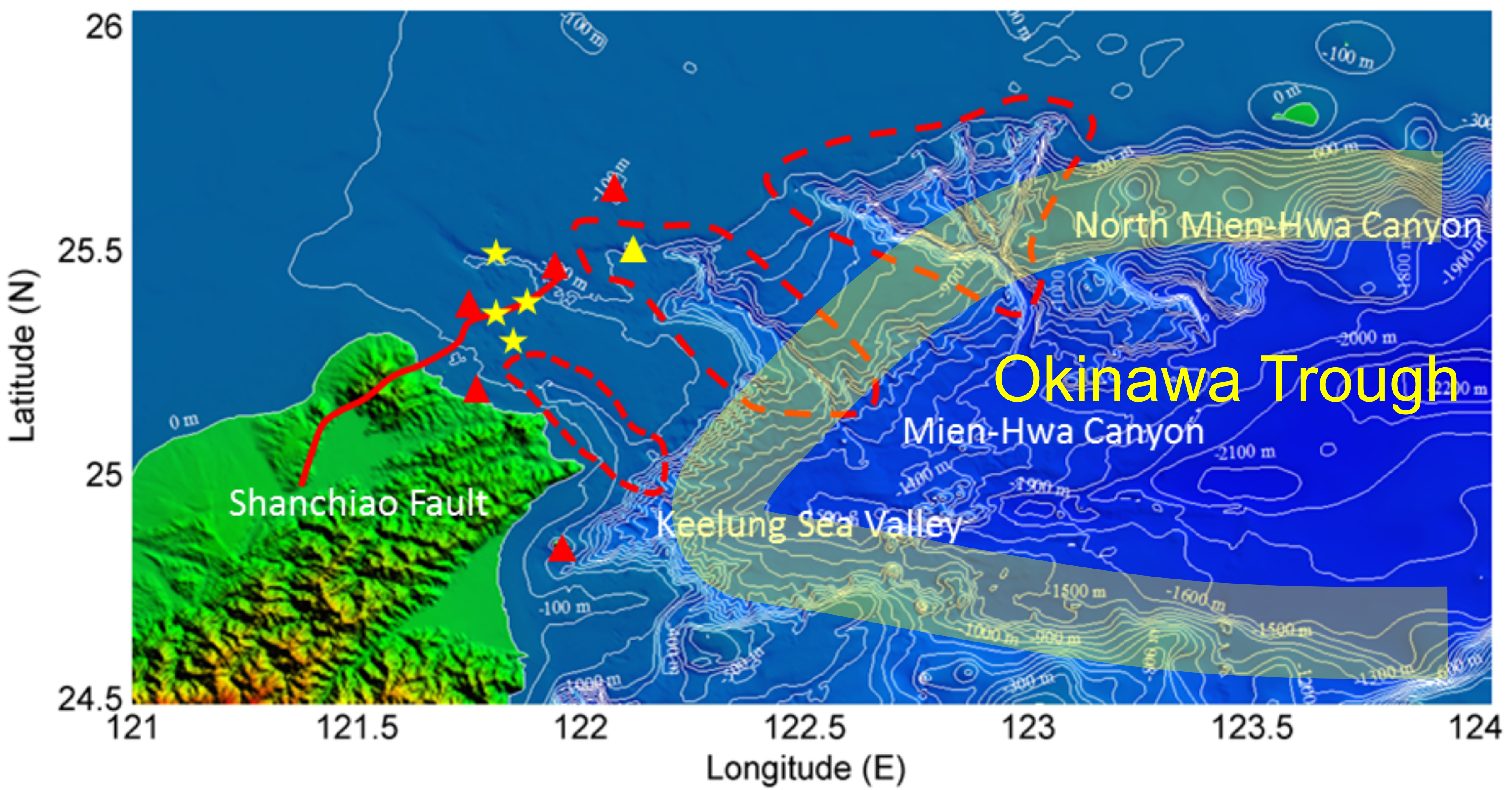


# Earthquake magnitudes proposed by previous studies were Mw 6.2~Mw 7.2

However, the simulated tsunami heights are less than 0.5m

| | Longitude | Latitude | Magnitude |
|---|---|---|---|
| Lee et al., 1976 | 121.7 | 25.5 | Mw=6.2 |
| Hsu, 1981 | 121.8 | 25.2 | Mw=7.0 |
| Tsai, 1985 | 121.7 | 25.3 | Mw=7.0 |
| Ma and Lee, 1997 | 121.7 | 25.5 | Mw=6.9~7.2 |
| Lin, 2006 | 121.7 | 25.3 | Mw=7.0 |
| Cheng, 2013 | 121.91 | 25.34 | Mw=7.0 |

# Steep slope and volcanos are presented in the near-field region




: Volcano — : Fault — : Submarine canyon

: Erupted record volcano (Chen et al., 2005)

: Epicenters of previous studies (Lin et al., 2006, Zheng et al, 2011, Tsai et al., 1985 & Ma et al., 1997)

We are going to perform the scenario studies. However, there are numerous of scenarios if we considered possible slope angels, lengths, depth, and locations……etc.

We want to develop a method that can help us analyzing the potential tsunami sources systemically.

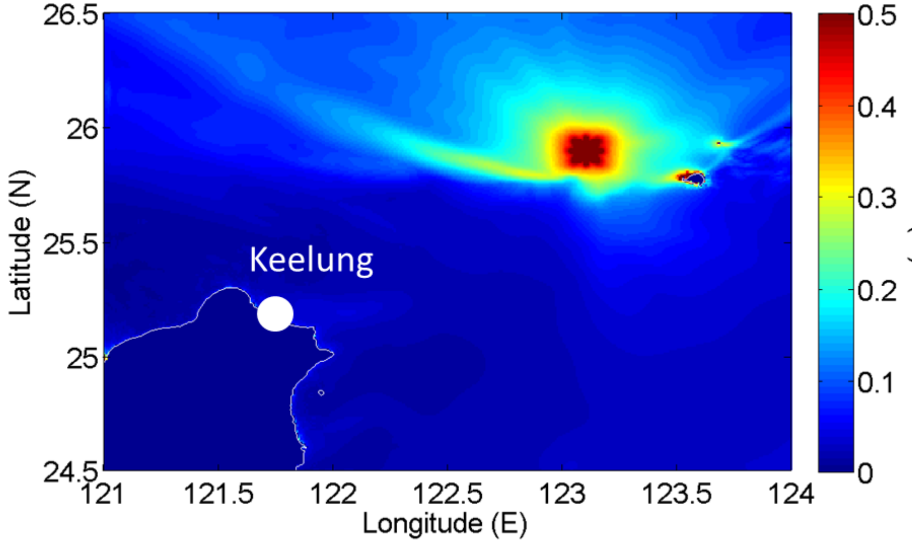
So, instead of simulating all possible scenarios form the sources to the study area, we want to trace back from the study area to the sources.

# Can we identify a potential tsunami source based on the distance in between?

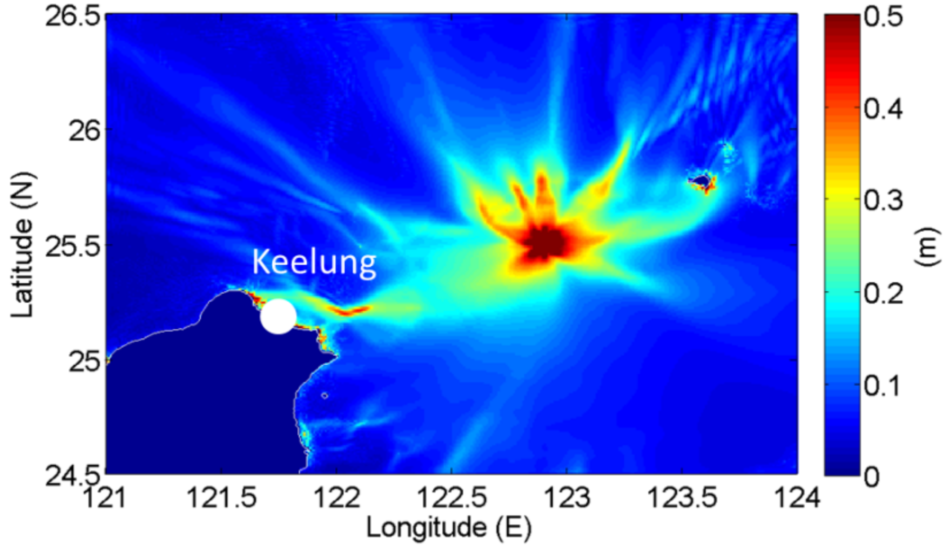
# Maybe yes, but risky.

# Within 100 km, two sources present different results.

海嘯源A




海嘯源B

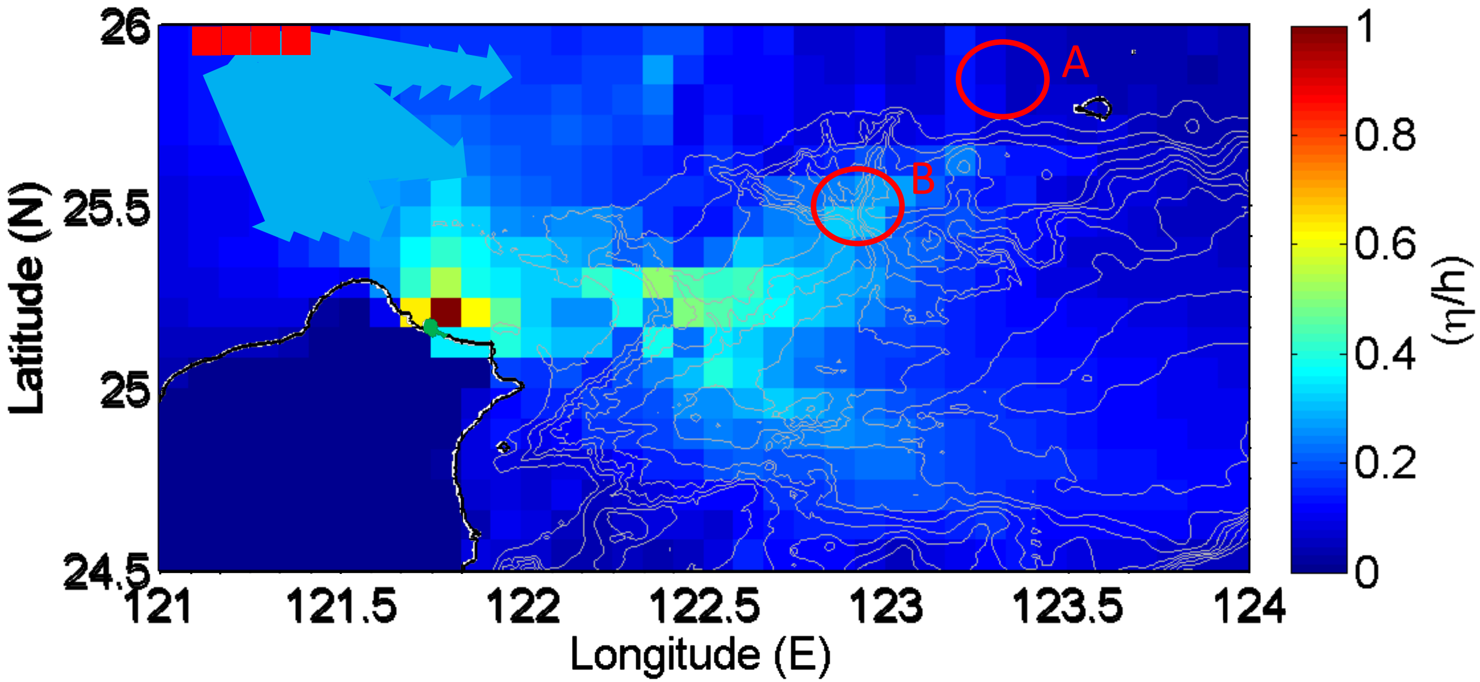



本案例中，海嘯源A與海嘯源B皆位於基隆港外海不遠處，然而其對基隆港之卻有極大差異。海嘯源A之能量主要朝北部傳遞，對基隆港幾乎無影響，然而海嘯源B之能量卻主要傳遞至基隆，對基隆港危害極大。

