# The early meteorological network of the *Societas Meteorologica Palatina* (1781-1792): Foundation, organization, reception.

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**Abstract.** The Societas Meteorologica Palatina arranged the first international meteorological network in a modern sense being in operation between 1781 and 1792 during the last period of enlightenment. A total of 39 stations contributed observations. The original aim was to investigate influences of the moon and planets on the atmosphere. Instruments were provided free, a physically very advanced instruction guaranteed reliable observational results and the data collected at three hours per day were printed at high costs in the Ephemerides Meteorologicae of Mannheim. This wealth of data has become a famous treasure trove for scientists and has been used later very often for climatic studies, climatic comparisons of different locations in textbooks, for overcoming wrong but generally accepted or even outdated (e.g. scholastic) views and find new explanations on meteorological phenomena, for studying extremes of meteorological parameters. Even in modern times, the data were evaluated and used to reconstruct historical weather maps. Although meanwhile some problems of the historical instruments have been recognised most of the conclusions are still basically correct. The data were also used for verifying geomagnetic models or proxy data from tree ring analysis. This network stimulated many scholars for special meteorological studies and was attractive for new stations to join the network. The early death of the meteorological secretary Hemmer and the Napoleonic wars brought about the end of the project. Nevertheless, many of the stations continued the observations using the available instruments.

# 1 Introduction

Galileo's famous aphorism "Measure what can be measured, and make measurable what cannot be" stimulated scholars as well as instrument makers in the period of enlightenment to a new approach in analysing and interpreting natural phenomena, including the atmosphere.[1] The philosopher Christian Wolff who had a strong spiritual influence on Enlightenment in Europe reformulated Galileo's aphorism in his "Mathematisches Lexikon" (Wolff, 1716, Sp. 863f.), without mentioning Galilei: *Ist eine Wissenschaft alles auszumessen, was sich ausmessen lässt* [There is a science of measuring all what can be measured]. When meteorological instruments became available, regular meteorological observations were started by interested professors at some universities or at scientific academies. The latter even included the intention for meteorological observations into their statutes. However, production and calibration of meteorological instruments were still a demanding task and no general agreement existed how observations should be performed. Each scholar and each institution set own rules and at best, data exchange was arranged on a private basis. In this situation the realisation of an international meteorological society by the Academy of Sciences in Mannheim was a very attractive, promising, and eventually successful project.

Countless publications appeared already on the Societas Meteorologica Palatina the most informative of which are Kistner (1930); Cappel (1980b); Cassidy (1985); Kington (1988); and Frångsmyr et al. (1990). All emphasise as the most important achievements:

- free provision of uniformly manufactured and calibrated instruments,
- instruction for installing instruments and doing observations,
- invitation of institutions rather than private persons as observers to ensure continuity,
- uniform observation times at 7 am, 2 pm, and 21 pm, the so-called Mannheim hours,
- uniform registers, to be sent in by diplomatic mail,
- printing the extenso observations in the Society's Ephemerides.

In the past several attempts were undertaken to set up a meteorological network: 1654-1667 by the Florentine Accademia del Cimento (10 stations), 1662 the Royal Society London (number of stations unknown), and in Paris by the Royal Society of Medicine in 1776 (32 to 65 stations). They weren't nearly as successful as the Academy in Mannheim (e.g. Libri, 1830; Hellmann, 1914; Rigby, 1965; Fleming, 2002; Camuffo, 2002b).

The progress achieved by the Societas Meteorologica Palatina consisted in the instruments which were manufactured under the supervision of a physicist and uniformly calibrated. This successful example has demonstrated the feasibility of international cooperation in meteorology which later served as a model when new measuring networks were set up. This meteorological network was created due to the personal engagement and organisational talent of its secretary, Johann Jakob Hemmer. The collected data have been re-evaluated since then for many applications. One should be aware that the local view of weather determined the imagination of the meteorological development and that farmers rules were the only known means for forecasting weather.

The purpose of the present work is to report on less known or even overlooked aspects (see below) but playing a role in the implementation of the Societas Meteorologica Palatina including the preceding mental development, instrumental deficiencies and data quality. Moreover, I will bring some examples for the broad reception of the datasets by scientists in many fields of knowledge.

During the last phase of enlightenment, the usefulness of scientific efforts played a predominant role under regents who had to decide which project should be funded. Two examples may illustrate this point: Lightning-rods had proven to protect buildings from ignition and physicists had understood the mode of functioning. Therefore, decrees were enacted to install lightning-rods on all public buildings (Mayr, 1788, p. 674, regulation from Dec. 23th, 1784). The second example is the drainage of moors in order to cultivate barren land. The governments expected that the productivity of their country would rise without, in that case, having knowledge of the ecological function of moors (Mayr, 1788, p. 663, regulation from May 15th 1783).

In meteorology of the 18th century the gravity pull of the moon on the atmosphere was known and assessed to be 850 times larger than the oceanic tide. While Daniel Bernoulli (1700-1782) had recognised the compressibility of the atmosphere and refrained from calculations of atmospheric tidal calculations (c, 1987, p. 270), Kratzenstein (1723-1795) considered the atmosphere as incompressible (Fig. 1) and expected a large lunar tide (Kratzenstein, 1747). The latter simple hypothesis had a better reception among scholars than mathematical unsolved problems.

Scholars argued that in the atmosphere predictable pressure oscillations would be induced by the moon and could be measured. A meteorological observation network would enable to analyse such regular waves and allow prediction of weather, once long enough time series of meteorological parameters were available. Agriculture would take profit from such predictions convincing Elector Karl Theodor from Palatine to invest money in such an important project. A rapid result was expected whereas any promotion of basic science was not a governmental goal. In continuation of the mechanics of Newton, the generally prevailing view was that the world is functioning like a machine.

## 2. Foundation

### 2.1 Foundation of the Societas Meteorologica Palatina

The foundation of a meteorological society in Mannheim was the result of a special constellation of several persons (Fig. 2; Kistner, 1930; Stengel and Ebersold, 1993): The privy counsellor and minister for educations Georg von Stengel (1721-1798) of Elector[2] Karl Theodor (1724-1799) had started private meteorological observations three times per day in 1758, and his son Stephan (1750-1822) helped him in cases when he was tied up with business. Karl Theodor was personally interested in physics and he made weather observations in his castles and during journeys (Kistner, 1930). He had studied law at the university of Leiden (The Netherlands) and probably might have come into contact with the widely known professors s' Gravesande or

Musschenbroek, who were teaching physics. Stephan von Stengel was an illegitimate child of the Elector, who followed him to Munich in 1779 as secretary, when Karl Theodor became successor of the childless Elector Max III. of Bavaria at the end of 1777.

90 Karl Theodor was interested in physics and had installed a collection of physical instruments, for which he hired the court chaplain Johann Jakob Hemmer (1733-1790) as custodian. Karl Theodor often spent several hours in the physical cabinet, learning physical experiments arranged by Hemmer. He had recognized the progress which could be achieved in explaining natural phenomena by means of experiments instead of magic explanations or the antiquated physics of the Jesuits, being based on their scholastic Aristotelian teaching methods or Descartes' meteorological theses (see 2.2).

95 After the move of Karl Theodor to Munich, Stephan von Stengel started meteorological observations and motivated a military engineer in Mannheim do the same at fixed times. They exchanged their data every 10 days and from Hemmer he obtained information on atmospheric electricity. St. v. Stengel prepared comparative tables which he regularly presented to Karl Theodor and he was able to arouse his interest. Inspired by the plan of Lorenz Böckmann (1741-1802) in Karlsruhe in the neighbour-state Baden to implement a meteorological network of 16 stations in 1779 (Cassidy, 1985; Lüdecke, 2010), Hemmer

100 as well as von Stengel discussed the possibility to implement another meteorological network in Palatine or even in Europe (Kistner, 1930; Stengel and Ebersold, 1993).

In Baden progress was hampered due to delay in manufacturing of meteorological instruments which eventually resulted in the failure of the project. However, Stephan von Stengel, being a good organiser of statesmanlike projects and having a good overview on meteorological observations already running at other places succeeded in motivating Elector Karl Theodor to

105 found a third meteorological class at the Academy of Sciences in Mannheim in 1780 and nominating Hemmer as the secretary (Fig. 3).

The scientific goal was to analyse periodic developments in the course of weather induced in the atmosphere by the gravitation of the moon (see section 2.2).

St. von Stengel and Hemmer had postulated that "harmonizing" instruments were necessary in order for the meteorological

110 network to become successful. Hemmer sent relevant expert reports to Stengel in Munich. Obviously, both knew of the difficulties in manufacturing and calibrating meteorological instruments. Karl Theodor could be convinced, that for the success of such a project, standard calibration instruments should be implemented in the entire network. Stephan von Stengel, after consultations with his father Georg von Stengel and Hemmer, worked out the document of the foundation charter which was signed by the Elector on September 15th, 1780, in Munich and who financed the instruments from his cabinet treasury.

115 To understand the enormous efforts and outstanding success of this initiative it is important to remember that doing science at that time was not a matter of course. Academies had to be protected by the country's regent and they had to achieve to be exempt from censorship. Although the Jesuit order was abolished, many former members remained in the teaching profession and tried to hinder academic research (Müller, 1986; 1993). Their method of teaching at the universities and grammar schools remained unchanged on the *Ratio Studiorum* introduced in 1599 and their influence persisted even after the abolition of their

120 order in 1773. In addition, Karl Theodor's confessor was an Exjesuit who was not well disposed toward the academy but who

had a significant influence on his decisions. Many progressive courtiers and members of the government or administrative officials, even if they were educated by Jesuits, became academic members although they rarely contributed to research. Their main task was to support and enable research activities, ward off hostile and envious currents and eliminate resistances since other parts of the society could not see a point in "useless" research. Thus, the academies in Mannheim and in Munich had to act wisely and clever at the time of feudalism.

Hemmer presented a speech to the Academy on 21th October 1780.[3] He was a well-known scientist who had published results of physical experiments, lightning rod installations, and application of electricity to heal human diseases. Thus, when Benjamin Thompson, the later Count Rumford, started his experiment in Mannheim to elucidate the existence of infrared heat radiation by drilling a cannon in order to demonstrate that phlogiston was not existing, Hemmer was invited as a critical observer and experienced experimentalist. If phlogiston should be responsible for the warming during drilling, the heating should cease when all phlogiston would have escaped. His drilling with a blunt drill was continued for many days but the cannon was as hot as at the beginning. They concluded that the heat was generated by friction and not by phlogiston (Meyer d. J., 1806-1808). Hemmer's organizational capability was gravely missed after he had died.

