Exercise 2

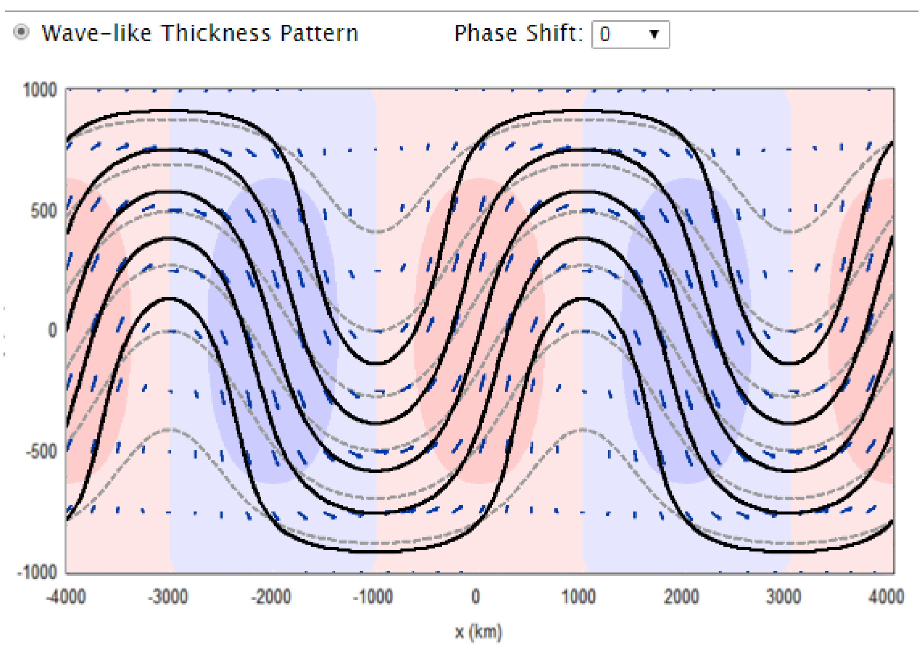
After examining the –pi/2, 0 and pi/2 widget cases answer the questions below. Consult your instructor to determine which exercises are required and in what format they should be completed.

1. Which phase shift resulted in the strongest differential absolute vorticity advection, and why?

   The 0 phase shift resulted in the strongest minima and maxima of differential absolute vorticity advection. In the 0 phase shift case, the height gradient is stronger and more amplified, thus leading to more curvature, and therefore more abs. vorticity advection.

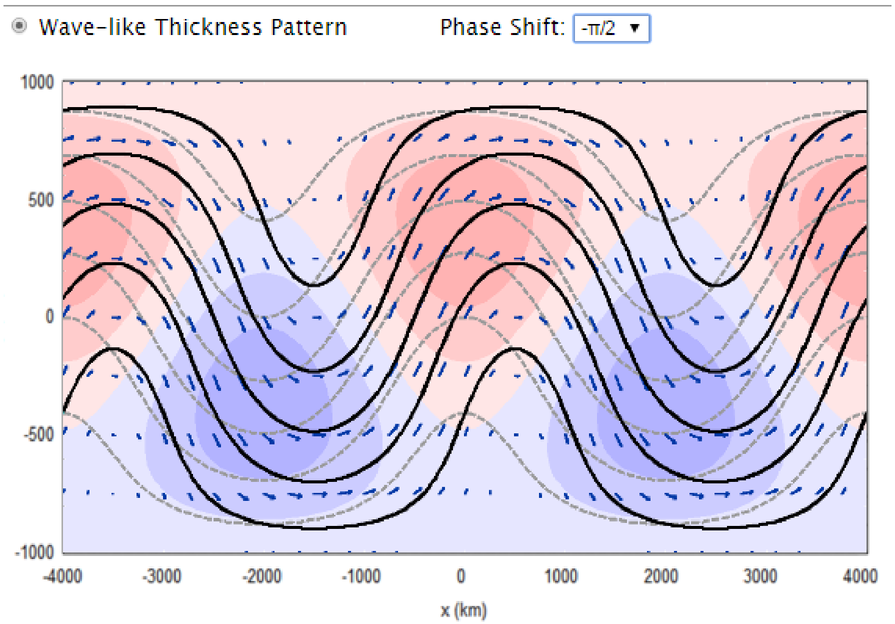
2. Which phase shift(s) resulted in 1000-500mb thickness advection maxima and minima being offset either latitudinally, longitudinally, or both, from the 500mb trough/ridge axes? Why? Explain in terms of thickness gradient and geostrophic wind.

