

**TRENDS AND PERIODICITY
IN THE LONGEST INSTRUMENTAL RAINFALL SERIES
FOR THE AREA OF MOST EXTREME RAINFALL
IN THE WORLD, NORTHEAST INDIA**

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ABSTRACT: The longest instrumental rainfall series have been investigated for the North Assam subdivision and 4 meteorological stations in Northeast India. Analysis of trends to annual and seasonal rainfall show these to be very stable, with no change in the rainfall over North Assam during the last 150 years. The Fourier analysis of fluctuations in rainfall series shows that the periodic signal of $T=3.5$ year is the strongest one. Such a signal, with the same phase, has been found for all rainfall stations of the North Assam subdivision and in all investigated seasons.

KEY WORDS: monsoon rainfall, trend, periodicity, northeast India.

INTRODUCTION

Studies of the annual/summer (south-west) monsoon variability on rainfall over India have a long history. Blanford (1886) first prepared annual rainfall series for British India, while Walker (1910) first analyzed the summer monsoon series for the period 1841-1908 and reported that no trend could be observed. Later many authors analyzed rainfall series for periods of different length using data from different raingauge networks. Parthasarathy and Mooley (1978) found that no trend was to be noted in the all-India annual monsoon rainfall series. By analyzing 1871-1988 monsoon rainfall data, Subbaramayya and Naidu (1992)

reported downward trends for rainfall during the late 19th century and the 1960s.

