台灣南高屏渦流之研究

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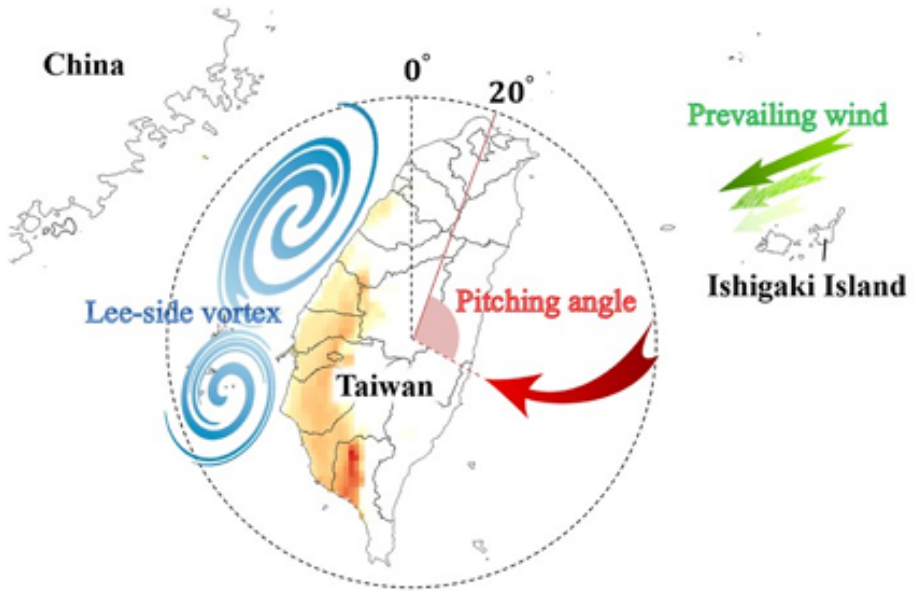
台灣的背風渦流

Lai and Lin(2020)

HIGHLIGHTS

- Pitching angle is the key factor to determine the location of pollution areas.
- Both of surface and boundary layer wind are important to inspecting concentration location.
- Low Froude number in most of air pollution events implied stable flow were split around topography.
- Lee-side vortices occurred at the ABL in most of the air pollution events.

GRAPHICAL ABSTRACT



台灣的背風渦流

Hsin-Chih Lai and Mei-Chi Lin(2020, AE)
渦流出現在925mb

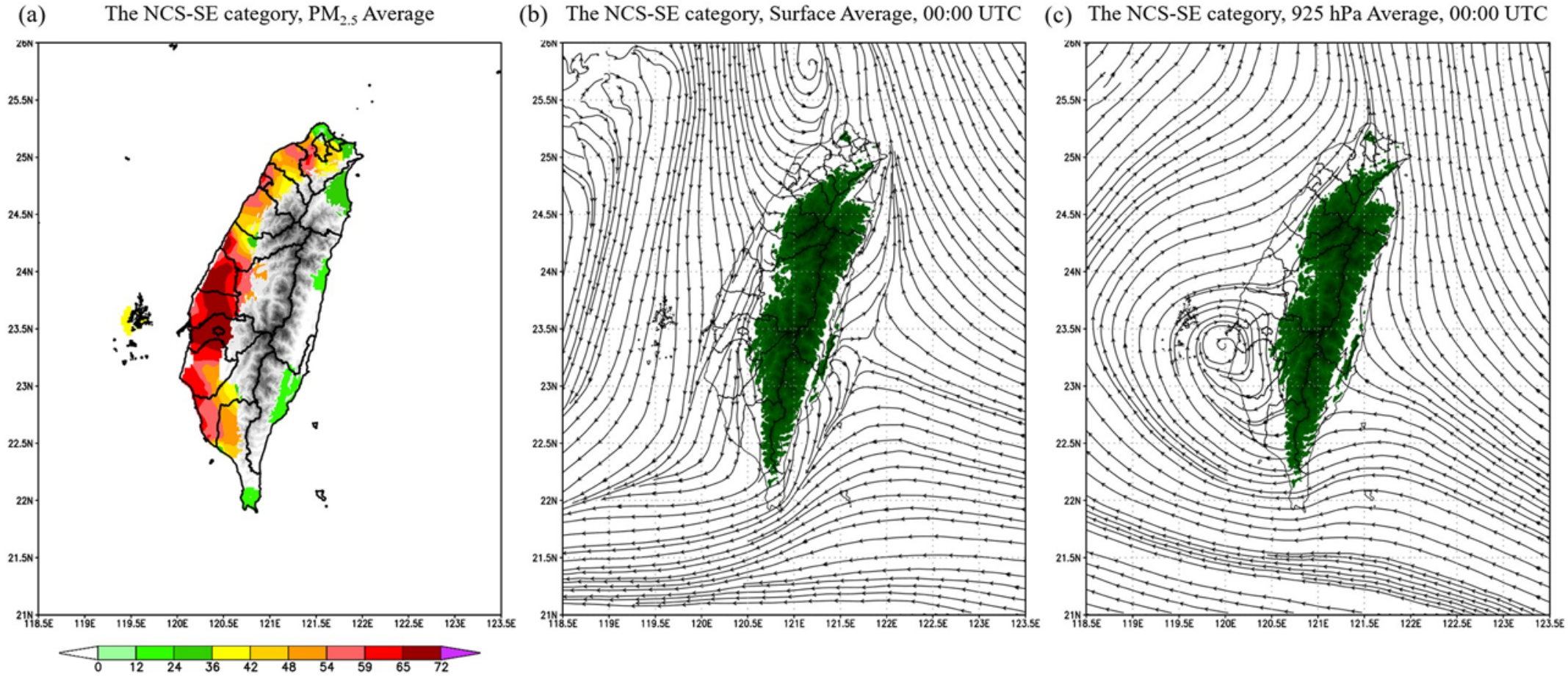
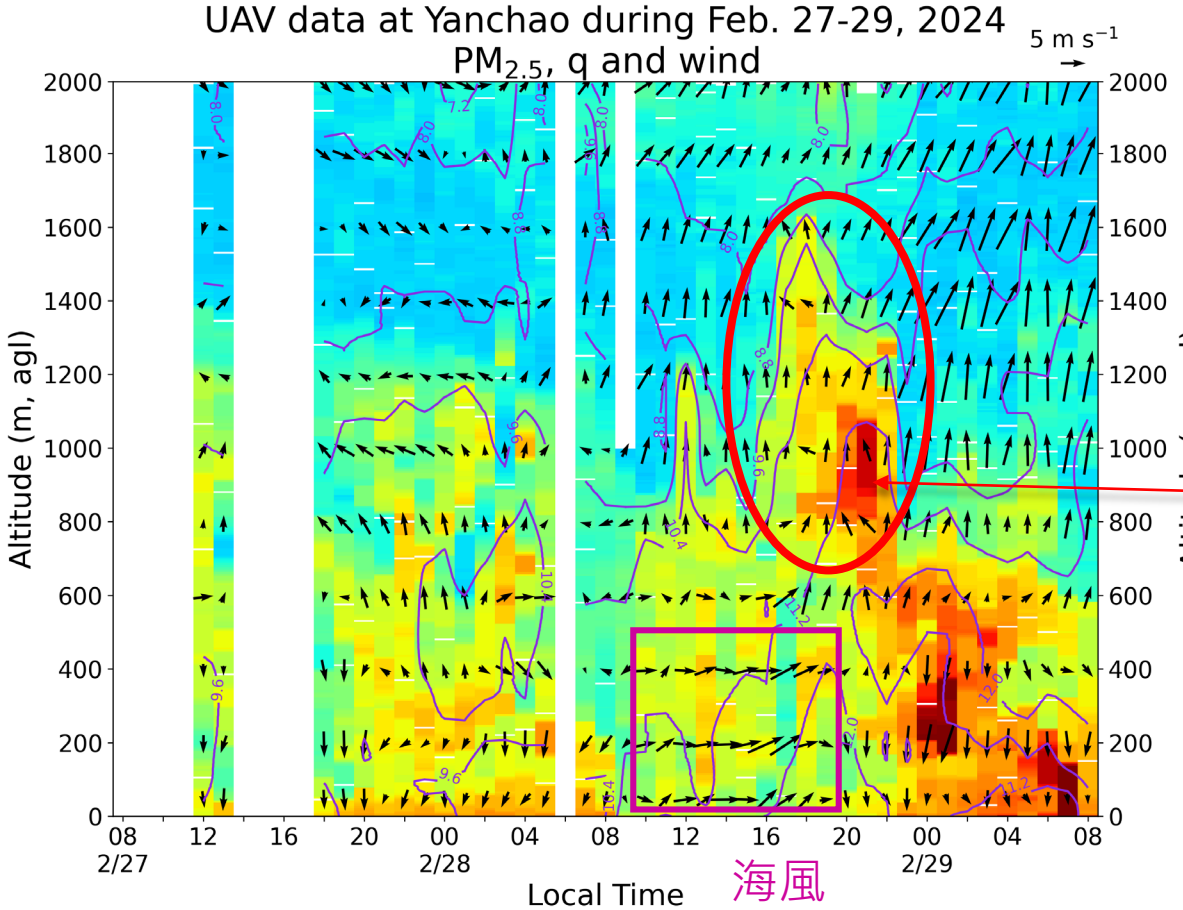


