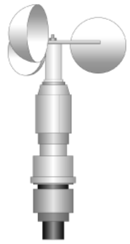


Write the Book on Weather Metrics

What country do you think has the wildest weather in the world? Which is the one with the most hurricanes, floods, tornadoes, blizzards, hail storms, droughts, and lightning strikes? It is the USA! Does that surprise you? With two coastlines exposed to storms that form at sea, plus frequent masses of cold, dry air coming down from the north meeting up with moist, warm air from the south, plus several mountain ranges to mix things up, the USA has all the right stuff to whip up plenty of weather excitement.

What does all this weather have in common? First of all—air! After all, weather is really all about the thin blanket of air surrounding Earth and what any particular part of it is doing. What is its temperature? How much water does it contain? How fast is it moving and in what direction? How dense is it? What gases are in it? What particles are in it?

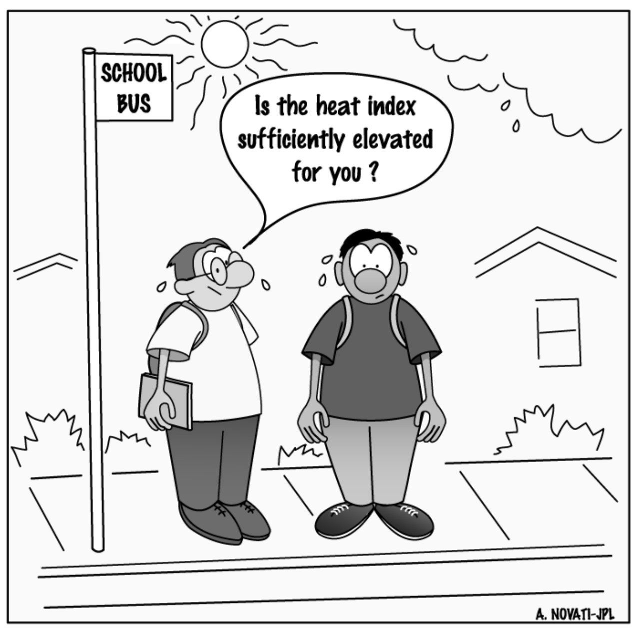
A Fragile Gauze

Our atmosphere, at least the lowest part of it that is dense enough to breathe, is really quite thin—about 6 kilometers (about 3.7 miles) thin. The few hearty souls who climb Mt. Everest (nearly 9 kilometers or 5.5 miles high) without oxygen are rare—and they often get very sick from the low air pressure and lack of oxygen. Ninety-nine percent of our atmosphere is in the 30 kilometers (19 miles) nearest the surface. If Earth were the size of a beach ball, its breathable atmosphere would be as thin as paper (Ahrens, p. 4) . Makes you think twice about smudging it all up and poking holes in it!

Earth's atmosphere is the source of life-giving oxygen for animals and carbon dioxide for plants. It is the blanket that protects us from either frying during the day or freezing to death at night. It is also the shield that keeps out most of the harmful radiation from the Sun, as well as meteoroids that would be raining down upon us from space. If not for the atmosphere, the oceans, lakes and rivers would soon boil off into space.

Our atmosphere is fragile, though. It reacts to energy being poured into it every day from the Sun, and, to a much lesser extent, to energy from Earth's rotation. And it reacts to gases and particles being pumped into it by modern human civilization. Understanding how the atmosphere behaves in response to all these influences is important if we are to live safely within it and learn to take care of it.

Entertain Your Friends: Talk about the Weather!



You may think weather makes for boring conversation—a topic of last resort if you can't think of anything else to talk about. But, understanding something about weather gives you more than just a nerdy way to ask "Hot enough for you?" If you know what causes different kinds of weather, how your local weather fits into the

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global picture, and how scientists study and measure weather, you will have lots of interesting and helpful information to share. Maybe someday you yourself will be able to help predict the weather or help protect our precious atmosphere.

