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DATA ARTICLE

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The London, Paris and De Bilt sub-daily pressure series

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Abstract

The construction of sub-daily pressure series is described for the cities of London (GB) and Paris (FR). The series extend back 1692 and 1748, respectively, and as such they represent two of the longest sub-daily series of barometric pressure available. These series are updated from the previously documented London and Paris daily series and offer more homogeneous series, and in the case of the London series a more temporally complete sequence of data. A pairwise homogenization procedure has been applied to the two series alongside the long series of pressure that exists for De Bilt (NL). The De Bilt series has been available for some time in the International Surface Pressure Dataset (ISPD), but further quality control and homogeneity-checking procedures have been applied to the data in this paper and therefore the three series are released together in this dataset. The series are of immediate interest for understanding changes to storm activity across the English Channel and North Atlantic region over an extended timeframe but may also be assimilated into reanalysis datasets such as the 20th-century reanalysis.

KEYWORDS

atmospheric blocking, atmospheric circulation, barometric pressure, NAO, storms

1 | INTRODUCTION

In two previous publications (Cornes et al., 2012a, 2012b; henceforth COR12a and COR12b), we described the construction of daily series of sea-level pressure for the cities of London and Paris. These series extend back to the late seventeenth century and constitute two of the longest series of barometric pressure available. The

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data have been used in several studies, such as the examination of changes in the atmospheric circulation over the last ca. 300 years across the North Atlantic/Western European region (Cornes et al., 2013) and for assimilation into the EKF400 paleo reanalysis dataset (Valler et al., 2022). Monthly means calculated from the daily series have found the greatest use in these analyses. However, the data are limited for examining long-term changes in synoptic activity because of the combination of daily mean values for certain sections of the series and values at fixed hours of the day for other—often earlier—periods. This is particularly the case for investigating changes in storminess and for the assimilation of the data into century-long, sub-daily resolution reanalyses such as the 20th-century reanalysis (Slivinski et al., 2019). In this paper, we describe new, sub-daily versions of the London and Paris series that consist of values at the recorded hours of observation throughout the series.

In the following section, we describe the sources used in the sub-daily London and Paris series and then the adjustments that have been applied to the data. The suffixes 'sub' and 'day' are used to distinguish between the sub-daily series and the previously released daily mean series. A different method of homogenization has been applied to these series, which involves a pairwise comparison between the two series and the long series of pressure that exists for De Bilt in the Netherlands. Although the De Bilt series has previously been homogenized, the series has been tested again in this paper. Additional quality control flags have been applied to the data, and therefore this series is included in the dataset alongside $\text{London}_{\text{sub}}$ and $\text{Paris}_{\text{sub}}$.

2 | DATA SOURCES

2.1 | The London series

$\text{London}_{\text{sub}}$ has been constructed in a similar manner to $\text{London}_{\text{day}}$ by joining and homogenizing data from a variety of sources (Table 1). The sources are mostly the same as those used by COR12a, but there are five notable differences, which are described in the following sub-sections.

2.1.1 | The Samuel Molyneux series (1717–1723)

A remarkable source of meteorological observations has been discovered that provides data for the period 1716–1723. The record was kept by Samuel Molyneux at Whitehall in the centre of London and consists of six observations per day of barometric pressure, temperature and from the 1st April 1717 (Julian Calendar) also of wind speed/direction and 'weather'; from 1719 humidity readings were also recorded. The observations were typically taken from 9 am to midnight at three-hourly intervals. The weather diary was known to Gordon Manley, and he provided a reference to the manuscript in Manley (1974). However, despite his stated intentions in that paper, Manley does not appear to have analysed the series in any detail before his death in 1980.

Samuel Molyneux was a Member of Parliament, and the diary was presumably kept in his rooms at the House of Commons since the dates coincide with his time in office. Molyneux was also a keen scientist; he was elected as Fellow of the Royal Society in 1712 and with the astronomer James Bradley conducted seminal studies in astronomy during the 1720s. Judging by notes in the diary, the recording of the observations was the duty of a servant and unusually for the time, the diary contains relatively detailed metadata. The barometer was made by the respected instrument-maker Hauksbee the Younger in 1716 and was graduated in English Inches to the precision of 0.01inHg (0.3 hPa). The thermometer was also made by Hauskbee and was of a closed design of around 4.5 inches (114 mm) in length. Data from that instrument have been used to adjust the barometer readings to 0°C (see Section 3 and Section S1.1). The scale on the instrument had 100 divisions with each division being 0.22 inch. The scale was inverted, such that zero marked 'extreme heat', 45 'temperate' and 95 'extreme cold'. Hauksbee kept a shop at Crane Court in London and was one of the finest instrument makers of the time and supplied instruments such as this during the 1710–1720s (Middleton, 1966).

Molyneux's observations are particularly valuable for the $\text{London}_{\text{sub}}$ series as the data cover the previously missing 1717–1723 period. As such, $\text{London}_{\text{sub}}$ provides a largely complete series of at least daily pressure readings for London from 1692 to the present. The Molyneux data also provide a more satisfactory calibration for the pressure readings extracted from the anonymous Holborn weather diary (1709–1716) and supersede those data for the period 1716–1717.

