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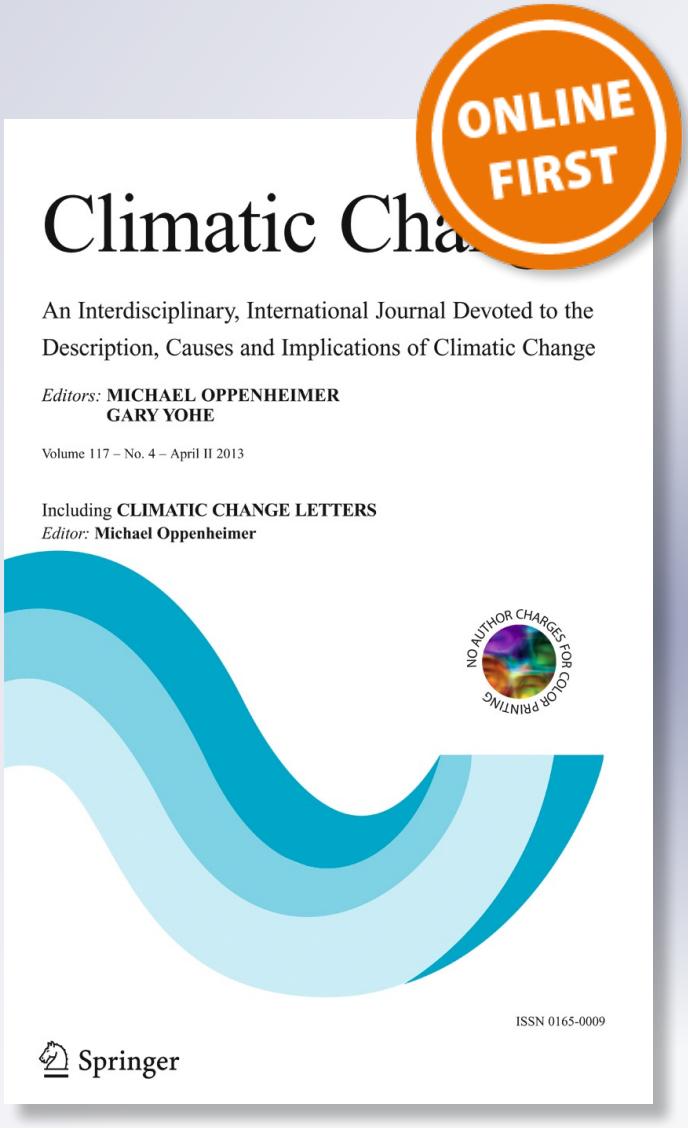

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The world's earliest instrumental temperature records, from 1632 to 1648, claimed by G. Libri, are reality or myth?

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Abstract In 1830, Libri announced the finding of a 16-year-long record of daily temperature observed in Florence, Italy, by Father Renieri before the activity of the *Medici Network* (1654 to 1670) that is usually considered the earliest instrumental series in the world. The Libri announcement was supported by the concurrent finding of a box with the early Little Florentine Thermometers that survived the Inquisition and was confirmed by Schouw, von Humboldt and Maxwell. However, all investigations made to find Renieri's observations were fruitless. This paper clarifies this complex situation differentiating between myth and reality. A careful analysis of the Libri's announcement in the historical context points out that Libri made the announcement while escaping for conspiracy from Florence and needed a scoop to be introduced in the French Academy of Sciences. For this reason he made a deliberate mix of new and old assertions, i.e. he claimed to have made new discoveries but without explaining too much and reporting misleading details about well known stories concerning the earliest meteorological observations. This induced people to suppose that further, earlier records existed. The consequence of this was that climatologists searched for years the claimed records. This paper shows that the Medici Network almost certainly contains the earliest exploitable instrumental observations. The possibility of finding a short series of observations prior to 1654 is remote.

