A1-8

A Diagnostic Case Study of Mei-yu Frontal Retreat near eastern Taiwan

(臺灣東部近海梅雨鋒面北退個案之分析診斷研究)

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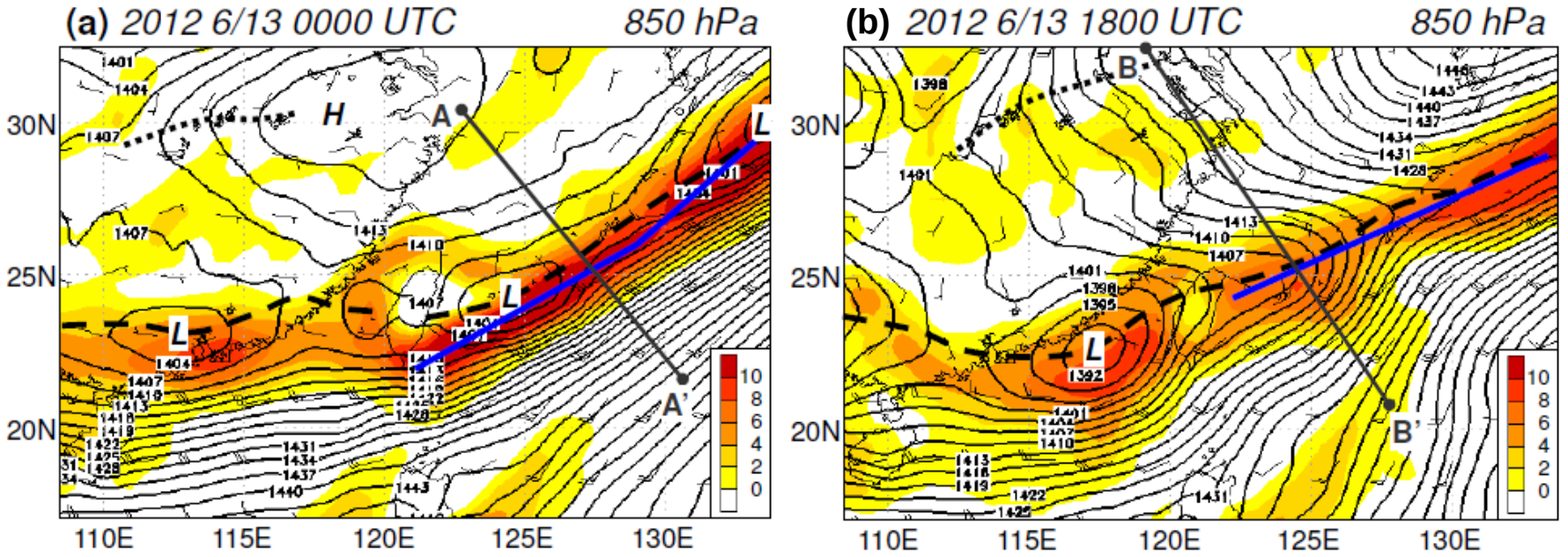
Presentation outline

- *An event of mei-yu frontal retreat east of Taiwan occurred during 13-14 June 2012 and was the most significant event in three seasons of 2012-14*
- *During the event, a meso-α-scale low also developed to the southwest of Taiwan, with organized MCSs along and south of the front*

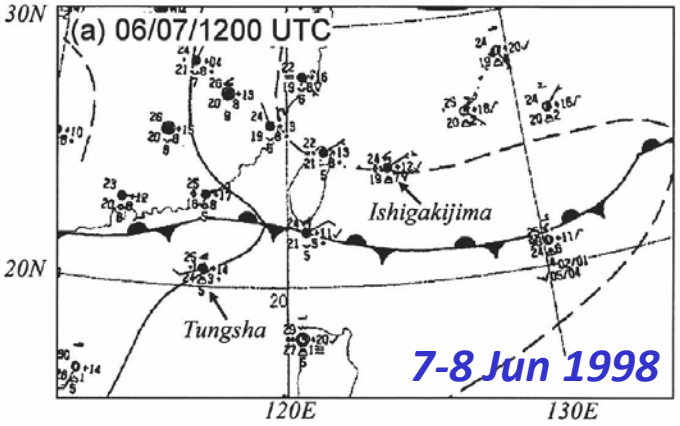


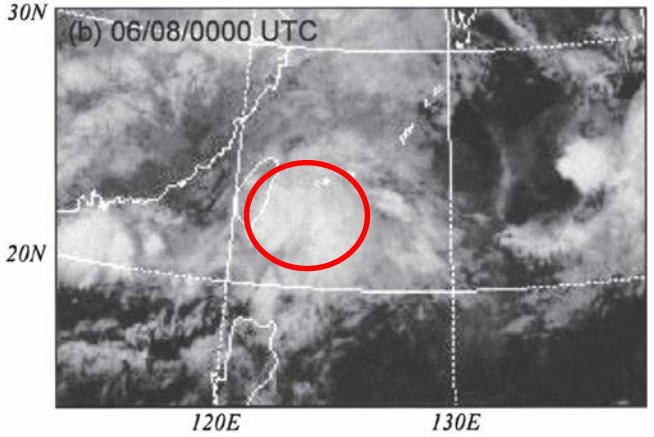
Z (gpm), u/v (m s^{-1}, full = 5 m s^{-1}), and ζ (10^{-5} s^{-1}, color) at 850 hPa

