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A STUDY ON THE COASTAL METEOROLOGICAL SERVICE IN THE CHINESE MARITIME SERVICE

Uno studio sul Servizio meteorologico costiero del Servizio Marittimo Cinese

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Abstract

In 1869, to ensure navigational safety and to develop meteorology, Robert Hart, the Inspector General of the Chinese Customs Service, planned to carry out a meteorological study of the Chinese coast. After the arrival of meteorological instruments, talent, and registers in China, the Customs Service launched large-scale, continuous meteorological observations from January 1st, 1874 until 1950. Through decades of weather services, the Customs Service gradually established a set of unified and standardized workflows including the observation, recording, sending, and receiving of weather data, as well as guidelines on how to display and present weather forecasts in alignment with contemporary international standards. As a result, a complex technical and social network was constructed, with the Customs Service as both the producer and consumer of weather forecasts. This paper draws on documentary archives to discuss how the western knowledge under the management of the Customs meteorological service was stored in traditional China.

Nel 1869, al fine di garantire la sicurezza della navigazione e sviluppare la meteorologia, Robert Hart, ispettore generale delle dogane cinesi, progettò di introdurre l'osservazione meteorologica fra i compiti delle Dogane. Dopo il successivo arrivo di strumenti meteorologici, talenti e registri in Cina, i servizi doganali iniziarono ad effettuare osservazioni meteorologiche continue su larga scala dal 1 gennaio 1874 al 1950 circa. Durante decenni di servizi meteorologici, le Dogane hanno gradualmente stabilito una serie di flussi di lavoro unificati e standardizzati tra cui l'osservazione, la registrazione, l'invio e la ricezione di dati meteorologici, nonché la visualizzazione e la presentazione delle previsioni meteorologiche secondo gli standard internazionali. Di conseguenza, fu costruita una complessa rete tecnica e sociale in cui le dogane erano sia produttori che consumatori di previsioni meteorologiche. Questo lavoro utilizza gli archivi documentari per analizzare come un sapere occidentale, la gestione del servizio meteorologico doganale, si è sedimentato nella Cina tradizionale.

Keywords: Chinese Maritime Customs Service (CMCS), Meteorological Service, code of signals.
Servizio doganale marittimo cinese (CMCS), Servizio meteorologico, codice dei segnali.

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Introduction

Beginning in the 1840s with the signing of a series of diplomatic treaties, the Qing Dynasty gradually opened its coastal and river ports for trade, and as a result, people and ships from Western countries began to enter China on a large-scale. However, with a large north-south span, a long coastline, foggy springs, frequent typhoons in the summer and autumn, and chilly air in the winter, China's coastal areas were among the most difficult in the world to navigate. Discussions among foreigners about people's health and the safety of navigation relating to the weather often appeared in books and newspapers. At the same time, in 1856, France was the first country to develop storm warning services using weather observations, such as temperature, pressure, and wind speed for weather analysis and forecasting. Therefore, meteorology became a national matter and was soon copied worldwide (Liu Zhao-Ming 1981, 185). One of the most notable influences in this trend was the establishment of the Zikawei（徐家汇）Observatory in Shanghai in 1872, known as the "first meteorological station in the Far East". The Zikawei Observatory was the successor to the French Jesuits' meteorological observations and related activities in Dongjiadu during the 1860s.

Although the Zikawei Observatory's achievements in meteorology were notable, it was the modern Chinese Customs Service that truly established the meteorological network that linked China's coast to the rest of East Asia. Established in 1854, for almost a century, the Chinese Maritime Customs Service (CMCS) functioned in mainland China until the establishment of the People's Republic of China in 1949. As China's foreign relations deepened, in addition to estimating and collecting taxes on foreign trade, the Customs Service duties expanded to include those in the maritime, educational, diplomatic, postal, meteorological, and other fields, becoming a comprehensive organization. Although subordinate to the central government, the Inspector General, a position that had always been held by a foreigner, had complete control over the Customs Service. The Customs Service's authority covered the whole country and even East Asia. In 1869, Robert Hart, the Inspector General, first proposed to establish meteorological stations, and by 1882, the Customs Service was cooperating with the Observatory in Zikawei to support weather observations free of charge and produce scientific results such as weather forecasts. As a result, the Customs Service meteorological stations became one of the key platforms for displaying weather warnings and alerting ships about extreme weather hazards. Over time, a network of meteorological science linking East Asia and the world was established.