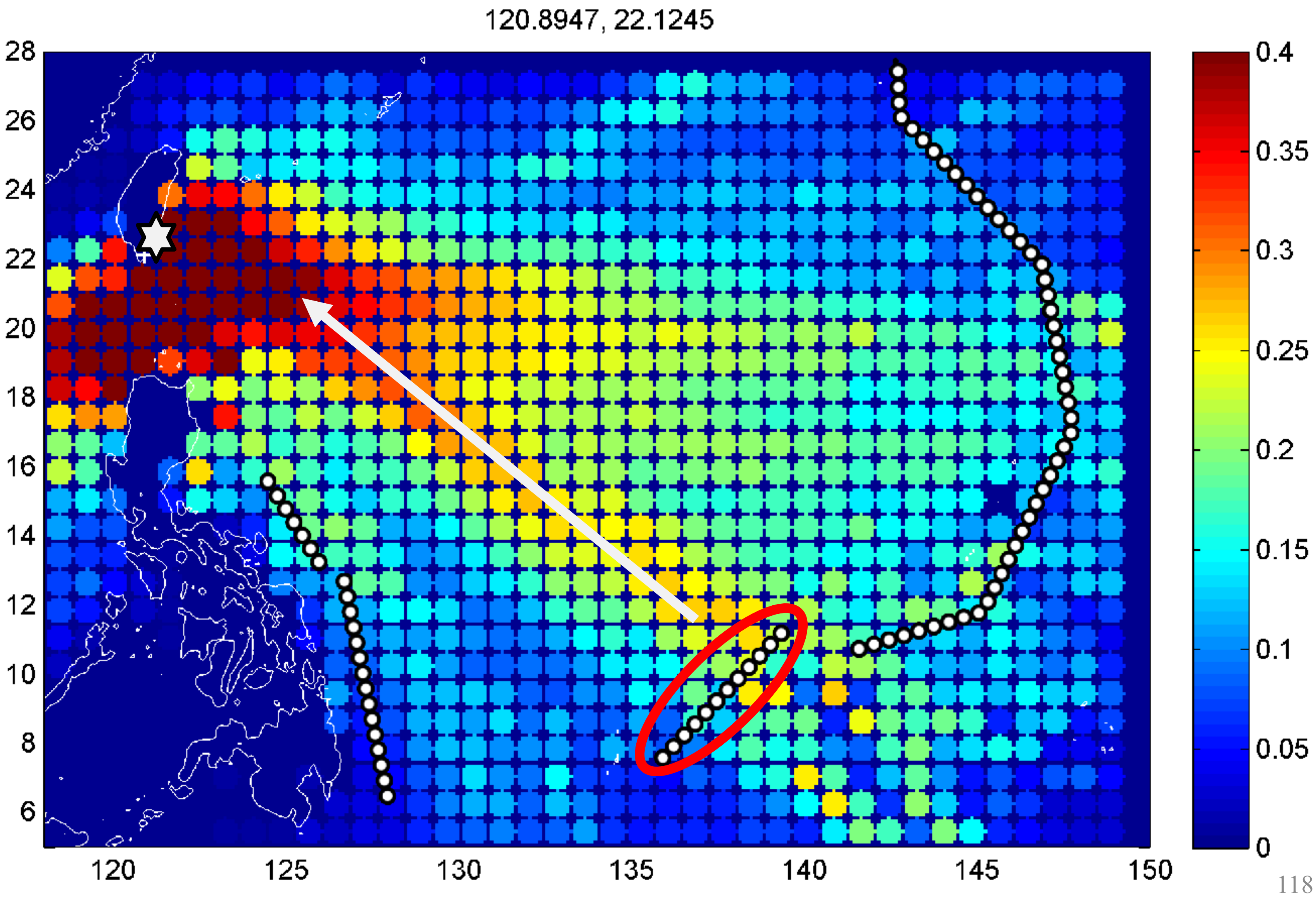
此案例突顯情境分析法之缺點，亦即有挂一漏萬之疑慮。

# Method of Impact Intensity Analysis (IIA)

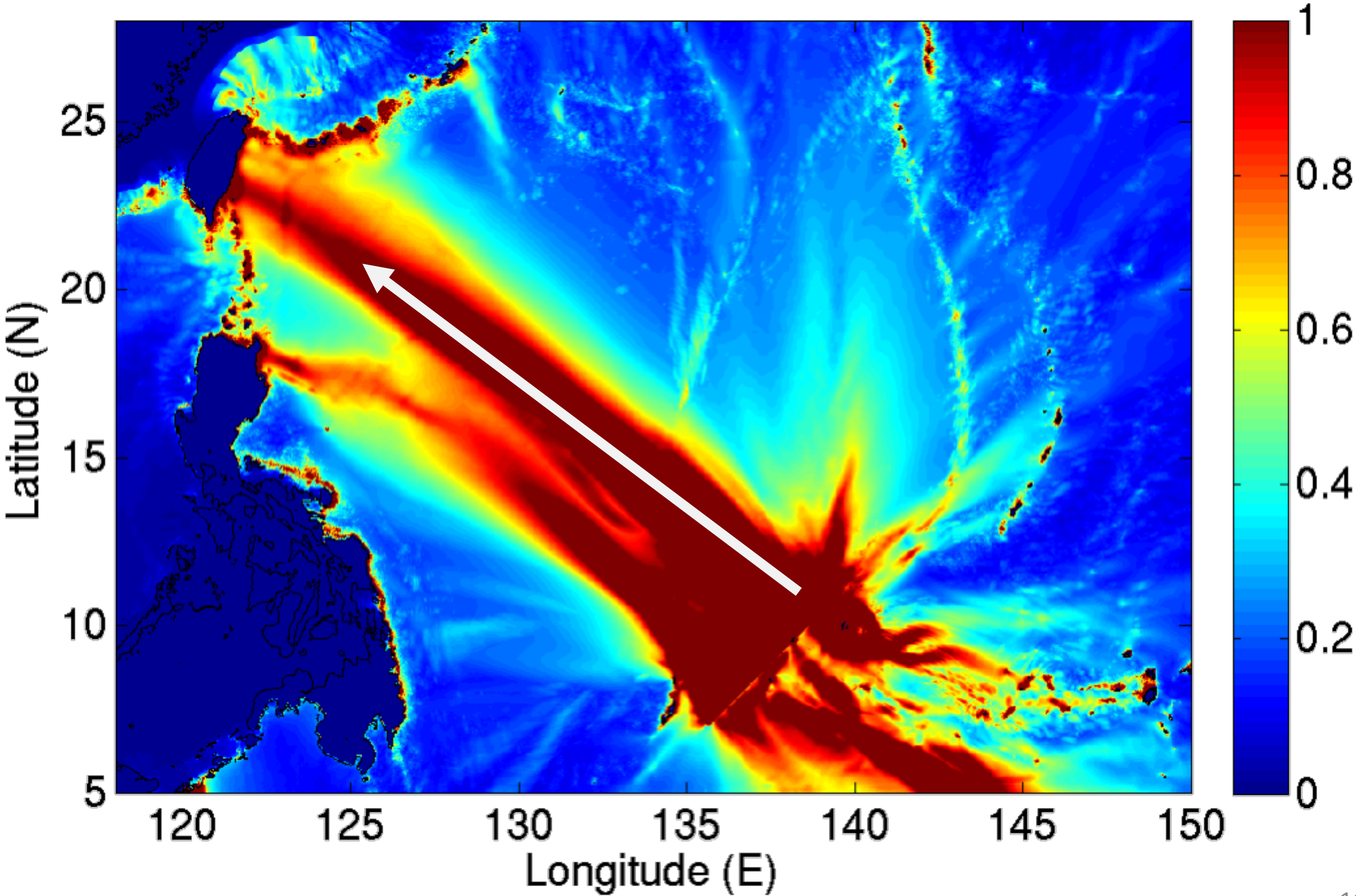
1. Discretized the computational domain into small uniform source regions
2. Calculate the wave propagation from each source region. (This requires high performance computation)
3. Record the maximum wave height (MWH) at the study area
4. Place the MWH value on the corresponding source region



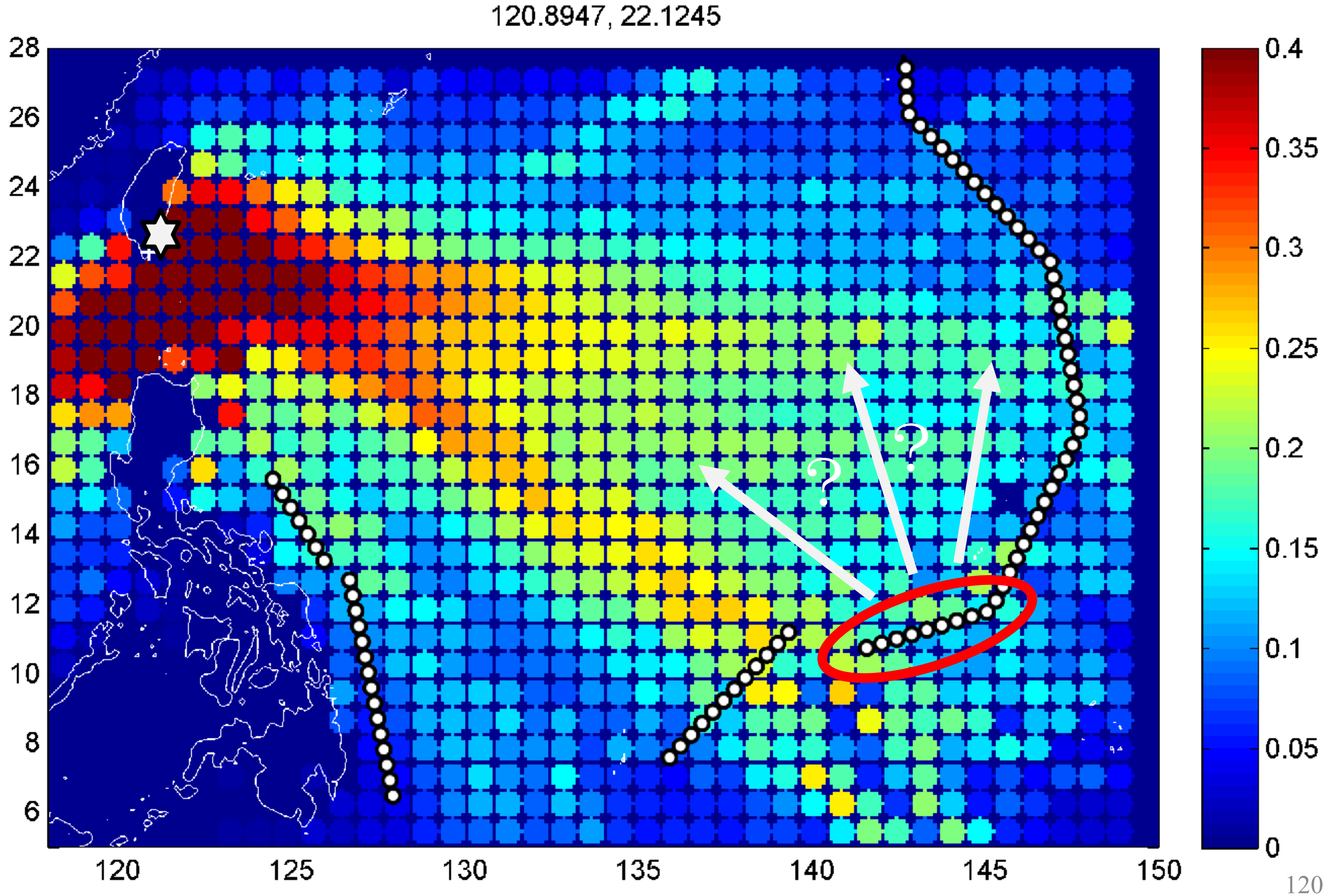
# IIA :九鵬 (22.124520, 120.894662)



