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Ideological and volume politics behind cloud water resource governance – Weather modification in China

Shiuh-Shen Chien[a,*], Dong-Li Hong[b], Po-Hsiung Lin[c]

[a] Department of Geography, National Taiwan University (NTU), Taiwan
[b] Department of Geography, NTU, Taiwan
[c] Department of Atmospheric Sciences, NTU, Taiwan

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ABSTRACT

Weather modification operations are the intntional alteration of weather and cloud water conditions using technologies such as cloud seeding. Post-socialist authoritarian China is the world's leading user of state power for rainfall enhancement through weather modification, with diverse purposes including agriculture production, water security, ecological preservation, and mega events. We argue that weather modification in China needs to be understood as a facet of ecological modernization, in which the authoritarian state believes that precipitation can be controlled through the use of advanced technologies, thus transforming clouds into a kind of cloud water resource. Two political dimensions are highlighted to understand precipitation control and utilization of cloud water: the first is a new ideological politics of the changing human-weather relationship from 'adaptation to the weather' to 'taming the weather"; the second is volume politics that presents unique characteristics of airborne water as opposed to terrestrial and groundwater.

1. Introduction: When cloud becomes cloud water resource

Fresh water is crucial to human life and civilization. Recent related studies have discussed important issues like neoliberalization and the marketization of drinking water resources, hydro-social modernization of mega hydraulic plants and dams, competition for water resources between industrial sectors, and the relationship between politics, poverty and water disasters (e.g., floods and droughts) (Bakker, 2010, 2012; Linton and Budds, 2014; Swyngedouw, 2009). While these studies have highlighted different dimensions in water governance and environmental politics, they largely focus on surface water.

This paper extends this analysis to cloud water, referring to the water contained in a cloud in a column of atmosphere. Cloud water can take the form of rain, snow, hail, cloud, and fog, and can be manipulated and modified via weather modification technologies, such as the use of cloud seeding. Weather modification is not advocated by the World Meteorological Organization and is not widely used in most countries due to both concerns of the morality and efficacy of such measures. Of 193 United Nations member states, only 42 countries have active weather modification programs.[1] However, weather modification is quite commonly used in China.

Over the past few years, China has emerged as the world's biggest user of rain enhancement technologies, and all provincial governments except Shanghai have established Weather Modification Bureaus with budgets for cloud seeding to 'control' cloud water within their jurisdictions. Furthermore, China uses weather modification technology not only to produce rain (during drought) and to prevent rain (for example, during the opening ceremonies of the 2008 Beijing Olympics Games and the 2014 Nanjing Youth Olympics Games), but also to prevent hail and to increase snow (for national winter sports competitions).

In China, clouds are no longer seen merely as an atmospheric weather feature. Instead, clouds are now regarded as a water resource for human exploitation. Local cadres describe cloud water resources as 'airborne water reservoirs (Ch. *kong zhong shui ku*)'. With the increasing importance of cloud water resources in China's environmental governance, 'forcible' and 'controllable' precipitation via weather modification has become intertwined with complicated social and political processes in the hydro-social cycle (Swyngedouw, 2009; Linton and Budds, 2014). This paper analyzes the political and social impacts of such cloud water resource manipulation in China, and argues that post-socialist state use of cloud water offers an opportunity to revisit two perspectives in water governance and environmental politics literature. The first is human-weather dynamics in relation to different functions

* Corresponding author.
E-mail address: schien@ntu.edu.tw (S.-S. Chien).

[1] WMO Expert Committee on Weather Modification Research Chairman Report, 2013 July. Downloaded from https://www.wmo.int/pages/prog/arep/wwrp/new/documents/3_6_WMO_Expert_Committee_Weather_Modification_Research.pdf, accessed by 2016/01/10.

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of clouds to humans, and the second is volume politics in association with the physical condition of clouds in the air. These two dimensions are not well accounted for in the existing literature which mainly focuses on surface water, and this paper aims to fill this gap.

Clouds have traditionally been defined in terms of their physical characteristics: visible masses of minute solid particle, liquid droplets and frozen crystals in the air. They were seldom seen as a useable resource. Today, however, with the frequency of weather modification, Chinese local officials now see clouds as an environmental resource over which they have jurisdictional authority, thus intentionally extending governmental control to meteorological materials and shifting the locus of the human-weather relationship from 'adaptation to the weather' to 'taming the weather'.

This phenomenon has also given rise to volume politics. By envisioning clouds as 'airborne water reservoirs', local officials emphasize the volume characteristics of clouds. Unlike terrestrial water which is either collected in lakes or flows through established river systems, cloud water moves freely through the atmosphere and cannot be neatly ascribed to a particular political jurisdiction. Scholars have argued that the traditional flat/ground ontology is not particularly useful when applied to volume-related research. Elden (2013) argued that, while traditional geo-politic discourses focus on area and territory, they ignored the importance and complexity of the vertical dimension—height and depth. However, power relations are unequally distributed and allocated in three dimensions, raising problems for two-dimensional geo-politic discourse, especially where underground spaces or the sky are controlled by various forces other than that on the surface. This has opened up a novel discussion of "politics of volume" in cases like underground tunnels (Elden, 2013), oceans (Steinberg and Peters, 2015), and air (Adey, 2015; Graham, 2015). Recent studies lead us to highlight the perspective of volume in addressing the vertical resource control, one of which certainly is weather and cloud water.

Many important questions remain unanswered. Under this new ideology of taming the weather, what discourses and technologies have been produced and manipulated by the China state to drive its local officials' enthusiasm for state-led weather modification? Whether central or local governments exercise authority over air-circulating cloud water? Who has decision making authority for weather modification in air space that is used to be operated by commercial or military aircraft? With answering these questions, this paper can supplement the existing literature on the political ecology of water, human-weather relation studies and environmental politics research.

Environmental operations in China should be understood as a means of ecological modernization in the context of authoritarian environmentalism (Mol, 2006, 2010; Eaton and Kostka, 2014). Ecological modernization holds that advanced technology should be used to either mitigate or adapt to challenges raised by environmental changes. Based on assigned performance evaluation, upward accountability and authoritarian legitimacy, China pushes the ecological modernization further that even the weather can be tamed, so the cloud can be transformed to be cloud water via weather modification. However, due to volume politics, cloud water utilization creates new tensions and difficulties as cloud water governance challenges conventional environmental governance practices that have been developed on a basis of the flat/ground ontology.

