天 氣 學 二
(Synoptic Meteorology II)

上課時間: 10:20～12:10 Wednesday, B105

授課教師: 游政谷

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Course Outline:

1. Extratropical cyclones

Definition and Introduction, Cyclogenesis, Petterssen Eq., Precipitation and rainbands associated with EC

2. Applications of hydrodynamic theories on weather analysis

Quasi-geostrophic theory and its application, Vertical motions

3. Tropical cyclones

Introduction, Structure, Development and motion of tropical cyclones (typhoons).

4. Regional and Mesoscale scale weather systems

Frontal convection, land-sea breeze, Fohn, Mountain-valley winds, Orographic precipitation, Squall lines, Mesoscale Convective Systems, Severe Storms, etc.

(Chap. 4 mostly discussed in the Weather Lab)

天氣學講義:

請自行下載列印（可至中尺度暨地形降水研究室網頁，點選天氣學講義）

參考書名

陳泰然，1987：天氣學原理，聯經出版社，337頁。

李清勝，2014：天氣學講義。

Anthes, R., 1982：Tropical Cyclones - Their Evolution, Structures and Effects. *AMS*, 208pp.

Bluestein, H., 1992：Synoptic-Dynamic Meteorology in Mid-latitudes. Vol. I, Oxford, 431pp.

-----, 1993：Synoptic-Dynamic Meteorology in Mid-latitudes. Vol. II, Oxford, 594pp.

Lackmann, G., 2012: Midlatitude Synoptic Meteorology. Dynamics, Analysis, and Forecasting. AMS, 345pp.

Carlson, T. N., 1991: Mid-Latitude Weather Systems. London and New York, 505pp.

Petterssen, S., 1956：Weather Analysis and Forecasting. Vol. I, II, McGraw-Hill Book Company, 428pp & 266pp.

Wallace and Hobbs, 2006：Atmospheric Science : An Introductory Surrey (2nd Edition). Elsevier, 483pp.

Houze, R. A. Jr, 2014: Cloud Dynamics (2nd Edition). Elsevier, 432pp.

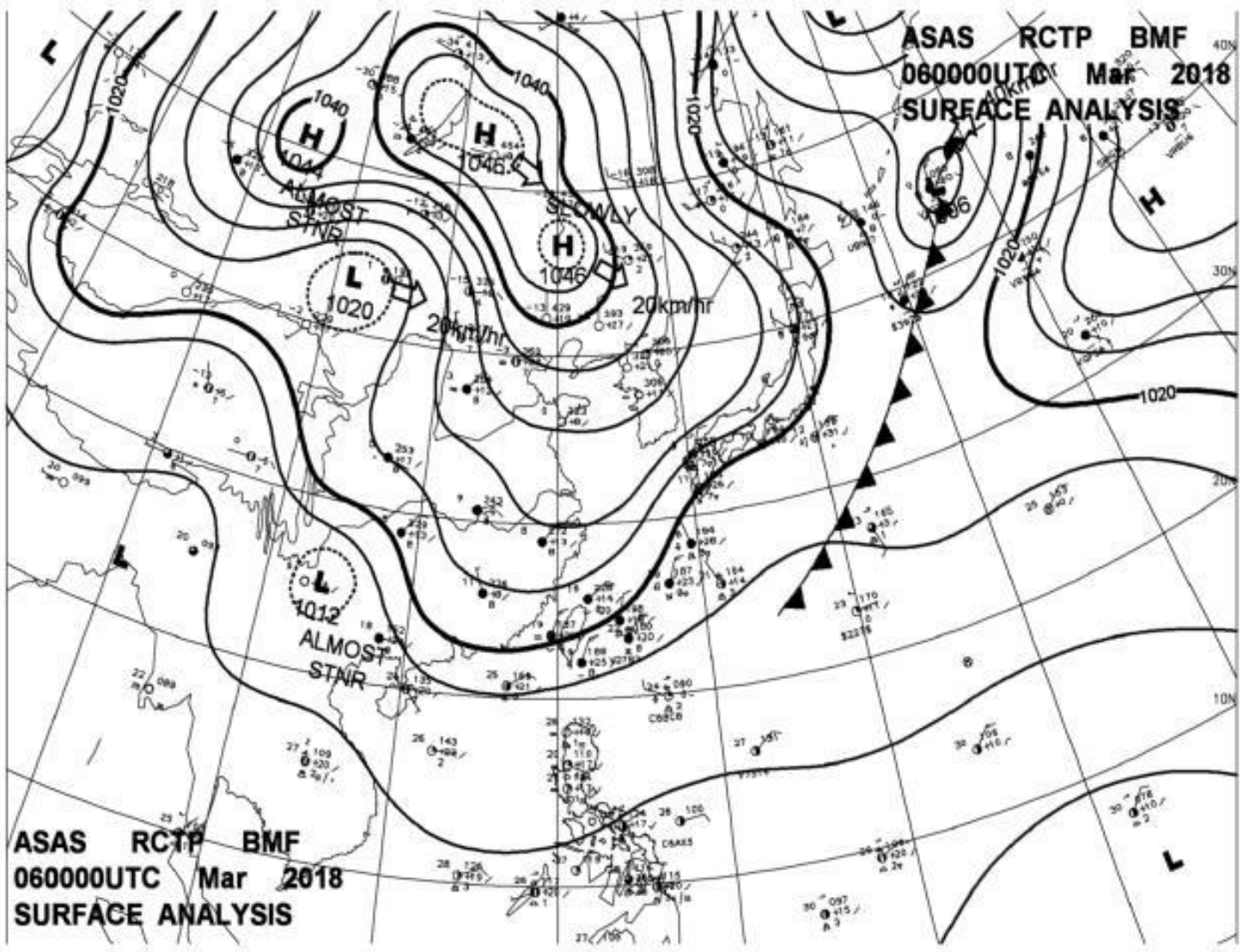
成績計算方式:

期中考試 30%
期末考試 35%
課堂表現 10%
作業成績 15%
出席率 10%

- 天氣學課程助教介紹
- 修課學生介紹
- 你仔細看過天氣圖嗎?有哪些天氣系統? 這些天氣系統的演變和重要性為何?

