COMMENTARY:

Global distribution of observed climate change impacts

Gerrit Hansen and Wolfgang Cramer

The scarcity of robust scientific evidence supporting the attribution of observed impacts to climate change in some vulnerable regions does not indicate that no such impacts have occurred.

Impacts of recent climate change have now been documented in all major regions of the world and in many natural and human systems. This is one key conclusion of the IPCC's Fifth Assessment Report (AR5), which was recently completed with the approval of its Synthesis Report in Copenhagen[1]. Over the last two decades, coverage of such observed impacts has been expanded from an initial focus on land ecosystems towards the marine realm, and to important features of human and managed systems, such as food production and human health. A central graphic from the IPCC Working Group II (WGII) report, a world map with impact icons symbolizing localized or regional-scale attributed impacts[3], was received with enthusiasm by the press and social media (Fig. 1). The array of impacts of recent climate change that have been observed globally is impressive. However, it is important to recognize that this map represents the state of knowledge on impacts that have been attributed to climate change, compiled through a rigorous analysis of the scientific literature. It is not a comprehensive summary of all adverse effects that could plausibly be linked to climate change.

Documented impacts

The evidence base for climate change impacts, from monitoring systems and environmental research, has been growing during the past two decades[2]. However, there still are more and higher-quality observations for such impacts in mid- to high latitude regions in the Northern Hemisphere than elsewhere. Some readers wrongly perceived the map (Fig. 1) as indicating that the northern regions were more strongly affected than southern regions. Also, the comparatively sparse documentation of climate change impacts in some of the most vulnerable regions of the globe could create the impression that the global burden of climate change impacts was not adequately portrayed. Hence a risk of misinterpretation arising from the uneven distribution and poorly defined spatial resolution of the icons on the map was identified during the finalization of the Synthesis Report.

To address these concerns, the philosophy for the map of the WGII findings was refined for the IPCC Synthesis Report. The revised map was produced by removing the spatial information about geographic location at the sub-continental scale. Instead, comprehensive lists of impacts identified for each world region were presented. In addition, a quantitative indication of the uneven regional distribution of climate change literature was provided (Fig. 2). This change aligned the data in the figure with the data in the underlying table, increased emphasis on the global distribution of observed impacts, and highlighted the issue of uneven literature coverage. While both figures contain the same data, the difficulty of their appropriate representation in a policy context highlights the need for better communication of the scientific basis for impact assessment, including the need to explain the full potentials and limits of detection and attribution analysis.

Standards

Scientific attribution of observed impacts to climate change requires time series of observations of sufficient length and quality for the affected system, and for both climatic factors and other important drivers of change, such as land use or economic development. Mere correlation between the changing climate and its presumed impacts is insufficient for attribution. Instead, understanding of all of the likely causes of change and their interaction is needed[4,5]. For a specific impact to be included in an IPCC assessment, a diligent examination of that specific case in the peer-reviewed literature must be available. As a result of these requirements, well-studied regions and systems with few confounding factors combined with a high sensitivity to climate feature more prominently in the list of attributed impacts[2,6]. The focus of attribution assessments is different from that of vulnerability or impact studies that assess how the impacts of future climate change will unfold, based on the sensitivity of a system to climatic factors, expected future climate change, and socio-economic factors delineating vulnerability. For such studies, the sensitivity of a system to climate change is often inferred from past responses to climate variability. However, impacts of natural climate variability do not constitute impacts of climate change.

Vulnerability

Responses to climate variability, for example harvest failure due to drought, are often more easily detected than responses to gradual changes in climate. However, a long-term change in climate variability — which would constitute climate change — is difficult to detect. Observed trends in frequency or intensity of climate extremes are still less conclusive, but trends have been documented for some types of extremes, in particular heat waves and heavy precipitation, in many regions[7,8]. Also, areas influenced by long-term natural climate modes such as the El Niño/ Southern Oscillation face an additional challenge in detecting a persistent trend in climate against the baseline of periodic change, and therefore in attributing observed effects to climate change.

In turn, this means that some of the most pronounced adverse effects related to climate, that is, those caused by extreme weather, can presently not be attributed to climate change directly even though they might be consistent with what one would expect to happen under a changing climate[9]. Progress is being made in assessing the role of anthropogenic forcing in occurrence

