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Climate Change Responses

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1.5°C or 2°C: a conduit's view from the science-policy interface at COP20 in Lima, Peru

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Abstract

An average global 2°C warming compared to pre-industrial times is commonly understood as the most important target in climate policy negotiations. It is a temperature target indicative of a fiercely debated threshold between what some consider acceptable warming and warming that implies dangerous anthropogenic interference with the climate system and hence to be avoided. Although this 2°C target has been officially endorsed as scientifically sound and justified in the Copenhagen Report issued by the 15th Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC) in 2009, the large majority of countries (over two-thirds) that have signed and ratified the UNFCCC strongly object to this target as the core of the long-term goal of keeping temperatures below a certain danger level. Instead, they promote a 1.5°C target as a more adequate limit for dangerous interference. At COP16 in Cancun, parties to the convention recognized the need to consider strengthening the long-term global goal in the so-called 2013–2015 Review, given improved scientific knowledge, including the possible adoption of the 1.5°C target. In this perspective piece, I examine the discussions of a structured expert dialogue (SED) between selected Intergovernmental Panel on Climate Change (IPCC) authors, myself included, and parties to the convention to assess the adequacy of the long-term goal. I pay particular attention to the uneven geographies and power differentials that lay behind the ongoing political debate regarding an adequate target for protecting ecosystems, food security, and sustainable development.

Keywords: Global average warming, Temperature targets, UNFCCC Structured Expert Dialogue, 2013–2015 Review, Uneven geographies

Background

The political origin and subsequent critique of the 2°C target

To date, the history of the 2°C target is well understood [1]. In the 1960s and 1970s, doubling CO_2 concentration scenarios estimated an approximate 2°C warming. Economist William Nordhaus [2], often cited as the source of the targets, used 2°C in his early cost-benefit analyses for emission reductions, albeit as a heuristic and not a normative policy prescription. Shortly thereafter, a reframing of the climate question shifted the discussion from emission reductions to risks of climate change at levels potentially tolerable or disruptive and harmful. In 1991, the first target-based approaches to climate policy emerged, including the so-called 'traffic light system' to delineate distinct levels of risk expressed in temperature rise per decade and associated sea level rise. They ranged from limited risk and damage (green) to extensive risk and damage (amber) and significant societal disruptions and possible tipping points (red) [3]. The boundary between green and amber was roughly associated with a 1°C increase while the boundary between amber and red approximated 2°C [1]. Only 5 years later, the 1996 European Union declaration proposed the 2°C target as the maximum allowable global temperature above pre-industrial times by 2100, mainly to avoid major losses to threatened ecosystems such as coral reefs [4].

Consequently, the 2°C target became an anchor in mitigation debates, reaffirmed then in environmental circles and embraced in several high-level policy domains, stretching from Greenpeace in the early 1990s to the G8 meeting in 2005. At COP15 in Copenhagen in 2009, the 2°C target was officially sanctioned as essential policy

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guidance, with the hope that it may subsequently become a legal goal in a new climate agreement. 'We agree that deep cuts in global emissions are required according to science, as documented in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report with a view to reduce global emissions so as to hold the increase in global temperature below 2 degrees Celsius…' [5]. In Cancun, at COP16 in 2010, parties agreed to reduce global greenhouse gas (GHG) emissions to keep the global average temperature below 2°C above pre-industrial levels, which became the so-called long-term global goal.

Despite the usefulness of the 2°C target as a 'boundary object' between science and policy makers [1] and its partial yet insufficient success in triggering political action, the target has been subject to repeated and partially severe criticism. Among parties to the United Nations Framework Convention on Climate Change (UNFCCC), many Caribbean states proclaimed already at COP15 that a 2°C temperature rise was unacceptable as a safe threshold for the protection of small island states and that even a 1.5°C increase would undermine the survival of their communities. At COP16 in Cancun 1 year later, the Alliance of Small Island States (AOSIS) reiterated this claim. Several least developed countries (LDCs) joined AOSIS insisting on a long-term goal that would lower rising global average temperatures to below 1.5°C warming, accounting jointly for more than 100 of all countries most vulnerable to the negative impacts of climate change. This majority (>70%) among the parties comprises, besides the low-lying small island states, essentially all low- and middle-income countries, with the exception of two lower middle-income countries (India, Indonesia) and a few upper-middle income countries such as China, Brazil, Argentina, and Mexico; the parties that support a 2°C target are all high-income countries and nine upper middle-income countries, the above four included [6]. The latter evidently unite the high-emitting, high-income OECD nations.

Critique of the 2°C target also came from scientists, ranging from climate scientists to economists, political scientists, human geographers, and other social scientists. Arguably best known is James Hansen's critique that, a decade ago, disapproved of the 2°C upper threshold for climate safety as irresponsible, arguing that it inappropriately accounted for climate sensitivity and climate feedback processes and, hence, committed the planet to significant warming [7]. Hansen subsequently urged abandoning the 2°C target altogether and committing to a 1°C danger limit [8] or a 350 ppm CO_2 target [9], which is lower than today's 400 ppm. '[T]he oft-stated goal to keep global warming less than two degrees Celsius (3.6 degrees Fahrenheit) is a recipe for global disaster, not salvation.' [10]. Others consider the 2°C target scientifically unfounded, due to insufficient data and reasoning [11,12]. Further scientists and environmentalists, including Paul Randers and Jorgen Gilding who outlined the need for emergency actions as part of their 'One Degree War Plan' [13], as well as Greenpeace and the Climate Action Network International have now also been advocating for limiting warming below 1.5°C. David Victor and Charles Kennel [12], while acknowledging that the 2°C target represents a bold and easy to grasp goal, contend that it is both essentially unachievable and impractical. Their suggestion to 'ditch' the 2°C warming target has now triggered a wave of contestation, mainly among climate scientists.

