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Geoengineering: A humanitarian concern

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Abstract The humanitarian sector is active at the global frontline of climate impacts, and has a track record in influencing the climate change policy agenda. Geoengineering is a humanitarian concern: the potential for deliberate large-scale intervention in the Earth's climate system has major implications in terms of impacts on the most vulnerable. Yet, so far the humanitarian community has largely been absent from geoengineering deliberations. Geoengineering may be perceived as too theoretical, too complex, and not imminent enough to merit attention. However, early engagement by the sector is imperative to ensure that humanitarian considerations are integrated into policy decisions. Those who can suffer the worst outcomes need to be involved; especially given the plausibility of "predatory geoengineering" where recklessly self-concerned actions may result in harmful consequences to others. This paper explores the humanitarian dimensions of geoengineering, specifically relating to solar radiation management (SRM). Drawing from the engagement of the Red Cross Red Crescent Climate Centre in SRM discussions, we discuss how to improve linkages between science, policy and humanitarian practice. We further propose the creation of a geoengineering risk management framework to ensure that the interests of the most vulnerable are considered and addressed - including the voices of all stakeholders.

Key Points:
- Geoengineering decisions are a humanitarian concern: the deliberate manipulation of the global climate can impact vulnerable people not included in decisions
- The Paris Agreement aspiration to keep global warming below 2°C did not aim to endorse SRM, but rather ambitious mitigation pathways
- If resources must be directed towards exploring geoengineering options, the needs and role of the most vulnerable should be given full consideration
- In the past 10 years, humanitarian players have been largely absent from discussions on geoengineering research and governance; a more proactive and anticipatory engagement is warranted

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1. Introduction

Less than two decades ago, science began loudly warning about the potential for climate change to transform our planet. This was seen by the humanitarian community as an issue outside their concern. Global warming seemed excessively complex, uncertain and distant in time: so far removed from imminent or even foreseeable priorities as to not warrant engagement. As a result, atmospheric science was the primary focus of early discussions on climate change within the scientific community and in the UN Framework Convention on Climate Change (UNFCCC) policy processes. Construed as a pollution problem, global warming grew without much attention to disaster risks or impacts on vulnerable populations [*Van Aalst et al.,* 2008]. During the first few years of the 21st century, when we started joining annual UNFCCC conferences as part of the delegation of the International Federation of Red Cross and Red Crescent Societies (IFRC), event participants would frequently ask us " … but what are you doing here? What does climate change have to do with humanitarian work?"

A lot has changed since then. Disaster risk reduction and development issues are now fully integrated into the climate change discourse [*Schipper and Pelling*, 2006; *IPCC – Intergovernmental Panel on Climate Change*, 2012]. All major humanitarian organizations have dedicated teams focusing on climate risks, and climate change is well reflected in mainstream humanitarian discourse [e.g. *United Nations*, 2016]. Civil society has also managed to organize and channel its concern for the world's most vulnerable, through a multiplicity of initiatives [*Suarez et al*., 2013]. Unfortunately, this growing involvement stems from the irrefutable evidence of advancing climate change, including observed impacts [*IPCC – Intergovernmental Panel on Climate Change*, 2014], and the now obvious fact that we must collectively prepare for the severe threats that await humanity in the foreseeable future.

The initial response to climate change, which prevailed throughout most of the 1990s, involved almost exclusively greenhouse gas mitigation. In the years after the 1997 Kyoto Protocol, *adaptation* became a second pillar in climate discussions. In recent years and especially since the Paris Agreement, "Loss and Damage" has become a third pillar. We suggest that *geoengineering* is now rising to be considered a fourth pillar of discussions on how to deal with climate change. Solar radiation management (SRM) can remake

our planet, but it is largely not on the radar screen of leaders and organizations shaping humanitarian research, policy, and practice. We argue that there are analogies between where geoengineering stands today in the eyes of humanitarians, and where climate change stood in those same eyes just over a decade ago.

Nobel laureate *Crutzen* [2006] made a compelling case in his influential essay published a decade ago in the journal *Climatic Change*, arguing that "the preferred way to resolve the policy makers' dilemma is to lower the emissions of the greenhouse gases." However, anticipating that mitigation would likely not happen at the rate needed, he posited that geoengineering could be part of the solution: "(…) although by far not the best solution, the usefulness of artificially enhancing earth's albedo and thereby cooling climate by adding sunlight reflecting aerosol in the stratosphere might again be explored and debated." *Crutzen's* [2006] essay set the foundations for an unprecedented surge in exploration of SRM [see *Royal Society*, 2009; *IPCC – Intergovernmental Panel on Climate Change*, 2011]: Geoengineering had entered the climate change discourse.

The implications of geoengineering can be massive in terms of the potential effects—wanted and unwanted—not only regarding of SRM deployment, but also in how even just a conversation about its potential use can change the dynamics of global climate processes. Debates range from regulating research [*Blackstock and Long*, 2010] to finances and governance [*Humphreys*, 2011], to critical social thought in response to the concept of the "anthropocene", i.e., humans as a force of nature of geological scale [*Clark*, 2014]. The title of a recent book on geoengineering sums it up compellingly: "The Planet Remade" [*Morton*, 2016].

