# Pre-1866 Extensions of the Southern Oscillation Index Using Early Indonesian and Tahitian Meteorological Readings

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ABSTRACT

Pressure data from Indonesia and Tahiti for years before 1866 are used to extend the Southern Oscillation index (SOI) back to 1841, with a gap between 1861 and 1865. Further extension is possible using an index of Jakarta rainday counts back to 1829. Rainday counts correlate ($r = -0.60$) with average Jakarta pressure for the June–November dry season over the 1876–1944 period. Although low, this correlation is still better than the correlation of tree rings with pressure or SOI. After 1950 the rainday count–pressure relationship alters, and by the 1990s 18% more raindays (an increase of seven per dry season) occur than the pressure would indicate. The dramatic increase in the size and population of Jakarta since 1950 is considered the most likely reason.

## 1. Introduction

The Southern Oscillation is the principal mode of pressure variability in the Tropics and it influences the climate of many regions of the world (Allan et al. 1996a,b). The phenomenon as measured by the Southern Oscillation index (SOI) has exhibited some unusual behavior during the past 20 years [see discussion in Trenberth and Hoar (1996); Harrison and Larkin (1997)]. It is important, therefore, that we have the longest records with which to characterize the phenomenon. The Jones (1989) Tahiti–Darwin SOI (T–D SOI) series is the longest available and makes use of additional pressure records from Indonesia and the South Pacific to extend the time series back to 1866, the year that marks the start of hourly pressure readings by the Royal Magnetic and Meteorological Observatory in Batavia (now Jakarta), Indonesia. Earlier data, however, some of it published at the time, is available from Indonesia. At the other center of the dipole there is also potential for extension, through a series of Tahitian pressure observations prior to 1866.

This study highlights the potential wealth of early meteorological records, from the colonial era, held principally in a number of European meteorological libraries and archives (most notably in the United Kingdom, the Netherlands, Germany, France, Belgium, and Spain). The major source of much of the world's climatic data is the excellent volumes of World Weather Records (WWR). The first year of most sites in WWR coincides within a few years of the opening of the national meteorological service. However, meteorological recording prior to that time was more extensive than is generally realized, but organized archiving of the basic raw data only began with the establishment of national meteorological agencies. Therefore, just because earlier data are not available in the WWR volumes or in other databanks (e.g., Bradley et al. 1985), this should not be taken as evidence that useful meteorological observations were not made. Systematic searches of some national meteorological libraries and national archives should be given greater priority than it currently enjoys.

A few small-scale, but successful, attempts to find

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early data have already been undertaken. Examination of the records of the British East India Company (BEIC) have revealed the existence of concise meteorological measurements for their observatory in Madras, India, dating back to 1796. Recovery of the monthly pressure records from this site is currently under way (P. Carroll 1997, personal communication). Similar long series may be retrieved from the BEIC's observatory in Singapore, which has already yielded the 1841–45 pressure data used in this paper. The Indonesian and Tahitian data described in the present paper represent a further example of successfully recovered early data, this time from archives in the Netherlands, Indonesia, the United Kingdom, and Tahiti. Nobody knows how much similar early data still remain hidden in these and other archives in the world; the currently recovered series probably only represents the tip of the iceberg.

In this paper, the early Indonesian and Tahitian pressure observations are brought together, carefully reviewed, and analyzed in an effort to extend the T–D SOI as far back in time as possible. The early Indonesian data effectively extend the Batavia/Jakarta pressure readings back to 1841, although with two major gaps (1855–58 and 1861–65). By a fortunate coincidence, the early Tahitian pressure data bridge the former gap, so that combination of the two sites enables extension of the monthly SOI series back to 1841, with only one major gap. Rainday counts can further extend the record back to 1829, as a statistically significant correlation exists between the number of Batavia/Jakarta raindays in the dry season and the T–D SOI. This paper exploits the availability of these data.

## 2. Data—Sources and homogenization

Various publications have assessed data quality and availability from Indonesia (1866→), Tahiti (1876→), and Darwin (1869→). These series are discussed briefly in the appendix. This section discusses earlier meteorological data discovered during this study for Indonesia and Tahiti.

### *a. Indonesia*

Indonesian meteorological readings prior to 1866 have to be handled with some suspicion. The main reason is that the observers in charge, mainly military medical officers, were simply ordered by their superiors to take the readings four times a day as part of their duty. Many officers, having no interest in meteorology whatsoever but knowing that failing to complete the forms at the end of the month would cause trouble, faked the observations, either by using observations from a previous year (sometimes in reversed order) or by filling in fictitious data. The medical authorities awakened to this widespread practice in the late 1850s (General State Archive of the Netherlands 1859; Anonymous 1858; Braak 1921), when the 1857 form from Ambon included detailed readings taken on *31* April.

The early records used in this study come from Buitenzorg (now Bogor) and Batavia (Jakarta).

#### 1) Buitenzorg (now Bogor, 50 km south of Jakarta) Botanic Garden, pressure, September 1841–June 1855

Meteorological observations were made under the responsibility of the Academy of Sciences of the Netherlands. The observation site was the military doctor's house, left of the entrance to the botanic garden. The observations were made by the doctor and his assistant; the doctor received an additional salary for this activity (Arsip National Republik Indonesia 1865). The observations include pressure readings reduced to 0°C but not to standard gravity or sea level, taken four or five times a day. The starting date of the observations is 16 September 1841; the readings were published until December 1854, with an extension to June 1855 in the form of anomalies, twice a day.

The Arsip National Republik Indonesia (1865) document indicates that the observations continued until December 1864. All post-1855 data were sent on a biannual or annual basis to the Ministry of Colonies in the Netherlands and then forwarded to the Royal Netherlands Meteorological Institute (KNMI) (General State Archive of the Netherlands 1857–66) but were not published. Despite our searches in Dutch and Indonesian archives, the 1855–64 readings could not be found.

In the pressure series that have been published (1841–55) there are 13 missing months. The measurements for June 1843 have not been published since there were hardly any days of observation. In the period August 1844–June 1845 no measurements could be taken since the barometer was broken and had to be replaced. After 1 July 1845 the observation series is uninterrupted, but the December 1850 measurements were mistakenly not sent to the Netherlands and hence also have not been published. The Buitenzorg observations were published by Onnen (1844) (September 1841–August 1842), Onnen and Roozeboom (1846) (September 1842–July 1844), Swaving (1848, 1849, 1850a) (July 1845–June 1848), and by KNMI (1855) (July 1848–June 1855). A calibration report of the barometer used in 1845–64 is available (Stamkart 1849). The observer for the period 1848–55, P. Swart, continued observing until his retirement in 1864 (General State Archive of the Netherlands, undated), after which the station was closed. The instruments, including the barometer, were then handed over to the newly founded Royal Magnetic and Meteorological Observatory in Batavia (Arsip National Republik Indonesia 1865).

Daily observations were digitized and the resulting monthly values were reduced to standard gravity and sea level (Letestu 1966), using the observed monthly temperatures and the mean vapor pressure. The data were corrected for the unevenly distributed observation hours using the mean diurnal cycle of mean sea level pressure (MSLP) from Berlage's (1940) 1866–1940 climate summary for Batavia (see the appendix). The Buitenzorg data include hourly readings once a month; the mean diurnal cycles of the Buitenzorg and Batavia pressure are the same within the uncertainty.

The doctor's house in Buitenzorg (described by Swaving 1850b), which was located left of the entrance to the botanic garden, could be identified on old maps. Its position is 131 ± 5 m west and 62 ± 5 m south of the TTG 9 benchmark, which is situated on the other side of the entrance. The geographic coordinates of the benchmark are 108°47′54.8″E and 6°36′9.0″S. The maps show that the house disappeared between 1891 and 1912 (Rijnberg 1992). Onnen (1844) reported the barometer's height above the ground to be 2 m. However, the height of the ground at the time is not known exactly; contemporary estimates range between 252 and 283 m (Swaving 1850b). The meteorological tables (Onnen 1844; Swaving 1848, 1849; KNMI 1855) indicate barometer heights of 273, 267.2, and 271 m. An on-site surveying in 1995, kindly performed by J. A. Bureau and K. Villanueva at the request of L. Polderman, from the TTG 9 benchmark indicated that the present ground elevation near the house's location is 268 m. However, it is not known how much soil might have been excavated or infilled since the house disappeared. According to Bureau and Villanueva an uncertainty of 2.5 m should be applied by extrapolating the present level to the past. This puts the doctor's barometer, which was mounted 2 m above the ground, at a height of 270 ± 2.5 m above mean sea level (MSL).

For the Buitenzorg pressure reduction to sea level we initially adopted a value of 270.6 m for the barometer height. However, this yielded a 10-yr mean pressure (1842, 1846–54) that was 1.1 mb lower than the Batavia 1866–1940 mean of 1009.8 mb (Berlage 1940). No 10-yr period in the 1866–1980 Batavia/Jakarta record differs by more than 0.25 mb from the 1866–1940 mean, so that the Buitenzorg series is clearly offset with respect to Batavia.

A systematic difference in MSLP between Buitenzorg and Batavia can be caused by the mountainous character of the Buitenzorg area (Schüepp et al. 1964); it can also originate from the adoption of an incorrect height. If the latter were the only cause, the real height of the barometer would have been about 280 m, and the real ground height near the doctor's house would have been about 278 m MSL. These values are still within the range noted by Swaving (1850b), but far outside the range indicated by Bureau and Villanueva. Therefore it seems likely that the large-scale terrain difference between Buitenzorg and Batavia also contributed to the offset.

The possibility remains that part of the 1.1-mb difference between Buitenzorg and Batavia arose from a low-frequency pressure excursion during the Buitenzorg observation period. However, comparison of Singapore's 1841–45 pressure (Elliott 1850) with its 1951–70 pressure shows no noticeable sign of such an anomaly, as the mean values of these two periods were equal within 0.1 mb. This led us to believe that the systematic part of the offset of the Buitenzorg pressure has a value of −1.0 ± 0.1 mb, and that within this 0.1 mb-range the Buitenzorg period was not affected by a natural low-frequency pressure excursion. A comparison of the extreme daily values in all 10-yr periods of Batavia with Buitenzorg supports these conclusions. Hence, a correction of +1.0 mb was applied to all Buitenzorg data in order to make them compatible with Batavia.

In March 1844 the Buitenzorg instrument started to malfunction. The daily pressure data and the observation log indicate a distinct drop of 2.9 ± 0.2 mb on 9 March. Between 9 March and 12 June the instrument appears stable, but on 12 June a further drop of 6.0 ± 0.1 mb was documented. The station readings for March–June were corrected for these subsequent drops and included in our table. The July 1844 measurements had to be omitted, as the daily readings indicate further rapid degradings of the instrument for which no corrections could be made. As noted earlier there were no readings from August 1844 to June 1845, during which time a new instrument arrived from the Netherlands.

