Assessing Climate Change’s Contribution to Global Catastrophic Risk

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A growing number of people and organizations have claimed climate change is an imminent threat to human civilization and survival but there is currently no way to verify such claims. This paper considers what is already known about this risk and describes new ways of assessing it. First, it reviews existing assessments of climate change’s contribution to global catastrophic risk and their limitations. It then introduces new conceptual and evaluative tools, being developed by scholars of global catastrophic risk that could help to overcome these limitations. These connect global catastrophic risk to planetary boundary concepts, classify its key features, and place global catastrophes in a broader policy context. While not yet constituting a comprehensive risk assessment; applying these tools can yield new insights and suggest plausible models of how climate change could cause a global catastrophe.

Climate Change; Global Catastrophic Risk; Planetary Boundaries; Food Security; Conflict

“Understanding the long-term consequences of nuclear war is not a problem amenable to experimental verification – at least not more than once” Carl Sagan (1983)

With these words, Carl Sagan opened one of the most influential papers ever written on the possibility of a global catastrophe. “Nuclear war and climatic catastrophe: Some policy implications” set out a clear and credible mechanism by which nuclear war might lead to human extinction or global civilization collapse by triggering a nuclear winter. While concerns about global threats from nuclear explosions had been raised since the Manhattan Project; they had previously been either vague (Russell 1961) or misplaced (Teller et al. 1946). Thus, even though Sagan’s thesis, and the models behind it, remain the topics of considerable scientific controversy, they transformed the way nuclear risk was perceived and addressed.

Today, global catastrophic climate risk research mirrors the condition of nuclear risk research in the early 1980s. Many climate scientists, global catastrophic risk scholars and environmental groups are seeking to raise awareness of the severe risk climate change poses to humanity. However, despite the well-developed consensus on the science of climate change and wide-ranging discussions about the threats it poses to individuals, communities and nations; there remains no clear and credible mechanism for how a changing climate could cause global civilization collapse or human extinction.

This paper aims to facilitate a transformation in how climate risk is perceived by building a framework to for assess its contribution to global catastrophic risk. It begins by reviewing the current state of global catastrophic climate risk research and its limitations (section 1) before describing a new set of conceptual and evaluative tools developed for improved assessment of GCR (section 2). Finally, it highlights some initial insights that can be gained from applying these
tools and suggests questions for future research, most notably concerning the possibility of positive feedback loops between collapsing sociotechnological and ecological systems – which we refer to as ‘global systems death spirals’ (section 3).

1 –Current Assessments of Climate Change’s Contribution to Global Catastrophic Risk
Global Catastrophic Risk (GCR) refers to risks “the potential to inflict serious damage to human well-being on a global scale” up to and including human extinction and civilizational collapse (Bostrom and Cirkovic 2008). Such risks are characterised by their potential both to take the lives of a significant portion of the human population and to leave survivors at heightened risk by undermining global resilience systems (Avin et al. 2018). There are at least three overlapping scenarios that would constitute such a catastrophe. First, the death of a large proportion of the global population (Cotton-Barratt et al. 2016 use a 10% threshold); second, a collapse of human civilization, diminishing human welfare and social complexity; third, a reduction in humanity’s long-term potential as a species for future technological, scientific, moral and cultural progress.

Recent studies of the possibility that climate change poses a GCR have tended to be both vague in their assertions and inconsistent in their conclusions. Many works, such as David Wallace-Well’s (2019) book *The Uninhabitable Earth* acknowledge this possibility, but shy away from considering it since doing so involves too much speculation. Others, such as Jem Bendall’s widely read (2018) paper, “Deep Adaptation: A Map for Navigating Climate Tragedy”, go too far in the opposite direction, speculating wildly about disaster scenarios without credible evidence.

There are certain widely accepted limits to our ability to survive climate change, for instance due to heat stress. These could become a serious issue for certain locations after about 7°C of global warming from pre-industrial levels, and for the majority of the world’s population after 11 (Sherwood and Huber 2010). Such scenarios are not impossible, as one recent assessment noted: “[o]n the highest emissions pathway ([R]epresentative Concentration Pathway] 8.5), a rise of 7°C is a very low probability at the end of this century, but appears to become more likely than not during the course of the 22nd century. A rise of more than 10°C over the next few centuries cannot be ruled out.” (King et al. 2015). However, this would require either that high levels of greenhouse gas (GHG) emissions continue far into the future or that natural feedback mechanisms are stronger than expected. However, other impacts of similar severity could be triggered by far smaller temperature increases.

One recent study, published in the *Proceedings of the National Academies of Science* suggests that a global temperature rise of more than 3°C would be “catastrophic” while a rise of more than 5°C would “pose existential threats to a majority of the population” from deadly heat the sea level rise. This conclusion was drawn on the basis that such levels of warming had not been seen within the previous 20 million years. The authors’ models suggest that within the next eight decades, there is a 5% chance of exceeding 5 degrees of warming (Xu and Ramanathan 2017).

