海洋大氣邊界層交互作用分析

中央大學 大氣科學系

張偉裕

Motivation

West Pacific High:

❖ Typhoon Track
❖ Thunderstorm over Taiwan
❖ Heat wave
❖ Precipitation [major source of fresh water]

SST gradient + Vertical wind shear + Low-Level Jet

❖ The leeside has thermodynamically advantageous:
1. → Lowering convective inhibition.
2. → SST gradient

❖ **Need SST, air-sea flux, low atmosphere boundary layer, environmental wind shear, and precipitation observation.**
❖ **Is ECMWF Reanalysis v5 (ERA5) sufficient?**

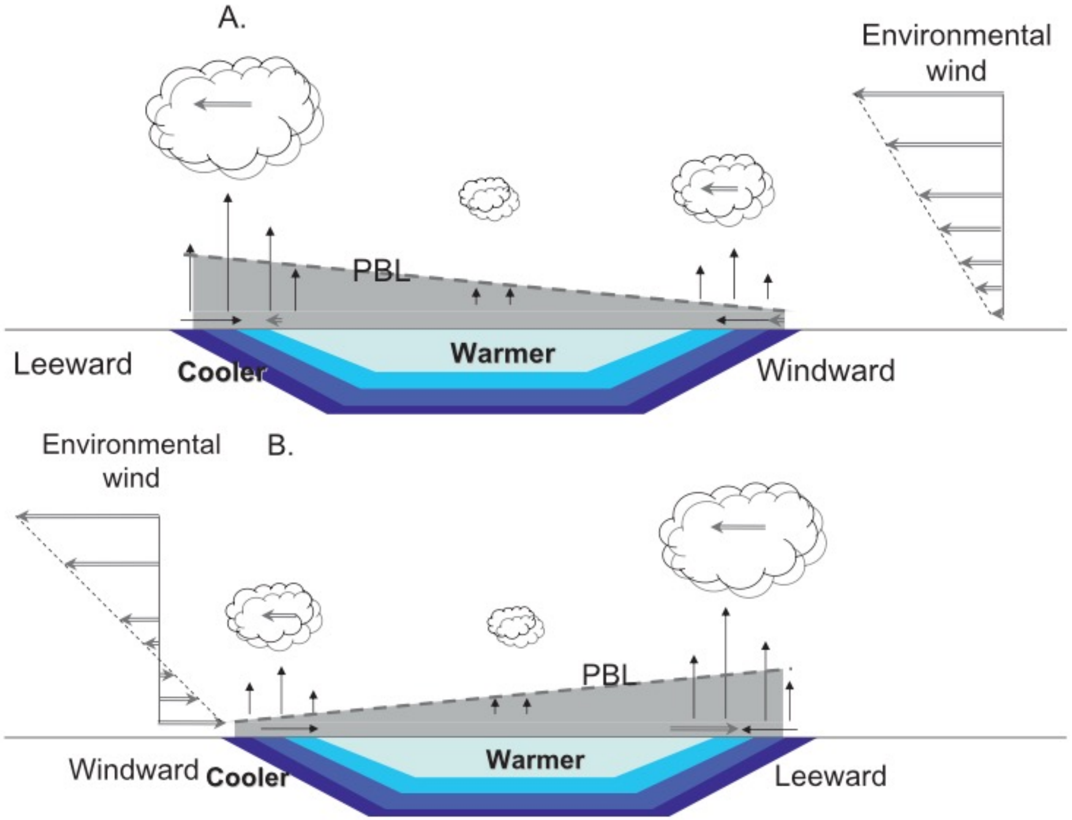
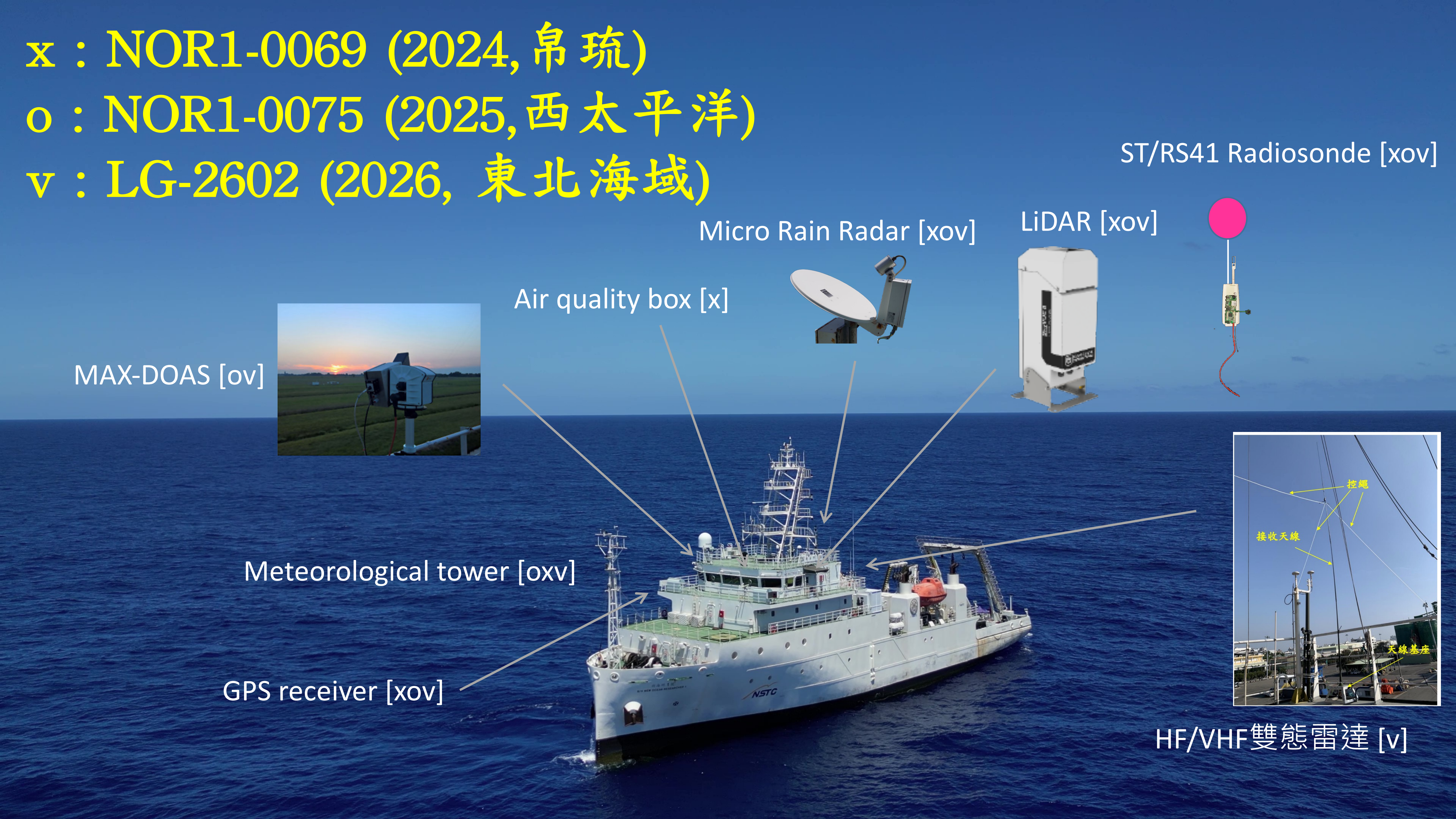


FIG. 11. Schematic representation of wind profiles and favored rainfall onset locations over a hypothetical oceanic warm patch, based on convergence at the lower boundary.

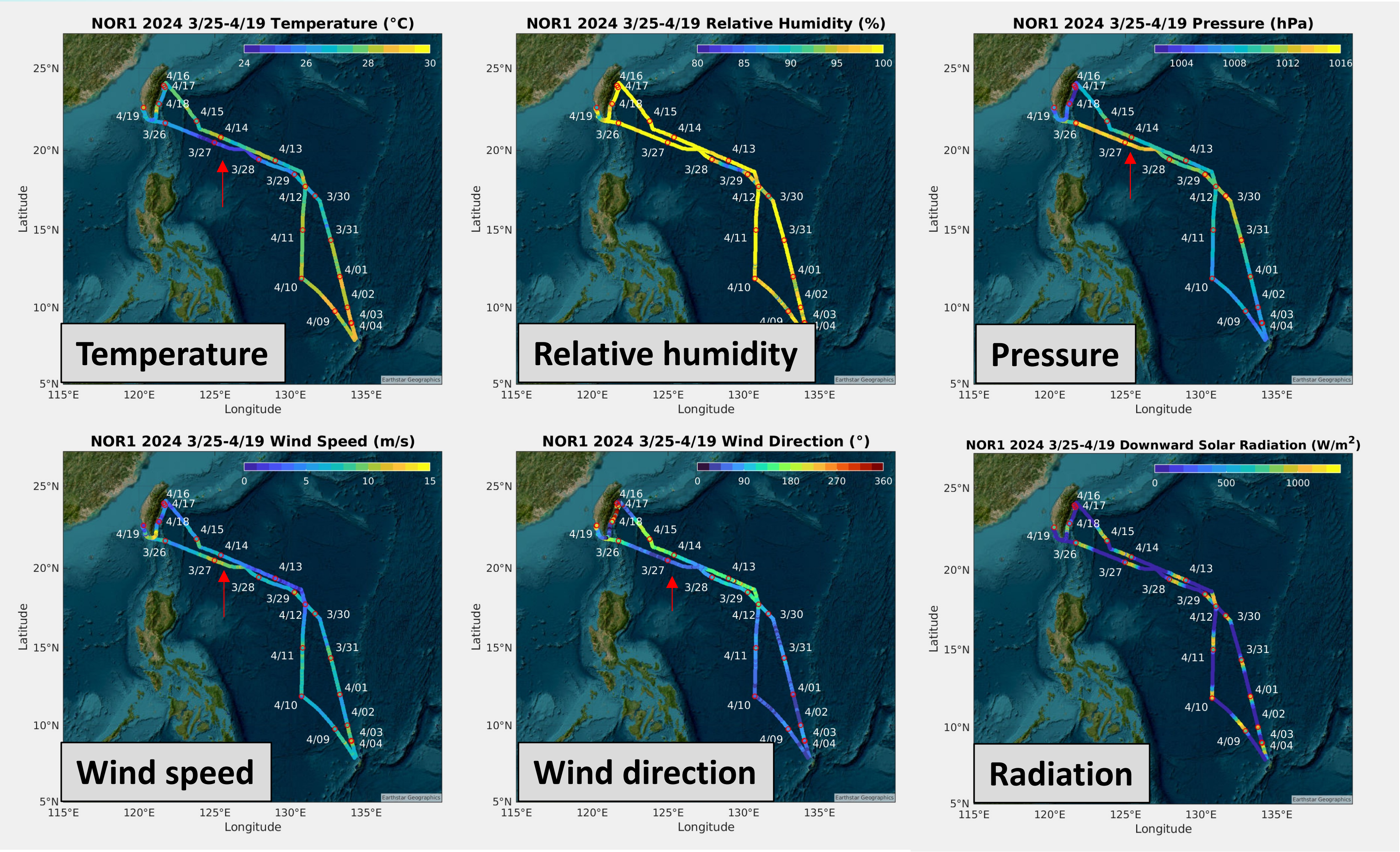
Lee et al. (2012)

