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Assessing organizational resilience to climate and weather extremes: complexities and methodological pathways

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Abstract This paper offers insights for assessing organizational resilience to the effects of climate change, specifically to climate and weather extremes. The assessment of organizational resilience to climate and weather extremes brings about several challenges due to (1) uncertainties about future climate change outcomes across temporal and spatial scales and (2) a lack of insight into what lead to organizational resilience, or which variables should be measured in a given study. We suggest methodological pathways for organizational managers to identify properties of future climate and weather extremes and to include them in resilience assessments. We also suggest approaches to identify factors that promote organizational resilience to selected climate and weather extremes. Findings are intended to help managers to understand how organizational resilience to climate and weather extremes can be enhanced.

1 Introduction

Organizations from sectors such as agriculture, insurance or energy are highly vulnerable to the effects of climate change, especially to extreme weather events and potential abrupt climate changes. It is expected that, in response to gradual changes in climate, much of the economic capital stock may adjust without major disruption (Berkhout et al. 2006; Hoffmann et al. 2009). For instance, building standards and infrastructure can be upgraded over time. However, several scientists highlight the need to consider the full range of possible climate change outcomes, including (1) greater climate variability (i.e., more frequent and/or severe weather extremes), and (2) a larger potential for abrupt climate change due to non-linear responses in the Earth's climate system (Schneider 2004; Solomon et al. 2007). These outcomes (broadly referred to in this paper as climate change related *climate and weather extremes*) could disrupt economies, industries and organizations in ways that prevent their timely repair or adaptation (National Research Council 2002).

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The central issue for organizations is whether they are able to handle disruptions that go beyond steady adaptations to gradual change and are sufficiently *resilient* to climate and weather extremes (i.e., whether they can absorb resulting impacts and recover while maintaining their function) (Linnenluecke and Griffiths 2010; McDaniels et al. 2008). Naturally occurring weather extremes already bring about major challenges to organizations, and their frequency and severity might significantly change due to climate change. Extreme climate change outcomes would be particularly impactful for organizations and industries which are specific to a particular location and adjusted to certain climatic conditions.

While resilience is generally seen as a desirable characteristic for organizations to deal with unexpected, abrupt and/or 'extreme' change (Weick and Sutcliffe 2007), the question of what leads to resilience in an organization is open to methodological inquiry and interpretation. Our paper is a first step towards addressing the question of how managers can assess their organization's resilience to climate and weather extremes. Such assessments can be used to identify actions to alter organizational resilience (Cumming et al. 2005).

Our focus on climate and weather extremes does not mean that gradual changes in climate (e.g., mean temperature rise) do not pose challenges in their own right. They constitute an important driver behind changes in weather extremes and non-linear abrupt climate change and can place significant stresses on organizations which may exceed their adaptation capacities (National Research Council 2002). For instance, the ability of water reservoirs to cope with gradual climate change can switch from adequate to inadequate even through very gradual changes in water supply (Arnell 2000; Wilbanks et al. 2007).

The assessment of organizational resilience to climate and weather extremes brings about several challenges. There are few insights into the operationalization and empirical assessment of the resilience concept, particularly in the context of climate change. Existing attempts to detect organizational resilience (or absence thereof) have employed retrospective analyses *after* an adverse impact has occurred (Somers 2009). The collection of empirical data and the interpretation of findings are easier retrospectively than the evaluation of organizational resilience to potential future impacts from climate and weather extremes. The key difficulty for resilience assessments in the context of climate and weather extremes lies in determining predictive elements of resilience to future impacts (Carpenter et al. 2005). The question remains whether and how future resilience can be anticipated and contributing factors recognized and isolated.

Our paper is structured as follows: First, we provide a conceptual frame of reference for understanding organizational resilience to climate and weather extremes. We then discuss complexities in assessing organizational resilience to these extremes and outline possible methodological pathways. The key contribution of paper is to provide a foundation for assessing organizational resilience to climate change and weather extremes.

