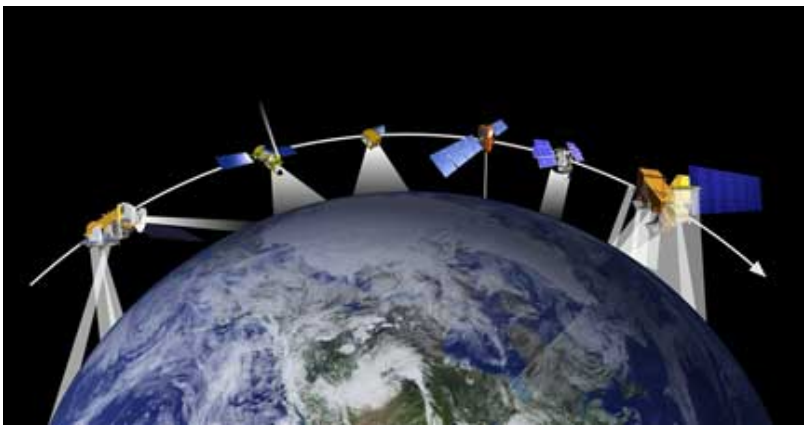
What else do we need to find out?

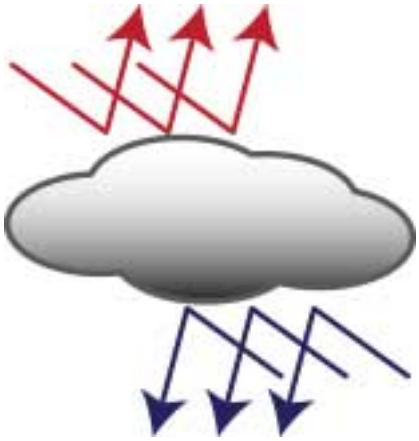
Can NASA help to answer scientists' questions?



NASA has more than a dozen satellites studying Earth. Many of these satellites carry several science instruments and study more than one question. The information these satellites gather will help climate scientists understand Earth as a very complex system or machine.

Here are some of the hard questions scientists are asking:

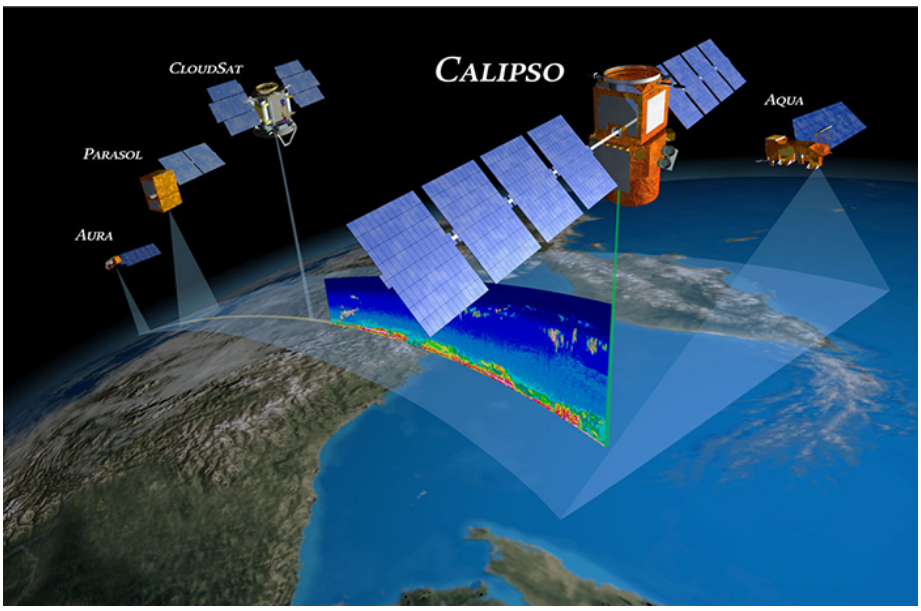
Do clouds make Earth warmer or cooler?