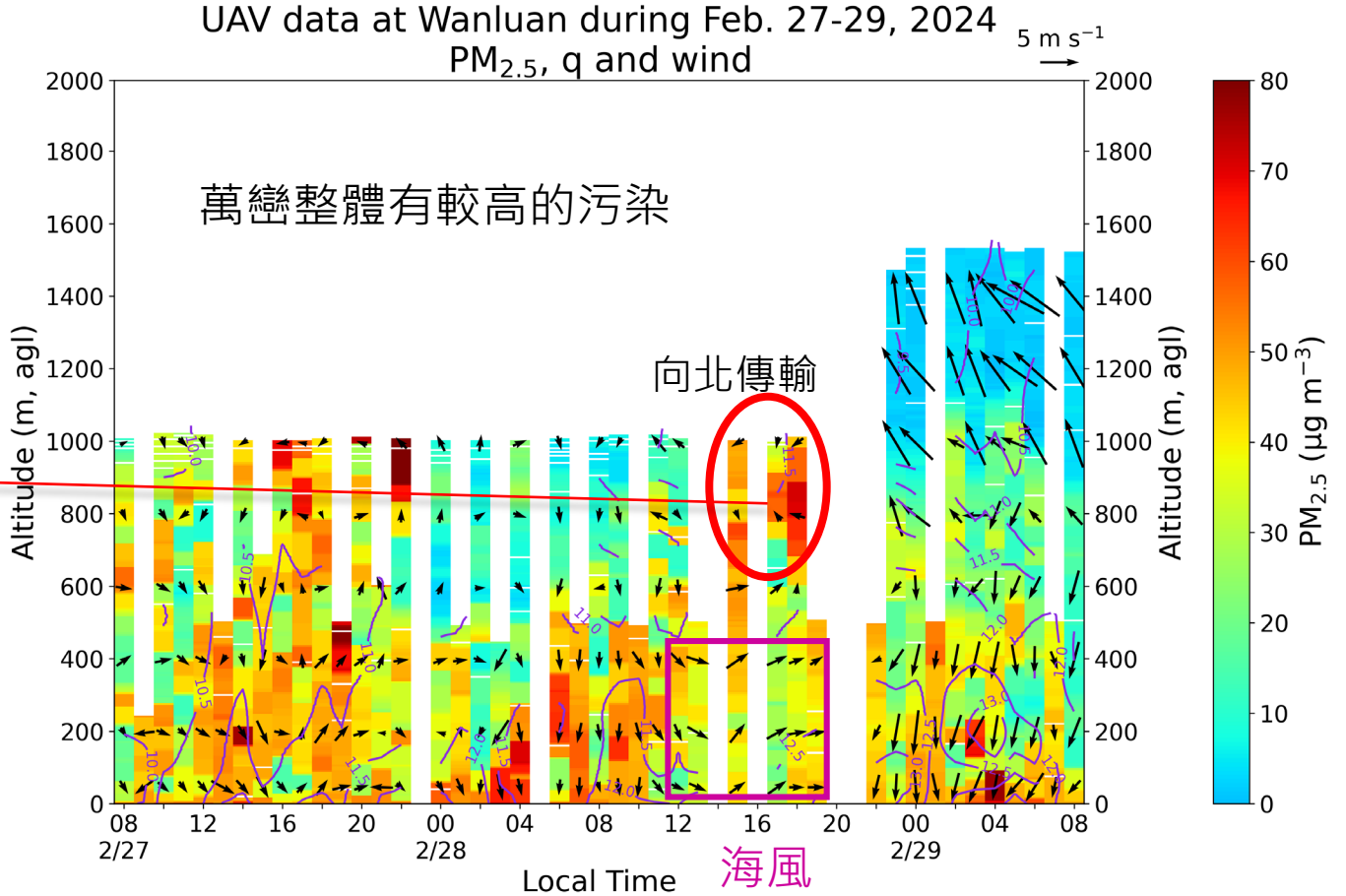
Fig. 10. $PM_{2.5}$ concentrations and flow fields of air pollution events in the NCS-SE category. (a) Distribution of $PM_{2.5}$ concentrations. (b) Flow field at 00:00 UTC on the surface. (c) Flow field at 00:00 UTC on the 925 hPa level. Terrain is showed by gray-color shaded from 500 m height with 500 m interval. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

IOP2 無人機觀測
(王聖翔-KPEx 高屏環流觀測實驗)

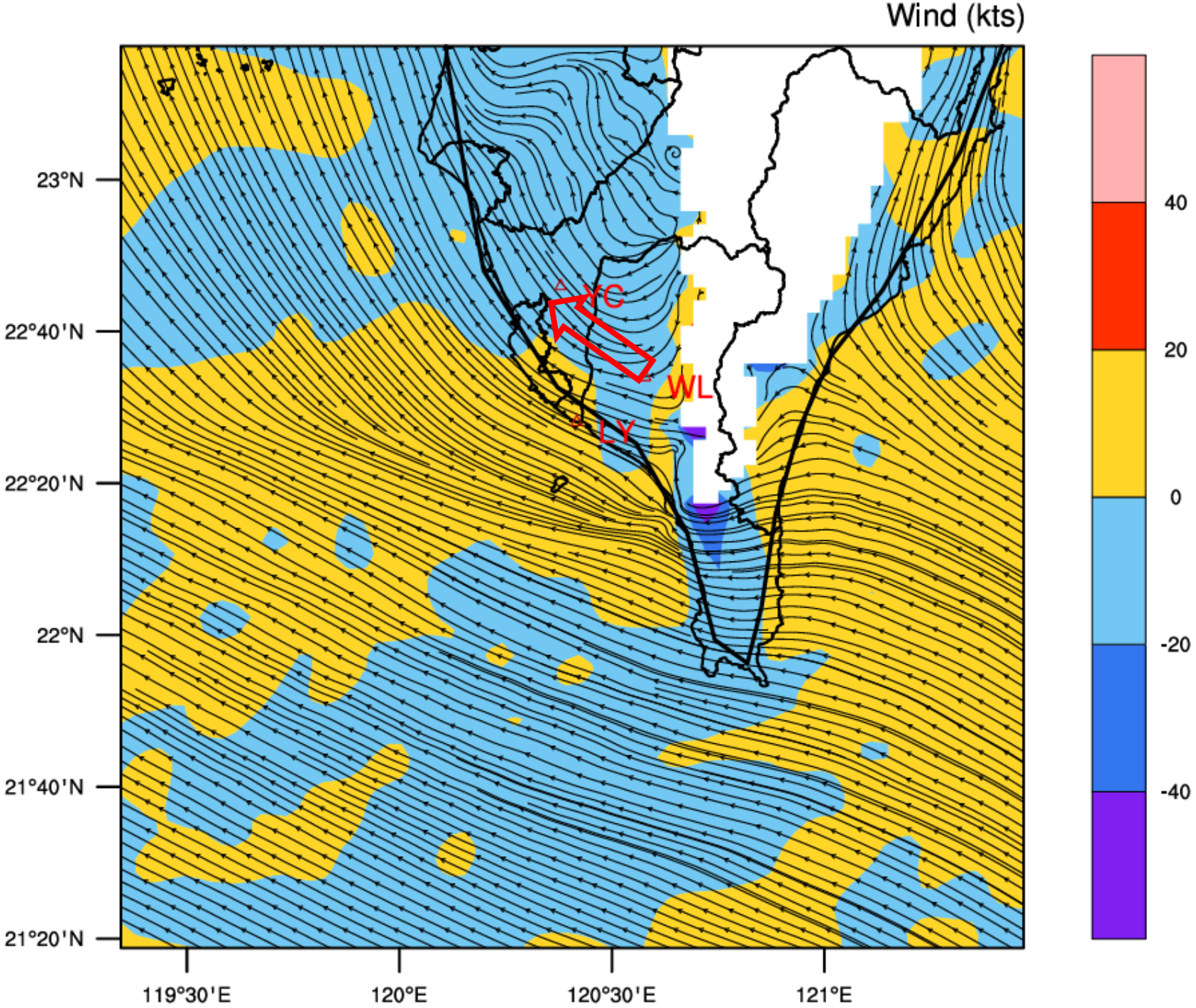
燕巢

萬巒

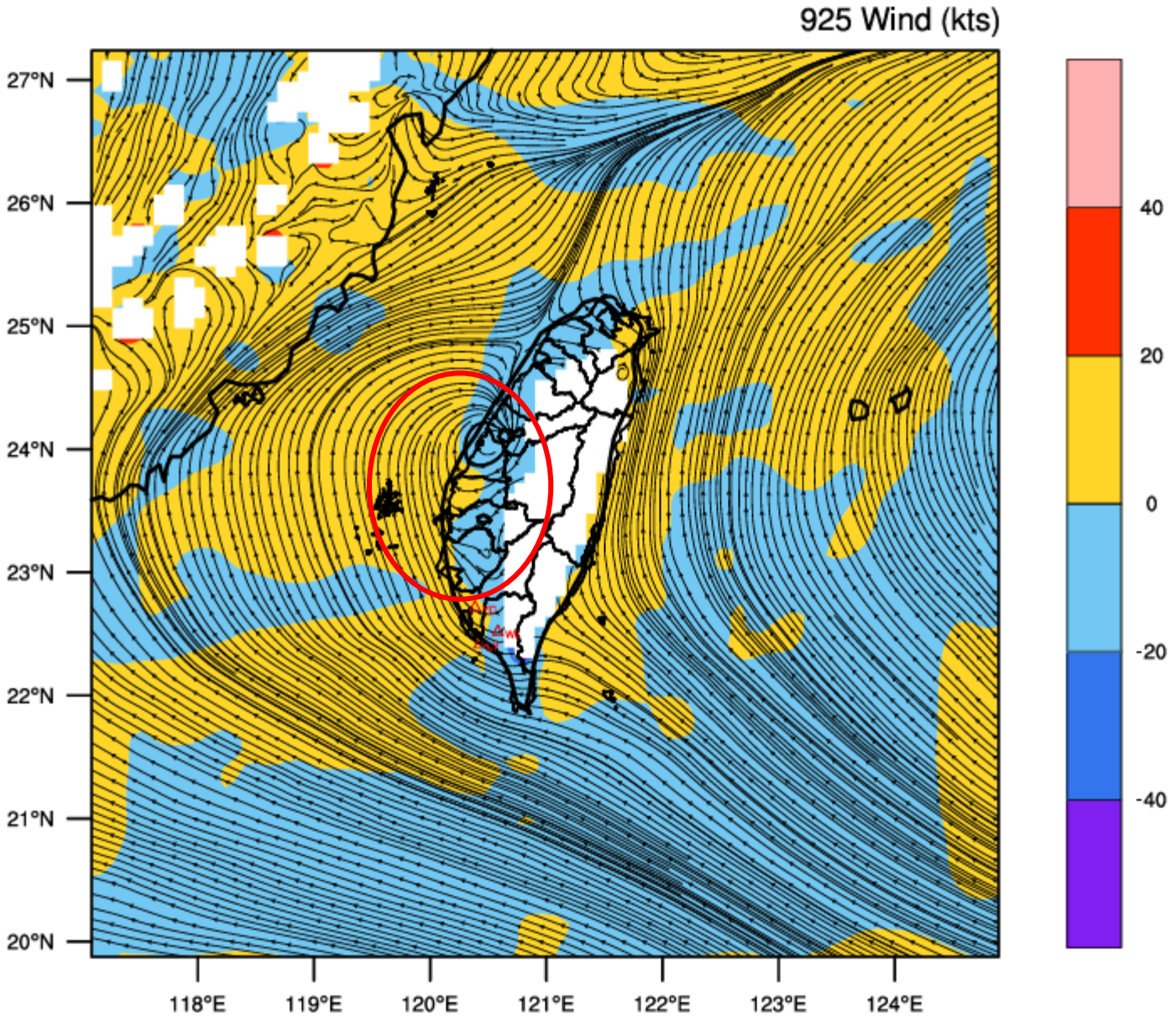




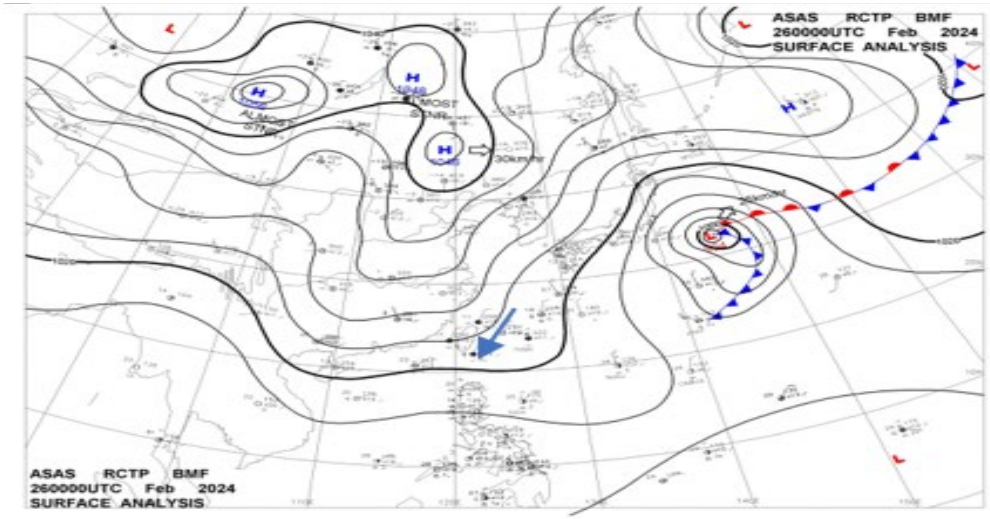
2024/2/28
20L


Wind (kts)
23°N
22°40'N
22°20'N
22°N
21°40'N
21°20'N
119°30'E
120°E
120°30'E
121°E
YC
WL
LY
40
20
0
-20
-40