The rest of this paper is organized as follows. Section 2 presents a theoretical review of the authoritarian environmentalism, ecological modernization and ideological change behind China's weather modification practices. Section 3 provides a brief history of weather modification in China and the rest of the world, including its origins and evolution over the past few decades. Section 4 discusses four kinds of weather modifications: (1) to enhance agriculture production in drought conditions, (2) to bolster drinking water resources, (3) for ecological preservation, and (4) to ensure appropriate weather for important events. Section 5 examines China's ideological and volume politics to provide insights into tensions and competition in weather modification.

2. Weather modification under ecological modernization and authoritarian environmentalism

2.1. Ecological modernization

Modernization, industrialization and urbanization have raised significant environmental challenges. In the mid-1980s, some European technological optimists began developing a perspective called ecological modernization, which saw advanced technologies and market systems as the best potential solutions for environmental problems (Hajer, 1995; Mol and Sonnenfeld, 2000; Mol and Spaargaren, 1993, 2000; Spaargaren, 1997; Spaargaren and Mol, 1992). This perspective holds that advances in knowledge and technology will allow human societies to create more effective tools to deal with environmental problems such as industrial pollutions and water shortages.

Earlier studies focused mostly on European cases and argued that ecological modernization processes are universal without geographical differences. Later work suggested that ecological modernization varies with political, social, cultural contexts (Buttel, 2000; Fisher and Freudenburg, 2001). In recent years, new studies on ecological modernization have focused on developing countries, with scholars paying specific attention on how post-socialist environmental governances implement environmental protection measures and promote economic development together (Mol, 2010; Rock, 2010). While existing ecological modernization studies have highlighted the dynamic relationship between technological advancement and environment protection, O'Connor (1991, 1994) states that certain political characteristics need to be included in any discussion of ecological modernization to account for dynamics between environment and economy. In addition, the political and power relations behind the governance of different kinds of environmental resources are also important factors (Swyngedouw and Heynen, 2003; Lee, 2014). Therefore, understanding China' complex ecological modernization processes requires consideration of its political contexts.

2.2. Authoritarian environmentalism

Despite rapid economic growth and dramatic social change, China is still governed by the authoritarian Chinese Communist Party (CCP), with the state holding near absolute power in terms of budget allocation and party cadres' personnel management. Authoritarian environmentalism refers to the state managing resources and exercising power in an authoritarian way in response to domestic and international environmental challenges.

First, authoritarian environmentalist states tend to prioritize their state interest above all else. In contrast, states which follow liberal and democratic environmentalism allow non-state actors to play a role in environmental decision processes (Beeson, 2010; Eaton and Kostka, 2014; Gilley, 2012). Second, under authoritarian environmentalism, the goal of environmental policy is to maintain state legitimacy and consolidate state power through selective modernization discourses and advanced technologies (Doyle and Simpson, 2006; Moore, 2014). Third, authoritarian states frequently emphasize the construction of large-scale hydrological infrastructure projects to present a particular political mission like unification (Wittfogel, 1957; Swyngedouw, 2007).

We further argue that an authoritarian ideology lies behind the state-centered interest in which the state can use its power to control not only the society but also the nature. China's legislative and judicial institutions lack real power, and civil society elsewhere are heavily repressed, allowing the authoritarian state to use whatever modern technology is at hand to tame the nature (and the environment) in the name of state interests. Thus, there is easy coexistence of the ideology of ecological modernization with authoritarian environmentalism practices.

2.3. Weather modification: from adaption to the weather to taming the weather

Under the context of ecological modernization, technological advancement can help humanity tame the nature as a resource for development and to simultaneously reduce industrial pollution and environmental degradation. While humans have sought to tame the nature since ancient times, the meaning of such activities has evolved over time. In agricultural societies, wild animals were domesticated as livestock as a source of farm labor, transport, food and industrial materials. Under the contemporary capitalism, industrialist society is entirely premised on an ideology of taming and exploiting the nature (Smith, 2010). However, until recently, such efforts have largely overlooked weather and climate systems.

Humanity has a long history of symbolic intervention in weather and other meteorological phenomena. For example, the Dragon King in Chinese culture and Zeus in Greek mythology are both rain gods, and a key function of civic and religious leaders in both societies was to propagate rituals as a means of interceding with the gods for favorable weather. More concrete approaches included building dikes, irrigation channels, dams and reservoirs to better manage water resources and mitigate the adverse effects of drought in the modern time. Today, many cities around the world have launched "sponge city" programs to absorb rainfall and thus prevent flooding. All these measures reduce risk from environmental uncertainty without altering weather systems, and can be classified as ways by which humanity 'adapts to the weather'.

However, in response to challenges posed by ongoing climate change, scholars have recently begun proposing global-scale geoengineering efforts including projects to reduce global temperatures by either (1) injecting aerosols into the stratosphere (Hulme, 2012), (2) reducing the speed of tropical cyclones (Klima and Morgan, 2012), and (3) modifying stratospheric water (Chen and Yin, 2014). Such proposals for atmospheric experiments on an unprecedented scale are highly controversial, but they are growing in support and ambition (Fleming, 2006, 2007, 2010; Hulme, 2012, 2014). These efforts demonstrate a faith that human technology can tame the weather and its related climate systems. This faith is reflected in the practices of ecological modernization in the meteorological dimension. Scholars have coined the term "Anthropocene" to denote the current time in which humans can, intentionally or otherwise, exert significant impacts on the Earth's geology, ecosystems and atmospheric systems (Castree, 2014a, 2014b).

We argue that weather modification can be regarded as a case of geo-engineering, as the current technology allows humans to move beyond purely symbolic actions to direct intervention in weather and meteorological phenomena to enhance or suppress precipitation, disperse fog, and prevent frost. China is by far the world's leader in weather modification operations and rain enhancement. The case of China reveals a changing ideology of the human-weather relationship. In the conventional ideology of 'adaption to the weather', human actions are designed to increase resilience and flexibility in the face of inexorable meteorological phenomena. However, weather modification and cloud water resource governance presents the possibility of human intentionality to alter and tame the atmosphere and larger-scale weather systems, a trend we denote as 'taming the weather'.[2]

3. A history of weather modification

3.1. Weather modification: a technical perspective

The most common form of weather modification is cloud seeding, in which substances such as silver iodide, potassium iodide and dry ice are dispersed within clouds to promote condensation of existing moisture to produce rain drops (see Fig. 1). However, seeding requires existing clouds, and cannot produce results from skies with insufficient moisture.

