

Is Rapid Climate Change in the Arctic a Planetary Emergency?

Peter Carter, November 2013 updated 2019.

Introduction

This paper presents a compelling case, supported by the climate change research, that the combination of:

- global inaction on greenhouse gas emissions,
- climate system inertias, and
- multiple enormous Arctic sources of amplifying feedbacks (covered in this paper) constitutes an extreme-risk planetary emergency, for the survival of civilization, the human race and most life

Research on climate change and the Arctic shows that we face a catastrophic risk of uncontrollable, accelerating global warming due to several amplifying feedbacks from enormous feedback sources in the Arctic. These include the Arctic snow/ice-albedo feedback and greenhouse gas feedbacks (methane, nitrous oxide, and carbon dioxide).

Under global warming, the Arctic is changing far faster than other regions of Earth. Numerous – and extremely large – Arctic sources of amplifying feedbacks are already responding (have been triggered in response) to rapid Arctic warming. These Arctic feedbacks, if not addressed in time (now) and with the appropriate degree of mitigation, can only be expected to accelerate the rate of global warming. They constitute a very large risk of planetary catastrophic consequences, including Arctic greenhouse gas feedback so-called "runaway" chaotic climate disruption / runaway global heating/ hot house Earth.

This paper describes global warming positive feedbacks already operant in the Arctic, and explains the large risk of planetary catastrophe they present. It presents the definitions used, global warming commitments, three crucial recent Arctic research papers, Arctic temperature increase, vulnerable carbon pools, tipping points as immediate danger (including Arctic methane hydrate risk from 2°C), a list of positive feedbacks in the Arctic, Arctic methane, a list of Arctic positive feedback planetary dangers, Arctic amplification, authoritative Arctic assessments that have pointed out the great risks of the rapidly changing Arctic, the IPCC confirmation of these points, and a conclusion.

Definitions

We apply the following:

We define "emergency" by the World Health Organization (2013) definition of "a managerial term, demanding decision and follow-up in terms of extra-ordinary measure.... It requires threshold values to be recognized.... Conceptually, it relates best to Response. Emergency preparedness: Actions taken in anticipation of an emergency to facilitate rapid, effective and appropriate response to the situation."

We define "risk" according to the formula used by the IPCC (2007, AR4 WG3 2.2.3): "the 'combination of the probability of an event and its consequences,' as defined in the risk management standard ISO/IEC Guide 73."

We define "positive feedback" according to the National Oceanographic and Atmospheric Administration (NOAA 2013a) definition, as "a process in which an initial change will bring about an additional change in the same direction." We note that this is a *process* that *will* cause an additional change. We therefore assume that once a positive Arctic feedback has started to add heat or greenhouse gases to the climate system, it will not stop without intervention.

We define "commitment" as unavoidable, locked-in warming from all sources. This includes warming we will not be able to avoid given the world's climate and energy policies as well as the inertias inherent in the climate system.

Commitments to Global Temperature Increase

Policy commitment. The combined national emissions reduction pledges presented to the United Nations commit the world to a warming of over 3°C by 2100 (Climate Action Tracker Dec 2018), which is over 4°C by 2300 total warming long after 2100 (NRC 2011).

Climate system commitment. Realized or transient warming is only about half of the full long-term equilibrium warming (NRC 2011). Air pollution aerosol cooling is a deferred warming. Carbon feedback emissions will add some warming. The physics of climate change therefore commits us to an irreversible warming of three times today's warming or more – 2.4°C mean, according to Ramanathan and Feng (2008).

Time frame commitment. Global warming lasts, in effect, forever:

The removal of human-emitted CO₂ from the atmosphere by natural processes will take a few hundred thousand years (IPCC 2014 AR5). This extremely long time required by sinks to remove anthropogenic CO₂ makes global warming, climate change and ocean acidification irreversible on human time scale. (IPCC 2013, AR5 WG1 6-6)

Global temperature and ocean acidification cannot stabilize without stopping additional CO₂ emissions, which includes anthropogenic and carbon feedback emissions. Therefore, feedback carbon emissions from large vulnerable Arctic carbon sources can make it impossible to ever stop global warming from increasing. "*In fact, only in the case of essentially complete elimination of emissions can the atmospheric concentration of CO₂ ultimately be stabilized at a constant level*" (IPCC 2007, AR4 FAQ 10.3). With already committed global warming, nothing short of an international emergency-scale response is required for world security.

