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JACOB BJERKNES AND THE WEATHER FORECAST IN PORTUGAL

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Abstract

In 1922, due to the initiative of António de Carvalho Brandão, the Meteorological Service of the Navy was founded in Portugal. This was the beginning of synoptic meteorology in the country. Brandão became not only the first director of that Meteorological Service but also one of the most known Portuguese meteorologists. Four years later, at an international meteorology meeting held in Zurich, Brandão announced the decision of the Portuguese government to install a wireless telegraphy station at Azores to provide meteorological services. In 1927, Colonel Emile Delcambre, head of the French meteorological services, and Jacob Bjerknes, the famous Norwegian meteorologist, came to Portugal to meet with Portuguese authorities and discuss details concerning the Azores international station. Bjerknes came earlier to study the local weather and to get acquainted with the Portuguese meteorology services. In the last day of his visit, 23rd May, he went to the University of Coimbra with Carvalho Brandão, where he delivered a conference, later published in O Instituto*, the journal of Coimbra's academic society. He then referred to the important role Portugal might play in European weather forecast and described a project of establishing several stations in Northern Atlantic to collect transmissions from all ocean liners and communicate this information to the International Meteorological Organization, founded in 1873. The international meteorological station of Azores started to operate in 1929. The inauguration was announced at the international meteorological congress held in Copenhagen in that same year. In 1934, the Meteorological Service of the Navy was receiving daily reports from meteorological observatories in Coimbra, Oporto, Azores and 30 other stations. Of these stations, 18 were international, i.e., their data were relayed abroad from Lisbon.*

We present an episode of the history of meteorology in Europe, between the two world wars, in which Portugal played a relevant role. But we start with a brief history of meteorology in Portugal to portray its state at the beginning of the twentieth century.

The Meteorology in Portugal in the Nineteenth Century

The first meteorological observations made with a scientific purpose were made in Portugal at the beginning of the nineteenth century. Although the major concern was to establish climatic patterns of some regions and to use this

information to improve public health, the hope was that the gathered data could be used to deduce major laws of atmospheric phenomena. This was the case of the observations done by Constantino Botelho de Lacerda Lobo (1754–1820), Professor of Physics at the Natural Philosophy Faculty of the University of Coimbra (UC), done at the Cabinet of Experimental Physics from 1812 to 1817. Unfortunately, these observations were of little scientific value, since they were made indoors and not at fixed hours. Also Marino Miguel Franzini (1779–1861) registered daily meteorological data in Lisbon, from 1816 to 1826 and again from 1835 to 1855. He set up a small observatory at his home, where he collected weather data, and applied statistical analysis to it (Nunes, 1988).

In 1843, Guilherme Dias Pegado (1803−85) requested the government to establish a meteorological observatory in Lisbon, as part of the Polytechnic School. The Prince Luís Observatory, the first Portuguese meteorological observatory, started to operate in October 1854. The first daily meteorological bulletin, which was delivered by the Paris Observatory from 1858 on, included Lisbon records. Storm warnings were issued, and alert signs were hoisted at the coastal stations (Ferreira, 1940). From 1865 on, the Lisbon's Observatory published a daily bulletin that provided the weather in Lisbon for the next day. Along the second half of the nineteenth century, it was a monitoring centre, gathering, in 1892, the observations of 14 national meteorological stations, seven in Spain and one in Ireland (Aires, 1892).

In Coimbra, the meteorological observations at the Physics Cabinet were resumed in 1853, being the results published in *O Instituto*, the literary and scientific journal of the academic society with the same name (Institute of Coimbra – IC), which had been founded in Coimbra in 1852 (Leonardo *et al.,* 2009). In the pages of this periodic several articles relating to meteorology appeared in its first years. Some of them stressed the urgency to establish a meteorological observatory in Coimbra in order to promote meteorological studies and to attain the same progress that was being achieved in other institutions, in the country and abroad. In 1861, the Faculty Council asked Jacinto António de Sousa (1818−80) to gather the necessary means to establish a meteorological observatory. Meteorological observations were initiated in the new observatory on 1 February 1864, while its construction continued. A telegraphic communication with the Meteorological Observatory Prince Luís was established in 1867, transmitting the morning daily observations (Lopes, 1893).