#### 2) BATAVIA (NOW JAKARTA) HOSPITAL, WELTEVREDEN, PRESSURE, 1846–48

Pressure was measured daily at 0930 and 1530 LT, reduced to 0°C but not to standard gravity or sea level. The monthly averages of the two observation hours were published by Maier (1850a,b; 1851), who had been the observer. The 3-yr Weltevreden period is also covered by the Buitenzorg series. The monthly values of the two series covary strongly, but the Weltevreden readings rise systematically with respect to Buitenzorg (2 mb in 36 months), either due to a malfunction of the Weltevreden instrument, or due to lack of observing discipline. The main contribution of this series to this analysis is that it proves the reality of the observed monthly fluctuations in the Buitenzorg readings.

#### 3) BATAVIA HARBOR (“TIMEBALL”), PRESSURE, AUGUST 1858–FEBRUARY 1861

Pressure was measured daily at 0900, 1200, and 1500 LT, reduced to 0°C and sea level but not to standard gravity, and the monthly averages of the three observation hours were published by Schwencke (1861a,b; 1862a,b), who was the officer in charge of operating the timeball of the harbor. This timeball consists of a large ball mounted at the top of a long, vertical pole, which at noon and other selected hours was released, allowing the ships to adjust their clocks. The Batavia timeball officer was also supposed to take the thrice-daily pressure observations; we assume that these readings were

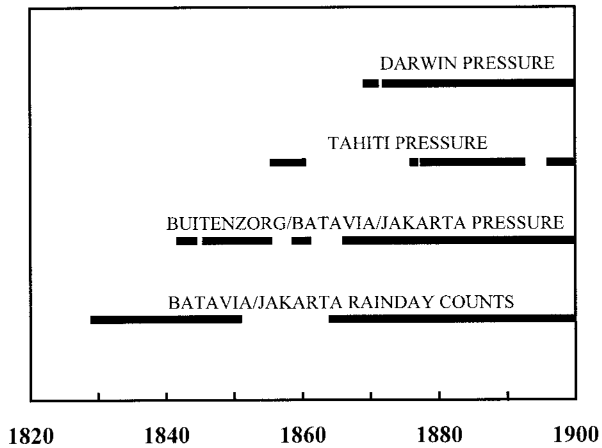


FIG. 1. Availability of pressure data up to 1900 for Darwin, Tahiti, and the Batavia region, and for rainday counts at Batavia.

displayed to adjust or recalibrate shipborne barometers. It is not known when this practice started. Neither Schwencke's predecessor W. F. Gijsens nor his successor A. Legel seems to have published meteorological data.

The 2.5-yr timeball pressure series is categorized by Braak (1921) as reliable. This view is supported by the agreement of the yearly means with the bracketed data in Table 1 of Schove and Berlage (1965). As the timeball readings were already reduced to sea level, we applied reduction to standard gravity and also corrected for the unevenly distributed observation hours, again using Berlage's (1940) climate summary for Batavia.

#### 4) BATAVIA, RAINDAY COUNTS, 1829–50

The author of this record (Tromp 1851) was the head of road maintenance in Batavia. His department was in charge of watering the dusty roads on dry days. The record lists the number of days per month of nonoperation of the maintenance staff. The rainday count is taken as the number of days in the month minus the watering days. Since neither the operational area nor the operational practice of the maintenance unit changed significantly during this period, the series is likely to be homogeneous and represents a good proxy of raindays. We compared the rainday counts with modern values and the agreement was best with raindays above a 1-mm threshold. The record was used in an early twentieth century analysis of dry spells in Indonesia (van Bemmelen 1916).

#### 5) COMPOSITE BUITENZORG/BATAVIA/JAKARTA SERIES

Table 1 shows the complete extended Jakarta pressure series, as based on Buitenzorg/timeball/Batavia/Jakarta, in which the missing Jakarta values for December 1945–December 1946 (see the appendix) were infilled from Darwin using regression that maintains the variance in the estimated data. The regression procedure (MOVE 3) is described in Vogel and Stedinger (1985). Table 2 lists the pre-1866 Batavia rainday counts, together with the estimations of SOI and pressure from these data (see section 3b).

### *b. Tahiti*

#### TAHITI, PRESSURE, JUNE 1855–JUNE 1860

The Tahiti pressure series published by Ropelewski and Jones (1987) starts in 1876. It is believed that earlier pressure measurements at the station exist, as meteorological readings are sporadically reported in newspapers (*Messenger of Tahiti*) from 1860 onward. It is not known exactly when records began. Despite searches of hospital, military, and national archives in the capital, Papeete (M. J. Salinger 1996, personal communication), no original readings could be found.

Meteorological data for Tahiti for the period June 1855–June 1860 were published by the Board of Trade (1861). Monthly mean observations are available for pressure, maximum and minimum temperature, humidity, rainfall, raindays, and wind direction. Pressure measurements (in inches) were taken four times a day. Although the hours are not stated it is likely that two of them are the thermometer measuring times of 0600 and 1300 LT. Data for January 1859 are omitted from the reports; the reason for this was that there were four missing days! Hurricanes were observed on 22 January 1856 and 29 February 1860, suggestive of El Niño conditions in these years.

The published observations were corrected by the observer for temperature, and then reduced to standard gravity and sea level (by adding 0.003 in. up to June 1858 and then adding 0.010 in. for the 3 and 10 ft MSL of the instrument; perhaps this break marks the foundation of the official station on the island). Because of the lack of information concerning all four observation hours, we could apply no correction for the diurnal cycle. The original measurements could not be located in the United Kingdom or France. This is a pity as the measurements were continued after June 1860 but not published; the governor of the colony preferred to substitute the meteorological reports with trade figures (Board of Trade 1861).

Table 3 gives the early Tahitian pressure observations and the post-1866 augmented values (see the appendix) of Ropelewski and Jones's (1987) Table 1. Figure 1 shows the availability of data up to 1900 in the Batavia region, Tahiti and Darwin.

## 3. Southern Oscillation indices

### *a. Pressure SOIs*

The SOI can be considered as the atmospheric manifestation of the El Niño–Southern Oscillation phenomenon (Allan et al. 1996a). There have been several def-

TABLE 1. Monthly mean sea level pressures (mb − 1000) of Jakarta, reduced to 0°C and standard gravity. The data for December 1945–April 1948, those for 1951–November 1956, and those for January–March 1957 are accurate to the first decimal only (see the appendix). Bottom = The 1866–1940 and 1951–80 means and standard deviations.

