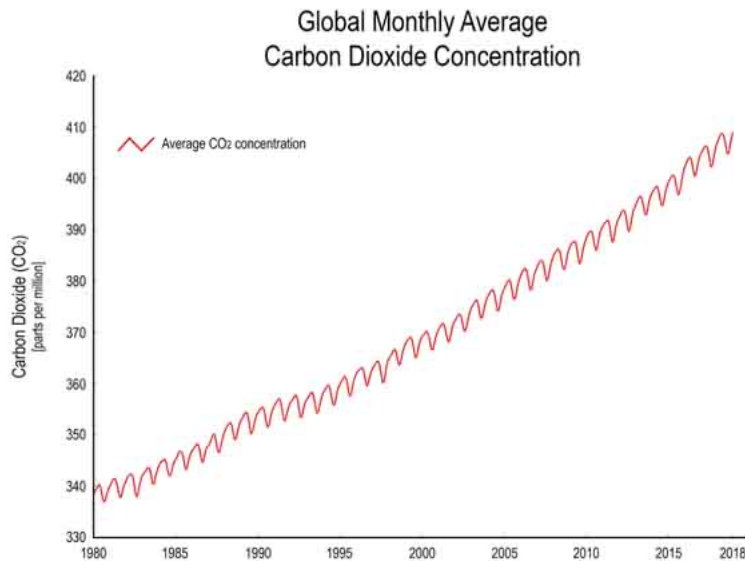


Global Warming is Real

For those who are truly interested in the science and truth versus denial relating to climate change - see the iPhone app **Skeptical Science**. The section called "Most Used" presents scientific rebuttals to 10 of the most commonly used statements of climate change deniers.

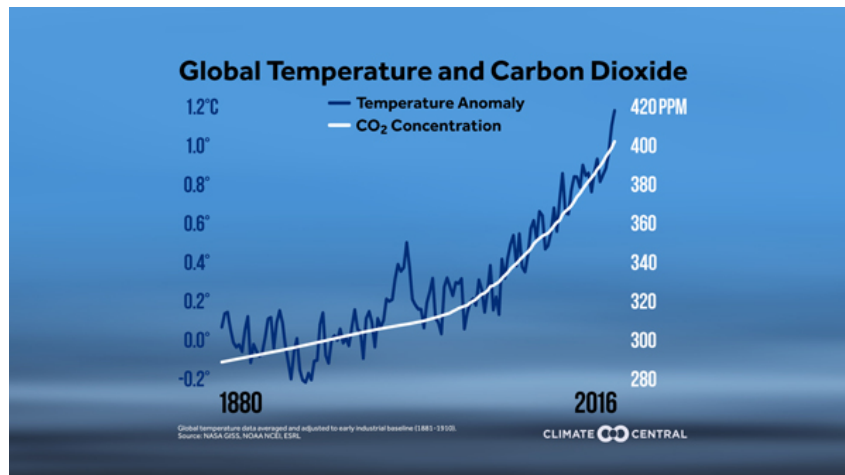
Some of the following pictures are from reference (15).

Beginning in 1990 atmospheric CO₂ levels have been monitored on the top of Hawaii's Mauna Loa.

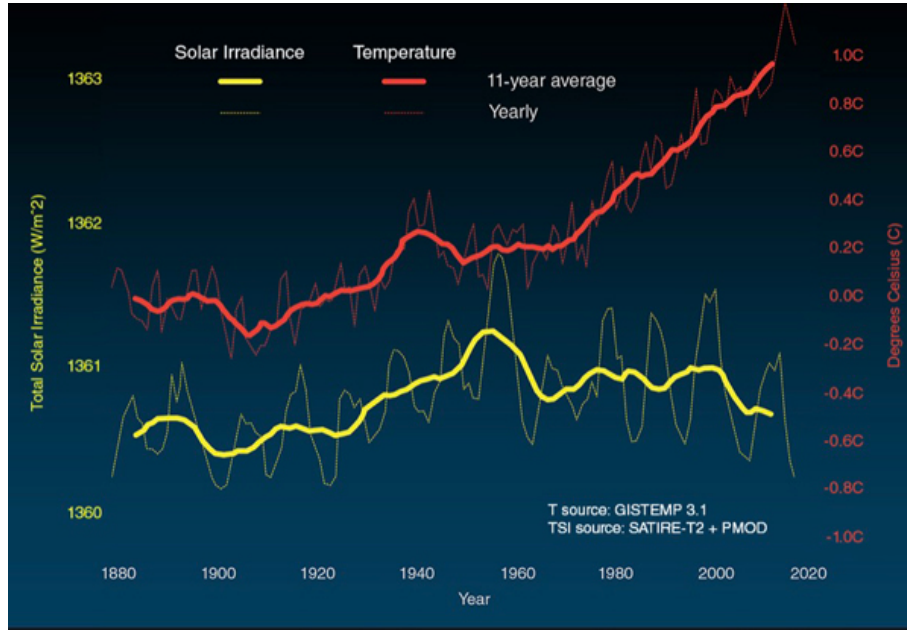


The level of atmospheric CO₂ has continued to rise despite the efforts of the IPCC and 27 COPs. The current level is 420 ppm.

There is a direct correlation between atmospheric CO₂ content and average global temperature.

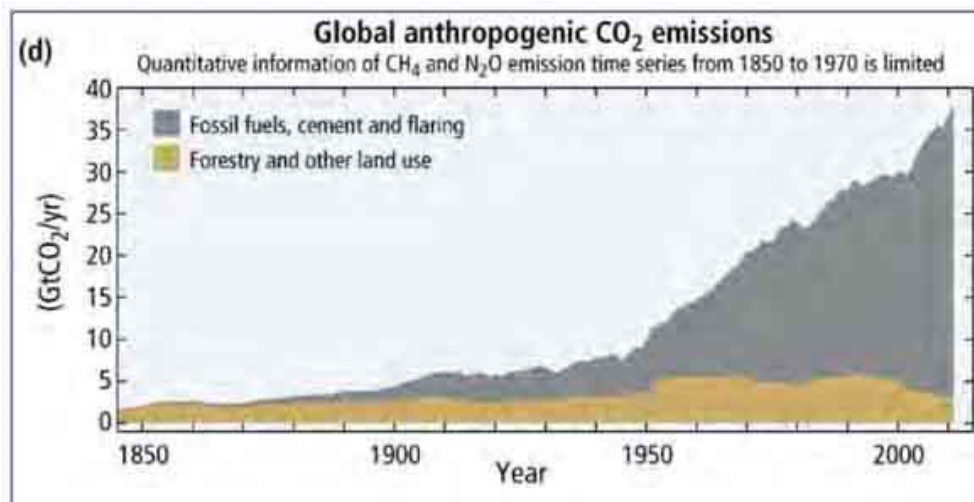


A common claim of climate change deniers is that global warming is all due to variations in the sun's output. The following shows this is not the case.

