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CHINESE CLOUD SEEDING PRACTICES ON THE TIBETAN PLATEAU

TOWARDS NEW FORMS OF HYDROHEGEMONY AND SECURITY DILEMMA?

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ABSTRACT

Since 1956, China has been developing cloud seeding techniques, initially for drought mitigation in Jilin Province. Over the decades, Chinese weather modification practices have expanded, culminating in a robust and ambitious state-led weather modification program: the Sky River initiative, launched in 2016 and located on the Tibetan Plateau. The installation of this weather modification infrastructure, set for completion in 2025, aims to increase precipitation over a vast area to mitigate water scarcity and support food security. While these efforts have the potential to alleviate domestic water shortages, they also raise significant geopolitical concerns. The Tibetan Plateau is the source of major rivers that flow into several neighboring countries; consequently, altering precipitation patterns through cloud seeding could impact water availability downstream, potentially leading to regional tensions. This situation exemplifies a form of hydro-hegemony, where China's unilateral control over transboundary water resources may disrupt existing power balances and create security dilemmas among neighboring nations, such as India. The environmental implications of large-scale weather modification- including potential ecological disruptions- and the ethical considerations of such interventions, further complicate the discourse. This research paper explores the intersection of China's weather modification practices and its larger geopolitical dynamics, assessing the potential for new forms of hydro-hegemony and the emergence of security dilemmas in the region.

CONTENT

INTRODUCTION

The geopolitics of ground water resources is well-documented and has been the subject of extensive scientific and strategic literature.[1] However, the geopolitics of atmospheric water resources remains much less explored, despite growing interest from numerous states seeking to induce its condensation and precipitation within their territories. The primary technique employed for this purpose is "cloud seeding", which involves the dispersion of chemical substances into clouds, and is currently deployed mainly for civilian purposes. While scientific consensus on its efficacy remains elusive, cloud seeding has become indispensable in European anti-hail operations.[2] In France, for example, a network of hundreds of cloud seeding generators is deployed to mitigate hail risks and safeguard food security.[3]

However, many countries, including the United States, Morocco, Senegal, Benin, Iran, Saudi Arabia, the United Arab Emirates, Jordan, India, China, Australia, and others, have also integrated cloud seeding as a routine practice to increase rainfall within their borders.[4] In total, around fifty states conduct weather modification operations globally. Among these, China is the largest investor in the sector, with all provincial governments except Shanghai establishing weather modification offices. Collectively, these offices employ approximately 40,000 people and allocate significant budgets to weather modification initiatives.[5] Cloud seeding is also utilized for air pollution mitigation, water resource security, snow generation, and controlling weather conditions for specific public events. After China, the United States, Thailand and India are the leading investors in operational weather modification programs.[6]

Because these techniques involve the chemical modification of the atmosphere and aim to influence the distribution of water resources, they are prone to tensions. Intra-national socio-environmental controversies have already emerged in territories where cloud seeding is routinely practiced. For instance, French ethnologist Jean-Louis Brodu documented mobilizations against anti-hail cloud seeding in Europe during the 1970s and 1980s. In northern Spain, rumors proliferated about "phantom planes stealing rain", allegedly causing severe droughts by seeding clouds. According to Brodu, these controversies were fueled

1. Afton Clarke-Sather, Britt Crow-Miller, Jeffrey M. Banister, Kimberley Anh Thomas, Emma S. Norman and Scott R. Stephenson, "The Shifting Geopolitics of Water in the Anthropocene", *Geopolitics*, 22, 2017, p. 332-359; John Agnew, "Water Power: Politics and the Geography of Water Provision", *Annals of the Association of American Geographers*, 101, 2011, p. 463-476; Nalin Kumar Mohapatra, "Geopolitics of Water Securitisation in Central Asia", *Geojournal*, 88, 2022, p. 897-916; Narendra Kumar Tripathi, "Scarcity Dilemma as Security Dilemma: Geopolitics of Water Governance in South Asia", *Economic and Political Weekly*, 46, 2011, p. 67-72.

2. Jean Dessens, José Sanchez, Claude Berthet, Lucía Hermida, Andrés Merino, "Hail Prevention by Ground-Based Silver Iodide Generators: Results of Historical and Modern Field Projects", *Atmospheric Research*, 170, 2016, p. 98-111.

3. Marine de Guglielmo Weber, "Weather Modification in France: The Case of Cloud Seeding", *La Revue de l'Energie*, 674, 2024, p. 39-48.

4. World Meteorological Organization (WMO), *Report from Expert Team on Weather Modification Research for 2012/2013*, 2013, June.

5. Shiuh-Shen Chien, Dong-Li Hong, and Po-Hsiung Lin, "Ideological and Volume Politics Behind Cloud Water Resource Governance – Weather Modification in China", *Geoforum*, 85, 2017, p. 225-233.

6. Polaris, "Cloud Seeding Market Share, Size, Trends, Industry Analysis Report, By Type", *Market Research Report*, 2022.

by factors such as shifts in agricultural production methods (e.g., greenhouse farming), interregional water transfer systems, and general resentment among small-scale farmers toward larger operations. Similar controversies were observed in France, where farmers accused cloud-seeding aircraft of exacerbating drought conditions, including the historic drought of the summer of 1986 in Dordogne. Beyond drought concerns, Brodu noted fears about cloud seeding's potential to trigger torrential rains, tornadoes, or hail in neighboring areas. These tensions are not an exclusively European phenomenon: protest movements by farmers have, for example, been observed in the United States in regions such as the Appalachians, Pennsylvania, West Virginia, Maryland and Virginia as early as the 1960s, and in Texas, where a protest against cloud seeding was organized in 2014. These local protests, rooted in broader socio-environmental conflicts, highlight the potential of cloud seeding to catalyze tensions.

Although cloud seeding is primarily aimed at advancing domestic economic activities, these practices may also be perceived by neighboring states as akin to resource appropriation—similar, for example, to excessive withdrawals from transboundary river basins. In this regard, the World Meteorological Organization noted in its 2001 final report of the 53rd session of the Executive Council that "legal aspects may assume particular importance when artificial weather modification activities are conducted in border regions."[7] In the absence of legal frameworks regulating civilian weather modification practices, border regions where such activities are deployed could experience heightened tensions over shared water resource management. One notable example, which we will explore in this research paper, is the Tibetan Plateau, where Chinese weather modification practices, and more precisely the Sky River project, have heightened Sino-Indian tensions. These practices are, indeed, increasingly concerning for India, not only due to their potential transboundary effects but also because Indian agriculture, hydroelectricity, and domestic consumption rely heavily on the water resources of the Tibetan Plateau. Furthermore, India's historical experience with China's water policies—particularly its large-scale dam-building projects on transboundary rivers—has heightened suspicions regarding Beijing's approach to resource management. The perception that China is unilaterally altering regional hydrological balances contributes to broader anxieties within India's security and policy circles.

