Climate Change
What the Current Literature Says about the Near and Medium Term Future
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My goal is to present the findings of the latest peer-reviewed studies about the earth's climate, and to do so in language understandable by the average person.

In particular, I will attempt to summarize what recent scientific literature says are the major impacts we face in the coming decades if we stay anywhere near our current path of growth in Green House Gas emissions, in particular, growth in the emissions of water vapor, methane and carbon dioxide.

These impacts include:

1. Temperature increases, especially over land, of some 10°F over much of the US
2. Semi-Permanent Dust Bowl conditions over the US Southwest
3. Sea Level rise of about 1 foot by 2050, then 4 to 6 more feet by 2100
4. Species loss on land and in the ocean
5. Unexpected impacts, such as the pine beetle infestation of the western Lodgepole Pine
6. Weather Extremes Intensification
7. Global Food Insecurity
8. Direct Health Impacts

I begin with a basic question: **How Much CO_2 is in the Atmosphere?**

I include below instrumentation readings from Mauna Loa in Hawaii, taken each May, and rounded to the nearest whole parts per million by volume. The reading from 1750 was clearly not from instrumentation but from the combined results of several CO_2 proxies. 1750 is included since that year is widely agreed to be just before the onset of large-scale industrialization.

Year	PPM CO_2	Year	PPM CO_2	Year	PPM CO_2	Year	PPM CO_2
1750	**278**	1971	329	1985	349	1999	371
1958	318	1972	330	1986	351	2000	372
1959	318	1973	332	1987	352	2001	374
1960	320	1974	333	1988	354	2002	376
1961	321	1975	334	1989	356	2003	379
1962	321	1976	335	1990	357	2004	381
1963	322	1977	337	1991	359	2005	382
1964	322	1978	338	1992	360	2006	385
1965	322	1979	339	1993	360	2007	387
1966	324	1980	341	1994	362	2008	389
1967	325	1981	343	1995	364	2009	390
1968	326	1982	345	1996	365	2010	393
1969	327	1983	346	1997	367	2011	394
1970	328	1984	348	1998	369	**2012**	**397**

I think that the average person needs to understand just how small the amount of CO_2 actually is. Notice in the table that we went from 278 parts per million by volume in 1750 to 318 parts per million by volume in 1958. Sometime in that period, we were at 300 parts per million by volume. Let's use 300 parts per million by volume merely since it is nice and round. Note that $\frac{300}{1000000} = 0.0003 = 0.03\%$. So, some time in there, 0.03% of the earth's atmosphere was carbon dioxide. As an illustration, let's take a cubic foot of air. A cubic foot contains 1728 cubic inches. 0.03% of 1728 is 0.5184 or about 0.5. So about half a cubic inch of every cubic foot of air then was CO_2. Now let's go to 2012. Rounding 397 to 400 parts per million in 2012, we have $\frac{400}{1000000} = 0.0004 = 0.04\%$ CO_2. Now back to the cubic foot of air. 0.04% of 1728 is 0.6912 or about 0.7. So, we've gone from just over 0.5 cubic inches of CO_2 in each cubic foot of air to just under 0.7 cubic inches of CO_2 in the same cubic foot of air all in somewhere between 200 and 300 years. What I keep in mind is that all the data says that during the period we were evolving, let's say for the past 500,000 years or so, the CO_2 level in our air was a nearly constant 275 parts per million by volume. Just look what has happened since 1750. CO_2 normally take geologic time scales, that is millions of years to change. We have forced an enormous change in a few hundred years or so.

Some of us are uncomfortable with parts per million by volume. So, I changed parts per million by volume to total weight of CO_2 in the atmosphere measured in units called metric tons or tonnes, each being 1000 kilograms. One tonne is equivalent to 2205 pounds. In 1750, we have a good estimate from gas bubbles in ice cores, and other methods, of some 2.173×10^{12} tonnes, or 4.79×10^{15} pounds, or about 2.4×10^{12} tons of CO_2 in the atmosphere.

From 1750 to 1960, the total weight of CO_2 in the atmosphere grew by roughly 250,000 million tonnes, at an annualized rate of 1,190.48 million tonnes per year. From 1960 to 2007, another 570,000 million tonnes were added at an annualized rate of 12,127.7 million tonnes per year, a rate just about 10 times faster than the rate during the previous two centuries.

In a look at the future, to achieve 571 parts per million by volume by 2100, we need to add CO_2 at a rate of 13,280 million tonnes per year. This is half of the CO_2 release rate today. To achieve 970 parts per million by volume we need to release 49,933 million tonnes per year, roughly twice today's rate. The climate community is tending toward the higher estimate since the three biggest sources of CO_2 on the planet, the United States, India and China show no signs of carbon mitigation.

