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Climate change trends in some of the rubber growing regions of North-East India

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Abstract

Climate change analysis has been conducted using daily surface meteorological datasets in respect of nine parameters from five rubber growing locations in the East and North-East India. Monthly, seasonal and annual variability in meteorological parameters showed decreasing trends in relative humidity, sunshine hours and pan evaporation rates coupled with increasing temperature extremes. Rise in mean temperature was seen to be highest (0.34 ^{0}C per decade) for Dhenkanal, Odisha state, India which experiences dry sub-humid type of climate. The data on relative humidity and temperature also revealed the fact that warm surface temperatures, along with limited moisture availability, may lead to lower relative humidity in the future, since all the stations are away from the moist coastal belts. Decreasing trends in sunshine hours were mainly observed during winter and post monsoon seasons with decreasing number of days even with the optimum required daily sunshine hours. The fact that there were no significant changes in the amount of rainfall or the number of rainy days was in conformity with several earlier reports in the northeast. Mean monthly decadal variations have also been tested with earlier and recent sets. With long term trends in most of the weather parameters, being lesser when compared to that of the traditional rubber growing regions in India, it is imperative that for rubber cultivation to thrive in this non-traditional belt, future policy inputs will have to be based depending on the magnitude of climate change effects.

Keywords: Climate change, decadal variations, Mann-Kendall, rubber

Introduction

The North Eastern (NE) region of India falls under the high rainfall zone with a subtropical type of climate. The varied physiological features and altitudinal differences gives rise to varied types of climates ranging from near tropical to temperate and alpine (Anup Das *et al*., 2009). The North Eastern Region (NER) comprises of the states of Arunachal Pradesh, Assam, Manipur, Nagaland, Meghalaya, Mizoram, Sikkim and Tripura. The region stretches between 21^{0}50' and 29^{0}34' N latitude and 85^{0}34' and 97^{0}50' E longitude. The region has a geographical area of 26.2 million hectares, which is 8 per cent of the total area of the country. Assam is situated in the center and the hill states (except Sikkim) are situated around it. Annual rainfall in the region is mainly received from the South-West monsoon *i.e.,* from the middle of May and continues till October. On an average, the NE region receives about 2450 mm of rainfall. The rainfall in the Cherrapunji-Mawsynram range receives 11,500 mm annually. Temperature varies from 15 to 32 ^{0}C in summer and 0 to 26 ^{0}C in winter. In the absence of scientific data about the vulnerability of the region to climate change, proper and timely agro-management practices, efficient use of inputs and latex harvesting methods are some of the management options that need to be popularized among the rubber farming community to mitigate the impact of climate change.

Climate change study mainly focuses on the changes in climatic variability over temporal scales. Climate change studies in Kerala state had revealed that local changes were different from the large

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spatial scale averages (Indrani and Abir, 2009). Even a slight rise in maximum temperature by 0.4 ^{0}C affected black pepper, cocoa and cardamom in the absence of soil moisture (Rao, 2009). Studies on monsoon rainfall in India showed a decreasing trend over east Madhya Pradesh and adjoining areas, North-East India and parts of Gujarat and Kerala (Kumar *et al.*, 2002). Rainfall and number of rainy days showed declining trends during the southwest monsoon (June to September) period at four different locations in Kerala (Krishnakumar *et al*., 2008a). Rise in maximum and minimum temperature was noticed since the last 49 years over Kerala (Rao *et al.,* 2008). Unlike seen in the rise of temperature trends, rainfall trends were uncertain at several locations in Kerala. (Krishnakumar *et al*., 2008b; Rao *et al*., 2009).

In a climate change study undertaken within rubber plantations in the traditional region of Kerala, it was found that there was a rising trend in the mean, maximum and minimum temperature, rainfall was becoming more skewed, and also a decreasing trend in bright sunshine hours per day (Raj *et al.,* 2011). Impact of climate change was felt most strongly through changes in climate extremes. In tandem with the expansion of rubber cultivation in the NE, it is imperative that crop management, improvement and protection strategies are to be adopted in tune with projected climate change to sustain rubber production in future. The following study would be assessing the major climatic factors affecting rubber cultivation in the different rubber growing regions in India. The study could also be useful as a fore-runner in addressing problems of decrease in survivability and yield depression, shift in climatically favourable areas or increase in the gestation period of rubber.

