AEROSPACE PALACE ACADEMY, NIGERIA
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LESSON 63: WEATHER PATTERNS IN THE SOLAR SYSTEM

Everybody is familiar with the weather on the Earth: sunshine, wind, rain, snow, and their variations. But the Earth is not the only place in the Solar System which has weather. Any place that has an atmosphere will have weather; any place with an atmosphere with a component which can be solid, liquid, or gaseous at reasonable temperatures can have rain or snow. Spacecraft that have visited other planets have recorded the weather in many of those places. Other spacecraft have photographed weather patterns on the Sun.

Next Generation Science Standards (NGSS):

- Discipline: Earth and Space Sciences
- Crosscutting Concept: Patterns.
- Science & Engineering Practice: Analyzing and Interpreting Data.

Note - While there are no NGSS to cover weather patterns on other planets, comparing and contrasting those conditions found on Earth with our neighboring planets is an excellent basis for study.

GRADES K-2

NGSS: Earth's Systems: Use and share observations of local weather conditions to describe patterns over time.

The students may want to watch a video of a tornado on the Sun which NASA's Solar Dynamics Observer satellite photographed in September 2016. That tornado was larger than the Earth and lasted for almost two days.

Much smaller tornado-like swirls, called "dust devils," form on Mars. The Spirit rover on Mars took a sequence of photographs of one such dust devil on March 15, 2005. (Another dust devil passed right over the Spirit rover, cleaning the dirt off of its solar panels and increasing the amount of electricity they could generate.) The Mars Reconnaissance Orbiter spacecraft took photographs of two other dust devils from space (the shapes look strange because the spacecraft is looking straight down on them from above).

You may want to compare the Martian dust devils to one on Earth.

GRADES 3-5

NGSS: Earth's Systems: Obtain and combine information to describe climates in different regions of the world.

On the Earth, warm air rises and the cooler air around it moves toward it to take its place. The rotation of the Earth imparts a spin to the inflowing air through something called the Coriolis Effect. The result is a cyclone, a weather system in which winds flow clockwise (in the Northern Hemisphere) or counterclockwise (in the Southern Hemisphere) toward a center of low pressure. (We should note that while hurricanes are cyclones, most cyclones are not hurricanes.)

Astronomers have also found storms on other planets in the Solar System. The Great Red Spot of Jupiter was first definitely seen in 1830, but may have been seen with early telescopes in 1665. (Giovanni Cassini saw a spot on Jupiter in 1665 and it was observed for half a century. Then there was a century-long gap in observations; either people simply did not see it or else the earlier spot dissipated and the present Great Red Spot formed later.) It may have existed from much earlier, but before 1665 people did not have anything with which to see it. Nobody knew what it was until the first spacecraft visited Jupiter in 1974 and showed that it is a massive storm, two or three times the size of the Earth in diameter.

Nor is the Great Red Spot the only storm on Jupiter. Smaller storms come and go on a continuous basis. In addition, the Juno mission to Jupiter has recently sent back pictures of storms over Jupiter's north and south poles. How long these storms last nobody knows; they have only just been discovered and not much is known about them.

Saturn also has large storms. Every few decades, a “Great White Spot” storm erupts on Saturn, lasts for a few years, and dissipates. Nobody knows why these storms grow so large while others do not. In addition, Saturn's north and south poles have large storms over them. Again, we have only just found them and so nobody knows how long they last, how they formed, or really much else about them at all. Curiously, the storm over Saturn's north pole is shaped roughly like a hexagon.

Here are some links about storms on other planets for further reading and information:

~~The Strange, Ferocious Extreme Weather of Our Solar System's Planets~~

~~The Most Extreme Weather in the Solar System~~

~~The Outer Planets~~ (including “Saturn's Cyclones” and “Storms on Jupiter”)

~~Are There Hurricanes on Other Planets?~~

GRADES 3-5 (CONTINUED)

Extraterrestrial Hurricanes: Other Planets Have Huge Storms, Too

What Are Storms Like on Other Planets?

GRADES 6-8

NGSS: Earth's Systems: Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions.

Dust storms can form wherever there is a solid material in very small pieces (the dust), a strong wind (to make the storm), and a lack of any liquid to bind the small pieces together. On the Earth, this happens around deserts or in other places during droughts. Dust storms, and their cousins sand storms (which involve grains of sand, which are larger than motes of dust), are regular features in the southwestern United States, India, central Asia, the Middle East, and North Africa. They also happen in other places like the central United States during dry spells. They can range from being simply an irritant to causing major problems. (Here is a web page with some suggested activities concerning dust storms.)

