Science Topic 02-25-25

CliSciPol

Climate Science and Policy for Nonscientists

One picture is worth a thousand words.

Climate Change, Detection, Causation, Models, Attribution—Definitions and Basic Principles

DEFINITIONS [IPCC AR6 WGI p.2222(2021)]

CLIMATE is usually defined as the average of the weather. … The classical period for averaging is 30 years, as defined by the World Meteorological Organization.

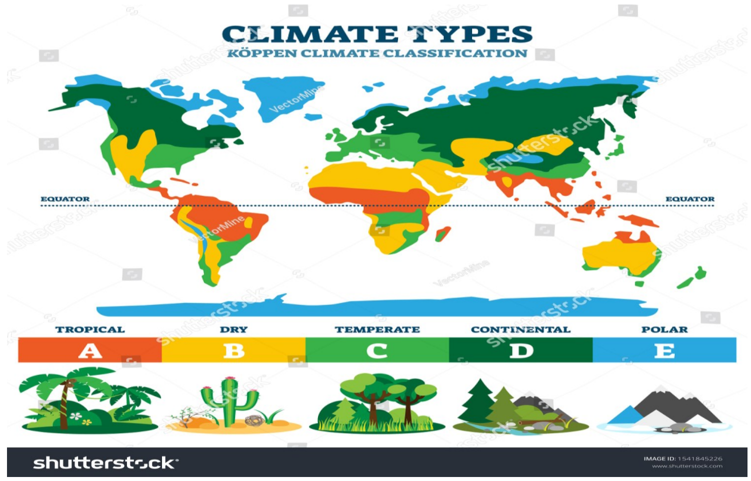
CLIMATE CHANGE is a change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer.

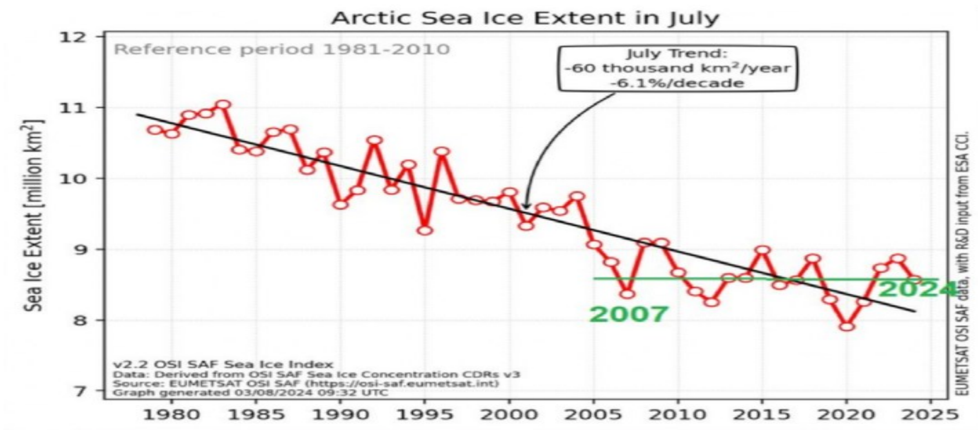
There is no precise definition of "climate" or "climate change." The definitions of these terms from the IPCC's 6th Assessment Report (2021), as set out above, are vague. Another short definition of climate change is -

A statistically significant change in some climate variable over a significant period of time.

Statistical significance is usually considered to require the 90% or 95% confidence level. A significant period of time is usually considered to be at least 30 years. But the period can be much longer depending on the natural variability of the variable being studied. Climate change can exist in a particular region or regions of the world as well as globally.

