

Lab - AOS 330
Measurement of Atmospheric Pressure

1 Objectives

- Gain familiarity with the techniques for reading standard barometers.
- Compute the sea level pressure and altimeter setting from the observed station pressure.
- Use the hydrostatic law to estimate the height of the AO&SS building from pressure observations.
- Introduction to the concept of instrument precision and its influence on derived quantities.

2 Materials

- Aneroid barometer
- Aneroid barometer handout

3 Introduction

Determination of the atmospheric pressure is perhaps the most fundamental measurement in meteorology. In measuring atmospheric pressure, we should keep in mind that we are simply “weighing” the column of air above the level of the barometer.

3.1 Fundamentals

Atmospheric pressure may be measured with a number of different types of instruments, the two most common being (1) the mercury barometer, in which the pressure of the atmosphere forces a column of mercury a proportional distance up into an evacuated glass tube, and (2) the aneroid barometer, in which the atmospheric pressure is measured by way of the degree of compression of an evacuated bellows.

An aneroid barometer is considerably simpler to use than a mercury barometer; one simply reads the position of a pointer against a calibrated circular scale. The simplicity of the aneroid barometer is counterbalanced by its lower accuracy, since the internal linkage mechanism is subject to friction, and the elastic tension in the evacuated bellows may weaken with time. Consequently, aneroid barometers are usually used for routine pressure observations, but they must be calibrated against the much more accurate mercury barometer. Usually, it is sufficient to determine an additive (or subtractive) constant correction that brings the aneroid barometer reading into agreement with the mercury barometer. Some barometers have a mechanism for easy on-the-spot recalibration, although these are also more susceptible to inadvertent adjustments and must be checked often.

3.2 Adjustment to Sea Level

All barometers measure atmospheric pressure at the altitude of the barometer. This measured pressure (following any appropriate temperature, gravity, or calibration corrections) is called the *station pressure* (p_0). Because of elevation differences between stations, particularly in the high plains and in mountainous regions, direct comparisons of station pressures are rarely meaningful, since differences will be dominated more by the altitude effect than by actual differences in atmospheric conditions. It is therefore standard to eliminate the effects of variable altitude by correction all observed station pressures to sea level. Essentially,

this correction entails adding the assumed weight of a *fictitious* column of air extending from the station elevation z_0 down to sea level. Since this correction depends not only on the station elevation but also on the temperature structure assumed for the fictitious column of air, different correction methods may lead to slightly different results, especially for high altitude stations.

For example, one may assume a representative absolute temperature T for the column, in which case

$$p_{sl} = p_0 \exp(z_0/H), \tag{1}$$

where the *scale height* H is given by

$$H = R_d T/g, \tag{2}$$

and $R_d = 287 \text{ J (kg K)}^{-1}$ is the *gas constant for dry air*.

Current practice in the United States is to assume that the temperature T of the fictitious column is simply the average of the current station temperature and that 12 hours previously, converted to Kelvin.

Other approaches are also in common use. For example, in aviation, the so-called *altimeter setting* is just a sea level pressure (expressed in inches of mercury) calculated based on the assumption that the fictitious column of air below the station has the temperature structure of the U.S. Standard Atmosphere (15°C at sea level; 6.5°C decrease with each addition kilometer of elevation). Because the Standard Atmosphere represents a fixed temperature profile, the correction to sea level is always the same for a given station elevation.

Regardless of the method used to compute the correction, the sea level pressure p_{sl} is always *greater* than the station pressure p_0 , except in the relatively rare case that the station is located below sea level.

4 Procedure - Part I

- 1) In class, read the station pressure on the aneroid barometer as carefully as you can, following the directions of the instructor. Depending on the barometer, you will either be reading the instrument in millibars or inches of mercury. Apply any known calibration correction to the value you read. Convert your final results to millibars, if necessary.
- 2) Given the current station temperature and the temperature from 12 hours ago, compute the sea level pressure in millibars. Be sure to record your complete calculation in your writeup to be turned in. Note that for the 8th floor, $z_0 = 295 \text{ m}$; for the 14th floor, $z_0 = 315 \text{ m}$.
- 3) If necessary, convert your station (not sea level) pressure to inches of mercury, using the conversion factor 0.02953 (inches Hg / millibar).
- 4) Add the appropriate correction (+1.03 inches Hg for the 8th floor, +1.10 inches for the 14th floor) to convert your previous result to an altimeter setting, expressed to the nearest 0.01 inches of Hg.
- 5) Record the above procedures and your results in your lab writeup.

5 Procedure - Part II

The class will divide into three roughly equal groups. Each group will be assigned one barometer. Each group will use their barometer to make measurements according to the following schedule:

Group 1	Group 2	Group 3
roof orientation	roof orientation	roof orientation
roof measurement	roof measurement	ground measurement
ground measurement	ground measurement	roof measurement

1. First, all groups will meet on the roof for a brief orientation.

2. Take your group's aneroid barometer to the ground floor OR the roof (see table above), and place the barometer on a level surface (e.g., a bench).
3. Each student in your group is to *independently* read the barometer to the nearest 0.1 millibar or 0.001" and note his/her reading *without telling the other students*. Write down your reading. **Twist the big knob a bit after each reading so that each student has to make a fresh start!**
4. After all students in the group have made their barometer readings, combine the readings onto a single master list for your group's barometer. The list should include the values read plus the name of the student who read them. **Give this list to the TA, who will photocopy it for the class.**

6 Analysis and Writeup - Part II

1. Examine the barometer readings recorded for the ground floor. Look for clear outliers. *Outliers* in any data set are those occasional values that don't seem consistent with the rest and are likely to be erroneous. In this case, I would consider any pressure value that differs by more than a full millibar from the average of the other readings to be a likely outlier.
2. Throw out any outliers you identified in step 1 (be sure to justify this decision in your writeup!), and compute the average \bar{p} of the remaining values.
3. Compute the standard deviation of the same set of values:

$$\sigma = \sqrt{\frac{1}{N-1} \sum_i [p_i - \bar{p}]^2}.$$

4. Repeat steps 1–3 for the rooftop barometer data.
5. The two averages you computed now represent your *best estimates* of the true pressure at ground level and on the rooftop. The corresponding standard deviations represent the estimated precision of the *individual readings*. The estimated precision of the *average pressure* you computed is then given by the so-called *standard error*, which is defined as

$$\hat{\sigma} = \frac{\sigma}{\sqrt{N}}$$

where N is the number of original values used to compute the average and standard deviation. What this formula tells you, among other things, is that the more independent measurements you have of something, the better the average will be as an estimate of the true value, assuming that the individual errors are random.

6. Use the two average pressure values you computed above, together with the hydrostatic relation, to estimate the building height. That is,

$$\Delta Z \approx -\frac{\Delta p}{\rho g}$$

where the average air density ρ between ground level and the rooftop. Estimate this density from the ideal gas law $p = \rho R_d T_v$ using the virtual temperature T_v given to you by the instructor and the *average* of your rooftop and ground-level pressures.

7. Estimate the *error* in your determination of ΔZ as follows: a) Compute the error in Δp as $\sigma_3 = \sqrt{\sigma_1^2 + \sigma_2^2}$. where σ_1 and σ_2 are your standard errors from step 5. b) Convert σ_3 to an estimated error σ_z in ΔZ using the above formula.
8. The actual height of the building is approximately 60 m. Compare this value with your estimate of ΔZ . Does it fall within the computed uncertainty? If it is wildly off, trace back through your calculations and see if you can figure out what went wrong.

Note: Please make sure write up your results neatly, and please attach all relevant worksheets.