1 Introduction

In climatology, a crucial issue is to go back in time, as far as possible, with our knowledge based on reliable instrumental readings. The 1654–1670 observations of the Medici Network constitute the earliest known record that has been analyzed and published (Camuffo and Bertolin 2012a). However, leading science historians and climatologists, i.e. Guglielmo

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Libri (1830) (Fig. 1) followed by Joakim Frederick Schouw (1839), Alexander von Humboldt (1848) and James Clerk Maxwell (1871, 1888) (Fig. 2), wrote that Father Vincenzo Renieri made regular temperature readings for over 16 years, possibly from 1632 to 1648, before the Medici Network, and that this record is the earliest in the world. However, no one found it.

The aim of this paper is to provide an answer to the fundamental questions: Were instrumental temperature records taken before the Medici Network and did they survive? What was the fate of the observations by Renieri? Are further efforts to seek missing records justified? These questions are crucial to the quest for unexploited data from the first half of the 17th century. This is a unique opportunity to calibrate proxy reconstructions in the pre-instrumental period in the middle of the Little Ice Age. To this aim, we will analyze when, how, why and by whom the first announcement of such record was made.

Going back to the 17th century in Florence, Italy, it is known that the Grand Duke Ferdinand II de' Medici (1610–1670), his brother Prince Leopold (1617–1675), with the scientific support of Galileo Galilei (1564–1642), his pupils and other scientists abandoned the official knowledge based on Aristotle and the Holy Bible and developed a new science, based on the objective observation and the measurement of natural phenomena. They investigated nature and invented, improved and developed several scientific instruments e.g. air and liquid-in-glass thermometers, the barometer, the condensation hygrometer, the evaporimeter, the densimeter and the raingauge. The Grand Duke founded the first Academy of Sciences, named the "*Accademia del Cimento*" (i.e. Academy of Experiment, which flourished from 1657 to 1667) and the first international network of regular weather observations, i.e. the *Medici Network* (which flourished from 1654 to 1670). The activity of the Academy is well known after the diary written by Alessandro Segni (Secretary from 1657 to 20 May 1660) and Lorenzo Magalotti (Secretary from 1660 to1667) and after the book "Saggi di Naturali Esperienze" (i.e. Examples of Experiments on Natural Philosophy (Middleton 1971)) edited by Magalotti in 1667, and by many other subsequent studies (Viviani 1717; Targioni Tozzetti 1780; Antinori 1841; Beretta 2000; Borchi and Macii 2009; Camuffo and Bertolin 2012a).

Fig. 1 Portrait of Guglielmo Brutus Icilius Timoleon, count Libri Carucci dalla Sommaja. Courtesy of Museum Galileo—Institute for the History of Science, Florence

Fig. 2 Portraits of Joakim Frederick Schouw (**a**), Alexander von Humboldt (**b**) and James Clerk Maxwell (**c**)

The *Medici Network* is less popular than the Academy, although some papers were concerned with it (Redi 1660; Targioni Tozzetti 1780; Libri 1830; Antinori 1841; Boffito 1926; Maracchi 1991; Miniati 1991; Galluzzi 2001; Borchi and Macii 2009; Camuffo and Bertolin 2012a). The Network was composed of 11 stations, i.e. Florence and Vallombrosa, Pisa, Cutigliano, Bologna, Parma and Milan in Italy, Innsbruck in Austria, Osnabruck in Germany, Warsaw in Poland and Paris in France. Florence and Vallombrosa were primary stations with almost unbroken records from 1654 to 1670; all others were secondary stations with fragmented activity, mainly focused to record the temperature in summer and winter, i.e. the extreme seasons. All the stations had identical spirit-in-glass thermometers, i.e. the Little Florentine Thermometers (LFT, Fig. 3) with the same calibration, supplied by the Grand Duke (Nollet 1740–1748; Cotte 1774; Targioni Tozzetti 1780; Libri 1830; Antinori 1841; Meucci 1873; Maze 1895a, 1895b; Middleton 1966; Vittori and Mestitz 1981; Camuffo and Bertolin 2012a). All stations had two LFTs exposed to open air, one of them on a North-facing wall, and one to the other side, in order to investigate the air temperature, the effect of sunshine, and the effect of winds blowing from North and South. In addition, pressure readings were made in Pisa in 1657 and 1658 (Camuffo et al. 2010). All observers were Jesuits and Benedictine Fathers who used the same sampling protocol and made regular temperature and weather observations scheduled every three (sometimes four) hours during the day and at the evening and nocturnal prayers. Readings were reported in standardized daily logs produced in duplicate: the original for the Grand Duke in Florence