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1841 | — | — | — | — | — | — | — | — | 10.79 | 10.51 | 9.37 | 8.54 |
| 1842 | 10.81 | 9.71 | 8.39 | 8.99 | 8.36 | 8.84 | 9.42 | 9.74 | 9.30 | 9.72 | 8.15 | 10.05 |
| 1843 | 9.81 | 10.59 | 8.79 | 9.24 | 7.62 | — | 9.55 | 10.16 | 10.01 | 10.26 | 8.15 | 10.37 |
| 1844 | 10.14 | 9.45 | 8.34 | 7.75 | 8.71 | 8.12 | — | — | — | — | — | — |
| 1845 | — | — | — | — | — | — | 9.95 | 10.18 | 11.02 | 10.51 | 10.58 | 9.57 |
| 1846 | 11.40 | 11.04 | 9.90 | 9.62 | 9.95 | 10.78 | 10.71 | 10.81 | 10.34 | 10.30 | 9.91 | 9.39 |
| 1847 | 9.80 | 9.35 | 10.10 | 9.52 | 9.92 | 10.07 | 9.75 | 9.89 | 10.25 | 10.36 | 9.61 | 7.96 |
| 1848 | 8.88 | 10.28 | 8.89 | 8.87 | 8.57 | 8.09 | 8.08 | 8.40 | 9.31 | 8.96 | 8.16 | 8.63 |
| 1849 | 9.28 | 9.77 | 9.96 | 8.60 | 8.53 | 9.51 | 9.26 | 9.19 | 8.72 | 9.10 | 8.75 | 8.10 |
| 1850 | 7.62 | 9.65 | 12.06 | 11.31 | 10.64 | 10.29 | 9.81 | 9.37 | 10.15 | 9.71 | 9.53 | — |
| 1851 | 9.90 | 9.57 | 9.02 | 8.91 | 9.46 | 9.48 | 8.80 | 10.07 | 10.11 | 10.81 | 8.30 | 10.50 |
| 1852 | 11.03 | 11.55 | 9.03 | 11.03 | 9.80 | 9.84 | 10.04 | 10.86 | 11.22 | 11.65 | 10.34 | 10.12 |
| 1853 | 11.23 | 9.81 | 10.49 | 9.86 | 10.10 | 10.32 | 10.94 | 10.03 | 10.84 | 10.97 | 9.72 | 9.70 |
| 1854 | 10.63 | 10.26 | 11.19 | 9.26 | 8.65 | 9.73 | 9.14 | 10.22 | 9.67 | 9.81 | 10.51 | 9.85 |
| 1855 | 9.56 | 12.30 | 10.35 | 10.40 | 11.11 | 10.27 | — | — | — | — | — | — |
| 1856 | — | — | — | — | — | — | — | — | — | — | — | — |
| 1857 | — | — | — | — | — | — | — | — | — | — | — | — |
| 1858 | — | — | — | — | — | — | — | 10.18 | 11.30 | 10.43 | 10.57 | 10.40 |
| 1859 | 9.60 | 10.86 | 10.67 | 9.98 | 10.05 | 10.48 | 10.66 | 10.36 | 10.45 | 10.56 | 10.71 | 10.31 |
| 1860 | 10.13 | 9.68 | 9.20 | 10.10 | 9.45 | 9.05 | 10.02 | — | 10.25 | 9.66 | 9.82 | 10.41 |
| 1861 | 10.35 | 9.22 | — | — | — | — | — | — | — | — | — | — |
| 1862 | — | — | — | — | — | — | — | — | — | — | — | — |
| 1863 | — | — | — | — | — | — | — | — | — | — | — | — |
| 1864 | — | — | — | — | — | — | — | — | — | — | — | — |
| 1865 | — | — | — | — | — | — | — | — | — | — | — | — |
| 1866 | 10.96 | 9.19 | 10.26 | 9.55 | 8.81 | 10.35 | 10.18 | 10.50 | 10.29 | 10.04 | 9.36 | 10.19 |
| 1867 | 11.32 | 9.34 | 10.80 | 9.53 | 8.77 | 9.69 | 9.96 | 9.93 | 9.76 | 9.25 | 11.12 | 10.41 |
| 1868 | 9.33 | 10.14 | 10.35 | 10.14 | 10.63 | 10.90 | 10.43 | 10.82 | 10.94 | 10.59 | 11.15 | 10.10 |
| 1869 | 11.62 | 10.97 | 9.96 | 9.99 | 9.17 | 9.77 | 10.45 | 10.41 | 10.88 | 10.40 | 9.53 | 9.04 |
| 1870 | 7.50 | 8.67 | 8.89 | 8.14 | 8.57 | 9.29 | 9.87 | 9.21 | 10.22 | 9.72 | 9.26 | 9.16 |
| 1871 | 8.60 | 8.92 | 9.53 | 9.30 | 9.34 | 9.72 | 10.13 | 10.27 | 10.12 | 9.63 | 8.88 | 9.52 |
| 1872 | 9.47 | 9.23 | 9.38 | 8.48 | 9.45 | 8.85 | 9.69 | 9.61 | 9.72 | 9.41 | 7.85 | 8.16 |
| 1873 | 8.62 | 9.03 | 9.04 | 8.49 | 8.20 | 9.66 | 10.01 | 10.01 | 10.63 | 9.87 | 10.37 | 9.65 |
| 1874 | 10.89 | 10.17 | 8.57 | 9.29 | 9.10 | 9.32 | 9.43 | 10.03 | 9.81 | 9.52 | 9.66 | 9.59 |
| 1875 | 8.63 | 8.72 | 9.34 | 8.60 | 9.13 | 9.52 | 10.35 | 10.32 | 10.59 | 9.32 | 10.09 | 8.44 |
| 1876 | 8.76 | 9.29 | 9.02 | 7.92 | 9.46 | 9.92 | 10.49 | 10.22 | 10.54 | 10.46 | 9.86 | 10.52 |
| 1877 | 11.65 | 11.29 | 10.70 | 10.16 | 9.73 | 11.60 | 12.10 | 12.53 | 12.29 | 11.92 | 10.85 | 9.69 |
| 1878 | 10.73 | 11.42 | 11.06 | 9.54 | 9.12 | 10.09 | 9.48 | 10.40 | 9.96 | 8.96 | 8.70 | 7.84 |
| 1879 | 8.61 | 8.84 | 9.09 | 8.85 | 8.00 | 9.53 | 9.28 | 9.80 | 10.04 | 9.90 | 9.16 | 7.93 |
| 1880 | 8.77 | 9.57 | 9.36 | 9.52 | 8.66 | 10.10 | 10.44 | 10.25 | 10.64 | 10.74 | 10.46 | 10.41 |
| 1881 | 10.25 | 11.34 | 10.62 | 9.61 | 9.26 | 9.37 | 10.92 | 10.92 | 10.76 | 10.01 | 8.48 | 8.64 |
| 1882 | 10.56 | 9.44 | 10.68 | 8.24 | 9.12 | 9.20 | 9.96 | 10.12 | 10.52 | 9.30 | 9.20 | 8.96 |
| 1883 | 9.93 | 9.58 | 9.96 | 9.00 | 9.24 | 10.21 | 10.73 | 10.40 | 11.24 | 10.45 | 8.72 | 11.10 |
| 1884 | 10.48 | 10.88 | 9.54 | 9.73 | 9.28 | 10.41 | 10.25 | 10.49 | 11.29 | 10.42 | 9.25 | 10.30 |
| 1885 | 11.82 | 9.46 | 10.82 | 9.17 | 9.85 | 9.86 | 10.97 | 10.72 | 11.37 | 11.16 | 10.88 | 9.48 |
| 1886 | 9.77 | 10.00 | 9.68 | 8.76 | 8.82 | 9.65 | 9.30 | 9.41 | 10.05 | 9.54 | 9.01 | 9.49 |
| 1887 | 8.38 | 9.21 | 9.12 | 8.73 | 9.46 | 9.42 | 10.49 | 9.96 | 10.80 | 10.02 | 9.69 | 9.10 |
| 1888 | 10.88 | 11.10 | 10.52 | 9.50 | 9.16 | 9.98 | 10.82 | 11.08 | 10.65 | 10.37 | 10.37 | 10.16 |
| 1889 | 11.14 | 10.96 | 11.57 | 9.42 | 9.32 | 9.66 | 9.45 | 10.60 | 9.89 | 10.09 | 8.46 | 8.33 |
| 1890 | 8.36 | 9.97 | 8.37 | 9.10 | 8.96 | 9.41 | 10.50 | 10.48 | 10.16 | 10.37 | 10.62 | 10.17 |
| 1891 | 9.34 | 11.24 | 9.98 | 10.20 | 9.42 | 10.25 | 10.50 | 11.68 | 11.57 | 9.94 | 10.02 | 10.64 |
| 1892 | 9.78 | 8.69 | 7.61 | 8.96 | 9.86 | 9.04 | 10.12 | 9.74 | 10.24 | 9.06 | 8.92 | 9.92 |
| 1893 | 8.42 | 9.89 | 9.80 | 8.76 | 9.37 | 8.98 | 9.49 | 10.14 | 10.33 | 9.94 | 9.60 | 9.74 |
| 1894 | 8.66 | 10.66 | 9.36 | 9.24 | 9.56 | 9.76 | 10.38 | 9.98 | 10.24 | 9.60 | 10.45 | 9.72 |
| 1895 | 9.30 | 10.26 | 9.13 | 9.65 | 9.94 | 9.65 | 10.22 | 9.70 | 10.46 | 9.68 | 10.86 | 8.89 |
| 1896 | 10.09 | 10.42 | 9.22 | 8.65 | 10.58 | 9.66 | 10.65 | 11.52 | 11.14 | 11.50 | 9.65 | 10.42 |
| 1897 | 10.36 | 9.09 | 10.10 | 9.73 | 9.52 | 9.82 | 10.50 | 10.48 | 10.57 | 10.61 | 9.65 | 8.61 |
| 1898 | 10.00 | 7.93 | 8.65 | 9.04 | 8.74 | 9.54 | 9.33 | 10.62 | 10.21 | 9.54 | 8.37 | 9.04 |
| 1899 | 9.17 | 9.78 | 9.32 | 9.65 | 9.53 | 10.45 | 10.45 | 10.08 | 11.38 | 10.80 | 11.05 | 9.72 |
| 1900 | 10.45 | 10.21 | 10.64 | 9.81 | 10.40 | 9.89 | 9.61 | 9.81 | 10.82 | 10.41 | 9.30 | 10.33 |
| 1901 | 10.29 | 10.58 | 10.32 | 8.74 | 9.49 | 9.80 | 9.48 | 10.58 | 11.38 | 10.54 | 9.70 | 10.05 |

TABLE 1. (*Continued*)

