



CHAPTER

30

Monitoring Weather

“Joy comes from simple and natural things, mists over meadows, sunlight on leaves, the path of the moon over water. Even rain and wind and stormy clouds may bring joy.”

—Sigurd Olson, American nature writer, founding father of the Boundary Waters Canoe Area, and recipient of the 1974 John Burroughs Medal, the highest honor in nature writing



The atmosphere swirls above us like a great, restless sea. Jet streams streak across the sky at hundreds of miles an hour. Polar air masses spill off the ice fields and roll toward warmer climes, while hot tropical air can be so still that a ship's sails can hang limp for days. Chinook winds sweep off the mountains, and thunderheads billow over the prairies, while high peaks seem to produce their own storms.

Thunder and silence, drought and rain, the seemingly random effects of weather are everywhere. Yet weather is not a series of isolated events. It is a constantly changing whole that is as remarkable for its thousand-mile bands of storms and calm as for the narrow paths of tornadoes and lightning bolts. As you travel the outdoors, you'll want to piece together the weather clues you see, hear, and feel so that you can predict the conditions to come in the next few hours and days. To do that, it helps to understand the big picture.

The Atmosphere

Breathing it throughout our lives, feeling it blow against our faces, and watching it move smoke, dust, sailboats, and clouds, we usually take the air around us for granted. The air we call atmosphere, composed primarily of nitrogen (78 percent) and oxygen (21 percent), rises some 60 miles above Earth's

surface, thinning until it vanishes into the vacuum of space. The atmosphere presses down on us at sea level with a force of about 14.7 pounds per square inch, but we are so accustomed to feeling that weight we seldom realize it is there unless we are changing elevations. Climb a mountain, though, and you will find the air getting thinner as you go higher. You might feel light-headed and short of breath. When you make an alpine camp, you also might notice that water on your backpacking stove boils at a lower temperature than at sea level.

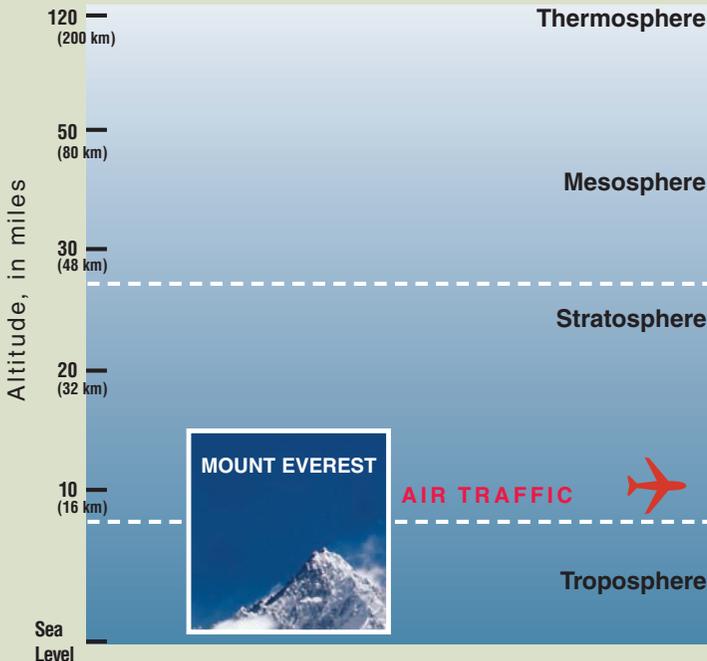
Water's Boiling Point

ELEVATION	DEGREES FAHRENHEIT
Sea level	212
1,000 feet	210
5,000 feet	202
8,000 feet	196
10,000 feet	192
12,000 feet	188
14,000 feet	184