Given the structural rivalries between the two countries, India's strategic community increasingly views weather modification as a potential tool for geopolitical leverage, further amplifying water-related issues in bilateral relations. The concept of "hydro-hegemony"—which traditionally refers to a state's domination over transboundary water resources through power asymmetries, legal instruments, and discursive control[8]—has primarily been applied to surface and groundwater management. However, this research paper suggests extending its analytical scope to include atmospheric interventions. By doing so, it highlights how weather modification technologies are, in themselves, instruments of

7. World Meteorological Organization, *Abridged Final Report of the 53rd Session of the Executive Council*, Annex III, 2001, Geneva, p. 111.

8. Mark Zeitoun, and Jeroen Warner, "Hydro-Hegemony—A Framework for Analysis of Trans-Boundary Water Conflicts", *Water Policy*, 8, 2006, p. 435-460.

state-led hydropolitics aimed at exerting control over water resources, and directly linked to the securitization—the process through which "securitizing actors transform issues that do not inherently threaten their existence into extreme security concerns by framing them as existential threats"[9]—of water resources.

The dual perspective presented here stems from a collaboration between two researchers from India and France respectively, and aims to highlight the scientific and strategic importance of examining this issue jointly. While cloud seeding is a growing concern for India, prompting reflections on atmospheric water governance, it is also a matter of strategic interest for France, for at least three key reasons. First, as the most active country in cloud seeding activities in Europe, France occupies a unique position that necessitates vigilance over the geopolitical implications of these operations, particularly in a context where climate and weather manipulation could become points of tension or leverage in international relations. Monitoring these activities is not just a matter of technical oversight but also of geopolitical foresight, ensuring that France can navigate potential conflicts and shape global norms regarding such interventions.

Second, France has yet to sign- and appears unwilling to sign- the United Nations Convention on the Prohibition of Military or any other Hostile Use of Environmental Modification Techniques (ENMOD), which prohibits the hostile use of environmental modification techniques. This omission places the country under growing scrutiny, both domestically and internationally, as questions arise about its stance on the ethical, legal and security dimensions of weather and climate interventions.

Finally, this case serves as a critical testing ground for understanding the broader geopolitical implications of cloud seeding projects. Beyond weather modification, it provides valuable insights into the future challenges posed by more ambitious atmospheric interventions such as climate engineering. Techniques like stratospheric aerosol injection, or ocean albedo modification, carry significant transboundary risks. The lessons learned from cloud seeding can inform the development of governance models, conflict resolution mechanisms and strategic frameworks to anticipate and mitigate the geopolitical repercussions of these emerging technologies.

9. Anjan Kumar Sahu and Surinder Mohan, "From Securitization to Security Complex: Climate Change, Water Security and the India-China Relations", *International Politics*, 59, 2022, p. 322.

WEATHER MODIFICATION IN CHINA: ECOLOGICAL MODERNIZATION, CLIMATE AND WATER SECURITIZATION

The history of weather modification in China

Since the mid-20th century, the intensity of weather-related hazards—such as droughts, floods, hailstorms and fog, combined with escalating water stress, has driven the advancement of weather modification initiatives in China.[10] Their origins can be traced to a research program initiated by Mao Zedong in 1956 titled "Preliminary Research on the Physics of Clouds and Precipitation and Artificial Rain"[11] (see Table 1). Two years later, the first field experiments were launched, to combat drought in Jilin Province.[12] During the 1960s and the 1970s many field experiments were also conducted for hail suppression[13] and were a primary motive for important progress in cloud modeling studies at the end of the century.

The operational planning of weather modification activities began in 1994 with the establishment of the National Coordination Committee of Weather Modification in order to facilitate the exchange of information between political and scientific actors, and the first Weather Modification Development Plan (1996–2010);[14] it was followed by two more plans: 2014-2020, and 2021-2025. The last one called for expanding the area covered by weather modification to 5.5 million square kilometers, more than half of the country's total land area.[15] Planning efforts were accompanied and strengthened by legal efforts, notably the Meteorological Law in 2000, which made the China Meteorological Administration (CMA) the coordinator of weather modification activities, and, in 2002, the Regulations on the Administration of Weather modification.[16] Weather modification received formal recognition as an important policy measure with its incorporation into the "Central Document No. 1"[17] of the years 2012 and 2013. Furthermore, in 2012 the Office of the State Council issued a document on "Opinion regarding further strengthening weather modification."[18]

10. Xueliang Guo, Danhong Fu, Xingyu Li, Zhaoxia Hu, Henchi Lei, Hui Xiao, and Yanchao Hong, "Advances in Cloud Physics and Weather Modification in China", *Advances in Atmospheric Sciences*, 32, 2015, p. 230-249.
11. Shiuh-Shen Chien, Dong-Li Hong, and Po-Hsiung Lin, "Ideological and Volume Politics Behind Cloud Water Resource Governance—Weather Modification in China", p. 225-233.
12. "60 Years of Weather Modification in China", *China Meteorological News Press*, 2018, September 13.
13. Xueliang Guo, Danhong Fu, Xingyu Li, Zhaoxia Hu, Henchi Lei, Hui Xiao, and Yanchao Hong, "Advances in Cloud Physics and Weather Modification in China".
14. Manon Simon, Jan McDonald, and Kerryn Brent, "Transboundary Implications of China's Weather Modification Program", *Transnational Environmental Law*, 12, 2023, p. 594-622.
15. China Meteorological Administration, "National Weather Modification Development Plan 2021–25", 2021.
16. Shiuh-Shen Chien, Dong-Li Hong, and Po-Hsiung Lin, "Ideological and Volume Politics Behind Cloud Water Resource Governance—Weather Modification in China", p. 228.
17. It is the first document issued by the Central Committee of the Chinese Communist Party every year after the spring festival and points at important issues for rural development.
18. Bettina Blumeling, Rakhyun E. Kim, and Frank Biermann, "Seeding the Clouds to Reach the Sky: Will China's Weather Modification Practices Support the Legitimization of Climate Engineering?", *Ambio*, 49, 2020, p. 365-373.

Table 1

Evolution of China's Weather Modification Program

YEAR	CHINA'S PRACTICES AND POLICIES ON WEATHER MODIFICATION
1949	The Central Military Commission Meteorological Bureau was established, it later became China Meteorological Administration (CMA), a public service agency directly affiliated with the State Council of the PRC since 1994.
1956-1967	Mao Zedong called for the pursuit of weather modification technologies under the "1956-1967 China Agriculture Development Framework". Following up, a research project titled "Prior Research on Cloud and Precipitation Physics and Artificial Rain" was undertaken as part of the "1956-1967 China Science Development Plan".
1958	The first aircraft artificial rain enhancement operation was executed in Jilin to fight droughts. With its first cloud seeding, this laid the foundation of a weather modification system in China.
1960-1990	China was actively engaged in the pursuit of ground observations, scientific experiments and research on weather modification.
1978	Chinese Meteorological Institute (CMI) was established.
1991	CMI was renamed China's Academy of Meteorological Sciences (CAMS). It is supported by both CMA and the Ministry of Science and Technology (MOST) of China and acts as the key research institution attached to CMA.
1994	China introduced a system of weather modification coordination. It aimed to facilitate the exchange of information by integrating resources drawn from research institutes, operational departments and ministries. This led to the formulation and publication of the 1996-2010 China Weather Modification Development Plan.
2000	The *Meteorology Law of the People's Republic of China* came into effect on 1 January 2000 to regulate the meteorological activities legally; it holds meteorological departments responsible for discharging administrative management functions.
2002	China passed the Regulations on the Administration of Weather Modification, the first national law to regulate weather modification activities.
2005	The weather was included in the list of key scientific research projects in the 11th Five Year Plan (2006-2010). Since then the weather has been a component of China's Five-Year Plans.
2007	Weather Modification Center of China Meteorological Administration (CMA) was established.
2010	In March, CMA released for the first time the four research projects consisting of weather, climate, applied meteorology and comprehensive meteorological observation. Meteorological Defence Plan as jointly released by CMA and NDRC aiming for a 50 per cent reduction in weather-disaster casualties and ration of ensuing economic losses to GDP. 12th Five Year Plan (2011-2015) first introduced "Climate Policy" as the key principle for sustainable development. It also introduced the concept of ecological modernisation in relation to the "construction of an ecological civilisation."