NOR1-0069 (2024, 帛琉) + NOR1-0075 (2025, 西太平洋)
LG-2602 (2026, 東北海域)

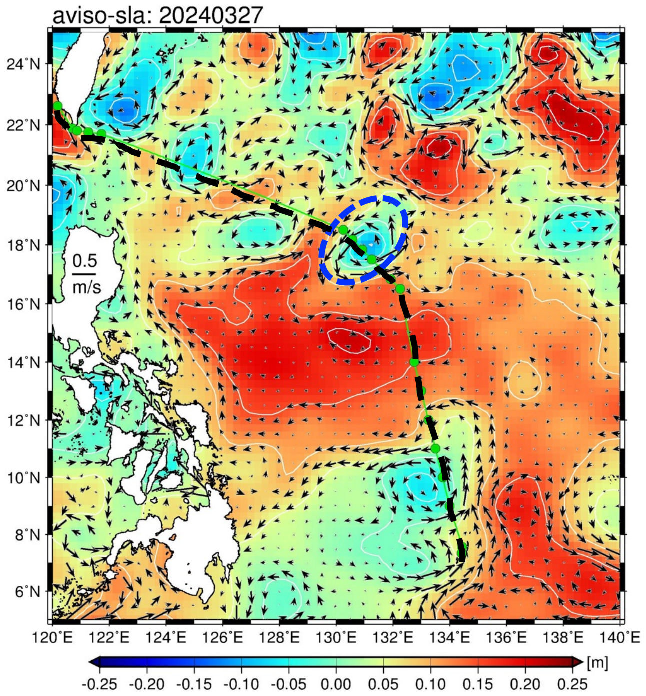
1. 西太平洋海洋降水資料分析：西太平洋微波降雨雷達觀測
2. 西太平洋海洋大氣邊界層、淨輻射資料分析
3. **建立大氣海洋跨域研究團隊(台灣大學、中央大學、中研院、台北大學、文化大學)**

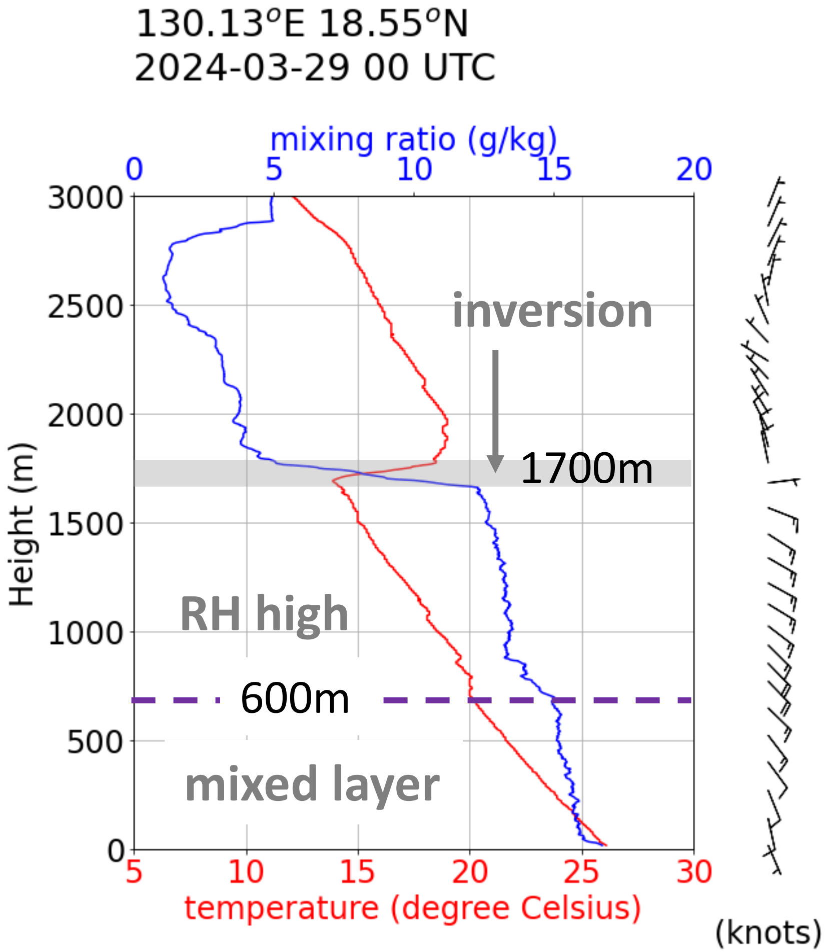

x：NOR1-0069 (2024,帛琉)
o：NOR1-0075 (2025,西太平洋)
v：LG-2602 (2026, 東北海域)
ST/RS41 Radiosonde [xov]
LiDAR [xov]
Micro Rain Radar [xov]
Air quality box [x]
MAX-DOAS [ov]
Meteorological tower [oxv]
GPS receiver [xov]
控繩
接收天線
天線基座
HF/VHF雙態雷達 [v]
NSTC

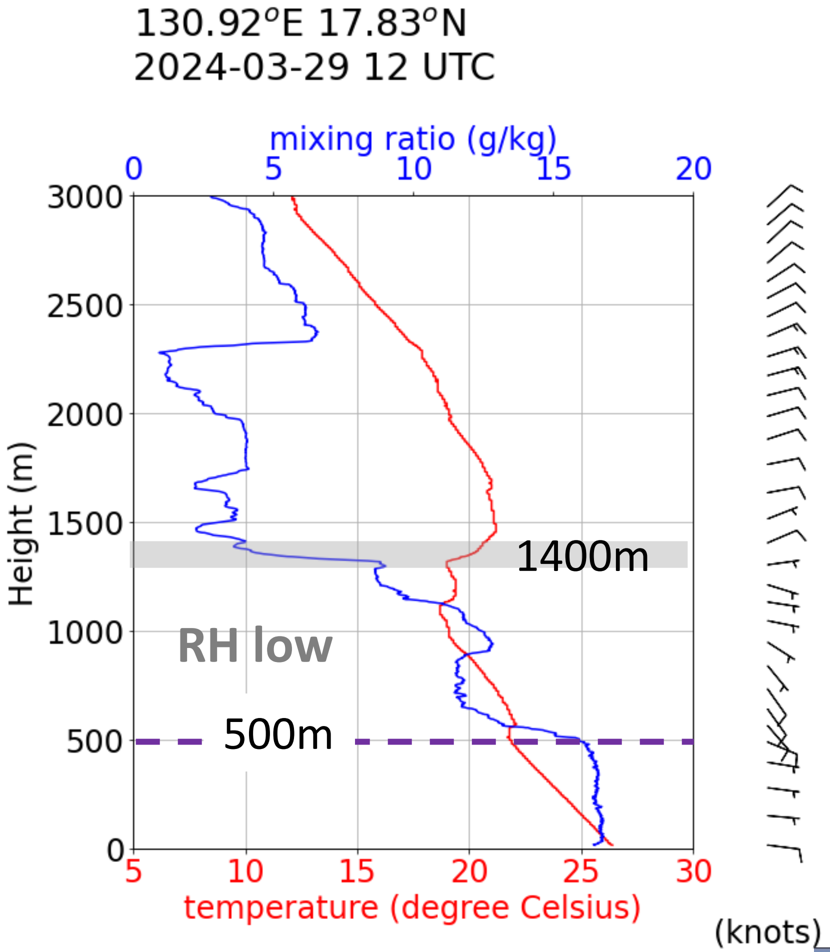
Atmospheric measurement – NOR1-0069 Palau

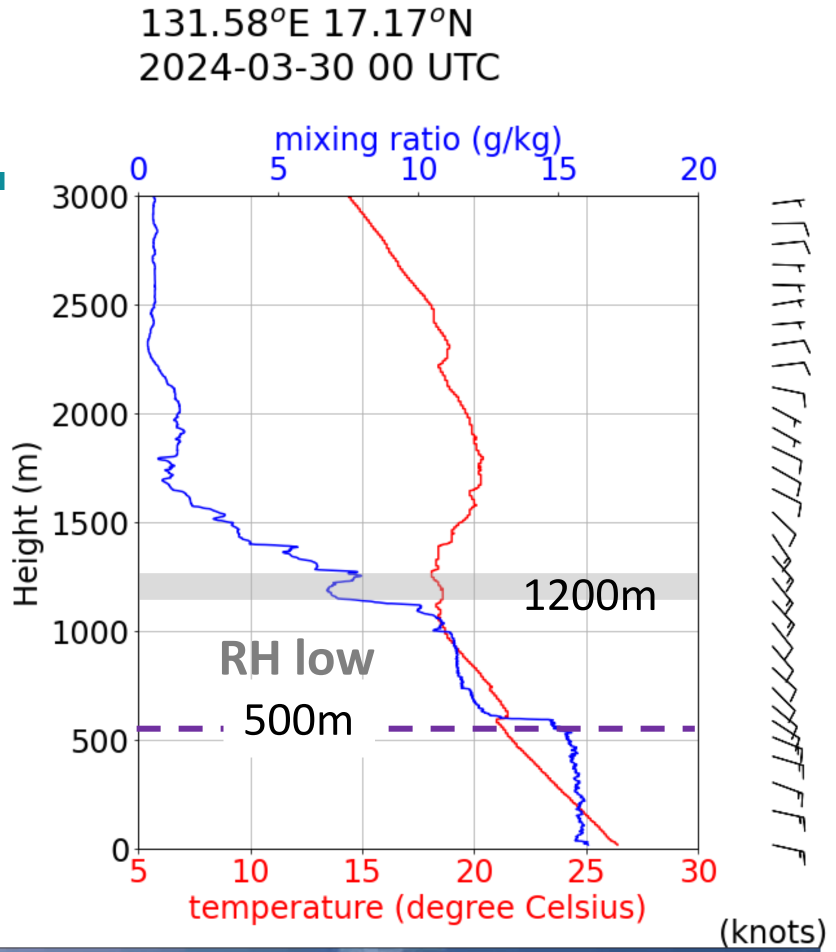


- Insignificant diurnal temperature change
- Humid environment
- Northeasterly to Southeasterly wind









❖ **Maritime boundary layer:**

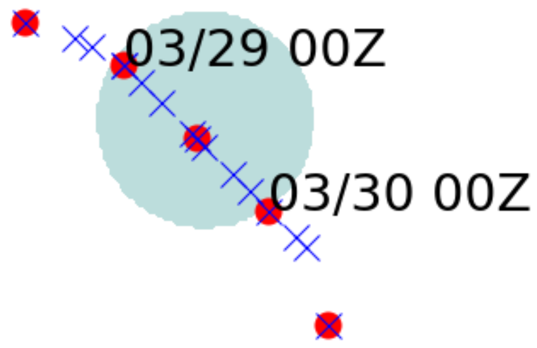
The mixed layer (MLH) & inversion layer (IL)

