Chapter 12
History of the Gdańsk Pre-Instrumental and Instrumental Record of Meteorological Observations and Analysis of Selected Air Pressure Observations

Janusz Filipiak and Mirosław Miętus

12.1 Introduction

As proven by the course of historical events, meteorological and climatic conditions determined the social and economic development of particular nations and regions. Despite a significant, scientific and technological progress they have still been deciding about the development of numerous areas.

Recently observed the climate change has significant consequences for the future of environment and mankind (IPCC 2007). Changes which we experience now have the global extent, anthropogenic origin, probably are non-inversed and very difficult to delay. Contemporary, instrumental meteorological observations cover only the period of last couple of centuries. For many reasons it is not satisfactory and therefore all attempts to prolong instrumental records in the past are very important. Many affords have been spent to search the missing early instrumental records as well as pre-instrumental information on past weather and climate (Manley 1974; Bärring et al. 1999; Jones et al. 1999; Camuffo and Jones 2002) For these reasons data archaeology and data rescue play an important role in modern climatology.

The history of meteorological observations in Poland has not been completely identified yet, what is mainly due to the fact that this country has a complex history.

In 1795, when Poland vanished from the political map of Europe, the development of particular areas and their inhabitants was determined by foreign superpower for 123 years. In the twentieth century, two World Wars were waged on the territory of Poland. The second of the mentioned above was aimed at a total destruction of Polish cultural and historical achievement.

J. Filipiak (✉) and M. Miętus
Department of Meteorology and Climatology, University of Gdańsk,
Dmowskiego 16a, 80-264 Gdańsk, Poland
e-mail: filipiak@ug.edu.pl

M. Miętus
Institute of Meteorology and Water Management, Podleśna 61, 01–673 WARSZAWA, Poland

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The extend of destruction, in terms of cultural heritage, technological infrastructure and the health condition of Polish population, led to focusing mainly on the reconstruction of the country from all the damages after the II World War. Similarly, Polish climatologists and historians, although perfectly educated and prepared to work with material evidence and old documents, were not interested into the history of meteorological observations at all. It must be emphasized that the search for the archive of a pre-war National Institute of Meteorology was held shortly after the war; however, it constitutes the only significant attempt of searching in such wide scale. Hence, it enabled some historical materials to be found and brought back to Poland.

It was not until the early 1990s when the search of historical meteorological materials was started in Polish libraries and archives. The research involved a significant number of abroad institutions, as well. This led to the discovery in the archive of the German Weather Service (DWD) archival materials concerning the territory of the contemporary northern and western Poland from the mid nineteenth century until 1945 (Miętus 1997). Some of the materials were brought to Poland in 2005 (Miętus and Czechowicz 2005).

Fleming (2002), in the history of meteorology explains the activities of many European scholars clearly and extensively, in terms of meteorological observations, the explanation of weather processes and the construction of the instruments. However, a little attention is given to the activity of the scholars and enthusiasts in these fields on the contemporary territory of Poland. Only the almanacs are rated, as being a popular way of presenting the seasonal and annual weather prediction, used mainly for agricultural purposes. Poland is marked as a place of the first editions of the mentioned above almanacs. Unfortunately, these issues are not considered important or significant. What is more, Fleming mentions Johann Kanold and his *Wrocław collection* (in German *Breslauer Sammlung*, 1717–1726). He emphasizes Kanold's influence on the development of the network of European meteorological observations and on the documenting (collecting and publishing) of the results of the observations. He does not, however, mention any Polish town which was to cooperate with Kanold. It is probably due to the fact that those aspects of activity in Poland have not been well known yet.

Limited amount of analysis carried out by the Polish climatologists, such as Trepińska (1988, 1997), Miętus et al. (1994), Miętus (1996, 1998a, 2007), Lorenc (2000), Bokwa et al. (2001), Limanówka (2001), Przybylak et al. (2005), Filipiak (2007a, b, 2009) include lots of interesting pieces of information concerning the subject mentioned above, although they are incomplete, and do not answer many questions.

The earliest known observations that come from the territory of Poland are dated to the sixteenth century. Bokwa et al. (2001) and Limanówka (2001) give lots of examples of notes concerning weather conditions in Cracow in early sixteenth century conducted by Marcin Biem, a professor in Cracow Academy (Jagiellonian Academy). Bokwa et al. (2001), Przybylak et al. (2005) and Nowosad et al. (2007) described also the climatological conditions in the north-eastern Poland in the second half of seventeenth century on the base of Jan Chrapowicki, the Polish nobleman and diplomat who was very enthusiastic about the weather and made notes about it almost every day.

However, Miętus et al. (1994), in accordance with the views presented by Klemm (1976), consider Abraham Rockenbachs, who conducted irregular meteorological observations from 1561 to 1564, as the most probable first meteorological observer in Polish Pomerania.

The paper focuses on the history of meteorological observations and measurements in Gdańsk since the moment when the first observers began to describe the weather conditions in the end of the seventeenth century till the last decades of the nineteenth century when the first national meteorological networks were established. Air pressure data were used as an example to evaluate the quality of the archival data and to perform some short climate analysis assessing the ability of the reconstruction of the climatic conditions in Gdańsk during the instrumental period.

12.2 We Have Known About This for Years

Taking Klemm's (1976) paper and two Hellman's works (1883 and 1901) into consideration, Miętus et al. (1994) quantified the beginning of meteorological observations in Gdańsk to be in 1655, and named Fryderyk Buethner (1622–1701), the first meteorological observer in this town. According to historians, Buethner was the fist mathematics professor in Academic Gymnasium and was at the same time given the position of a Chancellor of a parish school at Saint John's Church located in the centre of the town. Apart from being a mathematics professor, Buethner was a passionate astronomer and astrologist, what was common at those times. He was probably keeping touch with Jan Heweliusz (1611–1687), a famous astronomer from Gdańsk. He kept vivid correspondence with Wawrzyniec Eichstadt (1596–1660), who worked in Szczecin and collected notes concerning weather for at least 7 years.

Hellman (1883) mentions that Buethner's notes which concerned the weather in Gdańsk were included in manuscripts entitled "*Observationes meteorol. singulis diebus Callendarii annotae*". However, it is difficult to state whether that was true and where the *Callendars* were kept in Hellman's times. Hellman himself changed his mind and firstly pointed at the collection of Gdańsk Library and then the Bookshop of founded in 1742 the Natural Science Research Society of Gdańsk. Hellman probably did not study these *Callendars* or maybe did not even see them at all, as his opinion is based mainly on the earlier expressed opinions of other scholars who lived at Buethner's times. Fryderyk Buethner is considered to have been famous and appreciated by the society even outside Gdańsk, what is proven by the fact that he was given the privilege to publish the *Callendars* on his expense, what was very rare in those times. On the basis of other documents, Hellman noticed that, Buethner's work was not individual but he took advantage of gymnasium students. Despite having a positive recommendation of these notes, Hellman (1901) gives only one example of the observations, namely: *18.01.1657 – harsh blizzard, calm at noon, clear sunny*.

12.3 That Was the Beginning According to New Findings

Through the years, Buethner's *Callendars* were considered lost forever. The search carried out in the 1990s in two main libraries in Gdańsk, namely the Gdańsk Library of Polish Academy of Science (PAS) and the Main Library of Technical University of Gdańsk, the heir of the library of the Natural Science Research Society of Gdańsk, founded in eighteenth century was futile. The researches, carried out abroad or in other towns of Poland, have not been successful, as well. Buethner's *Callendars* were not even mentioned in the Great History of Gdańsk (Cieślak 1993) which was published in many volumes.

According to Miętus (2007), another query of the resources of the libraries mentioned above in 2005 enabled to find interesting meteorological materials, however, in the case of *Callendars* the results were fruitless, as well. The discovery of unknown materials was caused by the fact that the library of PAS had to move to another, new building. Therefore, the magazines were looked through and the catalogues updated due to the fact that "new" resources were found.

Among the materials that were discovered one can find a collection of regular publications marked by Wilhelm Misocacus. This collection is entitled "*Prognosticum oder practica auffs Jahr…*". They were released from 1577 to 1593, many years before the Buethner's *Callendars*. Each periodic "*Prognosticum...*" includes the description of the weather in terms of the seasons (Fig. 12.1).

It is not known, however, what those descriptions were based on, as the information about Misocacus observations is missing. A brief analysis of Misocacus works led to setting him an example of a typical scholar of those times, probably an astrologist, who shared the opinion about the astronomical influences upon the weather.

The next representative of a mentioned above stream in Gdańsk is Peter Krueger, a mathematics professor, who published "*Neuer und alter Schreibcallendar auffs Jahr...*" in the years 1609–1639. He described the predicted system of stars and then forecasted weather.

