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1 **Title: Reconciling justice and attribution research to advance climate policy**

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20

21 **Abstract**

22 The Paris Climate Agreement is an important step for international climate policy, but the
23 compensation for negative effects of climate change based on clear assignment of responsibilities
24 remains highly debated. Both from a policy and science perspective, it is unclear how responsibilities
25 should be defined and on what evidence base. We explore different normative principles of justice
26 relevant to climate change impacts, and ask how different forms of causal evidence of impacts drawn
27 from detection and attribution research could inform policy approaches in accordance with justice
28 considerations. We reveal a procedural injustice based on the imbalance of observations and
29 knowledge of impacts between developed and developing countries. This type of injustice needs to
30 be considered in policy negotiations and decisions, and efforts be strengthened to reduce it.

31

1 The Paris Agreement¹ of the United Nations Framework Convention on Climate Change (UNFCCC) is
2 considered an important milestone in international climate policy. Among the most critical points
3 during the Paris negotiations were issues related to climate justice, including the question about
4 responsibilities for the negative impacts of anthropogenic climate change. Many developing
5 countries continued to emphasize the historical responsibility of the developed world. On the other
6 hand, developed countries were not willing to bear the full burden of climate responsibilities,
7 reasons among others being the current high levels of greenhouse gas emissions and substantial
8 financial power of some Parties categorized as developing countries (i.e. Non-Annex I) in the
9 UNFCCC. Many Annex I Parties were particularly uncomfortable with the issue of 'Loss and Damage'
10 (L&D), which is typically defined as the residual, adverse impacts of climate change beyond what can
11 be addressed by mitigation and adaptation^{2,3}. Although L&D is now anchored in the Paris Agreement
12 in a separate article (Article 8)¹, questions of responsibility and claims for compensation of negative
13 impacts of climate change basically remain unsolved.

14 Claims for compensation, occasionally also called climate 'reparations'⁴, raise the question of who is
15 responsible for which negative climate change impacts, how to define such responsibilities and on
16 the basis of what type of evidence. Scientific evidence has become increasingly available from recent
17 studies and assessments, termed "detection and attribution of climate change impacts", revealing
18 numerous discernable impacts of climate change on natural, managed and human systems
19 worldwide⁵⁻⁷. In some cases, these impacts have been found to be substantial, but often the effects
20 of multiple non-climatic drivers ('confounders') acting on natural and especially human and managed
21 systems (e.g. land-use change, technical developments) have either been greater than the effect of
22 climate change or have rendered attempts to determine the relative importance thereof difficult. A
23 significant portion of attribution research has focused on the effects of increased atmospheric
24 greenhouse gas concentrations on extreme weather events, yet usually without adopting an impacts
25 perspective⁸. Recent studies have therefore emphasized the need for a more comprehensive
26 attribution framework that considers all components of risk (or L&D), including vulnerability and
27 exposure of assets and values in addition to climate hazards⁹. Other contributions have discussed the
28 role of attribution analysis for adaptation and L&D policies¹⁰⁻¹³.

29 How detection and attribution research could inform, or engage with climate policy and justice
30 debates is currently largely unclear. Some first sketches of a justice framework to address the
31 assignment of responsibility for L&D have recently been developed^{14,15}. However, the question of
32 which type of evidence would best cohere with each of the various concepts of justice has not been
33 addressed despite its importance for the achievement of progress in international climate policy.

34

1 In this Perspective we explore the different concepts and dimensions of normative justice research
2 relevant to issues of climate change impacts (see Textbox 1). We adopt a normative perspective and
3 analyze how the application of principles of justice can inform respective political and legal contexts.
4 We study the extent to which different forms of scientific evidence on climate change impacts,
5 including detection and attribution research (see Textbox 2), can contribute to, or inform, the
6 respective justice questions and related policy debates. Normative principles of justice define who is
7 morally responsible for an impact and how to fairly distribute the burdens of remedy. In the political
8 and in particular in the legal context liability defines an agent's legal duties in case of unlawful
9 behavior¹⁶. Liability of an agent for climate change impacts defines a legal duty to pay for remedy of
10 the negative effects. Liability can comprise compensation for L&D but also, for instance, include
11 fines^{17,18}.

12
13 In the following we first address questions of liability and compensation and why a potential
14 implementation faces many hurdles on the scientific, political and legal level. We then consider the
15 role that recognition of moral responsibilities for climate change impacts could play in fostering
16 political reconciliation processes. Third, we explore the feasibility of the principle of ability to assist
17 (or pay) and focus on risk management mechanisms as a response to immediate and preventive
18 needs. Finally, we address the uneven distribution of knowledge about impacts across the globe as
19 assessed in the 5th Assessment Report (AR5) of the Intergovernmental Panel on Climate Change
20 (IPCC), and reveal an additional injustice on a procedural level with important further implications for
21 policy and science.

