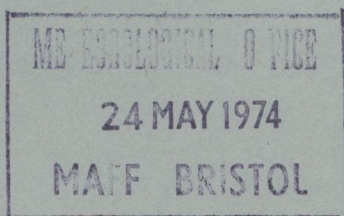


Met.O.871

METEOROLOGICAL OFFICE

*the  
meteorological  
magazine*



APRIL 1974 No 1221 Vol 103

Her Majesty's Stationery Office



# THE METEOROLOGICAL MAGAZINE

Vol. 103, No. 1221, April 1974

551.543.2:551.590.21

## THE VARIATION OF ANNUAL MEAN SURFACE PRESSURE OVER THE NORTHERN HEMISPHERE DURING THE DOUBLE SUNSPOT CYCLE

By M. K. MILES

**Summary.** Weighted annual mean surface pressure data over the northern hemisphere for the six sunspot cycles in the present century have been analysed by the method of superposition of epochs. These epochs have been the position of the year relative to sunspot maxima and minima during the three double sunspot cycles made up of cycles 14 plus 15, 16 plus 17, and 18 plus 19. The anomalies from the average for the period 1901-62 were then averaged for each year of the three even solar cycles and each year of the three odd cycles. The only significant difference between the even and odd cycles occurs in the latitude band 20-35°N, where it is found that the average pressure during the even cycles exceeds that during the odd cycles by 0.43 mb, which is significant at about the 1 per cent level. Some of the difference could, however, be due to a secular change.

**Introduction.** The study was undertaken in an attempt to reproduce a striking result described by Maksimov and Slepcev-Sevlevic.<sup>1</sup> Briefly, they found that around the sunspot maxima of the even sunspot cycles, surface pressure was below average in high latitudes and above average south of 40°N latitude, with the opposite pattern around the maxima of the odd cycles. In addition they found opposite but weaker patterns at the minima of the two cycles, giving thus three maxima and three minima during the double sunspot cycle. These are not, however, equally spaced or of equal amplitude, and the authors do not infer a seven-year cycle. They quote the amplitude of the major difference at high latitudes between the two cycles as about 2½ mb (complete range 5 mb) but do not say if this is taken from the longitudes (Greenland and Alaska) where the effect is strongest, or is a mean round the hemisphere. Since they were using smoothed annual pressures, this value is just about statistically significant even if the maxima had been selected.

**Procedure.** From the monthly mean surface pressures, stored on magnetic tape, annual mean surface pressures were formed. These were smoothed in the way that the Russian authors had described to give a weighted mean annual pressure  $P_w$  related to the unweighted means as follows :

$$P_w = \frac{1}{4} P_{u-1} + \frac{1}{2} P_u + \frac{1}{4} P_{u+1},$$

where  $P_{u-1}$  and  $P_{u+1}$  are the unweighted values for the year preceding and the year following the year to which  $P_w$  refers, and  $P_u$  is the unweighted value for that year.

The departures of the smoothed annual means from the average for the period 1901–62 comprising the three double sunspot cycles analysed by the Russian authors were then computed for each grid point from 20°N to 85°N for the northern hemisphere.

The next step was to find the average anomaly for each year of the three even sunspot cycles and each year of the three odd cycles. The designation of each of the years from 1901 to 1962 relative to the sunspot maxima and minima was done according to a paper by Vitinsky<sup>2</sup> in order to follow the Russian procedure exactly.

The distribution is given in Table I and it will be seen that because the sunspot cycles since 1928 have been about 10 years in length it was thought best to work with 10-year cycles to avoid too much duplication of years. This means of course omitting some years from the period before 1928 when the cycles were longer, but it is thought that the present allocation, if it differs at all from the Russian designation, will affect only one or two years before and after the sunspot minima, and will not in any way affect those around the maxima.

TABLE I(a)—DESIGNATION OF YEARS WITH RESPECT TO SUNSPOT MAXIMUM ( $X$ ) AND SUNSPOT MINIMUM ( $N$ ) FOR EVEN SOLAR CYCLES IN THE PERIOD 1901–62

Cycle No.	$N$	$N+1$	$X-2$	$X-1$	$X$	$X+1$	$X+2$	$X+3$	$N-2$	$N-1$
14	1901	1902	1904	1905	1906	1907	1908	1909	1911	1912
16	1923	1924	1926	1927	1928	1929	1930	1931	1931	1932
18	1944	1945	1945	1946	1947	1948	1949	1950	1951	1952

TABLE I(b)—DESIGNATION OF YEARS WITH RESPECT TO SUNSPOT MAXIMUM ( $X$ ) AND SUNSPOT MINIMUM ( $N$ ) FOR ODD SOLAR CYCLES IN THE PERIOD 1901–62

Cycle No.	$N$	$N+1$	$X-2$	$X-1$	$X$	$X+1$	$X+2$	$X+3$	$N-2$	$N-1$
15	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922
17	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942
19	1954	1955	1955	1956	1957	1958	1959	1960	1961	1962

**Analysis of results.** Figures 1(a) and 1(b) show the distribution of the mean anomalies averaged round several circles of latitude. Each value is a mean of 18 points at 75°N and of 36 points at the other latitudes.

The effect claimed by the Russian authors for high latitudes is not evident in any of the three top curves of Figure 1(a). The curves for latitudes 35° and 45°N, however, show the effect in some degree, though the most pronounced negative anomalies in the odd cycle are centred some three to four years after the sunspot maximum.

None of the anomalies (apart from one for latitude 75°N) approaches the value of 2½ mb quoted by the Russian authors. It may be that this value refers to the locations in Greenland and Alaska where the effects were said to be most marked, so the anomalies for two grid points, one in south-east Greenland and the other in Alaska, were examined. These anomalies are

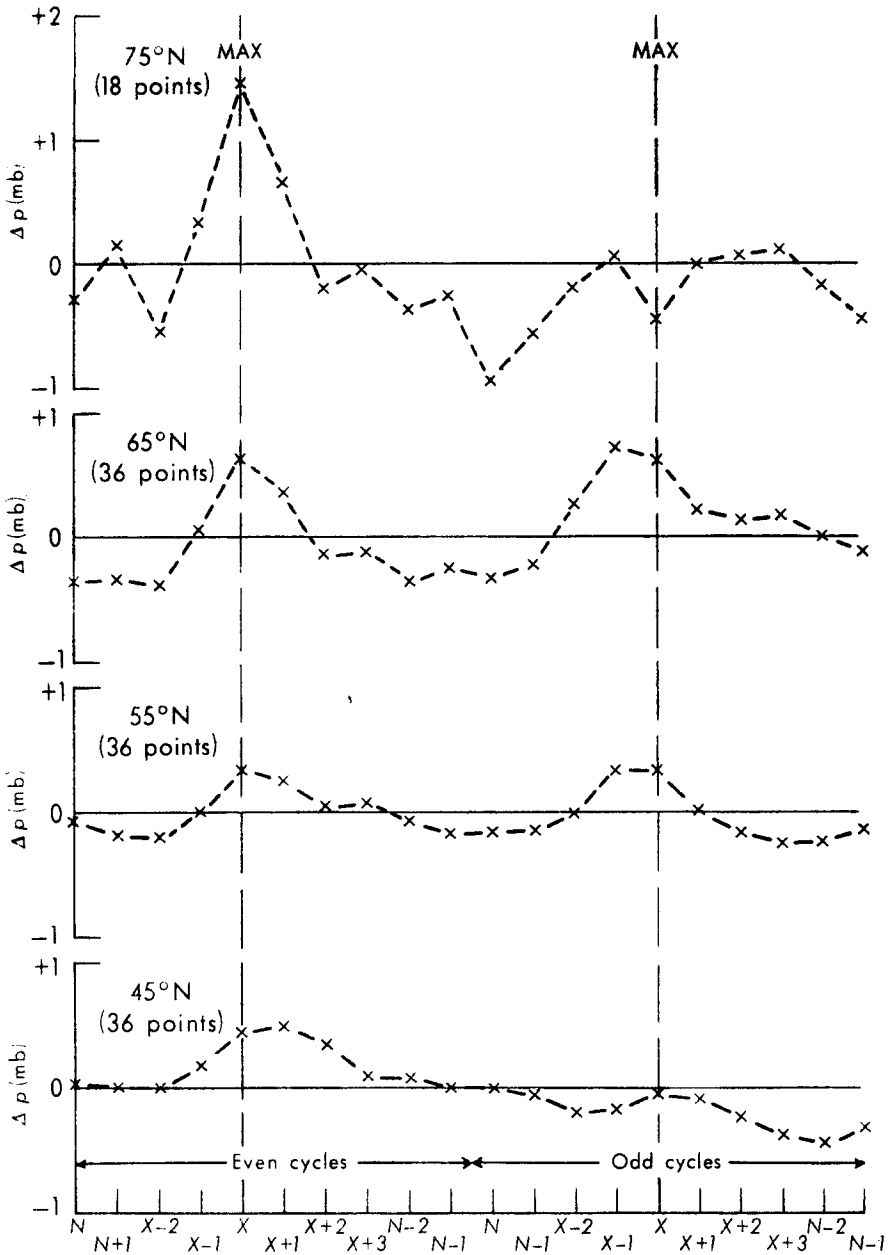


FIGURE 1(a)—AVERAGE ANOMALIES OF WEIGHTED ANNUAL MEAN SURFACE PRESSURE ALONG LATITUDE CIRCLES 45° TO 75°N DURING THREE DOUBLE SUNSPOT CYCLES (1901-62)

$X$  = year of maximum,  $X + 1$  = year of maximum plus one;  $N$  = year of minimum,  $N + 1$  = year of minimum plus one, etc.