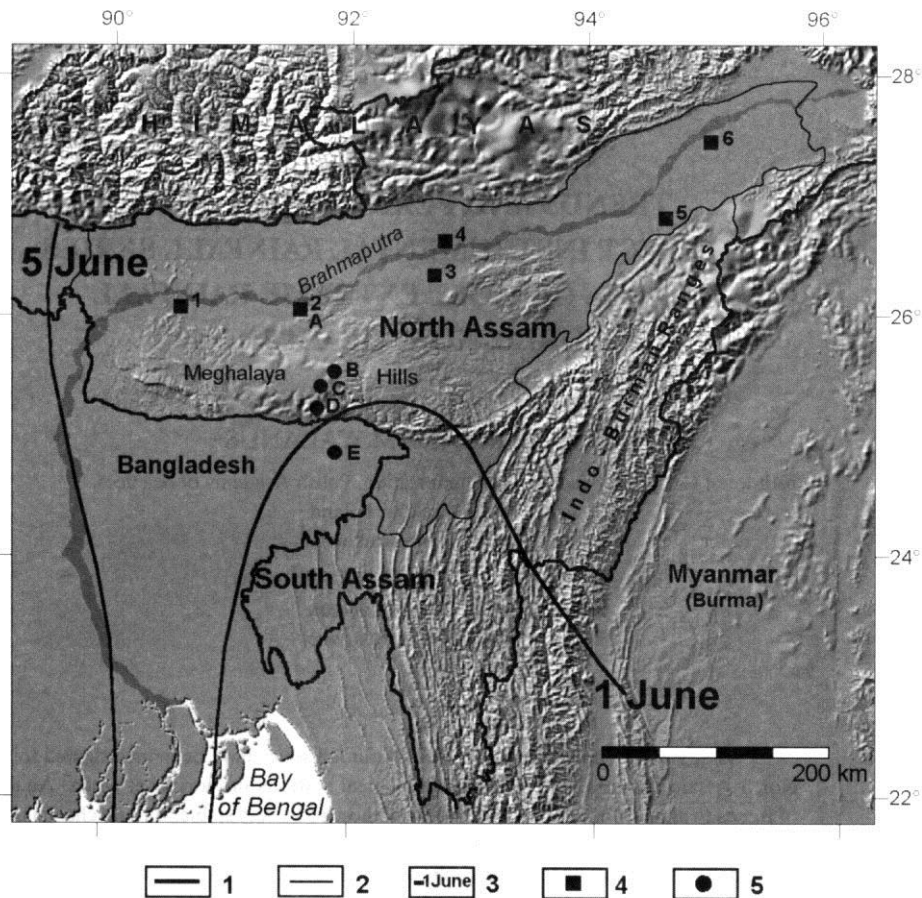


Figure 1. Location of Northeast India region with North Assam subdivision and Meghalaya Hills. 1—national border, 2—subdivision boundary, 3—location of rain gauge stations used by Parthasarathy et al. (1995) for the North Assam subdivision average rainfall calculation: 1 - Goalpara, 2 - Gauhati, 3 - Nowgong, 4 - Tezpur, 5 - Sibsagar, 6 - Dibrugar, 4 - stations used for detailed trend and periodicity analysis along profile: A—Gauhati, B—Shillong, C—Mawphlang, D—Cherrapunji, E—Sylhet (station in Bangladesh added only to show orographic effect); 4—normal dates of onset of the south-west monsoon (after Rao 1981).

Most studies therefore indicate that monsoon rainfall has been mainly random in nature over a long period of time, particularly on the all-India scale (Moley and Parthasarathy 1984). At the subdivisional and station scales the presence of some periods (especially in the range 2-3 years) have been found to be significant (Parthasarathy 1984). Unfortunately the source of these oscillations is not known and cannot be linked to the El Niño-Southern oscillation (ENSO)

in the tropics (Bhalme and Jadhav 1984) or to oscillation of stratospheric winds (Bhalme et al. 1987).

The northeast area of India (north of 21°N and east of 88°E, Figure 1) can be treated as a relatively separate macroregion (Winstanley 1973, Parthasarathy et al. 1987). Gregory (1989) found that linear trends indicating a reduction in rainfall come close to achieving significance over this area. Sontakee and Singh (1996) reported that summer monsoon rainfall is negatively but weakly correlated with that of Peninsular India and Rupa Kumar et al. (1992) found significant downward trends for monsoon rainfall over the period 1871-1984.

Detailed studies show differences within a region between two North and South Assam subdivisions, when it comes to rainfall trends and periodicity. Parthasarathy and Dhar (1974) noted an upward trend over North Assam and a negative one over South Assam for the period 1901-1960. Bhaskar et al. (1998) found significant downward trends for the North Assam subdivision for the periods 1871-1888, 1918-1962, and a significant upward trend for the period 1888-1918. The same authors noted a downward trend for South Assam for the years 1951-1994, and an upward trend for the years 1928-1951.

Studies at individual stations of North Assam have concentrated mainly on the abnormally high rainfall at Cherrapunji (Blanford 1889, Starkel 1972, O'Hare 1997, Singh and Syiemlieh 2001, Starkel et al. 2002). Cherrapunji has the world record for high rainfalls over durations of between 31 days and two years since 1860-61 (WMO 1986). Most authors agree that orography is the main cause of the enormous rainfall at this station.

DATA AND METHODOLOGY

The mean monthly rainfall data for the North Assam subdivision (1871-1999) have been taken from the published dataset of Parthasarathy et al. (1995). Additionally, long instrumental monthly mean rainfall data for the Cherrapunji (1872-2000), Shillong (1869-2000), and Gauhati (1848-2000) observatories were collected from the National Data Center, India Meteorological Department (IMD), Pune, and from the Assam State Electricity Board (ASEB) in the case of Mawphlang station (1899-1987). The data for North Assam were used as a background for a detailed analysis of annual and seasonal monsoon trends and periodicity along the profile Gauhati-Cherrapunji. The position and altitude of rain-gauge stations were verified using GPS and an altimeter during fieldwork in 2000.

Four climatic seasons are distinguished over northeast India (Rao 1981): winter (January-February), the pre-monsoon (March-May), the south-west monsoon (June-September) and the post-monsoon (November-December). The trends and periodicity of rainfall time series have been investigated for a whole year, and for the two seasons of the southwest monsoon, when 70 percent of pre-

precipitation falls, and of the pre-monsoon, when cyclonic storms form over the Bay of Bengal. The thunderstorms connected with the latter produce large amounts of rain (mango rains) in April and May, and are typical for northeast India (Pant and Rupa Kumar 1997).

The rainfall series have been statistically tested using Student's *t*. In the course of exploratory periodicity analysis of rainfall time series, a Fourier analysis was performed with the emphasis on a maximal periodic signal of $T=3.5$ year.

