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Promoting Meteorology in Rural Areas

Efforts to Develop Meteorology for Salt-Related Industries in the Republic of China

▼ **ABSTRACT** This article explores the endeavours undertaken to advance meteorology for the benefit of salt-related industries in the Republic of China in the early 20th century. Despite China's extensive history of incorporating meteorological knowledge into agriculture, insufficient consideration has been given to the assimilation of modern meteorological information for agricultural development. Consequently, this article narrows the focus to salt-related industries, drawing on two case studies to scrutinise the application of meteorology in agriculture and the variables influencing meteorological development. With the support of politician and industrialist Zhang Jian, the Junshan Meteorological Station supplied meteorological data to the Salt Reclamation Company. However, an overreliance on specific individuals led to a gradual decline in the later stages of the Junshan Meteorological Station. Conversely, the Zhejiang Salt Administration Bureau, which prioritised economic interests and collaborated with the government, established its meteorological network and effectively applied meteorological information to enhance production in the salt industry. This article assesses meteorology's role in fostering rural modernisation, asserting that the imperative for economic development played a pivotal role in expanding the reach of meteorological services. Thus, attention should be directed towards local entities rather than the central government.

▼ **KEY WORDS** Rural Development, Meteorological Application, Salt Related Industry, Republic of China

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Introduction

With its deeply ingrained social traditions and foundational role in the agricultural framework, the rural environment held a significant position in early 20th-century Asia. In Japan, while the Meiji reformers underscored national and industrial priorities, the Japanese government nonetheless instigated a rural revitalisation movement to maintain equilibrium amidst a farming downturn that impacted the country in the 1920s and 1930s.[1] Rural land was equally significant to China during the first half of the 20th century. Before 1949, China's countryside was vitally important, with seven or eight out of every 10 individuals deriving their livelihood from agriculture.[2] According to Kate Merkel-Hess's research, the Chinese Republican state implemented diverse models for rural reconstruction during the 1920s and 1930s, thus fostering a distinctly Chinese rural modernity. This paper contends that, in comparison to factors such as the peasant community, the economy, or social culture, meteorology offers a novel perspective to elucidate the modernisation of rural areas through the application of scientific knowledge.[3] Consequently, the interplay between meteorology and agriculture in the Republican era, as well as the role of meteorology in rural development, constitute the focal point of this article. In the Chinese Republican context, rural, or countryside, areas were delineated as social territories beyond the state's metropolitan confines, where the primary economic pursuits consisted of agriculture, fishing, and forestry.[4] Furthermore, China's delineation of the peasantry primarily encompassed those involved in the aforementioned industries, with the rural areas of China often engaged in diverse kinds of production due to their distinct geographical locations.[5]

This paper focuses on salt producers, in addition to the industries in which they were engaged. Salt emerges as a pivotal commodity in the Chinese historical annals, with the state monopoly on salt administration originating in the Han dynasty (202 BCE–220 CE) and persisting until the Qing dynasty (1644–1911). Consequently, the conundrum of managing this particular commodity, which was intricately entwined with the fabric of people's lives, became an imperative that the Chinese Republican State (1912–1949) had to address. Their objectives included nationwide standardisation and the identification of methodologies to curtail production costs, thereby effecting a reduction in prices. Furthermore, it was imperative that the livelihoods of salt producers and merchants remained minimally impacted while the policy was implemented.[6] Because China's coastal salt industry lacked advanced machinery and therefore followed a traditional approach until the Republican period, it remained firmly within the agricultural realm. Consequently, in the pursuit of alternative solutions, meteorology—a discipline with significant influence in the

1 Havens (1974, pp. 133–162).
2 Myers (1970, pp. 1–2).
3 Merkel-Hess (2016, pp. 3–14).
4 Zhao, Gao, Xu, &Yang (2015, pp. 20–43); Tao (1990, pp. 92–98); Weng (2018, pp. 184–203).
5 Zhao et al. (2015, pp. 236–292, 410–426).
6 Chu (1965, pp. 130, 136).

primary-production sector—also assumed a role in salt production, although it had previously been neglected in the field.[7]

Modern advances in meteorology stemmed primarily from the imperative to address extreme weather conditions. Owing to recurrent and calamitous hurricanes in the United States, American meteorologists endeavoured to discern the causes of, and potential countermeasures against, hurricanes. Therefore, the United States propelled meteorological progress and instituted its meteorological network at an earlier historical juncture than other nations.[8] Moreover, meteorological advancements played a pivotal role in society's assimilation of meteorological information for daily life and agricultural progress. Notably, meteorological infrastructures in the West Indies were established with assistance from the U.S. Weather Bureau, to provide hurricane warnings and support the interests of American investors in agriculture and the economy.[9] In contrast, Katharine Anderson, in her examination of the appearance of meteorology in 19th-century Britain, contended that meteorological development could be attributed to the joint efforts of official or semi-official institutions and the public.[10] To a certain degree, the trajectory of modern meteorology in China during the first half of the 20th century was also shaped by multifaceted influences, yet had its own particular qualities.

From the late 19th century, foreign powers and missionaries gradually erected observatories in China, such as the Zikawei Observatory, instituted by the Jesuits, and the Qingdao Observatory, founded by the German Navy.[11] Concurrently, the Chinese Maritime Customs, albeit under British stewardship, established its coastal-observational meteorological network.[12] The primary objective of these meteorological stations was to provide meteorological services for transportation and respond to weather-related disasters. Subsequently, with the advent of the first generation of meteorologists and official meteorological departments in China, stations were also established to cultivate the infrastructure and expertise of the local meteorological services, thereby further cementing the nation's meteorological independence.[13] Previous studies on the history of meteorology in modern China, or indeed in early 20th-century Asia, have tended to pay attention to the foreign-established meteorological stations and network. For example, with their extensive extant archives, the Zikawei Observatory and Hong Kong Royal Observatory have been analysed in terms of how they dealt with extreme weather events and provided meteorological forecasts.[14] However, such meteorological development was relatively passive for China, and it is still worth investigating further how China was able to develop meteorology

