Lessons for Science from the "Year without a Summer" of 1816

What Does It Take for Science to Respond to Climatic Change?

Science is responding in manifold ways to current climate change. What are the prerequisites for response, and how can we structure the response? By studying the historical climatic event "Year without a Summer" of 1816 and by relating to Fleck's theory of the genesis and development of a scientific fact, we posit that responding refers to making interlinkages between different notions of climatic change.

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Long-term observations of the atmosphere show that during the past four decades the global climate has changed substantially. By providing solid scientific information for stakeholders (governments, private sector, civil society), science responds to the perception of climate change and its impacts as a real-world problem. But what does it take for science to respond (i. e., to engage in observing and explaining climate change)? How does the response relate to perceptions of climatic change as harmful to society, nature, and the economy, requiring action? We developed this question while investigating a historical climatic event, the "Year without a Summer" (YWAS) of 1816, which had dire consequences for the affected population but was not of interest to contemporary scientists. More specifically, we ask: 1. How does science respond to climatic change? 2. What are the prerequisites so that science may be able to respond?

We conceive of responding to climatic change by science as linking observations, perceptions, and explanations of climatic change. Here, we propose a heuristic scheme to be used as a tool for studying the interlinkages between observations, perceptions, and explanations. With this scheme we follow the steps that have been taken in the past to understand the YWAS, showing how science can repeatedly learn from the same historical event as the context changes. The scheme also helps us to formulate hypotheses as to why science hardly responded to the northern hemispheric warming during the first half of the 20th century.

1816 – Year without a Summer

In the summer of 1816, Europe and North America suffered from adverse climatic conditions so severe that the year became known as a "Year without a Summer". It was exceptionally cool and rainy (Briffa et al. 1998, Luterbacher et al. 2004, Trigo et al. 2009), particularly in Switzerland (Auchmann et al. 2012), leading to widespread crop failure and severe famine (Pfister 1999). Today, causes of the YWAS are mostly attributed to the eruption of the volcano Tambora in Indonesia in April 1815, which injected huge amounts of sulphur into the stratosphere (e. g., Stommel and Stommel 1981, Stothers 1984).

Surprisingly, this climatic event received little immediate response from the scientific community. Investigating possible reasons for not responding may thus help elucidate prerequisites necessary for science to learn from climatic change. In a previous paper, we analysed the contemporary reactions of the scientific world and public communication in Switzerland, based on a systematic screening of selected scientific journals (see Bodenmann et al. 2011).[1] The detailed results were analysed in relation to Ludwik Fleck's theory of the genesis and development of a scientific fact (Fleck 1979).

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1 Among others we have analysed the *Bibliothèque britannique/universelle, Göttingische gelehrte Anzeigen, Annalen der Physik (Gilbert's Annalen)*, and *Philosophical Transactions of the Royal Society of London*. In addition, we have screened all newspaper editions from 1815 to 1817 of the *Neue Zürcher Zeitung* and the *Schweizerfreund* as well as the diary of Johann Peter Hoffmann (1753 to 1842), to consider also a personal perspective.

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Structuring the Study of Science Responses

We would like to take this work a step further by proposing a heuristic scheme which may serve as a tool for structuring the study of science responses to a specific event. The starting point of our considerations is an observed or perceived real-world event – in nature, society, economy – in need of explanation or action. According to Fleck, prerequisites to generating an understanding of an event as a scientific fact are:

1. the existence of a scientific community,
2. a scientific incentive for that community (i. e., the issue must fit their research agenda),
3. the ability of the community to develop concepts, including influx of other ideas as well as methods for (experimental) observation to come up with a consistent interpretation of results in a mutually adaptive process, and
4. a social incentive or public interest, due to how this event is perceived by the population.

For our purpose, it may be helpful to distinguish between three different notions of climatic change. With respect to Fleck, we distinguish between "observed climatic change" (instrumental and non-instrumental, direct observations of the weather) and "explained climatic change" (ideas of what could cause climatic change, e. g., scientific theories, but also astrology, superstition, God). The latter three ideas may serve, according to Fleck, as prescientific proto-ideas to guide the development of scientific facts. Our third notion, "perceived climatic change" (culturally shaped interpretations of climatic changes and occurred, probable, or possible harmful or beneficial impacts on society), refers to Fleck's fourth prerequisite. These notions are represented in figure 1.[2] Note that the figure accounts for a plurality of observations, explanations, and perceptions (e. g., different explanations, perception by different social groups, etc.), but also interlinkages and external influences.

