Linear Approximation to the US Standard Atmosphere

By Steve Kliewer   May 2011

Atmospheric Pressure is due to the weight of all of the air above a point (ignoring all dynamic effects such as motion, storms, and wind). For example: Imagine a column of air, 1 square inch in cross section, extending from my hand all the way to empty space. It would weigh just under15 lbs on that square inch of surface. Of course from hydrostatics we know that air is a fluid so this force is not only directed downward pushing my hand downward but also underneath pushing upward and on all sides. Thus this weight becomes a pressure and not a directed force.

US Standard Atmosphere – 1976 model

The most accepted mathematical model for our atmosphere is the *US Standard Atmosphere – 1976*. It is a complex model for temperature, density and pressure from sea level up through our mesosphere. We only need the part for pressure in the lower troposphere:

$P = P_0 * \exp(-h/h_0)$

The average pressure at mean sea level: P_0 = 1 atm = 101.33 kPa = 14.696 lb/in^2 = 29.921 inHg = 1013 mBar

The scale height: h_0 = 27672 ft = 8434.5 m

Chart 1
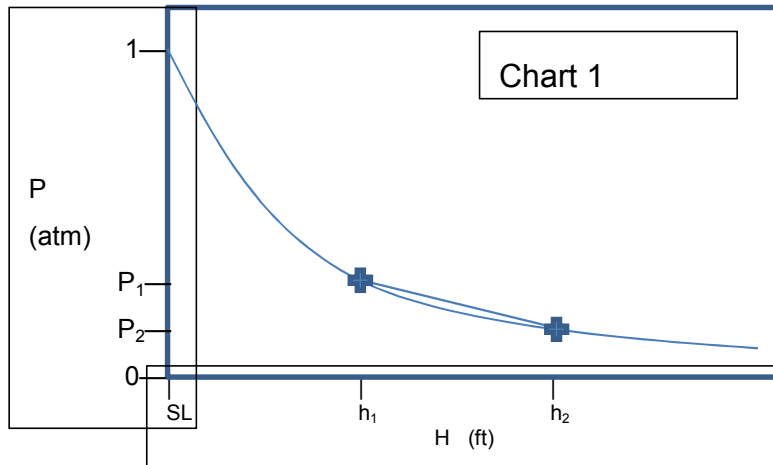
Table 1

H (ft)	P (atm)	P (kPa)
Sea Level = 0	1.0000	101.33
1000	0.9645	97.734
1500	0.9472	95.983
2000	0.9303	94.265

Since the Balloon Fest launch site (Tobin James Cellars in Paso Robles, CA) is at 1000 ft ASL, we expect pressures of 97.734 to 94.265 kPa.

Linear Approximation

This exponential curve can be modeled by a much simpler linear equation as long as we confine it to a smaller interval of altitude.

$P = m * h + P_0$ or $h = k_1 * P + k_0$ (as we will use it for the Vernier LabPro)

The slope, $k_1 = (h_2 - h_1)/(P_2 - P_1)$

The intercept, $k_0 = h_1 - k_1 * P_1$

Using the data in table 1:

k_1 = -288.3 ft/kPa = -87.87 m/kPa = -8904 m/atm = -29212 ft/atm

k_0 = 29175 ft = 8893 m

Details of the calculations are available in: *Linear Approx to the US Standard Atmosphere.xlsx*

Using Vernier's LabPro:

Typically we use a Barometer sensor (BAR-BTA) with the LabPro DAQ. This sensor is automatically detected and will default to a calibration of kPA when connected.

Most sensors generate a voltage that is proportion to the measured phenomena (i.e. pressure). The DAQ digitally measures the voltage and then applies a linear "calibration" to generate readings in the appropriate units.

Although it is possible to create your own calibration for the sensor such that the LabPro reads the barometer directly in meters or ft, it is usually easier to add a calculated column to the resultant data.

Assuming that data has been acquired in kPA, you should have two columns: Time (s) and Pressure (kPa). Under Data tab, click on New Calculated column. Name it Altitude (ft) and enter formula: -288.3*"Pressure"+29175. Adjust the value for k_0 to zero the starting altitude (adjusts for changes in local conditions).

Much more detail is available in: *Barometric Altimetry.doc*