Less well known perhaps is a critique from feminist social scientists who interrogate what may be deemed 'acceptable' and what may be 'dangerous', and for whom, and who contest the global community as a homogeneous entity. Joni Seager, for instance, demonstrates how notions of acceptability always mirror 'a prism of privilege, power, and geography' [14]. She argues that those for whom a 2°C target appears to be a relatively safe bet are the richer countries in temperate latitudes, as well as politicians and economists from the global North deeply entrenched in a masculinized rationality that nature can be controlled and that in the imminent climate race with inevitable winners and losers they will be among the former. Seager rejects the notion of a 2°C target as a real geophysical threshold that neatly distinguishes between little and much danger; instead, she argues that the target represents the point 'when global warming "comes" home to the rich world, …. when "their" [the others'] problems are likely to become "ours"' [14]. Diana Liverman [15] also emphasizes the uneven spatial geographies associated with global danger levels as even small temperature rises and other risks threatening vulnerable livelihoods in one locale would be offset by gains and benefits somewhere else. This unevenness, however, disappears in the aggregate and masks very concrete and embodied, lived experiences of danger. Moreover, danger at different temperature thresholds, as schematically illustrated in the iconic Burning Embers graphic introduced by the IPCC's Third Assessment Report, conveys considerable risk for certain unique and threatened systems at 2°C warming, such as glaciers, arctic and coastal ecosystems, as well as indigenous and small island communities. Yet, it obscures risks for millions of poor and vulnerable populations in the arguably less charismatic drylands. What is considered unique and threatened emerges from value judgments that, so far, have largely been in the scientific eye of the beholder, not the one endangered.

A degree of average global warming may indeed be the most convenient and compelling mathematical construction (the mean) of the overall severity of climate change impacts. Yet, not only does such a single-index of climate change risk inadequately capture the complexity of the climate system [12], it also poorly reflects locally experienced temperature increases and extremes and hence the large variation across regions and continents. No single person or any single species faces a global average. Archbishop Desmond Tutu was one of the most outspoken non-delegate critics in Copenhagen in 2009, drawing attention to the fact that a 2°C global average would mean 3°C–3.5°C or more for Africa, hence the 'cooking of the continent' and its condemnation to incineration and no modern development [16]. Abundant evidence from around the world confirms the uneven and localized impacts of already occurring climate change (0.8°C average global warming since pre-industrial times). This evidence does not only consider rising temperatures and sea level rise but also shifting trends in rainfall patters and extreme events and impacts such as floods, droughts, and heat waves. This evidence is most recently assessed and summarized in Working Group II of the Fifth Assessment Report (AR5), for the world regions and sectors including natural and managed systems, urban and rural areas, economic services, human health, livelihoods and poverty, and human security [17].

Most problematically, the notion of a scientifically sound and globally tractable 2°C target is often erroneously mapped onto Article 2 of the UNFCCC; an implied connection is made between 2° and 'dangerous', although no specific number is provided in the convention's text [14]. In fact, the convention does not define a dangerous level for global warming or a limit for GHG concentrations, arguably on purpose. It states as its ultimate objective to 'achieve … stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.' Rather than deliberating different danger metrics or avoiding serious damage, continuous debates revolve around pinpointing what precisely this temperature threshold for climate safety ought to be and how it translates into acceptable and unacceptable risk and damage and for whom. In the following section, I reflect on science-policy debates on adequate warming targets, through the lens of the fourth UNFCCC structured expert dialogue at COP20 in Lima, Peru, in early December 2014. My aim is to highlight arguments that explore whether a 1.5°C warming target by the end of the 21st century would indeed be a safer danger limit for humanity and, if yes, whether it is still within reach.

Inside the process: structured expert dialogues

Parallel to the COP16 decision to use the 2°C target as the long-term global goal to reduce GHG emissions, the parties also decided to periodically review the *adequacy* of this long-term goal and progress toward achieving it, in light of the ultimate objective of the convention. More importantly perhaps was the agreement to consider *strengthening* the goal, reflecting the best available scientific knowledge. The latter explicitly suggests consideration of a 1.5°C target, a limit that would potentially be safer but also require much more drastic mitigation action to avoid crossing over into a global 'danger zone'. This 2010 decision yielded commitment to the 2013–2015 Review. Upon its completion, the Conference of the Parties (COP) is expected to incorporate findings into the ADP, the Ad Hoc Working Group on the Durban Platform for Enhanced Action, established in 2011. The mandate of the ADP is to develop a new protocol, another legal instrument or an agreed outcome with legal force, to be completed and then adopted at COP21 in Paris in December 2015. This instrument would come into effect and be implemented in 2020. It is expected that it will stipulate one or the other temperature target as a legally binding goal.

At COP18 in Doha in 2012, it was agreed to establish a so-called structured expert dialogue (SED) to accompany the 2013–2015 Review, under the guidance of the convention's Subsidiary Body for Scientific and Technological Advice and the Subsidiary Body for Implementation (see Figure 1). The purpose of the SED is to ensure scientific integrity of the review process through a series of workshops and expert meetings and facilitate fruitful dialogue between experts and parties to the convention. Two co-facilitators, one from an Annex I party (all OECD countries and economies in transition) and the other from a non-Annex I party (all other nations), oversee the process and report back to the COP. Between June 2013 and June 2014, three SEDs had already taken place. As a coordinating lead author of the IPCC's AR5 (Chapter 13 Livelihoods and Poverty, Working Group II Impacts, Adaptation and Vulnerability) and a member of the core writing team of the AR5 Synthesis Report, I was invited to take part in the fourth SED organized at COP20 in Lima in December 2014. Updates on the 2013–2015 Review are accessible on the UNFCCC website [18].