The preeminent meteorological work of CMCS has attracted academic attention, especially regarding the issues in the development of the Customs Service meteorological network. Wu Yan used the perspective of the exchange of benefits to discuss the cooperation between the Customs Service and Zikawei Observatory in establishing a network of weather stations. Zhu Marlon discussed how business groups between ports pushed Hart to finally relinquish the Customs Service's dominance and to cooperate with the Zikawei Observatory. Robert Bickers outlined the early development of the modern meteorological infrastructure in China from 1869-1912 and examined the struggles and cooperation between the Customs Service, Zikawei Observatory, and the Hong Kong Observatory as they competed to be the center of meteorological research and weather forecasting in the region. In addition, Cheng Chunshu researched the Customs Service meteorological stations' network, while Wu Zengxiang's study of Customs Service meteorological observation and recording methods demonstrated the spatial and temporal distribution of stations, as well as their main characteristics. To link works from China to surrounding areas, P. Kevin MacKeown made a passing reference to Hart's meteorological work in his study of the role of the Hong Kong Observatory in the recent East Asian storm warning network. Yang Ping and Wang Zhiqiang sorted and discussed the development of the Customs Service meteorological work. Other scholars have collated and examined various local Customs Service meteorological archives for further analysis (Wu Yan 2009, 54-63; MacKeown 2010, 12-15; Zhu 2012, 20-71; Bickers 2016, 180-201; Yang Ping, Wang Zhi-qiang 2019, 24-32).

To further develop the previously mentioned past studies on the topic, this paper uses documentary archives to provide a micro-historical perspective on the management of Customs Service meteorological services, the origins of the Customs Service meteorological work, the observation, recording and transmission of meteorological data, and the evolution of meteorological warning systems in modern times. This research aims to provide a more comprehensive and insightful understanding of Customs Service and to discuss the interaction between modern meteorological science and human society.

The origins and organization of the Customs Service meteorological service

In 1867, Robert Hart, after looking at the maritime accidents off the coast of China over the previous 25 years, concluded that typhoons were one of the most common reasons for the accidents. The other common reason was carelessness on the part of the driver, causing the vessel to collide, catch fire, or run aground. To solve this problem, Hart believed that funds should be allocated to install lighthouses along the coast to alert incoming and outgoing ships[1]. In addition, in 1868, with the provisions of Paragraph 10 of the 1858 Sino-British *Agreement Containing Rules of Trade*, the Marine Department was established by CMCS to improve the access conditions and coastal navigation at China's ports of commerce[2]. After two years of construction, the Customs Service's lighthouse business had developed.

On November 12th, 1869, Hart further issued Circular No. 28, laying out the meteorological business of the Customs Service, "to establish a Meteorological Station in connection with each Office of Customs during the coming year"[3]. Considering that the geographical location of the Customs Service lighthouses differ by about 20 degrees of latitude and 10 degrees of longitude, and that no additional staff was required, it was only necessary to purchase meteorological instruments to start observing and recording the weather. Meteorological observations could reveal the laws of nature and provide the scientific community with a wealth of facts and data from the Chinese region that had hardly been systematically summarized before. Additionally, they could guarantee the safety of navigation and thus facilitate trade and commerce. Therefore, Hart sought the establishment of meteorological stations in some of the ports, and after a few years, the Customs Service weather stations would be put under the control of the weather station of Peking College (T'ung Wen Kuan) in the capital[4]. Moreover, Hart planned to collaborate with other regional meteorology departments "for the publication of meteorological observations, and exchange of weather-news by telegraph along the Pacific Coast of Asia"[5]. Therefore, an international network of scientific meteorological research, with the Customs Service taking the lead, would be established through the cooperation between China and the rest of East Asia.