Three Recent Papers that Reinforce the Arctic Planetary Emergency

Three recent Arctic studies relevant to tipping points show greatly increased Arctic risks to the planet.

i) Unprecedented recent summer warmth in Arctic Canada

According to Gifford Miller and colleagues (in press), who have been studying tundra plants on Baffin Island, the Arctic is now warmer than at any time in the last 44,000 years and perhaps for the last 120,000 years.

[R]adiocarbon dates on rooted tundra plants revealed by receding cold-based ice caps in the Eastern Canadian Arctic [...] show that 5000 years of regional summertime cooling has been reversed, with average summer temperatures of the last ~100 years now higher than during any century in more than 44,000 years, including peak warmth of the early Holocene when high latitude summer insolation was 9% greater than present. (Miller et al. in press)

ii) Speleothems reveal 500,000-year history of Siberian permafrost

The recent field research of Anton Vaks and colleagues (2013) deep in permafrost Siberian caves indicates that Siberian permafrost will release much more carbon, much faster ("global climates only slightly warmer than today are sufficient to thaw significant regions of permafrost") and that a global warming of 1.5°C or less is the thaw-down tipping point for terrestrial Siberian permafrost (Vaks et al. 2013).

iii) The degradation of submarine permafrost and the destruction of hydrates on the shelf of East Arctic seas as a potential cause of the "Methane Catastrophe": some results of integrated studies in 2011

A recent paper authored by 21 Russian scientists concludes that there is a planetary catastrophic risk from the enormous amount of subsea floor methane in the East Siberian Shelf, the largest shelf in the world. "The emission of methane in several areas of the ESS is massive to the extent that growth in the methane concentrations in the atmosphere to values capable of causing a considerable and even catastrophic warming on the Earth is possible" (Sergienko et al. 2012).

Arctic Temperature Increase

The Arctic is warming faster than anticipated (AMAP 2009). Due to Arctic amplification as a result of the decline of snow and sea ice albedo cooling the Arctic, temperature has been increasing rapidly, which is increasing the warming of Arctic greenhouse gas feedback sources.

Vulnerable Carbon Pools

Vast amounts of carbon are stored in the Arctic. The Arctic region contains about one third of the carbon held in the world's terrestrial ecosystems and 40 percent of the carbon in near-surface soils worldwide (AMAP 2009).

The Arctic is known to hold huge quantities of methane hydrate, which is frozen solid methane gas, under pressure, found deep below permafrost and beneath the seafloor of shallow Arctic continental shelves, where it is most vulnerable to ocean warming (AMAP 2009). There is a large pool of these hydrates; in the Arctic alone, the amount of methane stored as hydrates could be more than 10 times greater than the methane presently in the global atmosphere (IPCC 2013, AR5 WG1 TS 6-77). Permafrost and subsea floor methane hydrate are each a huge source of methane vulnerable to Arctic warming:

Permafrost, including the sub-sea permafrost on the shallow shelves of the Arctic Ocean, hold[s] at least twice the amount of carbon currently present in the atmosphere as carbon dioxide. Should a sizeable fraction of this carbon be released as methane and carbon dioxide, it would increase atmospheric concentrations, which would lead to higher atmospheric temperatures. That in turn would cause yet more methane and carbon dioxide to be released, creating a positive feedback, which would further amplify global warming. (IPCC 2013, AR5 WG1 TS FAQ 6.2)

Up to recently the Arctic is a sink for carbon dioxide and a source for methane. The 2016 NOAA Arctic Report Card, and the Sept 2019 IPCC Cryosphere Report find that the Arctic is now a carbon source. It is emitting more methane and unexpectedly large CO₂ emissions. The Arctic is estimated to be a source for 15-50,000,000 tonnes of methane each year, which is 3-9% of the global net methane emissions from land and sea (AMAP 2009). This makes the Arctic a potentially significant contributor to a large increase in atmospheric methane from feedback emissions, as well as CO₂.