2 Organizational resilience to climate and weather extremes

For most organizations, variability in climatic conditions such as interannual variability falls within a "coping range" (Smit et al. 2000; Yohe and Tol 2002). A coping range can be understood as a range of circumstances, described by one or more climate-related variables, that an organization can tolerate without experiencing adverse consequences (Fig. 1). The core of the coping range shows ideal conditions for organizational activities. Towards one or both edges of the coping range, conditions are not ideal, but tolerable. The edges of a coping range indicate boundaries beyond which consequences for organizational activities due to climate-related conditions (e.g., damages, losses in performance) become significant

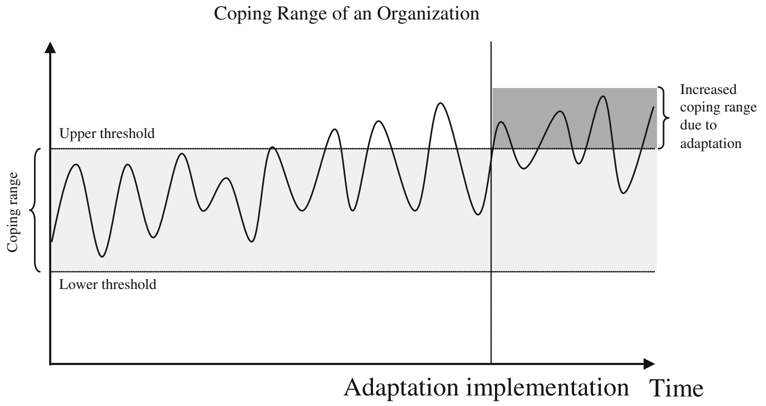

Fig. 1 Coping range of an organization. Source: Adapted from Carter et al. (2007), Lemmen and Warren (2004)

(Carter et al. 2007; Linnenluecke and Griffiths 2010). For instance, organizations in ecosystem-dependent industries such as agriculture or viticulture are highly reliant on certain patterns of temperature and rainfall. They are challenged by conditions outside these patterns, such as prolonged droughts. However, not all extremes are undesirable. Extremes such as droughts or floods are important to the health of many ecosystems, and associated industries and organizations have often a sufficiently broad coping range to deal with their impacts.

Climate change increases the risk that conditions outside the boundaries of the coping range occur. Such conditions can occur if an individual climate variable (e.g., temperature, rainfall) significantly deviates from ‘usual’ conditions (simple climatic extremes), or if a critical combination of different variables occurs (complex climatic extremes, such as hurricanes or droughts) (Schneider et al. 2001). Of concern is that climate change could bring about abrupt and persistent shifts in climate and weather patterns over entire regions (Alley et al. 2003; Hulme 2003; Scheffer et al. 2001), leading to catastrophic local or regional impacts if they were to occur (Wilbanks et al. 2007). However, more gradual changes may also exceed an organization’s coping range and lead to significant impacts if the coping range is narrow or the changes persistent. Although organizations can adapt to widen their coping range (examples are the development of drought resistant crops or flood barriers), adaptation measures usually require time for their implementation.

Some researchers argue that a ‘resilient’ organization is not affected by variability in climatic conditions over short periods, as it possesses a sufficiently wide coping range. They argue that the coping range represents a form of underlying resilience (Yohe and Tol 2002) due to which variability in climatic conditions has no significant consequences. In other words, an organization has full *impact resistance* to conditions that fall within the coping range. Other researchers suggest that organizations need resilience in situations that create vulnerability and require an unusual response (Lengnick-Hall and Beck 2003), and need to undertake steps to recover from impacts once the boundaries of the coping range have been exceeded. According to this perspective, the quick and/or full recovery of the organization (i.e., the rapidity, or amount of recovery) to a pre-disturbance or even an improved state are regarded as a resilient response.

