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Now more than ever: The need for more societally relevant research on vulnerability and adaptation to climate change

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A B S T R A C T

Geographers have a long history of contributing to basic, use-inspired, and applied research on one of the greatest challenges humanity has ever faced: global climate change. Their contributions cut across all the major traditions and subfields within geography, have aimed at a variety of scales, and have connected to the scholarship of other disciplines. Building on these past accomplishments, this paper argues that geographers must continue their interdisciplinary endeavors and engage now–even more so than before–in practice-relevant research, particularly in the area of the human dimensions of climate change. The paper points to a range of critical research needs in the area of vulnerability and adaptation, particularly focused on the US, and argues for rapid capacity building and far-reaching changes in the incentive structure for geographers to engage in practice-relevant research and in interaction with policy-makers and resource managers at the science-practice interface.

"We have before us an ordeal of the most grievous kind. […]
You ask, what is our aim? I can answer in one word:
It is victory, victory at all costs, victory in spite of all terror,
victory, however long and hard the road may be;
for without victory, there is no survival. […]
At this time I feel entitled to claim the aid of all, and I say,
"Come then, let us go forward together with our united strength."
Sir Winston Churchill (1940)[1]

Introduction

"Let us go forward together with our united strength," Churchill said on the eve of entering the long and arduous fight of liberating Europe and the world from Hitler's dictatorship and Nazi terror. Back in the day, that largely unknown, newly appointed politician called on his fellow countrymen to overcome petty divisions and stifling rivalries to face the bigger

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[1] This quote is from the first, brief speech Churchill gave as Prime Minister of Great Britain to the House of Commons on May 13, 1940 (Available from: Internet Modern History Sourcebook, http://www.fordham.edu/halsall/mod/churchill-blood.html [accessed June 1, 2009]).

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challenge: the grave reality of war and suffering and the hard work they all faced to achieve a greater–and necessary–good. "Let us go forward with our united strength" is the call again to address what some consider the greatest challenge humanity has ever faced: global climate change. Anthropogenic climate change and the emissions that drive it are accelerating (Canadell, Le Quere, Raupach, Field, Buitenhuis, Ciais, et al. 2007; Raupach, Marland, Ciais, Le Quere, Canadell, Klepper, et al. 2007); by all accounts, changes in physical and natural systems are emerging faster than many researchers have previously projected (e.g., Church & White 2006; Parry, Canziani, Palutikof, Linden, & Hanson, 2007; Stroeve, Holland, Meier, Scambos & Serreze, 2007); and the outlook–as summarized most authoritatively in the Fourth Assessment of the IPCC (Metz, Davidson, Bosch, Dave, & Meyer, 2007; Parry, Canziani, Palutikof, Linden, & Hanson, 2007; Solomon, Qin, Manning, Chen, Marquis, Averyt et al., 2007) and reinforced through the emerging research since–regarding our ability to contain climate change to 2 or even 3 °C above preindustrial temperatures through stringent mitigation efforts, avert the chance of crossing dangerous tipping points (e.g., Lenton, Held, Kriegler, Hall, Lucht, Rahmstorf, et al., 2008; Lindsay & Zhang 2005; Nepstad, Schwartzman, Bamberger, Santilli, Ray, Schlesinger, et al., 2006), and effectively manage the unavoidable impacts (e.g., Adger, Agrawala, Mirza, Conde, O'Brien, Pulhin, et al., 2007) is not particularly reassuring. A research endeavor that draws on public funds thus has an obligation to be responsive to these urgently growing interdisciplinary societal challenges; it must double its efforts to provide and facilitate the use of scientific knowledge to assist different actors in mitigating and adapting to climate change more rapidly, effectively, and without creating more undesirable consequences in the process; it must also strike a balance between active engagement to increase science's usefulness and use in practice on the one hand and a critical distance to decision-makers in order to remain an intellectually independent force demanding more systemic, deeper perspectives in policy and management.

In this context, it is not a gifted politician appointed by a king, but a self-appointed geographer with a passionate plea, who is making the case for facing the difficult challenges, changes, and trade-offs before us, for engaging in societally relevant research, for overcoming disciplinary and inter-disciplinary divisions that stand in the way of progress, and for offering a well-founded scientific foundation for decision-making to a society that can't wait. This paper aims to suggest some foci for use-inspired, societally relevant research, and why there is no time to lose to begin it.

