An Examination of the Northern Hemisphere Sea-Level Pressure Data Set

JILL WILLIAMS[1] AND HARRY VAN LOON

National Center for Atmospheric Research,[2] Boulder, Colo. 80303

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ABSTRACT

For each grid point (5° latitude by 5° longitude) and each season, the long-term mean sea-level pressure (1899–1972) and its standard deviation were found, using a data set compiled by NCAR. Individual deviations from the mean greater than three standard deviations were compared with nearby station data from *World Weather Records*. Some deviations were found in the sea-level pressure data and not in the station pressure data. Comparison was made between the NCAR sea-level pressure data set and the United Kingdom Meteorological Office data set; large differences are found since 1940 when the data sets started using different sources.

1. Introduction

van Loon and Williams (1976a, b) have studied surface temperature trends and circulation changes for the winter and summer of the Northern Hemisphere for the period 1900–72. The circulation changes were analyzed using sea-level pressure data, available for the period 1899–1972 on a 5° latitude-longitude grid for 20°N–85°N. As van Loon and Williams (1976a) pointed out, the sea-level pressure data are not without flaws. For the winter season (DJF) two examples of problems with the data were given: over the Asian highlands the average pressure rose 10 mb between 1956 and 1957 and in the Indian area there was a drop in the sea-level pressure between 1939 and 1940. For the summer season (JJA) van Loon and Williams (1976b) showed two further examples of problems: an abrupt change in the level of the pressure values at 20°N, 40°E in the early 1940's and a probably fictitious downward trend in Arctic sea-level pressures. The latter, a result of a lack of observations in the earlier part of the century and a tendency of the analysts to draw a semi-permanent high over the Arctic, was described by Rodewald (1950).

Madden (1976) has analyzed daily sea-level pressure values for the period 1899–1972 using the same data set. He found that over all of North Africa and South Asia north of 20°N, which is the southern limit of the data, the values of the sea-level pressure had abnormal variations during the period of World War II in general.

This paper reports on two further examinations of the sea-level pressure data, in order to find data problems. The first part compares large deviations from the long-term mean in the sea-level pressure data with station pressure data, thus defining grid points where large sea-level pressure deviations are not found in nearby station pressure data. The second part looks at the differences between two sets of sea-level pressure data, one compiled by the National Center for Atmospheric Research (NCAR) and the other by the United Kingdom Meteorological Office.

As our work on trends was based on seasonal averages we have examined the sea-level pressure by means of seasonal averages, too. A single monthly value may be quite wrong, but the seasonal mean containing it may nevertheless be acceptable according to our criteria. The reader should be aware of this and of the fact that the paper is therefore not a complete listing of the flaws in the data but only an indicator of limitations to its use.

The NCAR sea-level pressure data set is for the period 1899–1972 for a 5° latitude-longitude grid from 20°–85°N. The sources of the data are described by Jenne (1975). From 1899 to 1939 the data are from the U. S. *Historical Map Series*. Since 1939 several sources have been used.

2. Examination of large deviations from the mean in the sea-level pressure data

Since studies of the pressure data by van Loon and Williams (*op. cit*) have concentrated on seasonal means, the data in this analysis were similarly grouped into four 3-month seasons. Winter consisted of December, January and February, spring of March, April and May and so on.

For each grid point and for each season the long-term mean sea-level pressure (1899–1972) was calculated and the standard deviation from this mean

[1] Present affiliation: International Institute for Applied Systems Analysis, Schloss Laxenburg, Austria.

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TABLE 1. Summary of grid points at which large sea-level pressure deviations ($>3\sigma$) are not found in nearby station pressure data.*