22

23

1 **BEGIN TEXT BOX 1: Justice principles relevant for climate change impacts**

2 International climate policy is loaded with moral evaluations. The fact that emissions of greenhouse
3 gases from human activities lead to climate change is not morally blameworthy as such. In order to
4 assess emissions as ethically relevant it is necessary to evaluate their consequences based on
5 normative principles. The level at which climate change is “dangerous” in an ethically significant
6 sense has to be defined. Similarly, normative principles become relevant when differentiating
7 responsibilities in order to deal with the adverse effects of climate change^{16,19,20}. In climate policy, as
8 reflected in normative climate justice research, the following principles are relevant for establishing
9 who bears responsibility for climate change impacts and for remedying those impacts:

10 *Polluter-Pays-Principle (PPP)*: It is commonly accepted that those who have contributed or are
11 contributing more to anthropogenic climate change should shoulder the burdens of minimizing and
12 preventing climate change impacts in proportion to the magnitude of their contribution to the
13 problem. From a PPP perspective, it is not only high-emitting developed countries that are called into
14 responsibility to share the burden and assist low-emitting communities facing climate change risks,
15 but also high-emitting developing countries²¹⁻²³.

16 *Beneficiary-Pays-Principle (BPP)*: The BPP addresses important ethical challenges emerging from the
17 PPP such as that some people have profited from past emissions, yet have not directly contributed to
18 anthropogenic climate change. The BPP claims that those benefitting from the high emissions of
19 others (e.g. their ancestors or other high-emitting co-citizens) are held responsible to assist those
20 impacted by climate change irrespective of whether they themselves caused these emissions^{21,24-26}.

21 *Ability-to-Pay-Principle (APP)*: The PPP and BPP both establish responsibilities irrespective of the
22 capacity of the duty-bearers to contribute to climate change measures or reduce emissions. This can
23 result in detrimental situations for disadvantaged high emitters and beneficiaries, be it individuals or
24 countries. Following the APP only those capable of carrying burdens are responsible to contribute to
25 climate change measures or emission reductions^{21,23,27}.

26 In this Perspective, we deal with the APP under the label of “Ability-to-Assist-Principle” (AAP) in order
27 to broaden the perspective beyond monetary payments toward consideration of assistance with
28 climate change impacts more generally. Furthermore, we do not address the difference between the
29 PPP and the BPP because to a large extent the sets of duty-bearers identified by the two principles
30 overlap. None of the above principles provides any natural guidance on the threshold for emissions
31 in terms of quantity or historical date at which they become a morally relevant contribution to
32 dangerous climate change.

33 **END TEXT BOX 1: Justice principles relevant for climate change impacts**

1 **BEGIN TEXT BOX 2: Evidence that climate change has impacted natural and human systems**

2 Scientific evidence that human-induced climate change is impacting natural and humans systems can
3 come in a number of forms, each having different applications and implications²⁸. We draw here an
4 analogy to U.S. environmental litigation²⁹ where typically two types of causation are relevant:
5 "general causation" refers to the question of whether a substance is capable of causing a particular
6 damage, injury or condition, while "specific causation" refers to a particular substance causing a
7 specific individual's injury.

8 In the line of general causation, evidence for the potential existence of anthropogenic climate change
9 impacts is relatively abundant (for more examples and references see the main text). Long-term
10 monitoring may, for instance, reveal a trend toward more frequent wildfires in an unpopulated area.
11 These observations may have little to say about the relevance of climate change, or of emissions for
12 that climate change, but they can be useful for highlighting the potential urgency of an issue.

13 Another form of evidence may come from a mechanistic understanding of how a system should
14 respond to some change in its environmental conditions. The ranges of plant and animal species
15 may, for instance, shift polewards in response to an observed or expected warming. In this case, the
16 relevance to human-induced climate change may be explicit, but it remains unclear whether the
17 range shifts have indeed occurred.

18 In order to be confident that an impact of anthropogenic climate change has indeed occurred, more
19 direct evidence is required, akin to "specific evidence" in U.S. environmental litigation²⁹. The most
20 complete set of information for understanding past changes in climate and its impacts, commonly
21 referred to as "detection and attribution", combines observational and mechanistic evidence, by
22 confronting predictions of recent changes based on our mechanistic understanding with observations
23 of long-term variations³⁰. These analyses address two questions: the first, *detection*, examines
24 whether the natural or human system has indeed been affected by anthropogenic climate change,
25 versus changes that may be related to natural climate variability or non-climatic factors. The second,
26 *attribution*, estimates the magnitude of the effect of anthropogenic climate change as compared to
27 the effect of other factors. These other factors (also termed 'confounders') might be considered
28 external drivers of the observed change (e.g. deforestation driving land-cover changes).

29 Impacts of multi-decadal trends in climate have now been detected in many different aspects of
30 natural and human systems across the continents and oceans of the planet⁶. Analysis of the relevant
31 climate trends suggests that anthropogenic emissions have played a major role in at least two thirds
32 of the impacts induced by warming, but few of the impacts resulting from precipitation trends can
33 yet be confidently linked to anthropogenic emissions⁷. Overall, research on detection and attribution

1 of climate change impacts is still emerging and there remain few studies available that demonstrate
2 a causal link between anthropogenic emissions, climate trends and impacts.