Current data illustrates that the level of CO_2 over the time during which humans evolved and up through the onset of serious industrialization was a more or less constant 275 parts per million by volume. In 1955, the level was just under 320 parts per million by volume. In April 2012, the level was 396 parts per million by volume. In June 2012, one observation post recorded 400 parts per million by volume. Staying on the current path, the path of increasing CO_2 concentration, is called the Business as Usual Scenario. Under the business as usual scenario, atmospheric CO_2 will increase to about 850 parts per million by volume if not over 1000 parts per million by volume by the end of the century. Using the rounded 400 and the 1000 parts per million by volume figures and a span of a rounded 90 years until the turn of the century, we have $\frac{1000-400}{90} = \frac{600}{90} = 6.67$ parts per million by volume per year, average increase. What is noteworthy is that the 2007 International Panel on Climate Change said that this trajectory was the "worst-case scenario." The climate change deniers have turned what was the worst-case scenario into the current business as usual scenario! It is also worth noting that the expected levels of CO_2 will impact the 8 issues above, and those impacts, according to a study finished in 2009 by NOAA, will be "largely irreversible for 1000 years." We are currently introducing about 8.5 billion tons of carbon per year (about 31 billion tons of CO_2) into the atmosphere. Until the advent of the recent global recession, the rate of new CO_2 introduction into the atmosphere was rising at about 3% per year.

Most people I know believe, at least to some extent, that "natural cycles" in the earth's climate systems will clear the excess CO_2 from the atmosphere relatively quickly. They do not understand that the term "quickly" should be understood in a geologic time frame, that is the clearing will take tens or even hundreds of thousands of years, and in a human time scale, that excess CO_2 will wreak havoc with our weather and with our civilization for centuries, perhaps millenia. (Google "Carbon Cycle" if interested.)

Scientists, until recently, spent little time modeling the impacts of a rise to 800 to 1100 parts per million from our recent levels. Why they have chosen not to do so is grounds for speculation. Some authors suggest that they did not think that society would ever be so stupid to ignore their warnings. However, new scientific findings developed since the 2007 IPCC report was issued, and focusing attention on the new business as usual scenario, find that we are now 20 times as likely to experience global climate disruption as not.

So, I turn now to a discussion of the impacts and the disruptions of the increase in CO_2 levels.

Temperature Increases

MIT has doubled its 2100 global warming projection to 10°F, with 866 parts per million by volume and its Arctic warming projection to 20°F. The Hadley Climate Research Unit in England projects a 9°F to 12°F rise by 2100 while a NOAA led report predicts 9°F to 11°F warming over most of the US by 2090. These three estimates are in good agreement with each other.

In practical terms, by the year 2100, Kansas can expect temperatures over 90°F for some 120 days per year, temperatures of up to 122°F will be found in most of the central, southern, U.S. and much of Arizona would exceed 105°F for 98 days per year, 14 full weeks.

These conclusions are based on studies of 700 to 850 parts per million by volume, the old business as usual scenario. Under the new business as usual scenario, 900 to 1100 parts per million by volume, it could be hotter than calculated.

To summarize the current results, we have the following:

Emission Reduction Model	% Increase in GGE's by 2050	Temp Increase °C to °F in 2100
Business as Usual No Action Taken	132%	5.5-7.1°C or 9.9-12.8°F
Late and Slow Decline Action Starts in 2030	76%	4-5.2°C or 7.2-9.4°F
Early but Slow Decline Action Starts in 2010	0%	2.9-3.8°C or 5.2-6.8°F
Early and Rapid Decline Action Starts in 2010	–47%	2.1-2.8°C or 3.8-5°F

Please note that the last row in the table shows essentially what would happen if a magic wand was waved and we essentially stopped adding new CO_2 to the atmosphere altogether. What we have done already will result in a 4° to 5°F increase in global average temperature by 2100 with no added CO_2! Please note that the extreme weather we have recently seen is associated with a roughly 1°F increase since dust-bowl days.

Note again that this is the old Business as Usual, not the worst-case scenario. The new business as usual, the old worst-case scenario, has an effect on temperature over most of the US of 13°F to 18°F, while over the arctic it ranges up to 27°F. In fact, if we stay on our current emissions path, CO_2 levels in 2100 will hit levels last seen when the arctic was 29°F hotter on average.

Dust-Bowl-Ification

This issue may well have the impact of harming the greatest number of people over the next few decades.

A number of recent studies warn that the Southwest, parts of the Midwest, and many other highly populated parts of the globe are headed toward sustained, if not near permanent, drought and Dust-Bowl conditions. The studies make it clear that severe drought is one of the more robust responses to increased Green House Gas concentrations. If the drying is anything near what is expected, even under the old business as usual conditions, then a very large population will be affected in the coming decades over the whole US, southern Europe, Southeast Asia, Brazil, Chile, and most of Africa.

One study done in England came to the conclusion that 40% of the Earth's inhabited landmass will be under severe drought by century's end.

The studies make it also clear that these droughts will be different from previous droughts we have experienced in that they will be "very hot weather droughts."

Finally, a study conducted by NOAA found that once started, the "permanent dustbowls in our southwest and around the globe will be largely irreversible for 1000 years."