This paper aims to analyze what we see as humanitarian implications of the prospect of deliberately blocking sunlight to cool down the planet. We also call on humanitarians to understand the value of early and sustained engagement in explorations of geoengineering—a technologically feasible and politically plausible intervention that may shape the foreseeable future of climate risks. Section 2 explores the humanitarian dimensions of geoengineering. The third section posits the case of a small island village in West Africa as an analogy for the issue of externalities in SRM. Section 4 describes how the humanitarian community has—and largely has not—engaged in the geoengineering discourse. The final section with conclusions and recommendations also takes stock of what is needed in the next phase of climate discussions, including in terms of humanitarian engagement on geoengineering.

2. The Humanitarian Dimensions of Geoengineering

SRM proponents ask a valid question: Will the results of deploying geoengineering be worse than the alternative—inaction in the face of accelerating global climate change? The answer for now is both "We don't know" and "It depends." Given the prospects of geoengineering, it is our duty as disaster risk managers to consider Murphy's Law: we must anticipate what can go wrong with or without SRM—especially for those who lack the means to cope with surprises.

From the earliest publications about SRM, it has been made clear that the geoengineering option would require more knowledge than is currently available. *Crutzen* [2006] stated: "Given the grossly disappointing international political response to the required greenhouse gas emissions (…), research on the feasibility and environmental consequences of climate engineering (…), which might need to be deployed in future, should not be tabooed." He did address the potential risks: "The chances of unexpected climate effects should not be underrated, as clearly shown by the sudden and unpredicted development of the antarctic ozone hole." This is a critical aspect of many arguments against geoengineering. Science historian *Fleming* [2010] called it "untested and untestable, and dangerous beyond belief." Author and activist *Klein* [2014], opens the SRM chapter of her popular book on climate change with an 1895 quote by William James: "our science is a drop, our ignorance a sea." Even the book "A Case for Climate Engineering" [*Keith*, 2013] includes the following assertion: "Whoever concerns himself with big technology, either to push it forward or to stop it, is gambling in human lives." Without enough knowledge of system complexity, our decisions in a changing global climate will inevitably imply risks of commission and of omission (Figure 1).

