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Climate warming and natural disaster management: An exploration of the issues

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Abstract This paper explores two issues that have been receiving increasing attention in recent decades, climate change adaptation and natural disaster risk reduction. An examination of the similarities and differences between them reveals important linkages but also significant differences, including the spectrum of threats, time and spatial scales, the importance of local versus global processes, how risks are perceived, and degree of uncertainty. Using a risk perspective to analyze these issues, preferential strategies emerge related to choices of being proactive, reactive, or emphasizing risk management as opposed to the precautionary principle. The policy implications of this analysis are then explored, using Canada as a case study.

1 Introduction

The purpose of this paper is to examine one particular discourse, that being the use of risk management strategies as opposed to the precautionary principle, as they apply to two related issues—disaster risk reduction and adapting to climate change. Increasingly disaster risk reduction (DRR) and climate change adaptation (CCA), have received increasing attention in recent decades, both within academia and in the public/private spheres. The bodies of literature associated with these areas have historically tended to be independent of each other, although recently there are an increasing number of papers linking the two.

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There are good reasons for this linking since climate change is expected to increase the frequency and/or intensity of some natural hazards, and many actions taken to reduce disaster risk also make sense in terms of adapting to climate change (Venton and La Trobe 2008). In other words, there are co-benefits between social strategies needed for both issues; good disaster management results in being better adapted to many of the threats that may be made worse by climate change (and vise versa). And, it is important to note that the issue of adapting to climate change is being increasingly discussed, since even under optimistic scenarios the world is now committed to some (and perhaps a very large) degree of warming.

In spite of similarities of aims, process, potential benefits and converging political agendas in both disaster risk management and climate change adaptation, there are also significant differences between them that makes a merger of the fields and discourses challenging. These include the spectrum of threats, time and spatial scales, the importance of local versus global processes, how risks are perceived, and degree of uncertainty. In particular, dealing with disaster risk is a problem that is fairly well understood (though there are exceptions), while risks related to climate change are often poorly understood. These differences are significant; for example, when choosing between proactive versus reactive strategies, being reactive is often more appealing where uncertainties are large. Recent papers discussing these issues are Mitchell and van Aalst (2010), Tearfund (2008), Davies et al. (2009), Shaw et al. (2010) and Mercer (2010).

The following discussion is divided into three main sections: (1) the first reviews aspects of climate change science as it relates to extreme events and uncertainty, (2) the second section examines climate change adaptation and DRR from a risk perspective, particularly as it applies to relevant management strategies, and (3) the final section discusses a possible research agenda that results from the analysis.

2 The climate system and natural hazards

Climate change is sometimes referred to directly as a hazard or disaster, but it could equally well be viewed as the context within which hazard and disasters arise. By shifting context, risk is shifted as well. Climate (a concept that is essentially statistical in nature) and weather are related concepts, but climate is more than "average weather," being composed of seasonal and diurnal variations in weather elements that contribute to the ideas of norm, anomalies and extreme events. Shifts in weather result in variations in climate. As a simple analogy, the climate system can be considered as a heat engine, distributing excess radiation energy received by the earth from the sun in tropical latitudes towards polar latitudes where a radiation energy deficit is experienced. The energy difference results in a latitudinal temperature gradient that drives the general circulation (winds in the atmosphere and currents in the oceans) in the climate system. Fluctuations in these energy transport processes on longer-than-synoptic time scales and at various spatial locations constitute the cause of climate anomalies and extremes.

The most prominent and visible characteristic of the climate system is that it is variable. It fluctuates in response to external forcing (such as solar radiation from the sun) and to internal nonlinear dynamical processes on many different time scales, ranging from microscale processes in both space and time to increasingly larger scales that are global in extent. Hazard scales range from minutes (tornadoes) to millennium time scale events (such as the Medieval Warm Period and Little Ice Age). The impact of climate variability on various components that comprise the climate system, as well as on human socio-economic structures, depends significantly on time scale and spatial extent.

