天 氣 學 二
(Synoptic Meteorology II)

上課時間: 10:20～12:10 Wednesday, B105

授課教師: 游政谷

email: yuku@ntu.edu.tw

Chapter 3 Tropical Cyclones

3.3 Development and motions of TCs

Conditional Instability of Second Kind (CISK): Positive feedback between cumulus convection and large-scale rotational circulation

CISK scenario: Latent heat release associated with convection produces warm anomaly aloft, decreases surface pressure and increase radial pressure gradient force, enhance rotational flow and favor low-level frictional convergence, and then promote convection and latent heat release

Note that CISK requires a preexisting low pressure disturbance

Effective operation of CISK depends strongly on the relative scale of heating size (L, cloud clusters) and Rossby radius of deformation (L_R)

Schematic depiction of CISK

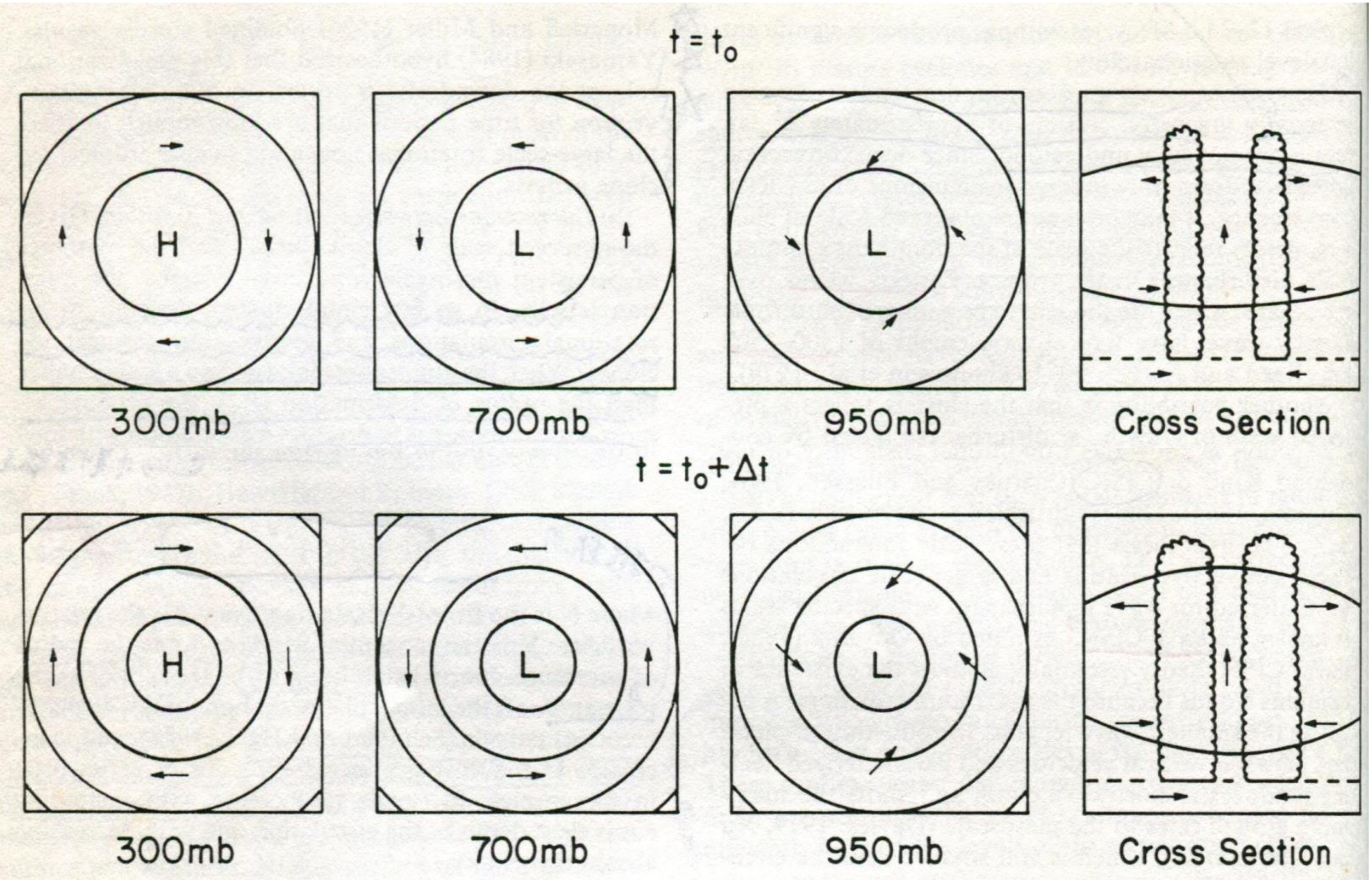


