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Radius of rainfall influence over Indian monsoon region

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The paper describes an analysis of rain gauge data to determine an appropriate radius of influence to use for the objective analysis of rainfall over Indian monsoon region. The correlation co-efficient (CC) of rainfall between rain gauges in discrete distance intervals is computed, and the distance at which CC falls to 0.3 is chosen as the radius of rainfall influence. The method is applied for the monthly mean rainfall observations for June, July and August of Indian summer monsoon 2001. The method is also tested for a few case studies in relation to varying geographical and synoptic situations. The study shows that the radius of influence of rainfall over Indian region, in general, is around 200 km, but it has certain day to day variations depending on the prevailing synoptic conditions. The finding of the study is expected to be very useful for the objective analysis of rainfall over Indian region.

Keywords: objective analysis of rainfall, radius of rainfall influence, monsoon

1. Introduction

Objective analysis of rainfall over highly complex inhomogeneous region like India is very challenging. There are various factors like topography, prevailing synoptic situation and its interactions with mesoscale systems, lack of rainfall observed data etc. are some of the key factors which posses difficulties in analyzing rainfall for any region and so Indian monsoon region is not an exemption. For current objective analysis methods used for rainfall analysis, initial assessment of the radius of rainfall influence is one of the most important parameter. This parameter is highly dependent on the geographical location. Any attempt for getting an estimate of this parameter for Indian monsoon region is therefore very useful. All the weighting functions that are proposed by various researchers (Cressman, 1959; Thiebaux and Pedder, 1987; Barnes, 1964 etc.) for the objective analysis of rainfall, appear as functions of the distance between the sites only. For instance, Thiebaux and Pedder (1987) weighting function is defined as:

$$W(r_{i,m}) = \left(\frac{R^2 - r^2{}_{i,m}}{R^2 + r^2{}_{i,m}} \right)^2 , \text{ for } \quad r_{i,m} < \mathrm{R}$$

$$= \qquad 0 , \qquad \text{for } \quad r_{i,m} \geq \mathrm{R}$$

where $r_{i,m}$ is the distance between i-th site and the estimation point m and R is the radius of rainfall influence.

As no well defined method is available, radius of influence is determined subjectively by personal experience varying from 150 km to 300 km for use in the objective analysis of rainfall (Roy Bhowmik et al., 2005; Mitra et al.,1997; 2003). The dimensionless weighting functions are suggested on the basis of the logical and geometrical conceptualizations. In reality, it is expected that the weights should reflect to a certain extent on the observational network and regional behavior in the occurrence of the phenomenon concerned. Therefore, the main purpose of the present study is to derive an objective method for determination of the radius of influence of rainfall over Indian monsoon region.

2. Methodology and data sources

Sen (1997) applied cumulative semivariogram (CSV) technique to determine the radius of influence of rainfall and weighting function over Turkey based on monthly mean rainfall data from 13 stations. The CSV is defined as a curve that shows the variation of successive half squared difference summation with distance. After certain distance, the curve becomes asymptotic which corresponds to the radius of influence. In the present study, correlation coefficient (CC) of rainfall among stations in relation to distance is used to determine the radius of influence of rainfall. The distance axis is divided into intervals of 10 km and subsequently CC is computed among the stations within an individual interval which is regarded as the representative value of CC for that interval. The distance at which CC curve starts becoming asymptotic is taken as radius of influence of rainfall. The distance of 10 km interval is considered due to the fact that this corresponds to the smallest distance between two stations.

Data used in this work are the observations of daily rainfall amounts accumulated over the past 24 hours and reported at 03:00 UTC of each day. For the present study a total of 1330 daily rain guage observations, received from synoptic and as well as DRMS (District-wise Rainfall Monitoring Scheme) network of India Meteorological Department (IMD) are used. Out of these, 576 synoptic stations spread all over the country (India) are from regular surface observatories for which real time rainfall observations are available in operational basis. The data used in this study is for the period from 1 June to 31 August of summer monsoon 2001. From the daily data, stations' monthly means are computed for each month. A computer program has been developed for computation of CCs in respect to the distance of 10 km intervals for each month and accordingly CC curve is constructed. In order to investigate the day to day variations of CC curve in relation to different synoptic situation a few selective case studies are also presented in this paper. The method is also tested for different sectors of India to investigate the geographical variations of radius of influence.

