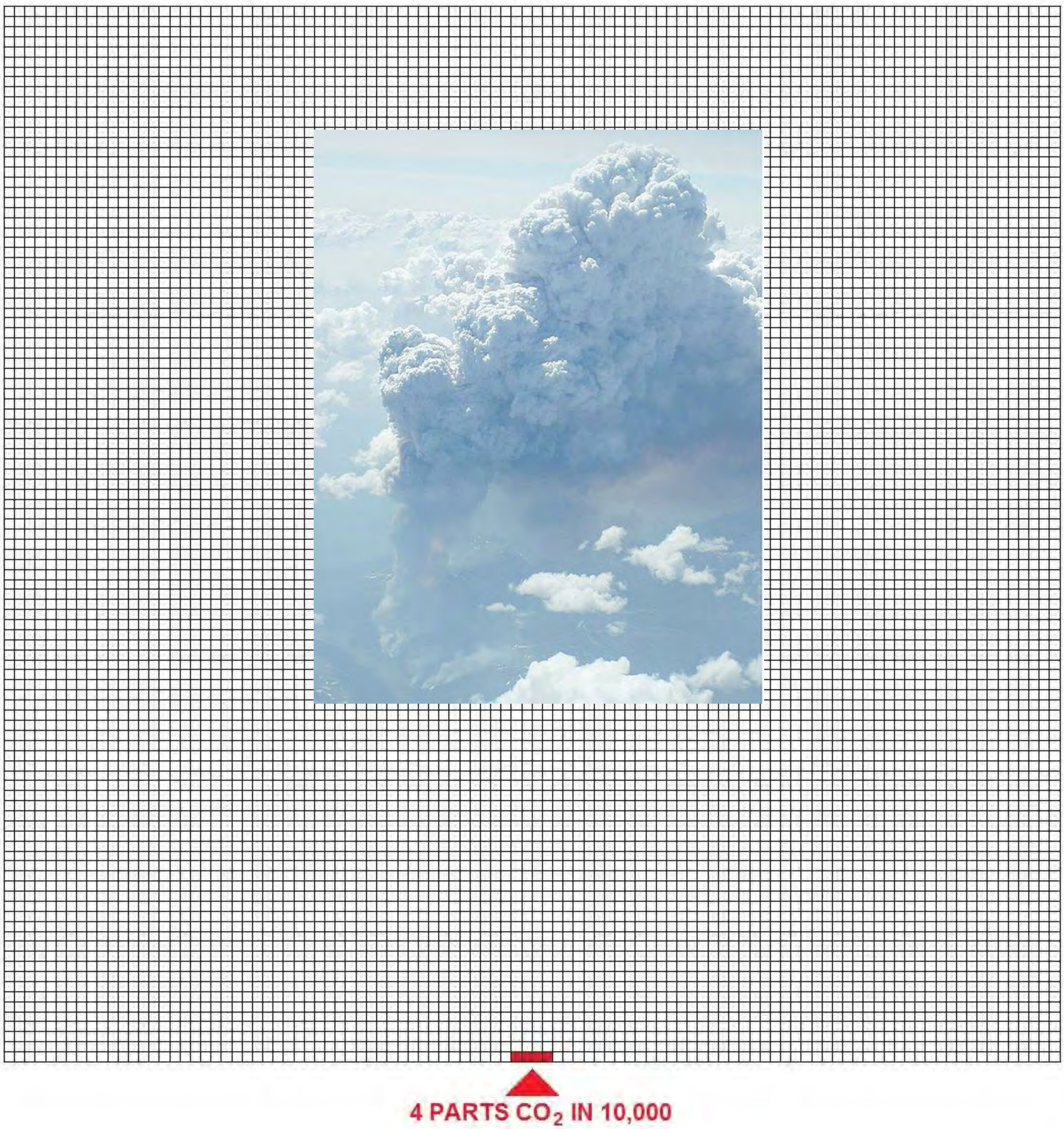

Views on the influence of CO_2 on climate

By Dick Thoenes, Ph.D.

Dr Thoenes is Emeritus Professor of Chemical Engineering

Eindhoven University of Technology, The Netherlands

FRIENDS OF SCIENCE
Providing Insight into Climate Science

A Word on Definitions

By Friends of Science Society

"Carbon" is tossed around in climate change discussions as a descriptive word for 'carbon dioxide' as in 'the Social Costs of Carbon." In fact, this is a misnomer. "Carbon" is actually soot, as seen in the microscopic image above. In the West, the emissions of soot are highly regulated. Soot is 'visible' pollution—like that of wildfires, diesel emissions, residential fire-places, and open cooking in developing nations. Soot also known as fine particulate matter or PM.2.5 (2.5 microns or less in size).

In climate discussions, carbon **di**oxide (CO2) is sometimes confused with carbon **mon**oxide (CO) —made up of one carbon molecule and one oxygen molecule. Carbon monoxide is a deadly gas and the result of incomplete burning of fossil fuels or biomass. Carbon monoxide is also invisible and tasteless, odorless, but is very dangerous.

By contrast, "carbon dioxide' (CO2) is made up of one carbon molecule and two oxygen molecules and is a tasteless, colourless, odorless, harmless gas that humans breath out at 40,000 ppm (parts per million) with every breath, and which is necessary for plant life and thus all life on earth.

About the Author

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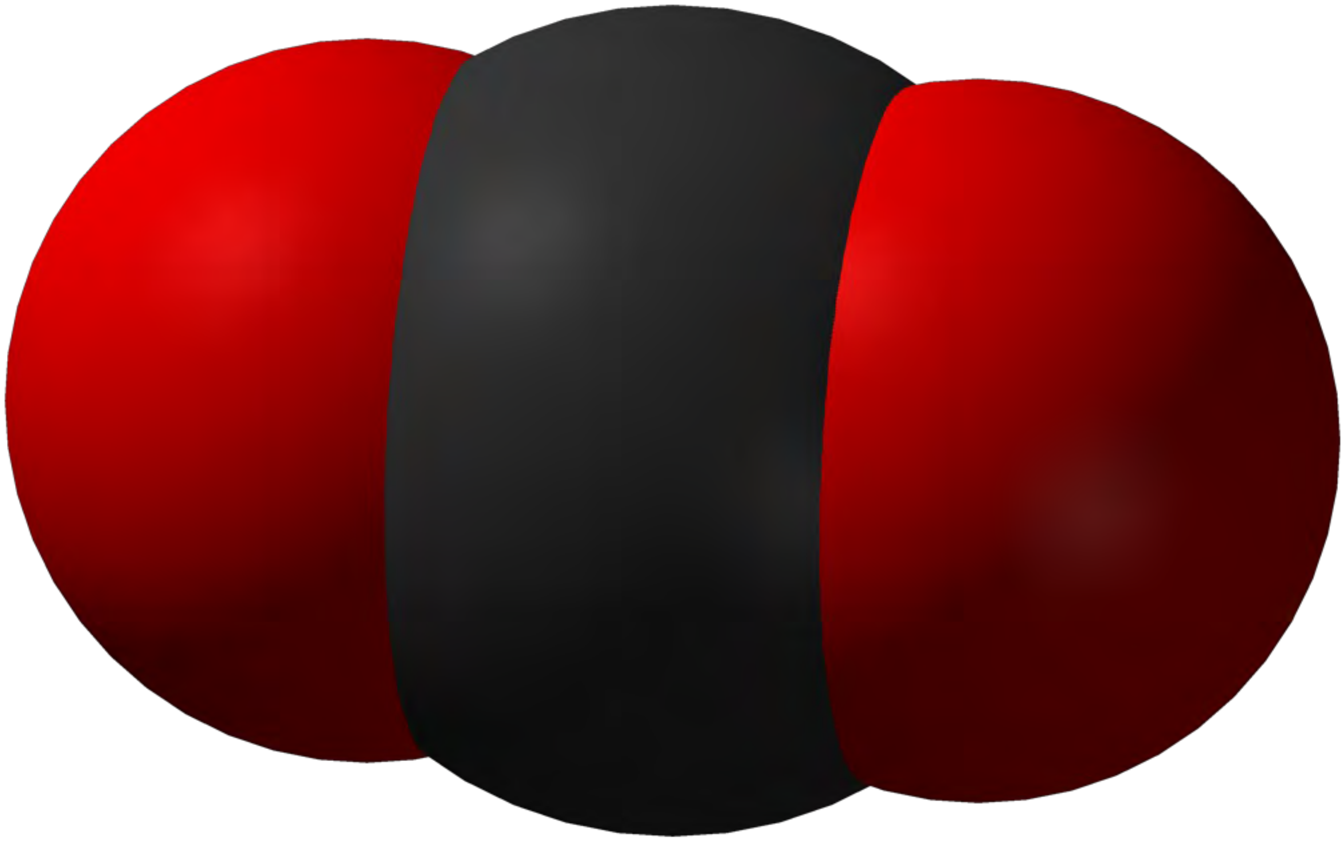
This document is based on an original commentary published in Dutch in
http://www.dagelijksestandaard.nl/2015/05/mijn-kijk-op-de-invloed-van-co2-op-het-klimaat/?utm_source=Dagelijkse+Standaard+List&utm_campaign=3749f17b52-nb&utm_medium=email&utm_term=0_ec416e99c9-3749f17b52-296387837
and was translated to English by the author
Formatting and inclusion of images and some additional relevant commentary
by Friends of Science Society for the sole purpose of aiding the layman in their review.
Many thanks to Hans Labohm for permission to republish an English version.



