

# 跨領域科學議題發想



全球暖化下，地震變多了嗎？

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# POSSIBLE TOPICS ?

颱風會引發地震嗎？

颱風會引發慢地震嗎？

地震前天氣現象的異常？

地震前海床活動有無異常？

潮汐引力與地震的關係？

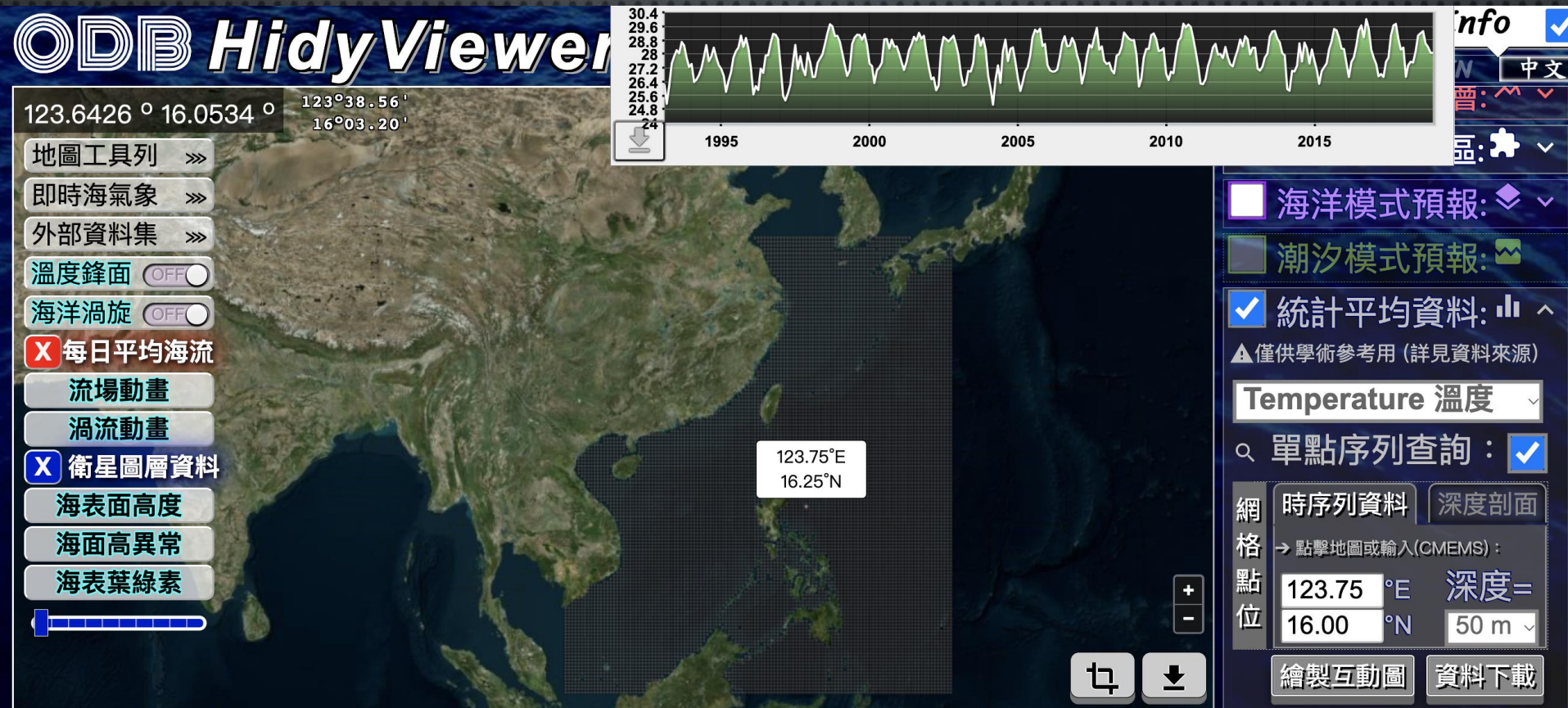
全球暖化影響了地震頻繁度？

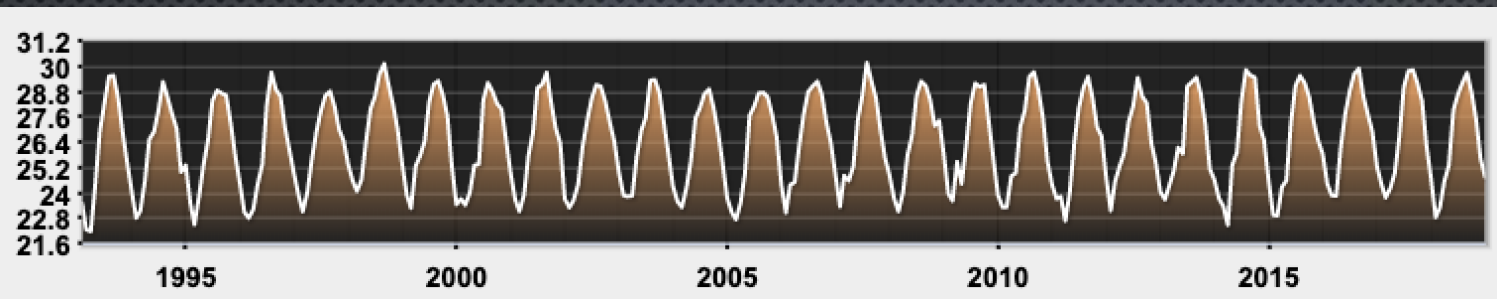
# 無腦探索篇

(1) 尋找海溫的時間序列

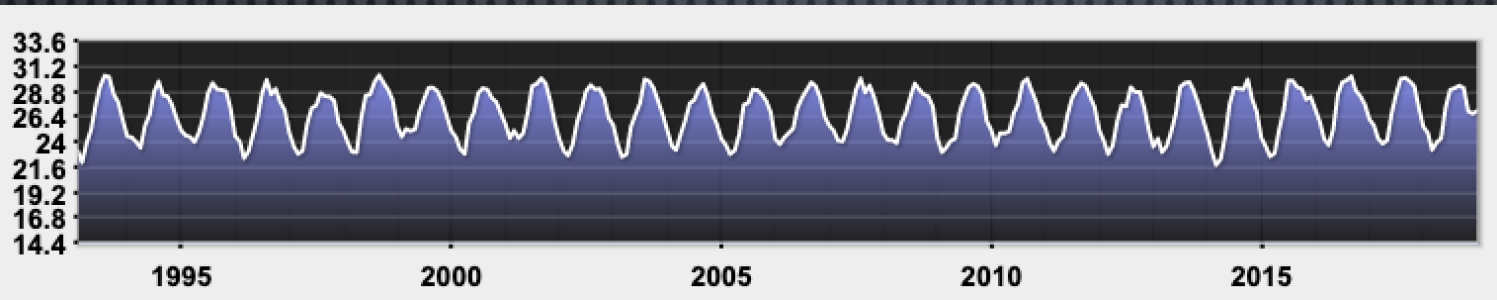
<https://odbgo.oc.ntu.edu.tw/odbargo/>

(右側)統計平均資料 → 單點序列查詢 → 時序列資料 → 在地圖上尋找你的網格位置

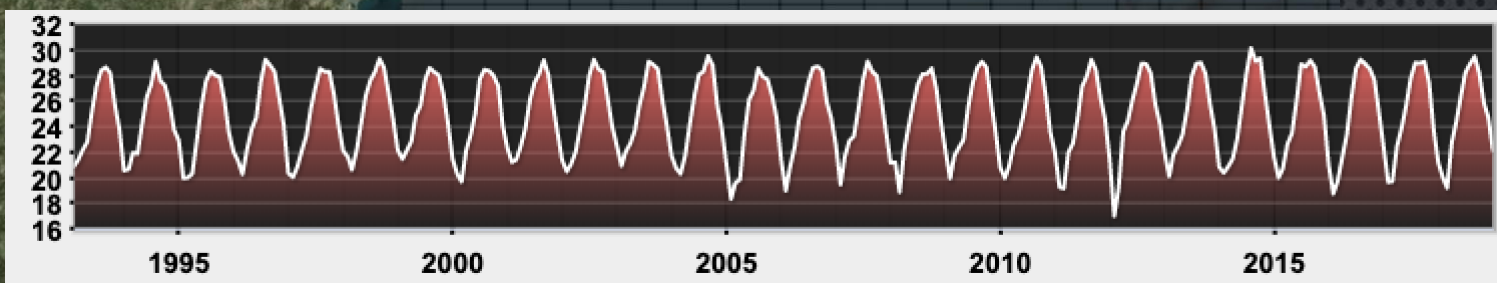




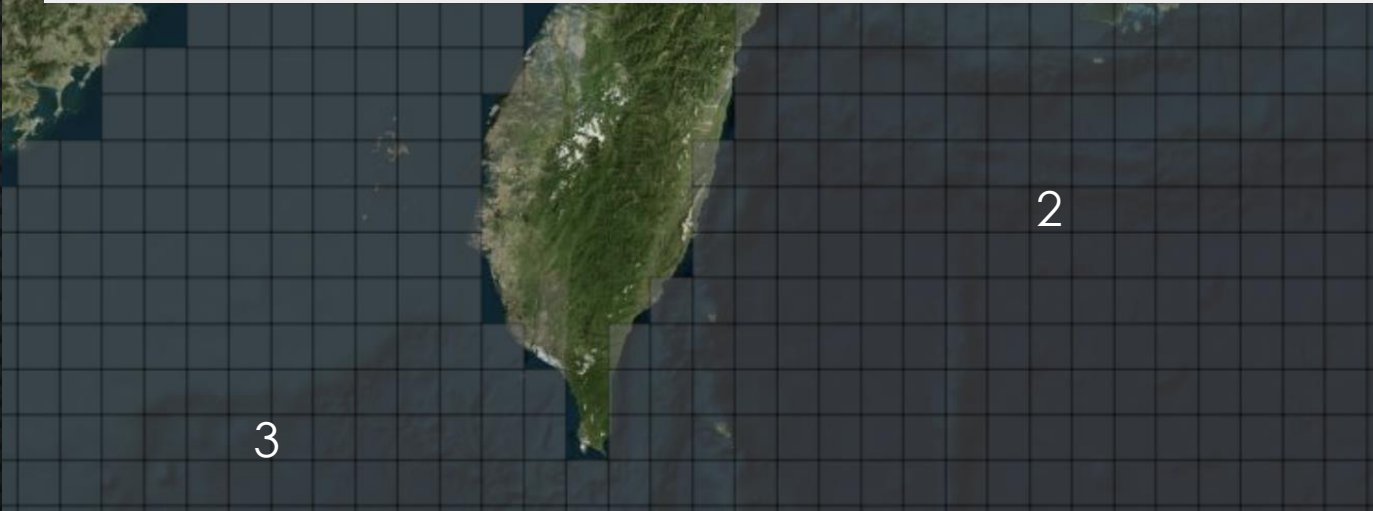
1

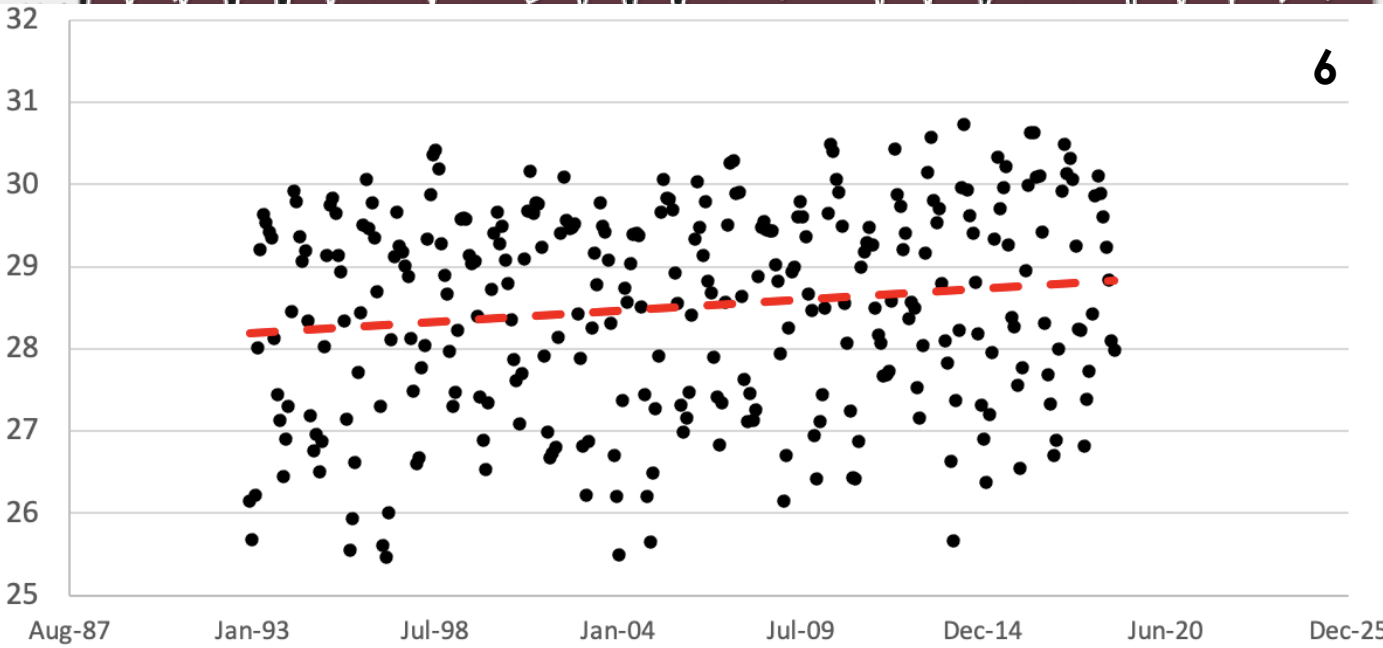
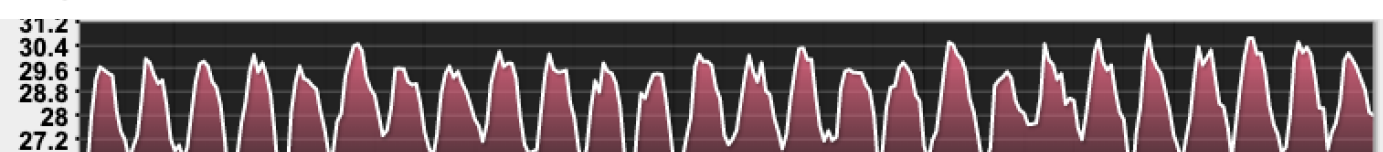
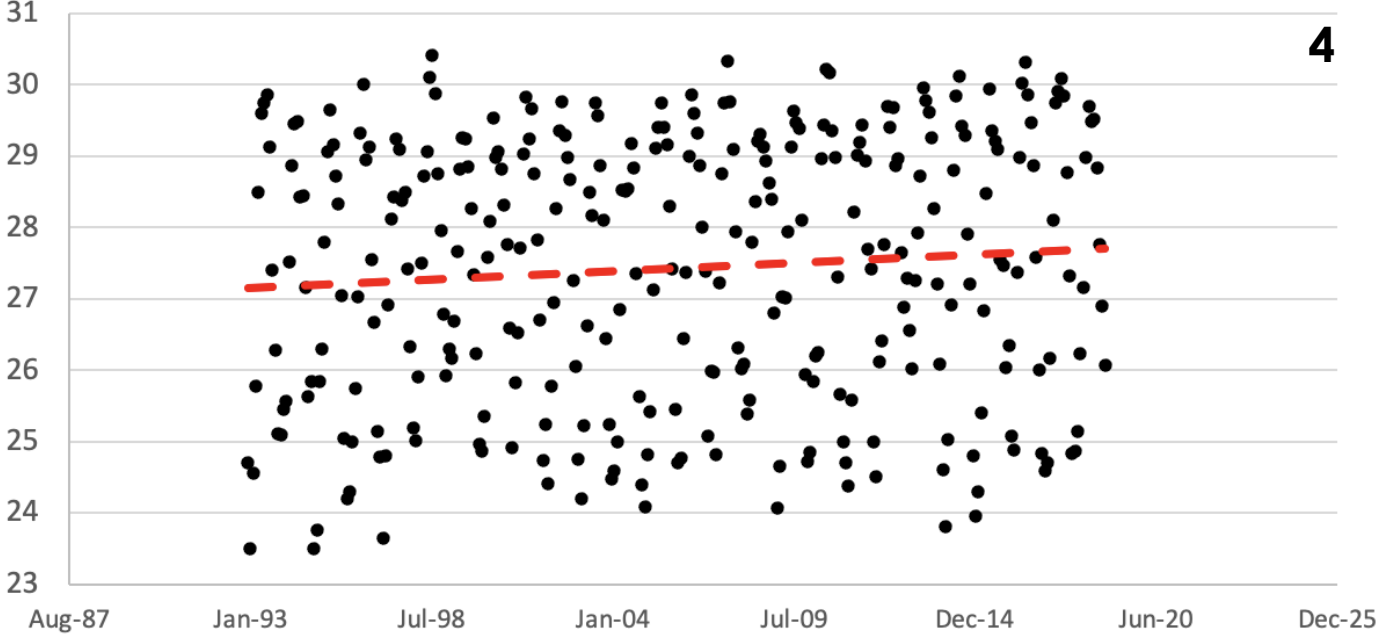