→ **Decreasing height**

MLH: 600 → 500 m

IL: 1700 → 1400 m

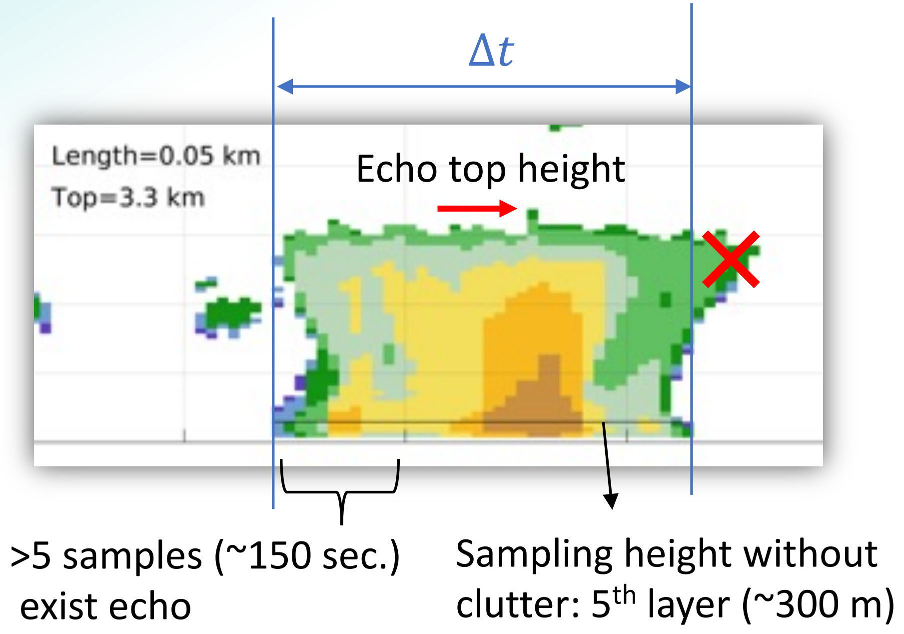
→ **Drier**

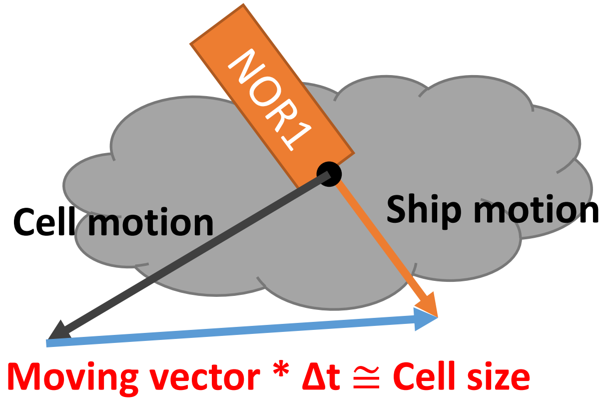


(台大大氣 林博雄老師)

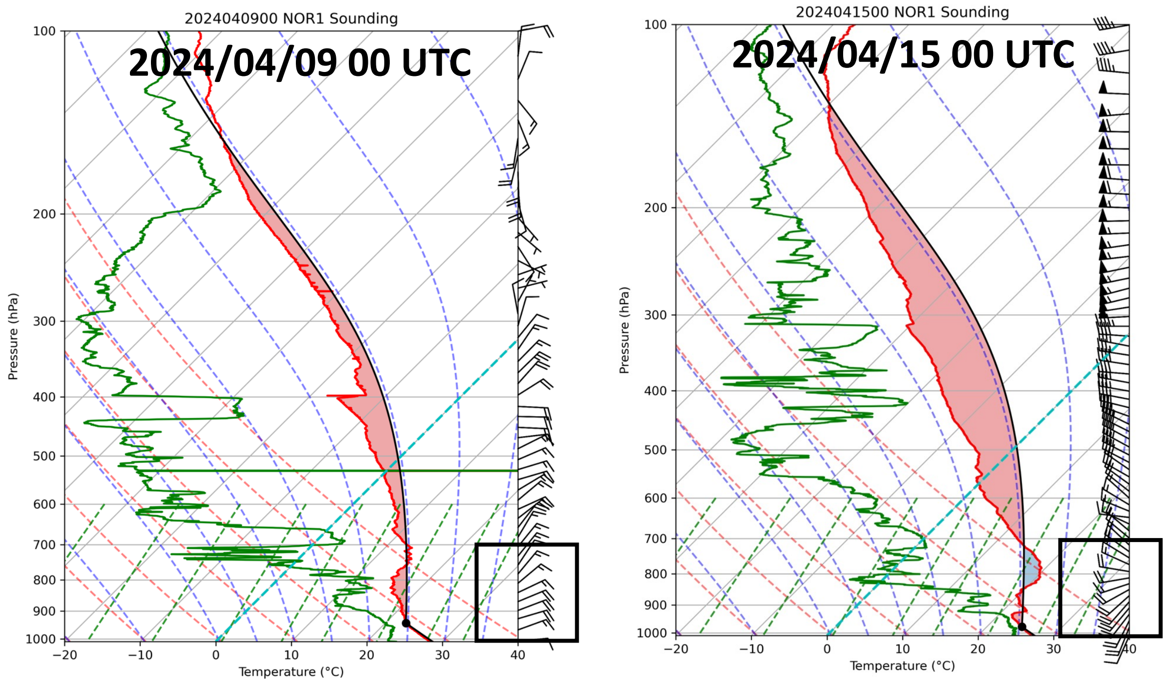
MRR-PRO Data Cell ID

- **Identification method**



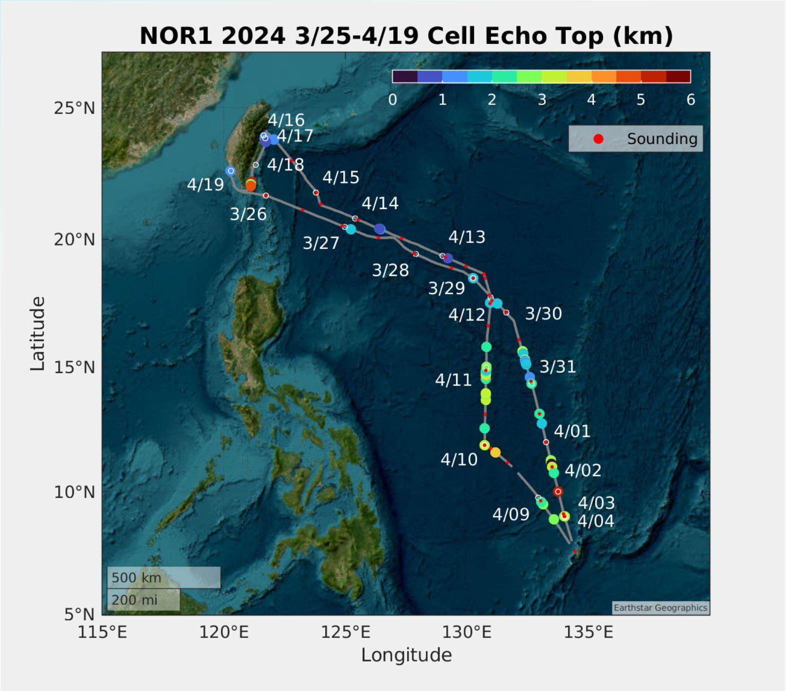


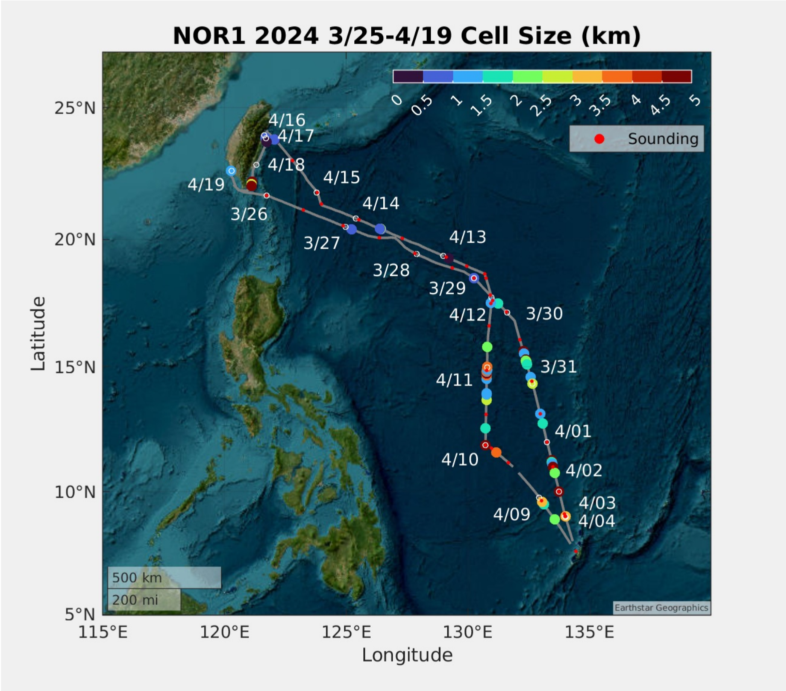
- Estimate **cell size** based on **ship motion** and **environment wind**

