Interannual Variations of Mean Monthly Sea-Level Pressure in January

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ABSTRACT

The standard deviations of mean sea-level pressure in January are compared for five discrete 16-year periods between 1901 and 1980. The changes from one period to another are large and larger in the North Atlantic than in the North Pacific Ocean. The differences between the periods are associated with variations in the position and central pressure of the Aleutian and Icelandic lows. There is no consistent link between the two lows as their central pressure varied in parallel till the late 1930s and oppositely thereafter.

1. Introduction

Maps of the standard deviations of monthly or seasonal mean pressures at sea level are available in the following publications: 1) Schumann and van Rooy (1951), Northern Hemisphere, 39 years; 2) Blackmon *et al.,* (1979), Northern Hemisphere, 11 years; 3) Trenberth and Paolino (1981), Northern Hemisphere, 53 years; 4) Godbole and Shukla (1981), Northern and Southern Hemisphere, 16 years.

It is immediately evident from a comparison of these publications that the standard deviation (SD) of sea-level pressure (SLP) is far from stationary, and that it is affected both by the length and the time of the period which is used. We shall give a description below of how the SD varied in one winter month, January, during 1901–1980, link the variations to the position and intensity of the Icelandic and Aleutian Lows and provide a brief comparison with the Southern Hemisphere.

2. The data

The data are SLP at grid points in the historical data set described by Jenne (1975). The set has flaws, many of which have been pointed out by Williams and van Loon (1976) and Trenberth and Paolino (1980), and there is no doubt that the SDs below may be affected by these flaws in some places and periods, although it is impossible to say, with accuracy, how big the effect is. An inspection of the daily synoptic maps indicates that the number of ships in the North Atlantic Ocean was always sufficient to ensure a reliable analysis of monthly means, in conjunction with island and coastal stations. The number of ships crossing the North Pacific Ocean in the early years of the century was low in comparison. A serious defect in that sector was, however, the lack of observations in Alaska and on the Aleutians.

We computed the SDs for the 80 years as a whole and for five discrete 16-year periods, 16 years being an arbitrarily chosen interval. The five periods are: (1) 1901–1916; (2) 1917–1932; (3) 1933–1948; (4) 1949–1964; and (5) 1965–1980, and the standard deviation is

$$\sigma = \left[\frac{\sum_{1}^{n} (x - \bar{x})^2}{n - 1} \right]^{1/2} .$$

3. Change in interannual variability

The general distribution of the 80-year standard deviations, Fig. 1, is well known with maxima near the Aleutian and Icelandic Lows and in the Asian Arctic. We examine the interannual variability along two meridians; the one, 35°W, runs through the largest SDs in the Atlantic Ocean, and the other, 165°W, does likewise in the Pacific Ocean. The Atlantic profiles in Fig. 2 show that the difference between the five periods is less than one millibar near 20°N but that at 35°N the 16-year SDs already have a range of 3 mb, which they retain as far as the polar circle for periods 2–5. The profiles do not necessarily run through the region of largest SD in each period. For this reason, the grid point with the largest standard deviation is shown on the illustration for each period.

Period 1 is quite different from the other four as the SD is not only well below the mean at all latitudes, but it decreases toward the north from 50°N. One's first reaction is not to believe the standard deviations from this period, but as mentioned above, there were abundant ships' observations and stations in Iceland

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and on Greenland during the whole time. Thus it is worth examining what distinguishes this period from the others.

A map of the standard deviations over the North Atlantic–European sector is shown in Fig. 3 for 1901–16. The isopleths are drawn through grid points of SD based on the historical SLP analysis; some SDs at stations for the same period are also shown on the map. In the long-term mean (Fig. 1), the maximum of 10 mb lies near Greenland's east coast; on the coast itself, Angmagssalik at 65.6°N, 37.6°W has a long-term standard deviation of 9.8 mb. In 1901–16, the maximum of ~8 mb was near the west coast of Ireland (Fig. 3), and the station value at Angmagssalik was only 4.7 mg. The highest values in 1901–1916 were about the same as the long-term values in the same place (cf. Figs. 1 and 3), so the difference of Fig. 3 from the long-term SD was principally in the region from Labrador across Greenland and the Norwegian Sea to Spitsbergen; i.e., the interannual variability in January was low in the domain of the Icelandic Low and its extension northeastward. Farther south, in the latitudes of the Subtropical High, the standard deviations in Fig. 3 were also lower than the 80-year values.