It was not until 2006, when Janusz Filipiak from the University of Gdańsk (Miętus 2007) came across a collection of Buethner's *Callendar* dated to years 1662–1701. The *Callendars*, that were discovered, were entitled "*Neuer und Alter SchreibCallendar/auffs Jahr nach unsers Herren Jesu Christi geburt MDCLXXIII auff den Danziger und umbliegender Behrter*". Hence, a question may be raised, namely whether or not we have come across another publication proving Buethner's activity as an astronomer and a meteorologist.

A straight answer is difficult to be given and impossible until Buethner's "*Observationes* ..." (mentioned by Hellman) are found and compared with the *Callendars*.

The analysis of the contents of the works recently found enables to estimate its actual state and scientific utility. The technical state seems to be intact. The writing is clear. All the information is written in tabular form (Fig. 12.2). One chart describes one month. Each month takes up two pages. On one side, always the left

PROGNOSTICVM
Oder Practica / auffs Jar nach der geburt vnsers HERRN vnd Seligmachers Jesu Christi/ 1577.
zu Ehren der Löblichen Königlichen Stadt Dantzigk Gepracticieret durch
D. Wilhelmum Misocacum/Medicum vnd Astronomum daselbst residirende.

Saturnus vnd Mars, tanquam causæ secundariæ sein Herren dieses Jars, Mars vnd Venus Mithülffer.

lichen Obrigkeit mitt / Vnnd ein Königreich wird viel distruction vnd verfolgung leiden / vnd verstört werden/ Auch sollen die Regenten etlicher stedten/als Obrigkeit/ Juristen/ Richter vnd Aduocaten betrübet sein/ vnd geengstigt werden / vnd etliche reiche Leute von jren Gütern beraubet werden (Gott bessers.) Diß sind die vornemsten zufellungen welche in dem gantzen Winter drewen/biß zum anfang des zukommen Lentzen.

Vorenderunge der Lufft in dem Vorwinter.

Vollmon den 6. Decembris/am Donnerstage des morgens vmb 4. vhr 43. minuten/kalt wetter geneigt zu schnee vnd frost/ bißweilen mit klarer lufft/ windig/ sonderlich den 11. vnd 12 dennoch geneigt zu schnee.

Letzt viertel den 12. Decembris/vormittag vmb 9. vhr 28. minuten/sehr kalt/frost/mit klaren tagen/ Sonabend geneigt zu vielem schnee / mit grosser turbation in der lufft Dinstag widerumb kalte lufft mit frost/vnd etliche dunckel kalte tagē/ biß zum ende dieses Letztē viertels.

New Christmon den 20. Decembris/am Donnerstag des morgens vmb 7. vhr 38. minuten/sehr kalt vnd frostig/mit schönen klaren tagen/ bißweilē auch mit fliegenden dunckele wolcken/ auff den Christabend sehr kalt/ auff den Christag ein wenig linder wetter/darnach widerumb frostig.

Erst viertel den 28 Decembris/am Freitage vormittag vmb 11. vhr 53. minut. sehr kalt / frostig mit klaren tagen vnd windig. Montag geneigt zu schnee. Von dem 2. vnd 3. Januarij böß wetter mit grosser turbation

B ij in der

Fig. 12.1 "*Prognosticum…*" by Misocacus, 1577 (from the collection of the Gdańsk Library of the Polish Academy of Science)

one, detailed astronomical information was put, including as follows: a date (day, month) and an extended non-astronomical information. There are different types of information on the other side (always the right one). They concern such data as: historical information, for example the history of Prussia in episodes, which, if we take the chronological *Callendars* into consideration, may be compared to a contemporary series. They were published in yearbook, month by month. The last column on the left which occupies at least a half of page's width, is left blank (without any printing).

The *Callendars*, published by Buethner, included mainly astronomical information, so they may be treated as astronomical ones. Moreover, in his *Callendars*, Buethner enclosed the information about the weather, as well. They are extremely brief and use only the following terms: *cold/hot air, windy, ground-frost, sunny, cloudy etc*. What is interesting about it, is that those pieces of information are printed. They are not the notes of the actual weather conditions on a particular day, as they were printed before the year they concerned. What are they then? How should they be treated? It seems that the discussed issues are explained in the volumes of *Callendars* which include hand-written registrations at the edge left column of the chart (the one that was left blank). There, the information, concerning the weather conditions is written either by one person or few people (different type

Fig. 12.2 *The Calendar* by Buethner, April 1674 (from the collection of the Gdańsk Library of the Polish Academy of Science)

of handwriting). Those registrations have some corrections made by another person or are marked with a symbol of acceptance. We may assume that Buethner's *Callendars* are forms of a tale about the weather, expected on particular days of the year (a kind of a forecast), and the hand-written elements were to verify prepared "forecasts" and to improve their accuracy in the coming years.

Everything leads to the conclusion that this opinion is justified, as Buethner lived and worked in Gdańsk at the same time as Heweliusz, the pride and household name of the town. It is very likely that they knew each other and worked nearby. Heweliusz, during public presentations of his research and the discussion carried out in the company of noble citizens of Gdańsk, had probably mentioned about the difficulties that he encountered during his observations, to name one – weather conditions. Bad weather, cloudy sky, rain or snow and low temperature must have disabled or limited his astronomical observations. Buethner's *Callendars* were away of assistance given to Heweliusz, a hint how to conduct the research and observations. It is difficult to support or reject this theory. What is not known, is how Buethner prepared his first versions of weather tales, published in the first annual *Callendar*. Perhaps, he had previously done some observations and included them in the mentioned by Hellman "*Observationes meteorol. Singulis...*" It is possible, if we take into consideration the fact that Hellman's notes, concerning the weather had come from 1657, while the *Callendars* really started in 1662. Moreover, it seems that Buethner shared a common view that weather is determined and influenced by the celestial bodies and repeats itself every 7 or 8 years. Thus, the information printed by Buethner in "*Neuer und Alter Schreibcallendar...*" may be considered a first preserved weather forecast for Poland and other regions, as well.

In Gdańsk, Daniel Gabriel Fahrenheit (1683–1736) took his fist steps literally and metaphorically. He was born in a merchant family. He was a keen physicist, who constructed different types of instruments, such as thermometers, weather glasses and altimeters. He was said to have been the inventor in 1713 of mercury thermometer and a thermometric Fahrenheit scale. Unfortunately, the date of inventing the scale and the process itself are ambiguous. Januszajtis (2005) claims Fahrenheit introduced his own scale in 1714, however, the experiments carried out in 1724 contributed to the correction of this scale. There is every possibility that the invention of this scale was inspired and supported by previous thermometric measurements, which had been conducted by Fahrenheit in Gdańsk in an extremely cold winter of 1708/1709.

Hellman (1883) and Momber (1906) mention an unknown publication that included the notes on the weather of en extremely harsh winter of 1709/1710. Unfortunately, neither of them gave the source of their information. Momber (1906) considered Johann Kanold (1717–1726, "*Sammlung von Natur – und Medicin – wie auch hierzu gehörigen Kunst – und Literatur – Geschichten*") as the source including the results of regular meteorological observations in Gdańsk in 1717. This publication has still been out of reach by us.

In Johan Adam Kulmus's (1721) and Janus Meteoroscopus's (1727) works we can find a wide range of information concerning weather. The authors not only name the dates of the occurrence of particular weather phenomena, but also try to give a careful and detailed consideration of their sources.

It was Momber (1906), who mentioned the thermometric measurements conducted in 1739 by Michael Christoph (Christian) Hanow in the Florentine scale. Hanow was the professor of Mathematics and Philosophy. He was the member of the Natural Science Research Society in Gdańsk, which was founded in 1743. Hanow is the author of more than 100 works in the field of physics, meteorology and natural science. He had been co-editing "*Danziger Erfahrungen*" (*Gdańsk Experiences*) since 1739, and was the editor of "*Acta Societatis Physicae Experimentalis*" since 1743. From the meteorological point of view, of his most significant achievement, we can consider the conduction of daily measurements and meteorological observations. The effects of those measurements carried out from 1739 to 1752 can be found in "*Danziger Erfahrungen*". Similarly, the Main Library of Gdańsk Technical University, owns the manuscripts of Hanow's observations, in three volumes coming from the whole period of observations, namely 1739–1772 (Fig. 12.3). The measurements have been carried out four times a day and include the following data: temperature, atmospheric pressure, total precipitation, humidity and the direction of wind. Apart of this Hanow attached information about daily weather conditions and the phenomena, as well as astronomical ones (Filipiak 2007a).

