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A note on the performance of climatic forecasts for Asia based on the periodic portion of the data: 1986–1987

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Abstract. Between 1973 and 1986 a group at the University of Wisconsin worked on the use of the periodic portion of climatic time series with the aim of exploring the potential for year-or-more in advance forecasting. This paper reports on the real time verification of the last sets of forecasts made by the group.

From spectra of temperature and cube-rooted precipitation the dominant frequencies were chosen. These were usually related to tidal frequencies. A Fourier series of these dominant terms was then fitted to the dependent data set and future values calculated. These were analyzed for forecast skill, and the skillful Fourier series retained. Real time forecasts were then made. Verification shows a low probability that the forecast skills were obtained by chance. It is suggested that the periodic term might be a useful addition to more standard approaches to long range forecasting.

Keywords. Climate forecasts; skill scores.

1. The forecasts

In March 1986 a bulletin containing forecasts of the monthly rainfall expected at a number of places in India during the upcoming two summer monsoon seasons was sent to about 250 interested people and organizations (Climate Forecast Group 1986a). In May of 1986 a similar bulletin containing forecasts of the temperature and precipitation for the subsequent five years of growing seasons for Eastern Europe, the Soviet Union and Northern Japan was sent to about 150 interested parties (Climate Forecast Group 1986b). These long-range forecasts were the outcome of refinements of the general method developed by a group at the University of Wisconsin and described in 1977 (Bryson 1977). Early results were discussed by Harnack and Sammler (1982) and by Bryson (1983). Forecasts of the Indian monsoon for 1982 were published before its onset (Bryson and Campbell 1982a) and the forecast verifications were presented after the monsoon season (Bryson and Campbell 1982b). This note reports on the verification of forecasts for the 1986–1987 period provided in the bulletins mentioned above.

In essence the method for making these multi-year forecasts of mean monthly temperature and precipitation is based on the observation that a portion of the variance of most climatic time-series appears to be stably periodic. An example is to be found in the results of Campbell (1983) and is partly described in Campbell *et al* (1983). He found that the dominant periodicities in the Indian monthly series appeared to be at known tidal frequencies, a result confirmed by others of the group for other regions. It is difficult to demonstrate the validity of this statement in general because the linear equivalent of a non-linear atmospheric response to the tidal forcing equations has many harmonics, beats, and aliases of the frequencies in the forcing equation.

As a consequence of this complexity, a heuristic forecast protocol was adopted. The spectra of all available long period climatic data series, for the area of concern, were examined for regionally present, significant concentrations of variance at a small set of dominant frequencies. Most of these could be identified with tidal frequencies or their aliases, beats and harmonics, both for soli-lunar and pole tides. In the case of precipitation, which is a highly skewed variable with respect to the mean, the data was first cube-rooted. These selected frequencies were then used to constitute a Fourier series from which values beyond the end of the series were computed, with the cube-rooted precipitation forecast cubed, of course. These values represent the forecasts.

In practice, the spectra were computed from a dependent data set prior to 1964, and the forecasts were made for 1965 onwards. Then the dependent data was extended one year and the procedure repeated for 1966 onwards. This iterative procedure gave a test set of forecasts for the post 1964 independent data period. Only then were these forecasts verified against the observed data to assess reliability. If good forecasts (i.e. better than chance) could not be achieved for a particular station, no more forecasts were attempted. Thus, the results described below are only for the locations for which such better than chance scores were obtained for the forecasts made for the months between 1960 and 1985, the independent data period.

Although the forecasts were expressed as the anticipated departure from the mean, in the case of temperature, and from the median, in the case of precipitation, the forecasts were also expressed in terms of which tercile of the 1951–1980 period encompassed the forecast. We have deliberately concentrated, in this report, on the accuracy with which the terciles could be predicted, simply because the extremes are important to the user. Predictions of small departures from the mean or median, which largely determine the skill score of "above or below" forecasts, are not very useful to the user.

It was recognized that the forecasts could "explain" no more of the variance than was contained in the periodic portion of the time-series.

2. Forecast skill attained

The scoring of the forecasts was based on the study of Preisendorfer and Mobley (1982) who emphasized the probability of getting a particular combination of zero class, one class, and two class errors by chance in a particular forecast test of predicted tercile. A particular problem arises occasionally when either the predicted or observed value falls on the value that divides the terciles. If the forecast and observed value both fall on the same tercile division, which occasionally happens, we counted the result as no class error. If either the observed or predicted value, but not the other, fell on the tercile boundary we scored half an error to each tercile. For example, if the forecast was for the lowest tercile and the observed as on the low-middle boundary, half a no-class error and half a one-class error was recorded. This causes a problem with calculating the probabilities, unless there are pairs of such cases, for the calculation involves factorials. In that circumstance we counted the fractional errors as being added to the 1-class errors.

