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# Determination of the premonsoon period and interannual variations of the premonsoon rainfall in the Himalayan foothills

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**Abstract**: A definition of the premonsoon period was proposed using Convective Instability Index (CII). The difference of the potential equivalent temperature between 850 and 600 hPa was defined as the CII. The seasonality of the CII around the northeastern part of the Indian subcontinent indicated over 0 values without winter season with the two maximal values around the 30th and 55th pentads, respectively. The premonsoon period was defined as an increasing period of the CII before the first peak. The averaged-beginning date of the premonsoon period was March 17, and the end date was May 25. Interannual variations of the premonsoon precipitation in Nepal from 1978 to 2002 using the defined period were shown with 177 mm of averaged precipitation. Moreover, the averaged premonsoon days were 68 days, and the premonsoon rainfall days were 66 days.
**Key words:** Premonsoon, daily precipitation, Himalayan foothills, Convective Instability Index.

## Introduction

The premonsoon season in South Asia is generally defined as the period from March to May before the monsoon onset. The rainfall obtained for the premonsoon season has an important role for the people who are living in the northeastern part of Indian subcontinent to plant the rainy season's rice, because the rainfall amounts directly affect the rice yield in these regions. However, the interannual variation of the premonsoon precipitation was difficult to evaluate because of the variability of the periods.

From a climatological perspective, the beginning of the rainy season has defined using a seasonal variation in precipitation exhibits characteristics specific to each region in Asia (Matsumoto, 1997; Qian and Lee 2000). In the southwestern part of the Indian subcontinent, in Kerala, a rapid and drastic increase in precipitation occurs at the onset of the monsoon period in early June. The characteristic is well known and is broadly used as an index of the monsoon onset in South Asia (Ananthakrishnan and Soman, 1988; Raju *et al.*, 2005). On the other hand, the precipitation increase occurring in mid-April is regarded as the early onset of the monsoon in the Indochina Peninsula (Matsumoto, 1997). However, the premonsoon rainfall, which is caused by the mid-latitudinal disturbances (Kiguchi and Matsumoto, 2005), also contributes the early onset. Fukushima (2012) reported that over 50% rainfall events were related to troughs or disturbances in Nepal during March to May. According to these results, the premonsoon rainfall is caused in particular region in South Asia, and is largely affected by the mid-latitudinal synoptic activity.

Moreover, the premonsoon rainfall is deeply related to the monsoon onset process around the Bay of Bengal (BoB). According to Minoura *et al*. (2003), deep cumulus convection occurs when the large-scale disturbances are formed over the BoB during the premonsoon season. It is due to a large convective instability over the BoB from mid-April to mid-May. Therefore, the abrupt onset of the South Asian monsoon is triggered by strong synoptic disturbances such as the monsoon vortex. The disturbance originated in Madden-Julian Oscillation (Lau *et al*., 1998), called the monsoon vortex, is considered to one of the trigger of the monsoon onset (Xie and Saiki, 1999).

Therefore, to reveal the characteristic of the atmospheric conditions and its regionality for the premonsoon season contributes to the investigation for the monsoon onset mechanism. Fukushima and Takahashi (2012) investigated the synoptic condition of the premonsoon season around the foothills of the Himalayas. The convective instability became large for mid-April to early June. The large convective instability was caused by both the water vapor increase near the surface and the decreasing of the westerly wind in the upper levels. The westerly winds correspond to the subtropical jet stream. During non-monsoon season, the subtropical jet stream strongly prevails near the southern slopes of the Himalayas (Yasunari, 1976a; 1976b). However, the jet stream retreats to the north of the Tibetan Plateau during the monsoon season. The development of the Tibetan high accompanied by heating over the Tibetan Plateau is closely related to the jet shift (Murakami, 1958). Using observational data in the Khumbu Himalayas, Ueno *et al*. (2008) noted that a seasonal change in local circulation occurred in two steps from premonsoon to monsoon season. The mountain-valley winds first weaken concurrently with the northward shift of the subtropical jet stream, and then active convections accompanied by the monsoon vortex formation occur in the BoB.

According to previous studies, the premonsoon season is a transitional period from winter to the monsoon onset characterized by large convective instability. The characteristic could be used for both the determination of the premonsoon period and the improvement of predictability of the premonsoon precipitation amount. To reveal the interannual variation of the premonsoon precipitation, it was tried to propose the new definition of the premonsoon period using a characteristic of the synoptic conditions of the atmosphere.