To achieve these goals, Hart delegated the responsibility to James Duncan Campbell, director of the Customs Service's London Office. From 1873 to 1882, Campbell was appointed by Hart to actively build a scientific network of people, purchasing meteorological instruments and registers and hiring meteorological personnel from abroad to successfully operate the Customs Service meteorological stations (Xu Wenxin 2022, 67-82). The collaboration of the Customs Service with the Zikawei Observatory began because the meteorology business of T'ung Wen Kuan never actually launched. In 1879, due to absence of T'ung Wen Kuan's meteorology business, A.M. Bisbee, the Divisional Inspector and Habor Master of Marine Department, instead presented the meteorological data measured at his port to the Zikawei Observatory for interpretation. In March 1882, to regulate this first collaboration, Hart ordered that meteorological observations at ports should be shared with other institutions with the permission of the Inspector General[6]. In May of that year, Hart also formally authorized the Commissioner to send copies of meteorological records to the Zikawei Observatory in the same form as before; however, in the future, they had to be officially forwarded by the local chief rather than sent directly on behalf of individuals[7].

Consequently, it was institutionally established that the Zikawei Observatory had the right to interpret

the Customs Service's meteorological data. This right was then gradually granted to more meteorological organizations, such as the Hong Kong Observatory and the Central Meteorological Observatory in Tokyo. Subsequently, the Customs Service-led East Asian meteorology network envisaged by Hart evolved into an equal, multi-sectoral collaboration with the Customs Service weather stations providing the basic data that was scientifically processed by the meteorological agencies represented by the Zikawei Observatory to produce weather forecasts that were then released to the public (Xu Wenxin 2022, 67-82).

After this collaboration began, the Customs Service did not slacken its meteorological work and sought to further optimize its organizational structure. Apart from the general control of the Imperial Maritime Customs Service, there was a lack of clarity about the authority of the various ports of entry, which included both the Inspector General and Commissioner, as well as Divisional Inspector and Habor Master. While cooperation between the parties was smooth, Hart became aware that certain issues such as how to improve the Customs Service's ability to record and report on weather observations as the volume of business grew and the demand for professionalism increased would need to be addressed.

In February 1892, Hart ordered a tally of the weather observations sent and received at the ports. For ports where no weather observations were carried out, he deemed it sufficient to just report the facts, while other ports were required to reply with information in the following format: (1) the name of the place, port, or the author of the report; (2) the time and frequency of sending; (3) by what means (e.g., mail, telegram, etc.) the report was sent; (4) whether the report had been published by the port of entry to which it was sent and by what means (e.g., Customs Notifications, Press, etc.); and (5) whether the report was published by the port of dispatch and in what manner (e.g., Customs Notifications, Press...)[8].

Likewise, in the received weather report form, four aspects should also be stated: (1) the name of the place, port, or by whom the report was received; (2) the time and frequency of receipt; (3) the way the report was received; and (4) whether it was published by the port where it was received and in what manner[9]. In this way, the Inspector General had a complete picture of the weather reports sent to and received at the various ports.

By 1903, the meteorological work of the Customs Service was placed under the sole responsibility of the Coast Inspector[10]. The Coast Inspector reported to the Marine Department, and, at that time, was managed by W.F. Tyler, the ex officio Harbour Master of Shanghai[11]. The Coast Inspector was primarily responsible for overseeing the maritime work at ports, for example, examining the "the condition of the local pilotage, the performance of Harbor duties by the local Harbor Masters"[12]. In the field of meteorological work "all new instruments that may be required should be indented for, and will be supplied by, the Coast Inspector's office, which will also see to the repairs of damaged instruments: and generally speaking, all questions of meteorological import, such, for example, as may be raised by Observatories, should be referred to the Coast Inspector". Additionally, the recording of meteorological observations, the sending of telegrams, and the timing of each should be standardized[13].