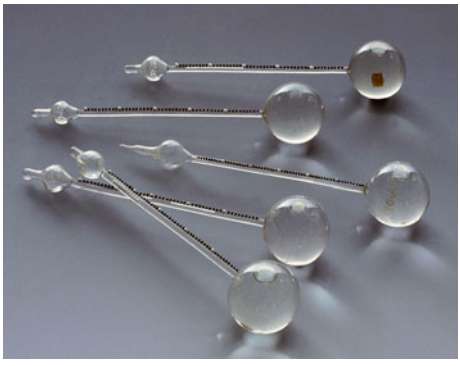

Fig. 3 Little Florentine Thermometers (LFT). Courtesy of Museo Galileo—Institute for the History of Science, Florence

and a spare copy for the station. The logs were sent daily or weekly to Florence, depending on the distance, via express messenger.

The preservation of all the Florentine documents and instruments was impossible for a number of reasons. The revolutionary ideas launched by Galileo and the Academicians were considered dangerous and heretical and the Inquisition sought to control the situation, with the result that several documents and instruments were destroyed. Florence was affected by repeated wars, and in particular in 1808–1814 the Napoleon troops closed all religious organisations and dispersed the archives. The Arno River overflowed its banks, invading the town in 1740 and more recently in 1966. In 1966, flood waters invaded the Museo-Galileo Institute and Museum of the History of Science (IMSS) and the National Central Library (NCL), damaging over 1,300,000 books. Waters transported a mixture of mud, sludge and black oil that impregnated everything and generated cellulose hydrolysis, book swelling and shrinkage, stains, moulds, and many other problems. A number of documents were lost, but not the hope of finding at least one of the two copies of the logs. For years we have searched through public and private archives and libraries to find the original documents, or their duplicates, that apparently disappeared.

Fortunately, many documents have survived over the centuries (Antinori 1858) and recently the two Florentine Libraries, i.e. IMSS and the NCL, finished the restoration and re-organization of all books and manuscripts after the terrible flood in 1966. Since 2007, all original documents and/or their electronic copies are available in the traditional form, or virtually in the digital library. Once the documents concerning the history, the data and the metadata of the Network have been made available at http://teca.bncf.firenze.sbn.it/manos/find.jsp (Keyword: Galileo; Archive nickname: Gal. followed by the manuscript number (they are several hundred documents)), we have recovered all of the records, transformed the original readings into modern units, tested the data quality, analyzed the climate signal and finally published the results about the atmospheric pressure observed in Pisa (Camuffo et al. 2010) and then the temperature in the seven Italian stations and Innsbruck (Camuffo and Bertolin 2012a, b).

The original instrumental readings remained unexploited untill now due to a number of difficulties, i.e.: to have access to the original documents; to read the 17th century's original handwriting; to recover a huge amount of readings, i.e. a reading every 3–4 h for 16 years for the two primary stations and shorter datasets for the eleven secondary stations; to change the date from the old Florentine calendar (beginning from March 25th) into the Gregorian date (beginning from January 1st); to transform the so called Italian time (the new day starting from twilight) into Central European Time (CET, starting from midnight) with a correction that changed day by day during the calendar year; to transform the original temperature scale in Galileo degrees (°G) into Celsius degrees (°C); similarly for the barometric pressure to be transformed into hPa. Finally, nobody knew the data quality and the risk connected with this research: historians were not interested to incomprehensible numerical readings, while climatologists understood that the work for data recovery and analysis was very time consuming, with the risk of getting obscure results if the observations, or the instruments, were hardly reliable.