An example of an extreme climate event is the prolonged drought of the 1930s, which combined with agricultural land management practices, resulted in the infamous Dust Bowl event, with severe social, economic and political impacts in North America (Ganzel 2003; Van der Schrier et al. 2006; Henry 1930). In more recent times, extreme weather events that caused large disasters include (1) Hurricane Katrina in August of 2005, which devastated the city of New Orleans, (2) the heat wave that hit Europe in the summer of 2003, with subsequent (less intense) heat waves in 2005, 2006 and 2007. In 2003, about 15,000 people died in France, with more than 30,000 deaths across Europe (Milligan 2004), (3) an extreme precipitation that resulted in extensive flooding in England and Wales (July 2007) (Stuart-Menteth, n.d), and (4) the Ice Storm of January 1998 that caused deaths mainly from hyperthermia and crippled the socio-economic infrastructure in the northeastern U.S. and eastern Canada (Higuchi et al. 2000; RMS special report 2008). These are just a few (and geographically biased) examples of recent extreme events that significantly impacted human systems. Of course other parts of the world have also been influenced by extreme weather conditions. For example, parts of Africa have experienced prolonged droughts and in 2006 the UN warned of a potential humanitarian catastrophe in eastern Africa.[1] Parts of Australia have also been hit by a prolonged drought in recent years, with devastating impact on its agricultural production (Karoly et al. 2003; Potgieter et al. 2005).

A shifting climate can affect natural and human systems due to changes in means or extremes. Changes in means could, for example, cause previously fertile agricultural regions to become less so as a result of less precipitation, or coastal areas to become uninhabitable due to sea level rise. These effects are likely to be of extreme importance in the future. Though these events can certainly be considered as creeping, slow onset disasters, the focus of this paper is more on shifts in the statistics of rare events, which impact society when they exceed coping capacities.

Natural disasters occur because of interactions between the natural, built and social systems. If climate change causes an increase in the frequency and/or intensity of some hazards (or a shift in their geographical location) then the number of natural disasters can be expected to increase. What does climate change science say about this issue? There is compelling evidence in our observed climate data and from the outputs of climate models that points to a warming climate (Intergovernmental Panel on Climate Change-WG1 2007a, b). Basic physics indicates that as the atmosphere warms, evaporation of water from the ocean surface will increase, adding more moisture to the atmosphere. This should result in an intensification of the hydrological cycle since a warmer atmosphere can hold more moisture, and is precisely what global climate models show as a consequence of a warming atmosphere. Expectations are, therefore, that along with a gradually warming climate there will be accompanying increases in many hazards (Intergovernmental Panel on Climate Change-WG1 2007a, b). Some hazards are confidently expected to become worse, such as heat waves, flood and drought. Confidence in predictions about others, such as tornadoes or hurricanes, is less.

Reducing risk related to climate change is achievable even without a detailed knowledge of how the future will evolve. Doing so, however, requires careful consideration of the potential effectiveness of different strategies within an uncertain environment. (For a detailed discussion on the uncertainty associated with the projection of future climate

[1] (http://earthhopenetwork.net/Deforestation_Climate_Change_Magnify_East_African_Drought.htm; http://www.voanews.com/english/archive/2006-04/2006-04-06-voa15.cfm?moddate=2006-04-06)

regime, see Supplementary Material). Some of these considerations include: the rationality of proactive versus reactive adaptive actions, whether enough information exists to do a robust risk assessment, or whether other strategies (for example, the precautionary principle) should be used. As well, many actions that make sense within the context of current disaster risk reduction approaches will also reduce risks related to hazards that may become exacerbated due to climate change. The following section considers these issues from a risk perspective.

3 A risk perspective

This section will consider the following aspects of risk as it relates to climate adaptation and disaster risk management: First, there are significant implications between choosing the precautionary principle as opposed to a risk management approach; second, climate change is an important modifier of risk, though often not explicitly accounted for in traditional disaster models; third, uncertainty is an important component of risk and has implications in terms of choice of adaptive strategy; fourth, by classifying risk factors, choices can be made for preferred mitigation and adaptive strategies.

3.1 Choosing process: The precautionary principle (PP) versus risk management (RM)

There are different ways to frame conversations around risk reduction measures, whether they are related to disasters or climate change. One discourse is whether to view it within the parameters of the precautionary principle[2] (UN University 2009) or within a risk management framework[3] (one example is the Stern Report (Stern 2007), which makes quantitative estimates of future GDP losses). Advocates of both approaches are common, and also commonly in conflict with each other. There are other discourses as well, not discussed in this paper, that include environmental or social justice (Mearns and Norton 2010), and technocratic (Pielke et al. 2008) versus resilience/ecological approaches (such as discussed by Gunderson and Holling 2001).

The precautionary principle is sometimes critiqued as being asymmetrical in that it does not consider the costs of inaction (Sunstein 2005). This is a valid observation, but it should be noted that the PP is rights-based and considers whether or not actions could arguably harm others, in the absence of proof that the actions are not harmful. In principle it could apply equally well to inaction, should the consequences of that be harmful to another; the burden of proof resides with the decision-maker for either action or inaction. This can be a very severe constraint, especially if there appears to be little justification for potential harm.

