Carbon Dioxide or Solar Forcing?

PersonalResearch

By: Nir J. Shaviv

Natural or Anthropogenic? Which mechanism is responsible for global warming over the 20th century?

According to the common perception, the temperature over the 20th century has been warming, and it is mostly anthropogenic in origin, with greenhouse gases (GHGs) being the dominant driver. Others, usually called "skeptics", challenge this view and instead claim that the temperature variations are all part of natural variability. As I try to demonstrate below, the truth is probably somewhere in between, with *natural causes* probably being more important over the *past* century, whereas *anthropogenic* causes will probably be more dominant over the *next* century. Following empirical evidence I describe below, about 2/3's (give or take a third or so) of the warming should be attributed to increased solar activity and the remaining to anthropogenic causes.

Like many others, I was personally sure that CO_2 is the bad culprit in the story of global warming. But after carefully digging into the evidence, I realized that things are far more complicated than the story sold to us by many climate scientists or the stories regurgitated by the media. In fact, there is much more than meets the eye.

What is the evidence for an anthropogenic effect?

The first question we wish to address is whether there is actual evidence indicating that greenhouse gases (GHGs) are responsible for most of the warming. Basically, we observe a temperature rise over the 20th century, and we measure a rise in the global concentration of CO_2 and other anthropogenic greenhouse gases. What is the evidence proving that the increase in the GHGs is the cause for the temperature increase?

The truth is that there is no real evidence for this link. Most of the "evidence" often mentioned in the media, is evidence for global warming (e.g., melting of arctic ice-sheets). But who said that this warming (which indeed took place over the 20th century) is because of GHGs? In fact, there is no substantial evidence which proves that CO_2 and other GHGs are the primary cause for the warming, and not some other mechanism. You may have seen articles which point to the contrary, that there is clear evidence, but if you dig deeply into them, you will realize that these are merely *suggestions* for a CO_2 climate link and not *evidence*.

The IPCC writes about fingerprinting the anthropogenic causes. In particular, their report states that (IPCC TAR §12.2.3):

> *"Different models may give quite different patterns of response for the same forcing, but an individual model may give a surprisingly similar response for different forcings. The first point means that attribution studies may give different results when using signals generated from different models. The second point means that it may be more difficult to distinguish between the response to different factors than one might expect, given the differences in radiative forcing."*

Hence, using models to find fingerprints is hard. If you read the TAR (in particular, chapter 12), you will find claims that the different warming in northern vs. southern latitudes, and tropospheric vs. stratospheric warming can be explained using anthropogenic GHGs operating together with sulphate aerosols, stratospheric ozone and even solar (total irradiance) forcing. Namely, the combination of the drivers can do a descent job in explaining the warming (IPCC TAR §12.4.3.2):

> *"In summary, the fixed pattern studies indicate that the recent warming is unlikely (bordering on very unlikely) to be due to internal climate variability. A substantial response to anthropogenic greenhouse gases appears to be necessary to account for recent temperature trends but the majority of studies indicate that greenhouse gases alone do not appear to be able to provide a full explanation. Inclusion of the response to the direct effect of sulphate aerosols usually leads to a more satisfactory explanation of the observed changes, although the amplitude of the sulphate signal depends on the model used. These studies also provide some evidence that solar variations may have contributed to the early century warming."*

But in itself it is not proof that GHGs are the major cause. These consistent results only indicate that CO_2 can explain the warming, not that it is the only possible explanation. Without other "suspects", it would be incriminating *circumstantial* evidence. However another very good candidate to explain a large fraction of the warming does exist, as I explain below.

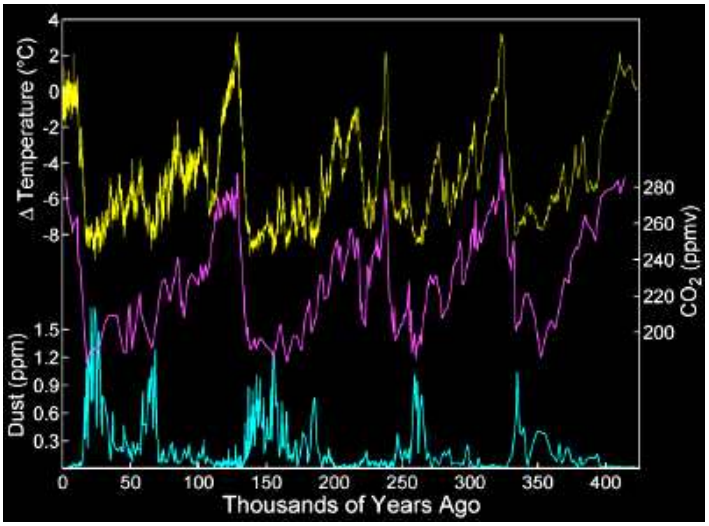

Fig. 1: Correlation between atmospheric CO_2 and climate. Nope, it is not proof that CO_2 is a major climate driver, since CO_2 can be driven by temperature changes. Specifically, warmer oceans requires larger atmospheric partial pressures of CO_2 to contain the dissolved gas in them. Of course, some of the temperature could be the result of CO_2 amplifications, but there is no way of knowing what fraction.

Of course, the beautiful correlation between CO_2 reconstructions and temperature on Earth over the multi-millennial time scale, as it apparent in the figure, is often used to demonstrate how CO_2 plays a role in large climate variations. This often misleads the laymen to believe that CO_2 is the climate driver, whereas in fact it could be the opposite, that the global temperature affects the equilibrium levels of CO_2. In reality it could be somewhere in between, that CO_2 is affected by the temperature and that it in turn causes a larger temperature variation. Just by itself, however, this correlation cannot be used to quantify the effect of CO_2 on the climate, which could be anywhere from no effect to all the effect. Thus, it is no proof that CO_2 is the main cause of the

variations over the 20th century. There is no such evidence.

As far as I see it, there are two main reasons why GHGs are blamed as the main cause of global warming even through there is no real incriminating evidence:

- Based on theory, increased levels of GHGs are expected to increase the global temperature.
- There is no other mechanism to blame for the warming. Without any other candidate, the only suspect, i.e. GHGs, must be the cause.

These are reasonable claims, except that they don't work for the case of anthropogenic warming. With regards to the first point, we will see below that even the sign of the anthropogenic contribution is unknown, let alone its magnitude.

As to the second point, there is another good mechanism to blame, that of *indirect* solar forcing. This mechanism can do just as good a job in explaining 20th century warming as CO_2, if not a better one.

The anthropogenic driving - How much is it?

If we wish to assess *theoretically*, how much is the anthropogenic contribution to 20th century warming, we have to address two questions, how much is the anthropogenic contribution to the changed radiation budget, and how changes in the radiation budget affect the global temperature. We begin with the anthropogenic contribution.

On average, every square meter of the global surface receives a flux about 240 Watts per square meter. Of course, equatorial surfaces receive more than polar regions, which is why this figure for the radiative flux is an average.

