Do You Believe In Global Warming?

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Introduction

Very often, when I talk to the public or the media about “global warming”, they ask me if I believe in global warming. This unfortunate question is apparently very popular among scientists as well. And I say ‘unfortunate’ because when we are dealing with a scientific problem ‘believing’ has no place. In science we either ‘prove’ or ‘disprove’. We ‘believe’ only when we cannot possibly prove a truth. For example, we may ‘believe’ in reincarnation or afterlife but we cannot prove either.

Now, you may argue that when we are dealing with a scientific problem, such as the recent “global warming” for which we cannot obtain experimental confirmation as to what is causing it (for the simple reason that we cannot repeat this experiment; we only have one realization of climate evolution), we may ‘form an opinion’ based on the existing scientific evidence in hand, current knowledge, possible theories and hypotheses, etc., but we should be skeptical of ‘beliefs’ which are rooted in religious/political origins.

The current state of affairs regarding global warming is divided into two major fractions. A large portion of climate scientists argues that most, if not all, of the recent warming is due to anthropogenic effects, which originate largely from CO_2 emissions from burning of fossil fuels. Another portion is on the other extreme: those who argue that humans have nothing to do with global warming and that all this fuss is a conspiracy to bring the West industrial world down! The latter group calls the former group “the catastrophists” or “the alarmists” whereas the former group calls the latter group “the deniers”. This childish division is complimented by another group the “skeptics”, which includes those like me who question the beliefs and try to look at all scientific evident before we form an opinion (the former group also considers skeptics as deniers).

What I would like to do in this statement is to take the position that all three groups have some points but none of the groups is close to a proof or undisputed evidence for its statements regarding global warming.

A skeptic's debate

A. Most, if not all, warming is due to human activity

CO_2 emissions are on the increase since the mid 20th century when measurements of concentration in the atmosphere of this gas started. Data show that the amount of CO_2 in the atmosphere is on the rise from the beginning of recording (mid 20th century) to present day. Based on the clearly understood physical feedback mechanism (more CO_2 → more infrared radiation absorbed → higher temperatures), and due to the overall positive trend in global temperature during this period, it is not a wild hypothesis to assume that anthropogenic effects cause the global temperature increase. However, there are issues with this thesis. The proof for this hypothesis has been based on General Circulation Models (GCMs). GCM simulations have completely dominated research on climate. There have been hundreds of control and forced simulations over the past decades. These simulations have reproduced the temperature variations in the 20th century and have provided projections of temperature changes into the 21st century under various CO_2 increase scenarios.

The observed global temperature record is characterized by regimes of positive trends (warming regime) and negative trends (cooling regime) superimposed on a low frequency (long term) slowly rising signal referred to as "global warming"(see Figure 1). Before 1910 we were in a cooling regime, from about 1910 to 1940 in a warming regime, from about 1940 mid-70s in a cooling regime, from late 70s to about 2000 in a warming regime and since then in a slightly cooling/flat regime that has been termed the "hiatus". GCMs explain these fluctuations about the low-frequency signal as the interplay of the two major forcings (aerosols and CO_2). When in this interplay aerosols win, then the planet cools, and when CO_2 wins the planet warms. The problem with this approach (which many call "fitting") is that it reduces decadal climate variability to a simple tug-of-war between aerosols and CO_2. A more significant problem, however, with GCMs is that there are too many variations of them (close to 40 GCMs available) differing in the details and parameterizations, and consequently in the predictions. There is, however, a growing concern about the ability of GCMs as more and more studies have shown that models, while they may agree when it comes to global averages, they don't agree with each other when it comes to dynamics.

In June 2013 I attended a conference on hurricanes and climate change. Report after report was showing climate model projections under some CO_2 rising scenario of frequency and intensity of hurricanes in the interval 2080-2100. Seventy years from now! And of course, those were dire predictions. How will they convince the public to pay any attention to these predictions when models cannot predict the next ten years? A typical response to this question is that the models have to be 'forced" long enough for the effect to emerge from background noise. I think that if models have to be forced with increasing CO_2 for 70 years, then, there is something wrong with the models.

