Climate-Change Summary and Update – Dr Guy McPherson

This printable version was extracted from an essay written by Dr. Guy McPherson, Professor Emeritus of Natural Resources and Ecology & Evolutionary Biology, School of Natural Resources and the Environment, University of Arizona. Last updated 2 August 2016.

You are encouraged to also read the online version of this document, which contains many supportive hyperlinks referencing original research and articles: https://guymcpherson.com/climate-chaos/climate-change-summary-and-update/

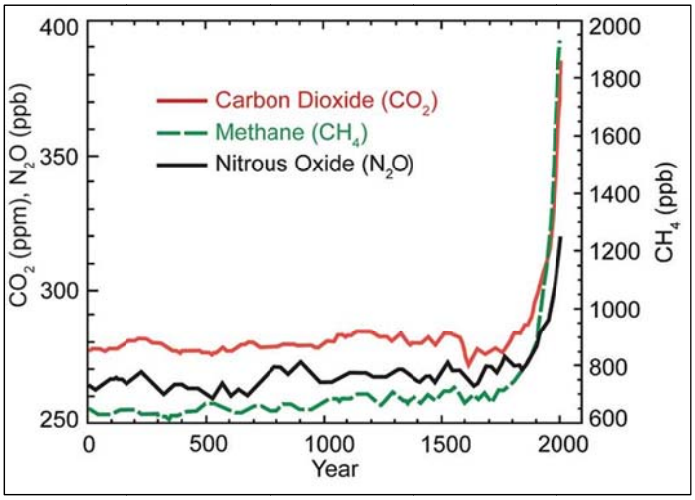
NB: This document was written before the ascendency of Donald Trump.

The Great Dying wiped out at least 90% of the species on Earth due to an abrupt rise in global-average temperature about 252 million years ago. The vast majority of complex life became extinct. Based on information from the most conservative sources available, Earth is headed for a similar or higher global-average temperature in the very near future. The recent and near-future rises in temperature are occurring and will occur at least an order of magnitude faster than the worst of all prior Mass Extinctions. Habitat for human animals is disappearing throughout the world, and abrupt climate change has barely begun. In the near future, habitat for Homo sapiens will be gone. Shortly thereafter, all humans will die.

There is no precedence in planetary history for events unfolding today. As a result, relying on prior events to predict the near future is unwise.

I'm often accused of cherry picking the information in this ever-growing essay. I plead guilty, and explained myself in an essay posted 30 January 2014. My critics tend to focus on me and my lack of standing in the scientific community, to which I respond with the words of John W. Farley: "The scientific case is not dependent on citation of authority, no matter how distinguished the authority may be. The case is dependent upon experimental evidence, logic, and reason." In other words, stop targeting the messenger.

American actress Lily Tomlin is credited with the expression, "No matter how cynical you become, it's never enough to keep up." With respect to climate science, my own efforts to stay abreast are blown away every week by new data, models, and assessments. It seems no matter how dire the situation becomes, it only gets worse when I check the latest reports.



The response of politicians, heads of non-governmental organizations, and corporate leaders remains the same, even though they surely know everything in this essay. They're mired in the dank Swamp of Nothingness. Margaret Beckett, former U.K. foreign secretary said in September 2008 on BBC America television, with respect to climate change: "Will it harm our children? Will it harm our grandchildren? Actually, it's a problem for us today." As Halldor Thorgeirsson, a senior director with the United Nations Framework Convention on Climate Change said on 17 September 2013: "We are failing as an international community. We are not on track." These are the people who know about, and presumably could do something about, our ongoing race to disaster (if only to sound the alarm). Tomlin's line is never more germane than when thinking about their pursuit of a buck at the expense of life on Earth.

Worse than the aforementioned trolls are the media. Fully captured by corporations and the corporate states, the media continue to dance around the issue of climate change. Occasionally a forthright piece is published, but it generally points in the wrong direction, such as suggesting climate scientists and activists be killed (e.g., James Delingpole's 7 April 2013 hate-filled article in the *Telegraph*). Leading mainstream outlets routinely mislead the public.

Mainstream scientists minimize the message at every turn, with expected results. As we've known for years, scientists almost invariably underplay climate impacts (James Hansen referred to the phenomenon as "scientific reticence" in his 24 May 2007 paper about sea-level rise in *Environmental Research Letters*). A paper in 27 June 2016 online issue of *Nature Climate Change* reinforces the idea of scientific conservatism, pointing out that dependence upon historical records leads to missing about one-fifth of global warming since the 1860s.

In some cases, scientists are aggressively muzzled by their governments. Britain's Royal Society began actively ignoring observational science about Arctic methane in 2014. Canada no longer allows some climate-change information into the public realm. Even museums are not safe from misinformation about climate science to appease fossil-fuel philanthropists, as reported in the 17 June 2014 issue of *AlterNet*. I'm not implying conspiracy among scientists. Science selects for conservatism. Academia selects for extreme conservatism. These folks are loathe to risk drawing undue attention to themselves by pointing out there might be a threat to civilization. Never mind

the near-term threat to our entire species (most couldn't care less about other species). If the truth is dire, they can find another, not-so-dire version. The concept is supported by an article in the February 2013 issue of *Global Environmental Change* pointing out that climate-change scientists routinely underestimate impacts "by erring on the side of least drama" (also see overviews of this phenomenon from 21 May 2014 and from 15 July 2014, the latter from the U.S. National Research Council as reported by *Truth-out*). Even the climatic response to greenhouse gases has been too conservative, as reported in the 14 December 2015 online issue of *Nature Climate Change*. And even the often-conservative Robert Scribbler points out in his 18 July 2014 essay: "NASA's CARVE study has been silent for a year, the University of Maryland has stopped putting out publicly available AIRS methane data measures, the NOAA ESRL methane flask measures, possibly due to lack of funding, haven't updated since mid-May, and even Gavin Schmidt over at NASA GISS appears to have become somewhat mum on a subject that, of late, has generated so much uncomfortable controversy." (*Apocalypse 4 Real* blog responded to Scribbler on 24 July 2014) Schmidt increased his efforts to discredit the work of other scientists in early October 2014 with unfounded, unprofessional behaviour. His insanity was made apparent in an interview for the August 2015 issue of *Esquire* with a single sentence: "There's no actual evidence that anything dramatically different is going on in the Arctic, other than the fact that it's melting pretty much everywhere."

In addition, the consolidation of the scientific publishing industry is accelerating, with expected, profit-based results. A paper published in the 10 June 2015 issue of *PLoS One* based on 45 million documents indexed in the *Web of Science* over the period 1973-2013 found that the top five most prolific publishers account for more than half of recent papers published.

Almost everybody reading these words has a vested interest in not wanting to think about climate change, which helps explain why the climate-change deniers have won. They've been aided and funded by the fossil-fuel industry, the memos from which "reveal decades of disinformation—a deliberate campaign to deceive the public that continues even today," according to an in-depth analysis from the Union of Concerned Scientists in July 2015.

Investigative journalist Lee Fang, writing for *The Intercept* on 25 August 2015, uncovers a relationship between climate-denying attorney Christopher Horner and big coal. Horner is an attorney who claims that the earth is cooling, is known within the scientific community for hounding climate change researchers with relentless investigations and public ridicule, and he often derides scientists as "communists" and frauds.

Horner is a regular guest on Fox News and CNN, and has been affiliated with a number of think tanks and legal organizations over the last decade. He has called for investigations of climate scientists affiliated with the Intergovernmental Panel on Climate Change and NASA, and inundated climate researchers at major universities across the country with records requests that critics say are designed to distract them from their work.

The 20 August 2015 bankruptcy filing of Alpha Natural Resources, one of the largest coal companies in America, includes line items for all of the corporation's contractors and grant recipients. Among

them are Horner individually at his home address, as well as the Free Market Environmental Law Clinic, where he is a senior staff attorney.

It's not only the scientists who underestimate the damage. It's the science itself, too. Consider, for example, information derived from satellites which, according to a March 2015 paper in Journal of Climate, significantly underestimate temperature of the middle troposphere. "In short, the Earth is warming, the warming is amplified in the troposphere, and those who claim otherwise are unlikely to be correct."

Some university professors will promote climate-change denial for the right price. According to the 8 December 2015 issue of *The Guardian*, "An undercover sting by Greenpeace has revealed that two prominent climate sceptics were available for hire by the hour to write reports casting doubt on the dangers posed by global warming." The professors in question are William Happer, the Cyrus Fogg Brackett professor of physics at Princeton University and Frank Clemente, professor emeritus of sociology at Pennsylvania State University.

Beyond Linear Change

I'm often told Earth can't possibly be responsive enough to climate change to make any difference to us. But, as the 27 May 2014 headline at *Skeptical Science* points out, "Rapid climate changes more deadly than asteroid impacts in Earth's past." That's correct: climate change is more deadly than asteroids.

Ever late to the party, the Intergovernmental Panel on Climate Change (IPCC) admits global warming is irreversible without geoengineering in a report released 27 September 2013. The IPCC is among the most conservative scientific bodies on the planet, and their reports are "significantly 'diluted' under political pressure." On 22 April 2014, *Truth-out* correctly headlines their assessment, "Intergovernmental Climate Report Leaves Hopes Hanging on Fantasy Technology." *Time* follows up two days later with a desperate headline, "NASA Chief: Humanity's Future Depends on Mission To Mars" (first up: greenhouses on Mars). As pointed out in the 5 December 2013 issue of *Earth System Dynamics*, known strategies for geoengineering are unlikely to succeed ("climate geo-engineering cannot simply be used to undo global warming"). "Attempts to reverse the impacts of global warming by injecting reflective particles into the stratosphere could make matters worse," according to research published in the 8 January 2014 issue of *Environmental Research Letters*. In addition, as described in the December 2013 issue of *Journal of Geophysical Research*: *Atmospheres*, geoengineering may succeed in cooling the Earth, it would also disrupt precipitation patterns around the world. In the Arctic, "any sea ice or snow retention as a result of geoengineering is lost within a decade," according to a paper in the 15 February 2014 issue of *Journal of Geophysical Research*: *Atmospheres*. Furthermore, "risk of abrupt and dangerous warming is inherent to the large-scale implementation of SRM" (solar radiation management), as pointed out in the 17 February 2014 issue of *Environmental Research Letters*. About a week later comes this line from research published in the 25 February 2014 issue of *Nature Communication*: "schemes to minimize the havoc caused by global warming by purposefully manipulating Earth's climate are likely to either be relatively useless or actually make things worse." Finally, in a blow to technocrats published online in the 25 June 2014

issue of *Nature Climate Change*, a large and distinguished group of international researchers concludes geo-engineering will not stop climate change. The U.S. National Academy of Sciences piles on with a report issued 10 February 2015, concluding geoengineering is not a viable solution for the climate predicament. An analysis in Europe reached the same conclusion in an assessment published 16 July 2015. As it turns out, the public isn't impressed, either: Research published in the 12 January 2014 issue of *Nature Climate Change* "reveals that the overall public evaluation of climate engineering is negative." Despite pervasive American ignorance about science, the public correctly interprets geo-engineering in the same light as the scientists, and contrary to the techno-optimists.

Unimpressed with evidence and public opinion, some scientists forge on, illustrating that the progressive perspective often means progresssing toward the cliff's edge. As reported in the 27 November 2014 issue of *New Scientist*, initial efforts to cool the planet via geo-engineering have taken shape and might begin in two years.

The IPCC operates with a very conservative process and produces very conservative reports for several reasons, among them the failure to include relevant self-reinforcing feedback loops (as pointed out in the 1 April 2015 issue of the *Washington Post*). And then governments of the world meddle with the reports to ensure Pollyanna outcomes, as reported by a participant in the process (also see Nafeez Ahmed's 14 May 2014 report in the *Guardian* and the 3 July 2014 paper in *National Geographic*). According to David Wasdell's May 2014 analysis, which includes a critique of the IPCC's ongoing lunacy, "equilibrium temperature increase predicted as a result of current concentration of atmospheric greenhouse gasses is already over 5°C." I see no way for humans to survive such a rise in global-average temperature.

Wasdell's analysis from September 2015 includes several noteworthy conclusions: (1) "Current computer estimates of Climate Sensitivity are shown to be dangerously low," revealing (2) "an eight-fold amplification of CO2 forcing (in contrast to the three-fold amplification predicted by the IPCC climate modelling computer ensemble), (3) "the 2°C target temperature limit is set far too high" (emphasis in original), and (4) "anthropogenic change is at least 100 times faster than at any time in the Paleo record." The report's bottom line: "There is no available carbon budget. It is already massively overspent, even for the 2°C target."

Further evidence of the conservative nature of the IPCC is revealed by a paper in the 8 January 2016 issue of *Journal of Geophysical Research*: Oceans focused on warming of the Northwest Atlantic Ocean: "The Intergovernmental Panel on Climate Change (IPCC) fifth assessment of projected global and regional ocean temperature change is based on global climate models that have coarse (∼100 km) ocean and atmosphere resolutions. In the Northwest Atlantic, the ensemble of global climate models has a warm bias in sea surface temperature due to a misrepresentation of the Gulf Stream position; thus, existing climate change projections are based on unrealistic regional ocean circulation. Here we compare simulations and an atmospheric CO2 doubling response from four global climate models of varying ocean and atmosphere resolution. We find that the highest resolution climate model (∼10 km ocean, ∼50 km atmosphere) resolves Northwest Atlantic circulation and water mass distribution most accurately. The CO2 doubling response from this model

shows that upper-ocean (0–300 m) temperature in the Northwest Atlantic Shelf warms at a rate nearly twice as fast as the coarser models and nearly three times faster than the global average."

Less than two weeks later, a paper in the 19 January 2016 issue of *Geophysical Research Letters* addresses the issue of Sandy-like superstorms under the influence of a substantially warmer Atlantic Ocean. The abstract of the paper includes these lines: "we find that possible responses of Sandy-like superstorms under the influence of a substantially warmer Atlantic Ocean bifurcate into two groups. In the first group, storms are similar to present-day Sandy …, except they are much stronger, with peak Power Destructive Index (PDI) increased by 50–80%, heavy rain by 30–50%, and maximum storm size (MSS) approximately doubled. In the second group, storms amplify substantially …, with peak PDI increased by 100–160%, heavy rain by 70–180%, and MSS more than tripled compared to present-day Superstorm Sandy."

Gradual change is not guaranteed, as pointed out by the U.S. National Academy of Sciences in December 2013: "The history of climate on the planet — as read in archives such as tree rings, ocean sediments, and ice cores — is punctuated with large changes that occurred rapidly, over the course of decades to as little as a few years." The December 2013 report echoes one from Wood Hole Oceanographic Institution more than a decade earlier. Writing for the 3 September 2012 issue of *Global Policy*, Michael Jennings concludes that "a suite of amplifying feedback mechanisms, such as massive methane leaks from the sub-sea Arctic Ocean, have engaged and are probably unstoppable." During a follow-up interview with Alex Smith on *Radio Ecoshock*, Jennings admits that "Earth's climate is already beyond the worst scenarios." *Truth-out* piles on 18 March 2014: "'**climate change'" is not the most critical issue facing society today; abrupt climate change is**." *Skeptical Science* finally catches up to reality on 2 April 2014 with an essay titled, "Alarming new study makes today's climate change more comparable to Earth's worst mass extinction." The conclusion from this conservative source: "Until recently the scale of the Permian Mass Extinction was seen as just too massive, its duration far too long, and dating too imprecise for a sensible comparison to be made with today's climate change. No longer. Piling on in January 2015, a paper in press in the journal *Progress in Physical Geography* concludes the abstract with this line: "All the evidence indicates that most long-term climate change occurs in sudden jumps rather than in incremental changes." The Brisbane Times catches up with abrupt climate change on 18 August 2014: "Let us be clear: if these methane escapes continue to grow, the risk is they could drive the planet into accelerated or 'runaway' global warming. The last time this happened, 50 million years ago, global temperatures rose by an estimated 9 or 10 degrees. In the present context, **that would mean the end of the world's food supply**." Robert Scribbler finally joins the uprising on 29 October 2014: "What is clear is that feedbacks to the human heat forcing are now starting to become plainly visible. That they are providing evidence of a stronger release from some sources on a yearly basis." The *Daily Kos* summarizes evidence indicating abrupt climate change on 14 March 2015 with an article headlined, "The Earth is set for Rapid Warming." A paper published online in the *Proceedings of the National Academy of Sciences* 12 October 2015 finds "abrupt changes in sea ice, oceanic flows, land ice, and terrestrial ecosystem response …. A particularly large number is projected for warming levels below 2°." The latter paper was the focus of an article in the 15 October version of the *Washington Post*. Also that month, a paper in the 15 October 2015 issue of *Paleoceanography* furthers the case for abrupt climate change: "This record reveals that the climatic shift during the early deglacial occurred

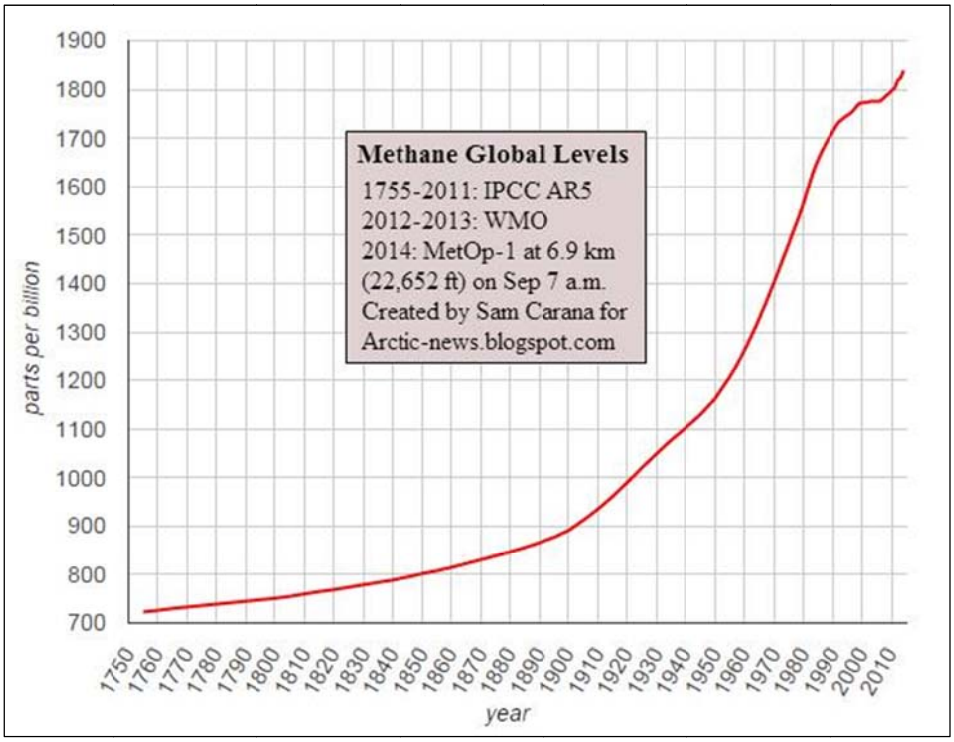
rapidly (explained co-author Kennett, a professor emeritus in University of California Santa Barbara's Department of Earth Science). "Of the 13 degree Fahrenheit total change, a shift of 7 to 9 degrees occurred almost immediately right at the beginning."

The California Climate Change Symposium was held in Sacramento on 24 and 25 August 2015. The conclusion is reported via headline in the 25 August 2015 edition of the Daily Breeze: "California climate researchers sound the alarm at symposium: 'There's no way out.'"

Susanne Moser, a leading Santa Cruz-based climate change researcher, was quoted in the article: "We need transformational change. We don't need more studies as much as we need to communicate the urgency …. We need to not debate forever." A scientist admitting we don't need more study of an issue is stunning.

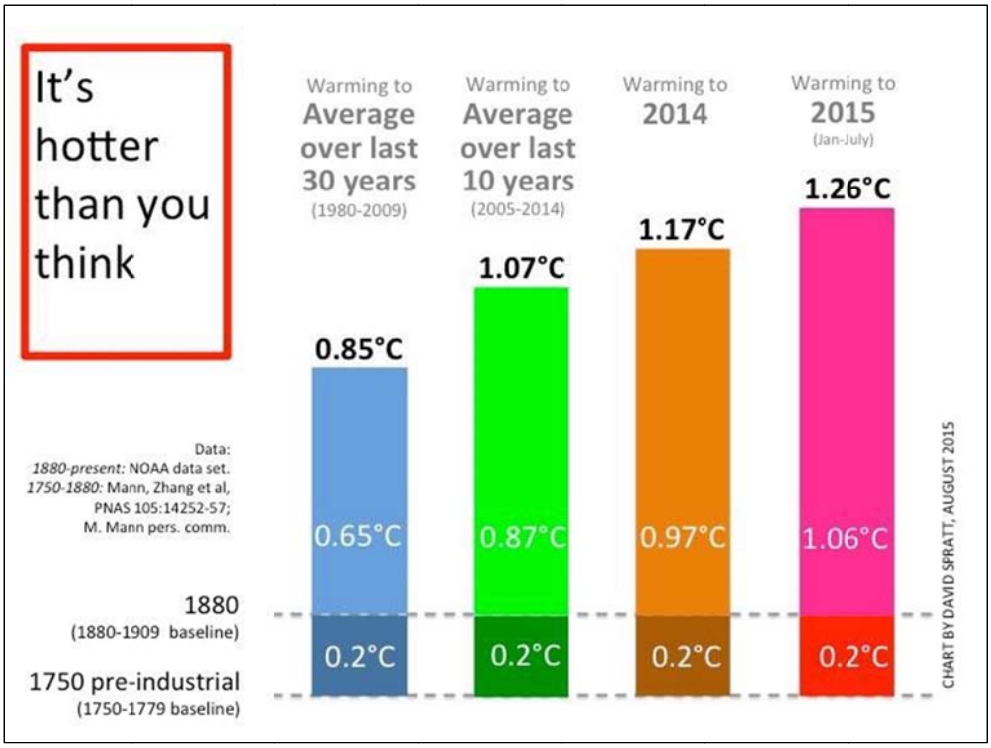
Regional warming events during the past 56,000 years were described in the 7 August 2015 edition of Science and led to the expectedly "unexpected" outcome: "Unexpectedly, rapid climate changes associated with interstadial warming events are strongly associated with the regional replacement/extinction of major genetic clades or species of megafauna." In short, "it doesn't bode well for the future survival of the world's megafauna populations". In this study, megafauna refers to animals exceeding 45 kg (about 99 pounds). Similarly, according to the abstract of a paper in the 17 June 2016 issue of *Science Advances*, "The causes of Late Pleistocene megafaunal extinctions (60,000 to 11,650 years ago, hereafter 60 to 11.65 ka) remain contentious, with major phases coinciding with both human arrival and climate change around the world. The Americas provide a unique opportunity to disentangle these factors as human colonization took place over a narrow time frame (~15 to 14.6 ka) but during contrasting temperature trends across each continent. … We identify a narrow megafaunal extinction phase 12,280 ± 110 years ago, some 1 to 3 thousand years after initial human presence in the area. Although humans arrived immediately prior to a cold phase, the Antarctic Cold Reversal stadial, megafaunal extinctions did not occur until the stadial finished and the subsequent warming phase commenced some 1 to 3 thousand years later. The increased resolution provided by the Patagonian material reveals that the sequence of climate and extinction events in North and South America were temporally inverted, but in both cases, megafaunal extinctions did not occur until human presence and climate warming coincided."

