114年
天氣分析與
預報研討會
2025 Conference on Weather Analysis and Forecasting

日期 9.2 週二 — 9.4 週四

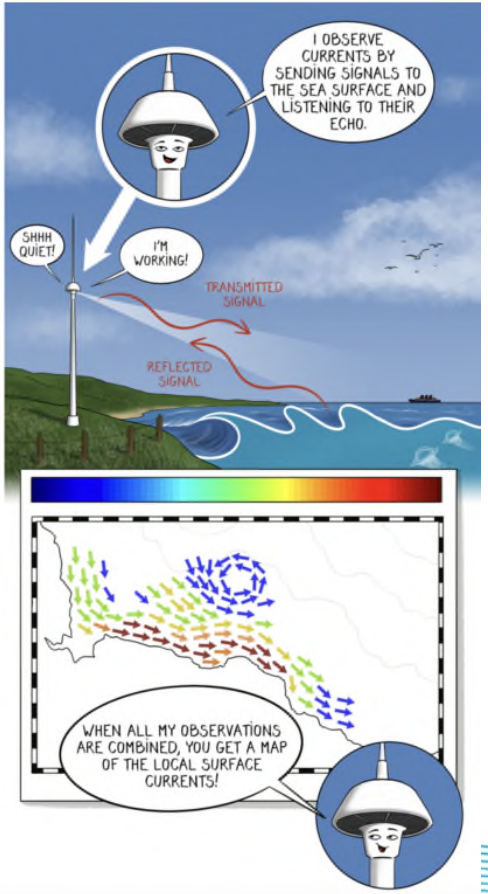
高頻雷達看南灣:
週期性降溫事件的動力來源

國家實驗研究院
台灣海洋科技研究中心
Taiwan Ocean Research Institute

陳少華、陳世明 114/9/4

No.A5-014

高頻雷達測流原理



Barrick et al., *Science*, 1977

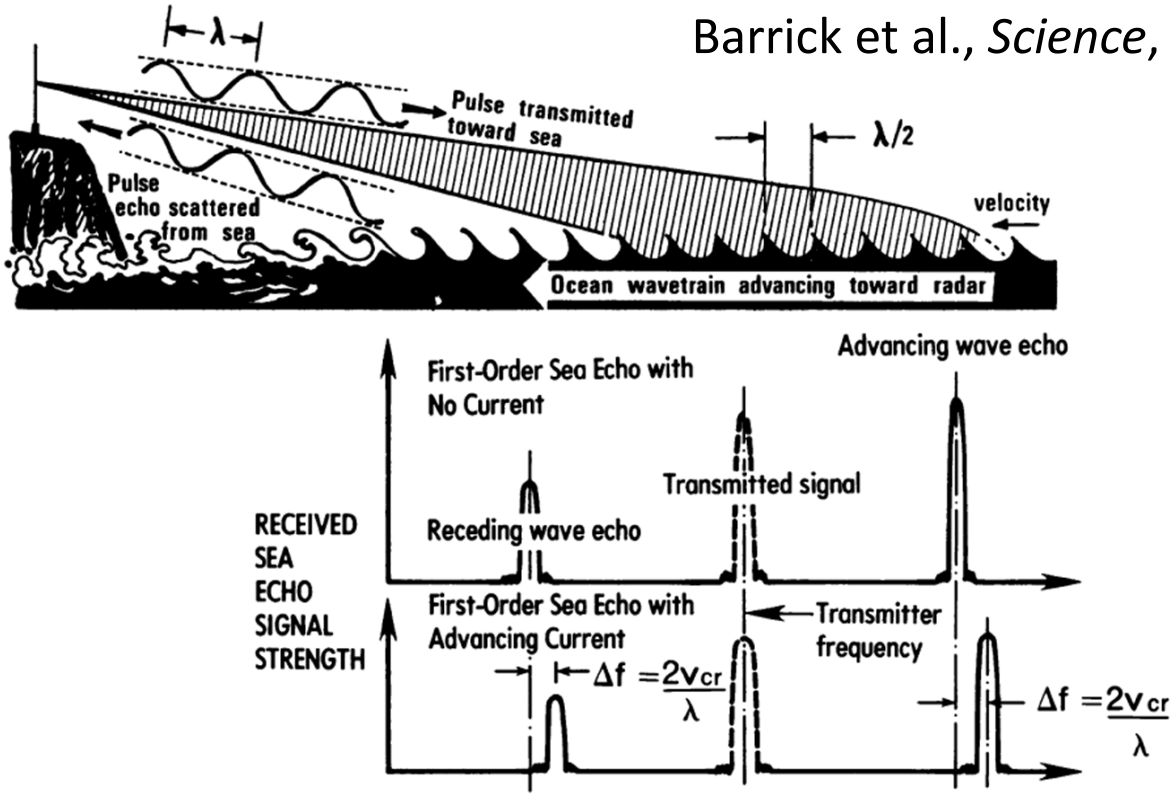
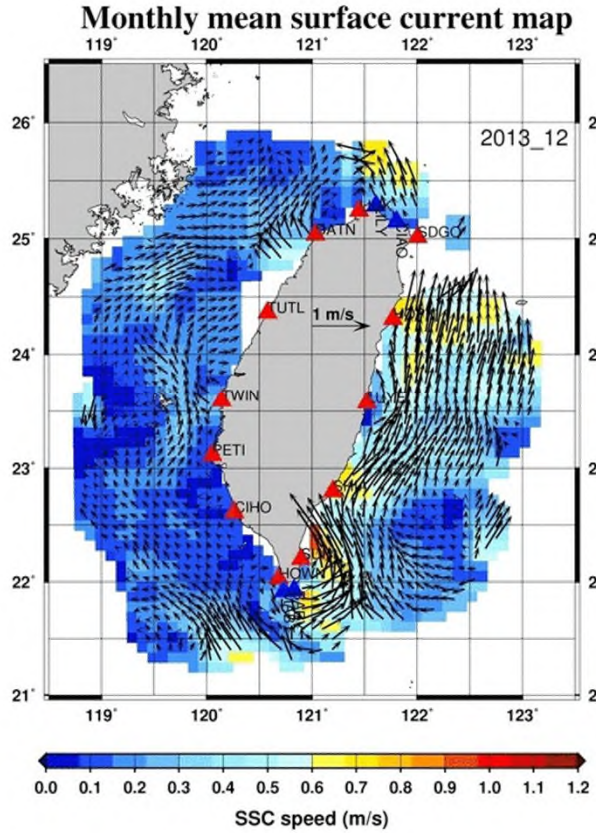
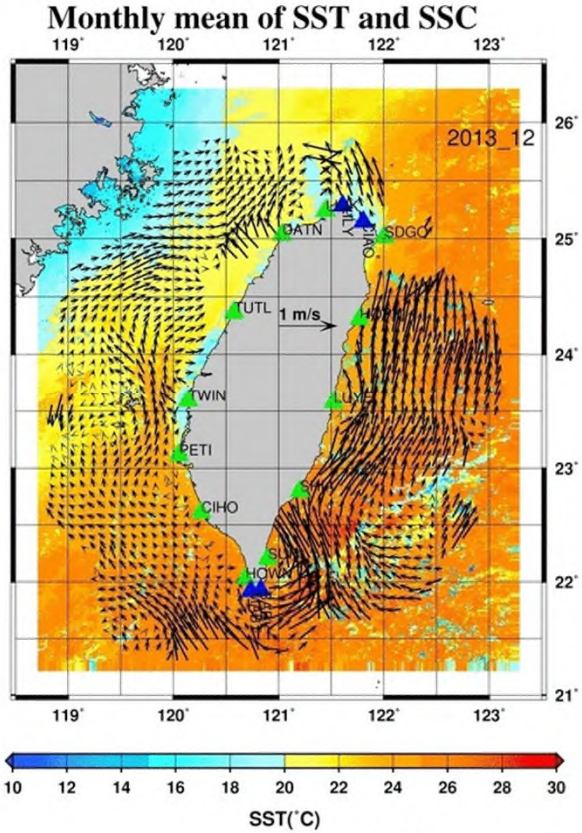