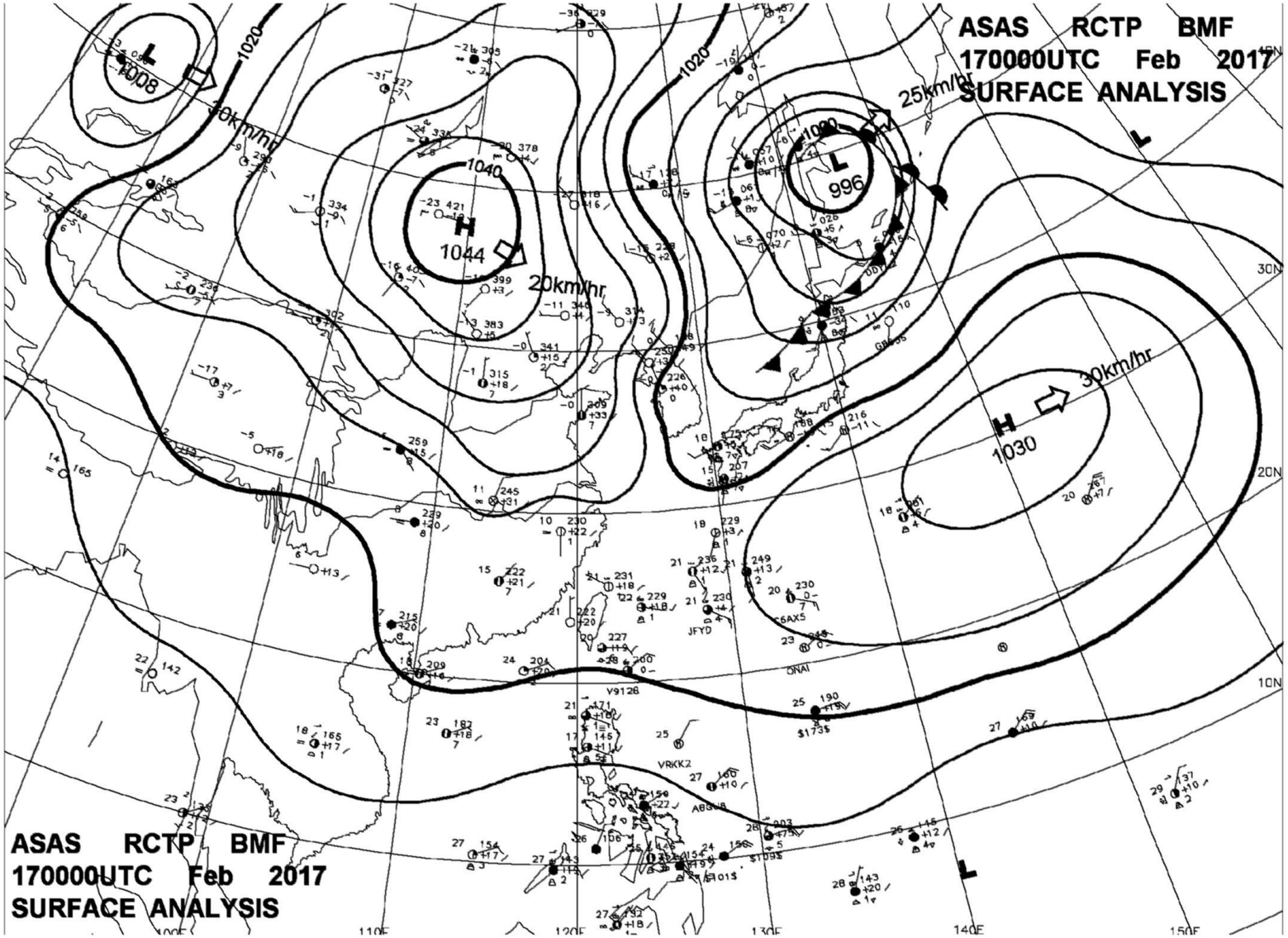
地面天氣圖 （早上8點, 6 March 2018 ）

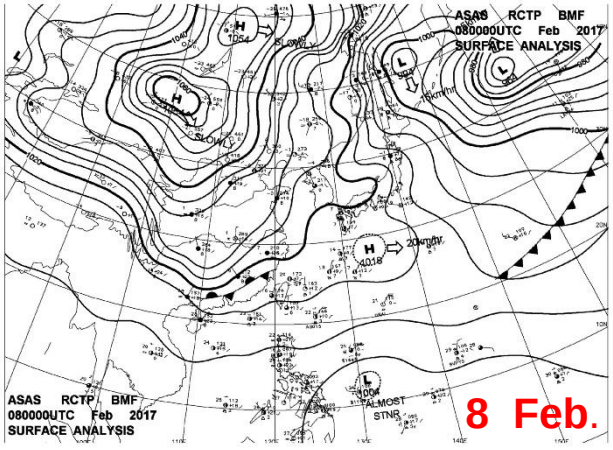
請指出有哪些天氣系統?



地面天氣圖 （早上8點, 17 Feb. 2017 ）

請指出有哪些天氣系統?

