Vertical Motion

Atmos 5110 Synoptic–Dynamic Meteorology I
Instructor: Jim Steenburgh
jim.steenburgh@utah.edu
801-581-8727
Suite 480/Office 488 INSCC

Suggested reading: These notes

Since synoptic scale vertical motions are difficult to observe or diagnose, we desire a conceptual model to help diagnose and interpret synoptic scale vertical motion from horizontal analyses. To do this, we begin with the continuity equation in pressure coordinates.

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

Integrating downward from the top of the atmosphere (p=0) to some pressure level p yields

$$\omega(p) = -\int_0^p (\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y})\partial p$$

Conclusion: The vertical motion at a given pressure level is directly related to the integrated divergence above that level.

- Positive integrated divergence (i.e., divergence) yields $\omega < 0$ (rising motion)
- Negative integrated divergence (i.e., convergence) yields $\omega > 0$ (sinking motion)

Or, if you prefer to avoid integrals, assume a mean divergence to obtain

$$\omega(p) \cong -(\overline{\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}})p$$

Possibilities:

- Since p>0, mean divergence above the pressure level (i.e., $\overline{\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}} > 0$) yields

$$\omega(p) < 0 \implies Rising\ Motion$$

- Mean convergence above the pressure level (i.e., $\overline{\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}} < 0$) yields

$$\omega(p) > 0 \implies Sinking\ Motion$$

What happens below the pressure level?

- Divergence at upper levels is typically accompanied by convergence at lower levels, whereas convergence at upper levels is typically accompanied by divergence at lower levels
- This is known as Dines compensation

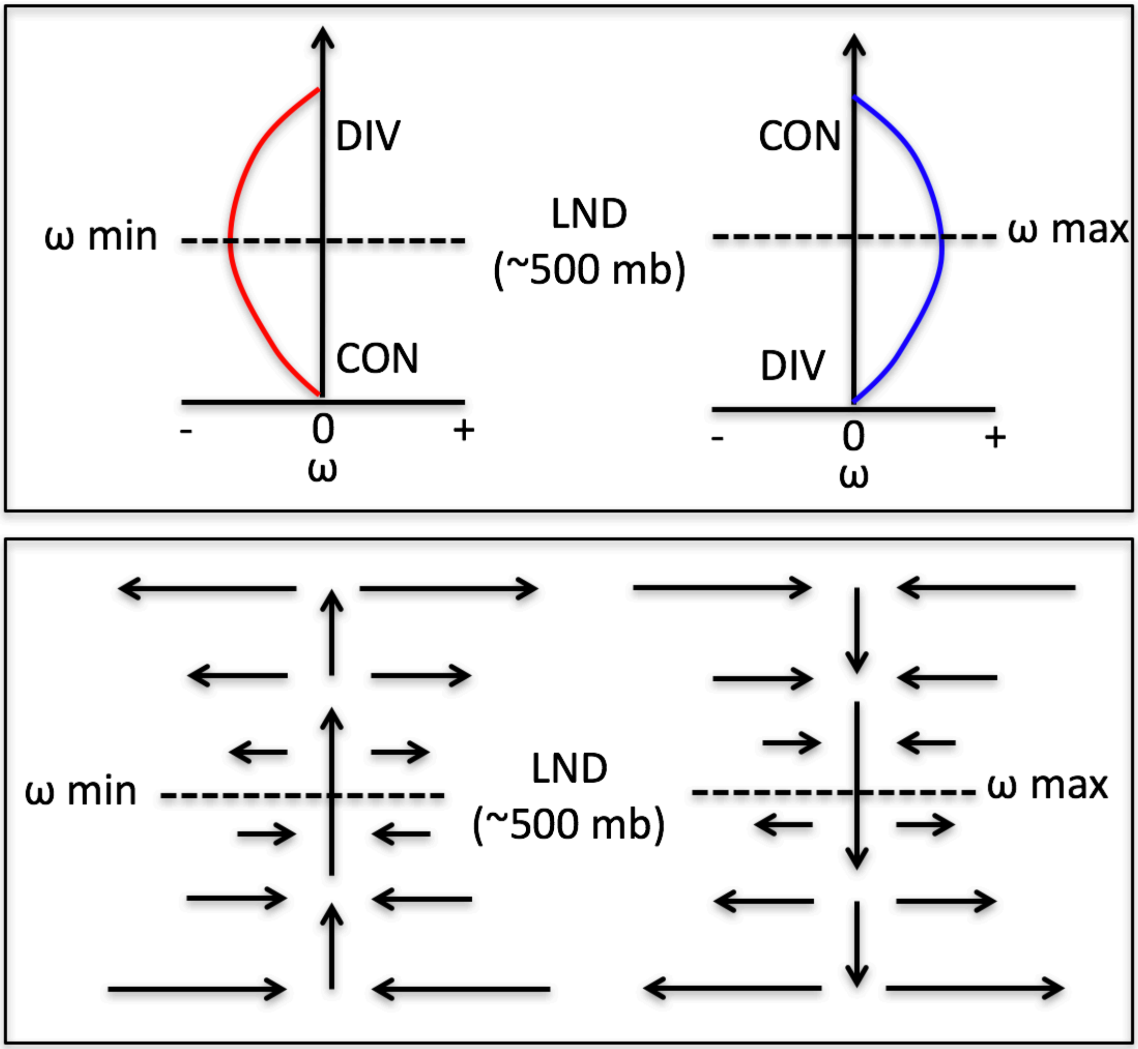
Putting it all together:

- The divergence must change signs *at least once* in a column
  - Upper-level divergence is accompanied by lower-level convergence and mid-level ascent
  - Upper-level convergence is accompanied by lower-level divergence and mid-level subsidence
- The level at which the divergence changes signs is known as the level of nondivergence (i.e., $\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$)
- A local maximum or minimum in vertical motion exists at the level of nondivergence since by continuity

$$\frac{\partial \omega}{\partial p} = -\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right) = 0$$

- On smaller scales, multiple levels of nondivergence and vertical motion maxima or minima can exists (e.g., mountain waves)

Resulting bow-string conceptual model



Class activity

Using the IDV bundle available at **Bundles-> 5110->Lab 2-Omega**, explore the relationship between vertical motion and divergence in the latest GFS forecast for the North Pacific Basin.