AOS 610 GFD I Fall 2024 Prof. Hitchman Name _____

Problem Set #2 10 points Due Thursday October 24, 2024

1. (1 pt) *Orbits* An orbit may be defined as occurring when $\vec{g}_{eff} = \vec{\nabla}\left(\Phi_g + \Phi_c\right) = 0$, where the gravitational and centripetal potential functions are Φ_g = G M/r and $\Phi_c = \Omega^2 r^2/2$. Solve for the distances r from the center of the earth for an object going around a) once every 23 hr 56 min (sidereal day) and b) once every 27.3 days.

2. (1.5 pts) *Circulation and vorticity*
a) What is the circulation about a circle of radius 500 km for a cyclonic vortex in the Northern Hemisphere, where the tangential wind speed increases outward at 10 m/s per 100 km?

b) What is the relative vorticity within the circle?

c) Evaluate the vorticity of the earth itself near the north pole, using the same method for a circle of radius 500 km centered at the north pole, assuming that the earth is in solid body rotation and the angular frequency is $\Omega = 7.292 \times 10^{-5}$ s^{-1}.

3. (1.5 pt) *Thickness*
a) Estimate the 1000-500 hPa thickness for an atmosphere with constant lapse rate 6.5 K/km and surface temperature T_o = 273 K.

b) Examine a 1000-500 hPa thickness chart from a weather analysis or numerical forecast, such as a "surface" chart from the NCEP NAM model, at http://www.aos.wisc.edu/weather/Models. The dashed yellow contours are labeled in decameters (multiply by 10 to get thickness in meters). Estimate the mean 1000-500 hPa thickness across the contiguous 48 states. Using this, estimate the magnitude of a typical thickness anomaly (departure from the mean).

4. (1.5 pts) *Geostrophic wind*
a) Estimate the geostrophic wind at 4 km over Tateno Japan in Fig. 2 of the article about Ooishi and b) compare with the radiosonde observations in Fig. 9 (1° latitude = 111 km).

5. (1 pt) *Thermal wind*
Surface winds are calm in Madison, but temperatures in the lower troposphere are observed to increase eastward at 1 K per 100 km. Estimate the wind speed and direction over Madison at 5 km altitude if the surface temperature is 290 K and the lapse rate is adiabatic.

6. (2.5 pts) *Plotting zonal mean temperature and zonal wind using PANOPLY*

Please read "Panoply_readme.txt" and "Panoply_tips.pdf", which include descriptions of how to add PANOPLY to your applications folder, tips on how to navigate the controls, and how to obtain data from NCAR's research data archive. For this problem you can download the two ERA5 files of monthly mean temperature and zonal wind from the class website.

a) Use PANOPLY to make meridional cross-sections of monthly mean ERA5 zonal wind and temperature for the domain 90S – 90N, 1000 hPa – 1 hPa for the year 2021. You could put them on one page and print it.

b) On the two zonal wind cross sections label the subtropical westerly jets (SWJs), polar night jets (PNJs), and subtropical easterly jets (SEJs) in both hemispheres.

c) Using the thermal wind concept, briefly describe how the major cold and warm regions in the temperature cross sections are related to the SWJ. Why does the SWJ decrease in strength above the tropopause?

7. (1 pt) *Rotating tank*. Considering the radial acceleration of fluid elements accomplished by the height gradient, derive a formula for the dependence of depth, h, on radius, r, for an incompressible fluid in solid-body rotation at angular frequency Ω in a cylindrical tank with a flat bottom and free surface. Let H be the depth at the center of the tank.