



Chapter 8: Essay

Winds From Water

Earth's atmosphere would be a boring place if it weren't for the moisture it contains. The vastly different specific heats of the oceans and continents also adds for excitement. But first imagine an Earth with no oceans, very dry air, and just a smooth surface of land. What would happen? Air close to the surface would be warmed by the solar heated surface. Air at higher elevations is farther from that warm surface and would therefore be much cooler.

On this pretend Earth, consider a large parcel of cool air way up high in the sky. If this parcel sinks downward, the greater atmospheric pressure closer to the surface causes it to compress, as shown in **Figure A**. This compression causes the parcel to heat up, like compressed air in a bicycle pump. As the parcel heats up, it expands thus becoming less dense than the surround lower air, which is why it rises back upward like a hot air balloon. The end result is that parcels of cold air tend to stay aloft. They can't sink any more than a cork floating on water.

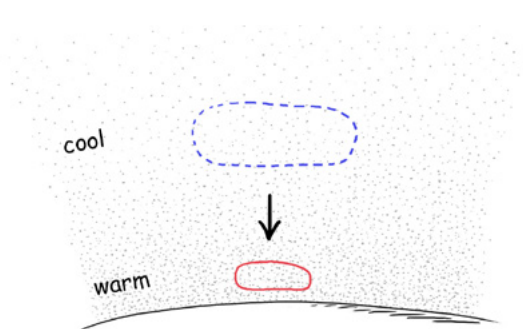


Figure A

An upper parcel of air is compressed if drawn downward. The compression causes it to warm up and expand (not shown) to become less dense than the surrounding air causing it to rise back upward.

Conversely, a parcel of warm air at the surface expands as it rises upward. As it expands, it cools down. As it cools down it becomes denser than the surround upper air and sinks back downward. So, on our idealized extremely dry planet, the atmosphere has a natural gradient of cooler air aloft and warm air close to the surface.

If a parcel of rising surface air contains water vapor, as within our real Earth's atmosphere, then the situation is quite different. As the moist rising air cools, much of the water vapor condenses into tiny droplets, which form a cloud, as shown in **Figure B**. The condensation of the water, in turn, releases large amounts of heat, as was described in Section 8.6. This heat of condensation compensates for the cooling that occurs as the rising air expands. As a result, a rising parcel of moist air, due to the heat of condensation, is able to remain aloft.

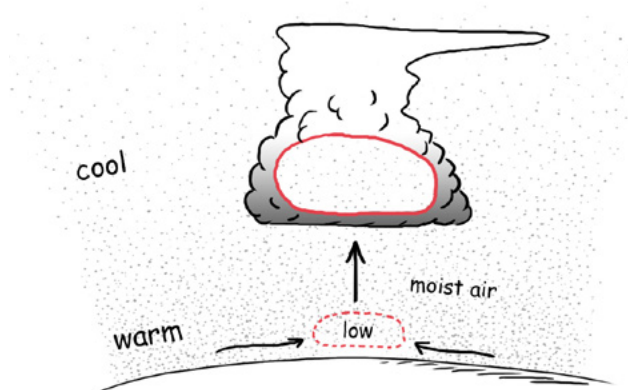


Figure B

Water condensing out of rising moist air forms clouds releasing heat, which allows the parcel of air to remain aloft.



This rising parcel of air leaves a partial vacuum in its wake, or, rather, a region of low pressure where there are fewer air molecules. Surrounding surface air flows inward toward this low-pressure region creating what we feel as wind. If the incoming air is also moist, it too will be able to rise resulting in an updraft. This process can continue until a huge cloud is formed creating what we recognize as a thunderstorm. Eventually, downdrafts complement the updrafts resulting in strong winds, heavy rain, and lightning. So, you see, the presence of water makes the weather rather exciting.

As wind rushes into the low-pressure region, you might think all these winds meet up at a single central spot. They would, except for that the Earth rotates. The regions of the storm system closer to the equator are spinning around Earth's axis faster than those farther from the equator. Winds moving toward the north or south pole are deflected a bit to the east, while winds moving toward the equator are deflected a bit to the west. Therefore, the winds don't meet exactly at the center of low-pressure. Rather their directions are skewed into counterclockwise rotation when in the northern hemisphere and clockwise when in the southern hemisphere.