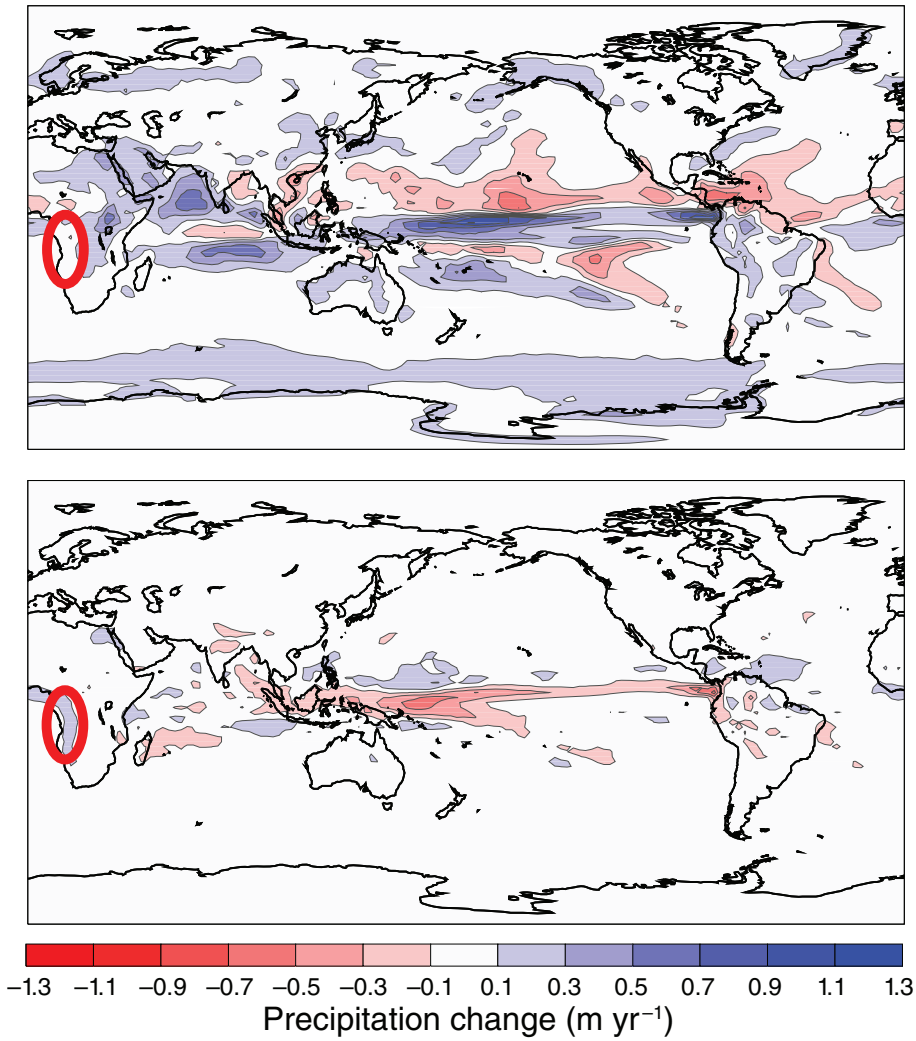

Figure 1. This early example of modeling results, from *Caldeira and Wood* [2008], contrasts a future with SRM (bottom) versus without (top). Ovals are added to highlight the increased rainfall anomaly for Gabon and other countries in West Africa, illustrating a key challenge: Who will take responsibility for unwanted negative consequences, even when expecting "net advantages"?

2.1. How to Decide? What Should Humanitarians Advocate for?

Crutzen proposed a sine qua non condition for actual intervention: "I must stress here that the albedo enhancement scheme should only be deployed when there are proven net advantages and in particular when rapid climate warming is developing." It is hard to disagree with the intention of that statement. Many questions emerge, such as how to define "rapid." From a humanitarian perspective, two key questions emerge:

- "Proven": How can we know that anything has been proven, given irreducible uncertainties? Local impacts are largely outside the scope of what our best global models can capture with or without SRM. Who decides if any proof is good enough?
- "Net": What about externalities? Can we accept net advantages that make a majority of people better off at the expense of worsening the situation for many people who are already among the most vulnerable and have no voice in geoengineering decisions?

A negative externality materializes when Party *P1* implements an activity or transaction that results in a benefit for Party *P1* and a cost to Party *P2*. In other words, when Party *P1* (i.e., a sufficiently rich set of nations or other agents) seeking benefit *B* (i.e., reduced impact of global warming) implements an Activity *A* (i.e.,

geoengineering) with consequences which cause losses or costs *C* (i.e., crop failure) to Party *P2* who did not choose to incur the negative impact (e.g., subsistence farmers in Gabon).

So far, greenhouse gas externalities have been allowed to prevail. This inertia can only be expected to become more entrenched if and when the climate system shows more signs of dangerous instability. Even under a "net advantages" scenario, if decisions are made to deploy SRM for the intended benefit of one portion of the global population while knowingly or unknowingly causing others to suffer, the burden is transferred. Building on previous work [see *Suarez et al.*, 2013], we propose to frame geoengineering research and policy agendas in a risk management framework—one that internalizes humanitarian externalities, explicitly integrating the role of the most vulnerable through *Learning, Preparing, and Preventing*:

- *Learning*: Identify likely costs *C*, and devote as much research effort to identifying these costs as benefits *B* are researched by *P1*. We should, for example, identify the subsistence farmers' likely costs due to crop failure as a result of SRM and devote as much research effort to assessing these costs as there is research by the developed nation that sponsors SRM research to identify the potential benefits (such as climate stabilization). This suggestion is particularly directed to climate scientists.
- *Preparing*: Identify and seek to include *P2* (e.g., the subsistence farmer) who would be excluded from decision making about activity *A*. Importantly, help *P2* understand decision processes so as to confer agency and capacity to influence her own future, supporting her in reducing likely costs *C* (i.e., avoiding crop failure by supporting transition to more adequate crops, or entirely different livelihood approaches). This suggestion is particularly directed to policy makers and the humanitarian sector.
- *Preventing*: Establish mechanisms that prevent the successful transfer of costs, thereby internalizing the externality. One example is environmental assurance bonds. This suggestion is particularly directed to stakeholders shaping climate policy and finance.

Rapidly becoming technically feasible as a "planetary emergency procedure" [*Kintisch*, 2010] somewhere, somehow, the intentional manipulation of the global climate may become politically feasible during our lifetime—and negative consequences will likely materialize at local scales whether SRM is deployed intelligently, irresponsibly, or not at all. The potential negative consequences of geoengineering are not necessarily limited to the local scale: entire regions may suffer externalities. As highlighted by *Morton* [2016], of the Sahel's four worst years of drought during the 20th century, three took place after explosive volcanic eruptions that injected aerosol particles in the upper atmosphere: the year after Katmai (Alaska, 1912) and the year of and after El Chichón (Mexico, 1982–1983) – events that mimic and even inspire SRM. Naomi *Klein* [2014, p. 275] poses a rhetorical question: "If the historical record, backed by multiple models, indicated that injecting sulfur into the stratosphere would cause widespread drought and famine in North America and Germany, as opposed to the Sahel and India, is it likely that this Plan B would be receiving such serious consideration?"

We fully acknowledge the risk–risk nature of the SRM proposition. Indeed, many of the concerns we have raised in the context of geoengineering could be applied to either the choice of deploying SRM *or* to the deliberate choice of no SRM. This point can be illustrated by two examples among some of our statements picked up by the media.

