Climatic Change (2010) 99:295–302
DOI 10.1007/s10584-009-9797-6

LETTER

“Reasons for concern” (about climate change) in the United States

A letter

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Received: 6 October 2009 / Accepted: 16 December 2009 / Published online: 10 February 2010

Abstract Article 2 of the United Nations Framework Convention on Climate Change commits its parties to stabilizing greenhouse gas concentrations in the atmosphere at a level that “would prevent dangerous anthropogenic interference with the climate system.” Authors of the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2001a, b) offered some insight into what negotiators might consider dangerous by highlighting five “reasons for concern” (RFC’s) and tracking concern against changes in global mean temperature; they illustrated their assessments in the now iconic “burning embers” diagram. The Fourth Assessment Report reaffirmed the value of plotting RFC’s against temperature change (IPCC 2007a, b), and Smith et al. (2009) produced an unpated embers visualization for the globe. This paper applies the same assessment and communication strategies to calibrate the comparable RFC’s for the United States. It adds “National Security Concern” as a sixth RFC because many now see changes in the intensity and/or frequency of extreme events around the world as “risk enhancers” that deserve attention at the highest levels of the US policy and research communities. The US embers portrayed here suggest that: (1) US policy-makers will not discover anything really “dangerous” over the near to medium term if they consider only economic impacts that are aggregated across the entire country but that (2) they could easily uncover “dangerous anthropogenic interference with the climate system” by focusing their attention on changes in the intensities, frequencies, and regional distributions of extreme weather events driven by climate change.

Electronic supplementary material The online version of this article (doi:10.1007/s10584-009-9797-6) contains supplementary material, which is available to authorized users.

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The Intergovernmental Panel on Climate Change (IPCC) offered further insight into what might constitute “dangerous anthropogenic interference with the climate system” (UNFCCC 1994) when it concluded with the unanimous consent of all signatory countries, that five ‘reasons for concern’ (RFC’s) identified in Smith et al. (2001) “remain a viable framework to consider key vulnerabilities” (IPCC 2007b, pg 19). These indicators of climate risk, designed explicitly to illustrate diversity across a range of metrics, include:

1. Risks to unique and threatened systems[1]
2. Risks of extreme weather events[2]
3. Distribution of impacts[3]
4. Aggregate net damages[4]
5. Risks of large scale discontinuities[5]

IPCC (2001a, b) portrayed the first systematic assessment of the RFC’s in the now iconic “burning embers diagram”—Figures 19-7 and SPM-2 of IPCC (2001a) and Figure SPM-3 in IPCC (2001b). IPCC (2007b, pg 19) subsequently indicated that the RFC’s were stronger because many risks had been “identified with higher confidence”, because some risks were “projected to be larger or to occur at lower increases in temperature”, and because “understanding about the relationship between impacts and vulnerabilities has improved”. Smith et al. (2009) updated this assessment and produced a comparable visual image for literature assessed since IPCC (2001a). It is important in reviewing this work to understand that risk is the product of probability and consequence; as a result, identical likelihoods across different risks need not imply identical levels of concern.

1 “Burning embers” for the United States

This brief note reports on the results of repeating the RFC exercise for the United States. Figure 1 depicts the US “embers” using the same color code as before - white indicates neutral, small negative, or positive impacts or risks; yellow indicates negative impacts for some systems, or low risks; and red means negative impacts, or risks that are more widespread and/or greater in magnitude.

[1] Assessment of the likelihood of imposing increased and significant damage or irreparable loss to unique and threatened systems such as coral reefs, tropical glaciers, endangered species, unique ecosystems, biodiversity hotspots, indigenous communities, etc.

[2] Assessment of the likelihood of extreme events driven by climate variability with substantial consequences for societies and natural systems such as increases in frequency or intensity of heat waves, floods, droughts, wildfires or tropical cyclones, etc.

[3] Assessment of the likelihood of disparities in climate-related impacts (either positive or negative) across regions of the country, across economic sectors, and/or across specific communities or groups of people.

[4] Assessment of the likelihood recognizing the damages of climate change through a global economic aggregate.

[5] Assessment of the likelihood and salience of certain phenomena, sometimes called singularities, that may have very large impacts on the global climate system.

