Could 2025 be the start of the GHG-Peak?

By John Benson

March 2025

1. Introduction

There is little doubt that we are approaching a time when greenhouse gas (GHG) annual emissions will peak. However, the exact definition of what this will look like, how long it will last, or whether there will be any oscillation (increasing and decreasing GHG-emission over several years) only the future will tell.

Scientists are hopeful this year could mark a critical turning point in the fight against climate change: the year when global greenhouse gas emissions peak. Annual emissions, driven mostly by the combustion of fossil fuels, seem to have nearly plateaued, increasing by about 1 percentage point each year for the past 2 years and totaling 41.6 billion tons in 2024. The rapid rise of electric vehicles, renewable energy, and reforestation has jostled with the countervailing forces of the energy-gobbling data centers powering artificial intelligence and rebounding fuel demand after a pandemic lull. As the world's largest emitter, China, continues its aggressive push into renewables, many researchers suspect this year could finally see a long-awaited drop. But even if the world reaches that milestone, it is expected to take several decades before the world reaches "net zero" and emissions return to preindustrial levels. And even then, the warmth from existing carbon dioxide will linger for centuries.[1]

Author's comment: The text *"…it is expected to take several decades before the world reaches "net zero" and emissions return to preindustrial levels."* May confuse some readers. It is assumed, that the emissions discussed in the prior paragraph are either measured or estimated emissions (the latter based on the sales of fossil-fuels, for instance). Even if the world's net "measured-emissions" reach zero, most of the world's smaller economies and/or those with inaccurate and incomplete emission and/or emissions-proxy monitoring will continue to grow along with their GHG emissions. With the current high-levels of GHG emissions in the atmosphere, much of past emissions are stored in the oceans, and as emissions in the atmosphere start to subside (hopefully in several decades) the GHG in the oceans will leak back out. Also, natural emissions are primarily driven by the world's temperature, which will continue to rise due to climate change (a.k.a. "global warming") and ditto the energy needed for cooling. The International Energy Agency has set 2050 as the goal to reach net zero, but I wouldn't want to make any bets on that date.[2]

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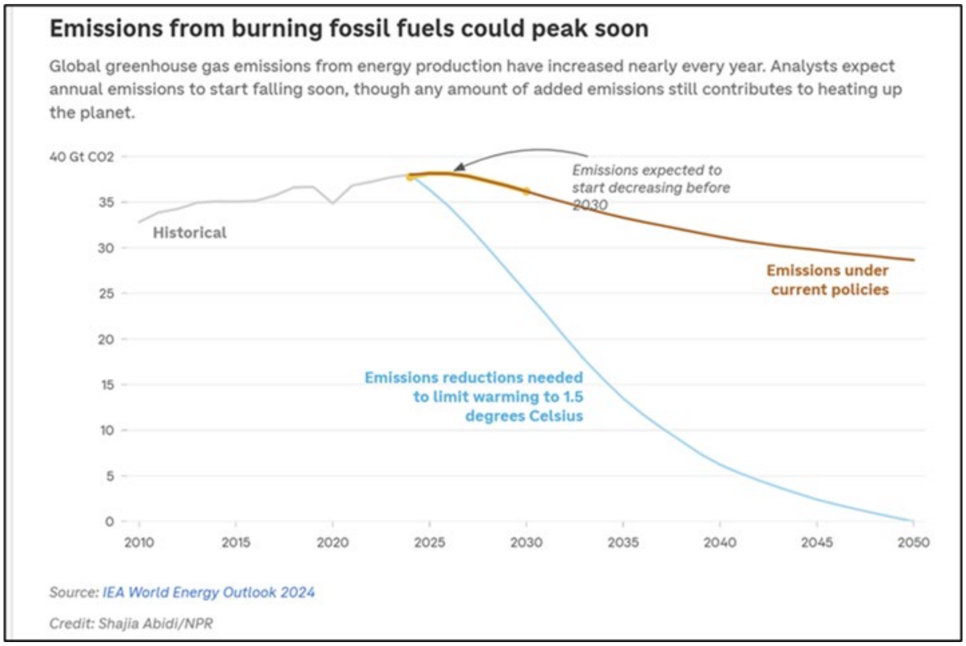
[1] Science Magazine, "News at a Glance" article "Peak emissions at last?" January 3, 2025, Note that access though the following link is limited, https://www.science.org/doi/10.1126/science.adv6038#:~:text=Scientists%20are%20hopeful%20this%20year%20could%20mark%20a,the%20year%20when%20global%20greenhouse%20gas%20emissions%20peak.