The geographic offering: the breadth of our climate change research and practice

In 2002, several prominent geographers wrote a provocative piece in The Professional Geographer, entitled "The Big Questions in Geography" (Cutter, Golledge, & Graf, 2002). One of the ten big questions proposed for the discipline was "How has the Earth been transformed by human action?"–a question which echoed several previous landmark publications in the field (Marsh, 1864; Thomas, 1956; Turner, Clark, Kates, Richards, Matthews, & Meyer, 1990) and which aimed to bring attention to the powerful potential of humans altering their environment.

Another geographer, James K. Mitchell, recently offered a complementary question, one that examined the human–environment interaction from the perspective of human responses to a variable and changing environment: "How do humans select a course of action in an ambient world replete with risks and opportunities that are incompletely known?" (Mitchell, 2008: 451).[2]

At the intersection of these two differently pointed arrows–the human transformation of the environment and the human adjustments to the environment–lies one critical component of the Earth system that is rapidly changing at the present time: the global climate. This major global transformation is front and center for many geographers at this time. In fact, over the last few decades, geographers have substantially contributed to answering a complicated set of questions surrounding climate change[3]:

- Is climate change happening and why?
- How does the climate system function and how is it changing as a result of the chemical alteration of the atmosphere?
- What are the environmental and societal impacts?
- How are climatic changes interacting with other stressors to magnify or attenuate the climatic changes?
- How are these processes interacting at and across different scales?
- What and who is vulnerable to the consequences, and why are some more vulnerable than others?
- What can be done to limit global warming (mitigation) and what can be offered to help ecosystems and societies plan for and deal with the consequences (adaptation)?
- What are the policy choices and how do they interact with other policy regimes?
- How can individuals be effectively engaged on such a global, complex issue–as private decision-makers, consumers, citizens, and in any number of social roles?

[2] Mitchell's question–posed in a reflection on the late Gilbert F. White's life work–is specific and central to the entire canon of White's contributions to geography. White's focus on human adjustments to the environment, however, has been discipline-shaping and is therefore interpreted here as a "big question" on par with any of the ten offered by Cutter, Golledge, & Graf. (2002).

[3] For brevity, this paper does not claim to offer a literature review of the full breadth of geographic contributions to this set of questions as they are simply too great in number. Many of these contributions have been cited over the years in the respective volumes of the four IPCC assessments (in 1990, 1995, 2001, and 2007), and geographers themselves have actively contributed as authors, editors and reviewers (to name just some of the participating US geographers in the most recent assessment–R. Barry, D. Carr, S. Cutter, H. Eakin, W. Easterling, R. Kates, G, Knight, L. Mearns, C. Polsky, D. Reed, B. Solecki, T. Wilbanks, J. Winkler, B. Yarnal, and others).

- What are the ethical implications and imperatives arising from humans (and some humans more than others) causing the Earth system to change fundamentally?

While geographers–like scholars in other disciplines–have most heavily worked on the first few questions, and thereby helped gather the overwhelming evidence that climate change is underway and at least over the past half century largely human-caused, the time has come to shift our focus more heavily toward the latter ones. More urgent work is to be done now, at a variety of scales, together with other scholars in multi-disciplinary teams to answer critical questions about vulnerabilities, impacts and response options, and collaborate with practitioners, resource managers, and policy-makers to develop practically relevant and needed answers. Geographers often insist that climate change must be understood and addressed in the larger context of Earth system transformation, sustainability, and the challenges of economic development, human well-being, and social justice. In fact, geographers are indispensible in connecting the dots between these issues across space, and in helping others understand the spatial variations and interdependencies in observed impacts and responses.

This paper argues, however, that geographers cannot rest on the laurels of their past achievements in fundamental and applied climate change research, and moreover that not enough of us are getting involved in this critical issue in the places where answers are needed most at this time: in the world of policy and practice. Geography through its institutional representatives and individual members must engage–now more than ever–in applied and use-inspired research, linking geographic knowledge to practical concerns (as argued by many others before me, e.g., Murphy, 2006; Murphy, de Blij, Turner, Gilmore, & Gregory, 2005; Turner, 2005; Ward, 2005, 2006). This engagement will help shape, question, and inform public debate and decision-making at a time when humanity is at a crossroad of deciding how, and how well, it will live on this planet.