As reported by Robert Scribbler on 22 May 2014, "global sea surface temperature anomalies spiked to an amazing +1.25 degrees Celsius above the, already warmer than normal, 1979 to 2000 average. This departure is about 1.7 degrees C above 1880 levels — an extraordinary reading that signals the world may well be entering a rapid warming phase." By July of 2015, Scribbler's writing had become alarming — consistent with the situation — even though he still refused to accept the concept of human extinction as he adhered to 2 C as a target.



Not to be outdone, now that abrupt climate change has entered the scientific lexicon, is dire news published in the 25 July 2014 issue of *Science*. "The study found that synchronization of the two regional systems began as climate was gradually warming. After synchronization, the researchers detected wild variability that amplified the changes and accelerated into an abrupt warming event of several degrees within a few decades." Global-average temperature rising "several degrees within a few decades" seems problematic to me, and to anybody else with a biological bent. As reported eight days later in *Nature Climate Change*, rapid warming of the Atlantic Ocean, likely caused by global warming, has turbocharged Pacific Equatorial trade winds. Currently the winds are at a level never before seen on observed records, which extend back to the 1860s. When this phenomenon ceases, likely rapid changes will include a sudden acceleration of global average surface temperatures.

A paper in the 10 November 2015 issue of *Nature Communications* reports that the pace of past episodes of climate change is likely to have been underestimated. The abstract concludes: "A compilation of 194 published oceanic and continental temperature changes spanning the Ordovician period (476 Myr ago) to the present provides a holistic picture of the attainable magnitude and rate of both warming and cooling episodes through Earth history across a range of measurement timespans. We demonstrate that magnitudes and rates of geological temperature changes in this compilation exhibit power law scaling with timespan, emphasising how geological data alias (sic) short-term climate variability. Consequently, the true attainable pace of ancient climate change may be commonly underestimated, compromising our understanding of the relative pace (and severity) of both ancient and recent climate change." In this case, the title of the paper tells the story: "Maximum rates of climate change are systematically underestimated in the geological record."



A paper published in the 9 March 2015 online issue of *Nature Climate Change* indicates that **we are on the verge of "near-term acceleration in the rate of temperature change." In this case, near-term means by 2020.** As indicated in the paper's abstract, "We find that present trends in greenhouse-gas and aerosol emissions are now moving the Earth system into a regime in terms of multi-decadal rates of change that are unprecedented for at least the past 1,000 years." "Anthropogenic carbon release rate unprecedented during the past 66 million years," according to the title of a paper in the 21 March 2016 online issue of Nature Geoscience. The summary of a paper in the 8 April 2016 issue of Science concludes: "The climatic changes during the PETM occurred over longer time scales than those of anthropogenic climate change. The impacts of the latter may thus be even more severe."

Deniers of abrupt climate change are running out of arguments. We are in the midst of abrupt climate change. This event has ample precedence, as reported in the aforementioned paper in *Nature Communications*. Even voices from the mainstream media are catching up to the reality of abrupt climate change. An article in the 11 January 2016 issue of *The New Yorker* points out the rapidity with which climate can change, leading to large numbers of dead humans: "One of the most important insights of recent studies is that, when the climate changes, it can do so swiftly and relentlessly. It is possible, in a human lifetime, to see sea levels rise and ice shelves break away, and, when they do, nothing about what happens next can be taken for granted. The climate record is full of sudden disasters." Sea-level rise is proceeding at the fastest rate in the last 28 centuries, according to a paper in the 22 February 2016 online edition of the *Proceedings of the National Academy of Sciences*. And record-setting hot years are attributed to anthropogenic climate change as far back as the 1930s, according to a paper in the 7 March 2016 online issue of *Geophysical Research Letters*.

As headlined in the 6 July 2016 issue of *Grist* magazine, "New York City hopes a 10-foot wall can save it from rising seas." I wouldn't bet on hope, prayer, or unicorns. And New York City will cease to exist in the years ahead.

Geoengineers will not be able to do away with rising seas, according to a paper published in the 10 March 2016 issue of *Earth System Dynamics*. The proposed approach of pumping water from the sea and storing it as ice on the continent of Antarctica will not delay sea-level rise. Rather, unless the seawater is pumped enormous distances at tremendous energy cost, the strategy will only accelerate the flow of the glaciers and it will all end up back in the sea again.

A study published in the 10 November 2015 issue of *Nature Communications* presents "geomorphological data that reveal the existence of a large buried paleodrainage network on the Mauritanian coast." An article the same day in *The Guardian* includes these lines: "A vast river network that once carried water for hundreds of miles across Western Sahara has been discovered under the parched sands of Mauritania. … Water may last have coursed through the channels 5,000 years ago." The Guardian quotes Russell Wynn at the National Oceanography Centre in Southampton, who was not involved in this study: "People sometimes can't get their head around climate change and how quickly it happens."

An article in press in the journal *Arctic, Antarctic, and Alpine Research*, presumably to appear in the February 2016 issue, reports on massive ice loss from the Mauna Loa Icecave in Hawaii. The icecave was surveyed in 1978, and then rediscovered by the authors of this study in 2011. Extensive measurements between 2011 and 2014 are reported as follows in the abstract: "Perennial ice still blocks the lava tube at the terminal end, but a previously present large ice floor (estimated 260 m2) has disappeared. A secondary mineral deposited on the cave walls is interpreted as the result of past sustained ice levels."

According to an article published in the 28 December 2015 issue of *Hawaii News Now*, a 1978 article published in the "Limestone Ledger" included a meticulous map of the 656-foot-long cave, and vital information about where permanent ice was found. But after reading the piece, the researchers quickly noticed something: The 1978 survey, which included photos, showed a contiguous, walkable ice floor (known as the "skating rink") and large ice blocks. In contrast, the team's new survey of the cave showed far less permanent ice. The team said the "skating rink" was gone by the time they conducted their multi-year analysis. All of the former known ice blocks had melted away, too. And ice patches on the wall are now seasonal, rather than year-round. In short, the research team found that in three decades, much of the ice in the ice cave had disappeared.

A paper in the 4 January 2016 online issue of *Nature Geoscience* further illustrates the rapid rise of contemporary changes in atmospheric carbon dioxide compared to past events, even those long-thought to be characterized by rapid change. "During the Aptian Oceanic Anoxic Event 1a, about 120 million years ago, … The rise of CO2 concentrations occurred over several tens to hundreds of thousand years." Contrary to the notion that this event transpired very quickly, according to the lead author of the paper: "The change, however, appears to have been far slower than that of today, taking place over hundreds of thousands of years, rather than the centuries over which human

activity is increasing atmospheric carbon dioxide levels." In other words, "rapid" in the fossil record is nothing compared to today.

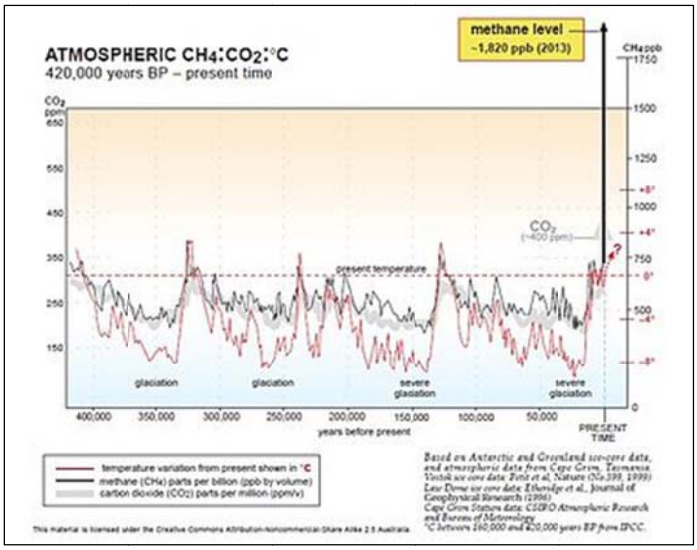
A paper in the 3 February 2016 issue of *Nature* finds a long-sought "smoking gun" with respect to carbon storage in the deep ocean. As it turns outs, carbon was stored in the depths of the Southern Ocean when atmospheric carbon dioxide levels were quite low. Further confirmation was published in the 9 May 2016 issue of *Nature Communications*: In the past 800,000 years of climate history, the transitions from interglacials and ice ages were always accompanied by a significant reduction in the carbon dioxide content in the atmosphere. It then fell from 280 to 180 ppm (parts per million). Where this large amount of carbon dioxide went to and the processes through which the greenhouse gas reached the atmosphere again has been controversial. This paper reports a major carbon dioxide reservoir at a depth of 2000 to 4300 metres in the South Pacific and it reconstructs the details of its gas emission history.

Extinction Overview

If you're too busy to read the evidence presented below, here's the bottom line: On a planet 4 C hotter than baseline, all we can prepare for is human extinction (from Oliver Tickell's 2008 synthesis in the *Guardian*). Tickell is taking a conservative approach, considering humans have not been present at 3.3 C or more above baseline (i.e., the beginning of the Industrial Revolution, commonly accepted as 1750). I cannot imagine a scenario involving a rapid rise in global-average temperature and also retention of habitat for humans. Neither can Australian climate scholar Clive Hamilton, based on his 17 June 2014 response to Andrew Revkin's fantasy-based hopium. According to the World Bank's 2012 report, "Turn down the heat: why a 4°C warmer world must be avoided" and an informed assessment of "BP Energy Outlook 2030" put together by Barry Saxifrage for the Vancouver Observer, our path leads directly to the 4 C mark. The conservative International Energy Agency throws in the towel on avoiding 4 C in a video from June 2014. The 19th Conference of the Parties of the UN Framework Convention on Climate Change (COP 19), held in November 2013 in Warsaw, Poland, was warned by professor of climatology Mark Maslin: "We are already planning for a 4°C world because that is where we are heading. I do not know of any scientists who do not believe that." Among well-regarded climate scientists who think a 4 C world is unavoidable, based solely on atmospheric carbon dioxide, is Cambridge University's Professor of Ocean Physics and Head of the Polar Ocean Physics Group in the Department of Applied Mathematics, Dr. Peter Wadhams, who says: "…the carbon dioxide that we put into the atmosphere, which now exceeded 400 parts per million, is sufficient, if you don't add any more, to actually raise global temperatures in the end by about four degrees." Adding to planetary misery is a paper in the 16 December 2013 issue of the Proceedings of the National Academy of Sciences concluding that 4 C terminates the ability of Earth's vegetation to sequester atmospheric carbon dioxide. According to a story in the 6 December 2015 issue of the *Washington Post*: "With no government action, Exxon experts … [said] average temperatures are likely to rise by a catastrophic (my word, not theirs) 5 degrees Celsius, with rises of 6, 7 or even more quite possible."

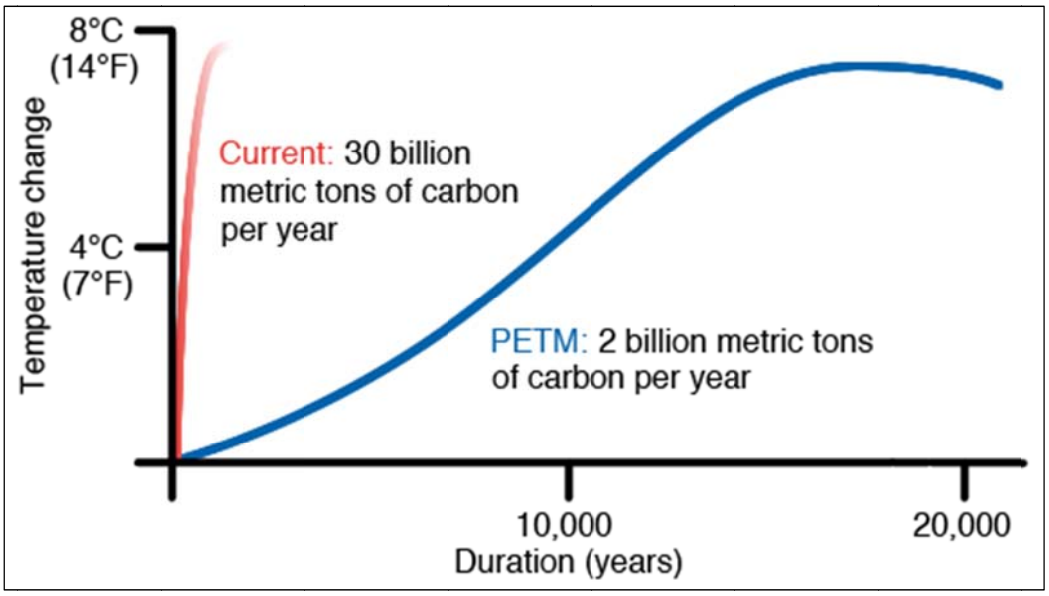
I'm not sure what it means to plan for 4 C (aka extinction). I'm not impressed that civilized scientists claim to be planning for it, either. But I know we're human animals, and I know animals require

habitat to survive. When there is no ability to grow food or secure water, humans will exit the planetary stage, as finally realized by the mainstream scientific community with a paper in the 2 October 2015 issue of *Science*: a stable food web was critical to the few species that survived the most severe mass extinction event in planetary history. Even 10-year-olds understand that climate change is poised to cause human extinction.



According to Colin Goldblatt, author of a paper published online in the 28 July 2013 issue of *Nature Geoscience*, "The runaway greenhouse may be much easier to initiate than previously thought." Furthermore, as pointed out in the 1 August 2013 issue of *Science*, in the near term Earth's climate will change orders of magnitude faster than at any time during the last 65 million years. Tack on, without the large and growing number of self-reinforcing feedback loops we've triggered recently, the **5 C rise in global-average temperature 55 million years ago during a span of 13 years** (subsequently strongly supported by a paper in the 15 December 2014 online issue of *Nature Geoscience* and then questioned in a paper from January 2015, and it looks like trouble ahead for the wise ape. This conclusion ignores the long-lasting, incredibly powerful greenhouse gas discovered 9 December 2013 by University of Toronto researchers: Perfluorotributylamine (PFTBA) is 7,100 times more powerful than carbon dioxide as a greenhouse gas in the atmosphere, and it persists hundreds of years in the atmosphere. It also ignores the irreversible nature of climate change: **Earth's atmosphere will harbour, at minimum, the current warming potential of atmospheric carbon dioxide concentration for at least the next 1,000 years**, as indicated in the 28 January 2009 issue of the *Proceedings of the National Academy of Sciences*. The marine situation is similarly catastrophic: *The Guardian's* headline from 16 July 2015 screams: "Warming of oceans due to climate change is unstoppable, say US scientists" in response to the annual *State of the Climate in 2014* report. According to a paper published in the 3 August 2015 issue of *Nature Climate Change*: "Carbon dioxide removal (CDR) from the atmosphere has been proposed as a measure for mitigating global warming and ocean acidification. … Focusing on pH, temperature and dissolved oxygen, we find that even after several centuries of CDR deployment, past CO2 emissions would leave a substantial legacy in the marine environment." In other words, removal of atmospheric carbon dioxide, even if it were possible, would be insufficient to overcome the damage experienced by the ocean.

Finally, far too late, the *New Yorker* posits a relevant question on 5 November 2013: Is It Too Late to Prepare for Climate Change? Joining the too-little, too-late gang, the Geological Society of London points out on 10 December 2013 that Earth's climate could be twice as sensitive to atmospheric carbon as previously believed. *New Scientist* piles on in March 2014, pointing out that planetary warming is far more sensitive to atmospheric carbon dioxide concentration than indicated by past reports. As usual and expected, carbon dioxide emissions set a record again in 2013, the 5th-hottest year on record (since 1850). Ditto for 2014 and 2015, the new hottest years on record. The previous top three hottest years (2010, 2005, and 2007) were influenced by El Niño events, which cause short-term warming of the Earth's atmosphere.



Rate of temperature change today (red) and in the PETM (blue). Temperature rose steadily in the PETM due to the slow release of greenhouse gas (around 2 billion tons per year). Today, fossil fuel burning is leading to 30 billion tons of carbon released into the atmosphere every year, driving temperature up at an incredible rate. Figure from http://www.wunderground.com/climate/PETM.asp?MR=1

Is There a Way Out?

All of the above information fails to include the excellent work by Tim Garrett, which points out that only complete collapse avoids runaway greenhouse. Garrett reached the conclusion in a paper submitted in 2007 (personal communication) and published online by *Climatic Change* in November 2009 (outcry from civilized scientists delayed formal publication until February 2011). The paper remains largely ignored by the scientific community, having been cited fewer than thirty times since its publication. Support for Garrett's work finally came from the broader scientific community with a paper published in the 15 July 2015 online issue of *Proceedings of the National Academy of Sciences*. But then, a later response to Garrett's work is the expected one, as elucidated by a paper in the 4 April 2016 issue of *Nature Climate Change*: "This highlights the importance of maintaining economic growth in a carbon-constrained world and reducing the cost of backstop measures, such as large-scale CO2 removal, in any ambitious consumption-maximizing strategy to limit peak warming."

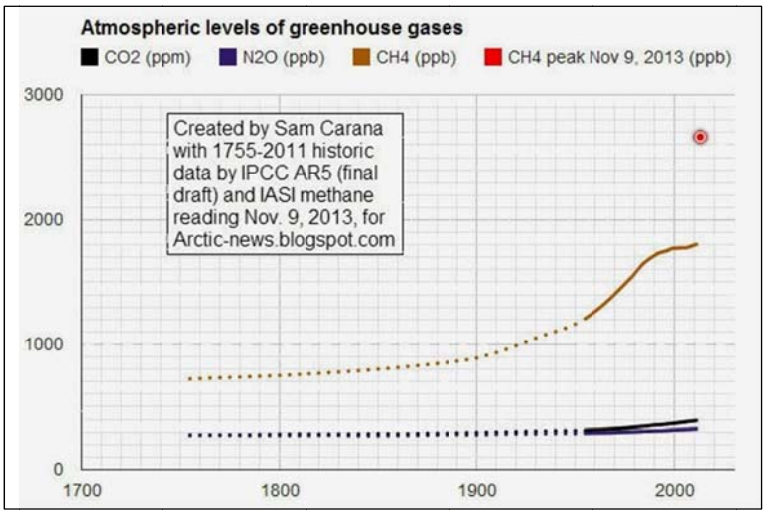
Garrett was preceded by Ted Turner. He pointed out on the 2 April 2008 edition of the *Charlie Rose Show* that continuing to burn fossil fuels "is suicide."

According to Yvo de Boer, who was executive secretary of the United Nations Framework Convention on Climate Change in 2009, when attempts to reach a deal at a summit in Copenhagen crumbled with a rift between industrialized and developing nations, "the only way that a 2015 agreement can achieve a 2-degree goal is to shut down the whole global economy." Politicians finally have caught up with Tim Garrett's excellent paper in *Climatic Change*.

In an interview with the November 2015 issue of *The Atlantic*, The world's richest man, Bill Gates, has said that the private sector is too selfish and inefficient to produce effective energy alternatives to fossil fuels. And he ought to know.

From the Associated Press on 1 December 2014 comes a story headlined, "Climate funds for coal highlight lack of UN rules." The article points out the difficulty associated with using tools from industrial civilization to address a predicament created by industrial civilization: "Climate finance is critical to any global climate deal, and rich countries have pledged billions of dollars toward it in U.N. climate talks, which resume Monday in Lima, Peru. Yet there is no watchdog agency that ensures the money is spent in the most effective way. There's not even a common definition on what climate finance is." The bottom line from this story: About a billion dollars intended to mitigate climate change has been used to fund coal-fired power plants, the worst emitter of carbon dioxide on the planet.

Writing for the Arctic News Group, John Davies concludes: "**The world is probably at the start of a runaway Greenhouse Event which will end most human life on Earth before 2040**." He considers only atmospheric carbon dioxide concentration, not the many self-reinforcing feedback loops described below. Writing on 28 November 2013 and tacking on only one feedback loop — methane release from the Arctic Ocean — Sam Carana expects global temperature anomalies up to 20°C by 2050 (an anomaly is an aberration, or deviation from long-term average). Small wonder atmospheric methane can cause such global catastrophe considering its dramatic rise during the last few years, as elucidated by Carana on 5 December 2013 in the figure below.



Lest we believe our profoundly large geographic distribution grants us the ability to avoid extinction, the title of an article in the 1 August 2015 issue of *Nature Communications* sets the record straight: "Geographic range did not confer resilience to extinction in terrestrial vertebrates at the end-Triassic crisis." The study refers to a mass extinction event about 200 million years ago.

Changing our dietary habits won't help, either. A paper published in the 24 November 2015 issue of *Environment Systems and Decisions* finds that switching from a typical U.S. diet to a healthier diet based on the 2010 USDA Dietary Guidelines accelerates environmental destruction. Seems vegetarianism has its costs, notably a large carbon footprint. In this case, the switch from 'typical' to 'recommended' comes with a 43% increase in energy use, "primarily due to USDA recommendations for greater Caloric intake of fruits, vegetables, dairy, and fish/seafood, which have relatively high resource use and emissions per Calorie."

Aliens probably won't save us from ourselves, either. A paper in the 20 January 2016 issue of Astrobiology indicates life on other planets likely would be brief and become extinct very quickly.

