**Science Topic 06-17-24**

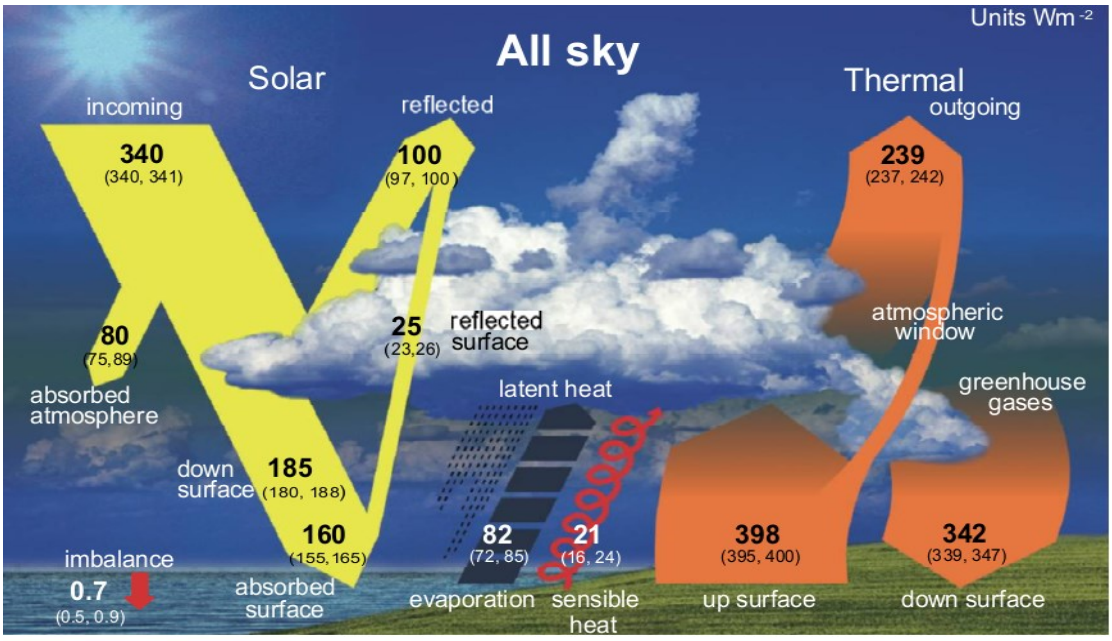
CliSciPol

# Climate Science and Policy for Nonscientists

One picture is worth a thousand words.

## EARTH'S ENERGY BUDGET

Analysis of Earth's Energy Budget ("EEB") shows the importance of clouds to the climate. Since scientists do not understand cloud formation, it shows the limitations of our present understanding of the climate, and, in particular, shows the uncertainty of our understanding of what has caused the global warming over the last 150 years.




The image is the EEB as presented in the most recent IPCC assessment report.[AR6 WGI p.934 (2021)] and demonstrates the central importance of clouds. The numbers in watts per square meter (W/m2) measure energy flows. The net of all the energy flows is what changes the earth's temperature. Virtually all of the earth's energy comes from the sun (incoming 340 with an uncertainty range of 340-341) in the form of shortwave radiation, while energy flowing out is longwave radiation, an important difference. (AR6 WGI p.933). The shortwave radiation coming in (that is not reflected) passes through the atmosphere with limited interference. But the longwave radiation going out, referred to as "Up Surface," is subject to the Greenhouse Effect. Much of it is absorbed by greenhouse gases and retained in the atmosphere, so the "Thermal Outgoing" (239) is significantly less than the Up Surface (398).

At the particular time, shown in the prior image, all the energy flows net to 0.7 in, which is shown in the lower left corner of the image. If over a period of time there is a net flow in, then global warming will occur. So the cause of global warming during a particular period depends on how much the 11 different numbers shown in the prior image (that are used to calculate the net imbalance) change over that period. The IPCC says that the Greenhouse Effect G = 159. (AR6 WGI p.968). This can be calculated, as shown, with an error range of 9.4, which is more than 13 times the net energy imbalance of 0.7. Scientists can not measure G with any precision.

## A Calculation of the Greenhouse Effect

| | W/M2 | Error Range |
|---|---|---|
| Up Surface | 398 | (395, 400) |
| Thermal Outgoing | -239 | (237, 242) |
| | --- | |
| Greenhouse Effect | 159 | (155.4, 164.8) |
| Differential | | 9.4 |

