Meteorological Instruments

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Meteorological Instruments

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Precipitation

Precipitation comes in different forms depending on the climate but the formation is basically the same.

In cold air high in the sky, rain clouds will often form. Rising warm air carries water vapor high into the sky where it cools, forming water droplets around tiny bits of dust in the air.

Water vapor condenses onto tiny particles in the atmosphere. As more water vapor condenses on the particle and it grows it becomes a cloud droplet. It grows bigger yet and until it is large enough to be a rain droplet.

Since it is very cold high in the atmosphere, the rain droplets freeze into tiny ice crystals which attract cooled water drops. The drops freeze to the ice crystals, forming larger crystals we call ***snowflakes***.

When the snowflakes become heavy, they fall. When the snowflakes meet warmer air on the way down, they melt into ***raindrops***.

The various forms of precipitation include:

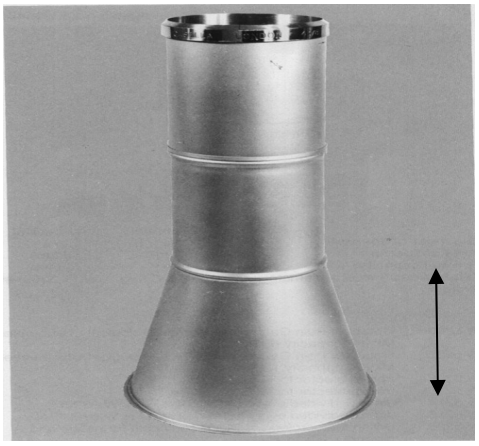
Snow, freezing rain, sleet, ice pellets, rain, hail, showers.

Be a Tropical Rain Maker!

Try this experiment, but ***only*** with adult supervision.
Boil water in a tea kettle. Watch the steam come out and go into the air. (Evaporation)
Put ice in a metal pie pan. Hold the pan over the steam and watch the drops form on the bottom of the pan. (Condensation)
As the drops grow in size, they will get heavy and start to fall. (Precipitation)

In the tropics, we experience (liquid) rainfall and the following are tools used to measure rainfall.

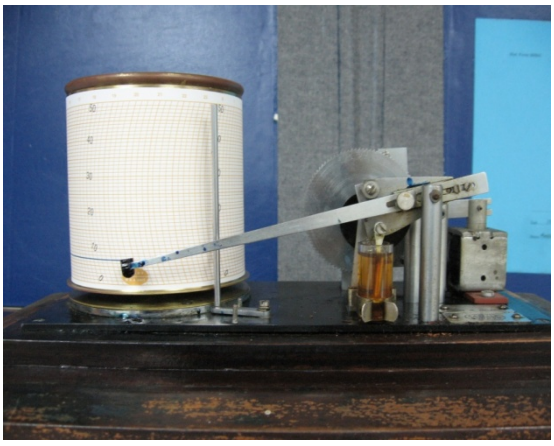
Raingauge



Bottom segment

- The bottom segment of this instrument is places firmly into the ground.
- Rainfall is collected in a bottle inside of the instrument.
- The bucket ensures retention of rainfall for measurement as it facilitates for overflow of the bottle in heavy downpours.
- This instrument should not be situated near tall buildings and trees since these obstruct the rain collection.

Rainfall Recorders



Rainfall Intensity Recorder

Rainfall Recorder

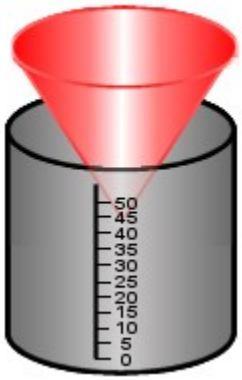
Make and Use your own Rain Gauge to Measure Precipitation

Overview

Students can use tap water to practice reading the measurement of the rain gauge in the classroom. They will be taking measurements to the nearest 1/4" (5mm). If there is a safe spot outside, the students can leave the gauge outside and take a reading after each rainfall, remembering to empty the jar after each reading. If the gauge can't be left outside, the students should place it outside on each rainy day.