2.1.1. "No One Likes to Be a Rat in Someone Else's Laboratory" (*New York Times*)

This statement was included in the piece by Henry *Fountain* [2014] entitled "Climate Tools Seek to Bend Nature's Path." The full quote by Pablo Suarez frames the idea that it is understandable to see skepticism emerge in response to the prospect of SRM as a potential decision made on someone else's behalf. Of course, in the current climate, everybody has no choice but to be immersed in an experiment of planetary proportions. With or without geoengineering, we are all lab rats in the greenhouse.

2.1.2. "We Let Them Eat the Risk That We Create" (*Mother Jones*)

This quote was included in the article by *Rendon* [2010] entitled "Who Eats Geoengineering Risk", as part of a broader point: unintended consequences tend to be suffered most by those with the fewest resources and the least say. Interestingly, other media venues and various stakeholders picked up these words as if they exclusively supportied an anti-geoengineering position … even though the actual statement explicitly

referred to the risks of ongoing climate change—not to SRM [see *Thompson*, 2010 for video evidence from the Asilomar Conference].

We have heard externalities invoked. "Externalities" sounds like an "Oops! Sorry … " It sounds like "I just didn't mean it." Well, Martinez-Alier calls externalities "a successfully transferred cost." Today, I would argue that anyone polluting the atmosphere is doing geoengineering. That is a deliberate transformation. We know. It used to be non-deliberate; now we know. "Externalities" equals "Let them eat it. Let them eat risk."

There are potential externalities in choosing to deploy or not deploy geoengineering. These depend on climate system dynamics, which the humanitarian sector needs to anticipate and prepare to address. Additionally, humanitarian and development stakeholders must assess potential risks associated with how people, organizations, nations and global financial regimes may react to the mere possibility of SRM. For example, *Morton* [2016, p. 366] writes: "A world in which two or more great powers believe that they have strong and opposed interests in the matter of solar geoengineering could be quite as scary as one in which geoengineering drained mitigation efforts of all ambition. Geoengineering might do more harm as a casus belli than through unintended and unwanted earthsystem side effects."

SRM could also indirectly but powerfully reshape the humanitarian funding landscape. Let's imagine a very poor region, already dependent on international aid for covering basic needs. It suddenly experiences extreme climate conditions, beyond the range of the historical record: unprecedented famine ensues, coincidentally following SRM deployment decided outside of a globally endorsed agreement. Under such a plausible scenario it is entirely possible that existing donors could be unable or unwilling to scale up their aid—or even reduce aid while pointing to the deployer of geoengineering as the culprit who should be responsible for covering increased costs of humanitarian and development work.

This behavior emerged during a game simulation at the Climate Engineering Conference held in Berlin in 2014. Building on the ideas presented in *Mendler de Suarez et al.* [2012], we designed and facilitated a playable system dynamic model to help participants experience the humanitarian complexity of future risks. In this simplified representation of reality, the entire system of solidarity that had been put in place during "normal" years simply fell apart as soon as a group of players decided to deploy SRM. Even those players whose climate improved after the simulated geoengineering intervention became less generous with disaster-hit neighbors. Surely the real world can yield even more complicated surprises.

3. The Case of Doun Baba Dièye: A "Predatory Geoengineering" Analogy?

Humanitarian work is all about addressing things gone wrong: Victims of disasters are often the victims of individual and collective failures to reduce disaster risks, and the more vulnerable are differentially impacted [*UNISDR*, 2015]. An analogy to potential SRM externalities is offered by the now former village of Doun Baba Dièye (15°57′N, 16°30′15″W), in West Africa. Inhabiting a small island upstream from the mouth of the Senegal River, the villagers of Doune Baba Dièye farmed the rich alluvial soil and were the principal producers of vegetables for the nearby city of Saint Louis, former capital of the federation of French West African colonies. Farming and fishing provided livelihoods for its more than 800 inhabitants. On September 1st 2003 the river reached the established flood warning level. Facing this threat—and public discontent—city authorities decided to take a drastic measure to rapidly alleviate the flood problem: to open a breach in the "Langue de Barbarie," the thin, sandy peninsula separating the ocean from the final section of the river. By creating a shortcut, the waters of the Senegal river would flow faster to the Atlantic and thus drain the flooded city of Saint Louis (population of about 175,000), while also protecting the city from future inundations.

Within a few hours of digging the channel, the river level was substantially lowered, and after 10 days it was down by about 80 cm—alleviating the risk of a humanitarian crisis for the city. When it was opened on October 3rd 2003, the breach measured 100 m long and just 4 m wide [*Mietton et al*., 2007]. It was known prior to the intervention that complementary measures would have been necessary, such as the construction of rigid structures to prevent erosion. However, facing the pressure of ongoing floods and limited resources, the breach canal was dug without these protective measures—and without proper understanding of the likely negative consequences or how to manage any unwanted effects. The breach began to widen rapidly as flood waters flowed through the sandy canal: in a fortnight it became about 400 m wide.