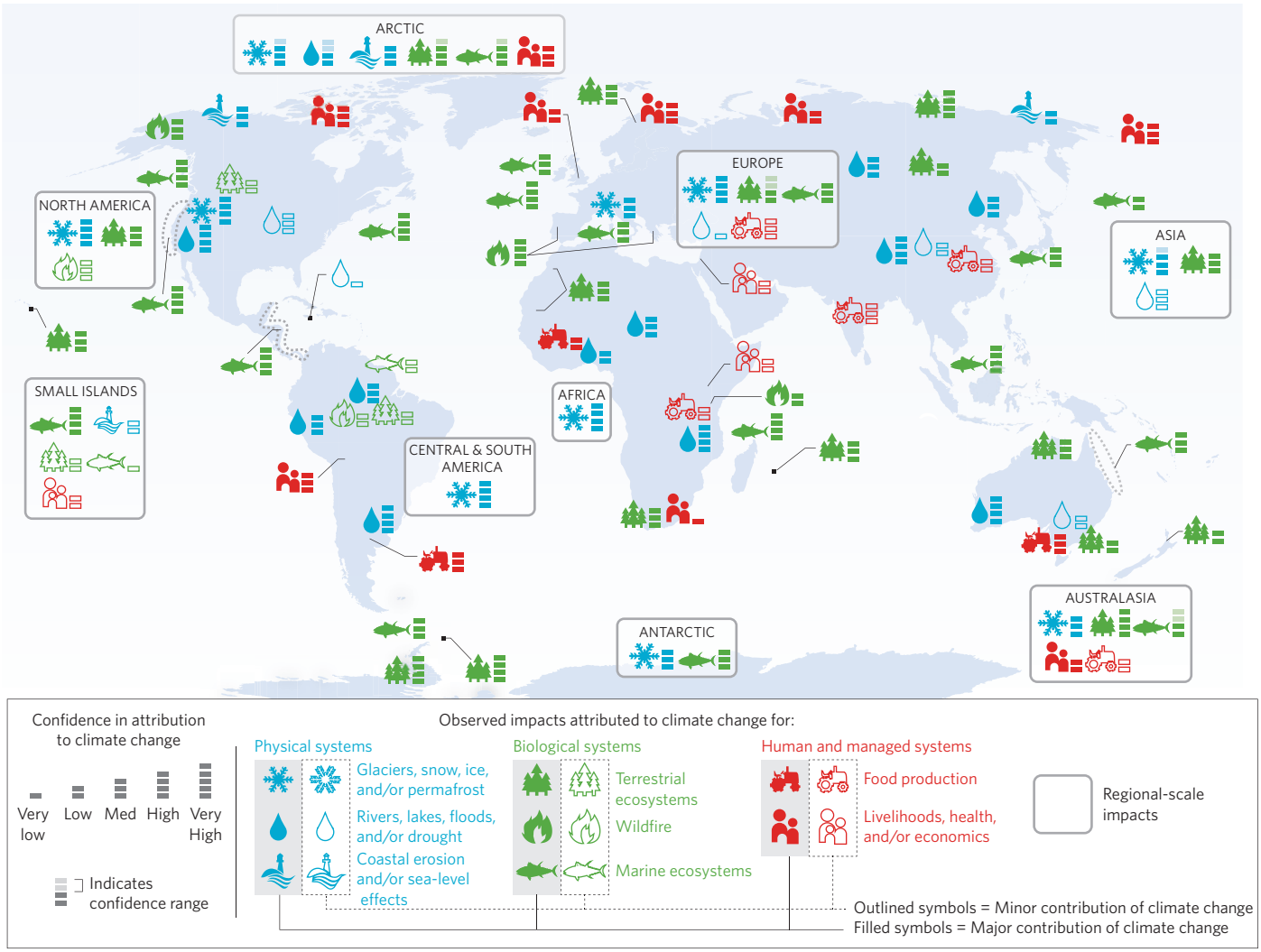

Figure 1 | Observed impacts of climate change. Global patterns of impacts in recent decades attributed to climate change, based on studies since the Fourth Assessment Report. Impacts are shown at a range of geographic scales. Symbols indicate categories of attributed impacts, the relative contribution of climate change (major or minor) to the observed impact, and confidence in attribution. Figure reproduced with permission from ref. 3, Cambridge Univ. Press.

and intensity of extreme weather[10] and individual events[11,12], but information on the latter is only available for a small set of events.

Human systems

A large fraction of the most robust evidence for the impacts of recent climate change is related to the cryosphere, or to ecosystems that are sensitive to temperature. In contrast, evidence for human systems is relatively sparse. Much of the reason for this is that humans are remarkably adaptable and often make adjustments in response to risks or impacts. In addition, humans operate in a complex world, with many factors changing simultaneously. Human systems can be impacted by climate change either directly, for example, increased heat-related mortality due to more frequent heat waves, or indirectly, by cascading effects of changes in the natural environment triggered by climate change. As the impacts of climate change become more pervasive in the natural environment, impacts on human systems that depend on them would be expected to unfold. Such impacts have been reported by many indigenous communities in northern high latitudes[13–15]. However, given the multitude and strength of other drivers of change, combined with the difficulty to assess services delivered by ecosystems, such cascading impacts on humans due to regional changes in climate are not yet well documented in other environments.