The two dimensions, *impact resistance* and *rapidity*, are illustrated in Fig. 2 with reference to a level of organizational performance (P). Organizational performance refers to a performance indicator such as financial performance or service output and can range from

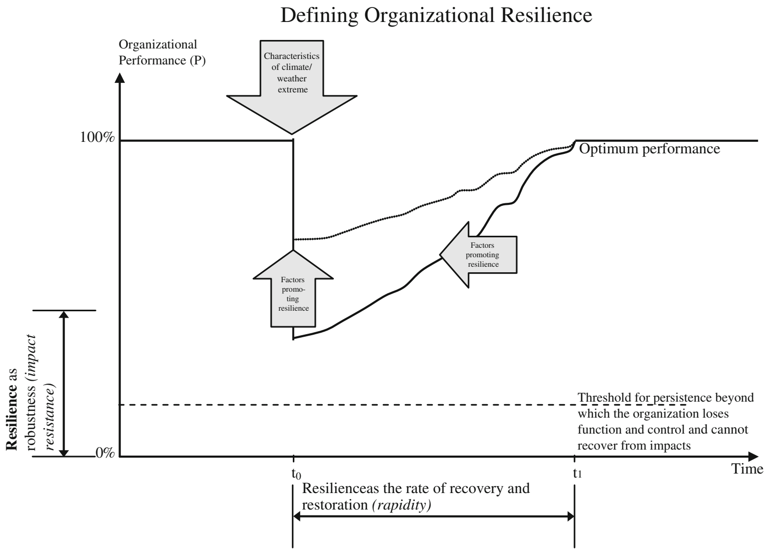

Fig. 2 Defining organizational resilience. Source: Adapted from Adger (2000), McDaniels et al., (2008), Linnenluecke and Griffiths (2010)

0% to 100%. For instance, for an energy distribution company organizational performance might refer to the percentage of customers that have full service access. The upper horizontal line in Fig. 2 indicates the optimum level of organizational performance (McDaniels et al. 2008). Changes in performance can occur when an organization is exposed to an adverse event (e.g., a drought or a cyclone). Organizational exposure to an adverse event occurring at t_0 can cause sufficient damage to the organization such that its performance is reduced by a certain percentage. The extent to which function is maintained (i.e., the extent to which performance is not driven to zero) reflects the *impact resistance* to a given shock (McDaniels et al. 2008). Restoration of the organization is expected to occur over time, as indicated in Fig. 2, until the time t_1, when it is completely restored. The rate with which recovery and restoration are achieved reflects the *rapidity* (Adger 2000).

Figure 3 illustrates hypothetical impacts of different types of climate and weather extremes on organizational performance. This figure combines insights from Figs. 1 and 2 to provide a frame of reference to understand organizational resilience to climate and weather extremes. Figure 3 shows an assumed ‘resilient’ response, and a ‘less’ or ‘not’ resilient response, potentially leading to organizational decline and failure. Figures 2 and 3 also show a threshold for organizational persistence (represented by the dashed horizontal line), that is, the amount of disturbance the organization can absorb before it loses vital components and functions and has to significantly alter or cease production and/or service delivery.

3 Complexities in assessing organizational resilience to climate and weather extremes

An assessment of organizational resilience to climate change related climate and weather extremes requires an understanding of (1) the physical characteristics of future climate and weather extremes and (2) factors promoting organizational resilience (see Fig. 2). This brings about complexities which we outline below.

