THE AMS WEATHER BOOK

JACK WILLIAMS

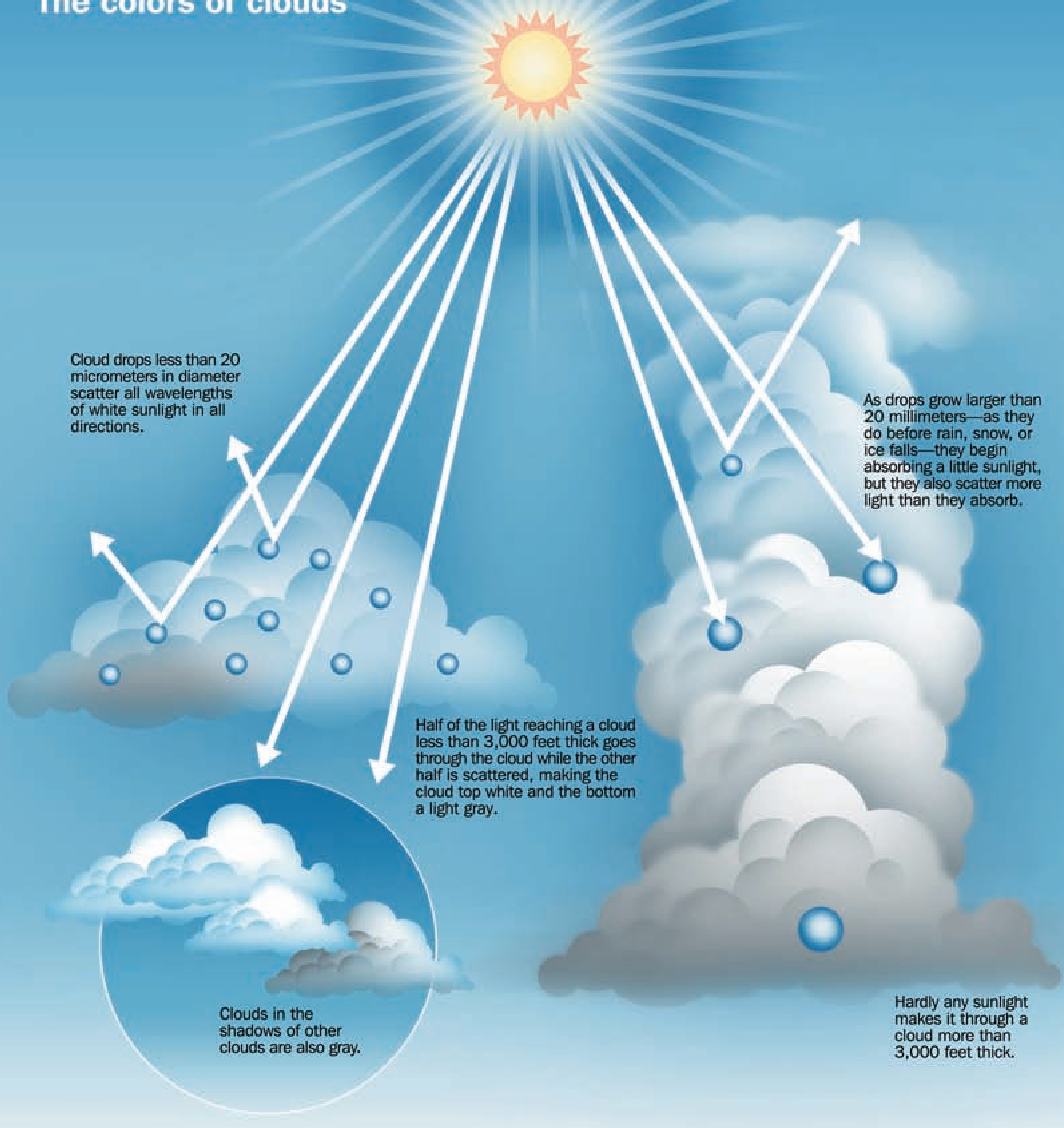
THE ULTIMATE GUIDE TO AMERICA'S WEATHER


N27545

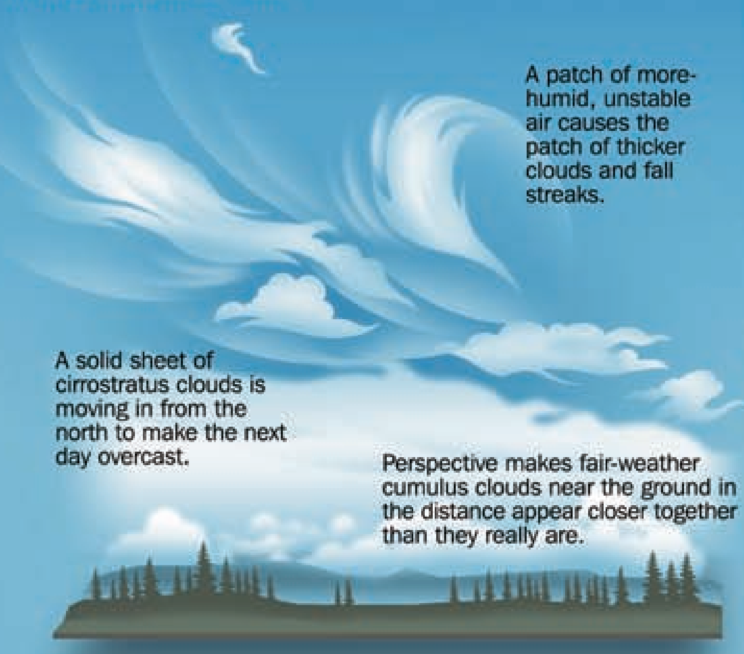
A gallery of clouds

Clouds form and stay in the sky only when the air is rising—sometimes only inches per hour, at other times at 100 mph. In Chapter 4, we see how clouds form and sometimes produce rain, snow, or ice and why some clouds are flat stratus clouds, while others are piled-up cumulus clouds.

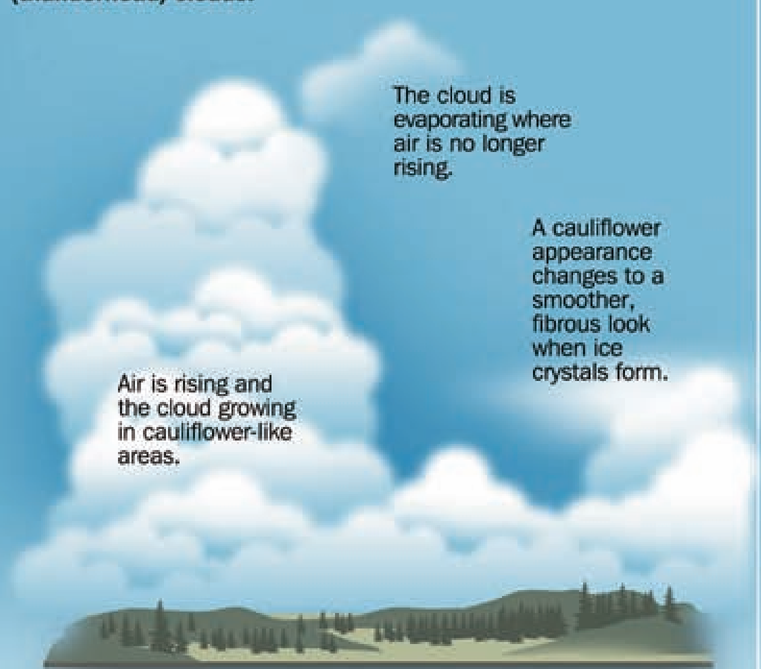
The colors of clouds



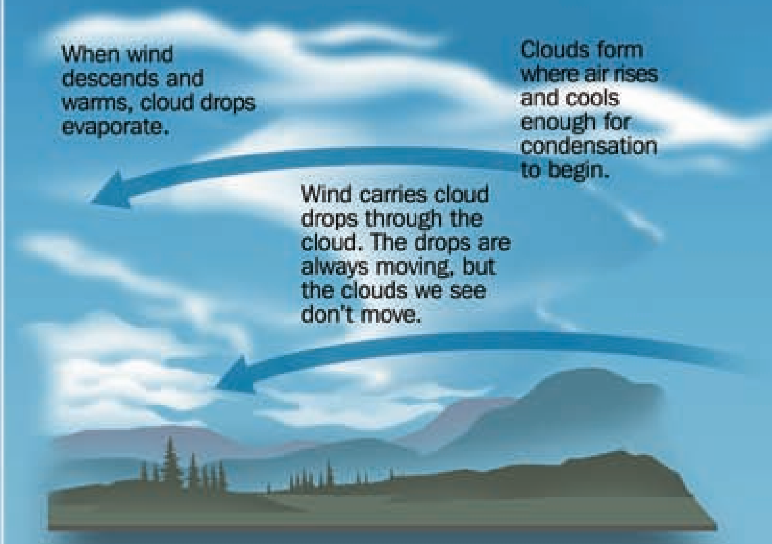
Fall streaks are ice crystals that are being pushed by high-altitude winds as they fall from tiny, puffy clouds, which are hardly visible at the tops of the streaks. Fall streaks are often called mares' tails.