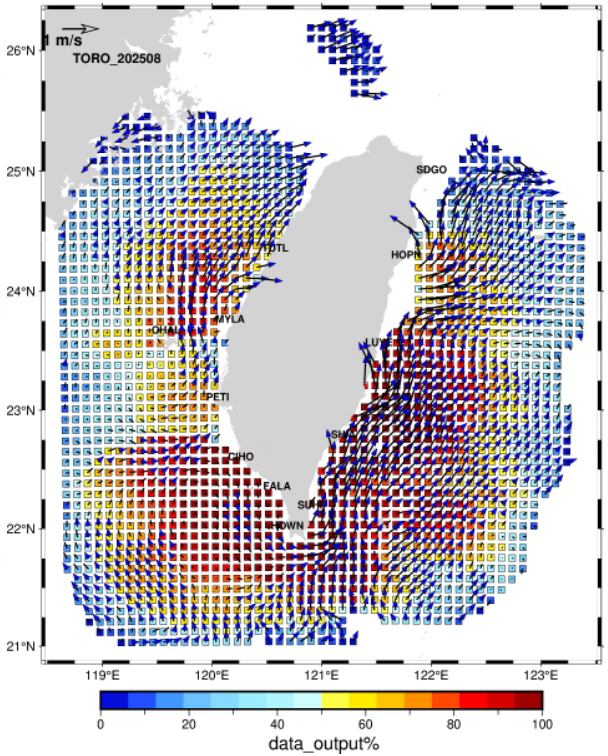
Fig. 1. Sketch showing the principles of first-order HF Bragg scatter from the sea, and resulting signal echo spectra without and with an underlying current.

