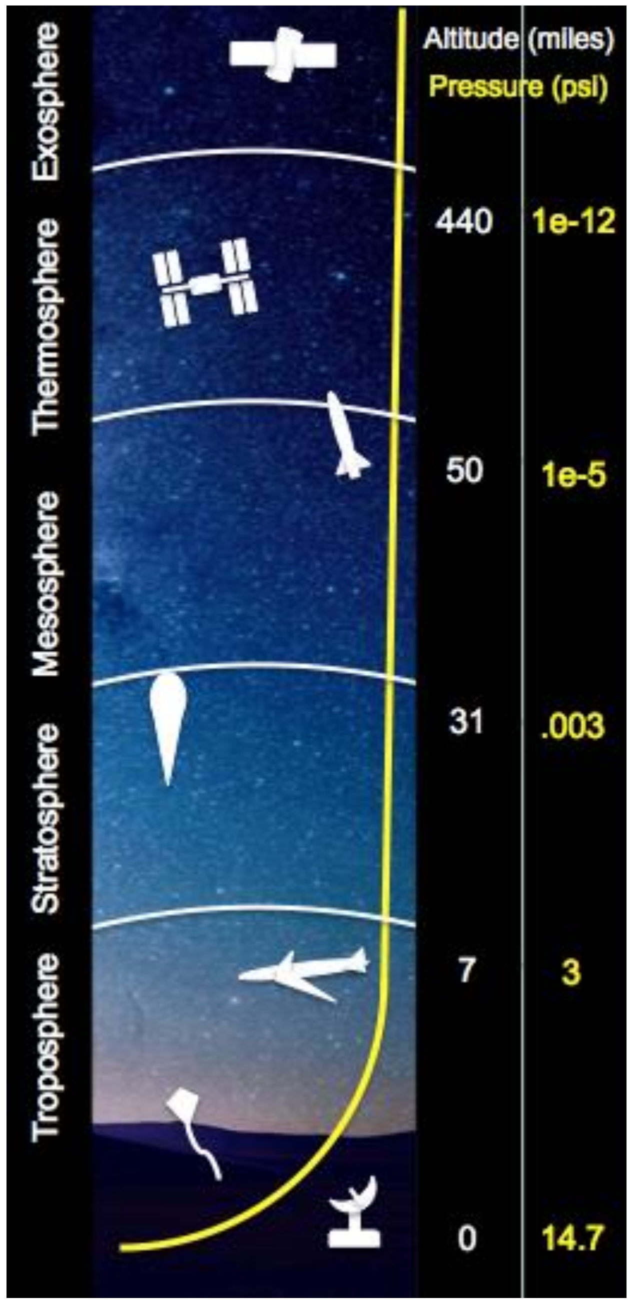
Barometric Pressure and the Atmosphere

Science

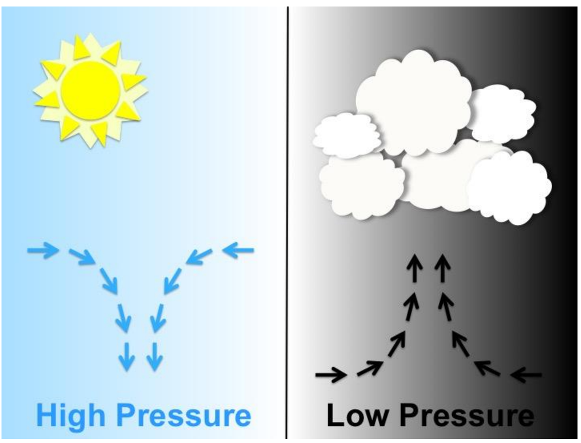
Barometric pressue, also known as atmospheric pressure, is the force exerted by the atmosphere at a given time, or "the weight of air". Barometric pressure is about 14.696 psi (pounds per square inch) at sea level and fuctuates depending on altitude and weather conditions. As altitude increases, the air becomes thinner and pressure decreases. The reason our ears pop when driving in the mountains of flying in an airplane is because the pressure inside our ears has to equalize with the decreasing pressure outside our ears. This phenomenon continues as we ascend further through all the layers of the atmosphere where the pressure drops to near zero. The wide range of barometric pressures in the atmsophere allow scientists to study the earth under different conditions than what are present on the earth's surface.