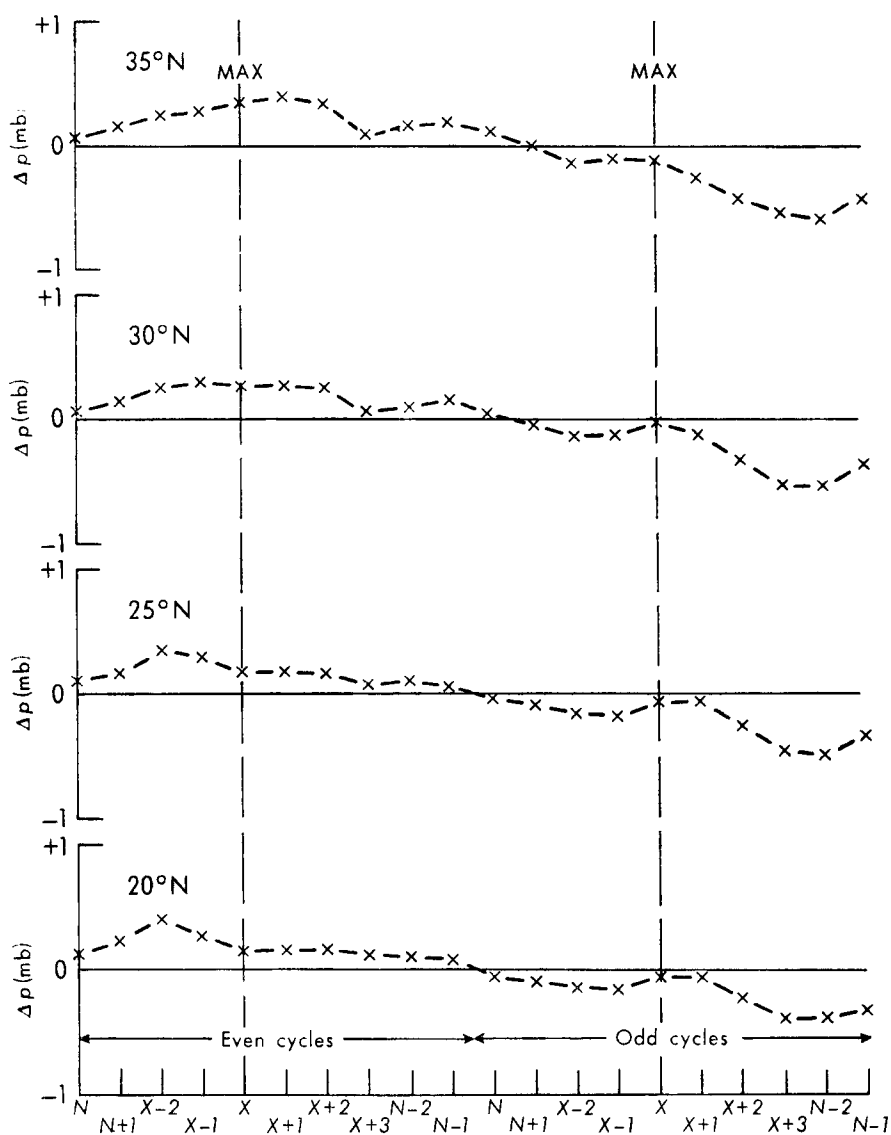


FIGURE 1(b)—AVERAGE ANOMALIES OF WEIGHTED ANNUAL MEAN SURFACE PRESSURE ALONG LATITUDE CIRCLES 20° TO 35°N DURING THREE DOUBLE SUN-SPOT CYCLES (1901-62)

36 points were used in the determination of the mean value for each latitude circle. See note under caption to Figure 1(a).



plotted in Figure 2. For the Greenland position there is some sign of the claimed effect, but for Alaska the pattern is almost reversed as far as the anomalies around the sunspot maxima are concerned. The distribution for a third location — over west Siberia — is also shown. This has so many peaks and troughs that it looks very like a random distribution.

The standard deviations of these weighted annual pressure means are as follows :

- 65°N 40°W (south-east Greenland) 1.3 mb
- 65°N 150°W (Alaska) 2.1 mb
- 65°N 80°E (west Siberia) 1.7 mb.

Each point on the graph is the mean of three years, so these will have standard deviations of 0.8, 1.2 and 1.0 mb respectively. Thus it is possible that any of the anomalies could have been produced by random effects.

To return to the anomalies meaned round the various latitude circles, are any of these clearly outside the value likely to arise from grouping of random data? Assuming that there are four independent values round the latitude circle in high latitudes, increasing to eight in low latitudes, the standard deviations for the mean values plotted in Figures 1(a) and 1(b) range from 0.5 mb in the north to 0.25 mb in the south. Once again, it is possible that all of these anomalies could have arisen by chance.

The distributions at 55° and 65°N suggest a weak effect with a period equal to the single sunspot cycle rather than an effect repeating after a double cycle. The amplitude is, however, insignificantly small, and the apparent regularity of the curve may in part be due to the use of weighted means. The anomalies in the subtropics, though never exceeding twice the standard deviation of the mean, appear to have a surprising amount of organization. The average anomaly for the 10 years of the even cycles is + 0.19 mb and that for the odd cycles is - 0.24 mb, giving a difference which is significant at about the 1 per cent level.

Some of this apparent organization may be due to a secular change in average pressure in the subtropics during the period 1901-62. Data derived from mean maps for 1900-39 and 1951-66 by Lamb, Collison and Ratcliffe,<sup>3</sup> show that the average pressure for latitudes 30° and 35°N in the latter period was 0.67 mb lower than in the former period. This in itself is not large enough to explain the difference in the means for the even and odd cycles, but it reduces it to an amount which is within the play of chance. It is planned to carry out an analysis of this sort for several stations in the tropics with surface pressure data going back to 1901 in an attempt to clarify this point.

**Conclusion.** An analysis of weighted annual mean surface pressures during the double sunspot cycle fails to reveal any unmistakable relation for the three double cycles between 1901 and 1962.

For a location in south-east Greenland there is some sign of an opposite behaviour in even and odd cycles but the magnitude of the effect is so small that it could have arisen by chance. For a location in Alaska the pattern is almost reversed, but again the anomalies could easily have arisen by chance.

For the subtropics there is a rather striking difference between the odd and even cycles, but some of this appears to be attributable to a secular change.

**Acknowledgement.** Mr S. P. Arnold (a vacation student) wrote the computer program for the extraction of the data on which this paper is based.

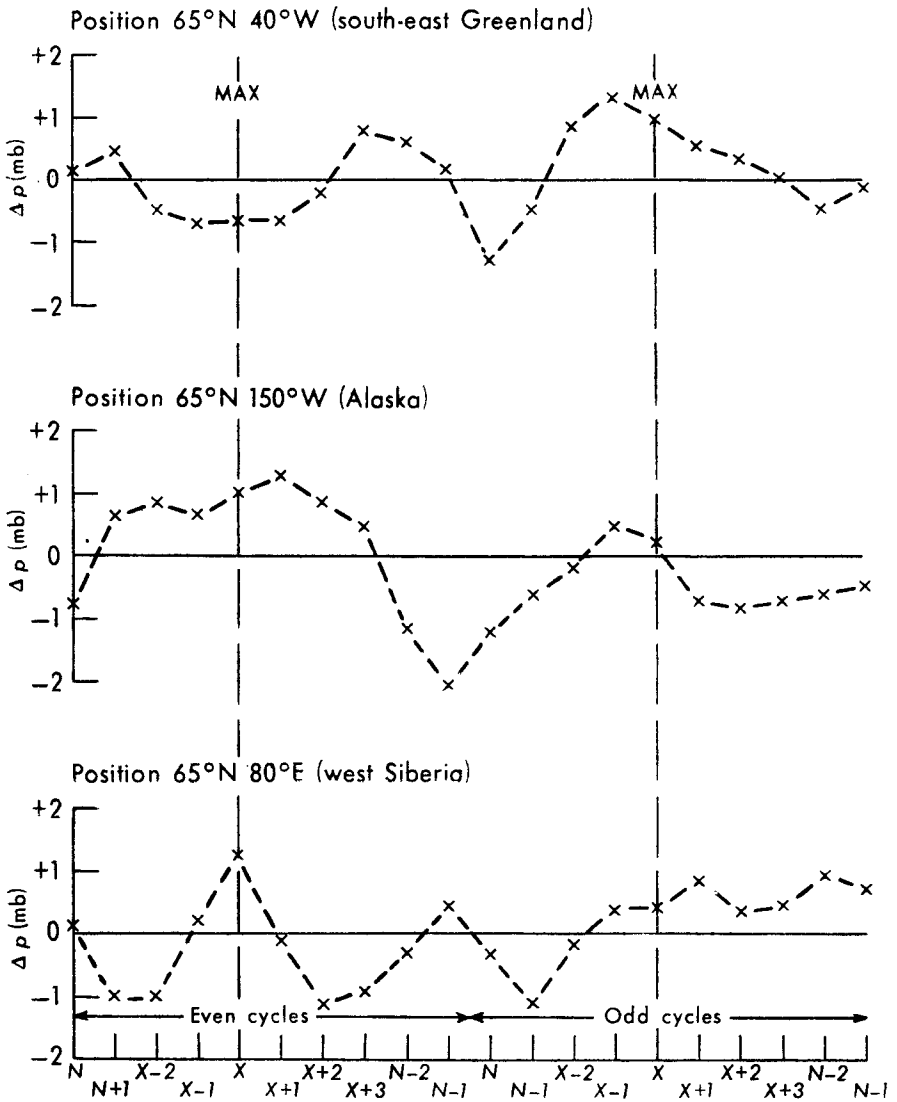


FIGURE 2—ANOMALIES OF WEIGHTED ANNUAL MEAN SURFACE PRESSURE AT THREE LOCATIONS DURING THREE DOUBLE SUNSPOT CYCLES (1901-62)

See note under caption to Figure 1(a).



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## A NOTE ON THE OPTIMUM AVERAGING TIME OF WIND REPORTS FOR AVIATION

By R. N. HARDY

**Summary.** For selected occasions over a three-month period at London/Heathrow Airport, winds averaged over intervals of from 30 seconds to 10 minutes were compared with the 30-second means at later times, simulating the procedure whereby wind observations provided by Air Traffic Control are used by a pilot. The results show that the best averaging time depends on the relative importance of errors of different magnitudes: the few very large errors can be reduced by using a 30-second average, at the expense of many more errors in the range 6-14 kt; the root-mean-square error is normally least with averaging over a period of 5-6 minutes.