The climatic effect of different global processes is usually quantified with their contribution to a net change in the average radiative flux. For example, doubling the amount of CO_2 in the atmosphere changes the radiative budget by about 4 W/m² (3.8 W/m² to be more exact), as if the sun was 4/240*100=1.7% brighter.

The scientific report of the Intergovernmental panel for climate change (IPCC) attempts to summarize the effects of all the drivers. This is displayed in the famous forcing graph below. There are several interesting points one should note. First, there is a large uncertainty in an anthropogenic contribution called the *indirect aerosol effect*. This effect arises from the fact that increased amounts of small particles in the atmosphere will alter the characteristics of clouds. This is best seen downstream of chimney stacks or in marine clouds in the form of ship tracks. Since cloud formation, and in particular, the characteristics of clouds, is not well understood, the indirect aerosol effect is highly uncertain. The second point to note is that the solar forcing quoted by the IPCC is 0.3 W/m². This does not include the effect of the solar modulated cosmic ray flux, which has ample evidence to support it, and no real evidence to refute it. If one includes the effects of cosmic rays, an additional 1 W/m² should be added because of the increased solar activity (which reduced the flux of cosmic rays reaching Earth, as will be explained below).

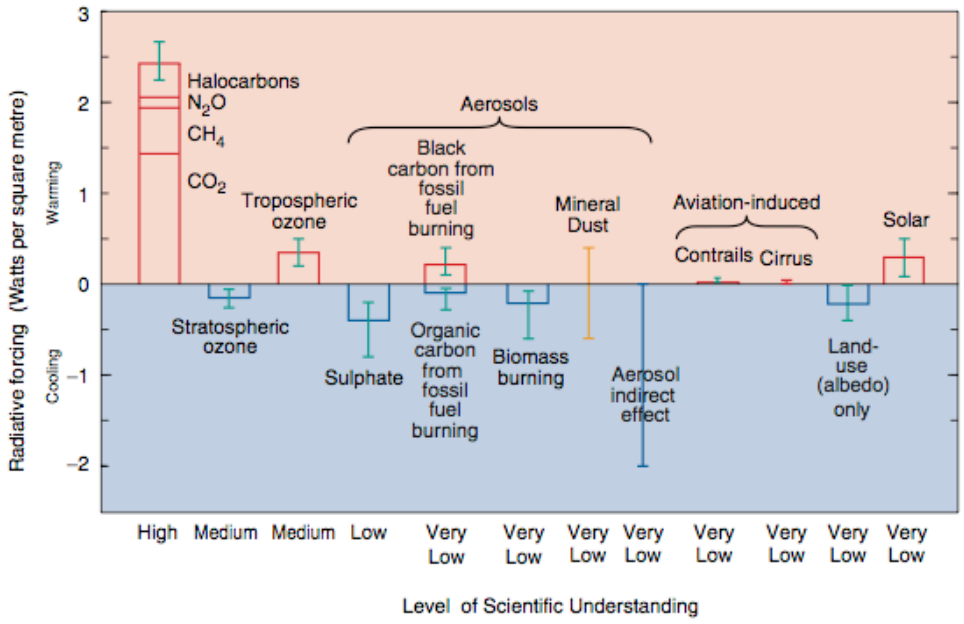

Fig. 2: Anthropogenic and Natural contributions to the net radiative forcing. Figure from the IPCC TAR. If one adds their numbers (which are supposed to capture the community's consensus, one finds an Anthropogenic forcing of: 0.8 ± 1.3 W/m² (where the errors were added in quadrature, assuming independence). In other words, the large uncertainty in the *indirect aerosol* effects, implies that the *sign* of the Anthropogenic contribution is unknown!

Evidently, we do not know the total Anthropogenic forcing. We don't know its sign. We also don't know its magnitude. All we can say is that it should be somewhere between -1 to +2 W/m². Sounds strange, but we may have actually been cooling Earth (though less likely than warming). It is for this reason that in the 1970's, concerns were raised that humanity is *cooling* the global temperature. The global temperature appeared to drop between the 1940's and 1970's, and some thought that anthropogenic aerosols could be the cause of the observed global cooling, and that we may be triggering a new ice-age (e.g., see wikiepdia for a summary)

Climate Sensitivity

Next, if we wish to translate the anthropogenic contribution to the radiative budget (assuming we knew it!) into a global temperature change, we need to know the *global climate sensitivity*. That is, we need to know the change λ in °C associated with a radiative forcing of 1 W/m². It can also be quantified with ΔT_{x2}, which is the temperature increase associated with doubling the amount of CO_2, i.e., a change of 3.8 W/m² in the radiative budget. If Earth behaved as an ideal black body, its sensitivity would be &lambda≈0.3°C/(W/m²), or ΔT_{x2}≈1.2°C. However, Earth's sensitivity does not necessarily behave like that of an ideal black body. The reason is that as the temperature changes, other variables affecting the temperature change as well. For example, increasing the radiation budget, increases the temperature. This will increase the amount of water vapor in the atmosphere. However, water vapor is a great GHG. So, this will tend to increase the temperature further, thus giving rise to a *positive feedback*, which increases the sensitivity. On the other hand, the larger amounts of water vapor in the atmosphere imply more cloud cover. Since clouds have a net tendency to cool, this will counter the increase in temperature, thus giving rise to a *negative feedback* that decreases the sensitivity.

The problem with numerical simulations of climate is that the feedbacks, especially those pertaining to cloud cover, are very poorly understood. As a result, any value in the range of T_{x2}≈1.5-4.5°C is believed to be

possible according to the IPCC. In other words, based on theory (well, numerical simulations to be more exact), the temperature change associated with doubled CO_2 is not known to within a factor of 3!

So, can CO_2 be incriminated?

Evidently, according to the scientists behind the IPCC report, i.e., those who *support* Kyoto:

- It is not clear how much is the actual anthropogenic contribution to a changed radiation budget (again, even the sign of the anthropogenic effect is not known).
- Even if the anthropogenic radiative forcing was better known, it is theoretically unclear by how much the temperature should have varied in response.

To get the temperature change due to the anthropogenic activity, one has to multiply these two numbers. Obviously, theory cannot tell us how much global warming we should have witnessed and how much we should see in the future. You are more than welcome to look up these numbers in the IPCC report, and realize for yourself that this is an unavoidable conclusion.

Clearly, the incrimination of CO_2 (and other GHGs) is primarily because we expect it to warm (see fig. 4), and we do see warming (see fig. 3), but it turns out that there are other suspects.

