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SCIENTIFIC PAPERS

No. 31 The three-dimensional analysis of meteorological data

By R. Dixon, B.Sc. and E. A. Spackman, M.Sc.

The advent of modern observational devices such as satellites and long-life free drifting balloons has greatly complicated the process of data analysis by computer. This paper presents a possible method for effecting this data analysis by fitting a high-power polynomial to all the observations from within a large volume of the atmosphere.

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No. 32 The Bushby-Timpson 10-level model on a fine mesh

By G. R. R. Benwell, M.A., A. J. Gadd, Ph.D., J. F. Keers, B.Sc.,
Margaret S. Timpson, B.Sc., and P. W. White, Ph.D.

A full description is given of the 10-level numerical weather prediction model which has been developed by the Meteorological Office during the past few years for use in investigating the dynamics of fronts and in predicting rainfall. The formulation includes representation of the effects of surface friction, topography surface exchanges of sensible and latent heat, sub-grid-scale convection, and lateral diffusion. An example of a recently computed forecast is included.

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SOME ASPECTS OF CIRCULATION CHANGES IN THE NORTHERN HEMISPHERE IN JANUARY IN THE 20th CENTURY

By N. E. DAVIS

Summary. *PSCM* type indices are calculated for January for various longitudes at 50–60°N for each year from 1899 to 1968. The indices show a considerable biennial oscillation but the overall correlation between longitudes 60° apart is small. Long-period changes in the mean values of the indices are related to the intensity of the centres of action in the atmospheric circulation.

Introduction. Murray and Lewis¹ derived four monthly indices (*P*, *S*, *C* and *M*) from the catalogue of daily weather types over the British Isles given by Lamb. Precise definitions are given in the paper, but briefly the *P* index is a measure of the difference in frequency of days of progressive and days of blocked synoptic types — *P* is positive when the bias is towards progressive types. The *S* index measures the difference in frequency of southerly and of northerly days — positive *S*, southerly bias. *M* measures the frequency of days with meridional (i.e. northerly or southerly) synoptic types. The *C* index gives the difference between the frequency of cyclonic and of anti-cyclonic days — *C* is positive when cyclonic days predominate. Recently Lamb² has revised his catalogue and Murray and Benwell³ have brought the *PSCM* indices up to date. Murray and Benwell showed how the indices were related to rainfall and temperature at places in the United Kingdom and how the indices had varied since 1865.

It was considered likely that if such indices were calculated for other longitudes their interrelation and long-term variability would show how global circulation changes affected various parts of the northern hemisphere and hence throw some light on the causes of such changes.

Derivation of data. The surface synoptic maps of the daily historical weather series from 1899 to 1962 were examined and for each day in January for each of the five 10-degree squares latitude 50–60°N and longitudes 50–60°E, 110–120°E, 170–180°E, 120–130°W and 60–70°W, a letter was assigned from the Lamb classification to describe the surface circulation over that particular square. Lamb in his classification of the U.K. (50–60°N, 0–10°W) circulation considered the situation over the whole 24 hours (midnight to midnight) but the historical weather series gave only one chart per day. This had to be taken

as representing the circulation for that day. This slight difference in the method of assigning letters would lead to slightly fewer cases of the non-directional types γ (anticyclonic) and ζ (cyclonic) being recorded at the other longitudes than would have been recorded if the classification procedure of Lamb had been followed strictly. The overall effect on the *PSCM* indices would be mostly in the *M* index which would tend to have higher values. For the period since 1962 for which historical maps have not yet been issued, synoptic maps published by the major meteorological centres in the northern hemisphere have been used.

The *PSCM* indices for each January for each of the 10-degree squares were then calculated according to the method given by Murray and Lewis.¹ Table I gives the overall 70-year mean of the *PSCM* indices for each longitude.

TABLE I—MEAN VALUES OF THE *P*, *S*, *C* AND *M* INDICES FOR JANUARY OVER THE 70 YEARS 1899 TO 1968

Index	0–10°W	50–60°E	110–120°E	170–180°E	120–130°W	60–70°W	Hemisphere
<i>P</i>	+14	+8	+3	–33	–13	+12	–1.5
<i>S</i>	+2	+8	–11	–3	+20	–18	–0.3
<i>C</i>	–4	–3	–18	+18	+3	+1	–0.5
<i>M</i>	+14	+21	+21	+24	+24	+26	+22

General circulation and mean values of the indices. The broad features of the circulation in January can be interpreted in terms of the values of the indices in this table by reference to the mean surface-pressure map for January over the 70 years 1899 to 1968 which is given in Figure 1.

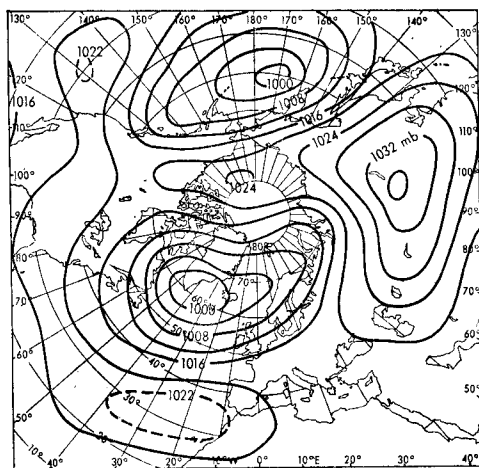


FIGURE 1—JANUARY MEAN SURFACE PRESSURE, 1899–1968

The Siberian anticyclone centred near 50°N, 100°E produces strongly negative values of the *C* index in the square 50–60°N, 110–120°E with weak progression but strong northerly bias leading into the Aleutian low which dominates the entire Pacific. The centre is near 50°N, 170°E, giving an intense cyclonic block in the square 50–60°N, 170–180°E. There is a marked southerly bias over the eastern Pacific and western North America with a mainly south-easterly flow over the square 50–60°N, 120–130°W to the north of the trough which extends eastward from the Aleutian low between latitudes 50° and 55°N. Over Labrador (50–60°N, 60–70°W) a strong northerly

outflow between the Icelandic low and the north-west Canadian surface high gives a minimum *S* value and a maximum *M*. The Icelandic low shows a marked trough extending into the Barents Sea giving maximum progressivity and minimum meridionality over the U.K. This progressivity continues into Russia but shows an increasing southerly component (at 50–60°N, 50–60°E) on the western flank of the Siberian anticyclone.

Table II gives the maximum and minimum values of each index at each longitude and its year of occurrence.

TABLE II—MAXIMUM AND MINIMUM VALUES OF THE INDICES AT EACH LONGITUDE

Index	0–10°W	50–60°E	110–120°E	170–180°E	120–130°W	60–70°W	Hemisphere
<i>P</i> Max.	+62 1921	+54 1934	+49 1962	–2* 1937, 1967	+26 1904	+47 1934	+25 1949
Min.	–52 1941, 1963	–46 1945	–42 1940	–62 1902	–62 1907	–49 1955	–32 1940
<i>S</i> Max.	+26 1924	+38 1915, 1938	+8 1911	+27 1950	+41 1958	+6 1963	+6 1966
Min.	–23 1945	–8 1950, 1964	–32 1933	–32 1931	0 1922	–39 1912	–9 1945
<i>C</i> Max.	+27 1948	+36 1950	+7 1946, 1961	+41 1905	+26 1925	+18 1931	+7 1913
Min.	–30 1953	–39 1945	–37 1944	–3 1956	–19 1950	–19 1956	–12 1954
<i>M</i> Max.	+40 1967	+38 1915, 1938	+36 1942	+39 1950	+41 1958	+41 1961	+29 1967
Min.	0 1921	+5 1945	+9 1913	+12 1916, 1943 * +11, 1969	+7 1917, 1937	+13 1962	+16 1902

All longitudes have shown years with both positive and negative values of the *PSC* indices except 120–130°W where the minimum *S* value has been zero. This variability in the values of the indices shows that in some years the normal flow over a particular square is reversed and the major centres of action are absent or far removed from their normal positions. As an example, Figures 2 and 3 give the mean surface-pressure maps for January 1940 and January 1949, the years with minimum and maximum values of *P* on a hemispheric basis, i.e. the years with minimum and maximum mean values of the *P* index averaged over the six longitudes. At 70°N between 10°E and 90°E, the pressure was more than 25 mb lower in 1949 than in 1940 but more than 25 mb higher near 45°N, 150°W. In 1949, the Icelandic low was displaced some 2000 km north-east, the Aleutian low 500 km north-west, and the Siberian high 500 km south, of the normal positions. The Icelandic low was 10 mb deeper and the Aleutian low 5 mb deeper than usual. In 1940, on the other hand, the Icelandic low was 1500 km south-west, the Aleutian low 1000 km south-east and the Siberian high 800 km north, of the normal positions. The Siberian high was 6 mb more intense, the Icelandic low 5 mb less deep and the Aleutian low 10 mb deeper than usual. Between 50°N and 60°N in 1940, an anomalous easterly gradient occurred all round the hemisphere but in 1949 an anomalous westerly gradient occurred between the same latitudes.

Considering Tables I and II together, the minimum mean values of the *P* index and maximum mean value of the *C* index is at 170–180°E. It is also the longitude with the minimum variability of the *P* index (a range of 60 (73 if the 1969 value is included) from –2 to –62 compared with a range of 114 at 0–10°W from +62 to –52) but maximum variability of the *S* index. These facts would point to the Aleutian low being the most constant

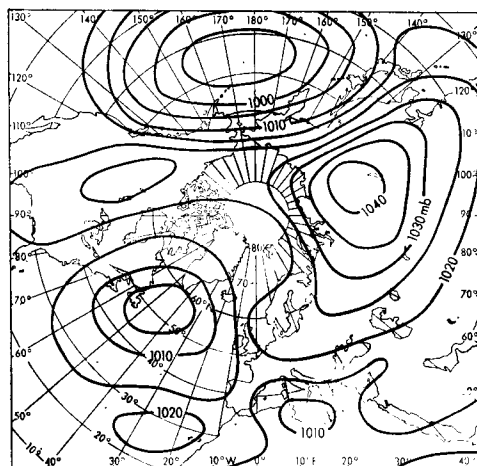


FIGURE 2—MEAN SURFACE PRESSURE, JANUARY 1940

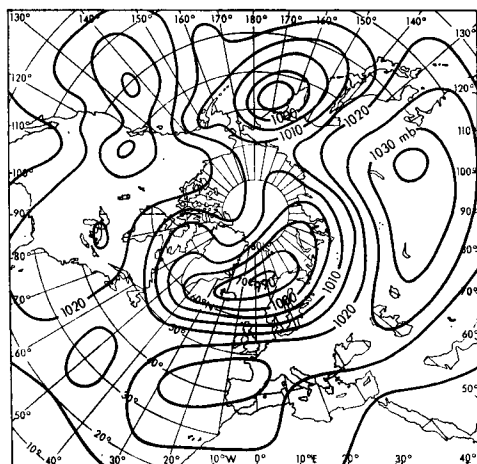


FIGURE 3—MEAN SURFACE PRESSURE, JANUARY 1949

and dominant feature of the January circulation with its major variation being in an east-west direction about its normal position near 50°N , 170°E . On the other hand, the European sectors 0 – 10°W and 50 – 60°E show the greatest variation in both the P and C indices, which indicates that the Icelandic low, especially its extension into the Barents Sea, is the least-constant feature of the January circulation. Figure 4 maps the standard deviation for the 70 Januarys about the 70-year mean. It shows maximum standard deviation near the centre of the Icelandic low with an area of high values extending eastwards well into the Arctic basin. In the Pacific the maximum standard deviation is not over the centre of the Aleutian low but some 20 – 30° to the east.