Tipped Over

On the topic of tipping points, we crossed the Rubicon in 2007 at about 0.76 C warming. At this point, according to David Spratt's excellent September 2013 report, "Is Climate Already Dangerous?", not only had Arctic sea-ice passed its tipping point, but the Greenland Ice Sheet was not far behind, as the Arctic moves to sea-ice-free conditions in summer (the U.S. Navy predicts an ice-free Arctic in summer 2016). Glaciologist Jason Box, an expert on Greenland ice, agrees that the situation is dire. Box was quoted in a 5 December 2012 article in the Guardian: "In 2012 Greenland crossed a threshold where for the first time we saw complete surface melting at the highest elevations in what we used to call the dry snow zone. … As Greenland crosses the threshold and starts really melting in the upper elevations it really won't recover from that unless the climate cools significantly for an extended period of time which doesn't seem very likely." (In January 2013, Box concluded we've locked in 69 feet — 21 meters — of sea-level rise.) A paper published in the 10 July 2015 issue of *Science* indicates a 1-2 C global-average temperature rise has contributed to rapid sea-level rise several times during the last 3 million years. Indeed, as stated in the September 2013 issue of *Global Policy*, "because of increasing temperatures due to GHG emissions a suite of amplifying feedback mechanisms, such as massive methane leaks from the sub-sea Arctic Ocean, have engaged and are probably unstoppable." By December 2013, the disappearance of Greenland's ice had accelerated to five times the pace of a few years previously, and IPCC was acknowledging they'd been far too conservative with past estimates. Continued conservatism is buttressed by research reported in the 16 March 2014 issue of *Nature Climate Change* indicating melting of Greenland ice accounts for about one-sixth of recent sea-level rise and also by research published in the 18 May 2014 issue of *Nature Geoscience* indicating Greenland's icy reaches are far more vulnerable to warm ocean waters from climate change than had been thought. From the 12 November 2015 online issue of *Science* comes a paper titled, "Fast retreat of Zachariæ Isstrøm, northeast Greenland." The abstract reads: "After 8 years of decay of its ice shelf, Zachariæ Isstrøm, a major glacier of northeast Greenland that holds a 0.5-meter sea-level rise equivalent, entered a phase of accelerated retreat in fall 2012. The acceleration rate of its ice velocity tripled, melting of its residual ice shelf and thinning

of its grounded portion doubled, and calving is now occurring at its grounding line. Warmer air and ocean temperatures have caused the glacier to detach from a stabilizing sill and retreat rapidly along a downward-sloping, marine-based bed. Its equal-ice-volume neighbor, Nioghalvfjerdsfjorden, is also melting rapidly." A paper in the 18 November 2015 issue of *The Cryosphere* points out that as Greenland climate is now rapidly warming, summer melt intensity no longer oscillates around its long term mean, and instead previously exceptional events are becoming normal. A paper in the 4 December 2015 issue of *Climate of the Past* indicates Greenland's glaciers are retreating at least twice as fast as any other time in the past 9,500 years. The study also provides new evidence for just how sensitive glaciers are to temperature, showing that they responded to past abrupt cooling and warming periods, some of which might have lasted only decades. A study published in the 16 March 2016 issue of *Geophysical Research Letters* finds that climate models commonly used to simulate melting of the Greenland ice sheet tend to underestimate the impact of exceptionally warm weather episodes on the ice sheet. The study investigated the causes of ice melt during two exceptional melt episodes in 2012, which occurred 8-11 July and 27-28 July. During these exceptional melt episodes, which can be regarded as an analogue to future climate, unusually warm and moist air was transported onto the ice sheet. During one episode, the researchers measured the ice sheet melting at more than 28 cm per day, the largest daily melt rate ever documented on the ice sheet. While the two brief melt episodes only lasted 6 days combined, or 6% of the melt season, they contributed to 14% of the total melt.

As I've come to expect, a paper in the 25 January 2016 online issue of the *Proceedings of the National Academy of Sciences* reports that previous research on the effects of climate change has underestimated thermal expansion due to warming of the ocean. In fact, thermal expansion is about twice as large over the past 12 years as previously assumed.

Further on the topic of northern ice, a research paper published in the 13 June 2014 of *Geophysical Research Letters* points out that **an ice-free Arctic is likely to cause rapid melting of Greenland ice**. According the 10 August 2015 issue of Newsweek, "National Geographic Has Redrawn Its Atlas Because of the Melting Arctic." **Between 1999 and 2014, Arctic ice extent declined by about two-thirds**. Further dismantling the arguments of climate-change deniers, a paper that appeared in the 4 December 2015 issue of Science Advances points out that the so-called Medieval Warm Period wasn't particularly warm, and the warming was restricted to the eastern North Atlantic region.

According to the 4 January 2016 issue of the Washington Post: "Rising global temperatures may be affecting the Greenland ice sheet — and its contribution to sea-level rise — in more serious ways that scientists imagined, a new study finds. Recent changes to the island's snow and ice cover appear to have affected its ability to store excess water, meaning more melting ice may be running off into the ocean than previously thought. … The … study … focuses on a part of the ice sheet known as "firn" — a porous layer of built-up snow that slowly freezes into ice over time." The abstract of the paper under consideration, published online in *Nature Climate Change* on 4 January 2016, includes these final lines: "Our observations frame the recent exceptional melt summers in 2010 and 2012, revealing significant changes in firn structure at different elevations caused by successive intensive melt events. In the upper regions (more than ~1,900 m above sea level), firn has undergone substantial densification, while at lower elevations, where melt is most abundant, porous

firn has lost most of its capability to retain meltwater. Here, the formation of near-surface ice layers renders deep pore space difficult to access, forcing meltwater to enter an efficient surface discharge system and intensifying ice sheet mass loss earlier than previously suggested."

Melting of Greenland's ice is linked to shrinking Arctic sea ice, according to a paper in the 26 February 2016 issue of *Journal of Climate*. Specifically, melting Arctic sea ice favours stronger and more frequent "blocking-high" pressure systems, which spin clockwise, stay largely in place and can block cold, dry Canadian air from reaching Greenland during summer. This phenomenon enhances the flow of warm, moist air over Greenland, thereby contributing to increased extreme heat events and surface ice melting.

A paper in the 9 June 2016 issue of *Nature Communications* includes data from the 2015 melt season. Titled "Arctic cut-off high drives the poleward shift of a new Greenland melting record," the abstract reports, "we show that the persistence of an exceptional atmospheric ridge, centred over the Arctic Ocean, was responsible for a poleward shift of runoff, albedo and surface temperature records over the Greenland during the summer of 2015." This finding is consistent with Jennifer Francis' long-disparaged idea about the loopy, wavy jet stream. The paper's abstract concludes: "The unprecedented (1948–2015) and sustained atmospheric conditions promoted enhanced runoff, increased the surface temperatures and decreased the albedo in northern Greenland, while inhibiting melting in the south, where new melting records were set over the past decade."

According to a study published 8 April 2016 in the journal *Science Advances*, melting ice sheets, especially in Greenland, are changing the distribution of weight on Earth. As a result, both the North Pole and the wobble, which is called polar motion, have changed course. The North Pole is on the run. It has taken a sharp turn to the east.

Ice matters. "Small fluctuations in the sizes of ice sheets during the last ice age were enough to trigger abrupt climate change," as reported in the 13 August 2014 issue of *Nature*. As pointed out in the 25 September 2014 issue of *Nature Communications*, ice sheets melt for centuries once they begin the process. Not surprisingly, subsequent papers published in the 10 October 2014 issue of *Environmental Research Letters* and also the 14 January 2015 issue of *Nature* indicate all previous work on the topic of sea-level rise has been conservative. In addition, sea-level rise is significantly slowed by land soaking up the extra precipitation associated with global-average rise in temperature. According to a paper in the 11 February 2016 issue of Science, "between 2002 and 2014, climate variability resulted in an additional 3200 ± 900 gigatons of water being stored on land, … slowing the rate of sea level rise by 0.71 ± 0.20 millimeters per year."

Habitat matters, too. Already, according to a paper published in the 28 August 2015 issue of *Nature*, "5.7% of the global total land area has shifted toward warmer and drier climate types from 1950–2010, and significant changes include expansion of arid and high-latitude continental climate zones, shrinkage in polar and mid-latitude continental climates, poleward shifts in temperate, continental and polar climates, and increasing average elevation of tropical and polar climates."

The abstract from a paper in the 6 May 2016 issue of *Environmental Research Letters* reads as follows: "Here, we present the first analysis of coastal dynamics from a sea-level rise hotspot in the Solomon Islands. Using time series aerial and satellite imagery from 1947 to 2014 of 33 islands, along with historical insight from local knowledge, we have identified five vegetated reef islands that have vanished over this time period and a further six islands experiencing severe shoreline recession. Shoreline recession at two sites has destroyed villages that have existed since at least 1935, leading to community relocations."

A paper published in the 29 June 2016 issue of *Nature* reports that climate change is disrupting the seasonal behaviour of Britain's plants and animals. The research analysed 10,003 long-term phenological data sets of 812 of the UK's marine, freshwater, and land-based plant and animal species collected between 1960 and 2012 on everything from fish spawning to plant flowering. According to the final paragraph of the paper: "Our approach makes the simplifying assumption that climatic change has an overriding influence upon seasonality. Nevertheless, our results suggest that systematic differences in climate sensitivity could result in widespread phenological desynchronization." Well, duh. Every species is well-adapted to a specific set of environmental conditions. Changing the conditions causes loss of habitat for every species. For some scientists, apparently this is a novel finding.

An article in the 3 July 2016 issue of the *New York Times* includes this brief, apocalyptic introduction: "Climate change is threatening the livelihoods of the people of tiny Kiribati, and even the island nation's existence. The government is making plans for the island's demise." Four days later, the *Times* reports about refugees leaving the shores of a former Bolivian lake: "The water receded and the fish died. They surfaced by the tens of thousands, belly-up, and the stench drifted in the air for weeks. … The birds that had fed on the fish had little choice but to abandon Lake Poopó, once Bolivia's second-largest but now just a dry, salty expanse. Many of the Uru-Murato people, who had lived off its waters for generations, left as well, joining a new global march of refugees fleeing not war or persecution, but climate change."

Predicting Near-Term Human Extinction

If you think we'll adapt, think again, even if you're the Wall Street Journal claiming on 2 September 2014 that it's too late for mitigation. The rate of evolution trails the rate of climate change by a factor of 10,000, according to a paper in the August 2013 issue of *Ecology Letters* focused on vertebrates. An example comes from the 20 January 2016 online issue of *Global Ecology and Biogeography* research focused on California, which has an extensive collection of herbarium records. The researchers used 681,609 georeferenced herbarium records to estimate mean shifts in elevational and climatic space of 4426 plant taxa, and found that non-native, invasive species were more likely to be expanding their ranges than native species. Furthermore, plants and animals did not move together in synchronized fashion, and thus leading to the suspicion that ecological communities are breaking down and disassembling. Tack on the following title from a 6 June 2015 paper in *PLos Biology* and it's easy to understand the importance of habitat for human animals: "Suitable Days for Plant Growth Disappear under Projected Climate Change: Potential Human and Biotic Vulnerability." Even once-rich habitats in Antarctica are becoming biologically impoverished as

icebergs, increasingly breaking free from the surrounding sea ice, scour the shallow-water rocks and boulders on which a diversity of creatures cling to life (according to research published in the 16 June 2014 issue of *Current Biology*). A paper in the 22 February 2016 issue of the *Proceedings of the National Academy of Sciences* reports that, consistent with research on vertebrates, butterflies cannot keep up with rapid changes in habitat. The bottom line of the abstract: "These results highlight a potentially common situation in changing environments: evolutionary changes are not strong enough to fully compensate for the direct adverse effects of environmental change and thereby rescue populations from extinction."

A study published in the 22 June 2016 issue of *Earth and Planetary Science Letters* reports that parts of the ocean became inhospitable for some organisms as the Earth's climate warmed 94 million years ago. As the Earth warmed, several natural elements — what we think of as vitamins — depleted, causing some organisms to die off or greatly decrease in numbers. The decrease of these trace metals also suggests a global expansion of oxygen deficiency, which could lead to larger dead zones in bodies of water around the world, meaning little to no life could exist in those areas.

On the other hand, a paper in the February 2016 issue of *Climatic Change* indicates that snakes are doing fine. "Detailed projections of potential future range shifts on distributions of the medically most relevant species indicated that North American species' ranges are likely to increase in the future, but mixed results were obtained for Latin American snakes." And it's not as if extinction events haven't happened on this planet, as explained in the BBC program, *The Day the Earth Nearly Died*.

The rate of climate change clearly has gone beyond linear, as indicated by the presence of the myriad self-reinforcing feedback loops described below, and now threatens our species with extinction in the near term. As Australian biologist Frank Fenner said in June 2010: "We're going to become extinct," the eminent scientist says. "Whatever we do now is too late." Filmmaker Werner Herzog, interviewed on 30 January 2013, says, "I'm convinced that our presence on this planet is not sustainable, so we will be extinct fairly soon." Anthropologist Louise Leakey ponders our near-term demise in her 5 July 2013 assessment at Huffington Post and her father Richard joins the fray in a video from December 2013. Canadian wildlife biologist Neil Dawe joins the party of near-term extinction in an interview 29 August 2013 and musician-turned-activist Sir Bob Geldof joins the club in a Daily Star article from 6 October 2013. Health officials add their voices to the discussion about extinction in late March 2014, although they view 4°C as a problem to be dealt with later. Writing for Truth-Out, journalist John Feffer writes in his 27 April 2014 essay: "The planet and its hardier denizens may soldier on, but for us it will be game over." American linguist and philosopher Noam Chomsky concludes we're done in a 15 June 2014 interview with Chris Hedges at *Truthdig*, saying climate change "may doom us all, and not in the distant future." Larry Schwartz, writing for *AlterNet* on 21 July 2014, concludes, "Many environmentalists think we have already passed the point of no return." Johns Hopkins professor and fossil hunter Ken Rose agrees in an interview published 29 July 2014: "We're in the middle of the sixth great extinction on Earth. It probably won't take too long for humans to go extinct." IT Project Manager Jennifer Hynes concludes near-term human extinction certain. Robert Scribbler concludes in his assessment of global methane release, "What I've just described is the process that most scientists believe occurred during the worst mass extinction event

in the geological past … what humans are now doing … may well be shockingly similar." Motivational speaker, writer, and politician Marianne Williamson concludes near-term human extinction in her early October 2014 interview with Thom Hartmann. Chris Hedges agrees in an interview conducted 22 November 2014. Hollywood catches up with reality as the 23 November 2014 episode of HBO's *The Newsroom* channels me. Randy Malamud, Regents' Professor at Georgia State University, writes for the Huffington Post on 8 December 2014: "it's time to accept our impending demise." Seemingly echoing many relatively wealthy, heterosexual, Caucasian men, writer Robert J. Burrowes adds his voice on 15 December 2014 in the Lahore Times (essay removed, but he writes in January 2016, "I expect human extinction by 2030 without a concerted and strategic effort by individuals, groups and communities"): "In essence then, it is fear that drives dysfunctional environmental behaviours. And, history tells us, fear will prevent us taking sufficient action in time." Paul Ehrlich absurdly hails the glories of civilization but correctly concludes human extinction in the near term with his 10 January 2015 interview with MSNBC. As indicated in the abstract of a paper published 19 June 2015 in Science Advances, **the "sixth mass extinction is already under way."** A coinciding interview with the paper's lead author includes this line from him: "life would take many millions of years to recover, and our species itself would likely disappear early on." Dave Thomas, writer for the 5 November 2015 edition of NBC's The Blacklist, develops a techno-fantasy "escape plan" from Earth in light of near-term human extinction. Jill Stein, United States presidential candidate from the Green Party, in an interview conducted by Chris Hedges in February 2016, states, "We are undergoing extinction that we will not survive." In the face of near-term human extinction, **most Americans view the threat as distant and irrelevant**, as illustrated by a 22 April 2013 article in the Washington Post based on poll results that echo the long-held sentiment that elected officials should be focused on the industrial economy, not far-away minor nuisances such as climate change.

Supporters of carbon farming — the nonsensical notion that industrial civilization can be used to overcome a predicament created by industrial civilization — claim all we need to do is fill the desert with non-native plants to the tune of an area three-quarters the size of the United States. And, they say, we'll be able to lower atmospheric carbon dioxide by a whopping 17.5 ppm in only two decades. Well, how exciting. At that blistering pace, atmospheric carbon dioxide will be all the way back down to the reasonably safe level of 280 ppm in only 140 years, more than a century after humans are likely to become extinct from climate change. And, based on research published in the 2 May 2014 issue of Science, soil carbon storage has been over-estimated and is reduced as atmospheric carbon dioxide concentration rises.

Afforestation and forest management are considered to be key instruments in mitigating climate change. But, as indicated by a paper in the 5 February 2016 issue of Science, the expansion of Europe's forests toward dark green conifers has stoked global warming. The darkly coloured evergreens have been planted for their ability to grow quickly with relatively little management, but their propensity to sequester atmospheric carbon dioxide has been outstripped by their dark colour. Thus, according to the abstract of the paper, "two and a half centuries of forest management in Europe have not cooled the climate."

According to the plan presented in the 23 August 2013 issue of Scientific American, the non-native plants, irrigated with increasingly rare fresh water pumped by increasingly rare fossil-fuel energy,

will sequester carbon sufficient to overcome contemporary emissions. Never mind the emissions resulting from pumping the water, or the desirability of converting thriving deserts into monocultures, or the notion of maintaining industrial civilization at the expense of non-civilized humans and non-human species. Instead, ponder one simple thought: When the non-native plants die, they will emit back into the atmosphere essentially all the carbon they sequestered. A tiny bit of the carbon will be stored in the soil. The rest goes into the atmosphere as a result of decomposition.

This essay brings attention to recent projections and self-reinforcing feedback loops (i.e., positive feedbacks). All information and sources are readily confirmed with an online search.

Large-scale assessments

- Intergovernmental Panel on Climate Change (late 2007):n1.8°C by 2100 (up to 4.5°C, depending upon emissions scenarios)
- Hadley Centre for Meteorological Research (late 2008): ~2°C by 2100
    - Later in 2008, Hadley Centre's head of climate change predictions Dr. Vicky Pope calls for a worst-case outcome of more than 5°C by 2100. Joe Romm, writing for Grist, claims, "right now even Hadley [Centre] understands it [> 5°C] is better described as the 'business-as-usual' case."
- United Nations Environment Programme (mid 2009): 3.5°C by 2100
- Hadley Centre for Meteorological Research (October 2009): 4°C by 2060
- Global Carbon Project, Copenhagen Diagnosis (November 2009): 6°C, 7°C by 2100
- United Nations Environment Programme (December 2010): up to 5°C by 2050
- International Energy Agency (May 2014): up to 6°C by 2050 with business as usual

These assessments fail to account for significant self-reinforcing feedback loops (i.e., positive feedbacks, the term that implies the opposite of its meaning). The IPCC's vaunted Fifth Assessment continues the trend as it, too, ignores important feedbacks. As with prior reports, the Fifth Assessment has been altered after the expert review stage, with **changes added that downplay the economic impacts of a warming planet**." Consider, for example, the failure to mention Arctic ice in the Working Group Summary released 31 March 2014. By 3 September 2014, even *Business Insider* was announcing via headline: "The Arctic Sea Ice Problem Is Actually Worse — Not Better — Than We Thought." The importance of Arctic ice in delaying catastrophic warming is enormous, as explained quite simply in 2007:

- Anyone who does not know what Latent Heat is will have a false sense of security. It is not hard to understand if I do not use physics jargon. Place on a hot stove a pot of cold water containing 1 kg of ice cubes. Stir the ice water with a long thermometer and take temperature readings. My question is: When will the thermometer begin to show a rise in temperature? Answer: After all the ice has melted. In other words, all the heat from the stove would first all go into melting the ice, without raising the water temperature. The amount of heat entering a system without raising the temperature of the system is called Latent Heat. It takes 80 calories of heat to melt one gram of ice. So in this case, the first 80,000 calories of heat from the stove went into melting the 1 kg of ice first. Only when

> the ice is all gone will the water temperature rise, and it will do so until it reaches 100°C, when the water will begin to boil. Once again, Latent Heat comes into play, and the water temperature will stabilize at the boiling point – until all the water has changed from liquid to vapour, at which point the temperature of the dry pot will rise to the temperature of the flame itself. So how does this apply to Earth's climate? Consider the Arctic Ocean to be a gigantic pot of ice water, and the sun as the stove. For as long as there is still sea ice to melt, the Arctic Ocean will remain relatively cool, in spite of the ever increasing solar heat entering the Arctic Ocean due to ever decreasing ice cover. **When the sea ice is gone in the summer, as early as the latter part of this decade, the Arctic Ocean's temperature will steeply rise, and when it does, so will the global mean temperature, and all hell will break loose.**

Between now and then, the Arctic Ocean continues to warm up. Some parts are warming faster than others, and ice is still providing a tremendous cooling impact where it persists.

On a positive note, major assessments fail to account for economic collapse. However, due to the **four-decade lag between emissions and temperature rise**, the inconvenient fact that the world has emitted more than twice the industrial carbon dioxide emissions since 1970 as we did from the start of the Industrial Revolution through 1970, and also due to the feedback loops described below, I strongly suspect it's too late for economic collapse to extend the run of our species. Indeed, as pointed out by Bruce Melton at *Truth-out* in a 26 December 2013 piece featuring climate scientist Wallace Broeker: "today we are operating on atmospheric concentrations of greenhouse gases from the 1970s. In the last 29 years we have emitted as many greenhouse gases as we emitted in the previous 236 years. Because of the great cooling effect of the oceans, we have not yet begun to see the warming that this recent doubling of greenhouse gases will bring." Greenhouse gas emissions continue to accelerate even as the world's industrial economy slows to a halt: **Emissions grew nearly twice as fast during the first decade of the new millennium as in the previous 30 years**, as reported in the 11 April 2014 issue of *The Guardian*.

As it turns out, the so-called 40-year lag is dangerously conservative. A paper in the 3 December 2014 issue of *Environmental Research Letters* indicates that maximum warming from carbon dioxide emissions occurs about one decade after a carbon dioxide emission. Rising emissions during each of the last many decades points to a truly catastrophic future, and not long from now. According to a paper in the May 2015 issues of *Geophysical Research Letters*, the planetary warming potential of carbon dioxide outstrips its warming potential for individual use within two months, and the carbon dioxide's cumulative radiative forcing exceeds the amount of energy released upon combustion by a factor of more than 100,000.

Guy Callendar pointed out the delayed influence of rising carbon dioxide on temperature in a 1938 paper in the *Quarterly Journal of the Royal Meteorological Society*. The hand-drawn figure from the paper shown below clearly illustrates an irreversible rise in global-average temperature beginning about 1915, a few decades after the consumption of fossil fuels increased substantially. Callendar's work was used by J.S. Sawyer in a 1972 paper published in *Nature* to predict an "increase of 25%

CO2 expected by the end of the century … [and] … an increase of 0.6°C in the world temperature" with stunning accuracy.

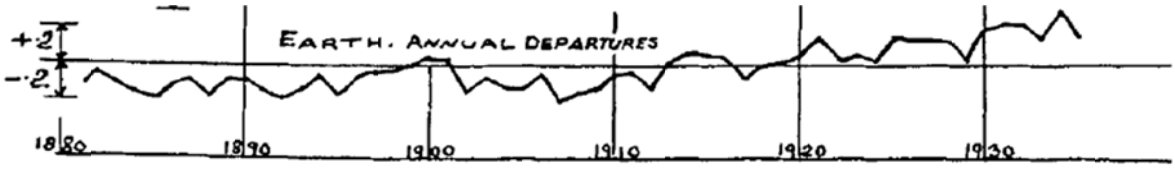


FIG. 4.—Temperature variations of the zones and of the earth. Ten-year moving departures from the mean, 1901-1930, °C.

Broadening the Perspective

Astrophysicists have long believed Earth was near the centre of the habitable zone for humans. Recent research published in the 10 March 2013 issue of *Astrophysical Journal* indicates Earth is on the inner edge of the habitable zone, and lies within 1% of inhabitability (1.5 million km, or 5 times the distance from Earth to Earth's moon). **A minor change in Earth's atmosphere removes human habitat. Unfortunately, we've invoked major changes**.

The northern hemisphere is particularly susceptible to accelerated warming, as explained in the 8 April 2013 issue of *Journal of Climate*. Two days later, a paper in *Nature* confirmed that summers in the northern hemisphere are hotter than they've been for 600 years. As pointed out by Sherwood and Huber in the 25 May 2012 issue of the Proceedings of the *National Academy of Sciences* and then by James Hansen in his 15 April 2013 paper, humans cannot survive a wet-bulb temperature of 35°C (95°F).