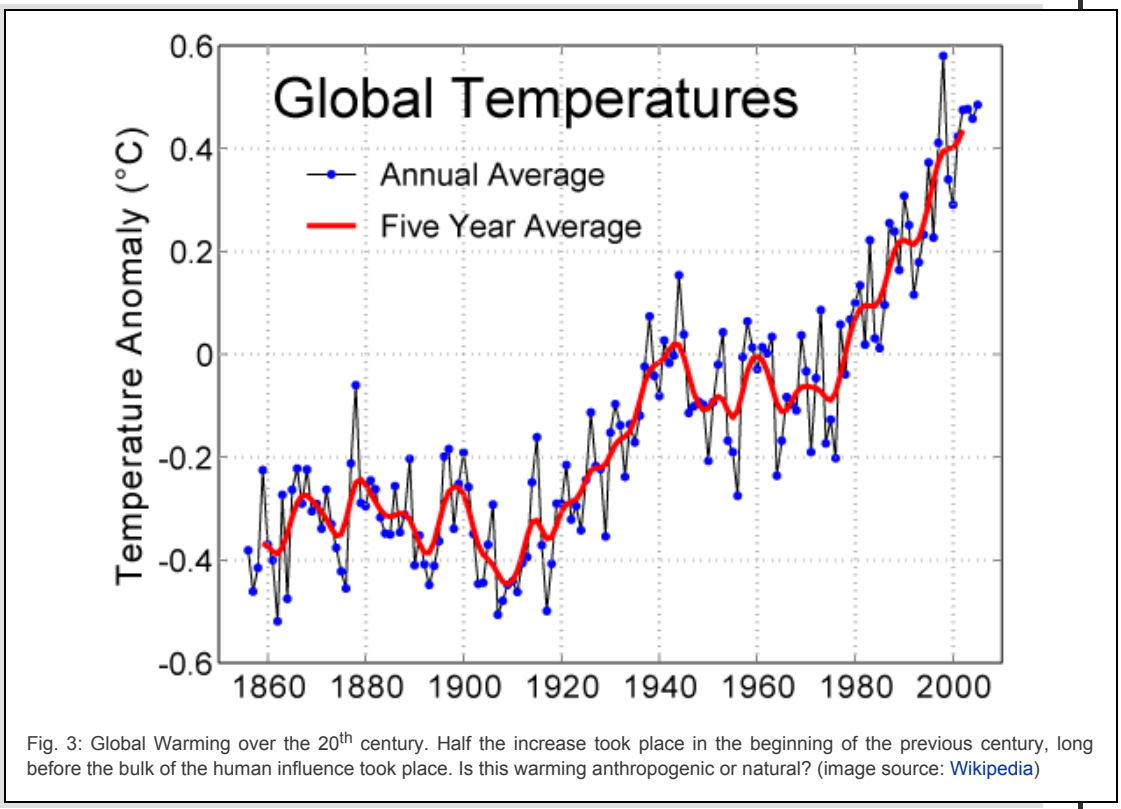

Fig. 3: Global Warming over the 20th century. Half the increase took place in the beginning of the previous century, long before the bulk of the human influence took place. Is this warming anthropogenic or natural? (image source: Wikipedia)

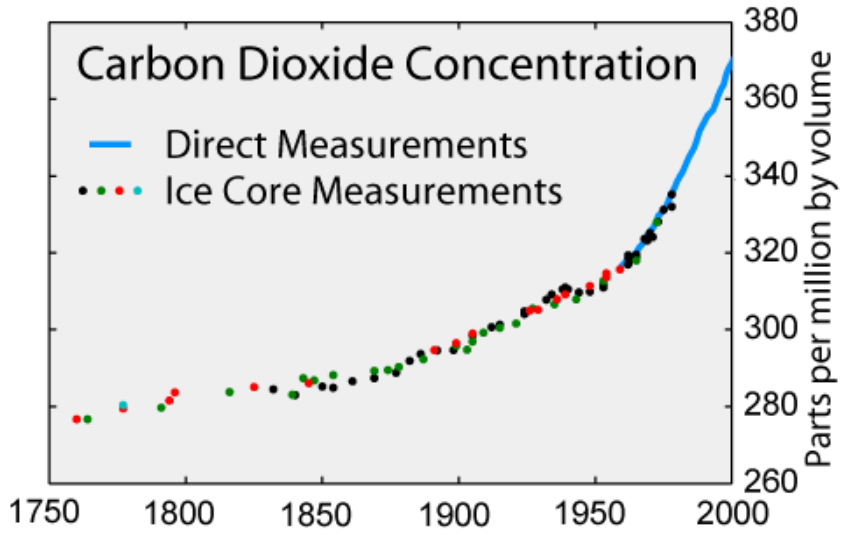

Fig. 4: Carbon Dioxide in the atmosphere. Just like the global temperature, it increased over the 20th century. Since theoretically we expect the gas to warm, it is often incriminated as the main culprit behind global warming. But there is no direct evidence proving that it is *it* which is the primary warmer and not another mechanism. (image source: Wikipedia)

An alternative explanation for global warming, or at least part of it

Solar activity appears to affect climate. This can be seen from many different correlations between solar activity on one hand, and climate on the other. These correlations exist on time scales ranging from the 11-year solar cycle to many millennia (for the two most beautiful correlations, see Neff et al, and Bond et al. in the refs below). Such a link is potentially important for global warming because over the 20th century, solar activity has been increasing.

Because the solar correlated climate variations are large, but the total solar irradiance variations are relatively small (a few 0.1%), the latter are most likely not the explanation of climate variability. Instead, different amplifying mechanisms were suggested, mechanisms which can amplify the non-thermal components of the sun (e.g., UV, X-ray, solar wind) and which can considerably vary between an active sun and a quiet one.

The leading mechanism to explain the large solar induced climate variability is through solar wind modulation of the cosmic ray flux reaching the Earth, which affects climate through modulation of the amount of atmospheric ionization. Over the past decade, many different pieces of evidence added up to a pretty coherent picture.

The activity of the sun manifests its self in many ways. One of them is through a variable solar wind. This flux of energetic particles and entangled magnetic field flows outwards from the sun, and impedes on a flux of more energetic particles, the cosmic rays, which come from outside the solar system. Namely, a more active sun with a stronger solar wind will attenuate the flux of cosmic rays reaching Earth. The key point in this picture is that the cosmic rays are the main physical mechanism controlling the amount of ionization in the troposphere (the bottom 10 kms or so). Thus, a more active sun will reduce the flux of cosmic rays, and with it, the amount of tropospheric ionization. As it turns out, this amount of ionization affects the formation of condensation nuclei required for the formation of clouds in clean marine environment. A more active sun will therefore inhibit the formation of cloud condensation nuclei, and the resulting low altitude marine clouds will have larger drops, which are less white and live shorter, thereby warming Earth.

Today, there is ample evidence to support this picture (a succinct introduction can be found here). For example, it was found that independent galactic induced variations in the cosmic ray flux, which have nothing to do with solar activity do too affect climate as one should expect from such a link. There are many more examples.

*[Added Note (4 Oct. 2006): These recently published **experimental** results stroingly point towards the validity of this link, as expected]*

So why is this link important for global warming? As previously mentioned, solar activity has been increasing over the 20th century. This can be seen in fig. 5. Thus, we expect warming from the reduced flux of cosmic rays. Moreover, since the cosmic ray flux actually had a small increase between the 1940's and 1970's (as can be seen in the ion chamber data in fig. 6), this mechanism also naturally explains the global temperature decrease which took place during the same period.