The reports from the first three SEDs—all before COP20—reveal the central role of the 1.5°C *versus* 2°C debate in exchanges between experts and parties. During SED1 [20], a representative of AOSIS, not surprisingly, requested assessments of impacts and risk at several levels of CO_2 concentrations and associated temperature, including explicitly at 1.5°C. This insight would be particularly crucial in order to better understand the risks of

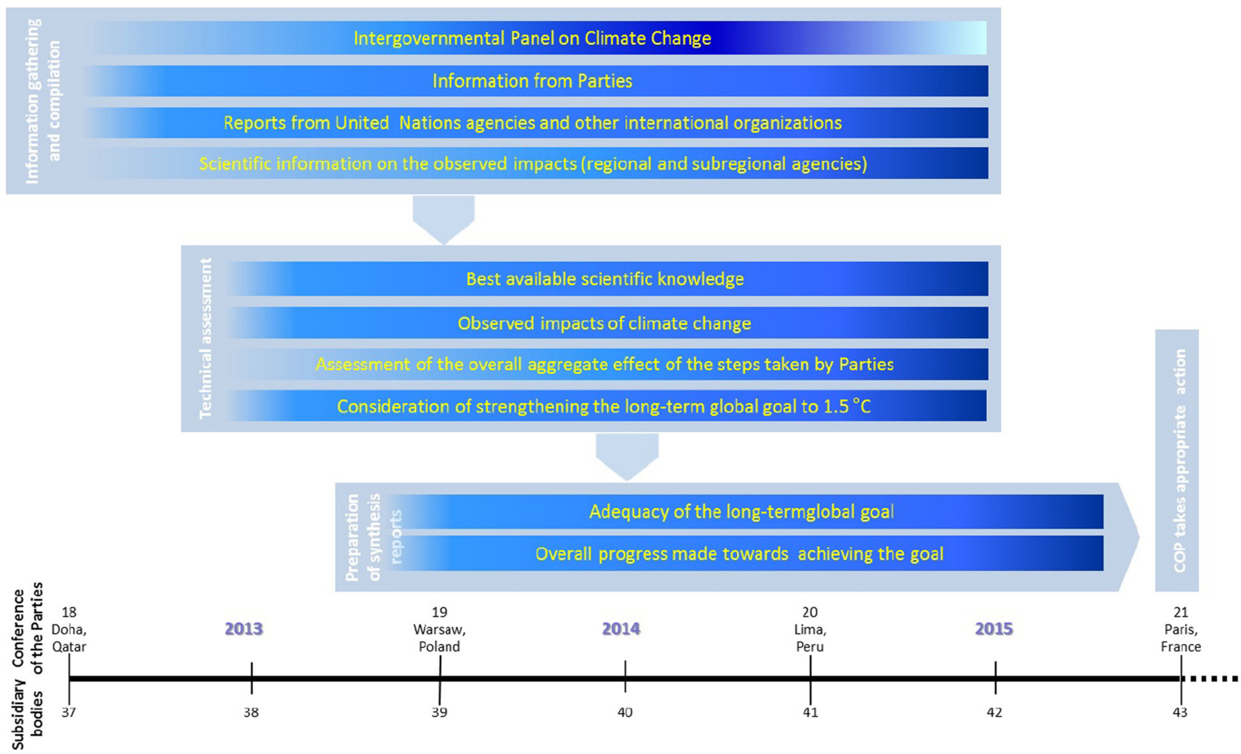

Figure 1 Phases of the 2013–2015 review, UNFCCC [19].

ocean acidification, sea level rise, and changes considered irreversible for human, physical, and ecological systems. During SED2 [21], the main findings from Working Group I were reiterated, namely that the global surface temperature is projected to exceed 1.5°C by 2100 relative to 1850–1900 for three of the four Representative Concentration Pathways (RCPs; the emission scenarios used in the Working Group I (WGI) of the AR5), except for the lower range of the most optimistic one (RCP2.6), although it could be as high as 2.3°C even under this scenario. Parties requested more details regarding regional differences to be caused by a 1.5°C and 2°C warmer world. From a science perspective, this information is difficult to provide, as the IPCC compared global and regional differences by RCP rather than by temperature differentials. One could, however, approximate the near-term (~2030–40) impacts of RCP2.6 with a 1.5°C warming above pre-industrial times by 2100.

This emerging incongruity between the IPCC temperature ranges and the policy-relevant yet contested temperature/danger targets became even more pronounced in SED3 [22]. Explaining the risk assessment approach employed in Working Group II to evaluate current risks, risks in the near-term (2030–2040), and risks in the long-term (2080–2100) in both a 2°C and 4°C warmer world, an IPCC expert showed increasing risks with increasing temperatures, and less and less potential for adaptation to reduce these risks. Responding to a renewed request to provide details on the specific consequences of a 1.5°C warming, the science expert pointed to the scarce literature that assesses impacts at this level, hence the limited representation in the AR5. More emphasis on this danger level in the assessment would not have been possible as all available literature has already been considered.

