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DIGISTAD

Disclosure of the hourly meteorological observations of the Amsterdam City Water Office 1784-1963

Final report

Hendrik Wallbrink and Theo Brandsma

De Bilt, 2008

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The KNMI-program HISKLIM aims at making historical land and sea climate data from Dutch sources physically accessible, with the highest possible time resolution and quality. The program started in 2000 and will run 5 to 10 years.

HISKLIM-1	Het KNMI-programma HISKLIM (HIStorisch KLIMaat) / T. Brandsma, F.B. Koek, H. Wallbrink en G.P. Können. (also KNMI-publication 191)
HISKLIM-2	Gang van zaken 1940-48 rond de 20.000 zoekgeraakte scheepsjournalen / H. Wallbrink en F.B. Koek. (also KNMI-publication 192)
HISKLIM-3	Historische maritieme winsdschalen tot 1947 / H. Wallbrink en F.B. Koek. (Memorandum)
HISKLIM-4	Onbekende weersymbolen in oude Extract-Journalen (1826-1865). / H. Wallbrink en F.B. Koek. (Memorandum)
HISKLIM-5	CLIWOC, Multilingual Meteorological Dictionary; an English-Spanish-Dutch-French dictionary of wind force terms used by mariners from 1750-1850 (also KNMI-publication 205)
HISKLIM-6	DIGISTAD (DIGitaliseren STADswaterkantoor). H.W. Riepma. (Memorandum)
HISKLIM-7	Parallel air temperature measurements at the KNMI-terrain in De Bilt (the Netherlands) May 2003–April 2005, Interim report. / H. Wallbrink and T. Brandsma. (also KNMI-publication 207)
HISKLIM-8	Hisklim COADS, Final report. / H. Wallbrink and F. Koek. (also KNMI-publication 210)

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HISKLIM 9

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Foreword

The manual digitization[1] and quality control of the 1.6 million meteorological observations of the Amsterdam City Water Office[2] (ACWO) was a sizable task that started in the year 2001. The work was performed within the DIGISTAD project by students working part-time for KNMI and by KNMI employees. The DIGISTAD project is part of the KNMI-program HISKLIM (Historical Climate; Brandsma *et al.*, 2000) that aims at making historical land and sea climate data from Dutch sources physically accessible, with the highest possible time resolution and quality. The first part of DIGISTAD (1784–1911) was finished in 2004 (Riepma, 2004), the second part in 2006. It was sad that the technical project leader Dick Riepma died on 10 June 2004. He completed the first part of the work with much dedication.

All historical data disclosed by HISKLIM are freely available for research, engineering, and the general public from the KNMI website at http://www.knmi.nl/klimatologie. For DIGISTAD this also includes images of the original observer logbooks, that served as a basis for typing the data into spreadsheets, and metadata information.

[1] By digitization we mean the actual keying of the data into spreadsheets and not merely making digital images of the hardcopy data. The latter we refer to as 'data imaging'.

[2] In the Netherlands known as ' Stadswaterkantoor in Amsterdam'.

1 Introduction

This report describes the digitization, the quality control, metadata and analysis of the hourly meteorological observations made at the Amsterdam City Water Office (ACWO) in the period 1784-1963. These observations are unique in the sense that they constitute the earliest known hourly long-term meteorological time series in the World. From 1784 onwards, air temperature, wind direction and wind force were observed hourly and from 1824 onwards hourly air pressures were added. In addition, there are descriptive observations of local weather. The time series are important for climate research and are now, together with the metadata and images of the original logbooks, freely available on the Internet.

In this section we present some background information of the ACWO observations, we define the problem, give the scope and objectives of the report and outline the structure of the report.

1.1 Background information

From about the year 1675 onwards, the ACWO was responsible for the water management of the canals in the city of Amsterdam. At that time, Amsterdam was situated along the open sea, and the canals in the city, which also served as sewer system, had to be flushed using the tide. The office is mainly known because of its hourly measurements of the sea level starting in 1700 (Van der Weele, 1971). Originally one assumed the so-called ‘Stadts Peijl’, a reference level fixed in 1684 by building marble level stones into eight sluices. In 1812-1813 the name ‘Amsterdams Peil’ was officially appointed and became known across the whole country. In 1875 a more accurate measurement of the water level was performed and the name ‘Normaal Amsterdams Peil’ was adopted. Again the old marble level stones served as a reference. The water level measurements of the office are available from the Archive of the municipality of Amsterdam (archive number: 335).

The meteorological observations of the office were made by its employees to support the watermanagement within the city. The watermanagement required shift-work, 24 hours per day. The latter made it possible to perform hourly weather observations, that were registered during the period 1784-1963 In the period 1700-1783 weather observations were performed irregularly a few times per day and consisted of only wind direction and speed. In the 1784-1963 period, the office moved to a new location three times.

At the beginning of this project, the earliest hourly time series in the Netherlands started in 1900 (though there are still tables in the KNMI-archives with hourly data of some of the main stations starting as early as 1849). Hourly observations provide an almost continuous image of the development of temperature, pressure, etc. during twenty-four hour periods. This is useful in climate research (computing trends for climate change detection, calculation of indices, study of urban heat island effect, etc).

1.2 Problem description

KNMI has a large backlog with respect to digitizing, quality control and supplying and managing of historical climate data (Brandsma *et al*, 2000). High-quality historical datasets are needed to properly assess climate change and variability (e.g. Klein Tank and Können,2003). Moreover, the datasets are also required to validate climate models. The output of these models is the basis for the development of climate change policies and climate scenarios for the 21^{st} century, which are increasingly being used in climate change impacts and adaptation studies.

The meteorological observations of the ACWO constitute one of the sources that is disclosed by KNMI. The DIGISTAD project deals with this unique source of important information for climate research.

1.3 Scope and objectives of the report

The main objective of this report is to describe the digitization and quality control of the handwritten data and metadata of the ACWO.

The work in this report is mainly restricted to the period with hourly observations 1784-1963. Besides meteorological information, the observer logbooks also contain observations of water levels at several locations. This information has not been digitized, though the information is available on the images that are provided together with the data on the Internet. The analysis of the data is restricted to that necessary to translate the units of the data to modern units and to that necessary for accessing the homogeneity of the air temperature and air pressure data.

The original project plan also mentions the digization of two other, though small, time series: the 17^{th} century time series of daily meteorological data of Leiden (1697-1698) and the Fremery time series with sub-daily data of Utrecht (1836-1846). Both time series have been digitized within the scope of DIGISTAD but are not dealt with in this report. The Leiden data is discussed in Können and Brandsma (2005). The data and metadata of both stations are available from the KNMI website at http://www.knmi.nl/klimatologie.