Using historic variations in climate and the cosmic ray flux, one can actually quantify empirically the relation between cosmic ray flux variations and global temperature change, and estimate the solar contribution to the 20th century warming. This contribution comes out to be 0.5±0.2°C out of the observed 0.6±0.2°C global warming (Shaviv, 2005).

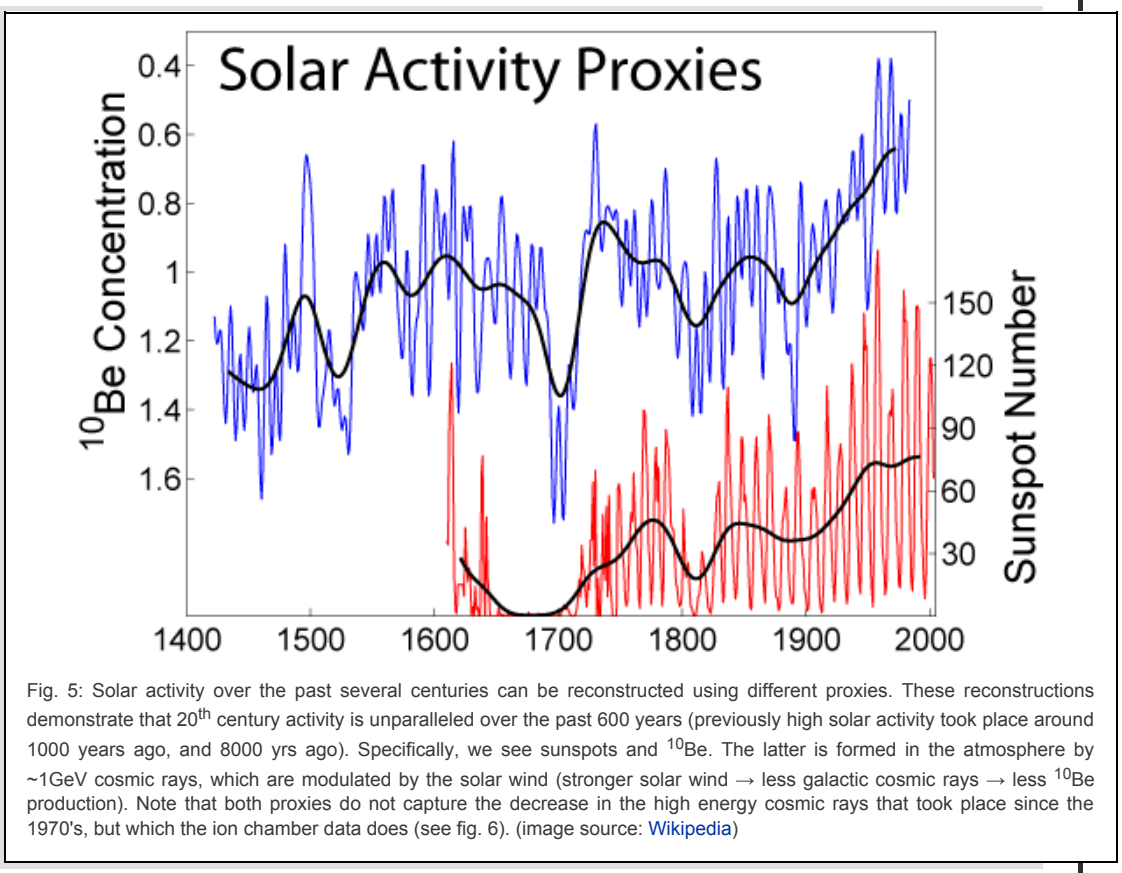

Fig. 5: Solar activity over the past several centuries can be reconstructed using different proxies. These reconstructions demonstrate that 20th century activity is unparalleled over the past 600 years (previously high solar activity took place around 1000 years ago, and 8000 yrs ago). Specifically, we see sunspots and ^{10}Be. The latter is formed in the atmosphere by ~1GeV cosmic rays, which are modulated by the solar wind (stronger solar wind → less galactic cosmic rays → less ^{10}Be production). Note that both proxies do not capture the decrease in the high energy cosmic rays that took place since the 1970's, but which the ion chamber data does (see fig. 6). (image source: Wikipedia)

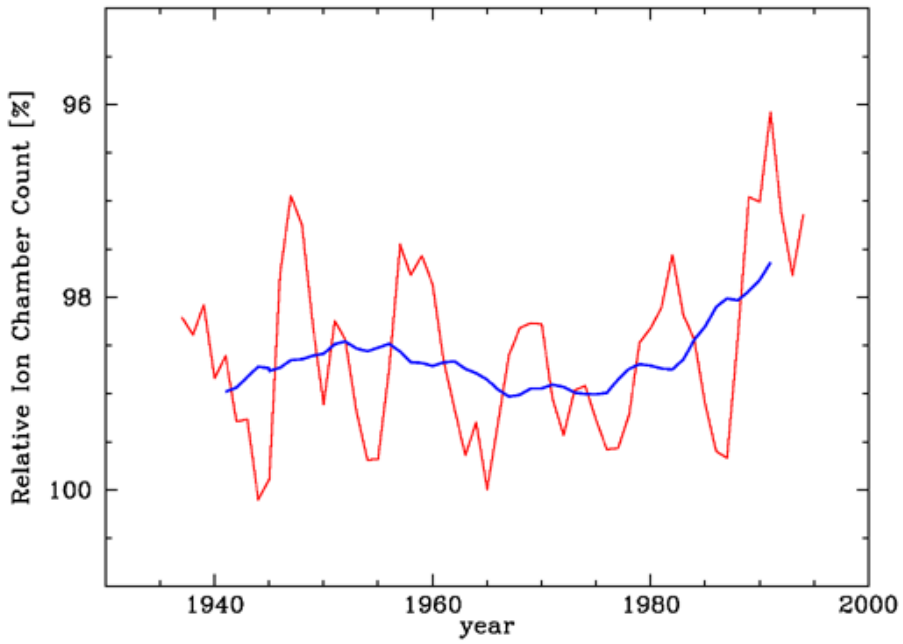

Fig. 6: The flux of cosmic rays reaching Earth, as measured by ion chambers. Red line - annual averages, Blue line - 11 yr moving average. Note that ion chambers are sensitive to particles at relatively high energy (several 10's of GeV, which is higher than the energies responsible for the atmospheric ionization [~10 GeV], and much higher than the energies responsible for the ^{10}Be production [~1 GeV]). Plot redrawn using data from Ahluwalia (1997). Moreover, the decrease in high energy cosmic rays since the 1970's is less pronounced in low energy proxies of solar activity, implying that cosmogenic isotopes (such as ^{10}Be) or direct solar activity proxies (e.g., sun spots, *aa* index, etc) are less accurate in quantifying the solar → cosmic ray → climate link and its contribution to 20th century global warming.

Summary

As explained above, there is no real direct evidence which can be used to incriminate anthropogenic greenhouse gases as the being the main factor responsible for the observed global warming. The reason these gases were blamed are primarily because (1) we expect them to warm and indeed the global temperature increased, and (2) there is no other mechanism which can explain the warming.