By the end of the nineteenth century, the meteorological services were centred in Lisbon. Beside the observatories of Lisbon and Coimbra, the Meteorological Observatory Princess Amelia was established in Oporto in 1888.

In the early twentieth century a *"sharp decline"* in the work done at the observatories of Coimbra, Oporto and Lisbon was visible, mainly due to internal disputes, lack of funding and staff scarcity (Leonardo *et al.,* 2011). A Technical Committee of Meteorology was appointed in 1921 to organize the meteorological services. It included, among others, Anselmo Ferraz de Carvalho and António de Carvalho Brandão. In 1914, Anselmo Ferraz de Carvalho (1878−1955) was appointed Director of the Coimbra Meteorological and Magnetic Observatory (MMO). This committee stated that there was a *"lack of meteorological stations in many regions"* and *"oceanic weather, in which we should work with other maritime countries, has long been abandoned between us"*, so that *"the actual weather service […] is fighting with many deficiencies derived from the lack of personal and material resources"* (cited in Leonardo *et al.,* 2011). The creation of a Central Institute for Meteorology was recommended, including a weather forecast and climate services. In spite of that, the scenario remained bleak.

Fig. 1: António de Carvalho Brandão.

The new methods of Weather Forecasting after the First World War

To endeavour in weather prediction, the study of meteorological phenomena within large areas by simultaneous observation of the atmospheric elements was needed. It was necessary to lay down a network of stations, spread around the country, including the Atlantic islands of Madeira and Azores, relaying surface weather observations made at periodic times. This organization was only possible with the creation of the Meteorological Services of the Navy in 1922. They were an initiative of Vice-Admiral Eduardo Augusto Neuparth (1859−1925) and the navy officer and meteorologist António de Carvalho Brandão (1878−1937). The General Marine Stewardship requested the MMO and other observatories to implement synoptic observations. Synoptic meteorology entailed the elaboration of meteorological maps, covering Western Europe, and the application of new methods to weather forecasting. Brandão played a key role in Portuguese meteorology, particularly in weather prediction, attending many international conferences on behalf of the government (e.g., London, 1921, and Utrecht, 1923).

Weather forecasting was still controversial in the scientific community at the beginning of the twentieth century (the Portuguese proverb that stated that *"if you want to lie, start predicting the weather,"* was difficult to override). Local weather forecasts done by João Carlos de Brito Capelo (1831–1901), when he was director of the Observatory Prince Luís in Lisbon, only indicated that day's probable weather. They were based in his continued attention to the state of the sky, guided by his sailor's sixth sense (Leonardo *et al*., 2011).

The 3rd Congress of the Portuguese and Spanish Associations for the Advancement of Science was held in Coimbra in 1925. Brandão presented the memoir "*The modern methods of weather forecast in Portugal".* According to Brandão, meteorology had improved in the last decades, leading to the *"formation of new hypotheses and the discovery of new laws and new methods for predicting the weather […], characterized by an intense scientific activity, looking at last to mark the actual beginning of a Meteorological Science, and thus the reasonable expectation of a scientific forecast of weather, at least in the short term".*

Modern meteorology had developed from the discovery of the laws that established the relation between atmospheric pressure and winds. The use of wireless telegraphy could open new horizons to the application of these laws to weather forecast. But the depiction of isobar lines, in spite of their relation to the winds, could not by itself allow their prediction a few hours later due to the ignorance of the evolution of the barometric field. To solve this problem, two major methods had been advanced since the First World War: the French method, based on variation nuclei and cloud systems, and the Norwegian method, based on the polar front theory.