3. Results and discussion

Monsoon depression is the main rain producing system of summer monsoon over Indian region which forms over the northwest Bay of Bengal and moves northwest wards across the country giving rise to heavy to very heavy falls during its passage. Western Ghats of India is another region where heavy orographic rainfall occasionally occurs during the active phase of monsoon due to the strong lower tropospheric westerlies. The rain shadow due to Western Ghats spreads over a large area over the peninsular India. The sub-

Table 1. CC in relation to distance.

Distance (km)	No. of station combinations	CC
10	213	0.74
20	913	0.80
30	2151	0.75
40	3830	0.71
50	5864	0.68
60	8250	0.66
70	10883	0.64
80	13828	0.60
90	17005	0.58
100	20544	0.54
110	24220	0.52
120	28137	0.48
130	32299	0.45
140	36726	0.43
150	41269	0.40
160	45935	0.38
170	50810	0.37
180	55930	0.35
190	61250	0.33
200	66618	0.32
210	72332	0.30
220	78010	0.29

divisions in northwest and southeast get the least amount of rainfall. Indian summer monsoon has got different phases like June, the onset phase and July the active phase. Again, break monsoon conditions takes place occasionally during August when subdued rainfall conditions prevails over most part

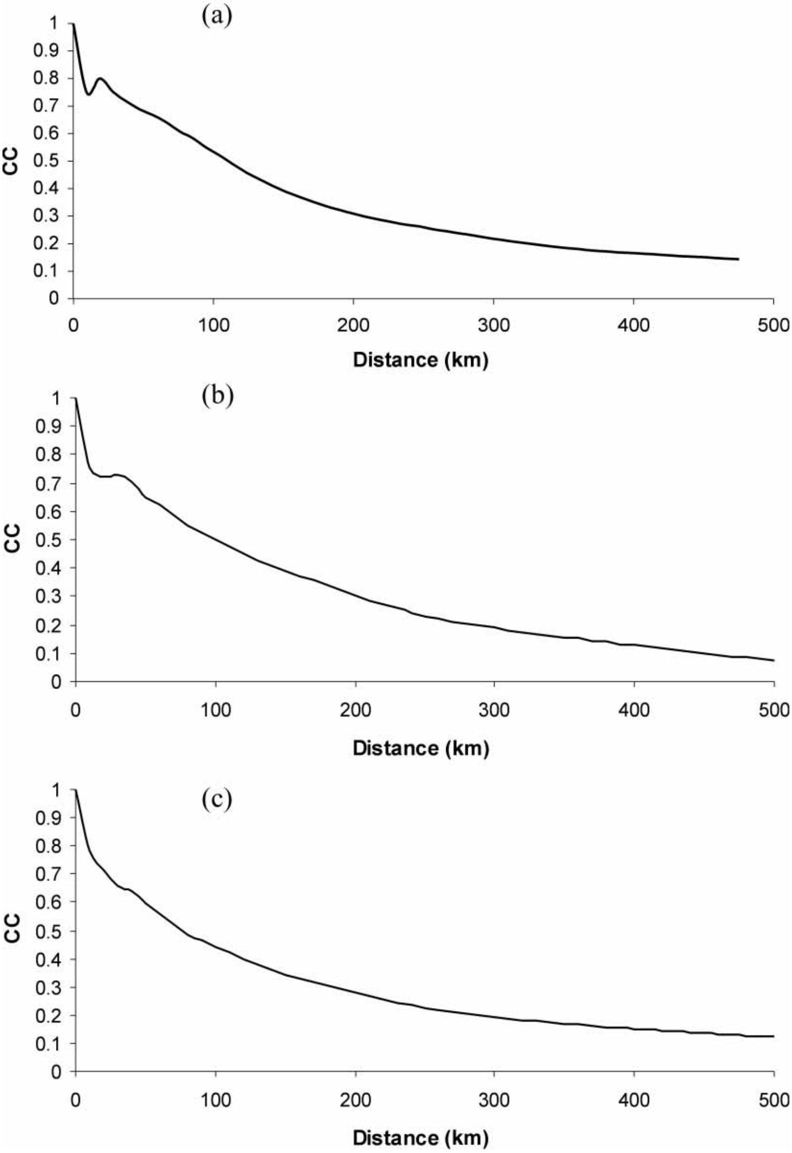

Figure 1. Cumulative semivariograms for the month of (a) June (b) July and (c) August, for the year 2001.