## 2.2 The Influence of Lambert and Toaldo

Johann Heinrich Lambert (1728-1777) was a member of the Bavarian Academy of Sciences and in a paper published in 1761 he developed a programmatic system for regular observations in agronomy, medicine and meteorology (Lambert, 1961). We have no information, whether Georg von Stengel or Hemmer in Mannheim or even Böckmann in Karlsruhe had received knowledge of this paper, but we cannot exclude, that they obtained a copy, since both academies exchanged information. Lambert recommended three observations per day and the use of a thermometer in the shadow and in the sun, barometer, atmospheric moisture, evaporimeter, pluviometer, measurement of soil temperatures in several depths, river level, windspeed and -direction, state of the heaven, cloud cover, meteorological events like fog, rain, thunderstorm, hail, and so on, state of soil (moist or dry), snow cover, colour of the heaven during sunrise and sunset, polar lights, sunshine duration, monthly minima and maxima of atmospheric pressure and other meteorological parameters and in a special column the phases of the moon, solar elevation, and positions of planets in the zodiac circle. He expected also to achieve recognizing any astronomical influences. In addition, a magnetic needle instrument should be observed to learn about changes of the geomagnetic field. In his "Exposé" he recommended a worldwide observation network (Lambert, 1973). This is important because at his time the local view on the weather was prevailing and atmospheric pressure systems and their extension were unknown.

In 1762, Lambert calculated the astronomical calendar of the Bavarian Academy of Sciences, where he reported in an annex "On the Meteorology", that analysis of atmospheric pressure data had shown only marginal effects by the moon (Lambert, 1762). As it often occurs in science, his insight was ignored and scholars tended to prove their own hypotheses, in this case the hypothesis of a strong influence by the moon.

Lambert recommended to compare the wind direction with the average atmospheric pressure (Lambert, 1765). He was one of the first to argue that wind forms as a result of differences in atmospheric pressure and overcame the traditional explanation

developed by Cartesius: Winds can be compared with vapours which move from one place to another where they can expand with less effort (Descartes, 1637, p. 189 f.). His experimental proof was the heating of water in a suffocated ball blowing out vapour off a hole in its wall.

Lambert's conclusion and recommendation was to investigate meteorology with the methods of astronomers. In this way, physical laws could be recognised and mathematically formulated. Once, the main laws were found, one could study the deviations and identify the responsible processes and become able to describe them mathematically. The mathematical formulas should be refined with time and would allow to obtain methods for meteorological predictions.

Toaldo in Padua was a representative of scientists being convinced that astronomical influences on atmospheric pressure and the development of the weather would exist. His agrometeorological essay which had won the price in 1774 of the academy in Montpellier, was published in Paris in October 1777 (Toaldo, 1777a) and translated in the same year into German (and other languages). At least three editions appeared. Toaldo had developed further earlier ideas of Duhamel (1623-1706) and Mairan (1687-1771). Also, Hemmer had received knowledge of Toaldo's paper, because early in 1779 he wrote to the Elector with the petition that the meteorological observations should be intensified with respect to agricultural requirements and be supplemented by observations on geomagnetism and atmospheric electricity. He requested, the physical cabinet should be moved to another location in the castle being closer to his living rooms, because the observer should be able to use the instruments between the regular observing hours in case when special meteorological events were occurring: "*Would Your Serenity be pleased, to install the meteorological instruments just mentioned in the physical cabinet, in order to start observations during the new year at this place in connection with other designated locations of your states, the next summer would be most suitable, because the preparation needs time and my lectures [public academic lectures] will start in autumn.*" (undated letter 1779 in: Generallandesarchiv Karlsruhe, Sign. 77/6400).

At this moment, Hemmer obviously thought only about setting up a national network intended to be similar to that in the neighbouring state of Baden. St. von Stengel now became the spiritual father for extending the network to an international dimension. This international network should be supplemented by regional networks in the Palatine and in Bavaria under the guidance of the academies in Mannheim and in Munich. In addition, Hemmer organised in the Palatine a phenological network with 94 observers (Cappel 1980b) underlining the expectation to learn more on the influence of meteorology on agriculture.

Toaldo had emphasised the importance of atmospheric electricity for plant growth and that people would have noticed, that electricity starts to form with sunrise and ceases with sunset: "We can conclude that scattering of the sunrays stimulates the formation of electricity, which moves to the earth taking vapor with it …" Toaldo knew of studies on atmospheric electricity performed in France, however, he relied upon unproven effects. In order to achieve progress Hemmer proposed that electricity should be measured at meteorological stations and he constructed an atmospheric electrometer for regular observations using the available experience. The first instrument was designed in 1749 by the clockmaker Jean-Baptiste Le Roy in Paris. Hemmer partly constructed his instrument according to the electrometer of (Nollet, 1753, Plate 4). Some people claimed to know that atmospheric electricity would be necessary for activating and vivifying the semen of plants (Stoll, 1790). Poey (1879) had compiled a number of publications from the 18th century on electrical effects on germination and growth of plants, including

those by the famous Linnaeus. This shows, that Toaldo was not alone with his opinion and Hemmer might have had knowledge of some more literature which would have confirmed his intention to measure atmospheric electricity.

190 The reason for the wide reception of Toaldo's ideas was the apparent evidence of astrometeorological effects of the moon on weather. Ultimately, this was a consequence of Newtons mechanics seeing the world as running like a clockwork. Toaldo claimed to have shown that atmospheric pressure was higher when the moon had its minimal distance from earth and vice versa. Due to the 19-year Saros-cycle, according to which the moon takes the same position, weather was expected to become predictable to some degree. From a today's statistical point of view this finding proved to be completely insignificant, however,

195 statistical methods did not exist at the time. In particular, Toaldo had not defined criteria on what should be understood by saying "the weather has changed or not changed" at full moon (Sheynin, 1984). However, everybody was impressed and believed in the effect of the moon on the air pressure, as was well known from the oceanic tides. Toaldo's influence was so large that Hemmer mentioned him in the foreword of the first volume of the Ephemerides.

Today we know, that a similar large effect in the atmosphere would require the incompressibility of the air as a prerequisite

200 (as with water) which, however, is not the case. Nevertheless, Stengel and Hemmer expected to become able to predict weather by analysing periodical fluctuations in time series if only long enough. St. von Stengel, being a member of the Bavarian Academy of Sciences, initiated a priced question on the effect of the moon on atmospheric pressure and they corresponded with Eberhard Schroeter in Petersburg who had developed a sophisticated method of calculating the aspects of planets and their influence on weather (Bavarian States Library, codex Cgm 6101 and Winkler, 2020, p. 44).

205 **3 Organisation**

**3.1 Instrumentation and instructions to observers**

Hemmer, being aware of the deficiencies in Böckmann's strategy chose a more successful way (Hemmer, 1779): he ordered the glassblower Carlo Artaria, who lived in Strasbourg and who had needed an overly long time in manufacturing the instruments for Baden, to come to Mannheim and produce the instruments for the Societas Meteorologica Palatina under his

210 own survey. Hemmer knew that harmonizing instruments needed special care which the usually freely working glassblower didn't consider: The tube of the thermometer must have a uniform calibre; the barometer must be completely free from air bubbles which easily tended to adhere at the inner surface of the glass tube when quicksilver was filled in and which he carefully removed by means of a thin iron wire. By this precaution he wanted to ensure a perfect vacuum. Hemmer preferred the Reaumur temperature scale to that of du Crest, Fahrenheit, de Lisle and others because the calibration could be reproduced

215 most suitably. He knew that the boiling point of water depends on atmospheric pressure and took care to set the relevant mark at the thermometer to average pressure at sea level.

A barometer with reduction thermometer, two thermometers for use in the shadow and the other "in the sun" and a goose-spell hygrometer belonged to the instruments distributed by the Societas Meteorologica Palatina which were provided on the expense of the Elector Karl Theodor. Declinometers, fabricated by Brander in Augsburg, were distributed to those who were

interested. They should be placed on a table of marble, being free from vibrations. A description of all instruments and how carefully they were manufactured and calibrated was published in Hemmer (1782a).

In his "Monitum", i.e. the instruction for the observers, Hemmer recommended the use of additional instruments like precipitation and snow gauges, an atmospheric electrometer, evaporimeter, and a wind vane, but he left it to the engagement of each observer. A universal time did not exist. Observation should be made at 7, 14, and 21 hours local mean solar time, however, not all stations followed this recommendation (e.g. in Petersburg the barometer was read at 6, 12 and 18 hours and the thermometer at 6, 14 and 22 hours). The amount of precipitation should be measured at 14 hours. A good clock should be available and the observers must be able to adjust it to the local solar mean time using a meridian line and a correction table. The universal time was introduced in 1884 (in Germany 1893). Uniform symbols were used to notify special meteorological events. At this time, many observers created own symbols (e.g. Wilse in Norway, (Federhofer, 2001)). Hemmer's meteorological symbols continued to be used in the US-army after 1816 (Chenoweth, 1996). In case of being unable to make an observation, another trained person should read the instruments. Additional observations should be noted at the beginning and end of extreme situations. The state of the heaven had to be observed as well as meteorological events like rain, snow, fog, hail, halos, cloud cover, polar lights, the levels of nearby rivers and the phase of the moon. Botanical resp. phenological and ornithological observations should be made as well as statistical information on the number of births, deaths, and illness of the local population; Hemmer's letter is transcribed in Cappel (1980a). The hope was, to recognize meteorological conditions, that would favour illness. The Latin language should be used. All stations should provide a short description of the location and the position of the instruments as well as their height above ground. Essays and papers on special findings were welcome. Every half year the monthly tables should be sent to the permanent secretary.

According to Hemmers recommendation to measure additional parameters the observer of Hohenpeissenberg informed the community of his newly constructed evaporimeter or atmidometrum (Schwaiger, 1783).

Electricity was the most important research field for physicists in the second half of the 18th century. Atmospheric electrometers were operated at several places (Mannheim, Hohenpeissenberg as mentioned; a Cavallo-type electrometer was operated by van de Perre in Middelburg because in the Netherlands effects of natural electricity on the healthy and ill body were of interest (Zuidervaart, 2006). The observation at an electrometer was dangerous, as the death of Richman in 1753 had demonstrated, who was hit by a lightning stroke when observing his instrument. Despite of this negative experience the observations were impressive. Hemmer's electrometers at Mannheim and Hohenpeissenberg allowed to measure the spark length at a gap of the antenna and thus conclude on the electrical field strength. Hemmer had also a method to distinguish whether a lightning stroke went from cloud to earth or from earth to cloud. The Hohenpeissenberg station at around 1000 m height gave insight into atmospheric electricity aloft and the noise of strong sparks at the electrometer gap could be heard throughout the large building, having three floors.