A comparison between the Holborn pressure observations and the Molyneux readings sheds new light on the scale used in the Holborn diary. One division on the Holborn scale equals 0.02inHg (0.7 hPa), with zero being at 28.0inHg (948.2 hPa) and the barometer appears to have the same scale as Hooke's second instrument that is described in Henderson (2007, p.145), and Patterson (1953, p. 62). The Holborn barometer had a scale that was half that of Hooke's main barometer and

TABLE 1 The components of the $London_{sub}$ data series.

Source	Period	Location (northing/easting)	Altitude (m)
John Locke	1691–1703	51.76; 0.21	55
Gresham College	1693–1693	51.52; 0.11	55
William Derham	1697–1709	51.56; 0.25	25
Holborn	1709–1717	51.52; −0.12	5
Molyneux – Whitehall	1716–1720	51.5; −0.13	20
Molyneux – Great George St.	1720–1723	51.5; −0.13	40
LWD – William Stukeley	1723–1723	51.49; −0.14	11
LWD – Francis Hauskbee	1723–1727	51.51; −0.11	31
LWD – James Jurin (Garlick Hill)	1728–1745	51.51; −0.09	25
LWD – James Jurin (Lincoln's Inn Fields)	1745–1750	51.51; −0.12	30
LWD – John Hooker (Tonbridge)	1750–1765	51.19; 0.28	61
LWD – Gentleman's Magazine	1765–1775	51.5; −0.15	20
Royal Society – Crane Court	1774–1781	51.52; −0.11	23.7
Thomas Hoy – Muswell Hill	1781–1781	51.59; −0.14	101.5
The Gentleman's Magazine	1782–1784	51.51; −0.11	15
Thomas Hoy – Syon House	1782–1784	51.48; −0.31	14
William Bent	1784–1786	51.51; −0.09	25
Royal Society – Somerset House	1787–1822	51.51; −0.12	23.7
Royal Society – Somerset House	1823–1841	51.51; −0.12	29.6
The Gentleman's Magazine (Cary et al.)	1824–1865	51.51; −0.11	15
Henry Belville – Prior Street	1842–1844	51.48; −0.01	21
William Rogerson	1843–1845	51.48; 0.00	25
Henry Belville – Hyde Vale	1844–1854	51.48; −0.01	29.9
RGO – Upper magnet room	1854–1917	51.48; 0.00	48.5
DWR	1861–1902	51.5; −0.13	5
RGO – New magnetograph house	1917–1920	51.48; 0.00	46.3
London (DWR)	1921–1930	51.46; −0.12	7
Kew Observatory (DWR)	1930–1948	51.48; −0.29	7
Heathrow Airport	1949 onwards	51.48; −0.45	25

Note: The period column indicates the range over which the particular source supplies data to $London_{sub}$ and does not indicate that the source was the sole contributor over that period.

had a rising scale (Hooke's main wheel barometer had a declining scale). On 7 January 1681, concurrent measurements are available from both instruments, which indicate that the scale used in Holborn is the same as Hooke's ‘parlour’ instrument. A comparison of the values against Molyneux's data indicate that the morning reading was taken at about 9 am, or a little before, and in the evening at 6 pm.

2.1.2 | London weather diary values (1765–1770)

The data for the period 1723–1773 used in $London_{day}$ had been extracted from Gordon Manley's London Weather Diary (LWD), which had been obtained from the *Gentleman's Magazine* periodical and adjusted to modern-equivalent values. These values were generally entered into the LWD in the unit of inches of mercury (inHg). However, for the period August 1765 to December 1770, the data had been entered in the unit of hPa, rounded to the nearest whole unit, which reflects Manley's assessment of the precision of the measurements. However, when calculating the variance using these daily values the magnitude is reduced for this period as a result of the rounding (see figure 8 of COR12a). To rectify this in $London_{sub,}$ the raw values for this period have been extracted directly from the *Gentleman's Magazine*. This is the same source used by Manley and to ensure consistency with the remainder of the LWD values, Manley's adjustments have been applied to the values as follows: December to February, +0.2inHg (6.8 hPa); March to April and October to November, +0.18inHg (6.1 hPa); May to September +0.15inHg (5.1 hPa). These adjustments were obtained from Manley's working notebooks that are kept at the Cambridge University Library Archive (see Section S4.1). These adjustments combine temperature (a subtracted value being greatest in the summer), a height adjustment (a positive constant value) and likely an index adjustment (positive constant) although the exact values of these components were not provided in Manley's notebooks.

2.1.3 | The Belville series (1843–1855)

For the period from 1843 to 1855, the barometer observations recorded in the private weather diary of John Henry Belville are used in $\text{London}_{\text{sub}}$. Belville was an assistant at the Royal Observatory Greenwich, but he also kept a personal diary of meteorological observations, which began in 1811 and was maintained until his death in 1856. The observations were initially kept at the observatory, but from 1822 he recorded the observations from instruments at his house close to the observatory. That remained the case throughout the diary, and while he moved house several times, he always lived in the vicinity of the observatory.

Belville was a highly regarded member of staff at the observatory (Hunt, 1999) and was expert in the recording of meteorological observations; he wrote treatises on both the thermometer and barometer, in which he describes the method of recording observations from these instruments and the corrections that need to be applied to the readings (Belville, 1850, 1858). As such, the barometric pressure readings in his diary are considered to be of a similar quality to the official measurements recorded at the Greenwich Observatory.

