ESCAP/WMO Typhoon Committee

ESCAP Economic and Social Commission for Asia and the Pacific

WORLD METEOROLOGICAL ORGANIZATION

Impacts and Prediction of Post-Landfall TC Remnant Vortices

XIANG CHUNYI

National Meteorological Center, CMA

Background

A "Decaying" System with Undecaying Impacts

The typhoon remnant vortex poses a major threat through prolonged extreme rainfall, often causing greater inland disasters than the landfall itself.

- Doksuri(2305) Haikui(2311)
- Gaemi(2403) Yagi(2411) Trami(2420)
- Danas(2504) Co-May(2508) Matmo(2521)

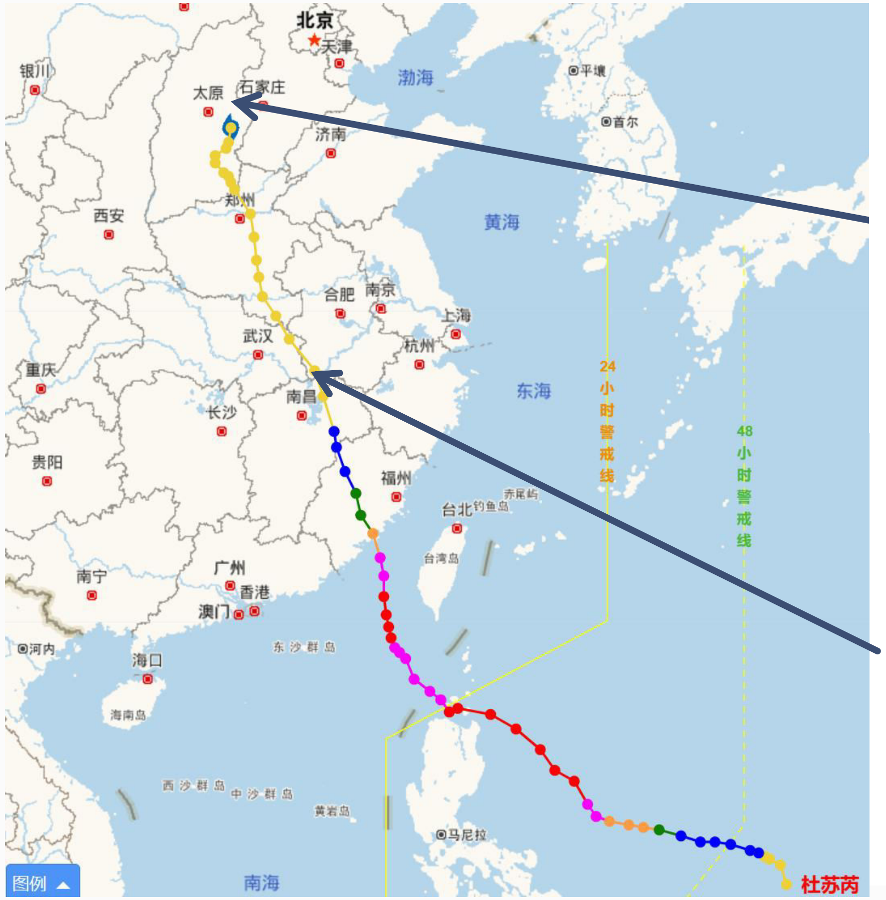
Urban Inundation

Flash Floods&Debris Flows

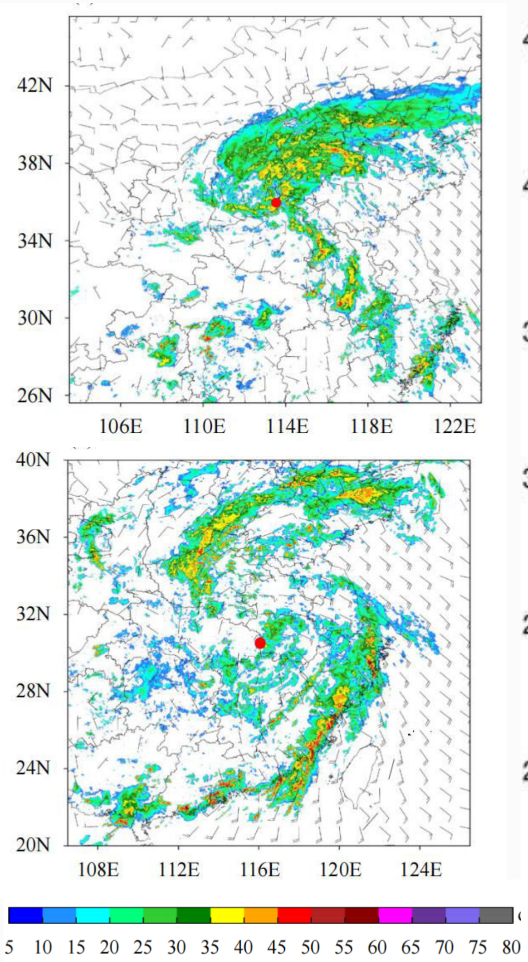
Seawater Intrusion

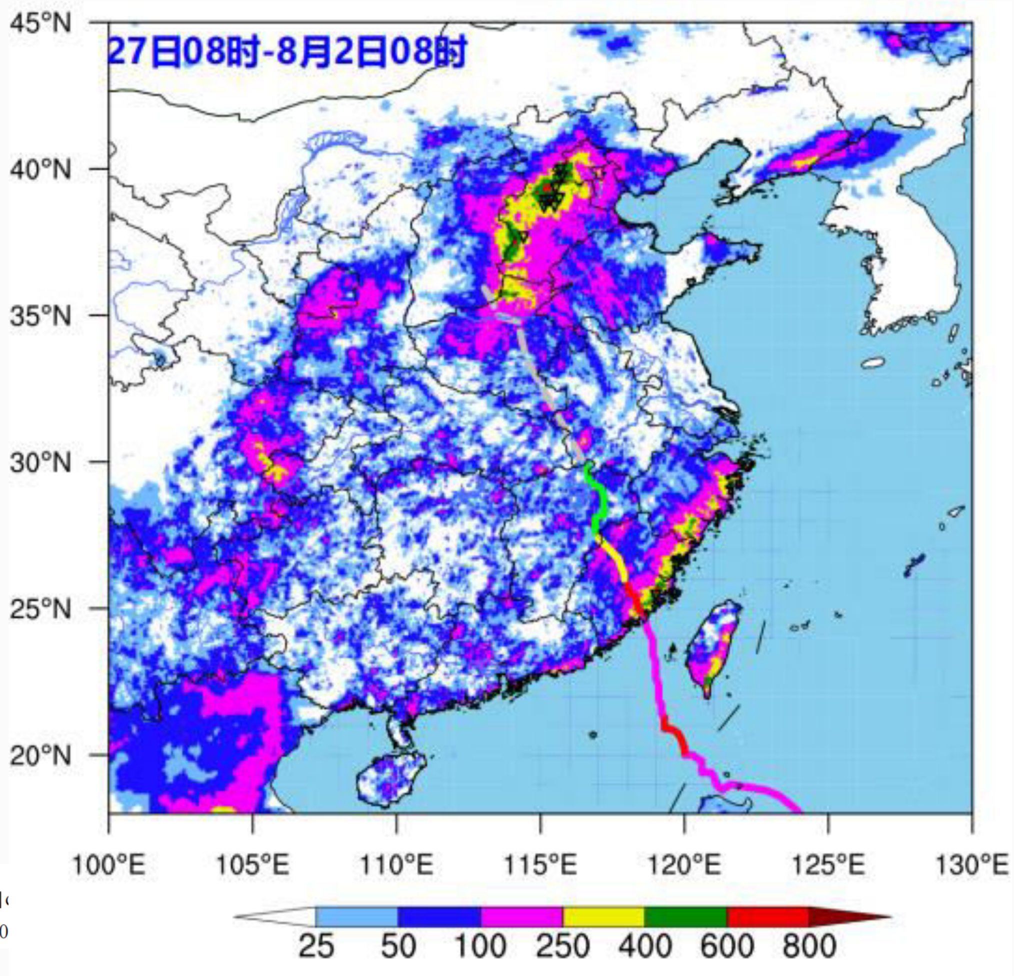
Background

- After making landfall, the strong winds and heavy rainfall of a tropical cyclone usually weaken rapidly.
- The accurate forecasting of the movement and intensity of these remnant vortices is crucial for preventing inland disasters and extending warning lead times.