7 Regarding the history of reform in salt industry, see Zeng (1984, pp. 30–48).
8 Fleming (1999, pp. 55–109).
9 Pietruska (2016).
10 Anderson (2005, pp. 41–86).
11 Udías (2015, pp. 157–174).
12 Bickers (2016, pp. 180–193).
13 Amelung (2021).
14 Pyenson (1993, pp. 157–206); Zhu (2012); H. Wang (2017); MacKeown (2011, pp. 42–65); Williamson & Wilkinson (2017, pp. 159–178); Mahony (2020).

independently and localise meteorological knowledge during this period of transition. For instance, Clark L. Alejandrino has investigated how meteorological advancement in Guangdong province allowed China to get rid of foreign intervention.[15] Sun Yibo has also examined official meteorological departments to provide a basic understanding of the institutionalisation of meteorology in China.[16] Nevertheless, owing to the concentration of meteorological stations in cities and the inadequacies in communication, the agricultural use of meteorology is rarely explored in the Republic of China's historical narrative.

China has harnessed meteorological expertise to enhance its agricultural pursuits for several millennia. For example, the invention of the 24 solar terms in ancient China, an astute reflection of climatic and temporal variations, provided detailed guidance to farmers. Moreover, the development of ancient Chinese meteorology offered peasants a helpful resource for understanding diverse meteorological scenarios.[17] Nevertheless, autocratic ancient Chinese rulers associated weather fluctuations with their rule, attempting, for instance, to bolster their sovereignty through rainmaking activities, and this fostered a difficult relationship between the peasantry and meteorological knowledge.[18] Consequently, with the advent of modern meteorology in China, it became imperative to harness its potential in the service of agriculture and to spread scientific awareness proactively among the rural populace. This paper scrutinises two attempts to benefit the salt-related industry in the Republic of China, and thereby advocates that attention be paid to local factors in meteorological progress, as opposed to relying only on the central meteorological department.

Research on rural China has historically gravitated towards localised archival scrutiny, with a lack of emphasis on scientific aspects. This enquiry draws predominantly on agricultural schematics and bureaucratic mandates archived in the Ministry of Agriculture and Forestry, as well as the repositories of the Academia Sinica housed in the Second Historical Archives of China and the Archives of the Institute of Modern History within the Academia Sinica. Furthermore, this article carefully examines a hitherto untapped source: the archives of the Zhejiang Salt Administration Bureau, housed in the Zhejiang Provincial Archives, which have only recently been made accessible to the public.

Junshan Meteorological Station (军山气象台)

Chinese authorities made attempts to introduce modern meteorology into the agricultural realm since its inception, but these yielded unsatisfactory outcomes. In the early 20th century, an extensive array of agricultural experimentation sites burgeoned under the auspices of local and central governments, with the express purpose of

15 Alejandrino (2019).
16 Y. Sun (2015, pp. 1–21).
17 W. Xu (2017).
18 Snyder-Reinke (2009, pp. 12–35).

infusing agriculture with the latest scientific principles and technologies for the pursuit of modernisation. Most of these sites, equipped with meteorological instruments, diligently amassed modern meteorological knowledge by recording temperature, humidity, rainfall, and ancillary data.[19] Regrettably, the government's stewardship of these sites of agricultural experimentation fell short in securing adequate funding for sustainable development, thereby limiting their impact on agriculture and rural areas. Some provinces did take further steps to popularise meteorology at the county level by provisioning rudimentary meteorological instruments. For instance, Shanxi province proactively constructed their psychrometers to "benefit the entirety of Shanxi province," yet the extent to which they genuinely conferred benefits or improved agriculture remains a matter of conjecture.[20]

In contrast to the official measures, the efforts of individuals in promoting science for agriculture bore fruit during the nascent phases of the Republic of China, and are epitomised by Zhang Jian and the Junshan Meteorological Station he founded. Zhang Jian (张謇, 1853–1926), a major industrialist, statesman, and pedagogue, straddled the twilight of the imperial epoch and the inception of the modern era. Like many of his contemporaries, Zhang reinvested the proceeds from his prosperous enterprises into modernising his local district, Nantong, situated in Jiangsu province.[21] However, Zhang, who held a pivotal role as leader of the constitutional movement in the Qing court and subsequently as the chief officer in the Ministry of Agriculture and Commerce of the Beiyang Government from 1913 to 1915, dedicated his efforts chiefly to the advancement of Chinese industry and commerce, espousing the ethos of "saving the country through industry."[22]

In Nantong, his native district, Zhang Jian established an industrial complex affiliated with the textile industry. In 1895, he drew up plans to inaugurate a textile factory in Nantong—the first factory of Dasheng, which went into operation in 1899. Dasheng was the cornerstone of the Nantong industrial complex, with virtually every other enterprise established by Zhang closely linked to it.[23] To augment his business ventures, Zhang secured a grant from the Qing court, with conditions stipulating that he use the salt fields along the northern Jiangsu coast for cotton-milling operations.[24] Owing to the increase in the production cost, the productivity of the salt fields had dwindled, rendering the land unsuitable for salt production. Devising strategies to optimise the utility of salt fields and addressing the predicament of salt producers became paramount.