2 The discovery announced by Guglielmo Libri

Guglielmo Brutus Icilius Timoleon, count Libri Carucci dalla Sommaja (1803–1869), hereafter Libri, was a well-renamed mathematician and historian of science whose scientific contribution was appreciated at his times and is still object of study (Maccioni Ruju and

Mostert 1995; Fiocca and Nagliati 2009). The 8th November 1830, Libri had an exciting lecture (Libri 1830) with breaking news at the *Académie Royale des Sciences* (Royal Academy of Sciences), Paris, as follows:

(i) Despite the Inquisition having dispersed and destroyed most documents and instruments of the Academy, in the previous year, i.e. 1829, a box was found at the Royal Museum of Physics and Natural History, Florence, in which many original LFTs miraculously survived. These instruments are now kept in IMSS (Galluzzi 1957). At the conference, everybody had the possibility of seeing these instruments because Libri gave two of them to the *Académie Royale*.

(ii) Also some registers containing a 16-year-long record of daily temperature observed in the Convent of St Mary of Angels, Florence, miraculously survived. Libri said that the observer was Father Renieri (1606–1648), a pupil of Galileo.

(iii) The title of the speech was that he calibrated the newly found LFTs with a Réaumur thermometer taking some 200 matched readings, making clear the scale and giving the key to interpret readings.

(iv) Libri made a comparison between these early data with a 10-year-long record, i.e. 1820–1829, taken at the Ximenian Institute, Florence, and concluded that the climate in Florence was substantially unchanged despite the clearing of wood lands around Florence.

The same text presented at the *Académie Royale* was summarized in *Antologia*, journal of sciences letters and Arts (Vieusseux 1830). In the introduction, Libri stated that the aim of the paper was limited to present his results after having determined the scale of the Florentine Thermometer. However, the announcement that Libri discovered the world's first temperature readings had an enormous impact. The lecture was immediately published in the *Annales de Chimie et de Physique* (Libri 1830), translated and reported in newspapers and scientific journals, e.g. Forbes (Forbes 1833) at the second Meeting of the *British Association for the Advancement of Science*. It was mentioned by leading scientists, e.g. Schouw (1839), von Humboldt (1848) and Maxwell (1871,1888), who reported an extended abstract of Libri's paper with some additional notes and their leading authority added relevance to the announcement.

3 The Schouw's expedition and the thermometric liquid: water or spirit?

Sixteen years of daily observations prior to 1647 were extremely attractive for the study of climate, and this caused many unfruitful searches in public and private archives and libraries. As Schouw heard this news, he immediately went to Florence to be first to reach data and publish results. In Florence, he had free access to the Grand Duke's library and found the well-known daily logs from 1655 to 1663 with five observations a day. He only copied the monthly averages that Domenico de' Vecchi, director of the *Astronomic Observatory of the Museum of Physics and Natural History* wrote in pencil when he made a short publication on such data, but with a slightly imprecise calibration. After lengthy investigation, Schouw doubted Libri's announcements. Two hypotheses are possible. In the first, Libri announced the discovery, but kept the records in a secret location to exploit them later. However, the situation was outside the control of Libri, who was unable to return in Italy for political reasons (see section 5). In the second hypothesis, the documents mentioned by Libri were the 1655–1663 documents that Schouw found in Florence. However, Schouw rejected this hypothesis because Libri said that a spirit-in-glass thermometer was used, and in the Florence documents Schouw found the note "water", referring to the thermometric liquid.

We note that the original diaries of the Academy exclude the use of water, but Schouw took the text literally, and this was the key reason to mislead. In the Italian language, the word for "water" is "*acqua*". However, in combination with other words this term may change meaning. In particular, the combination "*acqua-vite*", from the Latin "*acqua vitae*", French "*eau-de-vie*", literally "water of life" was derived from mediaeval alchemy for an aqueous solution of ethyl alcohol, i.e. ethanol. Popularly, "*acquavite*" is the alcoholic drink distilled from wine grapes, e.g. "*grappa*" or after fermentation of grape must (i.e. wine) and single distillation, e.g. "*cognac*". The typical percentage of ethyl alcohol by volume (ABV) of this beverage is 42 % ABV. However, "*acquavite*" can be refined with successive distillations to increase the percentage of alcohol. After refinement we obtain "*acqua-arzente*" (in Spanish "*aguardiente*", literally "burning water"), popularly 80 % ABV or more. The *Accademia del Cimento* clearly specified that the spirit of wine used in thermometers was "*acquarzente*" e.g. Secretary Magalotti (1667) who also sometimes uses the abbreviation "*acqua*", or Targioni Tozzetti (1780) in describing thermometers. In addition, Magalotti (1667) wrote that the pure water used in the early air thermoscopes was discarded as thermometric liquid because frost breaks the glass bulb and for this reason spirit was preferred. Finally, it was sufficient to have a look at the famous dictionary of the *Accademia della Crusca* (1612), the most authoritative source of the Italian language at those times, where the entry word "*arzente*" is explained: today used only in combination with "*acqua*"; "*acquarzente*" means refined "*acquavite*".

