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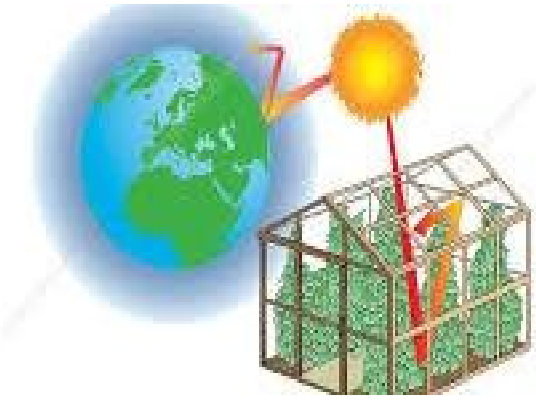
CliSciPol

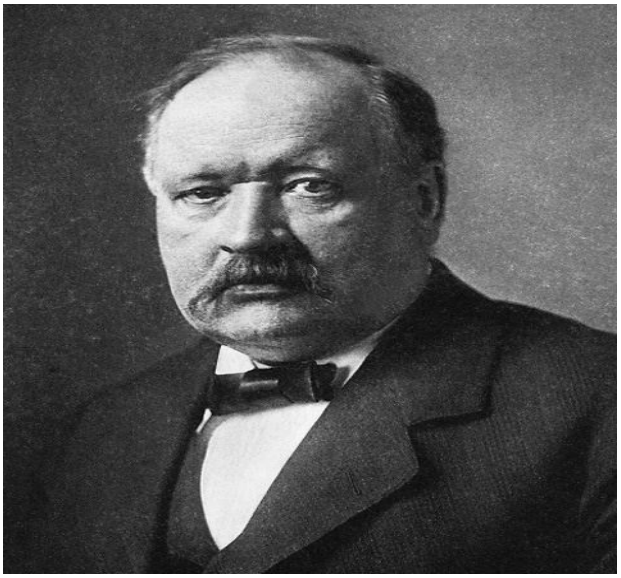
Climate Science and Policy for Nonscientists

One Picture is Worth a Thousand Words.

CO2 History since 1827 Shows How Much Climate Science Changes and How Much Uncertainty Still Exists as to the Strength of CO2 as a Greenhouse Gas.

In 1827 Fourier coined the term "greenhouse effect" to describe the heat trapping effect of certain gases in the atmosphere. That term has stuck although a better analogy is that of a sponge. The greenhouse gases are fairly evenly distributed throughout the atmosphere. They absorb outgoing heat radiation and then re-emit it in random directions with some of it coming back towards the earth. The effect is to delay the escape of heat energy from the earth. There is no barrier analogous to a greenhouse roof.

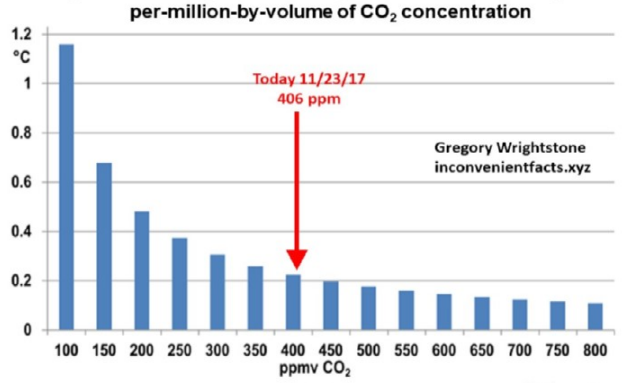




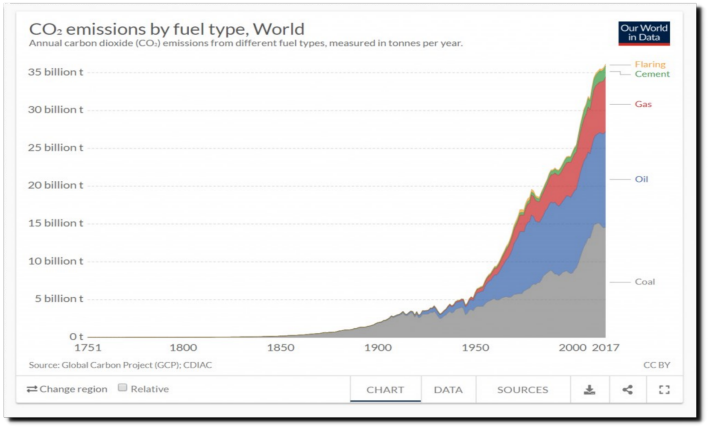
In the 1860s Tyndall identified CO2 as one of the greenhouse gases. In the 1890s Arrhenius (pictured at left) first theoretically assessed the strength of CO2 as a greenhouse gas, which scientists call its "Equilibrium Climate Sensitivity" or "ECS." ECS is defined as the amount the world will warm if CO2 levels are doubled. Arrhenius first estimated ECS = 5-6 C and was delighted, because such warming would greatly benefit his home country, Sweden. By the early 1900s he had further refined has theoretical calculations and concluded that ECS was in the range of 1.5-4.5 C.