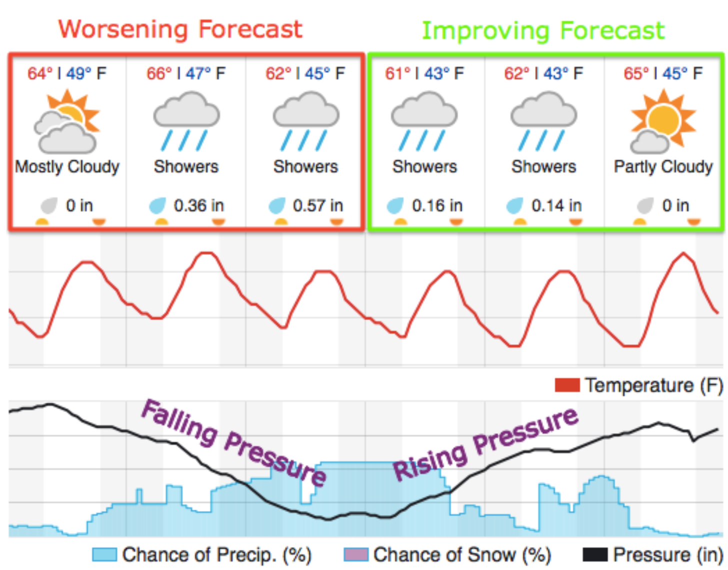
NASA performs research at a variety of altitudes to gain a more detailed view of the earth and earth systems. The following image highlights the variety of science platforms NASA utilizes, in ascendig order: ground stations, kites, airplanes, balloons, sounding rockets, ISS, satellites. For example, numerous earth science studies are performed at the bottom of the troposphere, or the earth's surface, in part because it is the most inexpensive form of data collection and because the data collected on the surface is the closest to the "true value" we can calculate. The surface data sometimes called "in situ" is often used as a validation for data collected about surface phenomenon from further up in the atmosphere. In contrast, there are experiements conducted at higher altitudes. A notable example is the International Space Station that resides in orbit in the thermosphere. The experiements conducted aboard the ISS are invaluable because they are conducted in a zero gravity environment and lend unique insights into the fores acting on the earth.

Pressure and Weather

In additon to altitude, barometric pressure also fluctuates with changing weather, or rather barometric pressure influences the weather. Typically high pressure is associated with nice, sunny, and clear weather and low pressure is associated with stormy and unpleasant weather.



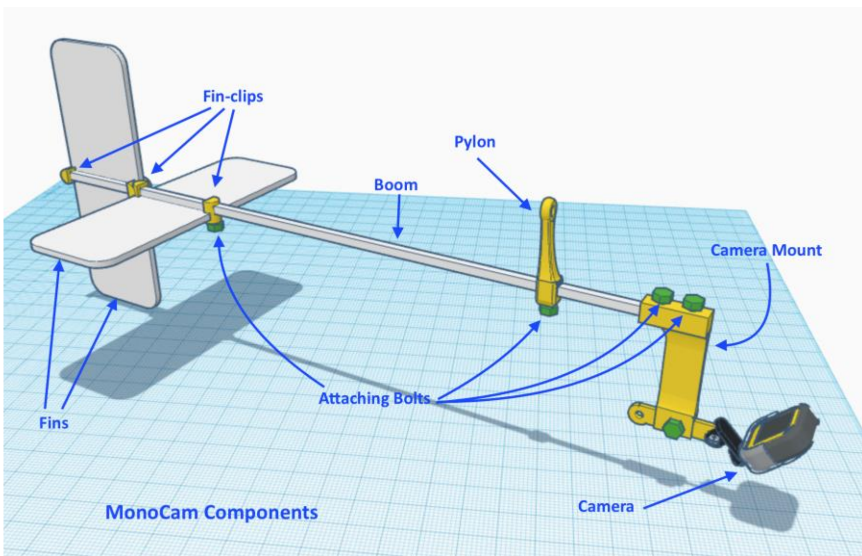
Lower atmospheric pressure allows the air to expand and rise into the cooler upper atmosphere where the air temperature decreases. Because cold air does not have a great capacity to hold moisutre, the cooler temperatures cause the water vapor to start to condense and form clouds that can lead to precipitation. Conversely, higher atmospheric pressure causes the air to move towards the warmer earth surface and the air temperature to increase. The warmer air is able to retain water vapor better than the cooler air and can hold onto the vapor long enough for it to evaporate in the sunlight leading to clear, dry, sunny weather. The following image is an example of 6 day weather forecast showing a dip in the barometric pressure when the forecast is for rain and a rise cooresponding with a sunny forecast.