To resolve this quandary, the Salt Reclamation Company (盐垦公司, hereafter SRC) was established. It focused on acquiring wastelands in proximity to salt fields for cotton cultivation, primarily in the northern regions of Jiangsu province. The

19 Wen (2004, pp. 347–393).
20 Frank (2023, pp. 4–5).
21 Chu (1965, p. ix).
22 Zhang Jian to Emperor Guangxu [Letter] (1895, Jul. 19), in Zhang Jian Quanji Bianweihui (2012, Vol. 1, p. 15–25).
23 Dasheng Xitong Qiyeshi Bianxiezu (1990, p. 24).
24 Nantong County Autonomous Association (1925, pp. 38–42).

first company, Tonghai SRC (通海垦牧公司), was founded in 1901 by Zhang Jian.[25] By cultivating reeds, the original salt-infused terrain underwent a gradual metamorphosis into arable land suitable for diverse crops, thereby rendering economic benefits through cotton cultivation. The SRC seemingly constituted a novel and experimental paradigm for exploring the nuances of modern agriculture, combining the reclamation of wastelands with the cultivation of lucrative cash crops. Despite its corporate structure, the SRC did not develop an economic model devoid of grassroots involvement, as it relied heavily on the active participation of local farmers and salt producers. In terms of production, the company collaborated with farmers by leasing them significant portions of land; the farmers remunerated the company with a share of the crops, particularly cotton, or with monetary payments.[26] This operational framework worked well for Nantong, given the higher tenancy and lower ownership rates, resulting in a relatively modest standard of living for the rural populace. Consequently, the establishment of the SRC served as a potent incentive for farmers to embark on a new and potentially improved life on these reclaimed lands. Additionally, a considerable number of salt producers, unable to persist in salt production, redirected their efforts towards participation in the SRC in order to increase their profitability.[27]

In addition to collaborating with farmers through lease agreements, the SRC also assumed responsibility for constructing public infrastructure and providing communal services.[28] The arduous process of converting coastal terrain into arable land spanned several years. Zhang Jian devised plans to erect a series of embankments and sluices to repel seawater and facilitate proper drainage for the farmland.[29] Furthermore, the Junshan Meteorological Station (JMS) was established to furnish SRCs with meteorological data. Nantong, situated on the coast, frequently had to deal with the impact of typhoons. For example, a severe typhoon ravaged Nantong in September 1902, causing extensive damage to embankments. Three years later, another typhoon battered the coast of Jiangsu province, necessitating additional funds to cover losses.[30] Recognising the impact of extreme weather on factories and acknowledging the significance of weather information for agriculture, Zhang Jian envisioned constructing a professional meteorological station.[31] The precursor to the JMS was a modest weather-observation station within the Nantong Museum, established by Zhang Jian in 1905 with the aim of disseminating knowledge to the general populace. Modern meteorology using advanced instruments was thus introduced by the Nantong Museum to disseminate scientific knowledge. In 1916, the JMS was ultimately constructed on Jun Mountain, in accordance with the standards

25 Hu (2013, pp. 33–57).
26 J. Sun (1984, pp. 12–35, 67–90).
27 Koll (2003, pp. 221–222).
28 Hu (2013, p. 70).
29 Koll (2003, p. 215).
30 Chu (1965, pp. 120–121).
31 Zhang [Order] (1914, Feb. 3), in Zhang Jian Quanji Bianweihui (2012, Vol. 1, p. 288–289).

of a regular station, and is considered to have been the first meteorological station operated by the Chinese without foreign assistance (Figure 1).[32]

Figure 1. Junshan Meteorological Station. From Jiangsu Shengli Nantong Zhongxue (1933, p. 1), *Jiangsu Shengli Nantong Zhongxue Xiaokan*, *12*.

Upgrading from the initial, rudimentary observatory to a well-equipped meteorological station highlights Zhang's appreciation for meteorology. Compared to others among China's contemporaneous meteorological stations, the JMS had a relatively good starting point. The station boasted wind-direction and speed recorders, rain gauges, barometers, and other internationally advanced meteorological instruments of that era, complemented by telephone and radio stations.[33] Evidently, Zhang made significant investments in the JMS, primarily funded by his income from the textile industry. To comprehend fully Zhang Jian's motives in founding a modern meteorological station, it is imperative to recognise his ambition. He harboured the aspiration of propelling China into prosperity and power, and emphasised education as the paramount means to attaining that. All his business endeavours served to further this overarching goal.[34] As science could propagate advanced knowledge and contribute to educational development, he also valued scientific progress. Despite his local activities, Zhang never lost sight of his broader goal of the complete modernisation of China. Concerning the construction of Nantong, Zhang asserted that his "aim was to gain self-government for one district so that when foreigners saw it, they would know that China still has men with ideas."[35] An advanced meteorological station served his aim of transforming Nantong into a model modern city, and demonstrated his substantial investment in the JMS. In a broader context, the establishment of JMS aligned with Zhang Jian's desire to reclaim state sovereignty. He contended that "if meteorology was not fully understood, autonomy could not be fully realised."[36] This connection between meteorology and sovereignty mirrored the case of reclaiming the Qingdao Observatory. Chinese meteorologists argued that Japan's occupation of the Qingdao

32 X. Wang (1995, pp. 214–215).
33 N. Xu (1995, pp. 216–218); Li, Qian, & Zhang (2020, pp. 72–76).
34 Chu (1965, pp. 176–182).
35 Zhang [Report] (1913, Nov. 8), in Zhang Jian Quanji Bianweihui (2012, Vol. 1, p. 257–260).
36 N. Xu (1995, p. 217).

Observatory violated China's meteorological sovereignty.[37] Thus, the influence of nationalism on Zhang is evident, and the establishment of a modern meteorological station served as his expression of nationalism in the realm of science.

The JMS benefited from Zhang's aspirations, gathering not only meteorological data, such as on precipitation, wind direction, temperature, and humidity, but also tidal and celestial data. From 1918, the meteorological station compiled an annual report, disseminating the year's observational records and research findings. These reports not only included analyses of the impact of meteorological factors on local crops, but also provided information on the general temperature, air pressure, precipitation, and the occurrence of typhoons. In order to expand its influence, the JMS took the initiative to translate the reports into English and sent them to meteorological stations in China and abroad. This strategy was successful in that foreign stations in over 40 countries, including the Paris Observatory and Tokyo Central Meteorological Observatory, exchanged their weather reports with the JMS.[38] Despite having only three personnel, the JMS exhibited exceptional efficiency and proficiency in their work. Backed by detailed data and cutting-edge instruments, on one occasion the JMS secured a place on the roster of international meteorological stations published in the United Kingdom. Zhang Jian also reaped rewards from the JMS's accomplishments, earning the lifetime honorary presidency of the Chinese Meteorological Society in 1924.[39]