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1902 | 8.57 | 12.62 | 9.46 | 9.44 | 10.37 | 10.04 | 10.72 | 10.21 | 11.37 | 11.33 | 10.48 | 9.50 |
| 1903 | 10.49 | 11.93 | 9.09 | 9.04 | 9.50 | 9.73 | 9.26 | 10.38 | 10.52 | 9.74 | 9.45 | 8.41 |
| 1904 | 9.26 | 9.48 | 8.92 | 8.77 | 9.13 | 10.44 | 9.86 | 10.62 | 11.06 | 9.49 | 11.04 | 10.02 |
| 1905 | 11.16 | 10.60 | 10.98 | 10.69 | 9.68 | 10.06 | 10.69 | 10.86 | 10.70 | 10.16 | 11.26 | 9.74 |
| 1906 | 9.65 | 9.77 | 10.54 | 9.44 | 9.42 | 10.04 | 9.28 | 10.02 | 9.60 | 9.98 | 9.82 | 8.98 |
| 1907 | 9.68 | 9.62 | 10.02 | 9.21 | 10.06 | 9.32 | 9.69 | 10.92 | 10.60 | 10.54 | 9.33 | 8.92 |
| 1908 | 11.08 | 8.32 | 9.70 | 8.41 | 9.62 | 9.92 | 10.54 | 10.01 | 10.24 | 9.76 | 9.45 | 8.68 |
| 1909 | 8.64 | 9.44 | 8.96 | 8.90 | 8.78 | 9.33 | 9.82 | 10.04 | 10.00 | 9.58 | 9.44 | 9.54 |
| 1910 | 8.08 | 7.90 | 8.96 | 8.53 | 9.44 | 8.85 | 9.33 | 9.33 | 9.34 | 10.22 | 8.92 | 9.01 |
| 1911 | 9.04 | 10.85 | 10.05 | 9.46 | 9.34 | 10.41 | 10.61 | 10.44 | 10.46 | 11.42 | 9.77 | 9.32 |
| 1912 | 11.12 | 10.17 | 10.01 | 10.28 | 9.94 | 9.97 | 9.78 | 10.30 | 10.12 | 10.64 | 9.16 | 9.80 |
| 1913 | 10.49 | 9.64 | 8.52 | 8.96 | 9.29 | 10.02 | 10.48 | 10.80 | 10.96 | 11.08 | 10.94 | 10.73 |
| 1914 | 11.73 | 11.14 | 10.26 | 10.53 | 9.74 | 10.24 | 10.52 | 11.52 | 11.25 | 11.52 | 9.53 | 10.04 |
| 1915 | 10.97 | 10.21 | 11.89 | 10.25 | 9.25 | 8.78 | 9.98 | 10.48 | 10.08 | 9.52 | 9.21 | 9.29 |
| 1916 | 10.00 | 9.09 | 8.94 | 9.30 | 8.89 | 8.76 | 9.12 | 10.30 | 9.10 | 8.97 | 8.46 | 7.13 |
| 1917 | 9.60 | 9.37 | 8.33 | 8.29 | 9.78 | 9.33 | 9.24 | 9.90 | 9.65 | 9.40 | 9.16 | 8.45 |
| 1918 | 9.33 | 10.80 | 10.74 | 9.56 | 9.41 | 10.52 | 10.72 | 11.34 | 11.92 | 10.86 | 9.86 | 9.82 |
| 1919 | 11.24 | 10.98 | 10.52 | 9.45 | 9.13 | 10.13 | 10.09 | 11.08 | 10.52 | 10.68 | 9.68 | 9.52 |
| 1920 | 10.10 | 10.48 | 9.60 | 8.94 | 9.82 | 9.32 | 9.94 | 10.50 | 9.54 | 10.25 | 8.61 | 8.76 |
| 1921 | 9.52 | 8.18 | 8.81 | 10.04 | 8.66 | 9.18 | 9.82 | 10.18 | 10.64 | 10.04 | 10.54 | 9.52 |
| 1922 | 9.13 | 9.01 | 9.30 | 9.28 | 9.32 | 9.22 | 10.09 | 9.80 | 10.00 | 9.88 | 9.45 | 8.57 |
| 1923 | 8.85 | 9.78 | 10.09 | 8.16 | 8.77 | 9.42 | 9.89 | 11.16 | 10.73 | 10.57 | 9.89 | 9.26 |
| 1924 | 10.60 | 9.01 | 9.49 | 8.89 | 8.97 | 10.04 | 10.38 | 10.26 | 10.41 | 9.64 | 9.21 | 10.60 |
| 1925 | 8.01 | 9.05 | 8.74 | 9.90 | 9.49 | 9.70 | 11.22 | 10.22 | 10.94 | 11.32 | 10.09 | 10.77 |
| 1926 | 10.80 | 10.90 | 10.90 | 9.84 | 9.38 | 10.38 | 9.94 | 10.94 | 10.10 | 9.69 | 9.40 | 8.32 |
| 1927 | 9.02 | 10.60 | 8.04 | 8.89 | 9.72 | 10.12 | 10.21 | 10.45 | 10.18 | 10.66 | 10.01 | 9.82 |
| 1928 | 10.00 | 9.37 | 9.04 | 8.60 | 9.32 | 9.01 | 9.72 | 10.85 | 10.12 | 9.85 | 10.08 | 8.44 |
| 1929 | 9.72 | 8.84 | 9.16 | 9.82 | 9.80 | 10.18 | 10.92 | 10.73 | 10.20 | 10.26 | 9.25 | 9.28 |
| 1930 | 9.76 | 11.26 | 9.57 | 9.04 | 10.32 | 9.61 | 10.49 | 10.89 | 11.05 | 10.58 | 11.18 | 9.92 |
| 1931 | 9.74 | 10.32 | 10.25 | 9.57 | 9.70 | 10.13 | 10.40 | 9.69 | 10.00 | 10.43 | 9.74 | 9.16 |
| 1932 | 10.78 | 10.25 | 9.68 | 9.81 | 9.21 | 9.52 | 9.46 | 9.95 | 10.25 | 9.63 | 9.73 | 9.13 |
| 1933 | 9.33 | 9.12 | 8.73 | 9.77 | 9.34 | 9.76 | 10.12 | 10.37 | 10.37 | 9.73 | 8.76 | 8.62 |
| 1934 | 8.57 | 9.37 | 8.46 | 9.04 | 9.92 | 9.68 | 9.65 | 11.06 | 10.72 | 10.21 | 9.52 | 9.96 |
| 1935 | 10.21 | 9.29 | 9.00 | 8.48 | 9.30 | 9.86 | 10.14 | 10.88 | 10.40 | 9.34 | 10.05 | 9.56 |
| 1936 | 9.19 | 10.32 | 9.82 | 8.74 | 8.33 | 10.14 | 10.36 | 10.54 | 10.04 | 10.38 | 10.11 | 8.62 |
| 1937 | 8.65 | 10.09 | 8.33 | 8.52 | 9.87 | 9.55 | 9.87 | 9.99 | 10.86 | 10.81 | 8.85 | 8.68 |
| 1938 | 9.76 | 9.69 | 8.79 | 8.82 | 8.35 | 9.72 | 9.56 | 9.62 | 9.90 | 10.25 | 9.24 | 8.51 |
| 1939 | 9.11 | 9.80 | 9.08 | 8.85 | 9.08 | 9.69 | 9.94 | 9.26 | 10.99 | 10.43 | 9.37 | 11.30 |
| 1940 | 9.77 | 11.03 | 9.85 | 10.13 | 9.36 | 10.26 | 11.33 | 11.08 | 11.51 | 11.78 | 9.28 | 10.90 |
| 1941 | 10.66 | 11.42 | 10.26 | 9.78 | 8.81 | 10.60 | 11.50 | 10.64 | 11.07 | 11.47 | 8.64 | 9.57 |
| 1942 | 10.10 | 10.50 | 8.68 | 10.25 | 8.45 | 9.30 | 10.39 | 10.06 | 10.45 | 9.76 | 9.49 | 9.42 |
| 1943 | 10.16 | 9.28 | 9.06 | 10.68 | 9.08 | 9.96 | 10.16 | 10.13 | 10.25 | 10.14 | 8.98 | 10.64 |
| 1944 | 10.85 | 9.97 | 10.34 | 10.30 | 9.64 | 10.42 | 10.89 | 11.10 | 10.71 | 10.17 | 8.91 | 8.43 |
| 1945 | 8.67 | 8.35 | 9.50 | 10.19 | 9.67 | 9.70 | 10.30 | 10.33 | 11.01 | 10.48 | 10.03 | 9.50 |
| 1946 | 9.90 | 8.90 | 10.20 | 9.90 | 9.60 | 10.30 | 10.70 | 10.70 | 11.00 | 10.90 | 9.80 | 9.60 |
| 1947 | 8.90 | 8.70 | 9.20 | 8.60 | 9.40 | 10.20 | 10.20 | 9.30 | 10.20 | 10.10 | 9.70 | 8.90 |
| 1948 | 10.30 | 10.10 | 9.80 | 9.40 | 9.51 | 9.92 | 9.62 | 9.54 | 10.38 | 10.10 | 10.03 | 9.10 |
| 1949 | 10.31 | 8.48 | 9.33 | 9.81 | 8.91 | 9.85 | 10.29 | 10.38 | 10.22 | 9.38 | 9.49 | 7.39 |
| 1950 | 8.19 | 8.90 | 8.77 | 8.12 | 8.56 | 8.41 | 9.78 | 9.92 | 10.32 | 9.43 | 7.96 | 9.39 |
| 1951 | 9.30 | 8.10 | 9.70 | 9.50 | 9.90 | 9.60 | 10.20 | 11.10 | 10.50 | 10.70 | 9.30 | 9.50 |
| 1952 | 9.80 | 8.40 | 8.80 | 9.80 | 8.80 | 9.90 | 10.20 | 9.90 | 10.20 | 9.50 | 8.50 | 10.80 |
| 1953 | 9.30 | 10.40 | 9.40 | 9.30 | 10.00 | 9.40 | 10.50 | 10.80 | 10.80 | 10.10 | 10.00 | 9.60 |
| 1954 | 8.00 | 9.70 | 9.50 | 8.20 | 8.10 | 9.10 | 9.10 | 9.10 | 9.90 | 10.00 | 9.80 | 8.30 |
| 1955 | 10.40 | 7.60 | 9.10 | 8.50 | 7.90 | 8.80 | 9.50 | 9.40 | 9.20 | 9.20 | 8.40 | 9.00 |
| 1956 | 8.10 | 8.10 | 9.20 | 8.30 | 8.30 | 9.10 | 9.20 | 9.10 | 9.20 | 9.30 | 9.70 | 9.22 |
| 1957 | 9.70 | 10.00 | 9.80 | 9.74 | 9.50 | 9.83 | 9.44 | 10.02 | 10.87 | 10.76 | 10.64 | 9.03 |
| 1958 | 11.58 | 10.21 | 9.95 | 9.58 | 9.30 | 9.41 | 9.94 | 9.51 | 10.09 | 9.83 | 9.70 | 10.55 |
| 1959 | 10.64 | 10.40 | 9.72 | 9.25 | 8.15 | 9.57 | 10.22 | 10.07 | 10.14 | 10.12 | 8.76 | 9.14 |
| 1960 | 9.83 | 9.83 | 9.32 | 8.92 | 8.57 | 9.74 | 9.41 | 9.44 | 9.00 | 9.81 | 9.24 | 9.16 |
| 1961 | 9.75 | 7.38 | 9.98 | 8.05 | 8.41 | 9.23 | 9.84 | 10.12 | 10.19 | 9.73 | 8.90 | 7.63 |
| 1962 | 7.55 | 9.50 | 8.43 | 8.69 | 8.03 | 8.93 | 9.02 | 10.07 | 9.51 | 8.97 | 8.95 | 9.00 |
| 1963 | 8.23 | 9.57 | 8.72 | 8.54 | 8.41 | 10.77 | 10.32 | 10.54 | 11.27 | 11.16 | 9.96 | 10.26 |
| 1964 | 10.12 | 9.08 | 9.64 | 8.51 | 8.83 | 9.44 | 9.57 | 9.89 | 9.12 | 9.41 | 9.10 | 9.83 |
| 1965 | 10.55 | 8.53 | 9.84 | 9.65 | 9.38 | 10.85 | 10.93 | 10.56 | 11.24 | 10.53 | 10.42 | 8.95 |
| 1966 | 10.71 | 9.53 | 9.04 | 8.89 | 10.11 | 11.03 | 9.94 | 10.33 | 10.67 | 10.24 | 9.28 | 8.24 |
| 1967 | 9.15 | 9.08 | 9.59 | 9.96 | 9.35 | 9.48 | 10.18 | 10.85 | 11.11 | 10.71 | 9.52 | 10.24 |

TABLE 1. (*Continued*)

