Optional Barometric Pressure Protocol

Purpose

To measure air pressure

Overview

Students record atmospheric pressure using a barometer or altimeter.

Student Outcomes

Students gain an understanding that barometric or altimeter pressure varies and its increase or decrease indicates an upcoming change in the weather.

Students learn that the air has weight.

Science Concepts

Earth and Space Science

Weather can be described by quantitative measurements.

Weather changes from day to day and over the seasons.

Weather varies on local, regional, and global spatial scales.

Atmosphere Enrichment

Air pressure is a measure of the weight of the atmosphere per unit area.

Changes in barometric pressure can be used to help predict weather.

Scientific Inquiry Abilities

Use a barometer or altimeter to measure barometric pressure.

Identify answerable questions.

Use appropriate mathematics to analyze data.

Develop descriptions and predictions using evidence.

Communicate procedures, descriptions, and predictions.

Time

5 minutes

Level

All

Frequency

Daily within one hour of local solar noon or at roughly the same time as the aerosol measurement if used as atmospheric pressure value for the *Aerosols Protocol*

Materials and Tools

Aneroid barometer or altimeter

Atmosphere Investigation Data Sheet

Prerequisites

None

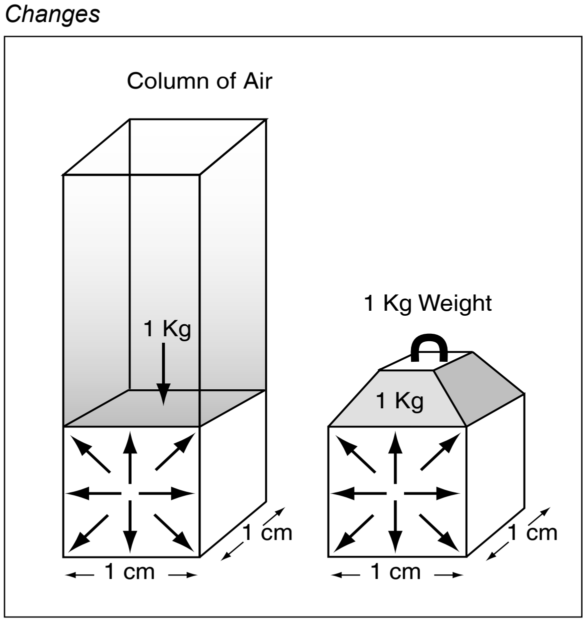
Optional Barometric Pressure Protocol – Introduction

Air is made up of molecules of nitrogen, oxygen, argon, water vapor, carbon dioxide, and other gases. Because these gases have mass, air is pulled toward the center of Earth by gravity. This force is what gives us weight, and the air also has weight. The greater the mass of air in a column above a specific area on the ground, the more weight the air has.

Pressure is defined as the force acting on a unit of area. Atmospheric pressure is the weight (force) of the air pushing on each unit of surface area on the ground. (A unit of area could be a square meter or a square centimeter – in other words, a unit in which area is measured.) Earth's atmospheric pressure is about 1 Kg/cm^2.

What is happening with atmospheric or barometric pressure? Think of a small cube of air sitting on Earth's surface. Above it, there is a column of air being pulled toward the surface by gravity. The force on the top of your cube of air is equal to the weight of the column of air above. The air in your cube transmits that force in all directions, pushing down on Earth's surface and horizontally on all the surrounding air. See Figure AT-PR-1. This is the atmospheric or barometric pressure, which is measured following this protocol.

Figure AT-PR-1: A Column of Air with Pressure Changes



You can think of this as being similar to the air in a ball. When you blow up a ball, you fill it with air until there is enough pressure to give the ball the bounce you want. The air inside the ball pushes on the surface by the same amount in all directions. When you put pressure on one place on the ball by hitting or kicking it, the air inside spreads that pressure in all directions, too.

Hundreds of years ago, scientists such as Galileo, Evangelista Torricelli, and Benjamin Franklin wondered about how changes of atmospheric pressure from day to day related to variations in the weather patterns they saw. Benjamin Franklin, for example, has been credited with observations that related the movement of low pressure systems (storms) along the northeastern coast of the United States, by comparing weather observations in his diary in Philadelphia with those of his friends in New York City and Boston.

