Tutorial 1

A. Vertical structure of the atmosphere

In the *hydrostaticly balanced* atmosphere the vertical pressure gradient is in balance with the gravitational force.

$$-\frac{1}{\rho}\frac{\partial p}{\partial z} = g$$

where g is the acceleration due to the Earth's gravity. The *hydrostatic balance* is applicable to most situations in the atmosphere, exceptions arising in the presence of large vertical accelerations such as are associated with thunderstorms.

Assume that the temperature varies linearly with height (z) i.e. $T = T_0 - \Gamma z$, where T_0 is the temperature at the ground level ($z = 0$) and Γ is the lapse rate.

1. Show how pressure and density vary with height.
   i. Assume that temperature does not change with altitude and takes values T_o =-10^oC, -30^oC and -50^oC that correspond roughly to eqautorial, mid-latitude and polar regions respectively.
      Assume that the pressure at the ground is $1000hPa$.
   ii. Assume different values of temperature at the ground level i.e. T_o =30^oC, 10^oC and -10^oC that correspond roughly to eqautorial, mid-latitude and polar regions respectively.
      In each case assume that the temperature changes linearly with height at a constant lapse rate, Γ, is equal to $1.4, 1.20.98, 0.6, 0, -0.2K/100m$.
      Assume that the pressure at the ground is $1000hPa$.
2. Estimate the altitude of the tropopause for different values of temperature at ground level and different lapse rates.
   Assume that the tropopause is at $p_t = 200hPa$.

B. **Potential temperature**

1. For a known profile of temperature $T(z)$ derive an expression for a profile of potential temperature $\theta(z)$. Then consider a case of temperature that varies linearly with height. Plot vertical profiles of potential temperature for different rates of change of temperature: $1.4, 1.20.98, 0.6, 0, -0.2K/100m$.
2. Potential temperature lapse rate

   Derive an expression for the change of potential temperature with altitude $\gamma_\theta = d\theta/dz$. Assume that the temperature changes with altitude liearly with a constant lapse rate γ i.e. $T(z) = T_0 - \Gamma z$. Plot in that case a profile of $\gamma_\theta(z)$.