Dust storms also form on the planet Mars. Since the entire planet is dry, the dust storms there are limited only by the size of the planet. They can start in a few hours and spread to cover the planet in a few days. It can take weeks for the dust to settle out of the Martian atmosphere. Interestingly, the structure of a localized dust storm on Mars is about the same as the structure of a localized dust storm on Earth.

Dust storms on Mars interfere with spacecraft there the way that dust storms on Earth interfere with activities here. Spacecraft in orbit, because they are outside of the atmosphere, are not directly affected—although if their mission involves taking pictures of the planet's surface they will not be able to do that. The primary mission of Mariner 9, the first spacecraft to orbit Mars, was delayed for two months as mission controllers waited for a massive dust storm to clear. (The occurrence of the dust storm was itself a major discovery; astronomers had suspected that they happened but this was the first time one had been seen clearly.) Dust storms will leave spacecraft on the surface of Mars, though, with a thin coat of dust. This is a serious issue when the spacecraft is powered by solar cells which rely on sunlight to generate electricity. On Earth, after a dust storm has left a layer of dust on everything, people can go out and clean it off; on Mars, they can't. (At least, not yet.) Mars also doesn't have rainstorms that would wash the dust off.

GRADES 9-12

NGSS: Earth's Systems: Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.

The only things that are absolutely necessary for a body in the Solar System to have weather are an atmosphere and an energy source. The atmosphere provides gas which makes the wind to blow and the energy source provides the impetus for the wind to blow. For there to be precipitation, there needs to be another material that can evaporate and condense at the temperatures found on the body.

Weather on the Earth is caused by a combination of two things. The first is the unequal heating of the atmosphere by the Sun between the Equator and the poles. The second is the water cycle, in which water is evaporated from the Earth's surface and condenses (or freezes) and returns to the Earth's surface. Similar causes—unequal heating and the cycle of some substance that can exist in different states—drive most of the weather around the Solar System.

Another energy source that drives weather on the outer planets is the heat left over from when they formed some five billion years ago. The planets Jupiter, Saturn, and Neptune radiate twice as much energy out into space as they receive from the Sun; the excess energy comes from inside of them. (The planet Uranus does not; scientists do not know why there is a difference here.) Jupiter's excess energy comes from the heat generated when its constituent parts collided with each other (the kinetic energy of the gas molecules and dust specks was converted to heat energy in the collision) and from the decay of radioactive atomic nuclei that it contained. Five billion years seems like a long time for something to cool down but this is a measure of just how big the outer planets are.

The overall density of the atmosphere combines with a planet's distance from the Sun to control its surface temperature. On Mercury and the Moon, which have no atmosphere (and therefore no weather), the surface temperatures swing wildly from day to night as the unfiltered solar radiation heats the surface during the day and then the surface radiates the heat out to space during the night. Temperatures on Mercury can reach 800ºF during the day and -300ºF during the night. The Moon, being farther from the Sun, does not get as hot; its temperatures range from 260ºF to -280ºF. (The Moon also rotates more quickly than Mercury, giving the surface less time to heat up or cool down.) On Mars, with its thin atmosphere, the temperature swings are much less extreme, ranging on the equator from about 70ºF during the day to -60ºF at night.

GRADES 9-12 (CONTINUED)

(As on Earth, Mars' poles are colder because they do not receive as much sunlight.) Earth, with its much denser atmosphere than Mars, has what we consider a fairly mild range of temperatures at the equator. Finally, Venus, with an atmosphere 90 times more dense than the Earth's, has a surface temperature that is fairly constant at 900^{o}F. The extreme greenhouse effect from Venus' atmosphere actually makes its surface hotter than the surface of Mercury.

There are other weather effects elsewhere in the Solar System that we also see on the Earth. Saturn's moon Titan sees rain, just as the Earth does, although instead of being composed of water the rain on Titan is composed of methane and ethane. The rain on Titan feeds streams which drain into lakes, as well. The storms on Jupiter and Saturn create lightning, just as thunderstorms on the Earth do.

You may want to point out to your students that just because we haven't seen a phenomenon somewhere, that is not by itself a reason to believe that it does not happen. Twenty years ago nobody thought that there was a hexagonal storm over Saturn's North Pole; that does not mean that the storm didn't exist. "Absence of evidence is not evidence of absence," the cosmologist Martin Rees said (and was quoted by Carl Sagan).

Sixty Years Ago in the Space Race:

During the month of June 1958, the United States launched eight suborbital rocket missions (seven successful), the United Kingdom launched four suborbital missions (three successful), and the Soviet Union launched three suborbital missions (all successful).