Meteorologists have long known that high pressure generally brings fair weather, and low pressure is associated with "bad weather" - although most meteorologists tend to like "bad weather" because that is when the weather is most interesting!

A "falling barometer" is generally considered to be an indication of worsening weather. A "rising barometer" often indicates improving weather.

Daily observations of barometric pressure will be useful to you as you study other meteorological observations. You may note how changes in pressure readings from one day to the next are related to the kinds of weather observations discussed above. In particular, you may begin to notice how your cloud type and cloud cover observations are related to pressure recordings, how higher values of precipitation are related to low pressure, and that during spells of dry weather, the barometer will give high readings.

There are two ways that barometric pressures are generally expressed. One way is as barometric station pressure, the actual pressure experienced at a site. Since barometric pressure varies with elevation, it is difficult to track the movement of weather fronts by comparing station pressure values from sites at different elevations. Therefore, pressures are commonly expressed as sea level pressures, which represent the equivalent pressure that would be experienced if a site was located at sea level. Converting to sea level pressure involves applying a correction that compensates for the effect of the elevation of a site on the station pressure. Therefore, when sea level pressures at various sites are compared, the elevations of the sites are not pertinent and changes in pressure are direct reflections of the affects of weather fronts.

Interpretation of the aerosols, ozone, and water vapor measurements requires knowledge of atmospheric pressure, either from your barometer or from another reliable source.

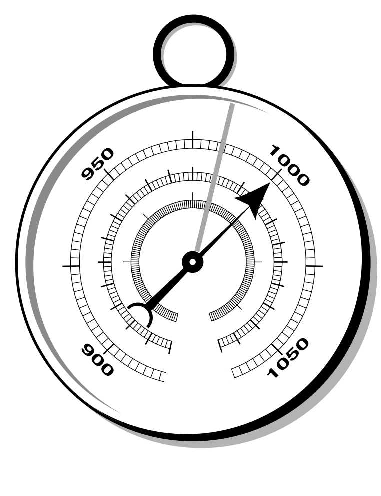
Teacher Support

The Aneroid Barometer and Altimeter

A device that can be used to measure atmospheric pressure is called a *barometer*.

The standard way of measuring pressure is to use a very sensitive mercury barometer, but these are expensive and mercury is poisonous. In order to make pressure measurements more accessible, the *aneroid barometer* was developed. Figure AT-PR-2 shows a typical aneroid barometer.

Figure AT-PR-2: Aneroid Barometer



Barometric Pressure = 1000 mbar

The barometer contains an expandable bellows. The bellows changes size as air pressure changes. When air pressure is high, the bellows is compressed, and when air pressure is low, the bellows expands. Because the bellows is attached to a needle that moves across a scale, the barometer reading changes as the air pressure changes.

Most standard aneroid barometers will be useful for schools at elevations below 500 m; for higher elevation stations, an altimeter that also provides barometric pressure readings is recommended. Meteorologists typically convert air pressure values at weather stations to sea level pressure, so that the horizontal pressure variations that are important to wind and weather patterns can be seen more easily. More information is provided in *Calibrating Your Barometer*.

Units of Atmospheric Pressure

Scientists who use mercury barometers report atmospheric pressure as the height of a column of mercury (in mm), with an average value at sea level of 760 mm of mercury. Another unit of measurement for atmospheric pressure, the Pascal, relates to the notion that pressure is a measure of force per unit area. Standard sea level pressure is 101,325 Pascals (Pa), or 1013 hectopascals (hPa) (1hPa = 100 Pa). Hectopascals and millibars (mbar) are equivalent units of measure. The unit millibar is derived from the force unit of dynes per square centimeter. Typical values of air pressure for locations near sea level vary from about 960 mbar for extremely stormy conditions to about 1050 mbar for strong high pressure conditions.