In spite of its less scientific character, the French method provided satisfactory results in weather prediction. By tracing lines of equal barometric variation in equal time intervals (3 h, 6 h, 12 h or 24 h), also called isallobar lines, it was possible to observe nuclei of maximum variation. The movement of these nuclei showed a perfect continuity, unlike the trajectory of the depressions, and this regularity could be used to draw new isobaric lines, for the next 12 h or 24 h, and to deduce the winds and the probable state of the weather. Besides the study of the maximum variation nuclei, the French method included the depiction of cloud systems in the synoptic charts. These large clusters of clouds formed according to certain principles and moved under certain rules. There were several kinds of cloud systems, each with special characteristics and some related to unstable weather and rain. Though its reliability, the cloud system process could not be implemented in Portugal or in other countries in the oriental margin of an ocean due to the extreme difficulty in determining the cloud systems coming from the west, even considering the observations aboard ships or other oceanic stations (Brandão, 1925).

The Norwegian method, the most scientifically advanced of the time, was based on surfaces of discontinuity between adjacent air masses with different temperatures: a warm mass of air coming from lower latitudes encountered a cold mass of air originated in the polar region. Due to the Earth's rotation, the movement of the warm mass had a component to the east while the cold air mass swayed to the west. The surface of boundary between both air masses was called the polar front.

This theory was proposed by the Bergen school, in Norway, founded and headed by the physicist Vilhelm Bjerknes (1862–1951), where a meteorology service operated and applied the new method to weather prediction (Friedman, 1989). The existence of these two adjacent air masses, within a fluid, with opposite directions of displacement tended to the formation of whirls by a process where a tongue of one of the masses was projected inside the other. This was the inception of a mid-latitude cyclonic event. The north extremity of the tongue of warm air was the centre of a barometric depression known as warm sector. In the northern hemisphere, the air moved around this depression, counter clockwise, and there was also an upward movement of the air mass within the warm sector that would give place to condensation and rainfall (Figure 2).

With the further movement to the east of the tongue of warm air, the warm sector would become bordered by two surfaces of discontinuity: a warm front ahead, moving slowly as the warm air mass is climbing over the colder air mass; and a cold front in the back, moving faster (Figure 3). Hence, the warm sector gradually decreases in width while the warm air rises in altitude, giving rise to an occlusion when this sector has vanished completely from the surface. The reported evolution of a cyclonic event was deeply related with the weather below in terms of temperature, pressure and rainfall (Brandão, 1925).

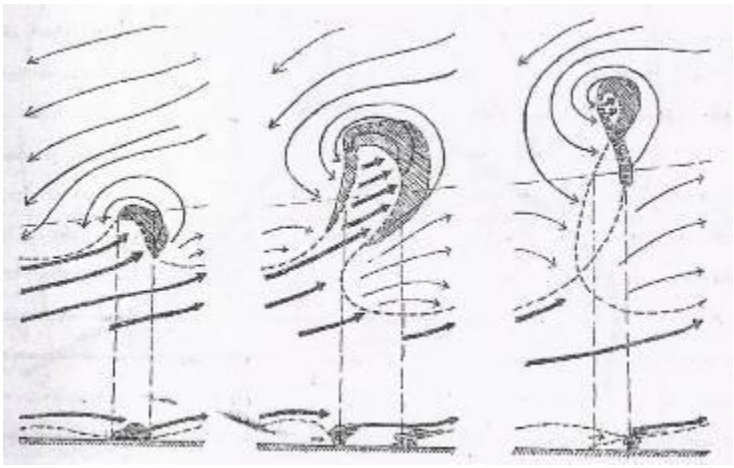

Fig. 2: Formation of a mid-latitude cyclone – front theory (Brandão, 1925).

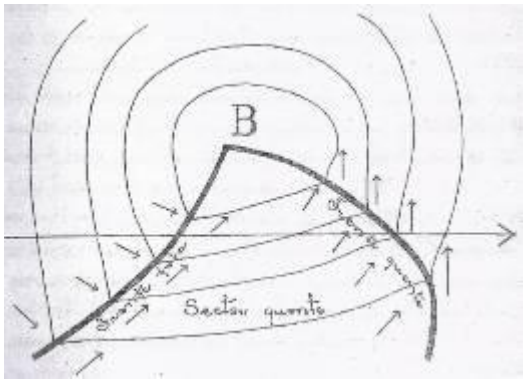

Fig. 3: Bjerknes' cyclone model (Brandão 1925).