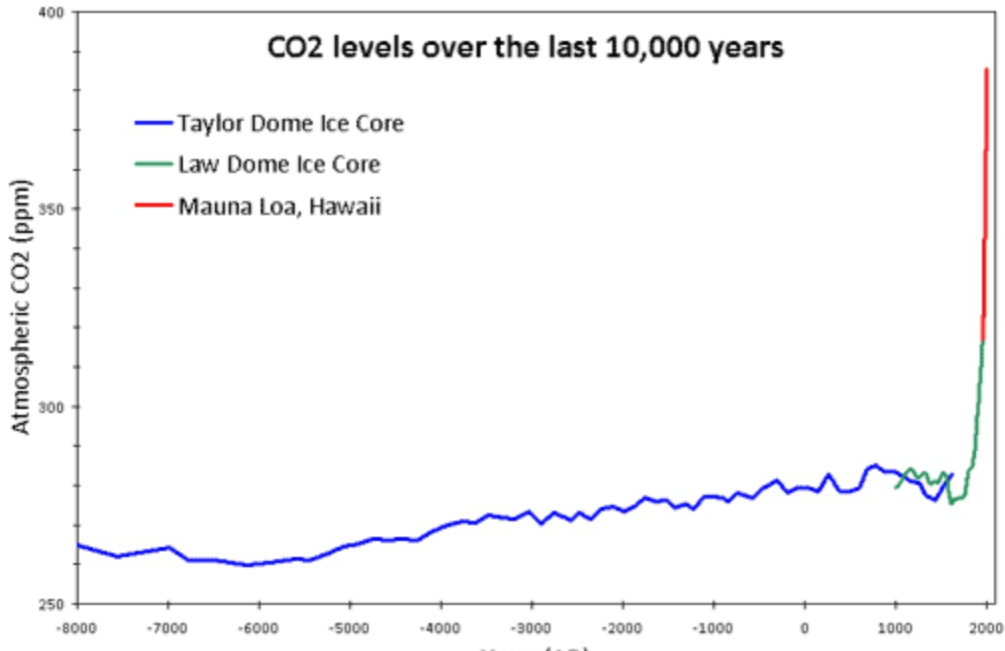


The average global temperature has continued to increase as solar radiation has remained stable or decreased.

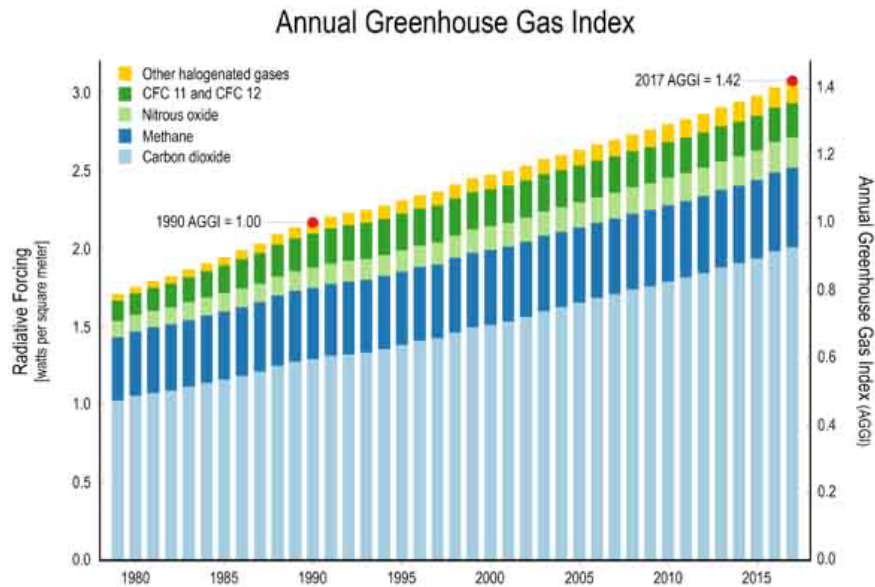
The majority of the accumulated CO₂ was from human sources - fossil fuels, cement and flaring of methane.



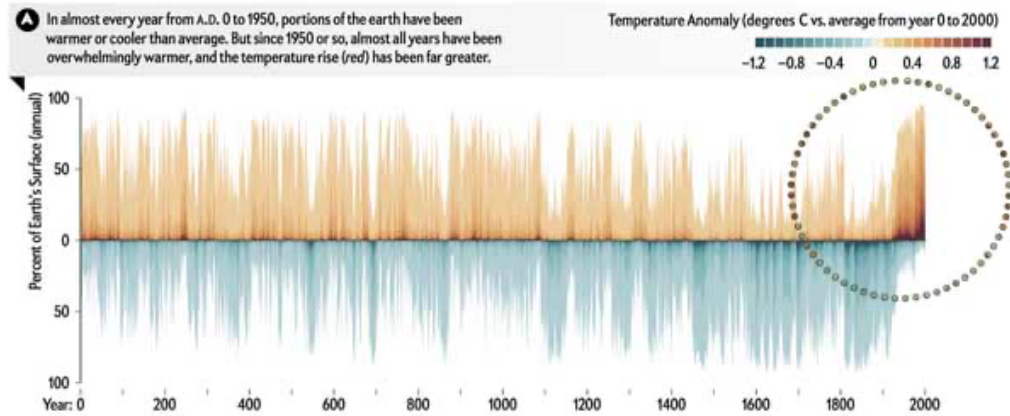
These levels are higher than they have been in 10,000 years.



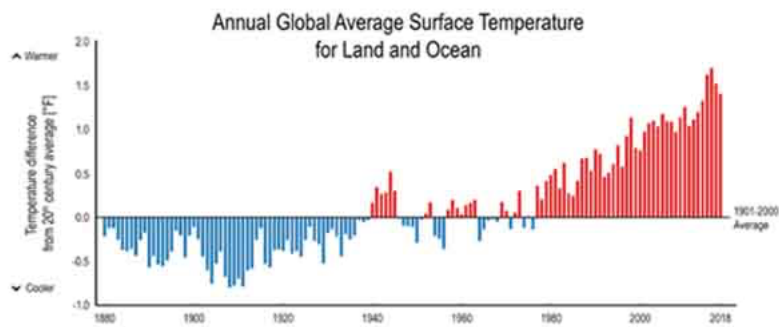
Gases other than CO₂ are also important but CO₂ is driving them all.



One claim of climate change deniers is that the present warming is simply the result of "natural climate variability." An article in the July 2019 Nature (ref 18) shows that interspersed warm and cold periods have occurred for the past 2,000 years but only in the recent past have the oscillations been predominately warming and hotter (see circle).

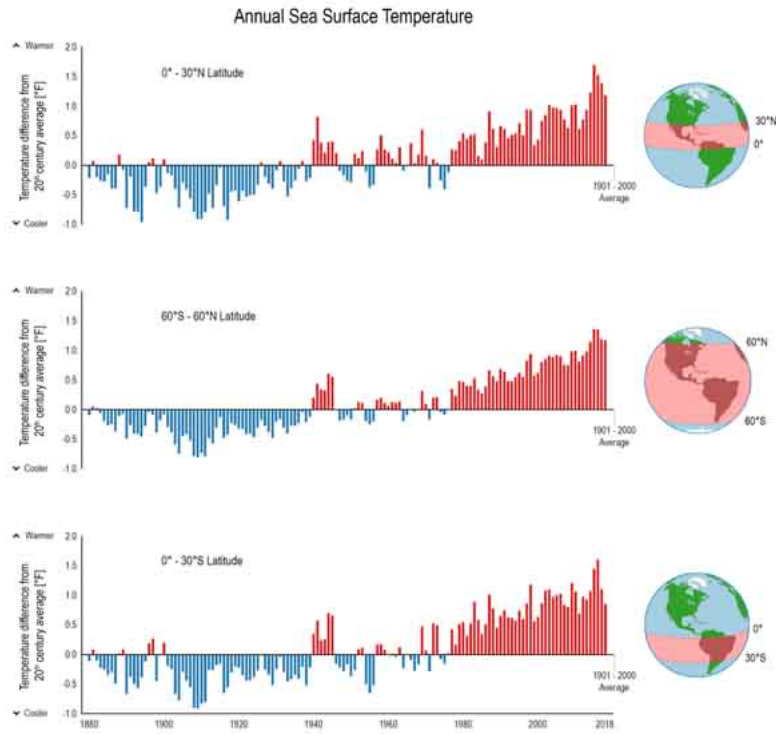


This is also apparent when focusing on the last 140 years (below).

