Accompanied Circulation Structure Analysis

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Introduction

In autumn, typhoons approaching Taiwan often exhibit an accompanied effect with the northeasterly monsoon, leading to prolonged heavy rainfall in the northeastern or eastern regions of Taiwan. Previous studies typically focused on data until 2011. Therefore, this study will focus on typhoon cases in the autumn seasons from 2000 to 2022. We will filter and identify typhoons that have actually demonstrated an accompanying effect. Synthetic analysis will be employed to discern the characteristics and accompanying hotspots of this effect.

Data & Method

- Data sourced from:

Database	Parameters
ECMWF ERA5	Convergence field Equivalent potential temperature
CWB Typhoon Database	Typhoon basic data
CWB CODiS	Station data
PCCU DBAR	Historical weather maps
NII Digital Typhoon	Typhoon position data

- First locate the area out northeast Taiwan where the mixing ratio and temperature gradients are highest. This area mark the frontal boundary between two air mass. Then, check the distribution and find value of equivalent potential temperature.

Case analysis

1. Typhoons generated and passing through the region between 16° to 26°N and 118° to 124°E (李等,2007) during September to December from 2000 to 2022.
2. 24-hour accumulated rainfall of Zhuzihu , Yilan, or Hualien is over 130 mm.
3. The track was similar to path 5 or path 6.

25 cases

The next step of screening is based on
1. the distribution of 925 hPa equivalent potential temperature,
2. 925 hPa convergence field,
3. the timing of rainfall diagram

A total of 7 cases:
2000 Xangsane   2017 Khanun
2009 Parma   2022 Nesat
2010 Megi   2022 Nalgae
2011 Nalgae

Fig 1. The selection criteria of autumn typhoon

- Among the 7 cases, taking Megi as an example, its period of accompanying lasted from October 20th, 15UTC to October 21st, 15UTC.
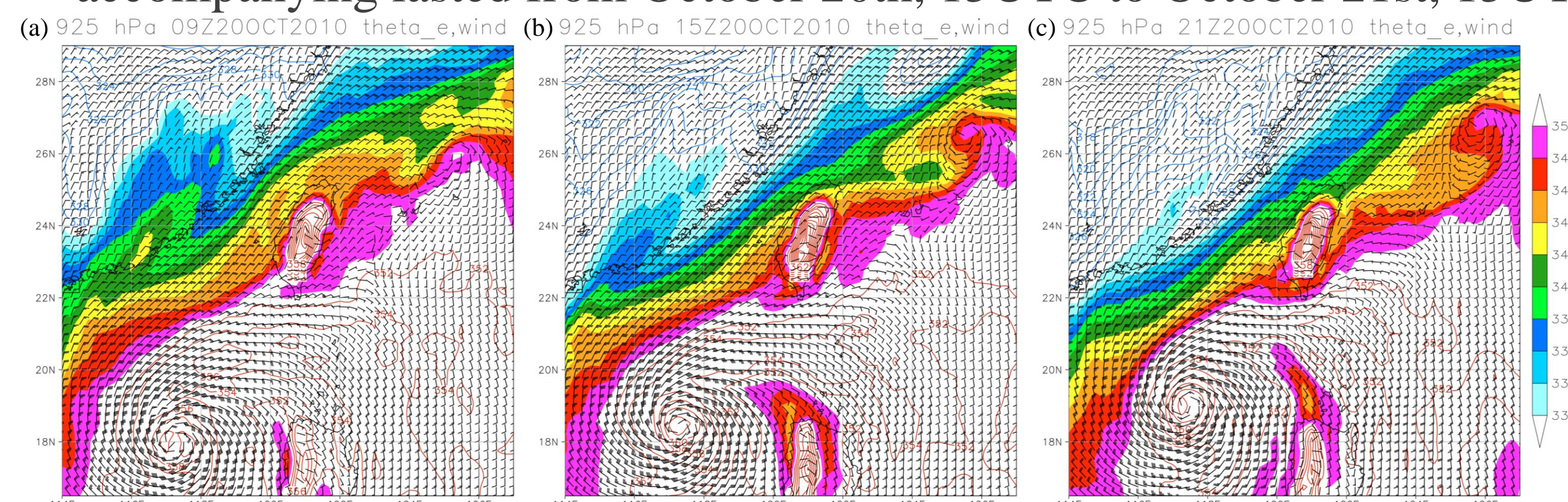