After Arrhenius's theoretical estimates, scientists, such as Angstrom, started measuring ESC in the lab. They discovered two things: (1) as measured in the lab, ECS was only about 1 C, and (2) ECS was a variable. As concentrations of CO2 rise, ECS decreases at a logarithmic rate. This is known as the Saturation Effect. The wetter a sponge gets, the less additional liquid it can absorb. These discoveries caused scientists to conclude that, although CO2 did have a warming effect, the effect was relatively small at the prevailing CO2 levels and would decrease as CO2 levels rose.

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

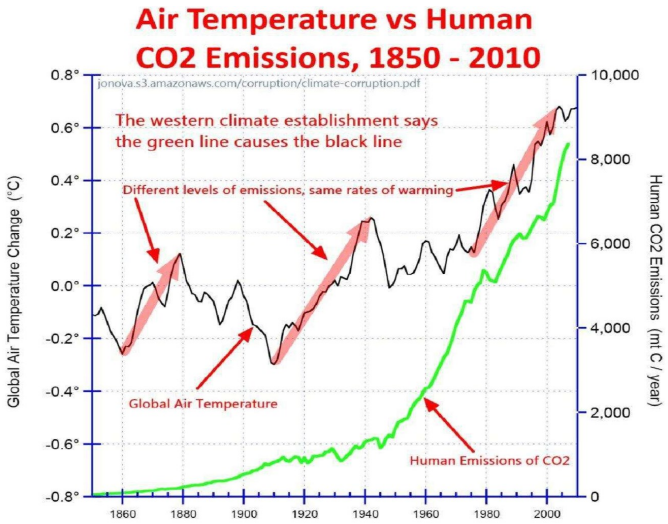


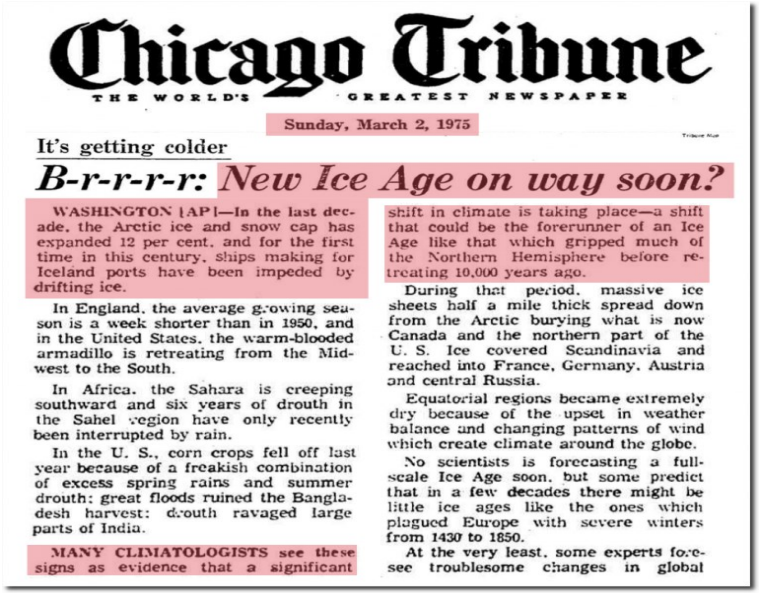
(Graph calculated using IPCC's formula $\Delta T_0 = \frac{5.35}{3.2} ln \frac{C}{C_0}$;
AR3, Ch. 6.1. Courtesy Monckton 2017)



In the first half of the 1900s human CO2 emissions were relatively small and were rising at a relatively slow rate. This changed around 1950 when the amount and the rate of emissions both increased dramatically. This dramatic rise has continued ever since at a relatively linear rate.

From 1910 to 1940 the irrelevance of CO2 was confirmed by actual measured world temperatures, which rose dramatically while atmospheric CO2 levels rose only from 300 ppm to 310 ppm, an increase of only 3%., which was much too small to have caused the 1910-1940 warming, and which suggested that natural forces were the principal drivers of world temperature change .





Chicago Tribune

THE WORLD'S GREATEST NEWSPAPER

Sunday, March 2, 1975

It's getting colder

B-r-r-r-r: New Ice Age on way soon?

