Impacts World 2013, International Conference on Climate Change Effects,
Potsdam, May 27-30

Detection and attribution of climate change impacts – is a universal discipline possible?

Gerrit Hansen, Daíthí Stone, Maximilian Auffhammer

Abstract— In the context of impacts research, detection and attribution exercises evaluate whether aspects of human and natural systems are changing in response to the impetus of climate change. Concepts and methods for detection and attribution have been established in the physical science community, evaluating changes in the climate system due to anthropogenic forcing. In contrast, a conceptual framework for detection and attribution of climate change impacts that is consistent and applicable across disciplines is still lacking.

In an attempt to overcome this methodological deficit, this paper outlines the major challenges involved in and provides workable definitions of detection and attribution in the context of impacts. Reaching beyond the current focus of the literature on hydrology and ecological effects, it sets a focus on challenges that are inherent in the particular dynamics of human and managed systems, including non-stationary baseline behaviour, multiple drivers, and active adaptation.

Index Terms—Detection and Attribution, Human and Managed Systems, Multiple drivers, Confounding Factors, Observed Impacts of Climate Change

———————————————————

1 Introduction

In the context of climate change impacts, detection and attribution (D&A) exercises evaluate whether aspects of human or natural systems are changing in response to the impetus of climate change. Detection and attribution of impacts has evolved within a framework originating from physical climate science, which uses concepts and methods established for detection of a change in climate, and its attribution to anthropogenic forcing (IPCC 2010). Studies explicitly attributing observed impacts to anthropogenic forcing are very rare, and limited to freshwater resources (e.g., Barnett *et al.*, 2008; Hidalgo et al. 2009; Min et al. 2011), and ecosystems (e.g., Parmesan and Yohe 2003; Rosenzweig et al. 2008; Poloczanska et al. 2013). The latter mostly rely on spatial pattern analysis based on a wide range of regional and local impact studies that document responses to observed climate trends (see Rosenzweig et al. 2007).

In order to extend D&A analysis to other impact systems, particularly those directly involving humans, manifold challenges remain at a conceptual level, including terminology, the consistency and transferability of metrics, types of evidence, the treatment of confounding drivers and the interpretation of event attribution. The following discussion will focus on D&A in the context of human and managed systems, and adopt the definitions of detection and attribution proposed in Stone et al. (2013),

- Detection addresses the question of whether a system is changing beyond what might be considered normal behavior in the absence of climate change,
- Attribution addresses the question of whether climate change has contributed substantially to the detected change in a system.

Note that in practice, detection and attribution may not be mutually separable, given that both detection of a change, and the evaluation of cause and effect must be based on explicit examination of all drivers of change in the system.

2 Non-stationary baselines and expected system behavior: Detection

In the context of human and managed systems normal system behavior is mostly non-stationary, and can be measured in the form of changing means (e.g. trends) or changes in variability (e.g. changing variances). In order for an impact to be detected in such changing environments, the outcome of interest has to have departed from expected "normal" behavior in a way consistent with a response to climate change (see figure 1). For many natural systems, the question arises if normal behavior is defined as an idealized pristine state, or includes alterations due to human influence.