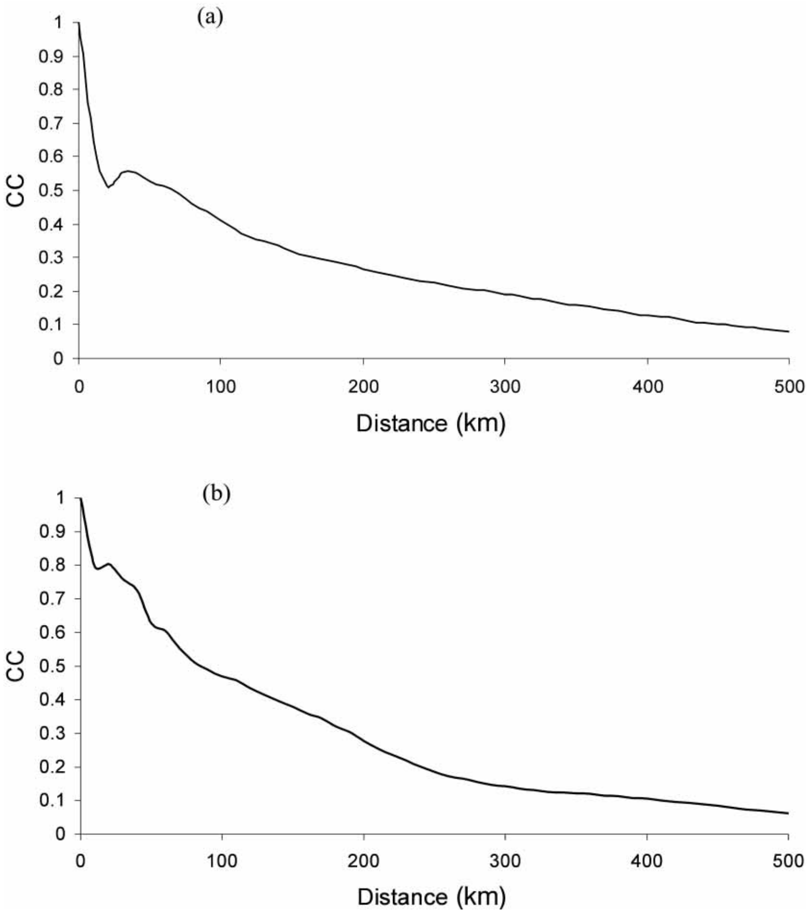

Figure 2. Cumulative semivariogram of June 2001 for the country (a) north of lat. 20 °N and (b) south of lat 20 °N.

of the country (except north-eastern part). Keeping these features of Indian monsoon in mind, the technique (CC as the function of distance) as described above is applied for the monthly mean observations as well as for varying synoptic cases and different sectors of India.

3.1. Monthly mean

Figure 1 illustrates the CC curve for the month of June. This shows that CC decreases and reaches an asymptotic value as the distance increases in different rate. The decrease is rapid up to 210 km when CC becomes 0.3. Thereafter CC reaches 0.1 at a distance of 500 km and CC curve remains almost horizontal. Initially, the CC curve has an intercept at the horizontal distance of 10 km which corresponds to the smallest distance between two stations. The CCs at 20 km and 30 km are higher than that of CC at 10 km. This may be due to convective nature of rainfall which dominates over Indian region. Number of combination of stations against distance and corresponding CC are shown in Table 1. For 10 km distance there are 213 combinations of stations, becomes 20544 for 100 km distance and 66618 for 200 km distance.

