NASA Facts

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Tropical Rainfall Measuring Mission

Anatomy of a Storm: The Differences Between Tropical and Mid-Latitude Storms

Whether you're on land at mid-latitudes or the open sea somewhere along the equator, the skyscape before and during a storm doesn't look dramatically different. The sky is cloudy, winds pick up and eventually it rains. But looks can be deceiving.

Tropical ocean and mid-latitude storms are quite different. The Tropical Rainfall Measuring Mission (TRMM) and other satellites, for example, have confirmed what seafarers observed centuries ago—ocean-borne storms produce little lightning. And unlike mid-latitude storms, which form when two major weather systems clash, ocean-borne storm formation is more akin to what happens when trains collide: as warm, moist air converges, it is forced upward resulting in a storm.

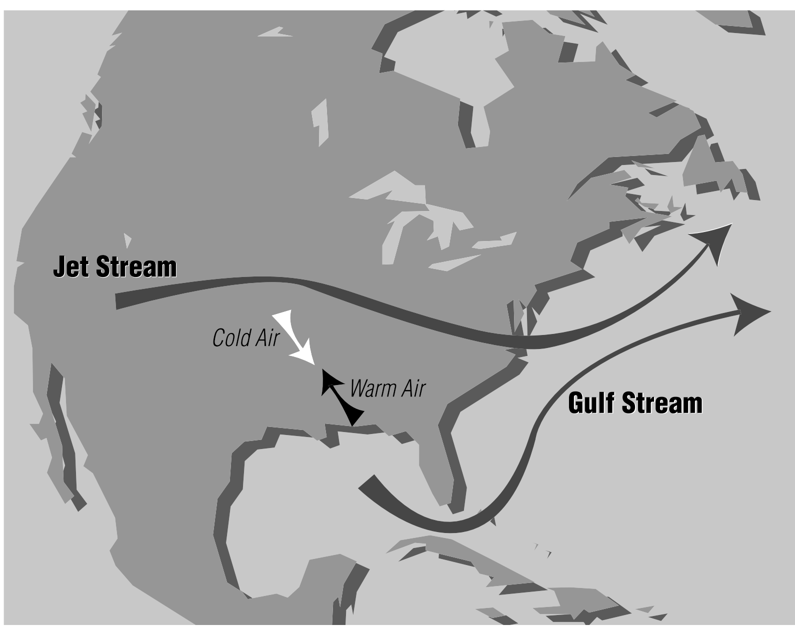

Figure 1. The convergence of cold air from the north and warm air from the south are the main ingredients in the recipe to create the world's strongest thunderstorms and tornadoes.

For those living in the United States, which has the distinction of having the world's wildest weather—where a normal year brings hurricanes, blizzards, subfreezing temperatures, jungle humidity and tornadoes—the differences are of particular importance. Tropical ocean and mid-latitude storms both can wreak havoc on the nation's economy, transportation and life itself.

Yet these two different types of storm systems actually perform a much-needed job. They ultimately make the planet livable, mixing cold, polar air with warm, tropical air balancing the Sun's uneven heating of the planet. With TRMM, designed to study rainfall in the tropical belts of the world, Earth scientists are beginning to gain a greater understanding of tropical ocean and mid-latitude storms and how they affect the Earth's climate.

Mid-Latitude Continental Storms

When a storm forms outside the tropics—called an extratropical cyclone-—it typically happens because warm, moist air streaming up from the tropics meets cooler, drier air sliding down from the polar latitudes (Figure 1). These opposing air masses come into conflict—as if they literally were at war—and cause the most dramatic weather changes and violent weather on the planet and account for most of the stormy weather in the United States (Figure 2).

These so-called fronts, named by Norwegian meteorologists after World War I because they resemble a battlefront, normally are part of large weather systems centered on areas of low atmospheric pressure. They are sharp, well-defined boundaries between air masses.

For the most part, these conflicts and resulting storms do little damage. They move cold air southward and warm air northward, helping to balance the Earth's heat budget. But not all storms caused by the clash of two weather systems are quite so placid.

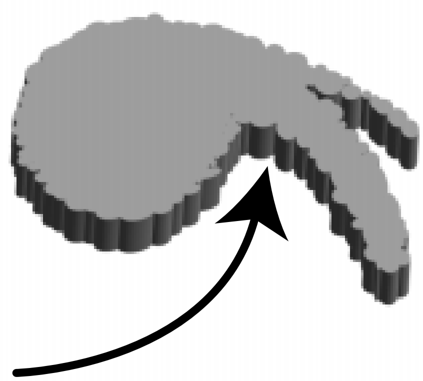

Figure 2. A mature extratropical cyclone, also called a comma cloud because of its appearance.

Thunderstorms, which can spin out tornadoes in the Midwest and South, can blast the Earth with damaging straight-line winds or spew chunks of ice (hail) that can beat a corn field into the ground. Thunderstorms cause flash floods, which are weather's biggest killer. And all thunderstorms produce lightning, the weather's second biggest killer in the United States.