A carbon dioxide molecule pictured much larger-than-life. Dr. Thoenes discusses its larger-than-life status in current climate change issues.

1. Why did we think that more CO_2 would warm the atmosphere?

This idea was based on the results of laboratory studies by Svante Arrhenius published in two papers in 1896 and in 1906. It followed from his first measurements that infrared radiation can be absorbed by air that contains CO_2 whereby heat is released. The surface of the earth receives energy from the sun and converts this into infrared radiation that is at least partially absorbed by CO_2 present in the atmosphere, which causes the temperature to rise. The temperature of the surface rises as well in order to maintain a constant heat flux into the atmosphere. This is called the “greenhouse effect”. From the heated air layer energy is transported upward.


UEBER DEN EINFLUSS
DES ATMOSPHÄRISCHEN KOHLENSÄUREGEHALTS
AUF
DIE TEMPERATUR DER ERDOBERFLÄCHE
VON
SVANTE ARRHENIUS.

MITGETEILT D. 8 JANUAR 1896.
GEPRÜFT VON R. RUBENSON UND B. HASSELBERG.

STOCKHOLM, 1896.
KUNGL. BOKTRYCKERIET. P. A. NORSTEDT & SÖNER.

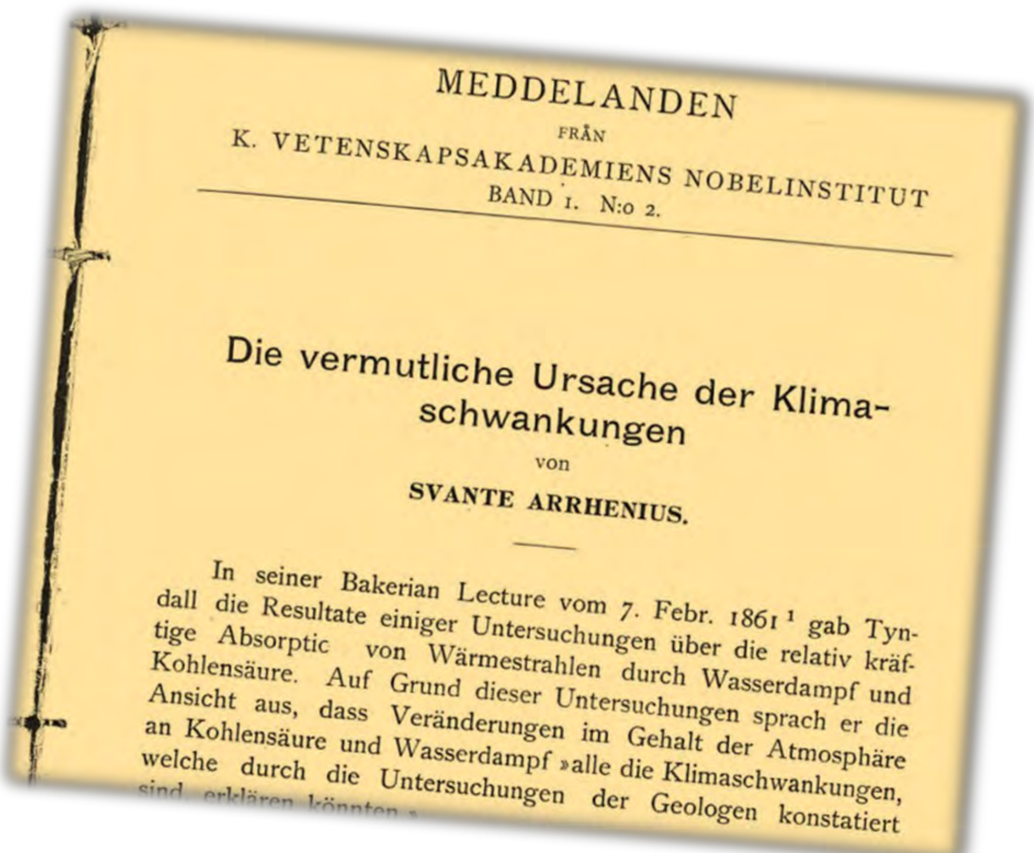
Background Information on Svante Arrhenius

His famous paper on the greenhouse effect and global warming. The Arrhenius equation is a simple, but remarkably accurate, formula for the temperature dependence of the rate constant, and therefore, rate of a chemical reaction. The equation was first proposed by the Dutch chemist J. H. van't Hoff in 1884; five years later in 1889, the Swedish chemist Svante Arrhenius provided a physical justification and interpretation for it. "In 1896 [Arrhenius] published a long memoir "On the Influence of Carbonic Acid in the Air Upon the Temperature of the Ground,' in which he developed a theory for the explanation of the glacial periods and other great climatic changes, based on the ability of carbon dioxide to absorb the infrared radiation emitted from the earth's surface. Although the theory was based on thorough calculations, it won no recognition from geologists." The article described an energy budget model that considered the radiative effects of carbon dioxide (carbonic acid) and water vapor on the surface temperature of the Earth, and variations in atmospheric carbon dioxide concentrations. Arrhenius argued that variations in trace constituents - namely carbon dioxide - of the atmosphere could greatly influence the heat budget of the Earth. Using the best data available to him (and making many assumptions and estimates that were necessary), he performed a series of calculations on the temperature effects of increasing and decreasing amounts of carbon dioxide in the Earth's atmosphere. (DSB Vol. I, pp. 296-302). [Attributes: Hard Cover] https://www.vialibri.net/552display_i/year_1896_0_840586.html

2. How important is the greenhouse effect of CO_2?

Arrhenius was interested in this effect because he wanted to explain the warming -up of the atmosphere after each ice age. In the mean time it has become clear that we owe the comparatively mild temperatures of the atmosphere to the combined greenhouse effects of CO_2 and water vapour (however, this is doubted by some scientists). The effect of water vapour is the largest by far. Arrhenius supposed that the atmosphere would become warmer in the future due to the burning of fuels. This is called the "additional greenhouse effect". He estimated this effect to be 5°C at a doubling of the CO_2-concentration, which was approximately 300 ppm at that time. In his second paper he corrected this, **the effect would not be 5 but 1.6ºC.**

> ***In 1906, Svante Arrhenius amended his view of how increased carbon dioxide would affect climate.*** *He published a paper in German. It was never translated at the time or widely distributed, though many European scientists knew of it and read it.*
>
> *In 2014 Friends of Science Society translated this paper into English for wider distribution..* http://www.friendsofscience.org/assets/documents/Arrhenius%201906,%20final.pdf


MEDDELANDEN
FRÅN
K. VETENSKAPSAKADEMIENS NOBELINSTITUT
BAND 1. N:o 2.