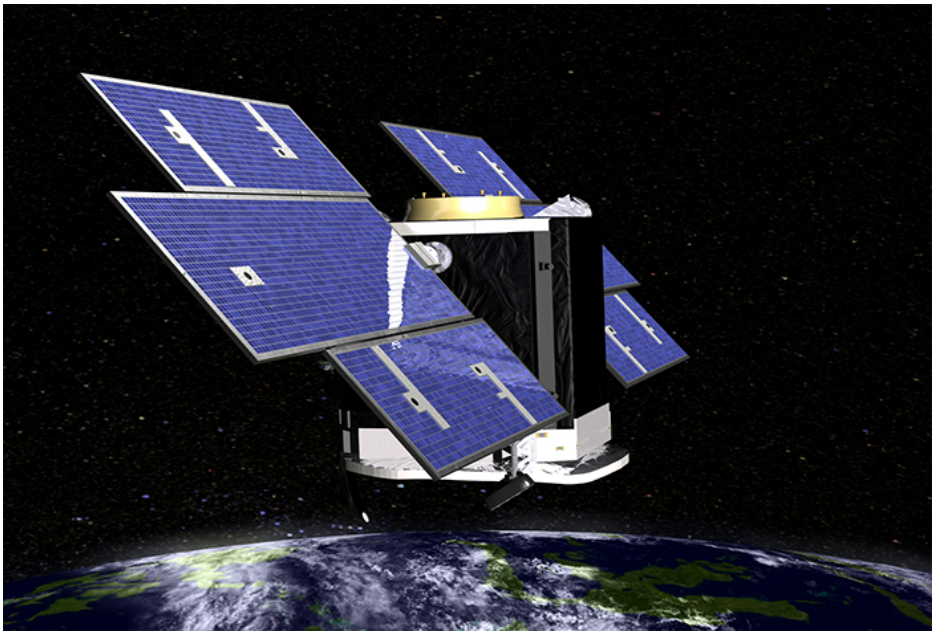
Water vapor is a powerful greenhouse gas. Warmer water evaporates faster than colder water, so as the ocean warms up, more water vapor goes into the atmosphere. This extra water vapor adds to the greenhouse effect making the ocean even warmer.

Now, when the water vapor cools, it condenses back into little droplets of liquid water, forming clouds. The more water vapor in the air, the more clouds. Bright white cloud-tops reflect a lot of sunlight back into space. But clouds also blanket Earth, keeping some of its heat from escaping.

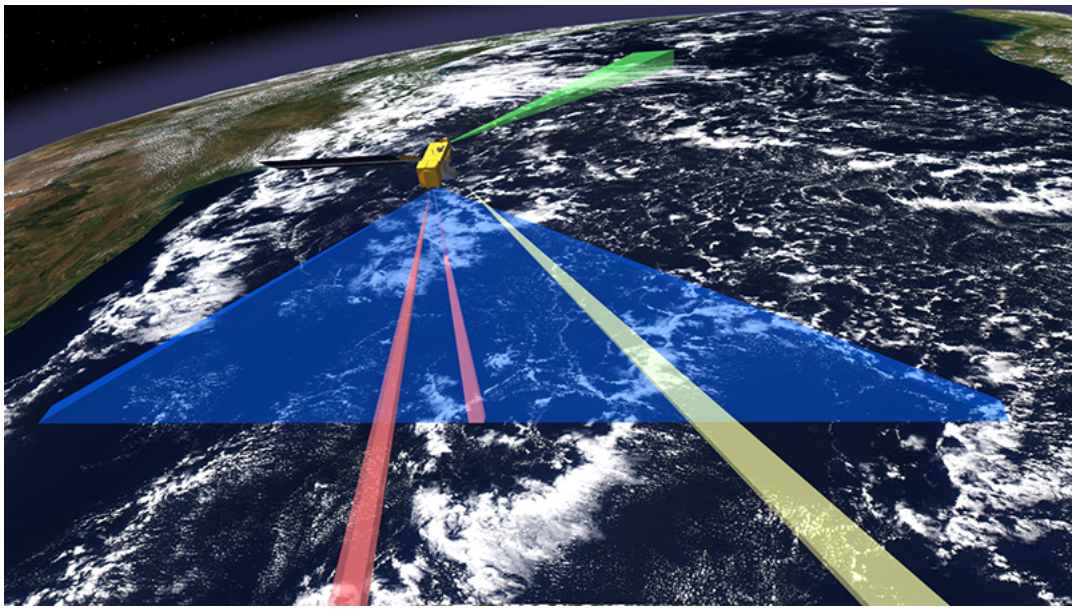
Here are some of the Earth missions that are helping to answer some of these questions:



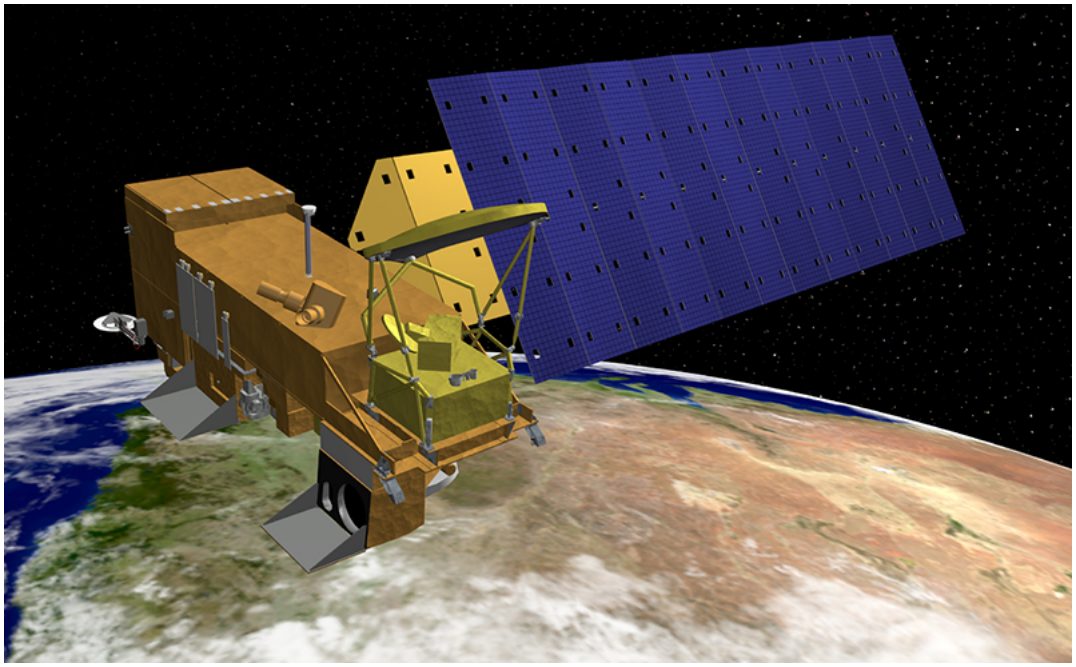
Calipso is helping scientists understand how clouds and aerosols (droplets that float in the air) affect Earth's weather, climate, and air quality. CALIPSO and CloudSat work together. CALIPSO is a joint U.S. and French satellite mission.



CloudSat collects 3-D information about clouds. CloudSat has radar that sees right into the clouds. CloudSat measures how thick the clouds are and how much water they contain.

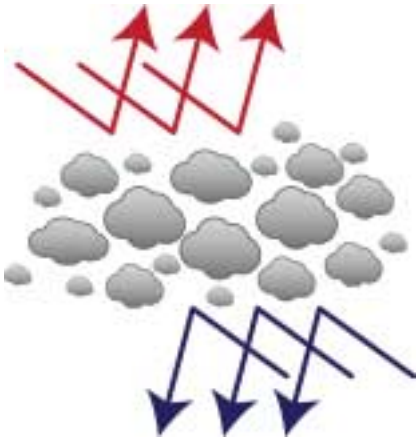


Terra carries instruments from Canada, Japan, and the U.S. It studies how the atmosphere, land, oceans, and heat and light energy interact. Terra has helped scientists measure how much carbon Earth's plants take out of the atmosphere, the height and movement of clouds, how Earth reflects and absorbs energy from the Sun, how many fires burn every day, and how pollution travels around the globe.



Aqua studies Earth's water cycle. It measures evaporation from the oceans, water vapor in the air, clouds, rain and snow, soil moisture, sea ice, land ice, and snow cover. Aqua also measures vegetation and temperatures, and radiation from the Sun and the Earth.