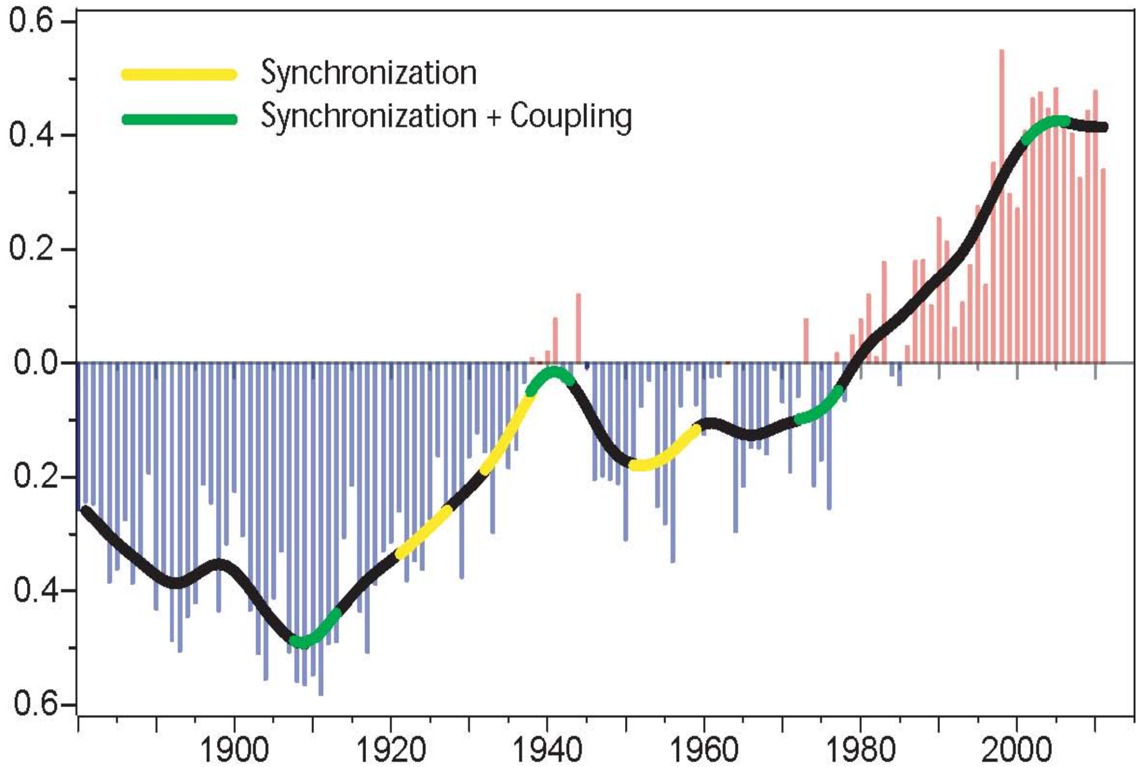
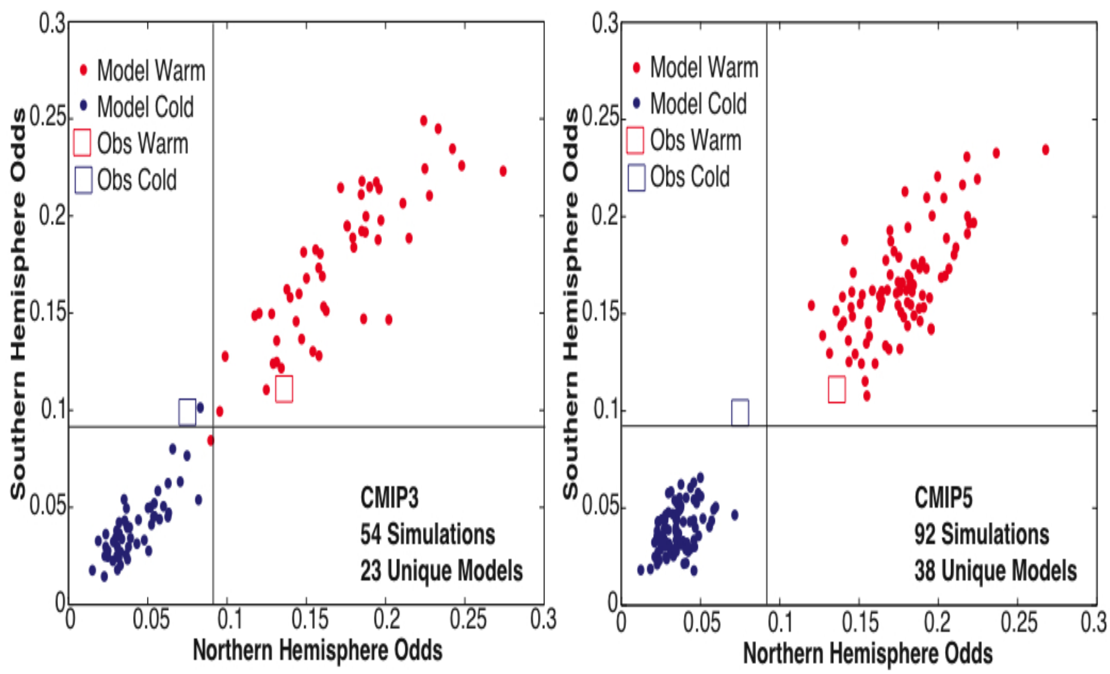