After a detailed survey of meteorological instruments, log sheets, transmission times, routes and targets, storm warning signals, and more at various ports[14], the Coast Inspector targeted improvement measures. For example, from 1904 onwards, all meteorological returns were to be sent to his office and then distributed from there, with a person later being specifically employed for this task[15]. These improvement measures unified the authority of meteorological reporting and optimized the working procedures, improving the efficiency of the Customs Service meteorological services.

Observation, recording, and transmission of meteorological data

In addition to the centralization and optimization of the administrative organization, the Imperial Maritime Customs Service also carried out a series of weather service workflow improvements, resulting in a

unified and standardized system. The observations and records of specific meteorological devices were eventually recorded on a professional form, called a register. In 1873, regarding the choice of the register, Hart sought the advice of a wide range of professionals to bring the Customs Service in line with international standards[16]. In September of that year at the International Meteorological Conference in Vienna, attendees suggested that the Conference could recommend the universal adoption of a registration form and the recording of items such as "barometric pressure, temperature, humidity, rain, wind, clouds and weather, and special phenomena"[17].

On August 24th, 1885, Colin Jamieson, the Commissioner in Swatow, suggested to Hart that the ports should use a new meteorological return that was prepared by the Commissioner in Amoy to reduce the number of daily observations from eight to four, with the observations being made at 3 a.m., 9 a.m., 3 p.m. and 9 p.m. The four points of time would be authorized by William Doberck, director of the Hong Kong Observatory, and would be "complete and sufficient" for meteorological science, except on typhoon days[18]. The observations in the table included: barometric pressure, air temperature (dry bulb, wet bulb, maximum, minimum, solar radiation maximum, ground radiation minimum), precipitation (the code of the rain gauge with information of height and duration), wind and wind direction, condition of the weather, accompanying notes, signature of the observer, etc.[19] The reduction in the number of observations would not only lighten the workload of the Customs Service staff, but it would also allow for more accurate values to be taken by Customs Services officers who did not specialize in meteorological work.

In 1887, Doberck completed his *Instructions for Making Meteorological Observations*, published by the Statistical Secretary of Imperial Maritime Customs Service, which provided an important professional reference for the Customs Service meteorological observations. The book was intended to be a reference for meteorological observers who recorded weather at Chinese treaty ports as far north as Newchwang and as far west as Ichang and Pakhoi, as well as for captains of ships from the various countries frequently sailing in Chinese waters. These instructions were professional and detailed. The covered the following: (1) the use and precautions of general meteorological instruments (such as barometers, thermometers, psychrometer, thermometer screen, and rain gauges) when conducting meteorological observations; (2) the natural properties of wind, clouds, and weather and recording standards; (3) the timing and frequency of observations for different systems (for example, Customs Service at 3 a.m., 9 a.m., 3 p.m., and 9 p.m.); (4) barometric calibration tables and more[20].

Furthermore, there was the issue of the normalization of observational data units. When the Vienna International Meteorological Conference was held in 1873, the committee strove to unite the English and metric system for meteorology, initially adopting a metric resolution. However, this measure was opposed and eventually both measurement systems were used in tandem[21]. For a long time, the English scale was a widely used and familiar system of measurement for mariners and the Customs Service, and the scales of the weather instruments used at the Customs Service weather stations also displayed imperial units. However, as the metric system became more widely used around the world, the lack in uniformity of the units of measurement caused many difficulties. The last thing presented in the weather record book were measurements in the metric system, and the Customs Service staff had to convert readings from inches and Fahrenheit to millimeters and Centigrade, thus increasing their workload. This problem was not resolved until 1932, when modern machines were introduced at the stations and the instruments were equipped with displays for metric and centigrade readings[22].