Grid point(s)	Year	Comments
		SUMMER (JUNE, JULY, AUGUST)
20°N, 10°E	1941	ltm=1008.2, p=1012.1. Compared with Aoulef, 27°N, 1°E (no nearer stations for check).
25°N, 45°E	1941	ltm=1000.9, p=1004.9. Compared with Khanaquin, 34°N, 45°E (no nearer stations).
70°N, 70°E	1922	ltm=1010.8, p=1017.5. Compared with Surgut, 61°N, 73°E.
20°N, 145°W 140°W 130°W 125°W	1909	Looked at 25°N, 125°W. ltm=1016.6, p=1019.2. Compared with San Diego, 32°N, 117°W.
25°N, 150°W 145°W 140°W 135°W 130°W 125°W		
30°N, 150°W 145°W 140°W 130°W		
20°N, 140°W 135°W 125°W 120°W	1946	Looked at 25°N, 125°W. ltm=1016.6, p=1019.5. Compared with San Diego, 32°N, 117°W.
25°N, 130°W 125°W 120°W		
20°N, 120°W 115°W	1913	Looked at 25°N, 125°W. ltm=1016.6, p=1019.1. Compared with San Diego.
25°N, 125°W 120°W		
60°N, 110°E 115°E	1922	Looked at 65°N, 115°E. ltm=1008.6, p=1016.8. Compared with Yakutsk, 62°N, 129°E.
65°N, 115°E 120°E 125°E 130°E 135°E 140°E		
		SUMMER (JUNE, JULY, AUGUST)
70°N, 80°E 85°E 90°E 95°E 100°E 105°E 110°E 115°E 120°E 125°E 130°E 135°E 140°E 145°E 150°E	1920	Looked at 70°N, 120°E. ltm=1009.9, p=1020.3. Compared with Yakutsk, 62°N, 129°E.
35°N, 50°E 55°E	1944	Looked at 35°N, 50°E. ltm=1004.1, p=997.1. Compared with Krasnovodosk, 40°N, 53°E.
35°N, 60°E 65°E		Looked at 40°N, 65°E. ltm=1005.4, p=1001.2. Compared with Krasnovodosk, 40°N, 53°E.
40°N, 65°E 70°E		
		AUTUMN (SEPTEMBER, OCTOBER, NOVEMBER)
30°N, 65°E	1951	ltm=1010.7, p=1003.7. Compared with Quetta, 30°N, 67°E.
35°N, 65°E	1939	Jump in data, not seen in Quetta data. ltm=1010.7, p=1005.2.
60°N, 75°E 100°E	1921	Looked at 65°N, 90°E. ltm=1014.7, p=1026.5. Compared with Turuhansk, 66°N, 88°E.
65°N, 70°E 115°E		
70°N, 60°E 125°E		
		SPRING (MARCH, APRIL, MAY)
20°N, 105°E	1939	ltm=1009.5, p=1005.9. Compared with Fort Bayard, 21°N, 110°E.
		WINTER (DECEMBER, JANUARY, FEBRUARY)
55°N, 115°W 90°W	1906	Looked at 65°N, 140°W. ltm=1017.8, p=1035.0. Compared with Dawson, 64°N, 139°W.
60°N, 145°W 95°W		
65°N, 150°W 100°W		
70°N, 170°W 105°W		

* ltm=long term mean sea-level pressure (1899–1972); p=sea-level pressure at grid point for season and year in question.

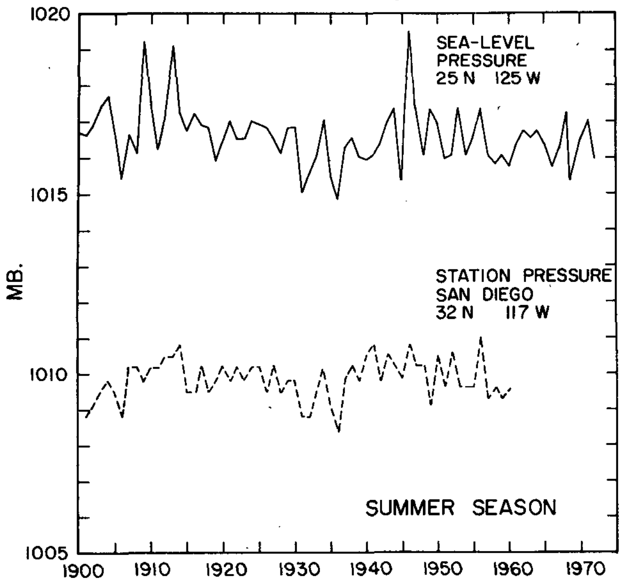

FIG. 1. Time series of sea-level pressure at 25°N, 125°W and station pressure at San Diego (32°N, 117°W) for summer.

was found. Seasonal values of sea-level pressure for each year were examined to find out if they deviated by more than three standard deviations from the mean. As far as possible, the years with large deviations ($>3\sigma$) have been compared with station pressure data from *World Weather Records*. Although not all large deviations are necessarily errors, and some values $\leqslant 3\sigma$ are of course erroneous, the screening should isolate large errors which have been introduced as the sea-level pressure maps were analyzed or as the data were compiled into a data bank for the computer. Where the large deviation occurs in both the sea-level pressure and station pressure, there is still the possibility of observer or instrumental error, but this has not been further investigated. In some cases no station is located near the grid point at which the large deviation occurs, so the value cannot properly be checked.