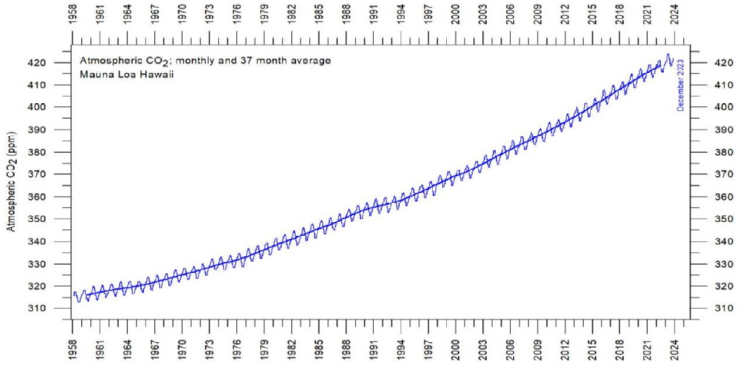
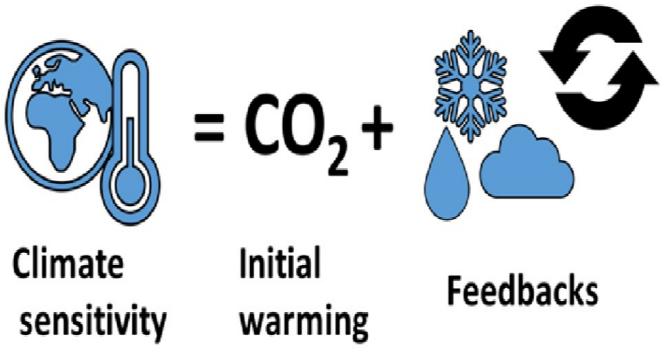



*FIGURE 25: Monthly amount of atmospheric $CO_2$ since March 1958, measured at the Mauna Loa Observatory, Hawaii. The thin line shows the monthly values, while the thick line is the simple running 37-month average, nearly corresponding to a running 3-year average.*

Atmospheric CO2 levels have been rising steadily since 1958. The CO2 Control Knob Theory asserts that rising greenhouse gas levels have been causing virtually all of the global warming since the preindustrial period. This is based on the belief that the other numbers in the EEB have been staying relatively constant while G, the gap between Up Surface and Thermal Outgoing, has been increasing .

A key uncertainty is the extent of feedback effects. Clouds remains the largest contributor to net feedback uncertainty. (AR6 WGI p.978). Many scientists claim that the cloud feedback effects are actually larger than the direct CO2 warming effect.




*Factors that determine climate sensitivity. After increasing carbon dioxide (CO) levels, there is an initial warming. This warming could be amplified or reduced by the net effect of feedbacks (weather processes that change the characteristic of the planet). Diagram by Femkemilene from WikiMedia Commons.*

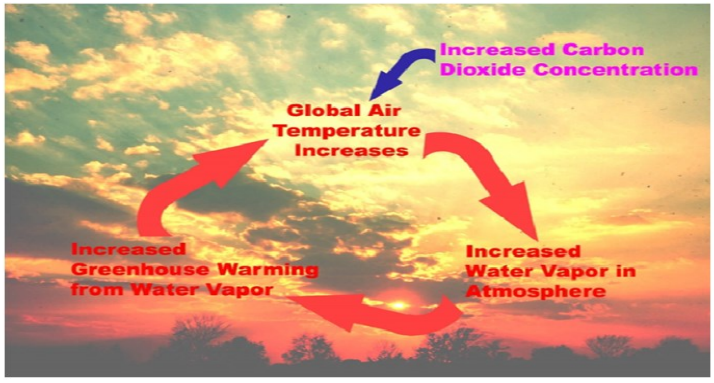
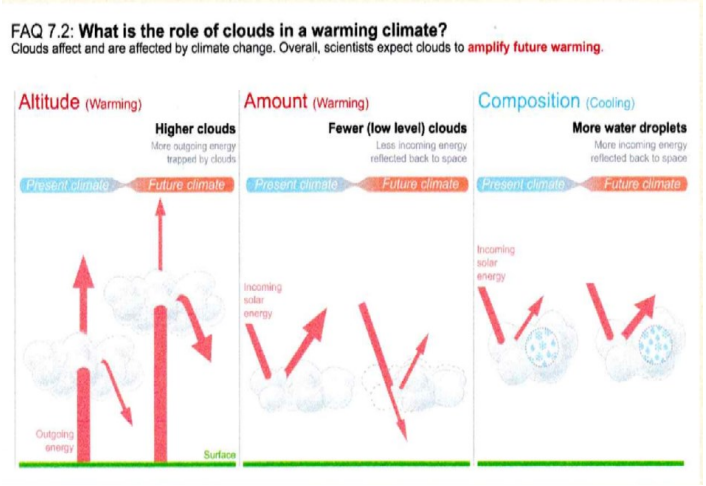
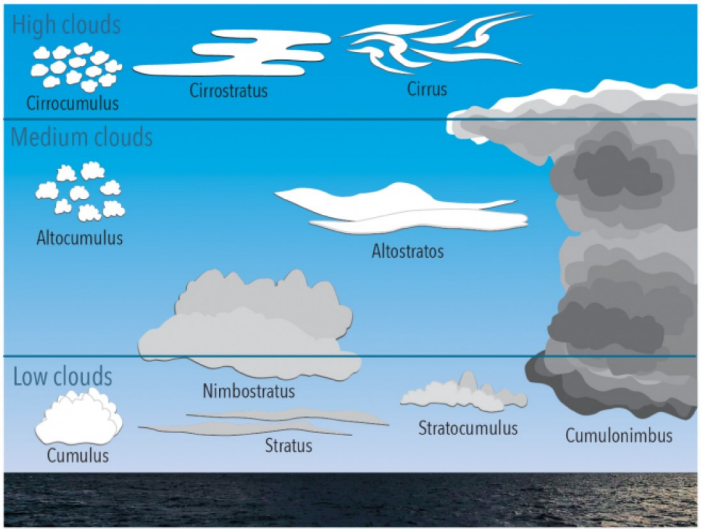