The configuration of specialist instruments at each weather station also began to change. Initially, Hart asked G.E. Airey, the Royal Astronomer, to draw up a list of instruments for the Customs Service weather stations, which would then be purchased in England by Campbell[23]. The first shipment of meteorological instruments arrived in China in 1873, including two complete barometers and four broken barometers[24]. Subsequently, as meteorology developed and there was an increased need to observe more, the Customs Service administration also equipped the weather stations with sets of professional meteorological in-

struments. By 1938, each Customs Service weather station was equipped with a complete set of instruments, including: a mercurial barometer with attached thermometer, a dry and wet bulb hygrometer, a maximum thermometer, a minimum thermometer, and a rain-gauge. For certain observation points, the Customs Service would also install the specifically appropriate equipment. For example, some of the uncovered lighthouse stations, namely North Saddle, Peiyüshan, T'urnabout, Lamocks, and Gutzlaff, were also equipped with barographs or anemometers[25]. Also, the meteorological returns were further refined to contain 13 columns and 8 daily observations (3.00, 6.00, 9.00, 12.00 (noon), 14.00, 18.00, 21.00 and 24.00), with a minimum of 4 daily observations being required (6.00, 9.00, 14.00, and 21.00 hours)[26].
There was also the issue of the choice of time zones for meteorological observations. In 1884, the International Meridian Conference was held in Washington, D.C., which adopted the Standard Time system and brought the world into the uniform system of time zones. During that period, the time used by the Zikawei Observatory's Time Ball on the Bund was still the Shanghai local mean time, and it was only in the late 19th-century that standard time was introduced. The standard time system was introduced in China in 1902, and by 1903 it was already in use at the Customs Service office in Shanghai, with other ports soon following suit[27]. In view of the long east-west span of China, in 1938, the timings of meteorological observations were divided into two time zones, UTC +7 and UTC +8, for broadcasting reports.
More precisely, 4 of the 52 weather stations (Chungking, Nanning, Lungchow, and Tengyueh) used the time zone of the seven eastern districts, with Chungking and Tengyueh being responsible for sending telegrams of the weather observations daily at 0500 and 1300 hours (for about 2 months), and an additional telegram at 2000 hours (about every 2 and a half months) during the typhoon season (from June 1st to October 31st). The remaining 50 stations followed the time zone of the eastern eight districts, with 25 stations being selected to send daily weather telegraphs at 0600 and 1400 hours (about every 2 months) and an additional one at 2100 each day during the typhoon season[28]. This measure facilitated the practical operation of the observers, and the observations and meteorologic results gained in accuracy.
From the rather small scale of their observations in 1869, the Customs Service meteorological observations gradually developed, and by 1905, there were 41 stations making regular observations with their records being sent to 5 observatories throughout East Asia[29]. In 1930, there were 61 Customs Service meteorological stations, 44 of which were land stations and 17 of which were lighthouse stations[30]. In 1935, observations were recorded at 46 Customs Service meteorological stations, 20 of which were lighthouse stations. Meteorological telegrams were transmitted from 24 of these stations to nine different addresses, requiring over 270 telegrams per day, or an average of over 40,000 sheets per year[31]. Furthermore, in March 1900, the results of meteorological observations taken by captains and other observers would be received by their local respective Customs Service office and be forwarded to the Zikawei Observatory[32] to remove concerns about postage[33]. This system was also designed to allow the Zikawei Observatory to receive more weather data to make increasingly objective and precise weather forecasts. The large amount of data needed to be sent daily to the different observatories in East Asia to produce scientific products such as weather forecasts had to then be returned to the Customs Service to be broadcast to the public. The telegraph was the main medium used to deliver this data.
After 1837, when Samuel Finley Breese Morse invented the first telegraph that could use code, the telegraph became more popular and technology advanced as it became more widely used. In 1869, the telegraph technology was first introduced to China and was soon applied to the transmission of meteorological information. The Great Northern Telegraph Company, for example, laid out water lines between Shanghai and Hong Kong in 1871, and established a telegraph station at Gatzlaff in 1874 to communicate with the shore and all the incoming and outgoing ships at Shanghai. Furthermore, daily weather forecasts produced by the Zikawei Observatory were sent to Shanghai to inform the shipping industry, and storm warnings were also issued by signals that were hoisted on flagpoles, thus saving countless lives[34]. After that, more telegraph companies joined in and offered the service free of charge.