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1968 | 9.21 | 10.77 | 8.87 | 9.75 | 8.97 | 9.76 | 10.01 | 10.49 | 10.77 | 10.54 | 10.83 | 8.95 |
| 1969 | 9.16 | 9.78 | 9.99 | 10.30 | 9.05 | 10.12 | 10.95 | 10.86 | 10.32 | 10.34 | 10.08 | 10.19 |
| 1970 | 10.59 | 10.75 | 9.12 | 9.55 | 8.76 | 9.96 | 10.83 | 9.71 | 9.16 | 9.20 | 8.99 | 8.78 |
| 1971 | 9.16 | 8.23 | 9.50 | 9.00 | 8.70 | 9.92 | 9.82 | 9.82 | 9.65 | 10.09 | 9.89 | 9.06 |
| 1972 | 10.24 | 8.71 | 9.93 | 10.28 | 10.22 | 9.71 | 10.78 | 10.85 | 10.88 | 11.13 | 9.86 | 10.22 |
| 1973 | 10.08 | 10.72 | 9.44 | 8.79 | 9.07 | 9.02 | 9.34 | 9.61 | 10.15 | 8.64 | 9.00 | 9.08 |
| 1974 | 8.72 | 8.66 | 9.60 | 8.77 | 9.04 | 9.50 | 9.96 | 9.64 | 9.51 | 9.30 | 8.88 | 9.02 |
| 1975 | 9.76 | 9.74 | 8.99 | 8.25 | 9.08 | 9.67 | 10.15 | 9.56 | 9.57 | 9.40 | 9.72 | 8.72 |
| 1976 | 10.30 | 9.79 | 9.32 | 10.41 | 10.66 | 10.39 | 11.21 | 11.20 | 11.59 | 9.99 | 9.10 | 9.65 |
| 1977 | 9.81 | 10.28 | 11.04 | 9.68 | 9.80 | 9.93 | 9.63 | 10.81 | 11.14 | 11.27 | 10.39 | 10.60 |
| 1978 | 10.28 | 11.69 | 9.49 | 9.84 | 8.16 | 9.05 | 9.16 | 9.81 | 10.23 | 10.04 | 10.35 | 10.24 |
| 1979 | 11.08 | 10.02 | 9.76 | 9.50 | 9.52 | 9.83 | 11.45 | 10.59 | 10.38 | 11.09 | 9.25 | 11.05 |
| 1980 | 9.62 | 10.41 | 10.45 | 9.34 | 9.72 | 10.06 | 10.56 | 11.17 | 10.95 | 10.44 | 9.63 | 9.25 |
| 1981 | 10.57 | 10.11 | 10.94 | 9.98 | 8.85 | 9.95 | 9.60 | 10.65 | 9.98 | 10.13 | 9.15 | 10.67 |
| 1982 | 10.34 | 9.79 | 9.71 | 9.91 | 9.74 | 10.97 | 10.97 | 11.51 | 12.02 | 10.89 | 10.08 | 10.06 |
| 1983 | 11.63 | 11.63 | 10.98 | 9.58 | 9.67 | 10.11 | 10.46 | 11.00 | 10.58 | 9.88 | 11.04 | 10.19 |
| 1984 | 9.12 | 8.38 | 9.90 | 9.06 | 9.23 | 9.98 | 9.55 | 10.09 | 10.17 | 10.91 | 9.79 | 8.59 |
| 1985 | 10.57 | 6.66 | 9.22 | 8.38 | 8.23 | 10.14 | 10.58 | 10.45 | 10.46 | 10.35 | 9.69 | 9.91 |
| 1986 | 9.53 | 10.28 | 9.12 | 9.38 | 9.94 | 8.91 | 10.88 | 10.09 | 11.09 | 10.92 | 10.58 | 10.94 |
| 1987 | 11.19 | 12.11 | 10.98 | 10.76 | 10.56 | 10.39 | 11.50 | 11.38 | 11.53 | 10.73 | 9.95 | 10.92 |
| 1988 | 9.73 | 9.95 | 8.43 | 9.42 | 9.42 | 10.27 | 10.06 | 10.25 | 9.45 | 9.43 | 9.06 | 10.20 |
| 1989 | 8.56 | 9.87 | 8.96 | 8.91 | 8.83 | 10.38 | 9.74 | 9.99 | 10.22 | 10.03 | 10.14 | 10.74 |
| 1990 | 9.78 | 11.07 | 10.98 | 8.90 | 8.83 | 10.03 | 10.57 | 10.95 | 10.99 | 10.32 | 10.23 | 10.10 |
| 1991 | 9.83 | 10.51 | 10.08 | 9.06 | 9.64 | 10.44 | 10.76 | 11.29 | 11.86 | 10.33 | 10.82 | 10.15 |
| 1992 | 12.25 | 11.05 | 10.86 | 10.14 | 9.39 | 9.36 | 10.76 | 10.67 | 10.34 | 10.57 | 10.28 | 10.80 |
| 1993 | 10.48 | 11.02 | 10.73 | 10.40 | 9.86 | 10.23 | 10.29 | 11.71 | 11.43 | 11.35 | 9.45 | 9.70 |
| 1994 | 9.69 | 9.30 | 10.29 | 9.67 | 10.45 | 9.98 | 10.86 | 11.38 | 11.93 | 11.06 | 9.90 | 10.50 |
| 1995 | 10.55 | 10.35 | 9.85 | 9.40 | 9.79 | 9.63 | 9.70 | 10.11 | 10.96 | 9.57 | 9.57 | 10.25 |
| 1996 | 9.45 | 9.51 | 9.13 | 9.12 | 10.24 | 9.61 | 9.75 | 10.37 | 9.17 | 9.85 | 8.95 | 10.25 |
| 1997 | 10.63 | 9.09 | 11.15 | 11.23 | 9.92 | 10.82 | — | — | — | — | — | — |
| 1876–1940 | | | | | | | | | | | | |
| Mean | 9.80 | 9.98 | 9.61 | 9.25 | 9.40 | 9.78 | 10.14 | 10.44 | 10.54 | 10.25 | 9.67 | 9.44 |
| Std dev. | 0.95 | 0.96 | 0.88 | 0.60 | 0.49 | 0.49 | 0.59 | 0.59 | 0.61 | 0.68 | 0.73 | 0.85 |
| 1951–80 | | | | | | | | | | | | |
| Mean | 9.69 | 9.50 | 9.51 | 9.23 | 9.06 | 9.70 | 10.05 | 10.16 | 10.24 | 10.05 | 9.54 | 9.44 |
| Std dev. | 0.93 | 1.04 | 0.53 | 0.67 | 0.72 | 0.55 | 0.65 | 0.62 | 0.74 | 0.70 | 0.63 | 0.81 |

initions based on a single or a weighted average of station pressure data. Currently the most widely used index is based on the difference of pressure data between Tahiti and Darwin (see discussion in Ropelewski and Jones 1987).

The T–D SOI is defined as the standardized difference between the standardized monthly pressures at Tahiti and Darwin. The period 1951–80 has been used as the base for defining the means and standard deviations for each month (see also Ropelewski and Jones 1987; Climate Analysis Center 1986; Allan et al. 1996a; Allan et al. 1996b).

The standardized pressure $P_s$ is given by

$$P_s = (P - \overline{P})/\sigma, \tag{1}$$

where $\overline{P}$ and $\sigma$ are monthly means and standard deviations, respectively, over the 1951–80 baseline period. The T–D SOI is calculated as follows (see also Ropelewski and Jones 1987):

$$\text{T–D SOI} = \frac{P_s(\text{Tahiti}) - P_s(\text{Darwin})}{\sigma[P_s(\text{Tahiti}) - P_s(\text{Darwin})]}. \tag{2}$$

Table 4 shows that the standardized pressures of both Jakarta and Tahiti [using Eq. (1)] correlate highly with the T–D SOI.

From Eqs. (1) and (2) it follows that the correlation coefficient $\rho_{\mathrm{X,SOI}}$ between the (standardized) pressure of a station X and the T–D SOI relates with the interstation correlation coefficients for pressure by

$$\rho_{\mathrm{X,SOI}} = \frac{1}{2}\sqrt{2}\frac{\rho_{\mathrm{X,T}} - \rho_{\mathrm{X,D}}}{\sqrt{1 - \rho_{\mathrm{T,D}}}}, \tag{3}$$

where T = Tahiti, D = Darwin, and X can be any station including T, D, or Jakarta. The absolute values of the correlation coefficients in Table 4 increase if the averaging time is increased and saturates for averaging times of about 5 months, implying that lower-frequency T–D SOI fluctuations are well represented by the single-station readings. The series is often displayed with smoothing of this order (Ropelewski and Jones 1987).

The T–D SOI has exactly zero mean and unit variance [Eq. (2)] over the 1951–80 period, and the same holds for the standardized single-site pressures. Hence, the

TABLE 2. Raindays 1829–50 of Jakarta as inferred from the road maintenance reports (Tromp 1851) and observed raindays 1864–65 (threshold is 1 mm). Bottom = observed means for 30-yr periods (threshold is 1 mm). Right columns: pressure (mb – 1000) and Jakarta SOI for the summer half year, inferred from the rain data.

| | | | | | | | | | | | | | Jun–Nov | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Pressure | SOI |
| 1829 | 25 | 18 | 15 | 12 | 17 | 16 | 10 | 4 | 4 | 9 | 17 | 23 | 9.6 | 0.7 |
| 1830 | 27 | 28 | 16 | 13 | 7 | 14 | 12 | 14 | 7 | 9 | 8 | 14 | 9.4 | 0.9 |
| 1831 | 24 | 15 | 16 | 8 | 3 | 5 | 6 | 12 | 3 | 6 | 13 | 21 | 10.1 | −0.1 |
| 1832 | 25 | 20 | 23 | 12 | 8 | 10 | 7 | 6 | 5 | 7 | 11 | 5 | 10.0 | 0.0 |
| 1833 | 19 | 22 | 18 | 11 | 16 | 8 | 0 | 3 | 0 | 0 | 12 | 2 | 10.8 | −1.3 |
| 1834 | 20 | 24 | 23 | 20 | 16 | 6 | 11 | 9 | 5 | 15 | 14 | 19 | 9.6 | 0.7 |
| 1835 | 25 | 26 | 24 | 7 | 4 | 0 | 2 | 5 | 3 | 13 | 13 | 20 | 10.4 | −0.6 |
| 1836 | 28 | 24 | 21 | 12 | 15 | 7 | 10 | 2 | 5 | 13 | 16 | 11 | 9.8 | 0.4 |
| 1837 | 30 | 26 | 13 | 12 | 12 | 13 | 12 | 14 | 5 | 14 | 15 | 17 | 9.1 | 1.4 |
| 1838 | 18 | 22 | 13 | 7 | 7 | 2 | 1 | 3 | 3 | 4 | 13 | 22 | 10.7 | −1.1 |
| 1839 | 25 | 18 | 16 | 16 | 4 | 5 | 8 | 10 | 5 | 14 | 14 | 20 | 9.7 | 0.5 |
| 1840 | 26 | 17 | 13 | 12 | 12 | 4 | 10 | 8 | 12 | 12 | 19 | 16 | 9.4 | 1.0 |
| 1841 | 19 | 18 | 14 | 13 | 10 | 7 | 8 | 1 | 3 | 4 | 10 | 14 | 10.5 | −0.7 |
| 1842 | 21 | 19 | 15 | 15 | 6 | 5 | 1 | 2 | 4 | 10 | 7 | 7 | 10.6 | −0.9 |
| 1843 | 28 | 26 | 21 | 13 | 10 | 10 | 3 | 10 | 9 | 7 | 10 | 11 | 9.9 | 0.1 |
| 1844 | 28 | 20 | 15 | 12 | 3 | 5 | 12 | 14 | 11 | 8 | 15 | 15 | 9.4 | 1.0 |
| 1845 | 13 | 11 | 12 | 14 | 5 | 6 | 6 | 2 | 12 | 13 | 10 | 20 | 9.9 | 0.1 |
| 1846 | 15 | 17 | 18 | 9 | 10 | 6 | 10 | 2 | 4 | 6 | 15 | 12 | 10.1 | −0.2 |
| 1847 | 13 | 23 | 21 | 12 | 9 | 3 | 14 | 3 | 11 | 8 | 13 | 15 | 9.8 | 0.3 |
| 1848 | 18 | 10 | 15 | 9 | 9 | 9 | 9 | 7 | 14 | 7 | 10 | 19 | 9.7 | 0.5 |
| 1849 | 19 | 18 | 14 | 6 | 9 | 3 | 12 | 5 | 8 | 2 | 12 | 9 | 10.2 | −0.2 |
| 1850 | 15 | 21 | 19 | 12 | 4 | 6 | 1 | 2 | 2 | 1 | 14 | 15 | 10.7 | −1.1 |
| Mean | | | | | | | | | | | | | | |
| 1829–50 | 21.9 | 20.1 | 17.0 | 11.7 | 8.9 | 6.8 | 7.5 | 6.3 | 6.1 | 8.3 | 12.8 | 14.9 | 10.0 | 0.1 |
| 1864 | 22 | 17 | 9 | 10 | 8 | 6 | 5 | 7 | 7 | 12 | 7 | 13 | 10.0 | 0.1 |
| 1865 | 23 | 11 | 15 | 12 | 5 | 8 | 5 | 3 | 3 | 2 | 13 | 12 | 10.3 | −0.5 |
| Means | | | | | | | | | | | | | | |
| 1871–1900 | 19.2 | 18.1 | 14.5 | 10.3 | 6.9 | 6.7 | 5.4 | 3.4 | 5.5 | 7.6 | 11.2 | 15.8 | 10.1 | −0.2 |
| 1901–30 | 18.1 | 17.1 | 14.9 | 10.5 | 8.8 | 7.1 | 5.1 | 4.0 | 4.9 | 8.4 | 11.7 | 14.5 | 10.1 | −0.1 |
| 1961–90 | 19.8 | 15.8 | 14.5 | 10.6 | 9.3 | 5.7 | 3.9 | 4.4 | 4.5 | 7.3 | 10.6 | 13.6 | 10.3 | −0.4 |