## Materials and Methods

Japanese 25-year reanalysis data (JRA-25) from 1979 to 2002 was used for calculating instability of the atmospheric circulations (Onogi *et al.*, 2007). To eliminate diurnal variations, the daily mean was calculated by averaging the data obtained at four time points each day: 00, 06, 12, and 18 UTC. The potential equivalent temperature ($\theta e$), were calculated using the data.

Moreover, to reveal the interannual variations into precipitation for the premonsoon period that was defined, the daily precipitation data set for Nepal provided by the Department of Hydrology and Meteorology in Nepal (DHM）was used. The data was digitized by Maeno *et al.*

(2004) using data books from 1976 to 1997. For the period from 1998 to 2002, digital data distributed by DHM was used. In this analysis, 87 stations with missing data were less than 20% of the entire study period were used (Fig. 1). The premonsoon precipitation amount in Nepal was calculated as follows: firstly, the daily average precipitation in Nepal (All-Nepal Daily Precipitation) was obtained to average daily precipitation data on each region. Secondly, the All-Nepal Daily Precipitation was integrated to calculate total amount of the premonsoon precipitation (All-Nepal Premonsoon Precipitation). The rainfall day was defined as exceed 0 mm of the daily rainfall in daily averaged precipitation in Nepal.

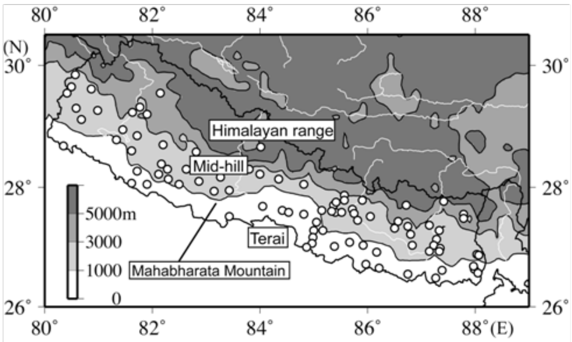


**Fig. 1.** Location map of raingauge stations used in this study

### Results and Discussion

**Definition of the premonsoon period using instability index:** A seasonal transition of synoptic conditions from winter to the summer monsoon season around the foothills of the Himalayas was evaluated using JRA-25 in previous study (Fukushima and Takahashi, 2012). According to the results, convective instability is one characteristic of the atmospheric condition for the premonsoon season. On the basis of this characteristic the author tried to define the premonsoon period for each year using an index of convective instability which was defined in originally. The difference of the equivalent potential temperature between different two levels has broadly used as an index of convective instability in the atmosphere in meteorology.

The large value of the equivalent potential temperature ($\theta_e$) was observed below 700 hPa, and the small value of the equivalent potential temperature was observed around 600 hPa in vertical from April to May in the previous study. Therefore, the Convective Instability Index (CII) is defined as: $\mathbf{CII} = \theta_{e(850hPa)} - \theta_{e(600hPa)}$

(Convective instability; CII > 0), where $\theta_e$ (850hPa) and $\theta_e$ (600hPa) are equivalent potential temperature at 850 hPa and 600 hPa, respectively.

The distribution of the climatological-seasonal variation in CII around 80°E to 90°E is shown in Fig. 2. Over 12 K of the CII values were observed around 15°N to 28°N from mid-April to early June. The region of 15°N to 28°N and 80°E to 90°E consists of large continental areas except for the sea area of the BoB. The positive values of CII were observed in the continental area during early February to early November around 20°N. On the other hand, the positive values of CII in the northern part (around 25°N) were observed in the middle of March. Therefore, the convective instability in the foothills of the Himalayas increased late, compared with the southern area near the BoB. Minoura *et al*. (2003) mentioned that an increase in large CII values defined by the *θe* difference between 1000 hPa and 700 hPa over the BoB is an essential factor in the abrupt onset of the Indian summer monsoon. They also noted a decrease of CII in the BoB during the monsoon period. Our findings about seasonal transition of CII near the BoB confirmed their date.

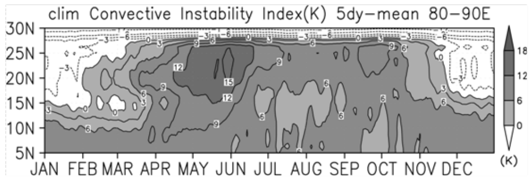


**Fig. 2**. Climatological-seasonal variation of CII in 80° to 90°E.The horizontal axis means time scale from January to December. The vertical axis shows latitudes. The CII values calculated for 5-day mean with averaged for the area from 80° to 90°E. The contours are shown in every 3K.

