Mind maps of climate models and their components:
http://proj.badc.rl.ac.uk/pimms/browser/CASCADE/ControlledVocabs/trunk/Software?rev=48&order=size

(Must have Flash player installed)

Secondary flow: a strategic tool. Examples:

① → Mean plus deviations

$\overline{\psi} + \psi'$ • climo + anomalies ← timescale separation

$\overline{\psi} + \psi'$ • smoothed + eddies ← spatial scale separation

$[\psi] + \psi^*$ ← • zonal mean + eddy

② → Flywheel plus engine

geostrophic wind

Contains most KE + "inertia" ← "the propensity to persist"

ageostrophic flow
• is many things! waves, turbulence, etc, etc!
• ONE PART is what maintains TWB
• divergent ⇔ ω, controls $\frac{d}{dt}$

ageostrophic winds doing their job to maintain: TWB in a geostrophic flow pattern:

- Two tools to do the job

1. $$\frac{d\vec{V}}{dt} = f(\vec{V}_a \times \hat{k}) \approx \frac{d}{dt}(V_g)$$ can adjust V_g

2. $$\frac{\partial \omega}{\partial p} = -(\vec{\nabla} \cdot \vec{V}) = -(\vec{\nabla} \cdot \vec{V}_a)$$

ageostrophic wind's divergent part connects to ω, which can adjust T (thickness)

via $\frac{dT}{dt} = \omega S_p$ ← "adiabatic cooling or warming"

← "static stability"

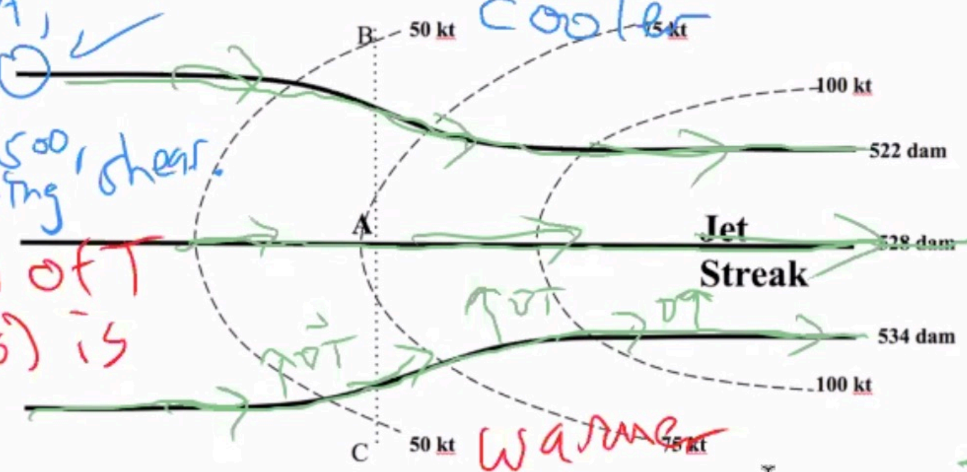
LMT_QGomega_and_Qvectors_11pages.pdf (page 1 of 11)

jet streak situation. Suppose the 1000-hPa geopotential height surface $Z_{1000} = 0$ everywhere (i.e., the 1000-hPa surface is flat, with no geostrophic wind at that level). On the following diagram, the 500-hPa height contours are shown as bold solid lines, and the 500-hPa isotachs are shown as dashed lines. The cross section B-C is marked for later reference.

$\Delta Z = Z_{500} - Z_{1000}$

At point A, $\left(-u_g \frac{\partial u_g}{\partial x}\right) < 0$ slowing V_{500}, decreasing shear.

Advection of T (thickness) is



$T \sim \Delta T$

T contours

$T + \partial T$

$-\vec{V}_g \cdot \vec{\nabla} T = 0$

they are $\perp$

LMT_QGomega_and_Qvectors_11pages.pdf (page 2 of 11)

This is Eq. (1.44) in MSM. Here, the subscripts "U" and "L" correspond to "upper" and "lower" levels, and "C" is a constant for a given pressure layer. **Would thermal wind balance be sustained in locations such as point A as the advective tendencies from a) and b) act together? Why or why not?**

d) If the answer to c) is "no," **explain the sense of the imbalance** that would develop at point A. In other words, would the vertical shear of the westerly flow become too weak for the north–south temperature gradient, or vice versa?