standardized pressure $P_s$ of these stations, multiplied by the sign of its correlation coefficient with the T–D SOI [Eq. (3)], enables gaps to be filled, from either side of the Pacific, in the T–D SOI without causing any reduction in the month-to-month variance of the series. Figure 2 compares the 5-month running mean (5-mrm) values of T–D SOI with the Jakarta SOI (which is $-P_s$) and the Tahiti SOI (which is $+P_s$) for the period 1971–95. Apart from a few outliers, the single-site SOIs compare well with the T–D SOI.

In Figure 3 the 1841–65 5-mrm values of the two single-site SOIs are plotted as time series. In mid-1855 (May–July) the 5-mrm's are calculated using monthly values of both stations, as the beginning of the Tahiti time series overlaps with Jakarta by one month (June 1855). At the other end of the Tahiti time series there is an overlap with Jakarta of almost 2 yr. The 5-mrm values of both stations indicate good consistency between their values. Table 5 shows the monthly values of both single-site SOIs for the period 1841–65.

Figure 4 shows the complete, extended time series 1841–1997 of the Jakarta SOI, with 1855–58 infilled by the Tahiti SOI. For comparison the T–D SOI is included. The thick lines in the figure are the 10-yr locally weighted running line smoother due to Cleveland (1979). Over their complete overlap from 1876 to 1997 (see the appendix) the correlation between the 5-mrm T–D and Jakarta SOIs is 0.74. The 1876–1997 Tahiti SOI is not included in the graph, as it is a constituent of the Tahiti–Darwin SOI itself [Eq. (2)] so that it automatically correlates better with that index than the Jakarta SOI does [see Eq. (3)]. Both SOI series shown in Fig. 4 indicate a tendency to more negative values since the mid-1970s, an unparalleled 20-yr sequence since 1841. Rather than concentrating on the 1990–95 period as in Trenberth and Hoar (1996) and Harrison and Larkin (1997) it might be more advantageous, despite statistical problems, to investigate this longer period.

### b. *Rainday SOI*

As pointed out by Ropelewski and Halpert (1987) and Allan et al. (1996b), the Southern Oscillation affects Indonesian rainfall mainly in the dry season. Based on 1876–1944 data we find a correlation coefficient of −0.60 between the number of Jakarta raindays (threshold 1 mm) in the 6-month period from June to November and the mean standardized Jakarta pressure over these

TABLE 3. Monthly mean sea level pressures (mb – 1000) of Tahiti 1855–60, reduced to 0°C and standard gravity, and the augmentation for 1866–1932 of Ropelewski and Jones's (1987) pre-1936 pressure table [* = values given in Ropelewski and Jones's (1987) Table 1; — = missing values]. Below: the 1951–80 means and standard deviations.

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1855 | — | — | — | — | — | 12.9 | 13.1 | 14.4 | 15.2 | 13.7 | 12.5 | 12.6 |
| 1856 | 9.7 | 11.2 | 12.6 | 12.9 | 14.1 | 14.3 | 14.7 | 16.4 | 15.8 | 13.5 | 13.5 | 12.2 |
| 1857 | 13.2 | 12.7 | 12.9 | 13.5 | 13.6 | 12.5 | 14.1 | 15.3 | 15.4 | 15.2 | 14.1 | 11.9 |
| 1858 | 11.7 | 12.1 | 9.9 | 12.1 | 12.4 | 14.3 | 15.0 | 13.8 | 14.1 | 15.0 | 13.6 | 13.8 |
| 1859 | — | 8.5 | 9.7 | 10.9 | 12.2 | 11.3 | 13.1 | 14.0 | 13.8 | 13.3 | 11.5 | 10.0 |
| 1860 | 11.3 | 9.3 | 10.3 | 11.4 | 12.1 | 14.5 | — | — | — | — | — | — |
| 1866 | 10.6 | 10.9 | 11.5 | 11.4 | 12.5 | 13.6 | 13.5 | 15.5 | 13.9 | 13.8 | 13.4 | 11.2 |
| 1867 | 12.3 | 11.2 | 12.8 | 12.8 | 13.0 | 13.3 | 14.4 | 14.8 | 13.9 | 12.1 | 12.4 | 10.0 |
| 1868 | 10.2 | 11.0 | 10.0 | 12.7 | 12.2 | 12.8 | 13.7 | 13.3 | 12.8 | 12.5 | 11.2 | 12.3 |
| 1869 | 8.5 | 11.6 | 13.0 | 11.7 | 13.0 | 14.0 | 15.6 | 14.5 | 14.1 | 13.7 | 11.9 | 10.5 |
| 1870 | 10.4 | 10.5 | 11.9 | 12.7 | 13.1 | 13.5 | 13.9 | 14.9 | 14.1 | 13.2 | 11.2 | 10.3 |
| 1871 | 9.2 | 11.6 | 10.4 | 11.5 | 12.3 | 14.0 | 14.4 | 15.2 | 15.0 | 13.1 | 11.4 | 12.6 |
| 1872 | 13.0 | 12.2 | 12.6 | 13.1 | 13.5 | 14.0 | 15.4 | 14.8 | 17.7 | 15.1 | 15.0 | 13.2 |
| 1873 | 13.1 | 14.3 | 15.5 | 14.5 | 15.4 | 14.6 | 14.4 | 14.7 | 13.8 | 11.5 | 11.5 | 11.0 |
| 1874 | 12.3 | 12.3 | 12.8 | 12.7 | 13.5 | 12.8 | 13.9 | 16.0 | 16.7 | 15.2 | 12.6 | 10.8 |
| 1875 | 11.9 | 11.0 | 12.2 | 13.1 | 13.2 | 15.0 | 13.0 | 14.5 | 14.3 | 12.6 | 9.9 | 9.5 |
| 1877 | 9.6 | 9.5 | 9.8 | 9.3 | 10.9 | 11.8 | * | * | * | * | * | * |
| 1892 | * | * | * | * | * | * | * | * | 13.6 | 13.7 | 10.1 | 11.3 |
| 1893 | 12.1 | 11.9 | 13.6 | 12.9 | 14.7 | 15.3 | 16.0 | 16.1 | 16.0 | 13.7 | 13.1 | 10.6 |
| 1894 | 12.1 | 12.9 | 13.0 | 12.9 | 12.3 | 14.2 | 15.5 | 12.2 | 14.2 | 14.3 | 10.9 | 11.6 |
| 1895 | 11.0 | 13.1 | 12.3 | 13.6 | 14.2 | 13.0 | 12.7 | 12.8 | 13.3 | 12.7 | 12.9 | 9.7 |
| 1906 | * | * | 11.8 | 11.3 | 11.7 | * | * | * | * | * | * | 11.0 |
| 1907 | 10.7 | 10.5 | 11.8 | 11.3 | 12.4 | 13.4 | 13.4 | 13.2 | 14.5 | 13.0 | 11.1 | 10.6 |
| 1908 | 10.5 | 12.0 | 10.6 | 11.7 | 13.0 | 13.6 | 16.0 | 14.7 | * | * | * | * |
| 1914 | * | * | * | 10.5 | 11.5 | 12.2 | 13.6 | 14.2 | 13.4 | * | 12.9 | 12.5 |
| 1915 | 7.7 | 11.3 | 10.6 | 11.8 | 14.6 | 15.9 | 16.7 | 16.4 | 15.2 | 14.4 | * | * |
| 1921 | * | * | 12.8 | 11.2 | 12.1 | 16.0 | * | * | * | * | * | * |
| 1927 | * | * | * | * | * | 14.2 | 13.7 | 14.0 | * | * | * | * |
| 1931 | * | * | * | * | * | * | * | 13.6 | 14.2 | 13.0 | 11.4 | 11.9 |
| 1932 | 10.3 | 11.5 | 10.8 | 9.8 | 12.9 | 13.6 | 12.1 | 14.1 | * | * | * | * |
| 1951–80 | | | | | | | | | | | | |
| Mean | 9.83 | 9.63 | 9.55 | 9.22 | 9.10 | 9.74 | 10.12 | 10.22 | 10.35 | 10.09 | 9.58 | 9.53 |
| Std dev. | 0.91 | 0.99 | 0.52 | 0.67 | 0.72 | 0.53 | 0.62 | 0.59 | 0.74 | 0.69 | 0.64 | 0.82 |

TABLE 4. Correlations between standardized pressures and Tahiti–Darwin SOI (1936–80). Upper-right panel: between monthly values; lower-left panel: between 5-monthly means.

| | SOI | Jakarta | Darwin | Tahiti |
|---|---|---|---|---|
| SOI | | -0.57 | -0.81 | +0.81 |
| Jakarta | -0.71 | | +0.69 | -0.25 |
| Darwin | -0.91 | +0.74 | | -0.32 |
| Tahiti | +0.89 | -0.53 | -0.62 | |

Monthly values

5-Monthly means

months. The correlation with T–D SOI is slightly lower at 0.54. For the other half year, which is the wet season, the correlation is less than 0.1. While the correlations may not seem to explain much of the variance of the pressure series (29%–36%), they are higher than tree-ring information from Java indicate (see discussion in Allan and D'Arrigo 1998).