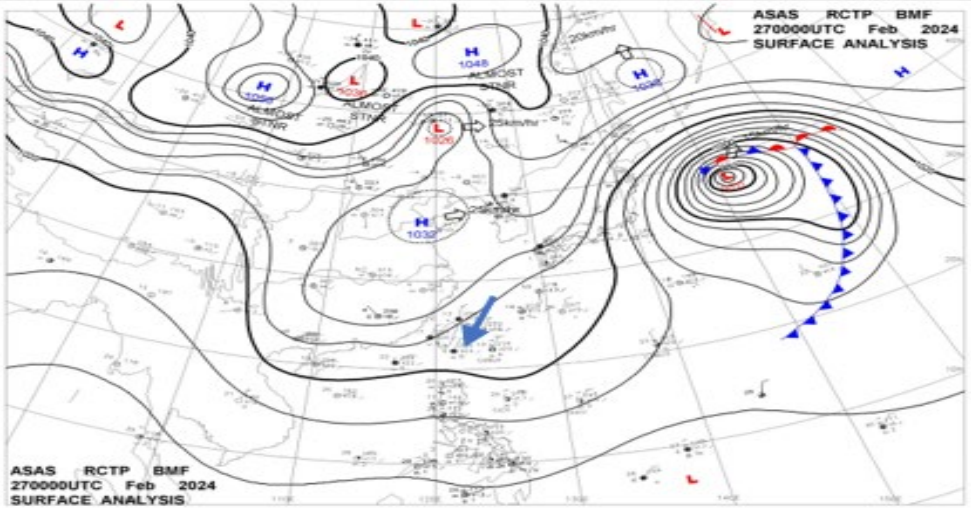
2024022820


925 Wind (kts)
27°N
26°N
25°N
24°N
23°N
22°N
21°N
20°N
118°E
119°E
120°E
121°E
122°E
123°E
124°E
40
20
0
-20
-40

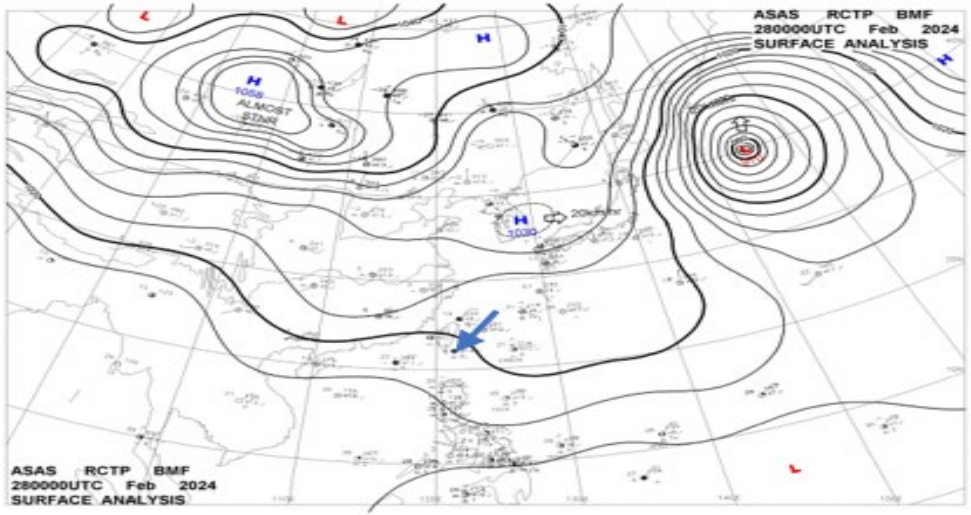
大尺度環流-地面天氣圖



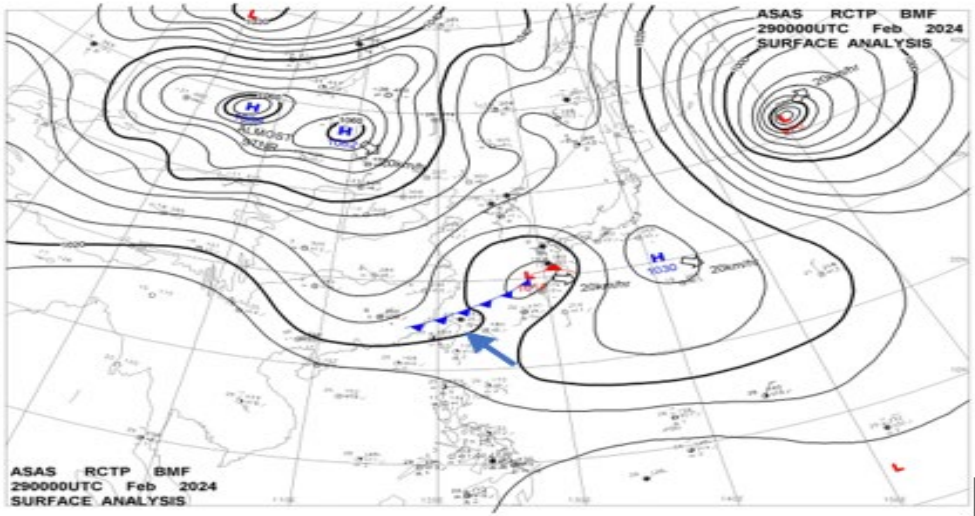
2/26 00Z 強烈大陸冷氣團



2/27 00Z 強烈大陸冷氣團↵



2/28 00Z 東北風

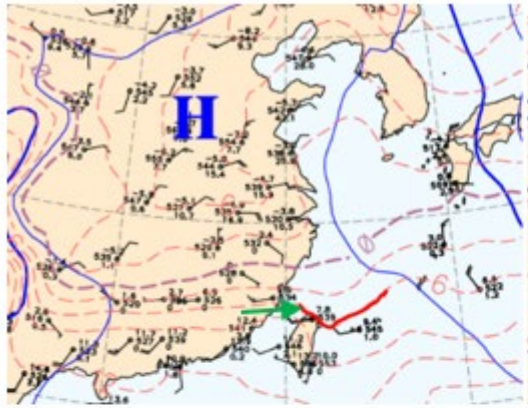


2/29 00Z 鋒面經過台灣北部↵

2/27-2/28 大陸冷高壓減弱 (1020 hPa 等值線北退)