The greatest need: practice-relevant vulnerability and adaptation research

The focus of this paper is primarily on applied and use-inspired basic research challenges (*sensu* Stokes, 1997): vulnerability and adaptation in the context of resilience and sustainability. A plethora of definition of each of these terms has been put forth by geographers and other scholars over the years, with persistent gaps, disconnects, overlaps, confusions, if not contradictions between different disciplines and fields hindering easy exchange, integration and synthesis (for some recent reviews, see, e.g., Adger, 2006; Füssel, 2007; Kasperson, Kasperson, & Turner, 2009; O'Brien, Eriksen, Nygaard, & Schjolden, 2007; Patt, Schröter, Klein, & De La Vega-Leinert 2009; Thomalla, Downing, Spanger-Siegfried, Han, & Rockström, 2006). The challenge of any scholar contributing to this work in the future is to be clear and upfront about the assumed meanings, thus helping others to see the relevance and connection to related work. For the purposes of this paper, I integrate various approaches to understand vulnerability as the susceptibility a coupled human–natural system to experience harm as a result of being exposed and sensitive to a perturbation (such as a climatic hazard) and lacking sufficient response (coping and adaptive) capacity to deal with the perturbation (e.g., IPCC, 2001; Turner, Kasperson, Matson, McCarthy, Corell, Christensen, et al., 2003). Adaptations–here more eclectically understood than some geographers historically have–involve various responses by or interventions in a system–varying along a spectrum of relatively superficial adjustments to deep systemic changes–that allow a system to avert or minimize the negative consequences of a perturbation or take advantage of beneficial ones arising from it (e.g., Burton, Kates, & White, 1993; Parry et al., 2007). Over relative short time scales, resilience refers to a complex system trait that allows it to "bounce back" from a perturbation and in so doing also adjust to changing environmental conditions while continuing to provide the goods, services, and functions it offers (e.g., Folke, 2006; Gallopín, 2006; Walker, Holling, Carpenter, & Kinzig, 2004). To the extent systems can be resilient over time while providing equitable access to life support and the basis for livelihood and economic activity, they may be considered sustainable (e.g., Eakin & Webhe, 2009; Perrings, 2006; for a detailed review of the interrelationship of these terms, see Moser, 2008b).

The choice of focus on vulnerability and adaptation is the result, partly, of this author's expertise and partly of research priorities identified by others. That said, all subfields of geography–including those that traditionally have been concerned with the physical and ecological aspects of climate change and those not concerned with climate change at all–will need to be at the table to rapidly improve our understanding of place-based vulnerability and adaptation responses. Thus, the focus here is primarily topical, rather than narrowly appealing only to geographers in the nature–society tradition of our discipline.

Why this focus? The primary answer to this question comes from the many gaps in understanding identified in the 2007 IPCC assessment (Parry et al., 2007) and, particularly, a recent review by the National Research Council (NRC) of the US Climate Change Science Program, which sponsors and loosely coordinates global change-related research with federal support in the US. In its review, the NRC concluded,

> "Our understanding of the impacts of climate changes on human well-being and vulnerabilities is much less developed than our understanding of the natural climate system. Progress in human dimensions research has lagged progress in natural science, and the two fields have not yet been integrated in a way that would allow the potential societal impacts of climate change and management responses to be addressed" (NRC, 2009a, 5).

The review further found that while discovery science and understanding of the climate system is proceeding well in the US, the preparation of that knowledge for use in decision-making, as well as the effective communication of scientific insights to stakeholders, lags significantly behind or is entirely inadequate (NRC, 2009a, 4–6; see also NRC, 2009b).

In this paper, I suggest narrowing the research priorities even further. A recent review of research and practice on US-focused vulnerability and adaptation found a persistent and significant "mismatch between the lack of, and the need for, scientific capacity, technical expertise and widespread, [decision] scale-relevant climate change and vulnerability information," thus producing a situation where the US at this time is rapidly entering "into an era of climate change consequences for which the country is ill-equipped" (Moser, 2009a, 26). Adaptation planning is beginning all across the US without an adequate scientific knowledge base (Moser, 2009a, 25). The review thus called on researchers and sponsors to make a "concerted effort […] to assess vulnerabilities, ascertain adaptation options, and determine relevant governance barriers at and across scales, and build the necessary capacity, skill, resource base, institutional mechanisms, and political will to help reduce and overcome [these barriers]" (Moser, 2009a, 26).[4]