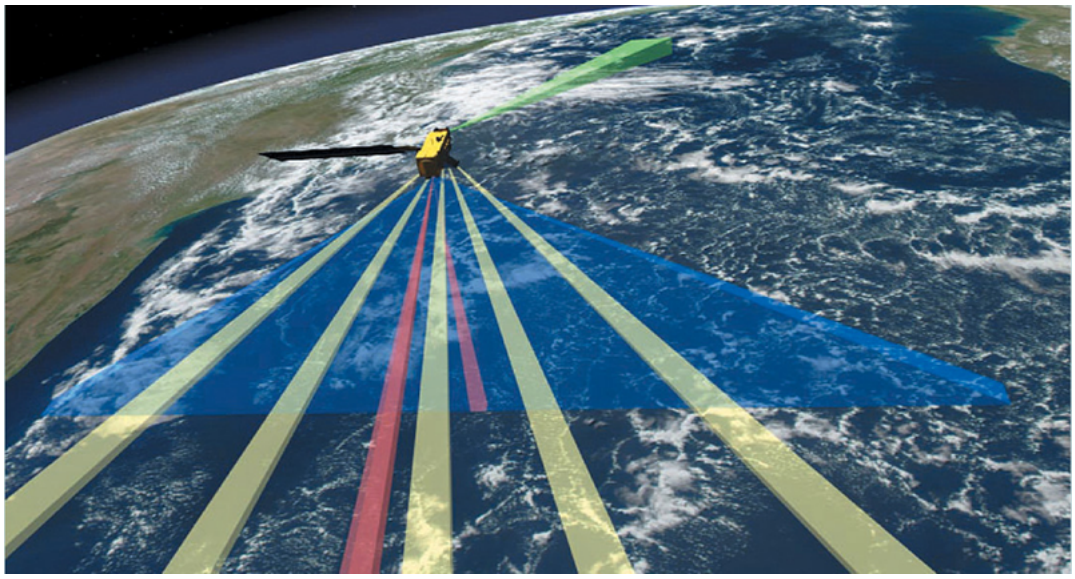
Do particles in the air make Earth warmer or cooler?



Aerosols are tiny particles or droplets of liquid floating in the air. Earth has lots of them. Some are natural. They might come from volcanoes, forest fires, vegetation, or sea spray. However, about 10% of the aerosols in our atmosphere come from human activity—for example, when we burn gas in our cars and coal in our power plants.

Scientists do not understand how aerosols affect regional and global climate. They are not even sure whether aerosols are warming or cooling our planet.

Instruments on these satellites are collecting information on aerosols:

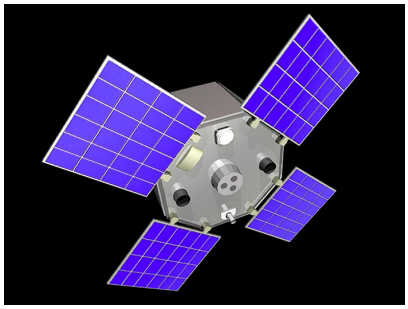


Aura studies Earth's atmosphere, including ozone and air quality changes, and their links to climate change. Ozone can be both helpful and harmful. High in the atmosphere, it protects us from the sun's harmful ultraviolet rays. But at lower altitudes it can act as a greenhouse gas and a harmful pollutant.

Do the Sun's natural cycles affect our climate?

We know that our Sun has an 11-year cycle. It is quiet for a while, then it gradually gets more active, up to its "solar maximum." Then it settles down again. Even so, its energy output varies only a tiny fraction (8/10,000ths or .08%) from lowest to highest output. We also think the Sun's energy output may vary over longer periods too. Scientists aren't sure about any longer-term cycles, though. That's because they have been closely monitoring the Sun for only about 40 years.

Two NASA Earth satellites that are studying the Sun are:



ACRIMSAT studies the Sun. Some scientists think that some of the global warming we are experiencing may be due to changes in the Sun. Even small changes over a century or more may cause significant climate change on Earth.

The Solar Radiation and Climate Experiment (SORCE) measures radiation from the Sun. SORCE will help scientists to understand long-term climate change, natural long-term variability in climate, and how to predict what will happen with the climate.

How much CO_2 can Earth suck out of the air?

Earth has a carbon cycle. That means carbon moves around, taking different forms at different times. Carbon stored in plants is returned as CO_2 to the atmosphere when the plants decompose, or when plants burn or their remains (that is, fossil fuels like gasoline, coal, or natural gas) burn. Carbon in the form of CO_2 leaves the atmosphere when the ocean absorbs it. Carbon in the form of CO_2 also leaves the atmosphere when plants use it in making food for themselves and the animals that eat the plants. When animals eat the plants, they store the plants' carbon in their bodies and breathe out some carbon in the form of CO_2 to the atmosphere.