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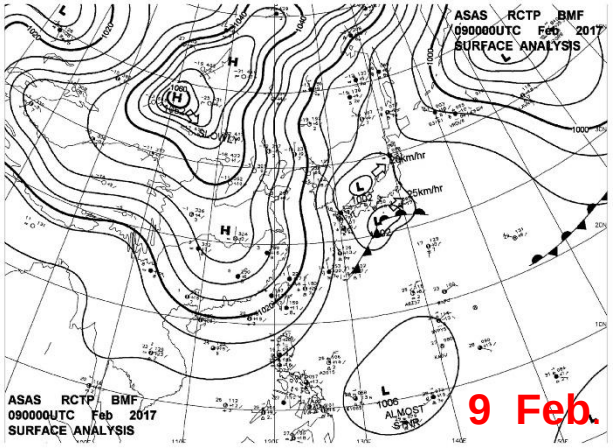
8 Feb.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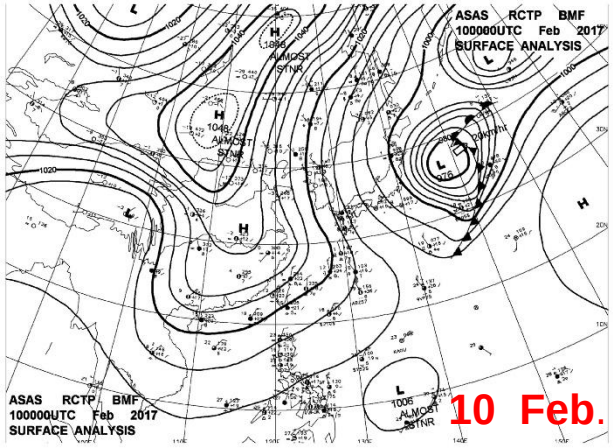
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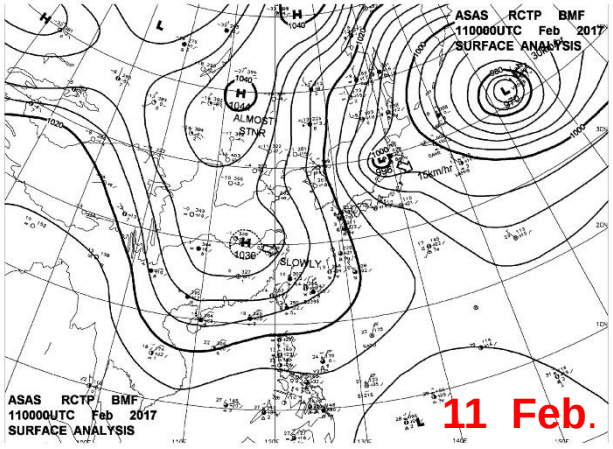
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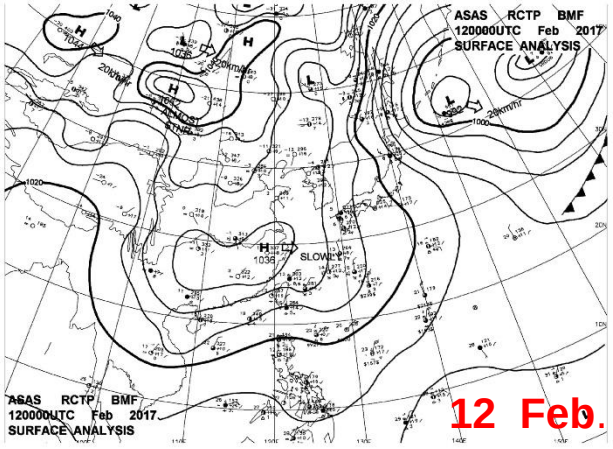
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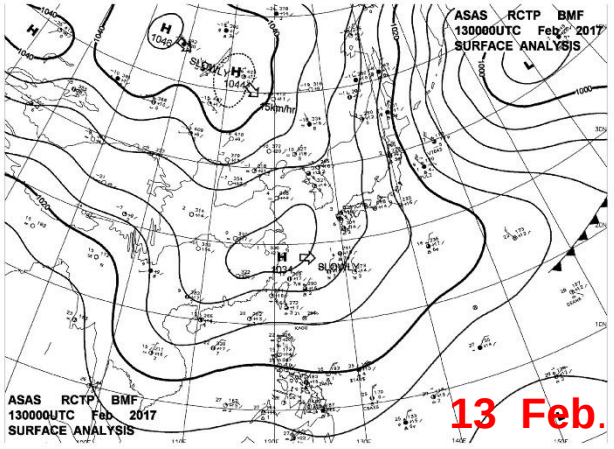
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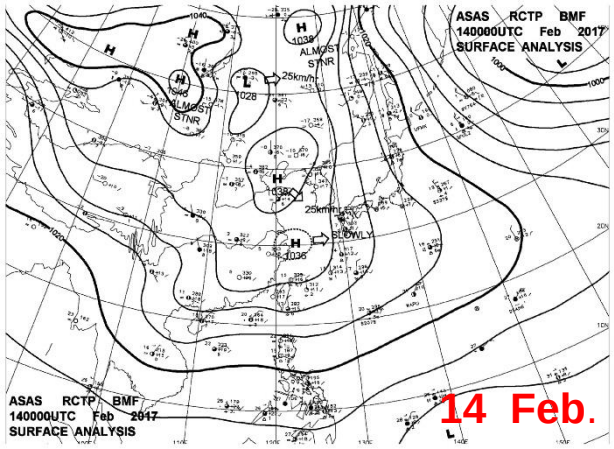
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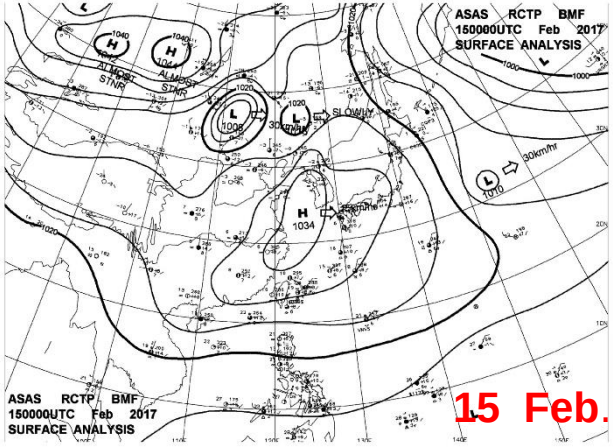
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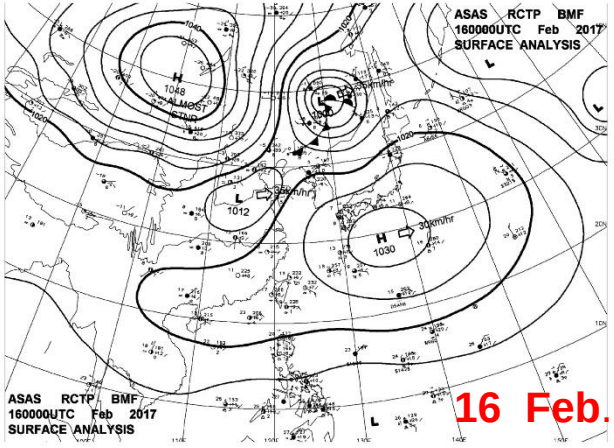
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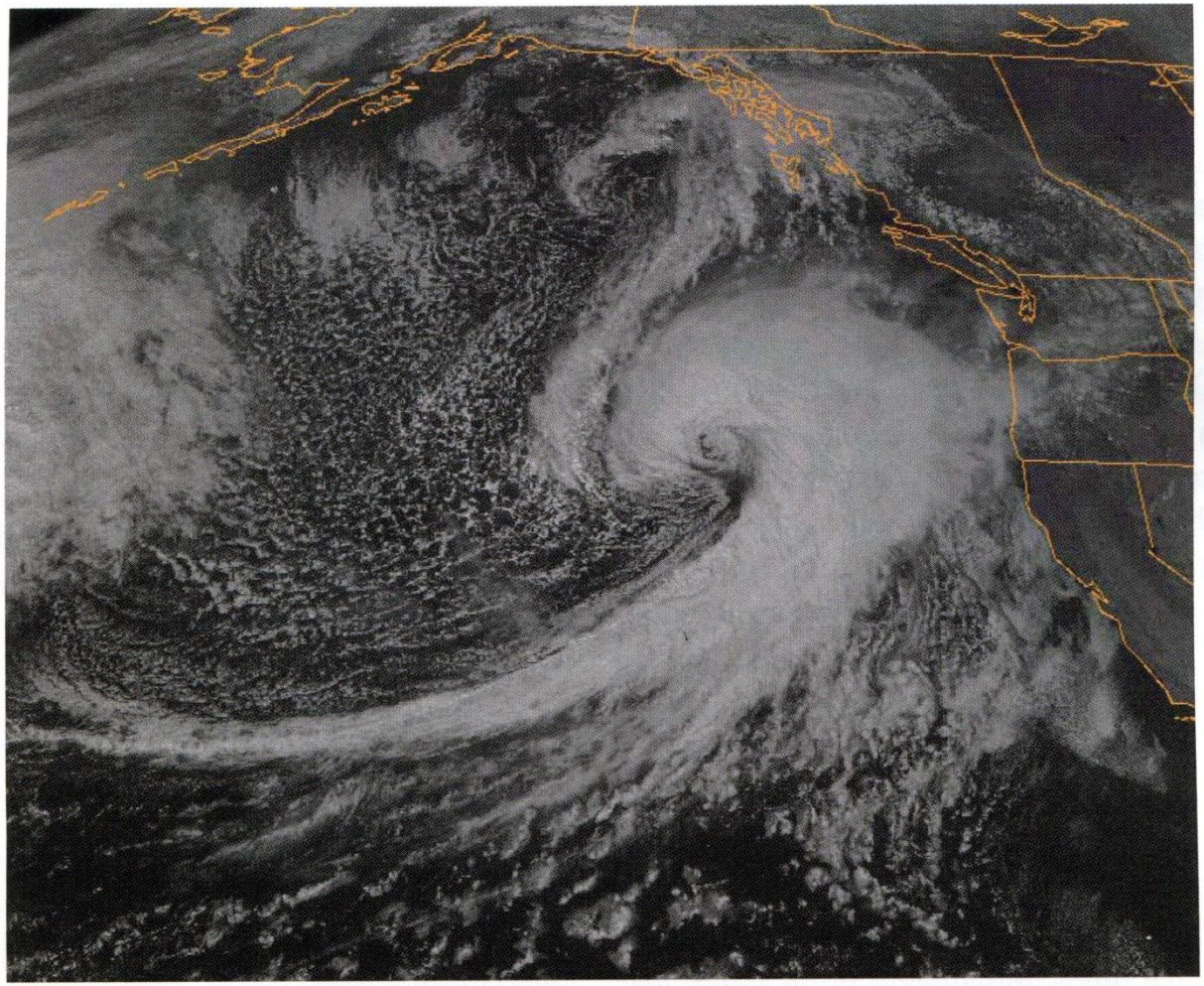
Chapter 1 Extratropical Cyclones