Not unexpectedly, therefore, since changes in advection cause changes in temperature (van Loon and Rogers, 1978), the interannual variability of the temperature in January was also low in this period. The low variability of temperature is demonstrated in Fig.

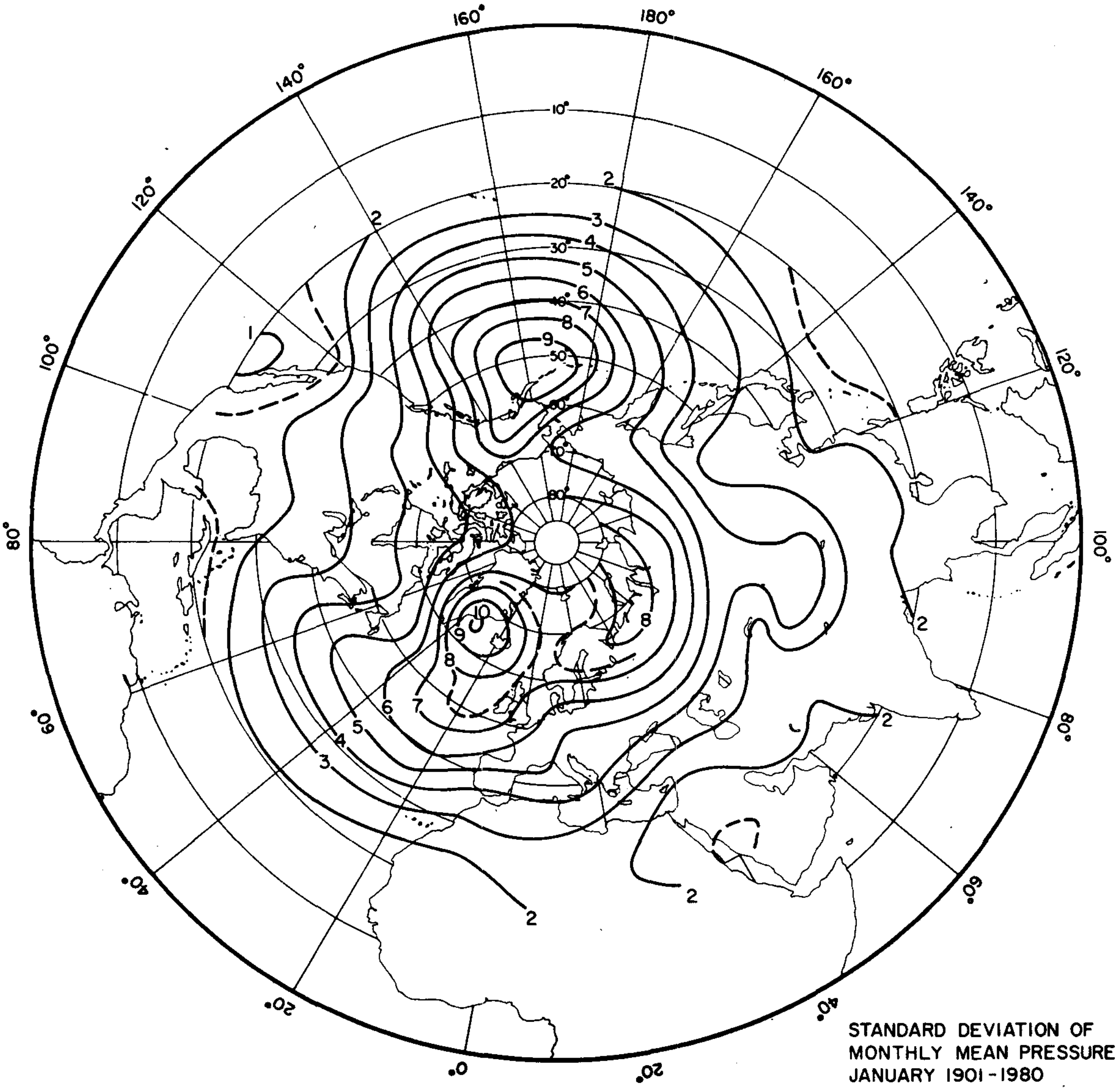

FIG. 1. The standard deviation of monthly sea level pressure (mb) for January 1901–1980.

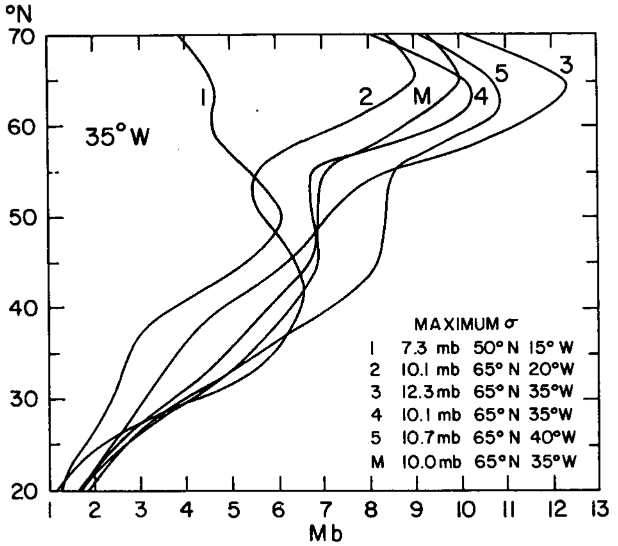

FIG. 2. Profiles of the standard deviations of monthly mean sea-level pressure in January along 35°W for 16-year periods: 1) 1901–16; 2) 1917–32; 3) 1933–48; 4) 1949–64; 5) 1965–80; (M) 1901–80. The position of the grid point with the largest standard deviation in the North Atlantic Ocean is given in the table to the nearest degree latitude and longitude for each period.

4 where the SD of temperature in 1901–1916 is compared with that for the period 1901–1980.

The changes in SD from one period to another are related to changes in the position and intensity of the Icelandic Low. In Fig. 5 we have plotted the mean latitude and longitude of this low in each January from 1901 to 1980 based on pressures in a grid of 5° latitude by 5° longitude. Because the grid pattern changed during the period and the 5° × 5° values were frequently obtained by interpolation within a coarser grid, the position and central pressures below are necessarily approximations.

The lowest pressure at a grid point in each January is at the bottom of Fig. 5. If the mean low had more than one minimum in a given January, the one with the lowest pressure was chosen to represent the center of the low. It is evident from Fig. 5 that the approximate positions and central pressures were comparatively stable during the first three decades of the century and that during the 1930s the variability increased and has since been high, particularly during the years 1935–1965.

There are other noteworthy features in Fig. 5. First, the latitude and longitude of the Icelandic Low tend

