

## Pre-1872 Extension of the Japanese Instrumental Meteorological Observation Series back to 1819

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### ABSTRACT

Instrumental observations from Dejima (Nagasaki), Japan, taken under the responsibility of the Dutch, covering the periods 1819–28, 1845–58, and 1871–78, have been recovered. The Dejima series overlaps by six months the modern Nagasaki Observatory series, which covers 1878–present. The recovered data extend the start of the instrumental Japanese series back from 1872 to 1819, leaving major gaps during 1829–44 and 1859–71.

### 1. Introduction

The urgent need for more reliable data on climate variability in the pre-twentieth-century period has led to various attempts to reconstruct the climate with the aid of early instrumental data, documentary data and paleo-proxy indicators (see, e.g., Jones 1994, 2001; Mann et al. 1998; Jones et al. 1998; Guiot 1992; Pfister 1985; van Engelen et al. 2001; Böhm et al. 2001). A primary problem of the early instrumental period is the poor coverage outside Europe in the early nineteenth and eighteenth centuries. Among the many blank spots is Japan, where the official meteorological network started in the 1870s.

As a follow-up of the work to recover early nineteenth-century Indonesian and Tahitian observations, which were used to reconstruct the Southern Oscillation index (Können et al. 1998), we present here the results of a search for early nineteenth-century instrumental data taken in the settlement of Dejima (Nagasaki, see Fig. 1)<sup>1</sup> in

Japan under responsibility of the Dutch government. Although our results enable us to add 30 years to the Nagasaki temperature series and to extend its start back from 1878 to 1819, the significance of the study reaches further than just an extension of the Japanese instrumental record back in time. First, the recovered series happens to be in a region of the earth that is poorly covered by instrumental data; second, it overlaps with the long daily series of visual weather reports for 1676–1868 as documented in diaries of Japanese administrators at many places in Japan (Mikami 1988; Mikami et al. 2000), of which one of the observation sites happens to be close to Nagasaki. The fact that the Dutch were allowed as the only Westerners to maintain a trade factory on the Japanese mainland, combined with the fact that in the 1840s the Dutch set up a meteorological network in their colonies, provides data to potentially calibrate this Japanese documentary series. It is also fortunate that the Dutch were allowed to continue their activities after the opening of the Japanese Empire in 1854. This causes the recovered series to overlap with the official Nagasaki Observatory, which was founded in 1878 within 1 km of Dejima. This overlap raises the Dejima series above the level of a stand-alone series.

Once again (e.g., Schove and Berlage 1965; Können et al. 1998; Allan et al. 2002), this study highlights the potential wealth of early meteorological records from the colonial era. These records are held not only in a number of European meteorological libraries and archives, but also hidden in archives outside Europe such as those in Indonesia and Japan. Some of the missing material may be available, but in archives that have not yet been searched. It is illustrative that during this search totally unexpected pre-1845 Dejima observations [covering

<sup>1</sup> Dejima was a small artificial island 190 m long and 75 m wide in the bay of Nagasaki, at a short distance (12 m) offshore (Figs. 1, 4). It was a trade factory of the Dutch East India Company during the period 1641–1861. During that period, it was the sole gateway for trade and science between Japan and the Western world. The word “dejima” translates from Japanese as peninsula. It is also referred to as Decima, Desima, Deshima, Desjima, and Dezima. We will refer to it as Dejima, which produces almost a correct pronunciation if read by a native English speaker. The Dutch Dejima staff consisted of only eight men, augmented by a handful of Japanese servants. Dejima was visited each autumn by a Dutch trade fleet. The Japanese government required that this fleet went back by 1 November at the latest.

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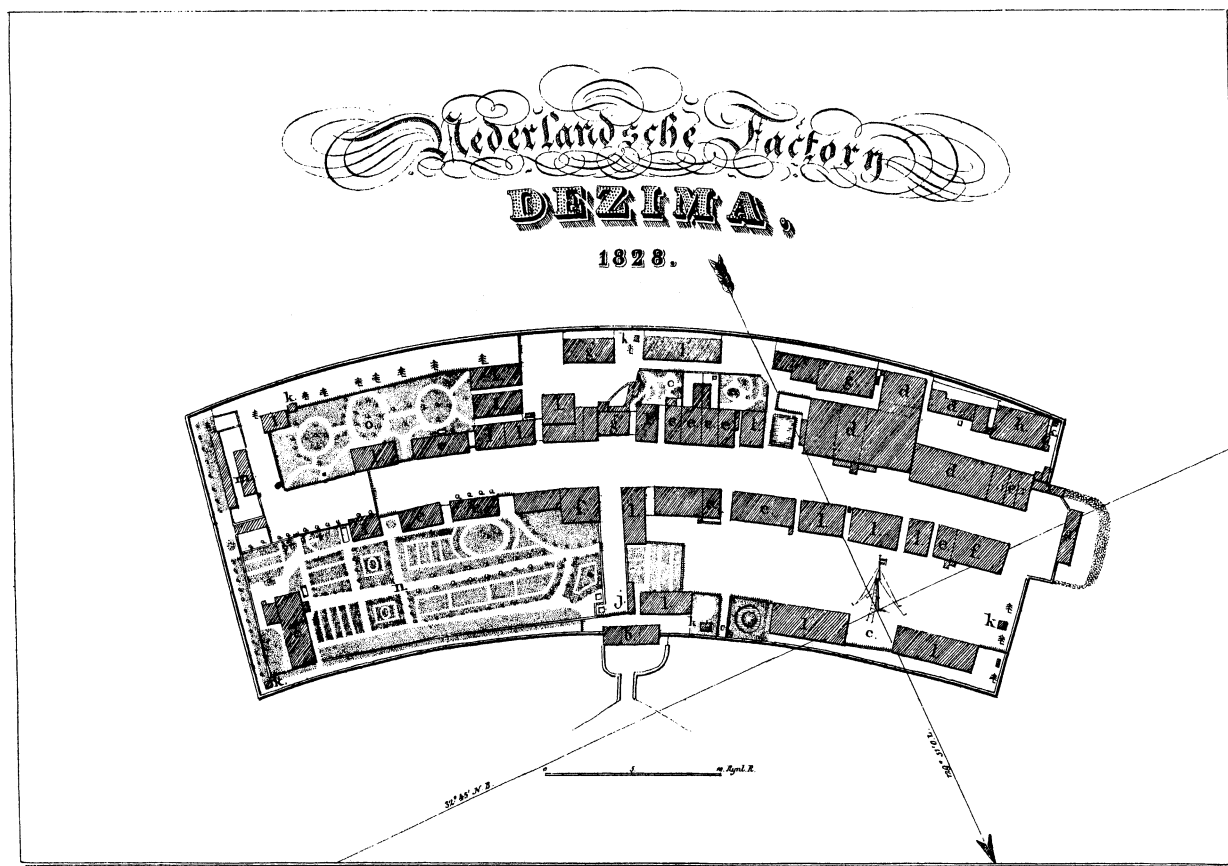


FIG. 1. Map of Dejima (1828) drawn by von Siebold. The island was 190 m long and was only 12 m offshore of the coastline of Nagasaki at the time. The bar indicates a distance of 10 Rhenish rods (1 RR = 3.7674 m). The meteorological instruments were in the house of the factory chief, which is building d in the upper right. The map is published in von Siebold (1897). Today the Dejima area is on the mainland and part of urban Nagasaki (see Fig. 4).