3 **END TEXT BOX: Evidence that climate change has impacted natural and human systems**

4

5

1 **Liability and compensation**

2

3 Compensation of those who suffer harm by those responsible for the harm, and more specifically,
4 responsible for the negative impacts of climate change, represents a legitimate claim from the
5 perspective of normative justice research^{23,31–33}. In their most common understanding, principles
6 such as the PPP or BPP provide the justice framework to identify those responsible for climate
7 change impacts and establish a basis for liability and compensation (see Textbox 1). However, issues
8 of compensation have not yet been sufficiently clarified and remain contested in international
9 climate policy. Driven by the pressure exerted by countries such as the U.S. and others, the notion
10 that L&D involves or provides a basis for liability and compensation has been explicitly excluded in
11 the decisions taken in Paris 2015¹. L&D has previously been thought to require consideration of
12 causation, as well as the deviations from some (possibly historical) baseline condition³⁴. The Paris
13 Agreement and related discussions have not offered any clarity about what type of evidence would
14 be required for claims of liability and compensation to be legitimate, either from a normative
15 perspective considering different principles of justice (see Textbox 1) or in relation to legal
16 mechanisms under international policy. Liability and compensation represent the strongest and most
17 rigid reference frame to clarify who is responsible to remedy climate change impacts, but also involve
18 major challenges, both in terms of policy and science, as we will outline below. Liability and
19 compensation involve clarification of impacts due to climate variability versus anthropogenic climate
20 change, since no one can be morally blamed or held legally liable for negative impacts wholly
21 resulting from natural climate variability^{21,22,27}. Accordingly, and as further detailed below, we
22 suggest that here the strongest scientific evidence in line with specific causation is required, i.e.
23 detection and attribution (see Textbox 2).

24 Figure 1 sketches a detection and attribution framework as it has been developed in recent
25 research^{30,35} and assessments⁶. It reflects the relation of climatic and non-climatic drivers and
26 detected climate change impacts in both natural and human systems at a global scale. As a general
27 guideline, changes in many physical, terrestrial and marine ecosystems are strongly governed by
28 climatic drivers such as regional changes in average or extreme air temperature, precipitation, or
29 ocean water temperature. Due to the high likelihood of a major anthropogenic role in observed
30 trends in these regional climate drivers, there is accordingly potential for high confidence in
31 detection and attribution of related impacts of anthropogenic climate change⁷.

32 The negative impacts of climate change potentially relevant for liability and compensation usually
33 concern human systems, and for these climatic drivers are typically less important than for natural
34 systems: any anthropogenic climate effect can be outweighed by the magnitude of socio-economic
35 changes, for instance considered in terms of exposure and vulnerability (e.g. expansion of exposed

1 assets or people, or increasing climate resilient infrastructure). As a consequence, as documented in
2 the IPCC AR5 and subsequent studies^{6,7}, there is currently only low confidence in the attribution of a
3 major climate change role in impacts on human systems, except for polar and high mountain regions
4 where livelihood conditions are strongly tied to climatic and cryospheric systems (Fig. 1).
5 In order to establish confidence in the detection of impacts, long-term, reliable, high-quality
6 observations, as well as better process understanding, are crucial for both natural and human
7 systems. Assuming that some substantial level of confidence will be required for issues of liability and
8 compensation, we need to recognize that a very high bar is set by requiring high-quality observations
9 over periods of several decades. Precisely these requirements are likely one of the reasons why
10 studies of detection and attribution of impacts to anthropogenic climate change are still rare.
11
12 In the context of liability and compensation a separate pathway to climate policy is being developed
13 in climate litigation under existing laws. In some countries such as the U.S. climate litigation has been
14 used to advance climate policy but so far only a small fraction of lawsuits have been concerned with
15 questions of rights and liabilities as related to damage or tort due to climate change impacts^{36,37}. In
16 the U.S. where by far the most such lawsuits are documented worldwide, several cases on imposing
17 monetary penalties or injunctive relief on greenhouse gas emitters have been brought to court but
18 so far, all of them have ultimately failed³⁸. One of the most prominent lawsuits is known as *California*
19 *v. General Motors* where the State of California claimed monetary compensation from six
20 automakers for damage due to climate change under the tort liability theory of public nuisance.
21 Damages specified for California included reduced snow pack, increased coastal erosion due to rising
22 sea levels, and increased frequency and duration of extreme heat events. As with several other
23 lawsuits, the case was dismissed on the grounds that non-justiciable political questions were raised.
24 Further legal avenues that have been taken and researched with respect to the negative impacts of
25 climate change include human rights in both domestic and international law^{34,39,40}.
26 Generally, currently available experiences cannot sufficiently clarify what type of evidence would be
27 needed in court to defend a legal case on climate change liability. However, there is useful precedent
28 from litigation over harm caused by exposure to toxic substance where typically specific causation is
29 required⁴¹. In our context, hence, this translates into detection and attribution of impacts of
30 anthropogenic climate change.
31 Overall, experience so far indicates that the hurdles are considerable, and they may range from
32 aspects of justiciability, to the proof required for causation, to the applicability of the no-harm rule
33 established in international law or of the application of extraterritoriality in human rights law^{29,39,42,43}.
34 Based on these challenges and on the analysis of precedents from cases with harm due to exposure
35 to toxic substances, some scholars favor ex-ante compensation as compared to ex-post