Similarly, the 2015 book *Climate Shock* analyses the uncertainty in standard climate models and finds a 3% chance of passing 6°C under an ambitious “low-medium emissions pathway” and an 11% chance of passing it under a more realistic “medium-high emissions pathway”. While stating that we cannot know the full implications of such a temperature rise, the authors describe it as an “indisputable global catastrophe” (Wagner and Weitzman 2015).
Finally, a more alarmist, and non-peer-reviewed, report by the National Centre for Climate Restoration suggested that global temperature increases of more than 3-4 °C “will drive increasingly severe humanitarian crises, forced migration, political instability and conflict” and “may result in ‘outright chaos’ and an end to human civilisation as we know it”, based on a limited scenario analysis. Citing the findings of Reilly et al. (2015), it estimates a 50% chance of crossing this threshold, even if commitments under the Paris Agreement are met (Dunlop and Spratt 2017).

These studies differ in their assessments of both the likelihood and impact of different levels of warming and fail to address the question of why or how certain levels of climate change could produce a global catastrophe or what response this warrants. This largely reflects the difficulty of these question, which relate to complex interacting global systems. However, it also highlights some limitations of current climate risk analysis.

First, studies tend to assess climate change primarily in terms of global mean temperature change, which is only one, albeit important, aspect of this risk. Our emission of GHGs is also affecting many other aspects of the global system, including rainfall patterns, ocean acidity, extreme weather and the balance of energy between the upper and lower atmosphere and the oceans, while local effects can differ markedly from the global average. To assess climate change’s impact on humanity we must think holistically about all of the impacts (Briggs, Kennel and Victor 2015).

Secondly, these assessments all build on existing climate and integrated assessment models. These are sophisticated scientific tools that represent our best, limited understanding of how climate change will affect human societies. However, they are not well suited to studying GCRs. One problem is that existing models, which are best-calibrated for scenarios close to the status quo, are widely acknowledged to perform poorly when applied to more extreme scenarios (Pindyck 2013, Weaver et al. 2017). More importantly, the greatest risks from climate change may be due to indirect effects, rather than the direct effects that these models concentrate on. Current models thus underestimate the potential upper limit for the damage that climate change can cause.

Finally, these assessments move in one direction: from future emissions pathways, to climate projections, to analysis of impacts. They pay insufficient attention to how the impacts of climate change are shaped by human responses. These may worsen or alleviate the risks. For instance, societies may respond with renewed cooperation and accelerated emissions reductions but they could also respond with an emergency geoengineering project or more draconian security measures. At best climate risk researchers’ focus on the limits to adaptation. But these needs to be coupled with a comprehension of social and environmental changes in a dynamic state of co-evolution.

Addressing these deficiencies requires anchoring impacts assessment to the expected social and ecological responses to climate change (Travis 2010). This is particularly pertinent when considering GCRs. Social and ecological collapse and other elements of a global catastrophe involve non-linear systemic shifts. Understanding these requires an assessment of their

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Note that other literatures also engage with the question of climate change and GCR. Some of these are cited later in this paper. One literature concerns the economics of global catastrophic climate risk, though usually this involves mere assumptions of its likelihood (see Gjerde et al. 1999, Weitzman 2009, Ng 2016). Another important literature relates to GCR and geoengineering (Baum et al. 2013, Halstead 2018)
complex causes and this demands that we think about future trajectories in more than just climatic terms. Such an assessment cannot be carried out without grasping how and when social and environmental responses might translate into a global catastrophe.

When scientists began studying nuclear winter, their first step was to demonstrate that this was a real catastrophic possibility. Only then did they calculate the necessary number and location of nuclear explosions that could trigger it. Climate risk researchers should emulate this strategy. The assessments we reviewed do too little in failing to specify what a climate catastrophe would be or how it might unfold, and thus went too far in how they described this risk. Doing better entails considering how a climate catastrophe might occur and working backwards to find the conditions that engender it. The next section describes one way to perform such an analysis.

2 – New Approaches to Studying Global Catastrophic Risk
We should not underestimate our species’ and civilization’s resilience and ability to adapt to changes. Humanity is widespread, we can survive, and even thrive, in most environments, including, for short periods, at the bottom of the ocean or the vacuum of space. To present a credible risk of producing a global catastrophe, any change would need to fall into one or more of the following classes:

1. Something so profound that adaptation is impossible;
2. Something so explosive that adaptation is unfeasible;
3. Something necessitating adaptation that is so complex or requires so much coordination as to be unachievable
4. Something that work against our efforts to adapt to them or adapt themselves to us; and

Historically, assessments of GCR have revolved around identifying changes that are sufficiently profound and/or explosive to pose a direct threat to humanity, which is unlikely to be the case for GHG induced climate change. However, recent years have seen the development of new conceptual and evaluative tools for assessing more complex catastrophes involving slow moving disasters, civilization vulnerabilities and systems collapse. These allow us to study a far wider range of risk drivers, including climate change.

Classifying the Features of Global Catastrophic Risk
One set of these tools examines how we classify the key features of risks for further analysis, applying lessons from risk analysis and disaster studies to global catastrophes. Researchers at the Centre for the Study of Existential Risk (CSER) have developed a scheme that classifies GCRs into three key components: “(i) a critical system (or systems) whose safety boundaries are breached by a potential threat, (ii) the mechanisms by which this threat might spread globally and affect the majority of the human population, and (iii) the manner in which we might fail to prevent or mitigate both (i) and (ii)” (Avin et al. 2018).

