ily therapy (Poerksen 2004). These lineages are all praxis lineages, as is science, so there is much to be drawn upon and institutionalised in ways that are socially valued and that attract investment

« 5 » Let me conclude with a plea. Let us not become stuck in a discursive trap about what second-order science is or is not. As Heinz von Foerster might say, how can we move forward in ways that maximise our choices? One way of doing this would be to address the question: What world(s) do we bring forth when we take responsibility for our observing? Or in Maturana's terms: What is it that we do when we do what we do when we claim to do second-order science/R&D (see Ison 2010)?

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On Detection and Attribution

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> Upshot • I discuss the concepts of detection and attribution as they are used in scientific discussions about the cause of global warming.

« 1 » In my commentary on Philipp Aufenvenne et al.'s target article I want to focus on §17, i.e., on "detection and attribution." I claim that their assertion "Since CO2 has long been known to be a greenhouse gas, the observed rise in CO2 concentrations within the atmosphere has suggested itself as the main cause of global climate change" is inaccurate as it applies only to the climate change that began to emerge in the 20th century, when it became clear that human activities would significantly increase atmospheric CO_2 concentrations. For older geologic eras, one would see parallel developments of CO_2 concentrations and temperatures, as derived from proxy records. But the accuracy and temporal resolution of these records was hardly sufficient to decide whether one would lead the other. Indeed, since no external cause for elevated or reduced CO_2 concentrations could be given, it is plausible that it CO_2 follows temperature. In the popular literature, the correlation of the two was made into an argument for elevated CO_2 levels being the cause of the ongoing process of global warming, but not in scientific circles.

« 2 » To deal with the recent change of climate, the concept of "detection and attribution" of Klaus Hasselmann (1979) was invoked, as rightly described by the authors.

« 3 » "Detection" means to identify a change as beyond the range of natural internal variations within the climate system; the presence of variations "without causes" is difficult to understand for lay people, who often enough insist that "where there is smoke, there is fire." The climate system is full of non-linear processes, which as a sum appear as something that is well-described by the mathematical construct of randomness (red noise, pink noise) with significant long-term variations (Hasselmann 1976). "Detection" means, if a dead body is found, that when the death cannot be explained by natural causes, detectives are then asked to look for suspects and to determine who may have done it.

« 4 » The second step is called "attribution." While detection represents a stringent statistical hypothesis test (with the difficulty of determining the appropriate null-distribution), attribution is a plausibility argument, namely: Which of the suspects best fits the profile of the crime? Of course, it can be that the series of suspects that is examined does not contain the real murderer, so that a misattribution takes place. In the end, an assertion is made that "we can explain the ongoing change" best by attributing x% of the change to process X, and y% to Y, etc. If done properly, a caveat "given our present understanding of the system and its sensitivity" is added.

« 5 » The expectations, or "signals" of how a certain possible "cause" may act on the climate system are derived from simulations with dynamical climate models that quantitatively describe these expectations (or "guess patterns"). The output of such models is also used to estimate the range of natural variations. Except for these two applications, the process of detection and attribution does not make use of climate models; instead it is an assessment of observed data.

« 6 » The detection and attribution efforts began to become successful in the mid-1990s (e.g., Hegerl et al. 1996), when analyzing global decadal trends in air temperature. In the meantime, other variables have also emerged as influenced by elevated atmospheric greenhouse gas presence (The International ad hoc Detection and Attribution Group, 2005). Approximately 1/2 or more of the centennial change is attributed to increased CO_2 concentrations and other greenhouse gases, while 1/2 or less may be due to changes in solar forcing, volcanism and aerosol forcing.

« 7 » In hindsight, in the 1980s we may have already detected a global change that needs explanation through external causes (Rybsky et al. 2006). Regionally and locally, the detection and attribution is more complicated (Barkhordarian, von Storch & Bhend 2013), as more "suspects" are present, such as massive changes in aerosol generation and land-use changes (urban developments).

« 8 » In summary, the issue of whether the recent climate change, in particular in terms of air temperature, is related to changes in the presence of greenhouse gases is not based on the co-variability of the presence of such gases and temperature, but on the detection of changes beyond the undisturbed regime, and the determination of the most plausible mix of causes. In terms of air temperature, the recent changes cannot be explained without making use of elevated greenhouse gas concentrations; this explanation is consistent with physical theory, but remains conditional upon the present body of scientific knowledge.

