DAILY METEOROLOGICAL OBSERVATIONS IN CÁDIZ – SAN FERNANDO. ANALYSIS OF THE DOCUMENTARY SOURCES AND THE INSTRUMENTAL DATA CONTENT (1786–1996)

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Abstract. Meteorological observations in the city of Cádiz are acknowledged as having been made from the middle of the 18th century onwards although they were only recorded and preserved in documentary form from 1789 onwards. Data readings were taken at the new Naval Observatory in San Fernando, ten kilometres from Cádiz, from 1797 onwards. Continuous series for temperature and atmospheric pressure at a daily resolution have been compiled and constructed from 1817 until 1996. The data series is composed of thrice daily observations made at Cádiz (1821–1880) by local observers and hourly data from Naval Observatory at San Fernando (1870–1996).

1. Introduction

Climatic research faces numerous challenges in the search for improvements in our knowledge about climatic variability on different scales, especially climatic variability brought about by the intervention of man in climatic systems through the effect of greenhouse gas emissions. The more we need to know about the future behaviour of climate, the greater is the need for finding and analyzing old climatic information. In this respect, the recent impetus given in fields such as historical climatology is clearly justified, although research leading to the homogenization of old instrumental series is also highly necessary.

During the 17th and 18th centuries, instrumental meteorological measurements were made by scientists, especially astronomers and physicians, who used very similar observation methods. The methods that were established during this time laid the basis for the standardisation of meteorological observation during the 19th and 20th centuries. Given the importance of their endeavours, documentary material can be used as a means of studying the history of science. The object of this paper, however, is to give details of the characteristics of an old instrumental series for the south-western sector of the Iberian Peninsula and its connection with an official, modern series for use in climatic research. This involves the identification, compilation and processing of meteorological observations in Cádiz and San Fernando from the middle of the 18th century up until the present day. Various climatologists have already shown interest in the series (Wheeler, 1992a, 1992b,

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1992c, 1995; Jones et al., 1997) as a result of its optimum geographical location in the extreme south-western corner of Europe which is favourable for the study of the variability in time of certain low frequency patterns of atmospheric circulation, such as the North Atlantic Oscillation. The possibility of generating high resolution data series more than two centuries long represents an important aid in the research of climatic variability with different time-space resolutions.

2. Historical Context

2.1. CÁDIZ: AN ENLIGHTENED, COSMOPOLITAN CITY

The origins of Cádiz go back to over 1,000 years BC and the city (Gadir o Gades) flourished under the Phoenicians and Romans. The city is set on an island connected to the mainland by a long isthmus that forms a wide, protected inlet. Its ease of defence and appropriateness as a harbour for both Atlantic and Mediterranean maritime traffic made it one of the most bustling urban and military centres under the Spanish Crown.

Another extraordinary stimulus for the city was commerce with America. Due to the technical difficulties that large ships had in getting to Seville along the River Guadalquivir, Cádiz became the port that held the shipping monopoly between Spain and her possessions in America from 1717 onwards (Anes, 1985). These advantageous conditions lasted until commerce with America was liberalized by the Pragmatic Law on October 12th, 1778 (Vicens Vives, 1985).

The city of Cádiz thus underwent an intense period of economic and social development that provided the economic, material and human resources that were necessary for a wide number of cultural and scientific endeavours. Culturally speaking, the number and the quality of newspapers in regular circulation exceeded those in any other city in Spain at the time. Events at the university were also very active; the Medical Faculty was created in 1748 with the clear vocation of studying illnesses related to long transoceanic voyages. As the city was densely populated, epidemic bouts were also of concern and certain physicians undertook programmes of meteorological observation in connection with these (Arejula, 1806).

Scientific activities carried out by the institutions and personnel of the Spanish Navy are especially interesting: the setting up of the Marine Guards Academy, which is where astronomical and meteorological observations with educational and research applications began, was the first step in the construction of the Naval Observatory. Periods spent in foreign research centres and the organization of scientific explorations to South America and Antarctica were among other interesting endeavours.

2.2. THE NAVAL OBSERVATORY

The Spanish Navy underwent positive developments in many aspects during the 18th century. Within the cultural context of the Enlightenment and under the pressure of the requirements of the Crown and its overseas dominions, the Bourbon dynasty built up the Spanish Navy both quantitatively and qualitatively. As a result of this, a group of important scientists came to be formed that was dedicated to research and teaching.

One of the first steps was the creation of the Marine Guards Academy on April 15th, 1717 (Vigón, 1985) which was set up to prepare naval personnel with the best technical and scientific training for commanding naval vessels. Midway through the century, a brilliant generation of young naval officers from the Academy had to tackle a very interesting series of scientific endeavours.

In September 1748, the French astronomer Luis Godin, who had collaborated with Jorge Juan and Antonio de Ulloa in the measurement of the arc of the meridian, was named director of the Academy. Under his auspices, astronomical and meteorological observations were given a positive stimulus within the Academy.