2

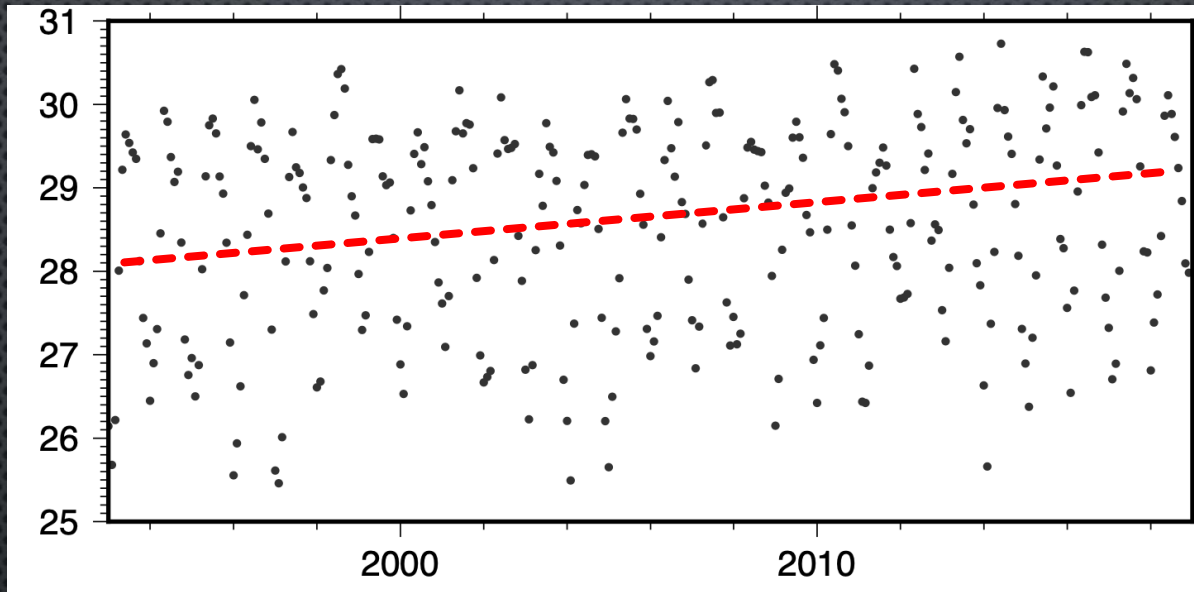


3

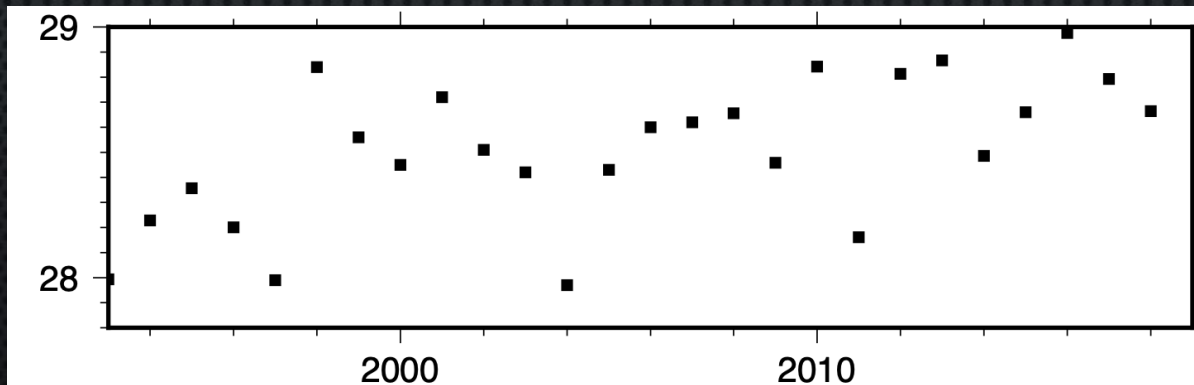




海表面温度(°C)

monthly  
data(regression  
line)

海表面温度(°C)

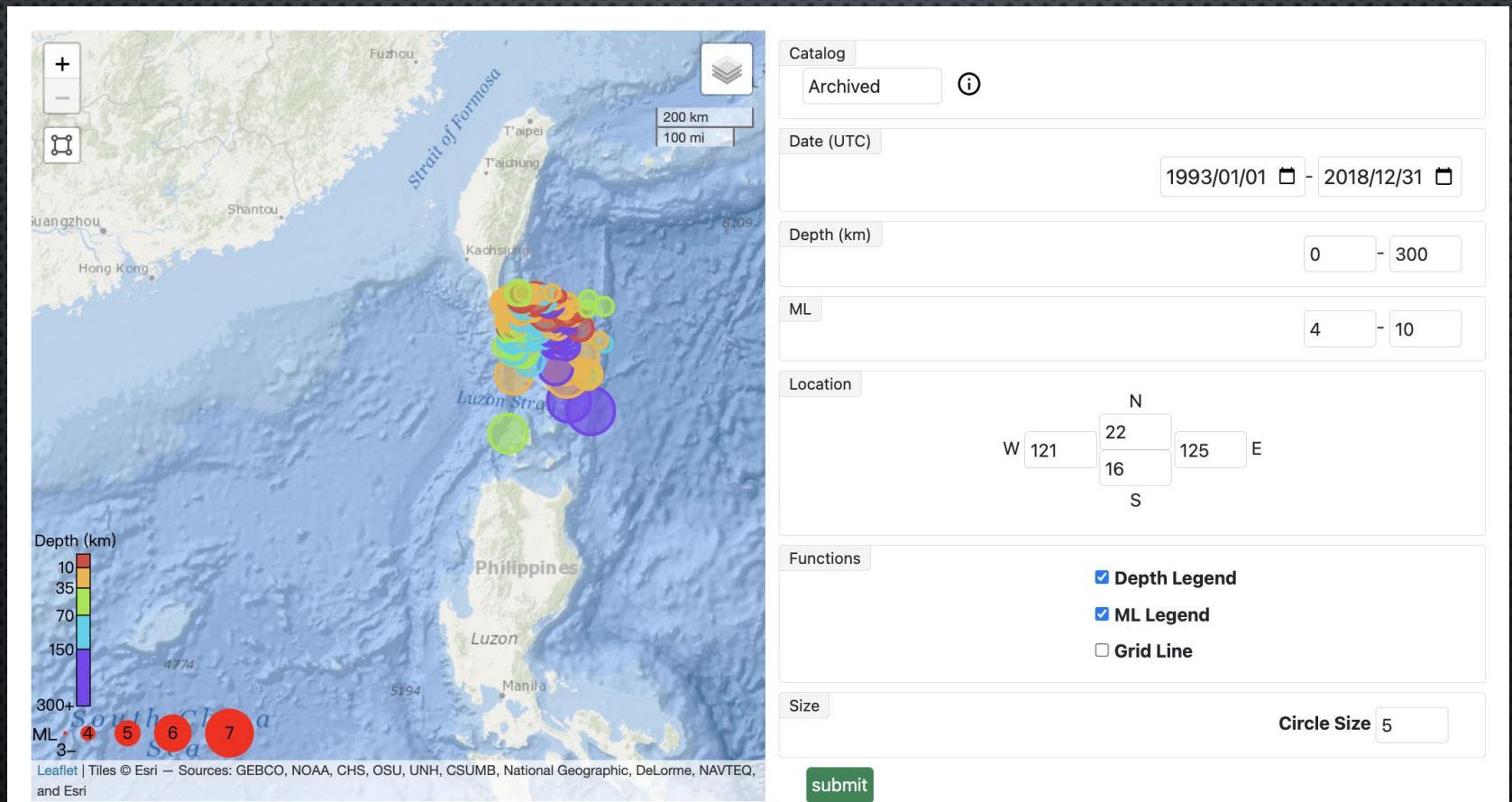
Yearly  
average

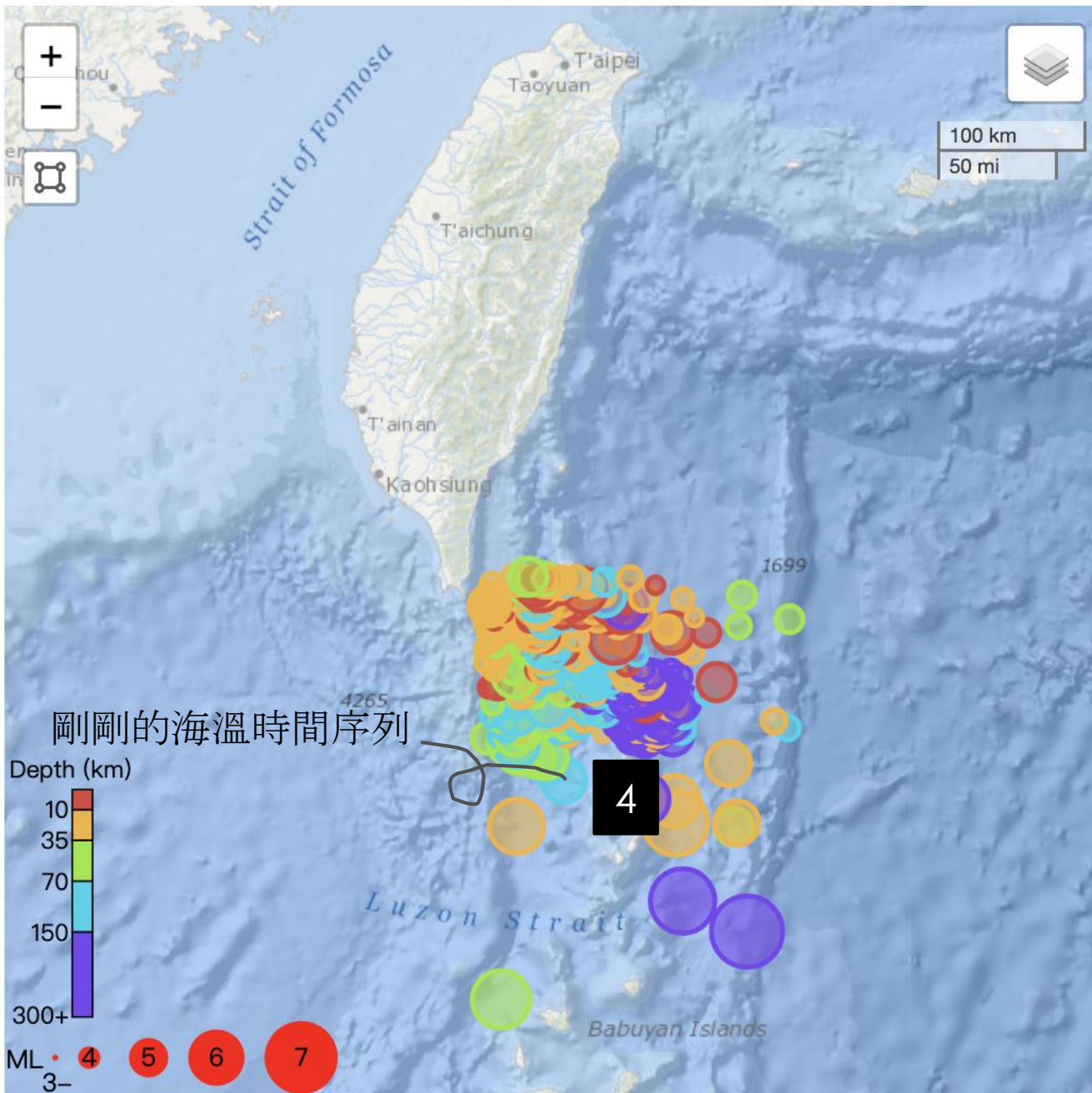
# 無腦探索篇

## (2) 尋找對應的區域地震活動

<http://tecdc.earth.sinica.edu.tw/tecdc/seis.php>

(右側)填入你要的空間、時間、地震深度和規模範圍 → *submit*







### (3) 下載地震活動時間序列

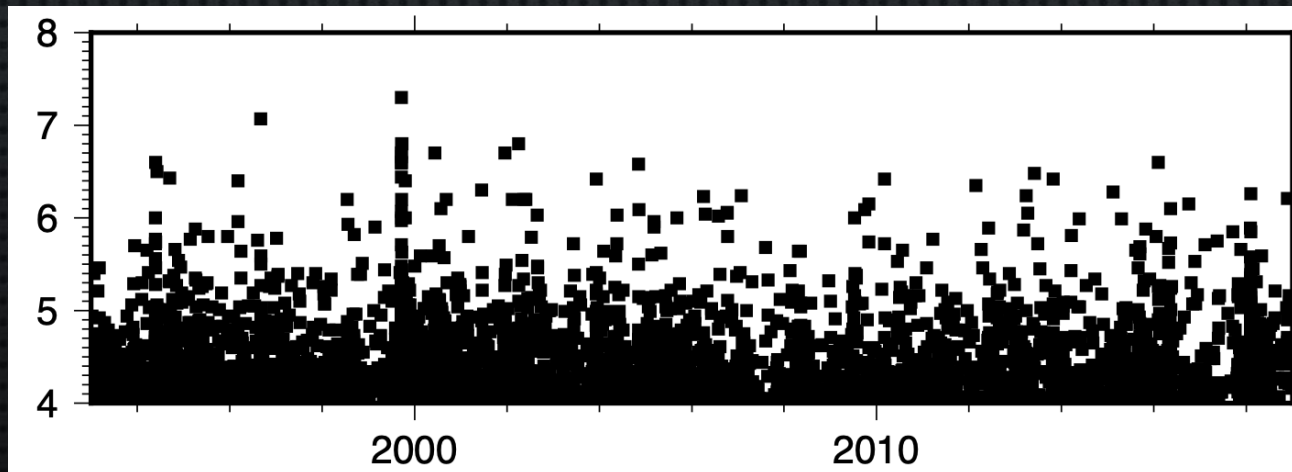
<https://gdmsn.cwb.gov.tw/catalogDownload.php>

填入你要的空間、時間、地震深度和規模範圍 → 送出

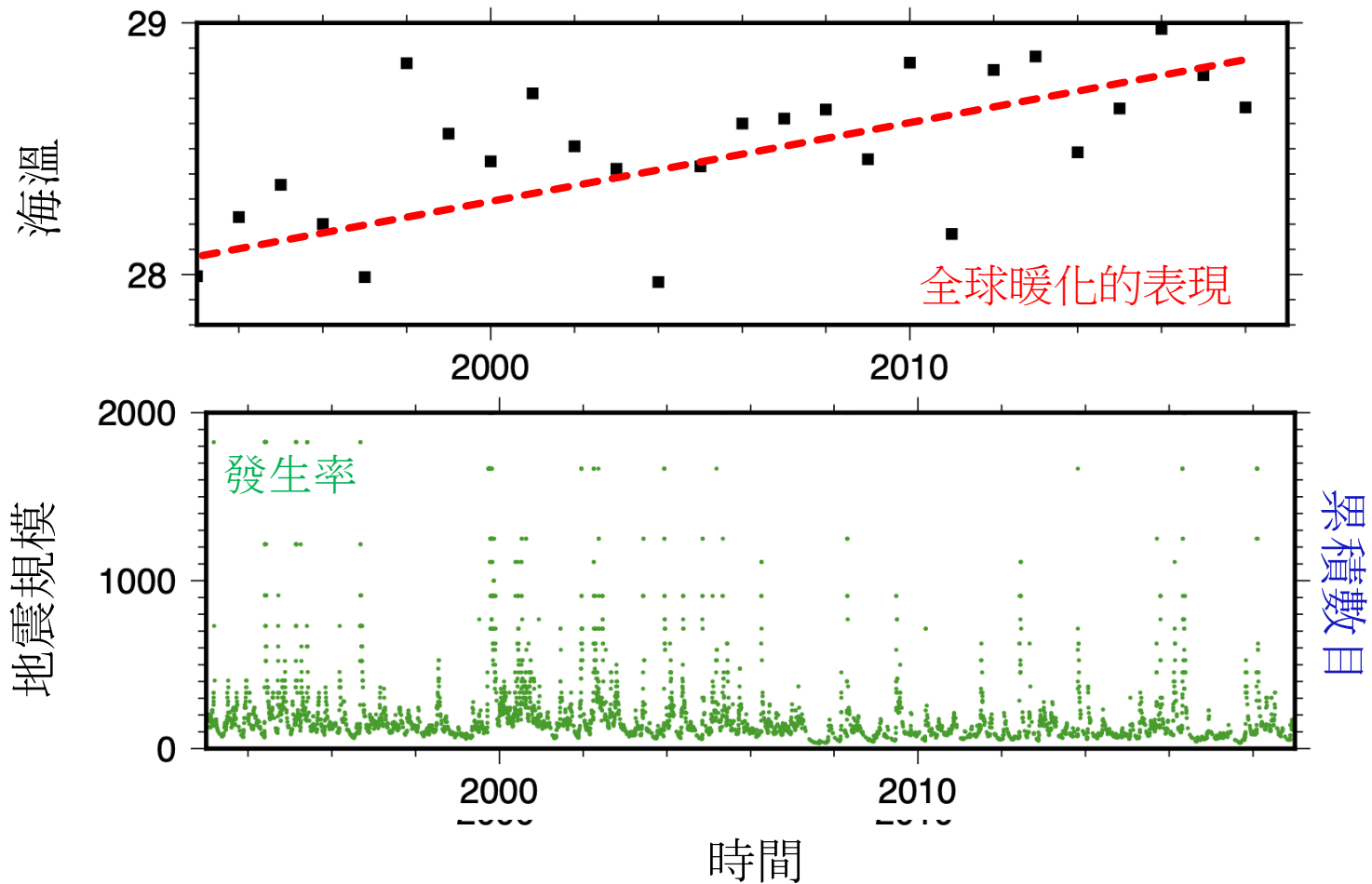
可依條件搜尋地震目錄

**\* 必填**

|   |                                       |   |                                       |
|---|---------------------------------------|---|---------------------------------------|
| 起始日期 *                                  | 起始時間 (UTC) *                          | 結束日期 *                                  | 結束時間 (UTC) *                          |
| <input type="text" value="1993-01-01"/> | <input type="text" value="00:00:00"/> | <input type="text" value="2018-12-30"/> | <input type="text" value="00:00:00"/> |
| 最小經度                                    | 最大經度                                  | 最小緯度                                    | 最大緯度                                  |
| <input type="text" value="121"/>        | <input type="text" value="125"/>      | <input type="text" value="16"/>         | <input type="text" value="22"/>       |
| min $M_L$ *                             | Max $M_L$ *                           | 最小深度                                    | 最大深度                                  |
| <input type="text" value="4"/>          | <input type="text" value="8"/>        | <input type="text" value="0"/>          | <input type="text" value="30"/>       |



# WHAT TO SEE?



別人要給你看什麼圖，才能說服你「地震發生的頻繁度變化，和全球暖化有關？」

# THIS IS WHEN YOU ASK...

## 等等！

1. 溫度升高, 為什麼地震活動度會被改變？

— 地震到底為什麼會發生？

— 哪一種物理模型, 能支持水圈 vs. 地圈的互動確實存在？

2. 就算物理過程可以合理化, 什麼規模的地震活動度會被改變？有沒有震源深度的限制？

# TO CONDUCT A SCIENCE PROJECT...

基礎紮根

發現問題

規劃研究

論證建模

表達分享

資料庫中能看到的，是地球哪些層圈的自然現象？

- 時間空間特徵是什麼？
- 物理機制是什麼？

我想要看到什麼？

資料的初步分析後，我能不能形成、訂定問題？

- (1) 建立假說
- (2) 設計變因
- (3) 資料統整與歸納

重新建立假說

講個好的故事

# 氣候變遷下地震變多了嗎？

基礎紮根

發現問題

規劃研究

論證建模

表達分享

氣候變遷的具體表現？  
時間空間特徵是什麼？  
地圈和氣圈是以什麼方式互動？

探索海洋和地物的資料庫後，  
我看到的問題是什麼？

今天的  
重點

- (1) 建立假說
- (2) 設計變因
- (3) 資料統整與歸納

重新建立假說

講個好的故事



翁博士的簡報

# 所謂發想... 是需要大量尋找相關資料的

- CAN CLIMATE CHANGE AFFECT THE NATURAL HAZARDS?  
氣候變遷下對天然災害的影響是什麼？
- UNDER WHICH CONDITIONS THE EARTHQUAKES CAN BE INDUCED?  
哪種條件下，氣候變遷能引發地震？
- HOW DO WE EXPLORE BY OURSELVES?  
我怎麼探索這個主題？