- *This case is examined and diagnosed in detail, along with the role played by the associated low development, with a focus on initial retreat*
- *Occurrence of frontal retreat in three seasons (2012-2014) is also recorded to examine the climatology and frequency of such events*

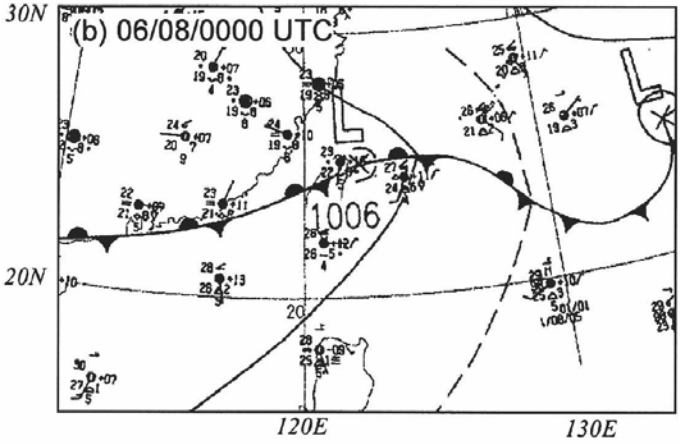
1. Introduction

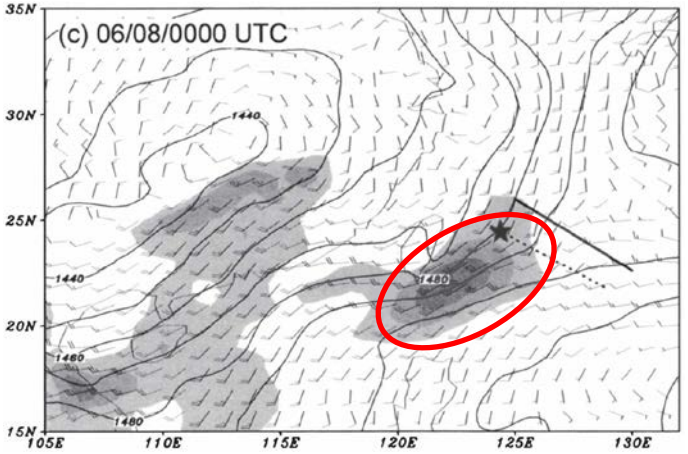
- *A mei-yu front may retreat (move northward) again after passing through Taiwan from north to south, and lead to a second period of heavy rainfall*
- *Past case studies suggest that mei-yu frontal retreat can be induced by latent heat release and strengthening of low-level jet (LLJ) near Taiwan*





Chen et al. (2006: MWR)





2. Data and Methodology

2.1 Data for Analysis and Diagnosis

- *Data: CWB weather maps, sounding/surface data, and MTSAT cloud imageries during case period*
- *ECMWF gridded analyses every 6 h, 0.5°x 0.5° for analysis and diagnosis on frontal movement, and 1.125°x 1.125° for potential vorticity (PV) inversion*

