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PERSPECTIVE

Seeding the clouds to reach the sky: Will China's weather modification practices support the legitimization of climate engineering?

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Abstract In this Perspective, we discuss whether in times of quickly proceeding global environmental change, radical global interventions like "climate engineering" may gain legitimacy in China and eventually be deployed or supported. We argue that one cornerstone for whether climate engineering, and solar radiation management in particular, could gain legitimacy in China, is its current weather modification programme. In China, weather modification is institutionalized and deployed on a large scale, and current narratives around the legitimacy to intervene into the local climate may provide a rationale for interventions such as solar radiation management. In the end, in the same way as Deng Xiaoping coined the phrase "stepping on stones to cross the river" in the era of China's Industrial Civilization, narrating China's "Ecological Civilization" may want to make use of "seeding the clouds to reach the sky". [See ESM for a summary of the article in Chinese.]

Keywords Anthropocene · China · Climate change · Climate engineering · Geoengineering · Weather modification

INTRODUCTION

Global climate change places novel and often uncomfortable questions for scholars of environmental policy and, more broadly, earth system governance. One is the emerging argument, made increasingly by some experts from North American or European research institutions, that the limitation of global warming to 2.0 °C above preindustrial levels—and even more so to not more than 1.5°—will require global programmes of "climate engineering". So far, there is widespread opposition to the idea of climate engineering, and to research on this topic, especially in industrialized countries (Corner et al. 2013; Macnaghten and Szerszynski 2013; McLaren et al. 2016). Additionally, so far this debate has been largely restricted to the "Western" academic community, especially in Germany, the United Kingdom and the United States (Biermann and Möller 2019).

The role and position of major developing countries has hardly been studied, leading to only a very limited picture of the entire global problematique. China, in particular, is a country that may have a very special position in the climate engineering discourse given its position as the world's largest emitter of carbon dioxide but at the same time also a country that is highly vulnerable to climate change. Until 2050, "approximately 30% of the regions in China would be affected by eco-system vulnerability, of which about 61% would be relatively vulnerable to precipitation variation" (Gao et al. 2018, p. 10).

Furthermore, China is currently one of the countries with considerable research and development investment in climate engineering (with a programme of US$ 3 million, see Temple 2017), next to programmes in the United States (the project ScoPEx with US$ 20 million, see Neslen 2017) and Germany (research funding made available of nearly EUR 10.5 million, Kiel Earth Institute, n.d.). According to Janos Pasztor, Executive Director of the Carnegie Climate Geoengineering Governance Initiative, "[b]ecause China is increasingly influential on climate issues, the broader significance of the [Chinese] geoengineering program may be the international example that it sets" (Temple 2017).

In this *Perspective*, we argue that to understand China's likelihood to possibly deploy climate engineering, we must

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take a closer look at current weather modification programmes and related narratives. We hereby focus on one approach to climate engineering, "solar radiation management". Solar radiation management aims at cooling the planet by increasing the amount of sunlight reflected back to space (Cao et al. 2015). One possible approach to solar radiation management is the injection of Sulphur particles into the stratosphere through airplanes flying at an altitude of 20 km. These particles reflect sunlight in a process that will eventually lead to a global cooling effect and at the same time will have additional effects on, for example, local weather patterns or the ozone layer (Sugiyama et al. 2016). From a lay person's perspective, this process is similar to weather modification techniques, where chemicals are injected into clouds to accelerate the creation of ice crystals that bring about rain (McLeod et al. 2018). One major difference, however, is the altitude on which the two measures operate, and, accordingly, the localization, extent and predictability of their effects.

While we hence acknowledge that solar radiation management and weather modification are to some extent different (see also Edney and Symons 2014; Weng and Chen 2014; Liu and Chen 2015; Moore et al. 2016), one cannot rule out that given similarities, weather modification could serve as a means *to incrementally build legitimacy for solar radiation management,* in China and beyond, which may ultimately make it possible to deploy it.