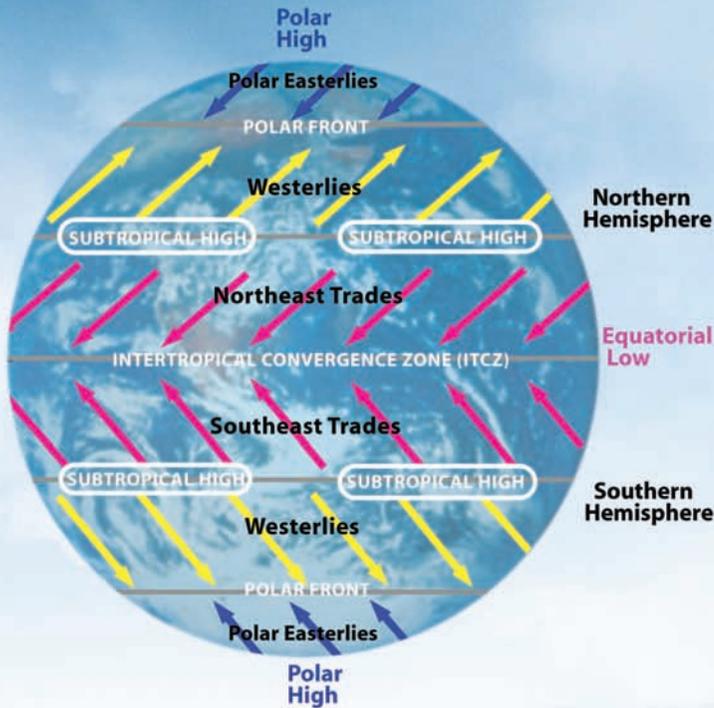
Atmospheric Strata

The layers, or *strata*, of the atmosphere are the *troposphere*, *stratosphere*, *mesosphere*, and *thermosphere*. Nearly all weather occurs in the troposphere, the level closest to Earth's surface. The troposphere varies in depth from 4 miles at the North and South Poles to about 10 miles at the equator.

The boundary between the troposphere and stratosphere is the *tropopause*, a lid on the weather-filled troposphere. The stratosphere above it is ideal for jet travel, since aircraft at that altitude are above most atmospheric disturbances.



GLOBAL PRESSURE AND WIND BELTS



Air Pressure and Atmospheric Temperature

The sun is the engine that drives Earth's weather systems. Solar radiation warms Earth, which in turn heats the envelope of air nearest Earth's surface. The sun's rays are more direct, thus more intense, closer to the equator, making the tropical latitudes warmer than the North and South Poles. The temperatures of large bodies of water change more slowly than the temperatures of land masses. The surface of bare soil heats and cools faster than forested regions at similar latitudes and elevations. The seasons affect rates of heating and cooling, too. All these factors result in wide temperature variations around the globe.

As hot tropical air lifts into the sky, cooler air from temperate latitudes is drawn in to fill the void. In turn, that air warms and rises, drawing in even more cooler air. Meanwhile, heated air migrating toward the Poles cools and descends. Warming and rising, cooling and sinking, the cycle goes on and on, producing and affecting patterns of weather all over the planet.

Cold, dense air is associated with higher pressure while lower pressure is the realm of warmer, lighter air. This fact partially explains the presence of semipermanent belts of high and low pressure that power large-scale wind circulations including the westerlies in the midlatitudes carrying storm systems from west to east across the United States.

Embedded in the prevailing westerlies are *jet streams*, fast currents in the flowing rivers of air. A few miles wide and some 30,000 feet above Earth, jet streams move along at several hundred miles an hour. Aircraft pilots traveling east across America sometimes seek out these persistent winds to help them speed their planes toward their destinations, though when they are traveling the other way they are careful to avoid the head-on force of a jet stream.

If Earth were smooth and made up of equal areas of land and water, the prevailing winds would blow in predictable patterns. However, the surface of the globe is irregular both in shape and composition. Mountain ranges jut into the sky, while plains and deserts lie flat. Some areas are heavily forested, others bare, some light in color, some dark. As a result of these variations, the atmosphere warms and cools unevenly, and the speeds and directions of the prevailing winds are altered by the drag of friction and by the physical barriers they encounter. Dividing, combining, weakening, and gaining strength, air masses swirl this way and that, responding to local temperature and terrain and to the presence of other air masses.

Highs and Lows

When warm, high-altitude air cools and sinks, it can form an area of high pressure known simply as a *high*. The barometer rises as a high takes shape, indicating an increase in atmospheric pressure. The dense air in a high-pressure region can keep other weather systems at bay, and the skies generally will be clear.