Correlation between the indices at the various longitudes. Table III gives the correlation coefficients between the indices at the various longitudes. Most of the correlation coefficients are insignificant and the table contains

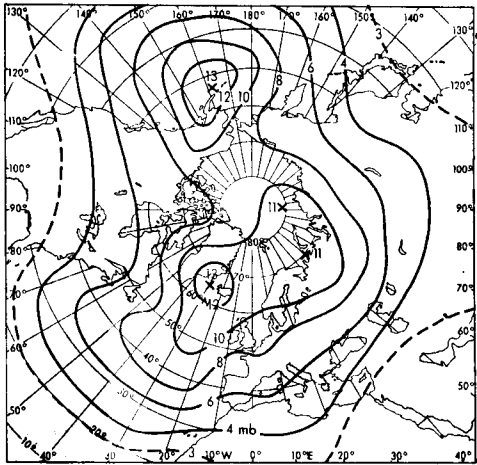


FIGURE 4—STANDARD DEVIATION OF MONTHLY MEAN SURFACE PRESSURE FOR JANUARY, 1899-1968

TABLE III—CORRELATION COEFFICIENTS BETWEEN INDICES AT VARIOUS LONGITUDES

Position	Lag	Position	Correlation coefficient
<i>P</i> index			
0-10°W	0	110-120°E	+0.36
0-10°W	0	60-70°W	+0.49
50-60°E	0	110-120°E	+0.35
110-120°E	0	170-180°E	+0.29
0-10°W	1	110-120°E	-0.23
50-60°E	1	50-60°E	-0.28
50-60°E	1	110-120°E	-0.29
170-180°E	2	170-180°E	+0.33
120-130°W	2	170-180°E	-0.32
120-130°W	2	120-130°W	+0.26
60-70°W	2	50-60°E	+0.31
0-10°W	2	50-60°E	+0.40
<i>S</i> index			
0-10°W	0	50-60°E	-0.32
0-10°W	0	120-130°W	-0.31
50-60°E	0	120-130°W	+0.25
110-120°E	0	60-70°W	-0.28
170-180°E	0	120-130°W	-0.23
60-70°W	1	60-70°W	+0.24
110-120°E	1	60-70°W	-0.29
170-180°E	1	50-60°E	+0.24
50-60°E	2	110-120°E	-0.24
110-120°E	2	170-180°E	+0.24
120-130°W	2	110-120°E	-0.29
<i>C</i> index			
0-10°W	0	50-60°E	-0.28
170-180°E	0	60-70°W	+0.25
110-120°E	1	50-60°E	+0.25
120-130°W	1	120-130°W	+0.32
60-70°W	1	50-60°E	+0.27
60-70°W	1	120-130°W	+0.31
120-130°W	2	120-130°W	+0.25
60-70°W	2	110-120°E	+0.25
60-70°W	2	120-130°W	+0.25
<i>M</i> index			
110-120°E	0	60-70°W	-0.26
60-70°W	1	170-180°E	+0.26

only those with the correlation coefficient ≥ 0.23 . With 70 pairs of values a correlation of about 0.23 is significant at the 5 per cent level and 0.30 at the 1 per cent level. Each part of Table III effectively considers about 90 correlation coefficients so that about 4 to 5 coefficients would by chance exceed 0.23 and about 1 would exceed 0.30. The actual numbers in Table III are two to three times greater — for the *P*, *S* and *C* indices — so that some of these coefficients must be significant. But there are only 2 correlation coefficients ≥ 0.23 for the *M* index, and these are therefore less likely to be significant.

Table III shows that for the *P* index there are correlations between the longitudes associated with the Icelandic low and its extension into the Barents Sea. This is a very variable part of the January circulation, and such correlations must mean that an exceptionally blocked or progressive situation over the U.K. ($0-10^{\circ}\text{W}$), often covers Europe and extends its influence across the Atlantic or into Siberia. There is a negative correlation in the *P* index with one-year lag at $50-60^{\circ}\text{E}$, which implies a biennial oscillation in the Barents Sea low. There are also positive correlations with a two-year lag at $170-180^{\circ}\text{E}$ and at $120-130^{\circ}\text{W}$, but a negative correlation with a two-year lag between $170-180^{\circ}\text{E}$ and $120-130^{\circ}\text{W}$. This implies a biennial oscillation in the Pacific but the oscillations in the eastern and western Pacific are out of phase.

The correlation coefficients for the *S* and *C* indices are more difficult to interpret. The mean of the *S* index at $60-70^{\circ}\text{W}$ over the period 1899–1933 is -21 and the mean over 1934–68 is -15 , which indicates an overall trend, namely a decrease in the northerly flow. Such an overall trend would account for the positive correlation coefficient in the *S* index with one-year lag. Again at $120-130^{\circ}\text{W}$, the mean of the *C* index over the period 1899–1933 is $+7$ and the mean over 1934–68 is -2 which indicates an overall trend, namely a decrease in cyclonicity. Such an overall trend would account for the positive correlation coefficients in the *C* index with one- and two-year lags.

Long-period changes in the values of the indices. Table IV gives the mean values of the *PSCM* indices for each 10-year period from 1899–1908 to 1959–68.

These tables show considerable fluctuations in the indices between one 10-year period and another, indicating preferred periods for certain types of circulation. They also show that on a hemispheric scale the first 30 years were generally progressive ($P \geq 0$) whilst the last 30 were blocked ($P < 0$), but that individual longitudes were at times not in phase. For example, the last 10 years, 1959–68, were the least progressive at $0-10^{\circ}\text{W}$ and $60-70^{\circ}\text{W}$ but at $170-180^{\circ}\text{E}$ they were more progressive than the average for the 70 years. Very broadly, the climatic changes in the indices can, to some extent, be explained by changes in the position of the main polar vortex between the Alaskan and European/Asian sectors of the Arctic causing variations in the strength and latitude of the main jet stream, accompanied by changes in the planetary wavelength in these sectors. The *S* index indicates what some of the wavelength changes may have been. The progressive period (1899–1938) at $0-10^{\circ}\text{W}$ and $60-70^{\circ}\text{W}$ was accompanied by a southerly component at $0-10^{\circ}\text{W}$ and a northerly at $60-70^{\circ}\text{W}$, which indicates a trough in the Atlantic; but in the blocked period 1939–68, there was a northerly component at $0-10^{\circ}\text{W}$ and the

TABLE IV—MEAN VALUES OF THE INDICES FOR SPECIFIED PERIODS FOR VARIOUS LONGITUDES AND THE HEMISPHERE AS A WHOLE

	Period	0-10°W	50-60°E	110-120°E	170-180°E	120-130°W	60-70°W	Hemisphere
<i>P</i>	index							
	1899-1908	+21	+18	+11	-37	-15	+18	+3
	1909-18	+14	+22	-3	-30	-16	+14	0
	1919-28	+35	+3	+19	-37	+2	+19	+7
	1929-38	+13	+2	-2	-33	-13	+22	-2
	1939-48	+3	-3	-9	-43	-7	+8	-9
	1949-58	+15	+11	+4	-28	-27	+6	-3
	1959-68	-1	0	+3	-29	-14	-3	-7
	1899-1968	+14	+8	+3	-33	-13	+12	-1
<i>S</i>	index							
	1899-1908	+4	+8	-6	-7	+14	-20	-1
	1909-18	+2	+10	-5	-1	+20	-25	0
	1919-28	+5	+3	-12	-3	+17	-21	-2
	1929-38	+4	+9	-14	-4	+17	-15	-1
	1939-48	+3	+9	-17	-11	+23	-17	-2
	1949-58	-3	+9	-13	+5	+23	-11	+2
	1959-68	-1	+11	-12	+3	+24	-15	+2
	1899-1968	+2	+8	-11	-3	+20	-18	0
<i>C</i>	index							
	1899-1908	-8	+3	-17	+21	+8	+5	+2
	1909-18	-8	+7	-18	+19	+8	+6	+2
	1919-28	+5	-7	-21	+23	+8	+1	+1
	1929-38	-7	-13	-23	+18	0	+4	-4
	1939-48	+1	-7	-18	+17	-1	-2	-2
	1949-58	-7	-3	-18	+12	-7	-6	-5
	1959-68	-5	+1	-12	+17	+2	+1	+1
	1899-1968	-4	-3	-18	+18	+3	+1	-1
<i>M</i>	index							
	1899-1908	13	21	19	21	20	25	20
	1909-18	16	21	16	26	23	30	22
	1919-28	10	21	23	26	23	29	22
	1929-38	15	21	21	25	23	25	22
	1939-48	15	21	24	21	27	24	22
	1949-58	15	18	21	27	26	25	22
	1959-68	16	22	21	23	26	27	23
	1899-1968	14	21	21	24	24	26	22

northerly at 60-70°W was at a minimum, which indicates an eastward movement of both the ridge over North America and the trough in the Atlantic.

Figures 5(a) and (b) give the 10-year running means of the *P* index. Figure 5(a) shows that longitudes 0-10°W, 110-120°E and 120-130°W all had maximum progressivity in the '20s and a minimum around 1940. But, whereas 110-120°E then returned to a near-average value for the 10 years 1959-68, the other two longitudes had lower minima, for 120-130°W in the period 1950-59 and for 0-10°W in the period 1959-68. The other three longitudes, Figure 5(b), show a minimum in the '20s, a maximum in the '30s and a minimum in the '40s. However, 170-180°E has recovered to near average and 60-70°W has fallen to a lower minimum in recent years. The overall conclusions from Figures 5(a) and (b) are that during the early part of the century, alternate longitudes (60° apart) tended to vary out of phase, that all longitudes reached a minimum around 1940 but, whereas the longitudes associated with the Pacific have shown near-average progressivity in recent years, the Atlantic longitudes have shown a further minimum (in recent years), especially at 0-10°W and 60-70°W, where the amount of progressivity (westerliness) has been less than at any time during the century. Figure 6 shows the 10-year (1959-68) mean departure of the surface pressure from the average for the whole period 1899-1968. During these 10 years, pressure averaged 9 mb above average over eastern Greenland and 3 mb below average north-west of the Azores, giving an anomalous easterly gradient across the Atlantic. In central England, with an anomalous east-north-east airflow, only the last two Januarys in the 10-year period showed mean temperatures

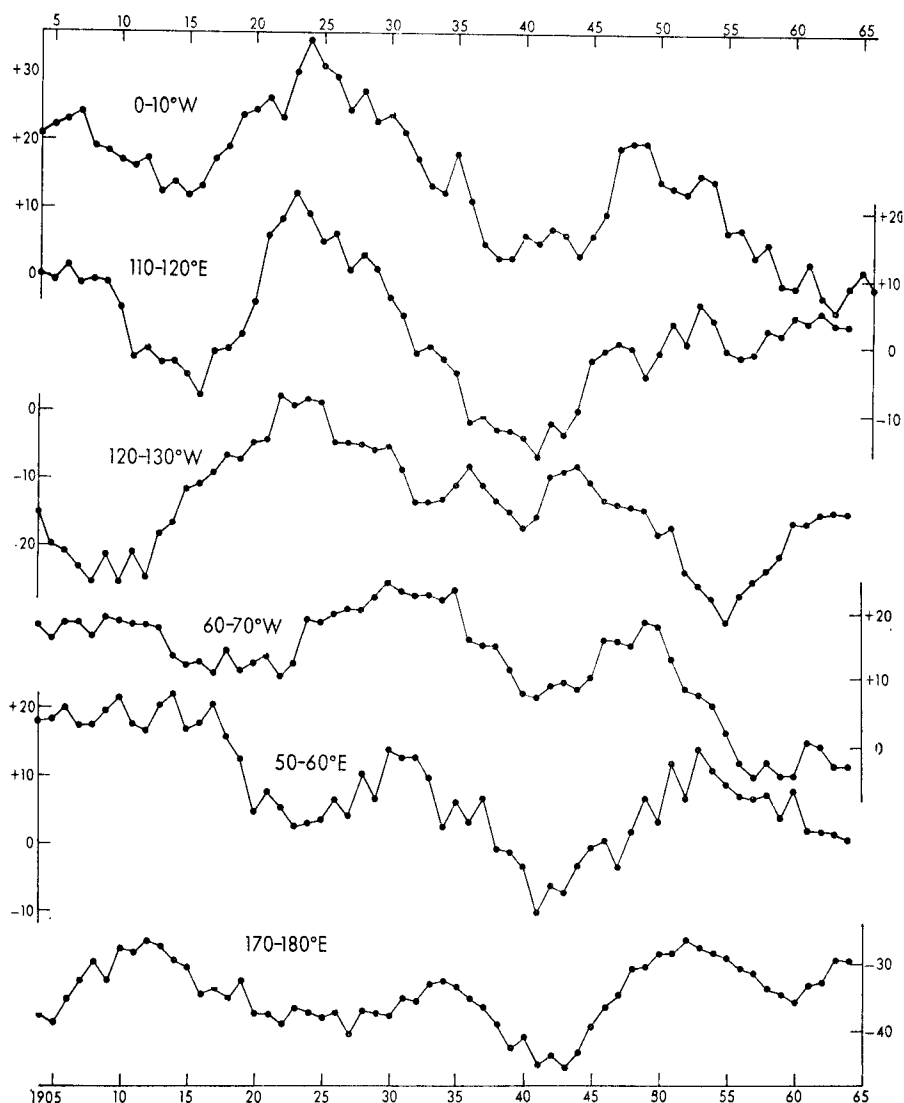


FIGURE 5—10-YEAR RUNNING MEANS OF P INDEX AT $50-60^{\circ}\text{N}$ FOR VARIOUS LONGITUDES, JANUARY 1899-1968

Means are centred on the middle of the 10-year period.

(a) $0-10^{\circ}\text{W}$, $110-120^{\circ}\text{E}$, $120-130^{\circ}\text{W}$

(b) $60-70^{\circ}\text{W}$, $50-60^{\circ}\text{E}$, $170-180^{\circ}\text{E}$

above average whilst in Newfoundland, with an anomalous easterly gradient from the Atlantic, only January 1964 showed below-average temperature. At the same time, pressure was below average over Kamchatka and above average near the centre of the Siberian anticyclone, giving increased progressivity at $110-120^{\circ}\text{E}$ and $170-180^{\circ}\text{E}$. By contrast, Figure 7 shows the 10-year mean departure of the surface pressure from the average for the whole period for the 10 years 1919-28 when progressivity was at a maximum at $0-10^{\circ}\text{W}$.