A critical system is one whose ordinary operation plays a crucial role in supporting humanity’s ability to survive in its current form. Their safety boundaries are the limit or scale of disturbance that could disrupt their normal functioning and trigger a significant reduction in the support they provide. Avin et al. (2018) distinguish between seven levels of critical systems
and order these according to their degree of dependence on, and emergence from, one another (See Figure 1).

![Diagram of critical systems hierarchy]

Figure 1: The hierarchy of critical global systems

When the safety boundaries of critical systems are breached, triggering them to enter an abnormal of failed state, this can have cascading effects, potentially spreading disruption both globally and to other systems. The mechanisms of this spread include: “natural global scale” mechanisms, such as changes to the stocks and flows of biochemicals; “anthropogenic network” mechanisms, such as the global energy distribution network; and mechanisms involving biological or informational replication, such as the spread of pests or ideologies.

Classifying risks by their critical systems and spread mechanisms not only provides an analytical tool for studying systemic risks without reducing their inherent complexity; it also helps identify policy levers and other opportunities for mitigating them. However, GCRs also involve significant challenges to designing and implementing such strategies, and these form the crucial third pillar of this scheme, which identifies four key classes of mitigation fragility: ‘individual,’ ‘interpersonal,’ ‘institutional,’ and ‘beyond-institutional’.

Hin-Yan Liu and colleagues (2018) built on this framework by incorporating additional insights from the field of disaster management. They argue that GCRs consist of three distinct components: hazards/threats (the precipitating cause of harm, such as climate change), vulnerabilities (the inability of critical systems to withstand threats without incurring damage, such as the loss of food or the collapse of institutions), and exposures (the features of human society that turn this system damage into personal harm, such as our reliance on just-in-time global food distribution networks or institutions of violence suppression). Vulnerabilities and exposures can themselves be categorised as ontological (inherent in human existence itself), intentional (created specifically by design) or relating to more complex social arrangements, either passively/indirectly or actively/directly (Liu, Lauta and Maas 2018). GCRs entail not only emerging threats to humanity’s future (such as AI, biotechnology, or indeed climate change) but also emerging vulnerabilities and exposures as well. They thus arise as much from the fragility
of our civilization or species as the threats we face. This underlines the importance of studying collective human organisation, including issues of global justice and resilience.

**Linking Planetary Boundaries to Global Catastrophic Risk**

A second suite of conceptual tools builds on the well-known 'planetary boundaries' framework for assessing threats to nine key components of the earth system (Steffen et al. 2015). This concept provides a useful tool for studying the broader systemic effects of climate change and humanity's other environmental impacts. Its empirical basis lies in the parameters of relative environmental stability provided by the Holocene epoch in which human civilization has arisen and how we are moving beyond these. While it provides some indication of where environmental threats to human civilization are likely to emerge, it says little about their impact on societies.

For this reason, Seth Baum and Itsuki Handoh have sought to expand the planetary boundaries concept by creating a framework called “Boundary Risk for Humanity and Nature” (BRIHN). This assesses the risk that crossing planetary boundaries will incur an irreversible loss for humanity (Baum and Handoh 2014). Their framework is based around the twin concepts of "resilience" (humanity’s ability to adapt to changes in the global systems that surround us) and its "probabilistic threshold" (the degree of change over which the risk of our resilience being insufficient to avoid an irreversible loss moves from a near impossibility to a near certainty). However, this important framework remains underdeveloped and only informally applied.

A similar, more evaluative, approach was taken by researchers at the UCLA Institute for Environment and Sustainability (Kareiva and Carranza 2018). They argue that crossing a planetary boundary is most dangerous where it is likely to produce reinforcing environmental feedback loops and multiplicative stresses (for instance when there are multiple spread mechanisms and mitigation fragilities). Yet, they find that most individuals expect global catastrophes to occur through scenarios involving simple and direct threats to life. Once again, they found that it is the challenge of responding to emerging risks that underlies their potential to precipitate global catastrophes. They further argue that we already know how to manage complex risks: by supporting heterogeneity, establishing a modular structure, creating redundancy, introducing balancing feedback to counteract reinforcing feedback and expecting surprises. Yet our lack of understanding of environmental risks could prevent us from deploying these strategies, thereby rendering global catastrophe more likely.7

**Integrating the Assessment of Governance and Global Catastrophic Risk**

A final set of tools combines risk assessment with insights from ethics and policy evaluation to assess humanity’s likely ability to respond to potential global catastrophes. This is vital given the centrality of human responses. We can either elevate or stifle the creation and spread of catastrophic risk.

For instance, Karin Kuhlemann (2019) has argued that climate change is one of a group of “unsexy” risks characterized by 1) declining access to resources that 2) results from collective action and 3) can be expected to pass a point at which we will become unable to satisfy the minimum requirements of well-being within the life expectancy of the youngest members of society (what she calls a "threshold of significance"). She argues that these risks are, by their

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7 Researchers at CSER are exploring the potential of a companion ‘civilization boundaries’ framework, based on observations of primary drivers of historical social and ecological collapses.
nature, less compelling than “sexy” risks, which are “neat, quick and techy,” such as nuclear war or biotechnological threats, echoing the conclusions of Kareiva and Carranza (2018). Unsexy risks also tend to be harder to predict and monitor and are more challenging to address because they relate to basic human functions such as consumption and reproduction. Kuhlemann argues that climate change, and other global environmental problems, are paradigmatic cases of unsexy risks, which makes them more, not less dangerous.