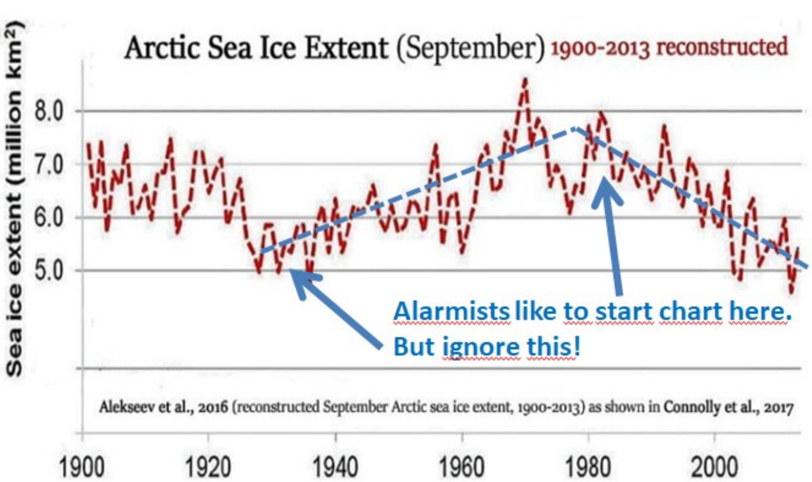
Scientists can calculate an average world temperature, but this is a mathematical construct. There is no such thing as a single world climate. Scientists generally divide the earth's land, which covers only 30% of the earth's surface, into five different, major climate regions. Changes in one land climate region are not necessarily matched in the others, and changes can be beneficial in one or more region but detrimental in one or more other regions.





DETECTION

The IPCC defines "detection" as "the process of demonstrating that climate...has changed in some defined statistical sense." The likelihood of occurrence by chance due to internal variability alone must be determined to be small, for example, <10%." (AR6 WGI p.2226). This corresponds to the 90% confidence level. But internal variabilities with long cycles complicate detection. For example, as shown above, a downward trend line can be drawn for Arctic sea ice over the last 43 years, suggesting climate change in the Arctic region, possibly caused by the rising atmospheric temperatures in the Arctic.



But, if the data is extended back to 1900, it suggests that some cyclical natural variability may be involved. A complicating factor is that the pre-1979 data is reconstructed and of a lower quality than the post-1979 satellite data, so it is subject to question, and some scientists dismiss it as unreliable.

This reconstruction shows that the Arctic was warmer than today in the 1930s, but some scientists dispute this reconstruction. When scientists disagree about the data, they probably also disagree about whether the data establishes climate change.

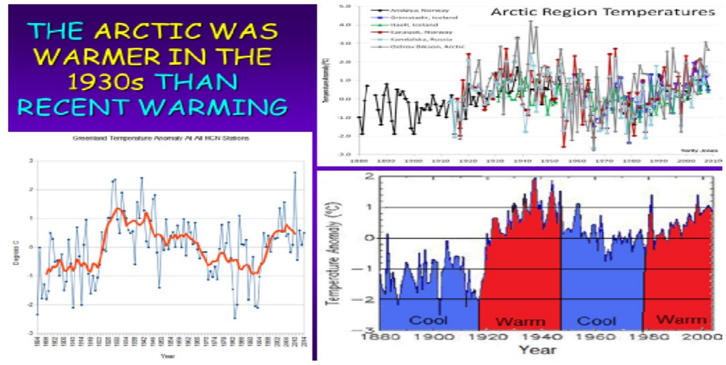


Figure 9. Arctic temperatures were warmer in the 1930s than today. The graph on the left shows temperatures in Greenland from 1894 to 2014 (high temperatures in left center during the 1930s) were warmer than today (right side). Upper right graph is Arctic temperature from Iceland, Russia, and Norway showing that the 1930s were warmer than recent decades. Lower right shows Arctic temperatures from 1880 to 2000 for 70 –90° latitude. Note that the 1920s and 1930s were warmer than 2000. (Easterbrook, 2016).