In 1753 Jorge Juan founded the Marine Guards Company Observatory, which was a joint service or section of the Marine Guards Academy. The Academy's facilities at the Castle in the city of Cádiz were used (Lafuente et al., 1988). The death in 1773 of Jorge Juan, who was a brilliant officer, led to the decline of the Observatory. Although personnel were attached to the Observatory, systematic observations were no longer made and neither were the instruments maintained nor documents with any observational data produced (Vigón, 1985).

There were also serious problems when the Academy of Marine Guards was moved to San Fernando in 1769 because lecturers had to travel to Cádiz to make the astronomical and meteorological observations. For this reason, no systematic observations were made during the 1770s and 1780s.

Systematic scientific activities began again after 1789 thanks to the efforts of José de Mazarredo. The facilities, equipment and personnel were reorganized and the decision made to carry out systematic astronomical and meteorological observations. The most important aspect, however, was that the observations were recorded in documentary form from this point on.

The increasing complexity of the scientific activities carried out within the scope of the Academy meant that the question of the Observatory's location arose again. It was thus decided to construct a special building for astronomical and meteorological observations on Torrealta Hill in San Fernando. The first stone was laid on October 3rd, 1793 and the building was completed in June 1797. Later improvements and extensions enabled the centre to maintain its original function as a centre of activities and research in astronomy, meteorology, seismology, magnetism, chronometry, geophysics, etc.

On July 23rd, 1797 José de Mazarredo received the permits and instructions to begin moving all of the instruments from the Cádiz Observatory to the new

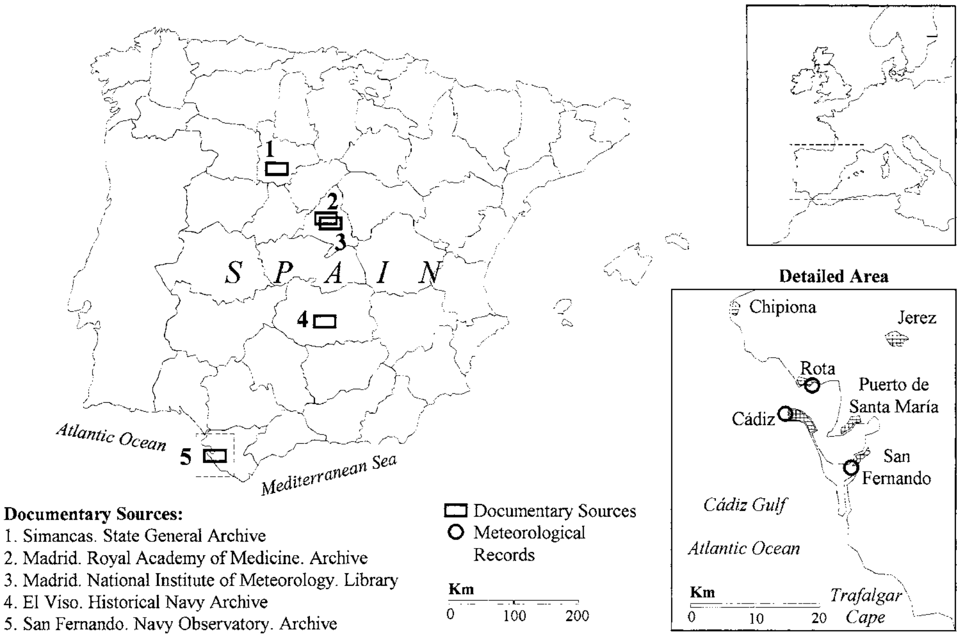

Figure 1. Location of the different series of observations used in this study.

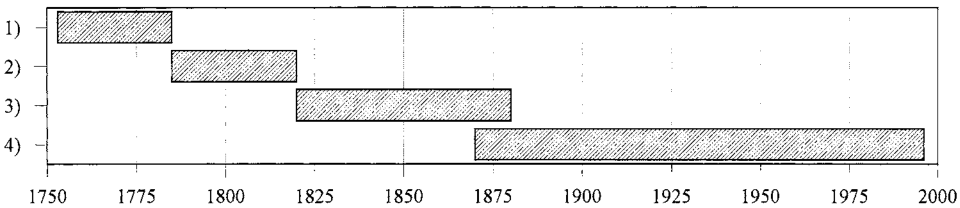

Figure 2. Distribution in time of the identified blocks of meteorological observation: 1) pre-documentary period; 2) discontinuous documentary period; 3) Urrutia brothers; 4) San Fernando Observatory.

location. The technical details of the move were taken care of by the director of the Academy, Vimercati, together with the Marquis of Ureña who had been closely involved with the design and construction of the Observatory.

3. The People and Institutions Involved in Meteorological Observation

The instrumental meteorological observations prior to the existence of an official meteorological service are relatively abundant for the Cádiz area. In general terms, four periods can be defined in keeping with the availability and quality of the meteorological records from each (see Figure 2).