As described by the United Nations Advisory Group on Greenhouse Gases in 1990, "Beyond 1 degree C may elicit rapid, unpredictable and non-linear responses that could lead to extensive ecosystem damage". But, as David Spratt points out in a video from October 2014, 0.5°C is a more reasonable target (he fails to recognize that 2°C is already locked in). James Hansen and crew finally caught up to the dire nature of 1°C warming 23 years after the U.N. warning, more than two dozen self-reinforcing feedback loops too late. On 12 August 2015, Hansen concluded, "temperature was at most 2°C warmer than pre-industrial climate" at any time during the run of humanity on Earth.

How important are these less-than-2°C targets? James Hansen is quoted in a 4 January 2011 interview with The Independent: "Two degrees Celsius is guaranteed disaster." And consider the 8 November 2014 headline at *Al Jazeera America*: "Capping warming at 2°C not enough to avert disaster, climate experts warn." Neither source recognizes that 2°C is already assured in the absence of fantasy technology: Specifically, as pointed out via the title of a paper published in the 3 August 2015 issue of *Nature Communications*, "Negative emissions physically needed to keep global warming below 2 °C." According to the abstract of the paper, this approach has "not been shown to be feasible." Finally, a paper in the 12 October 2015 online edition of *Nature Geoscience* concluded: "Delivery of palatable 2°C mitigation scenarios depends on speculative negative emissions or changing the past. Scientists must make their assumptions transparent and defensible, however politically uncomfortable the conclusions."

We've clearly triggered the types of positive feedbacks the United Nations warned about in 1990. Yet my colleagues and acquaintances think we can and will work our way out of this horrific mess with the tools of industrial civilization (which got us into this mess, as pointed out by Tim Garrett) or permaculture (which is not to denigrate permaculture, the principles of which are implemented at the homestead I occupy). Reforestation doesn't come close to overcoming combustion of fossil fuels, as pointed out in the 30 May 2013 issue of *Nature Climate Change*. Furthermore, **forested ecosystems do not sequester additional carbon dioxide** as it increases in the atmosphere, as disappointingly explained in the 6 August 2013 issue of *New Phytologist*. In addition, carbon stocks have been overestimated, as pointed out in the 18 December 2015 issue of *Nature Communications*. Adding egregious insult to spurting wound, the latest public-education initiative in the United States — the *Next Generation Science Standards* — buries the relationship between combustion of fossil fuels and planetary warming. The misadventures of the corporate government continue, even as collapse of ecosystems is fully under way. As pointed out in the April 2013 issue of *PLoS ONE* — too little, too late for many ecosystems — "**catastrophic collapses can occur without prior warning**."

Some green-washing solutionistas take refuge in the nuclear solution. It's astonishing what one can conclude when grid-tied electricity is a viewed as a natural right. James Hansen's endorsement notwithstanding, nuclear power plants contribute to, rather than prevent, additional warming of Earth. As pointed out by the *Bulletin of the Atomic Scientists* on 18 February 2016, climate change is accelerating, not slowing, with the construction and use of nuclear power facilities.

Let's ignore the models for a moment and consider only the results of a single briefing to the United Nations Conference of the Parties in Copenhagen (COP15). Regulars in this space will recall COP15 as the climate-change meetings thrown under the bus by the Obama administration. The summary for that long-forgotten briefing contains this statement: "THE LONG-TERM SEA LEVEL THAT CORRESPONDS TO CURRENT CO2 CONCENTRATION IS ABOUT 23 METERS ABOVE TODAY'S LEVELS, AND THE TEMPERATURES WILL BE 6 DEGREES C OR MORE HIGHER. THESE ESTIMATES ARE BASED ON REAL LONG TERM CLIMATE RECORDS, NOT ON MODELS."

In other words, near-term extinction of humans was already guaranteed, to the knowledge of Obama and his administration (i.e., the Central Intelligence Agency, which runs the United States and controls presidential power). Even before the dire feedbacks were reported by the scientific community, the administration abandoned climate change as a significant issue because it knew we were done as early as 2009. Rather than shoulder the unenviable task of truth-teller, Obama did as his imperial higher-ups demanded: He lied about collapse, and he lied about climate change. And he still does.

Ah, those were the good ol' days, back when atmospheric carbon dioxide concentrations were well below 400 parts per million (ppm). We'll blow through the 400 ppm mark soon, probably for the first time in 3.2 to 5 million years. And, as reported in the journal *Global and Planetary Change* in April 2013, every molecule of atmospheric carbon dioxide since 1980 comes from human emissions. Not to be outdone, methane levels reached an average mean of 1800 parts per billion (ppb) on the morning of 16 June 2013. The SWERUS C-3 expedition reported a second major methane seep on 3

August 2014 in the East Siberian Sea, including a local methane release of 3,188 ppb. Tacking on a few of the additional greenhouse gases contributing to climate change and taking a conservative approach jacks up the carbon dioxide equivalent to 480 ppm. Seeps are appearing in numerous locations off the eastern coast of the United States, leading to rapid destabilization of methane hydrates (according to the 25 October 2013 issue of *Nature*). The situation worsens with every report, too: A paper accepted for publication in *Geochemistry, Geophysics, Geosystems* on 1 October 2015 reports methane plumes bubbling out the Pacific Ocean off the coasts of Oregon and Washington. Lead author H. Paul Johnson says, "What we're seeing is possible confirmation of what we predicted from the water temperatures: Methane hydrate appears to be decomposing and releasing a lot of gas. If you look systematically, the location on the margin where you're getting the largest number of methane plumes per square meter, it is right at that critical depth of 500 meters." On land, anthropogenic emissions of methane in the United States have been severely underestimated by the Environmental Protection (sic) Agency, according to a paper in the 25 November 2013 issue of *Proceedings of the National Academy of Sciences*. This figure is 1100 ppb higher than pre-industrial peak levels. Methane release tracks closely with temperature rise throughout Earth history — specifically, Arctic methane release and rapid global temperature rise are interlinked — including a temperature rise up to about 1°C per year over a decade, according to data from ice cores. The **tight linkage between Arctic warming and planetary warming** was verified in an article in the 2 February 2014 issue *Nature Geoscience*, which found that the Arctic's cap of cold, layered air plays a more important role in boosting polar warming than does its shrinking ice and snow cover. A layer of shallow, stagnant air acts like a lid, concentrating heat near the surface. Finally, adding fuel to the growing fire, a paper in the 27 March 2014 issue of *Nature* articulates the strong interconnection between methane release and temperature rise: "For each degree that Earth's temperature rises, the amount of methane entering the atmosphere … will increase several times. As temperatures rise, the relative increase of methane emissions will outpace that of carbon dioxide."

How long will the hangover persist, after we're done with the fossil-fuel party? According to University of Chicago oceanographer David Archer: "The climatic impacts of releasing fossil fuel CO2 to the atmosphere will last longer than Stonehenge," Archer writes in his January 2008 book The Long Thaw. "Longer than time capsules, longer than nuclear waste, far longer than the age of human civilization so far." A paper in the 8 February 2016 online issue of *Nature Climate Change* points out the long-term impacts of ongoing changes in Earth's climate: "Here, we argue that the twentieth and twenty-first centuries … need to be placed into a long-term context that includes the … next ten millennia, over which time the projected impacts of anthropogenic climate change will grow and persist. This long-term perspective illustrates that policy decisions made in the next few years to decades will have profound impacts on global climate, ecosystems and human societies — not just for this century, but for the next ten millennia and beyond."

The 17 December 2015 issue of *Nature* includes a paper describing shifts in the assembly of plants and animals. The bottom line of the abstract: "Our results suggest that the rules governing the assembly of communities have recently been changed by human activity." What the authors fail to point out, of course, is that the human activity coincided with agriculture (i.e., civilization).

Attributing the damage to humans is an error. Attributing the damage to civilized humans would be more accurate.

According to a paper published 29 December 2015 online issue of *Reviews of Geophysics*, agriculture by humans 7,000 years ago likely slowed a natural cooling process. This paper settles a decade-long debate regarding the role of humans in global warming during the Holocene. In the absence of civilization, Earth would have entered the early stages of a natural ice age.

Self-Reinforcing Feedback Loops (also see analysis here)

1. This description combines sub-sea permafrost and methane hydrates in the Arctic. The two sources of methane are sufficiently similar to warrant considering them in combination. MSNBC knew about methane release from beneath the Arctic Ocean in 2007. Oddly, they seem to be ignorant about it today. And note that award-winning journalist Dahr Jamail's reporting about methane registered at spot #6 on Project Censored's 2014 compilation.

- About 250 plumes of methane hydrates are escaping from the shallow Arctic seabed, likely as a result of a regional 1 C rise in temperature, as reported in the 6 August 2009 issue of *Geophysical Research Letters*. Methane bubbling out the Arctic Ocean is further elucidated in *Science* in March 2010. As described in a subsequent paper in the June 2010 issue of *Geophysical Research Letters*, a minor increase in temperature would cause the release of upwards of 16,000 metric tons of methane each year. Storms accelerate the release, according to research published in the 24 November 2013 issue of *Nature Geoscience.* The latter paper also concludes **the East Siberian Arctic Shelf is venting at least 17 teragrams of the methane into the atmosphere each year, up from 0.5 teragrams just 7 years earlier** (a teragram is equal to 1 million tons). According to NASA's CARVE project, these plumes were up to 150 kilometres across as of mid-July 2013. Global-average temperature is expected to rise by more than 4 C by 2030 and 10 C by 2040 based solely on methane release from the Arctic Ocean, according to Sam Carana's research. Whereas Malcolm Light's 9 February 2012 forecast of extinction of all life on Earth by the middle of this century appeared premature because his conclusion of exponential methane release during summer 2011 was based on data subsequently revised and smoothed by U.S. government agencies, subsequent information — most notably from NASA's CARVE project — indicates the grave potential for catastrophic release of methane. (I doubt industrial civilization manages to kill all life on Earth, although that clearly is the goal.) Catastrophically rapid release of methane in the Arctic is further supported by Nafeez Ahmed's thorough analysis in the 5 August 2013 issue of the *Guardian* as well as Natalia Shakhova's 29 July 2013 interview with Nick Breeze. The 16 August 2013 issue of *Geophysical Research Letters* includes a report of the Siberian Kara Sea where "Arctic shelf region where seafloor gas release is widespread suggests that permafrost has degraded more significantly than previously thought." In early November 2013, methane levels well in excess of 2,600 ppb were recorded at multiple altitudes in the Arctic. Later that same month, Shakhova and colleagues published a paper in *Nature Geoscience* suggesting "significant quantities of methane are escaping the East Siberian Shelf" and indicating that

a 50-billion-tonne "burst" of methane could warm Earth by 1.3 C. Such a burst of methane is "highly possible at any time," according to Shakhova in July 2013, which echoes findings from 2008 (paradoxically, on 23 May 2015 Shakhova said, "We never stated that 50 gigatonnes is likely to be released in near or distant future"). In the 7 September 2015 issue of *Philosophical Transactions of the Royal Society* A, Shakhova and colleagues concluded that "progression of subsea permafrost thawing and decrease in ice extent could result in a significant increase in CH4 emissions from the ESAS" (East Siberian Arctic Shelf). In the 7 September 2015 issue of *Philosophical Transactions of the Royal Society* A, Shakhova and colleagues concluded that "progression of subsea permafrost thawing and decrease in ice extent could result in a significant increase in CH4 emissions from the ESAS" (East Siberian Arctic Shelf). Taking an expectedly more conservative approach, Peter Wadhams expects a **0.6°C rise in global-average temperature within five years after an ice-free Arctic,** more than sufficient to collapse civilization and enough to make Wadhams ponder human extinction.

- By 15 December 2013, methane bubbling up from the seafloor of the Arctic Ocean had sufficient force to prevent sea ice from forming in the area. Nearly two years after his initial, oft-disparaged analysis, Malcolm Light concluded on 22 December 2013, "we have passed the methane hydrate tipping point and are now accelerating into extinction as the methane hydrate 'Clathrate Gun' has begun firing volleys of methane into the Arctic atmosphere." According to Light's analysis in late 2013, the temperature of Earth's atmosphere will resemble that of Venus before 2100. The refereed journal literature tackles the topic of hothouse Earth with a paper in the 9 February 2016 issue of *Nature Communications*: "Water-rich planets such as Earth are expected to become eventually uninhabitable, because liquid water turns unstable at the surface as temperatures increase with solar luminosity. Whether a large increase of atmospheric concentrations of greenhouse gases such as CO2 could also destroy the habitability of water-rich planets has remained unclear. Here we show with three-dimensional aqua-planet simulations that CO2-induced forcing as readily destabilizes the climate as does solar forcing. The climate instability is caused by a positive cloud feedback and leads to a new steady state with global-mean sea-surface temperatures above 330°K" (330° Kelvin is about 57°C, compared to today's temperature of about 15 C). Two weeks after Light's 2013 analysis, in an essay stressing near-term human extinction, Light concluded: "The Gulf Stream transport rate started the methane hydrate (clathrate) gun firing in the Arctic in 2007 when its energy/year exceeded 10 million times the amount of energy/year necessary to dissociate subsea Arctic methane hydrates." The refereed journal literature, typically playing catch-up with reality, includes an article in the 3 February 2014 issue of *Journal of Geophysical Research: Earth Surface* claiming, "Sustained submergence [of these sediments] into the future should increase gas venting rate roughly exponentially as sediments continue to warm." Not surprisingly, the clathrate gun began firing in 2007, the same year the extent of Arctic sea ice reached a tipping point. Abundant evidence supporting the firing of the clathrate gun was collated and presented on 9 September 2012. Further confirmation the clathrate gun had been fired came from Stockholm University's Örjan Gustafsson, who reported from the Laptev Sea on 23 July 2014: "results of preliminary analyses of seawater

samples pointed towards levels of dissolved methane 10-50 times higher than background levels." Jason Box responds to the news in the conservative fashion I've come to expect from academic scientists on 27 July 2014: "What's the take home message, if you ask me? Because elevated atmospheric carbon from fossil fuel burning is the trigger mechanism poking the climate dragon. **The trajectory we're on is to awaken a runaway climate heating that will ravage global agricultural systems leading to mass famine, conflict. Sea level rise will be a small problem by comparison**." Later, during an interview with Vice published 1 August 2014, Box loosened up a bit, saying, "Even if a small fraction of the Arctic carbon were released to the atmosphere, we're fucked." Trust me, Jason, we're there.

- Simultaneous with the Laptev Sea mission, several large holes were discovered in Siberia. The reaction from an article published in the 31 July 2014 issue of *Nature* indicates atmospheric methane levels more than 50,000 times the usual. An article in the 4 August 2014 edition of *Ecowatch* ponders the holes: "If you have ever wondered whether you might see the end of the world as we know it in your lifetime, you probably should not read this story, nor study the graphs, nor look at the pictures of methane blowholes aka dragon burps."

- One of the authors of two research papers rooted in the Siberian Kara Sea concluded on 22 December 2014, "If the temperature of the oceans increases by two degrees as suggested by some reports, it will accelerate the thawing to the extreme. A warming climate could lead to an explosive gas release from the shallow areas." As we've known for a few years, 2°C is locked in.

- By late February 2015, the Siberian crater saga had become "more widespread — and scarier — than anyone thought," with numerous reports from the mainstream media. Naturally, these reports focused on economic impacts and the need for further research.

- Methane release from thawing offshore permafrost was further verified with research reported in the 7 August 2015 issue of *Journal of Geophysical Research*. This paper, for the first time, describes pingo-like features beneath the seabed offshore from Siberia.

- According to researchers quoted in the 22 September 2015 issue of *The Siberian Times*, a rare media outlet that is willing to address abrupt climate change in a meaningful manner, those massive craters on the Yamal Peninsula are, in fact, created by the release of methane. Furthermore, more craters are expected due to eruptions as permafrost continues to melt.

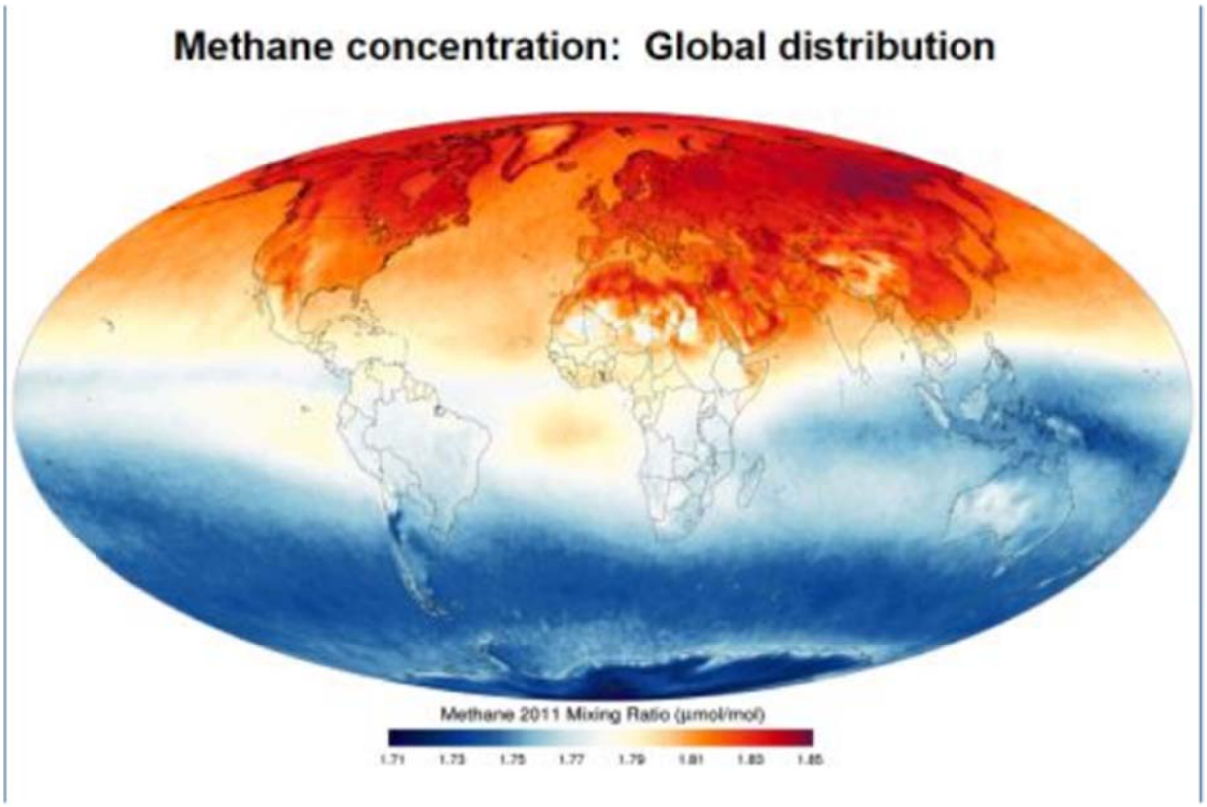
- It turns out those giant, methane-emitting craters in the Yamal region of Siberia have subsea counterparts. A paper in the 7 August 2015 issue of *Journal of Geophysical Research: Earth Science* connects the craters on land with those in the adjacent, shallow South Kara Sea. According a write-up in *The Siberian Times*: "Large mounds — described as pingos — have been identified on the seabed off the Yamal Peninsula, and their formation

is seen as due to the thawing of subsea permafrost, causing a 'high accumulation' of methane gas."

- The importance of methane cannot be overstated. Increasingly, evidence points to a methane burst underlying the Great Dying associated with the end-Permian extinction event, as pointed out in the 31 March 2014 issue of *Proceedings of the National Academy of Sciences*. As Malcolm Light reported on 14 July 2014: "There are such massive reserves of methane in the subsea Arctic methane hydrates, that if only a few percent of them are released, they will lead to a jump in the average temperature of the Earth's atmosphere of 10 degrees C and produce a 'Permian' style major extinction event which will kill us all. Apparently a 5°C rise in global-average temperature was responsible for the Great Dying, according to Michael Benton's book on the topic. In that case, the rise is temperature requires tens of thousands of years.

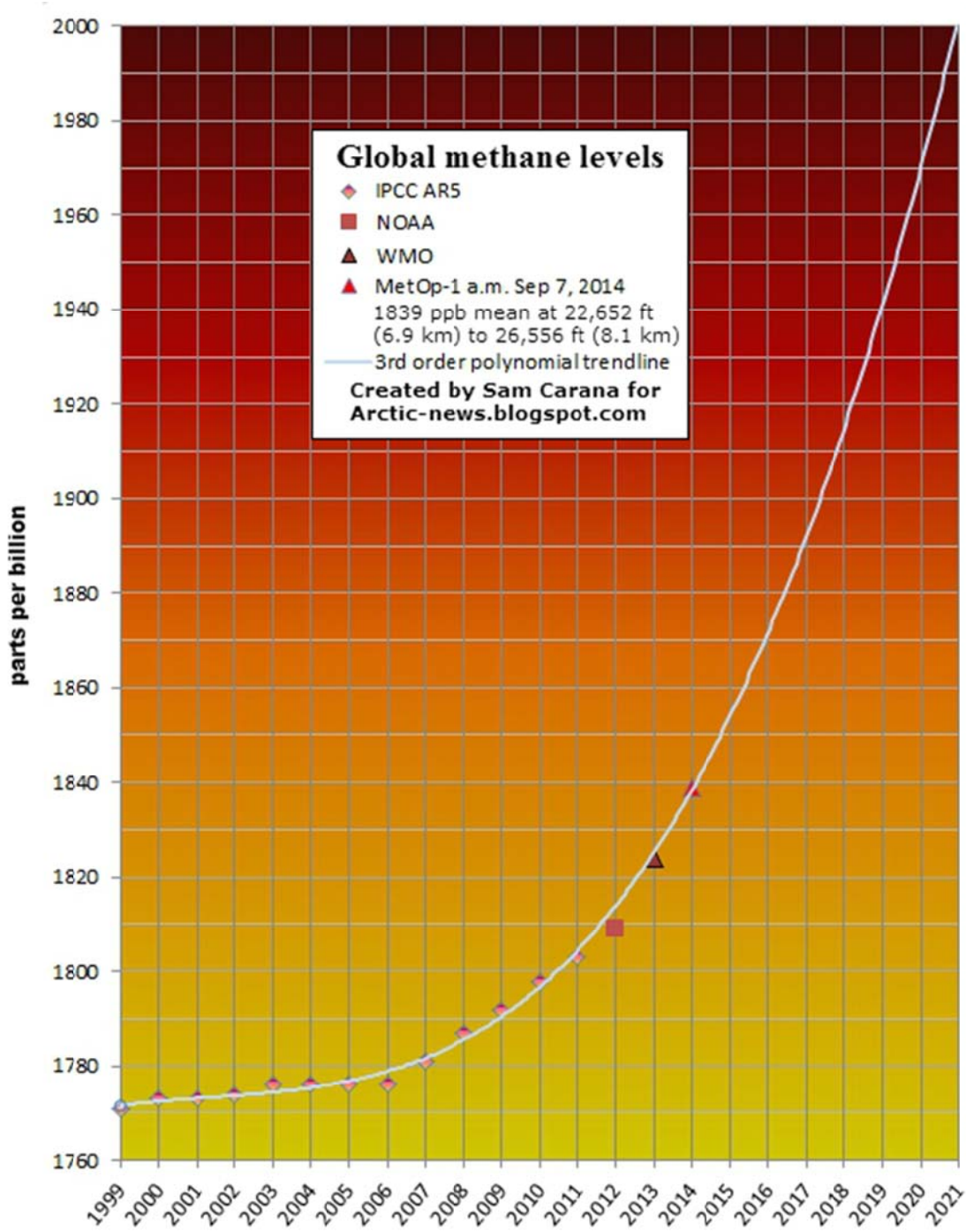
- Discussion about methane release from the Arctic Ocean has been quite heated (pun intended). Paul Beckwith was criticized by the conservative website, Skeptical Science.