Best evidence, though, comes from terrestrial ecosystems, suggesting significant differences in projected risk between 1.5°C and 2°C, especially in the Polar Regions, high mountain areas, and the Tropics. As for coral reefs, a temperature rise capped at <1.5°C would be needed to protect at least 50% of all existing coral reefs [22]. From the perspective of human and agricultural systems, the difference between a 1.5°C and 2°C global temperature increase is distinctly more difficult to assess as global average conditions become fuzzy when applied to local levels where impact studies are most abundant. Similarly, the adaptation literature typically does not distinguish between specific temperature limits and risk levels. Nonetheless, expected risks and impacts under these two temperature targets differ for low-lying coastal regions and dryland farming systems where significant threats and losses are already experienced. This is safe to suggest, even if global average warming levels cannot be neatly mapped onto context-specific conditions and estimate geographically and culturally specific danger thresholds.

While there is little doubt that risks of extreme events will increase with every notch on the temperature scale and hence heighten the risk of dangerous interference, the current literature on which the IPCC AR5 is based does not allow for extracting comprehensible consequences across sectors and regions regarding this 0.5°C temperature differential. A more insightful way perhaps of portraying differences is shown in Table 1; it illustrates CO_2-eq concentration levels, cumulative CO_2 emissions, and the likelihoods of meeting specific temperature targets by 2100 [23]. Staying below a global 1.5°C warming compared to pre-industrial times is unlikely for all concentration levels >500 ppm and more unlikely than likely for the 430–480 ppm range. Insufficient models exist to evaluate <430 ppm.

Expert-party exchanges during the first three SEDs with respect to what temperature target matters mirror earlier yet more antagonistic discussions at some of the AR5 approval sessions, and the political weight they carry. For instance, in Yokohama in March 2014 [24], authors and delegates spent a considerable amount of time negotiating the temperature axis of an updated version of the Reasons for Concern (also known as the Burning Embers diagram) during the approval of the Summary for Policy Makers of WGII. The draft version of this figure included only temperature change relative to the period 1986–2005 (left thermometer in Figure 2), starting from 0°C change, consistent with the scientific baseline used in all three working groups. However, as a response to the insistence on the part of some parties, including St. Lucia, Saudi Arabia, and Bolivia, a second thermometer was added to the right, illustrating approximate change since pre-industrial times (1850–1900), despite the much smaller available scientific data sets. No instrumental records allow going back as far as 1750. For many delegates, it was fundamental to *not* omit in this crucial figure the 0.61°C change that had been accumulating between 1850 and 1900 and the recent temperatures (1986–2005), change that results in concrete impacts felt already around the globe.

Moreover, fierce debates erupted over the visual highlighting of certain temperature targets in the graphic [24]. The draft version of the figure included two dotted horizontal lines, one at 2°C and the other at 4°C. Again, St. Lucia, supported by Dominica, Jamaica, Tuvalu, Cuba, Mali, France, and then also Germany, requested a third dotted line at 1.5°C, arguing that this line would be highly policy-relevant. Yet, others considered it policy-prescriptive and hence inappropriate for the IPCC whose mandate it is to be no more than policy-relevant. A compromise to add dotted lines at all 0.5°C increments, offered by the IPCC authors as well as Belgium, Austria, the U.S., and others, was rejected. In the end, the graphic was approved, without any horizontal lines, as most 'scientifically neutral.' This overt controversy

Table 1 Likelihoods of staying below specific temperature targets for various emission concentration pathways

CO_2-eq Concentration in 2100 (CO_2-eq)* Category label (conc. range)	Subcategories	Relative position of the RCPs*	Change in CO_2-eq emissions compared to 2010 (in %)*		Likelihood of staying below a specific temperature level over the 21st century (relative to 1850–1900)*			
			2050	**2100**	**1.5°C**	**2°C**	**3°C**	**4°C**
<430	Only a limited number of individual model studies have explored levels below 430 ppm CO_2-eq*							
450 (430 to 480)	Total range*	RCP2.6	−72 to −41	−118 to −78	*More unlikely than likely*	*Likely*		
500 (480 to 530)	No overshoot of 530 ppm CO_2-eq		−57 to −42	−107 to −73		*More likely than not*		
	Overshoot of 530 ppm CO_2-eq		−55 to −25	−114 to −90		*About as likely as not*	*Likely*	
550 (530 to 580)	No overshoot of 580 ppm CO_2-eq		−47 to −19	−81 to −59	*Unlikely**			*Likely*
	Overshoot of 580 ppm CO_2-eq		−16 to 7	−183 to −86		*More unlikely than likely**		
580 to 650	Total range	RCP4.5	−38 to 24	−134 to −50				
(650 to 720)	Total range		−11 to 17	−54 to −21			*More likely than not*	
(720 to 1,000)*	Total range	RCP6.0	18 to 54	−7 to 72		*Unlikely**	*More unlikely than likely*	
>1,000*	Total range	RCP8.5	52 to 95	74 to 178	*Unlikely**	*Unlikely**	*Unlikely*	*More unlikely than likely*

Source: IPCC AR5 Synthesis Report, 2014 [3]. *Footnotes explained in the original.