1.4 Structure of the report

In Section 2 we discuss the data and methods used in DIGISTAD. Section 3 presents a detailed presentation of the weather variables and their metadata. Section 4 deals with the analysis of the data. Some concluding remarks are presented in Section 5.

2 Data and methods

In this section we describe the data that have been used in the DIGISTAD project and the methods for digitizing the data, for quality control and for dealing with missing data.

2.1 Materials

The original observer logbooks are archived in the municipality archives of the city of Amsterdam (Gemeentearchief Amsterdam). Figure 1 shows some example pages of these books. The handwritten logbooks were put on microfilms in 1984 by the Amsterdam City Archive and KNMI obtained a copy the films. In total KNMI has 138 films for the period 1767-1963. To facilitate the digitization of the observations, the films were transferred to jpg-images within the DIGISTAD project. This work was done by the Netherlands Institute for Scientific Information Services (NIWI) in Amsterdam. Both the films and the CDs are stored in the archive of KNMI. The images are also put on the computer network of KNMI and are part of the regular back-up procedures.

2.2 Methodology

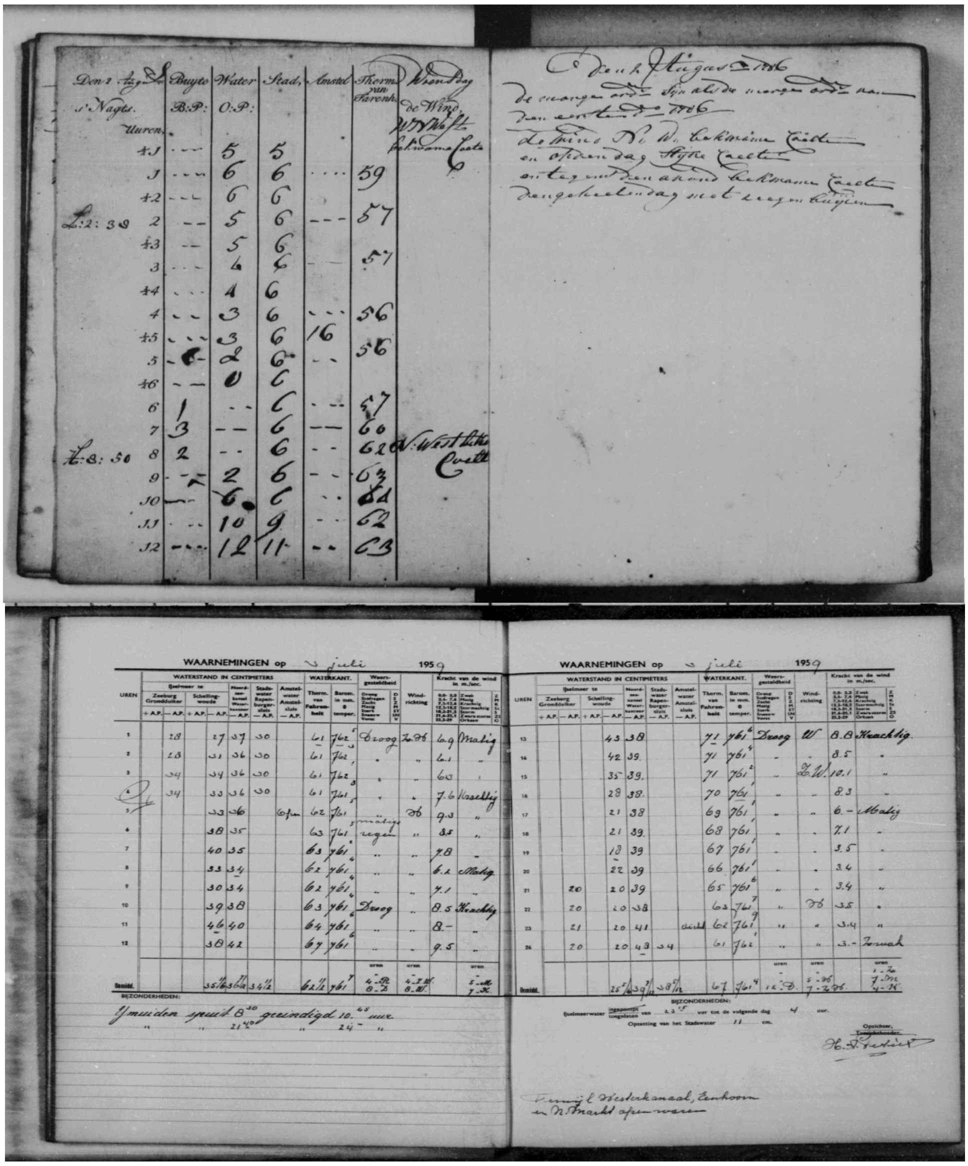
Digitization of the data
The images were used as a basis for digitizing all 1.6 million observations. Because the logbook pages on these images are handwritten, the use of automatic optical character recognition (OCR) was not obvious. Moreover, the handwriting is sometimes of doubtful quality. Therefore, the use of OCR software was not feasible within DIGISTAD and we had to key all data by hand. In the course of the project, we experimented with the use of speech recognition software. This was, however, not successful.

Several KNMI employees and 18 part-time students have been working on the project (see Appendix 1). We created 5 working places with two computers each, one for viewing the digital images with the handwritten observations and the other for keying in the data into a spreadsheet program (Microsoft Excel and Access).

All meteorological observations of air temperature, air pressure, wind direction and speed, and weather descriptions were digitized for the period January 1780 through 31 December 1963. In addition, meteorological remarks concerning e.g. lightnings, thunderstorms, heavy storms and ice thickness in the Amsterdam canals and parks were digitized as well.

Prior to 1784 there are no measurements of air temperature and air pressure in the logbooks. Only observations of wind direction, wind speed and weather have been collected at the Nieuwmarkt. Because of the absence of instrumental data together with the erratic behavior of the observation times the data was only partly digitized. For pre 1780 period, we only digitized the observations of wind direction and speed and weather from February 1767

Figure 1: Two example pages from the logbooks of the Amsterdam City Water Office: 2 August 1786 (upper) and 3 July 1959 (lower).



through April 1773.

The pre-1780 observations (non-instrumental), have the following observation times:

- ✓ 1700-1705. Random observation times at wind changes only.
- ✓ 1706-1729. Random observation times, two times a day and at wind changes.
- ✓ 1730-1774: two times a day around 6 am and 8 pm and at wind changes.
- ✓ 1775-1780: four times a day at 1 am, 8 am, 1 pm, 8 pm and at wind changes.

The observer logbooks for the period 1750-1765 are missing in the 'Gemeentearchief Amsterdam'.
The first part of the work was finished in 2004 (Riepma, 2004), the second part, including Quality Control (QC), in 2006.