A risk management framework is not rights-based but reflects a more utilitarian perspective, and within this context how risk is defined and measured will largely determine the outcome of a risk assessment. In this sense it is quite different from the PP. Green and Armstrong (2007) propose that "*A policy proposal should only be implemented if valid and reliable forecasts of the effects of implementing the policy can be obtained and*

[2] The precautionary principle states that burden of proof lies with those whose actions may cause severe harm, in the absence of a scientific consensus that the harm would not occur.

[3] Risk management is a systematic approach to managing risk based upon rational decision-making; it includes identifying and analyzing hazard, exposure and consequences, and determines which combinations of management strategies yield optimal outcomes.

the forecasts show net benefits" and that "*If governments implement policy changes without such justification, they are likely to cause harm*." This level of reliance upon having an accurate risk assessment as a basis for any action is extraordinarily limiting from a philosophical and methodological perspective and gives a great deal of power to those who formulate a RM strategy, as noted by Slovic (2000) who said "*Whoever controls the definition of risk, controls the rational solution to the problem at hand*". A RM approach, which is probably the dominant one used, compares costs and benefits of action and inaction, and is very sensitive to assumptions, methodologies and data.

In different situations there are good arguments for both the PP and RM approach, depending upon various factors such as scale, level of uncertainty and the nature of potentially adverse outcomes. The choice is critical in that it largely determines outcomes. For example, consider the case of small island states such as the Maldives that will be drowned (eventually) due to sea level rise. Using the PP inhabitants of these states would argue that the rest of the world would have no right to emit greenhouse gases that will in all likelihood create sea level rise, which will eventually destroy these states. Industrialized countries that gain their wealth from processes that emit greenhouse gases could use a RM approach, and justify it based upon economic gains from development in other populated parts of the world, thus arguing that overall wealth or happiness is increased. Similarly, multinational corporations that create vulnerable communities for the purpose of profit cannot justify it on the basis of the PP, but can using a RM process, depending upon how they define risk and benefit, and what calculus is used.

An example of this is the Bhopal industrial disaster. Largely as a result of cost cutting measures made for the purpose of maintaining profit at a Union Carbide subsidiary pesticide plant in a country desperate for economic development, the plant accidentally released 40 tonnes of methyl isocyanate gas near the community of Bhopal. The result was that thousands died and perhaps 100,000 sustained permanent disabilities. The PP would suggest that Union Carbide had no right to reduce safety in order to maintain profit for shareholders and that the government of India had no right to put local citizens at such high risk in order to foster economic development within the region. A RM approach that compared profit and development to the economic value of human life in Bhopal might suggest that safety reductions were a reasonable action; thus illustrating the point that risk is socially constructed, and that who benefits and who loses matters. Within Canada there are examples of both approaches being institutionalized, and these are discussed more in section 4.

Thus, there is a tension rooted in the values that underlie the choice of conceptual framework, within which decisions are constructed. This tension is strongly related to the issue of who benefits from which approach—the PP tends to favor more vulnerable and powerless groups in society, while the RM approach favors stakeholders with wealth and access to power structures. One successful application of the PP principle relates to the production and use of genetically modified foods in Africa. Some countries, Zambia for example, have refused to import them from the U.S. An example of the application of the risk management approach (an unsuccessful one) is the Aral Sea in Russia. Economic calculations suggested that it was a net economic benefit to drain the sea to support cotton production, though after it was drained some of the assumptions used to estimate impacts turned out to be invalid, resulting in much greater human and environmental impacts than predicted.

Ultimately this paper argues that although in some areas there is considerable overlap, that strategies for DRR and climate change adaptation require a different emphasis. The issue of how risk is modeled is an important one.

3.2 A classification/comparison

There are different ways to conceptually model and classify risk. Some discussion on risk modeling is included in the Supplementary Material. The discussion that follows considers some that are relevant to this discussion, and how they may be used to determine useful risk reduction strategies. Adams (1999) provides an analysis of three risk categories: (1) directly perceived, (2) perceived through science, and (3) virtual risk, where scientists do not or cannot agree and risk lies within the realm of hypothesis. He suggests that management strategies should be chosen depending upon the category of perceived risk: (1) Where risks are directly perceived it makes sense to act unambiguously and without hesitation; (2) where they are perceived through science the precautionary principle is sensible; (3) but where risk is virtual the PP "becomes an unreliable guide to action" (Adams 1999). Disasters can fall into any one of the 3 categories. The first applies to disasters that we have experienced or are obvious as a result of a cursory inspection (such as Hurricane Katrina), the second applies to many technological risks, or natural ones where science is able to assess natural forces (such as determining flood zones), and the third applies in cases where evidence is not clear. An example of the third is a scientific controversy regarding a fault line under Lake Ontario, Canada that runs close to the Pickering Nuclear Plant (Mohajer 1993).