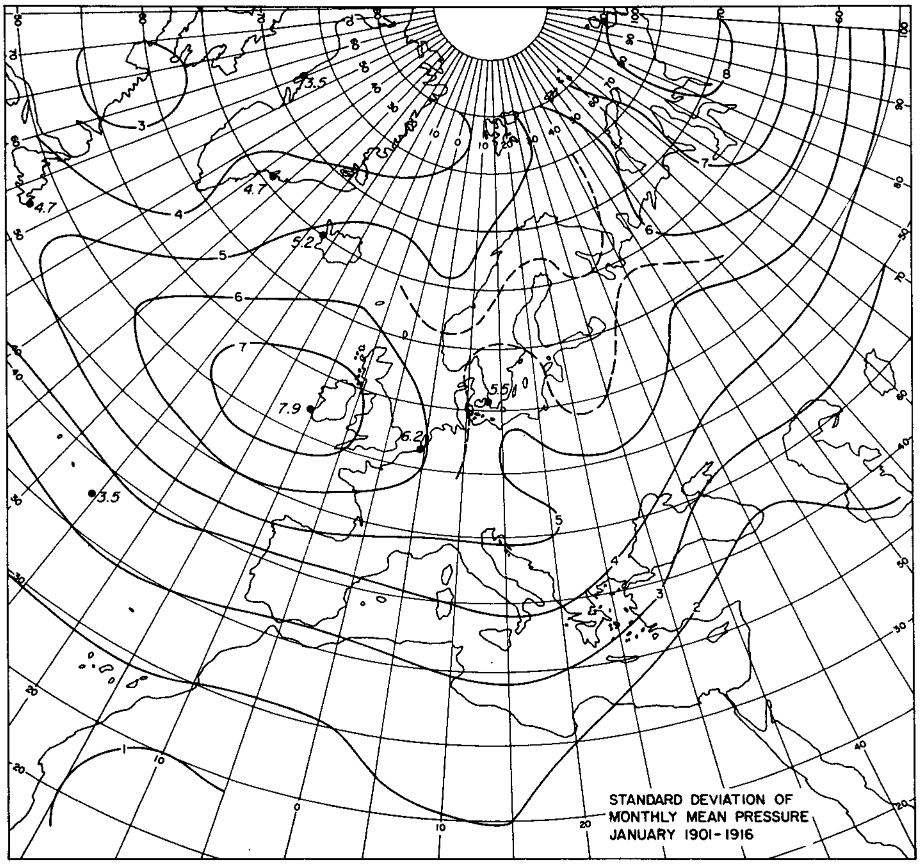

FIG. 3. The standard deviation of monthly mean pressure in January 1901–1916. The numbers are station values of the standard deviation for the same period.

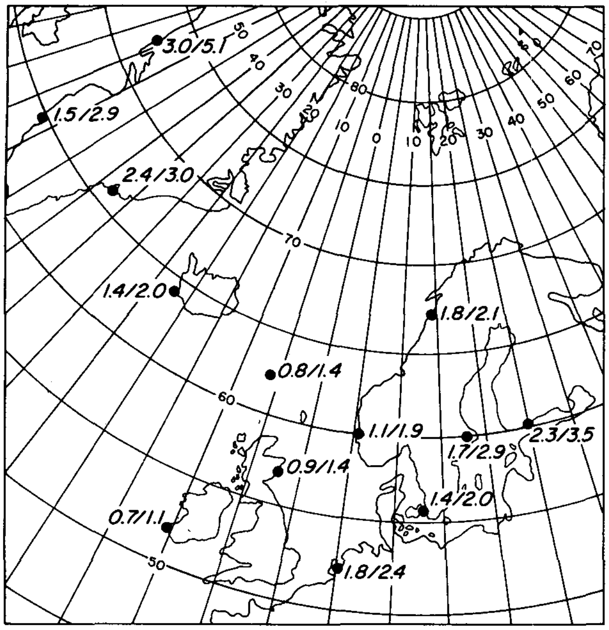

FIG. 4. The standard deviation of monthly mean temperature at stations in January 1901–1916 over that of January 1901–1980.

to vary in opposition on short time scales in the sense that when the mean low moves north it also usually moves east, and when it moves south it also moves west. There was evidently an overall drift toward the east from the 1930s into the 1960s and, at the same time, a rising trend in the central pressure of the low. Both followed opposite tendencies during the earlier decades. Finally, the large range of the central pressure >30 mb should be noted.