Tipping Points that Pose an Immediate Danger

In 2012, the director of the University of Western Australia's Oceans Institute, Professor Carlos Duarte, warned that "the Arctic region is fast approaching a series of imminent 'tipping points' that could trigger an abrupt domino effect of large-scale climate change across the entire planet" (University of Western Australia 2012):

If set in motion, they [tipping points] can generate profound climate change, which places the Arctic not at the periphery but at the core of the Earth system. [...] There is evidence that these forces are starting to be set in motion.[...] This has major consequences for the future of humankind as climate change progresses. (University of Western Australia 2012)

In a risk-analysis of global climate tipping points, the Potsdam Institute for Climate Impact Research explains how soon we could reach a methane tipping point, i.e., "at warming levels above 2°C," which could be as early as the 2040s (Betts et al. 2011):

Large amounts of methane are stored in ice form as methane hydrates in ocean floor sediments. A warming of the deep ocean may trigger the release of methane to the atmosphere and act as a strong positive feedback for global warming. Inventories, observations and modelling of the effects of methane hydrates are in a very early stage of scientific development. Preliminary results point to a very important potential effect: if methane hydrates start to decompose once warming penetrates to the deep ocean, the global climate system may move to a different state, in which the continuing release of methane prevents warming from slowing down, or decreasing, for millennia, even if anthropogenic greenhouse-gas emissions cease (Archer et al. 2009). Such preliminary results show this may happen at warming levels above 2°C, but this is highly uncertain given the level of understanding. (Frieler et al. 2011)

List of Positive Feedbacks Operant in the Arctic

Potentially very large Arctic positive feedbacks, which are all now operant, include the following (Vonk et al. 2012):

- declining Far North spring/summer snow cover albedo cooling
- declining summer sea ice extent albedo cooling
- methane emissions from warming Far North wetland peat
- methane and carbon dioxide emissions from thawing permafrost
- methane gas emissions from Arctic subsea floor methane (hydrate and free methane)
- nitrous oxide emissions from cryoperturbed permafrost

Nitrous oxide (N₂O) is an extremely powerful greenhouse gas. "Nitrous oxide, also being emitted, has 289 times the global warming effect of carbon dioxide and lasts in the atmosphere 115 years" (IPCC 2007). It is not generally realized that there may be a very large amount of N₂O coming out of the Arctic from cryoperturbed permafrost (Elberling et al. 2010; Repo et al. 2009). Thawing and refreezing permafrost is emitting N₂O in regional amounts that, extrapolated across all of the permafrost, would be a very large Arctic-wide emission of this potent greenhouse gas.

Carbon dioxide (CO₂) is also an issue in Arctic positive amplifying feedbacks. Collapsing coastal permafrost is emitting CO₂ in unexpectedly large amounts (Vonk et al. 2012) and unexpectedly large amounts of CO₂ at the start of the Arctic winter. Furthermore, although methane emissions last in the atmosphere as methane for just over a decade, methane's global warming effect continues because the chemically reactive methane is oxidized to other greenhouse gases, notably water vapour and CO₂ (IPCC 2007, AR4). Arctic feedback emissions therefore include serious amounts of CO₂, N₂O, and methane. CO₂ and N₂O last an extremely long time in the atmosphere. (Mastepanov et al. 2013)

Arctic Methane (CH₄)

Methane being emitted by the warming Arctic poses a risk of runaway global climate change. CH₄ has a global warming effect 80 times that of CO₂ over the 20-year period after its emission (IPCC 2013, AR5 WG1). Having increased 150% from 1850 to 2000, the atmospheric increase of CH₄ leveled off until 2006-7. But since 2007, it has been on a renewed, sustained increase accelerating to 2019.