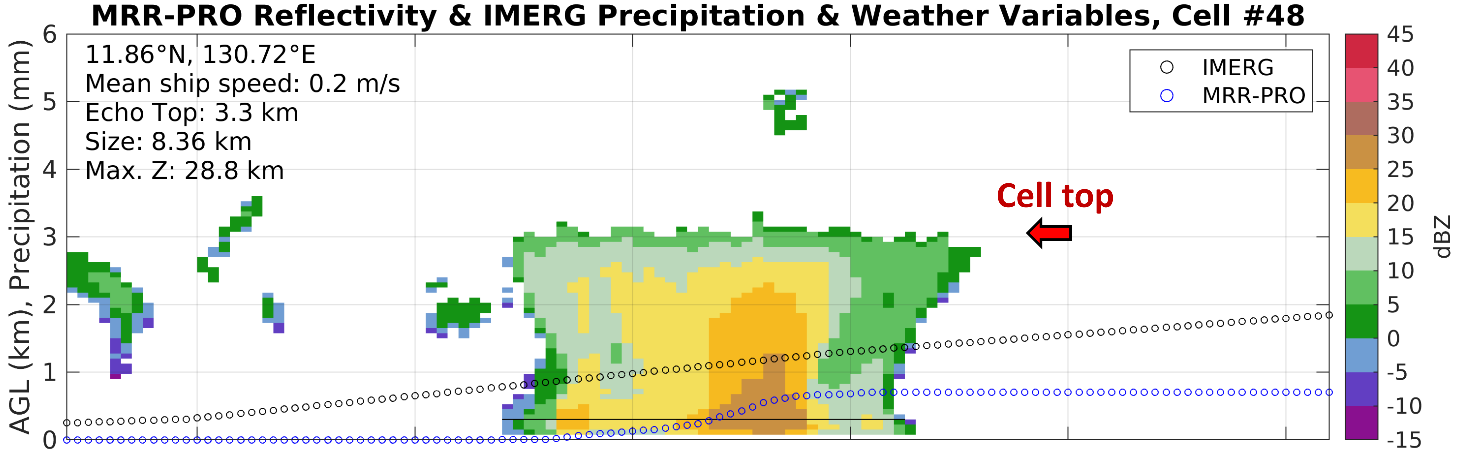


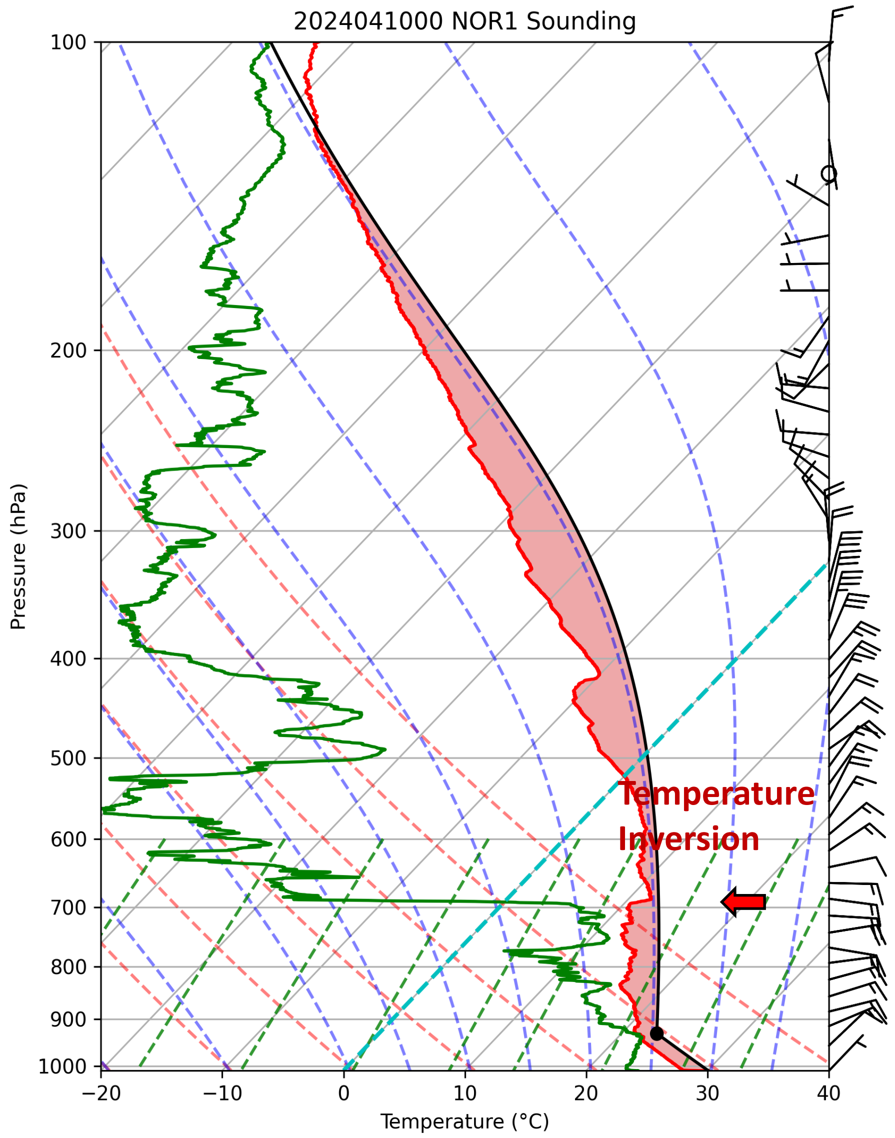
Take 0-3 km mean u-wind, v-wind as the cell motion.

Precipitation system over Ocean : Case Analysis

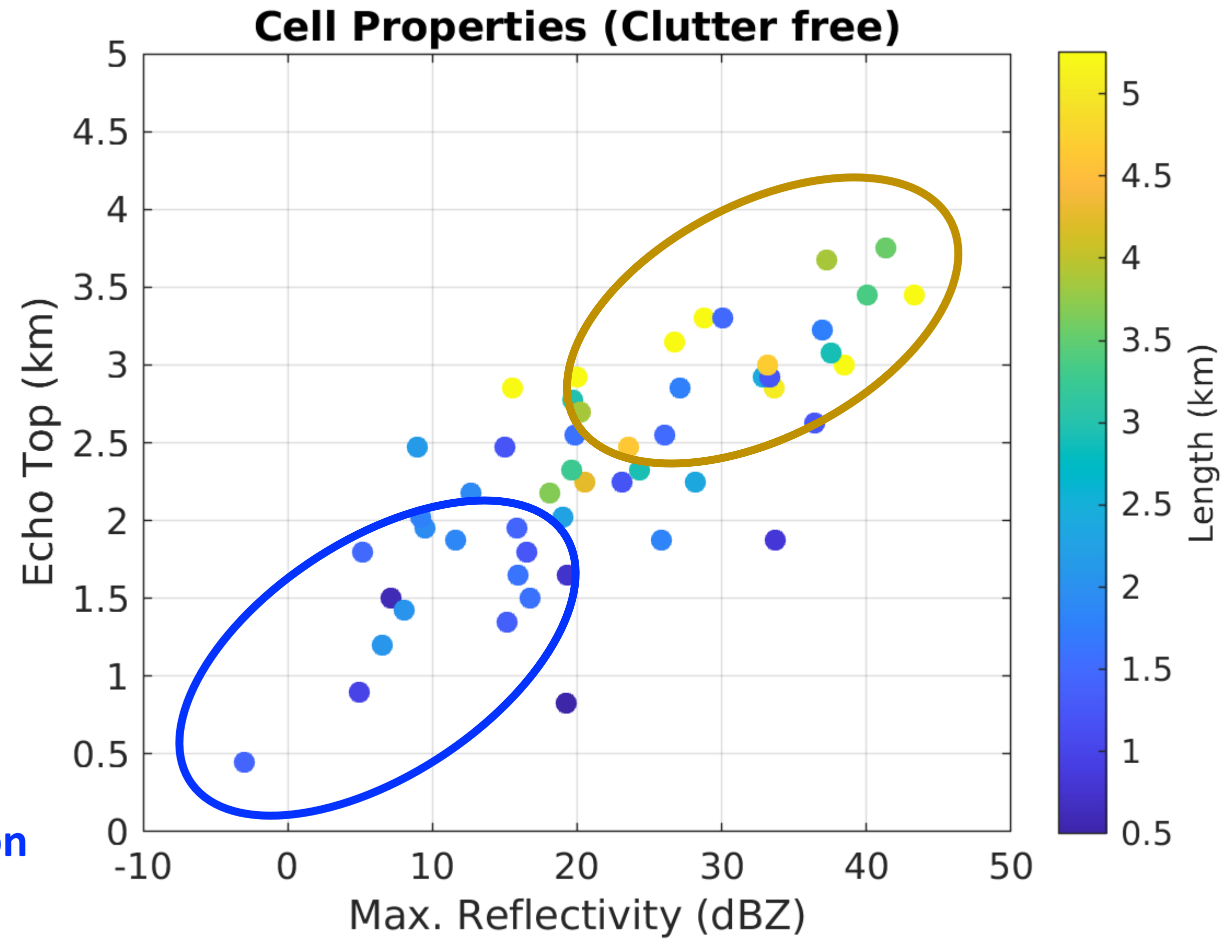








Result: Convection Properties

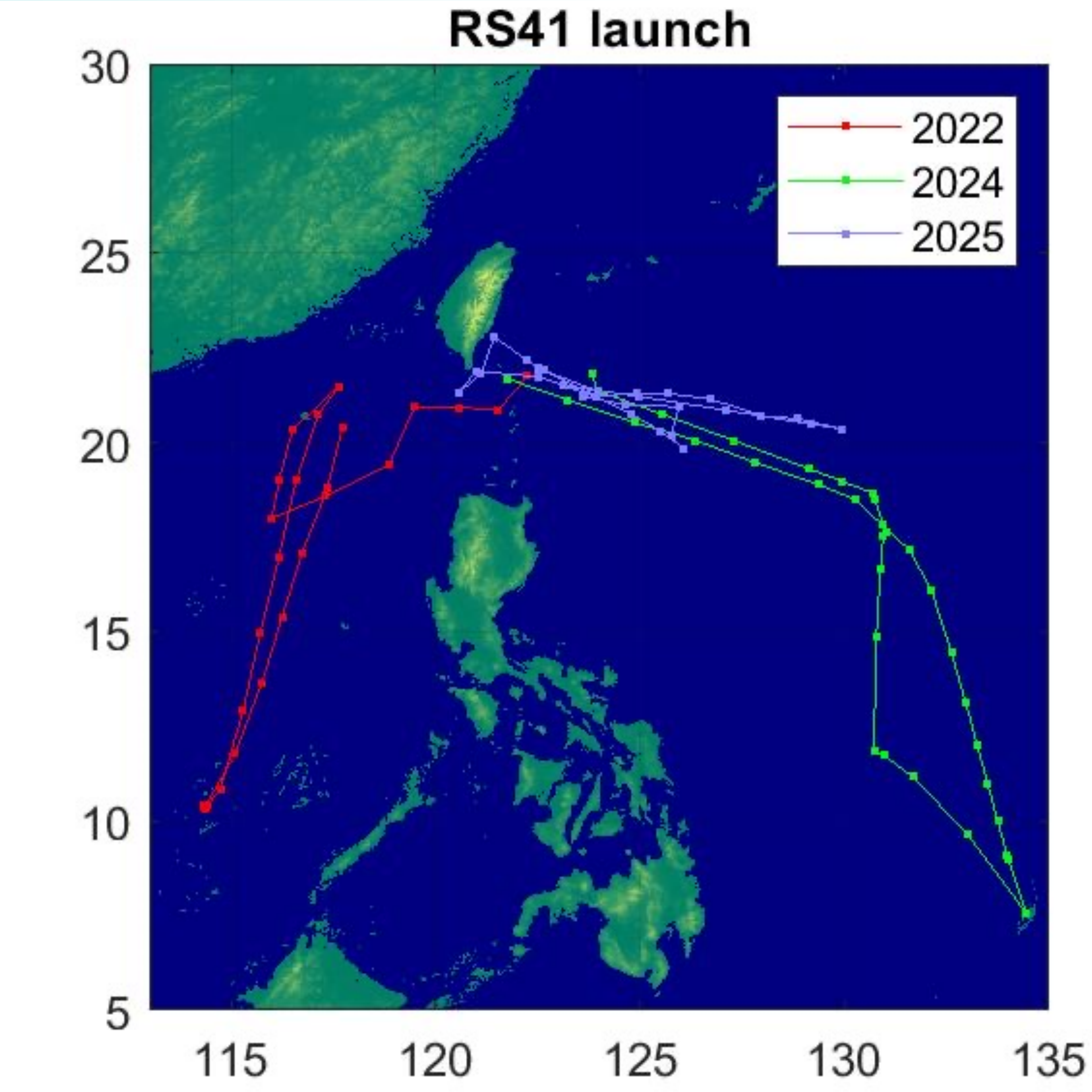


- ❖ Strong reflectivity
- ❖ Depper convection
- ❖ Larger size

- ❖ Weak reflectivity
- ❖ Shallow convection
- ❖ Small size

Echo Top Height ∝ Max. Z ∝ Size

低層大氣逆溫層特性分析



RS41 探空分析 (101筆資料)

