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The Asia-Pacific's role in the emerging solar geoengineering debate

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Abstract Increasing interest in climate engineering in recent years has led to calls by the international research community for international research collaboration as well as global public engagement. But making such collaboration a reality is challenging. Here, we report the summary of a 2016 workshop on the significance and challenges of international collaboration on climate engineering research with a focus on the Asia-Pacific region. Because of the

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region's interest in benefits and risks of climate engineering, there is a potential synergy between impact research on anthropogenic global warming and that on solar radiation management. Local researchers in the region can help make progress toward better understanding of impacts of solar radiation management. These activities can be guided by an ad hoc Asia-Pacific working group on climate engineering, a voluntary expert network. The working group can foster regional conversations in a sustained manner while contributing to capacity building. An important theme in the regional conversation is to develop effective practices of dialogues in light of local backgrounds such as cultural traditions and past experiences of large-scale technology development. Our recommendation merely portrays one of several possible ways forward, and it is our hope to stimulate the debate in the region.

1 Introduction

After more than 20 years of negotiations, the global community adopted the historic 2015 Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC), regarded as a key step to decarbonization of the global economy. However, the emissions reduction commitments made by the signatories to the Paris Agreement to date may put the globe on track for temperature increases of approximately 3.5 °C by 2100 (UNEP 2015). The undercurrent of climate pessimism has led to increasing interest in climate engineering, geoengineering, or climate intervention (Shepherd et al. 2009; IPCC 2014; Committee on Geoengineering Climate 2015). Among many proposed options, solar radiation management (SRM) (or albedo modification; Committee on Geoengineering Climate 2015) (sometimes also called solar geoengineering), and stratospheric aerosol injection (SAI) in particular, has received significant attention.

Because of societal and environmental concerns about SRM, researchers have called for and initiated global public engagement (SRMGI 2011; Carr et al. 2013), including outreach efforts to the Global South by the SRM Governance initiative (SRMGI) and local partners (http://www.srmgi.org/events/; Winickoff et al. 2015 for a review). There is a clear need to involve non-Western voices, including the Asia-Pacific region (Prantl 2011a, 2011b), given the potential environmental and geopolitical ramifications of SRM deployment to the region. Many Asian countries have seen their scientific prominence rise along with their economic might, which has also increased their greenhouse gas emissions. The Asia-Pacific also includes small-island states, which are highly

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vulnerable to climate change impacts (Nurse et al. 2014). Their views cannot be neglected in any SRM debate.

Global engagement, however, should not be limited to dialogues and conversations. Ideally, global engagement should involve research itself in some ways, spanning not only the natural sciences and engineering but the social sciences and humanities too. It should also include collaborative initiatives between developed and developing countries.

Indeed, the call for international research collaboration has increased substantially in the past several years. The Asilomar conference report (Asilomar Scientific Organizing Committee 2010) concludes: "[c]limate-engineering research should be conducted openly and cooperatively, preferably within a framework that has broad international support." The SRMGI (2011) states: "[e]arly collaboration on governance activities could be important for promoting cooperation on riskier SRM research (if it ever proceeds), and avoiding unilateralism." The United States National Academy of Sciences (Committee on Geoengineering Climate 2015) stated that it is important to "seek international involvement" if the USA decides to initiate a strategic research project. In making a case for field experiments, Long et al. (2015) noted that "small-scale experiments are an opportunity for international collaboration" and that "[g]lobal collaborators should be engaged as a precursor to more formal international cooperation."

And yet these calls for international research collaboration are notably thin in details. A number of critical issues need to be addressed if effective collaborative research protocols are to be developed (Ghosh 2014). Who should be involved in such a research collaboration scheme? How might we use the existing collaboration channels? What would be an important topic for research collaboration? Because of the potential of path dependency of research (Cairns 2014), it is crucial to posit these questions early on.