2.2 Diagnostic Methods

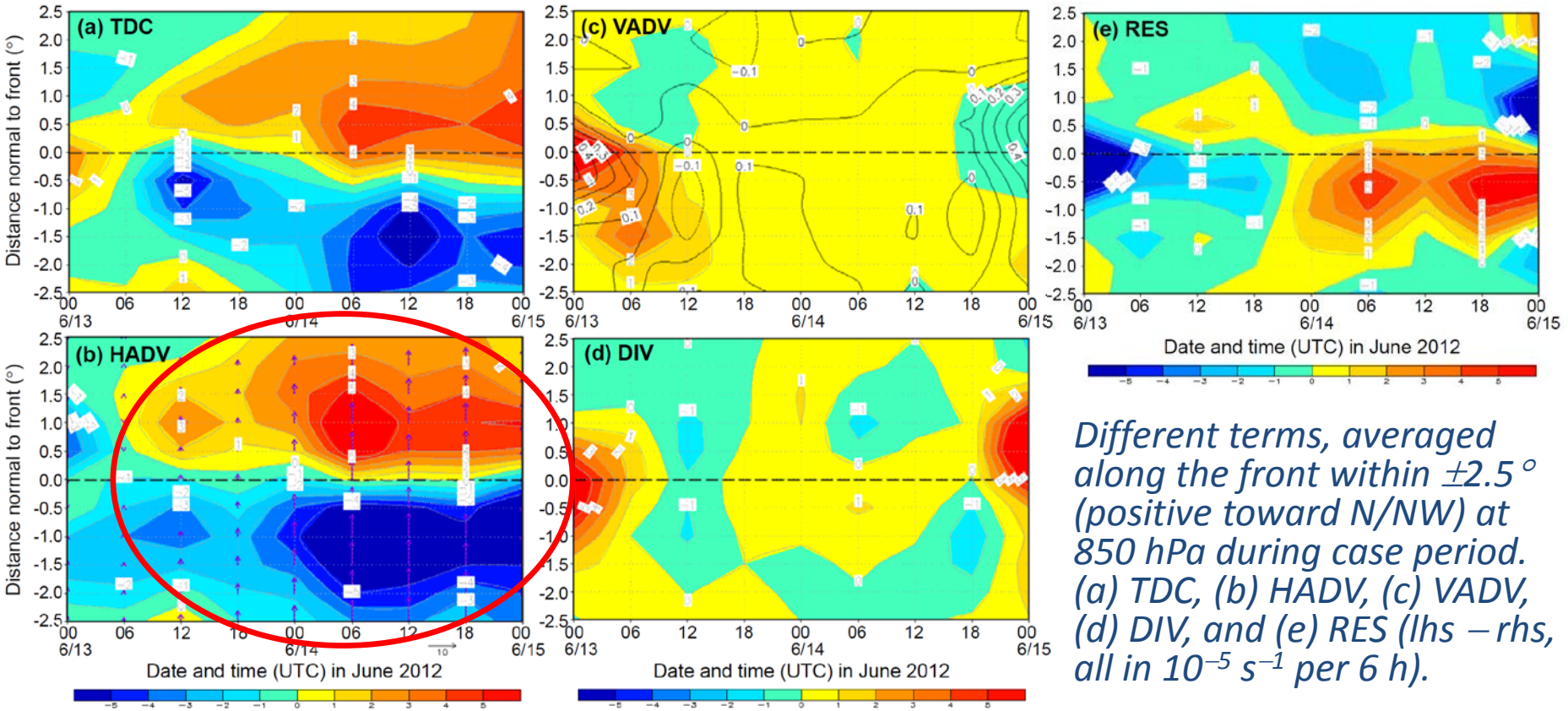
- *Diagnose frontal retreat at 850 hPa east of Taiwan using vorticity budget, local frontogenetical function (employing θ_e), and piecewise PV inversion*
  - *Data interpolated onto 0.5°x 0.5° grid on both sides along the length of front*
  - *Divide PV perturbations based on different circulation systems*
- *Diagnose the development of the low southwest of Taiwan also using piecewise PV inversion*
  - *Divide PV perturbations based on different level/moisture property*

3. Diagnosis of Frontal Retreat

3.1 Diagnosis using Vorticity Budget

$$\frac{\partial \zeta}{\partial t} = -\mathbf{v}_H \cdot \nabla_H(\zeta + f) - \omega \frac{\partial \zeta}{\partial p} - (\zeta + f)\nabla_H \cdot \mathbf{v}_H \qquad \textit{(at 850 hPa)}$$