❖ 2024、2025年：大氣海洋聯合觀測。

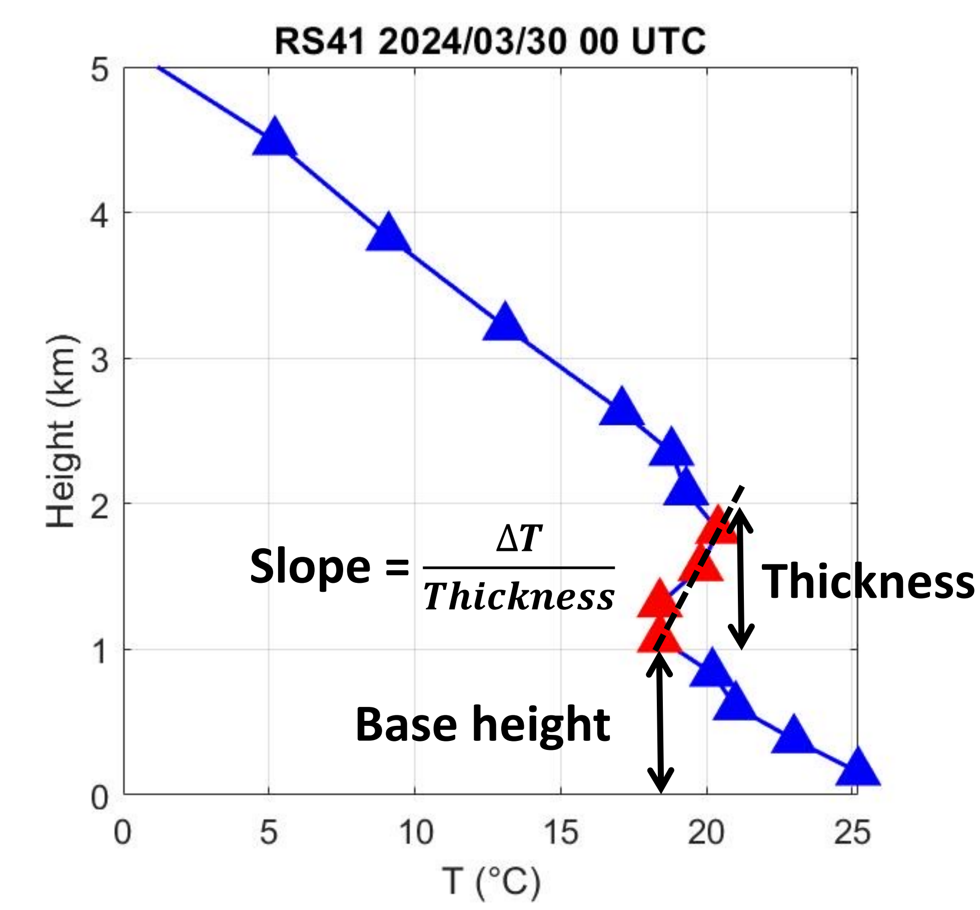
❖ 2022年(台大林博雄、隨中興老師)：南海雙島雨季觀測實驗

航程	日期
2022年	03/09 ~ 03/30
2024年	03/26 ~ 04/15
2025年	04/09 ~ 04/29

❖ **副熱帶高壓**內部下沉氣流導致之**trade wind inversion**高度、強度皆反映下沉氣流強度，同時inversion高度也是邊界層上界。

ETOPO Global Relief Model | National Centers for Environmental Information (NCEI)

RS41 Vaisala和ERA5 Reanalysis的比較 – trade wind inversion



❖ RS41 和 ERA5比較、計算inversion layer特徵。

❖ Inversion layer底部實際高度

→ base height

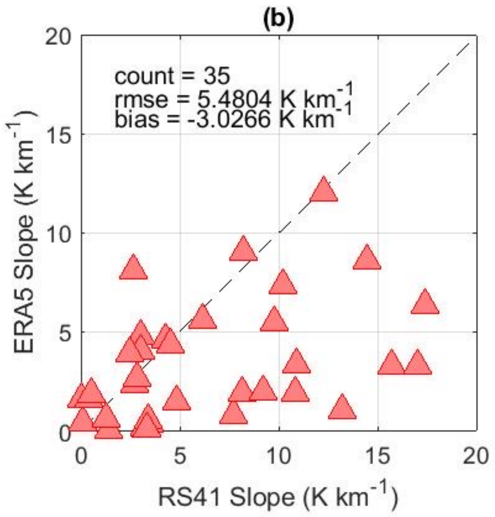
→ 逆溫厚度(thickness)

