How does the spin of the earth lead to the spin of a storm?

A laboratory experiment from the Little Shop of Physics at Colorado State University

Overview

The equator is hot; the poles are cold. So why doesn't cold air at the poles just slide down to the equator, and warm air here move to the poles?

This would happen, but for one fact: The earth rotates. This rotation complicates what would otherwise be a very simple motion, and it leads to bands of climate regions that circle the globe, and to the spin of large-scale storms.

Such phenomena are difficult to visualize since they occur on such a large scale. This activity will allow your students to bring these concepts down to a more manageable size as they watch weather phenomena develop on the table-top in a very simple system that is complex enough to simulate much of the complex behavior of moving air in the earth's atmosphere.

Necessary materials:

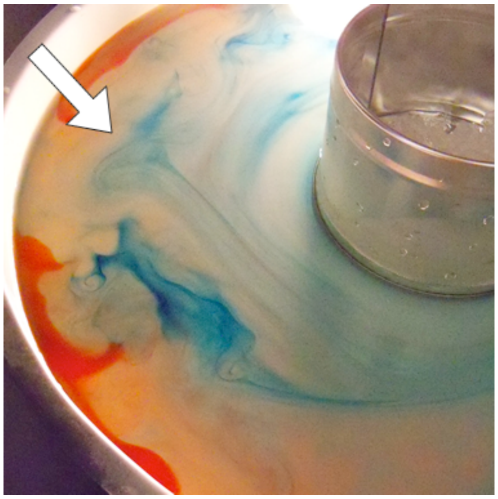
- Lightweight container with deep sides. We use a pan for casting stepping stones which we found at Hobby Lobby. We painted the inside white.
- Water (about 1 liter of warm liquid water and a cup of ice)
- Red and blue food coloring
- Heat lamp
- Turntable that rotates at approximately 3 rpm. We purchased this from Hobby Town. It's intended for models.
- Something to keep the ice from turning into icebergs that is a good thermal conductor. We used a small metal can.
- Level. The pan must be as level as possible; this is very important.

Necessary equipment for this experiment.

Theory

The thin blanket of atmosphere that envelops our planet has a big job to do—moving energy around. The sun heats the equator and the poles unequally. The gases that make up the atmosphere have the lofty responsibility of transporting the energy from the equator to the poles. Air warms and rises, moves toward the poles, and finally cools and sinks. Easy enough, but there's a catch. The earth is spinning. At the equator, the spin is pretty fast; it corresponds to a motion to the east at 1600 kilometers per hour. At the poles, the motion is much more gentle; a single rotation in 24 hours.

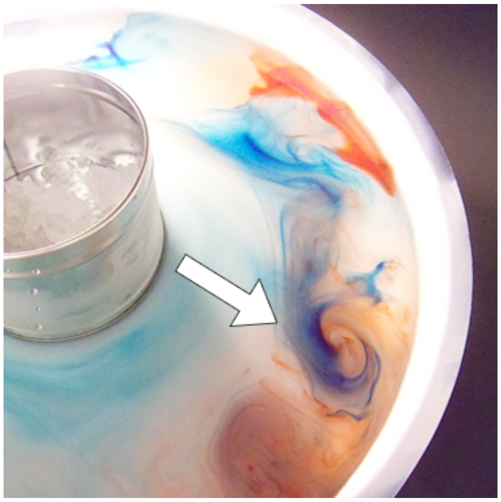
As the air moves from the equator toward the poles, it's this "sideways" motion that complicates things. Imagine an air mass at the equator. It's moving to the east at 1600 kilometer per hour—faster than the speed of sound! As it moves north, this motion continues, but the earth below it is moving more slowly. Net result: The moving air will turn to the right. We, who ride with the earth, term this apparent force the Coriolis force. This subtle force and is a key player in the weather patterns we experience every day.



Cold water from the "poles" is moving toward the equator, following a curving path as it trav-

Doing the Experiment

Proper set up is extremely important in this experiment, as is patience. You'll need a flat, extremely level surface where it won't get bumped or jostled. It is also important to note the locations of any air vents as they can cause problems. Make sure the pan is centered on the turntable and the ice container is centered in the pan. We find it useful to secure the ice container to the pan with glue or a suction saucer so that it won't sabotage the calm of the water. Fill the pan as deep as you can while still allowing it to spin smoothly on the turntable. We found that one liter of warm water works best. Position the heat lamp to shine on the outer edge. Reserve the ice for now. After you have your equipment set up, let it spin undisturbed for about two minutes, allowing perturbations to damp out.



A spinning "storm" forms.

Ask your students to gather around and observe. Gently fill the ice container and place a few drops of blue food coloring at its edges. Add a few drops of red along the outer edge of the pan. The food coloring will allow your students to see the motion of the fluid: red for the warm "air" at the equator and blue for the cold "air" at the North pole. Watch the simulation begin to develop and point out anything of note to your students. You will notice that the hot and cold "air" don't tend to mix but instead travel under or over one another.. If set up carefully, this simulation can run for several minutes and simulate many different atmospheric phenomenon: the jet stream, the doldrums, the trade winds, warm and cold fronts as well as hurricanes.

You will notice smooth lines of blue encircling the "North pole." As time goes on, this smooth line will develop waves that dip toward the "equator." You might see a wave dip very far down, as we see at times when cold Arctic air dips down to our latitude. If this piece dips far enough, it might separate and begin to swirl, forming into a "storm", which spins in the same sense as the turntable.

Summing Up

This experiment is a great way to step outside our planet and give ourselves a better perspective on a concept that is too large to tackle with conventional methods. A great extension to this activity would be relating what they are seeing (did see or will see) in the Spin Tank to actual weather maps. Interestingly, after the experiment has run its course, you can further enforce the importance of our spinning planet by turning the turntable off. Your students will see, almost instantly, how the dyes mix and the beautiful and complex system they had been watching fades into purple-grey nothingness.

For More Information

CMMAP, the Center for Multiscale Modeling of Atmospheric Processes: http://cmmap.colostate.edu

Little Shop of Physics: http://littleshop.physics.colostate.edu