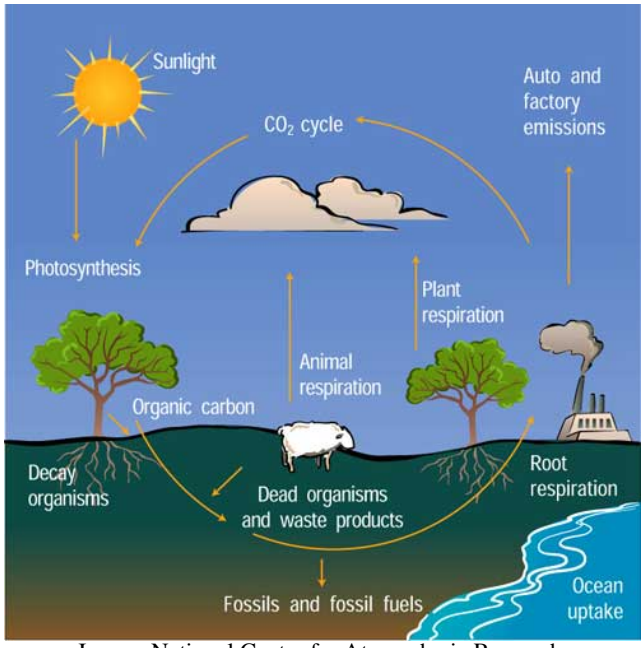


Image: National Center for Atmospheric Research

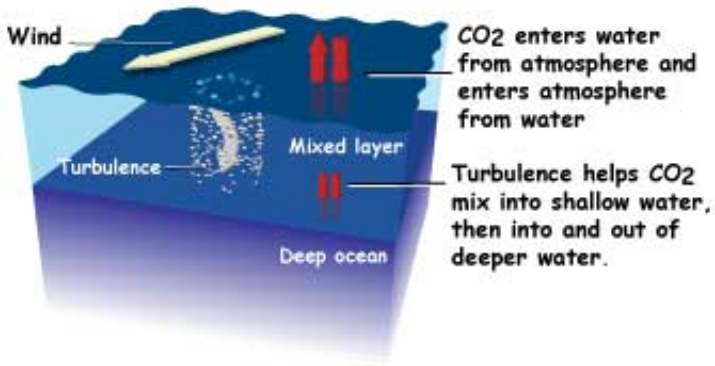
Carbon is always on the move. Plants use carbon dioxide and sunlight to grow. The carbon becomes part of the plant. Plants that die and are buried may turn into fossil fuels like coal and oil over millions of years. When we burn fossil fuels, most of this long-stored carbon quickly enters the atmosphere as carbon dioxide.

How does the ocean soak up CO_2?

Cold soda holds onto the bubbles much better than warm soda. That's because cold water holds more carbon dioxide than warm water does.

Now, scientists think that, between the ocean and the plants, Earth naturally takes up about half of the CO_2 that humans produce. Go, Earth! But as Earth warms up, will the ocean be able to absorb as much CO_2? Scientists are worried about that.

Think about what happens when you open a can of soda. The bubbles in soda are CO_2. If the soda is cold, you hear a little whoosh as a tiny bit of CO_2 escapes. If the soda is warm, the CO_2 might be so eager to escape that you get Old Faithful spewing out of the can. So, as the surface waters of the ocean warms up, the ocean may not be able to absorb and hold as much CO_2 from the atmosphere.

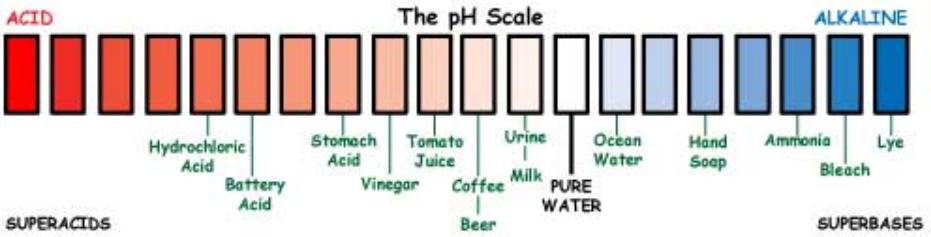


The ocean absorbs carbon dioxide from the atmosphere wherever air meets water. Wind causes waves and turbulence, giving more opportunity for the water to absorb the carbon dioxide.

Fish and other animals in the ocean breathe oxygen and give off carbon dioxide (CO_2), just like land animals. Ocean plants take in the carbon dioxide and give off oxygen, just like land plants. The ocean is great at sucking up CO_2 from the air. It absorbs about one-quarter of the CO_2 that we humans create when we burn fossil fuels (oil, coal, and natural gas.) If not for the ocean, we'd be in even worse trouble with too much CO_2.