TORI 高頻雷達觀測網：持續累積的觀測資料

國家實驗研究院 台灣海洋科技研究中心 Taiwan Ocean Research Institute



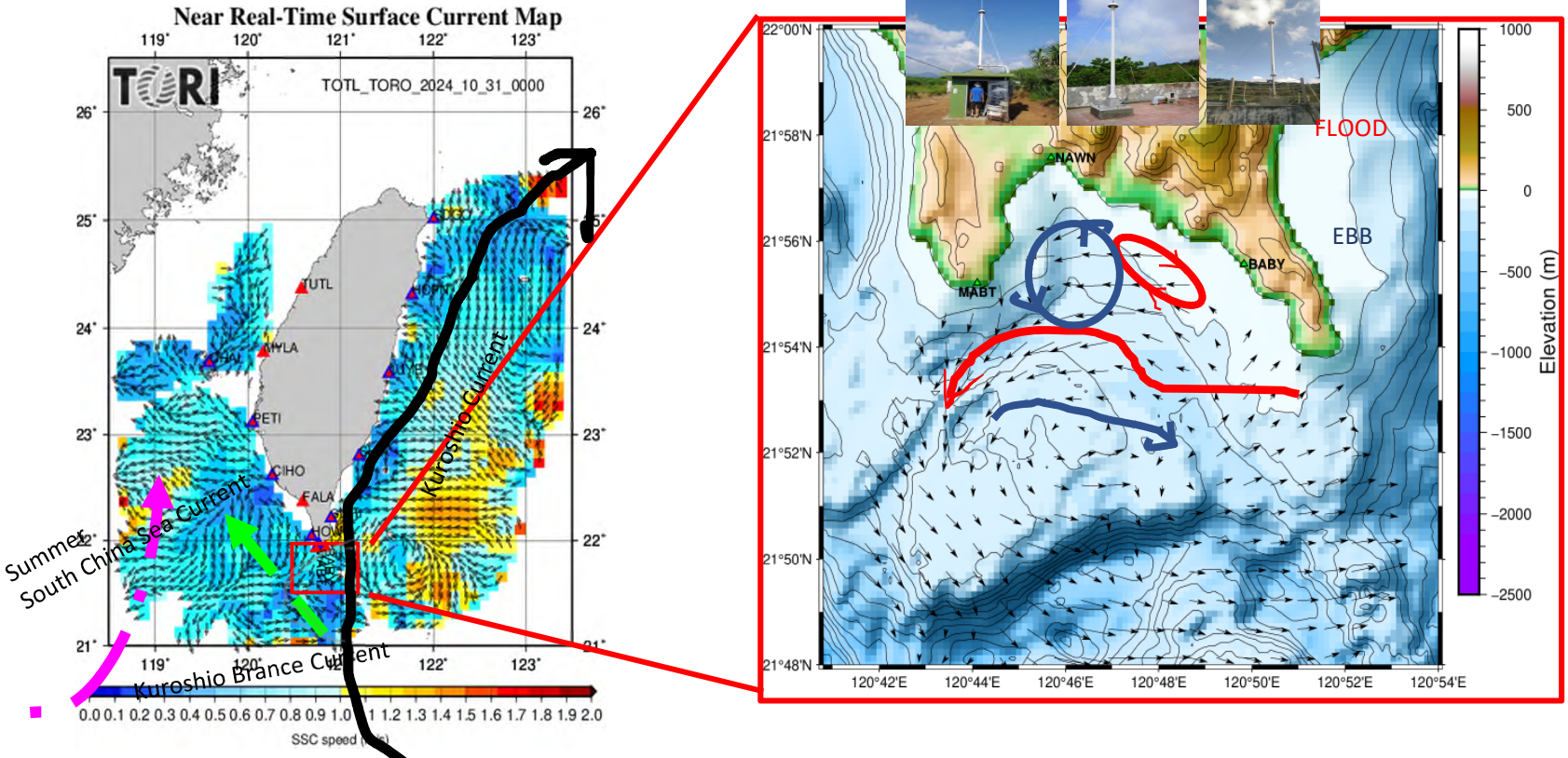




2013.12~2015.02

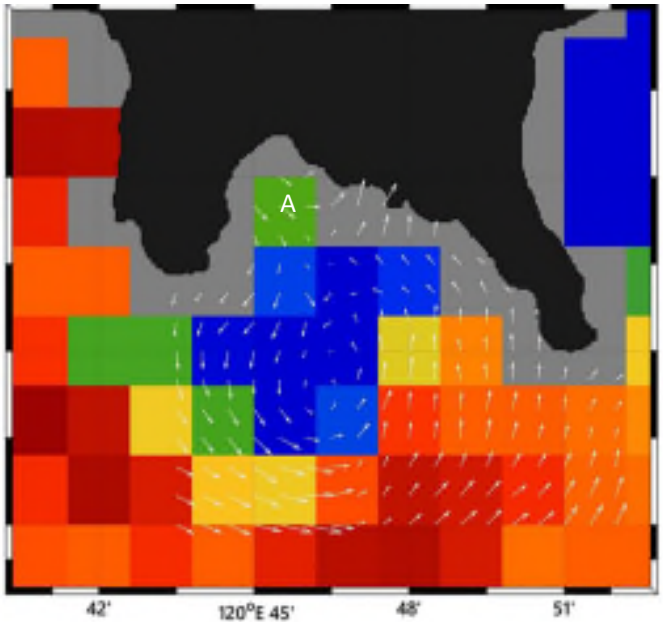
南灣海域特色與研究價值

TORI's HF system (CODAR type)



高頻雷達已應用於南灣溫降研究

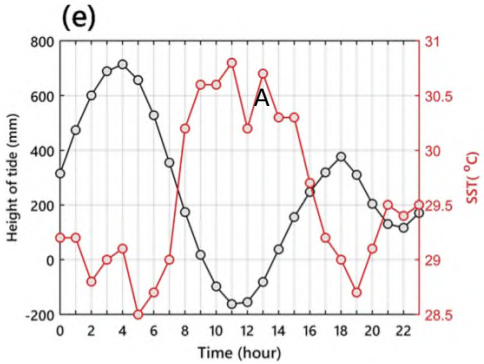
High Frequency Radar Data
(April–June, 2015–2017)



Himawari-8 SST data
from July 2015 to February 2018

Hsu et al.(2020)

海表溫度（SST）下降特徵
幾乎每天都會發生降溫事件
平均降溫幅度：約 **2 °C**
最大觀測降溫幅度：可達 **4.7 °C**
降溫速率：**0.3–0.5 °C/小時**
持續時間：約 **6.6 小時**
與氣旋性渦漩的生命週期一致



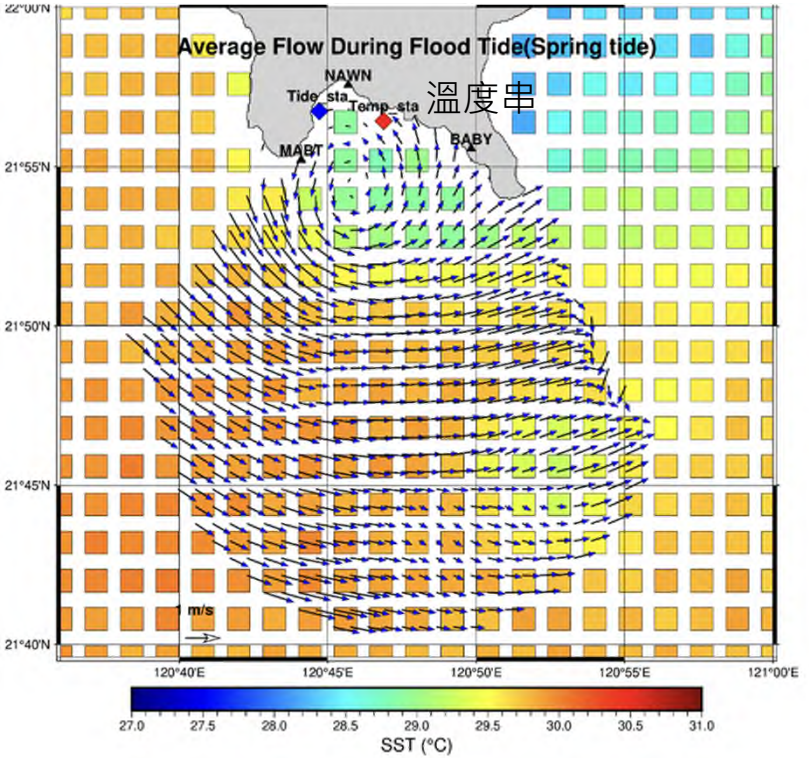
研究背景與動機

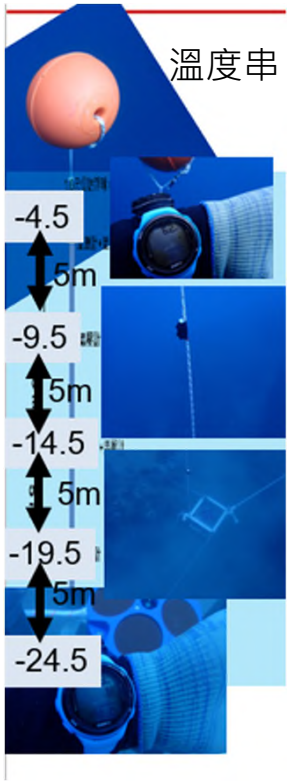
國家實驗研究院 台灣海洋科技研究中心 Taiwan Ocean Research Institute