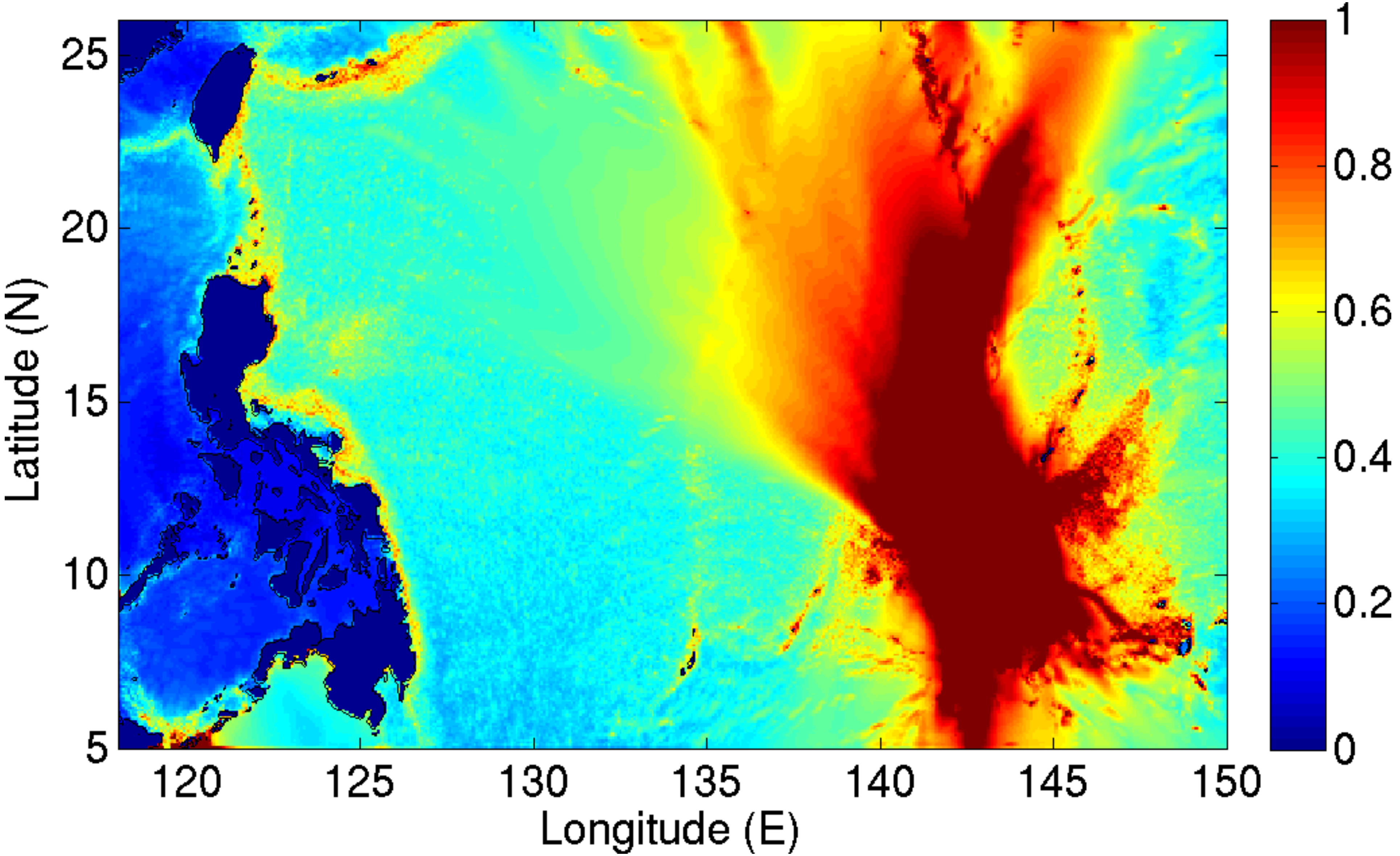
# T08, Yap Trench （亞普海溝）



# IIA :九鵬 (22.124520, 120.894662)

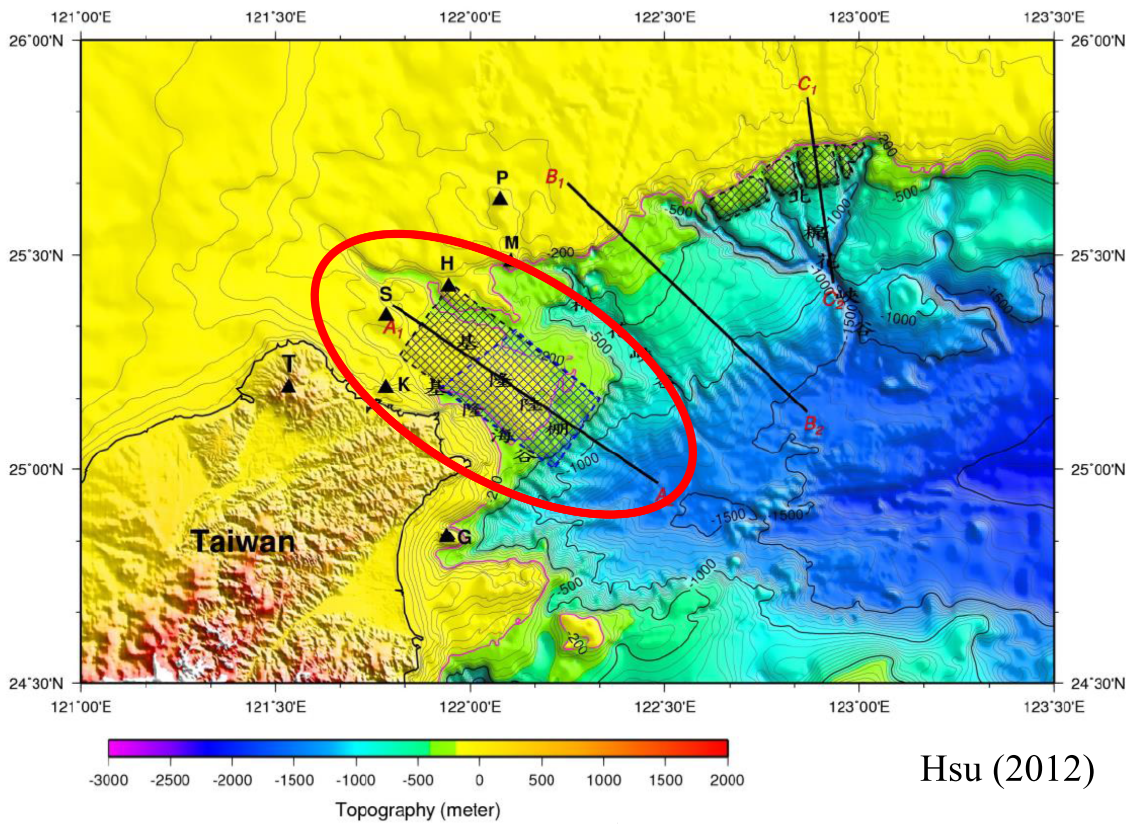


# 馬里亞納T09

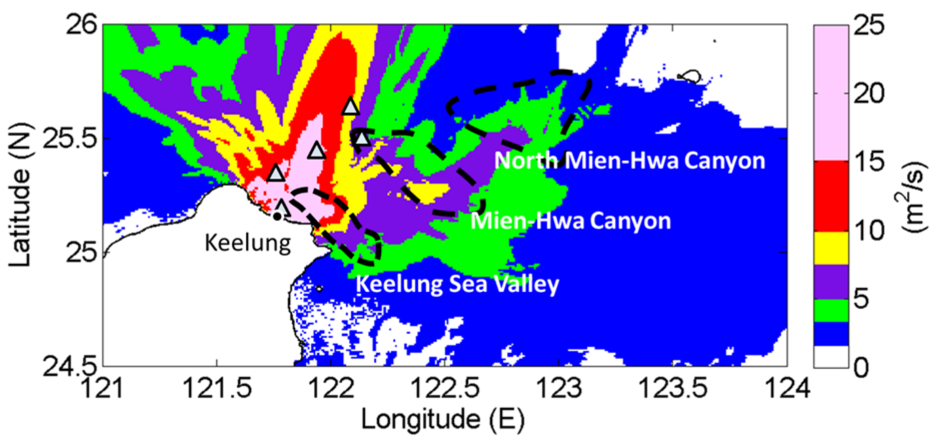


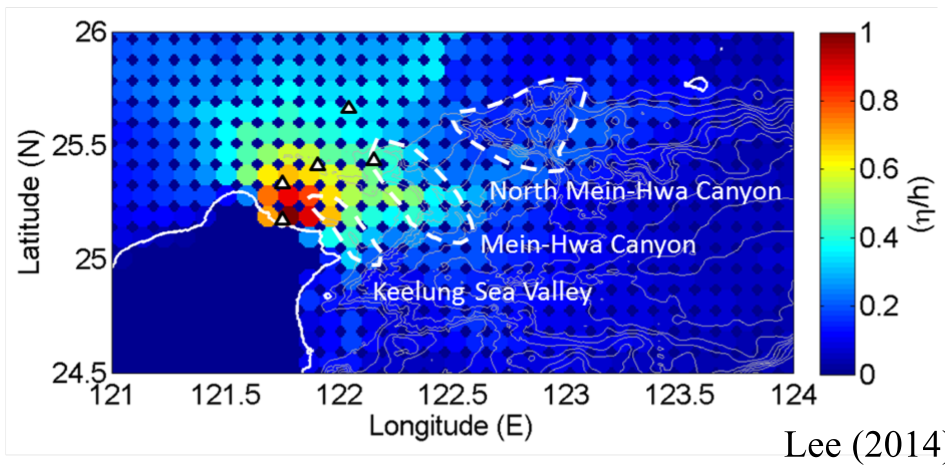
Latitude (N)
25
20
15
10
5
120
125
130
135
140
145
150
Longitude (E)
1
0.8
0.6
0.4
0.2
0

# 1867年基隆海嘯之還原與分析



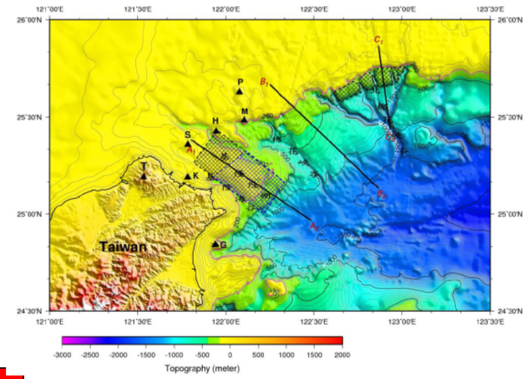

Hsu (2012)

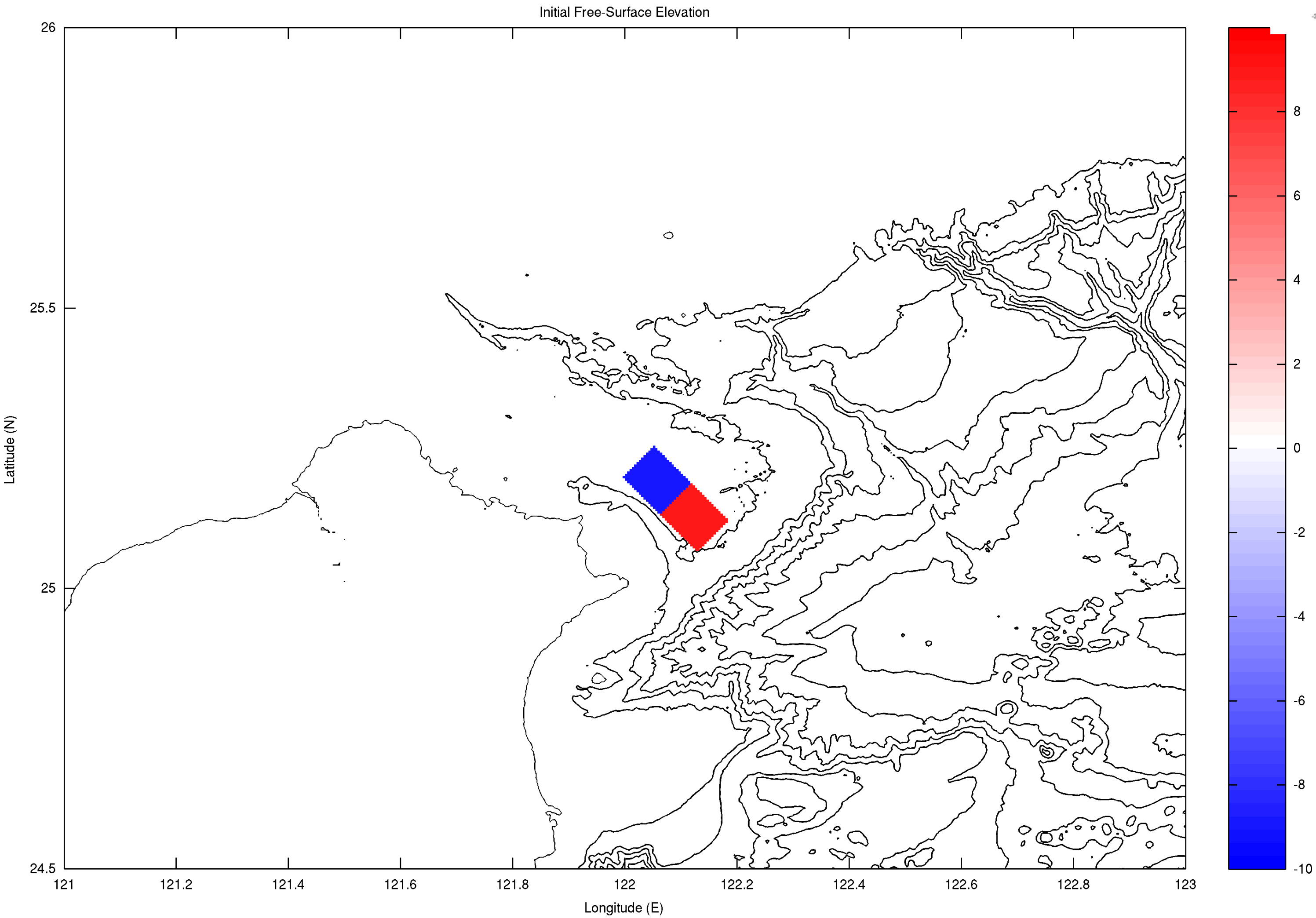


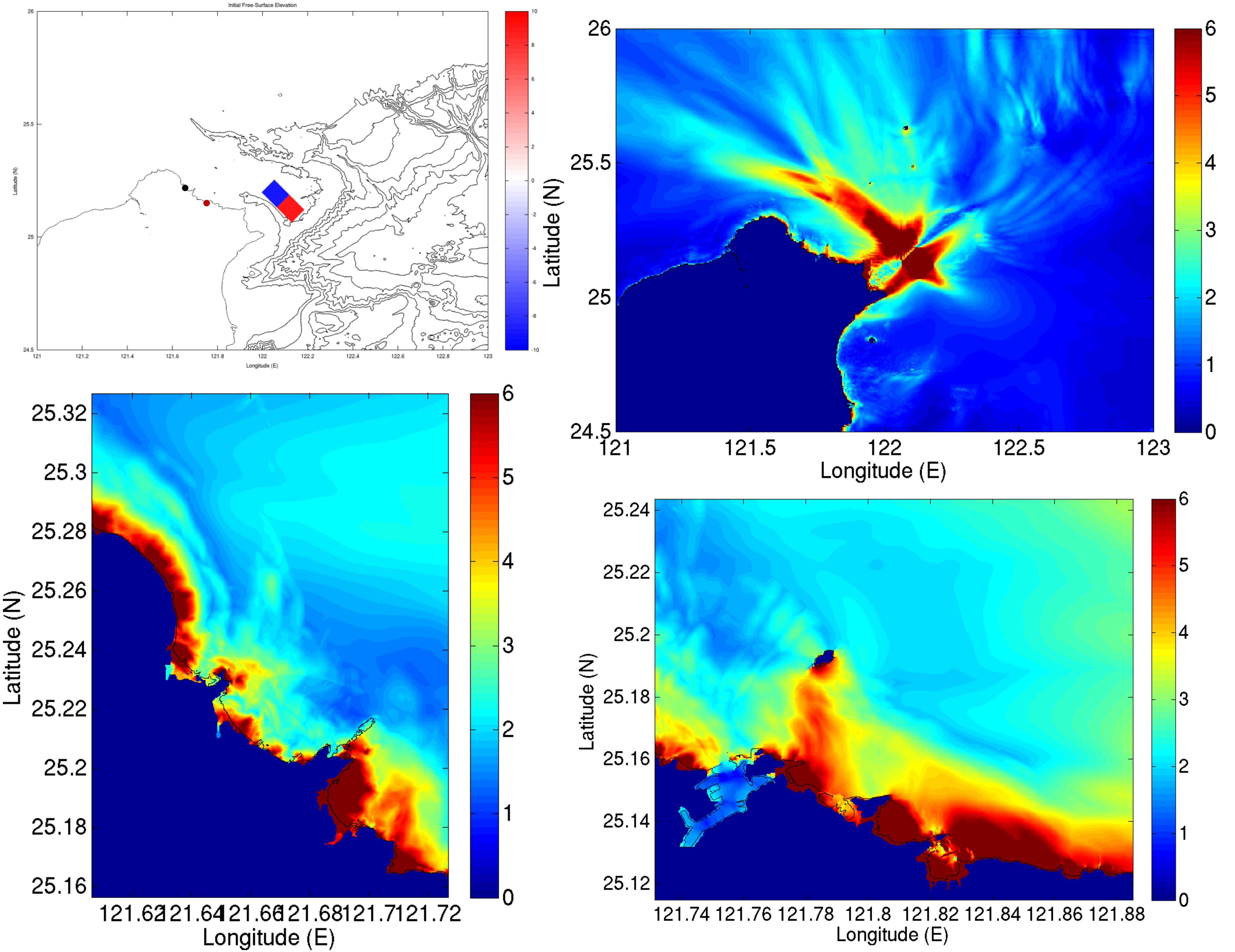

Lee (2014)

# 海底山崩 Case 2

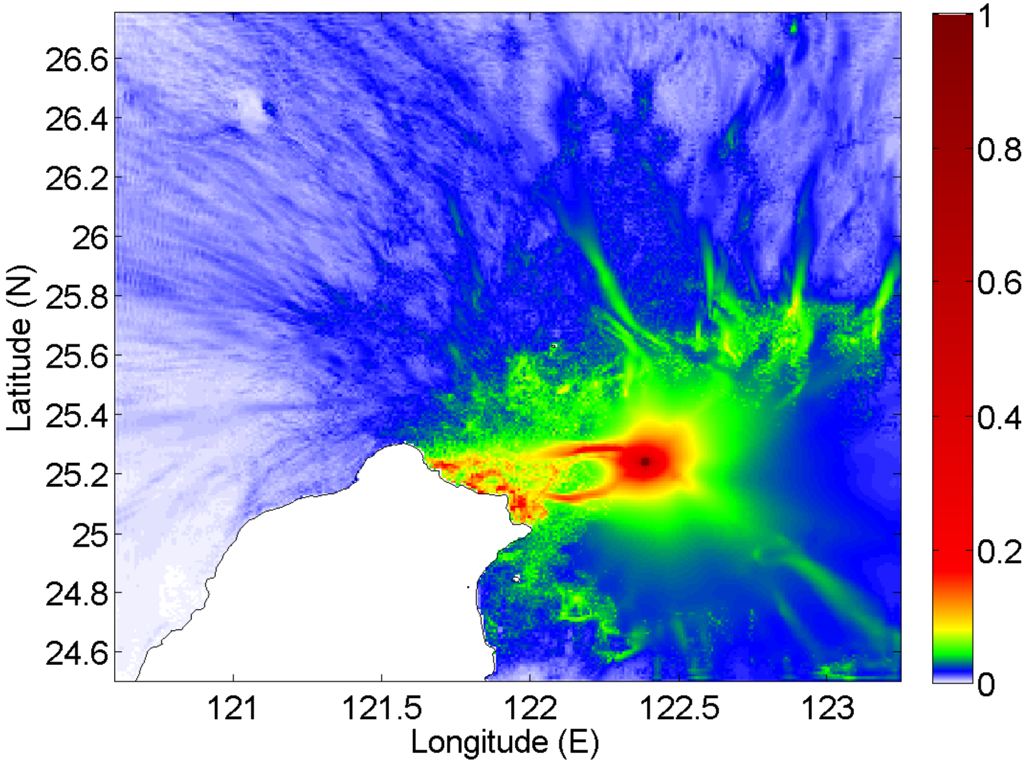



Length = 15 km
Width = 14 km

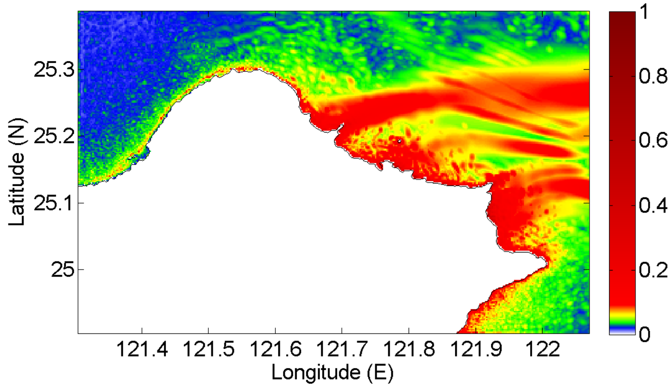

Initial Free-Surface Elevation
Latitude (N)
Longitude (E)
Latitude (N)
Longitude (E)
Latitude (N)
Longitude (E)
Latitude (N)
Longitude (E)