TDC HADV VADV DIV

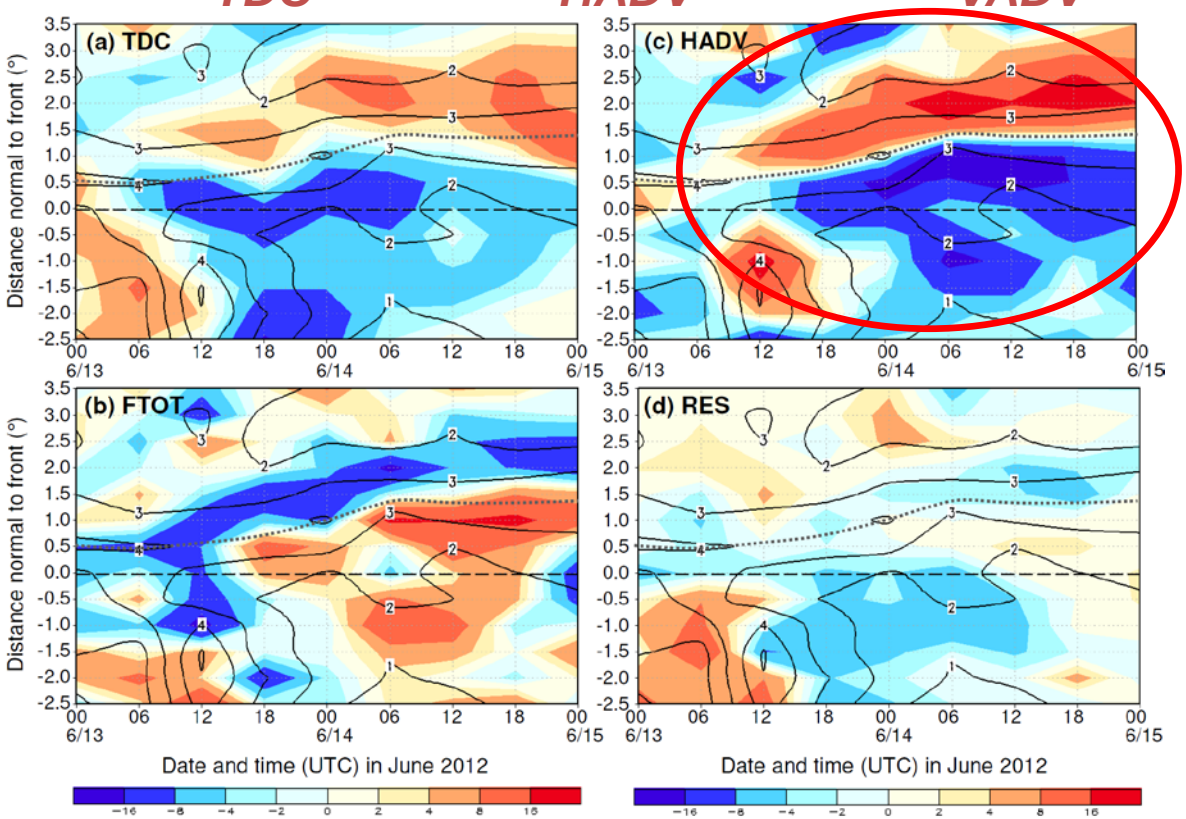


Different terms, averaged along the front within ±2.5 ° (positive toward N/NW) at 850 hPa during case period. (a) TDC, (b) HADV, (c) VADV, (d) DIV, and (e) RES (lhs – rhs, all in 10^{-5} s^{-1} per 6 h).

3.2 Diagnosis using Local Frontogenetical Function

$$\frac{\partial}{\partial t}|\nabla_H\theta_e| = -\mathbf{v}_H\cdot\nabla_H|\nabla_H\theta_e| - \omega\frac{\partial}{\partial p}|\nabla_H\theta_e| + \frac{d}{dt}|\nabla_H\theta_e| \quad \textit{(at 850 hPa)}$$

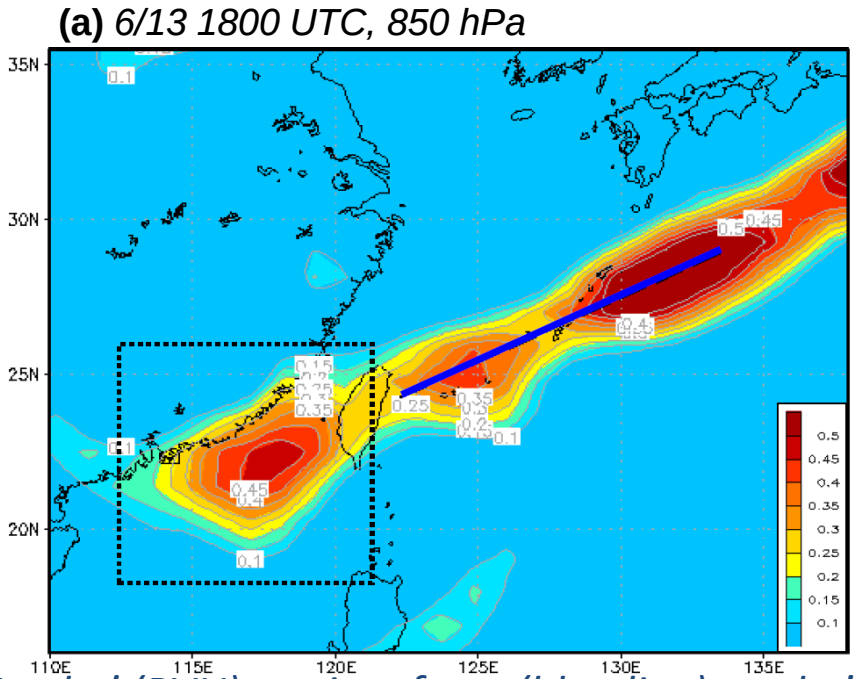
TDC HADV VADV FTOT



Different terms, averaged along the front from 2.5° south to 3.5° north at 850 hPa using (2-D) local frontogenetical function. (a) TDC (local frontogenesis), (b) FTOT (Lagrangian frontogenesis), (c) HADV, and (d) RES (lhs − rhs, all in 10^{-10} K m^{-1} s^{-1}). The gray dotted curve marks the axis of maximum (horizontal) θ_e gradient.

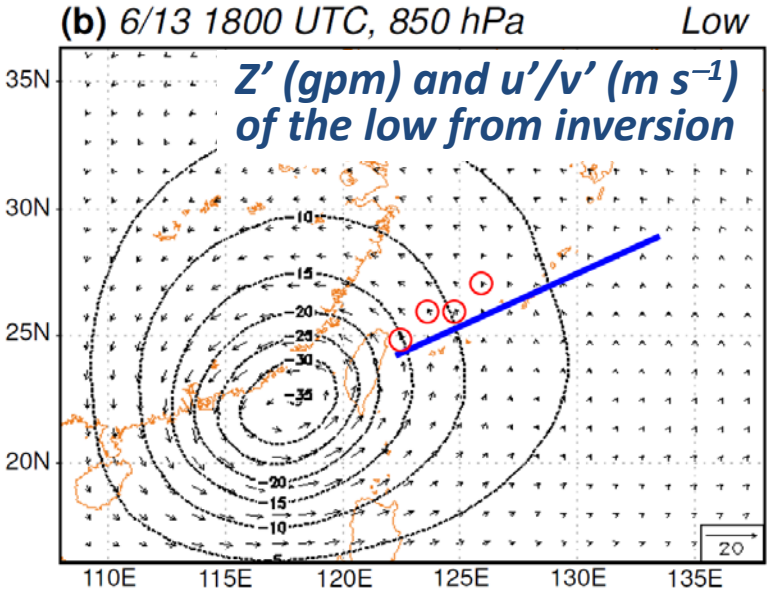
- *Both methods indicate that the appearance of southerly winds north of the front (and thus the retrogression of cold air) was the cause of the initial retreat, consistent with earlier studies.*