[2] See https://www.iea.org/reports/net-zero-by-2050

Also, an NPR Article referenced at the end of this paragraph, basically repeated the information from Reference 1 but also added an interesting chart (below).[3]

2. On the Other Hand

However, this is a complex issue, and as the above excerpt points out, there could be energy-demand factors driving the emissions to continue increasing. Also, Mother Nature may get to vote on this, as the same source (Jan 3 Science Magazine) offers in a different article, excerpted below.



For more than 20 years, NASA instruments in space have tracked a growing imbalance in Earth's solar energy budget, with more energy entering than leaving the planet. Much of that imbalance can be pinned on humanity's emissions of greenhouse gases, which trap heat in the atmosphere. But explaining the rest has been a challenge. The loss of reflective ice, exposing darker ground and water that absorb more heat, isn't enough to explain the deficit, and the decline in light-reflecting hazes as countries clean up or close polluting industry falls short as well. "Nobody can get a number that's even close," says George Tselioudis, a climate scientist at NASA's Goddard Institute for Space Studies.[4]

But Tselioudis and his colleagues now think they can explain the growing gap with evidence collected by a remarkably long-lived satellite. They find that the world's reflective cloud cover has shrunk in the past 2 decades by a small but tangible degree, allowing more of the sun's light in and boosting global warming. "I'm confident it's a missing piece. It's the missing piece," says Tselioudis, who presented the work last month at a meeting of the American Geophysical Union…

[3] Lauren Sommer, NPR, "When will greenhouse gas emissions finally peak? Could be soon," November 14, 2024, https://www.npr.org/2024/11/13/nx-s1-5178085/climate-change-emissions-peak-cop29
[4] Above Science Magazine Issue in Reference 1, "Earth's clouds are shrinking, boosting global warming."

Climate scientists now need to figure out what's causing these cloud changes. They also need to tackle a more alarming question: whether the trend is a feedback of climate change that might accelerate warming into the future, says Michael Byrne, a climate dynamics scientist at the University of St. Andrews. Although some models have predicted the cloud changes, Byrne says, "I don't think we can answer this question with much confidence."

Clouds come in all shapes and sizes, but two of the most consistent cloud swaths are formed by Earth's large-scale airflow patterns. One band, near the equator, stretches around the planet like a belt. It forms as trade winds of the Northern and Southern hemispheres converge, forcing moist air upward to cool and condense into clouds. Another band occurs in the midlatitudes, where jet streams usher large swirls of stormy weather around the planet.

In August 2024, Tselioudis and his coauthors reported that over the 35 years covered by weather satellite imagery, the equatorial cloud bands had narrowed, while the tracks of midlatitude storms had shifted toward the poles, hemming in the region in which they can form and shrinking their coverage. But the result, published in Climate Dynamics, was stitched together from many different satellites, each with its own quirks and errors, which made the researchers unsure the small trends they detected were real.

Now, the team has turned to a single satellite, NASA's Terra, which has been monitoring the planet for nearly a quarter-century. Looking at the same cloud systems, the team found exactly the same trends, with cloud coverage falling by about 1.5% per decade, Tselioudis says. "It's only now that the signal seems to be coming out of the noise." Bjorn Stevens, a climate scientist at the Max Planck Institute for Meteorology, says a couple of percentage points may not sound important. "But if you calculate these trends, it's massive," he notes. "This would indicate cloud-feedback that's off the charts."

The team also found that 80% of the overall reflectivity changes in these regions resulted from shrinking clouds, rather than darker, less reflective ones that could be caused by a drop in pollution. For Tselioudis, this clearly indicates that changes in atmospheric circulation patterns, not pollution reductions, are driving the trend.

The new work doesn't stand alone. Earlier this year, in Surveys in Geophysics, a group led by climate scientist Norman Loeb at NASA's Langley Research Center also traced the gap in the energy imbalance to declining cloud coverage. But Loeb, who leads work on the set of NASA satellite instruments called Clouds and the Earth's Radiant Energy System, which tracks the energy imbalance, thinks pollution declines may be playing an important role in the cloud changes, especially in the Northern Hemisphere. "The observations are telling us something is definitely changing," he says. "But it's a complicated soup of processes."