***Fig. 2.**, original caption: "This diagram shows the mechanisms behind a positive water vapor feedback loop. Increases in carbon dioxide, a greenhouse gas, cause a rise global air temperatures. Due to increased evaporation and since warmer air holds more water, water vapor levels in the atmosphere rise, which further increases greenhouse warming. The cycle reinforces itself. The background is a sunset through altocumulus clouds. Credit: NASA and NOAA 9) Historic NWS*

The IPCC believes that such feedback effects amplify human-induced warming. (AR6 WGI p.926). But the IPCC acknowledges a "small probability (less than 10%) of a negative cloud feedback" (AR6 WGI p. 975), i.e. a feedback that would reduce the warming, not amplify it. Some scientists, such as Nobel prize winner, John Clauser, believe that the feedback is negative.

It is agreed that different types of clouds at different altitudes have different feedback effects. Clouds on average cover 60-65% of the earth's land surface and 70% of the oceans. In general, lower level clouds tend to cool the earth while higher level clouds tend to warm the earth. (AR6 WGI p. 971)




There are 10 different types of clouds that exist at different altitudes, that vary from region to region, and that are continually changing in particular regions. The present state of science is incapable of determining the cloud feedback effect with any precision, as acknowledged repeatedly by the IPCC. For example, "Clouds remain the largest contribution to overall uncertainty in climate feedbacks." (AR6 WGI p. 95)

According to the CO2 Control Knob Theory, the greater the atmospheric CO2 level, the larger G (the Greenhouse Effect) should be as more outgoing longwave radiation is absorbed in the atmosphere. But, if anything, the rate of temperature rise has lagged slightly below the rate of CO2 rise.

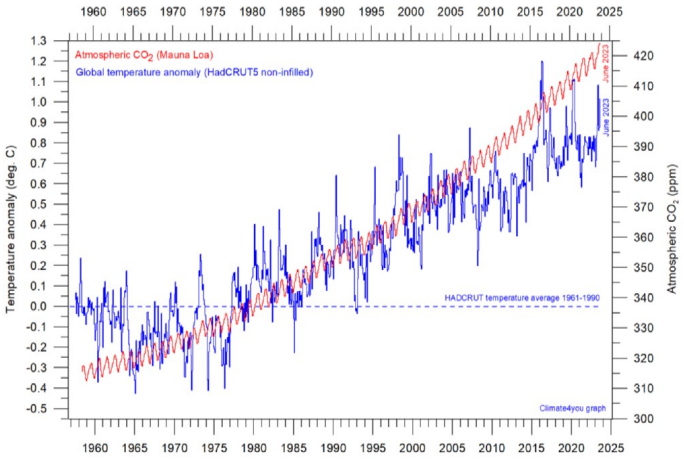
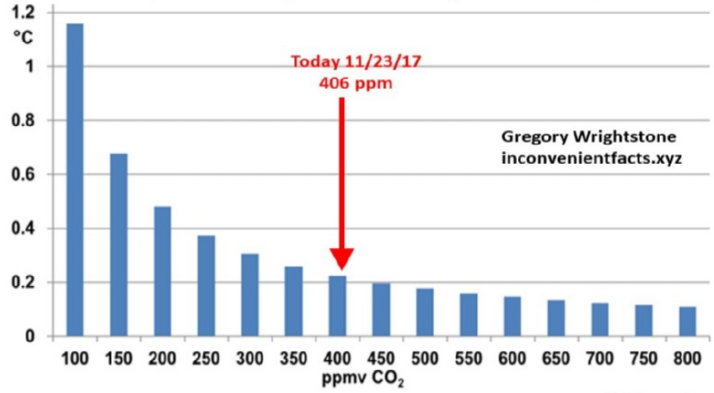