Although this reasoning seems logical, it turns out that (1) We don't even know the sign of the anthropogenic climate driving (because of the unknown indirect aerosol effects), and (2) There is an alternative mechanism which can explain a large part of the warming.

Solar activity can explain a large part of the 20th century global warming, on condition that there is a strong solar/climate link through modulation of the cosmic ray flux and the atmospheric ionization. Evidence for such a link has been accumulating over the past decade, and by now, it is unlikely that it does not exist.

This link also implies that Earth's global temperature sensitivity is also on the low side. Thus, if we double the amount of CO_2 by 2100, we will only increase the temperature by about 1°C or so. This is still more than the change over the past century. This is good news, because it implies that future increases in the amount of atmospheric greenhouse gases will not dramatically increase the global temperature, though GHGs will probably be the dominate climate driver.

A clarifying note

So, as you may understand, I am quite sure Kyoto is not the right way to go. I should however stress that there

are a dozen *good* reasons why we should strive to burn less fossil fuels.

The two primary reasons why fossil fuels are bad are of course pollution and depletion, while minor reasons include for example the fact that many fossil fuel reserves are controlled by unpleasant governments.

Thus, I am very much in favor, and always have been, in using less fossil fuels and keeping the environment clean (I am proud to say that I grew up in a solar house), but we should do things for the right reasons, not the wrong ones (and I don't see Kyoto addressing the right reasons). I am therefore in favor of developing cheap alternatives such as solar power, wind, and of course fusion reactors (converting Deuterium into Helium) which we should have in a few decades, but this is an altogether different issue.

More Reading Material

1. A short exposé about the evidence for cosmic rays and climate can be found in this non-technical article. In a while, a details summary of all the evidence pointing to a cosmic ray climate link will appear on this site.
2. More on the empirical determinations of Earth's climate sensitivity, and in particular, the role of cosmic rays, can be found here (somewhat technical).
3. The best example of cosmic rays flux induced climate variations, which are not related to solar activity, are the passages of the solar system through the milky way's spiral arms and the clear paleoclimate signal observed.

Notes and References

1. All the information about the evidence for global warming, about the anthropogenic climate drivers, and about the numerical models can be found in the Scientific Reports of the Intergovernmental Panel for Climate Change (IPCC). Their reports do not include deficient with regards to all which is related to solar forcing.
2. Perhaps the most beautiful correlation between a solar activity and climate proxies can be found in the work of U. Neff et al., *"Strong coherence between solar variability and the monsoon in Oman between 9 and 6 kyr ago"*, Nature 411, 290 (2001).
3. Another beautiful correlation between solar activity and climate can be seen in the work of G. Bond et al., "Persistent Solar Influence on North Atlantic Climate During the Holocene", Science, 294, 2130-2136, (2001).
4. The detailed analysis behind the empirical determinations of Earth's climate sensitivity, and in particular, the role of cosmic rays, can be found in: Shaviv N., *"On Climate Response to Changes in the Cosmic Ray Flux and Radiative Budget"* JGR-Space, vol. 110, A08105, 2005, (PDF).

Add new comment

The attribution of Global Warming

On July 9th, 2006 Anonymous (not verified) says:

1) The attribution of Global Warming to CO2, is not through simple correlation with data from ice ages as suggested here. See for example: http://en.wikipedia.org/wiki/Attribution_of_recent_climate_change

2) Sun activity is known for decades to have some impact on climate. However, the recent changes in sun activity are not larger than the one we have in the last 1000 years, while the global warming in that last 30 years is not similar to anything on the record.
Hence, the theory that the sun activity is related to the recent global warming was rejected again and again.
See: http://stephenschneider.stanford.edu/Publications/PDF_Papers/DamonLaut2004.pdf

Reply:

*1) If you read carefully the page you linked to, or better, the IPCC report, you'll find that the reason CO2 is implicated as the cause for global warming is **just as I explained above**, not because there is direct evidence proving that it is, but instead because there is **supposedly** no evidence that it is something different! In the particular wikipedia page you point out, it is written that:*

"Current studies indicate the latter is most likely, on the grounds that

- *estimates of internal variability from climate models, and reconstructions of past temperatures, indicate that the warming is unlikely to be entirely natural*
- *climate models, forced by changes in greenhouse gases and aerosols, reproduce the observed global changes; those forced by natural factors alone do not*
- *'fingerprint' methods indicate that the pattern of change is closer to that expected from greenhouse gas forced change than from natural change"*

Points 1 & 2 are just what I said above, as for the meaning of the "fingerprints", just read the following excerpt from the IPCC TAR §12.2.3:

“Different models may give quite different patterns of response for the same forcing, but an individual model may give a surprisingly similar response for different forcings. The first point means that attribution studies may give different results when using signals generated from different models. The second point means that it may be more difficult to distinguish between the response to different factors than one might expect, given the differences in radiative forcing.”

Namely, it is hard to fingerprint when different numerical simulations give different responses... Just seeing for example that the troposphere warms up more than the stratosphere, doesn't mean much.

This is also why global warming alarmists try to do their best to quench anything related to the the solar variability → cosmic ray flux → atmospheric ionization → low altitude cloud cover link which by now has ample evidence for support, both empirical and experimental. It would take the juice out of their arguments, since there is a mechanism which can explain the warming.

As for the paleoclimate cosmic ray link over the multimillion year time scale, it is not just a "simple correlations" as you point out. First, the correlations over geological time scales are statistically very significant. Unlike 20th century warming, which is almost monotonic (well, CO2 increase is, the temperature and solar activity had a decrease from the 1940's to 1970's), the CRF and temperature variations over the past billion years are very non-monotinic, making any correlation highly nontrivial. In addition, the correlations are based on redundant data sets (astronomical, meteoritic, sedimentation, geochemical). Throw away any data set, and you are still left with the same conclusions. Last, there is a physical picture linking cosmic rays to clouds, and by now, a large body of accumulating evidence to support it (including evidence for a physical picture).

2) "However, the recent changes in sun activity are not larger than the one we have in the last 1000 years, while the global warming in that last 30 years is not similar to anything on the record."

Wrong! Solar activity today is as high as it was a 1000 years ago, and so are the temperatures (for example, 1000 years ago, Vikings could map the northern shores of Greenland while today it they are still frozen). If you

are claiming this claim based on the famous hockey stick, you should know that it could not be recovered in any independent analysis (e.g., read this or that)

The paper by Damon and Laut that you point out is totally irrelevant to the issue. Why? They mostly discuss climate correlation with solar cycle length. Since nobody knows how the solar cycle length is expected to correlate (or not to correlate) with the cosmic ray flux, any such correlation, or lack of, is meaningless. It could very well be that this correlation found by Friis-Christensen and Lassen is coincidental. If you would have shown me a cosmic ray flux record (specifically, of 10 GeV cosmic rays) which doesn't correlate with climate (unless climate already has a large variability from another source), it would have been a different story. But there is no such record.

reply

Very interesting subject.

