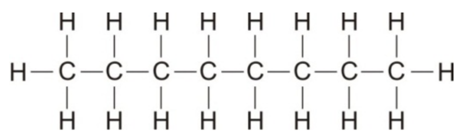
Article 1: Did you know? - Octane Combustion

There may be a need for a series of short articles that outline the scientific basis for global warming. Each article will attempt to discuss an aspect of the issue. Rough calculations will be used to give an approximate idea of the sizes of things. As the TV character Red Green said, “We’re all in this together.”

To begin, let’s start with the makeup of gasoline. Gasoline is a mixture of many different hydrocarbons but octane is a good approximation to the main constituent in gasoline and its chemical formula is C_8H_{18}. The geometry of this molecule is shown below:



When octane is burned the equation below describes the reaction with oxygen to produce water, carbon dioxide, and energy. You can see that the atomic species are not created or destroyed by the reaction; they are simply reorganized with a release of energy.

$$2 \cdot (C_8H_{18}) + 25 \cdot O_2 \quad = \quad 16 \cdot CO_2 + 18 \cdot H_2O + 42\,\frac{\mathrm{MJ}}{\mathrm{kg}}\; energy$$

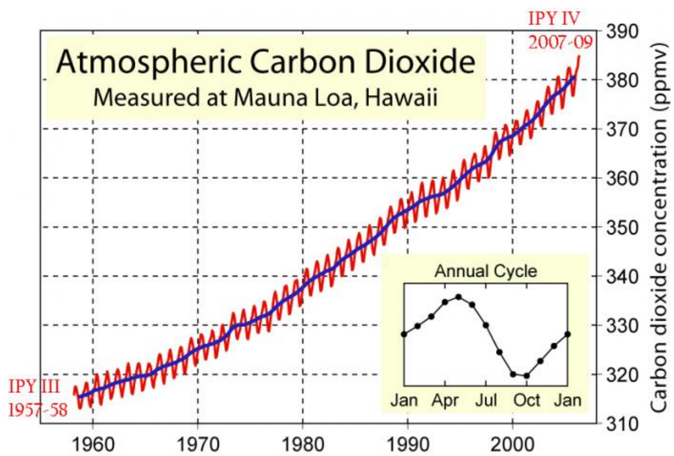
Gasoline is a remarkable as it’s a lightweight liquid that releases about 42 MJ/kg of energy. The MJ is a symbol for a mega-joule or one million joules. The joule is a unit of energy and is equivalent to the work needed to produce one watt of power for one second. The density of octane is about 0.7kg/litre so a litre of octane contains about 30 MJ and if you burn this at a rate of one liter every 6-minutes, like my truck on the highway, then this is equivalent to about 80,000-watts or 110 Hp. What a great power source!

Notice in the combustion equation above that for every 2 molecules of octane burned, 16 molecules of carbon dioxide are created. The atomic weights of carbon, hydrogen and oxygen are 12, 1, and 16 so every litre (or 0.7 kg) of gasoline we burn creates about 2.2 kg of carbon dioxide or about 3 times the original weight of the gasoline! Eighteen molecules of water are also created and lots of energy as noted above. Humans have benefitted greatly from the energy creation side of this reaction. Managing the waste carbon dioxide was not an issue when consumption was low, say 90 years ago, but consumption is now much larger and has been for perhaps 60-years. Carbon dioxide is a greenhouse gas in our atmosphere with a 100 to 500 year residence time. Current Canadian consumption of gasoline is about 40 billion litres per year. This is roughly equivalent to the volume of 13,300 hockey rink ice-surfaces filled to 2-m depth. Does that seem like a lot? Diesel consumption isn’t included! If you include the CO_2 from all the hydrocarbons that are burned globally (coal, oil, gasoline and natural gas) then the problem increases. The annual global hydrocarbon consumption from all sources (coal, oil gasoline & natural gas) is approximately 12 cubic kilometres or about 4 million hockey rink ice-surfaces filled to 2-m depth. Does that seem like a lot? Assuming the same 2.2 kg/litre in emissions used above the annual global CO_2 emissions weigh-in at about 26×10^{12} kg/year! The mass of the earth’s atmosphere is about 5×10^{18} kg so the annual emissions amount to about 5 parts per million (ppm) of the entire atmosphere. This shows human actions may be changing the composition of the atmosphere at the ppm level. These human caused CO_2 emissions have been going on since 1850 with the industrial revolution, and with its long residence time, and greenhouse warming effects, it is a real concern.