We believe that international research collaboration on field testing would be a crucial stepping stone if climate engineering were ever to be implemented peacefully, effectively, and equitably. Conversely, if one supports peaceful moratorium on climate engineering (either on field testing or deployment), then governments have to cooperate to comply with and enforce such a moratorium. Under both circumstances (field testing or moratorium), collaboration of social and natural scientists from different political jurisdictions would foster mutual learning and an effective dialogue on the global governance for climate engineering and enable useful assessment. Regardless of one's position, therefore, it is significant to explore how we can establish an international and cross-cutting collaboration on SRM research—be it science, governance, or public engagement.

Against this background, an international workshop on climate engineering was convened in Tokyo from March 22–23, 2016 to discuss the significance and challenges of international collaboration on climate engineering research with a specific focus on the Asia-Pacific region. The participants included natural scientists, social scientists, and humanities scholars. The organizing committee identified and invited researchers and experts from Japan, Asia, and the Pacific island as well as from the USA and Europe (Table 1). Our discussions focused primarily on SRM geoengineering options, particularly SAI.

This article summarizes and distills key messages as to how the Asia-Pacific region could contribute to international collaboration on climate engineering research. It is important to note that what we mean by "research collaboration" is not collaborative research for deployment of SRM but "research for assessment" along the lines of the interdisciplinary research programme funded by the German Research Foundation (Oschlies and Klepper 2017). Although such research may lead to deployment in the future, more comprehensive, coordinated and transdisciplinary assessment can also be conducive to a critical appraisal of technical, political and social

Table 1 Participants of the workshop (in the alphabetical order by last name). The affiliations correspond to those at the time of the workshop

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Joshua Horton	Harvard University
Atsushi Ishii	Tohoku University
Hiroki Kashimura	Japan Agency for Marine-Earth Science and Technology
Takanobu Kosugi	Ritsumeikan University
Atsushi Kurosawa	The Institute of Applied Energy
Penehuro F Lefale	Joint Centre for Disaster Research, Massey University
Jolene Lin	University of Hong Kong
Kooiti Masuda	Japan Agency for Marine-Earth Science and Technology
Hiroshi Mizutani	Nihon University
John Moore	Beijing Normal University
Kentaro Ono	Honorary Consul of the Republic of Kiribati in Japan
PAN Jiahua	Chinese Academy of Social Sciences
Andy Parker	Institute of Advanced Sustainability Studies
Masahiro Sugiyama	The University of Tokyo
Taishi Sugiyama	Central Research Institute of Electric Power Industry
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feasibilities of SRM. Thus, our recommendation centers on potential topics for transdisciplinary research of SRM assessment, and possible strategies for building capacity to enable such research in the Asia-Pacific region. Our recommendation, of course, does not fully represent concerns, interests or perspectives of people in the Asia-Pacific. It is, however, our hope that our proposal will stimulate more thinking and dialogue in the region on this fast-evolving and important issue.

2 Scientific needs of the Asia-Pacific

There is some evidence that, for people in the Asia-Pacific, the primary concerns over solar geoengineering are centered around its potential impacts and benefits rather than its mechanisms, although (initial, small-scale) field testing has attracted international attention (e.g., Temple 2017). This is exemplified by the new Chinese research program, the China Geoengineering Program (http://www.china-geoengineering.org/), which started in the summer of 2015. The program places a priority on impact analysis after consultation with stakeholders. Another example is the field study in the Philippines (O'Brien 2015). Respondents reported significant interest in the possible benefits and risks of climate engineering at the local level.

In recent years, the Geoengineering Model Intercomparison Project (GeoMIP) (Kravitz et al. 2011, 2013, 2015; http://climate.envsci.rutgers.edu/GeoMIP/) (with participation from Japan and China) has improved our basic understanding of SAI, including its risks and

benefits. A series of standardized computer simulations indicated that SAI generally could bring the climate closer to the pre-industrial than in global warming scenarios (Irvine et al. 2016), and could ameliorate various impacts, including those of climate extremes such as storm surges due to tropical cyclones (Moore et al. 2015). Modeling studies also showed limits to SAI. For instance, it cannot provide a perfect remedy to greenhouse gas-induced climate change, yielding geographically heterogeneous responses of temperature and precipitation. It cannot either address ocean acidification since it does not directly reduce the atmospheric concentration of carbon dioxide.