YEAR	CHINA'S PRACTICES AND POLICIES ON WEATHER MODIFICATION
2013	North-east China Regional Weather Modification Center was set up (First regional operational institution). In 2013, CMA issued a revised version of the four research projects proposed in 2010: weather, climate, applied meteorology and comprehensive meteorological observation for the timeline 2013-2020.
2014	24 October: The first national instruction on weather modification was issued by CMA, aiming to fuel the development of meteorological modernisation. 17 December: National Development and Reform Commission (NDRC) and CMA jointly issued *Development Planning for National Weather Modification (2014-2020)*.
2015	Modern Ark 60 (MA60), CMA's first weather modification aircraft was officially put into operation. China launched the Tianhe Project—also known as "Sky River"—it aims to guide rich water vapour that is in the air above the Yangtze River Basin northward to the Yellow River basin, where it would become rainfall. • It was conceived by Tsinghua University, Qinghai University, and Qinghai province's meteorological bureau with government funding and support from the China Aerospace Science and Technology Corp. (CASC), a state-owned company that plays a major role in China's space programme. • With information from remote-sensing satellites that track the movements of clouds, Sky River aims to influence precipitation and other weather patterns through artificial means: by releasing chemicals from airplanes to induce showers over farmland, for example, or by moving water from the Yangtze River to the more northern Yellow River.
2016	China's Ministry of Finance allocated 199 million Yuan (US $29.76 million) to its weather modification programme.
2018	China launched the largest weather-control machine to be installed in the Tibetan Plateau.
2020	In December 2020, China's State Council issued a circular stating that China will have a developed weather modification system by 2025.

Source: Jash 2020[19]

Weather modernization and climate securitization: towards unconventional water resource management

In an article entitled "China Focus: China forges ahead with meteorological modernization,"[20] the China Meteorological Administration declared in 2023 that "the country has built the world's largest comprehensive meteorological observation system": " The system consists of seven atmospheric background stations, 27 climate observation stations, nearly 70,000 automatic ground-based meteorological stations, 120 high-altitude meteorological stations, 242 new generation weather radars and seven in-orbit Fengyun meteorological satellites". This equipment, and the development of new specialized institutes – such as the

19. Amrita Jash, "China's Practice of Weather Modification: Implications for India", Issue Brief No. 215, Centre for Land Warfare Studies, 2020, March 16.

20. China Meteorological Administration, "China Focus: China Forges Ahead with Meteorological Modernization", 2023, March 29.

Chengdu Institute of Plateau Meteorology (CIPM) or the Institute of Desert Meteorology in Urumqi – exemplify the considerable efforts of China to improve its meteorological capabilities. This meteorological modernization has significantly progressed cloud seeding research in China, particularly through the development of advanced observational tools that are widely used in cloud seeding activities: radar, satellites, airborne measurements and operational mesoscale models.[21] In another article published by the China Meteorological Administration in 2018, entitled "60 years of weather modification in China", it is noted that at the time, China had established six regional weather modification centers, and possessed a space-ground-based operation system of 6500 antiaircraft artillery, 50 aircraft, 8200 rocket systems and 50000 professional and amateur crew team.[22]

These modernization efforts and the development of advanced meteorological technologies serve multiple purposes, including improving weather monitoring to prevent, warn against, and mitigate disaster, managing water resources and supporting ecological protection and restoration. As part of the broader agenda of ecological modernization[23] linked to the concept of ecological civilization, weather modernization is envisioned by the Chinese government as a means of simultaneously addressing climate and ecological challenges while sustaining economic development. There is a focus on "the adoption of high-tech water technologies and price mechanisms to treat polluted water and improve water infrastructure."[24] China is, indeed, one of the most water-scarce nations in the world, its per capita water supply being only one-fourth of the global average.[25] This challenge is not new for China and has long been a key political issue. According to the political scientist Scott Moore, the history of Chinese water policy can be divided into three distinct periods: the first, from 1949 to 1977, "characterized by small-scale irrigation and flood control based on mass labour mobilization" ; second, from 1978 to 1997, "defined by construction of large-scale flood control, wastewater treatment and water-supply infrastructure"; and a third, from 1998 to the present, "pluralizing water resource management to address new environmental challenges."[26] The pluralization process described by Moore refers to the diversification of actors, mechanisms and approaches in water management in China. This process includes the increasing involvement of non-state actors such as NGOs and local water user associations, the introduction of market-based mechanisms for allocating water resources, and the adoption of innovative governance tools. In this research paper, we argue that the expansion of Chinese cloud seeding practices exemplifies this pluralization process, which we also interpret as the diversification of water project types—from traditional infrastructure projects, such as dams, to novel and unconventional initiatives such as weather modification.

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21. Xueliang Guo, Danhong Fu, Xingyu Li, Zhaoxia Hu, Henchi Lei, Hui Xiao, and Yanchao Hong, "Advances in Cloud Physics and Weather Modification in China", p. 231.

22. China Meteorological Administration, "60 Years of Weather Modification in China", 2018, September 13.

23. Lei Zhang, Arthur P.J. Mol, David A. Sonnenfeld, "The Interpretation of Ecological Modernisation in China", *Environmental Politics*, 16, 2007, p. 659-668.

24. Shiuh-Shen Chien, Dong-Li Hong, Po-Hsiung Lin, "Ideological and Volume Politics Behind Cloud Water Resource Governance—Weather Modification in China", p. 229.

25. Hongzhou Zhang and Mingjiang Li, "Thirsty China and its Transboundary Waters", in *China and Transboundary Water Politics in Asia*, Routledge, 2017, p. 3.

26. Scott M. Moore, "Legitimacy, Development and Sustainability: Understanding Water Policy and Politics in Contemporary China", *The China Quarterly*, 237, 2019, p. 156.

Cloud seeding falls into what a UN Water Brief called "unconventional water augmentation opportunities", alongside techniques like fog water harvesting, or desalinated water.[27] It has been practiced worldwide for 70 years, but it has, recently, become a "long-term water resource management tool worldwide to alleviate water shortages and improve hydroelectric production."[28] For the Chinese government, cloud seeding serves multiple functions, including increasing rainfall and reducing hail to enhance agricultural productivity and ensure food security, particularly in regions like Jilin Province and the Yellow River Plain. It also aims to secure water resources for freshwater consumption and hydroelectric power generation, as seen in Yunnan and Sichuan Provinces. Additionally, cloud seeding plays a role in ecological restoration efforts such as the rainfall enhancement operations in the Sanjiangyuan National Nature Reserve, which are intended to restore the sources of the Yangtze, Yellow and Mekong Rivers.