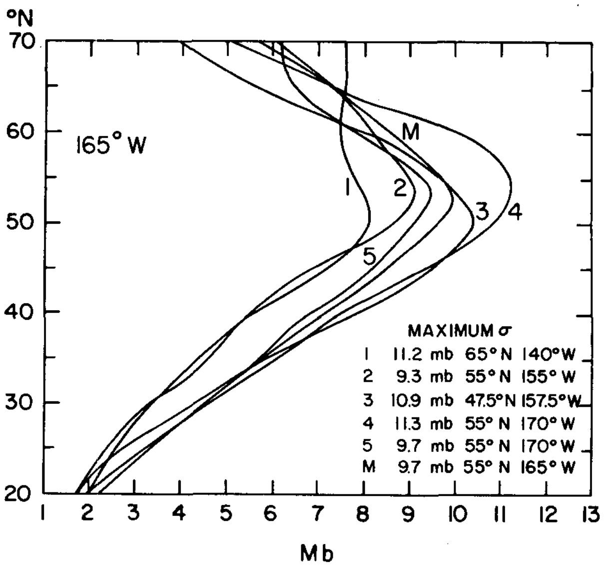

FIG. 6. As in Fig. 2, but for 165°W.

As mentioned in Section 2, because of the few stations in Alaska, there is less certainty during the first part of the century about the area dominated by the Aleutian Low but the following points may be made with some confidence for the period as a whole. Fig. 6 indicates that the change in SD from one 16-year period to another is not so large as that in the North Atlantic. At 35°N, e.g., the range of SD is 3 mb in the Atlantic and less than 2 mb in the Pacific. At 65°N, it is 8 mb in the Atlantic but only 2 mb in the Pacific. The sizes of the SDs in the two oceans are comparable so that at a specified latitude, the range

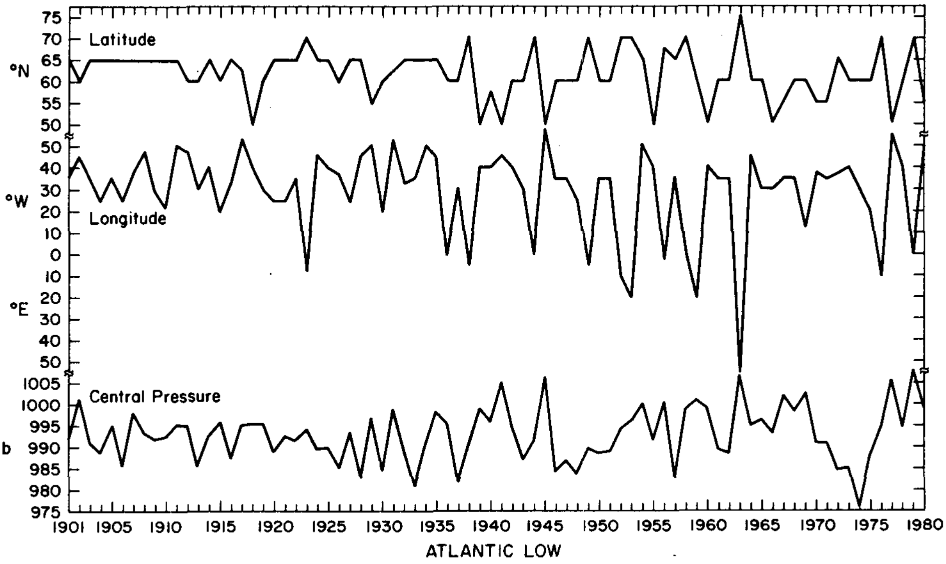

FIG. 5. Time series of (top) the latitude and longitude of the center of the Icelandic Low in January; and (bottom) the central pressure in the low.