WASHINGTON (AP)—In the last decade, the Arctic ice and snow cap has expanded 12 per cent, and for the first time in this century, ships making for Iceland ports have been impeded by drifting ice.

In England, the average growing season is a week shorter than in 1950, and in the United States, the warm-blooded armadillo is retreating from the Midwest to the South.

In Africa, the Sahara is creeping southward and six years of drouth in the Sahel region have only recently been interrupted by rain.

In the U. S., corn crops fell off last year because of a freakish combination of excess spring rains and summer drouth; great floods ruined the Bangladesh harvest; drouth ravaged large parts of India.

MANY CLIMATOLOGISTS see these signs as evidence that a significant shift in climate is taking place—a shift that could be the forerunner of an Ice Age like that which gripped much of the Northern Hemisphere before retreating 10,000 years ago.

During that period, massive ice sheets half a mile thick spread down from the Arctic burying what is now Canada and the northern part of the U. S. Ice covered Scandinavia and reached into France, Germany, Austria and central Russia.

Equatorial regions became extremely dry because of the upset in weather balance and changing patterns of wind which create climate around the globe.

No scientists is forecasting a full-scale Ice Age soon, but some predict that in a few decades there might be little ice ages like the ones which plagued Europe with severe winters from 1430 to 1850.

At the very least, some experts foresee troublesome changes in global

From 1940-1975 world temperatures fell while from 1950-1975 CO2 levels rose significantly, thus demonstrating tthe existence of cooling forces significantly more powerful than the CO2 warming force. In the 1970s scientists were warning of a coming ice age.

But in 1975 temperatures started to rise. In 1979 the Charney Report was published, which acknowledged that the direct CO2 greenhouse effect was relatively weak, as previously measured by scientists like Angstrom (ECS = about 1 C), but Charney presented a theoretical argument that rising CO2 levels also created significant cloud formation feedback effects. So the direct effect of a doubling of CO2 might be only a 1 C temperature rise, but it was theorized that cloud feedback effects might add another 0.5-3.5 C of warming. The report concluded with a best estimate that ECS = 3 C (1 C of direct warming plus 2 C of cloud formation feedback effects) with a range of 1.5-4.5 C.

IPCC #1 1990 REPORT - CONCLUSION ON CAUSATION

- "The size of [the warming over the last 100 years] is broadly consistent…with natural climate variability.
- Thus the observed increase could be largely due to this natural variability."

The IPCC issues assessment reports roughly every six years. Temperatures continued to rise after 1990, and the 1996 report (AR2) concluded that the "balance of the evidence" showed a "discernable" human influence on global climate. With every AR, up to and including AR6 (2021) the IPCC's conclusion on causation has changed, demonstrating that the science is not at all settled on the causation issue.

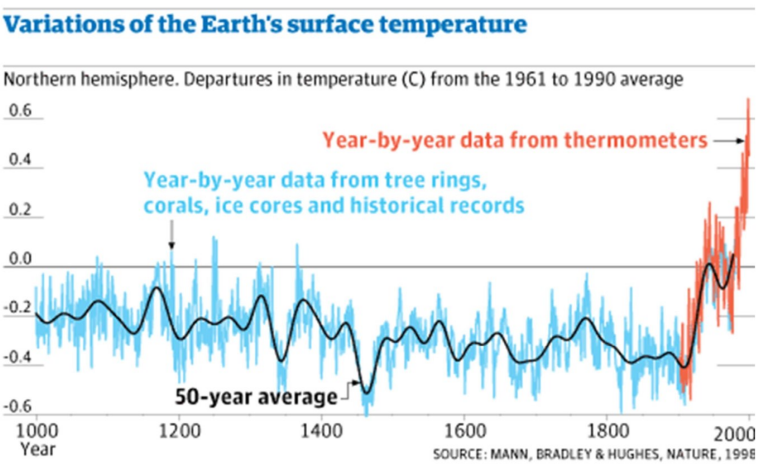


Figure 1. Factors that Determine Climate Sensitivity

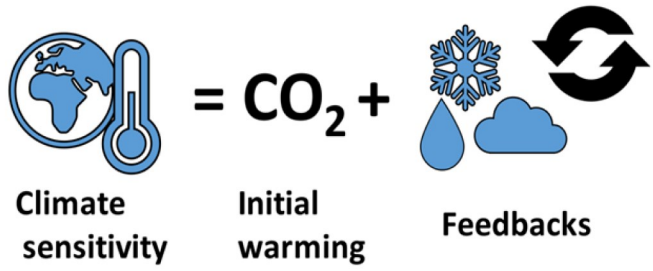


Figure 1. After increasing carbon dioxide levels, there is an initial warming. This warming could be amplified or reduced by the net effect of various feedbacks (weather processes that change the characteristics of the planet). Diagram by Femkemilene from WikiMedia Commons.