**Introduction.** Pilots need to know the surface wind on take-off and particularly on landing to ensure that the most suitable airspeed is used for the transition. Small eddies of some tens of metres in diameter which may take several seconds to pass an anemometer, affect an aircraft at the most critical times — flare, touch-down and lift-off — for less than one second and are of little consequence. At the other extreme, a mean wind over one hour measured at an anemometer may differ for a large part of that hour from the wind experienced by aircraft, because significant eddies have been smoothed out. Somewhere between these extremes lies an averaging period for surface winds which represents the best possible simple observation from a suitably sited anemometer for use by aviation.

There has not been a great deal of work specifically on this subject. The International Civil Aviation Organization<sup>1</sup> recommends that an airfield surface-wind reading should be averaged over two minutes, until this is shown to be inferior to a different interval. Sparks and Keddle<sup>2</sup> showed that in a particular synoptic situation, strong westerly winds in a warm sector, a 4-5-minute averaging period was better. This note presents the results of an experiment designed to extend this work, using winds from the Meteorological Office Mk 5 electronic anemometer system at Heathrow and electronic averaging circuits.

*Arithmetic averaging applied to a fluctuating signal consists of removing high-frequency oscillations whilst leaving low-frequency components unaltered. The analogy with simple capacitance-resistance (CR) electrical filters has been appreciated for many years. Jones and Pasquill<sup>3</sup> have shown how other turbulence statistics may be similarly obtained, while, more recently, Acheson<sup>4</sup> has discussed in some detail 'exponentially-mapped-post' (EMP) averaging, with particular reference to wind measurement. Kamamoto<sup>5</sup> carried out experiments using circuits with different time constants and found that the time constant should be from one-half to one-third of the required averaging period.*

**The Heathrow wind-averaging experiment.** An electronic averaging circuit, details of which are given elsewhere,<sup>6</sup> was connected to the Meteorological Office Mk 5 anemometer system at Heathrow early in May 1973. Thirty-second running means of wind speed and direction were displayed, and values were printed once every 30 seconds when required. To avoid a great deal of uninteresting data, the printer was only operated when the mean wind reached 15 kt, when cumulonimbus cloud or moderate precipitation was reported, or when fronts were forecast in the area. From 3 May to 7 August 1973, the period of operation of the experiment, data were collected for 266 hours; after scrutiny for wind changes, just over 100 hours' data for 42 periods of up to 4 hours each on 27 days were punched on to cards for processing.

An examination of anemogram traces over the same period showed that the averages recorded correspond closely to the variations shown on the charts, and that most of the largest changes had been logged and punched.

**Processing.** The wind averaged over periods of from 30 seconds to 10 minutes, ending at the same time, was compared with the 30-second average commencing some time later. This delay, or lag, was also varied from 30 seconds to 10 minutes. The averaged wind may be regarded as the 'observation'; the lag corresponds to the interval between the observation and aircraft touch-down; and the later 30-second average was taken to represent the 'actual' wind that an aircraft would have encountered. It is considered that a 30-second run of wind past a stationary anemometer will usually be equivalent to the distance covered in a few seconds of flight, and therefore represents eddy sizes of the correct order for this application.

It may seem that the problem resolves itself into selecting the averaging period which, for normal lags, reduces the root-mean-square (r.m.s.) vector deviation, or 'error', between observed and actual winds to a minimum. This is not necessarily so; Burnham<sup>7</sup> suggested that a change of wind speed of as little as 10 kt over a period of one or two seconds can in some circumstances be critical on approach, and, whilst he was concerned with gusts rather than changes in the expected mean wind, it is reasonable to assume that errors in the latter of less than 10 kt are of little interest, whilst above this limit they become increasingly important with size. It soon became clear during data-analysis that the averaging period giving the lowest r.m.s. difference rarely coincided with the period producing fewest errors exceeding 10 kt. Because of this, percentages of occasions with errors exceeding 10 kt were also considered, and also how the optimum averaging time varies if this threshold is changed.

**Results.** Thirty-two sample periods totalling 78 hours and 41 minutes contained differences between observed and actual winds (as defined above) of 10 kt or more with lags of 4 minutes or less, and the results presented here were computed by using these data only. In fact 624 minutes are lost in computing initial means and final lags, so that 68 hours and 17 minutes' data were used.

**Root-mean-square errors.** Figure 1 shows for each lag the amount, in units of 0.01 kt, by which the r.m.s. error exceeded the minimum r.m.s. value at that lag for each averaging time. It can be seen that if the lag is

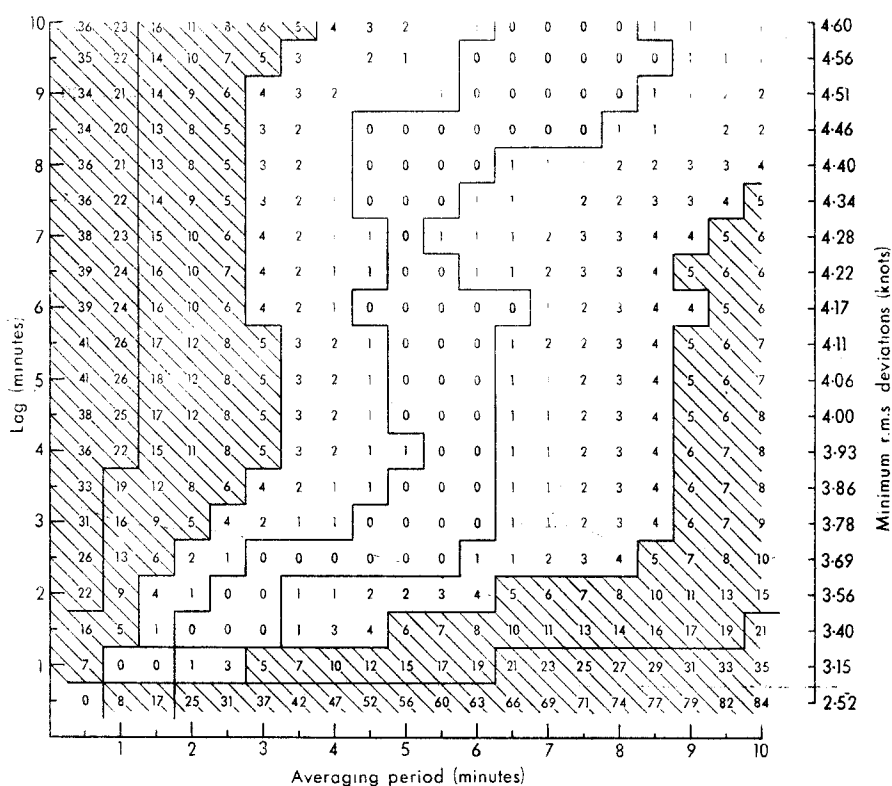


FIGURE 1—AMOUNTS BY WHICH THE ROOT-MEAN-SQUARE VECTOR DIFFERENCES BETWEEN OBSERVED AND ACTUAL WINDS, FOR EACH AVERAGING PERIOD AND LAG, EXCEED THE MINIMUM AT THAT LAG

Values are expressed in units of 0.01 kt, and minima are given at the right-hand side.

likely to be from  $1\frac{1}{2}$  to  $2\frac{1}{2}$  minutes the best averaging time on this basis is near 3 minutes; if the lag is expected regularly to exceed  $2\frac{1}{2}$  minutes then 5-6-minute averaging may be preferable. On the right-hand side of Figure 1 are listed the minimum r.m.s. values at each lag. The change with lag is clearly much greater than with averaging time. In practice anemometers are situated some distance away from the touch-down area and the effective lag, unless the anemometer is directly upwind, will rarely if ever be less than  $2\frac{1}{2}$  minutes.

**Percentage of differences exceeding 10 kt.** Figure 2 presents for lags of from 1 to 10 minutes and all averaging periods the percentage of vector deviations in the sample exceeding 10 kt. It is interesting to see that the number of large errors is, like the r.m.s. deviation, far more sensitive to changes in lag than in averaging time. For all lags, averaging over 5 minutes or more produces more large errors than does 3- $3\frac{1}{2}$ -minute averaging. If the lag is always expected to be 5 minutes or less, there is little to choose between averaging periods in the range  $1\frac{1}{2}$ -4 minutes.

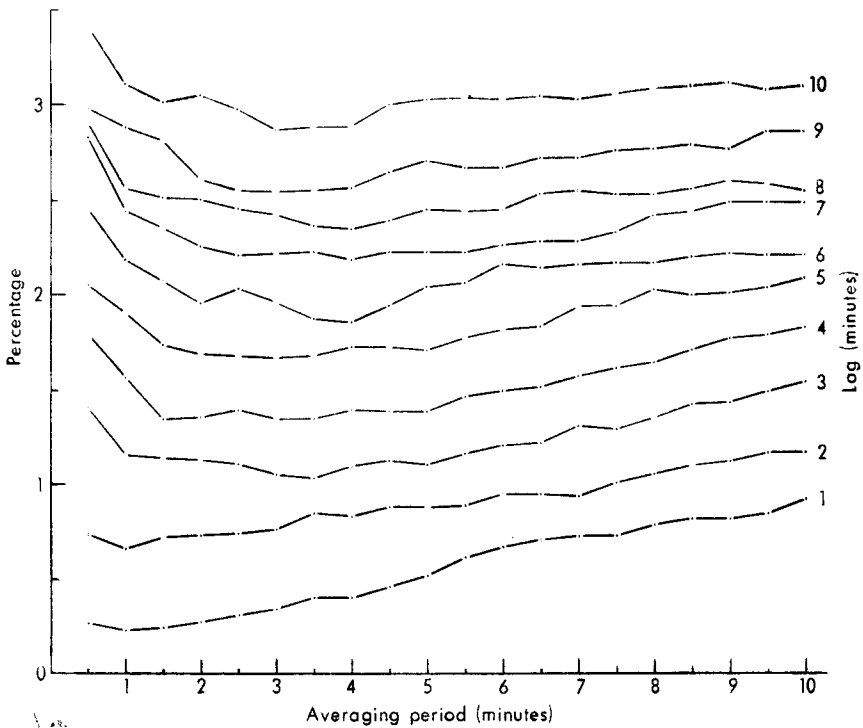


FIGURE 2—PERCENTAGE FREQUENCIES OF VECTOR DIFFERENCES BETWEEN OBSERVED WINDS, AVERAGED OVER PERIODS OF FROM 30 SECONDS TO 10 MINUTES, AND ACTUAL 30-SECOND MEAN WINDS AT LAGS OF FROM 1 TO 10 MINUTES, EXCEEDING 10 KNOTS IN MAGNITUDE

**Percentages of differences exceeding various thresholds.** Since the cut-off of 10 kt is to some extent arbitrary, Tables I(a) and I(b) have been compiled to show the effect of using different thresholds. Both tables give the total percentage of vector errors of magnitude greater than 2–18 kt, for various averaging times. Table I(a) is for a 5-minute lag, and Table I(b) for a 10-minute lag.