1.南灣高頻雷達資料
2.後壁湖水位站
3.溫度串（tori佈放）
4.SST資料
（2km空間解析度，每10分鐘一筆）

過去研究指出，南灣的週期性溫降可能受到多重機制驅動：

- 潮汐誘發渦旋（Lee et al., 1999）
- 地形效應造成的氣旋性渦旋（Hsu et al., 2020）
- 南灣外海渦漩造成灣內溫降（Lee et al., 2020）
- 呂宋海峽傳入的內潮波（Jan & Chen, 2009）





研究方法：Okubo-Weiss parameter

- $OW = S_n^2 + S_s^2 - \zeta^2$

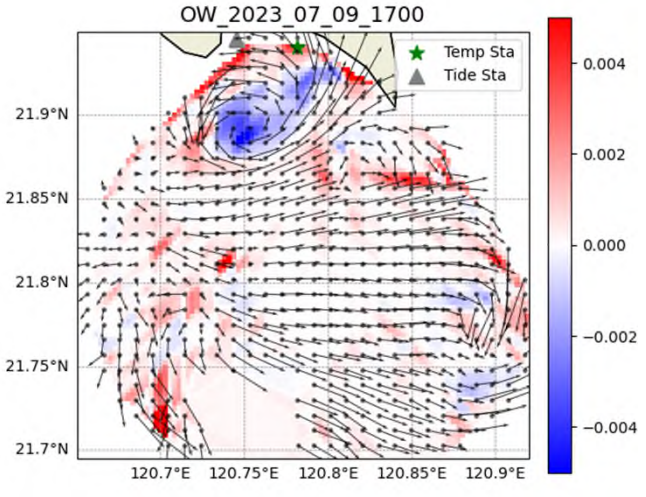
$$= \left(\frac{\partial u}{\partial x} - \frac{\partial v}{\partial y}\right)^2 + \left(\frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}\right)^2 - \zeta^2$$

$$\zeta = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$$

normal strain rate

shear strain rate

vorticity



- OW <0:

  rotation dominates → **vortex core**

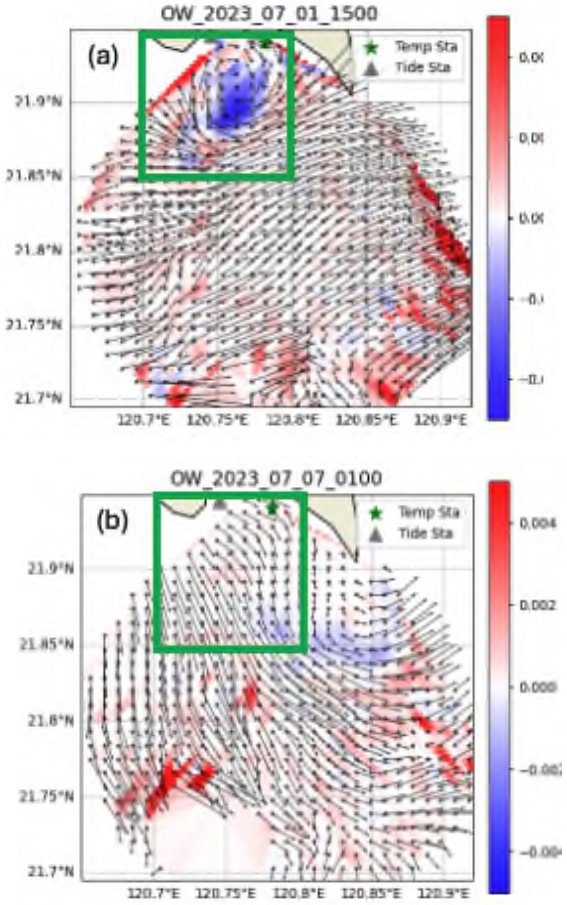
- OW >0:

  strain dominates → **shear flow**

研究方法

渦漩偵測（OW 指標判斷）

- 建立演算法以偵測渦漩事件
- 設定南灣海域內固定監測範圍：
  - ✓ 經度範圍：120.7°E – 120.8°E
  - ✓ 緯度範圍：21.85°N – 21.95°N
- 若監測範圍內有超過 10 個點的 Okubo–Weiss (OW) 值小於- 0.003，即判定為一次渦漩事件

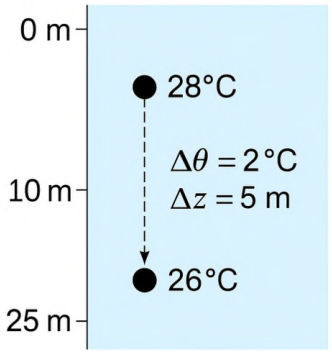


研究方法

內潮檢測（N^2 分層條件）

- 並非所有降溫事件都呈現明顯的渦漩訊號
- 過去研究指出，內潮也可能造成降溫
- 強烈的分層條件可使內潮波傳播並引起混合
- 本研究透過計算浮力頻率平方 (N^2)，檢視分層條件是否支持內潮混合作用

