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Continentality trends over India and the neighbourhood

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ABSTRACT. The paper is an extension of another article published by the author earlier. The purpose of the work presented herein is to emphasize the role of thermal continentalities in the study of general climatology. The parameter chosen for the analytical study is K* defined (previously) as the ratio of actual to expected summer concentrations of thermal efficiency, a concept first recognized by Thornthwaite.

Making use of the values of K* for about 250 stations in and around India, computed as explained in the previous paper, an iso-continental map was prepared and presented. The outstanding feature of the map is the division of the country into two major (the super and the sub-continental) zones of different continentality characteristics, the demarcating line being the isopleth of K* = 100 per cent. Comparison of this map with other climatic maps shows striking similarities to the moisture rather than the thermal indices, lending support to the view that the continentality traits of a region are determined essentially by its moisture regime.

The altitudinal variation of K* in the two zones referred above shows certain highly interesting features. Levels of normal continentality, continentality reversal and continentality invariance are identified and it is felt that further extension of the work on a quantitative basis may reveal other features of great significance to the physical climatology of India and the neighbourhood.

In a previous publication (Subrahmanyam 1957), the author described the application of Thornthwaite's concept of the summer concentration of thermal efficiency (Thornthwaite 1948) for the study of thermal continentality and its latitudinal variation over India. The influence of the inverted triangular shape of the peninsula, abrupt broadening of the sub-continent around 25° north latitude and the closing-in of the huge mountain chains in the extreme north, on the latitudinal variation of continentality both at the coastal and inland stations was briefly discussed therein. The present paper attempts to study the geographical distribution of the continentality factor K* (defined as the ratio of the actual to the expected summer concentrations of thermal efficiency, expressed as a percentage) as also its altitudinal variation.

The continentality factor K* was calculated, as explained earlier, for about 250 stations in India, Pakistan, Burma and Ceylon and the iso-continental map prepared with the help of these computed data, is presented in Fig. 1. In the preparation of this map no attempt was made to reduce the parameters to any standard level and therefore the map represents the net influence of elevation, slope, air-masses and other factors that are known to determine the nature and magnitude of continentality. An outstanding feature of the map is the trend of the 100 per cent continentality isopleth which starts from lower Baluchistan in the west, runs more or less horizontally eastward upto Bihar and then takes a sharp turn to the northwest and finally merges with the western flanks of the Himalayas. Another line of the same value starts at the northern boundary of the Kashmir territory, runs southwest and then mingles with the Hindukush mountain ranges after a short northward march close to the Northwest Frontier region. It is only the region bounded by these two iso-continentals (100 per cent) that appears to have a purely continental type of climate, characterized by extremes of temperature, low air humidities and comparatively clear skies, while the rest of the country possesses sub-continental (or oceanic) characteristics. The explanation for this feature is not difficult to seek; below the southern boundary of this zone the low continentality factors are

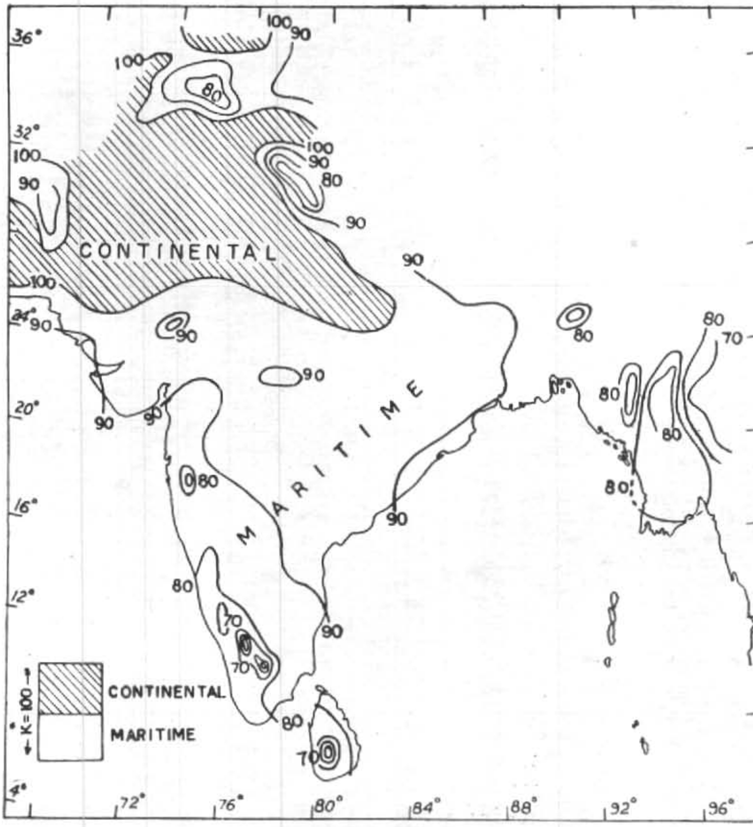

Fig. 1. India and neighbourhood—Isocontinentals

primarily due to the maritime air transported into the country by the summer monsoonal circulation. The sub-continental territory to the north on the other hand, owes its existence to the high elevations of the plateau land and the mountains.