   The phase shifts of pi/2 and –pi/2 resulted in thickness advection maxima and minima that were offset latitudinally and longitudinally from the ridge and trough axes. These differences are simply due to the location of the thickness contours with respect to height trough/ridge axes. In the 0 phase shift case below, we can see that the height contours and thickness contours are in alignment – their troughs and ridges are in the same place. The winds are largely parallel to the thickness contours (via the vectors themselves or the very elongated solenoids created by height and thickness contours) – this leads to lower values of thickness advection.



$$\left(\nabla^2+\frac{f_0^2}{\sigma}\frac{\partial^2}{\partial p^2}\right)\omega = \frac{f_0}{\sigma}\frac{\partial}{\partial p}\left[\mathbf{v}_g\cdot\nabla\left(\zeta_g+f\right)\right]+\frac{1}{\sigma}\nabla^2\left[\mathbf{v}_g\cdot\nabla\left(-\frac{\partial\Phi}{\partial p}\right)\right]$$

In the pi/2 case shown below, we see that the thickness trough and ridge are located slightly west of the height trough and ridge. This situation see winds cutting across *thickness contours at a greater angle just upstream of the base of the height trough and top of height ridge (solenoids are more box-like).*

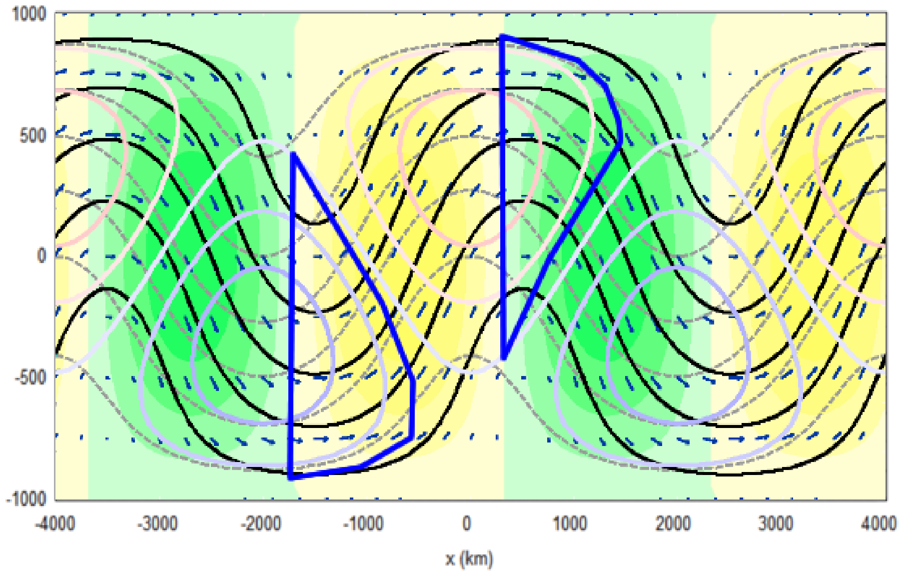


$$\left(\nabla^2 + \frac{f_0^2}{\sigma}\frac{\partial^2}{\partial p^2}\right)\omega = \frac{f_0}{\sigma}\frac{\partial}{\partial p}\left[\mathbf{v}_g \cdot \nabla\left(\zeta_g + f\right)\right] + \frac{1}{\sigma}\nabla^2\left[\mathbf{v}_g \cdot \nabla\left(-\frac{\partial \Phi}{\partial p}\right)\right]$$

3. Do the differential absolute vorticity advection term and thickness advection term always contribute to overall value of omega in the same manner (e.g. both contribute positively in the same location), or do they sometimes counteract each other? If they counteract, explain an example in which this occurred during your exploration.

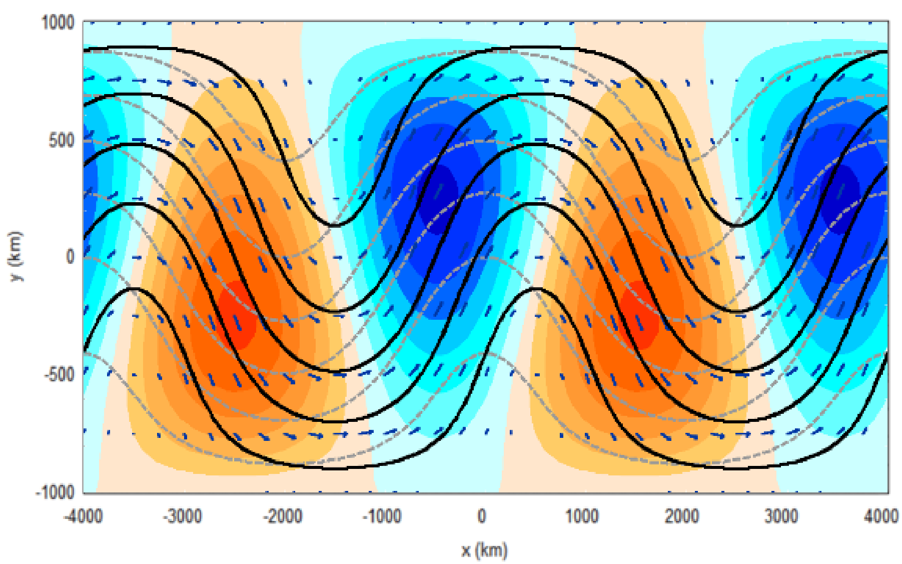
   They sometimes counteract each other. A good example of this occurs in the –pi/2 case. The image below shows differential absolute vorticity advection in color-shading, and contours of thickness advection. We can see that just east of the base of the trough, there is positive differential abs. vorticity advection in the same location as negative thickness advection – this region is outlined in dark blue. Similarly, just east of the height ridge the two forcings counteract each other again – this time with positive thickness advection in the same location as negative differential abs. vorticity advection (again outlined in dark blue). This creates the overall omega pattern seen in the second image below.