Quality control

Quality control (QC) of the data was performed, after digitizing the data, for every spreadsheet separately consisting of 5 years of data. The hour-to-hour differences in the air temperature and air pressure time series were graphically displayed and outliers in the series were detected. All suspect values were checked in the images and, if needed, corrected for. Most of the suspect values concerned typing errors. The correct values could easily be retrieved from the images. In other cases, obvious erroneous values were corrected by linear interpolation between neighboring values. For the categorical variables wind direction and speed, we constructed frequency distributions and checked those for irregularities. The remarks in the spreadsheets, typed in by the digitizers while digitizing, were visually checked.

Missing data

When data was missing or badly readable, we first checked the copies of the microfilms that were available at KNMI using a microfilm reader. It appeared that errors were sometimes made in the conversion of microfilm to the jpg images. Second, dates of the remaining missing or badly readable data were stored until all data were digitized. Then a complete list of the remaining missing days was send to the municipality archive of the city of Amsterdam. Whenever available, they made hardcopies of the missing days using the original logbooks. Finally, we used these hardcopies to key in the data. From the total of 1.6 million observations only 0.3% is missing.

3 Metadata description

In this section we present the metadata related to the observations of the ACWO. Sections 3.1 and 3.2 describe the measurement locations and deal with observation frequency and the units. Sections 3.3 through 3.7, present the metadata of each variable separately. Additional metadata information can also be found in Geurts and Van Engelen (1992).

3.1 Observation locations

In the 1700–1963 period the ACWO moved three time to a new locations in the city centre of Amsterdam. The four locations are depicted on the map in Figure 2 and the corresponding observation periods are given in Table 1 . Photographs/drawings of the locations are shown in Figures 3, 4, 5 and 6.

Table 1: Locations of the Amsterdam City Water Office in the period 1780-1963.

Location	From	Until
Nieuwmarkt/GelderseKade	01-01-1700	23-05-1861
Oosterdoksdijk/Kraansluis	23-05-1861	xx-xx-1868
Nieuwebrug/Zeerecht	xx-xx-1868	14-05-1878
Montelbaanstoren	14-05-1878	31-12-1963

xx = no information availble

Remarks on the relocations of the Amsterdam City Water Office
The information in Table 1 is confirmed by information found in the logbooks and some background documents. These documents contain several remarks hinting at relocations of the ACWO. The most important remarks are summarized below (in Dutch).

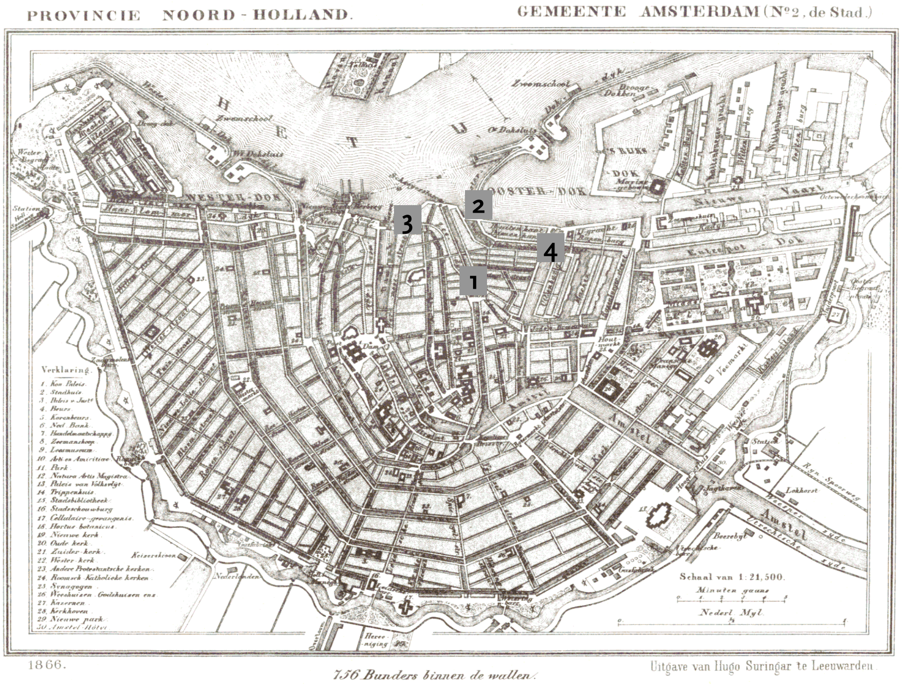
- ✓ Nieuwmarkt/GelderseKade. On 23-05-1861 the logbook states: ‘Voormiddag ten 9 uur zijn de laatste waarnemingen geschied in het oude Stadswaterkantoor op de Nieuwmarkt en ten 10 uur is men begonnen in het nieuwe gebouw op den oostelijke afsluitdijk’.
- ✓ Oosterdokdijk/Kraansluis. No direct logbook information available on the relocation to the Nieuwebrug/Zeerecht location (see also the remark below).
- ✓ Nieuwebrug/Zeerecht. ‘Stadswaterkantoor in gebouw Zeerecht, Kampersteiger 10, van 1868 tot half mei 1878’ (Archive of the municipality of Amsterdam). The building Zeerecht was broken down at the beginning of 1879.
- ✓ Montelbaanstoren. On 15-05-1878 the logbook states: ‘Namiddags 6 uur waargenomen aan en in de Montelbaanstoren alwaar het Waterkantoor thans is geplaatst’.

3.2 Observation time, frequency, units and periods

Table 2 presents for each parameter a summary of the units of the observations and the observation frequency for the 1784-1963 period. Each of the parameters is discussed in more detail in the subsequent sections.

The observation times of the ACWO are presented as they appear in the logbooks. The following should be noted with respected these times:

Figure 2: Map of the City Center of Amsterdam showing the locations of the Amsterdam City Water Office in the 1700–1963 period: (1) Nieuwmarkt/ Gelderse Kade. (2) Oosterdoksdijk/Kraansluis, (3) Nieuwebrug/Zeerecht, and (4) Montelbaanstoren.



1. From 1 January 1784 through 30 June 1937 the observation times are in local time AT (Amsterdam Time). AT = UTC + 19 min + 32.13 sec.
2. From 1 July 1937 through 16 May 1940 observation times are in Netherlands time NT (Netherlands Time). NT = UTC + 20 min.
3. From 17 May 1940 onwards Central European Time (MET) was introduced throughout the Netherlands and used as observation time at the ACWO. MET = UTC + 60 min.
4. Summertime was introduced in 1916 in the Netherlands and this continued through 1945. In the final period of the ACWO, 1946–1963, there was no summertime in the Netherlands.
5. In the period 16 May 1940 – 2 November 1942 summertime was used without interruption.
6. The logbooks indicate that summertime was used for the observations of the ACWO.
7. The start and end dates of the Dutch summertime can be found in e.g. Draaisma en Kaarls (1977) or at http://www.knmi.nl/VinkCMS/explained_subject_detail.jsp?id=24118.

