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An analysis of drought conditions in Central Vietnam during 1961-2007

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Abstract. Monthly rainfall data given by surface meteorological observations during the period 1961-2007 in Central Vietnam is used to calculate drought indices. Results show that drought conditions slightly increase in North Central Vietnam but decrease in South Central and Highland Central Vietnam. Significant drought periods often occur from January to March. The percentage of dry years during the period 1961-2007 is larger than that in the reference period of 1961-1990 in North Central while smaller in South Central and almost similar to that in Highland Central Vietnam.

Keywords: Drought, trend, Central Vietnam.

1. Introduction

Drought is undoubtedly one of the worst natural hazards [1]. This phenomenon is a normal feature of climate with inevitable occurrence appears [2]. Drought can appear in any place causing significant damage both in natural environment and in human lives. It may start at any time, last indefinitely and may attain many degrees of severity [3]. Therefore, it has been classified into different types such as meteorological, hydrological, economic, or agricultural drought [4]. Palmer (1965) defined drought as a prolonged and abnormal moisture deficiency. A drought period is an interval of time, generally of the order of months or years, when the moisture supply of a region consistently falls short of the climatically expected or climatically appropriate moisture supply [5].

Investigations of drought are carried out all over the world. However, because of the complexity of this natural phenomenon, a common methodology for drought studies has not yet been developed, althought some indices of drought are widely used [6]. Drought indices are normally continuous functions of rainfall and/or temperature, river discharge or other measurable hydrometeorological variable. Many indices have been devised for different types of drought, including the Rainfall Anomaly index, the Palmer Drought index (PDI), the Bhalme-Mooley index, the Standardized Anomaly index, etc [5,7-9]. The

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most well known and the widely used of the drought index is PDI. The index has been used in various studies to illustrate the areal extent and severity of drought in the northeastern United States during the early to mid-1960s and across the United States during the hot, dry summer of 1980 [10,11].

An analysis of moisture extremes over Europe shows strong decadal-scale variability in drought frequency with the 1940s and early 1950s experiencing widespread and severe droughts, which was repeated with the same pattern in 1989 and 1990 [12]. The summer of 1992 was extremely hot and dry in central and eastern Europe, as was the summer of 1995 throughout much of western Europe [13].

In this paper the frequency and intensity of the drought periods in Central Vietnam is investigated during the period 1961-2007.

2. Data and methodology

2.1. Data

Monthly rainfall data gathered from 25 surface meteorological stations in Central Vietnam is used. These stations are located in three climatic sub-regions including the North Central sub-region (10 stations), South Central sub-region (8 stations) and Highland Central sub-region (7 stations).

2.2. Methodology

Rainfall distribution is one of the basic indentifiers of drought occurrence in a given region. The index of anomaly P is calculated as [6]:

$$P_j = \frac{1}{n}\sum_{i=1}^{n}\frac{x_{ij}}{\overline{x}_i} \qquad (1)$$

where the symbol $j = 1, \ldots, N$ denotes years, x_i is the total annual precipitation in the i^{th} station, $\overline{x}_i$ is the averaged annual precipitation for the station i^{th}, and n is number of stations. Values of $P > 1$ indicate wet conditions, values of $P < 1$ indicate drought conditions, and $P = 1$ is normal condition.

The frequency distribution of annual precipitation is calculated in the range [3]:

$$\begin{aligned} &P < \overline{P} - 2s_p && \text{- extreme dry} \\ &\overline{P} - 2s_p < P < \overline{P} - s_p && \text{- dry} \\ &\overline{P} - s_p < P < \overline{P} + s_p && \text{- normal} \\ &P > \overline{P} + s_p && \text{- wet} \end{aligned} \qquad (2)$$

where P is precipitation in a particular year, $\overline{P}$ is the average precipitation during the period 1961-1990, and s is the standard deviation.

Statistical methods is used to analyse the long-term variations in precipitation. The long-term data series are smoothed by using moving averages and the linear trends are added.

