Domino Effects in the Earth System – The potential role of wanted tipping points

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Abstract

Vital parts of the climate system, such as the West Antarctic Ice Sheet, are at risk even within the aspired aims of the Paris Agreement to limit global temperature rise to $1.5 – 2^\circ$C. These so-called natural tipping elements are characterized by rapid qualitative shifts in their states once a critical threshold, e.g., of global mean temperature, is transgressed. We argue that the prevention of such unwanted tipping through effective climate policies may critically depend on cascading Domino effects from (anticipated) climate impacts to emission reductions via wanted social tipping in attitudes, behaviors and policies. Specifically, the latter has recently been noted as a key aspect in addressing contemporary global challenges, such as climate change, via self-amplifying positive feedbacks similar to the processes observable in climate tipping elements. Our discussion is supported with data on commonly observed linkages between (subjective) climate change knowledge, concern and consequential potential action and we argue that the presence of such interrelations serves as a necessary condition for the possibility of rapid climate action.
How climate tipping became real -or- The unwanted tipping point

There may have been a turning point in our thinking about climate change: In 2014, several research groups suggested that the Amundsen region of West Antarctica had entered a new dynamic regime, with glacier retreat controlled by the marine ice-sheet instability, which could lead to its collapse in the long-term (e.g., Rignot et al., 2014). Changes in the surrounding ocean circulation have initiated internal ice dynamics that essentially cannot be reversed. They will likely lead to a destabilization of this entire ice basin and subsequently to global sea-level rise (Joughin et al., 2014; Feldmann and Levermann, 2015). A lot is at stake: this part of West Antarctica alone holds enough ice to raise global sea level by more than one meter (Bamber et al., 2009), while all of the marine ice basins in Antarctica together have a sea-level equivalent of almost 20 meters (DeConto and Pollard, 2016).

The Antarctic Ice Sheet is only one of several crucial parts of the climate system which – though massive in size – are so fragile that they can be severely disrupted by human activity. For these so-called tipping elements, a small perturbation can suffice to push them into a qualitatively different mode of operation (Schellnhuber, 2009). Several such large-scale tipping elements have been identified in the climate system (Lenton et al., 2008; Levermann et al., 2012). Among the candidates with the most severe and far-reaching consequences for the entire planet are the Thermohaline Ocean Circulation (Caesar et al., 2018) and the Greenland (Rignot et al., 2014) and Antarctic ice sheets (Winkelmann et al., 2015) (left part of Fig. 1). The risk of transgressing their critical thresholds increases with continued greenhouse gas emissions and global warming (Church et al., 2013). The ice-sheets, along with coral reefs, mountain glaciers and the Arctic summer sea-ice, might in fact reach their tipping point even within the Paris Agreement’s target temperature range of 1.5 to 2°C of global warming (Schellnhuber et al., 2016). Interactions between these climate tipping elements (Kriegler et al., 2009) could trigger cascading effects and positive feedbacks that would further amplify global warming (Steffen et al., 2018; Lenton et al., 2019) (see potential feedbacks in Fig. 1).

With the recent observations from the Amundsen basin (Rignot et al., 2014), the rather theoretical notion of climate tipping has become a reality. Declared a “holy shit moment of global warming” by public media (Mooney, 2014), the implications are being widely discussed in science and the public (Lenton et al., 2019).

The need for social tipping -or- The wanted tipping point

Without a rapid reduction in anthropogenic greenhouse gas emissions, sea-level rise from the ice-sheets’ mass loss will continue for centuries or even millennia, changing the face of our planet as we know it (Clark et al., 2016). In order to keep global warming to “well below 2°C” compared to preindustrial levels and thereby avoid some of the most severe climate change impacts on the long-term, swift action is required: net-zero greenhouse gas emissions have to be achieved around mid-century, and the peak in emissions as early as 2020 (Figurees et al., 2017). This translates into roughly halving CO₂ emissions each decade until 2050 in order to meet the Paris climate target with a 75% chance (Rockström et al., 2017). However, in reality, global emissions have generally been rising over the past decades (Figurees et al., 2017).

We are thus facing a severe clash of time-scales, with the need to reverse the current trend in emissions in just a few years, while climate impacts will continue to manifest well beyond the end of this century. In order to overcome this dilemma and to meet the ambitious goals of the Paris Agreement, the amplifying feedbacks between climate tipping elements need to be matched with self-reinforcing effects within social systems bringing about

![Fig. 1. Domino effects in the Earth System. The knowledge of (anticipated or already observable) impacts caused by climate tipping elements (in green) such as the Antarctic Ice Sheet, Greenland Ice Sheet and the Thermohaline Ocean Circulation could lead to social tipping (in blue) via changes in attitudes, policies and – ultimately – behavior (for instance changes in consumption, production or land-use). In turn, processes within the social sphere can strongly affect the climate system through changes in greenhouse gas emissions. Green arrows denote possible feedbacks between the climate tipping elements. Plus (minus) signs indicate that the tipping of one element is likely to enhance (decrease) the possibility of another. Blue arrows indicate possible interactions in the social sphere.](image-url)
rapid societal changes, or social tipping. This notion of social tipping, where a relatively small perturbation shifts a social system into a qualitatively different state via self-amplifying effects, has received recent scholarly interest (Milkoreit et al., 2018; Farmer et al., 2019; Tàbara et al., 2018). As such, this definition of social tipping by means of positive feedback effects closely aligns with the proposed definitions of climate tipping elements (Lenton et al., 2008; Levermann et al., 2012).

