Changes in Temperature from Month to Month for Central England for a Quintile Distribution

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ABSTRACT

Anomalies from the respective decadal means of the monthly mean temperatures for central England covering a period of 250 years are ranked to form a quintile distribution. Contingency tables are then prepared which show the percentage frequencies of the changes in the temperature anomalies from one calendar month to the following calendar month for each quintile. Correlation coefficients for a lag of one month are computed for each calendar month-to-month change throughout the years, and for lags 1–12 months inclusive for the whole data series.

It is shown that persistence of extreme anomalies at certain times of the year are double the frequency which would be expected by chance, while the changes from one extreme quintile to the other occur with very low frequency compared with chance.

It is suggested that application of the tables would produce results as good, and perhaps a little better, at forecasting temperature anomalies for a month ahead than the official long-range forecasts supplied by the Meteorological Office for central and southeast England.

1. Introduction

Present interest in the results of long-range forecasts has renewed interest in the statistical relationships describing actual month-to-month changes in temperatures.

Craddock and Ward (1962) carried out a thorough analysis of persistence of temperature anomalies for 15 European stations. They showed the occurrence of significant persistence from February to March and from June through August. Changes from April to May and from October to November were shown to be random. Murray (1967) used central England temperatures from 1873 to 1963 to show that significant persistence was confined to extreme quintiles. In particular, the very cold anomalies persisted from January through April, while very warm anomalies persisted from June to July. However, Craddock and Ward remark that a minimum of 125 observations is needed to deduce meaningful conclusions from a quintile distribution. Manley (1974) has provided a series of

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TABLE 1. The quintile distribution of monthly mean temperature (°C) for central England (1721-1970).

QUINTILE		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	A	4.60	4.16	3.83	2.40	3.61	3.52	2.80	2.72	2.77	2.90	3.78	3.78
	B	1.43	1.56	1.32	0.96	0.96	0.82	1.03	0.72	0.86	0.89	1.04	1.32
2	A	1.42	1.55	1.25	0.95	0.95	0.81	1.00	0.71	0.85	0.88	1.03	1.31
	B	0.51	0.66	0.41	0.33	0.27	0.22	0.10	0.22	0.26	0.35	0.37	0.51
3	A	0.49	0.65	0.40	0.31	0.26	0.20	0.09	0.21	0.24	0.33	0.36	0.48
	B	-0.35	-0.32	-0.27	-0.21	-0.27	-0.25	-0.35	-0.21	-0.23	-0.21	-0.35	-0.27
4	A	-0.36	-0.34	-0.29	-0.22	-0.30	-0.27	-0.36	-0.24	-0.27	-0.24	-0.39	-0.28
	B	-1.37	-1.55	-1.28	-0.95	-0.99	-0.82	-0.97	-0.83	-0.84	-0.92	-0.96	-1.32
5	A	-1.38	-1.57	-1.29	-0.99	-1.05	-0.85	-0.98	-0.84	-0.88	-0.95	-0.99	-1.34
	B	-6.63	-5.91	-3.46	-3.24	-2.82	-2.53	-2.53	-2.58	-2.84	-4.24	-3.26	-4.04

reliable temperatures for central England for 250 years (1721–1970). In this study an attempt has been made to derive further information about the sequence of temperatures from one month to the next in order to determine if there is any regularity or order in the changes.

TABLES 2–6. Percentage frequencies of month-to-month changes for control quintile 1 to control quintile 5. The bold numbers indicate significance at the 1% level.

Control Quintile 1

Target	J-F	F-M	M-A	A-M	M-J	J-J	J-A	A-S	S-O	O-N	N-D	D-J
1	26	**37**	28	20	**40**	30	**34**	**36**	28	30	24	**32**
2	26	23	26	20	18	26	24	24	24	20	20	26
3	16	22	18	22	24	16	18	20	14	22	22	12
4	22	12	16	18	10	10	16	**8**	18	10	24	20
5	10	**6**	12	20	**8**	18	**8**	12	16	18	10	10

Control Quintile 2

Target	J-F	F-M	M-A	A-M	M-J	J-J	J-A	A-S	S-O	O-N	N-D	D-J
1	24	**34**	20	20	22	22	24	22	26	18	28	29
2	28	22	16	16	20	26	14	26	16	20	23	29
3	16	16	30	22	17	14	20	14	24	12	15	14
4	12	14	24	24	22	28	24	20	22	26	15	12
5	20	14	10	18	19	10	18	18	12	24	19	16

Control Quintile 3

Target	J-F	F-M	M-A	A-M	M-J	J-J	J-A	A-S	S-O	O-N	N-D	D-J
1	17	16	14	22	12	16	18	24	16	16	18	21
2	20	20	26	20	12	26	24	20	23	21	21	15
3	20	23	20	18	22	16	28	12	20	**33**	21	15
4	29	23	24	24	28	24	12	24	23	14	17	**32**
5	14	18	16	16	26	18	18	20	18	16	23	17

