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Three Pathways with Different Climate Change Risks and Additional Response Options Compared to IPCC AR6

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Abstract

The illustrative development pathways developed by the Intergovernmental Panel on Climate Change (IPCC) for the Synthesis Report of its Sixth Assessment Report (AR6 (1)) consider mainly different levels of mitigation and adaptation. This article expands the range of development pathways. One assumption is the crossing of tipping points of the climate system with positive feedback. A second assumption is the deployment of solar radiation modification triggered by significantly increase of loss and damage. A prerequisite for such deployment is additional scientific knowledge to inform decisions at the policy level.

Keywords: Development Pathways, Climate Change Risks, Solar Radiation Modification

1. Introduction

This review article informs about recently published information relevant for the assessment of climate change risks. Progress in reducing those risks as well as indications for their further increase will be provided. In order to avoid that humanity's relentless carbon emissions finally push the climate crisis into a new and accelerating phase of destruction this article will also inform about recent efforts to prepare for the possible implementation of solar radiative management (SRM) and offers three possible scenarios, two of them including SRM.

2. Recently Published Information

On 20th July a leading UK scientist, the former chair of the Intergovernmental Panel on Climate Change (IPCC), Bob Watson expressed in an BBC interview the view that the world will miss the 1.5°C warming limit [2]. In addition, these comments by Bob Watson were supported by Lord Stern, Chairman of the Grantham Research Institute on Climate Change and the Environment, later on during an interview with BBC's WATO programme [2].

This view is underpinned by climate experts at Climate Action Tracker who predicted after COP27 in 2022 that even with the new pledges made during COP27, world temperatures would rise 2.7°C above pre-industrial levels by 2100 [3].

The latest report by the International Energy Agency, published in March 2023 (IEA, (4)) highlighted that in 2022 the global energy-related CO_2 emissions grew by 0.9% or 321 Mt, reaching a new high of over 36.8 Gt.

Research performed by US scientists, published in December 2022 addressing: What Does Global Land Climate Look Like at 2°C Warming? is very relevant as it is based upon scenarios (SSP2-4.5 and SSP5-8.5) that reflect quite well the actual development of the global GHG emissions [5]. This study uses the recently released NASA Earth eXchange Global Daily Downscaled Projections (NEX-GDDP) CMIP6 data to provide a broad overview of projected changes in six key climate variables (near-surface relative humidity, precipitation, surface downwelling long-wave radiation, near-surface wind speed, mean near-surface air temperature) and two climate impact indicators (Fire Weather Index and WetBulb Globe Temperature) at a time when global warming exceeds 2°C. Analysis of global mean temperature changes indicates the 2040s as the decade when most CMIP6 models reach 2°C global warming with respect to a pre-industrial period (1850–1900). The study found that following a more ambitious emission scenario (SSP2-4.5) results in a delay of about 3 years compared to the less ambitious scenario (SSP5-8.5). The difference in global warming between these two scenarios in the long-term is of course much more significant: 3°C warming for SSP2-4.5 versus 4°C for SSP5-8.5. The study concludes that information about the spatial heterogeneity of these six climate variables are key in order to understand where and to what extent lives and livelihoods will be at risk in the future and more detailed analysis at local scale has been encouraged.

By end of August 2023 record-shattering heatwaves, wildfires and floods destroying lives in the US, Europe, India, China and beyond have been reported but even more severe extreme events

will be with us in the coming decades triggered by any further increase in global warming. With the words of the IPCC AR6 (1): Every increment of global warming will intensify multiple and concurrent hazards (high confidence).

Peter and Susanne Ditlevsen from the Niels Bohr Institute in Copenhagen informed in a recent publication (July 2023) that the Atlantic circulation is likely to collapse in the next 65 years, and the irreversible processes associated with its critical slowdown will manifest themselves by the middle of the century [6]. The Atlantic meridional overturning circulation (AMOC) is a major tipping element in the climate system and a future collapse would have severe impacts on the climate which will be not limited to the northern Atlantic. Whereas this assessment of the collapse of the AMOC seems to be quite robust the understanding of the impacts of such collapse is still quite limited.