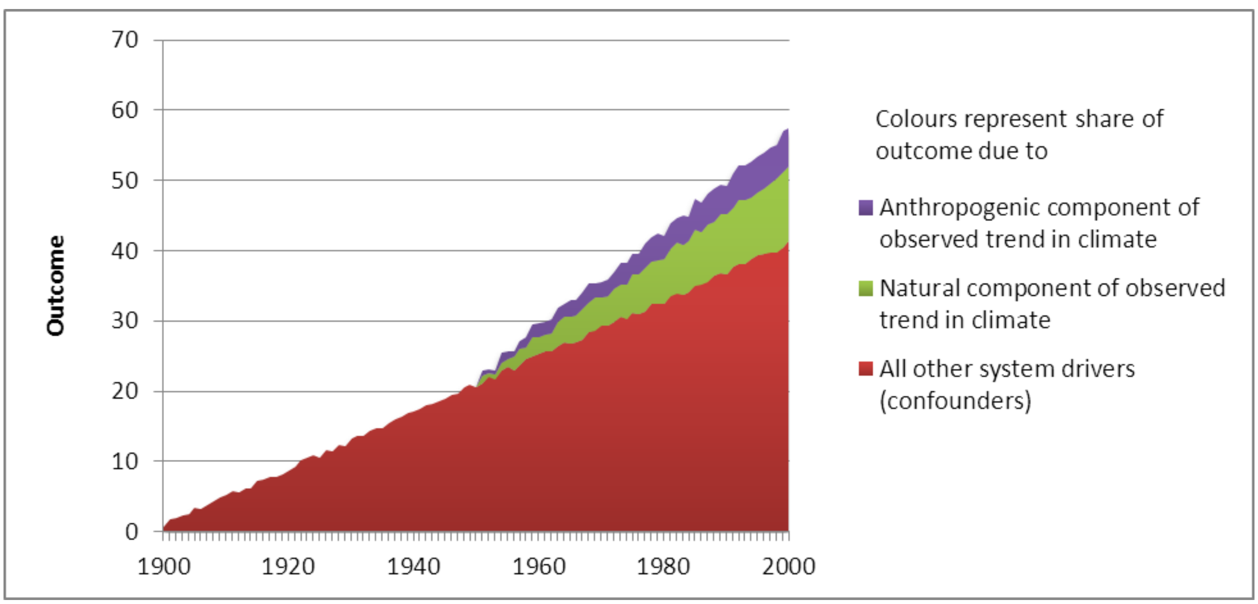

Figure 1 Illustrative example of a time series of a climate sensitive outcome, with red area representing the de-

velopment of that outcome under stationary climatic conditions, and the blue and green areas representing the change in the outcome due to recent climate change. The onset of deviation from normal system behavior can be clearly identified in the absolute outcome.

In order to identify "normal behavior" in the absence of climate change, substantial system process understanding is required, specifically that of the relative and joint roles of climate drivers and other, confounding drivers. No change from baseline in a (constant or trending) variable could still imply a detected change, if process knowledge indicates that (e.g. due to management changes, policy measures, introduction of a predator) there should have been a change (see Fig. 2).