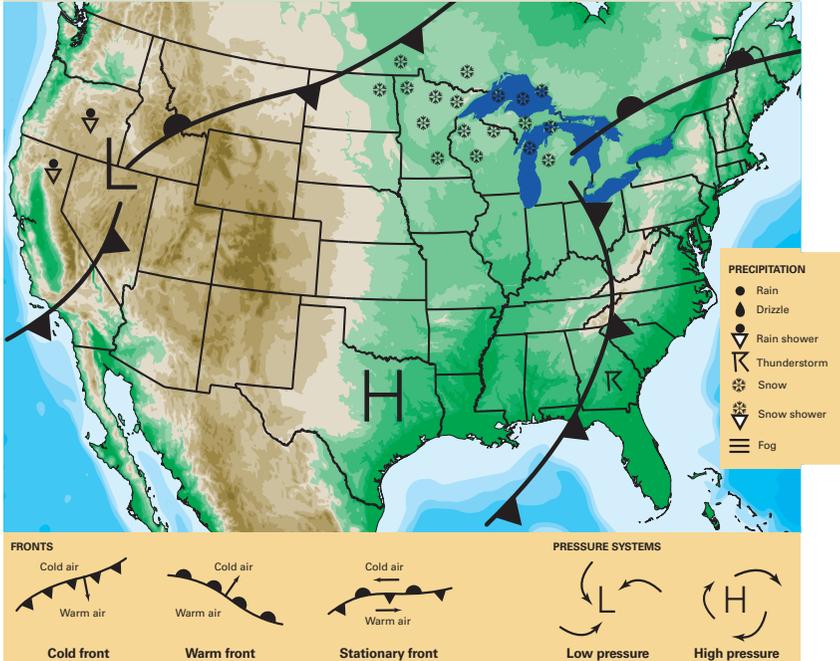
However, there is only so much atmosphere blanketing Earth; if the air is more concentrated in high-pressure areas, other parts of the sky must be areas of low pressure, or *lows*. As indicated by dropping barometric readings, the air in a low is less dense than that in a high, so it tends to draw in winds laden with moisture. As a result, lows are less stable, cloudier, and stormier than highs.

Polar air masses can bring cold, northerly air into the American heartland. When they collide with moist air masses drifting in from the Pacific Ocean and Gulf of Mexico, much of the country can expect rain or snow. Warm air near the equator tends to rise rather than move horizontally, creating great areas of calm called the *equatorial doldrums* and the *horse latitudes*. Sailing ships of old could languish in calm weather for weeks, waiting for a breeze to fill their slack canvas.

Meteorologists chart the sizes and shapes of highs and lows by preparing maps with lines connecting points registering identical pressure readings. While a topographic map shows variations in terrain by using contour lines to connect all points in an area that are the same elevation above sea level, a weather map uses lines called *isobars* to indicate the relationship of locations reporting the same barometric pressure. Just as contour lines ring a mountain, isobars encircle regions of high pressure, decreasing in value as they move away from the center. Likewise, isobars show low-pressure areas as valleys and sinks in the atmosphere in much the same way contour lines indicate valleys and lowlands on maps of dry land.

Weather Maps

You can access weather maps for any area of the globe via the Internet. Maps of your area can be found in daily newspapers and on televised weather reports. Satellite images show cloud movement across the United States and much of Canada.



The Coriolis Effect and Prevailing Winds

While Earth's great air masses are flowing from polar regions toward the tropics, the globe is rotating beneath them. As a result, the winds do not appear to travel in straight lines, but rather bend to the right in the northern hemisphere and to the left south of the equator. This phenomenon, named the *Coriolis effect* in honor of its 19th-century French discoverer, causes prevailing weather patterns to curve as they flow across the globe, and at times to overlap, collide, and mesh with one another.

Weather watchers have known about these patterns of air motion for centuries. Sailors since Columbus' time have traveled near the equator to let the trade winds of the tropical Atlantic Ocean push their ships west to America, and then returned to Europe in the westerlies farther north. Today's transcontinental bicyclists know they are more likely to have the wind at their backs when they pedal from the Pacific toward the Atlantic, but if they go the other way, they might fight headwinds much of the time.