2.1 *Indian monsoon forecasts*

Table 1 lists the overall verification scores for monthly summer monsoon rainfall forecasts for individual stations in India and Pakistan. It will be noted that for tercile forecasts the number of 0-class errors expected by chance is 1/3, while the expected number of 2-class errors is 2/9. Thus one expects the ratio of 0-class to 2-class errors to be 3/2. In no case is the ratio obtained that low. The expected number of 1-class errors is 4/9, and there are often more than the expected number. However, since only a fraction of the variance is contained in the periodic terms of the time-series, one expects too few forecasts based on the periodic portion alone to have large enough departures from the median to fall in the outer classes. None of the individual month probabilities of obtaining the observed scores by chance is as great as 5%. The two monthly forecast sets that reach 4% (August and September, 1986) are the two months with small numbers of verifiable forecasts due to missing data, and the probability calculation is sensitive to the total number of forecasts.

Since the forecasts for each station are done independently of other stations, it is reasonable to treat the aggregate of all forecasts as a single experiment. In this case the probability of achieving the observed scores by chance is 2·9 in 100 million. There have only been about 30 million pairs of monsoons since the Indian sub-continent has been attached to Asia.

Table 1 also gives the percent of all forecasts with zero-class errors compared with the percent that would have been obtained by always predicting the median value,

Table 1. Forecast verification for Indian monsoon forecasts using Wisconsin System 1986–1987.

(Forecasts of three equally likely classes–upper third, middle third or lower third of the record)

Date	Exact hits	1 Class errors	2 Class errors	Chance prob.	% Exact hits	% Using climatol.
1986			Precipitation			
May	8	15	3	0·011000	31	26
Jun	9	13	5	0·029000	33	31
Jul	10	18	2	0·002200	33	13
Aug	5	9	3	0·042000	29	35
Sep	7	8	3	0·040000	39	11
1987						
May	4	16	1	0·000650	19	19
Jun	12	10	2	0·005000	50	25
Jul	12	18	1	0·000510	39	0
Aug	6	14	2	0·007100	27	27
Sep	11	13	4	0·019000	39	21
All	84	134	26	2·9E-08	34	20

Note: The low probabilities of obtaining the forecast scores by chance are enhanced by the fewer than expected number of 2-class errors. The last two columns are based on only the correct third being forecast. The total number of forecasts verified each month varies with the availability of published data with which to verify the forecasts.

i.e. by using "climatology". In the long run one would expect 33·3% correct by predicting the middle class only, but in 1986–87 the score was only 20%. By contrast, the periodic-element forecast model gave 34% correct class forecasts.

2.2 *Northern Asia forecasts*

Table 2 displays the forecast results for Eastern Europe, the Soviet Union, and the Japanese island of Hokkaido. It was noted in the independent data test of the forecasts

Table 2. Forecast verification for Eurasia forecasts using Wisconsin System 1986–1987.

(Forecasts of three equally likely classes–upper third, middle third or lower third of the record)

Date	Exact hits	1 Class errors	2 Class errors	Chance prob.	% Exact hits	% Using climatol.
1986			Temperature			
May	4	11	3	0·020169	22	0
Jun	10	29	3	0·000083	24	46
Jul	15	24	2	0·000250	37	50
Aug	8	16	5	0·016721	28	28
Sep	10	18	1	0·000655	34	28
1987						
May	6	13	16	0·000141	17	31
Jun	14	19	8	0·019794	34	39
Jul	13	23	4	0·002564	33	36
Aug	11	25	6	0·003360	26	24
Sep	14	17	1	0·000406	44	31
All	108	188	52	6·91E-07	31	34
1986			Precipitation			
May	5	10	3	0·033279	28	11
Jun	23	16	1	0·000008	58	35
Jul	10	24	6	0·003622	25	17
Aug	12	16	2	0·002850	40	37
Sep	10	17	2	0·002950	34	14
1987						
May	6	20	5	0·002629	19	40
Jun	11	22	7	0·009737	28	35
Jul	20	15	5	0·001732	50	44
Aug	24	16	4	0·000170	55	56
Sep	11	15	7	0·026004	33	23
All	133	169	42	6·56E-09	26	35

Note: The low probabilities of obtaining the forecast scores by chance are enhanced by the fewer than expected number of 2-class errors. The last two columns are based on only the correct third being forecast. The total number of forecasts verified each month varies with the availability of published data with which to verify the forecasts.

that the European and far eastern forecasts were inferior to those made for the continental interior (figures 1 and 2). On the basis of our experience the same appears to be true for North America. This difference can be seen by comparing the skills of forecasts for the whole of northern Asia, as defined above, (table 2) with those for the whole of the USSR (table 3).