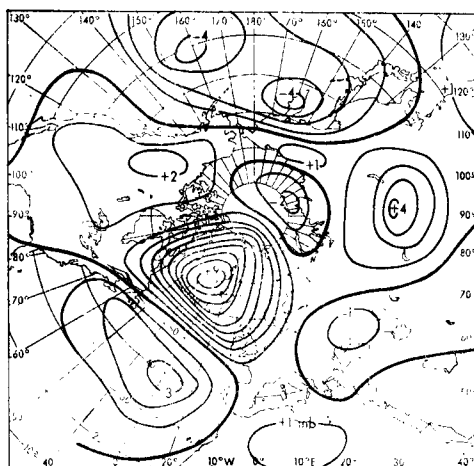


FIGURE 6—MEAN PRESSURE FOR JANUARY 1959-68 MINUS MEAN PRESSURE FOR JANUARY 1899-1968

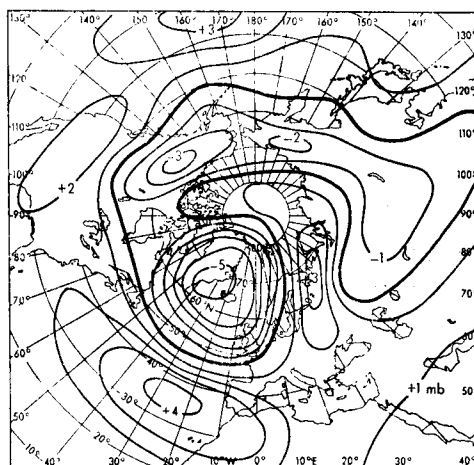


FIGURE 7—MEAN PRESSURE FOR JANUARY 1919-28 MINUS MEAN PRESSURE FOR JANUARY 1899-1968

During these 10 years pressure was 5 mb lower than average over the Denmark Strait and 4 mb above average near the Azores, giving an anomalous westerly gradient across the Atlantic into the U.K. In central England, only 1919 showed mean temperatures below average.

Figure 8 gives the 10-year running means of the S index. A minimum is shown for 60–70°W in the period 1911–20, for 120–130°W in 1921–30, for 50–60°E in 1923–32, for 110–120°E in 1936–45, for 170–180°E in 1938–47 and for 0–10°W in 1951–60. In this last period all other longitudes except 110–120°E show a maximum of the S index. Figure 9 shows the 10-year (1952–61) mean departure of the surface pressure from the average for the whole period 1899–1968. Pressure was 5 mb above the long-period average over Greenland and 3 mb below near the Gulf of Bothnia and near 40°N, 60°W.

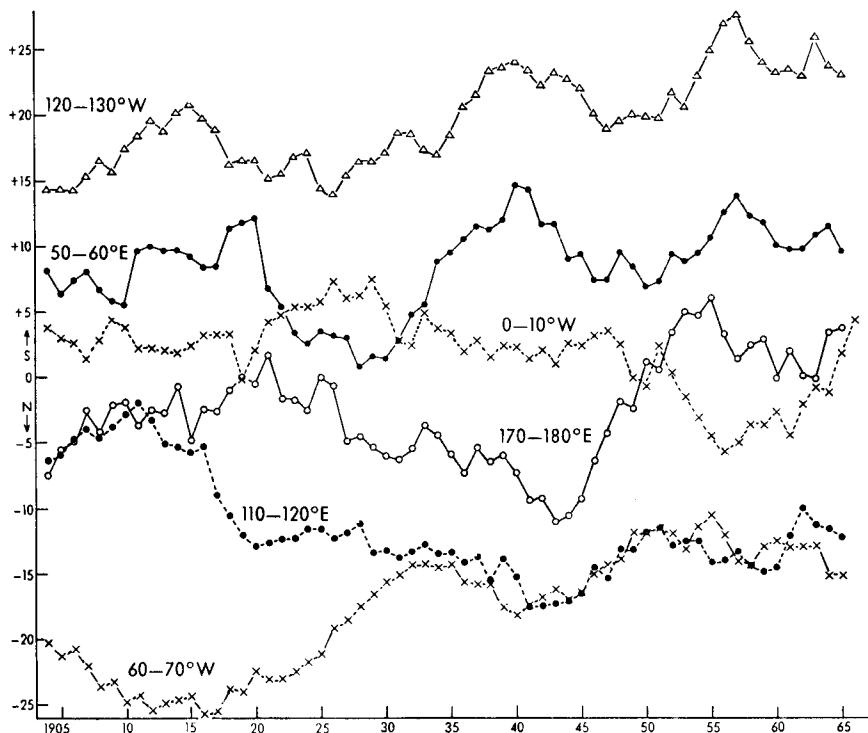


FIGURE 8—10-YEAR RUNNING MEANS OF S INDEX AT 50–60°N FOR VARIOUS LONGITUDES, JANUARY 1899–1968

Means are centred on the middle of the 10-year period.

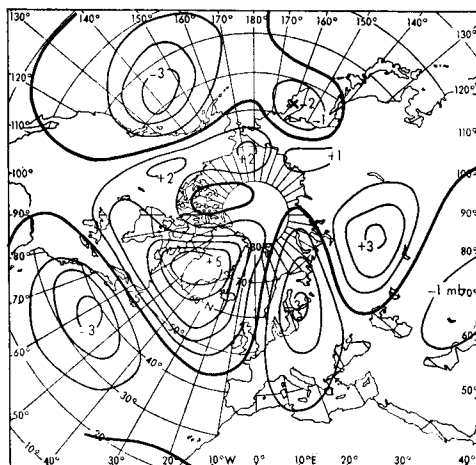


FIGURE 9—MEAN PRESSURE FOR JANUARY 1952–61 MINUS MEAN PRESSURE FOR JANUARY 1899–1968

There was only one January (1957) with temperature above average in central England in this 10-year period, and only one cold January (also 1957) in Newfoundland, whilst the Black Sea area had above-average temperatures, except in 1954 and 1957. Figure 8 also shows the increase in the *S* index at 60–70°W, which probably accounts for the positive correlation with one-year lag in Table III.

Figures 10(a) and (b) show the 10-year running means of the *C* index. Most longitudes show a long-period fluctuation in cyclonicity, e.g. 120–130°W (Figure 10 (a)) shows a maximum near the beginning of the period and a minimum around 1959 with a recovery since. At 120–130°W, both the maximum and minimum cyclonicity are associated with a minimum of the *P* index (see Figure 5(a)), though the *C* index is also high at the maximum of the *P* index around 1921. The 10-year mean surface pressure anomaly maps show these changes quite well; the period 1902–11, for example, shows a positive centre of +8 mb at 70°N, 140°W and a negative centre of –2 mb at the southern edge of the 50–60°N, 120–130°W square, giving a cyclonic block over this square; but for the period 1917–26 a negative centre of –4 mb is centred at the northern edge of the same square giving a progressive cyclonic type, consistent with the *P* index maximum around 1921. For the period 1948–57 a positive anomaly centre of +4 mb is centred at the northern edge of the 120–130°W square giving an anticyclonic block consistent with the generally low values of the *C* index about this time.

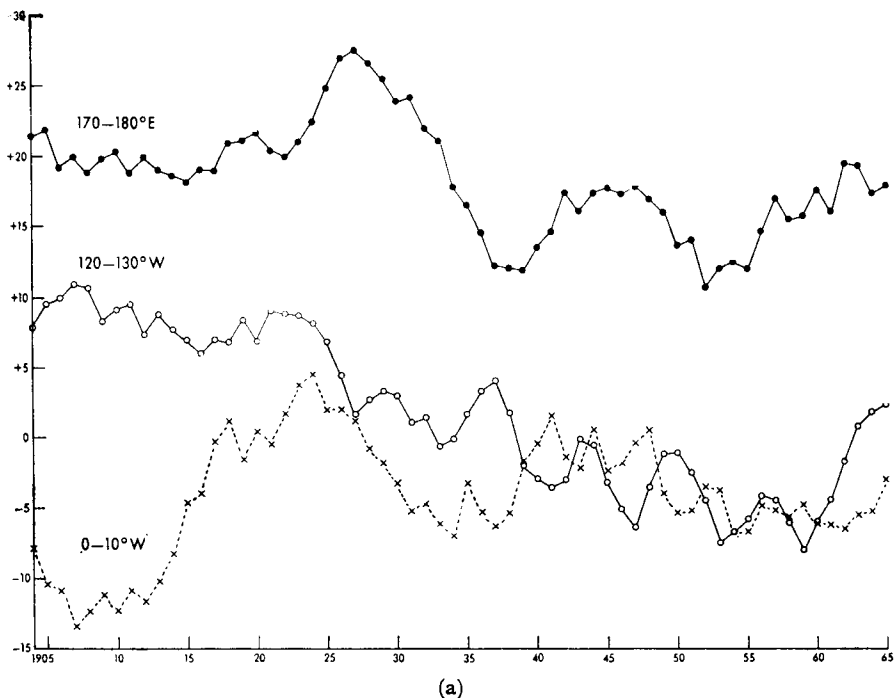
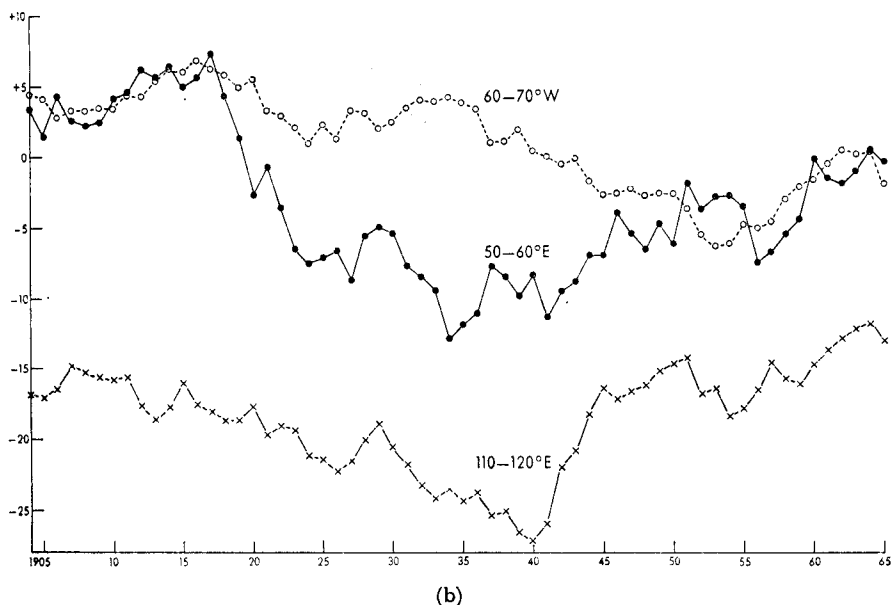


FIGURE 10—10-YEAR RUNNING MEANS OF *C* INDEX AT 50–60°N FOR VARIOUS LONGITUDES, JANUARY 1899–1968

Means are centred on the middle of the 10-year period.

(b)
FIGURE 10—continued

In Figure 10(b), the longitude 110–120°E also shows a long-period fluctuation in cyclonicity with a maximum near the beginning and end of the 70-year period and a minimum around 1940. This fluctuation is mainly in the opposite sense to that at 120–130°W.

An examination of charts depicting the pressure anomaly over 10-year periods from 1873 shows that :

- (a) The North Pacific in January was dominated by above-average pressure from about 1873 to 1920 and by below-average pressure from about 1925 to 1968, though a rise of pressure has apparently begun over the Aleutian Islands in recent years but not (yet) over Kamchatka.
- (b) Above-average pressure prevailed in the Iceland area in January from about 1873 to 1895 and again from 1940 to 1968 whilst below-average pressure prevailed from about 1900 to 1935.
- (c) Below-average pressure prevailed in January over Russia (north of 50°N and between 30°E and 120°E) from about 1873 to 1890, 1900 to 1925 and 1950 to 1960 but above-average pressure prevailed from 1890 to 1900, 1925 to 1948, and 1960 to 1968.
- (d) Below-average pressure prevailed over northern Canada in January from about 1875 to 1885, 1895 to 1905 and 1920 to 1945 but above-average pressure prevailed from 1885 to 1895, 1905 to 1918 and 1945 to 1968.

The oceanic areas appear to have a long 90–100-year cycle in surface pressure whilst the continental areas have shorter cycles of 30–50 years.

From the above it can be seen that the circulation changes over the northern hemisphere in January in the last 100 years have been highly complex. The major centres of action (the Aleutian and Icelandic lows) have undergone a long-period change with the probability that one whole cycle is nearing completion. The oscillations in the two oceans are not in phase, the Pacific

lagging behind the Atlantic. As a result, the continental areas show shorter-period oscillations in surface pressure as the planetary wavelength responds to the oceanic oscillations.

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551.507:352:681.3

A BRIEF SUMMARY OF THE METEOROLOGICAL RESEARCH FLIGHT DIGITAL MAGNETIC-TAPE DATA-RECORDING AND DATA-PROCESSING SYSTEM

By D. N. AXFORD

Summary. A new digital magnetic-tape data-recording system has been developed for use in the Meteorological Research Flight aircraft. The initial installation will be made into the MRF Canberra in 1972, and a similar system will be fitted into the Hercules C-130 aircraft due for delivery to MRF in 1973.