In the area of climate engineering, as with any novel and risky technology, policy-makers face tremendous uncertainties. Therefore, governments will need to support deploying technologies through their legitimate authority (see Morrow et al. 2013). Contrary to the belief that domestic resistance is not likely to constrain the Chinese government (see Lane 2013), we do not see China as an exception to this general need to generate legitimacy for the deployment of risky technologies. And it is here where we see weather modification as a possible stepping stone to incrementally build legitimacy for solar radiation management. This article hence contributes to an ongoing debate on whether the Chinese state is likely to implement climate engineering, and solar radiation management in particular (Edney and Symons 2014; Weng and Chen 2014; Liu and Chen 2015; Moore et al. 2016).

We start with a review of the state of climate engineering in China. Using the dimensions of political legitimacy as outlined in Holbig (2013), we then analyse to what extent weather modification is likely to provide grounds for domestic and international legitimization of solar radiation management in China. For our analysis, we reviewed literature on climate engineering in China, and conducted an online literature search of policy documents and government websites on weather modification in China, the latter all in the original language.

THE STATE OF THE DEBATE ON CLIMATE ENGINEERING IN CHINA

Climate engineering has not yet become a subject that China's major governmental agencies are concerned with. The State Council, the National Development and Reform Commission, Ministry of Ecology and Environment or National Energy Agency, they all remain silent about climate engineering on their websites.[1] Only China's Meteorological Administration has 15 entries for climate engineering (*qihou gongcheng*), five of which date back to 2010. The two latest articles are from 2016. The first article reports some findings of NASA on rapid global warming and mentions climate engineering as a possible solution (Wu 2016a). The other article discusses research on climate engineering and concludes that even the most promising climate engineering measures may not be able to cool the climate (Wu 2016b).

At present, climate engineering in China is foremost a topic for research. In 2012, climate engineering became listed as a research issue, and from then on, it was possible to apply to the National Natural Science Foundation of China for research funding on geoengineering (Weng and Chen 2014). The Ministry of Science and Technology funded a US$ 3 million programme on geoengineering that involves Beijing Normal University, Zhejiang University and the Chinese Academy of Social Sciences (Temple 2017). According to participants, the project is "the first for coordinated geoengineering research in China" (Cao et al. 2015, p. 193). Several articles have been published, as listed in Cao et al. (2015). The project wants to understand, among others, the physical mechanisms of geoengineering, "with the aim of designing optimal geoengineering schemes that are targeted to specific regions, in particular, China and the Arctic" (Cao et al. 2015, p. 193). Research is undertaken on land-based geoengineering schemes (e.g. irrigation and afforestation and reforestation—not typically seen as geoengineering in the West), ocean-based geoengineering and atmosphere-based geoengineering schemes. According to Cao et al. (2015, p. 194), "as a result of this coordinated geoengineering research project, China will play a key role in the international geoengineering research community by providing scientific advice for climate negotiation, planning, and coping strategies".

Other Chinese climate change scientists express "concern over the risks of geoengineering" (Weng and Chen 2014, p. 3; see also Edney and Symons 2014). However, they see some likelihood that the Chinese government may

[1] Search of websites of the State Council, the National Development and Reform Commission, the Ministry of Environment and National Energy Agency, using the terms "*qihou gongcheng*" and "*diqiu gongcheng*" on 9 May 2018, and no entries were returned.

deploy climate engineering technologies at some point. Moore, a Beijing-based US scholar working in this field, and colleagues (2016) argue that throughout China's history, its political leadership did not refrain from large-scale engineering projects. For example, large-scale afforestation and reforestation projects have been initiated by political leaders since the 1950s (Moore et al. 2016). A publication by two scholars from the Policy Research Centre for Environment and Economy of the Ministry of Environmental Protection in Beijing and the Chinese Academy of Social Sciences (Liu and Chen 2015) also refers to a legacy of large-scale engineering projects. They highlight that political leaders have always handled projects with great caution and have implemented them only after a long period of careful consideration and planning. They describe climate engineering as "the final alternative" or a "Plan B to conventional climate change mitigation measures" (Liu and Chen 2015, p. 200).

What is notable in the article of Liu and Chen (2015) is that the "social question" seems to be the parameter to which climate engineering must stand up to scrutiny. According to them, "conventional mitigation practices are not only economically expensive, but they also result in significant social impacts. Climate engineering measures with relatively small impacts and risks may be a reasonable alternative choice" (Liu and Chen 2015, p. 199). They also argue that consideration needs to be given to the fact that climate engineering measures, comparable to technologies as nanotechnology and transgenic technologies, do not result into "louder disputes with respect to their governance than the implications of their usage" (Liu and Chen 2015, p. 199). Consent by the public appears to be pivotal for the legitimacy of climate engineering.