For northern Asia temperature during the growing season is important, and so predictions were made for the temperature as well as the rainfall. In general, the temperature forecasts were better than the rainfall forecasts for lead-times of a few years, but the accuracy declined faster for temperature than for precipitation (figure 2). Why this should be so is not known, but it appears from the nature of the time-series that there are more aperiodic elements in the temperature than in the precipitation. For the temperature (precipitation) forecasts, the highest individual month probability of achieving the score by chance was near 2% (3%), and the overall probability was 6·9 in 10 million (6·6 in 1000 million) for the 1986–87 test. It must be pointed out, however, that for May 1987 the low probability of a chance score like that attained is low because the forecast set for that month was improbably bad.

For northern Asia, the expected number of correct-class forecasts with the use of the median or mean as the prediction is again 33·3% and that number was attained very nearly for the USSR as well as for all of northern Asia. For the USSR alone the periodic-element forecast model outscored "climatology" in the present test,

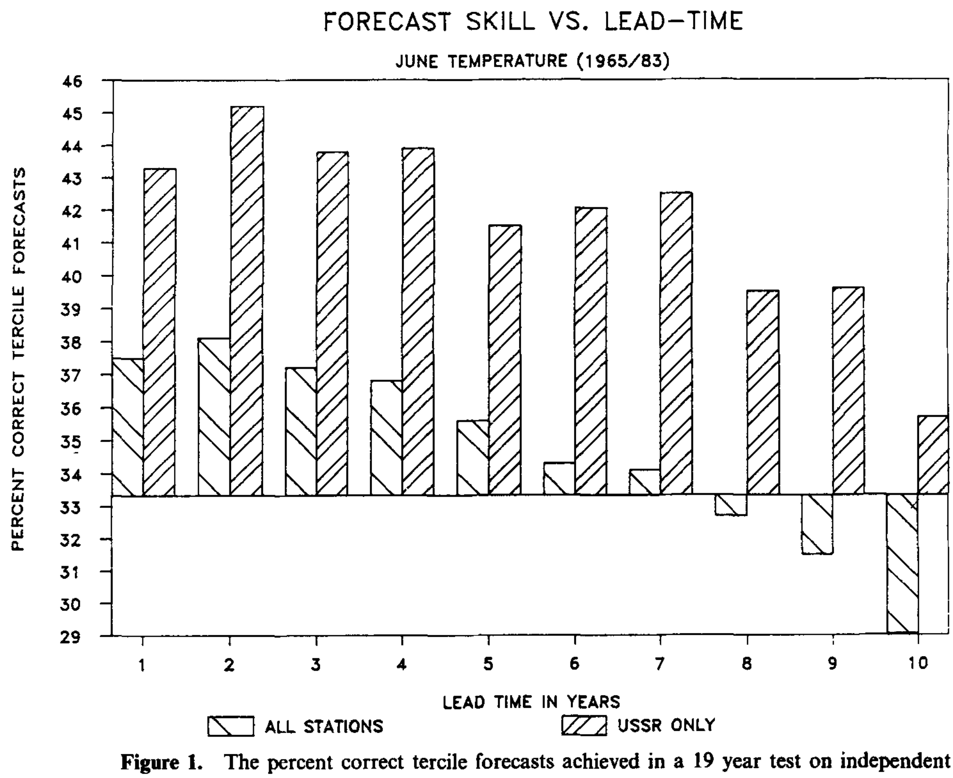

Figure 1. The percent correct tercile forecasts achieved in a 19 year test on independent data for northern Asia as defined in the text and for the USSR crop area only. The origin is set at 33·33%, the value expected by chance.

Table 3. Forecast verification for USSR forecasts using Wisconsin System 1986–1987.

(Forecasts of three equally likely classes–upper third, middle third or lower third of the record)

Date	Exact hits	1 Class errors	2 Class errors	Chance prob.	% Exact hits	% Using climatol.
1986			Temperature			
Jun	8	13	3	0·018187	35	38
Jul	8	15	2	0·005773	34	32
Aug	5	5	1	0·043960	45	27
Sep	3	10	1	0·009910	25	25
1987						
Jun	7	11	5	0·035465	29	44
Jul	7	15	3	0·010264	28	34
Aug	8	15	3	0·011119	31	21
Sep	8	9	1	0·010028	47	33
All	56	90	21	2·05E-05	34	32
1986			Precipitation			
Jun	14	8	1	0·000520	61	39
Jul	6	12	5	0·027584	26	11
Aug	3	8	0	0·009303	27	45
Sep	5	9	0	0·005574	36	4
1987						
Jun	7	13	2	0·010675	34	41
Jul	15	7	2	0·000554	65	48
Aug	14	11	2	0·002159	52	54
Sep	7	9	3	0·037637	39	24
All	72	75	16	3·82E-07	44	35

Note: The low probabilities of obtaining the forecast scores by chance are enhanced by the fewer than expected number of 2-class errors. The last two columns are based on only the correct third being forecast. The total number of forecasts verified each month varies with the availability of published data with which to verify the forecasts.

especially for the precipitation forecasts. This was not true for the larger northern Asia forecast set.