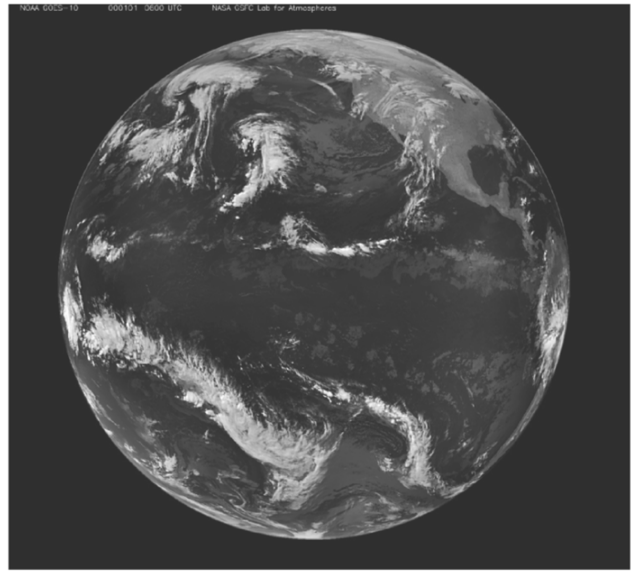
A meteorologist is a scientist who studies the atmosphere and weather. The first thing a science of anything does is figure out how to measure whatever it is trying to study. Weather presents quite a challenge. What can we measure in this complex, swirling soup of air we call our atmosphere?

To start, you can find out what the weather is like right now by going outside. Without knowing any weather words at all, you can see whether the temperature is just right or cool or downright cold. You can tell whether it is raining or snowing, whether the air feels dry or damp. You can tell whether it is windy and, by the way your hair or the trees are moving, what direction the wind seems to be going. After you have been observing for a while, you will be able to tell small differences in these conditions from day to day and hour to hour. You will notice that even when there are clouds, they are constantly changing and moving.

Giving Names and Numbers to the Air

Meteorologists measure all these characteristics very precisely, using all different kinds of instruments. They also have instruments to measure conditions that you may not be able to detect with your five senses. For example, air pressure can change ever so slightly from day to day, which can be a sign of clear weather or storms on the way. The amount of ultraviolet light (the culprit responsible for sunburns and skin cancer) coming through the atmosphere from the Sun can vary depending on the time of year, cloud cover, pollution, solar storms, and other factors.

Meteorology, like most other sciences, relies on technology to do its everyday work of forecasting weather. Technology is also necessary for understanding long-term climate changes and the effects of human activity. Technologies used by meteorologists range all the way from simple thermometers to very advanced and complex satellites, such as the GOES (Geostationary Operational Environmental Satellites) and POES (Polar-orbiting Operational Environmental Satellites).



This is the full-disk view GOES-west has of Earth. A map has been added underneath the GOES image to make it easier to see the continents.

Two GOES are in Earth orbits so high over the equator (35,800 km or 22,300 miles) that they orbit Earth only once per day. This means, of course, that they are always stationed "over" the same spot on Earth as Earth rotates on its axis once per day. The GOES take pictures and movies of Earth and the clouds and storms brewing in the atmosphere. They help greatly in doing short-term weather forecasting, so that when trouble is brewing in the atmosphere, people can be warned to "batten down the hatches" or get out of the way. GOES can also measure what is going on at different levels of the atmosphere by way of temperature, moisture content, wind speed and direction, and ozone distribution. (Ozone in the atmosphere helps shield us from harmful ultraviolet radiation from the Sun.)

The two POES have much lower orbits (830-870 km or about 515-540 miles), passing nearly directly over the North and South Poles. As they orbit, Earth turns beneath them. Thus the POES take images and monitor nearly the entire globe every six hours. Information from the POES help with longer term studies of weather and climate. They also measure atmospheric ozone, keeping an eye on the worrisome "hole" in the ozone that hangs out over Antarctica.

How Many Whats?

Scientists must agree on the units they will use to measure things. For example, length may be measured in meters or feet, distance (longer lengths) in kilometers or miles. Weight (or mass) may be measured in kilograms or pounds. Time is measured in seconds, minutes, hours, days, and so on. Speed is measured in kilometers per hour, miles per hour, meters per second, and so on.

Meteorologists also have units for everything they measure. We are all familiar with temperature units like degrees Celsius or degrees Fahrenheit. We know precipitation (like rain or snow) is measured in inches or feet (or millimeters or centimeters). But what kind of units are used to measure atmospheric pressure or UV (ultraviolet radiation) index? Or pollution in the air?

