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Himalayan snow cover area and onset of summer monsoon over Kerala, India

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सार — 1971–1981 की अवधि के लिए हिमालय के हिमाच्छादन विस्तार तथा केरल, भारत में ग्रीष्मकालीन मानसून के शुरूआत के बीच संबंधों की परीक्षा की गई है। हिमालय का हिमाच्छादन विस्तार उपग्रह से लिए गए चित्रों तथा उत्तरी गोलार्ध हिमाच्छादन चार्टों से तैयार किया गया है भारत मौसम विज्ञान विभाग से केरल में ग्रीष्मकालीन मानसून के शुरू होने की तिथियां उपलब्ध हुई हैं। इस आरंभिक अध्ययन ने संकेत दिए है कि फरवरी से अप्रैल मास तक हिमालय से पिघलने वाली औसतन बर्फ का केरल में मानसून के शुरू होन पर नकारात्मक सह-संबंध (सहसंबंध गुणांक 0.62) होता है। इससे निष्कर्ष निकलता है कि फरवरी से अप्रैल तक हिमालय पर यदि अधिक मात्रा में बर्फ पिघलती है तो केरल में ग्रीष्मकालीन मानसून जल्दी आता है और कम बर्फ गिरने पर ठीक इसके विपरीत की स्थिति होती है।

ABSTRACT. The relationship between the Himalayan snow cover extent and the onset of summer monsoon over Kerala, India, has been examined for the period 1971-81. The snow cover extent over the Himalayas has been derived from satellite images and Northern Hemisphere snow cover charts. India Meteorological Department (IMD) provides the onset dates of summer monsoon over Kerala. This preliminary study indicated that mean monthly snow cover area over the Himalayas for the months February through April had positive correlation (correlation coefficient 0.62) with the onset dates of summer monsoon over Kerala. This implies that large snow cover over the Himalayas for the months February through April was likely to be followed by an late onset of summer monsoon over Kerala and *vice versa*.

1. Introduction

The onset of summer monsoon over India is now recognized by some climatologists as a noteworthy climate singularity (Thambyahpillay 1960; Dey 1970). The onset occurs between late May and early July depending upon the latitudinal locations. During the onset period warm continental air mass over India is replaced by Southern Hemispheric maritime air mass (Findlater 1969). The onset of summer monsoon over a station is identified by the characteristic rise in the cumulative rainfall recorded at the station. India Meteorological Department (IMD) publish a chart of the dates of onset by identifying the characteristics rise in the trend of the cumulative rainfall curve over different meteorological stations. The onset of summer monsoon was found to be associated with the following events (Flohn 1957, Koteswaram 1958); (a) the initial formation of a weak trough between 90 deg. E & 100 deg. E longitudes at 700 mb level extending southward to about 20 deg. N latitude, (b) the development of an anticyclonic circulation over the Tibetan Plateau, (c) the appearance of an easterly jet stream well south of the Himalayas, (d) the displacement of the subtropical westerly jet stream north of the Himalayas, (e) the northward displacement of the north Pacific high from 13 deg. N in May to 23 deg. N by the end of June and (f) the withdrawal of the Arabian Sea high from central India to western Arabian Sea.

Blanford (1884) and Walker (1916) correlated the winter snow cover accumulation over the Himalayas and the summer monsoon rainfall over northwest India. Recently, Hahn and Shukla (1976), Dey and Kumar (1983) examined the relationship between the Eurasian/Himalayan snow cover area and the Indian summer monsoon rainfall. They found a negative correlation between the winter snow cover area over Eurasia/Himalayas and the summer monsoon rainfall over India. In the present paper, the authors have examined the relationship between the onset of summer monsoon over Kerala and the Himalayan snow cover area during the months February through April.

2. Data and methodology

Satellite images and mean monthly Northern Hemisphere snow cover charts supplied by NOAA-NESS

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TABLE 1

Mean monthly Himalayan snow cover area (February through April) departures in 10^5 km²

1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
—0.5	1.4	—0.5	—0.3	—0.7	—0.4	0.5	—0.4	0	1.2	—0.3

Sources : Satellite image and Northern Hemisphere snow cover charts.

TABLE 2

Dates of onset of summer monsoon over Kerala (India) and its departures from 11-year mean date

Year	Onset date over Kerala	Departure from 11-year mean date
1971	27 May	—4.8
1972	18 June	17.1
1973	24 May	—7.8
1974	26 May	—5.8
1975	31 May	—0.8
1976	31 May	—0.8
1977	30 May	—1.8
1978	28 May	—3.8
1979	11 June	10.1
1980	1 June	0.2
1981	30 May	—1.8

Source : *Monsoon Rainfall Summary* — a Supplement to *Indian Daily Weather Report* (IMD).

were used to obtain monthly snow cover area over the Himalayas between 25 deg. N & 35 deg. N latitudes and 60 deg. E & 150 deg. longitude. *Monsoon Rainfall Summary* — a supplement of *Indian Daily Weather Report* published by IMD provided the dates of onset of summer monsoon over Kerala.

Digital planimeter was used to measure the snow cover area over the Himalayas for the period 1971 to 1981. The data prior to 1971 were not used due to some missing data over the Himalayan region in the NOAA-NESS charts. The mean monthly snow cover area for the months of February through April was computed and expressed as departures from 11-year (1971-81) mean and are presented in Table 1. The dates of onset of summer monsoon over Kerala are expressed as derivations from 11-year mean and are given in Table 2. In Table 2, the negative departures from 11-year mean indicated early onset of summer monsoon over Kerala and positive departures indicate late onset.