1819–28; von Siebold (undated)] were almost simultaneously rediscovered, first by TT (Tsukahara 1996, 1998) and then again by TM and GK (see authors' names on title page). Recently, new historical research on the records of meteorological observations before 1850 has started to be carried out by one of our authors (TT). As a part of its results, in Japan an Osaka 1827–33 series taken by the Japanese scientist Hazama Shigeyoshi (1786–1838), and a series covering the period 1838–55 from Edo (present-day Tokyo), taken by the Tokugawa governmental bureau of calendar making, were rediscovered 50 years after Amano (1952, 1953) first examined them. They are under scrutiny for more specific studies by one of us (Tsukahara 2003, manuscript submitted to *Historia Scientiarum*). These Japanese meteorological observations were associated with the development of astronomical research by the so-called Dutch Study scholars, as a result of Japan's modernization and the introduction of modern Western instruments. During this Japanese recovery effort, another author (GK) found a document in Japanese in the university library of Leiden (Anonymous 1826), referring to temperature readings in Tokyo in the mid-1820s. Finally, Demarée recently lo-

cated two eighteenth century Dejima temperature series of one year's length each (Demarée and Mikami 2000). The series cover 1775/76 and 1779, and may represent the earliest instrumental records of Japan. These incidents suggest that the sources are by no means exhausted. Cooperation between climatologists and historians is indispensable to explore them effectively.

In this paper, the 1819–78 Dejima and Nagasaki observations are brought together, carefully reviewed, and analyzed in an effort to extend the instrumental Nagasaki Observatory series 1878–present as far back in time as possible. For the time being, the results are presented as a description of the climate evolution 1819–present in Japan to be used in two later studies: 1) to place the Nagasaki record in the context of instrumental temperatures for Kyushu and Honshu, Japan; and 2) as a calibration tool for the long 1676–1868 Nagasaki documentary series.

## 2. Dejima–Nagasaki data—Sources and description

The data found can be divided into six categories. For convenience we introduce separate names for the

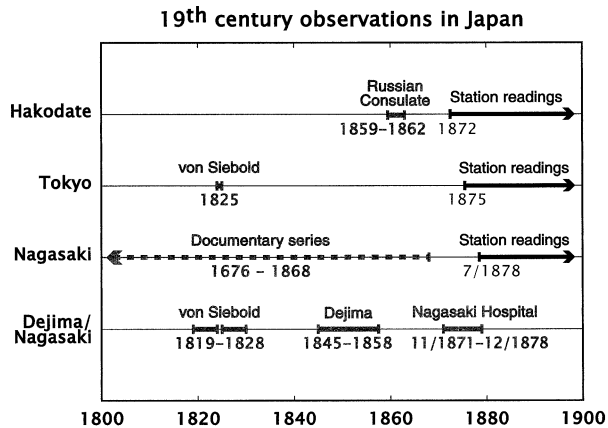


FIG. 2. Pre-1900 availability of meteorological data in Japan. (black) Official meteorological stations. (gray) Data recovered in this study.

various subseries. The first four categories (sections 2a–2d) are data taken under the responsibility of the Dutch. A main motivation for them to collect these observations was that climate parameters and epidemic diseases were supposed to be directly linked. Usually, the Dejima medical doctor in charge was responsible for these meteorological observations (see Beukers 2002 for more details). He, or his assistant, took the observations. In the pre-1858 period, the Dejima staff were relieved by the ship convoy, which arrived annually in the early autumn.

The Dutch observations in Japan continued after the opening of the Japanese Empire, but in 1859–62 they were augmented by observations at the Russian General-Consulate in Hakodate on Hokkaido (Albrecht 1858, 1861, 1862) and in the early 1870s by observations taken by the British (Tizard 1876). One of the latter British stations was a lighthouse near Nagasaki, the data of which form the discussion in section 2e. In the 1870s, the official Japanese meteorological network was established, of which data taken at Nagasaki Observatory here form the discussion in section 2f. Figure 2 shows schematically the availability of nineteenth-century meteorological data for Japan.

#### a. 1819–28, Blomhoff–von Siebold series at Dejima

These observations were taken at Dejima by the chief of the Trade Factory, J. Cock Blomhoff (1819–23; Blomhoff series) and then by the medical doctor, P. F. von Siebold (1825–28; von Siebold series) and are of air temperature, and (from 1826 onward) of pressure and humidity. There is a 14-month gap between the two series, namely, 1 November 1823–31 December 1824. The von Siebold series has a 1-yr gap 1 November 1825–31 October 1826. The data of Cock Blomhoff and von Siebold are in the von Siebold collection [von Siebold (undated)]. The Blomhoff data are in von Siebold's handwriting and apparently copied by him from an older document. The von Siebold data 23 September 1827–

28 are in two versions: one apparently being the originals in his own handwriting [documents 20211–20239; the documentation numbers are according to the von Siebold catalog by V. Schmidt (1989)] and a copy by an anonymous copyist (documents 04928–04956). For the period January–December 1825, there were parallel readings in Tokyo (documents 20123–20145); von Siebold also observed during his journey from Nagasaki to the Palace of the Shogun in Edo (now Tokyo) during March–July 1826 (documents 20149–20162).

Thermometer readings were made in full degrees Fahrenheit. In the period 1819–22, the temperature sometimes refers to readings inside the building also. No calibrations of the thermometer were reported in the lists. However, in the Dejima chief's diary (Cock Blomhoff 1820), Cock Blomhoff reports: "6 January 1820. All night heavy snowfall, rain, hail and freezing weather. And indeed last night and this morning the Fahrenheit's thermometer indicated 32 degrees." Similar reports in the chief's diary are on 12 and 21 January 1820 (Cock Blomhoff 1820), and 20–23 January 1823 (Cock Blomhoff 1823). This indicates a correct 0°C level of the thermometer throughout the Blomhoff series. It seems likely that von Siebold replaced Cock Blomhoff's thermometer by a new one, although the instrument description by von Siebold (undated) in document 20211 and its duplicate page 04930 is not unambiguous about this.

Pressure is recorded only in the von Siebold series, although Cock Blomhoff in his Dejima chief's diary (Cock Blomhoff 1820, 1823) also occasionally reports pressure. Apparently, Blomhoff's list of systematic pressure readings has been lost. The von Siebold pressure readings extend from 1 November 1826 to the end of his list, 30 September 1828. The readings of Blomhoff in the chief's diary, as well as von Siebold's readings after 22 September 1827 were in English inches (a unit of 2.54 cm) divided in decimals. However, the von Siebold readings November 1826–21 September 1827 are in non-English inches, which are divided in lines according to the duodecimal system (12 lines = 1 in.). From the pressures we inferred that the unit refers to French inches (a unit of 2.707 cm), being 1/12 of the French foot, referred to as "Pied de Roi" ("foot of the King"). See, for a conversion table of old units, Middleton (1964, p. 173).

Although there is no mention in the chief's diary and the von Siebold documents, it appears that the barometers were regularly replaced. It looks as if von Siebold never used Cock Blomhoff's (English inch based) barometer, but started the series with his own (French inch based) one, apparently received in 1826. We conclude from the change of units that the latter was replaced by English-inch-based instruments on 22 September 1827; no observations were taken that day. Middleton (1964) comments that it was customary in Europe at the time to use either an English- or French-inch-based instrument. Barometers measuring in English inches were

TABLE 1. Observation hours for Blomhoff data (1818–23) and von Siebold data (1825–28) at Dejima. The different observation schedules are labeled as a,b,c. The observation schedule was according to local time (LT = UTC + 0840). The times are reduced to Japan standard time (JST) (JST = UTC + 0900). Pressure is available from Nov 1826 onward. The Corrections column gives the annual-mean correction factors (rounded to the first decimal) that must be added to the arithmetic averages over the observation hours of the schedule to obtain the 24-h means. Observations in parentheses have not been used in that calculation.