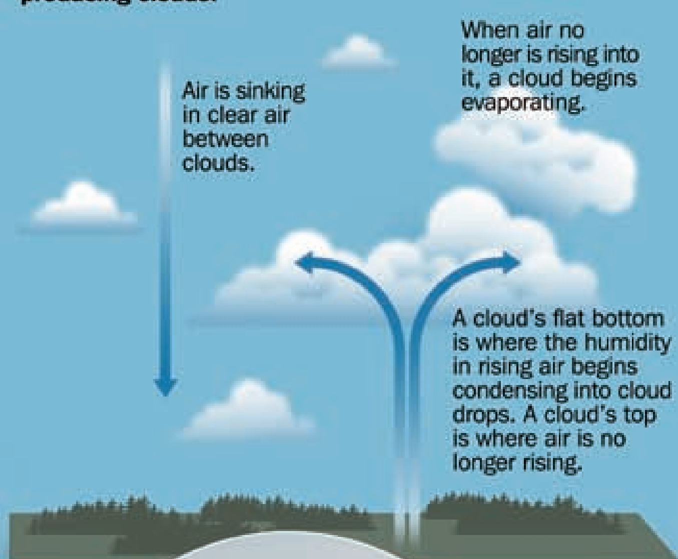
Cumulus congestus clouds like these can grow into large cumulonimbus (thunderhead) clouds.



Lenticular clouds like the ones below are commonly seen downwind from mountains. Wind blowing over the mountains from the right continues rising and then descends as shown by the arrow on the drawing.



Fair-weather cumulus clouds like these don't produce rain or snow. Sometimes, however, clouds that look like fair-weather cumulus grow into larger, precipitation-producing clouds.



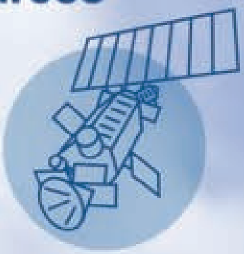

NAPA AUTO PARTS

Weather forecasts from start to finish

All weather forecasts begin with collecting data about the current state of the atmosphere, the oceans, and the earth's surface and sending the data to forecasters. While meteorologists can produce short-term, localized predictions using local data, most of today's forecasts seen on television or the Web as well as the specialized forecasts, such as for aviation, are based on global data and forecast products (maps and text) from the U.S. NWS Centers for Environmental Prediction based in the Maryland suburbs of Washington, D.C., or from similar centers in other nations.

1 Global data sources

Weather satellites



Weather balloons

Automated reports from airliners

Weather radar

Government and private surface observations

Ocean and lake buoys

More than 240 million atmospheric and oceanic observations flow to the NWS National Centers for Environmental Prediction (NCEP) supercomputers in the Washington, D. C., area each day.

2 NWS National Centers for Environmental Prediction

IBM supercomputers prepare the data for use in computer models—called data assimilation—and run different forecasting models that produce a variety of forecast maps and text products.

NCEP products are available on computer servers to government and private forecasters, other nations, and the public

The forecasting enterprise

Meteorologists generally refer to National Centers for Environmental Prediction products as "guidance" because they aren't always the final word for localized or specialized predictions. The organizations in this section are some of the many that make use of NCEP products. Some of these organizations also run their own forecasting models or use products from other centers such as the European Centre for Medium-Range Weather Forecasts in Reading, England, or from universities and research centers.

122 NWS regional offices

Issue weather warnings such as for tornadoes. Produce public forecasts for their areas.

NWS Storm Predication Center

Norman, Oklahoma

Issues tornado and severe thunderstorm watches. Produces national fire weather products.

NWS National Hurricane Center

Miami, Florida

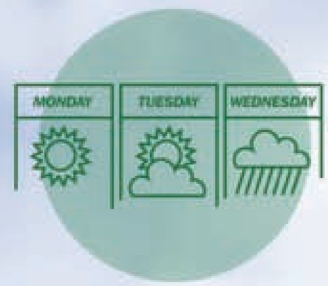
Forecasts tropical storms and hurricanes in the Atlantic, Caribbean, Gulf of Mexico, and Pacific east of 140° W longitude.

21 NWS aviation center weather service units at air traffic control centers.

Provide air traffic controllers with weather information.

U.S. military forecasters

Produce forecasts for land, sea, and air operations.



Private forecasting companies

Provide specialized forecasts for a variety of businesses including air lines, shipping companies, power companies, and the news media.

Television meteorologists

Use NCEP and local NWS office information and sometimes images or data from private firms to produce forecasts.

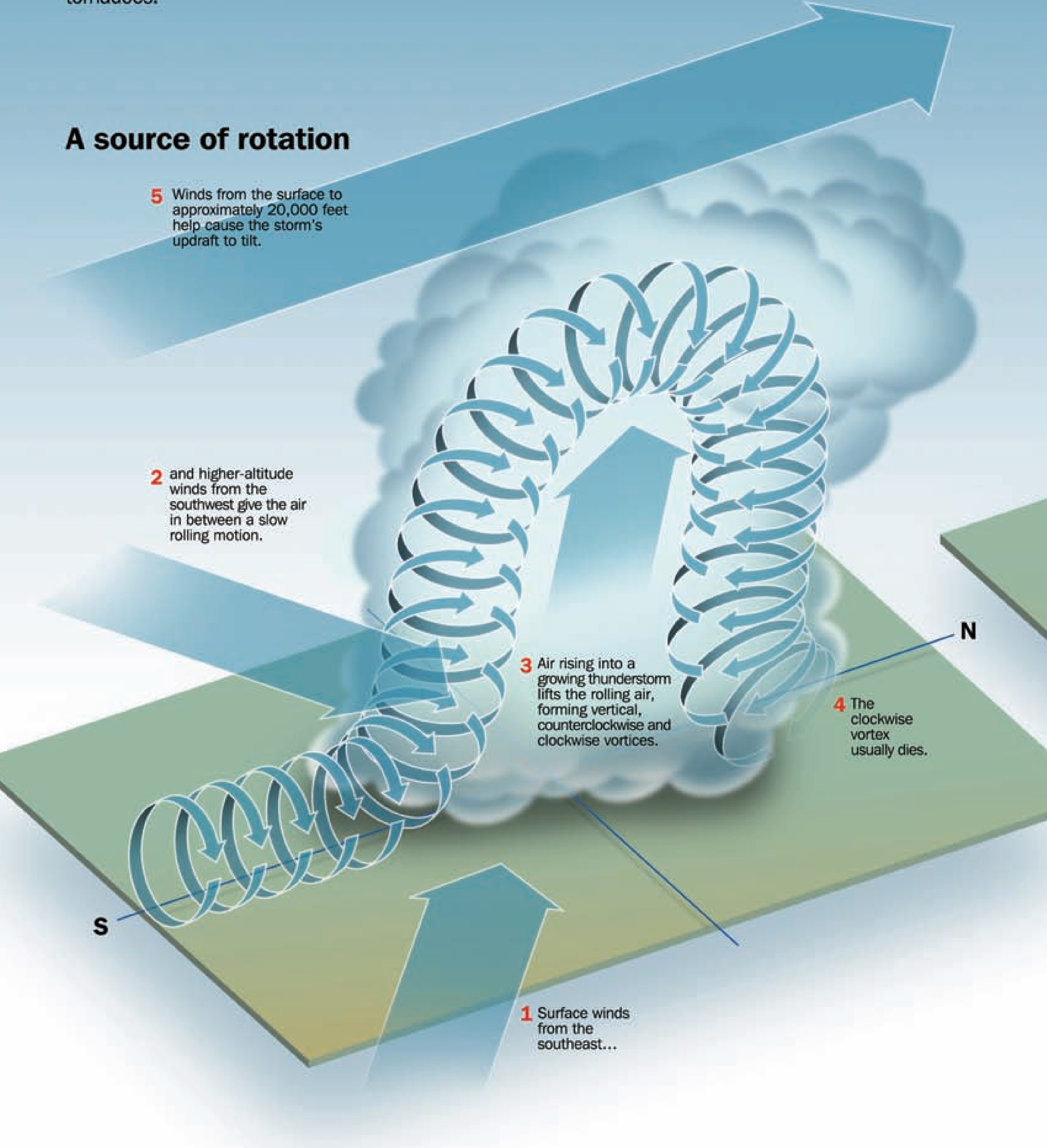
World Wide Web and newspapers

Private companies or television meteorologists produce forecasts for newspapers and online Web sites. NWS products are also available on the Web.