As temperatures continued to rise in the 1980s, the Charney theory acquired more and more backers, and by the late 1980s scientists were warning about dangerous threatened global warming. The United Nations' Intergovernmental Panel on Climate Change (the "IPCC") was formed in 1988 and issued the first of its comprehensive assessment reports in 1990. Perhaps the most important finding in each AR is the finding on the causation of the 20th century global warming. AR1 concluded that the warming over the prior 100 years could be largely due to natural variability.

IPCC #2 1996 REPORT - CONCLUSION ON CAUSATION

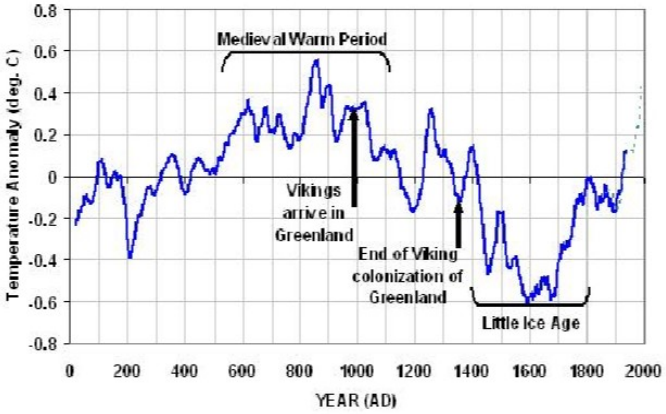
- **"The balance of evidence suggests a discernable human influence on global climate."**

In 1998 Michael Mann published a paper with a world temperature reconstruction going back a thousand years and showing temperatures flat up to the post-industrial period and then rising dramatically as the world industrialized. This graph is colloquially known as the "hockey stick" graph. The IPCC now regularly refers to the modern warming as "unprecedented" in relation to prior centuries, as shown in this graph.

AR3 (2001) gave determinative weight to the Mann paper in concluding that natural variability over the prior centuries was negligible, and that therefore most of the warming over the "last 50 years" (1951-2001) "likely" (better than a 66% chance) was due to the greenhouse effect. But from 1940-1975 world temperatures were declining, as shown above, so the warming period addressed was the 26 years, 1975-2001. AR3 did not discuss the causes of the 1910-1940 warming.

IPCC #3 2001 REPORT - CONCLUSION ON CAUSATION

- "MOST of the observed warming over the last 50 years is LIKELY to have been due to the increase in greenhouse gas."



In reaching its conclusion AR3 ignored the prior scientific majority view that there had been a Medieval Warm Period ("MWP"), significantly warmer than the present, and a Little Ice Age that was significantly colder than the present. The traditional understanding was that the post-industrial warming was primarily a normal, natural recovery from the unusual temperature lows of the Little Ice Age.

The MWP temperature has been much debated and has been the subject of over 100 papers that reach significantly different conclusions. But the great majority of the papers, as shown, have concluded that the MWP was warmer than today (the Current Warm Period). When the Vikings came to Greenland around the year 1000, it was, in fact, a green land - hence the name. The Viking settlement was possible only because the climate was warm enough to allow barley to be grown. Then as the climate cooled with the advent of the Little Ice Age, crops failed, and the Viking Greenland settlements had to be abandoned.