How to Estimate Buoyancy Frequency (N^2) Using Temperature Only



$$N^2 = -g\alpha\frac{\partial\theta}{\partial z}.$$

α = thermal expansion coefficient of seawater

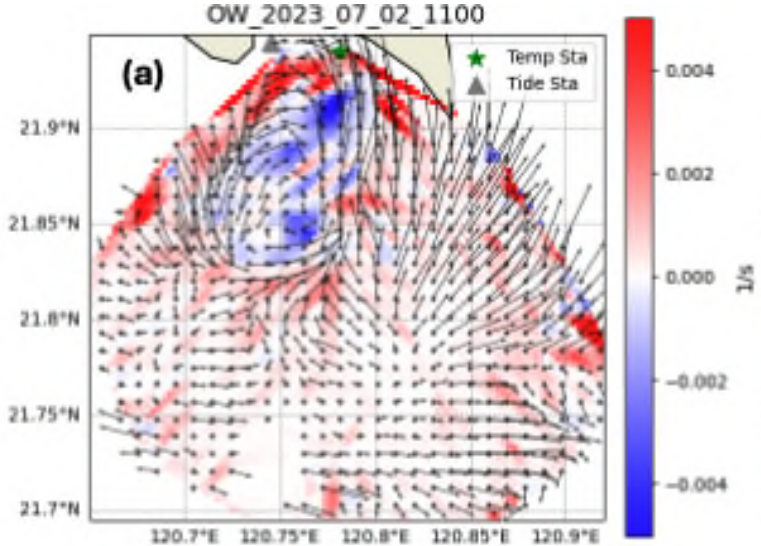
Where: g = 9.81 m/s², α ≈ 2 × 10^{-4} °C^{-1}, ∂θ/∂z = vertical temperature gradient

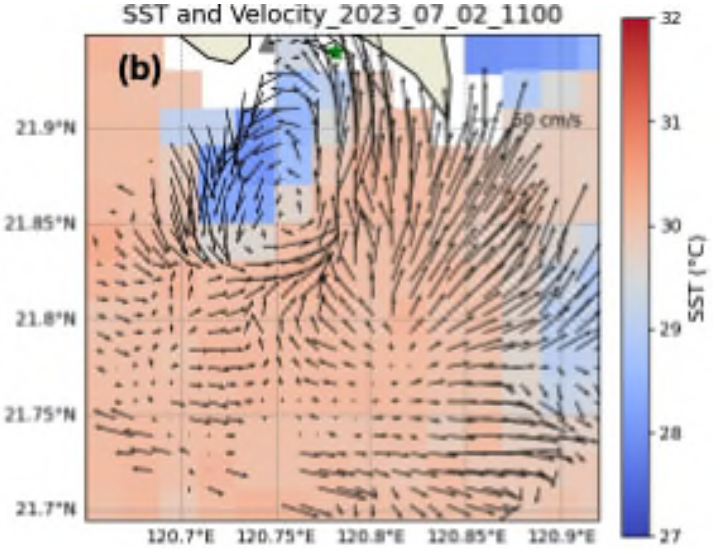
$$\frac{\partial\theta}{\partial z} = \frac{26-28}{5} = -0.4^{\circ}C/m$$

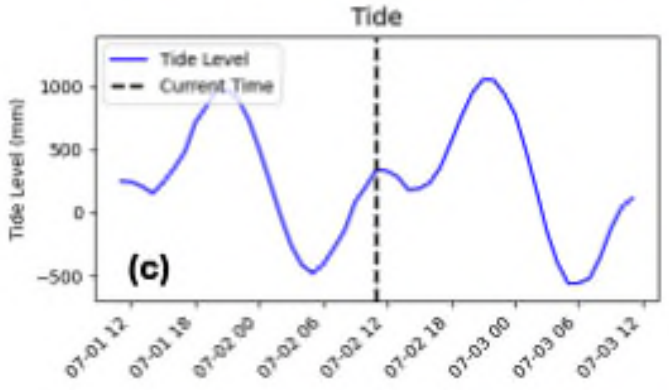
$N^2 = -9.81 \times 2 \times 10^{-4} \times (-0.4) = 7.8 \times 10^{-4} s^{-2}$.

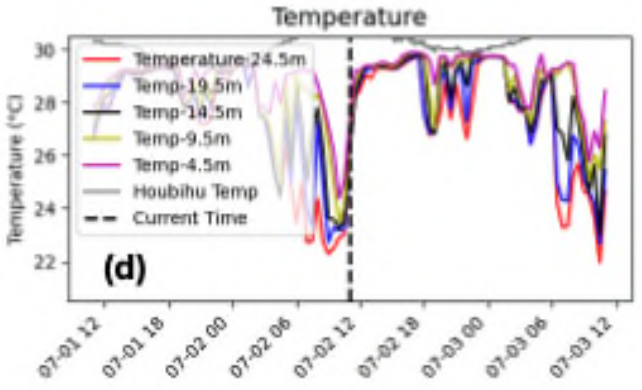
Positive N^2 indicates stable stratification.