Starting date	Observation hours (JST)	Indoor/outdoor	Schedule	Corrections	
				Temperature	Pressure
Cock Blomhoff at Dejima (8 m MSL)					
24 Dec 1818	(Mittag)	(Indoor)			
1 Jul 1819	(Morgen, Mittag,) Abend*	Outdoor	a	+0.8°C	
1 Nov 1819	(Mo,) Ab	Outdoor	a	+0.8°C	
19 Mar 1820	(Mo, Mi,) Ab	Outdoor	a	+0.8°C	
21 Jan 1821	(Mo, Mi,) Ab	(Indoor and) Outdoor	a	+0.8°C	
1 Feb 1822	(Mo, Mi,) Ab	Outdoor	a	+0.8°C	
1 Jul 1822	(Mo, Mi,) Ab	(Indoor and) Outdoor	a	+0.8°C	
von Siebold at Dejima (8 m MSL)					
1 Jan 1825	Mo, Mi, Ab*	Outdoor	b	+0.2°C	
1 Nov 1826	0620, 0920, 1220, 1520, 1820, 2220	Outdoor	c	-0.4°C	+0.0 mb
23 Sep 1827	0620, 1220, 2220	Outdoor	b	+0.2°C	-0.2 mb

\* The times of Morgen, Mittag, Abend correspond to those in schedule b (see text).

subdivided into decimals, while those using French inches were subdivided into lines (twelfths).

In the introduction to his last list of readings (covering 23 September 1827–30 September 1828), von Siebold (undated; documents 20211 and 04930) gives a detailed description of the new barometer. Actually there were two of them; they were almost identical and homemade in Dejima by von Siebold himself. Readings of both barometers are recorded in the lists until 5 July 1828, which is the day that one of them broke (document 20234). No correction for temperature seems to have been applied to the barometer readings, at least prior to 22 September 1827. Comparing the annual-mean diurnal course of the six-times daily observations (1826–27) with that in the 1991–96 pressure data confirmed this.

The replacement of the barometer on 22 September 1827 was accompanied by a drop in pressure of about 7 mb; this bias persisted until von Siebold's last reading on 29 September 1828. About 2 mb of the drop might be caused by an (undocumented) introduction of the 0°C reduction of the barometer, but the 5-mb drop that remains is unacceptably large. It is plausible that the drop is due to a failure of the new, syphon-type barometers to record the absolute value of the pressure accurately. If the post-22 September 1827 readings are corrected for this 7-mb bias, then the values in the von Siebold series look reasonable.

In the 1819–28 observations, only von Siebold recorded air humidity. It was measured by his homemade hygrometer “manufactured from a hair of a Japanese beauty, which was scalded in soda and then in pure water” (von Siebold, undated, documents 20211 and 04930). In our article, we do not consider these readings.

The pressure and temperature observations were usually taken three times a day, referred to as “Morgen,” “Mittag,” and “Abend” (morning, midday, and even-

ing). There is no explicit mention of the observation hours in the von Siebold documents. However, for 1828 there are two lists of 2-hourly observations of pressure and temperature during two full days, on 19–20 February 1828 (not 12–13 February as stated in document 04957; see his original list, documents 20224/5), and 25–26 August 1828, respectively. These lists indicate that from September 1827 until the end of the von Siebold series in September 1828, the observing hours were 0600, 1200, and 2200 local time (LT), where Dejima LT = UTC + 0840. It is likely that the same schedule applies to 1825–October 1826, in which von Siebold also observed three times a day. For November 1826–21 September 1827, there are six observations a day. The transition to the September 1827–September 1828 list indicates that the first and the last one refer to 0600 and 2200 LT, respectively. Fitting to the annual mean diurnal course of Nagasaki Observatory III 1978–99 reveals an observation schedule of 6, 9, 12, 15, 18, and 22 LT.

For the Blomhoff data (1818–23), there is no direct check of the times corresponding to Morgen, Mittag, and/or Abend. We assume in our calculations that, as with the von Siebold data, the Blomhoff's Morgen, Mittag, Abend corresponds to 0600, 1200, and 2200 LT, respectively. The different observation schedules in the Blomhoff/von Siebold period are depicted in Table 1.

Figure 3 compares the mean November–September diurnal temperature course of Nagasaki Observatory III with the von Siebold November 1826–September 1827 data. The close agreement strengthens the credibility in the quality of the von Siebold series.

#### b. 1845–58–62, Dejima series

This category concerns the official Dutch observations at Dejima. The first observers were the medical



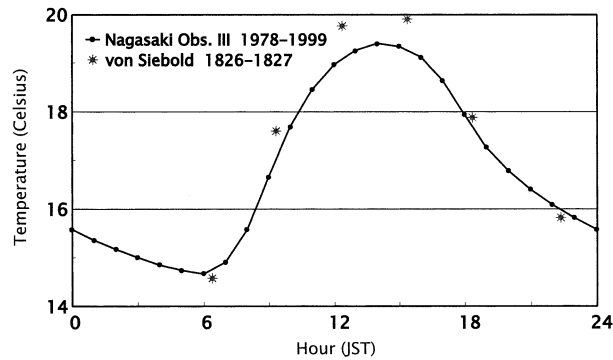


FIG. 3. Mean diurnal course in the von Siebold temperatures Nov 1826–Sep 1827 compared with the mean diurnal course Nov–Sep in the Nagasaki Observatory III data 1978–99.

doctor, O.G.J. Mohnike (1845–51) and his assistants, J.A.G.A.L. Basslé (1845–48) and F. C. Lucas (1848–52). After the death of Lucas in October 1852 Basslé took over for another year, and was succeeded by the medical doctor, J. K. van den Broek (1854–57) (Dejima documents 1853). The last observer was the medical doctor, J. L. C. Pompe van Meerdervoort (1857–62). It is likely that the observations after September 1861 were taken at the newly founded Dutch hospital of Nagasaki rather than at Dejima. The data for January 1845–September 1848, October 1848–July 1856, and November 1857–December 1858 were published by Stamkart (1851), Royal Netherlands Meteorological Institute (KNMI) Yearbook (1855, 1856), and Pompe van Meerdervoort (1859a,b), respectively. The Dejima observations February–June 1850 and October 1852–September 1853 are missing in the KNMI Yearbooks, but those of 1852–53 are available as Dejima documents (see section 2c). Post-1858 data seem lost. A detailed observation instruction by E. Wenckebach from 1844 is present in the von Siebold collection [von Siebold (undated)]. Among other facts, it directs that the original should be

kept at the station while two copies should be sent to the Dutch authorities in Indonesia.

The observations include temperature, pressure, humidity, rainfall, wind direction, and force (4-point scale), cloud cover and (before October 1848) cloud motion. The observation hours were basically 0600, 0900, 1530, and 2200 LT. For the 1845–September 1848 data, the 2200 data are presented only for cloud and pressure, while pressure, temperature, humidity, and clouds are published as 10-day means. For October 1849–September 1855, there were hourly observations of pressure, temperature, clouds, and wind for one day in each month. For November 1855–July 1856, only pressure and temperature anomalies were available. Contrary to what is suggested in the table caption of the pressure anomaly list (KNMI Yearbook 1856), the pressures were the average over four observation hours instead of one (Table 2). Temperature anomalies refer to averages of two observation hours, 0600 and 1500 LT., the values presented as anomalies from a climatology. This climatology is not published, but the fact that the anomaly table runs back to December 1853 (however, for 0600 and 1530 LT instead of 0600 and 1500 LT), enables us to reconstruct this climatology from the daily tables. Table 2 shows the observation hours of the lists of Dejima and the Nagasaki Hospital.

The thermometer was attached on the outside of the north wall of the second floor of the house of the factory chief. It was positioned 1 m from the wall and at 8 m above sea level (Stamkart 1851). However Pompe van Meerdervoort (1859b) reports that his readings refer to the average of three thermometers, located at the inside of windows of three different rooms, but with free access to the wind. Although it is not clear when the thermometer moved from the outside to the inside, Pompe van Meerdervoort's (1859b) text gives the impression that he did it himself.