Therefore, China's weather modification activities mainly fall into two categories theorized by Joronen et al.: "preventive weather modification", which aims to reduce the severity of extreme weather events and can serve as part of an adaptation strategy to climate change; and "weather modification for development aid", which seeks to "ensure the habitability of a geographic area"—for example, by increasing precipitation in drought-stricken regions.[29] Apart from these main functions, cloud seeding is also used in China to combat air pollution as well as to control weather conditions during public events. For instance, during the 2008 Olympic Games the International Olympic Committee considered postponing the games due to high air pollution levels until induced rainfall was used to reduce pollution and prevent heavy rains forecast for Beijing.[30] A total of 1,104 rain dispersal rockets from 21 sites in Beijing were fired and intercepted a stretch of rain belt from moving towards the Olympic stadium.[31] More recently, in 2021, when the Chinese Communist Party observed its centenary celebrations in Tiananmen Square, a research paper from Tsinghua University claimed that an extensive cloud-seeding operation in the hours before the event ensured clear skies and low air pollution.[32] According to a report by the *South China Morning Post*, the research paper estimated that the artificial rain generated during the operation reduced PM2.5 air pollutant levels by over two-thirds, significantly improving air quality from "moderate" to "good" as per World Health Organization standards.[33] This refers to what Joronen and her colleagues call "luxury weather modification", which

27. UN-Water Analytical Brief, Unconventional Water Resources. 2020, June 5. Other techniques which are studied in this brief are micro-catchment rainwater harvesting, offshore and onshore deep groundwater, municipal wastewater, agricultural drainage water, water transportation through iceberg towing, or ballast water.

28. A.I. Flossmann, et al., *Peer Review Report on Global Precipitation Enhancement Activities,* 2018.

29. Sanna Joronen, Markku Oksanen, and Timo Vuorisalo, "Towards Weather Ethics: From Chance to Choice with Weather Modification", *Ethics, Policy & Environment,* 14, 2011, p. 55-67. The difference between preventive weather modification and weather modification for development aid lies in the fact that the former focuses on forecasting extreme weather events that have not yet occurred, while the latter seeks to improve existing unfavorable conditions.

30. Shiuh-Shen Chien, Dong-Li Hong, Po-Hsiung Lin, "Ideological and Volume Politics Behind Cloud Water Resource Governance—Weather Modification in China", p. 225-233; Manon Simon, Jan McDonald, and Kerryn Brent, "Transboundary Implications of China's Weather Modification Programme", p. 594-622.

31. "Beijing Disperses Rain to Dry Olympic Night", *China Daily*, 2008, August 9.

32. Helen Davidson, "China 'Modified' the Weather to Create Clear Skies for Political Celebration—Study", *The Guardian*, 2021, December 6.

33. Stephen Chen, "China 'Modified' the Weather as Communist Party Marked Centenary in Beijing", *South China Morning Post*, 2021, December 5.

involves responding to the desire for "certain weather conditions, at a specific location, at a specific time."[34] This type of weather modification is considered morally questionable due to potentially conflicting interests as the weather preferences of different stakeholders regarding local conditions may differ.

While event-driven weather modification holds significant importance (a point we will revisit in the second part of this research paper), the majority of China's financial and technical efforts in this domain are primarily directed towards mitigating meteorological hazards and increasing water resources to support agricultural and energy needs. On the Chinese territory, two main weather modification experiments are being carried out: one consists of an orographic cloud-seeding experiment in six provinces of Northwest China; the other is the Chinese Randomized Precipitation Enhancement Experiment (CRPEEX) in four provinces.[35] In order to secure its domestic water resources, in 2016 China also launched Sky River, i.e. a weather modification project on the Tibetan Plateau, particularly in the Sanjiangyuan region of Qinghai Province. As the source of most of Asia's major rivers—such as the Indus, Ganges, Brahmaputra, Irrawaddy, Salween, Mekong, Yangtze, and Yellow Rivers—the plateau supplies water to nearly half of China's northern plain. However, growing water demands in northern China, combined with the effects of climate change, are creating increased water stress and are driving the Chinese government to multiply resource transfer initiatives from the South to the North. Named after atmospheric rivers—airborne streams that transport large volumes of water vapor—this project identifies a convergence of atmospheric rivers above the Sanjiangyuan region, where the water vapor could be strategically transformed into rainfall. To achieve this, China has installed numerous automated, remote-controlled chimneys designed to seed the atmosphere based on data from an atmospheric monitoring system developed by the China Aerospace Science and Technology Corporation (CASTC). The goal is to intercept the Indian monsoon over the Tibetan Plateau and direct part of it northward—specifically to the arid Yellow River Basin—to increase annual water supplies by 5 to 10 billion cubic meters.[36] To date, the China Meteorological Administration has installed over 500 ground-based generators for cloud seeding on the plateau. The ultimate objective, however, is to deploy tens of thousands of generators covering an area of up to 1.6 million square kilometers.[37]

Chinese cloud seeding practices go beyond weather modernization and water management. They also contribute to climate and water securitization—more specifically, the securitization of economic development in response to climate threats.[38] The Chinese drive to secure domestic water resources is evident not only in discourse—such as former Chinese

34. Sanna Joronen, Markku Oksanen, and Timo Vuorisalo, "Towards Weather Ethics: From Chance to Choice with Weather Modification", p. 59.

35. Ali M. Abshaev, Andrea Flossmann, Steven T. Siems, Thara Prabhakaran, Zhanyu Yao, and Sarah Tessendorf, "Rain Enhancement Through Cloud Seeding", M. Qadar et al. (eds), *Unconventional Water Resources*, Springer, 2022, p. 44.

36. Stephen Chen, "China Needs More Water, So It's Building a Rain-Making Network Three Times the Size of Spain", *South China Morning Post*, 2018, March 26.

37. Manon Simon, Jan McDonald, and Kerryn Brent, "Transboundary Implications of China's Weather Modification Program".

38. Anjan Kumar Sahu, "From the Climate Change Threat to the Securitisation of Development: An Analysis of China", *China Report*, 57, 2021, p. 192-209.

Premier Wen Jiabao's statement that water scarcity threatens "the survival of the Chinese nation"[39]—but also in the active involvement of security and military institutions in climate-related policies. This is exemplified by the integration of climate issues into military operations other than war (MOOTW).[40] For instance, in July 2020, 29,000 troops from the People's Liberation Army (PLA) and the People's Armed Police (PAP) participated in disaster relief operations following severe flooding in southern China.[41] Weather modification is closely tied to this process, as it often relies on military-grade equipment. A notable example is the Twin-Tailed Scorpion: a strike and reconnaissance drone, typically used for carrying ammunition during military operations, which was repurposed in the summer of 2024 to deploy silver iodide for a cloud seeding trial.[42] This securitization process is further exemplified by the involvement of the state-owned CASTC in the Sky River program. As China's leading space and defense contractor, CASTC spearheads other ambitious national projects, including lunar exploration and the construction of China's space station—generating concerns about the potential militarization of space. Similarly, the security—or even military—dimension of China's weather modification practices raises concerns in India.