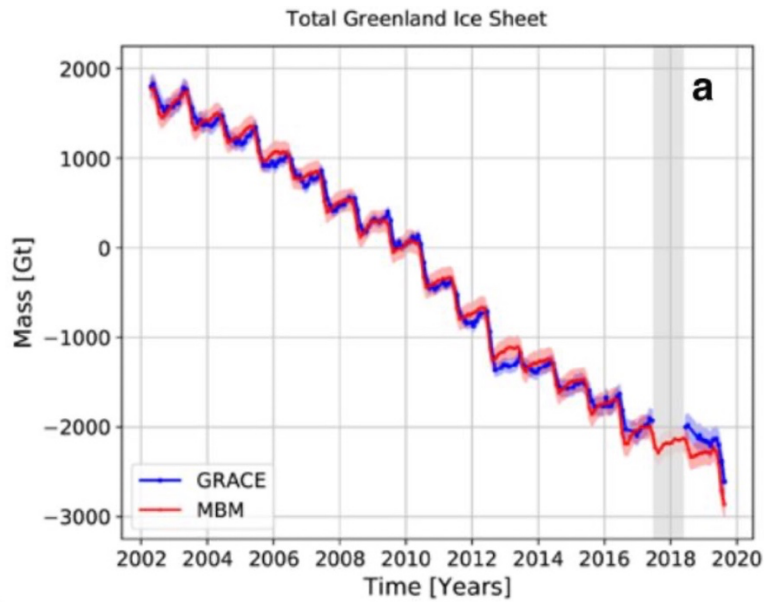


It really is getting hotter - obvious if you listen to weather reports.

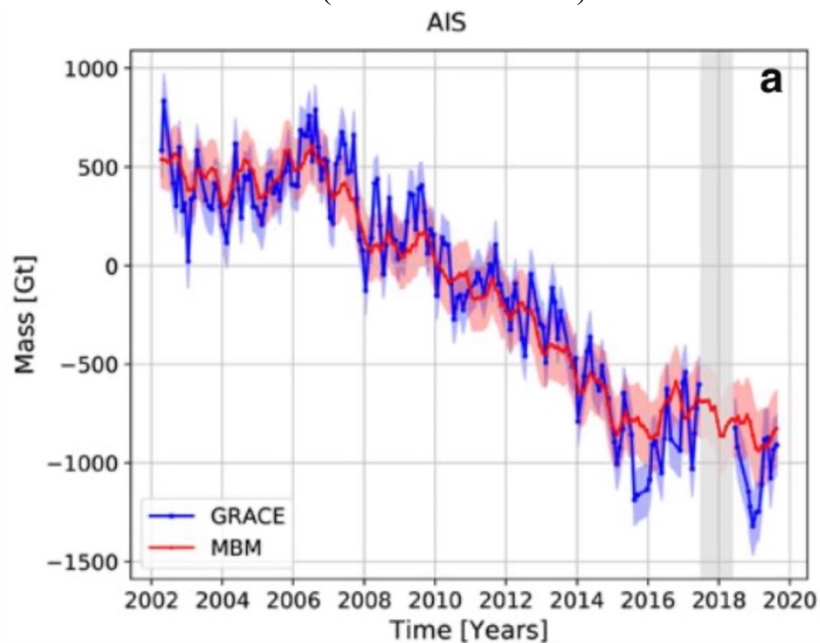
The seas all over the world are warmer.



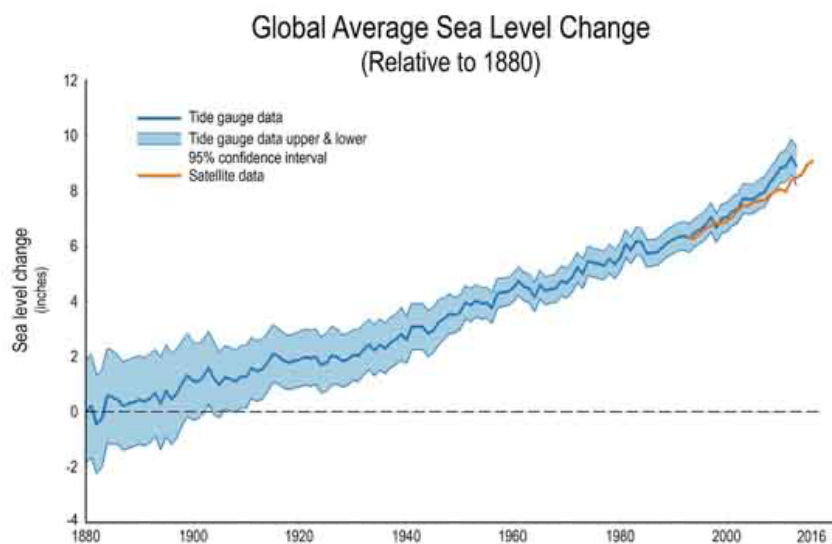
The Arctic and Antarctic ice is melting.



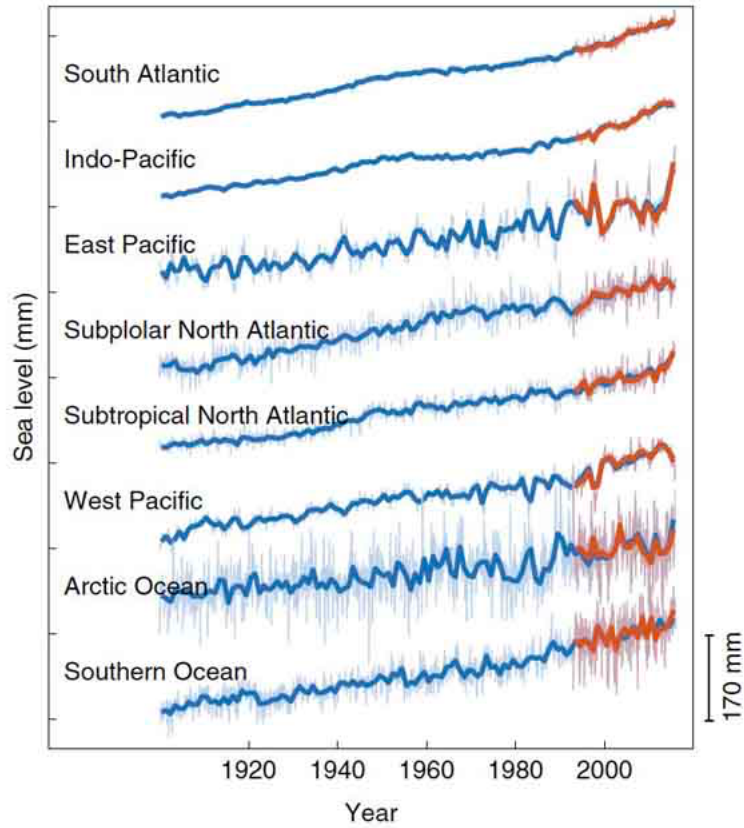
AIS (Antarctic Ice Sheet)



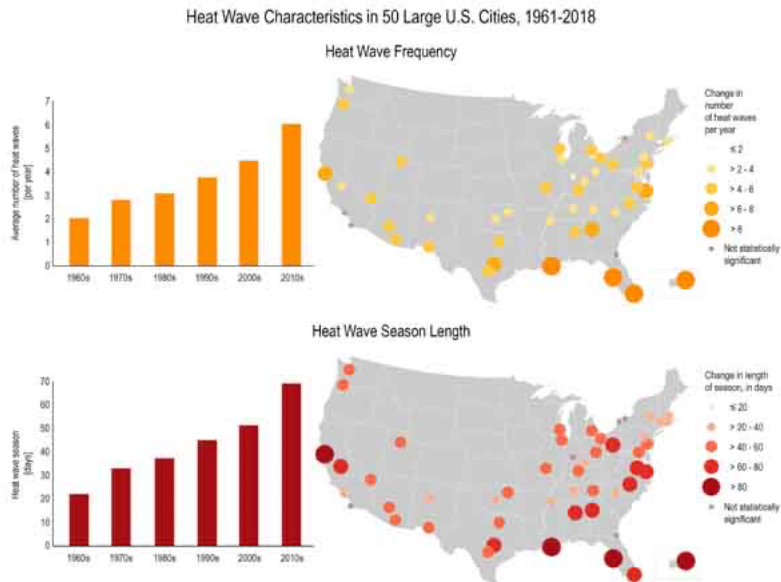
And thus the sea levels are rising.