In $\text{London}_{\text{sub}}$, Belville's twice-daily barometer observations have been used for the period 1843–1855. These observations were taken at 9 am and 2 pm and the series is remarkably complete, with only an occasional missing observation. These missing values have been filled using the barometer readings kept by another assistant at the Greenwich Observatory, William Rogerson. Like Belville, Rogerson lived close to the observatory and kept a personal diary of meteorological readings. These observations were published in monthly editions of *The Nautical Magazine*.

2.1.4 | The Royal Greenwich Observatory (RGO) series

As with $\text{London}_{\text{day}}$ the observations recorded at the RGO are a major component of the new London pressure series. In the original series, the 24-h mean values of pressure were used for the period 1843–1920. These values were compiled in the *Reductions of the Meteorological Observations of the Greenwich Observatory* publication using hourly observations from a photographic barometer that had been calibrated using eye readings of the Newman no. 42 barometer taken at 0900, 1200, 1500 and 2100 (local time [LT] which is equivalent to GMT/UTC). To complete $\text{London}_{\text{sub}}$ over this period, these manual readings were digitized but to reduce the amount of digitization the 2100LT values were not recovered.

2.1.5 | The daily weather report series

For the period from 1921 to 1948, MSLP values recorded for London in the Met Office's Daily Weather Reports (DWR) have been used in $\text{London}_{\text{sub}}$. The data were recorded at up to seven times per day and have the advantage of already being adjusted to sea level (Hawkins et al., 2022). The values were generally recorded at the Kew Observatory. However, until 31 March 1921 the 0100GMT and 2200GMT values were recorded at the Met Office headquarters in South Kensington. Earlier values from the DWR were also used to complete missing values in the RGO series (see Table 1).

2.2 | The Paris series

Until 1872, the same component series as $\text{Paris}_{\text{day}}$ are used in the sub-daily series (Table 2). However, from

TABLE 2 The components of the Paris Series.

Source	Period	Location (northing; easting)	Altitude (m)
Joseph Delisle, Hotel de Cluny	1747–1759	48.85; 2.34	57
Augustin Roux	1760–1776	48.85; 2.34	57
Pere Louis Cotte, Montmorency	1776–1784	48.98; 2.32	106.5
Paris Observatory	1785–1872	48.836; 2.337	67
Paris-Montsouris Observatory	1872 onwards	48.817; 2.333	78[a]

[a]For the period 1892–2011, the altitude was 77 m.

TABLE 3 The barometers used at the Paris-Montsouris observing station since 1872.

Period	Instrument	Description
16/6/1872–20/12/1953	Large cistern Tonnelot barometer in units of mmHg	Built according to Renou's instructions and compared against a Fortin barometer.
21/12/1953–1/6/1988	Roy, compensated scale, Tonnelot barometer	
2/6/1988–23/3/2011	Digital L.E.E.M barometer	The exact end date of this instrument is uncertain
24/3/2011 onwards	Digital Vaisala PTB220	

1872 through to present-day, pressure data recorded at the Montsouris Observatory have been used. This marks a significant change from $\text{Paris}_{\text{day}}$ which used data from several different stations over that period. Newly digitized values recorded at the Paris Observatory have also been used for the period 1798–1872.

2.2.1 | Paris observatory series

Until 1798, the data have been extracted from the same source as used in $\text{Paris}_{\text{day}}$. However, from 1798 to 1872 the data used in $\text{Paris}_{\text{sub}}$ have been digitized from three successive periodicals: the *Journal de Physique et de Chimie* (1798–1815); the *Annales de Chimie et de Physique* (1816–1856); the *Annales de l'Observatoire* (1856–1872) (see Section S4.2). The digitization was done in two phases: Météo-France digitized the three-hourly observations between 9 am and 9 pm (LT) from 1816 to 1829 and 1856 to 1880 (excluding 1870); the noon observations for the missing periods were digitized separately to complete $\text{Paris}_{\text{sub}}$. Noon was chosen because these were the values that had been digitized for $\text{Paris}_{\text{day}}$ before 1785 and prior to 1816 these were the only values that were published in the *Journal de Physique*.

2.2.2 | Paris-Montsouris series

The Montsouris Observatory was established in June 1869. Initially, three-hourly eye readings were recorded between 6 am and midnight (LT) but for the period September 1890 to September 1895 the three-hourly observations started at 1 am (LT). Prior to the introduction of the automatic digital barometers in 1988, barographs were used outside of the operating hours of the observatory (Table 3). For the early part of the record a self-recording, photographic barometer made by Salleron was used (Harding, 1881). From 1978 until 1988, a mercury barometer[1] was used during the station's operating hours and the data were supplemented by aneroid barograph readings during closed hours. The barograph was produced by Jules Richard/Richard-Pekly.[2]

Paris-Montsouris is designated as a World Meteorological Organization (WMO) Centennial Observing Station on account of the length of the series and the quality of the metadata, standardization of the measuring practices, the quality control of the data and the homogeneity of the station's location (WMO, 2022). Indeed, while the observation height changed three times over the course of the series (Table 2) the difference only amounted to around 1 m.