With the advantage of the JMS, the SRCs experienced a phase of rapid development in the 1910s. After Zhang Jian tried to stimulate land reclamation by improving legal conditions in 1914, new enterprises proliferated swiftly.[40] Besides recording local meteorological data from Nantong, the meteorological station communicated daily with the Zikawei Observatory in Shanghai to acquire information about the surrounding regions, which was subsequently relayed to SRCs in Nantong and northern Jiangsu. Most SRCs, in turn, informed reclamation-area tenants of weather broadcasts. For instance, the Yuhua SRC (裕华公司) promptly communicated weather conditions to local farmers and amassed meteorological data for over two decades.[41] While assessing the impact of the weather station on SRCs through cotton production in northern Jiangsu province may seem unconventional, the core of the initiative was an attempt to employ modern meteorological science to guide agricultural production. Furthermore, SRCs' development led to advancements in rural Nantong and improved living standards for farmers. Firstly, it addressed challenges faced by salt producers, offering a new form of livelihood by converting unprofitable salt fields into cultivatable land.[42] Secondly, an influx of farmers into Nantong from other areas fostered the development of cotton-production technology and the establishment of

37 Liu (2024).
38 Junshan Meteorological Station (1931, pp. 1–5); Junshan Meteorological Station (1920, pp. 2–3).
39 X. Wang (1995, p. 215).
40 Gu (2003, pp. 55–92).
41 Hu (2013, p. 81).
42 Chu (1965, pp. 114–115).

local villages.[43] Consequently, the prosperity of the Nantong area became inseparable from the rise of the SRC, and the JMS contributed significantly to these enterprises.

Compared to government-operated meteorological stations, the JMS had the advantage of better-targeted, private funding, and indeed received considerable support for its establishment. However, the drawback lay in an excessive dependence on individuals, raising concerns about the sustainability of funding. The situation changed after Zhang's death in 1926, and his accomplishments at the JMS were not maintained. This was partly due to the unstable situation in China in the 1920s and the particular circumstances in Nantong, where the city lacked the motivation and means for development, relying too heavily on Zhang Jian's impetus.[44] After 1926, the JMS was renamed the Junshan Meteorological Station of Agricultural Science of Nantong University (南通大学农科军山气象台), and in January 1935 it was taken over by the Department of Construction of Jiangsu province (江苏省建设厅).[45] It appeared that, in terms of investment in and influence on the meteorological station, both the local university and the provincial government departments were far less effective than Zhang Jian. Consequently, the JMS gradually lost its leading position in China, its standards fell to a similar level as other provincial meteorological stations, and its services to surrounding agriculture weakened. The JMS's case is representative of the role personal initiative played in scientific development. Although Zhang Jian invested significant sums, and the JMS managed to gain wide attention in meteorological circles, its development depended largely on investors. This meant that the withdrawal of investment or the unfortunate death of investors often led to the stagnation or even failure of scientific projects. It suggests that personal support for science is more likely influenced by subjective factors, which imposes limitations on scientific progress. Individual reform projects could not transcend the unfavourable operating environment. In the political context, the establishment of the JMS and the SRC was largely due to Zhang Jian's personal efforts, but his important position in the Beiyang Government also implies that his activities were influenced by politics.

The Zhejiang Salt Administration Bureau (两浙盐务管理局)

From 1928, the Nationalist government, founded by the Kuomintang party, replaced the Beiyang Government. The Nationalist government formulated more systematic and ambitious plans than the former regime. China had also ushered in a relatively stable decade, with the Nationalist government emphasising the interventionist role of central government and the development of the state-owned economy. In terms of meteorology, a group of Chinese meteorologists educated overseas, such as Zhu

43 Chang (1998, pp. 66–101).

44 Chu (1965, pp. 176–177).

45 Jieshou Nantong Junshan Qixiangtai Hezuo Banfa [Cooperation method for receiving the Nantong Junshan Meteorological Station] (1930, Jan.), 393/2885, Second Historical Archives of China, Nanjing, China (hereafter SHAC); Wen (2004, pp. 357–358).

Kezhen (竺可桢), held official positions after 1928.[46] However, the application of modern Western meteorological knowledge and of instruments imported from overseas to develop Chinese meteorology did not amount to a complete replica of the Western model. Moreover, although Chinese meteorologists actively participated in international conferences in order to strengthen exchanges with the global meteorological community, they hoped to develop more independent domestic meteorological stations.[47] As a result, they tried to localise Western meteorological knowledge to meet China's particular needs, as demonstrated in the case of the Zhejiang Salt Administration Bureau (ZSAB). The ZSAB was established in 1937 by the Zhejiang Provincial Government to oversee the coastal province's sea-salt production. After 1928, privately operated salt fields were progressively transitioned into official operations. During the 1930s, the salt tax constituted nearly a quarter of the Nationalist government's primary financial revenue streams, the second highest contribution after the customs tariffs, which made up a 40% share.[48] Furthermore, authorities sought to rectify the monopoly on salt production and marketing by salt merchants.[49] The ZSAB emerged as a result of this reform, with a role akin to that of a provincial economic department. Examining the administration of ZSAB's salt works provides insights into the role of local institutions in employing science to foster rural development.

To some extent, the Nationalist government did engage with peasants, but its endeavours in the early 1930s encountered challenges. In Zhejiang, radical Kuomintang party members aimed to implement reform programmes but found themselves at a disadvantage due to their urban background and lack of local experience.[50] Since most salt fields were situated in rural areas, the salt producers in the fields were predominantly peasants, and problems emerged in attempts to communicate with them. In July 1936, a salt riot erupted in Daishan, Zhejiang province, with over 3000 salt producers clashing with local government departments over unreasonable salt reforms, resulting in numerous casualties and loss of property.[51] Addressing salt-related issues necessitated not only economic initiatives but also the gradual incorporation of political and social measures. Recognising the significance of salt fields, the ZSAB endeavoured to develop meteorology to advance their economic interests. The period covered in this article spans from 1946 to 1949. Due to the Second World War, the Nationalist government did not regain control of Zhejiang province and the salt fields until 1945. Additionally, post-war developments deepened the understanding of meteorology. Focusing exclusively on this 4-year period, this article contends that the ZSAB utilised this short time for meteorological development and the improvement of the salt industry.