Supercells and tornadoes

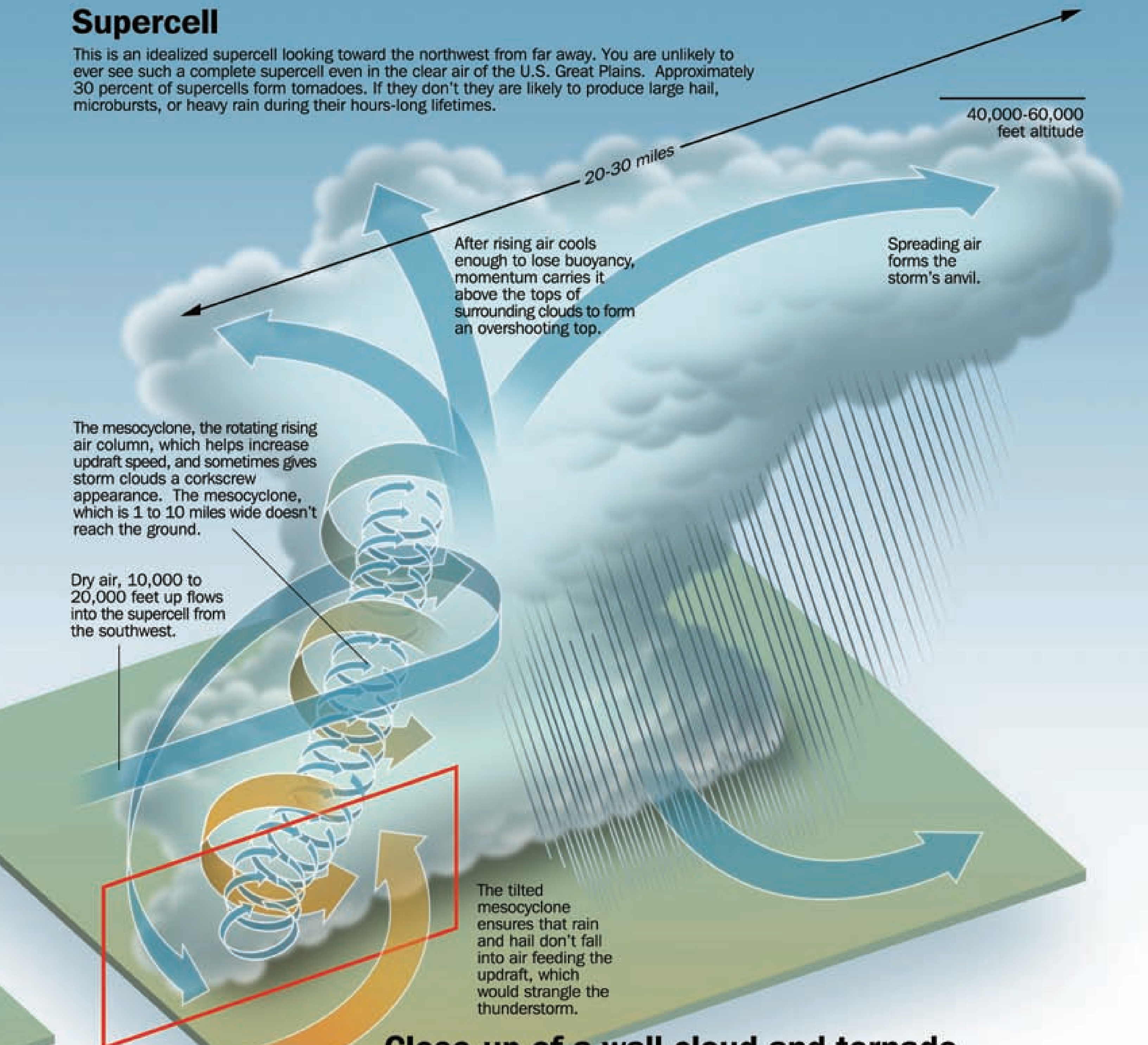
The strongest tornadoes spin out of large, long-lasting supercell thunderstorms. Despite great progress over the past several years, scientists are still learning how supercells concentrate enormous amounts of energy and give air violent swirling motions of destructive tornadoes.

A source of rotation

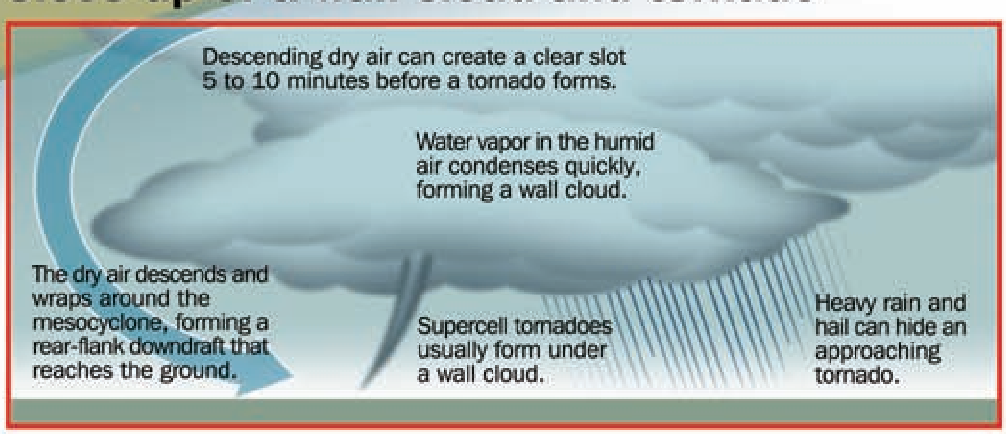


Supercell

This is an idealized supercell looking toward the northwest from far away. You are unlikely to ever see such a complete supercell even in the clear air of the U.S. Great Plains. Approximately 30 percent of supercells form tornadoes. If they don't they are likely to produce large hail, microbursts, or heavy rain during their hours-long lifetimes.