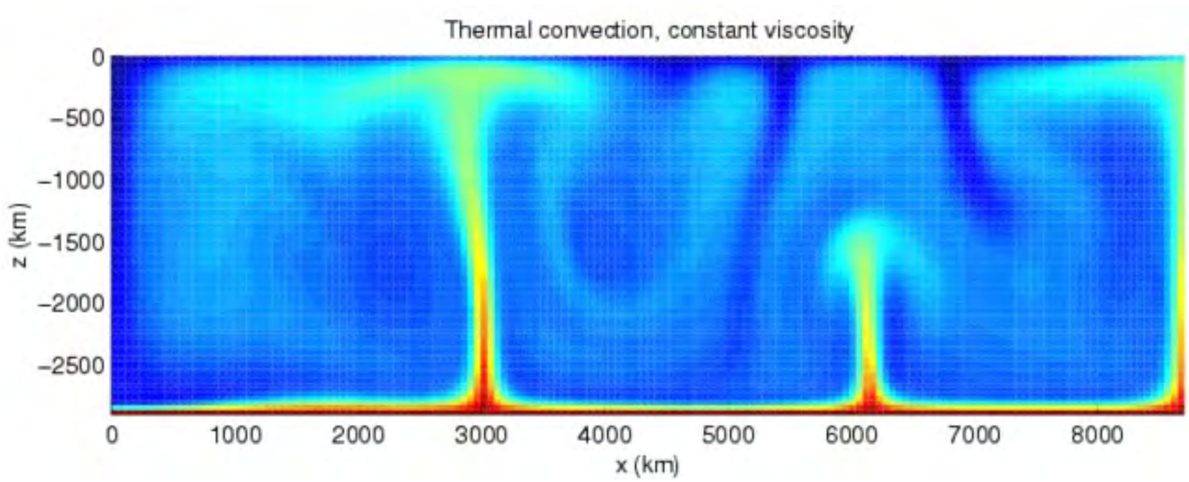
Die vermutliche Ursache der Klimaschwankungen
von
SVANTE ARRHENIUS.

In seiner Bakerian Lecture vom 7. Febr. 1861 [1] gab Tyndall die Resultate einiger Untersuchungen über die relativ kräftige Absorptic von Wärmestrahlen durch Wasserdampf und Kohlensäure. Auf Grund dieser Untersuchungen sprach er die Ansicht aus, dass Veränderungen im Gehalt der Atmosphäre an Kohlensäure und Wasserdampf »alle die Klimaschwankungen, welche durch die Untersuchungen der Geologen konstatiert sind, erklären könnten.»

Scanned original: http://www.friendsofscience.org/assets/documents/Arrhenius1906.pdf

In the nineteen eighties the first paper was often cited, and it was feared that the rising CO_2-content, caused by the increasing use of fossil fuels, would result in a considerable heating of the atmosphere. The second paper was rediscovered after 2000 (I believe). The effect appeared then less threatening, but still significant. As far as I know, the second estimate is now generally considered to be correct.

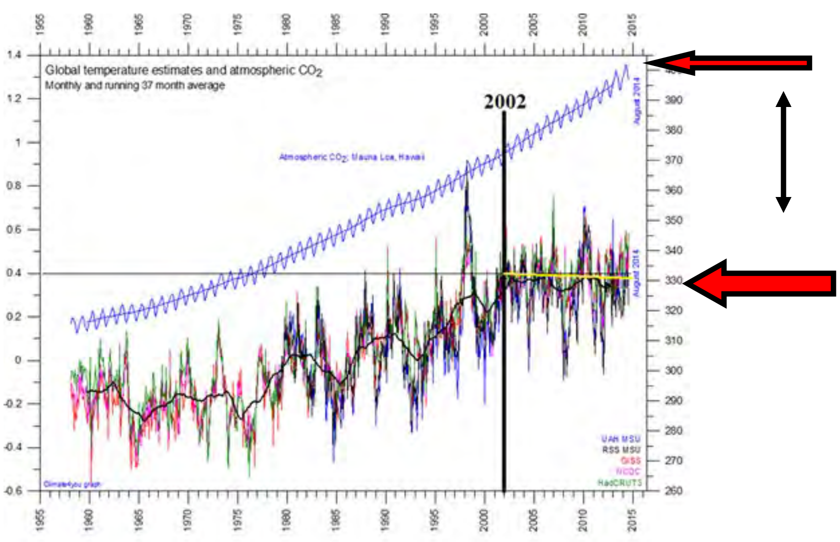
It is sometimes claimed that the earth's surface is heated by back radiation from the heated air layer, containing CO_2. This is incorrect, as heat cannot flow from lower to higher temperatures.



3. Has the “additional greenhouse effect” of CO_2 been proven in the real world?

No, it has not. It is not possible to carry out suitable experiments in the atmosphere. In the atmosphere no significant heating was observed in the second half of the 20th century, despite an enormous rise in CO_2-content. The temperature rise over the entire 20th century also comprises the rise of 0.4 degrees in the years between 1900 and 1940, (when industrial emissions were low) which certainly cannot be attributed to CO2 and is therefore not relevant in this context. There was only a temperature increase between 1979 and 1998 (0.4°C).

The rise between 1945 and 2000 was only about 0.2 degrees which I consider not significant, since the accuracy of determining a world average in my opinion is on the order of 0.5 degrees (average over day and night, all days of the year and all places on earth; the last is the most difficult to average correctly—see Section 6, second half). But during that same time the rise in CO2 content was enormous, and this did not cause a corresponding temperature increase.



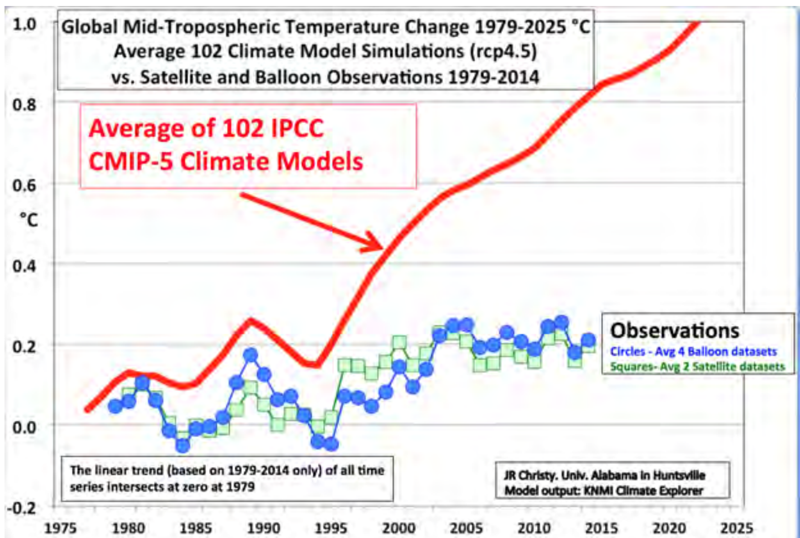
This graph shows a steady rise in CO2 in the blue jagged line.

The five multi=colored lines show the uneven responses of temperatures from the 5 datasets of global mean temperatures.

Warming has not been significant, nor does it follow with the rise of CO2, especially not since 1999 when it has flat=lined and some reviewers see a cooling trend.

Graph: Ole Humlum Climate4You
Yellow trend line added.

From 1940 to 1979 there was a slight decrease (0.2°C) and after 1998 the mean temperature remained practically constant. The average rise since 1940 was about 0.2°C. The CO_2-content increased all the time. The significance of these temperature changes is doubtful as can be seen from the graph on the previous page and the ones below (see also Section 6). When measurements do not agree with the theory, I find that the theory is wrong.

