天 氣 學 二
(Synoptic Meteorology II)

上課時間: 10:20～12:10 Wednesday, B105

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Chapter 2 Quasi-geostrophic Theory and Its Application

2.4 Computation and measurements of vertical motions

- ω Equation
- The kinematic method
- The adiabatic method
- Radar-derived vertical velocities

  --- Conventional Doppler radar

  --- Vertical-pointing Doppler radar
- In-situ measurements of vertical velocity by aircraft and Ultrasonic Anemometer

QG Omega Equation

$$\left(\nabla^2 + \frac{{f_0}^2}{\sigma}\frac{\partial^2}{\partial p^2}\right)\omega = \frac{f_0}{\sigma}\frac{\partial}{\partial p}\left[\overrightarrow{V_g}\cdot\nabla\left(\frac{1}{f_0}\nabla^2\Phi + f\right)\right] + \frac{1}{\sigma}\nabla^2\left[\overrightarrow{V_g}\cdot\nabla\left(-\frac{\partial\Phi}{\partial p}\right)\right]$$

Advantage: Vertical motions can be estimated through geopotential height information

Disadvantage: Complicated computation and the uncertainties associated with non-QG forcings (e.g., topographic effects, friction, and convection)

The kinematic method

Continuity equation

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial \omega}{\partial p} = 0$$

Advantage: No particular assumption for estimating vertical motions

Disadvantage: Require horizontal divergence information that is usually difficult to measure accurately on the synoptic scale

The adiabatic method

Thermodynamic equation

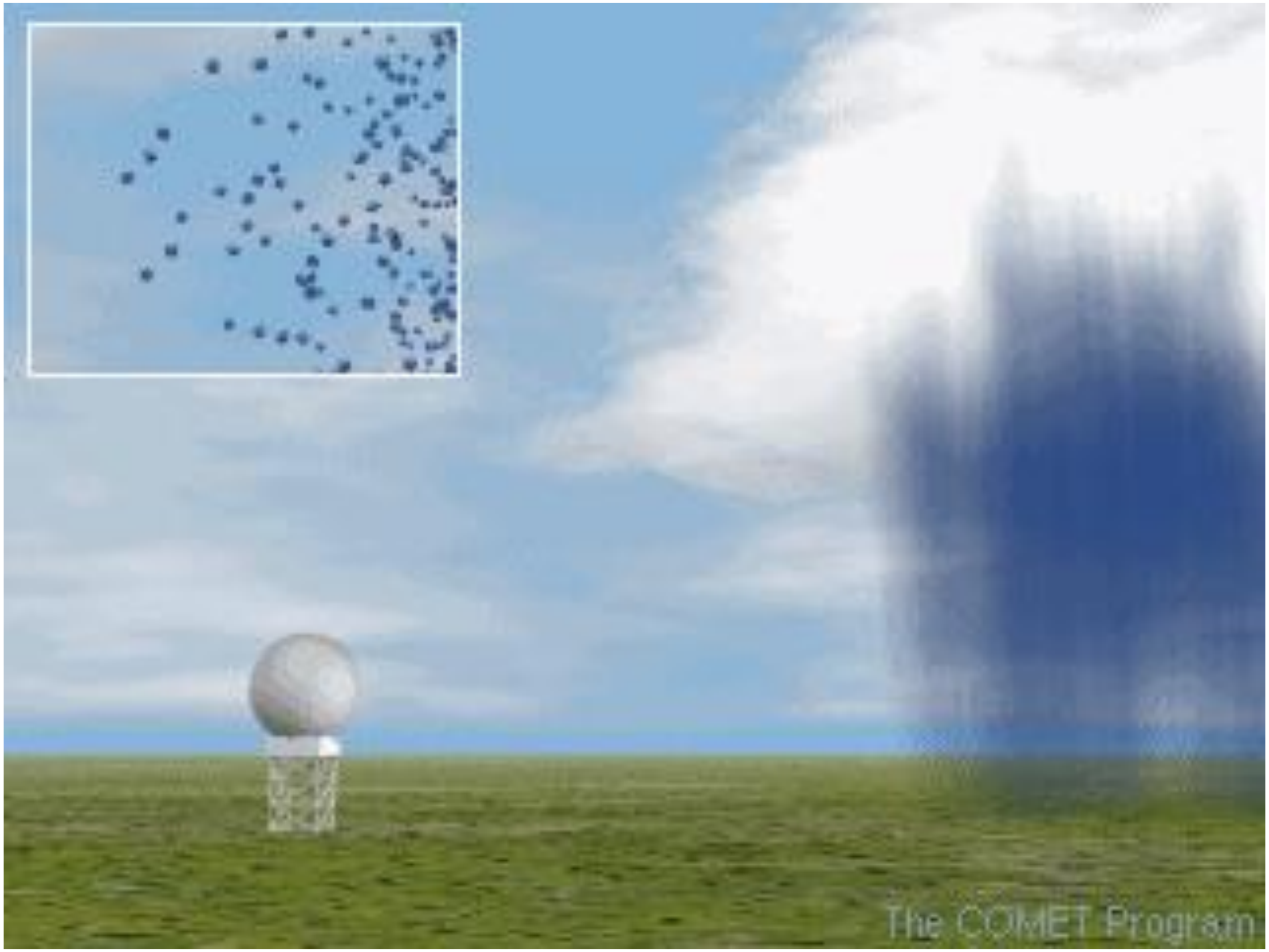
$$\left(\frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y}\right)_p - S_p\omega = \frac{\dot{q}}{c_p}$$