The effect of elevation on the reduction of continentality can be seen from the regions of weak continentality in the mountainous territories. Amidst the gradual increase of K* from southwest to northeast over the peninsula, the islands of low continentality are chiefly due to the hilly prominences. The same is true of the central portion of Ceylon and the mountain tracts of Burma; the K*-High in central Burma is due to the Irrawaddy valley. In the southwestern Himalayas too are places with very low values of continentality (K* less than 60 per cent) and the Sulaiman ranges in the Baluchistan have recorded values around 80 per cent.

The above distribution of continentality points to the thermal adjustment of the country in relation to its geographical and climatic diversity; the sub-continental character of a major portion of the country clearly shows the dominating influence of maritime air-masses on the climatology of India. It may be observed from the striking similarities of the iso-continental map presented in Fig. 1 to other climatic maps (Subrahmanyam 1956, Carter 1954) that the continental features of the country are determined more by its humidity rather than temperature regime. This is understandable in view of the fact that in generally humid climates the maximum temperatures are not very high nor the minimum temperatures too low; in other

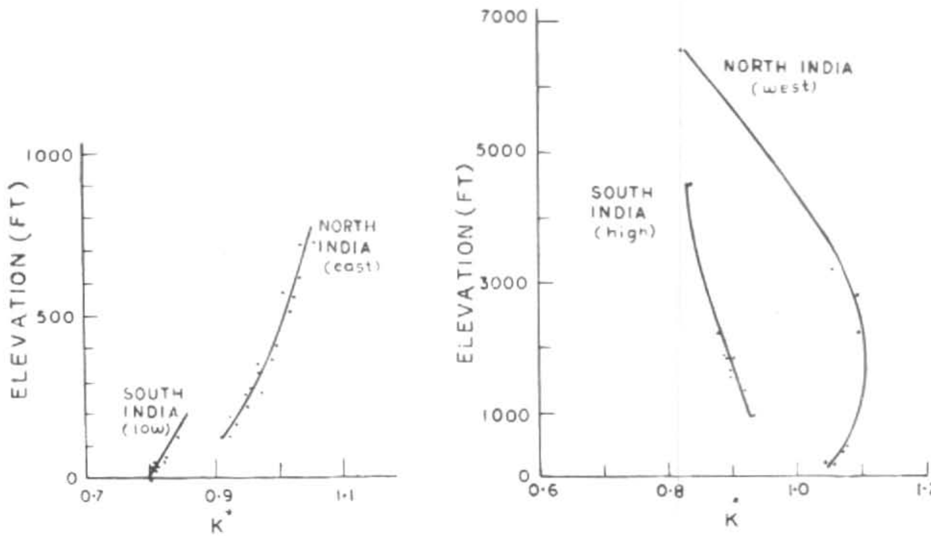

Fig. 2. Variation of K* with elevation

words, the temperature ranges are not large compared to drier climates with otherwise similar meteorological conditions.

According to Zenker's formulae (Conrad 1946), the continentality coefficient, K, should decrease with elevation since the mean annual temperature range itself decreases with altitude. It is certainly not correct to consider this continentality diminution with elevation as an increase in oceanicity without taking into account the simultaneous reduction in the mean temperature. Incorporating, therefore, a term for the local temperature gradient (in the vertical) in the expression for the continentality coefficient would, perhaps, eliminate or minimize this effect and produce a more realistic picture. Nevertheless, a general survey of the altitudinal variation of K* would, by itself, constitute an interesting preliminary study. More intensive analysis should initially eliminate the influence of one factor over the other (elevation and distance from the maritime source) before the patterns and trends of continentality distribution could be interpreted.

Broad analysis of the features of continentality variation with height was made by choosing representative stations (Table 1) from north and south India belonging essentially to the super- and sub-continental zones referred to earlier. The resulting curves, presented in Fig. 2, fall into two different categories. South India is surrounded on three sides by sea, has no appreciable areal extent and the hills too are not very prominent. This is perhaps the reason why the range of variation of K* is small. In north India, on the other hand, the land mass has an extensive east-west spread and the monsoon too is channelled in such a way that its influence becomes increasingly smaller as one progresses north and northwest. This readily accounts for the generally high values of continentality in this part of the sub-continent. Two features, however, stand out very prominently regarding the height variation of K*; in both south and north India, at low elevations, K* increases with height and above a certain level in this northern section, it seems to attain constancy. In order to nullify the effect of latitude on continentality variation, stations were chosen for this study, that lie approximately in the same latitudinal belt (27°—28°N in the north and 17°—18°N in the south). In spite of this, two situations arise in south India for low and high elevations without much of a continuity in