# CAN CLIMATE CHANGE AFFECT THE NATURAL HAZARDS?

氣候變遷下對天然災害的影響是什麼？

Earthquake

volcano

landslide

flood

cyclone

drought

地下的：地球物理管

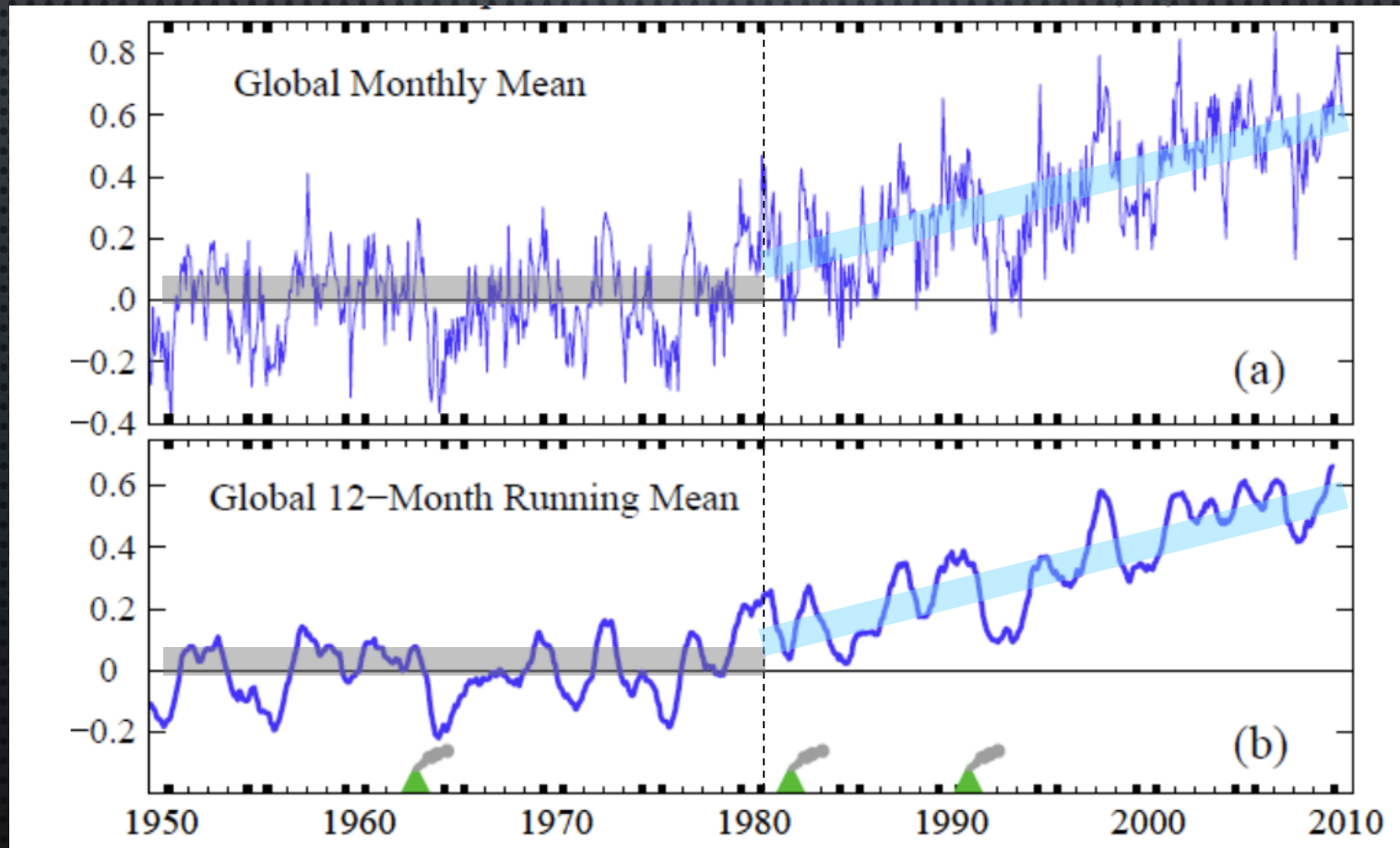
*geophysical hazards*

地上的：大氣/水文管

*meteorological / hydrological hazards*

# GLOBAL WARMING: SURFACE TEMPERATURE

相對於 1951-1980 的地表溫度，1980-2010 間逐年上升。  
累積升高值達 0.5 度，而每年升高  $0.5/30 = 0.0167$  度/年。

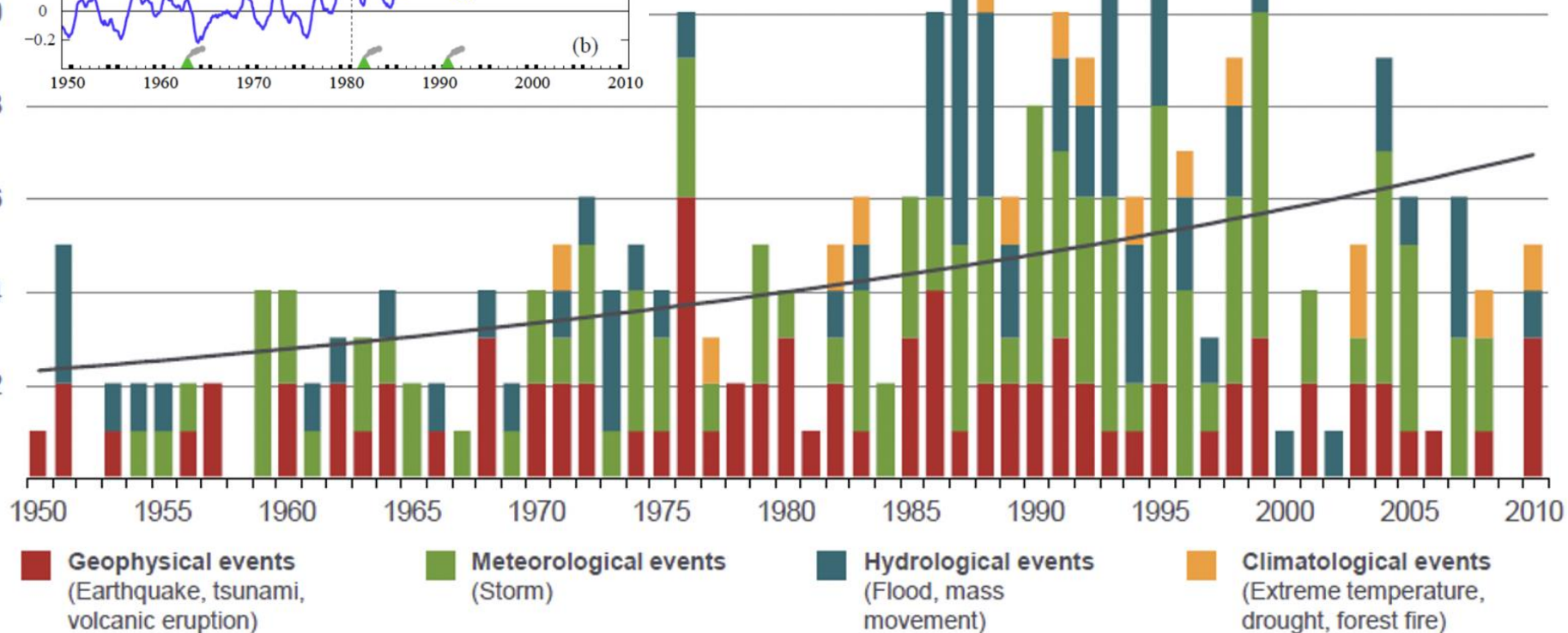
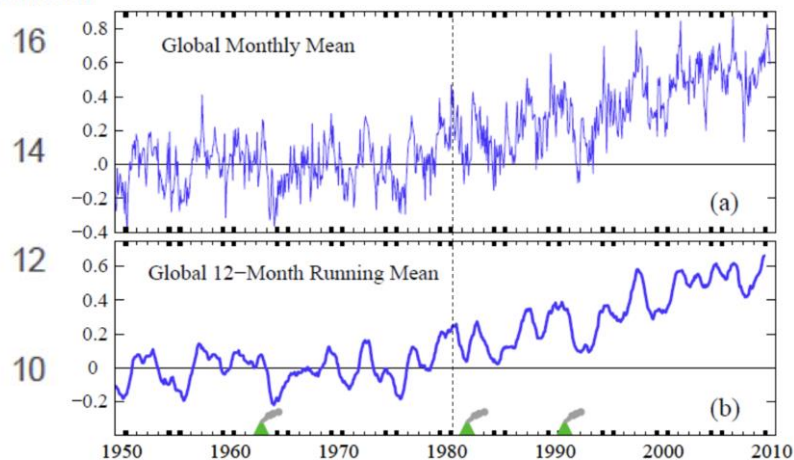