Figure 1: Global temperature variations in the last 130 years. See text for explanation and discussion.

In a recent study, my collaborator and I compared 23 climate models (Climate Model Intercomparison 3; CMIP3) at the dynamics level (*Steinhaeuser and Tsonis,* 2013). We found in both, control and forced runs, especially for temperature and precipitation (two fields that are projected in a global warming scenario) that the models do not agree between them very well. The models display significant spread between them. Moreover, we found that they don't agree with observations. The spread has been narrowed in the CMIP5 generation by tuning the models to agree more with each other but the agreement with reality has widened (see Figure 2 and its caption). The bottom line here is that GCMs are in actuality empirical models, they don’t represent a climate theory. At resolutions lower than the grid spacing all processes are parameterized but each model employs different parameterizations. It’s not surprising, therefore, that all models used to project climate evolution in the 21st century missed completely the so-called “hiatus”. The “hiatus” refers to the leveling-off of global temperature since about 2000 even though the levels of CO_2 have continued to increase. Climate models are not very reliable, we don't understand the climate system very well, and we simply need more work to understand natural variability. I am not saying that climate models are useless. They are the only tools we have. But they are just that: tools. And, to be fair, the deniers do not have any better models to support their arguments.

So, do I think that there is an anthropogenic influence on climate? I actually do. After all in the last 200 years, we have modified 17% of the land surface of the planet. We have cleared many forested areas, we have developed energy consuming industries and large cities, we drive cars, etc. We obviously interact with the environment. This should have some have effects on climate. But is this alone responsible for "global warming"? My opinion is no, and I will now present some scientific arguments and results that suggest that other factors may be playing a significant role in climate dynamics.



<u>Figure 2:</u> In this figure the basic question asked is very simple: What are the odds that a given month in the past 5 years was extremely warm (or cold) relative to the base period 1979-2011, for an arbitrary location in either the Northern or Southern Hemispheres? Our definition of extreme here is among the warmest (or coldest) 3 months in this period, so the base probability is 3/33 ~ 0.09, which is the intersection of the lines in the figure. This is a question we can ask observations (here the ERA-Interim 2-meter temperature), as well as climate models (CMIP3 and CMIP5, near-surface air temperature), and compare the answers. What we find is that there appears to be an emerging confirmation bias in models. During the CMIP3 period (left panel), there were reasonable models analogs for the observed state, even though the model mean significantly overpredicts warm events and underpredicts cold events

relative to the observations in both the Northern and Southern Hemispheres. For CMIP5, these model analogs have disappeared, and the model results are all converging on a "solution" that excludes the observed state at a p >0.99 level of confidence. This strongly hints at an emerging confirmation bias, with the models evolving to resemble each other ever more closely in each progressive model generation.