This situation is similar (if sometimes less crass) in other developed nations, where adaptation research also has been neglected relative to other climate change work. A growing number of researchers are thus calling for more research on vulnerability and adaptation not only in poorer, developing nations, but also in developed nations (e.g., Adger, Dessai, Goulden, Hulme, Lorenzoni, Nelson, et al., 2009; Easterling, Hurd, & Smith, 2004; Moser & Luers, 2008; O'Brien, Eriksen, Sygna, & Naess, 2006; Pielke, Prins, Rayner, & Sarewitz, 2007). The factors that are contributing to this adjustment in geographic focus include the following: (a) recent experiences with climatic extremes in highly developed nations (such as the extreme heat wave of 2003 in Europe, Hurricane Katrina in the US in 2005, the extensive drought in Australia in 2007); (b) much less adaptation being observed in developed nations than is judged to be needed or would be expected judging by the greater adaptive capacity of richer nations; (c) the persistent and widening gap between rich and poor in most countries of the world; (d) a growing concern with the faster-than-expected pace of climate change and abrupt shifts in climate; (e) the challenges resulting from system lags in both social and natural systems, e.g., requiring societal responses well before systems reach (hard-to-identify) tipping point; (f) a growing recognition of the importance of limits and barriers to adaptation that can limit the on-the-ground realization of adaptive capacity; and finally, (g) the realization among practitioners in developed nations that very little scientific information is available on which rational adaptation planning and decisions can be based (e.g., Adger, Dessai, et al., 2009; Adger, Lorenzoni, & O'Brien, 2009; Moser, 2009a).

With anthropogenic climate change now well underway and an irreversible commitment to further climatic changes due to greenhouse gases already emitted into the atmosphere, Earth's environment and societies all over the world will face further climatic change, further environmental and social impacts, and the need to reduce, minimize, and manage the unavoidable consequences of climate change (Parry et al., 2007; Rosenzweig, Karol, Vicarelli, Neofotis, Wu, Casassa, et al., 2008; Solomon et al., 2007; Solomon, Plattner, Knutti, & Friedlingstein, 2009). What kind of research then could geographers undertake that would support the rapidly growing demand for relevant information?

Use-inspired research on vulnerability and adaptation: some strategic guidance

Fully understanding the real importance and potential severity of climatic change for any location (both the impacts experienced locally and those affecting other regions but impacting local communities and sectors indirectly) requires placing climate change into the real-world context of multiple stressors, on-the-ground vulnerabilities, and the actual capacity of communities, businesses, and local and state government institutions to respond to rapidly unfolding changes in the physical and social environment. The knowledge base to date is partial at best. The social science contributions to our understanding of these vulnerabilities, impacts, and adaptation options have been particularly limited to date and whatever related and relevant knowledge does exist in other (sub)disciplines is not yet fully integrated into our understanding.

What is required now are analyses of a far broader set of issues than standard climate change impacts and economic impacts assessments, including the social, socio-economic, demographic, institutional, legal, technological, ethical, organizational, ecological, and cultural aspects of societal functioning, management, and policy-making. With such a wide-open research agenda, questions about "filling knowledge gaps" really become questions about "beginnings" and "strategic guidance and priorities." The suggestions below are offered in this spirit. They draw on expert input elicited by the author (Moser, 2008a, 2008c), research priorities identified in the most recent IPCC assessment (Parry et al., 2007), the 2008 US Climate Change Science Program update of its strategic research plan (CCSP, 2008), and several recent NRC documents (NRC, 2009a, 2009b).

Vulnerability-focused research

Vulnerability-focused research–while benefiting from significant geographic scholarship and an important theoretical foundation (e.g., Burton et al., 1993; Luers, Lobell, Sklar, Addams, & Matson, 2003; Polsky, Neff, & Yarnal, 2007; Schröter, Polsky, & Patt, 2005; Turner et al., 2003)–must be expanded both conceptually, but maybe more importantly (and ironically) geographically. With notable exceptions, more vulnerability research has focused outside the US than on different US regions, communities, and sectors.

[4] The congressionally mandated NRC study entitled America's Climate Choices (http://americasclimatechoices.org/) also focuses strongly on emerging research and decision-support needs to inform future US mitigation and adaptation responses. In particular, it reinforces the call for vulnerability and adaptation research.