1.1 Definition and Introduction

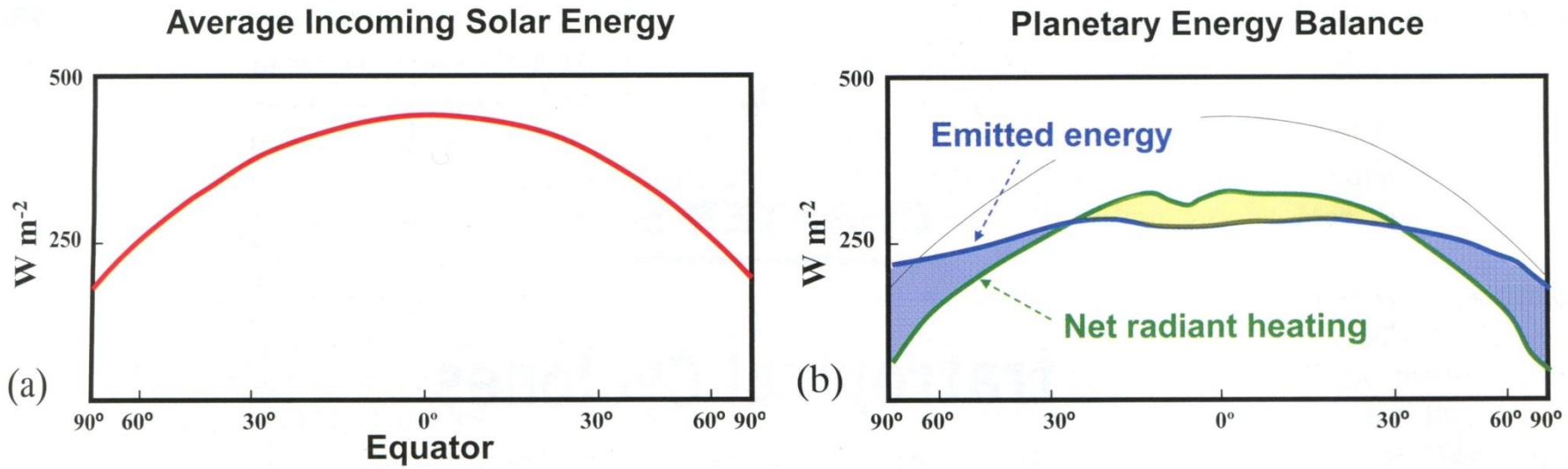


Geostationary Operational Environmental Satellite-8 (*GOES-11*) visible satellite image, 2200 UTC 8 Oct 2007.