The CC curve for the month of July (Figure 1(b)) shows CC as 0.3 at 200 km and becoming 0.1 at the distance of 425 km. For the month of August (Figure 1(c)) 0.3 CC occurs at 190 km distance and 0.1 CC at 430 km dis-

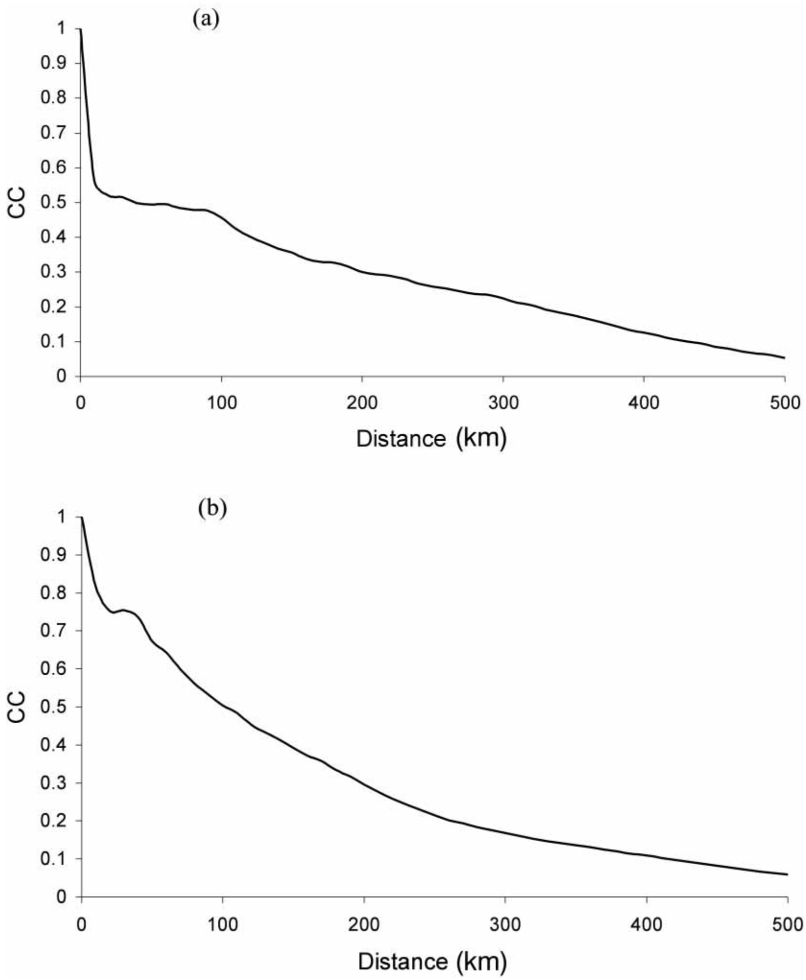

Figure 3. Cumulative semivariogram of June 2001 for the country (a) east of long. 80 °E and (b) west of long. 80 °E.

tance. Both the curves show an intercept at the distance of 10 km. In compare to June, the intercept appears flat in July and August when large scale rainfall features become more dominant.

3.2. Geographical variation

In order to examine the geographical variation of CC against distance, Figure 2(a,b) respectively present the CC curve for the northern part of country, north of 20 °N and southern part of country, south of 20 °N for the month of June. For the northern part of the country 0.3 CC occurs at 190 km and 0.1 CC at 480 km distance. For the southern part of the country CC is 0.3 at 195 km and 0.1 at 400 km distance. The intercept at 10 km distance is noticed in both the CC curve.