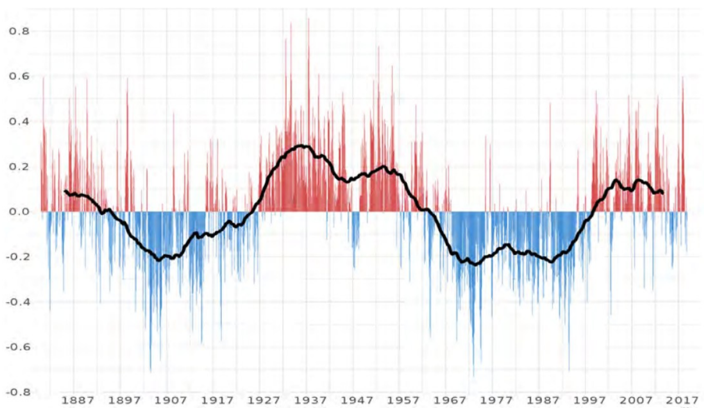
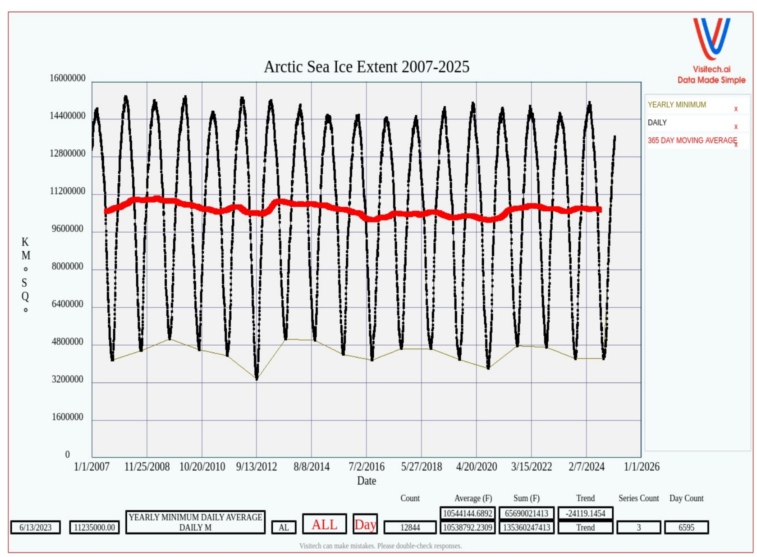


Figure 4.4. The Atlantic Multidecadal Oscillation (AMO) index showing positive (red) and negative (blue) phases. Source: https://commons.wikimedia.org/wiki/File:Atlantic_Multidecadal_Oscillation.svg

Some scientists point to an ocean current, the Atlantic Multidecadal Oscillation (AMO), which has a 60-70 year cycle, as an example of natural variability, and as a significant cause of the changes in Arctic sea ice. And some go further to suggest that the AMO combined with the Pacific Decadal Oscillation (PDO) is a significant cause of recent global warming. Both points are disputed.

If a trend line is drawn from 2007, Arctic sea ice appears to be unchanged over the most recent 18 years. So has there been climate change with respect to Arctic sea ice? Is the statistical likelihood of any change >90%? The IPCC confuses the issue by introducing a qualitative term "likely," meaning a probability of 66-100%. (AR6 p.4). Opinions are expressed, such as, "Globally averaged precipitation over land has *likely* increased since 1950." (AR6 p.5). So is that climate change or not? In what regions has the precipitation increased and in what regions declined? In what regions is this change beneficial and in what regions detrimental?



DETERMINATION OF CAUSATION

Unfortunately, once climate change is detected it is very difficult for climate scientists to determine its causes, because the climate is so complex. A change of climate may be caused by a number of different factors working together. Scientists usually prove causation by controlled experiments performed in the laboratory, but it is virtually impossible to simulate the climate in the lab. Arctic sea ice provides an example of the difficulties of determining causation.

Assume that melting Arctic sea ice is determined to be an example of regional climate change. Some scientists attribute this to rising Arctic temperatures. Others attribute it to a combination of the AMO and the PDO. Even with only two possible causes, proof one way or the other is difficult, and scientists disagree. If a number of factors combine to cause a particular change, then the problem becomes how to determine the relative importance of each cause, i.e. to quantify the amount of each cause's contribution.

To find causes scientists start by trying to find correlations. Cause and effect must be correlated, and cause must precede effect in time. For example, variations of the AMO and PDO have been shown to have a high correlate with Arctic temperatures, suggesting that the AMO and PDO cause most of the changes in Arctic temperature. But correlation alone does not prove causation. The causation might be in the other direction, or there might be some other cause of both variables.