Weather forecast by the Norwegian method relied in the regularity of the movement of the cyclonic event and its discontinuity surfaces. Therefore, the approximation of a front produced changes in pressure, temperature and wind direction. The passage of a warm front, where a retreating cold air mass was pursued by a warm current that was bound to rise (Figure 4), gave place to a temperature rise, the opposite occurring with a cold front, where a moving wedge of cold air caused the ascension of a mass of warm air (Figure 5). Both events generated the rising of hot air, which originated condensation and rain (*ibid*).

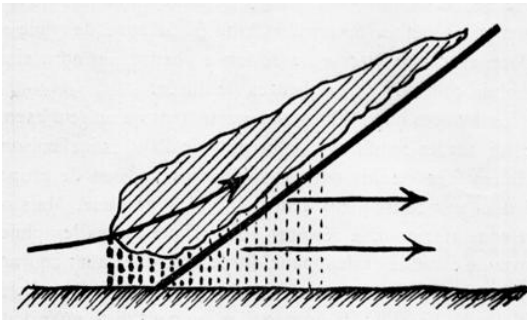

Fig. 4: Warm front (Bjerknes, 1928).

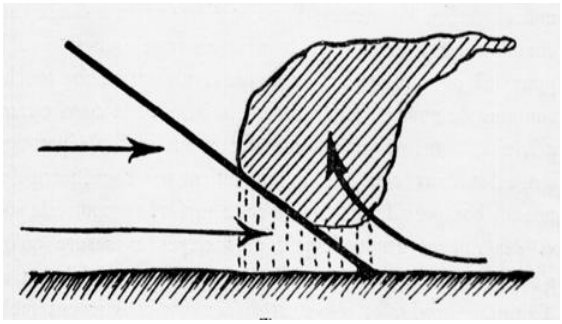

Fig. 5: Cold front (Bjerknes, 1928).

In Coimbra's congress Carvalho Brandão met António Gião (1906-69), then a young student of the University of Coimbra. In the same year, Gião departed to study at the Institute of Physics of the Globe, in Strasbourg, where he became a geophysical engineer. In 1927, Gião took an internship at Bergen School where he met Jacob Bjerknes (1897–1975), Vilhelm's son, who then headed the Norwegian National Weather Service (Gião, 1927).

Bjerknes and the International Meteorological Station of the Azores

The implementation of a worldwide weather forecasting service, based on the Norwegian method, depended on the existence of a large network of stations collecting meteorological information, especially over the North Atlantic. Also, the installation of radio transmitters aboard transatlantic liners allowing them to regularly relay meteorological data while crossing the ocean, would give additional coverage to the project. This was the issue in the meteorology international meeting which took place in Zurich in 1926. Carvalho Brandão, as chief of the Portuguese meteorological service, announced there the commitment of the Portuguese government to establish an international meteorological station at the Azores, which was prepared to receive and relay by radio meteorological data emitted by ships in the region. A committee, composed by Jacob Bjerknes and General Émile Delcambre (the director of the French meteorological services), was set up to follow this matter until its final resolution (Leonardo *et al.,* 2011).

Fig. 6: Jacob Aall Bonnevie Bjerknes (Bjerknes, 1928).

Jacob Bjerknes was a member of the group of meteorologists, led by his father, which developed the model of mid-latitude cyclones based in the front theory. In May 1927, he came to Portugal to study the local meteorology and to meet the Portuguese government to stress the urgency of the meteorological station of the Azores (Delcambre and Brandão were also present). This station would solve *"a problem that concerns the scientific bodies of Europe, in charge of the study and weather prediction"* due to the lack of observations in the Northern Atlantic.