# 李俊叡模擬（中大水海所海嘯科學研究室）

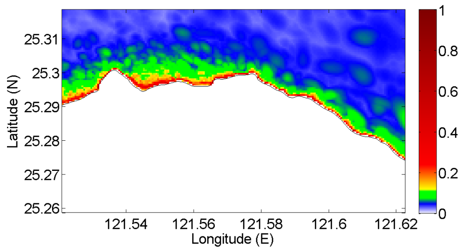



**潛在山崩位置B**

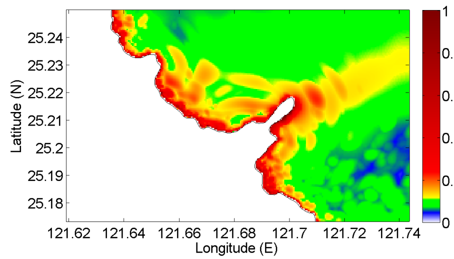
主要影響:貢寮、金山、基隆



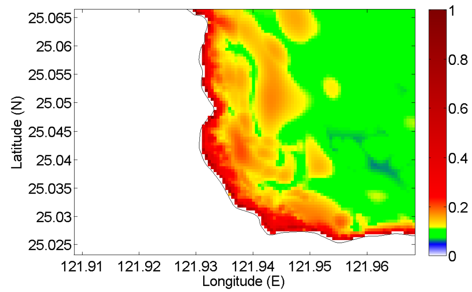

核一



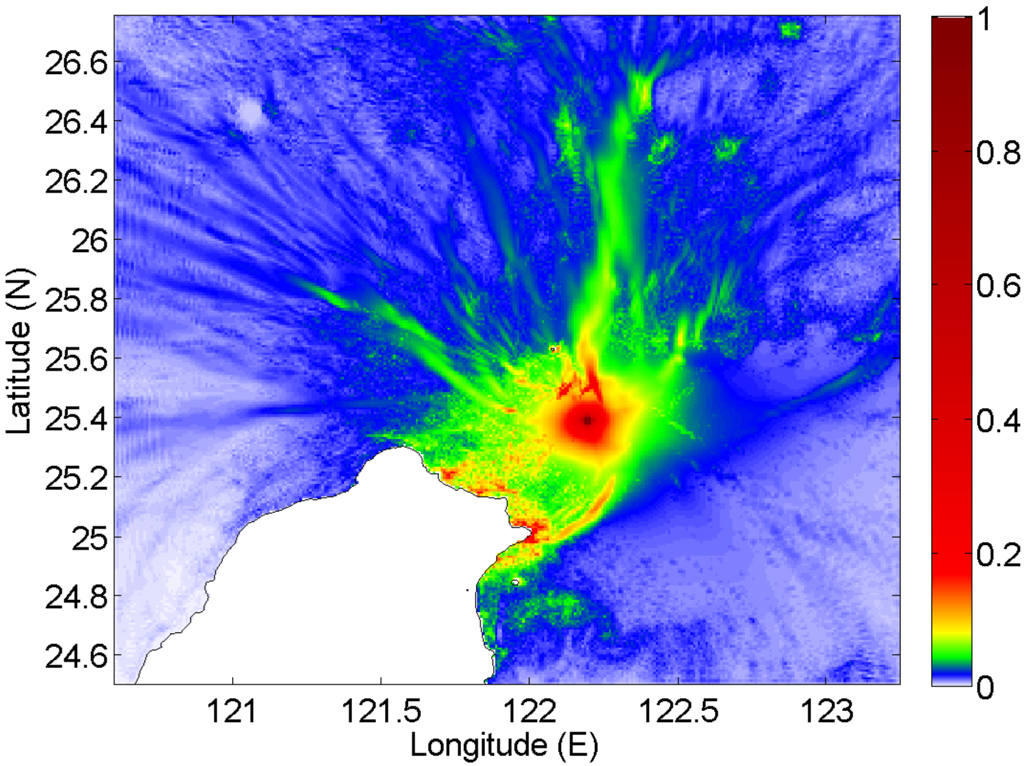

核二




核四

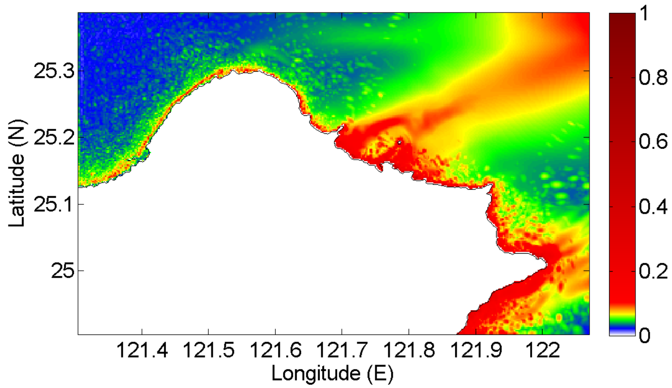


李俊叡模擬（中大水海所海嘯科學研究室）

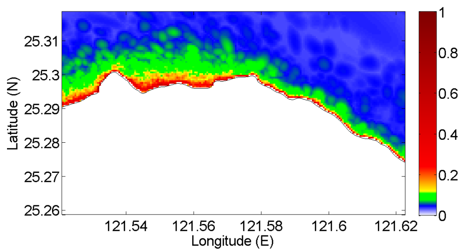



# 0801-04潛在火山

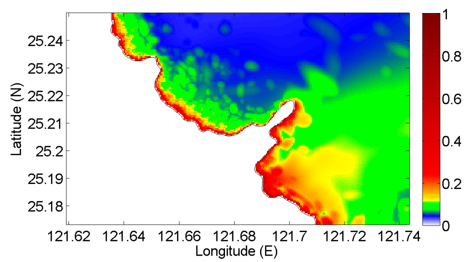
主要影響:貢寮、金山、基隆



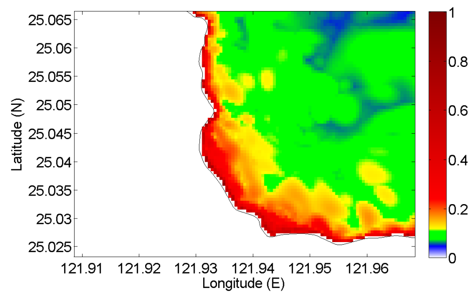

核一



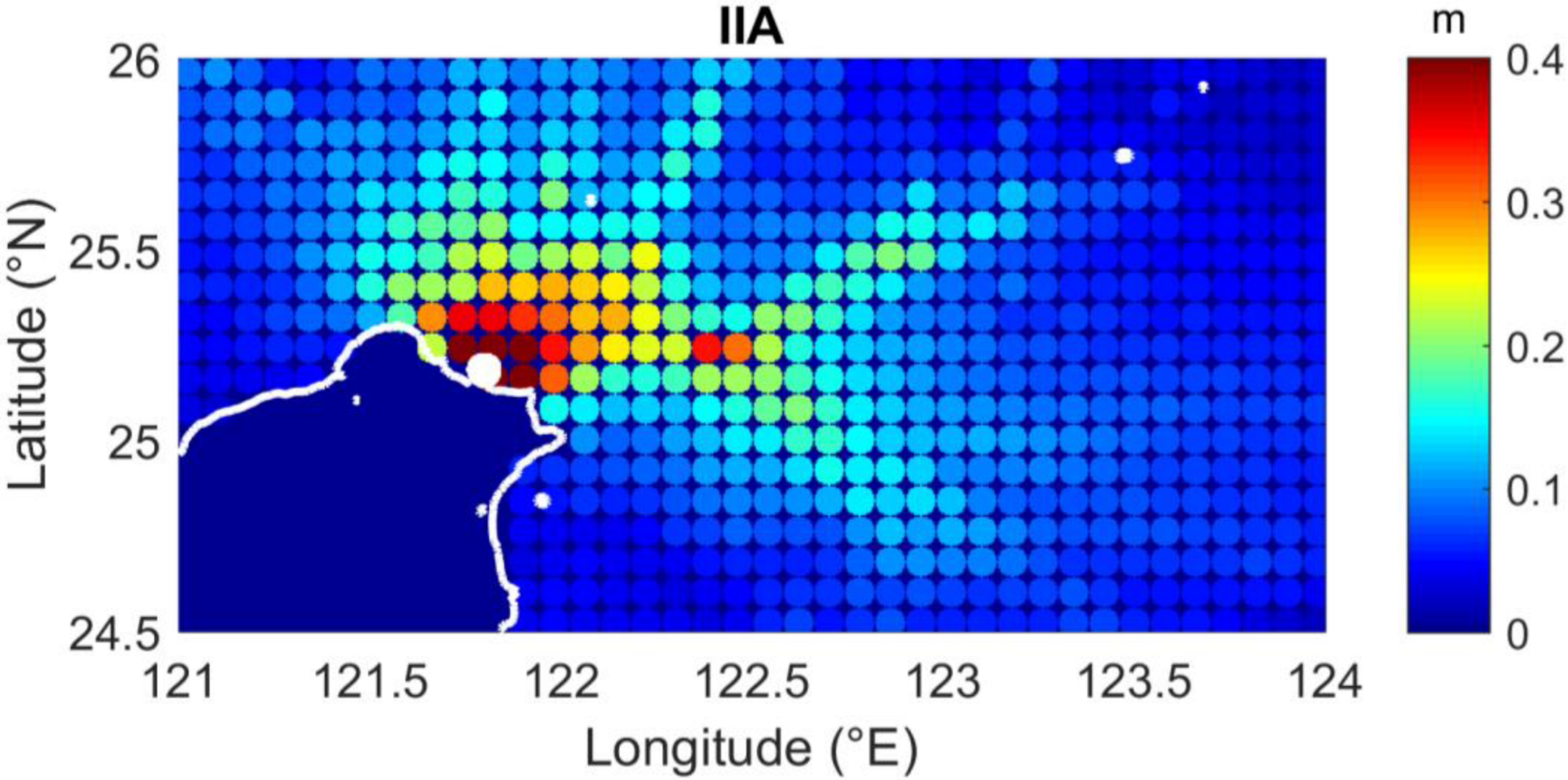

核二




核四



# 基隆港IIA分析結果



IIA
m
0.4
0.3
0.2
0.1
0
26
25.5
25
24.5
Latitude (°N)
121
121.5
122
122.5
123
123.5
124
Longitude (°E)

# 中央氣象局海嘯預估波高分級表

| 分級 | 海嘯預估波高 | 人的感受 | 建築物及船隻情形 | 影響範圍 |
|---|---|---|---|---|
| 1 | 小於1公尺 | 人在海中會感受到強大的水流 | 沿岸漁業養殖設施可能會被沖毀；小型船隻可能會遭受衝擊而翻覆。 | |
| 2 | 1至3公尺 | 人會被海嘯沖走 | 較低的建築物會被淹沒；中小型船隻會遭受衝擊而翻覆。 | 沿岸低窪地區會遭受海嘯侵襲 |
| 3 | 3至6公尺 | 人會被海嘯沖走 | 建築物會被淹沒，且受到大型漂浮物衝擊而損壞；船隻會遭受衝擊而翻覆。 | 近岸地區會遭受海嘯侵襲 |
| 4 | 大於6公尺 | 人會被海嘯沖走 | 建築物會被淹沒，且受到大型漂浮物衝擊而損壞；船隻會遭受衝擊而翻覆。 | 近岸地區會遭受海嘯侵襲 |

# 地震-海嘯關係圖
# Seismic-Tsunami Relationship, STR
## 吳函分析結果（中大水海所海嘯科學研究室）

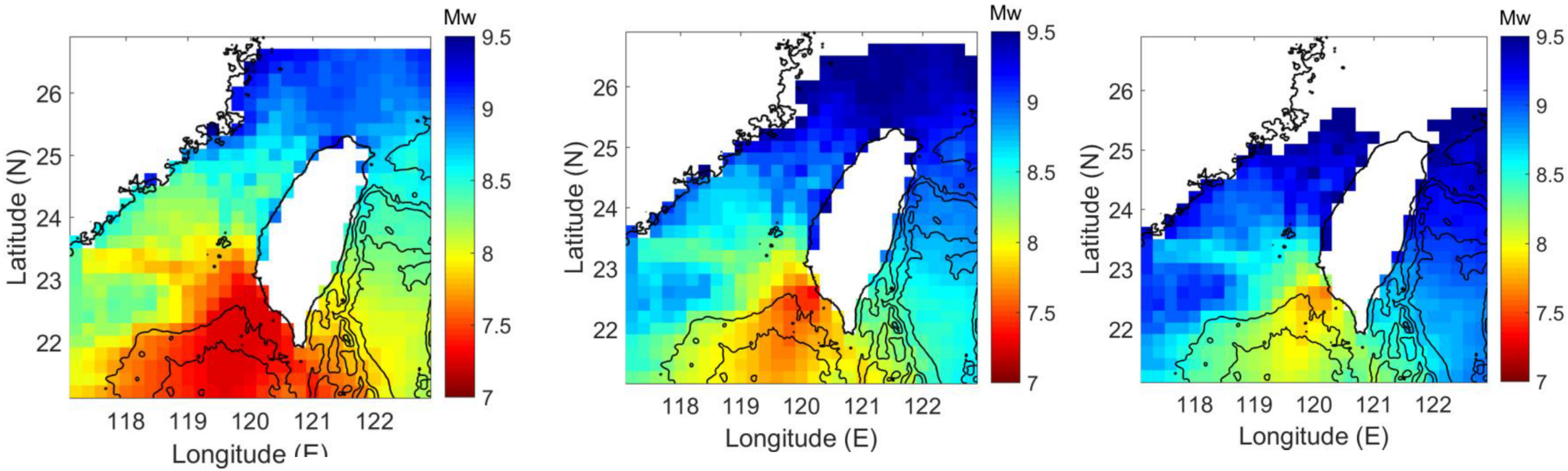



圖 4-30　高雄之 STR 結果 (單位：地震矩規模 Mw，由上至下之目標波高分別為 1 公尺、3 公尺、6 公尺)

STR 將以地震矩規模 ($M_W$) 圖像化表示 IIA 之圖，使 IIA 之分析結果更能被理解，使得重要城市或設施之防災單位可迅速了解突發之地震會造成多大之波高及危害。STR 將 IIA 之參數個別測試其影響強度，並透過 Source-Scaling Relationship for M 4.6–8.9 Earthquakes (Yen and Ma, 2011) 查詢 IIA 所相對應之長 $L$、寬 $W$、高 $D$ 之影響力，使分析結果以相應之地震矩規模 ($M_W$) 圖像化表示之。