3. Himalayan snow cover area and onset of summer monsoon over Kerala

The variation of mean monthly snow cover area for the months February through April over Himalayas was examined in relation with the corresponding variation of dates of onset of summer monsoon over Kerala for the study period 1971 to 1981 (Fig. 1). The analyses of data for 11-year indicated a positive correlation between Himalayan snow cover area and the dates of onset of summer monsoon. This implies that more than 11-year mean snow cover area during the months February through April over Himalayas was likely to be followed by an early onset of summer monsoon than 11-year mean date and *vice versa*. This type of positive correlation holds good for the study period except for 1977 when a negative relation was observed. The correlation coefficient between the two variables is 0.62.

The value of correlation (γ) is significant at 5% level of significance. The significant value of γ suggests a linear relation between the summer monsoon onset date deviations (O_d) and the snow cover area deviations (s) :

$$O_d = a + bs$$

The estimates of a and b are (Fig. 2)

$a = 0.75$ day

$b = 11.6 \times 10^{-5}$ days/km²

It may be seen from above equation that knowing s, the snow cover area deviation, the onset date of summer monsoon over Kerala may be estimated.

4. Results and discussion

The onset of summer monsoon over Kerala correlates with the Himalayan snow cover area during the months February through April. The Himalayan snow cover extent may indirectly affect summer monsoon activity over India in terms of onset over Kerala

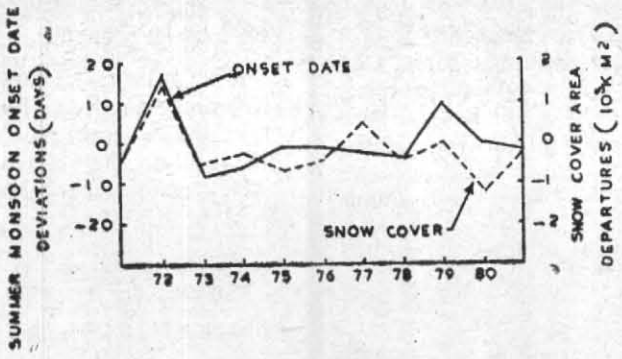

Fig. 1. Variation of mean monthly Himalayan snow cover area (Feb through Apr) and the corresponding onset dates over Kerala

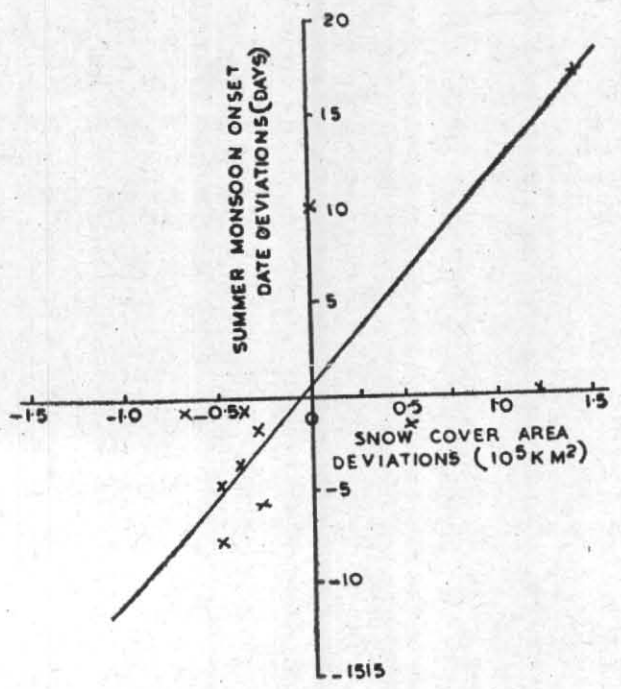

Fig. 2. Relationship between Indian summer monsoon onset date deviations and mean monthly Himalayan snow cover area deviations

in the following way. Larger snow cover area during the months February through April increases surface albedo which may lower atmospheric temperatures and increase sea level pressure over the continents, thereby weakening the monsoon circulation (Manabe and Hahn 1977; Winston and Krueger 1977). This weakening of monsoon circulation may delay the onset of summer monsoon over Kerala and *vice versa*. Note that the direct relation between Himalayan snow cover area and dates of onset of summer monsoon over Kerala does not hold true for 1977 when perhaps some other factors have had pronounced effect on the monsoon circulation. The warming of surface waters in the eastern equatorial Pacific Ocean referred to as El Nino events has been found to be ossociated with below normal rainfall over India (Rasmusson and Carpenter 1983). The fluctuations of the larger scale April pressure index of the Southern Oscillation has

been found to be correlated with monsoon activity over India (Bhalme *et al.* 1983). Rasmusson and Carpenter (1982) observed that the atmospheric response to EI Nino includes a modification of the normal Walker and Hadley circulations which in turn may result in abnormal variation in snow cover area over the Himalayas thereby affecting the onset of summer monsoon over Kerala.

5. Summary and conclusion

The relationship between variations of monthly (February through April) snow cover area over the Himalayas and the corresponding dates of onset of summer monsoon over Kerala has been examined for the period 1971 to 1981. The study with 11 years data indicates that there is direct relation between the onset of summer monsoon over Kerala and the Himalayan snow cover area during the months February through April. This implies that larger area snow cover extent over Himalayas during the months Febbuary through April was likely to be followed by late onset of summer monsoon over Kerala and *vice versa*.

To conclude, this preliminary study reveals that Indian summer monsoon activity in terms of onset over Kerala is probably the result of a series of feedback mechanisms wherein Himalayan snow cover is but one significant parameter.

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