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Pattern characteristics of Indian monsoon rainfall using principal component analysis (PCA)

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Abstract

In the present study the Principal Component Analysis (PCA) is used to determine the dominant rainfall patterns from rainfall records over India. Pattern characteristics of seasonal monsoon rainfall (June–September) over India for the period 1940 to 1990 are studied for 68 stations. The stations have been chosen on the basis of their correlation with all India seasonal rainfall after taking the '*t*' Student distribution test (5% level). The PCA is carried out on the rainfall data to find out the nature of rainfall distribution and percentage of variance is estimated. The first principal component explains 55.50% of the variance and exhibits factor of one positive value throughout the Indian subcontinent. It is characterized by an area of large positive variation between 10°N and 20°N extending through west coast of India. These types of patterns mostly occur due to the monsoon depression in the head Bay of Bengal and mid-tropospheric low over west coast of India. The analysis identifies the spatial and temporal characteristics of possible physical significance. The first eight principal component patterns explain for 96.70% of the total variance.

Keywords: Monsoon rainfall; Principal component analysis; Variance; Monsoon variability

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1. Introduction

Indian summer monsoon variability is a much discussed and researched field, yet there is a considerable scope for further understanding. The southwest monsoon, which contributes more than 75% of the annual rainfall, is a major factor of Indian economy. It is however noted that the monsoon rainfall over different parts of the country shows considerable interannual variability. Thus the interannual variability of summer monsoon rainfall is a complex phenomenon and is known to depend upon the regional circulation as well as global circulation. Year to year variation of southwest monsoon and seasonal rainfall forecasting have been the major concern of Indian Meteorologist for more than a century (Normand, 1953; Jagannathan, 1960; Rao, 1965, 1976; Hastenrath et al., 1983). According to an analysis by Subbramanyya (1968), there is a negative correlation in rainfall between the northeastern and west central parts of India, but this analysis does not indicate, as to how much variance is explained by different rainfall patterns.

Principal Component Analysis has certain advantages over the conventional orthogonal functions, since they are not of any predetermined form, but are developed as unique functions from the data matrix. This is particularly useful if nothing is known in advance about the existence or nature of the component patterns.

Stidd (1967) used empirical orthogonal functions to represent the seasonal rainfall variations of rainfall over Nevada and found that the first three terms in order of an increasing importance account for 93% of the variance in the original 12×60 matrix data. It has been found that these have features in common with the three natural cycles of precipitation. Bretherton et al. (1992) have used comparative measure to explain the observed co-variance matrix between the fields using a small number of the dominant modes.

Singh (1999) has shown the percentage of variance explained in different categories of monsoon rainfall (normal, flood and drought years) and concluded that the pattern has a possible physical significance. Recent studies have been carried out to use the PCA techniques by Webster et al. (1998), Compagnucci et al. (2001), Penarrocha et al. (2002), Mohapatra et al. (2003), Lana et al. (2004), Bordi et al. (2004) and Tosic (2004). In the present study, the principal component analysis is used to determine the dominant rainfall patterns from the rainfall records over India. Pattern characteristics of seasonal monsoon rainfall (June–September) over India for the period 1940 to 1990 are studied for 68 stations.

2. Analysis and computing procedure for data sets

The monsoon seasonal average rainfall data (in cm) between June and September for the period 1940 to 1990 for 68 stations has been considered in this study. The data has been taken from the India Meteorological Department (I.M.D.) Pune. The Indian monsoon rainfall over India during the month of June to September (122 days) exhibits interesting oscillations over the country.

In the present analysis the rainfall over the country has been expressed as a linear combination of orthogonal function. Principal components are a set of the orthogonal