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46 Z. Wang (2002, pp. 300–312).
47 Liu (2021, pp. 226–271).
48 Zhu [Diary] (1946, Feb. 18), in Zhu Kezhen Quanji Bianji Weiyuanhui (2006, Vol. 10, p. 47).
49 Ding & Tang (1997, pp. 133–169); Kurlansky (2003, pp. 372–377).
50 Miner (1980).
51 Ye (2012, pp. 32–39).

Meteorological information was important for the ZSAB. Salt formation is closely linked to temperature, and the impact of rainy days on salt-drying necessitated that the ZSAB pay attention to meteorological phenomena.[52] Furthermore, natural disasters, especially typhoons, significantly affected salt production and the lives of salt producers in the fields. In 1948, a severe storm near the Dasong salt field (大嵩盐场) of the ZSAB resulted in substantial damage, including the destruction of nearly 10,000 kg of plant ash stored for salt production, covering an area of approximately 2,000 hectares. Two fishermen even lost their lives in the storm.[53] These economic losses and casualties drew the attention of the ZSAB. During the Republican era, provincial-level meteorological stations were primarily established by provincial departments, and the central meteorological department could only offer limited assistance. For instance, the Department of Construction for Zhejiang province (浙江省建设厅, DCZP) was responsible for establishing meteorological stations in Zhejiang, while the Bureau of Education of Guangdong province oversaw local observatories in Guangdong. Although both provinces established a relatively systematic meteorological network in response to natural disasters, they had both encountered financial constraints, raising questions about the extent to which these provincial meteorological stations could serve rural areas and agriculture.[54] The original idea of the ZSAB was probably not to establish meteorological observatories, but rather to rely on meteorological stations built by other institutions. As early as 1942, the ZSAB had asked the DCZP to provide weather reports from the coastal counties for research.[55] Nevertheless, the incompleteness of these records reduced their usefulness, and frequent communication for meteorological data also made administration less efficient. It therefore seemed reasonable for the ZSAB to construct its own meteorological observatories. In contrast to cases in Guangdong, where intellectuals and ambitious local warlords played pivotal roles in establishing meteorological stations, the ZSAB's case highlights the contribution of economic organisations. Thus, this article asserts that the ZSAB genuinely expanded the scope of meteorology, ultimately enabling it to benefit the general population.

This was not the first instance of salt fields establishing their own meteorological stations to facilitate production. In 1945, salt fields in Taiwan had specific meteorological monitoring institutions that published their observation records for three consecutive years, from 1945 to 1947.[56] The clear advantage of this approach lay in the prompt access that salt fields gained to timely weather information, yet the issue of expenditure should not be overlooked. Owing to the limited meteorological

52 Liangzhe Yanwu Guanliju (ZSAB) to Zhongyang Qixaingju (CMB) [Letters] (1946, Aug. 20), L057/009/0413, Zhejiang Provincial Archives, Hangzhou, China (hereafter ZPA).

53 Zhejiangsheng Qixiangsuo Gedi Linian Tianzai Diaocha Biao [Natural disasters investigation form of Zhejiang meteorological stations over the years] (1948, Oct. 21), L057/009/1794, ZPA.

54 Alejandrino (2019, pp. 166–174).

55 Meteorological Report from the Liangzhe Yanwu Guanliju (ZSAB) to the Zhejiangsheng Jiansheting (DCZP) (1942, May 11), L057/008/0097, ZPA.

56 Caizhengbu Taiwan Yanwu Guanliju (Taiwan Salt Administration of the Ministry of Finance) to Liangzhe Yanwu Guanliju (ZSAB) [Letter] (1948, May 10), L057/009/0413, ZPA.

resources in Republican China, the ZSAB opted to collaborate with the Central Meteorological Bureau (中央气象局, CMB), the official department that oversaw meteorology nationally, to jointly set up observatories. During the Republican period, although the central agencies intended to build meteorological stations nationwide, they were mainly responsible for building high-level stations due to their limited manpower and financial resources. For example, two first-class meteorological stations were built in Wuhan and Xi'an in the 1930s.[57] Hence, the central meteorological agencies supported local stations mainly by training personnel and providing specific equipment.

In a letter the ZSAB sent to the CMB in 1946, they stress that the impetus for advancing meteorology was to "scrutinize the weather in coastal fields and refine salt production technology."[58] Although sea-salt drying technology had existed in China since ancient times, innovations were made during the Republic of China era. Notably, salt producers adapted by configuring the salt flats into new shapes in response to beach conditions. Moreover, by harnessing the wind and tide, salt producers could separate different categories of salt brine into different fields, thereby reducing labour costs and augmenting salt production efficiency.[59] The Republican era was therefore a period of innovation in salt-drying technology, in which meteorology played a role. This suggests that meteorological services not only participated in their own development but also catalysed advancements in other technologies.