# NUMBER OF NATURAL HAZARDS

大氣、溫度、水文系統的表現，在1980年以來有上升的趨勢。但是地球物理系統，卻沒有顯著的數量變化。

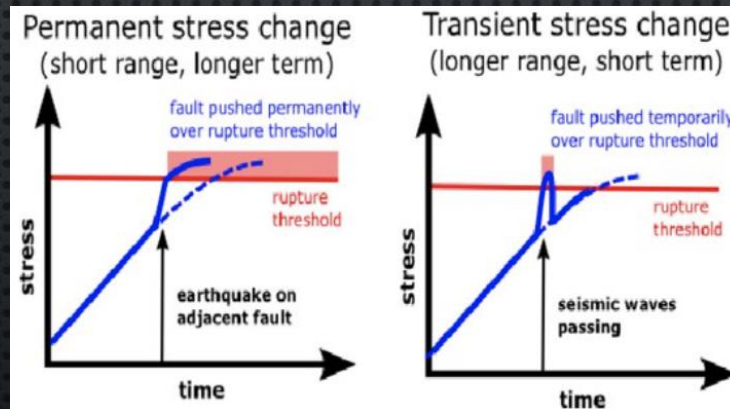
Number





# UNDER WHICH CONDITION THE EARTHQUAKES CAN BE INDUCED?

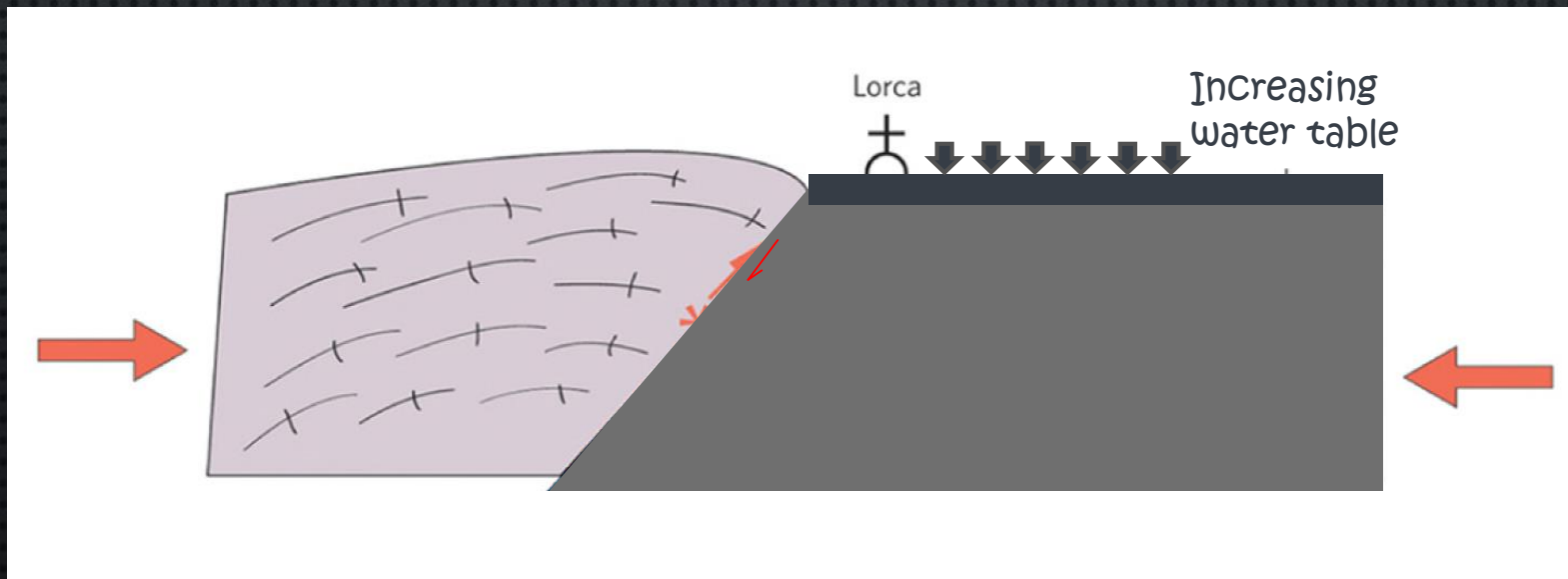
## 哪種條件下，氣候變遷能引發地震？



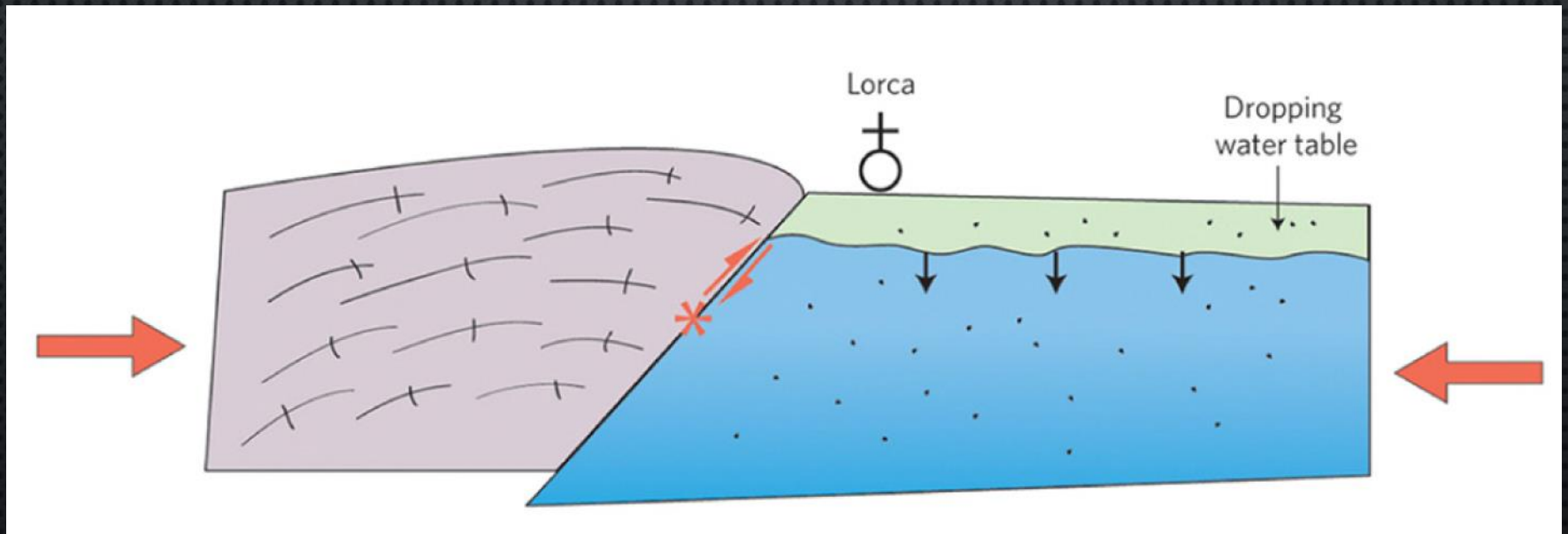
地表過程，只要能造成質量體的變化，就會對下方的斷層造成影響。

地表以下，和地表以上  
是用「應力」來互動！

Q: 當平地降雨突然變多，地下水位變高了，  
對這個斷層的影響是：(1) 加速 (2) 抑制 它的移動？



Q: 那，當地下水位變低的時候呢？  
對斷層的影響是: (1) 加速 (2) 抑制 它的移動？



# CONDITION FOR TRIGGERED/INDUCED EARTHQUAKES 地震的觸發條件

$$\tau_{cri} = \mu(\sigma - P) + \tau_0$$

$\tau_{cri}$ : 達到破裂時所需  
最小破壞剪應力

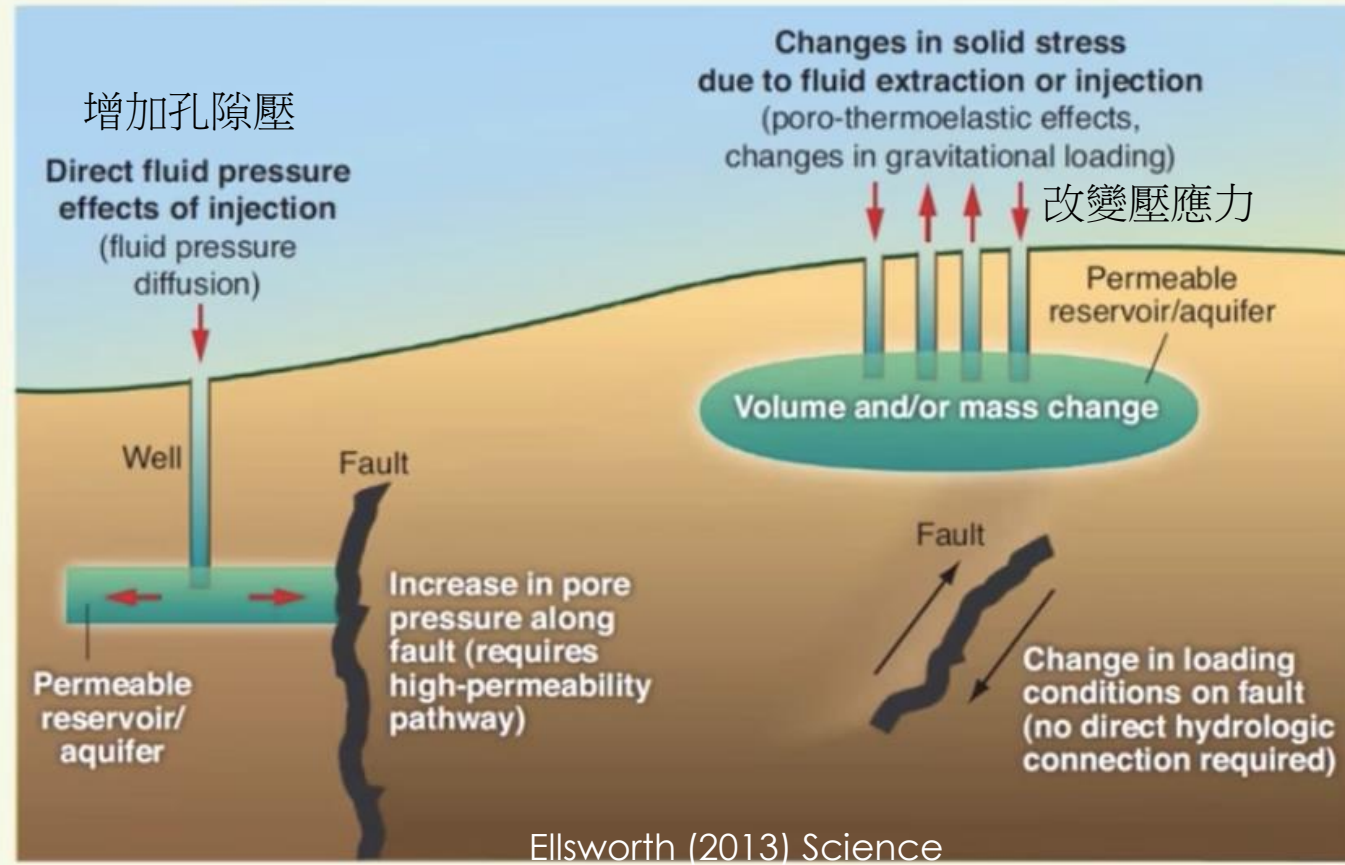
$\sigma$ : 給定之正向應力

$\mu$ : 摩擦係數

$P$ : 孔隙壓

$\tau_0$ : 欲開始滑動時的  
岩石內聚力

## Human Activity can Induced Earthquakes in Two Ways



增加孔隙壓 / 減少正向應力：減少達到破裂時所需之最小剪應力

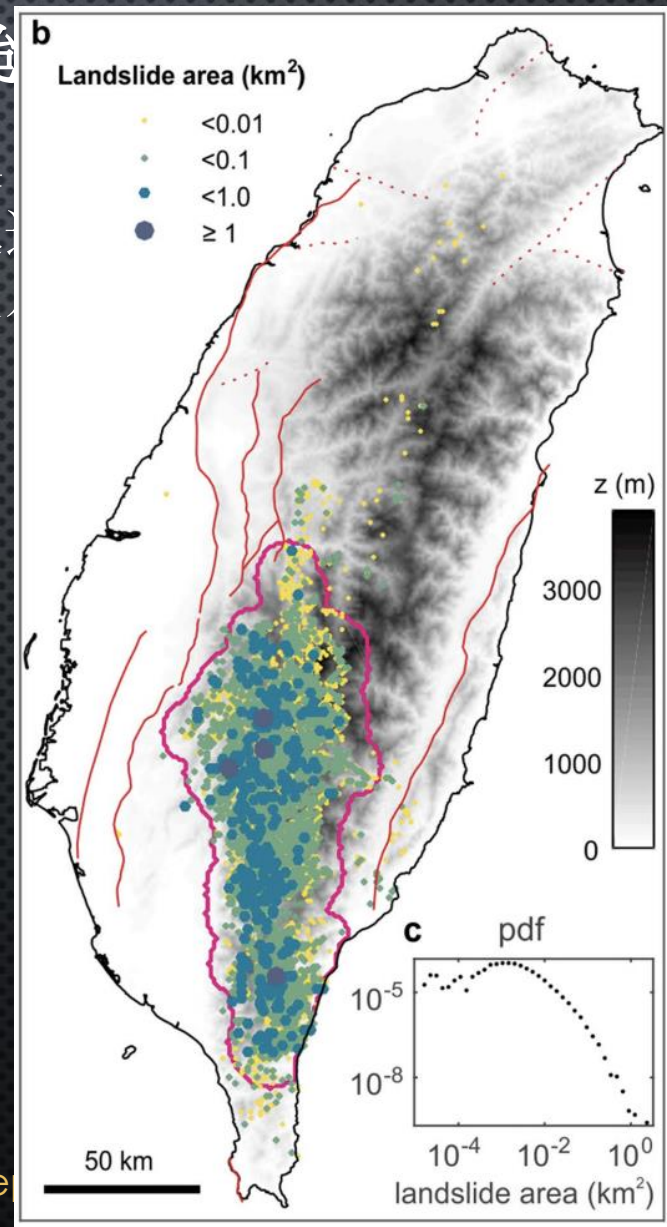
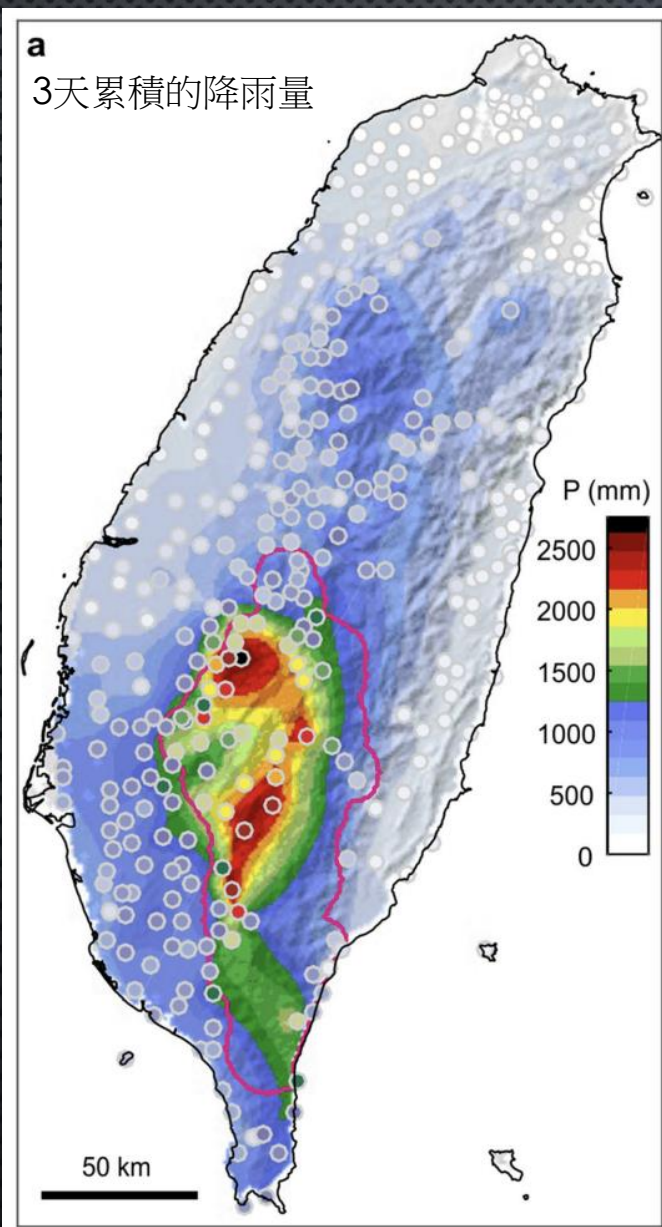
# 案例一：劇烈降雨帶來的「侵蝕作用」

## 2009/8/8 莫拉克颱風

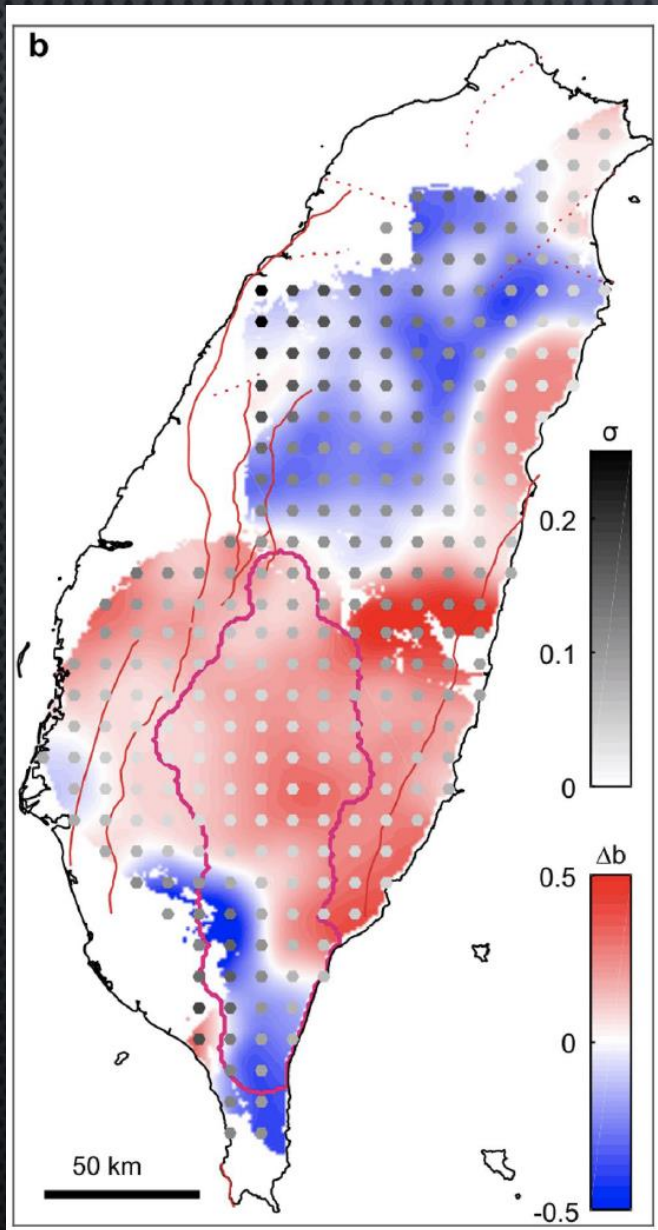
三天豪大雨，帶來1854  
677人死亡，共有254處  
受災，六大公路系統及  
創！

引發的大規模的土  
石流，造成了高雄  
縣甲仙鄉小林村的  
「小林部落」滅村，  
474人被活埋。

Steer et al. (2020) Scientific Re



## 地震活動的變化



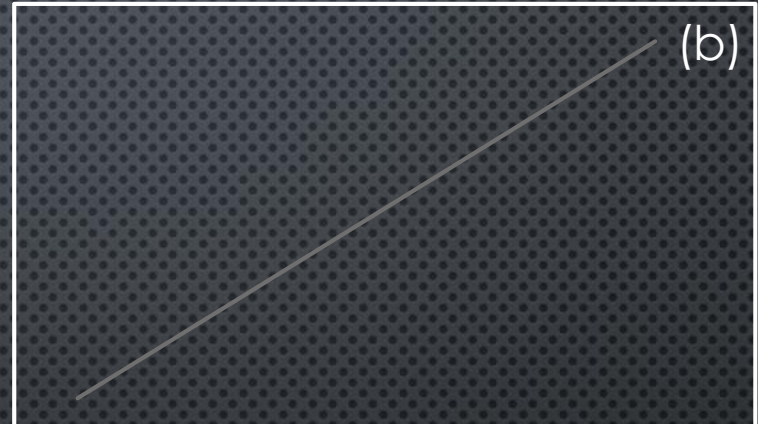
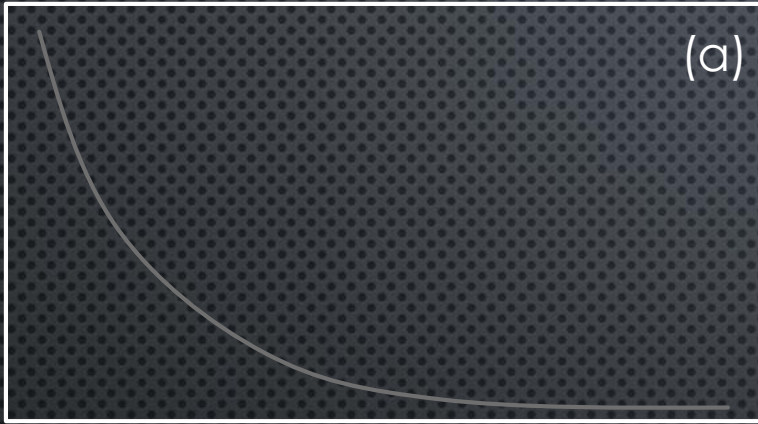
(1) 莫拉克前後各2.5年，地震數量差多少？

不只局限於顯著的土石流區域，宜蘭附近亦有明顯的數量增加。

(2) 到底是哪種規模的地震數量增加？

宜蘭附近： $\sigma$ 值減少（大地震數量增加）  
土石流區域： $\sigma$ 值增加（小地震數量增加）

# (補充) 地震發生次數和規模呈現什麼樣的關係?



地震次數

地震規模



# (補充) 怎麼量化?

- 地震規模越小，次數越多
- 規模與次數之關係一般以 Gutenberg-Richter關係式表示:

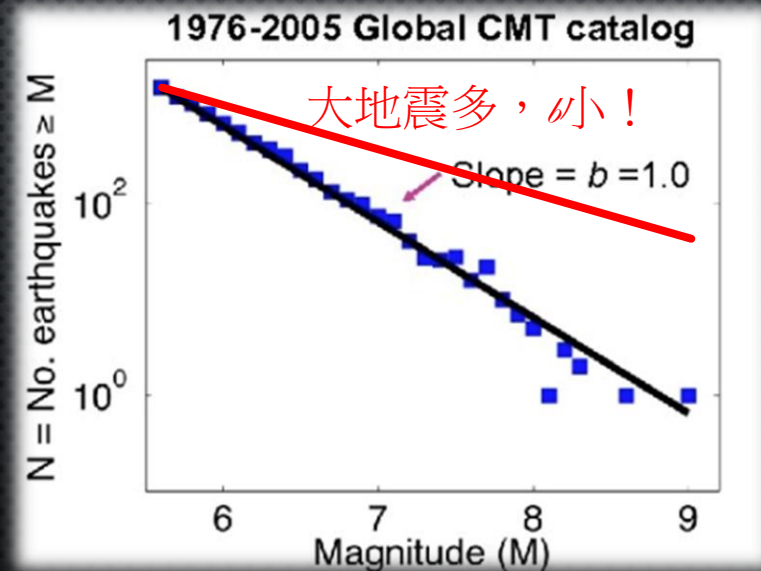
$$\log N = a - bM$$

N: 某單位時間內規模介於某範圍內的地震發生次數

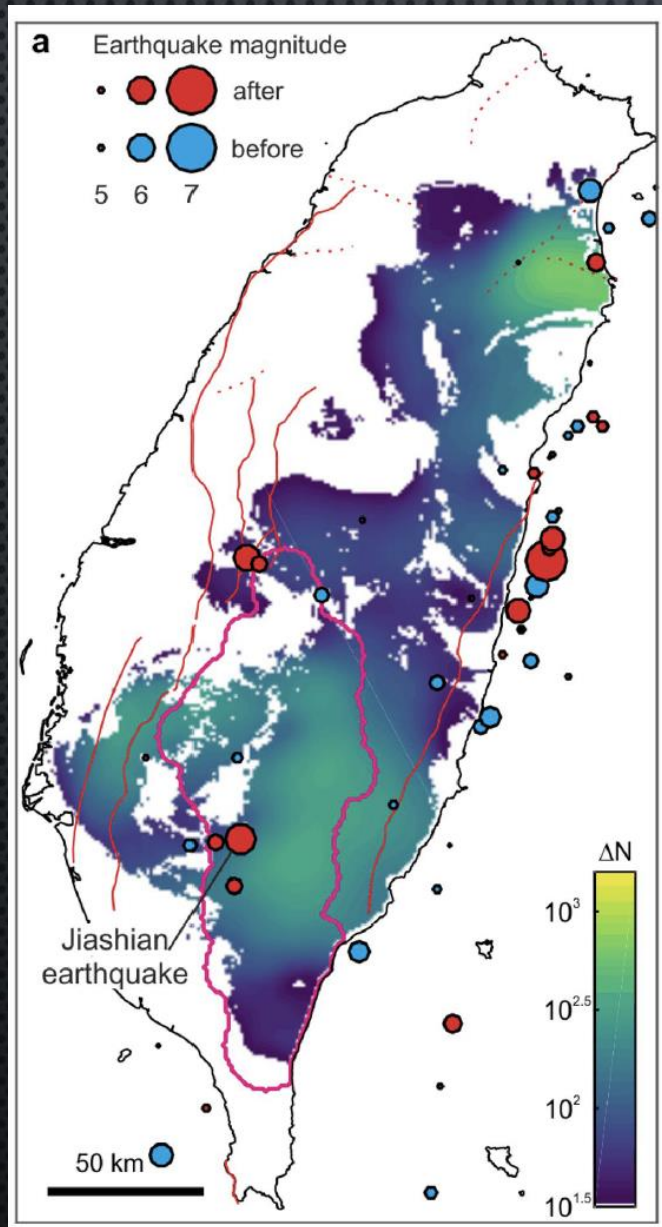
a: 特定區域內地震發生頻率之高低

b: 此特定區域內大地震與小地震發生機率之相關性

| 規模    | 每年發生次數  |
|-------|---------|
| > 9.0 | 0       |
| 8~8.9 | 1       |
| 7~7.9 | 18      |
| 6~6.9 | 108     |
| 5~5.9 | 800     |
| 4~4.9 | 6,200   |
| 3~3.9 | 49,000  |
| 2~2.9 | 300,000 |