Introduction. A data-recording system has been developed by the British Aircraft Corporation for use in the Meteorological Research Flight (MRF) aircraft. The initial installation into the Canberra will be made in 1972, and a similar system will be fitted into the Hercules C-130 aircraft due for delivery to MRF in 1973. The following is a brief description of the system for the use of potential users of the C-130 or Canberra. Further details can be supplied by MRF if required.

General description of the MRF system. A block diagram of the recording and processing system is shown in Figure 1. The equipment (see Plates I-IV) consists of four separate parts :

- | | |
|-----------------------------|---|
| (a) The airborne equipment. | (c) The ground replay unit. |
| (b) The system test-box. | (d) The transcription and data-processing system. |

The airborne-equipment signal conditioning unit accepts the transducer inputs which may consist of various levels of d.c. voltage, synchros, variable resistances or digital information, and converts them into either a d.c. voltage of 2-volt peak-to-peak full scale, or a suitable binary digital output. The analogue signals are fed to a multiplexer which connects them serially through a sample-and-hold amplifier to an analogue-to-digital converter (ADC) within the data acquisition unit. Digital inputs are interleaved with the analogue inputs via a separate digital multiplexer, and the final all-digital data are fed to the tape recorder serially at 640 samples per second.

The system test-box allows simulated digital and analogue signals to be fed into the airborne equipment, giving an overall functional test to the system. Calibrations of the transducers themselves are normally made the subject of a separate laboratory experiment.

The ground replay unit consists basically of a tape transport for replay, a decommutator and control box and an ultraviolet (UV) recorder. This enables analogue recordings to be made from the eight most (or least) signif-

icant bits from any six data channels and the time channel. A display of recorded time is also provided and an indication of parity errors. Also an edit track can be added to the tape by means of a switch. Both the test box and the replay unit are transportable by air and can be used in any part of the world.

The transcription and data-processing system is installed in the MRF building at the Royal Aircraft Establishment, Farnborough. An interface unit detects whether the edit track has been added (or whether a manual switch has been set) and if so transfers the data into blocking stores in the memory core of a small general-purpose computer (PDP8/I). The PDP8/I controls the blocking of the data and the recorder control functions, and uses its data-break facility to transfer the data, in a suitable format, on to a computer-compatible tape in the form of two 6-bit words plus a parity bit for each 12-bit data word. The computer is also used to change data words with parity errors into an easily recognized 'all-ones' data word. IBM compatible tape marks, inter-record gaps and inter-file gaps are also generated by the PDP8/I. The computer-compatible tape may be read back into the PDP8/I at a later stage for further processing on-site, or alternatively it may be presented to a large computer for more lengthy analysis with, perhaps, the use of sophisticated output peripherals.

The airborne recording equipment (Plate I). The airborne recording system (see Figure 1) consists of five main blocks, namely :

- (a) A signal conditioning unit.
- (b) A data acquisition unit.
- (c) A tape recorder.
- (d) A remote-control panel.
- (e) Power supplies.

Data are recorded in digital format on 16-track magnetic tape. Fifteen of the tracks are utilized during the airborne recording, the remaining track being used for editing purposes during replay and transcription. Three of the tracks are used for clock, parity and multiplexer frame-synchronization signals, while the remaining 12 tracks constitute the 12-bit data word. The track allocation on the tape is shown in Table I.

TABLE I—TRACK ALLOCATION ON AIRBORNE RECORDING TAPE

Track numbers	Signals
1 to 6	Data (track 1 is LSB)
7	Clock
8	Parity
9 to 14	Data (track 14 is MSB)
15	Frame synchronization
16	Not used in air (reserved for edit facility)
LSB = least significant bit MSB = most significant bit	

The units (a) and (b) above are shown in block-diagram format in Figures 2 and 3. While the initial installation is designed particularly to accommodate the Canberra inputs described in Table II, the circuits used for signal conditioning can be generalized to deal with a variety of other inputs, and space has been left for future expansion.

The initial programme (defined by the parameter allocations shown in Table III) can be changed by rewiring two matrix patch boards within the data acquisition unit.

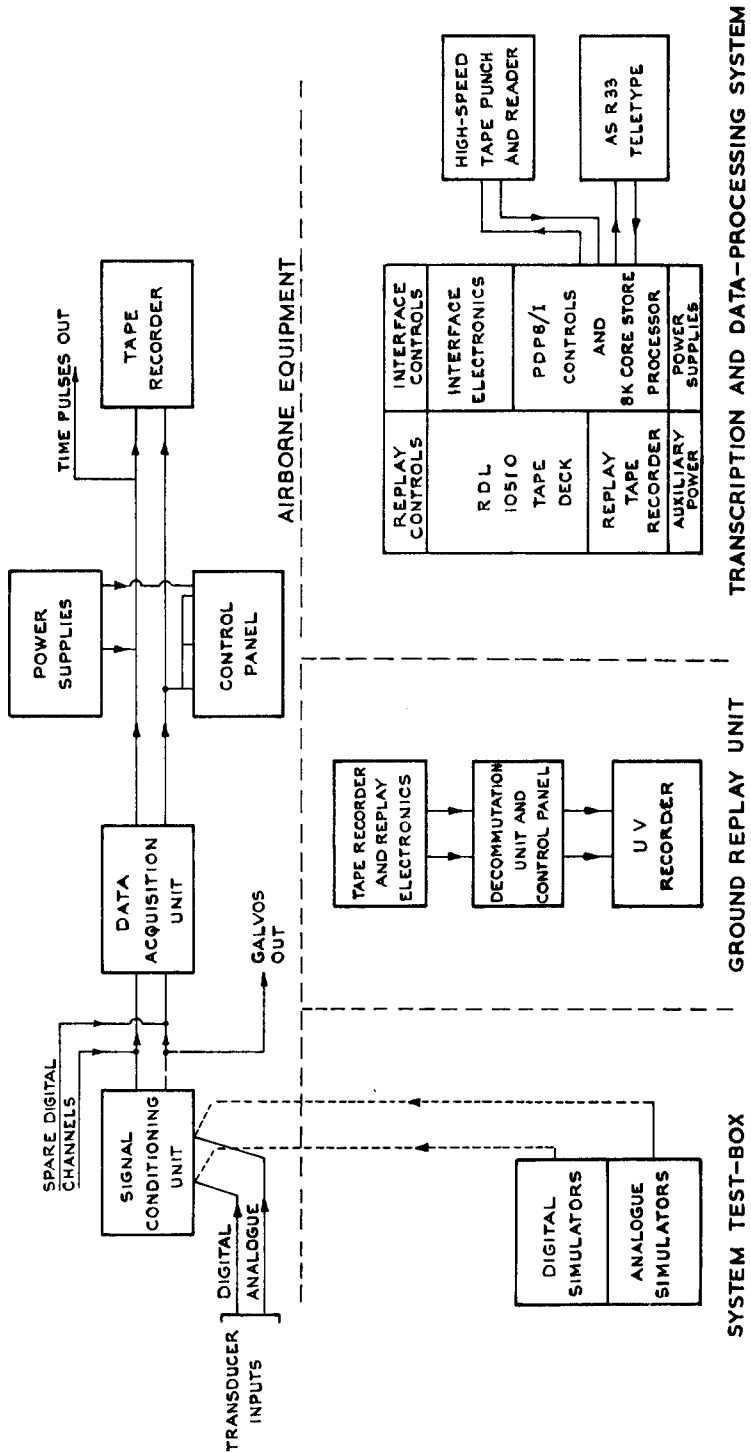


FIGURE 1—MRF DATA-RECORDING AND PROCESSING SYSTEM

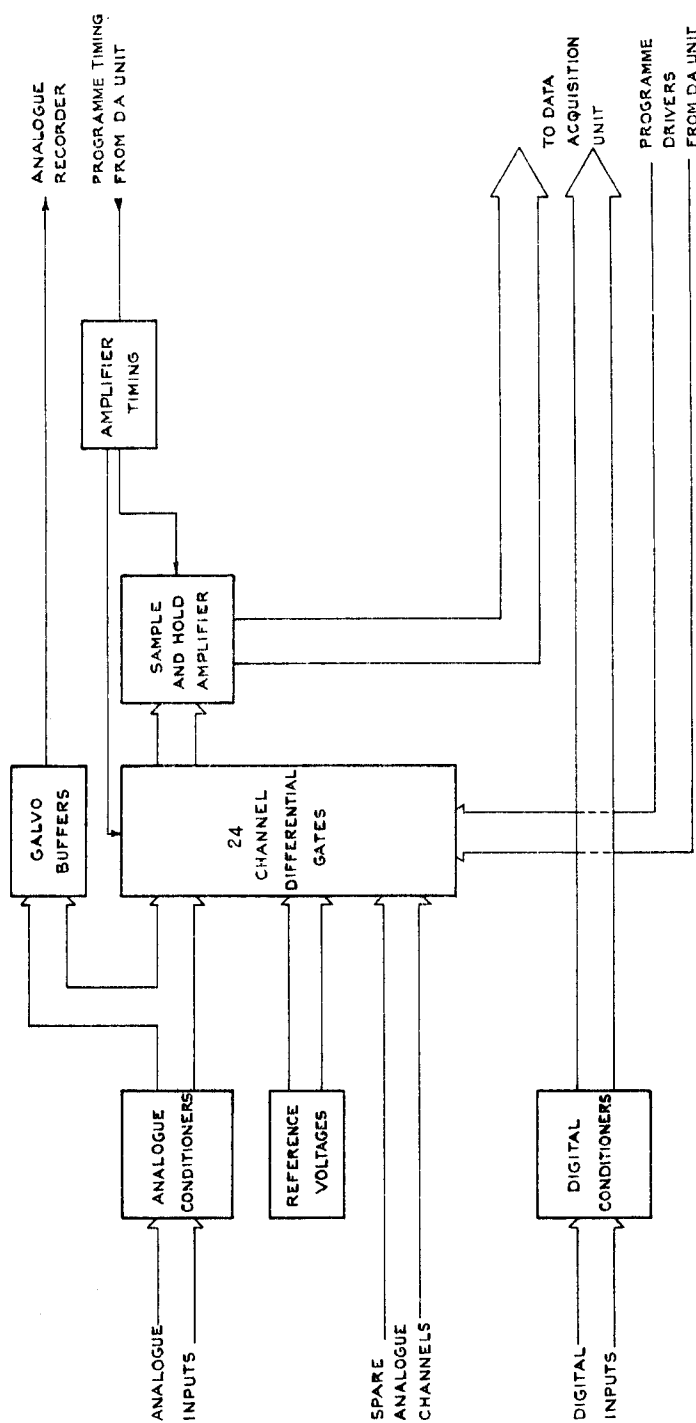


FIGURE 2—SIGNAL CONDITIONING UNIT

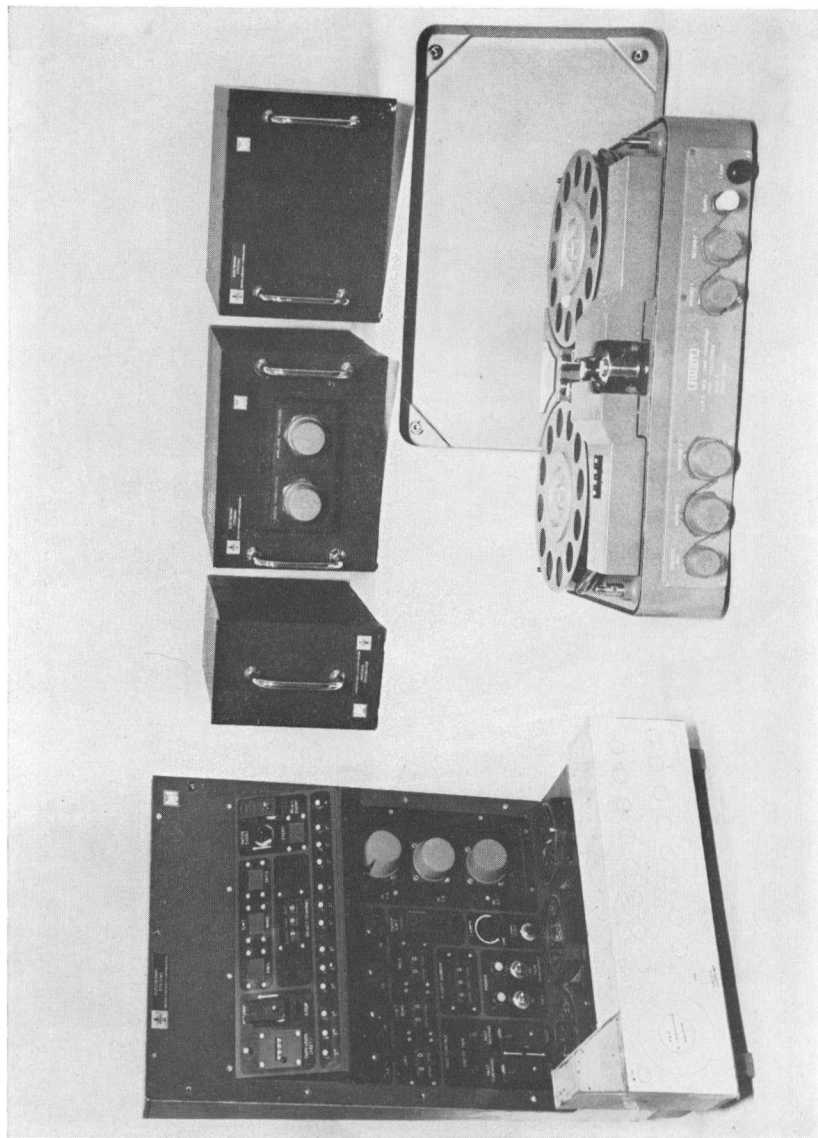


PLATE I—METEOROLOGICAL RESEARCH FLIGHT AIRBORNE RECORDING EQUIPMENT

See page 329.

