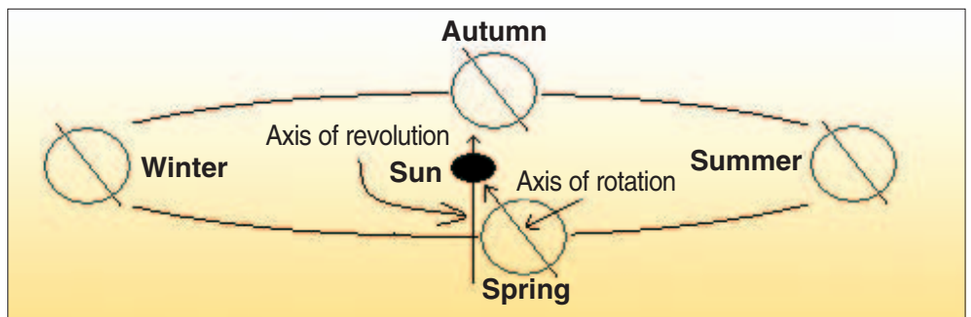
Artifacts in the history of climate

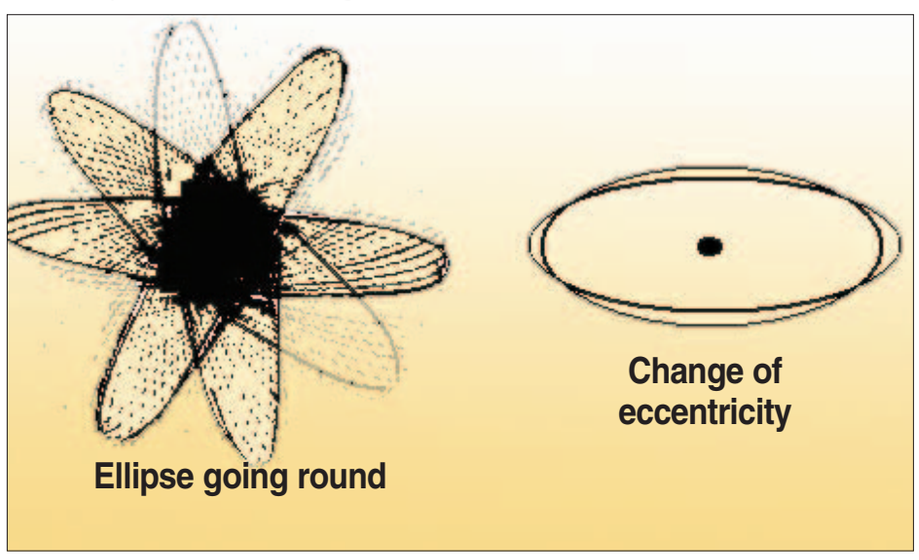
1.5 million years of the earth's climate has come into sharper focus, says s ananthanarayanan