- Robert Scribbler provides a terrifying summary 24 February 2014, and concludes, "two particularly large and troubling ocean to atmosphere methane outbursts were observed" in the Arctic Ocean. Such an event hasn't occurred during the last 45 million years. Scribbler's bottom line: "that time of dangerous and explosive reawakening, increasingly, seems to be now."



Sam Carana includes the figure below in his 10 September 2014 analysis. Based on data from several reputable sources, **exponential release of methane clearly is under way**. Robert Scribbler reaches the conclusion, finally, on 8 December 2014.

A paper published in the 22 December 2015 online issue of the *Proceedings of the National Academy of Sciences* reports, "that emissions during the cold season (September to May) contribute ≥50% of annual sources of methane from Alaskan tundra, based on fluxes obtained from eddy covariance sites and from regional fluxes calculated from aircraft data. … The dominance of late season emissions, sensitivity to soil conditions, and importance of dry tundra are not currently simulated in most global climate models."



2. Warm Atlantic water is defrosting the Arctic as it shoots through the Fram Strait (*Science*, January 2011). Extent of Arctic sea ice passed a tipping point in 2007, according to research published in the February 2013 issue of *The Cryosphere*. On 6 October 2012, *Truth-out* cites Peter Wadhams, professor of ocean physics at Cambridge University: "The Arctic may be ice-free in summer as soon as 2015. Such a massive loss would have a warming effect roughly equivalent to all human activity to date. In other words, **a summer ice-free Arctic could double the rate of warming of the planet as a whole**." Subsequent melting of Arctic ice is reducing albedo, hence enhancing absorption of solar energy. According to NASA on 17 December 2014, "the rate of absorbed solar radiation in the Arctic in June, July and August has increased by five percent" since 2000. "Averaged globally, this albedo

change is equivalent to 25% of the direct forcing from CO2 during the past 30 years," according to research published in the 17 February 2014 issue of the *Proceedings of the National Academy of Sciences*. Destabilization of the deep circulation in the Atlantic Ocean may be "spasmodic and abrupt rather than a more gradual increase" as earlier expected, according to a paper published in the 21 February 2014 issues of *Science*. Models continue to underestimate results relative to observations, as reported in the 10 March 2014 issue of *Geophysical Research Letters*. Consider, for example, the thinning "by more than 50 metres since 2012 — about one sixth of its original thickness — and that it is now flowing 25 times faster," as reported in the 23 December 2014 issue of *Geophysical Research Letters*. Rapid ice melt in the region is explained as a product of warm-air advection, air mass transformation, and fog in the June 2015 issue of *Geophysical Research Letters*.

3. Peat in the world's boreal forests is decomposing at an astonishing rate (*Nature Communications*, November 2011)

4. **Ozone, a powerful greenhouse gas, also contributes to mortality of trees** (*Global Change Biology*, November 2011). Tree mortality reduces uptake of atmospheric carbon dioxide and instead accelerates the contribution of carbon dioxide into the atmosphere. Forest dieback resulting from atmospheric ozone is the primary topic addressed by Gail Zawacki at *Wit's End*.

Analysis of tropospheric data has linked elevated levels of ozone with Indonesian forest fires, according to a paper in the 13 January 2016 issue of *Nature Communications*. Like methane, ozone is a potent but short-lived greenhouse gas. As indicated in the abstract: "This study suggest a larger role for biomass burning in the radiative forcing of climate in the remote TWP (Tropical Western Pacific) than is commonly appreciated."

5. Invasion of tall shrubs warms the soil, hence destabilizes the permafrost (*Environmental Research Letters*, March 2012). Further elucidation of this phenomenon included study of 25 species, and ~42,000 annual growth records from 1,821 individuals, as reported in the 6 July 2015 online issue of *Nature Climate Change*.

6. Greenland ice is darkening (*The Cryosphere*, June 2012). As reported in the 8 June 2014 issue of *Nature Geoscience*, "a decrease in the albedo of fresh snow by 0.01 leads to a surface mass loss of 27 Gt" annually. Any reduction in albedo is a disaster, says Peter Wadhams, head of the Polar Oceans Physics Group at Cambridge University. As pointed out by Robert Scribbler on 1 August 2014, we've removed the plug and, like the water leaving a tub, acceleration is under way: "Extensive darkening of the ice sheet surface, especially near the ice sheet edge, is resulting in more solar energy being absorbed by the ice sheet. Recent studies have shown that edge melt results in rapid destabilization and speeds glacier flows due to the fact that edge ice traditionally acts like a wall holding the more central and denser ice pack back." Jason Box registers his surprise with a photo essay on 29 October 2014. A paper in the 15 December 2014 issue of *Proceedings of the National Academy of Sciences* provides the first comprehensive picture of how Greenland's ice is vanishing and concludes "that Greenland may lose ice more rapidly in the near future than previously thought." Research reported in the 17 December 2015 issue of *Nature* calculates spatial ice mass loss around the entire Greenland Ice Sheet from 1900 to the present and finds "that many areas

currently undergoing change are identical to those that experienced considerable thinning throughout the twentieth century." According to one of paper's co-authors "the average mass loss rate over the past decade is much larger than at any other time over the last 115 years."

Adding to the rapidity of ice melt on Greenland is cloud cover. A paper published in the 12 January 2016 edition of *Nature Communications* shows that clouds are playing a larger role than previously understood in heating the Greenland Ice Sheet. Clouds trap heat, thus accounting for as much as 30% of the ongoing melt of the ice sheet.

According to a paper in the 3 March 2016 issue of *The Cryosphere*, the darkening Greenland ice sheet started becoming significantly less reflective of solar radiation from around 1996, with the ice absorbing 2% more solar energy per decade from this point. "Future darkening is likely underestimated," according to the paper's abstract.

7. Methane is being released from beneath Antarctic ice, too (*Nature*, August 2012). This third primary source of methane — in addition to permafrost and the shallow seabed — potentially is enormous. According to a paper in the 24 July 2013 issue of *Scientific Reports,* melt rate in the Antarctic has caught up to the Arctic and the West Antarctic Ice Sheet is losing over 150 cubic kilometres of ice each year according to CryoSat observations published 11 December 2013, and Antarctica's crumbling Larsen-B Ice Shelf is poised to finish its collapse, according to Ted Scambos, a glaciologist at the National Snow and Ice Data Centre at the annual meeting of the American Geophysical Union. A paper in the 12 September 2014 issue of *Science* concluded the major collapse of the Larsen-B Ice Shelf in 2002 resulted from warm local air temperatures, indicating the importance of global and local warming on ice dynamics. Two days later a paper in *Nature Climate Change* indicates that this sensitivity to temperature illustrates "that future increases in precipitation are unlikely to offset atmospheric-warming-induced melt of peripheral Antarctic Peninsula glaciers." A study published in the 1 June 2015 issue of *Earth and Planetary Science Letters* finds the last remaining section of Antarctica's Larsen B Ice Shelf, which partially collapsed in 2002, is quickly weakening and is likely to disintegrate completely before the end of the decade. Meanwhile, the Larsen-C Ice Shelf is poised to collapse, according to an article in the 13 May 2015 issue of *The Cryosphere*. A paper in the 8 February 2016 online issue of *Nature Climate Change* reinforces prior findings about the collapse of major ice shelves in Antarctica. Some of these country-sized, so-called "safety bands" are extremely dynamic and therefore susceptible to rapid breakup. The rate of loss during the period 2010-2013 was double that during the period 2005-2010, according to a paper in the 16 June 2014 issue of *Geophysical Research Letters*. **By mid-May 2015 the sudden onset of ice loss in Antarctica was large enough to affect Earth's gravity field**, as reported in the 21 May 2015 issue of *Science*. According to NASA climate scientist Eric Rignot in early 2015, "the fuse is blown." Rignot goes on to explain this "shattering" moment and also points out the utter ineptitude by climate scientists at explaining the situation to the public. According to research reported in the 26 March 2015 issue of *Science*, "West Antarctic losses increased by 70% in the last decade, and earlier volume gain by East Antarctic ice shelves ceased." Loss of Antarctic ice is accelerating even in areas long considered stable, as documented in the 24 July 2013 edition of *Scientific Reports*. Based on gravity data published in the 1 April 2015 issue of *Earth and Planetary Science Letters*: "During the past decade, Antarctica's massive ice sheet lost twice the amount of ice in its western portion

compared with what it accumulated in the east, according to Princeton University researchers who came to one overall conclusion — the southern continent's ice cap is melting ever faster." The faster-than-expected narrative continued into 10 July 2015, when a paper in *Science Advances* found that geothermal activity was contributing to rapid melting of the West Antarctic Ice Sheet. The 14 March 2016 issue of *Nature Geoscience* includes a paper about Antarctic ice shelves concluding that "loss of ice shelf mass is accelerating, especially in West Antarctica, where warm seawater is reaching ocean cavities beneath ice shelves. … We conclude that basal channels can form and grow quickly as a result of warm ocean water intrusion, and that they can structurally weaken ice shelves, potentially leading to rapid ice shelf loss in some areas." According to a paper in the 20 June 2016 issue of *Nature Communications*: "Here we report the discovery of a massive subsurface ice layer, at least 16 km across, several kilometres long and tens of metres deep, located in an area of intense melting and intermittent ponding on Larsen C Ice Shelf, Antarctica. We combine borehole optical televiewer logging and radar measurements with remote sensing and firn modelling to investigate the layer, found to be ~10°C warmer and ~170 kg m−3 denser than anticipated in the absence of ponding and hitherto used in models of ice-shelf fracture and flow." **The Antarctic Peninsula is one of the fastest warming spots on the planet**, and it was thought that the rising air temperature was driving the melt of the glaciers along its fringes. But it is actually warm ocean waters that are eating away at the ice along part of its western side, a group of scientists reported 15 July 2016 in the journal *Science*. Further confirmation of large methane releases is revealed by **noctilucent clouds** over the southern hemisphere from 21 November 2013 to 6 December 2013.

It's not just Antarctica spewing methane hydrates from beneath the ice. Ice sheets may be hiding vast reservoirs in the Arctic, too, as reported in the 7 January 2016 issue of *Nature Communications*. As reported in the abstract, "recent dating of methane expulsion sites suggests that gas release has been ongoing over many millennia. Here we synthesize observations of ~1,900 fluid escape features — pockmarks and active gas flares — across a previously glaciated Arctic margin with ice-sheet thermomechanical and gas hydrate stability zone modelling. Our results indicate that even under conservative estimates of ice thickness with temperate sub-glacial conditions, a 500-m thick gas hydrate stability zone — which could serve as a methane sink — existed beneath the ice sheet. Moreover, we reveal that in water depths 150–520 m methane release also persisted through a 20-km-wide window between the subsea and sub-glacial gas hydrate stability zone. This window expanded in response to post-glacial climate warming and deglaciation thereby opening the Arctic shelf for methane release."

8. Forest and bog fires are growing (in Russia, initially, according to NASA in August 2012), a phenomenon consequently apparent throughout the northern hemisphere (*Nature Communications*, July 2013). The *New York Times* reports hotter, drier conditions leading to huge fires in western North America as the "new normal" in their 1 July 2013 issue. A paper in the 22 July 2013 issue of the *Proceedings of the National Academy of Sciences* indicates boreal forests are burning at a rate exceeding that of the last 10,000 years. Los Alamos National Laboratory catches on during same month. According to reports from Canada's Interagency Fire Centre, total acres burned to date in early summer 2014 are more than six times that of a typical year. This rate of burning is unprecedented not just for this century, but for any period in Canada's basement forest record over the last 10,000 years. A comprehensive assessment of biomass burning, published in the 21 July

2014 issue of *Journal of Geophysical Research: Atmospheres*, explains most of the global-average increase in temperature and explains that biomass burning causes much more global warming per unit weight than other human-associated carbon sources. By early August 2014 tundra fires were burning just 70 miles south of Arctic Ocean waters and the fires were creating their own weather via pyrocumulus clouds. According to a paper published in the 14 July 2015 issue of *Nature Communications*, the length of the fire season has increased nearly 20% since 1979.

Ignition sources are on the rise, too. According to a paper in the 14 November 2014 issue of *Science*, each 1°C rise in global-average temperature contributes to a 12 ± 5% increase in lightning strikes.

According to a paper in the 6 October 2015 online issue of the *Proceedings of the National Academy of Sciences* comes a paper describing how the 0.5°C rise in global-average temperature associated with the Medieval Climate Anomaly — commonly called the Medieval Warm period — contributed to substantial increase in area burned. According to the abstract: "Warming of ~0.5°C ~1,000 years ago increased the percentage of our study sites burned per century by ~260% relative to the past ~400 y."

According to a paper in the 16 March 2016 issue of *Global Ecology and Biogeography*, climate change is adversely altering the ability of Rocky Mountain forests to recover from wildfire. Specifically, warm, dry conditions in the years following fires impede the growth and establishment of vulnerable new post-fire seedlings. Not only does climate change contribute to more and larger fires in the region, thus killing the trees in the forest, but post-fire recruitment is reduced by the same conditions that contribute to the more and larger fires.

9. Cracking of glaciers accelerates in the presence of increased carbon dioxide (*Journal of Physics D: Applied Physics*, October 2012)

10. The Beaufort Gyre apparently has reversed course (U.S. National Snow and Ice Data Centre, October 2012). Mechanics of this process are explained by the Woods Hole Oceanographic Institution.

11. Exposure to sunlight increases bacterial conversion of exposed soil carbon, thus accelerating thawing of the permafrost (*Proceedings of the National Academy of Sciences*, February 2013). Subsequent carbon release "could be expected to more than double overall net C losses from tundra to the atmosphere," as reported in the March 2014 issue of *Ecology*. Arctic permafrost houses about half the carbon stored in Earth's soils, an estimated 1,400 to 1,850 petagrams of it, according to NASA, which is more than twice as much as already exists in the atmosphere. Peat chemistry changes as warming proceeds, which accelerates the process, as reported in the 7 April 2014 issue of *Proceedings of the National Academy of Sciences*.

12. The microbes have joined the party, too, according to a paper in the 23 February 2013 issue of New Scientist. A subsequent paper in the 22 October 2014 issue of *Nature* illustrates the key role of a single species of microbe in amplifying climate change.

13. According to a paper in the 12 April 2013 issue of Science, a major methane release is almost inevitable from permafrost in Alaska, which makes me wonder where the authors have been hiding. Almost inevitable, they report, regarding an ongoing event. Trees are tipping over and dying as permafrost thaws, thus illustrating how self-reinforcing feedback loops feed each other. A paper in the 6 April 2015 online issue of *Nature* concludes: "The heat production is not only expected to accelerate the organic carbon decomposition and potentially the amounts of carbon emitted to the atmosphere but could be the tipping point that will lead to the loss of evidence of early human history in the Arctic, which so far has been extremely well preserved in the top permafrost." The rapidly decaying permafrost is largely recent in origin, according to a paper in the 27 April 2015 issue of *Geophysical Research Letters*, and is leading to a "runaway effect." The resulting carbon is entering "the atmosphere at breakneck speed," according to an analysis published in the 27 April 2015 issue of *Geophysical Research Letters*. A paper in the 1 February 2016 issue of the *Journal of Geophysical Research: Biogeosciences* finally indicates the scientific literature is catching up to the reality of the dire situation: "our results suggest that this subarctic tundra ecosystem is shifting away from its historical function as a C sink to a C source." Slowly catching up to reality, a paper in the 12 March 2016 issue of *Climate Change Responses* indicates "the large stocks of carbon stored in graminoid soils should be more susceptible to mineralization in a warming Arctic." In other words, climate warming accelerates carbon release from thawing Arctic soils.

According to a paper in the 20 June 2016 issue of *Environmental Research Letters*, permafrost thaw has risen fourfold in some Arctic regions during the last 50 years.

14. Summer ice melt in Antarctica is at its highest level in a thousand years: Summer ice in the Antarctic is melting 10 times quicker than it was 600 years ago, with the most rapid melt occurring in the last 50 years (*Nature Geoscience*, April 2013). According to a paper in the 4 March 2014 issue of *Geophysical Research Letters* — which assumes relatively little change in regional temperature during the coming decades — "modeled summer sea-ice concentrations decreased by 56% by 2050 and 78% by 2100". Citing forthcoming papers in *Science and Geophysical Research Letters*, the 12 May 2014 issue of the *New York Times* reported: "A large section of the mighty West Antarctica ice sheet has begun falling apart and its continued melting now appears to be unstoppable. … The new finding appears to be the fulfilment of a prediction made in 1978 by an eminent glaciologist, John H. Mercer of the Ohio State University. He outlined the vulnerable nature of the West Antarctic ice sheet and warned that the rapid human-driven release of greenhouse gases posed 'a threat of disaster.'" Although scientists have long expressed concern about the instability of the West Antarctic Ice Sheet (WAIS), a research paper published in the 28 August 2013 of *Nature* indicates **the East Antarctic Ice Sheet** (EAIS) has undergone rapid changes in the past five decades. The latter is the world's largest ice sheet and was previously thought to be at little risk from climate change. But it **has undergone rapid changes in the past five decades, signalling a potential threat to global sea levels.** The EAIS holds enough water to raise sea levels more than 50 meters. According to a paper in the July 2014 issue of the same journal, the southern hemisphere's westerly winds have been strengthening and shifting poleward since the 1950s, thus quickening the melt rate to the point of — you guessed it — "results that shocked the researchers." A paper presented at the late 2014 meeting of the American Geophysical Union concludes, "comprehensive, 21-year analysis of the fastest-melting region of Antarctica has found that **the melt rate of glaciers there has tripled during the last**

decade." The 16 March 2015 online issue of *Nature Geoscience* adds to the misery and identifies melting from below Totten Glacier. Specifically, a paper published in the 19 May 2016 issue of *Nature* finds the Totten Glacier capable of "repeated large-scale retreat and advance," with the researchers concluding the glacier is "fundamentally unstable."

A paper in the 12 October 2015 issue of *Nature Geoscience* reports that the Antarctic ice is melting so fast that the stability of the whole continent could be at risk by 2100. No surprise about that long-into-the-future date, of course. But the paper uses two emissions scenarios to predict a doubling of surface melting of the ice shelves by 2050 and, with one emissions scenario, Antarctic ice shelves would be in danger of collapse by century's end.

According to a paper in the 2 November 2015 online issue of the *Proceedings of the National Academy of Sciences*, "if the Amundsen Sea sector is destabilized, then the entire marine ice sheet will discharge into the ocean." This appears to be admission of "self-sustained ice discharge from West Antarctica."

According to a paper published in the 26 November 2015 issue of *Nature Communications*, "Outlet glaciers grounded on a bed that deepens inland and extends below sea level are potentially vulnerable to 'marine ice sheet instability'. This instability, which may lead to runaway ice loss, has been simulated in models, but its consequences have not been directly observed in geological records. Here we provide new surface-exposure ages from an outlet of the East Antarctic Ice Sheet that reveal rapid glacier thinning occurred approximately 7,000 years ago, in the absence of large environmental changes. Glacier thinning persisted for more than two and a half centuries, resulting in hundreds of metres of ice loss."

15. Increased temperature and aridity in the south-western interior of North America facilitates movement of dust from low-elevation deserts to high-elevation snowpack, thus accelerating snowmelt, as reported in the 17 May 2013 issue of *Hydrology and Earth System Sciences*.

16. Floods in Canada are sending pulses of silty water out through the Mackenzie Delta and into the Beaufort Sea, thus painting brown a wide section of the Arctic Ocean near the Mackenzie Delta brown (NASA, June 2013). Pictures of this phenomenon are shown on the NASA website.

17. Surface meltwater draining through cracks in an ice sheet can warm the sheet from the inside, softening the ice and letting it flow faster, according to a study accepted for publication in the *Journal of Geophysical Research: Earth Surface* (July 2013). Further support for this idea was reported in the 29 September 2014 issue of *Nature Communications*. It appears a Heinrich Event has been triggered in Greenland. Consider the description of such an event as provided by Robert Scribbler on 8 August 2013:

- In a Heinrich Event, the melt forces eventually reach a tipping point. The warmer water has greatly softened the ice sheet. Floods of water flow out beneath the ice. Ice ponds grow into great lakes that may spill out both over top of the ice and underneath it. Large ice damns (sic) may or may not start to form. All through this time ice motion and melt is

> accelerating. Finally, a major tipping point is reached and in a single large event or ongoing series of such events, a massive surge of water and ice flush outward as the ice sheet enters an entirely chaotic state. Tsunamis of melt water rush out bearing their vast floatillas (sic) of ice burgs (sic), greatly contributing to sea level rise. And that's when the weather really starts to get nasty. In the case of Greenland, the firing line for such events is the entire North Atlantic and, ultimately the Northern Hemisphere.

Based on data collected in 2011, a paper published online in the 13 July 2015 issue of *Nature Geoscience* finds: "Given that the advection of warm, moist air masses and rainfall over Greenland is expected to become more frequent in the coming decades, our findings portend a previously unforeseen vulnerability of the Greenland ice sheet to climate change." Briefly, melting of the "Greenland ice sheet has been shown to accelerate in response to surface rainfall and melt associated with late-summer and autumnal cyclonic weather events."

18. Breakdown of the thermohaline conveyor belt is happening in the Antarctic as well as the Arctic, thus leading to melting of Antarctic permafrost (*Scientific Reports*, July 2013). In the past 60 years, the ocean surface offshore Antarctica became less salty as a result of melting glaciers and more precipitation, as reported in the 2 March 2014 issue of *Nature Climate Change*.

19. Loss of Arctic sea ice is reducing the temperature gradient between the poles and the equator, thus causing the jet stream to slow and meander (see particularly the work of Jennifer Francis, as well as the article in the 20 November 2014 issue of the *Washington Post*). The most extreme "dipole" on record occurred during 2013-2014, as reported in the *Geophysical Research Letters*. One result is the creation of weather blocks such as the recent very high temperatures in Alaska. This so-called "polar vortex" became widely reported in the United States in 2013 and received the attention of the academic community when the 2013-2014 drought threatened crop production in California. Extreme weather events are occurring, as reported in the 22 June 2014 issue of *Nature Climate Change*. Also called Rossby Waves, these atmospheric events are on the rise, as reported in the 11 August 2014 edition of the *Proceedings of the National Academy of Science*. A paper co-authored by Francis in the 6 January 2015 issue of *Environmental Research Letters* concludes with this line in the abstract: "These results suggest that as the Arctic continues to warm faster than elsewhere in response to rising greenhouse-gas concentrations, the frequency of extreme weather events caused by persistent jet-stream patterns will increase." Regarding the Rossby Waves, a paper in the 24 April 2015 edition of *Journal of Geophysical Research: Atmospheres* includes this comment: "We also found a positive feedback mechanism resulting from the anomalous meridional circulation that cools the mid-latitudes and warms the Arctic, which adds an extra heating to the Arctic air column equivalent to about 60% of the direct surface heat release from the sea-ice reduction." Francis' work was further validated in the 31 August 2015 online issue of *Nature Geoscience* in an article titled, "Two distinct influences of Arctic warming on cold winters over North America and East Asia."