Another reason for the weaker documentation of some impacts on human systems is the difference in disciplinary approaches used to establish causality between quantitative and qualitative sciences[5]. Detection and attribution standards have been developed by natural scientists, and usually rely on statistical methods and numerical models[4]. Some areas of explicit concern in the context of climate change, such as impacts on small-scale farming, informal economies and settlements, livelihoods and poverty, are predominantly discussed in literature that is qualitative in nature, and does not easily lend itself to statistical approaches. Indeed, a large part of that that literature is focused more on current vulnerabilities and future risks in a context of multiple stressors rather than quantitative evidence of those impacts that are already manifest.

No evidence of absence

The recent IPCC report has shown that it is possible to integrate different sources of evidence, data of differing quality, and various disciplinary approaches into an

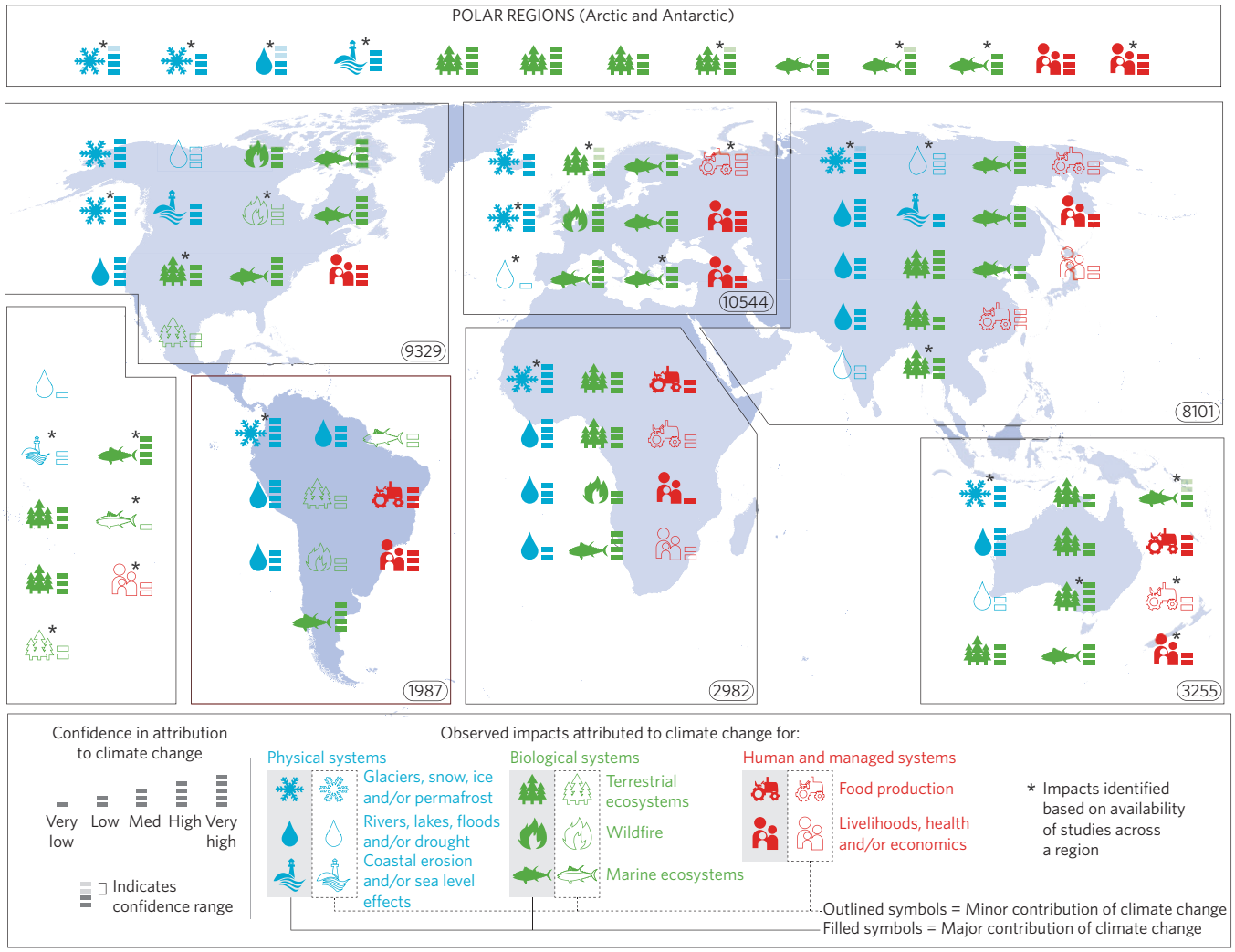

Figure 2 | Revised schematic of the observed impacts of climate change. Symbols indicate categories of attributed impacts, the relative contribution of climate change (major or minor) to the observed impact, and confidence in attribution. The numbers in ovals summarize the number of all climate change-related scientific studies published between 2000 and 2010 for each region, as a proxy for the difference in the regional literature base. Figure reproduced with permission from ref. 1, Cambridge Univ. Press.