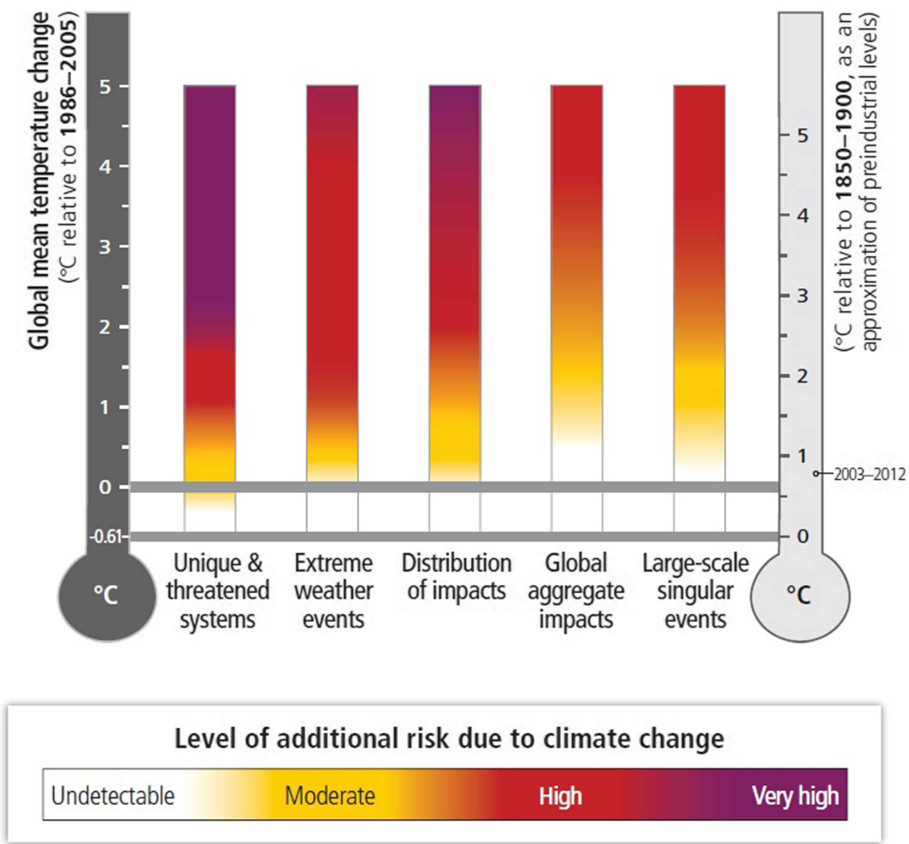

Figure 2 Climate-related risks expressed through the Five Reasons for Concern. The color shading indicates the additional risks due to climate change when a temperature level is reached and then sustained or exceeded. Source: IPCC AR5 WGII Summary for Policy Makers, 2014. [17].

around legends, units, and lines may seem tangential from a science perspective. Yet, these disputes are politically vital and indicative of the high stakes in negotiating warming targets and the resulting consequences as part of the UNFCCC 2013–2015 Review.

During the approval negotiations of the Synthesis Report in Copenhagen in October 2014, debates on mitigation pathways prompted Bolivia and Nicaragua to object to the acceptance of the 2°C over the 1.5°C target, upon which the IPCC Chair reminded the parties of the panel's mandate to assess consequences of a 2°C warming [25]. Differences regarding the inclusion of 1.5°C in a contested box on AR5 information relevant to Article 2 of the UNFCCC, defining the ultimate goal of the convention, remained unresolved. Several parties considered an explicit reference to 1.5°C as policy-prescriptive and again inappropriate for an IPCC document. This two-page box was ultimately not included in the released Synthesis Report. The ongoing UNFCCC 2013–2015 Review and the possible consideration of changing the target for the long-term goal from 2°C to 1.5°C 'may have spilled over into the IPCC process' and prevented agreement on a piece of information the parties themselves had explicitly requested [26].

At the fourth structured expert dialogue (SED4) at COP20 in Lima, a 2-day event, the experts' task was to provide evidence that would allow for assessment of the adequacy of the long-term global goal in terms of preventing unacceptable consequences for natural and human systems and risk management. Evidently, for representatives of the IPCC, our place was not to proclaim what may be adequate and what may be acceptable but rather to present information from the report that speaks to impacts and risks at various temperature levels. First reviewed were consequences under a 1.5°C *versus* a 2°C world for ecosystems and food production [27]. With reference to the former, the difference between the two temperature targets would increase risk for marine species from moderate to high, accounting for both ocean warming and ocean acidification, with 20%–50% of corals and mollusks affected. Limiting warming at 1.5°C would still yield a number of avoided impacts, such as keeping sea level rise <1 m, saving half of the world's corals, and leaving some of the Arctic summer ice intact. However, crop yields would turn largely negative from the 2030s onward with more severe impacts after 2050. A representative of the World Health Organization stressed that there was no 'safe limit' for health, as current impacts and risks from climate change and variability were already unacceptable, impacting people's health significantly and inequitably [28]. A poignant example are excess deaths during heat waves (e.g., >10,000 deaths during the Russian heat wave in 2010), and still higher risks expected under a 1.5°C warmer world (e.g., rise in undernutrition, food- and water-borne infections, and occupational ill-health).

My charge at SED4 was to illustrate consequences from climate change for sustainable development with relevance for assessing the adequacy of the long-term global goal [29]. Given that the AR5 WGII does in no specific chapter assess impacts on sustainable development, not under a 2°C world and even less so under a 1.5°C future, a cross-sectional view seemed most opportune. My specific emphasis was on climate change impacts on livelihoods, migration, and conflict, relevant to and overlaid onto the summary risks as depicted in the first four of the five Reasons for Concern (see Figure 2). As expected, the differentiation between 1.5°C and 2°C danger for sustainable development remains challenging.