Societal transformation, where a system shifts from one state to a qualitatively different one has often been a key marking of historical transformations. These shifts can be sudden, such as the “Velvet Revolution” in communist Czechoslovakia, where the ruling party fell within a matter of a few days, consequently leading to an end of the command economy and the establishing of a parliamentary republic. On the other hand, such shifts can also occur on comparably slower time-scale, like the decades-long “civil rights movement” in the United States, culminating in the 1960’s with a series of legislation banning formalized discriminatory practices, guaranteeing equal access to education, labor, housing and voting rights. In addition rapid societal change can even be caused by unanticipated forces, such as the Fukushima Disaster in Japan affecting rapid shifts away from nuclear energy production in Germany.

It remains to note that, in contrast to most natural tipping elements, social tipping elements can have positive or negative consequences for the coupled socio-ecological Earth system. As such, their classification, much more than for natural tipping elements, is often based on normative judgement (Tàbara et al., 2018; Farmer et al., 2019).

Anticipated climate impacts as potential drivers of social change

It has been well established that meeting the aims of the Paris Agreement is not only necessary but also still physically feasible in the climate system (e.g., Schellnhuber et al., 2016). However, the questions remains as to what such feasibility entails in the social sphere.

Effective mitigation of climate change requires behavioral change on the individual level, but, importantly, also the implementation of coordinated climate policies. Climate action on both levels requires a sufficiently high level of awareness and climate change concern to allow spreading of individual behavioral change on social networks and the support of global climate policies through democratic institutions. A number of factors including values, attitudes and political orientations, as well as other indicators, such as demographic characteristics, knowledge,
risk perception and trust, have all been linked to climate change awareness and concern (Hornsey et al., 2016). More importantly, subjective climate change knowledge, or climate literacy, has been shown to be a strong positive predictor of such climate change concern (Kahan et al., 2012). At the same time, climate change concern has been shown to be strongly related to engagement in environmentally friendly actions, albeit less strongly than with climate policy support (Hornsey et al., 2016).

Given the need for rapid social changes, we question whether it is possible that anticipated impacts of climate change can affect behaviors and/or increase the likelihood of climate change ameliorative policies. Generally, the perceptions of risks have been broadly noted as key drivers of behavior, such that the more an individual perceives a certain risk, the more likely they are to act in ways that aim to minimize these risks. The role of such anticipated risks has been discussed with respect to a broad range of behaviors and aspects, such as health (Brewer et al., 2007; Floyd et al., 2000), financial decision making (Weber, 2004; Weber et al., 2012), or sexual behaviors (Bentin et al., 1993). Specifically with respect to climate change, increased risk perceptions have been found to motivate individuals to engage in more climate friendly behaviors (O’Connor et al., 1999; Semenza et al., 2008) as well as support climate policies (Leiserowitz et al., 2013; Smith and Mayer, 2018).

Drawing from environmental psychology, Kollmuss and Agyeman (2002) establish a theoretical framework noting the interplay between internal (e.g., motivation, values, attitudes) and external factors (e.g., institutional, economic, cultural) driving individual likelihood to engage in environmentally friendly behaviors. Internal motivations, such as concerns, can drive pro-environmental actions, most effectively when they are in synergy with other internal and external factors. And while knowledge of climate change is related to concerns, the relationship between knowledge and behavioral change is often indirect, filtered via external (institutional, economic, cultural) and internal (motivation) factors. Previous research also noted positive relationships between knowledge and concerns for the polar regions (Hamilton, 2008; 2012), but as of current, there is limited empirical research on the drivers of environmental actions in relation to the such aforementioned changes.

To illustrate the potential of anticipated climate impacts to induce a change in people’s attitude we present an exploratory analysis of the relationship between knowledge, concern and willingness to engage in behavioral ameliorative action in response to observations in the polar regions, Fig. 2. Specifically we utilize a novel survey of 2904 German respondents in the German GESIS Panel (August to October 2017) (GESIS, 2018), a nationally representative, probability-based, mixed mode access panel, utilizing online and mail-in responses (Bosnjak et al., 2013).

