12.812: Problem set 1

The purpose of this first problem set is to give you practice using the zonal and time eddy/mean decomposition, using the sigma coordinate, and assessing large-scale observational and reanalysis data.

1. **Space and time decomposition into eddies and means:** In class, we discussed how variables may be split into means and eddies with respect to both a time and zonal mean. We decompose a variable $A$ into a time mean and eddy as

$$A = \overline{A} + A',$$

and into a zonal mean and eddy as


(a) Beginning with these expressions, show that the time and zonal mean meridional temperature flux $[vT]$ may be decomposed as follows:

$$[vT] = [v][T] + [v'][T'] + [v^*T^*].$$

(b) Explain in words what each of the three contributing terms are in this decomposition of the temperature flux.

2. **Vertical coordinate systems:** The sigma vertical coordinate is widely used in modeling and analysis of the atmospheric general circulation. The sigma coordinate is defined by $p = \sigma p_s$ where $p$ is pressure and $p_s$ is surface pressure. For the $(x,y,\sigma)$ coordinate system, and working within the hydrostatic approximation, show that the continuity equation is given by

$$\frac{\partial p_s}{\partial t} + \nabla \cdot (p_s \mathbf{v}) + \frac{\partial (p_s \dot{\sigma})}{\partial \sigma} = 0,$$

where $\dot{\sigma} = d\sigma/dt$ is the Lagrangian rate of change of $\sigma$ and $\mathbf{v} = (u,v)$ is the horizontal fluid velocity. The simplest approach is to consider the conservation of mass in an infinitesimal fluid element following the flow, as demonstrated for pressure coordinates in the class notes. It is also acceptable to take the continuity equation in the $(x,y,p)$ coordinate system as a starting point.

3. **Comparison of observational and reanalysis datasets:** Calculate the zonal and time mean surface precipitation rate using reanalysis and using a global observational precipitation dataset. The time mean should be over a period of at least ten years. Some gridded datasets are linked to at www.cdc.noaa.gov/data/gridded/.

(a) Plot and compare the results versus latitude for annual mean statistics.

(b) Briefly describe the observational and modeling contributions to each estimate of the precipitation rate. (This will typically require you to look up reference papers on the reanalysis and observational datasets that you use).

(c) Discuss possible reasons for discrepancies.