Meet the Four Horsemen of Kinematics! $\frac{\partial u}{\partial x}, \frac{\partial u}{\partial y}, \frac{\partial v}{\partial x}, \frac{\partial v}{\partial y}$

① Divergence $\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right)$ $\underline{\vec{\nabla} \cdot \vec{V}_h}$

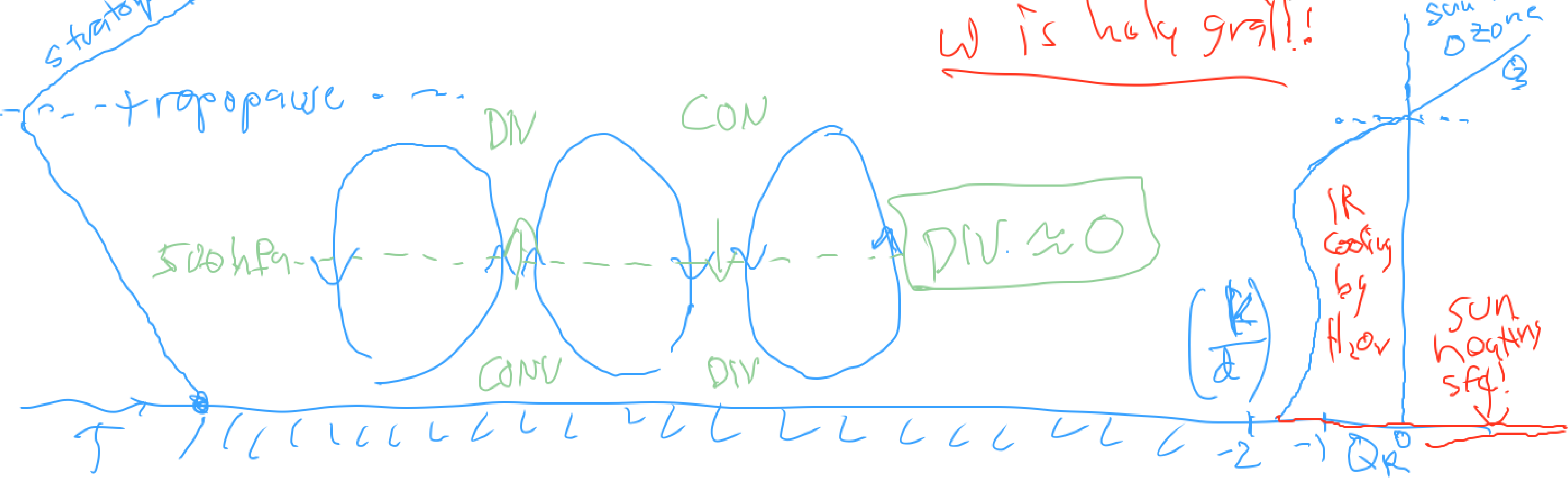
Meteorological importance: continuity (mass)

$$\boxed{0 = \vec{\nabla} \cdot \vec{V}_h + \frac{\partial \omega}{\partial p}}$$

when $p_{hyd}(z)$ is used as vertical (mass) coord.

Our handle on vertical motion! for large scales, w is "small (10^{-3} or less of u, v) but critical" — condensation, clouds, rain, storms

$\underline{\omega \text{ is holy grail!!}}$



② Vorticity: why important?

$$\frac{\partial}{\partial y}\left[\frac{\partial u}{\partial t} = \text{transport} + f\underline{v} - \Pi_x\right]$$

$$\frac{\partial}{\partial x}\left(\frac{p}{\rho_0}\right)$$

$$-\frac{\partial}{\partial x}\left[\frac{\partial v}{\partial t} = \text{transport} - fu - \Pi_y\right]$$

$$\frac{\partial}{\partial t}\underbrace{\left(\frac{\partial u}{\partial y} - \frac{\partial v}{\partial x}\right)}_{-\zeta} = \text{Trasport terms} + f\underbrace{\left(\frac{\partial v}{\partial y} + \frac{\partial u}{\partial x}\right)}_{(\nabla_h \cdot V_h)} + 0$$

as desired!

Why construct $\left[\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right]$?

What property does it have that helps us?

Hint: eliminate Π (or Φ in p-coords)

At 500 hPa, where $\vec{\nabla} \cdot \tilde{V}_h \approx 0$,

$$\underbrace{\frac{d}{dt}(\zeta) = 0}_{\text{daydream}} \quad + \underbrace{\text{stuff}}_{\text{nightmare of reality}}$$

CONSERVATION!

Two poor cousins remain: def1 & def2

magnitude

$\sqrt{(def1^2)+(def2^2)}$

Coordiate independent (fundamental)

angle relative to grid.

poorest cousin (a direction)