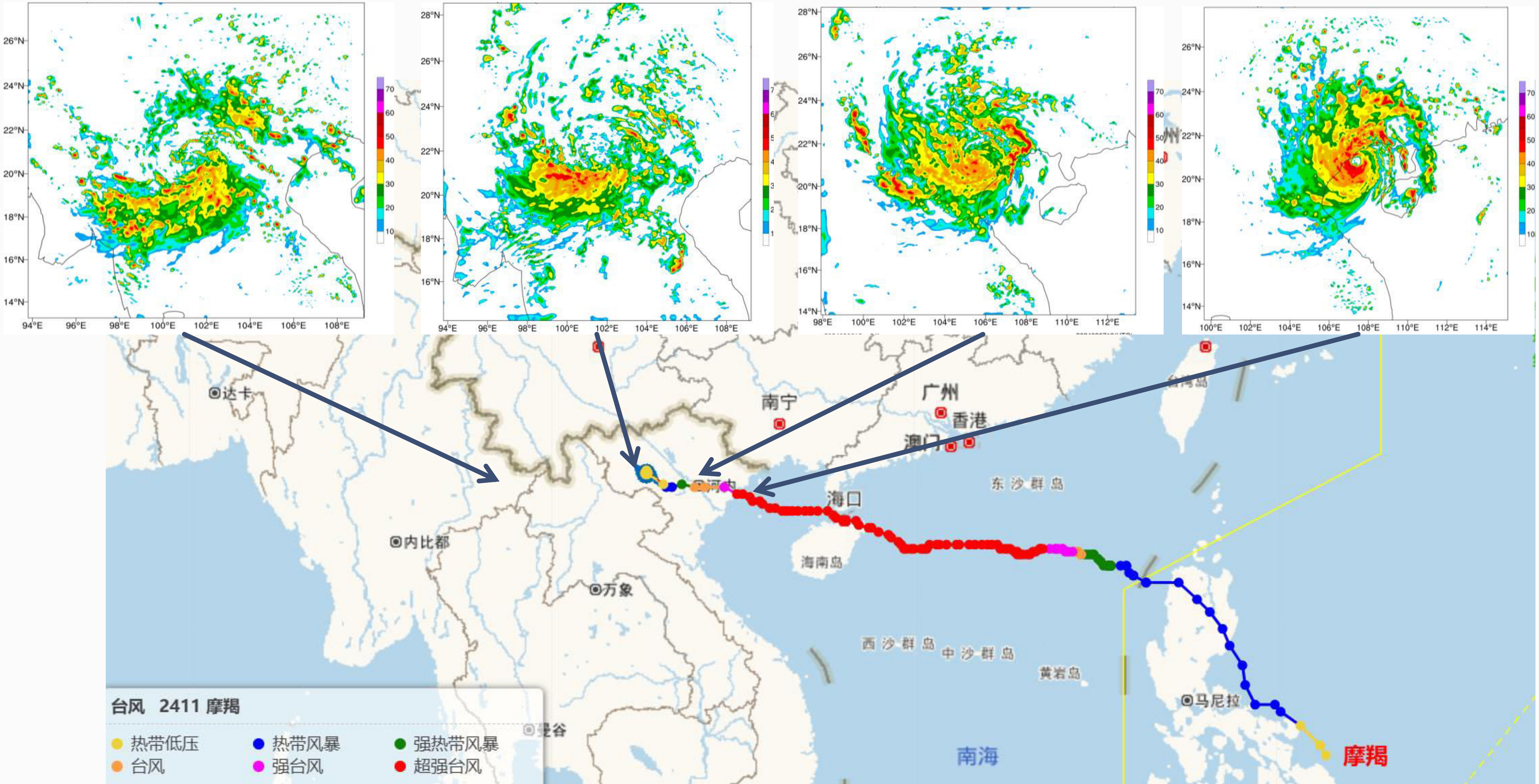
Doksuri(2305)





Background

- After making landfall, the core (known as "**Remnant Vortex**")does not dissipate immediately.
- Instead, it can continue to move far inland, where it may trigger persistent heavy rain, strong winds, and even induce secondary weather hazards in areas **far from the coastal regions**.



Yagi(2411)

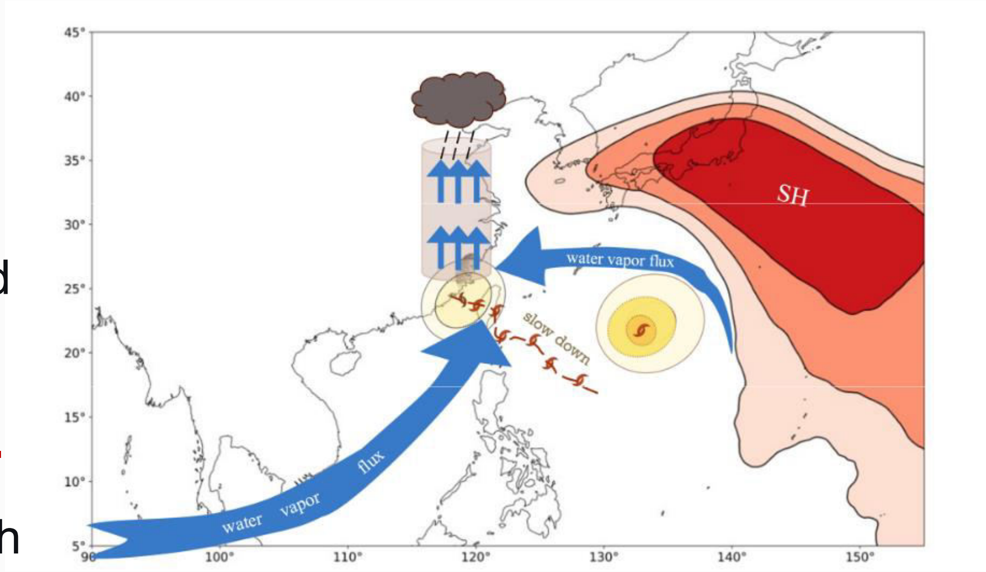
Background

1. Statistical Characteristics:

- The average overland duration is 31hrs, **with 55%** of TCs persisting for 1/2 day to 2 days (Li Ying et al., 2004).
- Intensity drops from 34 m/s pre-landfall to 20 m/s 24 hours post-landfall, with the **most rapid weakening occurring within the first 6 hrs** (Yu et al., 2017).
- About **24% of landfalling TCs re-intensify** after moving back over the ocean, primarily due to the smooth marine surface and higher Sea Surface(Zhu et al. 2020)

2. Mechanisms for Prolonged Maintenance:

- Continued **moisture supply**, **intrusion of weak cold air**, or moving into an upper-level divergence zone favor longer inland duration (Chen Lianshou et al., 2004).
- Long-lasting TCs tend to move **northward ahead of a long-wave trough**, approaching the mid-latitude baroclinic zone with a **low-level jet moisture channel** (Wang et al., 2024).