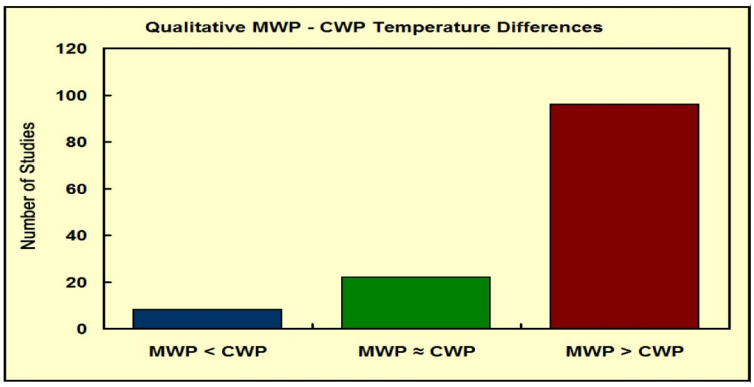


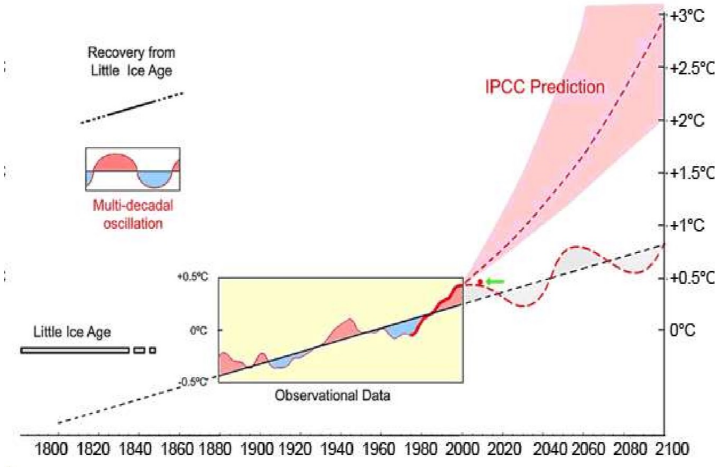
Figure 4.2.2.3. The distribution of studies that allow a qualitative determination of whether peak Medieval Warm Period temperatures were warmer than (red), equivalent to (green), or cooler than (blue) peak Current Warm Period temperatures.

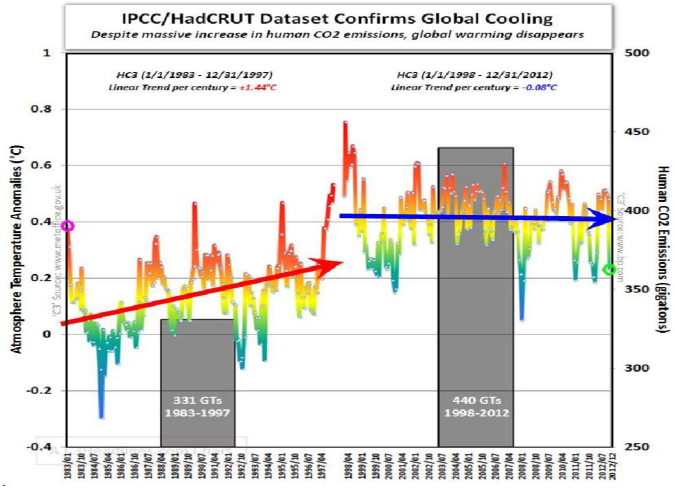
IPCC #4 2007 REPORT - CONCLUSION ON CAUSATION

- "MOST of the observed increase in global average temperatures since the mid-20th century is VERY LIKELY due to the observed increase in greenhouse gas."

In 2007 in AR4 the IPCC went further than it had gone in AR3 to conclude that "most" of the warming since 1951 was "very likely" (better than a 90% chance) caused by greenhouse gases. Again the warming 1910-1940 was not addressed. The likelihoods in IPCC ARs are subjective estimates made by principal authors. They are not findings contained in published papers, and the rationales for the various estimates are not explained.

In AR4 the IPCC presented an actual prediction (based on computer climate models) of 3 C warming over the 21st century although the actual measured (observed) temperature trend was only around 1 C per century. All the models used by the IPCC assumed ESC => 3 C based on the Carney theory (still unproven) that there will be large cloud formation feedback effects.



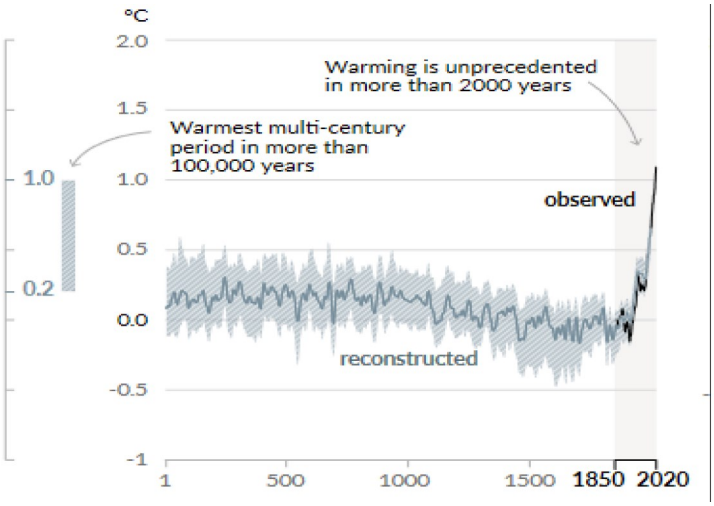


In the years after 2007 and after AR4's publication, a number of published papers revealed serious flaws with the data and methodology used by Mann in creating his "hockey stick" graph. Mann's conclusions were generally discredited. Also, measured world temperatures from year-to-year ceased increasing. In fact, they were arguable flat, or even very slightly declining, from 1998-2012, suggesting that ECS was much lower than previously believed.