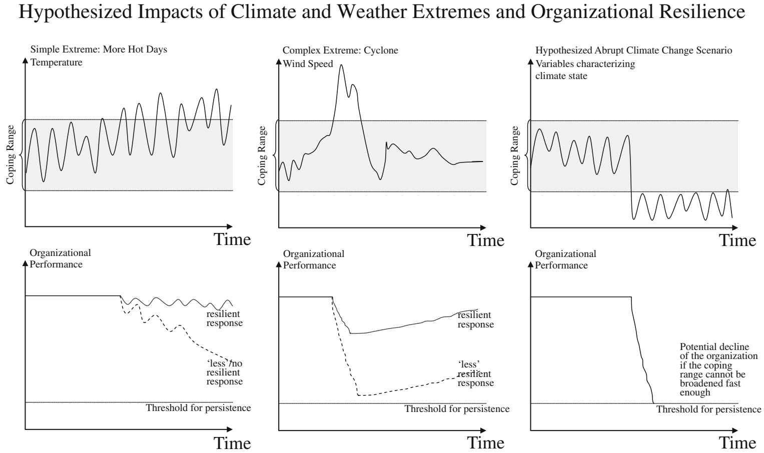

Fig. 3 Hypothesized impacts of climate and weather extremes and organizational resilience

3.1 Uncertainties regarding future climate and weather extremes

Climate change is a multi-scale phenomenon with a range of potential outcomes and impacts across multiple temporal and spatial scales (Clark 1985). Much progress has been made in recent years to understand and project future climate change. Since the IPCC Third Assessment Report, confidence has increased that some weather extremes will become more frequent, widespread and/or intense during the 21st century. However, many of the current projections have been developed for a global or regional level. The ability to assess organizational resilience to future climate and weather extremes is limited by uncertainties about climate change outcomes at a relatively fine-grained geographical and sectoral scale, and by uncertainties about organizational developments (Wilbanks et al. 2007). In the absence of precise projections for the magnitude, timing and location of impacts, the question arises how information about future climate and weather extremes can be derived on an organizationally relevant scale.

3.2 Difficulties in identifying factors promoting organizational resilience

In addition to understanding future climate and weather extremes, it is necessary to determine what leads to organizational resilience, or which variables should be measured in a given study to determine future resilience (Cumming et al. 2005). Theoretical insights suggest that *impact resistance* is promoted by decentralization, diversity and redundancy of organizational resources and structure, while *rapidity* is promoted by processes to identify problems, establish priorities, mobilize resources and deploy them appropriately (Bruneau et al. 2003; Vogus and Sutcliffe 2007). However, defining a priori the variables that will lead to organizational resilience can result in conclusions which are largely driven by the initial selection of variables (Cumming et al. 2005).

The prominent empirical approach for assessing organizational resilience has been case-focused research (e.g., Gittell et al. 2006; Meyer 1982). Researchers have undertaken retrospective case analyses to identify capacities (i.e., resources, structures, processes) that organizations used to preserve and/or restore their performance in the context of adverse events (ranging from internal crises to large-scale external impacts).

These studies usually offer a diagnosis of what *happened* in a certain situation, and how future organizational resilience can be improved based on past insights. The themes that emerged in empirical studies show similarities to the theoretical propositions above. For instance, Meyer (1982) suggested that slack (i.e., 'redundant') resources are important for organizations in absorbing the impacts from adverse conditions.

While illustrating important points, it is likely that existing theoretical and case insights have not yet uncovered the full range of factors leading to resilience. Furthermore, the context-dependency of factors promoting organizational resilience is not well understood. Impacts from climate and weather extremes on industries and organizations could depend on aspects such as the lifetime, mobility and manageability of capital stocks (factories, infrastructure), the abruptness and predictability of any changes (Alley et al. 2003; National Research Council 2002), and the size of the organization relative to the event. Retrospective event studies of past episodes of organizational decline and recovery do in all probability not provide insights into resilience to future climate impacts (Linnenluecke and Griffiths 2010).

4 Methodological pathways for assessing organizational resilience to climate and weather extremes

In order to overcome some of these challenges, this section outlines potential methodological pathways for assessing resilience in organizations. We suggest ways to identify properties of future climate and weather extremes as well as factors that promote organizational resilience to these extremes.

4.1 Identification of properties of future climate and weather extremes

Below, we discuss three approaches (climate projections, analogues, and high impact studies) as a basis for deriving information about future climate and weather extremes.