As one result of the polar vortex, boreal peat dries and catches fire like a coal seam (also see the paper in *Nature*, published online 23 December 2014, indicating "the amount of carbon stored in peats exceeds that stored in vegetation and is similar in size to the current atmospheric carbon

pool"). The resulting soot enters the atmosphere to fall again, coating the ice surface elsewhere, thus reducing albedo and hastening the melting of ice. Each of these individual phenomena has been reported, albeit rarely, but to my knowledge the dots have not been connected beyond this space. The inability or unwillingness of the media to connect two dots is not surprising, and has been routinely reported.

20. Arctic ice is growing darker, hence less reflective (*Nature Climate Change*, August 2013)

21. Extreme weather events drive climate change, as reported in the 15 August 2013 issue of *Nature* (August 2013). Details are elucidated via modelling in the 6 June 2014 issue of *Global Biogeochemical Cycles*. Further data and explanation are presented in the 27 April 2015 online issue of *Nature Climate Change*.

"Explaining Extreme Events of 2014 from a Climate Perspective" was published by the *Bulletin of the American Meteorological Society* in their December 2015 issue and draws on conclusions from 32 international teams of scientists who investigated 28 separate weather events. Findings of this report, released on 5 November 2015, include the following: "Human activities, such as greenhouse gas emissions and land use, influenced specific extreme weather and climate events in 2014, including tropical cyclones in the central Pacific, heavy rainfall in Europe, drought in East Africa, and stifling heat waves in Australia, Asia, and South America."

According to a paper in the 13 June 2016 issue of the *Proceedings of the National Academy of Sciences*, atmospheric aerosols strengthen storm clouds, thus leading to extreme weather. An abundance of aerosol particles in the atmosphere — constantly added via industrial activity — can increase the lifespans of large storm clouds by delaying rainfall, making the clouds grow larger and live longer, and producing more extreme storms.

For many years, scientists have cautioned that individual weather events couldn't be attributed to climate change. Now, however, specific extreme weather events can be attributed to climate change. A 200-page, March 2016 report from the *National Academies of Science, Engineering, and Medicine* examines the current state of science of extreme weather attribution, and identifies ways to move the science forward to improve attribution capabilities.

22. Drought-induced mortality of trees contributes to increased decomposition of carbon dioxide into the atmosphere and decreased sequestration of atmospheric carbon dioxide. Such mortality has been documented throughout the world since at least November 2000 in *Nature*, with recent summaries in the February 2013 issue of *Nature* for the tropics, the August 2013 issue of *Frontiers in Plant Science* for temperate North America, and the 21 August 2015 issue of *Science* for boreal forests. The situation is exacerbated by pests and disease, as trees stressed by altered environmental conditions become increasingly susceptible to agents such as bark beetles and mistletoe (additional examples abound).

One extremely important example of this phenomenon is occurring in the Amazon, where drought in 2010 led to the release of more carbon than the United States that year (*Science*, February 2011).

The calculation badly underestimates the carbon release. In addition, ongoing deforestation in the region is driving declines in precipitation at a rate much faster than long thought, as reported in the 19 July 2013 issue of *Geophysical Research Letters*. An overview of the phenomenon, focused on the Amazon, was provided by *Climate News Network* on 5 March 2014~. "The observed decline of the Amazon sink diverges markedly from the recent increase in terrestrial carbon uptake at the global scale, and is contrary to expectations based on models," according to a paper in the 19 March 2015 issue of *Nature*. Finally, according to a paper in the 1 July 2016 issue of *Global Biogeochemical Cycles*, the 2010 drought completely shut down the Amazon Basin's carbon sink, by killing trees and slowing their growth.

Tropical rain forests, long believed to represent the primary driver of atmospheric carbon dioxide, are on the verge of giving up that role. According to a 21 May 2014 paper published in *Nature*, "the higher turnover rates of carbon pools in semi-arid biomes are an increasingly important driver of global carbon cycle inter-annual variability," indicating the emerging role of drylands in controlling environmental conditions. "Because of the deforestation of tropical rainforests in Brazil, significantly more carbon has been lost than was previously assumed." In fact, "forest fragmentation results in up to a fifth more carbon dioxide being emitted by the vegetation." These results come from the 7 October 2014 issue of *Nature Communications*. A paper in the 28 December 2015 online issue of the *Proceedings of the National Academy of Sciences* indicates Amazon forest could transition to savanna-like states in response to climate change. Savannas are simply described as grasslands with scattered trees or shrubs. The abstract of the paper suggests that, "in contrast to existing predictions of either stability or catastrophic biomass loss, the Amazon forest's response to a drying regional climate is likely to be an immediate, graded, heterogeneous transition from high-biomass moist forests to transitional dry forests and woody savannah-like states."

The boreal forest wraps around the globe at the top of the Northern Hemisphere. It is the planet's single largest biome and makes up 30 percent of the globe's forest cover. Moose are the largest ungulate in the boreal forest and their numbers have plummeted. The reason is unknown.

Dennis Murray, a professor of ecology at Trent University in Peterborough, Ontario, thinks the dying moose of Minnesota and New Hampshire and elsewhere are one symptom of something far bigger – a giant forest ecosystem that is rapidly shrinking, dying, and otherwise changing. "The boreal forest is breaking apart," he says. "The question is what will replace it?"

Increasing drought threatens almost all forests in the United States, according to a paper in the 21 February 2016 online issue of *Global Change Biology*. According to the paper's abstract, "diebacks, changes in composition and structure, and shifting range limits are widely observed."

For the first time scientists have investigated the net balance of the three major greenhouse gases — carbon dioxide, methane, and nitrous oxide — for every region of Earth's land masses. The results were published in the 10 March 2016 issue of *Nature*. The surprising result: Human-induced emissions of methane and nitrous oxide from ecosystems overwhelmingly surpass the ability of the land to soak up carbon dioxide emissions, which makes the terrestrial biosphere a contributor to climate change.

An abstract of a paper to be published in the April 2016 issue of *Biogeochemistry* includes these sentences: "Rising temperatures and nitrogen (N) deposition, both aspects of global environmental change, are proposed to alter soil organic matter (SOM) biogeochemistry. … Overall, this study shows that the decomposition and accumulation of molecularly distinct SOM components occurs with soil warming and N amendment and may subsequently alter soil biogeochemical cycling." In other words, as global temperatures rise, the organic matter in forests appears to break down more quickly, thereby accelerating the release of carbon into the atmosphere.

23. Ocean acidification leads to release of less dimethyl sulphide (DMS) by plankton. DMS shields Earth from radiation. (*Nature Climate Change*, online 25 August 2013). Plankton form the base of the marine food web, some populations have declined 40% since 1950 (e.g., article in the 29 July 2010 issue of *Nature*), and they are on the verge of disappearing completely, according to a paper in the 18 October 2013 issue of *Global Change Biology*. As with carbon dioxide, ocean acidification is occurring rapidly, according to a paper in the 26 March 2014 issue of *Global Biogeochemical Cycles*. Acidification is proceeding at a pace unparalleled during the last 300 million years, according to research published in the 2 March 2012 issue of *Science*. Over the past 10 years, the Atlantic Ocean has soaked up 50 percent more carbon dioxide than it did the decade before, measurably speeding up the acidification of the ocean, according to a paper published in the 30 January 2016 issue of *Global Biogeochemical Cycles*. Not surprisingly, the degradation of the base of the marine food web is reducing the ability of fish populations to reproduce and replenish themselves across the globe, as reported in the 14 December 2015 online edition of the *Proceedings of the National Academy of Sciences*.

Diatoms, one of the major groups of plankton, is declining globally at the rate of about one percent per year, according to a paper in the 23 September 2015 issue of *Global Biogeochemical Cycles*.

The Southern Ocean is acidifying at such a rate because of rising carbon dioxide emissions that large regions may be inhospitable for key organisms in the food chain to survive as soon as 2030, according to a paper in the 2 November 2015 online issue of *Nature Climate Change*.

A paper in the 26 November 2015 issue of *Science Express* indicates millennial-scale shifts in plankton in the subtropical North Pacific Ocean that are "unprecedented in the last millennium." The ongoing shift "began in the industrial era and is supported by increasing N2-fixing cyanobacterial production. This picoplankton community shift may provide a negative feedback to rising atmospheric CO2." One of the authors of the papers is quoted during an interview: "This picoplankton community shift may have provided a negative feedback to rising atmospheric carbon dioxide, during the last 100 years. However, we cannot expect this to be the case in the future."

Further research on primary productivity in the ocean was published in paper in the 19 January 2016 issue of *Geophysical Research Letters*. Referring to the Indian Ocean, the abstract concludes, "future climate projections suggest that the Indian Ocean will continue to warm, driving this productive region into an ecological desert."

For the first time, researchers have documented algae-related toxins in Arctic sea mammals. Specifically, toxins produced by harmful algal blooms are showing up in Alaska marine mammals as far north as the Arctic Ocean — much farther north than ever reported previously, according to a paper in the 11 February 2016 issue of *Harmful Algae*. The abstract indicates, "In this study, 905 marine mammals from 13 species were sampled including; humpback whales, bowhead whales, beluga whales, harbour porpoises, northern fur seals, Steller sea lions, harbour seals, ringed seals, bearded seals, spotted seals, ribbon seals, Pacific walruses, and northern sea otters. Domoic acid was detected in all 13 species examined and had the greatest prevalence in bowhead whales (68%) and harbor seals (67%). Saxitoxin was detected in 10 of the 13 species … These results provide evidence that … toxins are present throughout Alaska waters at levels high enough to be detected in marine mammals and have the potential to impact marine mammal health in the Arctic marine environment."

24. Jellyfish have assumed a primary role in the oceans of the world (26 September 2013 issue of the *New York Times Review of Books*, in a review of Lisa-ann Gershwin's book, *Stung! On Jellyfish Blooms and the Future of the Ocean*): "We are creating a world more like the late Precambrian than the late 1800s — a world where jellyfish ruled the seas and organisms with shells didn't exist. We are creating a world where we humans may soon be unable to survive, or want to." Jellyfish contribute to climate change via (1) release of carbon-rich feces and mucus used by bacteria for respiration, thereby converting bacteria into carbon dioxide factories and (2) consumption of vast numbers of copepods and other plankton.

25. Sea-level rise causes slope collapse, tsunamis, and release of methane, as reported in the September 2013 issue of *Geology*. In eastern Siberia, the speed of coastal erosion has nearly doubled during the last four decades as the permafrost melts. And it appears sea-level rise has gone exponential, judging from *Scribbler's* 4 May 2015 analysis. Considering only data through 2005, according to a paper published 28 September 2015 in the *Proceedings of the National Academy of Sciences*, **the 500-year return time of floods in New York City has been reduced to 24.4 years**.

26. Rising ocean temperatures will upset natural cycles of carbon dioxide, nitrogen and phosphorus, hence reducing plankton (*Nature Climate Change*, September 2013). Ocean warming has been profoundly underestimated since the 1970s according to a paper published in the online version of *Nature Climate Change* on 5 October 2014. Specifically, the upper 2,300 feet of the Southern Hemisphere's oceans may have warmed twice as quickly after 1970 than had previously been thought. According to a 22 January 2015 article in *The Guardian*, "the oceans are warming so fast, they keep breaking scientists' charts."

Another indication of a warming ocean is coral bleaching. The third global coral bleaching event since 1998, and also the third in evidence, ever, is underway on Australia's Great Barrier Reef. According to Australia *National News* on 28 March 2016, a survey of the Great Barrier Reef reports 95% of the northern reefs were rated as severely bleached, and only 4 of 520 reefs surveyed were found to be unaffected by bleaching.

27. Earthquakes trigger methane release, and consequent warming of the planet triggers earthquakes, as reported by Sam Carana at the *Arctic Methane Emergency Group* (October 2013)

28. Small ponds in the Canadian Arctic are releasing far more methane than expected based on their aerial cover (*PLoS ONE*, November 2013). This is the first of several freshwater ecosystems releasing methane into the atmosphere, as reviewed in the 19 March 2014 issue of *Nature* and subsequently described by a large-scale study in the 28 April 2014 issue of *Global Change Biology*. Release of methane from these sources in the Arctic and Greenland, according to the 20 May 2012 issue of *Nature Geoscience*, "imply that in a warming climate, disintegration of permafrost, glaciers and parts of the polar ice sheets could facilitate the transient expulsion of 14C-depleted methane trapped by the cryosphere cap."

The mechanism underlying methane release in these systems is poorly understood. If sunlight drives the process, as suggested by a paper in the 22 August 2014 issue of *Science*, then amplification is expected over time as ponds and lakes are increasingly exposed.

Water bodies within Africa's interior are adding significantly to the overall release of greenhouse gases into the atmosphere, according to a paper in the 20 July 2015 online edition of *Nature Geoscience*. Specifically, "total carbon dioxide-equivalent greenhouse-gas emissions [are] … about 0.9 Pg carbon per year, equivalent to about one quarter of the global ocean and terrestrial combined carbon sink."

Large water bodies beneath deserts could profoundly worsen the situation. According to a paper published in the 28 July 2015 issue of *Geophysical Research Letters*, a large carbon sink or pool lies beneath the Tarim basin in Xinjiang, China. The hidden pool of water stores "more carbon than all the plants on the planet put together. While more water may sound like a good thing, researchers believe that if this carbon were to escape into the atmosphere, we would be in serious, serious trouble." Specifically, the senior authored explained in an interview: "It's like a can of coke. If it is opened all the greenhouse gas will escape into the atmosphere."

A paper in the 29 October 2015 issue of *Limnology and Oceanography* also addresses the issue of methane release from lakes. A write-up for the general public titled, "Global Warming Will Progress Much More Quickly than Expected, Study Predicts" includes this line: "The findings suggest we have a 'vicious circle' ahead of us in which the burning of fossil fuels leads to higher temperatures, which in turn trigger higher levels of methane release and further warming." This is a fine explanation for a self-reinforcing feedback loop.

A study published in the 17 November 2015 edition of *Nature Geoscience* shows that lakes in the northern hemisphere will probably release much more carbon dioxide due to global climate changes. The investigation, based on data from more than 5,000 Swedish lakes, demonstrates that carbon dioxide emissions from the world's lakes, water courses, and reservoirs are equivalent to almost a quarter of all the carbon dioxide produced by burning fossil fuels.

Citing two recent journal articles, a paper in the 19 November 2015 issue of *Yale Environment 360* concludes, "the world's iconic northern lakes are undergoing major changes that include swiftly warming waters, diminished ice cover, and outbreaks of harmful algae." The lakes include Lake Baikal, "the deepest, largest in volume, and most ancient freshwater lake in the world, holding one-fifth of the planet's above-ground drinking supply. It's a Noah's Ark of biodiversity, home to myriad species found nowhere else on earth."

Further support for the importance of streams and rivers as sources of atmospheric methane comes from a paper published in the November 2015 issue of *Ecological Monographs*. The headline of the write-up for the general public tells the story: "Greenhouse gas emissions from freshwater higher than thought."

A paper in the 23 November 2015 issue of *Journal of Geophysical Research: Biogeosciences* found, according to the abstract: "A sediment upwelling at the end of the thaw season likely contributed to these [methane] emissions. We suggest that, unlike wetlands, shallow seasonally ice-covered lakes can have their highest methane emission potential in the cold season, likely dominating the spring methane release of subarctic landscapes with high lake coverage." In other words, as with methane release from the Arctic Ocean, methane release is abundant during the cold season. According to a paper in the 16 June 2016 online issue of *Geophysical Research Letters*, "Our findings indicate that permafrost below shallow lakes has already begun crossing a critical thawing threshold approximately 70 years prior to predicted terrestrial permafrost thaw in northern Alaska."

As reported in the 16 December 2015 issue of *Geophysical Research Letters*: "In this first worldwide synthesis of in situ and satellite-derived lake data, we find that lake summer surface water temperatures rose rapidly (global mean = 0.34°C decade−1) between 1985 and 2009."

A paper in the 4 January 2016 online edition of *Nature Geoscience* finds, "lakes and ponds are a dominant methane source at high northern latitudes." "By compiling previously reported measurements made at a total of 700 northern water bodies the researchers have been able to more accurately estimate emissions over large scales. They found that methane emissions from lakes and ponds alone are equivalent to roughly two-thirds of all natural methane sources in the northern region."

According to a paper in the 1 February 2016 issue of *Nature Geoscience*, ponds less than a quarter of an acre in size make up only 8.6% of the surface area of the world's lakes and ponds, yet they account for 15.1% of carbon dioxide emissions and 40.6% of diffusive methane emissions.

29. Mixing of the jet stream is a catalyst, too. High methane releases follow fracturing of the jet stream, accounting for a previous rise in regional temperature up to 16 C in less than 20 years (Paul Beckwith via video on 19 December 2013).

30. Research indicates that "fewer clouds form as the planet warms, meaning less sunlight is reflected back into space, driving temperatures up further still" (Nature, January 2014)

31. "Thawing permafrost promotes microbial degradation of cryo-sequestered and new carbon leading to the biogenic production of methane" (*Nature Communications*, February 2014). According to a paper in the 21 October 2015 issue of the *Proceedings of the National Academy of Sciences*,: "The observed DOC [dissolved organic carbon] loss rates are among the highest reported for permafrost carbon and demonstrate the potential importance of LMW [low–molecular-weight] DOC in driving the rapid metabolism of Pleistocene-age permafrost carbon upon thaw and the outgassing of CO2 to the atmosphere by soils and nearby inland waters."

32. Over the tropical West Pacific there is a natural, invisible hole extending over several thousand kilometres in a layer that prevents transport of most of the natural and man-made substances into the stratosphere by virtue of its chemical composition. Like in a giant elevator, many chemical compounds emitted at the ground pass thus unfiltered through this so-called "detergent layer" of the atmosphere.~ Global methane emissions from wetlands are currently about 165 teragrams (megatons metric) each year. This research estimates that annual emissions from these sources will increase by between 17 and 260 megatons annually. By comparison, the total annual methane emission from all sources (including the human addition) is about 600 megatons each year. (*Nature Geoscience*, February 2014)

33. "Volcanologist Bill McGuire describes how rapid melting of glaciers and ice sheets as a result of climate change could trigger volcanoes, earthquakes, and tsunamis" (13 February 2014 issue of *The Guardian*. According to a paper published online in the 5 February 2015 issue of *Geophysical Research Letters*, "underwater volcanoes defy expectations and erupt in bursts rather than a slow pace."

34. Deep ocean currents apparently are slowing. According to one of the authors of the paper, "we're likely going to see less uptake of human produced, or anthropogenic, heat and carbon dioxide by the ocean, making this a positive feedback loop for climate change." Because this phenomenon contributed to cooling and sinking of the Weddell polynya: "it's always possible that the giant polynya will manage to reappear in the next century. If it does, it will release decades-worth of heat and carbon from the deep ocean to the atmosphere in a pulse of warming." (*Nature Climate Change*, February 2014; model results indicate "large spatial redistribution of ocean carbon," as reported in the March 2014 issue of the *Journal of Climate*)

35. Increased atmospheric carbon dioxide causes soil microbes to produce more carbon dioxide (Science, 2 May 2014)

36. Reductions in seasonal ice cover in the Arctic "result in larger waves, which in turn provide a mechanism to break up sea ice and accelerate ice retreat" (*Geophysical Research Letters*, 5 May 2014). Further corroboration is found in the 27 March 2015 issue of *Geophysical Research Letters*.

37. A huge hidden network of frozen methane and methane gas, along with dozens of spectacular flares firing up from the seabed, has been detected off the **North Island of New Zealand** (preliminary results reported in the 12 May 2014 issue of the *New Zealand Herald*). The first evidence of widespread active methane seepage in the Southern Ocean, off the sub-Antarctic island

of South Georgia, was subsequently reported in the 1 October 2014 issue of *Earth and Planetary Science Letters*.

38. As reported in the 8 June 2014 issue of *Nature Geoscience*, rising global temperatures could increase the amount of carbon dioxide naturally released by the world's oceans, fuelling further climate change

39. As global-average temperature increases, "the concentrations of water vapor in the troposphere will also increase in response to that warming. This moistening of the atmosphere, in turn, absorbs more heat and further raises the Earth's temperature." As reported in the paper's abstract: "Our analysis demonstrates that the upper-tropospheric moistening observed over the period 1979–2005 cannot be explained by natural causes and results principally from an anthropogenic warming of the climate. By attributing the observed increase directly to human activities, this study verifies the presence of the largest known feedback mechanism for amplifying anthropogenic climate change." (*Proceedings of the National Academy of Sciences*, 12 August 2014) According to a July 2015 report in *Skeptical Science*, "water vapour feedback roughly doubles the amount of warming caused by CO2. So if there is a 1°C change caused by CO2, the water vapour will cause the temperature to go up another 1°C. When other feedback loops are included, the total warming from a potential 1°C change caused by CO2 is, in reality, as much as 3°C."

40. Soil microbial communities release unexpectedly more carbon dioxide when temperatures rise (*Nature*, 4 September 2014). As a result, "substantial carbon stores in Arctic and boreal soils could be more vulnerable to climate warming than currently predicted."

41. "During the last glacial termination, the upwelling strength of the southern polar limb of the Atlantic Meridional Overturning Circulation varied, changing the ventilation and stratification of the high-latitude Southern Ocean. During the same period, at least two phases of abrupt global sea-level rise—meltwater pulses—took place." In other words, when the ocean around Antarctica became more stratified, or layered, warm water at depth melted the ice sheet faster than when the ocean was less stratified. (*Nature Communications*, 29 September 2014) Robert Scribbler refers to AMOC as "the heartbeat of the world ocean system." As reported in the 23 March 2015 online issue of *Climatic Change*, the slowing of the AMOC is "exceptional" and is tied to melting ice in Greenland. This twentieth-century slowdown apparently is unique, at least within the last thousand years.

42. "Open oceans are much less efficient than sea ice when it comes to emitting in the far-infrared region of the spectrum. This means that the Arctic Ocean traps much of the energy in far-infrared radiation, a previously unknown phenomenon that is likely contributing to the warming of the polar climate." (*Proceedings of the National Academy of Sciences*, November 2014)

43. Dark snow is no longer restricted to Greenland. Rather, it's come to much of the northern hemisphere, as reported in the 25 November 2014 issue of the *Journal of Geophysical Research*. Eric Holthaus's description of this phenomenon in the 13 January 2015 edition of *Slate* includes a quote from one of the scientists involved in the research project: "The climate models need to be adding in a process they don't currently have, because that stuff in the atmosphere is having a big climate

effect." In other words, as with the other major self-reinforcing feedback loops, dark snow is not included in contemporary models.