As a result in AR5 (2013) the IPCC backed off its causation conclusion in AR4 (2007). It increased its confidence in its conclusion to "extremely likely" (better than a 95% chance) but only found that greenhouse gases were responsible for more than "half" of the warming 1951-2010. The IPCC acknowledged, in effect, that natural forces and natural variability could have caused up to half of that warming, which only existed from 1975-1998. Again the warming 1910-1940 was not addressed.

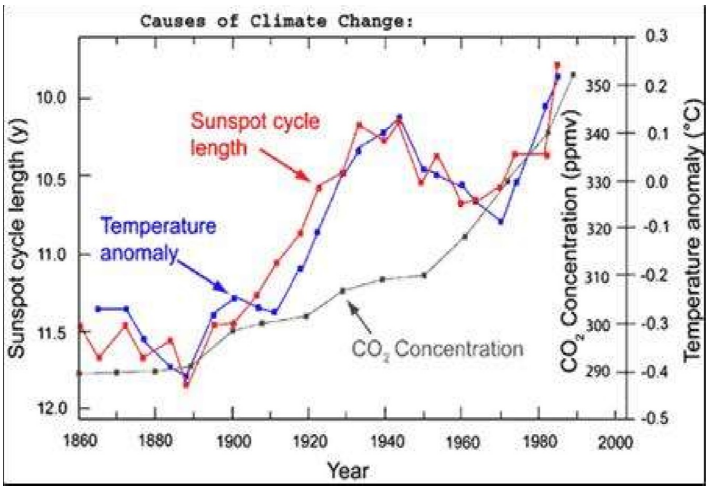
IPCC #5 2013 REPORT - CONCLUSION ON CAUSATION

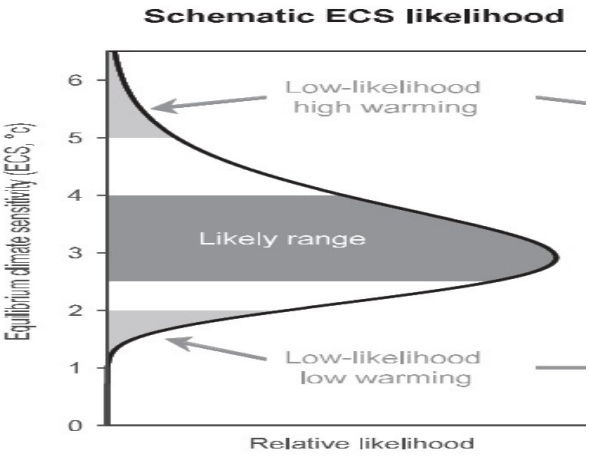
"It is EXTREMELY likely that MORE THAN HALF of the observed increase in global average surface temperature from 1951-2010 was caused by the increase in greenhouse gas."



In AR6 (2021) the IPCC brought back the hockey stick graph (although not relying on Mann's publications) and again claimed that modern temperatures are "unprecedented." (AR6 WGI p.6). (See Fn.1) . The IPCC concluded that, since the pre-industrial period, global surface temperature has risen 1.09 C and that human activity had caused about 1.07 C of the 1.09 C. (AR6 WGI p.5). There was no explanation as to how human activity could have caused the warming 1910-1940 when CO2 levels were hardly rising at all.

It is now generally agreed that the world has, in fact, warmed about 1.1-1.2 C from the pre-industrial period, and that human activity has caused some significant amount of this warming. But there is significant disagreement as to the amount of this warming that has been caused by natural forces and by natural variability. For example, many scientists believe that solar variability has caused a significant amount of the warming. (See on this website the Science Topic titled "Sun").





Accepting for the moment the IPCC position that rising CO2 levels have caused most of the post-industrial world temperature rise, there remains the question of CO2's strength as a greenhouse gas, which determines how much temperatures will rise in the future. What is the correct value for ECS? Unfortunately there remains to this day great uncertainty as to cloud formation feedback effects, which, according to the Charney theory, make up about 2/3ds of ECS. AR6 could only state a "likely" range for ECS between 2.5 C and 4.0 C . (AR6 WGI p. 58) and a "very likely" range of 2-5 C. These are huge uncertainties.