3 | HOMOGENIZATION

The corrections applied to the raw observations to convert the data to modern-equivalent values are largely the same as those used in COR12a, b, although the diurnal adjustment has not been applied. The series of pressure that exists for De Bilt back to 1743 in the Netherlands was tested for homogenization alongside the London and Paris data for the period 1747 to present. Quality control testing was applied to the data prior to homogenization checking (see Section S2). Calendar dates prior to 1754 in the London series have been adjusted from the Julian to the Gregorian calendar where necessary. The Revolutionary calendar dates used for the Paris Observatory data over the period 1798–1805 have been converted to equivalent Gregorian dates (see Section S1.1).

3.1 | Preparation of the London data

The 0900 (LT or equivalently GMT/UTC) observations are the most consistent in the London series and hence these values were subjected to homogenization testing. Prior to the application of those tests the observations from the Royal Society's Cavendish barometer (1774–1822) were adjusted to account for drift in the readings as in COR12a.

The 1780s remain a difficult period to homogenize due to the number of series required to form a complete series

[1]See http://bibliotheque.meteo.fr/exl-php/musee/INV00000143

[2]http://bibliotheque.meteo.fr/exl-php/musee/INV00000276
http://bibliotheque.meteo.fr/exl-php/musee/INV00000127

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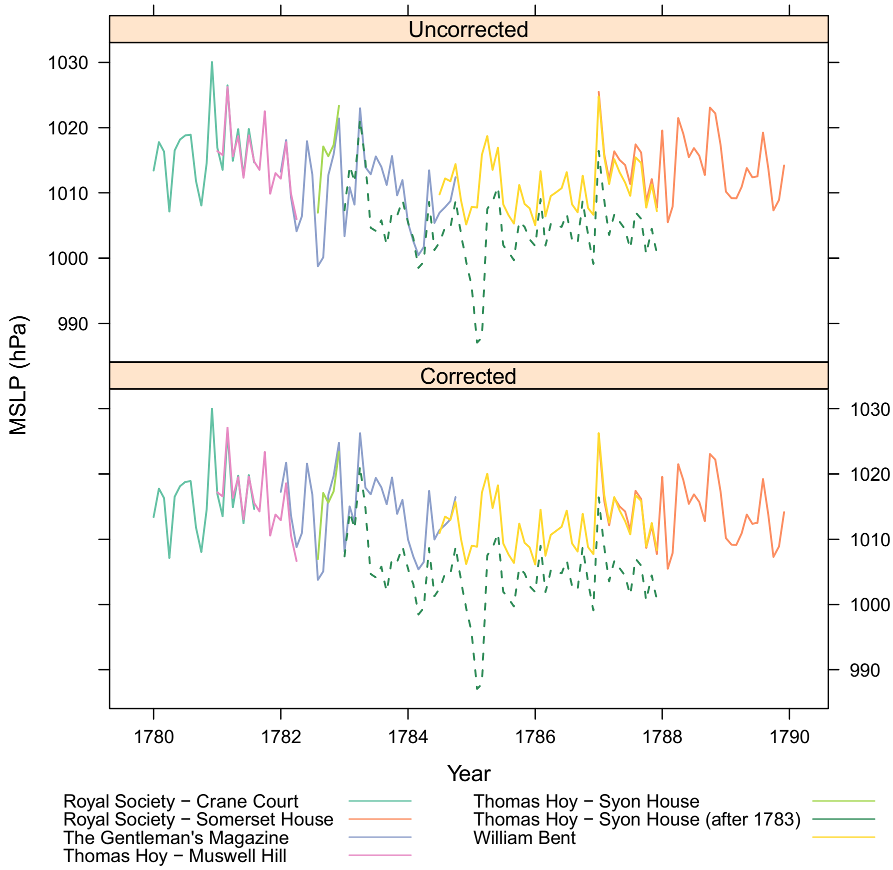

FIGURE 1 Monthly mean sea-level pressure values between 1780 and 1790 calculated from the six available sources of data. The top row shows the values adjusted to modern standards and to sea level but otherwise unhomogenized and the bottom row shows the homogenized values. The Hoy series after 1783 were not used in London$_{sub}$ and are shown (with a dashed line) for reference.

TABLE 4 The order of adjustments for homogenizing the London data over the period 1782–1786 using the regression of the independent series against the dependent series over the model period. The model was then used to adjust values over the correction period.

Order	Independent series	Dependent series	Model period	Correction period
1	William Bent	Royal Society – Somerset House	1787-01-01–1787-12-31	1784-07-01–1787-12-31
2	The Gentleman's Magazine	William Bent	1784-01-01–1784-12-31	1782-01-01–1784-10-31
3	Thomas Hoy – Muswell Hill	Royal Society – Crane Court	1781-01-01–1782-07-31	1781-01-01–1782-07-31

and because each of those series contain inhomogeneities (Figure 1). The values recorded by Thomas Hoy at Syon House were a significant component of London$_{day}$ over this period but were only used in London$_{sub}$ to complete missing values in other series. This is because the series contains more inhomogeneities than other series, and the data contained anomalously low values during the year 1785. Also, in contrast to London$_{day}$ an incremental homogenization procedure was used in London$_{sub}$ for the period 1782–1786, whereby overlapping segments were regressed in turn against segments considered homogenous or against segments that had been homogenized in a previous step (see Table 4). This reduces the size of, but does not preclude, the corrections obtained from the statistical homogenization procedure (Section 3.4).