44. The "representation of stratospheric ozone in climate models can have a first-order impact on estimates of effective climate sensitivity." (*Nature Climate Change*, December 2014)

45. "While scientists believe that global warming will release methane from gas hydrates worldwide, most of the current focus has been on deposits in the Arctic. This paper estimates that from 1970 to 2013, some 4 million metric tons of methane has been released from hydrate decomposition off Washington [state]. That's an amount each year equal to the methane from natural gas released in the 2010 Deepwater Horizon blowout off the coast of Louisiana, and 500 times the rate at which methane is naturally released from the seafloor." (*Geophysical Research Letters*, online version 5 December 2014)

46. "An increase in human-made carbon dioxide in the atmosphere could initiate a chain reaction between plants and microorganisms that would unsettle one of the largest carbon reservoirs on the planet — soil" (*Nature Climate Change*, December 2014)

47. Increased temperature of the ocean contributes to reduced storage of carbon dioxide. "Results suggest that predicted future increases in ocean temperature will result in reduced CO2 storage by the oceans" (*Proceedings of the National Academy of Sciences*, January 2015)

48. According to a paper in the 19 January 2015 issue of *Nature Geoscience*, melting glaciers contribute substantial carbon to the atmosphere, with "approximately 13% of the annual flux of glacier dissolved organic carbon is a result of glacier mass loss. These losses are expected to accelerate."

49. According to a paper in the 20 April 2015 online issue of *Nature Geoscience*, ocean currents disturb methane-eating bacteria. "We were able to show that strength and variability of ocean currents control the prevalence of methanotrophic bacteria", says Lea Steinle from University of Basel and the lead author of the study, "therefore, large bacteria populations cannot develop in a strong current, which consequently leads to less methane consumption."

50. Arctic warming is amplified by phytoplankton under greenhouse warming (*Proceedings of the National Academy of Sciences*, 12 May 2015). Temperatures in the Arctic are warming considerably faster than the global average, largely because of diminishing sea ice. According to this research, the biogeophysical effect of future phytoplankton changes amplifies Arctic warming by 20%.

51. Cryptogamic covers, which comprise some of the oldest forms of terrestrial life, have recently been found to fix large amounts of nitrogen and carbon dioxide from the atmosphere. They are sources of greenhouse gases, notably including nitrous oxide and methane, with higher temperatures and enhanced nitrogen deposition contributing to amplification (*Global Change Biology*, 7 July 2015).

52. The impact of phytoplankton is not restricted to the Arctic, either. Rather, plankton in the Southern Ocean is responsible for creating nearly half of the water droplets in the clouds during the summer, thus serving as a cooling agent (*Science Advances*, 17 July 2015).

53. "Observations show that glaciers around the world are in retreat and losing mass" (*Journal of Glaciology*, July 2015). According to the final lines of the abstract: "Glaciological and geodetic observations (~5200 since 1850) show that the rates of early 21st-century mass loss are without precedent on a global scale, at least for the time period observed and probably also for recorded history, as indicated also in reconstructions from written and illustrated documents. This strong imbalance implies that glaciers in many regions will very likely suffer further ice loss, even if climate remains stable."

54. From a paper in the 1 September 2015 issue of *Nature Communications* comes evidence that increased ocean acidification drives irreversible, large increases in nitrogen fixation and growth rates of a key group of ocean bacteria known as Trichodesmium. Trichodesmium is one of the few organisms in the ocean that can "fix" atmospheric nitrogen gas, making it available to other organisms. It is crucial because all life — from algae to whales — needs nitrogen to grow. Climate change could send Trichodesmium into overdrive, with no way to stop, thus reproducing faster and generating lots more nitrogen. Without the ability to slow down, however, the bacteria has the potential to gobble up all its available resources, which could trigger die-offs of the microorganism and the higher organisms that depend on it. The change is projected to be irreversible and large even after being moved back to lower carbon-dioxide levels for hundreds of generations. According to the abstract of the paper: "This represents an unprecedented microbial evolutionary response, as reproductive fitness increases acquired in the selection environment are maintained after returning to the ancestral environment."

55. The extinction of megafauna both at land and at sea has led to a shortage of mega manure (*Proceedings of the National Academy of Sciences*, 26 October 2015). As a result, the planet's composting and nutrient-recycling system is broken. Other factors have contributed to extinction of large animals, too, but the role of megafauna poop in ecosystem function has been little studied in the past.

56. A paper in the 26 November 2015 issue of *Science* reports the rapid increase in coccolithophores in response to increased carbon dioxide. These algae make it more difficult to remove carbon dioxide from the atmosphere in the short term.

57. The "apparent sensitivity of respiration to night-time temperatures, which are projected to increase faster than global average temperatures, suggests that C stored in tropical forests may be vulnerable to future warming," according to a paper published in the 7 December 2015 online issue of *Proceedings of the National Academy of Sciences*. The paper suggests that hotter nights may actually wield much greater influence over the planet's atmosphere than hotter days — and could eventually lead to more carbon flooding the atmosphere.

58. According to a paper in the 18 December 2015 issue of *Science Advances*, "Many large tropical trees with sizeable contributions to carbon stock rely on large vertebrates for seed dispersal and regeneration, however many of these frugivores are threatened by hunting, illegal trade, and habitat loss. … we found that defaunation has the potential to significantly erode carbon storage even when only a small proportion of large-seeded trees are extirpated." In other words, climate change that causes loss of habitat for animals reduces the ability of tropical forests to store carbon, thus creating a self-reinforcing feedback loop.

59. From the 22 December 2015 online issue of the Proceedings of the *National Academy of Sciences* comes a paper pointing out the link between Arctic sea ice and regional precipitation. The abstract of the paper includes the following lines: "Global climate is influenced by the Arctic hydrologic cycle, which is, in part, regulated by sea ice through its control on evaporation and precipitation. … We find that the independent, direct effect of sea ice on the increase of the percentage of Arctic sourced moisture … likely result in increases of precipitation and changes in energy balance, creating significant uncertainty for climate predictions." In other words, to quote the lead author of the paper, "If you remove sea ice from an Arctic area, you open up the ocean to the atmosphere, and evaporate more water, which forms precipitation."

60. The terrestrial biosphere is a net source of greenhouse gases to the atmosphere, according to a paper in the 10 March 2016 issue of *Nature*: "We find that the cumulative warming capacity of concurrent biogenic methane and nitrous oxide emissions is a factor of about two larger than the cooling effect resulting from the global land carbon dioxide uptake from 2001 to 2010. This results in a net positive cumulative impact of the three greenhouse gases on the planetary energy budget."

61. The abstract of a paper published in the 14 March 2016 issue of *Nature Geoscience* includes these telling lines: "Ice wedges are common features of the subsurface in permafrost regions. They develop by repeated frost cracking and ice vein growth over hundreds to thousands of years. … We find that melting at the tops of ice wedges over recent decades and subsequent decimetre-scale ground subsidence is a widespread Arctic phenomenon. Although permafrost temperatures have been increasing gradually, we find that ice-wedge degradation is occurring on sub-decadal timescales. … We predict that ice-wedge degradation and the hydrological changes associated with the resulting differential ground subsidence will expand and amplify in rapidly warming permafrost regions."

Vladimir Romanovsky, a UAF geophysics professor who monitored ice wedge degradation for the study at a site in Canada, said the overall conclusions of the study were striking. In an interview coincident with publication of the paper, he said, "We were not expecting to see these dramatic changes. … Whatever is happening, it's something new for at least the last 60 years in the Arctic."

62. Increased atmospheric carbon dioxide makes rainwater more acidic. The result is a relatively weak form or carbonic acid. The rain falls on limestone and related carbonate rocks, thus releasing carbon dioxide from the rocks into the atmosphere. The stronger the carbonic acid, the more the limestone dissolves, hence releasing more carbon dioxide.

63. According to a paper published 22 June 2016 in *Nature Communications*, there's a strawberry-colored algae blooming in the northern reaches of Earth. As more algae bloom, more snow thaws. And, nourished by the unfrozen water, even more of the microorganisms are able to grow. And so on. It's a self-reinforcing feedback loop of the irreversible variety. I'll quote from the abstract: "Red snow, a common algal habitat blooming after the onset of melting, plays a crucial role in decreasing albedo. Our data reveal that red pigmented snow algae are cosmopolitan as well as independent of location-specific geochemical and mineralogical factors. The patterns for snow algal diversity, pigmentation and, consequently albedo, are ubiquitous across the Arctic and the reduction in albedo accelerates snow melt and increases the time and area of exposed bare ice. We estimated that the overall decrease in snow albedo by red pigmented snow algal blooms over the course of one melt season can be 13%. This will invariably result in higher melt rates."

64 and 65. A study published in the 11 July 2016 online issue of *Nature* thoroughly documents one of the most profound planetary changes yet to be caused by a warming climate: The distribution of clouds all across Earth has shifted. Specifically, the shift has expanded subtropical dry zones, located between around 20 and 30 degrees latitude in both hemispheres, and also by raising cloud tops. Each of these changes worsens overall planetary warming. According to a story in the Washington Post accompanying the paper's release, each of these two changes to clouds is a positive feedback to climate change.

66. A paper in the 25 July 2016 online issue of *Nature Geoscience* confirms and quantifies the long-held suspicion that the ability of land plants to store carbon declines as Earth warms. The reduced storage of carbon leads to higher atmospheric carbon dioxide, thus increasing Earth's temperature and contributing to a self-reinforcing feedback loop.

67. Arctic drilling was fast-tracked by the Obama administration during the summer of 2012.

68. Supertankers are taking advantage of the slushy Arctic, demonstrating that every catastrophe represents a business opportunity, as pointed out by Professor of journalism Michael I. Niman and picked up by Truth-out (*ArtVoice*, September 2013)

69. As jet planes burn fuel and release carbon dioxide, the atmosphere warms and causes head winds to build up (*Nature Climate Change*, published online 13 July 2015).

As nearly as I can distinguish, **only the latter three feedback processes are reversible** at a temporal scale relevant to our species. Once you pull the tab on the can of beer, there's no keeping the carbon dioxide from bubbling up and out. These feedbacks are not additive, they are multiplicative: They not only reinforce within a feedback, the feedbacks also reinforce among themselves (as realized even by *Business Insider* on 3 October 2013). Now that we've entered the era of expensive oil, I can't imagine we'll voluntarily terminate the process of drilling for oil and gas in the Arctic (or anywhere else). Nor will we willingly forgo a few dollars by failing to take advantage of the long-sought Northwest Passage or make any attempt to slow economic growth.

See How Far We've Come

Never mind that American naturalist George Perkins Marsh predicted anthropogenic climate change as a result of burning fossil fuels in 1847. Never mind the warning issued by filmmaker Frank Capra in 1958 or the one issued by U.S. President Lyndon Baines Johnson in February 1965 or the one issued by Austrian philosopher Ivan Illich in his 1973 article in Le Monde: "the impact of industrially packaged quanta of energy on the social environment tends to be degrading, exhausting, and enslaving, and these effects come into play even before those which threaten the pollution of the physical environment and the extinction of the (human) race." Never mind the warning and plug for geo-engineering issued by U.S. President Lyndon B. Johnson's Science Advisory Committee in 1965: "The climate changes that may be produced by the increased CO2 content could be deleterious from the point of view of human beings. The possibilities of deliberately bringing about countervailing climatic changes therefore need to be thoroughly explored." Never mind the warning from Walter Cronkite on the nightly news in 1980. Never mind the **1986 warning** from NASA's Robert Watson of "human misery in a few decades" and **eventual human extinction as a result of climate change**. Never mind the arguments from policy advisers to Ronald Reagan and George H.W. Bush, as report in the 3 December 2015 issue of Washington Post: "Global warming will have 'profound consequences,' one document warns, and the United States 'cannot wait' until all scientific questions are resolved before taking action." Never mind the warning from the United Nations in 1989: "entire nations could be wiped off the face of the Earth by rising sea levels if the global warming trend is not reversed by the year 2000." Never mind the "regime shift" that occurred in the 1980s, as reported in a 23 November 2015 paper in *Global Change Biology*. Never mind that climate risks have been underestimated for the last 20 Years, or that the IPCC's efforts have failed miserably, or that **the IPCC uses a faulty, conservative approach**, as pointed out in the September 2014 issue of *American Meteorological Society*. After all, climate scientist Kevin Anderson tells us what I've known for years: **politicians and the scientists writing official reports on climate change are lying, and we have less time than most people can imagine**. (Consider the minor example of the U.S. Environmental Protection Agency "underestimating" by 100 to 1,000 times the methane release associated with hydro-fracturing to extract natural gas, as reported in the 14 April 2014 issue of the *Proceedings of the National Academy of Sciences*.) Never mind James Hansen's 10-year warning in 2006. Never mind David Wasdell pointing out in 2008 that we must have a period of negative radiative forcing merely to end up with a stable, non-catastrophic climate system. Never mind that even the *Atlantic* is displaying "five charts about climate change that should have you very, very worried." Never mind that atmospheric carbon dioxide is affecting satellites. Never mind that even the occasional economic analyst is telling climate scientists to be persuasive, be brave, and be arrested. Never mind that Peruvian ice requiring 1,600 years to accumulate has melted in the last 25 years, according to a paper in the 4 April 2013 issue of Science. And never mind that summer warming in the interior of large continents in the northern hemisphere has outstripped model predictions in racing to 6-7 C since the last Glacial Maximum, according to a paper that tallies temperature rise in China's interior in the 15 May 2013 issue of the *Proceedings of the National Academy of Sciences*. And finally, never mind that **the IPCC's projections have been revealed as too conservative time after time**, including low-balling the impact of emissions, as pointed out in the 9 March 2014 issue of Nature Climate Change. On 24 March 2014, renowned climate scientist Michael Mann commented on climate change as reported in the IPCC's Fifth Assessment: "**It's not far-off in the future and it's not exotic creatures — it's us and now**." On 29 July 2015, Michael Mann

accepted the work of James Hansen and colleagues and concluded climate change had gone exponential. He continues with a mix of fantasy-inspired hope and very conservative reality, but he agrees that climate change has hit the "tipping point" indicating exponential change. As the Fifth Assessment admits, climate change has already left its mark "on all continents and across the oceans."

Climate-change projections have vastly underestimated the role that clouds play, meaning future warming could be far worse than is currently projected, according to research published in the 8 April 2016 edition of *Science*. According to the paper's abstract: "Global climate model (GCM) estimates of the equilibrium global mean surface temperature response to a doubling of atmospheric CO2, measured by the equilibrium climate sensitivity (ECS), range from 2.0° to 4.6°C. Clouds are among the leading causes of this uncertainty. Here we show that the ECS can be up to 1.3°C higher in simulations where mixed-phase clouds consisting of ice crystals and supercooled liquid droplets are constrained by global satellite observations. The higher ECS estimates are directly linked to a weakened cloud-phase feedback arising from a decreased cloud glaciation rate in a warmer climate."

Never mind all that: Future temperatures likely will be at the higher end of the projected range because the forecasts are all too conservative and also because climate negotiations won't avert catastrophe. In addition, according to a paper in the 29 June 2016 issue of *Geophysical Research Letters*, climate sensitivity increases as the planet warms. Specifically, according to the paper's abstract: "Future global warming from anthropogenic greenhouse gas emissions will depend on climate feedbacks, the effect of which is expressed by climate sensitivity … We obtain constrained estimates of CO2 and climate sensitivity before and during the PETM and of the PETM carbon input amount and nature. Sensitivity increased … into the PETM."

Through late March 2013, global oceans have risen approximately ten millimetres per year during the last two years. This rate of rise is over three times the rate of sea level rise during the time of satellite-based observations from 1993 to the present. Ocean temperatures are rising, and have been impacting global fisheries for four decades, according to the 16 May 2013 issue of *Nature*. According to the World Meteorological Organization's July 2014 report, the world is nearly five times as prone to disaster as it was 40 years ago. The number and economic cost of weather-related disasters has increased during each of the last four decades.

Actually, catastrophe is already here, although it's not widely distributed in the United States. Well, not yet, even though the continental U.S. experienced its highest temperature ever in 2012, shattering the 1998 record by a full degree Fahrenheit. But the east coast of North America experienced its hottest water temperatures all the way to the bottom of the ocean. The epic dust bowl of 2012 grew and grew and grew all summer long. As pointed out in the March 2004 issue of Geophysical Research Letters, disappearing sea ice is expectedly contributing to the drying of the western United States (more definitive research on the topic appeared in the December 2005 issue of *Earth Interactions*). Equally expectedly, the drought arrived 40 years early.

Researchers compared drought predictions for the second half of the 21st century with reconstructions of drought conditions dating back to the 11th century and found that the Central Plains and Southwest U.S. could experience the driest conditions in nearly a millennium. The results were published 12 February 2016 in *Science Advances*. The abstract concludes: "Notably, future drought risk will likely exceed even the driest centuries of the Medieval Climate Anomaly (1100-1300 CE) in both moderate (RCP 4.5) and high (RCP 8.5) future emissions scenarios, leading to drought conditions without precedent during the last millennium."

Even James Hansen and Makiko Sato are asking whether the loss of ice on Greenland has gone exponential (while ridiculously calling for a carbon tax to "fix" the "problem"), and the tentative answer is not promising, based on very recent data, including a nearly **five-fold increase in melting of Greenland's ice since the 1990s and a stunning melting of 98 percent of Greenland's ice surface** between 8 and 15 July 2012. The explanation for this astonishing event comes from a paper published in the 10 June 2014 issue of the *Proceedings of National Academy of Sciences*: "The same mechanism drove two widespread melt events that occurred over 100 years apart, in 1889 and 2012. We found that black carbon from forest fires and rising temperatures combined to cause both of these events." Further elucidation is provided in the 14 June 2014 issue of *Journal of Geophysical Research: Atmospheres*. The mainstream media are finally taking notice, with the 18 July 2013 issue of *Washington Post* reporting the ninth highest April snow cover in the northern hemisphere giving way to the third lowest snow cover on record the following month (relevant records date to 1967, and the article is headlined, "Snow and Arctic sea ice extent plummet suddenly as globe bakes"). Even the 5 August 2015 issue of *Rolling Stone* includes an article headlined, "The Point of No Return: Climate Change Nightmares Are Already Here." According to a paper in the 9 July 2016 issue of *Geophysical Research Letters*, the Greenland Ice Sheet lost one trillion tons of water due to melt during the four-year period from 2011 through 2014. That's about double the typical rate of loss during the 1990s through mid-2000s. Subsequently, Greenland's contribution to sea-level rise also doubled, meaning that Greenland alone contributed 0.75 mm of sea-level rise every year during the 2011 to 2014 period.

On a particularly dire note for humanity, climate change causes early death of 400,000 people each year causes early death of five million people each year. Adding to the misery are interactions between various aspects of environmental decay. For example, warming in the Arctic is causing the release of toxic chemicals long trapped in the region's snow, ice, ocean and soil, according to research published in the 24 July 2011 issue of Nature Climate Change.

Greenhouse-gas emissions keep rising, and keep setting records. According to 10 June 2013 report by the International Energy Agency, the horrific trend continued in 2012, when carbon dioxide emissions set a record for the fifth consecutive year. The trend puts disaster in the cross-hairs, with **the ever-conservative International Energy Agency claiming we're headed for a temperature in excess of 5 C.** The *U.S. State of the Climate* in 2013, published 17 July 2014 as a supplement to the July 2014 issue of the Bulletin of the American Meteorological Society, concludes:

- Ocean surface continues to warm
- Sea levels reach a record high

- Glaciers retreat for the 24th consecutive year
- Greenhouse gases continue to climb
- The planet's surface remains near its warmest
- Warm days are up, cool nights are down

Completely contrary to the popular contrarian myth, global warming has accelerated, with more overall global warming in the 15 years up to March 2013 than the prior 15 years. While adhering to the impossible-to-achieve and nonsensical political target of 2 C, a paper in the 3 July 2015 issue of *Science* points out that "as far down as 700 metres the water temperatures have risen, which has forced some species to migrate." A related paper in the 9 July 2015 issue of *Science* found a majority of the heating in the ocean after 2003 was occurring in the Western Pacific and the Indian Oceans 100 to 300 meters below the surface. Seventeen months later, *Science* finally catches up in their 22 August 2014 issue. This warming has resulted in about **90% of overall global warming going into heating the oceans**, and the oceans have been warming dramatically, according to a paper published in the March 2013 issue of *Geophysical Research Letters*. A paper in the 20 March 2014 issue of *Environmental Research Letters* points out that surface temperatures poorly measure global warming. Even *Slate* magazine figured it out by 5 November 2013, and *The Guardian*'s headline from 13 November 2013 announces, "Global warming since 1997 more than twice as fast as previously estimated, new study shows." About 30% of the ocean warming over the past decade has occurred in the deeper oceans below 700 meters, which is unprecedented over at least the past half century. According to a paper in the 1 November 2013 issue of *Science*, **the rate of warming of the Pacific Ocean during the last 60 years is 15 times faster than at any time during the last 10,000 years**. By the end of 2013, the fourth-hottest year on record, the deep oceans were warming particularly rapidly and NASA and NOAA reported no pause in the long-term warming trend. "In 2013 ocean warming rapidly escalated, rising to a rate in excess of 12 Hiroshima bombs per second — over three times the recent trend." **When the heat going into the ocean begins to influence land-surface temperatures, "rapid warming is expected**," according to a paper published 9 February 2014 in *Nature Climate Change*. According to James Wight, writing for *Skeptical Science* on 12 March 2014, "Earth is gaining heat faster than ever." A paper published in the 18 January 2016 online edition of *Nature Climate Change* found that "more than 90 percent of the heat trapped by greenhouse gas pollution since the 1970s has wound up in the oceans, and … a little more than a third of that seafaring heat has worked its way down to depths greater than 2,300 feet (700 meters)." The bottom line from the paper's abstract: "nearly half of the industrial-era increases in global OHC [Ocean Heat Content] have occurred in recent decades, with over a third of the accumulated heat occurring below 700 m and steadily rising." Even land-surface records do not reveal a hiatus in warming, as reported in the 3 June 2015 issue of *Science*. A paper in the 20 June 2016 issue of *Nature Climate Change* concludes that the so-called slowdown in global warming during the early 2000s is attributable to two factors, a negative phase of the Pacific Decadal Oscillation and also increased aerosols from Chinese industrial activity. The latter is the significant contribution of this study, and it demonstrates the two-sided coin associated with industrial activity. Specifically, the greenhouse gases that serve as heat blankets over Earth are accompanied by aerosols, especially those associated with burning dirty coal, which reflect incoming sunlight. The latter phenomenon has been largely understudied and incorrectly viewed as relatively unimportant.

Coincident with profound ocean warming, **the death spiral of Arctic sea ice is well under way**. As reported in the 22 February 2014 issue of *Geophysical Research Letters*, sea-surface temperatures have increased 0.5 to 1.5 C during the last decade. "**The seven lowest September sea ice extents in the satellite record have all occurred in the past seven years**."

In the category of myth busting comes recent research published in the August 2013 issue of *Proceedings of the National Academy of Sciences*. Contrary to the notion that changing solar radiation is responsible for rising global temperature, the amount of solar radiation passing through Earth's atmosphere and reaching the ground globally peaked in the 1930s, substantially decreased from the 1940s to the 1970s, and changed little after that. Indeed, the current solar activity cycle is the weakest in a century. In addition, according to a paper in the 22 December 2013 issue of *Nature GeoScience*, climate change has not been strongly influenced by variations in heat from the sun.