And lastly, the heat, drought, and increased insect infestation could drive an increase in wildfires as seen recently in Colorado.

Sea Level Rise

The 2007 IPCC report low-balled sea level rise estimates suggesting the sea level might increase "only" by a foot or two by 2100. What the report ignored was a process called Dynamic Ice-Sheet Disintegration. This is the process, only recently studied, through which melt water percolates through ice sheets and speeds up their downhill motion by essentially lubricating the bottom of the sheet so that it slides more easily, and the lack of a retarding ice pack on the near-shore ocean surface allowing the speed of glacier motion toward the ocean to markedly increase.

A series of major reports including the effects of dynamic disintegration provide estimates of a sea level rise of 1 to 2 meters (3 to 6.6 feet) by 2100.

To put this in context, a one meter rise in seal level would flood 17% of Bangladesh reducing its rice-farming land area by 50%. Southern Louisiana and South Florida would necessarily be abandoned.

Species Loss on Land and Sea

The 2007 IPCC report stated that a global average temperature increase of 3.5°C relative to 1980 would produce a 40-70% loss of species around the globe. The predicted 5.5°C would probably put extinctions beyond the high end of that range.

The Royal Society recently concluded that "the current rate of species extinctions exceeds anything in the fossil record."

In *Nature*, we find that "when CO_2 levels hit about 500 parts per million by volume, you put calcification out of business in the oceans." That means that the calcareous shells of shellfish, corals, and so on would cease to develop. And most recently, *Nature* said, "Global warming blamed for 40% loss in the ocean's phytoplankton."

Unexpected Impacts

If we get to 800 parts per million by volume, let alone 1000 parts per million by volume, or higher, we are far outside the bounds of simple mathematical projection, particularly as those levels relate to synergies called feedback loops. We can get hints, however, by looking at the effects that the roughly 1°F warming since the dust-bowl has had.

The clearest example is the Pine Bark Beetle. Once limited to one or two generations per year, the slight temperature increase has allowed three or four. The new infestation in British Columbia is projected to kill 80% of the merchantable and susceptible lodgepole pine in parts of British Columbia within 10 years. Forests once able to uptake and absorb carbon are becoming areas of net carbon addition to the atmosphere.

As the Arctic warms, permafrost regions, vast in area, will thaw, releasing enormous volumes of CO_2 and methane, another potent greenhouse gas, into the atmosphere, as their peat decays. The potential increase in warming due to this process is difficult to calculate.

As the tropics warm and the warm weather extends toward the poles, the available habitat for mosquito and other insect transmitters of tropical disease expands. As CO_2 is absorbed by the oceans, the pH of the sea water drops changing the nature of the medium supporting sea life. Who knows what may come of all this.

Extreme Weather

Warm air can hold more water vapor than cool air. This is simple physical science. When warm air rises, it cools, forcing some of the water vapor to condense out of that air. This process is one of the roots of an unavoidable problem. When water evaporates, it absorbs quite a bit of heat. That amount of heat is called water's heat of vaporization. When the vapor condenses, it releases that heat causing the rising air to rise ever faster, entraining surrounding air rich in water vapor which releases, and resulting in storms that are more intense and energetic than otherwise. So, warmer air, more water vapor, more water vapor, more intense storms.

As air near the tropics gets warmer, global circulation patterns in the oceans and in the atmosphere are affected potentially resulting, for example, in the northward and southward push of desert regions from their present geographical positions.

The magnified warming in the arctic will reduce the temperature gradient going poleward from the tropics and may result in a breakdown, to some as yet unpredictable extent extent, in the patterns of prevailing winds and ocean currents we have known so long.

Food Insecurity

In over two decades of tracking world food prices, the U.N. Food and Agricultural Organization Price Index has never stayed so high for so long.

One analysis has just concluded that “Half of the world’s population could face a climate-driven food crisis by 2100.” And this is based on a 700 parts per million by volume analysis with no consideration of drought or other climate impacts.

Direct Health Impacts

A June 2011 report from the Union of Concerned Scientists, among other reports, concluded that America faces:

- More than doubled asthma rates and a lengthened asthma season
- Threatened access to clean drinking water
- Increases in airborne and insect borne illnesses
- Increases in diarrheal, respiratory, and heart disease
- Increased risk of salmonella and other food storage related illnesses
- Increase in hospitalization rates
- Magnified health risk among low-income communities, children, the elderly, and the obese

As the major British medical journal, the *Lancet*, concluded, “Climate change is the biggest global health threat of the 21st century.”

Conclusion

Everyone I know hopes that the unrestricted emissions of greenhouse gases into the atmosphere will not do any harm. However, that possibility is vanishingly small. We remain near the worst-case emissions pathways, and, thanks to the very energetic and very successful actions of the climate change deniers, there is little prospect of any meaningful national or global action any time soon. Many impacts are coming faster than predicted by the 2007 IPCC report and the call to action from the overwhelming majority of climate scientists remain ignored.

We cannot let this happen. It is humanity’s self-destruction.