Hayles Geoscience Surveys Ltd.
Selkirk, Manitoba - July 2011

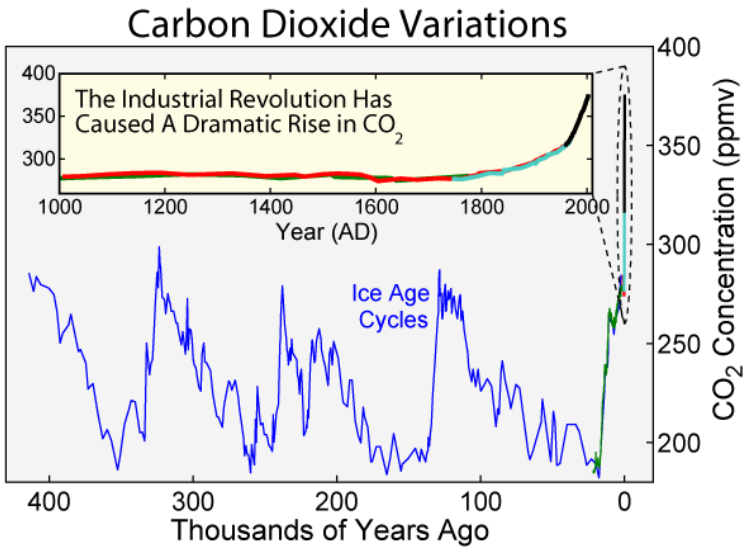
Article 2: Did you know? - Atmospheric Carbon Dioxide

This second article continues what was started in article one. In the last article we saw how hydrocarbon burning by humans is adding carbon dioxide to the atmosphere. A history lesson is in play here. The atmosphere has evolved over billions of years and its composition is vital to almost all life on earth. The four most abundant gases in our atmosphere are nitrogen (78%), oxygen (21%), argon (0.9%) carbon dioxide (0.039%). Oxygen is vital for most life on earth. The astronomer Carl Sagan, described the thickness of the atmosphere with a comparison that if the earth was the size of a basketball then the atmosphere thickness would be similar to a coat of varnish over the basketball. How very thin and fragile it is. Most of the atmosphere lies within 6 km of the surface while the radius of the earth is about 6000 km. Starting in 1958 and continuing to the present a set of very accurate measurements of carbon dioxide concentration in the earth's atmosphere has been collected by Charles David Keeling. The graph below shows this set of measurements plotted from 1958 to about 2009 and is known as the Keeling curve.



At the start of the graph in 1958 the CO_2 concentration is about 315 parts per million (ppm) and at the end in 2007 the concentration is about 380 ppm. So there's been an increase of 65 ppm in about 50 years. The short term oscillation on this graph is an annual pattern that has been called the natural breathing mode of the earth. Most of the land mass on earth is in the northern hemisphere so the spring and summer-growth to fall and winter decay cycle is dominated by the plants in the northern hemisphere. From October to April carbon dioxide levels increase due to decay of plants causing the release of CO_2 back to the atmosphere. From May to September, when plants are growing in the northern hemisphere, carbon dioxide is removed from the atmosphere by photosynthesis and incorporated into plant leaves and stems. This cycle repeats annually and accounts for the oscillation. Plants growing and dying in an annual pattern affect the atmosphere!

What's causing the steady increase in CO_2 in the atmosphere in the Keeling curve? The obvious answer, as we saw in article one, is the excessive burning of hydrocarbons by humans. Now let's look more into the earth's history. Let's look at what the ice cores from glaciers in Greenland and Antarctica tell us about CO_2 concentrations in the atmosphere in the past. When snow falls on a glacier and accumulates year after year, small amounts of air bubbles become locked-in with the snow as it turns into ice and if the ice is sampled later the constituents of that air can be analysed. Oxygen isotope ratios in the water contained in these ice cores also records the approximate temperature of the atmosphere. These ice core measurements are indirect and are called 'proxy' measurements of the composition and temperature of the atmosphere. Repeat measurements by different groups sampling ice cores from separate areas of the world all give similar results.