With respect to the post-2006/7 atmospheric CH₄ increase (partly put down to subarctic wetland peat; see below), "uncertainties in emission trends [of global methane] do not allow definitive conclusions [about sources] to be drawn" (Kirschke et al. 2013).

Scientists think that this increase is due to feedback emissions rather than human sources (Fisher et al 2011). The feedbacks have been attributed to CH₄ from wetland peat, mainly in the tropics with some in the Far North; methane monitoring is insufficient to be certain. The highest atmospheric CH₄ level is at Lac La Biche, on the southern edge of the vast Canadian wetlands (NOAA, 2013b).

[A] rise in natural wetland emissions and fossil fuel emissions probably accounts for the renewed increase in global methane levels after 2006, although the relative contribution of these two sources remains uncertain. A better quantification of the global CH₄ budget, with regular updates as done for carbon dioxide, will be key to both embracing the opportunities and meeting the challenge. (Kirschke et al. 2013)

The catastrophic dangers of Arctic methane and the inadequacy of the knowledge base are documented in the review, "Global Atmospheric Methane in 2010: Budget, Changes and Dangers":

Natural emissions of CH₄ are likely to increase in a warmer climate; however, the magnitude and rate of change of future emissions from natural sources are largely unknown. There are large amounts of carbon stored as organic matter in permafrost or as CH₄ hydrates in the ocean sediments. However, it is not clear how quickly these carbon stores can be released and how much would survive microbial oxidation between the source and the atmosphere. The risk of a rapid increase in CH₄ emissions is real but remains

largely unquantified. During the first half of 2009, globally averaged atmospheric CH₄ was 7ppb greater than it was in 2008, suggesting that the increase will continue in 2009. There is the potential for increased CH₄ emissions from strong positive climate feedbacks in the Arctic where there are unstable stores of carbon in permafrost ... so the causes of these recent increases must be understood. (Dlugokencky et al. 2011)

Methane feedback has become more important because it has been ascertained that the natural warming out of ice age glacials is primarily driven by methane feedback emissions and most likely from wetlands (Levine et al. 2011; Levine et al. 2012).

Shallow Arctic sea sediments, especially offshore of Siberia, are thought to be rich in organic matter that may be emitted to the atmosphere as the seawater temperature increases. In addition, ice hydrates deep within the Arctic sea shelf sediments may destabilize due to warmer water temperatures and release methane to the atmosphere. Currently, the amount of CH₄ emitted to the atmosphere by these processes is thought to be about one third of that emitted from wetlands in the Arctic tundra (Shakova et al., 2010; McGuire et al., 2012); however, the sparseness of atmospheric observations makes this difficult to confirm. (Bruhwiler & Dlugokencky 2012)

There is evidence from satellites that subArctic wetland peat has been emitting much more methane (Bloom et al. 2010).

Arctic methane from extremely large feedback sources constitutes a risk of so-called runaway global climate change. According to the risk formula cited above (IPCC 2007, AR4 WG3 2.2.3), this is a very large risk.

We have made an assessment of the available scientific literature on CH₄ feedbacks related to natural sources of CH₄ from wetlands, permafrost, and ocean sediments. In summary, the complex and non-linear processes governing the sources and atmospheric chemistry of CH₄ cause feedback loop between the climate, the terrestrial vegetation as the source of the BVOCs [biogenic volatile organic compounds], the oxidation capacity of the atmosphere, and the atmospheric CH₄ burden. The feedback loop can be described in simple terms as follows: rising CH₄ emissions from wetlands, thawing permafrost, and destabilizing marine hydrates increase atmospheric CH₄ concentrations; this increase in CH₄ concentration, amplified by the effect of CH₄ on its own chemical lifetime, results in a greater radiative forcing on climate and terrestrial ecosystems. The ecosystems, given our current understanding, respond to the warmer, more humid conditions by an increase in BVOCs, which further augments the chemical lifetime of CH₄. Finally, the resulting additional radiative forcing [from fast responding wetland CH₄] could lead to more or faster thawing of permafrost, further destabilization of marine hydrates, and potentially even larger wetland CH₄ emissions. (O'Connor et al. 2010)