It is quite clear from the minimum values (underlined) that in both cases the small proportion of very large errors is reduced still further if a short averaging time is used, at the expense of a considerable increase in errors between 2 and 12 kt.

Unfortunately the percentages of errors exceeding different thresholds are not directly comparable, because the 68-hour sample was selected to include, as far as possible, all large wind changes over the 98-day period of the experiment. This aim was not completely realized, and it is considered that a better estimate of the overall percentages for summertime in southern England of errors of 10 kt or more, would be one-tenth of those given.

It is interesting to note that the largest vector errors are not associated with periods of strong mean winds but rather with sudden changes of direction. Figure 3 shows two such cases; on 3 May, Figure 3(a), a change of 180 degrees

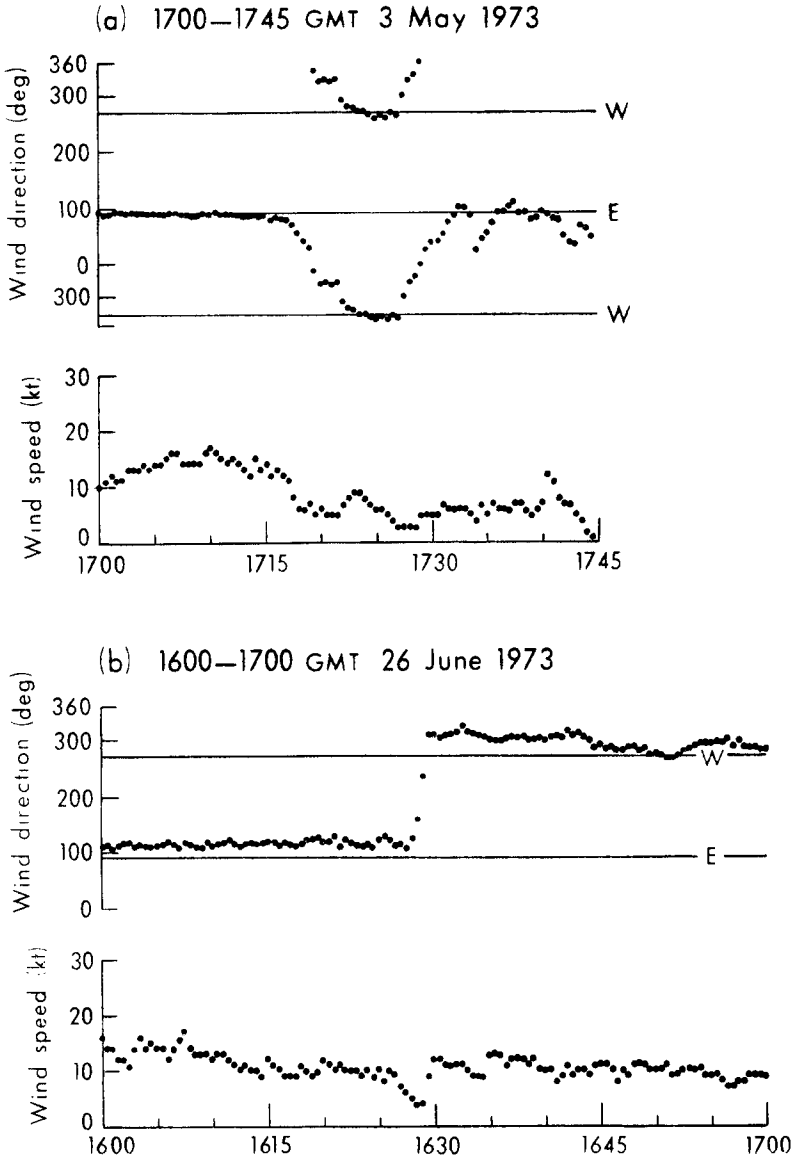


FIGURE 3—EXAMPLES OF SUDDEN LARGE CHANGES IN WIND DIRECTION

over 10 minutes was maintained for only a short period, and on 26 June a 180-degree change took place over 2 minutes and persisted. On both occasions thundery activity was reported in the area and the second undoubtedly marked the passage of an organized frontal system.

TABLE 1(a)—PERCENTAGE FREQUENCIES OF VECTOR DIFFERENCES BETWEEN OBSERVED WINDS, AVERAGED OVER VARIOUS AVERAGING PERIODS, AND ACTUAL 30-SECOND MEAN WINDS, EXCEEDING GIVEN MAGNITUDES, FOR A LAG OF 5 MINUTES

Averaging period <i>min</i>	Magnitude of vector error (knots)				
	2	6	10	14	18
$\frac{1}{2}$	76.9	15.4	2.05	0.52	0.11
2	71.5	11.7	<u>1.68</u>	0.45	0.21
4	69.0	10.5	1.72	0.52	0.23
6	68.8	10.0	1.81	0.63	0.29
8	68.8	<u>9.8</u>	2.03	0.71	0.34
10	<u>68.7</u>	10.0	2.09	0.76	0.39

Minimum values at each threshold are underlined.

TABLE 1(b)—PERCENTAGE FREQUENCIES OF VECTOR DIFFERENCES BETWEEN OBSERVED WINDS, AVERAGED OVER VARIOUS AVERAGING PERIODS, AND ACTUAL 30-SECOND MEAN WINDS, EXCEEDING GIVEN MAGNITUDES, FOR A LAG OF 10 MINUTES

Averaging period <i>min</i>	Magnitude of vector error (knots)				
	2	6	10	14	18
$\frac{1}{2}$	80.3	18.8	3.42	<u>1.10</u>	0.31
2	75.0	15.4	3.05	1.11	0.35
4	72.9	14.0	<u>2.88</u>	1.17	0.44
6	<u>72.3</u>	13.3	3.03	1.23	0.49
8	72.4	13.0	3.09	1.28	0.51
10	73.0	<u>12.8</u>	3.10	1.37	0.50

Minimum values at each threshold are underlined.

**Conclusions.** Differences between an observed wind and the actual wind encountered some time later can be reduced substantially if the delay is reduced to a minimum. This is more critical than the time over which the observation is averaged. Implicit in this conclusion is the desirability that the anemometer should be near, or slightly upwind of, the touch-down area.

To minimize the r.m.s. error, averaging over 3 minutes or more is best except at very short lags. This reduces the variability of observations in stationary situations at the expense of a slow response to the occasional abrupt change.

Errors in excess of 10 kt can be minimized by using a  $1\frac{1}{2}$ -4-minute average except at very short lags when a  $1-1\frac{1}{2}$ -minute reading is preferable.

If it is desired to reduce the number of infrequent large errors, greater than about 15 kt, which, on the evidence of this sample, occur on average for about 1 minute in 2000, then a 30-second average is best.

To summarize: a two-minute averaging period appears to be a satisfactory compromise; if it were reduced then the number of large errors, already

very small, would be reduced still further at the expense of many more deviations in the 6–14-kt range; if it were increased, then more encountered winds would be within 2 kt of the observed wind, but there would be more frequent large errors.

It should be noted that the results presented in this paper refer to summer in southern England, and that results for winter may be somewhat different.

Finally, the experiment demonstrated the ease with which remote digital displays of wind speed and direction, averaged as desired, can be obtained from the Mk 5 anemometer system.

**Acknowledgements.** The author gratefully acknowledges the co-operation of Mr C. R. Barrington and the Meteorological Office observing staff at London/Heathrow Airport.

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### NOTE ON ERRORS THAT MAY BE INDUCED BY USING VISIBILITY OBSERVATIONS TAKEN AT GREATER THAN HOURLY INTERVALS

By R. K. HINZ and G. E. CARROLL

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**Summary.** Parameters describing the low-visibility regime at John F. Kennedy International Airport, New York, for the period 1959–64 were derived by using observations taken at one-hour intervals. Three-hour-interval observations were simulated using the one-hour observations. Comparison of these data sets indicates that marked errors can be introduced in estimates of frequency of occurrence of very low visibilities and in estimates of consecutive hours of occurrence of low visibilities, by sampling at greater than one-hour intervals.

**Introduction.** Shellard,<sup>1</sup> in this journal, demonstrated that a 'very satisfactory' estimate of annual fog frequency could be obtained from observations taken at six-hour intervals. Subsequently Kelly<sup>2</sup> showed that for a specific data set the use of observations taken at three-hour intervals overestimated by only about 4 per cent the total hours of occurrence of fog of 12 hours' duration or more with a visibility of less than 220 yards.

Prior to undertaking an analysis for a study to compare the low-visibility regime at John F. Kennedy International Airport, New York, with that for the adjacent offshore region,<sup>3</sup> the effect of the use of three-hour-interval observations as compared with one-hour-interval observations was re-examined.



This examination was necessitated by the initiation of a program at most U.S. Weather Bureau (now National Weather Service) Stations on 1 January 1965 whereby the number of hourly observations punched for recording on magnetic data-processing tape was reduced from 24 to 8 per day. Moreover the offshore station used for the study, Ambrose Light Station, New York, reported visibility only six times per day. This note is presented to demonstrate the substantial errors that can be caused by using visibility observations taken or recorded at three-hour intervals as compared with one-hour intervals.

**Data used.** The 12-year period 1959-70 was selected for the study, and the data for Kennedy Airport, recorded at one-hour intervals, were therefore available for the 1959-64 segment of the study period. A computer program was written to count the number of consecutive hours, using the one-hour observations, of occurrence of visibilities within selected low-visibility classes. This program was subsequently modified and 'runs' (consecutive hours of occurrence) of low visibilities for sampling at three-hour intervals were generated beginning with the hours 0000 LST (local standard time), followed by 0300 LST, 0600 LST, . . . , 0100 LST followed by 0400 LST, 0700 LST, . . . , and 0200 LST, followed by 0500 LST, 0800 LST, . . . . For the three-hour sampling the assumption was made that each observation of a visibility represents three hours of occurrence of that visibility, as assumed by Shellard and Kelly. The results are presented in Table I.