3. Results and discussion

The long-term variations of annual precipitation anomaly index in the three sub-regions in Central Vietnam are shown in Figure 1 where 5-years moving average and the linear trends are given. The linear trends are negative for North Central and positive for South Central and Highland Central Vietnam. This implies that drought conditions increase in North Central but decrease in South Central and Highland Central Vietnam. However, it should be noted that the rate of changes is very small. The driest years in North Central Vietnam during the period are 1969, 1977, and 1988 with P index in the range of 0.7 and 0.8. In

South Central Vietnam, the low values of *P* appear in 1982 and 2004. Other considerable dry years are 1961, 1967, 1968, 1977, and 1989. The driest years in Highland Central Vietnam are 1963 and 1977. It is important to note that there are some differences in the classification of dry years between the three sub-regions. The only dry year in the whole Central Vietnam is the year 1977.

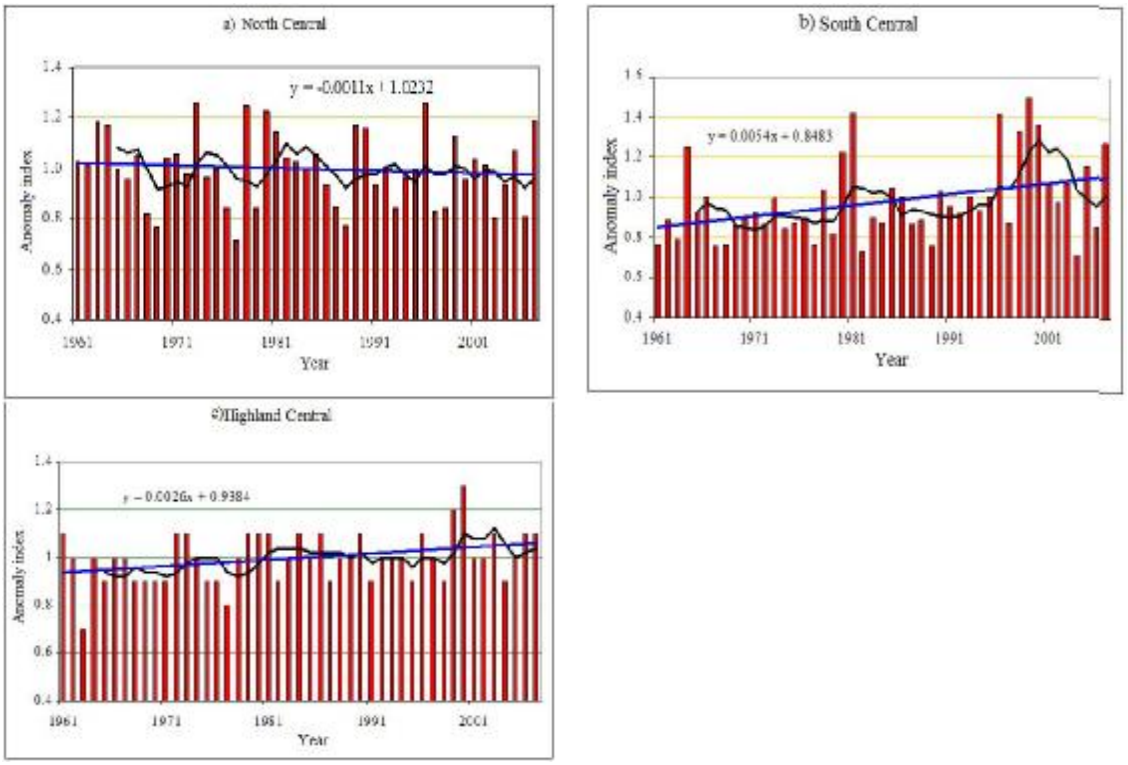

Figure 1. Long-term variations of the area-averaged precipitation anomaly index (colunms) for North Central (a), South Central (b) and Highland Central (c) Vietnam during 1961-2007. 5-years moving average (curves) is used and the linear trends are given (lines).