Developing, inventorying, and monitoring key vulnerability indicators

Projecting future vulnerabilities requires adequate understanding of current conditions, trends, and causalities. The development and ongoing monitoring of telling social indicators of each of the components underlying vulnerability has lagged much behind this recognition, though important geographic work is available as a foundation (e.g., Clark et al., 1998; Eriksen & Kelly, 2007; Luers, 2005; O'Brien, Leichenko, Kelkar, Venema, Aandahl, Tompkins, et al., 2004; Rygel, O'Sullivan, & Yarnal, 2006; Wu, Najjar, & Siewert, 2009; Wu, Yarnal, & Fisher, 2002). In some instances, data are not gathered or stored; in others they are potentially available for analysis, but not in accessible or useful formats (e.g., economic activity data at the community level). Much information is not geo-referenced, is not consistent, or involves significant data gaps, and thus is not easily integrated with other data. Conceptual challenges related to developing meaningful vulnerability indices persists (e.g., the importance of social capital is extremely difficult to capture in geo-referenced data), though a growing literature on this topic from a variety of disciplines exists (e.g., Bankoff, Ferks, & Hilhorst, 2004; Cutter & Finch, 2008; Eriksen & Kelly, 2007; Schmidtlein, Deutsch, Piegorsch, & Cutter, 2008; and the above mentioned works). Clearly, vulnerability requires integration of both physical, ecological, and social variables, but which are relevant in each case? How does different weighting influence interpretation? How can spatial coverage be improved? How can the indices be usefully linked to planning, prioritization, and decision-making? And what infrastructure is required to ensure monitoring over time given the dynamic nature of vulnerability? Even though there is research to draw on, a remarkable disconnect persists between applied climate impacts and adaptation-related research conducted across the country and this more sophisticated geographic understanding of vulnerability. Hardly any of the emerging adaptation policy efforts emerging across the US draw on this research, and, in fact, proceed without any sophisticated benchmark on vulnerability (which indices could provide) (Moser, 2009a).

Improving understanding of all components of vulnerability (exposure, sensitivity, and response capacity)

Vulnerability research in the US to date has focused mostly on the exposure to physical hazards such as sea-level rise related inundation, or extreme heat. Only in the public health context have assessments also focused on selected factors that affect sensitivity (e.g., age or ethnicity), or response capacity (e.g., social isolation, poverty). Many more factors (e.g., cultural, institutional, social) affect the different dimensions of vulnerability of individuals and communities but these have not been explored systematically across the range of climate-sensitive sectors. If adaptation at the local, state, and federal level is to be informed adequately, such information needs to be generated widely, beginning with regions either already actively involved in adaptation planning or perceived as particularly at risk to particular climate change impacts (Karl, Melillo, & Peterson, 2009).

Improving understanding of multi-stressor causes of vulnerability

To individuals, resource managers, policy-makers, and business leaders, climate is just one of many factors that influence their smaller, daily and larger, episodic decisions. Non-climatic factors can affect people's priorities as well as their vulnerabilities to additional climatic stressors (e.g., Dalby, 2009; O'Brien & Leichenko, 2000). Thus it is important to understand this real-world context in which current or future climate stresses could fall. For example, under what circumstances does globalization increase or decrease adaptive capacity? What other non-climatic stressors matter? Such questions could be explored through historical case studies as well as scenario- and sensitivity analyses, recognizing that socio-economic conditions are hard to project and can change quite rapidly. They could also be investigated in sensibly focused regions–such as a metropolitan area like Los Angeles or the Northeast corridor–where multiple stressors constantly interact in a spatially and functionally coherent context. Investigating the multiple influences that cause vulnerability would point to leverage points for intervention no matter what the future climate may be, thereby increasing a system's overall resilience.

Determining distributional impacts of environmental changes in key sectors

To date, most climate change impacts work at the state or national scale has been for entire sectors (e.g., water, crop agriculture, or energy) as if they are homogenous and will be affected equally by climatic stresses in the future. It has been recognized for more than a decade, however, that impacts will not be felt uniformly (e.g., National Assessment Synthesis Team, 2000). In the water sector, for example, climate-induced water scarcity could be felt quite differently by communities supplied by large water utilities compared to communities not currently connected to these large water suppliers. Some social science research thus distinguishes weather-related water scarcity from human-induced scarcity, raising important questions about access and political power, not just traditional water rights. This example illustrates how the capacity to identify and implement different adaptive options could vary significantly, and thus give a more differentiated picture than mere downscaling of climate projections could provide. Understanding which communities, regions, or businesses could be hardest hit will allow identification of "hotspots of vulnerability" and, thus, prioritization of adaptation support.

Investigating ripple effects and higher-order impacts

To date, almost no studies exist anywhere of the higher-order impacts of climate change, though historical experience with extreme events (climatic or otherwise) suggests they may be at least as important and sometimes longer lasting than the initial incident (e.g., Pidgeon, Kasperson, & Slovic, 2003). Both historical analyses and future-oriented scenario studies that systematically trace the evolution of risk amplification/attenuation and ripple effects within sectors or regions would be useful. Similarly, studies that examine the impacts of climate change experienced outside of a particular region, but which are likely to affect another region of interest through market-based mechanisms, transportation, energy or information infrastructure or other linkages are largely missing but needed.