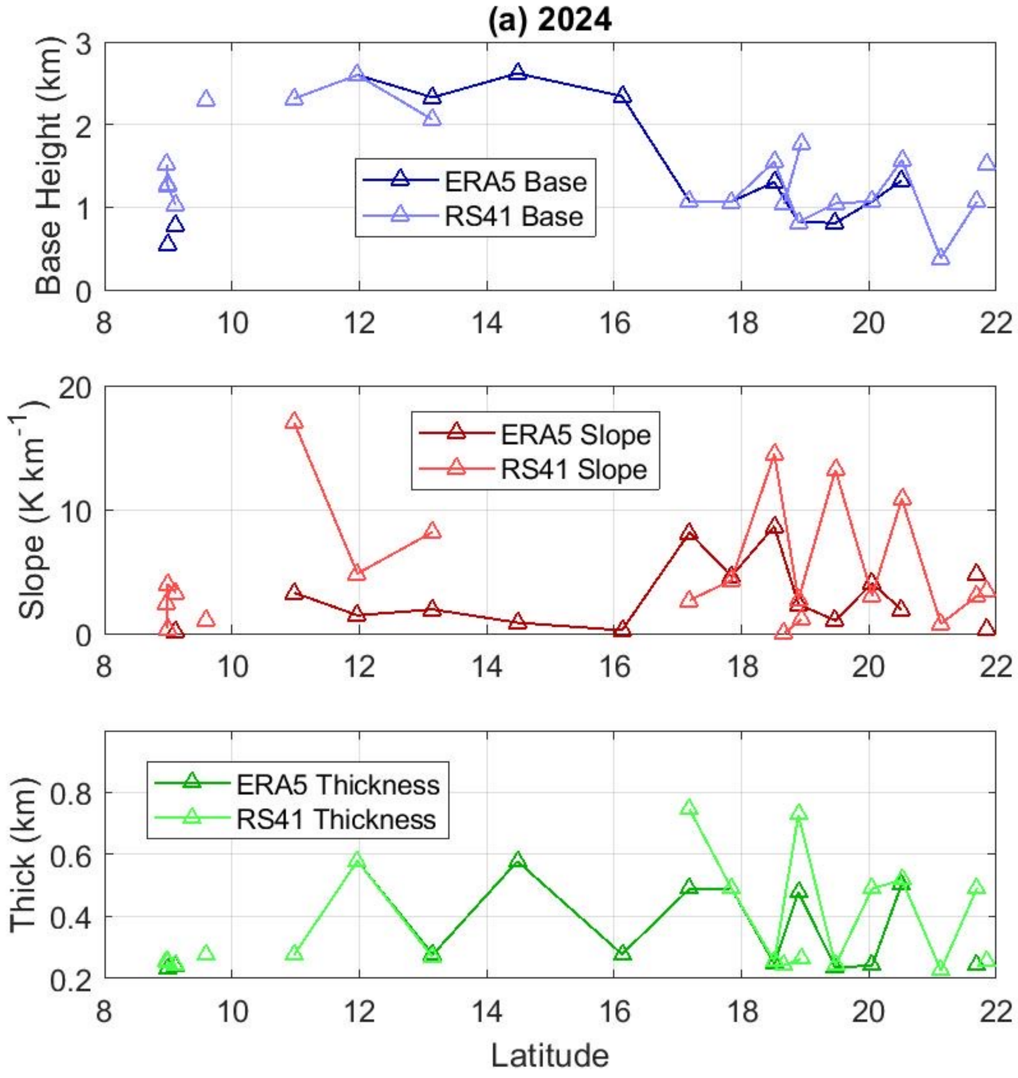
→ 隨高度增溫的斜率(slope)。

RS41 Vaisala和ERA5 Reanalysis的比較 – trade wind inversion

2024年 RS41 與 ERA5 比較：

- ❖ Base height 、 Thickness ERA5 無偏差
- ❖ **Slope：ERA5 明顯低估**

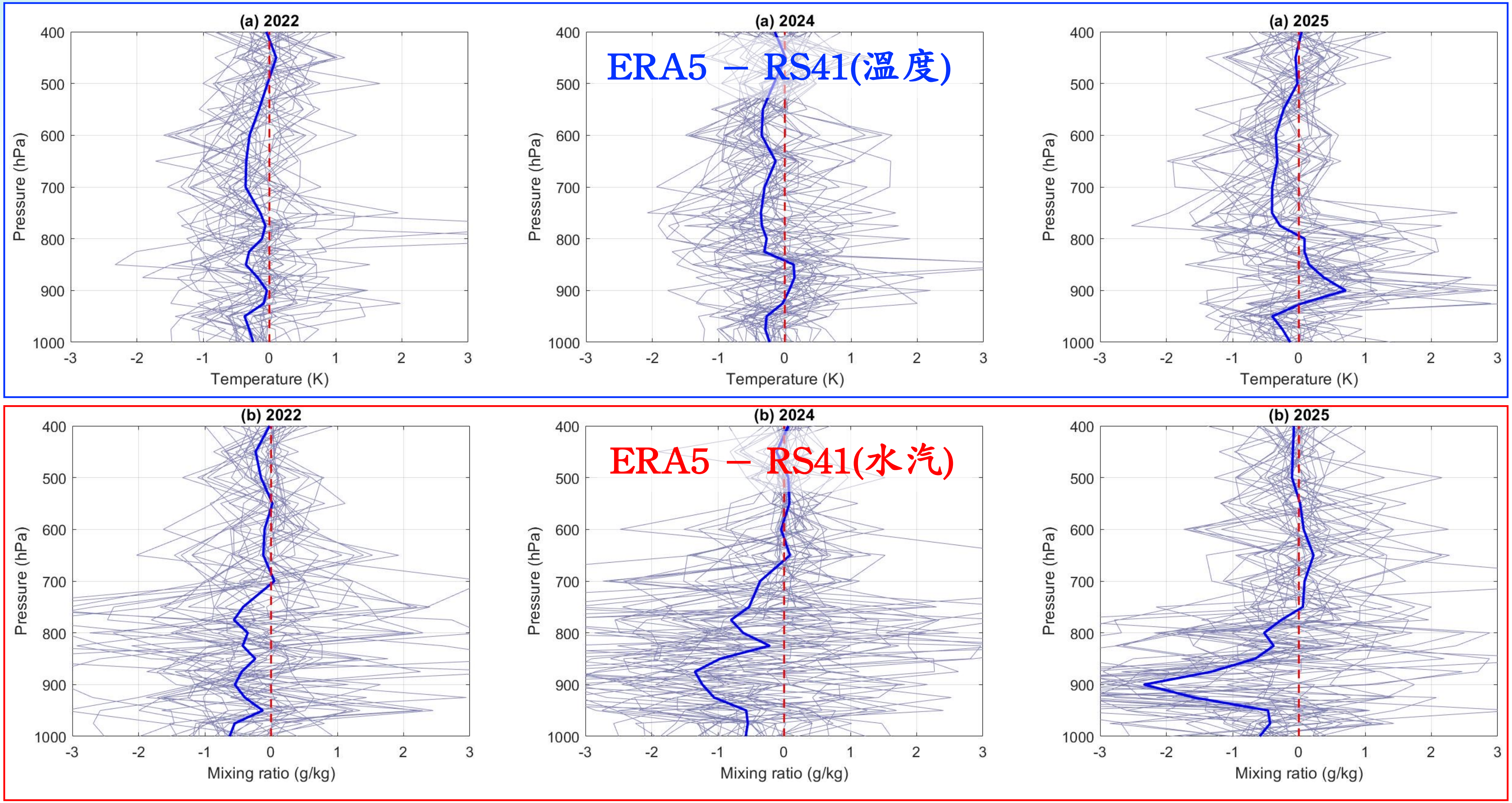




	ERA5 有	ERA5 沒有
RS41 有	35	**25**
RS41 沒有	3	38

❖ **ERA5 沒有正確掌握逆溫 → 42%**

RS41 Vaisala和ERA5 Reanalysis的比較 – trade wind inversion

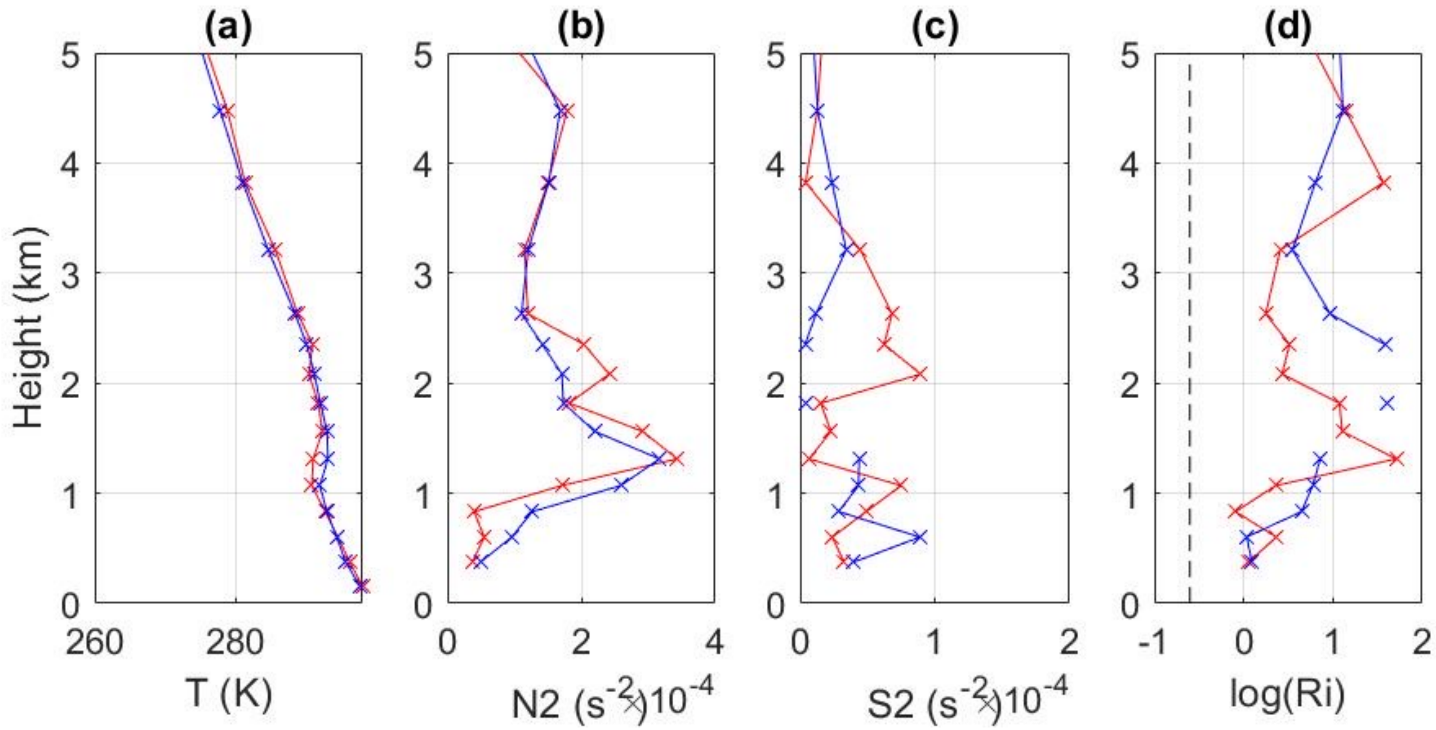


RS41 Vaisala和ERA5 Reanalysis的比較 – gradient Richardson number

$$R_i = \frac{N2}{S2} = \frac{\frac{g}{\theta_v}\frac{\partial \theta_v}{\partial z}}{\left(\frac{\partial u}{\partial z}\right)^2 + \left(\frac{\partial v}{\partial z}\right)^2}$$

浮力項 (靜力穩定度)

剪切項 (動力不穩定)

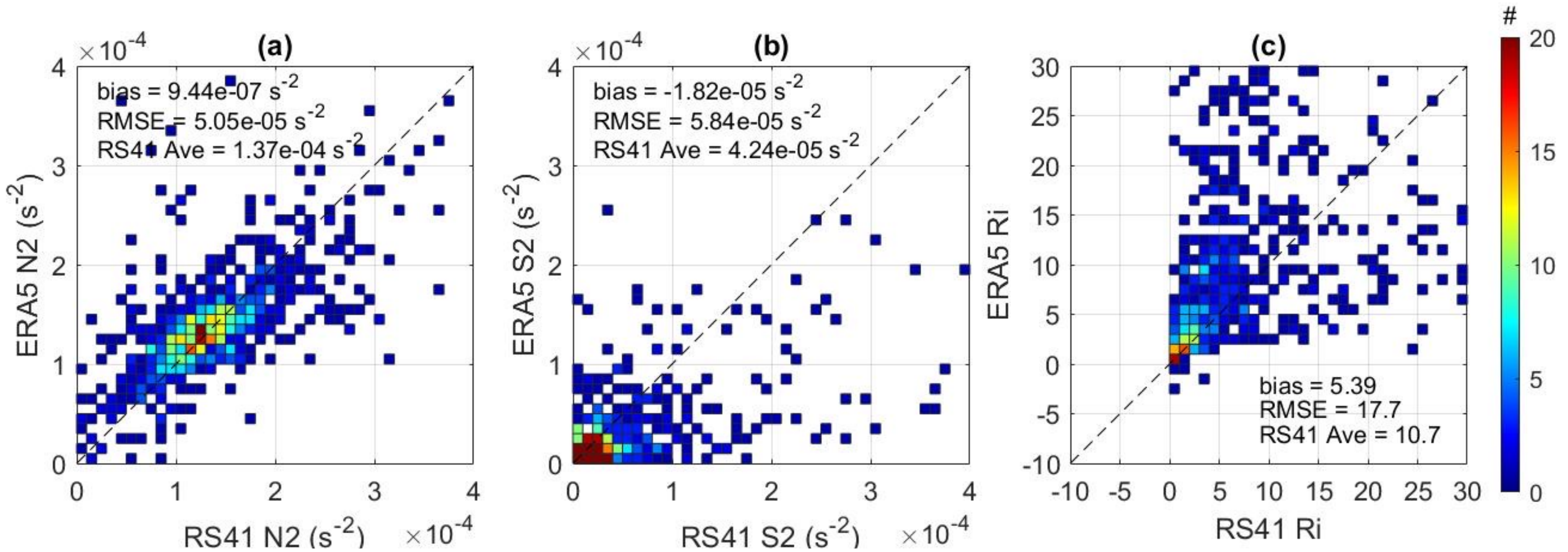


以 2024/03/26 00UTC 為例:

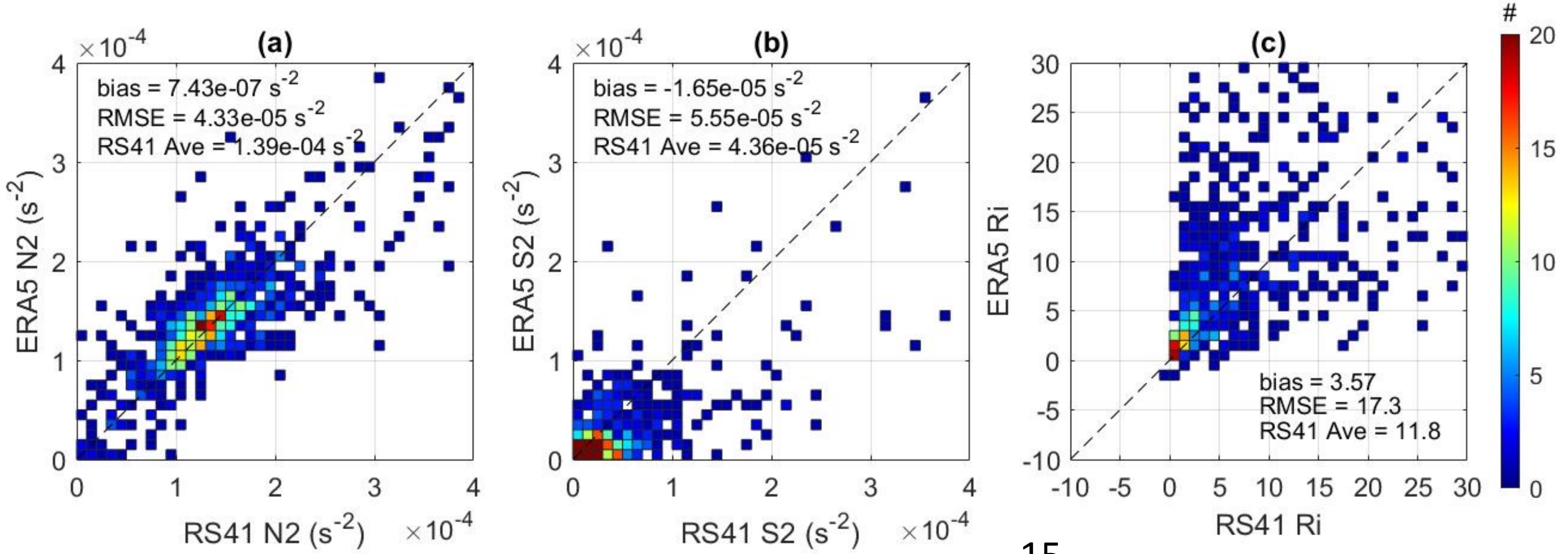
- ERA5在溫度分布、垂直靜力穩定度N2上的掌握良好。
- 動力上剪切項S2，ERA5和RS41的差異大。
- Richardson number的偏差。