# 地震活動的變化



(1) 莫拉克前後各2.5年，地震數量差多少？

不只局限於顯著的土石流區域，宜蘭附近亦有明顯的數量增加。

(2) 到底是哪種規模的地震數量增加？

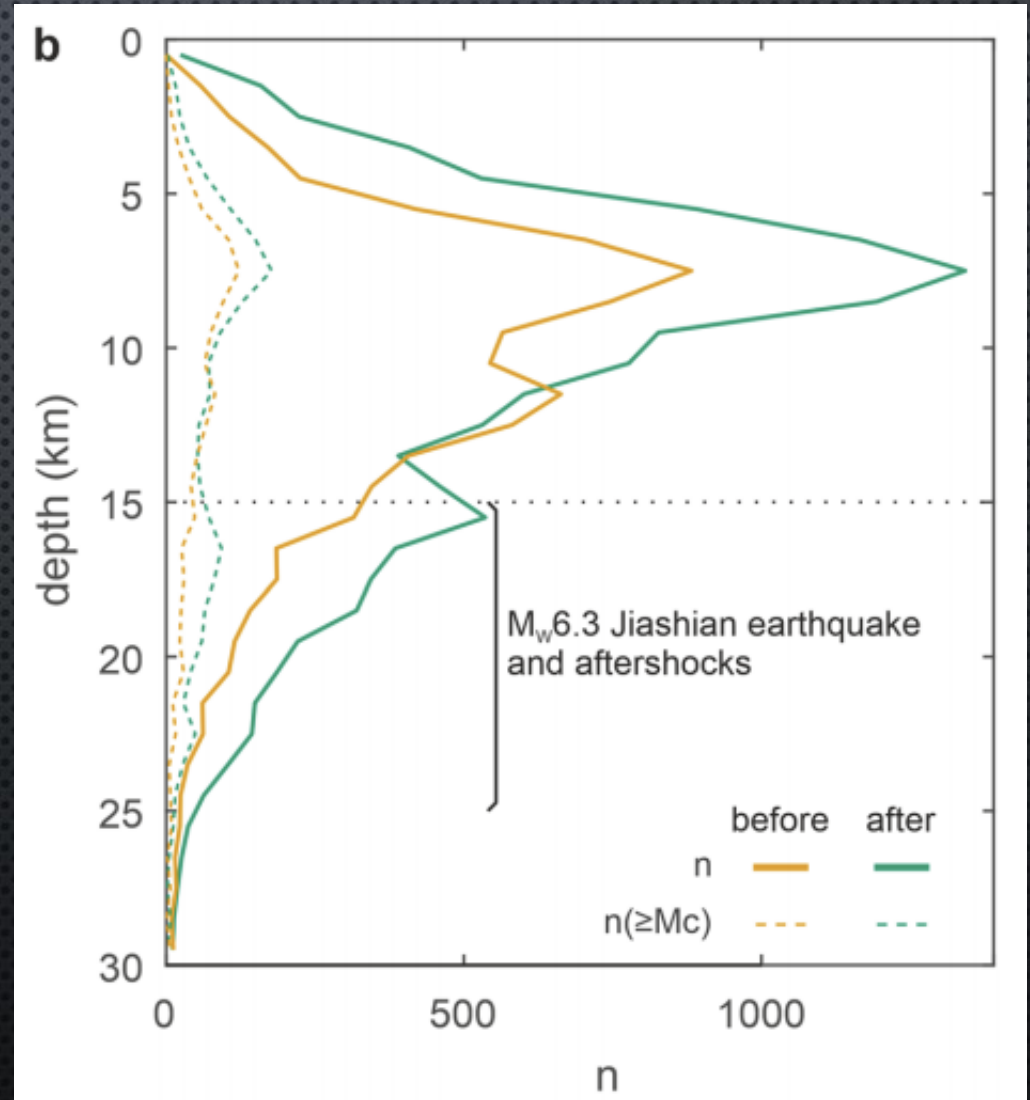
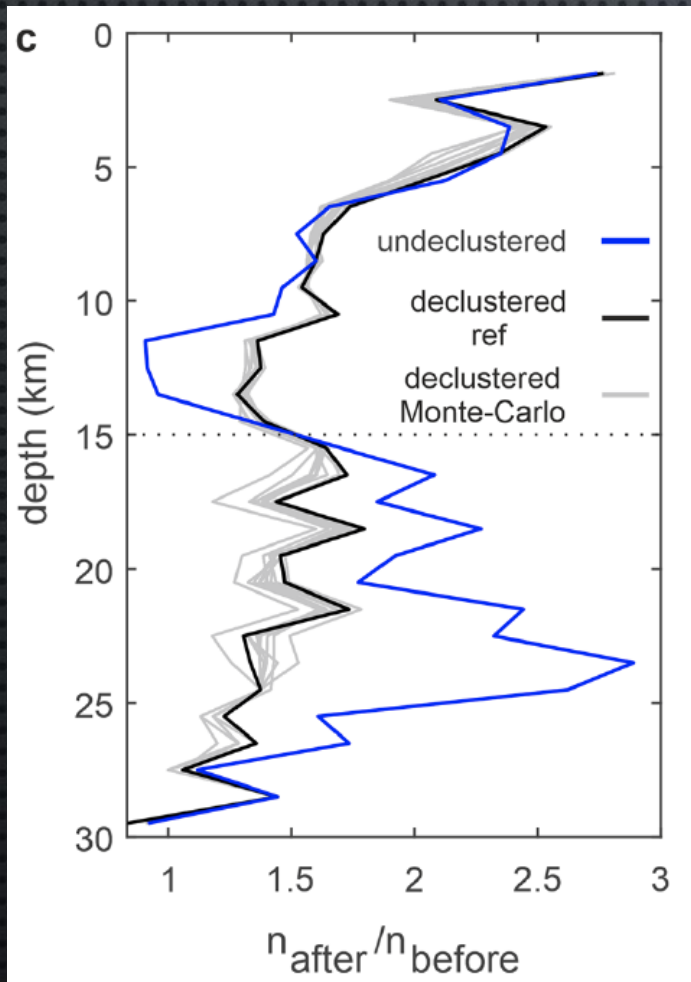
宜蘭附近： $\Delta N$ 值減少（大地震數量增加）  
土石流區域： $\Delta N$ 值增加（小地震數量增加）

(3) 有沒有可能小地震是「非土石流」事件造成的？

M<sub>6.4</sub>的甲仙地震，就發生在2010/3/4。

「跟主餘震有關」 → 把餘震去除

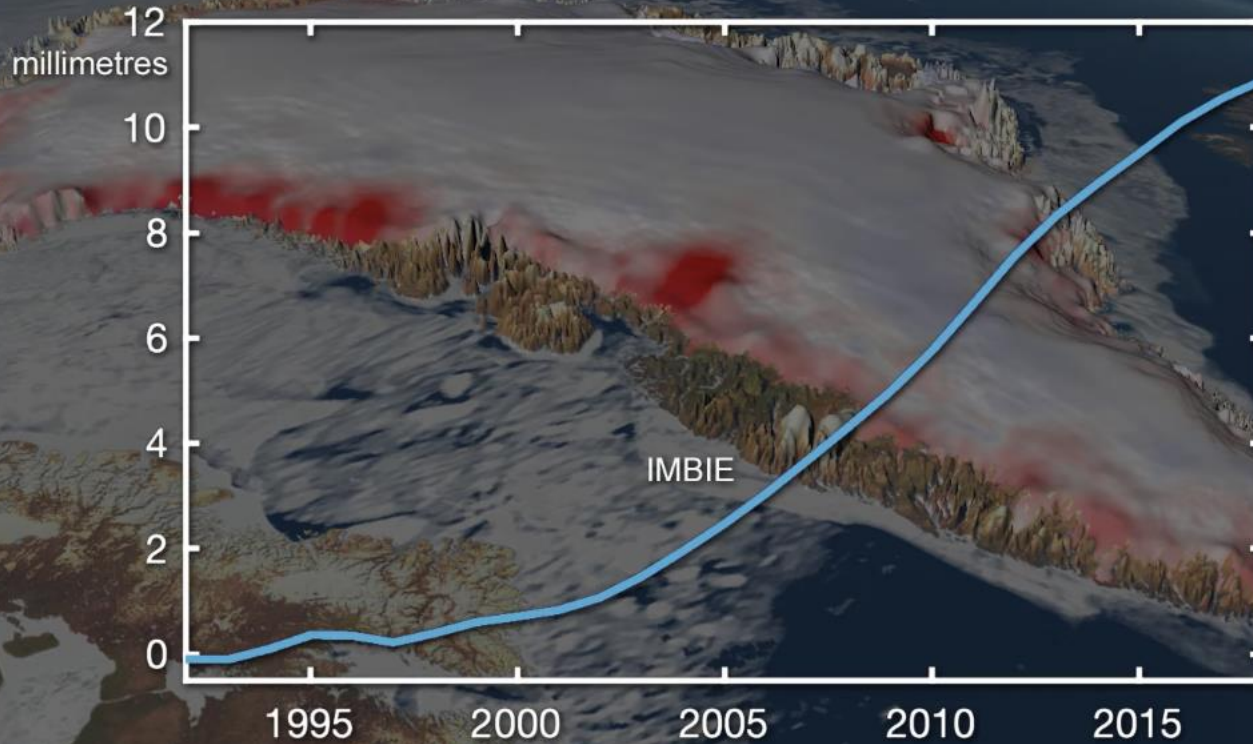
把餘震去除 (*declustered*) 後，發現颱風後 2.5 年，  
地震活動明顯地增加！



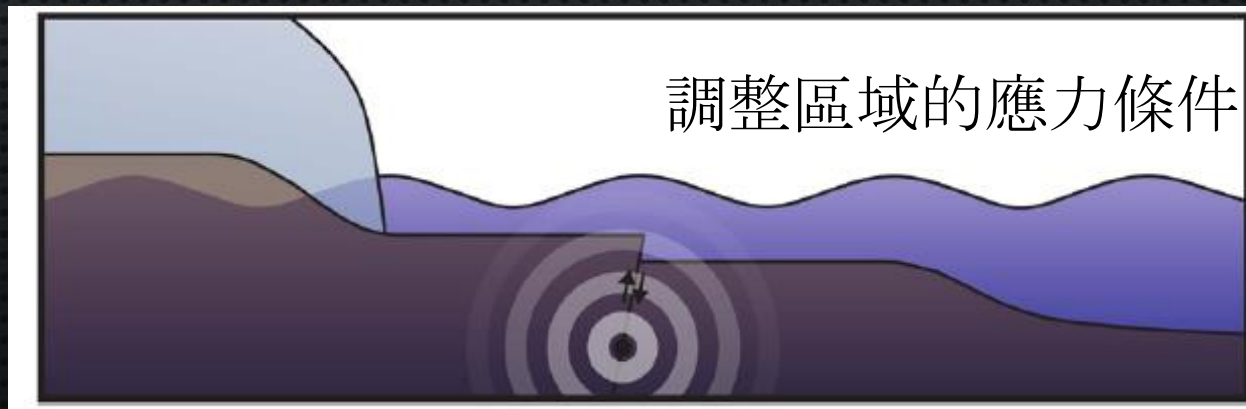
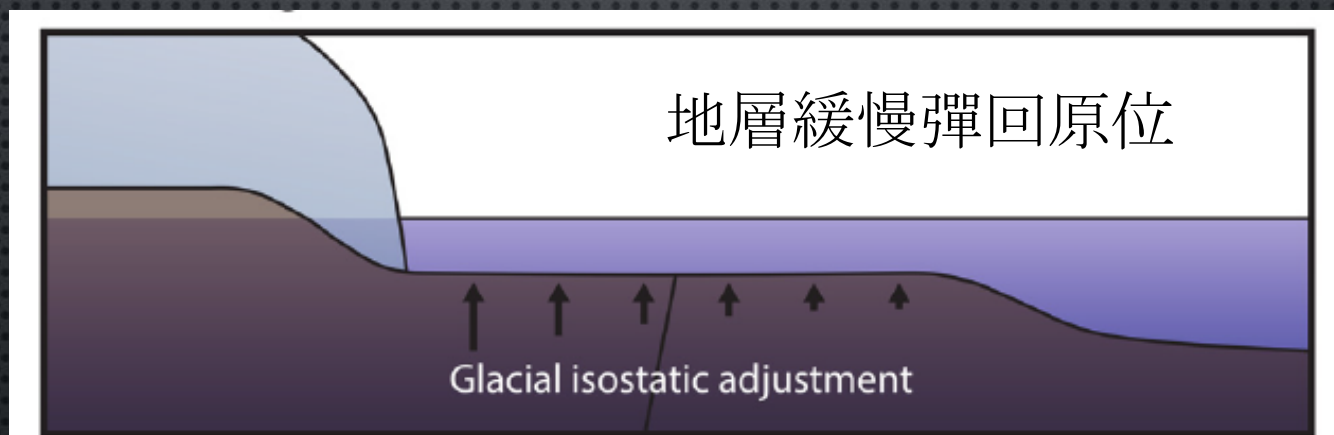
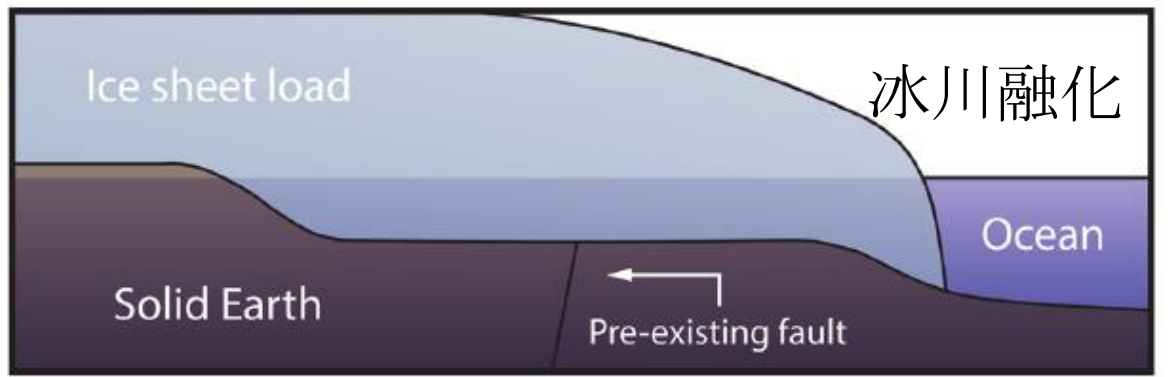
# 案例二：冰凍圈的融化

## Greenland Ice Sheet Contribution to Global Sea Level

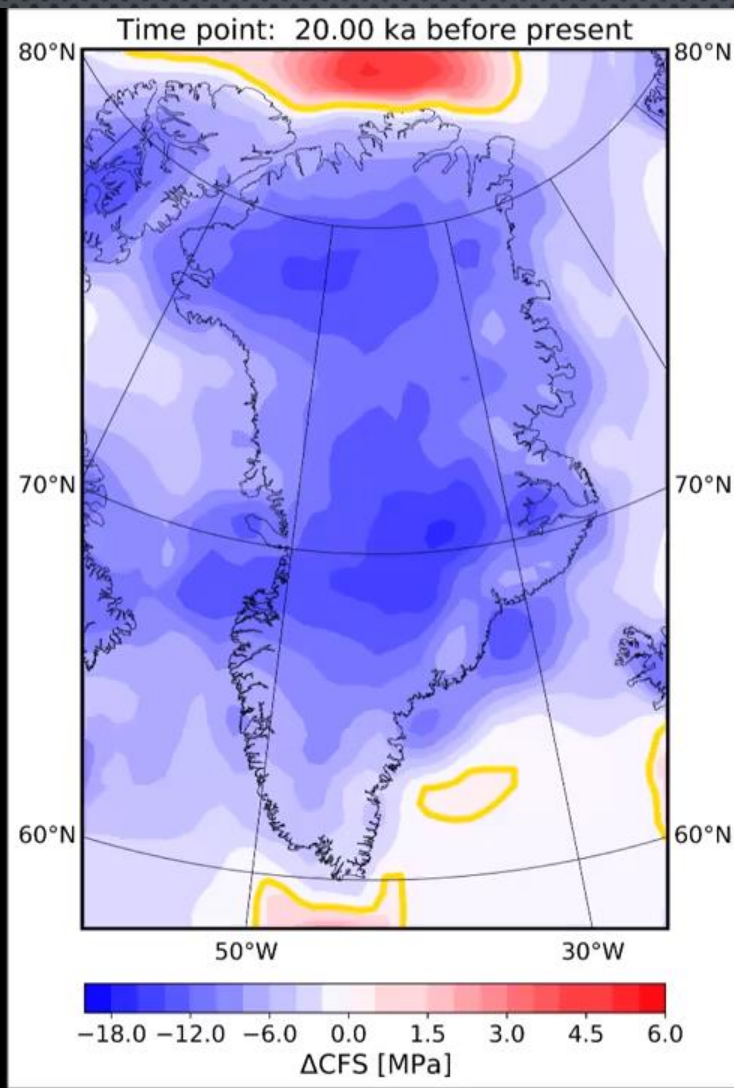
1993年起全球海面已上升了超過 1 cm，格陵蘭和南極的冰川加速融化，有著極重要的貢獻...



