

Tutorial 1

A. Vertical structure of the atmosphere

In the *hydrostatically 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 surface temperature ($z = 0$) and Γ is the lapse rate.

1. Determine how pressure and density vary with altitude.
 - i. Assume that the temperature does not change with altitude and takes the values $T_o = -10^\circ C$, $-30^\circ C$ and $-50^\circ C$, corresponding approximately to equatorial, mid-latitude and polar regions, respectively.
Assume that the surface pressure is $1000hPa$.
 - ii. Assume different values of the surface temperature, i.e., $T_o = 30^\circ C$, $10^\circ C$ and $-10^\circ C$, corresponding approximately to equatorial, mid-latitude and polar regions, respectively.
In each case, assume that the temperature changes linearly with height at a constant lapse rate, Γ , equal to $1.4, 1.2, 0.98, 0.6, 0, -0.2K$ per 100 m.
Assume that the surface pressure is $1000hPa$.
2. Estimate the altitude of the tropopause for different values of surface temperature and different lapse rates.
Assume that the tropopause pressure is $p_t = 200hPa$.

B. Potential temperature

1. For a given temperature profile, $T(z)$, derive an expression for the corresponding potential temperature profile $\theta(z)$. Then consider the case in which the temperature varies linearly with height. Plot the vertical profiles of potential temperature for different lapse rates: 1.4, 1.2, 0.98, 0.6, 0, $-0.2K$ per 100m.
2. Potential temperature lapse rate
Derive an expression for the vertical gradient of potential temperature, $\gamma_\theta = d\theta/dz$. Assume that the temperature changes linearly with altitude linearly at a constant lapse rate, i.e., $T(z) = T_0 - \Gamma z$. In this case, plot the profile of $\gamma_\theta(z)$.