紅線 — RS41　藍線 — ERA5

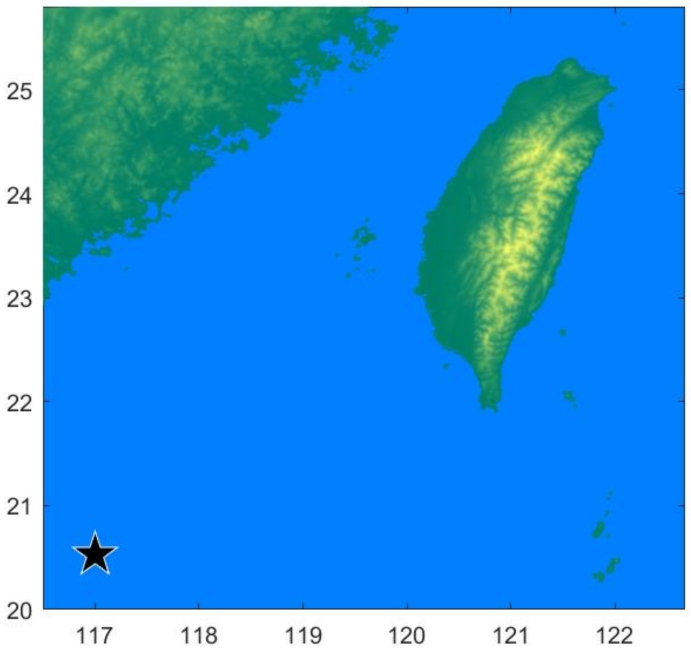
00 UTC
白天
(47 RS41)
1000~300hPa



12 UTC
夜晚
(45 RS41)
1000~300hPa



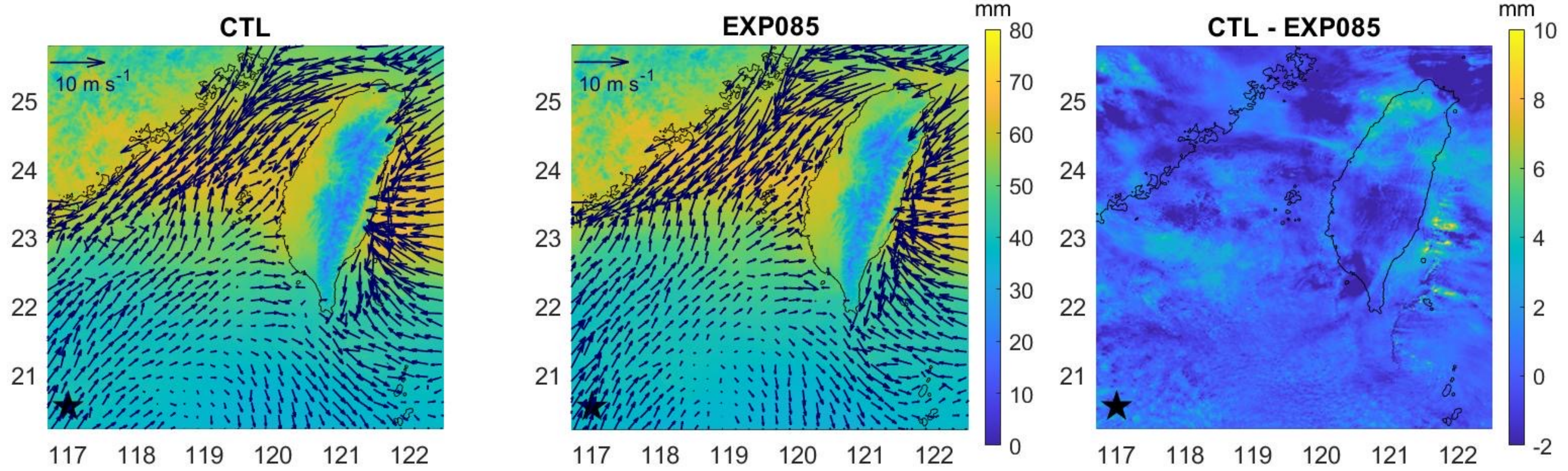
❖ Weather Research & Forecasting Model (WRF)，高解析度區域(3 km)。
❖ 模式設定**參考中央氣象署作業系統**。
❖ 模擬時間為：2025年4月22日 00UTC～4月25日 00UTC
❖ 實驗設計：根據 2025年 NOR1-0075 海洋觀測資料，調整可感熱通量 (sensible heat flux, SH) 及潛熱通量 (latent heat flux, LH)參數化方案至原本的85%。
❖ 實驗目的：春季微弱鋒面之海氣交互作用模擬(SH及LH)敏感度分析。



❖ 控制組(CTL)：WRF 預設 COARE 參數化模型。
❖ 實驗組(EXP085)：SH及LH 根據觀測資料減少 15%。

❖ **可降水量(TPW)：CTL > EXP085，差異可達 10 mm。**

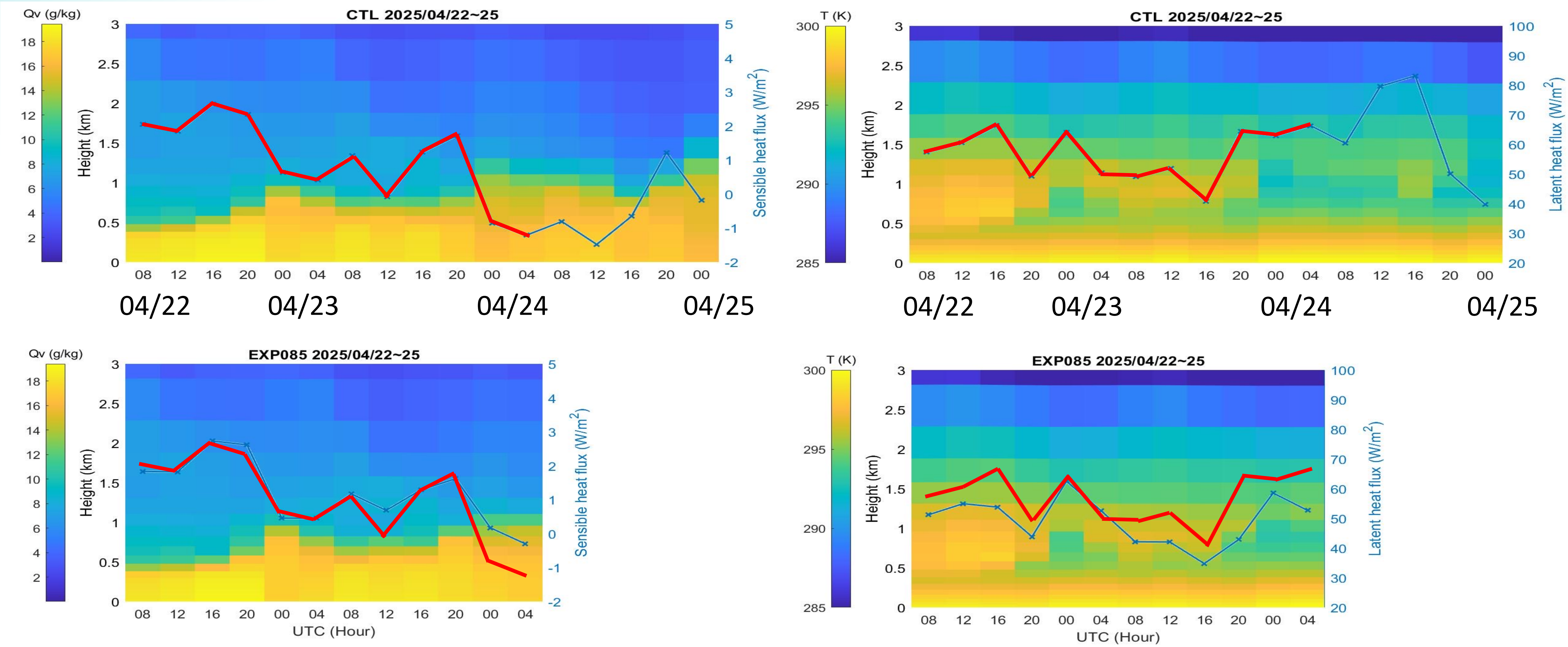
❖ **根據觀測修改 SH及LH，透過海氣交互作用，改變可降水量約 5~10%。**



❖ CTL 及 EXP085 在海面 SH 差異較小(左圖，實線)，LH數值在 EXP085有明顯較低(右圖，實線)。

❖ CTL 及 EXP085 在溫度剖面差異不大(右圖，shading)，而EXP085 水汽剖面厚度略低(左圖，shading) 。

❖ 實驗結果顯示：海氣交互作用中的水汽，**透過 LH 過程傳送到大氣減少**。水氣對於天氣系統的發展極為重要。



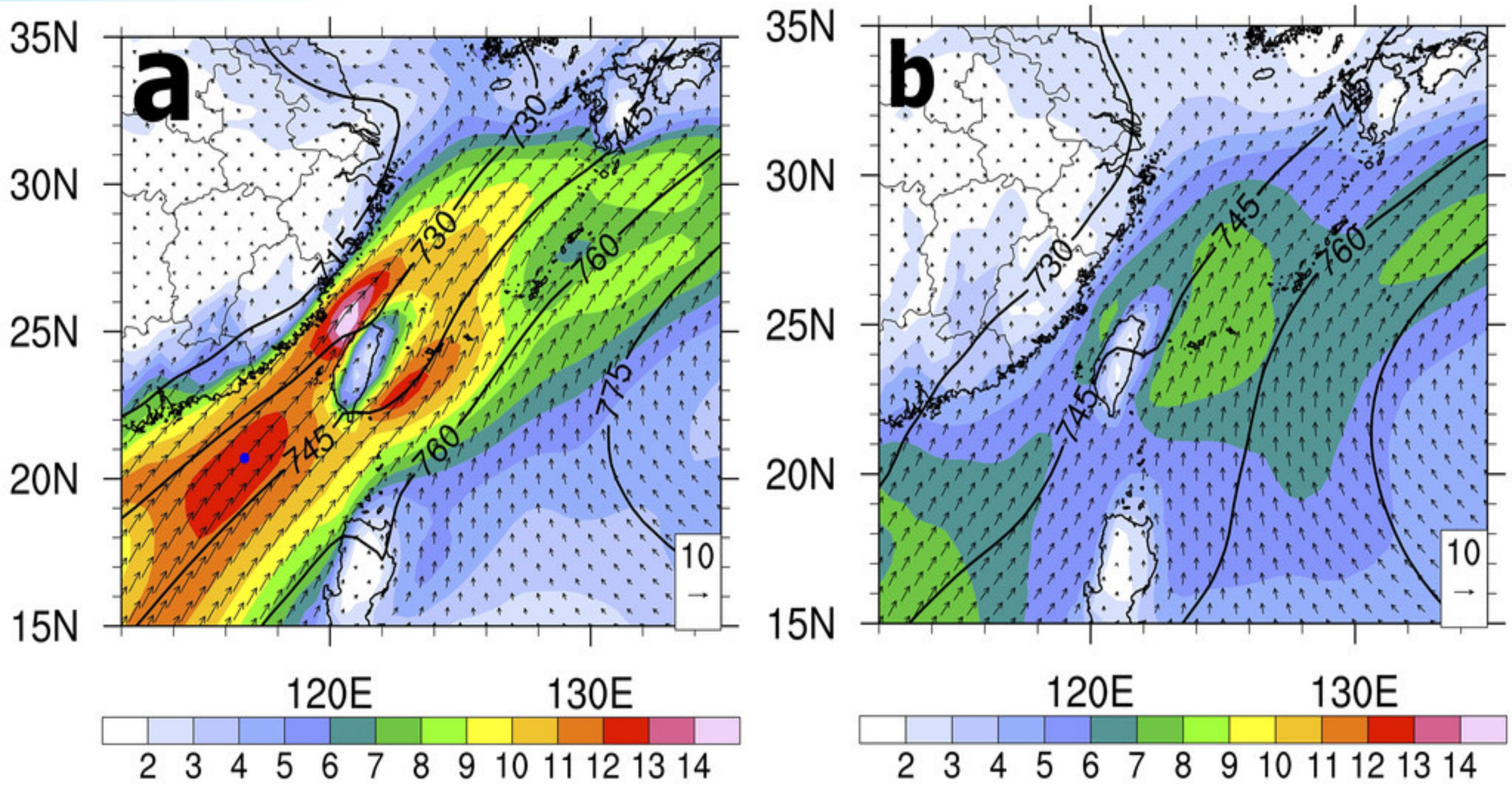
Using the high-resolution data observed by shipborne instruments to study the characteristics of the marine atmospheric boundary layer and low-level jets