Fig 2. The 925 hPa equivalent potential temperature analysis chart for Typhoon Megi in 2010. (a)102009Z (b)102015Z (c)102021Z
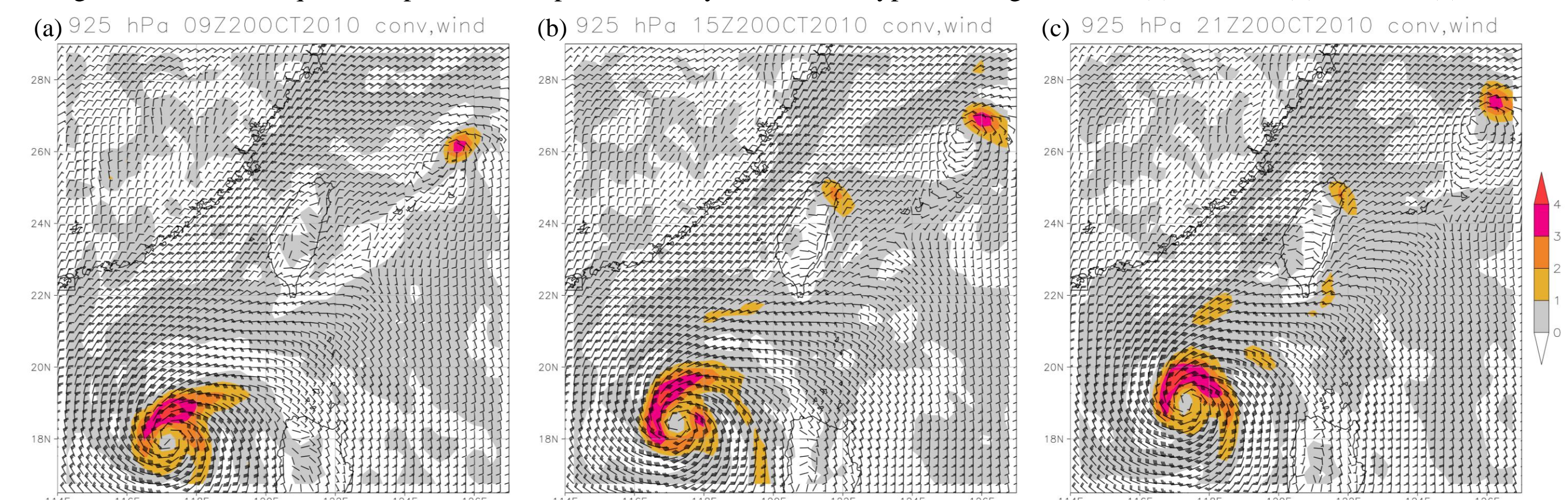

Fig 3. 925 hPa convergence field analysis chart of Typhoon Megi in 2010. (a)102009Z (b)102015Z (c)102021Z
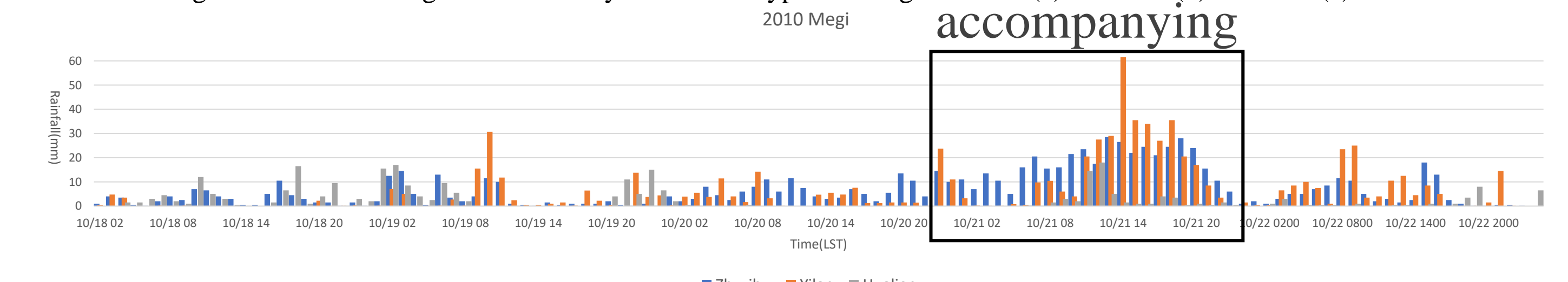

Fig 4. The timing of rainfall diagram of Typhoon Megi in 2010.