As you go up in altitude, there is less air above you. Less air means less mass and less weight pushing down on the surface. So atmospheric pressure decreases as you go up in the atmosphere, and high elevation locations have lower air pressure values than low elevation locations. A good approximation of this is that for every 100 meters higher you go in the atmosphere, pressure will decrease by about 10 mbar. This works well up to about 3,000 meters above sea level. If your elevation above sea level were 1,000 meters, your normal pressure range would be roughly 860 to 950 mbar.

How to Place the Aneroid Barometer or Altimeter

In GLOBE we use a standard aneroid barometer or an altimeter. It should be mounted securely on a wall in the classroom, since air pressure is equal inside and outside the building. It should not rattle or shake back and forth. It should be mounted at eye level on the wall so that students can read it accurately. The barometer must first be calibrated against a standard value, either by calling a local government agency for assistance, or by following the instructions given in *Calibrating Your Barometer*. Your barometer should be recalibrated at least every six months.

Questions for Further Investigation

After recording your pressure readings for a month, make a graph of your pressure observations and also plot the daily precipitation. Do you see a relationship between these observations?

Is there any relationship between your data from the *Cloud Protocols* and barometric pressure?

Use pressure data from several GLOBE schools adjusted to sea level pressure to see if you can locate where high and low pressure areas are for a given day. How well do your findings compare with weather maps from your local newspaper or any other source?

Calibrating Your Barometer

When your barometer arrives, it most likely will have been calibrated at the factory. But it is necessary to calibrate the barometer yourself before you install the instrument. First, inspect your barometer; it will most likely have two different scales, one in millibars (or hectopascals) and one in millimeters (or centimeters) of mercury. All of your measurements for GLOBE should be taken in millibars or hectopascals (remember, these are equivalent).

There is a needle that can be set to the current reading each day – you should do this each day after you take your pressure reading. When you take tomorrow's reading, your barometer's set needle will read yesterday's value, and you can instantly compare to see whether pressure is higher or lower now than the day before!

To calibrate your barometer, you will have to find a local reliable weather information source, which provides measurements of pressure. A weather service or weather bureau office, agricultural extension office, newspaper, radio, or television station may be useful here.

Be sure that the reading is expressed as a sea level pressure. If the units of this pressure reading are not millibars or hectopascals you will need to convert the reading using the factors given below.

Conversion of Pressure Units

What if my units of pressure are not given to me in millibars or hectopascals?

This is quite likely in many locations, depending on the source of the calibration information. Use the table below to change the units of pressure to millibars from the units given.

Convert from	**Multiply by this factor**
Inches of mercury	33.86
Centimeters of mercury	13.33
Millimeters of mercury	1.333
Kilopascals	10
Pascals	0.01

Once you have obtained an accurate sea level pressure reading in millibars or hectopascals, reset your barometer to this pressure reading using a small set screw on the back of the barometer (this should only be done by the teacher!).

The barometer will then display the sea level pressure at your site accurately, within the limits of the scale on the barometer. If you move the barometer to a site with a different elevation you will need to calibrate the barometer based on a sea level pressure for that site.

Optional Barometric Pressure Protocol

Field Guide

Task

Measure the barometric pressure.

Reset the “set needle” to today’s reading of barometric pressure.

What You Need

- ❑ A properly mounted aneroid barometer or altimeter
- ❑ *Atmosphere Investigation Data Sheet* or *Aerosols Data Sheet* or *Ozone Data Sheet* or *Water Vapor Data Sheet*
- ❑ Pen or pencil

In the Classroom

1. Record the time and date on the *Atmosphere Data Sheet.* (Skip this step if you are using the *Aerosols, Ozone,* or *Water Vapor Data Sheet.*)
2. Tap gently on the glass cover of the aneroid barometer to stabilize the needle.
3. Read the barometer to the nearest 0.1 millibar (or hectopascal).
4. Record this reading as the current pressure.
5. Set the “set needle” to the current pressure.

Frequently Asked Questions

1. If we missed reading the barometric pressure for a day or more (over the weekend, holiday, vacation, etc.), can we still report the pressure today?

Yes, you are only reporting today's pressure, so please report it as often as possible.