Materials and methods

Daily datasets ranging from 16 to 30 years duration collected by the Rubber Research Institute of India (RRII) from five different agro-meteorological stations in the NE region have been

Table 1. Rubber growing stations of the NE region and the data duration utilized for the study

Location	Latitude	Longitude	MSL	Duration
Agartala (Tripura)	$23^0$57'N	$91^0$21'E	30 m	1984-2013 (30 years)
Guwahati (Assam)	$26^0$03'N	$91^0$53'E	103 m	1989-2013 (25 years)
Tura (Meghalaya)	$25^0$34'N	$90^0$14'E	405 m	1995-2013 (19 years)
Nagrakata (West Bengal)	$26^0$51'N	$88^0$57'E	69 m	1995-2013 (19 years)
Dhenkanal (Odisha)	$20^0$02'N	$72^0$54'E	69 m	1998-2013 (16 years)

Table 2. Increasing (↑) and decreasing (↓) trends of monthly and annual meteorological variables for Agartala

Month	T_x	T_n	A_t	R_{h1}	R_{h2}	S_h	E_v	R_f	R_d
Jan				↓	↑	↓	↓		↑
Feb				↓		↓			
Mar				↓		↓	↓		
Apr							↓		
May							↓		
Jun							↓		
Jul	↑		↑				↓		↓
Aug							↓		
Sep							↓		
Oct						↓	↓		
Nov				↓		↓	↓		
Dec	↓				↑	↓	↓		
Annual	0.043	ns	0.026	-0.1	ns	-0.049	-0.092	ns	ns

(ns – not significant)

utilized for the study. These agro-meteorological stations situated in rubber growing areas comprises five stations *viz*., Agartala (Tripura), Guwahati (Assam), Tura (Meghalaya), Nagrakata (West Bengal) and Dhenkanal (Odisha). The details of the RRII station and data duration are given in Table1. The Tura station is situated in a comparatively higher altitude compared to the other stations. Dhenkanal is situated in lower latitude while Nagrakata is situated in the foothills of the Himalayas in the north.

The average monthly, seasonal and annual period based parameters chosen were rainfall amount (R_f), number of rainy days (R_d), maximum temperature (T_x), minimum temperature (T_n), average temperature (A*t*), morning relative humidity (R_{h1}), afternoon relative humidity (R_{h2}), bright sunshine hours (S_h) and pan evaporation (E_v). Slopes based on linear regression method and the non-parametric Mann-Kendall trend statistics (Gemmer *et al*., 2004; Liu *et al.,* 2008; Yang *et al*., 2010) were applied to the time series data sets.

Table 3a. Slopes of linear trend equations of observed seasonal meteorological factors for five different rubber growing stations in the NE India

	Agartala	Guwahati	Tura	Nagrakata	Dhenkanal
Maximum temperature					
Winter	0.000	*0.073	0.053	0.053	0.126
Pre-monsoon	0.031	**0.042	*0.066	**0.058	**0.226
Monsoon	*0.029	0.045	0.021	0.013	0.114
Post-monsoon	0.010	***0.065	0.004	0.002	**0.162
Annual	0.043	***0.057	**0.052	0.027	0.001
Minimum temperature					
Winter	0.009	-0.029	-0.006	**0.185	-0.076
Pre-monsoon	**0.029	0.004	-0.017	0.038	-0.018
Monsoon	0.022	0.022	-0.036	0.118	-0.075
Post-monsoon	**0.050	-0.028	-0.036	0.168	-0.018
Annual	-0.010	0.000	-0.120	***0.009	**0.077
Average temperature					
Winter	0.010	0.024	0.018	*0.019	0.040
Pre-monsoon	0.022	0.015	0.021	*0.025	0.039
Monsoon	*0.027	0.011	0.041	**0.033	*0.039
Post-monsoon	*0.029	0.015	-0.012	0.009	0.032
Annual	**0.026	0.010	0.018	**0.010	0.034
Relative humidity (Morning)					
Winter	***-0.240	-0.137	0.107	0.085	0.241
Pre-monsoon	-0.058	0.087	0.051	0.020	0.096
Monsoon	-0.072	-0.020	**0.233	0.097	-0.125
Post-monsoon	***-0.150	0.088	0.050	0.082	*0.275
Annual	**-0.100	0.036	*0.157	0.082	-0.007
Relative humidty (Afternoon)					
Winter	0.099	*-0.092	0.183	-0.068	-0.78
Pre-monsoon	-0.009	*-0.098	0.023	*-0.314	-0.522
Monsoon	0.110	-0.242	*0.478	-0.123	-0.763
Post-monsoon	**0.193	-0.312	0.104	-0.486	-1.000
Annual	0.128	*-0.230	**-0.255	-0.292	-0.077