Beaufort Scale

Developed in the 1800s for the British Royal Navy by Rear Adm. Sir Francis Beaufort, the Beaufort scale is a tool for estimating the force of the wind.

WIND SPEED IN MILES PER HOUR	EFFECTS
Less than 1	Smoke rises straight up; air is calm.
1–3	Smoke drifts.
4–7	Wind is felt on the face; leaves rustle.
8–12	Leaves and twigs constantly rustle; wind extends small flags.
13–18	Dust and small paper are raised; small branches move.
19–24	Crested wavelets form on inland waters; small trees sway.
25–31	Large branches move in trees.
32–38	Large trees sway; must lean to walk.
39–46	Twigs are broken from trees; difficult to walk.
47–54	Limbs break from trees; slight structural damage (chimney posts and shingles are blown off roofs); extremely difficult to walk.
55–63	Trees are uprooted; considerable structural damage occurs.
64–74	Extensive, widespread damage; seldom experienced inland.
75 and up	Hurricane: extreme destruction, severe and extensive damage.

Fronts

Study weather maps for several days in a row, and you'll see that the North American continent can contain a number of air masses, some dominated by high pressure, some by low. Some might be moving very fast, perhaps

pushed along by prevailing winds out of the west. Others might remain stationary for several days. Those pushing in from the Gulf of Mexico or the Pacific Ocean can be loaded with moisture, while cold, high-pressure air masses moving into the prairies between the Appalachians and Rockies are likely to be dry.



As you examine the isobars on a weather map, pay special attention to the areas where different air masses meet. These boundaries are known as *fronts*, and it is along fronts that many changes in weather occur. For instance, a region of cold, dry air overtaking a warm, moist air mass will wedge under the warm air. As the warm air rises, it cools, and the moisture it carries can condense and fall as rain. Observers on the ground probably will notice a shift in the direction of the wind and a variation in temperature as the front moves through and the new air mass establishes itself overhead. They also can watch changes in the shapes of clouds. If they know what to look for, they can predict a change in the weather several hours or even a day before it occurs.



Nimbostratus clouds

Clouds have long fascinated observers, both for the beauty of their shapes and for what they can tell us about changes in the weather.

Clouds

Rising air often lifts moisture into the atmosphere. If it encounters microscopic particles of dust, smoke, or other condensation nuclei, moisture will attach to the particles and form clouds. There are three basic forms of clouds described by their appearance and given their Latin names—*cumulus* (heap), *cirrus* (curl of hair), and *stratus* (layer).

The term *nimbus* (Latin for “violent rain”) describes any cloud from which precipitation might fall; thus, a *nimbostratus* is a layer cloud capable of producing rain. The prefix *alto-* indicates that a cloud is in the middle altitudes of the lower atmosphere, between 6,500 and 23,000 feet above Earth’s surface. An *altocumulus* is a fluffy heap cloud floating between 1 and 4 miles overhead.

The International System of Cloud Classification

Beyond identifying the basic shapes of clouds, meteorologists have devised a system for classifying 10 principal cloud types. Arranged by the clouds that form highest in the atmosphere, they are:

- **Cirrus**—thin, wispy clouds sometimes described as mare’s tails or curls of hair
- **Cirrocumulus**—small cloudlets that resemble ripples or grains
- **Cirrostratus**—thin veil of cloud that covers the sky
- **Alto cumulus**—globes of clouds in patches or layers
- **Altostratus**—thin cloud sheets or layers that appear bluish or gray
- **Nimbostratus**—dark layers of ragged clouds, usually carrying rain
- **Stratocumulus**—sheets of lumpy clouds, usually with some dark patches
- **Stratus**—uniform, low layers of clouds that cover the entire sky
- **Cumulus**—large, individual puffy clouds that appear in heaps
- **Cumulonimbus**—large, towering clouds associated with thunderstorms



Cumulus



Cirrus



Stratus

Using Clouds to Predict Weather

The movement of a frontal system often is heralded by a procession of different cloud types, each signaling a greater likelihood that local weather conditions are about to change. The first sign of an approaching storm might be the appearance in a clear sky of high, feathery cirrus clouds known as *mare’s tails*. Over the course of several hours or days, they will thicken until the sun is hidden behind a thin cirrostratus veil. A gray curtain of altostratus clouds comes next, followed by a moist blanket of dark stratus clouds rolling close to Earth. Finally, nimbostratus clouds, black and threatening, bring the rain.