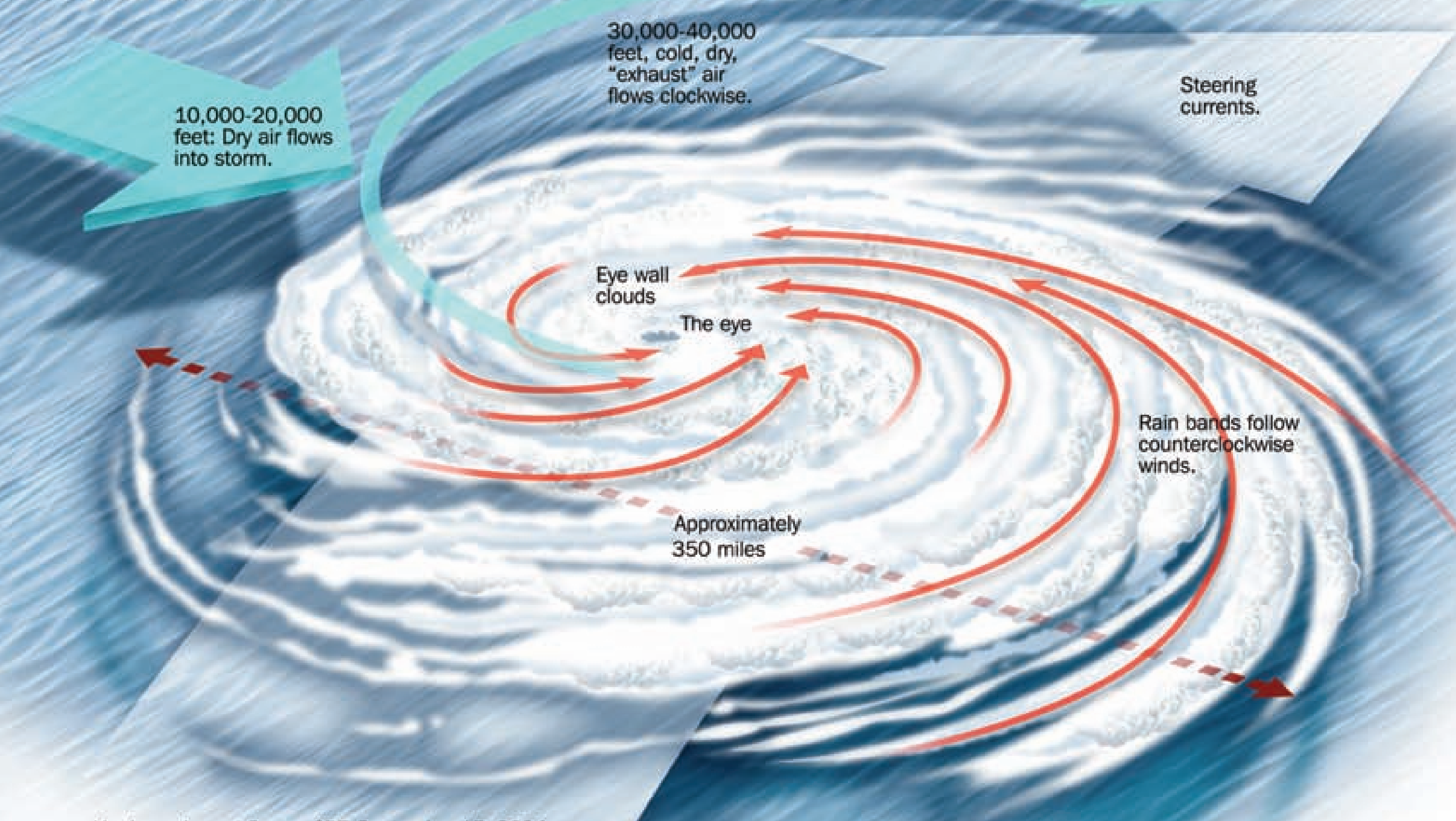
Close-up of a wall cloud and tornado



Inside a hurricane

Satellite images make hurricanes look relatively simple: A swirl of clouds wrapped around a clear eye. In reality, a hurricane is an incredibly complex mixture of swirls within swirls, rising and sinking air, energy exchanges, and reactions back and forth between the storm and the surrounding air and the underlying ocean and land.

Major hurricane features and influences

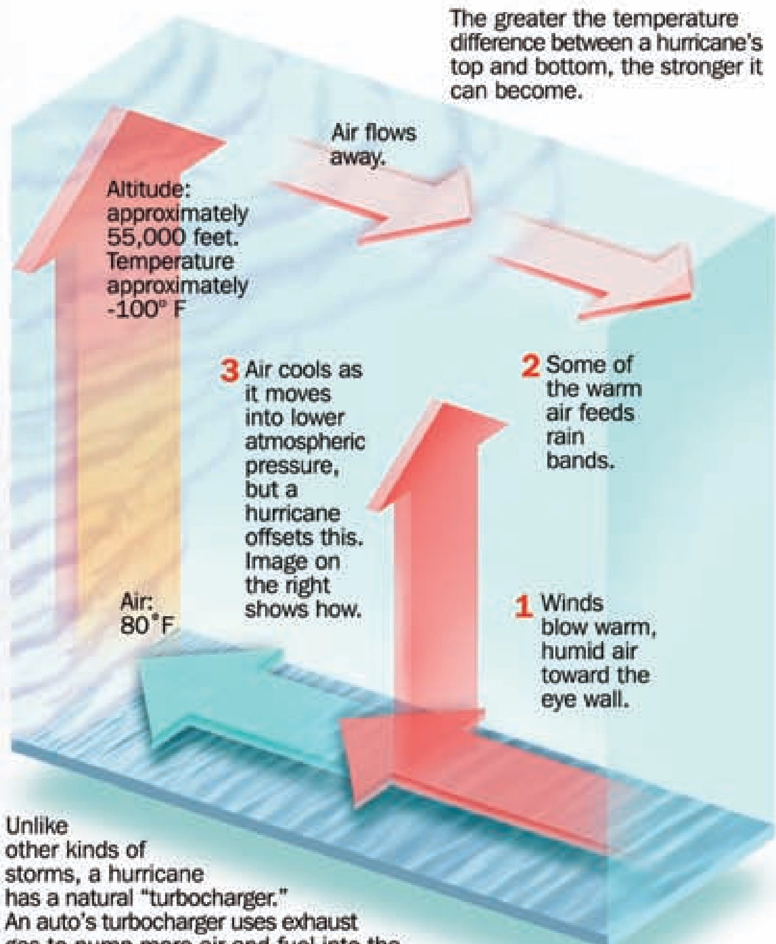


Hurricane Ivan at 9 a.m. CDT, September 15, 2004, eighteen hours before its eye came ashore near the Florida-Alabama border. At the time, warm Gulf of Mexico water was adding energy to Ivan, but the cold, dry air from the west caused the storm to begin to weaken before it moved ashore.

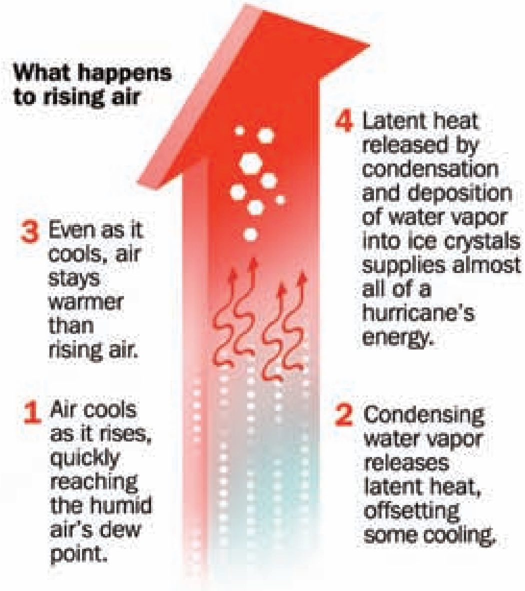
In the middle of it all

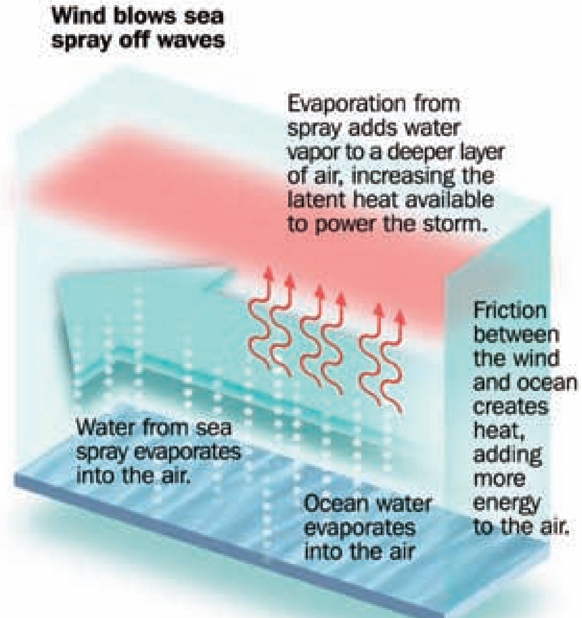
The hurricane heat engine

Like the engine in your car, a hurricane is a heat engine that converts potential energy into motion: wind, which in turn powers waves and storm surge. The images below are an idealized look at a hurricane's energy flow.