Tabel 2: Meteorological parameters, observation times and units.

*At 0100, 0800, 1300 and 2000 hour. In addition, observations were also made at wind changes but not systematically.

Parameter	From	Until	Units	Observation frequency
Temperature				
	03-02-1784	31-12-1963	Fahrenheit	Hourly
Air pressure				
	01-01-1824	31-12-1963	mmHg	Hourly
Wind direction				
	01-01-1780	31-12-1785	16 point compass	Four times a day*
	01-01-1786	04-02-1852	8 point compass	Four times a day*
	04-02-1852	31-12-1963	8 point compass	Hourly
Wind speed				
	01-01-1780	04-02-1852	Sailor's wind terms	Four times a day*
	05-02-1852	19-04-1860	Sailor's wind terms	Hourly
	19-04-1860	31-12-1855	Amsterdam wind terms	Hourly
	01-01-1956	31-12-1963	KNMI wind terms	Hourly
	01-01-1956	31-12-1963	m/sec	Hourly
Weather/meteorological remarks				
	01-11-1781	30-07-1795	Descriptive terms	At 0100 and 1300
	04-02-1852	31-12-1963	Descriptive terms	Hourly
	04-02-1852	31-12-1963	Descriptive	In case of (thunder) storms and hail

Figure 3: Location of the Amsterdam City Water Office (indicated by the black arrows) at the Nieuwmarkt/Geldersekade. (1700–1861). Upper figure: drawing from the year 1743 with on the left the 'Boomsloot' and on the right a part of the Nieuwmarkt with building 'The Waag'. Lower figure: drawing from about the year 1850 with in the background the Nieuwmarkt with building 'The Waag'. Note the instrument on the left of the NNW facing front wall of the office (white arrow). Images are obtained from the 'Amsterdam Gemeente Archief'.

Figure 4: Location of the Amsterdam City Water Office at the Oosterdoksdijk/Kraansluis (1861–1868). The photo shows the Waaleilandsgracht viewed from the Oosterdoksdijk with in the middle the 'Kraansluis' and on the left the small wooden building of the Office (indicated by the black arrow). Today Kraansluis is called Prins Hendrikkade. Image obtained from the 'Amsterdam Gemeente Archief'.

Figure 5: Location of the Amsterdam City Water Office at the Nieuwebrug/Zeerecht (1868–1878). The photo shows the Office housed in building 'Zeerecht' (as indicated by the black arrow). The Office was situated in front of the present Prins Hendrikkade 50, in former days Kampersteiger 10. Image obtained from the 'Amsterdam Gemeente Archief'.

Figure 6: Location of the Amsterdam City Water Office at the Montelbaanstoren (1878–1963). The photo shows a view of the Montelbaanstoren with the Oude Schans canal. Right of the Montelbaanstoren the bridge over the Waaleilandsgracht is visible. The Stadswaterkantoor was situated in and around the first floor of the Montelbaanstoren (see arrow). Image obtained from the 'Amsterdam Gemeente Archief'.

3.3 Air temperature

The instruments used for measuring air temperature (and also air pressure), are not always comparable to the instruments we know today. The First International Marine Meteorological Conference was held in Brussels in 1853. Till that time the imperfection of meteorological instruments was notorious. The mercury of the thermometers and barometers often was contaminated and instrument makers seldom determined the real errors of the instruments. This should be taken into account while using the data.

The original temperatures are given in degrees Fahrenheit throughout the observation period. Only from 01-01-1863 until 25-03-1863 the Celsius scale has been used temporarily. The Stadswaterkantoor observers crossed out the Celsius values in the logbooks and noted the converted Fahrenheit values into the logbooks instead. During the brief period 13-03-1863 until 16-03-1863 the Celsius values are not crossed out and not converted to Fahrenheit in the logbooks. These Celsius values have been converted afterwards at KNMI according to:

$$T_F = \frac{9}{5} T_C + 32 \tag{1}$$

where T_F is temperature in Fahrenheit and T_C is temperature in Celsius. The temperature time series can easily be transformed in units Celsius using the inverse of Equation 1.

There is hardly any information available about the thermometers. From the logbooks it follows that the thermometers are cleaned and repaired regularly (missing hours in the time series). However, information about the type of thermometer or calibration information is not available. There is also no information in the logbooks about the precise location of the thermometers. The drawing of the Nieuwmark/GelderseKade location (Figure 3, lower part) in Section 3.1 indicates that temperature was measured outside on a NNW-facing wall. Nieuwmark/GelderseKade location was used until May 1861. At that time KNMI was involved in the observations and it seems likely that the observations were taken outside in the shade. Comparison with modern-day observations may provide more information about the characteristics of the measurement location. This will be discussed In Section 4.

3.4 Air pressure

The barometer readings in the logbooks are presented tenths of mm Hg. From 01-01-1863 onwards barometer readings are reduced to a temperature of 0°C according to:

$$p = p'(1 - 0.00018 T_C) \tag{2}$$

where p is the reduced pressure and p' is the unreduced pressure , both in mmHg. The temperature correction in Eq (2) was commonly used for the other KNMI stations as well. No information about barometer corrections prior to 1863 is available. Comparisons with the air pressure series of Utrecht/DeBilt confirms that the barometer readings are not corrected for temperature before 1863.

From 10-11-1865 until 18-05-1897 also additional barometer readings have been collected twice a day (mostly at 8 am and 8 pm) or three times a day (8 am, noon and 8 pm) and written down in the datum column of the observer's logbook. These pressure observations are slightly higher, about 0.5 mm on an average, than the regular hourly observations. The reason for the additional barometer readings is not known and they have not been digitized.

Hardly any information is available about the barometers used. The logbooks show that they have been repaired and cleaned regularly (missing hours in the time series). Again, there is no information about barometer type or calibration. Also information about the measurement location e.g. in or outside the building or in a cold or heated room is not available.

In the KNMI-yearbook of 1855 it is written that the director of the institute, Prof. Buys Ballot, supplied KNMI calibrated meteorological instruments to Amsterdam. Although it is not mentioned to whom these instruments were supplied, it is likely that also the ACWO obtained instruments. Especially, the quality of the air pressure observations improved from that year onwards as will be shown in Section 4 where we discuss the homogeneity of measurements.

3.5 Wind direction

It is not described how wind direction was observed at the ACWO. However, long before the start of the observations of the office, it was common practice to use the weathercock on top of a nearby tower or the pennant of a nearby moored sailing ship to observe the wind direction. From about 1850 onwards, wind vanes and anemometers have been introduced in the Netherlands. With the help of historical pictures of the Stadswaterkantoor buildings we have tried to find some clues about the wind direction observations at the different observation locations.