According to an article of the Guardian informing about the XIII SCAR Biology Symposium (31 July - 4 August 2023, Christchurch, New Zealand) Antarctica is currently (in 2023) experiencing dramatic changes at unprecedented rates, marked by repeated extreme events [7]. These include circum Antarctic summer heatwaves and an autumn heatwave last year, with temperatures soaring up to 40°C above the average. Moreover, both last summer and this winter, sea ice extent has reached record lows. These changes have happened even faster than scientists predicted. In this context it is worth noting that one of the consequences of a breakdown of AMOC would be transport of heat by the Atlantic into Antarctica.

Given this significant expected increase in climate change risks that cannot be avoided by mitigation and adaptation alone it is not surprising that activities have started to make additional options viable, such as solar radiation management (SRM), to better manage climate change risks. SRM is a technique that seeks to reflect sunlight away from the Earth in a bid to cool the planet. The scale and impact necessary to make a difference is massive, making SRM a controversial approach. For Shuchi Talati, founder and executive director of The Alliance for Just Deliberation on Solar Geoengineering, "the real (Stratospheric Aerosol Injection – one option of SRM) controversy is around research, and like, what type of research to do and where we're prepared to draw the line." When the foundational stage of R&D is not handled properly, the domino effect can be catastrophic [8].

In June 2023, the White House published a congressionally-mandated report on SRM including a research plan and research governance framework, and the European Union announced its support for international efforts to assess the risks and uncertainties of SRM and promote discussions at the highest international levels on a potential international framework for its governance [9,10]. This level of political engagement by the EU and US around the topic of SRM and its governance are an important step to close gaps in knowledge with the goal to better assess any potential risks related to the implementation of SRM.

But beyond improving understanding the risks associated with SRM it is also important to address its governance. Concerns have been raised that preventing and controlling unwanted SRM deployment may be its greatest governance challenge. Such risk is quite real because of SRM's capacity for widespread environmental effects, technological simplicity, and relatively low direct financial costs of deployment which give it—and especially Stratospheric Aerosol Injection —high leverage.

One or a few countries—including those other than superpowers—could begin SRM before and/or contrary to any international consensus. This could be seen as problematic even if SRM were widely expected to be beneficial. Uni- or mini-lateral SRM might be domestically motivated by severe and sudden climate impacts, consequent popular unrest, and/or a desire to provoke the rest of the world to reduce emissions more aggressively and enhance internationally finance adaptation. Either way, threats or actions in this area could precipitate international tension and conflict.

C2G, the Carnegie Climate Governance Initiative, informed in its August newsletter that for a growing number of UN and other intergovernmental processes the risk of ungoverned SRM is becoming a cause for concern and that the international discussion about SRM and its governance is well underway [11].

The following three development scenarios have been designed to trigger further discussion at the highest political level in order to better manage the increasing risks driven by climate change.

2.1 Scenario A

Key elements, as suggested in this paper:

1. Stringent and binding commitment to mitigate greenhouse gas emissions coherent to limit warming to 2°C.

Meeting this goal should still be possible by mitigation only according to the AR6 from the IPCC (1). It is also suggested to strengthen this requirement by including some enforcement action if a country fails to deliver the necessary emission reduction. E.g. by enhancing its amount of carbon dioxide removal by Direct Air Capture and permanent storage. Such binding commitment is necessary in order to hedge against the moral risk of even further delay of mitigation respectively GHG emission reduction activities. Meeting the 2°C temperature goal would require that net zero CO_2 emissions will be reached around 2070 and net zero GHG emissions around 2090 (1).

2. SRM to compensate global warming should be limited to 0.5°C – a level of cooling in the range of the cooling triggered by the eruption of the Mount Pinatubo in 1991 [12]. In combination with the above requirement addressing mitigation and carbon neutrality this would allow to avoid overshooting of the 1.5°C target. Given the experience and studies available from that eruption should help to assess the risks associated with that level of cooling and to inform a risk-risk assessment [13].