*significant at 0.1 level; **significant at 0.05 level; ***significant at 0.001 level

Table 3b. Slopes of linear trend equations of observed seasonal meteorological factors for five different rubber growing stations in the NE India

	Agartala	Guwahati	Tura	Nagrakata	Dhenkanal
Bright sunshine hours					
Winter	***-0.071	*-0.058	**-0.090	**-0.152	-0.023
Pre-monsoon	-0.008	0.026	-0.023	0.003	-0.017
Monsoon	**-0.052	0.000	-0.075	*-0.053	*-0.090
Post-monsoon	***-0.083	-0.015	***-0.102	***-0.138	*-0.086
Annual	*-0.049	-0.003	-0.029	**-0.075	***-0.090
Evaporation					
Winter	***-0.056	*-0.033	-0.016	-0.031	**-0.267
Pre-monsoon	***-0.080	**-0.084	-0.019	-0.038	0.334
Monsoon	***-0.128	**-0.082	-0.042	0.034	**-0.410
Post-monsoon	**-0.040	-0.013	*-0.031	-0.016	*-0.178
Annual	***-0.092	**-0.057	0.002	-0.031	-0.031
Total rainfall					
Winter	-1.141	-1.266	0.000	-2.750	*11.700
Pre-monsoon	-1.955	-9.351	29.067	39.300	**-60.331
Monsoon	-1.924	-4.267	23.800	-7.610	28.542
Post-monsoon	-3.881	-0.120	0.7540	-2.913	-0.825
Annual	-28.183	-16.453	-18.914	25.357	-14.867
No. of rainy days					
Winter	-0.073	-0.133	0.000	-0.133	**3.500
Pre-monsoon	-0.257	0.028	-0.455	-0.100	1.333
Monsoon	-0.243	-0.273	0.400	0.083	*5.786
Post-monsoon	-0.083	0.000	0.000	-0.308	*4.857
Annual	-0.250	-0.333	0.000	-0.375	-0.429

*significant at 0.1 level; **significant at 0.05 level; ***significant at 0.001 level

The non-parametric Mann-Kendall and Sen's methods were used to determine whether there was a positive or negative trend in weather data with their statistical significance. It was established that the results of using the Mann-Kendall and Sen's tests demonstrated good agreement of performance in detection of the trend for meteorological variables (Milan and Slavisa, 2012).

The four seasons considered for the analysis were winter (January-February), pre-monsoon (March-May), monsoon (June-September) and the post-monsoon (October-December) season. The frequency (days) of annual extreme climatic events has been calculated by considering the respective thresholds for each parameter as the sum of long-term mean plus its standard deviation and termed as extremes in this study. In the case of rainfall and relative humidity, the threshold represents the mean of the long term values. The study shows changes in the duration of extremes observed over a long-term period at a place. In order to compare the long duration decadal variability in the case of Agartala, monthly data from 1968 to 1978 obtained from the India Meteorological Department (IMD) were supplemented for the study. The month-wise decadal variations were compared with that of the recent decade to identify any discernible changes between the temperature curves.