Two calibrations of the freezing point of the ther-

TABLE 2. Same as Table 1 except observation hours for Dejima and Nagasaki Hospital 1845–77. The different observation schedules are labeled as A, B, C, etc. Italicized schedule designations refer to pressure observations.

Starting date	Observation hours (JST)	Schedule	Corrections	
			Temperature	Pressure
Dejima (8 m MSL)				
1 Jan 1845	0620, 0920, 1550, <i>0620, 0920, 1550, 2220</i>	A/B	–0.2°C	–0.1 mb
1 Oct 1848	0620, 0920, 1550, 2220	B	+0.1°C	
1 Oct 1849	0620, 0920, 1520, 2220	C	+0.1°C	
1 Jun 1851	0620, 2220	D	+1.5°C	–0.3 mb
1 Jul 1851	0620, 0920, 1520, 2220	C	+0.1°C	–0.1 mb
1 Oct 1851	0620, 0920, 1550, 2220	B	+0.1°C	–0.1 mb
14 Nov 1855	0620, 1520, <i>0620, 0920, 1520, 2220</i>	E/C	–0.2°C	–0.1 mb
10 Nov 1857	0620, 0920, 1550, 2220	B	+0.1°C	–0.1 mb
Hospital (37.0 m MSL)				
1 Nov 1871	0720, 1220, 1820	F	–0.5°C	+0.0 mb
1 Nov 1874	0720, 1420, 1920	G	–0.4°C	+0.2 mb

ometer have been reported during periods with snow cover. On the first occasion on 17 January 1848 (Stamkart 1851), the thermometer was found to be correct; for the second one (4 February 1852) the thermometer was found 0.8°C too high (KNMI Yearbook 1856). This offset has been taken into account by KNMI from 1852 onward in the KNMI Yearbook (1855, 1856) data. However, it is not clear whether Pompe van Meerdervoort's (1859a,b) data also needed this correction and if so, whether it has been applied.

The mercury syphon barometer was at 8 m above sea level, being located in the room of the house of the factory chief that had the thermometer attached at the outside (Stamkart 1851). The instrument was new and sent by von Siebold from the Netherlands in 1844 (KNMI Yearbook 1855). A second barometer of the same type (described by Stamkart 1849) became available later and was used October 1848–October 1851. Because of an obvious malfunction, only the highest and lowest readings in that period are published. After 1851, the observations were resumed with the original barometer. The barometer was regularly compared with shipborne barometers and reported to be correct (KNMI Yearbook 1856; Pompe van Meerdervoort 1859b). Pompe van Meerdervoort (1859b) reports that the barometer showed a bias in the period November 1857–June 1858 and was replaced by another one afterward. He corrected his 1858 observations for this bias, but it was not clear whether the 1857 data were also corrected.

The original lists contained pressure readings and temperature of the barometer (see Dejima documents 1853); reduction to 0°C was done afterward. The KNMI publications do not include the barometer temperatures. However, Pompe van Meerdervoort (1859a,b) lists for 1857–58 do, suggesting that the published barometer readings were not reduced to 0°C. The annual and diurnal variations in Pompe van Meerdervoort's data suggest that this was indeed not the case. Following the Dutch custom of the nineteenth century, the published Dejima pressure data were reduced to 0°C, but not corrected for gravity. This policy was also applied to the data published before the foundation of the KNMI in 1854, as is stated explicitly in Onnen (1844). There is no indication that reduction to sea level has been applied to the data taken at Dejima.

Rainfall was recorded all the time, but published only from 1852 onward. The reason was that by then the malfunctioning rain gauge had been replaced by two new ones (Dejima documents 1853). Still, the interpretation of the readings causes trouble, as sometimes (e.g., in Pompe van Meerdervoort 1859a,b), the cumulative amount from the start of the month or from a rainy period was published instead of daily amounts. The rain gauge is described in the Wenckebach instructions [von Siebold (undated)] and by Pompe van Meerdervoort (1859b). In our article, we do not consider the rainfall readings.

The Dejima observations after 1858 have not been

located, although it is known that Pompe van Meerdervoort continued observing till his departure in 1862 (Geerts 1875; General State Archive of the Netherlands 1857–1866). If Pompe van Meerdervoort did carry his observations back to Holland, then they were lost as he was shipwrecked (but survived) on his return trip. The personal archive of Pompe van Meerdervoort in the Leiden Town Archive does not contain any weather observations. At the moment the Dejima observations 1859–62 must be considered lost. This is unfortunate, as there is now no overlap with the Hakodate 1859–62 series (Albrecht 1858, 1861, 1862), which is the only instrumental series within Japan known by us that ran parallel with the Dejima series.

The Dutch weather observations were probably discontinued after Pompe van Meerdervoort's departure in November 1862, to be resumed only in 1871 (see section 2d). As long as the post-1858 Dejima lists remain lost, this causes a gap of almost 13 yr in the Dutch data.

#### c. 1852–53, *Dejima documents*

This is the missing year in the published Dejima series (KNMI Yearbook 1856). The measurements have been lost for more than a century, but were accidentally recovered from a forgotten KNMI archive at Rotterdam Harbour. These handwritten data (Dejima documents 1853) start on 1 October 1852 and cover 12 months. The meteorological contents are the same as in the Dejima series and include rainfall. The pressure is not corrected to 0°C but the barometer's temperature is reported. The observer was Basslé.

#### d. 1871–78, *Nagasaki Hospital*

The Dutch weather observations, which were apparently discontinued in 1862, were resumed in November 1871 from the Nagasaki Dutch Hospital. The Hospital was founded on 20 September 1861 (Pompe van Meerdervoort 1868) and located 500 m southeast of Dejima (Fig. 4). The reservoir of the barometer was at a height 37 m above sea level (Geerts 1875; KNMI Yearbook 1875). The first observer was the pharmacist A.J.C. Geerts; in 1874 he was succeeded by the medical doctor, W.K.M. van Leeuwen van Duivenbode. The latter left Nagasaki in March 1879 (*Japan Daily Herald*, 1879). Presumably he was the last Dutch doctor.

The daily data for November 1871–December 1877 are in the KNMI Yearbooks (1875, 1876, 1877). Monthly averaged values of pressure and temperature for 1878 are in the KNMI Yearbook Second Series (1878). In the KNMI Yearbook Second Series 1876 and 1877, daily pressure [reduced to 0°C and sea level, but not corrected for gravity, see Geerts (1875)] and temperature anomalies as well as rainfall in 1876–77 have also been published.

Post-1878 Nagasaki data are printed in the KNMI Yearbook Second Series 1879–80, but a comparison of