Depending on cloud properties, cloud seeding can be conducted through three different mechanisms. In static cloud seeding, grains of dry ice or silver iodide are spread to condense moisture within mid-latitude cold clouds composed by ice and super cooled droplet. The chemical substances catalyze the condensation and growth of ice that then precipitate out as rain. Dynamic cloud seeding is similar to static cloud seeding, except that the volume of seeding substances is increased one hundred times, producing latent heat which drives updrafts and thermals, thus drawing additional moisture into the cloud. Hygroscopic cloud seeding is more commonly used in tropical areas and involves the dispersal of salts to create larger rain drops, which then absorb smaller drops as they fall from the cloud.[3] Seeding substances can be dropped from airplanes flying above the cloud, or shot into the clouds from ground-based artillery (see Fig. 2).

3.2. Outside China: from military applications to commercial development

In the 1940s, Bernard Vonnegut found that injecting silver iodide smoke into clouds could prevent precipitation (Harper, 2008; Qiu and Cressey, 2008). Following WWII, the U.S. Army and General Electric collaborated on the development of "weather weapons", including techniques for thinning cloud cover to allow for aircraft takeoff and landing in poor weather conditions (Harper, 2008; Martin-Nielsen, 2012). During the Vietnam War, the U.S. Army used weather modification technology to prolong the monsoon season in an attempt to soften road surfaces, cause landslides along roadways, and wash out river crossings in enemy-held territory. The project was suspended after being reported by the New York Times in 1972,[4] and in 1975 the US and the USSR reached an agreement expressly forbidding the use of meteorological weapons.

During the Cold War meteorologists led by Irving P. Krick of the California Institute of Technology attempted to develop weather modification technologies for economic and civil purposes, but these attempts met with considerable resistance (Fleming, 2010). The World Meteorological Organization (WMO) recommends against the use of weather modification in response to climate change, and only 1/4th of the world's nations currently engage in active weather modification. Weather modification programs in the US and the Australia are mostly conducted by commercial companies to generate support for hydroelectric power generation or to produce snowfall for ski resorts (Harper, 2008).

China is quite unique in its official and widespread use of weather modification, with provincial weather modification programs employing around 40,000 people. In 2012, of a total of about 3 thousands county-level administrations, more than 2 thousands use artillery and rocket launchers for rain enhancement, hail suppression and fog dispersal, and all except the Shanghai provincial-level administration

[2] Here we do not mean that the taming the weather is the only ideology impacting the human-weather relationship in China. To adapt to extreme weather challenges, China has also practiced the ideology of adaption to the weather by establishing 'sponge cities' covering more than 400 km2 in hundred cities, making China become the world's largest such effort as of the time of writing in 2017.

[3] News source: Can China Control the Weather? Howstuffworks, http://science.howstuffworks.com/nature/climate-weather/meteorologists/cloud-seeding.htm/printable 2013/06/12, accessed by 2016/01/10; and Cloud Seeding: A Brief History and an Introduction to the Science, WildCard, http://wildcardweather.com/2013/06/12/cloud-seeding-a-brief-history-and-an-introduction-to-the-science/, accessed by 2016/01/05.

[4] See news source: Hersh, S. M. (1972) Rainmaking is used as weapon by U.S., New York Times, 3 July 1972, p.1.

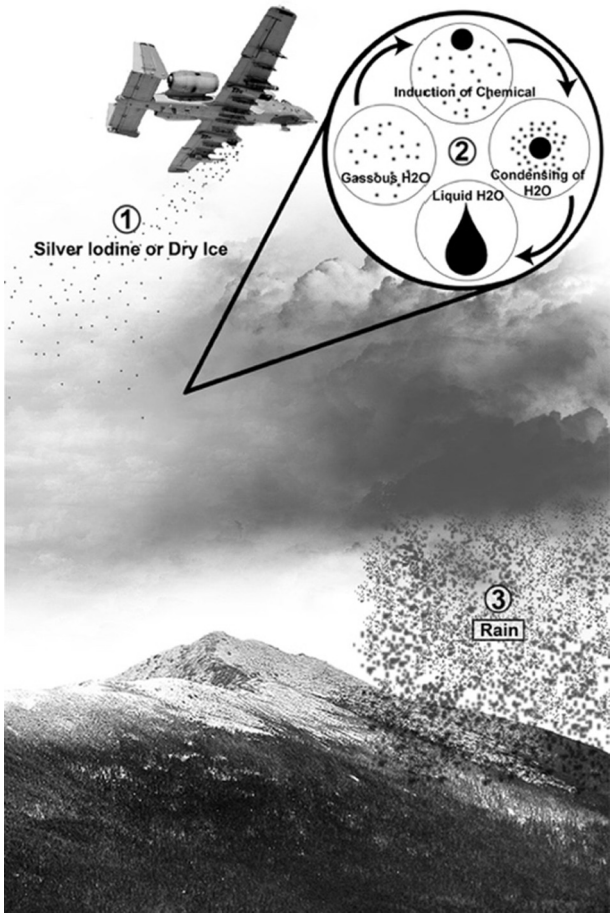


Fig. 1. Concept of weather modification for rain enhancement.
Source: Wikipedia https://en.wikipedia.org/wiki/Cloud_seeding.

Fig. 2. Mobile rocket launchers used for precipitation enhancement.
Source: taken by the author.

Table 1
Chinese weather modification in selected years since the mid 1990s.
Source: Adapted from Yao (2013) and http://fortune.com/2017/01/24/china-government-artificial-rain-program/.