Global loss of sea ice matches the trend in the Arctic. It's down, down, and down some more, with the five lowest values on record all happening in the last seven years (through 2012). As reported in a June 2013 issue of *Science*, **the Antarctic's ice shelves are melting from below**. When interviewed for the associated article in the 13 June 2013 issue of *National Geographic*, scientists expressed surprise at the rate of change. Colour me shocked. Three months later, the 13 September 2013 issue of *Science* contains another surprise for mainstream scientists: The Pine Island Glacier is melting from below as a result of warming seawater. And four months after that dire assessment, the massive glacier was melting irreversibly, according to a paper in the 12 January 2014 issue *of Nature Climate Change*.

Earth may well be headed for an ocean nearly devoid of life. All life on Earth arose from the ocean. As the ocean goes, so do we. According to Robert Scribbler on 28 August 2015, shades of a Canfield ocean induced by hydrogen sulfide in "odd-smelling, purple-colored waves appearing along the Oregon coastline are a sign that it may be starting to happen." Scribbler quotes Peter Ward's book, Under a Green Sky:

- Finally we look out on the surface of the great sea itself, and as far as the eye can see there is a mirrored flatness, an ocean without whitecaps. Yet that is not the biggest surprise. From shore to the horizon, there is but an unending purple colour – a vast, flat, oily purple, not looking at all like water, not looking anything of our world. No fish break its surface, no birds or any other kind of flying creatures dip down looking for food. The purple colour comes from vast concentrations of floating bacteria, for the oceans of Earth have all become covered with a hundred-foot-thick [30m] veneer of purple and green bacterial soup.

The 28 August 2015 edition of *Beach Connection* attributes the purple waves to an abundance of a jellyfish-like creature called a salp. The jury is still out.

Then See Where we're Going

The climate situation is much worse than I've led you to believe, and is accelerating far more rapidly than accounted for by models. Even the U.S. Centers for Disease Control and Prevention acknowledges, in a press release dated 6 June 2013, **potentially lethal heat waves on the near horizon**. Piling on a month later, the World Meteorological Organization pointed out that Earth experienced unprecedented recorded climate extremes during the decade 2001-2010, contributing to more than a **2,000 percent increase in heat-related deaths**. Even the United States federal government admits, in a report dated 4 April 2016, that climate change is making Americans sick. Specifically, the report concludes that "global warming will make the air dirtier, water more contaminated and food more tainted. It warned of diseases such as those spread by ticks and mosquitoes, longer allergy seasons, and thousands of heat wave deaths. Environmental Protection Agency chief Gina McCarthy said if that's not enough, climate change affects people's mental health, too."

On the topic of the spread of deadly disease, a paper in the 18 January 2016 online issue of *Trends in Parasitology* includes the following lines in the abstract: "Intensification of food production has the potential to drive increased disease prevalence in food plants and animals. Microsporidia are diversely distributed, opportunistic, and density-dependent parasites infecting hosts from almost all known animal taxa. They are frequent in highly managed aquatic and terrestrial hosts, many of which are vulnerable to epizootics, and all of which are crucial for the stability of the animal–human food chain. Mass rearing and changes in global climate may exacerbate disease and more efficient transmission of parasites …. strong evidence exists for an increasing prevalence of microsporidiosis in animals and humans, and for sharing of pathogens across hosts and biomes."

A paper in the 10 June 2016 issue of *Science Advances* points out that the effects of climate change in one place can radiate all over the world. The abstract of the paper concludes: "Since 2001, the economic connectivity has augmented in such a way as to facilitate the cascading of production loss. The influence of this structural change has dominated over the effect of the comparably weak climate warming during this decade. Thus, particularly under future warming, the intensification of international trade has the potential to amplify climate losses if no adaptation measures are taken."

Although climate change's heat — not cold — is the real killer, according to research published in the December 2013 issue of the Journal of *Economic Literature*, swings in temperature may be even more lethal than high temperatures. Specifically, research published in the 29 January 2014 issue of the *Proceedings of the Royal Society of London* indicates insects are particularly vulnerable to temperature swings.

Ice sheet loss continues to increase at both poles, and **warming of the West Antarctic Ice Sheet is twice the earlier scientific estimate**. Arctic ice at all-time low, half that of 1980, and the Arctic lost enough sea ice to cover Canada and Alaska in 2012 alone. In short, summer ice in the Arctic is nearly gone - an event that last occurred at least about 2.6 million years ago, approximately coincident with the appearance of the genus Homo on Earth. Among the consequences of declining Arctic ice is extremes in cold weather in northern continents (thus illustrating why "climate change" is a better term than "global warming"). In a turn surprising only to mainstream climate scientists, **Greenland ice is melting rapidly**.

The Eemian interglacial period that began some 125,000 years ago is often used as a model for contemporary climate change. However, as pointed out in the 5 June 2012 issue of Geophysical Research Letters, the Eemian differed in essential details from modern climatic conditions. The Eemian is a poor analog for contemporary climate change, notably with respect to the rapid, ongoing disappearance of summer ice in the Arctic.

Even the conservative International Energy Agency has thrown in the towel, concluding that "renewable" energy is not keeping up with the old, dirty standard sources. As a result, the International Energy Agency report dated 17 April 2013 indicates the development of low-carbon energy is progressing too slowly to limit global warming.

The Arctic isn't Vegas — **what happens in the Arctic doesn't stay in the Arctic** — it's the planet's air conditioner. In fact, as pointed out 10 June 2013 by research scientist Charles Miller of NASA's Jet Propulsion Laboratory: "Climate change is already happening in the Arctic, faster than its ecosystems can adapt. Looking at the Arctic is like looking at the canary in the coal mine for the entire Earth system." In addition, "average summer temperatures in the Canadian Arctic are now at the highest they've been for approaching 50,000 years" (and perhaps up to 120,000 years) according to a paper published online 23 October 2013 in *Geophysical Research Letters*. Regional warming is accelerating because the Arctic is rapidly losing ice, according to a paper published in the October 2014 issue of *The Open Atmospheric Science Journal*. "Barrow, the most northerly community in Alaska, observed a warming of 1.51°C for the time period of 1921-2012. This represents about twice the global value, and is in agreement with the well-known polar amplification. For the time period of 1979-2012, … a mean annual temperature increase of 2.7°C is found, an accelerated increase of warming over the prior decades. … The large amount of open water off the northern coast of Alaska in autumn was accompanied by an increase of the October temperature at Barrow by a very substantial 7.2°C over the 34 year time period."

On the topic of rapidity of change, a paper in the August 2013 issue of *Ecology Letters* points out that rates of projected climate change dramatically exceed past rates of climatic niche evolution among vertebrate species. In other words, vertebrates cannot evolve or adapt rapidly enough to keep up with ongoing and projected changes in climate. Furthermore, microbes in soil — organisms that exert enormous influence over our planet's carbon cycle — may not be as adaptable to climate change as most scientists have presumed, according to a paper published 2 March 2016 in *PLOS One*: "This study capitalized on a long-term reciprocal soil transplant experiment to examine the response of dryland soils to climate change. The two transplant sites were separated by 500 m of elevation on the same mountain slope in eastern Washington state, USA, and had similar plant species and soil types. We resampled the original 1994 soil transplants and controls, measuring CO2 production, temperature response, enzyme activity, and bacterial community structure after 17 years." The bottom line, according to a write-up at Phys.org: "The scientists found less adaptability than they expected, even after 17 years. While the microbial make-up of the samples did not change much at all, the microbes in both sets of transplanted soils retained many of the traits they had in their "native" climate, including to a large degree their original rate of respiration." In other words,

even the smallest of organisms are not able to keep up with changes in climate. Rather, biological activity in soils is relatively constant in the face of large rapid changes in climate.

How critical is Arctic ice? Whereas nearly 80 calories are required to melt a gram of ice at 0 C, adding 80 calories to the same gram of water at 0 C increases its temperature to 80 C. Anthropogenic greenhouse-gas emissions add more than 2.5 trillion calories to Earth's surface every hour (ca. 3 watts per square meter, continuously).

Interactions among feedbacks produce non-linear results. The sudden, cascading nature of non-linearities is explained well in a paper published in the 11 November 2015 issue of *Interface*. Interactions among feedbacks are particularly obvious in the Arctic. For example, as reported in the 5 May 2014 issue of *Geophysical Research Letters*, "further reductions in seasonal ice cover in the future will result in larger waves, which in turn provide a mechanism to break up sea ice and accelerate ice retreat." Another example in the region comes from the 10 September 2015 issue of *Geophysical Research Letters* with a paper titled, "Rising methane emissions from northern wetlands associated with sea ice decline." As is clear from the title, the paper demonstrates "that rising wetland methane emissions are associated with sea ice retreat." More evidence of these types of interactions is on the rise. A paper in the 5 October 2015 issue of *Philosophical Transactions of the Royal Society A* takes the average of two conservative warming scenarios offered by the IPCC and concludes frozen soil carbon — found primarily in the form of methane — responds rapidly to warming. Specifically, "for every one degree Celsius of global warming, the amount of permafrost carbon that enters the atmosphere is equivalent to 1.5 years of global carbon dioxide emissions." Yet another example of interactions between self-reinforcing feedback loops was reported in the 29 October 2015 issue of *Scientific Reports*. In this case, tundra fires were blamed for thawing permafrost. More fires means more carbon in the atmosphere. Ditto for methane release from thawing permafrost. So, more fires means more methane release from thawing permafrost, which creates enhanced conditions for more and larger fires. A paper published in the 10 November 2015 online issue of *Scientific Reports* provides an example between formation of sea ice and methane release: "Arctic amplification of global warming has led to increased summer sea ice retreat, which influences gas exchange between the Arctic Ocean and the atmosphere where sea ice previously acted as a physical barrier. Indeed, recently observed enhanced atmospheric methane concentrations in Arctic regions with fractional sea-ice cover point to unexpected feedbacks in cycling of methane." A paper in the 23 November 2015 issue of Journal of *Geophysical Research: Earth Surface* further elucidates the interaction between wildfire and permafrost melt: "Climate warming is shown to be the dominant factor for permafrost reduction. The warming trend of climate reduces permafrost extent in this region from 67% at present to 2% by 2100. …. Since active layer is thicker after a fire and cannot recover in most of the areas, the fire effects on active layer are widespread. On average, fires thickens (sic) active layer by about 0.5 m. The fire effects on active layer increased significantly after 1990 due to climate warming." The January 2016 issue *of Annals of Applied Bio-Sciences* includes a paper titled, "Positive feedback between climate change, forest pests and the carbon cycle." This is one of those rare cases in which the title tells the story. This is yet another example of an interaction among self-reinforcing feedback mechanisms.

According to a paper in the 22 February 2016 online issue of *Geophysical Research Letters*, "permafrost thaw is equally important as fire history to explain" changes in percent tree cover (PTC) during the 2000-2014 period. In addition, "at the southern margin of the permafrost zone, PTC loss due to permafrost thaw outweighs PTC gain from post fire regrowth. These findings emphasize the importance of permafrost thaw in controlling regional boreal forest changes over the last decade."

Ocean acidification associated with increased atmospheric carbon dioxide is proceeding at an unprecedented rate — the fastest in 300 million years — leading to great simplification of ecosystems, and capable of triggering mass extinction by itself. **Already, half the Great Barrier Reef has died during the last three decades** and the entire marine food web is threatened. As with many attributes, the Arctic Ocean leads the way in acidification. Similarly to the lag in temperature relative to increase greenhouse gas emissions, changes in ocean acidity lag behind alterations in atmospheric carbon dioxide, as reported in the 21 February 2014 issue of *Environmental Research Letters*. Further adding to the interactions involving ocean acidification comes from a paper in the 18 April 2016 issue of *Nature Geoscience* reporting that ocean acidification is an important consequence of the release of carbon dioxide into the atmosphere from fossil fuel burning. Specifically, when excess atmospheric CO2 reacts with seawater it forms carbonic acid, which, in turn, "acidifies" the ocean, causing dramatic changes to ocean ecosystems. The Arctic Ocean is particularly sensitive to such changes. This latest study proposes a novel mechanism for Arctic Ocean acidification involving release and subsequent breakdown of organic matter from thawing permafrost and carbon-rich river runoff in seawater. In other words, melting of permafrost on land leads to accelerating acidification of the ocean.

A study published in the 18 April 2016 online issue of *Nature Geoscience* indicates a strong contribution of freshwater and terrestrial carbon to acidification of the East Siberian Arctic Shelf. The study includes Igor Semiletov and Natalia Shakhova as co-authors, and it indicates the interaction among the self-reinforcing feedback loops studied, freshwater melt, permafrost, and ocean acidification.

Observations made since 1999 indicate that in some locations, acidity has already surged past levels researchers didn't expect to emerge until the year 2100, due in part to "extreme aragonite undersaturation." Aragonite is a form of calcium carbonate that is pervasive in the ocean. It tilts ocean chemistry toward the base level of the pH scale. Carbon in the water tilts the pH scale toward the acid level. The degree to which the water is saturated with aragonite is a marker of overall calcium levels — and a marker of acidification caused by increasing loads of carbon in the water.

Even bacteria are negatively affected by ocean acidification. According to a paper in the 11 January 2016 issue of *Nature Climate Change*, these miniscule organisms function as the wastewater treatment plants of the ocean. At the same time, bacteria help release nutrients such as nitrogen and phosphorous, which are essential to the food chain.

A metaanalysis of 632 published experiments published in the 12 October 2015 online edition of the *Proceedings of the National Academy of Sciences* quantified the direction and magnitude of ecological change resulting from ocean acidification and warming and found simplication as the rule.

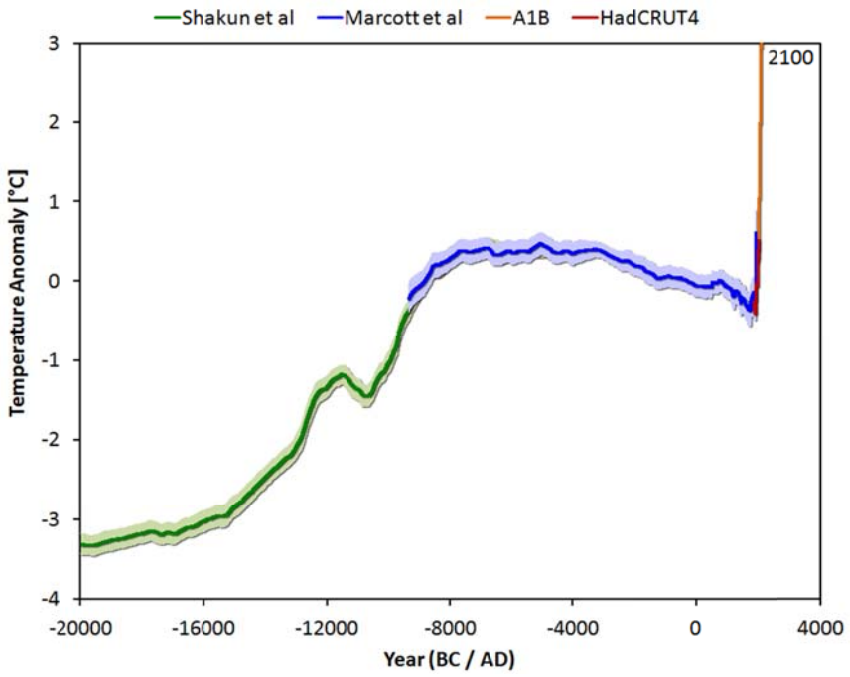
According to the abstract: “Analysis of responses in short- and long-term experiments and of studies at natural CO2 vents reveals little evidence of acclimation to acidification or temperature changes, except for microbes. This conceptualization of change across whole communities and their trophic linkages forecast a reduction in diversity and abundances of various key species that underpin current functioning of marine ecosystems.”

An increasing number of scientists agree that warming of 4 to 6 C causes a dead planet. And, they go on to say, we’ll be there much sooner than most people realize. The abstract from a paper published in the 25 November 25 2015 online issue of *Bulletin of Mathematical Ecology* includes the following lines: “the depletion of atmospheric oxygen on global scale (which, if happens, obviously can kill most of life on Earth) is another possible catastrophic consequence of the global warming, a global ecological disaster that has been overlooked.” The study shows that an increase in the water temperature of the world’s oceans of around six degrees Celsius — which some scientists predict could occur as soon as 2100 — could stop oxygen production by phytoplankton by disrupting the process of photosynthesis. According to a headline at the University Center for Atmospheric Research, “Widespread Loss of Ocean Oxygen to become Noticeable in 2030s.” The study published in Global Biogeochemical Cycles includes the following line in the abstract: “Our results clearly demonstrate the strong impact of natural climate variability on interior oxygen distributions.” Even if humans could breathe underwater, we’d need oxygen to do it.

Clive Hamilton concludes in his April 2013 book *Earthmasters* that “without [atmospheric sulphates associated with industrial activity] … Earth would be an extra 1.1 C warmer.” This estimate matches that of James Hansen and colleagues, who conclude 1.2 C cooling (plus or minus 0.2 C) as a result of atmospheric particulates (full paper in the 22 December 2011 issue of *Atmospheric Chemistry and Physics*). Both estimates are conservative relative to a paper in the 27 May 2013 issue of *Journal of Geophysical Research: Atmospheres*, which reports ~1 C temperature rise resulting from a 35-80% reduction in anthropogenic aerosols. In other words, collapse takes us directly to 2 C within a matter of weeks. A paper in the June 2016 issue of *Energy Policy* finds, “it is unlikely that the <2 °C goal can be met. Focus should be placed on expanding renewable energy as quickly as possible in order to limit warming to 2.5–3 °C." A paper published in the 14 March 2016 online issue of *Nature Geoscience* finds that Earth’s climate sensitivity is slightly higher than that assumed by global climate models and much higher than reported in other observational studies. Specifically, atmospheric aerosol loading “caused a cooling that masked approximately one-third of the continental warming due to increasing greenhouse gas concentrations over the past half-century.” Consistent with this result, another paper in the same issue of *Nature Geoscience* concludes that “air quality regulations in the Northern Hemisphere, the ocean and atmospheric circulation, and Arctic climate are inherently linked.” Specifically, measures to enhance air quality by limiting pollution have served to warm the Arctic region.

According to a paper in the 24 November 2013 issue of *Nature Climate Change*, **warming of the planet will continue long after emissions cease**. Several other academic scientists have concluded, in the refereed journal literature no less, that **the 2 C mark — long a political target, not a scientific target except among misinformed scientists — is essentially impossible** (for example, see the review paper by Mark New and colleagues published in the 29 November 2010 issue of the

Philosophical Transactions of the Royal Society A and the following line from a paper in the 12 March 2014 edition of *Review of European, Comparative & International Environmental Law*: "countries are farther from meeting their targets and the global community is farther from reaching the goal of limiting warming to 2°C above pre-industrial levels than emissions data suggest"). The German Institute for International and Security Affairs concluded 2 June 2013 that a 2 C rise in global-average temperature is no longer feasible (and *Spiegel* agrees, finally, in their 7 June 2013 issue), while **the ultra-conservative International Energy Agency concludes that, "coal will nearly overtake oil as the dominant energy source by 2017 … without a major shift away from coal, average global temperatures could rise by 6 degrees Celsius by 2050, leading to devastating climate change."** Climate scientist Paul Beckwith has indicated that Earth could warm by 6 C within a decade (he drops the "could" in reinforcing the point in a 25 November 2014 video, "**Abrupt climate change is underway already**", and he also concludes Earth could experience a 16 C temperature rise, albeit from 5 C lower than today's global-average temperature). Beckwith is quoted by Dahr Jamail in the 13 January 2015 issue of *Truthout*: **"It is my view that our climate system is in early stages of abrupt climate change that, unchecked, will lead to a temperature rise of 5 to 6 degrees Celsius within a decade or two."** If you think Beckwith's view is extreme, consider (1) a similar rise in global-average temperature based on a modelling analysis published in the December 2012 issue of *Journal of Climate*, (2) the **5°C rise in global-average temperature 55 million years ago during a span of 13 years** (reported in the 1 October 2013 issue of *Proceedings of the National Academy of Sciences*, and strongly supported by a paper in the 15 December 2014 online issue of *Nature Geoscience* before being questioned by a January 2015 paper in Climate of the Past), and also (3) the reconstruction of regional and global temperature for the past 11,300 years published in *Science* in March 2013. One result is shown in the figure below.



It's not merely scientists who know where we're going. The Pentagon is bracing for public dissent over climate and energy shocks, as reported by Nafeez Ahmed in the 14 June 2013 issue of the *Guardian*. According to Ahmed's article: "Top secret US National Security Agency (NSA) documents disclosed by the Guardian have shocked the world with revelations of a comprehensive US-based

surveillance system with direct access to Facebook, Apple, Google, Microsoft and other tech giants. New Zealand court records suggest that data harvested by the NSA's Prism system has been fed into the Five Eyes intelligence alliance whose members also include the UK, Canada, Australia and New Zealand." In short, **the "Pentagon knows that environmental, economic and other crises could provoke widespread public anger toward government and corporations" and is planning accordingly**. Such "activity is linked to the last decade of US defence planning, which has been increasingly concerned by the risk of civil unrest at home triggered by catastrophic events linked to climate change, energy shocks or economic crisis — or all three." In their 2014 *Quadrennial Defense Review*, the U.S. military concludes~: "Climate change poses another significant challenge for the United States and the world at large. As greenhouse gas emissions increase, sea levels are rising, average global temperatures are increasing, and severe weather patterns are accelerating."

Director of the Central Intelligence Agency of the United States John Brennan delivered a speech 16 November 2015 at the Opening Session of the Global Security Forum 2015, held at the Centre for Strategic and International Studies. He addressed climate change, and I apologize for his misogyny in these lines: "Mankind's relationship with the natural world is aggravating these problems and is potential source of crisis itself. Last year was the warmest on record, and this year is on track to be even warmer. Extreme weather, along with public policies affecting food and water supplies, can worsen or create humanitarian crises. Of the most immediate concern, sharply reduced crop yields in multiple places simultaneously could trigger a shock in food prices with devastating effect, especially in already-fragile regions such as Africa, the Middle East and South Asia. Compromised access to food and water greatly increases the prospect for famine and deadly epidemics."

"Climate warming is predicted to reduce omega-3, long-chain, polyunsaturated fatty acid production in phytoplankton," according to the title of a paper in the 12 April 2016 online edition of *Global Change Biology*. These essential fatty acids are vital to the health of all vertebrates, with a direct relationship to cardiovascular and immune system health, as well as neurological function, vision, and reproduction.

The situation on land is worsening, too, as a result of climate change. Rising levels of atmospheric carbon dioxide have reduced protein in goldenrod pollen, a key late-season food source for North American bees. The title of a paper in the 13 April 2016 issue of *Proceedings of the Royal Society B* tells the story: Rising atmospheric CO2 is reducing the protein concentration of a floral pollen source essential for North American bees.

The global police state has arrived, and it's accompanied by subtle changes in Earth's rotation that result from the melting of glaciers and ice sheets (i.e., **climate change is causing Earth's poles to shift**).

https://guymcpherson.com/climate-chaos/climate-change-summary-and-update/