The following figure (Ref 17) shows that these sea level rises are truly world-wide. Climate change deniers love to claim the sea level is not rising everywhere. This clearly shows the falsity of this claim.

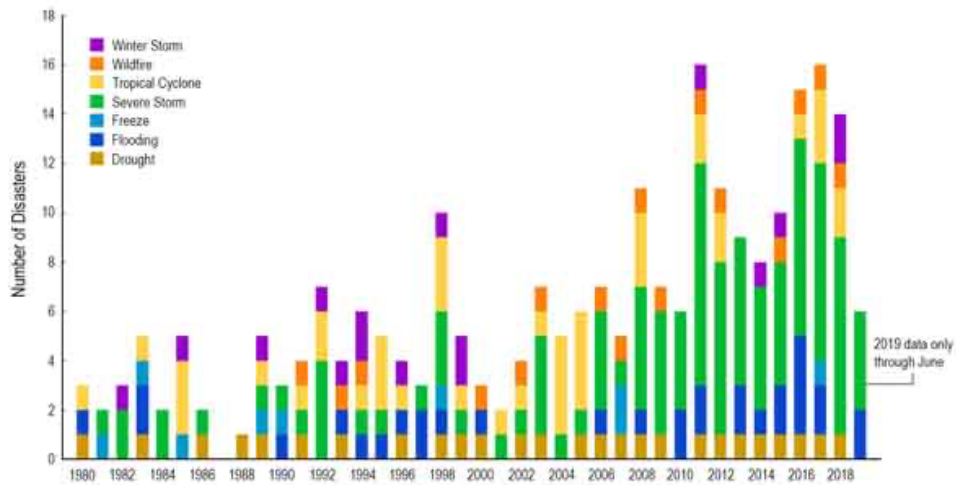


Heat waves are increasing in frequency and duration.

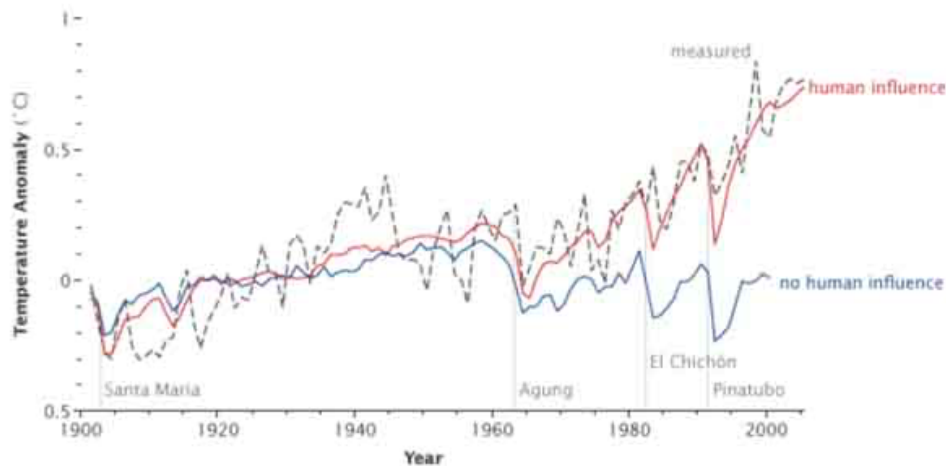


And the economic costs progressively increase.

U.S. Billion Dollar Weather and Climate Disasters



A major reason that scientists think the current warming is not from natural influences is that, over the past century, scientists from all over the world have been collecting data on natural factors (non-human influence) that influence climate—things like changes in the Sun’s brightness, major volcanic eruptions, and cycles such as El Niño and the Pacific Decadal Oscillation. These observations have failed to show any long-term natural changes that could fully account for the recent, rapid warming of Earth’s temperature.



Human influence alone is responsible for the current high levels of atmospheric CO₂.

2018 UN IPCC Climate Report - A world of worsening food shortages and wildfires, and a mass die-off of coral reefs as soon as 2040. The damage would come at a cost of \$54 trillion.

A landmark report from the United Nations’ Intergovernmental Panel on Climate Change (IPCC) scientific panel on climate change paints a far more dire picture of the immediate

consequences of climate change than previously thought and says that avoiding the damage requires transforming the world economy at a speed and scale that has “no documented historic precedent.”

The report was written and edited by 91 scientists from 40 countries who analyzed more than 6,000 scientific studies. The Paris agreement set out to prevent warming of more than 3.6 degrees above preindustrial levels — long considered a threshold for the most severe social and economic damage from climate change. The new report concludes that we really need to limit it to 1.5 C. The consequences of warming above that level: more heat waves, more severe rain and snow events, higher sea levels, damage to agriculture and displacement of millions of people.

It is not the purpose of this page to review the vast amount of science supporting the reality of global warming or the politics and funding of the global warming deniers. This is well covered in the attached references. Instead, this page will present a few of the areas of most concern to us and most importantly, see Position Paper, ways in which the the Comings Foundation might help.

Despite the fact that 100% of the scientists who have actually done research and published in the field of climate science believe that global warming is real, is due to the massive burning of fossil fuels, and is a threat to the world economies, some scientists whose expertise is in other fields have joined a group of global warming deniers. Whole books have been written about the origin, politics and funding of the global warming deniers (Refs 1-5).

The Consequences of Increased Global Warming

Melting Ice



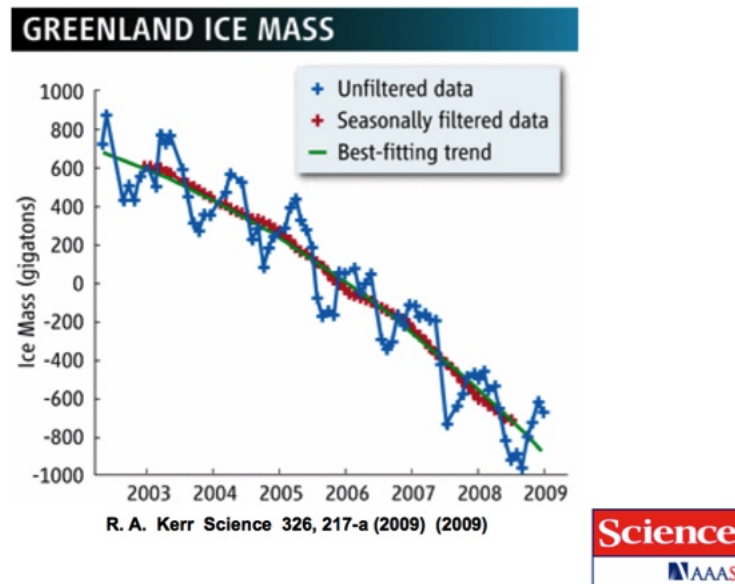
Ice is at the core of the controversy. If global warming is real, the global ice caps will start to melt and this will cause a rise in sea level. If left unchecked this will be the source of one of many of the negative consequences of global warming.

Since oceans have a great capacity to adsorb and buffer CO₂ the deniers claim this has had no adverse effect and that there is no evidence that the global ice caps are melting. While direct

observations suggest various ice sheets in some places are melting and decreasing in size, the deniers claim that this is all counterbalanced by expansion of ice sheets in other places.