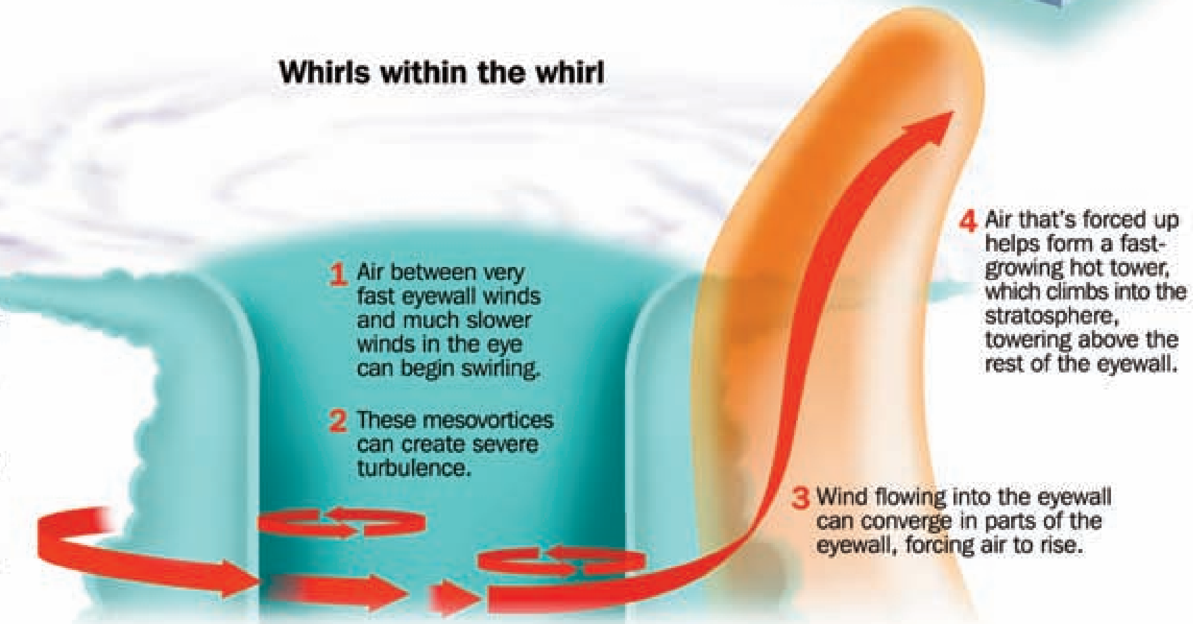
Unlike other kinds of storms, a hurricane has a natural "turbocharger." An auto's turbocharger uses exhaust gas to pump more air and fuel into the engine. By tapping exhaust energy that would otherwise be lost, the turbocharger increases the engine's efficiency. A hurricane uses energy to create winds. Feeding some of this energy back into the "engine" via frictional heat increases the storm's efficiency.

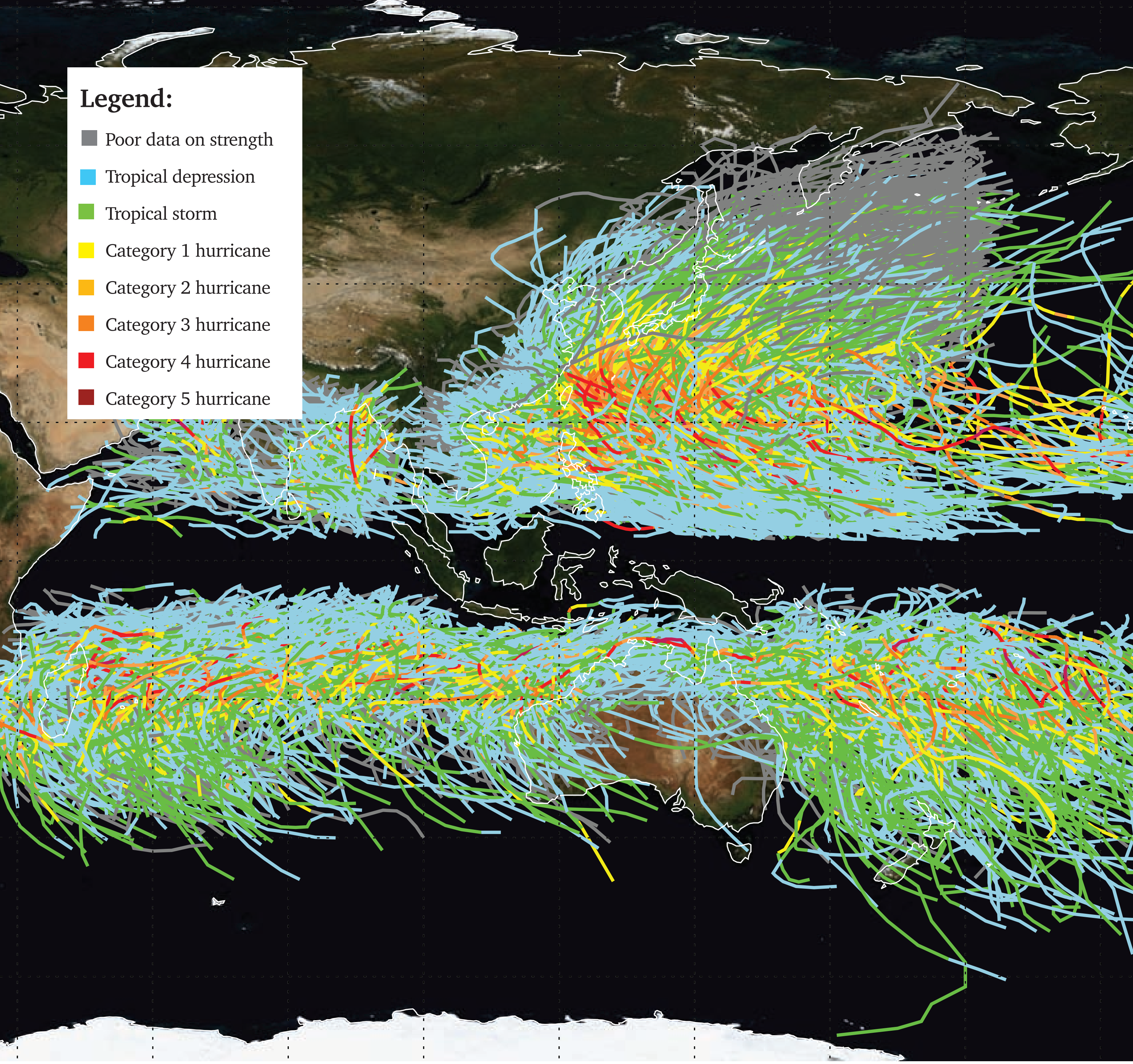




Whirls within the whirl

Joanne Simpson and Herbert Riehl first proposed the hypothesis in 1958 that hot towers are the main driving force of the Hadley Cell. In the late 1990s scientists using evidence from observations and computer models hypothesized that hot towers are also a key to hurricane intensification.

