Trees that carry tales

Their growth rings have been found to record events of El Niño in past ages, says s ananthanarayanan

THE El Niño effect, which brings periodic luxuriance to the vegetation of the west coast of South America, is a major, periodic climate feature, of the kind that affects the weather worldwide. But with the world weather and life, in general, being so interconnected, it has become customary to say, when things go wrong, that "maybe it's El Niño", and maybe not without reason!

This weather phenomenon of the Pacific has been studied in recent times and scientists have learnt to anticipate El Niño events pretty accurately. But with the progress of global warming, these predictions may get uncertain, which would create problems for a world already facing the difficulties of warming. The only way to better understand El Niño in unknown conditions is to study the record over centuries, when world temperatures and sea levels have moved up and down.

Professor Jinbao Li of the International Pacific Research Center, University of Hawaii at Manoa, and associates report, in *Nature Climate Change*, of important advances in getting such information for the last 1,100 years from the record in tree trunks in the US south-west.

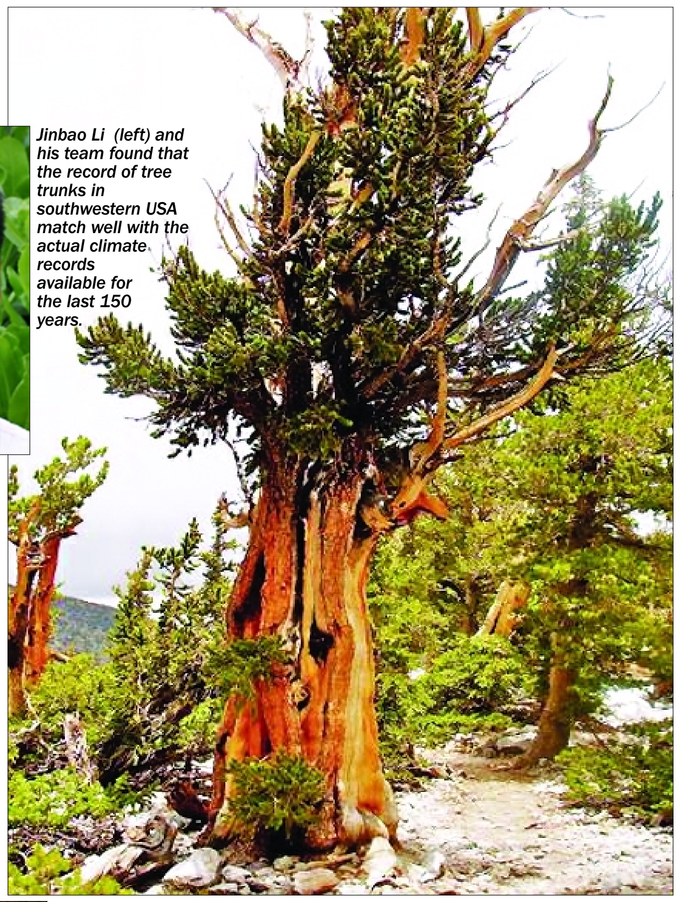
El Niño

The usual weather in the Peruvian coast is cool and dry – which makes for good fishing but not much vegetation. In contrast, the other side of the Pacific, the eastern side of Australia, is warm and humid. With warm water rising and pushed by winds from the east, the water level around Australia is actually a whole metre higher than along South America. The piling up of water in the Australia side causes deep, cool water to "well up" in the Peru side, which brings nutrients to the surface and makes for the great fishing!

Now, usually in December, when it is warmest in the Southern hemisphere, warm water invades the Peruvian coast and ruins the fishing, for some time at least. But every once in a way, often every other year but sometimes as far as 10 years apart, the warm inflow is large, indeed, and there is torrential tropical rain. The fishing is wrecked, no doubt, but the vegetation flourishes, "the desert becomes a garden", they say. Because this happens around the time of Christmas, they say it is the coming of the baby Christ, *El Niño*, the *little one*. The other extreme, of very dry weather, is named in the opposite gender, *La Niña*.

Such major changes in large masses of air and water naturally affect winds and currents at the global level and the onset of El Niño signals weathermen the world over to watch for local effects. And in recent times, as El Niño is carefully monitored and can be predicted accurately, precautions are taken in time everywhere and it is only in unusual years when El Niño comes unexpectedly or with great severity that surprising things need to be blamed on *the little one*.