渦漩造成的降溫事件

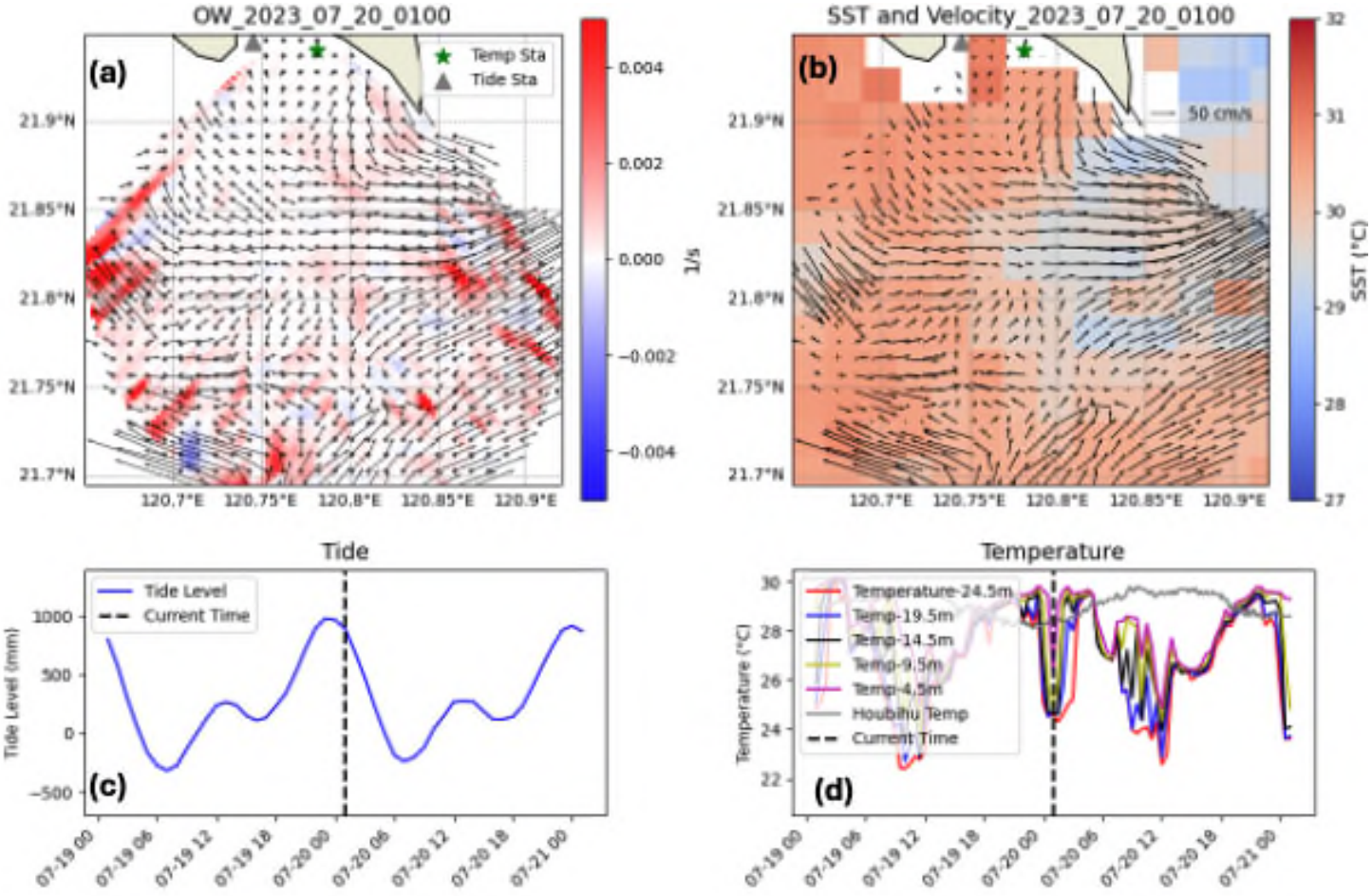

OW_2023_07_02_1100
(a)
Temp Sta
Tide Sta
21.9°N
21.85°N
21.8°N
21.75°N
21.7°N
120.7°E
120.75°E
120.8°E
120.85°E
120.9°E
0.004
0.002
0.000
−0.002
−0.004
1/s


SST and Velocity_2023_07_02_1100
(b)
50 cm/s
21.9°N
21.85°N
21.8°N
21.75°N
21.7°N
120.7°E
120.75°E
120.8°E
120.85°E
120.9°E
32
31
30
29
28
27
SST (°C)


Tide
Tide Level
Current Time
(c)
Tide Level (mm)
1000
500
0
−500
07-01 12
07-01 18
07-02 00
07-02 06
07-02 12
07-02 18
07-03 00
07-03 06
07-03 12