Advantage: No need for the measured divergence

Disadvantage: Local rate of change of temperature is difficult to estimate over a wide area, and the uncertainties associated with diabatic effects.

Radar-derived vertical motions

氣象都卜勒雷達藉由反射電磁波來反推空間的風場與降雨資訊

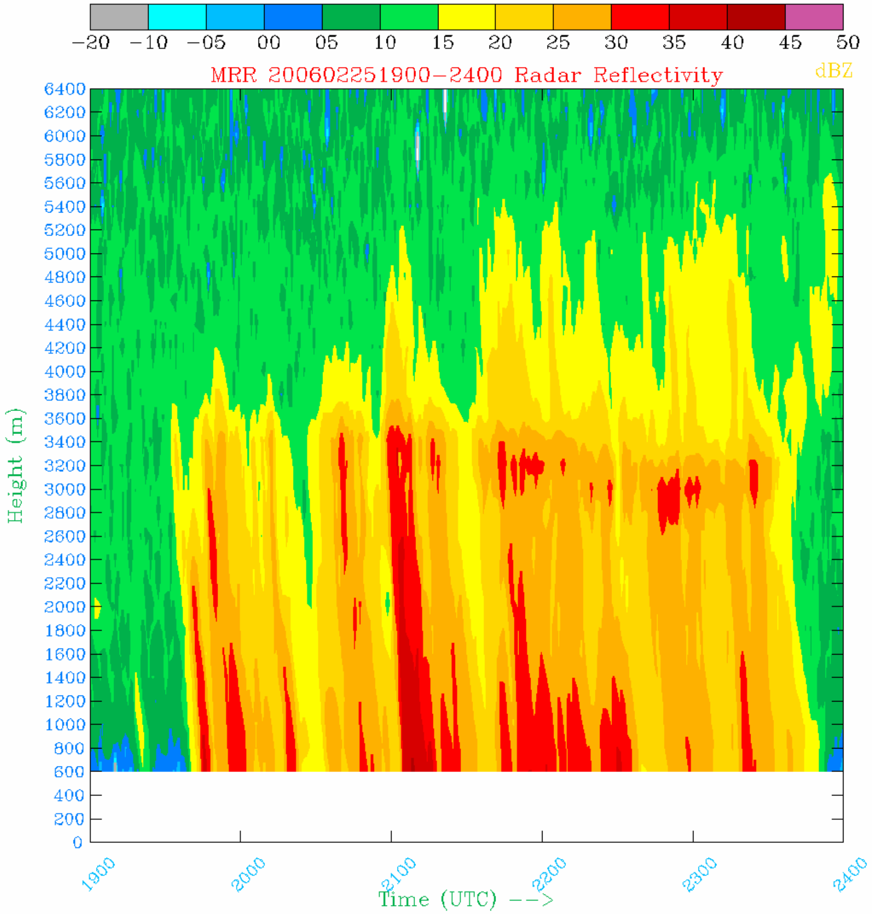


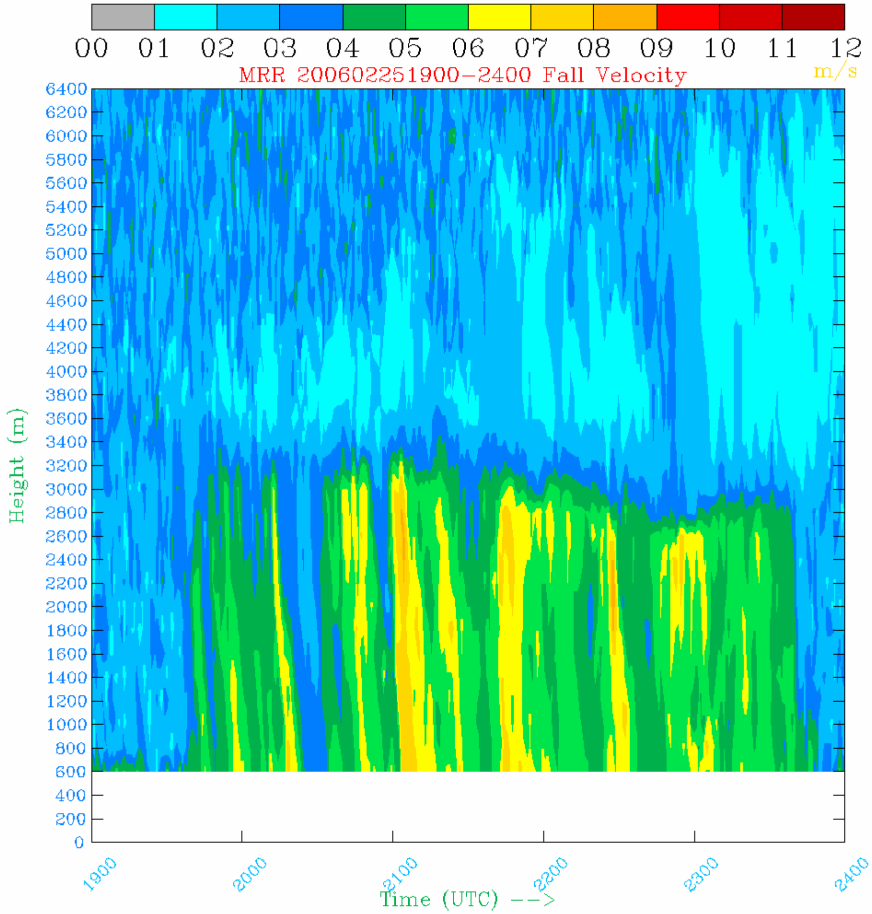
氣象都卜勒雷達可獲得準確的水平風場，再利用anelastic continuity equation
經由垂直積分進一步獲得垂直速度