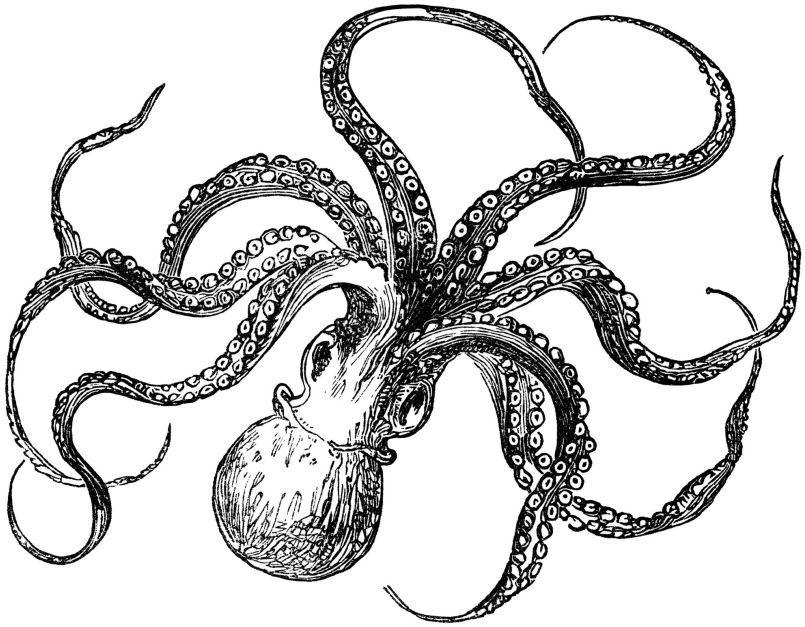
However, the ocean and everything in it are paying a price. The ocean is becoming more acidic.

What does this mean? Liquids are either acid or alkaline. Each liquid falls somewhere along a scale with acid at one end and alkaline at the other.

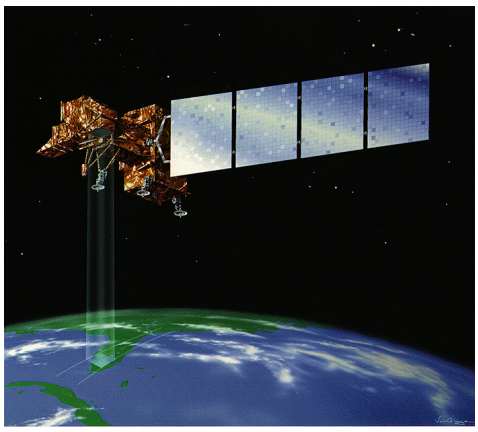


Normally, ocean water is less acidic than fresh water. Unfortunately, as the ocean absorbs more and more carbon dioxide from the atmosphere, it becomes more acidic. Lemon juice is an example of an acidic liquid. Toothpaste is alkaline. The ocean is slightly alkaline.

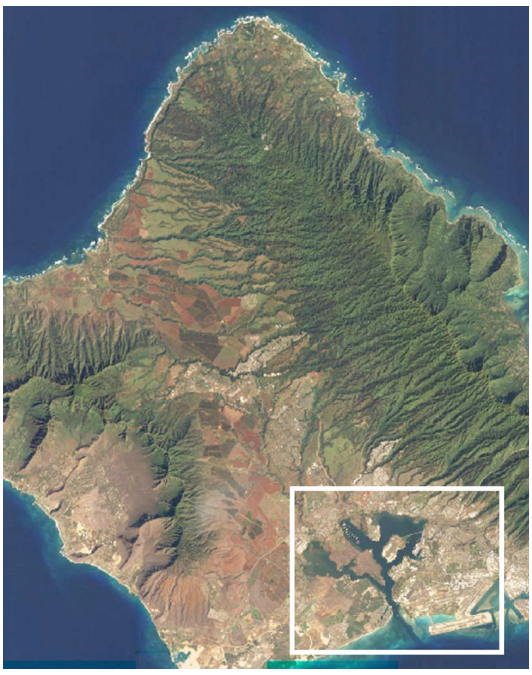
However, when the ocean absorbs a lot of CO_2, the water becomes more acidic. The alkalinity of the ocean is very important in maintaining a delicate balance needed for animals--like the mussels in this picture—to make protective shells. If the water is too acidic, the animals may not be able to make strong shells. Corals could also be affected since their skeletons are made of the same shell-like material.



Satellites that study these and other aspects of the carbon cycle are:



Landsat 7 has a very special instrument that can 'see' features on the ground as small as a house. The instrument can also see more different colors of light than human eyes can see. Landsat images have been color enhanced to help our human eyes see all the details and colors the Landsat instrument sees.