The Gravity Recovery and Climate Experiment (GRACE) satellite has now solved this issue. Rather than measuring the volume of ice sheets every few years as most earlier surveys have done, GRACE “weighs” them from month to month with a pair of spacecrafts launched in March 2002 (Ref 5). Flying in tandem 220 kilometers apart, the satellites can measure subtle variations in the **pull of gravity** as they pass over a large mass on the surface. By beaming microwaves from one to the other, they precisely gauge the changing distance between them as the added mass tugs first on the leading satellite and then on the trailing one. Changes in gravity from pass to pass reflect changes in the icy mass below.

This has shown that the mass changes of Greenland and Antarctica 2002 to 2009 have all been negative. On Greenland the rate of ice mass loss doubled over this time with an acceleration of -30 cubic kilometers lost per year. This is illustrated in the following figure.

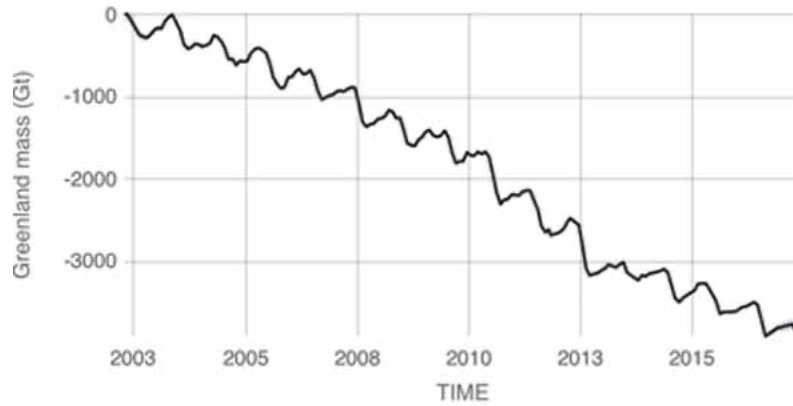


AS

The trend line of Greenland ice mass (green) curves downward with time, suggesting that losses have been accelerating. (6).

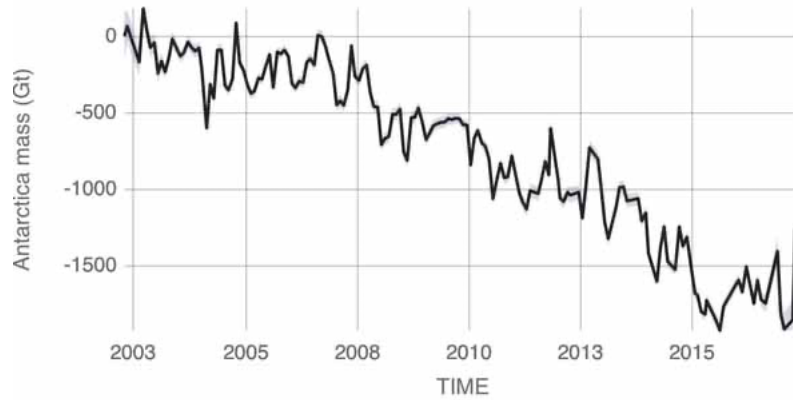
The GRACE satellites continued to obtain data. What happened in Greenland after 2009 and what happened in Antarctica from 2002 to 2016 is shown in the following two figures.

Results of GRACE for Greenland from 2002 to 2016. NASA



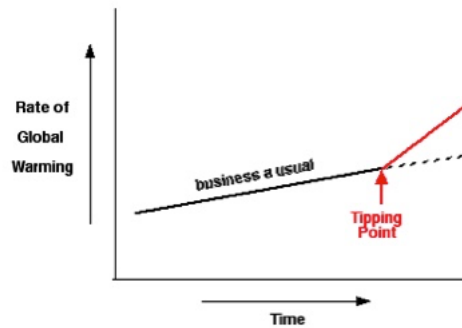
Source: climate.nasa.gov

Results of GRACE for Antarctica from 2002 to 2016. NASA



Source: climate.nasa.gov

Tipping Points. The term tipping point refers to levels of global warming that once reached result in a rapid acceleration (positive feedback) in the rate of warming above what would occur with a simple extrapolation of business as usual.



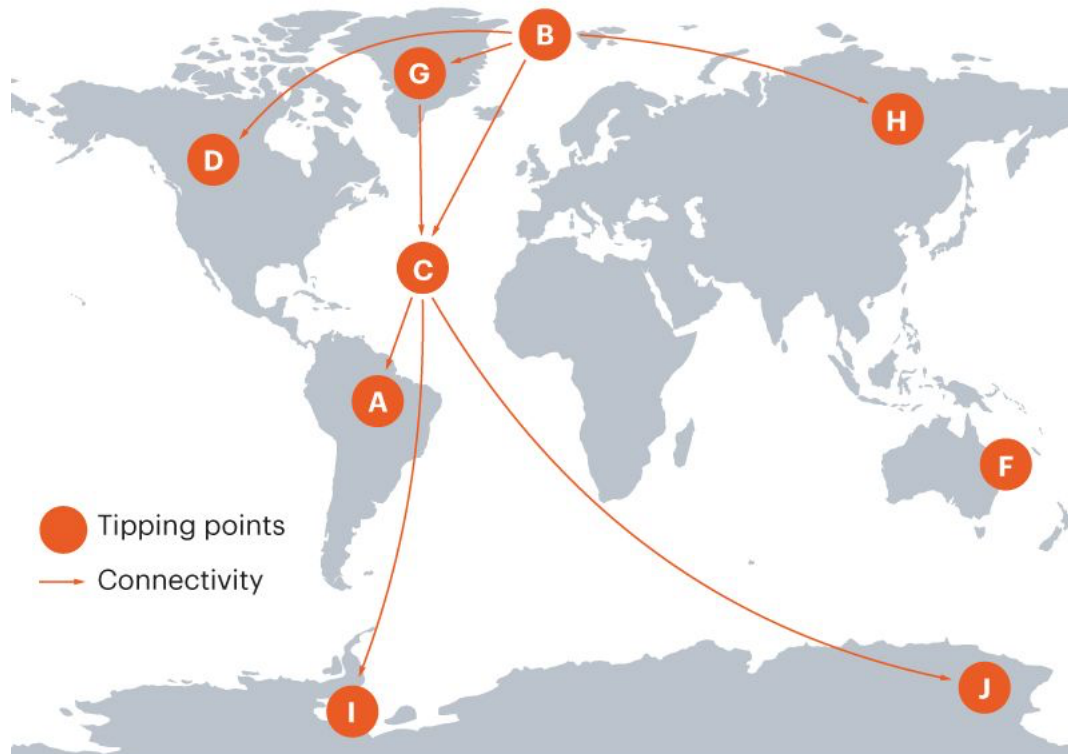
Concept of Tipping Points

Positive feedback means that each increase stimulates a further increase. Positive feedbacks have the capability of taking off exponentially. They are extremely dangerous.

The following figure shows the worldwide location of some of the most serious tripping points (19). See also (7) and (8).

RAISING THE ALARM

Evidence that tipping points are under way has mounted in the past decade. Domino effects have also been proposed.



A. Amazon rainforest
Frequent droughts

B. Arctic sea ice
Reduction in area

C. Atlantic circulation
In slowdown since 1950s

D. Boreal forest
Fires and pests changing

F. Coral reefs
Large-scale die-offs

G. Greenland ice sheet
Ice loss accelerating

H. Permafrost
Thawing

I. West Antarctic ice sheet
Ice loss accelerating

J. Wilkes Basin, East Antarctica
Ice loss accelerating

©nature

These were originally proposed to occur after to 2oC to 6oC of global warming. The most recent assessments indicate some are occurring now and more will occur with as low as a 1.5oC rise. The ones occurring now are the following.

Melting of the Tundra Permafrost with Release of Gigatons of Methane and Carbon Dioxide.