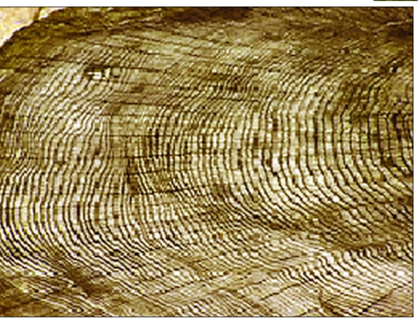
Except that global warming may change this stable picture. With the melting of glaciers, the Greenland ice mass, the changes in ocean currents and salinity patterns, El Niño may become quite unpredictable. This would then impact global weather, which may, in turn, drive El Niño to grow more erratic. While there have been times in the past when global temperatures were high and comparable to what we may face in a few decades, to help us prepare, we have no records of the timing of past El Niño events.



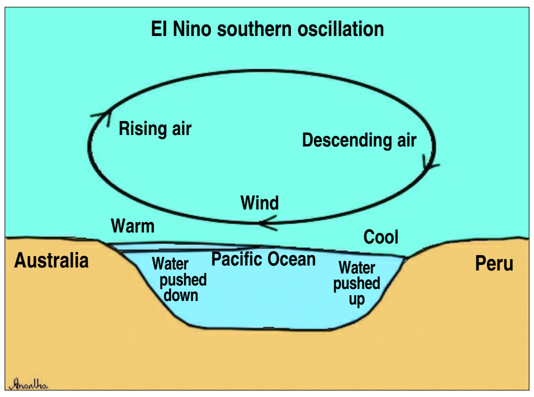
Jinbao Li (left) and his team found the record of tree trunks in southwestern USA match well with the actual climate records available for the last 150 years.

Tree records

This is where the work of the group at Manoa may prove to be the answer. Trees that grow over many years mark each year by a visible ring of growth around their girth. Apart from growth upwards and at the stems and leaves, the tree also grows outwards. The growth is the fastest during the warm and damp months but slows down when it is cool and dry. The tissue that forms during fast growth is less dense, while that which forms slowly is dense. The difference in tissue shows in the cross section of the tree trunk as rings, marking the fast and slow growth in each annual cycle.



Growth rings sample in Bristol zoo, England.



Trees thus mark each year with a separate growth ring, a record that reflects the climatic conditions during that year. A good growing season would produce a wide ring, while a drought year would be marked by scant growth and a narrow ring. Sometimes, fluctuating weather in the same year can result in more than one ring and very, very rarely, a poor year can result in no ring. And in this way, sampling of trunks of trees in an area can reveal the climatic conditions over a long span of time, even centuries, or with some trees, a millennium! The field of work is called *dendrochronology* and involves understanding the growth patterns of different trees, principles of statistical sampling and also related dating technology, to confirm and verify what the tree trunks reveal.

The work of Jinbao Li and his international team have found that the record of tree trunks in southwestern USA match well with the actual climate records available for the last 150 years. Even going back a few hundreds of years, the data is in agreement with the results of carbon dating of organic matter in coral reefs. "Our work revealed that the towering trees on the mountain slopes of the US southwest and the colourful corals in the tropical Pacific both listen to the music of El Niño, which shows its signature in their yearly growth rings," explains Li. "The coral records, however, are brief, whereas the tree-ring records from North America supply us with a continuous El Niño record reaching back 1,100 years."

What the rings reveal

The rings reveal that El Niño behaviour has been highly variable over the centuries. The interesting thing is that peaks and lows agree with evidence of varying Pacific climate, as revealed by the structure of lake-bed sediments. The weakest El Niño period, the Medieval Climate Anomaly, of the 11^{th} century, for instance, corresponds to a period when the eastern tropical Pacific was cool. This correspondence of El Niño events to specific ocean temperature markers, during periods of high and low variability, promises better predictions from ocean and other data.

"Since El Niño causes climate extremes around the world, it is important to know how it will change with global warming," says co-author Shang-Ping Xie. "Current models diverge in their projections of its future behaviour, with some showing an increase in amplitude, some no change, and some even a decrease. Our tree-ring data offer key observational benchmarks for evaluating and perfecting climate models and their predictions of the El Niño-Southern Oscillation under global warming."