1 compensation and refer to experiences with monetary disaster funds used to compensate affected
2 victims⁴¹. It is interesting to note that in one of the very few lawsuits on climate change liability that
3 have been accepted by a court ex-ante compensation is claimed. In this currently ongoing legal case
4 at a German court, a citizen of the city of Huaraz in Peru is suing RWE, a large German energy
5 producer, for their cumulative emissions causing an increased local risk of floods from a glacier lake
6 in the Andes that formed as glaciers receded. Specific causation is likely required for this case but
7 additional difficulty arises from proving the relation of harm of an individual to emissions. From an
8 attribution point of view governments are in a better position to claim compensation than individuals
9 because damages due to climate change can be aggregated over time and space over their territory
10 and/or economic interests⁴⁴.

11 In conclusion, at the current state of legal practice, political discussions and available scientific
12 evidence, significant progress in terms of liability and compensation seems rather unlikely in the near
13 future. Politically, creating a monetary fund in line with considerations of ex-ante compensation may
14 yet be the most feasible mechanism. In the following, we present two alternative approaches to
15 achieve justice in relation to climate change impacts.

16
17

18 **Recognition of responsibilities and reconciliation**

19

20 As a first alternative we refer to the notion that legitimate claims of justice may extend beyond
21 questions of liability and compensation, involving instead restorative justice, and more specifically
22 recognition and acknowledgement of moral responsibilities for climate change impacts¹⁴. Following
23 from that, we argue that recognition of responsibilities would be a first important step in any process
24 of reconciliation.

25 Reconciliation is often discussed in the context of normative restorative (or transitional) justice
26 research, which typically relates to the aftermath of violence and repression^{45,46}. In this context it is
27 argued that recognition of wrongs is important in order to attain and maintain social stability⁴⁷. In the
28 case of the negative effects of climate change, recognition could play a similar role. However, since
29 the most negative effects of climate change will occur at least several decades from now, ex-ante
30 recognition of responsibilities of climate change impacts would be required to support maintaining
31 social stability. Recognition of responsibilities neither is the final step nor does it exclude the
32 possibility of compensation, but we suggest it can represent a fundamental element in the process,
33 especially where recovery has limitations. This is particularly the case when impacts of climate
34 change are irreversible, such as for submersion of low-lying islands, permafrost thawing in the Arctic,
35 or loss of glaciers in mountain regions⁴⁸⁻⁵¹.

1 On the level of scientific evidence, recognition of responsibilities as a first step in a reconciliation
2 process implies clarification of those who caused, or contributed to, negative impacts of
3 anthropogenic climate change, and of those who suffer the damage and losses. If the goal is a
4 practical first step in a reconciliation process between those generally contributing to and those
5 generally being impacted by climate change, rather than experiencing a specific impact, then we
6 argue that basic understanding of causation (i.e. general causation) could provide sufficient evidence.
7 Understanding of general causation (see Textbox 2) can rely on multiple lines of evidence collected
8 from observations, modeling or physical understanding, but not all are necessarily required and nor
9 do they all have to concern the exact impact and location in question²⁸. According to physical
10 understanding, for instance, warming implies glacier shrinkage and thus changes in the contribution
11 of ice melt to river runoff^{52,53} or formation and growth of glacier lakes with possible lake outburst
12 floods and associated risks^{54,55}. As another example, given the sensitivity of crops such as grapes or
13 coffee to changes in temperature, precipitation, and soil moisture⁵⁶⁻⁵⁸ we can expect that yield,
14 quality, phenology, pest and disease, planting site suitability and possibly supply chains may be
15 affected⁵⁹⁻⁶². However, our understanding will be limited with respect to the exact magnitude of
16 these impacts, especially along cascades of impacts from crop production to food supply. Further
17 challenges arise from ongoing adaptation in human and managed systems, in particular for
18 agricultural systems as demonstrated in recent studies^{63,64}.

19 Thus, while we suggest that understanding of general causation could serve the reconciliation
20 processes, the value and limitations of this sort of evidence may vary among different types of
21 impacts and is not likely to be sufficient to attain justice in the full sense. In climate policy, as the
22 Paris negotiations have shown, many countries do in fact recognize some moral responsibility for
23 impacts of climate change, but are reluctant to define any legal implications thereof in more detail.
24 Against this background, we believe that explicit recognition of moral responsibilities for climate
25 change impacts plays a significant role in fostering cooperation among the Parties to the UNFCCC.

26
27

28 **The ability to assist principle and risk management**

29

30 Discourses on global justice provide the grounds for a second alternative beyond liabilities and
31 compensation. A number of scholars offer arguments to distinguish between responsibilities to assist
32 and claims for compensation from those liable for harm⁶⁵⁻⁶⁸. Ability to assist (AAP) is in line with the
33 APP (see Textbox 1) and assumes an assignment of responsibilities proportional to economic,
34 technological and logistic capacities. With regard to climate change impacts specifically, we argue
35 that prioritizing the ability to assist is supported in the following contexts^{15,67,69}: when a projected

1 climate impact is severe and immediate help is needed; when there is missing clarity on whether the
2 party causing a negative impact did something morally wrong; or when the party responsible for the
3 impact is not able to provide full recovery. It is important to note that prioritizing AAP does not mean
4 that PPP and BPP should be dismissed altogether. Rather we think that AAP is more plausible and
5 feasible in the aforementioned contexts than the other justice principles.