Significant evidence regarding unique and threatened social systems exists in the literature for indigenous people such as the Inuit and the Sami in Arctic Regions, and some for high mountain communities such as the Aymara in the Andes; they indicate moderate risks already under the current 0.8°C warming. Between the current level and an expected 2°C temperature rise, indigenous and other unique human systems will face increasingly higher risks of losing their land, their cultural and natural heritage, community cohesion, sense of place, and identity. This would disrupt cultural practices embedded in their livelihoods, with very limited options for successful adaptation. Given that the assessment of risks under a 2°C warmer world is largely based on expert judgment, drawing upon the best available scientific literature and empirical, context-specific evidence rather than model simulations, it is not possible to differentiate which communities may cross a lower 1.5°C global danger threshold first and where. Moreover, due to the fact that risks are a result of climatic hazards (including but not limited to increasing temperature) combined with exposure and vulnerability, the state-of-the-art scientific knowledge is unable to confidently pinpoint a global danger level that adequately represents locally experienced realities. Vulnerability is dependent on adaptive potentials as well as uneven development pathways and inequalities baked into any society, most often along the lines of gender, race, age, class, ethnicity or indigeneity, and (dis-)ability. Despite these caveats, even the flattening aggregate assessment for unique and threatened systems signals high risks at 2°C warming, bordering on 'very high'. This 'very high risk' category required, for the first time in the history of the iconic Burning Embers diagram, a new color (purple).

Extreme events such as floods, hurricanes, and heat waves are also expected to cause high risk in a 2°C warmer world, yet not very high. These events will put at significant danger disadvantaged populations in megacities like Lagos, Mexico City, or Shanghai, people whose livelihoods are dependent on natural resources such as agriculturalists and pastoralists and at risk from conflicts over scarce resources between them, and people who are displaced or forced to migrate. Under extreme events, the ability to move at 1°C, 1.5°C, or 2°C global warming will likely depend on factors other than temperature. Rather, people who are trapped due to high environmental vulnerability and low levels of well being will be the first to cross over into a danger zone, at all levels of temperature increase, although many more with continued increases.

Regarding distribution of impacts, the zone between a 1.5°C and 2°C warming reveals increasing aggregate risks from moderate to close to high. Again, danger and risk will be unevenly distributed, with higher risks and earlier impacts for socially marginalized groups, the elderly and children, and outdoor workers, as well as for people who may shift from transient to chronic states of poverty. This unevenness already affects millions under a 1.5°C increase, and likely many more under a 2°C warming, particularly in low-latitude and low- and middle-income countries. With respect to global aggregate impacts, risks appear still moderate at both temperature levels. Yet, again, aggregate measures such as impacts on a nation's GDP mask asset losses and dangers to livelihoods of the poor and disenfranchised across regions. The poorest are often too poor to make a dent in GDP. Or they engage in the informal sector not captured in national statistics. Also, these aggregate assessments do not include large-scale singular events or the irreversibility of impacts, meaning that danger levels are likely underestimated in the color ranges of the Reasons for Concern graphic.

The take-home message was threefold: first, critical thresholds for communities and society do *not* result from global aggregates as implied in the summary figure Reasons for Concern, but from locally experienced realities. Second, critical thresholds of climate stressors occur in combination with other stressors and jointly exacerbate livelihood struggles, especially among disadvantaged populations. Third, rather than debating a global temperature average that poorly reflects localized manifestations of imminent danger, a more adequate yardstick to assess thresholds for climate insecurity may be needed. This could include monitoring at the local level when and why people transition from acceptable to unacceptable in their livelihood decisions.

The SED4 discussion between parties and experts further substantiated these points, in a rhetorically remarkable pattern. The large majority of parties are intimately familiar with the text in the approved AR5 summary documents as well as the underlying chapters. Nonetheless, in order to get specific insights on record within the UNFCCC protocol, several delegates started their interventions with 'On page x of chapter y, you state z. Can you confirm that?' As IPCC authors of these texts, we typically can and are delighted to explain further. One question from Singapore was framed to underscore, for the records in the review process, that certain risks were already catastrophic for people and natural systems in their region while only moderate in the aggregate. Along the same lines, Ethiopia re-emphasized the uneven distribution of risks for the African continent which masks regional and sectoral dangers. Others, such as Bolivia and Palau, wanted to hear confirmed the crucial role of and recognition for indigenous knowledge for adaptation. Brazil, albeit accepting the possibility of a limit at 1.5°C, questioned whether temperature was indeed the only available metric to take into consideration for a long-term global goal. Botswana raised the subject of costs for mitigation, adaptation, loss and damage, technology transfer, and finance associated with both temperature targets and avoidance of danger zones. Trinidad and St. Lucia stressed regional differences in risk from ice sheet loss and coral bleaching. Finally, the United States suggested a qualitative decision framework and place-specific risk assessments that would allow characterizing differential impacts and risks under a 1.5°C and a 2°C world in a holistic manner.

The consensus that transpired during this SED4, although it remained for the parties to articulate, was that a 2°C danger level seemed utterly inadequate given the already observed impacts on ecosystems, food, livelihoods, and sustainable development, and the progressively higher risks and lower adaptation potential with rising temperatures, combined with disproportionate vulnerability. In fact, the AR5 states that limits to adaptation are expected at all levels of global average temperature increase, 1.5°C included. The poor and disadvantaged in particular, and threatened ecosystems, are already in multiple danger zones and any additional temperature increase, coupled with other climatic hazards, would further exacerbate precarious conditions. Echoing Michael Mann's assessment of the colored risks on the precursor version of the Reasons for Concern graphic from 2009, 'it would seem difficult for the risk averse among us to accept anything above… ~1°C … where the distribution of impacts begins to weigh heavily toward being adverse across diverse regions' [30]. One may argue that even those who inhabit the temperate regions, are most privileged, or 'feel lucky' (in Mann's terms) would find it troubling to justify a 2°C danger limit, given the growing signals for future harm. A low temperature target is the best bet to prevent severe, pervasive, and potentially irreversible impacts while allowing ecosystems to adapt naturally, ensuring food production and security, and enabling economic development to proceed in a sustainable manner, as prescribed in the convention.