Arctic tundra is releasing methane, but inadequate monitoring makes it difficult to calculate how much will be released in the future. Future emissions of carbon from tundra could be as CH₄ or as CO₂. The amounts of each must be known in order to assess how great the impact could be. "Thawing permafrost has strong potential to affect the global climate system acting through release of greenhouse gases [mainly methane] to the atmosphere" (Anisimov & Reneva 2006).

In 2007, researchers from the Zackenberg research station in Northeast Greenland made a surprising discovery. In autumn, when the surface of the tundra freezes and ice is formed, large quantities of methane are released. The quantities released were so large that the annual CH₄ emissions had to be doubled in the calculation of the tundra's CH₄ budget. According to researcher Magnus Lund, "It's a problem in the Arctic that we don't perform measurements at enough locations. The variation between locations is substantial both for CO₂ and not least for methane" (Aarhus University 2013).

List of Potentially Catastrophic Arctic Planetary Dangers

The potential rapid Arctic warming induced global catastrophic impacts are:

- declining spring-summer Far North snow and summer Arctic sea ice with declining Arctic albedo cooling effect (the cause of Arctic amplification and a positive global amplifying feedback)
- multiple Arctic positive greenhouse gas emitting feedbacks that will add to global warming and the risk of "runaway" global climate change (the Arctic holds by far the largest pool of carbon vulnerable to warming)
- a large sudden methane release from subsea floor methane gas hydrate
- disruption to the thermohaline ocean circulation (extreme cold affecting Europe, an issue this paper does not address)
- irreversible destabilization of the Greenland ice sheet (very long term sea level rise, not addressed in this paper)
- risk of increased and prolonged Northern Hemisphere extreme heat, drought and flooding events resulting from the loss of Arctic snow and summer sea ice albedo cooling (impacting northern hemisphere and therefore world food security, not addressed in this paper)

Although this paper only addresses the Arctic positive feedbacks, the above list shows the very high risk of planetary catastrophes due to Arctic warming.

Arctic Amplification

The melting of Arctic snow and sea ice, a common factor in all of the above global catastrophic risks, will continue at an increasing rate because of Arctic amplification. Arctic amplification is a vicious cycle set off by Arctic warming up to four times the global average rate over the past three decades (Screen et al. 2012). Arctic spring-summer snow and Arctic summer sea ice are in a long established rapidly declining trend. "The extent of snow cover and sea ice in the Northern Hemisphere has declined since 1979, coincident with hemispheric warming and indicative of a positive feedback of surface reflectivity on climate" (Flanner et al. 2011).

Research has found that Arctic amplification is mainly a result of the loss of Arctic albedo from the melting of snow and ice (Screen & Simmonds 2010). The rate of loss of Arctic albedo determines the rate of future Arctic warming amplification, which depends greatly on the sea ice extent loss rate. While computer model projections show an Arctic summer free of sea ice in decades, the extrapolation of volume and extent loss trends indicates a matter of years, as pointed out by Peter Wadhams. Professor Wadhams is extremely concerned that the virtual total loss of Arctic summer sea ice will result in a large boost in Arctic methane emissions, in particular from below the sea floor of the East Siberian Arctic shelf (personal communication 2012).

The year 2012 set a record for Arctic albedo loss. The rapid albedo loss is a result of the Far North spring/summer snow cover receding more rapidly, meltwater cooling on the surface of the Greenland ice sheet, and the thinning as well as the collapsing extent of the Arctic summer sea ice. Research estimates that the albedo effect of the Far North snow cover is equivalent to that of the Arctic summer sea ice (Flanner et al. 2011). This Arctic albedo loss is enough to become a significant global feedback, boosting the rate of global warming.