3.1. PRE-DOCUMENTARY PERIOD (1753–1785)

Astronomical and meteorological observations by the Spanish Navy began relatively early on. Following the setting up of the Astronomical Observatory in the Marine Guards Academy in Cádiz, systematic instrumental observations of great potential interest for present-day climatic research would have been possible had it not been for the irregular form in which the activities were handled, which impeded the making of systematic observations and their conservation with any form of documentary support (Wheeler, 1995).

There is reference in documentary sources to the existence of meteorological instruments but their use was linked to teaching activities at the Academy and not to observational practices. There were no meteorological instruments at the Observatory in 1759 according to an inventory. At the Academy, however, there were three thermometers and a barometer stored in boxes, together with two English barometers with thermometers (AGS, Marina, leg. 98, document 40, 1759, 'Inventario de los instrumentos y demas aderentes que al presente existen en la Real Academia de Guardia-Marinas y Observatorio del Castillo').

The same situation of instrument availability continued during the following 20 years although no observations at all were made. Before dying, the founder of the Observatory himself deplored the lack of interest in making meteorological observations and in the taking care of instruments which had been brought from England and were very expensive (Lafuente et al., 1988). The material was kept in closed boxes and it probably received but limited use for teaching purposes and in the students' practicals at the Academy.

Activities of a cultural or scientific nature in the city of Cádiz may have encouraged endeavours to make meteorological observations. The Enlightenment fomented such activities. Research done on documentary and bibliographical sources, however, has pointed out the lack of documentary sources or any type of publication during this period that would have enabled the conservation of data with any meteorological observations.

3.2. THE DISCONTINUOUS DOCUMENTARY PERIOD (1786–1820)

The activities at the Navy Observatory only regained their original character from 1789 onwards when the naval authorities decided to make necessary replacements to the instruments and to start the documentary recording of observations (AGMAB, Marine Guards, Cádiz, leg. 630, 13 January 1789). The Navy's meteorological observations however suffered from various interruptions. Firstly, there was the change of location of the facilities to San Fernando, as has been described previously. Secondly, the Napoleonic Wars also seriously affected observations because all of the personnel at the Observatory were at one time or another mobilized during the war in the defence of the city of Cádiz. There was also the problem that meteorological observations were neither top priority nor a foremost activity. As a secondary activity associated with astronomical work the weather observations were discontinued.

In civilian circles, anonymous observers began to send their data to local newspapers to ensure that people were informed of them. Hardly anything is known of the conditions in which these recording were made and they present the same problem as the Naval Observatory's recordings in that both recordings and press collections conserved from this period are fragmentary. The number of newspapers increased during the 19th century and their coverage in terms of time is practically complete. Daily meteorological data appear in almost all of them, and they are clearly the work of different observers. This is good proof of the scientific activity that private individuals were carrying out in the city of Cádiz and in practical terms it provides complementary meteorological data which are always useful when working with old, instrumental observations. Mention is made of the more important newspapers for their importance in the process of making this information known and preserving the meteorological records: *Diario Mercantil*, *El Globo*, *El Comercio*, *El Nacional*, *Nuevo Defensor del Pueblo*, *Redactor General*, *El Tiempo*.

3.3. SYSTEMATIC, PRIVATE ENDEAVOURS – THE URRUTIA BROTHERS (1821–1880)

Amongst all the different private individual observers that have come to light in the city of Cádiz, the endeavours of the Urrutia brothers undoubtedly stand out. They made daily meteorological observations using French instruments (the temperature was read in Reamur degrees and atmospheric pressure readings were in Paris inches) and used methods that were almost identical to those established by L. Cotte for the *Royal Société de Médicine de Paris* (Fierro, 1991). Their methods are very similar to those of other observers of the period, such as F. Salvá and P. Vieta in Barcelona from 1780 until 1853 (Barriendos et al., 1997).

The most outstanding fact of the observations made by the Urrutia brothers is their persistence, both in terms of duration and the methodology that was applied. They generated 60 years worth of thrice daily observations between 1821 and 1880 with no apparent anomaly. As far as the conditions of observation are concerned, unfortunately neither the details of where their observatory was nor what instruments they used are known. No problems in the series were detected either as a result of changes in the instruments, place or methods of observation.

In contrast to this absence of metadata information, the Urrutia brothers made their observations known through the local press (*El Globo*, *El Comercio*) as well as generating documents of their daily data. Luck has it that these manuscript documents were deposited in the Library of the Spanish Meteorological Office in Madrid (previously the Spanish Meteorological Service). Present-day use of these data for climatic purposes has thus been possible.

Over 50 notebooks contain observations from October 1820 to 1880. Several copies of these notebooks also exist in the city of Cádiz (AHGMC, 'Observaciones meteorológicas hechas en Cádiz por Tomás, Jesús y Luís de Urrutia . . . ', 5 vols., 1860, 1862, 1863, 1864, 1866). The Spanish Meteorological Office Library holds a complete collection of notebooks, however, which was probably donated by a member of the family. Only the notebooks for 1851 and 1852 are missing from the collection.