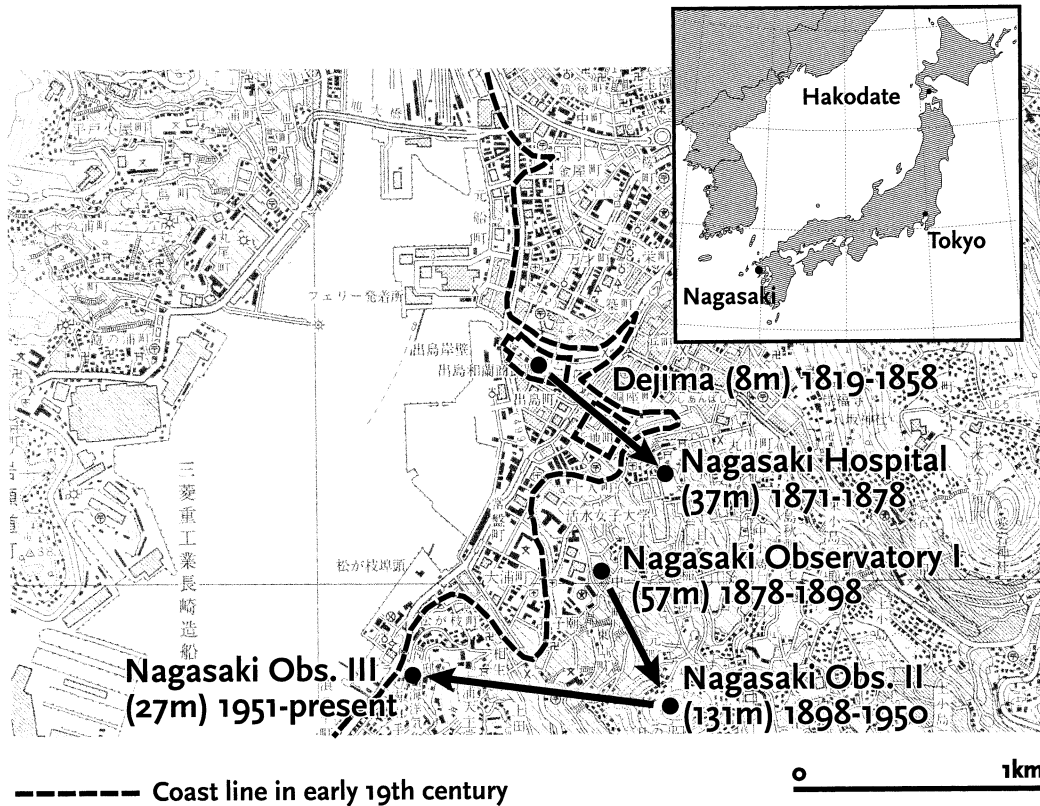


FIG. 4. Location of the observation sites 1819–2000 in Nagasaki. The coastline of the early nineteenth century has also been indicated.

their climatology (KNMI Yearbook 1880) with the Climatic Records of Japan data (CMO 1954) reveals that all published data from January 1879 onward were data measured at Nagasaki Observatory and not Hospital readings. Apparently, the Hospital readings stopped around the time that van Leeuwen van Duivenbode left. Only for the period July–December 1878, were there parallel-published readings at the Hospital and the Observatory. It is unclear, however, whether the December 1878 Hospital average (KNMI Yearbook 1878) was based on readings that covered the entire month.

A station description of the Hospital and climatological values for November 1871–December 1872 were published by Geerts (1875). The 1872 readings are also in Jelinek and Hann (1875). There is a discrepancy between the 1871–72 data in the KNMI Yearbook (1875) and Geerts (1875) as Geerts indicated an observations schedule of 0900, 1200, 1500, and 1800 LT with the KNMI Yearbook stating 0700, 1200, and 1800 (Table 2). The temperature values for November 1871–December 1872 in Geerts (1875) are on average  $0.6^{\circ}\text{C}$  higher than those in the KNMI Yearbook. We compared the monthly values after correcting for the unevenly distributed observation hours of the various schedules (see section 3b). It was found that the difference and the standard deviation in the set of months was minimized if it is assumed that Geerts actually refers to 0700, 1200,

1500, and 1800 LT (0900 LT then being a printing error) and that KNMI dropped the 1500 observations in the KNMI Yearbook.

The Hospital pressure data exhibit a sudden downward-jump of about 4.5 mb on New Years Day 1873; from 1 November 1874 onward (the first day published in KNMI Yearbook 1876) the pressure regained the old level. The obvious explanation is that the observer or KNMI failed to apply the height correction to the readings.

If for the overlapping period July–November 1878 the Hospital temperature data after all corrections (section 3) are compared with Observatory I series then the difference over these five months is  $0.05 \pm 0.24^{\circ}\text{C}$ . This indicates agreement within the observational error. For pressure, the difference is  $1.32 \pm 0.26$  mb, indicating that 1878 Hospital pressures were systematically too high compared to Observatory I.

#### e. 1871–74, Nagasaki Lighthouse

Since the late 1860s, 15 lighthouses were established on the southeast and southwest coastal waters of Japan. At each lighthouse, a meteorological register was kept recording pressure (in English inches and decimals, reduced to  $0^{\circ}\text{C}$  and sea level, but not to standard gravity), temperature, and rainfall. The observation hours were



0900 and 2100 LT. The list includes Nagasaki. Its lighthouse is on the island of Iojima, 10 km WSW of Dejima. The observation height in the lighthouse was 59.4 m (195 ft). The registers were collected by the head of lighthouses in Yokohama (a British citizen) and bound together. Tizard (1876) has analyzed the data 1871–74. He reduced all pressures to 0°C and sea level, but as it turns out, the reported Iojima pressures were among the data that had already been reduced. So his published pressures do not refer to 0°C and sea level, as he claims, but (for Iojima) to –19°C and 59.4 m *below* sea level instead. This is the reason that his comparison of Iojima with the Dejima 1845–55 averages revealed a then unexplained bias (Tizard 1876). In his book (Tizard 1876), a list of average 1871–74 values of pressure, temperature, and rain for each month was published. The original daily lists and monthly summaries could not be found.

The potential merit of the lighthouse normals 1871–74 is their capability to extend the Nagasaki series for the period January–October 1871, by comparing the 4-yr averages with those of the Hospital. However, for temperature as well as for pressure this turned out to be unfeasible. The reason for temperature is that there is low spatial correlation between a coastal zone station (Dejima) and an open sea station (Iojima). For pressure, the reason is the unrealistic values of Iojima, particularly in January–April. Therefore we decided to exclude the lighthouse data from the analysis.

#### f. 1878–present, Nagasaki Observatory

The Nagasaki Observatory was founded in 1878 and has been moved twice since (see Fig. 4). We refer to these locations as Nagasaki Observatory I, II, and III, respectively. Observatory I (height above MSL 57.6 m) was effective from 1 July 1878; Observatory II (height 131.5 m) was effective from 1 August 1898; Observatory III (height 26.4 m) was effective from 1 January 1952. The three locations were within 1 km of each other and about 1 km south of Nagasaki Hospital and Dejima (Fig. 4). The nuclear bomb epicentre [9 August 1945, 1102 Japan standard time (JST)] was 3.7 km north of Dejima (5 km north of Observatory II) and the accompanying fire did not reach these sites. At that time, Observatory II was in operation. Although the buildings were damaged, the observation schedule remained uninterrupted in 1945, and continued even on the bombing day.

The monthly data 1878–1952 come from Climatic Records of Japan (CMO 1954), augmented for the two missing temperature months October–November 1893 by the data in World Weather Records (WWR; Clayton 1927). For pressure, July 1889 is missing. Table 3 shows the way the monthly temperature averages in Climatic Records of Japan (CMO 1954) and for the period thereafter were calculated. It is not clear though, whether the observation hours in Table 3 represent only a part of

the total observation schedule that was actually taken. The WWR 1878–83 values were calculated similarly to the Climatic Records' data 1883–86, as could be verified with the minimum/maximum temperatures published in the Climatic Records of Japan (CMO 1957). The remainder of the WWR Nagasaki data are the same as the CMO (1954) data. Although not explicitly stated in the Introduction to the Climatic Records of Japan (CMO 1954), the pressure data were corrected to standard gravity and mean sea level. A comparison with the modern (1991–96) hourly pressure data confirmed this.

