A calendar does not simply refer to that piece of paper which decorates the walls—pandering to the vanities of petty Roman dictators. In the Indian context, the calendar must be able to determine the rainy season just as the year (*varṣa*) relates to rain (*varṣā*) in the language. To this end, consider the more recent event of three years ago, which demonstrated the continuing contemporary importance of the calendar for purposes of Indian agriculture, and shows the havoc that can even today be caused by a "delayed monsoon" or a bad calendar. To bring out the flavour of the events as they were experienced, the boxes 4.1 and 4.2 draw verbatim from articles written at that time.

Box 4.1. The not-too-soon monsoon of 2004

"Drought grips half the country: 274 of 524 Met Districts Get Deficient or Scanty Rainfall" screamed the top-left headline of *The Times of India* (New Delhi, Friday, 30 July 2004, Late City Edition). It is raining cats and dogs outside, and the *Hindustan Times, Bhopal HT Live* of the same day (31 July) points out on its front page that, after the recent heavy showers, only one district in MP remains classified as having scanty rainfall (-60% of average). The Met department has issued a warning of further heavy rains. The basis of the *Times of India* report is clear from the punny "Wither report" graphic which accompanies the headline, but is based on nine-day old data (as of July 21). Admittedly, it has been many years since I have thought of *The Times of India* when I was looking for an instance of responsible journalism; however, what is one to make of the fact that the MP government itself had already prepared a plan asking the centre for Rs 200 crores as drought relief? Obviously, the government could not have waited for the drought to become full blown. According to another report, the Central government has already released Rs 50 crores to MP by way of drought relief. However, with reports of floods from Assam to Mumbai, and various places in between, it might have been better to prepare for flood relief!

More seriously, although the *HT Bhopal Live* report tells us that the rains have arrived just in the nick of time to save the crop, the TOI in a related report (p. 8) sounds the sombre warning that normal rainfall now may not save the crop a significant proportion of which was sowed long ago.

Clearly, agricultural operations were significantly mistimed, and that can be potentially damaging to the crop. But what was the reason for this mistiming? To repeat the question I raised last year: was the monsoon delayed or is the calendar wrong?

India has officially recognized two calendars, and according to the traditional *pañcāṅga*, the current month is an *adhika māsa*—an intercalary month—it is an additional *Sāwan*, and, as any child knows, *Sāwan* and *Bhādon* are the months in which it rains. The second month of *Sāwan* commences on 17th Aug 2004, and since there are two *Sāwan*-s, Rakhi comes as "late" as 29 August. So the monsoon has arrived pretty much on time according to the traditional calendar, exactly as happened last year, when, too, the monsoon was declared to be delayed according to the Gregorian calen-

dar, according to which the monsoon should have arrived long ago, by the first week of July. So who or what is to blame for the wrong timing of agricultural operations: the monsoons or the Gregorian calendar?

As an illustration of the old adage—that those who don't learn from history are condemned to repeat it—it should be pointed out that the same point had been made a year earlier, but it did not quite register with those in authority.

Box 4.2. Could India's "failed" monsoon have been predicted by the right calendar?

Agriculture traditionally was the mainstay of the Indian economy, and still remains vital to the Indian economy. Accordingly, a method of timekeeping in the form of a good calendar remains a critical technology in India. Traditional calendar-making techniques, calibrated over centuries, therefore, deserve serious consideration and evaluation, and should not be rejected in a cavalier manner.

Consider the current situation. This year [2003] the monsoon did not arrive for so long that there was a severe water crisis, and the government declared the state to be severely drought affected. Eventually the monsoon has arrived, after nearly a month of delay, and in Bhopal at least, the deficit has been wiped out, with floods in nearby rivers. (It is still raining heavily, but water is still being supplied only on alternate days!)

The question is this: was the monsoon delayed? or is the calendar wrong?