Broadly this data suggests that knowledge about changes in the polar regions is directly linked to concerns for this area, and further, concerns are positively related to the willingness to engage in ameliorative actions (in this case driving one’s car less). Hence, we find the expected indirect link between (subjective) knowledge and one’s willingness to change certain behaviors that appears to be via the corresponding concerns. As such, there is preliminary evidence that concerns for the changes in the polar region may effect change in people’s behaviors. These observed links between subjective knowledge and concern, as well as concern and potential action are a necessary condition for behavioral and social transformation, i.e., social tipping to occur. In other words if either a direct link between knowledge and concern or concern and behavior would be absent such transformations or tipping would possibly be far less likely to occur. The present analysis mainly intends to show that changes in behavior may come about as the result of transformations along such a chain of processes. We show that the (German) public seems to recognize and anticipate changes in the polar region which they consequently see as a potential threat to future generations. Assessing whether this state ultimately leads to environmental action may be determined by a multitude of additional variables that require further in-depth analysis.

Hence, further research needs to engage in understanding the possible mechanisms and potential drivers behind the relationship between knowledge, concerns and behaviors. As noted by Kollmuss and Agyeman (2002), several barriers limit the possibility for behavioral changes, such as higher costs of engaging in new behaviors (Diekmann and Preisendörfer, 2003), or limiting cultural, economic or political factors. We also note that knowledge may be further fostered by novel foci in education or increased media coverage. In addition, behavioral change can certainly also result from processes other than subjective knowledge and concern, e.g., new technologies or changing socio-economic conditions. Ultimately, individual actions themselves may be followed by emergent collective action as well as consequential environmental regulations and climate policies.

**Domino effects in the Earth System**

In summary, we ask, somewhat provocatively, whether changes in perceptions of natural dynamics in the Polar regions can raise concerns about climate change enough to tip behaviors and climate policies for achieving substantive reductions in greenhouse gas emissions (Shi et al., 2015; Kahan et al., 2012). The answer seems to be two-fold: A priori, it may come as a surprise that people are concerned about ongoing or future changes in Antarctica at all, since sea-level rise through ice loss – compared to typical individual and political time horizons – is a very slow process. The most severe impacts will most likely only manifest beyond the lifetime of even our grandchildren’s generation (Clark et al., 2016). Therefore, it is all the more remarkable that knowledge about the dynamics in polar regions still correlates with an increased concern about climate change in general, as indicated by the survey data. Ultimately, this concern can (as suggested by our data as well as earlier studies in, e.g., Horsey et al., 2016) have a positive impact on attitudes towards climate change and the associated willingness to engage in environmentally friendly actions. This clearly shows a potential for societal change as a response to anticipated climate tipping.

Further, increased concerns towards the environment have the potential to effect policy changes. Changes to public opinion can punctuate previously stable and ‘sticky’ institutions, leading to policy change (Baumgartner and Jones, 2010). Also, broad social activism can spur generation new political coalitions, or effect a change shift in the priorities of existing ones (Sabatier, 1988; Weible and Sabatier, 2017).

However, it would take a number of steps, i.e., policy and/or economic changes to have a direct impact on emissions that in turn
reduce the risk for a tipping of, e.g., the Antarctic Ice Sheet. This implies that social tipping as a whole is more than the change in a single observable, but rather a possible cascading domino effect of intertwined processes, e.g., through social, political and financial networks.

Future work should thoroughly address several issues that so far hinder an in-depth analysis of social tipping elements in the Earth System. First, a concise definition of social tipping should be developed as the basis for community-driven efforts to classify and investigate the dynamics behind past and possible future tipping events. We suggest that such an endeavour requires a broad discourse among an interdisciplinary community of social and natural scientists with the goal to develop a common terminology and understanding of sudden shifts in social systems. The process that lead to a proposal for a definition of natural tipping elements can serve as a guideline to develop similar concepts for social tipping as well. From there, theoretical and numerical models of social tipping should be developed to foster the understanding of underlying (individual) micro- and (emerging) macro-dynamics that eventually lead to the emergence of social tipping points. Such models should be validated against (longitudinal) social science data to test for their validity, better inform the estimation of involved parameters and to prioritize the inclusion of underlying dynamics and processes. With respect to the data presented above, future work should aim at obtaining longitudinal observations of knowledge, concern and associated action or behavior to better understand changes in the temporal feedbacks between the observed variables. Such longer running data would, together with further treatments of potential biases, allow for statements other than exemplary providing a current snapshot of public discourses and possible pathways for social transformation. Specifically, such an assessment would expand our understanding of the complex interplay between knowledge, concern and action beyond the previously observed direct and indirect patterns that are recaptured by our analysis.

Hence, it requires joint efforts from different disciplines, such as the social sciences, physical Earth system sciences as well as mathematics and numerics to investigate the processes behind potential Domino Effects in the intertwined Earth System where wanted social tipping has the potential to prevent crossing dangerous unwanted climate tipping points.

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