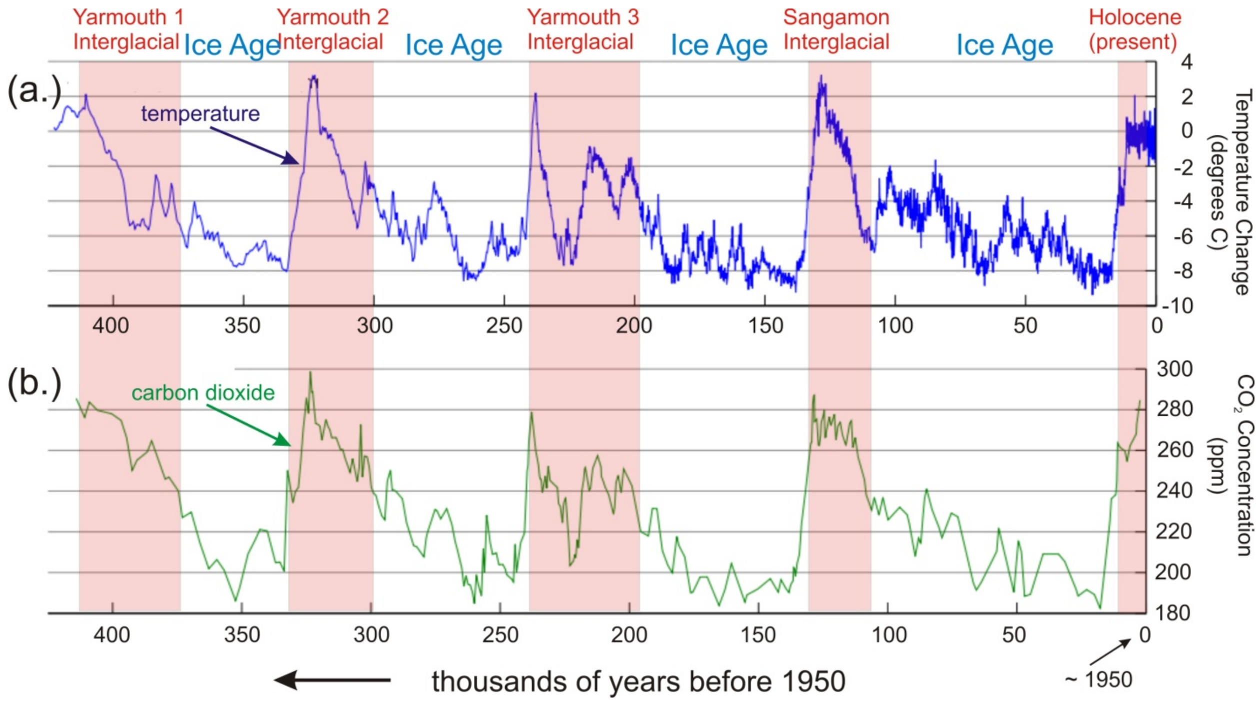


There are two graphs shown in the figure above. The inset extends the Keeling curve back 1000 years and has been called the 'hockey-stick' graph. The lower graph shows CO_2 concentrations over the last 400,000 years as measured by proxy using glacier ice cores. This record is a 100 times longer than recorded human history! What you can see here is that CO_2 concentrations cycled between about 180ppm and 280ppm for most of this time period depending on glacial conditions and around about 1800 (the time of the Industrial Revolution) levels have steadily risen. Please note CO_2 levels have increased about 100ppm since the start of the Industrial Revolution and that CO_2 levels are much higher now than at any time in the last 400,000 years! The increase in CO_2 is of great concern as the atmosphere and earth system may react in a way that might harm life on earth. One estimate is that CO_2 concentrations greater than 350 ppm may cause serious problems for life on earth. With concentrations now at 390 ppm and growing by 2 ppm per year this is a serious situation.

By ominous comparison, CO_2 makes up 95% of the atmosphere on Venus, nitrogen is 3.5% and there is no oxygen. The temperature on the surface of Venus is approximately 450ºC! Maybe it is not sensible to make this comparison as Venus is closer to the sun, does not have its own internal magnetic field, and has had a different history than the earth. However, CO_2 is the main constituent in Venus's atmosphere and perhaps, by mismanagement, humans are nudging the Earth's atmosphere in the wrong direction.

Article 3: Did you know? - Global temperature and CO_2

Imagine a 2-km thick glacier covering Manitoba, and almost all of Canada. This has happened four times in the last 400,000 years! The figure here shows some evidence.



Graphs of the temperature (a.) and CO_2 concentration (b.) in the atmosphere are shown here going back 420,000 years from about 1950. The measurements are from ice cores drilled in the ice cap, at Vostok, Antarctica to a depth of about 3-km. The temperature information is from oxygen isotope ratios in the ice and the CO_2 concentrations in (b.) are measured from gas bubbles trapped in the ice. These records show four periodic changes of about 10 degrees C over 400,000 years. Low temperatures indicate ice ages and high temperatures the interglacial warm periods. The cold spells tend to be twice as long as the warm spells and these cold spells permitted continental sized glaciers covering much of Canada. These graphs indicate our atmosphere-ocean-earth system is relatively unstable and there are some slow but powerful forces at play. Who would want to live in this neighbourhood with the risk of 2000-m of ice in the driveway?

One very important detail, that can't be seen in the graphs, is that the temperature changes always occur before the CO_2 changes by several hundreds of years. So, it is the temperature variations that are cause the CO_2 variations. This is because once temperatures change, it takes several hundreds of years before the oceans can react by either removing or releasing CO_2 to the air. When ocean temperatures warm, CO_2 is released back to the air due to the lower solubility of CO_2 in the ocean as temperatures rise. When temperatures get colder, the ocean has a greater capacity to store CO_2 and concentrations in the air drop. In a way, this plot shows the ocean breathing! The glacier collapses often occur in less than 3000 years.

Ok, so what causes the global temperatures to change? Periodic variations of the Earth in its orbit are believed to be the main culprits. The ellipticity variations have a period of about 100,000 years and the tilt of the earth's axis varies in a 41,000 year cycle. These orbital effects are small but are believed to trigger other feedbacks that strengthen the effect. Variations in heat from the sun are too small to be the answer.

These graphs also describe sea levels. At the peak of the last glaciation, so much water was locked-up in the continental glaciers that sea levels were about 100-m lower than now. That's four changes in global sea levels of over 100-m in 400,000 years. Our ancestors must have been constantly on the move during this time.

If projections are right, and we do not sharply reduce our carbon dioxide emissions, then the ice locked up in the Greenland and Antarctic ice sheets may start to melt. Indeed, this melting has already started. Complete melting of the Greenland ice cap would add about 6 to 7-m to global sea levels. Much of the world's population lives near sea level so significant upsets are probable in the future.