The ZSAB received relatively professional guidance from the CMB on setting up meteorological observatories. According to the regulations, each station was equipped with specific instruments, generally consisting of one shutter box, one wind vane, one large evaporation dish, and one rain gauge. Additionally, the CMB supplied dry and wet bulbs, thermometers, maximum and minimum thermometers, and rain cups.[60] Although the ZSAB's meteorological observatories lagged in instrument sophistication compared to the earlier JMS, their purpose—serving a specific economic department of the government—rendered these instruments essentially adequate for gathering meteorological information in salt fields. The data observed was mainly transferred to higher-level provincial meteorological stations within China or the CMB, unlike the JMS, which was in a high demand for exchanges of information with foreign stations. A comprehensive "Meteorological Observation Manual" of nearly 200 pages was disseminated to every ZSAB station. The manual expounded on meteorological observation methods, foundational meteorological knowledge, instrument usage, and instructions for recording and transferring data.[61] This detailed manual was largely responsible for training local staff, covering nearly all the meteorological knowledge required for a local weather surveyor. It is noteworthy that there was a persistent shortage of meteorological observation personnel during the

57 Wen (2004, pp. 368–394); Wu (2007, pp. 71–84).
58 Liangzhe Yanwu Guanliju (ZSAB) to CMB [Letter] (1946, Aug. 20), L057/009/0413, ZPA.
59 Ding & Tang (1997, pp. 135–142).
60 Orders from Liangzhe Yanwu Guanliju (ZSAB) to Yanchang (salt fields of the ZSAB) (1946, Oct. 17), L057/009/0413, ZPA.
61 Qixiang Cebao Shouce [Meteorological Observation Manual] (1948, Oct.), L057/009/1793, ZPA.

Republican era, a problem exacerbated by the fact that most personnel trained by central meteorological institutions were assigned to their affiliated stations or military departments.[62] Although it lacked support from the CMB in terms of personnel, the ZSAB addressed this issue by appointing Xiao Qingzhong (萧庆忠), a 1935 graduate of the Beiping Salt Special School (北平盐务专门学校), who previously held the position of salt-quality inspector at the Yuyao Salt Field (余姚盐场), to serve concurrently as a meteorological observer.[63] In view of the scarcity of technical personnel with a certain level of knowledge in salt fields, individuals such as Xiao, who possessed a college degree, were deemed suitably qualified, even though the knowledge required for monitoring salt differed significantly from that used in meteorological observation. Consequently, it became imperative for these non-professional personnel to attain a certain degree of mastery in meteorological observation skills. In this regard, it appears that the ZSAB valued expeditious results, choosing to distribute a comprehensive weather manual for self-study instead of sending staff on systematic training courses. Another reason may have been the inability of official meteorological departments, such as the CMB, to train a large number of technicians in a short timeframe. Nevertheless, this issue underscored the challenge of ensuring the professional competence of personnel.

The CMB and the ZSAB appeared to harbour divergent perspectives regarding technical personnel. The ZSAB sought more professional guidance, anticipating the dispatch of staff by the CMB for training. However, the CMB deemed the observation tasks in the salt fields to be uncomplicated, and thus dismissed the necessity of deploying staff.[64] The two bodies failed to reach a consensus on this matter, which culminated in the CMB's decision not to assign specialised technicians. As outlined earlier, this discourse underscores the fact that the CMB, as the central meteorological institution, employed distinct strategies for meteorological development for the diverse regions of the Republic of China. Specifically, the CMB prioritised the construction of meteorological stations of elevated standards for those situated in frontier regions.[65] As Mark Frank's research has shown, meteorological stations were built by the CMB in Tibet in the 1940s so as to consolidate the Nationalist government's territorial control.[66] Conversely, the organisation of meteorological networks below the provincial level relied on local governments and institutions. Without aid from the central meteorological institution, the ZSAB turned to local support. The aforementioned technician, Xiao Qingzhong from the Yuyao Salt Field, was dispatched to nearby meteorological stations to acquaint himself with instrument operations. The salt field's office believed:

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62 Zhu Kezhen to Academia Sinica [Letters] (1929, Jan. 30), 393/274, SHAC. See also Dai Li, intelligence director of the Kuomintang, to Academia Sinica [Letters] (1944, Dec. 18), 393/149, SHAC.

63 Yuyao Yanchang (Yuyao Salt Field) to Liangzhe Yanwu Guanliju (ZSAB) [Letter] (1947, Aug. 11), L057/009/0413, ZPA.

64 Caizhengbu Yanwu Zongju (General Salt Administration of the Ministry of Finance) to Liangzhe Yanwu Guanliju (ZSAB) [Letter] (1946, Nov. 8), L057/009/0413, ZPA.

65 Jiangsu Meteorological Bureau (1995, pp. 1–13).

66 Frank (2021, pp. 1–18).

> Due to the different specifications of the instrument and the uncertain authenticity of the test results, relying solely on the distributed meteorological observation manual makes conducting observation work challenging. Therefore, visits are conducive to acquainting oneself with meteorological station operations.[67]

In 1947, Xiao organised two visits: one to the Dinghai Meteorological Station and the other to the meteorological stations of the DCZP. His visits yielded valuable insights. He reported: "Some meteorological instruments of the ZSAB are still in short supply, and existing instruments display significant errors that require calibration. Additionally, more guidance on weather measurement is needed."[68] Xiao's report indicated that operational reliance on the manual alone was insufficient for the meteorological observatory. Despite grand ambitions and concerted efforts by Republican institutions to foster meteorological development, they overlooked, or at least failed to prioritise sufficiently, the implementation of these plans.[69] To some extent, it suggested that the top-level designers did not adequately comprehend the basic level. The ZSAB, in this case, attached more importance to the establishment of meteorological observatories than the CMB did. The request for professional personnel illustrates the ZSAB's aspiration to establish an effective meteorological observation network, in which technical personnel were sent to visit and study professional meteorological stations. Consequently, it implies that meteorological development was a goal the ZSAB aimed to accomplish.

In the process of constructing meteorological observatories, local institutions, particularly the ZSAB, encountered substantial challenges. The administrative inefficiency of the government system at that time led to delays in policy implementation. Although a consensus on constructing weather observatories in salt fields was reached in October 1946, several were not established until 1947, prompting the General Salt Administration of the Ministry of Finance (财政部盐政总局) to urge that the project be completed.[70] Funding also presented an obstacle. As posited in this article, the ZSAB established meteorological observatories primarily due to economic interests, and they considered both cost and benefit. Funding to build meteorological observatories in salt fields was primarily borne by the ZSAB, while cooperation with the CMB centred on loans of instruments and meteorological observation guidance. It is worth noting the method of instrument loaning proposed by the CMB, which aimed at fostering meteorological development. In exchange for lending meteorological instruments without charge to other agencies, the CMB required these agencies to provide meteorological information. This initiative not

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67 Yuyao Yanchang (Yuyao Salt Field) to Liangzhe Yanwu Guanliju (ZSAB) [Letter] (1947, Aug. 11), L057/009/0413, ZPA.