Write the Book on Quantifying the Weather

Here's a project you can do that will give you a chance to find out more about the different types of things meteorologists measure and how. In doing this project, you will go on a kind of scavenger hunt, using books, the internet, newspapers, magazines, and your own imagination. Your finished product will be a book of weather terms that you have made yourself.

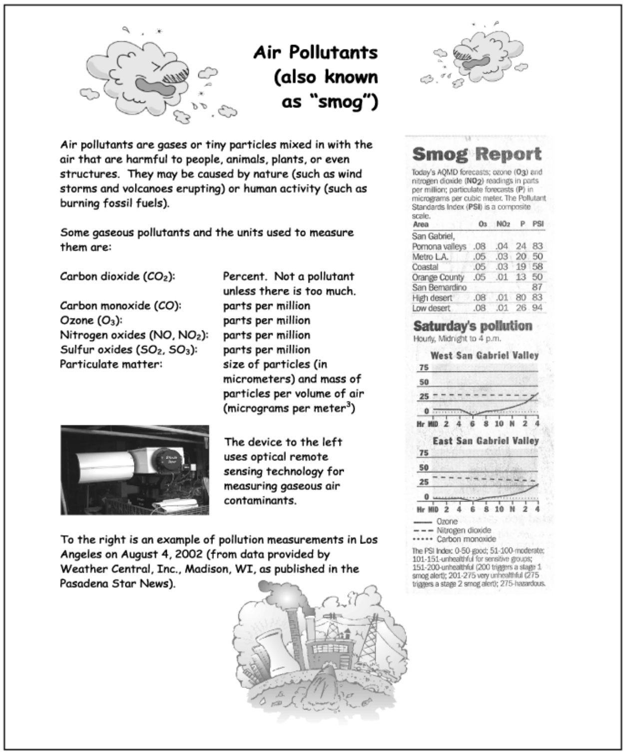
Each page of the book will be about one of the weather terms in the list below. Your teacher will help you decide how many pages to put in your book. At the end of this article is a list of suggested sources for information, including books and web sites.

For each page of the book:

1. Write the name of the **weather term** at the top of the page.
2. **Define** the weather term (use the dictionary).
3. Tell what kind of **unit** is used to measure this characteristic of the weather.
4. **Describe** and, if you can, **show or draw a picture** of an instrument or device used in measuring this characteristic of the weather, or what different kinds of data must be combined to calculate the measurement. For example, you will find that heat index depends on both temperature and relative humidity.
5. For the rest of the page, do one (or more) of the following:
   - Show how the measurement is calculated. Or show how to convert from one type of unit to another. For example, you could show how to convert a temperature measurement from degrees Celsius to degrees Fahrenheit or the other way around.
   - Include a clipping of an article from the newspaper, magazine, or the internet that has a story about this characteristic of the weather. For example, "precipitation" could include a news story about the devastating effects of drought on the farmers in Iowa. Or, including a clipping of an article that mentions the same unit of measurement used for this characteristic of the weather.
   - **Draw a picture** that you think illustrates something about the characteristic. For example, you could draw pictures of different types of clouds.
6. Last, design a nice, weather-related **cover** for your book.

On the next page is a list of weather terms from which to choose and some hints about what you might like to investigate to fill up your page (after you have defined the term, given the unit of measurement, and described the instrument(s) used to measure it).

Choose Some Weather Terms for Your Weather Book



Air Pollutants (also known as "smog")

Air pollutants are gases or tiny particles mixed in with the air that are harmful to people, animals, plants, or even structures. They may be caused by nature (such as wind storms and volcanoes erupting) or human activity (such as burning fossil fuels).

Some gaseous pollutants and the units used to measure them are:

Carbon dioxide (CO_2):	Percent. Not a pollutant unless there is too much.
Carbon monoxide (CO):	parts per million
Ozone (O_3):	parts per million
Nitrogen oxides (NO, NO_2):	parts per million
Sulfur oxides (SO_2, SO_3):	parts per million
Particulate matter:	size of particles (in micrometers) and mass of particles per volume of air (micrograms per meter^3)

The device to the left uses optical remote sensing technology for measuring gaseous air contaminants.