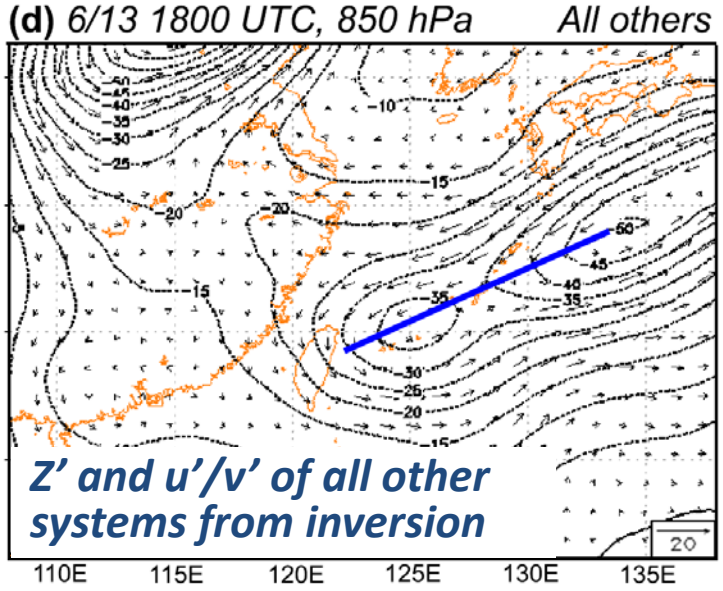
3.3 Diagnosis using Piecewise Potential Vorticity Inversion



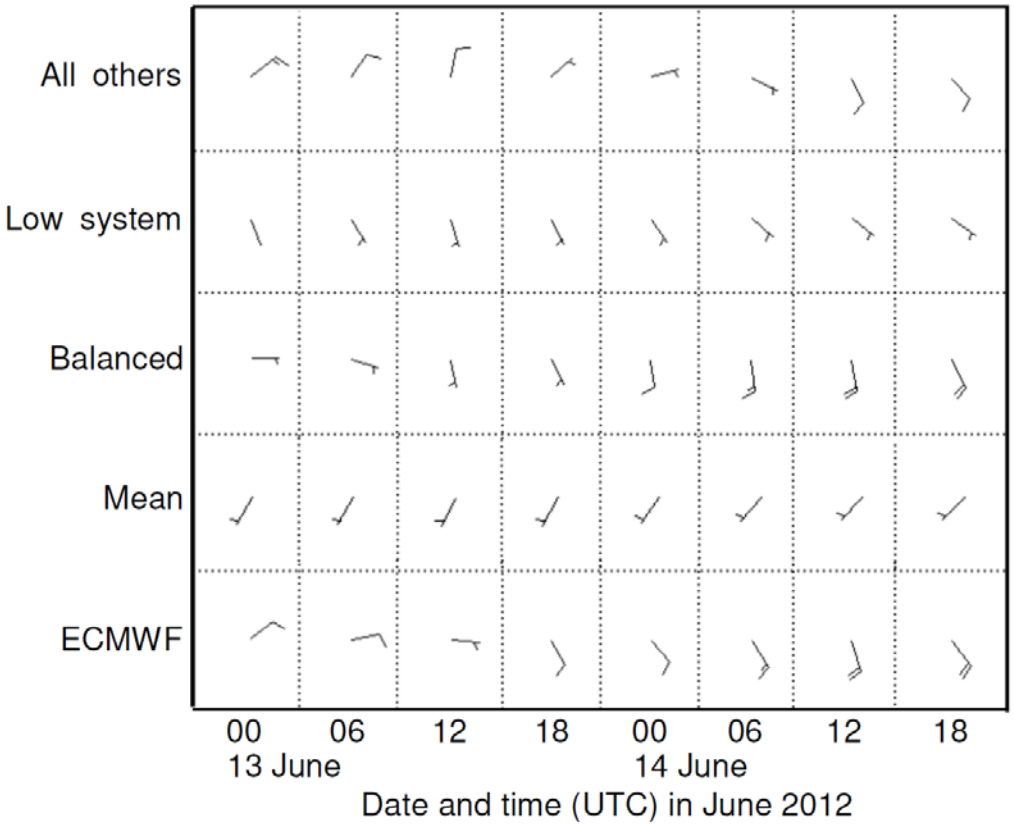
Total q' (PVU), mei-yu front (blue line), and q' region associated with the low (dotted box)

- *Region of PV perturbation (q') associated with the low to the SW of Taiwan identified at each time*
- *Height and wind anomalies from each system are obtained through PV inversion*