# 冰川融化如何引發觸發地震



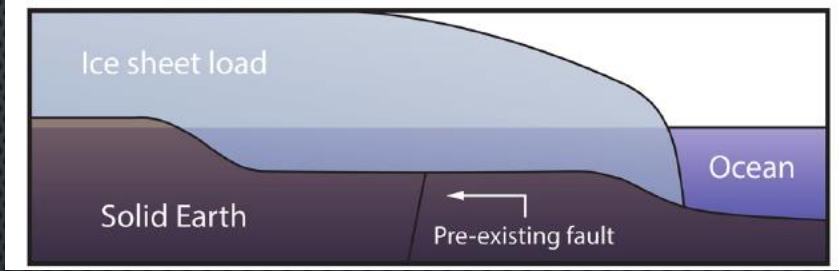
# 格林蘭的冰川融化，兩萬年來累積的應力變化：



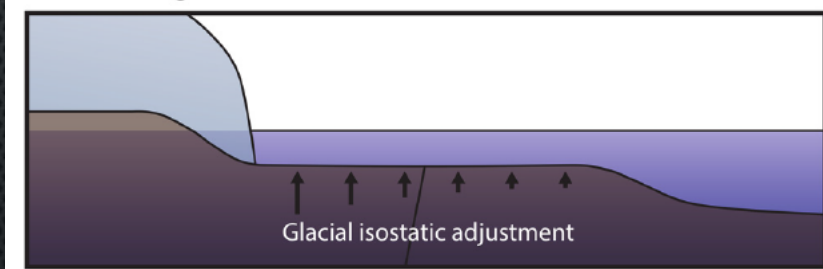
# 冰川融化

格林蘭的冰川融化，一萬年以來累積的應力變化，可以製造43.7 m的斷層錯動量。

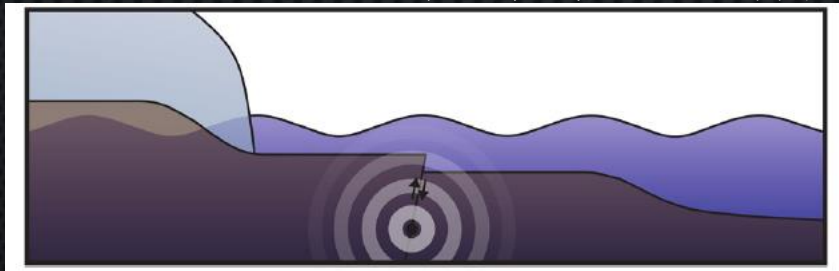
冰川融化



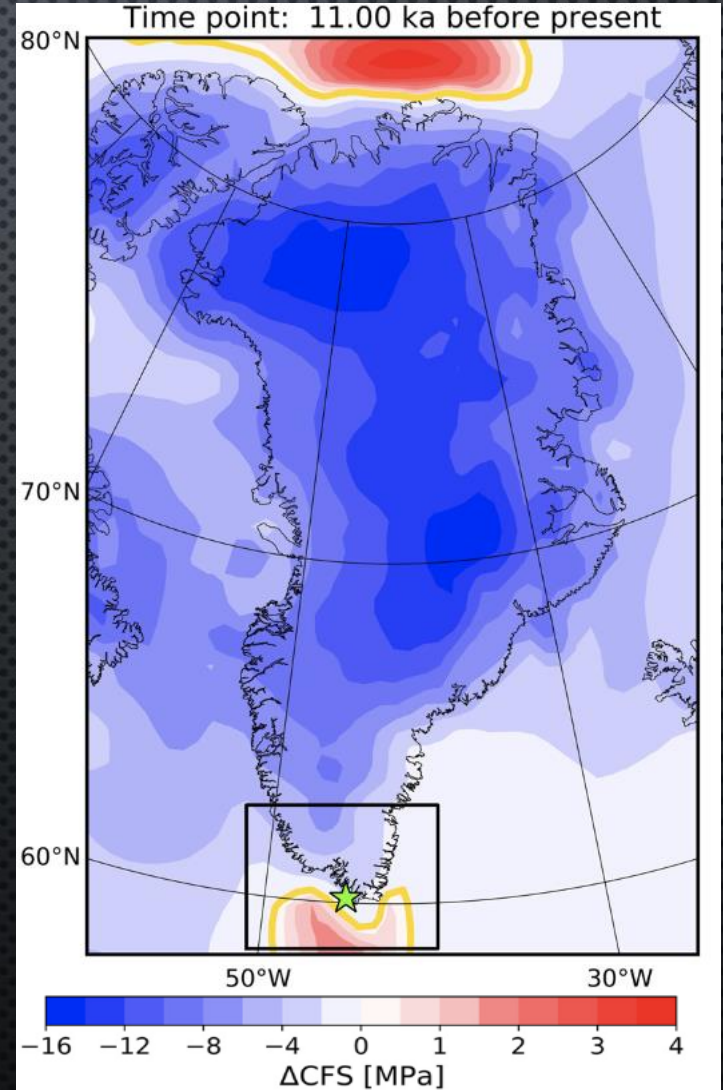
地層緩慢彈回原位



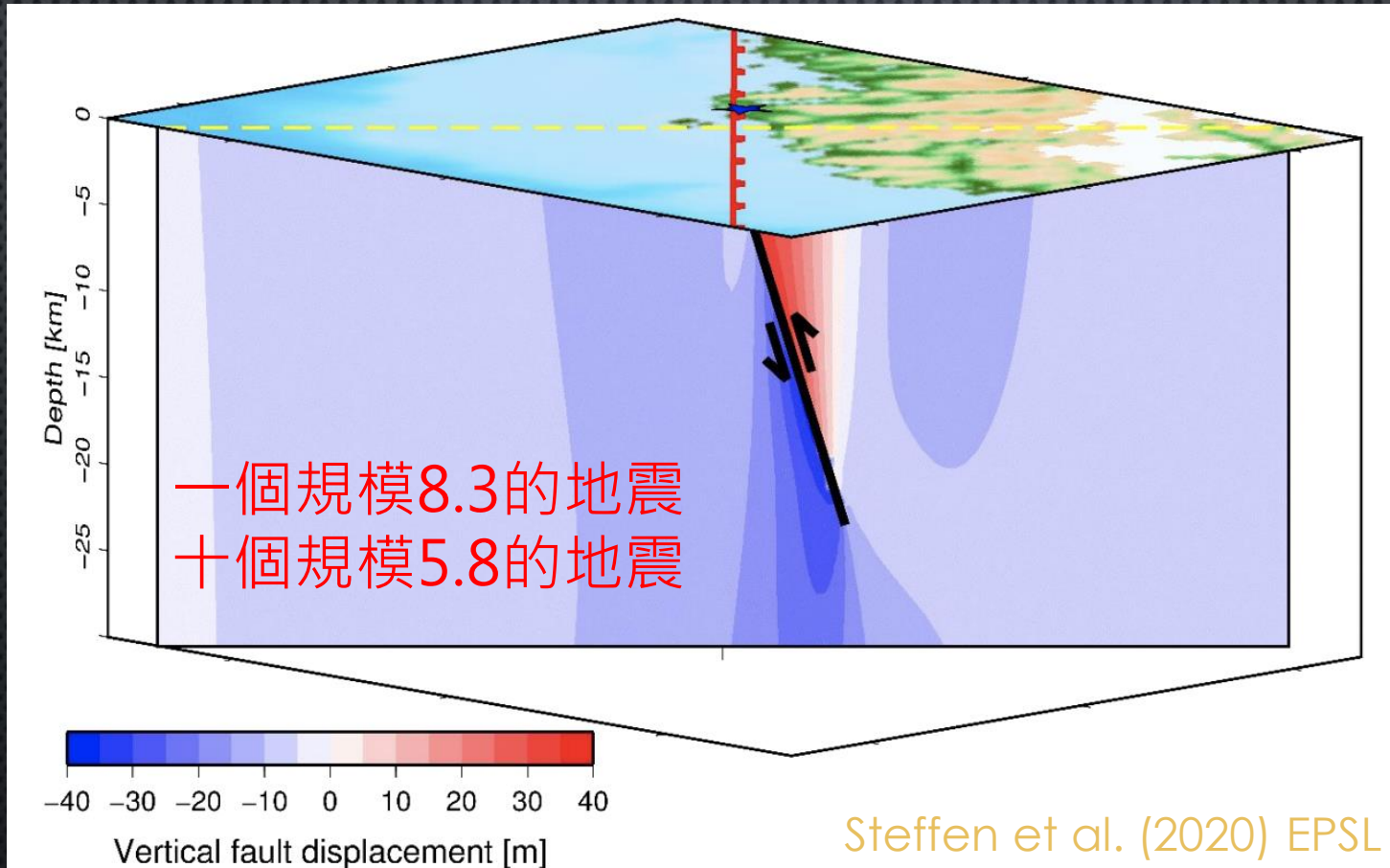
調整區域的應力條件



Steffen et al. (2020) EPSL



43.7m 的錯動量，對應到規模多少的地震？



**Seismic moment  $M_0 = \mu dA$**

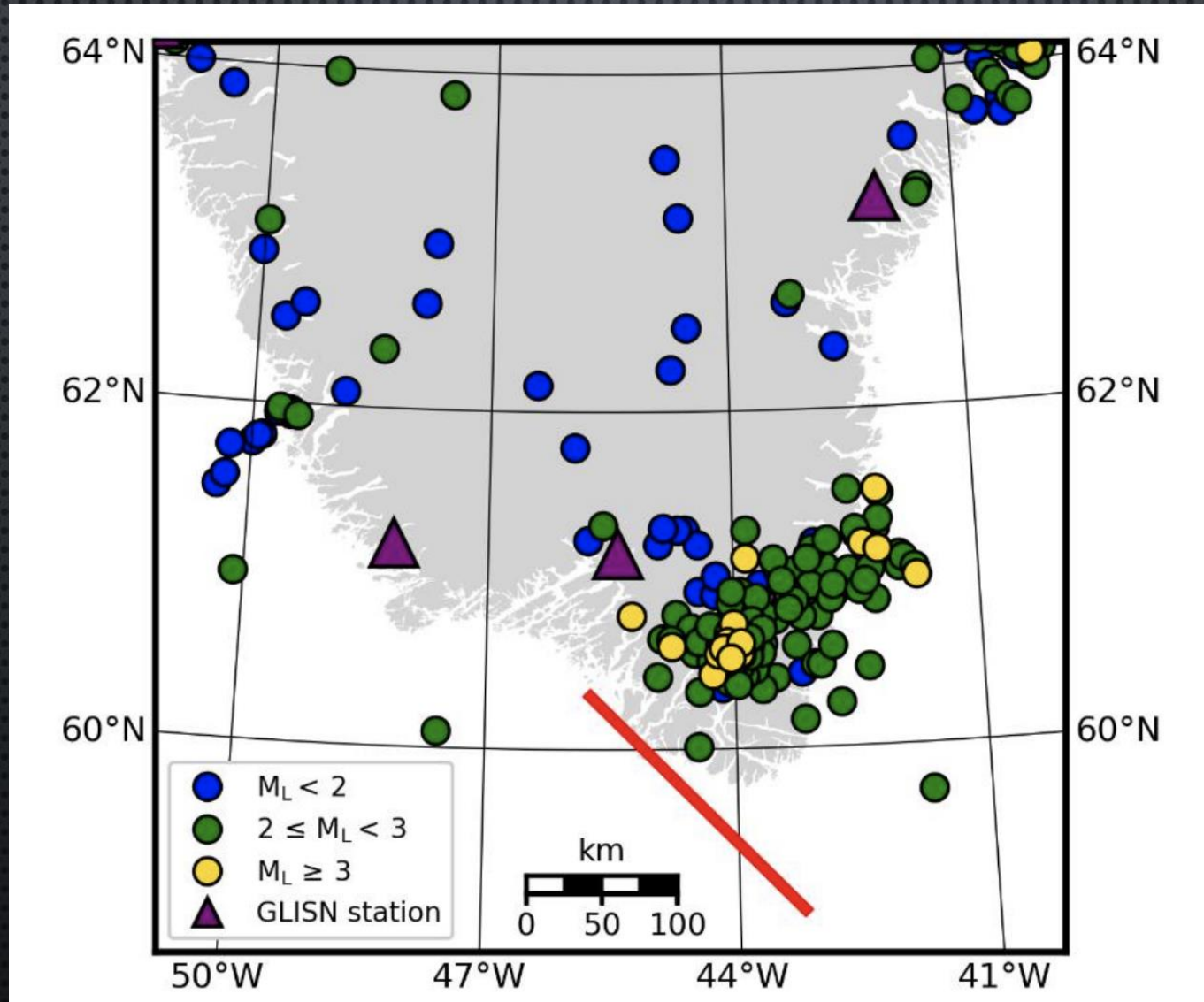
where  $d$  = avg slip,  $A$  = fault area;  $\mu$  = shear modulus  
average shear modulus ( $\mu$ ):  $3E+11 \text{ dyne/cm}^2$



$$M_w = \frac{\log M_0}{1.5} - 10.73$$

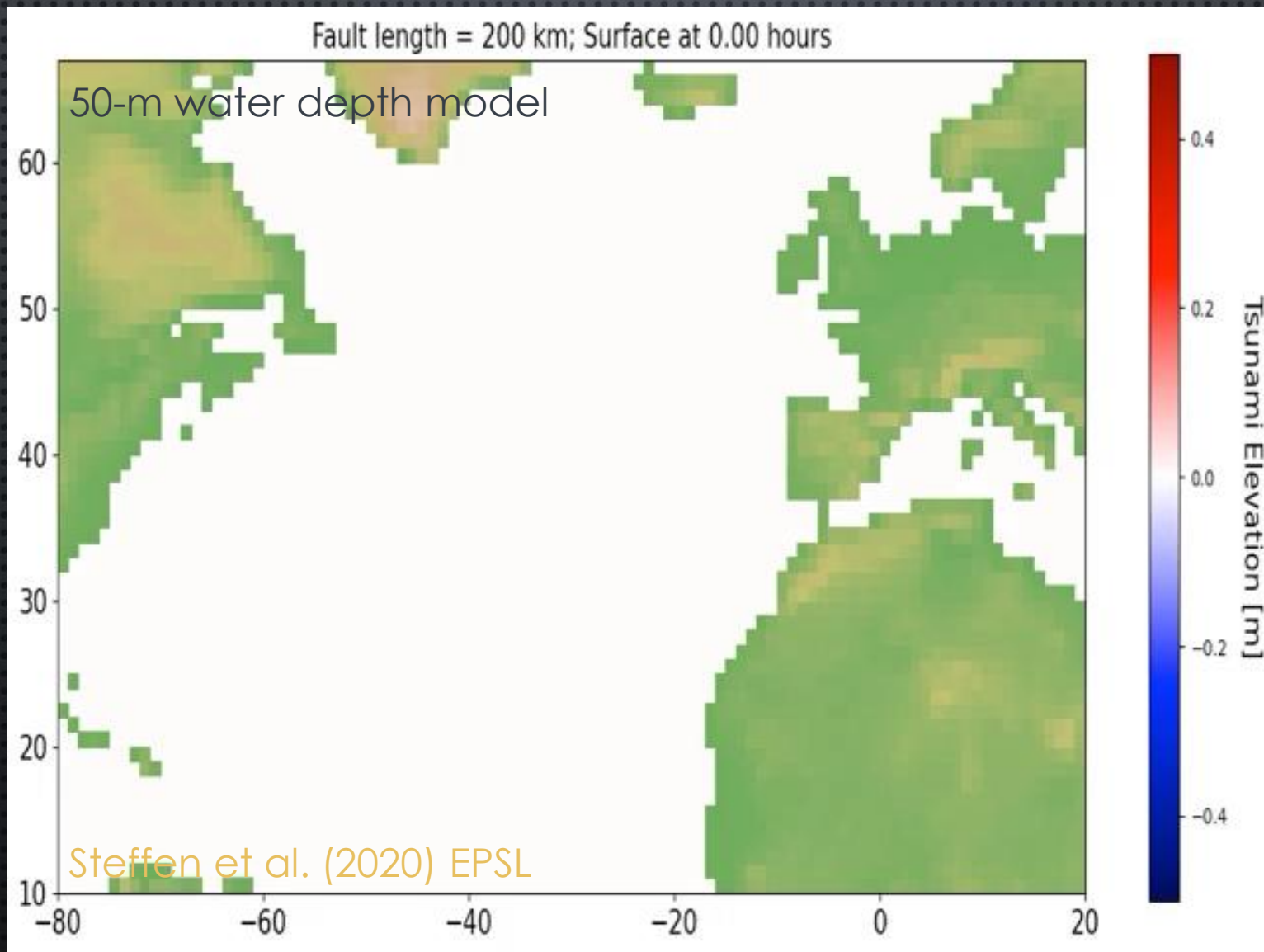


事實上絕大多數的地震，規模都小於3!

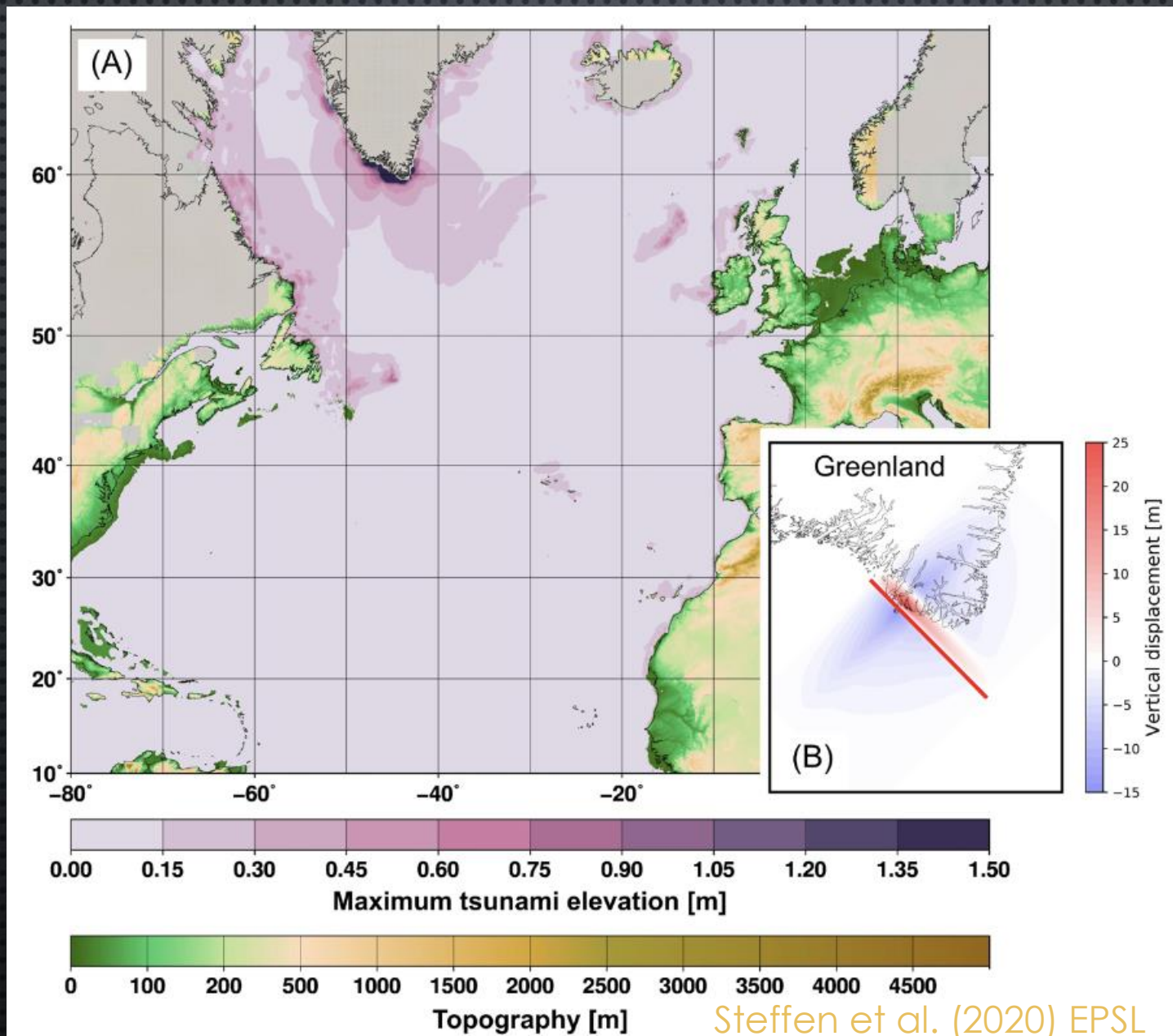


Steffen et al. (2020) EPSL

單一地震事件，會造成海嘯嗎？可高達7 m！



將在北大西洋造成7.2 m的海嘯，在加拿大沿岸甚至可以高達7.8m!

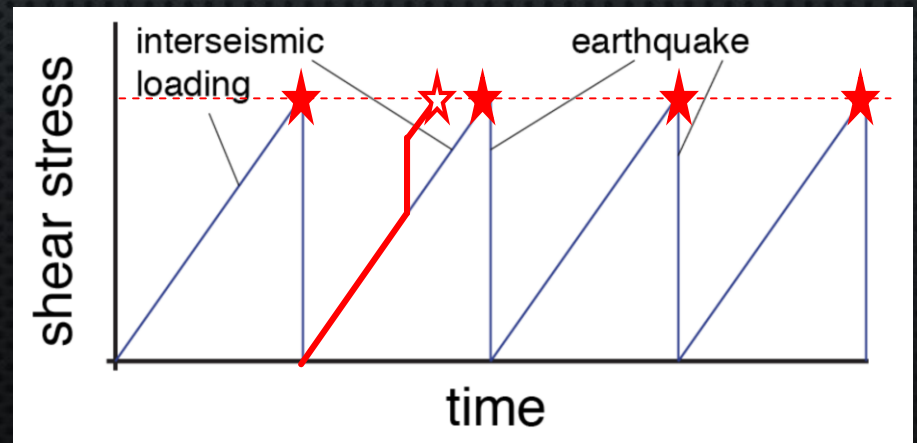


Steffen et al. (2020) EPSL

# SUMMARY?

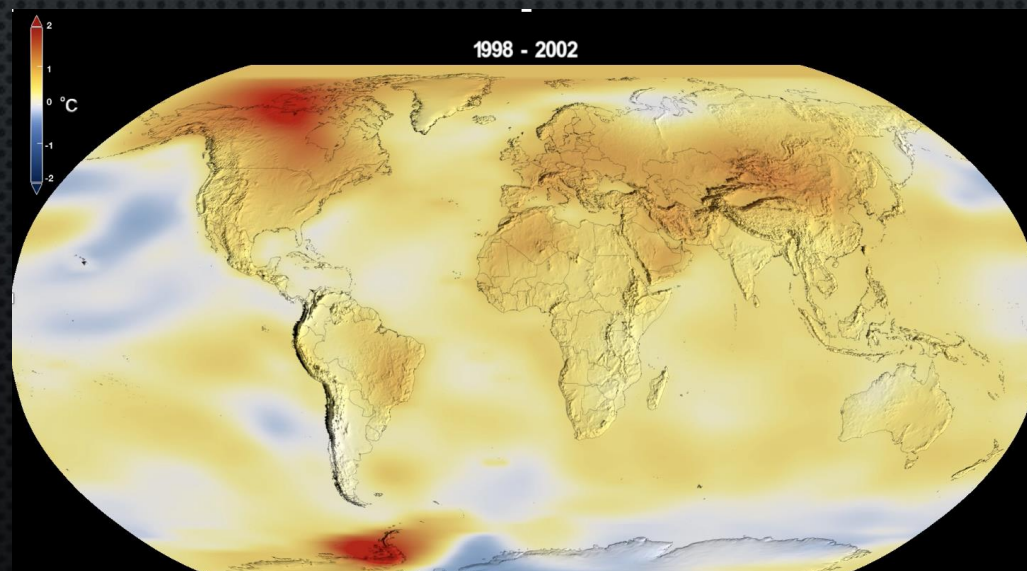
## 全球暖化造成的極端事件能觸發地震，學理上有根據，但觀測證據並不充分

- 全球暖化下造成的極端天氣，直接衝擊大氣條件，使得颱風、乾旱、水災等等的頻繁發生。地球物理的災害，以地震最為難以預測。它，受到了怎麼樣的影響？
- 事實上，和大氣相關災害相比，全球並沒有顯著的「長期地震數量變化」趨勢。然而，單一事件的觸發關係已經屢屢被提出，只要有質量 (SURFACE LOADING) 的變化，就會影響地下的應力條件，讓地震的觸發成為可能。
  1. RAINFALL INDUCED WATER TABLE CHANGE AND FLUID DIFFUSION
  2. EROSION INDUCED MASS WASTING
  3. DEGLACIATION OF ICE SHEET



# Summary 11: 人人可以做科學

- 這個問題，你也可以在資料庫中探索！
  - (1) 尋找研究區域：哪裡有顯著的全球暖化特徵？
    - 溫度逐年上升 & 海水面逐年變化特別顯著的區域
    - 避開構造運動活躍的區域
  - (2) 找到這個區域的海洋、大氣資料，量化不同參數的時間變化
    - 什麼狀況下，逐年變化的趨勢不再出現？(例如不同緯度的海溫分層效應)
  - (3) 找到這個區域的地震活動，量化地震活動率、規模與數量隨時間的變化
  - (4) 依據上兩項的相關性，提出可受驗證的假說



建議：避開構造活動非常活躍的區域

# 三 三 三

## 這個題目，我可以怎麼探索？

海溫資料：亞洲太平洋資料研究中心 (APDRC)



The banner features the APDRC logo on the left, which includes a globe icon. To the right of the logo, the text reads "ASIA-PACIFIC DATA-RESEARCH CENTER" in large, bold, black letters, with "of the IPRC" in smaller text below it. Underneath, a smaller line of text states "IN THE SCHOOL OF OCEAN AND EARTH SCIENCE AND TECHNOLOGY AT THE UNIVERSITY OF HAWAII AT MĀNOA". Below the banner is a navigation bar with a light blue background, containing links for "Home", "New", "Data", "Projects", "Servers", "Tutorials", and "IPRC". On the right side of the navigation bar, there is a white box with the text "ENHANCED BY Google" and a blue search button with a magnifying glass icon.