4.1.1 Climate projections

Climate projections, together with observations of already occurring changes in climate, provide a quantitative basis for estimating likelihoods for many aspects of future climate change. Model simulations cover a range of possible futures. Many simulations are based on idealized of greenhouse gas (GHG) emission or concentration assumptions that were developed in the IPCC Special Report on Emissions Scenarios (SRES) (Nakićenović et al. 2000). The SRES presented four narrative storylines (the 'A1', 'B1', 'A2' and 'B2' worlds which are considered to be equally plausible), representing different demographic, social, economic, technological and environmental developments (Nicholls 2004).

The SRES storylines formed the basis for the development of quantitative estimates of GHG emissions and coarse resolution climate projections. Based on these projections, researchers have attempted to determine the likelihood of both gradual changes and changes in extreme events on global and regional scales. For some extremes (e.g., cold extremes), where there is good reason for expecting considerable spatial coherence in the sign, and perhaps even the magnitude, of a trend, global and regional projections from coarse resolution models might provide some quantitative information for resilience assessments (Barros et al. 2009). However, for many extremes (e.g., heavy rainfall events) coarse resolution model projections may only be able to provide qualitative information (Barros et al. 2009). For some classes of extremes (especially abrupt changes in climate, see below), the information on projected changes from climate models is very limited.

4.1.2 Analogues

The properties of a known event may be a useful analogue for studying similar future events (Ebi et al. 2003). Data for analogues can be derived from past conditions (*temporal analogues*) or conditions that occurred in another region (*spatial analogues*). The suitability of a certain event as an analogue requires expert judgment regarding its meteorological plausibility (i.e., how well it replicates an anticipated future condition) (Carter et al. 2007). Examples of events that could serve as analogues (and that are likely or very likely to change in frequency and/or severity by the end of the 21st century) include the 2003 European heat wave as well as the intense summer precipitation and flooding in Bangladesh and Norway (Mirza 2003; Næss et al. 2005). Analogues are plausible in that they reflect a real situation, but may have limitations as no two places or periods of time are identical in all respects (Carter et al. 2007). A past event may not be representative of future events; it might be weaker or shorter or different in other aspects (e.g., its geographical extent). Similar issues arise for geographical analogues as regions differ on important factors such as economic standards (Ebi et al. 2003). The suitability of analogue events should be considered along with information on accompanying changes in mean climate (Carter et al. 2007).

4.1.3 High impact studies

Few studies have been conducted on the impacts of abrupt climate change, brought about by events such as an abrupt cessation of the North Atlantic Meridional Overturning Circulation or rapid global sea level rise. One recent study assumed an extreme sea level rise of 5 m over a century (from 2030 onwards) to investigate the limits of societal adaptation in the Rhine delta (Netherlands), the Thames Estuary (UK) and the Rhone delta (France) (Tol et al. 2006). A second study assumed a sea level rise of 2.2 m by 2100 and outlined impacts for Europe (Arnell et al. 2005). Both studies rely on expert assessments to describe potential impacts. No assessments have yet been undertaken that investigate the consequences of such abrupt changes for specific organizations or industry sectors.

4.2 Identification of factors promoting organizational resilience

In addition to deriving information about future climate and weather extremes, the challenge is to assess organizational resilience to the selected event(s). Below we outline four different approaches to conduct resilience assessments.

4.2.1 Business loss estimation models

Property loss estimations (i.e., estimations of damage of structures such as buildings, bridges, highways) have been a prominent approach in the insurance industry to inform insurers of their potential liability in case of a disaster (Rose 2004). In addition, *business interruption loss models* have been developed to assess organizational resilience (specifically *impact resistance*) as the difference between actual direct output losses resulting from an extreme event, and projections of potential (i.e., likely maximum) losses (Rose 2004). A common approach to project potential losses is to assume a linear relationship between input and output losses (i.e., 40% loss of electricity input due to a disaster is assumed to result in a 40% reduction in organizational production and output for the disruption period). Actual direct output losses can be determined using survey data (Tierney 1997) or simulation models (Rose and Lim 2002). In other words, these models assume that resilience is the reduction of losses from a particular event.