Nick Bostrom (2018) also proposes a model of GCRs based on governance failures, this time related to the “civilizational vulnerability” that is due to our “semi-anarchic default condition” (a world order characterized by a limited capacity for preventive policing, a limited capacity for global governance, and diverse motivations among state and nonstate actors). Under such conditions, Bostrom argues that our civilization is vulnerable to two classes of threat (each of which can be split into two further sub-classes):

1. A technology that makes it too easy for individuals or small groups with the appropriate motivation to cause mass destruction (see also Torres 2016), so that it is either:
   a. extremely easy to cause a moderate amount of harm, or
   b. moderately easy to cause an extreme amount of harm.

2. A level of technology that strongly incentivizes actors to use their powers to cause mass destruction (see also Torres 2018), so that either:
   a. powerful actors can produce civilization-devastating harms and face incentives to use that ability, or
   b. a great many actors face incentives to take some slightly damaging action such that the combined effect of those actions is civilizational devastation.8

Bostrom does not believe that climate change in its current form is a significant contributor to GCR because he does not believe it will cause a sufficient amount of damage. On the other hand, he concedes that global warming presents actors with the kind of incentive structure described under 2b and suggests possible scenarios under which it could produce a global catastrophe. However, he believes that only a global surface increase of 15-20°C would be “a truly civilizational threat”, although he provides little support for this claim.

3 – Applying These Tools
Together, these tools provide the basis for new ways of analysing climate change’s contribution to GCR. This analysis starts by considering the range of climate change’s direct and indirect impacts. Next, it assesses the critical systems vulnerable to being disrupted by these and how a combination of human exposure and cascading spread mechanisms might escalate critical systems failures into a global catastrophe. Finally, it identifies the opportunities and obstacles to mitigating such a global catastrophe and evaluates the likelihood of success.

8 There is also a third, type-0, vulnerability, to a technology that carries a hidden risk such that the default outcome when it is discovered is inadvertent civilizational devastation. However, this stems from our epistemic default position rather than the semi-anarchic condition of civilization.
Breaching Climate Change as a Planetary Boundary

While most of the impacts of climate change have fallen within the range of what was experienced during the Holocene, the rate of change has not and we are now beginning to see climate change push beyond these boundaries. In the latest edition of the planetary boundaries framework, climate change is placed in the zone of increasing risk, implying that while this planetary boundary has been breached, there remains some potential for normal functioning and recovery (Steffen et al. 2015). It thus lies between what the authors identify as the ‘safe zone’ and other ‘high risk’ transgressions, such as disruption to biochemical flows of nitrogen and phosphorus and loss of biosphere integrity.

In their assessment of BRHIN, Baum and Handoh (2014) note that climate change is the planetary boundary for which the risk to humanity has received most meaningful consideration and appear to support the view that this is deserved. Yet, as we have seen, little of this research concerns climate change’s extreme or catastrophic effects. Kareiva and Carranza (2018) argue that, despite currently falling outside of the area of high risk, climate change has the clear potential to push humanity across a threshold of irreversible loss by “changing major ocean circulation patterns, causing massive sea-level rise, and increasing the frequency and severity of extreme events ... that displace people, and ruin economies.” Even if we were resilient to each threat individually, the spectre of collapse would loom large if they were to occur rapidly and simultaneously.

One scenario that has received comparatively more attention is that the global climate could cross a tipping point at which environmental feedback loops (such as declining albedo from melting ice or the release of methane from clathrates) and cascading effects (such as shifting rainfall patterns that trigger desertification and soil erosion) begin accelerating. This would imply that climate change ceases to be primarily driven by anthropogenic activity. Change could be accelerated and begin to fall outside of human control (King et al. 2015, Steffen et al. 2018). Under such conditions, the probabilistic thresholds (in Baum and Hando’s sense) for a near impossibility and a near certainty of a global catastrophe may move very close together. That is, it may take only a small change in the dynamics of the earth system for humanity to move from a state of almost perfect safety to one of almost inevitable catastrophe.

Climate change may threaten civilization in other circumstances as well. Climatic changes are already implicated in the collapse of many previous societies and civilizations, including the Anasazi, the Tiwanaku, the Moche, the Akkadians, the Western Roman Empire, the lowland Maya, the Khmer empire and dozens of others (Diamond 2005, Fagan 2008). These provide a precedent for how a changing climate can trigger or contribute to societal breakdown. At present, the analysis leaves much to be desired. The IPCC has labelled its findings as “low confidence” due to a lack of understanding of cause and effect and restrictions in historical data (Klein et al. 2014). Further study and cooperation between archaeologists, historians, climate scientists and global catastrophic risk scholars could overcome some of these limitations by providing a better understanding of how the impacts of climate change translate into social transformation and collapse. There is also the potential for larger studies into how global climate variations during the Holocene have coincided with collapse and violence, building on existing studies at the regional level (Zhang 2005; 2006). However, these need to be interpreted and generalized with care given the differences between societies, and between pre-industrial states and modern society.
Societies also have a long history of adapting to, and recovering from, such collapses (McAnay and Yoffe 2009). Such recoveries, though, have occurred in the stable context of the Holocene, with fully functioning ecosystems. A return to agrarian or hunter-gatherer lifestyles could be more painful, and more likely to be permanent, in a world of climate change and ecological disruption. Our vulnerability to collapse is also enhanced by our dependence on many interlinked sociotechnological systems. The failure of multiple systems could produce a drastic and sustained reduction in our ability to support ourselves (Kemp 2019b).