Year	Weather modification investment (RMB)	Artillery deployed	Rocket launchers deployed
1993	80 million	3500 +	200 +
2003	330 million	7000 +	4000 +
2012 (or 2016)	1.5 billion (2016)	7000 + (2012)	7500 + (2012)

carried out weather modification using 37 airplanes equipped with silver iodide, dry ice and liquid nitrogen generators.[5] Between 2002–2012, China conducted more than half a million weather modification operations, resulting in the release of 500 billion tons of rain and preventing about 10 billion RMB in potential economic loss. Nearly all such operations were conducted by the Chinese state at different administrative scales (see Table 1).[6]

3.3. China: state-led meteorological modernization

Behind cultural impulses aimed at resolving perceived developmental 'lateness' for fast modernization (Zhang, 2006; Shen, 2015), China's leadership has long been fascinated with weather modification and human control of weather. Mao Tse-tung endorsed the pursuit of weather modification technologies in the 1956–1967 China Agriculture Development Framework (Ch. *quanguo nongye fazhan gangyao*). Later, a research project entitled 'Prior Research on Cloud and Precipitation Physics and Artificial Rain (Ch. *yun yu jiangshui wuli guocheng he rengong kongzhi shuifen zhungtai de shiyan yanjiu*)' was undertaken as part of the '1956–1967 China Science Development Plan (Ch. *quanguo kexue fazhan guihua*)'.[7] In 1958, cloud seeding was used for the first time in China to combat severe drought in Jilin Province.

From the 1960s to the 1990s, China actively pursued ground observations, scientific experiments and basic researches for weather modification. In 1994, China introduced a system of weather modification coordination (Ch. *rengong yingxiang tianqi xiediao huiyi zhidu*) to integrate resources from related research institutes, operational departments and ministries and to facilitate information exchange. This coalition published the '1996–2010 China Weather Modification Development Plan (Ch. *quanguo rengong yingxiang tianqi fa zhan guihua* 1996–2010)' (Committee of Weather Modification of China Meteorological Science Association (Ch. *zhongguo qixiang xuehui rengong yingxiang tianqi weiyuanhui*), 2009).

Weather modification became increasingly institutionalized in China after 2000 with the passage of the Meteorological Law (Ch. *qixiangfa*) which required the China Meteorological Administration to organize, coordinate and guide weather modification activities, including operations, demonstrations and research nationwide. In 2002, China passed the Regulations on the Administration of Weather Modification (Ch. *rengong yingxiang tianqi guanli tiaoli*), the first national law to regulate weather modification activities. In 2012, China's State

[5] Source: powerpoint presentation in 2013 by Dr. Zhanyu Yao, a key scientist in weather modification at Chinese Academy of Meteorological Sciences. Downloaded at 2016/01/10 from http://www.capital.cl/wp-content/uploads/2013/06/zhanyu-yao.pdf. And a 2012 Brochure of Central Meteorological Administration of China, downloaded from http://www.cma.gov.cn/en/aboutcma/brochure/201203/P020120319791316093320.pdf at 2016/01/15.

[6] News source: China to increase weather manipulation program, the Watchers, 2012/05/25/, accessed by 2016/01/15 from https://watchers.news/2012/05/25/china-to-increase-weather-manipulation-program/.

[7] We use the term 'artificial' (Ch. *rengong*) to reflect the terminology used in the context that China's government sees weather modification and production of rainfall in the way of a natural-social dualism, as opposed to the social-hydro entangling process adopted in this paper.

Council also published Opinions Regarding Further Strengthening of Weather Modification Works (Ch. *jinyibu jiaqiang rengong yingxiang tianqi gongzuo de yijian*), and additional pronouncements included the '2014–2020 China Weather Modification Development Plan (thereafter 2014–2020 WM plan) (Ch. *quanguo rengong yingxiang tianqi fazhan guihua* 2014–2020)' and '2011–2015 National Meteorological Development Plan (Ch. *qixiang fazhan guihua* 2011–2015)'. Weather modification was also included in a list of key scientific research projects since the 11th Five Year Plan (2006–2010).

Weather modification is seen as a critical aspect of the modernization of China's meteorological services. China is frequently subject to natural disasters including typhoons, flooding, blizzards, droughts, dust storms, hailstorms, and heavy fog. These disasters were estimated to cost the country the equivalent of an average of 2.8% of annual GDP between 1911 and 2008 (Yao, 2013).[8] In recent years, China has modernized its meteorological equipment and restructured related organizations to upgrade its capacity for meteorological monitoring and intervention. This 'meteorological modernization (Ch. *qixiang xiandaihua*)' process therefore should be understood as part of China's ecological modernization project in the early 2010s. China officially introduced the concept ecological modernization in relation to the "construction of an ecological civilization (Ch. *shengtai wenming jianshe*)" in its 12th Five-Year National Plan (2011–2015), with a focus on the adoption of high-tech water technologies and price mechanisms to treat polluted water and improve water infrastructure.

Under the context of meteorological modernization, China's Central Meteorological Administration (CMA) currently employs about 35,000 staff, including a thousand research scientists (i.e., Ph.D. holders), along with another 4000 staff with post-graduate degrees. The CMA coordinates the Chinese Academy of Meteorological Science (CAMS), which offers graduate and Ph.D. programs, and is one of the world's leading atmospheric science research institutions.

In addition, new institutes specializing in specific climate phenomena have been established to conduct basic scientific research and develop advanced technologies, reflecting China's size and diverse climate environments. These institutes focus on urban meteorology (Beijing), desert meteorology (Urumqi), typhoons (Shanghai), tropical marine meteorology (Guangzhou), arid meteorology (Lanzhou), plateau meteorology (Chengdu), and heavy rain (Wuhan). Research facilities include high performance computers, weather radar, meteorological satellites, and domestic and global telecommunication systems to facilitate the integration of observations and data sharing for weather forecasting and climate predictions. These developments are emblematic of the considerable improvements made to the organizational capabilities of China's meteorological systems over the past years.

4. Chinese local weather modification operations

4.1. National policy background

China coordinates weather modification efforts with other ecological and environmental plans. For example, in the 2014–2020 weather modification plan, weather modification tasks are integrated with other national plans including (1) National Main Functional Area Planning (Ch. *quanguo zhuti gongnengqu guihua*), (2) National Plan for Fighting Against Droughts (Ch. *quanguo kanghan guihua*), (3) 2009–2020 100 Billion Additional Food Productivity Plan (Ch. 2009–2020 *quanguo xinzeng 1000yi liangshi shengchan nengli guihua*), (4) 2013–2020 National Plan for Ecological Preservation and Construction (Ch. *quanguo shengtai baohu yu jianshe guihua*), and (5) 2011–2015 Water Resource Development (Ch. *shuili fazhan guihua* 2011–2015).