Thunderstorms

Thunderstorms are convective storms that typically occur during the spring and summer months. The process is similar to the convective processes seen when water boils in a pot.

These storms begin when warm humid air rises from the ground (called an updraft). The ascending air cools to its dew point and a cloud begins to form from condensation. As water vapor in the upper portions of the cloud becomes supercooled, raindrops begin to form and fall, dragging down cooler air and producing downdrafts. Updrafts continue to feed warm humid air into the maturing storm cloud. When downdrafts grow in strength, they eventually choke off the updraft, which starves the storm of its supply of humid air. The storm dies (Figure 3).

While the storm is growing, however, cumulus clouds—low-level clouds that are often dark on the bottom, with tops resembling a giant white cotton ball—expand vertically into monster cumulonimbus clouds.

These thunderheads vary in altitude, from dark lower portions below 5,000 feet (1,500 meters) to white, anvil-shaped tops that can reach up to 50,000 feet (15,250 meters). They may appear as single clouds or as part of a wall of an advancing storm system. In either case, they contain large amounts of moisture, including hail. Advanced sensors on TRMM can "see" these cloud tops and peer deeper into their core to understand how storms produce rainfall and fuel the atmospheric engine.

Lightning

One of the distinctive side effects of a thunderstorm is lightning, which has played a dominant role in mythology, and is responsible for the deaths of hundreds of people and millions of dollars in property damage each year. Without lightning, there would be no thunder.

At its simplest level, lightning is caused by the build up of an electrical charge in large, vertical-forming clouds. Initially, a cloud builds up an electrical charge of approximately 300,000 volts per foot (1 million volts per meter) by the rise and fall of air currents. The electrical charge is transferred through the cloud as raindrops, hailstones and ice pellets collide with smaller water droplets and ice. A falling stream of electrons creates a negative charge, which accumulates in the lower part of the cloud; the rising stream creates a positive charge, which accumulates in the upper part of the cloud. Lightning neutralizes these charges.