3. In addition, binding commitments in investment in an agreed amount of carbon dioxide removal by Direct Air Capture and permanent storage is required in order to be sure that before

starting deployment of SRM its implementation will be for a quite limited amount of years. This requirement will allow to reduce the level of warming to be compensated by SRM year by year after global carbon neutrality has been reached.

This requirement is needed to address overshooting of 1.5°C and to significantly reduce the time we would need SRM; current capacity of about 6000 t/yr is much too small. The goal should be to achieve at least a removal rate of about 10 Gt CO_2/yr which is about ten times larger than the natural removal rate of CO_2. A company (Climworks) announced recently that it plans to scale up the removal rate to 1 Gt CO_2/yr by 2050 [14].

The need to have decisions by consensus and given the diversity of vulnerability to the impacts of climate change, the political challenge to agree on the above suggested binding requirements in the little amount of time left before the increase of 1.5°C is achieved (about 10 years) is significant. Such scenario would require a very strong political will by all countries to the UNFCCC (United Nations Framework Convention on Climate Change) and a broadly accepted risk-risk assessment.

Nevertheless, this scenario A would very likely represent that scenario which offers the best available development pathway with minimized climate change risks.

2.2 Scenario B

Scenario B describes what might happen if the necessary political will for the above commitments is not available. Under scenario B the current Paris Agreement will remain the main basis for global action to address climate change risks. Thus, scenario B does not assume additional actions beyond those already identified in National Determined Contributions (NDCs) and being implemented. Under scenario B climate change risks are not adequately addressed due to other political challenges (e.g. migration, inflation, geo-politics) that are dominating the political agenda, in particular of the big and powerful countries.

Missing the pre-requisites for SRM (research, hedging against termination risk, agreement on governance, more stringent mitigation goals, goals for Direct Air Capture and Storage (DAC-S)) also does not allow to overcome the barriers for deployment of that approach without risking conflicts with organizations/countries opposing such approach. Recognition of the significant impacts of climate change risks for development comes too late to trigger meaningful actions to manage those risks.

Global warming will therefore continue, tipping points of the climate system will be crossed. Global warming between 1°C ~ 3°C can cause summer melting of the Arctic Sea ice, melting of the Greenland ice sheet, extinction of Alpine glaciers, melting of the West Antarctic ice sheet, and coral bleaching. As the current expected warming level by 2100 is about 2.7°C these tipping points might be crossed. The OECD, the Organization for Economic Co-operation and Development, described the dire consequences of crossing these tipping points of the climate system and how to take account of the threat of tipping points in climate policy [15].

Given that these tipping points also show positive climate feedback and thus trigger even more warming this could result also in crossing tipping points between 3 and 5°C global warming (eg. dieback of the Amazone rainforest, degradation of boreal forests, Boreal Permafrost collapse).

Climate will not stabilize but positive feedback mechanisms will ultimately result in warming that make large parts of the world unhabitable for people. Many of them (if not most of them) will die from hunger and lack of water and heat waves and natural disasters (storms, floods) and a great number of species will also disappear.

The pathway of scenario B will be significantly lower compared to the BAU pathway in the figure SPM 6 of the SYR of IPCC AR6 (1) and more and more shocks will disrupt development on Earth. It represents that scenario with the poorest development for natural and human systems and with the highest extinction rate of species worldwide, a scenario that would result in a situation that has occurred only five times until now in the history of our planet. The last mass extinction has been around 65 million years ago which resulted in the elimination of about 50% of species at that time [16].

2.3 Scenario C

Scenario C assumes that the ever-growing dire consequences of global warming finally help to establish the necessary broad political will necessary to finally limit the risks of climate change. Under scenario C the key elements that might be agreed finally are:

1. Stringent and binding commitment to mitigate greenhouse gas emissions coherent to limit warming to 2.5°C.

Compared to scenario A more irreversible processes might have been triggered already by warming; eg. more species might have already been lost compared to scenario A, more people will have lost their livelihoods and their life, more people would have experienced loss and damage.