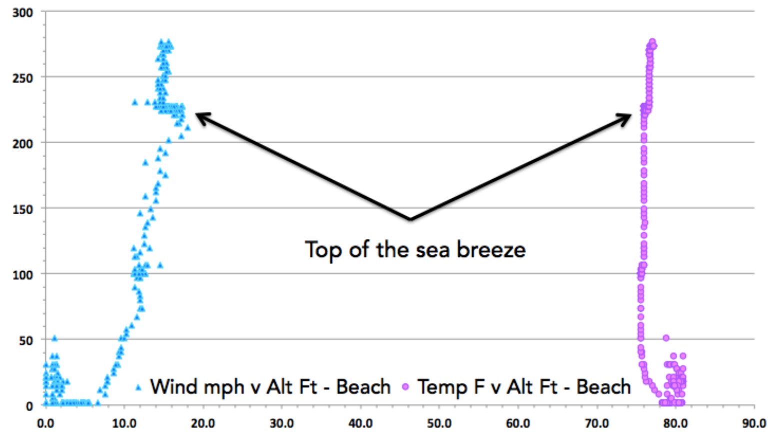
It's important to monitor barometric pressure because of the great effect it has on earth systems. Collecting readings from barometers allows for more accurate weather forecasting and mitigating the dangers of sever storms. Also being aware of pressure changes is important for human health. Rapid changes in altitude and pressure can cause sickness and death. Some extremes include hikers climbing Mt. Everest that have to take breaks along their assent to let their bodies acclimate to the changing pressure and scuba divers who have to slowly ascend and descend in the water to keep from getting the bends. More commonly people suffer from altitude sickness when traveling to higher elevations because of the lack of oxygen in low atmospheric pressure.

AREN Technologies

In addition to the atmspheric science that NASA conducts to monitor earth systems from a global perspecitive, smaller NASA organizations like AREN operate closer to the surface. AREN stands for AEROKATS and ROVER Education Network, and is an education and outreach organization that engages students and life long learners in their local environments. Within AEROKATS (Advancing Earth Research Opportunites using Kites and Atmospheric/Terrestrial Sensors) participants use a kite based platform to collect scientific data and images from an aerial persepctive. In order to collect the data we mount aeropods with various instrumentation and attach them to kites that can fly up to 500ft. Aeropods (following figure) are a stick with a camera/sensor on one end, fins that keep it stable and directionally oriented with the wind on the other end, and a a connector in the middle that attaches it to a kite. Because aeropods are primarity 3D printed, they can be outfitted with a variety of instrumentation.



One instrument in paritcular is the Kestrel 5500 weather meter. As the kite pulls the instrument higher into the atmosphere, it collects a profile of a number of weather readings includining temperature, wind speed, wind direction, humidity, and pressure. These readings can be used to learn more about the weather patterns in that particular region. One example is a from a flight along the coastline. The graphic below shows wind and temperature on the x-axis and altitude on the y. From the data you can see a sizable blip at about 250 ft. where the wind speed drops off and the temperature increases. This effect is due to the sea breeze. It's a very localized phenomenon where the cooler high pressure air over the ocean moves inland towards the warmer low pressure air over the land and creates a convection. The movement of air causes a breeze coming off the water. The sea breeze only occurs a small distance inland and up into the atmosphere as depicted by the data and we're able to record it and study it using kites and aeropods.



Objective

Introduce the concept of barometric pressure and its significance in weather phenomenon. Teach the students the mechanics of the barometer and how it measures changing pressure. Introduce the students to collecting, analyzing, and interpreting data. Build teamwork and communication skills.

Overwiew

Students will split into groups of 3, each with a specific role in the experiment. Students will construct barometric pressure gauges (barometers), monitor them throughout the week, and record the changes. They will also analyze trends in the barometric pressure with relation to weather patterns.

Time

Construction: 30 minutes

Data recording: One reading takes 10 minutes

Age Group

Most appropriate for 5-8 grade level

Materials

- Cup or jar
- Safety glasses
- Large latex balloons
- Rubber band
- Straws
- Tape
- Cardstock
- Scissors
- Markers
- Copy of barometer diagram and data sheet

Preparation

- Make sure to pick out a cup or jar that has stiff sides so that the changes in pressure will affect only the balloon and not the container itself.
- Lay out the materials for each student or group of students.
- Pass out the barometer diagram as well as the data log sheet.
- Each student should wear a pair of safety glasses while working with the glass jar.