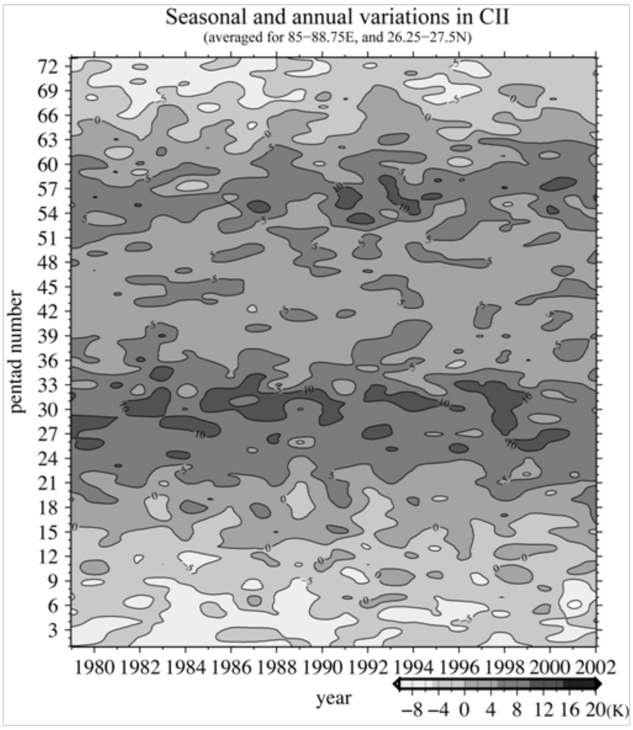


**Fig. 3.** Seasonal and annual variations of CII.The horizontal axis means year from 1979 to 2002. The vertical axis indicates the pentad numbers from 1 to 73. The CII values were averaged for the area of 26.25°-27.5°N, and 85°-88.75°E. The contour shows every 5 K of CII values.

Fig. 3 represents the secular variation off seasonal transition of CII. The maximal values are almost concentrated around 30th and 55th pentads. The 30th pentad is a period from 26th to 30th May. And the 55th pentad is a period from 28th September to 2nd October. On the other hand, the CII values decrease between the two maximal values. Moreover, the second peak is unclear compared with the first peak except for 1987 and several years of 1990s. Before the first peak, the CII values increase gradually. The pentad that the values exceed 0 is around 15th to 20th pentads. As a result, the timing of seasonal transition of CII is almost fixed on each year except for small inter annual variation within several pentads.

Then the premonsoon period as an increasing phase of CII values was defined for each year. This definition is separated with the determining of starting and ending dates, as shown in Fig. 4. The start date of the premonsoon season was determined as the first day of the 1st pentad of the CII over 0 value with continuous 3 pentads. A daily variation of the CII is considered to be eliminated by the definition. In contrast, the end date of the premonsoon season was defined as the end day of the maximal pentad of CII values on each year; however, only the first peak earlier than the 45th pentad was selected. The premonsoon period on each year was defined as between the starting and the ending date.

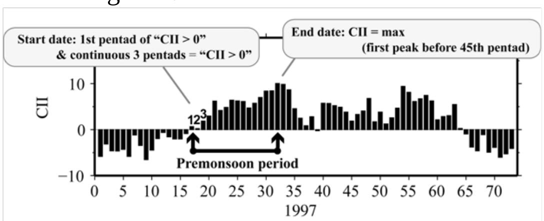


**Fig. 4.** Method of determination for the start date and the end date of the premonsoon period using CII.The horizontal axis means the pentad numbers. The vertical axis indicates the CII values.