"Responding to climatic change" means changing the different notions according to the links between them. It serves to achieve coherence and improve knowledge with the help of further research and observation, or by admitting external influences. In this way, generating a scientific fact may change "explained climatic change", "observed climatic change", or "perceived climatic change", through the linkages (arrows) between the different notions (figure 1).

For our specific case, we can now map the findings from Bodenmann et al. (2011) on the historical understanding of the YWAS onto such a heuristic scheme (figure 2). Figure 3, then, shows a scheme representing today's understanding.

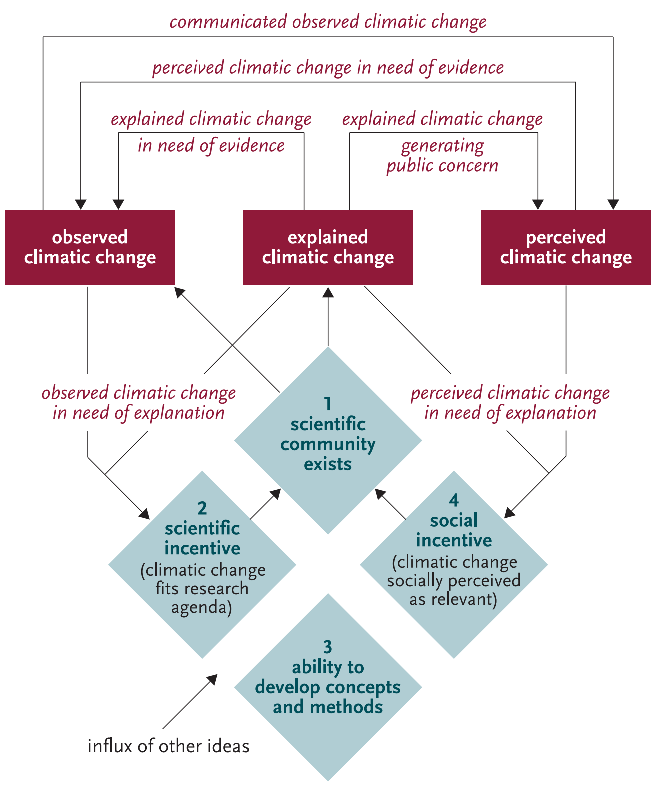
2 Note that when applying the heuristic scheme in a present-day scientific context, modelling and computer simulation may be used as approaches for dealing with data, explanations, and impacts. Hence, observations, perceptions, and explanations may have the form of "modelled climatic change" in science.

"Experiment of Nature" – The "Year without a Summer" and Contemporary Science

The Tambora eruption and its aftermath can be considered as an "experiment of nature" that occurred during a historically interesting period. Enlightenment thinking was prevalent only in the educated urban population. Some natural sciences such as geology were prospering, while others, particularly atmospheric sciences, were not yet developed at all.

Although the event was perceived as catastrophic, the immediate response of the scientific world was limited. There was no scientific community that could have defined it as their central research problem. Scientists only voiced themselves to refute some of the public ideas, namely that sunspots or lightning conductors were to blame. Scientific responses to the YWAS emerged a few years later from reinforcing older ideas that existed in active scientific communities. The climatic deterioration around the YWAS was addressed by studying the relation between glacier changes and climate (Venetz 1833), work that eventually became influential for the development of the ice age theory. Others addressed the relation between forest management and climate (Kasthofer

FIGURE 1: Heuristic scheme showing the three different notions of climatic change (rectangles), interlinkages between them (arrows), and their relation to Fleck's prerequisites for the generation of a scientific fact (diamonds). Prerequisites are the existence of a scientific community **(1)**, willing to make it a central research topic **(2)** and able to develop concepts and methods **(3)**, as well as a society that is concerned about the problem **(4)**.



1822), which was another established topic at the time. The first scientific explanation of the cold summer of 1816 in Europe – namely that huge masses of ice drifting in the North Atlantic had cooled Europe (Barrow 1819) – can be seen in the context of attempts to find the Northwest Passage and thus originated from yet another existing scientific community.