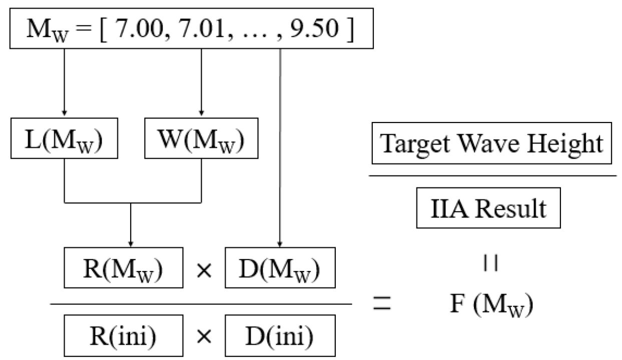
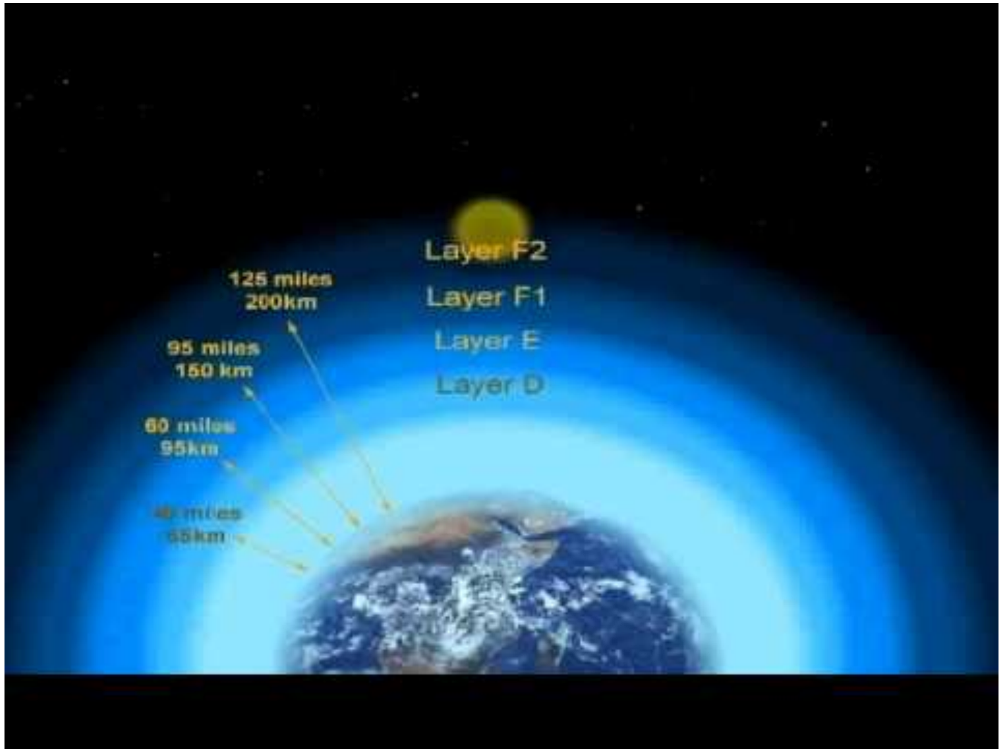
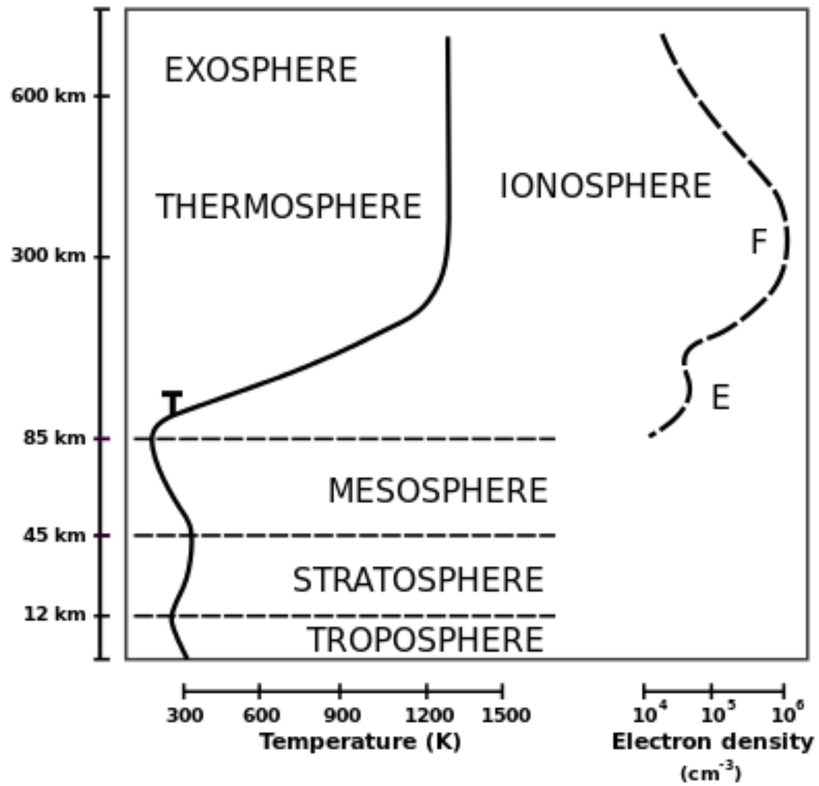



圖 2-5 將 IIA 之值轉換為 Mw 表示之流程圖

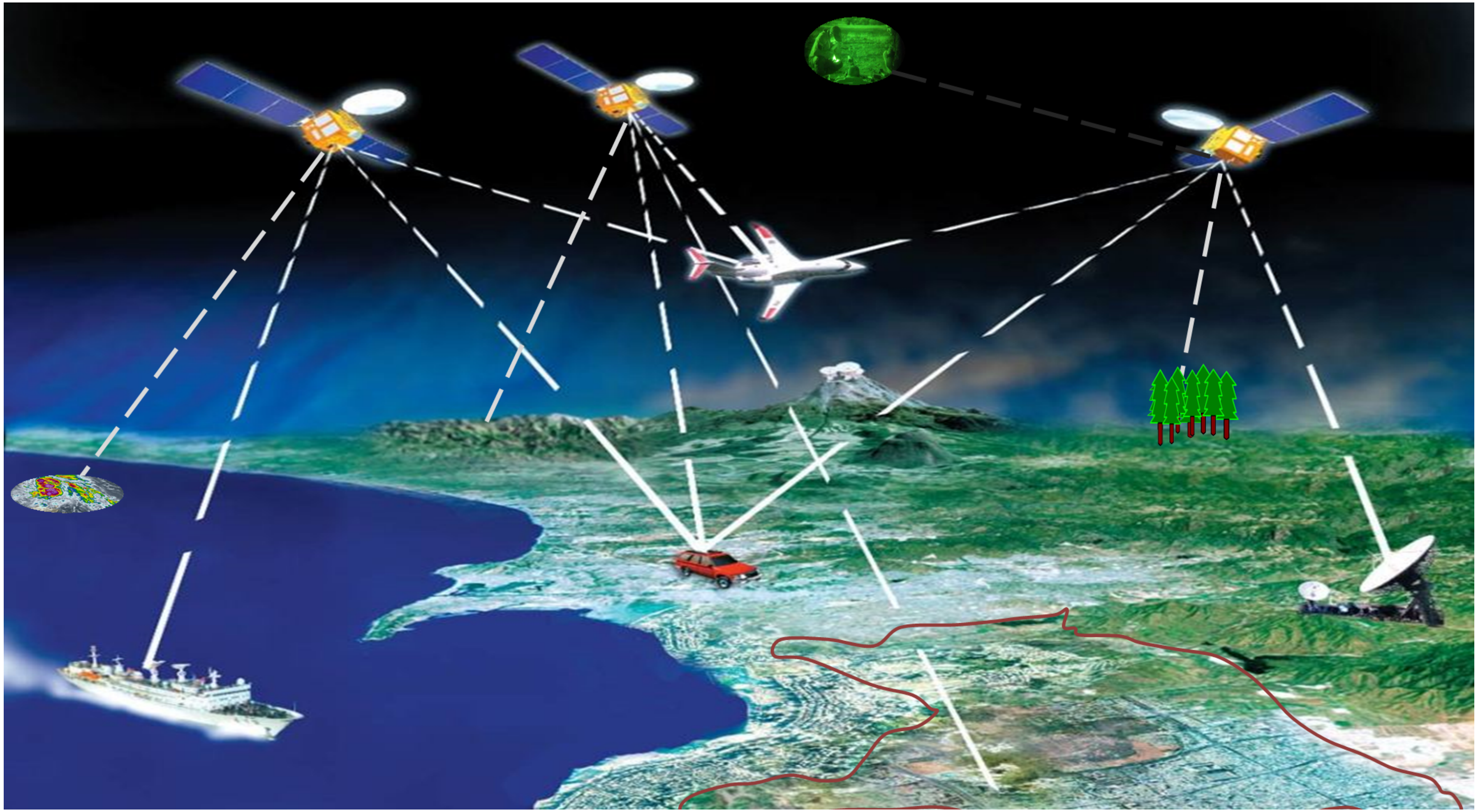
# Ionosphere



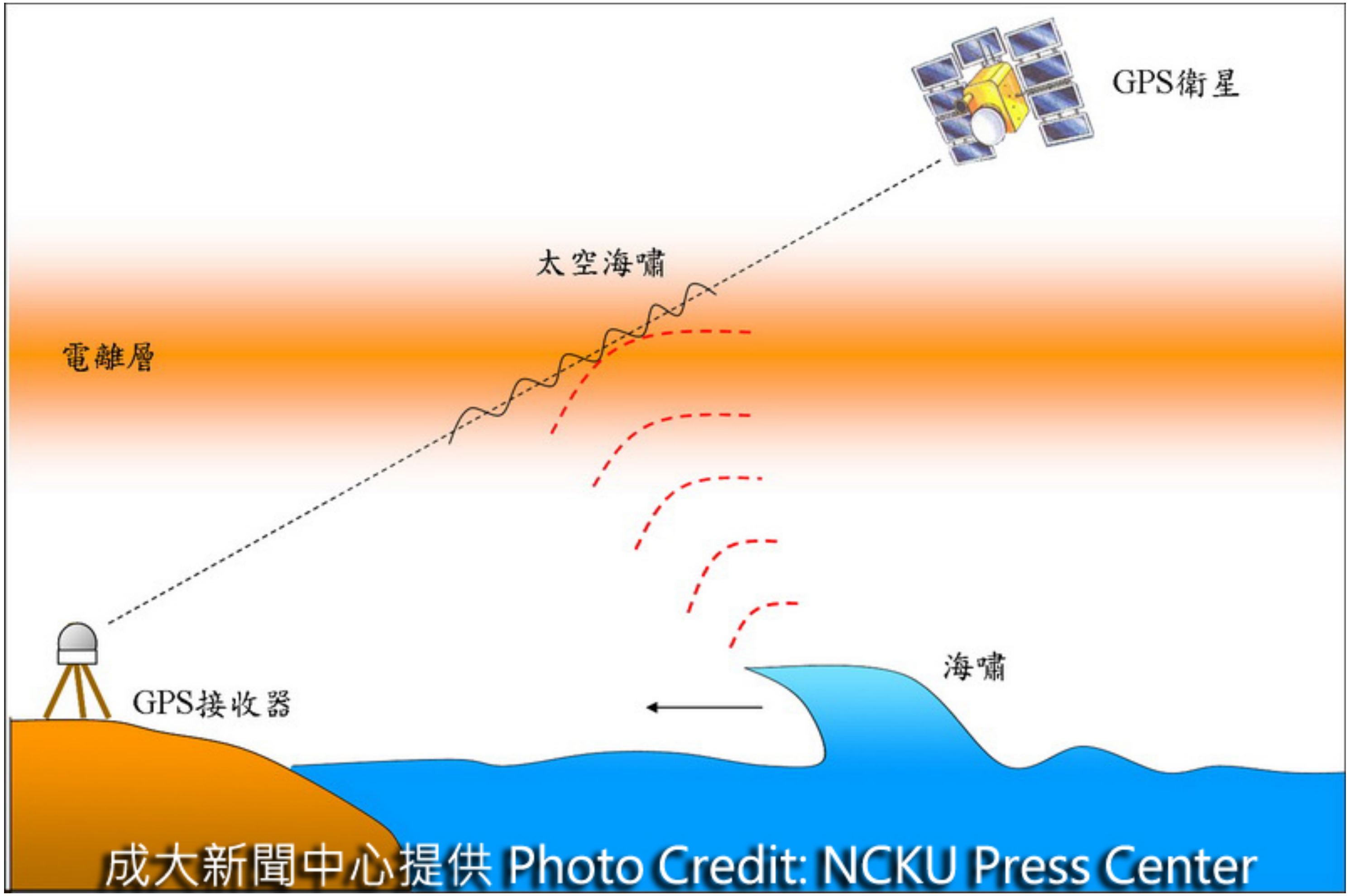
Layer F2
Layer F1
Layer E
Layer D
125 miles
200km
95 miles
150 km
60 miles
95km

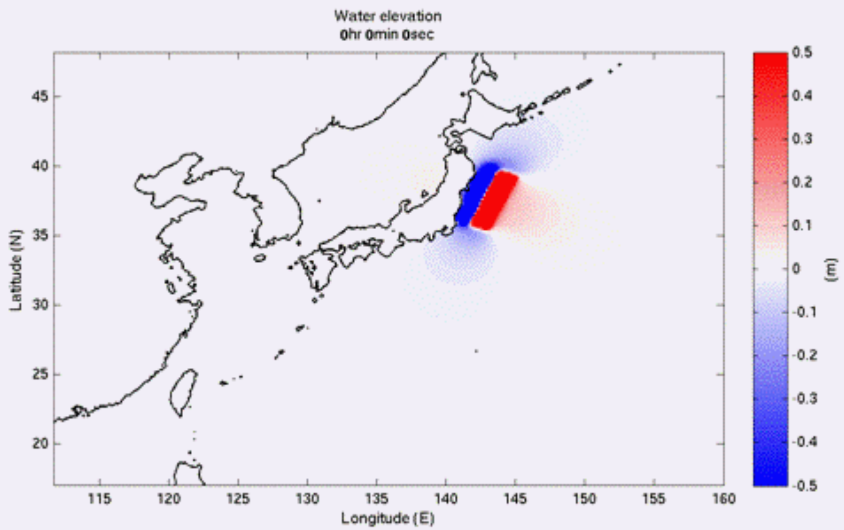
EXOSPHERE
THERMOSPHERE
IONOSPHERE
F
E
MESOSPHERE
STRATOSPHERE
TROPOSPHERE
600 km
300 km
85 km
45 km
12 km
300
600
900
1200
1500
Temperature (K)
10^4
10^5
10^6
Electron density
(cm^-3)



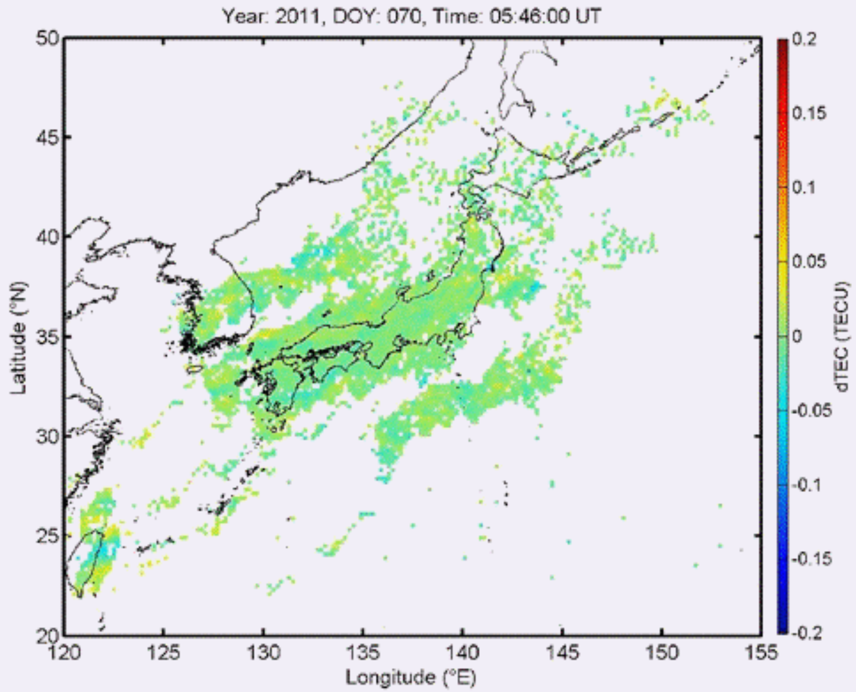
# Ionosphere Perturbed by Tsunamis (Iononami)



