A cloud-seeding rocket launched to ease the drought in Bayannur, Inner Mongolia in July 2018. Scientists are testing such technologies to alter rainfall patterns. PC: *China Dialogue*.

Sky River

Promethean Dreams of Optimising the Atmosphere

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Proposed in 2016, the Sky River Project promised to scale up China's weather modification practices by moving water vapour from the southern Tibetan Plateau to northern China, working as an 'aerial corridor' for the South–North Water Transfer Project. Although the engineering project has not come to fruition, the concept of a 'sky river' is itself noteworthy for its inventors' explicit goal of allowing surface and atmospheric waters to be managed together. Sky River is Promethean in that it advances a mechanistic and techno-optimist vision of the atmosphere as a set of relations to be modelled, modified, and optimised for human use..

In the summer of 2022, China's Yangtze River Basin suffered a record-breaking drought and heatwave caused by anthropogenic climate change, which damaged crops, caused electricity shortages and industrial shutdowns, and led to scarcity in drinking water supplies. Of course, water paucity is not new to China, given that the country has 18.5 per cent of the world's population and only 7 per cent of its freshwater, which is also very unevenly distributed. For decades, the People's Republic of China (PRC) has responded to water insecurity in ways broadly consistent with what John Dryzek (2013: 58) calls 'promethean environmentalism'—a form of environmental thought that recognises the severity of problems (rather than denying them) and calls for resolving them through technology. Whereas some forms of

Promethean environmentalism focus on the market as the purveyor of necessary technology, Dryzek identifies another type, associated with the likes of Bjorn Lomborg, and the Chinese State, which confronts environmental problems with large-scale engineering projects directed by government intervention. This is exemplified by the gargantuan South–North Water Transfer Project (南水北调, SNWTP)—an extraordinarily costly infrastructure project to transfer water from the Yangtze River to the much drier north of the country. The SNWTP has entailed the displacement of hundreds of thousands of people and created myriad harmful ecological consequences (Moore 2014; Webber et al. 2017).

Though perhaps the most well known, the SNWTP is not the only Promethean solution to water scarcity on offer in China. Notably, provinces along the Yangtze responded to the 2022 drought by stepping up their weather modification efforts, shooting silver iodide into clouds in the hope of inducing rain (Deng et al. 2022). In this essay, I consider China's weather modification efforts, and particularly the Sky River Project (天河工程), in relation to the theme of 'Prometheus in China'. As an engineering project, Sky River promised far more than it could deliver. Nevertheless, I argue that the scientific conceit on which it is based is itself noteworthy, in that it calls for making the atmosphere work as a water conveyance infrastructure. This imagination entails the enframing of moisture in the sky as a resource to be integrated with terrestrial water resources, engineered, and controlled through technology.

Weather Modification

The desire to shape the weather is ancient, but direct material attempts to intervene in the behaviour of clouds did not begin in earnest until after laboratory experiments at General Electric in the 1940s showed that seeding supercooled clouds of water vapour with silver iodide could cause water droplets to freeze and fall as snow (Qiu and Cressey 2008; Fleming 2010). These experiments motivated military and civilian efforts in the United States and other countries to use seeding techniques on real clouds. Revelations of US classified operations during the Vietnam War to try to prolong the monsoon to wash out transportation infrastructure led to a public outcry (Fleming 2010). In 1978, the international Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques came into force, prohibiting the hostile use of environmental modification with the potential to produce 'widespread, long-lasting and severe' harm (Fleming 2010).

Today, more than 50 countries undertake weather modification programs (Muñoz 2017). Interest has only grown with climate change—for example, in the United States, climate change–induced drought is reinforcing efforts in western states where ski resorts, power companies, and state governments have been involved in cloud-seeding for decades. This is despite the fact that atmospheric scientists remain largely unconvinced about the efficacy of cloud-seeding to control precipitation given the natural variability of rainfall and the difficulties in proving causality due to the mismatch between the scales of seeding and impact (Rauber et al. 2019).