At this time, it was unclear, whether electricity would be necessary for the formation of hailstones (e.g., Seiferheld, 1790). A simple phenomenological hypothesis was based on the argument that hail would occur only in electrified clouds, i.e., in which lightning was observed. Bertholon (Academy of Montpellier), a well-known expert on electrical phenomena, reported

experiments of Nollet, who had covered the bulb of a thermometer with a piece of linen saturated with spirit of wine. Then the thermometer was electrified by means of an electricity generating machine and he could "prove" that this thermometer cooled much more than an unelectrified thermometer. Another conclusion was, that lightning rods would drain the electrical fluid from the atmosphere, and consequently would help to prevent hail formation. He also argued that lightning rods would rebuff thunderstorm clouds (Bertholon, 1792). Nollet claimed contrarily, that lightning rods would attract flashes which was denied by Hemmer. These few examples illustrate the need for continuous observations on atmospheric electricity. However, science was still in a state where electrical and magnetic phenomena were observed but by far not interpreted correctly. Many basics had to be studied and discovered before progress could be achieved. Priestley had cited Beccaria's opinion, that strong electricity would bring hail pieces closer together than snow crystals (Priestley, 1767). Hail clouds therefore would appear much darker than snow clouds or rain clouds. On the other hand, he described an experiment performed in 1767 where he could not accelerate the freezing of water by electrifying it. – These few examples show, that many conclusions were amateurish and circumstantial but scholars felt convinced since the majority believed in them. Progress occurred finally when experiments were repeated by others and logical doubts arose.

The Palatine instruments were used at some of the observation sites for a long time: at Hohenpeissenberg until 1840 and at Prague until 1829 (Fritsch, 1850; Lamont, 1851), in Cambridge until 1802, and probably also for similar long times at other sites. Samuel Williams in Harvard considered Hemmer's barometer to be correct and he reduced his old to the new barometer (Middleton, 1964).

Some of the instrumental deficiencies were known to Hemmer, others were unknown such as the rising zero point of the thermometers due to shrinking of the thermometer bulb which was first realized and described by Bellani (1808) and Yelin (1824). To overcome the incompleteness of the goose spell hygrometer (Retz, 1786), Hemmer launched a price question by the Mannheim Academy in 1783. The price was awarded to Toaldo and his nephew Chiminello in Padua. The main unsolved problem was the availability of fixpoints. Chiminello had developed a procedure to take into account the thermal expansion of mercury (for details see Cocheo and Camuffo (2000); Camuffo (2014). However, the goose spells were not perfectly round and their volume individually changed with temperature such that each instrument would have required an individual correction. In addition, we now know that the adaptation time upon a rapid change of humidity is a function of temperature (Winkler, 2015). Hemmer gave also advice how to construct wind vanes in such a manner that they easily follow the wind direction.

The available instruments were not sufficient in order to describe all processes or effects of meteorology in nature or on human health. Therefore, observers should note agricultural phases like blooming of fruit-trees, growth and harvest of crops and especially nutrient plants, bird migration, illness of cattle, level of rivers, floods and extraordinary events. In addition, the number of births and deaths of the local population, and various diseases should be reported.

## 3.2 Organising and establishing the network

Hemmer and von Stengel knew about existing weather observations at many places (Marseille 1749; Berlin 1721, Petersburg, Göttingen, Padua and others). They selected those which seemed to be reliable and were operated continuously. The central station (Fig. 4) was established in the Castle of Mannheim with Hemmer as observer and secretary. He wrote invitation letters to more than 50 potential institutions and he was assisted by diplomatic connections. To implement new stations invitation letters were not sufficient but the observers had to be approved and paid by the superiors and diplomatic support was necessary. V. Stengel travelled through Bavaria and won six monasteries for cooperation (Stengel and Ebersold, 1993; Martius, 1859). These stations delivered data starting from 1781. Due to numerous diplomatic and scientific connections he and Hemmer selected international stations, but they also refused the participation of interested scientists when the distance was not large enough (Cassiy, 1985). In 1785 Hemmer mentioned in an overview of the first years of activities, that he had obtained support by many influential men in other states and countries (Hemmer, 1785/86):

In Rome the papal librarian cardinal Zelada and the electoral ambassador Count Antici helped to install the observer Calandrelli. Both were members of the Academy of Mannheim.

In Bologna, the Count of Savioli, member of the Academy in Mannheim, arranged the meteorological station in Bologna with Matteucci as observer.

The capuchin general Erhard von Radkersberg, living in Munich since 1779, agreed that monks of Milan should do the observations at the hospice on St. Gotthard in Switzerland.

Baron von Dalberg in Mainz, also governor of Erfurt, agreed that meteorological observations were performed at the University of Erfurt.

Baron of Beveren arranged the station in Düsseldorf.

Mr. David, electoral agent and secretary of the legation in Paris supported the installation of French stations.

Bugge in Copenhagen supplied the station in Spideberg with instruments rebuilt after Hemmer's models and the station in Moscow obtained rebuilt instruments from the Academy of Sciences in St. Petersburg.

Van de Perre in Middelburg bought instruments from Hemmer on his own costs, because, as a private man, he could not guarantee uninterrupted observations. This shows, how careful Hemmer and v. Stengel selected stations for the European network. Thus, the Societas adopted a coordinating and standardising function in unifying the scattered observations and providing instruments from the same manufacturer. This new and outstanding function was even emphasised and recognised by the philosopher Schelling (Schelling, 1861, p. 492).

The monastery Polling in Bavaria was also interested in participating in the network but was rejected. In his reply Hemmer stated that the meteorological society is not allowed to sell any instruments against payment. He would only have helped the Duke of Saxony-Gotha and van de Perre in Middelburg with paid instruments (Hemmer, 1782b).

All observers were nominated as external members of the Meteorological Class of the Academy of Sciences in Mannheim and listed regularly in the "Kurpfalzbaierischer Hof- und Staatskalender".

The very successful organization and detailed description by Hemmer, how the instruments were manufactured and calibrated, stimulated other academies to imitate the organization of national meteorological networks: In 1785 the Newspaper of Mannheim (Nov. 15th) reported that the Swedish king had concluded to establish a meteorological network in his kingdom after the model of the Societas Meteorologica Palatina (Mannheimer Zeitung, CXXXVIII, Nov. 15th, 1785). The Swedish Academy of Sciences had made a corresponding proposal.

Similarly, the Academy of Sciences in St. Petersburg achieved that the Russian Emperor agreed to establish a meteorological network in all Russian provinces and to provide instruments built after the models of Hemmer (Hemmer, 1785/86). In Spain, there was hope to include Madrid as a new station and instruments had been sent to minister of state Florida Blanca (ibid.). However, this aim was not realised for unknown reasons. Also, in India, initial ambitions to arrange meteorological stations could not be realised.

Some of the invited persons refused after having firstly agreed to do observations: Lichtenberg (1742-1799) in Göttingen, for example, confirmed primarily his participation and was very interested to obtain a hygrometer, which he was lacking and which he needed for his lectures (Lichtenberg, 1985, Vol. II, undated letter No. 760, [1780]).[4] Later he urged his colleague Gatterer, who was already performing observations, to take over this duty. He also promised to ask his friend Jean Deluc in London, although being unable in his position as lecturer of the Queen, to observe personally, for helping to find observers in England. No success could be achieved with British stations, although the Academy in Mannheim had nominated scientists in Dublin and Edinburgh as members (Cassidy, 1985). Scholars from Lemberg, Lisbon, London, Paris, Turin and Vienna were also invited, but they did not participate.

Gatterer from Göttingen, on his turn, rated Wilse in Norway to be unable in systemising the complex processes of the atmosphere.[5]

The instruments like barometer and thermometer were sent out in duplicate, because many of them broke during shipping. Printed tables were distributed to facilitate and harmonize the notification. The Mannheim hours were not obeyed at all stations, as already mentioned. The printed tables should also help to achieve a high uniformity and completeness. The notification of positive and negative temperatures was explained. A special advice was given to avoid errors in thermometers by the radiation of candles which were needed in winter or at night to read the outside thermometers.

Although the instruction was detailed, some of the stations kept the window of their observing room open during fine weather. The observations were shipped to Mannheim not by the ordinary post but through diplomatic channels.[6] Any risk with regard to a possible loss of data should be avoided.

A total of 57 stations were invited to participate in the network and about 20 of them sent in observations in the first year (Voss, 1984). Data were published. Finally, data of only 39 stations were printed, some of which reported only for a few years (Fig. 5; Table in Appendix). The reason why another 18 stations did not send in data were complex: at some of them, only broken instruments arrived, others like London or Vienna might have had no confidence in the success of the project. In the first volume of the Ephemerides, the letters of confirmation were published. Père Louis Cotte in Paris, although having agreed to contribute to the network, never sent in data, probably because of broken instruments.[7]

Von Stengel succeeded in convincing the prelate of the Bavarian monastery of Rottenbuch, being responsible for the operation of the station Hohenpeissenberg, to install another atmospheric electrometer (Bertucci, 2007; Winkler, 2005). He personally brought the fragile barometers and thermometers to some of the Bavarian stations.

355 At some of the places meteorological observations already existed, although with interruptions: e.g. in Berlin (1719) (Cubasch and Kadow, 2011), Bologna (Camuffo, 2002b), Göttingen (Gatterer, 1780); Copenhagen (1767) Geneva (1753) (Häderli et. al., 2020), Marseille (1749), Regensburg (1773), Padua (1725), Petersburg (1751), Prague (1775), Stockholm (1756) (Moberg et al, 2002), Sagan (1773) (Felbiger, 1773), Würzburg (1773) (Rudloff, 1967; Camuffo, 2002b; Winkler, 2020). The new society thus coordinated these activities.

360 Phenological observations were initiated by the Societas Palatina in many countries like Belgium (Ihne, 1894; Demarée and Chuine, 2006), Italy, France, Norway, Russia, or supplemented in Germany, Switzerland, Sweden and Finland (Cappel, 1980a). In Mannheim the military major Denis started phenological observations in 1783.

At some stations physicians studied the disease pattern of the local population: M. Güthe and J. N. Fischer in Mannheim, Winkler in Regensburg, Cloos in Stockholm, and van Breda in Delft (Hemmer, 1785/86). They provided the requested data.

365 The network became well known and stimulated scientists to report data from additional stations outside the meteorological society, e.g. meteorological data from the African Isles of France (Mauritius) and Bourbon (Reunion) were reported by M. Brunel, member of the Académie des Sciences de Bréziers, and data of Poona in India by the Belgian scholar Malavois (Ephemerides of 1788, p. 400). In 1791 Brunel was nominated as an external member of the Academy of Sciences in Mannheim (Voss, 1994).

370 Both, the regular instrumental observation and observation of the state of the heaven turned out to be most important for scientific progress. Although not published in the Ephemerides and although many interpretations were later found to be wrong, meteorological phenomena were discovered and described: e.g. the thunderstorm hook (Heinrich, 1794). Another point was the overcoming of religious practices in handling natural hazards, e g. ringing church bells or shooting guns in order to disperse thunderclouds.