The background to this question is as follows. The traditional Indian calendar uses the sidereal year, while the Julian and Gregorian calendar uses the tropical year. The sidereal year is the time period in which the sun returns to the same position with respect to the stars—it is the orbital period of the earth around the sun—while the tropical year is defined as the time between two successive vernal equinoxes. The sidereal year involves the motion of the earth relative to the stars, and is MORE than 365.25 days (365.256363 days, approximately), while the tropical year involves the motion of the sun relative to the earth, and is LESS than 365.25 days (365.24219 days approximately, at the present epoch). The difference between the two types of years is approximately 20 minutes per year (1223 s), which can become substantial over long periods. The difference is attributed to the precession of the equinoxes: the axis of the earth is thought to precess like a top, so that it points to different points in the sky at different times along a cycle of some 26,000 years (i.e., Polaris was not the north-star a few thousand years ago, and will not be the north star a few thousand years from now). One sidereal year is roughly equal to $1 + \frac{1}{26000}$ or 1.000039 tropical years.

The Julian calendar was based on the tropical year or the equinoctial cycle; so is its corrected version—the Gregorian calendar (which is the calendar in current use).

The Gregorian calendar reform committee tried to consult Indian calendrical sources, as I have pointed out elsewhere—in connection with the transmission of the differential calculus from India to Europe. Christoph Clavius was the head of the Gregorian calendar reform committee, and just prior to the Gregorian calendar reform of 1582, Clavius' student, Matteo Ricci, was in India, in Cochin, searching for Indian calendrical manuals, after having been appropriately trained for this purpose. (I have a photocopy of Ricci's original handwritten letter.) Europe then lacked the knowledge needed for a precise determination of the length of either the tropical or the sidereal year.

The Gregorian calendar reform itself was initiated because the Julian calendar fixed the length of the year very crudely—in my opinion just because the Romans were not adept with fractions. Because of the error in the second decimal place (the Julian calendar took the year to be exactly 365.25 days) the Julian calendar slipped by about 1 day every 128 years or so ($365.25 - \frac{1}{128} = 365.24218$ days), and had, by 1582 CE, slipped about 10 days out of phase in the 1250 odd years since the Council of Nicaea fixed the date of Easter, by fixing the date of the vernal equinox on XII calends (21 March). Thus, towards the end of the 16th c. CE, the vernal equinox used to arrive around 11 March on the Julian calendar. The Gregorian calendar reform corrected that by (a) advancing the calendar by 10 days, and (b) by making every centennial year (e.g. 1700, 1800, etc.) not a leap year, except when divisible by 400 (e.g. 2000). Basically, by removing some 3 leap days in 400 years (or 1 day in 133 years) the Gregorian reform corresponded to a more accurate figure for the fractional part of the length of the tropical year, which it set at $365.25 - \frac{1}{133.3} = 365.2425$ days. This correction of the calendar was needed for the very practical purpose of fixing latitude from observation of solar altitude at noon. (Navigation was, then, extremely important for Europe, which was then way behind the Indians and Arabs.) Although everything in Europe, including the mode of dress, required clerical approval, there could not have been any serious doctrinal considerations: the date of Easter was fixed at Nicaea more from a desire that Christians ought to differ from the Jews, and that objective would have been unaffected by a change in the date of the vernal equinox on the calendar. There was no doctrinal pressure from the Protestants for such a change—quite to the contrary they initially opposed the change, then later accepted it. Furthermore, the difference of ten days was too little to have had a visible effect on the seasons. But such a major step obviously had to have had a strong practical motive, which was why it was accorded religious approval.

The critical input needed for the reform of the Julian calendar was the exact length of the tropical year, sometimes called the problem of epacts in theological terminology. The Roman church had tried to find a solution to this problem since pope Hilarius in the 6th c. CE, but these attempts were unsuccessful, despite access to all works in the Roman empire, including obviously the works of "Claudius Ptolemy" of Alexandria—in the form in which they then existed, if they did. The length of the year was, however, very accurately known in India at least since about the 3rd c. CE.

Gregory's bull only mentions a book by one Alyosius Lilio brought to his attention by his brother Antonio Lilio, who apparently used the Alphonsine tables, and thus obtained this information from Arabic sources like Copernicus did. While this information from Arabic sources had been around for some time in Europe, Europeans lacked the means to verify it. Hence, quite possibly the critical input that the Jesuits in India provided was an "independent" confirmation of the validity of those figures, giving the green signal to Gregory.

The change of calendar did initially become a religious issue, since this changed also the date of Easter on the civil calendar (the sole point on the agenda at the Council of Nicaea, which hence practically defined the Nicene creed). Protestants, among others, opposed the papal bull. The reformed calendar was eventually accepted in Britain and in USA (then a British colony) only in 1752, by advancing the calendar by 11 days and implementing the rest of Clavius' recommendations.