Weather Modification and Ecological Civilisation in China

The scepticism of atmospheric scientists has not stopped China from developing the world's most extensive and institutionalised weather modification program. Between 1995 and 2003, the country spent US$266 million on weather modification. The China Meteorological Administration organises, coordinates, and guides weather modification activities. All provincial-level governments except Shanghai's have established weather modification bureaus, with budgets to 'control' weather in their jurisdictions, altogether employing about 40,000 people (Chien et al. 2017). In 2020, a new central government plan called for the area covered by weather modification to expand to 5.5 million square kilometres—more than half the country's

total area (CMA 2021). The sheer scale and the deep institutionalisation of weather modification in China's administrative system indicate that clouds are viewed not as mere atmospheric features, but rather as a resource from which water can be extracted and used.

Weather modification within China is commonly deployed for four reasons: ecological preservation, increasing agricultural production, securing water resources and, most notoriously, securing good weather for important events, such as the opening ceremony of the 2008 Beijing Olympic Games (Chien et al. 2017). Of note here, official sources refer to rain enhancement as a technique for safeguarding ecological security (生态安全), protecting 'ecological construction' (生态建设), ecological restoration (生态恢复), and helping to achieve 'ecological civilisation' (生态文明) (Bluemling et al. 2020). Indeed, news reports about weather modification efforts regularly describe cloud-seeding to produce rain as playing an important role in the 'construction of ecological civilisation' (生态文明建设).

'Ecological civilisation' entered the national political discourse in 2007 with the endorsement of then president Hu Jintao and was subsequently enshrined in both the Chinese Communist Party (CCP) Constitution and the PRC Constitution. Under Xi Jinping, it has been discursively coupled with the 'Chinese Dream' (中国梦), the building of 'Beautiful China' (美丽中国), and the 'Two Mountains Theory' ('clear waters and clean mountains are as valuable as gold and green mountains', 绿水青山就是金山银山) (Goron 2018; Marinelli 2018). As a sociotechnical imaginary, ecological civilisation draws selectively on reductionist interpretations of China's traditional philosophies to assert cultural and national continuity while distinguishing China's path from that of 'the West'. At the same time, ecological civilisation maintains a longstanding focus on scientific and technological solutions to ecological crises (Hansen et al. 2018). Economic growth is left unquestioned because it is assumed that it is precisely such growth that will produce the techno-fixes needed to secure the transition to the ecologically civilised future.

Jesse Rodenbiker (In press) argues that ecological civilisation is premised on a fundamentally mechanistic approach to managing nature, which is conceptualised as a set of modular biophysical relations that can be measured, modelled, altered, and optimised for human use. He traces how systems science became prominent in Chinese ecology, with techniques such as functional zoning deployed for the purpose of optimising socionatural systems. This resonates strongly with Dryzek's (2013: 62) observation that 'the key Promethean metaphor is mechanistic. Machines are constructed from simple components … [T]hrough the application of human skill and energy … they do useful things.' I argue that Sky River is Promethean in this sense: it is a mechanistic and techno-optimist vision of the atmosphere as a set of relations that can be modelled, modified, and optimised for human use.

The Sky River Project

The Sanjiangyuan ('Source of the Three Rivers' 三江源) area of Qinghai Province, on the Tibetan Plateau, encompasses the headwaters of the Yellow, Yangtze, and Mekong rivers. Often referred to as China's 'water tower', its representation as a zone crucial to the country's ecological security has justified, among other things, the resettlement of more than 50,000 Tibetan herders (Yeh 2009). The state's interest in safeguarding ecological security also includes weather modification activities in the region. For example, the government claims that rain enhancement activities since 2006 have increased the area of two lakes at the headwaters of the Yellow River by 33 square kilometres and 64 square kilometres (Chien et al. 2017; Bluemling et al. 2020)—though, notably, the expansion of lakes is also one of the key effects of climate change on the Tibetan Plateau due to melting permafrost and glaciers and the fact that most of the lakes there are endorheic (closed-basin).

Launched in 2016, the Sky River Project promised to radically scale up weather modification by intercepting water vapour from the Indian monsoon over the southern Tibetan Plateau and channelling it to the parched Yellow River Basin

in northern China, where it purportedly would fall as rain over an area of 1.6 million square kilometres, thereby increasing water supply by 5–10 billion cubic metres annually (Chen 2018; Pike 2018; Zheng 2016; Yang 2018). Government reports called it an 'aerial corridor' for the SNWTP (Gan 2018), asserting an equivalency between ground and air transport of water.