2/26-28地面東北風

大尺度環流-850hPa天氣圖

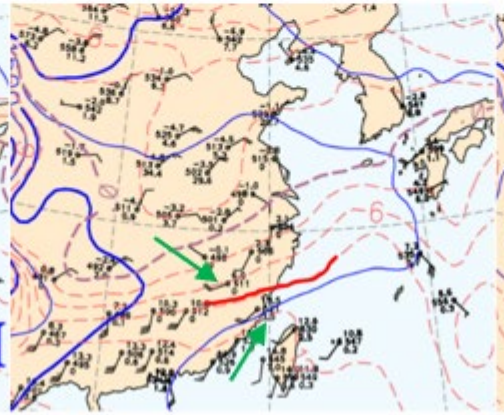


2/26 12Z 850hPa

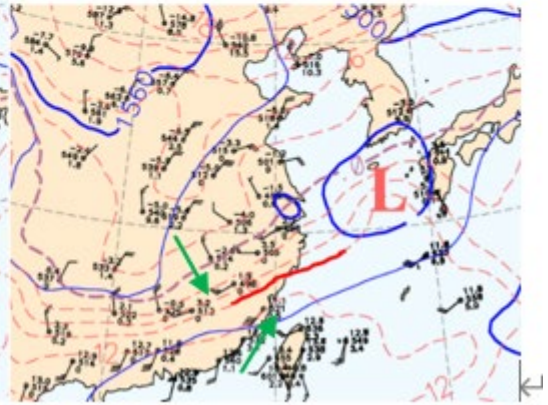
2/27 00Z 850hPa

2/27 12Z 850hPa

2/28 00Z 850hPa



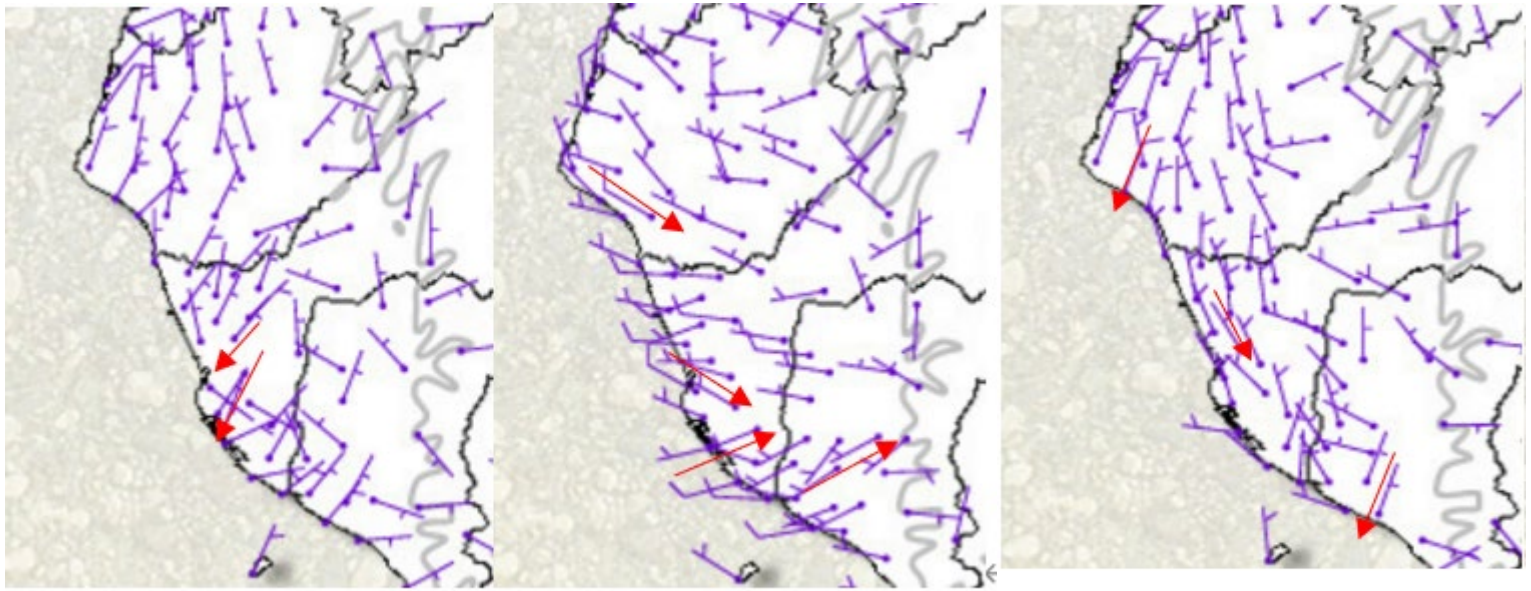
2/28 12Z 850hPa



2/29 00Z 850hPa

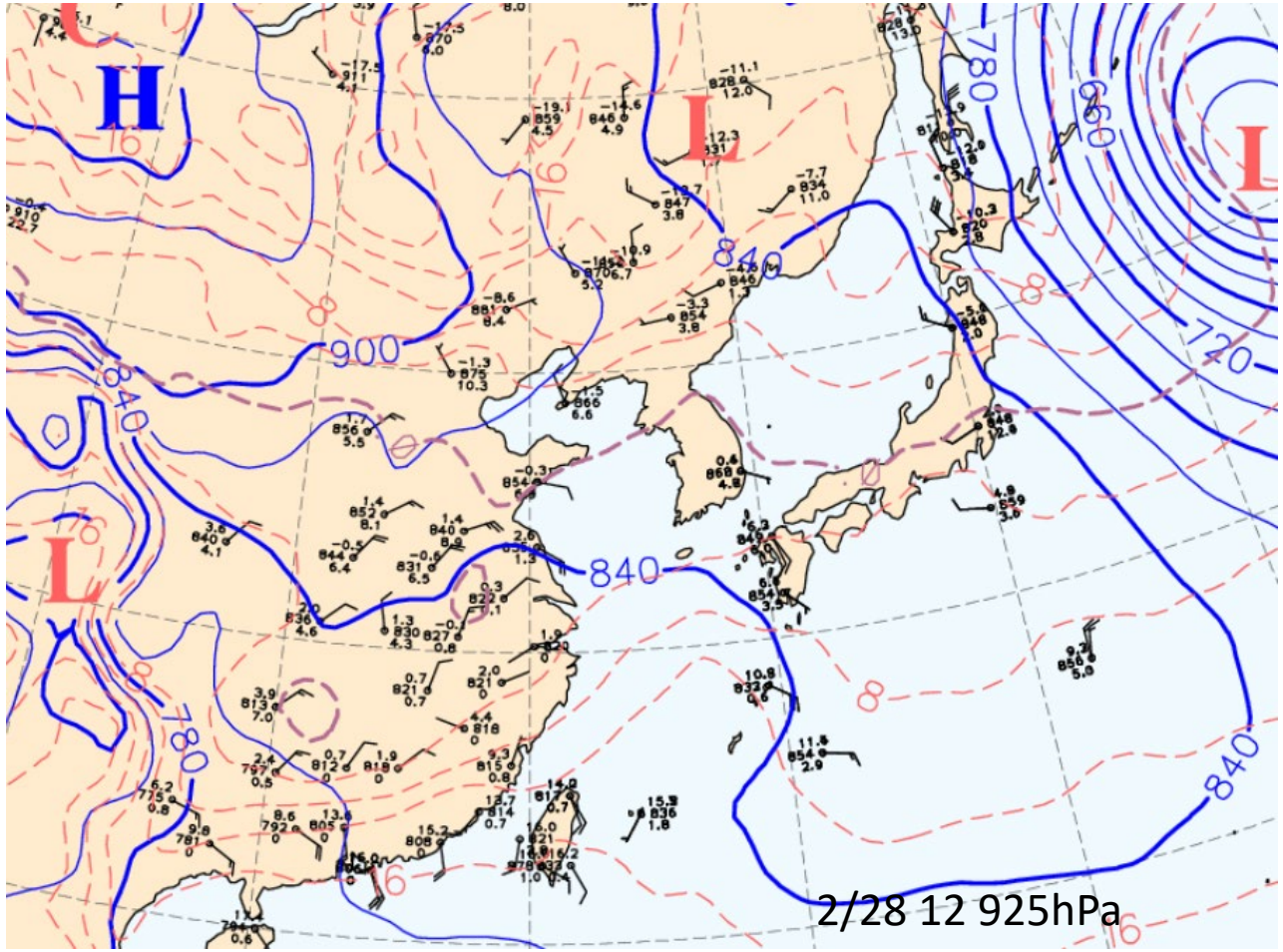
- 2/28 6℃等溫線北退
- 2/29華南冷空氣逐漸接近台灣。
- 2/27 12Z-2/29 00Z台灣為西南風

區域環流

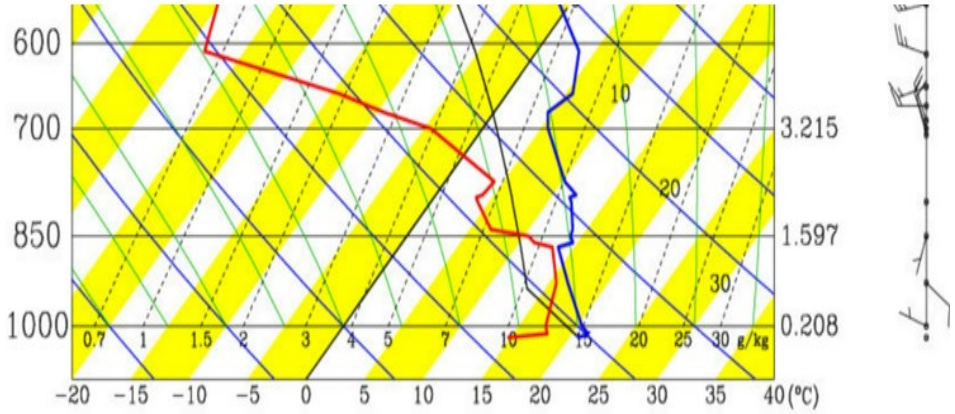


- 2/28高壓減弱，局部環流顯著。
- 0800L高雄東北風(大尺度環流+離岸風)
- 1400L高雄北部西北風(海風)，南部西南風(海風)
- 2000L台南東北風(大尺度環流+離岸風)，高雄西北風(海風)