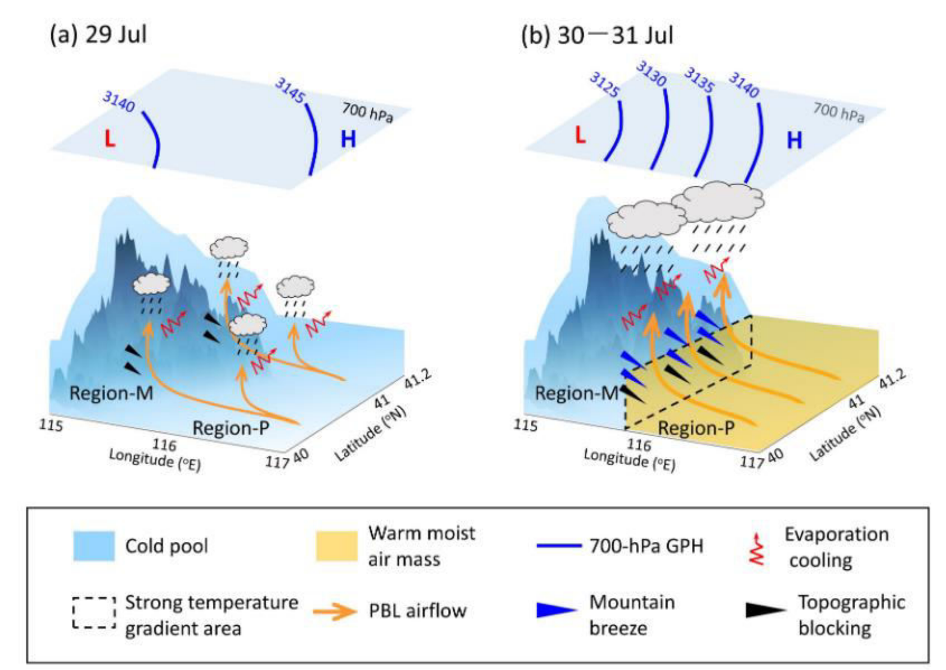


(Wang et al., 2024)

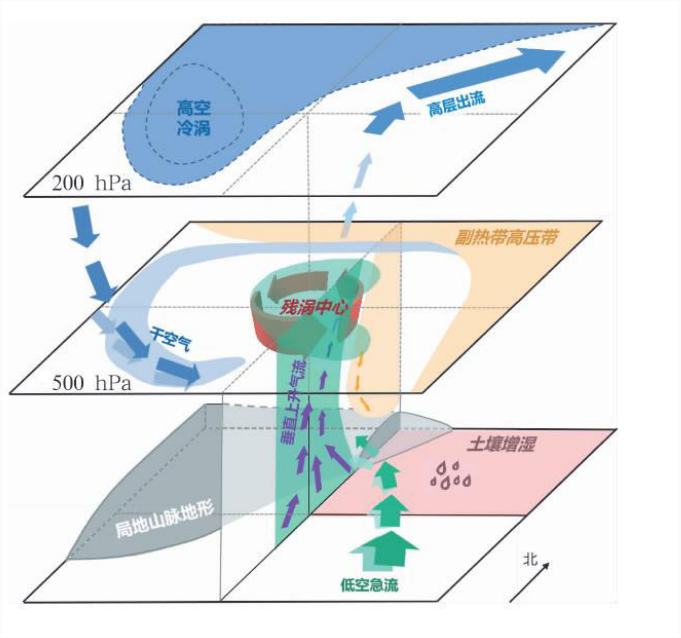
3. Impacts of Underlying Surface:

•**Windward slopes** of coasts and mountains enhance convergence and convection, potentially causing re-intensification(Gao et al., 2024).

•**Inland-saturated soil** and **large water bodies** (e.g., lakes, reservoirs) can act as latent heat sources, leading to maintenance or strengthening (Chen Lianshou et al., 2004; Wei et al., 2013; Xiang et al., 2024).



(Gao et al., 2024)



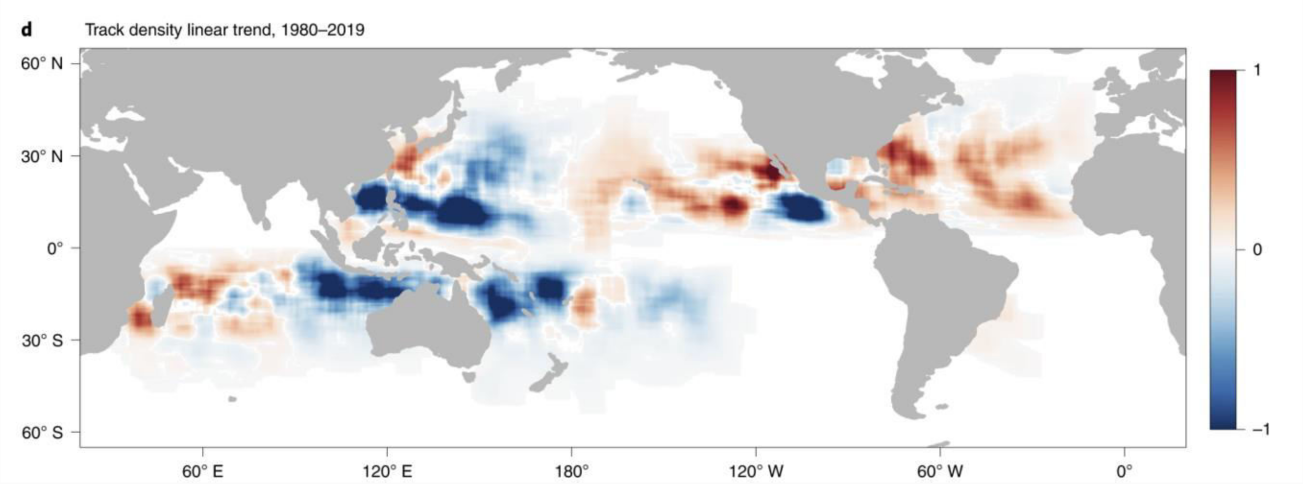
(Xiang et al., 2024)

Background

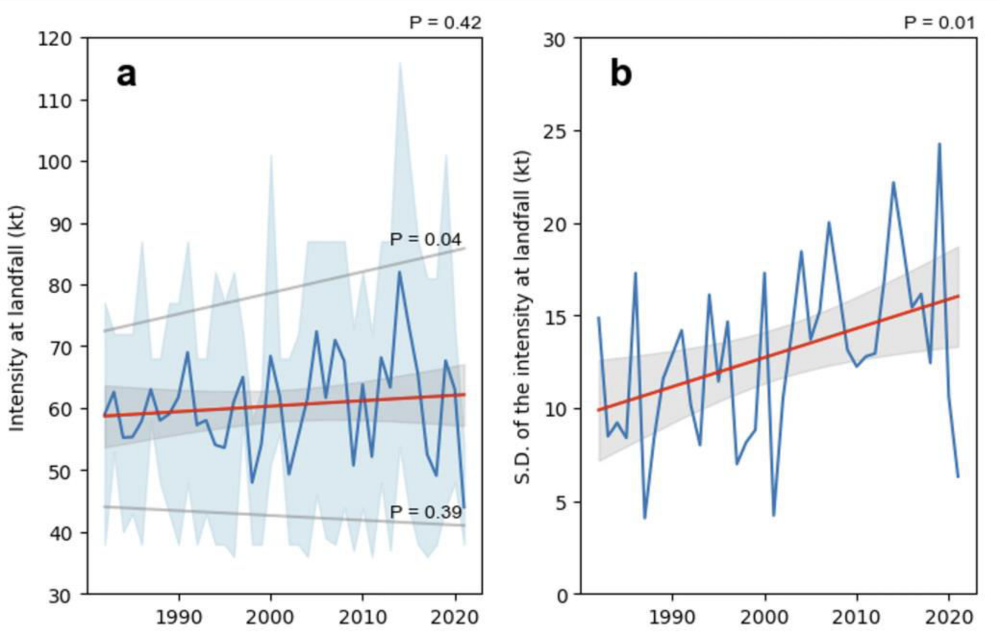
4. Observed Trends in a Warming Climate

•Under global warming, the likelihood of extreme rainfall from typhoon remnant vortices has increased in recent decades.(Chavas and Chen, 2020; Chan et al., 2022)

•A clear trend is emerging: there are **more northward-moving typhoons**, covering longer overland distances. Consequently, the average landfall intensity of typhoons has increased significantly. (Studholme et al., 2022; Tu et al. 2025)



(Studholme et al., 2022)



(Tu et al. 2025)