Finally, climate change may contribute to GCR via other environmental impacts. Apart from being a planetary boundary in its own right, Steffen et al. (2015) point out that climate change is intimately connected with other aspects of the Earth system (see table 1). Climate change is thus identified by the authors as one of two ‘core’ boundaries with the potential “to drive the Earth system into a new state should they be substantially and persistently transgressed”. This transformative potential was elaborated on in future work describing how the work could be irrevocably thrown towards ‘Hothouse Earth’ state with even temperature rises as low as 2°C (Steffen et al. 2018).

**Table 1: Relationship of climate change to other planetary boundaries (after table S3 in Steffen et al. 2015)**

<table>
<thead>
<tr>
<th>Boundary</th>
<th>Current State</th>
<th>Relationships with Climate Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stratospheric Ozone Depletion</td>
<td>Safe</td>
<td>Affects atmospheric circulation, including storm tracks and rainfall patterns. Cools the surface and the stratosphere.</td>
</tr>
<tr>
<td>Freshwater Use</td>
<td>Safe</td>
<td>Harms ecosystems, reducing carbon sinks in vegetation and soils; increase in CH4 emissions from ponds and irrigation. Decreases carbon transport from land to ocean via rivers.</td>
</tr>
<tr>
<td>Ocean Acidification</td>
<td>Safe</td>
<td>Driven by the level of Carbon Dioxide in the atmosphere. Weakens marine carbon sinks via chemical and biological feedback.</td>
</tr>
<tr>
<td>Land System Changes</td>
<td>Increasing Risk</td>
<td>Historically 15-20% of GHG emissions come from land system change. Climate Change alters the productivity of agricultural and forest land.</td>
</tr>
<tr>
<td>Biochemical Flows</td>
<td>High Risk</td>
<td>Nitrogen-fixing species affect radiative forcing. N2O is a strong, long-lived GHG. NH3/NH4+ and NOx contribute to aerosol formation.</td>
</tr>
<tr>
<td>Biosphere Integrity</td>
<td>High Risk / Unquantified</td>
<td>Falling terrestrial and marine ecosystem resilience increases the risk of climate-induced tipping points, reducing their capacity to act as carbon sinks.</td>
</tr>
<tr>
<td>Atmospheric Aerosol Loading</td>
<td>Unquantified</td>
<td>Alters tropical atmospheric circulation and precipitation patterns. Black and brown carbon deposits on snow and ice cause melting.</td>
</tr>
<tr>
<td>Novel Entities</td>
<td>Unquantified</td>
<td>Chlorofluorocarbons (CFCs) and Hydrofluorocarbons (HFCs) are strong GHGs.</td>
</tr>
</tbody>
</table>

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9 Even if anthropogenic GHG emissions were to cease immediately, the climate would continue changing for decades, if not centuries, to come (Meehl et al. 2005).
One of the strongest of these connections is between climate change and the other ‘core’ planetary boundary: biosphere integrity (the survival of complex adaptive ecosystems supporting diverse forms of life). The IPCC are highly confident that climate change is adversely impacting terrestrial ecosystems, contributing to desertification and land degradation in many areas and changed the range, abundance and seasonality of many plant and animal species (Arneth et al. 2019). Similarly, the IPBES has reported that climate change is restricting the range of nearly half the world’s threatened mammal species and a quarter of threatened birds, with marine, coastal, and arctic ecosystems worst affected (Diaz et al. 2019). According to one estimate, it could cause 15-37% of species to become ‘committed to extinction’ by mid-century (Thomas et al. 2004).

Disruption to biosphere integrity can have profound economic and social repercussions, ranging from loss of ecosystem services and natural resources to the destruction of traditional knowledge and livelihoods. For instance, desertification, which threatens a quarter of Earth’s land area and a fifth of the population, is already estimated to cost developing nations 4-8% of their GDP (D’Odorico et al. 2013). Many other rapid regime shifts involving loss of biosphere integrity have been observed, including shifts in arid vegetation, freshwater eutrophication and the collapse of fish populations. There is a theoretical possibility of still more profound regime shifts at the global level (Rocha et al. 2018). However, the potential contribution of loss of biosphere integrity to GCR is yet to be assessed. Kareiva and Carranza (2018) argue that it is unlikely to threaten human civilization, due both to a lack of plausible mechanisms for this threat and the fact that “local and regional biodiversity is often staying the same because species from elsewhere replace local losses”. However, in their classification of GCRs, Avin et al. (2018) suggest the potential for ecological collapse to threaten the safety boundaries of multiple critical systems with diverse spread mechanisms at a range of scales, from the biogeochemical and anatomical to the ecological and sociotechnological. Both these studies were conducted largely for conceptual purposes and should not be taken as rigorous analyses of this risk. This topic warrants further investigation.