On September 21st, 2006 BKC (not verified) says:

Very interesting subject. Are you saying that only cosmic rays with energies of >10GeV predominately affect cloud cover/climate? And the graph above only depicts energies in the 10s of GeV range? Do you have an (online) update/source for this graph with more recent data?

Also, have you seen the following paper at http://dx.doi.org/10.1029/2006GL026389? Any comments?

Thanks,

Bob

Comments: a) Yes, it is predominately high energies. Lower energy cosmic rays are simply stopped higher up the atmosphere, and their secondaries don't make it to the troposphere where all the action takes place. b) No, don't have. I actually looked for good data to extend it , but without success. c) Will have to take a careful look at the paper. At first glance it appears interesting. Cheers,
- Nir

reply

Cosmic rays/solaractivity

On November 9th, 2006 Paul Biggs (not verified) says:

I'm surprised that you haven't mentioned the possibilty of 'global cooling' in the near future equivalent to a Dalton or Maunder Minimum:

http://science.nasa.gov/headlines/y2006/10may_longrange.htm

May 10, 2006: The Sun's Great Conveyor Belt has slowed to a record-low crawl, according to research by NASA solar physicist David Hathaway. "It's off the bottom of the charts," he says. "This has important repercussions for future solar activity."

"The slowdown we see now means that Solar Cycle 25, peaking around the year 2022, could be one of the weakest in centuries," says Hathaway.

This is interesting news for astronauts. Solar Cycle 25 is when the Vision for Space Exploration should be in full flower, with men and women back on the Moon preparing to go to Mars. A weak solar cycle means they won't have to worry so much about solar flares and radiation storms.

On the other hand, they will have to worry more about cosmic rays. Cosmic rays are high-energy particles from deep space; they penetrate metal, plastic, flesh and bone. Astronauts exposed to cosmic rays develop an increased risk of cancer, cataracts and other maladies. Ironically, solar explosions, which produce their own deadly radiation, sweep away the even deadlier cosmic rays. As flares subside, cosmic rays intensify—yin, yang.

Using historical sunspot records, Hathaway has succeeded in clocking the conveyor belt as far back as 1890. The numbers are compelling: For more than a century, "the speed of the belt has been a good predictor of future solar activity."

If the trend holds, Solar Cycle 25 in 2022 could be, like the belt itself, "off the bottom of the charts."

reply

Cosmic rays modulation of the cloud effects on the radiative flu

On January 5th, 2007 Joel Katzin (not verified) says:

Nir,

Thanks for your public interest. I find your comments useful.

I am concerned about the apparent lack of correlation between the shortwave reflections and CRF as measured by the neutron counter (figure 6 on my DRAFT copy of "Cosmic rays modulation of the cloud effects on the radiative flux in the Southern Hemisphere Magnetic Anomaly region"). To what extent do the measurements of the neutron flux represent the part of the CRF responsible for ionization at low cloud level?

Joel

reply

There is a Positive Trend in the Incoming ICR.

On November 19th, 2007 Nasif Nahle (not verified) says:

You say that there is not a positive trend in the flux of interstellar cosmic rays and you're wrong. Voyagers 1 and 2 detected anomalies in the flux of Interstellar Cosmic Rays at the Termination Shock of the solar system. The data shows clearly that the intensity of interstellar cosmic rays are increasing. The last point of those records can go as far as 2025 and it is a very sharp increase.

Please, read this page and open your eyes:

http://www.biocab.org/Cosmic_Rays_Climate_Change.html

There you will verify that the Interstellar Cosmic Rays are increasing, and you'll find also the cause.

reply

Recent warming, but no trend in cosmic rays flux

On December 20th, 2006 M. (not verified) says:

The entire argument about cosmic rays as the driver of the global Warming in the last decades fails if there is no trend in cosmic rays flux over this period.
Guess what? There is no trend. See: http://www.realclimate.org/index.php?p=42

(the only place where there is a trend is in a figure on this web page...)

All the rest of this page recycles old arguments of Global Warming deniers. The answer to most of them can be found here:

http://illconsidered.blogspot.com/2006/02/how-to-talk-to-global-warming-sceptic.html

And here:
www.realclimate.org

reply

Dear M.

On January 16th, 2007 shaviv says:

Guess what?

There is a trend. The catch which neither you nor the proprietors of realclimate realize is that the energies relevant for low altitude ionization are way higher than the low energy records either you or they look at.

In all solar activity proxies, one can see that on top of the 11-year solar cycle, there is a secular change over the 20th century: Increase from 1910 or so to 1940, decrease to the 70's and then an increase. The catch, however, is that the secular trend at different energies is different. At low energies (which are not relevant to the amount of atmospheric ionization, but which keep on being mentioned by you or others), the increase from the 70's is week, though it is still there, and comparable to the decreased from the 1940's. When measured with high energies (e.g., as measured with muon ionization chambers), namely, at energies relevant to the amount of atmospheric ionization, the increase is larger, more than the decreased from the 1940's to 1970's.

In any case, if you read this scientific paper which I published in JGR, you'll see that the best fit estimate that I get is that solar activity explains 2/3's or so of the warming. This would imply that a good fraction of the warming from the 70's could be anthropogenic, however, we don't really know that, it would again be circumstantial evidence without a smoking gun (see above article...).

reply

M.Funny how you limit the

On February 16th, 2007 Anonymous (not verified) says:

M.
Funny how you limit the argument to the period of recent warming, conveniently overlooking the inconvenient truth that solar magnetic activity has been uniformly high over this period of warming and excluding the well documented climate history over the past centuries where sunspot activity, and cosmic ray activity, match climate history rather well. I guess you didn't read the above post before commenting.

Why exclude so much known climate hitory from the argument? My guess is that the real denialists are on the AGW side of the argument, and your argument is one piece of supporting evidence.

A thought experiment.
Imagine turning on an oven, then saying that the element had nothing to do with the temperature rise because the temperature rose over time, and not the instant the element was turned on. This is apparently your argument when you say that cosmic ray activity has been constant while temperatures warmed. I am not trying to make a thermodynamic climate argument so spare me the flames on my simplistic model. I just want to point out that the logic of your premise is flawed.

reply

CO2

On January 23rd, 2007 Anonymous (not verified) says:

I have a problem with the notion that increasing CO2 content is a cause of atmospheric warming. If you want warm one million pounds of air one degree F you will need to supply 250,000 BTU's to do this since the specific heat of air, at sea level, is 0.25 BTU/pound/Deg F. Adding 100 pounds of CO2 (100 ppm) and expecting such a performance is hard to imagine since CO2 has a specific heat of 0.20 and every one degree increase in CO2 temperature gets you only 20 BTU per degree for an incremental 100 pounds. Water vapor on the other hand is a much more potent climate driver since there is a much larger content with a large variation, from under one percent (10,000 ppm) to close to 10 percent(100,000 ppm). Water vapor has a specific heat of around 0.75 BTU/pound/Deg F. Based on this the influence of CO2 on climate seems trivial.

reply

Regarding the specific heat of CO2

On January 27th, 2007 shaviv says:

Dear Anonymous person,

I think your somewhat confused about the way CO2 and water acts as greenhouse gases. It is true that these gases have a finite heat capacity but the total energy they can store in the atmosphere is relatively slim (actually the latent heat of water is important for climate, as it is used to advect energy from tropical regions to high latitudes, but that's besides the point).