GEOPOLITICAL AND MILITARY ASPECTS OF CHINESE WEATHER MODIFICATION: ISSUES AND CONCERNS

Anjan Kumar Sahu and Surinder Mohan argue that "the discourse of threat influences the interstate relations that include the sharing of transboundary river water between the neighboring states."[43] In the case of China-India relations, the situation is made more complex by the fact that China acts as a "hydro-hegemon" referring to the concept of "hydro-hegemony" defined in the introduction. China controls major transboundary rivers, including the Mekong, Brahmaputra and Indus. Its extensive dam-building projects like those on the upper Mekong (Lancang) and Yarlung Tsangpo (Brahmaputra) have raised concerns among downstream countries like India, which fear reductions in water flow and increased Chinese leverage over their water security. Furthermore, China's reluctance to engage in binding international water agreements reinforces its hydro-hegemonic position, allowing it to unilaterally shape regional hydropolitics. Indeed, the absence of binding agreements allows hydro-hegemonic states to unilaterally manage water resources, often to the detriment of downstream countries[44]—a situation particularly evident in basins where upstream nations have greater political, economic or military power and use their strategic position

39. Quoted in "Desperate measures", *The Economist*, 2013, October 12.

40. Carine Pina, *La Chine et les opérations militaires autres que la guerre (军队非战争军事行动) à l'étranger. Quelles conséquences sur le dilemme de sécurité?*, IRSEM Report n°115, 2024, March.

41. John Dotson, "The PLA Is Mobilized for Flood Relief in Eastern China", China Brief, 20, 2020.

42. Hayley Wong, "China Tests Drone-Based Cloud Seeding in Xinjiang to Bring Rain to Dry Regions", *South China Morning Post*, 2024, August 7.

43. Anjan Kumar Sahu and Surinder Mohan, "From Securitization to Security Complex: Climate Change, Water Security and the India-China Relations", *International Politics*, 59, 2022, p. 323.

44. Melvin Woodhouse and Mark Zeitoun, "Hydro-Hegemony and International Water Law: Grappling with the Gaps of Power and Law", *Water Policy*, 10, 2008, p. 103-119; Harsh Vasani, "International Water Law and Hydropolitics: An Enquiry into the Water Conflict Between India and Nepal", *Water International*, 48, 2023, p. 259–281.

to control water flow, access and allocation.[45] This dynamic has fueled geopolitical tensions, particularly between China and India, where water disputes intersect with broader strategic rivalries. The Sino-Indian boundary issue is linked to the Brahmaputra, as it overlaps with the disputed claims in the Eastern Himalayas[46]—which China claims as "South Tibet", and is administered by India as the state of "Arunachal Pradesh."[47] Although existing analysis primarily focuses on groundwater resources, the incorporation of weather modification practices into China's broader securitization of climate change and water resources represents a significant challenge within the context of China-India relations, as will now be explored.

Weather Modification within the Context of China's Hydro-hegemony

In June 2023, the National Development and CMA convened a meeting on weather modification work, boasting about China's operational strength in large-scale and effective weather modification with a complete system[48] thereby clarifying the importance Beijing attaches to weather modification. However, these activities raise significant concerns for its Indian neighbor due to a key factor: namely, the lack of comprehensive data, research and transparency regarding their transboundary effects, which could lead to unforeseen consequences and cascading impacts. When conducted for the benefit of one's own interest, such activities may indeed have an undesirable impact on others. From this perspective, it is important to question the shift from weather conditions determined by chance to weather conditions determined by choice, which implies that there would be "winners and losers" in these practices.[49] Within this framework, the question of "risk"—spanning environmental, social, and financial domains—becomes central,[50] and is directly linked to the uncertainty surrounding the effects of cloud seeding when practiced on a large scale and which remain poorly understood.[51]

This reflects a first concern for India: that Chinese weather modification activities could have unintended consequences on regional weather patterns, thereby indirectly affecting India's climate and water security. Tibet, where the Sky River project is currently being

45. For instance, Ethiopia's construction of the Grand Ethiopian Renaissance Dam (GERD) on the Blue Nile has proceeded without a comprehensive agreement with downstream countries, such as Egypt and Sudan.

46. Hangzhou Zhang, "Sino-Indian Water Disputes: The Coming Water Wars?", *WIREs Water*, 3, 2016, p. 155.

47. Amrita Jash, "China Claims, but India Administers-Where does Arunachal Pradesh Stand in the India-China Boundary Dispute?", *The Borderlens*, 2022, September 14.

48. China Meteorological Administration, "Weather Modification Development in China Has Scored Remarkable Results", 2023, June 28.

49. Sanna Joronen, Markku Oksanen, and Timo Vuorisalo, "Towards Weather Ethics: From Chance to Choice with Weather Modification", p. 63.

50. Heidi Werosta, Ashley Van Name, and Alyssa Stansfield with Julie M. Fagan, "Weather on Demand. Past Cases and Future Risks of Cloud Seeding Efforts as a Solution to the Global Water Crisis", Rutgers University, 2016.

51. Moreover, experts argue that given its authoritarian political system, China lacks a system of checks and balances to facilitate the implementation of potentially controversial projects. As a result, the scientific evidence and political justification for weather modification are not subject to debate or discussions and therefore, the leadership's propensity for technological intervention in taming different weather systems is rarely challenged by alternative viewpoints. Shiuh-Shen Chien, Dong-Li Hong, Po-Hsiung Lin, "Ideological and Volume Politics Behind Cloud Water Resource Governance—Weather Modification in China", p. 231; Dale Jamieson, "Ethics and Intentional Climate Change", *Climatic Change*, 33, 1996, p. 323–336; Alan Witt, "Seeding Clouds of Uncertainty", *Jurimetrics*, 57, 2016.

installed, is the source of Asia's most important rivers, including the Indus, Ganges, Brahmaputra, Irrawaddy, Salween and Mekong- constituting the lifeline of nearly 3.4 billion or 46 per cent of the world's 7.06 billion population.[52] Consequently, any alterations to the Tibetan ecosystem could potentially have far-reaching consequences for neighboring South and Southeast Asian countries, as well as for lower riparian states such as India. In this respect, China's cloud seeding activities may have implications, whether intentional or not, for Indian states such as Arunachal Pradesh, Assam and Sikkim in the east; Uttarakhand and Himachal Pradesh in the central region; and the Union Territory of Ladakh in the west, along the border with China. Although these potential impacts remain uncertain,[53] the concerns they raise are tangible and have significant political ramifications in India, fueling debates and tensions regarding the country's water and climate security.