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Of elongation

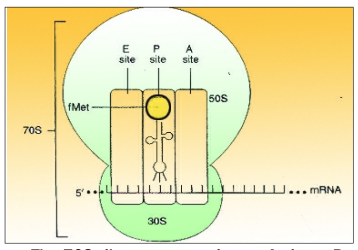
tapan kumar maitra **clarifies the successive stages of prokaryotic translation**

PROKARYOTIC translation is to position the second transfer RNA, which is specified by the codon at the A site. The second transfer RNA is positioned in the A site of the ribosome so it is able to form hydrogen bonds between its anti-codon and the second codon on the messenger RNA. This step requires the correct transfer RNA, another GTP, and two proteins called elongation factors — EF-Ts and EF-Tu.

EF-Tu, bound to GTP, is required to position a transfer RNA into the A site of the ribosome. After the transfer RNA is positioned, the GTP is hydrolysed to GDP + Pi. Upon hydrolysis of the GTP, the EF-Tu/GDP complex is released from the ribosome. EF-Ts is required to regenerate an EF-Tu/GTP complex. EF-Ts displaces the GDP on EF-Tu. Then a new GTP displaces EF-Ts and now the EF-Tu/GTP complex can bind another transfer RNA.

Here again, the hydrolysis of GTP changes the shape of the GTP so that the EF-Tu/GDP complex can depart from the ribosome after the transfer RNA is in place in the A site the ribosome at the end of this step. EF-Tu does not bind $fMet\text{-}tRNA_f^{Met}$, so this blocked (formylated) methionine cannot be inserted into a growing peptide chain.

It takes several milliseconds for the GTP to be hydrolysed and another few milliseconds for the EFTu/GDP to actually leave the ribosome. During those two intervals of time, the codon-anti-codon fit of the transfer RNA is scrutinised. If the correct transfer RNA is in place, a peptide bond forms. If not, the charged transfer RNA is released and a new cycle of EF-Tu/GTP-mediated testing of transfer RNAs begins. The error rate is only about one mistake in 10,000 amino acids incorporated into protein. The speed of amino acid incorporation is about 15 amino acids per second in prokaryotes and about two to five per second in eukaryotes.



The 70S ribosome contains an A site, a P site and an E site that can receive tRNAs with the messenger RNA running through the bottom of the sites.

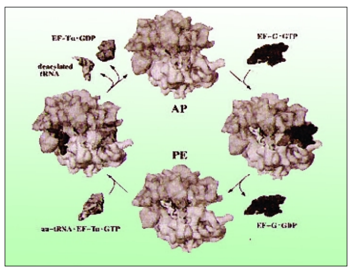
Peptide bond formation

The two amino acids on the two transfer RNAs are now in position to form a peptide bond between them; both amino acids are juxtaposed to an enzymatic centre, peptidyl transferase, in the 50S subunit. This enzymatic centre — an integral part of the 50S subunit — was originally believed to be composed of parts of several of the 50S proteins. Now, however, it is believed to have ribozymic activity, enzymatic activity of the ribosomal RNA of the ribosome.

The enzymatic activity involves a bond transfer from the carboxyl end of N-formyl methionine to the amino end of the second amino acid. Every subsequent peptide bond is identical, regardless of the amino acids involved. The energy used is contained in the high-energy ester bond between the transfer RNA in the P site and its amino acid. Immediately after the formation of the peptide bond, the transfer RNA with the dipeptide is in the A site and a depleted transfer RNA is in the P site.

Translocation

The next stage in elongation is translocation of the ribosome in relation to the transfer RNAs and the messenger RNA. Elongation factor EF-G — earlier called translocase — catalyses the translocation process. The ribosome must be converted from the pre-translocational state to the post-translocational state by the action of EF-G, which physically moves the messenger RNA and its associated transfer RNAs. This movement is accomplished by the hydrolysis of a GTP to GDP after EF-G enters the ribosome at the A site. After the first post-translocational state is reached, the depleted transfer RNA in the E site is ejected, leaving the ribosome ready to accept a new charged transfer RNA in the A site. A computer-generated diagram of a ribosome shows all three transfer RNA sites occupied. In eukaryotes, three elongation factors perform the same tasks that EF-Tu, EF-Ts and EF-G perform in prokaryotes. The factor eEFla replaces EF-Tu, eEF1bg replaces EF-Ts and eEF2 replaces EF-G.



Cycle of peptide bond formation and translocation on the ribosome.

When translocation is complete, the situation is much the same again except that instead of $fMet\text{-}tRNA_f^{Met}$, the P site contains the second transfer RNA ($tRNA^{Phe}$) with a dipeptide attached to it. The process of elongation is then repeated with a third transfer RNA coming into the A site. The process repeats from here to the end synthesising a peptide starting from the amino (N-terminal) end and proceeding to the carboxyl (C-terminal) end.