Photo of the MRR

Damage by Typhoon Haitang 18 July 2005

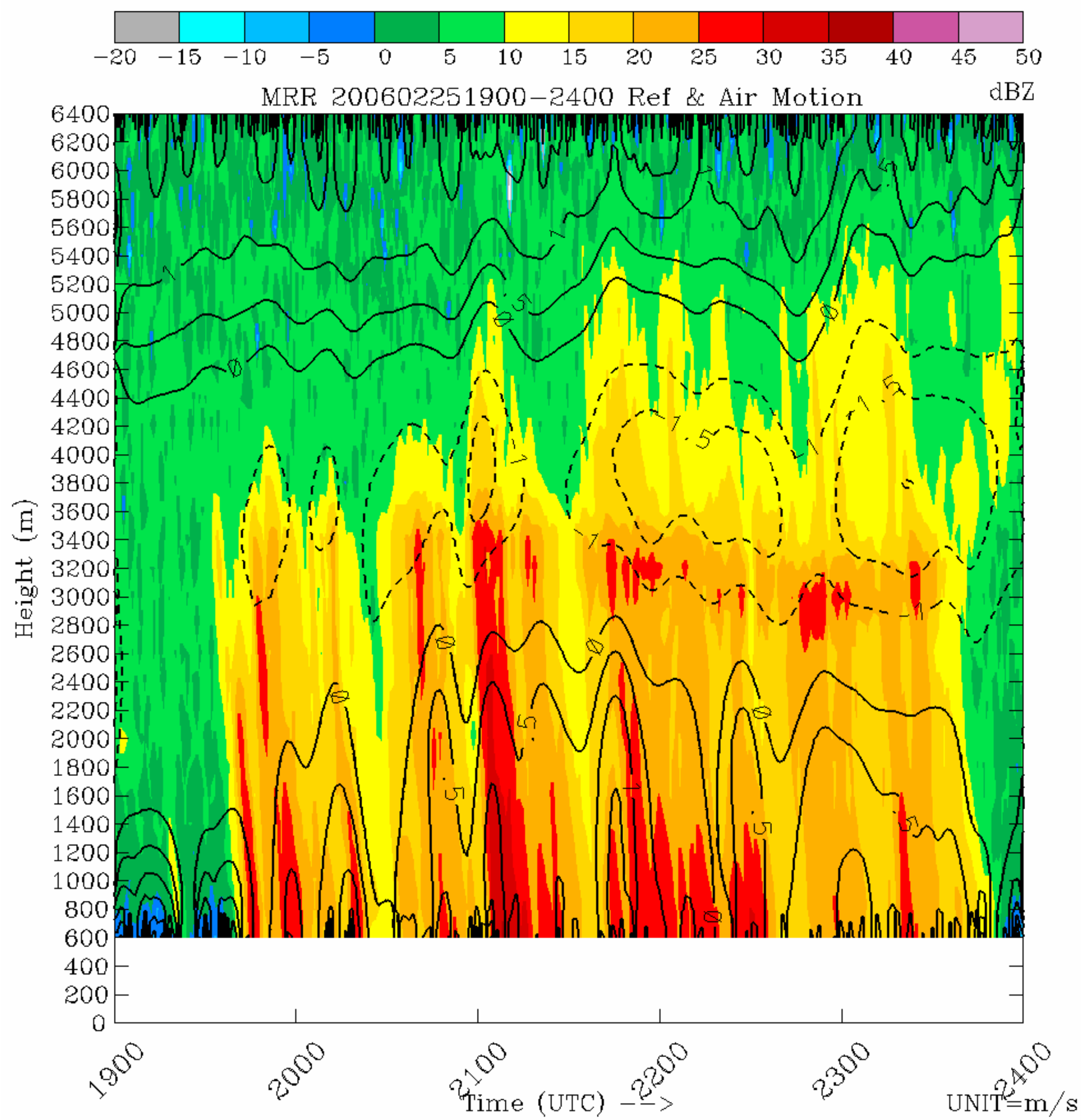
東北季風影響臺灣期間微波降雨雷達所觀測到之雷達回波及雨滴落速
(2006年2月25日19時到24時)





東北季風降水之空氣垂直速度與雷達回波

(2006年2月25日19時到24時)



NOAA P-3 Aircraft

A convective line developed offshore in southeastern Taiwan during TAMEX (Jorgensen et al. 1991)

Flight-level data collected as the aircraft penetrated the line (Yu et al. 2001)