- *Main result of PV diagnosis on frontal retreat:*

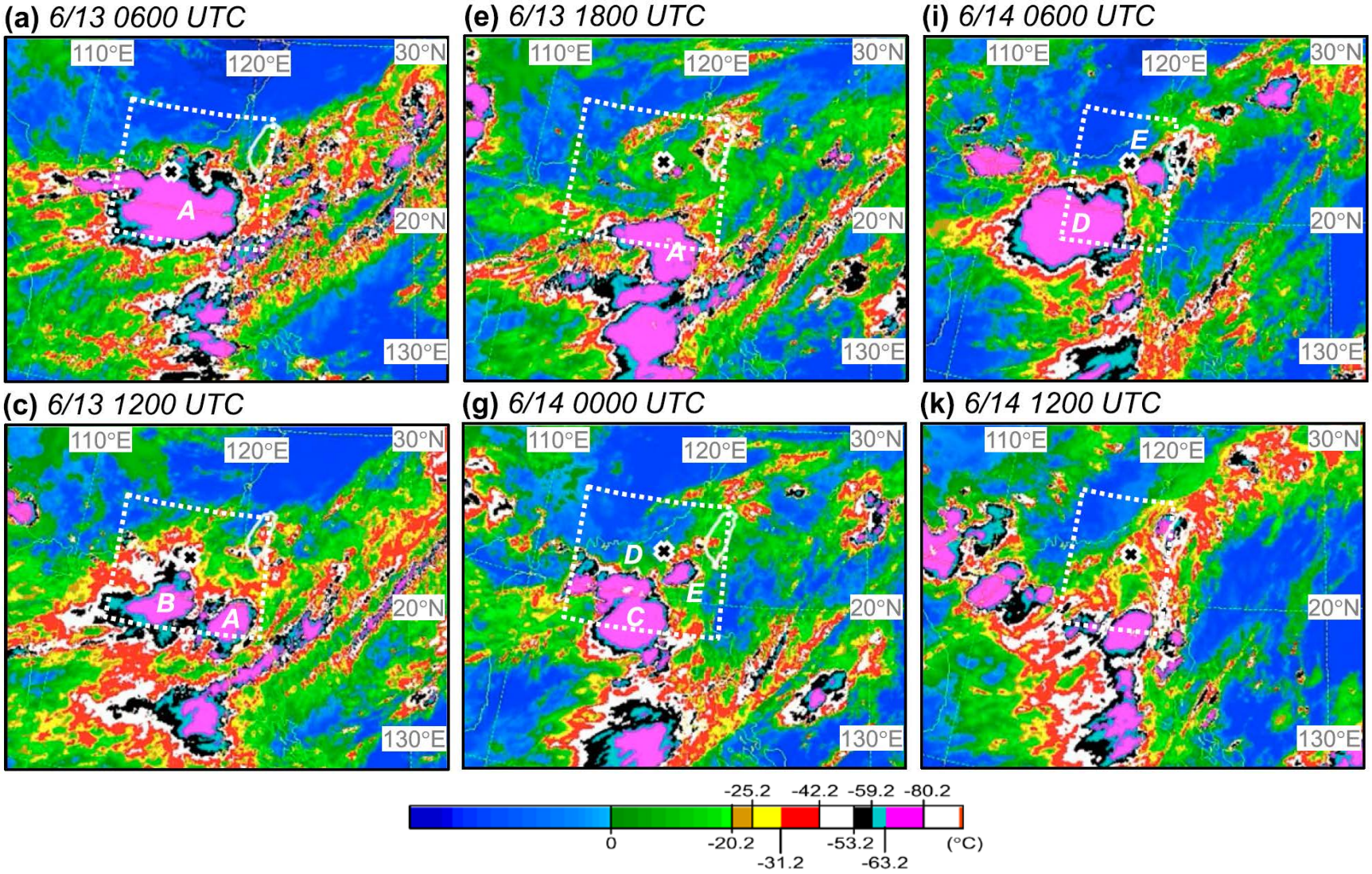


PV diagnostics of 850-hPa mean wind (full = 5 m s^{-1}) at grid points just north of the front from different circulation systems during the case period.

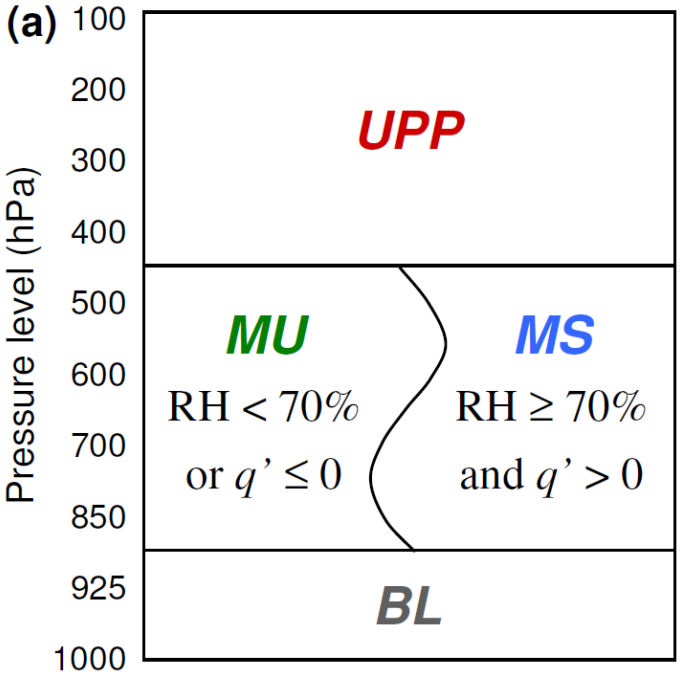
- *Result of piecewise PV inversion further confirms that the deepening low over the southern Taiwan Strait provided the southerly winds east of Taiwan where the retreat started*