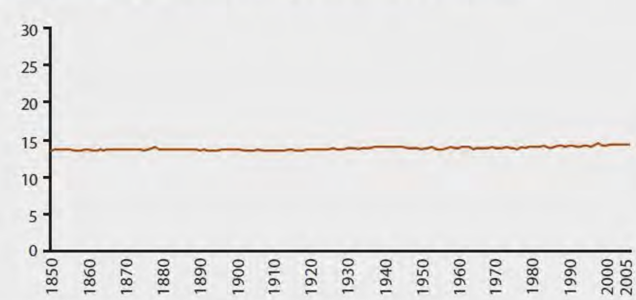


Reference: Graph compiled by Dr. John Christy, University of Alabama in Huntsville. Climate models output from KNMI Climate Explorer here. Satellite observation from University of Alabama in Huntsville here and Remote Sensing Systems here. Balloon observations are from four weather balloon radiosonde datasets.

Also, we should be careful with the use of the term "climate". Originally this term referred to the local climate of a country or a region. When we now read in the papers about "the climate", this means an average "world climate". However, such a climate does not exist and cannot be rigorously defined. Similarly a "mean temperature" cannot be determined unambiguously (see Section 6).

"Global warming" graph when seen in degrees instead of tenths of degrees shows the earth's temperature is "remarkably stable" over 100 years to quote Dr. Ivar Giaever, Noble Prize winner in Physics 1973.

Figure 2: Global Mean Temperature (1850–2006)



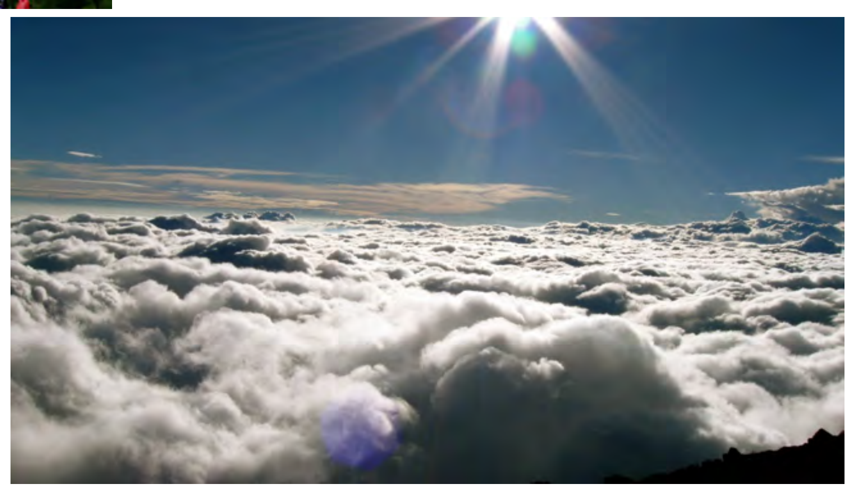
Source: Derived from the US Bureau of Meteorology Data http://www.bom.gov.au/web01/ncc/www/cli_chg/timeseries/global_t/0112/global/latest.txt

4. Why is it that we hardly notice any additional greenhouse effect?

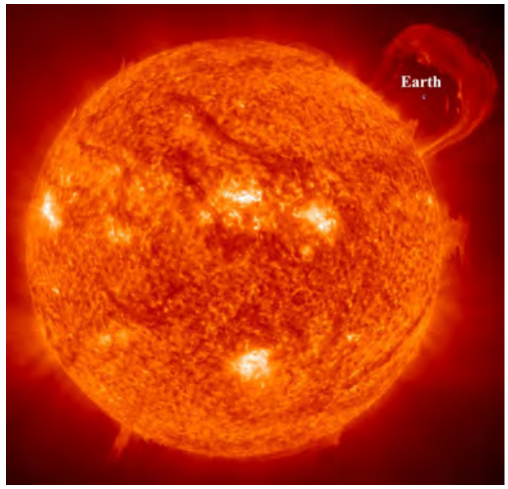
The greenhouse effect of CO_2 has been confirmed in laboratory experiments; there is no doubt about that. The problem is that the results of laboratory experiments cannot be applied directly to the atmosphere. The physical situation in the atmosphere is much more complicated and cannot be reproduced in the laboratory. In the real atmosphere a number of additional phenomena occur simultaneously, such as solar radiation, reflection at water and ice surfaces, evaporation of water, convection (horizontal and vertical air flows), formation of clouds (that radiate upward and reflect solar radiation), rainfall, snow, etc. We cannot predict the simultaneous occurrence and the interaction of all these phenomena, especially since they vary considerably from one location to the next. It is important to note that the evaporation of water and the formation of clouds counteract any heating and act as a negative feedback. **In fact, it has not been shown conclusively that addition of CO_2 to the atmosphere has a definite influence on climate.**

"Smith botanic garden greenhouse". Licensed under CC BY-SA 3.0 via Wikipedia - https://en.wikipedia.org/wiki/File:Smith_botanic_garden_greenhouse.JPG#/media/File:Smith_botanic_garden_greenhouse.JPG

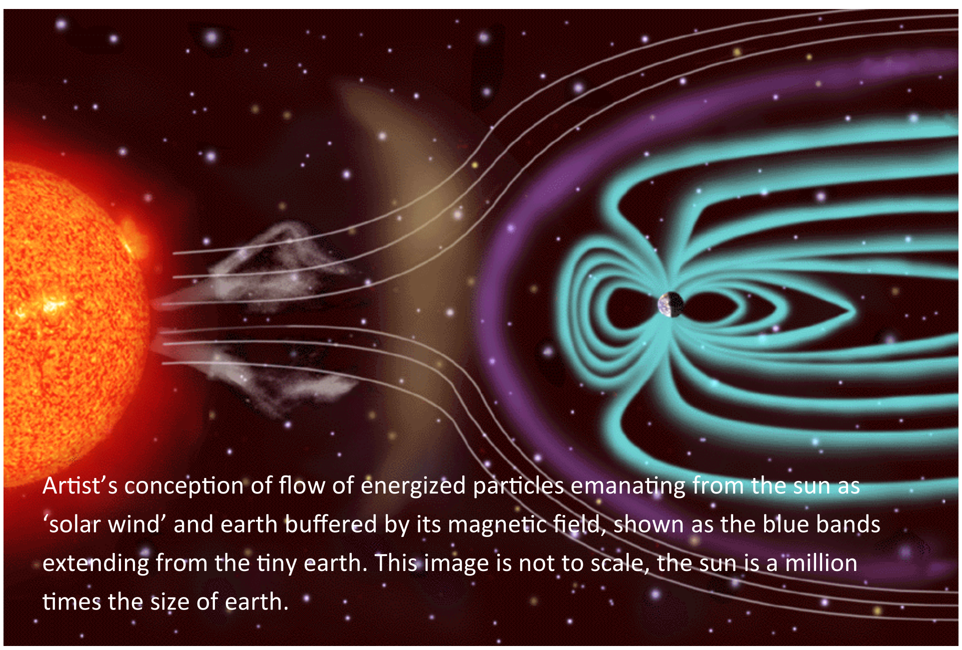
Unlike a greenhouse, earth has no impenetrable glass roof. Many unpredictable factors alter climate, often dramatically. Clouds cannot be modelled and they remain a great mystery of climate and a significant factor.



5. Are there other factors that influence the climate?



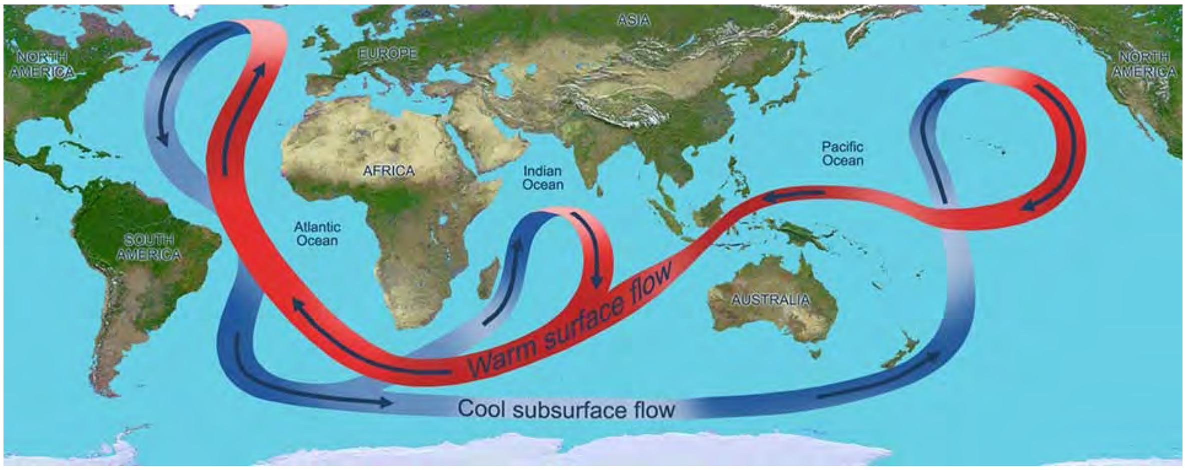
Yes, there are two natural phenomena that influence temperature and that can fluctuate capriciously. These are the solar activity and the large circulating ocean currents.