For some, particularly environmentalists and climate scientists, climate change risk lies in category 2, but for much of the public it lies in category 3 as a result of lack of knowledge or personal experience, and disinformation campaigns carried out by climate deniers (Hansen 2008; Union of Concerned Scientists 2007). From this perspective the precautionary principle may be a difficult political choice.

Other risk classification schemes exist, such as by Renn and Klinke (2001), Hovden (2004), and Kristensen et al. (2006). Given the context of the above discussion and building upon the classification schemes of these three papers, the authors suggest the following classification scheme (Table 1) as one useful to compare these two issues. This table suggests, for a number of categories, which management strategies are most desirable. The ticks in the right hand columns propose that for climate change adaptation the bulk of the assignments are in favor of the precautionary principle and being reactive, while for disaster management the assignments of risk management and proactive strategies dominate. This table can be critiqued in that it is overly simplistic, by presenting these strategies as being mutually exclusive. This is a valid observation since they can be used in tandem in a decision-making process. They are, however, dichotomous, and we argue that the way different factors apply to climate change and natural disasters points to strong asymmetries that are reflected in this table.

We are not arguing for a 1:1 correlation between DRR with RM and proactive strategies, as opposed to CCA being reactive and emphasizing the PP. Depending upon the specific situation, either may be supported by strong arguments. We do suggest, however, that given the different system characteristics, that RM strategies have a much greater relevance to DRR than CCA, and that PP approaches have much greater relevance for CCA than for DRR.

The differences between DRR and CCA can be illustrated by posing questions typically asked by these communities:

- Typical questions associated with responding to the threat of climate change are: "What will the impact of climate change be on X?" (impact perspective), "How can the emissions of greenhouse gases be reduced in order to slow climate change and provide more time for adaptation?" (mitigation perspective), or "What actions can society take

Table 1 Preferred strategies for various factors in managing risk from climate change and natural disasters with respect to management strategies (in the opinion of the authors)

Factor	Comments	PP	RM	Reactive	Pro-active
Predictability & uncertainty of impacts at local level (for adaptation)	Climate change: low predictability and high uncertainty	X		X	
	Natural disasters: high predictability and low uncertainty in the statistical sense, though individual events may be difficult to forecast.		X		X
Level of scientific knowledge	Climate change: many important unknowns	X		X	
	Natural disasters: well understood in general		X		X
Level of public knowledge	Climate change: generally poorly understood	X		X	
	Natural disasters: far better understanding, though myths still exist		X		X
Level of social controversy	Climate change: there is still a significant public debate on how climate change should be dealt with. Strong disconnect between those who benefit from emissions of GHG and those who suffer.			X	
	Natural disasters: general agreement that disaster mitigation is good. In many cases there is a strong disconnect between those who benefit from the construction of vulnerable communities and those who suffer when disaster strikes.				X
Type of risk • Directly perceived, • Perceived through science, • Virtual	Climate change: either (a) perceived through science or (b) virtual, (depending upon one's belief system)	(b) X	(a) X	(a) X (b) X	
	Natural disasters: either (a) directly perceived or (b) perceived through science.		(a) X (b) X		(a) X (b) X
Risk perception	Climate change: primarily cognitive			X	
	Natural disasters: both experiential and cognitive				X
Focus on • Hazard • Vulnerability	Climate change: in theory, society can control how much climate change occurs from GHG, though in practice it is hugely challenging. Once climate change occurs, there is no or little control over most hazards. To a large extent we can modify vulnerability.	X		X	X
	Natural disasters: there is no or little control over most hazards. To a large extent we can modify vulnerability.		X		X
Scale of impacts • Spatial • Temporal	Climate change: impacts will be global in scale, both because of shifts in means and extremes. Changes may extend for centuries or more.	X			X
	Natural disasters: local to regional in spatial scale. Impacts last years to decades.	X			X
Potential consequences	Climate change: over a large range of scales, from global to local, climate change has the potential to reshape the world in a much more hazardous way for decades to centuries.	X			X
	Natural disasters: at scales from local to regional, natural disasters can have devastation consequences for years to decades.	X		X	X
Reversibility (mitigation)	Climate warming: reversing atmospheric concentrations of CO_2 and many impacts (e.g. ecosystems) must occur at a global level and will be very slow, taking centuries or more.	X			X
	Natural disasters: changing mitigation strategies can be done over time scales of years to decades	X	X		X