Atmospheric sciences did not exist, and processes in the atmosphere were of little interest to researchers. Consequently, the YWAS had little direct effect on building up this community. At most, through demonstrating the general lack of knowledge, the perception of the YWAS might have contributed to the establishment of new meteorological observatories such as the one on the Great St. Bernard Pass in Switzerland one year later (Pictet 1817).

Until today, the "experiment of nature" has seen several phases of renewed interest (see also Dörries 2006 for the following). In each phase, the YWAS of 1816 was analysed in a new context, with new methods and research questions to produce new "explained climatic changes" which can be mapped onto the heuristic scheme. These phases were triggered by new "experiments" (volcanic eruptions, starting with Krakatau in 1883, see figure 4, p. 172), by public and political debate (e.g., nuclear winter, see Crutzen and Birks 1982), or scientific discussion in other fields (e.g., asteroid impacts as cause for the Cretaceous-Tertiary extinction, Alvarez et al. 1980), and they reinforced existing discussions and interests (e.g., causes of ice ages, changes in solar radiation, optical and microphysical properties of aerosols, climate impacts on society, and stratospheric dynamics).

Learning from the "Year without a Summer"

Today, the YWAS is perceived also as a "worst-case realisation" of natural climate variability (figure 3). Given present modelling capabilities and the corresponding public expectations, predicting immediate climatic effects of an eruption seems possible. Revived interest is also related to the debate on climate engineering through stratospheric sulphur injection (Crutzen 2006), which requires detailed knowledge of aerosol microphysics, atmospheric chemistry, and dynamics. The YWAS of 1816, which also fell into a secular minimum of solar activity known as the "Dalton Minimum", is an opportunity to test and develop ideas, thus affecting current "explained climatic changes" (e.g., concerning the >

FIGURE 2: Heuristic scheme of linkages between observed, perceived, and explained climatic change and prerequisites applied to the historical understanding of the "Year without a Summer" of 1816.

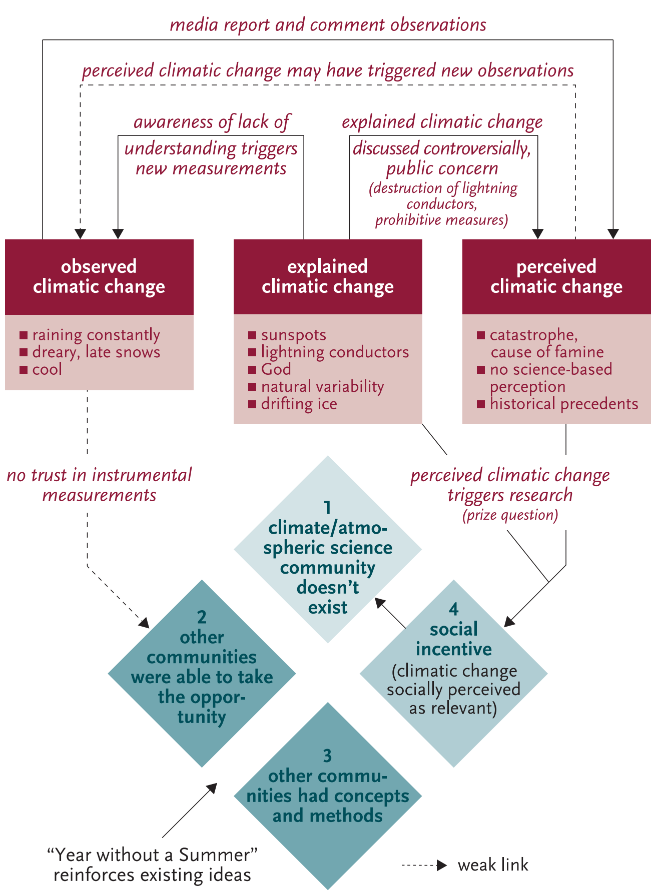
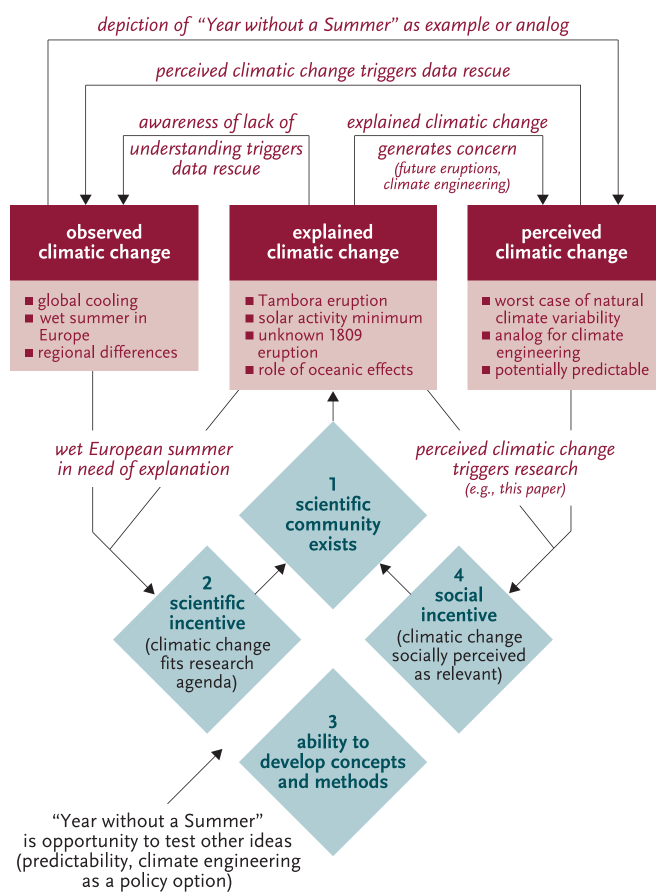