Arctic amplification being observed today is expected to become stronger in coming decades, invoking changes in atmospheric circulation, vegetation, and the carbon cycle, with impacts both within and beyond the Arctic (Serreze & Barry 2011).

Authoritative Arctic Assessments

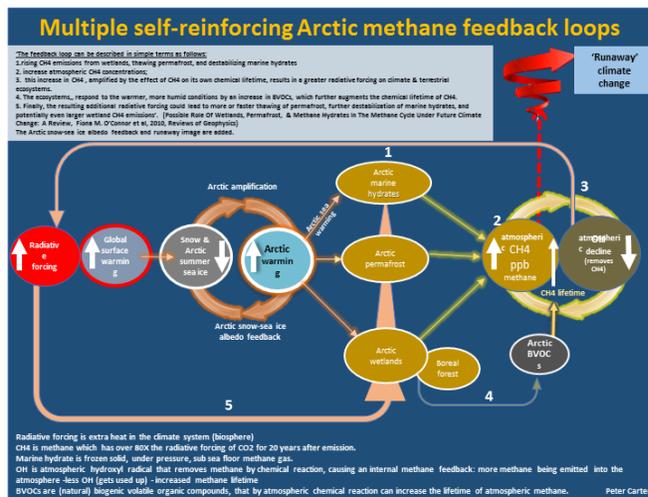
James Hansen has made public statements that the Arctic summer sea ice had passed its tipping point, putting the world in a state of planetary emergency. Hansen has made high level presentations explaining the state of planetary emergency, which involves ice sheets, Arctic summer sea ice and Arctic methane positive feedback. He has been explaining for some years that our global warming status amounts to a planetary emergency because of climate inertia, "warming in the pipeline," and tipping points that include ice sheet disintegration and frozen methane in tundra and on continental shelves (Hansen 2010).

In 2007, J. Hansen was lead author of a paper warning that our emissions and Arctic feedbacks are putting our planet in peril. "Recent greenhouse gas emissions place the Earth perilously close to dramatic climate change that could run out of our control, with great dangers for humans and other creatures. The Arctic epitomizes the global climate situation" (Hansen et al. 2007).

The risk of Arctic feedback runaway was described in 2010 by F O'Connor, Possible role of wetlands, permafrost, and methane hydrates in the methane cycle under future climate change: A review. *Reviews of Geophysics*.

"In summary, the complex and nonlinear processes governing the sources and atmospheric chemistry of CH₄ cause a feedback loop between the climate, the terrestrial vegetation as the source of BVOCs, the oxidation capacity of the atmosphere, and the atmospheric CH₄ burden. The feedback loop can be described in simple terms as follows: rising CH₄ emissions from wetlands, thawing permafrost, and destabilizing marine hydrates increase atmospheric CH₄ concentrations; this increase in CH₄ concentration, amplified by the effect of CH₄ on its own chemical lifetime, results in a greater radiative forcing on climate and terrestrial ecosystems. The ecosystems, given our current understanding, respond to the warmer, more humid conditions by an increase in BVOCs, which further augments the chemical lifetime of CH₄. Finally, the resulting additional radiative forcing could lead to more or faster thawing of permafrost, further destabilization of marine hydrates, and potentially even larger wetland CH₄ emissions."

The Arctic runaway carbon dynamic planetary catastrophe



Possible Role Of Wetlands, Permafrost, & Methane Hydrates In The Methane Cycle Under Future Climate Change: A Review, Fiona M. O'Connor et al, 2010, *Reviews of Geophysics*)

Image P. Carter

The Arctic region is already undergoing abrupt climate change, which risks abrupt *global* climate change due to the multiple Arctic positive feedbacks.