Artist's conception of flow of energized particles emanating from the sun as 'solar wind' and earth buffered by its magnetic field, shown as the blue bands extending from the tiny earth. This image is not to scale, the sun is a million times the size of earth.

Solar activity (which manifests itself through sunspots) causes the "solar wind", i.e. a flow of charged particles that are emitted by the sun and fly into space. They also hit the earth, and interact with the cosmic radiation (coming from distant stars), that in its turn influences cloud formation in the atmosphere, which determines how much solar irradiation reaches the earth's surface. By this complicated mechanism, an increased solar activity gives rise to a higher temperature of the atmosphere.

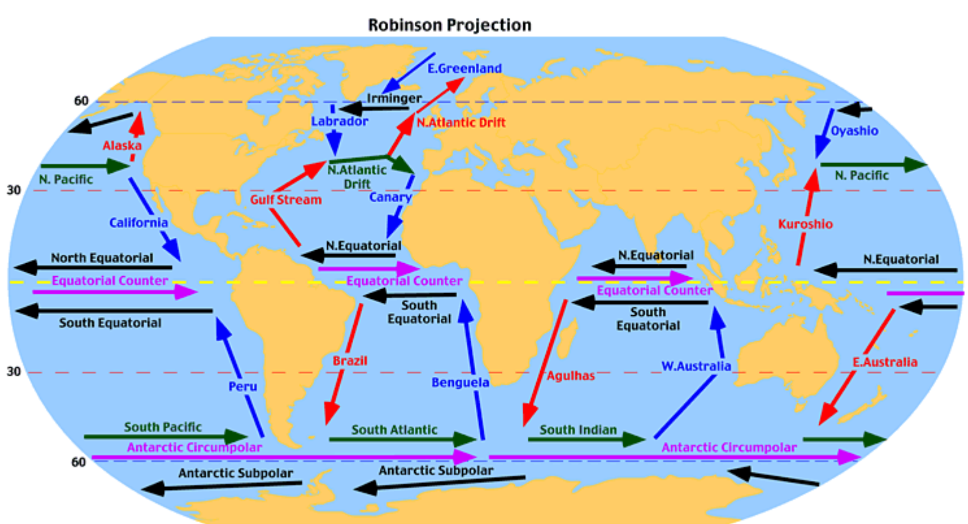
Solar activity changes slowly and unpredictably, although cyclicities on multi-decadal and larger scales have been recognised. In the last quarter of the 20th century solar activity was high, after 2000 it decreased and now (2015) it is very low. It is *possible* (but not proven) that the measured temperature increase of 0.4°C (1979-1998) was caused by the high solar activity.



The Great Ocean Conveyor or Thermohaline Cycle continuously moves warm surface water down deep in the ocean where it cools and likewise brings cold water up from the depths. http://oceanservice.noaa.gov/facts/coldocean.html

The circulating ocean currents distribute the excess heat, that is received from the sun in the tropics, over the surface of the earth. When in a certain year a little more warm water streams to one of the poles, it gets a little warmer there. And vice versa. This also influences the average world temperature. As far as I know, the cause of these changes in ocean currents is still being debated. These two effects are probable causes of the random variations in the average world temperatures, that can vary from one year to the next between 0.1 and 0.5°C.

Simplified Surface Ocean Current Diagram. Red arrows indicate warm poleward flowing currents, blue arrows indicate cold equatorward flowing currents. Other colors indicate currents that primarily transport eastward or westward. This map was created by Michael J. Pidwirny, Department of Geography, Okanagan University College



http://www.met.nps.edu/~psguest/polarmet/climate/climfig4.html

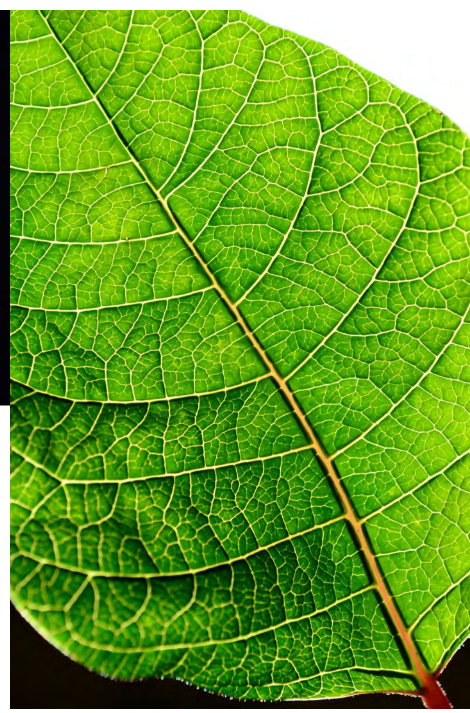
6. Complications and uncertainties

There are important uncertainties, not only in the quantitative effects of CO_2, but also in the mass balances of the CO_2-flows. These mass balances are quite complicated. The different natural flows, which are much larger than the human emissions, are not known with sufficient accuracy. The four large natural flows are: the production of CO_2 by decomposition of dead vegetation, the desorption of CO_2 from warm ocean waters, the absorption of CO_2 from the air by growing vegetation, the absorption (dissolution) of CO_2 in cold ocean waters. These flows are all more than ten times larger than the human emissions and they can change gradually with time. However, these changes cannot be measured accurately. Therefore we do not know for sure whether an increase in CO_2 -content of the atmosphere is actually caused by burning of fuels, although this seems plausible (however doubtful, see below). It can also be caused by a temporary increase of the natural production or a decrease in natural consumption (that are not coupled directly).

Another thing that is uncertain, is the fraction of human CO_2-emissions that remains in the atmosphere. Of all the CO_2-flows that enter the atmosphere, from both natural and human origin, about 98% is absorbed by nature (plants and oceans). The 2% of the flows that stays behind in the atmosphere corresponds to the measured increase of the CO_2-content. It is not at all clear that this has any relation to human CO_2-emissions.

Humans breathe out CO2 at 40,000 ppm per breath. Image source: http://www.medicalnewstoday.com/articles/271813.php

CO2 is the breath of life for plants as they grow —once they have matured and they begin to decompose, CO2 is the release of life as it returns naturally into the air from decomposed bio-mass. This is a natural cyclical phenomenon in concert with the seasons.