Charney and the IPCC have theorized their ECS values. By contrast, over the last 20 years there have been numerous published papers that estimated ECS based on actual current measured data. Three important generalizations can be made about these estimates: (1) Scientists still widely disagree on the correct ECS value. (2) There is a distinct downward trend in the estimates. (3) Most of the estimates made in the last 10 years are between 1 C and 2 C (1.8 F and 3.6 F), much lower than the IPCC "best estimate" of 3 C. (AR6 WGI p.93).

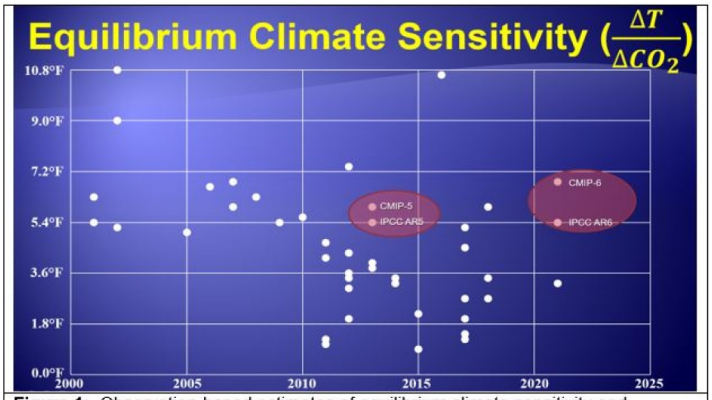
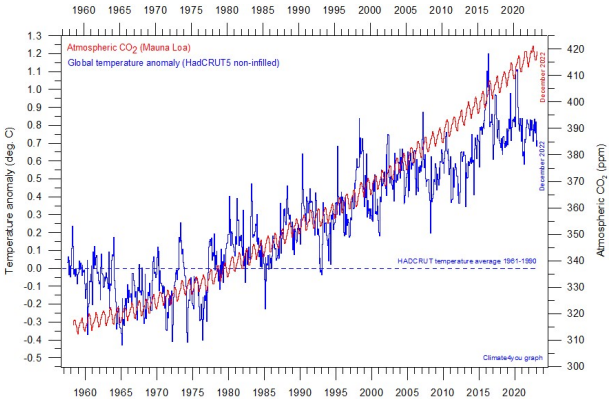
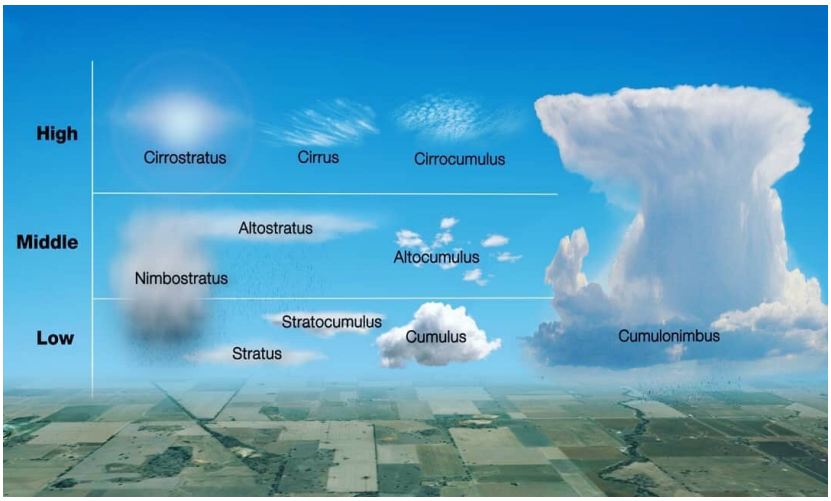


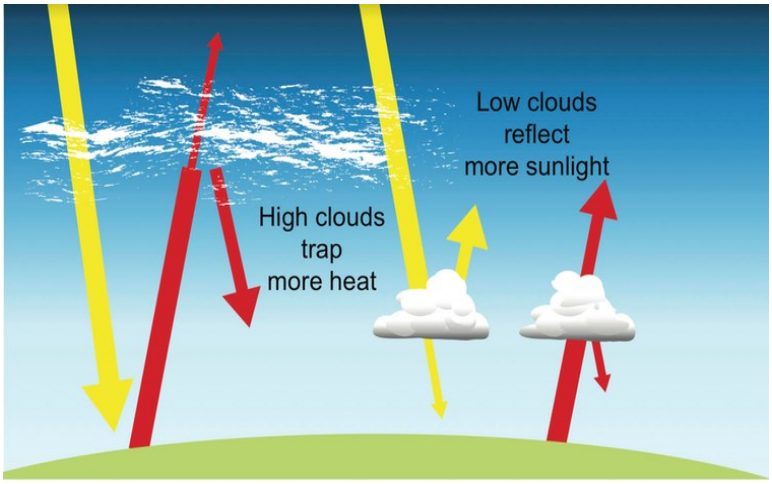
Figure 1: Observation-based estimates of equilibrium climate sensitivity and estimates from CMIP-5 and 6 and IPCC AR5 and AR6.