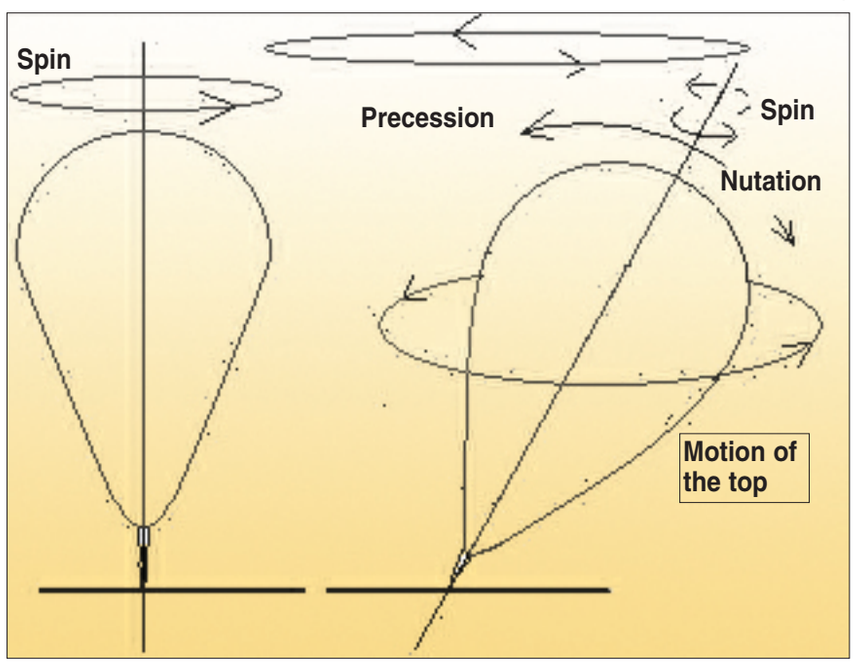
UNDERSTANDING how the earth's climate system functions is vital to make the right moves in response to climate change. But climate is a complex system, affected simultaneously by the seasons, by ocean currents, Polar ice mass, winds and the composition of the atmosphere. Tracking the changes in markers of climate over the ages helps identify the effect of different influences in the process. Records contained in fossil records and samples of ancient ice have been the most useful to test theories of how the climate has been changing. Scientists at the Cambridge Department of Earth Sciences report in the journal, *Science*, that they have mapped a more accurate time-line of climate by separating the changes in otherwise combined indicators of the temperature of the sea and the volume of ice at the Poles, over the ages.

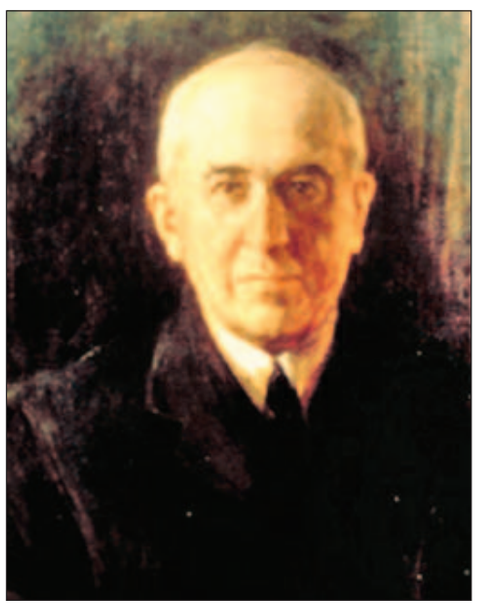
The chief reason for the seasons, summer and winter, is the fact that the axis of the daily rotation of the earth is inclined at an angle to the axis of the annual revolution of the earth around the sun. The fact that one half of the earth has summer while the other half has winter, and the



The N or S hemisphere is more exposed to the sun for part of the year, while the other is less exposed, because of tilt. How much more, or less, depends on the tilt. Greater tilt leads to more extreme seasons.







Milutin Milankovic.

Harry Elderfield.

concentration of land mass in the northern hemisphere, drives winds and ocean currents and brings about the nearly constant cycle of seasons that we have grown used to. But the basic drivers, which are the tilt of the axis of rotation and the there are more intense summers and winters and when the earth moves away or closer to the sun in its path of revolution, there are ups and downs in the amount of heat that the earth receives.

The rotation motion of the earth gives it a stable orientation, just like the rotation of a child's common spinning top. While the top is at a good speed, this gives it stability and it spins upright. If forces of wind, obstructions or friction cause any "tipping" to one side, forces come into action to pull the top back upright. But the swing back to upright overshoots, as a tilt on the other side, which is again pulled back to upright – resulting in a "rocking" of the axis of spin – a motion known as *nutation*. At the same time, the spinning at an angle to the vertical, while the top is leaning over, brings in a horizontal motion of the axis, which swings round and round – a motion known as *precession*.