Table 1 (continued)

Factor	Comments	PP	RM	Reactive	Pro-active
Violation of equity	Climate warming: very large. Many of the peoples most affected are the least responsible for the problem.	X			
	Natural disasters: very large. Many of the peoples most affected are the least responsible for the problem.	X			
The difficulty in establishing appropriate (representative) performance measures	Climate warming: challenging from an adaptation perspective.	X		X	
	Natural disasters: not difficult for many factors, since risks are well defined.		X		X

PP precautionary principle, *RM* risk management

The bottom 2 categories of this table are adapted from Kristensen et al. (2006)

now in order to better prepare for and adapt to the negative impacts of climate change?" (adaptation perspective).

- Typical questions associated with disaster management would be "How can one design systems that minimize the impact of extreme events, given various financial and other constraints?" (management perspective), "What actions can people, communities or organizations take to make themselves reasonably safe from hazards?" (adaptation perspective), or "How can people and communities be empowered, such that they have the knowledge and capacity to prepare for and respond to their hazardous environment?" (vulnerability/resilience perspective).
- Without taking away from the usefulness and validity of the above questions, it is also the case that to a large extent these questions are typically framed by organizational, disciplinary and political boundaries that tend to exclude alternate viewpoints.

But, the above questions might all be considered as **parts** of a larger inquiry, that being "How safe a world should we create and leave to future generations?" (sustainability perspective). By asking questions in an integrative way, DRR and CCA become two parts of one larger issue with clear linkages between them. In order to understand DRR and CCA more holistically the subject under consideration needs to be broadened so that it is inclusive of both—that is, that they are not viewed separately but as two aspects of one issue (Pielke 2004).

How safe a world we should strive for encompasses more than climate change and disaster management—other issues such as species extinction, social justice and toxic chemicals intrude. And, once considered, more linkages emerge. This is a reflection of what has been called the 1st law of ecology—that "everything is connected to everything else" (Commoner 1971).

Resolutions to these questions are embedded within the social fabric, and lead us towards examining the institutional and political possibilities of integrating climate change and disaster management.

3.3 Management strategies

The traditional problem of adapting to natural hazards within a stable climate is fairly well-defined. Well-defined problems are characterized by rational decision-making and formal reasoning, sufficient information to produce well recognized solutions and consensus (Runco and Pritzker 1999). Strategies developed to address natural disaster adaptation include building codes, standards, land use planning, insurance, emergency management organizations, professions such as meteorology and engineering, and institutions that provide warnings of impending hazardous events. Though we do not always adapt well to risks from natural hazards, these strategies can be very effective when implemented.

By contrast the problem of adapting to a hazardous environment within the context of climate change is much more ill-defined. Ill-defined problems are characterized by varying definitions of the problem, a lack of understanding, a lack of consensus, a need for new information, requirements for creating problem solving, and the use of postformal reasoning including problem finding, dialectical reasoning and reflective judgment (Runco and Pritzker 1999). In an uncertain future the traditional adaptive strategies listed above become more challenging to implement—for example, how should a community plan for the hundred-year flood when the magnitude of such an event may change greatly in coming decades and uncertainty is high?

We suggest that there are four issues, in particular, that need to be considered when selecting and developing management strategies:

(1). How should one priorize use of the precautionary principle or risk management? (Note that the authors do not consider them to be necessarily mutually exclusive).
(2). To what extent should management strategies be proactive as opposed to being reactive?
(3). To what extent should strategies be prescriptive, institutionalized and rigid, (or the opposite)?
(4). How should the institutions we use and create, reflect the above?

In a well-defined system, a risk management approach and being proactive makes good sense; cost-benefit analyses, even with the methodological problems they have, can be reasonably well calculated and discussed. In an ill-defined system, such as natural disasters within the context of climate change, the precautionary principle is much more attractive - and there are two contrasting arguments to be made with respect to being proactive. The first is that being reactive is rational when the future is highly uncertain. This is particularly true where the response to hazards can be quickly and easily adjusted (e.g. insurance rates) and system impacts are reversible. The second argument is that being proactive is rational. This makes sense when hazard management involves long term investment (such as with some kinds of infrastructure), when system impacts are not reversible and reflects the notion that uncertainty increases risk. It becomes even more attractive when there are co-benefits and/or strategies that are no-regret. The large inertia in the climate system and many affected systems (such as ecosystems) strengthens this argument. Any analysis should be made using a systems approach that takes into account the numerous and complex sets of cause and effect, as portrayed in Fig. 1.