利用船載儀器觀測之高解析度資料探討海洋大氣邊界層及低層噴流特性

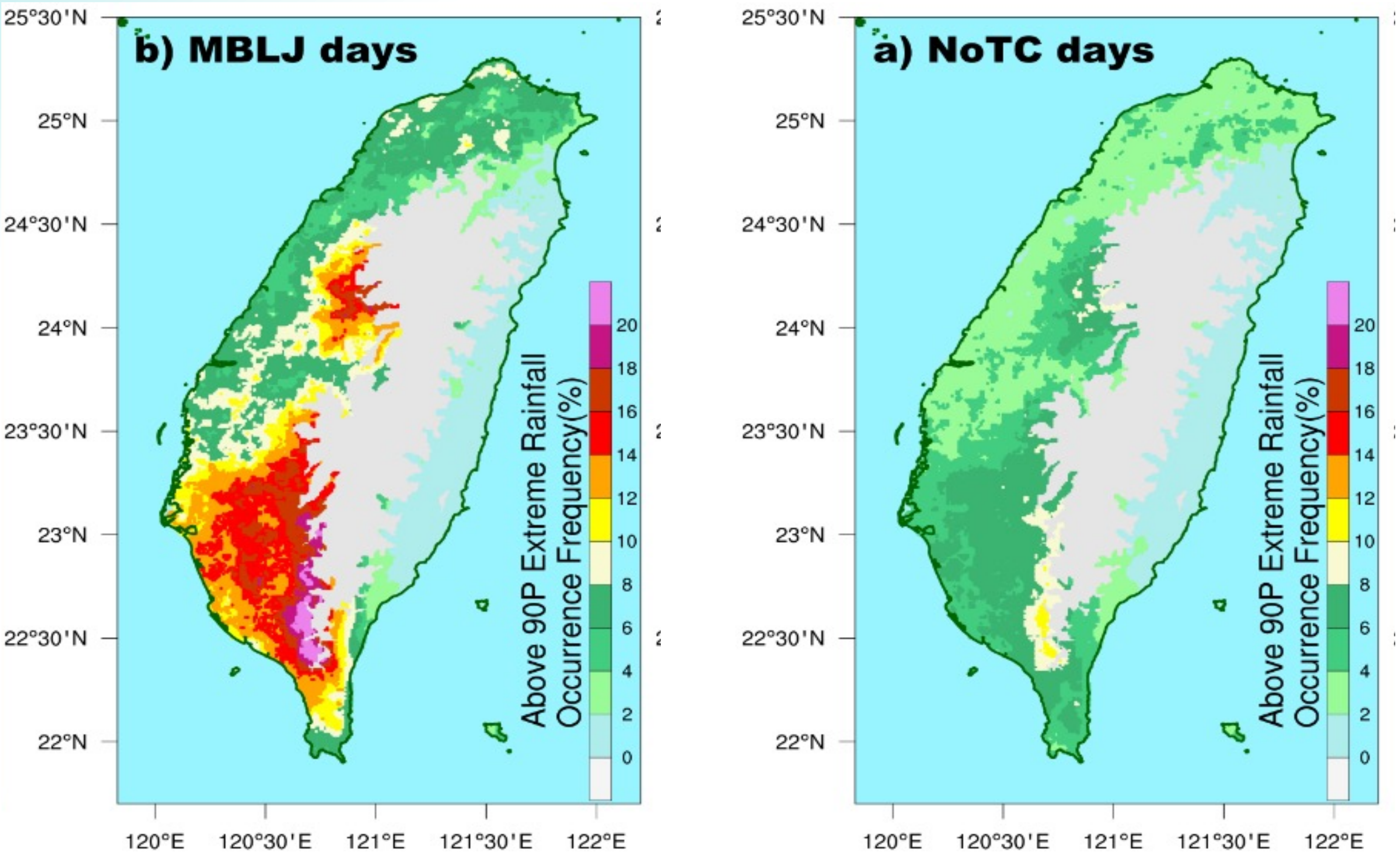
廖宇慶
國立中央大學大氣科學系

LLJs	Synoptic-system-related Low-Level Jet (SLLJ)	Marine Boundary Layer Jet (MBLJ)	Barrier Jet (BJ)
Altitude	700-850 hPa	Marine boundary layer ~ 925 hPa	~ 1.0 km
Occurrence	SE flank of a deepened frontal cyclone originated from a Tibetan Plateau/YunGui Plateau lee vortex Increased pressure gradients	Deepened Mei-Yu trough in SE China + Westward extension of WPSH Sub-synoptic pressure gradients	Terrain induced Windward-ridge/Leeside trough Local pressure gradients
Timing	April to July	June	SLLJ or MBLJ exists
criteria	> 12.5 m/s	① Below 900 hPa: WS > 10 m/s and ① Below 4 km from the max. wind height to the minimum aloft: WS decreases by at least 3 m/s	> 14 m/s
	Central China	Northern South China Sea	Parallel to the coastal terrain off the NW Taiwan coast

Marine Boundary Layer Jet (MBLJ)



(a) Composite 925 hpa wind speed (color shading in ms^{-1}), wind direction (arrow) and geopotential heights (contour in gpm) for the MBLJ days; (b) same as (a), but is the June monthly mean (adopted from Tu et al. 2019).



(a) Above 90th percentile extreme rainfall occurrence frequency (%) below 1.0 km height over Taiwan for the June climatology from 1999-2018 without the influence of tropical cyclones (438 NoTC days). (b) As in (a), but for MBLJ days when southwesterly MBLJ occurs over Dongsha Island (courtesy of Dr. Chuan-Chi Tu).

規劃新增儀器

❖ 國立中央大學太空科學與工程學系 朱延祥,蘇清論

艦載HF/VHF雙態雷達海面傳播實驗

❖ 國立中央大學大氣科學系 王聖翔

船載海洋表面輻射通量觀測 (與 NASA合作)

❖ 國立中央大學大氣科學系 張偉裕

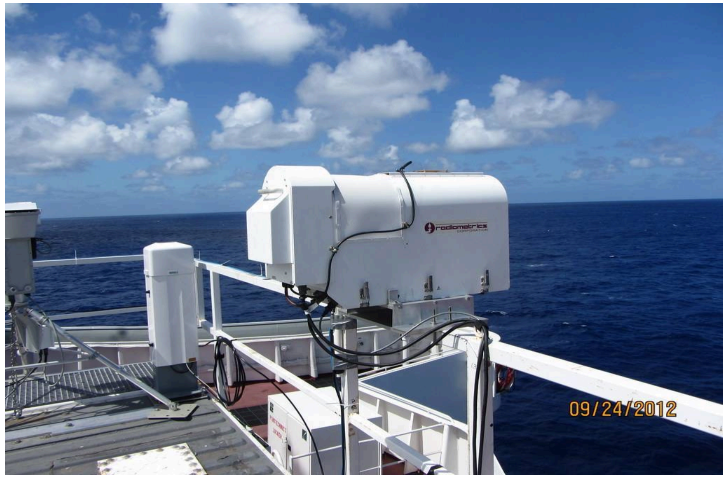
船載雨滴譜儀(台大海研所責儀)

微波降雨雷達，可量測降水粒子結構隨高度的變化。

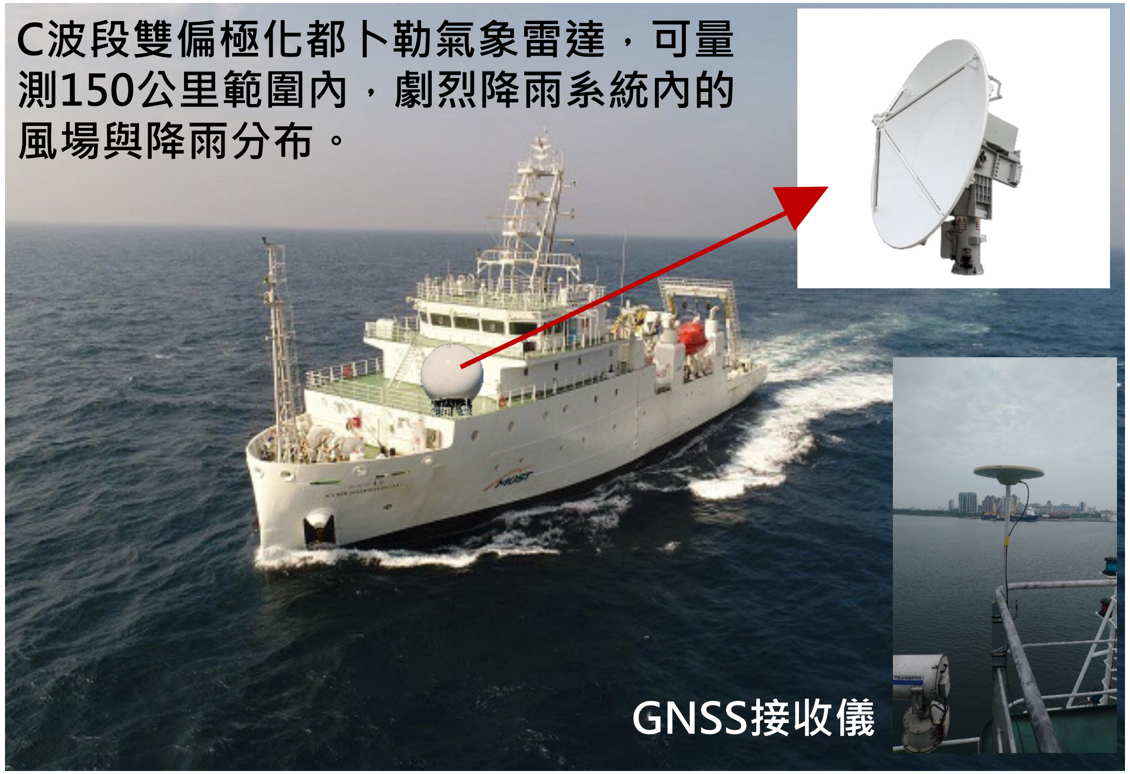
W波段船載式雲雷達，可量測10~15公里範圍內，雲霧內的風場與雲滴特徵。

從晴天到雨天, 1D 到 3D , 海洋到大氣

氣球探空系統，在晴空及降雨情境下均能施放，可量測大氣的風場，溫度，壓力與濕度的垂直結構。



微波幅射儀，可量測儀器上方的溫度與水氣垂直結構。



C波段雙偏極化都卜勒氣象雷達，可量測150公里範圍內，劇烈降雨系統內的風場與降雨分布。

都卜勒風光達，可在晴空下量測10公里範圍內大氣的風場與氣膠分布。

Goals of this proposal

1. Study air-sea interaction from SST to MBL. Moisture flux over various ocean conditions.
2. Understand dynamic/thermodynamic/microphysical structure and time-space characteristics (diurnal cycle) of the marine LLJs.
3. Perform data assimilation to improve the model simulations of the marine ABL and LLJs.
4. Provide validation data over oceans for satellite measurements (e.g., TASA's GPSRO, GNSS-R/TRITON, and others) and CWA's ocean/atmosphere models.
5. Provide critical local data sets for training artificial intelligence systems.