# Tsunami Simulation VS Ionnami
# 2011 Tohoku Earthquake & Tsunami

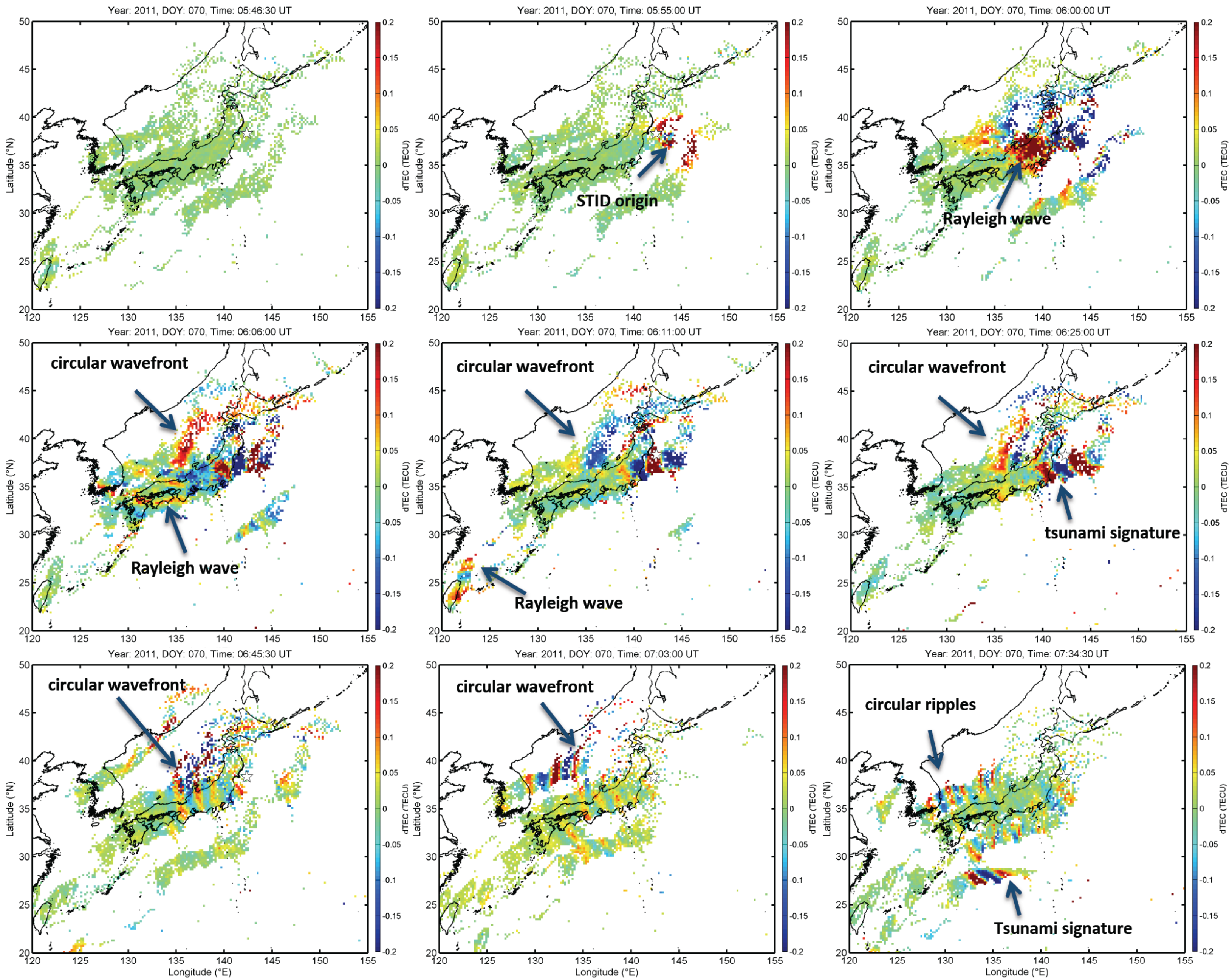



（吳祚任）

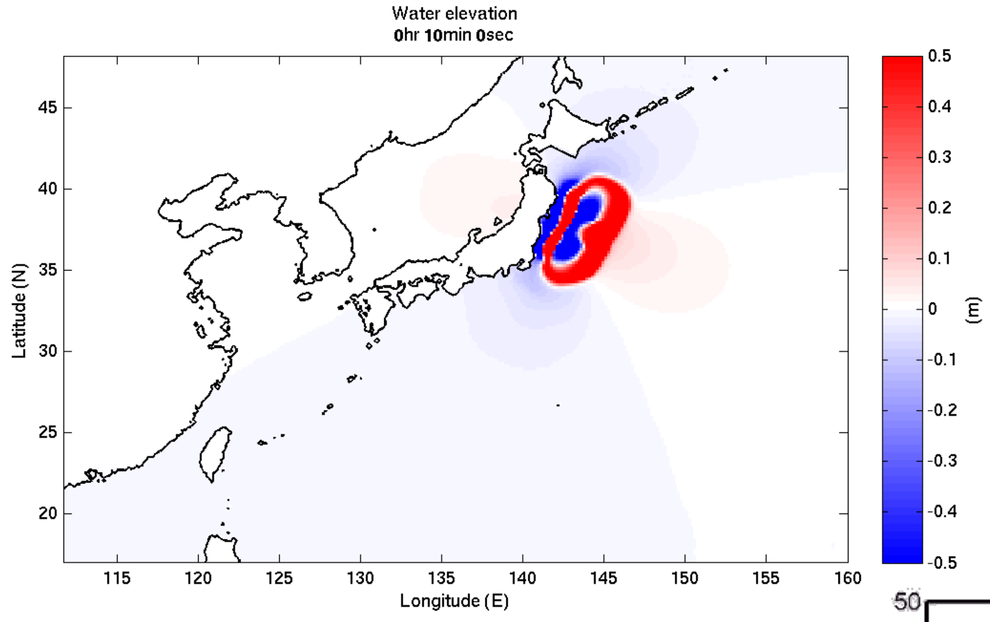



（劉正彥）

# Ionosphere perturbed by the 2011 Tohoku earthquake and tsunami

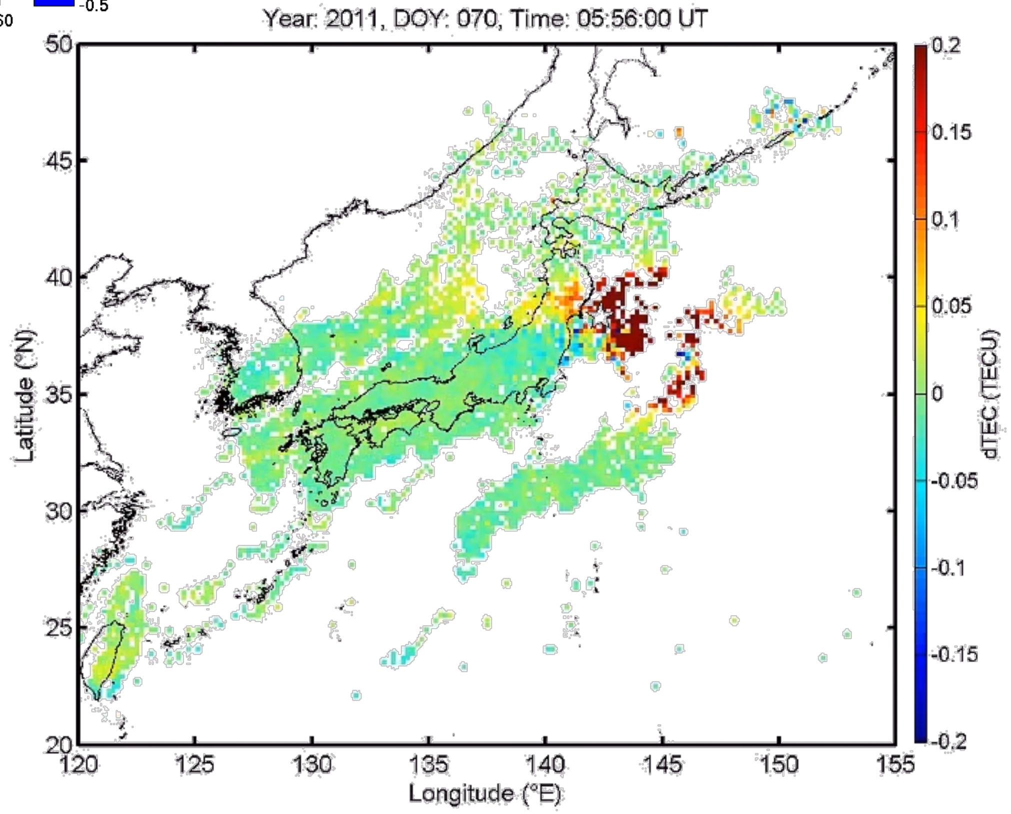


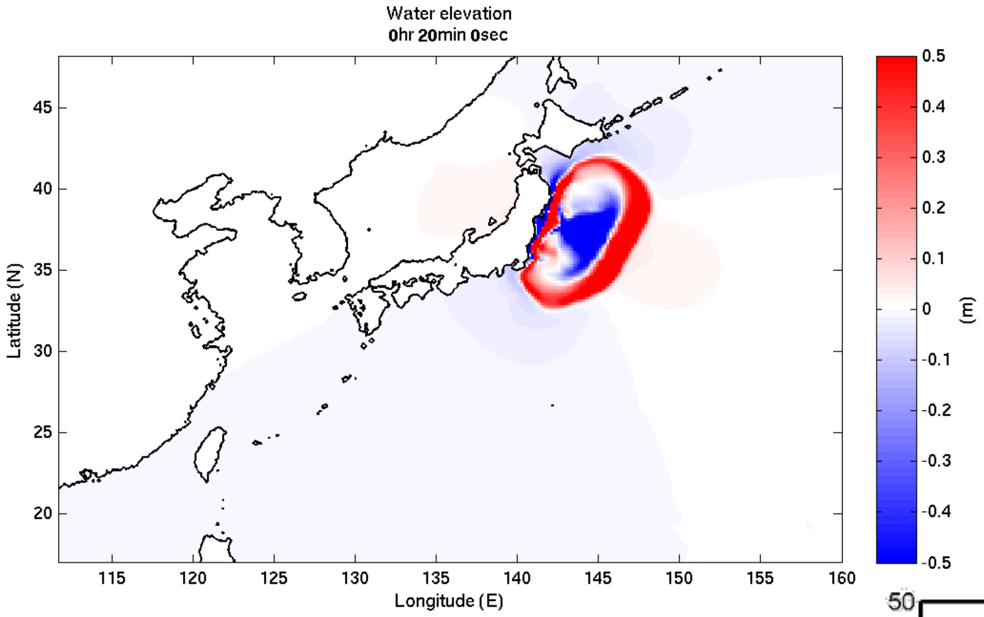

Liu et al. (JGR 2011)