Consider the case of proactive versus reactive urban flooding mitigation strategies as an example. For many cities this problem may become more severe in the future due to changes in the hydrological cycle (as well as due to subsidence and sea level rise). For the replacement of defunct or the installation of new sewer systems there are strong proactive arguments to be made, to consider larger diameter pipes to accommodate larger flows in the future. However, for existing ones that are deemed adequate for current climate regimes, reactive strategies may make more sense since replacement is extremely costly and a "monitoring and react" strategy can avoid up-front costs, while still having the potential to adequately address the problem in the future—if and when it occurs. Alternately, an approach based upon the immediate installation of green roofs might be deemed effective even if future flood related benefits are uncertain, because of co-benefits associated with reducing urban heat island effects. It must be emphasized that actions taken to reduce vulnerability to future climate extremes creates current benefits, since it results in improved DRR.

A discussion of urban flooding might take on a RM versus PP tension, if it related to the development of new areas that might become significantly at risk to flooding in the future, even though current risk is low. The issue is complicated because benefits might largely flow within the "here and now", whereas threats, if they develop, would accumulate in the future. The PP could be used to argue against development (perhaps creating parkland instead), while a RM approach applying discounting to future costs might well favor development.

Overly rigid institutions can be a problem for effective disaster management, as shown by the Department of Homeland Security and FEMA in their response to Hurricane Katrina. For ill-defined systems where risks are not well known it makes sense for institutions to adopt a flexible structure that can learn and adapt to changing environments (Gunderson and Holling 2001). This is called adaptive management, which is a decision-making approach that is appropriate where uncertainty is large. Adaptive management is an iterative process that links science with social processes and requires long term institutional commitment. It is iterative in nature, and relies upon system monitoring and testing as a way to learn and adapt. For more information on adaptive management, the reader is referred to (Williams, et al. 2007; Holling 1978, and Moore and Michael 2009). Salafsky et al. (2009) list several conditions that warrant an adaptive management approach, these including, (1) the system is complex, (2) the world is a constantly and unpredictably changing place, (3) immediate action is required, (4) there is no such thing as complete information and (5) society can learn and improve. These criteria apply well to adapting to climate change, and moves away from the notion of "best practices" that is fundamental in much of emergency and disaster management. Existing disaster management institutions

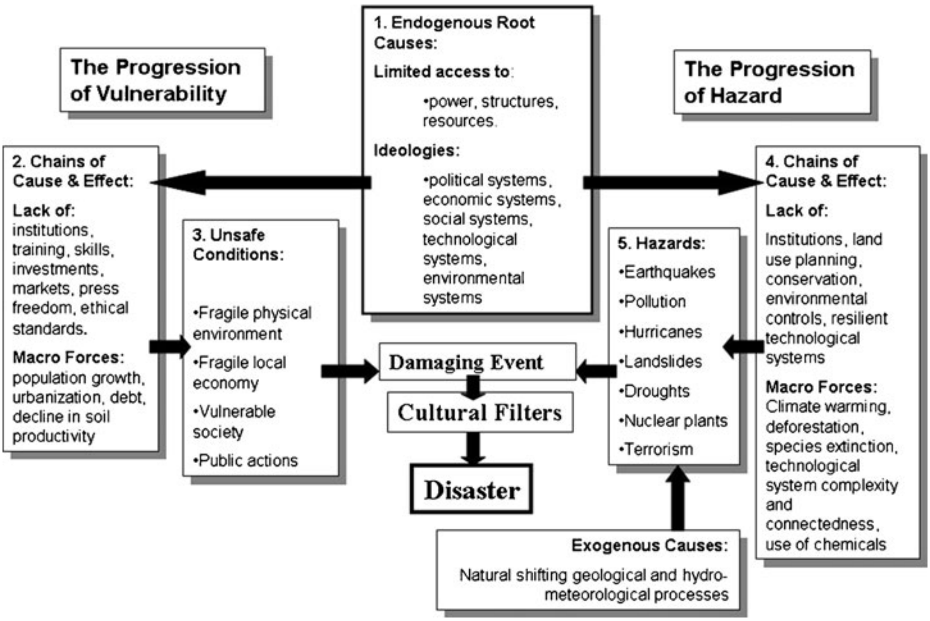

Fig. 1 "Modified Pressure and Release Model" of a Disaster (Etkin 2009)

are sometimes critiqued as being overly bureaucratic, rigid and insular, all of which are not ideal for addressing ill-defined problems.