- When the accompanying effect began, the boundary zone reached over Yilan, and continuous rainfall commenced. The accompanied rainfall ceased as the boundary zone moved away.
- Among the 7 cases, they can be further classified into 3 types:
  1. The boundary zone over Yilan starts to move either southward or northward.
  2. It begins with accompanying from over Hualien, then moves northward to the Yilan area before shifting southward again.
  3. The boundary zone occurs off the southeastern coast of Taiwan, yet the accompanying effect has already taken place.
- To avoid noise or signal interference, the synthesis analysis will focus on the first type, involving Parma, Megi, Khanun, and Nesat.

Synthetic analysis

- The boundary zone lingered in northern Taiwan before the onset of the accompanied effect.
- As the accompanied effect began, the 344K line representing the boundary moved southward and halted over Yilan.
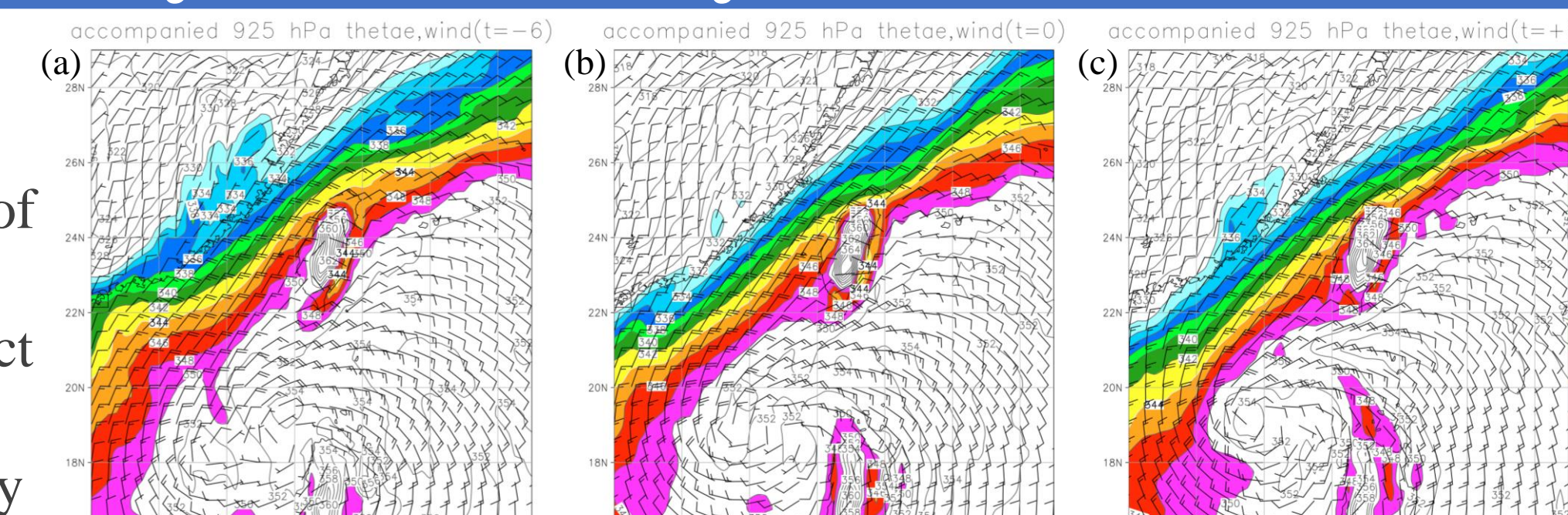

Fig 5. The Synthetic Chart of Equivalent Potential Temperature at 925 hPa for the First Type of Accompanying Typhoons. At (b) the start of accompanying effect, denoted as t=0, (a) occurred 6 hours prior (t=-6), and (c) occurred 6 hours later (t=+6).

- Winds were uniform before the accompanied effect, and its speed were 10-12m/s near Yilan. While accompanying, a strong wind axis formed and parallel to the boundary zone. Yilan's coastal winds peaked at 20-22m/s, adding to the dynamic instability.