The project was undergirded by several academic papers introducing the term 'sky river' (天河), led by Wang Guangqian, then president of Qinghai University and an academician of the Chinese Academy of Sciences (Wang et al. 2016; Li et al. 2018; Wang et al. 2018). Their initial paper was quickly followed by the establishment of the Sky River Project, which was described as involving a network of 'tens of thousands' of cloud-seeding chambers on the Tibetan Plateau that would burn silver iodide, which would then be swept into the sky river (Chen 2018). Project proponents described the combustion chambers as being designed 'using cutting-edge military rocket engine technology' (Chen 2018). In addition, China Aerospace Science and Technology Corporation (CASC), a major space and defence contractor, was slated to develop a network of satellites to monitor the monsoon and gather real-time atmospheric data, which would then be connected to the automated and remotely ignited and operated burners, to send precipitation northwards. The Xinhua News Agency quoted the president of CASC saying that the six-satellite network would be launched by 2022, after which the Sanjiangyuan area could be monitored once every hour. A model of the first of the planned satellites, Tianhe-1 (Sky River-1), was displayed at the twelfth China International Aviation and Aerospace Exhibition in Zhuhai in 2018.

Headed by Wang Guangqian and including researchers from Tsinghua University, the Qinghai Meteorological Bureau, and Qinghai University, the project was featured in Qinghai Province's Thirteenth Five-Year Plan, receiving RMB53 million (US$7.7 million) from the province and Qinghai University, as well as RMB 1 million from Tsinghua University. In 2016, it was also designated as a 'national key research project' and accepted by the Ministry of Science and Technology as a project of international significance (Pike 2018). Initial tests were conducted in 15 ground operations in the Sanjiangyuan National Nature Reserve, including in Dari County, Golog, the Qilian Mountains, and the Kunlun Mountains (Gan 2018). In 2018, the *South China Morning Post* interviewed a project researcher who reported that 500 iodide burners had already been deployed in Tibet and Xinjiang, among other areas, and were showing 'very promising results'.

However, in late November 2018, the project attracted significant criticism. An article published by *ScienceNet.cn*, a website affiliated with the Chinese Academy of Sciences, quoted one Chinese scientist as saying: 'This is an absurd fantasy project with neither scientific basis nor technical feasibility' (Yang 2018). Another said: 'The decision-making department ignored the many doubts of meteorologists and insisted on quickly promoting the Tianhe Project.' Another argued: 'It is beyond the capability of human beings to make rain fall in the Yellow River Basin instead of the Yangtze River Basin' (Gan 2018; Yang 2018; Gan and Wang 2021).

In late 2018, investigative journalists from *Southern Weekend* (南方周末) visited the Tsinghua University lab responsible for the project but were not allowed to enter (Yang and Fang 2018). When they interviewed Shaanxi Zhongtian Rocket Technology Company, which manufactures the burners, they were told: 'The leaders think this project is not very convenient to talk about … I don't want to mention the "Tianhe Project" now' (Yang and Fang 2018). Since the end of 2018, there have been no new official pronouncements regarding Sky River's promises and achievements. A search of the official WeChat accounts of Tsinghua University, Qinghai University, and the Qinghai Meteorological Bureau turned up no references to Sky River. A retrospective account of Wang Guangqian's 10 years of achievements in 'counterpart support' at Qinghai University also contained no references to it (Guangming Daily 2021), and other sources suggest the project has been suspended (Gan and Wang 2021).

According to a US-based atmospheric scientist familiar with the project, as of 2022, Wang's team is continuing its research on Sky River weather modification in Qinghai, but in a greatly scaled

Silver iodide burning chamber in Shigatse, Tibet Autonomous Region. PC: China Meteorological Administration.

back way, and with a new focus on precipitation microphysics in addition to weather modification. Their research has been deliberately shielded from the public eye due to the controversy that erupted in 2018.

Sky River as a Promethean Concept

The papers by Wang and his colleagues assert a distinction between the well-known concept of 'atmospheric rivers' (大气河流)—flowing columns of condensed water vapour that transport most water vapour outside the tropics—and the 'sky river' (天河), which they define as 'highly structured water conveyance systems' at the regional and global levels (Wang et al. 2016: 656). This distinction was widely panned by atmospheric scientists in the *ScienceNet.cn* debate, as well as others I interviewed, all of whom said the sky river concept is no different from that of atmospheric rivers. In the words of one interlocutor familiar with the debate, it was just a 'big fancy exciting new name' used 'to obtain a large sum of funding'.