2. I really don't understand the difference between barometric station pressure and sea level pressure.

Since weather stations are spread all over the world at many elevations, and since pressure decreases rapidly with elevation, meteorologists need a way to map horizontal pressure patterns using a constant reference altitude. The easiest way to do this is to convert all observed pressure values to sea level pressure. In GLOBE barometric pressures are reported as sea level pressures but can be accessed and visualized as either sea level or station pressures, as the database is capable of making corrections to compensate for elevation changes.

3. In the 2002 version of the *Optional Barometric Pressure Protocol* **directed us to report pressure values to GLOBE as Station pressures. Why has this changed?**

GLOBE originally asked for pressure values as station pressures since this is the form that they are used in to analyze Aerosols data. However, we realized that this negates the educational benefits of looking at sea level pressures, which are direct indicators of the movement of storm systems. Using station pressures also makes obtaining calibration readings difficult since these readings are typically expressed as sea level pressures. Therefore, we have changed to sea level pressure as the standard way for expressing barometric pressures in GLOBE.

4. What if I want to convert a sea level pressure to a station pressure?

To convert a sea level pressure to a station pressure you will need to know your elevation above sea level (See the GPS Protocol) and the current temperature at your location. The temperature can be estimated if you do not have a measurement of it.

This conversion relates to one of the first lessons of atmospheric science, namely the concept that pressure decreases exponentially with altitude and that this decrease is characterized by a distance called the scale height. Some advanced students may wish to pursue this further using atmospheric science textbooks. What follows is the formula for the conversion and the origin of the constant involved, which is the scale height.

$$\text{Station pressure} = \text{Sea level pressure} \times e^{-\text{elevation} / (\text{temperature} \times 29.263)}$$

where:

Station pressure = the barometric pressure at your elevation in millibars (hectopascals)

Sea level pressure = the equivalent pressure at sea level in millibars (hectopascals)

elevation = the elevation of the station in meters

temperature = current temperature in degrees Kelvin (°K)

temperature (°K) = temperature (°C) + 273.15

the constant 29.263 is in units of meters per degree Kelvin (meters/°K)

$$29.263\ (\text{m}/{}^\circ\text{K}) = \frac{1000\ (\text{g/kg}) \times R}{M_{air} \times g}$$

R is the molar gas constant (= 8.314 Joules per mole per degree Kelvin)

1000 is to convert kilograms to grams (1 Joule = 1 kg m^2/sec)

M_{air} is the molecular weight of air (= 28.97 grams per mole)

g is the acceleration of gravity at Earth's surface (= 9.807 kg per second per second)

If you multiply this constant (29.263) by a temperature of 0°C, you get a value of 7993 meters or approximately 8 km. This is the scale height of Earth's atmosphere under average conditions (as given in the U. S. Standard Atmosphere).

A simplified conversion, which should only be used for stations at elevations below a few hundred meters, is:

Station pressure = Sea level pressure – (elevation/9.2)

The correction factor of 9.2 in the above formula is very nearly the change in elevation (vertically) that will correspond to a 1 millibar change in pressure, as given in the U. S. Standard Atmosphere.

5. Why do we have to reset the "set needle" each day?

The set needle is used to identify the previous pressure reading. Using it, you can instantly compare the current pressure reading to the previous one. For example, if the pressure is lower today than yesterday, you might ask yourself if the weather is stormier?

6. How accurate are these pressure readings, compared to those that might be taken with mercury barometers?

Today's aneroid barometers are not as accurate, in general, as well-made mercury barometers. There are some electronic barometers that have very accurate measurements, but the relatively inexpensive instruments that meet GLOBE specifications have all the necessary accuracy for our pressure measurements (about 3 to 4 mbar).

7. Why does pressure always decrease with height in the atmosphere?

Because pressure is a measure of the mass of the atmosphere above you (air does have mass!), as your elevation increases, there is less air above you, so pressure is less.

8. Why do high altitude GLOBE schools have to use an altimeter?

Most aneroid barometers are designed to be used near sea level. Altimeters are special aneroid barometers designed to be used at higher altitudes (including aircraft). At an altitude of 500 m above sea level, we would expect atmospheric pressure to be no greater than 1000 mbar and down to as low as 900 mbar for intense storms. Most aneroid barometers, however, have 950 mbar as the lowest possible measurement.