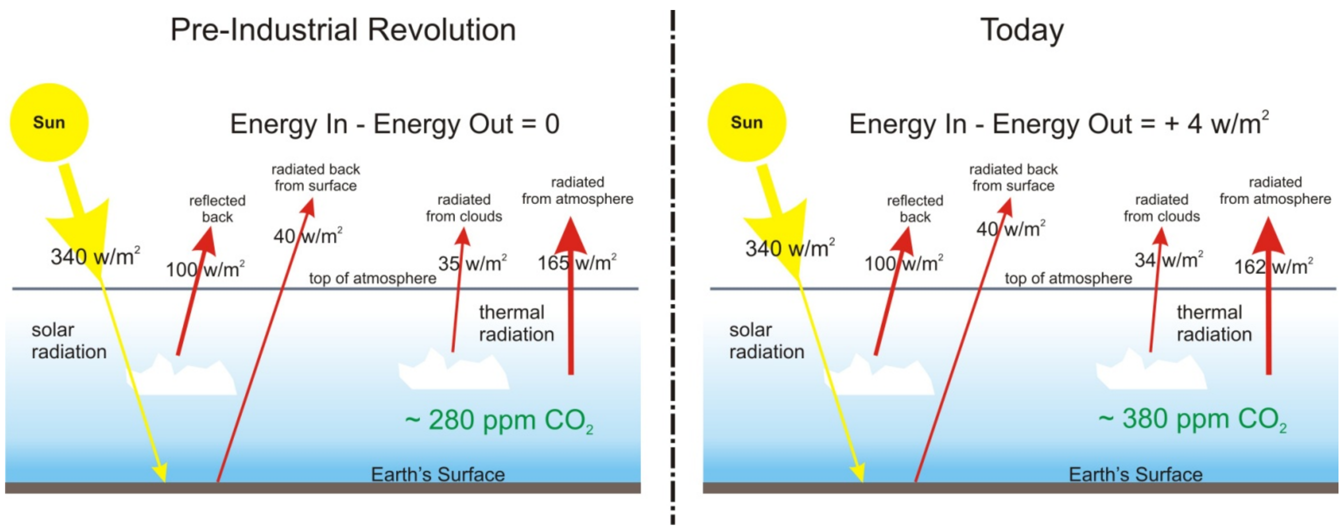
Looking at the graph, the latest interglacial period, the Holcene, has been going on for about 10,000 years and judging from the patterns one might predict we are due for another ice age. It is doubtful however, that another ice age can ever start again as 200 years of CO_2 emissions have overwhelmed the natural forces that were at play before we came on the scene. One estimate is that if CO_2 levels are doubled in the atmosphere, the average earth's temperature will increase 1.5 to 4.5 ºC. Because the effects are slow in this huge system it may take several hundred years to see the full effect.

Civilization is in a dilemma. The problem may be similar to what the helmsman steering the Titanic experienced after being warned from the crow's nest that there is an iceberg dead ahead. Even with an immediate course correction, the Titanic was unable to react fast enough. Too much momentum, too little control, too little warning, and bang! One could ask why they were going so fast in ice-berg alley in the first place but you already know this story. With the great complexity, instability, and very long reaction times involved with our atmosphere-ocean-earth system and the very powerful forces at play we must be very careful we do not blunder into our own atmospheric version of ice-berg alley with too much momentum and too little control to avert disaster. We must be very careful to understand exactly what we're doing. Sharp reductions in our consumption of carbon-based fuels would help. As Red Green would say "We're all in this together.".

Article 4: Did you know? - Solar Energy and the Greenhouse Effect

The last article showed that the climate has cycled between warm spells and ice ages four times in the last 400,000 years. Small changes in the earth's orbital position and feedbacks on earth are believed to be the main cause. This article will describe incoming energy from the sun and interactions with the atmosphere. Interactions occur between solar radiation, clouds, carbon dioxide, aerosols, soot, and the oceans are all going on. Some of these interactions are not well understood.

Most life on earth derives its energy from the sun. Plants use sunlight to create their own energy through photosynthesis while animals gain their energy from eating plants or eating other animals that eat plants. It's that simple. Ultimately the energy is from the sun. Even our hydrocarbon fuels (gasoline, oil, coal, natural gas) come from previous life forms and that's why they are called 'fossil' fuels. So anything that upsets the atmospheric energy balance with the sun needs to be looked at carefully as almost all life on earth relies on the sun. There is a lot at stake! Too much sun and you cook, too little and you're frozen. It's a very fine balance that nature has set. The figure below compares the energy balance between incoming and outgoing solar radiation from pre-industrial revolution times and the present day.



The sun provides about 340 watts per square metre to the earth. To get an idea of this imagine the heat from three 100-watt light bulbs spread over a one metre by one meter area. A single 100-watt light bulb gets much too hot to touch after it's been on for a while so there's lots of heat coming in from the sun. About 100 watts per square metre however are reflected right back out from cloud tops, ice caps and the oceans. So this leaves 240 watts per square metre to heat up the atmosphere, and the surface of the oceans and land. The earth and oceans manage to re-radiate about 40 watts per square metre of thermal energy on average back in to space at night. Thermal energy stored in the atmosphere and clouds also radiates about 165 and 35 watts per square metre on average back into space. So 340 watts per square metre came in and 340 watts per square metre went out, energy balanced, and our world was a happier place! This was the situation before the industrial revolution around about 1750.