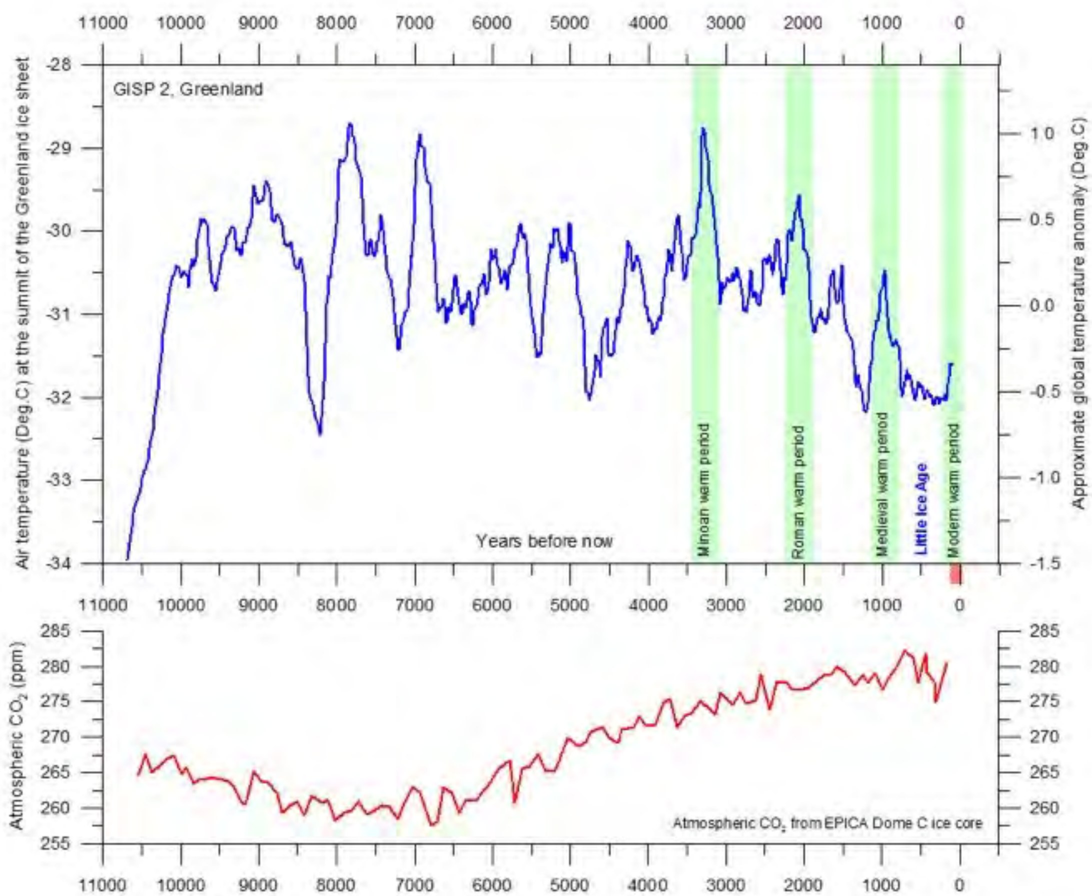


"Backlit green poinsettia leaf" by Fasaxc - Own work. Licensed under CC BY-SA 3.0 via Wikimedia Commons - https://commons.wikimedia.org/wiki/File:Backlit_green_poinsettia_leaf.jpg#/media/File:Backlit_green_poinsettia_leaf.jpg

http://www.mysticchrist.co.uk/blog/post/samhain_skeleton_leaf_reflection

What causes the magnitude of these fractions? Will they remain constant? That is uncertain, because the increasing CO_2-content of the atmosphere plant growth increases gradually across the globe. Therefore the CO_2-absorption by plants will increase, but ultimately also there will be an increase of the decomposition of plant debris. We cannot determine these developments accurately, so it is possible that the 2% (that accumulates) will gradually increase **or** decrease. In the latter case the CO_2-content might become constant (this is speculation, of course).

The claim that about half of the human industrial CO2 emissions remain in the atmosphere is certainly incorrect. The natural absorption processes do not distinguish between CO_2 from different origins. This error is based on the observation that the accumulation of CO_2 is about equal in volume to half of the human emissions, but that is pure coincidence.

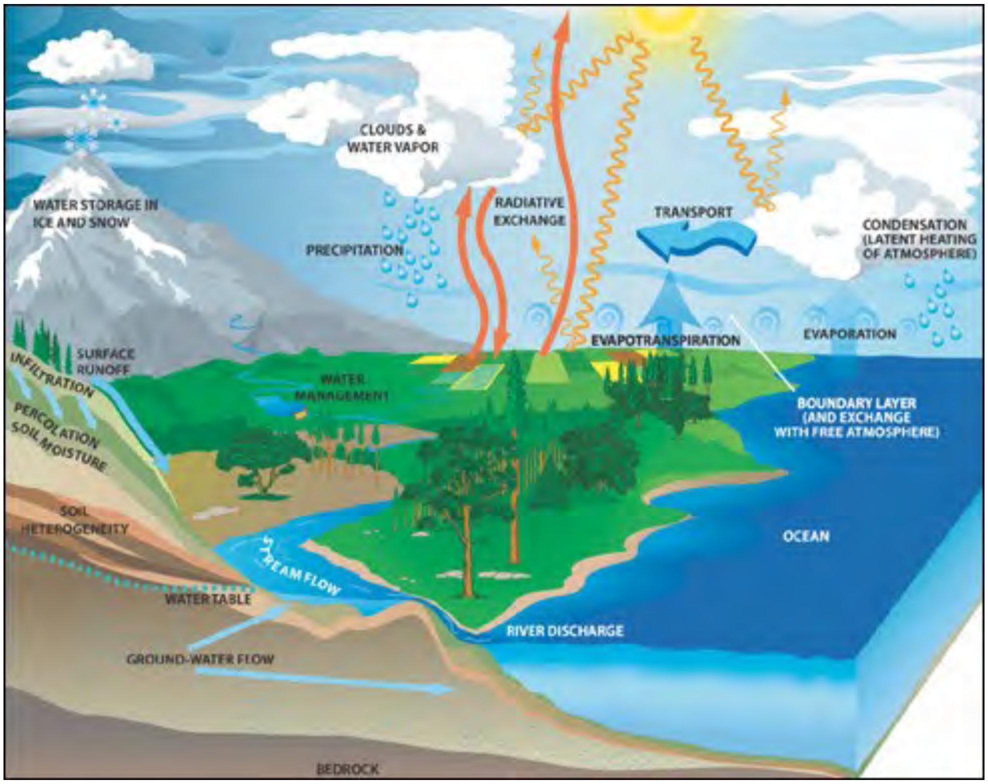


This graph of Greenland Ice Cores—long tubes of ice drawn from the depths of ancient Greenland glaciers have CO2 concentrations trapped in the ice from thousands of years ago. This shows that carbon dioxide (CO2) as in the red line of the bottom part of the graph above, does not have a direct correlation to temperature. Look at the temperature graph in the top graph, shown in blue. This graph shows that over time, temperatures have gone up OR down in opposition to the quantity of CO2 in the air—and most recently, that despite CO2 going up a lot, overall temperatures declined dramatically (even though, if you ONLY measured it from 1850, it would look like things had warmed up.).

White Cliffs of Dover

The oceans contain about 50 times more CO_2-than the atmosphere, mostly as bicarbonate (HCO_3^--ions, which is a compound of CO_2 and hydroxyl ions, OH^-, and which can decompose again at higher temperature). When the temperature of the ocean goes up a little, more CO_2 will enter the atmosphere, and when the temperature goes down, more CO_2 will enter the water. Small changes of the CO_2-content of the water correspond with large changes in the atmosphere.

Also, some CO_2 is constantly removed from the cycle by the formation of calcium carbonate ($CaCO_3$) as shells of marine organisms, that sink to the bottom. We do not know how much this is, but it is probably not negligible. The chalk cliffs found e.g. near Dover in England, and in many other places around the world, are of this origin (they came up through a rising of the sea bottom).



Water Cycle

http://science.nasa.gov/earth-science/oceanography/ocean-earth-system/ocean-water-cycle/

Another complication is the fact that the solar energy that is received by the earth's surface, is transported upward by three mechanisms simultaneously: evaporation of water, followed by condensation and cloud formation, heat transfer by convection (air flow) and infrared radiation followed by (partial) absorption. Though the emphasis is usually on radiation, it is actually the least important (10-20% of the total). This limits the greenhouse effect. Energy is transported upward by these three mechanisms, but ultimately the energy is radiated into space from the upper layers of the atmosphere. A quantitative description of these processes is hardly possible, since they vary enormously between one location and the next.

We know that the evaporation of surface water (including water in wet earth) plays an important role in our climate. When the air temperature starts to rise, evaporation increases which slows down the heating (therefore temperature variations are smaller in wet countries such as the Netherlands than in dry areas, e.g. deserts). Also, evaporation leads to the formation of clouds, which reduce irradiation of the surface. These processes diminish the greenhouse effect (so called negative feedback). We cannot measure this accurately world wide.