**Discussion.** The purpose of the Kennedy Airport - Ambrose Light Station comparison<sup>3</sup> was to examine the characteristics of the offshore low-visibility regime, which could have an important effect upon operations at a proposed offshore 'jetport'. Two areas of deviation in Table I which are the result of three-hour sampling that are significant to these operations are (a) estimates of the frequency of occurrence of very low visibilities, and (b) estimates of consecutive hours of occurrence of low visibilities.

(a) *Estimates of the frequency of occurrence of very low visibilities.* Based on hourly observations, the total occurrence of visibility less than 50 yards is 67 hours (Table I). By comparison, the total hours of occurrence for three-hour-interval sampling are the following (the times in parentheses indicate the first hour of the sampling period, and the percentages indicate the percentage differences from the preceding hourly estimates):

1. 48 hours (0000 LST)      -28.4 per cent
2. 75 hours (0100 LST)      11.9 per cent
3. 78 hours (0200 LST)      16.4 per cent.

The data presented by Shellard in his Tables I and II for visibilities less than 44 yards show differences comparable with those above:

Station	Type	One-hour observations	Three-hour observations	Percentage difference
<i>Average number of hours per annum</i>				
Mildenhall	rural	20	14	-30.0
West Raynham	rural	17	13	-23.5
Croydon	urban	21	23	+9.5

Shellard's comment that 'very satisfactory estimates of annual frequency can be obtained using observations made at 0300, 0900, 1500 and 2100 G.M.T.' must be evaluated in the light of what is 'very satisfactory'.

TABLE 1—CONSECUTIVE HOURS OF OCCURRENCE OF SELECTED LOW VISIBILITIES AT NEW YORK/KENNEDY AIRPORT, 1959-64, BASED ON HOURLY AND THREE-HOURLY OBSERVATIONS

		Consecutive hours of occurrence(Y)																																	Total hours Σ/Y	Percentage difference from hourly obs
		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	33		
		Number of occurrences ( / )																																		
Visibility less than 50 yd																																				
Hourly observations		12	7	5	1	2	0	0	0	0	0	0	1																							
Three-hourly obs																																				
starting at		0000	10	1	1	0	1	0	0	0	0	1	1																							
		0100	19	1	1	0	0	0	0	0	0	1	1																							
		0200	16	1	3	0	0	0	0	0	0	1	1																							
Visibility less than 1/4 n. mile																																				
Hourly observations		115	56	37	19	8	5	8	0	5	2	2	1	0	1	2	0	1	(1)																	
Three-hourly obs																																				
starting at		0000	97	25	46	12	12	12	3	3	3	3	3						0																	
		0100	92	35	11	11	5	5	5	5	5	5	5						0																	
		0200	102	19	18	18	2	4											0																	
Visibility less than 1/2 n. mile																																				
Hourly observations		128	50	46	39	18	14	11	10	4	3	4	0	0	3	2	2	0	0	0	0	0	1	0	0	1										
Three-hourly obs																																				
starting at		0000	130	48	30	17	8	6	6	6	6	6	6						2																	
		0100	122	55	21	17	5	7	7	7	7	7	7						1																	
		0200	121	44	23	23	9	6	6	6	6	6	6						2																	
Visibility less than 1 n. mile																																				
Hourly observations		203	96	67	48	28	31	21	11	9	7	5	4	4	1	6	1	3	1	2	0	0	0	0	0	0	0	0	0	0	0	0	1			
Three-hourly obs																																				
starting at		0000	185	82	31	31	16	16	16	16	16	16	16	10	10	10	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3			
		0100	177	79	42	42	12	12	11	11	11	11	11	11	11	11	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7			
		0200	181	79	33	33	18	18	18	18	18	18	18	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10		

All times are expressed in Local Standard Time.

The data in the last column of Table I indicate that the percentage of error increases as the visibility class considered decreases. As a measure of deviation ( $D_t$ ) in per-cent of the three-hour estimates from the related one-hour estimate, let

$$D_t \doteq \text{abs. } D_1 + \text{abs. } D_2 + \text{abs. } D_3,$$

with  $D_1 = ((z_1 - X)/X) (100)$ ;  $D_2 = ((z_2 - X)/X) (100)$ ;  $D_3 = ((z_3 - X)/X) (100)$ , where  $z_1, z_2, z_3$  are the three-hour estimates of the total hours of occurrence of visibility in a visibility class, and  $X$  is the total of hours of occurrence of that visibility based upon one-hour observations. The absolute value (abs.) of the deviations is used because  $X$  is the mean of  $z_1, z_2$ , and  $z_3$  and algebraically the sum of the deviations around the mean of a sample is zero.

In order to test the significance of the apparent relationship between  $D_t$  and visibility class, additional one-hour-interval and three-hour-interval samples were generated from the data for Kennedy Airport for the two-year period 1959-60 and for the four-year period 1959-62. These data are combined with the data in the last two columns in Table I and are presented as Table II.

TABLE II—VISIBILITY CLASS LIMIT, DEVIATION ( $D_t$ ) AND TOTAL HOURS OF OCCURRENCE BASED ON ONE-HOUR OBSERVATIONS OF VISIBILITY IN EACH VISIBILITY CLASS ( $X$ ) FOR THREE-HOUR OBSERVATIONS AT KENNEDY AIRPORT

Visibility class limit yards	1959-64		Sample period 1959-62		1959-60	
	$D_t$	$X$	$D_t$	$X$	$D_t$	$X$
50	56.7	67	56.0	50	114.2	14
506	12.6	700	17.2	464	17.4	218
1012	5.1	1114	8.4	739	4.5	353
2024	3.1	1988	2.2	1323	3.3	658

Plotting deviation ( $D_t$ ) against visibility class results in an approximately hyperbolic curve. A reciprocal transformation was applied to the values of  $D_t$  to obtain a straight-line regression.<sup>4</sup> The least-squares regression line passing essentially through the origin was computed for the transformed values ( $1/D_t$ ) on visibility class. The resulting regression coefficient was  $2.0 \times 10^{-1}$ . Analysis of variance for the linear regression is presented as Table III.

TABLE III—ANALYSIS OF VARIANCE FOR LINEAR REGRESSION OF THE RECIPROCAL OF DEVIATION ( $1/D_t$ ) ON VISIBILITY CLASS

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value
Due to regression	1	0.20954	0.04391	96.45518*
Deviation about regression	10	0.02134	0.00046	
Totals	11	0.23088		

\* Significant at the 0.1 per cent level.

It is clear from the  $F$ -value that an increase in the percentage of error is significantly related to a decrease in the visibility value considered. This is most likely due to the shorter duration of periods of lower visibilities in fog.<sup>5</sup>

(b) *Consecutive hours of occurrence of low visibilities.* Along with the total hours of occurrence of low visibilities, the persistence of low visibility has a marked effect upon airport operations, and thus often has a financial impact upon airport users. 'Bottleneck delays' due to low visibility result in a queueing effect for arriving aircraft. This effect is cumulative with the waiting line, and thus aircraft holding time, reaching its greatest length at the end of the period of curtailed service.<sup>6</sup> As the length of the waiting period increases, the number of aircraft diversions and cancellations increases.

Table I shows that the longest period of consecutive hours of occurrence of visibility less than  $\frac{1}{4}$  nautical mile (n. mile) was 17 hours. By comparison, the samples generated at three-hour intervals suggest occurrences of 18, 21 (2 occurrences), and 24 consecutive hours with visibility less than  $\frac{1}{4}$  n. mile. Examination of the left-hand side of Table I reveals that three-hour observations inherently over-estimate the number of three-hour runs for all visibility classes. It is apparent from Table I that marked variation exists between three-hour sampling and hourly sampling as well as among the three-hour-interval samples.

For the Kennedy Airport-Ambrose Light Station study the sample period for the comparison of persistence of low visibilities was shortened from the 1959-70 period to the 1959-64 period for which hourly observations for Kennedy Airport were available. The Ambrose observations had been taken six times per day. Runs at four-hour intervals were therefore generated from the Kennedy Airport observations beginning with the hours 0000 LST, 0100 LST, 0200 LST and 0300 LST. These four samples were compared and the largest number of occurrences for each four-hour interval is reported in Table IV. This technique maximizes the runs of consecutive hours of low visibility at Kennedy Airport and thus results in the most conservative estimate of differences of persistence between Kennedy Airport and Ambrose Light Station. The greater incidence of protracted periods of low visibilities at Ambrose Light Station as compared with Kennedy Airport, shown by the results in Table IV, supports the hypothesis that, in general, sea fogs tend to be prolonged by comparison with land fogs.<sup>7,8</sup>

TABLE IV—RUNS OF CONSECUTIVE HOURS OF LOW VISIBILITIES, 1959-64, NEW YORK/KENNEDY AIRPORT AND AMBROSE LIGHT STATION, NEW YORK

Visibility	Station	Consecutive hours of occurrence							
		1-4	5-8	9-12	13-16	17-20	21-24	24-30	31-36
		<i>number of runs</i>							
Less than 50 yd	Kennedy	19	2	1					
	Ambrose	24	49	17	4	1			
Less than $\frac{1}{4}$ n. mile	Kennedy	96	22	10	6	1			
	Ambrose	58	91	25	8	4	7	1	3
Less than $\frac{1}{2}$ n. mile	Kennedy	129	53	17	7	2	2		
	Ambrose	72	102	29	10	7	5	1	3

**Conclusion.** Sampling at greater than hourly intervals can introduce significant errors in estimates of frequency of occurrence of very low visibilities.

When comparing the low-visibility regimes at different stations one should compare statistics derived in like manner from the basic data, even if this involves debasing the statistics from some of the stations where the data are capable of greater resolution.

**Acknowledgement.** The authors wish to thank Mr C. L. Hawson, Meteorological Office Headquarters, Bracknell, for his valuable comments in revising their original manuscript.

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## MEASUREMENTS OF THE SWING OF A BALLOON PAYLOAD

By J. S. FOOT, E. L. SIMMONS and A. E. WHITTAKER

**Summary.** An instrument is described for measuring the angular swings of a balloon package. Results are presented from a flight which indicated that the large swings of approximately  $\pm 25$  die away rapidly as the rate of ascent is reduced.