NORTH ASSAM RAINFALL PATTERN AND ITS SIGNIFICANCE

The investigated North Assam subdivision covers the two states of Assam and Meghalaya and has a total area of 56,339 km². The average annual rainfall calculated from 6 stations for the period 1871-1999 reached 2,226 mm (Figure 1). However, subdivisions are administrative demarcations and do not represent internally cohesive areas. This can be seen clearly in the case of North Assam. This zone is characterised by an extreme contrast between the southern part (Meghalaya) with an annual rainfall of 11,000 mm at Cherrapunji station, and the Brahmaputra Valley (Assam) in which only 1600 mm annual rainfall is noted in Gauhati (Figure 2).

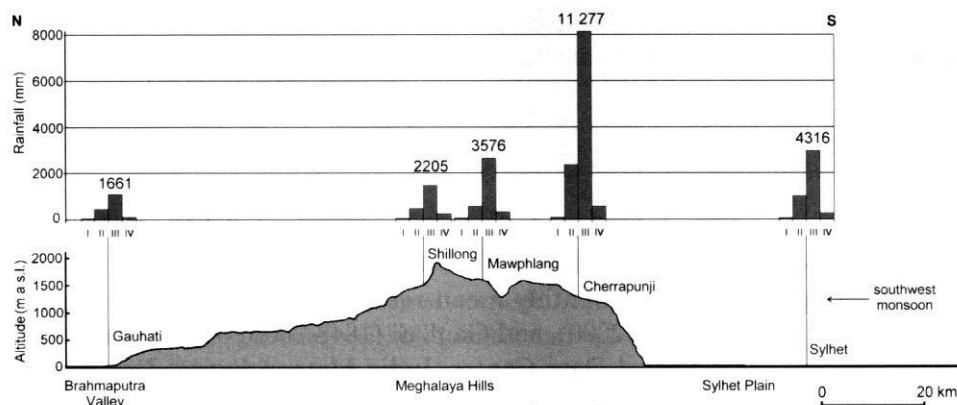


Figure 2. Cross section of the Meghalaya Hills with seasonal rainfall distribution for uniform period (1901-2000).

I—winter, II—pre-monsoon, III—south-west monsoon, IV—post-monsoon.

The Meghalaya Hills, a relatively small region located between the Brahmaputra Valley in the north and the Bangladesh floodplains in the south, plays an especially important role. They form the first orographic barrier for the humid southwest monsoon winds on their way from the Bay of Bengal. The Meghalaya Hills account for about 20-25 percent of rainfall input during spring and in June

even though they represent only 2 percent by area of the Ganges, Brahmaputra and Meghna basins (Hofer 1997). The rainfall over the southern slopes of the Meghalaya Hills is very important, perhaps even decisive, in the flood processes noted in Bangladesh (Hofer, Messerli 1997). Dhar and Nandargi (1998) also rate the north-east among the flood-prone areas in which a majority of floods in India occur.

THE TREND TO RAINFALL DATA

Visual inspection of rainfall time series suggests that no evident trend is present in the data (Figure 3). The numerical, statistical, approach to the question of the trend is as follows. In line with Ockham's razor, the simplest approach is used. The data series is divided in half and the simplest statistical test (Student's *t*) is used to answer a question as to whether on average, the first and second halves of the series differ. The results are given in Table 1.