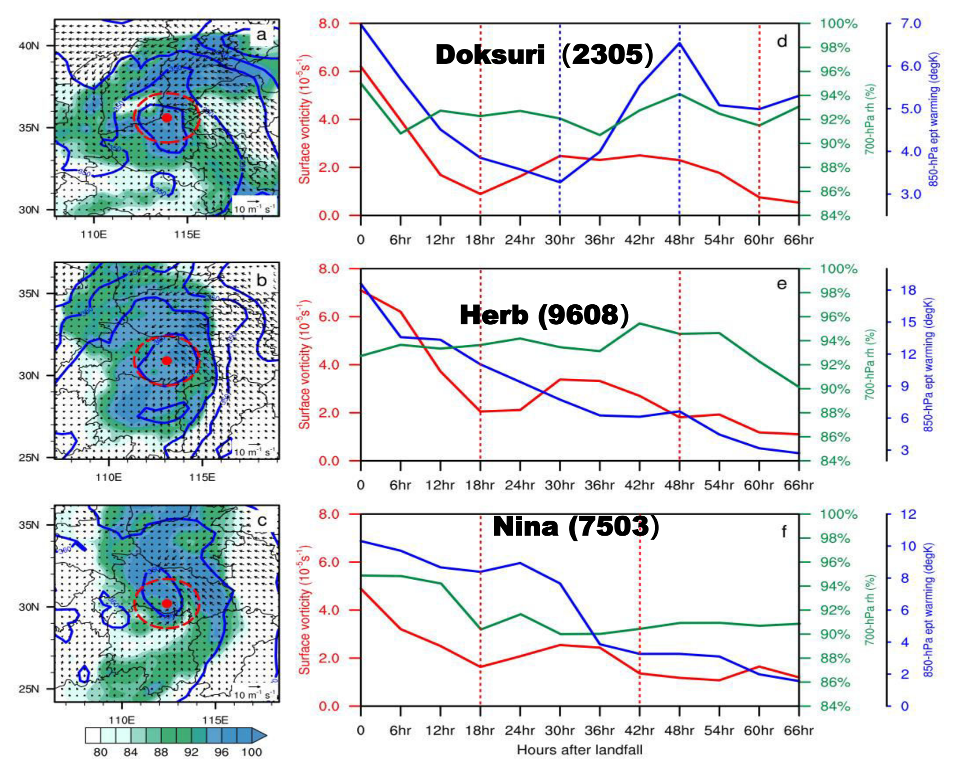
Three criteria are used to identify the core characteristics of tropical-cyclone remnants:

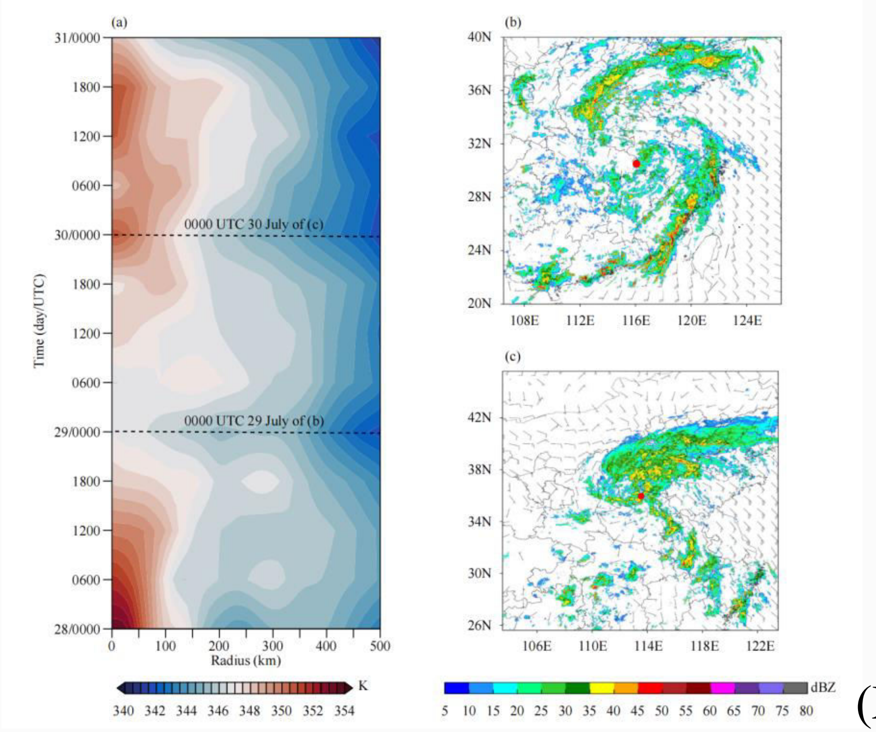
(1) surface wind-field circulation; (2) relative humidity within a specified radius of the remnant center;

(3) temperature anomaly relative to the surrounding environment within the same radius.

Table 1. Basic information on three TCs with long-lasting remnants activities after landfall

TC name	Landfall date, location, and intensity (Beaufort wind scale)	Life span after landfall (h)	Duration of TD over land (h)	Distance over land (km)
Nina	4 August 1975, Jinjiang of Fujian, TY (12)	96	84	1678
Herb	1 August 1996, Fuqing of Fujian, TY (12)	66	36	1186
Doksuri	28 July 2023, Jinjiang of Fujian, STY (14)	70	48	1635





(Xiang et al., 2024)

- **Topographic lifting** on the northern flankdrives enhanced diabatic heating through forced ascent.
- **Warm, humid surface conditions** persist, while a cold pool develops over the western mountains, boosted local latent-heat flux.

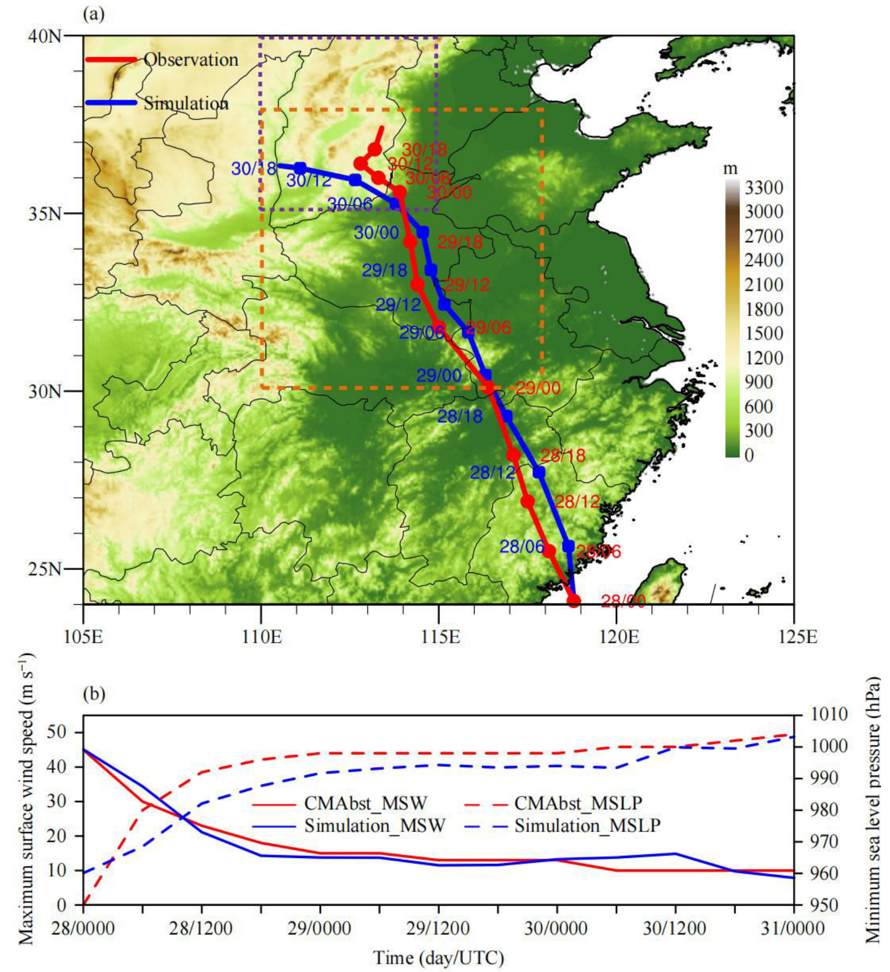


Table 2. Information on numerical experiments and related settings

Numerical experiment (abbreviation)	Experiment setting
Control run (Control)	Initial topography, initial latent heating/evaporation
No Taihang Mountains (No_topo)	Topography = 0 in the purple box (35°–40°N, 110°–115°E)
No evaporation from surface (No_evap)	Evaporation = 0 in the orange box (30°–38°N, 110°–118°E)
Double Taihang Mountains (Double_topo)	Topography = 2 times the initial topography in purple box
Double evaporation from surface (Double_evap)	Evaporation = 2 times the initial evaporation in orange box