The Customs Service also set up a process for sending weather telegraphs. For example, in 1904, it was stipulated that weather telegraph observations be made at 6 a.m. and 3 p.m. and be sent to the telegraph office for dispatch as soon as possible. The observations from Pakhoi, Kiungchow, and Canton were sent to the Hong Kong Observatory, Swatow to the Hongkong and Zikawei Observatories, and Amoy, Ningpo, Chinkiang, Kiukiang, Hankow, Ichang, Chungking, Chefoo, and Newchwang to the Zikawei Observatory. Furthermore, the meteorological telegrams were required to be bound and sent to the Coast Inspector monthly[35].
At the same time, the improvement, simplification, and harmonization of meteorological codes also facilitated the efficient transmission of meteorological data. In 1904, the Inspector General established that meteorological telegrams were to be divided into two groups of five characters composed as "BBBDD FWTTM". BBB was the barometer's measurement, DD was for the direction of the wind, F was for the wind speed, W was for the weather conditions, TT was for the temperature, and M was for difference between the wet and dry bulbs[36]. In 1914, the sharing of meteorological data by the Customs Service was further extended with the free transmission of telegrams to Peking Observatory[37]. In 1916, the Observatory of the Ministry of Agriculture and Commerce was added to the network and they changed the code to "BBBTT HDDVA", with BBB representing the barometer's measurement, TT representing the temperature, H representing the humidity, DD representing the direction of the wind, V representing the wind speed in meters per second, and A representing the weather conditions[38]. In 1930, the Hong Kong Meteorological Conference changed the meteorological code to a six-letter code, enriching the meteorological information that was convened.

Receipt and presentation of meteorological forecasts

Based on the meteorological data from the Customs Service land and lighthouse stations, professional scientific institutions, represented by the Zikawei Observatory, produced scientific products, such as weather maps, which were released to the public to alert them of weather conditions. The weather signal was an important vehicle for the presentation of this meteorological public service. As early as 1884, the Zikawei Observatory erected a signal pole on the Quai de France and hung flags on it to convey weather information, providing weather service to the public at the Shanghai port. This was a departure from the previous practice of warning vessels of dangers without informing them of the specific conditions[39]. By seeing the weather signals and with some general meteorological knowledge, the crew would know and then avoid the storm's path.
On January 1st, 1898, due to the Customs Service, the weather warning symbols prepared in 1897 by Louis Froc, the Director of the Zikawei Observatory, were officially applied to all major Chinese treaty ports. This new service, called the Typhoon and Storm Warning Service on the Coast of China, made use of the flags of the International Code and Marryat's Code. The Customs Service used a combination of Arabic numerals and the flags of the International Code to broadcast two weather conditions: typhoons or depressions and storm or gale warnings. For typhoons or depressions, a total of 91 flags displayed the future direction of the wind and other information, covering areas ranging from the Philippines and Vietnam in the south, to the Korean Peninsula and Siberia in the north, to Japan in the east, and to the Yangtze River Basin in the west. For storm or gale warnings, a G flag was used to indicate a storm, with two consecutive Arabic numeral flags to indicate the direction (13 directions). If there was a gale, a V flag was added, signalling that the center was near the place indicated by the code.
This symbol system used semaphores from the International Code of Signals, which was already available from the Customs Service, and was transmitted free of charge by telegraph companies thus providing shipping security at an exceptionally low cost. The system, which had a uniform and simple weather warning signal, had also been adopted by observatories in Manila, Tokyo, and Taiwan.