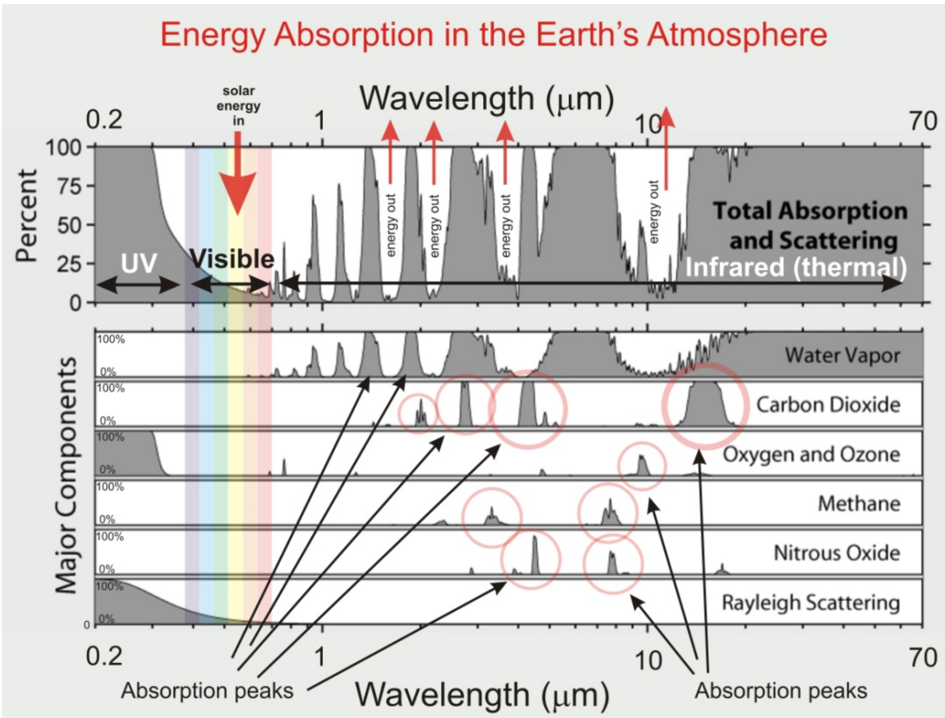
Since the industrial revolution about 100 parts per million of extra CO_2 has been added to the atmosphere reducing the amount of thermal radiation that can escape back to space. CO_2 is transparent to incoming solar radiation but it absorbs outgoing thermal radiation and keeps it from going back into space. If there was no CO_2 in the atmosphere the global average temperature would drop about 25C so removing all the CO_2 in the atmosphere would put us in the deep freeze. The increase in temperature due to gases in the atmosphere is known as the 'greenhouse effect'. Joseph Fourier, the famous French physicist, first described the 'greenhouse effect' in the 1820s.

Now only 336 watts per square metre are now being radiated back into space due to the increased CO_2 concentration but the incoming energy is still 340 watts per square metre. That's a 4 watt per square metre heating effect now in the atmosphere. That's like placing 2 to 3 of the small LED Christmas tree lights every square metre of the planet! It might not seem like much but you know the atmosphere is very sensitive to even small changes in energy or composition.

So where is the 4 watts per square metre going? Well, it's heating up the atmosphere and oceans. More heat in the atmosphere causes more intense and severe weather systems. A global temperature increase of about 1.2C is expected from the additional 4 watts per square metre. This rise will probably be amplified by increased water vapour and reduced energy reflected from snow covered areas due to melting of these snow packs, which means the increase will be more like 2.5C. Again, small changes get amplified by other factors. This 2.5C increase in global temperatures is a huge change and it's from a 100 parts per million increase in CO_2 concentration! That's sensitive! Imagine the change if we ignore the warnings and continue business as usual CO_2 emissions? Our atmosphere needs health care!

Article 5: Did you know? - Greenhouse Gas Characteristics

The last article described the heat-trapping ability of carbon dioxide in the atmosphere. This article gives a more detailed description of the thermal absorption characteristics of carbon dioxide, ozone, methane and nitrous oxide in our atmosphere. It's possible to identify a gas by how it absorbs different wavelengths of light as the light passes through it. The energy that is absorbed by the gas is uniquely related to the gas and the absorbed energy tends to heat up the gas just a little. The graphs provided show absorption peaks from ultraviolet through the visible region to infrared light for the primary greenhouse gases.   Most of the incoming solar energy that gets to the earth's surface is centred in the visible region while most of the thermal energy sent back to space by the atmosphere is in the infrared region.



Absorption peaks for greenhouse gasses in the atmosphere are shown above.

As you can see from the graph, water vapour is the strongest greenhouse gas with multiple absorption peaks across the plot. For wavelengths greater than about 15 micrometers water vapour blocks thermal radiation. Water, however, covers over 70% of the earth's surface so there can be no effective human control of water vapour in the atmosphere. There is just too much water on the planet to even think about controlling water vapour. The only thing that controls water vapour in the atmosphere is temperature. Higher temperature allows more water vapour and if temperatures drop, water vapour will turn into either rain or snow.