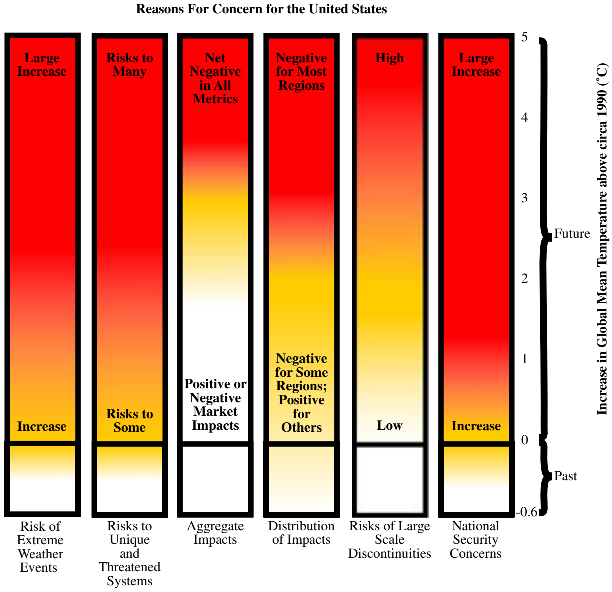

Fig. 1 Risks from Climate Change by Reason for Concern for the United States. Climate change consequences for the United States are plotted against increases in global mean temperature (°C) after 1990. Each column represents country-specific outcomes associated with increasing global mean temperature for each of the now six RFC's. The color scheme is the same as IPCC (2001a, b) and Smith et al. (2009): white indicates neutral or small negative or positive impacts or risks, yellow indicates negative impacts for some systems or low risks, and red means negative impacts or risks that are more widespread and/or greater in magnitude. The historical period 1900 to 2000 warmed by 0.6°C and led to some impacts. It should be noted that this figure addresses only how risks change as global mean temperature increases. The sensitivities of risks to rates of warming are not reflected. Nor do the RFC's explicitly address when impacts might be realized, and they do not account for the effects of different development pathways on vulnerability

1 Risks of extreme weather events

IPCC (2007a), NSTC (2008), and USGCRP (2009) attributed observed increases in the frequency of droughts and heat-waves (with associated wild-fires), extreme precipitation events, and pervasive outbreaks of pests across the US to recently observed trends warming and precipitation. This ember therefore begins yellow. It turns to red between 1.5°C and 2°C above the 1990–2000 global average to reflect the projected amplification of these risks through the middle of this century across the United States; see Panel A in Table 1 of the Electronic Supplemental Material (ESM) for selected evidence in support of this judgment.

2 Risks to unique and threatened systems

Rosenzweig et al. (2008) concluded that the number of observed impacts had dramatically increased since IPCC (2001a) on the basis of a meta-analysis of studies that covered over 29,000 systems. In their meta-analysis, the western part of the United States showed a large cluster of statistically significant observed impacts—strong evidence that this ember should begin yellow. As indicated in Panel B of Table 1 in the ESM, NSTC (2008; Sections V.1.a and V.1.c) and USGCRP (2009) meanwhile pointed to combinations of climate change, associated disturbances (e.g., flooding, drought, wildfire, insects, ocean acidification), and other global change drivers (e.g., land use change, pollution) to conclude that the resilience of many ecosystems is likely to be exceeded this century. Indeed, many of the climate effects on US ecosystems and wildlife *may* be driven by potential changes in the intensity and frequency of extreme events, such as floods, and disturbances, such as wildfires. As a result, the progression from yellow to red for this second ember roughly parallels the ember for risks of extreme weather events.

3 Aggregate impacts

Nordhaus and Boyer (2000) estimated the economic cost of climate change for the United States at 0.45% of mid-century market GDP for a 2.5°C warming relative to 1990 levels.[6] Ackerman et al. (2009) offered higher estimates derived from the model employed by Stern et al. (2006); they incorporated a distribution of climate sensitivities, alternative specifications of non-market damages, and various assumptions about the treatment of the economic consequences of catastrophic events; and they produced mean estimates of damage of 1.5% of GDP by 2100 associated with more than 3°C warming. Of this total, they attributed only 0.4% of GDP loss to market impacts.[7] Stern et al. (2006) had listed total damages in 2100 for the United States at 0.4% of GDP, but they attributed only a small fraction to market-based impacts. Given the magnitude of the market-based estimates relative to GDP, but mindful of wide uncertainty, incompletely understood non-market damages and the potential for abrupt climate change, the United States ember for "aggregate impacts" turns from white to light yellow around 2°C, but it does not turn red until global mean temperature increases reach 3°C.