Understanding impacts in the "forgotten" sectors

There is a temptation to focus impacts and adaptation research almost exclusively on economically important, politically vulnerable, or especially climate-sensitive sectors or regions. While these characteristics present defensible justifications to continue doing just that, it is equally defensible to ask, what are we missing? Experience demonstrates again and again that the greatest consequences of an extreme event often arise from unexpected interactions, higher-order consequences, overlooked sources of vulnerability, and ignored or unknown constraints on response capacity. For example, thus far, there is hardly any literature on the expected consequences of climate change for small businesses, even though much local economic activity and jobs, potentially significant wage losses, and critical community interactions are bound up in this sector. Moreover, what could happen in smaller economic sectors–such as the winter tourism sector, the wine growing sector, organic farming, or fisheries–in terms of contribution to a state's economic growth and indicators, could be crucially important to local or regional vulnerability and response capacity, thus affecting vulnerabilities to other climatic or non-climatic shocks.

Impacts within sectors under stress

Geographers are accustomed to using historical analogues of climate extremes to improve the understanding of who is vulnerable and why, and who responds how to which set of circumstances. Little work of this sort, however, has been undertaken in the US to support adaptation planning or to increase regional resilience (Moser, 2009a, 2008b). For example, what happens when numerous communities or regions are affected at once by a series of coastal storms? How do communities deal with situations when firefighting resources are stretched thin during times with great numbers of wildfires across a state? Who suffers, who collaborates, who fights, who wins, and who goes dry when most of a region is in a drought? What mechanisms do affected entities employ to deal with widespread stress? Studies investigating such cases–i.e., the within-sector, across-region (or horizontal) connections, sometimes over significant distances ("teleconnections" not just in the physical, but also the socio-economic sense, see Adger, Eakin, & Winkels, 2009)–can ground assessments of different adaptation options in empirical reality, unearth potential conflict situations, and offer opportunities to address them preemptively.

Adaptation-focused research

Adaptation–as defined above–are the actions undertaken to avert or minimize negative impacts of a perturbation or take advantage of the beneficial ones that may arise from it. Such actions vary in the depth of the intervention (and system changes intended or achieved), the timing when–relative to the perturbation–they are undertaken, and who carries out the action (Adger et al., 2007). While vulnerability-focused research can help identify intervention options and suggest ways of prioritizing adaptation actions, the research areas suggested below focus on specific questions related to the feasibility, interactions, and effectiveness of different adaptation actions–an area of research relatively neglected to date.

Integrated, cross-sector impacts and response assessments

A particularly challenging research questions is how to conduct integrated assessments of climate impacts and response options with interactions across sectors. While quite sophisticated integrated assessment models exist, few if any focus on the community or state level, and few are advanced enough to integrate adaptation responses. The next generation of integrated assessments thus needs to take into account the direct impacts of climate change, within and across sectors, and the additional direct and indirect impacts of adaptation responses to the experienced climate changes. A similar challenge lies yet ahead in investigating the mutual influences of mitigation and adaptation responses. While individual studies of potentially positive or negative synergies of societal responses or policies exist, such assessments are not conducted systematically or routinely, and certainly not as standard procedure prior to passing legislation or implementing policies. Such research would require multi-disciplinary, cross-sector teams, adoption of a systemic perspective, careful analyses of causal connections, and systematic sensitivity analyses of different assumptions and linkages.

Understanding the factors that allow, facilitate, and increase adaptive learning

There is a substantial literature on adaptive assessment and management and on all manner of social learning (e.g., Gregory, Failing, & Higgins, 2006; Hennessey, 1994; Pulwarty & Melis, 2001; Walters, 1986). While the former has been promoted repeatedly as the most appropriate form of resource management under highly uncertain environmental, social, and policy conditions, the approach has run into significant hurdles in practice (e.g., Mclain & Lee, 1996; van der Brugge & van Raak, 2007). Continued dedication to on-the-ground, experimental research with mechanisms facilitating deliberate learning on how to implement adaptive management would be helpful and relevant in several natural resource sectors (e.g., habitat conservation, fisheries, marine protected area management, forestry) (NRC, 2009b). Scenario-based experimentation and learning could also yield important insights. The bigger question, however, could be how organizations, individual decision-makers, and entire societies can be encouraged and enabled to learn and–against the all-too-common tendency to prefer familiarity, well-established rules, and a routine-based daily life–to learn faster and better in the face of rapidly changing conditions. Important research questions remain to be answered and tested empirically on: the incentives and disincentives for learning, knowledge networks, and impediments to knowledge flow relevant for adaptation decisions; the importance of leaders; and processes of diffusion of adaptation innovations (technologies and practices).