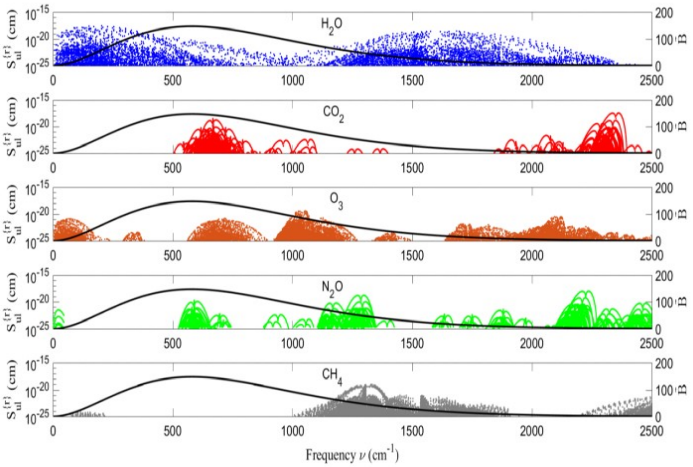

**Figure I-3: Less global warming for each additional 50 parts-per-million-by-volume of $CO_2$ concentration**




**(Graph calculated using IPCC's formula $\Delta T_0 = \frac{5.35}{3.2} ln \frac{C}{C_0}$;**
AR3, Ch. 6.1. Courtesy Monckton 2017)

Some scientists contend that, as CO2 levels rise, there is a saturation effect, i.e. with rising CO2 levels, the atmosphere becomes less able to absorb the outgoing longwave radiation. This has been measured in the lab, and the saturation level can be calculated by formula. This was acknowledged by the IPCC in AR1 p. 49 (1990), but has been largely ignored since.

The reason for the saturation effect is found in quantum mechanics. Molecules of CO2 in the air can absorb energy only of particular wavelengths. So once all the energy of those wavelengths has been absorbed, adding more CO2 to the air does not result in any more absorption. The image shows the energy wavelengths (frequencies) that can be absorbed by the various greenhouse gases. The top line is for H2O (vapor and clouds) and the second line for CO2.




## What are the 3 Most Important Greenhouse Gases?

| | Concentration in the Air ppm | % Total Effect |
|---|---|---|
| Water vapor/ Clouds | 10,000-40,000 | 70-95% |
| CO2 | 415 | 4-20% |
| Methane | <2 | 1-10% |

The prior image also confirms that H20 (water vapor and clouds) absorb by far the most outgoing energy, because H2O molecules can absorb energy over most of the outgoing spectrum, and because there is so much more H2O in the air than CO2 or methane or any of the other trace greenhouse gases. The contribution of H2O varies around the world with the humidity, the cloudiness, and the temperature. There is no agreement on an exact number, but H2O probably causes somewhere between 70% and 95% of the total Greenhouse Effect.

The IPCC focues on the "human-made" greenhouse gases, which omits H2O. [See e.g. this image from AR1 p. xx (1990)]. H2O is not human made. This image shows that the greenhouse effect of CO2 is be 3.7 times (55/15) greater than the effect of methane.

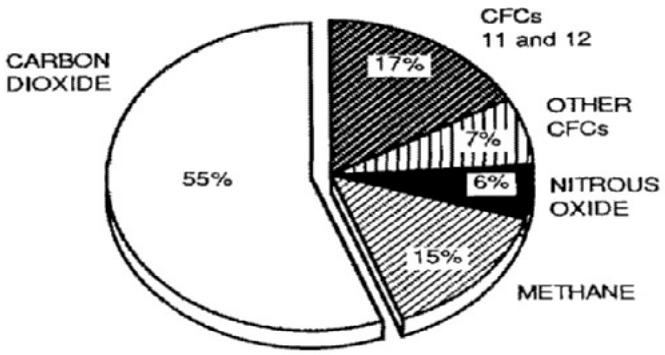
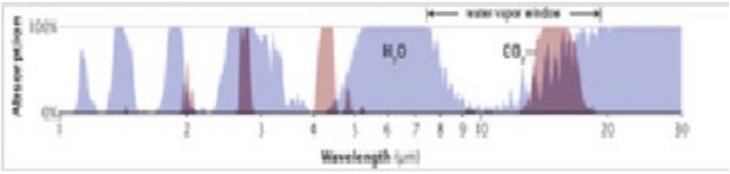


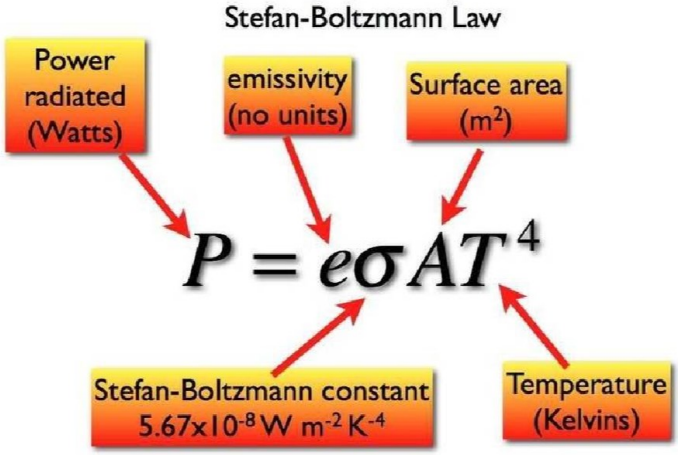

**Figure 7:** The contribution from each of the human-made greenhouse gases to the change in radiative forcing from 1980 to 1990. The contribution from ozone may also be significant, but cannot be quantified at present.