Moreover, significant issues and uncertainties remain with important areas of SRM impacts such as agriculture (Pongratz et al. 2012; Xia et al. 2014; Yang et al. 2016), ecosystems (Russell et al. 2012), and human health (Effiong and Neitzel 2016). Impact analyses to date have been limited to basic climatic variables (temperature and precipitation) but extreme events such as storm surges (except for the aforementioned study), as well as health and many biosphere processes have yet to be adequately explored, not to mention the associated uncertainties. These are particularly acute problems for the Asia-Pacific region given its extremely polluted cities and pressures on agriculture for food security, along with the impacts on other natural resources (water and biodiversity in particular).[1]

Evaluating such impacts would necessitate finer-resolution data as well as a suite of different impact models. Climate modeling researchers can collaborate with ongoing projects focusing on various areas of impacts, such as Coordinated Regional Climate Downscaling Experiment (CORDEX), Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP) (as mentioned already by Irvine et al. 2016), and Agricultural Model Intercomparison Project (AgMIP), in order to improve their analysis.

Impact analysis is an area where scientists in the Asia-Pacific region can contribute greatly. With the data from projects like GeoMIP openly available, scientists and researchers from the region can get access to the data and conduct research, utilizing local knowledge about key sectors. It will also be a useful exercise for the local researchers to appreciate strengths and limits of the prevailing mode of modeling research.

There is, however, a simple but formidable hurdle: sharing of large data. Analyzing potential impacts, benefits, and risks of climate engineering would require data inputs from GeoMIP and related exercises. The practical difficulties of downloading terabytes of data remain considerable in many developing countries, though once the data is downloaded it can be analyzed with standard software in reasonable times on personal computers.

A more significant challenge is how to assist capacity building of local research community in the region. Capacity building is often used in the context of international development to refer to the process by which individuals or organizations in developing countries improve their skills and knowledge in order to achieve a certain goals (e.g., United Nations Committee of Experts on Public Administration 2006). Here capacity building can more specifically indicate the activities that stimulate the technical capacities for local scientists in the Asia-Pacific to participate in an international research program of impact analysis of climate engineering such as GeoMIP.[2] The local community can perhaps leverage existing channels of international research network on climate change impacts and adaptation between developed and developing countries. Since impact analysis of climate engineering is somewhat

[1] Note that some of these issues will be taken up by GeoMIP6 (Kravitz et al. 2015).

[2] There is an ongoing joint research activity between a Harvard research group and their Philippines counterpart, which is looking into agricultural impacts of SRM.

similar to that for anthropogenic global warming (except for potentially important caveats such as the effects of ultraviolet and diffuse visible radiation), one could combine a training session of impact analysis along with that on SRM.

There remain the difficulty and uncertainty of the current generation of climate and earth system models to predict key impacts of solar geoengineering, such as local agricultural damages (Xia et al. 2014), but this is also true to general projections of climate change impacts. Capacity building therefore can serve as an opportunity to train local scientists about uncertainties in impact assessment of both anthropogenic climate change and SRM.

3 How to engage the Asia-Pacific

Public engagement is crucial for governance of climate engineering research (Carr et al. 2013). Climate engineering, if deployed, would have global impacts. It is thus normatively justified that those who will be affected should have a right to say about whether and how research should proceed, since research is the gateway for potential wide-scale deployment (Rayner et al. 2013). More precisely, it is because climate engineering is surrounded by deep uncertainty in terms of the potential impacts of its deployment and high societal stakes. Some have argued that because it is an archetype of so-called "post-normal" science (Funtowicz and Ravetz 1993; Bellamy et al. 2012; Sugiyama et al. 2017), climate engineering requires wide public deliberation, not limited to scientists and experts but open to ordinary citizens, including indigenous and socially disadvantaged people that might be disproportionately impacted by deployment (Corner et al. 2012; Carr et al. 2013; Winickoff et al. 2015; Burns and Flegal 2015).