Just as these motions of the top are because of its spin and the force of gravity, the whole earth is also affected because of its spin, once in 24 hours, and the different gravitational forces of the sun and the moon and also of the large planets of the solar system. The angle of tilt, which is about 23.5 degrees at the present time, swings, in a form of *nutation*, between 22.1 and 24.5 degrees over a period of 41,000 years. The earth is now about halfway, and moving towards the lower limit.

When the angle of tilt is low, the summers and winters are less severe. Given this effect and the fact that the land mass on the surface of the earth is more at higher latitudes, a lower angle of tilt implies less melting of Arctic ice and an approach to an ice age!

Precession, or the swinging around of the axis of spin, follows a cycle of some 26,000 years. Orientation of the axis of spin also affects the effective angle of tilt and hence the seasons. In addition, thanks to the effect of the large planets Jupiter and Saturn, there is variation of the shape of the path of the earth around the sun. The shape is almost a perfect circle and only 2.8 per cent off, on the average. But this slight "ovality" also has a cycle, from 0.5-5.8 per cent, over 41,000 years. And then the direction of the longer ends of the oval also turns around, once every 23,700 years, creating a motion that is shaped like a rosette!

At the time of World War I, a Russian astronomer and multifaceted scientist, Milutin Milankovic, worked on the collective effect of the earth's different motions on the amount of heat that it received from the sun and the effects on climate. He was able to mathematically work out the changes in the incoming solar radiation (insolation) from the sun over a period of 600,000 years and demonstrate that it was variation in insolation, or *insolation cycles*, that brought about the series of ice ages!

History of climate

The physical journey back in the history of the earth's climate is carried out with the help of markers of temperature, salinity, etc, which are preserved in rock, vegetable remains or ice which was formed during past times. A readily available source of information about climatic shifts is in deep-sea fossil remains. The antiquity of these remains, to put a date on the place where they were found, is estimated by studying oxygen atoms that are locked in the samples. Oxygen occurs in two forms — O_{16}, which is the normal and abundant form, and traces of O_{18}, which has the higher mass number of 18 and is radioactive. The ratio of the two kinds of oxygen in the oceans is affected by ambient conditions that include the temperature and the quantity of water that is locked in the form of Arctic ice. As remains of living things contain oxygen in the ratio that existed at the time they were alive, these deep-sea fossils indicate ancient conditions.

But because these records are affected by both factors — temperature as well as the quantity of Polar ice — the picture that is painted is not complete. Efforts to prise apart the two reasons have not proved successful and it has not been possible to pinpoint the reason for changes in the ratio of the two forms of oxygen. Was it temperature change because of the position of the earth or was it more or less ice at the Poles? The work of the team at the University of Cambridge has overcome this difficulty by developing an alternative marker, which depends only on temperature. This data of pure temperature change then allows the existing data to be corrected to indicate only levels of Arctic ice — and we have complete data, both sea-water temperature as well as global ice volume, and this data accounts for the last 1.5 million years.

The method used by the Cambridge researchers was to look at the ratio of magnesium to calcium in the deep-sea fossils. It is easier for magnesium to be incorporated in organisms at higher temperatures. Higher levels of magnesium then indicate higher temperatures of sea water at that moment in geological history. This detailed information, of both temperature and global ice, is important for making sense of a transition in climate that took place some 1.25 million to 600,000 years ago. Before this transition, the swing, from ice ages to warm climate and back, happened every 41,000 years. But after the transition, the switch has been taking 100,000 years.

"Previously, we didn't really know what happened during this transition, or on either side of it," says Professor Harry Elderfield, who led the research team. "Before you separate the ice volume and temperature signals, you don't know whether you're seeing a climate record in which ice volume changed dramatically, the oceans warmed or cooled substantially, or both. "Now, for the first time, we have been able to separate these two components, which means that we stand a much better chance of understanding the mechanisms involved. One of the reasons why that is important is because we are making changes to the factors that influence the climate now. The only way we can work out what the likely effects of that will be in detail is by finding analogues in the geological past, but that depends on having an accurate picture of the past behaviour of the climate system."

The writer can be contacted at simplescience@gmail.com