Fig. 3.25 Schematic depiction of CISK. Initially there is an anticyclone aloft and a cyclone in the lower troposphere. Ekman convergence in the boundary layer provides moisture to a population of precipitating clouds. Most of the diabatic heat source is balanced by the adiabatic cooling associated with the induced transverse circulation. However, there is a slight warming and accompanying thickness change, yielding a more intense anticyclone aloft, a more intense cyclone below, increased Ekman convergence, more clouds, etc. (Schubert and Hack, 1982).

When consider only earth rotation, L_R physically represents the traveling distance of gravity waves on the temporal scale of f^{-1}, expressed as

$$L_R = \frac{\sqrt{gH}}{f}$$

where g is gravity and H is the mean depth of the fluid

A general expression of L_R applicable for tropical cyclones is

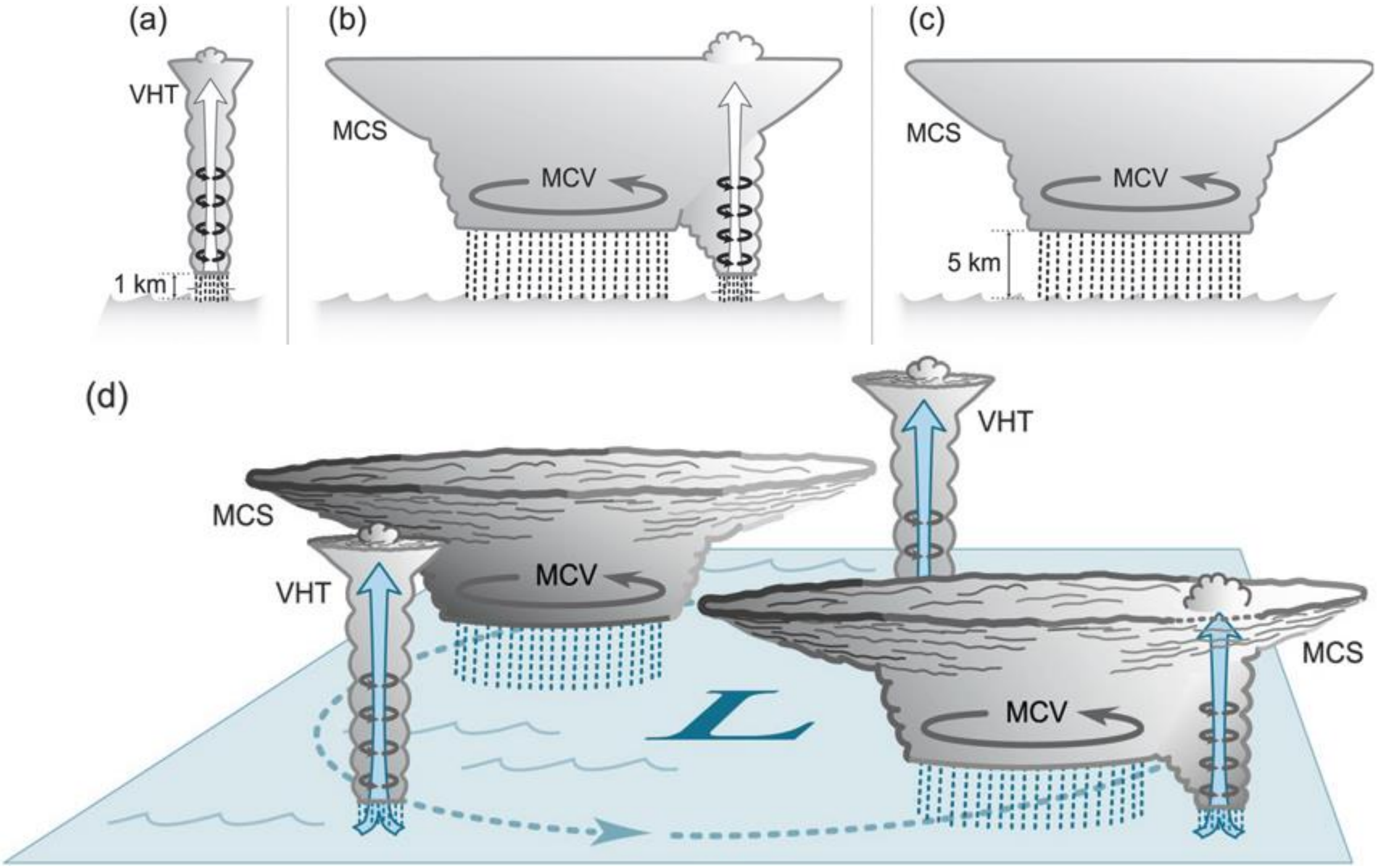
$$L_R = \frac{NH}{(f+\zeta)^{1/2}(\frac{2V}{r}+f)^{1/2}}$$