To the right is an example of pollution measurements in Los Angeles on August 4, 2002 (from data provided by Weather Central, Inc., Madison, WI, as published in the Pasadena Star News).

Smog Report

Today's AQMD forecasts; ozone (O_3) and nitrogen dioxide (NO_2) readings in parts per million; particulate forecasts (P) in micrograms per cubic meter. The Pollutant Standards Index (PSI) is a composite scale.

Area	O_3	NO_2	P	PSI
San Gabriel, Pomona valleys	.08	.04	24	83
Metro L.A.	.05	.03	20	50
Coastal	.05	.03	19	58
Orange County	.05	.01	13	50
San Bernardino				87
High desert	.08	.01	80	83
Low desert	.08	.01	26	94

Saturday's pollution

Hourly, Midnight to 4 p.m.

The PSI Index: 0-50-good; 51-100-moderate; 101-151-unhealthful for sensitive groups; 151-200-unhealthful (200 triggers a stage 1 smog alert); 201-275 very unhealthful (275 triggers a stage 2 smog alert); 275-hazardous.

Sample page for Weather Book.

Temperature: What unit is normally used in the U.S.? In Canada and Europe? How do you convert from one to the other?

UV index: What kinds of measurements are used to come up with this number? Why is this measurement so important to our lives? What do the "Sun Protection Factor" (SPF) numbers mean on sunscreen lotions?

Barometric pressure: What are some different technologies and units used to measure this characteristic? What causes it? What makes it change?

Wind speed: What turns a tropical breeze into a hurricane?

Heat index: Why is this number, which is calculated from the real temperature and relative humidity, sometimes very important to know?

Wind chill factor: What two measurements are used to calculate this number and why is it sometimes very important to know?

Relative humidity: Why does this number change as the temperature changes? How does it affect our comfort level?

Dew point: If this number goes up, what other measurement has also gone up?

Precipitation: What's the difference between the units used for different types of precipitation?

Probability of rain: What does this really mean? Is it dependable as an absolute predictor of what will happen?

Hurricane scale: How do meteorologists decide how to rate a hurricane using this scale?

Tornado scale: How do meteorologists decide how to rate a tornado using this scale?

Solar radiation: What are some characteristics of the atmosphere (or Sun) that would cause this measurement to vary?

Sunrise/sunset: Why do these measurements vary throughout the year? Can scientists predict these accurately?

Cloud types: What altitudes do these different kinds of clouds occupy: stratus, cirrus, cumulus, cumulonimbus, nimbus, altocumulus, lenticular. Can you foretell anything about the weather by looking at them? What do they look like?

Air pollutants (gases and aerosols): What are some of the pollutants caused by human activity? What are their sources? What are "greenhouse gases"? Where are the highest concentrations?

Acid rain (acidity): What kinds of effects does acid rain have? How can scientists figure out where this stuff comes from?

Pollen count: Who cares about this? Could this also be a form of pollution caused by human activity?

Visibility: Who cares about this?

BECOME A WEATHER WIZARD!

In some places—maybe where you live—weather is a very important part of planning, especially leisure time planning. For example, in looking forward to your weekend, wouldn't it be nice to know it was going to be sunny and clear on Saturday, but rain buckets on Sunday? That way, you'd have a good reason for putting pleasure before business, planning something fun outdoors for Saturday and your homework for Sunday.

