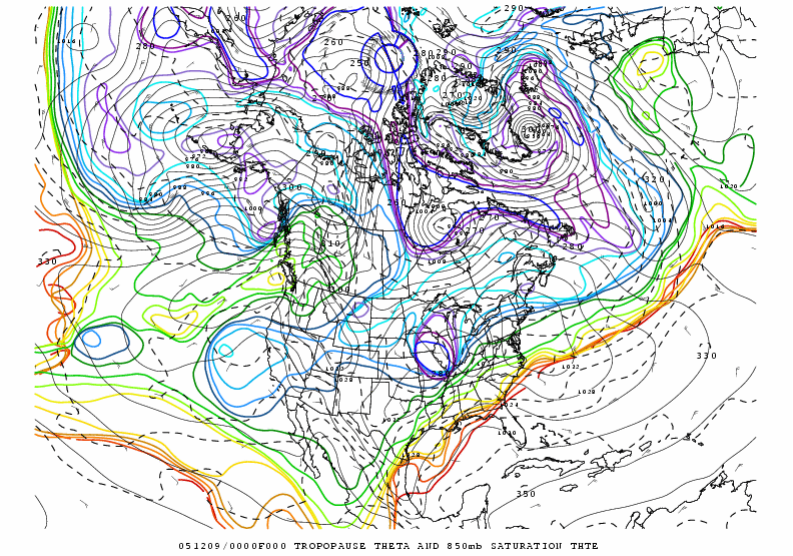
Isentropic Potential Vorticity Maps



12.803 Brian Tang 10/23/2006

Ertel PV

$$q = \alpha\left(\nabla \times \vec{u} + 2\vec{\Omega}\right) \bullet \nabla\theta$$

In isentropic coordinates (x,y,z,t) → (x,y,θ,t) :

$$q \cong -g\frac{\partial\theta}{\partial p}\left(f + \left(\frac{\partial v}{\partial x}\right)_\theta - \left(\frac{\partial u}{\partial y}\right)_\theta\right)$$

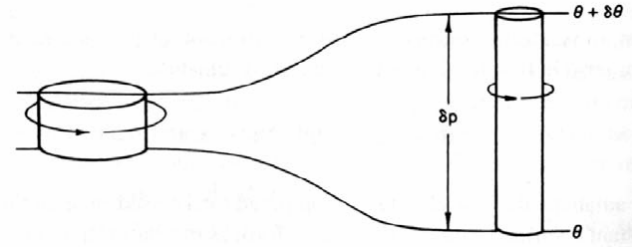
Assumptions: w small, slope of θ surfaces small, hydrostatic balance

Ertel PV

For inviscid and adiabatic flow, Ertel PV is conserved:

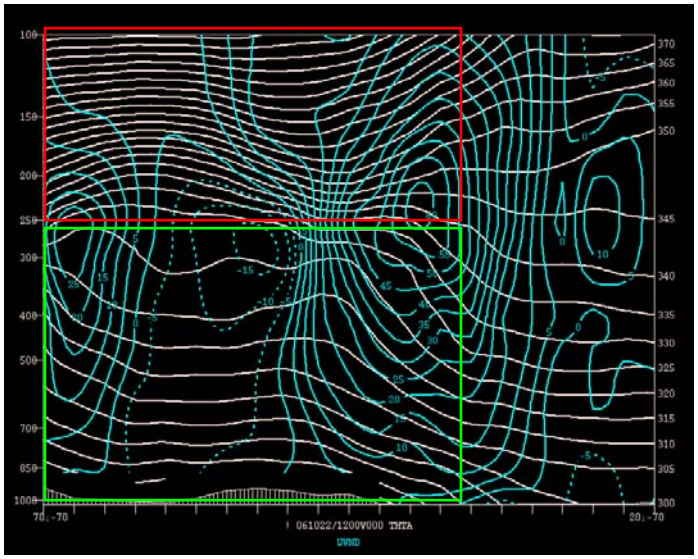
$$\frac{Dq}{Dt} = 0$$

PV is the absolute vorticity a fluid column would have if it were brought to some reference depth.



