Monsoon rainfall cycles as depicted in ancient Sanskrit texts

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Year to year variation of Indian monsoon rainfall is described qualitatively in some ancient Sanskrit texts. Interestingly, these are cyclic with periods of 3, 5, 7, 18 and 60 years. Time series analysis of actual seasonal rainfall data shows that at very near the above periods the spectrum has significant peaks. The Venus visibility portent stated in the Arthaśāstra appears to be a proxy for the near three-year fluctuation cycle in the rainfall.

The season that brings rainfall to large parts of the country, now called the monsoon, has left its imprint in all types of literature starting from the *Ṛgveda*. Vedic literature describes figuratively the evaporation–rainfall cycle (*Ṛgveda*: 1.164.51), and knows the sun as the cause of rainfall. It even has a hymn dedicated to the frogs who sound in chorus at the start of the rains, much like the students learning the Veda. While a bounteous monsoon kept the people happy, its vagaries were dreaded. Stories of droughts and failure of rainfall were quite common in the legends, particularly when people shifted their location. One such 12-year long drought was the reason for Bhadrabāhu and his followers to emigrate from Bihar to distant Karnataka in the 3rd century BCE[1]. Failure of rainfall for 12-years might be an exaggeration, but people should have been as eager as now are to have a reliable forecast on what they could expect from the clouds. The most significant feature of the monsoon is its annual recurrence and the year-to-year variation in the amount of rainfall, called inter annual variability (IAV). At present, IAV is characterized by fixing a normal (time average) and expressing the yearly rainfall in terms of percentage variation about this long-term normal. It is now well known that the variation comprises of oscillatory patterns around 2–3, 5–7, 11–12, 18–20 and 60 years[2]. Narasimha and Kailas[3] through wavelet analysis found almost the same periods for the first four modes. These are not perfect repeating cycles, but narrow-band oscillations with slowly varying amplitude and phase around the indicated central periods. The above quantitative understanding is based on the analysis of long-time series data of Indian rainfall for the last 100 years. However, all persons dependent on the monsoon for their profession recognize IAV of the seasonal rainfall in their own way. It is common among farmers and villagers to talk of a season being similar to the one a few years back. They intuitively recognize IAV in terms of similarity or lack of it, compared with some past year fresh in their memory. This would be clearly due to the influence that rainfall has on their personal lives. A question that arises in this connection is; considering the deep influence that monsoon has had on Indian culture and life, how was IAV described and characterized? Was there any effort in ancient India to quantify IAV? The present note attempts to address these questions by tracing IAV-related descriptions in ancient Sanskrit literature.

Venus appearance cycle

Kautilya's *Arthaśāstra* is a book on Statecraft, with considerable information on administrative procedures of the governments of his days (*c*. 4th century BCE)[4]. He describes under the chapter on agriculture (II.24) how to measure rainfall and also gives the amount of rainfall (presumably some kind of average) in the important provinces of his kingdom. Since rainfall figures were collected by empowered officials and used by the decision makers, Kautilya's methods are expected to be rational. Quite intriguingly, he mentions that rainfall for the season depends on the visibility of Venus (*tasyopalabdhiḥ……śukrodayāstamayacārebhyaḥ……śukrādvṛṣṭiriti*||). At first reading this appears to be an astrological prescription, based more on belief rather than empirical observations. However, on closer scrutiny this statement is seen to reflect the near three-year oscillation in monsoon rainfall. Kautilya expects good rainfall if Venus were to be sighted in the eastern sky during the monsoon season. The season being of four months according to the text, this precursor for making a forecast should refer to the first month of the season. Now, Venus as a morning object is visible for about eight months and becomes invisible for about 50 days, before rising in the evening in the western sky. The synodic period of Venus is nearly 584 days. Hence, once seen in the early part of the monsoon season, Venus will not be seen in the subsequent season, which is only one year away. Also, when seen next after its cycle of 584 days, the season will not be rainy. But, interestingly, after one more round, that is, after nearly three years, Venus would be visible in the beginning of the monsoon season. Thus, the correlation prescribed by Kauṭilya is based on an uncanny observation of occurrence of two contemporaneous natural events with nearly the same period. Since any such cyclic trend is not perfectly periodic, the correlation will drift over time with no unique practical implication. This could be the reason for the development of longer cycles for predictive purposes.