Midlatitude weather is primarily influenced by some sort of traveling disturbance (e.g., a minimum in the pressure field), today, recognized as extratropical cyclones

溫帶氣旋經常伴隨顯著的雲雨系統或較劇烈的天氣

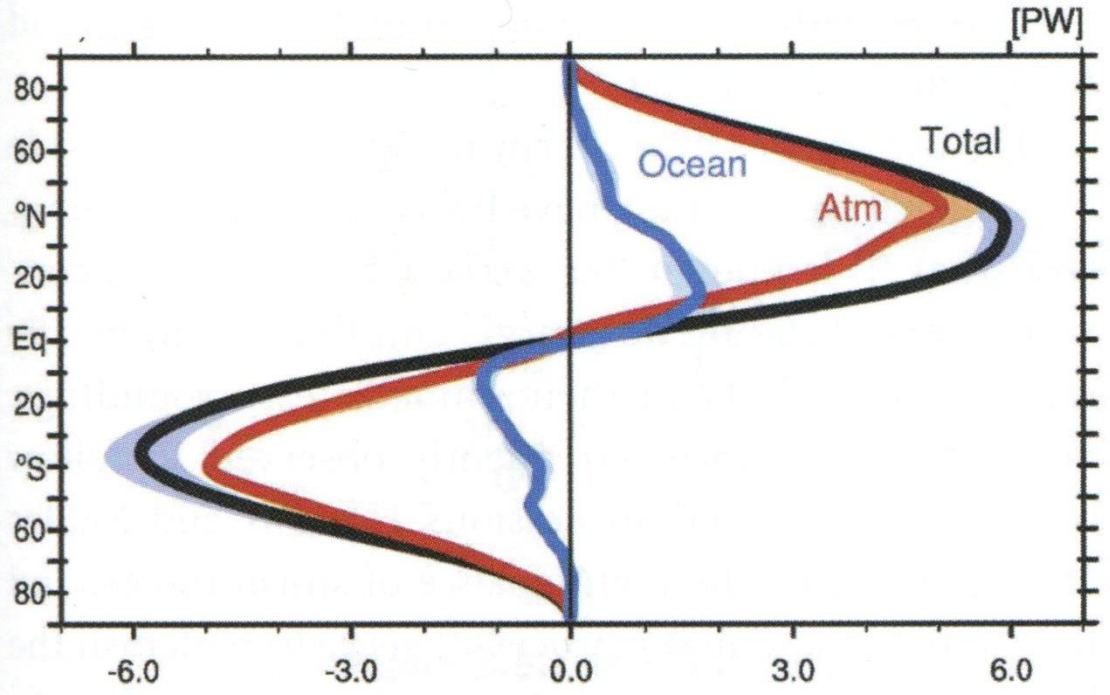
Roles of Cyclones in Earth's Climate System



(a) Average flux of solar radiation reaching the top of the atmosphere. (b) Thin black curve as in (a), blue curve is average outgoing radiant energy flux, green curve is net radiant heating, and shaded areas represent the difference between emission and absorption [adapted from Gill (1982), originally from Winston et al. (1979)].

根據圖b, 赤道低緯區域會持續增暖, 高緯極區會持續降溫, 但事實上並非如此? 為什麼?

Extratropical cyclones are essential disturbances acting to mix tropical and polar air and serving to reduce the overall equator-to-pole temperature gradient

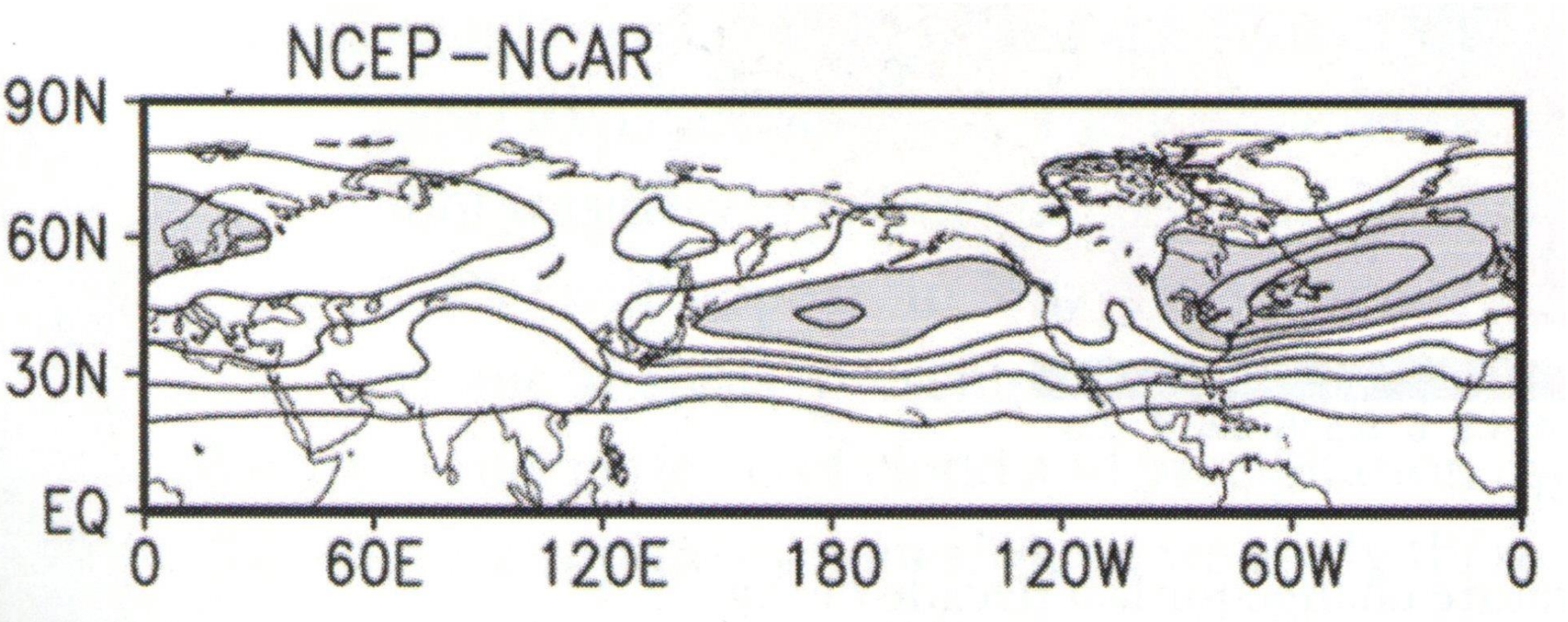


Annually and zonally averaged northward heat transport in petawatts (PW, 10^{15} W) to balance the net radiative imbalance; total transport shown by black curve, partitioned into atmospheric (red) and oceanic (blue) contributions. Uncertainty is shown as shading of the 2σ range. Negative values in the Southern Hemisphere are consistent with poleward transport there as well (from Fasullo and Trenberth 2008, their Fig. 7d).

年緯向平均向北熱能傳送分布
紅線: 大氣
藍線: 海洋
黑線: 大氣+海洋

熱能傳送最大值發生在中緯度

Northern Hemisphere storm track defined using the standard deviation of filtered 500-mb geopotential height from NCEP-NCAR reanalysis during 1982-94 (Chang 2009)



Obvious zonal variations of storm track and note maximum over the ocean (why?)