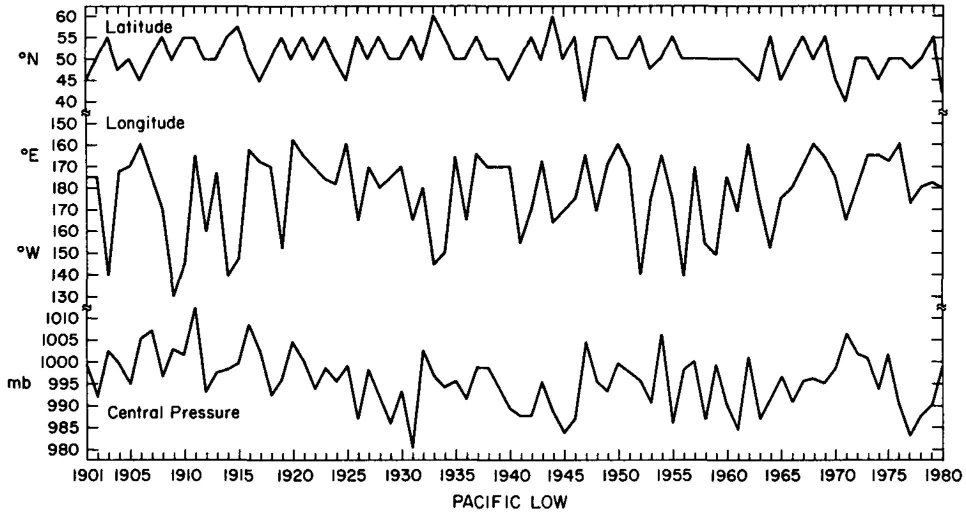

FIG. 7. As in Fig. 5, but for the Aleutian low.

of the 16-year SD as a percentage of the mean SD for the 80 years is smaller in the Pacific Ocean.

One reason for the smaller inter-period variation of SD in the Pacific is apparent in Fig. 7. The latitude of the center of the Aleutian Low has a smaller range than that of the Atlantic Low, and the longitude of the center was more variable than that of the Atlantic center in the beginning of the period than later. As in the Icelandic Low, the central pressure in the Aleutian Low decreased during the second and third decades of the century.

A plot of three-year running means of the central pressure in the two lows, Fig. 8, reveals some interesting features. For instance, it is clear that the tendency for the pressure in the Aleutian and Icelandic Lows to vary in opposition, which was noted by van Loon and Rogers (1978), became more pronounced after 1938. Before that time, the pressures ran parallel most of the time. This observation fits the fact (van Loon and Madden, 1981) that the SLP north of 50°N in the Atlantic Ocean after World War II was positively correlated with the Southern Oscillation but that before the war the sign of the correlation in the North Atlantic was usually the same as that in the Pacific, which was always negative.

This lack of a consistent relationship between the Aleutian and Icelandic Lows may indicate that there is no important constant physical link between the two, and the changing relationship may simply reflect statistical sampling variations between often related variability. The oscillations which dominate the North Pacific Ocean, i.e., the Southern and North

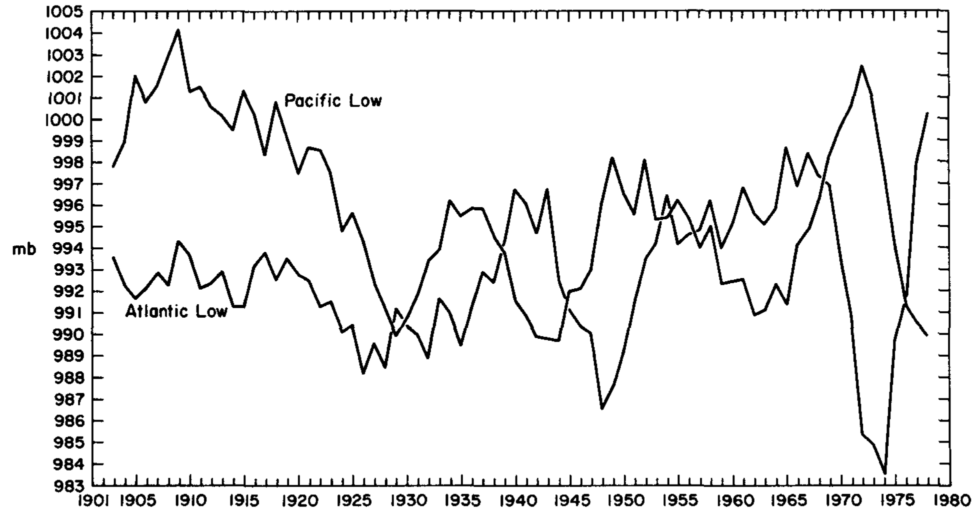

FIG. 8. Three-year running means of the central pressure in the Aleutian and Icelandic Lows in January plotted against the middle year.