Of course, not all clouds signal bad weather. Cirrus clouds detached from one another indicate that the weather will stay fair for a while. A mackerel sky formed by cirrocumulus clouds that look like the scales of a fish usually promises fair weather, but it also might bring unsettled conditions with brief showers. Outdoor groups eager for dry trails welcome the sight of cumulus clouds. On hot days, however, travelers are wise to keep an eye on swelling cumulus clouds and take cover if those clouds develop into dark cumulonimbus thunderheads, the breeders of violent storms.

For information on preparing for different kinds of weather in the backcountry, see the chapter titled “Planning a Trek.”



Thunderstorms

A thunderstorm bearing lightning, heavy rains, and strong winds can be a menace to anyone in its path. The danger increases if the storm also generates hail or spawns tornadoes.

A thunderstorm begins when cumulus clouds surge into the sky, gaining thousands of feet of elevation in a few minutes. The surge is powered by solar heat churning the atmosphere and by winds converging and forcing moisture-laden air upward. Air will continue to rise, carrying moisture with it, as long as it is warmer than the atmosphere around it. When the moisture begins to cool and condense, cumulus clouds transform into cumulonimbus clouds. These thunderheads can billow to altitudes of 60,000 feet where the boundary of the troposphere prevents further ascent and horizontal winds flatten the tops of the clouds to create the distinctive anvil shapes of fully developed thunderheads.

Eventually the rising air can no longer support all the moisture lifted high into a thunderhead, and the moisture will rush back to Earth as rain and sometimes hail. The descending precipitation drags air with it, and that might create strong winds near the ground. Heavy precipitation also drains the energy from a thunderstorm. Within half an hour of the start of rain, a storm is often over. If it is part of a broader weather front, it might give way to steady rain.

Heat generated as the sun beats down on prairie regions provides the energy driving the formation of thunderstorms. In mountainous zones, warm air rising up alpine slopes can encounter instability in the atmosphere above, generating thunderstorms in the afternoon, even if the morning skies were clear.

Hail

A pellet of ice descending through a thunderhead might grow as it is coated with freezing moisture. Some pellets are caught in a cycle of updrafts and descents, increasing in size as they swirl through the clouds until they become too heavy for the winds to keep aloft.





Lightning

Lightning kills about 90 people each year in the United States. Charged with 100 million volts of electricity and traveling at 31,000 miles per second, lightning heats a narrow pathway of air to 45,000 degrees Fahrenheit. The resulting violent expansion and subsequent rapid collapse of the air causes a clap of thunder.

The basic electrical charge of Earth's surface is negative, while that of the upper troposphere is positive. Lightning forms when electricity moves between areas of opposite electrical charge.

When the weather is clear, there is nothing between the ground and the sky to conduct electricity, but when a thunderhead forms, positive and negative charges build within its parts, allowing lightning to travel within a cloud, between clouds, or from a cloud to the ground.

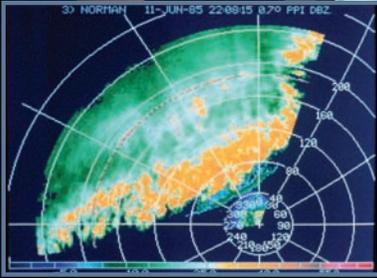
The instability of electrical charges within a cloud is heightened by collisions of ice crystals and hail, and by differences in air temperature at different altitudes. When the imbalance becomes great enough between negatively charged and positively charged areas of clouds, or between a cloud and the ground, electrons form a pathway called a leader and flood from one zone to the other. If that connection includes Earth's surface, electrons will take the path of least resistance—through a solitary tree, perhaps, or the summit of a mountain—and a lightning strike occurs.