# 10 min

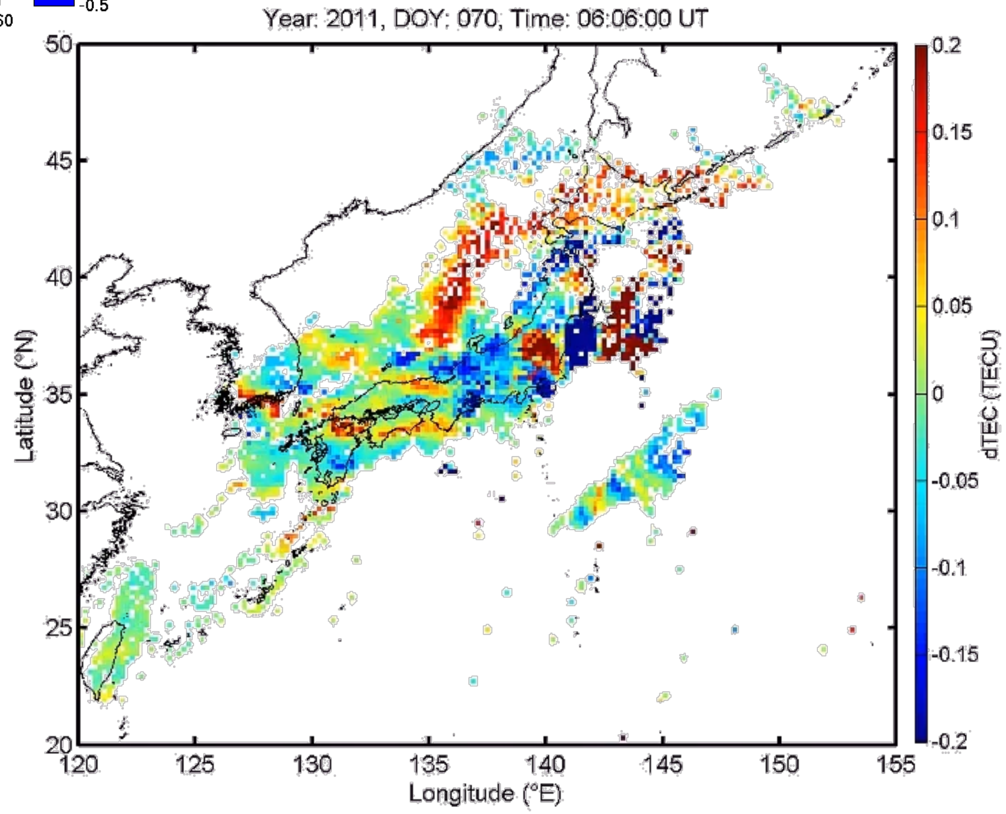
地震初期，電離層訊號包含地震波與海嘯波。

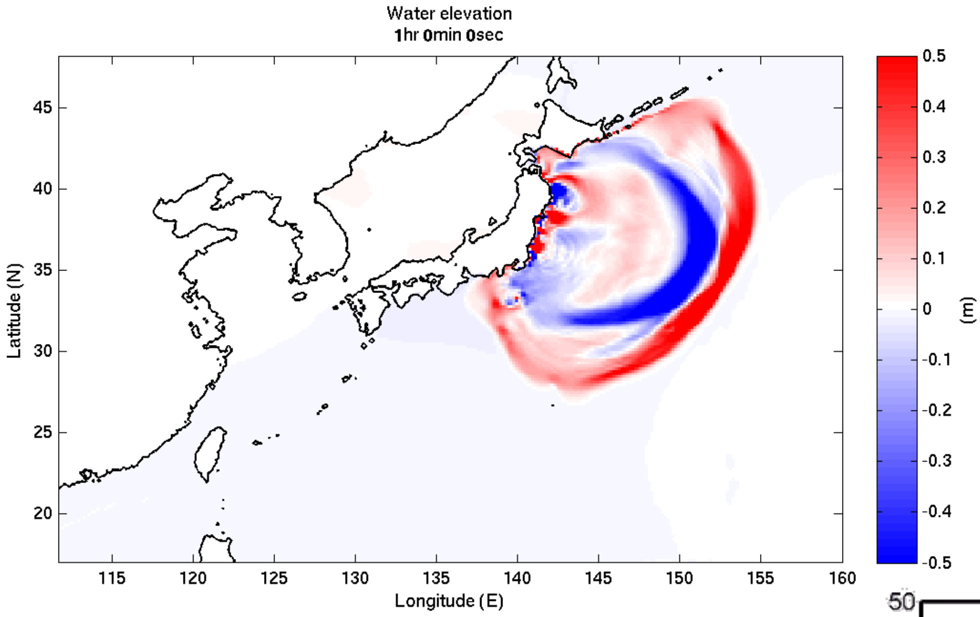





# 20 min

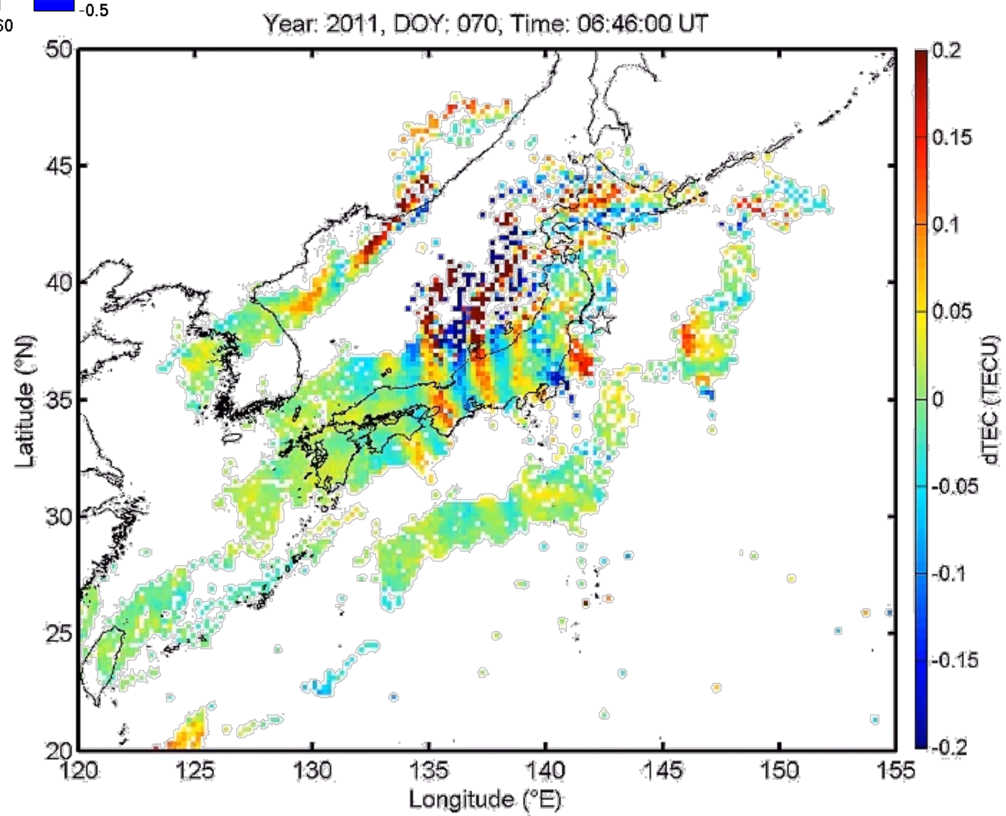
地震發生20分鐘後，地震波迅速向外傳播，海嘯波則傳遞致福島外海。電離層之訊號明顯顯示此現象。