The ECS estimates have been trending downward primarily, because, ever since the rate of CO2 rise became significant around 1960, world temperatures have only been rising slowly, and arguably now at a slower rate, than the rise of CO2. If there were significant cloud formation feedback effects, as theorized by Charney and by the IPCC, these effects should have caused world temperatures to rise much more rapidly than they have over the last 60 years. The IPCC still has no explanation for the 1910-1940 temperature rise, which suggests the existence of warming forces other than human activity.

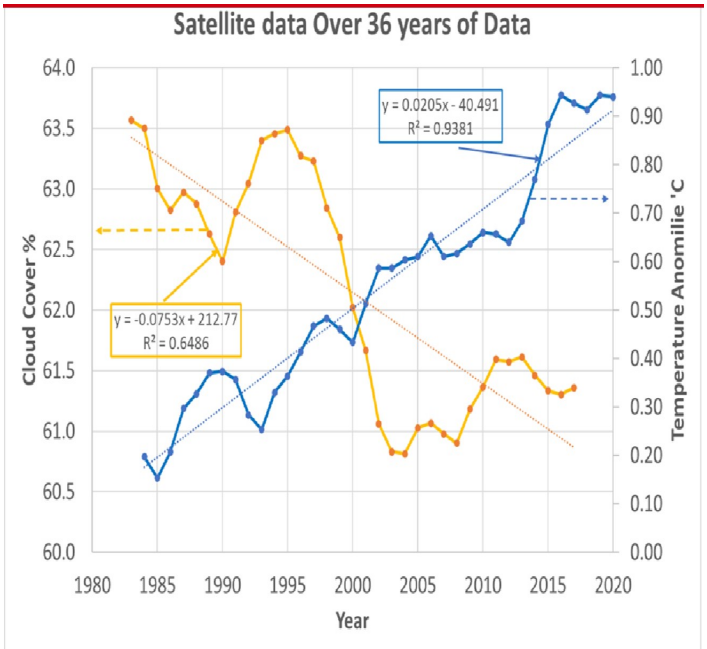
The unfortunate reality is that clouds are very complex. There are 10 basic types of clouds that tend to exist at different altitudes. Each type of cloud affects differently the flow of heat energy in the atmosphere. Scientists still do not understand the process of cloud formation and can not model cloud behavior.





And clouds tend to have different effects depending on their altitude. Some types of clouds at particular altitudes have a cooling, as opposed to a warming, effect.

Scientists have relatively little hard data on clouds, because they are so variable and so difficult to measure, but some of data shows that world cloud cover has decreased while world temperatures have been rising. The Charney theory calls for cloud cover to be increasing, not decreasing. Some scientists argue that the decrease of cloud cover has caused some significant part of the modern global warming, because less cloud cover means more solar radiation can reach the earth. The cause of the decreasing cloud cover is unknown, and the significance of the decrease, if it exists, is disputed.

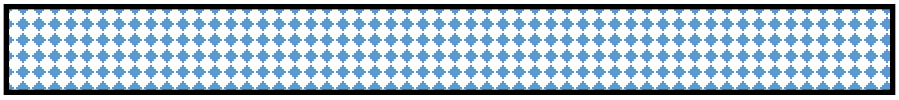


CONCLUSION

Scientists' today still do not understand cloud formation feedback effects and can not calculate them with any degree of certainty. But all the IPCC models that calculate dangerous future warming assume large cloud formation feedback effects that result in ECS = 3 C or more. The IPCC admits the extent of the uncertainty when it acknowledges a "very likely" range for ECS of 2-5 C. This huge range of uncertainty spans outcomes from beneficial warming (ECS = 2C) to very dangerous warming (ECS = 5 C).

Many recently published papers estimate ECS to be in the range of 1-2C, based on actual data. An ECS in this range results in warming over the next century that is clearly mild and beneficial. (See on this website the Science Topics posts "Global Warming to 2100" and "Greening World").

Footnote 1: The hockey stick graph in AR6 (2021) has been disputed for basically the same reasons as was the original Mann hockey stick graph. Even if the conclusions of the particular paper that presented the new graph are accepted as based on valid evidence, they represent a minority view of world temperatures over the last 1,000 years.



All citations are to the Intergovernmental Panel on Climate Change's publication, Climate Change 2021 The Physical Science Basis, the first part of the Sixth Assessment Report (AR6).