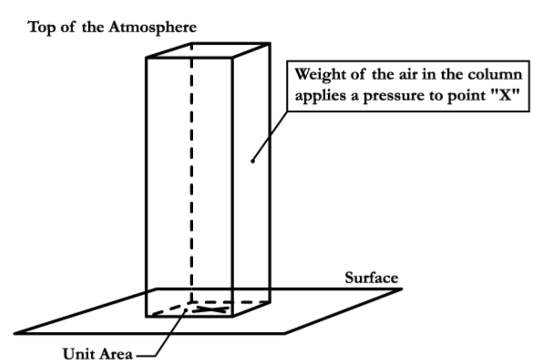
Weather is just about the most complex and unpredictable natural occurrence humans have to deal with. However, predicting weather is finally getting to be less of an art and more of a science. Using images and other data from the satellites called GOES and POES, and from other kinds of sensing technologies, along with computers to analyze the data, scientists are beginning to make some sense of it all. For example, thanks in part to real-time (meaning right this second) information from the GOES, meteorologists (scientists who study the weather) have gotten very good at predicting what is going to happen in the next 12 to 24 hours. If it's a hurricane about to come ashore on the east coast of the U.S., 12 hours' warning can save hundreds of lives, giving people the opportunity to evacuate inland or go to higher ground. Of course, it is very important that such warnings be highly accurate, or people won't pay any attention to them. They will think that the weather forecasters are just crying "Wolf!" one more time.

On TV weather reports, you've probably seen weather forecasters point to maps and use terms like "cold front," "high-pressure system," "barometric pressure," and "jet stream" to describe the major trends and weather systems influencing our entire continent. In addition to showing satellite images of clouds, TV forecasters and newspapers sometimes uses lines and symbols on a map to help convey this big picture. Of course, this map of an area over 3,000 miles wide and just about as long will not tell you whether it is snowing right this second in downtown St. Paul or hailing in east North Hampton. It will tell you what kind of weather each of those local places is most likely having.

Let's learn to read one of these maps—or even draw one. First, we need to understand a little about what the symbols mean. Here are the most common weather concepts you will see illustrated on a weather map. There's a whole lot more to know about all these ideas, but these explanations may get you started.

HIGH AND LOW PRESSURE AREAS:

Did you realize that you have hundreds of pounds of air pushing on your body all the time? Of course, your body evolved under all this pressure, so you can handle it! (That's why astronauts need pressurized space suits to do their space walks. Otherwise, they'd explode!—well, not really, but their blood would boil, which is just as unpleasant.) All the air above you in the atmosphere is being held near Earth's surface by gravity, just like everything else that doesn't float off into space. For every square centimeter of Earth's



surface, the atmosphere above it, all the way up to space, weighs about 1.03 kilograms, which exerts a normal sea level pressure on you of 14.7 pounds per square inch! Earth's atmosphere extends up more than 150 kilometers (more than 100 miles), but half of it is in the lowest 5.5 kilometers (3.3 miles).

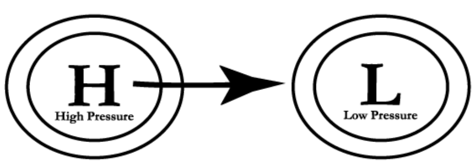
So, all these interesting statistics aside, the point is, air exerts pressure because of its weight. But it also exerts pressure because of its temperature. Molecules of air are in constant motion, bumping against each other and bouncing off in all directions. The warmer the air, the more active its molecules and the more pressure it exerts (provided its container doesn't expand).

Thus, because of gravity, the atmosphere near the surface is "heaviest," especially when it is cold, and would seem to exert the most pressure. But because of heat energy, the molecules of warmer air push out in all directions, serving to increase pressure. The important thing is, air does not exert the exact same amount of pressure everywhere. And from this fact, comes a lot of weather!

Remember this: Air tends to move from high pressure areas to low pressure areas.

The pressure difference between two points is called a *pressure gradient*. The force that moves the air from high to low pressure areas is called the *pressure gradient force*.

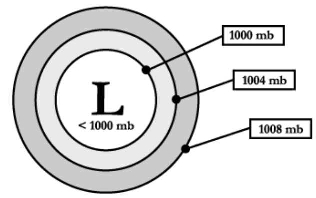
It is common for high pressure areas to have fair weather.