Furthermore, in his works Hanow described his views on nature and the beginnings of all the processes that influence the weather in a detailed way (the second volume of "*Philosophiae naturalis – Aerologia at hydrologia, scientiam, aeris, et aquae*"). In the second volume of the work entitled "*Selteheiten der Natur und Ekonomie*" we can find a notice about the probable beginning of the measurements conducted with instruments in Gdańsk (after Januszajtis 2005).

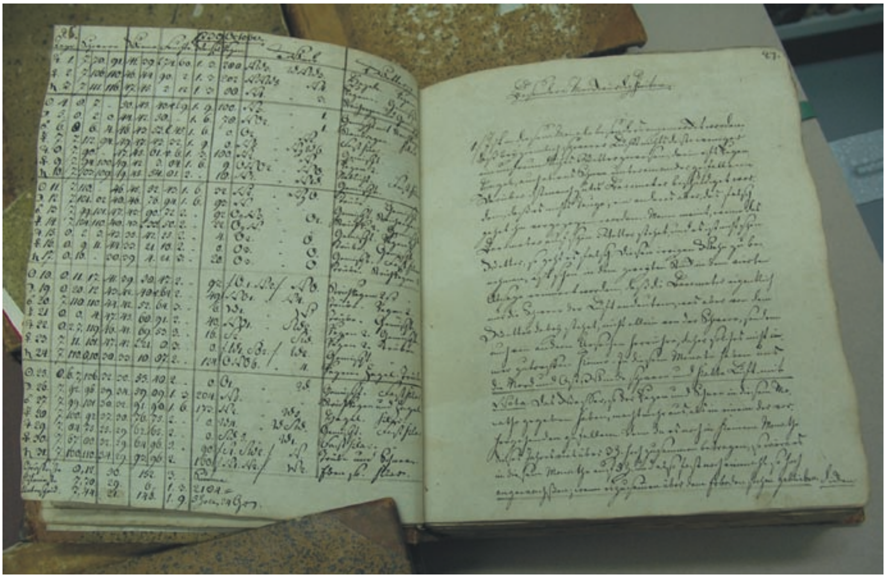

Fig. 12.3 The manuscript of meteorological records by Hanow (from the collection of the Main Library of the Technical University in Gdańsk)

> *a thermometer famous for its accuracy which was in use in 1709… numerous people sent their servants to the house of Wilke to see how cold it was. The Wilke's thermometer belonged to and was described by Krikart… He was believed to had owned this instrument 20 years earlier, but it was Fahrenheit, who filled it with alcohol in 1708.*

Gottfried Reyger, a well known botanist from Gdańsk was interested also in medicine, mechanics, electricity and meteorology. He claimed, in his works, that his meteorological measurements were carried out in 1730–1749 (in one of his works he even mentioned the period up to 1755). However, specific information about the results of the observations is missing. The following Reyger's works should be listed: *Beobachtungen der Witterung in Danzig, die Beschaffenheit der Witterung in Danzig volume 1, vom 1722 bis 1769* and *volume 2, vom Jahr 1770 bis 1786*. Those works include a broad analysis of weather conditions in terms of several dozen years in Gdańsk. Those analyses do not, however, focus on quantity, therefore results of measurements and observations are not quoted. It seems that due to the fact that the Scientific Society in Gdańsk led a very active life and met for public debate, Reyger in fact carried out meteorological observations but his notes have either been lost forever or have not been found yet.

Two manuscripts including the results of the measurements of the temperature and the direction of the wind together with the description of the weather from 1744–1784 and the recordings of atmospheric pressure from 1755–1760 and 1764–1784 were left by Carl Gottfried Minor. He was another keen meteorologist from Gdańsk and an associate member of the Society. His name, together with the year 1752, was engraved on the famous so-called *Fahrenheit thermometer*, which was the eighteenth century instrument inscripted with a few measurement scales, such as Fahrenheit, Réaumur and Florentine. This may suggest the name of the owner, as well as the manufacturer of this instrument.

The results of the measurements of atmospheric pressure, temperature and wind direction conducted twice a day can be found in Johann Eilhard Reinick's manuscript written in Latin; information on weather phenomena was also added. Reinick was a medicine doctor as well a trained physician. He was especially interested in research concerning the influence of height on pressure.

Johann Conrad Eichhorn's notes found among the archival collection include the results of his meteorological measurements conducted from 1764 to 1790. They concerned mainly the measurements of the atmospheric pressure, read with varied frequency (from two to even four times a day) and of sporadically taken recordings of the temperature and the direction of wind. In one of the Eichhorn's manuscripts a very interesting and useful figure which presents the comparison of three different temperature's scale used in Gdańsk has been found (Fig. 12.4). This figure allows recalculating the readings of temperature by Reiger, Fahrenheit and Eichhorn.

A manuscript that was probably written by Fuellbach comes from the turn of eighteenth and nineteenth century. Fuellbach was a watchmaker and an astronomer's assistant. The content of the material, concerns the results of the measurements from 1783 to 1806 conducted in the astronomical observatory which was destroyed by the French during the battle in the beginning of nineteenth century. The manuscript, however, is incomplete from 1783 to 1784 and in 1795. The measurements of the atmospheric pressure, temperature and power of the wind were taken every morning and evening (and since 1787 at noon, as well).

The next meteorologist in Gdańsk was Sturke, about who little is still known. His manuscript includes the measurements and meteorological observations conducted from 1788 to 1812. The observations were done twice a day, between sunrise and sunset and they included pressure, temperature and direction of the wind. There are some pieces of information missing in the materials that were discovered. Moreover, there are numerous interruptions in terms of measurements from 1788 to 1789 and a complete lack of information from 1811. Unfortunately, we don't know what caused the disturbances in the notes. Significant advantage of

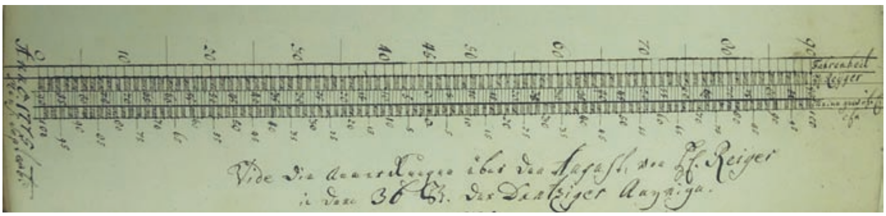

Fig. 12.4 The comparison of three different temperature's scale used in Gdańsk prepared by Reiger (from the collection of the Main Library of the Technical University of Gdańsk)

Sturke's work is numerous descriptions of the atmospheric phenomena, which took place in Gdańsk.

It was at the end of eighteenth century, in 1793, when Johann Kleefeld, a legal advisor and director of the town library, started his thermometric measurements. Unfortunately, there were significant objections to their accuracy. According to Momber (1906), Kleefeld started regular thermometric measurements in the area of the contemporary Długa Street (house number 51, in the city centre), after mastering the methodology and the instruments. The location of his observatory was the following (after Momber 1906):

> *The house was situated in the centre of the town. A lot of sunlight entered the room on the south, but in winter, the house was in the shade of nearby buildings. The north side of the building looked out onto the yard and was illuminated by direct sunlight only in summer and only in early morning hours as the nearby tall buildings (including the Church) limited the horizon. Similar problems were encountered on the east side of the building sheltered by the town hall. A direct north-east wind could only enter the yard. The instruments, such as thermometer or hygrometer were installed at the height of 28 Paris feet on both the south and the north side.*

Kleefeld read the instruments (mercury thermometers in Réaumur scale) only when they were in the shade. The observations from 1813 to 1845 were in accordance with the regulations of Societas Meteorologica Palatina in Mannheim at 6 a.m., 2 p.m. and 10 p.m. The hours of morning observations had oscillated between seven and eight in the morning until 1812 and had been taken at 9 a.m. for several months.

Simultaneously, Kleefeld's work was followed by the measurements of temperature, atmospheric pressure, direction and power of wind and the occurrence of rain, storm or other meteorological phenomena, conducted by Fryderyk Strehlke from 1826 to 1831 and from 1839 to 1850 in 2-h intervals of time. Strehlke's observatory from 1839 to 1850 was situated in the churchyard of the house of the headmaster of old Saint Peter's Gymnasium, (43.2 Paris feet high). From May to August, the thermometers were not sheltered against the sunlight in the early morning hours. Strehlke, according to the regulations of the Prussia Meteorological Institute, conducted his observations three times a day, namely at 6 a.m., 2 p.m. and 10 p.m., until August 1880. He changed the place of his observations seven times, moving them sometimes to distant districts of the town. There is some information missing in Strehlke's observations. The most significant ones are the lack of observations at 6 a.m. from October 1843 to November 1847. The lack of sheltering of the thermometers from the morning sunshine from April to September is a negative feature of Strehlke's observations from 1841 to 1850.