2. Binding investment in an agreed amount of carbon dioxide removal by Direct Air Capture and permanent storage.

Compared to scenario A more GHGs will have to be removed from the atmosphere which would translate in a longer period of time to deploy SRM and/or in a higher rate of removal.

3. No SRM to compensate global warming over and above 1.0°C.

The risks associated with SRM would be significantly higher compared to scenario A, given that SRM should cool the planet by 1.0°C under scenario C compared to 0.5°C under scenario A.

The assumption is that in 25 years from now the losses and damages due to climate change are so significant that people are willing to cross the social tipping points necessary to achieve net zero CO_2 emissions by about 2090 and to fulfil all safeguards in order to be in a position to deploy SRM and finally will also end up with a warming level of 1.5°C hopefully in about 2200.

It remains to be seen how many human and natural systems will

survive such strong overshooting due to the further delay in decisive action.

The more people delay the described activities the more people will have to suffer. Communication that can be understood easily by all will be key to speed up action. Scenario C as described is only one of many options for a scenario between A and B. Whereas scenarios A and B describe the envelope of possible risks of development pathways with a focus on climate change risks, scenario C as described above is only one option of a scenario with climate change risks between those of scenarios A and B.

One sub-scenario of scenario C would be a scenario that only addresses the first more stringent commitment compared to the Paris Agreement, the legally binding commitment to mitigate greenhouse gas emissions coherent to limit warming to 2.5°C. This sub-scenario would not allow to implement SRM due to the lack of governance, the lack of current understanding of the risks of this approach and the lack of addressing the key risks inherent in SRM according to the advice of scientists and without risking significant tension among countries [17]. However, even that scenario would reduce climate risks compared to scenario B. Most importantly, it would buy negotiation time to work towards implementation of CDR and SRM.

Another sub-scenario C would go a step further compared to the sub-scenario described above: it might limit the extent to which SRM would be implemented – eg. to 0.5°C cooling. It would thus introduce a trial-and-error approach. Whether or not that would be beneficial is difficult to say, because such sub-scenario might soon end up with larger cooling by SRM, thus increasing the risk of abrupt global warming (termination risk).

Probably the most challenging element of scenario C from a policy perspective would be the agreement on binding investment in an agreed amount of carbon dioxide removal by Direct Air Capture and permanent storage. Because those that emitted most of the emissions resulting in global warming will not be alive anymore; to identify a fair contribution would be very challenging, in particular how to implement one of the key principles of the UNFCCC, the principle of common but differentiated responsibilities (CBDR, 18). Voluntary pledges might be an option but given the huge amount of money that will be required and the many decades that that burden will be with the countries it seems a very difficult topic. But there are people that are willing to invest into that technology – as the example of CLIMWORKS and its planned roadmap until 2050 shows. It would therefore be great to see not only one company like CLIMWORKS but many, based in different geographies, working with different approaches of DAC-S.

The above examples show that we might end up in a stepwise approach. Under all circumstances, it seems important to always have in mind the necessary risk reduction in the long-term and not only the short-term burden.

3. Conclusion

It will depend on the decisions of all how the actual development pathway will look like. The objective should be to work towards crossing social tipping points (NOTE 1) in order to manage the climate change risks in a meaningful manner. I do hope that this review article will help to enhance efforts to try to come as close as possible to scenario A in order to reduce the burden for future generations, our grandchildren, as much as possible.

NOTE 1: Social Tipping Point is a point within a social system at which a small quantitative change can trigger rapid, nonlinear changes "driven by self-reinforcing positive-feedback mechanisms, that inevitably and often irreversibly lead to a qualitatively different state of the social system." [19].

NOTE 2: Crossing social tipping points should have the goal to agree on the requirements identified in scenarios 1 and 3.

NOTE 3: A prerequisite for crossing the above identified social tipping points might be to make addressing climate change risks the top policy issue at the highest political level.

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