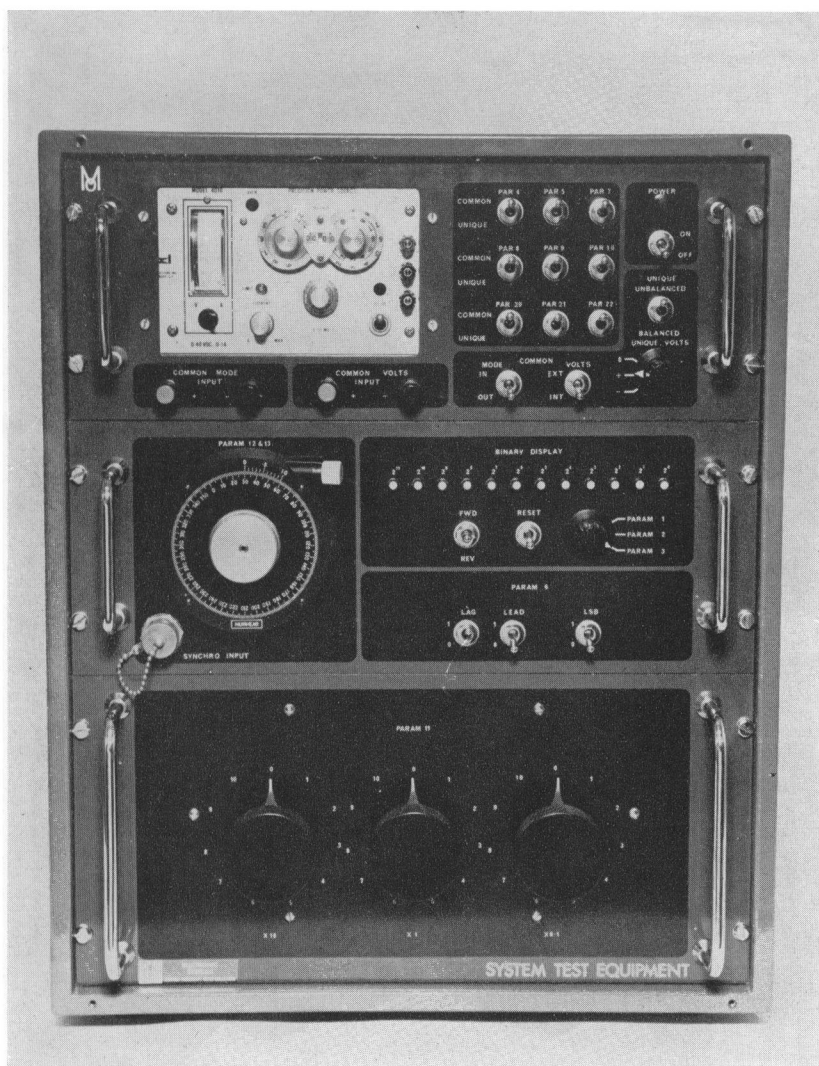


PLATE II—THE SYSTEM TEST-BOX

See page 329.

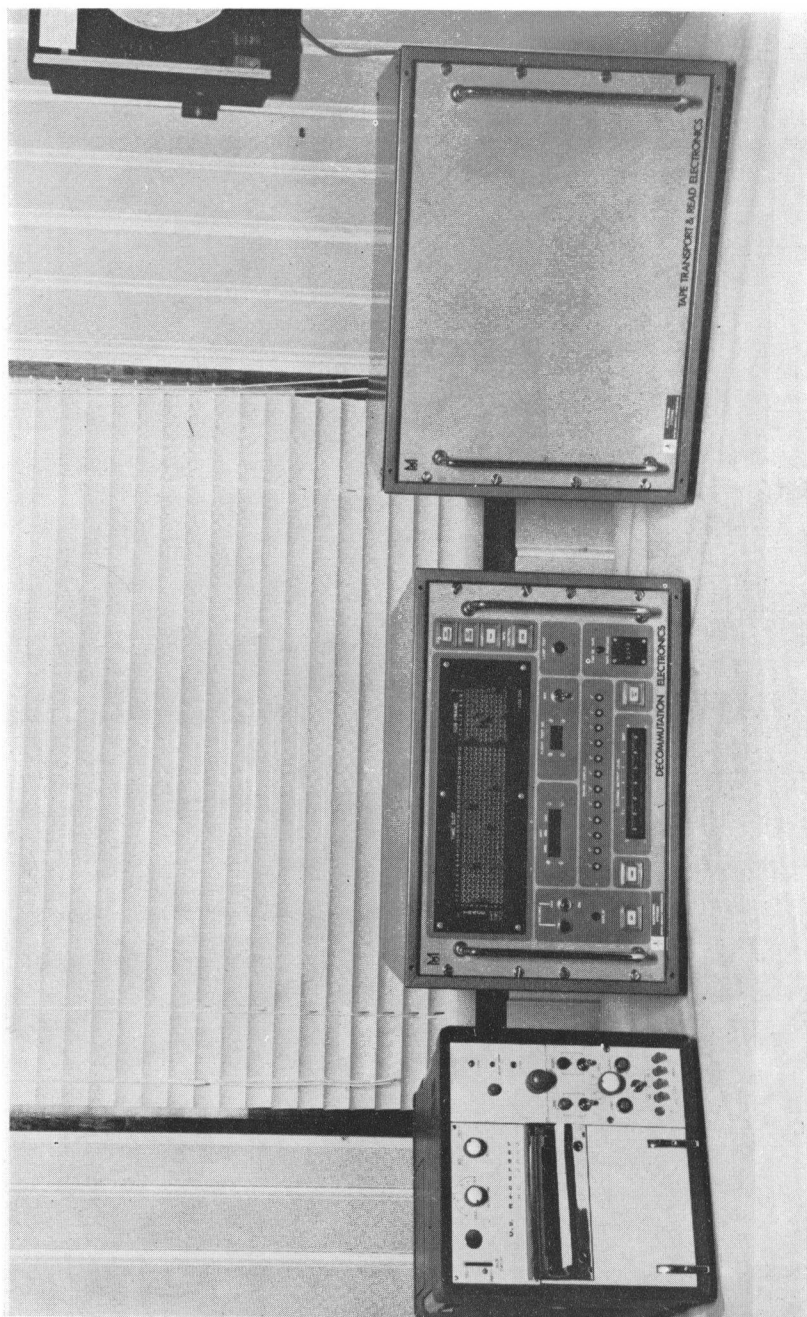


PLATE III—GROUND REPLAY UNIT

See page 329.

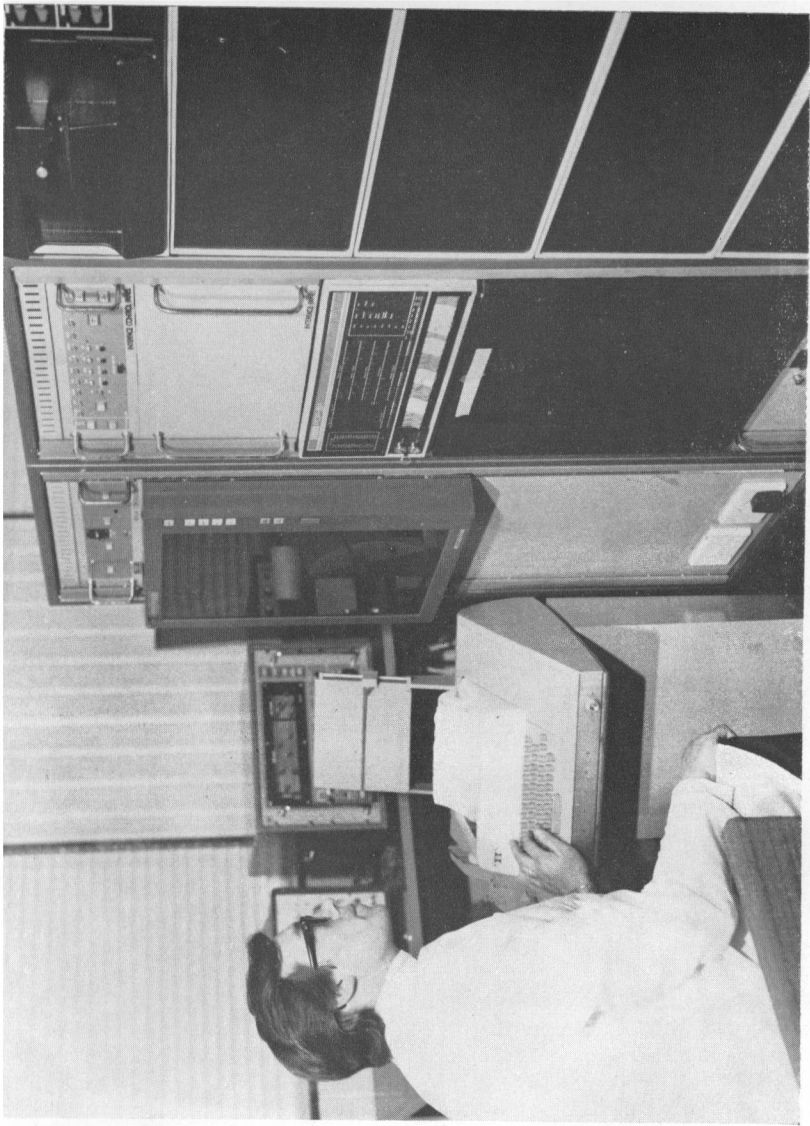


PLATE IV—METEOROLOGICAL RESEARCH FLIGHT TRANSCRIPTION EQUIPMENT

See page 329.