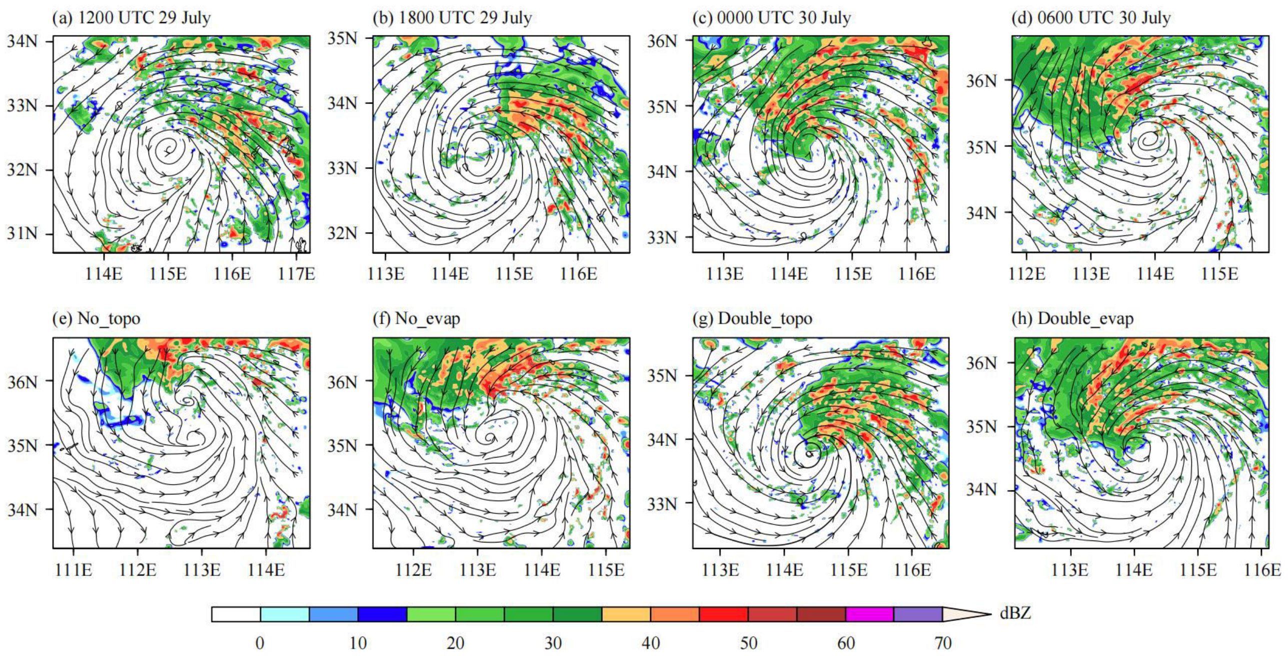
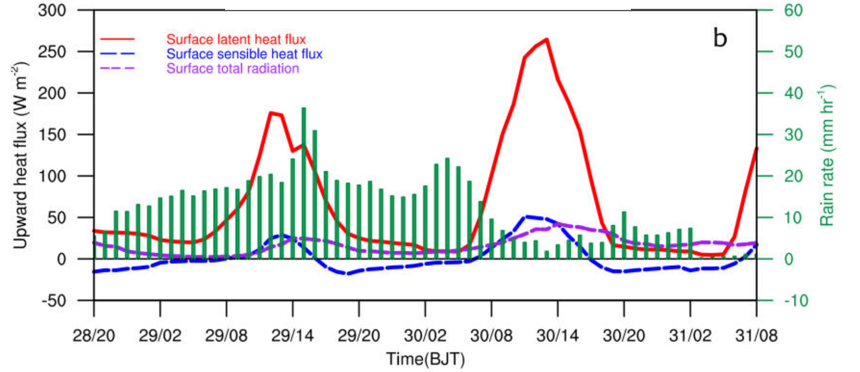


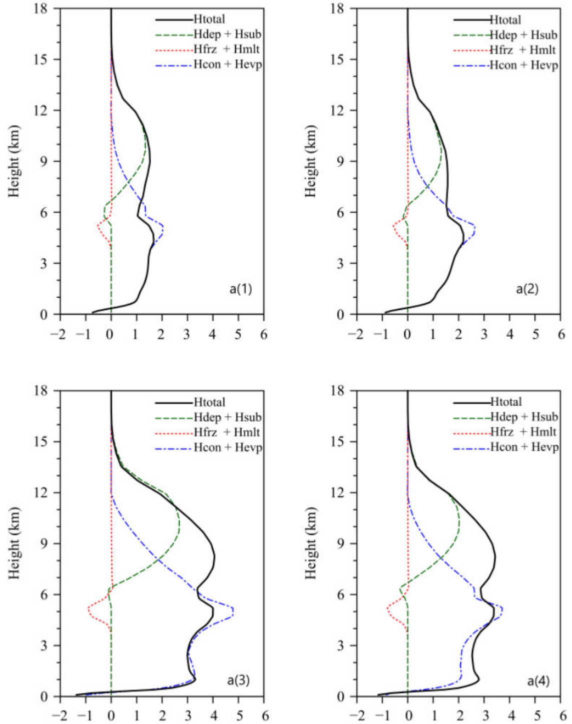
Fig. 10. Simulated composite radar reflectivity (shading; dBZ) and horizontal winds (streamlines; indicating directions) at the height of 2 km valid at (a) 1200 UTC 29 July, (b) 1800 UTC 29 July, (c) 0000 UTC 30 July, and (d) 0600 UTC 30 July, for (a–d) the control run and at 0000 UTC 30 July for (e) No_topo, (f) No_evap, (g) Double_topo, and (h) Double_evap runs.

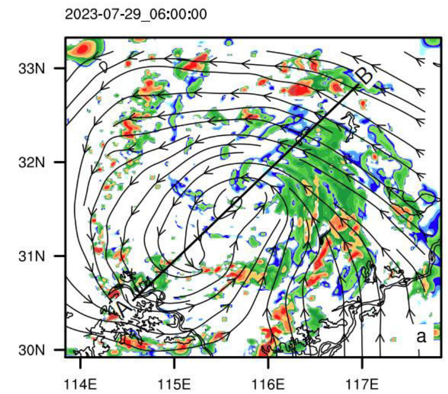
- Possible causes of the residual vortex revival: **nearly saturated warm-moist air** was lifted and condensed, releasing **abundant latent heat .**
- Land–atmosphere interactions underlying these revival mechanisms remain to be fully resolved.