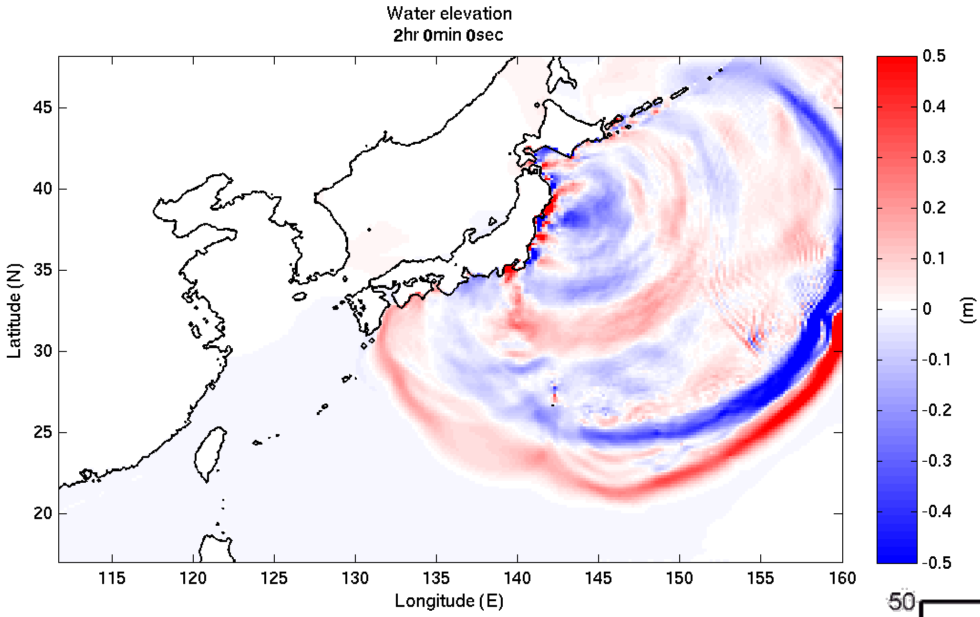





# 1 hr

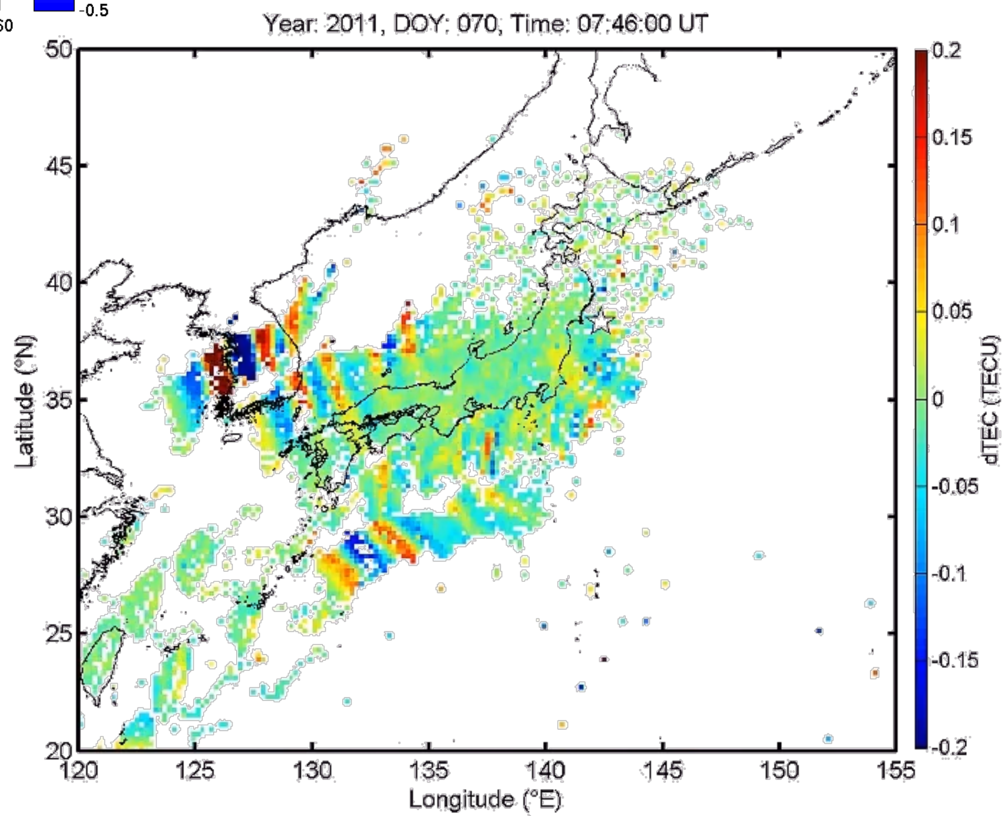
地震發生後1小時，海嘯持續往南傳遞，電離層之訊號與海嘯波訊號相當吻合。



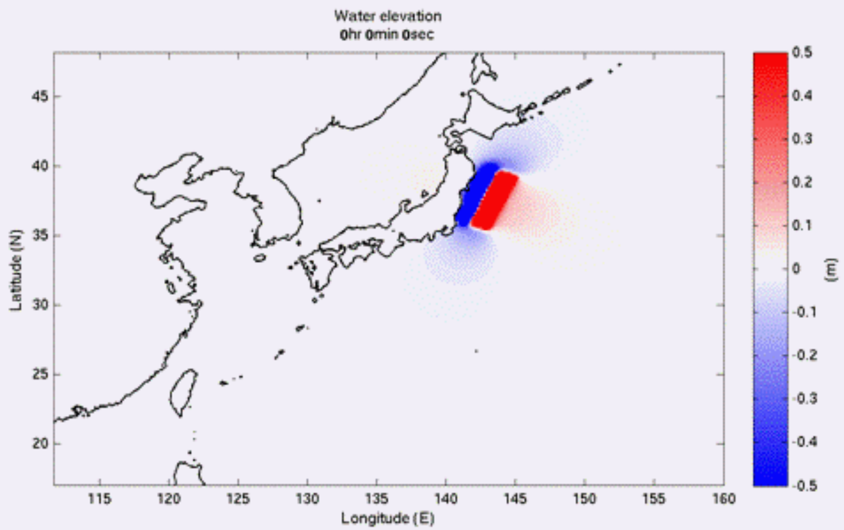


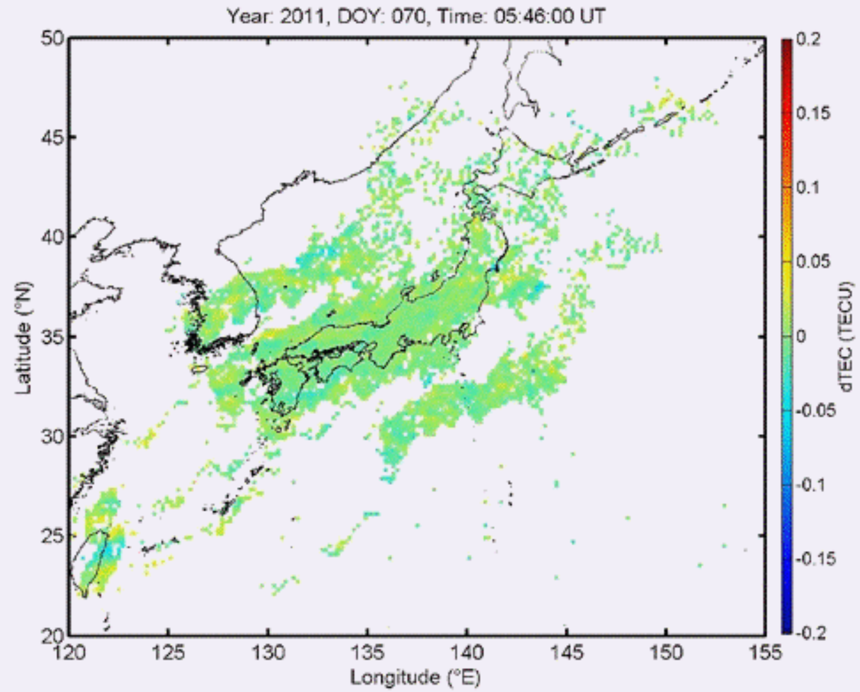

# 2 hrs

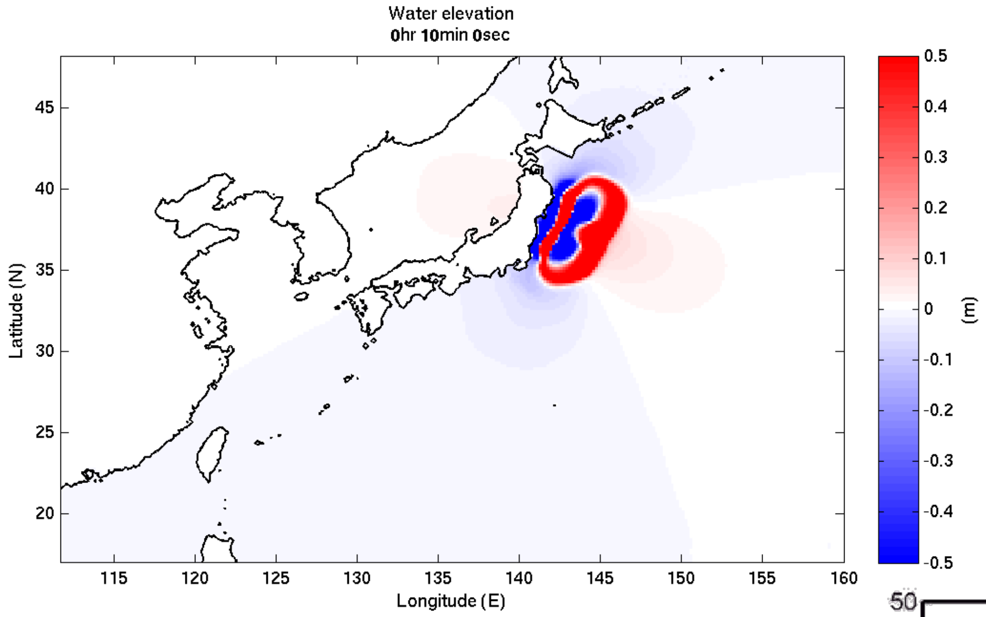
地震發生後2小時，海嘯傳遞至琉球島弧，電離層之訊號與海嘯波訊號亦相當吻合。



# 海嘯模擬與電離層訊號比對

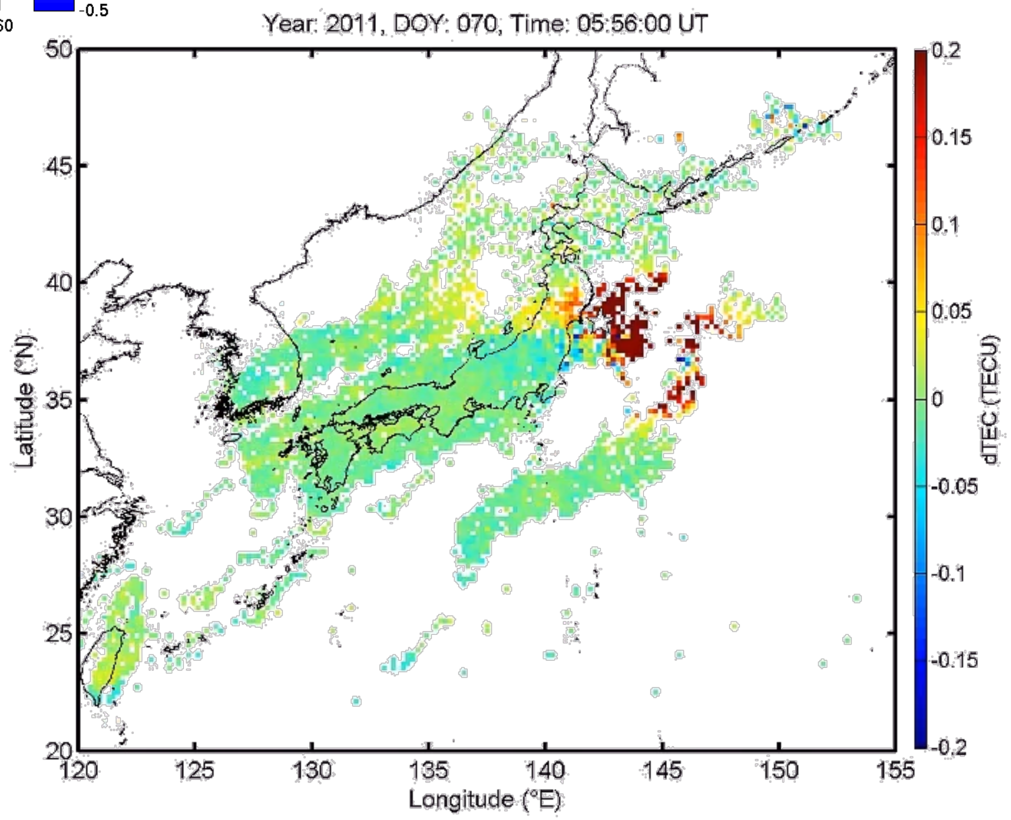


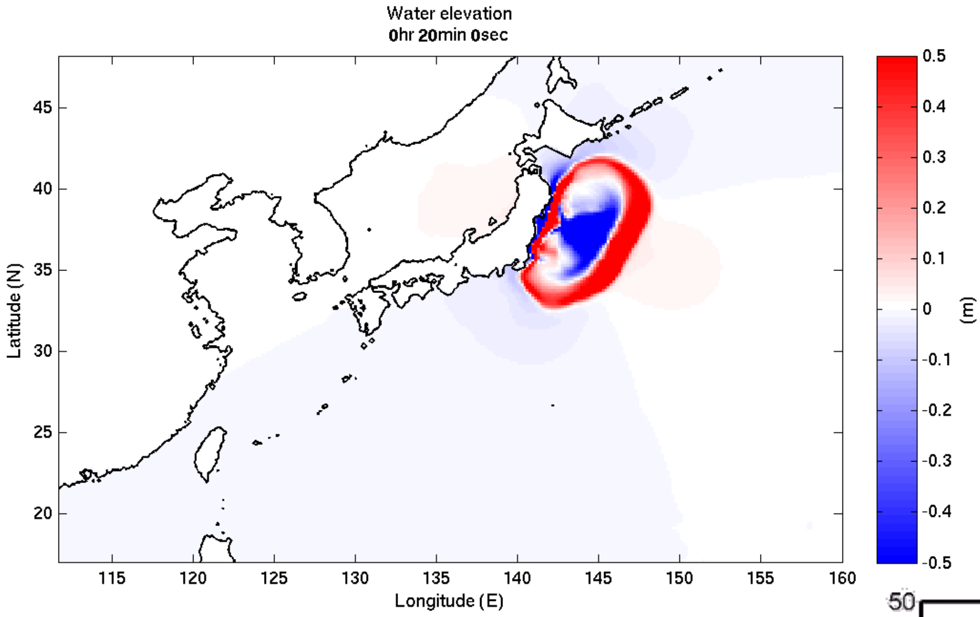






# 地震後10分鐘

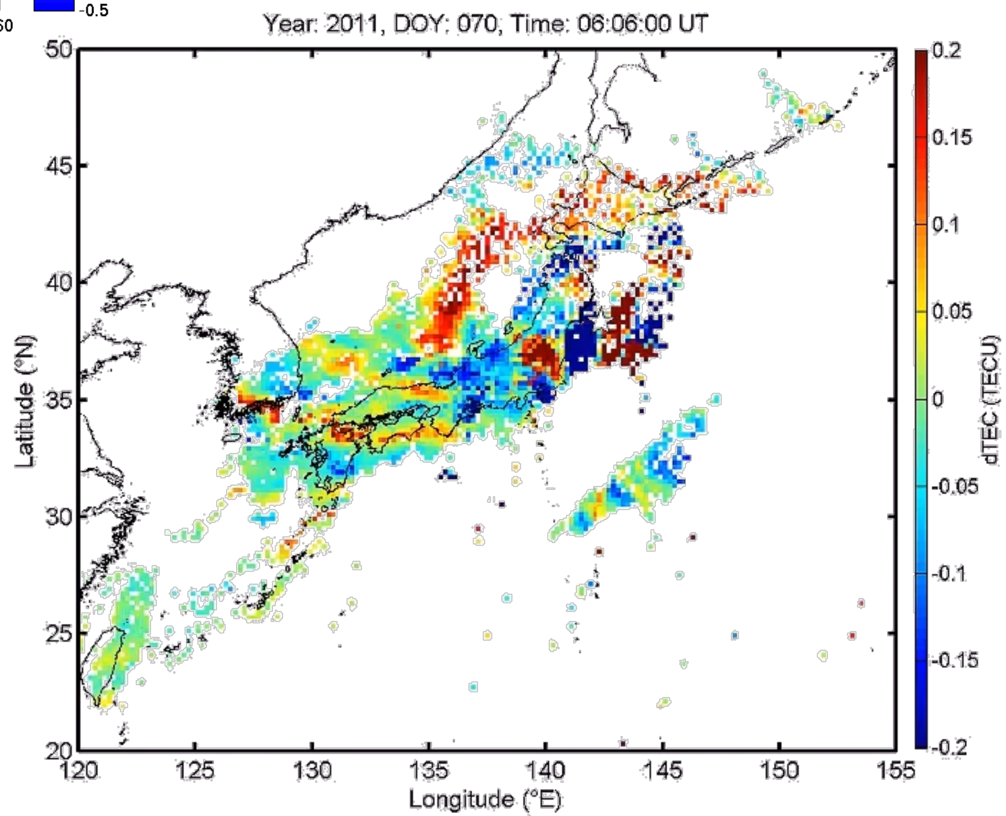
地震初期，電離層訊號包含地震波與海嘯波。



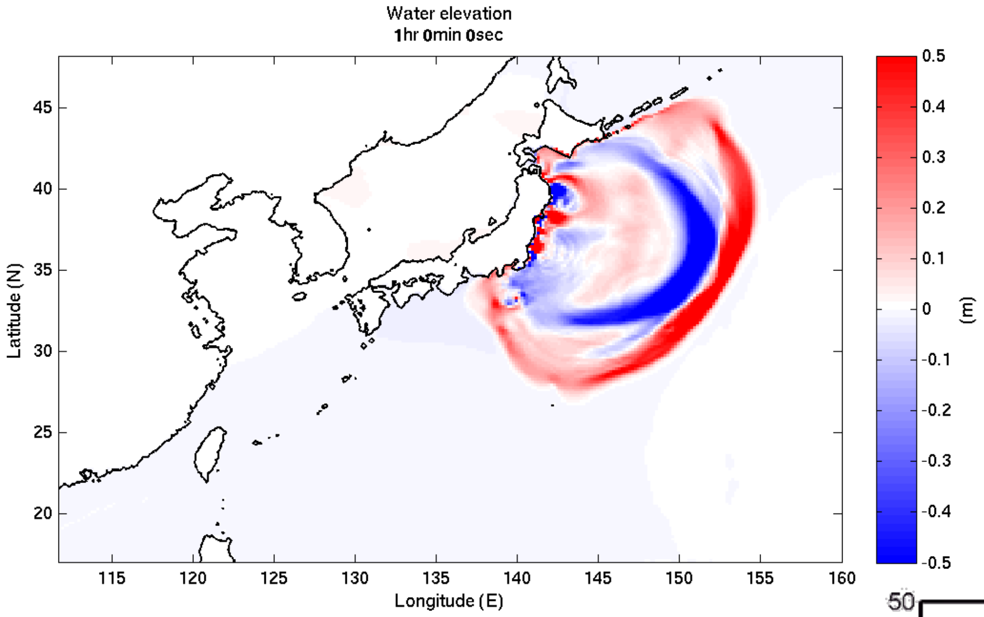



# 地震後20分鐘

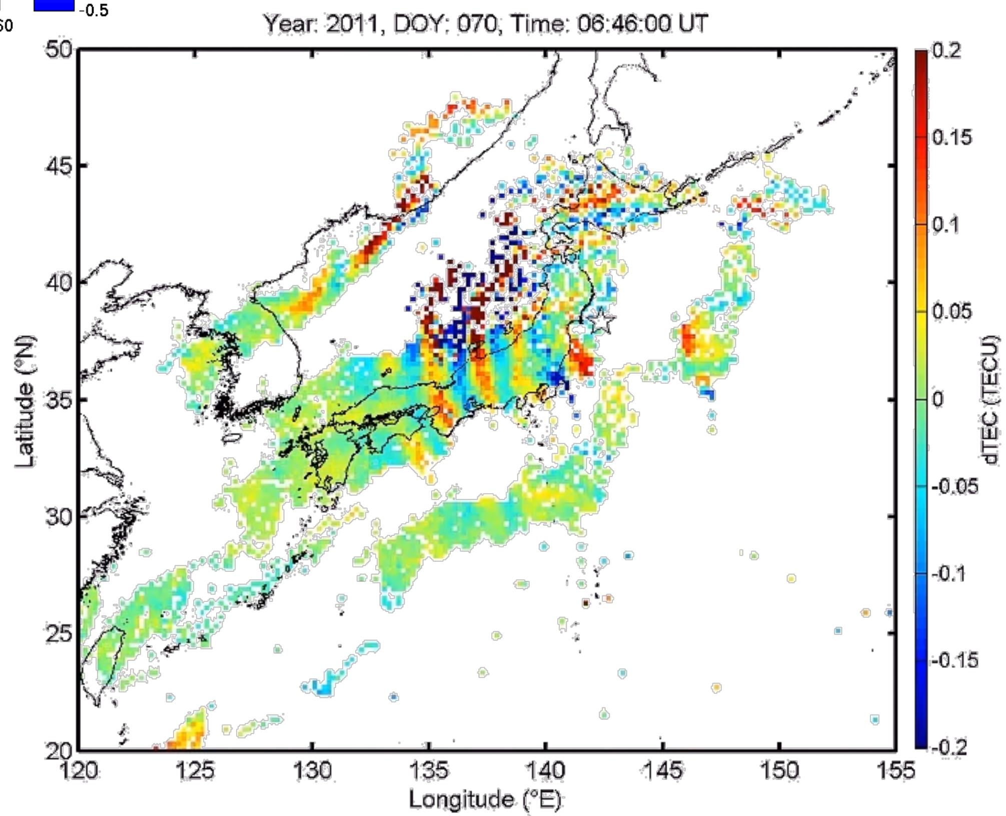
地震發生20分鐘後，地震波迅速向外傳播，海嘯波則傳遞致福島外海。電離層之訊號明顯顯示此現象。

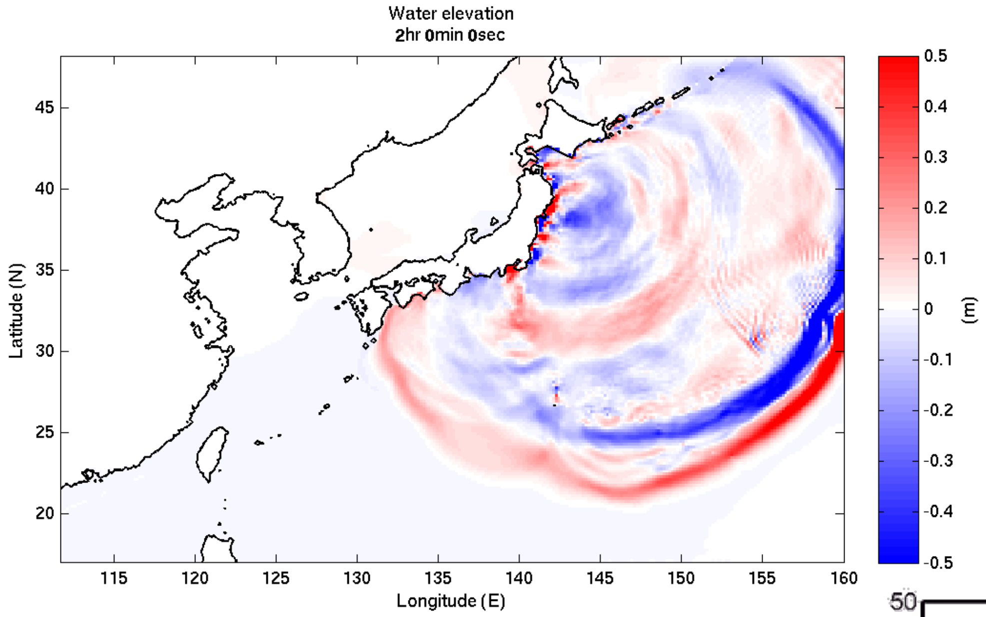


# 地震後1小時



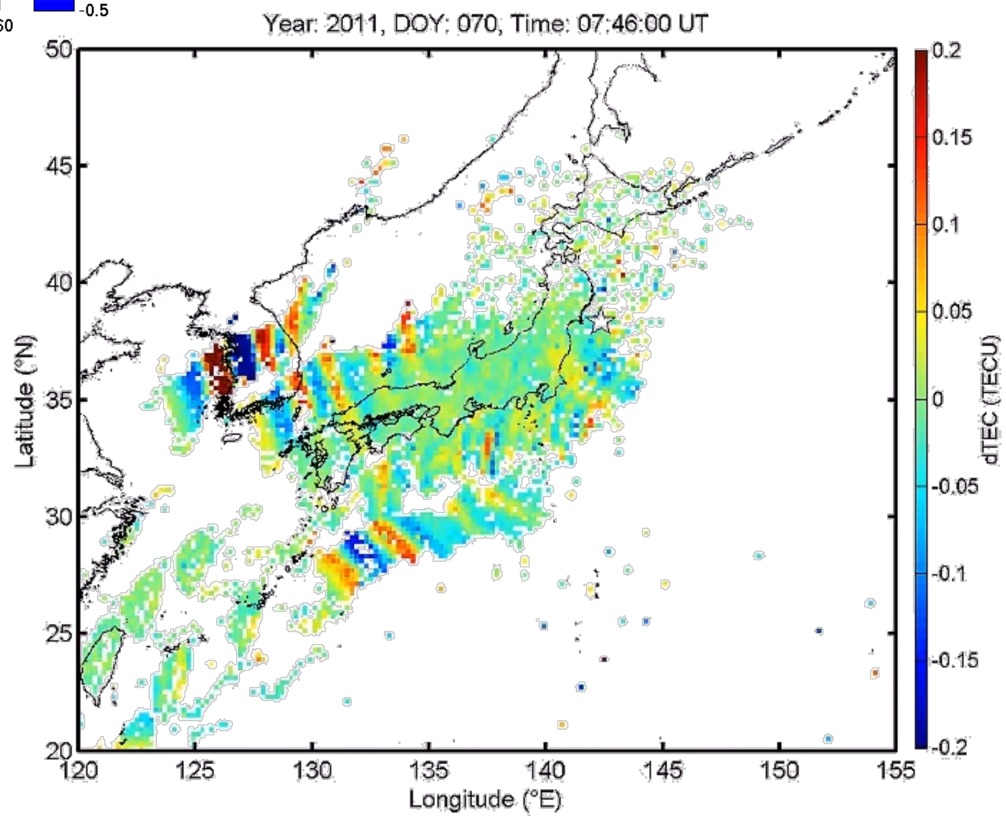

地震發生後1小時，海嘯持續往南傳遞，電離層之訊號與海嘯波訊號相當吻合。






# 地震後2小時

地震發生後2小時，海嘯傳遞至琉球島弧，電離層之訊號與海嘯波訊號亦相當吻合。



# Conclusion

- By the assist of Dr. Simon Lin, ASGC, the tsunami research became tsunami early warning.
- Inundation and runup are important.
- Good bathymetry data is the key to the good inundation result.
- We are trying to producing a low-cost and robust tsunami early warning system.
- The Iononami from GPS can help us to identify the tsunami at the early stage of the event.
- IIA and STR can provide important information for tsunami wave height without using a computer.
- We want to contribute to the society for tsunami hazard mitigation.
- Questions for Prof. Wu?
- tsoren@ncu.edu.tw