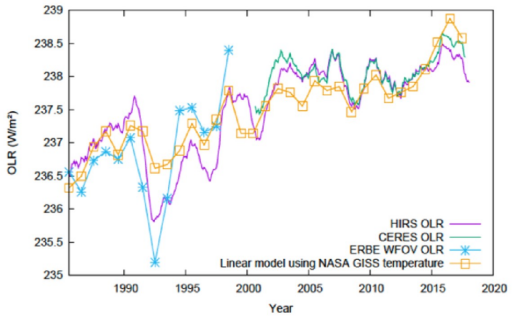
Atmospheric gases only absorb some wavelengths of energy but are transparent to others. The absorption patterns of water vapor (blue peaks) and carbon dioxide (pink peaks) overlap in some wavelengths.[23]

This image is another representation of how much more energy water vapor can absorb than CO2, and it also shows how much the absorption spectrum for CO2 molecules overlaps wavelengths that water vapor already absorbs, which further reduces the Greenhouse Effect from adding additional CO2 to the atmosphere.

As time passes, other numbers in the EEB change. For example, Up Surface emissions increase with temperature according to the Stephan-Boltzman Law. The earth has warmed a little over 1 C since the preindustrial period. (AR6 WGI p.5). This formula calculates that Up Surface emissions will increase 5.47 W/m2 as a result. Meanwhile CO2 has been rising at only 2.5 ppm per year, and the effect of that has been decreasing due to the Saturation Effect.




But most scientists also believe the lower atmosphere is now **saturated** with CO2. Adding more CO2 will have little to no further warming effect. Furthermore, greenhouse gases have a cooling effect in the upper atmosphere. The climate crisis narrative pushed by some scientists argues that increasing levels of CO2 from burning of fossil fuels will continue to warm the earth by trapping more (Outgoing Longwave Radiation – OLR) infrared heat. Based on the greenhouse effect, that theory is plausible. **But the scientific evidence refutes it.**

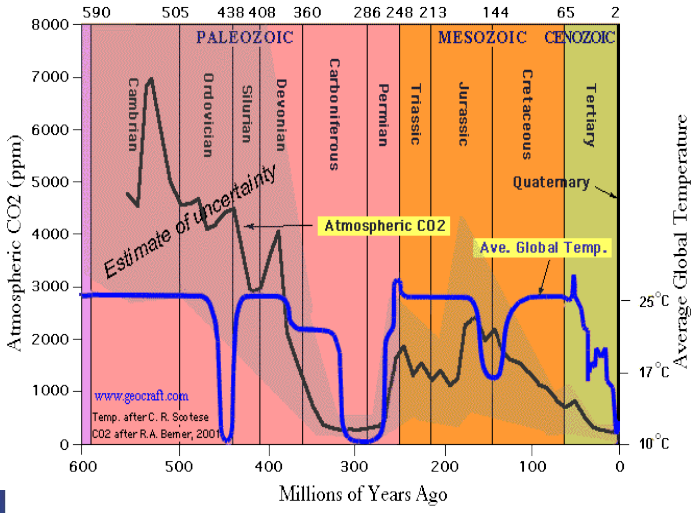


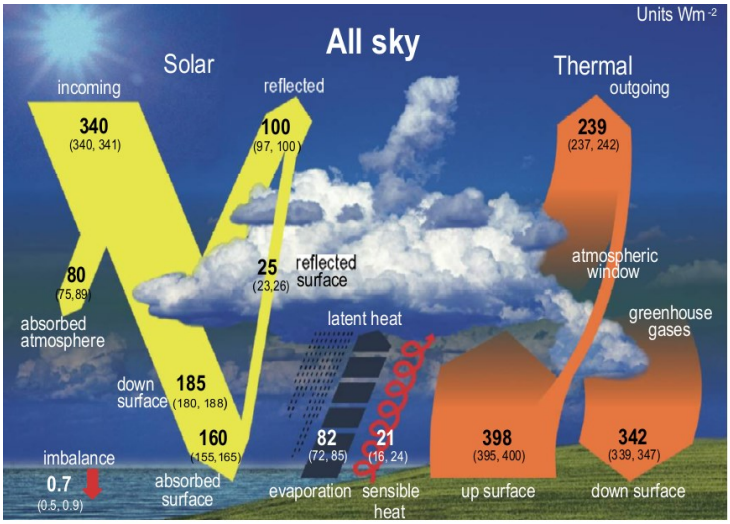

Satellites can now measure how much OLR is escaping to space. **If the climate crisis narrative is true, more CO2 would trap more OLR, so less OLR escaping to space should be detected.**

But since 1985, satellites have detected that **OLR had increased by about 2 W/m2 by 2018**. (Watts per meter squared, W/m2, a Watt is a measure of energy per second ). That observed increasing OLR either means heat is more easily escaping, or the earth is heating via another dynamic.