[8] Source: 2013 presentation by Dr. Zhanyu Yao, a key weather modification researcher at the Chinese Academy of Meteorological Sciences. Downloaded at 2016/01/10 from http://www.capital.cl/wp-content/uploads/2013/06/zhanyu-yao.pdf.

Weather modification plans are also coordinated with official tasks assigned by state regulations. For example, the Article 3 of the PRC Weather Modification Law and Article 45 of the PRC Meteorology Law, state:

> *Weather modification refers to efforts aimed at rain or snow enhancement, hail suppression, rain suppression, fog dispersal, and frost prevention. Weather modification exerts an artificial influence on local atmospheric physical and chemical processes through scientific and technological means in order to avert or mitigate meteorological disasters and rationally utilize climate resources.*

However, in practice, local cadres typically engage in cloud seeding for four key reasons: (1) to increase agriculture production, (2) to secure water resources, (3) for ecological preservation, and (4) to secure good weather for important events. This fourth item is nearly unique to China, and is not listed in the state regulation.

4.2. Agricultural production

Agricultural production is highly sensitive to weather conditions, and increasing agricultural yields was the original intent for the development of weather modification in China. In 1958, China conducted its first precipitation enhancement in Jilin Province, a major food production area in Northeast China which was suffering from severe drought. Jilin has since become a leading proponent of rain enhancement, especially for food production.

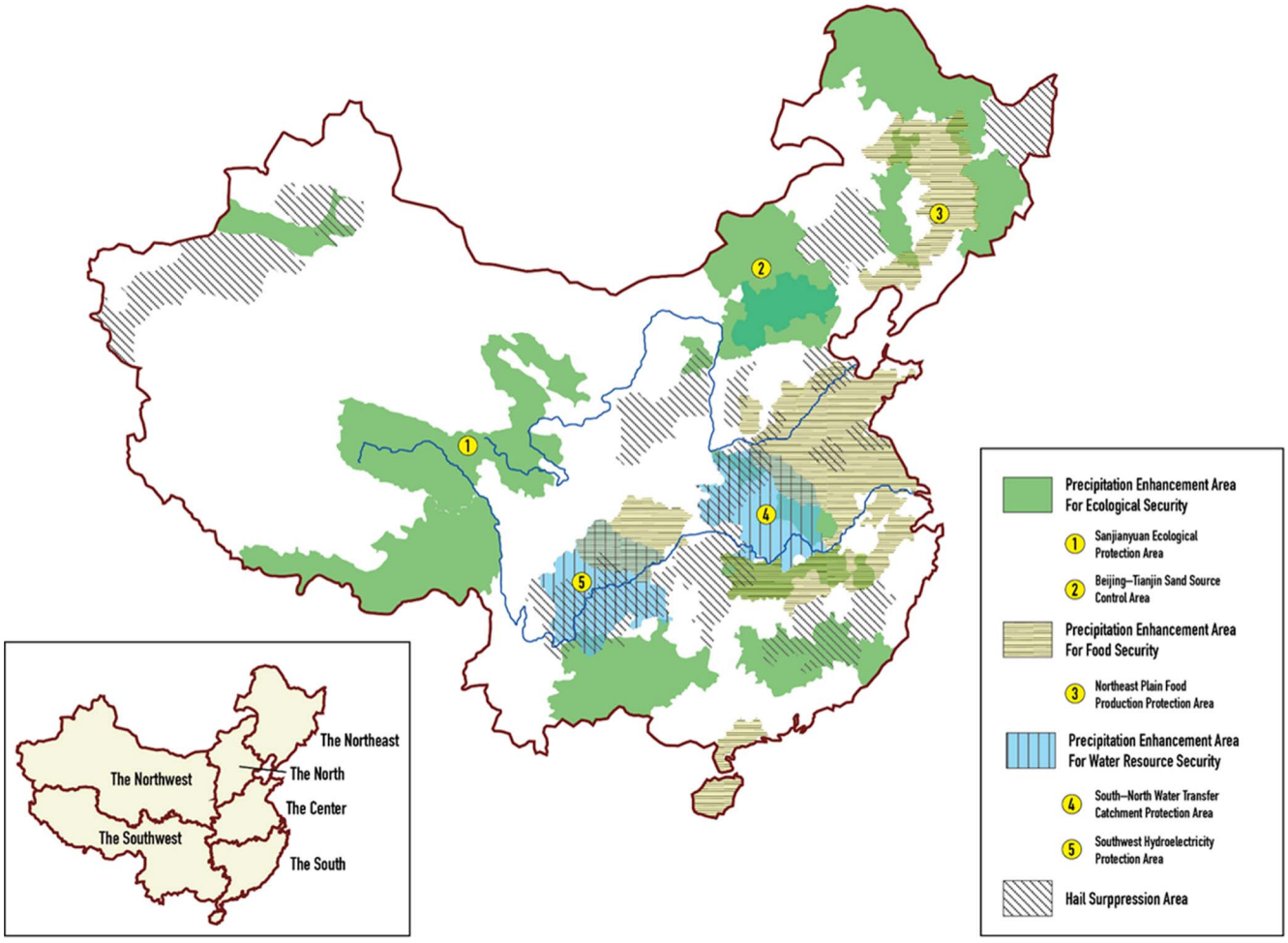
To ensure domestic food security under constant population growth, the Chinese government is committed to increasing overall food production to 100 billion tons by 2020. One of the biggest constraints for this ambitious goal is unpredictable weather conditions and an unstable water supply. For example, China's Northeast Plain and the Yellow River Plain produce more than 63% of the country's food. However, these regions are also subject to frequent drought, water supply instability, and aquifer depletion. Thus, one of the main goals of China's weather modification efforts is to stabilize water supplies in these regions. In addition to rain enhancement, such efforts include hail suppression to protect food and economic crops, including tea, tobacco, and cotton (see Map 1).