6 In the context of climate change impacts, we suggest that AAP includes an ex-ante component to
7 facilitate prevention of and preparedness for L&D. Many different mechanisms exist to meet
8 responsibilities to assist in the aforementioned sense and context, including reconstruction,
9 programs to strengthen preparedness and institutions responsible for risk management, or
10 technology transfer. Most of these mechanisms can be accommodated under the perspective of
11 integrative risk management⁷⁰.

12 Appropriate identification and understanding of risks, and how risks change over time, is an
13 important prerequisite for risk management. In the IPCC AR5 risk is defined as a function of (climate)
14 hazard, exposure of assets and people, and their vulnerability⁷¹. For the climate hazard component of
15 risks, extreme weather events are a primary concern. A large number of studies have identified
16 observed trends in extreme weather, both globally⁷²⁻⁷⁴ and regionally^{75,76}, and have examined their
17 relation to anthropogenic climate change^{77,78}. Particularly challenging and debated is the attribution
18 of single extreme weather events to anthropogenic climate change^{8,77,79-81}. On the other hand,
19 disaster risk studies focusing on L&D due to extreme weather events generally have concluded that
20 the observed strong increase in monetary losses is primarily due to changes in exposure and
21 wealth⁸²⁻⁸⁴, with a dynamic contribution from vulnerability⁸⁵. For instance, for detected changes in
22 heat related human mortality, changes in exposure, health care or physical infrastructure and
23 adaptation are important drivers and often outweigh the effects of climate change⁸⁶⁻⁸⁹.

24 Risk management yet should not only be concerned with impacts of extreme weather events but also
25 with negative effects of gradual climate change on natural, human and managed systems. Based on
26 the assessment of the IPCC AR5, concern for unique and threatened systems has mounted for Arctic,
27 marine and mountain systems, including Arctic marine ecosystems, glaciers and permafrost, and
28 Arctic indigenous livelihoods⁶. Impacts of gradual climate change are often exacerbated by extreme
29 events, thus enhancing risks and complicating attribution⁹⁰. Furthermore, impacts of climate change
30 usually occur within a context of multiple non-climatic drivers of risk. Effective identification of
31 specific activities to reduce risk may require estimation of the relative balance of the contributions of
32 climatic and non-climatic drivers. However, understanding of general causation, in the form for
33 instance of process-based understanding, may not provide sufficient precision to distinguish the
34 relative importance of the various drivers; in that case, more refined information generated through

1 detection and attribution analysis may be required. This, however, implies the availability of long-
2 term data which is limited in many developing countries.

3 In the context of international climate policy, assistance provided to strengthen risk management is
4 largely uncontested and is supported in many documents⁹¹. Hence, political feasibility, the justice
5 basis and potential progress in scientific evidence make risk management a promising vehicle for
6 addressing climate change impacts.

7
8

9 **Injustices from the imbalance of climate and impact monitoring**

10

11 Depending on the approaches outlined in the previous sections, observational monitoring of climate
12 and impacts can be of fundamental importance in order to provide the necessary causal evidence,
13 and to satisfy justice claims posed by many Parties. In this light, it is informative to consider the
14 distribution of long-term climate observations, as well as that of the detected and attributed impacts
15 as assessed by the IPCC AR5⁶. As Figure 2 shows, the distribution of both long-term recording
16 weather stations and observed impacts of climate change is unequal across the globe. Observations
17 of non-climatic factors, which are important to assess the magnitude of impacts of climatic versus
18 non-climatic factors, are not shown in Figure 2 but are likely to show a similar imbalanced pattern.
19 The analysis of attributed impacts based on IPCC AR5⁶ reveals that more than 60% of the attributed
20 impacts considered come from the 43 Annex I countries while the 154 Non-Annex I countries feature
21 less than 40% of the observations (Fig. 3). This imbalance is even larger if the least developed
22 countries (LDC) and the countries of the Small Island Developing States (SIDS) (80 countries together)
23 are considered, for which less than 20% of globally detected and attributed impacts are reported.
24 While different identified impacts in the IPCC AR5 reflect different degrees of aggregation (e.g.
25 aggregating phenological shifts across species on a continent into a single impact unit), this
26 aggregation tends to be amplified in Annex I countries, and thus understates the geographical
27 contrast in terms of available evidence between developed and developing countries. Additionally,
28 Non-Annex I, LDC and SIDS countries generally have a higher proportion of impacts with very low and
29 low confidence in attribution to climate change whereas Annex I countries have more impacts with
30 high confidence in attribution. The assignment of confidence thereby typically relates, among other
31 things, to the quality and duration of available observational series⁹²⁻⁹⁴; this also holds for the
32 attribution of observed climate trends to greenhouse gas emissions⁹⁵. This imbalance thus reflects an
33 unequal distribution of monitoring for physical as well as for biological, managed and human
34 systems.