Stratification & PV

$$q \cong -g\frac{\partial\theta}{\partial p}\left(f + \left(\frac{\partial v}{\partial x}\right)_\theta - \left(\frac{\partial u}{\partial y}\right)_\theta\right)$$



Stratosphere:

$\frac{\partial\theta}{\partial p}$ large

→PV large

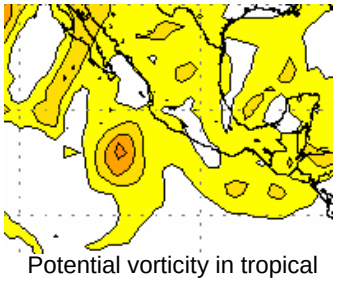
Troposphere:

$\frac{\partial\theta}{\partial p}$ small

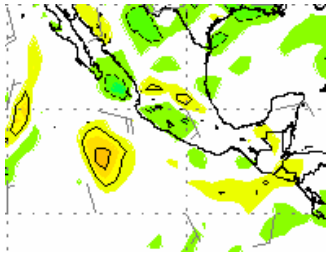
→PV small

Rel. Vorticity & PV

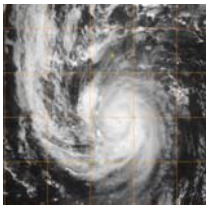
$$q \cong -g \frac{\partial \theta}{\partial p}\left(f + \left(\frac{\partial v}{\partial x}\right)_\theta - \left(\frac{\partial u}{\partial y}\right)_\theta \right)$$



Potential vorticity in tropical mid-troposphere



500mb relative vorticity in tropical mid-troposphere



Hurricane Paul

PV Units

$$q = \left[m^2 s^{-1} K kg^{-1} \right]$$

UGH!!!

$$1PVU \equiv 10^{-6} m^2 s^{-1} K kg^{-1}$$

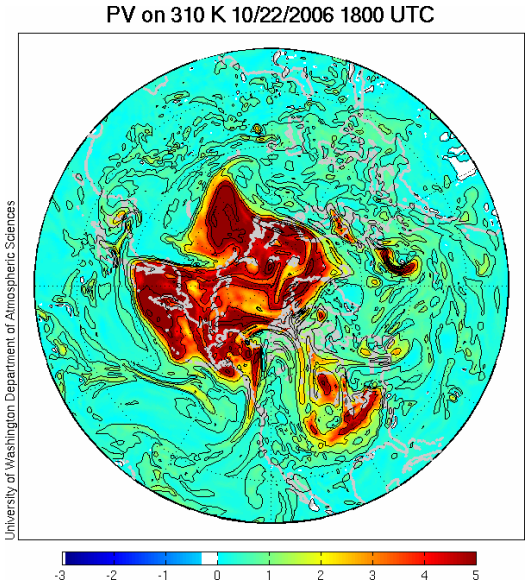
NOTE: This is a different unit than QGPV, which just has units of vorticity

Typical PV Values:

- TROPOSPHERE: <1.5 PVU
- STRATOSPHERE: >4 PVU

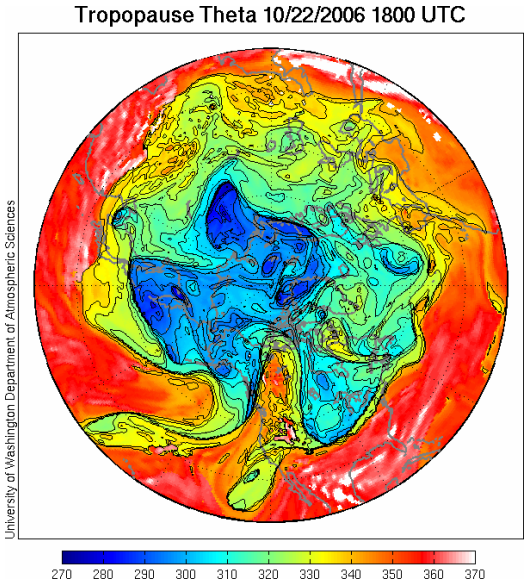
Constructing PV Maps

Method 1: Pick an arbitrary θ surface and calculate the PV on this surface



Constructing PV Maps

Method 2: Pick an arbitrary PV surface and calculate the θ on this surface



Which Method?