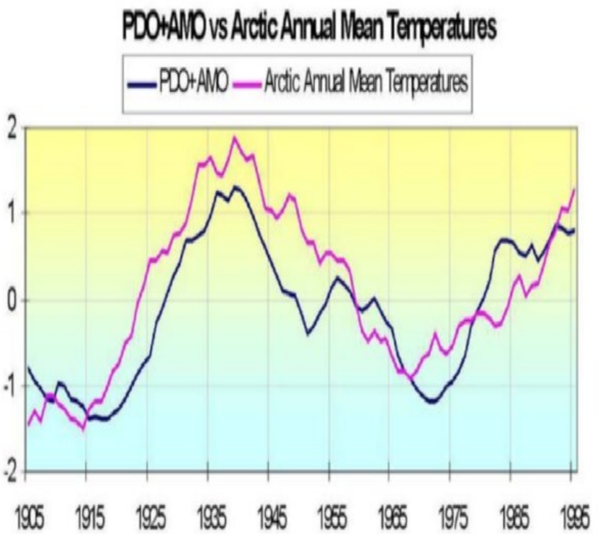
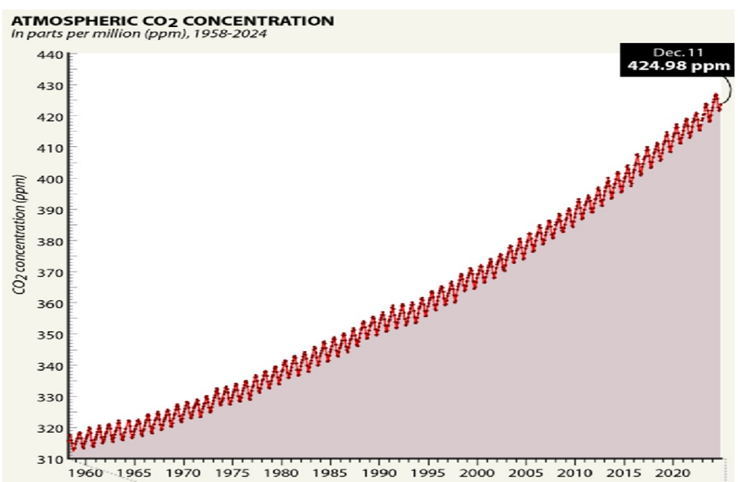
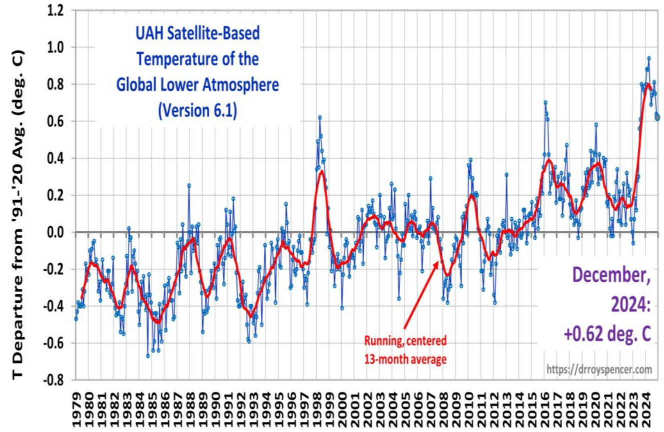


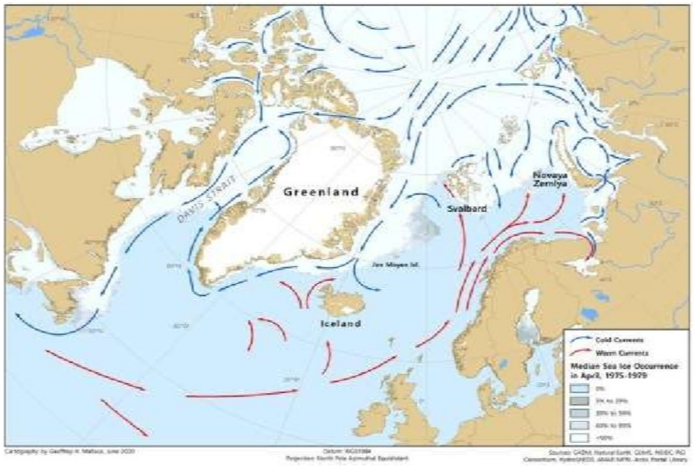
Figure 15: PDO+AMO versus Arctic Annual Mean Temperatures



Atmospheric CO2 levels have been rising since the Industrial Revolution and at a significantly increased and steady rate since 1958, but Arctic temperatures declined from 1940 to 1968, as shown in the prior graph. Non-correlation is generally accepted as proof of non-causation.

As previously shown, Arctic sea ice has been unchanged since 2007, but world temperatures have been rising since 2008, so for the period 2008-2025 Arctic sea ice does not correlate with global temperature.





Another important piece of evidence is the location of the Arctic sea ice melt. It has not been in the regions of the Arctic with the warmest atmospheric temperatures. Rather the melting has been in the parts of the Arctic Ocean that are warmed by the AMO

In conclusion, even if it is agreed that there is climate change with respect to Arctic sea ice, there is disagreement as to its causes. In fact, rising temperatures and the AMO may each contribute, so the problem is not either-or but becomes to determine the amount of each factor's relative contribution.