Make a Rain Gauge

A. **Materials**
- Clear plastic ruler
- Cylinder shaped clear jar
- Rubber band
- Funnel
- Transparent tape



B. **Procedure**
1. Remove the jar's label.
2. Attach the ruler to the outside of the jar with the rubber band; make sure that the bottom edge of the ruler is even with the bottom of the jar. Or secure the ruler inside the jar so it is standing vertically with the end at the base of the jar/bottle. Tape the ruler in place so the numbers can be read from the outside of the jar/bottle.
   Note: As an alternative to a ruler, you can use a permanent marker to mark the inches/centimeters on clear tape affixed vertically to the outside of the jar/bottle beginning at the base to the outside of the jar/bottle. Cover the marks with a second piece of clear waterproof tape.
3. Place the funnel in the top of the jar. The top end of the funnel should cover the entire mouth of the jar.
4. If you would like, you can practice filling the jar with water and measuring the total amount.

Use a Rain Gauge to measure Precipitation

A. **Materials**
- Rain Gauge

B. **Procedure**
1. Put the jar out in the rain. Note: the rain gauge should not be put near or under trees or too close to buildings which may block the rain.
2. Read the ruler to determine how much rain was collected.
3. Empty the jar **after each use**.

Atmospheric Pressure

Air pressure is the force exerted on you by the weight of tiny particles of air (air ***molecules***).

Although air molecules are invisible, they *still have weight* and *take up space*.

- When air is compressed, i.e. have a smaller volume, it is said to be "under pressure".

Atmospheric Pressure affects the Wind.

Pressure may change horizontally due to uneven heating of the earth's surface. This causes a pressure gradient to develop.

Cold air weighs more than warm air, so the pressure of cold air is greater. When the sun warms the air, the air expands, gets lighter and rises.

Cooler, heavier air blows to where the warmer lighter air was. Pressure gradient force causes wind to blow from high pressure area to low pressure area.

If the high pressure area is very close to the low pressure area, or if the pressure difference (or temp difference) is very great, the wind can blow very fast.

Changes in Atmospheric Pressure indicate coming Weather

Air pressure can tell us about what kind of weather to expect as well.

- If a *high pressure* system is on its way, expect cooler temperatures and clear skies.
- If a *low pressure system* is coming, then look for warmer weather, storms and rain.

Measurements

An Italian scientist named Torricelli built the first barometer in 1643.

Barometers are used to measure the current air pressure at a particular location in "inches of mercury" or in 'millibars' (mb). [29.92 inches of mercury is equivalent to 1013.25 mb].

Earth's atmosphere is pressing against each square cm of you with a force of 1 kilogram per square centimeter. The force on 1,000 square centimeters is about a ton!

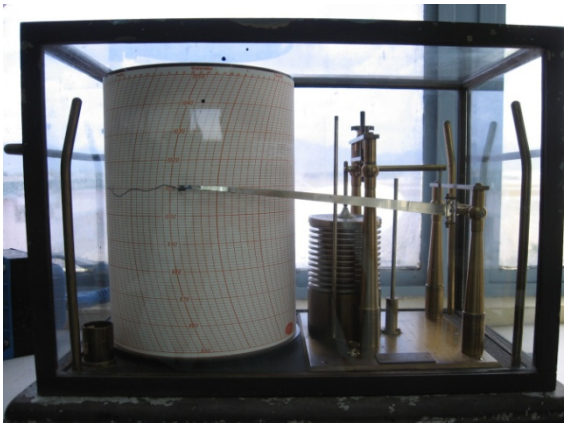
Mercury Barometer

- A glass tube with lower end dipped in mercury.
- Mercury fills tube except for a few inches at the top where a vacuum exists.
- A very sensitive instrument.

Reading a Mercury Thermometer

- The attached thermometer is read.
- A vernier scale is set - making it at the same level as the mercury.
- The reading is taken at the top of the mercury.
- Corrections are made to the readings.

Aneriod Barograph



- Movement of arm depends on the response to variations in atmospheric pressure.
- The disc-shaped boxes bulge outward when pressure falls, and corresponding markings are made on the graph.