Perhaps the most dangerous aspect of Arctic climate change is the risk of passing tipping points. The Arctic region arguably has the greatest concentration of potential tipping elements in the Earth system, including Arctic sea ice, the Greenland ice sheet, North Atlantic deep-water formation regions, boreal forests, permafrost and marine methane hydrates. Recent analyses have added several more candidates. The array of tipping elements in the Arctic [is] not independent – they are causally connected to one another, and to other areas for concern. Warming of the Arctic region is proceeding at three times the global average, and a new "Arctic rapid change" climate pattern has been observed in the past decade. Near complete loss of the summer sea ice, as forecast for the middle of this century, if not before, will probably have knock-on effects for the northern mid-latitudes, shifting the jet streams and storm tracks. Several tipping elements have already been set in motion and changes are accelerating. (Duarte et al. 2012)

Arctic experts continue to warn that the rapid Arctic change is a clear danger to our planet and our future: Arctic response to global warming is already very strong, very rapid, and of major global significance. It poses an immediate and troubling danger to global climate that will likely have severe consequences

both for the biosphere and [for] the human economy.... Arctic [methane] hydrates have long been identified as a likely source of strong positive feedback. (Nisbet et al. 2013)

A 2010 paper on Arctic methane positive feedback sources concluded that, based on a comprehensive review of the literature, "significant increases in methane emissions are likely, and catastrophic emissions cannot be ruled out" (O'Connor et al. 2010).

A recent Arctic assessment, *Snow, Water, Ice and Permafrost in the Arctic* (AMAP 2012), explains that "the past six years (2005–2010) have been the warmest period ever recorded in the Arctic. There is evidence that two components of the Arctic cryosphere – snow and sea ice – are interacting with the climate system to accelerate warming."

Loss of ice and snow in the Arctic enhances climate warming by increasing absorption of the sun's energy at the surface of the planet. It could also dramatically increase emissions of carbon dioxide and methane and change large-scale ocean currents. The combined outcome of these effects is not yet known. (AMAP 2012)

The most recent full assessment of the Arctic Climate Impact Assessment was published in 2004 (ACIA 2004). That assessment "focused on how climate change influences the Arctic cryosphere, rather than the other way around" (UNEP 2012). It did record, however, the risk of feedback Arctic greenhouse gas emissions and also that the extent of such risk had not been determined. The situation is the same today but with stronger evidence of an extreme risk.

[T]he carbon stored in northern boreal forests, lakes, tundra, the Arctic Ocean, and permafrost is considerably greater than the global atmospheric pool of carbon. [...] Because low temperatures have been so important for the capture and storage of atmospheric carbon in the Arctic, projected temperature increases have the potential to lead to the release of old and more recently stored carbon to the atmosphere. The release of stored carbon will increase atmospheric greenhouse gas concentrations and provide a positive feedback to the climate system....

18.4.3. Abrupt climate change and extreme events. There may be an abrupt release of carbon dioxide and methane from thawing permafrost in marine sediments. [...] In the marine environment there are vast stores of methane and carbon dioxide in the form of gas hydrates. Even the release of the small percentage of methane from gas hydrates could result in an abrupt and significant climate forcing.

As anthropogenic climate change continues, the potential exists for oceanic and atmospheric circulation to shift to new or unusual states. The likelihood of any such shifts or changes occurring is not yet well established but if the future is like the past the possibility for abrupt change and new extremes is real.

[I]t is important to re-emphasize that climate and UV radiation changes in the Arctic are likely to affect every aspect of human life in the region and the lives of many living outside the region. While more studies and a better understanding of the expected changes are important, action must begin to be taken to address current and anticipated changes before the scale of changes and impacts further reduces the options available for prevention, mitigation and adaptation. (ACIA 2004)

Finally, the Arctic Climate Change and Security Policy Conference in 2008 (Yalowitz et al. 2008) determined that research into the science of Arctic climate change is deficient:

Global warming is accelerating the pace at which climate change is affecting the Arctic region as well as climatic and environmental conditions in the U.S. While evidence that global warming is affecting both the Arctic region and the world's environment is incontrovertible, the scientific basis for understanding these phenomena and the information available for making policy decisions remains inadequate. In order to define issues for decision and set priorities for action, governments should demand accelerated scientific study of issues critical to informed policy making and should be willing to fund needed research. (Yalowitz et al. 2008)

IPCC Confirmation of Arctic Feedback Catastrophic Risk, Including Methane Hydrate

Does the IPCC record a risk of climate catastrophe due to Arctic warming? Yes, the IPCC Fourth Assessment Report (2007) recognized the risk of catastrophic impacts from Arctic carbon feedbacks – specifically from subsea methane hydrate. What follows are IPCC references to catastrophic feedback risk from Arctic warming that go back over a decade.