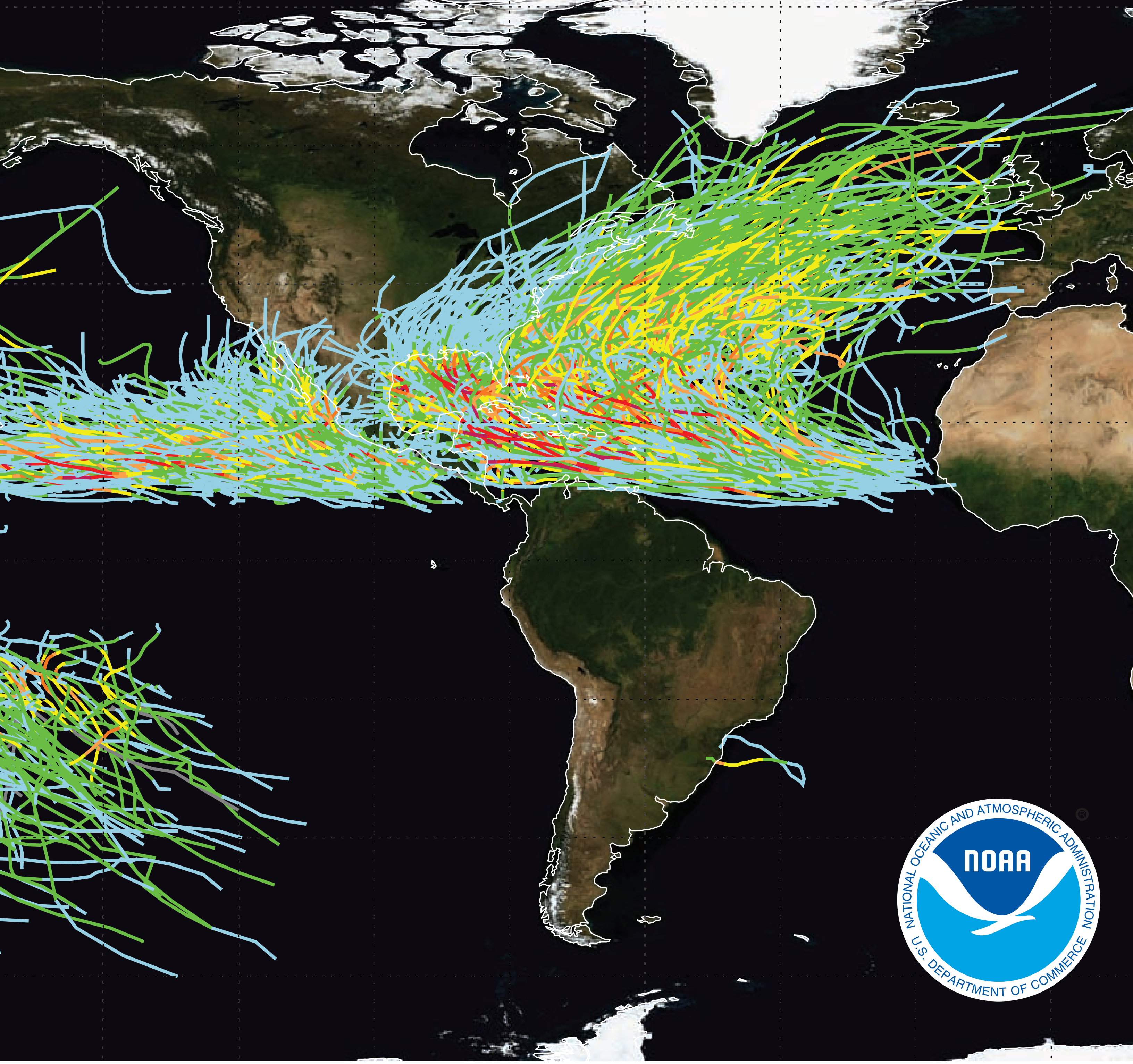




The image on these two pages, which was created by NOAA, shows all of the world's known tropical cyclones from 1947 through 2007.

thirty-six hours. Fortunately, it weakened to barely a Category 3 storm with 115-mph winds before hitting extreme southwestern Louisiana just east of the Texas border.

Then, in the twenty-four hours ending at 1 a.m., October 19 of the same year, Wilma strengthened from a 69-mph tropical storm to a 172-mph Category 5 hurricane, which the Hurricane Center described as "an unprecedented event for an Atlantic tropical cyclone. It is fortunate that this ultrarapid strengthening took place over open waters, apparently void of ships, and not just prior to a landfall." Wilma reached its peak sustained wind speed of 184 mph on October 19. Wilma weakened to a Category 4 hurricane with 150-mph winds before hitting the Mexican resort island of Cozumel on October 21. It weakened only slightly more before hitting Cancun six hours later. The two days between Wilma reaching Category 5 and its landfall gave Mexican authorities time to move thousands of residents and tourists to safety. In wreaking havoc on Cancun, Wilma could have killed many



more than the four people who died in the storm.

We can only imagine how many people either of these hurricanes would have killed if they had rapidly intensified into a Category 5 storm less than two days before hitting places such as the Florida Keys, the Tampa Bay area, New Orleans, the Galveston-Houston area, or one of the many other heavily populated locations on the Atlantic Ocean or Gulf of Mexico coasts.

In this chapter and in the two preceding chapters, we've examined thunderstorms, tornadoes, organized groups of thunderstorms, weather fronts, and tropical cyclones that are responsible for most of the deadly events that from time to time make big weather news. In the next chapter, we will learn about a few kinds of less-dramatic weather that at times can be more deadly or costly than tornadoes or hurricanes.

Into the heart of hurricanes

When Nicole Mitchell graduated from high school, her mother and stepfather, who were both in the National Guard, suggested the Guard would be a good way to pay for college.

"At first I was a little resistant," she says, but the Minnesota Air National Guard's available jobs included weather forecasting. "I was always into math, I loved science, and I loved the outdoors. Weather fit. I didn't think of using it as a career, but it just stuck."

Nicole Mitchell is a Weather Channel meteorologist who also flies with the Air Force Reserve Hurricane Hunters, where she has one big advantage: she doesn't suffer from air sickness.

In addition to helping her pay for college, Guard service led Mitchell into a dual career as an on-camera meteorologist at the Weather Channel in Atlanta, and as an Air Force Reserve weather officer with the 53rd Weather Reconnaissance Squadron based in Biloxi, Mississippi.

In the military she received an education equivalent to that of an undergraduate meteorology major, and she worked as a forecaster in Europe, Saudi Arabia, and the United States.

Mitchell began her civilian career at a Duluth, Minnesota, television station "where you dabble at everything … reporting … a little producing" and on-air weather, which led to other television jobs. While completing her Air Force degree in weather, she was also earning a University of Minnesota bachelor's degree in speech-communications, which qualified her for an officer's commission.

Mitchell transferred to the Hurricane Hunters in 2003, and her first flights were into winter storms, which the 53rd also flies into. Her first tropical storm was Charley over the Caribbean Sea in August 2004, when forecasters thought—based on satellite estimates—that its maximum winds were only 45 mph. The WC-130 airplane flew into Charley as low as 500 feet above the ocean. "It was more intense than anyone thought. We observed hurricane-force surface winds in the northeast quadrant—far greater than expected. You usually don't want to be at a low level in an intense storm. I could see the ocean swirling, which was fascinating."

On storm flights, Mitchell is the flight meteorologist and mission director. "I kind of direct where plane is going to go, but the pilot is the aircraft commander" with a veto on anything dangerous.

Airplanes fly through hurricanes from side to side across the eye, usually at least 5,000 feet above the ocean, several times during an average mission, which typically lasts ten hours but can exceed thirteen hours. Usually an airplane encounters strong turbulence for only a few minutes each time it flies through the most intense winds around the eye. But Hurricane Emily in July 2005 was an exception. "We had turbulence most of the storm. After five or six hours of turbulence I was just exhausted, my body was saying, enough of this," Mitchell says.

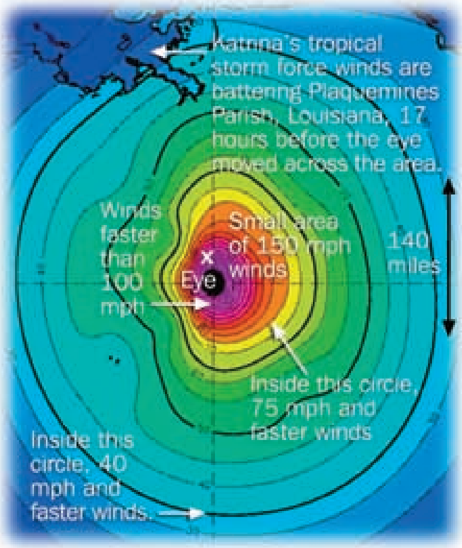
At times Mitchell is a little torn between her two jobs, especially in 2005 when she flew into four hurricanes and three tropical storms. "That year was insane … I was driving back and forth almost every weekend between Atlanta and Biloxi to go fly. If there is a landfalling storm, that's when I need to be flying. At the same time, the Weather Channel needs everyone on deck." However, the Weather Channel has enough on-camera meteorologists that it can spare her for storm flying.

"It's a fascinating job," Mitchell says. "I think for anyone who's a meteorologist and has a sense of adventure, which I definitely do, it's kind of a perfect melding of science and adventure."

Measuring hurricane winds

On Sunday, August 28, 2005, Hurricane Katrina was closing in on Louisiana and Mississippi with 150 mph winds. The image below on the left shows the distribution of Katrina's winds at 1:30 p.m. CDT that day. The 150 mph winds were confined to an area only a few miles across in the northeast eyewall.

Katrina's winds at 1:30 p.m. August 28, 2005

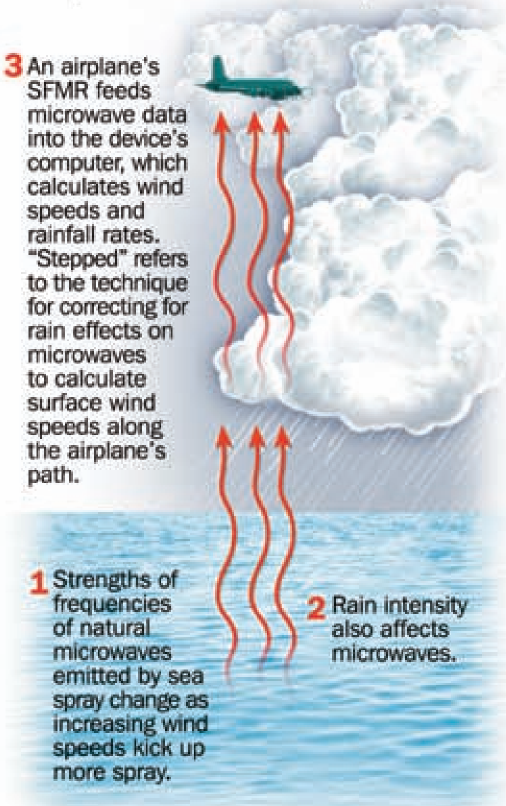


Better wind measurements

Satellites can give estimates of hurricane wind speeds, but airplane reconnaissance is needed to collect the detailed wind data like that displayed on the map. Such information shows areas in the greatest danger from a storm.