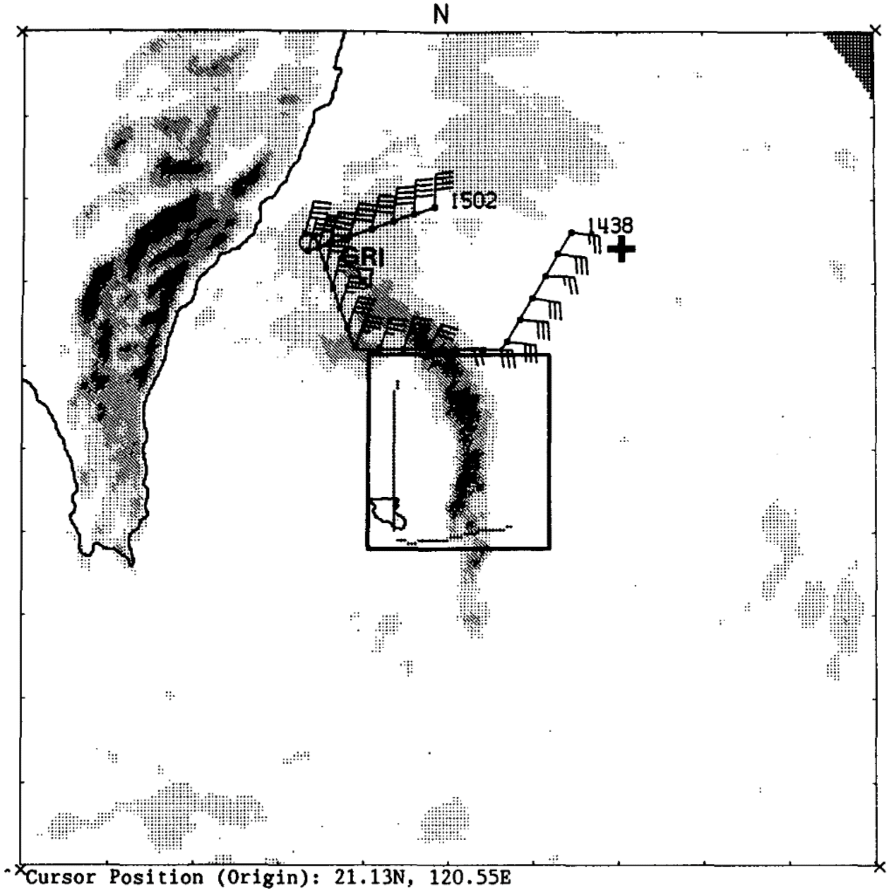


FIG. 2. Composite radar reflectivity map over a 10-min period from 20 scans of the P-3's lower fuselage C-band radar. During the composite period, the aircraft executed an L-shaped flight pattern (solid line). The composite was constructed by maximizing the radar reflectivity from each sweep at each grid point. The radar echoes over Taiwan