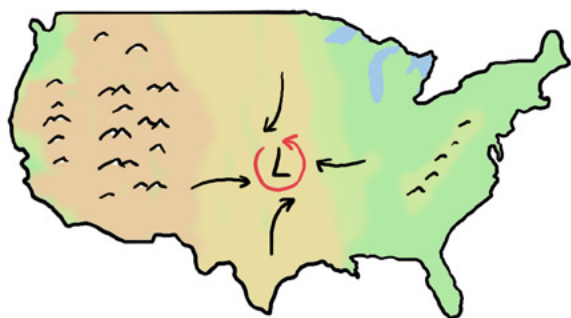


Figure C

Within North America, southward moving air veers westward while northward moving air veers eastward causing a counterclockwise rotation around a low-pressure zone. This happens because Earth rotates on its axis.

For a large thunderstorm, this spin plays a role in the formation of a tornado, which is a region of intense low pressure that sucks everything upward in a spiral fashion. The wind speeds are quite high because of the conservation of angular momentum. When an ice skater pulls her arms inward during



Figure D

Thunderheads and tornados gain their energy from the condensation of water.

a spin—she spins faster. Similarly, the tornado is a region where the storm's angular momentum is focused into a small diameter—the smaller the diameter, the faster the wind speeds and the greater the tornado's destructive power.

Thunderstorms are fed by warm moist air. So, they rarely happen in the winter when the air is not only cold but dry. Thunderstorms are quite common over maritime tropical regions, usually in the afternoon when the air is warmest. Under the right conditions, multiple tropical thunderstorms can join into a single much larger system. A region of very low pressure develops about which these merging multiple thunderstorms rotate. Moist air rushes inward and then spirals upward driven by the warmth released upon the condensation of that moist air. The system starts out as a tropical storm, which can potentially grow into a hurricane that turns like a pinwheel due to Earth's rotation—always counterclockwise in the northern hemisphere and clockwise in the southern hemisphere.

A hurricane is a moisture-driven positive feedback loop, which means it reinforces itself so long as there is a source of warm ocean water. A parcel of warm moist air rises and continues to rise because of the released heat during condensation. This draws in more warm moist air that also rises