Although nothing was known of the working conditions of this self-sacrificing Cádiz family, even the Spanish Meteorological Office itself used the Urrutia brothers' rainfall data in publications on climate:

> The brothers Tomás, Jesús and Ignacio de Urrutia carried out careful and patient observations, including those which are included for rainfall, on their own account and in their own Observatory, the location of which is totally unknown (despite efforts to find out where it is). The original notebooks in which they appear are conserved in the Madrid Library of the Spanish Meteorological Office, apart from those for 1851 and 1852 which are missing in their entirety. (Servicio Meteorológico Nacional, 1943.)

3.4. SYSTEMATIC, OFFICIAL ENDEAVOURS – THE SAN FERNANDO OBSERVATORY (1870–1996)

The Naval Observatory at San Fernando was almost one hundred years old when meteorological observation was given higher priority at the institution amongst its various responsibilities. No specific indication was given by official scientific or military authorities to start making systematic observations. The State had a modest network at the time of around 20 observatories, whose results were centralized at the Astronomical and Meteorological Observatory in Madrid, the result of the Royal Decree of 15 July 1865 (García & Giménez, 1985).

The determination of the director, Cecilio Pujazón, helped to turn the San Fernando Observatory into one of the best centres for meteorological observation in Spain. The institution had the optimum potential for acquiring instruments, assimilating techniques and methods that had been tried and tested and especially maintaining and repairing meteorological instrumental whenever this was necessary (González, 1992).

Observations like the ones being carried out at the present time began on January 1st, 1870, although the San Fernando Observatory began its activities as a meteorological centre according to an official order dated September 28th, 1876.

Any alterations to the activities have been minimal. Initially, 16 daily observations were made (0000, 0200, 0300, 0400, 0600, 0800, 0900, 1000, 1200, 1400, 1500, 1600, 1800, 2000, 2100 and 2200). Just a few years after observations began, the order was given to make them every hour, which meant 24 daily data covering the following parameters:

(a) atmospheric pressure;
(b) temperature;

(c) vapour pressure;
(d) relative humidity;
(e) wind direction and speed;
(f) state of the sky, types of cloud and atmospheric phenomena.

Monthly summaries are also given with the daily data for:

(a) average daily pressure;
(b) average, maximum and minimum daily temperatures;
(c) temperature at a depth of 1.30 metres;
(d) prevailing wind, average speed, maximum gust speed, direction;
(e) average cloud cover (eighths);
(f) duration during the day;
(g) sunshine;
(h) total daily rainfall;
(i) average daily relative humidity;
(j) total daily evaporation;
(k) vapour pressure.

The only period when observations were not made was a few months between 1989 and 1990, when the changeover occurred between the manual and automatic stations. This interruption happened at the same time as another at the nearest official observatory in the city of Cádiz. The availability of data from the observatory at the Rota naval base, 6 km away Cádiz (see Figure 1) compensates for this without any problems.

Series like this with an hourly resolution for over 120 years are not very abundant in Europe. As the Observatory is an important reference centre for different scientific activities in Spain (chronometry, astronomy, seismology, magnetism and geodesy), its publishing facilities have also been used in the transcription and publication of all the data. The yearbooks that were published every year from 1870 to the present without interruption (*Anales del Instituto y Observatorio de Marina. Observaciones Meteorológicas, Magnéticas y Sísmicas*, Royal Naval Observatory, Section 3, San Fernando) are to be found in many different libraries.

4. Characteristics of the Climatic Series

4.1. DATA COLLECTION

Once the documentary and bibliographical sources with daily instrumental observations had been identified, the data were compiled and computerized. This activity was different for each of the periods with available observations (Figure 2). In the case of the first period of discontinuous observations (1786–1820), the area under study offered an abundance of both private, individual and official meteorological

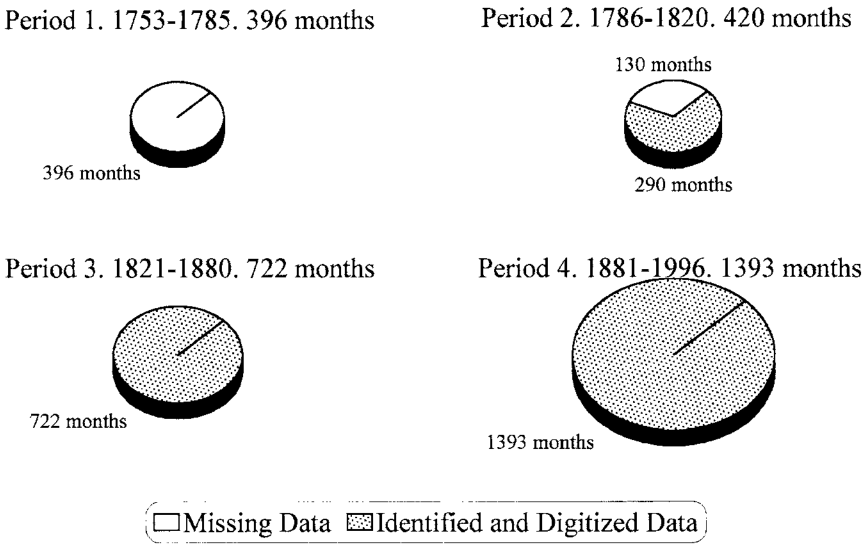

Figure 3. Periods of time covered by the observations. Monthly resolution.

observers. The limited degree of co-ordination, however, and the irregular conservation either in document form or for local newspapers, makes it difficult to construct a definitive data series on a daily resolution. Certain endeavours that are scientifically interesting were sometimes of limited duration (Marquis of Ureña, autumn of 1803, 'Anales de Ciencias Naturales', 32 pp. Printed tables conserved in the Archive of the Real Academia de Medicina in Madrid).