If global circulation changes are at work, an urgent question is whether they will continue, says Tiffany Shaw, a climate dynamics scientist at the University of Chicago. The same models that predict a narrowing of the equatorial storm belt also suggest climate change will cause air over the eastern Pacific Ocean to warm faster than the west, weakening an important branch of the large-scale circulation. But for the past few decades, the eastern Pacific has actually been cooling, strengthening these winds instead. Other observations, meanwhile, suggest the rest of the circulation is weakening. The confusion makes it hard to know whether the cloud banks will continue to shrink as the world warms…

2.1. Additional Information on NASA Program

In the second paragraph above reference is made to "*NASA's Clouds and the Earth's Radiant Energy System*." This is critical to measuring whether to subject of the prior subsection is real, and ongoing, so thought I had better dig a bit deeper.

Clouds and the Earth's Radiant Energy System (CERES) is an on-going NASA climatological experiment from Earth orbit. The CERES are scientific satellite instruments, part of the NASA's Earth Observing System (EOS), designed to measure both solar-reflected and Earth-emitted radiation from the top of the atmosphere (TOA) to the Earth's surface. Cloud properties are determined using simultaneous measurements by other EOS instruments such as the Moderate Resolution Imaging Spectroradiometer (MODIS).

Results from the CERES and other NASA missions, such as the Earth Radiation Budget Experiment (ERBE), could enable nearer to real-time tracking of Earth's energy imbalance (EEI) and better understanding of the role of clouds in global climate change.[5]

The role of clouds in modifying the earth's radiation balance is well recognized as a key uncertainty in predicting any potential future climate change. This statement is true whether the climate change of interest is caused by changing emissions of greenhouse gases and sulfates, deforestation, ozone depletion, volcanic eruptions, or changes in the solar constant.

This paper presents an overview of the role of the National Aeronautics and Space Administration's Earth Observing System (EOS) satellite data in understanding the role of clouds in the global climate system. The paper also gives a brief summary of the cloud/radiation problem, and discusses the critical observations needed to support further investigations…

[5] Wikipedia Article on "Clouds and the Earth's Radiant Energy System," https://en.wikipedia.org/wiki/Clouds_and_the_Earth%27s_Radiant_Energy_System

2.2. Clouds and the Earth's Radiant Energy System (CERES)

2.2.1. What is CERES?

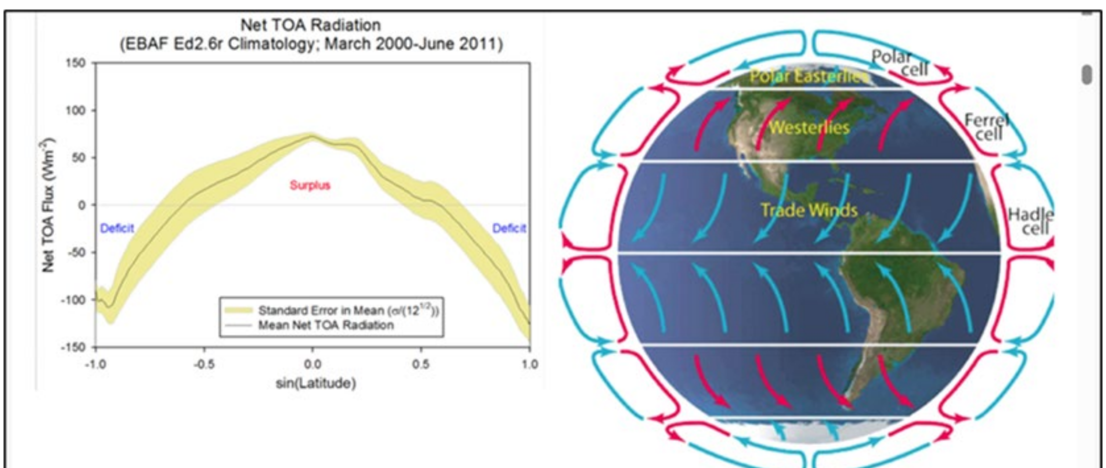
Climate is controlled by the amount of sunlight absorbed by Earth and the amount of infrared energy emitted to space. These quantities–together with their difference–define Earth's radiation budget (ERB). The Clouds and the Earth's Radiant Energy System (CERES) project provides satellite-based observations of ERB and clouds. It uses measurements from CERES instruments flying on several satellites along with data from many other instruments to produce a comprehensive set of ERB data products for climate, weather and applied science research.[6]

2.2.2. Science

In order to make reliable projections of climate and plan as a society for potentially significant environmental changes, a process-level understanding of the flow of energy within the climate system and how it interacts with Earth's subsystems (atmosphere, hydrosphere, lithosphere and biosphere) is needed.

