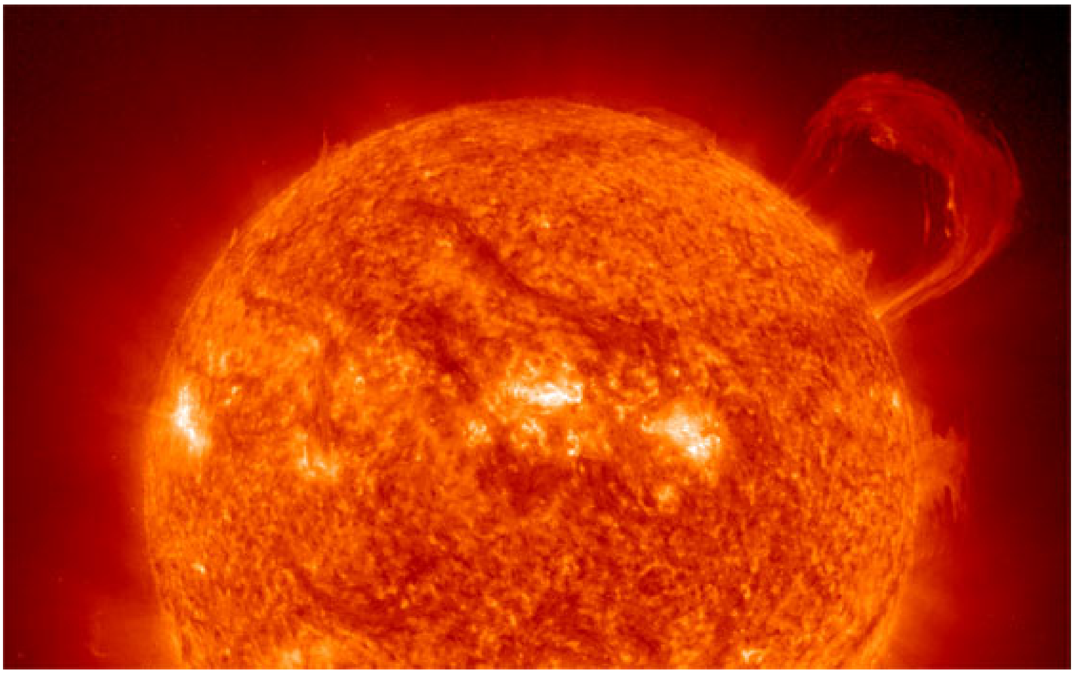

Extreme Ultraviolet Imaging Telescope (EIT) image of the sun with a huge, handle-shaped prominence

This website presents a data-rich view of climate and a discussion of how that data fits together into the scientists' current picture of our changing climate. But there's a great deal that we don't know about the future of Earth's climate and how climate change will affect humans.

For convenience and clarity, climate scientists separate things that affect climate change into two categories: forcings and feedbacks.

Also, climate scientists often discuss "**abrupt climate change**," which includes the possibility of " **tipping points**" in the Earth's climate. Climate appears to have several states in which it is relatively stable over long periods of time. But when climate moves between those states, it can do so quickly (geologically speaking), in hundreds of years and even, in a handful of cases, in only a few decades. These rapid 'state changes' are what scientists mean by abrupt climate change. They are much more common at regional scales than at the global scale, but can be global. State changes have triggers, or "tipping points," that are related to feedback processes. In what's probably the single largest uncertainty in climate science, scientists don't have much confidence that they know what those triggers are.

Below is an explanation of just a few other important uncertainties about climate change, organized according to the categories forcing and feedback. This list isn't exhaustive. It is intended to illustrate the kinds of questions that scientists still ask about climate.

Forcings

Solar Irradiance. The sun has a well-known 11-year irradiance cycle that produces about .1% variation in output. [1] Solar irradiance has been measured by satellite daily since the late 1970s, and this known solar cycle is incorporated into climate models. There is some evidence from proxy measurements-sunspot counts going back centuries, measurements from ancient trees, and others-that solar output varies over longer periods of time, too. While there is currently no evidence of a trend in solar output over the past half century, because there are no direct observations of solar output prior to the 1970s, climate scientists do not have much confidence that they understand longer-term solar changes. A number of U.S. and international spacecraft study the sun.