Instructions

1. Take a pair of scissors and cut the open end of the ballon off.
2. Stretch the balloon over the opening of the cup/jar.
3. Take a rubber band and hold the balloon in place over the cup/jar.
4. If the cup/jar is small you may want to attach two straws together to create one larger straw because the effect of the barometric pressure will be smaller and less noticable on a single straw.
5. Place the straw so that it's laying flat across the the top of the cup/jar and the end of the staw is in the middle of the balloon and tape it in place. Make sure to use a thin piece of tape otherwise the tape will hold the straw in place instead of moving with the balloon.
6. Create a gauge by taking a piece of cardstock that's at least 2 inches taller than the jar and 3 inches wide and fold it long ways so that it can stand upright.
7. Make a mark on the card stock of the current straw position measuring from the bottom of the straw and label that point zero.
8. Create a series of marks above and below the zero point every 1/16 inch, label with negative numbers below the zero and positive numbers above the zero.
9. Come back in a couple hours and record the new position of the staw according to the directions below.

Collecting and Recording Data

After the barometers are built, one data point should be collected at the zero measure mark and another should be made a couple hours later to see how the student's individual barometers compare to each other's. If the barometers are significantly different from another it's important to address the possible design flaws that caused the inconsistency. When taking a reading make sure to measure from the bottom line of the straw and record the positive or negative tick number.

“Current Position” is the positive or negative number where the straw is currently positioned. “Change Since Last Measurement” is the positive or negative difference from the last reading. For example if you take a reading in the morning of -2 and by the afternoon the straw is positioned at 2, the current position is 2, but the change is +4 because the pressure increased 4 ticks from -2 to +2. Also “Weather Observations” is a space for students to record the local weather at the time of data collection, the more detail the better.

Technology

To briefly summmarize the machanics of this type of barometer, as the pressure outside the jar increases, the outside air tries to compress and move towards the lower pressure air inside the jar, pushing the balloon inward and elevating the straw. Conversely, when the outside pressure decreases, the higher pressure air inside the jar tries to expand and move towards the lower pressure outside the jar stretching the balloon outwards and lowering the straw. Because the air within the jar is sealed in by an elastic surface, it is not able to equalize to the air around it, and you can see the expanding and contracting volume of the air as the pressure changes.

Operations

A couple skills to emphasize throughout this activity are teamwork and communication where each person has an equal voice. One suggested way to emphaze these skills is to create groups of 3 and allow the students to decide among themselves which of the following roles they’d like to perform:

Engineering Technician: The engineering technician is responsible for building the barometer and maintaining it through the duration of the project, including performing quality control and verifying that the instrument is performing as it should. They can also work with the group towards determining ways to calibrate the instrument as well as ways to improve on the design.

Data Monitor: The data monitor is responsible for monitoring how the barometer changes and recording the data on the data sheet. The data monitor can decide with the group the time and frequency of data collection to provide the most meaningful results. It’s important for the data monitor to pay close attention to any unusual changes in the barometer and communicate them to the engineering technician to determine if the instrument needs repairs.

Science Analyst: The science analyst is responsible for analyzing the data and figuring out the significance of the readings. They will focus on the science of barometric pressure and determining if the local weather corresponded with barometric pressure as predicted. They will also communicate with the data monitor to keep up to date on data reading and with other groups to compare findings and hypothesize about different results.

When the students have gathered a weeks worth or barometric presure readings, the scientist should share their results and observations with the class. With all the data collected, the class can collectively look at the data and the variations between individual readings as well as look for trends in the how the pressure correlates with local weather. A couple questions to address with the class are: How much variation is there in the data? What could cause variations between two different barometers? How elese could you design a barometer to reduce variation? What are ways you could calibrate the barometer? Was the hypothesis of low pressure being associated with stormy weather shown in the data? What other experiements could you conduct?

Continuation

Once the students have completed the above activity and feel they have a good grasp on barometric pressure and barometers, it could be interesting to take the experiment one step further. Maybe consider a design challenge where the students are asked to design and create a barometer for Mars where the barometric pressure is a lot lower. What would that look like? How would it need to be different from a barometer on earth?

Data Sheet

Date	Time	Current Position	Change Since Last Measurement
________	________	________________	______________________

Weather Observations ____

Date	Time	Current Position	Change Since Last Measurement
________	________	________________	______________________

Weather Observations ____

Date	Time	Current Position	Change Since Last Measurement
________	________	________________	______________________

Weather Observations ____

Date	Time	Current Position	Change Since Last Measurement
________	________	________________	______________________

Weather Observations ____

Date	Time	Current Position	Change Since Last Measurement
________	________	________________	______________________

Weather Observations ____

Date	Time	Current Position	Change Since Last Measurement
________	________	________________	______________________

Weather Observations ____

Date	Time	Current Position	Change Since Last Measurement
________	________	________________	______________________

Weather Observations ____

Barometer Diagram