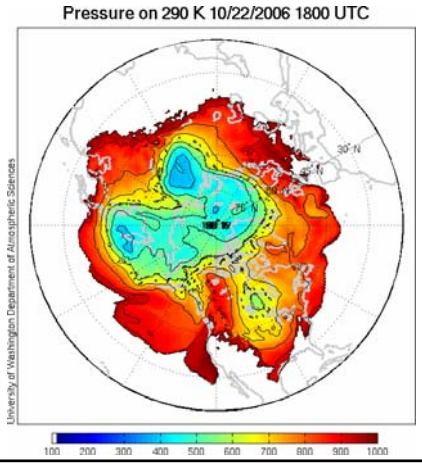
The two methods are analogous to using pressure vs height (geopotential) as the independent vertical coordinate

$$(\nabla p)_z : (\nabla \phi)_p :: (\nabla q)_\theta : (\nabla \theta)_q$$

Though unlike *p* and *z*, there may not be a 1-1 mapping between *q* and θ

Caveat using method 1:

Theta surfaces tend to slope with latitude and one has to be cautious to chose an appropriate θ depending on the problem.



Dynamical Tropopause

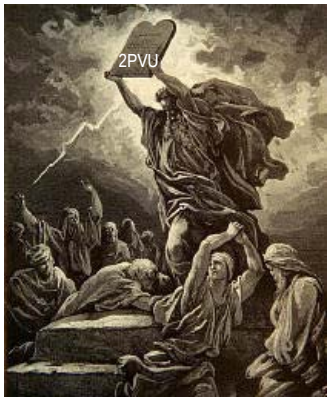
For this class, we are interested in studying the behavior of Rossby waves (Eady edge waves) at the vertical "boundaries" of the system, namely the surface and the tropopause.

Mid-latitude synoptic scale weather systems tend to have their maximum amplitude (in vorticity) near the tropopause, hence it is more intuitive to define a dynamical tropopause based on PV and use method 2

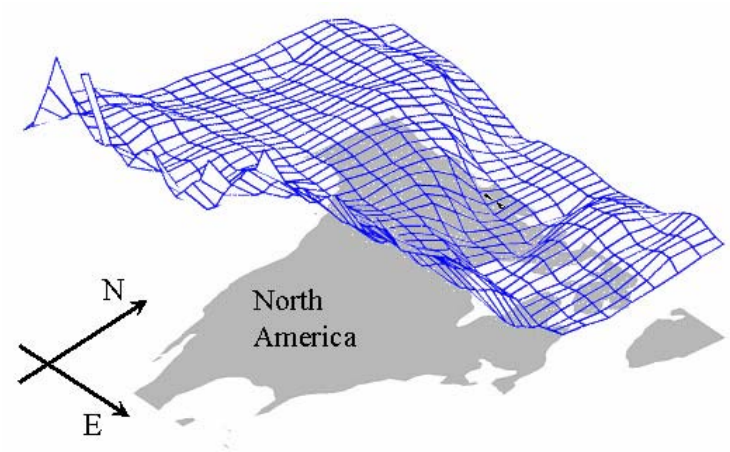
TROPOSPHERE: <1.5 PVU

DYNAMICAL TROPOPAUSE: 2PVU

STRATOSPHERE: >4 PVU



Dynamical Tropopause



The dynamical tropopause evolves in time and space due to day to day weather variations.

Theta Anomalies on Dynamical Tropopause

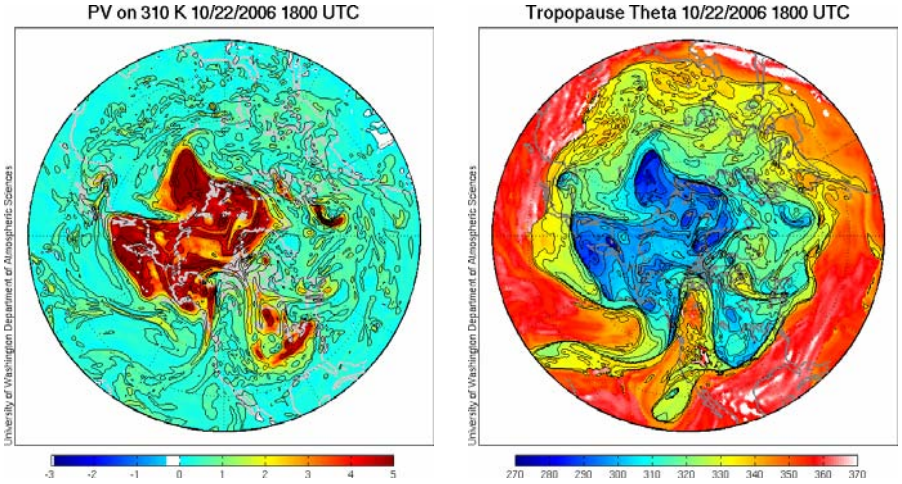
Invoking QGPV, recall at the upper boundary :

$$q'_p = -\delta(p - p_t)\frac{fR}{S_t p_t}\left(\frac{p_t}{p_o}\right)^{R/c_p}\theta'\Big|_{p_t}$$