### 3. Data homogenization

#### a. Correction to differing observation schedules

The correction factors were determined straightforwardly from the modern hourly Nagasaki Observatory III data of temperature (1978–99) and pressure (1991–98). We calculated for temperature (pressure is treated analogously) over the monthly average values 1978–99 of  $\Delta$  for each observation schedule:

$$\Delta = T_{24} - [T(t = t_1) + T(t = t_2) + \dots + T(t = t_m)]/m, \quad (1)$$

where  $T_{24}$  is the average based on all 24 observation hours,  $m$  the number of daily observations in the schedule,  $(t_1 \dots t_m)$  the times of the observation schedule and  $T(t = t_1), T(t = t_2), \dots, T(t = t_m)$  the values of the temperature at times  $t_1 \dots t_m$ , averaged over 1978–99 and the month that is considered. Observed temperatures  $T_{\text{obs}}$  in a given month/year, averaged over the observation times  $t_1 \dots t_m$ , were then reduced to an estimated 24-averaged value  $T_{\text{av}}$  by

$$T_{\text{av}} = T_{\text{obs}} + \Delta. \quad (2)$$

The values of  $\Delta$  averaged over the year are given in the last column of Tables 1–3. We calculated  $T_{\text{obs}}$  over all available observation hours of a given month, with two exceptions. First, in the Blomhoff data (1819–23) the morning and midday observations are not considered because of problems with solar radiation exposure of the thermometer; see the next section. Second, the temperature data of Nagasaki Observatory I for the 1883–85 period published in the Climatic Records of Japan (CMO 1954) represent averages using readings at 0950, 2150 JST,  $T_{\text{min}}$  and  $T_{\text{max}}$ . These averages were converted by us to values corresponding to observation schedule NA (Table 3) with aid of the Climatic Records of Japan (CMO 1957), before application of Eqs. (1)–(2).

Equation (2) assumes implicitly that the correction factors derived from the 1978–98 and 1991–98 data are representative for the entire period. In case the baseline period shows a trend, as is the case for temperature, this need not beforehand true. However, as Fig. 3 illustrates, the diurnal course seems unaffected by a trend in the mean.

The reduction method applied here is very simple;



TABLE 3. Observation hours for Nagasaki Observatory based on monthly values 1878–1952 calculated in Climatic Records of Japan (CMO 1954). The different observation schedules are labeled as NA, NB, NC, etc. Observation times prior to 1886 were in local time (=UTC + 0840). These times are reduced to JST (JST = UTC + 0900). The Corrections column gives the annual-mean correction factors (rounded to the first decimal) that must be added to the arithmetic averages over the observation hours of the schedule to obtain the 24-h means. Italicized schedule designations refer to pressure observations.

Starting date	Observation hours (JST)	Schedule	Corrections	
			Temperature	Pressure
Nagasaki Observatory I (57.6 m MSL)				
1 Jul 1878	0950, 2150, <i>0950, 1550</i>	NA	+0.0°C	−0.7 mb
1 Jan 1886	0200, 0600, 1000, 1400, 1800, 2200	NB	+0.0°C	+0.0 mb
1 Apr 1897	0100, 0200, 0300, . . . , 2300, 2400	Hourly	—	—
Nagasaki Observatory II (131.5 m MSL)				
1 Aug 1898	0100, 0200, 0300, . . . , 2300, 2400	Hourly	—	—
1 Jan 1940	0600, 1400, 2200	NC	+0.1°C	+0.1 mb
Nagasaki Observatory III (26.4 m MSL)				
1 Jan 1951	0600, 1400, 2200	NC	+0.1°C	+0.1 mb
1 Jan 1953	0300, 0600, 0900, . . . , 2100, 2400	ND	+0.0°C	+0.0 mb
1 Jan 1960	0100, 0200, 0300, . . . , 2300, 2400	Hourly	—	—

more sophisticated methods exist (see e.g., Moberg et al. 2000; Zaiki et al. 2002). Since we do not know the monthly averages at all observation hours, the present method is applied throughout the series as this procedure better maintains the relative homogeneity 1819–present.

#### b. Temperature corrections

Temperatures were converted from Fahrenheit to Celsius where needed (1819–28) and then the monthly averaged temperatures were reduced to a height of 26.4 m, which is the height of Nagasaki Observatory III. The difference in height was accounted for by the moist adiabatic lapse rate:

$$T(26.4) = T(h) + (h - 26.4) \times 0.006, \quad (3)$$

where  $h$  is the station height in meters (8 m for Dejima),  $T(h)$  is the temperature at station level in degrees Celsius, and  $T(26.4)$  the temperature at Nagasaki Observatory III level.

When the Blomhoff temperatures (1819–20) are reduced to 24-h averages according to Eqs. (1)–(2), there is an apparent unrealistic offset in the annual averages of about 2°C with respect to the remainder of the Dejima/Nagasaki series, including the von Siebold series 1825–28. The annual course of the Blomhoff series also shows erratic behavior, indicating sun exposure of the thermometer. Night temperatures are least affected by this effect (Chenoweth 1993). Therefore, we omitted the morning and midday Blomhoff observations from the analysis and used the Abend (evening) data only (see Table 1). Although this lowers the temperatures in the 1819–23 data, a comparison with the remainder of the series indicates that these early data still contain an offset of the order of 1°C. Averaged over May–September, the offset with respect to the long-term average is 2.4°C, but averaged over the remaining months it is zero. This annual course in the bias seems related with a screening

effect, possibly by heat radiation from the wall to the closely attached thermometer. An additional uncertainty in the Blomhoff reduction based on Abend only, arises from the sensitivity to the exact time to which Abend refers. If Blomhoff's Abend observation (Table 1) would refer to 2100 LT instead of 2200 LT, then the average temperature after reduction (schedule a) would be 0.3°C less (see Fig. 3). These problems do not emerge in the von Siebold data (1825–28), see Fig. 3. Apparently, von Siebold's improved the thermometer screening and put the instrument farther away from the wall of the house. Also, his observation schedules are clear.

The first six months of the Blomhoff series (1819) refer to indoor temperatures and 1200 LT only. Although later years have simultaneous indoor/outdoor readings, we found no satisfactory way of relating the indoor readings with the outdoor air temperature. Therefore the January–June 1819 readings were omitted in the analysis.

The air temperatures in the Dejima documents (1852–53) were lowered by 0.8°C throughout to account for the reported offset (KNMI Yearbook 1856; see section 2b) in the Dejima data. Table 4 shows the monthly averaged values of Dejima/Nagasaki temperatures 1819–80 and Fig. 5 the time series of annual values 1820–1999.

#### c. Pressure corrections

Pressure in the early von Siebold series (1826–27) was reduced from French inches and duodecimals (lines) to millimeters by dividing the lines by 12 and then multiplying the inches by 27.07. Pressure in the later von Siebold series (1827–28) were reduced from English inches and decimals to millimeters by multiplying the inches by 25.4.

The Dejima pressures in the documents (1852–53) and in 1857–58 were reduced to 0°C with aid of the