Bjerknes was invited by Ferraz de Carvalho, on 23rd May 1927, to speak at the IC on *"Les bases scientifiques et techniques de la prévision du temps et le rôle du Portugal à ce rapport"*. He presented his polar front theory and the means to apply it to weather prediction. In his paper, published in *O Instituto*, he recalled the importance of weather forecasts for maritime countries. A system of stations relaying atmospheric data abroad by wireless telegraphy, scattered across the globe, was essential. In a map, Bjerknes showed the location of weather stations that, according to the international plan, would receive information from vessels with radio emitters that were regularly transmitting meteorological data within the areas covered by each station. These stations would relay the information, three or four times a day at established international hours, to the European Meteorological Services. The region covered by the Azores, Madeira and the Portuguese coast encompassed a large ocean surface. The others were the Bermudas and, further north, Newfoundland, Greenland and Iceland (Bjerknes, 1928).

Although a Meteorological Service had been established in Azores in 1901 (with four observatories) (Tavares, 2009), the International Meteorological Station of Azores, in Faial Island, only became operational in 1929. Delcambre, in the International Meteorological Congress of Copenhagen which took place in that same year, pointed out the highest service which was being provided to science by Portugal. He said it was one of the most important events contributing to the progress of meteorology in the century, adding that it was the beginning of a new era: indeed, the Azores station was the completion of a vast international network, a base to aero-transatlantic navigation. In Copenhagen the major collective emitters for the northern hemisphere were created. They should incorporate and link together emissions received from several international weather stations (Morna, 1935). The Azores' Station information was included in the collective emissions from Western Europe.

The Portuguese Meteorological Services before the Second World War

From its creation until 1946, the Meteorological Service of the Navy (MSN) was responsible for weather forecasting. In 1934, the MSN was receiving daily reports from meteorological observatories in Coimbra, Oporto, Azores and 30 other stations (26 in the continent, 2 in Madeira and Azores and 2 in Green Cape). Of these, 18 were international, i.e., their data were relayed abroad from Lisbon. More than 80% of the words used in the Navy radiotelegraphic services were taken by the meteorological services. The service produced daily meteorological maps of Europe and the Oriental Atlantic (Figure 7) along with weather forecasts (Morna, 1935).

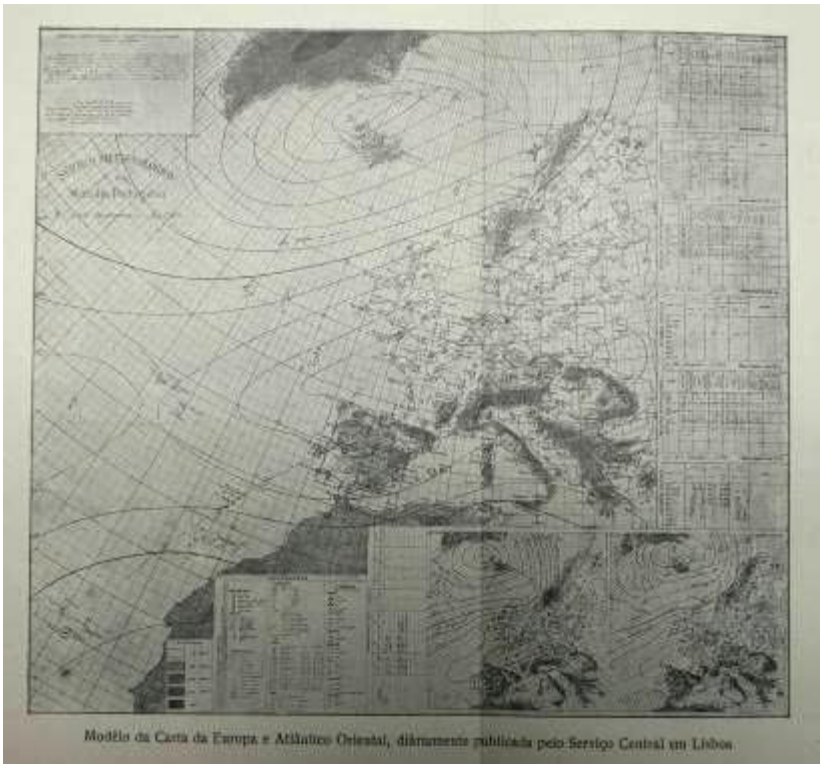

Fig. 7: Meteorological map of Europe and Eastern Atlantic (Morna, 1935).