The opinion piece of two scholars from the Chinese Academy of Social Sciences (Weng and Chen 2014) and the article of Edney and Symons (2014) are the most doubtful about China taking unilateral measures to implement climate engineering. According to Weng and Chen (2014), uncertainties associated with solar radiation management and possible social disruption make the deployment of such technologies unlikely. Edney and Symons (2014, p. 1) find that "no significant constituency is currently promoting unilateral implementation of SRM [solar radiation management]".

According to an online survey covering 514 Chinese undergraduate students, climate engineering can count on some support by part of the population (see Sugiyama et al. 2016). Students are aware and concerned about climate change, with 97.5% believing that global warming is happening, and among them, 88.3% think that climate change is mostly caused by human activities. On a four-point scale, only 6% are "not at all worried", or "not very worried", about global warming, and 99% of the respondents ask from their country to make a large- or medium-scale effort to reduce global warming regardless of possible economic consequences. After being introduced to information about stratospheric aerosols, the share of respondents that is positive about their use is always larger than of those rejecting it. For example, 61.9% of the respondents "strongly" or "somewhat" would accept the use of stratospheric aerosols if it helped avert massive and irreversible impacts from global warming. 60.7% of the respondents "strongly" or "somewhat" accept the use of stratospheric aerosols to get more time to cut carbon emissions (see Sugiyama et al. 2016). On the other hand, the study by Edney and Symons (2014), based on an analysis of state newspaper articles, finds that public attitude is rather mixed.

In conclusion, this review suggests that climate engineering might be politically accepted in China as a solution if research and development showed that measures bear smaller risks for society than conventional climate change mitigation measures. Furthermore, there seems to be a chance that climate engineering gains acceptance by parts of Chinese society.

WEATHER MODIFICATION REGULATION AND PROGRAMMES IN CHINA

While climate engineering is currently still merely a research topic in China, weather modification has been applied on a large scale for long. China's *Weather Modification Administration Regulations* (State Council 2002, own translation) define weather modification in Article 3 as follows: "weather modification refers to preventing or mitigating meteorological disasters, the rational use of climate resources, and, under appropriate conditions, implementing activities like cloud seeding, hail prevention, elimination of rain, the elimination of fog or frost, by means of scientific (and technological) methods that artificially influence local climatic physical and chemical processes". Related functions hence are to mitigate the effects of drought, increase water levels in rivers and reservoirs, prevent and mitigate hailstorms, or eliminate fog around airports and roads and to guarantee the weather for important events.

The China Meteorological Administration (CMA) is the governmental authority in charge of overseeing weather modification. It is directly subordinate to the State Council. In the list of responsibilities of the China Meteorological Administration, weather modification belongs to the Administration's responsibilities of disaster prevention (CMA 2011). In 2007, Weather Modification Offices were set up on all levels of government, down to the level of the city or district.

The State Council's (2002) "Weather Modification Administration Regulations" is an early means to institutionalize weather modification. It distinguishes responsibilities across administrative levels. The national level supports research and technology development for weather modification (Article 7). The provincial level decides on the location of weather modification, based on local climate particularities and geographical conditions (Article 8). Weather modification then shall be carried out under the leadership and coordination of the government above the county level (Article 4). The meteorological department on the level of the county has to develop plans for weather modification (Article 5). Results and progress of weather modification shall then be assessed by external experts. Such assessments also serve as a basis for the performance evaluation of the department.

The Regulations furthermore specify details of weather modification operations. The personnel that carries out weather modification must be registered with the local police (Article 10). The local police needs to be informed of interventions, to be able to carry out safety protection measures. Rockets must be produced by enterprises designated by the China Meteorological Administration (Article 15). The transport of these rockets falls under the regulations of the administration of weapons and explosives (Article 16). The local people's army assists in the storage of weather modification devices (e.g. rocket launchers, shells or rockets) (Article 17).