地震資料：地震學研究機構聯合會



The banner has a dark purple background. On the left, there are logos for "NSF" (National Science Foundation) and "SAGE". In the center, the "IRIS" logo is displayed in a large, white, serif font, with a white seismic waveform above the letters "I" and "R". To the right of the "IRIS" logo, the text "Incorporated Research Institutions for Seismology" is written in a smaller, white, sans-serif font. In the top right corner, there are links for "contact us" and "staff sign in". At the bottom of the banner, there is a navigation bar with a dark purple background, containing links for "DATA", "INSTRUMENTATION", "EDUCATION", and "ABOUT", followed by a white search button with a magnifying glass icon.



1. 進入網頁

[http://apdrc.soest.hawaii.edu/data/data.php?discipline\\_index=2](http://apdrc.soest.hawaii.edu/data/data.php?discipline_index=2)

- Home
- New ▾
- Data ▾**
- Projects
- Servers ▾
- Tutorials ▾
- IPRC

**Search by**

- All Server Types ▾
- All Data Types ▾
- All Grid Types ▾
- All Time Coverages ▾
- Atmospheric ▾
- All Temporal Resolutions ▾

2. 選取資料型態: *Ocean*

- All Disciplines
- Air-sea Flux
- ✓ Ocean**
- Atmospheric
- Terrestrial

|                |  |
|----------------|--|
| Server Type:   | All Server Types, Live Access Server (LAS), OPeNDAP, DCHART  |
| Data Type:     | All Data Types, In-situ Observations, Satellite/Remote Observations, Model Results, Reanalysis Products    |
| Grid Type      | All Grid Types, Gridded data (x,y,z,t), Station data, Along track, Lagragian                               |
| Time Coverage: | All Time Coverages, Forecast, Near real-time, Fixed time (static), Non-static, Climatology, Paleo, No time |
| Discipline*:   | All Disciplines, Air-sea Flux, <b>Ocean</b> , Atmospheric, Terrestrial                                     |

### 3. 哪種海溫是你要的?

(1) 六小時一點

(2) 表面溫度

(3) 按「Next」

[Datasets](#) > [APDRC Public-Access Products](#)

Click on a dataset to continue

Select dataset:

- [6 hourly, Surface](#)
- [Daily Climatology, Pressure Level](#)
- [Daily Climatology, Surface](#)
- [Monthly Average Pressure](#)
- [Monthly Average Surface](#)
- [Monthly Climatology, Pressure Level](#)
- [Monthly Climatology, Surface](#)

[Datasets](#) > [APDRC Public-Access Products](#) > [JRA-25](#) > [Monthly Climatology, Surface](#)

Select a variable and then click **Next >** to proceed to the Constraints page.

Dataset variable(s):

[Reset](#) | [Select all](#) | [Unselect all](#)

- \*\* 6-hourly convective precipitation rate ac
- \*\* 6-hourly large-scale precipitation rate ac
- \*\* 6-hourly snowfall rate water equivalent ac
- \*\* clear sky downward long wave flux at surface mn
- \*\* clear sky downward solar flux at surface mn
- \*\* clear sky upward long wave flux at top mn
- \*\* clear sky upward solar flux at surface mn
- \*\* clear sky upward solar flux at top mn
- \*\* column total of diabatic heat mn
- \*\* column total of meridional water vapor flux mn
- \*\* surface snowfall rate water equiv.
- \*\* surface specific humidity
- \*\* surface std. dev. of ir t over 1x1 deg area
- \*\* surface surface roughness
- \*\* surface temp.
- \*\* surface total cloud cover
- \*\* surface u wind
- \*\* surface upward long wave flux
- \*\* surface upward short wave flux
- \*\* surface v wind
- \*\* surface vertical speed shear
- \*\* surface water temp.

**Next >**



#### 4. 選取資料的展現 (view) 和輸出 (output) 方式

**i** [Datasets](#) > [APDRC Public-Access Products](#) > [JRA-25](#) > [Monthly Climatol](#)  
Variable(s): \*\* sst and sea ice surface temperature snp

Select your desired view (geometry of output) and output (type)  
Then set the 4-D region (lon-lat-depth-time) and any additional options

Select view:

Longitude-Latitude map (xy)

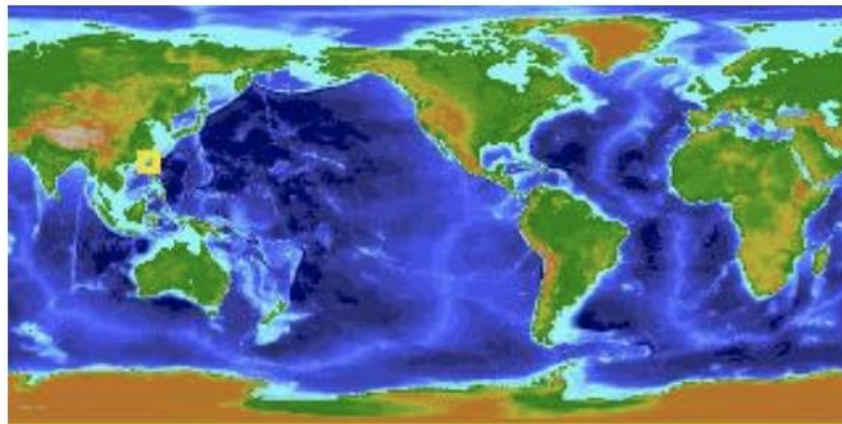
Select output:

Color plot

Select region:

Full Region

[Use the interactive map](#) [Help](#)



Select time range:

01  Jan  1979  00:00   
22  Aug  2011  00:00

畫出 1979~2011 的海溫變化

- Longitude-Latitude map (xy)
- Longitude-time hofmoeller (xt)
- Latitude-time hofmoeller (yt)
- Longitude line (x)
- Latitude line (y) 畫時間序列
- Time series (t)**
- xyt volume

- Line plot**
- Line plot comparison 幫你畫出來
- Table of Values (text)
- NetCDF file
- ASCII file
- Desktop application data access scripts
- Interactive Download

## 5. 選取資料空間、時間範圍

**Select view:** Time series (t) ▾  
**Select output:** Line plot ▾  
**Select region:** Full Region ▾ **Go** →  
[Use the interactive map](#) [Help](#)

✓ Full Region

Africa

Asia

Australia

Europe

North America

South America

Indian Ocean

North Atlantic

Equatorial Atlantic

South Atlantic

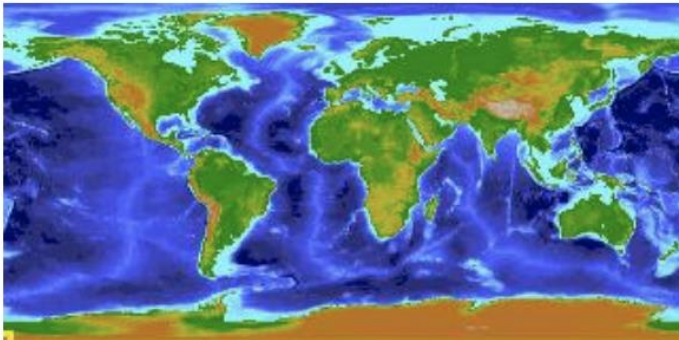
North Pacific

Equatorial Pacific

South Pacific

事實上如果你要畫 *time series* (t)，只需要輸入經緯度，還有指定資料期間！

**Help** **Reset**



**Zoom +** **Zoom -**

89.142 S  
180 W 180 W  
89.142 S  
**Go**

**Select time range:** 01 ▾ Jan ▾ 1979 ▾ 00:00 ▾  
22 ▾ Aug ▾ 2011 ▾ 00:00 ▾

# Output: Line plot

✓ Line plot

Line plot comparison

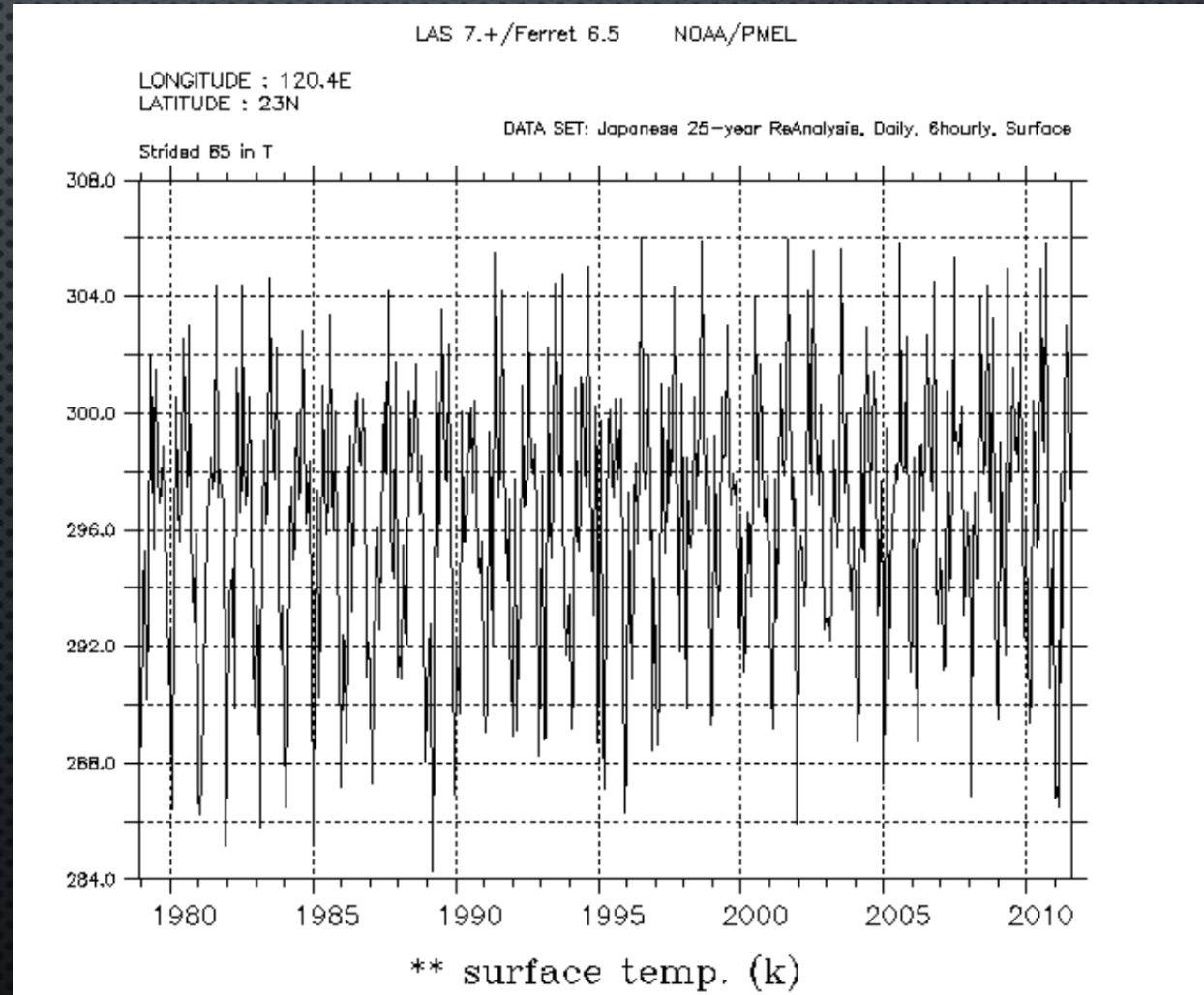
Table of Values (text)

NetCDF file

ASCII file

Desktop application data access scripts

Interactive Download



# Output: ASCII file

- Line plot
- Line plot comparison
- Table of Values (text)
- NetCDF file
- ✓ ASCII file
- Desktop application data access scripts
- Interactive Download

```
VARIABLE : ** surface temp. [k]
DATA SET : fcst_phy2m
FILENAME : 6_hourly-surface
FILEPATH : http://apdrc.soest.hawaii.edu/dods/public_data/JRA-25/
BAD FLAG : -9999
SUBSET   : 47685 points (TIME)
LONGITUDE: 120.4E
LATITUDE : 23N 120.4E
```

|             |    |       |
|-------------|----|-------|
| 01-JAN-1979 | 00 | 288.5 |
| 01-JAN-1979 | 06 | 293.8 |
| 01-JAN-1979 | 12 | 291.1 |
| 01-JAN-1979 | 18 | 289.4 |
| 02-JAN-1979 | 00 | 289.6 |
| 02-JAN-1979 | 06 | 293.9 |
| 02-JAN-1979 | 12 | 291.8 |
| 02-JAN-1979 | 18 | 289.8 |
| 03-JAN-1979 | 00 | 289.5 |
| 03-JAN-1979 | 06 | 294.1 |
| 03-JAN-1979 | 12 | 291.7 |
| 03-JAN-1979 | 18 | 289.3 |
| 04-JAN-1979 | 00 | 289.3 |
| 04-JAN-1979 | 06 | 293.4 |
| 04-JAN-1979 | 12 | 291.2 |
| 04-JAN-1979 | 18 | 287.9 |
| 05-JAN-1979 | 00 | 287.7 |
| 05-JAN-1979 | 06 | 293   |
| 05-JAN-1979 | 12 | 291.2 |
| 05-JAN-1979 | 18 | 288.8 |
| 06-JAN-1979 | 00 | 288.8 |
| 06-JAN-1979 | 06 | 293.6 |
| 06-JAN-1979 | 12 | 290.9 |
| 06-JAN-1979 | 18 | 288.5 |
| 07-JAN-1979 | 00 | 288.2 |

這邊也有 *Tutorials* 讓你參考喔！



IN THE SCHOOL OF OCEAN AND EARTH SCIENCE AND TECHNOLOGY AT THE UNIVERSITY OF HAWAII AT MĀNOA

Home New Data Projects Servers **Tutorials** IPRC

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SAGE



Incorporated Research Institutions for Seismology

DATA INSTRUMENTATION EDUCATION ABOUT Q



進入網頁

<https://ds.iris.edu/ieb/>

The screenshot shows the IRIS Earthquake Browser interface. At the top, it says "IRIS Earthquake Browser" and "Options >". Below the title bar is a world map with numerous colored dots representing earthquake locations. On the right side, there are several filter panels:

- Maximum earthquakes:** 1000
- Select earthquakes by:** Newest
- Time Range:**
  - Earliest Available (c.1970)
  - Latest Available
- Magnitude Range:**
- Depth Range (km):**
- Data Source:**
- Apply** button
- Earthquake Count:** 1000 of 2857347 (1000 visible)
- Other things to try:**
  - Show plate boundaries: Off
  - Animate the earthquakes: New!
  - Go to a new: Region / Topic
  - View earthquakes as: Table
  - 3D View
  - Earthquake Stats: New!
  - Download as: Excel NetCDF

At the bottom left, there is a legend for Depth (km) and Magnitude (Size). The map includes labels for various countries and regions in Chinese.

## 2. 先選擇時期 (Time Range)、規模 (Magnitude Range) 和深度範圍 (Depth Range)

**Options >**

*Make changes, press Apply:*

Maximum earthquakes: 5000 ▼

Select earthquakes by:  
Newest ▼

**Time Range:**

Earliest Available (c.1970)  
2021-01-01 [calendar icon]

Latest Available  
2021-05-05 [calendar icon]

**Magnitude Range:**

**Depth Range (km):**

**Data Source:**

你要求的地震最多只能到這個數字！

下載時這些地震依據什麼排列？

## 3. 選擇區域

Earthquake Count:  
2801 of 2801 (2801 visible)

*Other things to try:*

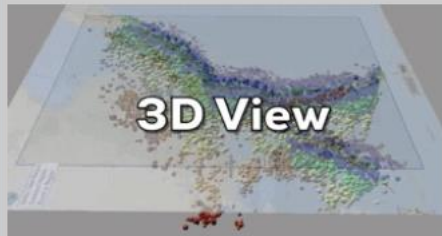
Show plate boundaries: On ▼

Animate the earthquakes: **New!**

Go to a new: Region / Topic ▼

View earthquakes as: Table

**3D View**



(若不選就給你全球！)

✓ **Region / Topic**

(more to come!)

----- regions -----

- Polynesia
- Fiji/Tonga Region
- Cascadia
- Aleutian Isles
- Japan Region
- Southeast Asia
- Central America
- Western South America
- E. Mediterranean
- East African Rift
- Horn of Africa

----- topics -----

- 2004 Asian Tsunami Disaster
- Deep Quakes Under Italy
- Mystery Under Romania
- 2002 Manchester UK Swarm
- Deepest Large Quakes

4. 按下「Apply」

Apply

Make changes, press Apply:

Maximum earthquakes: 25000

Warning: Allow more time when large numbers of quakes are displayed.