Another uncertainty is the greenhouse effect of water vapour, that is much larger than the effect of CO_2 and which varies enormously around the world. We cannot accurately determine this effect. Therefore it is not possible to assign a given temperature change to CO_2 alone.

The reported average temperatures are computed from temperature measurements around the world in a special manner, that accounts for the areas where no measurements are available. This calculated average temperature is not so accurate as it may seem. Also, it is not constant, and can vary without any external influence.

This can occur as a result of changes in phase transitions, such as evaporation, condensation, melting of ice, formation of ice from water, evaporation of ice and formation of ice from moist air. All these processes are coupled with production or consumption of heat. The extent of these phase transitions can vary due to varying water streams or winds. And they cause heating or cooling of the surroundings. All these phenomena take place because the atmosphere and the oceans are not in equilibrium.

When it is observed, for example, that in a certain period polar ice sheets have melted (as happens periodically), then this is not a sign of warming of the globe, but rather of cooling. When ice melts, heat is extracted from the surroundings. (mostly from the water).

The non-equilibrium situation is caused by the fact that heat is constantly added or removed from the earth (due to solar irradiation and radiation of infrared into space), which causes large scale water and air currents around the globe.

A consequence of this is that it is not really possible to determine an average temperature with an accuracy smaller than 0.5°C (see the end of Section 5). Smaller variations in the average temperature are therefore not significant.

It also follows from this that a mean "world climate" cannot be defined.

Average these temperatures and see what you get. Remember that oceans cover 71% of the earth's surface. Using only the first Celsius figure, rounded off, the answer is 87 degrees C divided by 6 = 14.5 degrees C avg Western Hemisphere temperature. This is not a useful number and tells us nothing about local climate conditions or trends.

North Pole winter	**−34 °C (−29 °F).**
Vancouver, BC	11.0 °C (51.8 °F)
Washington, DC	37 days at or above 90 °F (32.2 °C) and 64 nights at or below freezing
Rio de Janeiro, Brazil	23 to 27 °C (73 to 81 °F)
Buenos Aires, Argentina	12 to 17 °C (54 to 63 °F) and drop to 3 to 8 °C (37 to 46 °F
South Pole summer	−25.9 °C (−15 °F) January −45 °C (−49 °F) March

7. The unpredictability of the climate.

For a long time we assumed that the future climate could be predicted if we would possess the following two things:

- **A climate model** that describes the world climate in sufficient detail (in this context, a model is a set of mathematical equations).

- **Sufficient climate data** (from the whole globe) that could be fed into the model to make it suitable for predicting the future climate.

However, both ideas are incorrect. There are too many uncertainties (Section 6) to make a sufficiently accurate model. Our present climate models are very advanced but do not comprise all relevant processes. But even if we had such a perfect model, we still could not predict the future climate, since the world climate behaves as a “chaotic” system.

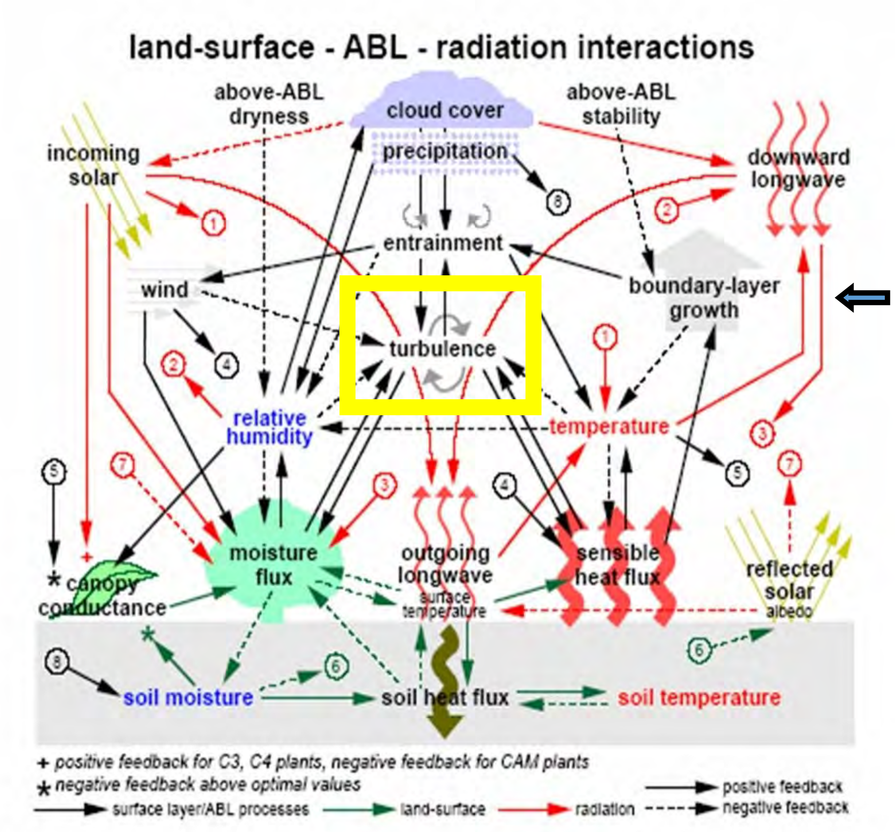
A visualization of air turbulence from the wing tip of an aircraft. Weather systems exhibit similar large and unpredictable turbulence and ‘chaos’ on vastly larger scales.

"Airplane vortex edit" by NASA Langley Research Center (NASA-LaRC), Edited by Fir0002 - This image or video was catalogued by Langley Research Center of the United States National Aeronautics and Space Administration (NASA) under Photo ID: EL-1996-00130 AND Alternate ID: L90-5919.TLicensed under Public Domain via Wikimedia Commons - https://commons.wikimedia.org/wiki/File:Airplane_vortex_edit.jpg#/media/File:Airplane_vortex_edit.jpg

http://www.wunderground.com/wximage/pasocorto/248

Chaotic in this sense is a mathematical concept that means that the system is described by a number of simultaneous non-linear differential equations.

Such systems are extremely sensitive to initial conditions, such as temperatures measured at certain points at certain times. Small variations in these data (smaller than the accuracy of measurement) may result in completely different outcomes. Therefore, the future of the world climate cannot be predicted from atmospheric models.



Yellow box added to highlight turbulence in chaotic system

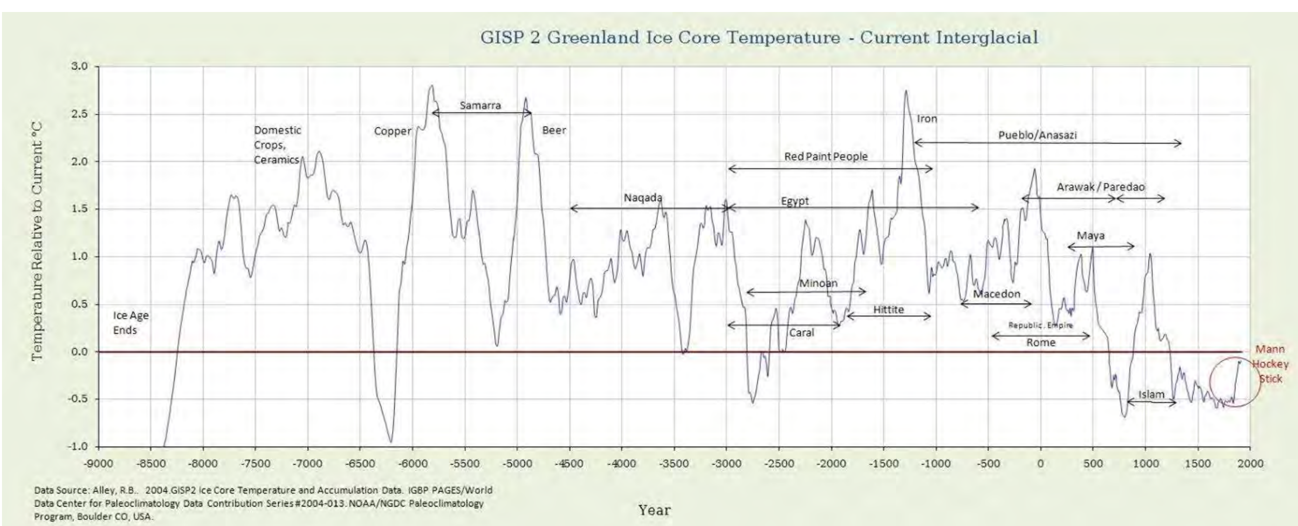
http://www.knmi.nl/research/atmospheric_research/pagina_4.html

8. Does the world warm up or not?

This question cannot be answered. We can ask the following questions that can be answered: Has the world warmed up until now? Is it expected that the world will warm up in the future?