Five-year cycle

In the Vedic period the country followed a luni-solar calendar. While the original form and evolution of this is not known in all its details, what has come down to us from the *Vedānga Jyotiṣa*[5] is a calendar comprising five years as a unit, called the *Yuga*. It appears that this calendar was used till about 4–5 century CE, when the yearly calendar of the *siddhāntic* astronomy became popular. Varāha-mihira, in his *Bṛhat-samhitā*[6], presents the older five-year division for rainfall prognosis. This appears in Chapter 8, verses 24 and 25.

Samvatsaro'gniḥ parivatsaro'rka
idādikaḥ śītamayūkhamālī|
Prajāpatiścapyanuvatsaraḥ
syādidvatsaraḥ śailasutāpatiśca||

Vṛṣṭiḥ samādye pramukhe
dvitīye prbhūtatoyā kathita tṛtīye|
Paścājjalam muñcati yaccaturtham
svalpodakam pañcamamabdamuktam||

Whether or not the forecasts came true, the variability here was taken to be cyclic with a five-year period. The concept of a normal year which gets rainfall evenly throughout the season is basic to this model. The five years of the Vedic calendar with their names, regent deities and rainfall character are said to be: *Samvatsara–Fire; Parivatsara–Sun; Idāvatsara–Moon; Anuvatsara–Prajāpati* and *Idvatsara–Rudra*. Rainfall would be evenly distributed in the first year. The second year gets good rainfall in the beginning of the season only. Rainfall will be excessive in the third year. In the fourth year of the cycle rainfall will be delayed. Rainfall will be deficient in the fifth year. This type of variability attribution should have been in vogue since ancient times, the roots of which are lost. This also gives raise to a question about how to decide the position of a year in the cycle. The ancient *Vedānga Jyotiṣa* definition is quite unambiguous that the *Samvatsara* started with the winter solstice at the star Dhaniṣṭhā (~Beta-Delphini). This would have been the case around 1400 BCE[5]. However, Varāhamihira prescribes another way of fixing the years of this cycle, which is not important for the present discussion.

Seven-year cycle

Among the available Sanskrit books on agriculture, the *Kṛṣiparāśara* occupies an important place as it records ancient practices quite accurately. Published and studied widely in the recent years[7], the date of the work is unknown. The contents, however, hint at a period later than the Vedic five-year cycle discussed above. It appears to belong to the early centuries of the Common Era, since it uses the Śaka Era (78 CE) in its algorithm for prognosis of rainfall. It postulates a seven-year cycle, based on the presumed influence of the seven planets on the rainfall. Historically this has a parallel with the development of the names of the seven days of the week, attributed the sun, moon and the five planets which most probably happened at the beginning of the Common Era. Even though this basis appears hypothetical, the way the cycle was used leads to an interesting pattern. Perhaps the agriculturists observed more variation than they were able to verbally describe in terms of the previous three- and five-year cycles. The years in the seven-year cycle had no names and hence a peculiar way of prognosis was proposed. Let the year under consideration counted from the beginning of the Śaka Era be N. The forecast of the seasonal rainfall for the year was based on the remainder of the fraction $[(3N+2)/7]$. The remainder would be one of the seven integers (1, 2, …7) associated with the seven planets. Depending on this result the rainfall was forecast, as shown in Table 1.

In the long run, the above thumb rule results in a seven-year cycle of remainders not in the above order, but as [… 2,5, *1*, *4*, *7*, *3*, *6*, *2*, *5*, 1, 4, 7, 3, …]. It is interesting to note that the results do not follow the order of the planets, which is in the order of the names of the week days. There are two years described as *Uttamā* or best in the above prescription. These are associated with Mercury and Venus, but separated by either two or three years, which is reminiscent of the near three-year Venus visibility cycle. The formula mentioned above for fixing the year within the cycle is not available in the *Bṛhat-samhitā*[6]. But in chapter 19, similar rainfall descriptions are given for years ruled by the respective planets.