4.3. Water security

In China, temporal and spatial distributions of precipitation are highly non-uniform, with 60–80% of rainfall concentrated in the monsoon season, and 84% of national water resources located in southern China (Wang, 2010). Since 2002, China has begun to construct a large-scale South-to-North Water Transfer project (Ch. *nanshui beidiao*), which aims to transfer water from the midstream of the Yangtze River basin to China's northern provinces (including Hubei, Henan, Hebei, Beijing, and Tianjin). Despite abundant precipitation in the Yangtze River basin, annual variation is considered to be too large to provide a stable supply of water to the North (Chen and Tian, 2013). Therefore, the project also calls for cloud seeding in some South-to-North water transfer catchment protection areas in the Yangtze River basin [see Map 1]. Water resources are also intimately related to hydroelectric power, and China has constructed many dams and hydro-power plants along the Yangtze River in Yunnan and Sichuan provinces, where natural precipitation is regularly supplemented by rain enhancement.

4.4. Ecological preservation

The third goal of the weather modification project is to ensure ecological preservation by enhancing rainfall in ecologically vulnerable areas subject to environmental degradation. Rain enhancement is officially listed as a method to prevent and restore environmental degradation in the 2014–2020 National Plan for Ecological Preservation and Construction.



Map 1. Weather modification operations in China.–
Source: Compiled by the authors based on the 20142020 China Weather Modification Development Plan.

The Sanjiangyuan National Nature Reserve contains the sources of three of China's major rivers and is the most representative case for the use of weather modification for ecological preservation and restoration. Rain enhancement efforts have been conducted at this area since 2006, and official claims suggest that the results have respectively increased the area of Zhaling and Eling Lakes by 33 and 64 square kilometers.

Rain enhancement has also been conducted in and around Beijing and other major cities to control sandstorms and haze for agricultural purposes. For example, in February 2014, Hebei province launched 199 rockets and 106 artillery shells to seed clouds in response to a month-long haze. In Nanjing, rain enhancement was conducted at Liuhe and Pukou to mitigate haze in November 2013. Chengdu and Xiamen also conducted rain enhancement improve air quality. [9]

Weather modification is also used to address environmental pollution, for example, to prevent and control Cyanophyta in lakes. Increased water temperatures provide ideal conditions for bacteria blooms which produce Cyanophyta. In 2010, the Jiangsu Meteorology Administration seeded clouds to produce rain over Lake Tai, resulting in a rapid and significant decrease in water temperature, thus suppressing Cyanophyta (Wang and Chen, 2015). In sum, weather modification, especially rain enhancement, is now widely used for ecological preservation and restoration in China

4.5. Mega events

Russia and China are known for using cloud seeding to prevent rain on important events, including national day parades. Weather modification for such mega events in China dates to the early 1980s.[10] The most famous instance of such intervention was the opening ceremony of the 2008 Beijing Olympics Games.[11] Event-driven weather modification has been used for international and local events, including the 2000 Henan Chrysanthemum Festival, the 2004 ceremony marking the administrative upgrade of Ulanqab in Inner Mongolia, the 2004 International Grassland Culture Festival in Shanxi, the 2008 50th anniversary of the Ningxia Autonomous Region, the 60th anniversary of People's

[9] It should be noted that the effectiveness of weather modification for haze suppression is questionable. See "Peking University Professor: Weather modification has limited impacts to hail suppression *(Beida jiaoshou: yong rengong jiangyu jianmai xiaoguo youxian)"*, Times Weekly *(shidai zhoubao)* (2014/3/6) http://news.sina.com.cn/c/sd/2014–03-06/155429640169.shtml accessed by 2016/02/15.

[10] To secure good weather for National Day parades in 1984, the Meteorological Bureau of the China Air Force organized a team to practice weather modification. The dark clouds above Tiananmen Square then disappeared, allowing CCP Air Force fighter pilots to perform a disaggregated display in the clear sky. News source: "Competing against the sky- Beijing reduce raining scientifically (*yutian jiaojin: Beijing 'renyingban' kexue xiaoyu*)", TVBS, 2007/08/07, http://www2.tvbstv.com/entry/315465, accessed on 2016/01/31.

[11] Soon after China was named host of the 2008 Olympics Games, the Beijing Meteorological Bureau (BMB) started conducting local climate surveys around the venues and stadiums to be used for the Games. The original date for the opening ceremonies was subsequently moved from July 25 to August 8 because the BMB suggested that interfering with rainfall from the original date would have adverse effects on regional agriculture. News source: "China set new historical records in providing meteorological-related services during the Olympics and Paralympic Games (*woguo chuangxia duoxiang aoyunhui canaohui qixiang fuwu shijie jilu*)", China Meteorological News Agency, 2008/09/23, http://big5.gov.cn/gate/big5/www.gov.cn/gzdt/2008–09/23/content_1103045.htm, accessed by 2016/01/15.

Republic of China in Beijing in 2009, the 11th National Games of China in various cities of Shandong in 2009, the 2010 Asian Games in Guangzhou, and the 2014 Summer Youth Olympics in Nanjing. (Committee of Weather Modification of China Meteorological Science Association (Ch. *zhongguo qixiang xuehui rengong yingxiang tianqi weiyuanhui*) 2009).

It should be noted that, despite lack of a legal basis, event-driven weather modification has been institutionalized. In 2015, the Meteorological Bureau of China even published an official document to standardize workflows for event-based meteorological services (Ch. *daxing huodong fuwu zhinan gongzuo liucheng*).[12] To qualify for coverage under meteorological services, such events must involve the participation of at least one thousand people or be organized by state and local governments for specified political, economic, or cultural purposes. The workflow identifies four stages: preparation, rehearsal, performance, and evaluation. In the performance stage, weather modification is officially listed as a means of securing good weather for the staging of events, along with intensive observation and frequent forecasts.

Thus, over thousands of years, official efforts to influence weather in China have shifted from rituals to pray for sufficient rainfall and good harvests to the use of modern technology to actively modify the weather. The scope of weather modification activities covers nearly the whole of China, and the frequency and purpose of such interventions has increased over the years. However, such actions entail many conflicts, negotiations, and compromises among different stakeholders. In the following section, we present how different ideological and volume politics have been produced and manipulated to facilitate the enthusiasm for local authorities in taming the weather as part of a process of exploiting cloud water resources via weather modification.