4 Distribution of impacts

Many, if not all, of the risks associated with extreme weather events and threatened systems noted in Panels A and B of Table 1 of the ESM have asymmetric spatial coverage. Panel C of Table 1 in the ESM illuminates this asymmetry with some examples, many of which have already been observed. Zahran et al. (2008), for example, show that regional diversity in vulnerability to climate along US coastlines can be attributed not only to the regional nature of coastal storms (exposure), but also to the regional nature of local development (sensitivity). IPCC (2007a) projected a tendency for drying in mid-continental areas during the summer due to higher temperatures and associated this trend with a greater risk of droughts in those regions. Strzepek et al. (2009) showed significant increases in the frequency of mild and extreme drought across the southwest, far west, and mid-continent region through 2050, but small reduction in the northeast. Kates et al. (2006) showed quite clearly that sensitivity was, in the aftermath of Hurricane Katrina, highest among the poor, the elderly, and perhaps the ethnically disadvantaged. Pest infestation, the incidence of heat-waves, and dramatic increases in the return-times of severe coastal storms could easily be added to this discussion, but a fundamental point

[6] This estimate includes a willingness to pay 0.44% of market GDP to eliminate a 1.2% chance that a permanent loss of 25% of global economic income might occur.

[7] The high tails of the Ackerman et al. (2009) estimates do not identify temperature increases; they are much higher, but they generally run 75% below the reported global totals.

is emerging. Distributional impacts that are buried in the aggregation of national economic estimates are *frequently* driven by the incidence of extreme events *and/or* the incapacity of specific communities or systems to respond. Since many of these impacts have already been observed and attributed at least in part to climate change, this ember starts yellow, and turns to red at lower temperatures than the aggregate impacts ember; the exact location of the transition depends on how equity across regions and communities is valued.

5 Risks of large scale discontinuities

IPCC (2007a) reported a number of potential futures that would involve large scale and possibly abrupt climate change. NSTC (2008) and USGCRP (2009) reported similar concerns in brief discussions of ice-sheet contributions to global sea level rise and the chance of significant weakening of major ocean currents. Smith et al. (2009) amplified both of these assessments by reporting that the risk of additional contributions to sea level rise from both the Greenland and possibly Antarctic ice sheets may be larger than projected by ice sheet models and could occur over shorter time scales. They reported non-zero likelihoods of sea level rise in excess of 4 meters; and they could not dismiss the concern that the climate system could be committed to that future if global mean temperature rose about 2.5°C above 1990 levels.[8] Smith et al. (2009) also noted increased confidence in projections of carbon cycle feedbacks with potentially far reaching consequences. Since manifestations of any of these sources of abrupt change could appear across the United States, the ember depicted in Fig. 1 duplicates the ember crafted for the globe by Smith et al. (2009).

6 National security concerns

The Military Advisory Board (MAB 2007) conducted thorough review of climate-based security concerns for the United States. They focused particular concern on geo-political instability that could be generated by observed and prospective manifestations of climate change in Asia, Africa, South America, Europe and the Arctic of the sort reported in Tables 20.9 and TS.4 in IPCC (2007a). MAB authors concluded that “projected climate change poses a serious threat to America’s national security” (Finding 1) in large measure because “climate change acts as a *threat multiplier* for instability in some of the most volatile regions of the world” (author emphasis in Finding 2) and because “projected climate change will add to tensions even in stable regions...” (Finding 3). The very same concerns were raised by Woolsey (2009), and they have recently gained further support in Peters (2009) and Burke et al. (2009). Since most of the evidence that supported these findings was derived from “risks of extreme weather events” distributed across the globe, the global ember from Smith et al. (2009) replicated in Fig. 1 is a preliminary representation of the sensitivity of US national security concerns to changes in global mean temperature.

[8]Smith et al. (2009) showed the red shading beginning at around 2.5°C because that was “the midpoint of the warming range cited for partial deglaciation and the possible trigger for commitment to large-scale global impacts over multiple-century time scales” (pg. 4136).