There are enormous quantities of naturally occurring greenhouse gasses trapped in ice-like structures in the cold northern muds and at the bottom of the seas. These ices, called **clathrates, contain frozen methane**. Methane is more than 80 times as strong a greenhouse gas as carbon dioxide and is eventually converted to CO₂. Arctic and boreal permafrost contain 1,460–1,600 Gt organic carbon, almost twice the carbon in the atmosphere. There are 400 gigatons of methane locked in the Arctic tundra. A further temperature increase of a few degrees centigrade could begin to melt the arctic tundra resulting in giant “burps” of methane gases.

Monitoring by Russian scientists suggests that the permafrost shell is already starting to break up in places releasing millions of tons of methane into the atmosphere of the Arctic. Especially worrying is the observation that up to 10 percent of this area is now being punctured by so-called **taliks**. These are areas of thawed permafrost that provide avenues for the ready escape of methane and opportunities for warmth to penetrate deep into the frozen hydrate beneath.



The Batagaika crater (talik) in eastern Siberia, half a mile wide and growing, is the largest in the Arctic (16)



The ancient soils of Arctic permafrost, seen here in the wall of the above crater. They hold the organic remains that died thousands of years ago. All this carbon has been safely sequestered in frozen earth, until NOW.

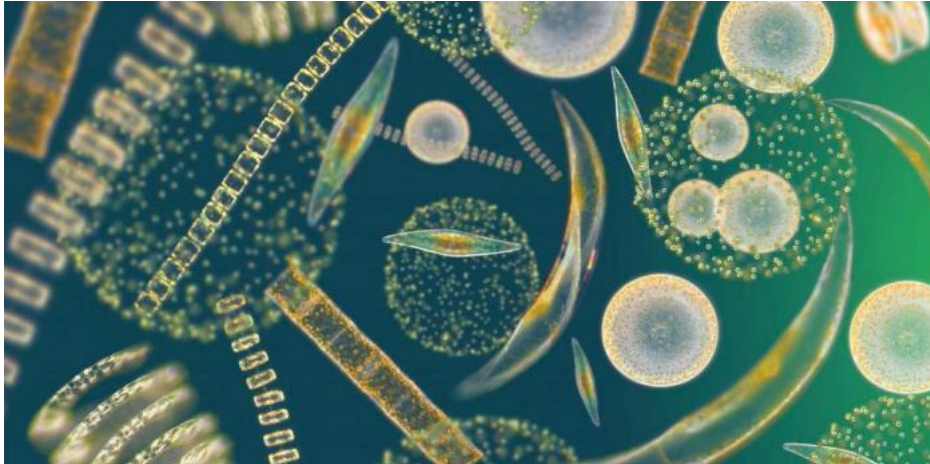
Natalia Shakhova (14) of the University of Alaska's International Arctic Research Center is concerned that up to 50 billion tons of methane could be released abruptly and without warning from the Arctic seabed, pushing up the methane concentration of the atmosphere 12-fold virtually overnight and **driving cataclysmic warming**. Once triggered the increase in temperature would start a vicious cycle of the release of even more and more methane (i.e. positive feedback). This scenario is not just the ramblings of environmental scare mongers. It has happened before (9-10, 14).

The most recent of these catastrophes occurred about 55 million years ago in what geologists call the Paleocene-Eocene Thermal Maximum (PETM) when volcanic methane burps caused rapid warming and massive die-offs, disrupting the climate for more than 100,000 years. The granddaddy of these catastrophes occurred 251 million years ago, at the end of the Permian period, when a series of volcanic methane burps came close to wiping out all life on Earth. More than 94 percent of the marine species present in the fossil record disappeared suddenly as oxygen levels plummeted and life teetered on the verge of extinction. Over the ensuing 500,000 years, a few species struggled to gain a foothold in the hostile environment. It took 20 million to 30 million years for even rudimentary coral reefs to re-establish themselves and for forests to re-grow. In some areas, it took more than 100 million years for ecosystems to reach their former healthy diversity (8).

There are 10,000 gigatons of methane clathrates under the continental shelves. However, in contrast to the permafrost methane, which could be released in a short time frame, it is estimated that sufficient ocean warming to release these underwater clathrates may take much longer. (ref 9).

The release of methane from volcanoes triggered these past tripping points. According to the U.S. Geologic Survey burning fossil fuels releases 150 times the amount of CO₂ as emitted by volcanoes. Through the mechanism of burning fossil fuels humans are clearly capable to reaching the methane “burp” tipping point. **Once it is reached there is virtually nothing that can be done to rescue the earth from serious harm. The answer is prevention.**

Loss of Ocean Phytoplankton



Phytoplankton consist of two species, **cyanobacteria**, and **single celled algae**. Both are capable of photosynthesis and thus of converting CO₂ to sugars and O₂. In the early earth, **cyanobacteria were responsible for the production of the oxygen in the atmosphere**. It took about a billion years of producing oxygen before all the oxygen sinks, such as iron containing rocks, were filled and the levels of oxygen in the atmosphere began to rise. In recent years remarkable facts about the role of ocean phytoplankton in the carbon dioxide cycle of the earth have been uncovered.

Obtaining this data required the Coastal Zone Color Scanner (CZCS) satellite launched by NASA. It was found that **phytoplankton incorporated 45 to 50 billion tons of carbon into their cells each year** (Ref 11). This was twice the level of all previous estimates. In addition, it was found that **land plants incorporated 52 billion tons of inorganic carbon each year, half of previous estimates**. In summary, although they amount to less than 1% of the photosynthetic biomass of the earth, **phytoplankton contributes almost half of the total photosynthetic activity**. This difference is due to the fact the land plants have an average turnover of once every 10 years compared to once a week for the active phytoplankton (11). When the phytoplankton dies, they sink to the bottom of the ocean effectively burying the carbon dioxide.

This massive effect of phytoplankton on fixing carbon dioxide means that anything that inhibits phytoplankton turnover would have a profound effect on global warming. If the phytoplankton pumping CO₂ to the deep ocean stopped tomorrow the level of CO₂ in the atmosphere would eventually rise by an additional 200 ppm. Unfortunately, this carbon cycle is inhibited when ocean water warms. Warm water is less dense and does not mix as well with the nutrient-rich cold water beneath it. **Global warming as already begun to slow down the sequestration of CO₂ by phytoplankton**. Further warming will produce a positive feedback to further global warming.

Forest Wildfires.

The Camp Fire, California.



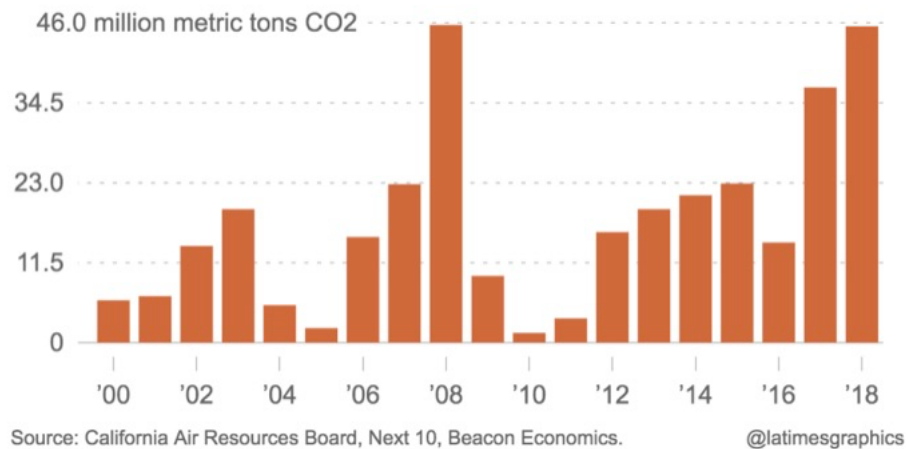
Sydney, Australia fire storm.