Classifying Climate Change’s Contributions to Global Catastrophic Risk
Assessment climate change’s contribution to GCR must go beyond this planetary boundary concept. In addition to identifying critical systems whose safety boundaries are most likely to be breached by climate change, we need to understand how such breaches might cascade into a global catastrophe. Taking Avin et al.’s list of critical systems, we note that previous studies have mostly focused on the physical and biogeochemical systems along with the lower-level critical systems that are most directly related to human health and survival. However, this represents a very limited assessment of risk as it only accounts for climate change as a direct hazard/threat and our “ontological” vulnerabilities to it. A more comprehensive risk assessment must consider the higher-order critical systems threatened by climate change on which we depend, either passively (through a lack of alternatives) or actively (through intentional design).

A greater threat to humanity is likely to occur when sociotechnological and environmental systems are tightly coupled, creating a potential for reinforcing feedback loops. If environmental change produces social changes that perpetuate the environmental change then this could actively work against our efforts at adaptation. Where this change has the potential, via
humanity’s vulnerabilities and exposure, to produce significant harm, then we describe such a loop as a ‘global systems death spiral.’ Such a death spiral could produce a self-perpetuating catastrophe, whereby the energy and resources required to push back against social and ecological collapse are beyond the means of a dwindling human society, effectively countering our efforts at adaptation. Feedback loops like this could thus create tipping points beyond which returning to anything like present conditions could become extremely difficult. Global systems would shift to very different states where the ultimate prospects for humanity will likely be bleaker. In this section, we focus on the potential for one such spiral to emerge between an ecological system (the biosphere) and two sociotechnological systems we have studied (the human food and global political systems). Figure 2 illustrates one model for such a spiral.

![Figure 2: A global systems death spiral](image)

**The human food system**

Climate change’s impact on biosphere integrity could harm the human food system due to loss of ecosystem services, disruption of the cycles of water, nitrogen and phosphates, and changes in the dynamics of plant and animal health (Bélanger and Pilling 2019). Crossing this planetary boundary is already having severe implications for global food security, including loss of soil fertility and insect-mediated pollination (Diaz et al. 2019).

Despite significant increases in food productivity, systems for the production and allocation of food are enduring an extraordinary amount of stress. The sources include climate change, soil erosion, water scarcity, and phosphorus depletion. An expanding global population and rising standard of living are increasing the demand for food. Simultaneously the natural resource base, arable land and freshwater upon which food production stand are being degraded. While global food production has increased dramatically over the past century to meet rising demand, these constraints and risks are increasing the vulnerability of our global food supply to abrupt and global disruption that could constitute a global catastrophe in its own right (Baum et al. 2015).
Climate change will reduce food security in at least three interconnected ways. First, it will affect growing conditions. This include direct threats to agricultural yields from heat, humidity and precipitation in many areas, although initially improving conditions in some (Lott, Christidis and Stott 2013). Second, it will increase the range of agricultural pests and diseases (Harvell 2002). Third, it will increase the occurrence of extreme weather events that impair the integrity of food production and distribution networks, from production to harvest, post-harvest, transport, storage, and distribution, thereby increasing our vulnerability and exposure to supply shocks (Bailey et al. 2015). Given the high degree of interconnectivity and feedback within the global food system, our initial research suggests that any one of these effects could trigger scenarios that would critically undermine the global food system to meet existing demand, let alone rise to the challenge of continuing to grow (Tzachor 2019).

The IPCC estimate with medium confidence that at around 2°C of global warming the risk from permafrost degradation and food supply instabilities are projected to be very high, while at around 3°C of global warming risk from vegetation loss, wildfire damage, and dryland water scarcity are also projected to be very high (Arneth et al. 2019). Very few studies have considered the impacts of 4°C of global warming or more. The IPCC highlighted research finding that this could cause a decrease of 19% in maize yields and 68% in bean yields in Africa, and an 8% reduction in yields in South Asia by 2050; there will also be a substantial undesirable impact on fisheries. Any potential agricultural gains from climate change across all regions will be lost by this point (Porter et al. 2014). Furthermore, multiple extreme weather events could disrupt food distribution networks (Baily and Wellesley 2017). Finally, there is the potential, as yet largely unknown, for global climate change to become even more rapid and abrupt, producing a very serious disruption to the global food supply (Baum et al. 2015). Such conditions will lead to falling supplies, rising prices and increased risk of famine and conflict (Natalini, Jones and Bravo 2015).

While there are opportunities to adapt, disruption to the entire global food system cannot be resolved via food aid alone. Indeed, there is the potential for unhelpful isolationist or heavy-handed responses. These trends could push the global food system to a point where it can no longer supply a growing human population with the minimum nutrition for well-being requirements; making food security for all an unachievable goal. This point would thus constitute what Kuhlemann (2019) terms a ‘threshold of significance.’ Whether greater than expected levels of climate change or a greater than expected negative response from the global food system to climate change are likely to pose the greater threat to food security is not something we are currently able to assess.