CERES data are enabling this by providing accurate observations of how Earth's energy flows are varying in time and space and how clouds and aerosols are affecting Earth's energy budget. The data help to evaluate and constrain state-of-the-art weather and climate models, which we rely upon to predict our future weather and climate. In addition, CERES provides key data for applied science research involving the energy and agricultural sectors.

The distribution of energy within the climate system is a fundamental property our planet. Regional imbalances in radiation give rise to atmospheric and oceanic circulations, which transport heat around the globe. CERES precisely tracks changes in Earth's radiation budget with remarkable precision and accuracy. CERES data, combined with other data sources describing clouds, aerosols, precipitation, and atmospheric and oceanic state, provide the information needed to understand the underlying processes affecting atmospheric and oceanic circulation changes in a changing climate.



The radiation imbalance between low and high latitudes is balanced by equator-to-pole heat transported by the atmosphere and oceans. The regional pattern of net radiation thus drives the atmospheric and oceanic circulations.

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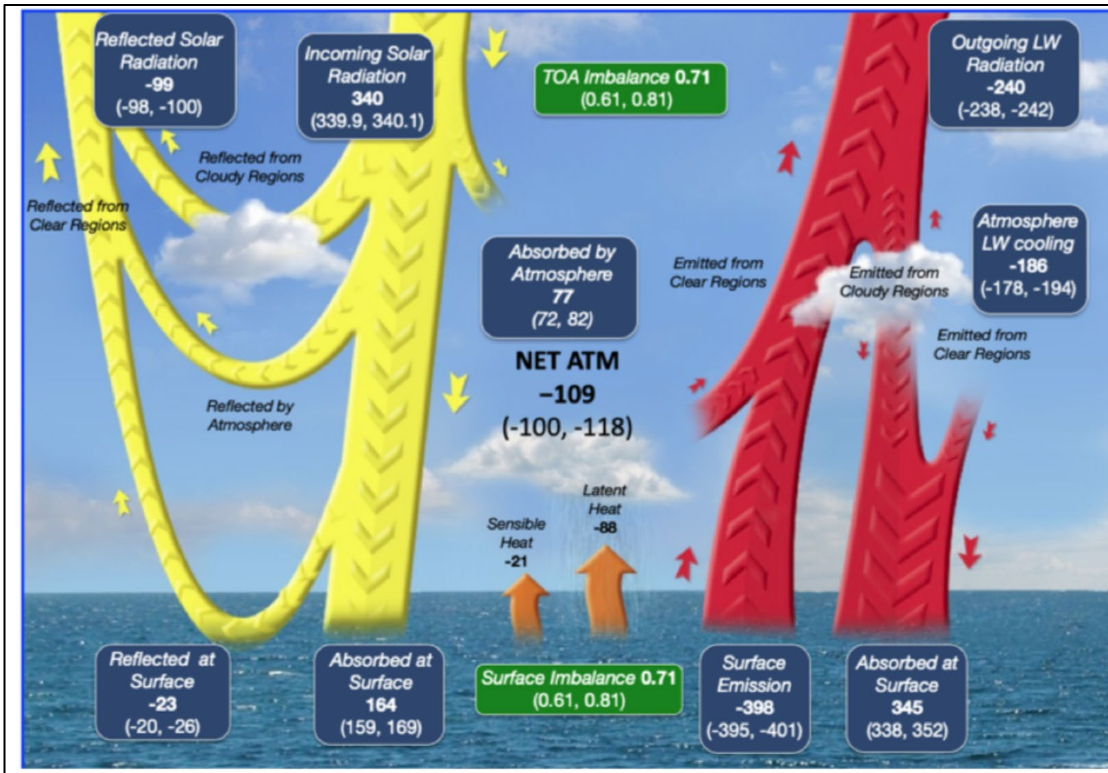
[6] NASA Official: Norman Loeb, Page Editor: Ed Kizer, April 23, 2024 https://ceres.larc.nasa.gov/

Global Mean Energy Budget: *Weather and climate are fueled by the amount and distribution of incoming radiation from the sun. About one-third of the incoming solar radiation is reflected by clouds, aerosols, molecules and the surface, half is absorbed at the surface and the remainder is absorbed by the atmosphere. Earth cools by emitting thermal infrared radiation to space, which nearly balances the energy absorbed from the sun.*

At the surface, temperatures would be 33°C cooler without greenhouse gases like water vapor and CO_2, and clouds. These absorb surface infrared radiation and re-emit most of it back to the surface. Globally averaged, the surface has a net surplus of radiant energy while the atmosphere has a net loss. To make up for this imbalance, sensible (conduction & convection) and latent heat (evaporation) are transferred from the surface to the atmosphere. The surface radiation budget thus sets an upper limit on the hydrological cycle (evaporation/precipitation).