Fig 6. The Synthetic Chart of wind field at 925 hPa for the First Type of Accompanying Typhoons. (a)t=-6 (b)t=0 (c)t=+6

- The south features the typhoon's equivalent barotropic system, while the north is dominated by the northeast monsoon's baroclinic system. These two systems intersect at approximately 25 °N.
- As the cold high-pressure system gradually moves southward, the temperature distribution shifts from being uniform to baroclinic. The thickness of air masses also decreases as they move towards lower latitudes.
- The cold and dry tongue descends southward, the upper atmosphere is invaded by the southern winds of the typhoon above 850 hPa, and its uplift along cold air favorable for convection, also enhancing atmospheric instability.
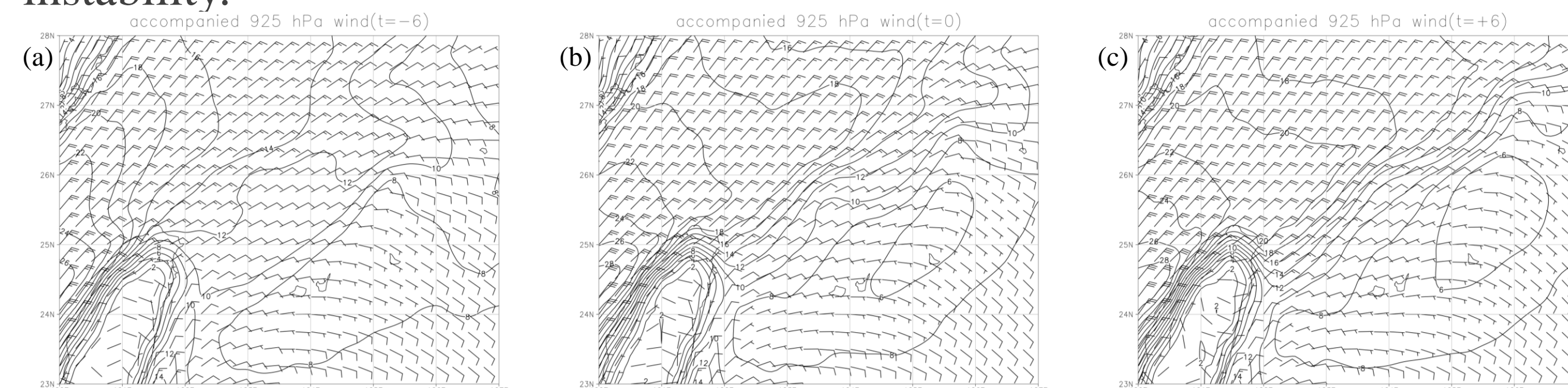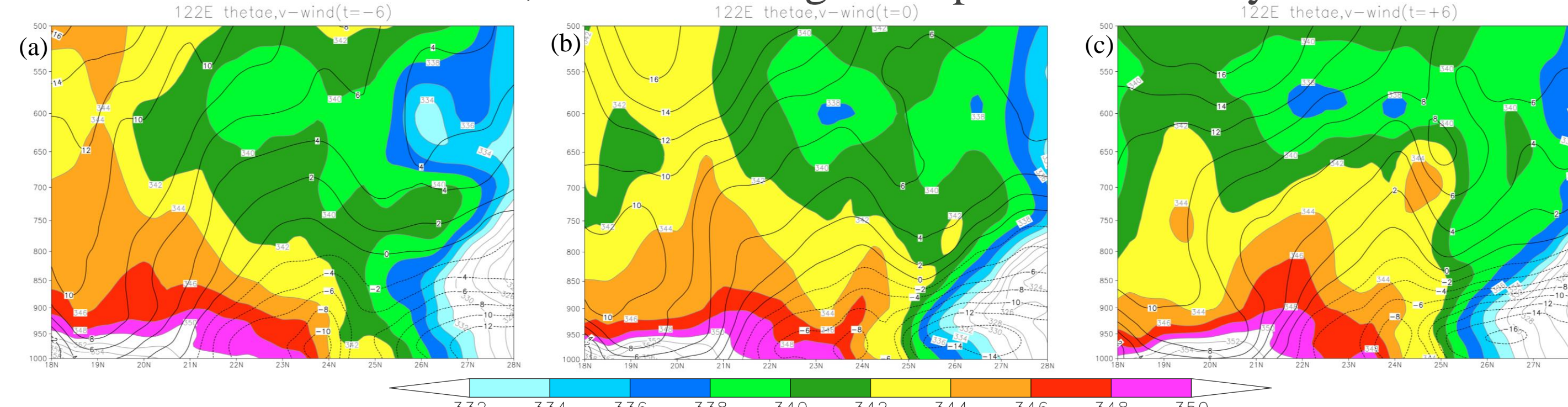