The way water vapor and CO2 affect climate is through their effect on the flow of energy. When present, the gases don't let radiation escape from Earth as easily, forcing the equilibrium temperature to become higher.

reply

CO2 or solar?

On January 27th, 2007 Sean (not verified) says:

Hi Nir: A point about fusion reactors. We don't and never will need them. Why use an unproven and undeveloped energy technology when a well proven and developed one has existed for 60 years? I'm talking about Fast Breeder Reactors. Check it out. Using both uranium and thorium reserves, all of humanity will have all the pollution free energy we would ever need for 11.2 billion years. Wind, solar, fossil, hydro, bio and conventional nuclear energy is not required.

Kudos on your article. It was quite excellent!

Best

Sean.

reply

Fast Breeder Reactors vs. Fuction Reactors.

On January 27th, 2007 shaviv says:

Sean, your point about fast breeder reactors is of course totally valid. There are however three problems with fission reactors in general.
a) Waste. Of course, there are reasonable solutions for that, but not much more than "reasonable".
b) Potential accidents. e.g., three mile island, Chernobyl (Incidentally, Chernobyl occurred because some safety mechanisms were deliberately switched off in order to run a test, to see whether the backup diesel generators can cool the core in case of an external power failure). A good solution for that is to build the reactors underground as Teller and Sakharov suggested, but it would make them more expensive.
c) You don't want Plutonium in the wrong hands (i.e., by renegade countries). Fast breeder reactors would give them just that.

For comparison, there is only one problem with fusion technology... it isn't here yet...

reply

Radioactive waste only a political problem

On February 8th, 2007 Eduardo Ferreyra (not verified) says:

Nir,

I would like to note that Three Mile Island was not an “accident”, but merely an excessively hyped

incident, as global warming is being hyped now. The amount of radiation leaked was nil --that is in the range of millirems, way down the natural radiation background levels. Even so, there were reports at the time that the "incident" was deliberately caused (green anti nuke activist Jimmy Carter was then president).

The incident happened just three days after FEMA (Federal Emergency Management Agency) was established. The agency was scheduled to go into activity several weeks later, but somehow they hurriedly called all personnel on duty –just in time for the "incident". It was a very minor one.

*On the other hand, radioactive waste is a political issue. Technically and scientifically has been completely resolved using many different techniques for extracting the radioactivity from spent fuel and concentrating it in a 4% volume (plutonium) that can be used as fuel by fast breeders that will consume all of it, leaving no waste. The rest of the spent fuel *96#% volume is converted in low level waste (LLW) that can be handled without expensive precautions and stored safely with no fear of radioactivity pollution.*

Italian scientists Carlo Rubia's work at CERN has shown many years ago the possibility of eliminating High level waste. The decision is totally political. And there is where anti-nuke activist come into action stopping the definitive solution.

Your works is going to become a pain in the neck for the IPCC and its cohort.

reply

Interesting points!

On February 9th, 2007 shaviv says:

I wasn't aware that the 3-mile island accident was an "accident". Very interesting. I do agree with you that with relatively little effort, nuclear fission power can be a better (and environmentally friendlier) solution than all other currently available technologies, whether fossil fuels or renewable. In the long run, it is clear to me that nuclear fusion (i.e., Hydrogen or Deuterium into Helium) will be our source of energy.

Although I think of myself as an environmentalist (I care about many environmental issues), I think that the Greens (as in Greenpeace) are too extreme. Most tackle issues emotionally instead of rationally and end up doing more damage than good.

reply

If interception by solar

On February 10th, 2007 John Tillman (not verified) says:

If interception by solar wind of extrasolarsystem alien space invading cosmic rays affects climate on earth, where we have thick layers of ionosphere, stratosphere & troposphere, can climatic cycles here be compared & contrasted with those on Mars, the density of whose atmosphere resembles our stratosphere & of course whose composition is largely of "greenhouse gases"?

reply

Probably not on Mars

On February 10th, 2007 shaviv says:

The cosmic ray / cloud mechanism is most likely not important on Mars because Mars doesn't lack dust particles in its atmosphere to serve as cloud condensation nuclei. (Impliying that growing the CCNs is not a bottle neck in cloud formation as it is over the oceans on Earth).

There could of course be other mechanism which would make the red planet sensitive to solar activity. If there are such, climates here and there would correlate.

reply

New(ish) fission reactor technologies

On April 29th, 2007 Rick Mott (not verified) says:

I did a brief talk at my kids' school on this topic for Earth Day; thought it was appropriate. :)

There is fission technology available which makes the loss-of-coolant type of accident (TMI, Chernobyl) nearly impossible. It uses lead, or a lead-bismuth eutectic mixture, as the working fluid instead of water. LBE melts at about 124 degrees C and doesn't boil until 1700 degrees C, so "passive safety" is feasible -- convective operation, no pumps, no pressurization.

Furthermore, it uses fast neutrons instead of thermal neutrons, which have several nice properties from a waste and proliferation viewpoint. Fast neutrons have a much higher cross section for the transuranics with intermediate half-lives which cause so much trouble in waste, permitting them to be destroyed in a combined-cycle plant with fuel reprocessing. They also create relatively large amounts of even-number isotopes of plutonium (e.g. 238, 240) compared to the odd-numbered 239 used in weapons, making diversion to weapons use much more difficult. Combined-cycle waste volume can be reduced by a factor of 1000. A good reference for a technically literate general audience is the article entitled "Heavy Metal Nuclear Power" by Loewen in the Nov/Dec 2004 issue of American Scientist.

The Russian Alfa-class submarines used lead-cooled reactors, primarily for quiet operation (no pump noise) so there is a substantial body of practical experience available.

A final thought from a different field of technology. What we really fear from radioactive waste is cancer. When we speak of the need to sequester radwaste for 10,000 years, we are not taking into account the likely advances of medical technology. Consider medicine in Ben Franklin's time compared to today, then look 200 years ahead for the cancer treatment/prevention implications. My personal prediction is that our descendants will robotically mine our "10,000 year" waste dumps within two or three centuries for fuel and other useful materials.

reply

Seasonally-resolved energy

On November 1st, 2010 smith111 says:

Seasonally-resolved energy balance models having air−surface, land−ocean and Northern and Southern Hemisphere resolution are used to elucidate the possible relative importance of several external factors on the climate of the past century 70-403. The model used here allows a direct comparison of observed and simulated temperatures from the same physical domains—over land and sea separately in each hemisphere 70-442. The availability of independent temperature records in two hemispheres significantly increases the number of independent degrees of freedom in the data available to 'verify' the simulations 70-404. Independent volcanic effects are found in both hemispheres, while similar responses for the more globally distributed CO2 and tentatively identified solar forcings are found in the two hemispheres 70-441. The empirically derived CO2 equilibrium doubling response for air surface temperature is 1.6plusminus0.3°C, although the statistical significance of this result is uncertain.

reply

FAR updates

On February 6th, 2007 Phil Cowans (not verified) says:

Nir,

Thanks for an interesting and informative article. I wonder if you could comment on the changes to the conclusions drawn from Figure 2 in light of the updated data in the recently published FAR SPM? It seems that they explicitly give a total forcing of 1.6 W/m^2 with an error range of 0.6 to 2.4 (see Figure SPM-2, http://www.ipcc.ch/SPM2feb07_new.pdf).