After Strehlke's death meteorological observations in Gdańsk were conducted only in the Navigation Academy. They were limited to three times a day registration (8 a.m., 12 p.m. and 4 p.m.) of temperature and pressure. However, according to contemporary scholars (Momber 1906) those observations were far from quality ones.

A meteorological observatory in Nowy Port (Neufahrwasser) was set up in 1876. This observatory did measurements at 8 a.m., 2 p.m. and 8 p.m., according to the regulations of the Nord Deutsche Seewarte in Hamburg. Moreover, the maximum and minimum temperatures were registered twice a day. The station was situated 2 m above the see level, the thermometers were installed 2 m above the ground.

12.4 The Gdańsk Air Pressure Series – Evaluation of Metadata

The identification, collection of information and data sources have significantly increased the volume of historical meteorological data from Gdańsk available for the analysis of the regional and local climate change. However, the scale of problems to deal with is considerable. The reconstruction of the climatic series comprises scanning of the documents, digitization of the contained data and its interpretation which is both time and money-consuming. This task is still in progress which is caused by the scope of the material.

Collection of dispersed archived materials and creation of their digital image is not a sufficient action to receive the reliable long-term climatic series. Another very important issue is that it is difficult to obtain reliable material from measurements lasting many years. In the paper below the atmospheric pressure data can be used as an example demonstrating the potential ability to reconstruct the long-term climatic series of Gdańsk and problems connected to the interpretation of climatic trends.

As was described in the above introduction the history of meteorological observations and measurements in Gdańsk is long and complicated. The entire instrumental series can be divided into a sub-periods which can be listed in following manner. The Early Observers period, 1739–1806, covers the initial years of the measurements when they were conducted with the instruments mostly invented by the observers themselves, often in their flats. No general regulations of observations existed till 1780, when the international network of weather observations in which meteorological data were simultaneously recorded according to the observational code was set up (Societas Meteorologica Palatina organized by Johann Hemmer, court chaplain to Karl Theodor, Prince Elector of the Palatinate). This leads us to the recognition of the next sub-period – The First Meteorological Networks, covering the years from 1807 to 1875. The measurements were conducted with the instruments produced by the renown manufacturers and professionally calibrated. However, the instruments were still located in the homes of the observers. Only during the second half of the nineteenth century the first national meteorological networks were established. The third sub-period – Modern Measurements – began in 1876 when the station in Neufahrwasser started to work. Since then the measurements in Gdańsk were done only in the meteorological stations operated by the professional observers according to the generally obligatory standards and regulations.

Three ten-year periods were selected to present the variability of the atmospheric pressure in Gdańsk (Fig. 12.5). Each one of the selected series corresponds with the periods of history of meteorological observations. On the basis of the results of the analysis the problems connected with the methodology of the measurements, incomplete metadata and interpretations of the data can also be highlighted and explained.

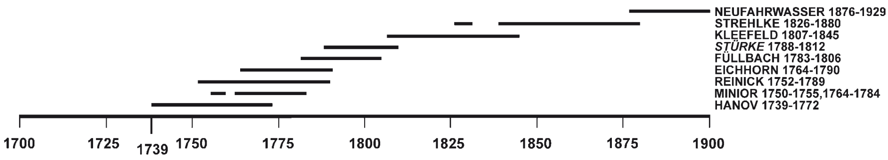

Fig. 12.5 Temporal distribution of the identified periods of air pressure measurements till the end of the nineteenth century

12.4.1 Reinick Series

As it was pointed out above Johann Eilhard Reinick conducted measurements from the beginning of 1752 till the last days of 1789. The notes concerning the atmospheric pressure contain the records of the element readings twice a day – in the morning, at 7 a.m. (titled in manuscript as *mane*) and in the evening, at nine, sometimes 10 p.m. (*vespere*) (Westphal 1820). Though Reinick started to measure temperature also in the afternoon (*p. meridie*, which most probably means *post meridie*), he did not change the observation hours of atmospheric pressure measurements apart from rare events when Reinick registered additional record at 12 or 3 p.m.

Reinick's barometer was scaled in Paris inches and lines (1 Paris in. = 27.07 mm). The way of registering the pressure records changed twice during the observations period. Initially Reinick wrote his readings in inches divided into 12 lines (recorded as e.g. 27 in. and 9½ lines). In February 1756 it has changed into the division of inches into 120 parts (e.g. 28 in. 51 lines) and finally 2 months later Reinick started to register pressure in inches divided into 12 lines, which by turns were divided into 12 parts (e.g. 27 in. ten lines seven parts (Gran?)).

We have still not found the detailed description of the measurement place. Kleefeld (1826) describing the temperature measurements in Gdańsk stated only that Reinick's observational place is located about 40 Paris feet above sea level. Establishment of the place of Reinick's observations is somewhat difficult. Actually we can do it hypothetically, basing on the information presented in the short history of meteorology in Gdańsk described in the *Schriften der Naturforschende Gesellchaft in Danzig*, volume 8, edited in the 150th anniversary of institution of that society. The most probable place of observations, building of Gruene Tor, was marked in the Fig. 12.6. It is about four-floor high building located on the Motława River bank, closing the Royal Route – the most representative road in Gdańsk. The windows of the building are oriented W-E. Maybe the lately found another manuscript by Reinick – *Von der Schwere und ausdehunden Kraft der Luft* will give more precise answer. Unfortunately, similarly to other found manuscripts, the information was recorded in the Gothic handwritten character in the eighteenth century German language (with borrowings from Polish and Dutch) so consulting both a historian and translator is necessary.

The Reinick series is characterized by the accuracy and care. Only in the initial year 1752 as well as in the final period of observations, in 1789, weeks before Reinick's death, the gaps and missing values can be observed. The total sum of the

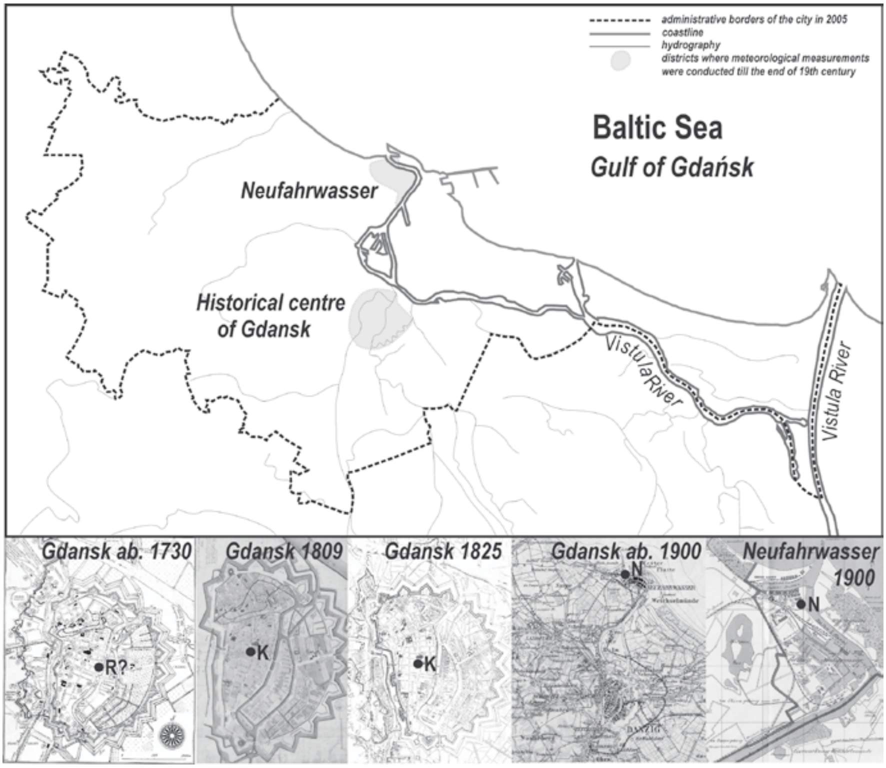

Fig. 12.6 The maps of Gdańsk presenting the development of the city and the places of measurements and meteorological observations described in the paper: R? – Reinick (1752–1789, probable place), K – Kleefeld (1807–1845), N – Neufahrwasser (1876–1919)

missing values in the 10-year-long period 1752–1761 selected for analysis does not exceed 2% of observations.