Eighteen-year cycle

Relation of this cycle with rainfall is through prescribing conditions for sowing of seeds, depending on the position of the imaginary dark planet *Rāhu* among the 27 *nakṣatras* or stars along the ecliptic. This principle, which is included in many of the currently available Hindu almanacs (*pañcānga*), goes under the name of *Rāhu*- or *Phani-chakra*, literally the *Rāhu*- or the serpent-cycle. The relatively ancient nature of this practice will be clear when it is noted that modern Indian astrologers talk of *Rāhu* and *Ketu* as the ascending and descending lunar nodes. It may be noted here that identification of *Rāhu* with the ascending lunar node is a late development after mathematical astronomy got established firmly in India *c.* 5th century CE. Prior to this, as evidenced in the epics *Mahābhārata* and *Rāmāyaṇa*, *Rāhu* was considered to be the intervening dark planet responsible for causing both solar and lunar eclipses. Clearly, the use of the *Phaṇi-chakra* should have been more ancient than the development of *siddhāntic* astronomy and knowledge of moon's path cutting the ecliptic at two points. Traditional almanacs contain a section on agriculture and rainfall, where one can find a sinuous, snake-like figure, sometimes three-layered, with 27 small circles arranged along the centre line referring to the ecliptic. The prescription for sowing seeds depends on the relative position of the moon with respect to *Rāhu* placed at the tail of the figure, the details of which are not of interest here. The number eighteen is of considerable importance in ancient Indian literature. This arose out of the knowledge of the 18-year eclipse cycle which can be easily traced to the mystical lunar number 3339 appearing in the *Ṛgveda* related to similar lunar eclipses[8].

Sixty-year cycle

The sixty-year cycle arises as the product of the Vedic five-year cycle and the twelve-year sidereal cycle of Jupiter. The basis of this appears to be purely arithmetical. Rainfall description for a year within this cycle is given by *Varāhamihira* in detail. It is doubtful whether

Table 1. The seven-year cycle

Remainder of $[(3N + 2)/7]$	Associated celestial object	Expected rainfall in the year N
1	Sun	Average, moderate (*Cittalā*)
2	Moon	Heavy (*Ugrā*)
3	Mars	Gentle or feeble (*Mandā*)
4	Mercury	Very good (*Uttamā*)
5	Jupiter	Satisfactory (*Śobhanā*)
6	Venus	Excellent (*Uttamā*)
7	Saturn	Dry and dusty (*Hīnā*)

this was put to any practical application. For example, *Kṛṣiparāśara*, the classical text on agriculture, does not recommend this cycle.

Complex variability patterns

It has been noted that the ancient variability descriptions were essentially qualitative, to be understood by personal experience. The word *Cittalā* used several times in the *Kṛṣiparāśara*, has the meaning of being moderate, similar to the modern average. The state of rainfall in other years was calibrated with respect to such a year. The *Kṛṣiparāśara*, apart from the seven-year cycle, lists yet another pattern which is quite complex. This has four states denoted as *ativṛṣṭi, anāvṛṣṭi, suvṛṣti* and *cittalā*. These four types of rainfall can be translated as excessive, deficient, sufficient and normal respectively. The rainfall for the monsoon season is decided by the position of moon (*nakṣatra*) at the spring equinox. The *naksatra* series started with *Kṛttikā*, including *Abhijit* as in the Vedic period (2nd–3rd millennium BCE). Normal rainfall was expected only when the equinox moon coincided with either the *Aśvini* or the *Svāti naksatra*. It was deficient when moon at equinox was with *Kṛttikā, Hasta*, *Anurādha* or *U. Bhādra*. It was sufficient when moon was with *Bharaṇi*, *Citrā*, *Visākhā* or *Revati*. In all the other 18 cases the rainfall would be excessive. Whatever be the basis of this prognosis, the interesting feature of this proposition is the inherent 18–19-year cycle of the four types of rainfall. This arises out of the coincidence of the lunar and solar cycles at the above period, with possible error of one *nakṣatra* position. This is similar to the *Rāhu-chakra* cycle of 18 years mentioned above. Whether or not the ancients knew the correct reasons for this cycle, the fact remains that a weak 18–19-year peak can be observed in the spectrum of many real geophysical time-series data[9,10].