Table 1. Coefficient a_1 in regression equations for five sub-periods over the three sub-regions

Sub-regions / Sub-periods	North Central	South Central	Highland Central
1961-1970	-0.0232	-0.0035	-0.0085
1971-1980	-0.0022	0.0143	0.0042
1981-1990	-0.0048	-0.0213	0.0012
1991-2000	0.0064	0.0579	0.0285
2001-2007	0.0122	0.0176	0.0143

Values of coefficient a_1 in the regression equations of what for five sub-periods over the three sub-regions are given in Table 1. The sign of this coefficient indicates the increasing trend (positive) or decreasing trend (negative) of the precipitation anomaly index. It is seen that drought conditions increase during the three first sub-periods in North Central Vietnam in which the first period 1961-1970 has the largest rate of change. The increasing trends of dry conditions also happen in 1961-1970 and 1981-1990 in South Central and during the first sub-period in Highland Central Vietnam. The decreasing trends of dry conditions occur in the whole Central Vietnam during the two last sub-periods where the most significant change is in 1991-2000 in South Central Vietnam.

Monthly variations of the precipitation anomaly index for three sub-regions are shown in Figure 2. Dry conditions often occur from December to July in North Central, from January to August in South Central and from November to April in Highland Central Vietnam. Significant droughts mainly happen from January to March in the whole Central Vietnam. The difference in drought occurrence between the three sub-regions is due to the local characteristics of rainy season.

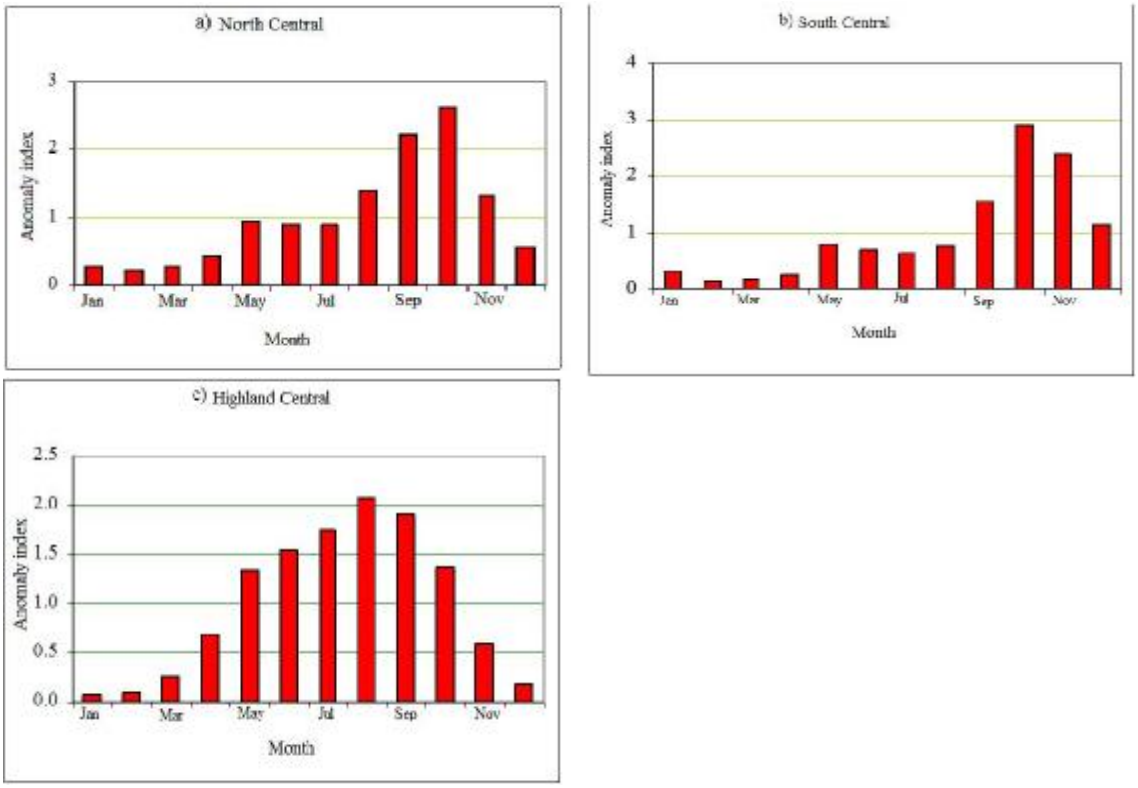

Figure 2. Monthly variations of the area-averaged precipitation anomaly index for North Central (a), South Central (b) and Highland Central (c) Vietnam.

