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Global change

The past and future of El Niño

Sandy Tudhope and Mat Collins

A new study of past variations in El Niño behaviour provides a much improved record from pre-instrumental times. It will be a valuable resource for testing the models used in climate prediction.

Droughts, floods, forest fires and changed patterns of storms and ocean conditions — these are some of the hallmarks of the El Niño Southern Oscillation (ENSO) climate cycle. On page 271 of this issue, Cobb *et al.*[1] describe how their analysis of fossil corals provides new evidence of how the ENSO cycle can strengthen and weaken without an obvious external driving force. Not least, these data provide helpful indications as to how ENSO might change in the future.

El Niño events occur every three to seven years, and arise naturally through the strong inter-action between the ocean and atmosphere in the tropical Pacific[2]. The effects are felt worldwide because the tropical Pacific is a powerful source of heat for driving atmospheric circulation. Even small changes in the sea-surface temperature in this region have major repercussions for global climate. Dry conditions in the western Pacific, warmer-than-average conditions in the northern United States and wetter-than-average conditions to the south, and suppressed hurricane development in the Atlantic, are all indicators of an El Niño event. Consequently, when the ENSO cycle is particularly strong, as occurred in 1982–83 and again in 1997–98, the changed weather patterns have profound social, economic and ecological consequences[3].

Although much of the basic physics of the ENSO cycle is now reasonably well known, some aspects remain poorly understood. What, for instance, causes one El Niño event to be different from another? One obstacle to progress is the paucity of instrumental data before the mid-twentieth century. From the data that do exist, it is clear that ENSO varies considerably in strength and frequency, but the instrumental records are too short to tell with confidence if this variability is internal or driven by changes in background climate[4].

Cobb *et al.*[1] use the skeletons of annually banded reef-building corals as natural 'proxy' archives of tropical climate, and thereby extend the record of ENSO further into the past. Their approach involves analysing the oxygen isotopic composition of the coral skeletons as a measure of the combined effects of changes in sea-surface temperature (through a temperature-dependent fractionation between water and calcium carbonate), and seawater isotopic composition (which is strongly influenced by rainfall and evaporation). At their study site, Palmyra Island in the central tropical Pacific, warm temperatures and increased rainfall during the El Niño phase of the Southern Oscillation combine to drive the oxygen isotopic composition of the coral skeletons towards lighter (more negative) values. The excellent match between an isotope record from a living coral and the instrumental records of recent ENSO activity provides proof of concept.

However, living corals yield only about 100 years of record, so Cobb *et al.* also analysed cores collected from ancient corals, washed onto the top of the reef by storms. Using an approach borrowed from tree-ring reconstructions of climate, they combine high-precision dating with 'wiggle matching' of the monthly-resolution isotope records to create continuous coral chronologies. The final record is not complete: they have reconstructed several periods, representing a total of some 430 years since about AD 930, but the method has yielded much more robust, and extended, ENSO proxy records than have been produced before for this period.

The key finding is that ENSO appears to have varied considerably in strength over the past millennium, with changes occurring rapidly, on timescales of decades or so. Compared with earlier periods, the events in the twentieth century appear to have been relatively strong, but not exceptionally so. The inferred changes in ENSO strength do not appear to be correlated with documented changes in Northern Hemisphere regional climate — for instance, the Little Ice Age

100 YEARS AGO

Rutherford and Soddy pointed out that the almost invariable presence of helium in minerals containing uranium indicated that that gas might be one of the ultimate products of the disintegration of the radio-elements. Rutherford, moreover, determined the mass of the projected particle which constitutes the "α-ray" of radium to be approximately twice as great as that of the hydrogen atom, an observation that points in the same direction… We have been engaged for some months in examining the spectrum of the "radio-active emanation" from radium… We have found that after removing hydrogen and oxygen from the gases evolved from 20 mgrs. of radium bromide, the spectrum showed the presence of carbon dioxide. On freezing out the carbon dioxide, and with it, a large proportion of the radium "emanation," the residue gave unmistakably the D_3 line of helium.

ALSO…

It has been stated that the radium rays have been successfully applied in the treatment of a case of cancer by Prof. Gussenbauer, of Vienna. The tumour completely disappeared as a result of the application, radium bromide being made use of as a source of the rays. The early publication of these details in the public Press before there has been time to test the method effectually is much to be deprecated.

From *Nature* 16 July 1903.

50 YEARS AGO

Personality Development. By J. S. Slotkin.
The author, who is a social anthropologist, begins by saying that he has tried to work out a systematic theory of personality development, from the hypotheses and evidence of various relevant sciences. The material is, however, systematic only in so far as it has been distributed under four major headings: inheritance, socialization, culturization and individualization. Within each of the fields the approach is mainly descriptive and anecdotal, and is adorned by a wealth of quotations from ancient and modern writers. It may well be that in the meantime this kind of approach is repaying. Certainly it does not suffer from the aridity of some recent statistical work in the same field. But perhaps we can only be scientific about people if we are content to be dull.

From *Nature* 18 July 1953.

(seventeenth to nineteenth centuries) or the Medieval Warm Period (eleventh to fourteenth centuries). Nor do they seem to tie in with reconstructions of volcanic and solar behaviour that might drive climate change. The authors conclude, quite reasonably, that much of the variability seen in ENSO strength over the past millennium was probably not driven by external factors.