Figure 2. Satellite imagery from Google Earth shows dramatic changes since opening the breach to accelerate drainage of the Senegal River and reduce flood risk in a city further north. The villagers of Doun Baba Dièye were not part of the decision-making process to alter the sand barrier that protected it from the open ocean. Six people were killed in 2010 during what in the eyes of the community was an unprecedented coastal storm.

In 6 years, the breach had become about 2 km wide (see Figure 2), exposing the island of Doune Baba Dièye to the open sea. Residents were not involved in the decision-making process, and faced an entirely new set of threats since there was no longer any land separating them from the Atlantic Ocean. Villagers reported going to bed in fear of being caught by giant waves at night. Six — including two children — were lost to the sea when a coastal storm hit on the night of February 27th 2010 — a type of natural hazard that they had never before experienced. Homes that formerly had a 100 m of healthy mangroves between them and the river waters were one night demolished by sea waves. Fishing was also impacted by changes in currents and salination of the river water. Soils in farmers' plots along the river became so salty that vegetable farming was no longer possible. The Red Cross Red Crescent Movement has a mandate to reduce human suffering, so colleagues from local, provincial, national, regional, and global teams worked with the Doune Baba Dièye community trying to address their new problems in various ways. Stakeholder engagement efforts brought decision makers to the island to discuss early warning systems [see *Macklin*, 2009]. Psychosocial support was offered to the relatives of the deceased.

Yet, the magnitude and inexorable advance of problems caused by the breach vastly exceeded the capacity of the IFRC and partners to provide adequate support to islanders (see Figure 3). Without being compensated for their losses, the entire community had to relocate — by 2016 not one single home remained spared from the ocean's destructive forces (see Figure 4).

The deliberate manipulation of the Senegal River mouth to change the natural system by opening the breach and protecting the city of Saint Louis may be construed as satisfying the criteria posed for geoengineering by *Crutzen* [2006]:

- "Proven": the intervention was deployed when rapid and threatening change was demonstrably occurring, and there were proven net advantages, at least from the perspective of flood risk management: as shown in Figure 5, the breach led to an immediate reduction in the magnitude of the physical variable that was considered a threat (i.e. river level in lieu of global temperature).
- "Net": the intervention helped protect a city of over a hundred thousand people while dramatically worsening conditions for a village of less than a thousand. A situation analogous to the "trolley problem" [a thought experiment in ethics oftern invoked in SRM contexts, see, for example, *Summers and Zeckhauser*, 2008], only that those deciding were those saved — at the expense of sacrificing someone else. A successfully transferred cost.

Figure 3. Humanitarian workers arriving to Doun Baba Dièye after the first coastal storm event destroyed homes and caused fatalities in this until-recently riverine community (*photo: Janot Mendler de Suarez*).

Dealing with harm suffered by the most vulnerable is decidedly a humanitarian concern, regardless of causes … But entirely new dimensions of harm may arise from the uncharted territory of climate change as well as geoengineering response to it. The Doun Baba Dièye case reminds us of a concept that emerged during an informal conversation with our colleague Hugo Slim: "predatory adaptation"—the behavior that emerges when one entity deals with change through actions that harm another entity, especially when reconfiguring how threats and opportunities are allocated in space and time [adapted from *Slim*, 2015]. Do we need to be concerned about the possibility of "predatory geoengineering"? It is technologically possible to deliberately shift rainfall and temperature patters through SRM. What if such successful transfer of costs yields net advantages globally and benefits for the deciders, but knowingly causes harm to many others? What if those excluded from such decision are already at the edge of survival, and not protected from new threats? While fully aware that there is a very low probability of such scenario for the foreseeable future, it illustrates the range and complexity of plausible futures that may await an already overloaded humanitarian system.

4. Humanitarian Engagement in Geoengineering Discussions

Despite evidence about the potential consequences for the most vulnerable associated with the prospect of decisions involving large-scale deployment of SRM, the humanitarian community has hardly been engaged in the 10 years of increasingly concrete discussions on SRM sparked by *Crutzen's* [2006] essay. To our knowledge, the Red Cross Red Crescent Climate Centre has been the sole humanitarian actor consistently playing a role in these discussions. The humanitarian community is generally engaged in much more immediate concerns. But even for the climate units in multilateral humanitarian organisations, which have an explicit mandate to also be looking at longer-term climate impacts and potential solutions that will help manage risks over time, geoengineering has remained a relatively obscure topic.

Figure 4. The breach intervention successfully protected the city of Saint Louis, but led to the complete destruction of the village of Doun Baba Dièye. Villagers had to migrate, without compensation for their loss of homes, land, and livelihoods.