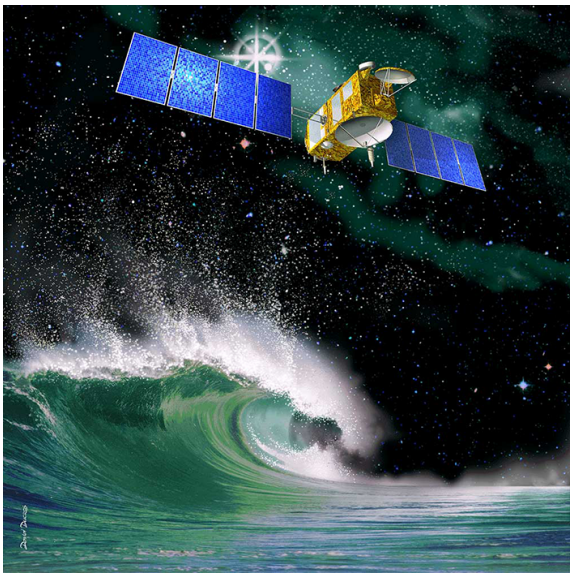
Earth Observing-1 developed and tested advanced new imaging technologies that will improve future earth imaging observatories and make them less expensive. This earth Observing 1 image is the island of Oahu, Hawaii. In the square is the airport in Honolulu. At a larger size, you can see the airplanes on the runway!

How will melting ice sheets affect ocean currents?

Ocean currents have a lot to do with Earth's climate, spreading some of the heat at the equator to other cooler parts of the planet.

Melted ice creates nice, fresh—not salty—water. But, as you know, the ocean is salty. Very salty. If you've ever swum in the ocean, you know floating in salty water is easier than in fresh water. That's because salty water is denser (heavier) than fresh water. Also, cold water is denser than warm water. So, that means cold, salty water will sink below fresh water. As the ice sheets melt, a lot of fresh water is being dumped on top of the salty water. Could this incoming fresh water somehow disturb the ocean currents? Could melting ice in the Arctic and Greenland actually work to cool Earth? Most scientists doubt it, but no one really knows.

Some NASA missions studying the oceans and major currents are:



Jason-1 measures sea surface height. Where the ocean is warmer, sea level is slightly higher. Jason-1 measures height from itself down to the Earth's surface (land or water). Images like this one are made from Jason-1 data, showing the variations in ocean surface height around the world.

The Ocean Surface Topography Mission (OSTM) on the Jason-2 satellite is a follow-on to Jason-1. It studies sea surface height—which gives information about ocean temperature—for climate forecasting research and science and industrial applications.

Aquarius measures the salinity, or saltiness, of the ocean surface all over Earth. It will monitor changes in salinity over time. It will help scientists understand Earth's water cycle, ocean circulation, and climate. Aquarius was launched in 2011.

How will climate change affect rain and snow?

Which places will get wetter and which will get drier?

Change is already happening. Even in the U.S., extremes of wet and dry are creating problems. For example, the Sierra Nevada mountain range in California has had less snowfall in the past decade. California's cities and agriculture depend on water from the melting snowpack from the Sierras. Is it going to get worse? How much worse? How soon?

Other parts of the U.S. have suffered from too much rain and more than the usual number of intense storms. As the ocean gets warmer, more evaporation will make more clouds and more rain and perhaps more hurricanes. Can we predict where floods will occur and prepare for them?

Some NASA missions that are studying these changes are:

--The Tropical Rainfall Measuring Mission (TRMM) measures rainfall all around the tropics where most of the world's rain falls. These measurements will help scientists know what the normal rainfall is and maybe what the normal changes are from one year to the next.

--The Gravity Recovery and Climate Experiment (GRACE) mission has twin spacecraft that orbit about 130 miles apart. GRACE maps Earth's gravity, which varies from place to place. This data has many uses, including helping missions that use measure their height above Earth (like Jason-1 and OSTM/Jason-2) work accurately.