Yet another variability pattern was based on the position of the moon when the first rains occurred at the start of the season. This is similar in spirit to the above four states of rainfall, but the details are different, since the quantity of seasonal rainfall is forecast in Droṇa measures. This pattern has been critically investigated with statistical details already and hence will not be detailed here[11].

Intra-annual variability

As is well known, rainfall exhibits considerable month-to-month variation within a given year. The texts *Kṛṣiparāśara* and *Bṛhat-samhitā* throw some light on how this issue was addressed in ancient India. Starting from the Vedic period, it was well known that the rainy season was dependent on the sun and not on the moon. Since the more ancient time-keeping was based on the moon, the annual rainfall cycle would have necessitated synchronization of the solar and the lunar year. The Sanskrit word *varṣa* means rainfall but denotes year also. Similarly, another popular word for year is *abda*, literally giver-of-water. Thus, naming the months and seasons with respect to the sun in addition to the already existing lunar months was introduced. This is quite evident in the Yajurvedic texts which name the twelve solar months as *Madhu, Mādhava*, *Śukra*, *Śuci*, *Nabha*, *Nabhasya*, *Iṣa*, *Ūrja*, *Saha*, *Sahasya*, *Tapa* and *Tapasya*. The word *Madhu-māsa* stands for the spring month in popular parlance even now, except that this is neither same as the lunar month *Chaitra*, nor the solar month *Meṣa* (*Chittirai* in Tamil), of the present-day religious almanacs. Lack of synchronization of the present Hindu solar calendar (*souramāna pancānga*) with the seasons is due to wrong interpretation of ancient texts. These were appropriate for their times, but now need correction due to precession of equinoxes. In addition, the relation between the solar zodiac defined with respect to the equinoctial point and the fixed sidereal zodiac (*nakṣatra*) of the Vedic period was misunderstood by some influential authors on astrology. Thus we see the Vedic solar *uttarāyaṇa* or the winter solstice day being equated with *makara sankrānti*, which in turn is wrongly shown to be occurring on or about 14 January, whereas the correct date should have been around 22 December, the shortest day in the civil calendar. Hence, to map ancient seasonal information as given in Sanskrit texts to modern times, a correction of about three weeks is necessary. This is essential to appreciate the within-year rainfall pattern as described by ancient authors in terms of the solar *nakṣatra* notation, which was formulated when the sun at vernal equinox (0° longitude) was stationed near the visible star *aśvini* (Beta-Arities?) in the 2nd century CE. Presently, the equinox in the civil calendar is on 22 March and hence if we talk of *aśvini-rain*, according to ancient practice, it has to be during the dates 21 March–3 April and not 13 April–26 April, as shown in the traditional almanacs[12]. Varāha-mihira was well aware of the connection between the monsoon season and the position of the sun. In chapter 28, verse 20 of his *Bṛhat-samhitā*, rains are said to be certain when the sun passes through the asterism *ārdra*. If the vulgate almanacs are followed, this corresponds to 22 June–5 July, whereas the observational results of the ancients correspond presently with 30 May–11 June. This is well known to be the period of onset of the southwest monsoon over large parts of the subcontinent. Such considerations become particularly important when villagers use their folkloric knowledge of proverbs such as 'if it does not rain in the *Hasta* (asterism), one's mother will also not give food'. This should be taken to correspond to 4–16 September, whereas the *pañcāngas* mark this for 27 September–10 October. The risk associated with wrong identification of the position of the sun among the *nakṣatra* increases when seed-sowing operations are undertaken based on ancient beliefs. For example, in some areas of Karnataka, farmers believe that sowing during *punarvasu* rains leads to a rich harvest of groundnuts. This period should be taken as 12–25 June and not 6–9 July as shown in the *pañcāngas*.