**Introduction.** The measurements were conducted to determine the required angular slew-rates from a balloon-borne sun-seeker, but seem of wider interest because there are a number of experiments in which some knowledge of the angular excursions of a balloon payload are desirable. The apparent solar zenith angle at the package was observed by measuring the output of an upward facing silicon solar cell.

**Description of the apparatus.** In order to give the solar cell a fairly accurate cosine response and to reduce interference by sky-light, a piece of opal glass and a red glass filter were placed above the cell, while linearity was ensured by using an amplifier which presented a low input impedance. The output of the amplifier was fed into a voltage-controlled oscillator, which modulated a 27.5-MHz transmitter. The cell was mounted at the centre of a 'spider' with arms about 210 mm long suspended by three wires. The cell was levelled by rotating the suspension point with the cell in full sunlight and adjusting until the output was independent of azimuth.

If  $\theta$  is the mean solar zenith angle and  $\varepsilon$  the excursion from this, the transmitted frequency is given by

$$f = f_0 + A \cos(\theta + \varepsilon)$$

$$= f_0 + A (\cos \theta + \varepsilon \sin \theta - \frac{1}{2!} \varepsilon^2 \cos \theta + \frac{1}{3!} \varepsilon^3 \sin \theta + \dots).$$

Hence  $(f^- - f^+) / (\bar{f} - f_0) \approx 2\varepsilon \tan \theta (1 - \varepsilon^2/6)$ , where  $f^+$  and  $f^-$  are the frequencies for the angular excursions  $\pm \varepsilon$  respectively,  $\bar{f}$  is the mean value of the frequency when the excursions are small and  $f_0$  the frequency when the cell is not illuminated. The term in  $\varepsilon^2$  can be neglected for values of  $\varepsilon$  up to  $20^\circ$  so we have

$$\varepsilon = \frac{1}{2} \cot \theta (f^- - f^+) / (\bar{f} - f_0).$$

Solar zenith angles are calculated from the *Nautical Almanac*, so there is no calibration needed except for the levelling referred to above, and a check that a cosine response is obtained and that  $f_0$  remains constant over the expected range of battery voltage and temperature.

**Results.** The apparatus was flown on 3 occasions of which the last (15 June 1973 at Beaufort Park) is described in detail. On this occasion the balloon ascent was controlled by a baroswitch-actuated valve and a controlled leak. Figure 1 shows the balloon height measured by radar plotted against time. The baroswitch was set to actuate at about 15 km. With the leak provided, 0.3 m of 32-mm-diameter pipe, it took approximately 20 minutes to lose free lift and start descending. Figure 2(a) is representative of the first 30 minutes of the flight. The amplitude of swing thereafter increased until minute 56, by which time the swing had become quasi-periodic with large and variable amplitude, as shown in Figure 2(b). As the rate of ascent began to decrease the amplitude decreased until minute 71, when the ascent rate was less than 1 m/s and the swing was less than  $\pm \frac{1}{2}^\circ$ . Figure 2(c) shows that from minute 71 to 74 the swing remained at this low level, but built up after this time when the balloon was descending at a speed greater than 2 m/s. The three supporting wires interrupted the sunlight as the sonde rotated and gave rise to a fine structure on the trace which is not shown in the Figure. The speed of rotation during the period from minute 71 to minute 74 was 16 rev/min. As the rate of descent increased the oscillation built up rapidly, but then decreased towards minute 92 (Figures 2(d) and

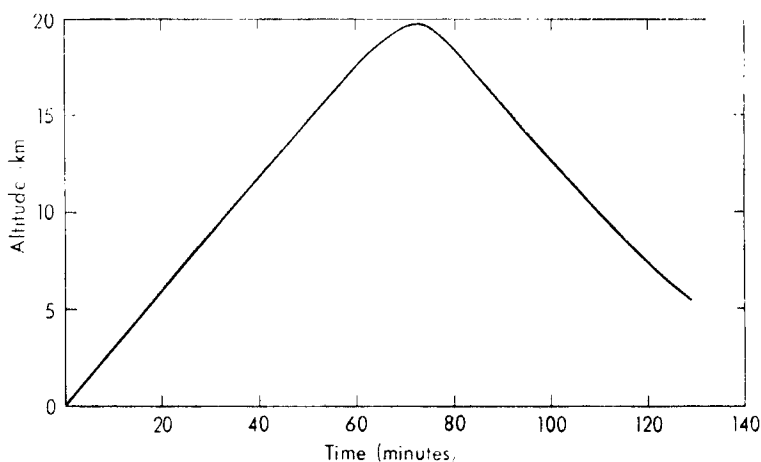


FIGURE 1—ALTITUDE OF THE BALLOON MEASURED BY RADAR VERSUS TIME

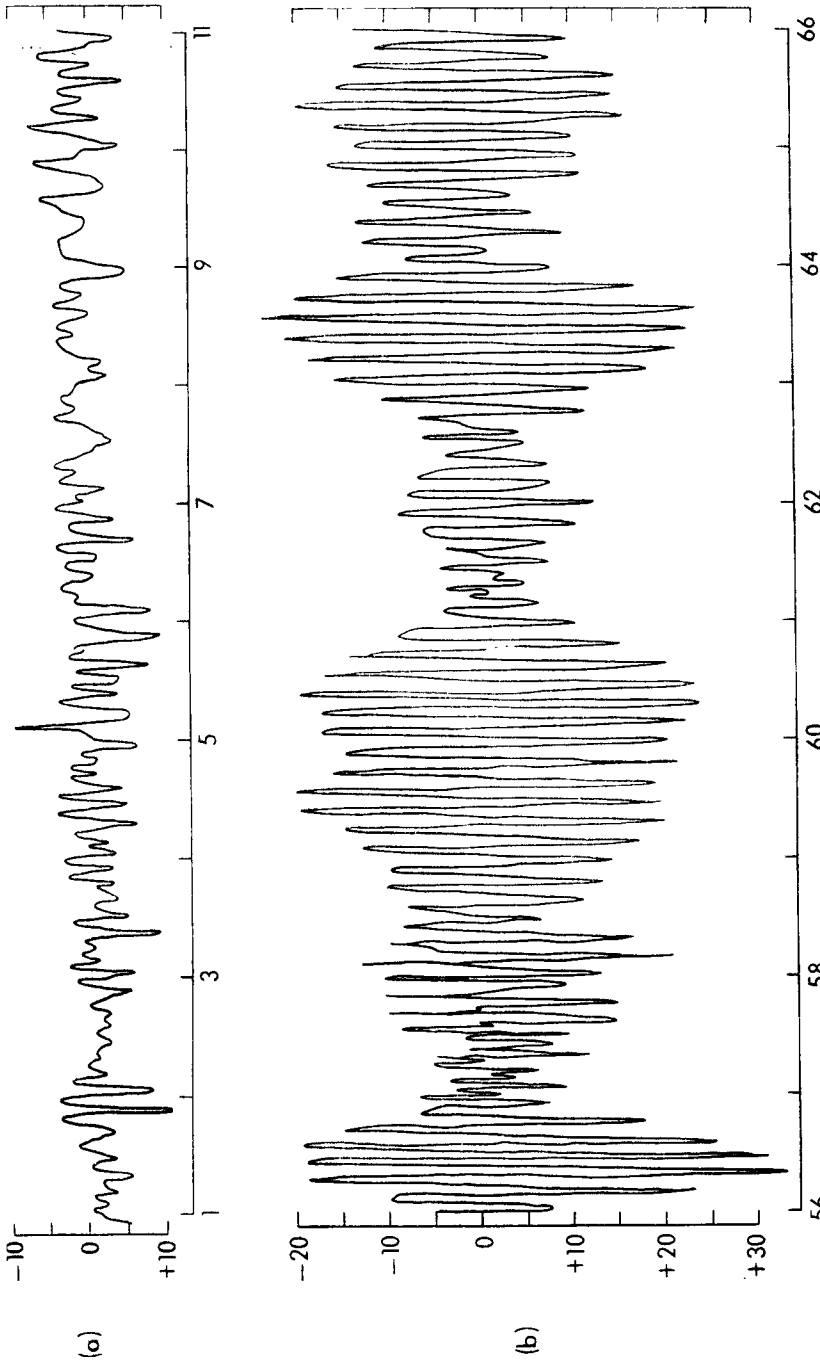


FIGURE 2 — TRACINGS OF SELECTED PORTIONS OF THE RECORDED OUTPUT OF THE TELEMETRY FREQUENCY METER  
The vertical scale gives the angular excursion in degrees and the horizontal scale the time in minutes.