The carbon dioxide absorption peaks are the next largest in the plot above with peaks at about 2, 3, 4.5 and 15 micrometres. The peaks at 4.5 and 15 micrometers are the largest. So increases in CO_2 concentration cause increases in temperature which in turn boosts the water vapour in the atmosphere which in turn increases the greenhouse effect. This is an example of an amplifying feedback that has been mentioned in past articles.   Carbon dioxide and water vapour play for the same team.

Ozone, methane and nitrous oxide also show significant absorption peaks in the graph above. Rayleigh scattering shown in the plot is what causes the sky to be blue.

The table below lists some characteristics of these and other gases that contribute to greenhouse warming. The radiative forcing column in the table lists the estimated amount of heating that each gas contributes at present to the atmosphere.

Gas	**1750 Level**	**Current Level**	**Increase since 1750**	**Warming Factor**	**Radiative Forcing**	**Lifetime in atmospere**
	(ppm)	(ppm)	(ppm)		**(w/m^2)**	**(years)**
Carbon dioxide	280	388	108	1	1.46	~100 - 300
Methane	0.7	1.745	1.045	72	0.48	12
Nitrous oxide	0.270	0.314	0.044	289	0.15	114
CFCs	0	0.000533	0.000533	2 to 12000	0.17	100
Sulphur hexafluoride	0	0.000007	0.000007	16000	-	800-3200

Although methane makes up a much smaller concentration in the atmosphere than CO_2 it is about 72 times more effective at trapping heat than CO_2. There are significant reservoirs of methane in the northern peat bogs and on the undersea continental shelf regions that may be released if warming is allowed to continue. A partial release of some of these reserves would cause even more warming.

Nitrous oxide makes up an even smaller concentration in the atmosphere than methane but it has a warming factor of 289 times that of CO_2 and has a long lifetime in the atmosphere.

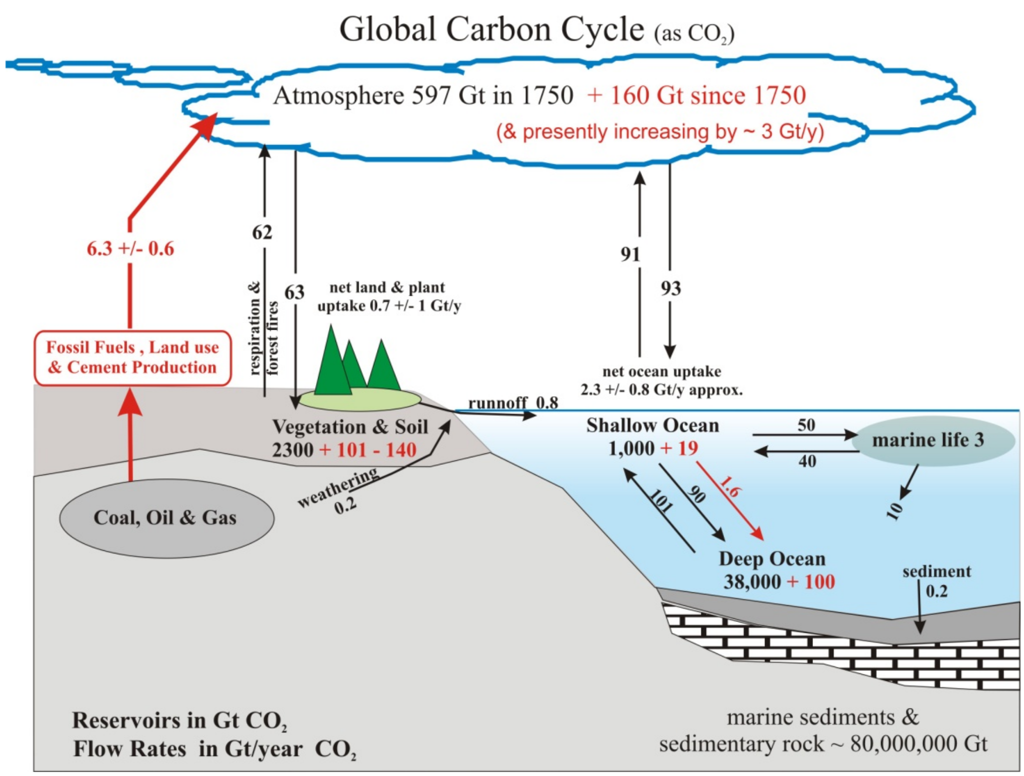
The chlorofluorocarbons (CFCs) are manmade chemicals that were used as the cooling agent in refrigerators. They are non-toxic and non-flammable and have a long lifetime in the atmosphere. CFC use in spray cans was stopped in 1978 in the USA and Canada due to concern about the atmosphere. Guess what? In 1985 a large hole in the ozone layer in the upper atmosphere was observed over Antarctica and the cause was found to be CFC's. Ozone levels in the upper atmosphere were being destroyed by chlorine which was being freed from the CFC molecules by ultraviolet light bombardment in the upper atmosphere. Chlorine is highly reactive so its presence, in even tiny amounts, makes a big difference. The concentration of CFC's responsible for the ozone hole was less than 1 part-per-billion! Fortunately, the international community agreed in Montreal in 1987 to ban the manufacture and use of CFCs in a phased approach.