Satellites in orbit above the atmosphere can measure both Solar Incoming radiation and Thermal Outgoing. From 1985 to 2018 3 different satellite systems measure Thermal Outgoing increasing around 2 W/m2 despite the Greenhouse Effect caused by rising CO2 and other greenhouse gases.

Some significant negative feedback effects must exist, because otherwise the earth would have suffered runaway global warming at various periods in the past. For example, during the Cambrian Era CO2 levels spiked to 7,000 ppm (versus today's 420 ppm) but temperatures did not increase. Over the last 600 million years the earth has usually been much warmer than today and CO2 levels have been much higher.

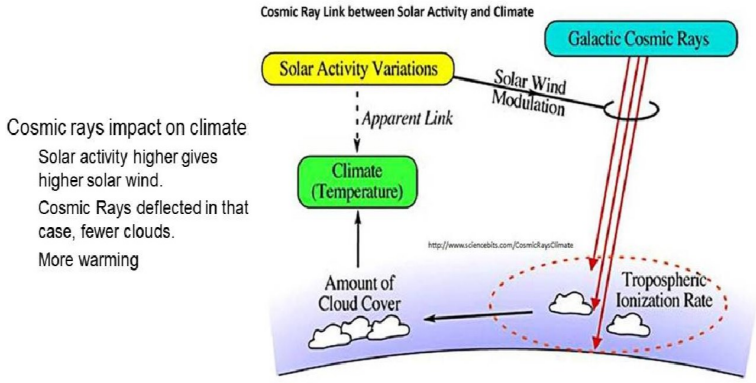



Also crucial in determining the cause of global warming is whether there has been any change in: (1) incoming solar radiation (shown as 340 with an error range of 340-341), or (2) solar radiation reflected off clouds (shown as 100 with an error range of 97-100). If incoming solar was 341 rather than 340, this would more than account for the 0.7 net imbalance. If reflected solar was 99 rather than 100, this would more than account for the 0.7 net imbalance.

## Cosmic Rays Heavily Influence Cloud Formation

The effect of the sun on the climate is extremely complex and, as yet, uncertain and much disputed. (See CLISCIPOL Science Topic: Sun). Of particular relevance here is the theory that varying solar cosmic rays (not shown at all in the EEB) cause changes in the earth's cloud cover and hence the amount of solar radiation reflected. Scientists do not yet understand the process of cloud formation.



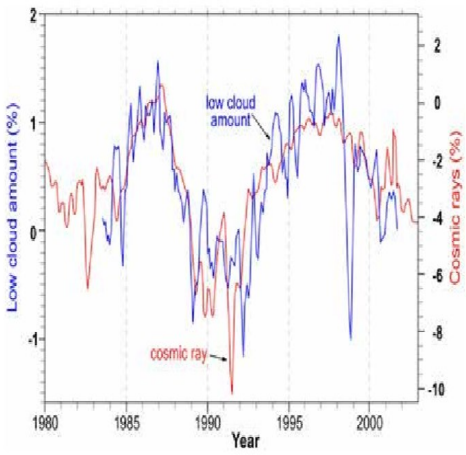
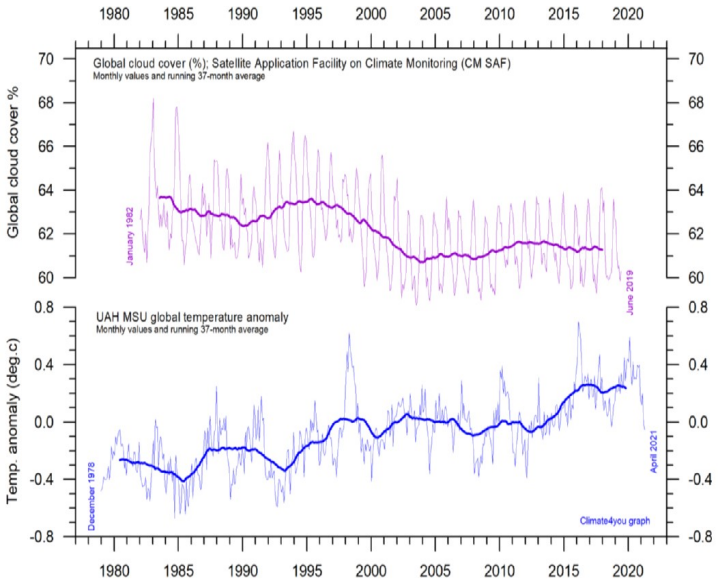
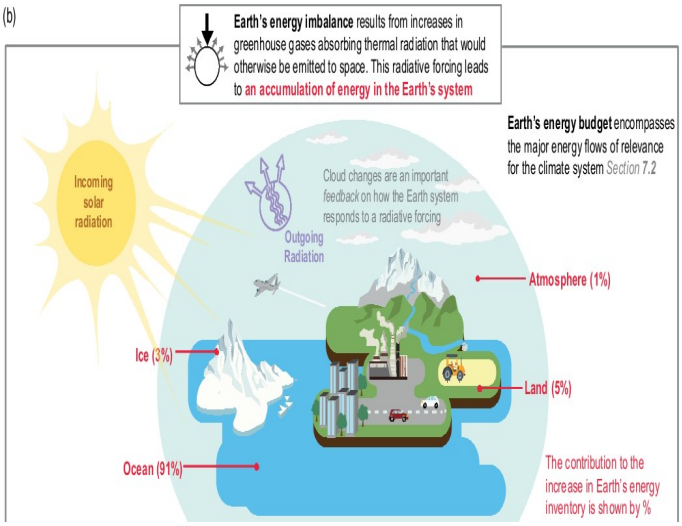