The global political system
Disrupting the global food system can create and exacerbate conflict, migration, and state failure (Brinkman and Hendrix 2011). However, this once again needs to be seen against the backdrop of a global political system under stress, with climate change as a significant contributing factor. Climate change influences political systems in many ways, from being a locus of activism and a stimulus for reform, to driving rising inequality and population displacement (Arneth et al. 2019, Diffenbaugh and Burke 2019). This is not a new phenomenon. Changes in the climate are believed to have contributed to conflict between people and states throughout human history, driven by resource scarcity, displacement and inequality (Lee 2009, Mach et al. 2019). As part of a comprehensive risk assessment of climate change, David King and colleagues (2015) conducted an extensive literature review on climate change and conflict and
used this to inform a series of international wargaming exercises. These found that climate change is expected to increase international conflict while highlighting the role that climate-induced migration and displacement, state failure, and water and food insecurity are likely to play in driving this (see also Natalini, Jones and Bravo 2015, Mach et al. 2019).

Quantitative studies of the impact of climate change on violence and conflict have provided more mixed results. A survey of empirical research by Detges (2017) found that there may be multiple differing trends: extreme weather events appear to have more significant effects on violence than do long-term climate trends, while small-scale conflict and interpersonal violence appear to be more affected as a result than large-scale conflicts and international war. Empirical studies also support the conclusion of qualitative and theoretical research that climate change’s impact on conflict is predominantly as a risk multiplier and intensifier. Thus, it appears that climate change serves more to increase our vulnerability to other conflict-inducing factors, such as loss of livelihood, migration, environmental change and food insecurity, than acting as a direct cause of conflict (Schubert et al. 2008, Hsiang et al. 2013, Abel et al. 2019).

Of particular relevance to GCR is the effect of climate change on the risk of nuclear war (Parthemore, Femia and Werrell 2018). While several authors have discussed this possibility, it has never, to our knowledge, been rigorously assessed. Climate change is unlikely to directly trigger nuclear conflict, but the impacts may create conditions more conducive to a nuclear exchange. As a recent model of the risk of nuclear war highlights, precipitating events with the potential to trigger a nuclear exchange are not uncommon (Baum, de Neufville and Barrett 2018). This model outlines 14 different causal pathways to an exchange, including the escalation of conventional wars and international crises, human error, and the emergence of new non-state actors. For all but two of these, they identified historical events that could have precipitated a nuclear exchange. This suggests that the absence of nuclear conflict since World War II is not due to a lack of potential causes, but rather the global political system’s ability to deescalate them. Thus, the real significance of climate change may be its capacity to increase our vulnerability to precipitating events. The combination of social, political and environmental disruption, a lingering sense of global injustice, and rising food, water, and energy insecurity could increase the probability that crises escalate, or that false alarms are mistaken for genuine emergencies. We believe that this is a possibility in need of further research.

The emergence of a global systems death spiral
Yet, we should not conclude that a nuclear exchange is the only, or even most likely, scenario in which climate change could produce a global catastrophe. Significant disruption to the global political system could be very catastrophic in other ways. Conflict and political instability, even of moderate severity, are themselves two of the most significant drivers of biodiversity loss due to breakdowns in monitoring governance, and (public and private) property rights (Baynham-Herd et al. 2018). This connection creates a potentially reinforcing feedback loop between loss of biosphere integrity, food insecurity and political breakdown.

The mechanisms by which these failures might spread include a large number of the natural, anthropogenic, and replicator effects identified by Avin et al. (2018), making them harder to contain. At the natural level, climate change involves changes to the global atmospheric and biogeochemical systems that propagate around the world and also raises the spectre of other naturally spreading harms like global ecological collapse. At the anthropogenic level, the global interconnectedness of sociotechnological systems means that while small shocks are easier to
recovery from, larger shocks can be harder to contain and control. Finally, biological and informational replication can also spread the negative impacts of climate change, from vector-borne diseases and invasive species to climate fatalism and dangerous geoengineering technologies.

Given these numerous spread mechanisms, critical system failures could precipitate global catastrophes. Furthermore, this is unlikely to be the only set of interlinked systemic disruptions that climate change could create (other death spirals could involve bioinsecurity and disease), nor are these the only causal connections between these systems. Until we understand the nature of such death spirals better we must act cautiously. We now turn to consider how to achieve this.

**Opportunities and Obstacles for Reducing Climate Change’s Contribution to Global Catastrophic Risk**

Global catastrophes are not inevitable. Risks exist because global catastrophes are avoidable, but there are significant challenges to avoiding them. An assessment of GCR must, examine mitigation measures.

Many of the opportunities and obstacles for managing GCR are common across the different drivers of risk, including climate change and other environmental problems, dual-use applications of biotechnology and nuclear technology, and naturally occurring disasters like asteroid impacts and volcanic super-eruptions. Our opportunities range from improving governments’ understanding of global catastrophes (Sepasspour 2019) and the representation of future generation’s interests (Jones et al. 2018) to a new focus for international diplomacy (Farquhar et al. 2017). These obstacles we face range across the individual (cognitive bias towards the near-term and sense of disempowerment) and interpersonal scales (distrust, communication difficulties and value misalignment), to the institutional scale (weak decision-making mechanisms and institutional inertia) and beyond (the challenges of ensuring global compliance and coordination after decisions have been made). Avin et al. (2017) identified many such obstacles, which we summarize in table 2.