12.4.2 Kleefeld Series

Describing the location of his observatory (Fig. 12.6), as was cited above, Kleefeld (1826) added the detailed information about the position of the barometer. According to the Royal Government levelling it was elevated 41 Paris ft and 11.863 in. above sea level (43 Reinische ft and 5.5), which means 13.64 m a.s.l. In his manuscript (both rough and fair copies) Kleefeld registered atmospheric pressure in Paris inches and lines, by turns in the printed version of the results of his observations we can notice unusual values without explanation about units, for example 338. After the checking it became clear that Kleefeld expressed the values of element in Paris lines only.

During the whole observation period a Pistor barometers were used, as Kleefeld stated "*All what I describe were observed with the best instruments from Pistor, Mendelssohn, renard and Chevallier in Paris*". The important fact is that temperature inside the room where the barometer was exposed was measured too. The most probably it was thermometer annexed to the barometer and it was scaled in Réaumur scale.

The Kleefeld series have a few serious gaps. They occurred often during the initial period of observations (till 1809) and the observations at 2 p.m. were the most incomplete. Much less numerous gaps can be observed in the morning and evening observations registers. After the 1809 the gaps were very rare. They occurred in November and December 1813 and were caused by the bombardment during the siege of the city by Russian troops. Unfortunately, the part of instruments was destroyed then (hygrometer and rain gauge).

12.4.3 Neufahrwasser Series

The complete records of the observations conducted in the seaside district of Gdańsk – Neufahrwasser (Fig. 12.6) were published in *Deutschen Meteorologischen Jahrbuch*. Data were enriched with the important information about the instruments' exposition. Additionally, in 1927 Johann Staben published in *Schriften der Naturforschenden Gesellchaft in Danzig, vol. 17* article *Zum Klima von Danzig-Neufahrwasser*. Thus, the barometer was mounted 4.5 m above the ground (11.1 m above sea level). The observations were conducted by the head of the Hauptagentur der Deutschen Seewarte (Staben 1927).

Though the data in *Jahrbuch* were complete, the period 1881–1890 selected for analysis is, unfortunately, characterized by two gaps. The periods Jan–Feb 1885 and May–Jun 1886 are missing because of the errors during the scanning of the data. All the data presented in *Jahrbuch* were reduced to 0°C, gravity and to sea level.

12.5 Reduction of the Pressure

All pressure data obtained from the measurements should be recalculated. The reduction to sea level pressure, gravity and 0°C should be taken into account. The procedures of the reductions are explained in details in WMO publication (WMO 1983). Additionally introduced corrections may concern thermal stratification, adhesion and hysteresis (Różdżyński 1995), however its influence on the barometer registers in such analysis is negligible. As our analysis applies to the historical data conversion of units to hPa has to be done.

Thus the reduction was performed to all data of Reinick and Kleefeld series. Reduction to 0°C was based the assumption that Reinick's and Kleefeld's barometers were accurate at that temperature, however it is more certain with the respect to the Pistor barometer used by Kleefeld. Reduction was made using the equation (Moberg et al. 2002):

$$p_0 = g_n \bullet \rho_0 \bullet H_T \bullet (1 - \gamma \bullet \Delta T) \bullet 10^{-5}$$

where

$$\Delta T = T - T_{0^\circ C}$$

where ρ_0 is air pressure reduced to 0°C (273.16 K), g_n is normal gravity acceleration (9.80665 m s^{-1}), ρ_0 is density of mercury in normal conditions (13.57904 × 10^3 kgm^{-3}), H_T is height of the mercury column in barometer at temperature *T* (in °C), γ is the bulk expansion of mercury (1.818 × 10^{-4} K^{-1}) and *T* is the temperature at measurement moment (in °C).

There was no problem to use as *T* the barometer temperature in case of Kleefeld series (with conversion of R° to C°). The earlier measurements were lacked in such measurements. The simple calculation with taking into account only the temperature from the Reinick's thermometer exposed outside was also not advisable since the homogenization of that series has not been applied yet. Provided that the measurements were carried out by Reinick in the heated room the thermal coefficients characteristic for the each month were adopted basing on the Kleefeld's temperature readings conducted in similar conditions. The error of such calculation is generally lower than ±0.1 hPa and its accuracy can be regarded as sufficient.

The reduction to normal gravity was performed using the formula (Moberg et al. 2002):

$$p_g = \frac{g_\pi}{g_n} \cdot p_o$$

where p_g is air pressure at station altitude reduced to 0°C and normal gravity, and g_n is gravity at station latitude (9.81078 ms^{-1} at 54°20'N).

And the reduction to sea level was made using the equation (Moberg et al. 2002):

$$p_s = p_g \bullet e^{\left(\frac{g_\pi \cdot z}{R \cdot T_m}\right)}$$

where p_s is air pressure reduced to 0°C, normal gravity and sea level, *z* is barometer altitude in meters, *R* is gas constant for dry air (287.04 J × K^{-1} × kg^{-1}) and T_m is mean air temperature in K in the air column between station level and sea level.

12.6 Selected Statistical Analyses of the Pressure Series

The three selected pressure series were briefly analysed in terms of some properties of daily, monthly and annual values. Additionally, the short comparison with the homogenous pressure data from Uppsala (observations from 1722) and Stockholm (from 1756) was performed. The reconstruction and homogenization of the chosen series was performed within the EU project IMPROVE. Uppsala is located about 600 km and Stockholm about 550 km north from Gdańsk, which are rather long distances. Unfortunately, no other stations with long enough homogenous daily air pressure series exist. However, the important issue was the similarity of the geographic environment of all three stations' location in the basin of the Baltic Sea, in the lowlands. The next feature is the proximity of both stations to the sea (Gdańsk – in the coast, Stockholm – 25 km from the sea and Uppsala 70 km).

Figure 12.7 represents the course of daily means of atmospheric pressure within three selected 10-year-long Gdańsk series. The daily means were calculated as the arithmetic average of the available values, that is in case of Reinick series it was defined as an average of morning and evening observations and in case of other series it is an average of three daily observations.

The range of the mean daily air pressure in all selected periods varies from 970 hPa to 1,050 hPa. The mean air pressure in the following periods equals as follows: 1,011.6 hPa (Reinick series), 1,016.0 hPa (Kleefeld series) and 1,013.5 hPa (Neufahrwasser series). The differences between particular periods are considerable thus the question about the reasons arises. So far, the initial analysis of the course of the daily means in the selected periods highlights the very high values in 1811 and during the first half of 1812. The measured air pressure daily means were greater than 10–15 hPa on average in comparison with the following years.

The comparison of Kleefeld series with the data from Swedish stations in Uppsala (Fig. 12.7) and Stockholm confirms the anomalously high values of air pressure in the indicated period in Gdańsk. The difference of annual value of air pressure between Gdańsk and Swedish stations in 1811 exceeded 10 hPa and was 4 hPa in 1812 while in the following years of the described period it was 2–3 hPa. Most probably it is the evidence of inhomogeneity in the Gdańsk series.

In two other selected periods 1752–1761 and 1881–1890 it is possible to observe the great variability of air pressure daily means in Gdańsk, but the constant anomalously high difference between the registers in Gdańsk and Uppsala (Fig. 12.7) as well as between Gdańsk and Stockholm no longer exist. However sporadically existing great differences between air pressure daily means in Gdańsk and Uppsala are surprising, for example 27–28 Feb 1753 (Fig. 12.8). The daily mean air pressure in Gdańsk was almost 40 hPa higher than in Uppsala what is unlikely taking into account the development of synoptic situation. The greatest noted gradients between Gdańsk and Uppsala reached no more than 30 hPa for example when very active pressure low crossed along the Baltic Sea in 26–27 Feb 1990 (Miętus 1998b). In case of the extremely strong pressure high the noted gradient did not exceed 20 hPa (30 Jan 1972, Miętus 1998b). While there is a lack of other long daily air pressure registers from the area of the Southern Baltic Sea basin (the Stockholm series begins with 1756) it is difficult to point out which series is erroneous. When we analyze the registers of Reinick and Uppsala series from the proceeding and following few days and, additionally, the values of air pressure noted in Gdańsk simultaneously with Reinick by the other observer – Hanow (Hanow 1739–1772) it is clearly showed that the pressure values from analyzed days in Uppsala series are incorrect.