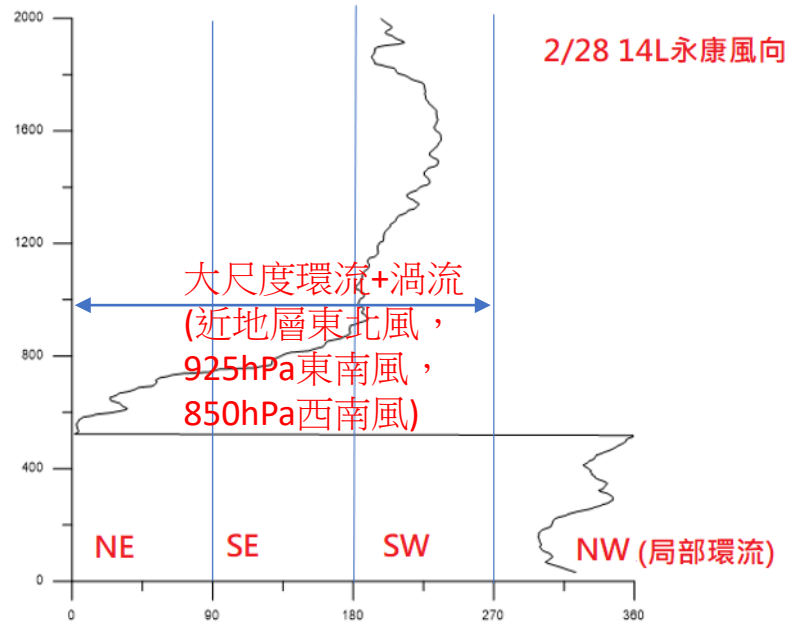
大氣垂直結構

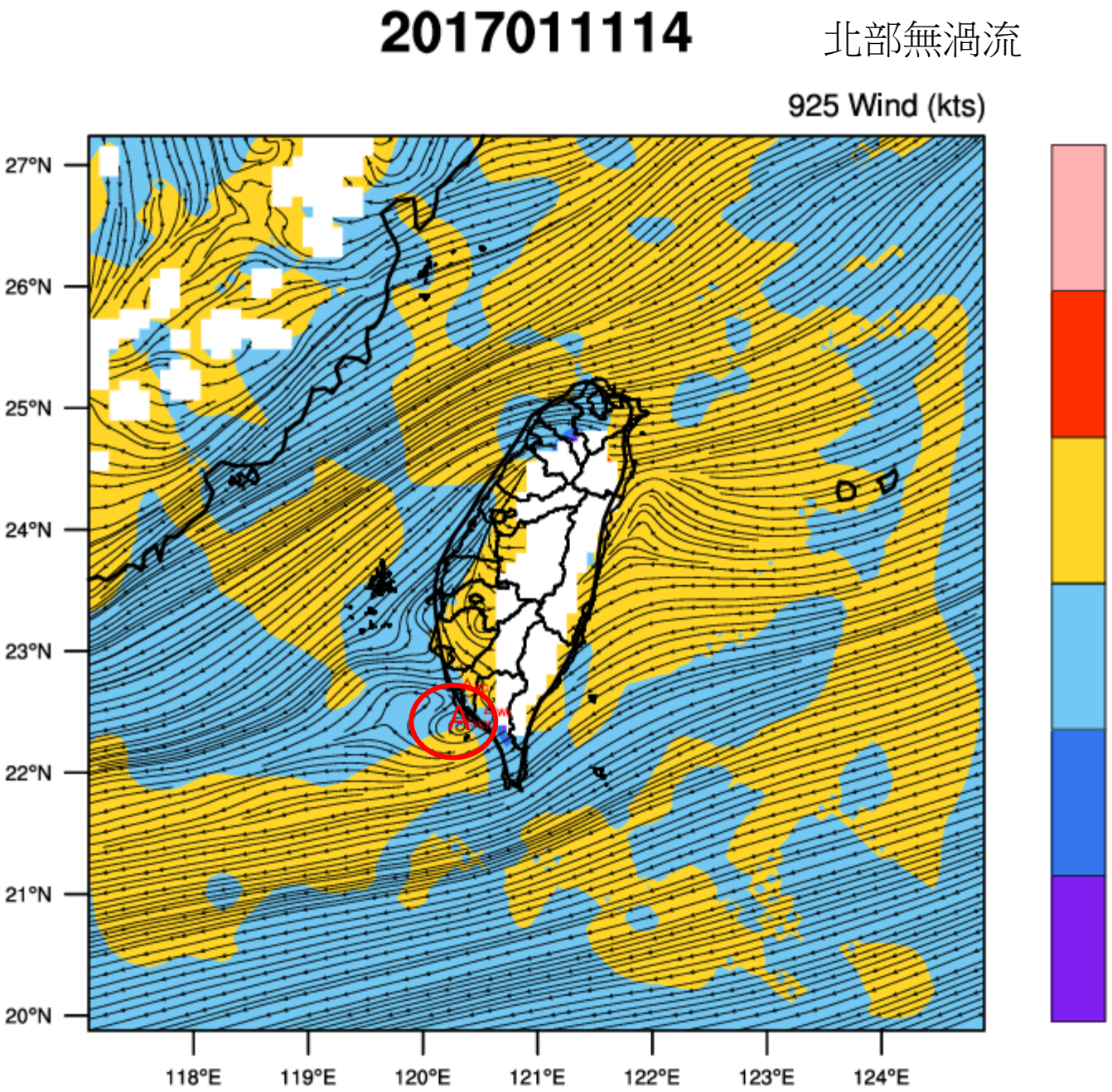


2/28 12 925hPa



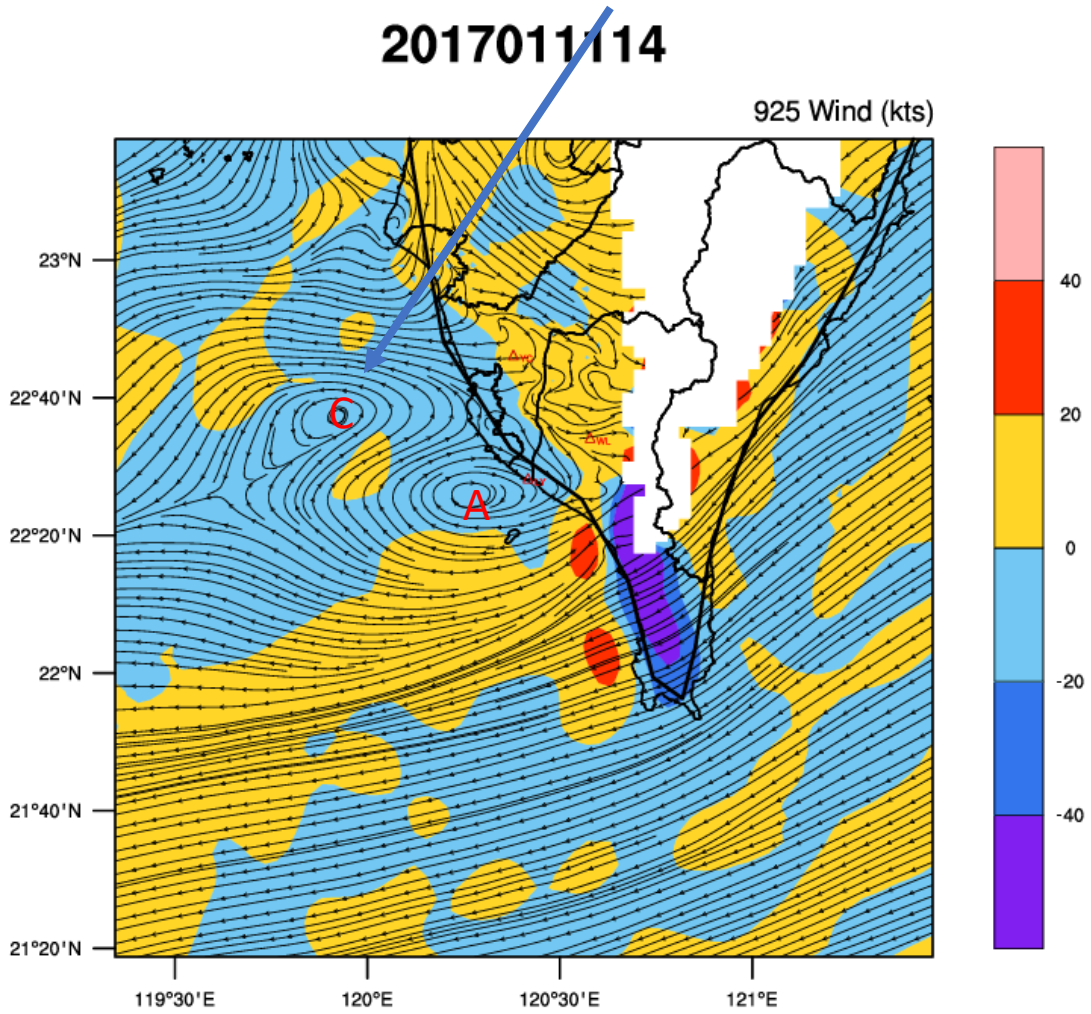
2/28 12Z 屏東地面西北風、900hPa 東南風、850hPa 西南風。





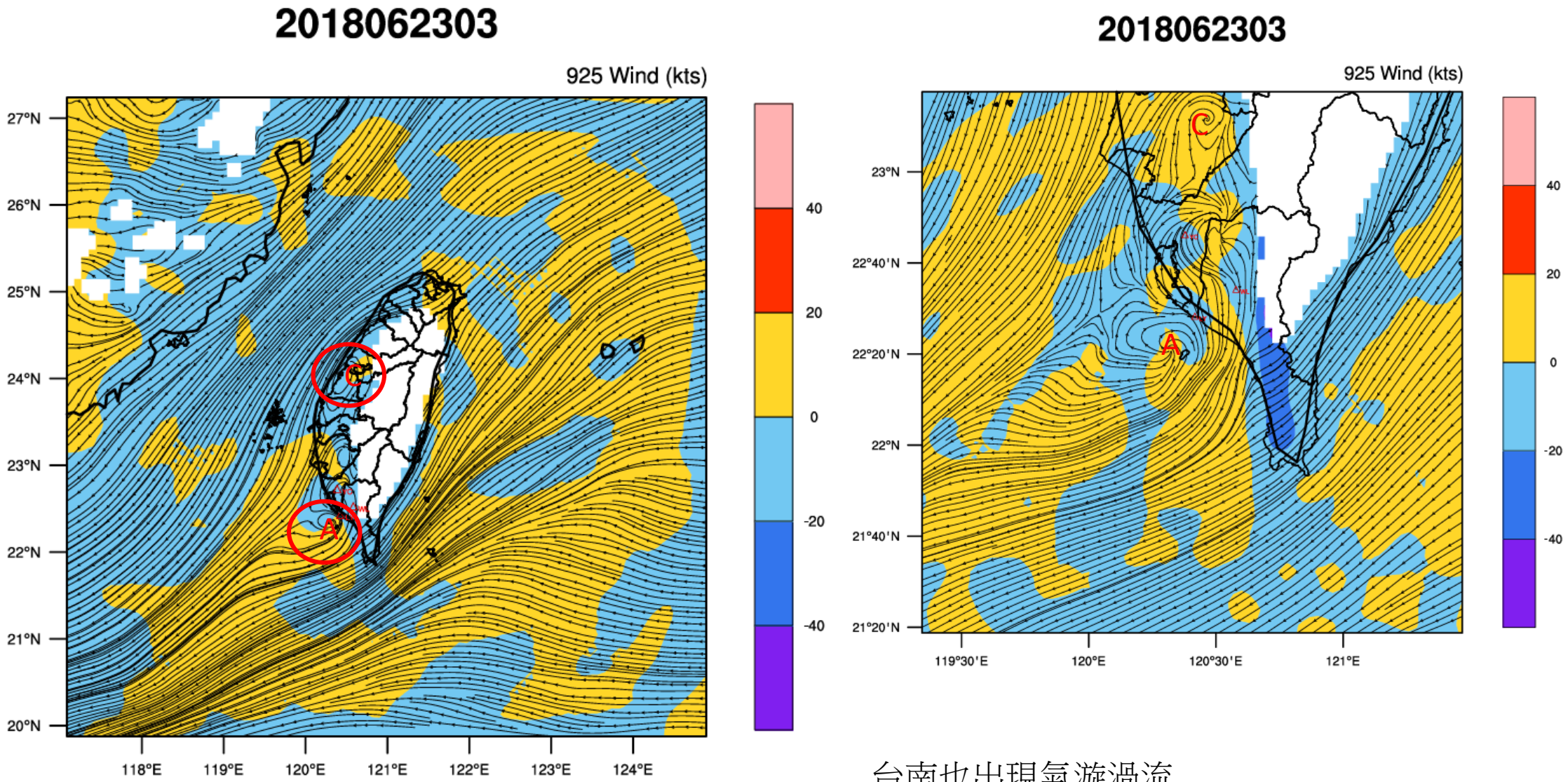
北部無渦流

細網格呈現高雄外海氣漩渦流
若是海風效應，可以到750m？



高雄外海C及A渦流均向岸風
利於空氣汙染堆積內陸

夏天弱東北風更容易出現背風渦流



台南也出現氣漩渦流

背風渦流的理論

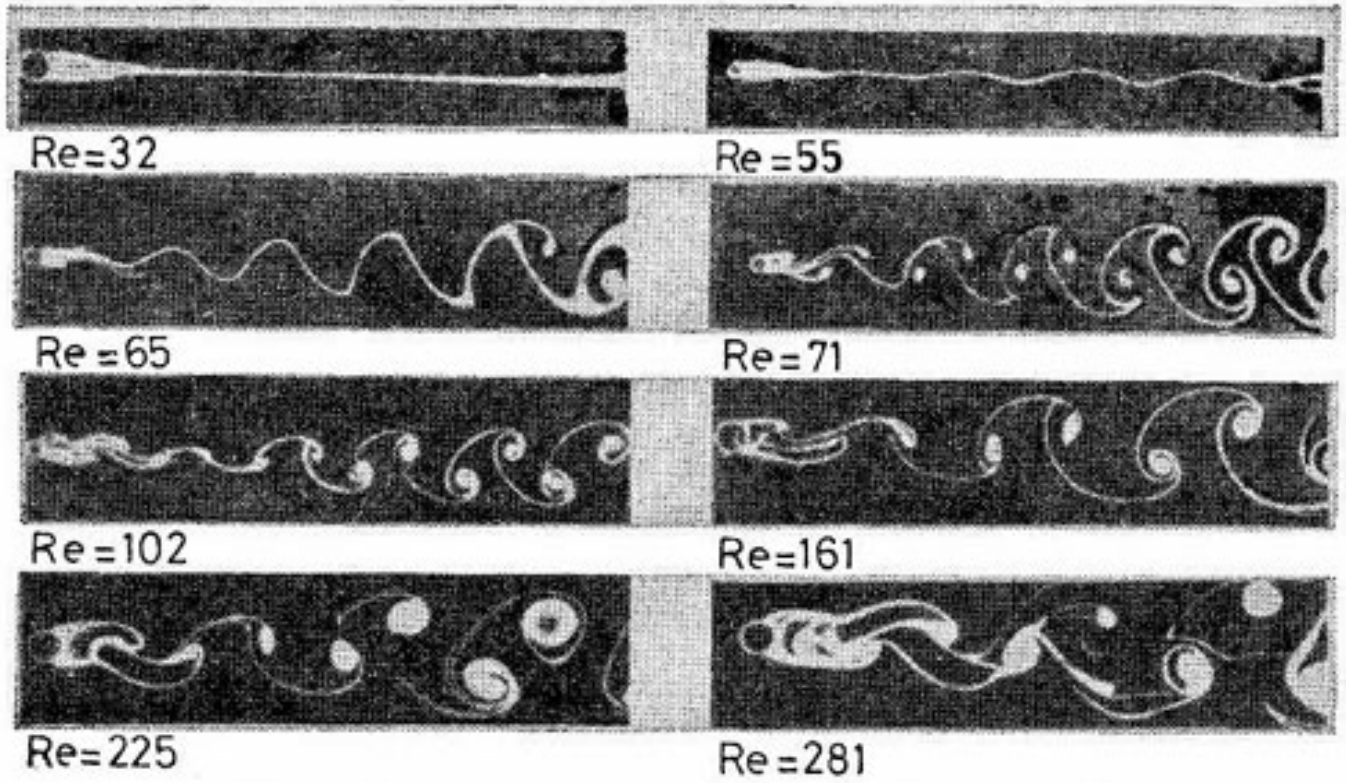


Fig. 9. Kármán vortex street under different Reynolds Numbers (After Homann, 1936)

The Clouds with the Shape of Kármán Vortex Street in the Wake of Cheju Island, Korea

By Kiyoshi Tsuchiya