In Figure 3 the percentage distribution of the years in seperate sub-periods according to the drought criteria (2) is given. The five sub-periods are 1961-1970, 1971-1980, 1981-1990, 1991-2000 and 2001-2007. The distribution of these sub-periods is compared to that of the reference period 1961-1990. The extreme dry condition only occurs in North Central and Highland Central Vietnam with low frequency and have little changes between the sub-periods. The largest percentage of extreme dry years is nearly 8% in Highland Central Vietnam during the first sub-period 1961-1970. In general, the variation in the percentage of dry years between the sub-periods is the largest in South Central and the smallest in Highland Central Vietnam. It is clearly found that the percentage of wet years more increases in the two last sub-periods than in the reference period in South Central and Highland Central Vietnam. The averaged percentage of dry years during 1961-2007 is 17.64% compared to 15.7% in the reference period in North Central, 9.56% compared to 12.5% in South Central and 13.3% compared to 13.2% in Highland Central Vietnam.

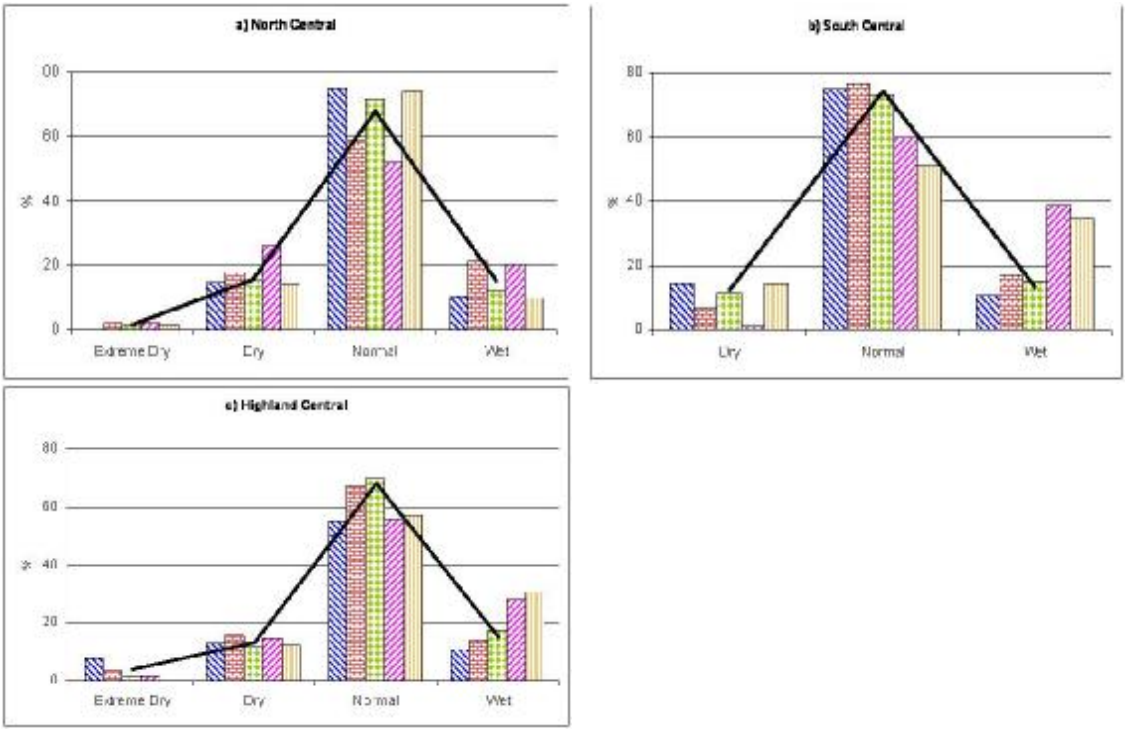

Figure 3. Distribution (in %) of extreme dry, dry, normal and wet years in North Central (a), South Central (b) and Highland Central (c) Vietnam for five periods and the reference period 1961-1990.