To give an indication of the magnitude of the adjustments that have been applied to the data, we take the Royal Society's observation recorded at 9 am at its premises in Crane Court on 1st January 1774. A pressure of 29.57inHg was recorded and adjustments for cylinder capacity (−0.0015inHg) and capillarity (+0.04inHg) were applied to give 29.61inHg. Converting to the unit of hPa (1inHg = 33.8639 hPa) and applying an adjustment for temperature (−0.4 hPa using the reading from the attached thermometer), and then adjusting to standard gravity (+0.5 hPa) and to sea level (+3.0 hPa) gives 1005.9 hPa. An adjustment of +0.7 hPa was then applied, which combines the correction for drift described above and the homogeneity correction (see Section 3.4). This yields a corrected value of 1006.5 hPa.

3.2 | Preparation of the Paris series

For the purposes of homogenization, only the noon values in Paris$_{sub}$ were used for homogenization because this is the most consistent observing schedule. However, as described above, for the period 1890–1895 the values were recorded at 1300LT (1250 UTC).

An index correction of ¾ Paris Line (0.4 hPa) was applied to the Paris Observatory data for the period 1/1/1789 to 21/5/1800 as suggested from notes that accompany the data tables in the *Annales de Chimie*, from where the data were extracted. For the period 1816–1824, an incorrect coefficient had been used in the original source to reduce the values to 0°C and the adjustments listed in Table 5 were applied to the data for the respective month of the year following the recommendations of Renou (1881). Examination of the Paris data relative to the London and De Bilt series prior to statistical homogeneity checking indicated that the data were too low by around 5 hPa between 20/4/1765 and 18/8/1765. Since such a short period would not be reliably detected by the homogenization process, this adjustment was made prior to applying the checks and adjustments described in Section 3.4. The apparent drift in the Roux series and the early Paris Observatory that was described by COR12b was re-examined and the adjustment was not deemed necessary in the $Paris_{sub}$ series.

TABLE 5 Adjustments applied to the Paris data from 1816 to 1824 to account for an incorrect temperature adjustment coefficient used in the original tables.

	Adjustment	
Month	mmHg	hPa
1	0.08	0.11
2	0.12	0.16
3	0.16	0.21
4	0.22	0.29
5	0.29	0.39
6	0.35	0.47
7	0.38	0.51
8	0.38	0.51
9	0.35	0.47
10	0.27	0.36
11	0.18	0.24
12	0.10	0.13

Over the period 1880–1902, the MSLP values recorded at Paris-Montsouris are too low by an average of 0.5 hPa compared with the series recorded at the Parc St. Maur Observatory (as used in the $Paris_{day}$ series). This is assumed to be the result of recording error and the monthly mean values at Paris-Montsouris were adjusted over that period to the Parc St. Maur means. This adjustment was interpolated to the daily resolution using the method described in Section 3.4.

3.3 | Preparation of the De Bilt series

The De Bilt series has been constructed by joining together the data recorded at Zwanenburg and Utrecht, as described by Labrijn (1945), with the series from De Bilt (see Table 6). The Zwanenburg and Utrecht data were adjusted to an equivalent De Bilt value using overlapping data segments. About 6% of the Zwanenburg data were missing and have been filled in with the data recorded in Haarlem (which is 7 km to the west of Zwanenburg). As a result, the Zwanenburg section now has only 0.7% missing data. This series of observations is currently available in the International Surface Pressure Dataset (ISPD, Cram et al., 2015).

3.4 | Breakpoint detection and correction

The three series were homogenized over the period December 1747–December 2022 using the HOMogenization softwarE in R (HOMER) software package, version 2.6 (Mestre et al., 2013). The De Bilt series has previously been corrected for the largest inhomogeneities but was tested again in the context of the other two stations. In the absence of suitably located pressure series that can be used as reference series, the London and De Bilt series prior to 1747 were tested for homogeneity independently

TABLE 6 The components of the De Bilt series. The observation times have been converted from Local Time to UTC where necessary.

Station	Period	Measurement schedule	Observation time (UTC)	Location (northing; easting)
Zwanenburg	1743–1850	Three per day	7,13,22	52°23′ N; 04°45′ E
Utrecht	1851–1896	Three per day	7:40,13:40,21:40[a]	52°05′ N; 05°08′ E
De Bilt	1897–1901	Three per day	7:40,13:40,18:40	52°06′ N; 05°11′ E
De Bilt	1902 onwards	Hourly	0:40,1:40, ...,23:40[b]	52°06′ N; 05°11′ E

[a]In the year 1896, the 21:40 measurements changed to 18:40 UTC.

[b]From 1951 onwards the measurement times changed to 1, 2, ..., 24 UTC.

using the F-test from the RH-tests package (version 4, Wang & Feng, 2013) as in COR12a,b.

HOMER was developed as part of the COST action HOME project and combines PRODIGE, ACMANT and a joint detection algorithm. The software is designed to be run in a semi-automatic, iterative manner whereby the different homogenization tests are applied to the data in turn and metadata are incorporated as necessary. The pairwise test relies on the fact that between breakpoints a series is homogeneous, and the breakpoints are different across the stations. This is a reasonable assumption to make with the three series tested here since they were recorded in different countries and so are unlikely to suffer from common changes in recording policy.