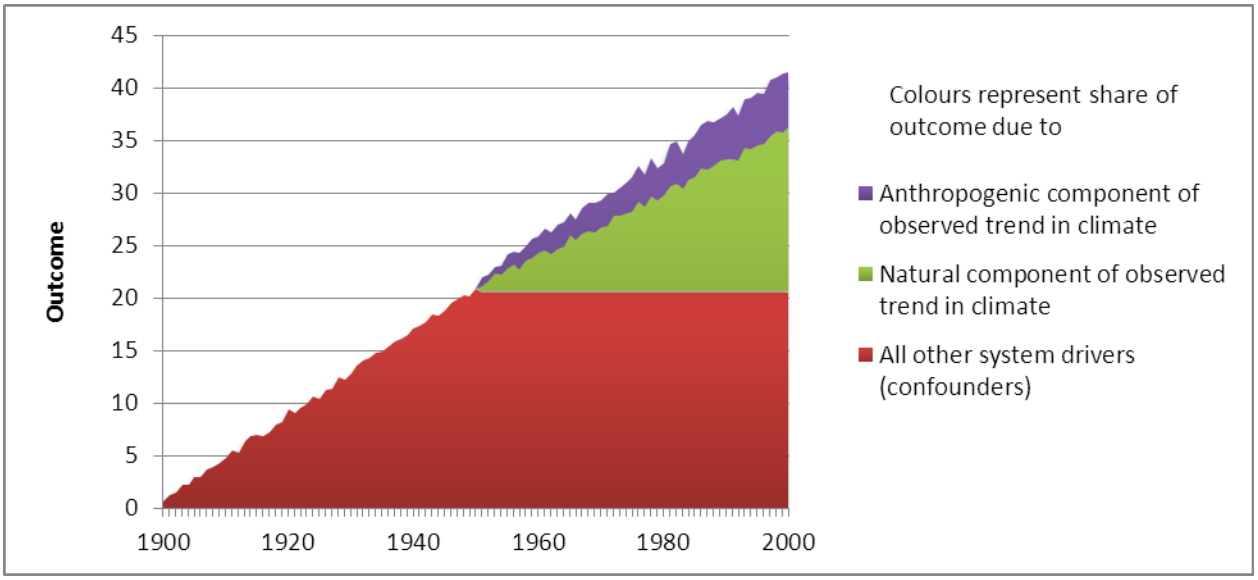

Figure 2 Illustrative example of a time series of a climate sensitive outcome, with red area representing the development of that outcome under stationary climatic conditions, and the blue and green areas representing the change in the outcome due to recent climate change. While the baseline conditions (red area) shows a dramatic change (e.g. due to a policy measure) from a trending to a constant outcome in the middle of the century, the overall outcome does not show any change, thus masking the existing climate change effect.

For example, it has been argued that changes in vulnerability (e.g. due to improved disaster risk management, or better building codes) are not properly represented in studies examining trends in normalized losses due to extreme weather events, although a systematic bias has not been found (Bouwer 2011). This also implies the question whether active adaptation resulting in no change in the observed variable constitutes detection (see section 8).

3 Relative contribution in a multi-driver context: Attribution

Attribution needs to examine all drivers of change that influence the system, and evaluate their relative contribution to the detected change. Attribution implies the testing of a hypothesis: stating attribution to climate change implies that the role of climate change cannot be excluded as the cause of an observed effect. Assessing the magnitude of climate contribution to an impact is a separate, but equally important matter in an attribution exercise.

Following from the above, an attribution statement needs a qualifier describing the relative importance of climate change to an observed impact. This involves either simply an ordinal statement (e.g. climate is the main influence responsible for a change) or a cardinal statement, which of course requires estimation of the exact relative magnitude of the contribution of climate change in relation to other drivers. A key challenge for all attribution exercises consists in accounting for non-additive effects of several interacting drivers.

4 Climate trends or anthropogenic forcing - to what are we attributing?

A fundamental issue for D&A concerns the appropriate end-point of attribution. For understanding current impacts in the context of future climate change, including calibration of estimates of future impacts, one needs to consider attribution to anthropogenic climate forcing. Given the impetus of D&A research originating from the United Nations Framework Convention on Climate Change, this end-point has often been considered the main goal (Zwiers and Hegerl 2008). However, another motivation for D&A research is to improve understanding of vulnerabilities to long-term climatic trends, informing decisions selecting adaptive measures for reducing vulnerability and increasing resilience. The tendency for these trends to continue in the future is certainly of interest, however it is not central to "bottom-up" adaptive planning (Hulme et al. 2011), while understanding interactions and non-additive effects of multiple drivers is a key concern (Parmesan et al. 2013). The implications of this distinction are reflected in conflicting viewpoints about the priorities for attribution research in the context of ecological impacts (see Brander et al. 2011; Hoegh-Guldberg et al. 2011; Parmesan et al. 2011).

5 How can we use existing observed evidence?

The signal of global (anthropogenic) climate change has emerged from the natural variability of the climate system over the past few decades. At the regional scale, evidence of climatic trends is less clear cut, and more difficult to attribute to anthropogenic forcing (Stone et al. 2009; Stott et al. 2010), though progress is being made in linking local temperature changes to climate change, and understanding their perception (e.g., Howe et al. 2012; Ruddell et al. 2012).