$$Q = H_L + H_s + H_r$$



$$H_{total} = H_{con} + H_{epv} + H_{frz} + H_{mlt} + H_{dep} + H_{sub}$$





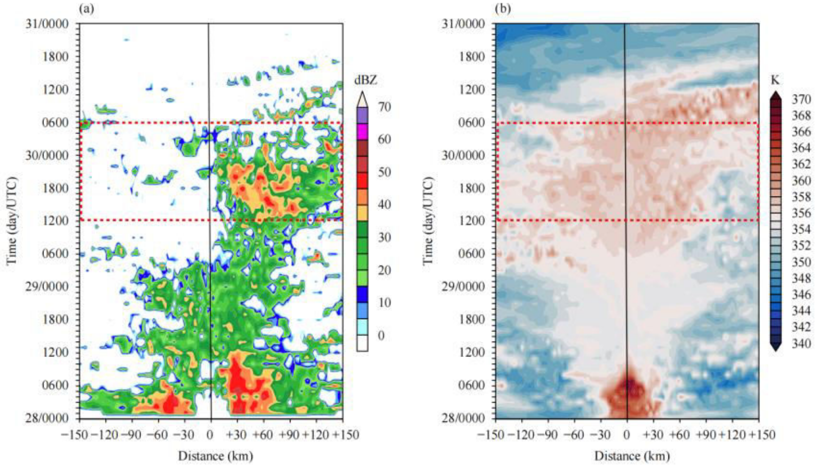
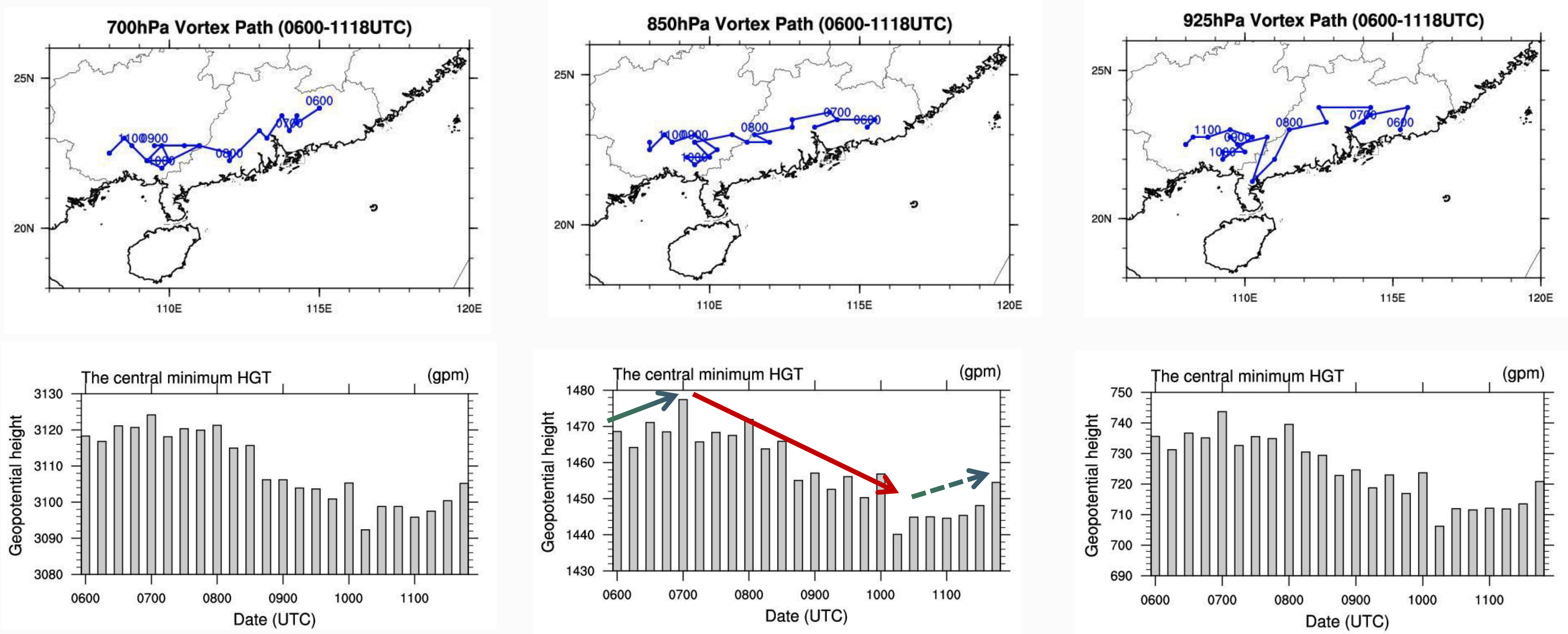


Fig. 9. Hovmöller diagram of (a) simulated composite radar reflectivity (shadings; dBZ) at the height of 2 km and (b) equivalent potential temperature (shading; K) at 850 hPa within 150 km along northeast to southwest of the center of TC remnants. The dashed red box denotes the period of remnants revival. The *y*-axis is the time (day/UTC) in and *x*-axis is the relative distance (km, with −/+ denoting left/right side) to the center.

ig.10. Vertical profile of simulated latent heating rate (a1-a4 are 2906UTC, 2912UTC,3000UTC and 3006UTC respectively, nit: K/hr) , time evolution of surface heat flux (lines, unit:Wm²)

Remnant Vortex Identification:

Utilize multi-source data including radar echoes and surface stations for operational monitoring.

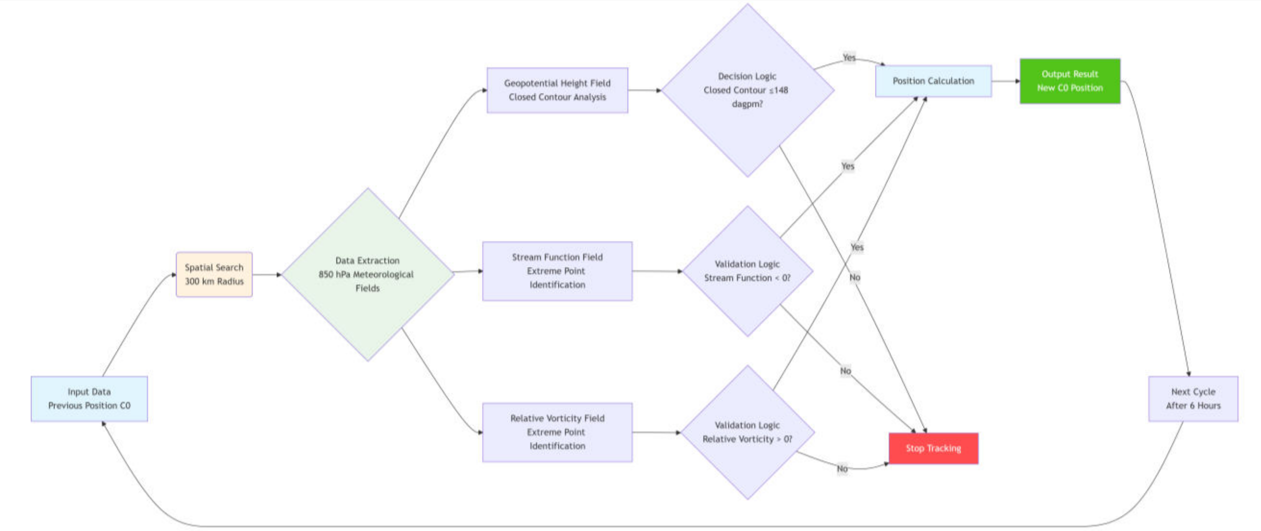


Objective Indentification for Residual Vortex of a Post-landfall Tropical Cyclone

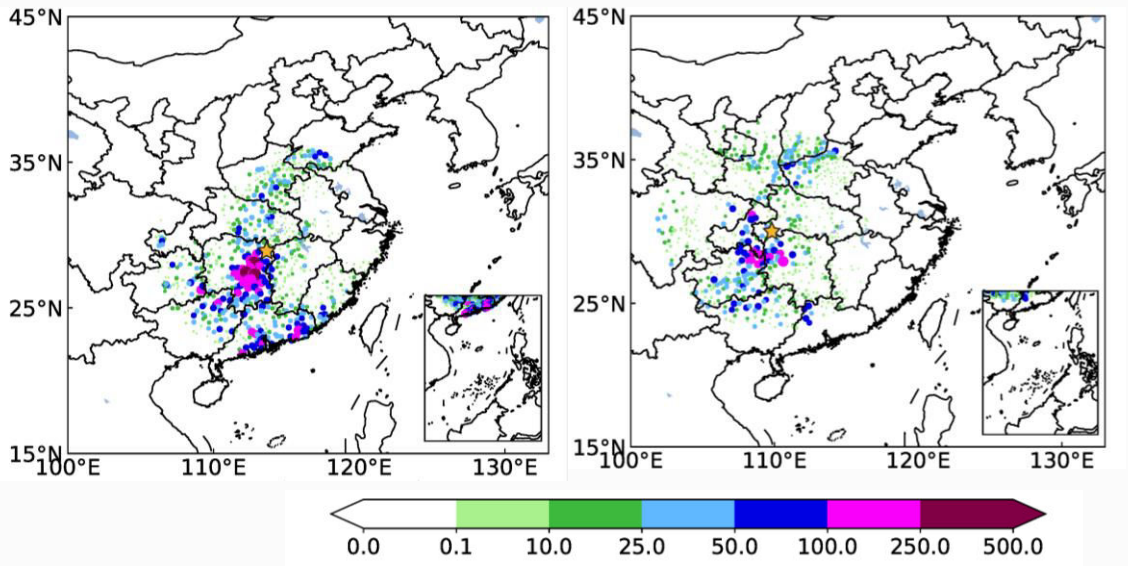
Initial Condition (C1): Start from the previous TC center or remnant position (C0) 6 hrs ago.
Closed Contour Check(C2): At the 850 hPa level, there must exist closed contours of 148 dagpm or below, and the center of low geopotential height of these closed contours must be within 300 km of C0.
Remnant Vortex Position Update(C3): If c2 is satisfied, within a circular region of radius 300 km centered at C0, calculate the positions of extreme points for three fields at 850 hPa:

- Extreme point of stream function (should be negative, indicating cyclonic vortex).
- Extreme point of relative vorticity (should be positive, indicating cyclonic vortex).
- Extreme point of geopotential height (should be the minimum point, indicating low center).

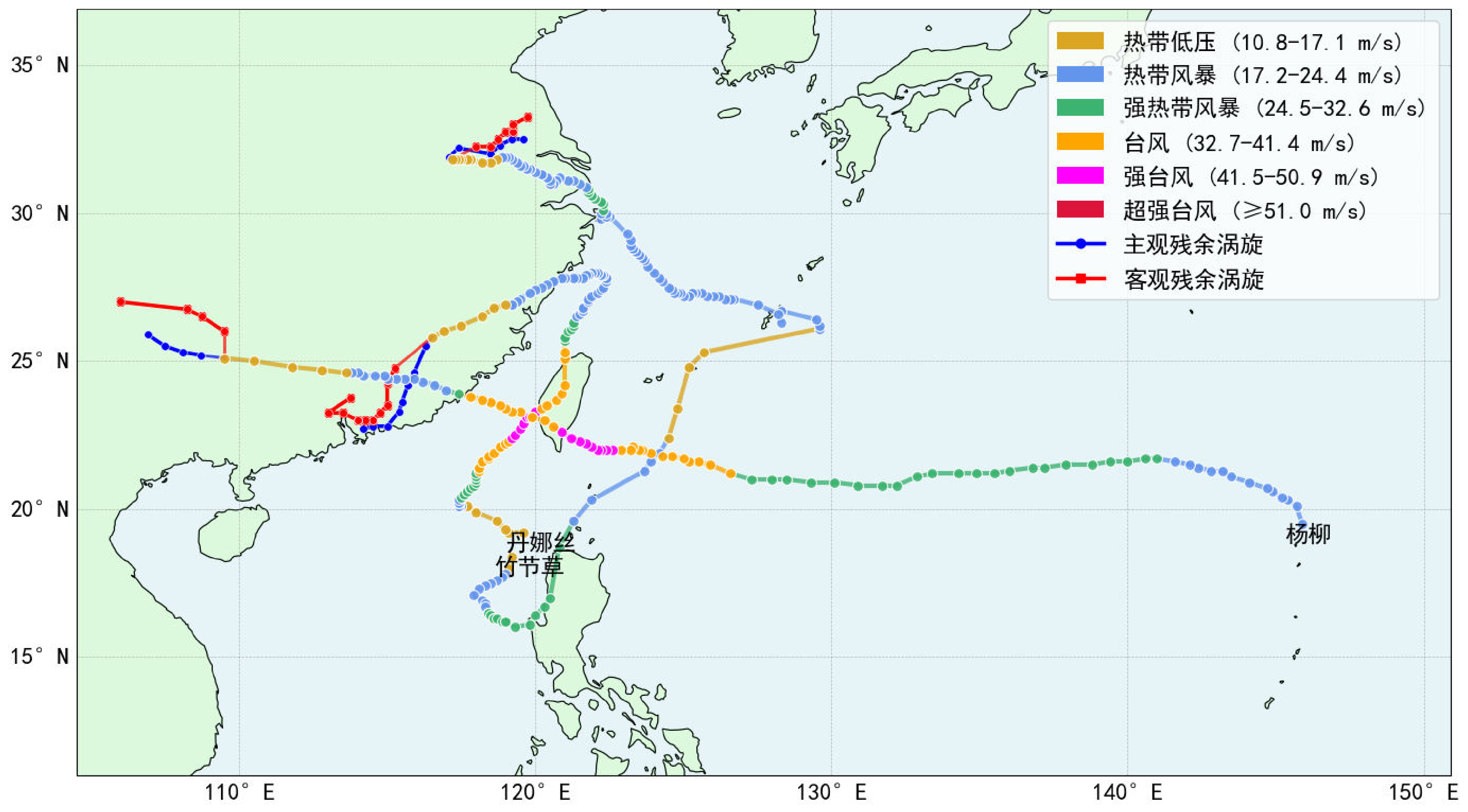
Average these three extreme points as the new C0 and continue tracking.
Termination Conditions: Tracking stops if any of the C3 conditions are satisfied.