Weather modification received formal recognition as an important policy measure when it was incorporated in the "Central Document No. 1" of the years 2012 and 2013 (*yihao wenjian*) (see Ministry of Agriculture 2012; Central Government of the People's Republic of China 2013). The "Central Document No. 1" is the first document issued by the Central Committee of the Communist Party every year after the spring festival and points at important issues for rural development (*sannong*). Furthermore, the Office of the State Council in 2012 issued an "Opinion regarding further strengthening weather modification" (Office of the State Council 2012; in the following referred to as "Opinion on Weather Modification"). Opinions "communicate government policies" and propose solutions "on issues of importance to the Chinese authorities" (Practical Law UK Glossary 2018).[2] The "Opinion" sets forth the establishment of a sound weather modification system by 2020. Development goals are an increase in rain and snow by more than 60 billion tons annually, and an increase in the area under hail protection from 470 000 km^2 to more than 540 000 km^2.

The current National Weather Modification Plan (2014–2020) as a tool to further promote and implement weather modification follows the first "National Weather Modification Development Plan" (2008–2012). In every of the six regions that are mapped out in the plan (Northwest, Southwest, Southeast, Centre, Huabei and Northeast China), "focus areas" of hundreds of square kilometres are outlined, with respective targeted interventions. These focus areas are categorized according to their function, that is, "protection of food security", "protection of ecological security" and "protection of water security". We may hence challenge the finding of Weng and Chen (2014, p. 3) that weather modification is implemented "only under specific weather conditions, and in a small range of area" in China. Given the scope of administrative regulations and the ambitiousness and comprehensive coverage of the plan, weather modification appears rather institutionalized in China. In China, one single province can be as large as a European mid-sized state. The National Weather Modification Plan asks provinces to cooperate even more in their implementation of weather modification (see below), which means that the scope of weather modification may have the potential to influence the regional weather.

DOMESTIC POLITICAL LEGITIMIZATION OF WEATHER MODIFICATION

We now assess how and to what extent the government and public authorities in China create internal legitimacy for existing programmes of weather modification, keeping in mind potential similarities to a possible future deployment for the legitimization of solar radiation management.

We use the dimensions of political legitimization as outlined in Holbig (2013), which are based on the model of political legitimacy by Beetham (2013). Our analysis hence starts out with the question how the government normatively justifies its authority to use weather modification. We then continue by asking what "normative justification of performance" is employed by the government to substantiate that weather modification is the right means to previously defined ends. And finally, the question is whether and how the government claims public consent for weather modification. Understanding how weather modification programmes are politically legitimized will provide insight into the possible expansion of such strategies of political legitimization to solar radiation management.

[2] Thomson Reuters 2018, Practical Law UK Glossary, "Guiding opinion (zhidao yijian)". https://uk.practicallaw.thomsonreuters.com/2-522-0010?originationContext=document&transitionType=DocumentItem&contextData=(sc.Default)&firstPage=true&comp=pluk&bhcp=1.

Legitimacy through alignment with state ideology

First, ideology is an important means in China to legitimize a policy measure (Holbig 2013; Brown and Berzina-Cerenkova 2018). Every leader develops a guiding ideology that will be paramount for the time of tenure. This guiding ideology will be passed on to subsequent leaders, and throughout time, new political programmes or policies will list and use ideologies from preceding leaders to create legitimacy.

Regarding weather modification, the paragraphs on "guiding ideology" and "basic principles" in the State Council Office's Opinion on Weather Modification (Office of State Council 2012) provide a point of departure for the political legitimization of weather modification. Under "Guiding ideology", the document says: "Under the guidance of Deng Xiaoping's theory and the important ideology of the 'three representatives', deepening the implementation of the Scientific Outlook on Development, weather modification shall be made a powerful means to mitigate and prevent disasters, build an agricultural public service system and guarantee water resources security" (Office of State Council 2012, own translation). The "basic principles" see a continued commitment to "'people orientation', putting the safety of people's lives and property first", as central (Office of State Council 2012, own translation). While Deng Xiaoping's theory and Jiang Zemin's "three representatives" can be seen as only remotely related to weather modification, Party General Secretary Hu Jintao's "people-oriented development" and "scientific outlook on development" feature more prominently in the legitimization efforts of weather modification. For the sake of maintaining analytical depth, our focus will be on the former.