Exploring feasibility (limits) of adaptation strategies

As discussed above, research on adaptation to date has focused predominantly on adaptive capacity–on what it is, which factors contribute to it, and how it could be limited in specific contexts. Much less research has focused on specific ways to build it when it is lacking and to link it to broader sustainable development goals. Even less is known about society's ability to use its adaptive capacity in practical reality (e.g., Pielke et al., 2007; Moser, 2009b). Many adaptation strategies proposed to date have been quite general–take the notion of retreat from the coastline as sea level rises–without systematic testing of the actual feasibility (economic, technological, environmental, institutional, organizational, social, political, or cultural) in specific contexts. Such assessments of adaptation barriers may not only give a more realistic sense of real-world, context-specific adaptive capacity, but also lead to a more realistic set of adaptation strategies that can overcome existing constraints. They would shed light on the role of non-climate drivers in adaptation decision-making (e.g., Eriksen & O'Brien, 2007). Decision-makers also require cost-benefit or cost-effectiveness analyses of different adaptation measures, offering insights on one important, if insufficient criterion of feasibility.

Adaptation decision mapping

Adaptation actions will frequently (but certainly not exclusively) be local and, therefore, dispersed and difficult to inform efficiently. Nonetheless, it may be possible to draw "decisions maps"–reflections of real-world decision procedures (e.g., in siting decisions, long-term planning processes, operational management and so on) that clearly mark all relevant steps and inputs from contributing institutions or individuals. These "decision maps" could identify leverage points at higher levels to affect widespread change in climate-relevant decision-making, effectively identifying "mainstreaming" opportunities. Such research could also assist in the cross-scale integration of adaptation responses as systems at different levels either require support from others or affect the adaptation decision space of other jurisdictions. Finally, a significant contribution can be made by the behavioral branches of geography and neighboring disciplines by improving our understanding of ways to foster behavior change in the wider populace, which will clearly be needed to gain political support and to implement both mitigation and adaptation policies.

Assessment of capacity and limits to short-term coping responses under increasing frequency of extreme events

One of the clear messages from climate change research to date is that climatic extremes will become more frequent, and in some instances (such as heat waves) more intense (Karl et al., 2008). If these projections bear out, public and private resources to prepare for, deal with, and recover from extreme events will be taxed more frequently. Time between events will become shorter, increasing the potential for maladaptations; hasty responses may reduce vulnerability in the short-term but increase it in the long-term, or create new and unintended negative consequences. Historical experiences with disasters also suggest that local resources are typically insufficient to deal with large disasters, thus requiring supra-local resources. If extreme events become more widespread, however, questions arise as to the reliability of this sort of external support. Both interactive, scenario-based experiments and modeling studies that investigate how response capacity could fare in a high-frequency-extremes future would reveal important new insights on vulnerability and on how to improve a community's, state's, or nation's emergency response capacity and long-term plans to increase resilience.

Prospects of adaptation to abrupt change (climatic or otherwise)

Most climate change impacts and adaptation research undertaken in recent years (say, two IPCC assessment cycles) has used a common set of climate scenarios (the SRES scenarios used by IPCC) (Nakicenovic, Alcamo, Davis, de Vries, Fenhann, Gaffin, et al., 2000). This practice has facilitated comparison and integration and as such is a laudable sign of progress over previous research. In light of recent research on tipping elements and abrupt shifts in climate (e.g., Lenton, Held, Kriegler, Hall, Lucht, Rahmstorf, et al., 2008), it would be advisable, however, to expand the set of climatic assumptions. In fact, the most recent IPCC assessment called for more exploration of the outlier trends, the uncomfortably "fat" (i.e., difficult to predict) tails of the distribution, or even scenarios of abrupt change, rather than solely focus on central tendencies. To avoid being completely blind-sided, more exploratory research on scenarios of extreme and abrupt climate change is required using many interactive, qualitative, and quantitative scenarios. Such research promises to reveal otherwise unexplored, hidden vulnerabilities, allows opening up of "taboos" and seemingly untouchable assumptions, and enables creative thinking of adaptation options otherwise not considered.

Supporting geographers' engagement with practitioners and policy-makers through capacity building and structural changes

The research needs identified above offer virtually endless local, regional, and sectoral applications. Given the relative dearth of vulnerability and adaptation research for the US, rapidly ramping up geographic (and other disciplinary and multi-disciplinary) research in these areas would be an enormous improvement over the existing situation, both in terms of advancing the knowledge frontier and for practical purposes. To maximize the practical usefulness, however, scientists must not simply pursue their discovery-driven research interests, but be more proactive in reaching out to practitioners, learning about their specific information needs, building trusted relationships, and actively engaging with them in knowledge co-production.[5]

[5] For an extensive review and synthesis of the relevant literature on improving the science-practice relationship, see NRC (2009b).