溫帶氣旋(extratropical cyclone, sometimes called extratropical low, extratropical storm)的定義:

Any cyclonic-scale (1000-4000 km) storm that is not a tropical cyclone, usually referring only to the **migratory frontal cyclones (移行鋒面氣旋)** of middle and high latitudes. [AMS Glossary of Meteorology]

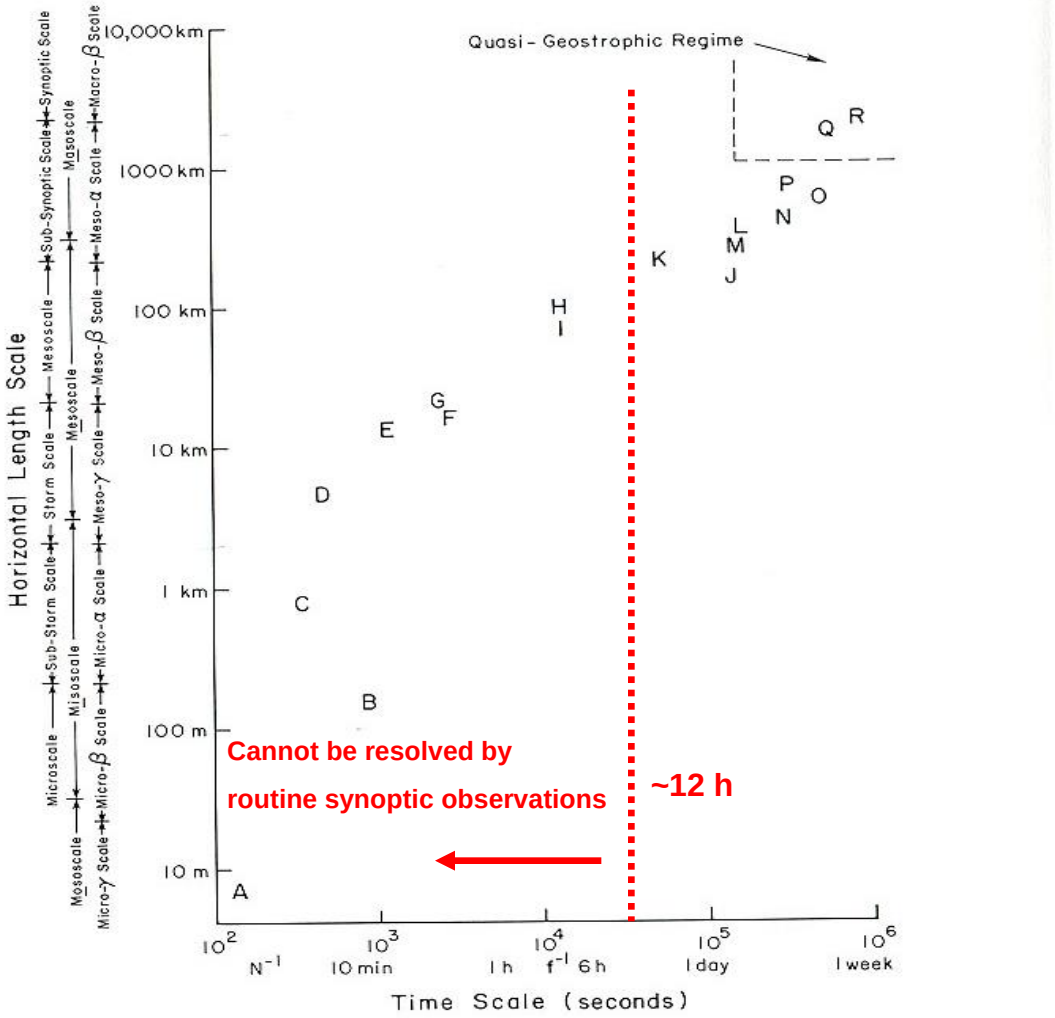
氣旋（cyclone）原指氣旋式旋轉之封閉環流（close circulation），但目前則傾向於指氣旋尺度（1000~4000 km）之環流。溫帶氣旋之英文為extratropical cyclone，即為非熱帶氣旋之氣旋尺度風暴（cyclone-scale storm），故包含位於中、高緯度之氣旋。然而若照中文字義，溫帶氣旋和mid-latitude cyclone較一致，Carlson的書名即為〝Mid-latitude Weather Systems〞；不過由於中緯和高緯之氣旋結構和特徵相同，且有別於熱帶氣旋，故midlatitude cyclone和extratropical cyclone通用。

Weather systems on or near the ground

Disturbance	Scale	Duration	Max. wind
Extratropical cyclone	500–2000 km	3–15 days	55 m s^{-1}
Cold front	500–2000 km	3–7 days	25 m s^{-1}
Anticyclone	500–2000 km	3–15 days	10 m s^{-1}
Warm front	300–1000 km	1–3 days	15 m s^{-1}
Hurricane	300–2000 km	1–7 days	90 m s^{-1}
Tropical cyclone	300–1500 km	3–15 days	33 m s^{-1}
Tropical depression	300–1000 km	5–10 days	17 m s^{-1}
Dry front	200–1000 km	1–3 days	20 m s^{-1}
Midget typhoon	50–300 km	2–5 days	50 m s^{-1}
Mesohigh	10–500 km	3–12 h	25 m s^{-1}
Gust front	10–300 km	0.5–6 h	35 m s^{-1}
Mesocyclone	10–100 km	0.5–6 h	60 m s^{-1}
Downslope wind	10–100 km	2–12 h	55 m s^{-1}
Macroburst	4–20 km	10–60 min	40 m s^{-1}
Microburst	1–4 km	2–15 min	70 m s^{-1}
Tornado	30–3000 m	0.5–90 min	100 m s^{-1}
Suction vortex	5–50 m	5–60 s	140 m s^{-1}
Dust devil	1–100 m	0.2–15 min	40 m s^{-1}