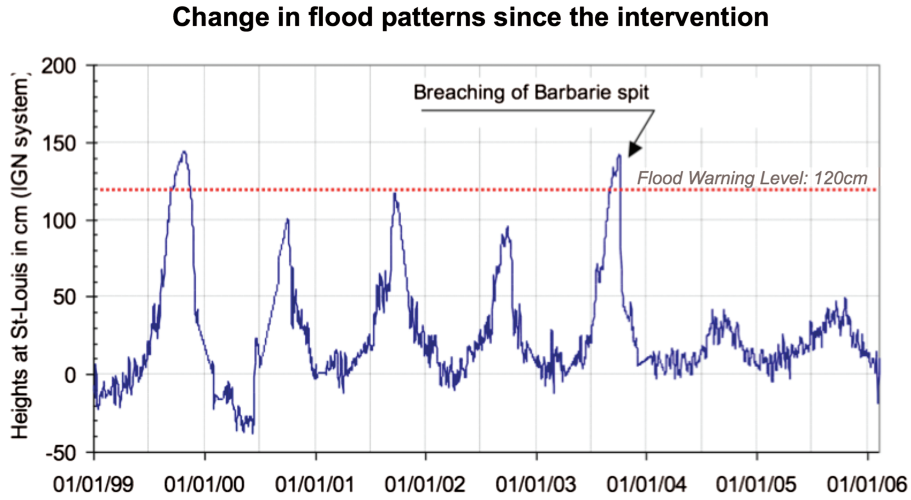

Figure 5. The breach intervention across from the island village of Doun Baba Dièye altered the hydrological behavior of the Senegal River mouth, immediately lowering flood waters and reducing subsequent peaks in the city of Saint Louis [source: *Mietton et al*., 2007]. As intended, the intervention resulted in proven net benefits in terms of flood impacts. Impacts beyond the city, however, were entirely unaddressed.

Naturally, many of the discussions have been very technical, requiring sufficient expertise on climate science and an understanding of why such engagement would be relevant, as well as a mandate to engage in an unexplored area of policy making. The Climate Centre, a reference center of the international Red Cross and Red Crescent Movement, does have that mandate, and people with the science and policy backgrounds to engage. Table 1 presents a chronology of the principal instances of the Centre's engagement on the humanitarian aspects of geoengineering.

One example of the role the humanitarian community can play is the testimony requested by the Science and Technology Committee of the UK House of Commons, addressing the possible regulation of geoengineering [*House of Commons, Science and Technology Committee*, 2010]. When parliamentarians asked "how do you think the international community should involve the developing countries in the geoengineering debate?," the first expert witness in that session, former Chief Scientific Advisor to the UK government Sir David King, suggested to engage only the developing countries that can be considered "emerging powers," since the focus for poorer countries should be adaptation and economic growth—with geoengineering not "an issue that comes to them." The second witness, Maarten van Aalst, then associate director and lead climate specialist at the Red Cross Red Crescent Climate Centre, argued differently: it is important to engage least developed countries not only for fairness reasons but even for strategic considerations—plus of course there is a need to address potential side effects of interventions "particularly on the most vulnerable populations, who are not paying for the solutions so they do not get to have a say." After mentioning the case of Doun Baba Dièye, humanitarian engagement was the primary vehicle for this perspective over the course of the parliamentary hearings.

Despite the clear relevance noted above, the near complete list of engagements in Table 1 illustrates the limited extent of contributions by the broad humanitarian community to discussions on geoengineering. Reasons for this limited involvement merit investigation: understanding the causes can help shape efforts to design and facilitate engagement when conditions merit more attention from humanitarian stakeholders. Notwithstanding, engagement of the humanitarian community in climate change discussions at large has increased dramatically over the same period. Around the year 2000 there was almost no interest in climate change as a humanitarian concern, and climate change adaptation was not seen as overlapping with humanitarian work. This changed mainly because adaptation increasingly focused on current impacts and extremes, rather than only long-term trends in average conditions. This led to a stronger focus on vulnerability and exposure—areas where humanitarian actors traditionally have expertise and interventions to offer. These overlaps were also expressed by the convergence of disaster risk reduction and climate change adaptation [e.g. *IPCC*, 2012]. The engagement of the humanitarian community has been welcomed even more strongly in the context of the UNFCCC Loss and Damage discussions, where many actors are sharing

Table 1. Red Cross Red Crescent Climate Centre Engagement in Geoengineering Endeavors