The impact of a comparatively weak climate signal is often concealed by the effects of other anthropogenic drivers, such as land use, pollution, or economic development (e.g., Nicholls et al., 2009; Bouwer 2011; Hockey et al. 2011). Also, autonomous or planned adaptation offset a share of the adverse effects, thereby masking impacts of climate change (see section 8).

Key challenges for current assessments therefore include the limited knowledge on processes and mechanisms involved in environmental systems undergoing change from multiple stressors, limited understanding of causality within complex networks of social systems, and how climate drivers and their perception influence those, as well as the limited availability of long-term observations. The need for long-term monitoring has been highlighted frequently (e.g., Rosenzweig et al. 2007; Rosenzweig and Neofotis 2013). Even if the monitoring is stable through time, the nature of the outcome being monitored may have changed, for instance through technological innovations.

Many complex systems lack clarity of the existence or nature of discrete components, or of rules governing behavior, particularly when humans are involved. Consequently, some research in the social sciences focuses on qualitative observations and descriptive, non-numerical understanding of how systems behave and interact. Given that “evidence-based strategies must not ignore the evidence” (Piontek et al. 2013), any comprehensive D&A framework will need to be able to accommodate both qualitative and quantitative evidence.

It follows that statistical signal detection methods using univariate time series data often provide an insufficient toolset for D&A. D&A of impacts must be a fundamentally cross-disciplinary effort, involving concepts, terms, and standards spanning the varied requirements of various disciplines.

6 Do Not Confuse Climate Sensitivity with Detection of Impacts

There is a large literature statistically estimating the sensitivity of human and natural systems to climate. This usually involves correlating outcomes with climate for observations across space and/or time. It is important to recognize that these studies do not necessarily estimate an impact of climate change.

There are cases where data are insufficient for quantitative measurement of an impact, while given climate trends and known sensitivity strongly suggests that climate change will have affected the system.

Another important issue is the treatment of the impacts of climate variability. In the context of human systems, impacts of extreme weather or climate shocks are the rare occasion where a climate related signal is emerging from the noise. However, it is important not to confuse such indications of climate sensitivity with detected impacts of climate change. Also, climate extremes can constitute a necessary but not sufficient condition for an impact.

7 Is adaptation something we detect, attribute, or adjust for?

Adaptation happens in response to an observed or anticipated change. Autonomous adaptation of species to warmer conditions, such as shifts in distribution or earlier onset of spring phenology events, has served as measures for detection of climate change.

In human systems, autonomous adaptation may also involve expectations about future developments. For example, farmers may plant different varieties in response to several dry years, but may decide to invest in irrigation equipment if they expect those conditions to continue. Generally, in systems where the precautionary principle is followed, such as the public health sector, any hint of detection will trigger measures to reduce exposure and/or vulnerability, with the intention of removing any response signal (Carson et al. 2006).

Planned adaptation may happen independently of any observed effects, or as a response to impacts that are anticipated to increase. As adaptation planning is becoming more commonplace, the effect of such measures designed to deal with future climate change will distort the observations of impacts through reductions in exposure and vulnerability, and increased resilience.

Unless adaptation can be accounted for in an appropriate and consistent way, D&A analysis may never be able to inform us whether climate change is impacting human systems, or whether our adaptation measures where successful. This has important implications for the assessment of costs of climate change, in the form of both adverse impacts, and investments in adaptive measures. Therefore, adequate metrics and a framework that allow for monitoring adaptation, and subsequent adjustment within impact studies, are urgently needed.

8 Conclusions

D&A of impacts is important to inform the political process, to evaluate scenarios and projections, and to improve system understanding in a multi-driver context.

Though ultimately, the outcome of D&A studies in human and managed systems may remain limited due to the challenges described above, such exercises are incredibly useful to improve system understanding, identify climate sensitivities, and critically evaluate what we know about vulnerability of human systems to climate change. The consistent treatment of adaptation constitutes a key challenge herein.

References

Barnett, T.P et al., 2008. Human-induced changes in the hydrology of the western United States. Science, 319(5866), 1080-1080.