Select earthquakes by:

Largest

Time Range:

Earliest Available (c.1970)

1980-01-01



Latest Available

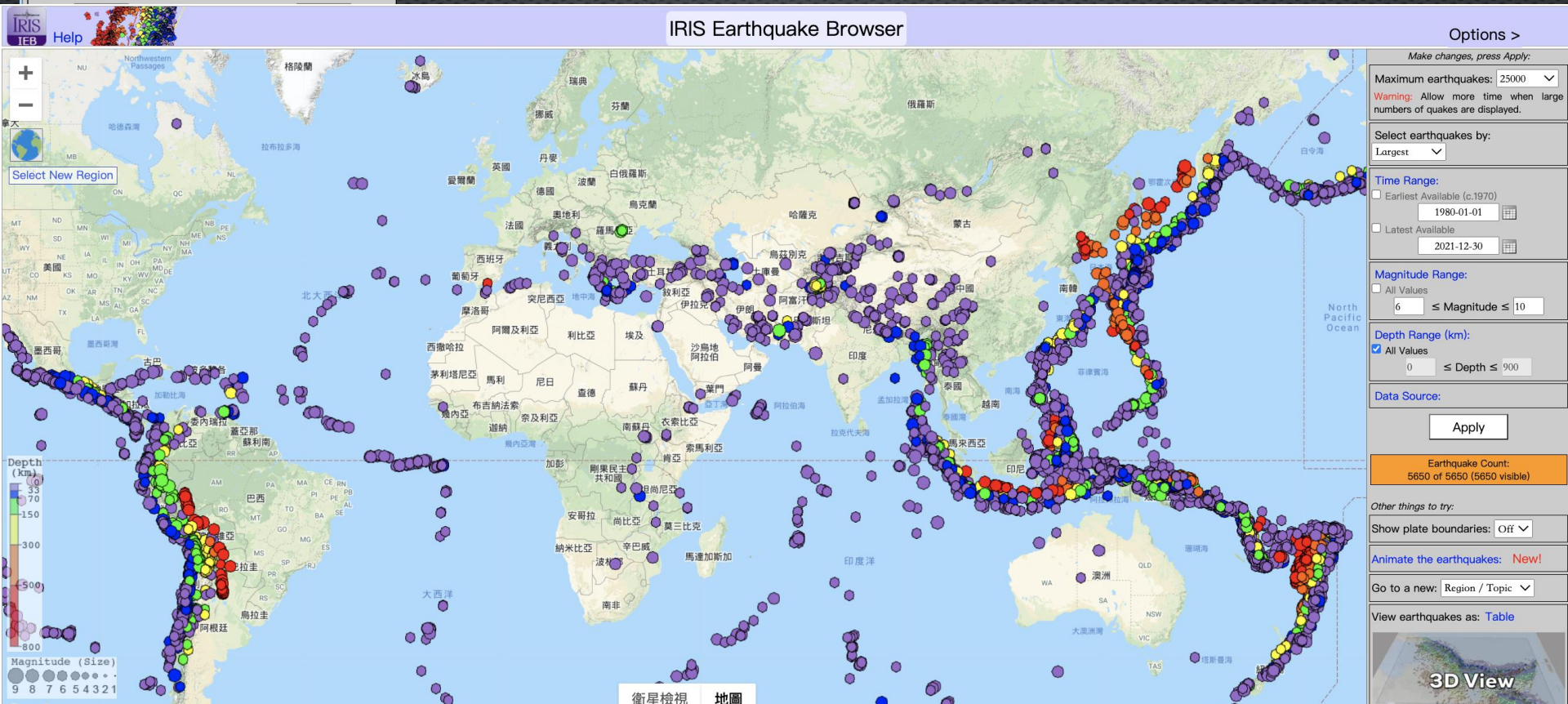
2021-12-30



Magnitude Range:

All Values

# Output: map



# Output: map

5. 按下「Export」，就可以把資料下載下來！

Earthquake Count:  
1000 of 48855 (1000 visible)

Other things to try:

Show plate boundaries:  Off ▼

Animate the earthquakes: New!

Go to a new:  ▼

View earthquakes as: [Table](#)

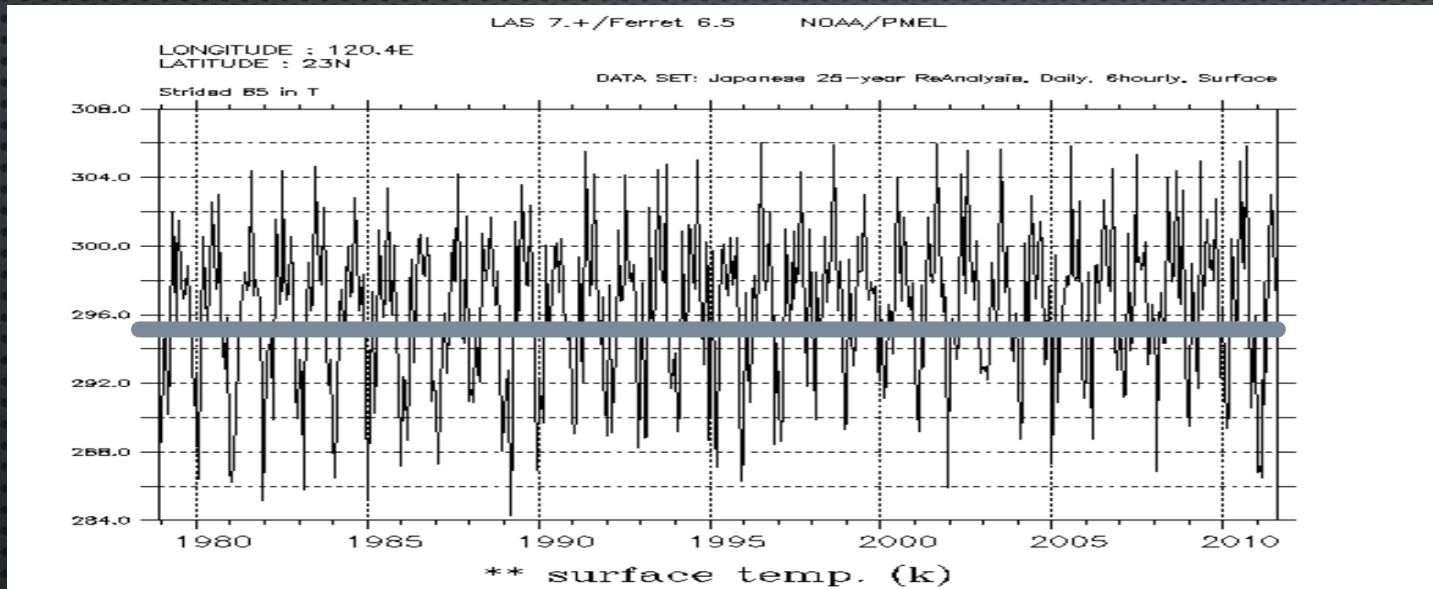
 3D View

IEB\_export (8)

| Year | Month | Day | Time     | Lat      | Lon      | Depth | Mag | Region                              | Timestamp  |
|------|-------|-----|----------|----------|----------|-------|-----|-------------------------------------|------------|
| 2021 | 12    | 29  | 21:30:22 | 36.9982  | 94.6585  | 10    | 5   | northern Qinghai, China             | 1640813422 |
| 2021 | 12    | 29  | 20:32:52 | -7.5547  | 127.7579 | 157.7 | 5   | 135 km NE of Lospalos, Timor Leste  | 1640809972 |
| 2021 | 12    | 29  | 18:25:51 | -7.5465  | 127.5764 | 164.3 | 7.3 | 125 km NNE of Lospalos, Timor Leste | 1640802351 |
| 2021 | 12    | 29  | 16:47:08 | 34.713   | 25.1184  | 64.9  | 5   | 32 km S of Pýrgos, Greece           | 1640796428 |
| 2021 | 12    | 29  | 05:08:09 | 34.8334  | 25.1386  | 64.5  | 5.7 | 19 km S of Pýrgos, Greece           | 1640754489 |
| 2021 | 12    | 29  | 00:01:00 | 9.8601   | 93.4354  | 92.4  | 5   | 213 km SSE of Port Blair, India     | 1640736060 |
| 2021 | 12    | 27  | 13:31:04 | 35.5622  | 74.8131  | 10    | 5.2 | 60 km SE of Gilgit, Pakistan        | 1640611864 |
| 2021 | 12    | 27  | 09:44:06 | -34.8911 | -108.113 | 10    | 5   | southern East Pacific Rise          | 1640598246 |
| 2021 | 12    | 27  | 00:11:49 | 22.7361  | 143.143  | 112.7 | 5.2 | Volcano Islands, Japan region       | 1640563909 |
| 2021 | 12    | 26  | 18:59:02 | 35.1923  | 26.9659  | 10    | 5.6 | 25 km S of Fry, Greece              | 1640545142 |

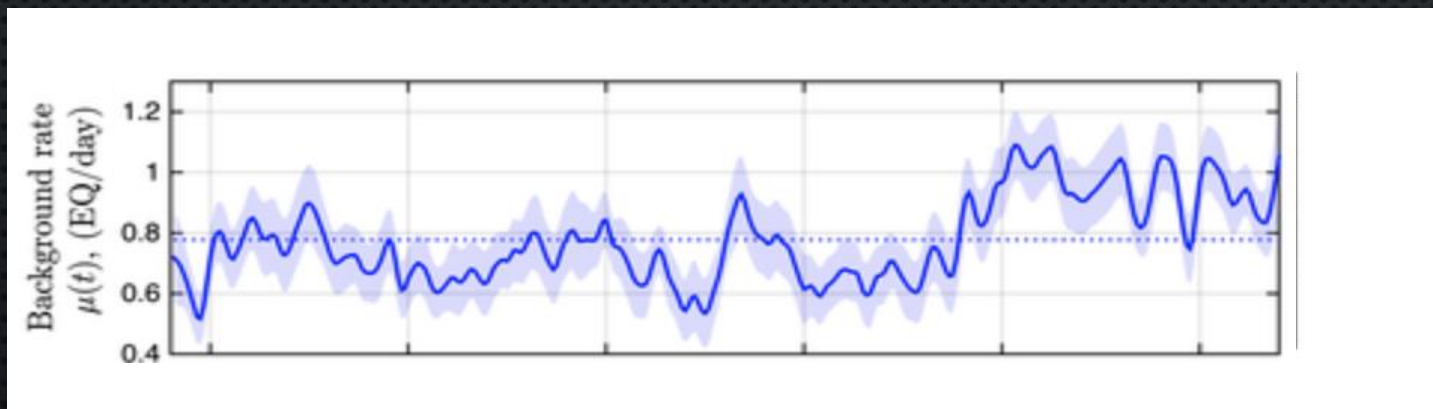


# COME UP WITH YOUR OWN PLAN NOW!



Sea surface temperature

\* 選取「海溫和海平面高相關的區域」為佳！



Earthquake activity

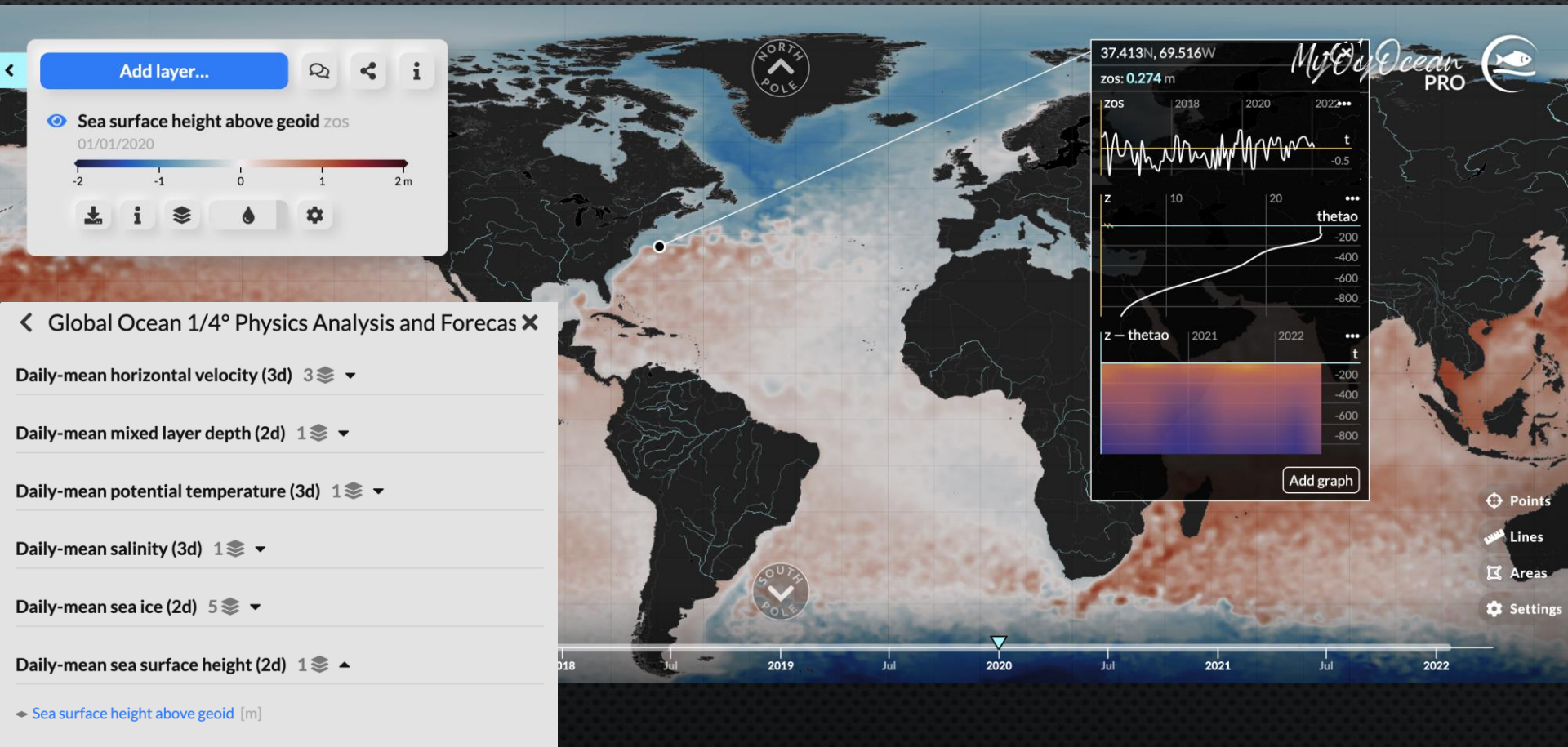
- \* 篩選規模
- \* 篩選深度
- \* 篩選空間範圍

# 海高 SURFACE HEIGHT

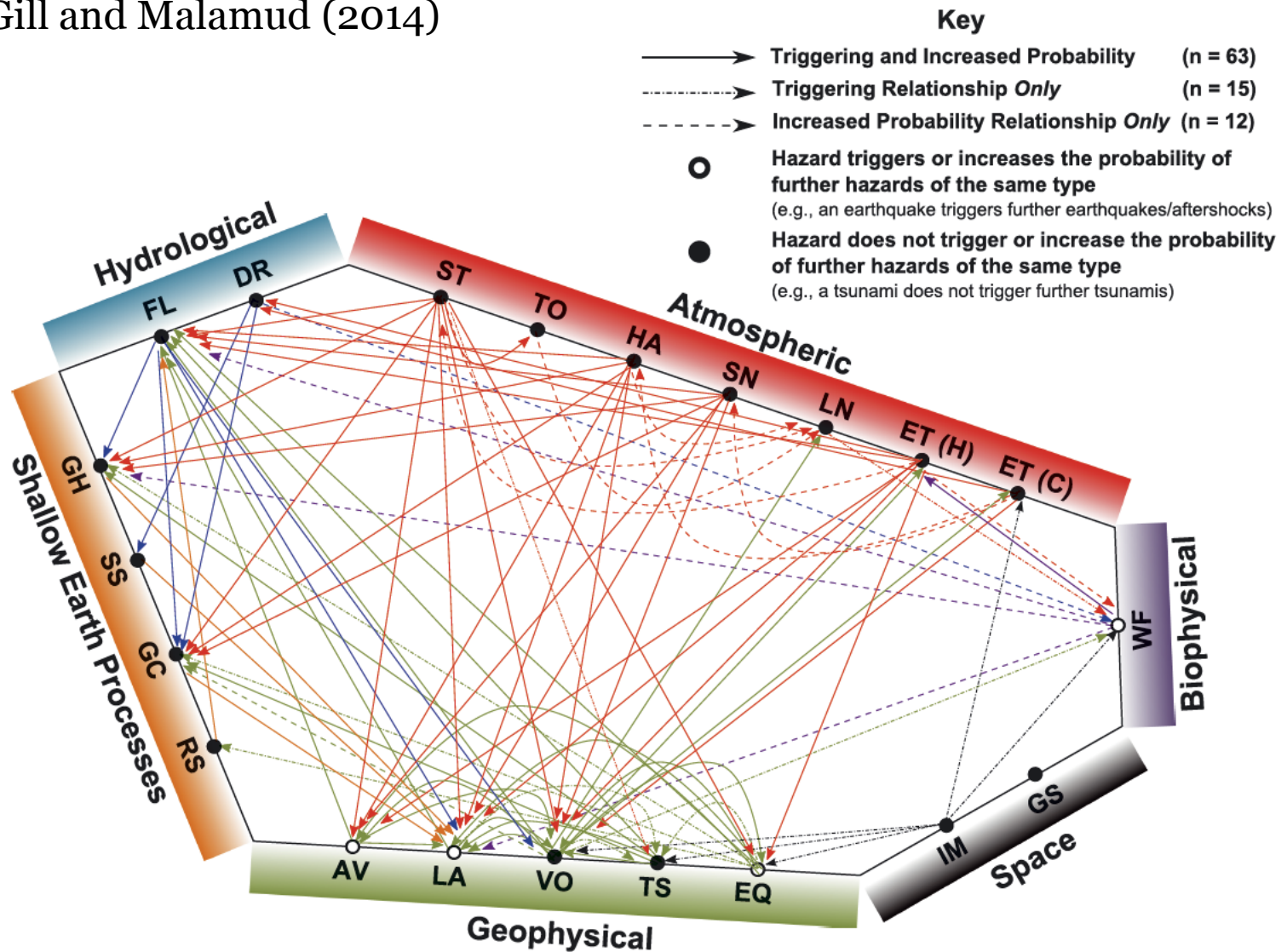
<https://marine.copernicus.eu/access-data/myocean-viewer>

Add layer → 按 sea surface height

→ 選 **Global Ocean 1/4° Physics Analysis and Forecast updated Daily**



# Gill and Malamud (2014)



EO = earthquake, TS = tsunami, VO = volcanic eruption, LA = landslide, AV = snow avalanche, RS = regional subsidence, GC = ground collapse, SS = soil (local) subsidence, GH = ground heave, FL = flood, DR = drought, ST = storm, TO = tornado, HA = hailstorm, SN = snowstorm, LN = lightning, ET (H) = extreme high temperatures, ET (C) = extreme cold temperatures, WF = wildfires, GS = geomagnetic storms, and IM = impact events. Hazards groups follow the same color coding as in Figure 2.

# REFERENCE

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