Precision Aneroid Barometer

- An aneriod capsule attached to a pivoted bar that is free to move with changes in pressure enclosed in a metal case.
- Displacement of the bar caused by the movement of the capsule is measured by a micrometer screw.
- Electrical sensors gives visible signal when contacts of the bar and screw meet.

Make and Use Your Own Barometer to Measure Air Pressure

Overview

Take a deep breath while holding your hand on your ribs and observe what happens. Did you feel your chest expand? Why did it expand?

Air pressure expands because the air molecules take up space in your lungs, causing your chest to expand. Furthermore, air can be compressed to fit in a smaller volume since there's a lot of *empty* space between the air molecules. When compressed, air is placed under high pressure. Meteorologists measure these changes in the air to forecast weather, and the tool they use is a **barometer**.

Make a Barometer

A. **Materials**

1. wide-mouthed glass jar or small coffee can
2. balloon (recommended) or plastic wrap
3. rubber band
4. scissors
5. drinking straw
6. cardboard strip
7. glue (recommended) or tape
8. ruler and pen or pencil
9. small piece of modeling clay
10. shoe-box sized cardboard box

B. **Procedure**

1. Cut the narrow opening of the balloon off.
2. Cover the top of the jar with the balloon so that it is airtight and use the rubber band to hold it in place. IMPORTANT: the seal should be **airtight** (If you are using plastic wrap, it should make an airtight seal around the rim of the jar).
3. Place a small amount of glue in the middle of the balloon and carefully place the side of one end of the straw on the glue so that the other side extends over the edge of the jar.
4. While the glue is drying, fold a piece of cardboard (see photo) so that it can stand on its own.
5. Carefully, mark lines .5 cm apart and write "Low Pressure" at the bottom and "High Pressure" at the top.
6. Once completed, place the barometer and the scale in the shoe-box sized cardboard box so that the end of the straw with the clay just reaches without touching the scale. Tape both the barometer and the scale into place so they cannot move.

C. **How does this measure air pressure?**

High pressure will make the balloon seal dip causing the straw go up. Low pressure will make the balloon puff up causing the straw to go down.

Wind

Wind blows from high pressure area to low pressure area.

Large scale atmospheric / wind circulations transfer heat from the tropics to the temperate and polar regions, as the difference in temperatures create a pressure gradient.

Coriolis Effect affect the wind flow as moving objects are deflected to the right in the Northern Hemisphere caused by the rotation of the earth.

Without instruments, wind speed can be averaged by observing flags, trees or the ocean waves and using Beaufort Scale.

Wind from thunderstorms and hurricanes can cause serious damage to buildings and infrastructure. Tornadoes continue to cause massive damage and loss of lives in 'Tornado Alley' (Texas, Kansas and Oklahoma) in the United States.

A tornado over the sea (or any water body) is called a 'waterspout' and is common in the Tropics.

Gusts are short bursts of high speed wind.

Wind is measured in metres per second, kilometres per hour, miles per hour and knots.

1 metre / second = 1.95 knots

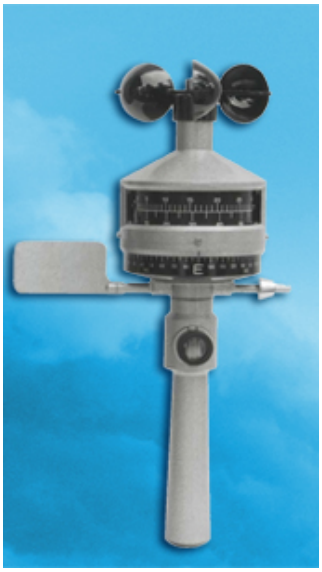
= 3.61 km/hr

= 2.25 miles/hr

Wind direction is considered as the direction *from* which the wind is blowing.

Thus, wind measurements are vectors since magnitude of speed and direction are considered.

Hand-held Anemometer



- Portable instrument for instantaneous wind speed and wind direction measurements.

Cup Counter Anemometer

- Wind pushes into the cups causing the instrument to spin. The amount of rotations is recorded by the counter on the device. This gives an idea of the wind speed.
- Placement of this instrument is critical. It should not be close to buildings or tall obstructions. Tall obstructions cause eddies, turning in the wind around obstacles.