Results and discussion

Monthwise trends

The study was carried out even for the rubber growing areas of Tura, Nagrakata and Dhenkanal, despite having a low duration of dataset, primarily

Table 4a. Linear trend slopes of the annual frequency (days) of extreme climatic events (based on thresholds) for Agartala, Guwahati and Tura rubber growing stations

Stationwise climatic parameters	Threshold	Slope	Significance level
Agartala			
Maximum temperature	days > 34.0 ^{0}C	1.235	**
Minimum temperature	days > 25.8 ^{0}C	1.429	***
Average temperature	days > 29.6 ^{0}C	0.600	ns
Relative humidity (morning)	days > 90%	-3.692	***
Relative humidity (afternoon)	days > 63%	0.250	ns
Bright sunshine hours	days > 9.3 h	-4.000	***
Evaporation	days > 4.2 mm day^{-1}	-4.222	***
Rainfall	days > 20.3 mm day^{-1}	-0.067	ns
Guwahati			
Maximum temperature	days > 33.8 ^{0}C	1.633	**
Minimum temperature	days > 23.6 ^{0}C	0.261	ns
Average temperature	days > 28.4 ^{0}C	0.714	ns
Relative humidity (morning)	days > 88%	-0.171	ns
Relative humidity (afternoon)	days > 68%	-2.809	*
Bright sunshine hours	days > 8.5 h	-2.721	***
Evaporation	days > 3.3 mm day^{-1}	-4.393	***
Rainfall	days > 15.1 mm day^{-1}	-0.207	ns
Tura			
Maximum temperature	days > 32.3 ^{0}C	1.000	ns
Minimum temperature	days > 22.3 ^{0}C	0.529	ns
Average temperature	days > 27.0 ^{0}C	0.000	ns
Relative humidity (morning)	days > 86%	2.000	ns
Relative humidity (afternoon)	days > 68%	1.600	ns
Bright sunshine hours	days > 8.4 h	-5.286	ns
Evaporation	days > 4.0 mm day^{-1}	-4.429	***
Rainfall	days > 27.4 mm day^{-1}	0.727	ns

ns – not significant; *significant at 0.1 level; **significant at 0.05 level; ***significant at 0.001 level

because of absence of long-term data from the IMD in such remote rubber growing stations. A 30 year period is long enough to filter out any inter-annual variation or anomalies, but also short enough to be able to show longer climatic trends. Long-term averages would converge to a constant state given a sufficiently long averaging period (WCDMP, 2007). Therefore, a closer time scale of monthly time series analysis has been shown for Agartala in Table 2. Significant increasing trend in T_x was seen only during the July month. As a whole, the annual trend showed an increase of 0.43 ^{0}C per decade in Agartala. The mean annual temperature showed an increasing trend of 0.26 ^{0}C per decade. With no particular significance of monthly trends in T_n, the annual mean temperature trend increase could be a result of the increasing trends mainly contributed by the T_x. Annual R_{h1} showed a decreasing trend, while there was no change for R_{h2}. Annual negative trend of bright sunshine hours was mainly contributed by the winter and post monsoon seasons. While E_v showed negative trends on almost every month, the rainfall amount did not show any significant change. The monsoon month of July registered a decreasing trend in the number of rainy days although no annual trends were noticed. This shows that in Agartala either there is a possibility of a slow tendency of a shift in the peak rainfall

Table 4b.Linear trend slopes of the annual frequency (days) of extreme climatic events (based on thresholds) for Nagrakata and Dhenkanal rubber growing stations

Stationwise climatic parameters	Threshold	Slope	Significance level
Nagrakata			
Maximum temperature	days > 33.2 ^{0}C	1.333	*
Minimum temperature	days > 24.4 ^{0}C	1.900	ns
Average temperature	days > 28.5 ^{0}C	1.000	*
Relative humidity (morning)	days > 92%	2.000	ns
Relative humidity (afternoon)	days > 65%	-2.769	ns
Bright sunshine hours	days > 8.4 h	-4.824	***
Evaporation	days > 2.9 mm day^{-1}	-2.692	ns
Rainfall	days > 35.8 mm day^{-1}	0.400	ns
Dhenkanal			
Maximum temperature	days > 38.0 ^{0}C	2.464	*
Minimum temperature	days > 26.0 ^{0}C	-1.582	ns
Average temperature	days > 31.5 ^{0}C	-1.000	ns
Relative humidity (morning)	days > 88%	2.036	ns
Relative humidity (afternoon)	days > 59%	-5.439	*
Bright sunshine hours	days > 9.4 h	-3.958	*
Evaporation	–	–	–
Rainfall	days > 13.0 mm day^{-1}	-1.958	ns

*significant at 0.1 level; **significant at 0.05 level; ***significant at 0.001 level

period or that the rainfall amount is getting skewed (Raj *et al.,* 2011).