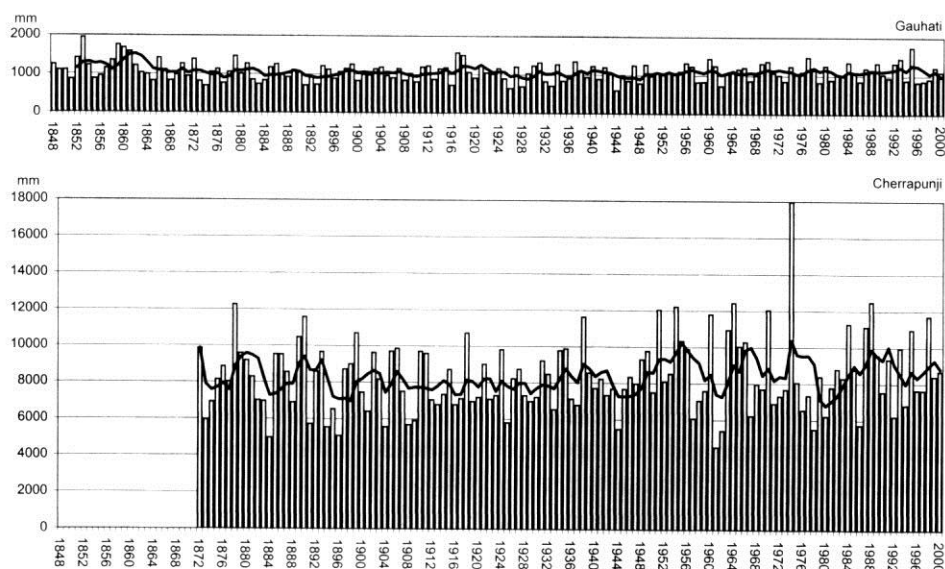


Figure 3. Plots of the south-west monsoon rainfall series at the two selected stations Gauhati (Brahmaputra Valley) and Cherrapunji (Meghalaya Hills). Continuous curve shows 5 years moving average.

The values of *t* are generally small (under the null hypothesis of no trend, the expected value of *t* is 0, and its standard deviation 1). The sign to *t*-values may have some geographical meaning, since the positive trend is obtained for stations in close proximity Shillong, Mawphlang and Cherrapunji, while the Gauhati and North Assam subdivisions have a negative trend. It must be mentioned, however, that the negative *t* values are by no means significant statistically. The highest

obtained positive value $t = 2.23$, if taken as a number alone, gives a relatively significant p-value of 0.030. However, taking into account the fact that 2.23 is the extreme of 12 values, the significance of the value drops significantly. The average $t_{av} = 0.658$ ($n=15$), gives a significant p-value=0.01. However, the assumption of independence of 15 values of t , necessary for such a conclusion, is evidently broken by the fact that both the North Assam and Gauhati values are of negative sign, while all others are positive. The final conclusion is that there is no trend to rainfall data in the region.

Table 1. Student's t-values for difference between later and earlier half of time series.

Raingauge station	Series length (years)	Year	Pre-monsoon	South-west monsoon
North Assam (6 stations average)	129	-0.44	-0.51	-0.51
Gauhati	152	-0.28	-0.63	-0.46
Shillong	134	2.01	1.25	1.26
Mawphlang	75	1.45	2.23	0.66
Cherrapunji	129	1.63	0.58	1.63

To enhance the significance of that conclusion, two remarks on the general statistical features of the time series tested may be added. The coefficients of variation for all sites, excluding Assam, are close together at $v = 0.2 - 0.3$, while for all the regions of Assam $v = 0.1$, and is less, as may be expected for a large area with many raingauge stations averaged. The coefficient of asymmetry for all series is of the order of 0.5 - 1.0 (and half of that for Assam), as may be expected for positive, random data with v of around 0.25.

As a general conclusion the given rainfall series may be treated as a stable, random time series. Only the average values are of climatological significance. However, in the next section an attempt is made to find a periodic structure to the rainfall data.

PERIODICITY: THE PERIODIC SIGNAL OF $T = 3.5$ YEAR

In the course of the exploratory data analysis of the rainfall time series, a Fourier analysis has been performed. For the statistical significance assessment it is important to mention that the plot on Figure 4 is the first obtained in data exploration. It is clear that the periodic component with a period $T=3.5$ year is of maximal amplitude. The horizontal scale is that of the period of the periodic component. Maximal amplitude is obtained for $T=3.5$ year. The second one is about $T=11$ year, although the evidence for this is too weak to connect rainfall with the

sun's activity. Similarly, the 3.5 year period seems not to be statistically significant, anyway that is of maximal amplitude.