1 The results of this analysis imply new kinds of injustices involved in the approaches discussed above.
2 Whichever approach is chosen, the unequal distribution of observed and attributed impacts, and of
3 the confidence in assessments, implies an unjustified disadvantage for those most in need of
4 assistance. The more impacts are detected and their attribution to climate change is clarified the
5 better it is understood (i) what responsibilities would have to be recognized, (ii) what the appropriate
6 measures of risk management might be, and (iii) what would represent appropriate methods of
7 compensation for negative climate change effects on natural and human systems. In this respect
8 many Non-Annex I countries seem to be disadvantaged as compared to Annex I countries. This
9 disadvantage represents a form of procedural injustice in negotiating and deciding when, where and
10 what measures are taken. Hence, the point here is not the potentially unfair outcomes of
11 negotiations but the fairness of the process of negotiating itself. The imbalance of the distribution of
12 detected and attributed impacts was in fact an issue during the final IPCC AR5 government approval
13 process⁹⁶, indicating concern that voices from some actors and parties might be downplayed or
14 ignored due to lack of hard evidence for perceived impacts.

15 Against this background, we argue in line with a version of the APP (AAP) that countries with
16 appropriate economic, technological and logistic capacities should enhance the support for countries
17 with limited available resources or capacity along two lines of actions and policy: i) to substantially
18 improve monitoring of a broad range of climate change impacts on natural and human systems; ii) to
19 strengthen local human resources and capacities in countries facing important climate change
20 impacts to a level that ensures an adequate quality and extent of monitoring and scientific analysis.
21 This proposal is perfectly in line with the UNFCCC and decisions taken at recent negotiations
22 including COP21^{1,91}, and actions and programs underway in several Non-Annex I countries, hence
23 strongly increasing its political feasibility. The lack of monitoring and observations has been long
24 recognized but the related procedural injustice has not received much discussion. Our analysis
25 intends to provide the justice basis and context to justify strengthening these efforts.

26 However, even if such efforts are substantially developed in the near future, a major challenge
27 remains in how to cope with non-existing or low-quality observational records of the past decades in
28 countries where no corresponding monitoring had been in place. Reconstruction of past climate
29 change impacts and events exploiting historical satellite data, on-site field mapping, searching
30 historical archives, etc. may be able to recover missing data to some extent. Different and diverse
31 forms of knowledge existing in various regions and localities can be of additional value but need to
32 be evaluated in their respective context to avoid simplistic comparisons of, for instance, scientific
33 versus local knowledge⁹⁷. Substantial observational limitations, however, will likely remain and the
34 implications for the aforementioned approaches toward justice need to be seriously considered.

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Developing evidence for just policy

In this Perspective we discussed different approaches towards justice regarding negative climate change impacts. We argued that depending on the approach chosen, different kinds of evidence concerning detection and attribution of climate change impacts are needed. Establishing liabilities in a legal or political context to seek compensation sets the highest bar, and we suggest that it requires detection and attribution in line with specific causation. However, in general the level of scientific evidence currently available rarely supports high confidence in linking impacts to emissions, except for some natural and human systems related to the mountain and Arctic cryosphere and the health of warm water corals. Hence, claims for compensation based on liabilities will likely continue to encounter scientific hurdles, in addition to various political and legal hurdles.

Understanding the role of climate change in trends in impacted natural and human systems at a level of evidence currently available can still effectively inform other justice principles which in our view are politically much more feasible, namely recognition of responsibilities and ability to assist.

Attribution research can clarify responsibilities and thus facilitate their recognition; and it can enhance the understanding of drivers of risks as a basis for improved risk management. More rigorous implementation of risk management is actually critical to prevent and reduce future L&D. Whether recognition of responsibilities and APP / AAP are politically sufficient to facilitate ex-ante compensation, for instance with the creation of a monetary fund for current or future victims of climate change impacts, needs yet to be seen.

Finally, the imbalance of observed and attributed climate change impacts leaves those countries most in need of assistance (i.e. SIDS and LDC countries) with relatively poor evidence in support of appropriate risk management approaches or any claim for liability and related compensation in international climate policy or at courts. We have argued that evidence in line with general causation may be sufficient for recognition of responsibilities, and hence, this may well speak in favor of this justice approach, considering the aforementioned limitations in observations and attribution.

Recognition of responsibilities cannot represent the final step to attain justice, however, and we therefore suggest that two issues remain crucial: i) procedural injustice resulting from an imbalance of detected and attributed impacts should be considered as a fundamental issue in negotiations and decision making in international climate policy; and ii) monitoring of climate change impacts in natural and human systems, and local capacities in developing countries need to be substantially strengthened. Efforts taken now will be of critical value for the future when climate change impacts are expected to be more severe than experienced so far.

1 **Author contributions**

2 C.H. and I.W.-H. designed the basic concept and arguments of the paper, supported and advised by
3 D.S. and W.C. C.H. and D.S. analysed the impacts data and prepared the figures. All authors
4 contributed to the writing of the text.