2 Concluding remarks

"Reasons for Concern" for the United States depicted in Fig. 1 are the product of one researcher's opinion, but they were informed by extensive discussions with many others. Different people put the transitions from one color to the next in slightly different places, but two robust though qualitative conclusions emerged. On the one hand, US policy-makers will not discover anything really "dangerous" over the near term if they consider only economic impacts that are aggregated across the entire country. They would, in that case, not be impressed by the risks imposed by climate change on market-based activities within the borders of the United States. On the other hand, they *might* uncover "dangerous anthropogenic interference with the climate system" by focusing their attention on changes in the intensities, frequencies, and regional distributions of extreme weather events.

The first conclusion is almost a corollary of the observation that aggregate economic estimates of damages too often ignore low probability risks of non-market impacts and socially contingent consequences; see Yohe and Tirpak (2008) and Yohe (2009), for example.

The second conclusion is more intriguing, and requires an even more cautious interpretation. Authors writing about the "burning embers" have always taken great care to emphasize that the RFC's alone cannot be the basis of any policy intervention because too much complication is either buried or missing in their construction. For example, RFC's reflect adaption only to the extent the capacity to respond is included in the underlying literature, and it has long been understood that the capacity to adapt depends on development pathways that cannot be reflected in simple calibrations of changes in global mean temperature.

It is also widely understood that climate change is but one of a multitude of drivers for regionally and socially diverse vulnerabilities. Sorting out the relative contributions of climate and non-climate sources of stress to cumulative vulnerability is similarly beyond the scope of any single RFC calibrated to changes in global mean temperature.

Finally, it is important to highlight the fact that "National Security Concerns" emerged from a non-scientific community. In the case of this RFC, therefore, special care must be taken not to make too much of its inclusion in Fig. 1. Dalby (2009), Barnett (2009) and Liverman (2009) have, for example, warned that the association of national security with climate change may have heretofore been overstated; i.e., that "determinism in this arena is likely to be overstated scientifically and dangerous politically".[9] Still, the intelligence and defense communities of the United States *are* concerned about climate change, because their concerns *are* derived from a growing understanding of the issues involved, and because they *are* particularly good at coping with high consequence (even if low probability) events. It is therefore appropriate to include the sixth RFC because, as with the others, its inclusion is intended to do nothing more than "aid readers in making their own determination" about risk. IPCC (2007b, pg. 64) confirms that determining what constitutes "dangerous anthropogenic interference with the climate system" involves value judgments. Science cannot make

[9]Thanks are due to a serious and conscientious referee for making this point, as well as for its skillful wording.

value judgments, but it can support well-informed considerations and direct decision-makers to critical issues where they may uncover "key vulnerabilities." This was the intent of the five original RFC's, and it is equally true even if it was the decision-makers themselves who began the conversation.

In sum, any one of the *six* RFC's described here could easily lead a reader to discover something "dangerous" for the United States—but only after more careful analysis that accounts for complications like adaptation, multiple sources of stress, and unfounded determinism. Superimposed against ranges of temperature trajectories, the identified critical ember could even suggest when such danger might begin to materialize. Schneider (2009) and Kerr (2009) have already shown by example how effective visual representations like Fig. 1 can be in communicating this message to a wide audience of interested citizens. Properly viewed, therefore, national RFC's can effectively direct domestic decision-makers and citizens alike toward areas of concern where the more detailed analyses and more comprehensive assessments can most productively direct future research even as they inform current policy negotiations.

Acknowledgements The subjective shadings of the Reasons for Concern for the United States displayed in Fig. 1 benefited from discussions at the Energy Modeling Forum's 15th meeting on Climate Change Impacts and Integrated Assessment in Snowmass, CO on July 2, 2009 as well as private conversations with James Neumann, Kenneth Strzepek, John Weyant, Kathy Jacobs, Kris Ebi, Joel Smith, Phil Mote, Robert Kates, Thomas Wilbanks, Jeremy Martinich, Ben DeAngelo, Marcus Sarofim and two insightful but anonymous referees. Caroleen Verly from Industrial Economics, Inc. did an exceptional job tracking down the references that populate the SOM where "chapter and verse" is carefully cited. Michael Mastrandrea provided the graphic support required to prepare Fig. 1. The author gratefully acknowledges the financial support of the US Environmental Protection Agency's (EPA's) Climate Change Division (Contract #GS-10F-0224J).

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