

$$\frac{\partial \mu}{\partial t} - \nabla^2 + \frac{\partial \phi}{\partial x} = 0$$

$$\frac{|D\mu/Dt|}{FV} \sim \frac{V\mu/L_y}{FV} \sim \frac{10}{10^4 \cdot 10^5}$$

$$\frac{D}{Dt} \sim V/L_y \sim 1$$

$$\frac{Dv}{Dt} + fu + \frac{\partial \phi}{\partial y} = 0$$

$$\frac{\left| \frac{Dv}{Dt} \right|}{|fu|} \sim \frac{v^2/L}{fu} \sim \frac{1}{10^4 10^5 10} \sim 10^{-2}$$

For geostrophic flow

$$f v_g = - \frac{\partial \Phi}{\partial y}$$

$$f u_g = + \frac{\partial \Phi}{\partial x}$$

$$U = U_g$$

$$U = U_g + U_a$$

$$U_a \sim U_g$$

$$\frac{D}{Dt} u - f v + \frac{\partial \Phi}{\partial p} = 0$$

$$\frac{D}{Dt} u_g - f v_a - f v_g + \frac{\partial \Phi}{\partial x} = 0$$

$$\frac{D}{Dt} u_g - f v_a = 0$$

$$\downarrow \quad \textcircled{H} + w \frac{\partial \theta_0}{\partial z} = 0$$

$$\phi = g \textcircled{H}$$

$$p_b + w \left(g \frac{\partial \theta_0}{\partial z} \right) = 0$$

N^2

$\frac{1}{\partial_0}$

$\frac{\partial_0}{\partial Z}$

$\frac{D_b}{Dx} +$

$w N^2 = 0$

$$\frac{\partial u_g}{\partial x} + \frac{\partial v_g}{\partial y} + \frac{\partial v_a}{\partial y} + \frac{\partial w}{\partial z} = 0$$

$$= 0$$

$$\frac{\partial v_a}{\partial y} + \frac{\partial w}{\partial z} = 0$$

$$\frac{D}{Dt} = \frac{D_a}{Dt} + (v_a \frac{\partial}{\partial y} + w_a \frac{\partial}{\partial z})$$

Thermal wind

$$f u_g = - \frac{\partial \Phi}{\partial y}$$

$$f \frac{\partial u_g}{\partial z} = - \frac{\partial}{\partial y} \frac{\partial \Phi}{\partial z} = - \frac{\partial b}{\partial y}$$

$$+ \frac{\partial u_y}{\partial z} = - \frac{\partial b}{\partial y}$$

$$+ \frac{\partial u_g}{\partial z} = \frac{\partial b}{\partial x}$$

Cross-Frontal Circulation

Take $\frac{\partial}{\partial y}$ (thermo eq)

$$\frac{\partial}{\partial y} \left\{ \frac{D}{Dt} b + \omega N^2 \right\} = 0$$

$$\begin{aligned}
 & 2 \frac{\partial}{\partial y} \left(\frac{\partial b}{\partial y} \right) + u_g \frac{\partial}{\partial x} \left(\frac{\partial b}{\partial y} \right) \\
 & + v_g \frac{\partial}{\partial y} \left(\frac{\partial b}{\partial y} \right) + w \frac{\partial}{\partial z} \left(\frac{\partial b}{\partial y} \right) + \frac{\partial b}{\partial x} \frac{\partial u_g}{\partial y} + \\
 & \frac{\partial b}{\partial y} \frac{\partial v_g}{\partial y} + \frac{\partial b}{\partial y} \frac{\partial w}{\partial z} + \frac{\partial b}{\partial z} \frac{\partial u_g}{\partial y} +
 \end{aligned}$$

$$\dots \left(\frac{\partial}{\partial y} w \right) N^2 + w \frac{\partial}{\partial y} N^2 = 0$$

$\downarrow$

$$\frac{D}{Dt} \left(\frac{\partial b}{\partial y} \right) = - \frac{\partial \log}{\partial y} \frac{\partial b}{\partial x}$$

$$- \frac{\partial v_a}{\partial y} \frac{\partial b}{\partial y} - \frac{\partial v_k}{\partial y} \frac{\partial b}{\partial y} - \dots$$

$$\begin{aligned}
 \dots \left\{ \frac{\partial w}{\partial y} \right\} \left\{ n^2 + \frac{\partial b}{\partial z} \right\} \\
 \frac{D}{Dt} \left(\frac{\partial b}{\partial y} \right) = \left(\frac{\partial}{\partial t} - \frac{\partial v_a}{\partial y} \frac{\partial}{\partial y} \right) \\
 - w \left(n^2 + \frac{\partial b}{\partial z} \right)
 \end{aligned}$$