The figure below shows Earth's global mean energy budget derived primarily from the CERES team. Each of the boxes are parameters in CERES data products, available at various time and space scales over the entire CERES period. TOA = top of atmosphere.



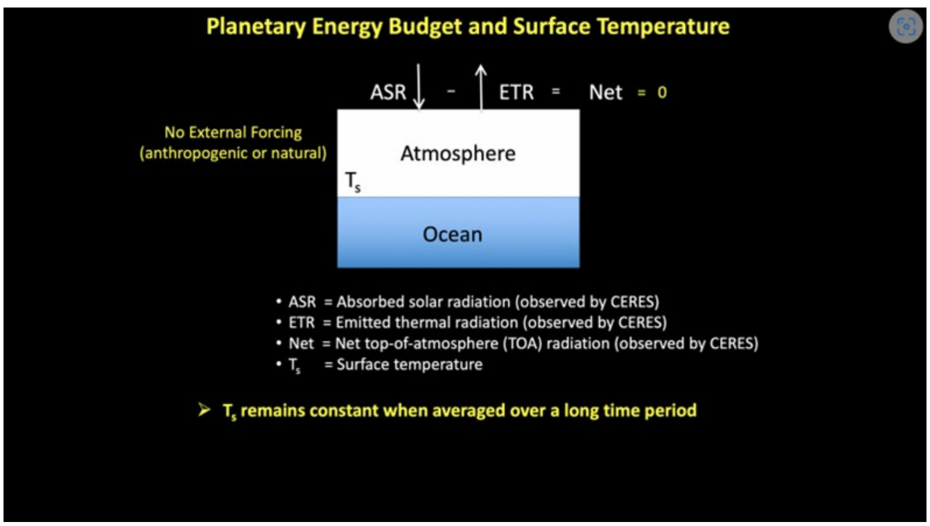
Earth's global mean energy budget for July 2005–June 2015.

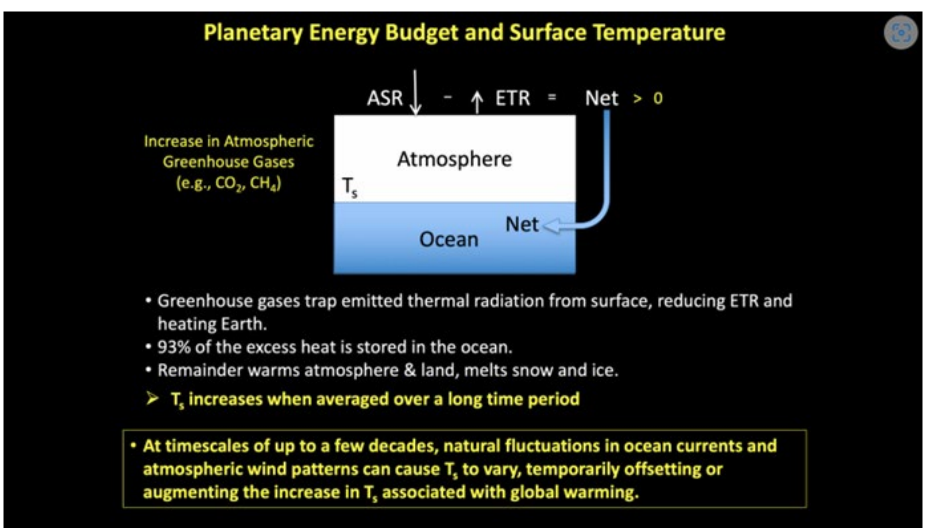
Earth's Energy Budget and Surface Temperature: *With no external forcing on the climate system (human-caused or natural), the long-term average of absorbed solar radiation (ASR) by the planet should be equal to the emitted thermal radiation (ETR) to space. In this scenario, surface temperature remains constant when averaged over a long time period.*

Increases in atmospheric greenhouse gases (CO_2, CH_4, etc.) trap more of the emitted thermal radiation from the surface, thereby reducing ETR and leading to a net gain of energy. This is referred to as "Earth's Energy Imbalance (EEI)". Its magnitude is about 0.7 Wm^2 (or 0.3% of ASR). Most of this excess energy (93%) is stored as heat in the ocean. The remainder warms the atmosphere and land, and melts snow and ice.