FIGURE 3: Heuristic scheme of linkages between observed, perceived, and explained climatic change and prerequisites applied to the current understanding of the "Year without a Summer" of 1816.



role of the oceans see Stenchikov et al. 2009). Recent data rescue and reconstruction activities, as part of a broader effort towards better depicting natural climate variability, have targeted the YWAS and have produced new "observed climatic changes" (Trigo et al. 2009, Auchmann et al. 2012).

Conclusion

Structuring historical and current understandings of the YWAS with the help of the heuristic scheme shows that responses can be understood from interlinkages between observation, perception, and explanation. However, only if several further requirements are met do these responses contribute to improving the understanding of climatic change as a basis for coping with pressing real-world problems. The historical understanding was dominated by uncontroversial perceptions of the catastrophic event in society, while measurements, scientific explanations, and a scientific community were lacking. Today's complex response is embedded in a more comprehensive scholarly understanding of climatic changes; incentives include exploring policy options and scientific reputation in advancing understanding.

Can we apply the heuristic scheme to the case of global warming?[3] In the present situation, science does respond to this observed and perceived climatic change because the prerequisites are met. However, a strong regional and northern hemispheric warming was already observed in the early 20th century (Jones et al. 1999). Yet, science in the 1930s did not respond very strongly to this warming phase. The heuristic scheme can help to pose questions and raise hypotheses. For instance, we may raise the following: Contrary to the YWAS, observations, explanations (albeit immature), and also a scientific community existed at least to a certain degree (though without the capability of performing climate projections) in the 1930s. Contemporary scientists noted the climate change and published about it (e. g., Scherhag 1939). Nevertheless, the event was not perceived as a pressing real-world problem; if it had, it might have affected the scientific response. In addition to the differences in the political, social, and economical situation in the 1930s and 1940s compared to the present, the value judgements – and hence perception[4] – also were different. This is evident in an article by Callendar (1938), who addressed the warming and related it to the CO_2 increase, but concluded that "the combustion of fossil fuel (...) is likely to prove beneficial to mankind". According to Weart (2008), connecting the temperature rise with CO_2 "was not a pressing issue" at that time.

This leads to the question of whether it would have been possible, given the state of the art of climate science at that time, to foresee the consequences we perceive today. According to Weart (2008, p. 18), this has not been the case, and scientific incentives were missing: "Most scientists gave short shrift to any theory whatsoever. They set climate change aside as a puzzle too difficult for anyone to solve with the tools at hand.