The rainday counts in Table 2, therefore, provide a method to estimate values of Jakarta pressure and SOI for the June–November half years. The estimations are obtained by regression, again using the MOVE 3 procedure (Vogel and Stedinger 1985), which maintains the full variance in the estimates. Using 1876–1944 as a baseline, this yields for the Tromp (1851) rainday counts for 1829–50 the following relationships:

$$P[\text{Jakarta (mb)}] = 1010.0 - 0.034(\text{RD} - 47.8),$$
$$\text{Jakarta SOI} = 0.07 + 0.054(\text{RD} - 47.8). \qquad (4)$$

For the Batavia /Jakarta rainfall counts 1864–1996 the relationship (again using the 1876–1944 baseline) is

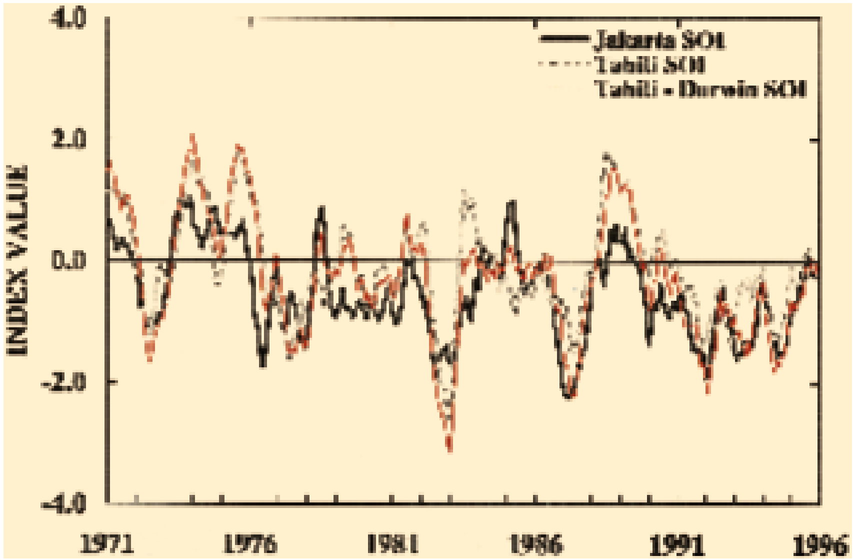


FIG. 2. Comparison of single-site SOI of Jakarta (black) and Tahiti (gray) with the Tahiti–Darwin SOI (red), for the period 1971–95. A 5-month running mean is applied.

$$P[\text{Jakarta (mb)}] = 1010.2 - 0.036(\text{RD} - 38.8),$$

$$\text{Jakarta SOI} = -0.24 + 0.057(\text{RD} - 38.8). \quad (5)$$

In Eqs. (4) and (5), RD is the number of Jakarta raindays in June–November. The results for 1829–50 [based on Eq. (4)] and for the years 1864–65, when no pressure data from Jakarta are available, are included in the right-hand columns of Table 2.

Figure 5 shows the June–November Jakarta SOI with that obtained from the raindays [using Eq. (5) for 1864 onward]. The agreement between the two series over the period 1866–1960 is reasonable, but after 1960 the rainday SOI (RD SOI) increases with respect to the Jakarta SOI: the Jakarta SOI decreased slightly, whereas the RD SOI remained about the same. A possible explanation is an increased urban effect on raindays due to the rapid growth in size and population of Jakarta during this period. To adjust the rainday-count series to the earlier years requires by the 1990s a reduction of 7 days per dry season (i.e., there are about 18% more

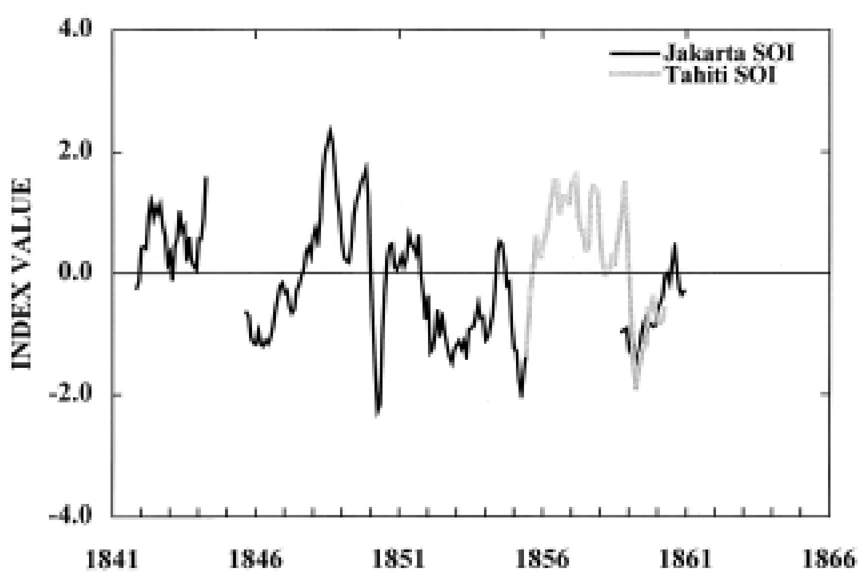


FIG. 3. SOI 1841–65, based on single-site pressure readings of Jakarta (1841–55; 1858–61) and Tahiti (1855–60). A 5-month running mean is applied. The line for the Jakarta SOI is black, the one for the Tahiti SOI is gray. Near the transition from black to gray in mid-1855 the running means are based on monthly values from both stations (see also Table 5).

TABLE 5. Single-station SOIs 1841–61 from pressure readings. Roman: Jakarta SOI from Buitenzorg/Batavia (timeball) readings; Italics: Tahiti SOI.

| Year | Jan | | Feb | | Mar | | Apr | | May | | Jun | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1841 | | — | | — | | — | | — | | — | | — |
| 1842 | | −1.20 | | −0.20 | | 2.12 | | 0.36 | | 0.97 | | 1.56 |
| 1843 | | −0.12 | | −1.05 | | 1.36 | | −0.01 | | 1.99 | | — |
| 1844 | | −0.48 | | 0.05 | | 2.20 | | 2.21 | | 0.48 | | 2.86 |
| 1845 | | — | | — | | — | | — | | — | | — |
| 1846 | | −1.83 | | −1.48 | | −0.74 | | −0.59 | | −1.22 | | −1.95 |
| 1847 | | −0.11 | | 0.15 | | −1.11 | | −0.44 | | −1.18 | | −0.67 |
| 1848 | | 0.87 | | −0.75 | | 1.16 | | 0.54 | | 0.68 | | 2.93 |
| 1849 | | 0.44 | | −0.26 | | −0.85 | | 0.93 | | 0.73 | | 0.35 |
| 1850 | | 2.22 | | −0.15 | | −4.82 | | −3.11 | | −2.19 | | −1.06 |
| 1851 | | −0.22 | | −0.07 | | 0.93 | | 0.47 | | −0.56 | | 0.41 |
| 1852 | | −1.44 | | −1.97 | | 0.90 | | −2.69 | | −1.02 | | −0.25 |
| 1853 | | −1.65 | | −0.30 | | −1.87 | | −0.95 | | −1.44 | | −1.12 |
| 1854 | | −1.00 | | −0.74 | | −3.18 | | −0.05 | | 0.57 | | −0.05 |
| 1855 | | 0.14 | | −2.69 | | −1.60 | | −1.76 | | −2.83 | *−1.14* | −1.03 |
| 1856 | | *−0.84* | | *−0.03* | | *0.92* | | *1.55* | | *2.28* | | *0.87* |
| 1857 | | *1.75* | | *1.24* | | *1.22* | | *2.37* | | *1.54* | | *−1.72* |
| 1858 | | *0.64* | | *0.73* | | *−1.73* | | *0.45* | | *−0.25* | | *0.87* |
| 1859 | | 0.10 | *−2.33* | −1.31 | *−1.93* | −2.20 | *−1.19* | −1.13 | *−0.55* | −1.36 | *−3.44* | −1.41 |
| 1860 | *0.35* | −0.47 | *−1.65* | −0.18 | *−1.34* | 0.58 | *−0.51* | −1.31 | *−0.70* | −0.53 | *1.15* | 1.18 |
| 1861 | | −0.70 | | 0.26 | | — | | — | | — | | — |

raindays in the dry season than there were before 1950). Prior to 1950 the size of Jakarta had changed very little since the mid-nineteenth century. The Batavia/Jakarta rainday series 1864–1950 can be considered to be homogeneous and unaffected by increased urbanization. In the 1876–1944 Jakarta series there are no clear signs of changes in the relationship between SOI and rainday count, certainly not in the perspective of what happened since.

Another possible explanation for the change in the RD SOI as opposed to the Jakarta SOI is due to long-term fluctuations in SOI and rainfall relationships. Nicholls et al. (1996, 1997) indicate that for Australian rainfall SOI relationships ‘‘since the early 1970s rainfall appears to have been greater, relative to the SOI, than was the case in earlier years . . . .’’ Despite this we consider the increased urbanization as the most likely cause for the post-1950 change in SOI–rainday relation in the readings of Jakarta.