Wave-like Thickness Pattern Phase Shift: -π/2



$$\left(\nabla^2+\frac{f_0^2}{\sigma}\frac{\partial^2}{\partial p^2}\right)\omega=\frac{f_0}{\sigma}\frac{\partial}{\partial p}\left[\mathbf{v}_g\cdot\nabla\left(\zeta_g+f\right)\right]+\frac{1}{\sigma}\nabla^2\left[\mathbf{v}_g\cdot\nabla\left(-\frac{\partial\Phi}{\partial p}\right)\right]$$

Wave-like Thickness Pattern Phase Shift: -π/2



$$\left(\nabla^2+\frac{f_0^2}{\sigma}\frac{\partial^2}{\partial p^2}\right)\omega=\frac{f_0}{\sigma}\frac{\partial}{\partial p}\left[\mathbf{v}_g\cdot\nabla\left(\zeta_g+f\right)\right]+\frac{1}{\sigma}\nabla^2\left[\mathbf{v}_g\cdot\nabla\left(-\frac{\partial\Phi}{\partial p}\right)\right]$$

4. Which phase shift shows a situation in which the low pressure system would weaken? Explain why.

   Pi/2 shows a situation in which the given low pressure system would weaken. This scenario shows positive omega values over nearly the entire area of 1000 mb low pressure, which would cause it to "fill in".

5. Which phase shift shows a situation in which the low pressure system would strengthen? Explain why

   The -pi/2 phase shift shows a case in which the given low pressure system would strengthen. This scenario shows negative omega values over nearly the entire area of 1000 mb low pressure, which would cause pressures to lower further.

Exercise 3

After examining the -pi/2, 0 and pi/2 cases and answering the questions in Exercise 2, apply your knowledge to answer the questions using the imagery below. The first image contains contours of 1000mb heights, and the second image contains black contours of 500mb heights overlaid on color-shaded 1000-500mb thickness. Consult your instructor to determine which exercises are required and in what format they should be completed.

1. Which phase change does this situation most closely represent? *(-pi/2,* 0 or pi/2)

We can see that the thickness trough is just to the west of the height trough at 500 mb, and the surface low is to the east of height trough axis.

2. Approximately where would you expect differential geostrophic absolute vorticity advection to be maximized according to the 500mb height map? Minimized? You can use parts of states, cities or landmarks to narrow your description.

Maximized to the east of the trough, and centered over strongest height gradient there – so the highest values in panhandle regions of OK and TX, and lower/ moderate values spreading eastward into rest of OK, eastern KS and western MO.

Minimized areas are a little harder to tell because the height gradient is not as strong where we see the ridge is most pronounced – so could guess southwestern MT, western WY, east & central Utah, northeast AZ.

3. Approximately where would you expect geostrophic thickness advection to be maximized? Minimized? You can use parts of states, cities or landmarks to narrow your description.

Maximized near central KS and across MO (see small solenoids).

Minimized along where solenoids are small in west central NM, and again along eastern portion of TX panhandle.

4. Summarize how and where the two terms would combine to create total ascent (negative omega values).

Based on previous answers, we'd expect positive omega values (descent) in the areas including western WY, central & eastern UT and northeast AZ.

Differential positive abs. vorticity advection and thickness advection are of opposing signs and would cancel in NM and the TX panhandle region, creating neutral or weakly pos/neg values depending on exact location.

Negative omega values (ascent) would be strong just to the north and east of TX/OK panhandle intersection, and would extend into KS and MO.

5. Through experience, you know that the precipitation patterns within a midlatitude wave train do not exactly match the regions of ascent that we've outlined in this example and within the widget. What kinds of processes are missing from the QG Omega Equation that help account for the difference in the omega field and the cloud/precipitation shields?

Some processes that could be cited:

- *Boundary layer processes tied to friction*
- *Latent heating/cooling exchanges*
- *Radiative processes*
- *Small-scale convective processes*
- *Orographic effects*
- *Frontal circulations*