The motivation for people-oriented development was to "help close the gap between officials and the people they were meant to be serving" (Brown and Berzina-Cerenkova 2018, p. 327). The term originates from philosopher Mencius' *yi ren wei ben*, that is, 'putting people first'/'person as the core' (Brown and Berzina-Cerenkova 2018, p. 327). Also the China Meteorological Administration sees itself in a tradition of adhering to "people-orientation" (CMA 2011). For weather modification, "people orientation" translates into the protection of people's life and property and the minimization of disaster losses (Office of the State Council 2012). In the section "societal benefit", the National Weather Modification Plan (NDRC and CMA 2014, p. 67, own translation) says: "Weather modification is the Party's and the government's livelihood project to promote socio-economic development and protect people's safety and welfare, its service to the public to protect national food security, water resources security and ecological security". Weather modification is hence framed as a "service", for example, for socio-economic development (NDRC and CMA 2014, p. 11) or the "national economy" (NDRC and CMA 2014, p. 51), or as having a "public service and societal management function" (NDRC and CMA 2014, p. 67, own translation).

Weather modification is also seen as a "service" to agricultural production (NDRC and CMA 2014, p. 67). The 2012 Opinion on Weather Modification foresees the strengthening of weather modification to service agricultural production, where weather modification for some years has been playing a supporting role (Liu and Chen 2015, p. 200). The National Weather Modification Plan also addresses local governments in vulnerable agricultural areas to use weather modification. It asks to create meteorological conditions that are conducive to crop growth and allow for a stable production of grain (NDRC and CMA 2014, p. 4). Weather modification here again is presented as serving the people or as supporting agriculture in producing food and to guarantee food security, respectively.

A further way to provide political legitimacy for weather modification, as a strongly anthropogenic intervention, is to point at the function of weather modification to "safeguard ecological security" (*baozhang shengtai anquan*) (see e.g. NDRC and CMA 2014, p. 8). Safeguarding ecological security also falls under "people-oriented development" as, according to Xi Jinping, "the most important for 'putting people first' simply is not to destroy, in the process of development, the environment in which humans exist" (Qiao 2017, own translation). Safeguarding the environment hence happens for the sake of people-oriented development. Hereby, events such as haze and fog are seen as the target of weather modification, as they pose a threat to human health, transportation and the urban environment, as well as severely impact societal production and people's everyday lives (NDRC and CMA 2014, p. 8). This means that events like haze that can result from human activities, are at the same time the target of a much more severe intervention like that of weather modification.

The National Weather Modification Plan also refers to sectoral plans to provide legitimacy for weather modification. It argues that the *National Ecological Protection and Construction Plan* (2013–2020) asks for the further development of weather modification to protect "ecological construction". And it refers to the *National Drought Relief Plan* that is said to propose the use of weather modification to develop the use of "cloud water resources in the air" (*kongzhong yun shui ziyuan*). Interesting in this regard is how language frames the view on the severity of an intervention. The Meteorological Agency's Newspaper refers to weather modification as "Taking from cloud-based water to develop ecological restoration" (*jie yunduan huoshui kaifa shengtai xiufu*) (China Meteorological Agency Newspaper 2018). Clouds hence are seen as water

that is stored at a different location in the hydrological cycle from which one can use it in form of a "climate resource" (*qihou ziyuan*). This to some extent also sheds light on China's "Ecological Civilization". The implementation of the National Plan for Weather Modification (2014–2020) is seen as part of the Ecological Civilization, that is, as providing a "more effective guarantee" (*geng youxiao de baoxian*) to develop an Ecological Civilization (NDRC and CMA 2014, p. 58).

Political effectiveness

A second dimension of political legitimacy is claims towards the eventual effectiveness of weather modification. According to the China Meteorological Administration and the National Development and Reform Commission (2014), since 2008, the national government has allocated a total of 1.723 billion Renminbi (about 223 million euro) to weather modification, which was complemented with a total of 6.512 billion Renminbi (about 844 million euro) by local governments. The average annual area affected by operations to artificially increase precipitation is referred to as 5 million km^2, which is more than half of the area of China. The area under flood protection control is given as 500 000 km^2, which is comparable to the size of Spain.