TABLE 1

Station	Latitude (N)	Elevation (ft above m.s.l.)	K*
A. *South India (Low elevations)*			
Calingapatam	18° 20′	19	0·802
Alibag	18 38	23	0·807
Bombay	18 54	37	0·830
Gopalpur	19 16	56	0·836
Visakhapatnam	17 42	126	0·846
B. *South India (High elevations)*			
Nizamabad	18 40	1250	0·917
Gulbarga	17 21	1503	0·894
Sholapur	17 40	1570	0·893
Ahmednagar	19 05	2154	0·877
Poona	18 32	1834	0·887
Mahabaleswar	17 56	4534	0·832
Hyderabad	17 26	1778	0·900
Hanamkonda	18 01	881	0·928
Jagdalpur	19 05	1815	0·896
C. *North India (West)*			
Sibi	29 33	441	1·077
Nokkundi	28 49	2229	1·085
Dalbadin	28 54	2785	1·093
Kalat	29 02	6616	0·826
Bhawalpur	29 24	384	1·070
Panjgur	26 58	3177	1·054
Jacobabad	28 17	185	1·047
Sukkur	27 42	221	1·058
D. *North India (East)*			
Hissar	29 10	725	1·051
Delhi	28 35	714	1·029
Aligarh	27 53	615	1·031
Bareilly	28 22	568	1·000
Agra	27 10	553	1·020
Mainpuri	27 14	516	1·015
Bahraich	27 34	407	0·990
Gonda	27 08	360	0·986
Gorakhpur	26 45	254	0·973
Motihari	26 40	218	0·945
Dharbhanga	26 10	161	0·928
Jalpaiguri	26 32	271	0·953
Purnea	25 46	124	0·919
Dhubri	26 01	115	0·903
Gauhati	26 11	182	0·918
Tezpur	26 37	258	0·943
Sibsagar	26 59	317	0·966
Dibrugarh	27 28	348	0·963

the trend of variation. In north India, stations tend to be grouped separately for the eastern and western sections. A careful examination of Fig. 1 reveals the underlying cause, for, in north India, the eastern and western divisions are climatically controlled differently and, therefore, have different continentality characteristics. Detailed study indicates more interesting features of the altitudinal variation of K* in these diverse sections. For the elevations of stations in the east, K* increases from about 90 per cent through 100 per cent to 105 per cent (maritime-normal-continental) while in the west even at low elevations the factor is 105 per cent (continental) which increases to about 110 per cent (more continental) and then shows a gradual decline, the level of this continentality reversal being about 1500 ft. In the belt chosen for south India (high), it is hard to ascertain this level but the curve establishes beyond doubt the existence of such a reversal level. In contrast, in the eastern section of north India, no evidence of any reversal is apparently available.

A feature of presumably great climatic significance is that the whole of south India has continentality factors less than 100 per cent, implying that it has an essentially maritime type of climate; the increase of K* with height at low elevations does not, however, throw any level on to the absolutely continental category (K* in excess of 100 per cent), the maximum computed value for this parallel being only 92·8 per cent. In north India the situation seems to be more interesting, for, K* has values greater than 100 per cent even at the surface levels in the west and these rise to about 110 per cent before the level of continentality reversal is reached. From this level upward K* decreases steadily with height and attains its normal value of 100 per cent around 4200 ft. On the east, stations at low elevations have maritime features as may be seen from the values of K* being less than 100 per cent and the general rise of K* with height brings about normal continentality at about 450 feet above sea level. Another conspicuous feature in the south as well as in the eastern section of north India is that the decrease of K* with respect to elevation becomes less rapid with increase of altitude and shows a tendency towards constancy at higher elevations. Such a level of 'Continentality Invariance', as it may be called, does not seem to exist in the western section of north India where K* continues its steady and rapid decrease with height without evidence of any change in rate.

It would be of extreme academic interest to investigate if such situations prevail in other sections of India, as well as Burma and Ceylon. The poor density of the net-work of climatological stations is a serious handicap for any such systematic study but the search for the real physical causes for these various features would constitute an important contribution to the descriptive climatology of the Indian sub-continent.

REFERENCES

Carter, Douglas B.	1954	*Publ. Clim., Johns Hopk. Univ. Lab. Clim.*, **7**, 4.
Conrad, V.	1946	*Trans. Amer. Geophys. Un.*, **27**, 5.
Subrahmanyam, V. P.	1956	*Indian J. Met. Geophys.*, **7**, 3, p. 253.
	1956	*Ann. Ass. Amer. Geogr.*, **46**, 3.
	1957	Summer concentration of thermal efficiency as an index of thermal continentality, *Indian Geogr.*, **1** and **2**, 2 and 1.
Thornthwaite, C. W.	1948	*Geogr. Rev.*, **38**, 1.