Global Annual Mean Surface Air Temperature Anomalies and Their Link with Indian Summer Monsoon Failures

S. S. Dugam, S. B. Kakade and *R. K. Verma*
Indian Institute of Tropical Meteorology, Pune–411005, India
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ABSTRACT

Analysis of the global mean annual temperature anomalies based on land and marine data for the last 88 years (1901–1988) of this century has been carried out with a view to find any relationship with failures in Indian summer monsoon rainfall. On the climatological scale (i.e. 30 years) it has been noticed that there is an abnormal increase in the frequency of drought years during epochs of global warming and cooling, while it is considerably less when global temperatures are near normal. Results are unchanged even when the data are filtered out for ENSO (El–Nino Southern Oscillation) effect.

It has also been noticed that during warm and cold epochs in global temperatures the amount of summer monsoon rainfall decreases as compared to the rainfall during a normal temperature epoch.

I. INTRODUCTION

Monsoon being a thermally driven large scale circulation, any change in global temperatures ought to be reflected in the monsoon precipitation. The present paper deals with anomalies on a climatological scale (i. e. 30 years) in global mean annual temperatures and their possible relationship with monsoon (June–September) rainfall in general and monsoon rainfall failures in particular. Bradley et al. (1987) have pointed out noticeable effect of ENSO events on the hemispheric mean data of temperature and precipitation patterns. Verma et al. (1985, 1986, 1987) have shown that there is a remarkable correspondence between climatic variability of the NH (Northern Hemisphere) surface air temperature and the monsoon on the time scale of a few decades–warmer and stable epoch over the NH being favourable for the monsoon and vice–versa. Some of the other studies on related subjects are Lamb (1975), Budyko (1977), Angell and Korshover (1978), Barnett (1978), Jones et al. (1986), and Verma et al. (1985, 1986, 1987).

II. DATA AND ANALYSIS PROCEDURE

The updated data of all India summer monsoon (June–September) rainfall (hereafter referred to as monsoon rainfall) are obtained from Mooley and Parthasarathy (1978, 1984). Whenever the normalized value of rainfall is −1.00, that year has been defined as a year of monsoon failure (drought year). Monsoon rainfall data for the last 88 years (1901−1988) are used to delineate years of monsoon failure. Non–overlapping 3–decadal means of rainfall are also computed. The global mean annual temperature data for the same 88 years (1901−1988) have been obtained from the recent study of Jones (1988). He has developed the best possible estimate of changes in the global mean temperature, with data over the oceans included and also provided the temperature data series after subtracting the "SOI explained" part. However, the coverage is not uniform and there are substantial gaps, particularly over the southern ocean areas between 40°S and 60°S.

Non–overlapping 3–decadal means of global mean annual temperature anomalies have been computed and their possible linkage with 3–decadal means of monsoon rainfall and frequency of drought years have been investigated. Computations have been carried out with data both inclusive and exclusive of ENSO effect on global temperature.

The entire period of last 88 years is divided into three shorter periods on physical / climatological basis—mainly on the basis of the large scale monsoon activity in terms of the mean rainfall and the frequency of droughts (i. e. smaller mean rainfall and greater frequency of droughts during the first and last periods of 1901–1930 and 1961–1988 and comparatively larger mean rainfall and lower frequency of droughts during the second period of 1931–1960). Temperaturewise also, these periods are separable though not by that large degree as seen in the monsoon activity. We have divided the entire period into almost 3 periods of equal length as the short–term climatic fluctuations are observed to be of the order of 3 decades.

III. VARIABILITY OF THE MONSOON RAINFALL AND OCCURRENCES OF DROUGHTS

Table 1 gives the mean monsoon rainfall for the three–decadal periods–1901–1930, 1931–1960 and 1961–1988 (incomplete). It also gives the frequency of drought years as defined by the above criterion for the same periods. The first and last periods show high frequency (7 and 9 respectively) of droughts and considerably less mean monsoon rainfall (82.3 cm and 83.3 cm respectively). The frequencies are tested and found to be statistically significant at 5% level. In the middle period (1931–1960), while the occurrence of droughts is very much less (2), the mean monsoon rainfall exceeds normal rainfall by 4%.

Table 1. Three Decadal Means of Global Annual Mean Temperature Anomalies and Monsoon Rainfall

Period	Global temperature anomaly with ENSO (℃)	Global temperature anomaly without ENSO (℃)	Mean rainfall (cm)	Total No. of years of monsoon failure	Years of monsoon failure
1901–1930	–0.183	–0.180	82.3	7	1901, 1904, 1905 1911, 1918, 1920 1928
1931–1960	0.00	0.00	87.7	2	1941,1951
1961–1988*	+0.064	+0.064	83.3	9	1965, 1966, 1968 1972, 1974, 1979 1982, 1986, 1987

* Incomplete 3 decades

IV. VARIABILITY OF GLOBAL MEAN ANNUAL TEMPERATURE

Table 1 also shows the mean values of global annual temperature anomalies for the same three 3–decadal periods of 1901–1930, 1931–1960 and 1961–1988 (incomplete). In the first tri–decadal period there was significant cooling over the globe (mean anomalies were −0.183°C and −0.180°C, with and without ENSO effect respectively). During the middle tri–decadal period the means were 0.0°C (~ −0.001°C) in both cases, i.e. the temperatures were almost normal. In the latest tri–decadal period there has been a clear warming over the globe though its magnitude is less than the cooling in the first period. (Mean anomalies are +0.06°C and +0.064°C respectively). This analysis reveals that the ENSO does not seem to affect global cooling or warming seriously on short–term climatic scales of 3–decades.

V. RELATIONSHIP BETWEEN GLOBAL TEMPERATURES AND MONSOON RAINFALL

Table 1 shows the behaviour of global temperatures and monsoon rainfall during the three periods of 1901–1930, 1931–1960 and 1961–1988. The three periods seem to correspond to three epochs, both in global temperatures and monsoon rainfall. First epoch (1901–1930) was of global cooling at which time the frequency of monsoon failures was large and average rainfall less. Second epoch (1931–1960) was of global temperatures which could be termed as normal, as during this period many climatic parameters showed low variability. During this epoch the frequency of monsoon failures reduced considerably and the average rainfall increased. Lastly, there is the current epoch of global warming with greater number of monsoon failures and reduced average rainfall.

VI. CONCLUSIONS AND DISCUSSIONS

Changes in global temperatures have their impact on monsoon rainfall on short–term climatological scale.

(1) Whenever there is global warming or cooling there is a general drop in monsoon rainfall and the frequency of monsoon failures increases.

(2) An epoch of normal global temperatures is also an epoch of normal monsoon activity with less monsoon failures and good rainfall.

(3) The inclusion or exclusion of ENSO effect does not seem to affect global cooling or warming on the climatological scale.

It is rather difficult to offer a simple explanation for a complex relationship of monsoon with climatic fluctuations on three–decadal scales. However, one may attempt it within the concept of climatic marginality put forward by Parry and Carter (1985) and taken further by Wigley (1985). According to them the frequency of extreme events might change dramatically as a result of even a small change in the mean climate. It, therefore, seems plausible that the rather sudden change in the mean temperature or in the mean climatic state from a stable climate influenced the variability of large scale atmospheric circulations over the globe like monsoon, through altered frequency of extremes.

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