Briefly, Schouw was not familiar with Italian language and traditional spirits; he was unable to interpret the headword and remained doubtful, but at the end he surprisingly accepted Libri's breaking news.

4 Strong and weak points supporting Libri's announcement

Libri's announcement was not precise and the early record was never found. For this reason it is useful clarify what is credible and what is not before advancing other hypotheses.

A strong point in favour of Libri is that, 11 years later, the Director of the Museum of Physics and Natural History, Florence, i.e. Vincenzo Antinori (1841), the person who really discovered the box with the LFTs, in one of his papers made a respectful citation to Libri.

In the first part of the paper, Libri draws a short history of the *Accademia del Cimento* that was familiar to him (Libri 1830). However, a first surprising mistake is found on page 356 when he mentioned among the most active members of the Academy Father Vincenzo Renieri (1606–1648) and Father Bonaventura Francesco Cavalieri (1598–1647). Both of them were dead about 10 years before the Academy was founded in 1657. This was an incredible slip, or a deliberate error, for a historian of science dealing with his own home story. However, this detail passed unobserved or it seemed irrelevant and was neglected. Libri was clever in creating breaking news after known things but presented in a way to confuse unfamiliar readers. Most of his article is correct, but the wrong mention to Renieri and Cavalieri brought the reader to misleading conclusions.

In the next page (Libri 1830) he repeated the same mistake in the context of the registers with observations miraculously survived. He also omitted to specify where the documents were found and preserved. Once again, he repeated that the author of the newly found temperature records was Father Renieri, a pupil of Galileo, famous for having cooperated in the discovery of the satellites of Jupiter (Fig. 4) with 16 years of telescope observations, i.e. 1609–1618 and 1638–1644 (Renieri 1647). Renieri is not known to have ever made temperature readings.

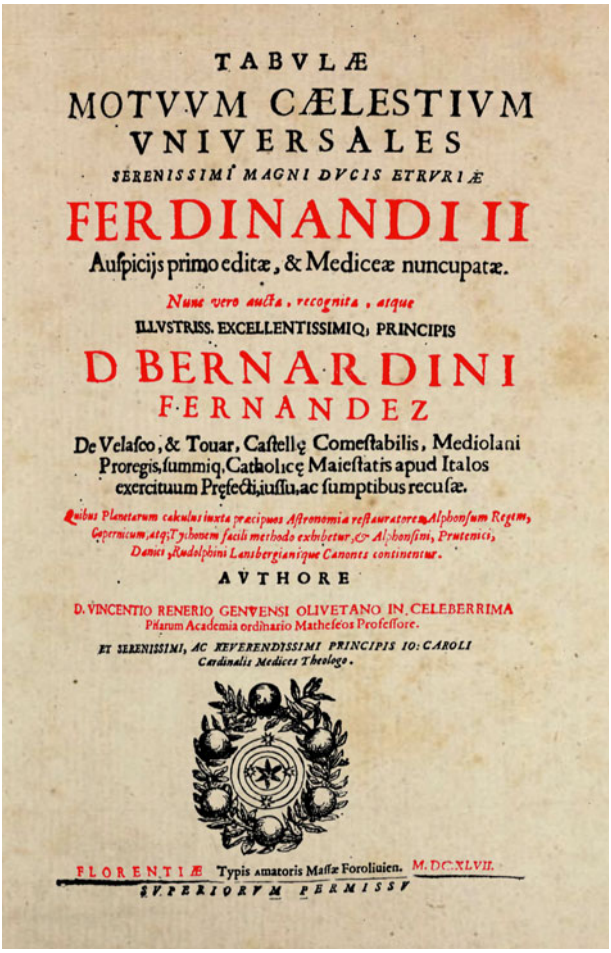
TABVLÆ
MOTVVM CÆLESTIVM
VNIVERSALES
SERENISSIMI MAGNI DVCIS ETRVRIÆ
FERDINANDI II
Auſpicijs primo editæ, & Mediceæ nuncupatæ.
Nunc vero aucta, recognita, atque
ILLVSTRISS. EXCELLENTISSIMIQ; PRINCIPIS
D BERNARDINI
FERNANDEZ
De Velaſco, & Touar, Caſtellę Comeſtabilis, Mediolani
Proregis, ſummiq; Catholicę Maieſtatis apud Italos
exercituum Prefecti, iuſſu, ac ſumptibus recuſæ.
Quibus Planetarum calculus iuxta præcipuos Aſtronomiæ reſtauratores Alphonſum Regem,
Copernicum, atq; Tychonem facili methodo exhibetur, & Alphonſini, Prutenici,
Danici, Rudolphini Lansbergianique Canones continentur.
AVTHORE
D. VINCENTIO RENERIO GENVENSI OLIVETANO IN CELEBERRIMA
Piſarum Academia ordinario Matheſeos Profeſſore.
ET SERENISSIMI, AC REVERENDISSIMI PRINCIPIS IO: CAROLI
Cardinalis Medicis Theologo.
FLORENTIÆ Typis amatoris Maſſæ Foroliuien. M.DC.XLVII.
SVPERIORVM PERMISSV