Indeed, on several occasions, India's political community has raised concerns regarding the transboundary impacts of Chinese activities, particularly in Indian states bordering China. For instance, in 2017, while addressing the unusual nature of floods in the Indian state of Assam, then Minister of the State, Hemanta Biswa Sarma stated during a press conference: "During the floods, we did not have any abnormal rainfall here. I had met the Arunachal Pradesh chief minister, who told me that there was no excess rainfall in that state as well. Then, where did the water come from? … China, for mysterious reasons, is not sharing the hydrological data with India."[54] Thereafter, in 2018, Sarma further pointed out that Assam and Arunachal Pradesh are suffering due to interference from China in the natural ecosystem in Tibet, stating that despite no massive rainfall, Assam being a lower riparian state witnessed "extensive flooding" given there was "third wave of the flood"[55] in 2017.[56]

In this context, India's concern is driven by a confluence of several interrelated phenomena: the emergence of natural disasters whose attribution is unclear; the awareness that China is actively developing weather modification infrastructure; and the absence of shared hydrological data concerning river flows, which further intensifies India's sense of insecurity and distrust. While India's Ministry of External Affairs called it "premature" to link it with the floods in Assam, however, he confirmed that India had "not received hydrological data from the Chinese side,"[57] – under the existing bilateral Memoranda of Understanding (MoUs)[58] where China is expected to provide hydrological data information

52. Aparna Roy, "'Weather War': A latest addition to the Sino-Indian conundrum?", Observer Research Foundation, 2018, August 22.

53. The impact of weather modification operations remains uncertain due to the lack of systematic studies and the difficulty of isolating their effects from natural climatic variations. Current weather models do not allow for a clear distinction between induced precipitation and what would have occurred naturally. This uncertainty is even greater when operations are conducted on a very large scale, as atmospheric dynamics become increasingly complex and difficult to predict.

54. "Flood May Have Been Caused by Heavy Rain in China: Assam Minister", *The Economic Times*, 2017, August 23.

55. Richard Davies, "India – Third Wave of Flooding Hits Assam, 2 Million Affected", *Floodlist*, 2017, August 14.

56. Bikash Singh, "China Reportedly Building Weather Modification System, Centre Alerted", *The Economic Times*, 2018, March 28. The Brahmaputra originates from Tibet and flows into Arunachal Pradesh and Assam and later drains into the Bay of Bengal through Bangladesh.

57. "Rajnath Urges Free Flow of River Data to Mitigate Floods", *The Times of India*, 2017, September 29.

58. Department of Water Resources, River Development and Ganga Rejuvenation, "India-China Cooperation".

of the Brahmaputra river (Yarlunng Zangbo in Chinese, signed in 2002)[59] and Sutlej river (*Langqen Zangbo* in Chinese, signed in 2005)[60] during the flood seasons (May to October). In addressing the flood situation in India, Indian Home Minister Rajnath Singh pointedly remarked: "Some may ask, what kind of diplomatic efforts should be taken to solve the flood problem? Hydrological data of some rivers that come from another country [China] should be shared."[61] It should be noted that the absence of data sharing by Beijing with New Delhi may impede India's preparedness to address potential natural disasters.

The issue of hydrological data highlights a second significant concern for India. In addition to fearing the unintended side effects of Chinese weather modification activities, India is also apprehensive that these interventions could further strengthen China's hydro-hegemony. This dominance, already well-established in the management of groundwater resources, has been evident in several key instances. In the background of Chinese intrusion into the Galwan Valley in 2020[62] in Eastern Ladakh, satellite images showed that China was trying to divert the waters of the Galwan River and change the landscape of the Galwan Valley with new tracks and river crossings- despite the Chinese assurance that it would not block waters of south and westward flowing rivers.[63] More recently, on December 25, 2024 the Chinese government approved the construction of the world's largest dam,[64] the Motuo project, in the lower reaches of the Brahmaputra/Yarlung Zangbo in Tibet—the biggest infra project with an estimated cost of around US$ 173 billion and expected to generate nearly 300 billion kilowatt-hours (kWh) of electricity annually, or three times more energy than the Three Gorges Dam.[65] Given its concerns, the Indian government is "on alert" over Beijing's proposed dam build-up;[66] while India's Ministry of External Affairs issued a statement saying: "The Chinese side has been urged to ensure that the interests of downstream states of the Brahmaputra are not harmed by activities in upstream areas. We will continue to monitor and take necessary measures to protect our interests."[67]

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59. In this, the information is shared from three hydrological stations—Nugesha, Yangcun and Nuxia— lying on the mainstream of the Brahmaputra. MoU in this connection was further renewed in 2008, 2013 and 2018 and has expired on June 5, 2023 and is under process of renewal through diplomatic channels.

60. In this, the data is shared from a station at Tsada. China last supplied the monsoon data for Sutlej river for the flood season in 2021 and the MoU is now under process of renewal through diplomatic channels.

61. "Rajnath Urges Free Flow of River Data to Mitigate Floods".

62. Where Indian and Chinese military clashed on June 15, 2020.

63. Maj Gen AK Chaturvedi, "Diversion of Galwan River", *Strive*, 2021, February 22.

64. The dam is part of China's 14th Five-Year Plan (2021-2025) and National Economic and Social Development and the Long-Range Objectives Through the Year 2035.

65. Holly Chik, "China Approves Tibet Mega Dam that Could Generate 3 Times More Power Than Three Gorges", *South China Morning Post*, 2024, December 26.

66. "India on Alert Regarding China's Proposed Dam on Brahmaputra: Rajnath Singh", *The Hindu*, 2025, January 8.

67. "India Reacts to China's Dam Plan, Vows to 'Protect Our Interests'", *Hindustan Times*, 2025, January 3. Although Beijing has assured that the Brahmaputra project will have 'no negative impact' on downstream countries (India and Bangladesh), evidence from China's dams on the Mekong River suggests otherwise. Some studies have claimed that the drought in the Lower Mekong Basin in 2019 that affected Laos, Thailand, Cambodia, and Vietnam was caused by China purposely holding back water in its reservoirs—this when combined with low levels of precipitation, has triggered droughts, increased sediment load, and upended the food security for the lower riparian countries. Scholars such as Dr. Kalyan Rudra have also argued that "[i]f the dam trapped sediment, that would make the soil along the river downstream less fertile and erode riverbanks and coastlines in India." In addition, the dam is to be built in a sensitive geography located along a tectonic plate boundary prone to earthquakes. "'Dam Over Brahmaputra Won't Impact Water Flows to India': China after New Delhi Registers Protest", *The Times of India*, 2025, January 6; Milton Osborne, "Chinese Dams and the Mekong Drought", *The Interpreter*, 2020, August 11; Roshani

The backdrop to these concerns is China's distinct approach to transboundary water governance. Being Asia's "upstream superpower", China has not committed to a clear, independent transboundary river policy, which would include internationally agreed-upon guidelines for managing shared waterways. Furthermore, China is not a signatory to either of the two key global water conventions,[68] further limiting transparency and cooperation. Instead, China's management of transnational rivers is governed primarily through bilateral agreements,[69] often relying on non-binding soft law instruments.[70] Given that China has not established consistent rules for water management, there is a heightened fear that its weather modification efforts could further consolidate its control over transboundary water resources, with little regard for the potential consequences for its neighbors.

To summarize, the securitization of water resources by China is technically embodied in the construction of what could be termed "water-grabbing" infrastructure (dams, cloud seeding). First China "acts as a hydro-hegemon" and fails to "attenuate the Indian fears by refusing to enter into a joint water-sharing agreement;"[71] secondly India now considers its water resources as a security issue. This situation appears to contribute to the deterioration of relations between the two countries. This dynamic is intrinsically tied to a form of militarization of water issues, as well as the possibility that China may weaponize water resources for geostrategic purposes. This aspect will be explored in the next section.