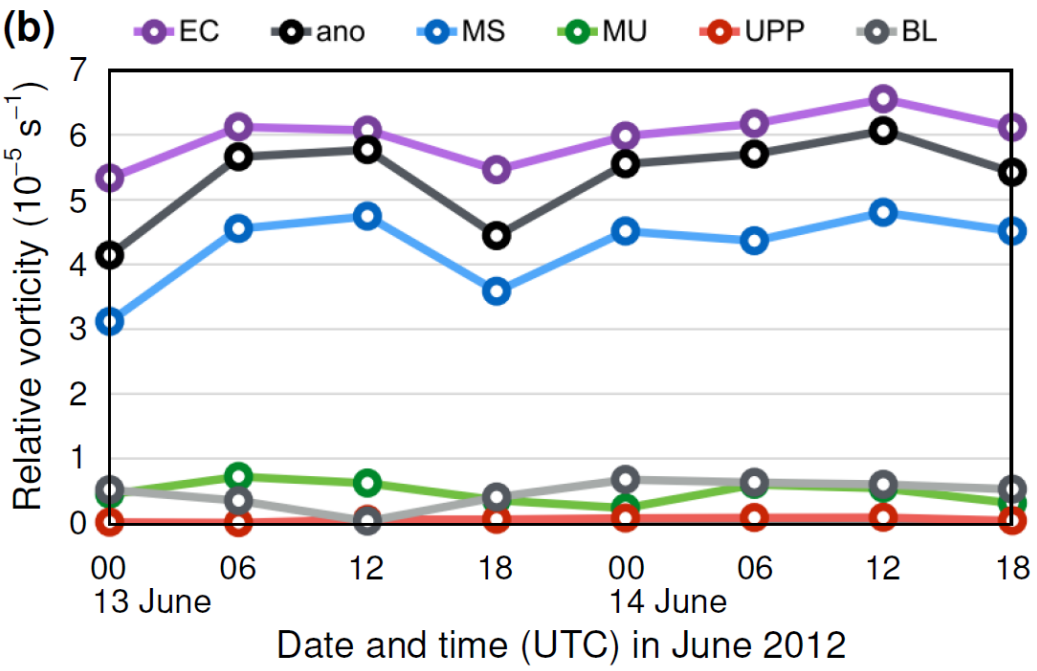
4. Diagnosis of Low Development near Taiwan

- *The low to the southwest of Taiwan was accompanied by persistent, active, and organized MCSs during much of its deepening stage*



- *Method to partition q' based on level, q' and moisture, following earlier studies (e.g., Chen et al. 2003, 2006, 2008)*





***UPP**: upper-level, **BL**: boundary layer,*
***MS**: mid-level saturated (linked to LH), and*
***MU**: mid-level unsaturated (dry)*

Contributions toward areal-mean ζ (10^{-5} s^{-1}) of the low at 850 hPa during case period.

- *PV inversion diagnosis indicates that the low intensified in response to the latent heating, consistent with satellite imageries and earlier results*

5. Climatology of Occurrence Frequency

TABLE 1. List of frontal retreat events, including event period and duration (h), length (degree longitude) and total distance (degree latitude) of retreat, and location [southern China (SC), Taiwan Strait (TS), and/or east of Taiwan (EOT)] within the rectangular area of 20°–30°N, 110°–130°E during May–June of 2012–14. The length and total distance are mean values over the retreat period, and the case in the present study is event No. 4. The total numbers of frontal passages in the three seasons are 11, 9, and 12, respectively.

No.	Year	Time period and duration	Section length (°)	Distance of retreat (°)	Location
1	2012	0600–1200 UTC 11 May (6 h)	7.0	3.1	SC
2		0000–1200 UTC 12 May (12 h)	6.3	2.9	SC
3		1200 UTC 22 May–0000 UTC 23 May (12 h)	5.0	2.3	SC
4		1200 UTC 13 Jun–0600 UTC 15 Jun (42 h)	14.3	4.9	TS, EOT
5		0000–1800 UTC 16 Jun (18 h)	7.8	2.6	SC, TS, EOT
6		1800 UTC 24 Jun–0600 UTC 25 Jun (12 h)	13.0	2.9	SC, EOT
7	2013	0600 UTC 17 May–0600 UTC 18 May (24 h)	7.8	2.9	SC
8		1800 UTC 19 May–0000 UTC 20 May (6 h)	11.5	1.5	SC, TS
9		1200 UTC 21 May–0600 UTC 22 May (18 h)	11.2	1.4	SC, TS, EOT
10		0000–1800 UTC 31 May (18 h)	13.3	2.9	SC, EOT
11	2014	1200–1800 UTC 6 May (6 h)	11.5	2.9	TS, EOT
12		0600–1800 UTC 7 May (12 h)	9.8	2.5	TS, EOT
13		0000–1200 UTC 19 May (12 h)	11.0	1.0	SC, TS, EOT
14		0000–1800 UTC 21 May (18 h)	10.0	4.0	SC, TS
15		1200–1800 UTC 19 Jun (6 h)	17.0	3.7	SC, EOT
16		0600 UTC 24 Jun–0000 UTC 25 Jun (18 h)	13.3	3.7	SC, TS, EOT
17		0000–0600 UTC 29 Jun (6 h)	17.0	2.9	SC, EOT