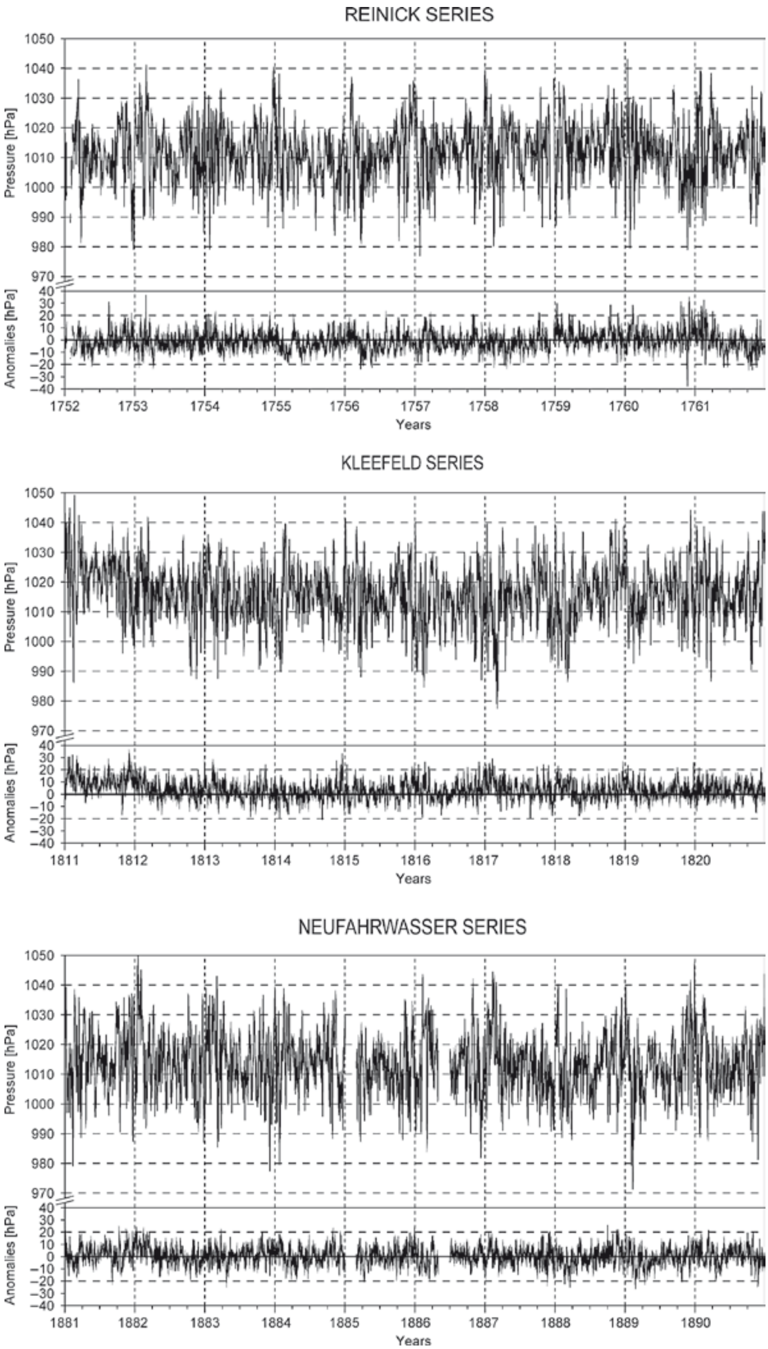

Fig. 12.7 Daily mean pressure values of the Gdańsk series in three selected periods and differences between Gdańsk and Uppsala series.

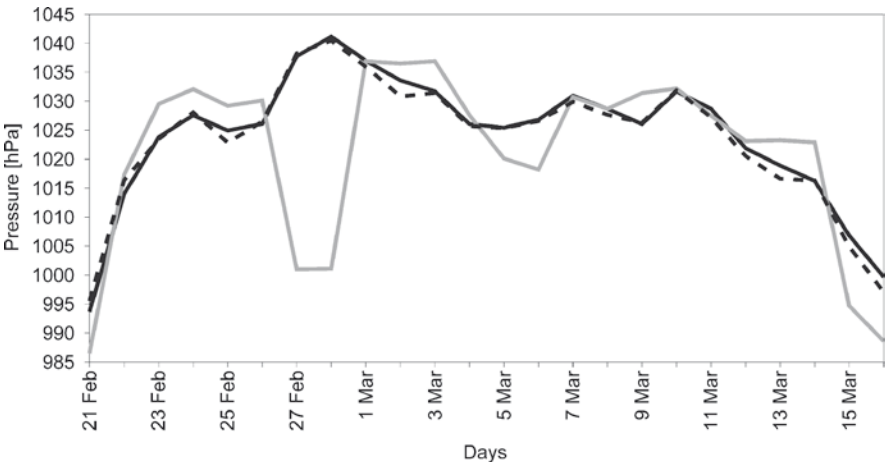

Fig. 12.8 Daily mean pressure in Gdańsk (Reinick series – *black solid line* and Hanow series – *dashed line*) and Uppsala (*grey line*) in the period 21.02-16.03.1753

Another considerable discrepancies between Reinick and Uppsala series values occurred in the wintertime 1760/61. However, additional reference air pressure series from Stockholm is available for this period. The air pressure values registered in Gdańsk were also greater than in Stockholm, but the differences between Gdańsk and Stockholm were in half less than those between Gdańsk and Uppsala.

The additional, homogenous data from Stockholm helps to assess the inter-station comparative analysis of Gdańsk series. What is important, the correlation coefficient between Gdańsk and Stockholm series is somewhat greater than for the pair of station Gdańsk-Uppsala. For the period 1756–1762 the value of correlation coefficient between Gdańsk and Stockholm daily means is 0.82, while in the case of the Gdańsk versus Uppsala it is 0.77. In the subsequent periods the correlations between Gdańsk and Swedish series generally increased. In case of period 1811–1820 it was 0.80 for the pair Gdańsk-Stockholm and 0.78 in case of Gdańsk-Uppsala, and for the latter period the values were 0.83 and 0.81 respectively. The Swedish series are better intercorrelated, the correlation coefficient is almost one, however in the case of the period 1756–1761 its value is 0.94.

The smallest discrepancies between Gdańsk series and Swedish data are characteristic for the latter of the selected periods. The annual air pressure mean in Gdańsk-Neufahrwasser was greater than 0.8 hPa than in Stockholm and 0.6 hPa than in Uppsala. The comparison in the initial period (1752–1761) showed that Uppsala was characterized by the pressure greater by 0.9 hPa than Gdańsk. During the period 1811–1820, as was mentioned above, the mean difference of annual air pressure in Gdańsk and Uppsala was considerable and exceeded 3 hPa.

The differences between air pressure daily means in Gdańsk-Neufahrwasser and Uppsala very rarely are greater than 20 hPa. Only during winters of 1882/83 and 1888/89 the episodes of the great pressure gradient between Polish and Swedish coasts occurred, resulting in severe wind erosion in the area of Southern Baltic.

Table 12.1 Standard deviation values of daily mean air pressure (hPa) in Gdańsk, Uppsala and Stockholm in the analysed periods

Station	Period 1752–1761	1811–1820	1881–1890
Gdańsk	9.50	9.47	10.19
Stockholm	–	11.69	12.03
Uppsala	11.99	11.26	12.01

However, the difference between Gdańsk and Stockholm was always smaller than between Gdańsk and Uppsala.

The greatest variability of the air pressure In Gdańsk was observed during the period 1881–1890, when the standard deviation of daily means equalled 10.19 hPa (Table 12.1). During both earlier periods the value of this estimator was smaller by about 0.70 hPa. Both Swedish stations were characterized by the greater dispersion of air pressure values than it was recorded in the case of Gdańsk.

The great scatter of air pressure values is characteristic for the cold season what is reflected in the standard deviation. Greatest absolute values of this estimator in the period 1752–1761 were met in Gdańsk and Uppsala in January (respectively about 11.88 hPa and 13.59 hPa). The latter seasons, compared with eighteenth century, had lower absolute values of standard deviation. In the period 1811–1820 the absolute values of standard deviation were characteristic for March in Gdańsk (10.65 hPa) and in Swedish stations in January again (12.18 hPa in Stockholm and 12.52 hPa in Uppsala) meanwhile in the period 1881–1890 October was the month of the greatest dispersion of analyzed element values (10.77 in Gdańsk, 14.18 hPa in Stockholm and 14.24 in Uppsala). The smallest standard deviation values of air pressure in the period 1752–1761 were characteristic for August in Gdańsk (4.54 hPa) and June in Uppsala (6.62 hPa). In the period 1811–1820 it was July, when the absolute minimum values of standard deviation occurred in each station: 5.19 hPa in Gdańsk, 6.06 hPa in Stockholm and 6.18 hPa in Uppsala. In the latest period the smallest absolute values in April were characteristic for each of the stations. The value of this estimator was 6.92 hPa in Gdańsk, 8.32 hPa in Uppsala and 8.36 hPa in Stockholm.