In their assessment of the current state of weather modification in the country, the National Development and Reform Commission and the China Meteorological Administration see weather modification as having become an important "service to the public" in the context of national and local governments' coordinated development (NDRC and CMA 2014). According to them, 22 provinces have incorporated weather modification in their local socio-economic development plans and 1702 counties have established weather modification agencies. According to the current Plan (NDRC and CMA 2014), the physical infrastructure for weather modification in China comprises 6761 cannons for increasing rainfall or preventing hail, 7632 rocket launchers, 414 ground burners, 44 aircrafts and 5471 standardized operation sites. Since 2008, a total of 328 000 weather modification operations have been carried out. A major problem is seen in the small size and reach (both in terms of coverage area and height) of equipment (NDRC and CMA 2014). Furthermore, even though the National Development and Reform Commission and the CMA (NDRC and CMA 2014) admit that coordination of weather modification across provinces is still being developed, they state that under national guidance, plans and input, a coordinated working structure between the national government and local governments has been set up.

For example, the agencies resume that cross-provincial joint rainfall enhancement works have had clear effects (NDRC and CMA 2014, p. 4). According to them, in the Sanjiangyuan Nature Reserve, artificial rainfall increases since 2006 led to an additional 43.2 billion cubic meter of precipitation (NDRC and CMA 2014, p. 4). Even the reappearance of the Yellow River's "thousand-lake landscape" is attributed to weather modification (NDRC and CMA 2014, p. 4). The area of the Zaling Lake is said to have increased by 32.69 km^2, and that of the Eling Lake by 64.36 km^2 (NDRC and CMA 2014, p. 59). According to the National Development and Reform Commission and the China Meteorological Administration (2014), artificial precipitation has since 2009 contributed to the goal of the 2008–2020 plan to increase national grain production capacity by 55 million tons. In conclusion, it appears that the National Development and Reform Commission and the China Meteorological Administration do see legitimacy for weather modification based on its performance.

Consent

Third, to provide political legitimacy for weather modification, the Chinese government also suggests having the support and consent of society for this large-scale intervention into the local climate. For example, the National Development and Reform Commission and the China Meteorological Administration reason that "weather modification has received widespread recognition by society, and particularly met with farmers' high expectations" (NDRC and CMA 2014, p. 10; own translation) because of its contribution to an increase in national grain production capacity.

The National Development and Reform Commission and the China Meteorological Administration (2014) appraise that the use of weather modification for the implementation of major events has created some legitimacy for an intervention into the local climate. Weather modification was used for the Beijing Olympics, the 60th anniversary of the founding of the People's Republic, the Guangzhou Asian Games, the Xi'an International Horticultural Exposition and the Nanjing Youth Olympic Games. According to the National Development and Reform Commission and the China Meteorological Administration (2014, p. 9), interventions led to "universal praise from all walks of life" (*shehui gejie de pubian zanyu*). A further way how the government appears to claim legitimacy for weather modification domestically is by pointing at its scope in relation to other countries. The National Weather Modification Plan sees the extent of weather modification in China as ranking first in the world (NDRC and CMA 2014).

POSSIBLE LEGITIMATION OF CLIMATE ENGINEERING BY CHINA

As we argued above, what sets China apart from most other countries is that China claims that its interventions into the local climate have been both successful and met with public consent. In addition, China's performance on weather modification has in part been positively appraised internationally, for example, when weather modification was employed to keep the opening day of the 2008 Beijing Olympics dry (Qiu and Cressey 2008), even though this intervention also raised some controversy (see McLeod et al. 2018).

What could these findings imply for a legitimization of measures like stratospheric Sulphur injections as part of solar radiation management?

First, concerning climate engineering techniques that are comparable to weather modification (e.g. cloud seeding), China's internal legitimacy regarding weather modification could be mobilized towards building external legitimacy in the international community for certain approaches to climate engineering. The Chinese government could argue, for example, that most of its people support large-scale interventions into the climate system at local to regional levels; this could then be a powerful source of external legitimacy against the backdrop of China being vulnerable to climate change.