Fig. 4 Front cover of Renieri's book *Tabulae motuum caelestium* (1647)

Libri's reference to Renieri was crucial to establish when such observations were made. Considering that Renieri died on 5 November 1648, the observations were referred to 1632–1648 at the latest. Libri let the reader guess and draw conclusions. Libri wrote that observations had been gathered over 16 years, and this is correct if we consider that the Convent of St Mary of Angels operated within the Medici Network from 1654 to 1670, i.e. 16 years. To say that a 16-year-long record, i.e. from 1654 to 1670, existed in the Convent of St Mary of Angels is formally true, but this was not a novelty. As opposed, the Libri's announcement induced to suppose that he had miraculously found additional readings for 16 years in a period before the well-known Medici Network.

Libri reinforced the misleading interpretation by writing that the miraculously found registers preceded by some 50 years all known meteorological data. If we consider that regular observations started in 1716 in Padua by Giovanni Poleni (Camuffo 2002; Camuffo and Bertolin 2012c) and in Bologna by Jacopo Bartolomeo Beccari (Baiada 1986; Comani 1987), we obtain 1666, i.e. the readings of the Medici Network. However, this was not a novelty. Therefore, Libri's statement lead one to suppose that the observations were made 50 years before the Medici Network, going back to 1604. However, the spirit-in-glass

thermometer was invented and produced in 1641 (Magalotti 1667; Antinori 1841) and Renieri died in 1648. Renieri could have observed only from 1641 to 1648, i.e. 7 years in total, not 16 years.

Later on, Libri (Libri 1830) wrote that the discovery of the box with the LFT enabled him to compare the LFT with a Réaumur thermometer and find the key to know the LFT scale and interpret the registers. This was a strong point. Libri made a reasonably good work in cross comparing the old LFT with a contemporary thermometer. However, this was not a great scientific advancement because the LFT scale was already known after the book "*Traité de Météorologie*" (Treatise of Meteorology) by Father Louis Cotte (1774) who published a table with the cross comparison of 15 thermometric scales in use at his time, including the LFT. Therefore, his contribution was to confirm the known scale, or to propose one close to it. However, he claimed to have discovered the scale. This was risky because Father Louis Cotte and his treatise were popular in France.

Next, Libri (Libri 1830) wrote that making a comparison between these early, mysterious data and the observations from 1820 to 1829 in Florence, he found that the climate had not changed very much over the last 150 years although woods were cut in the Apennines around Florence. An easy calculation gives 1670, i.e. once again the end of the observations of the Medici Network. The conclusion is that the mysterious data were exactly the data of the Medici Network and not a novel finding.