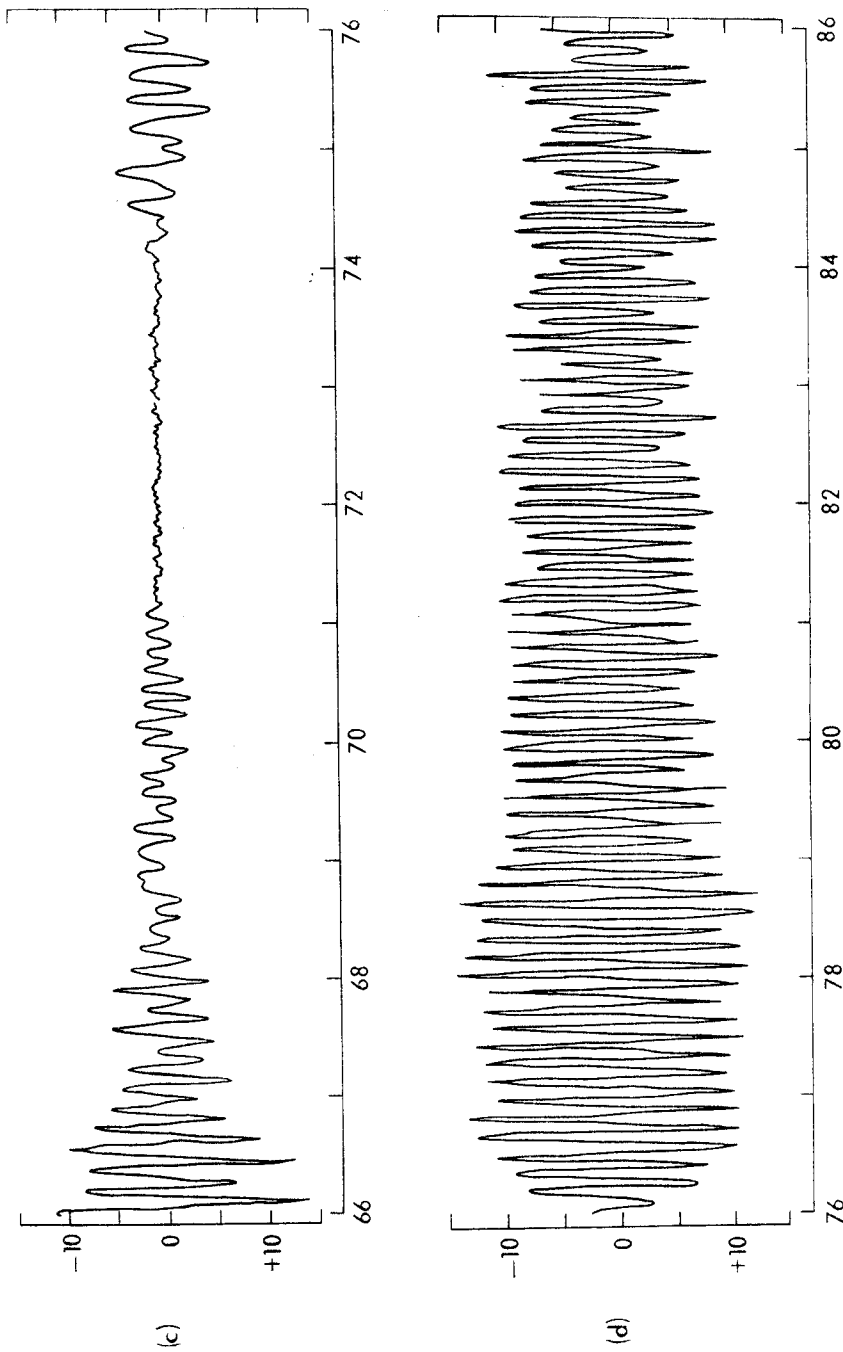


FIGURE 2 —continued

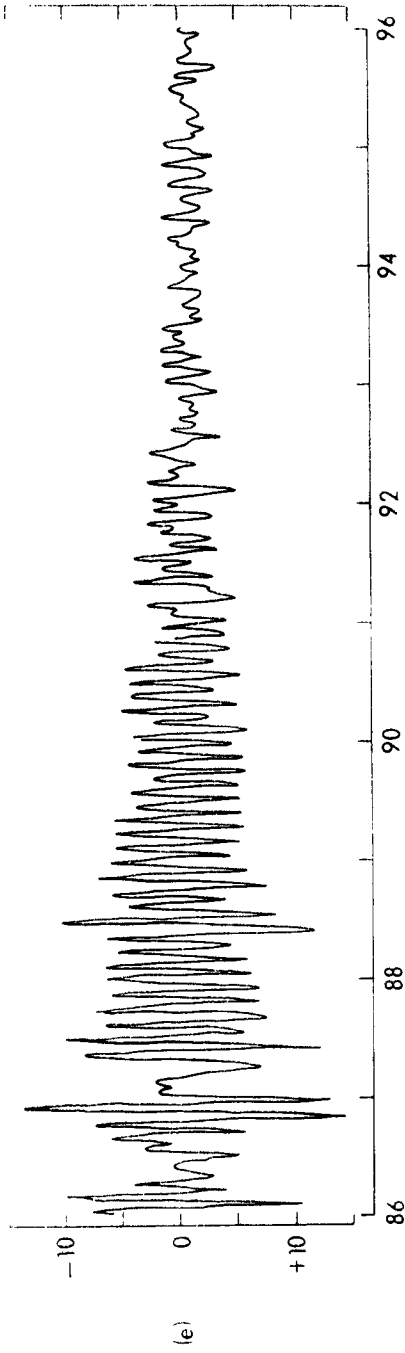


FIGURE 2 *continued*

2(e)) and remained similar until loss of contact at minute 129. On the descent the aerodynamic properties were different from those on the ascent, since the sonde was supported by the partially deflated balloon assisted by a paper parachute attached to the radar target in the conventional manner.

**Discussion.** The flight achieved its purpose in demonstrating the small amplitude of swing encountered under the conditions under which the sun-seeker will be used, when the descent rate is less than 2 m/s. The swinging at higher speeds represents a number of features which are only partially understood. They are apparently fairly typical because similar results were obtained on other flights.

The period, calculated from those regions where the swinging appeared roughly sinusoidal, was 9.8 s on the ascent, decreasing progressively during the descent to 7.1 s. The length of the train, excluding the balloon, was 27 m, and the period on the ascent is that for a simple pendulum of length 24 m, so one may picture the whole system pivoting about a point near the balloon. On the descent the equivalent simple-pendulum length decreased to 12.5 m. It is difficult to account for this short period except in terms of strong forcing.

The maximum amplitude of swing was  $\pm 25^\circ$ , which corresponds approximately to a periodic horizontal velocity of the package relative to the balloon of magnitude 7 m/s.

There does not appear to be any correlation between the swinging of the balloon and the wind shear calculated from the radar data. In particular the regions of shear traversed on ascent and descent must have been similar, but the pattern of swinging is noticeably different. We conclude that the swinging is mainly controlled by the aerodynamics of the balloon itself so that the results obtained are not peculiar to one day and a particular relation between the direction of the sun and the wind-shear vector.

**Acknowledgements.** Thanks are due to Messrs E. W. C. Harris and J. Fitzsimons for help with the launching of the balloons.

551.553.11

## A SHORT NOTE ON A SEA-BREEZE CROSSING EAST ANGLIA

By M. F. SMITH

(Meteorological Office, Honington)

**Summary.** A remarkable sea-breeze front with considerable radar echoes but no significant cloud or weather was tracked 85 nautical miles inland from the coast of East Anglia.

**Introduction.** This note describes the passage of a sea-breeze front across East Anglia on 14 June 1973.

**Synoptic situation.** At 15 GMT an anticyclone was centred over the southern North Sea and Low Countries with a south-westerly gradient wind of 15 kt\* over southern England.

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\* Distances, heights and speeds are given in traditional British units. Conversion factors to metric units are: 1 knot  $\approx$  0.5 m/s; 1 mile  $\approx$  1.6 km; 1 foot = 0.3048 m; 1 nautical mile  $\approx$  1.86 km.

**Radar echo.** Honington Air Traffic Control radar reported at 18 GMT a line of echoes following the shape of the coastline and about 5 miles wide from the north Norfolk coast, over Honington, to Essex. This anomalous propagation slowly dissipated after 19 GMT.

**Temperature gradient** (Figure 1). The sea surface temperatures were generally 12°C and maximum coastal temperatures were in the range 14–18°C while temperatures inland reached 20°C.

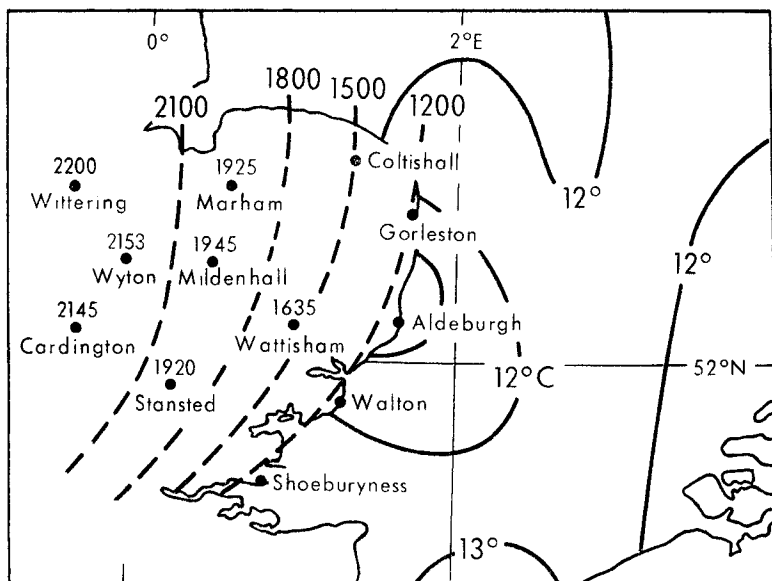


FIGURE 1 —MEAN SEA SURFACE TEMPERATURE ISOTHERMS 11–15 JUNE 1973 AND POSITIONS AND TIMES OF SEA-BREEZE REPORTS

Times are in GMT.

**The sea-breeze front.** A glider pilot from Tibbenham airfield (about 15 miles south-south-west of Norwich) reported that the front extended to 4000 ft when it passed over Tibbenham at 15 GMT. This height is supported by the 12 GMT Hemsby ascent (Figure 2). The Cardington BALTHUM ascent at 2241 GMT showed cooling to about 2100 ft (Figure 3). Backing winds on the 12 GMT Hemsby ascent and on a PILOT ascent from Shoeburyness at 1035 GMT suggested cold advection (see Table I).

**Progression of the sea-breeze front** (Figure 1). South-easterly winds occurred on the East Coast by about 12 GMT. The front progressed at approximately 5 kt and passed through Honington at 1810 GMT with a maximum gust of 20 kt, a temperature fall of 4 degC and a rise in relative humidity of 20 per cent. After 18 GMT the front accelerated and reached Cardington at 2145 GMT and Wittering at 22 GMT. It was not possible to follow the penetration any further as winds were light and radiation was taking place.