where N is the Brunt-vaisala frequency, ζ is the relative vorticity, V is the tangential wind, r is the radius of flow curvature; the denominator represents the inertial stability

When $L > L_R$, wind field is adjusted to mass field, and vice versa

What is the physical meaning of L/L_R? How to reduce the ratio?

Roles of MCVs in contributing to tropical cyclogenesis (Houze 2010)



Factors influencing motions of tropical cyclones

- **Environmental steering**

Considerable uncertainty as to the atmospheric level or layer that primarily determines the tropical cyclone motion

- **β effect**
- **Structural characteristics (Storm-scale asymmetries)**
- **Orographic and frictional effect**
- **Interaction between tropical cyclones (Fujiwhara effect, 藤原效應)**
- **Non-linear interaction between tropical cyclones and environment**

Comparison between the mean currents and mean motions for five tropical cyclones (dashed arrows represent cyclone motions)

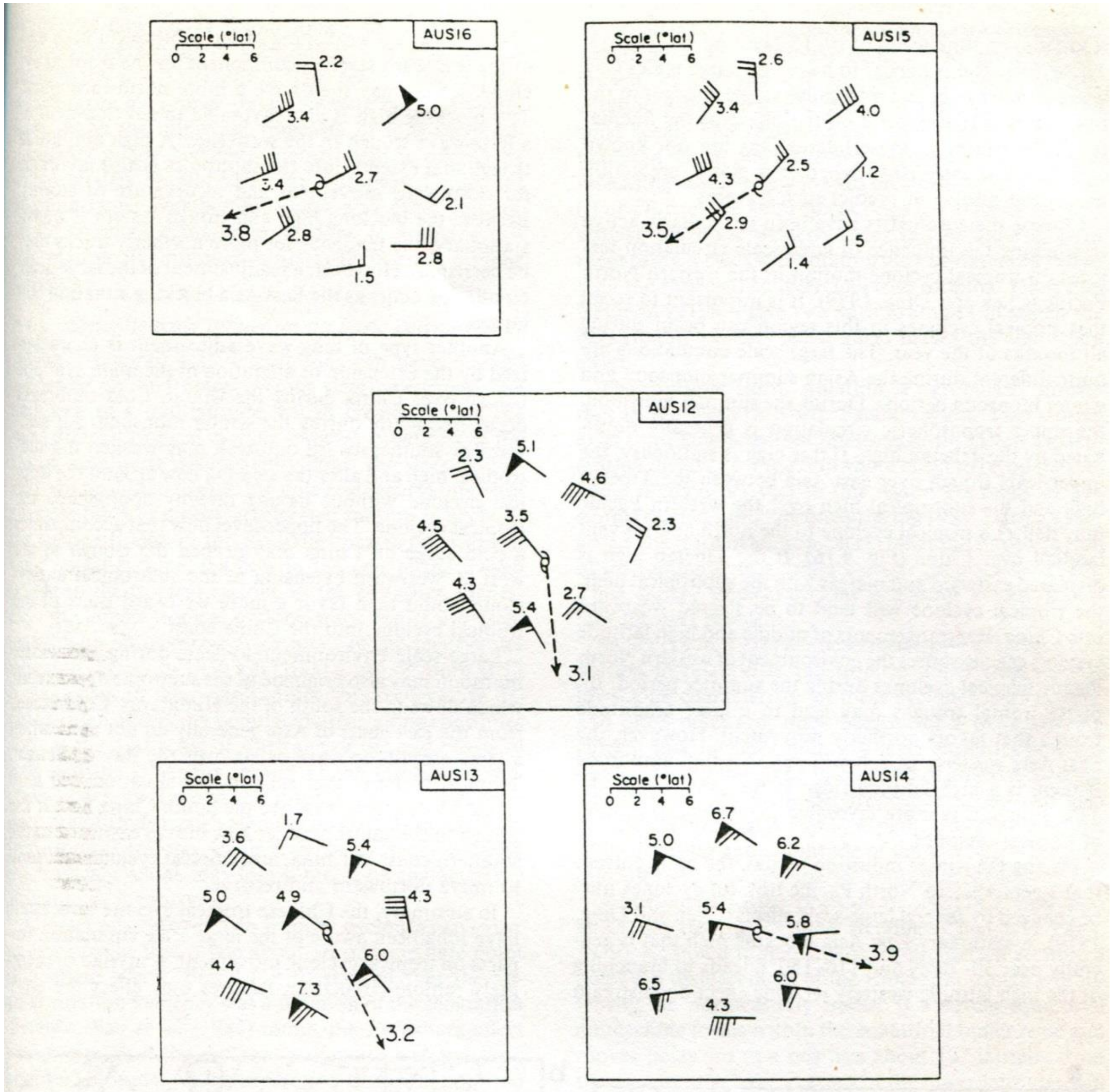


Fig. 4.15 Basic currents and mean motion for five composite Southern Hemisphere cyclones (after Holland, 1984). Each inset contains the 800–300 mb mass-weighted mean current (after the symmetric cyclone wind field has been removed) at eight octants and a nominal radius of 6° latitude. The azimuthally averaged basic current is shown at the center, and the cyclone motion is indicated by the dashed arrow. Speed convention is one barb = 1 m s^{-1} and actual speeds are also shown.

Schematic illustrating vorticity tendency caused by β effect in a tropical cyclone