- ✓ Nieuwmarkt/GelderscheKade 1780-1861 (Figure 3). The figure does not show a wind direction device. Probably the flags and pennants on top of the towers of the nearby building 'de Waag' at the Nieuwmarkt were used for estimating the wind direction.
- ✓ Oosterdoksdijk/Kraansluis 1861-1868 (Figure 4). Two wooden masts on top of the Stadswaterkantoor can be seen but no wind vane attached. It is likely that the pennants of the moored sailing ships, along the quay close to the Stadswaterkantoor, were used for estimating the wind direction.
- ✓ Nieuwebrug/Zeerecht 1868-1878 (Figure5). An aërosklinoskoop can be seen on the pictures. A wind vane measuring the wind direction cannot be seen. The pennants of the moored sailing ships along the Kampersteiger were likely used for estimating the wind direction.
- ✓ Montelbaanstoren 1878-1963 (Figure 6). The flags and pennants on top of the tower were used for estimating the wind direction. In the period 1956-1963, the wind direction was measured with a wind vane at 20 m height.

Table 2 in Section 3.2 presents Information about the observations times and units.

3.6 Wind force

In general, wind force in the Netherlands was estimated from the turning speed of the wings of a windmill (using the so-called Millscale[3]). The ACWO, however, started with force observations as used by sailors. Probably this can be traced back to Amsterdam as a seaman's city. Sailor's wind force names are corresponding to numbers as used by Beaufort. Comparing seaman's wind force numbers with the same wind force numbers on shore is hardly possible because of the different meaning of the wind force. Wind force 4 on land (moving of a pennant or leaves at a tree) means something

[3] 'Molenschaal' in Dutch

else than wind force 4 at sea (Bramzijls koelte). In addition, wind force estimates on land are more subjective than at sea because of the large heterogeneity of the land surface (buildings, trees, etc.).

From 19 April 1860 onwards the names of the wind force changed in the logbooks from seaman's names to Amsterdam wind force names. In the KNMI yearbooks 1868 and 1870 Prof. Buys Ballot presented a table showing corresponding wind force names between the sailor's 'koelten' and the Amsterdam wind force names. With the help of that table and remarks in the yearbooks, we were able to construct Table 3. From 1956 onwards, the wind force names in use by the KNMI were adopted.

Table 3: Corresponding names for the wind speed and equivalent wind speeds in use at the Stadswaterkantoor 1780-1963.

Amsterdam 1780-1860	Amsterdam 1860-1955	Amsterdam 1956-1963	Equivalent, m/sec 1956-1963	Beaufort Number
Stil/Bijna stil	Stil/Bijna stil (until 1890)			0
Slappe koelte Matige koelte*	Zacht	Zwak	0.0– 3.3	0, 1, 2
	Matig	Matig	3.4 – 7.4	3, 4
Bekwame koelte	Wakker	Krachtig	7.5 – 12.4	5, 6
Stijve koelte	Glad	Stormachtig	12.5 – 18.2	7, 8
Storm	Hard/Rukwind	Storm	18.3 – 21.5	9
Harde storm	Storm/Harde storm	Zware storm	21.6 – 25.1	10
		Orkaan	25.2 – 29.0	11

* The wind speed name 'Matige koelte' has only been used 65 times. All occurrences are in the period October 1857 and 1858.

From 1956 onwards wind speed was measured in m/sec by an anemometer and noted in the logbooks. An extra column was added for the translation of wind speed to wind force. For this translation, the WMO equivalents according to Simpson (1926) were used. For that purpose the headers of the logbooks in this period contain a table that relates the wind force to the corresponding wind speed intervals.

3.7 Weather and meteorological remarks

From 1781 until 1795 the most prevailing weather situation over the past 12 hours (see Table 2) was reported in the logbooks, e.g. rain, hail, and snow (often together with the intensity of the showers). From 04-02-1852 onwards, the weather situation was reported hourly.

Special meteorological phenomena have been written down as separate remarks outside the standard columns. For instance: thunderstorms, lightning's and heavy showers/rains together with their observation time, ice thickness in canals and parks (from 1865 until 1909), foggy or hazy weather, etc. The descriptive notes for both weather and meteorological remarks are presented in two separate columns in the data files. They are given in Dutch without translation.

4 Analysis of the data

In this section we present the temperature and air pressure time series. For both series we assess their homogeneity. Our purpose is not to homogenize the series but rather to assess the magnitude of the inhomogeneities.

4.1 Air temperature

Figure 7 presents the annual mean values of the mean (*T*g), maximum (*T*x), and minimum temperatures (*T*n). The values were obtained by sequentially calculating the daily mean values, monthly mean values and annual mean values. The daily *T*x and Tn values are calculated, respectively, as the maximum and minimum of the 24 hourly values. Daily values of *T*g, *T*x and *T*n were set to missing with > 3 missing hours, monthly means with > 2 missing days and annual means with > 0 missing months. The annual percentage of missing hours is presented in Figure 8.

The 1784–1963 mean values are 10.2°C for *T*g, 13.0°C for *T*x and 7.6°C for *T*n. The corresponding 1971–2000 mean values of the nearby Schiphol airport are 9.8, 13.4 and 6.1°C, respectively. Because of the different periods, the values of the two stations are not directly comparable (the 1961–2000 period shows a warming trend compared to the earlier period). They do, however, indicate relative warmth of Amsterdam compared to Schiphol, especially for *T*n which is 1.5°C higher for Amsterdam compared to Schiphol. The latter is common for stations like the ACWO situated in the urban heat island of Amsterdam. It should be noted that because of their calculation from the 24-hourly values, the real *T*x and *T*n values of ACWO are in reality about 0.3°C more extreme than those presented above.