This irregularity means that there is an overlap of different observers at certain times, while at others there was a total interruption in the observations or absence of documents. Situations when data are absent occur relatively frequently. During the 1786–1820 period, the following interruptions occurred:

- partial lack of data: 1788, 1795, 1799, 1801, 1802, 1812 and 1816;
- total lack of data: 1796, 1797, 1798, 1810, 1811, 1814 and 1815.

The 1786–1820 period has only 69% of the data that should exist (290 months out of a total of 420). Two periods are lacking data to an important degree. Between 1795 and 1799, the problem may be attributed to the construction of the new observatory at San Fernando, with observations necessarily being interrupted, instruments and personnel transferred, relocation, etc. The lack of data during the 1810–1816 period is justified by the disturbances caused by the Napoleonic Wars.

Fortunately, the period of observations covered by the Urrutia brothers (1821–1880) and the San Fernando Observatory (1870–1996) is optimal in terms of time coverage. The Urrutia brothers' period is only interrupted in 1851 and 1852, and this gap is covered by the local press. The Naval Observatory period is only briefly interrupted in 1989, which is covered by data from the Rota observatory.

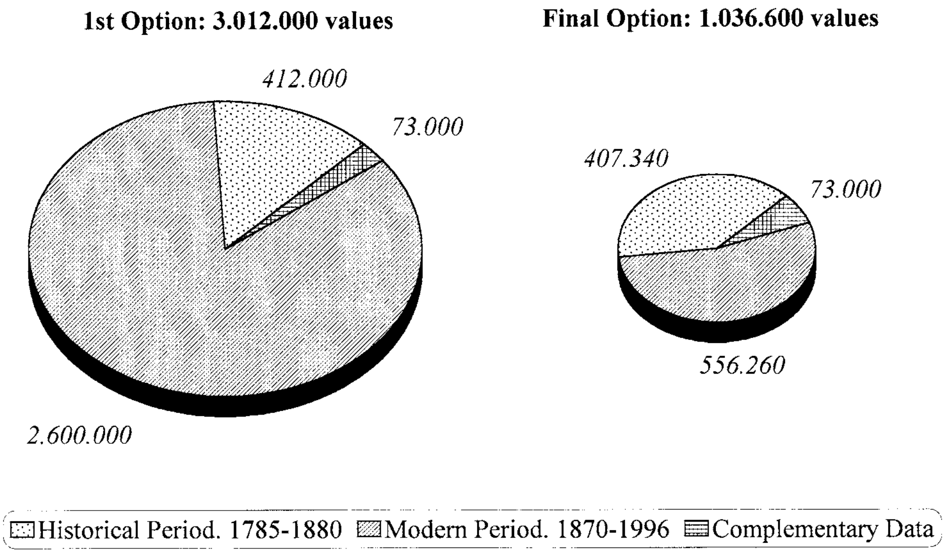

Figure 4. Amount of data to be computerized; first option: computerization with an hourly resolution; last choice: computerize the maximum, minimum and average values.

The computerised parameters were those available for the whole series of data. This means limiting them to those that exist from the initial observations at the end of the 18th century. Up to six observed daily parameters are thus available:

- air temperature;
- atmospheric pressure;
- wind direction;
- state of the sky (and existence/absence of rainfall);
- rainfall (daily from 1848);
- notable atmospheric phenomena (fog, snow, hail, etc.).

When the data series was being generated, the possibility was raised of computerizing all of the collection of data with an hourly resolution at the San Fernando Observatory (over 125 years' worth). This would have meant computerizing over 2,500,000 values (Figure 4) just for this period alone, which would have left the historical period, with only a maximum of three daily observations, out of balance.

Although observations were made every hour in the modern period (1870–1996), only the data for maximum, minimum and average daily temperatures, together with average daily atmospheric pressure, have been computerised. There is therefore a total of 4 values per day.

In addition, the monthly average hourly values corresponding to each of the 24 daily observations were also computerized (73,000 records). This enabled the diurnal temperature and barometric patterns to be constructed and any fixed-hour observations in the first, older period to be used to obtain average, minimum and maximum values for each day.