TABLE 4. Monthly mean temperatures 1819–80 for Nagasaki. The data are reduced to a height of 26.4 m (the station height of Nagasaki Observatory III). The two rows of 1878 labeled by *a* and *b* refer to the Dutch and Japanese data, respectively. The more uncertain values and years in the table are marked by an asterisk. “—” means missing. Monthly, seasonal, and annual Nagasaki temperatures 1819–present are available from the Climatic Research Unit Web site at <http://www.cr.uea.ac.uk/cru/data/nagasaki.htm>.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1819*	—	—	—	—	—	—	28.8*	32.4*	27.9*	19.4	11.8	11.4
1820*	3.7	8.9	11.1	16.6	21.5*	23.9*	29.6*	29.8*	25.6*	19.9	12.8	6.8
1821*	4.7	6.2	9.9	17.5	22.2*	24.9*	29.3*	30.3*	30.0*	16.6	11.7	8.8
1822*	5.8	7.0	10.5	13.5	19.3*	24.5*	27.4*	29.5*	28.5*	18.7	12.3	7.8
1823*	6.4	9.1	9.5	15.2	18.5*	24.4*	29.7*	28.2*	25.6*	20.3	—	—
1824	—	—	—	—	—	—	—	—	—	—	—	—
1825	6.1	6.8	9.3	14.4	20.2	22.4	26.2	26.1	23.6	20.1	—	—
1826	—	—	—	—	—	—	—	—	—	—	13.5	6.9
1827	4.8	6.4	10.0	16.2	19.6	23.8	28.3	30.1	26.4	18.6	11.5	8.3
1828	7.7	6.5	8.7	13.1	18.9	22.2	26.0	27.9	24.6	—	—	—
1845	7.9	7.9	10.6	14.9	19.0	22.7	27.1	26.9	22.8	17.5	11.2	5.8
1846	4.3	6.2	8.0	15.5	16.6	21.5	25.2	28.2	26.7	19.3	11.9	9.0
1847	6.4	6.2	10.2	16.0	17.9	21.6	26.4	26.5	24.4	17.9	14.6	9.5
1848	5.8	6.7	10.7	15.3	20.6	21.9	26.9	26.5	24.0	19.8	11.4	9.6
1849	6.1	10.5	11.3	14.7	18.9	21.7	24.7	27.7	25.7	18.4	11.2	7.9
1850	5.4	—	—	—	—	—	25.9	26.3	23.7	18.7	12.8	7.6
1851	6.3	5.8	9.7	13.9	18.2	21.1	26.0	27.0	23.1	17.3	15.2	6.9
1852	5.2	4.2	8.1	12.9	18.2	22.5	27.5	27.3	24.3	17.9	13.5	7.3
1853	6.4	5.8	10.0	15.1	18.8	23.5	28.5	27.9	24.0	16.5	13.1	6.9
1854	5.9	6.2	9.5	12.8	18.0	21.3	25.4	26.8	23.4	16.8	11.8	6.3
1855	3.4	4.9	9.2	15.3	18.4	22.0	26.2	26.1	23.9	—	13.0	8.4
1856	4.0	4.7	9.8	14.2	19.4	22.1	28.3	—	—	—	—	—
1857	—	—	—	—	—	—	—	—	—	—	13.8	8.7
1858	6.6	6.9	9.5	14.4	19.4	22.1	25.8	26.3	24.5	18.3	—	—
1871	—	—	—	—	—	—	—	—	—	—	13.2	7.2
1872	4.3	4.8	10.9	16.4	19.5	22.5	27.0	27.0	23.5	9.2	13.0	9.4
1873	5.6	6.6	8.6	15.8	20.6	22.9	26.5	26.3	24.9	17.4	12.2	8.6
1874	4.8	7.3	10.2	13.9	18.0	23.3	26.8	25.7	22.0	17.1	12.1	9.3
1875	6.1	5.8	12.3	14.1	19.4	22.6	27.7	28.5	24.2	18.9	12.6	7.2
1876	5.9	7.9	10.9	14.9	19.8	22.2	26.3	27.9	24.9	19.0	11.7	8.3
1877	6.6	7.0	9.0	15.5	20.6	22.8	27.3	26.2	22.5	16.6	12.5	8.9
1878 <sub>a</sub>	4.9	6.4	9.7	15.0	17.8	22.1	25.7	27.4	25.3	20.2	12.9	9.4
1878 <sub>b</sub>	—	—	—	—	—	—	26.1	26.7	25.1	19.4	12.4	7.5
1879	6.1	8.0	9.0	14.3	18.7	22.0	26.7	27.7	23.5	17.4	12.4	9.1
1880	5.2	8.6	10.1	14.2	19.4	21.3	25.4	25.9	23.9	19.1	12.0	5.8

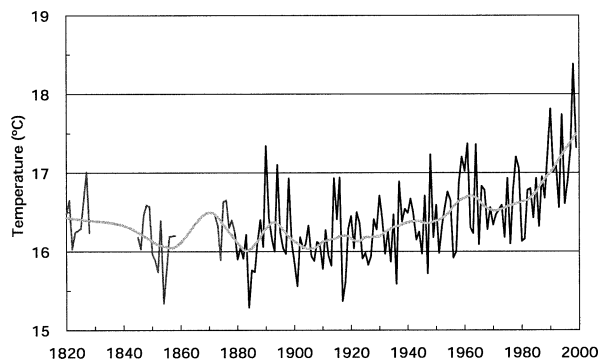


FIG. 5. Time series of Nagasaki annual mean temperatures 1878–1999 with its extensions back to 1820. The black line is from Nagasaki Observatory (1879–1999); the gray line is from the data recovered in this study. The annual-mean 1820–23 values were lowered by 1°C with respect to Table 4 to account for heat radiation effects in summer (see text, section 3b). The thick light-gray line represents a 20-yr smoother (Cleveland 1979).

tables by Kämtz (1832) that were used at the time (Onnen 1844). The formula reads

$$P(0^\circ) = P(t)(1 - 1.62 \times 10^{-4} T_{\text{bar}}), \quad (4)$$

where  $T_{\text{bar}}$  is the reported barometer temperature in Celsius and  $P$  the pressure. For the temperature correction of the von Siebold data we used for  $T_{\text{bar}}$  the reported air temperature. After this reduction, we added 7.2 mb to all von Siebold pressures after 22 September 1827 to account for the observed bias (see section 2a).

Pressures printed in the Dutch nineteenth-century publications refer systematically to values that are not corrected for gravity (see section 2b). For the observing conditions at Dejima (observing height 8 m) the height correction happens to cancel out with the gravity correction (−1.15 mb). Hence no corrections for gravity or height have to be applied afterward to the von Siebold data and the Dejima data.

The Hospital pressure values were first corrected for gravity by subtracting 1.15 mb. Then for the period January 1873–31 October 1874 the pressures were re-

TABLE 5. Same as Table 4 except monthly mean sea level pressures 1826–80 for Nagasaki, reduced to 0°C and standard gravity. Units are (mb – 1000).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1826	—	—	—	—	—	—	—	—	—	—	18.0	18.7
1827	19.2	22.4	14.9	12.2	12.4	16.5*	10.9	16.0*	10.4	13.7	21.1	23.2
1828	20.9	21.2	20.1	17.3	13.2	8.2	8.4	8.1	10.9	—	—	—
1845	22.6	16.7	19.2	15.2	10.6	8.2	8.2	6.0	11.6	16.5	21.7	22.5
1846	24.2	20.6	19.2	13.4	13.3	9.5	9.6	2.2	11.9	13.7	23.0	20.5
1847	20.7	18.7	16.9	14.7	12.4	8.2	6.9	6.7	11.9	16.5	18.3	18.0
1848	20.8	20.8	15.6	15.6	9.8	7.3	8.4	10.2	8.6	—	—	—
1849	—	—	—	—	—	—	—	—	—	—	—	—
1850	—	—	—	—	—	—	—	—	—	—	—	—
1851	—	—	—	—	—	—	—	—	—	—	17.8	21.9
1852	21.0	22.6	17.9	15.8	9.7	7.8	11.1	10.3	11.4	17.3	18.2	20.0
1853	20.0	19.5	17.2	13.0	10.1	8.7	8.8	6.1	7.8	19.1	19.6	24.1
1854	22.8	20.0	20.8	14.5	14.3	9.2	8.8	8.5	13.5	20.1	20.6	22.5
1855	19.9	20.8	19.0	17.2	13.4	8.7	7.8	7.2	11.1	—	22.5	18.1
1856	23.6	21.3	18.2	13.2	12.5	9.2	12.0	—	—	—	—	—
1857	—	—	—	—	—	—	—	—	—	—	17.5	21.8
1858*	15.0*	15.2*	15.8*	14.2*	13.4*	12.1*	17.2*	4.9*	9.9*	11.3*	14.8*	15.6*
1871	—	—	—	—	—	—	—	—	—	—	20.1	22.6
1872	23.7	22.7	18.1	16.3	12.3	10.9	7.1	5.3	12.1	16.6	21.7	20.0
1873	19.7	19.4	20.9	15.9	11.3	7.3	11.0	9.6	9.6	16.5	20.7	21.2
1874	22.8	20.4	17.9	16.4	10.1	10.1	7.5	8.0	12.4	17.1	21.9	21.1
1875	21.2	21.0	17.7	15.2	13.8	9.0	8.7	8.8	10.8	16.3	20.0	19.9
1876	22.1	20.7	17.9	13.4	12.7	8.7	9.8	10.4	11.1	17.0	17.8	22.7
1877	24.3	20.9	17.7	17.8	13.2	10.7	11.5	8.4	13.6	17.7	21.9	21.2
1878 <sub>a</sub>	23.8	23.3	22.8	17.9	11.7	9.4	10.4	9.9	9.0	17.9	22.8	21.5
1878 <sub>b</sub>	—	—	—	—	—	—	9.9	8.5	7.3	16.1	21.3	20.2
1879	22.5	19.2	17.6	15.2	9.8	9.3	10.3	9.7	9.7	17.9	18.4	16.3
1880	23.1	18.9	18.1	16.4	11.5	8.2	5.1	3.9	12.9	15.4	19.3	22.7