overarching assessment of the impacts that are attributable to climate change[2]. The assessment combined numerous published studies based on observational records of observed change, as well as on documented change in one or several climate variable(s). In some cases, despite the expectation that impacts might have occurred, individual elements of the causal chain leading from changes in climate to changes in the respective impact system were not addressed in scientific studies, making attribution impossible. Coastal degradation is a prime example for the difficulties met when assessing observed impacts: tide-gauge records documenting local sea-level rise may not be available or complete for some regions. Even if those records are available, the observed changes in sea level may have causes other than global warming: sediments trapped by large dams, changes in local current systems, and subsidence due to hydrocarbon or groundwater removal all contribute to relative sea-level changes[16,17]. In addition, the impacts of higher sea level depend on flood remediation, changes in coastlines due to infrastructure and urban developments, settlement patterns and other factors determining risk from floods. So while it is likely that, in many coastal settings, recent damages are partially caused by global sea-level rise, the absence of sufficient data often precludes attributing that impact to any particular cause.

Hence, while the presence of an impact icon on the map is always based on detection of a specific change, and its attribution to climate change, the absence of an icon can be due to a wide range of reasons. These include the lack of studies addressing a certain impact, or the failure of the available studies to rigorously attribute an observed change to recent climate change, but none of these can be taken to imply that no such impacts have occurred.

Attribution and risk

The scientifically robust attribution of observed impacts to climate change is important for several reasons — including overall understanding of systems, both natural and human and the development of resilient strategies for adaptation — as it examines important drivers of change and their interaction. But a summary of attributed impacts is not a complete inventory of the current effects of climate change, or a sole indicator of present

and future risk. It is obvious that the manifestation and attribution of a certain climate change effect carries a strong message concerning future risk. However, the fact that an impact has not occurred, or has not been documented, offers no indication for the absence of such a risk.

At the same time, although climate change may act synergistically with other risk factors, and will continue to gain importance as the rate and scale of climate change increases, it must be recognized that the most important driver of current risk for human systems related to environmental degradation is not necessarily (global) climate change, but also other issues such as land-use change, air pollution and poverty.

Unambiguous message

The map originally provided by WGII (Fig. 1) informed about the status of knowledge on observed and attributed effects of climate change with some regional specificity. In one sense, empty spaces and missing icons provide information about the current gaps in that knowledge. However, many factors could contribute to these gaps, including the possible lack of data, a shortage of scientific studies, or the actual absence of any impacts of climate change.

Both representations are valid ways to convey a large amount of complex information in a scientifically consistent way. However, what the scientific community perceives as useful extra information could be confusing or misleading to another group of stakeholders. The revised version of the map (Fig. 2), while losing some of the spatially explicit information, addresses important sources of concern and highlights the main messages of the assessment: The fact that impacts of climate change occur worldwide, and the urgency of addressing climate change. ❐

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COMMENTARY:

Adaptive development

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Adaptive development mitigates climate change risks without negatively influencing the well-being of human subjects and ecosystems by using incentives, institutions, and information-based policy interventions to address different components of climate risks.

With the emergence of adaptation as a key focus for those interested in effective responses to the impacts of climate change, it is increasingly important to better understand the relationship between adaptation and development. Many decision-makers in developing and developed countries distinguish between the two because they view support for adaptation as additional to existing development aid. This distinction is also viewed as important to prevent the diversion of adaptation-related funds towards conventional development objectives and programmes. But for many, a firm division artificially separates policy goals that should be integrated for more efficient outcomes, for example, by mainstreaming climate concerns into overall development goals[1–3].

Intuitively, it is easy to accept that development and adaptation are not equivalent even if a well-articulated and theoretically informed relationship has been difficult to pinpoint: both adaptation and development are fraught and contested concepts. But difficulties in distinguishing adaptation from development hinder empirical research on the subject and are an obstacle to policy innovations. We suggest that adaptation and development in the context of climate change can be separated by a focus on risks and risk management, and that this difference is paramount because climate change risks are redefining what development policies can accomplish. Such a focus can also help in devising more concrete and targeted strategies to reduce adaptation deficits, defined as the gap between the need for adaptation versus current and anticipated future adaptation actions[4].

Over the past century, development approaches have been linked to specific policy orientations: solving poverty through economic growth; addressing inequality through redistribution; and more recently, preventing environmental degradation through sustainable resource use[5]. These development approaches do not focus on risk management as a central policy goal, even if their implementation sometimes