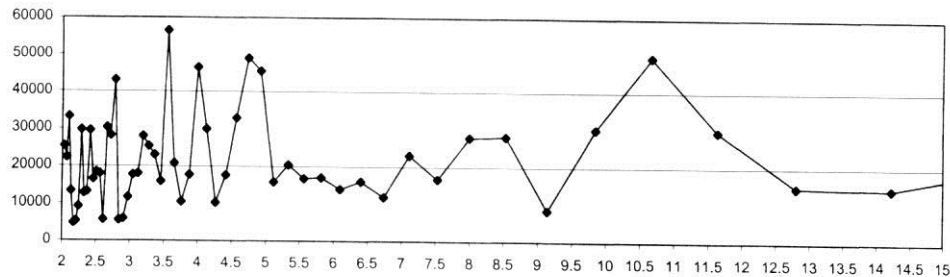


Figure 4. Fourier analysis result of rainfall time series for southwest monsoon season (June-September) at Cherrapunji station. On the horizontal axis the period T is plotted (the scale is not linear for T because it is linear for frequency, i.e., the reciprocal of T).

The 3.5 year period is known to be present in many rainfall and river runoff time series from Central Europe (Walanus 1990, Walanus and Soja 1995). The origin of such 'strange' period is yet to be discovered. It is possible that no such origin exists at all and that the 3.5 year periodicity is simply random fluctuation. In any case, it would seem interesting to search for the spatial distribution of this fluctuation. To find more time series with such a period is the only way to track the mentioned fluctuation or to seek the climatological cause of it.

The first step is to compare rainfall series from neighbouring sites. The comparison would, however, be more significant from the natural point of view if performed on the basis of the time scale (time domain) instead of frequency (or period; i.e. frequency domain). On Figure 5 twelve series are presented in the 'light' of the 3.5 year periodicity. The series are filtered by a Gaussian band-pass filter of $T = 3.5$ year; relatively narrow but wide enough to retain visible fluctuations of amplitude of the 3.5 year component, over tens of years.

Two features of plots are examined. The first is the existence of fragments of the order of the 20 year length of higher amplitude of 3.5 year periodic component. Those fragments are, more or less, synchronous over sites and over seasons. The second important feature is that the 3.5 year periodicity is synchronous itself.

The sites are close together, so such parallelism of (filtered) series may be expected. Nevertheless, it proves that the periodicity discussed is not a random fluctuation of one site's rainfall, but is of, at least regional significance.

What is interesting is that both kinds of synchronisms appear between the non-overlapping 'pre-monsoon' and 'southwest monsoon' seasons. It means that rainy phases, within a 3.5 year period, are visible not only in one 'season' but also in all. It seems to agree with the conclusion of a regional (global?) rainfall correlation with a 3.5 year periodicity.