Scale and duration of middle- and high-level disturbances

Disturbance	Horizontal scale	Duration
Long wave	8000–40000 km	15+ days
Short wave	3000–8000 km	3–15 days
Cyclone wave	1000–3000 km	2–5 days
Jet stream	1000–8000 km	5–15 days
Low-level jet	300–1000 km	1–3 days
Jet streak	200–1000 km	2–5 days
Anvil cluster (MCC)	50–1000 km	3–36 h
Individual anvil	30–200 km	1–5 h
Supercell storm	20–50 km	2–6 h
Cumulonimbus	10–30 km	1–3 h
Cumulus	2–5 km	10–100 min
Overshooting dome	2–5 km	2–10 min
Tornado vortex signature	1–5 km	20–90 min
Overshooting turret	100–500 m	1–3 min
Thermal	100–1000 m	5–20 min
In-cloud turbulent eddy	10–100 m	Variable



Horizontal-length scales and time scales for the following atmospheric phenomena: A, dust devils; B, tornadoes and waterspouts; C, cumulus clouds; D, downbursts; E, gust fronts; F, mesocyclones; G, thunderstorms; H, sea/land/lake breezes, mountain–valley circulations, and meso-highs and meso-lows; I, precipitation bands; J, coastal fronts; K, mesoscale convective systems; L, the low-level jet; M, the dryline; N, "bombs" and tropical cyclones; O, upper-level jets; P, surface fronts; Q, extratropical cyclones and anticyclones; and R, troughs and ridges in the baroclinic westerlies.

Q: Extratropical cyclones and anticyclones

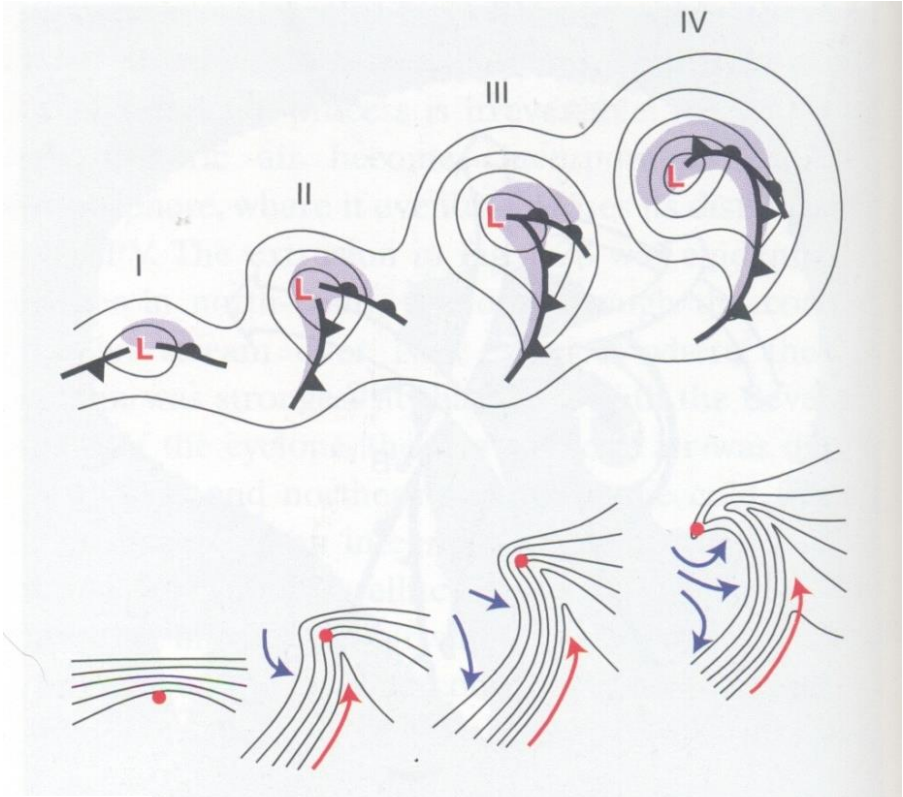
R: Troughs and ridges in the baroclinic westerlies

Only Q and R fit well in the quasi-geostrophic regime

Timeline of events and advances both within and outside the field of meteorology.

	1850	1850 British Meteorological Society (later Royal Meteorological Society) founded
U.S. Civil War (1861-65) First Trans-Atlantic Telegraph	1860	
	1870	1870 U.S. Weather Bureau established
		1872 publication of *Monthly Weather Review* by U.S. Weather Bureau
	1880	
1887 Hertz: first radio transmission		
	1890	1890 U.S. Weather Bureau becomes civilian
First zeppelin airship	1900	
Dec. 1903 Wright Bros. 1st flight		1904: V. Bjerknes outlines numerical weather prediction
First AM radio broadcast		
	1910	
World War I (1914-1918)		1919 Founding of American Meteorological Society
	1920	1922 Richardson publishes results of first NWP effort
1927: Lindbergh- First solo trans-Atlantic flight		1928: CFL condition for numerical stability published
	1930	
		First U.S. radiosonde launch
World War II (1939-1945) 1st electronic computers	1940	

Norwegian polar front cyclone model devised by J. Bjerknes and collaborators of the Bergen School during 1920s.