68 Yuyao Yanchang (Yuyao Salt Field) to Liangzhe Yanwu Guanliju (ZSAB) [Letter] (1947, Oct. 8), L057/009/0413, ZPA.

69 In 1929, Chinese meteorologist Zhu Kezhen had proposed establishing an extensive national meteorological network within 10 years, but this plan was not achieved during the Republican era; see Amelung (2021).

70 Caizhengbu Yanwu Zongju (General Salt Administration of the Ministry of Finance) to Liangzhe Yanwu Guanliju (ZSAB) [Letter] (1947, Dec. 24), L057/009/0413, ZPA.

only increased the utilisation of meteorological instruments but also expanded the coverage of meteorological observation.[71] Moreover, meteorological knowledge and services became more widespread. This approach appeared to offer those institutions unable to afford instruments the opportunity to establish observatories.

In hindsight, once the personnel problem discussed above had been partially solved, the ZSAB was able to avoid exorbitant costs through the utilisation of existing structures.[72] Although the CMB could offer support with instruments, the types and quantities of those available for lending was restricted. Consequently, the ZSAB still had to procure certain instruments independently. In 1947, technician Huang Shanguang (黄善广) from the Dingdai Salt Field (定岱盐场) intended to apply for 150,000 yuan to manufacture a wind vane.[73] Given the widespread inflation at that time, this large figure nonetheless had limited purchasing power.[74] However, the ZSAB deemed the budget excessively large and ultimately deferred the application, asserting that "the instrument was not urgently needed."[75] As a result, the weather observatories might only have been capable of meeting the ZSAB's meteorological information requirements at a fairly low level.

To a certain extent, this article argues that the ZSAB effectively applied meteorology to serve its economic interests. By the end of 1949, a total of 14 salt fields had either established their own observatories or, at the very least, used meteorological instruments for observation, including Yuyao, Qianqing, Ningshu, Zhexi, Yuquan, Beijian, Dingdai, Changlin and Huangyan, Haisha, Zhenhai, Baolang, Luli, and Shuangsui.[76] It was uncommon for a provincial economic department to boast such a multitude of meteorological observation points. The work of these observatories was also noticeable, with the ZSAB creating a form to compare changes in meteorological measurement and yield for analytical purposes. According to the table, meteorological data—including weather, temperature, humidity, wind power, evaporation, salt-brine density, and sea-water density—were recorded meticulously, alongside daily salt production and cumulative production.[77] This form had to be filled out as often as possible in accordance with the instruments used and the observer's feelings, and on the fifth of each month the previous month's form was to be submitted.[78] Although the precise manner in which the ZSAB leveraged this information to draw conclusions remains somewhat unclear, results could still be

71 Ge Jiguan Shangjie Qixiang Yiqi Banfa [Measures for the Borrowing of Meteorological Instruments by Various Departments] (designed by the CMB) (1947, Apr.), Lo57/009/0413, ZPA; Shu (1995, pp. 14–17).

72 Caizhengbu Yanwu Zongju (General Salt Administration of the Ministry of Finance) to Liangzhe Yanwu Guanliju (ZSAB) [Letter] (1947, Apr. 10), Lo57/009/0413, ZPA.

73 Dingdai Yanchang (Dingdai Salt Field) to Liangzhe Yanwu Guanliju (ZSAB) [Letter] (1947, May 19), Lo57/009/0413, ZPA.

74 "Wujia Pubian Shangchang Shimian Xiaotiao" (1947).

75 LiangzheYanwu Guanliju (ZSAB) to Dingdai Yanchang (Dingdai Salt Field) [Letter] (1947, Aug. 1), Lo57/009/0413, ZPA.

76 Yanchang Cehousuo Liebiao [List of observatories in salt fields] (1948, Dec.), Lo57/009/0413, ZPA.

77 Liangzhe Yanwu Guanliju Geshu Youguan Qixiang Baobiao [Relevant meteorological report forms of the ZSAB] (1948, Nov.), Lo57/009/1795, ZPA.

78 Tianbiao Shuoming [Instructions for filling out the form] (1948), Lo57/016/1789, ZPA.

analysed on the basis of the form, which revealed that salt production would increase concomitantly with rising temperatures and decreasing humidity.

Besides, the continuous observation records of meteorology and production for over a year indicated that the ZSAB's plan had been implemented effectively. The total production of the ZSAB in 1946 amounted to 4.5 million dan, while in 1947, the year in which most meteorological stations were completed, production surged significantly to 5.9 million dan.[79] It is plausible that meteorology played a role in increasing production. Despite a dip to 4.2 million dan in 1948 due to the civil war, this figure remained nearly equivalent to the production in 1946.[80] In addition to production, attention was also directed towards salt quality and its correlation with meteorology. For instance, based on their report, it was demonstrated that fine weather was more conducive to the production of high-quality salt.[81] This outcome was supported in advice from technician Tu Qintong (屠钦桐), who contended that

> The salt formation rate was slow in autumn and winter, often taking one or two days to harvest salt. Due to the extremely cold climate in the morning and evening, needle shaped crystals were formed in the salt, which affected the quality of salt. Therefore, salt producers should be guided to reduce the amount of brine, thus salt harvesting should be done in the middle of the day when the sunlight was strong so that the needle shaped crystals could be dissolved and leached away.[82]

Both salt production and salt quality were pivotal for the subsistence of a salt field. With an understanding of the relationship between meteorological information and these two elements, the ZSAB could potentially develop the salt fields more efficiently. Moreover, an observatory was established at the Dingdai Salt Field, the site of the previously mentioned salt producers' riot.