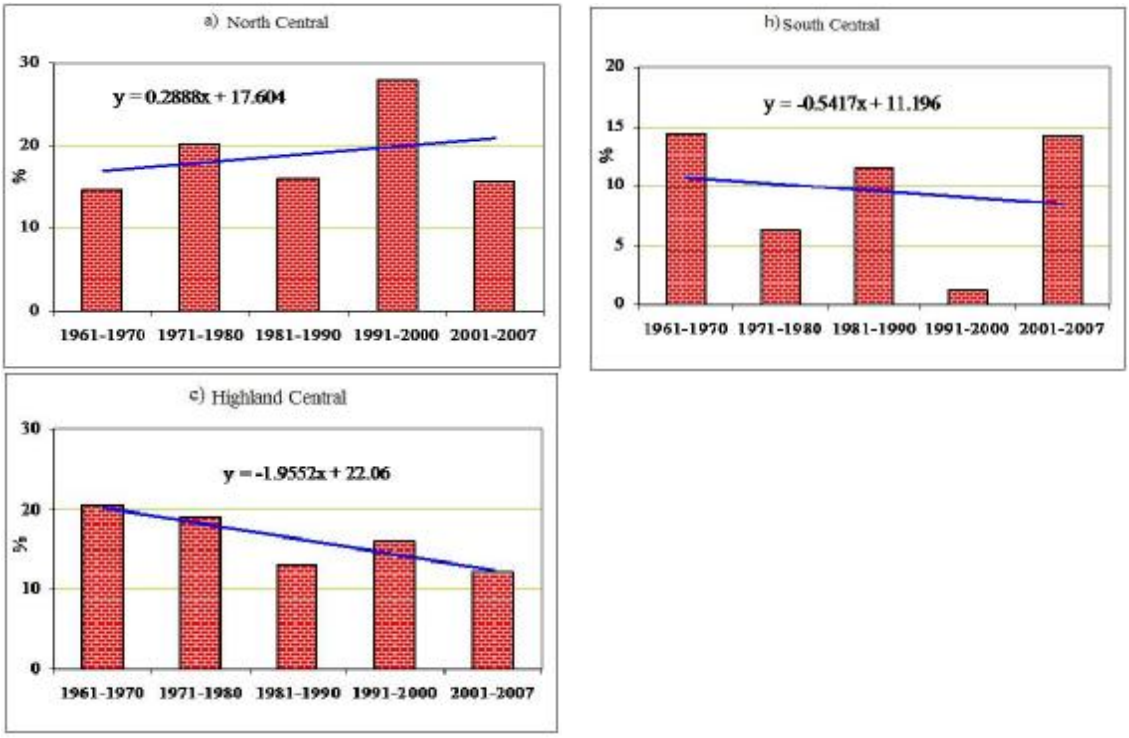

Figure 4. The linear trends of the percentage of extreme dry and dry years for North Central (a), South Central (b) and Highland Central (c) Vietnam for five sub-periods.

The percentage of extreme dry and dry years over the sub-regions for the sub-periods is clearly shown in Figure 4. It can be seen that dry conditions slightly increase in North Central while decrease in South Central and Highland Central in which the rate of change in Highland Central Vietnam is the largest. The maximum percentage of dry years occurs in the sub-period 1991-2000 in North Central and the minimum value is in South Central Vietnam in the same sub-period.

4. Conclusion

The results of this study show that drought conditions slightly increase in North Central while decrease in South Central and Highland Central Vietnam during 1961-2007. The increasing trend of drought conditions happens in the first period 1961-1970 in the whole Central Vietnam in which the rate of change in North Central Vietnam is the largest. The decreasing trend of drought conditions occurs in the whole Central Vietnam during the two last sub-periods where the most significant change is in 1991-2000 in South Central Vietnam. The averaged percentage of dry years during 1961-2007 is larger than that in the reference period 1961-1990 in North Central while smaller in South Central and almost similar to that in Highland Central Vietnam.

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