Sulphur hexafluoride is used in some specialized manufacturing and in high-voltage electrical systems and in ventilation and gas-flow studies. Concentrations in the parts-per-trillion are significant! This gas has a very long life in the atmosphere and is a very potent greenhouse gas with a warming factor of 16000 times that of carbon dioxide.

Once again, we see the atmosphere shows great sensitivity to even very small concentrations of some gasses or changes in energy input. Our atmosphere is in a fine balance that we upset at our peril.

Article 6: Did you know? - Global Carbon Cycle

Everyone knows CO_2 is increasing in the atmosphere. Let's look at an aspect of why this is happening. In the figure, the global carbon cycle is shown for the time period around 1750 before the Industrial Revolution, and additional human-induced changes since then are also shown.   The approximate sizes of the global reservoirs are shown in Gigatons (Gt) which is equivalent to a billion metric tonnes and the arrows on the figure represent annual flow rates in Gigatons per year (Gt/y) between the reservoirs. The reservoir sizes and flow rates in 1750 are shown with human-caused changes since then added or subtracted.   The numbers are from publications by the Intergovernmental Panel on Climate Change and the United Nations and the represent the situation approximately the 1990's. As you can see in the figure, the atmosphere presently stores about 760 Gigatons while the soil, shallow oceans and deep oceans store about 2300, 1000, and 38,000 Gt respectively. You can also see large annual flow rates between the atmosphere, soil and vegetation and the shallow oceans. The world's limestones, deposited in the oceans over hundreds of millions of years, are estimated to contain 80,000,000 Gt!



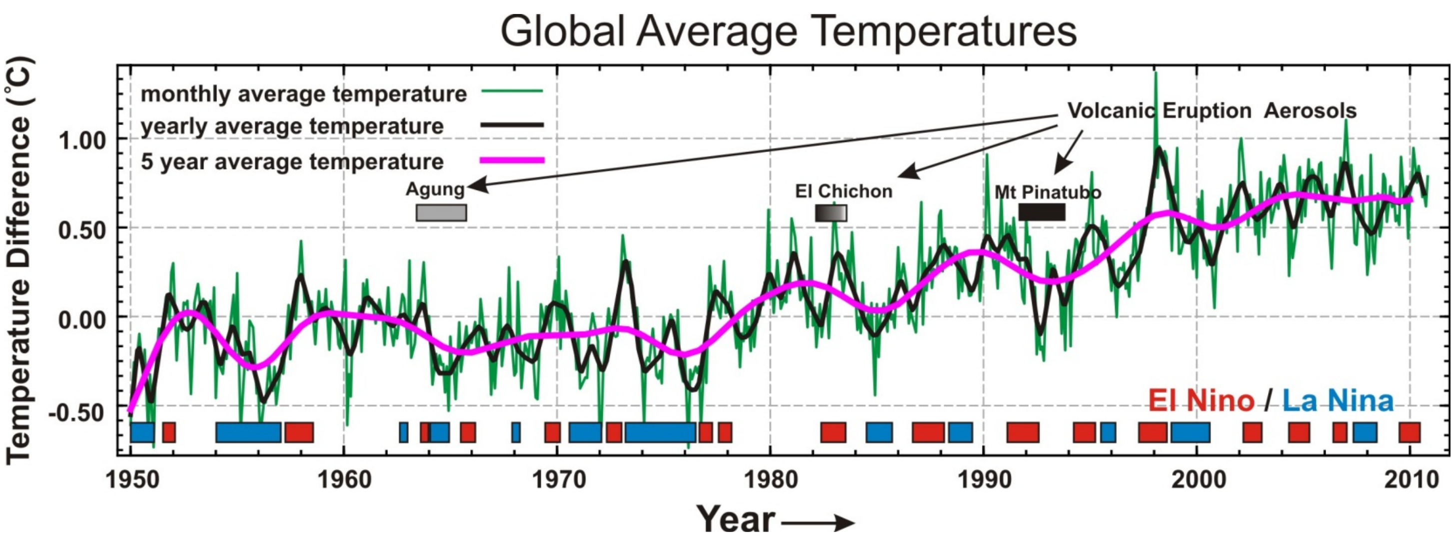
Prior to 1750 there was a rough balance between annual CO_2 emissions to the atmosphere and storage in soil and the oceans. As you can see in the figure these are large reservoirs with big annual exchange rates. The annual exchange between the oceans and the atmosphere is about 92 Gt, while the annual atmosphere-to-earth exchange is about 62 Gt. Presently, the burning of fossil fuels places about 6.4 Gt of CO_2 per year into the atmosphere but, as you can see in the figure, exchanges back to the land or to the shallow ocean only amount to about 3 Gt per year. So we're emitting about double what nature can manage to exchange with the shallow ocean and land/vegetation reservoirs. The word 'exchange' here is used because CO_2 is stable in the atmosphere, oceans and in the soil and is not easily broken down like some other greenhouse gasses. Methane, by comparison, reacts with OH radicals naturally present from the breakdown of water so methane doesn't stay around long in the atmosphere. Carbon dioxide however is very persistent. It is used by plants in photosynthesis, is stored in plant tissues, is stored in the soil, dissolves in water in the oceans, and is used by tiny marine organisms to make their shells which then sink to the ocean floor. The oceans, land and atmosphere each are constantly exchanging CO_2. It shows up everywhere.