From a water security dilemma to a weather militarization?

As mentioned earlier, since 2008 Beijing has been actively engaged in large-scale event-driven weather modification practices. Additional examples can be found in instances such as the Asian Games in Guangzhou in 2010, the G20 Summit in Hangzhou in 2017, or the national military parade in 2019. These, and similar examples highlight that China's use of cloud seeding extends far beyond ecological or environmental purposes. Instead, it aligns with broader state objectives, projecting an image of technological prowess and national

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Jain, "China in the Mekong: The Evolving Dragon", Observer Research Foundation, 2024, October 11; Tiffany May, Isabelle Qian, and Suhasini Raj, "China's Large and Mysterious Dam Project Is Alarming Neighbors and Experts", *The New York Times*, 2025, January 27; "China Defends Plan to Build World's Largest Dam Over Brahmaputra River in Tibet; Says Will Not Affect Lower Reaches", *The Economic Times*, 2025, January 4.

68. The two conventions are: 1997 UN Convention on the Law of the Non-navigational Uses of International Watercourses (entered into force on August 17, 2014) and 1992 UN Economic Commission for Europe (UNECE) Convention on the Protection and Use of Transboundary Watercourses and International Lakes (entered into force October 6, 1996).

69. Genevieve Donnellon-May, "Hydro-Hegemon? Complexities of Shared Rivers Between China and India", *The Interpreter*, 2023, May 9.

70. China's transboundary water treaties place a strong emphasis on procedural rules, particularly information sharing and technical cooperation. A closer look at these provisions, however, leave questions as to how prescriptive these requirements are regarding hydropower construction and operation. Besides, Articles 11 and 12 of the Watercourses Convention provide procedural rules requiring a process of consultation and prior notification for planned measures that may have significant adverse impacts, including, for example, those arising from hydropower construction. China's treaties provide limited obligations of prior notification. For details see, Patricia Wouters, A. M. Daza-Clark, and D. J. Devlaeminck, "China's transboundary hydropower development at home and abroad: exploring the regulatory interface between international water law and international economic law", *Frontiers in Climate*, 5, 2024, January 23.

71. Anjan Kumar Sahu and Surinder Mohan, "From Securitization to Security Complex: Climate Change, Water Security and the India-China Relations", p. 336.

strength to both domestic and international audiences. By deploying weather modification as a tool for orchestrating ideal conditions during key events, China reinforces its narrative of technological and political control, making it a symbol of both modernity and state capacity. These events prove that China does not use the cloud seeding technology solely for ecological or environmental concerns: rather, these activities are mainly driven by the objective of fulfilling the state's strategic interests. Clearly, the 2008 Beijing Olympics were to witness a rain-free event, projecting to the world China's capabilities of controlling the weather- both symbolic and significant. Achieving technological prowess in weather modification adds a new dimension to China's quest for "technological superiority/supremacy,"[72] a pursuit that is intricately linked to the country's broader geopolitical strategy. Indeed, on January 1, 2022, a new version of the Law[73] on China's Science and Technology (S&T) Advancement came into effect- reflecting China's determination to lead globally in scientific and technological endeavours and to become the world's science and technology powerhouse.[74]

The ability to influence weather patterns in these ways demonstrates China's ambition to control not only its internal environment but also to project its technological prowess on the global stage. It is a means of asserting power, strengthening its leadership in global affairs, and elevating national prestige. Within this framework, weather modification serves as a tool of both technological and political control, further solidifying China's position as a rising global power with unmatched state capacity. This pursuit of technological superiority holds significant geopolitical implications, particularly for countries in discord with China, and especially for China's neighboring states with which it has adversarial relations, such as India. The growing technological capabilities, including in weather modification, not only heighten these tensions but also intertwine environmental and security concerns in ways that are central to understanding regional power dynamics. In this context, Barry Buzan's concept of a "security complex" is particularly relevant.

The "Security complex" refers to "a set of states whose major security perceptions and concerns are so interlinked that their national security problems cannot reasonably be analyzed or resolved apart from one another."[75] In the context of climate and water securitization, the sharing of transboundary water resources—whether ground or atmospheric—creates conditions particularly conducive to the emergence or intensification of rivalries. This dynamic often leads to an interstate security dilemma, which Robert Jervis defines as a situation where "many of the means by which a state tries to increase its security decrease the security of others.[76] In the case of India, faced with China's growing capabilities in weather modification, this dilemma manifests as follows: India must choose between

72. Julian B. Gewirtz, "China's Long March to Technological Supremacy", *Foreign Affairs*, 2019, August 27.

73. For details see, The National People's Congress of the People's Republic of China, "Law of the People's Republic of China on Scientific and Technological Progress", 2021, December 24.

74. Xuan-Thao Nguyen, "Tech Supremacy: The New Arms Race Between China and the United States", *Journal of Corporation Law*, 49, 2023, p. 106.

75. Barry Buzan, Jaap de Wilde, and Ole Wæver, *Security: A New Framework for Analysis*, Lynne Rienner, 1998, p. 12.

76. Robert Jervis, "Cooperation Under the Security Dilemma", *World Politics*, 30, 1978, p. 169.

reacting, which risks escalating tensions, or refraining from action, thereby allowing its vulnerabilities vis-à-vis China to increase.

In January 2024, India's Defence Minister made a strong statement, saying "[c]limate change in the country [India] is not just a weather-related phenomenon, but the matter is related to national security", as he proclaimed:

> Certain [Indian] border States like Uttarakhand, Himachal Pradesh, Sikkim, and Union Territories (UT) like Ladakh have noticed an increase in the number of natural disasters in recent years. The Himalayas extend to other states as well, but such incidents are confined to certain States only, and we cannot ignore that" and further affirmed that, "India's Ministry of Defence has taken it very seriously and will seek help from friendly countries to study and rule out any involvement of any enemy country on this issue.[77]

While there was no direct mention of China, the hint was very clear because, as mentioned above, these Indian states border Tibet and are the areas where the disputed Line of Actual Control (LAC) between India and China, that is the western sector (Aksai Chin in Ladakh region), the middle sector (Himachal Pradesh and Uttarakhand) and the eastern sector (Sikkim and Arunachal Pradesh). Besides, the term "enemy" itself is self-explanatory as India has adversarial relations with China.[78] This statement further illustrates India's own process of water securitization, and its growing distrust of China's weather modification techniques, rooted not only in concerns about the potential or actual unintended effects of these practices, but also in the fear that such practices could be exploited for geostrategic and military purposes. For example, when New Delhi raised the issue of the non-provision of hydrological data, Beijing cited "technical reasons."[79] However, this also coincided with the 73-day Doklam stand-off between the two countries that took place during the peak monsoon period.[80] While China resumed the sharing of data in 2018, Indian officials are concerned about the possibility of China using such unilateral steps as a bargaining tactic against India in times of crisis. In the case of weather modification, the possibility of China using weather as a mean of causing floods or inducing droughts is a cause of concern for India.[81]