Seasonwise trends

Seasonal level change in slopes of the nine parameters is given in Tables 3a and 3b for the five rubber growing stations. Excepting Agartala, all other stations showed increasing trends in T_x during the pre-monsoon season. In Dhenkanal, it was more reflected on the highly decreasing trend of the pre-monsoon season R_f (Table 3b). Annual increase of T_n was found only in Nagrakata and Dhenkanal. The climate types (Koppen's classification) for Nagrakata and Dhenkanal are warm temperate and dry sub-humid respectively. In Nagrakata, the increasing trend in A_t was seen in all seasons except the post-monsoon season. Tendency of rise in annual mean temperature was seen to be highest for Dhenkanal (0.34 ^{0}C per decade). Highly significant decreasing trends were observed for both the morning and afternoon relative humidity values for Agartala during the post monsoon season. Warmer surface temperatures, along with limited moisture availability, may lead to lower relative humidities in the future than are experienced today (Pierce *et al.,* 2013). This could have an effect on hydrological and ecological processes that are sensitive to humidity, such as evapotranspiration (Friend, 1995), runoff, and plant growth (Leuschner, 2002). Strong indications of decreasing trends in daily sunshine hours were seen for all seasons except the pre monsoon season for almost all stations. The projection in negative slope was more pronounced in Dhenkanal.

Solar radiation (sunshine duration) has profound influence on surface temperature, evaporation, the hydrologic cycle and ecosystems and it is the primary source of energy required for sustenance of life on this planet. It has been proved that sunshine duration over India has decreased for all months and the decreasing trends were significant at 99 per cent for January to May and October to December (Jaswal, 2009). Table 3b shows that the results obtained for the slopes of S_h

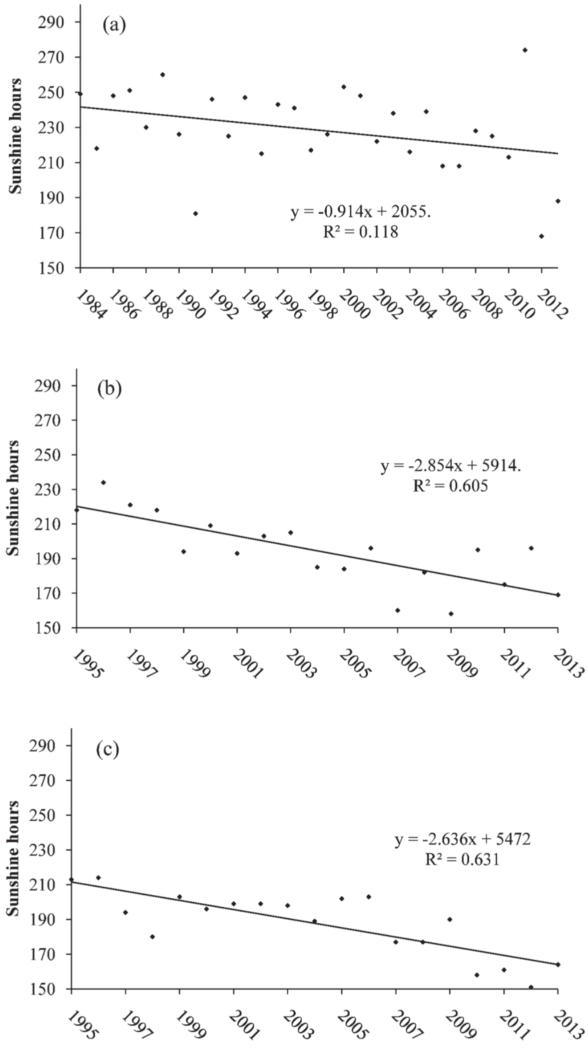

Fig. 1. Annual decreasing trends of daily Bright Sunshine Hours > 5.6 hours for (a)Agartala, (b) Tura and (c) Nagrakata

are in conformity with that of Jaswal, (2009) and the decreasing trends were mainly observed during winter and post monsoon seasons. While only a 0.3 per cent decrease in annual sunshine hours was noticed in Guwahati, the highest decrease of 9 per cent was observed for Dhenkanal. E_v showed a decreasing trend for all seasons in Agartala with a projection of an annual decrease of 0.92 mm per decade followed by Guwahati (0.57 per decade). Jhajharia *et al*. (2009) in a study found that out of 11 sites, nine sites showed decreasing E_v trends in the monsoon and pre monsoon seasons in the NE India. Chattopadhyay and Hulme (1997) also reported that E_v decreases mainly in pre-monsoon and monsoon seasons. No significant changes in the annual rainfall components (rainfall amount and rainy days) were noticed under the study period.