Bouwer, L.M., 2011. Have disaster losses increased due to anthropogenic climate change? Bulletin of the American Meteorological Society, 92(1), 39-46.

Brander, K. et al., 2011. The value of attribution. Nature Climate Change, 1(2), 70-71.

Carson, C. et al., 2006. Declining vulnerability to temperature-related mortality in London over the 20th century. American Journal of Epidemiology, 164, 77-84.

Hidalgo, H. et al., 2009. Detection and attribution of streamflow timing changes to climate change in the western United States. Journal of Climate, 22(13), 3838-3855.

Hockey, P.A.R. et al., 2011. Interrogating recent range changes in South African birds. Confounding signals from land use and climate change present a challenge for attribution. Diversity and Distributions, 17, 254-261.

Hoegh-Guldberg, O. et al., 2011. Difficult but not impossible. Nature Climate Change, 1(2), 72-72.

Howe, P.D. et al., 2013. Global perceptions of local temperature change. Nature Climate Change, 3, pp 352-356.

Hulme, M. et al., 2011. Is weather event attribution necessary for adaptation funding? Science, 334, 764-765.

IPCC, 2010. Meeting Report of the Intergovernmental Panel on Climate Change Expert Meeting on Detection and Attribution Related to Anthropogenic Climate Change. In: [Stocker, T.F., C.B. Field, D. Qin, V. Barros, Plattner, M. Tignor et al.(eds.)]. IPCC Working Group I Technical Support Unit, University of Bern, Bern, Switzerland, pp. 55.

Min, S.K. et al., 2011. Human contribution to more-intense precipitation extremes. Nature, 470(7334), 378-381.

Nicholls, R.J. et al., 2009. Coastline degradation as an indicator of global change. In: Climate Change: Observed Impacts on Planet Earth. [Letcher, T.M. (ed.)]. Elsevier, pp. 409-424.

Parmesan, C. and G. Yohe, 2003. A globally coherent fingerprint of climate change impacts across natural systems. Nature, 421, 37-42.

Parmesan, C. et al., 2011. Overstretching attribution. Nature Climate Change, 1, 2-4.

Parmesan, C. et al., 2013: Beyond climate change attribution in conservation and ecological research. Ecology Letters, (accepted).

Piontek, F. et al., 2013: Climate Impacts Research: A Vision for the Next Decade. Background document for the IMPACTS WORLD 2013 conference and beyond. Potsdam Institute for climate impact research, pp. 1-12.

Poloczanska, E.S. et al., 2013. Global imprint of climate change on marine life. Nature Climate Change, (submitted).

Rosenzweig, C. and P. Neofotis, 2013: Detection and attribution of anthropogenic climate change impacts. Wiley Interdisciplinary Reviews: Climate Change, 4(2), 121-150.

Rosenzweig, C. et al., 2007. Assessment of observed changes and responses in natural and managed systems. In: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. [Parry, M.L. et al. (eds.)]. Cambridge University Press, Cambridge, U.K, pp. 79-131.

Rosenzweig, C. et al., 2008. Attributing physical and biological impacts to anthropogenic climate change Nature, 453(7193), 353-357.

Ruddell, D. et al., 2012. Scales of perception: public awareness of regional and neighborhood climates. Climatic Change, 111(3), 581-607.

Stone, D.A. et al., 2013. The challenge to detect and attribute effects of climate change on human and natural systems. Climatic Change, (submitted).

Stone, D.A. et al., 2009: The detection and attribution of human influence on climate. Annual Review of Environment and Resources, 34, 1-16.

Stott, P.A. et al., 2010: Detection and attribution of climate change: a regional perspective. Wiley Interdisciplinary Reviews: Climate Change, 1(2), 192-211.

Zwiers, F. and G. Hegerl, 2008: Climate change: attributing cause and effect. Nature Reports Climate Change, 453, 296-297.