During the repetitive aspect of protein synthesis, two GTPs are hydrolysed per peptide bond: one GTP in the release of EF-Tu from the A site and one GTP in the translocational process of the ribosome after the peptide bond has formed. In addition, every charged transfer RNA has had an amino acid attached at the expense of the hydrolysis of an ATP to AMP +PP. There is some evidence that the action of EF-Tu hydrolyses two GTPs.

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Tribute to quantum uncertainty

With the world celebrating Werner Heisenberg's 110th birth centenary, parthasarathi chakraborty **harks back to his almost prophetic insight**

FAMOUS German physicist and philosopher Professor Werner Heisenberg, who laid the foundation of quantum mechanics, discovered an apparent baffling theory – the principle of uncertainty. He received the Nobel Prize in the early 1930s for his pivotal role in shaping today's modern concept of atoms and molecules and his remarkable and almost prophetic insight led to a fundamental change of our understanding of nature and science.

Heisenberg's 110^{th} birth centenary (1901-2011) is being celebrated throughout the world in a befitting manner.

In nature, there are many processes where changes are made in distinct separate steps.

Each step consists of a definite increment of quantity — ie, a definite quantity is involved and the change is quantised. The electron inside an atom moves in a distinct orbit. The electron jumps to a separate distinct orbit if it loses or gains energy. There is no scope of the moving electron to rest in between orbits. The situation is similar to climbing up a staircase. You cannot rest a foot in between two steps of a staircase.

However, many processes in nature are incompatible to quantised processes. In this case, the changes take place in a continuous, smooth manner. Here any quantity or amount of change may be involved. When a bird, like an albatross, moves high in the sky, its distance from the surface of the earth increases not in a series of jumps but smoothly and continuously.

Werner Heisenberg.

In a quantised phenomenon, energy is either emitted or absorbed discontinuously in bundles.

One of these bundles is known as "quantum" and the theory that substantiates the quantised process is called quantum theory. This theory is important in the prediction of most of the physical and chemical properties of a substance.

Though the mathematical equation of quantum theory is intricate, some assumptions need to be considered leading to results that are an approximation of truth. Nonetheless, the theory is extremely useful.

Heisenberg's uncertainty principle states that it is impossible to determine correctly both the position of an electron as well as its momentum. Measuring the position of an electron would definitely disturb the electron. Then the value of its momentum would be uncertain. Similarly, any attempt to measure the momentum of an electron would lead to uncertainty of its position. That is to say, the more precisely the position is determined, the less precisely the momentum is known and the converse is true.

Niels Bohr's theory of the atom states that an electron occupies a definite fixed orbit while moving round the nucleus. The situation is similar to the movement of the earth in its orbit around the sun. In a hydrogen atom, according to Bohr, an electron is moving in a fixed orbit around its tiny nucleus.

Quantum mechanics describes the hydrogen atom in a different way. Heisenberg considered the electron a negative charge cloud that surrounds the nucleus of a hydrogen atom. With the help of quantum mechanics, we can calculate the probability of finding the maximum electron density within a certain region of space — a region known as orbital. Atoms have their atomic orbitals and molecules have molecular orbitals.

The shape of the orbitals may be determined by the Erwin Shrödinger wave equation.

Heisenberg was profoundly influenced by the work of Albert Einstein and Bohr in formulating the uncertainty principle. He recognised neutrons and protons as fundamental nuclear particles, discussed various nuclear components, their binding energies, stabilities and developed a theory of the structure of an atom. He also worked on a "Unified Theory" of matter.

"I have come to like Heisenberg very much; he is popular and highly esteemed by everyone here.

His talent is tremendous, but what I especially like about him is his pleasant, unassuming nature, good humour and eagerness and enthusiasm." This is what Max Born said to Heisenberg's professor, Arnold Sommerfeld.

Heisenberg succeeded in blocking a contract for the development of an atomic bomb. He was horrified at the prospect of such a bomb being placed in Hitler's hand. Healso opposed Chancellor Adenauer's acceptance of Nato plans to equip West Germany with nuclear weapons. He was a great philosopher of science and, like Plato, searched for ideas behind every fact.

According to Heisenberg, "at the beginning was the particle. The elementary particles incorporate symmetry, they are simple representation but they are originally consequences of symmetries."

Without the principle of uncertainty, the world of atoms and molecules would have been much more intricate to recognise.

The writer is former reader of chemistry, Presidency College, Kolkata, and was associated with the University Grants Commission