The final result of the data research and compilation can be quantified in general terms as follows (Figure 4):

Historical period	407,340 values
Modern period	556,260 values
Complementary data	73,000 values
Total	1.036,600 values

4.2. UNIT CONVERSION

The adaptation of the compiled data to modern unit systems does not pose any great problems, but the criteria for the process of conversion need to be explained and justified. With respect to temperature, the observations in Cádiz and San Fernando were made both in Reaumur and Fahrenheit degrees. Thermometers with the Centigrade scale were only used at the San Fernando Observatory from 1870 onwards. This means that conventional conversion formulae need to be applied to the old data and to the Urrutia brothers' data.

Obtaining conventional modern units for atmospheric pressure has been somewhat more difficult. During the period covered by the San Fernando Observatory data were taken in mercury millimetres (mmHg). This measurement was converted to DecaPascales (DPa), according to the International Unit System (1 mmHg = 13.33 DPa).

The historical period presents a glaring variety in the use of different units of measurement, as is the case with temperature. This is undoubtedly related to the different manufactures of the barometers used up until the end of the 19th century before the introduction of the Decimal Metric System. Three different systems have been encountered during the historical period for measuring the length of the mercury column in the barometers, with values being expressed in either French inches (Paris foot), English inches and Castilian inches (Burgos foot). The different processes of conversion to millimetres were taken from the meteorology manual published a few years after the Decimal Metric System was introduced in Spain. The conversion values have four decimal points:

French inch	27.0696 mm	French line	2.2558 mm
English inch	25.3995 mm	English line	2.1166 mm
Castilian inch	23.2195 mm	Castilian line	1.9349 mm

(Basora, 1865)

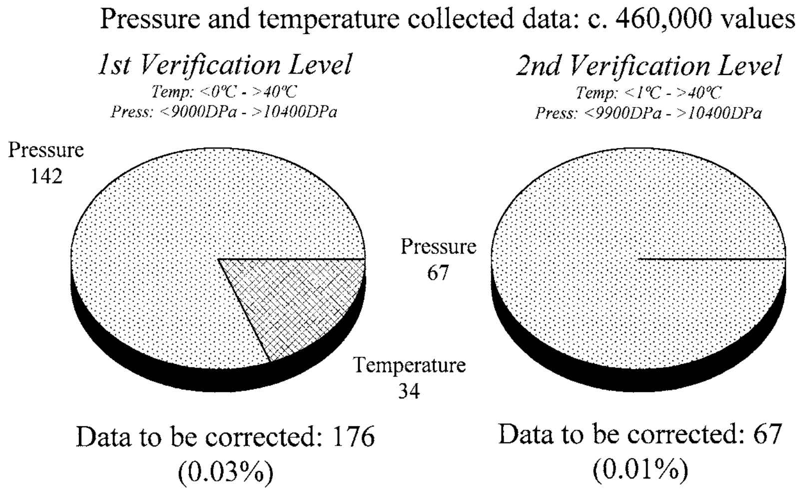

Figure 5. Number of erroneous data detected and corrected after two stages of error checking, with extreme threshold levels established for this for the series on pressure and temperature.

4.3. DATA VERIFICATION

The computerization of such large quantities of data inescapably carries with it the possibility of involuntary errors, either those entered directly from the manuscripts and in the publishing process or when the data are entered into computer spreadsheets. Throughout the whole process of research, the information on temperature and pressure that has been entered from different sources in computerized form has undergone the necessary checks to identify and correct different types of error. For this purpose, the extreme threshold levels for temperature and pressure given in Figure 5 were established over two successive stages. The computerised values above and below the upper and lower threshold levels respectively were checked with the original ones, except for the pressure values below 9000 Dpa, which were obviously erroneous.

A total of 176 errors (142 for atmospheric pressure and 34 for temperature) were detected at the first check level. This represents 0,03% of data computerized. A second check level, which was even stricter than the first, detected 67 errors, all of them for atmospheric pressure. The level of error for the whole data total was reduced to 0,01%. At this point, it was decided to stop the process of data correction for it was obvious that real, correct data would otherwise begin to be altered.

5. Structure of the Definitive Climatic Series

The daily meteorological observations that have been selected to construct the definitive series for Cádiz/San Fernando make up a very varied list of observers

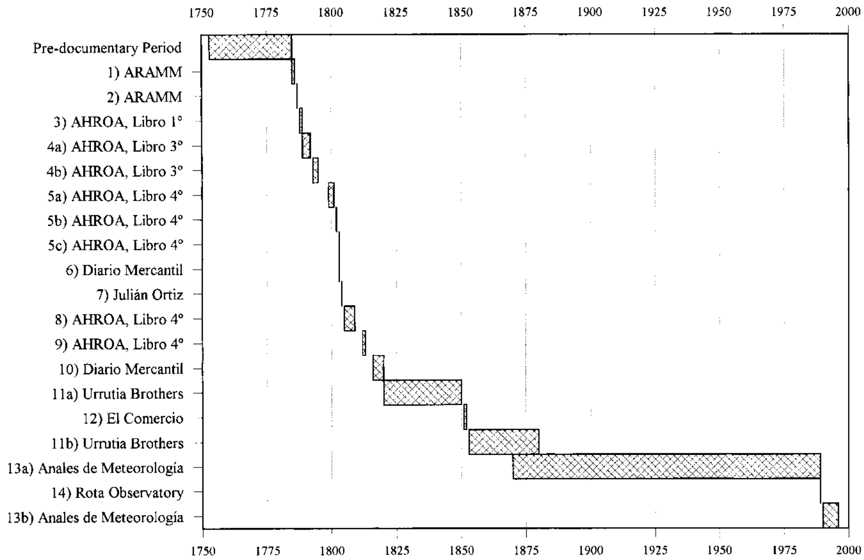

Figure 6. Time span of the meteorological series for Cádiz/San Fernando.