Studies on business interruption impacts (e.g. Rose and Lim 2002) typically seek to determine business losses from actual events and have limited insights regarding predictive elements of future resilience which are of particular interest to this paper. However, researchers have also modeled business interruption losses under hypothetical circumstances (terrorist attacks, water utilities disruptions) to estimate the effects of resilience adjustments (Rose and Liao 2005; Rose et al. 2007). Such modeling could be applied to assess hypothetical losses of future climate and weather extremes. However, models provide only rough estimates and are based on a priori assumptions regarding which factors could lead to organizational resilience (and should therefore be included into a model). Furthermore, there are significant difficulties associated with gathering input data for these models.

4.2.2 Resilience indicators

Another way to assess resilience might lead via indirect inferences and proxies in form of resilience indicators or ‘surrogates’ (Carpenter et al. 2005) that represent the key features of organizational resilience in a certain context. Bruneau et al. (2003) developed indicators to assess the two dimensions of resilience (impact resistance and rapidity). Their suggested indicators included measures of the availability of backup/duplicate systems, resources and supplies, as well as the existence of planning and decision-support systems. Similarly, McDaniels et al. (2008) attempted to characterize factors leading to both impact resistance and rapidity within critical infrastructure systems in the case of an extreme event (broadly defined in their study as encompassing earthquakes, storms, floods, or terrorism). Their indicators included an assessment of ex-ante decisions such as planning, learning from past events, and the availability of back-up systems (promoting impact resilience and rapidity) and ex-post adjustments such as changing routines to minimize strains on infrastructure systems and requesting external support (promoting rapidity).

The transferability of existing indicators to the context of future climate and weather extremes and specific industry sectors or organizations is yet unclear, and there are few guidelines for indicator development. Carpenter et al. (2005) suggested that resilience indicators should correspond in a specified way to theoretical aspects of resilience (e.g., impact resistance). An indicator should be reliable so that independent observers with the same information would assess the indicator in the same way. Resilience indicators are likely to be context-dependent (e.g., on a type of extreme event), and the nature of this context-dependency should be spelled out. It should be possible to assess an indicator for a range of organizations or for an organization over time. Any single indicator should be part of a set of complementary indicators that address multiple aspects of resilience. The validity of resilience indicators can principally only be assessed by studying the relation between indicators and observed organizational resilience once an adverse event occurs. There are four general empirical approaches for indicator development (Carpenter et al. 2005):

- *Historical profiling:* The history of an organization can be assessed to understand its coping range and past exposure to weather extremes, and to determine factors that contributed to impact resistance and rapidity.
- *Stakeholder or expert assessments:* Aspects of organizational resilience can be identified through workshops or expert interviews aimed at building a common understanding of what constitutes organizational resilience in a certain context.
- *Case study comparison:* Organizations that have many similarities, but appear to be affected by a climate or weather extreme in different ways, can be examined to assess observable properties that may be related to resilience.
- *Model explorations:* In addition, model explorations (see section above) can be used to gain insights into factors potentially leading to organizational resilience.

Each approach has different strengths and weaknesses. Historical profiling and case studies are largely based on retrospectives insights and might have limited applicability to future changed conditions of climate and weather extremes. Stakeholder and expert assessments are mainly dependent on the knowledge of individuals, but allow a range of opinions to be included. Models might reveal insights into factors potentially promoting resilience, but they are a simplification of reality which is reduced to key model parameters (Jentsch et al. 2006).

4.2.3 Scenarios

Scenarios may provide another avenue to study organizational resilience to future changes in climate and weather extremes. Scenarios can be defined as "a plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about driving forces and key relationships" (Baede 2007: 951). Scenarios can be derived from quantitative projections, but are often based on qualitative information such as expert opinions and are sometimes combined with a narrative storyline (Baede 2007). Scenarios have been used in organizational settings to for strategic planning under uncertainty. For instance, energy and petrochemicals company Shell developed scenarios on future developments in energy supply, use and needs. As scenarios are focused on future developments, they provide a possible approach to outline interconnections between climate change, the development path of an organization (e.g., potential changes in its coping range and factors promoting resilience) and other non-climate related factors (e.g., economic and infrastructure developments) at different scales and over time (Wilbanks et al. 2007).