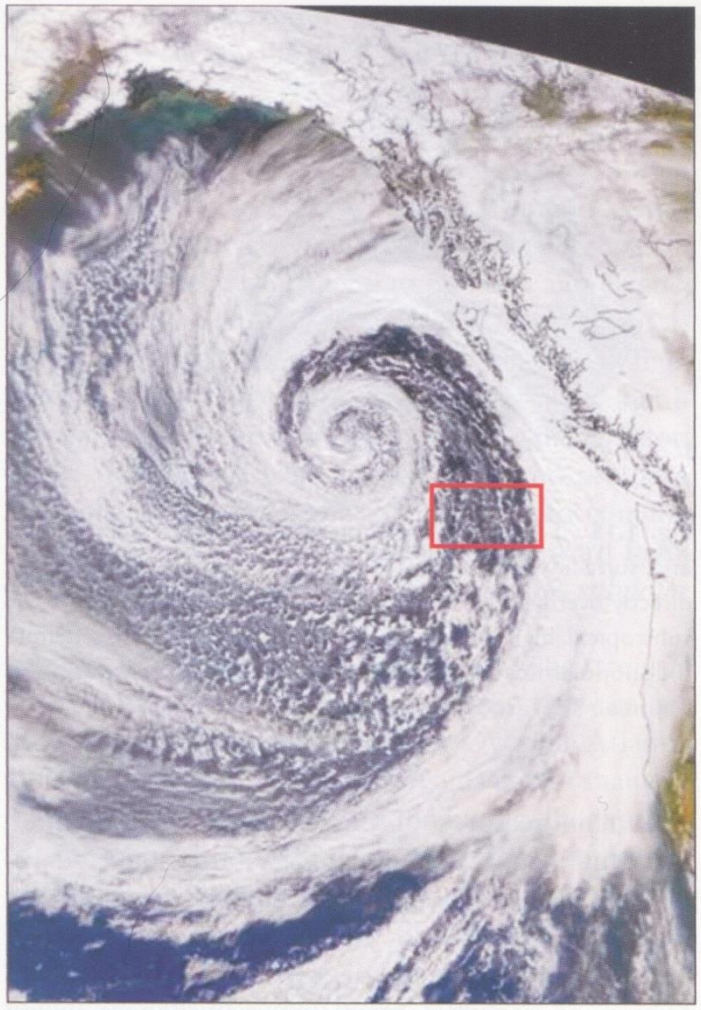


Schematic showing four stages in the development of extratropical cyclones as envisioned in the Norwegian polar front cyclone model. Panels I, II, III and IV represent four successive stages in the life cycle. (Top) Idealized frontal configurations and isobars. Shading denotes regions of precipitation. (Bottom) Isotherms (black) and airflow (colored arrows) relative to the moving cyclone center (red dot). Red arrows indicate the flow in the warm sector, and blue arrows indicate the flow in the cold air mass. Frontal symbols are listed in Table 7.1. [Adapted from *Mon. Wea. Rev.*, **126** (1998) p. 1787.]

上圖:
陰影區代表降水區

下圖:
紅點代表氣旋中心
實線代表等溫線
藍(紅)色箭頭代表相對於氣旋中心的暖(冷)區氣流形式

An example of extratropical cyclone not fitting the cyclone model



An intense extratropical cyclone over the North Pacific. The spiral cloud pattern, with a radius of nearly 2000 km, is shaped by a vast counterclockwise circulation around a deep low pressure center. Some of the elongated cloud bands are associated with frontal zones. The region enclosed by the red rectangle is shown in greater detail in Fig. 1.21. [NASA MODIS imagery. Photograph courtesy of NASA.]

Cloud pattern of a tropical cyclone

The cloud pattern associated with Hurricane Floyd September 14, 1999. The eye of the hurricane is clearly visible. The radius of the associated cloud system is ~600 km. Data from NOAA GOES satellite imagery. [Photograph courtesy of Harold F. Pierce, Laboratory of Atmosphere, NASA Goddard Space Flight Center.]

Some of the most intense cyclones developing over the ocean exhibit significant departures from the cyclone model, especially with warm core, spiral cloud bands coiled up tightly about the cyclone center, and stronger warm front.

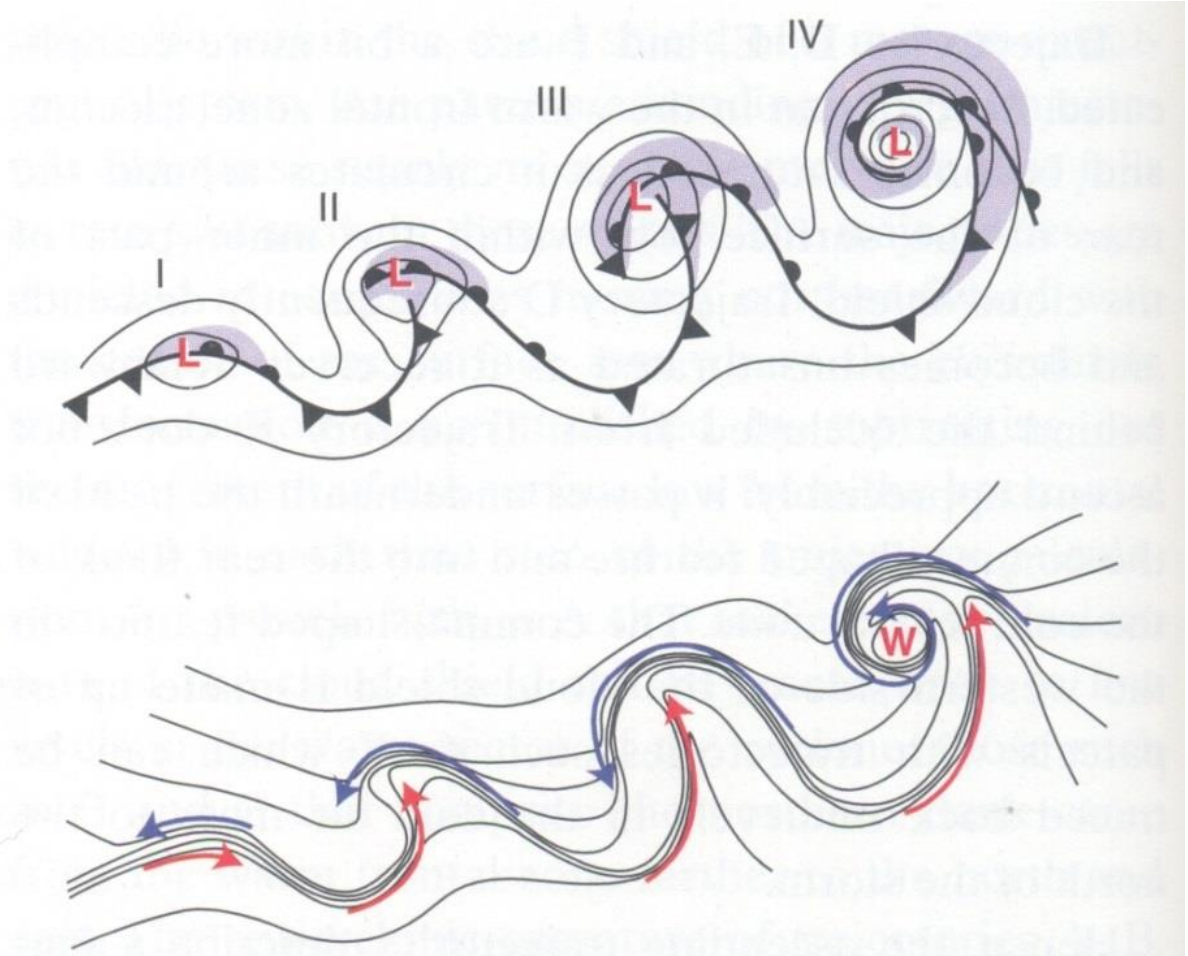


Fig. 8.32 As in Fig. 8.31 but for tightly coiled, warm core storms. [From *Extratropical Cyclones: The Erik Palmén Memorial Volume*, Amer. Meteorol. Soc. (1990) p. 188.]