Risk of Catastrophic or Abrupt Change: The possibility of abrupt climate change and/or abrupt changes in the earth system triggered by climate change, with potentially catastrophic consequences, cannot be ruled out. Positive feedback from warming may cause the release of carbon or methane from the terrestrial biosphere and oceans. (IPCC 2007, AR4 WG3 2.2.4)

Cryospheric Topics: As permafrost thaws due to a warmer climate, CO₂ and CH₄ trapped in permafrost are released to the atmosphere. Since CO₂ and CH₄ are greenhouse gases, atmospheric temperature is likely to increase in turn, resulting in a feedback loop with more permafrost thawing. The permafrost and seasonally thawed soil layers at high latitudes contain a significant amount (about one-quarter) of the global total amount of soil carbon. Because global warming signals are amplified in high-latitude regions, the potential for permafrost thawing and consequent greenhouse gas releases is thus large. (IPCC 2007, AR4 WG1 1.4.5)

Polar Regions: In both polar regions, components of the terrestrial cryosphere and hydrology are increasingly being affected by climate change (very high confidence). These changes will have cascading effects on key regional bio-physical systems and cause global climatic feedbacks (very high confidence). (IPCC 2007, AR4 WG2 15)

Methane Hydrate Instability / Permafrost Methane: Methane hydrates are stored on the seabed along continental margins where they are stabilised by high pressures and low temperatures, implying that ocean warming may cause hydrate instability and release of methane into the atmosphere. Methane is also stored in the soils in areas of permafrost and warming increases the likelihood of a positive feedback in the climate system via permafrost melting and the release of trapped methane into the atmosphere. Both forms of methane release represent a potential threshold in the climate system. As the climate warms, the likelihood of the system crossing a threshold for a sudden release increases. Since these changes produce changes in the radiative forcing through changes in the greenhouse gas concentrations, the climatic impacts of such a release are the same as an increase in the rate of change in the radiative forcing. (IPCC 2007, AR4 WG1 8.7.2.4)

Global Climate Projections: [S]ome sources of future radiative forcing are yet to be accounted for in the ensemble projections, including those from land use change, variations in solar and volcanic activity [...], and CH₄ release from permafrost or ocean hydrates. (IPCC 2007, AR4 WG1 10.5.1)

Assessing Key Vulnerabilities and the Risk from Climate Change: AR4 temperature range (1.1-6.4°C) accounts for this [climate-carbon cycle] feedback from all scenarios and models but additional CO₂ and CH₄ releases are possible from permafrost, peat lands, wetlands, and large stores of marine hydrates at high latitudes. (IPCC 2007, AR4 WG1 Table 19.1)

The 2014 5th assessment

Conclusion

This paper presents evidence that the rapid changes taking place in the Arctic constitute a planetary emergency. Multiple Arctic amplifying feedbacks could tip the planet into runaway global climate change. Yet not only are all (known) Arctic positive feedbacks from enormous vulnerable carbon pools now operant, the world is also committed to a much higher degree of warming than the warming that has triggered these Arctic feedbacks.

Secondary evidence provided in this paper shows that there is substantial uncertainty as to the actual magnitude and rate of emissions from the Arctic greenhouse gas (CH₄, CO₂ and N₂O) sources with continued global warming. But recent evidence (Sergienko et al. 2012; Vaks et al. 2013; Miller et al. in press) indicates that the risks are much greater than had been thought. It is time to declare the Arctic planetary emergency.

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