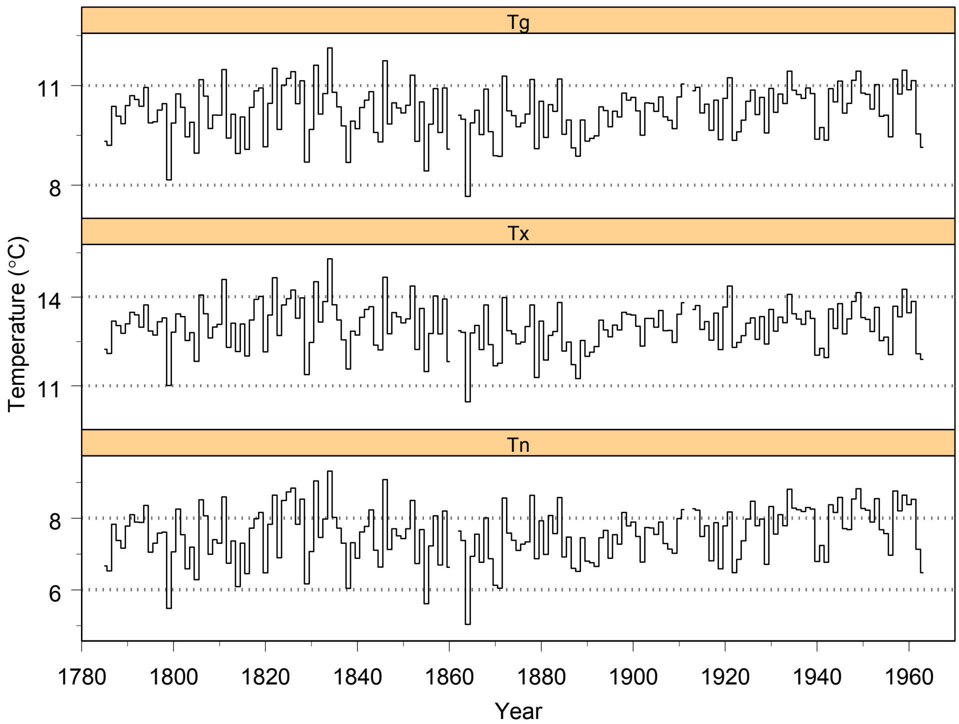


Figure 7: Annual mean values of the daily mean (*T*g), maximum (*T*x), and minimum temperatures (*T*n) for the 1784–1963 period.

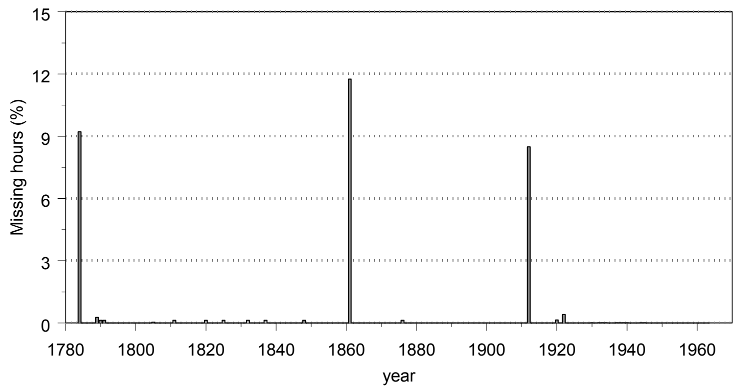


Figure 8: Annual percentage of missing hourly observations (1784–1963).

Homogeneity testing

Inhomogeneities may be introduced in a meteorological time series by e.g. relocation of a station and changes in: instrumental design, position of instruments, procedures, and surroundings of stations. A good indicator of such changes is the diurnal temperature range DTR. Figure 9 shows the mean DTR for the summer half year. The vertical lines indicate the position of so-called break-points as determined with the Standard Normal Homogeneity Test (SNHT, Alexanderson, 1986). All break point are statistically significant at the 0.05 level. At the year where a break-point was detected the series was split and the test was again performed on the parts before and after the break. This process was repeated till no statistically significant breaks could be identified. The last two relocations of the ACWO (see Table 1) resulted in detectable breaks in the DTR but the first relocation is not visible. In addition there is a clear break in 1923/24. There is no indication for this break in the (sparse) metadata.

An alternative way of testing the homogeneity of a series is to compare the series (candidate series) with a homogeneous reference series. The reference series is subtracted from the candidate series and the SNHT-test is applied to the residual series. Here we use the annual mean temperatures of the so-called Zwanenburg/De Bilt series (Labrijn, 1945; Van Engelen en Nellestijn, 1990) as a reference series. Although the homogeneity of that series is somewhat debated, in combination with the test of the DTR above it should give a good indication of the inhomogeneities in the annual mean *Tg* of ACWO. Only months are considered with non-missing temperatures for both series.

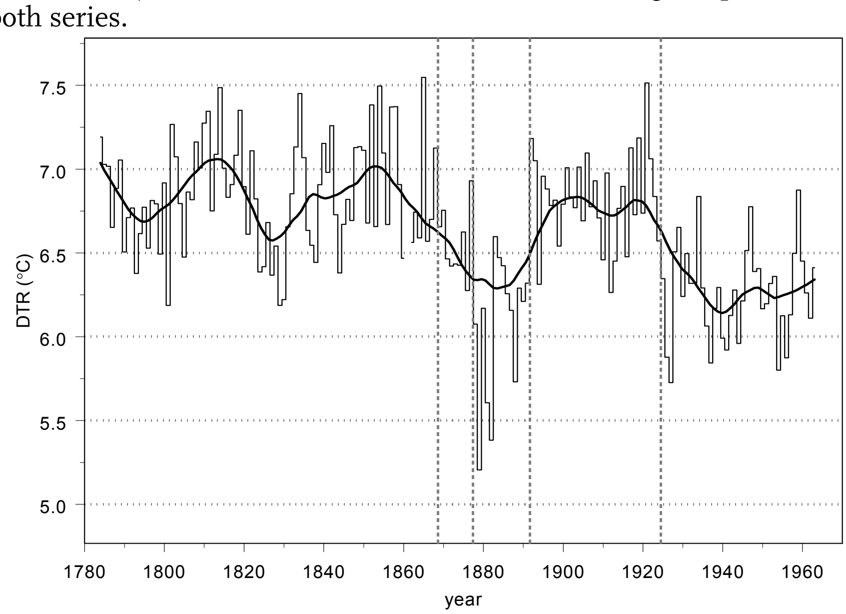


Figure 9: Mean diurnal temperature range (DTR) for the summer half year (April-September) for the 1784–1963 period. The dashed vertical lines give the position of the statistically significant breaks. The thick solid line is a locally-weighted running-line smooth curve using the data from the 20 nearest years in each year.

Figure 10: Mean annual temperature difference ΔT (ACWO minus Zwanenbrug/De Bilt) for the 1784–1963 period. The dashed vertical lines give the position of the statistically.