This type of interaction is not common practice for many reasons–including both discipline-internal and -external factors that constrain geographers' greater involvement in public affairs, researchers' general reluctance to interact with practitioners, and the lack of institutional and financial support for societally relevant and particularly social science research on global change (e.g., Cloke, 2002; James, Gray, Martin, & Plummer, 2004; Martin, 2001; Nellis, Monk, & Cutter, 2004; Staeheli & Mitchell, 2005; NRC, 1997). These challenges will not be reiterated in any detail, but researchers and sponsors must recognize that the research priorities proposed here, and the pursuit of more practice-oriented, use-inspired science, will not happen without a concerted effort to overcome the structural barriers that have impeded them in the past. Among the most critical needs are:

- Rapid building of human capital, i.e., the number of adequately trained individuals to tackle the expanded research agenda outlined here–through student support, internships and institutional exchanges, post-graduate training, and post-docs, and through active recruitment of researchers–in subfields of geography that focus on vulnerability and adaptation or on other social-scientific contributions to climate change
- Concomitant with the growth in capacity, a gradual but significant increase in research funding (e.g., through specialized mechanisms and competitions) for previously neglected areas
- Graduate and post-graduate training and practical experience in working at the science-practice interface
- Active grooming of geographers and other social scientists for work in interdisciplinary teams and on global challenges like climate change
- Public support, visibility, rewards, and other institutional incentives to stimulate and encourage the type of research proposed here
- Active encouragement of geographers and colleagues from other social sciences entering the world of practice (government agencies, NGOs, and other institutions commonly involved in knowledge-action systems) to increase the understanding and receptivity for social science in the world of practice

While focused training in geographic sub-disciplines will continue to be critical for producing high-quality researchers and research, meeting the challenges of climate change will also require highly cross-trained generalists (with training in both the physical and social sciences) who can serve as translators and intermediaries between research, decision-makers and wider stakeholder communities. Geographers may be ideally trained to fill these roles, but the discipline as a whole, the wider academy, and universities will need to overtly and explicitly value producing these types of graduates whether or not they continue on in academia. The growing interest in decision support (NRC, 2009b), including the establishment of a National Climate Service, as well as adaptation policies and programs at various levels of government across the US, point to the growing need for individuals with solid, but broad scientific training, substantial communication and social skills, and the ability to draw on the best scientific knowledge to develop the most adequate policyand management responses to climate change.

The geographic advantage: deepening the geographic commitment to addressing climate change

In conclusion, a word must be said about directing this research agenda toward geographers. By no means do geographers have a "territorial claim" on the research challenges related to the human dimensions of climate change–nor should they. On the contrary, the breadth of the agenda demands multi-disciplinary and integrative research, as well as the experiences of many who are already familiar with working at the science-practice interface. At the same time, geographers have a history of being interdisciplinary in training and orientation. Moreover, our particular training and perspective gives us a "geographic advantage" that should not go unrecognized or unused to its fullest extent. According to Hanson (2004, 720), "the geographic advantage confers an understanding of: relationships between people and the environment; the importance of spatial variability (the place dependence of processes); processes operating at multiple and interlocking geographic scales; and the integration of spatial and temporal analysis." Or as Skole (2004, 742) put it, "The advantage to geography is our ability to link spatial technologies and the measurements and observations they enable to the people–environment approach."

Climate change demands precisely these perspectives, contributions, and outreach to others. Given the "bottleneck" in vulnerability and adaptation-related knowledge relevant to policy and decision-making in particular (Moser, 2009b; Vogel, Moser, Kasperson, & Dabelko, 2007), our discipline–so centrally placed and uniquely qualified–must make particularly strong efforts to build the scientific insights and capacity to support both the efforts of the US and others in facing the challenges of climate change. Such efforts clearly raise unavoidable ethical dilemmas (as many have cautioned about geography's engagement with policy and practice, e.g., Harvey, 1984 or Staeheli & Mitchell, 2005) and demand that–although we do not necessarily always know how to resolve them–we name and confront them. As Harvey (1984) once put it, geographers are asked to make a "dual methodological commitment to scientific integrity and non-neutrality." If Churchill's words from 70 years ago apply to today's challenges of safe-guarding current and future societies' well-being and of protecting and restoring the life-support systems of this planet, then "*We have before us an ordeal of the most grievous kind*" indeed, and one that we are likely to meet successfully only if we consciously "*go forward together with our united strength*."

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