Control Quintile 4

Target	J-F	F-M	M-A	A-M	M-J	J-J	J-A	A-S	S-O	O-N	N-D	D-J
1	12	**8**	22	18	10	24	14	12	10	21	20	13
2	14	22	20	24	25	14	16	14	22	21	22	13
3	**32**	18	22	18	23	26	22	30	24	18	16	**33**
4	21	28	12	28	20	22	19	24	18	24	18	13
5	21	24	24	12	22	14	29	20	26	16	24	28

Control Quintile 5

Target	J-F	F-M	M-A	A-M	M-J	J-J	J-A	A-S	S-O	O-N	N-D	D-J
1	18	**4**	16	20	16	**8**	10	**6**	18	16	10	**6**
2	14	12	10	18	24	**8**	22	16	18	12	14	16
3	18	24	12	20	14	26	14	22	16	22	20	24
4	16	22	24	**8**	20	18	28	24	21	24	30	25
5	**34**	**38**	**38**	**34**	26	**40**	26	**32**	27	26	26	29

2. Results

The data were first divided into decades and decadal averages computed so that periodicities greater than 10 years could be eliminated. Anomalies from the decadal means were then calculated for each of the 3000 months and these were ranked for each month of the year. Table 1 shows the ranges of the anomalies for each month and quintile (°C).

The distribution of month-to-month changes was then found by counting the number of cases which occurred for each month for the 5×5 contingency table. We will define the temperature of a given month as the control temperature T_i and that of the following month as the target temperature T_j. We then have 25 different possibilities for T_{ij}; $i,j=1$–5 inclusive.

Tables 2–6 show the percentage frequencies for each month-to-month change throughout the period for each of the five possible control temperature quintiles. The frequencies shown in bold numbers indicate significance greater than 1%, using a chi-square test for the individual values.

Table 2 for control quintile 1 (very warm anomalies) shows significant persistence from February to March, May to June, July through September and December to January. There is a significant low frequency of changes from quintile 1 to quintile 5 from February to March, May to June and July to August. For April to May it is noted that the distribution of frequencies is particularly even, implying that after a very warm April, a cold May is as likely as a warm May. An even distribution also occurs for control quintiles 2, 3 and 4, though quintile 5 does show significant persistence.

Table 3 shows only one frequency significant at the 1% level, i.e., for the change T_{21} from February to March. However, the changes T_{22} and T_{21} from December to January are significant at the 5% level. Of some interest is the indication of a cool July following a warm June given by T_{24} in Table 3. This is the largest of any change from quintile 2 from June to July, and is only just below the 5% significance level. This feature may be related to a slight monsoon influence over the Eurasian continent.

The changes from quintile 3 and 4 to other quintiles are mainly random, but those for quintile 5 in Table 6 exhibit considerable persistence for T_{55}, particularly from January through March and from June to July. This persistence of unusually cold months is the strongest feature of all the month-to-month changes.

Table 7 shows the sum total of all combinations of T_{ij}. These have been plotted as percentage frequencies in Table 8. The overall effect of persistence is well pronounced with maximum frequencies for T_{11} and T_{55} and minimum frequencies for T_{15} and T_{51}.

Correlation coefficients were also computed from the whole data set for each month-to-month change. The seasonal curve is shown in Fig. 1. The highest correlation, indicating significant persistence, occurs from February to March and again from June to

TABLE 7. Annual total of all month-to-month changes.

Annual Total

Control \ Target	1	2	3	4	5
1	**181**	**138**	112	92	74
2	**144**	**127**	105	**122**	102
3	106	**124**	**122**	**136**	110
4	93	115	**142**	**125**	**131**
5	74	92	116	**131**	**189**

TABLE 8. As in Table 7, but expressed as percentage frequencies.

Control \ Target	1	2	3	4	5
1	**30·3**	**23·1**	18·8	15·4	12·4
2	**24·0**	**21·2**	17·5	**20·3**	12·0
3	17·7	**20·7**	**20·4**	**22·7**	18·5
4	15·3	19·0	**23·4**	**20·6**	**21·4**
5	12·2	15·3	19·3	**21·8**	**31·4**

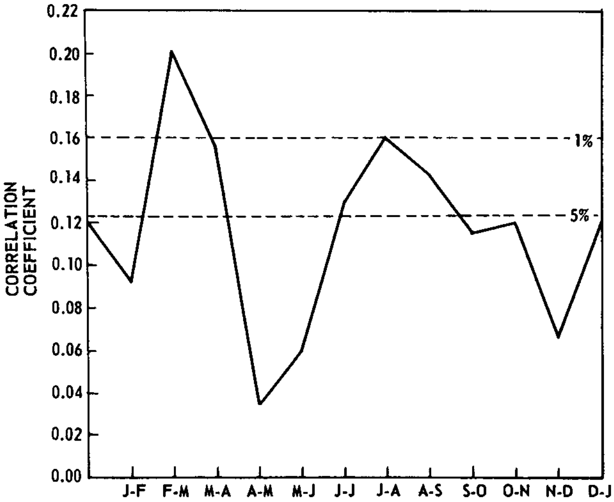

FIG. 1. Correlation coefficient of temperature anomalies, using a 1 month lag, for each month of the year.