HOMER tests the homogeneity of monthly mean series and hence the three data series were averaged prior to testing. Following the recommendations of Mestre et al. (2013), an interactive procedure was used. The pairwise detection was first applied to annual and summer/winter seasonal averages, and this was followed by the joint detection test. The identified breakpoints were assessed at each stage and dates were adjusted where appropriate using metadata and the other breakpoints were subjectively assessed for accuracy. The series were then adjusted for the identified breakpoints using the additive ANOVA method and the corrected series were then subjected to further pairwise and joint detection tests. This procedure was repeated three times in total and the ACMANT test was also applied to the corrected series at the end of the testing procedure. Where the date of the changepoint was not recorded in the metadata the likely month of the change was determined using the HOMER algorithm that allows the changepoints to be moved from the default end-of-year positions to a month within ±2 years.

Monthly varying adjustments are generated by the ANOVA method in HOMER. This is a particular advantage of using this software for the homogenization of these long pressure series as artificial seasonal effects may be present in the data because of poorly located barometers and/or inadequate temperature adjustments, particularly where internal barometer temperature measurements have been estimated. The monthly adjustments were applied to the daily series using the interpolation method described by Vincent et al. (2002). This method maintains the monthly mean adjustment values and ensures that discontinuities are not introduced across adjacent months.

The breakpoints identified in the series are listed in Table 7, with time series of the adjustments shown in Figures 2 and 3. The De Bilt series was considered homogeneous, and no further adjustments were considered

TABLE 7 The breakpoints identified in the London and Paris series.

Date	Step size (hPa)	Description
London		
12–1709[a]	+6.8	End of the Derham series
11–1716[a]	−3.6	End of Holborn series
04–1745[a]	+3.5	Start of Jurin series at Lincoln's Inn Fields
12–1754	−6.51	Start of the Hooker series
12–1764	+1.56	–
12–1773	+2.88	End of the Gentleman's Magazine series
10–1780	+1.26	–
12–1783	−4.45	–
12–1786	+4.05	Start of the Royal Society series at Somerset House
Paris		
12–1749	−2.41	Start of Delisle's barometer 'B' series
12–1759	+8.60	Start of the Roux series
02–1762	−1.45	–
06–1785	+1.29	Start of the Paris Observatory series
12–1789	−2.57	–
08–1800	+0.71	–
12–1858	+0.72	–

[a]Breakpoint and adjustment determined using RH-tests.

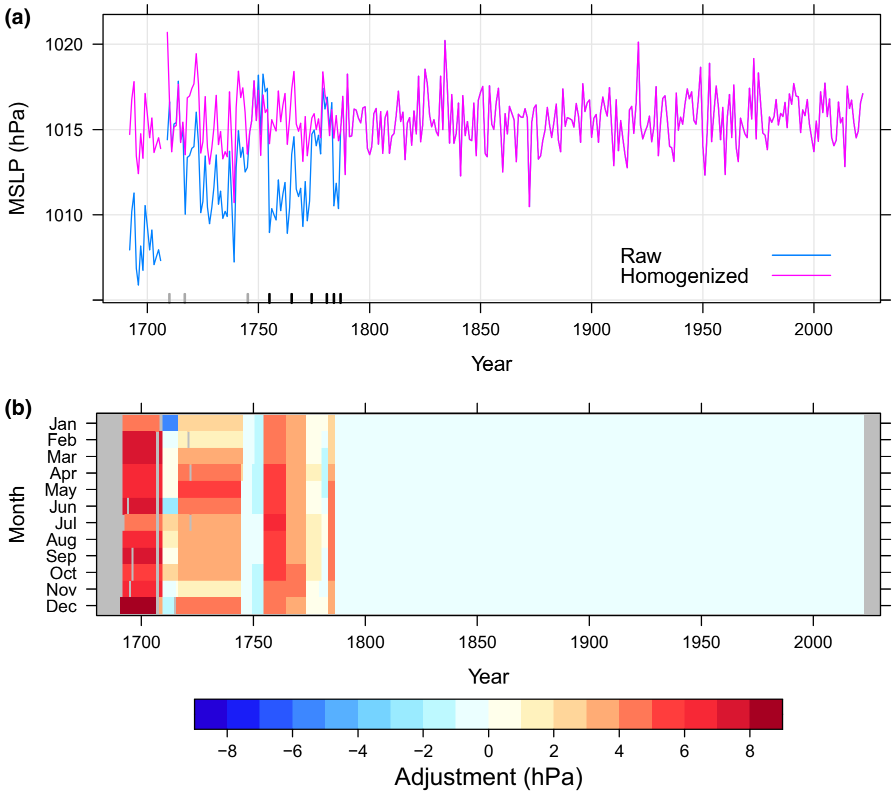

FIGURE 2 Annual mean values in the raw and homogenized London series (a) and the monthly adjustments that are applied to the raw data (b). In (a), the black and grey bars indicate the Homer- and RH-tests-derived breakpoints, respectively.

