$-\partial/\partial y$ $\quad \frac{D_h u}{Dt} - fv = -\frac{1}{\rho_0}\frac{\partial \tilde{p}}{\partial x} \qquad \frac{\partial p}{\partial x} = \frac{\partial \tilde{p}}{\partial x}$

$\rho = \rho_0 + \rho_*(z) + \tilde{\rho}(x,y,z,t)$

$\partial/\partial x$ $\quad \frac{D_h v}{Dt} + fu = -\frac{1}{\rho_0}\frac{\partial p}{\partial y}$

$|\tilde{\rho}| << |\rho_*| << \rho_0$

$$\frac{\partial \tilde{p}}{\partial z} = -\tilde{\rho} g$$

$$\frac{D_h}{Dt} = \frac{\partial}{\partial t} + u\frac{\partial}{\partial x} + v\frac{\partial}{\partial y}$$

$\nabla \cdot \vec{u} = 0$

h horizontal

$$\frac{\partial \tilde{\rho}}{\partial t} + \vec{u}_h \cdot \nabla \tilde{\rho} + w\frac{\partial \rho_*}{\partial z} + w\frac{\partial \tilde{\rho}}{\partial z} = 0$$

$\frac{D\rho}{Dt} = 0$

$\frac{\partial p}{\partial z} = -\rho g$

$\frac{\partial p_*}{\partial z} = -\rho_* g$

$$N^2 = -\frac{g}{\rho_0}\frac{\partial \rho_*}{\partial z}$$

$$\frac{D_h \tilde{\rho}}{Dt} = \frac{\rho_0 N^2}{g} w \Rightarrow \frac{\partial w}{\partial z} = \frac{g}{\rho_0}\frac{D_h}{Dt}\left[\partial/\partial z\left(\frac{\tilde{\rho}}{N^2}\right)\right]$$

$-\partial w/\partial z$

$\eta = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$

$\frac{D_h f}{Dt} = \beta v$

$$\boxed{\frac{D_h}{Dt}(\eta + f) + \left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right)(f + \cancel{\eta}) = 0}$$

no derivatives

η scales as $\frac{U}{L}$

$\eta/f \qquad \frac{U}{fL} = Ro$

$\rho = -\frac{1}{g}\frac{\partial p}{\partial z}$

open ocean

$|\eta/f| << 1$

$$\frac{D_h}{Dt}(\eta + f) + \frac{f}{\rho_0}\frac{D_h}{Dt}\left[\frac{\partial}{\partial z}\left(\frac{1}{N^2}\frac{\partial \tilde{p}}{\partial z}\right)\right]$$

Approx as geostrophic

$$v_g = \frac{1}{\rho_0 f_0}\frac{\partial \tilde{p}}{\partial x} \qquad u_g = -\frac{1}{\rho_0 f}\frac{\partial \tilde{p}}{\partial y}$$

$$\frac{D_g}{Dt}\nabla_h^2 \tilde{p} + \frac{D_g}{Dt}\left[\frac{\partial}{\partial z}\left(\frac{f_0^2}{N^2}\frac{\partial \tilde{p}}{\partial z}\right)\right] + \beta\frac{\partial \tilde{p}}{\partial x} = 0$$

$$\tilde{p} = \Pi(z)\, Q(x,y,t)$$

Title JavaScript

```
1 Write your code here
```