5. Politics of chinese state-led weather modifications

Here we discuss two kinds of politics related to weather modification in China: ideological politics regarding state power over the weather and volume politics in conflicts between different governmental organizations. Ideological politics is highly related to the general authoritarian essence of the post-socialist Chinese state, including the lack of transparency in policy debates, quick response to local demands, and eagerness to project a strong state image. Volume politics entail sky-space management conflicts between the military and local governments and tensions over cloud water rights between central government agencies and among neighbouring local administrations.

5.1. Ideological politics: discourses to support taming the weather

The WMO takes a dubious stance on the effectiveness of weather modification. Quantifiable evidence for increased precipitation is hard to establish because of the difficulty in designing controlled experiments. Generally speaking, combining approaches such as measurements of cloud properties, numerical modelling and randomized and targeted seeding experiments in particular locations are needed to better estimate increased precipitation as a result of weather modification. This lack of solid empirical evidence makes it difficult to produce accurate cost-benefit analyses and most of the world's state meteorological agencies take a very cautious view towards weather modification.

However, despite these empirical caveats, weather modification operations in China have intensified over the years, with reported annual rain enhancement increasing from 30 billion tons in the early 2000s to 50 billion a year in the late 2010s.[13] Furthermore, whereas previous weather modification efforts involved the special deployment of mobile equipment in the face of a specific crisis, today some counties have installed permanent artillery and rocket launchers specifically for weather modification. These fixed launchers allow for weather modification whenever suitable cloud conditions are available. This tendency towards fixed facilities (Ch. *dingdianhua*) and regular operations (Ch. *changtaihua*) for weather modification display China's enthusiasm for the practice, in sharp contrast with most other countries. We discuss three different political factors that attribute to the ideological belief in China that the state can and should control the weather system.

First, the authoritarian CCP lacks a system of checks and balances to facilitate the implementation of potentially controversial projects. Thus, the scientific evidence and political justification for weather modification is not subject to debate or broad discussion. In addition, the leadership's propensity for technological intervention in taming different weather systems is rarely challenged by alternative viewpoints.

Second, local cadres are not elected democratically by local people but are rather assigned by upper-level administrators. However, when dealing with environmental crises, farmers are likely to vent their frustrations on local officials, who see weather modification as a means of at least being viewed to respond to local demands, regardless of the actual efficacy of these methods. Lu Da-ren, a researcher at the Beijing-based Institute of Atmospheric Physics, Chinese academy of Science noted in an interview in Nature that "maybe it is not as effective as one thinks…. But, from the farmers' point of view, it is better than nothing."[14]

Third, China seeks to impose state control over the weather as a projection of state power at various levels. Weather modification to prevent rainfall from disrupting the opening and closing ceremonies of the Olympics reflects Chinese nationalism, in particularly demonstrating China's successful rise from rural poverty to economic powerhouse with advanced technological prowess. This kind of showcase mind-set also occurs at the local level where local cadres jockey for promotion by outshining their peers through the smooth staging of prominent outdoor events.

It also needs to be noted that the even under the authoritarian China, there are criticism over weather modification like to what extent should the state seek to engineer the climate, and to whose ends (Fleming, 2010). In February 2009, Beijing resorted to cloud seeding to induce snowfall following four months of drought. This 'modified' snowfall lasted for around three days but led to the closure of 12 main roads, [15] causing considerable traffic disruption and inconvenience. A man-made blizzard in November 2009 caused over RMB 50 million worth of damage and 40 deaths along with traffic accidents, flight delays, cancelled classes, and extensive tree damage (Smit, 2015). Similarly, in Qinghai, weather modification to combat drought has created problems for sheep herders, with heavy rainfall causing injury to their livestock. This type of imbalanced distribution of benefits has raised concerns that stirred a moral debate as to whether state actors should act with greater caution when considering weather or climate modification measures, and also who should be responsible for unexpected adverse outcomes caused by weather modification?

5.2. Politics of the volume: control of air-based resource and space

China faces volume-dimension governance obstacles when

[12] Document code: Meteorological Industry Standards of PRC (*zhonghua renmin gongheguo qixiang xingye biaozhun*) QX/T 274-2015.

[13] Data for the late 2000s is from news source: "China to increase weather manipulation program", 2012/05/25/, downloaded from 2016/01/15 from http://thewatchers.adorraeli.com; data for the early 2000s is from news source: "Meteorology: taming the sky". Nature, 2008/06/18 http://www.nature.com/news/2008/080618/full/453970a.html. Two links are accessed by 2016/01/30.

[14] News source: Meteorology: Taming the sky, Nature, 2008/06/18, http://www.nature.com/news/2008/080618/full/453970a.html, accessed by 2015/01/31.

[15] News source: China to increase weather manipulation program, 2012/05/25, the Watchers, 2012/05/25, http://thewatchers.adorraeli.com/2012/05/25/china-to-increase-weather-manipulation-program/, accessed by 2016/01/10.

conducting weather modification operations, particularly given a lack of jurisdictional boundaries over cloud water as opposed to surface water. We identify three dimensions of volume politics behind governing atmospheric water vapour in clouds. The first is the tension between the military sector and local governments. Weather modification entails the airborne dispersal of chemicals, and thus falls under the jurisdiction of China's Ministry of Defence. As a result, military approval is required for all kinds of cloud seeding. A weather modification coordination meeting held in Zhejiang in November 2015 entailed discussions of multiple topics including application procedures for cloud seeding and means of preventing interference with civil and military aviation, illustrating the potential complexities involved in weather modification efforts.[16]

For example, while weather modification efforts successfully ensured clear skies for the 2008 Olympics in Beijing, the 2014 Youth Olympics in Nanjing were marked by drizzle partly because of the failure of local governments to secure approval from the military authorities to coordinate seeding efforts for best effect. This discrepancy has to do with the difference in administrative authority of the respective government officials. Whereas the party secretary of Beijing, the national capital, is ranked as a provincial-level cadre as well as a member of the CCP Politburo, the party secretary of Nanjing, the capital of Jiangsu Province, is only ranked as a prefecture-level party cadre, and thus did not have the political clout to demand compliance from the leadership of the Nanjing Military Region.[17]

The second is tension between the central and local governments. Central-local water political conflicts in China and elsewhere are largely resolved through legal means. For example, China's Water Law assigns ultimate jurisdiction over all water resources to the central government, which then grants authority to provincial governments to coordinate efforts and initiatives within their jurisdictions. However, China's current legal framework on water does not clarify jurisdictional control over cloud water. Conflicts exist between the Water Law and the Meteorological Law, with the latter encouraging local authorities to use "climate resources" within their jurisdictions.