B. Climate modes and climate variability

Let us return and concentrate now on Figure 1. This figure shows the yearly anomaly values of global temperature (blue negative anomalies, red positive anomalies). The black solid line is a smoothed version of this record. It is evident from the smoothed version that on decadal time scales there are times when the global temperature trend is shifting from negative to positive and vice-versa. These "shifts" are superimposed on a low-frequency signal known as "global warming". We considered four major climate modes (the North Atlantic Oscillation, the North Pacific Index, ENSO, and the Pacific Decadal Oscillation). These modes represent three major oceanic modes and one major atmospheric mode (NAO) that significantly affect climate. We constructed a network between them and studied its properties, specifically its synchronization and the coupling between the modes. Before discussing the results think of synchronized swimming. Four swimmers are executing their program. Their coupling is very week (limited to soft touching or coming very close to each other). Under these conditions most likely they will execute their program well. Imagine now that their coupling is strong (say they hold each other's hands). In this case, it is easy to imagine that they will most likely desynchronize very quickly. This very simplified example provides the basic principles behind the theory of synchronized chaos. When nonlinear oscillators are coupled and in a synchronized state, an increase of the coupling strength above a certain threshold causes a bifurcation that takes the system to some other state.

The part of the black line in Figure 1 that is colored yellow indicates that the four climate modes are synchronized during a period when the coupling between the modes is *not* increasing. The part colored green indicates periods when the modes are synchronized and the coupling is increasing. Thus, we see that the network synchronized six times. In the periods 1908-1913, 1921-1925, 1932-1943, 1952-1957, 1975-1979, and 1998-2003. In the periods 1921-1925, 1932-1938, 1952-1957 synchronization is not associated with an increasing coupling strength and no change in the temperature trend is taking place. However, in the periods 1908-1913, 1939-1943, 1975-1979, and 1998-2003, synchronization is associated with an increase in coupling strength. Especially for the last case, we predicted in 2009 that the global temperature would not be rising in the next couple of decades, a prediction that has been verified. As the modes keep on synchronizing and the coupling strength keeps on increasing, at some coupling threshold the synchronized state is destroyed and climate shifts into a new state characterized by a reversal in global temperature trend. I would like to stress here that the shifts are explained via a dynamical mechanism without the need of the aerosols vs. CO_2 tug-of-war. This mechanism appears to be an intrinsic mechanism of the climate system as it is found in both control and forced climate simulations, and in proxy climate records [*Tsonis et al*., 2007; *Wang et al*., 2009, *Swanson and Tsonis* 2009, *Tsonis and Swanson*, 2011]. Note that other studies have also considered these and other modes to explain global temperature variation [e.g. *Wyatt et al*. 2012].

Clearly, there is something in the intrinsic variability in global temperature that is dynamical in origin.

C. Cosmic rays

Another aspect in the global warming and climate change debade, is the effect of cosmic rays on climate. The basic principles behind a possible connection between galactic cosmic rays (CR) and global temperature (GT) areas follow: It has been known since the invention of the cloud chamber in 1911 by Charles Thomson Rees Wilson that ionizing radiation leads to atmospheric cloud nucleation. Although the prime source of ionizing radiation in the global troposphere is CR, the flux of CR reaching the troposphere depends on the solar wind.

