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Addressing the limits to adaptation across four damage–response systems

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ABSTRACT

Our ability to adapt to climate change is not boundless, and previous modeling efforts show that future policy decisions about climate change are affected when adaptation limits are exceeded. Adaptation limits are delineated by capacity thresholds, after which climate damages begin to overwhelm the adaptation response and net adaptation goes negative. The levels of such thresholds depend on the complex interaction of different environmental (climatic and ecological) and human response (technological and societal) systems. In this paper, the interactions among these sub-systems are explored and four novel archetypical climate damage and adaptation response systems are developed. These damage–response systems can be described by the level of their adaptation limits thresholds, the pathways of adaptation capacity degradation and failure, and the recoverability or permanence of such climate losses once the adaptation limits have been surpassed. Policy options upon reaching the limits to adaptation include investment in more of the same technology, implementation of new and more effective adaptation, or transformational adaptation that allows the damage–response system to become more resilient. Attention is drawn to the need for greater understanding of the uncertainties of adaptation limits, how to raise the effective capacities and lifetime ranges of adaptation (and thus delay adaptation failure), and what policy options exist when adaptation limits are breached.

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1. Introduction

Our ability to adapt to climate change is not boundless, as each type of adaptation response has a limited capacity. The set of available adaptations encompasses a large array of strategies that are specific to particular economic sectors affected by climate change (for example, agriculture, transportation, infrastructure, energy) and types of climate damages that are faced (sea-level rise, droughts, floods, heat waves). The point at which each strategy reaches its limit will vary as well across these sectors facing different damages, where the maximum effectiveness of each response is constrained by the interaction of climatic, ecological, technological, and societal systems.

Over the long term, an effective response portfolio to climate change includes both mitigation and adaptation, as the two strategies are complementary tools of climate change risk management (Felgenhauer and Webster, 2013; IPCC, 2014). The relationship is summarized by Mastrandrea and Schneider (2010), ‘‘what cannot be prevented through mitigation must be adapted to; what we cannot cope with by

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adaptation, we must prevent," and Oreskes et al. (2010), "... the less we mitigate, the more we shall have to adapt. Furthermore, the less we mitigate, the more likely we are to face challenges that surpass our capacity to adapt without pain and suffering." Arguments for prioritizing adaptation comes from its supposed affordability, because there is a perception that it is too late for mitigation to be effective (Oreskes et al., 2010, 1017–1018), or because it is more politically feasible to implement at the local level because of its concentrated rather than global benefits. The pessimistic view is that while humans have always changed with their environment it is also true that environmental stressors have overwhelmed the ability of earlier societies to adjust, causing collapse (Diamond, 2005).[1] Humans have never experienced the speed of climate change that is expected to occur during this century (Rogelj et al., 2012). Absent aggressive global mitigation, the likelihood of meeting an internationally accepted global mean temperature change target of 2 °C continues to fall (Rogelj et al., 2012). A mean temperature change beyond this level, for instance a 4 °C change, will bring increasingly severe impacts that may surpass society's ability to adapt. A 6 °C global mean temperature change resulting from doubled atmospheric CO_2 concentrations and slow climate feedbacks would "severely challenge the viability of contemporary human societies" (Rockström et al., 2009). Responding to such extreme impacts will require "fundamental socioeconomic and technological transformation, rather than adjustments [of existing systems]—assuming such transformations are achievable through planning at all" (New et al., 2009). Adaptation limits, however, will become relevant before such extreme points are reached.

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5) finds that an adaptation limit is reached "when adaptation efforts are unable to provide an acceptable level of security from risks to the existing objectives and values and prevent the loss of the key attributes, components or services of ecosystems" (Klein et al., 2014). Relatedly, Moser and Ekstrom (2010) define limits as "obstacles that tend to be absolute in a real sense: they constitute thresholds beyond which existing activities, land uses, ecosystems, species, sustenance or system states cannot be maintained, not even in a modified fashion." Building on Klinke and Renn (2002), Dow et al. (2013) define an adaptation limit as "a point at which an actor can no longer secure valued objectives from intolerable risk through adaptive action." Preston et al. (2013) relatedly introduce the concept of an "adaptation frontier" defined as "a socio-ecological system's transitional adaptive operating space between safe and unsafe domains," beyond which adaptation is limited. The limits to adaptation can also be seen through a sustainability lens (Eriksen et al., 2011), where sustainability means meeting "the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland Commission, 1987). Sustainable systems in a strict sense are those that continue to function through time as expected, while a system is unsustainable if at some point in the future it stops working in its current form.

[1] See the Electronic Supplementary Material (ESM) for additional background.

In this paper, I define adaptation limits as the point at which the level of climate damages has surpassed the capacity of the current adaptation approach, and net adaptation (adaptation benefits minus damage costs) has dropped to zero. After this point, existing adaptation responses could still be providing damage-reducing benefits, but the total amount of damages will exceed the adaptive capacity. Adaptation limits matter for making policy decisions because they exist and will be surpassed, which will require that failing adaptation be replaced with other pre-existing policy responses or new approaches that have yet to be developed and tested. Results from integrated assessment models of the global climate and economy show that when adaptive capacity is overwhelmed it becomes costly to societal welfare, requiring substitution with other policy responses (Felgenhauer and Webster, 2014; de Bruin and Dellink, 2011). Adaptation limits have been recognized at the U.S. national policy level (U.S. EPA, 2010; Titus, 2011), and a National Research Council report called for more research into understanding the "thresholds or tipping points for climate change impacts, which in turn helps to determine the limits of adaptation," as well as for contingency plans to be developed for times when adaptation limits have been reached (NRC, 2010, 205).

In order to understand adaptation limits within different damage–response systems, this paper looks at adaptation under assumed optimal decision-making conditions. Thus, adaptation proceeds if the resulting benefits from damage reduction outweigh the costs of implementation. Adaptation investment decisions are informed by uncertain expectations of climatic damages and associated vulnerabilities. Optimal implementation of an adaptive response means that it is not constrained by implementation, informational, or cognitive barriers (Oreskes et al., 2010; Moser and Ekstrom, 2010; Hulme et al., 2009; Moser, 2009; Inderberg and Eikeland, 2009; Eisenack et al., 2014). It is important to note that barriers are distinctly different from limits, though the two terms have been used interchangeably (e.g., Bardsley, 2014). Barriers to adaptation are obstacles that prevent implementation of a fully optimal adaptation response, such as inadequate information and experience, inadequate institutional support, lack of resources and technology, and behavioral impediments (NRC, 2010).[2]

In this paper, I outline a new framework for understanding the limits to climate change adaptation from a systems perspective. From Meadows (2008), a system is "an interconnected set of elements that is coherently organized in a way that achieves something," often with the goal of ensuring "its own perpetuation." I review the literature on human and natural systems, as well as the limits of adaptation in different damage sectors. What I call the climate damage–adaptation response (or damage–response) system is the dynamic space of possible climate impacts and human responses to those impacts. I develop four different archetypes of such systems that trace the pathways of adaptation degradation and failure in response to rising damage levels. Exploring the behavior of these damage–response systems can help to inform policy decisions when adaptation limits are approached and surpassed. The research motivation is to explore the factors that

[2] For more on adaptation barriers, see the ESM.

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