Fig 7. The Synthetic Chart of Equivalent Potential Temperature at 122°E for the First Type of Accompanying Typhoons. (a)t=-6 (b)t=0 (c)t=+6

- The boundary zones in the first two categories show significant variations in the southwestern sea area due to the influence of typhoon positions and paths. In contrast, the northeastern sea area exhibits a similar pattern.
- The accompanying positions of the seven cases are summarized, with typhoons mostly experiencing accompanying effects after passing through Luzon Island.
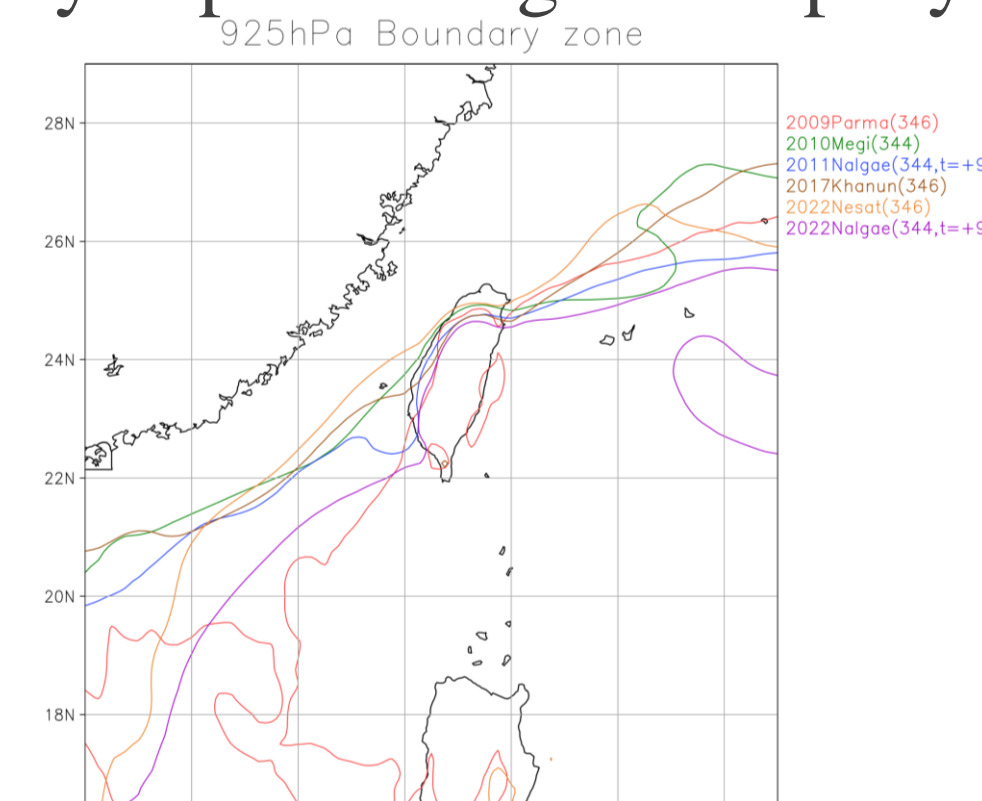