duced to sea level using a simplified version of the well-known formula given by Schüepp et al. (1964):

$$P(\text{sea level}) = P(h) + 0.1251(1 - T/273)h, \quad (5a)$$

where  $h = 37$  m:

$$P(\text{sea level}) = P(37 \text{ m}) + 4.63 - 0.017T, \quad (5b)$$

in which  $T$  is the barometer temperature in Celsius and  $P$  in mb. For  $T$ , we inserted the reported air temperature.

Table 5 shows the monthly averaged values of De-

jima/Nagasaki pressures 1826–80. Note that the 1858 data contain five outliers up to the  $5\sigma$  level, one of them (July) noticed by the observer himself (Pompe van Meerdervoort 1859b). We consider these as indicative of the malfunctioning of Pompe's barometer during the entire year. Figure 6 shows the time series of annual values 1827–1999.

#### d. Homogeneity tests

To check the homogeneity of the Dejima/Hospital/Nagasaki series, we ran the Standard Normal Homogeneity Test (SNHT; Alexandersson 1986), the Buishand range test (Buishand 1982), and the Pettitt test (Sneyers 1995) over the series of annual, seasonal, and monthly pressure and temperature. For the motivation of the choice of these three location-specific homogeneity tests see Wijngaard et al. (2003). Prior to the calculations, the annual temperatures 1820–23 were lowered by 1°C with respect to Table 4 (see section 3b) while the pressures of 1858 were omitted in the series (see section 3c).

None of these tests were able to detect an inhomogeneity in the temperature or pressure series around the year 1878, which is the year where the transition from the Dutch data to the Nagasaki Observatory occurs. The monthly, seasonal, and annual series all fail to give any indication that points to 1878 as being a suspect year.

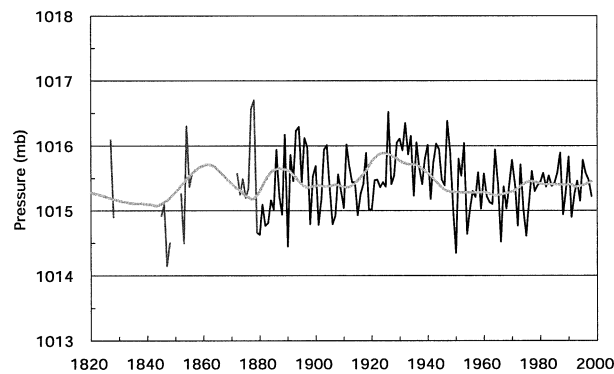


FIG. 6. Time series of Nagasaki annual mean pressures 1878–1998 with its extensions back to 1827. The black line is from Nagasaki Observatory (1879–1999); the gray line is from the data recovered in this study. The 1858 data are omitted. The thick light-gray line represents a 20-yr smoother (Cleveland 1979).

From this result we infer that it is meaningful to extend the Nagasaki Observatory pressure and temperature series 1878–1999 backward in time by the composite Blomhoff/von Siebold/Dejima/Hospital series 1819–78.

If these tests are run over the nineteenth century period until 1890, all pressure series pass them successfully with the exception of their very beginning, where the SNHT test spotted the anomalous high values of the first observed summer pressures (1827). For temperature, the Buishand and SNHT tests indicate a break in all months May–September as well as for the summer season series at the transition of the Blomhoff/von Siebold data to the Dejima series. Apparently, this is related with a remaining effect of sun exposure on the thermometers used by von Siebold (see section 3c). In the 1820–90 annual temperature series (with the corrected 1819–23 values), none of the tests were capable to detect an inhomogeneity.

Considering the seasonal pressures for entire period 1827–1998, all three tests indicate at the 5% confidence level a possible break in homogeneity in 1892 in autumn while the Buishand test suggest a break in spring also. Also in the annual values the Buishand range test finds a suggestion for this break, but the other tests fail to detect this possible break even at a confidence level of 5%. From this evaluation we conclude that the pressure series can be regarded to possess a reasonable level of homogeneity for the entire period.

Considering the seasonal temperatures for the entire period 1820–1999, none of the three tests detects any inhomogeneity in the post-1845 values until 1935. In the remaining part of the series, all three tests detect at a 1% confidence level various homogeneity breaks in the annual values as well as in all four individual seasons, occurring in the period 1935–57. The SNHT, Buishand range, and Pettitt tests point to homogeneity breaks in 1957, 1947, and 1936, respectively. None of these dates correspond to a relocation of Nagasaki Observatory (Table 3). It remains to be investigated whether these breaks are real inhomogeneities or whether they are related to the increase of the urbanisation effect in the Nagasaki record.

#### 4. Discussion and conclusions

We have detailed the history of recording at Dejima from 1819 to 1858, and at Nagasaki Hospital from 1871 to 1878 and corrected both the temperature and pressure readings to modern units and for many problems related to the observation schedules and the various changes of location. Until (and if) more information can be located, this represents the best that can be done at the present. The homogeneity tests indicate that it is justified to extend the temperature and pressure series of Nagasaki Observatory 1878–present back with the recovered data. The extended Nagasaki series contain two mayor gaps, 1829–44 and 1859–71. The most uncertain periods in the pre-1878 data are 1819–23 for temperature (because

of problems related to the direct exposure of the thermometer to solar radiation, problems with heat radiation from the wall of the building to the thermometer during the summer nights, and problems related with the determination of the observation hours). For pressure, the most uncertain period is 1858 (because of likely barometer malfunction) followed by June 1827–September 1828 (because of the high values in the 1827 summer months and because of an unexplained offset in the values October 1827–September 1828, which we have corrected for). Apart from the data presented here, also data on wind, clouds, precipitation, and humidity are available in the sources. We hope that this study encourages others to continue searches in archives in Japan, Indonesia, and the Netherlands to locate the data for the missing years.

The data represent a significant extension of the modern Nagasaki record and provide instrumental evidence for Japan for a period when no other measurements were believed to be available. No homogeneity test of the extended Nagasaki series points toward a break in 1878, which is the year where transition from the Dejima/Hospital observations to the modern Nagasaki observation series takes place. The extension will be particularly important in attempts to determine the usefulness of the Japanese documentary data 1676–1868 (Mikami et al. 2000) for which it was believed that there was no overlap with instrumental data. For this purpose, extended series of other elements than temperature and pressure may appear even more important. They are potentially available from the Dutch data. The merging of the long documentary series with the instrumental series will be discussed in a later paper. In another paper we will address the representativeness of the Nagasaki record in the context of Japanese records since the late 1870 from Kyushu and Honshu. Although the results of the homogeneity tests indicate that the 2°C trend in the post-1950 Nagasaki data of Fig. 5 is a real effect, its cause has still to be analyzed. In that paper we will therefore also address the potential significance of any urbanisation influences in the twentieth century.

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Brandsma (KNMI) calculated the smoother over the data and M. H. Kaltoven (KNMI) digitized the Dejima documents.

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