Past engagements	
2009	First conversation on humanitarian implication of geoengineering, at IIASA
	COP15: panel on "Geoengineering, Global Equity and Sustainable Development"
2010	Asilomar International Conference on Climate Intervention Technologies: presentation, and contribution to final text of conference statement, highlighting "social, humanitarian and environmental issues" [see *AICCIT – The Scientific Organizing Committee for the Asilomar International Conference on Climate Intervention Technologies*, 2010]
	United States Government Accountability Office: contribution to a technology assessment of geoengineering in response to a request from the U.S. House of Representatives' Committee on Science and Technology [see *US GAO – United States Government Accountability Office*, 2011]
	Great Britain Parliament House of Commons Science and Technology Committee: invited witness to a hearing on the regulation of geoengineering [see *House of Commons, Science and Technology Committee*, 2010]
	Publication of article at *Geoengineering Quarterly* [*Suarez et al.*, 2010]
2011	Solar Radiation Management Governance Initiative conference: game facilitation highlighting challenges in stakeholder representation [see *SRMGI – Solar Radiation Management Governance Initiative*, 2011]
	Documentary film "Playing God with Planet Earth": humanitarian dimensions featured in the context of Doun Baba Dièye geoengineering analogy [see *CBC – Canadian Broadcasting Company*, 2012]
2012	"Geoengineering Our Climate: Science, Ethics and Governance" event: contribution to working groups
	COP18: organized expert presentation on SRM at *Development & Climate Days* [see *Suarez et al*., 2013b]
2013	Publication of Earthscan Working Paper [see *Suarez et al.*, 2013a]
	Summer School on Geoengineering at Harvard University: game session on SRM
2014	Climate Engineering Conference 2014: member of advisory group, game session on humanitarian work in a geoengineered climate [see *Low et al.*, 2014]
2015	Support fieldwork in the Philippines by SRM research team from Harvard University
	Numerous events and workshops
2016	Forum for Climate Engineering Assessment (member of FCEA board of advisors)
	Carnegie Climate Geoengineering Project (advisory meeting)
Ongoing engagements	
Climate Engineering Conference 2017 (member of CEC17 advisory group)	
Support for SRMGI to organize workshops in developing countries	
Working paper on geoengineering basics for humanitarians (forthcoming)	

and shaping the important role that the humanitarian system already plays in dealing with loss and damage from current extremes, variability, and change.

However, it should be noted that these developments did not happen by chance. There was a deliberate effort to engage the development and humanitarian community in climate change discussions. There was a choice to nurture inclusion of their expertise in academic communities working to advance scientific understanding of vulnerability, impacts, and adaptation. For instance, the *Development & Climate Days* held annually for the past dozen years during the middle weekend of the Conference of the Parties to the UNFCCC, and a range of science-policy interface meetings deliberately designed to bring together the different communities (often focusing on the most vulnerable groups).

Humanitarian arguments, and advocacy by the most vulnerable countries at the Paris COP, played a strong role in the Paris Agreement aspiration to keep global warming limited to 2°, and to aim for keeping it below 1.5°. This aspiration has already been invoked to suggest that the Paris Agreement implicitly calls for geoengineering, given that modeling results indicate that even the most optimistic mitigation scenarios will not get us to the 1.5° target [e.g. *Horton et al*., 2016]. However, it should be noted that many of the

actors proposing the 1.5° target in the Paris agreement (especially those representing the most vulnerable), did not aim to endorse a package that included SRM, but rather just aimed for very aggressive mitigation pathways. If in the context of the Paris agreement the most vulnerable can now be implicitly invoked in arguments for geoengineering, then we must call for a much more explicit engagement of those groups and their priorities, as well as a clearer framing of the range of implications of the 1.5° target.

4.1. Looking Ahead

Examining our options to manage climate change in coming decades, one could argue that too little attention for adaptation to ongoing climate change will inevitably lock parties to the UNFCCC into dealing with loss and damage—here the humanitarian community has stepped up to the plate. One could argue that too little attention for mitigation (and a continued 1.5° or 2° aspiration) locks UNFCCC parties into geoengineering, with severe implications for another layer of risk to be managed (namely the changing threats associated with SRM decisions).

These emerging issues are likely to be covered in the forthcoming IPCC Special Report on 1.5°. In the same way that progress on adaptation has not come just from science, but through a deliberate strategy of atypical stakeholder engagements, a similar process will be needed for discussions on SRM. However, based on past experience humanitarians who lack climate science expertise are unlikely to actively engage unless there is much stronger sense of "imminence" of humanitarian implications—by which time it may be too late to contribute meaningfully to decision-making processes. With the Paris Agreement coming into force, the time for scaling up humanitarian engagement in SRM may have arrived.

There can be value in thinking of the humanitarian sector as "boundary organizations" that mediate learning and dialogue processes between science and society. As argued by *Guston* [2001], following Bruno Latour, boundary organizations are involved in "coproduction"—the simultaneous production of knowledge and social order—by facilitating collaboration between scientists and nonscientists.

We invite our peers to note that there can be numerous benefits for civil society organizations when engaging in geoengineering conversations. First and foremost, humanitarians enrich the diversity of perspectives. Many SRM meetings can be dominated by analytically rigorous thinking somewhat disconnected from the turbulent and noisy realities experienced by disaster managers: Those with hands-on experience know quite well that when things go catastrophically wrong for the most vulnerable, it tends to be as a result of events, decisions, and actions that do not fit neatly into mathematical models or policy frameworks. For example, during a geoengineering governance meeting in late September 2016, after hearing the interventions from experts from various fields, we highlighted that some of the language revealed "potentially delusional assumptions of rationality" about motivations, incentives, and triggers likely to shape SRM decisions and actions.