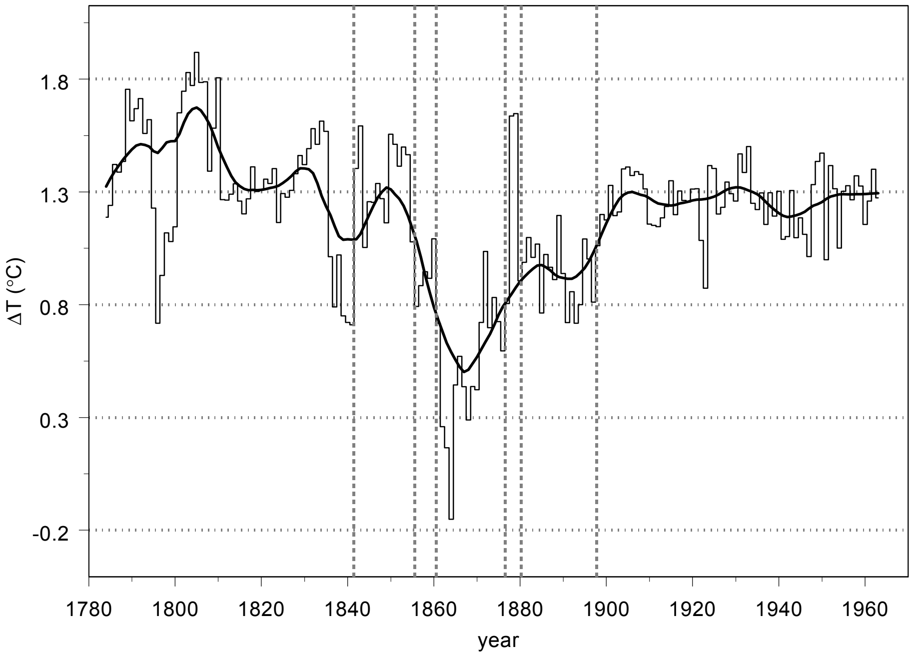


Figure 10 shows the breaks in the residual ΔT series. In contrast to Figure 9, we do see a break here at the time of the first relocation of the ACWO in 1861. The break in 1868 (second relocation), however, is visible in the graph but is not detected as statistically significant. Around the third relocation there are two breaks visible. The breaks in 1841, 1855 and 1897 cannot be explained from the metadata and are also not apparent in Figure 9. The break in 1897 may (partly) result from a relocation in the Zwanenburg/De Bilt series (from Utrecht to De Bilt) which is exactly at that time. The 1923/24 break in DTR (Figure 9) is not visible here. This confirms the idea that changes in DTR are not always accompanied by changes *T*g.

4.2 Air pressure

Figure 11 presents the annual mean air pressures. As for temperature, the values were obtained by sequentially calculating the daily mean values, monthly mean values and annual mean values. The annual percentage of missing hours is presented in Figure 12. All pressures are corrected for temperature and converted to hPa. No corrections were applied for observation height, gravity, index correction, etc. Normally all corrections added together are constant and can be determined by comparison with the modern-day long-term mean air pressures of a nearby station.

The annual mean air pressures before 1856 show a rather strange behavior. There is a strongly increasing trend in this period which must somehow be related to a slowly deteriorating barometer. As noted in Section 3.4, it is likely that the ACWO obtained a barometer of KNMI in the year 1855. After this year the air pressures show a strong drop (Figure 11). Figure 13 presents the standard deviation of the day-to-day air pressure differences. For each month we calculated the standard deviation of the day-to-day air pressure differences and these values were subsequently averaged for each year. Except for the first three years of the series, the average level of the standard deviation is rather constant. This may be an indication that adequate ho-

Figure 11: Annual mean air pressure values for the 1784–1963 period.

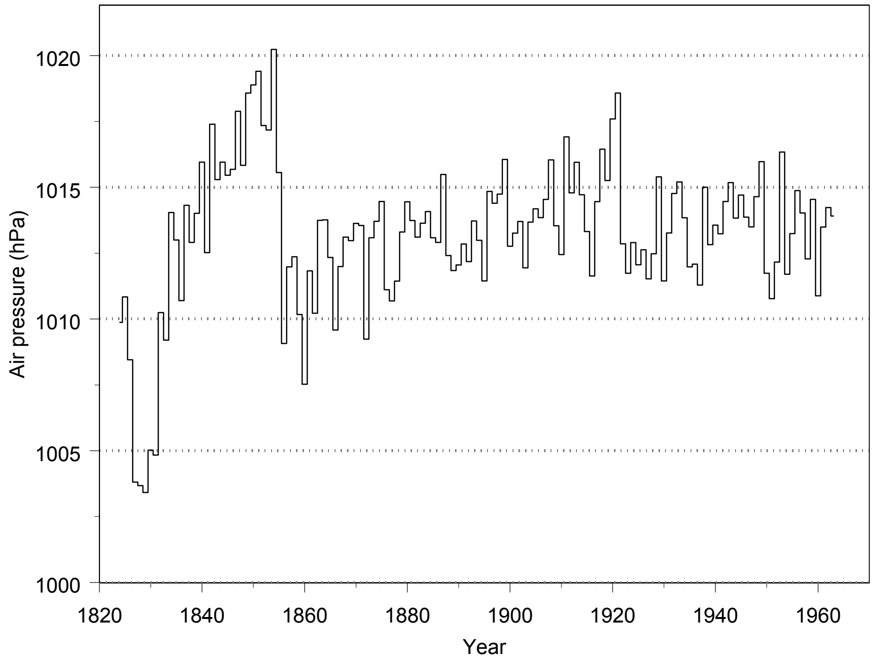
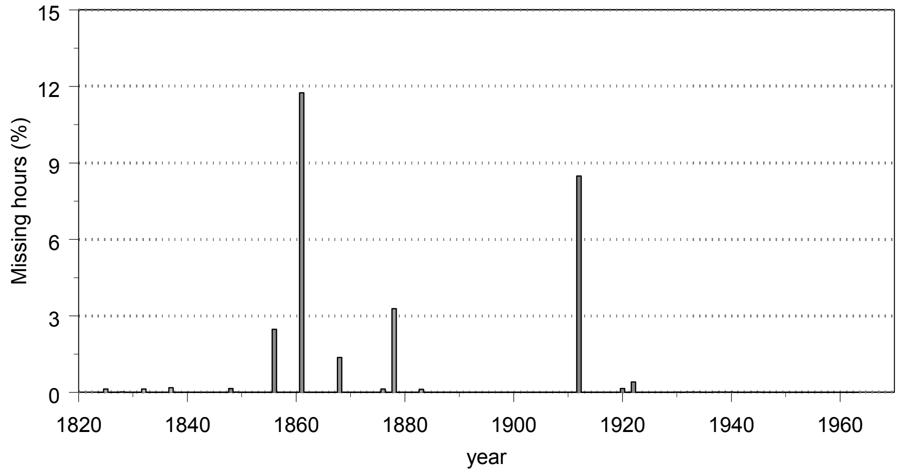


Figure 12: Annual percentage of missing hourly air pressure observations (1824–1963).



mogenization of the 1827-1855 part of the series is possible, despite of the strong trend in the mean air pressures.

As for temperature, we compare the ACWO mean pressure values with those of the nearby Schiphol airport. For the 1856–1963 period the long-term mean air pressure of ACWO equals 1013.3 hPa compared to 1015.3 for Schiphol airport (1971–2000). There is thus a negative bias in the ACWO air pressures of about 2.0 hPa. The mean standard deviation of the day-to-day air pressure differences for the 1856–1963 period equals 5.8 hPa compared to 6.0 hPa for Schiphol (1971–2000). The difference of 0.2 hPa in these values is small.