However, public engagement of climate engineering faces numerous—both practical and normative—challenges. And the challenges deepen further as one goes beyond the rich Western democracies into the culturally and economically heterogeneous Asia-Pacific region.

First, there is a question on who are the publics and stakeholders that should be engaged, and how we should weigh opinions of them in light of different cultural and socio-political backgrounds and vulnerabilities to climate change. From a liberal democratic perspective, all individual voices should be respected equally (Corner and Pidgeon 2010; Wong 2013). However, it could be argued that groups that are particularly vulnerable to climate change, such as the Pacific islands, should have their voice privileged in the climate geoengineering debate.

Meanwhile, in societies where Confucian values have been historically and culturally embedded, including East Asian countries such as China, Korea, and Japan, public participation may not necessarily translate into equal participation by autonomous individuals. Rather, Confucian-based cultures are inclined to support a meritocratic system for deliberations, in which the decisions of the "virtuous and capable leaders" are widely respected (Wong 2013). In other words, public engagement of all individuals in a symmetric manner will not be a universal moral foundation—for some occasions and cultural contexts, different modes of engagement may need to be pursued.

Second, who would be most trusted to lead a local conversation on climate engineering in the Asia-Pacific? There is, of course, no universally applicable mode of conversation of climate engineering (Rayner et al. 2013). In the experience of engagement with African stakeholders, Winickoff et al. (2015) asserted that the conversation must be contextualized by local communicators. Likewise, in the Asia-Pacific context, the input of regional scientists and experts would be important as well. On the other hand, in some countries with a strong tendency of multilateralism (e.g., Japan and India), internationally acclaimed experts could

also be influential in national debate about geoengineering (see Asayama and Ishii 2014 concerning the high authority the Intergovernmental Panel on Climate Change (IPCC) commands in Japan, for example).

Third, many Asian countries have a long history of artificial rainmaking, and countries such as China have had large-scale civil engineering projects (see Edney and Symons 2014; Weng and Chen 2014; and Moore et al. 2016, for the context in China). Citizens might be inclined to associate SRM with these other technologies, which in turn could affect their perceptions on it. For example, Sugiyama et al. (2016) attribute high alleged awareness in China, India, and the Philippines found in their web-based survey to such historical contexts. How should we then consider these local contexts when engaging citizens and stakeholders in the region?

Given the different modes of trust across the region and various local backgrounds, there is no ready-made public engagement method; one might have to adjust or create their own engagement practices to effectively and substantively capture their local societal stakes (Carr et al. 2013).

Cultural differences notwithstanding, several studies on public perceptions on climate geoengineering in the Asia-Pacific region evince some clear sentiments. An in-depth interview with local stakeholders in the Philippines (O'Brien 2015), a web-based public opinion survey with college students in six Asia-Pacific countries (Sugiyama et al. 2016), and focus groups with Japanese ordinary citizens (Asayama et al. 2017) all reveal that the Asia-Pacific people are cautiously and conditionally in favor of SRM research (but not necessarily field experiments). More importantly, these results also show that the respondents tend to support a fairly strict interpretation of the Oxford Principles (Rayner et al. 2013) and demand strong international cooperation. Although these studies are limited in coverage and representativeness, a propitious foundation might exist to foster multi-dimensional public engagement in the Asia-Pacific region, even in the face of the challenges attendant to heterogeneous and intercultural backgrounds.

Finally, early public engagement on emerging technologies such as SRM faces the issue of framing effect (Bellamy et al. 2012). Strong normative framing such as "climate emergency" could prematurely close down the decision context and exclude diverse perspectives should be brought into a debate (Asayama et al. 2017). In countries vulnerable to harms caused by anthropogenic global warming (e.g., Pacific Islands), such an emotionally-anchored problem framing may create a strong sense of hope for solar geoengineering, which could in turn eliminate a room for critical conversation. In engagement processes, extra careful attention should be paid to problem framing and language used to communicate.