Conclusions

Significant negative impacts, limits to adaptation, and anticipated worsening of trends from a 0.8°C warming since pre-industrial times onwards already indicate a clear need for strengthening the long-term global goal. The jury from the entire 2013–2015 Review is still out—the final report is expected for June 2015—and, thus, no particular reference to an explicit 1.5°C target is included in the Lima Call for Climate Action. Yet, specific remarks with respect to this lower temperature limit were made throughout the COP negotiations, particularly in the context of the ADP preambular paragraphs (the drafting of a new agreement) and adaptation discussions [31]. For instance, Tuvalu for the LDCs requested to keep temperature increase below 1.5°C. South Africa stressed the need for the long-term goal to be consistent with science results while the EU called for explicit reference to the 2°C target [31]. With the currently implemented mitigation policies, however, the world is likely on track to 3.7°C–4.8°C warming by 2100 [32]. At this point, let us consider the realistic prospects, requirements, and associated costs for staying below a 1.5°C warming throughout the 21st century.

IPCC results suggest that limiting temperature increase to <1.5°C by 2100 would require concentration of less than 430 ppm CO_2-eq [23,32] (see also Table 1), an enormous challenge. Efforts to link, in one single graphic illustration, temperature targets from the Reasons for Concern with cumulative CO_2 emissions by 2100 (with an uncertainty range) and emission reductions required by 2050 resulted in the arguably most compelling integrative IPCC chart ever, depicted in Figure 3 and presented at SED4 in Lima. Under the best case scenario, such an ambitious target would mean peaking close to 1.5°C by mid-century before slowly declining to below this level. While the literature on the feasibility of reaching this target remains scarce, aggressive mitigation strategies would be fundamental, without any further delay. This entails not only swift global cooperation and exemplary institutional agreements but also massive investments in decarbonizing the global economy