**Table 2: A Classification of challenges to mitigating Global Catastrophic Risk (after figure 3 in Avin et al. 2018)**

<table>
<thead>
<tr>
<th>Level</th>
<th>Prevention and Mitigation Fragilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual</td>
<td>Cognitive biases; Disempowerment; Lack of motivation; Need for reflection; Poor risk perception; Skill shortages; and Value misalignment</td>
</tr>
<tr>
<td>Interpersonal</td>
<td>Communication failure; Conflict; Interconnectedness; Exclusion of marginalised groups; Reputation management; Inequality; and Mistrust</td>
</tr>
<tr>
<td>Institutional</td>
<td>Institutional path dependence; Conflicts of interest; Corruption; Poor incentives and information flows; Management/PoW structure; and Resource/Staffing shortages</td>
</tr>
<tr>
<td>Beyond Institutional</td>
<td>Defection and Enforcement; Coordination and Responsibility; Diversity; Poor governance; Institutional mix; Monitoring/Surveillance failures; and Representation</td>
</tr>
</tbody>
</table>

If we could overcome these obstacles, we would likely find that we already have a good idea of what is needed to prevent global catastrophes, even where they are caused by long-term systemic processes like climate change. These include:
• creating redundancy and supporting ecological and economic heterogeneity so that we do not rely on conditions being just right for a small number of species, economic models, and other systems we are reliant on;

• establishing a modular structure that allows us to localize systemic failures and prevent them from spreading globally; and

• introducing balancing feedback and adaptive management to counteract reinforcing feedback, such as ‘tail risk treaties’ that pre-commit countries to enhanced action should circumstances turn out to be worse than expected.

Policies like these could enhance global resilience and give us a far greater appreciation of the risks to humanity, thereby overcoming many of the barriers to mitigating them. Yet few of these options are being actively explored, or even studied. They thus present an important subject for future research.

However, there are some obstacles and opportunities that remain relatively unique to the current situation around climate change due to its nature as a slowly unfolding global catastrophe originating from global coordination failures and complex system dynamics. One of these is the difficulty in moving from the assessment and management of the individual impacts we have described here to the overall risk from climate change on humanity. Ecological collapse, food insecurity, and conflict can all be assessed as individual contributors to GCR and managed in a piecemeal fashion, such as through enhanced international diplomacy, bioengineering or new agricultural techniques. If regenerative and redistributive food systems would make extreme weather events easier to withstand then it certainly makes sense to work towards this, whether or not are caused by climate change. Similarly, active conservation or bioengineering may be able to preserve climate-threatened biodiversity, while effective diplomacy, sustainable security, and nuclear disarmament may reduce the threat of catastrophic conflicts, irrespective of their cause. It can thus be challenging to identify and address those features of these risks that correspond to climate changes unique contribution. This is a non-trivial issue for risk classification and communication purposes, but one that is already being addressed in areas such as extreme weather (Mann, Lloyd and Oreskes 2017). We are convinced that a reductive approach to the assessment and management of climate changes contribution to GCR could miss important systemic interactions and effects. Furthermore, if all these risks can be lowered by ambitious action to tackle climate change, thus treating the underlying disease, common sense would suggest that this should at least form part of our risk management strategy alongside the treatment of its individual symptoms.

Another challenge is that the slow emergence of climate change’s impacts makes it hard to predict how much action we need to take now in order to stave off a catastrophe in the future. It is possible that at least some of these effects will be outweighed by the pace of technological development and that we could potentially overshoot in our efforts to avoid them. However, as Karin Kuhlemann notes, slowly emerging risks present unique challenges and opportunities. For example, slow-moving, complex catastrophes are easier to ignore than more explosive ones, encouraging people to question whether they should be the generation to respond. Together with people’s shifting baselines about what is normal, they also make it harder to identify when a threshold of significance has been crossed. Similarly, as Nick Bostrom points out, we are presently in a semi-anarchic state of global governance and this appears to offer poor incentives for the development and implementation of risk mitigation tools, and rather supports a global
culture of risk denial and inaction. Accurately predicting ecological tipping points and technological breakthroughs is thus not only difficult, but positively discouraged, and so wagering that techno-fixes will consistently outstrip environmental crises is a reckless gamble. This does not nullify the crucial role that technology can and will play in addressing climate change’s contribution to GCR. Technological fixes for climate change are not the only policy proposals that have uncertain time frames, success rates, and side-effects; the same can be said of social and economic fixes as well. It is thus doubly important that we move to a paradigm in which this risk, and thus the costs and benefits of different proposals for managing it, can be better assessed.

4 – Conclusion
There is much we do not know about climate changes contribution to GCR, including discrete future impacts at temperatures beyond 3°C or humanity’s resilience to climatic disruption. The dynamics and tipping points of global ecological and social systems remain highly uncertain. This is especially true given the lack of attention being paid to creating regenerative and resilient global systems. Instead the drive for economic growth and efficiency is making these systems more complex, tightly coupled and vulnerable. However, we must not confuse epistemic humility with either fatalism or impotence. We can, and should, do more to assess and manage climate change’s contribution to GCR.

Climate change should thus be studied alongside other contributors to GCR and further research is needed both to understand the scale of its contribution and how to manage it. New techniques that are being developed by global catastrophic risk scholars point the way towards a better research agenda. If well designed and implemented alongside other tools, these could form the basis of a proper assessment of this risk. The impacts of climate change are global and complex; a meaningful understanding of the plausible worst-case scenarios will require the concerted efforts of many researchers across the GCR, climate science, and policy communities.

References


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