So if more CO_2 is added in the atmosphere, it rapidly gets shared with plant, soil, and ocean reservoirs but it does not get removed. Physical and biological processes move the CO_2 around but once you've emitted it, it will be around for a very long time. Increased CO_2 in the atmosphere causes more greenhouse heating, which boosts the water vapour, which in turn increases the heating effect even more. Higher ocean water temperature reduces the solubility of inorganic CO_2 in the ocean (just like warm pop loses its fizz). Marine biological activity is also reduced in warmer oceans. Both of these factors tend to shift CO_2 in the ocean back to the atmosphere in another feedback loop. So, the residence time for CO_2 in the atmosphere is very long due to its chemical stability and the large annual exchanges between big reservoirs. The build-up in the atmosphere the last two hundred years also supports this long time. As long as the CO_2 is in plant matter, or is dissolved in the oceans it is able to easily go back into the atmosphere. When CO_2 ends up in marine sediment, then it's on a more long-term removal path, which takes hundreds of thousands to millions of years. CO_2 concentrations in the atmosphere are now much higher than at any time in the last 650,000 years as observed in the ice core records. The increase has also occurred much faster than any changes that have been observed in the ice core or geologic records.

What started out as an interesting experiment with fossil fuels has inadvertently got out of control. We have changed, and are even accelerating changes to our atmosphere and oceans that are irreversible within hundreds to thousands of years. Very significant reductions in CO_2 emissions to the atmosphere are needed globally, and the sooner we do this, the better. As Red Green would say "We're all in this together".

Article 7: Did you know? - Observed Temperatures 1950 to 2010

This article discusses global temperatures from 1950 to 2010 and some differences between weather and climate. The figure shows a graph of the global average temperatures from1950 to 2010 from the HadCRUT3 data-set available from the Met Office Hadley Centre and the Climatic Research Unit in the UK. This data combines land and sea surface temperature measurements recorded at many thousands of locations all over the world. Monthly, annual, and five-year average temperatures are plotted from 1950 to 2010. This data is referenced often by the Intergovernmental Panel on Climate Change 2007 Assessment Report. There are some interesting things here.



As you can see, there is a gradual increase of about 0.5º C from 1950 to 2010. The monthly data is more erratic, as expected, than the annual or five-year average temperatures and there is still considerable variation year to year. The uncertainty in measurement is approximately ± 0.07º C so the increase since 1950 greatly exceeds the measurement uncertainty. As noted in previous articles, this 0.5º C temperature increase is almost certain to be caused by CO_2 emissions from fossil fuel use. Increasing CO_2 concentrations in the atmosphere are increasing temperatures worldwide.

El Nino and La Nina events are shown across the bottom of the plot. El Nino events occur when warmer than average surface water occurs in the eastern Pacific Ocean often centred offshore of Peru. La Nina occurs when there is colder than average surface water in the eastern Pacific. These cyclic changes in the surface water temperature in the Pacific Ocean have a strong effect on global temperatures.

Please note there is a fairly good correlation between global temperatures and the El-Nina / La Nina events. El Nino correlates with warmer temperatures while La Nina periods correlate with colder temperatures.

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What is interesting is that you can start to see the difference between ‘weather’ and ‘climate’ in this data. The gradual increase in temperature across the plot can be considered a climate change while the more erratic changes are more weather-related and correlated, at least in a good part, by El Nino to La Nina events. Climate is more a long-term, say 30-year average value, while weather is more short-term day-to-day, month-to-month and year to year.

Three volcanic eruptions are also shown in the plot. Volcanic eruptions often blast large amounts of fine silicate ash and even finer sulphate particles high into the atmosphere. Both the ash and the sulphates tend to reflect sunlight back to space and reduce the energy reaching the earth and its atmosphere. The ash, being heavier, tends to get washed out within a few months but the sulphate aerosols tend stay for a few years. The Mt Pinatubo eruption in 1991 caused a cooling effect of about 0.4 watts per square metre for about 2 years due to sulphates blocking incoming sunlight. It appears, from the graph, that this cooling effect was so strong that it overpowered the El Nino warming around this time.

In reviewing the graph, global temperatures now appear much more predictable than the common concept of a chaotic long-term weather system that could never be modeled or understood. It appears that if you know the CO_2 concentration, the status of the El Nino / La Nina cycle, and the amount of aerosols in the atmosphere you can make a fairly good long-term global temperature prediction.

This graph shows real evidence of global climate change. The changes are irreversible by natural processes in many hundreds of years. If global temperatures have increased by 0.5º C since 1950 what might the future hold? It’s reasonable to expect a similar or even larger temperature increase in the next 50 years since our CO_2 emissions have been, and still are, increasing every year. There will be long-term consequences due to the emissions we’ve already made. Rising sea levels and more violent weather systems present a significant problem. If we can all sharply reduce our emissions it would help to minimize the possibility of some of the more drastic long-term changes that are predicted. As Red Green would say “We’re all in this together”.

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