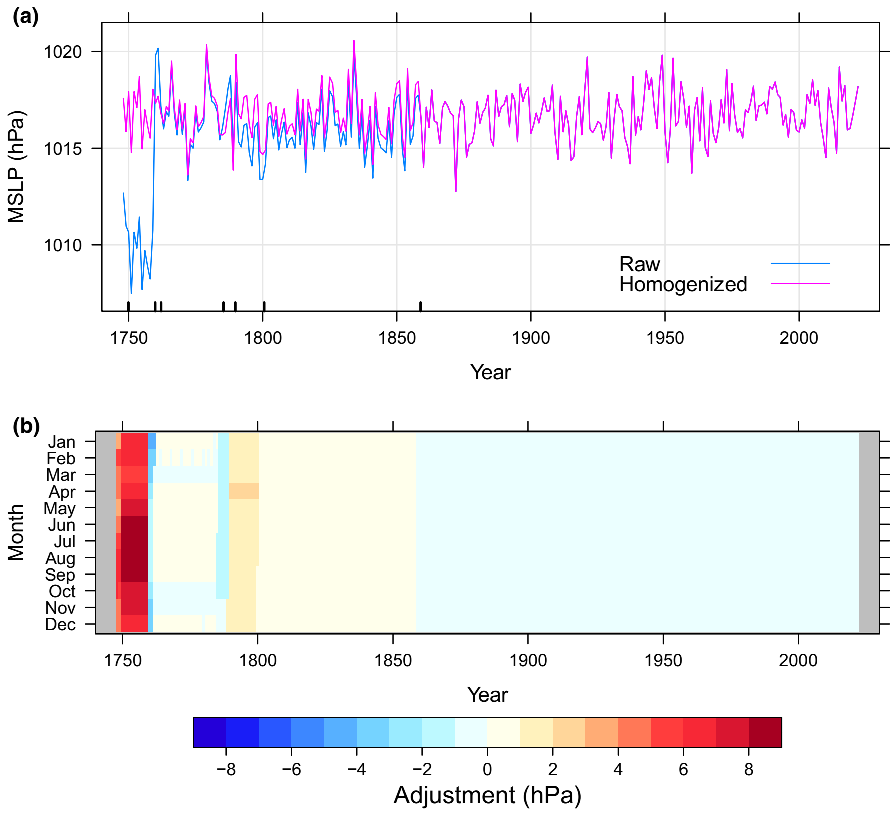

FIGURE 3 As Figure 2 but for the Paris series.

necessary. In the London series, changepoints were only detected prior to 1787, and that shift coincides with the reinstating of observations at the Royal Society following the gap in 1781–1786. This result also corresponds to tests that were conducted between overlapping segments of data (Section S3).

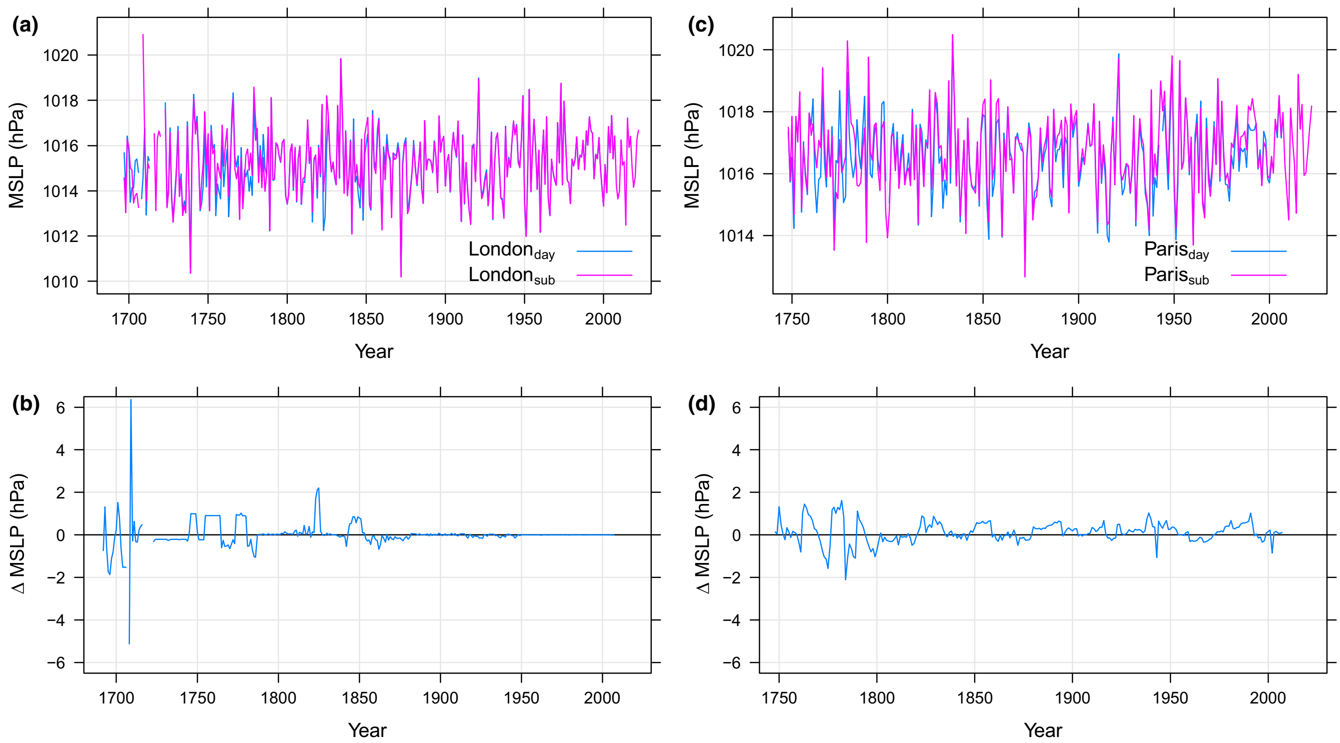

FIGURE 4 Annual mean sea-level pressure values calculated from the London and Paris series. The bottom row shows the sub-daily series subtracted from the daily series. Note the different x-axes in the London and Paris plots.