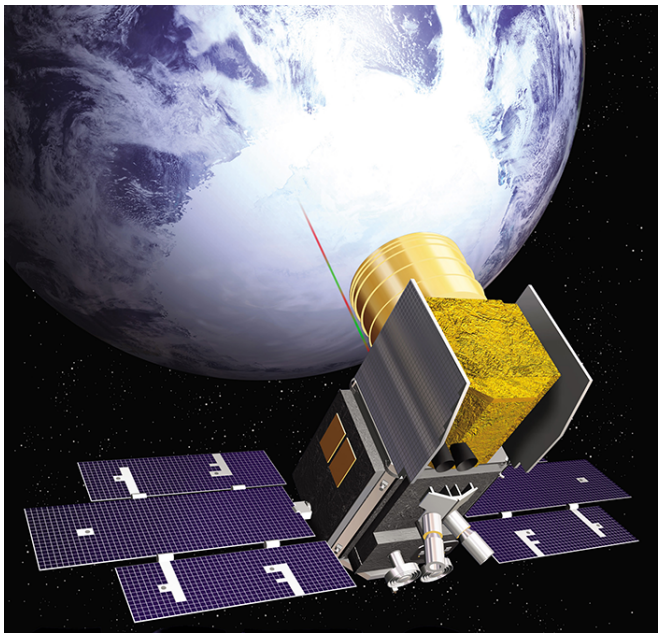
-- Landsat 7 has a very special instrument that can 'see' features on the ground as small as a house. The instrument can also see more different colors of light than human eyes can see. Landsat images have been color enhanced to help our human eyes see all the details and colors the Landsat instrument sees.

How high and how fast will sea level rise?

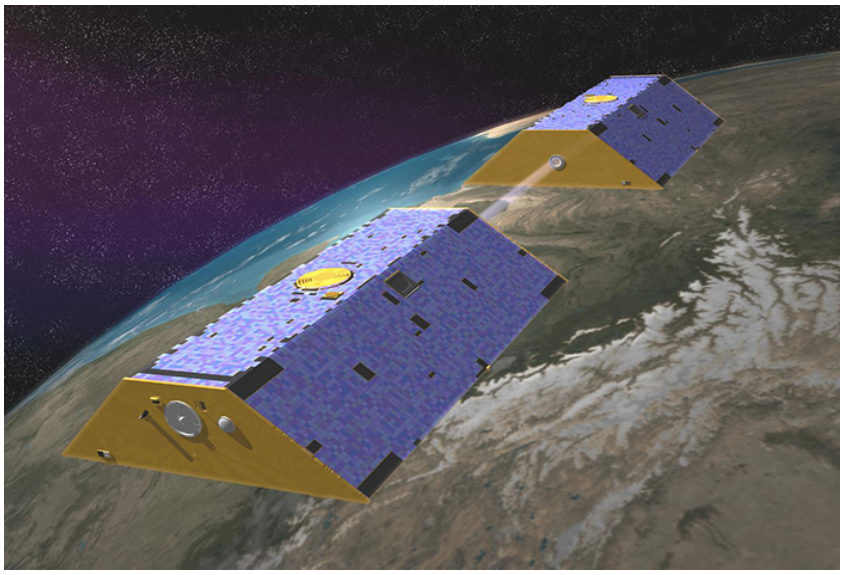
We don't know enough about Earth's ice to know just how many meters sea level is likely to rise as ice melts in various locations. And we don't know how fast it could rise. Also, ice is bright and reflects a lot of sunlight. When it melts, more energy is absorbed by the dark ocean. How much difference will this make?

On the left, the bright, white Arctic ice reflects a lot of sunlight, bouncing it back into space. On the right, much of the ice has melted. The ocean absorbs more sunlight than ice does, so the ocean warms up, melting even more ice.

Some NASA satellites studying these questions are:



IceSAT studies Earth's ice sheets and how they change. It observes whether the ice is growing or shrinking, and how fast. ICESat will help scientists predict how ice sheets and sea level will respond to future climate change.



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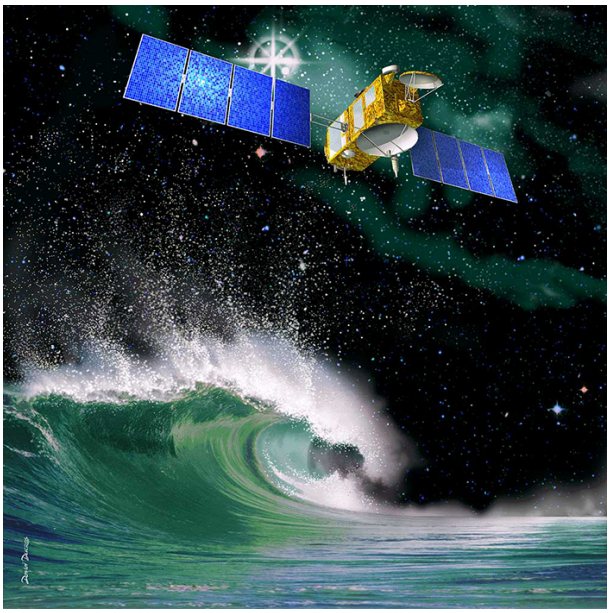

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