The trees and forest and the soil store huge amounts of CO₂. The process of photosynthesis, unique to plants, converts atmospheric CO₂ into oxygen and carbon contained in sugars, lignin, cellulose, and other compounds. When trees die this carbon is sequestered into the soil. As the global temperature increase the forests become drier and susceptible to **large forest wildfires which release these huge amounts of CO₂** leading to further warming.

The following figure shows the amount of carbon released by California Wildfires.

Carbon emissions from California wildfires



(Los Angeles Times)

In 2008 and 2018 wildfires in California released 48 million metric tons of CO₂. A 500 MW coal fired power plant releases 4 million tons per year. Thus, these two seasons each released the **equivalent of 11 years of CO₂ released by coal fired power plants.** While on other years there was less release of CO₂ by wildfires, California represents only a fraction of worldwide fires.

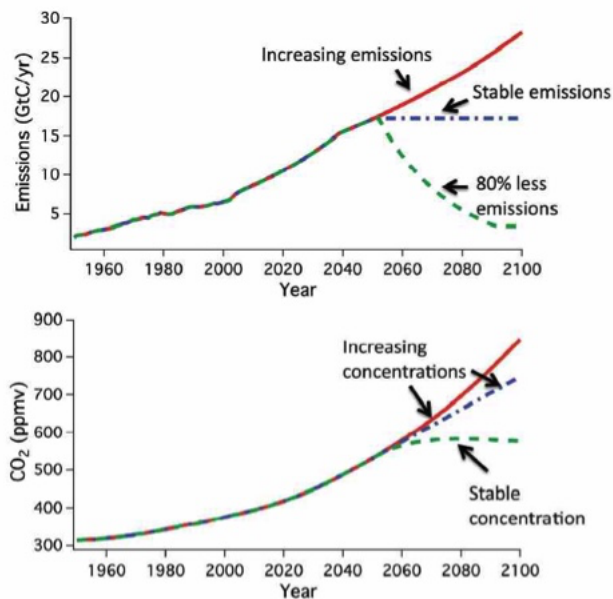
Loss of the Earth's Albedo.

The albedo of an object is a measure of **how strongly it reflects light and thus heat.** The albedo of the polar ice sheets contribute significantly to cooling the earth because of the heat they reflect back into space. As the polar ice sheets melt this cooling effect is progressively lost leading to more warming and more melting ice. As shown in the figures above there has been a significant loss of ice and thus albedo in both Greenland and the Antarctic.

The following, which summarizes some of the consequences of global warming was adopted from the 2010 report of the National Research Council (12). In their executive summary they point out that:

Because carbon dioxide in the atmosphere is long lived, it can effectively lock the Earth and future generations into a range of impacts, some of which could become very severe. Therefore, emissions reduction choices made today matter in determining impacts experienced **not just over the next few decades, but in the coming centuries and millennia.** Climate changes caused by carbon dioxide are expected to persist for many centuries even if emissions were to be halted at any point in time.

The NRC report also demonstrates that stabilizing atmospheric carbon dioxide concentrations will require deep reductions in the amount of carbon dioxide emitted. **Emissions reductions larger than about 80 percent are required to approximately stabilize carbon dioxide concentrations.** This is illustrated in the following figure.



The Top panel shows that stabilizing current emissions would, of course, stabilize the amount of CO₂ emitted to the atmosphere. However, as shown in the bottom panel, **only an 80% reduction in current emissions would stabilize the level of atmospheric CO₂.**

Temperature Extremes

Extreme temperatures are expected to increase in a warmer world. For example, for about 3°C of global warming, 9 out of 10 northern hemisphere summers are projected to be “exceptionally warm” in nearly all land areas, and every summer is projected to be “exceptionally warm” in nearly all land areas for about 4°C, where an “exceptionally warm” summer is defined as one that is warmer than all but about 1 of the 20 summers in the last decades of the 20th century.

Extreme Precipitation Draught in Australia



Extreme precipitation is likely to increase by about 3-10% per degree C as the atmospheric water vapor content increases in a warming climate, with changes likely to be greater in the tropics than in the extra-tropics (this sensitivity may decrease somewhat as the warming progresses).

Hurricanes and Typhoons

suggest that the average intensity of tropical cyclones (as measured by the wind speed) is likely to increase by 3-12% per degree C for the cube of this wind speed, often taken as a rough measure of the destructive potential of storm winds.

Snow Cover and Snowpack

Current trends in snow cover over the Northern Hemisphere suggest that the snow cover season has shortened, and spring melt is occurring earlier compared to the last 50 – 100 years. Snowpack is a vital determinant of the availability of fresh water. The consequences of the elimination of the snowpack in the Sierras would be disastrous to the water supply of Los Angeles. In 2023 there was some dramatic relief of low snowpack by a series of "atmospheric rivers."

Flooding

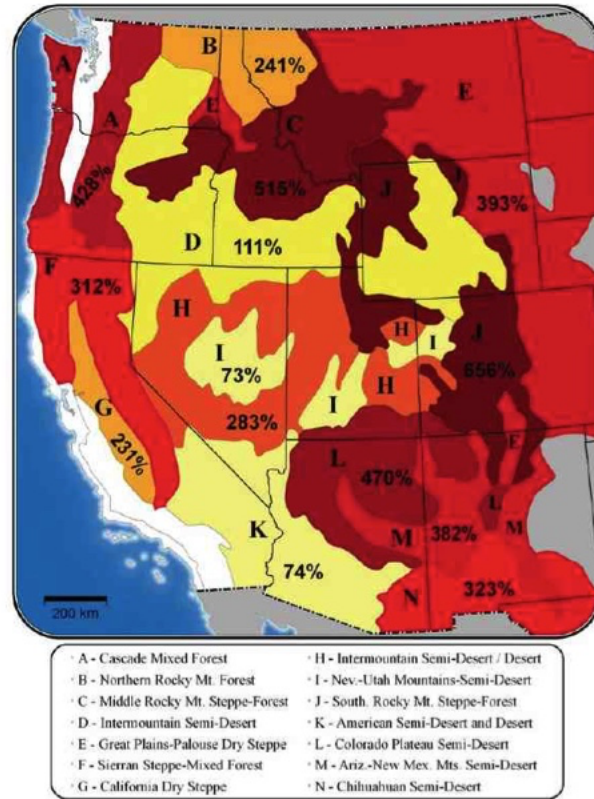


Flooding in Grafton, IL by the Mississippi

Global warming of 2°C would be expected to lead to average yield losses of U.S. corn of roughly 25% ($\pm 16\%$ very likely range) unless effective adaptation measures are discovered and implemented.

Fires

Studies suggest that warming of 1°C (relative to 1950-2003) is expected to produce increases in median area burned by about 200-400%. This is illustrated below.



Percent increase relative to 1950-2003 in medium annual area burned for the Western United States with a 1°C increase in global average temperature.

Ocean Acidification



Rising atmospheric CO₂ alters ocean chemistry, leading to more acidic conditions (lower pH) and lower chemical saturation states for calcium carbonate minerals used by many plants, animals, and microorganisms to make shells and skeletons.

The patterns and rates of ocean primary production will change due to higher sea surface temperatures and increased vertical stratification, altering the base of the marine food-web. The geographic range of many marine species is shifting poleward and to deeper waters due to ocean warming.

Coral bleaching

Over the last several decades, warmer sea surface temperatures have led to widespread **tropical coral bleaching and increased coral mortality**, and warming and more local human impacts are associated with declines in the health of coral reef ecosystems worldwide. **Bleaching can occur for sea surface temperature changes as small as +1-2°C above maximal summer sea surface temperatures**, which corresponds to global average warming of about 1.5-3°C.