## 4. Conclusions

Extensions to the SOI before 1866 have been made using early Indonesian meteorological data (from pres-

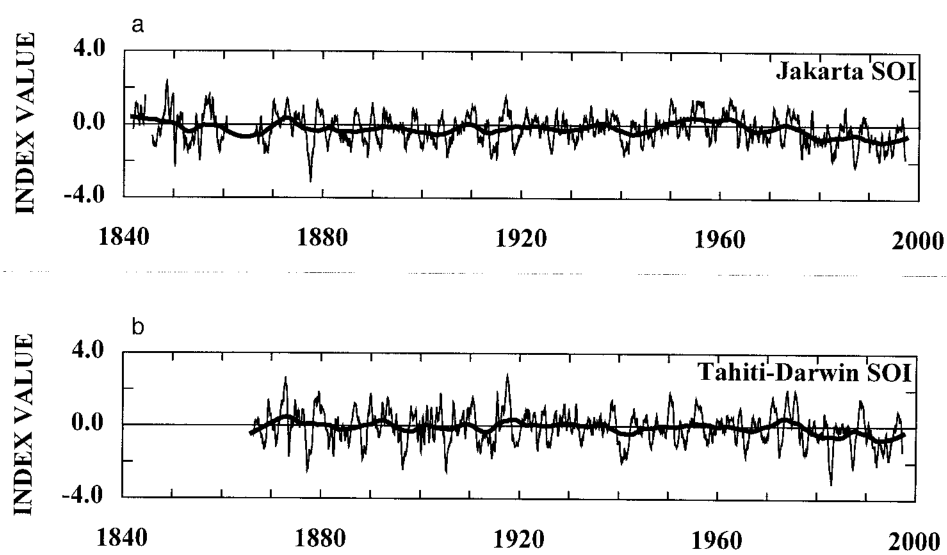


FIG. 4. (a) Time series of the Jakarta SOI 1866–1997 with its extension back to 1841 (see also Fig. 3). (b) Tahiti–Darwin SOI 1866–1997. A 5-month running mean is applied. The thick lines represent a 10-yr smoother (Cleveland 1979).

TABLE 5. (*Continued*)

| | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|
| 1841 | — | — | −0.74 | −0.66 | 0.26 | 1.12 |
| 1842 | 0.96 | 0.68 | 1.28 | 0.47 | 2.20 | −0.76 |
| 1843 | 0.76 | 0.01 | 0.31 | −0.30 | 2.19 | −1.15 |
| 1844 | — | — | — | — | — | — |
| 1845 | 0.15 | −0.02 | −1.05 | −0.65 | −1.64 | −0.15 |
| 1846 | −1.02 | −1.04 | −0.13 | −0.35 | −0.59 | 0.06 |
| 1847 | 0.45 | 0.43 | −0.01 | −0.44 | −0.11 | 1.83 |
| 1848 | 3.02 | 2.83 | 1.27 | 1.56 | 2.19 | 1.00 |
| 1849 | 1.21 | 1.56 | 2.07 | 1.37 | 1.24 | 1.66 |
| 1850 | 0.36 | 1.28 | 0.13 | 0.48 | 0.01 | — |
| 1851 | 1.91 | 0.15 | 0.18 | −1.08 | 1.97 | −1.31 |
| 1852 | 0.01 | −1.12 | −1.32 | −2.28 | −1.28 | −0.84 |
| 1853 | −1.38 | 0.22 | −0.81 | −1.31 | −0.29 | −0.32 |
| 1854 | 1.39 | −0.09 | 0.78 | 0.34 | −1.53 | −0.51 |
| 1855 | *−0.88* | *−0.16* | *0.87* | *0.03* | *0.70* | *1.48* |
| 1856 | *0.85* | *2.03* | *1.47* | *−0.21* | *1.87* | *1.11* |
| 1857 | *0.20* | *0.82* | *1.07* | *1.80* | *2.58* | *0.83* |
| 1858 | *1.18* | *−0.82* −0.02 | *−0.24* −1.43 | *1.56* −0.54 | *1.99* −1.64 | *2.58* −1.19 |
| 1859 | *−0.88* −0.94 | *−0.60* −0.31 | *−0.54* −0.28 | *−0.44* −0.73 | *−0.48* −1.86 | *−0.91* −1.07 |
| 1860 | 0.04 | — | −0.01 | 0.56 | −0.45 | −1.20 |
| 1861 | — | — | — | — | — | — |

sure data to 1841 and with less accuracy from rainday counts in the dry season to 1829). Although there are a few gaps and missing months in the pressure series, the missing months can be reliably estimated because there is about six months between independent values (see Trenberth and Hoar 1996; Harrison and Larkin 1997) in the Jakarta series. Early Tahitian pressure data for the 1855–60 period have infilled one gap leaving the major remaining gap the period from March 1861 to December 1865. It is clear from both Jakarta and Tahiti that the data to infill this gap were taken but at this present time they cannot be located and must be presumed lost.

The extended series enables recent behavior of the SOI to be placed in an even longer-term context. Both the T–D SOI and Jakarta SOI have tended toward more negative values since the late 1970s. This is the most marked decadal or bidecadal excursion of the index since the 1840s. How unusual the 1990–95 period might be has been discussed by Trenberth and Hoar (1996) and by Harrison and Larkin (1997). The slightly longer Jakarta SOI developed here is unlikely to assist in such discussions but it can potentially be used to consider the excursion since the late 1970s. The extended series, including the additional rainday-based data, should be particularly useful in paleoclimatic attempts to extend SOI measures farther into the past (see review by Allan and D'Arrigo 1998). Indeed it might prove a fruitful

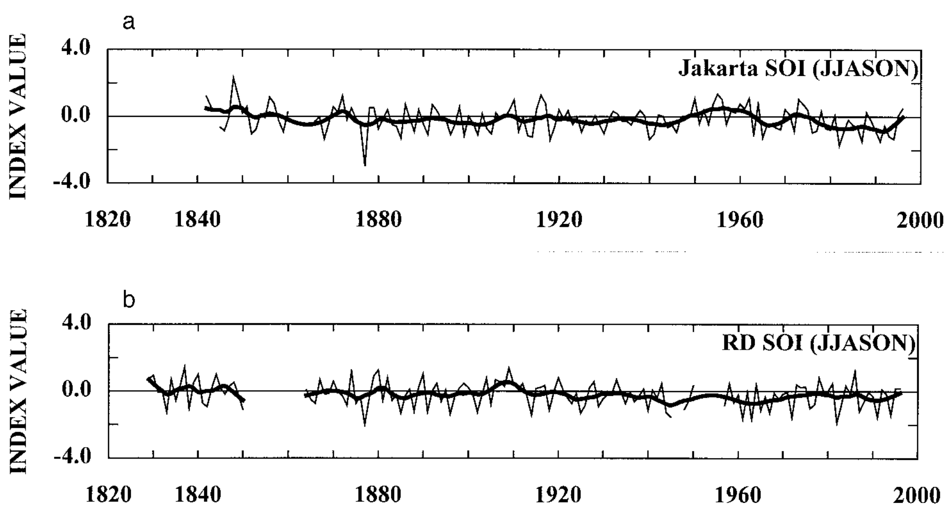


FIG. 5. (a) Time series of the Jakarta SOI 1841–1996 for the dry season (Jun–Nov). (b) Jakarta SOI 1829–1996 as inferred from the number of raindays (RD) in the dry season. The thick lines represent a 10-yr smoother (Cleveland 1979).

exercise to compare the 1841–75 SOIs produced here with previously produced proxy (mainly tree-ring based) reconstructions.

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## APPENDIX

## Known Data Sources

### *a. Batavia/Jakarta Observatory, raindays and pressure, 1864–1997*

Hourly recording of meteorological elements at the Batavia/Jakarta Observatory (BJO) began in 1866, although rainfall had been recorded since 1864. In the period 1864–75 no observations were made on Sundays, apart from daily precipitation amounts. Hourly recordings were stopped on 18 November 1945 because of political instability. The Observations Made at Secondary Stations of Indonesia (OSSI) yearbooks indicate that during 1946 no pressure observations were taken at any place in Indonesia. Semarang resumed in January 1947, and Jakarta Kemayoran (this is the former Jakarta airport, located 6 km north of BJO) resumed in February 1947. BJO resumed rainfall recording on 1 January 1948, and pressure and other elements followed on 1 May 1948. In Table 1 the BJO pressures from February 1947 until April 1948 were taken from Kemayoran, after a subtraction of 0.2 mb to account for a bias in the Kemayoran readings with respect to BJO, which is apparent from the June–December 1948 period. The Jakarta pressure of January 1947 has been estimated from Semarang. The remaining missing months (December 1946–December 1947) have been estimated from Darwin, using regression that maintains the variance of the estimated data. This procedure (MOVE 3) is described in Vogel and Stedinger (1985).

Although the BJO observations continued after 1948, there are no BJO yearbooks published from 1951 until 1958. Pressure data of this period are published in WWR and OSSI, although incomplete. A search in the archives of the Geophysical and Meteorological Agency (BMG) in Jakarta resulted in the recovery of the BJO Monthly Summaries of Daily Values (MSDV) for December 1956 and for April 1957–December 1958; a handwritten list of Climatological Normals (CLINO) 1931–60 with all 1951–58 monthly pressure data, rounded to the first decimal, was also found. The 1951–58 data in Table 1 are based on MSDV where possible, and on the CLINO list for the remaining months.

The regular publication sequence of BJO yearbooks continued until 1980; from 1981 onward the observations were published as MSDV. All yearbooks of the Batavia/Jakarta Observatory from 1864 to 1980 and their MSDV continuation thereafter, as well as the OSSI yearbooks, are available from KNMI. Between 1875 and 1935 a climate summary for the Batavia/Jakarta Observatory was published every 10 years in the BJO yearbooks. Another summary appeared in 1940 (Berlage 1940). Data from the latter source have been used in the present study to correct the Buitenzorg and timeball data for problems with varying daily observation schedules.

### *b. Tahiti and Darwin, pressure, 1876 and 1869–1997, and their extensions back to 1866*

For this study, the basic pressure data for Tahiti and Darwin come from a number of sources [WWR, Ropelewski and Jones (1987), Allan et al. (1991), and the Tahitian Meteorological Service]. These various sources were intercompared and where differences occurred, the most reputable source (generally the original meteorological service value) was accepted.

The Tahiti series starts in 1876 but its first 57 yr are not complete (Ropelewski and Jones 1987). In the data used here these missing data have been estimated by regression with two sites: Suva, Fiji (1877), and Apia, Samoa (1892–1932), again using the MOVE 3 regression procedure in order to maintain the variance of the estimated data (Vogel and Stedinger 1985). The regression relationship is best with Apia, Samoa. Values prior to 1876 have been estimated by MOVE 3 regression with Santiago. The regression estimate with Santiago is worse than those with Suva or Apia [see Jones (1989) and Ropelewski and Jones (1987), for more details]. The infilled data are shown in Table 3.

The Darwin series starts in March 1869 and is complete from 1872 (Allan et al. 1991). The few missing months for 1869–72 and the values for 1866–69 have been estimated by MOVE 3 regression with Batavia/Jakarta. From the augmented Tahiti and Darwin series, the T–D SOI is calculated on a monthly basis from 1866 onward.

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