and institutions. Unfortunately, it has not been possible to establish a definitive, continuous series from the partial series of observations. As has been mentioned beforehand, there is total or partial lack of data for what is an important number of years during the period from 1786–1820. Neither are there any long periods of overlap between series, which would have enabled any differences between them to be adjusted without any serious problem. The final result appears in Figure 6 and in the following list.

(1) Period	**31/12/1785 – 30/11/1786**
No. of months	11
Time	1200
Location (altitude)	Cádiz
Thermometer (units)	Unknown (°R, 1/10 dg.)
Barometer (units)	Unknown (French inches, inch/line/fraction of line)
Institution	Jerónimo Sánchez Buitrago (private observer)
Documentary Source	ARAMM, Manuscripts, 12-8-Molina-31
(2) Period	**1/1/1787 – 31/8/1787**
No. of months	8
Time	0700, 1200, and 1900
Location (altitude)	Cádiz
Thermometer (units)	Unknown (°R, 1/10 dg.)
Barometer (units)	Unknown (French inches, inch/line/fraction of line)
Institution	Jerónimo Sánchez Buitrago (private observer).
Documentary Source	ARAMM, Manuscripts, 12-8-Molina-31

(3) period	**12/10/1788 – 5/1/1789**
No. of months	3
Observations (time)	1 (1200)
Location (altitude)	Cádiz. Tower of the Castillo de la Villa 36.32N – 6.18W (41,23 m. a.s.l.)
Thermometer (units)	Unknown (°F, 1/10 dg.)
Barometer (units)	Unknown (English inches, 1/100 inch)
Institution	Naval Observatory
Documentary Source	AHROA, 'Quaderno para anotar las observaciones hechas en el Real Observatorio de Cádiz', Book 1°, 1 vol.
(4a) Period	**12/1/1789 – 15/3/1792**
No. of months	39
Observations (time)	3 (0800-1000, 1200, 2000-2200)
Location (altitude)	Cádiz. Tower of the Castillo de la Villa 36.32N – 6.18W (41,23 m. a.s.l.)
Thermometer (units)	Unknown (°F, 1/10 dg.)
Barometer (units)	Unknown (English inches, 1/100 inch)
Institution	Naval Observatory
Documentary Source	AHROA, 'Examen y Resultado de las Observaciones semanarias, según el art. 18 de la Instrucción Provisional. Libro 3°', 1 vol.
(4b) Period	**1/3/1793 – 18/6/1795**
No. of months	28
Observations (time)	3 (0800, 1200, 1800)
Location (altitude)	Cádiz. Tower of the Castillo de la Villa 36.32N – 6.18W (41,23 m. a.s.l.)
Thermometer (units)	Unknown (°F, 1/10 dg.)
Barometer (units)	Unknown (English inches, 1/100 inch)
Institution	Naval Observatory
Documentary Source	AHROA, 'Examen y Resultado de las Observaciones semanarias, según el art. 18 de la Instrucción Provisional. Libro 3°', 1 vol.
(5a) Period	**1/1/1799 – 31/8/1799, 1/1/1800 – 6/9/1801, 1/12/1801 – 11/12/1801**
No. of months	41
Observations (time)	3 (0600, 1200, 1800)
Location (altitude)	San Fernando
Thermometer (units)	George Adams (°F, 1/10 dg.)
Barometer (units)	George Adams (English inches, 1/100 inch)
Institution	Naval Observatory
Documentary Source	AHROA, 'Quarta Clase. Física Celeste. Meteorología. Libro 4°'.