375 Because Hemmer's organization and management of this station network had previously turned out to be exceedingly efficient based on steering the individual stations from a central station, which also collected and published the data, it became a model for later meteorological and other networks e.g. that of the Magnetic Association of Göttingen organised by Humboldt and Gauss in 1834.

**3.3 Expenses to print the Ephemerides**

380 The costs for paper and printing of the first three data volumes were very high and appreciably stressed the academic fund for other tasks (Archive of Bavarian Academy of Sciences, Sign. VII, I 26, l: fol. 4.):

| | |
|---|---|
| Descriptio Instrumentorum | 28 Gulden (florines) 32 Kreuzer |
| Ephemerides 1783, Vol. I | 1285 Gulden 22 Kreuzer |
| Ephemerides 1784, Vol. II | 1604 Gulden 21 Kreuzer |

385    Ephemerides 1785, Vol III        1942 Gulden 35 Kreuzer

To rate these expenses, we can compare them with Hemmer's yearly salary as secretary of the Meteorological Society, which amounted to 300 Gulden. The whole budget of the Academy amounted to 6000 Gulden, from which 1200 Gulden had to be paid to other societies. The budget was not raised when the meteorological class was arranged. Interests arising from the foundation capital could not compensate the expenses of the meteorological class. After summing up the salaries only 1500

390    Gulden remained for printing the Meteorological Ephemerides. Thus, it became difficult to publish the data of all stations in extenso in each year. Clearly, a single academy was financially overwhelmed with the high printing costs of this European project but no effort was undertaken for sharing the costs among more participants.

To remain able to print the following volumes, the number of stations from which the data were published was either reduced or the data were not printed completely, but only daily or monthly means. When in later years the financial resources reduced

395    further, the members of the Academy abdicated their weekly fee for attending the sessions (Fuchs, 1963).

Progress was slow and small; scientific meetings could have been helpful but were too difficult to organise. Instead, scientific academies in numerous cities allowed to discuss findings and scientific questions. The local view on the weather still prevailed and large-scale (synoptic) pressure systems and their movement were unknown.

The great interest in observing nature stimulated engagement and participation, although most scholars of that time can be

400    compared to unexperienced pupils and adolescents who are in the process of learning and who make many mistakes and misinterpretations, because the magnitude of effects are overinterpreted.

Lalande mentioned in his Bibliographie astronomique (1803) the 10th volume of the Ephemerides for the year 1790, printed in 1793. He regretted very much the reduced size of the volume comprising only 319 pages, whereas the volume of 1783 had 800 pages. For scholars the completeness of the observed datasets was much more important than the commercial aspects.

405    **3.4 Hemmer's death and the demise of the Societas Meteorologica Palatina**

On April 28th 1790, Hemmer suddenly suffered from an attack of weakness ("Hypochondriasis") while he was installing a lightning rod. He died few days later on Mai 3th at the age of 56 years (Budde, 2014). An autopsy showed heart problems, causing a stroke (Anonymous, 1915). During the past two years he had suffered from palpitations. The engine of the meteorological society was now without steam. Ten of Hemmer's scientific papers were printed in the last physical volume of

410    the Acta Academicae Theodoro Palatina in 1790.

After Hemmer's death in 1790, no new secretary of the meteorological society was nominated. As editor of the Ephemerides the physician Melchior Güthe (1753-1812) was employed. The engagement and energy, which Hemmer had brought in, was missing and the whole project slowed down (Stephan, 2017). Güthe even didn't take care of the observations in the meteorological cabinet and had no interest in the physical cabinet and he refused to take over the correspondence. St. von

415    Stengel deplored this development very much, but neither he nor his father was in a position to bring the academy of sciences in Mannheim back to the earlier efforts in meteorological research. A successor with the personal engagement of Hemmer couldn't be found.

Soon after Hemmer's death the situation of the Academy of Mannheim deteriorated more and more. The budget was based to a great part on interest income from mortgages being invested in several hypothecary credits created mainly at the left side of river Rhine. When in the beginning Napoleon wars, the French troops advanced in 1792 to the Rhine the academic budget diminished dramatically (Kreutz, 2014): already since 1791 no price question could be issued. Since 1793 vacant positions at the academy were not filled again and since 1794, when the left side of river Rhine was occupied completely, no volume of the academic series Acta Academiae Theodoro Palatina could be printed. Thus, personal and financial bottlenecks induced the demise of the meteorological society. In the meantime, it had become evident, that periodic variations in atmospheric pressure by the moon were very small and the hope of becoming able to make a meteorological prognosis had to be abandoned. The Academy of Sciences in Munich, operating a regional network, ended this project in 1800 with the argument that the observers had only provided a collection of data (Winkler, 2020; protocol of Febr. 4$^{th}$, 1800). Maybe, that after Karl Theodor's death in 1799, anti-academic forces in the new government in Munich had requested to terminate the project.

In November of the year 1795, the western wing of the castle of Mannheim was shot on fire by Austrian troupes. In this part the meteorological cabinet was destroyed including the archive with the irreplaceable original meteorological tables, a terrible loss for science. This violent destruction of the centre of the Meteorological Society implied the end of the coordination and collection of the tables.

In is astonishing that in 1802, seven years after the last volume of the Ephemerides was printed, the "weather society" with all national and international members was still mentioned in the official calendar "Kurfürstlich Pfalzbaierischer Hof- und Staatskalender auf das Jahr 1802" which means, that the Societas Meteorologica Palatina formally still existed, although being inactive since many years and although the founder Karl Theodor had died in February of 1799.

## 4. Results and Reception

### 4.1 Data quality

Since the measurement of atmospheric pressure was regarded as more important than that of ambient temperature, some of the stations like Regensburg (Ratisbonum) and Hohenpeissenberg kept the window of the observing room open during fine weather for the first years as mentioned above. Thus, temperatures measured in a screen at an open window could be partly biased by air from the interior of the building.

The data collected in the 12 Ephemerides have often been considered as representative for the pre-industrial period, especially with regard to obtaining information about climate change. However, this somewhat indiscriminate adoption of these data needs to be scrutinized: With respect to the temperature records, it has been overlooked, that the zero point of thermometers was not stable as mentioned above. Hemmer, although he didn't know of this effect, emphasized from experience that it was necessary to manufacture all instruments from the same glass. In the 1820s this effect was discussed broadly and most physicists attributed it to the atmospheric pressure which would compress the evacuated thermometers (e.g. Yelin, 1824). In

450 the 1880s, the instability of the glass could be attributed to the glass mixture. Mixtures for thermometers were optimized and the cause for the secular rise of thermometer zero points was better understood (Krause, 1974; Winkler, 2009a; 2009b). This secular rise of the zero point was of the order of 0.65°C in the first 5-6 years (Lamont, 1851; Winkler, 2009a). Nevertheless, many homogenizations were performed without considering the instrumental bias. In 1826 the zero point of the thermometer in Stockholm was checked and found to be too high by 0,75°C, unfortunately without notifying the period in which this

455 thermometer was used (Moberg et al., 2002). The recognition of the instable zero point of thermometers did not lead to corrections of past data at all stations. Recently, Pappert et al. (2021) have applied these findings for correcting and homogenising temperature and pressure observations of the Palatina network to make the data more usable for climate change issues.

Other instrumental deficiencies and uncertainties of historical thermometry are described for example in (Pelz, 1993). Brander

460 as an experienced and thorough manufacturer of thermometers had already arranged an intercomparison with other manufacturers (Christin in Lion, France and König in Franecker, The Netherlands) in 1757 and achieved good agreement (Winkler, 2017). But even when temperatures of neighbouring stations agree well, the thermometers might suffer from a similar rise of the zero point.

Other instrumental deficiencies were recognized earlier: barometer deterioration due to oxidation of mercury or by penetration

465 of air into the vacuum. The capillary depression was studied by (Pilgram, 1788) but no conclusions were drawn on the barometer reading technique or on necessary corrections to be applied. It was also unclear whether the mercury position should be read at the top of the meniscus or at the edge of the mercury column at the glass wall. Later it turned out that the height of the cap may vary with time depending on the chemistry of the glass influencing the contact angle because the glass changed its volume due to slow diffusion effects in the crystalline structure of sodium and potassium ions. This is important when

470 homogenisation is undertaken.

The hygrometers in use provided some coarse information on humidity. For the goose spell hygrometers, Chiminello in Padua had developed a method compensating the thermal expansion of mercury on its volume (Cocheo and Camuffo, 2000; Camuffo, 2002b), and he won half of the corresponding price of the Academy of Sciences in Mannheim in 1783 (Hemmer, 1783/84). However, a uniform volume change of goose spells with temperature can be expected only when they are more or less perfect

475 in roundness (Winkler, 2009b). Heinrich in Regensburg performed comparisons of goose spell and gut string hygrometers (Fig. 6) which showed, that the goose spell hygrometer reacted relatively linearly whereas the gut string did not.

The magnetic needle in the declinometer could be disturbed by iron pieces near the instrument. Such a disturbance was unknown at that time.

Despite of these instrumental deficiencies, a multitude of valuable information on basic meteorology, weather and climate has

480 been derived from the data pool collected by the Societas Meteorologica Palatina.

**4.2 The Ephemerides and scientific results presented therein**

In the Ephemerides the data were published partly in extenso partly as monthly means. For a long time, this collection of data was the only basis for scientific use (Fig. 7).

485 Short reports on special themes were also printed in the Ephemerides as shown below. In most cases only observations and their interpretations were reported. Real physical understanding was low at that time; however, physical methods were applied:

- Ephemerides 1783 (Vol. IV, 1785): Hemmer wrote on the dry fog over Europe 1783, not accepting the widespread hypothesis of its volcanic origin. The availability of a hygrometer allowed to conclude that the turbidity of the air was not caused by water droplets (Stephan, 2017; Cappel, 1980c).

490
- About the same item more opinions were presented by König, Maret, Senebier. van Swinden. Holmius described the eruption of Laki in Iceland and its destructive effects.

- Other scientists argued that the dry fog originated from the earthquake in Calabria in February 1783 (Torcia, 1784). At this time, no information and even no imagination existed on the strength and direction of the upper airflow. As a consequence, erroneous conclusions were drawn easily.

495
- Planer: Diurnal pressure variations based on readings every 4 hours were attributed to the effects by the moon, atmospheric electricity and wind.

- In the second volume Steiglehner published a comparison of the barometric pressure readings at three stations (Regensburg, London and Petersburg) between December 1775 and January 1776. Based on these data he recognized the eastward propagation of pressure minima. Steiglehner's primary idea was a study of the number and mean duration

500 of "pressure oscillations" per year which he adopted and continued as a similar approach of van Swinden in the Netherlands. He hoped to become able to predict the pressure tendency for the next three hours as argued in another private publication (Steiglehner, 1783).