Fig 8. The distribution of the 925 hPa boundary for the first two types. The first type marks the beginning of the accompanied effect; the second type indicates the boundary when it is closest to Yilan.
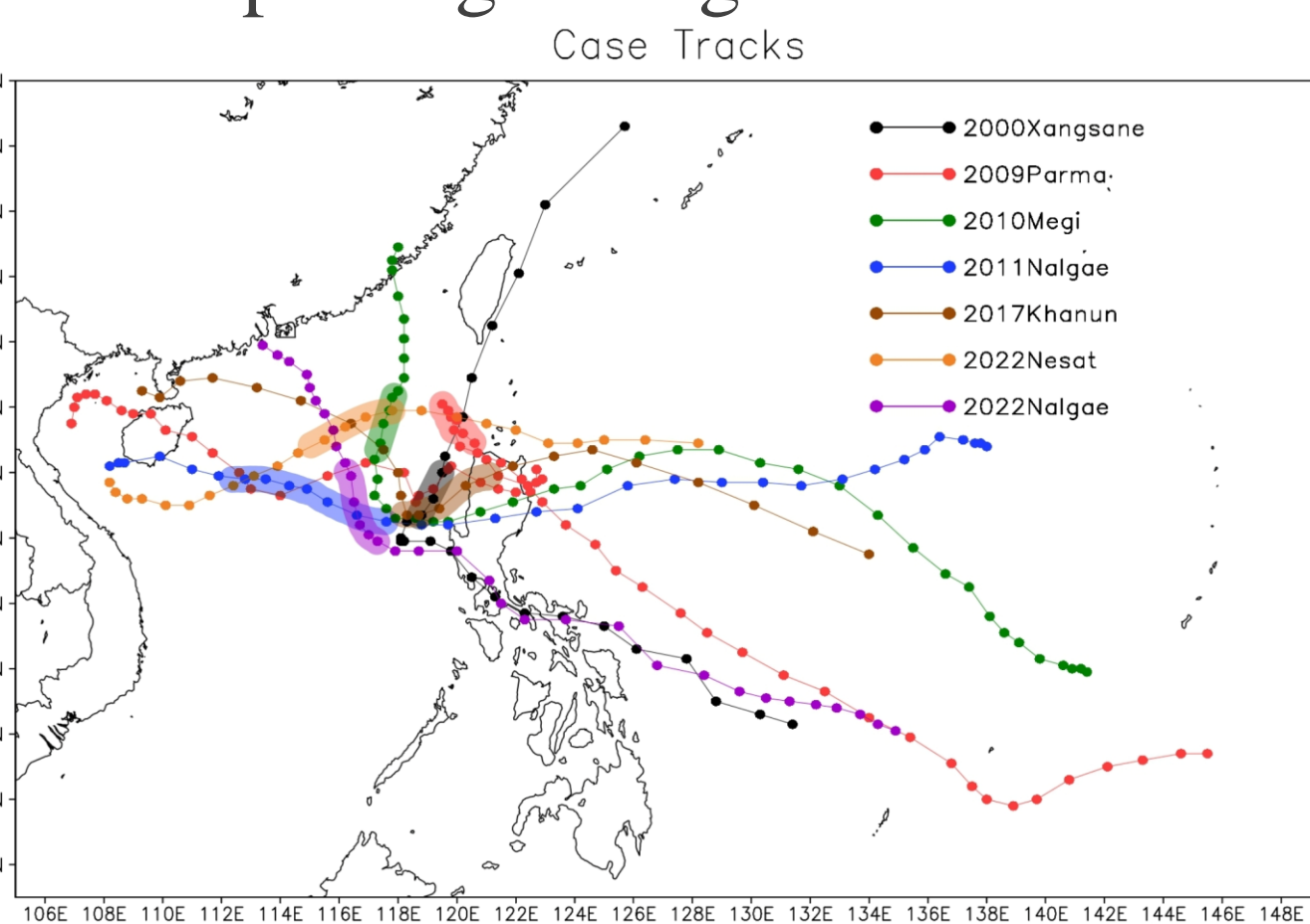

Fig 9. The tracks and accompanying positions of all cases.

Conclusion

1. During accompanying, the boundary typically appears in the area around Yilan or Hualien, exhibiting a northeast-southwest orientation, with a strong wind axis.
2. The temperature of this air boundary ranges from about 21 to 22°C, with a mixing ratio between 16 to 18g/kg. The corresponding equivalent potential temperature ranges from 342 to 346K.
3. Vertical profiles indicate that during accompanying periods, a cold tongue descends in the lower levels, while warm air rises along the cold high-pressure system, facilitating convective development.
4. After 2000, accompanied effect tend to happen within the region of 15.5°N to 20.5 °N, and 112.0 °E to 121.5 °E.

Reference

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