Title: Clouds & Earth's Climate - Patrick Taylor - Video Transcript

Video Transcript (Video link: https://youtu.be/Y8DMPSBHXo0)

Our climate is changing. Over the last 130 years, the global mean surface temperature has warmed by more than one degree Celsius, which is more than 1.8 degrees Fahrenheit. Clouds have influenced how much the Earth has warmed over this time, but it is unclear by exactly how much. More on clouds in a few minutes.

On this animation, warming is illustrated by the increasingly red color across the planet. While 1.8 degrees Fahrenheit may feel small, this amount of temperature change is a big deal at the planetary scale. It's actually more than five times larger than what we would expect from natural changes in temperature that we see for one year to the next. More striking is that the twenty warmest years on record have all occurred in the last 22 years, since 1998. This means that a 22-year-old and a 100-year-old have both lived through the twenty warmest years in the modern record.

This warming across the planet is happening because of the increase in carbon dioxide in the atmosphere. The increase in carbon dioxide is a direct result of human activities and primarily the burning of fossil fuels.

My name is Patrick Taylor and I'm a climate scientist at NASA Langley Research Center. My research aims to understand how energy flows across our planet, and in particular how clouds influence the flow of energy. I'm also a member of the Clouds and Earth's Radiant Energy [System] science team. We call it the CERES project for short. CERES is the only project worldwide whose prime objective is to produce global climate data records of Earth's radiation budget and clouds over many decades. CERES does this from space by using six different instruments on four different satellites.

For most of our science research at NASA, we use satellite data. This animation shows our Earth-observing fleet. It is comprised of more than 20 different satellites. You may be wondering why there are so many. I like to think of Earth's climate as a puzzle where the pieces of the puzzle are the atmosphere, ocean, land, plants, animals, ice, and humans. No single instrument or mission can observe all pieces of this puzzle, so we need many satellites to see the whole picture.

The CERES and MODIS instruments are specially designed to observe and study Earth's radiation budget and clouds. These instruments are located on satellites that are

found in sun-synchronous, polar, low-Earth orbit. This means that these satellites observe the entire globe twice a day and always at the same time of day. In order to be in this orbit, these satellites are placed at an altitude of 440 miles above the Earth's surface. This is much closer to the Earth than geostationary weather satellites are. Geostationary satellites are found about 22,000 miles above the Earth's surface. From that far away it's much harder to see the detailed features of clouds. Low-Earth orbiting satellites provide a much closer look and resolve the finer details which are important to understanding just how clouds work.

As I mentioned before, the CERES project observes Earth's energy budget. Earth's energy budget is determined by the amount of sunlight that's absorbed by Earth and the amount of infrared energy emitted to space. Earth's energy budget is important for climate because the difference between these two energy fluxes controls Earth's temperature. I like to think of energy as the money of the climate system. Just like you cannot buy or sell something without money changing hands, the temperature cannot change and it doesn't rain unless energy moves from place to place. When there is more infrared energy lost to space than sunlight absorbed, Earth's temperature drops. When there's more sunlight absorbed than infrared energy loss to space, Earth's temperature rises, like it is now. Right now, the increasing amount of carbon dioxide in the atmosphere is keeping the infrared energy that was once lost to space trapped inside the Earth system, causing it to warm.

This animation shows CERES data that has been collected showing how and where Earth cools by losing infrared energy to space. The regions in the oranges and bright yellow colors are losing the most energy to space. These tend to be the warmest places and are especially in desert regions. The purple and white colors show places where there is much less energy lost to space. These places are colder, so they tend to be Arctic and Antarctic, but are also places with lots of clouds like the Amazon, Central Africa, and the tropical western Pacific region.

The next animation shows CERES observations of reflected sunlight from the Earth. The blue colors show you regions of the world that reflect little sunlight back to space. These are primarily found over the oceans. The green and bright white colors show you places on the planet that reflects a lot of sunlight to space. These are the polar regions that are covered by lots of bright white ice and snow, as well as some places in the tropics that have lots of clouds. So it's interesting that in both of these cases I brought

up clouds. You may have also noticed that the first letter in the CERES acronym stands for clouds.

Clouds are an important part of Earth's climate. Not just because they rain, but because they change Earth's energy budget. Clouds reflect something back to space that cools the planet. You can feel this effect on your skin on a hot day when a cloud comes overhead and momentarily blocks the sunlight. Your skin immediately feels cooler. Clouds also reduce the amount of infrared energy lost to space. This warms the planet. This is because clouds are found in the atmosphere above the surface which has a colder temperature than the surface. So clouds can either have a cooling effect or a warming effect. Whether clouds warm or cool the surface depends on their height and the amount of water that they contain. In general, high clouds tend to have a warming effect and low clouds tend to have a cooling effect.

The CERES data shows us that not all clouds are created equal. From this animation, we can see that the effect of clouds is different across the Earth. The greenish and blue colors show you places where clouds have a cooling effect. This is generally found over regions of the ocean where there are lots of low clouds which reflect a lot of sunlight. Places that have higher clouds reduce the amount of infrared energy lost to space and warm the planet. The yellow colors in this animation are found primarily over land and in the polar regions, showing the clouds have a warming effect there. The total effect of clouds on the planet is to be a cooling effect.

In sum, Earth's energy budget and the role that clouds play in it are very important to our climate system and are a very active area of research. Clouds around the planet are responding to the increasing temperatures, and clouds in different regions are changing differently. There are some regions where clouds are happening less frequently, other regions where cloud tops are getting higher, and yet other regions where the amount of liquid water in the clouds is getting larger. Exactly how clouds change and how these changes influence Earth's energy budget over the coming decades will have a strong influence on how much and how fast our climate changes. Understanding how clouds influence the flows of energy around the planet is critical to determining our climate future. Meaning how clouds change will affect how hot and dry summers will become, the frequency of extreme weather events, and also where it rains, when it rains, and how hard it rains. At NASA, we're using satellite data to try to get to the bottom of this so that society can thrive on this changing planet.