Sea Level



Assuming a doubling in ice discharge from both Greenland and Antarctica, the total global average sea level rise would be 0.88 ± 0.12 m by 2100. We therefore estimate a range of total **global sea level rise in 2100 of about 0.5 to 1.0 m (1.6 to 3.3 ft)**.

It has been projected that 0.5 meters of sea level rise would increase the number of people at **risk from coastal flooding each year by between 5 and 200 million as many as 4 million of these people could be permanently displaced as a result. More than 300 million people currently live in coastal mega-deltas and mega-cities located in coastal zones.** The corresponding projections for 1.0 m of sea level rise the number of people at risk of flooding each year would increase by 10 to 300 million.

Rising sea-levels will impact key coastal marine ecosystems, coral reefs, mangroves, and saltmarshes, through inundation and enhanced coastal erosion rates.

Electricity

Climate change is expected to increase electricity demand and affect production and reliability of supply. Observed correlations between daily mean near-surface air temperature and electricity demand suggest warmer summer temperatures and more frequent, severe, and prolonged extreme heat events could increase demand for cooling energy.

Human health

Heat-related illness and deaths occur as a direct result of sustained, elevated levels of extreme temperatures during heat waves, which are projected to increase with increasing temperatures.

Climate change is likely to **affect the geographic spread and transmission efficiency of illnesses and disease carried by hosts and vectors**, but complexity precludes any quantitative estimates of the relationship between incidence of a given disease and temperature change.

Ecology and Ecosystems

For at least the last 40 years, many species have been and are currently shifting the timing of spring events in concert with warming temperatures. Examining 542 species of plants and 19 of animals, a large effect on timing of blooming, egg laying and migrating was found. In a study of 21 European countries for the last 30 years of the 20th century found a total of **78% of species were shifting their spring timing earlier and only 3% were shifting it later**.

As the climate has warmed many species have been and are continuing to track this warming by shifting their ranges into areas that before warming were less hospitable due to cooler temperatures.

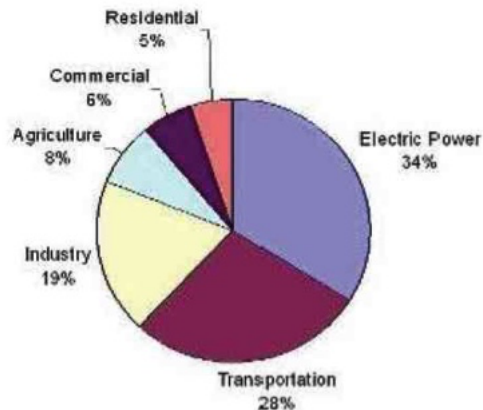
Historically, extinctions of most species have been found to be due to various stresses, such as land-use change, invasive species, and hunting, but now the vulnerability of many species to extinction is enhanced with the added stress placed upon them by climate change.

Increase in earthquakes and tsunamis.

An additional potential consequence of global warming has been well documented by Bill McGuire in his book *Waking the Giant: How a Changing Climate Triggers Earthquakes, Tsunamis, and Volcanoes* (13). Many studies have shown that raising (or falling) sea levels can trigger these events. As shown by very recent history, giant tsunamis can kill many thousands of people and disrupt nuclear power plants.

Source of CO₂ in the United States.

An essential aspect of knowing how to cut back on CO₂ emissions is knowing where the CO₂ comes from. The following figure shows the sources of CO₂ emissions in the U.S.



Greenhouse emissions by sector in the U.S.

The number of electric, fuel cell, and plug in hybrid cars will increase dramatically in the next 50 years helping to relieve the contribution of transportation to CO₂ emissions. This leaves converting the production of electric power away from coal and toward solar, wind, and geothermal as the major goal in the fight to significantly reduce CO₂ emission.

It is clear that **global warming poses a significant problem to virtually all aspects of human existence on this fragile planet.** As outlined above **the economic impact of a 2 to 4°C rise in global temperature is huge. It is 100 to 1000-fold greater than the cost of reducing CO₂ emissions now.**

Two approaches to global warming are clearly needed:

1. Reduce CO₂ emissions.
2. Remove CO₂ from the atmosphere and safely sequester it.

The Enhanced Weathering page leads to a document entitled:

How to Combat Global Warming

The Addendum page leads to a document entitled:

How the Different Parts of the U.S. Government and the Private Sector Can Help with Using Enhanced Weathering, OAE and eOAE to Combat Global Warming

The links to the 2018 National Climate Change Assessment are:

URL for scientific report 4th National Climate Change Assessment Vol I.

<https://science2017.globalchange.gov>

URL for Climate Change Effects

Vol II. Impacts, Risks, and Adaption in the U.S.

<https://nca2018.globalchange.gov/>

References

1. Hansen, James. *Storms of My Grandchildren: The Truth about the Coming Climate Catastrophe and Our Last Chance to Save Humanity*. Bloomsbury Press, New York, 2009.
2. Schneider, S.H. *Science as a Contact Sport: Inside the Battle to Save Earth Climate*. National Geographic Society, Washington D.C., 2009.
3. Dreskes, N and Conway, E.M. *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming*. Bloomsbury Press, New York, 2010.
4. Mooney, Chris. *The Republican War on Science*. Basic Books, New York, 2006.
5. Pielke, Jr., R. *The Climate Fix*. Basic Books, New York, 2010.
6. Kerr, R.A.: *Both of the World's Ice Sheets may be shrinking faster and faster*. Science 326: 217,2009.
7. Kriegler, E., Hall, J.W., Hermann, H., Dawson, R. and Schellnhuber, H.J. Imprecise probability assessment of tipping points in the climate system. *PNAS* 106:5041-5046, 2009
8. Lenton,T.M., Hermann H., Kriegler,E., Hall, J.W., Lucht, W., Rahmstorf, S. and Schellnhuber, H. J. Tipping elements in the Earth's climate system. *PNAS*.105:1786-1793, 2008
9. Atcheson, J.: *Methane Burps: Ticking Time Bomb*. Baltimore Sun, Dec 15, 2004.
10. Benton, M.J.: *When Life Nearly Died: The Greatest Mass Extinction of All Time*. Thames & Hudson, London, 2005.
11. Falkowski, P. The Power of Plankton. *Nature* 483:517-520, 2012.
12. *Climate Stabilization Targets: Emissions, Concentrations, and Impacts over Decades to Millennia*. Committee on Stabilization Targets for Atmospheric Greenhouse Gas Concentrations. National Research Council, National Academics Press, 243 pp, 2010. To download a free copy goto: <http://www.nap.edu/catalog/12866.html>

13. McQuire, B. *Waking the Giant. Waking the Giant: How a Changing Climate Triggers Earthquakes, Tsunamis, and Volcanoes*. Oxford University Press, USA 2012.
14. Shakhova, N. et al. Anomalies of methane in the atmosphere over the East Siberian Shelf: Is there any sign of methane leakage from shallow shelf hydrates? *Geophysical Research Abstracts* **10**: EGU2008-A-01526 European Geosciences Union General Assembly, 2008.
15. The Climate Report 2018. The National Climate Assessment - Impacts, Risks, and Adapt in the United States. U.S. Global Change Research Program.
16. C. Welch: The Threat Below. Arctic Permafrost is thawing much faster than expected. Reshaping the land and releasing carbon gases that could speed climate change. *National Geographic* Sept, 74-99, 2019.
17. Dangerdork, S. et al: Persistent acceleration in global sea-level rise since the 1960s' *Nature Climate Change* 9:705-710, 2019.
18. Neukom, R. et al. No evidence fo globally coherent warm and cold periods over the preindustrial Common Era. *Nature* 371:550-554, 2019.
19. Lenton, T M. et al. Climate tipping points - too risky to bet against. *Nature* 575:592-595, 2019.