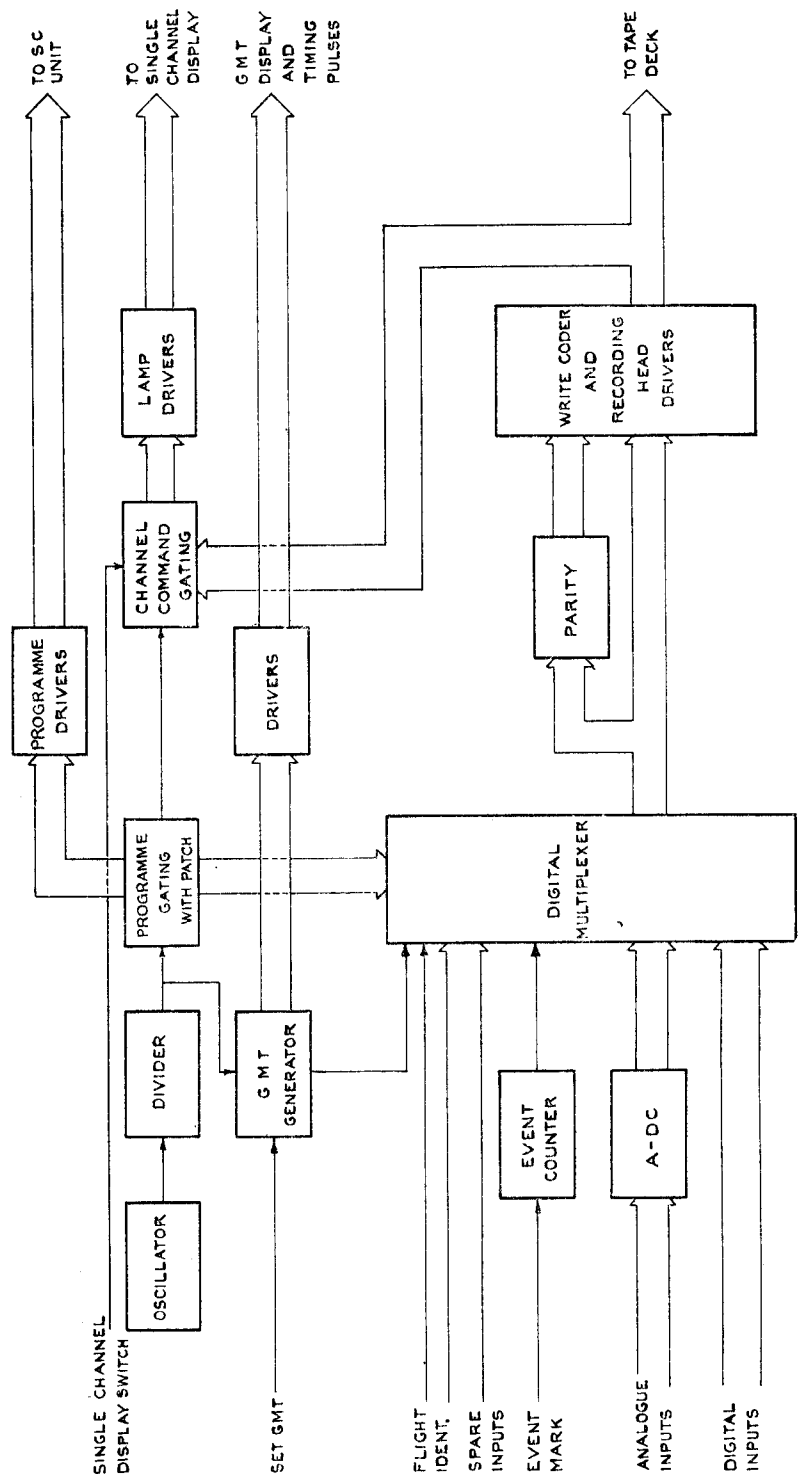


FIGURE 3—DATA ACQUISITION UNIT

TABLE II—DETAILS OF TRANSDUCER INPUTS USED IN THE METEOROLOGICAL RESEARCH FLIGHT CANBERRA

Parameter	Unit	Range	Instrument	Minimum sampling rate per second	Absolute accuracy	Resolution	Type
					<i>per cent of full excursion</i>		A=analogue D=digital
1. Vertical velocity	ft/s	±100	INS	20	±0.25	0.25	D
2. Ground speed E-W	ft/s	±800	INS	20	±0.025	0.025	D
3. Ground speed N-S	ft/s	±800	INS	20	±0.025	0.025	D
4. Pitch angle	degree	±10	INS	20	±0.25	0.1	A
5. Roll angle	degree	±20	INS	20	±0.5	0.25	A
6. Azimuth angle	degree	0-360 (a) 11 LSB (b) 11 MSB	INS	20	±0.01 (of 360°)	0.01	D
7. Angle of attack	degree	±10	Wind vane	4	±0.1 (of 300°)	0.1	D
8. Angle of sideslip	degree	±10	Wind vane	80	±0.25	0.1	A
9. Static pressure	mb	100-1050	Capacitive	20	±0.15	0.05	A
10. Pitot static pressure	mb	0-300	Capacitive	40	±0.25	0.1	A
11. Temperature	°C	+40 to -80	Platinum resistance	40	±0.2	0.01 (0.1 with range splitting)	A
12. Doppler ground speed	kt	100-700	Synchro-digital converter	2	±0.1	0.1	D
13. Doppler drift angle	degree	±20	Synchro-digital converter	2	±0.25	0.25	D
14. Standard time	second	24 hours	Crystal oscillator	2	10 ⁻⁷	$\left. \begin{array}{l} \times 1 \text{ s} \\ \times 10 \text{ s} \\ \times 1 \text{ min} \\ \times 10 \text{ min} \\ \times 1 \text{ h} \\ \times 10 \text{ h} \end{array} \right\}$ (a) x 1 s (b) x 10 min	D
15. Event mark	number	0-99	Contact	4			D
16. Temperature switch position	number	0-9	Contact	4			D
17. Reference voltage	volts	+0.45	BAC reference	2	±0.05	0.05	A
18. Reference voltage	volts	0	BAC reference	2	±0.05	0.05	A
19. Reference voltage	volts	-0.45	BAC reference	2	±0.05	0.05	A
20. Vertical velocity	ft/s	±600	INS	2	±0.25	0.1	A
21. Ground speed E-W	ft/s	±4500	INS	2	±0.25	0.1	A
22. Ground speed N-S	ft/s	±4500	INS	2	±0.25	0.1	A
23. Flight identifier		000-999	Switched	2	±0.25	0.1	D

INS = inertial navigation system

LSB = least significant bit

MSB = most significant bit

TABLE III—INITIAL PARAMETER ALLOCATIONS

(a) Allocations in the multiplexer sub-frame

	A			D			A			D			A			D																
Sub-frame positions	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Parameter allocations	LF	7	8	11	6a	--	LF		4	7	8	10	--	--	--	1	9	7	8	11	6a	--	--	2	5	7	8	10	--	--	--	3

(b) Low-frequency allocations

Sub-frame number	1	2	3	4	5	6	7	8	9	10
Analogue parameter	-	-	20	21	22	17	18	19	-	-
Digital parameter	14a	15	16	12	13	14b	15	16	6b	23

A = analogue D = digital LF = low frequency

Summary of the airborne recording equipment specification.

Inputs	Initially 13 analogue, 12 digital. Can be expanded to 24 analogue, 24 digital.
Analogue signal levels	Standardized to 2-volt peak-to-peak in the signal conditioning unit. Initial unit accepts the parameters shown in Table II.
Digital inputs	12 bits.
Input filtering	Low pass, cut off above 4 Hz, greater than 34 dB down at 20 Hz with stable frequency and attenuation characteristics. Applied to parameters 4, 5, 7 and 8 in Table II.
Sampling rate	640 samples per second consisting of two 320-sample main frames. Each main frame consists of 10 sub-frames consisting of 32 samples. Sampling rates can be chosen between 2 samples per second and 80 samples per second by suitably wiring a matrix board.
Time standard	Time is set by thumbwheel switches and started by means of an 'enter' button. It is recorded in binary-coded decimal format in hours, minutes and seconds.
Time standard accuracy	Better than 1 part per million.
System accuracy	± 0.1 to ± 0.25 per cent absolute accuracy for selected parameters.
Bit errors	Less than 1 in 10^5 bits.
Tape-deck specification	See Table IV.
Power supplies	200-volt 400-Hz 3-phase aircraft supplies.
Environment	-10°C to $+35^{\circ}\text{C}$; sea level to 50 000 feet, specified vibration, shock, acceleration and crash conditions defined in <i>British Standard BS 2G 100, Part 2</i> .

TABLE IV—SUMMARY OF THE AIRBORNE TAPE DECK SPECIFICATION

1. Tape tracks	16 on one-inch tape.
2. Tape heads	33-track type Gresham AE10 of which only the centre 16 tracks are fitted. Nominal gap width 100 micro-inches.
3. Capacity	2300 feet of 0.001 inch base 'thin oxide' tape on 8 inch precision spools.
4. Tape speeds	$\frac{1}{32}$, $\frac{1}{16}$, $1\frac{1}{2}$, $3\frac{1}{2}$, $7\frac{1}{2}$, 15, 30 inches per second. $\frac{1}{16}$ in/s used during airborne recording giving a maximum record time of 8 hours 7 minutes. Fast forward and rewind.
5. Recording technique	NRZI (non return to zero mark).
6. Character density	682 $\frac{1}{2}$ samples per inch.
7. Tape controls	Remote. Footage indicator also remote.
8. Physical dimensions	19 × 11 × 5 $\frac{1}{4}$ inches, 45 lb weight (\approx 20 kg).
9. Power supplies	28-V d.c. aircraft supplies, 5-amp max.
10. Operational environment	Temperature: -10°C to $+35^{\circ}\text{C}$. Altitude: sea level to 50 000 feet (\approx 16 km). Vibration, shock and crash conditions: as laid down in relevant parts of <i>British Standard BS 2G 100 Part 2</i> .

The system test-box (Plate II). A simple method of calibrating and ground testing the recording system is of great importance. In general the calibration of the transducers themselves is a separate matter, but the calibration of the rest of the system is achieved by using a test-box which will simulate the presence of the transducers. The digital display of one channel of data is then immediately available for examination on the control panel, and also the signals can be recorded on the magnetic tape, and replayed and processed in the normal way.

The test-box provides the following facilities :

- (a) Precision (± 0.05 per cent) d.c. supplies from which simulated analogue signals of known voltage are derived.
- (b) A precision (± 0.05 per cent) 3-decade resistance box to simulate the temperature resistance bridge.
- (c) A synchro fitted with a vernier setting dial accurate to 10 minutes of arc energized from a 400-Hz static inverter.
- (d) A simulated 14-bit digital input controlled by switches to test the azimuth decoding circuits.
- (e) A motor-driven contact arrangement similar to that employed in the inertial navigation system (INS) (see Table II). The motor can be driven backwards or forwards, and a display of the total contact counts is provided. This tests the logic circuits of the pulse counters used for parameters 1, 2 and 3.

The test-box will occasionally be taken with the aircraft away from MRF both in the United Kingdom and abroad but it will not be operated in the air.

The ground replay unit (Plate III). This unit is intended to provide a 'quick-look' replay and editing facility for the airborne recording equipment. It will be taken abroad with the aircraft for ground use at the field base, and thus is built to meet a world-wide environment. The unit allows the airborne magnetic tape to be replayed, and provides the following facilities :

- (a) Analogue traces of any six parameters selected from the data on the magnetic tape may be recorded on a UV recorder by suitably programming a patch board. A further trace is recorded giving an indication of the standard time. The airborne tape can be replayed at eight times the recording speed. Also an event mark is made if a parity error occurs on the data, and a 'parity fail' lamp is lit for 1 second on the display.
- (b) A digital lamp display of the 12-bit data word selected from any channel.
- (c) A three-decimal visual display of the flight identifier.
- (d) A visual decimal display of the recorded standard time in hours, minutes and seconds.
- (e) During replay, selected portions of the flight tape may be marked in the 'edit' track by means of a button or switch. This 'edit' mark may be used by the transcription system.

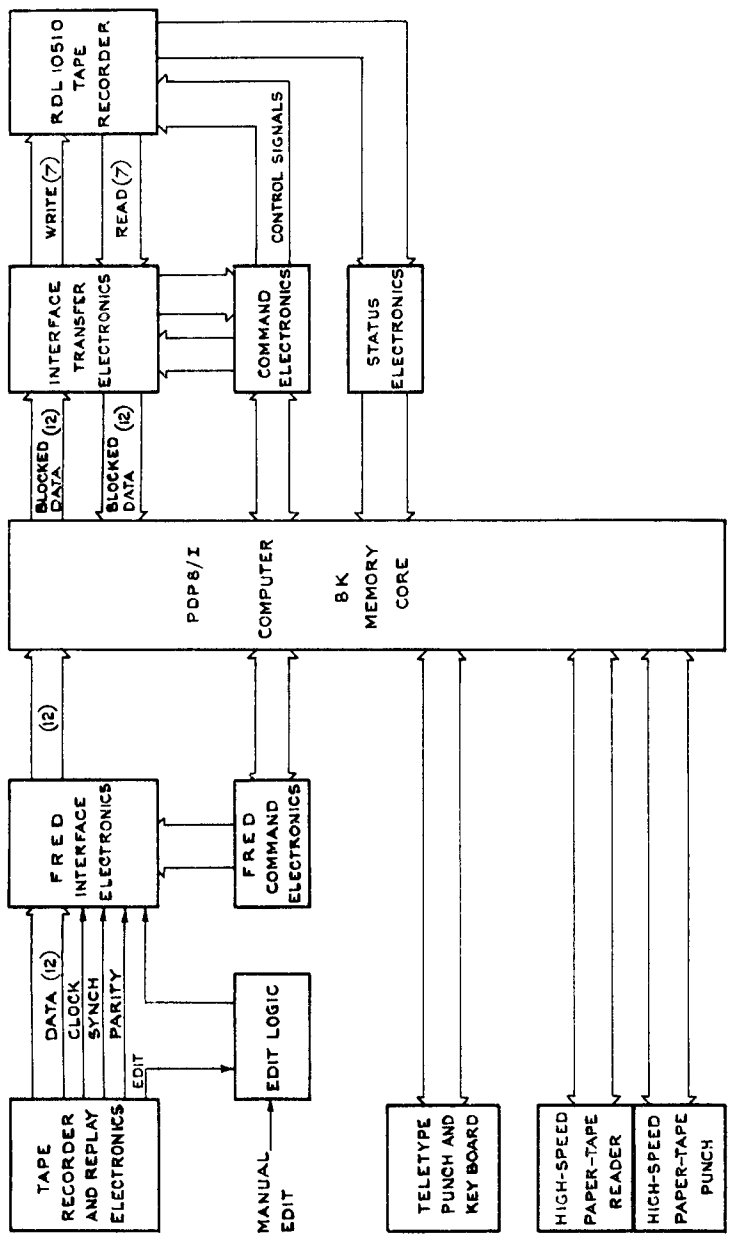


FIGURE 4—TRANSCRIPTION AND DATA-PROCESSING SYSTEM

The transcription and data-processing system.

(a) *The transcription equipment* (Plate IV). The transcription equipment provides a means for the automatic conversion of selected portions of the flight tape into 7-track computer-compatible tape. The system, shown in Figure 4, uses the tape recorder and replay electronics from the ground replay unit to provide the initial data. The edit signal is either added by means of a switch on the unit, or has already been added during the replay phase. In either case the flight replay edited data (FRED) interface electronics detect the presence of the edit signal and thereupon transfer the 12-bit data words into blocking banks within the memory core of a small inexpensive general-purpose computer (a Digital Equipment Corporation PDP8/I). This computer is used to control the data-blocking and recorder control functions, and to provide further facilities. In particular, the presence of a parity error is detected in the incoming data word, and the word is replaced with an 'all-ones' character in the memory in place of the erroneous data. The data are read out on to a standard commercial computer-type magnetic-tape handler via the computer's 3-cycle data-break facility. This enables the transfer from the memory core to be very rapid since it by-passes the computer accumulator stores and acts in response to a request initiated by the interface electronics. The 12-bit data are broken into two 6-bit words in the interface, and a parity bit is generated for each. The output tape is written at a packing density of 556 rows per inch. The computer is programmed to provide the necessary inter-record gaps, and inter-file gaps. A standard IBM-type tape mark can also be added by means of a push button.