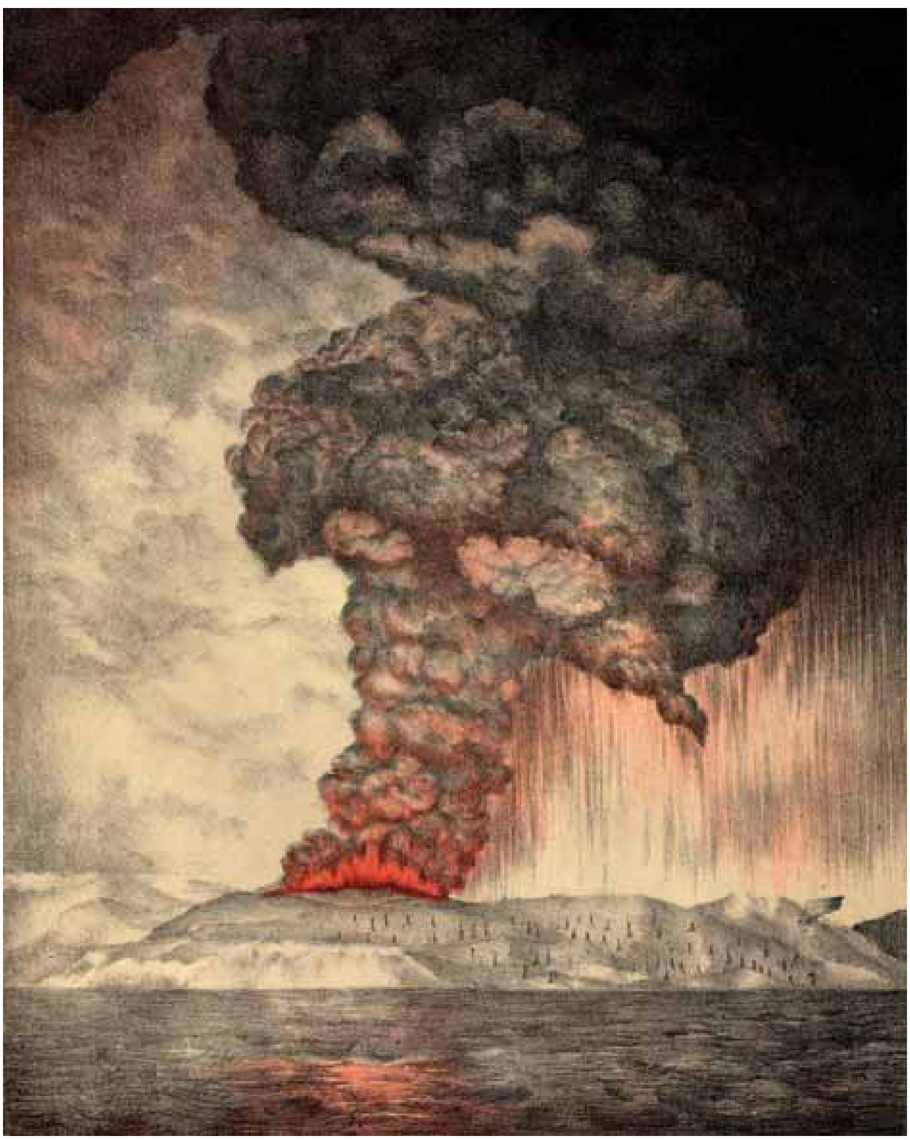


FIGURE 4: Eruption of Krakatau in 1883 displayed in a lithograph taken from Symons (1888). This eruption was the first natural catastrophe of global magnitude that was almost immediately recognised as such and studied by science (see Dörries 2003).

The idea that humans were influencing global climate by emitting CO_2 sat on the shelf with the other bric-a-brac, a theory more peculiar and unattractive than most."

After all, the early 20th century warming, similar the YWAS, has also undergone cycles of interest and is today considered very relevant for understanding regional climatic mechanisms and their interaction with the hemispheric scale (Brönnimann 2009, Semenov and Latif 2012). Only a more detailed study of this period may provide answers; by proposing our heuristic scheme, we do not intend to provide new ideas. We see it as a tool that helps to better acknowledge the relevance of these ideas, and especially of combining them, e. g., in considering coherence between scientific and social incentives for how to proceed in science.

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3 With respect to the recent global warming, see also Bodenmann (2008) for a philosophical analysis of causal claims in the arguments of the Intergovernmental Panel on Climate Change.

4 Perception of climatic change is historically and culturally shaped, as expressed in visualisations of climatic change (Brönnimann 2002).

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