The influence of the pressure gradient force

Barometric Pressure:

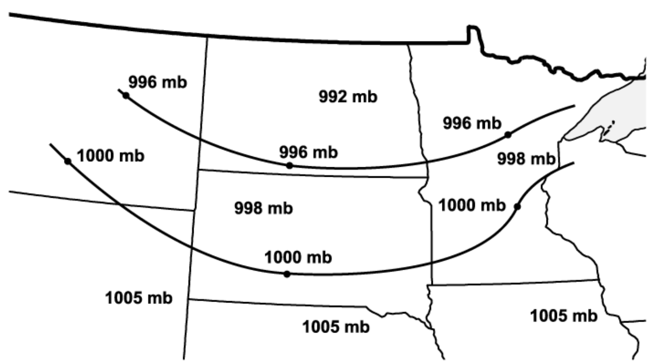
Barometric pressure means the same thing as atmospheric pressure, but it is an actual measurement taken with an instrument called a barometer. Barometers may measure pressure in *atmospheres* (atm), *inches of Mercury* ("Hg), *millibars* (mb), or other units. Weather forecasters on TV usually use "Hg, while meteorologists usually use mb. Normal atmospheric pressure at sea level is defined as 1 atm, which corresponds to 29.92 "Hg or 1013.25 mb. Barometric pressure readings are taken at many locations by the National Weather Service and combined to produce maps showing high and low pressure areas, thus helping to predict what the weather will do over large regions in the immediate future.



Region of LOWEST pressure relative to its surroundings

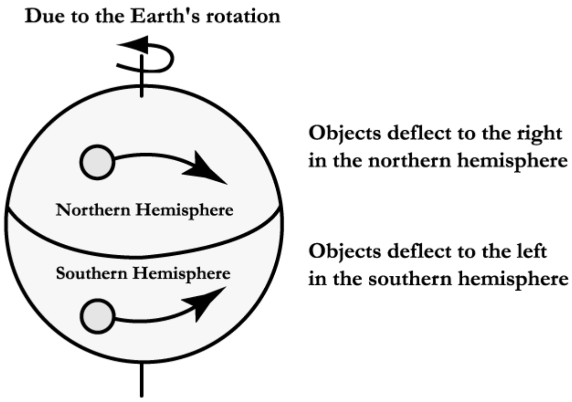
Isobars:

If many barometric pressure readings are taken and recorded on a map, and then the readings that match are connected by a line, you have an isobar. Maps showing isobars are very useful in locating areas of high and low pressure, which, in turn, help predict which way the air masses are and will be moving. This moving air is also what we call wind, and wind drives the major weather surface features, such as highs, lows, and fronts, which, in turn affect weather.



Warm Front:

A warm front is the transition area where a mass of warm air is moving in to replace a mass of cold air. But, the pressure gradient force isn't the only force acting to move air. Other forces come in and really complicate things. The biggest stirrer of the atmospheric soup is Earth's rotation. It causes the air north of the equator to tend to curve toward the right and the air south of the equator to curve to the left. This movement, of both air and oceans, is called the Coriolis effect.



So with air moving in curves, interference (friction) from such obstacles as mountains, trees, and buildings, plus the heating and cooling of the atmosphere from day to night, you can begin to see why predicting the weather isn't easy!

Warm fronts usually move from southwest to northeast, bringing higher humidity. Warm fronts are usually drawn on a weather map using a solid red line, with half-circles on the side that points toward the cold air being replaced.

Cold Front:

A cold front is the transition area where a mass of cold, dense (high pressure) air is moving in to replace warmer air. Cold fronts typically move from northwest to southeast. When a cold front passes through, the temperature can drop 15º F in an hour. A cold front is represented on a weather map by a solid line (usually blue), with triangles pointing toward the warm air it is replacing.

Jet Stream:

Jet streams are fairly narrow bands of very high speed winds in the upper atmosphere. They generally blow from west to east. Strong temperature differences cause great pressure differences (gradients) at high altitudes. These winds can reach 150 miles per hour or more. You can see why airline pilots flying across country from west to east like to take just the right route and fly at just the right altitude to get a kick in the tail (and save lots of fuel) from the jet stream—and why flying east to west, they try to avoid it!

Rain, snow, ice, and thunderstorms:

These terms need little explanation. These conditions are the end products of which we are all too aware! These forms of precipitation (water falling from the sky) result from the pressure gradients, cold fronts, and warm fronts, as well as ocean temperatures and currents, and a few dozen other factors.

Find Out More

The United States has the wildest, most extreme weather of any country on Earth. Learn more about how weather works by reading these books and visiting these websites:

The Weather Book: An Easy-to-understand Guide to the USA's Weather, by Jack Williams, published by *USA Today*.