In Table 1 we list for each season the grid points where and years when deviations from the long-term mean greater than three standard deviations occur, and where nearby station pressure data showed no evidence of the large deviation. In some cases it was not entirely clear whether the deviations were evident in the station pressure data and for these we have conservatively assumed that the sea-level pressure data are correct. When the deviation occurs at a number of grid points over an area, one of the grid points was compared with station data. Since station pressure data are not available in *World Weather Records* after 1960, and since some grid points are not close to available stations with pressure data, Table 1 does not represent all of the large deviations found in the sea-level pressure data set. For instance, for the winter season (DJF), 35 occasions of a deviation $>3\sigma$ were found in the sea-level pressure data set and 11 of these could not be compared with nearby station pressure data. For autumn 9 out of 33 large deviations could not be checked and similar numbers are found for the other two seasons.

The first point to note from examination of Table 1 is that most of the large deviations present in the sea-level pressure but not in the station pressure occur before the 1940's. The summer season (JJA) has more data problems than the other three seasons; although many of the deviations in the summer are only 3–4 mb from the long-term mean the standard deviations are correspondingly small. The largest deviation in the summer season is found at a number of grid points at 70°N, an example of which is 70°N, 120°E in 1920 when the long-term mean of 1009.9 mb was exceeded by more than 10 mb. At a nearby station (Yakutsk, 62°N, 129°E) this large deviation in the pressure is not seen. Such an anomalously high value in the sea-level pressure data will influence trends computed for periods containing the deviation, particularly those starting or ending in 1920.

Figs. 1–5 illustrate some of the data problems listed in Table 1. In Fig. 1 the sea-level pressure at 25°N, 125°W is compared with the station pressure at San Diego (32°N, 117°W) for the summer season. At 25°N, 125°W there are large deviations from the long-term mean pressure value in 1909, 1913 and 1946. Fig. 2 illustrates the sea-level pressure at 35°N, 50°E and station pressure at Krasnovodosk (40°N, 53°E) again from the summer season. Two features are noteworthy in this comparison. First, the sea-level pressure in 1944

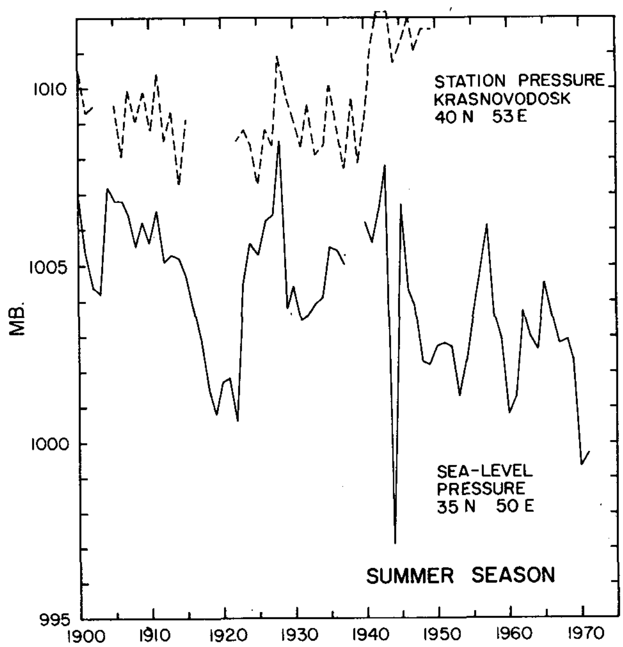

FIG. 2. Time series of sea-level pressure at 35°N, 50°E and station pressure at Krasnovodosk (40°N, 53°E) for summer.