It is an even more significant source of concern due to the limited effectiveness of the ENMOD Convention, which entered into force on October 5, 1978. This Convention was adopted following the denunciation by the USSR of the United States' military use of weather modification techniques. Under its 'Operation Popeye", the United States used cloud seeding techniques from Thailand over Cambodia, Laos, and Vietnam to induce rain thereby extending the monsoon season and flooding the Ho Chi Minh Trail (the system of supply routes used by enemy fighters in Vietnam) in support of its efforts in the War

77. Dalip Singh, "Rajnath Hints at the 'Enemy Country' Behind Extreme Natural Disasters in Border States", *The Hindu Business Line*, 2024, January 20.
78. Amrita Jash, "Is China Modifying the Weather? India Has Concerns", Observer Research Foundation, 2024, March 15.
79. "No Hydrological Data from China in 2017, India Monitoring Water Flow in Trans-Border Rivers", *The Economic Times*, 2018, March 24.
80. "Annual Data Sharing By China On Brahmaputra, Sutlej River Begins", NDTV, 2021, June 2.
81. Aparna Roy, "'Weather War': A Latest Addition to the Sino-Indian Conundrum?"; Amrita Jash, "Is China Modifying The Weather? India Has Concerns".

in South-East Asia.[82] To date, the Convention has 78 State Parties. Russia and the United Kingdom ratified it in 1978, the United States in 1980 and China in 2005.[83] It categorically prohibits "the States Parties from engaging in military or any other hostile use of environmental modification techniques having widespread, long-lasting or severe effects as the means of destruction, damage or injury to any other State Party."[84] However, a 1996 US Air Force report clearly indicated that, while the ENMOD Convention had "prevented the United States from studying climate modification processes that could have widespread, long-lasting, or severe effects", there were still possibilities "within the limits of established treaties" for using "localized precipitation modification in the short term, over a small area, and potentially with positive effects."[85] This suggests that, despite the restrictions of the ENMOD Convention, weather modification can still be applied in specific, limited contexts, thereby allowing for military uses that align with the treaty's parameters.

This raises a crucial question about the interpretation of the Convention's scope. As Fabienne Quilleré-Majzoub points out, "the belligerent or malicious intent, the will to cause serious harm to another State, is the key to the applicability of this convention. It is thus the intention pursued by the State using environmental modification techniques that determines whether their use is lawful or not."[86] This definition, based on intent, undermines the applicability of the measure— one could imagine that a State responsible for harm caused to the territory of other States might argue the inapplicability of the convention by claiming the damages were unintended. Clearly this is all the more likely in the case of Chinese weather modification practices, which, while presented as domestic practices, have dual-use properties that may be used for military applications that would be very difficult to prove.

Several other international legal frameworks could regulate weather modification practices that cause transboundary harm. For example, the no-harm principle under customary international law, the Articles on State Responsibility (ILC), or the Rio Declaration's precautionary and prevention principles. However, attributing specific harm to weather modification practices would be extremely challenging. Establishing a causal link between a state's intervention and a particular meteorological event requires robust scientific evidence, which is often complicated by the natural variability of weather patterns. Furthermore, the inherent unpredictability of weather makes it difficult to isolate the effects of human intervention from natural fluctuations. Even if a weather modification activity coincides with an extreme weather event in a neighboring country, distinguishing whether the event was a direct consequence of the intervention or merely a natural occurrence would require sophisticated climate modeling and long-term atmospheric data. Scientific uncertainty in

82. Ibid.

83. More recently, the last countries to sign it were Nicaragua in 2007, Honduras in 2010, Cameroon and Estonia in 2011, Kyrgyzstan in 2015, and Palestine in 2017. The Convention has also been ratified or signed by all European Union member countries, except for Croatia, Malta, Latvia, and France. France is one of the three nuclear states not party to ENMOD, along with Israel and North Korea.

84. United Nations Office for Disarmament Affairs, "Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD)".

85. US Air Force, "Weather as a Force Multiplier: Owning the Weather in 2025", 1996, p. 13-14.

86. Fabienne Quilleré-Majzoub, "A qui appartiennent les nuages? Essai de définition d'un statut des nuages en droit international public", *Annuaire français de droit international*, 50, 2004, p. 653-667.

such cases could provide plausible deniability for states engaged in weather modification, complicating efforts to hold them accountable under international law.

CONCLUSION

China's weather modification program reflects a multifaceted approach to addressing both climate-related challenges and water resource management. Rooted in the country's efforts to modernize its meteorological infrastructure, these initiatives seek to mitigate the impacts of extreme weather events, enhance agricultural productivity, and secure water resources in a context of growing environmental pressures. Weather modification, particularly cloud seeding, has evolved from experimental practices to a key component of national policy aimed at supporting ecological restoration and economic development. Through projects such as Sky River, located on the Tibetan Plateau, China is pursuing large-scale interventions to manage water availability in its northern regions, illustrating a proactive response to water scarcity exacerbated by climate change and industrial demands. These practices, part of a broader strategy of ecological modernization, are increasingly integrated into the country's long-term development goals, underlining the central role of technological innovation in adapting to and mitigating climate and water-related challenges.

While Chinese cloud seeding practices have become a domestic tool for increasing water availability and securing agricultural and energy needs, they also reflect a deeper securitization of water and climate issues. China's approach to water management, including its expanding cloud seeding efforts, is part of a broader hydro-hegemonic strategy to assert control over shared water resources while prioritizing its own security. This mirrors China's past tactics in transboundary water governance, such as its large-scale dam projects on the Mekong, Brahmaputra, and Yangtze rivers, where it has exerted influence over water flow without engaging in comprehensive consultation or binding agreements with neighboring countries. As such, China's actions raise significant geopolitical and environmental concerns, and amplify Indian fears of growing Chinese control over critical water resources. Changes in precipitation caused by cloud seeding on the Tibetan Plateau could, indeed, have cascading effects on India's water resources.

It is not easy to forecast with certainty the possible consequences of China's weather modification practices in the Tibetan plateau. Unfortunately, the uncertainty surrounding this issue does not favor cooperation; quite the opposite, it serves as fertile ground for conflict, particularly in a context already marked by structural tensions and a Chinese hydro-hegemony amplified by the regional securitization of climate change. Given China's technological advantage, Indian officials and researchers feel the need to remain vigilant, focusing on monitoring and observing developments. The historical precedent of states using weather as a weapon against adversaries provides a potential framework for future actions, especially considering that ENMOD doesn't prevent such practices. The core issue lies in the intent behind weather manipulation, and without guarantees, there remains the possibility that China could use such technologies for purposes other than benign ones.

Ultimately, the ongoing developments in China's weather modification practices highlight the pressing need for discussions on the governance of atmospheric interventions. This situation underscores the importance of establishing frameworks for the use of weather modification technologies, emphasizing transparency, scientific collaboration, and multilateral oversight to mitigate the risk of regional tensions and conflicts. Given the shared concerns of India and France regarding the geopolitical and environmental implications of weather modification practices, both countries may find it productive to explore potential avenues for collaborative engagement. The co-authorship of this paper by a French and an Indian researcher reflects not only a common interest in understanding the challenges associated with these technologies but also a recognition of the need for the development of governance frameworks to address them.

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