4 Advancing governance discussions in the region

What would be the first step to facilitate effective international conversation and collaboration for climate engineering governance? It is unclear if the global community will embark on small-scale field experimentation to speed up serious consideration of climate engineering, or refrain from such a pathway. However, it would be prudent for the Asia-Pacific region to take steps to foster an atmosphere of mutual understanding and a platform for knowledge-sharing, given how long it takes to institutionalize a governance framework.

Creating a network of experts could be a good starting point as in the case of Africa (Kassaye 2014). Since climate engineering is a low priority in many jurisdictions in the Asia-Pacific region, given many other pressing issues such as economic growth and local environmental pollution (as illustrated by Lin 2015 for the Association of Southeast Asian Nations (ASEAN)), we believe that a formal intergovernmental structure for the region would not be

feasible at least for the time being. Thus, a good initial step might be for states in the Asia-Pacific region to establish a network of researchers and stakeholders, in careful coordination with public engagement considerations mentioned in the previous section (see also Dilling and Hauser 2013). Regardless of how SRM develops, building regional capacity and scientific connections should be a useful exercise.

Initially it might be most practicable to establish a voluntary, ad hoc group of researchers, with subsequent creation of a government-appointed body. Such a network of experts would constitute a bridge toward a more formal institutional framework when climate engineering gets placed on the agenda of an intergovernmental panel or negotiations.

Capacity building or development should also be encouraged before establishing a formal Asia-Pacific intergovernmental framework. First and foremost, there is an urgent need to undertake an assessment of the current situation (situational analysis) regarding programs and activities related to climate engineering in the region. It is particularly important to identify mitigation and adaptation research efforts in the region given their potential pertinence to climate engineering. The situational assessment would provide the necessary foundation for formulating a capacity development strategy for climate engineering in the Asia-Pacific region.

Another point concerns transparency and accountability. As the research progresses, the countries in the region must be apprised of the results. It is essential to identify the independent scientists and experts, or suitable bodies, who can monitor research activities, but who are not directly involved in the SRM research that is undertaken.

It is also critical to systematically foster a conversation in the region to raise awareness and knowledge about climate engineering in ways that are responsive to local and historical contexts (e.g., personal communication with Kentaro Ono, Honorary Consul of the Republic of Kiribati in Japan on July, 23rd, 2016). Efforts are already underway in the Asia-Pacific region, including outreach meetings conducted by SRMGI in concert with local partners in India (with the Council on Energy, Environment and Water in 2011 and 2016), China (with the Chinese Academy of Social Sciences, and the Chinese Association of Science and Technology) (Edney and Symons 2014), Pakistan (with the Sustainable Development Policy Institute in 2011 and 2016), Bangladesh, Thailand, and the Philippines (all three in 2017). Also of note are a 2011 conference in Singapore (RSIS Center for NTS Studies 2011), another 2-day conference in India in 2014 (CEEW and InSIS 2014), a Fiji workshop in 2014 (Beyerl and Maas 2014; Lefale and Anderson 2014), a 2017 meeting held by the World Agroforestry Center Philippines and a Harvard research group in Manila, and our own Tokyo workshop. However, to date, these initiatives have been mostly small in scale and restricted to ad hoc, one-off events (Winickoff et al. 2015). The network group mentioned above should include local scientists and support sustained efforts to foster a regional conversation about climate engineering in various communities.

5 A way forward

Given the discussions above, what would be a fruitful approach to foster international research collaboration on climate engineering across the disciplines from natural sciences to social sciences and humanities? As a concrete first step, we propose the following:

(1) Exploit the synergy between climate impact analysis and impact studies of climate engineering, which should be combined with capacity building exercises in the Asia-Pacific.

(2) Establish an ad hoc Asia-Pacific experts working group on SRM, which should work with existing collaboration channels, including the Asia-Pacific Network (APN) for Global Change Research and Future Earth, and should also explore appropriate modes of engagement in different political/cultural contexts.