are ground clutter. The domain of the map is 240 × 240 km^2. The small box centered on the line is the 54 × 54 km^2 Doppler analysis domain. The wind observations (1 full barb = 5 m s^{-1}) were determined from an earlier 300-m track and show the cyclonic shear across the band.

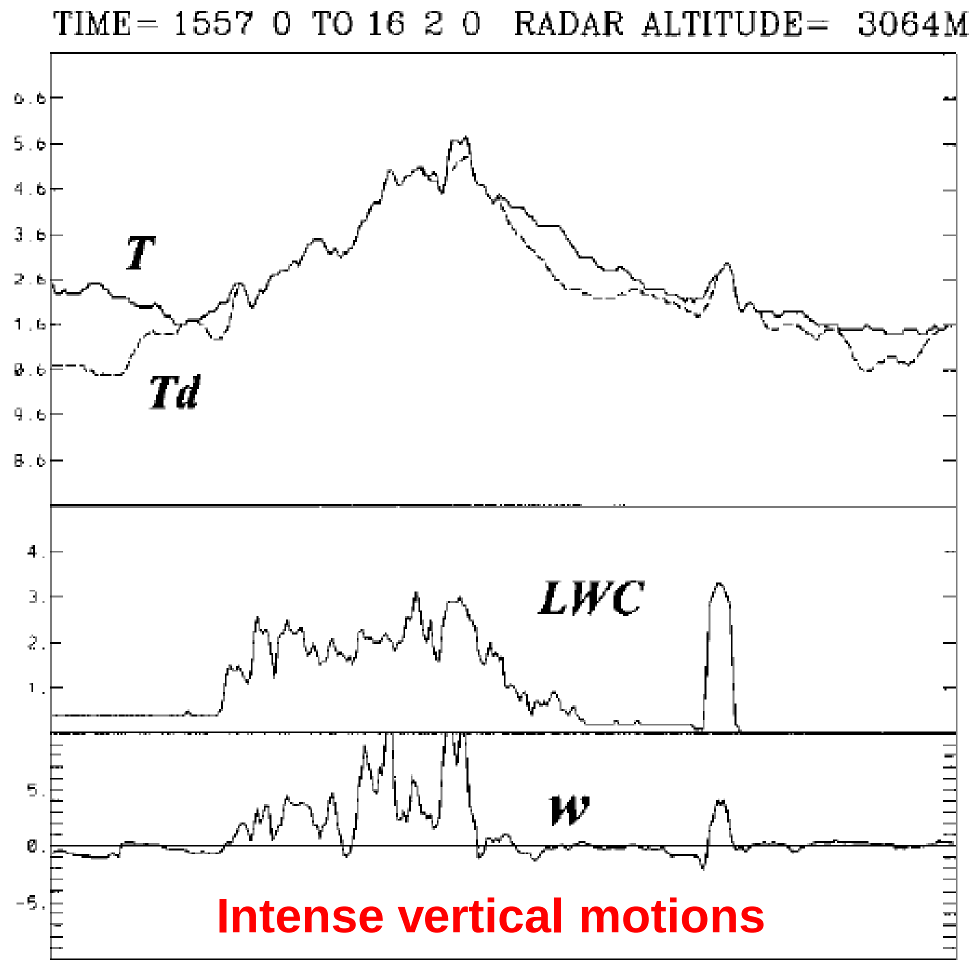


Photo of a 3-Axis Ultrasonic Anemometer

(NTU observational site)