Japan Meteorological Agency

(*Manuscript received 9 May 1969, in revised form 14 October 1969*)

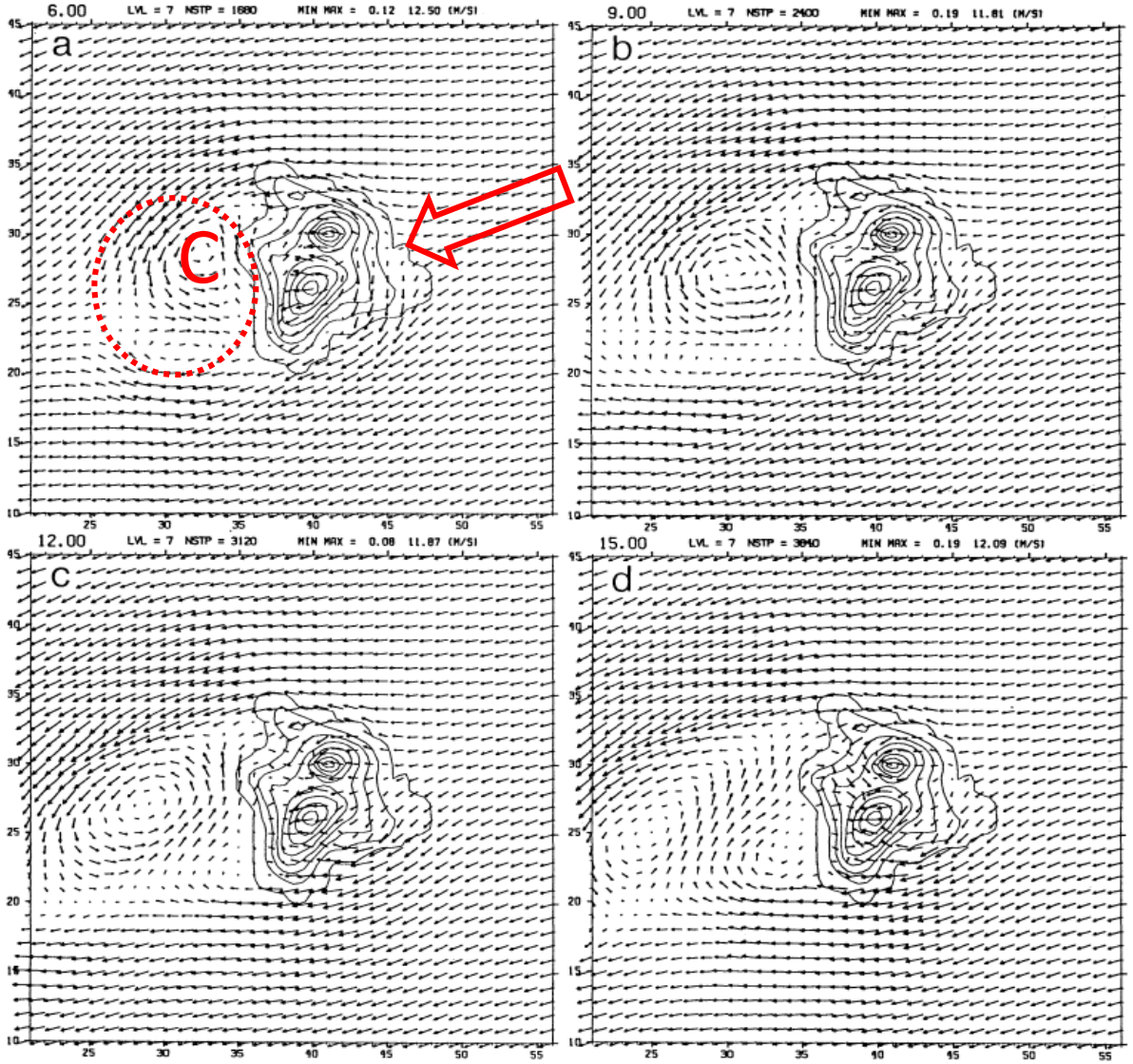
Based on detailed experiments, Blenk et al (19 35) pointed out that Kármán vortex street is formed when Reynolds Number defined by Eq. (13) is in the following range: $60 < Re < 5000$.

$$Re = \frac{Ud}{\nu} \qquad (13)$$

U:速度；d:障礙物高度；v：黏滯性

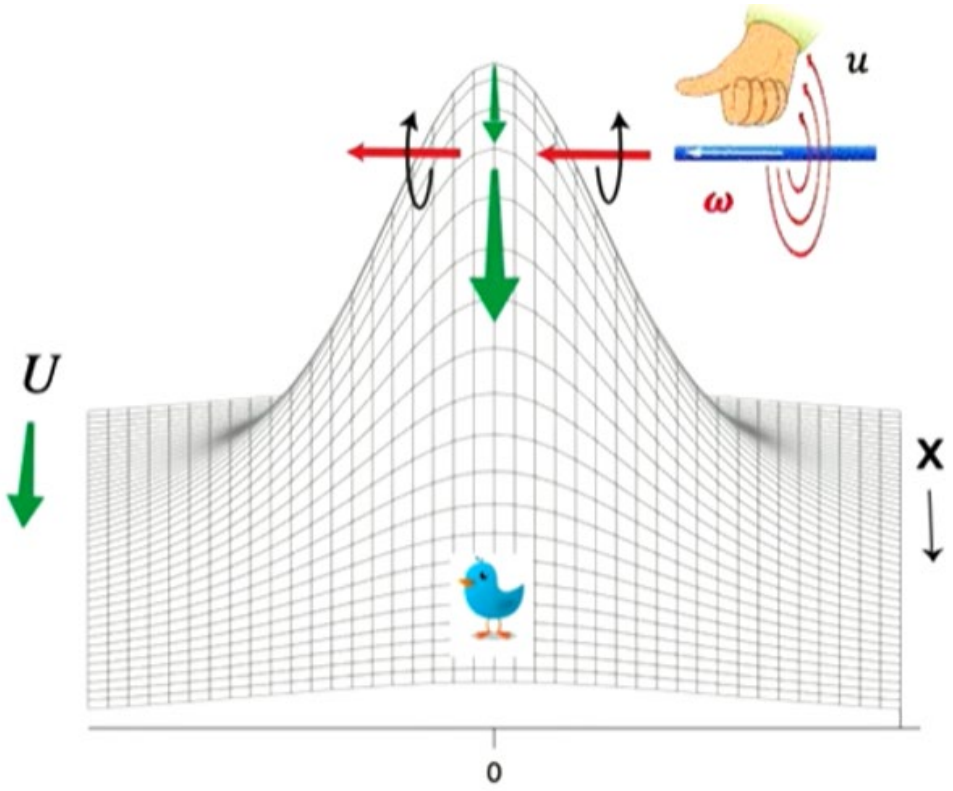
背風渦流的理論

A Three-Dimensional Simulation of Airflow and Orographic Rain over the Island of Hawaii.
Kyozo Ueyoshi and Young-June Han, 1991, Meteorological Society of Japan.