South China, Taiwan Strait, East of Taiwan

- *During mei-yu seasons of 2012-14, about half of the fronts near Taiwan (17 out of 32) exhibited frontal retreat along certain segment, so the phenomenon is more frequent than previously believed*
- *The present case was the most significant event*

6. Conclusion

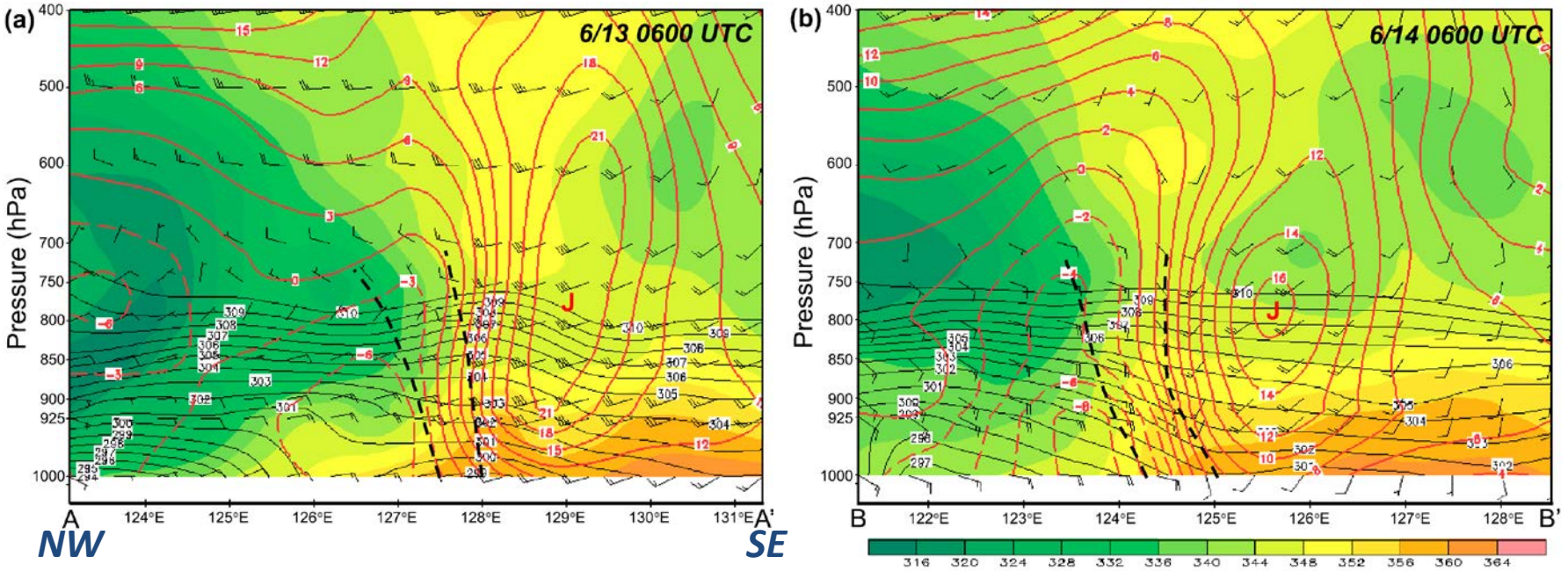
- *The appearance of southerly winds, and thus the retrogression of cold air, to the north of the front was the cause of the initial retreat in the event*
- *the deepening low to the southwest of Taiwan (over the southern Taiwan Strait) provided the southerly winds east of Taiwan for the initial retreat*
- *The low was accompanied by persistent and active MCSs, and it deepened in response to latent heating*
- *During the retreat, the mei-yu front essentially turned into a warm front with corresponding characteristics*

--- The End ---

Thank you for listening! Questions?

- ***Reference:*** *Wang, C.-C., G. T.-J. Chen, and K.-H. Ho, 2016: A diagnostic case study of mei-yu frontal retreat and associated low development near Taiwan. Mon. Wea. Rev., 144, 2327-2349.*

- *During retreat, the front exhibited characteristics consistent with a warm front in vertical structure and associated weather changes*



Vertical cross sections of θ_e (K, color, every 4 K), θ (K, black, every 1 K), u/v (barbs, full = 5 m s^{-1}), and wind speed normal to plane (red)

- *However, none of the 17 events was analyzed as warm front during the retreat*
- *It is hoped that current study can help raise the awareness of such events of mei-yu frontal retreat*