**Figure 3:** Correlation between cosmic radiation and global low cloud cover from 1980-2003 since the beginning of systematic cloud data collection.[157]

A supporter of this theory has produced this graph showing a high correlation between solar cosmic rays and low clouds, which reflect incoming solar radiation and cause cooling.

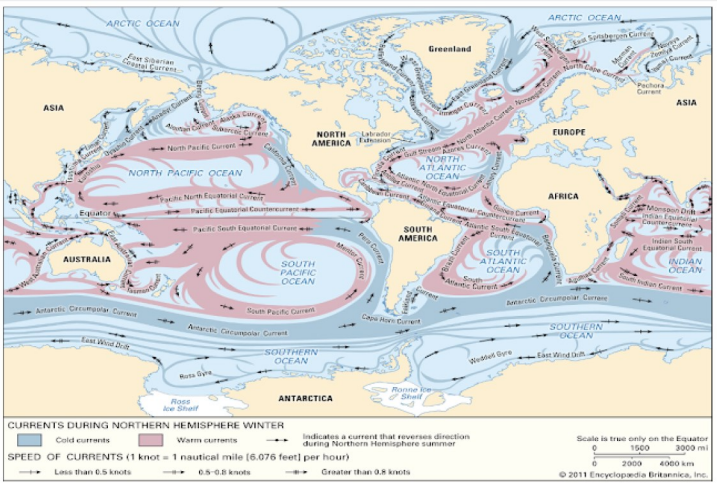
As shown in this graph there is data showing that global cloud cover has been diminishing since 1980 (hence allowing more incoming solar radiation to reach the earth) while could account for the rising temperatures from 1980 to 2020 shown in blue.

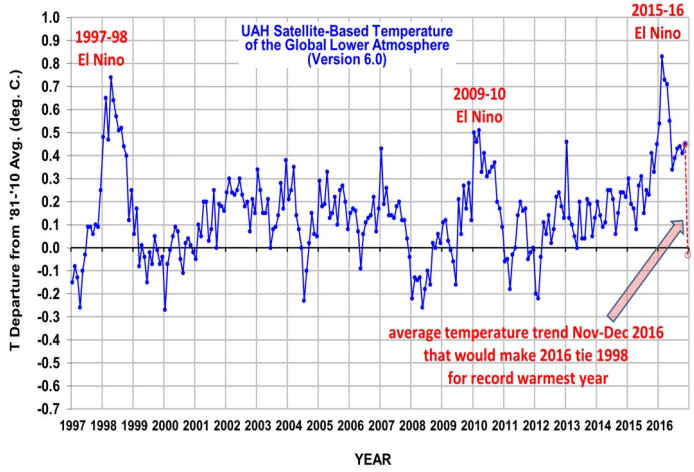



The IPCC's EEB is incomplete in that make no attempt to represent the exchange of heat energy between the oceans and the atmosphere. The oceans cover 70% of the earth's surface. The IPCC acknowledges that some 91% of incoming solar radiation is stored in the oceans. (AR6 WGI p.930). Only 1% is stored in the atmosphere and directly warms the atmosphere.

The earth's oceans have a number of strong and important currents that are driven in part by the temperature differentials that exist in the oceans. The average temperature of the oceans is about 39 F whereas the temperatures of much of the tropical ocean surfaces are above 80 F. Wherever ocean surfaces are warmer than the atmosphere, they warm the atmosphere. Wherever ocean surfaces are colder than the atmosphere, they cool the atmosphere.




There are 2 currents of particular importance for present global warming - (1) the El Nino Southern Oscillation ("ENSO"), and (2) the Atlantic Multidecadal Oscillation ("AMO"). ENSO operates in the Southern Pacific, and AMO in the Northern Atlantic. It is undisputed that the ENSO warm cycle is strong enough to boost global temperatures, as shown.