The efficiency of the weather prediction service in the Atlantic was tested by the preparation of the flight across the Atlantic of the airplane ESA (*Espírito de Santo Agostinho*), from Lisbon to New York, in 1931 (Morna, 1934). The help of the MSN to decide the best route was requested by the flight crew, composed of Costa Veiga, Christhien Johnson and Willy Rody (Figure 8). This endeavour ended in a sea landing due to lack of fuel, the meteorological services being essential to rescue the pilots. According to the Spanish journal ABC, in 16 September 1931, *"the atmospheric conditions of the Atlantic are still being those predicted by the Meteorological Service of the Navy ministry. Everything seems to indicate that the aviators had displaced themselves from the route that those services delineated"*.

Despite the successes of the weather services, meteorological science was scarcely studied in Portugal. An exception was António Gião, one of the most renowned Portuguese meteorologists. Gião published *La Mechanique Différentielle des Fronts e du Champ isallobarique* (1930), a book containing forewords from Delcambre and Jacob Bjerknes. He had proposed to the National Board of Education in Portugal the creation of an Institute of Atmosphere Mechanics. The board counter offered him a scholarship, which he refused.

Brandão resumed the state of the art of meteorology science in an article entitled *Importance of General Movements in the study of the atmosphere*, published in 1931 in *A Terra,* a Portuguese journal on geophysics. He addressed the Norwegian method, stating that it *"did not lead in turn to a defined method of prediction, but merely to the acquisition of scientific knowledge on certain atmospheric phenomena in the dynamic point of view, hitherto almost unexplored […], the famous Norwegian method is but one method of analysis and diagnosis of meteorological situations […] [in] the regions where the discontinuities of meteorological elements occur"*. Regarding Gião's studies, *"however it should represent a major advance in meteorological science, still Gião's method cannot, naturally, give us a definitive solution to the problem of prediction"* (Brandão, 1931).


DIARIO ILUSTRADO DIA 7 DE OCTUBRE DE 1931. NUMERO SUELTO 10 CENTS.

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DIARIO ILUSTRADO. AÑO VIGESIMOSEPTIMO N.º 8.959

Fig. 8: The pilots of ESA after their rescue.

In 1933, the Society of Meteorology and Geophysics of Portugal (SMGP) was founded in Coimbra, being Anselmo de Carvalho its Honorary Chairman. Albeit its ambitious goals and the major figures involved, it did not receive the required government support to become permanent and was extinguished after a few years (Leonardo *et al.,* 2011).

By then, various meteorological services were scattered by several state and government departments, like the Civil Aviation Secretariat, the Observatory Prince Luís and the Meteorological Service of the Azores, under the ministry of Education; Meteorological Services of the Navy, supervised by the ministry of the Navy; the General Directorate of the Agricultural Services, under the ministry of Economy; and similar services in the ministries of the Army and of the Colonies.

* * *

Brandão, who always sought to implement scientific meteorology, established contacts with major European figures like Delcambre, Bjerknes and Shaw. His great ambition was the creation of a National Institute of Meteorology. According to Gião *"His project and initiatives collided with a wall of envy, with the rivalry of pulverized services in multiple ministries, and was with the bitterness of not being able to do anything that he passed away prematurely."* A major difficulty was the systematic lack of financial resources and qualified personnel. An example was the inability to meet Gião's challenge to create an institute devoted to the study of the atmosphere.

International pressure for advancing meteorology in Portugal has always been present, especially from the days when the gathered observations, particularly in the Atlantic islands, became essential to the development of the global effort of weather forecasting (Leonardo *et al*., 2011).

Only in 29th August 1946, after the war's end, the creation of the National Meteorological Service was established, integrating all the meteorological services that were dispersed among different institutions and observatories.

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