

SIO 217B Atmospheric and Climate Sciences II

Exercise #13

1. a) The continuity equation tells us that the difference in pressure vertical velocity between two pressure surfaces is related to the average horizontal divergence within the layer when calculated in vertical coordinates of pressure (not log pressure). Consider values of horizontal divergence $\nabla \cdot \mathbf{V}_1$, $\nabla \cdot \mathbf{V}_2$, and $\nabla \cdot \mathbf{V}_3$ provided at pressure levels p_1 , p_2 , and p_3 , respectively ($p_1 < p_2 < p_3$). How can we calculate the mean divergence $\langle \nabla \cdot \mathbf{V}_{1-3} \rangle$ of the layer between p_1 and p_3 ? First we will assume that

$$\langle \nabla \cdot \mathbf{V}_{1-2} \rangle = (\nabla \cdot \mathbf{V}_1 + \nabla \cdot \mathbf{V}_2) / 2 \quad \text{and that} \quad \langle \nabla \cdot \mathbf{V}_{2-3} \rangle = (\nabla \cdot \mathbf{V}_2 + \nabla \cdot \mathbf{V}_3) / 2.$$

Then we will average $\langle \nabla \cdot \mathbf{V}_{1-2} \rangle$ and $\langle \nabla \cdot \mathbf{V}_{2-3} \rangle$ with weighting by thickness in pressure.

$$\langle \nabla \cdot \mathbf{V}_{1-3} \rangle = [(p_2 - p_1) \langle \nabla \cdot \mathbf{V}_{1-2} \rangle + (p_3 - p_2) \langle \nabla \cdot \mathbf{V}_{2-3} \rangle] / (p_3 - p_1)$$

Download files containing $\nabla \cdot \mathbf{V}_{700}$, $\nabla \cdot \mathbf{V}_{600}$, and $\nabla \cdot \mathbf{V}_{500}$ for 1993 March 14 00Z. Based on the method outlined above, calculate the average divergence within the layer between 700 hPa and 500 hPa. Plot the average divergence within the 700-500 hPa layer in the domain 20-50°N, 270-310°E using intervals of $2 \times 10^{-5} \text{ s}^{-1}$. You will need to divide your input data by ten to obtain these units.

Download files containing ω_{700} and ω_{500} for 1993 March 14 00Z. Calculate the average vertical gradient of pressure vertical velocity ($\partial\omega/\partial p$) within the layer between 700 hPa and 500 hPa (similar to your calculation for Exercise #3). Convert your units to be the same as for horizontal divergence (10^{-5} s^{-1}). Plot contours of $\partial\omega/\partial p$ on the same plot as horizontal divergence using a different color or line pattern.

b) Note that contours of $\partial\omega/\partial p$ are nearly identical to but have opposite sign from contours of $\nabla \cdot \mathbf{V}$ (perfect correspondence cannot be expected due to errors introduced by averaging discrete pressure level data). Why do these two terms cancel?

2. a) Write down an equation for calculating the pressure vertical velocity at pressure level p_1 in terms of pressure vertical velocity at pressure level p_2 and the average horizontal divergence within the layer between p_1 and p_2 .
- b) Calculate ω_{500} from the model data for ω_{700} , $\nabla \cdot \mathbf{V}_{700}$, $\nabla \cdot \mathbf{V}_{600}$, and $\nabla \cdot \mathbf{V}_{500}$ and plot it in the domain 20-50°N, 270-310°E using intervals of 20 hPa hr⁻¹. To check your results, plot model ω_{500} using a different color or line pattern (there will not be exact correspondence).
3. a) Write down an equation for converting vertical velocity in pressure coordinates to vertical velocity in height coordinates.
- b) Download the file containing T_{500} for 1993 March 14 00Z and use it to convert model ω_{500} to w_{500} . Plot calculated w_{500} in the domain 20-50°N, 270-310°E using intervals of 10 cm s⁻¹.