The air pressure ≥ 1,030 hPa was relatively twice more frequently in Gdańsk in the latter periods when it constituted over 6% of all registers of air pressure, in comparison with the initial one, when it was over nearly 3.3% of observations (the frequency of occurrence was not expressed in absolute values because of the different number of air pressure registers per day in the analysed periods). Such high pressure was registered first of all in January in the period 1752–1762 and 1811–1820 meanwhile in the period 1881–1890 the pressure ≥ 1,030 hPa occurred most frequently in February. The very few cases of such high pressure were noted in the warm seasons. The air pressure ≤ 990 hPa occurred much more rarely than cases with high pressure in Gdańsk (Reinick series – 2% of observations, Kleefeld series – 1% and Neufahrwasser series – almost 1.5%) and they were noted the most frequently in January (Reinick series) and March (Kleefeld and Neufahrwasser series). During the months of the warm season (from April to September) such low pressure had not been observed almost at all.

The results of analysis of Figs. 12.9 and 12.10 clearly highlight the synchronicity of air pressure variability in the area of the Southern Baltic Sea basin. Analyzing the courses of monthly mean pressure values in three analysed stations in the period 1752–1761 we can find the greatest differences between Gdańsk and Uppsala in the first half of 1752, in 1755 and in 1761. For the later period, 1811–1820, the differences between Gdańsk and Swedish stations were characteristic from the beginning of the period to the half of 1820, as it was stated above; then all series were synchronous. However, the air pressure registers in Gdańsk till the end of the period were somewhat greater than in Swedish stations. Bärring et al. (1999) analyzing monthly pressure variations in Lund from 1780 to 1997 defined period 1780–1820 as experiencing high pressure in early spring (March and April). One can observe in the period 1811–1820 (Fig. 12.9) a number of high air pressure values in March and April exceeding 1,017 hPa (1813, 1814, 1817), but no significant tendency is noticeable. In the last analysed period the occurrence of discrepancies between mean monthly values in Gdańsk and Swedish stations in autumn and winter 1881 and in autumn 1883.

The mean annual pressure cycles of daily means in Gdańsk in the analysed period were compared with the analogical ones in Swedish stations (Fig. 12.10). One can observe the substantial coincidence of variability of air pressure in the area of the Baltic Sea basin. Among the most typical features are: considerable air pressure changes in January and February, relatively high pressure in spring, summer minimum and successive increase in autumn till the following minimum in November and December. In the period 1752–1761 very low minima in February and November as well high pressure in September and January occurred. The values of element in Uppsala and Stockholm were greater than in Gdańsk from April till September. In the period 1811–1820 minimum in the beginning of March was stronger than in November. The greatest absolute values of air pressure were noted in the second half of March. The air pressure in Gdańsk dominated the values in Swedish stations within the whole year. The period 1881–1890 was characterized by the very strong maximum in January and February and then in September. Minima of air pressure occurred in March and in late autumn.

The series from Gdańsk and Swedish stations were additionally compared to the average annual cycle form Hel, 1971–2000 (Miętus et al. 2002–2004), located 25 km far from Gdańsk in a peninsula (unfortunately there were too many relocations of station in Gdańsk in this period which eliminated the possibility of use of this series). Statistically insignificant changes of air pressure in Europe in the scale of instrumental measurements period were reported by Bärring et al. (1999) in the analysis of the long-term variability of air pressure in Lund since 1780, Maugeri et al. (2002) in the paper on the series from Milan (since 1763), and Bergström and Moberg (2002) who reconstructed air pressure in Uppsala since 1722. Thus one might observe the most important features of variability of air pressure in the different periods in the area of the Southern Baltic Sea basin within instrumental observations period. In the first of periods selected for analysis daily means of air pressure in Gdańsk and Uppsala were lower than those in the last normal period of the twentieth century in Hel during the whole year. The second of the analyzed periods was

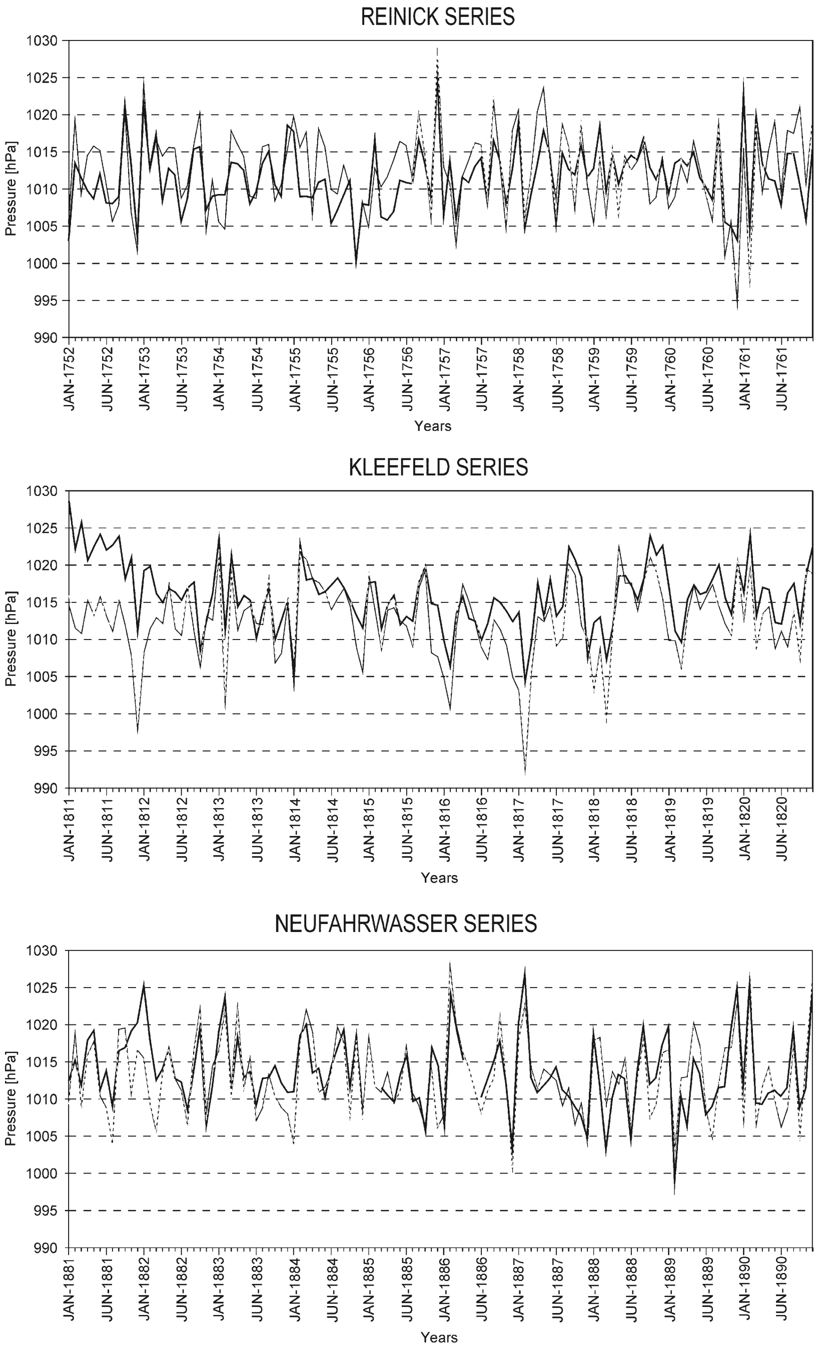

Fig. 12.9 Monthly mean pressure values of the Gdańsk (*bold solid line*), Uppsala (*thin solid line*) and Stockholm (*dashed line*) series

