Problem sheet 1

1. The weather forecast on 19 May 1997 reported a tornado in Leek, Staffordshire. The diameter of the tornado was approximately 100m, and peripheral wind speeds of up to 70 ms^{-1} were estimated. Calculate the circulation around the perimeter of the tornado, and hence estimate the value of the vorticity within the tornado. Assuming the vorticity of the pre-thunderstorm air was $10^{-4}s^{-1}$, estimate the factor by which the air column had been stretched.

2. Imagine that Concorde is flying at speed u from New York to London along a latitude circle. The deflecting force due to the Coriolis effect is toward the south. By lowering the left wing ever so slightly, the pilot (or onboard computer) can balance this deflection.

   (a) Draw a diagram of forces - gravity, uplift normal to the wings and Coriolis - and use it to deduce that the angle of tilt, θ, of the aircraft from the horizontal required to balance the Coriolis force is

   $$tan\ \theta\ =\ \frac{fu}{g} \tag{1}$$

   (b) If u = 600 ms^{-1}, compute the angle.

   (c) What analogies can you draw with atmospheric circulation?

3. Estimate the Rossby number in each of the following situations, and hence deduce whether the rotation of the Earth is likely to have an important effect:

   (a) the atmospheric jet stream

   (b) the river Thames at Oxford

   (c) a tornado

4. What is the surface pressure difference required between two meteorological stations located 500km apart at 45°N to maintain an average geostrophic wind speed of 20 ms^{-1} between them? Give your answer in hPa (or mb).

5. Consider a horizontally uniform atmosphere in hydrostatic balance. The atmosphere is isothermal with a temperature of -10°C. Surface pressure is 1000 mb. Consider the level that divides the atmosphere into two equal parts by mass (i.e. one half of the atmospheric mass is above this level and the other below). What is the altitude, pressure and density at this level?

6. Suppose that the Earth is flat! Specifically, consider it to be a thin circular disk (of radius 6370 km), orbiting the Sun at the same distance as the Earth does currently. The planetary albedo is 30%.The vector normal to one face of this disk always points directly at the sun, and the disk is made of perfectly conducting material, so both faces of the disk are at the same temperature. Calculate the emission temperature of this disk, and compare with the emission temperature for a spherical Earth.