It follows from measurements that the atmosphere warmed in the period 1979-1998 by 0.4ºC, but it is doubtful whether this is significant (see Section 6). There was also some warming before 1940, but there were little CO_2-emissions then, so it must have had other causes.

We cannot say if the earth will warm up in the future, since the climate is essentially unpredictable (Section 7). We can however have *expectations.* We know that of the infrared radiation that can be absorbed by CO_2, already more than 90% is absorbed already and converted into heat. When the CO_2-content rises, the absorption can never be more than 100%, of course. This will correspond to a temperature rise of less than 2ºC. We know however that this would have more advantages than disadvantages. The advantages are: higher crop yields and less energy consumption (which would amount to many billons of dollars each year). Because of the negative feedbacks, the temperature rise will probably be much smaller (alas). Many astronomers predict cooling in the near future, which would be far more disadvantageous than heating.



The above graph analyzes ice cores drawn from ancient depths in Greenland and cross-references temperature proxies (remnants of plant growth, cross-referenced tree rings, etc) with known archeological, geological, and anthropological evidence or markers that indicate likely temperature conditions. Regional temperatures and climate patterns do vary (i.e. Medieval Warm Period was warm and stable in Europe, but brutally hot in the southwestern USA (of today) with mega-epoch droughts of up to 100 years. (Source: Brian Fagan "The Great Warming") However, it is clear that global temperatures have been much warmer and much cooler. Humanity progressed more in warmer times.

9. Can we arrive at a conclusion?

Originally we thought that there would be a relation between the CO_2-content of the atmosphere and the average temperature. This has been demonstrated for the geological history, during the last few hundred thousand years. However it follows from geological research that a temperature increase always *preceded* a rise in CO_2-content (no doubt by desorption from the oceans). There are no indications that CO_2 can cause significant temperature rises (more than a few tenths of a degree). We now know that the large number of processes taking place in the atmosphere are so complex that we will never be able to make a quantitative description.

Clouds forming over the Atlantic ocean off the coast of Brazil.

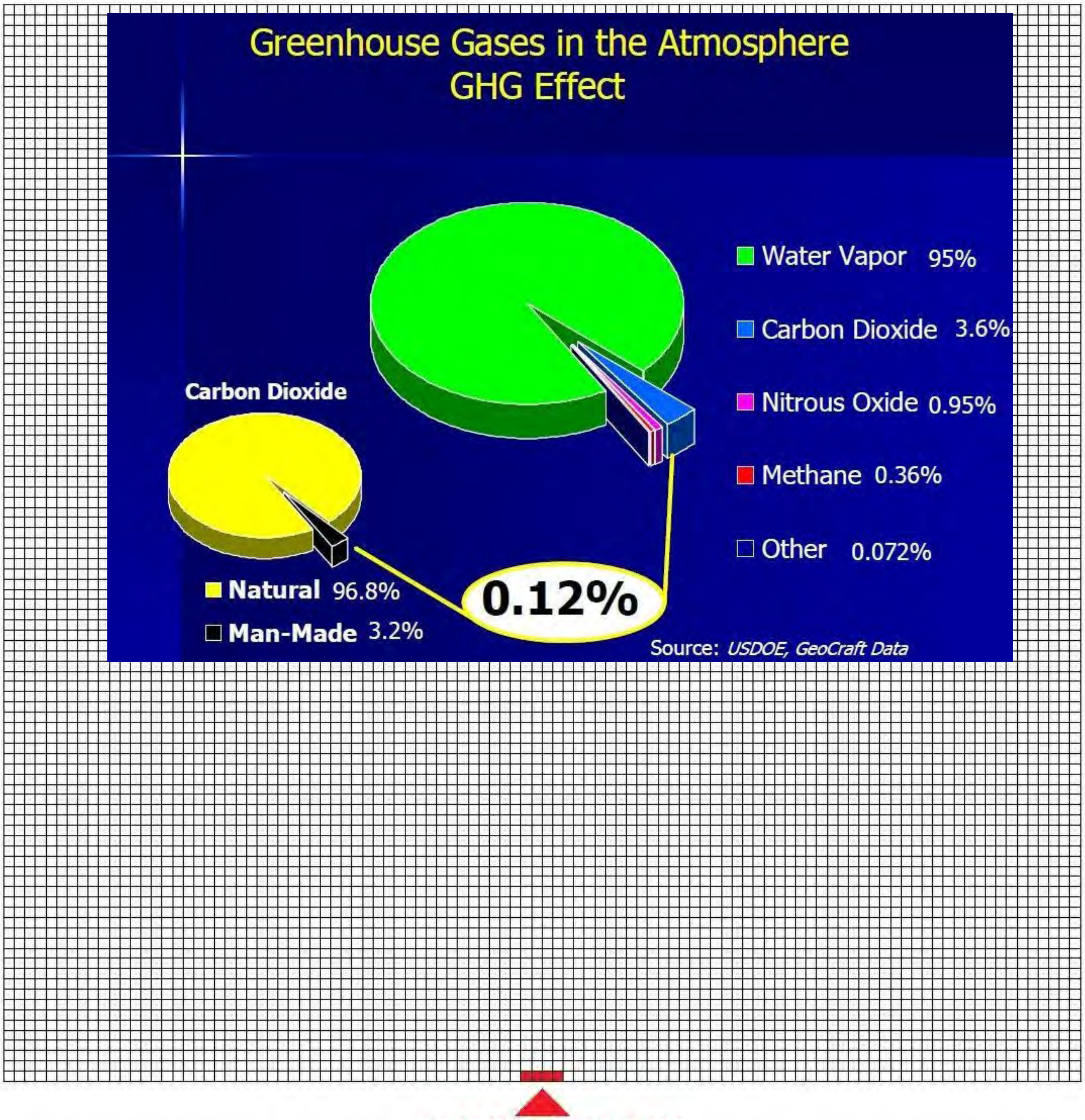
Should it not worry us that we keep putting large amounts of CO_2 into the atmosphere? As far as we know, larger CO_2-content has only advantages (more plant growth) but no disadvantages. In certain geological periods the CO_2-content was much higher than today, without any dramatic effects.

Some people point to a possible acidification of the oceans by CO_2, but in my opinion that is not likely. The water of the oceans is slightly alkaline, and with more CO_2 it could become a little less alkaline, but never acidic. This is because of the “buffering” action of the system containing CO_2, bicarbonate and carbonate ions.

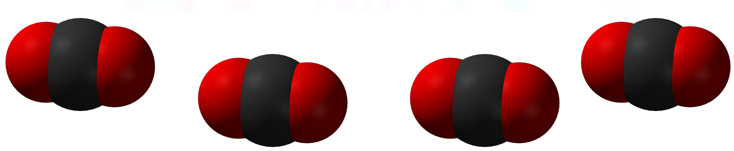
10. Consequences

My conclusion is that it is *impossible* that a significant climate change can take place due to rising CO_2-emissions. This means then that all measures to reduce CO_2-emissions are useless. This would have enormous financial consequences for society.

The Hague, 4th June 2015



4 PARTS CO_2 IN 10,000



About

Friends of Science have spent a decade reviewing a broad spectrum of literature on climate change and have concluded the sun is the main driver of climate change, not carbon dioxide (CO_2). The core group of the Friends of Science is made up of a growing group of Earth, atmospheric, astrophysical scientists and engineers who volunteer their time and resources to educate the public.

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