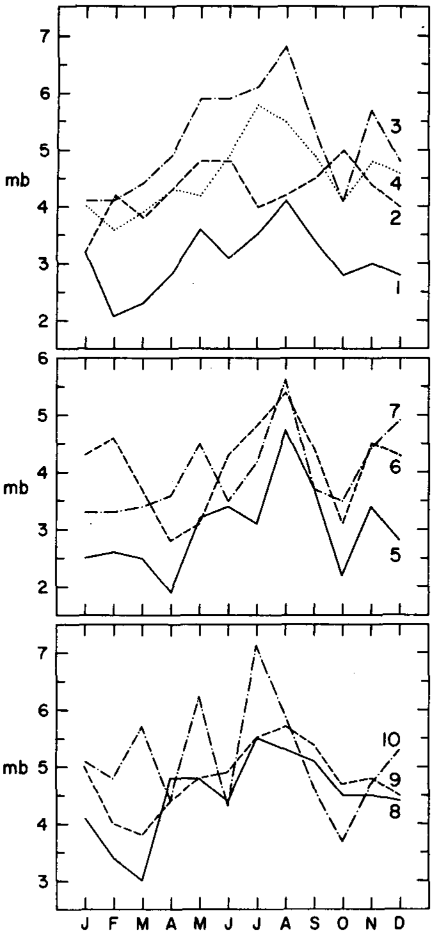

FIG. 9. Annual course of the standard deviations of monthly mean pressures at stations in the Southern Hemisphere whose position and length of record are given in Table 1.

Pacific Oscillations, may thus sometimes be in-phase with the North Atlantic Oscillation and sometimes out-of-phase with it (van Loon and Madden, 1981).

4. The Southern Hemisphere

Fewer than 15 years of daily analyses of SLP over the Southern Hemisphere are available from a period with an adequate coverage of Antarctica, and over the vast southern oceans there are too few stations to allow a complete analysis of SD from station values alone. Thus Fig. 9 is only shown to give the reader an idea of the meridional distribution of SD along a section in each southern ocean. The names and positions of the stations in the figure are in Table 1 together with the number of years used to compute the SD.

TABLE 1. Positions of the stations in Fig. 9; the number of years for which standard deviations could be computed; and the standard deviations of mean annual sea level pressure.

Station	Position	n	σ_{year}
1. Gough Island	40°S, 10°W	24–26	0.9
2. So. Georgia	54°S, 37°W	64–66	1.4
3. Argentine Island	65°S, 64°W	34	1.2
4. Halley Bay	76°S, 27°W	24–25	1.5
5. N. Amsterdam Island	38°S, 78°E	30	1.0
6. Kerguelen Island	49°S, 70°E	29–30	1.3
7. Syowa	69°S, 40°E	15–16	1.5
8. Chatham Island	44°S, 177°W	30	1.6
9. Campbell Island	53°S, 169°E	38–40	1.6
10. d'Urville	67°S, 140°E	19–22	—

The annual curves in Fig. 9 are irregular, but the SDs are generally bigger in winter than in summer. At the four Antarctic stations (3, 4, 7 and 10) the SD in winter ranges from 5.5 to just over 7 mb. The largest SDs are, however, not necessarily on the Antarctic coast. If they bear the same relationship to the center of the Antarctic trough as the SDs do to the central lows of the Northern Hemisphere, the SDs of the Southern Hemisphere are apt to be biggest over the Antarctic Ocean.

As in the Northern Hemisphere, the variation of SD from one period to another is large. For example, at Orcadas which has the longest record at high southern latitudes (61°S, 45°W), the SD in July varied from 2.8 mb in 1917–1932 to 5.7 mb in 1949–1964; and in November from 4.2 mb in 1917–1932 to 7.5 mb in 1949–1964. Similarly large ranges are found at the stations in and around New Zealand.

The results of this limited study suggest that it is wise to consider not only the large interannual variability in both hemispheres when one evaluates the results of special experiments, but also the large changes in this variability from one period to another.

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