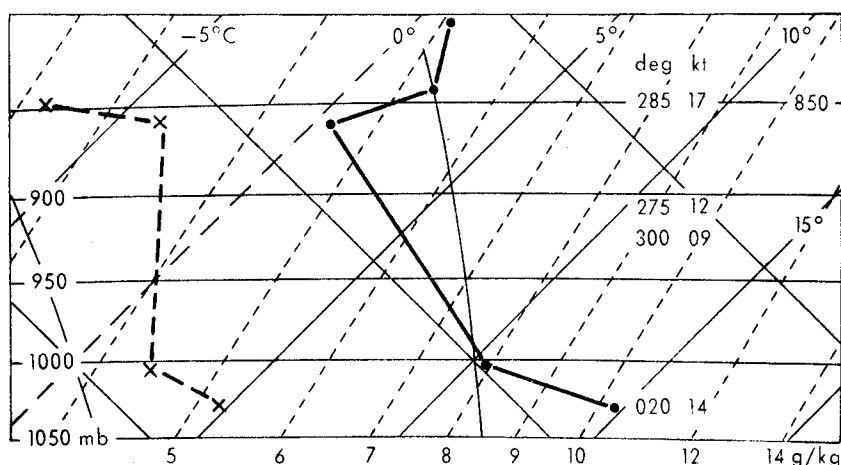


FIGURE 2—HEMSBY RADIOSONDE ASCENT FOR 12 GMT, 14 JUNE 1973

—•— Dry-bulb temperature      x --- x Dew-point temperature

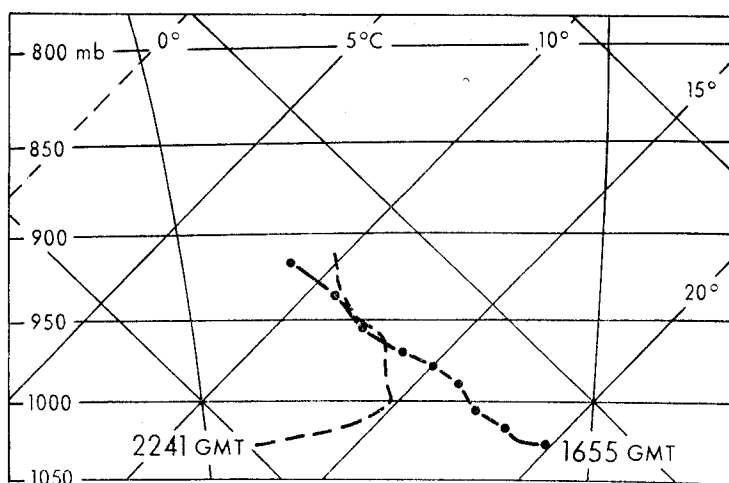


FIGURE 3—CARDINGTON BALTHUM DRY-BULB CURVES FOR 14 JUNE 1973

TABLE I—SHOEBURYNNESS PILOT ASCENT AT 1035 GMT, 14 JUNE 1973

Height metres	Wind direction degrees from north	Wind speed knots
10	115	08
150	120	12
300	110	08
450	075	03
600	030	07
750	340	10
1000	330	11

**Discussion.** The progress of this sea-breeze front was remarkable as it penetrated 85 nautical miles inland against a 10-kt westerly component to a height of 5000 ft and the initial temperature differential was only 8 or 9 degC. There was no low cloud when the front passed Honington and only small amounts had been reported over East Anglia throughout the afternoon. Some patches of altocumulus and cirrus were reported. The assumption was made that the anomalous propagation (anaprop) was attributable either to the inversion at about 4000 ft or to the inversion created near the surface by the sea-breeze.

## REVIEWS

*Advances in satellite meteorology*, edited by A. I. Burtsev, P. N. Belov and Sh. A. Musaelyan. 240 mm × 165 mm, pp. vi + 305, *illus.* (translated from the Russian by the Israel Program for Scientific Translations, Jerusalem and London), John Wiley and Sons Ltd, Baffins Lane, Chichester, Sussex. 1973. Price: £7.50.

This is the first volume of a collection of papers dealing with varied aspects of satellite meteorology. Thirty papers and their bibliographies demonstrate the intense interest and activity in satellite research in the U.S.S.R. The satellite is evidently seen as providing the answer to many of our present meteorological problems!

As might be expected at the present stage of progress, only a modest number of papers deal with the elementary subjective aspects of photographic interpretation of visual pictures. Of interest to users of automatic picture transmission (APT) photographs will be the papers 'Utilization of satellite information in synoptic practice' by E. P. Dombkovskaya and V. F. Chernova, 'Some parameters of cyclonic vortices' by T. P. Popova, and 'The cloud field and cyclogenesis' by T. P. Popova and T. A. Irisova. Mesoscale features are investigated in 'Cellular convection in a vorticity field' by N. F. Vel'tishchev and A. A. Zhelnin, and 'Cloud eddies in wakes of islands' by T. Kh. Geokhlanyan.

Other papers in the same tradition but with a geographical emphasis are concerned with the more usual aspects of synoptic processes, e.g. 'Depressions and cloud systems over the Pacific Ocean' by Yu. V. Kurilova and I. R. Egorova. From this, the following extracts which agree with our own experience are worth quoting: 'The occlusion process in fast-moving depressions over the ocean occurs in a shorter period than that displayed on synoptic maps by frontal analysis', 'according to the cloudiness, occluded fronts occur in the form of strongly-bent spirals. Thus, satellite information leads to the conclusion that Bergeron's ideas about backbent occlusions are near the truth' and 'according to satellite data, the cloud system of an occlusion is maintained longer than the occluded front itself on synoptic maps'.

In many meteorological services, subjective interpretation of APT photographs is used as a basis for the laborious preparation of nephanalyses. Here is an obvious need for automatic picture processing by computer. Aspects of this problem are tackled in 'Computer processing and analysis of TV cloud

photographs' by I. S. Solov'eva, D. M. Sonechkin and V. F. Kharitonov; the corresponding problem of infra-red interpretation is dealt with in 'Automatic analysis of cloud cover by infra-red photography of the earth from Meteor satellites' by D. M. Sonechkin and L. M. Soskin. Many other papers deal with infra-red measurements and include problems of determining cloud tops, of vertical temperature profiles and of radiation flux. Also included is the computation of heat flux for use in numerical weather forecasting.

Objective analysis is an obvious field for the application of satellite data and the problem of using Satellite Infra-Red Spectrometer (SIRS) data must be well known to most forecasters. One paper deals with the effectiveness of utilizing cloudiness data obtained from satellites in objective analysis of the wind field, and another paper with the calculation of geopotential fields at various atmospheric levels from data on the overall cloudiness and temperature. With primitive-equation models, the moisture field is of great importance and this is reflected in the fact that five papers are devoted to the analysis of atmospheric moisture.

Apart from one or two instances where interest is mainly theoretical, the papers are characterized by a refreshing directness of approach, a somewhat naïve appeal to statistical method and a concern for the practical need. They will be a source of interest and knowledge to practising forecasters and others concerned with the application of satellite techniques to current problems. The translation is adequate and very few errors were noted.

T. H. KIRK

*Modifying the weather* by W. R. D. Sewell *et alii*. 225 mm × 150 mm, pp. xvi + 349, *illus.*, Department of Geography, University of Victoria, Victoria, British Columbia, Canada. 1973. Price: \$4 (paperback).

Despite its title this volume has little to tell about the techniques of weather modification or the science of atmospheric physics upon which it must be based. The authors are concerned almost entirely with the impact of weather modification upon individuals and on society, if and when any substantial changes in weather can be achieved by artificial means. They consider how the community should decide whether the benefits of weather modifications for some activities outweigh its less welcome effects on others, also what organizations are needed to control and manage weather modification and what its potential effects may be.

The book is made up of the background papers presented at a 'Symposium on Human Interactions with the Atmosphere' held at Boulder, Colorado in October 1972. Some 50 people attended and a synthesis of the discussion is incorporated in the papers as published. There are nine authors, each having written one chapter except for one with joint authorship. Some overlap is inevitable, but the topics covered are broadly: social research on the impact of weather modification, public concern on the scientific response to it, ecological effects, urban and agricultural effects on climate, assessment of benefits and political aspects. Dr W. R. D. Sewell contributes an introductory survey and final summary.

The reader will probably ask himself whether it is a good thing that this book has been published, or indeed whether it was appropriate to hold a



symposium on human interactions with the atmosphere. Although there are some local weather changes which can be caused by man's activity, deliberate or accidental, it is not the local clearance of cold fog or the urban heat island on a winter night which are the concern of the authors. Their main discussions centre around rainfall augmentation, hail suppression, hurricane modification and other activities with a potentially wide impact. By presenting them as public issues of importance, the book necessarily creates the impression that a major control over the weather will soon be achieved. This is not so, and if rainfall augmentation amounts at most to 10 or 15 per cent, regarded by many responsible scientists as optimistic even in favourable locations, it is doubtful if the public would be aware of any change in the weather regime unless told by the meteorologist. Is it then wise to initiate a public debate among non-scientists on the social implications of weather modification when the scientific justification for expecting any significant impact is so slight, and the scientist can give no valid advice on what artificial weather changes are possible?

In a number of places the book criticizes the scientists who advise that funds to develop weather modification should be channelled primarily into meteorological research and thus be used to develop further the activities from which scientists personally benefit. However, this is, surely, better justified than devoting substantial funds to social surveys and development of a management structure for projects which as yet have no adequate technical basis.

The scientific reader of this volume will, however, be given a useful reminder of the social and political background within which the applications of science must be developed. Only in rather restricted fundamental fields can scientific research be regarded as an end in itself. The meteorologist cannot ignore the applications of his studies, although he may well question whether there is a need for the elaborate studies of their implications which are advocated by the authors. The normal machinery of government has handled issues of far greater importance in the past without social surveys and cost-benefit analysis, etc. If issues of peace and war, public health, finance, etc. can be handled by parliamentary debate and the machinery of democracy, why does weather modification need special treatment?

On the more technical level the scientific reader will find interest in Dr Chagnon's bibliography of urban and agricultural effects on climate although his review of it may be regarded as somewhat uncritical. Dr Sewell's opening review of the history of weather modification in the U.S.A. and Dr Holden's account of some of the politics behind it will also interest the professional reader.

J. S. SAWYER

## OBITUARY

It is with regret that we record the death on 6 January 1974 of Mr A. R. Belton, Higher Scientific Officer, Met. O. 12.



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## NOTICES

It is requested that all books for review and communications for the Editor be addressed to the Director-General Meteorological Office, London Road, Bracknell, Berkshire, RG12 2SZ, and marked "for Meteorological Magazine."

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Printed in England by The Bourne Press, Bournemouth, Hants.

and published by

HER MAJESTY'S STATIONERY OFFICE

21p monthly

Annual subscription £2.82 including postage

Dd. 507044 K16 4/74

ISBN 0 11 722135 x