One example is weather modification conducted over the catchment areas of the Central Route of South-North Water Transfer Project in Henan and Hubei to supply water to the Greater Beijing region. Linking the shortage of surface water in North China with the abundance of cloud water in Central China raises questions as to whether cloud water over Henan and Hubei should belong to the people and governments of the source provinces, or are Henan and Hubei under obligation to share this resource with Beijing and other provinces? This situation illustrates the volume complexity of cloud water governance at the intersection of the hydrological cycle and cross-regional politics, as precipitation control is exercised in one place to address water shortages in another place.

This kind of volume politics has now become increasingly sensitive as individual provinces have begun to pass divergent regulations on the use of climate resources. For example, in 2012 Heilongjiang passed the Climate Resource Investigation and Protection Act (Ch. Heilongjiang *qihou ziyuan tance yu baohu tiaoli*). One year later, Jiangsu passed a regulation called the Climate Resource Protection, Development and Utilization Act (Ch. Jiangsu *qixiang ziyuan baohu yu kaifa liyong tiaoli*). To counterbalance local conflicts, the central government officially divides the country into six macro-regional divisions, with one province in each group coordinating weather modification (see Map 1).[18]

However, until conflicts between the Water Law and the Meteorological Law are resolved, competition for climate resources in general, and for cloud water in particular, will continue between the central and local governments.

Finally we discuss the tension between neighbouring city governments. Conflicts over surface water access and distribution among cities and regions are commonplace all over the world. However, airborne water resources have even emerged as a point of contention in China. In July 2004 five cities in Henan (Pingdingshan, Zhumadian, Leihe, Xucang, and Zhoukou) sought to relieve drought conditions by seeding clouds, but upstream cities (Pingdingshan and Xucang) leached significant amounts of precipitation from clouds, leaving downstream cities (particularly Zhoukuo) with little or no precipitation, resulting in accusations of rain "theft".[19] In February 2009, similar accusations were made in Wuzhou, in Guangxi Province and in Xian and Xiyang, in Shannxi Province.

This political conflict is due to current CCP personnel management practices that encourage local cadres to compete for development resources, without clearly designating stewardship or user rights for airborne resources. The career advancement of local cadres is determined in large part by their success in mobilizing and competing for resources according to clear spatial definitions, with cadre performance assessed based on the territory under their jurisdiction (Chien, 2015). Thus, competition for vaguely-regulated cloud water resources raises difficult geopolitical regulatory challenges (Dalby, 2015; Yusoff, 2013).

6. Conclusions: taming the weather, Chinese style

The existing social science literature on water usage have paid insufficient attention to cloud water in the form of rain, snow, hail, cloud, fog. This paper illustrates the weather modification dynamics between the state, society and airborne water in the context of China's authoritarian environmentalism and ecological modernization. About 70% of China's county-level administrations operate weather modification bureaus and regularly use state power to conduct weather modification, either causing or preventing the precipitation of cloud water in the interests of water security, food production, ecological preservation and the staging of large scale outdoor events.

In the context environmental science, policies are implemented with limited transparency, and local leaders use weather modification measures to appease local farmers and to demonstrate hosting of important events. In addition, forced transformation of cloud water complicates volume politics. For example, weather modification can bring local authorities into conflict with the military which has jurisdiction power over China's airspace. Competition for cloud water also occurs among various central and local stakeholders.

This paper expands the scope of investigation to include cloud water and offers greater sensitivity to the social construction of this particular concept of water. One theoretical and one policy implications are raised. Optimizing the effectiveness of weather modification requires consideration of several variables including the timing of conducting weather modification, location of rocket launchers and impacted areas (ground horizon), and cloud seeding elevation (vertical position in the air). The manipulation of cloud water informs a better theoretical understanding of a highly complicated hydro-social cycle in terms of how social, political and economic processes regulate the human and state

[16] Others included information sharing among operation sites, warehousing and transportation of mobile rocket launchers, and co-operation between the meteorological and forest sectors. See News source: Zhejiang: Strengthening coordination in weather modification (*Zhejiang: jiaqiang kongyu xiediao zhuanti bushu renying gongzuo*), Agency of China Meteorological News, 2015/11/10, http://www.cma.gov.cn/2011xwzx/2011xgzdt/201511/t20151110_297070.html, accessed on 2016/01/31.

[17] Interview source: BJ 151108. The interviewee is a key weather modification scientist at the China Academy of Meteorological Science.

[18] Each weather modification division covers a few provincial-level administrations, and the leading stakeholder province is decided in terms of advantageous location along with previous research and experience in weather modification and coordination. Jilin is assigned to manage the Northeast Division, Gansu for Northwest, Beijing for North China, Henan for Central China, Sichuan for Southwest, and Jiangxi for Southeast.

[19] See news source: Beijing Youth Daily, March 09, 2009, 'The dream of building an aerial water reservoir: competition in weather modification ('*kongzhong shuiku' zhi meng: rengong zengyu jing sai*)", North News Agency, 2009/03/13, http://tech.big5.enorth.com.cn/system/2009/03/13/003926674.shtml, accessed by 2016/01/10.

use of water resources (Bakker, 2012; Linton and Budds, 2014; Swyngedouw, 2009)

Finally, lack of proper coordination of weather modification activity can lead to charges of "rain stealing" between neighbouring regions. Weather monitoring technology and information is now more publically available, and local residents have grown increasingly sceptical of government claims regarding the benefits of cloud seeding. This raises moral issues regarding state intervention in natural processes, the equitable distribution of resources, and best practices for weather modification to minimize harm. Further research for suitable solutions is needed for both China and the world at large, as China seeks to export its weather modification experience and technologies abroad.

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