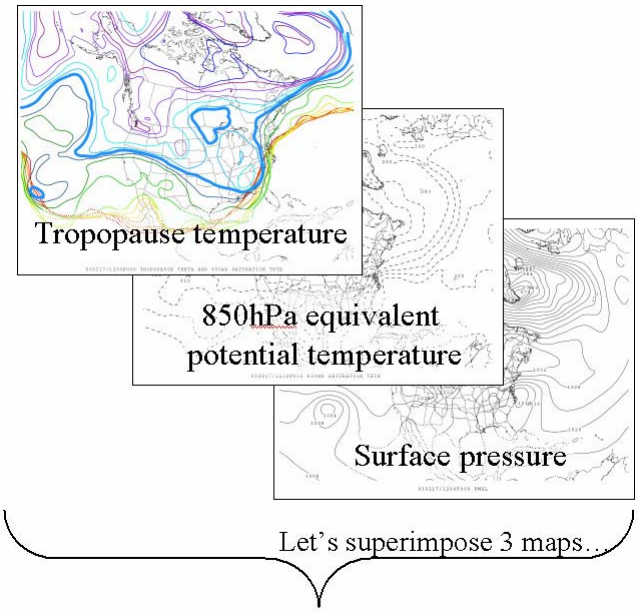
A positive θ anomaly on the dynamical tropopause is equivalent to a negative potential vorticity anomaly. A negative θ anomaly is equivalent to a positive potential vorticity anomaly.

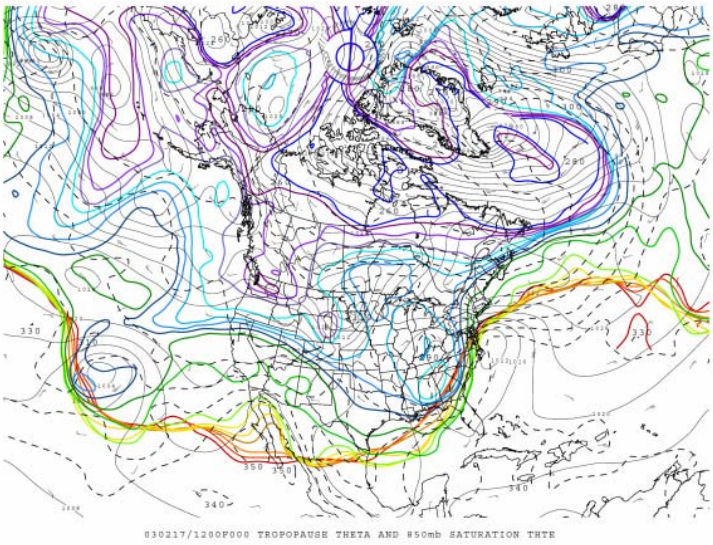
An anomalously high dynamical tropopause is usually associated with an upper level anticyclone, and an anomalously low dynamical tropopause is usually associated with an upper level cyclone.

At the lower boundary, the sign relationships are reversed.

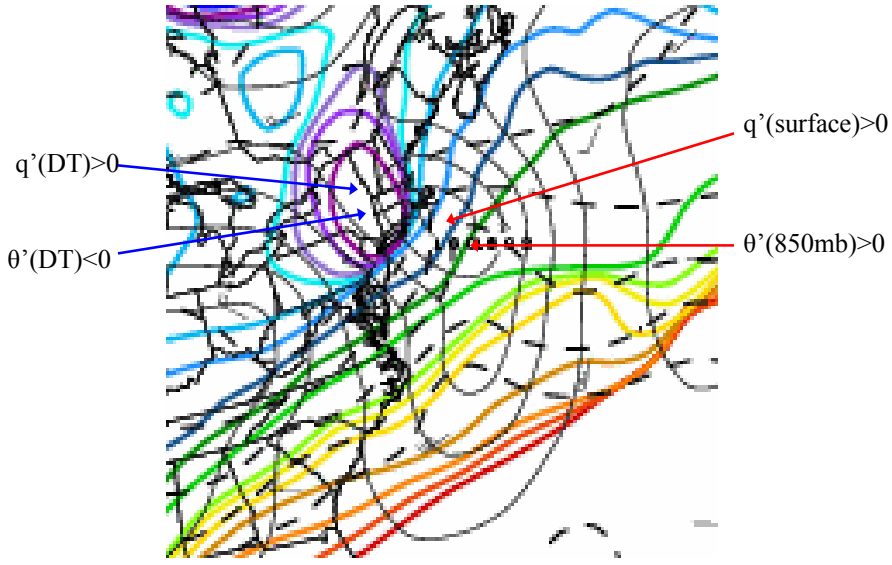


MIT Dynamical Tropopause Maps





Potential temperature of the tropopause ( ), 850hPa equivalent potential temperature (----------), and surface pressure (———) at 12GMT on February 17, 2003.