Discussion

Year-to-year variation in the amount of rainfall during the monsoon season is of considerable current interest to people in several walks of life. That this was so even in ancient times should not be surprising, considering the strong dependence of agriculture on rainfall. What turns out to be remarkable is that some significant oscillatory features in monsoon rainfall as we know them today, were already known to the ancients. How they were able to decipher these signatures is a matter of conjecture. We have to surmise that even if records were not maintained as in modern days, at least those kingdoms and provinces that followed the *Arthaśāstra* of Kauṭilya had a method for measuring rainfall. The near three-year cycle known presently as the ENSO (El Nino Southern Oscillation) was clearly known to Kautilya in terms of a proxy, namely the visibility of Venus. This does not mean that Kautilya was the originator of this concept. Utpala (9th–10th century CE) in his commentary on the *Bṛhat-samhita* of Varāha-mihira (5th–6th century CE) quotes extensively from the works of Parāśara, who describes an ancient observational tradition originating around 1400 BCE[13]. An important property ascribed to Venus by Parāsara is *arka-varṣa-nigraham* or control of sun-induced rains. Thus, it is quite likely that the three-year rule associated with Venus visibility was known in India since ancient times. Failure of this rule in several years could have encouraged detailed observations, eventually leading to empirically propose 5, 7 and 18-year cycles for the summer monsoon rainfall. The basis for these cycles is not available in the literature, even though from modern analysis these cycles are known to be realistic.

Within the year rainfall also exhibits fortnightly, monthly and seasonal fluctuations. These are generally described in the texts in terms of the position of the sun and moon among the *nakṣatras*. The position of the sun with respect to the fixed stars, as observed from the earth, changes over long periods of time due to precession. Hence matching of time-marking statements and folkloric proverbs with modern-day civil calendar dates has to be done after correcting the dates given in the traditional almanacs. An objection to this may be to raise the issue of whether in ancient times the solstices were observed on the correct dates. That the ancients observed this within an error band, better than at present, is evidenced by stone and copper-plate inscriptions with dates for the winter solstice available in the volumes of *The Indian Antiquary*[14]. For example, the Śravana-belagola Kannada inscription of Hoysala Vīraballāla records the winter solstice in the Śaka year 1104 to be on *puṣya bahula tadige śukravāra*. This corresponds to Friday, 25th December 1181 CE. Similarly, according to the Terawan copper-plate inscription of Kalyāṇa, the winter solstice was observed in the Śaka year 1182 on *puṣya vādi saptamī śanidina*, corresponding to Saturday, 25 December 1260 CE. As recently as in the 18 century, the Melkote inscription of Krishnaraja Wodeyar of Mysore, records *uttarāyaṇa-makara sankrānti* on 29 December 1724 CE.

Summary and conclusion

IAV patterns of monsoon rainfall as described in ancient Indian texts have been presented here. It is interesting to note that the dominant periods were taken to be 3, 5, 7, 18 and 60 years. Time-series analysis of actual seasonal rainfall data of the past 100 years shows that near the above periods the spectrum has significant peaks. It is now known that the ENSO oscillations of 2–3 year period explain maximum variance of the year-to-year fluctuations[2]. The Venus visibility portent of Parāśara, stated also in the *Arthaśāstra* appears to be a proxy for this ENSO signature.

For understanding the within-year variability of rainfall, ancient texts have to be interpreted after making correction for the precession of equinoxes. Blind following of the texts, in letter but not in spirit, has led to marking of the date of winter solstice (*makara sankrānti*) as 14 January in the *pañcānga*s. Hence the traditional dates of expecting rainfall depending on the sun's *nakṣatra* as given in the *pañcānga*s, are to be advanced by about three weeks for practical use in agricultural operations. It is known that astronomically wrong information, particularly of the solstices and equinoxes, has crept into several of the printed *pañcānga*s[15]. This calls for serious introspection and discussion on the part of socio-religious leaders with scientific temperament to reform the traditional almanacs, so that culturally important astronomical events such as equinoxes and solstices are observed on the naturally correct dates of the civil calendar.

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