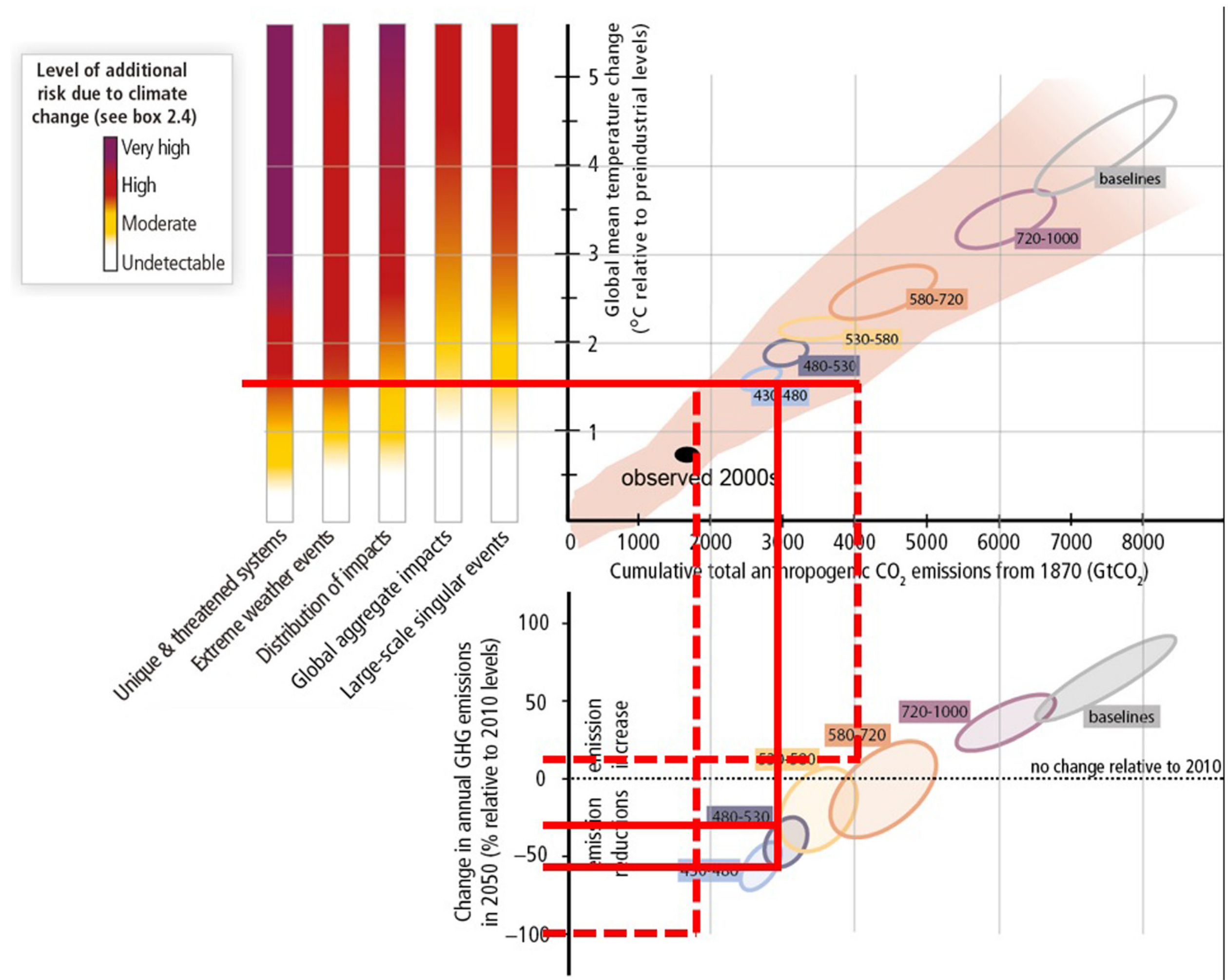

Figure 3 The relationship between risks from climate change, temperature change, cumulative CO_2 emissions, and changes in annual GHG emissions by 2050. The pink plume is from WGI complex models and includes the uncertainty from non-CO_2 gases and climate and carbon cycle uncertainty, using the likely range. The ellipses show results from the WGIII models, using a simple climate model, not including climate and carbon cycle uncertainty. The red lines are an example of how to read the figure; they are not included in the version of the released Synthesis Report. Special thanks to Stéphane Hallegate and IPCC colleagues for guiding authors and parties through this application. The horizontal red line in the top part of the figure indicates a 1.5°C warming over pre-industrial times, connected to cumulative CO_2 emission levels, for the average climate response (solid vertical line down), for large climate sensitivity (dotted vertical line down to the left of the solid line), and for low climate sensitivity (dotted vertical line down to the right of the solid line). Through the horizontal lines in the bottom part of the graphic, levels of risks can now be connected to GHG emission changes by 2050, again for an average climate response and high- and low-sensitivity scenarios. Added uncertainty arises from action on non-CO_2 gases, timing of pre-2050 action, and ambition of post-2050 action [23,35].

with zero net emissions before the end of the century as well as substantial and early negative emissions, particularly carbon dioxide removal strategies such as carbon capture and storage (CCS). Yet, some CCS strategies are technologically not yet available, too costly, too risky, or not ready to be scaled up, while bioenergy-driven CCS triggers competition over land and may well threaten food security. Delaying action will substantially increase costs, with mitigation costs already highest for Africa [22], and likely close the small window available. While some argue that a 1.5°C scenario is still feasible, others judge it as no longer within reach [12,33,34].

Without a doubt, it is in the utmost interest of a large number of countries to pursue the 1.5°C target, as ambitious or idealistic it may appear to date, and to see it anchored as a binding goal in the next agreement, as a possible outcome of the 2013–2015 Review. Parties like small island states and many others whose vulnerability is extremely high and their survival at stake are the most vocal. Their persistence is particularly crucial in the absence of other, more, and more tangible and complementary targets and indicators or, as Victor and Kennel [12] call them 'vital signs of planetary health', potentially including CO_2 concentrations, ocean heat content, high-latitude temperatures, locally valued resources, and actual, experienced human stress or distress. But such alternative metrics that motivate change in people's actions and policy making will not be available for COP21 in Paris in 2015. There may also be another reason why many parties support the strengthening of the long-term global goal toward a lower target, against all odds, and why others are vehemently opposed to it, despite growing indication of unacceptable harm and danger. This additional reason is highly political and closely tied to a different topic of negotiation at recent COPs, and equally fiercely debated—loss and damage.

Loss and damage was first considered under the Cancun Adaptation Framework of 2010. It considers approaches to address loss and damage that are associated with climate change impacts in developing countries that are particularly vulnerable to the adverse effects of climate change. COP19 produced the Warsaw International Mechanism for Loss and Damage associated with Climate Change Impacts. It pays particular attention to extreme weather and slow onset events and requests Annex I countries to provide finance, technology, and capacity building to developing countries. For AOSIS, the LDCs, and the African Group, it has been crucial to distinguish loss and damage and associated financial commitments from adaptation as the former addresses limits to adaptation under extreme events or potentially irreversible conditions. Equally important for the same parties in Lima was the inclusion of a loss and damage paragraph as a distinct element into the scope of the 2015 agreement, yet opposed by the United States, Japan, Australia, The Russian Federation, and Switzerland [31].

The unevenness of the political landscape in discussions around 1.5°C/2°C as well as loss and damage is staggering. Analogous to Seager's [14] and Liverman's [15] claims with respect to differential interpretations of dangerous interference, this unevenness epitomizes geographies of privilege, power, and inequality. For the LDCs and AOSIS, where impacts are already felt most severely, a 1.5°C target enshrined in a 2015 agreement would not only constitute a legally binding goal. It would also, perhaps ultimately more importantly, provide a potential justification for earlier and higher loss and damage compensation in the (likely) case the target is exceeded. This could well be a way of addressing inequity through the backdoor. Crossing a signpost signals failure, failure of the international community to protect, and it would allow all of us to hold our elites accountable [36]. In practical terms, this could mean millions and trillions of US$, even if such funds could never replace lost land or livelihoods. For less vulnerable nations endowed with high national income and located in less risk-prone exposure latitudes, the stakes in the loss and damage debate tied to a lower temperature target are enormous. Combining a strengthened long-term global goal and loss and damage compensation, especially outside of adaptation finance, would represent a massive financial obligation for the rich world, for decades to come.

The crux of the matter is no longer about the scientific validity of one temperature target over another, although debates are likely to continue for a while, nor about the likelihood of crossing a computational global threshold at a specific point in time. Neither is it about conducting more studies or running more sophisticated simulations on lower temperature targets or CO_2-eq concentrations, knowing that those we have to date are scarce and the targets essentially impossible to reach. It is first and foremost about overcoming deeply entrenched divisions on value judgments, responsibility, and finance. It is about our respective willingness to understand and buffer against risks and to pay for abatement and compensation, not merely about reaching or not reaching a single-index number goal. It is about acknowledging that negative impacts of climate change under a 0.8°C temperature increase are already widespread, across the globe, and that danger, risk, and harm would be utterly unacceptable in a 2°C warmer world, largely for 'them'—the mollusks, and coral reefs, and the poor and marginalized populations, not only in poor countries—even if this danger has not quite hit home yet for 'us'. And this is why this political process is so extraordinarily difficult and slow, and nonetheless necessary.

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