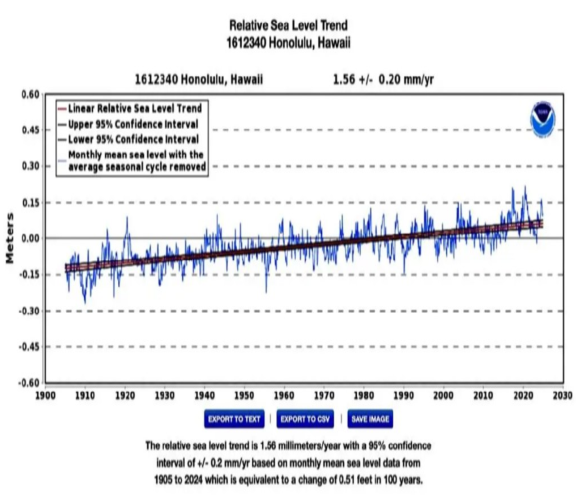
The AMO has been in its warm phase, but in a very few years the AMO is expected to switch to its cold phase. If Arctic sea ice starts to increase despite continuing rising Arctic and world atmospheric temperatures, then this would be strong evidence that the AMO and natural variability have been the principal cause of the changes in Arctic sea ice.

The difficulty of proving the cause of melting Arctic sea ice is typical of the difficulties in proving the cause of changes in other climate variables. It is generally agreed that the world has warmed over the last century, but what caused the warming? It is generally agreed that CO2 caused some significant part of the warming, but did it cause 40% of the warming, 75%, or 100%? Due to the complexity of the climate system scientists disagree.

MODELS

Models necessarily make assumptions as to causation. If a scientist has a theory about how the world climate works, for example, about how rising CO2 levels cause rising temperatures, the scientist may create a computer model that performs the calculations to predict the temperature rise that follows a particular rise in CO2 level. Many such models have been created that calculate large temperature rises. All such models necessarily assume that CO2 is a powerful cause of rising temperature. But before any model's calculation is relied upon, the model's accuracy must be verified, which means verifying the assumptions of causation and the other assumptions used in the model's calculation. This is difficult and usually disputed because of the complexity of the climate.

The media commonly presents alarming model calculations while failing to give any consideration to the accuracy of the model or to the reasonableness of the assumptions used in performing the calculations. For example, a media article may report that a new model calculates that sea levels "may" rise by 3-5 feet by the year 2100. But actual tide gauge data shows, for example, that Honolulu sea levels (reasonably typical) have been rising steadily since 1905 at a rate of only six inches per century, or 4.5 inches by 2100. The model cited by the media needs to be verified, and the assumptions used shown to be reasonable before numbers calculated by the model are taken seriously.



ATTRIBUTION

What is commonly called "Attribution Methodology" (AM) is a complicated form of statistical analysis and probability calculation. It is applied to produce conclusions that commonly appear in the media, such as -

> Climate change made Hurricane Milton 40% more likely, or
>
> Climate change boosted Hurricane Milton's rainfall by 20-30% and its wind speed by 10%.

AM is an attempt to prove climate change causation by purely statistical methods, rather than by empirical or scientific methods. It necessarily uses climate models, and so should not be credited unless the accuracy of the underlying models have been established.

This methodology originated with a paper by Allen and Tett, published in 1999, that proposed an application of the Generalized Least Squares regression statistical methodology to reach conclusions about climate change. Allen and Tett claimed that their application and use of this methodology complied with the Gauss-Markov Theorem and hence was correct. But statisticians disagree about whether AM does comply with Gauss-Markov.

Also, to apply AM the user must create a model of the climate without climate change. This involves speculating about what the world's climate would be like today if CO_2 levels and temperatures had not risen during the post-industrial period. These speculations then lead to further speculations about whether Hurricane Milton would have occurred, or what Hurricane Milton would have been like, without climate change. The output of this model is then compared to the actual Hurricane Milton, and statistics are used to conclude, for example, that Hurricane Milton would not have occurred without climate change, or that climate change made Hurricane Milton's rainfall 20-30% higher and its wind speed 10% higher than they would have been without climate change.

Empirical data and actual science do not justify such conclusions. AM is an attempt to prove causation using a disputed statistical method and speculations without providing empirical or scientific support.

Work Cited

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