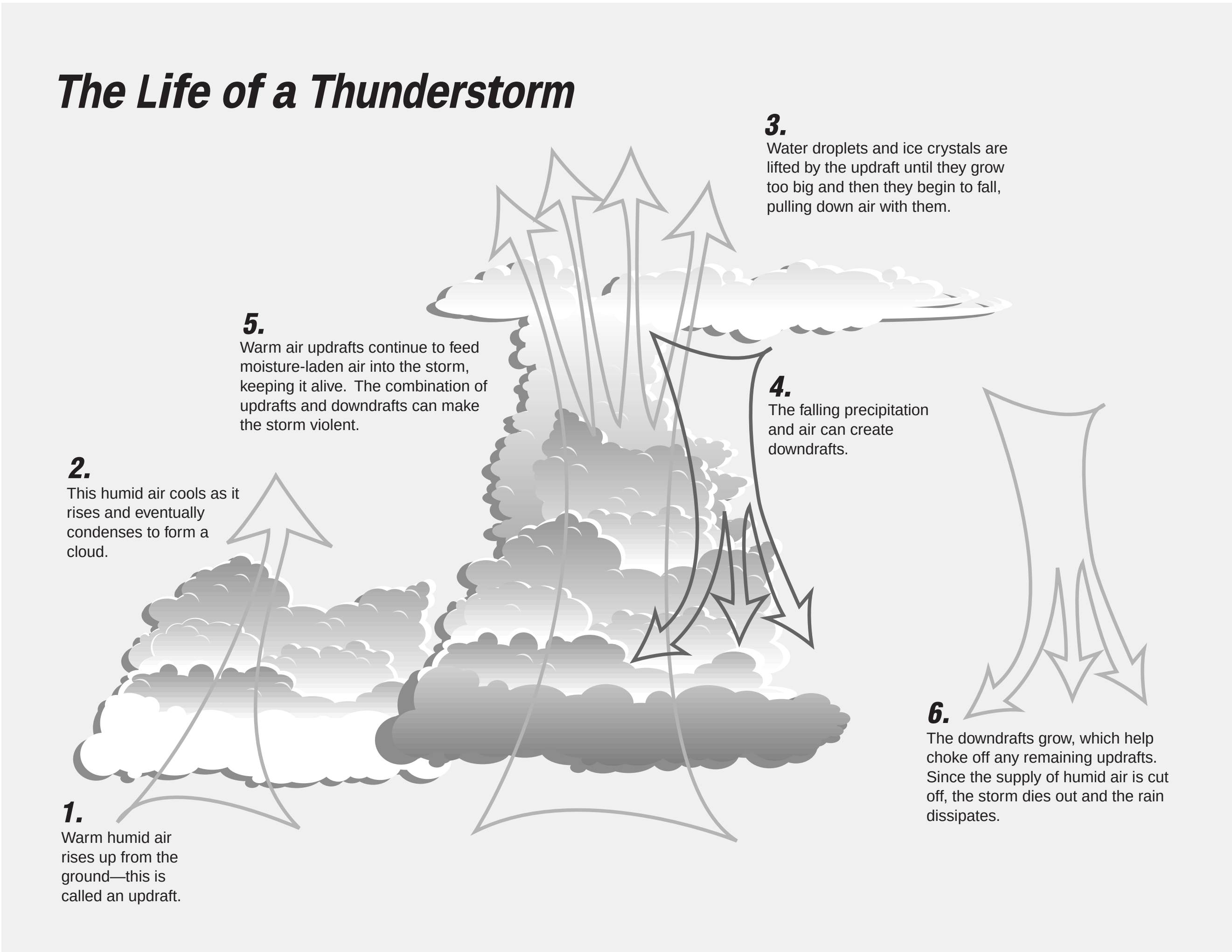

Figure 3. The life cycle of a single-cell thunderstorm.

Scientists have long known that large, vertical storm clouds contain a higher percentage of particles or ice, which in turn plays a central role in the build up of the electrical charges. The process still isn't well understood, but TRMM's ability to distinguish various ice and water particles in storms is beginning to shed light on how lightning is produced and under which conditions.

Tropical Ocean Storms

Meteorologists have studied tropical storm systems over the land for more than 20 years using ground-based radar, special aircraft instruments and weather ground stations. Now, for the first time with TRMM, they are able to make extremely precise radar measurements of storms over the ocean, where conventional ground-based instruments cannot see. The resulting data has provided invaluable insights into the dynamics of tropical storms and resulting rainfall—important information given the fact that two-thirds of the world's global rain falls in tropical areas.
What TRMM and conventional instruments have made clear is that tropical storms are a very different beast compared with their mid-latitude brethren.

Tropical storms typically form when large masses of air near the ocean or land converge. This convergence could be likened to a train wreck. The colliding air masses are forced upward. This blending is quite different from what happens in mid-latitude storms, which are caused by the clashing of two opposing air masses. Their interaction is like mixing water and vinegar; they don't mix well.

In addition, tropical systems have weaker streams of air flowing upward—updrafts—and therefore, tend not to support the larger ice particles needed for lightning. That may be why tropical storms typically don't produce as much lightning. They also rarely produce tornadoes. In fact, they are only a menace to populated areas because of the large amount of rainfall they produce, which can lead to severe flooding. However, the processes that produce the rainfall also drive the circulation of air that affects weather around the globe.

Hurricanes

Hurricanes are in a class of their own. Tropical storms become hurricanes when their wind speeds exceed 74 miles per hour, stirring up more than a million cubic miles of the atmosphere every second.

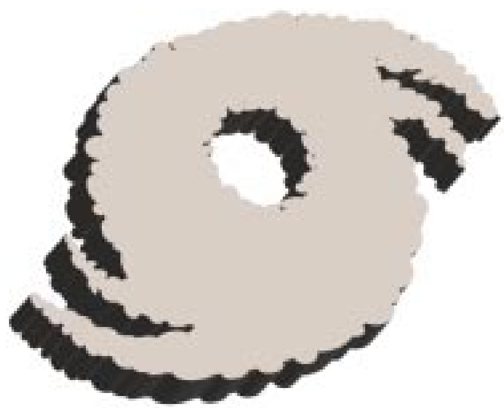

Figure 4. A mature tropical cyclone. The lowest pressure associated with the storm is found in the center, an area called the eye.

They develop over tropical ocean regions in the late spring, summer, and early fall when the sun heats up huge masses of moist air. An ascending spiral motion results and when the moisture of the rising air condenses, it releases energy called latent heat. As the air rises in the column, it gains more strength and energy. Winds and clouds increase, creating a low-pressure area called the eye (Figure 4).

We can compare hurricanes to huge machines, heat engines that convert the warmth of the tropical oceans and atmosphere into wind and waves. The heat dissipates as the spinning bubble of hot air moves toward the poles—and the continental United States, sometimes causing a great deal of hardship for people living along the vulnerable coastlines.

TRMM will give scientists a better understanding of what parts of a hurricane produce rainfall and why, as well as possibly resolve the question of how much latent heat or "fuel" hurricanes of differing strengths release into the atmosphere and whether they affect overall weather circulations.

But perhaps most importantly to people most vulnerable to the fury of a hurricane, TRMM will add to scientists' understanding of cloud formation, latent heat and rainfall—knowledge needed to improve computer-based weather modeling. With this data, meteorologists may be able to more precisely predict the path and intensity of these storms.

Conclusion

By studying tropical rainfall on both regional and global scales and by distinguishing between the role played by ocean versus land-based storms, TRMM is offering scientists the most detailed information to date on the internal processes of these powerful storms, leading to new insights about their influence on global climate patterns.