To extend the service and cater to the fishing vessels and sampans that were more threatened during the typhoon season, the Customs Service decided that the lighthouses along the Chinese coast should repeat the storm warning signals issued by the Zikawei Observatory. However, most lighthouse stations did not have telegraphs and could not directly receive information from the observatory, so they relied on the help of nearby sailing ships who flew signal flags to inform the lighthouse stations and other ships about weather conditions[40]. Due to this situation, the Storm Signal Repeating Code was designed. The new code was an abbreviated version of the previous storm signal. Based on the arrangement and combination of the flags, this code could show six different weather conditions[41].

At the same time, the Imperial Maritime Customs Service also divided the coast of China into seven regions from south to north with each region possessing a specific Repeating Stations. For example, District V's geographical scope was from Nimrod Sound (Lat. 29°30') to Haichow Bay (Lat. 35°) and included the Customs Service Districts: Ningpo (North) and Shanghai. There were five Repeating Stations in this area: Steep Island, Chinhai, Ningpo, North Saddle, and Shaweishan[42]. It was stipulated that a Repeating Station should hoist the corresponding sign in 24 hours unless other ships sent another signal before the 24 hours[43]. However, this was insufficient in practice, and the Zikawei Observatory then changed the requirement to instead repeat within three and a half days for each ship after the time given by the signal station. For example, if the signal were sent the previous day's morning, it could not be transmitted until noon of the current day; if the signal were sent in the previous day's afternoon, it could not be transmitted until after dark of the current day[44]. This activity was supported by many steam ships. Until May 10th, 1907, there were 119 ships assisting this service[45].

Although the two previously mentioned systems brought great convenience to navigational safety, after extensive practice, they were found to have a fatal shortcoming – when there was no wind, it was difficult for people to recognize the shape and color of the flags, foundational to the flag system; this turned out to be a widespread problem. Therefore, in 1909, the Customs Service cooperated with the Zikawei Observatory and decided to replace the flags with geometric shapes. At first, there were six symbols that represented numbers: the sphere, the cylinder, the cone, arrows pointing up and down, and two cones positioned point to point or base to base[46]. This new system was simple and easy to understand and was quickly accepted by crews[47]. However, according to practical experience, the Customs Service Coast Inspector W.F. Tyler believed that the new system had two flaws. First, the location given was too unclear, and he thought that the location range should be expanded by specifying an area or location through latitude and longitude. Second, the visibility of the hanging meteorological symbols was insufficient. To the Customs Service, it was necessary to select the best one from three symbols of the disc, diamond, and square. These were the three geometric shapes in use at the time, but there was not much difference between them. After a long discussion, it was concluded that the diamond was the best choice, and the disc was the least suitable[48].

Based on this, in 1914, Froc and R.P. Gauthier proposed two new types of cylinders (or discs) for a total of 10 symbols to represent information such as latitude and longitude. After two years of experiments by the Customs Service, the optimal size of each symbol was determined, enabling it to be seen clearer at a distance[49]. On February 1st, 1918, the Customs Service officially established the new signal system as the China Seas Storm Signal Code. This new code was implemented in the Storm Signal Stations of the Maritime Customs, the French Municipal Storm Signal Station at Shanghai, and the British Storm Signal Station at Weihaiwei[50]. In contrast to the previous system, the new system used 10 kinds of cylinders as symbols, which increased the recognizability of the symbols. The new system also made the weather warning communication faster and more accurate, expressing the latitudinal and longitudinal information of the storm position in decimal notation. Furthermore, the information of the new code was also richer, and included the time, center position of the typhoon or continental depression, the movement direction, the radius, the intensity, the key elements of gale signals' threat area, the general direction, etc.[51]

The system, according to Froc, and "its consecration by a long experience, since it has been at work in

its essential features, in fact in its actual form, since 1883, and its extreme simplicity, each commanding officer being able at first sight to make out what it means, without referring to a table or a book for the numerous (40 perhaps) different systems of each country in the world[52]". Later, in 1930, when the Conference of Directors of East Asian Weather Services Hong Kong was held, the director of the Hong Kong Observatory suggested that the China Seas Storm Signal Code should be slightly modified and extended to the entire East Asia region. This proposal was approved by the participants and, in subsequent practice, the entirety of East Asia, except Korea, had unified in their display of weather signals.