For information on protecting yourself and others from lightning, see the chapter titled "Managing Risk."

Local Weather

Despite the broad application of basic principles of meteorology, weather conditions in your area might not match the overall patterns of prevailing winds, highs and lows, and fronts. That's because the weather in each part of the country is influenced by local terrain, bodies of water, and a host of other variables. For instance, coastal regions might be cooler and moister than territory a few miles inland. A mountain range might force warm air to rise, wringing out its moisture as snow and rain. Prairies can allow fronts to roll unimpeded for hundreds of miles.

Learning the patterns of weather in your part of the country can be very satisfying and useful. Glance at the sky whenever you are outdoors and notice the kinds of clouds you see, the direction of the wind, and the sort of weather you're having. Gradually you can build up enough observations to realize that winds from a certain direction usually indicate rain, and that clouds of a certain type mean the skies will clear soon.



Resources for Forecasting Weather

Radio, television, and newspaper weather reports and forecasts can give you some guidance as you prepare for a trek adventure. So can Internet sites devoted to meteorology. Up-to-the-minute weather information is also available from the National Oceanic and Atmospheric Administration (NOAA). NOAA Weather Radio, operating on high-band FM frequencies, transmits updates that can be received by special receivers and by AM/FM radios equipped with a weather-band feature.

Learn the historical weather extremes for the area you plan to travel, and prepare for somewhat worse conditions than the norms. If extreme weather does occur, you will be able to cope with it.



Meteorologists have many tools for gathering information. Among the most effective is Doppler radar, capable of showing squall lines and other weather features moving through an area.



Traditional Weather Signs

There is plenty of folklore connected with weather. “Red sky at morning, sailor take warning,” goes one old saying, often true since the brilliance of a sunrise can be caused by moisture in the air that later in the day turns to rain. As for “Red sky at night, sailor’s delight,” a brilliant, red sunset usually indicates that there is clear, dry air to the west, the direction from which most storms come.

Animals also play a role in weather lore. Perhaps you’ve heard old-timers base their predictions of the severity of an upcoming winter upon the woolliness of caterpillars or the thickness of squirrels’ coats. Birds, their hollow bones especially sensitive to changes in atmospheric pressure, might alter their flying habits to match certain changes in the weather, and many other animals are thought to become restless and seek shelter long before humans are aware of an approaching storm.

Regardless of whether there is sufficient scientific data to support the claims of folklore adages, old sayings and beliefs provide a fascinating glimpse into the way weather predictions were made before the development of accurate measuring devices. Consider these ages-old indicators of fair weather and foul listed on the following page.

Signs of Fair Weather

Expect pleasant weather when you see some of these signs:

- “Red sky at night, sailor’s delight.” The dust particles in the dry air of tomorrow’s weather produce a glowing red sunset.
- “Swallows flying way up high mean there’s no rain in the sky.” Swallows are birds that catch and eat flying insects. In the high air pressure that comes with fair weather, insects can be carried aloft by air currents.
- “If smoke goes high, no rain comes by.” Campfire smoke rises straight up when there is no wind. Still air is generally stable and won’t move moisture into an area.
- “When the dew is on the grass, rain will never come to pass.” Dew forms when air moisture condenses on cool leaves and grass. That happens especially during the cool, clear nights that come with good weather and high pressure.

Signs of Stormy Weather

The following signs suggest bad weather is on the way:

- “Red sky at morning, sailor take warning.” Dry, dusty air is moving away from you toward the east. Clouds and moist air might be coming in from the west.
- “Swallows flying near the ground mean a storm will come around.” The low air pressure that pulls in stormy weather causes insects to fly close to the ground on heavy, moist wings. Swallows feeding on them will follow.
- “If smoke hangs low, watch out for a blow.” Low air pressure can prevent campfire smoke from rising very high.
- “When grass is dry at morning light, look for rain before the night.” On a cloudy night, grass might not cool enough for dew to form.

“The weather is always doing something . . . always getting up new designs and trying them on the people to see how they will go.”

—Mark Twain (1835–1910), American author and satirist