12.804
Project 5
Waves on the Tropopause-atmospheric data

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1 Isentropic Potential Vorticity

The isentropic (or Ertel) potential vorticity q is defined as:

$$q = -g(\zeta_\theta + f)\frac{\partial \vartheta}{\partial p} \tag{1}$$

where ζ_θ is the relative vorticity on an isentropic surface, f is the Coriolis parameter, p is pressure and g the acceleration due to gravity. The potential vorticity q is conserved in adiabatic, frictionless motion.

We can evaluate the distribution of potential vorticity on isentropic surfaces using atmospheric data as follows.

1.1 PV on isentropic surfaces

First use GEMPAK program *gdcross* to plot meridional and zonal sections over the US region of the following quantities that will be used to compute PV:

(a) potential temperature - see example file ~lab/12804/pvfront/gdcross.thta_n_s. Identify and describe the shape of the tropopause in relation to the shape of the isentropes

(b) absolute vorticity ($\zeta_\theta + f$) with potential temperature as the vertical coordinate - see example file ~lab/12804/pvfront/gdcross.avor. Where is the absolute vorticity a maximum?

A more complete 'summary' of the dynamics is revealed through the potential vorticity distribution.

(c) Plot meridional and zonal sections of PV with potential temperature as the vertical coordinate - see example file ~lab/12804/pvfront/gdcross.ipv. Where is PV high and where is it low? Identify and describe the shape of the tropopause in relation to PV distribution. Mark the PV surface which could be used to identify the tropopause.

1.2 Tropopause maps

Use GEMPAK program *gdcntr* to plot PV on a sequence of isentropic surfaces over the US, starting from 350 K in the stratosphere and moving down to 280 K in the lower troposphere, at 10 K intervals - see example file ~lab/12804/pvfront/gdcntr.ipv_310

By identifying the tropopause as the 2 PVU contour, plot the position of the tropopause on each isentropic surface - see example file ~lab/12804/pvfront/gdcntr.trop_310. Tropopause temperature maps are obtained by superimposing many such contours, corresponding to different theta surfaces, on a single map.

Tropopause temperature maps, such as those prepared here, are routinely displayed in the Synoptic Laboratory.

2 Waves on the tropopause

Here we will use daily tropopause maps to study the propagation of waves on a potential vorticity front. The objective of the study is to interpret these maps in terms of Rossby waves propagation on the tropopause identified as a potential vorticity front. The winter time is particularly appropriate to this study because of the presence of strong upper level jets which act as wave guides.

Compute the potential vorticity over the hemisphere on a particular day on a chosen θ surface - 310^0K, for example. The potential vorticity increases as one moves from the troposphere to the stratosphere.

Identify the tropopause as a potential vorticity contour. Inspect a sequence of daily maps of potential vorticity - follow the evolution of the tropopause by concentrating on one particular value of potential vorticity (i.e. 2.0 PVU contour).

2.1 Rossby waves

Interpret the propagation of waves on the tropopause in terms of the dispersion relation of Rossby waves:

$$c = U - \frac{\beta}{\left(k^2 + \frac{1}{L_r^2}\right)} \tag{2}$$

where U is the zonal wind , k is the zonal wavenumber and L_r is the Rossby radius of deformation. Choose waves of varying wavelength and discuss if the observed phase speed fits the theorethical Rossby waves dispersion relation. If not, why not?

2.2 Waves on a PV front

Let us suppose that the PV jumps discontinuously from a value of q_0 to $q_0 + Dq$ - (see Project 4:Waves on a PV front - Numerical Model). Follow the evolution and estimate the speed of travel of undulations on your tropopause maps and try to interpret it using the numerical model. How does the speed depend on wavelength and the magnitude of Dq? Choose waves of varying wavelength - does it conform to the dispersion relation of a wave propagating on a PV front? If not, why not?

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