SIO 217B Atmospheric and Climate Sciences II

Exercise #25

1. a) Write down a generic equation for Ertel potential vorticity.

   b) Download the files containing temperature, geopotential height, zonal wind component, and meridional wind component at the 1000, 925, 850, 775, 700, 600, 500, 400, 300, 250, 200, 150, 100, 70, and 50 hPa levels (a total of fifteen levels) for 1993 March 14 00Z. Calculate potential temperature at all pressure levels (as in Exercise #23). For each longitude point between 260-300°E along the 35°N latitude line, interpolate potential temperature and meridional wind to regular vertical intervals between 0 and 16 km (as in Exercise #23). Plot contours of potential temperature and meridional wind in a longitude-height cross-section figure for 260-300°E and 0-16 km elevation along the 35°N latitude line (as in Exercise #23). Use contour intervals of 10 K and 10 m s^{-1}.

   c) Calculate the vertical component of relative vorticity at all pressure levels using a centered finite difference method in spherical coordinates (as in Exercise #15). Assuming that relative vorticity on pressure surfaces is the same as relative vorticity on potential temperature surfaces, calculate Ertel potential vorticity at the 925, 850, 775, 700, 600, 500, 400, 300, 250, 200, 150, 100, and 70 hPa pressure levels using a centered finite difference method for approximating $\partial\theta/\partial p$. Multiply by 10^6 to convert to potential vorticity units (1 PVU = 10^{-6} K m^2 kg^{-1} s^{-1}). For each longitude point between 260-300°E along the 35°N latitude line, interpolate potential vorticity to regular vertical intervals between 0 and 16 km. Add contours of potential vorticity to contours of potential temperature in the figure. Use a contour interval of 1 PVU.

2. For each latitude point between 25-60°N along the 290°E longitude line, interpolate potential temperature, zonal wind, and potential vorticity to regular vertical intervals between 0 and 16 km (as in Exercise #24). Plot contours of potential temperature, zonal wind, and potential vorticity in a latitude-height cross-section figure for 25-60°N and 0-16 km elevation along the 290°E longitude line. Use contour intervals of 10 K, 10 m s^{-1}, and 1 PVU.

3. Note that potential vorticity is very large in the stratosphere. For this reason, the midlatitude tropopause is sometimes defined to be the 2 PVU surface. Potential vorticity is also non-negligible in the troposphere along the polar front (i.e., cold and warm fronts in the plots).

   a) It is very difficult for air parcels to move adiabatically between the troposphere and stratosphere due to differences in buoyancy. Instead, it is much easier for air parcels to move along a potential surface. There is only one general location in the plots where air parcels can move between the troposphere and stratosphere along a potential temperature surface. What is the name of the meteorological feature at this location?

   b) It is also very difficult for air to move adiabatically between regions of different potential vorticity due to conservation of angular momentum. Instead, it is much easier for air parcels to move along a potential vorticity surface. Looking at the plots, are there any locations where air parcels can easily move adiabatically between the troposphere and stratosphere?