We below elaborate on each point in turn.

5.1 Synergy between impact analysis of anthropogenic global warming and climate engineering

There are some commonalities between analyses of climate change impacts and benefits and risks of climate engineering, at least at the first-order approximation. A number of initiatives have been conducted to train scientists from developing countries so that they can perform vulnerability analysis and adaptation research in their own countries/regions. Including GeoMIP-related datasets in such a training course allows researchers to smoothly obtain hands-on experiences with geoengineering research, which also circumvents the difficulty of transferring large-scale data over the internet. Participants in such a program should learn uncertainties and understand strengths of, and limits to, the major modeling methodologies. Moreover, exploiting this synergy might enable overcoming one of the hurdles in the region: the lack of funding for this emerging topic.

Indeed, the China Geoengineering Program will host a first summer school in July 2017, in Beijing,[3] offering teaching courses with some support for students and researchers from the developing world, along with access to a large collection of data from the GeoMIP climate scenarios from many models, as well as higher resolution data from in-house models. Initiatives like this would help also educate local communicators for geoengineering.

5.2 Asia-Pacific working group on SRM governance

The Asia-Pacific can follow the lead of African academics by establishing its own working group on SRM research and governance. Following ground-breaking outreach meetings of the SRMGI in 2012 and 2013 (African Academy of Sciences and SRMGI 2013), a pan-African working group was established in 2014, aiming to create a bottom-up African initiative on SRM governance (Winickoff et al. 2015). A similar Asia-Pacific group could be a focal point of governance discussions and various research activities, and particularly research for assessment.

Although the Tokyo workshop invited mostly researchers, the next logical step would be to involve stakeholders from governments, the business sectors, and civil societies. Initially, the working group can start as a small voluntary group. But as it grows, it needs to collaborate with existing research networks related to climate change and global environmental change, within and outside the Asia-Pacific region. In the future, it might be ideal that the working group would collaborate with communities in other regions such as the African group and a newly established Academic Working Group on International Governance of Climate Engineering, an initiative of the Forum for Climate Engineering Assessment (http://ceassessment.org/awg/).

[3] http://www.china-geoengineering.org/index.php?m=content&c=index&a=show&catid=326&id=180, retrieved on April 25, 2017.

The working group would face several critical questions. Who should lead the working group and hence the debate of SRM governance? How can the working group ensure and expand representation in the region? Who should financially support this working group? As mentioned above, the Pacific islands have strong stakes and concerns over climate change impacts, and these vulnerable countries indeed may as well take the lead. But these countries require financial support because of their limited financial resources. Should the working group be funded by a global or multilateral scheme such as the APN (http://www.apn-gcr.org/), SysTem for Analysis, Research & Training (START) (http://start.org), and/or Future Earth (http://www.futureearth.org/)? Or should a single country, such as China and Japan, fund such a group? If it relies too much on a single country or entity, some may question its legitimacy as a forum for governance discussions. And would it be better to establish separate fora for academic and stakeholder discussions? The working group should carefully contemplate these items as it proceeds and should learn from past experiences of the IPCC, i.e., how the IPCC expanded participation from developing countries with its institutional innovation (Agrawala 1998).

Last, but not least, the working group also has an important task to develop effective communication and engagement strategies in light of different cultural backgrounds. As indicated above, efforts to foster deliberation in the region will need to acknowledge a wide range of cultural traditions, including different views of authority and attitudes toward the relationship between humans and nature.

As a first workshop of its kind, we could not elaborate on various important issues. For instance, what kind of factor (e.g., severe damage caused by extreme weather, geopolitical tensions within the region or across other regions) would motivate the Asia-Pacific region, currently passive in the global governance debate, to take the initiative? Would international and interdisciplinary collaboration in the region take a shape different from that in Europe or North America? What would the effective method to enlarge representation (both in terms of the number of countries and variations of cultures and values) be? These issues can be a good starting point for cultivating reflexive dialogues on future research and governance of solar geoengineering and climate change at large.

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