The AMO includes the Gulf Stream, which has a strong warming influence on Europe and Scandinavia. It also has a roughly 60 year cycle of rising and falling surface temperatures, and, since about 1975, AMO has been in the warming phase of its cycle. Some scientists believe that the AMO has been a major cause of the global warming and cooling since the preindustrial period, as suggested by the adjoining graph. The IPCC rejects this position but does not acknowledge the disagreement on this issue.

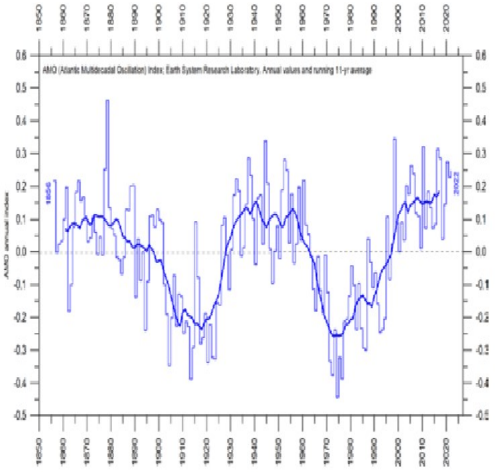


Figure 38: The Atlantic Multidecadal Oscillation

Annual Atlantic Multidecadal Oscillation (AMO) detrended and unsmoothed index values since 1856. The thin blue line shows annual values, and the thick line is the simple running 11-year average. Data source: Earth System Research Laboratory, NOAA, USA.

## CONCLUSION

Global warming or cooling is caused by an imbalance in EEB, the Earth's Energy Budget. To calculate the imbalance numerous variables must be netted out against each other, and the resulting imbalance is a very small number in relation to the error ranges of the numbers used in the calculation. A major source of uncertainty is the role of the sun, clouds, and the oceans. Scientists agree that the Greenhouse Effect has caused some significant part of the global warming since the preindustrial period, but scientists can not presently tell us with any greater precision how much, and the role of the sun, clouds, and the oceans can not be quantified..

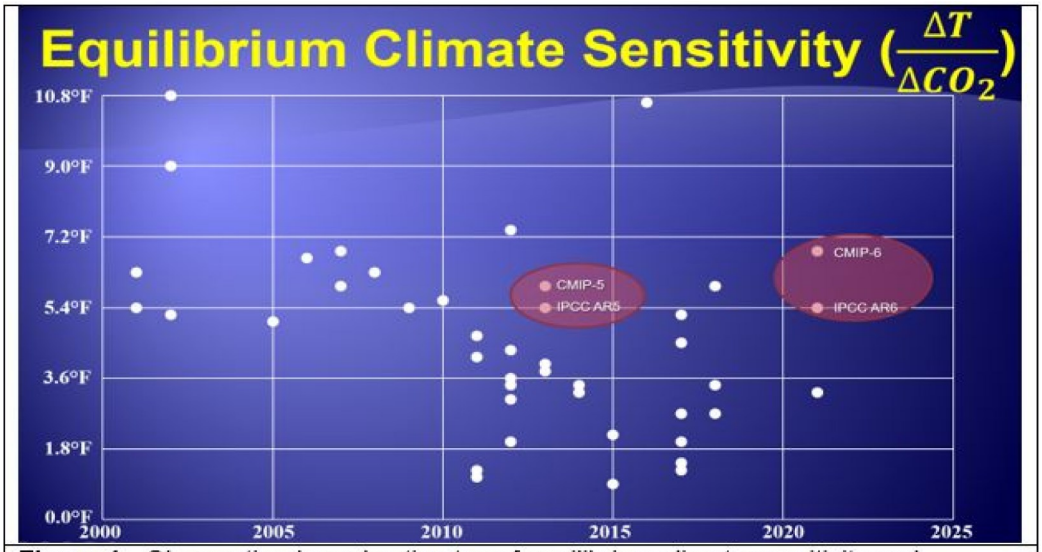



**Figure 1:** Observation-based estimates of equilibrium climate sensitivity and estimates from CMIP-5 and 6 and IPCC AR5 and AR6.

The causation issue can also be approached from a totally different direction by trying to determine the strength of CO2 as a greenhouse gas. Scientists call this effort the attempt to determine Equilibrium Climate Sensitivity ("ECS"). Low ECS (say 1.0-2.0 C = 1.8-3.6 F) means that forces other than CO2 have been contributing to global warming. A high ECS (say 3.0 C = 5.4 F or above), as claimed by the IPCC, supports the CO2 Control Knob Theory that greenhouse gases have caused virtually all the warming since the preindustrial period. As shown, there is significant disagreement among scientists as to the correct number for ECS, and most of the estimates over the last 15 years, based on observations, are below 2.0 C or 3.6 F. (See CLISCIPOL Science Topic: Global Warming to 2100).

## Works Cited

Intergovernmental Panel on Climate Change First Assessment Report, (1990) (AR1)

Intergovernmental Panel on Climate Change Assessment Report 6, Working Group I, The Physical Science Basis (2021) (AR6 WGI)