e) **Based on your answer to d), what would need to happen in order to bring the atmosphere back toward thermal wind balance in the vicinity of point A?**

The magnitude of the temperature gradient would need to decrease by $\frac{dT}{dt} = \omega S_p$

AND/OR

The magnitude of vertical wind shear would need to increase by $\frac{d\vec{V}_s}{dt} = f\vec{V}_a \times \hat{k}$

get rid of Φ

b. (5 points) **What is the final relative circulation** around the loop?

$$\frac{d\vec{V}}{dt} = f(\vec{V} \times \hat{k}) - \nabla \Phi$$

two approaches: → derivatives (construct a equation)

→ integrals

$$\boxed{\oint \frac{d\vec{V}}{dt}\, dl = \oint f(\vec{V} \times \hat{k})\, dl} + \cancel{\oint \nabla \Phi\, dl} \to 0$$

$\oint (\nabla \Psi)\, dl$ around any closed loop $= 0$

c. (5 points) **What tangential wind speed** does this imply? **Clockwise or counter-clockwise?**

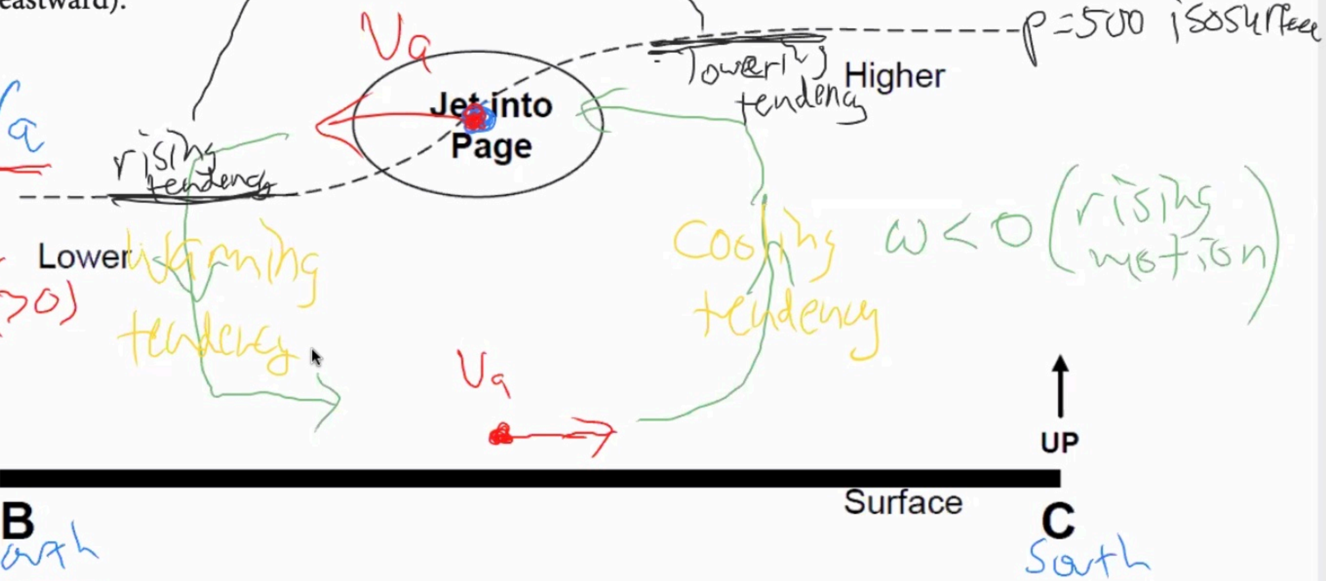
could work with this for circular loop changes its area or radius.

these help restore TWB because

f) What sort of vertical circulation (in this case, in the y–z cross-sectional plane) would be required to bring about the needed changes (that is, to restore or maintain thermal wind balance)? Remember, a "circulation" needs to satisfy mass continuity. Consider the vertical cross section below corresponding to the B-C cross section above. The perspective is from the west (i.e., you are standing with your back to the wind, looking eastward).

$$\frac{du_g}{dt} = fV_a$$

need it to be positive (>0) (into the page) at upper level.



Sketch the ageostrophic circulation (using vertical and horizontal arrows) that would be needed to bring the atmosphere back towards thermal wind balance