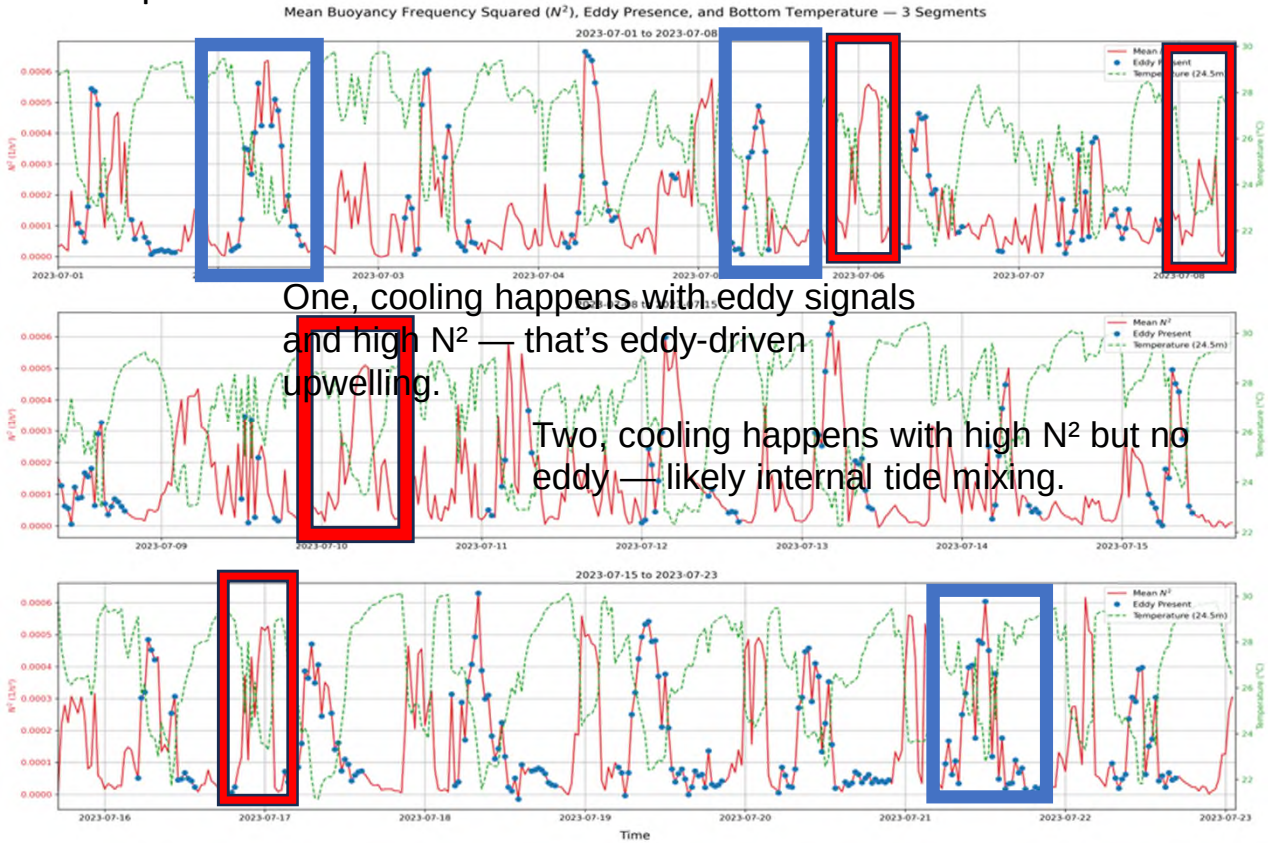

Temperature
Temperature-24.5m
Temp-19.5m
Temp-14.5m
Temp-9.5m
Temp-4.5m
Houbihu Temp
Current Time
(d)
Temperature (°C)
30
28
26
24
22
07-01 12
07-01 18
07-02 00
07-02 06
07-02 12
07-02 18
07-03 00
07-03 06
07-03 12

非渦漩降溫事件


OW_2023_07_20_0100
(a)
Temp Sta
Tide Sta
21.9°N
21.85°N
21.8°N
21.75°N
21.7°N
120.7°E
120.75°E
120.8°E
120.85°E
120.9°E
0.004
0.002
0.000
−0.002
−0.004
1/s
SST and Velocity_2023_07_20_0100
(b)
50 cm/s
32
31
30
29
28
27
SST (°C)
Tide
Tide Level
Current Time
Tide Level (mm)
1000
500
0
−500
(c)
07-19 00
07-19 06
07-19 12
07-19 18
07-20 00
07-20 06
07-20 12
07-20 18
07-21 00
Temperature
Temperature-24.5m
Temp-19.5m
Temp-14.5m
Temp-9.5m
Temp-4.5m
Houbihu Temp
Current Time
Temperature (°C)
30
28
26
24
22
(d)

分層、渦漩與降溫事件的關聯

At 24.5 m depth



One, cooling happens with eddy signals and high N² — that's eddy-driven upwelling.

Two, cooling happens with high N² but no eddy — likely internal tide mixing.

結論

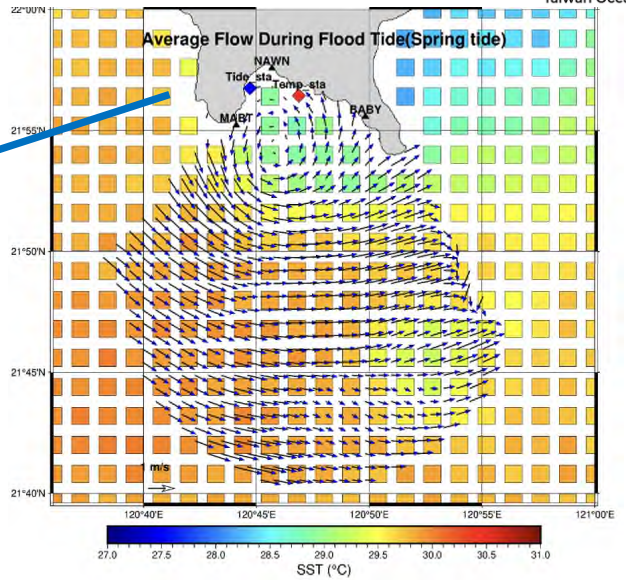
- 南灣週期性溫降由多重機制驅動，並非單一因素
- 渦漩事件可解釋部分降溫，內潮混合也扮演重要角色
- 高頻雷達搭配溫度串與 SST，可有效釐清動力來源
- 此研究對區域海洋動力理解與珊瑚礁保育具有應用價值

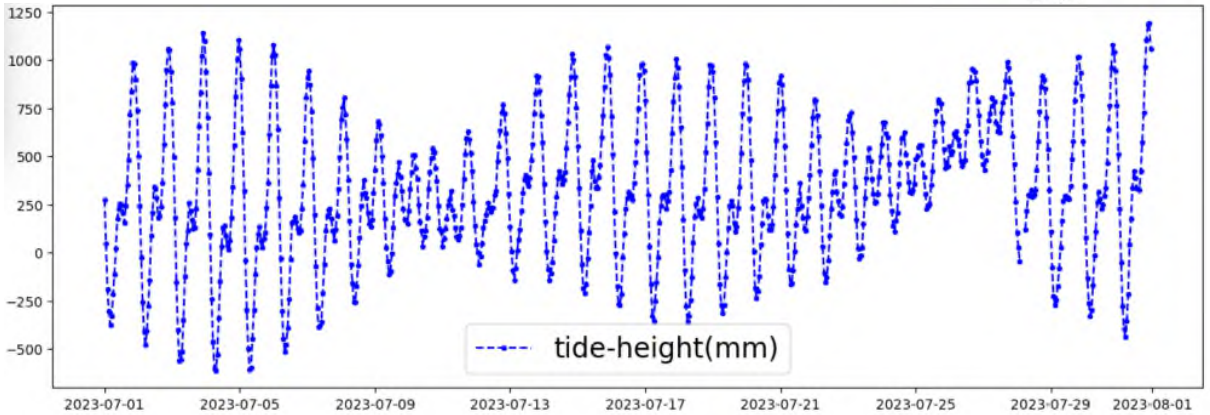
Thank you for listening

Research is not only about data, but also about people behind the science.