At time scales of up to a few decades, natural fluctuations in ocean currents and atmospheric wind patterns can cause surface temperature to vary, temporarily offsetting or augmenting the increase in surface temperature associated with global warming. The so-called "Global Warming Hiatus" between 1999 and 2014 and the current higher-than expected global warming are recent examples.

CERES tracks changes in EEI, ASR and emitted thermal radiation (ETR) and their regional distribution. The observations describe Earth's response to the combined effect of external forcing of the climate system as well as natural fluctuations within it.

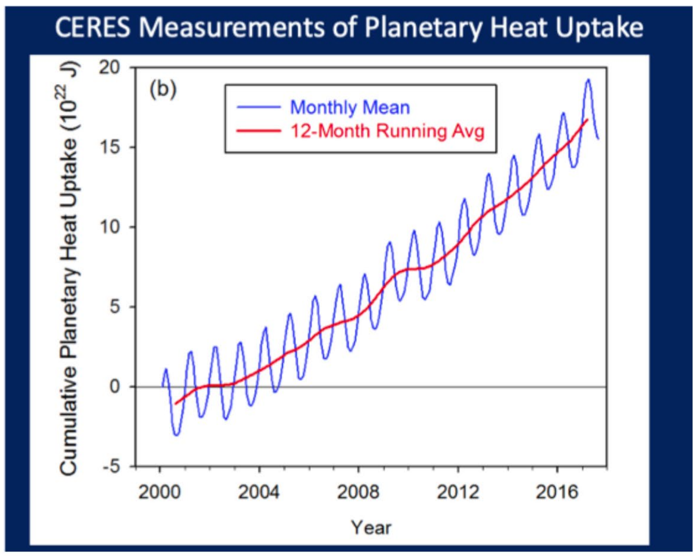




Earth's energy imbalance results in heat being stored in the climate system (mainly in the oceans). It represents the forcing Earth has yet to respond to. In order to restore a balance between ASR and ETR, Earth's mean temperature must increase.

The excess energy being gained by Earth can be tracked very precisely with CERES. The figure on the next page shows how the planetary heat uptake has increased every month since 2000. The oscillations about the long-term trend are due to the annual cycle in global mean net flux, which is positive between October and April and negative between May and September.

The planetary heat uptake accounts for the entire energy added to or removed from the climate system. It arguably provides a more fundamental measure of global warming than global mean surface temperature, which is influenced by other decades-long processes internal to the climate at the air-sea interface.



Cumulative planetary heat uptake from CERES. A one-time adjustment to the CERES global mean net top of atmosphere (TOA) flux for 07/2005-06/2015 was applied to ensure consistency with in-situ EEI over the same period. J = Joules. 1 MWh = 3,600 Joules (J), and the vertical axis of this units are in 10^{22} J, so the energy shown by the chart is huge.

Arctic Energy Budget: *We know that sea-ice fraction has been declining rapidly over the past 30 years. What does CERES tell us about how absorbed solar radiation has changed since 2000? Since sea-ice is far more reflective than open ocean, one might expect the long-term decline in sea-ice fraction to be accompanied by a gain in absorbed solar radiation. However, absorbed solar radiation is also influenced by clouds, which also are very efficient at reflecting solar radiation. It turns out that regional increases in absorbed solar radiation correspond to areas of decline in sea-ice fraction. Changes in cloudiness appear to play a negligible role in observed Arctic darkening.*

One of the greatest challenges in predicting how much the Earth will warm in response to a doubling of atmospheric CO_2 involves the representation of clouds and their interactions with ERB in climate models. CERES data products have been developed specifically to meet this challenge by providing a comprehensive suite of variables that describe clouds and their influence on ERB…

Cloud Radiative Effects (CRE): *Clouds can cool the Earth by reflecting shortwave solar radiation back to space. Clouds can warm the Earth by absorbing longwave infrared radiation from the surface and re-emitting it back down to the surface. These two processes are observed by calculating the difference between the outgoing radiation measured by satellite instruments under clear-sky and cloudy conditions. This difference is called "Cloud Radiative Effects" or CRE.*