It is evident that the observatories in salt fields primarily concentrated on recording meteorological data rather than delivering weather forecasts, since the latter necessitated more professional knowledge and instruments, which could not be provided by the ZSAB given its circumstances at that time. Understandably, the measures that the salt fields could adopt when applying meteorology also faced limitations, and were primarily geared towards safeguarding equipment and raw materials in response to extreme weather, and thereby mitigating economic losses.[83] Nonetheless, this article contends that the application of meteorology by the ZSAB substantially fulfilled its need to enhance its economic interests, and the failure to take further

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79 One dan (担) is equal to 50 kg. Liangzhe Yanwu Guanliju 1946nian Nianbao [Annual Report of the ZSAB in 1946] (1946), L057/005/1826, ZPA. See also Liangzhe Yanwu Guanliju 1947nian Nianbao [Annual Report of the ZSAB in 1947] (1947), L057/012/1679, ZPA.

80 Liangzhe Yanwu Guanliju 1948nian Nianbao [Annual Report of the ZSAB in 1948] (1948), L057/007/2305, ZPA.

81 Liangzhe Yanwu Guanliju Geshu Youguan Qixiang Baobiao [Relevant meteorological report forms of the ZSAB] (1948, Nov.), L057/009/1795, ZPA.

82 Jishuyuan Tu Qintong Jianyi Gaijin Gechang Zhiyan Jishu Tigao Yanzhi [Technician Tu Qintong suggested improving salt production techniques in each field to enhance salt quality] (1948, Dec. 3), L057/016/1789, ZPA.

83 Zhejiangsheng Qixiangsuo Gedi Linian Tianzai Diaocha Biao [Natural disasters investigation form of Zhejiang meteorological stations over the years] (1948, Oct. 21), L057/009/1794, ZPA.

measures was the outcome of several factors. First, the social unrest and economic downturn of the late 1940s impacted the administration of the ZSAB.[84] Additionally, the optimal utilisation of meteorology to promote technological innovation remains a question requiring contemporary study. The extant sea-salt manufacturing industry also confronts the challenge of surmounting the constraints imposed on its development by meteorological factors.[85] In addition to economic interests, the meteorological observatories of the ZSAB contributed to the advancement of meteorology within the academic context. The absence of systematic marine meteorological records represented one of the deficiencies in meteorological observation during the Chinese Republican era. Hence, records pertaining to salt fields served to rectify such a deficiency, providing a reference for the weather conditions in the adjacent counties and villages. To some extent, this also promoted the advancement of meteorological instruments. According to the Zhenhai Salt Field, the baume hydrometer used for measuring salt-brine density was produced by the Guoguang Instrument Company, but the paper rolls in the hydrometer caused the instrument to be inaccurate. They therefore asked for more accurate one, and this requirement was set out in the list of meteorological instruments purchased by the ZSAB.[86]

Conclusion

This article has examined meteorology's role in rural economic development during the Republican era, arguing that the localisation and application of meteorological knowledge is a way for rural areas to pursue modernity. To explore this, the article concentrated on salt, a sector which has had a distinctive and pivotal role in Chinese history. In an effort to reform the historical monopoly system of salt merchants, the Republican state initiated a series of reforms within the salt industry. However, this endeavour posed a challenge as a significant portion of people whose livelihoods revolved around the salt industry faced an uncertain future. Thus, addressing this predicament emerged as an imperative for both economic development and social stability. It is apparent that increasing salt production to meet daily and industrial needs was the industry's key goal in the first half of the 20th century, but various technologies were employed by different countries. The United States and Europe increased their mining of rock salt through technological innovation and mechanised production, as well as by replacing wood with coal fuel.[87] Due to geographical constraints, Japan mainly needed to expand the production of sea-salt areas, including the development of salt fields in the Taiwan and Manchuria regions that it occupied

84 Zhejiangsheng Yanye Fazhan Xianzhuang [Recent situation of salt industry in Zhejiang Province] (1948), L057/006/1720, ZPA.

85 Ding & Tang (1997, pp. 187–206).

86 Zhenhai Yanchang (Zhenhai Salt Field) to Liangzhe Yanwu Guanliju (ZSAB) [Letter] (1948, Dec. 29), L057/016/1425, ZPA.

87 Multhauf (1978, pp. 39–100); Kurlansky (2003, pp. 214–256).

at that time.[88] However, given the relatively underdeveloped technology during the Chinese Republic, the range of measures that could be taken were limited, and so meteorology became a focal point. This article has identified two different economic solutions, with meteorology involved in both cases. Zhang Jian sought to resolve the issue by establishing the SRC, and a modern meteorological station, the JMS, was then founded to provide meteorological services for a considerable number of SRCs in Nantong. The case of Zhang, a prominent figure in the late Qing Dynasty and early Republican China, exemplifies how individuals can propel scientific progress. However, the JMS case also revealed a conspicuous weakness—an increasing dependence on individuals, which ultimately heightened the uncertainty and unsustainability of the development.

Functioning as an economic entity, the ZSAB adopted a more direct approach to address the salt problem, endeavouring to increase salt output to foster economic growth. This article has argued that the ZSAB offers an example of relatively successful outcome. While the ZSAB observatories were established during the late 1940s, an era of maturity in the construction of meteorological stations, the article has contended that these grassroots observatories indeed met the requirements of those who built them, particularly in the realm of advancing economic interests. It is important to underscore that the principal recipients of meteorological services identified in this article were those living in rural areas, including the peasantry. It may therefore be argued that the grassroots-level requirements for science, in pragmatic terms at least, could more effectively guide the conception and execution of scientific programmes than the development plans of top-level scientific institutions. In the face of constraints on resources, such as a lack of funds, the measures implemented to surmount these challenges were commendable. In this context, both widespread participation and instrument loans emerged as economic factors that helped meteorological initiatives make an impact on rural development. During periods when governmental support for science was limited, individuals and organisations assumed a substantial role in advancing science, commonly serving as the impetus for scientific progress.

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