Aerosols, dust, smoke, and soot. These come from both human and natural sources. They also have very different effects on climate. Sulfate aerosols, which result from burning coal, biomass, and volcanic eruptions, tend to cool the Earth. Increasing industrial emissions of sulfates is believed to have caused a cooling trend in the Northern Hemisphere from the 1940s to the 1970s. But other kinds of particles have the opposite effect. The global distribution of aerosols has only been tracked for about a decade from the ground and from satellites, but those measurements cannot yet reliably distinguish between types of particulates. So aerosol forcing is another substantial uncertainty in predictions of future climate.

Feedbacks

Clouds. Clouds have an enormous impact on Earth's climate, reflecting back into space about one third of the total amount of sunlight that hits the Earth's atmosphere. As the atmosphere warms, cloud patterns may change, altering the amount of sunlight absorbed by the Earth. Because clouds are such powerful climate actors, even small changes in average cloud amounts, locations, and type could speed warming, slow it, or even reverse it. Current climate models do not represent cloud physics well, so the Intergovernmental Panel on Climate Change has consistently rated clouds among its highest research priorities. NASA and its research partners in industry, academia, and other nations have a small flotilla of spacecraft and aircraft studying clouds and the closely related phenomenon of aerosols.

Carbon cycle. Currently, natural processes remove about half of each year's human carbon dioxide emissions from the atmosphere, although this varies a bit year to year. It isn't well understood where this carbon dioxide goes, with some evidence that the oceans are the major repository and other evidence that land biota absorbs the majority. There is also some evidence that the ability of the Earth system to continue absorbing it may decline as the world warms, leading to faster accumulation in the atmosphere. But this possibility isn't well understood either. The planned Orbiting Carbon Observatory mission will mark NASA's first attempt to answer some of these questions via space observations.

Ocean circulation. One very popular hypothesis about climate change is that as the Earth as a whole warms, ocean circulation in the Atlantic will change to produce cooling in Western Europe. In its most extreme form, this hypothesis has advancing European ice sheets triggering a new ice age. A global-warming induced ice age is not considered very likely among climate scientists. But the idea highlights the importance of ocean circulation in maintaining regional climates. Global ocean data sets only extend back to the early 1990s, so there are large uncertainties in predictions of future ocean changes.

Precipitation. Human civilization is dependent upon where and when rain and snow fall. We need it for drinking water and for growing our food. Global climate models show that precipitation will generally increase, but not in all regions. Some regions will dry instead. Scientists and policymakers would like to use climate models to assess regional changes, but the models currently show wide variation in their results. For just one example, some models forecast less precipitation in the American southwest, where JPL is, while others foresee more precipitation. This lack of agreement on even the direction of change makes planning very difficult. There's much research to be done on this question.

Sea level rise. In its 2007 Fourth Assessment Report, the Intergovernmental Panel on Climate Change used new satellite data to conclude that shrinkage of ice sheets may contribute more to sea level rise than it had thought as recently as 2001. The panel concluded that it could not "provide a best estimate or an upper bound for sea level rise" over the next century due to their lack of knowledge about Earth's ice.[2] There are 5-6 meters worth of sea level in the Greenland ice sheet, and 6-7 meters in the West Antarctic Ice Sheet, while the much larger East Antarctic Ice Sheet is probably not vulnerable to widespread melting in the next century. Many hundreds of millions of people live within that range of sea level increase, so our inability to predict what sea level rise is likely over the next century has substantial human and economic ramifications.

1 *Claus Frohlich and Judith Lean, “Solar radiative output and its variability: evidence and mechanisms,” The Astronomy and Astrophysics Review, 2004,*

doi:10.1007/s00159-004-0024-1.
[2] *IPCC Fourth Assessment Report, Summary for Policymakers, p. 7*

http://climate.nasa.gov/uncertainties/