The system also includes the facility to retrieve data from the computer tape, reassemble the 6-bit characters into 12-bit words and store them in the PDP8/I memory core as a block of data. Again the 3-cycle data-break transfer-mode is used. This allows data to be read back into the computer for initial processing in the laboratory. In addition the computer has been extended by the inclusion of a standard high-speed paper-tape reader and punch to allow for rapid reprogramming when desired.

(b) *Data processing.* The collection of digital data on a computer-compatible tape is only of use provided the necessary software (programming) has been developed so that the tape can be played back through a computer to obtain printed or graphical outputs of the relevant meteorological measurements. With a recording rate of 640 samples per second, 2 304 000 measurements of raw data will be made each hour so it is essential that the software be capable of dealing with this mass of data quickly and efficiently.

Tapes produced by the transcription system can be fully processed on a large computer (the RAE ICL 1907 or the Meteorological Office IBM 360/195), and they may also be partially processed by the PDP8/I. Programmes to deal with the current requirements are being developed at MRF, and further extensions and improvements to the system are under active consideration.

Acknowledgements. This system has been developed over several years and many people have been involved. In particular Mr D. R. Grant (MRF 1962-66) who initiated the first specification and Mr C. J. M. Aanensen, Head of MRF 1966-71, should be mentioned. Expert advice and encouragement have been freely given by the Instrumentation and Ranges Department of RAE Farnborough.

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THE ROUTINE PROCESSING OF CURRENT RAINFALL DATA BY COMPUTER

By P. G. ALLEN

Summary. The method used by the Meteorological Office for the routine work of checking and summarizing current rainfall data in 1971 is outlined. The processes have been developed from those described by Bleasdale and Farrar in 1965 and now include Scottish and Northern Irish data. Further developments are due to take place shortly using the new IBM 360/195 computer.

Nature of rainfall data available. Originally there were only two types of reports, either daily or monthly, with a few weekly records being included with those from monthly gauges. Now there are increasing numbers of so-called 'daily' reports which do not include weekend readings. This has been caused by the decline in the numbers of truly private observers and the spread of 5-day working among local authority, water board, and river authority staffs. The situation is causing difficulties in some areas where it affects 25 per cent of the daily reports received. An attempt to use the computer quality control to estimate correct daily figures has been made. All data for England and Wales from 1961 and from Scotland and Northern Ireland from 1971 have been so amended; however, these estimates have not been annotated in any way so there is the danger they may be used in the future as genuine daily values.

From 1 January 1971, Scottish and Northern Irish data have also been included in the full cycle of data processing. Earlier use of a computer for checking and summarizing data was described in 1965.*

Types of error in order of prevalence.

- (a) Misreadings, misplaced decimals, mistakes in copying and mistakes in arithmetic.
- (b) Accumulations over more than one day, sometimes indicated, but quite often entered as normal daily readings.
- (c) Displacement of correct readings to incorrect days, persistently, fairly often but irregularly, or only occasionally and erratically; frequently caused by observations made at non-standard times.
- (d) Inadvertent omissions, observations made but not written down.
- (e) Occasional errors due to temporary disturbance of exposure or mischievous interference.
- (f) Systematic errors due to faulty exposure or defective equipment. A new defect, more prevalent in the last two years, is the breaking off of the rim on certain glass-fibre laminate gauges. The rim on these gauges is attached by ferrous rivets to the main body so that in normal use rusting takes place and the rim becomes detached. The removal of this rim increases the diameter such as to increase the catch by approximately 42 per cent. If more than one gauge in an area is damaged in this way it can make the task of detection by computer processes very difficult. A special watch on this type of tulip-shaped glass-fibre gauge is therefore necessary.

* BLEASDALE, A. and FARRAR, A. B.; The processing of rainfall data by computer. *Met Mag*, London, 94, 1965, pp. 98-109.

In an attempt to reduce errors (a), (b) and (c) a leaflet, giving a standard method of entry of readings on the postcard forms, has been issued to all stations where difficulties were noticed.

Maps. As an aid to quality control the areal analysis programme has been adapted so that station values can be plotted by computer. This routine is available to plot data on any one of five scales for a maximum of 8 consecutive days, or for monthly or annual totals. The scale recommended is 1 : 250 000 so that the computer output can be used with the existing computer area-index maps on a light-table to identify the stations. A maximum of 8 'area-days' for each run is recommended, i.e. one area for 8 days, two areas for 4 days, etc. The programme will also produce isohyets from the data, in contour print form, using all available stations in the area on the scale 1 : 625 000. An area of exceptionally close isohyets or apparently unrealistic patterns suggests data errors in the vicinity.

Computer programmes for quality control. The steps of the procedures covering the routine monthly input of data on to magnetic tape and the quality control of the data are limited by the capacity of the computer used. The present machine KDF9 handles up to 400 stations at a time as opposed to the 256 of the earlier one. The areas at present in use are based mainly on natural river basins, groups of basins within river authority areas, or tributary areas in the larger basins. Figure 1 gives a map of the computer areas and it has recently been found necessary to subdivide areas 34 and 35 as they were too large for practical use. A flow diagram and timetable for the steps of the quality control are given in the appendix; the process from initial punching of paper tapes to final transfer of magnetic tape to archives takes about 1 year 9 months from the beginning of the year of the data concerned.

For any one month and a given area, the steps may be described as follows.

Firstly a backing-tape (register of station particulars) of all stations currently forwarding data is made. This backing-tape is produced for each month by up-dating the previous version; each station contains particulars of the station number, height above sea level, average annual rainfall, grid reference, and county number.

Programme 1 (Inserting rainfall readings to magnetic tape containing backing-tape details).

- (a) Reports already sorted into numerical order and computer areas are sent to be punched on to paper tape in a form that includes indicators used in subsequent processing.
- (b) This programme then transfers the data to magnetic tape if the station is registered on the backing-tape and is for the correct month. If not, a print-out of the station number not accepted is given.
- (c) For data accepted certain checks are made :
 - (1) Arithmetical — print-out of total of daily values if not in agreement with that given.
 - (2) Too many or too few daily values — actual number on paper tape listed.
 - (3) No total — station listed and correct value given.

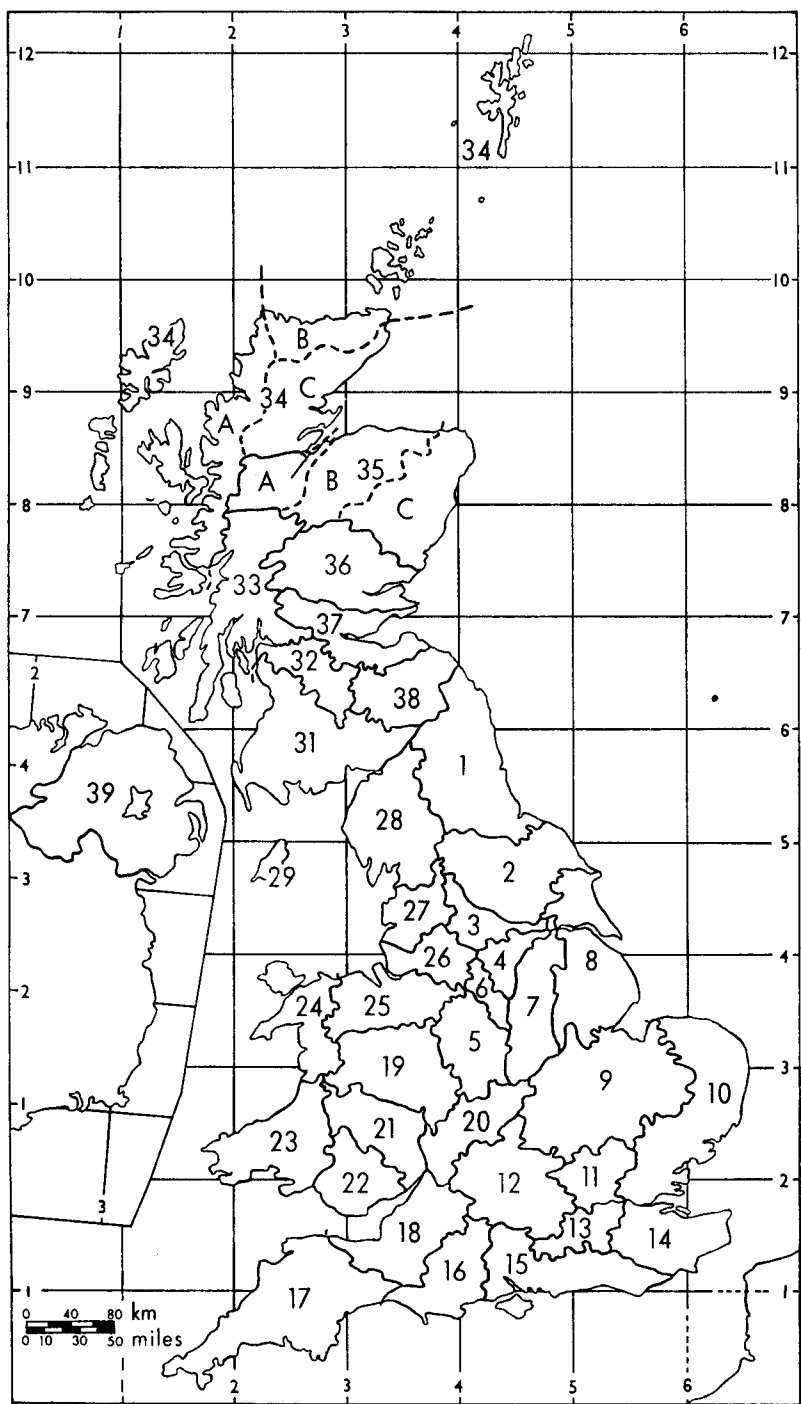


FIGURE 1—MAP OF THE COMPUTER AREAS

Values for stations reporting 12-hour amounts are added by the programme and the resultant 24-hour amounts checked as above. For data queried by checks (1), (2) and (3) a separate tabulation of all readings is given.

- (d) A print-out of all data accepted, whether queried or not, is then given, plus a missing-station list.

This input programme is repeated as necessary, including amendments to queried stations until the data are considered complete and devoid of processing errors. See Appendix (a)–(c).

Programme 2 (Main quality control). With this programme a quality control is made of the reported rainfall amounts. As inch readings are now in the minority it is carried out in millimetres, with inch reports being converted by the programme.

The various steps are :

- (a) *Indicated accumulations.* Indicators have been put on tape for accumulated values which are now subjected to checking. Comparisons are made with up to six stations within a square area of 12.8 km semi-diagonal. Stations used and estimates suggested are tabulated and printed separately, the estimates also being stored and annotated so as to be used in subsequent checks and printed at the end of this programme.
- (b) *Daily values assessed.* The main development in this section of the programme has been to relate the assessments to per cent of average annual rainfall. In this way allowance has been made for the variation between sites and for elevation and geographical position.

Calculations are made of the area mean daily falls which are then converted to daily mean percentage, A , of area annual average; the standard deviation, σ_d , of the station values used in finding the mean is noted. The values of the mean percentage plus $2\sigma_d$ (i.e. $A + 2\sigma_d$) and the mean percentage minus $2\sigma_d$ (i.e. $A - 2\sigma_d$) are registered for each day of the month. All station daily values are then converted to percentages, S , of station annual average. These station daily percentage figures are then checked to identify those which appear too high or low, on the following basis :

$$\text{Too high} \quad \frac{S - (A + 2\sigma_d)}{S} > 0.25,$$

where 0.25 is a control factor which has been found acceptable over 10 years of data from England and Wales.

$$\text{Too low} \quad S < (A - 2\sigma_d).$$

All values found outside these limits are then annotated for later tabulation and a separate list is given of suspect actual values, daily station percentages and the control factors.

- (c) *Monthly values assessed.* Each monthly total is tested by comparison with up to six stations within a square area of 12.8 km semi-diagonal, but the values used are the totals expressed as percentages of station annual averages.

A control factor $(T - B)/\sigma_m$ is used where

T = total under consideration expressed as percentage of station annual average.

B = mean of the monthly values for the six stations used in the comparison, expressed as a percentage of the annual average of the stations.

σ_m = standard deviation of the station values used for B .

Stations are suspected if this factor is outside the limits $+1.5$ to -1.5 .

The control factor is unreliable when σ_m is small (that is, when all other totals are much the same) so an overriding check is now built in. No stations are indicated as suspect unless $T/B \leq 0.85$ or ≥ 1.15 .