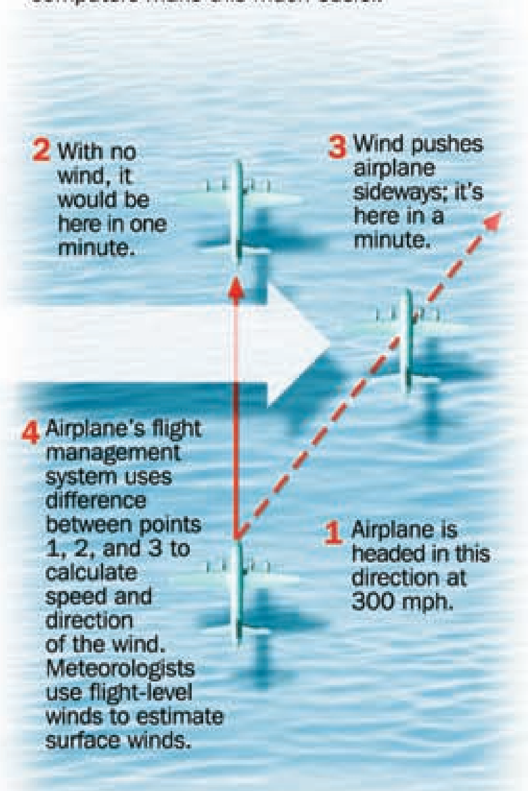
SFMRs

Stepped-frequency microwave radiometers (SFMRs) on NOAA WP-3 and Air Force Reserve WC-130 hurricane hunters are the primary method of measuring the surface wind speeds of hurricanes from airplanes.

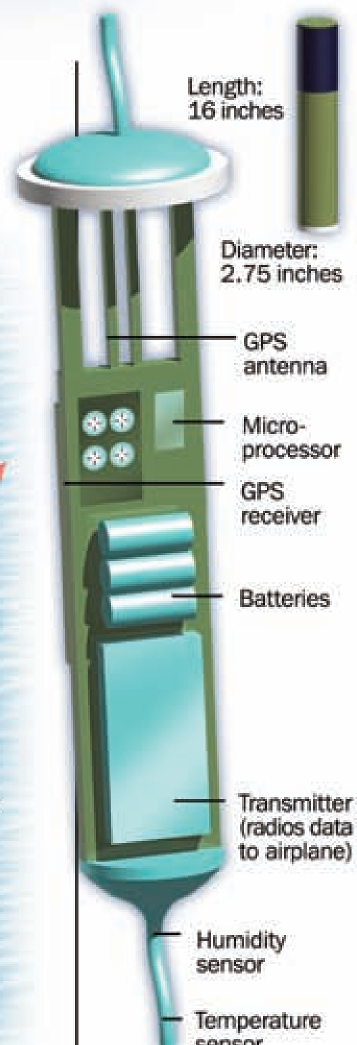


Calculating hurricane winds

Hurricane hunter navigators and meteorologists have always used the airplane's path over the ocean to calculate flight-level wind speed and direction. Today's GPS navigation and computers make this much easier.