The solar wind is a stream of ionized gasses that blows outward from the Sun, and its intensity varies strongly with the level of surface activity on the Sun. The Earth's magnetic field shields the planet from much of the solar wind, deflecting that wind like water around the bow of a ship. When solar activity is great, the solar wind is strong, swiping away CR arriving at the top of the atmosphere. These CR are hypothesized to affect cloud formation and cloudiness, and therefore GT. The net radiative effect of cloudiness depends on the difference between incoming solar radiation and outgoing longwave radiation. Increased cloudiness in the upper troposphere reduces outgoing longwave radiation, thereby resulting in warming of the planet. Increased cloudiness in the lower troposphere causes less incoming radiation, and therefore cooling of the planet. Data suggest that the amount of CR is positively correlated with the amount of low-level clouds but has no effect on middle- or high-level clouds. Although this is still an open question, the reduction in flux in CR in times of high solar activity is hypothesized to result in less cloud nucleation and fewer cloud condensation nuclei, and consequently, reduced low-level cloud amount. This, in turn, leads to a higher solar radiation flux at the Earth's surface, and warmer temperatures. Conversely, a weaker solar wind results in cooler temperatures. The actual chemical processes and reactions involved in this problem are complex, but a growing body of experimental and theoretical work has uncovered a chemical pathway by which CR ionization may increase nucleation rates to levels appropriate for cloud condensation nuclei. This suggests a superficially simple network linking the Sun, CR, and global climate, with the interaction between the Sun and CR having a potential influence on the climate system.

In a recent article *Tsonis et al. (2015)*, presented a mathematical analysis based on the convergent cross mapping, which uses observational time series data to directly examine the causal link between CR and year-to-year changes in global temperature. Despite a gross correlation, we find no measurable evidence of causal effect linking CR to the overall 20th-century warming trend. However, on short interannual timescales, we find a statistically significant, although modest, causal effect between CR and short-term, year-to-year variability in global temperature that is consistent with the presence of nonlinearities internal to the system. Thus, CR appear to be a nontraditional forcing in the climate system on short interannual timescales. Their effect represents another interesting piece of the puzzle in our understanding of factors influencing climate variability that should not be ignored.

D. Solar activity

If somehow we could switch the Sun off, weather and climate will seize to exist. All weather, and as a consequence climate, is the result of solar radiation. It is well established that the solar output is not constant. It varies and fluctuates at many time scales and changes in global temperature follow. Therefore, there should be no question about Sun's influence on climate.

E. Closing remarks

In the realm of deniers, skeptics, and believers, science has been compromised. I usually don't bother with pseudo-scientists and ignorant people abusing the freedom of the Internet by writing and posting nonsense comments. But I have grown wary of what is going on with the debate on the overblown and misdirected issue of "global warming". The fact that scientists who show results not aligned with the mainstream are labeled deniers or skeptics is the backward mentality. We don't live in the medieval times when Galileo had to admit to something that he knew was wrong to save his life. I stated in my introduction, I often hear the question "Do you believe in global warming?" or a statement like "I believe global warming is happening". The word "Believe" is used when you cannot prove something. Science is all about proving, not believing. In that regard, I am a skeptic not just about global warming but also about many other aspects of science. All scientists should be skeptics. Science would have never advanced if it were not for the skeptics. Climate is too complicated to attribute its variability to one cause. We first need to understand the natural climate variability. Only then we can assess the magnitude and reasons of climate change. It is my educated opinion that many forces have shaped global temperature variation. Human activity, the oceans, and extraterrestrial forces (solar activity and cosmic rays) are all in the mix. Having no strong evidence for the relative controbution of these three major players, I will attribute 1/3 to each one of them.

Two final points. First, all the interactions of humans with the environment are part of our technological evolution. During this evolution, we could not go directly from living in the dark ages to a clean energy technology. There was no other way but to use fossil fuels and other pollution-producing agents. Is this enough to ruin the planet by altering the climate system, a system that has undergone major changes throughout the ages? Second, I will argue that, while we should try our best to take care of our planet, “global warming” is not the only urgent planetary emergency. Overpopulation, poverty, infectious diseases and the effect of globalization in spreading them, the water crisis, energy, food availability and safety, political instability and terrorism, the global economy, even cyber security, are far more urgent problems with potentially catastrophic results for humanity.

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