Solutions to Activity 4: Mount Washington Weather

1 Measuring Atmospheric Lapse Rate near Mount Washington

The following are observations from our three stops while travelling to the summit. Note that these are the observations taken with our portable weather stations and may not exactly match the observations from other sources.

- **Stop 1: Pinkham Notch**
  - Air Temperature = 76.6°F = 24.7°C
  - Pressure = 955 hPa
  - Elevation = 670 m (2200 ft)
  - Sky Conditions = 50% cloud cover, cirrus, stratus, and cumulus
  - Wind = 4 mph
  - Sky Temperature = 27.1°F

- **Stop 2: Auto Road**
  - Air Temperature = 70.0°F = 21.1°C
  - Pressure = 887.6 hPa
  - Elevation = 1219 m (4000 ft)
  - Sky Conditions = cirrus and cumulus, 50% cloud cover
  - Wind = calm
  - Sky Temperature = 10.2°F clear sky, 45.1°F cloudy sky

- **Stop 3: Summit**
  - Air Temperature = 58.8°F = 14.9°C
  - Pressure = 820 hPa
  - Elevation = 1920 m (6288 ft)
  - Sky Conditions = Mostly cloudy with cumulus, stratus, cirrus, undercast, cumulonimbus in distance
  - Wind = west at 10 mph
  - Sky Temperature = 40.6°F (cloud temperature at Alpine Garden)
From these data, we can calculate an atmospheric lapse rate \((\Gamma)\), i.e. the rate of temperature decrease with height. Using the temperature observations at Pinkham Notch and Mount Washington Summit, we obtain:

\[
\Gamma = \frac{\Delta T}{\Delta Z} = \frac{14.9^\circ C - 24.7^\circ C}{1920m - 670m} = -7.8^\circ C/km
\]

This is between the dry adiabatic lapse rate \((9.8^\circ C/km)\) and the average moist adiabatic lapse rate \((6.5^\circ C/km)\). This indicates that the air was fairly moist, which makes sense given the cloud cover and rain showers that occurred as we descended the mountain.

2 Finding the Elevation of Mount Washington Using Pressure Data

As when we estimated the height of the Green Building using hydrostatic balance, we can also estimate the elevation of Mount Washington using pressure data. To determine the summit elevation, we employ the hydrostatic balance relation with constant atmospheric density to obtain:

\[
z_{\text{summit}} = z_{\text{Pinkham Notch}} + \frac{\Delta P}{g\rho_o} = 670m + \frac{95500Pa - 82000Pa}{(9.8\frac{m}{s^2}) \times (1.2\frac{kg}{m^3})} = 1817m
\]

This estimate is a bit low; the summit is actually at an elevation of 1920 m.

2.1 Alternative Method: accounting for change in atmospheric density

A more accurate summit height can be found using both hydrostatic balance and the ideal gas law. In differential form, with \(z\) referring to height in the atmosphere, \(R\) a constant, \(T\) a reference (isothermal) temperature, \(p\) for pressure, and \(\rho\) for density, the hydrostatic balance equation and ideal gas law are, respectively

\[
\frac{dP}{dz} = -\rho g
\]

and

\[
P = \rho RT
\]

We can then rearrange the ideal gas law for density and substitute that expression into the hydrostatic balance equation to obtain

\[
\frac{-RT}{g} \int_{P_{\text{Pinkham Notch}}}^{P_{\text{Summit}}} \frac{dP}{P} = \int_{z_{\text{Pinkham Notch}}}^{z_{\text{Summit}}} dz
\]

where \(R = 287 \frac{J}{kgK}\) and we can use an average temperature for \(T \sim 293.4K\) (average of our
three temperature measurements).

$$\frac{-RT}{g} \ln \left( \frac{P_{\text{summit}}}{P_{\text{PinkhamNotch}}} \right) = Z_{\text{summit}} - Z_{\text{PinkhamNotch}}$$  \hspace{1cm} (6)

$$Z_{\text{summit}} = 670m - \frac{287 J}{kgK} \cdot 293.4K \cdot \frac{9.8 m}{s^2} \ln \left( \frac{820 hPa}{955 hPa} \right) = 1979m$$  \hspace{1cm} (7)

This estimate is closer to the actual value of 1920 m. This should be the more accurate method because it accounts for the decrease in atmospheric density with height.