Extreme climatic events

Table 4a and 4b shows results of extremes obtained for the same station-wise parameters after estimating the annual frequency of days above the thresholds as shown. Annual extremes in T_x of >2 days were observed in Dhenkanal compared to all other stations excepting Tura. However, extremes in T_n was observed only in Agartala at 99 per cent level. Only Nagrakata showed significant annual increase of A_t by >1 day compared to other stations. With decreasing trends noted in the value of relative humidity, the R_{h1} factor for only Agartala showed a highly significant decreasing trend of extremes (>90%) over 3 days. Decreasing trend in R_{h1} has an important bearing on the exploitation of the rubber tree crop, where early morning high relative humidity helps in maximizing exploitation of the crop through tapping. Extremes of S_h showed that

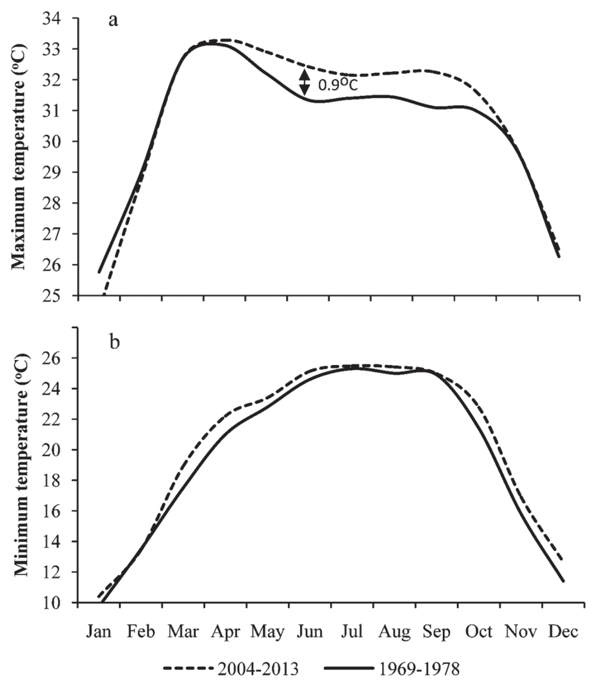

Fig.2. Recent decadal variations of (a) maximum temperature and (b) minimum temperature with earlier records during the pre and post monsoon periods in Agartala

all stations except Tura experienced a negative trend. The annual decrease in extreme sunshine days for the stations studied was 3 to 4 days.

It has already been established that a daily sunshine duration of >5.6 hours is optimum for rubber yield (Rao *et al*., 1998). Therefore, the annual frequency of days with >5.6 sunshine hours have been plotted and significant decreasing trends were observed in Agartala, Tura and Nagrakata as shown in Figure 1. The negative slope was highest for Nagrakata. Tendency of extremes of E_v showed an overall reduction over four days in a year for Agartala, Guwahati and Tura. Rainfall as expected from the previous results did not show any significant change in its extremes for any station.

Long-term events

The comparison of mean monthly maximum and minimum temperature over the first decade of the available data (1969-78) with that of the recent (2004-13) are shown in Figure 2. The difference between the two decades was significant (0.9 ^{0}C) during the monsoon season for the maximum temperature (Fig. 2a) while it was 1.2 and 1.1 ^{0}C respectively for the pre monsoon and post monsoon seasons (Fig. 2b).

Conclusion

The study reveals some impending facts about the level of climate change occurrences that could be of reasonable concern in the context of future expansion of rubber cultivation in this non-traditional area. Decreasing trends in relative humidity, sunshine hours and pan evaporation rates, coupled with increasing temperature extremes, will result in adopting changes in the agro-management and practices in rubber cultivation which will likely prove to be a challenge to the small holder farmers of this region.The study necessitates further analysis with long-term datasets on a larger geographical extent so as to accurately project climate variability effect on rubber growing areas.

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