Homogeneity testing
For testing the homogeneity of the series only the 1856-1963 period is considered. Homogeneity testing of the annual mean pressure series (conform the testing for temperature) shows only one statistical significant breakpoint, namely in the year 1878. This corresponds to third and last relocation of the ACWO (see Table 1).

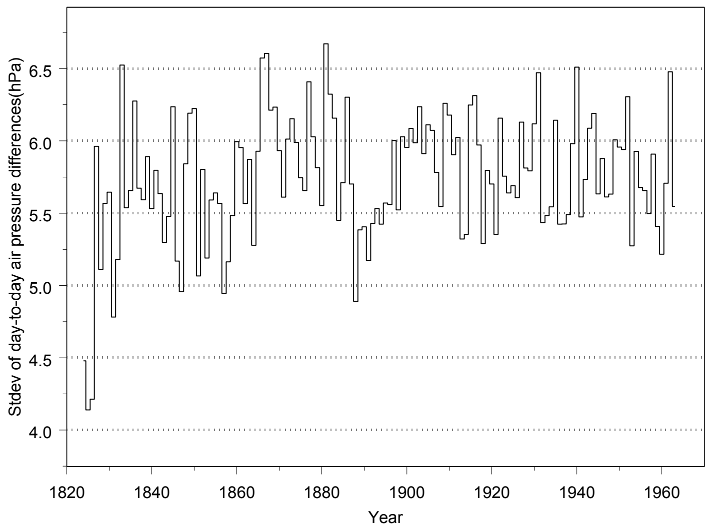


Figure 13: Standard deviation of the day-to-day air pressure differences (calculated per month and averaged for each year).

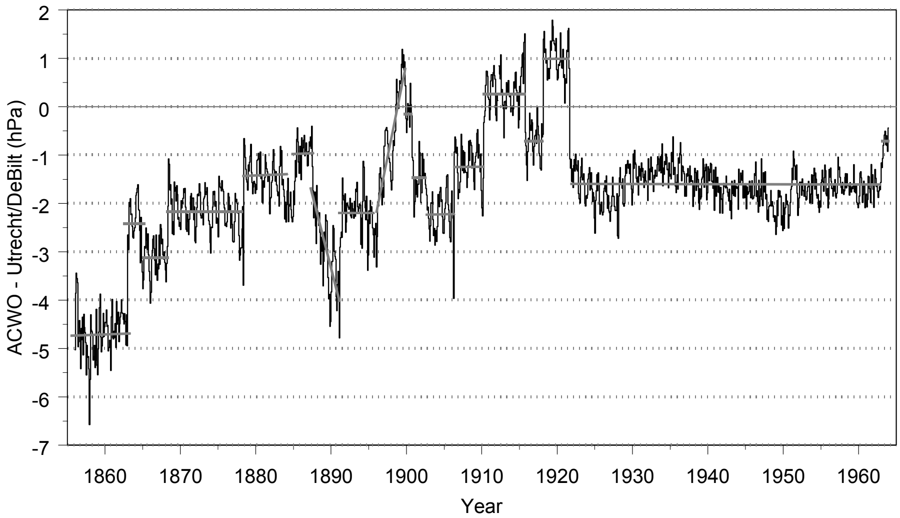


Figure 14: Monthly mean air pressure differences ACWO minus the references series Utrecht/De Bilt for the 1856-1963 period. The thick gray lines give an indication of the position and magnitude of the inhomogeneities in the ACWO series.

In the relative homogeneity test, we compared the ACWO series with the Utrecht/De Bilt pressure series (situated about 35 km Southeast of Amsterdam). The latter series may be considered as a homogeneous reference series. As for temperature, the reference series is subtracted from the candidate series and homogeneity test are applied to the residual series. For the 1855–1901 part only three times daily values were available for the Utrecht/De Bilt series. For ACWO the corresponding hourly air pressure values were selected and used to calculate the daily, monthly and annual mean values. For the 1902–1963 period the series were compared using the daily means as calculated from the 24 hourly values.

Figure 14 presents the monthly air pressure difference series (ACWO – Utrecht/De Bilt). Because of the spatial consistency of air pressure, the comparison with a nearby station removes almost all of the natural noise and the biases or trends, if present, can be visually be detected. Therefore, the use of the SNHT could be skipped here. The figure shows that there are a lot of inhomogeneities where the differences between ACWO and Utrecht/DeBilt vary between –4.8 and +1.0 hPa. Looking in detail to the figure reveals that the unknown relocation time in 1868 (see Table 1) is probably in the month of May. The long-term mean air pressure of between Schiphol airport (and thus ACWO) and De Bilt (1971–2000) equals –0.2 hPa.

5 Summary and conclusions

In this report we described the digitization, quality control, metadata and analysis of the unique long-term hourly meteorological observations of the ACWO (1784–1963). At the start of the project, the logbooks of the ACWO were available at KNMI on film. We transferred the films to digital images, which were used to key in all of the 1.6 million handwritten observations into spreadsheets by hand.

The observations were quality controlled. Missing data were as far as possible recovered from the films and, in the end, also from the original ACWO logbooks in the Archive of the Municipality of Amsterdam. A total of only 0.3% of the observations must be considered as missing. We searched for metadata in several archives and described the available metadata in the report. Unfortunately we did not find information on the type of instruments used for measuring air temperature and air pressure. Also the exact location of the instruments is not known.

It was shown that there are several inhomogeneities in the air temperature and air pressure series. Therefore, the data cannot directly be used to calculate trends and variability of climate. To correct for the inhomogeneities further research is needed.

All data, including the original images of the logbooks are made freely accessible via the KNMI website at: http://www.knmi.nl/klimatologie. A very special historical high-resolution dataset is now available for research and for the general public.

Acknowledgements

We thank our colleague Jan Huizinga for his involvement in all matters dealing with the hardcopy archive of KNMI (including the ACWO films). We are also grateful to our colleague Jon Nellestein for archiving the digital data and metadata and putting these on the Internet.

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Appendix A: Staf

(1) Persons that contributed to the actual digitization of the data

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Ruud Kamminga
Hans Olminkhof
Rob Verrips

Part-time students:
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Carlijn Gommans
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Kevin Koen San Lie
Dirk-Sytze Kootstra
Alja van der Kooij
Willem Messer
Maurice Mourad
Jurgen Neimeijer
Marcia van Og
Dorothee Pellegrom
Jolanthe Schretlen
Ralf Schrijvers
Marja Segers
Sietske van der Sluis
Linde van Otterdijk

(2) KNMI employees involved in managing the project

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Rinus Rauw
Dick Riepma
Hendrik Wallbrink