Conclusion

Beginning with Hart's 1869 proposal of the Customs Service Meteorological Plan to his entrusting Campbell to seek professional advice from overseas, purchase meteorological instruments, and search for meteorological personnel, the configuration of the Customs Service Meteorological Observation Station was gradually put into place. January 1st, 1874 saw the beginning of a large-scale and successful operation to perform systematic weather observation. In May 1882, the Imperial Maritime Customs Service officially issued a circular order to share the Customs Service meteorological observation data with the Zikawei Observatory free of charge, providing an important data source for the latter to make weather forecasts and other scientific products. Subsequently, the Customs Service expanded the entitites with which it shared data, including the Hong Kong Observatory, the Tokyo Meteorological Observatory, Peking's Central Observatory, and the Agricultural and Commercial Weather Observatory. To transfer the data more quickly and efficiently, the Customs Service, through years of cooperation, developed a set of workflows.

First, the observation and recording of meteorological data was closely related to the development of professional meteorological theory. Initially, only temperature, pressure, wind speed, and wind direction were recorded. This was gradually expanded to include measurements such as dryness, humidity, and weather conditions, and with the invention of new meteorological instruments, more accurate weather data could be observed and recorded. Moreover, the deepening of international cooperation in meteorology led to the gradual harmonization of the units of measurement and registers of meteorological observations, foundational to the Customs Service meteorological work. Second, the telegraph became an important medium for the sending and receiving meteorological data. Also, the Customs Service offices were divided into zones according to the geographical location of the various meteorological stations and transmitted their meteorological data to their respective observatories. Additionally, the gradual revision, simplification, and unification of meteorological codes also provided convenience for high-speed data transmission. Finally, the weather data was gathered at the various observatories and interpreted in a specialized way to produce scientific products such as weather forecasts, especially typhoon warnings, which provided important alerts to ships located along the southeast coast of China. Weather alerts were then once again returned to important Customs Service weather stations, which were responsible for displaying specific weather symbols as well as informing people and ships about storms and how to avoid them. In this regard, the Customs Service and the Zikawei Observatory had, after years of practice and experimentation, continually improved sets of meteorological codes, gradually converting from the flag signals to a letter coding system that allowed observers to more clearly see the hanging signals and, therefore, understand their corresponding meanings.

Owing to this rigorous and standardized workflow, the Customs Service established a complex technical and social network in which the Customs Service was both a producer and a consumer of weather forecasts. Through specific technical training and guidance, the Customs Service appointed personnel such as lighthouse keepers to serve as meteorological observers, so that they could learn to use and repair professional meteorological instruments, read, and correct the tables of meteorological instruments, and

follow the unified register. The numbers were recorded in the registers and then forwarded to various observatories throughout East Asia. The weather forecasts that were produced based on the meteorological data observed by the Customs Service became an important platform for displaying the weather symbols after returning to the Customs Service. The influence was mutual; technology can help human society to avoid natural disasters. However, things did not go completely smoothly in this process. For example, due to raging typhoons, there was often a delay when the weather data from each lighthouse station was sent to the observatory. This was disastrous for the observatory, which needed to receive data as quickly as possible. In other instances, due to delays by the staff of the telegraph company, the telegram warnings about the weather situation were often not sent in time.

In sum, through interaction and cooperation, the Customs Service demonstrated its vast organizational and cooperative capabilities, and gradually established a meteorological service system with both scientific and practical benefits. During this process, the Customs Service accumulated a large amount of meteorological data, which not only greatly guaranteed the safety of navigation, but also contributed to the study of historical meteorology in East Asia. The system formed a complex network linking weather data to weather information to science, technology, and, ultimately, human society. Through this process, we can understand the Customs Service as a government agency that, through its diversity and work with scientific institutions, promoted navigation and meteorology from the middle 19th-century to the early 20th-century.

Notes

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