Uses of Tropopause Maps

See Hoskins, McIntyre, and Robertson paper for very in depth look at specific uses of PV maps, which include:

•Cutoff lows & tropopause folds

•Blocking patterns (one of the 12.804 labs)

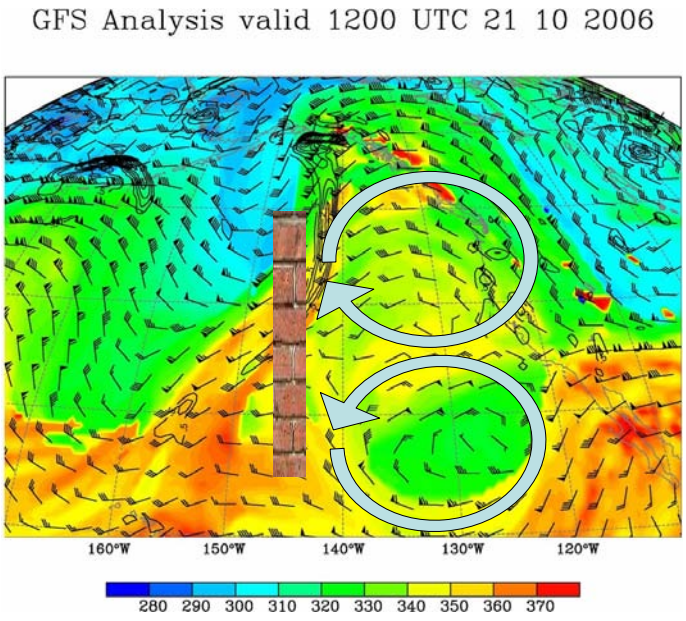
•Cyclogenesis (baroclinic instability)

And also…

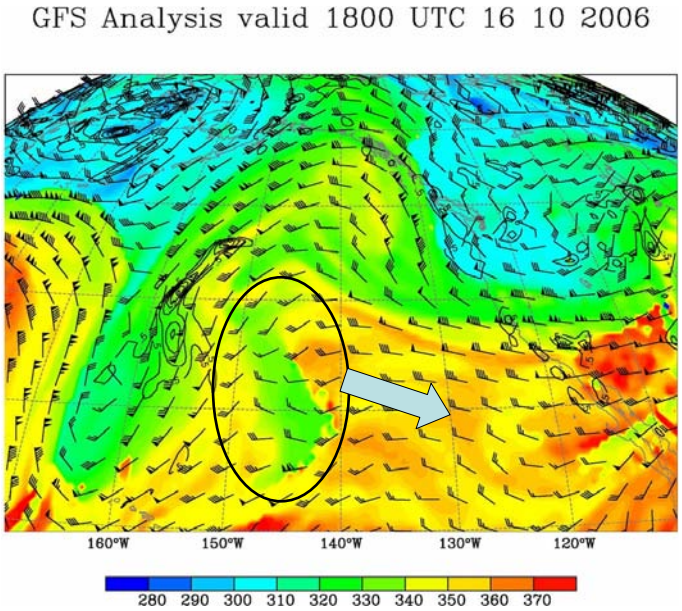
•Diagnosis of flows and jets at the tropopause (aircraft)

•Non-conservation of PV (moist convection)

Blocking Pattern



Blocking Pattern



Conservation of PV

Conditions are nearly inviscid and adiabatic at the mid-latitude and high-latitude tropopause on timescales of days, so PV is at first order advected around by the winds on the dynamical tropopause.

LINK

Q: What can cause local sources and sinks of PV?

LINK

PV Maps on the Web

http://wind.mit.edu/~gempak/pv.html

http://www.atmos.albany.edu/facstaff/rmctc/DTmaps/animSelect.php

http://www.atmos.washington.edu/~hakim/tropo/

12.803 Quasi-Balanced Circulations in Oceans and Atmospheres
Fall 2009