Not only can humanitarians interact with people and organizations fundamentally interested in the same core concerns (i.e., how to help humanity deal with changing risks?), but also help find information, ideas, and talents that are valuable in serendipitous ways. For example, through engagement in SRM discussions, the Climate Centre has attracted unusual collaborations, spawning innovations in fields ranging from atmospheric chemistry to an artistic experimental performance by world-class artist Tomás Saraceno [*Benn*, 2015; *Suarez*, 2015]. We have gained awareness of the observed and projected impacts of large, explosive volcanic eruptions on regional climates [*Robock*, 2013; *Morton*, 2015], and are working with new partners on a proposal to better understand and anticipate humanitarian needs after the next large sunlight is blocked by stratospheric aerosols resulting from the next climate-changing volcanic eruption.

Finally, we note that there may also be dangers in stronger engagement of the humanitarian sector in geoengineering. Two issues are particularly worth highlighting: Firstly, humanitarian involvement could serve to legitimize what emerges from SRM conversations. We are not just responsible for what we say: we are also responsible for what people hear and interpret of our words, actions, and omissions. This is especially relevant because when the audience shifts, the message changes, so a careful and informed approach needs to be developed. Secondly, there is the potential moral hazard that more attention to SRM will serve as a distraction for mitigation and adaptation efforts. This issue has been amply addressed by a diverse range of voices from strongly opposed to actively supporting SRM to most key players in between, yet

the humanitarian sector has much to learn about how its positions and actions may influence wider forces shaping causes and consequences of our changing climate vis a vis geoengineering.

5. Conclusions and Recommendations

As researchers working on climate and disasters in the humanitarian sector, we are simultaneously mesmerized and alarmed by the prospect of geoengineering. Altering the Earth's climate, whether unintentionally through anthropogenic greenhouse gas emissions or deliberately through geoengineering, is an experiment in which every person on our planet is potentially a test subject [*Suarez et al.,* 2010]. Vulnerable populations are likely to be differentially and disproportionately impacted. Our main concern is that their voices will not be heard and considered with sufficient weight in decision making about SRM. This applies from decisions about investments in research to actual application at scale, whether through globally agreed mechanisms, or through unilateral action — such as the "Geopiracy" scenarios depicted by *ETC Group* [2010], or the cleverly benevolent "Concert" of nations hypothesized by *Morton* [2016].

At stake is a moral dilemma: how to weigh the risk of negative impacts of geoengineering on some vulnerable groups against the risk of climate change impacts which may affect them or other vulnerable groups, possibly at an even larger scale? In the humanitarian sector, the *Sphere Project* [2016] offers minimum standards that begin with *Protection Principle 1: Avoid exposing people to further harm as a result of your actions*. While framed in the context of humanitarian response, extending this mindset to the geoengineering issue would imply strong aversion towards taking or endorsing action that can expose people to unknown harm. As is often the case in frameworks guiding human behavior, the risk of action is more explicitly addressed than the risk of inaction.

What we ask is caution first. We should do all we can to avoid having to face an SRM decision-making process. But if humanity does have to confront it, we propose it be guided by a few key principles. Of course, the precautionary principle applies. Fairness, with special care for those most affected and least able to cope. Inclusiveness, to ensure all perspectives are heard. Attention to risk management, accepting uncertainty as an element of the decision making. Very importantly, addressing externalities through the "learning, preparing and preventing" framework discussed in Section 2 above. And finally, prevention of the possibility of predatory geoengineering.

Applying these principles to truly participatory processes, the global community could begin to construct research and governance frameworks. The result may be a conclusion that the risks are too high, or that the risks only become acceptable when humanity is confronted with dramatic climate change scenarios, such as the runaway scenarios involving unwanted positive feedbacks or tipping points that according to *IPCC* [2015] are not likely to be reached this century. Should we reach such scenarios, participatory processes should consider arrangements for risk management — including compensation, to be agreed in advance — similar to the sort of safeguards applied to potential involuntary displacement of people by major development investments [e.g., *World Bank*, 2016].

It is strongly preferable to agree on the mechanisms, roles, and responsibilities for implementation well in advance, rather than when confronted with actual impacts (such as in the case of the current loss and damage discussions in the UNFCCC, which have many similar elements of uncertainty about attribution of impacts, and have become highly political).

Crutzen [2006] concluded his essay with this statement: "Finally, I repeat: the very best would be if emissions of the greenhouse gases could be reduced so much that the stratospheric sulfur release experiment would not need to take place. Currently, this looks like a pious wish." As humanitarians, we keep actively advocating for and investing to advance climate change mitigation, as well as adaptation with fair and effective mechanisms to address Loss & Damage. If these approaches are not enough, the humanitarian dimensions of geoengineering, including research, policy, and practice, will need to be thoroughly considered. In the context of tipping points or runaway climate change scenarios, SRM could help reduce impacts on some of the most vulnerable, but global power dynamics are not set up to ensure that the interests of the most vulnerable are elicited, considered, and addressed. In the coming years, resources should be directed not only towards better understanding of geoengineering options and their implications at the macro level, but also in full consideration of the most vulnerable, including ways to analyze and address the risks they face. Geoengineering *is* a humanitarian concern.

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