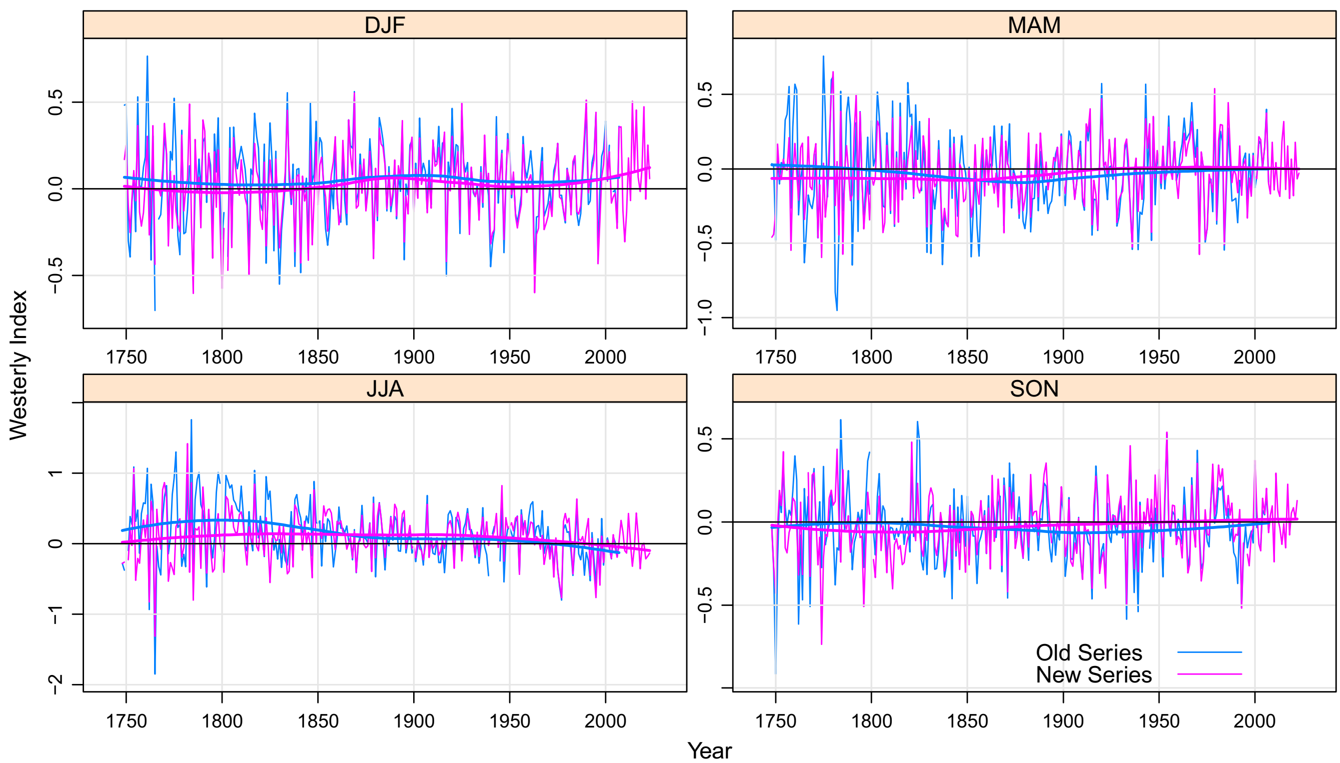

FIGURE 5 Comparison of the Westerly Index published by Cornes et al. (2013) and the new index.

4 | COMPARISON OF THE LONDON AND PARIS DAILY/SUB-DAILY SERIES

The London/Paris monthly series and Paris–London westerly index have been constructed in the same way as in Cornes et al. (2013) by applying a diurnal adjustment to the sub-daily values. To examine significant differences in the daily and sub-daily series, annual averages have been calculated from the monthly series (Figure 4). Throughout the late-nineteenth/twentieth century the $\text{London}_{\text{day}}$ and $\text{London}_{\text{sub}}$ series are generally consistent. However, prior to that period larger differences occur because of the different series used in $\text{London}_{\text{sub}}$ or the different homogenization adjustments that have been applied to the data (especially during the 1780s). A large difference occurs during 1823–1825, which results from the discovery that temperature correction had already been applied to the Royal Society data during that period.

For the Paris series, differences of ±2 hPa are evident throughout the period. As with the London series this occurs from the use of different data series, notably the use of the Paris-Montsouris data since the 1870s, and the different homogenization/quality control checks that have been applied to the data.

Relatively large differences exist in the two versions of the westerly index in individual yearly values. Differences occur in all seasons (Figure 5) although the low-frequency variability is broadly similar during the winter. A significant difference exists before the 1850s in the spring but particularly the summer season, where the relatively large positive values in the original index are not apparent in the new series. This likely results from the improved source of data used for Paris, which also have improved temperature adjustments.

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OPEN RESEARCH BADGES

This article has earned Open Data and Open Materials badges. Data and materials are available at Open Science Framework (https://doi.org/10.6084/m9.figshare.24242302.v1).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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