The drivers in the IPCC SRES scenarios (population, economic growth, technology, governance, see above) are all highly relevant for organizational development. However, few characterizations have been developed that relate specifically relate to (1) climate and weather extremes and (2) impacts from these extremes as they could affect different industry sectors or organizations (Wilbanks et al. 2007). Researchers have therefore suggested the application of 'what if' scenarios to explore consequences associated with extremes which are not chosen based on likelihood (Swart et al. 2004). As detailed information on climate and weather extremes is often not available on a local scale and for the near-term planning horizon (Carter et al. 2007) the construction of 'what if' scenarios requires expert input.

4.2.4 Identification of thresholds

Existing conceptualizations of organizational resilience are largely concerned with the preservation and/or restoration of organizational performance when encountering disruptions. However, thresholds exist within organizations that—when exceeded—lead to a situation where the organization loses its function and cannot recover from impacts. A single exceedance of the coping range does not necessarily mean that a critical resilience threshold is passed (Fig. 3). In practice, organizational resilience thresholds are therefore difficult to define. Arnell (2000) suggested two approaches: (1) estimating whether a threshold would be exceeded under a number of climate change scenarios and (2) identifying what changes (e.g., in temperature, precipitation) would cause an organization to approach or exceed a critical threshold.

Furthermore, organizations themselves impact the resilience of the Earth's climate system. The financial growth of organizations (often advocated as a key element of organizational resilience in the business literature) and the aggregate level of corporate activity are a contributing factor to climate change and to potentially high-consequence climate change outcomes. It might therefore be more important to understand the *nature* of organizational activity (e.g., whether innovative steps are taken to mitigate climate change) and to assess the long-term resilience of coupled industrial and ecological systems (Levin et al. 2001; Whiteman et al. 2004). Further work is required to better understand possible thresholds and non-linearities in the Earth's climate along with triggering mechanisms.

5 Implications for resilience assessments

This section draws together the different methodologies pathways. Table 1 summarizes existing and potential application options and limitations resulting from the combination of different methodologies. The choice of a methodology should depend on the goal(s) of a resilience assessment (i.e., to estimate business losses and resilience, to develop resilience indicators, to build scenarios, or to identify thresholds), the timeframe of a study, as well as the plausibility that certain types of climate and weather extremes could occur in a certain region or location (considering that some events might occur unexpectedly). Resilience assessment studies can evaluate single future events (e.g., an extremely hot day, a drought, a cyclone), or changes in the frequency and/or severity of extreme events (e.g., more extreme hot days per year, a succession of two or more droughts, or high sea levels coinciding with a tropical cyclone) (Barros et al. 2009). In the former case, analogues would be the more appropriate choice; in the latter case, data from climate projections would be required.

Another important aspect for consideration is a differentiation between near- and long-term projections. Changes in extremes over the next few years to a decade are unlikely to be qualitatively very different from changes observed in recent decades. However, it is anticipated that some extremes will exhibit much larger changes towards the second half of the 21st century (Barros et al. 2009). Existing high impact studies focus on timeframes until the end of the 21st century and beyond (Arnell et al. 2005; Tol et al. 2006), but impacts may not be relevant for some industries and organizations considering their expected life span (even though their emissions may have been driving climate change).