Sea Level Data

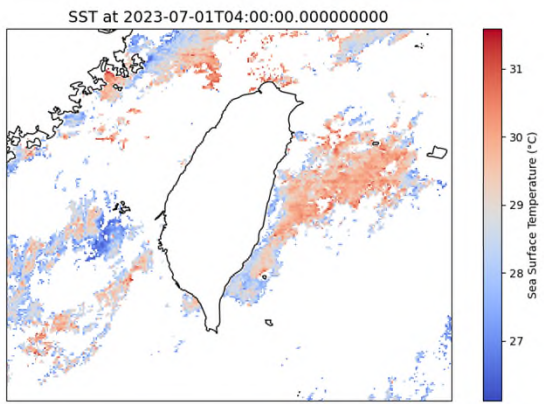
Tide gauge data (every 6 min) from **Houbihu Station**, Central Weather Administration (CWA), Taiwan

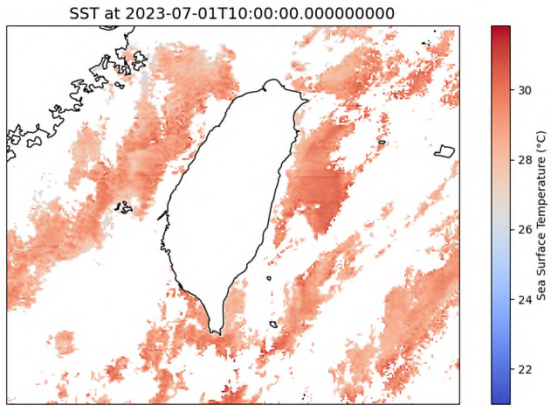




Himawari-8
Sea Surface Temperature (SST)

- Operated by **Japan Meteorological Agency (JMA)**
- Equipped with **Advanced Himawari Imager (AHI)**
- Covers Asia-Pacific with **10-min intervals**
- Spatial resolution: **~2 km**

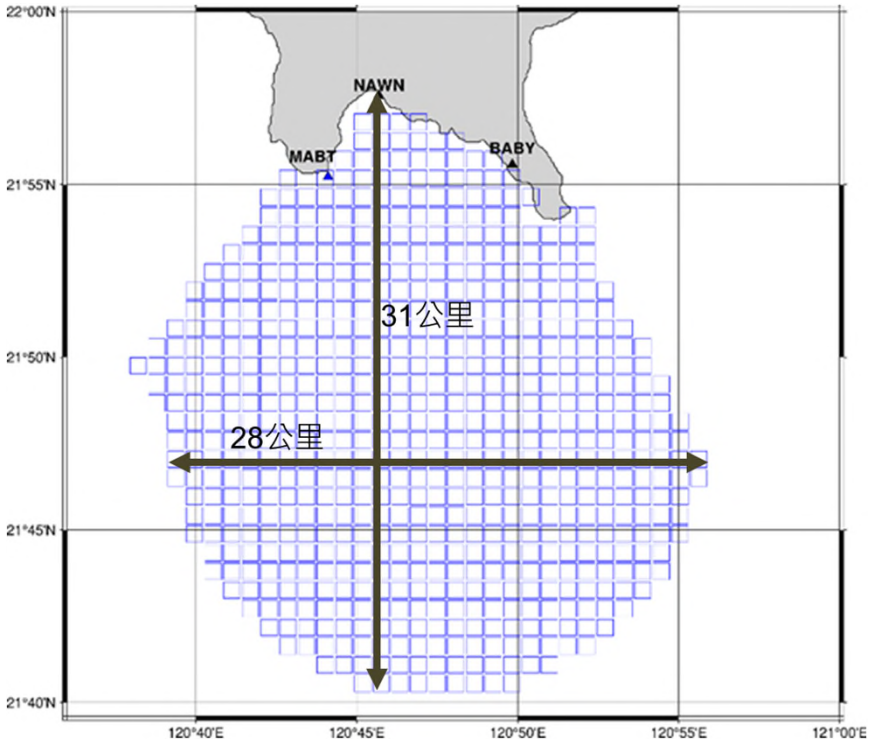




HF Radar Surface Currents

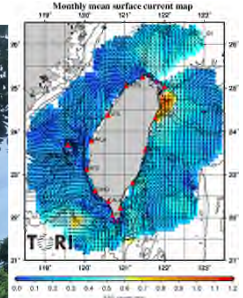
HF radar data

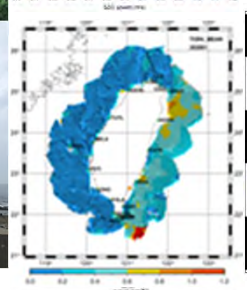
- **Temporal resolution**: 1 hr
- **Spatial resolution**: 1 km
- **Observation range**: up to 31 km offshore

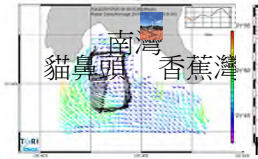


TORI's HF system

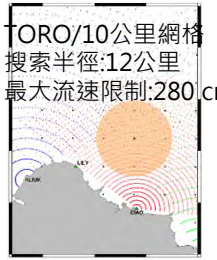
CODAR



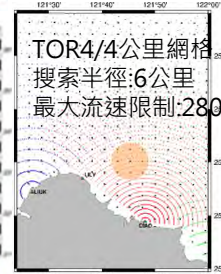


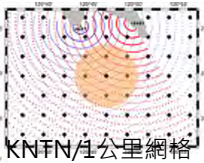


TORO/10公里網格
搜索半徑:12公里
最大流速限制:280 cm/s

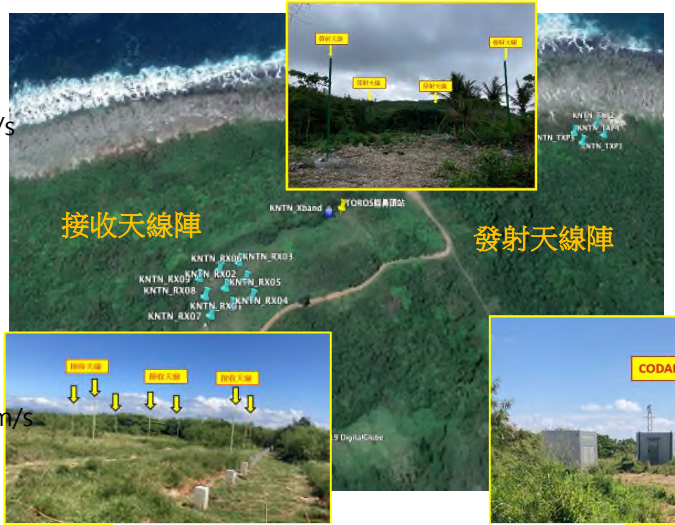


TOR4/4公里網格
搜索半徑:6公里
最大流速限制:280 cm/s





KNTN/1公里網格
搜索半徑:1.5公里
最大流速限制:250 cm/s



LERA

5dB attenuator removed
TX Power: 10W -> 30W

ubuntu Linux