September. It is lowest from April to May and a second minimum appears from November to December. Finally, correlation coefficients were computed from the data for lags of 1 to 12 months inclusive. The curve illustrated in Fig. 2 decays from a positive coefficient of 0.26 for a lag of 1 month to zero for a lag of 10 months.

The correlation coefficient is significant for the first 4 months. It is interesting to note the significant persistence for a 6 month lag, and the negative correlation coefficient for lag 12. This latter feature may be attributed to the biennial oscillation (Newell *et al.* 1972). It is noted that due to the large number of observations even small correlations are statistically significant.

3. Monthly forecasts

It is of some interest to relate the tables to long-range forecasting for a month ahead. An analysis was therefore made of the verification table (Jenkinson, 1975) for temperature forecasts issued by the U. K. Meterological Office for the whole of the United Kingdom for the period December 1963 to May 1975 inclusive. Table 9 shows the results as a percentage difference from chance frequency. In the predicted column are five prediction schemes. The persistence forecast is simply obtained by assuming the following month's anomaly will be the same as that of the preceding month, while the optimum probable change is based on Tables 2–6 inclusive. The first vertical column is based on the data forming a pure quintile distribution. The second vertical column is based on the actual anomaly distribution which occurred during the 137-month period. This distribution was skewed toward cold anomalies.

It is noted that the Meteorological Office forecast accuracy for the actual data is 4.9% better than chance, whereas pure persistence is 4.3% and the optimum method 6.0% better. Of course, Tables 2–6 only refer to central England whereas the verification results refer to the whole of the British Isles. Nevertheless, it is pertinent to compare the verification accuracy with that which might be obtained by other prediction schemes.

TABLE 9. Prediction success expressed as percent better than chance for long-range forecasts of temperature for a month ahead n the United Kingdom.

	Observed	
Prediction scheme	Quintile distribution	Actual distribution
Actual prediction	6.6	4.9
All average	0.0	4.0
All very cold (quintile 5)	0.0	3.0
Persistence	4.8	4.3
Optimum probable change	6.4	6.0

4. Conclusions

Persistence of anomalies of monthly mean temperatures for central England from one month to the next is highly significant for the extreme quintiles. Very cold months appear slightly more persistent than very warm months. The climate as a whole is highly resistant to changes from the uppermost to the lowest quintile and vice versa. However, the latter changes do occur with chance frequency from April to May.

The changes from month to month are most persistent from February to March and from June to September, and least persistent from April to May and from November to December. April to May appears to be a time of year when changes occur in a mainly random fashion. For periods longer than one month the correlation coefficient decays as the lag is increased although there is a small peak at 6 months.

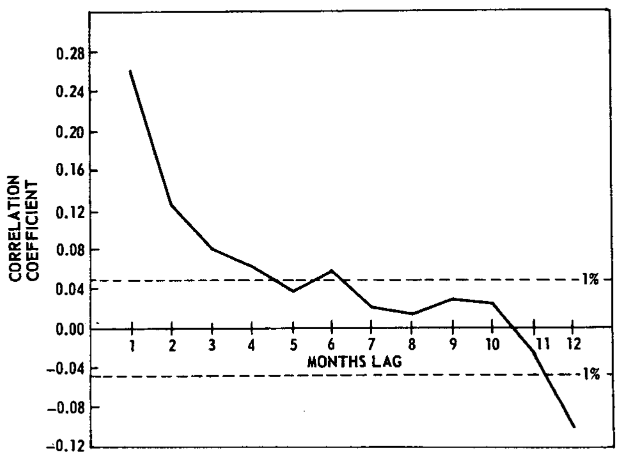

FIG. 2. Correlation coefficient of temperature anomalies for lags of 1 to 12 months, inclusive.

There is also evidence of the biennial oscillation for a lag of 12 months.

It is suggested that the choice of the most likely quintile for the following month would produce rather better results than those predicted by existing analogue methods. If, in fact, the verification score is expressed as a percentage frequency better or worse than chance, then the score computed from the contingency tables 2–6, using the most likely or optimum value of the frequency, is marginally better than that computed from the verification table compiled by Jenkinson (1975). The Jenkinson table relates to the whole of the British Isles but there is no obvious reason to suppose that the region of central England would show a verification success greatly different from the whole country.

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