Anemograph

- A graph connected to the dials records the wind speeds and directions on a continuous basis for a monthly period.

Wind Vane

- This device gives the direction *<u>from which</u>* the wind is blowing.

Make and Use Your Own Wind Vane to determine Wind Direction

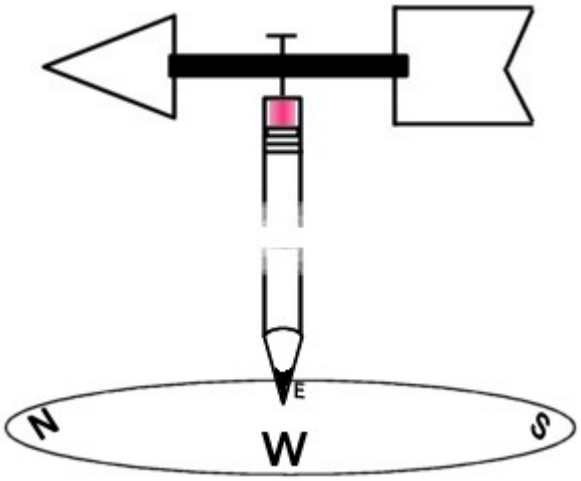
Overview

Knowing the direction of the wind is an important part of predicting weather because wind brings us our weather. To determine wind direction, a wind vane spins and points in the direction from which the wind is coming and generally has two parts, or ends: one that is usually shaped like an arrow and turns into the wind and one end that is wider so that it catches the breeze. The arrow will point to the direction the wind is blowing from so if it is pointing to the east, it means the wind is coming from the east. Additionally, wind direction is where the wind is blowing from. Therefore a west wind is blowing from the west. To use a wind vane, you must know where north, south, east, and west are.

Make a Wind Vane

A. **Materials**

- Tag board or manila file folder
- Straight pin
- Scissors
- Glue
- Pencil with a new eraser
- Plastic drinking straw
- Modeling clay
- Paper plate



B. **Procedure**

1. Cut out an arrow point 5cm long.
2. Cut out an arrow tail 7cm long.
3. Make 1cm cuts at the ends of each straw.
4. Slide the arrow point and the arrow tail into the cuts in the straw. wind vane
5. Push a straight pin through the middle of the straw and into the eraser end of the pencil.
6. Stick the sharp end of the pencil into a lump of modeling clay; this will be your base.
7. Mark north, south, east, and west on the paper plate
8. Put the clay on a paper plate.
9. Test out your Wind Vane: Blow on the vane and make sure that the arrow can spin freely.

Solar Radiation

Solar radiation is probably the most important element of climate.

Solar radiation heats the Earth's surface which in turn determines the temperature of the air above.

The receipt of solar radiation drives evaporation, so long as there is water available.

Heating of the air determines its stability, which affects cloud development and precipitation. Unequal heating of the Earth's surface creates pressure gradients that result in wind.

Just about all the characteristics of climate can be traced back to the receipt of solar radiation.

Campbell-Stokes Sunshine Recorder

- A solid glass sphere resting on an adjustable support.
- The sun’s rays are focused by the sphere, thus burning a mark onto a card held inside the bowl.
- Three cards are used: summer card (long & curved), winter card (short & curved) and equinoctial card (a straight card). This is because of the apparent movement of the sun.

Evaporation

Evaporation is the process by which water is converted from its liquid form to its vapour form and thus transferred from land and water masses to the atmosphere. It is an important process in the water cycle.

Evaporation from the oceans accounts for 80% of the water delivered as precipitation, with the balance occurring on land, inland waters and plant surfaces.

Three key parts to evaporation are heat, humidity, and air movement.

Laundry on a clothes line will dry (by evaporation) more rapidly on a windy day than on a still day.

Evaporation Pan

- A pan filled with water to a known depth.
- The stilling well is placed in the pan and supports the hook gauge, which is used to measure the height of the water in the pan.
- Over a 24 hour period some water would be added by rainfall and removed by evaporation.
- Rainfall is recorded and is thus known. Therefore the volume of water evaporated can be derived.