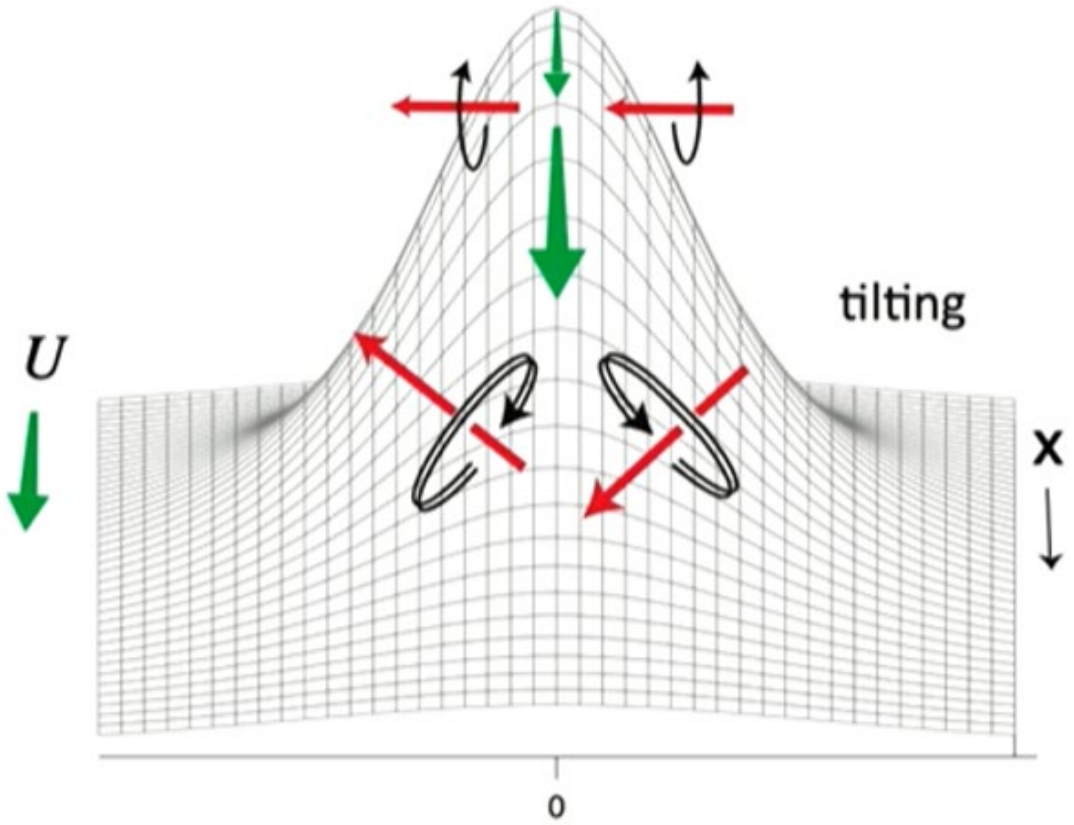


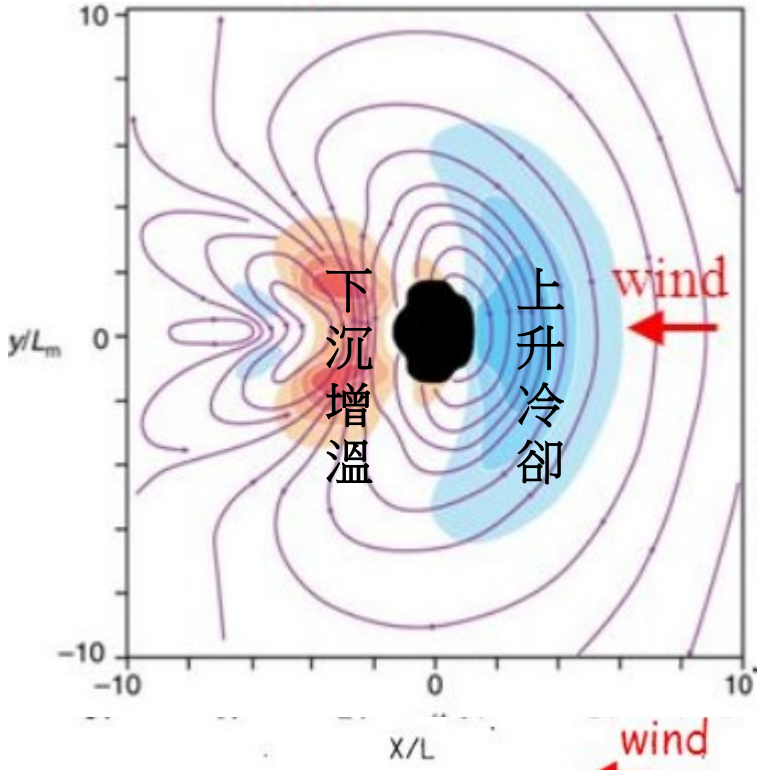
邊界層發生(925hPa)有渦流
地面不一定有渦流
氣流過山與繞山(Fr)
過山：形成上升冷卻、下沉增溫
繞山：黏滯力的效應

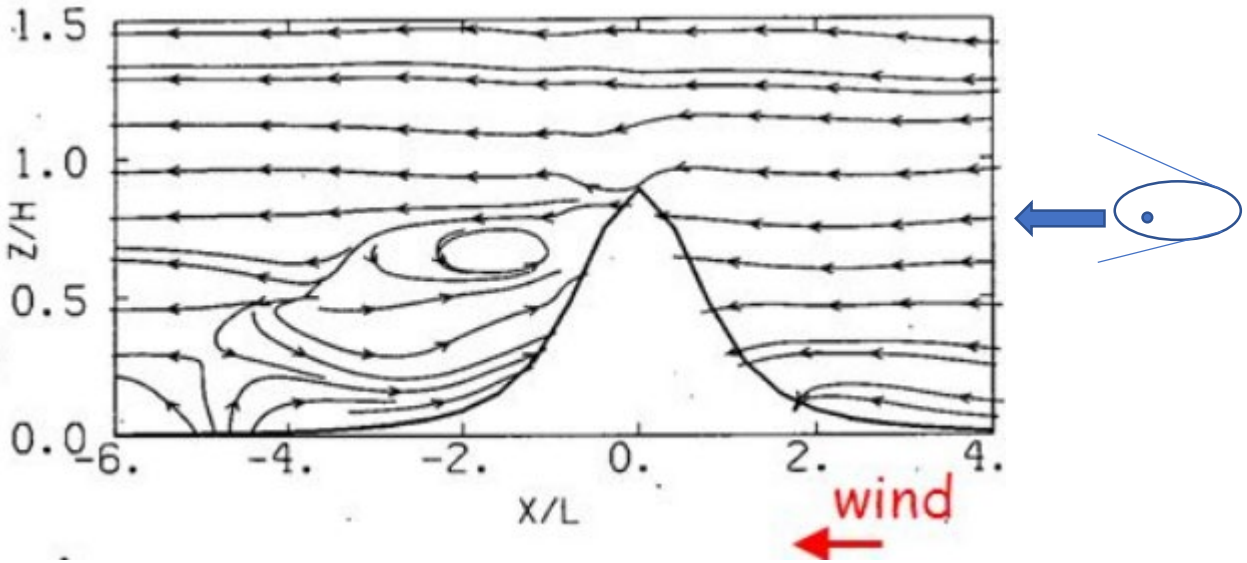
Tilting of baroclinically generated vorticity

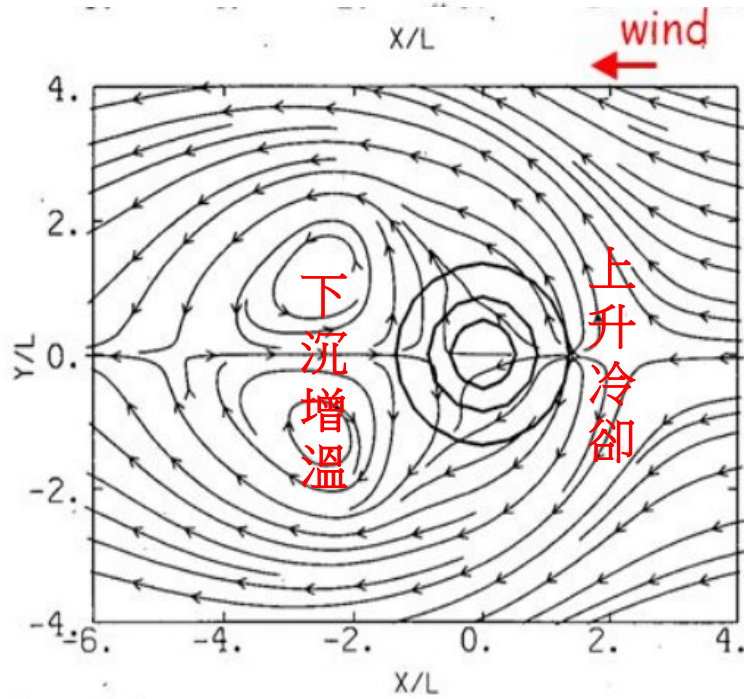


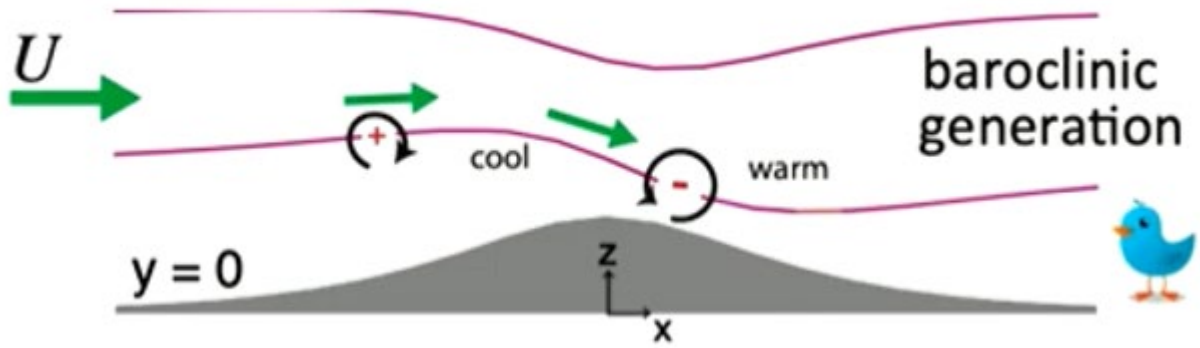
Smolarkiewicz and Rotunno
(1989, *J. Atmos. Sci.*)