3. Discussion

There is little guidance in the literature on what constitutes "good" skill for forecasts of one or more years. However, the low probability of chance achievement of the verification scores reported here argues that the forecasts indeed captured a significant part of the variance of temperature and rainfall, especially in middle and south Asia. Comparison with the skills of month or season forecasts as reported by Preisendorfer

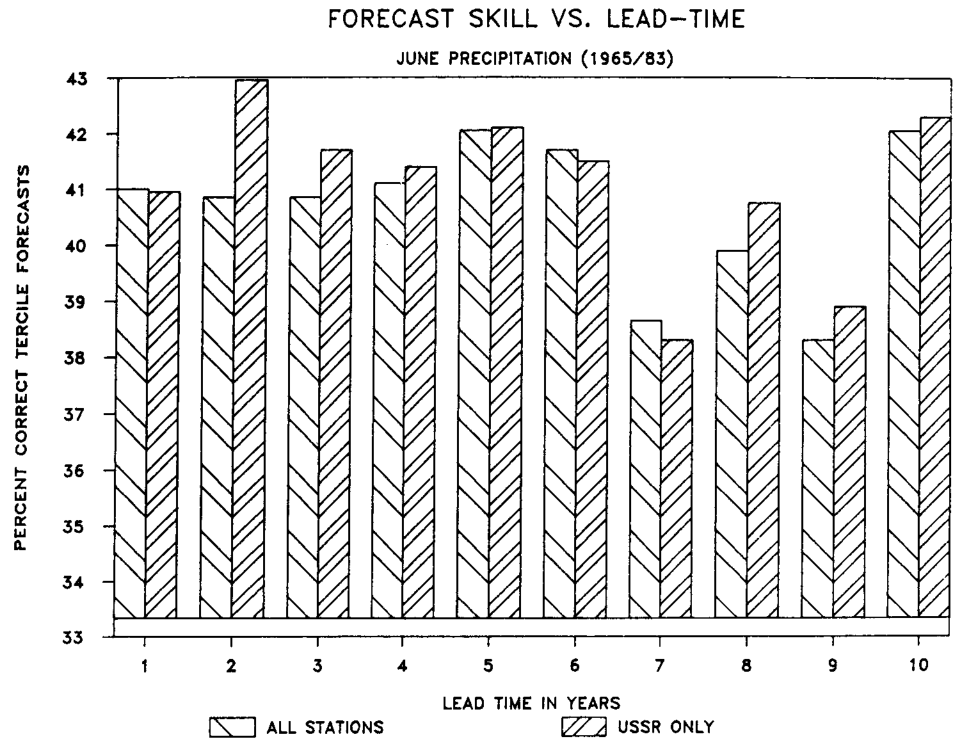

Figure 2. Probability of obtaining the observed forecast accuracy by chance, for forecasts made on the 19 year independent data series, as a function of lead time (all northern Asia stations). Similar results were obtained for other months.

and Mobley (1982) indicates that the skills reported here are at least as good as other monthly and seasonal forecasts considered in Preisendorfer and Mobley (1982).

It is often said of month-in-advance forecasts that to beat persistence a forecast method must be very good indeed. We have not discussed the skill of a persistence forecast here because the rationale is not clear and tests we have made indicate that year-in-advance persistence skill is as often negative as positive. Since the whole annual cycle of synoptic patterns intervenes in a year, it does not make sense to assume that some element of the pattern in a month will persist to the same month the following year. Anti-persistence for a one year interval is easy to understand when one notes that most stations evidence some sort of quasi-biennial variation. For those without a quasi-biennial variation, longer term periodicities will simulate persistence. This type of persistence is built in to the method discussed here, and comparison with pure persistence would be meaningless.

Whether these forecasts are usable is a different question. The Indian monsoon forecasts made with the current model have been used by the Central Arid Zone Research Institute in Jodhpur, Rajasthan, India since about 1981. They have been used to advise the District Agents as to optimal cropping strategies for the coming season. The agents then advise the farmers. They report quite useful results. (Dr. A N Lahiri personal communication 1985)

It appears to the authors that the results of this experiment indicate that there is a significant forecasting advantage to be obtained by recognizing the periodic component of the climatic time-series. Perhaps if this element were combined with other factors affecting the climatic series higher forecast skills could be achieved than by using one component of the system alone.

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