Though neither calendar has changed significantly in the last 500 years, perceptions have. Therefore, ironically, after independence, the Indian calendar reform committee adopted the Gregorian calendar without much ado! In its report, the Indian calendar reform committee,[21] dominated by M. N. Saha (and N. C. Lahiri), simply stated that it is obvious that seasons depend on the tropical year.

> For calendarical purpose [sic], it is unmeaning to use the sidereal year. . . as then the dates would not correspond to seasons. The use of the tropical year is enjoined by the Hindu astronomical treatises like the *Sūrya Siddhānta* and the *PañcaSiddhāntikā*. But these passages have been misunderstood, and Indian calendar makers have been using the sidereal year with a somewhat wrong length since the fifth century AD.

If that is so, then the traditional Indian calendar ought to have slipped out of phase by around 21 days over the last 1500 years. Such a major failure should be pretty obvious, but is it? (Also, I don't see the part about "misunderstanding", since Āryabhaṭa, prior to Varāhamihīra and the *PañcaSiddhāntikā*, unambiguously advocates the sidereal year.)

Exactly how is it obvious that one must use the tropical year? While it is true that physically the sun is the main source of heat, one does not merely want to determine the hot and cold seasons—for the key feature of the calendar in India relates to the monsoons, which are the mainstay for agriculture. The monsoons depend upon the wind regime.

The wind regime or global circulation is not, however, decided solely by the position of the sun. Hot air rises at the equator, but it does not descend at the poles. Because of the so-called Coriolis force, due to the earth's rotation, the air is deflected and descends before the horse-latitudes.

The monsoons, thus, depend also upon the Coriolis force. The Coriolis force is an inertial force. The only possible inertial frame being a frame fixed relative to the

distant stars, the Coriolis force hence relates to the sidereal motion of the earth. Thus it might be that the monsoons relate also to the sidereal year.

At any rate, the monsoons have arrived on time according to the Indian calendar, since Rakhi too was "very late" this time, and the current month is still *Srāvana*. (The calendar we are talking about was calibrated for Ujjain, about 150 km from Bhopal.) The monsoons, however, are delayed by a month according to the Gregorian calendar: or, to put it differently, the Gregorian calendar has given the time of the monsoons in a grossly incorrect way. If the monsoons depend only on the tropical year, then, because of the difference between the tropical and the sidereal year, it is the Indian calendar that ought to have been out of phase by three weeks (around 21 days).

Admittedly, the argument sketched above is no more than a conjecture at this stage, but it does show that there is no particular basis to the belief that the tropical year decides the periodicity of the monsoon. Actually solving the Navier–Stokes equations over a long period to ascertain what the periodicity of the monsoon depends upon is a supercomputing problem (still a "grand challenge problem" according to NASA). In the absence of an actual solution, the assertion that the monsoons should have a simple periodicity depending upon the tropical year is also not particularly credible, but is merely an article of belief. At any rate, one cannot consider as obvious that the seasons depend only on the tropical year, and that the traditional Indian calendar is hence wrong. Perhaps this is so, but there is nothing obvious about it, and a study at least is needed, to establish things either way. The tropical year might well work for the seasons in Europe, but the considerations in India are obviously different. (I may note in passing that what is required obviously is a causal rather than a statistical account.)

There could, of course, be other reasons why sidereal time was used in Indian astronomy. The rotation of the earth varies less than the apparent motion of the sun around the earth, so that the sidereal year provides a better method of timekeeping. It is better suited to planetary models, for the sidereal year is the "actual" time for the earth's orbit. It is also a more convenient method of timekeeping: for stellar transits are easy to observe, etc.

A sidereal day is 23 hours, 56 minutes, 4.09 seconds, about 4 minutes *less* than a tropical day (in contrast to the sidereal year), so that there are 366.2422 sidereal days in a tropical year, compared to 365.2422 tropical days.

If the matter of the traditional calendar is re-opened, it will be necessary, of course, also to summarize—if not sort out—the whole vexatious issue of the precession of equinoxes vs libration: whether or not the precession of the equinoxes is actually taken into account in the Indian astronomical literature.

(A similar story was repeated in 2006, but it is too late to include those details in this book.[22])