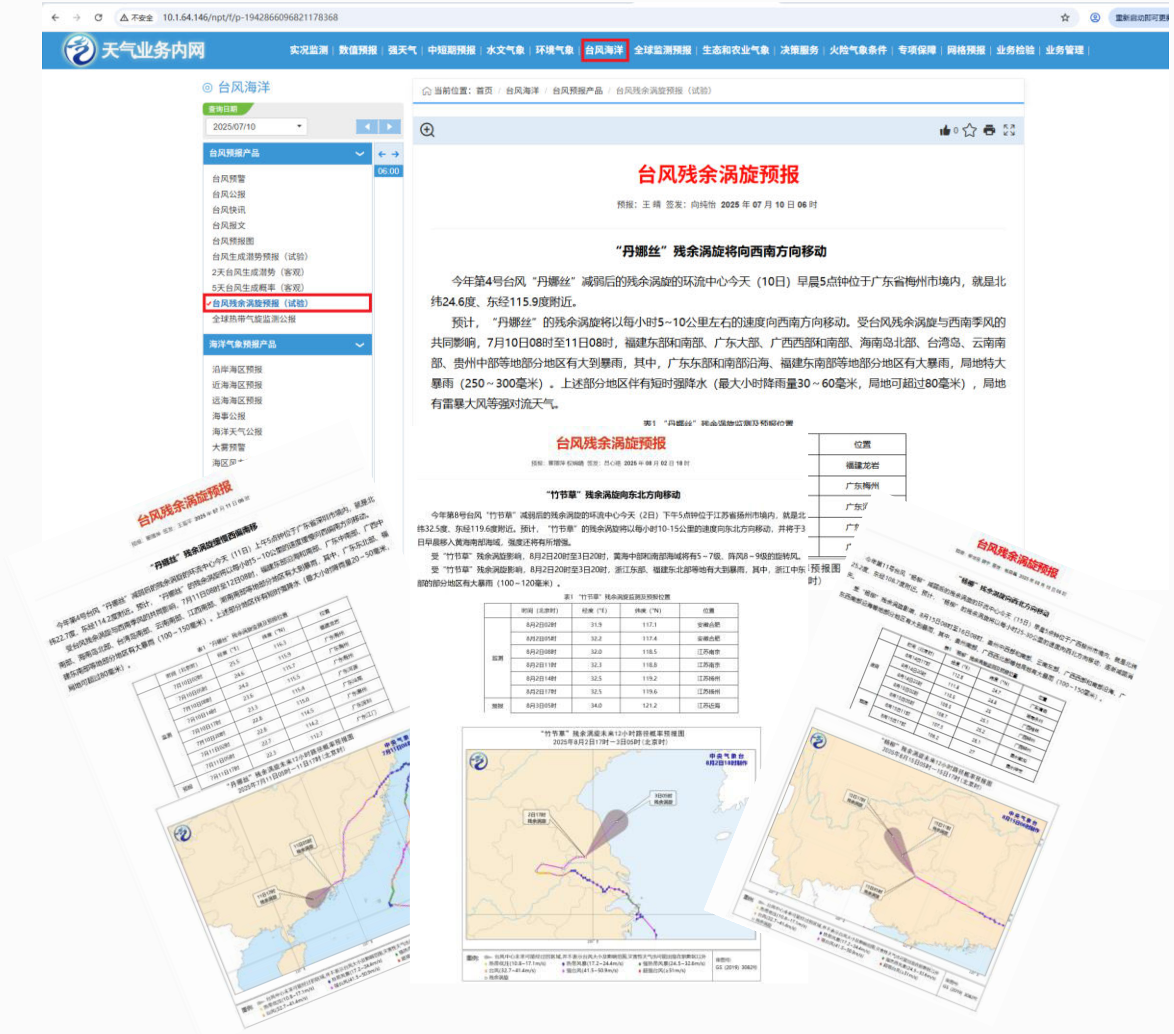
Schematic Diagram



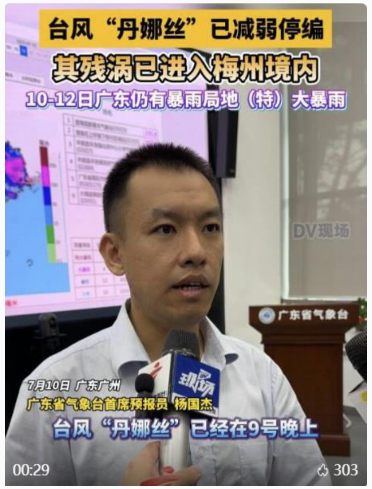
Objective identification of TC post-landfall remnant vortices in 2025 (experimental)



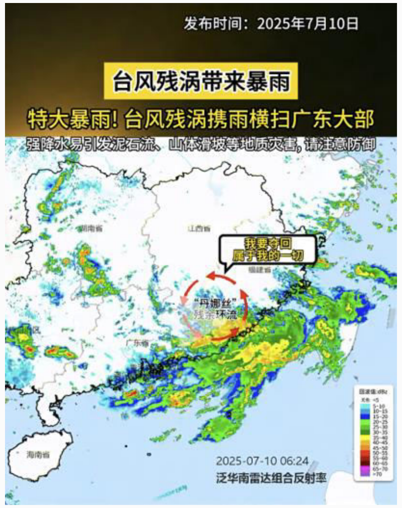
When the remnant vortex circulation of a Post-landfall TC continues to exist and exert impacts after landfall, an experimental forecasting for the typhoon's residual vortex will be issued to assist local governments in understanding the persistent effects of the typhoon.



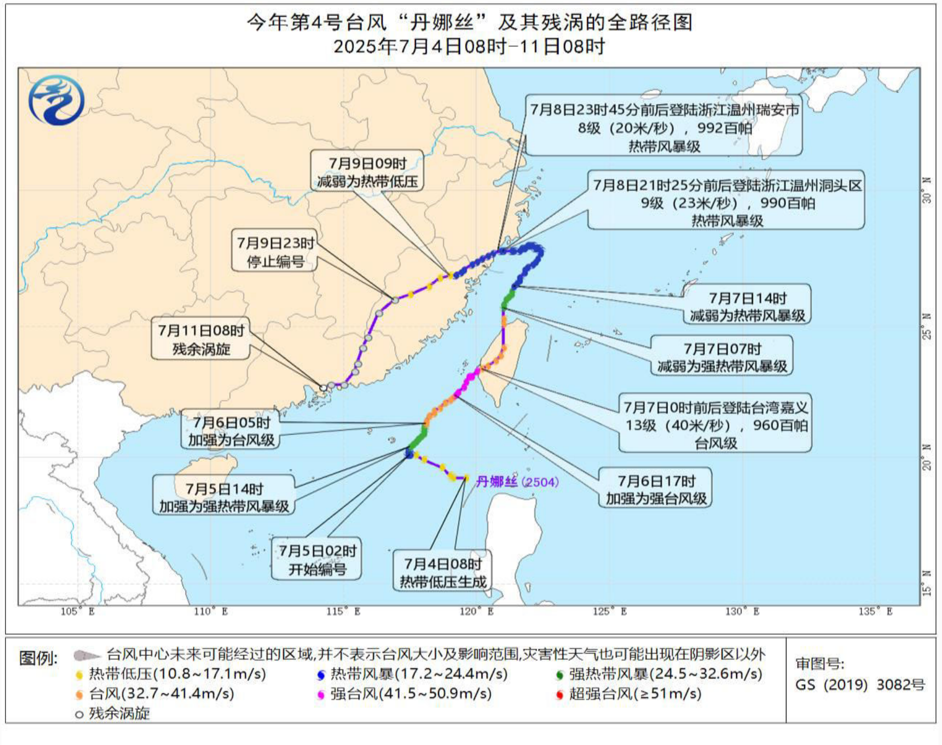
首席说天气丨台风"丹娜丝"残涡南移 广...

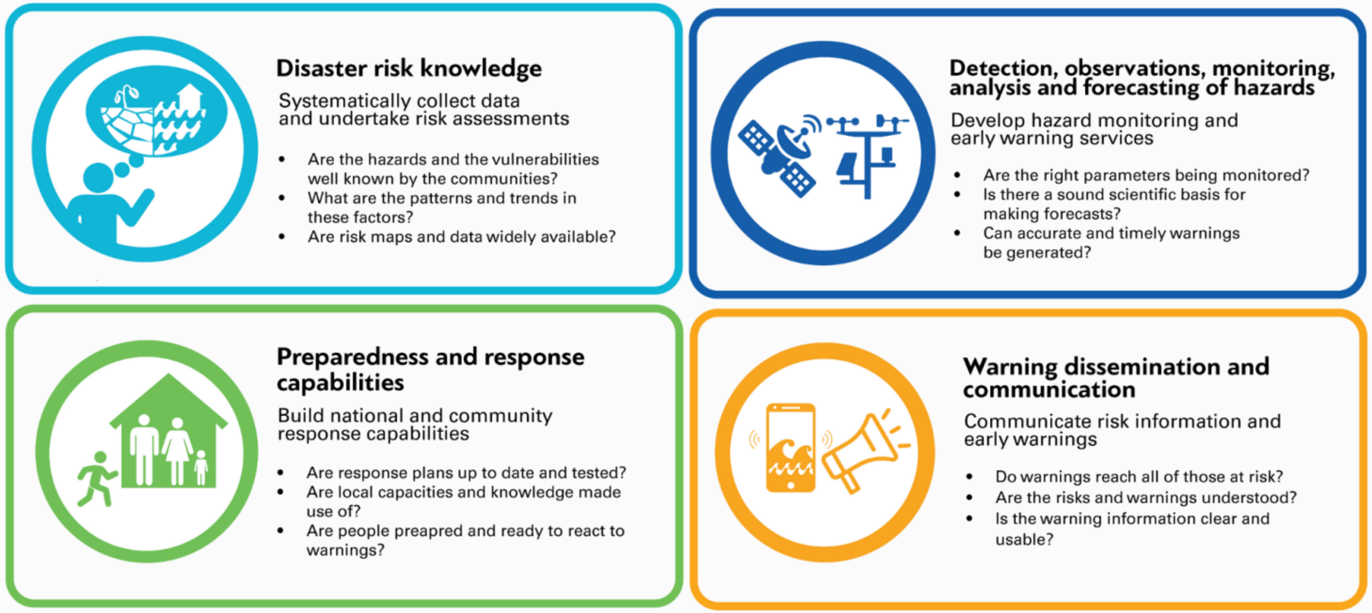


..."台风"竹节草"再度加强，残涡将影响...



Ultimately, enhancing our prediction of these **post-landfall TC remnant** is key to building resilience against the entire lifecycle of a tropical cyclone.





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Thank you!

XIANG Chunyi(xiangcy@cma.gov.cn)

Typhoon and Marine Meteorological Center,

National Meteorological Center,

China Meteorological Administration.