Essentials of Meteorology: An Invitation to the Atmosphere by C. Donald Ahrens. ISBN 0-534-37200-7. Brooks/Cole, Thomson Learning, 2001.

SciJinks Weather Lab, **scijinks.nasa.gov .**

The Space Place, **spaceplace.nasa.gov** (search for "weather").

National Oceanic and Atmospheric Administration (NOAA), **www.noaa.gov/**, plus NOAA's Weather Education site, **www.education.noaa.gov/cweather.html** .

NOAA's Photo Library, **www.photolib.noaa.gov/** .

NOAA's GOES Satellites home page, www.oso.noaa.gov/goes/ .

GOES Project Science page, rsd.gsfc.nasa.gov/goes/text/hotstuff.html .

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MAKE A WEATHER MAP

Make photocopies of the map of North America on the next page. You will be drawing weather symbols on a copy of the map. Pick one of the weather situations described in the paragraphs below (quoted or adapted from reports in the *Los Angeles Times*) and using the symbols shown on the map's legend, draw a U.S. weather map for that day. After you've done a few of these, those TV and newspaper weather maps should look much more interesting!

WEATHER DAY 1:

"High pressure strengthening over the eastern Pacific will maintain mostly sunny skies along much of the West Coast today. An area of low pressure will curve northward into Canada, creating cloudy skies above the Pacific Northwest. An upper-level disturbance cruising through the Southwest will trigger scattered rain and mountain snow showers, while low pressure developing east of the Rockies produces rain and snow through much of the Plains. Partly cloudy skies will cover the Great Lakes region and most of the Northeast. Thunderstorms will rattle parts of the Southeast."

L.A. Times, *March 11, 2001*

WEATHER DAY 2:

"Warm and humid air spilling northward from the Gulf of Mexico will combine with a warm front to trigger widely scattered afternoon showers and thunderstorms across the Southeast today. Clouds will linger over western Washington; otherwise, mostly sunny skies and locally breezy conditions will prevail through the West. The Rockies will remain dry, except for a chance of afternoon storms in the southern sections. Sunny, dry weather will continue in the Midwest. A low-pressure system will produce showers and storms from the mid-Atlantic states to the lower Mississippi Valley."

L.A. Times, *July 29, 2001*

WEATHER DAY 3:

"A low-pressure system . . . will slide down into the Southeast today, drenching much of the region with locally heavy showers and thunderstorms. The West Coast will continue to bask under sunny skies and seasonable conditions. Late-summer monsoonal moisture will produce partly cloudy skies and isolated afternoon storms over the Rockies and the Southwest. A cold front will advance into the Upper Midwest, triggering scattered showers and storms across the Plains and western Great Lakes. High pressure will promote sunny skies through the Northeast."

L.A. Times, *September 2, 2001*

WEATHER DAY 4:

"High pressure will promote mostly sunny skies, dry conditions and locally gusty winds across the Southwestern states today. A few showers, however, will dampen the Pacific Northwest, with areas of rain and snow occurring above the central Rocky Mountains. Low pressure, coupled with an associated frontal system, will trigger scattered showers from the eastern Great Lakes to the central Appalachians. Another low south of this storm will set off scattered showers and thunderstorms over the central and southern plains. Partly cloudy skies will continue to cover the Eastern Seaboard."

L.A. Times, *October 12, 2001*

WEATHER DAY 5:

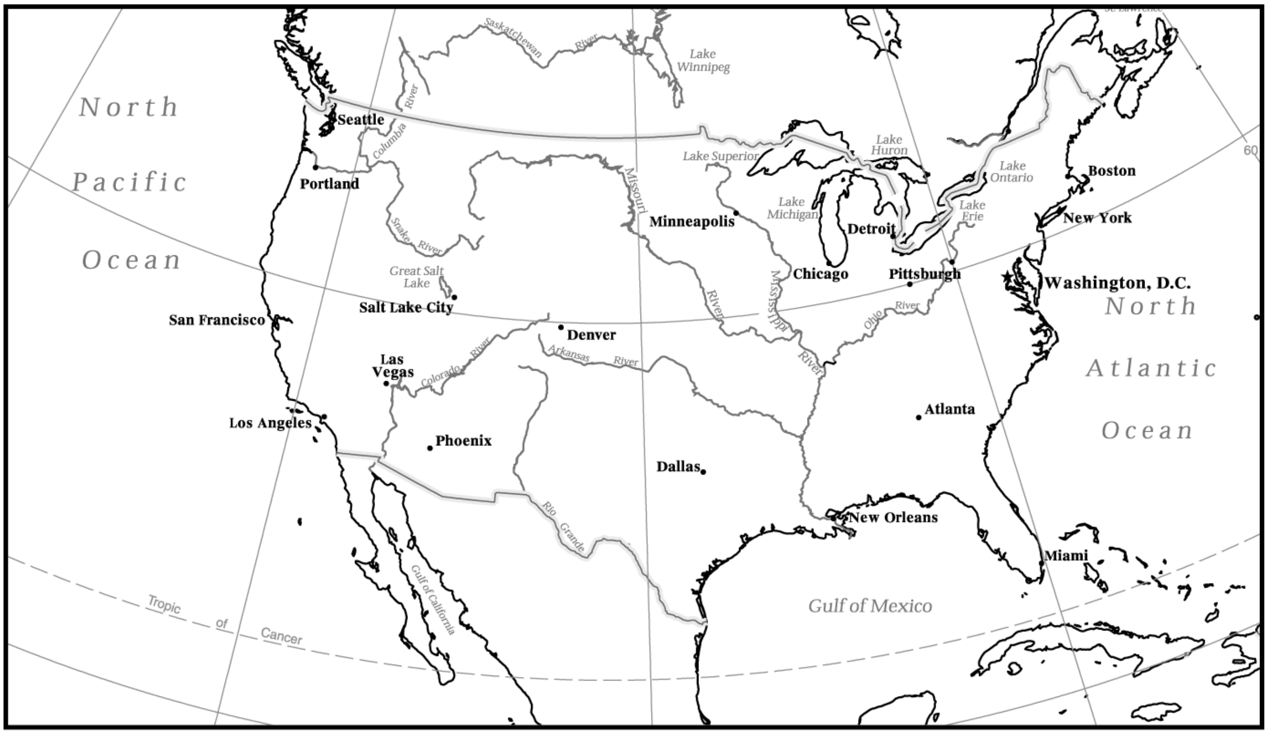
"Mostly cloudy skies, light rain showers and higher-elevation snowfall will prevail along the West Coast from Central California northward today as a . . . [low pressure system] pushes in from the eastern Pacific. Skies will become cloudy over the northern Rockies, remaining partly cloudy to the south. High pressure will keep the Plains and the Midwest mostly sunny and warmer as winds become southerly. A few showers may develop in Texas. Mostly sunny skies, windy and cool conditions will continue through the Northeast, while sunny skies and mild weather grace much of the Southeast."

L.A. Times, *November 11, 2001*

WEATHER DAY 6:

"Low pressure above northeast Canada will swing a cold front over the entire East Coast today, causing rain and cooler conditions along the region, and afternoon snow in western New England. High pressure ridging over the Pacific Northwest will maintain sunny to partly cloudy and seasonable conditions through much of the West. Snow showers may still fall in the north Rockies, while sunny, cool weather prevails in the Plains in the wake of the system that moved into the East. Thunderstorms may erupt in Florida. Jet stream curving south from over western Canada and into Montana. Also, jet stream curving northeast from New Mexico up over New England."

L.A. Times, *March 3, 2002*



H **High Pressure**

L **Low Pressure**

00.0 **Barometric pressure with isobar** *

Jet Stream
High altitude
high speed winds

Warm Front
Warmer air
replacing cooler

Cold Front
Cooler air
replacing warmer

Rain

Snow

Thunderstorm

Ice

*** Although isobars often appear on weather maps, they may not be mentioned in the word descriptions of the overall weather picture.**

National Aeronautics and Space Administration

National Oceanic and Atmospheric Administration

Please take a moment to evaluate this product at **http://ehb2.gsfc.nasa.gov/edcats/educational_wallsheet**
Your evaluation and suggestions are vital to continually improving NASA educational materials. Thank you.

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