Stevenson Screen

To obtain measured parameter of weather at a particular place, instruments should be placed at that specific location. However, the instruments must be protected from the direct effects of the elements (sunshine, rainfall, wind) yet be able to be influenced by them as would occur in the real world.

Thus, it was necessary to devise a house for the delicate instruments.

The Stevenson screen holds instruments that may include thermometers, a hygrograph and a thermograph and thus, forms part of a standard weather station.

- A doubled-louvered wooden box that is used to house thermometers and other instruments from precipitation and radiation while also allowing free passage of air.
- The screen stands 1.25m above the ground covered with short grass – this ensures that the ground does not heat up quickly and the heat from the ground does not influence the temperatures of the thermometers housed in the screen.
- The screen faces north in the Northern Hemisphere and south in the Southern Hemisphere. This is so to ensure that the inside of the screen is never exposed to the sun.
- It is louvered so that air can pass through the screen – ventilation.

Temperature

At the atomic level, temperature is the measure of the average speed (kinetic energy) of the molecules and atoms on substance. Higher temp means higher average speed of particles.

Temperature is a physical property of matter that quantitatively expresses the notions of hot and cold. Objects of low temperature are cold, while various degrees of higher temperatures are referred to as warm or hot.

Air temperature is a very important part of weather measurement. The temperature of the air is always changing. Heat flows only from regions of higher temperature to regions of lower temperature.

Scales used to measure temperature are Kelvin, Celsius and Fahrenheit.

Temperature readings collected are Maximum Temperature, Minimum Temperature, Dry Bulb / Actual Temperature and Wet Bulb Temperature, Dew Point Temperature, Sea Surface Temperature, Soil Temperature, Water Temperature, etc.

Thermometers are used to measure temperatures.

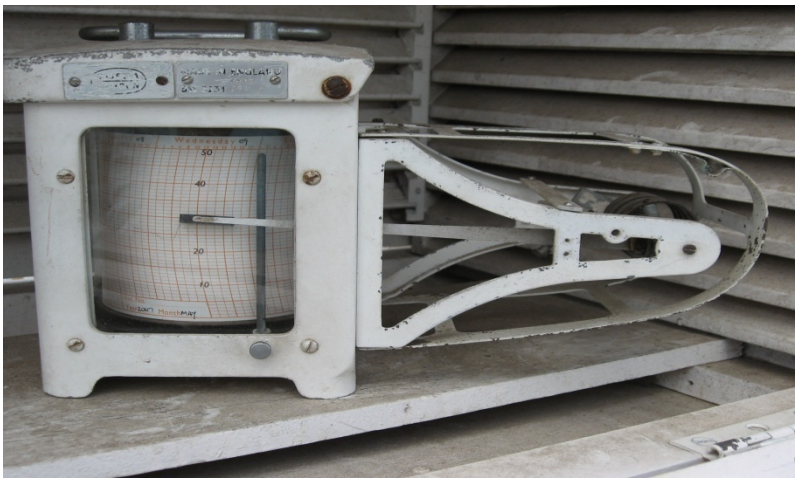
Mercury Thermometers measure high temperatures since mercury is sensitive to temperature changes.
Alcohol-in-Glass measures low temperatures since alcohol does no freeze.
Thermographs use bi-metallic strip which is made up of different metals that react differently to heat.

Thermometers

- Dry bulb and wet bulb thermometers are supported vertically. The wet bulb thermometer is has its bulb wrapped in a muslin and the wick in a reservoir of distilled water. Together, they measure the relative humidity.
- The dry bulb thermometer measures the temperature of the atmosphere.
- The wet bulb thermometer measures the temperature of the atmosphere if the atmosphere is 100% saturated.
- Low humidity occurs when the difference between the dry bulb temperature and the wet bulb temperature are far apart.
- High humidity occurs when the difference between the dry bulb temperature and the wet bulb temperature are close together.

- Maximum and minimum thermometers are supported horizontally and measures the maximum (daytime) temperature and minimum (night time) temperature respectively. They must be read at least twice a day. Usually it is done every main hour (8a.m., 2p.m., 8p.m., 2a.m.)
- All are mercury-in-bulb thermometers except the minimum thermometer, which is an alcohol-in-bulb thermometer.
- Care must be taken when reading thermometers to avoid errors due to parallax.

