SIO 217B Atmospheric and Climate Sciences II

Exercise #11

1. The hypsometric equation tells us that the geopotential thickness between two pressure surfaces is proportional to the average temperature of the layer when calculated in vertical coordinates of log pressure. Consider values of temperature T_1, T_2, and T_3 provided at pressure levels p_1, p_2, and p_3, respectively ($p_1 < p_2 < p_3$). How can we calculate the mean temperature $<T_{1-3}>$ of the layer between p_1 and p_3?

   First we will assume that $<T_{1-2}> = (T_1 + T_2) / 2$ and that $<T_{2-3}> = (T_2 + T_3) / 2$.

   Then we will average $<T_{1-2}>$ and $<T_{2-3}>$ with weighting by thickness in log pressure.

   $<T_{1-3}> = [(\log p_2 - \log p_1) <T_{1-2}> + (\log p_3 - \log p_2) <T_{2-3}>] / (\log p_3 - \log p_1)$

   This can be rewritten as

   $<T_{1-3}> = [\log(p_2 / p_1) (T_1 + T_2) / 2 + \log(p_3 / p_2) (T_2 + T_3) / 2] / \log(p_3 / p_1)$

   Download files containing T_{1000}, T_{925}, T_{850}, T_{775}, T_{700}, T_{600}, and T_{500} for 1993 March 14 00Z. Based on the method outlined above, calculate the average temperature of the layer between 1000 hPa and 500 hPa. Calculate the thickness of the layer between 1000 hPa and 500 hPa based on the mean layer thickness (units are gpm). Plot the average temperature and thickness of the 1000-500 hPa layer in the domain 20-50°N, 270-310°E. Use contour intervals of 3 °C and 60 dkm. Note the similar contour spacing between the two parameters. If the average temperature of the 1000-500 hPa layer increases by 1 °C, then the thickness of the layer will increase by about 20 dkm.

2. Download the files containing Z_{1000} and Z_{500} for 1993 March 14 00Z. Add your calculated 1000-500 hPa thickness to obtain Z_{500}. Plot contours of calculated Z_{500} in the domain 20-50°N, 270-310°E using conventional 6 dkm intervals. To check your results, plot contours of model Z_{500} on the same plot using a different color or line pattern. There will not be exact correspondence; in particular, calculated Z_{500} is slightly lower than model Z_{500} in regions of warm temperature due to the absence of virtual temperature effects (we did not include the influence of water vapor on lowering the density of air in our calculation of 1000-500 hPa thickness).

3. Calculate 1000-500 hPa thickness from model Z_{1000} and Z_{500}. Plot contours of this thickness along with Z_{1000} and Z_{500} in the domain 20-50°N, 270-310°E using different colors or line patterns (if possible). Use conventional 6 dkm intervals for all three parameters. Note how the smaller values of 1000-500 hPa thickness (due to colder temperature) in the northwest part of the domain cause the lowest values of Z_{500} to occur west of the lowest values of Z_{1000}.

4. **Optional.** Download the file containing SLP for 1993 March 14 00Z. Plot SLP and 1000-500 hPa thickness in the domain 20-50°N, 270-310°E. This combination is a very common meteorological chart. Note the resemblance between this plot and the plot of Z_{1000} and T_{1000} in Exercise #8. Since temperature gradients are strongest near the surface, the pattern of

1000-500 hPa thickness is closely associated with the pattern of T1000. You can use a SLP/thickness chart to infer locations of fronts and regions of warm and cold advection near the surface.