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1 **Figure captions**

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3 Figure 1: A schematic detection and attribution framework for impacts on natural and human
4 systems. The left part (in light grey) indicates the different impacts and the respective level of
5 confidence in detection and attribution of a climate change influence as assessed in the IPCC
6 Working Group II 5th Assessment Report (AR5)⁶. Boxes with a thick (thin) outline indicate a major
7 (minor) role of climate change as assessed in [6] (note that this IPCC assessment⁶ did not distinguish
8 between natural and anthropogenic climate change in relation with impacts). The right part (in
9 darker grey) of the figure identifies important climatic and non-climatic drivers of detected impacts
10 at global scales. The attribution statements for the climatic drivers are from IPCC WGI AR5⁷⁷ and
11 refer to anthropogenic climate change. Trends in the graphs are all for global drivers and represent
12 from top to bottom the following: TAS: mean annual land air temperature⁹⁸; TXx (TNn): hottest
13 (coldest) daily maximum (minimum) temperature of the year⁹⁹; TOS sea surface temperature¹⁰⁰ (all
14 units are degrees Celsius and anomalies from the 1981-2010 global average); SIC: northern
15 hemisphere sea ice coverage¹⁰⁰ (in million km²); Popul: total world population (in billions); GDP:
16 global gross domestic product (in 2005 USD); Life exp. and health expend.: total life expectancy at
17 birth and public health expenditure (% of GDP) (Data sources: The World Bank ,World Bank Open
18 Data, <http://data.worldbank.org/>).

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21 Figure 2: World map showing the distribution of Global Historical Climatology Network (GHCN)
22 stations and the number of detected impacts as assessed in the IPCC WGII AR5⁶. It distinguishes
23 between Annex I countries (in red colors), Non-Annex I countries (in green colors), and regions not
24 party to the UNFCCC (grey colors). The GHCN is the largest publicly available collection of global
25 surface air temperature station data. The shaded regions correspond to the regional extent of
26 relevant climatic changes for various impacts, rather than of the impacts themselves, as determined
27 in [7]; a few impacts are not included due to insufficient information for defining a relevant region.

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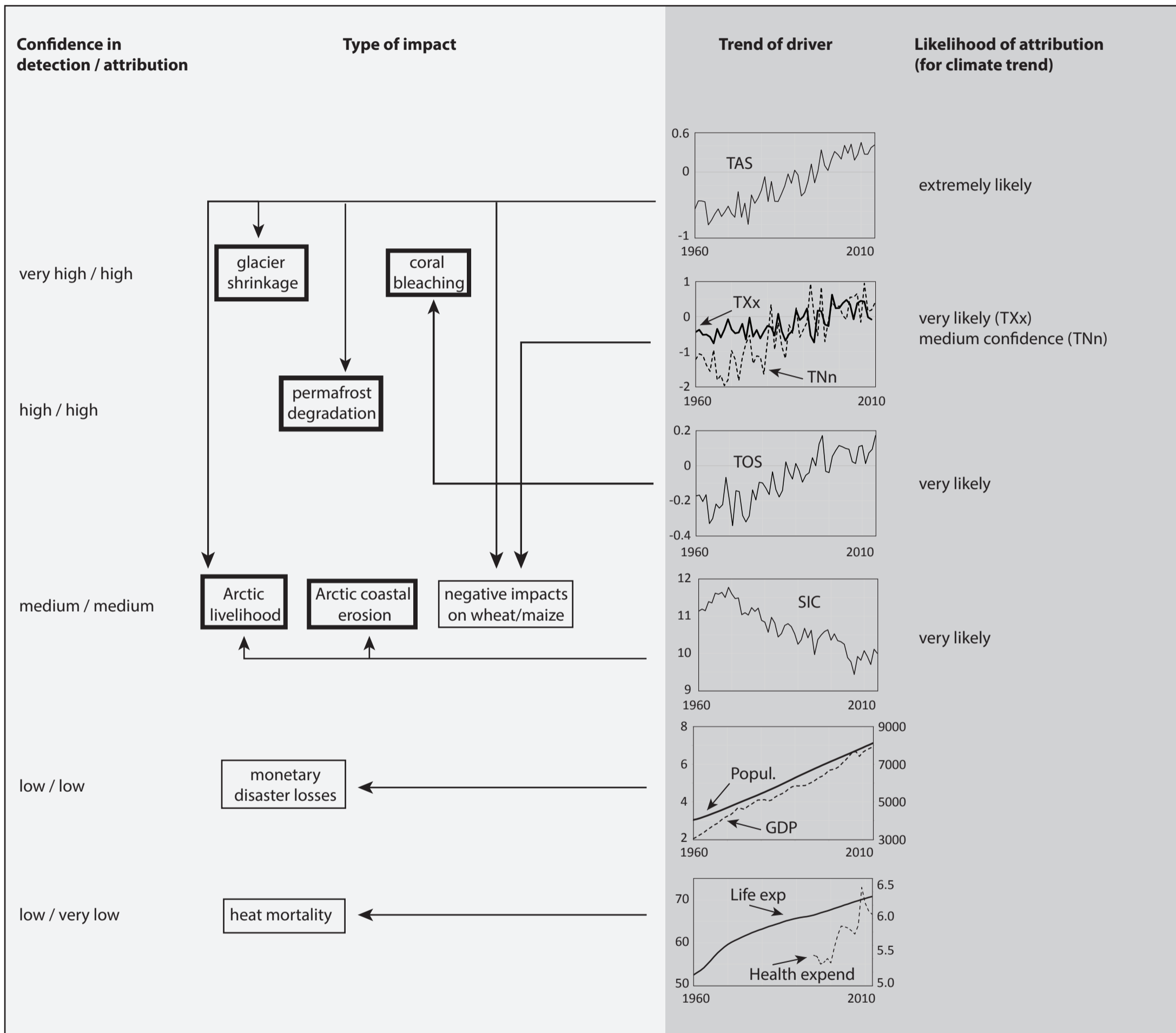
30 Figure 3: Distribution of attributed climate change impacts in physical, biological and human systems
31 as assessed in the IPCC WGII AR5⁶, showing an imbalance between Annex I, Non-Annex I, and Least
32 Developed Countries (LDC) and Small Island Development States (SIDS). Three confidence levels of
33 attribution are distinguished. Note that LDC and SIDS are also part of Non-Annex I countries.