- S. Williams presented yearly barometric and thermometric maxima and minima from Bradford (USA) for the years 1771 to 1776. Wigglesworth presented monthly barometric and thermometric maxima and minima of the years 1781

505 - 1783.

- In the Ephemerides for 1787 (Vol. VI), van de Perre published observations of tides at Middelburg, Vlissingen and Westcapella.

- Hemmer presented hourly data of atmospheric pressure monitored with the recording barometer of Changeux in the volume VI of the Ephemerides containing the data of 1788 and he became aware that a daily cycle existed which,

510 therefore, he could only attribute to influences by the sun, but not the moon (Hemmer, 1790).

- Chiminello had calculated daily courses of the temperature of Padua for the years 1788 and 1789 (Ephemerides of the year 1789, printed 1793) and Toaldo presented average temperatures of several cities in Italy, including Rome, Chioggia, and Padua, however, only the number of years of observation were given but not the overall period.

The attractiveness of the Ephemerides was obviously large and many additional observations could have been accepted for
515 inclusion. However, the printing costs were very high and the volumes sold less frequently than expected.

After Hemmer's death in 1790, the physician Johann Melchior Güthe (1753-1811) edited the following volumes, without investing the necessary energy or enthusiasm. Thus, volumes XI and XII appeared only in 1794 and 1795, respectively.

The Bavarian and many international stations continued their observations until 1803, when the monasteries were secularized, except Hohenpeissenberg, where the observer was obliged by the ministry to continue the observations without interruption.
520 Many other stations of the network continued the observation program as well.

In 1806, the Academy in Mannheim was closed and the remnant documents transferred to Munich. Among these were the lead letters with the symbols for typesetting (Archive of Bavarian Academy of Sciences, Sign. VII 453 - 454).

## 4.3 Early and modern scientific evaluations of the meteorological observations

525 The collected data found a broad interest very early: Thomas Jefferson, the later president of the United States, while travelling through Marseille in 1787, asked his correspondent W. Short in Paris in a letter of May 5th, to buy for him the first volumes of the Ephemerides (Jefferson, 1983). He might have been informed about them during a visit to the Academy or the astronomical observatory of Marseille. The data of the meteorological society were evaluated very often which shows the exceptional importance of the Ephemerides. The data have been used in numerous textbooks especially for presenting climatological
530 information (Kämtz, 1831, 1832, 1836). Only few examples of the scientific outcome are listed below, without claim of completness, and shall illustrate this.

1. The frequent cold weather in upper Bavaria was wrongly attributed entirely to the proximity of the Alps. However, by an evaluation of temperatures as a function of the elevation of stations, Stephan von Stengel showed that the elevation rather than the distance from the Alps is responsible for the local average temperature (Stengel, 1786).

535 2. To facilitate the pressure readings to the prescribed temperature of 10° Reaumur Guarin Schlögl (1752-1788), observer at Hohenpeissenberg, calculated tables from which the correction value could be retrieved (Schlögl, 1787). The pressure range, for which his tables could be applied, included the highest station, St. Gotthard in the Alps. Although the adopted coefficient of expansion of mercury was slightly too large, these tables helped to avoid errors, when the pressure reduction would be calculated manually.

540 3. In 1791 the observer Albin Schwaiger compiled a climatology of the station Hohenpeissenberg using the first ten years (Schwaiger, 1791). This work was stimulated by his abbot, who saw a need in presenting the observations to the public. In 1811 a second but unchanged edition appeared.

4. Père Cotte in Paris published a similar evaluation in 1792 for a number of French stations: barometric variations; numbers of frost days; magnetic declination, and other variables (Cotte, 1792).

545 5. Gelas Karner (1763-1816), another observer at Hohenpeissenberg, calculated the elevations asl. of 8 Palatina stations from barometric data in a very time-consuming work and published the results in 1812 (Karner, 1812).

6. Similarly, Placidus Heinrich from the monastery St. Emmeram in Regensburg calculated the height of stations along the river Danube down to Budapest (Heinrich, 1812). His results agree remarkably well with modern heights. This was the first paper from a station on the slope of a European river. This work was stimulated by Alexander von Humboldt, whom Heinrich had met in Paris.

7. In 1813 Placidus Heinrich published a climatological study on the temperature of St. Peterburg (Fig. 8), for which he had evaluated the data from 1772 to 1792, i.e. including the period covered by the Societas Meteorologica Palatina (Heinrich, 1813). His impetus was to inform scientists at least in Germany about the harsh climate in Russia. In order to enable a comparison with other cities he shifted the observations to the Gregorian Calendar being in use in Russia until 1918. He also recalculated the temperature for the scale of Reaumur from original Delisle's scale. In addition to the monthly mean temperature, he indicated the extremes.

8. An early evaluation of extremes and mean values of heat and cold from the Ephemerides has been conducted by Holyoke, a Massachusetts physician in Salem, USA. He was interested in excess heat and cold of America beyond that of Europe in the same latitude (Holyoke, 1793). His unrealistic conclusion was that the pine forests were causing the cold in America whereas in Europe the cutting down of forests since many centuries had brought a much milder climate. Being an adherer of the phlogiston theory, he was convinced that huge evergreen pine forests would absorb large amounts of phlogiston thus permanently producing dephlogisticated i. e. cold air. This is a typical example of obstructions in learning processes at that time.

9. An overview of the strong frost in December 1788 has been worked out by Strnad in Prague by evaluating the $8^{th}$ volume of the Ephemerides. He compared the peculiarities reported from all stations of the Palatina network and calculated cold-sums to be able to compare the winter strength in the different regions of Europe (Strnad, 1793). However, no map was constructed.

10. In 1817 A. von Humboldt used the temperature data of the Palatine Society and some other stations for the first construction of global isotherms (Humboldt, 1817). It is important to mention that for this construction he applied a reduction of the temperature of elevated locations to sea level and considered data quality as well as the lengths of observation periods. His idea was stimulated by the traditional so-called Macrobius maps of the climatic zones in which the isotherms run parallel to the equator (Humboldt, 1837), (Fig. 9). Using observed temperatures mainly from the Ephemerides Humboldt could show that the isotherms were not parallel to the equator and that in Europe the isotherms extended further to the north (a consequence of the heat transport by the Gulf-stream, which was still unknown at his time). Humboldt's graphical visualisation was an important progress as compared to the presentation of data in a simple table.

Macrobius was a Latin philosopher of the fifth century who had firstly described climatic zones in his Commentary of Ciceros work. Although he hardly can be considered as the inventor of climatic maps, this type bears his name. Examples of Macrobius-type maps can be found in many major libraries (Destombes, 1964, p. 85-95). The validity of the orientation of the climatic zones shown there was not questioned until Humboldt's analysis.

11. In 1818, Schön in Würzburg published a book on *Basics of the Atmosphere and Weather*. Here he presented graphs of the yearly variation of meteorological elements (Fig. 10). He also demonstrated, by connecting months with similar solar elevation, the asymmetric deviation of the yearly temperature variation from the sinusoidal solar insulation peaking at June 21th (Schön, 1818).

585
12. Volney investigated the influence of the sea on the temperature of coastal stations in France in 1821 and recognized the increasing continental influence with the distance from the coast (Volney, 1821).

13. In eastern Europe, the data of the station Budapest were used to extrapolate to meteorological parameters of other stations like Temeswar (Csernus-Molnár and Kiss, 2011; Csernus-Molnár et al., 2014).

14. Polar lights should be observed in the meteorological network and Aaspas evaluated the observations, regarding the
590
modern knowledge (Aspaas and Hansen, 2012), They counted about 1400 observations in the Ephemerides but their verification showed, that a large part of them were misinterpretations because noctilucent clouds were interpreted as polar lights. However, the data were used already earlier to identify the „polar-light-oval" (Fritz, 1874).

After strong solar mass eruptions auroras can be seen even in Mediterranean countries. In the Ephemerides (1788) auroras were reported on October 22/23 1788 at many stations (Rome, p. 96; Geneva, p. 332; Budapest, p. 354; Padua, p. 363). In
595
Mannheim a large deviation of the magnetic declination was noted and at Hohenpeissenberg, although overcast, unusual variations of the magnetic needle were reported. Hattori et al. (2021), who had found simultaneous reports on polar lights in Japan, could conclude on an extremely strong solar storm disturbing the geomagnetic field just before the onset of the Dalton minimum (1795 to 1830).

15. The variations of the magnetic needle during polar light events were known before 1750. Hemmer and other observers
600
confirmed this interaction by own observations (Hemmer, 1792). Wilse in Norway also described such effects (Federhofer, 2014) as well as the observer on Hohenpeissenberg (Bay. Akad. d. Wissenschaften, 1782-1796, vol. 1, 1783, p. 76). In 1806, Humboldt termed the effect of polar lights on the magnetic needle as magnetic storm. The periodicity of sun spots and declination was analysed by (Wolf, 1861, 1862), using stations of the Societas Meteorologica Palatina. Meanwhile, we understand the effect as an interaction of ring-currents induced in the high atmosphere by solar proton events with the
605
magnetic field of the earth.

16. The observations of magnetic declination turned out to be more valuable than originally expected. For example, books on applied geography of Hungary mentioned the historical data (Hunfalvy, 1882). Modern methods allow to calculate the secular change of the geomagnetic field (Fig. 11). The historical measurements were used for verification and quality control (Hunfalvy, 1882; Korte et al. 2009). Similarly, modelling of daily variations of the geomagnetic field (Cnossen
610
and Matzka, 2016) could be verified with historical measurements at Rome and Mannheim and allow to conclude on long-term variations in the ionosphere due to interactions with the solar activity from Maunder-minimum to the present status.

17. The pressure observations were used to construct first synoptic maps. The first trial was made by (Brandes, 1826), who used deviations from the mean instead of the unreduced pressure (Fig. 12). In 1898, Hildebrandsson and Teisserance de Bort (1898), who applied the meantime collected meteorological knowledge, showed isobars in a re-evaluation and by

615      plotting wind arrows they could demonstrate the convergence of surface-near air into a low. The discovery of this phenomenon is usually ascribed to Dove (1857). More recently, monthly pressure maps for 1781-1788 were calculated by Gisler (1985) and daily pressure maps were drawn by Kington (1988) using the data of the Ephemerides. A similar evaluation considering some improvements was published by McNally (2004). In all cases, the data of the Palatine Society provided an important data source.

620 18. Using the historic observations, the global circulation patterns between 1781 and 1785 have been reconstructed by (Yiou et al., 2014), in order to visualise the dispersion of the ash-cloud of the Laki eruption in Iceland over Europe in 1783. A thesis at the University of Rennes focused on the same eruption in using the Ephemerides (Hellmann, 2021).