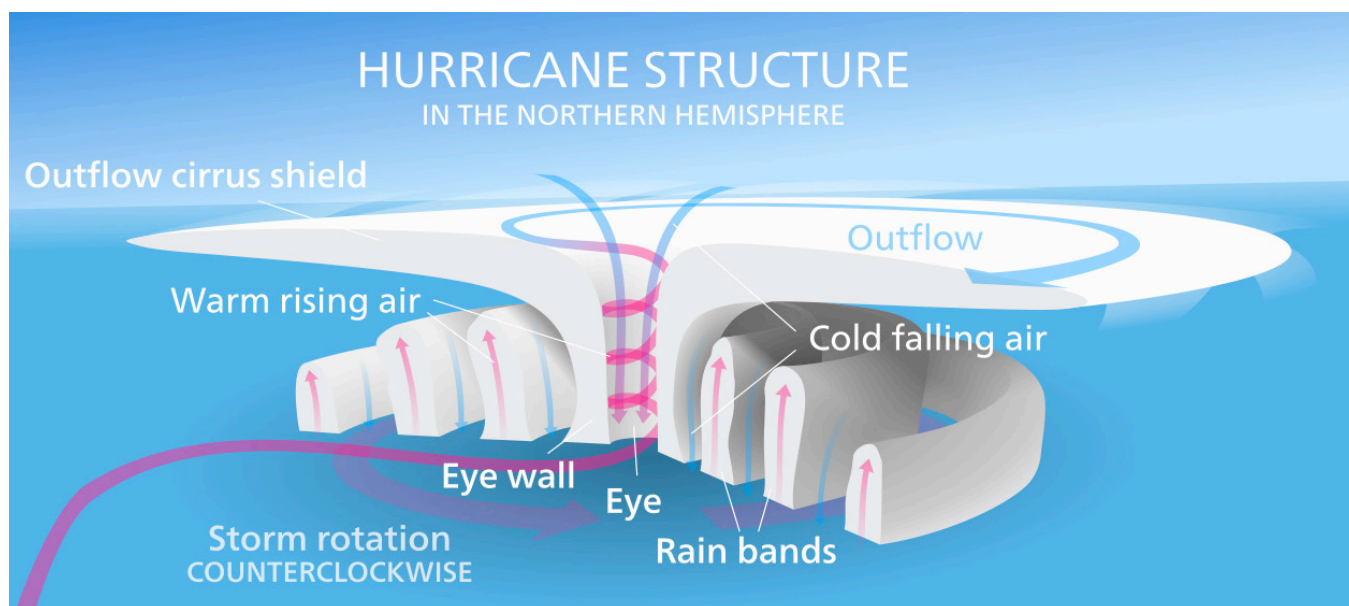


Figure F

The anatomy of a hurricane. Moist warm air is drawn to the central eye, which is a region of intense low atmospheric pressure.



Figure E

Hurricanes arise from the evaporation followed by condensation of water found within warm moist tropical air.

thus pulling in even more warm moist air. This cycle—essentially a natural heat engine—continues to build on itself creating a storm of planetary proportion. The upward lift of a hurricane is so powerful that it can raise the sea level beneath it by several meters. The heightened sea level is called a *storm surge*. An active hurricane over warm waters can be stopped if strong upper-level winds from outside the system are able to disrupt the upward flow pattern. Once over land, the hurricane is deprived of its warm water energy source and eventually dies out, but not without first causing massive destruction from winds, heavy rains, and storm surge flooding to the coastal communities.

CONCEPT CHECK

Why are there practically no winds on Venus?

CHECK YOUR ANSWER One of the main reasons there are practically no winds on Venus is because there are no oceans on this planet and very little water within the atmosphere.

Think and Discuss

1. As described in Section 8.5, water has a high specific heat. Does water's high specific heat cause more dramatic weather or less dramatic weather?
2. Which would be of greater concern: the average temperature of the atmosphere going up by 3°C or the average temperature of the oceans going up by the same amount? Why?
3. How can you simulate the spin of a hurricane north of the equator using a pencil held between the palms of your hands? Should your left hand come toward you or away from you?
4. Why do tornados in the northern hemisphere tend to track toward the northeast?





Author Responses to Think and Discuss

1. Both! Island communities enjoy temperatures that remain fairly constant throughout the year. Stable temperature, in turn, support stable weather patterns. Water's high specific heat, however, means that it is able to hold onto relatively large amounts of energy, which can be used to drive dramatic weather events, such as a hurricane.

2. The specific heat of water is much greater than that of air. This means that it takes much more energy to raise the temperature of water than the temperature of air by the same number of degrees. Mostly, however, the combined mass of the oceans is billions of times greater than the mass of the atmosphere. So, if our oceans went up by 3°C , then that would mean our planet has absorbed that much more thermal energy. The oceans would expand, which would raise sea levels significantly. Furthermore, the warm ocean would warm up the air as well. In short, our oceans going up by 3°C would be much, much more problematic than the atmosphere going up by 3°C . Though there is evidence indicating that a 3°C increase in average atmospheric temperatures is also fraught with threats to living systems on this planet, including ourselves.

3. Hold the pencil between the palm of your hands and move your right hand away from you and your left hand toward you. In such a manner you'll see the pencil rotating counter-clockwise.

4. At mid-latitudes, where most tornados form, weather prevails eastward. But because of the Earth's spin, the southern portion of a thunderstorm is moving eastward a bit faster than the northern portion. Imagine you were driving a bulldozer eastward in a parking lot and your southern treads started moving faster than your northern treads. What would happen? You would find yourself veering to the north (to your left). Similarly, north of the equator, thunderstorms at mid-latitudes, and the tornados they may contain, tend to track toward the northeast. If a tornado is coming your way directly from the southwest, and you don't have safe shelter, you would be best to head away from it as fast as you can in a southeast or northwest direction.