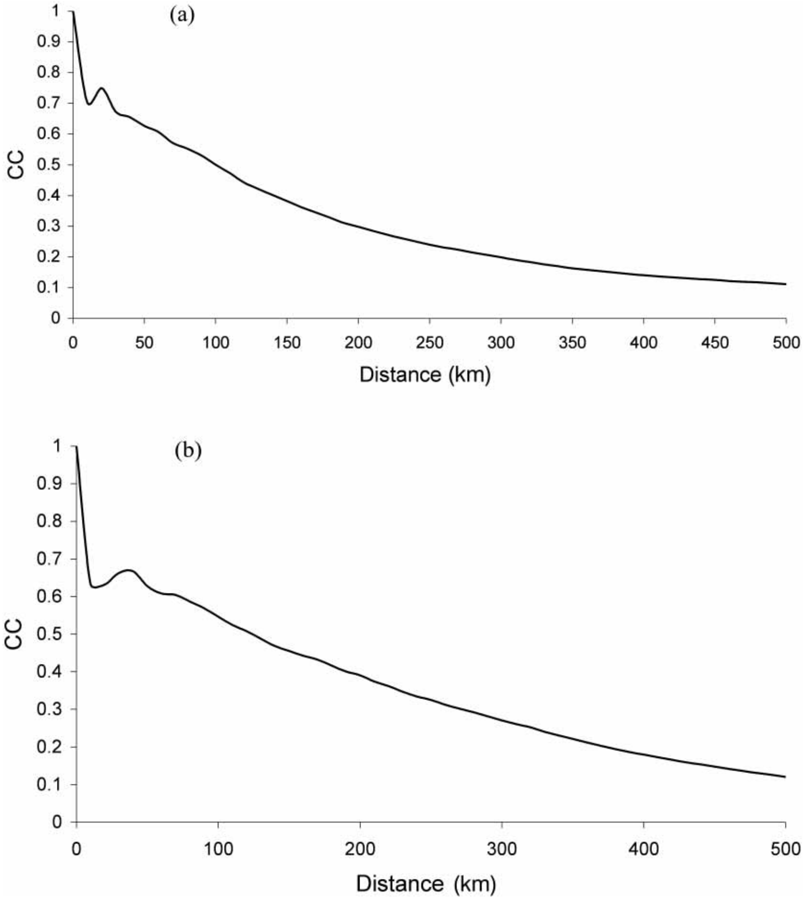

Figure 4. Cumulative semivariogram for (a) 1 June, (b) 14 June, (c) 15 June and (d) 1 August.

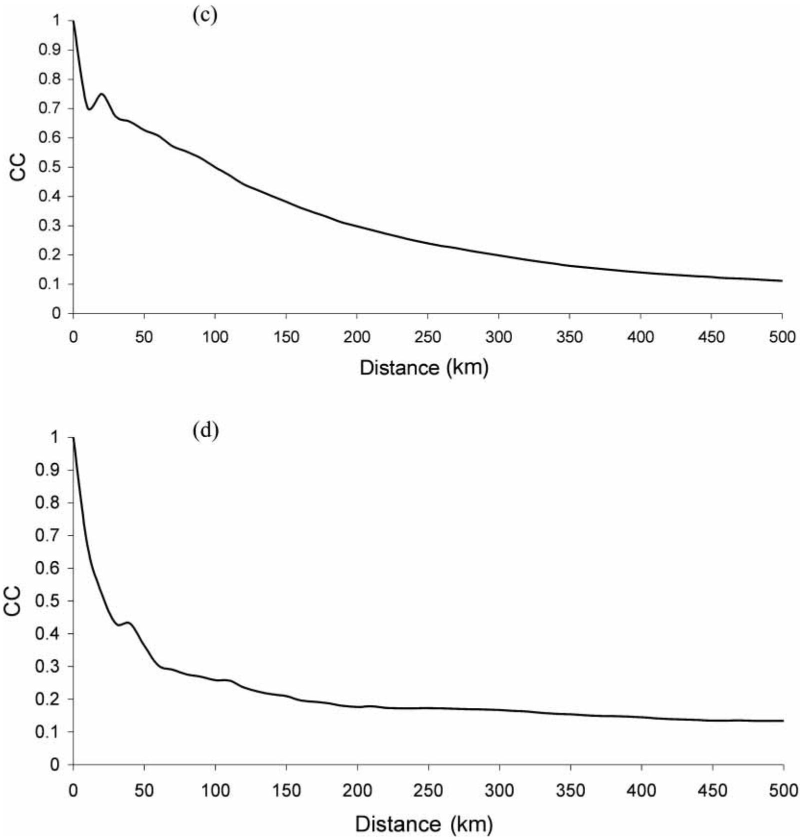

Figure 4. cont.

Figure 3(a,b) respectively present the CC curve for the eastern part of country, (east of 80 °E) and western part of country (west of 80 °E) for the month of June. For the eastern part of the country 0.3 CC is noticed at 190 km and 0.1 CC at 400 km distance. For the western part of the country CC shows 0.3 CC at 200 km distance and 0.1 CC at 450 km distance.

3.3. Case studies

In order to examine day to day variation of CC curve against distance, case studies (Figure 4(a-d)) are selected for 1 June during the onset phase of monsoon, 14 and 15 June during the active phase of monsoon when a monsoon depression lay over the central India and for 01 August when break monsoon condition prevailed over the country.