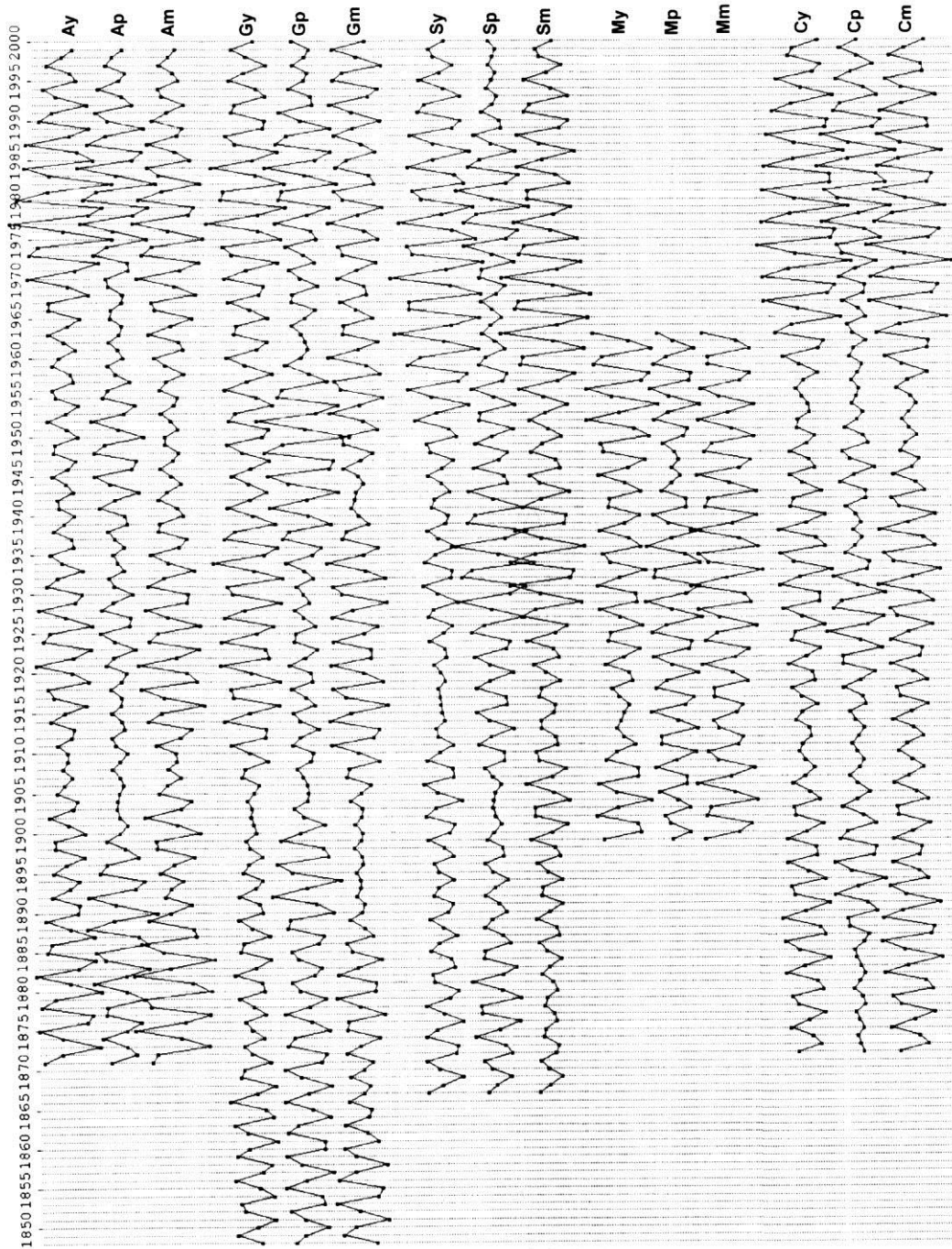


Figure 5. Filtered rainfall time series, i.e. presented in the 'light' of 3.5 year periodicity.

Stations: A— North Assam subdivision, G—Gauhati, S—Shillong, M—Mawphlang,

C—Cherrapunji; seasons: y—year, p—pre-monsoon, m—southwest monsoon.

The filter is a relatively narrow Gaussian band-pass filter of $T=3.5$ year.

CONCLUSIONS

Trend analysis for annual and seasonal rainfall series shows these to be very stable, with no change in the rainfall over North Assam over at least the last 150 years. This confirms the general view that monsoon rainfall is trendless and is mainly random in nature over a long period of time. These stable conditions are seen not only on the all-India scale, but also at subdivision and station level. While t-values are non-significant, a positive value (positive trend) is obtained for stations in Meghalaya: Shillong, Mawphlang and Cherrapunji, while the Gauhati and North Assam stations located in the Brahmaputra Valley are of negative value. Differences can be connected with modified climatic conditions over the Brahmaputra Valley, as located in the 'rain shadow' between two belts of high precipitation: the Meghalaya Hills and Indo-Burman Ranges in the south and the Himalayas in the north.

The analysis of fluctuations in rainfall series shows that the periodic signal of $T=3.5$ yr is the strongest one. Signals with the same phase have been found at all rainfall stations and in all investigated seasons over the North Assam subdivision. A similar signal is also known to be present in other parts of the world (e.g., central Europe) in rainfall and river runoff series. We can assume that, while the source of the signal is not known, the periodic component of $T = 3.5$ year is independent of local or regional climatic conditions over monsoon areas like India.

These conclusions do not change the fact that the monsoon is highly variable in intensity from year to year, and that extreme average precipitation values with a contrasting rainfall pattern exist in the North Assam. These have an important, especially hydrological, significance over a much larger area. The documented rainfall conditions stable in time can give a good basis for future research, e.g., on the influence of land use changes on soil erosion, the water balance or the river regime on different scales.

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