5 Was Libri a reliable source?

The failure of the Schouw investigations and all the hypotheses made so far raise doubts concerning the validity of Guglielmo Libri's claims. No doubt that he had an eventful life (Appleton & Company 1870; Alessandra et al. 1995; Del Centina and Fiocca 2010). Libri was a brilliant mathematician, and professor at the University of Pisa, who published remarkable books on theory of numbers, geometry, physics and history of sciences. Aged 20, he was appointed Professor of Mathematical Physics at the University of Pisa but he was dismissed after the first year. In 1830 he participated in an unsuccessful insurrection against Leopold II of the Augsburg-Lorena family that succeeded the Medici as rulers of Florence. For this reason he was considered obnoxious, and accused of conspiracy; briefly, he fled to France to avoid being arrested. Thanks to the friendship of François Jean Dominique Arago, Libri had the chance of being introduced to the *Académie Royale* (French Royal Society), Paris, where he had his famous speech that created the long series of problems we are dealing with.

Three years later, Libri was naturalized as a French citizen and had a brilliant career: he was appointed member of the *Académie Royale* as successor of Adrien-Marie Legendre, who is died 10 January 1833. He soon became professor at the *Sorbonne*, Paris was also appointed at the *Collège de France*, awarded "*Légion d'honneur*" and became Chief Inspector of French Libraries. He was also a renowned historian of science and wrote the famous book: "*History of Mathematical Sciences in Italy from the Renaissance to the 17th Century*" (Libri 1838–1841).

However, Libri felt under suspicion for theft of many precious books and in 1848 a warrant was issued for his arrest. He escaped from France and fled to London, shipping 18 large trunks of books and manuscripts, about 30,000 items in total. In 1850, the French Court found him guilty of theft. However, in London he had good life selling thousands of books stolen in Italy and France. In 1868 his health deteriorated and he returned to Italy to spend the last year of his life.

6 Would it be possible to discover other readings prior to the Medici Network?

Somebody might wonder what happened from the invention of the thermometer (in 1641) and barometer (in 1643) to 1654? Would it be possible to find short series?

Magalotti (1667) wrote that the Academicians made a number of observations to see when and how water from different springs kept in some vessels of different types was frozen over, when exposed to the north or the south of walls, making reference to blowing winds. Unfortunately we have some tables with the temperature of vessels, of freezing waters, but not a clear indication about the day, the hour of the readings and the air temperature.

However, it is highly probable that regular temperature and weather observations were performed for a certain period before the official start of the Medici Network, with the aim of checking instrument performance, observational methodologies and establishing sampling protocols. It seems unlikely that the Grand Duke could start with a well-organized international network of regular meteorological observations without having previously tested everything in his Florence headquarters. The problem is that these preliminary observations might have been disregarded and lost because they were considered to be of little relevance. In fact, the main interest was focused on the comparison between different sites, i.e. an international Network to include different geographical locations.

7 Conclusions

This paper has demonstrated that the story of 16 years of meteorological observations taken in Florence before the foundation of the Medici Network was most likely an exciting myth generated by G. Libri and supported in good faith by J.F. Schouw, A. von Humboldt and J.C. Maxwell. In reality, in his famous speech, Libri never explicitly made clear that he had found a 16-year-long record with observations taken before AD 1654, but instead presented two distinct, well-known facts: the historic 1654–1670 observations of the Medici Network and the recent finding of a box full of LFTs. However, Libri was obscure with a mix of old and new, inducing people to suppose that other earlier records existed and were just discovered.

The myth was favoured by some glaring mistakes, the main one being that the observer was Father Vincenzo Renieri who observed the satellites of Jupiter for 16 years with the newly invented telescope, but is not known to have ever measured temperature. Libri was not a mythomaniac; he was escaping for conspiracy from Florence pursued by the police of Tuscany and Austria and likely bluffed to get a second chance in Paris with a breaking conference and the gift of two LFTs. The apparent bluff lasted for almost two centuries, but it now appears almost certain that the earliest exploitable instrumental observations made in the world were taken within the Medici Network, 1654–1670.

The possibility of finding further occasional temperature readings and especially a short series of regular observations prior to 1654 to test the Network operative protocols is extremely remote but cannot be excluded.

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