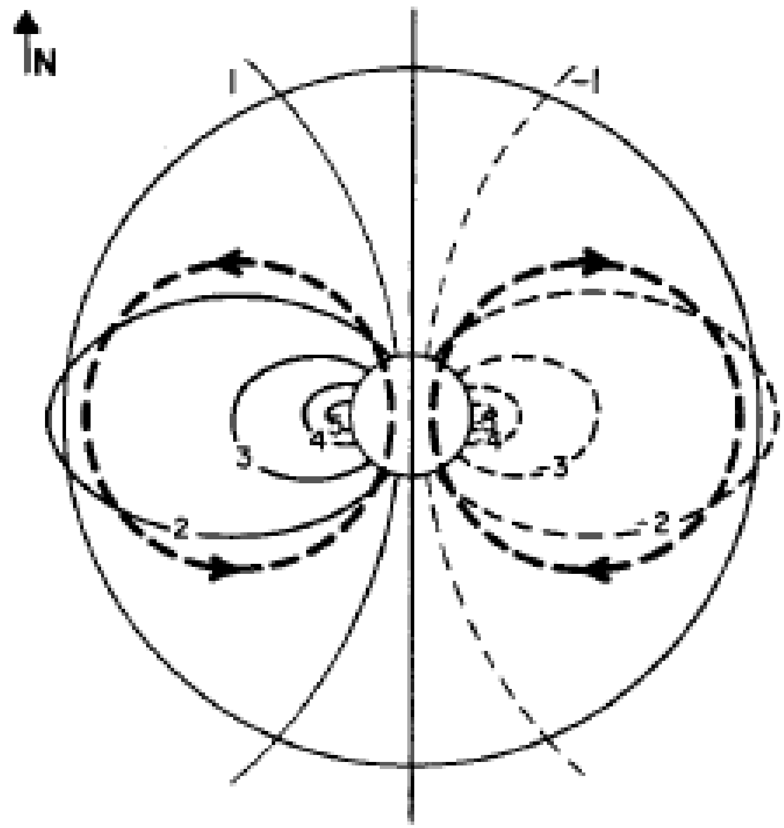
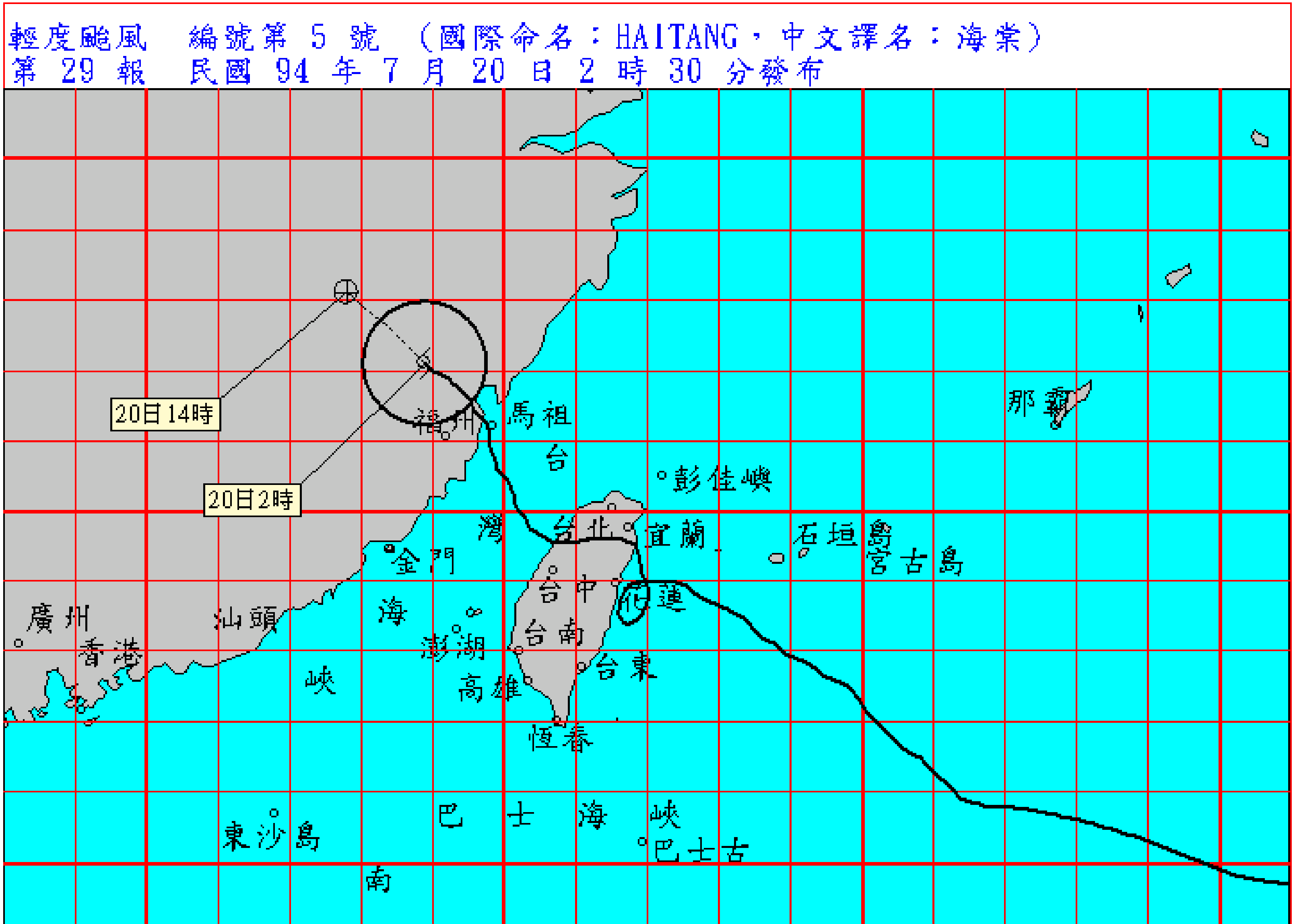
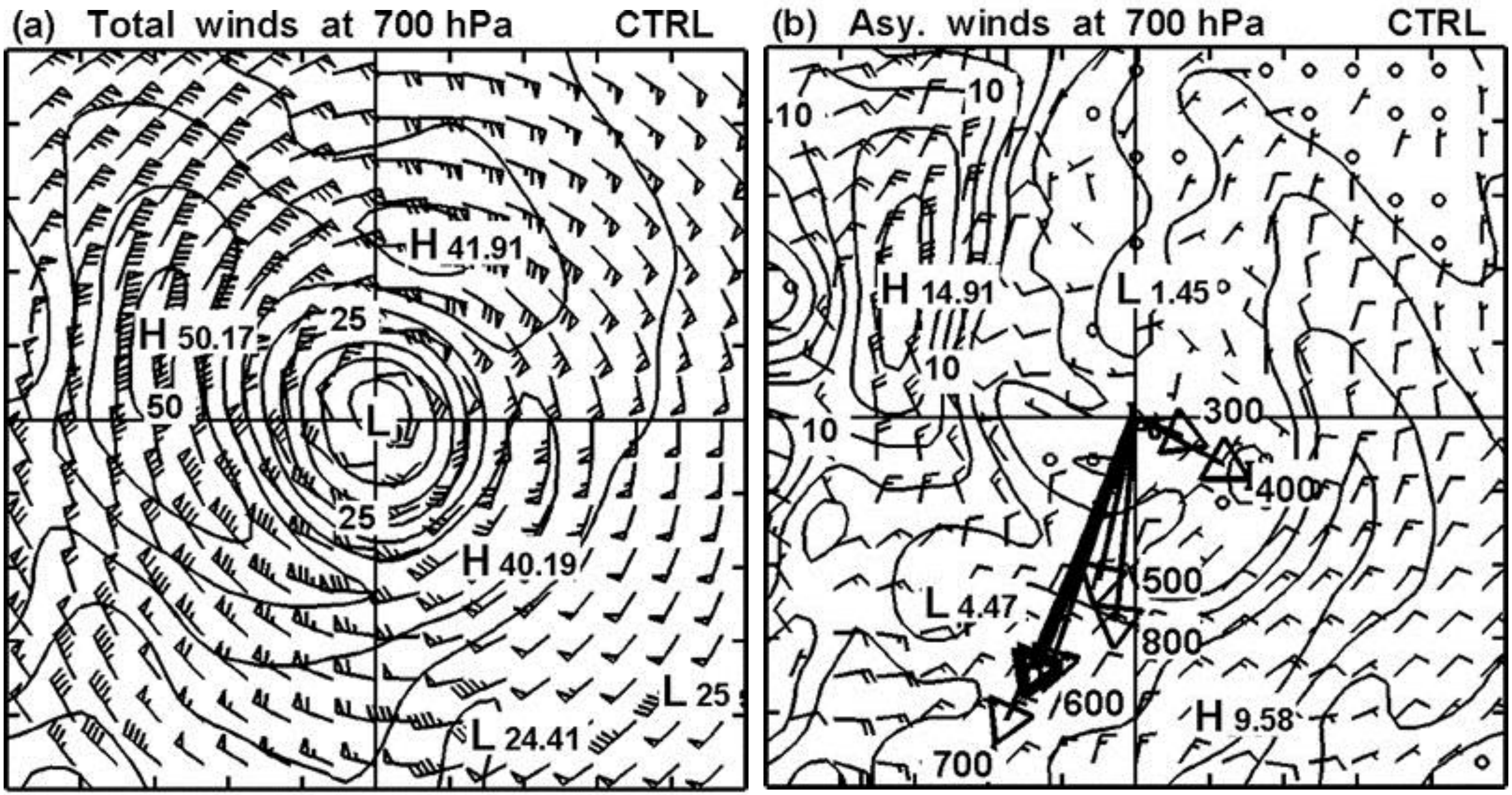


FIG. 3. Field of $\partial\zeta/\partial t$, in arbitrary units, centered on a symmetric, nondivergent Northern Hemispheric cyclone on a beta plane with no basic flow. Heavy dashed lines show the induced secondary circulation as a result of the vorticity changes.

A looping track of Typhoon Haitang (2005) as it approached the eastern coast of Taiwan



Simulated total winds and asymmetric winds for Typhoon Haitang (2005) (Jian and Wu 2008)



(a) Simulated total wind fields (contour interval of 5 m s^{-1}) and (b) the asymmetric wind fields (contour interval of 2 m s^{-1}) at 700 hPa from experiment CTRL after 33-h model simulation (one full wind barb = 5 m s^{-1}). The boldface arrow in (b) indicates the storm motion vector (3.3 m s^{-1}). The open arrows show the average asymmetric flow within 100-km radius from the storm center at the indicated vertical levels (hPa). The domain in each panel is 200 km × 200 km

Fujiwhara effect associated with Typhoon Parma and Melor (2009) with a distance of ~1200 km