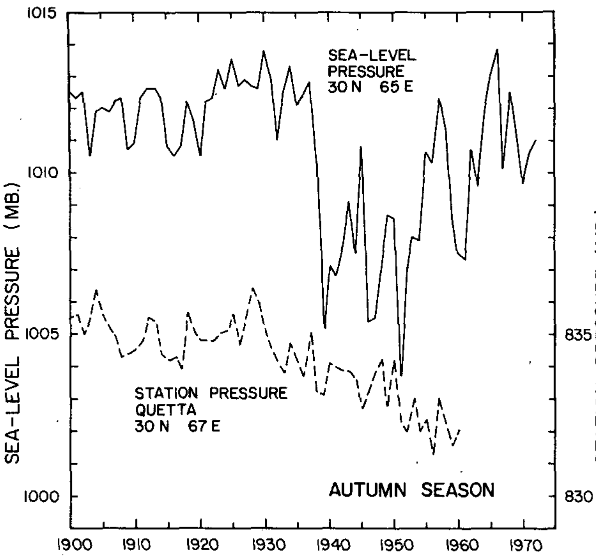

FIG. 3. Time series of sea-level pressure at 30°N, 65°E and station pressure at Quetta (30°N, 67°E) for autumn.

has a value of 997.1 mb, while the preceding year and following year are about 10 mb higher and such a large depression is not evident in the station pressure data. Second, for the years roughly spanning the period of World War I and the Russian Revolution (1915–22) data are not available in *World Weather Records* for stations such as Krasnovodosk. The drop in the sea-level pressure values in this period cannot, therefore, be verified.

In Fig. 3, the sea-level pressure at 30°N, 65°E and the station pressure at Quetta (30°N, 67°E) are compared for the autumn season. Between 1900 and 1940 the maxima and minima in the data sets correspond reasonably well. From 1938–39 there is a large drop in the sea-level pressure and there is a rise

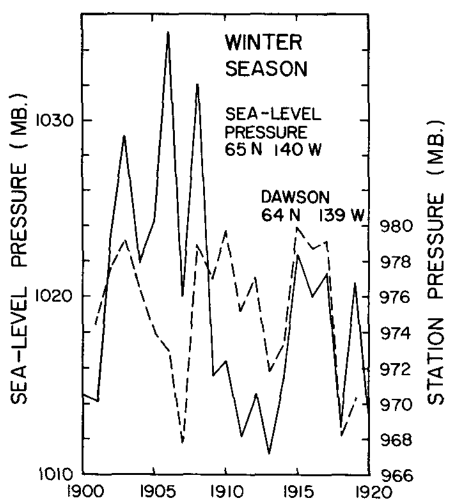

FIG. 4. Time series of sea-level pressure at 65°N, 140°W and station pressure at Dawson (64°N, 139°W) for winter.

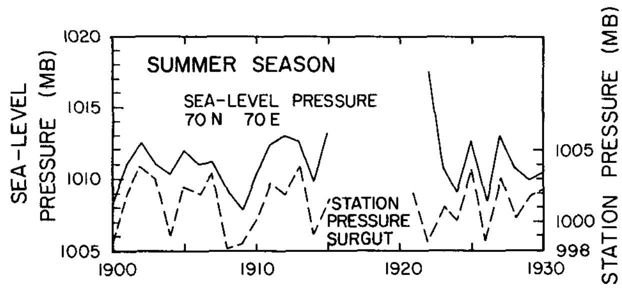

FIG. 5a. Time series of sea-level pressure at 70°N, 70°E and station pressure at Surgut (61°N, 74°E) for summer.

of about the same amount in the early 1950's. These changes are not seen in the station pressure (Quetta) which declines steadily from 1928 to 1960.

The sea-level pressure at 65°N, 140°W is compared with the station pressure at Dawson (64°N, 139°W) for the winter season and the period 1900–20 in Fig. 4. In all years except 1906 the correspondence between the maxima and minima in the two data sets is clear. In 1906, however, there is a peak of 1035 mb in the sea-level pressure data set which is not seen in the station pressure data. The change in general level around 1908 is also suspicious and not confirmed by the station data.