« 9 » In the public domain, this rather sophisticated assessment transforms to the

assertion that the cause of climate change, and increasingly violent weather extremes, is due to the ongoing human emission of greenhouse gases. Such a transformation of scientific assessments is not surprising when post-normal conditions prevail, as in the case of climate sciences and climate policies (von Storch 2009).

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First Aid for Climate Research with Second-Order Science

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> Upshot • On an epistemological level, Aufenvenne, Egner and von Elverfeldt argue convincingly for an increasing role for second-order science in climate research. However, the authors partially underestimate the already increasing role of reflexive critique in climate discourse, and they do not yet fully take into account the radical changes in our conception of climate change through the deployment of a second-order approach.

« 1 » The target article by Philipp Aufenvenne, Heike Egner and Kirsten von Elverfeldt article makes a highly welcome and necessary contribution to the debate of the current status of climate research in the climate debate. Climate science has had a spectacular career since human induced green house gas emissions were singled out through detection and attribution. After the 2007 Nobel Prize for Peace for the IPCC and Al Gore, a series of scandals and public debates haunted climate research. From then on, its public reputation suffered. Nonetheless, climate politics relied on science-based goals (such as the 2-degree target) and turned into an "anti-politics machine" (Ferguson 1994), while the political debate subsequently shifted into climate science.

« 2 » This is where the target article comes in. The authors argue that in the course of the climate debate, climate science has lost public trust. Knowledge about climate change is partially uncertain, tentative and temporary. According to the authors, this undermines public expectations towards science and scientific knowledge. They see this as part of a general feature of "second modernity" (Beck, Giddens & Lash 1996), which is characterized by an increasing destabilization of values and institutions in society (§1). While climate research might be an indicator for the ills of a "second modernity" or not, there is certainly more to the current crisis, as the authors also suggest in their article, even though tentatively and somewhat reluctantly.

« 3 » The authors frame the communication problem mostly in terms of epistemology. In order to improve public communication, they suggest supplementing or even replacing first-order climate science with second-order science. Consequently, they discuss and convincingly suggest applying mode-2 research, post-normal science, self-reflexivity and a change in theoretical scientific perspectives to "complex and/or non-linear systems" in order to overcome the current problems in public-science communication. This is well argued and serves as a necessary and provoking contribution to the debate about the role and status of climate research in climate politics and communication. The authors spend a great deal of time on explaining the difference between first-order and second-order science; in doing so, they sometimes reduce climate science to just another example of science in general. This reduction does not always do justice to the prominent and special role of climate science; they neglect the fact that climate science has a troubled history of its own. In my opinion, a more ethnographic approach in terms of science and technology studies could provide a more detailed insight into the workings of the current status and dynamics of climate research.

« 4 » In the following, I would like to extend further the argument that a second-order science approach should also take into account the cultural and political history of climate research; a dimension that is only sporadically highlighted by the authors. Their focus on mainly epistemological and generalizing aspects tends to miss out some of the specific features that distinguish the climate debate from other debates and climate science from other sciences. Most of all, there is more to the debate than only smoothing out communication between science and the public; from a second-order science approach, the definition and understanding of the climate change problem itself possibly has to change. The understanding of anthropogenic climate change as catastrophic and carbon-based, as Jerry Ravetz[1] characterizes the dominant science-based climate discourse, reduces the climate problem to a governance problem using technological criteria such as mitigation, adaption and resilience. The social and political dimension of unequal access to and use of fossil fuels, of social inequality and environmental justice, for example, are excluded from this discourse.

« 5 » Thus, the article is somehow trapped in an unsolved tension between epistemology and politics. The authors tend to attribute the polarized nature of the climate debate to epistemological problems and to the unwillingness of scientists to disclose and discuss uncertainty. But how does this relate to their statement that from the beginning, climate change was a political hypothesis (§17)? If this is true – and I have no doubt it is – there is more to the crisis in climate research than only epistemological problems in communicating uncertainty. Of course, there is: the authors rightly mention the (in)famous hockey stick debate as an example of the crisis of climate research (§17). A well-chosen example, as it serves as an indicator for the increasing politicization and scandalization of climate research. But the authors tend to underplay the political and cultural context of these "religious wars" (§29) and how climate research turned into

1| "Climategate: Plausibility and the blogosphere in the post-normal age," by Jerry Ravetz. Retrieved from http://wattsupwiththat.com/2010/02/09/climategate-plausibility-and-the-blogosphere-in-the-post-normal-age/ on 23 October 2014.