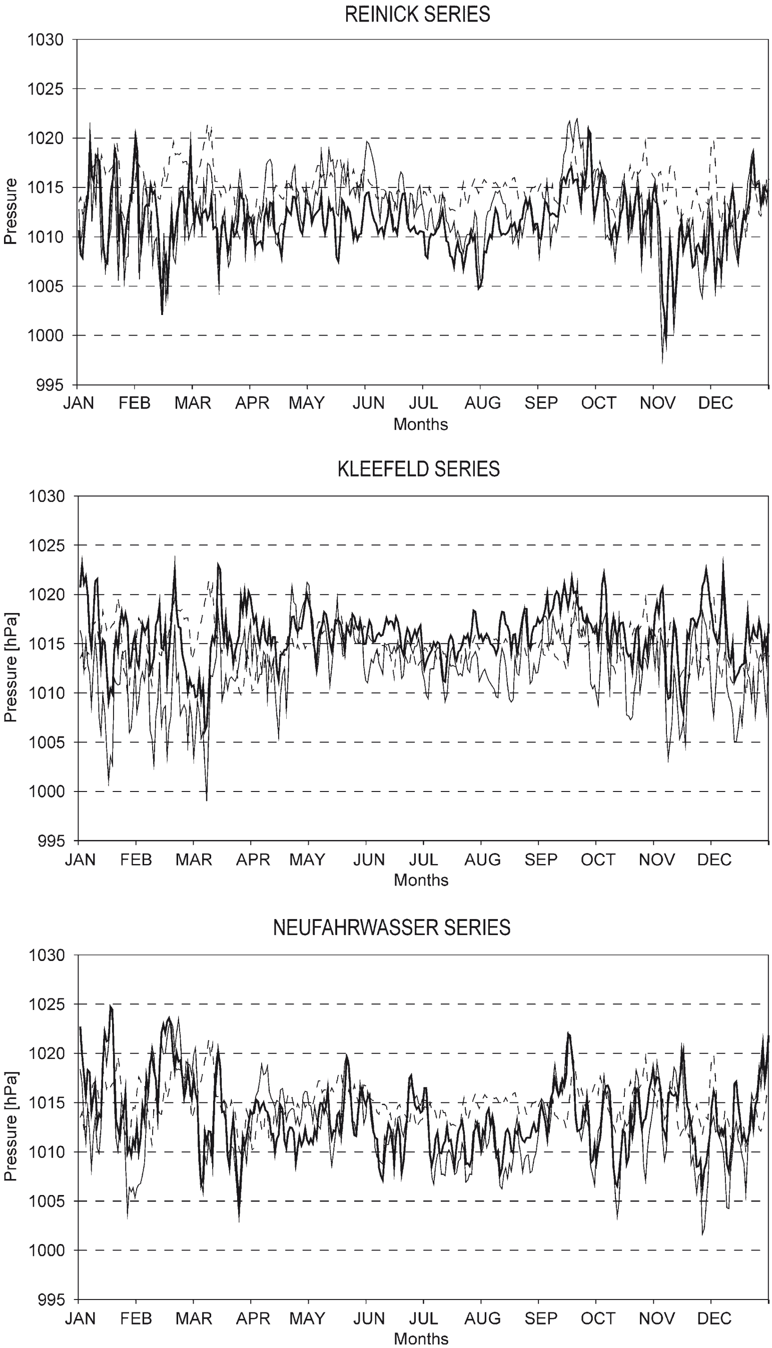

Fig. 12.10 The annual course of daily mean air pressure in Gdańsk (*bold solid line*), Uppsala (*thin solid line*) and Hel (period 1971–2000, *dashed line*)

characterized by the similar air pressure values in Gdańsk as in Hel, apart from the greater pressure in Gdańsk in spring and early autumn. In Swedish stations the lowest air pressure values in January and February occurred. In the latter period the air pressure in Gdańsk and in Swedish stations was comparable with the values in Hel except for the lower summer minimum in the nineteenth century.

Results of the analysis obtained so far proved the air pressure measured in Gdańsk to be consistent with the registers in Swedish stations. The observed differences can result from the effects of natural variability of the element in the stations distant more than 500 km from each other but can also occur due to different number and times of pressure observations. The calculation of daily mean values from the different number of observations conducted in various hours can not be sufficient to obtain the reliable research material. Thus the knowledge of real daily pressure cycle is necessary to construct model appropriate to eliminate the bias caused by the changing times of observations. It was possible to present here the seasonal mean diurnal pressure cycle in Gdańsk, 1987–2000 (Miętus et al. 2002–2004) (Fig. 12.11), which is consistent with the results presented in literature (Chapman and Lindzen 1969; Maugeri et al. 2002). Two maxima (at 9 and 21 UTC) and two minima (six and 12 UTC in winter and three and 15 UTC in the other seasons) can be observed. Taking into account the Reinick's observations conducted twice a day, respectively at 7 and 21–22 LT (local time) it is clearly showed

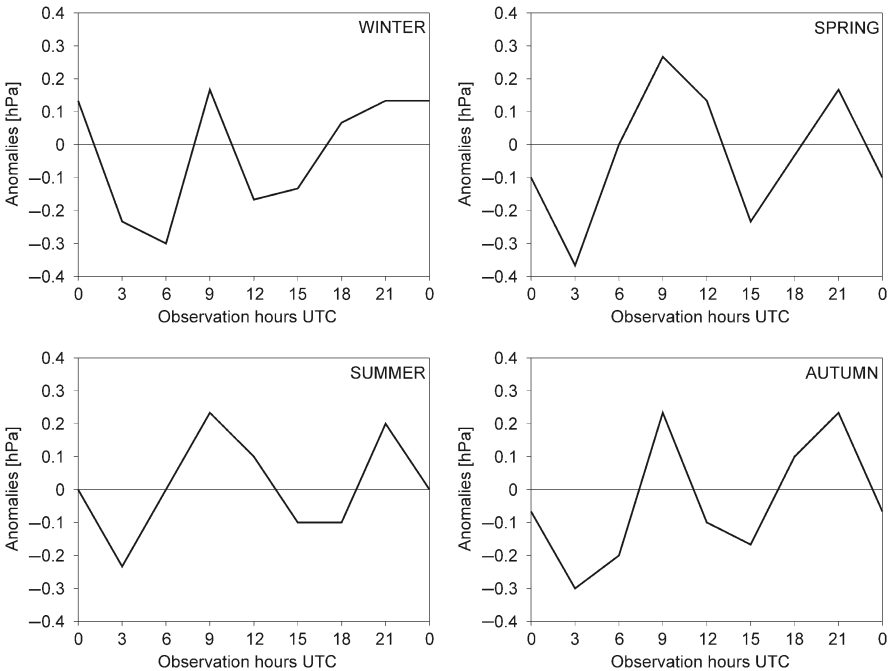

Fig. 12.11 Seasonal mean diurnal pressure cycle in Gdańsk, 1987–2000, calculated from eight observations per day, the observation times are presented according to UTC

that the simplified way of calculating the daily mean based only on two observations can cause the errors. The method of correction has to be applied to adopt all data to the real values of daily mean. For instance the greatest absolute errors found in early period observations in Milan (before 1834) were equalled 0.5 hPa in May. However, they did not exceed 0.2 hPa generally (Maugeri et al. 2002).

12.7 Summary

The analysis concerning the collection of information and other notes about meteorological observations and measurements conducted in Gdańsk seem to influence and enrich the hitherto existing knowledge on meteorological observations, as well as the beginning of regular measurements. A described history of meteorological observations taken by particular keen scholars ascertains the opinion that regular measurements and observations embarked in Gdańsk had started even before 1739 and they have been continued up to now.

It seems to be possible to reconstruct climatic series of Gdańsk since 1739. The data from earlier sources are still not available or refer to isolated periods. Additionally, sometimes they are characterised by considerable subjectivity. The most complete data characterizes elements such as air temperature, atmospheric pressure and wind speed and direction. The series of the other elements (humidity, precipitation, cloudiness) have got periods with missing data. The short breaks in observations took place not only in the eighteenth century but also in following centuries. It has been caused by the breaks during the wars, short discontinuations of the observations, or the limitation in the frequency of the readings of the instruments.

The preliminary results of atmospheric pressure data analysis collected by Reinick, Kleefeld and station in Neufahrwasser in Gdańsk did not reveal the errors in data which could eliminate them from the further analysis. However, the number of problems appeared concerning for example anomalously high values of atmospheric pressure of the Kleefeld series in comparison with both two other Gdańsk series as well as series from Uppsala and Stockholm.

The next important issue is related to the data homogenization and metadata. In practice it is difficult to obtain homogeneous data from long-term measurements. Climatic series, apart from natural variability of the climate, show additional impact of artificial factors. The homogeneity of the Gdańsk series, like many other long series, is disturbed by numerous random phenomena like relocations of the measurement places, changes in instruments as well as slow and persistent change of the surroundings of the station connected to the development of the city. In the scale of the examined period from 1739 till the beginning of the 20th Gdańsk enlarged its area and population several times. Only the application of homogenization methods will allow to uncover the heterogeneity in series and removal of the effects of artificial changes by introducing appropriate numerical amendments.

The comparative analysis of series from Gdańsk and Uppsala revealed also considerable discrepancies between data from some particular days from the eighteenth century, which was the most probably caused by the errors in the Swedish data. However, the paper was not intended as the attempt to question the homogenous series from Uppsala. The chance to verify the existing climatic datasets from the area of the Southern Baltic Sea basin appeared as well as more intensified assessment on climate change in this area will be possible soon.

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