The implications of the above discussion on management strategies is explored more in section 4, which considers what is known within the Canadian policy environment, in terms of how different strategies are embedded in legislation.

4 Policy complexities within the Canadian context

Although, climate change adaptation (CCA) and DRR differ significantly in terms of their predictability, timescale and geographic scope, our ability to reduce social vulnerability and increase resilience, to both, is impacted by political choices. At the institutional level, choices concerning the use of particular climate data or specific risk decision-making frameworks, will determine whether or not CCA policy is flexible, proactive, and effective. However, little research to date has examined institutional capacity to address CCA, particularly in light of the uncertainty of predicting climate change at the local spatial scale. In other words, at present we do not know how our political and institutional strategies fare with respect to climate change adaptation (Eakin and Lemos 2010).

Research questions into various aspects of political institutions and CCA arise from the arguments presented in this paper. First and foremost, we suggest that adaptation strategies must be flexible given the uncertainties in predicting regional climate changes.[4] Yet research to date, has not explored the question of institutional flexibility. To what extent are our current political institutions flexible or rigid? How can flexibility or rigidity be measured and compared? Moreover, are our current political institutions capable of an adaptive management approach and integrating new information into their decision-making models and policies as it becomes available? In some cases, the answer is yes. For example, recently, the National Building Code of Canada was modified to be updated every 5 years, and the inclusion of climate change is expected in the 2015 national building code (Rhodes 2008). Previously, the National Building Code was based on historical climate data; however, the new approach will include projected climate data, in determining the code. The National Building Code is but one example of a policy attempt at integrating new climate change information into its formulation. How many policies are being reformulated to include new climate data and climate projections? Which policies are becoming more flexible? Are the relevant policies being changed to include new climate information? All of these questions require further examination, if we are to evaluate the ability of our institutions to use new climate information.

Moreover, the basis on which environmental law can be made and implemented in Canada is determined, in part, by the constitutional division of powers. This division of powers which relegates certain aspects of environmental governance to the Federal government and others to the Provincial government may complicate our institutional capacity to adapt to climate change. The shared federal-provincial jurisdiction gives the provinces responsibility over the management of natural resources while the federal government is responsible for matters of an inter-provincial nature. In the context of climate change, the division of powers in Canada has been pointed to as a serious institutional and political constraint on the federal capacity to mitigate greenhouse gas emissions and meet its international commitment to the Kyoto targets (Paehlke 2008). Like in the case of GHG

[4] Over time, improved science and prediction models may reduce uncertainty.

mitigation, the impacts of climate change will not necessarily fall within political boundaries, complicating the flexibility of governments to act and develop appropriate legislative responses to a changing environment. How does the fragmentation of environmental law in Canada impact our ability to implement flexible adaptation policy and governance? One example that brings this issue to the forefront is the expected decline in the water level of the Great Lakes under conditions of climate change. The management of this projected environmental change could present a jurisdictional problem at the municipal, provincial, national and international level. The institutional ability to integrate water resource management and climate change adaptation, at these various institutional scales, is unknown.

Second, this paper has suggested that the choice of risk assessment is critical in determining the appropriateness or effectiveness of climate adaptation strategies. The complexity and variability of the climate system entails that adopting only utilitarian risk assessment models is inappropriate for the problem of climate change, and as argued above, an emphasis on the precautionary approach may be better suited for many adaptation policies. However, precautionary and proactive approaches are often difficult to implement politically due to the uncertain costs, long time frame, economic discounting, unpredictable benefits, and the nature of electoral politics. Do current adaptation strategies and policies rely on a risk management approach, the precautionary principle, or some alternate approach? Where does one type of approach dominate? Why? A systematic cataloguing of the conceptual frameworks that inform the construction of adaptation policies has not been constructed to date. In addition, where adaptation policies exist or are being developed, there has been no systematic inquiry into whether or not those strategies are proactive or reactive. We do not know the answer to the following questions: Which types of decision-making models inform the Canadian Environmental Assessment Act (1992), the Environmental Protection Act (1999), the Canada Water Act (1985), Health of Animals Act (1990), the Department of Natural Resources Act (1994), the Oceans Act (1996), the Species at Risk Act (2002), or the Canada Wildlife Act (1985)? Are these decision-making frameworks relevant given projected climate change? Are these laws proactive or reactive? Will these laws be capable of considering climate change? Many of Canada's environmental laws predate 2000, and as such questioning the relevance of these laws, and their ability to include climate change considerations, are imperative in evaluating Canada's current institutional capacity to adapt to climate change. A Federal inquiry into the capacity of Canadian governmental institutions to adapt to climate change or assist in community adaptation to climate change, given existing legal frameworks, has yet to enter the purview of Canada's parliament.