19. An apparent cluster of floods could be recognized in the mid-1780's. The winters in 1784 and 1789 were extremely cold and the Palatina network data shows these conditions spreading all over Europe: The temperature in Padua stayed below

625      zero for many days in January and dropped as low as -12°C in February 1784. As a consequence, the Lagoon of Venice froze in both years (Camuffo et al., 2017), and Lake Constance in 1789 (Meichle, 1963). The river Rhine was also frozen. Due to a rapid warming in February 1784 a centenary flood causing huge damages occurred in many parts of Europe (Anonymous, 1784). In the Ephemerides such events were not explicitly mentioned, although the observers might have reported them. However, using the published data, the meteorological situation could be reconstructed (Brázdil et al,

630      2010).

20. A historic storm over the North Sea on 21/22th March 1791 causing a flood in Hamburg could be re-analysed by Lamb (1991). At this time the moon had a minimal distance to earth. Historical storm surges in the Adriatic Sea have been re-evaluated by (Raicich, 2015).

21. The quality of historical precipitation measurements was studied by Braun, who investigated errors due to placing the

635      precipitation collector in different heights above ground. He compared, amongst others, data collected by Böckmann in Baden with those collected by Hemmer (Braun, 1885). A recent attempt to reconstruct a long series of precipitation measurements for the station of Padua was tried by Camuffo et al. (2020).

22. Astro-meteorological influences of the moon and the planets on weather as postulated by Hell in Vienna (Hell, 1775) and Toaldo in Padua (Toaldo, 1777b) had stimulated the work of the Palatine meteorological network. This hypothesis was

640      later re-examined by (Lamarck, 1798; Cotte, 1805; Ellinger, 1814; Celoria, 1874), however, due to missing knowledge of statistical significance they erroneously believed to have proven an effect of the moon on meteorological processes.

23. The temperature measurements of the Palatine network have turned out to be important for comparison resp. calibration of proxy-data derived from tree-ring evaluations (Holopainen, 2005) or from mussel shells (Grafenstein et al. 1996). The cold year 1784 already mentioned above was responsible for an exceptionally narrow tree ring in Northern Europe, and

645      also here the data of the Ephemerides were used for confirmation (Kalela-Brundin, 1996). The data of the Palatina network has been used to calculate European maps of the deviation of the summer temperature from the mean (Schweingruber et al., 1991).

24. The synopsis of time series of atmospheric pressure gave insight into parallel developments at various places which paved the way for recognising the extension of atmospheric pressure systems (Daniell, 1827).

650  25. Nicander in Stockholm constructed a meteorological table for a 21-year period ending in 1795, i. e. including the Palatina period, in order to investigate the influence of weather on mortality due to different diseases. He was convinced that influenza in Sweden could originate from Siberia and vice versa. When he compared the barometric variations with diseases no clear results were obtained (Nicander, 1801). This first trial to study meteorological influences on human health was imitated by other scientists. The concept of the Societas Meteorologica Palatina to collect meteorological

655  together with data of diseases provided the necessary basis. After a comparative study on influenza waves in Europe in the year 1782 about one third of the population of Rome and nearly all of the population of Regensburg fell sick with this infection (Ripperger, 1892). This information could be based on data of the Ephemerides.

### 4.4 Poor knowledge and lessons to be learned

Due to the prevailing focus on the local weather no information existed on large-scale pressure systems and on wind systems

660  in upper atmospheric levels. Thus, the data were often prone to misinterpretations. As mentioned earlier, the dry fog in the year 1783 originated from the volcano Laki in Iceland. Many scholars had doubt that the ash could be transported over such far distances. Professor Lichtenberg at the University of Göttingen, who thought about the unusual dry fog, was convinced, that it was responsible for frequent thunderstorm formation. He termed this mysterious fog as "nebula nebularum" and investigated the air quality but found no conspicuous change of the properties (Hochadel, 2009). Therefore, he supposed that

665  the air might have lost some of its constituents because they were washed out by rainwater. Being unable to find a convincing explanation he wished that the strange fog would have stayed in Calabria, where he assumed its origin.

Another misinterpretation was published by Hemmer in 1790: He had proven in an experiment that a flame would produce free electrical charges. This led him to conclude that a fume from a house was strongly electrified and had attracted parts of a cloud passing that place (Hemmer, 1990).

670  Schön in Würzburg also studied the results of the meteorological society being stimulated by Heinrich in Regensburg. He found the pressure variations to increase with increasing latitude (Schön, 1818; Daniell, 1827). Because no stations in high latitudes were available, he concluded that the barometric variation would generally increase with increasing latitude.

A very important progress for science during the enlightenment era was the edition of numerous journals in all countries. Here, new ideas were scrutinized and the interpretation of experiments was questioned. When studying historical papers, we easily

675  recognise that most scholars were well informed about the state of knowledge. The data of the Palatina were used immediately after appearance with many attempts for interpretation and gaining understanding. For example, (Rosenthal, 1784/85) compared the temperatures of the two neighbouring stations Hohenpeissenberg (ca. 1000 m) and Andechs (ca 700 m) and found the pressure difference to be not constant in the yearly course. He concluded the atmospheric pressure data could be doubtful. He didn't know that in winter Andechs was frequently lying within the cold valley pool where the pressure was

680  higher due to the greater density of air whereas Hohenpeissenberg was mostly above the topping inversion. Despite these

misinterpretations, the harmonized instruments provided correct results and the exploration of new unexpected phenomena led to scientific and methodological progress.

Other scholars were glad that by such an observation program as set up by the Societas Palatina antiquated opinions would be overcome such as: "the atmosphere and especially clouds should be regarded as the footrest of God" (Ernesti, 1773; Hollmann, 1783). Such opinions were deduced from bible translations and still taught by theologists who educated the pupils and students. Thus, the observation of meteorological phenomena was an important step to a physical view on nature.

The available instruments misled some scholars to believe in meteorological effects which in fact did not exist as such. Although many errors and misinterpretations occurred, the data base in the Ephemerides remained available and was used by persons who had not been observers in the network. More political insight into the usefulness of such a long-term and diverse data collection is needed with respect to its fostering of both progress in science and education for the general benefit of society. However, decision makers still need to be convinced that basic science fundamentally depends on data to be evaluated without the expectation of immediate commercial applicability.

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[1] While Kleinert (2009) could not identify the source with the original quote, Haustein (2004) states as the source Galileo: Il saggiatore (1623).

[2] The Palatinate was one of seven more important of the many princedoms and counties forming Germany during the period of the Holy Roman Empire. Its sovereign was one of the seven „electors", being empowered to elect the German King.

[3] The speech was held in German but printed in Latin in the first volume of the Ephemerides (1783), p. 18-23.

[4] On 27th May 1781 Lichtenberg mentioned in a letter (no. 817) to the printer Schwan in Mannheim, that he had not obtained the promised instruments. In a third letter to the Scientific Society of Göttingen, dated 29th Nov. 1781 (letter no. 876), he explained not to be able to do the observations due to lack of time and that Gatterer most easily could take over the task.

[5] Gatterer's disregard of Wilse is mentioned in a circulation letter (Lichtenberg, 1985, Vol. II, letter No. 838 of 7th Jul. 1781). Wilse had previously published two books referring to meteorology (Wilse, 1778; Wilse, 1780) which were known to Gatterer.

[6] Private contacts were also typical in this time and were used for a safe shipment of the tables: e.g. Bernoulli took over meteorological tables from Marseille (letter Bernoulli to secretary Lamey, 15th Aug. 1793 in Generallandesarchiv Karlsruhe, Abt. S, Kremer-Lamey, vol. 133, fol 189.

[7] Cotte's letter to Lavoisier, cited by Cassidy (1985, footnote 55). Cassidy mentions in footnote 12, that only one of three cases with instruments reached Cotte but the instruments were broken during control by customs. One of the lost shipments contained the barometer and thermometer, the other the declinometer. However, they reappeared in 1789 in a bureau en Champagne (p. 194).

[8] Reproduction of a collage containing the foundation charter. This collage in the Library of German Weather Service was most probably compiled on the occasion of the 200-year anniversary of the Societas Meteorologica Palatina in 1981.

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The contact author has declared that he has no competing interests.

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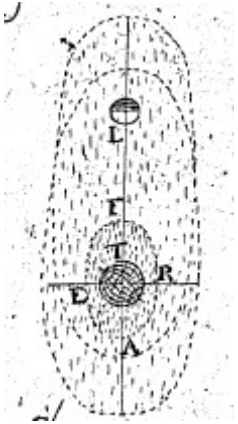
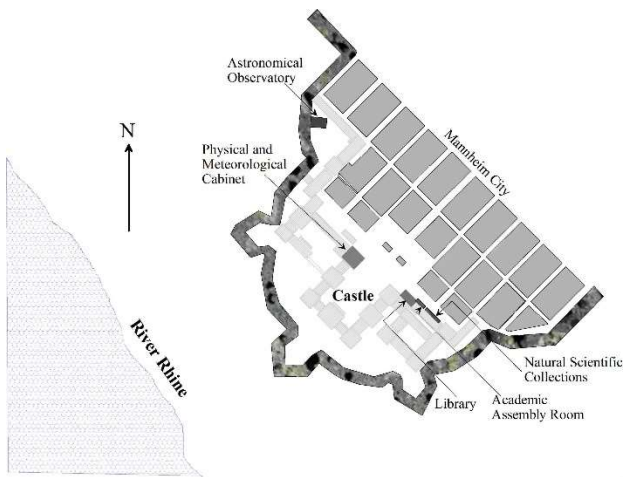
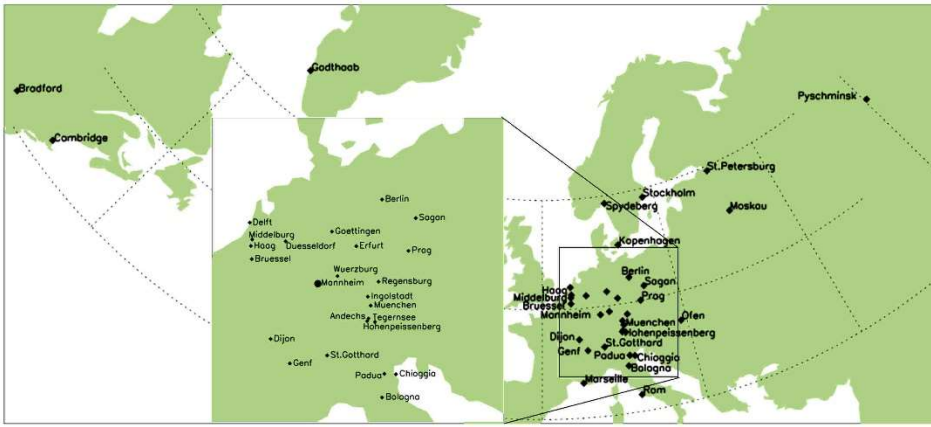