Thermograph



- Thermograph consists of a bi-metallic spiral coils and uncoils with changes in temperature. This action causes movement of an attached pen.
- This is a chart that is changed on a weekly basis.

Make and Use Your Own Thermometer to measure Temperature

Overview

Temperature is measured with a *thermometer*. As the air gets hotter, the level of the liquid rises and, as the air gets cooler, the level falls. It is recommended to begin by giving each group a thermometer and let each student practice reading the indoor temperature. Students should look straight at the thermometer at eye level.

Make a Thermometer

A. **Introduction:** You will learn how a thermometer works by making it however you will need a commercial thermometer to record the outside temperature.

B. **Materials**
- Rubbing Alcohol
- Water
- Cylinder shaped clear jar or bottle (bottles with a narrow neck work best)
- 1 straw
- Modeling clay
- Food coloring

C. **Procedure**
1. Remove the jar's label.
2. Remove the top from the jar make a small hole (just big enough so the straw can fit in).
3. Pour equal amounts of cold water and rubbing alcohol into the jar/bottle, filling it to about 1/4 of the container.
4. Add two - three drops of food coloring.
5. Close the bottle and make a small hole in the lid (just big enough to insert the straw).
6. Place the straw in the jar/bottle so that the bottom of the straw is submerged in the liquid but not touching the bottom of the container.
7. Seal the top of the bottle with the modeling clay so that it has a tight seal and so the straw stands upright.
8. Test your thermometer
    A. Grasp the jar/bottle with your hands and hold on for 5 five minutes. What happens
    B. Place your thermometer in a pan of cold water. What happens?
    C. Place your thermometer in a pan of hot water. What happens?




Humidity

Absolute humidity is the mass of water vapor divided by the mass of dry air in a volume of air at a given temperature. The hotter the air is, the more water it can contain.

Relative humidity is the ratio of the current absolute humidity to the highest possible absolute humidity (which depends on the current air temperature).

A reading of 100 percent relative humidity means that the air is totally saturated with water vapor and cannot hold any more, creating the possibility of rain.

Humans are very sensitive to humidity, as the skin relies on the air to get rid of moisture. The process of sweating is your body's attempt to keep cool and maintain its current temperature.

If the air is at 100-percent relative humidity, sweat will not evaporate into the air. As a result, we feel much hotter than the actual temperature when the relative humidity is high.

If the relative humidity is low, we can feel much cooler than the actual temperature because our sweat evaporates easily, cooling us off.

Hygrograph

- Hygrograph depends on the reaction of human hair to humidity.
- The length of the hair increases with increasing relative humidity.

Radiosonde

A radiosonde attached to a weather balloon measures weather conditions higher up in the atmosphere.

The radiosonde has sensors that can take readings of meteorological parameters at different levels and layers in the atmosphere and a transmitter then allows this data to be transmitted to a computerized system.

Parameters measured are temperature, dew-point, atmospheric pressure, geo-potential height, wind speed and direction.

Glossary of Terms

Aneroid – without fluid

Bi-metallic strip – equal lengths of different metals are riveted together so that they would not move separately. When heated, one metal expands more than the other and the strip bends. Bi-metallic strips are used in fire alarms, thermostats and in thermographs.

Displacement – the amount by which something is moved from its usual position.

Equinox – the time or date when day and night are of equal length (about 20 March and 22 September).

Evaporation – the process where liquids turns into vapour.

Graph – a diagram which shows how two or more sets of numbers relate with each other. In meteorological terms, it is usually how the parameters change with time.

Housing – a space or accommodation; an enclosure.

Meter – a device that measures and records the quantity, degree or rate of something.

Parallax – the apparent difference in position of an object when viewed from different positions. To avoid parallax, the instruments are read at eye level.

Segment – each of the parts into which something is divided.

Vernier - an additional scale which allows a measurement to be read more precisely.

Wind-run - the total distance (or amount) of wind that has travelled over a particular area over a period of time. This measurement helps determine the rates of evaporation.

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