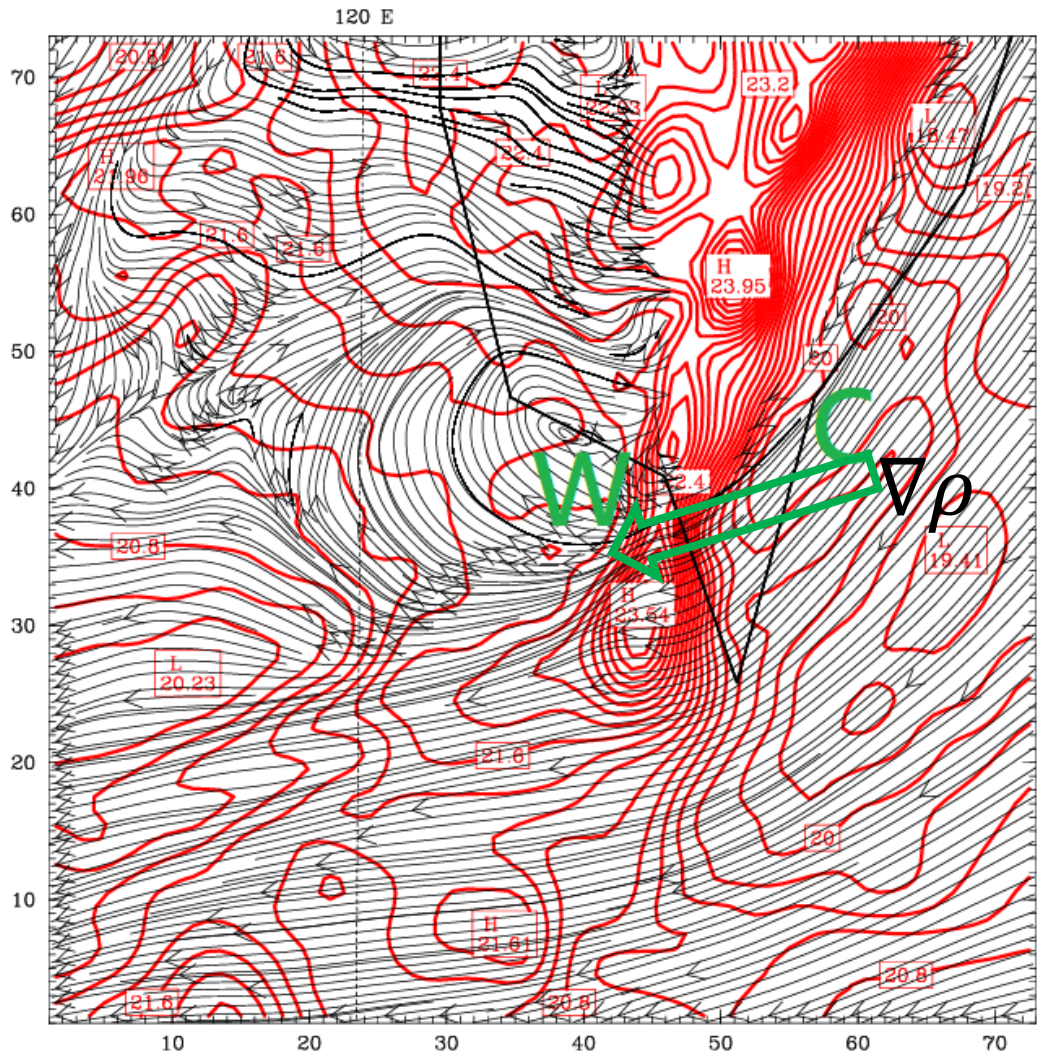


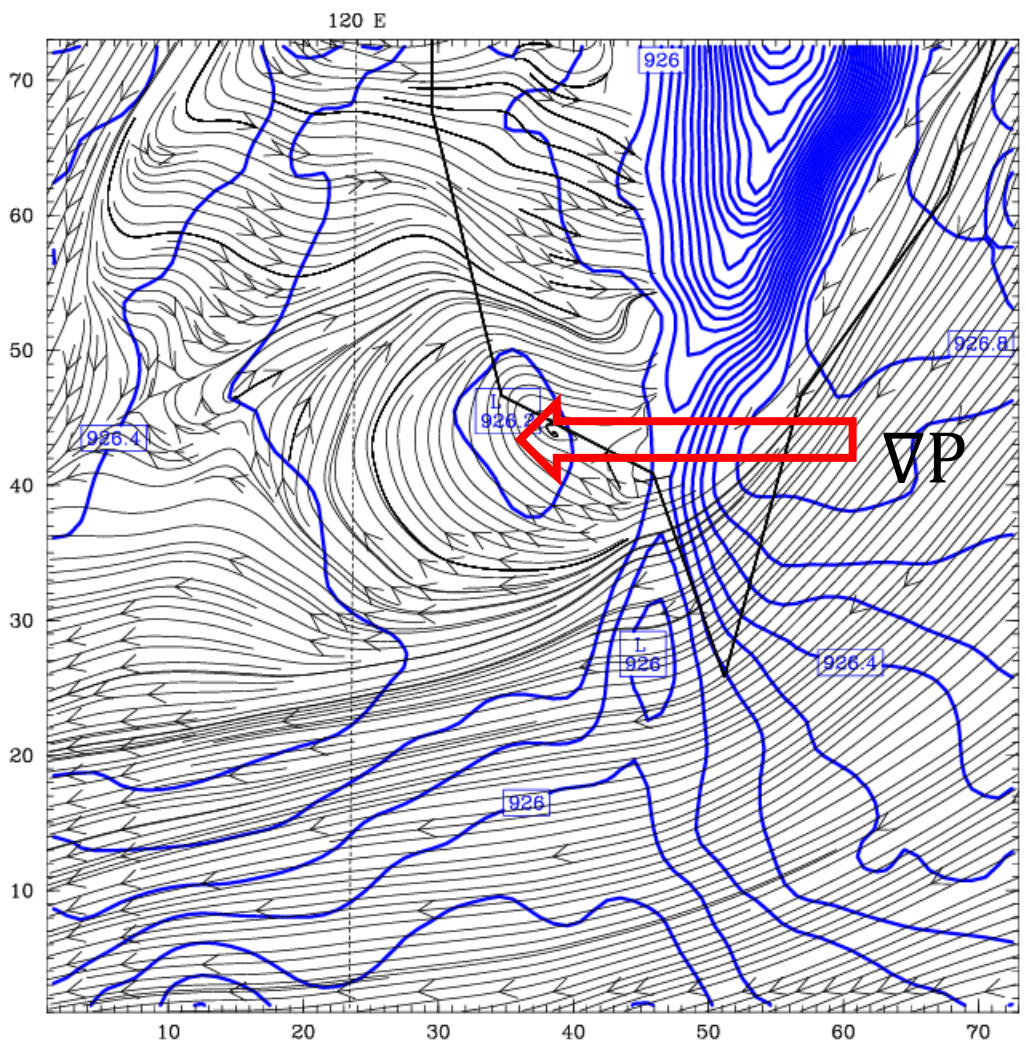

10
0
−10
y/L_m
−10
0
10
X/L
下沉增溫
上升冷卻
wind


1.5
1.0
0.5
0.0
Z/H
-6.
-4.
-2.
0.
2.
4.
X/L
wind


wind
4.
2.
0.
-2.
-4.
Y/L
-6.
-4.
-2.
0.
2.
4.
X/L
下沉增溫
上升冷卻


U
cool
warm
baroclinic generation
y = 0
z
x

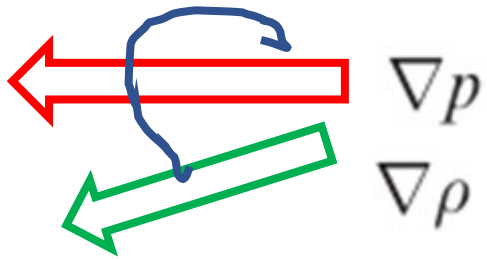

Dataset: 0526 RIP: L0526slp
Init: 1200 UTC Thu 25
Fcst: 18.00 h
Valid: 0600 UTC Fri 26 May 17 (0000 MDT Fri 26
Temperature
at height = 0.75 km
sm= 2
Horizontal wind streamlines
at height = 0.75 km
120 E
W
C
∇ρ


Dataset: 0526 RIP: L0526slp
Init: 1200 UTC Thu 25
Fcst: 18.00 h
Valid: 0600 UTC Fri 26 May 17 (0000 MDT Fri 26
Pressure
at height = 0.75 km
sm= 2
Horizontal wind streamlines
at height = 0.75 km
120 E
∇P

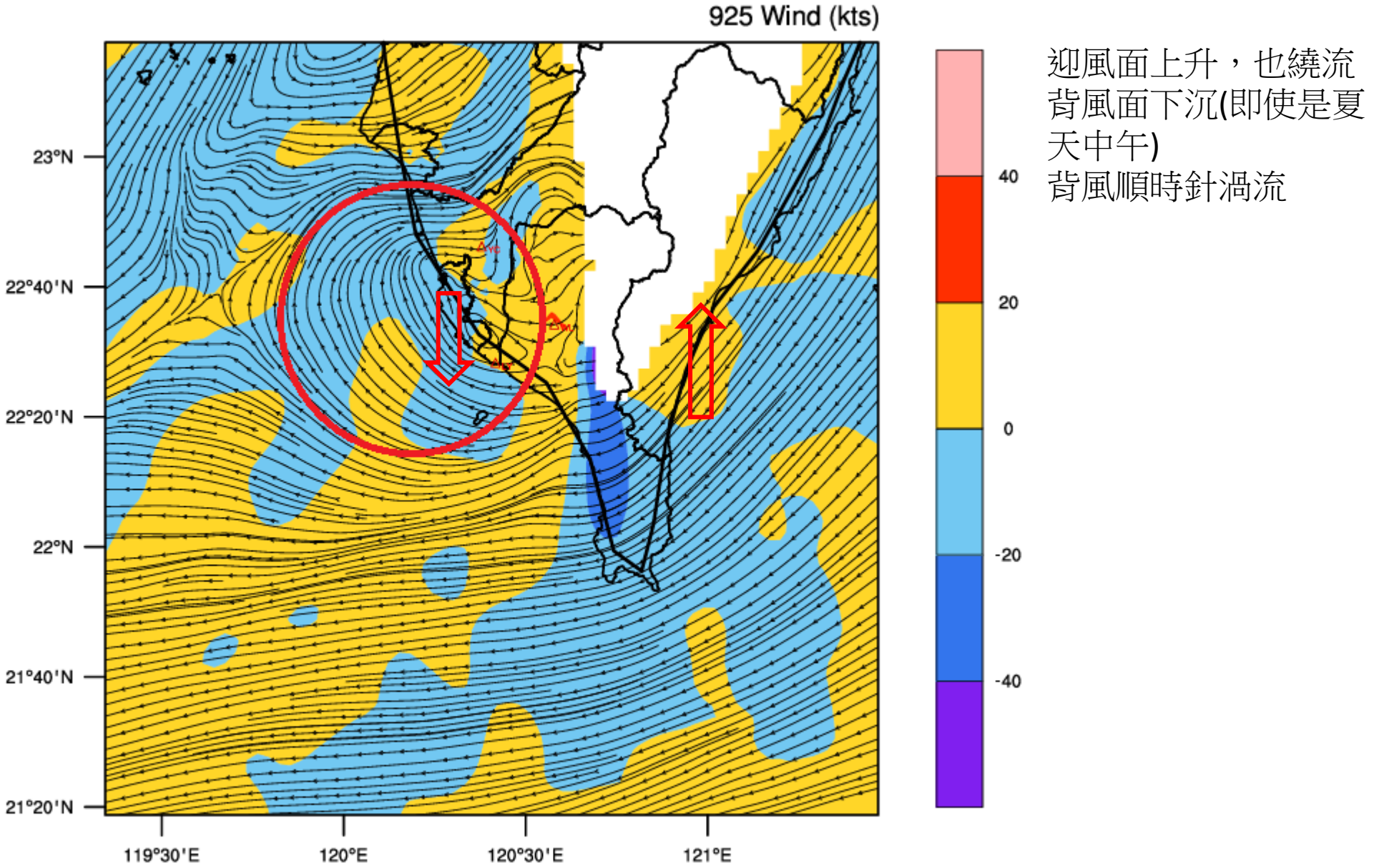
2017052612

$$\frac{\partial \omega}{\partial t}$$ 正比於

$$\frac{\nabla \rho \times \nabla p}{\rho^2}$$



產生負垂直渦度-反氣旋順轉



迎風面上升，也繞流
背風面下沉(即使是夏天中午)
背風順時針渦流

結論：

- 空氣汙染與渦流關係密切。
- 渦流、海陸風、邊界層結構密切相關。
- 台灣山脈造成複雜環流，渦流生成、發展、移動、週期，需更進一步分析。
- 釐清複雜地形的氣流行為，需要中尺度動力氣象理論與應用層面更廣泛的整合。