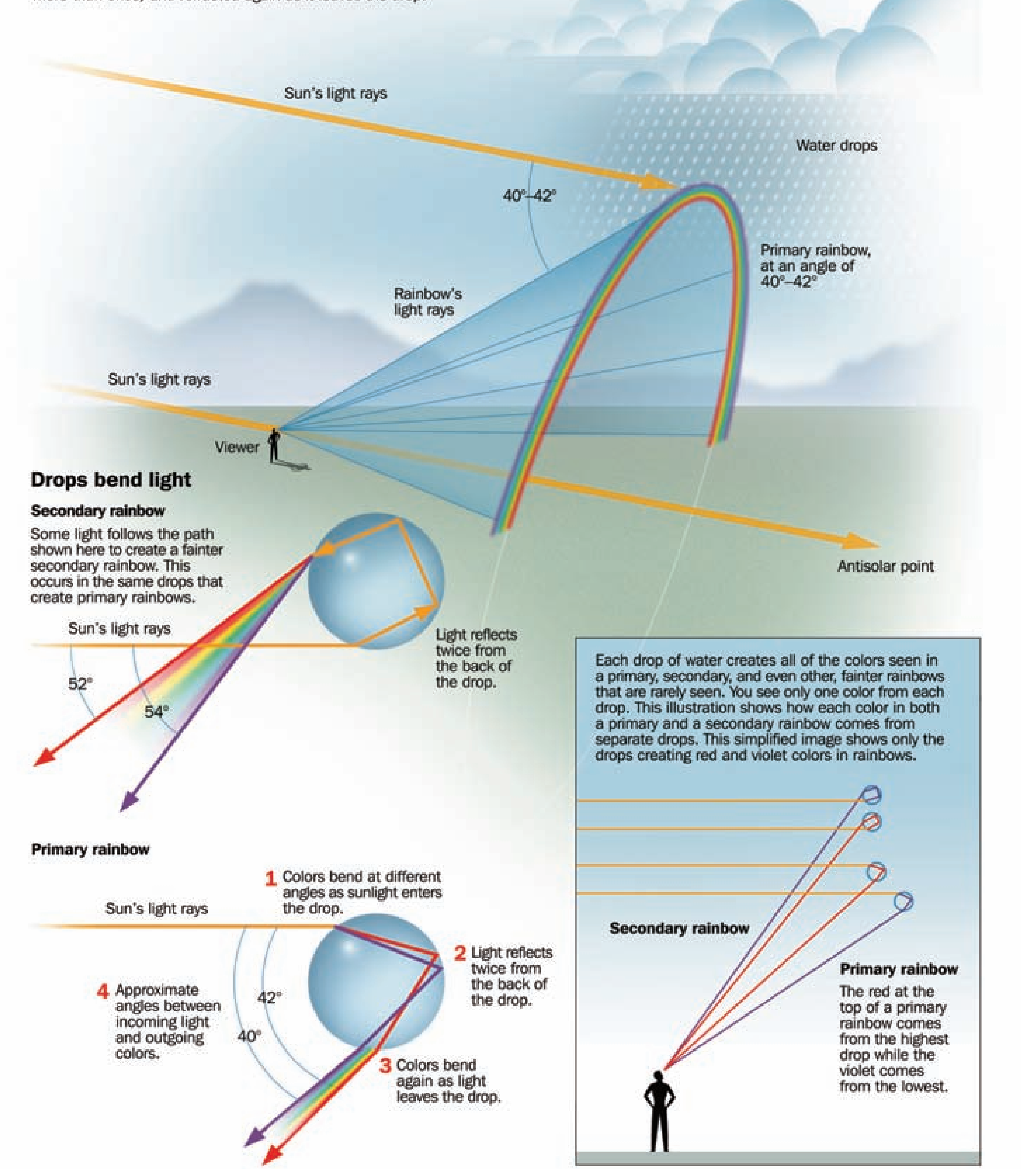


Close up of a GPS dropsonde



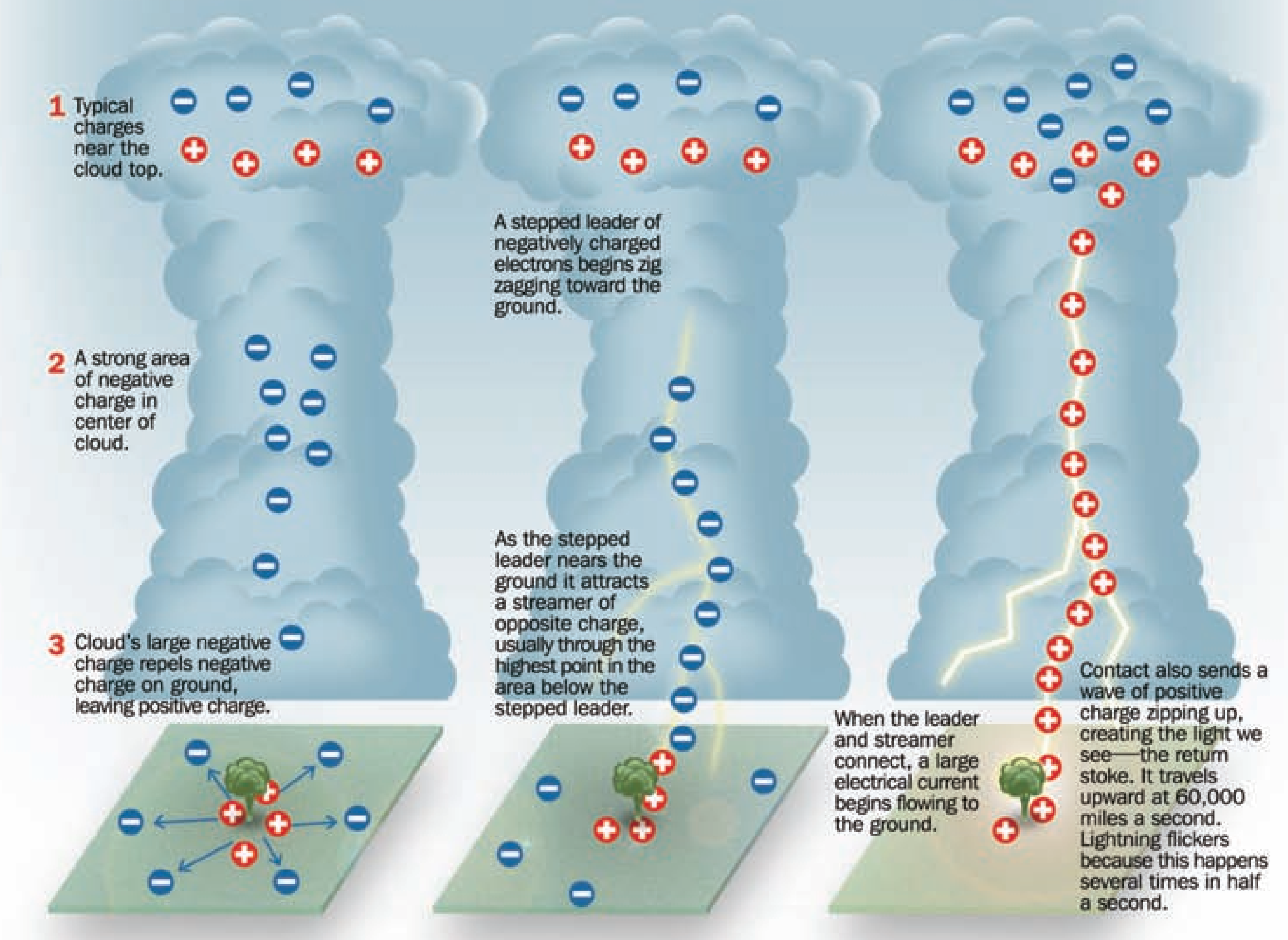
How water drops make rainbows

You see a rainbow only when the sun is behind you, as you look toward water drops in the air. Light is refracted (slightly bent) as it enters a drop, reflected from the back of the drop (sometimes more than once) and refracted again as it leaves the drop.



Lightning

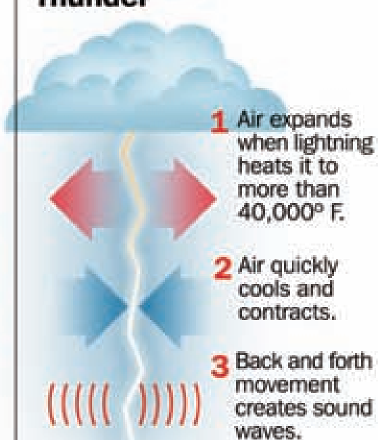
Lightning begins when turbulent mixing of water drops and ice in a cumulus cloud builds positive and negative charges in different parts of the cloud. For reasons that scientists don't completely understand, the electrical potential energy (measured in volts) between these areas grow large enough to send huge electrical sparks between areas of opposite charge within the cloud, between the cloud and the air or another cloud, or between the cloud and the ground.



Bolts from the blue

Lightning has been measured hitting the ground under clear sky more than 25 miles from the parent thunderstorm.

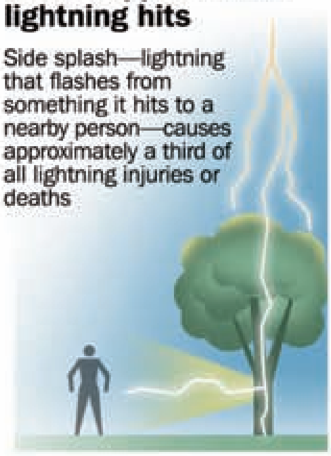
Thunder



Sound waves from different parts of the lightning stroke take slightly different times to reach our ears, making thunder rumble.

What happens when lightning hits

Side splash—lightning that flashes from something it hits to a nearby person—causes approximately a third of all lightning injuries or deaths



Lightning often flashes over the outside of the victim, leaving few external injuries.

- The intense heat of a lighting bolt comes and goes too quickly to cause major burns.
- Lightning does heat metal objects next to skin, causing burns.
- Heat can turn sweat into steam in an instant, blowing off shoes and ripping clothing.
- Lightning's electromagnetic field induces electrical currents that cause potentially fatal injuries including heart stoppage, and long-lasting nerve damage for survivors.

THE AMS WEATHER BOOK

THE ULTIMATE GUIDE TO AMERICA'S WEATHER

JACK WILLIAMS

With Forewords by Rick Anthes and Stephanie Abrams

As the monstrous and soon to be infamous Hurricane Katrina approached New Orleans, the National Weather Service issued this dire warning: "Devastating damage expected. . . . A most powerful hurricane with unprecedented strength. . . . Most of the area will be uninhabitable for weeks." Few Americans would deny the eerie accuracy of that prediction or forget the destruction wrought by that vicious storm.

Extreme weather like Katrina can be a matter of life and death. But even when it is pleasant—72 degrees and sunny—weather is still central to the lives of all Americans. Indeed, it's hard to imagine a topic of greater collective interest. America has one of the most varied and dynamic weather systems in the world. Every year, the Gulf coast is battered by hurricanes, the Great Plains are ravaged by tornados, the Midwest is pummeled by blizzards, and the temperature in the Southwest reaches a sweltering 120 degrees. Whether we want to know if we should close the storm shutters or just carry an umbrella to work, we turn to forecasts. But few of us really understand the science behind them.

All that will change with *The AMS Weather Book*. The most comprehensive and up-to-date guide to our weather and our atmosphere, it is the ultimate resource for anyone who wants to understand how hurricanes form, why tornados twirl, or even why the sky is cerulean blue. Covering everything from daily weather patterns to air pollution and global warming, *The AMS Weather Book* will help readers make sense of news about the weather, cope with threats, and learn how integral oceanic and atmospheric science are to navigating our place in the physical world.

Written by esteemed science journalist and former *USA Today* weather editor Jack Williams, *The AMS Weather Book* explores not only the science behind the weather but also the stories of people coping with severe weather and those who devote their lives to understanding the atmosphere, oceans, and climate. The book's profiles and historic discussions illustrate how meteorology and the related sciences are interwoven throughout our lives. Words alone, of course, are not adequate to explain many meteorological concepts. To illustrate complex phenomena, *The AMS Weather Book* is filled with engaging full-color graphics that explain such concepts as why winds blow in a particular direction, how Doppler weather radar works, what happens inside hurricanes, how clouds create wind and snow, and what's really affecting Earth's climate.

For Weather Channel junkies, amateur meteorologists, and storm chasers alike, *The AMS Weather Book* is an invaluable tool for anyone who wants to better understand how weather works and how it affects our lives.

Jack Williams is a former editor of the *USA Today* Weather Page and the author of *The USA Today Weather Book*. He is the public outreach coordinator for the American Meteorological Society.

"I am often asked what book I would recommend to aspiring young meteorologists or climatologists. I will be spreading the word about this one. Whether for the weather enthusiast or the reader simply curious about the many faces of our ever-changing atmosphere, *The AMS Weather Book* is a must read! Meticulously researched and beautifully written, Jack Williams's book is incredible."

—Tom Skilling,
WGN/*Chicago Tribune* Chief Meteorologist

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Promotions Manager
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