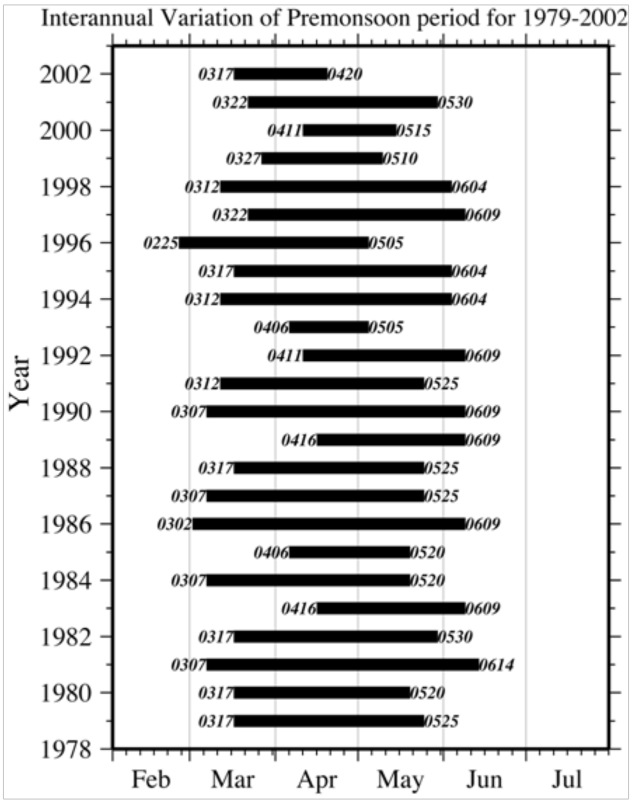


**Fig. 5.** Interannual variation in premonsoon period for 1979 to 2002.The horizontal axis means day of year. The vertical axis indicates year. Black bar indicates the premonsoon period on each year. The number, which is displayed beside, of the bar means the start or end date of the premonsoon period.

**Interannual variations in the premonsoon period:** The inter annual variation in the premonsoon period from 1979 to 2002 is represented in Fig. 5. The averaged beginning pentad was the 16th pentad (the date was March 17) and the ending was the 29th pentad (the date was May 25), respectively.The earliest date of the premonsoon start was recorded on February 25, 1996; the latest date was displayed on April 14 of 1983 and 1989. On the contrary, the earliest ending of the premonsoon period was shown on April 20, 2002; the latest ending was recorded on June 14, 1981. March17 was considered the start date in 1979. The premonsoon rainfall phenomena occurred after the beginning of premonsoon period described (not shown). Similarly, the premonsoon rainfall occurred after the start date of March 7, 1990. The official averaged monsoon onset date from 1968 to 2002, provided by DHM, is June 14. The few-days time lag was shown between the end date of the premonsoon period and the monsoon onset date, which can be due to the unclear peak value of the CII in many years. However, the premonsoon period as a prior period of the monsoon season on each year can be provided by the definition.

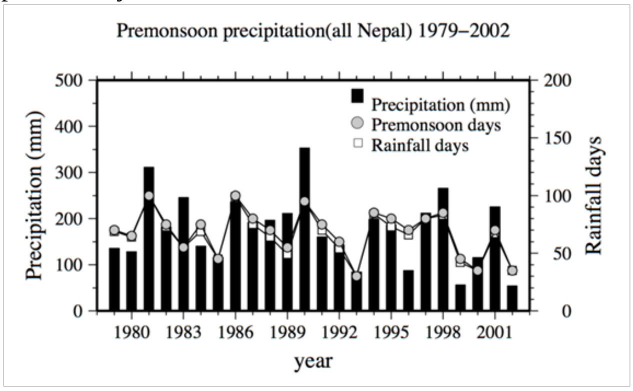


Fig.6. Interannual variations in premonsoon precipitation, premonsoon days, and premonsoon rainfall days for 1979 to 2002 in Nepal (All-Nepal premonsoon precipitation). The horizontal axis means year. The vertical axis indicates the precipitation amounts and the number of days. Black bars show the premonsoon precipitation. Filled circles with gray represent the number of premonsoon days. Opened squares mean the number of rainfall days for the premonsoon period.

**Interannual variations in premonsoon precipitation:** The premonsoon precipitation was calculated by using the defined new premonsoon period. Fig. 6 shows interannual variations in the premonsoon period and All-Nepal premonsoon precipitation. The averaged value of the premonsoon precipitation was 177 mm. Premonsoon period included 68 days on average with 66 days for the premonsoon rainfall days.The year with the smallest number of premonsoon days was the year 1993, and the years with the highest number of premonsoon days were 1981 and 1986. The number of rainfall days during the premonsoon period was dependent on the number of premonsoon days with a few exceptions. The maximal premonsoon precipitation was observed in 1990. The maximal rainfall year was same as another definition using the premonsoon precipitation average for March to May (not shown). However, the new premonsoon precipitation for 2000 was different. The end date of the premonsoon period in 2000 was defined as May 15. The precipitation observed after May 15 is considered as a contribution to the three-month average precipitation in 2000.

In this study, the new definition of the premonsoon period was proposed and secular variation of the premonsoon period and premonsoon precipitation were evaluated using the definition. From the result, 97% days of the premonsoon period recorded rainfall from 1979 to 2002. However, the averaged total premonsoon precipitation was below 200 mm. The daily rainfall intensity was estimated to be not strong during the premonsoon season from the results. On the other hand, the precipitation varied by year with the differences of more than 100 mm. The rice yield or the size of harvest of the vegetables might be affected by the large inter annual differences of the premonsoon precipitation. Therefore, the new definition should be useful for the evaluation or estimation of the agricultural products. However, although the start date of the premonsoon season could be predicted using CII index, more extended investigations should be made for a more accurate prediction of the “premonsoon onset” using the index.

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