Second, China can claim that it has been active and cooperative in the international climate regime. In the run-up to the 2015 Paris Agreement, China began to assume some shared responsibility, and it now fully acknowledges that, after a period of nearly thirty years of economic development and associated environmental pollution, it can no longer hold the industrialized economies solely accountable for climate change (e.g. Dimitrov 2016). China fully subscribes to the principle of equity and common but differentiated responsibilities and respective capabilities as prescribed in the Paris Agreement (e.g. Voigt and Ferreira 2016). Responding to the expectations of the rest of the world, China announced in 2015 that, by 2030, it will cut its carbon emissions per unit of GDP (emissions intensity) by 60–65% from 2005 levels (UNFCCC 2015). In 2017, China was a major destination for renewable energy investment, accounting for 45% of global investment (Frankfurt School-UNEP 2018). However, should global climate governance fail to deliver, China could at some point claim, given above-mentioned efforts, that it would be time for a "Plan B".

Third, China could obtain external legitimacy using its strong status among developing countries. There is little dispute that China still needs to meet the basic human needs of tens of millions of its people who are living in poverty. Therefore, China may have more legitimacy to engage in climate engineering than the industrialized countries, sustained by China's narrative of "people-oriented development". A comparison could even be drawn between China and some developing countries that are particularly vulnerable to climate change such as Tuvalu, which some commentators argue to have legitimate reasons to pursue unilateral action on climate engineering (e.g. Millard-Ball 2012).

Finally, China would be in a good position to mobilize external recognition by the international community, especially at the regional level with its neighbouring states. Large-scale cloud seeding intended for engineering the regional climate, for example, would have hard-to-prove transboundary impact, due partly to the sheer size of China. These projects are likely to take place on arid land where more rain is required, which is the northern and western part of China. Bordering countries in that region such as Mongolia, Kazakhstan, Kyrgyzstan and Tajikistan have relatively sparse populations. To the extent that there is any significant transboundary environmental impact, China may offer joint projects and share "credit" for creating planetary cooling effects or form a regional climate engineering alliance. In fact, in the context of weather modification, the China Meteorological Administration and the Mongolian Meteorological Administration in 2015 were cited as having a "close and amicable collaboration" (*miqie youhao de hezuo*) in the field of climate change and weather modification (China Meteorological Agency Newspaper 2015). In the context of China's "Belt and Road Initiative", the country is said to have exported weather modification technology, and to have provided technical support and established business collaboration on weather modification with countries like Mongolia (Xinhua News Agency 2018).

Also in the context of China's new multi-million research programme on climate engineering, the country has taken steps to incorporate countries like the Philippines and Bangladesh into discussions on the issue (Temple 2017). With these regional efforts, backed with large-scale investment in research, China could potentially bring climate engineering into international climate change negotiations as a feasible and legitimate measure. China might eventually even seek to form a strategic alliance with other interested parties, especially from the Global North.

CONCLUSION

This *Perspective* article analysed how far political legitimacy for the implementation of weather modification programmes in China could be extended to solar radiation management. We conclude that weather modification could become a stepping stone to create political legitimacy to

implement climate engineering, and here in particular solar radiation management. In the same way as Deng Xiaoping coined the phrase "stepping on stones to cross the river" for the era of the Industrial Civilization, in China's political system, narrating the new era of the "Ecological Civilization" may at some point want to make use of "seeding the clouds to reach the sky".

We find that weather modification is aligned with the governmental ideology of "people-orientated development" and is framed as a "service" to the nation that "taps water" from the clouds to manage it according to local needs. In the same way as weather modification "puts people first" (*yi ren wei ben*), also climate engineering is seen in light of the "social question" (Liu and Chen 2015) of public consent and as a means to avoid societal impact. With both measures' legitimization relating to "people orientation", climate engineering could easily build upon the ways that weather modification has been ideologically legitimized. A (non-representative) survey among undergraduate students in China showed that the government might have the consent of at least part of the public. For weather modification, the government claims that the public praises the effects of such programmes. Here, the state is presented internally as having the administrative and organizational capacity to implement interventions into the local climate. It cannot be ruled out that, at some point, the government might seek to extend such strategies to interventions into the regional or even global climate, should certain types for instance of solar radiation management become globally more accepted. Given China's long-standing experience with weather modification, we conclude that compared to other countries, China might have some ground to build upon if it ever came to legitimizing solar radiation management measures both domestically and internationally.

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