Phil

reply

I will certainly comment on it.

On February 6th, 2007 shaviv says:

Dear Phil,

I will certainly comment on the forcing, and that's a promise. However, I cannot do it now. This is because I cannot address a political statement (the Summary for Policy Makers) since it doesn't have any science in it, just quotes, and I cannot address the actual scientific report because it will be out only in a few months!

Cheers,
Nir

reply

IPCC

On February 16th, 2007 aaron (not verified) says:

Nir, While there is no science to investigate in policy summary, there is some interesting logic that may give you idea of what is to come.

reply

Dear Nir Shavivl try to ask

On February 26th, 2007 Gaudenz Mischol (not verified) says:

Dear Nir Shaviv

I try to ask a question for which I haven't found an answer myself. Perhaps you can help me.

It is often stated and seems to be accepted that there is a lag of temperature with the increase of CO2 until new radiative equilibirum is achieved. So if we would cut back the emissions of CO2 so that the level in the air would remain the same, we still would see a further increase of temperature. My question is how long this lag will be? Is there an estimation of this lag?

Now, the sun seems to be on a high level of activity compared to the beginning of the 20th century but does not seem to show any trend since this high level was reached around the fifthies of the last century. If we now assume a lag of temperature to equilibrium when increasing CO2, is there a similar lag for an increased solar activity or not? Or is this new radiative equilibrium reached more or less immediately with increased solar activity? Contrary to CO2 which captures heat within the atmosphere, the increased solar light reaching earth's surface (by reduced cloud cover) would heat up the surface but not the atmosphere and the increased heat would be reradiated back into space?

Sorry for the bad english but I hope you understand my questions

Thanks for your answer

Gaudenz

reply

Cloud model question

On March 15th, 2007 Ed Gerck (not verified) says:

The experimental evidence claimed to support your CR (cosmic ray) hypothesis of a CR-cloud-temperature coupling assumes that Earth's cloud formation model AND the temperature model remain unchanged for hundreds of millions of years (neglecting the odd-ball possibility that their changes would always be mutually compensating). The same models that are valid today would be valid, for example, through periods of much higher volcanic activity, different geographic arrangements and foliage (albedo), and different atmospheric composition. Do you think this is reasonable, and why? Thanks.

reply

To Ed Gerck

On April 1st, 2007 shaviv says:

You're certainly correct that the CR hypothesis, when applied to geological time scales, assumes that the mechanism of CR affecting clouds has been unchanged. Is it reasonable? Well, to make it work, the mechanism needs clean air (which you always had over at least parts of the oceans) and nucleating aerosols (e.g., as you get from DMS, which is primarily formed by phytoplankton which exists for a looooooong while), so yes, it is reasonable that the mechanism has been operational, though quantitatively it may have changed somewhat.

reply

Lags

On March 17th, 2007 M. Simon (not verified) says:

Gaudenz,

First rule of the universe: there are always lags. The speed of light is limiting if nothing else.

What you want to know is if the lags are significant for your process.

First off we know that in the mid latitudes there is on the order of a 45 day delay between increasing solar input (local) and rising temperatures.

And that is just one heat sink. Then you have the oceans. etc.

==========

Nir,

Did you look at that fusion page? We really need to get the initial experiments done ($2 million 1 year). The guy giving the lecture is Dr. Robert Bussard once of the AEC.

The initial experiments will confirm the previous data and refine the reaction constants. $200 million to scale it up to power production size. Cost of electricity from the unit - .1 cent per KWh. Most of the capital cost is in converting the 2 Million volt DC output to AC.

If you want to go to e-mail I can explain the concept to you. It works (used in portable neutron generators [D-T fuel]). The question is can it be scaled to break even? Power output goes up as the 7th power of size. Reactivity goes up as the 5th power.

The math for the magnetics is beyond me. The rest is standard high school physics (AP - LOL).

msimon6808
at
yahoo

dot
com

Most of what has to be done for the power reactor is engineering.

reply

To Gaudenz , nope didn't have time to go over.

On April 1st, 2007 shaviv says:

I barely have time to answer the comments... (I am teaching a new course this semester, and desperately trying to get ahead in research).
I'll probably look into it in a few weeks (the least).
Cheers,
-- Nir

reply

Nir,Great read. Good to see

On March 27th, 2007 Tim (not verified) says:

Nir,

Great read. Good to see an alternative view to what could be the driver of the earths climate. Interesting, Australian aborigines have a much longer record of climate than us "civilised" folk and they have a 10-12year cycle that appears to follow the cosmic ray trends. They also have a ~100+ year cycle and a longer 1000++ (10000++) year cycle known as fire or ice. Makes me think we have alot to learn as climate change has been happening longer than the last 30 or so years as Mr Gore explains.

I find the spin people use to justify their beliefs are classic. Examples;
CO2 levels in the atmosphere correlate directly with human population (lots of breathing) and thus population control can avoid climate change (hard to disprove)
Melting of the Artic ice sheet is good as shipping route will become shorter and transportation costs much less. Brillant thinking.

Its good to see someone trying to bring the big picture into focus rather than most of the reactionists and doomsday blah blah we see. Keep uup the good work.

reply

To Tim,

On April 1st, 2007 shaviv says:

Your comments about the Australian aborigines is interesting, but not surprising. After an interview on local prime-time TV, I received quite a few responses. One of them was from a history researcher who studies fashion over the ages. She said that it is quite clear from the fashion's point of view that Europe was experiencing a warm period in the middle of the middle ages (e.g., monk's dress code including sandals). Climate change has been happening for ages, long before Al Gore came.
Cheers,
Nir
p.s., Talking about aborigines, yesterday, my son and I happened to practice throwing a boomerang. Amazingly, the thing works!

reply

THis is a big business

On June 23rd, 2008 total impact (not verified) says:

i watched the other day a special documentary about the "business" of enviorment.
many scientistcs are envolved in the climate change research because it apparently brings a lot "money" from the goverment...even if their work contradicts with proven research results, they keep doing it because the benjamins are still coming :)

thanks for your great post on this subject.

Kif.

reply

CO2 ??

On March 30th, 2007 Anonymous (not verified) says:

You have lots of data and other information. What I don't see, unless I missed it, is a Heat Balance showing how an increase of CO2, and only CO2, of the order of 100 ppm of atmospheric content, can raise the temperature of the atmosphere by one degree C or F?

Unless it can be shown and verified it is hard for me to believe that CO2 is such a bad actor .

reply

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