In addition to garnering funding, however, the goal of asserting Sky River as a distinct concept (even if not valid to atmospheric scientists) was to affirm an equivalency between the atmosphere and the ground to apply the same types of optimisation techniques used terrestrially. This is evident in claims that Sky River would be an 'aerial corridor' for the SNWTP. It is also plainly stated in one of Wang's co-authored papers introducing the goal of the Sky River concept: 'We proposed a concept of "Sky River" ... to explain how the atmospheric water *could be utilised*' (Wang et al. 2018: 110; emphasis added).

The original 2016 paper published in Chinese describes the significance of Sky River in terms of national economic development, ecological civilisation construction, national security, and geopolitics (Wang et al. 2016: 653). It argues that 'traditional water management techniques' have reached their limit for dealing with China's 'absolute water shortage'. Thus, 'the materialisation of cloud water resources through weather modification is a process of opening a new source to counter the "throttling" of surface water resources' (Wang et al. 2016: 653). Discussing the Sanjiangyuan area, they note:

> At present, the rate of conversion of natural precipitation is very low ... [I]f a new inter-basin water transfer model is developed

> through the use of cloud water resources, there is hope to solve the problem of the arid climate … [I]t is relatively simple and easy to modify the temporal and spatial distribution of natural precipitation through human intervention into the weather … Spatial water transfer can be conducted between the Yellow River Basin and the Yangtze River Basin, forming a new inter-basin transfer model, which would greatly ameliorate north China's serious shortage of water resources, enormously promoting the coordinated development of society, economy, and the environment. (Wang et al. 2016: 653)

The 2018 paper by Wang and his colleagues introducing the concept to the Anglophone literature is similar in its framing of clouds as 'atmospheric water resources', which should be coupled with conventional surface water resources in the 'water resource configuration infrastructure' (Wang et al. 2018: 110). To achieve 'comprehensive development of atmosphere–surface water resources', the authors use shallow water equations that are also used for modelling dynamics of flows in rivers, the ocean, and the atmosphere, and extrapolate from there to develop 'a new vision' of the water cycle (Wang et al. 2018: 109, 117). This assertion that sky rivers are generalised phenomena approachable through familiar fluid mechanics is, in turn, 'key to develop[ing] a novel strategy in developing atmospheric water resources by joint management of atmospheric and surface water resources' (Wang et al. 2018: 117). In short, the scientific endeavour is aimed at allowing surface and atmospheric waters to be modelled and managed together in the service of China's ecological security.

Promethean Dreams for the Nation

To the atmospheric scientists who publicly criticised the project, the problem appears to be the fact that the Sky River team is made up entirely of hydrologists, with no atmospheric science or meteorological expertise, and that this is what led to the overhyped concept and project. While this is no doubt part of the story, my goal here is to point to the Promethean thinking embedded within both the state-sponsored scientific endeavour and the scientific publications that underpin it. Though the deployment of Sky River may be suspended, the team behind it has not given up on its project. And, even without Sky River, there are already hundreds of silver iodide burners on the Tibetan Plateau—part of a vast bureaucratic machinery of civilian as well as military weather modification.

Moreover, Promethean stories about Sky River continue to circulate on Weibo and other social media sites—often described in nationalist terms. One post from June 2022, entitled 'China's Determination! Three Super Projects about to Be Unveiled, with a Scale Ranking First in the World', provides no new information about the project beyond the initial 2018 reports, but concludes with the declaration that 'once the project is complete, it will shock the world' (Science Knowledge Show 2022). A blogger who reported in 2021 on the suspension of the project noted that it could take 50 years to realise the 'transfer of water through the sky to fall as remote precipitation' but argued: 'If we do not do research on this project, it will not happen in China, but rather will be realised in a foreign country' (Changyun Hezu Shamo zbb 2021). As a third example, a video by a microblogger who often posts about infrastructure, states that once the project is complete, 'those foreign experts who made those irresponsible remarks [casting doubt on the project] will eat their words', and solicits support from viewers by asking: 'If you think our country's capital construction is awesome, please cheer them on in the comments!' (Aishang Kepu n.d.). The Promethean dream of deploying a distributed terrestrial–atmospheric–orbital network of silver iodide burners, satellites, and data to optimise the distribution of water resources across China lives on. ■

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