As mentioned above with reference to Fig. 1, considerable amounts of station pressure data are missing in the area and period affected by the Russian Revolution. The sea-level pressure data set also has missing values for the same reason, but sea-level pressure data, which are questionable, are given for some grid points in this area and period. Fig. 1 illustrates one problem in this regard and Fig. 5 gives two further examples. In Fig. 5a, the summer sea-level pressure at 70°N, 70°E and station pressure at Surgut are compared. The fluctuations in the data sets are very similar except in 1922, when the sea-level pressure has a very high value whereas there is a minimum in the station pressure. The sea-level pressure at 65°N, 90°E in the autumn similarly shows an extremely high value in 1921 when records resume, and this maximum is not seen in the station data (Fig. 5b).

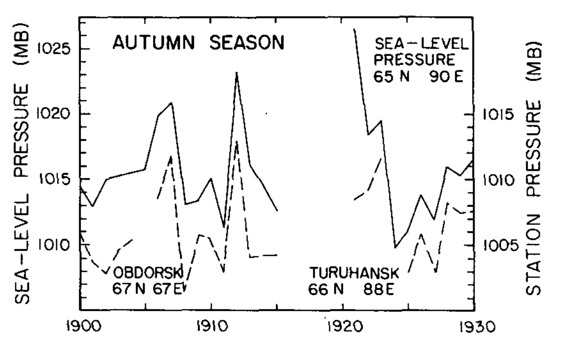

FIG. 5b. Time series of sea-level pressure at 65°N, 90°E and station pressure at Obdorsk (67°N, 67°E) and Turuhansk (66°N, 88°E) for autumn.