- (d) *Check on daily values of zero.* All zeros are now tested for any day on which the mean for the area (in original units) is more than 2.5 mm and the standard deviation of those values is less than the mean. Otherwise the check is, as yet, unchanged from the 1964 version (see footnote, p. 340), except that suspect values are annotated with M for missing value or U for indicated accumulation, in the main tabulation.
- (e) *Tabulation of all values for manual checking.* A full print-out of all daily and monthly values is made. The 1971 version is now in millimetres with an indicator against reports originally made in inches. Modifications giving extra information are :
 - (1) Monthly totals as per cent of station annual average.
 - (2) All suspect values and accumulated values in (a), (b) and (d) are annotated thus: H for high; L for low; M for missing; A for indicated accumulation with E for last day of accumulation; U for unindicated accumulation.
- (f) *Heavy falls.* A separate print-out of all daily falls of 50.0 mm or more is used for special investigations.

After the tabulated print-outs have been produced they are scrutinized and subjected to further checks by eye. Correspondence then takes place with observers or authorities whose reports have not been accepted. Final amendments are made, and then transferred to magnetic tape, with any late data, via paper tapes and programme 1. Appendix (d).

Programme 3. This programme is then run; it is a monthly routine of recycling (subjecting the data to another cycle of quality control) the monthly totals of all stations, the total for a station (as per cent of annual station average) being compared with the mean for the six nearest stations — a similar process to programme 2(c). The departures are not printed if they fall within a certain narrow range, so that those which are printed indicate monthly values approaching or exceeding the criterion of acceptability. For a station with a missing value the programme estimates a probable value using the six nearest stations' percentage figures. This programme, using only station monthly totals, can compare stations across computer area boundary lines and is therefore an important step in co-ordinating one area with another. Appendix (e).

Amendments found necessary on expert scrutiny are also written to magnetic tape via paper tape and programme 1. Appendix (f).

Programme 4. The final step in quality control, is to recycle the whole year's monthly totals, check them and give seasonal values (in absolute as well as percentage units). The programme is run from an annual magnetic tape consisting of all the 12 monthly tapes combined with an annual backing-tape section. Appendix (g), (h).

Any amendments necessary after checking and reading-back against original data have then to be inserted by a special annual tape-amendment programme. Appendix (i). The decision as to whether or not data are fit for publication is made at this stage. Appendix (j).

APPENDIX

Flow diagram and timetable for steps in quality control

Progression of data	Timetable	Total time taken
(a) Paper tapes punched: magnetic-tape input using programme 1 as required.	1 month Between 5 and 10 runs of programme 1	
(b) Rainfall extracted from CLIMAT reports using paper tapes and programme 1.		
(c) Programme 2 giving main quality control print-out.		
(d) Amendments and late information input via paper tapes and programme 1.	2 months Approximately 3 more runs of programme 1	$M+1$ month
(e) Recycling of monthly totals using programme 3.	1 month	$M+3$ months
(f) Amendments and very late data input via paper tapes and programme 1.	12 separate monthly cycles 2 runs of programme 1 per month	$M+4$ months
(g) Monthly tapes combined to form annual magnetic tapes.	A few days	$T+4$ months
(h) Annual recycling via programme 4.	2 or 3 months	$T+5$ months
(i) Amendments and insertions of back data to annual tape via special programme.	1 month	$T+8$ months
(j) Clean archives annual magnetic tape.		$T+9$ months

M = month of data concerned

T = year of data concerned

REVIEWS

Computer processing of meteorological data, by S. L. Belousov, L. S. Gandin and S. A. Mashkovich. 245 mm × 173 mm, pp. vi + 210, *illus.* (translated from the Russian by Israel Program for Scientific Translations, Jerusalem), Keter Press Ltd, 15 Provost Road, London NW3 4ST, 1971. Price: £6.30.

This is a well-written book which does not appear to have suffered in translation from Russian to English. As far as I am aware it is the only textbook which deals specifically with the problems of automatic processing of meteorological data and the book lives up to the high reputation of the authors.

The subject is not one which has been given a great deal of publicity but it is a very important one. Operational numerical weather prediction is quite impracticable unless the data are processed automatically with a high degree of quality control and it is also becoming increasingly advantageous to have climatological data stored in machine assimilable form. The complexity of the computer programmes required to achieve an adequate data bank is considerable and I welcome this textbook which highlights some of the principles which are involved, frequently describing with the assistance of flow diagrams the best way in which the programme should be written.

The novel part of the book is contained in the first chapter which deals with the extraction and decoding of usable meteorological data from the telecommunication system. Methods of quality control of data are gone into at some length, and it is this first chapter that makes the book worth while. The following three chapters deal with various aspects of objective analysis, theoretical and practical considerations both being considered. The authors have done their best to deal with the techniques that are being practised in different countries, but have naturally been rather more expansive concerning the techniques currently in use in the Soviet Union. The final chapter deals with practical problems which arise in an operational environment concerned with numerical weather prediction.

My one criticism of the book is that it over-emphasizes those aspects of data processing related to numerical weather prediction and omits other requirements such as the preparation of data banks in machine assimilable form for climatological and research purposes, where there is time to effect a higher degree of quality control. Nevertheless, I strongly recommend this book to anyone concerned with automatic data-processing or objective analysis of meteorological data.

F. H. BUSHBY

Atmospheric circulation and the related wind fields over the North Pacific, by A. I. Sorkina. 245 mm × 175 mm, pp. iv + 218, (translated from the Russian by Israel Program for Scientific Translations, Jerusalem), Keter Press Ltd, 15 Provost Road, London NW3 4ST, 1971. Price: £5.

The original book by A. I. Sorkina was published in Moscow in 1963 and the English translation by M. Levi was published last year. The author classified nearly all the daily synoptic maps for the North Pacific for the years 1899–1939 and 1954–59 (over 16 000 synoptic maps in all) into eight main types and eight sub-types of large-scale synoptic process. Detailed information is presented on the frequency of occurrence of each synoptic type for each month of the period investigated. Most of the book is then concerned with presenting and discussing statistical synoptic information such as the seasonal and secular variations in the frequency of occurrence of the synoptic types, the mean duration of individual types at different times of the year and the chance of any particular synoptic type being followed by the other types.

The synoptic-type classification approach is a well-established method which has inherent drawbacks. Subjective selection is involved in deciding what the fundamental types are, as well as in trying to put the daily synoptic

maps into the correct class. Despite these faults, the method has produced in this instance meaningful statistical data on broad-scale synoptic processes over the North Pacific, and this information is not readily available elsewhere in English.

This small book is easy to understand but tedious to read. The main value rests in the tables and diagrams which form about half the book. One irritation to the reviewer was the inadequate bibliography which omitted information on several authors who were actually referred to in the book.

R. MURRAY

General circulation of the atmosphere, edited by B. L. Dzerdzeevskii and Kh. P. Pogosyan. 240 × 165 mm, pp. x + 402, *illus.* (translated from the Russian by the Israel Program for Scientific Translations, Jerusalem). Keter Publications Ltd, 15 Provost Road, London NW3 4ST, 1971. Price: £5.

This book consists of 24 contributions on a wide range of subjects presented at a conference in the U.S.S.R. at the end of 1964. However, the book was not published (in Russian) till 1968 and this translation appeared in 1971. Thus some of the contributions are inevitably somewhat dated, e.g. those on numerical models (Mashkovich), uses of satellites (Malkevich), stratospheric and mesospheric circulation (Dubentsov), laboratory models (Bonchkovskaya) and planetary atmospheres (Golitsyn and Moroz).

Of the remainder the four longest reports (30 to 34 pages each) are among the most interesting. Kolesnikova and Monin present a rather detailed review of spectra with discussions of the minimum centred around 30 minutes, of climatic fluctuations and of the absence of a peak near 11.5 years associated with the sunspot cycle. Pogosyan, Pavlovskaya and Shabel'nikova give results of a study using Kats' circulation indices (referenced but not defined) of zonality and meridionality at 500 mb and 100 mb for three regions; they reach conclusions unfavourable to the use in long-range forecasting of classifications of circulation types or relationships between adjoining regions such as are described by Girs in this collection; also 'the role of the stratosphere as well as of sunspot changes is not predominant in the development of synoptic processes in the troposphere'. Kitaigorodskii and Volkov review the problem of determining surface momentum and heat fluxes between ocean and atmosphere and attribute the wide range of estimates of surface drag coefficients and the uncertain relation of z_0 to u_* to the dependence of the atmospheric turbulence on the complex structure of the swell due to other than local winds. Petrosyants discusses the forcing of the flow by mountains, especially the central Asian massif. This paper is open to criticism in its use of maps of divergence without discussion of accuracy, but at least the evidence is presented to the reader — in contrast to several of the other contributions where, perhaps through a desire for brevity, insufficient evidence or only a reference is provided.

Other useful contributions include that by Feigel'son who stresses the difficulties of allowing properly for the optical properties of clouds in radiation calculations (part of a wider field reviewed by Rakipova and Shneerov), Khrgian's discussion of attempts to model the ozone distribution and Girs' review of his and others' work on circulation types and epochs. The last includes

a forecast for 1965–78 which seems too vague for failure! Girs' epochs (1900–28, 1929–39, 1940–48, 1949–60) differ from those derived by Dzerdzeevskii (up to 1916, 1916–52 approximately) who used his daily classifications by 'elementary circulation mechanisms' from 1900, presumably because different criteria were used. Girs considers the sunspot cycle important and Dzerdzeevskii reviews the literature on this topic.

Other subjects covered include use of orthogonal functions with pressure fields (Yudin) (his conclusions should be read in the light of Kutzbach's results*), kinetic-energy partitioning (into mean/eddy and zonal/meridional components) (Gruza), three aspects of atmospheric energies (Borisenkov), southern-hemisphere circulation (Astapenko and Gaigerov), the use of jet streams as circulation indicators (Dzhordzhio) and pressure–wind relations near the equator (Dobryshman). An ocean–atmosphere interaction model is proposed by Laikhtman, Kagan and Timonov, but the solutions to a simple version are not well presented. Marchuk and Temnoeva's solution of quasi-steady equations seems out of place (a discussion of finite-difference methods might have been more appropriate). Obukhov and Fortus's 3 pages on correlation functions are spoiled by a poorly explained diagram and Drozdov's 14 pages on rainfall–temperature relations are indigestible, only partly because of a complete lack of diagrams and a missing table.

The large number of references (over 600, two-thirds of them Russian) may be of value. There are far too many errors, some of them new in the translation, e.g. omission of a figure caption on p. 294. Reading the book is also made more difficult by occasional incorrect or stilted translation, e.g. 'eddy' instead of 'vorticity', 'influence of shores' instead of 'coastal effects'.

To summarize, the value of this collection is reduced by the uneven coverage of its subject, the poor presentation by some of the writers and its delayed publication. It is not a book to be read from cover to cover, but the specialist may find in it interesting viewpoints or some useful references.

P. R. ROWNTREE

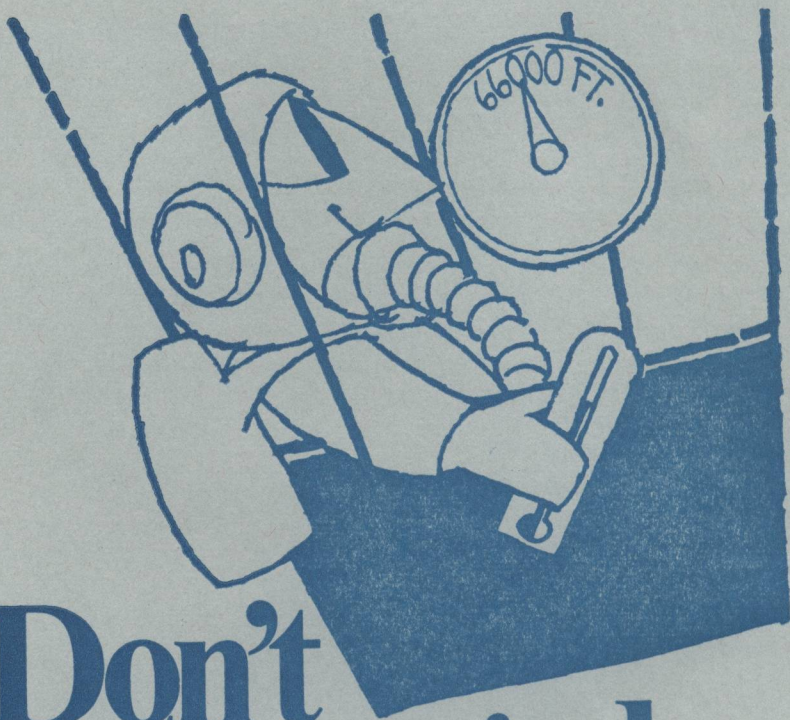
PUBLICATIONS RECEIVED

The following have been received from the Meteorological Institute of the University of Thessaloniki :

Observations météorologiques de Thessaloniki, 1966 and 1967. 1972.

The cooling power in Thessaloniki — Greece. By G. C. Livadas and Chr. J. Balafoutis.

* KUTZBACH, J. E.; Large-scale features of monthly mean northern hemisphere anomaly maps of sea-level pressure. *Mon Weath Rev*, Lancaster, Pa, 98, 1970, pp. 708–716.



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NOTICES

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