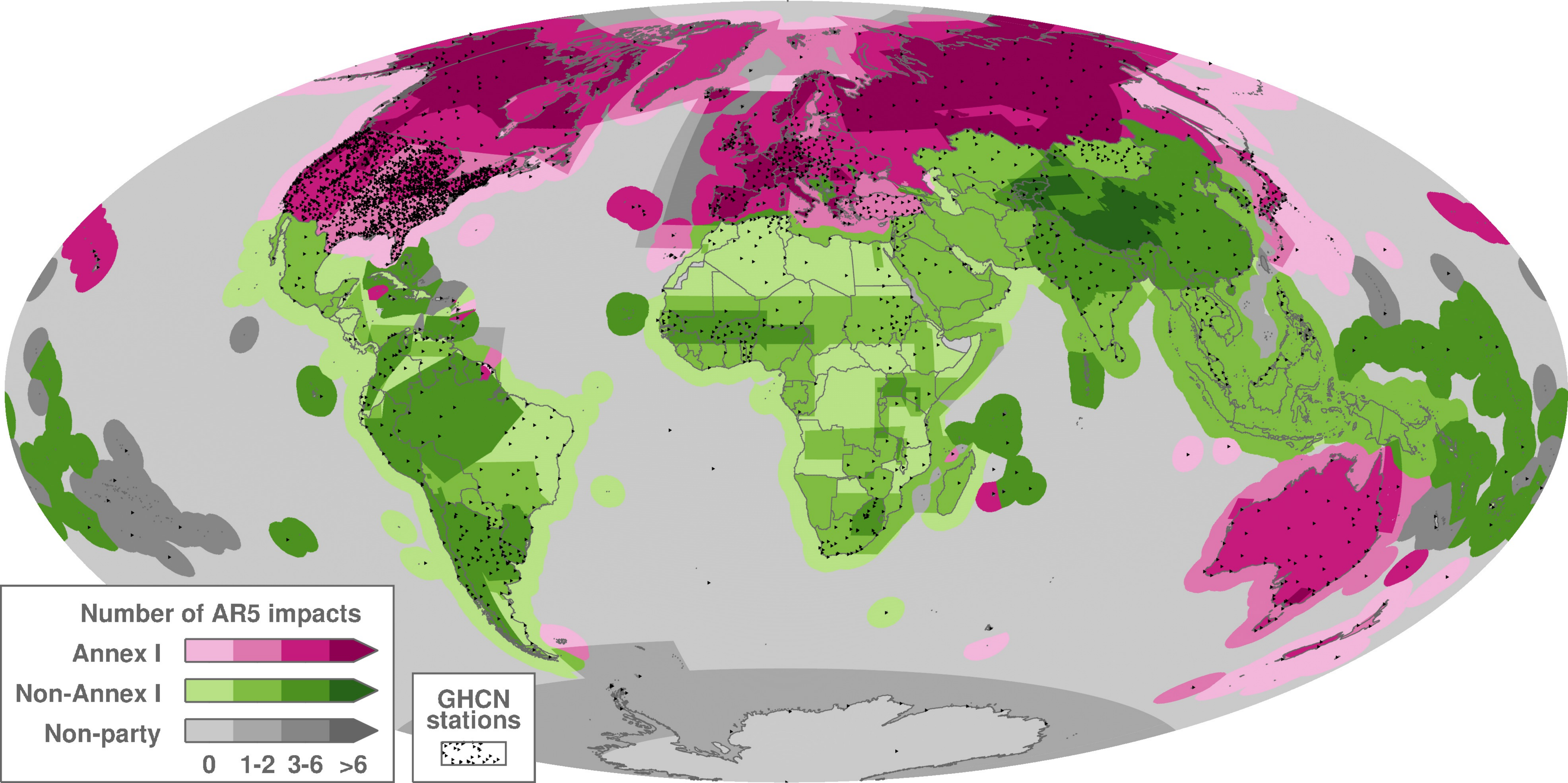
34

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Impacts

Drivers (climatic and non-climatic)





Number of AR5 impacts

Annex I



Non-Annex I



Non-party



0 1-2 3-6 >6

**GHCN
stations**