In case of 1 June, CC is found to be 0.3 at a distance of 190 km and thereafter asymptotic starts and at 450 km CC reaches 0.1. For the case of 14 June

CC becomes 0.3 at 260 km distance and 0.1 at 480 km distance. On 15 June CC remain as 0.3 at 200 km and 0.1 at 450 km. In case of 1 August, considerable difference is noticed in the CC curve when CC becomes 0.3 at 90 km distance and asymptotic started at 200 km at the CC of 0.2. The initial intercept is found to occur at 30 km distance.

All these results illustrated above suggest that the CC as the function of distance as defined in this study is a decreasing function which reaches the asymptotic value as the distance increases at different rates. The case studies show that there is some day to day variation in CC curve and the distance for the occurrence of 0.3 CC fluctuates from 90 km to 260 km. But, in general, CC reaches 0.3 near 200 km distance and 0.1 at 450 km distance. This indicates rate of decrease of CC after 200 km is significantly low, which means that after a certain distance (to be specific when CC becomes 0.3), there is little regional effect of one station on other stations' rainfall amount. This distance (200 km) is specified as the radius of influence of rainfall.

At the beginning, all the CC curves have an intercept at the distance of 10 km which corresponds to the smallest distance between two stations. This kind of intercept is also reported by Sen (1997). For the cases when mesoscale convective systems are dominant, the intercept is very sharp and for the large scale system it is flat.

Initially, the original CSV method (based on successive half squared difference summation with distance) as proposed by Sen (1997) was attempted for the Indian region but asymptotic curve could be reached only after 2000 km (Figure not shown), which is unrealistic to consider as radius of influence. The radius of influence Sen (1997) got around 100 km for Turkey from the use of 13 rain gauge stations. But the method could not produce realistic radius of influence over India from the use of large number of (about 1330) rain gauge stations.

4. Summary and concluding remarks

Due to various reasons, rainfall over Indian monsoon region is highly inhomogeneous and anisotropic. Thus all the rainfall analysis methods, which employ conventional objective analysis scheme using radius of influence have its own inherent problems and thus the corresponding rainfall analysis may not reproduce the realistic rainfall characteristics. The technique of correlation co-efficient (CC) as the function of distance is applied for objectively determination of radius of influence of rainfall over Indian monsoon region. The technique proposed here, takes into account collectively the site configuration as well as meteorological event behavior in a regional sense. The method provides an objective tool for determining the radius of influence value from rainfall observations. The study shows that the radius of rainfall over Indian region, in general, is around 200 km, but it has certain day to day variation depending on the synoptic and geographical conditions.

Radius of influence thus determined is expected to be very useful for the objective analysis of rainfall over Indian region. As the radius of influence is case (event) sensitive, the study also suggests that prior to the application of objective analysis of daily rainfall, it is necessary to determine the radius of influence from the same data base for using it in the analysis scheme. Very recent study of Roy Bhowmik et al., (2005) shows that the gridded rainfall analysis at the resolution of 1 ° grid, produced with radius of influence as 200 km has the capability to resolve synoptic as well as mesoscale features of monsoon precipitation system over Indian region.

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SAŽETAK

Radijus utjecaja oborine nad područjem monsuna u Indiji

S. K. Roy Bhowmik, D. Joardar i Ananda K. Das

Ova studija prikazuje analizu mjerenja kišomjernih postaja radi određivanja odgovarajućeg radijusa utjecaja za potrebe objektivne analize oborine nad područjem monsuna u Indiji. Računao se koeficijent korelacije oborine između kišomjernih postaja na diskretnim intervalima te je koeficijent korelacije od 0.3 odabran kao radijus oborinskog utjecaja. Metoda je primijenjena na srednje mjesečne vrijednosti oborine za razdoblje lipanj-kolovoz 2001. tijekom ljetnog monsuna u Indiji. Ova metoda također je testirana na nekoliko odabranih slučajeva zbog variranja geografskih i sinoptičkih situacija. Studija pokazuje da je radijus utjecaja oborine nad područjem monsuna u Indiji općenito oko 200 km, iako postoji određena dnevna varijabilnost koja ovisi o prevladavajućim sinoptičkim uvjetima. Rezultati ove studije korisni su za potrebe objektivne analize oborine nad područjem Indije.

Ključne riječi : objektivna analiza oborine, radijus oborinskog utjecaja, monsuni

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