Third, the pressure and release (PAR) disaster model (Fig. 1) suggests that economic systems and development are critical in determining vulnerability to climate hazards. Moreover, the PAR model suggests that vulnerability and resilience are first and foremost impacted by political and economic (and perhaps environmental) forces. Nevertheless, to date it is unclear to what extent adaptation strategy and policy addresses the root causes of vulnerability. Are institutions and policies addressing economic systems and development as they relate to resilience to climate change and climate adaptation? The extent to which economic and development concerns are included in adaptation strategies at the national level has not been examined. Alarmingly, in the Canadian context, in 2010 the National Roundtable on Environment and Economy suggested an action plan for Canada, called 'Climate Prosperity', which seeks to change the perceptions of Canadians, to view climate change 'from a risk to an opportunity' and 'from a cost to an investment'. Moreover, the action plan suggests that climate change adaptation is 'not just about coping with climate change, but prospering through it' (NRTEE 2011). This approach to climate change adaptation is a far cry from using a precautionary approach to climate change, and frames risk reduction in linear terms whereby economic growth and climate prosperity is the means by which Canada can adapt to expected changes. The implications of using the geophysical transformation of climate change to generate economic growth, without addressing underlying uneven development and its relation to vulnerability, may result in maladaptation (Burton 1997). For example, in the context of the Canadian Arctic, the Northern Strategy is the most comprehensive Federal strategy towards the North that takes climate change into serious consideration (Government of Canada 2009). However, the strategy does not take a risk perspective or a precautionary approach, and instead aims to achieve socio-economic development in the North through the extraction of resources such as oil, gas, and minerals, the expansion of Arctic shipping routes, the development of Arctic tourism, and the growth of commercial fishing North of 60 (Government of Canada 2009). Already, fierce community opposition to these plans can be found in the files of the Nunavut Impact Review Board, and in the recent legal battle over Lancaster Sound (NIRB 2010; CBC 2010). The limits of the division of powers in dealing with Arctic climate change informs these developments, as stalled devolution over water resources, has entailed that the Federal intention to appropriate of Northern resources in the context of climate change is legal and within its jurisdiction. In light of research, by Berkes and Jolly (2001) or Ford et al. (2006), this current Federal approach to climate change in the Arctic fails to consider the growing evidence from experts regarding the social changes that are necessary for climate change vulnerability reduction in the Arctic.

Moreover, other communities that depend on environmental resources (such as forestry, fishing, and agriculture) may be particularly vulnerable to climate change. Evaluating how governments are adapting to climate change while considering economic and development needs of resource dependent communities is also important. For example, British Columbia's Future Forests Ecosystem Initiative seeks to incorporate CCA into the provincial governance framework including legislation, policies, procedures and systems under or supporting the Ministry of Forests Act, the Forest Act, the Range Act, the Forest and Range Practices Act, and the Wildfire Act (Government of British Columbia 2008). However, how this adaptation initiative addresses economic and development concerns as they relate to climate change has not been discussed. Evaluating the adaptive capacity of communities entails evaluating how our institutions address the root causes of vulnerability to climate change.

5 Conclusion

The risk environment facing the world's societies in 2011 is enormously complex, and increasingly requires integrated and holistic methodologies that incorporate a variety of management approaches. This paper has considered the relative merits of risk management versus the precautionary principle, and proactive versus reactive strategies, with respect to climate change adaptation and disaster risk reduction. Our analysis suggests that though it depends upon the particular issue being examined, that risk management tends to be preferentially associated with disaster risk reduction while the precautionary principle is generally more relevant to climate change adaptation. Similarly, disaster risk reduction favors proactive approaches, while reactive strategies often are more appropriate for climate change adaptation issues. The reasons for this relate to different system characteristics of disaster risk reduction and climate change adaptation (Table 1), associated with uncertainty, reversibility and type of risk. There are significant implications in terms of institutional characteristics, policy and legislation, but as yet no comprehensive studies exist to clarify how they fare in this regard. Further research could examine how our current adaptation measures and institutions perform given the complexity of the climate system and the need for flexibility and precaution. In addition, investigation and theorization regarding how our current institutions need to evolve is imperative to the development of effective and relevant adaptation strategies and policies.

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