(5b) Period	**30/10/1802 – 31/12/1802**
No. of months	2
Observations (time)	3 (0800, 1400, 2200)
Location (altitude)	San Fernando
Thermometer (units)	Unknown (°F, 1/10 dg.)
Barometer (units)	Unknown (French inches, inch/line/fraction of line)
Institution	Naval Observatory
Documentary Source	AHROA, 'Quarta Clase. Física Celeste. Meteorología. Libro 4°'.
(5c) Period	**1/1/1803 – 17/10/1803**
No. of months	10
Observations (time)	3 (0800, 1200, 2100)
Location (altitude)	San Fernando
Thermometer (units)	Unknown (°R, 1/10 dg.). In room.
Barometer (units)	Unknown (English inches, inch/line/tenth of line)
Institution	Naval Observatory
Documentary Source	AHROA, 'Quarta Clase. Física Celeste. Meteorología. Libro 4°'.
(6) Period	**30/10/1803 - 29/12/1803**
No. of months	3
Observations (time)	3 (0800, 1400, 2200)
Location (altitude)	Cádiz
Thermometer (units)	Unknown (°F, 1/10 dg.)
Barometer (units)	Unknown (French inches, inch/line/fraction of line)
Institution	Juan Manuel de Arejula. Private observer
Documentary Source	Arejula (1806)
(7) Period	**1/1/1804 – 31/12/1804**
No. of months	12
Observations (time)	2 (0800, 1400)
Location (altitude)	Cádiz, in front of Naval Academy (18,11m. a.s.l.)
Thermometer (units)	Unknown (°F, 1/10 dg.)
Barometer (units)	Unknown (English inches, 1/100 inch)
Institution	Julián Ortiz Canelas (Naval officer observer)
Documentary Source	Ortiz (1805)
(8) Period	**1/1/1805 – 31/12/1809**
No. of months	60
Observations (time)	2 (0800, 1400). 1809 only 1400
Location (altitude)	San Fernando (39,75 m. a.s.l.)
Thermometer (units)	Dollond (°F, 1/10 dg.)
Barometer (units)	Megniè (French inches, inch/line/tenths of line)
Institution	Naval Observatory
Documentary Source	AHROA, 'Quarta Clase. Física Celeste. Meteorología. Libro 4°'.

(9) Period	**1/5/1812 – 31/12/1813**
No. of months	20
Observations (time)	1 (1200)
Location (altitude)	San Fernando (27,86 m. a.s.l.)
Thermometer (units)	George Adams (°F, 1/10 dg.). In room.
Barometer (units)	George Adams (English inches, 1/100 inch)
Institution	Naval Observatory
Documentary Source	AHROA, 'Quarta Clase. Física Celeste. Meteorología. Libro 4°'.
(10) Period	**30/8/1816 – 31/12/1820**
No. of months	53
Observations (time)	3 (0900, 1200, 1800). 1819 0600 by 0900
Location (altitude)	Cádiz
Thermometer (units)	Unknown (°F, 1/10 dg.)
Barometer (units)	Unknown (English inches, inch/line/hundredths of line)
Institution	Private observer unknown
Documentary Source	*Diario Mercantil*, local newspaper
(11a,b) Period	**1/10/1820 – 31/12/1850, 1/1/1853 – 19/11/1880**
No. of months	698
Observations (time)	3 (dawn, noon, after dark)
Location (altitude)	Cádiz. 36.32N – 6.18W
Thermometer (units)	Unknown (°R, 1/10 dg.)
Barometer (units)	Unknown (French inches, inch/line/fraction of line)
Institution	Urrutia Brothers. Private observers
Documentary Source	BINM, 'Observaciones de los Hermanos Urrutia', 60 vols.
(12) Period	**1/1/1851 – 31/12/1852**
No. of months	24
Observations (time)	3 (dawn, noon, after dark)
Location (altitude)	Cádiz
Thermometer (units)	Unknown (°R, 1/10 dg.)
Barometer (units)	Unknown (English inches, 1/100 of inch)
Institution	Unknown private observer
Documentary Source	*El Comercio*, local newspaper
(13a,b) Period	**1/1/1870 – 31/5/1989, 1/1/1990 – 31/12/1996**
No. of months	1507
Observations (time)	24 (1 per hour)
Location (altitude)	San Fernando. 36.28N – 6.12W (28,48 m. a.s.l.)
Thermometer (units)	Casella (°C, 1/10 dg.)
Barometer (units)	Newmann. Fortin System (mmHg.), 29.17m. a.s.l.
Institution	Naval Observatory
Documentary Source	'Anales de Meteorología'. Yearly publication. 127 volumes.
Note	1/1989 and 7/1990 from the Rota Naval Meteorological Observatory.

(14) Period	**1/6/1989 – 31/12/1989**
No. of months	7
Observations (time)	3 (0700, 1300, 1800)
Location (altitude)	Rota. 36.38N – 6.19W (21 m. a.s.l.)
Thermometer (units)	Unknown (°C, 1/10 dg.)
Barometer (units)	Unknown (DPa). 23 m. a.s.l.
Institution	Spanish Meteorological Office (INM)
Documentary Source	Direct data sent from the West Andalusia INM Regional Centre.

6. Conclusion

Meteorological observations in the Cádiz-San Fernando area in the far south-western corner of Europe go back to the middle of the 18th century when they were carried out by enlightened private endeavours and the Spanish Navy. Documentary records appear in 1789. From 1820 onwards, series of various meteorological parameters, mainly temperature and atmospheric pressure, with a daily resolution can be constructed from the records made by the Urrutia brothers. The existence of 24 daily observations made at the San Fernando Naval Observatory going back over a century long will enable the construction of diurnal rhythms that can prove useful for obtaining maximum and minimum values in preceding periods. The constructed pressure series will increase our knowledge of the North Atlantic Oscillation pattern and, along with temperature, enable advances to be made in the analysis of climatic variability at different time scales.

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