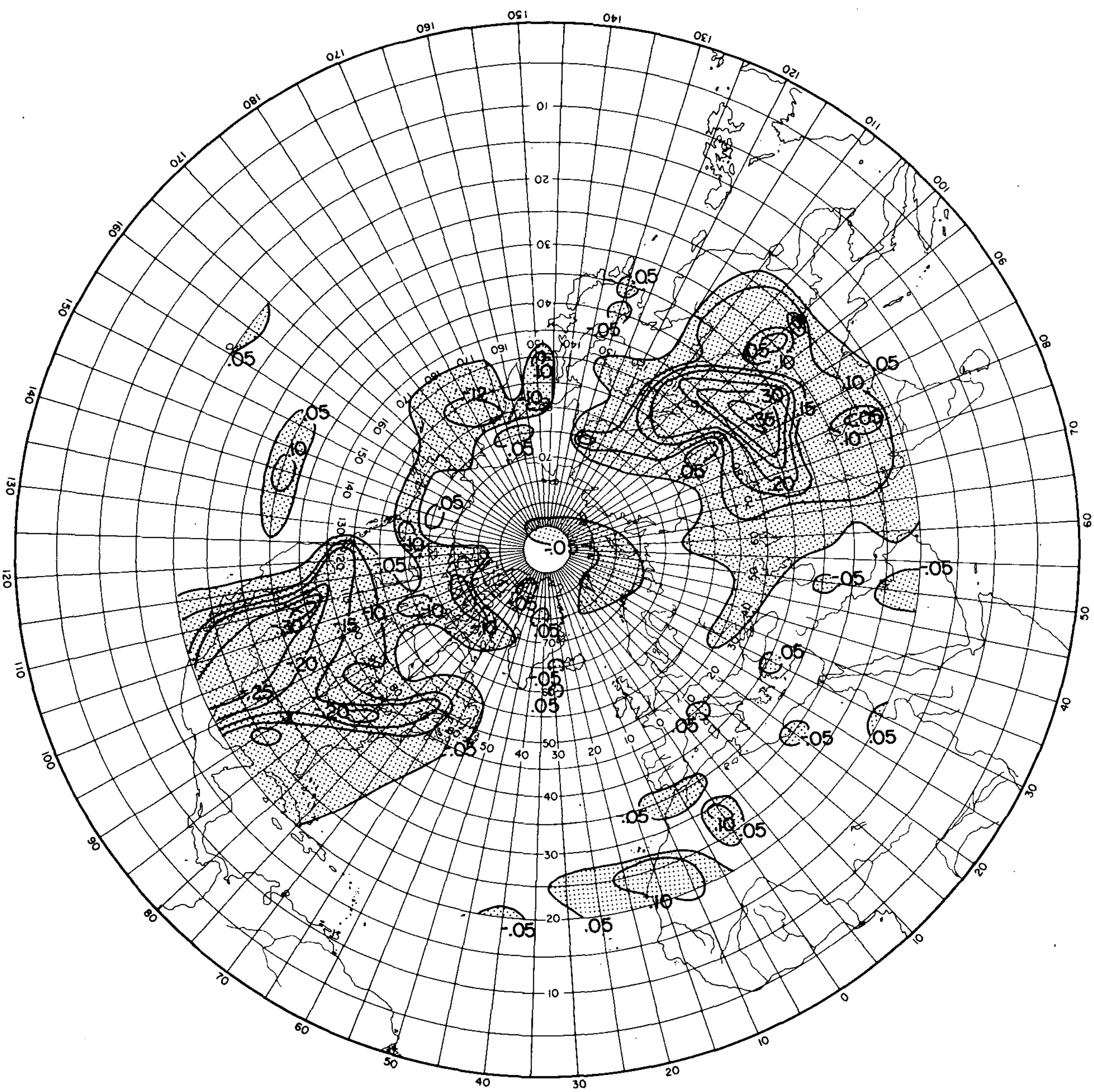

FIG. 6. Difference between slope of regression line of sea-level pressure in Meteorological Office and NCAR data sets. Regression calculated for summer, 1955–69. Only areas where difference is greater than 0.05 mb year^{-1} are plotted.

3. Comparison of two sea-level pressure data sets

In addition to the data set compiled by NCAR (Jenne, 1975) and briefly described above, we have examined the sea-level pressure data set compiled by the UK Meteorological Office (MO).

Both sets use the same source for the period 1899–1939, but after December 1939 the sources differ in the two periods 1940–48 and 1966–72. In the period 1949–65 both are based on the U. S. *Historical Map Series* data, but for the NCAR version the data were digitized at the National Climatic Center under Navy contract and analyzed by the Navy's operational objective analysis program while the MO version was supplied by ESSA (now NOAA).

A comparison of the two data sets has been made in the following way. van Loon and Williams (1976a, b) have computed 15-year and longer term trends in the seasonal means of sea-level pressure data by calculating a linear trend line fitted by least squares through the pressure values. Geographical distributions of the slope of the trend line at each grid point for different time periods have been examined.

With the MO sea-level pressure data we have similarly computed the slope of the regression line

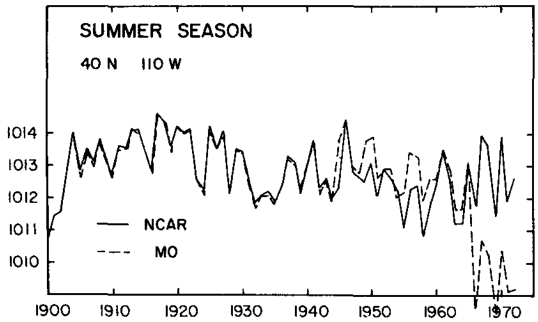

FIG. 7. Time series of sea-level pressure at 40°N, 110°W in the Meteorological Office and NCAR data sets for summer.

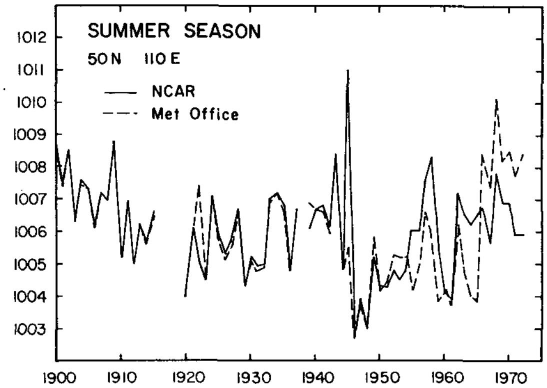

FIG. 8. As in Fig. 7 but for 50°N, 110°E.

for each grid point for different periods. Since both data sets use the same source until 1940, the trends in the data are the same (within the limits of rounding error) for the period between 1899 and 1939. Fig. 6 shows for the period 1955–69, summer season, the distribution of points where the absolute value of the difference between the trend in the MO data and that in the NCAR data is greater than 0.05 mb year^{-1}. It is immediately clear that there are large differences between the two sea-level pressure data sets, with the largest differences occurring over mountain areas. At 40°N, 110°W over the Rocky Mountains the difference in the slope of the regression line between the MO and NCAR data sets is 0.30 mb year^{-1}, a difference of 4.5 mb over the 15-year period. It is notable that the major differences are over mountain areas.