**Figure 1: Gravitational deformation of the earth's atmosphere A by the moon L (Kratzenstein, 1747: Table in annex, Fig. 1).**

1045

**Figure 2: Portraits of Karl Theodor (Bavarian National Museum, Munich, Inv. No. L 2009/40.1), Stephan von Stengel (Reiss-Engelhorn-Museum, Mannheim, photo: Jean Christen), Johann Jakob Hemmer (private property).**

1050 **Figure 3 Collage containing a copy of the foundation charter in the Library of German Weather Service, most probably compiled on the occasion of the 200-year anniversary of the Societas Meteorologica Palatina in 1980 (Symposium, Mannheim, October 13th-15th 1980).**

1055 **Figure 4: Central station of the Societas Meteorologica Palatina in the Castle of Mannheim (historical situation showing the city wall, the castle and parts of the adjacent city). A model of the meteorological cabinet is available in TECHNOSEUM Mannheim (photo: Klaus Luginsland). The antenna of the atmospheric electrometer is seen on the roof to the right of the wind vane.**

1060 **Figure 5: Map with stations of the network of the Societas Meteorologica Palatina (1781-1792). Table 1 in the annex lists the stations and the duration of observations.**

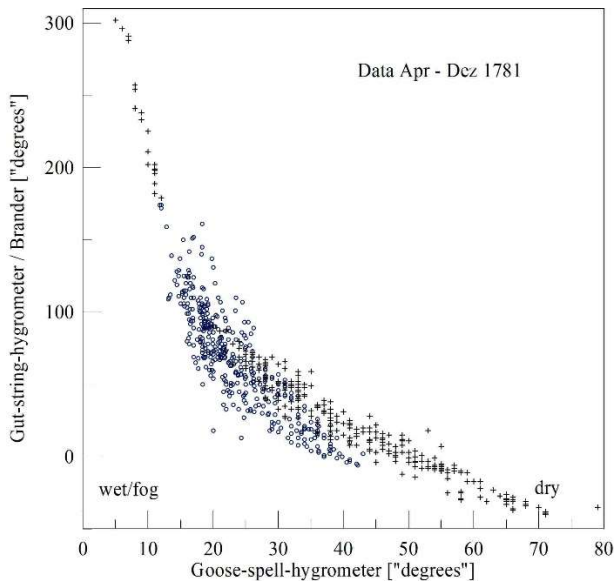



**Figure 6: Comparison of goose spell vs. gut string hygrometers in Regensburg, 1781 (crosses: April – May 1781; circles: September**
1065 **– December 1781). Although Hemmer knew the gut-string hygrometer, he preferred the goose-spell instrument, which had a better linearity with humidity.**

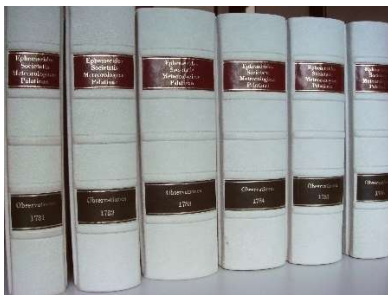



**Figure 7: Ephemerides Meteorologicae Palatinae (photo: Peter Winkler, Observatory Hohenpeissenberg, 2006).**

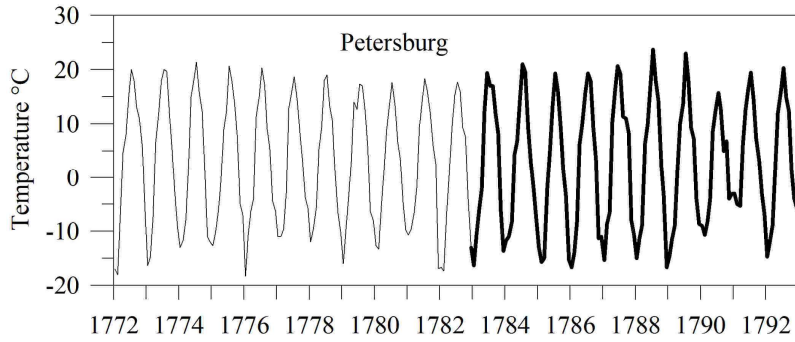



**Figure 8: Monthly mean temperatures of St. Petersburg. The bold line shows the data taken from the Ephemerides of the Societas meteorologica Palatina.**

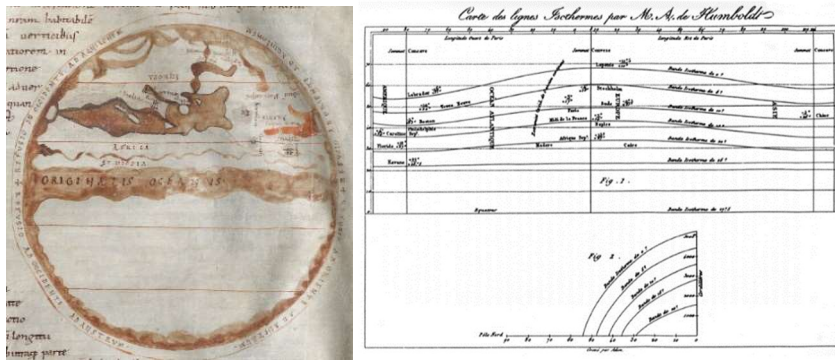



**Figure 9: Left: Example of a traditional Macrobius map (Bavarian States Library), Clm 6362; fol. 74$^r$, miscellany, containing Macrobius' Commentaries on Cicero's "The Dream of Scipio" (11. century; a similar map in Clm 15378, fol. 217r, 15$^{th}$ century) shows also five climate zones running parallel to the equator. Right: Humboldt's isotherms in 5°R distance (Humboldt, 1817) in the section 90° W to 120° E, the central vertical line marks 8° E. Continents are not indicated. His analysis showed that the isotherms do not run parallel to the equator. The lower panel shows the dependence of temperature on height (asl.) and, correspondingly, on geographical latitude.**

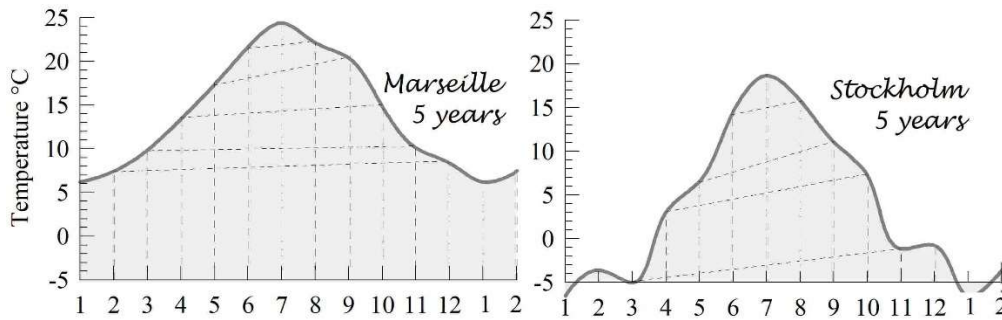



**Figure 10: Average yearly cycles of temperature at Marseille and Stockholm according to Schön (1818). The Y-scales, missing in the original, have been supplemented, harmonised and the units changed to °C. Schön connected months with the same solar elevation by inclined lines, in order to visualise the asymmetry of the yearly course of the temperature in relation to the sun's elevation.**

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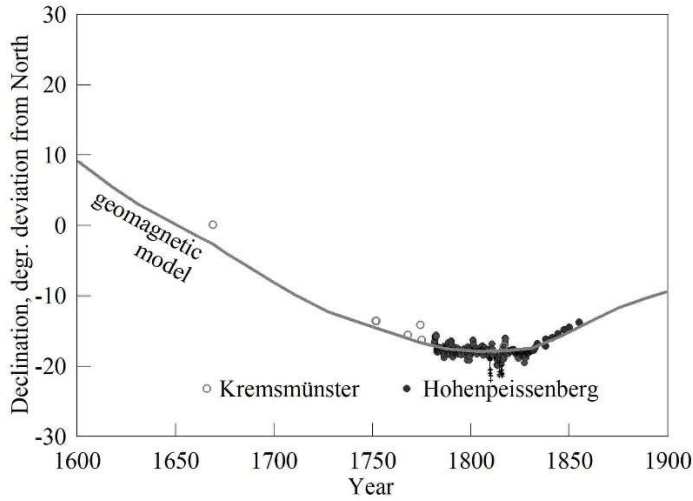
**Figure 11: Secular variation of the magnetic declination (model and observations) adapted from Korte et al. (2009). Crosses mark unreliable measurements, because the declinometer deviated from the northern direction.**

1090
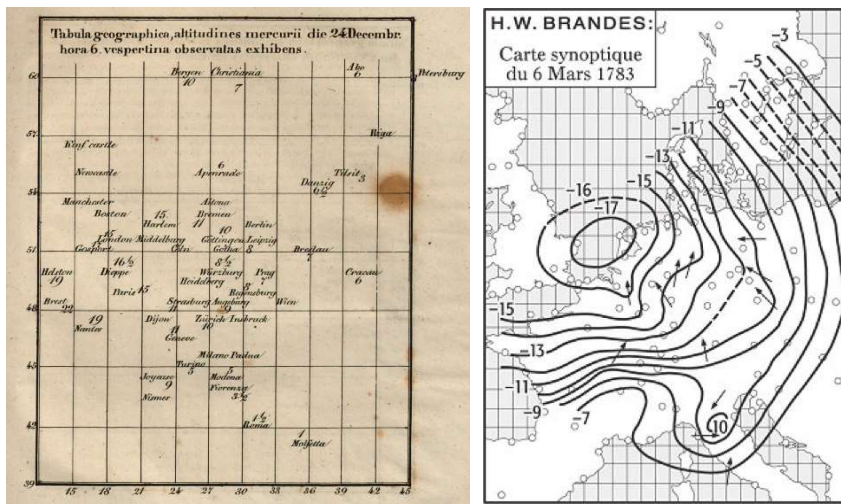
**Figure 12, left: First synoptic map of Dec. 24th 1783 based on data from the Ephemerides and supplemented by further observing stations, designed by (Brandes, 1826, Annex with a total of three maps); numbers show the negative pressure deviation from the**
1095 **stations average in Parisian lines (1 line=2,256 mmHg) the meridians are given in degrees east of the isle of Ferro, now El Hierro. Right: a reconstruction of the isobars by Hildebrandsson and Teisserance de Bort (1898) using data from the Ephemerides and the method of Brandes for March 6th 1783. In addition, they added reported wind vectors from which the convergence of the air flow to the pressure minima became obvious. Brandes had not yet recognised this physical law.**

 **Appendix**

**The Observers**

In the Meteorological Ephemerides of the Bavarian Academy of Sciences the observers are indicated more precisely than in the Ephemerides of Mannheim.