While this paper focuses primarily on the organizational level, organizations are intrinsically linked to structures and processes at other levels (e.g., governments,

Table 1 Methodological pathways for studying resilience in organizations

		Identification of Properties of Future Climate and Weather Extremes		
		Projections	Analogues	High Impact Studies
Identification of Factors Promoting Resilience	Business loss estimation models	Applicability Projections can be used with business loss estimation models if sufficient information is available on the properties of future climate and weather extremes.	Applicability Analogues can provide input data for modeling business interruption losses under a hypothetical scenario involving the impact of a certain climate or weather extreme.	Applicability High impact studies can be used to identify economic loss implications for industries or organizations under abrupt climate change.
		Limitations ➢ Coarse resolution climate projections do not provide precise data on the nature of many future climate and weather extremes on an organizationally relevant scale. ➢ Event-specific data is needed in order to estimate resulting business losses and resilience.	Limitations ➢ Business interruption loss models provide only very rough estimates and are often based on linear assumptions. ➢ Property loss estimations are primarily used for assessing monetary losses due to a specific event, rather than for estimating resilience.	Limitations ➢ Very limited existing research on the economic impacts and estimated business losses associated with abrupt climate change (National Research Council 2002).
	Resilience indicators	Applicability Resilience indicators can be developed to illustrate an organization's impact resistance and rapidity. Projections can show if there is an increased risk that conditions outside the boundaries of the coping range occur.	Applicability Potential use of analogues in simulation exercises to assess organizational resilience via indicators in a simulated environment; simulations are already being used in organizational settings (e.g., crisis management).	Applicability Resilience indicators can be developed based on the lifetime of the capital stock, the mobility of organizations, and the abruptness of the change (Linnenluecke et al. 2011; National Research Council 2002).
		Limitations ➢ Limited progress on and understanding of indicator development in the context of climate and weather extremes to date.	Limitations ➢ Limited progress on and understanding of indicator development in the context of climate and weather extremes to date.	Limitations ➢ This approach requires an understanding of the abruptness and predictability of any high impact or abrupt changes in climate.
	Scenarios	Applicability Research has been undertaken to analyze potential impacts of climate change on socio-economic systems under different	Applicability Temporal and spatial analogues can provide input data for 'what if' scenarios.	Applicability 'What if' scenarios of high impact events have been used in pervious studies (see Arnell et al. 2005; Tol et al. 2006).

Table 1 (continued)

	Identification of Properties of Future Climate and Weather Extremes		
	Projections	Analogues	High Impact Studies
	climate change scenarios (e.g., to crop yields and production, see Parry et al., 2004). Some use of scenario planning in organizational practice.		
	Limitations	Limitations	Limitations
	➢ Existing studies do not specifically focus on climate and weather extremes.	➢ The use of analogues requires expert judgment regarding the meteorological plausibility.	➢ The construction of 'what if' scenarios requires expert input.
	➢ Limited information on future changes in the frequency and/or intensity of extremes make estimations of resulting business losses and resilience difficult.	➢ Past events may not be representative of future events.	➢ The application of this method has been left at the industry/ sectoral level.
Threshold identification	Further work is required to understand mechanisms triggering thresholds, both within organizations and the climate system. Even if data is available before and after a disturbance, thresholds might be difficult to determine.		

industry institutions, policy changes). In case of an adverse event such as a drought, resources are often imported from the regional or state level to subsidize organizational resilience. Many affected businesses are then able to 'bounce back' and could be considered as resilient, but may have survived only due to external support. If many organizations have to be subsidized in a similar way, the resilience of an entire region could decline (Carpenter et al. 2001). A loss of resilience of structures and processes at larger scales may have major consequences for organizations. For instance, critical infrastructure failures after a hurricane may result in impacts that can be felt by organizations that were not directly impacted (Wilbanks et al. 2007). Consequently, it may be necessary to consider various level of analysis in a single study (see O'Brien et al. 2004).

6 Conclusion

This paper is intended to enable managers to analyze organizational resilience appropriate to an organization's potential exposure to future climate and weather extremes. Organizations exposed to storm surges will potentially have different resilience requirements to those exposed to droughts. We hope that this paper provides a foundation for interdisciplinary insights on problems of significant concern to organizations and serves as a foundation for future work in the area. There are significant opportunities for location- and sector specific studies to improve understandings of organizational resilience to climate change impacts.

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