Fig. 7 shows the sea-level pressure values from both data sets for the period 1900–72, at 40°N, 110°W, where the difference in slope is largest in summer (Fig. 6). Between 1900 and 1944 both sets have the same pressure value (apart from very small, insignificant differences because of computing rounding errors). Between 1944 and 1965 the MO values are generally higher than the NCAR values but the differences are only about 1 mb at most and the pattern of year-to-year variations is the same. In 1966 the MO sea-level pressure value drops, and for the period 1966–72 the two data sets again show the same pattern but with the MO pressure values about 3 mb lower than those of the NCAR data set. We should note that the change in the MO data set in 1966 coincides with the change of data source from the U. S. *Historical Map Series* to the Meteorological Office. For the period 1955–69 it is clear in Fig. 7 where the difference in trends in Fig. 6 arises.

Figs. 8 and 9 show the differences in the sea-level pressure values over the Asian highlands in the two data sets. At 50°N, 110°E (Fig. 8) in the summer season the two data sets again show large differences after 1940. The NCAR data set shows a large peak in 1945 which does not occur in the MO data. The MO values again show a change in level after 1965. At 40°N, 90°E (Fig. 9) in summer, the largest difference between the two data sets occurs in 1956, when the NCAR pressure value is 3.5 mb greater than that in the MO data. This difference gives rise to the difference in trends of 0.35 mb year^{-1} for the period 1955–69 as shown in Fig. 6.

Fig. 10 shows the distribution of grid points where the absolute value of the difference between the MO and NCAR trends is greater than 0.05 mb year^{-1} for the winter season and the period 1955–69. While the same tendency for the largest differences between the two sea-level pressure data sets to occur over mountain areas is observed, the distribution is not exactly the same as that in the summer (Fig. 6). In winter the trends differ by 0.20 mb year^{-1} over Greenland; in the summer there is little difference between the trends. In the summer differences are quite large over eastern United States but these differences are not found in winter.

4. Discussion

van Loon and Williams (1976a, b) and Madden (1976) have previously pointed out problems with

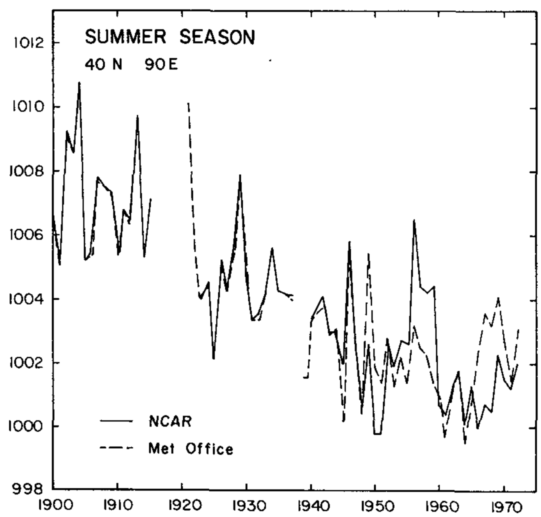

FIG. 9. As in Fig. 7 but for 40°N, 90°E.