Some literature with information about observers or supplementing information is indicated at the end of the Table.

1105 **Table A1**

| Germany | Observers | Profession | data in Ephemerides |
|---------|-----------|------------|---------------------|
| Andechs 710 m asl. Monte Andex | Placidus Schärl (1731-1814) Clemens Kettl (1751-1808) Joseph Sanftl (1753-1803) Edmund Hochholzer (1764-1830) | Benedictines, monastery Andechs | 1781 1782 1783-1785 1786-1792 |
| Berlin Berolina | Nicolas de Beguelin (1714-1789) Franz Karl Achard (1753-1821)[1] | Members of Academy of Sciences | 1781-1787 1787-1788 |
| Düsseldorf | Matthias Pfennings[2] (1736-1783) Abt Johann Liessem (1759-?) | Acadademy of fine Arts | 1782 1783 |
| Erfurt Erfordia | Joh. Jacob Planer (1743-1789)[3] | Prof. medicine, chemistry, botany | 1781-1788 |
| Göttingen Gottinga | Christoph Gatterer (1759-1838)[4] | Prof. history | 1783-1785; 1787 |
| Hohenpeißenberg 988 m asl | Cajetan Fischer (1739-1790) Guarin Schlögl (1752-1788) Herkulan Schwaiger (1756-1830) Albin Schwaiger (1758-1824)[5] | Augustine priests, physicists, monastery Rottenbuch | 1781-1792 |
| Ingolstadt Ingolstadia | Coelestin Steiglehner (1738-1819)[6] | Prof. experimental physics | 11.1781-12.1782 |
| Mannheim | JJ Hemmer (1733-1790)[7] member of Academy of Science | Court priest, physicist | 1781-1790 1790-1792 |
| Munich Monachia | Theophilus Huepbaur (1749-1825)[8]; Maximus Imhof (1758-1817)[9] | Priest Priest, physicist | 1781-1787 1788-1792 |
| Regensburg Ratisbona | Placidus Heinrich (1758-1825)[10] | Benedictine Priest, physicist | 1781-1792 |
| Sagan | Christian Procop Theodat Preus[11] | Augustine; optician, | 1781-1792 |

| | († 1808) | astronomer | |
|---|---|---|---|
| St. Zeno | observator ignatus | Augustine | 1781 |
| Tegernsee | Gotthard Durmayr (1725-1783) | Benedictines | 1781-1782 (1783) |
| | Heinr. Donaubauer (1749-1826) | monastery Tegernsee | 1783 |
| | Maurus Magold (1761-1837) | | 1783-1786 |
| | Ottmar Schmid (1757-1822) | | 1786-1788 |
| | Martin Frischeisen (1766-1825) | | 1788-1790 |
| | Maurus Magold (1761-1837)[12] | | 1790-1792 |
| Würzburg Herbipolis | Ambrosius Egell (1732.1801)[13] | SJ, Prof. nat. science | 1781-1788 |
| Foreign countries | | | |
| Bologna Bononia | Petronio Matteucci (1717-1800)[14] | astronomer | 1782-1792 |
| Bradford | Samuel Williams (1743-1817)[15] | Prof. nat. science | 1782- |
| Brussels Bruxellae | Théodore Augustin Mann (1735-1809)[16] | Priest, Abbot; perman. secretary of the Academy | 1782, 85, 86, 1788-92 |
| Cambridge (Mass.) Cantabrigia | Edward Wigglesworth 1732-1794[17] | Prof. Theol. | 1785-1786 |
| Chioggia Fossa Claudia | Josepho [Giuseppe] Vianelli (1720-1803)[18] | Doctor of pharmacy. | 1782-1789 |
| Copenhagen Hafnia | Thomas Bugge (1740-1815)[19] | Astronomer | 1782-1788 7, 12, 21 hours |
| Delft | Hendrik van Swinden (1746-1823)[20] | Advokat | 1784; 1786 |
| Hague Hagen | van Swinden (see above)[20] | | 9.1782-12.1784 |
| Dijon | Hugues Maret (1726-1786)[21] M. Louis Caillet (1736-1800) | Dr. med.; Seretary of the Akademy of Dijon | 1783-1784 |
| Edsberg | Jacob Nicolai Wilse (1735-1801)[22] | Priest | 1787 |
| Geneva | Jean Senebier (1742-1809) Marc-Auguste Pictet (1752-1825)[23] | Preacher; librarian Physicist | 1782-1789 |
| Godthaab | Andres Ginge (1754-1812)[24] | Priest | 1786-1787 |
| La Rochelle | Pierre Seignette (1735-1807)[25] | Secret. Academy Scie. | 1782-1790 |

| | | | |
|---|---|---|---|
| Rupella | | | |
| Marseille Massilia | Jacques de Silvabelle (1722-1801)[26] | Astronomer | 1782-1792 |
| Middelburg Neth. Metelloburg | Adriaen van de Perre (1738-1790) [27] | Instrument maker | 6.1782-1788 8, 14, 21 hours |
| Moscow Moscovia | Heinrich Gottlieb Engel (1720-1785);[28] J. Gotthelf Stritter (1740-1801)[29] | Operator at hospital Court counsellor | 1783-84 1785-89; 1791-92 (96) |
| Ofen Buda | Franz Weisz (1717-1785)[30] Franz Bruna (1745-1817)[31] Franz Taucher (~1747-?)[32] | Astronomers at observatory Gerardsberg all three were Exjesuits | 1782-1785 1785-92 1785-92 |
| Padua Patavia | Guiseppe Toaldo (1719-1797); Vincenzo Chiminello (1741-1815)[33] | Astronomers Padua | 1781-1792 |
| Petersburg Petropolis | J. Albrecht Euler (1734-1800)[34] | Perpetual secretary of Academy of Sciences | 1783-1792 |
| Prague Praga | Antonin Strnad (1746-1799)[35] | Astronomer | 1782-87; 1789-91 |
| Pyschminsk | Benedikt Franz Johann Hermann (1755-1815)[36] | Engineer | 1791-1792 |
| Rome Roma | Abt Giuseppe Calandrelli (1749-1827)[37] | Astronomer | 1783-1792 |
| Spydeberg | Jacob Nicolaj Wilse (1706?-1786)[38] | see Edsberg | 1784-1786 |
| St. Gotthard 2093 m asl. | P. Onofrius; Laurentius Belmas de Caladray[39] | Priests | 1781-1791 1792 |
| Stockholm Holmia | Henric Nicander (1744-1815)[40] | Astronomer | 1783-1792 |

1 Allgemeine Deutsche Biographie, 1, 1875, p. 27-28.

2 Pfennings (Phennings) was Ex-Jesuit (†1783). Seiner kurfürstl. Durchleucht Hof- und Staatskalender, 1782, S. 359. After the abolition of the Jesuits in 1773, a congregation of secular priests continued to exist in Düsseldorf.

3 Deutsch and Börngen (2010, 2011). Planer observed mostly at 6 or 7 am, 14 am and 22 am.

1110   4 Heß (1878). Observations were continued in Göttingen after 1787, but not published in the Ephemerides. Neues Hannoversches Magazin 1803, Sp. 119 ff.

5 Winkler (2006).

6 Heinrich (1819).

7 Stephan (2017). Hemmer had Karl König as assistant.

1115   8 Bock (1802; Mayer and Westermayer, 1884, S. 518).

9 Bock (1802; Poggendorff (1863).

10 Hartmann (1829). Heinrich had several assistants who helped when he was busy.

11 Leipeld (1853, S. 246).

12 Bayerische Akademie der Wissenschaften, 1782-1796, Vol. 1783 (1785); Scheglmann (1908); Winkler (2020); Donaubaur seems to have assisted to Durmayr who had become sick.

13 (Hellmann (1883, S. 109).

14 Dizionario Biografico degli Italiani, Vol. 72 (2008).

15 Curti et al. (1970).

16 Demarée et al. (1994; Collart (2022). Mann had probably two assistants Needham and Chevalier.

17 Vinovskis (1971).

18 After Garlato (1883, p. 55), Vianelli was termed as "medico et meteorologo".

19 Bugge (1816).

20 Otto (1838, S. 430).

21 Gurlt and Hirsch (1886, Vol. 4, 1896, S. 133).

22 Wilse had sent his „Meteorographia Compendiosa" (1778) to Hemmer in 1782 (Federhofer, 2001).

23 Sigrist (2009); Cetta (2011); Häderli et al. (2020).

24 Ginge went to Godthaab in 1782 and sent meteorological observations to Bugge in Copenhagen who provided the first instruments (Egede, 1790, p. 307). He later obtained instruments from Hemmer and placed them in the church, who published the results 1786 and 1787 (Demarée and Ogilvie (2021, p. 145).

25 Rainguet (1851, p. 552).

26 Masson (1921, p. 783-787).

27 Dutch instrument maker (Zuidervaart, 2006).

28 J. G. Engel was born near Halle in Saxony, Germany (Goldbeck, 1783); he had employments at many locations in Russia before he became operator at the first military hospital in Moscow in 1762. He observed at 6, 14 and 22 hours but in parts of 1782 at 7, 14, and 22 hours.

29 Poggendorff (1863). Stritter, born in Germany, was a teacher of history and deputy head at the Gymnasium of the Academy of St. Petersburg, before he changed to Moscow in 1785, where he became conservator of the imperial archive (Friedrich, 1893). He regularly sent his observations to the Academy of Sciences in Petersburg, as is noted in the protocols.

30 Poggendorff (1863); Hunfalvy (1882, p. 863).

31 Poggendorff (1863).

32 Wurzbach (Vol. 43, 1881, p. 135).

33 Camuffo (2002b); Torcia (1784); Chiminello was the nephew of Toaldo.

34 Stäckel (1910).

35 Novotná and Kalvoda (2013). The Observatory was situated in the Clementinum, 2nd floor in his dwell (Fritsch, 1850).

36 Flügel (2006).

37 Wolfschmidt (2022).

38 Federhofer (2001).

39 Both were Capuchin monks from Milan.

40 Yaskell (2008).

**Figure A1: First row (left to right): Franz Karl Achard, Berlin (a); Nicolas de Beguelin, Berlin (b); Thomas Bugge, Copenhagen (c); Giuseppe Calandrelli, Rome (d); Vincenzo Chiminello, Padua (e); Giuseppe Tolado, Padua (f); second row: Alexander Euler, Petersburg (g); Coelestin Steiglehner, Ingolstadt (h) (photo Peter Ferstl); Benedikt Franz Hermann, Pyschminsk (i); Christoph Gatterer, Göttingen (j); Theophilus Huepbaur, Munich (k); Maximus Imhof, Munich (l); third row: Theodore Augustine Mann,**