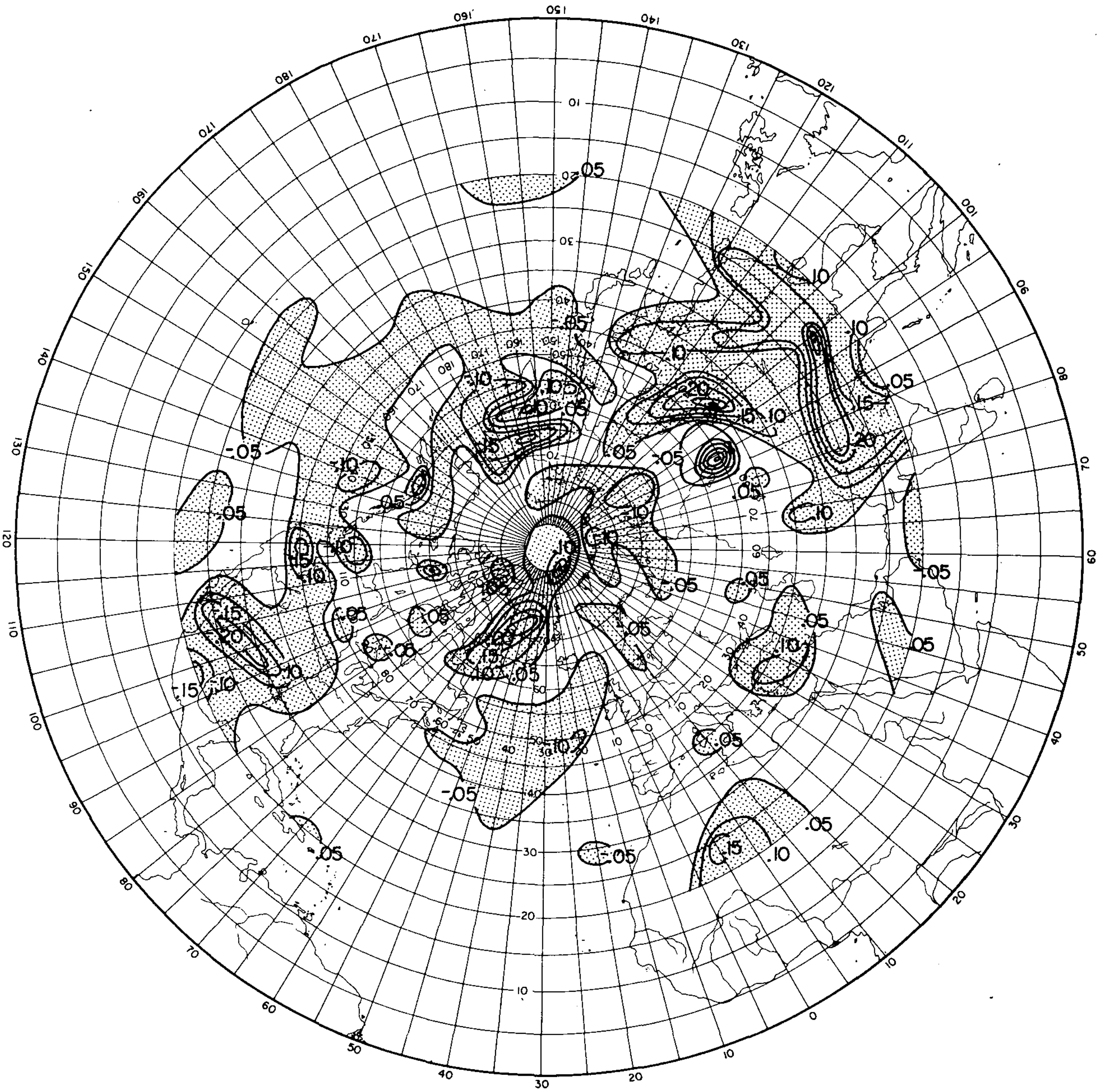

FIG. 10. As in Fig. 6 but for winter, 1955–69.

the sea-level pressure data set, which were briefly described in the Introduction. The present study has used two more approaches to show further problems. An analysis of deviations greater than three standard deviations from the long-term mean at each grid point has shown that in each season some large deviations occur in the sea-level pressure which do not occur in nearby station pressure data. At some grid points large deviations occur for which there are no nearby station pressure data for comparison.

Comparison of the sea-level pressure data set for the Northern Hemisphere compiled by NCAR with that compiled by MO shows that since 1940 the two data sets have used different sources, which have given rise to some quite large differences between the data sets, particularly over mountain areas.

The exact cause for the large differences over mountain areas of two sets of sea-level pressure data is not known, but it is probably related to the differences in the treatment of sea-level pressure in mountain areas between objective and subjective analysis schemes. The comparison of the data sets suggests that we should not take too seriously the values of trends in the sea-level pressure data at grid points at or above 1–1.5 km above sea level. Wahl (1972) in a study of Northern Hemisphere 700 mb data has also noted the sensitivity of such data to changes in the analysis techniques used to derive the hemispheric grid-point data.

The frequent large discrepancies between station pressure and sea-level pressure changes and the large differences in trends in the sea-level pressure data computed from two data sets are alarming. The preliminary results from this study suggest that a detailed check of the sets and a comparison between them are necessary, so that a more reliable sea-level pressure data set can be made available for the purposes of studying the global atmospheric circulation and recent changes.

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