So, where does this leave us in attempting to predict future ENSO activity? Cobb *et al.* show that, as ENSO varies significantly on its own — that is, even without greenhouse warming — we might expect changes beyond those experienced in the twentieth century. Looking to other periods in the past there is increasing evidence that the ENSO cycle may have been weak, or even absent, between about 14,000 and 5,000 years ago[5,6]. The most likely explanations involve the sensitivity of ENSO to changes in the length and timing of the seasons resulting from the precession cycle in the Earth's orbit[7]. ENSO may also have been generally weaker during the cooler conditions of the last glacial period (100,000–20,000 years ago)[6]. These data hint that the ENSO system is sensitive to background climate, and that it may well respond to future greenhouse warming. But it is not easy to tell what this response will be — there is no past equivalent of expected twenty-first-century climate.

Cobb *et al.* looked at ENSO during a period of relatively little global climate change. The future is almost certainly going to be radically different, with predictions of a 1.5–6.0 °C rise in global mean temperature within the next 100 years[8] — potentially almost as much change as that between the last glacial period and the present interglacial. The only realistic hope for predicting the response of ENSO to this warming lies in the use of coupled ocean–atmosphere climate models. Some of the best of these models now generate a realistic ENSO cycle but produce a wide range of predicted outcomes for ENSO in a warmer world, from a significant strengthening of the cycle, to no effect or even a weakening[9,10]. Equally important in terms of potential social and economic consequences are changes in 'average' conditions, for example towards a more El Niño-like background state with associated reduction in rainfall over much of southeast Asia and South America[11].

The use of proxy data about past conditions has been limited in evaluating global ocean–atmosphere climate models[12], partly because modellers find it difficult to deal with isolated, short and imprecisely dated records like those from fossil corals. But such tests are crucial. The study of Cobb *et al.* is a step towards the more complete multi-proxy[13] archives of climate that will be needed. ■

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Quantum physics

Uncertain future

Miles Blencowe

The uncertainty principle limits the accuracy of measurement at the quantum level. A device sensitive to subatomic-scale displacement has come close to revealing that principle in action in the macroscopic world.

In 1927, Werner Heisenberg introduced his famous quantum principle[1], which states that the uncertainties in the position and the velocity of a particle are inversely proportional to each other: a particle's position or its velocity can be known precisely, but not both at once. This principle is one of the cornerstones of quantum mechanics, and is traditionally relevant to the domain of subatomic particles. But what about more familiar macroscopic objects, comprising many atoms, that we think of as possessing simultaneously well-defined positions and velocities of their centre-of-mass? If we could be sufficiently precise in our measurements on such objects, would we encounter the quantum uncertainty principle at work?

On page 291 of this issue, Knobel and Cleland[2] address this question. They describe an exquisitely engineered device — a vibrating crystal beam, only a thousandth of a millimetre long, and an extremely sensitive motion detector — that is capable of detecting displacements as small as about one-thousandth of a nanometre, or one-hundredth of the size of a single atom. The beam may seem tiny by everyday standards, but its mass is equivalent to that of about ten billion atoms. A demonstration of the

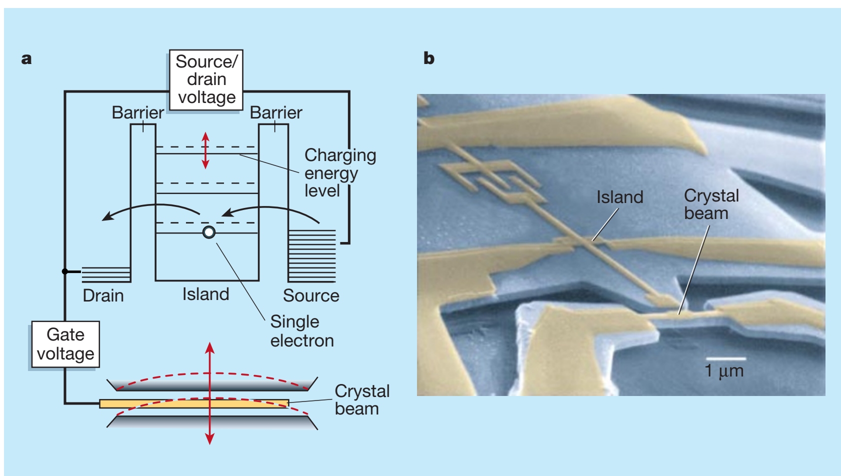

Figure 1 **Closer to the limit. Knobel and Cleland[2] have built a device, based on a single-electron transistor, to investigate the effect of Heisenberg's uncertainty principle on a macroscopic system.** a, **Electrons tunnel from the source to the island and then to the drain, constituting a flow of current. The voltage between source and drain is only strong enough to charge the island by one electron at a time (as indicated by the position of the source level relative to the island charging levels). If the gate voltage is varied, this causes the island charging levels to shift, changing the magnitude of the tunnelling current. Alternatively, fixing the gate voltage and allowing the crystal beam to bend also shifts the levels and modulates the tunnelling current.** b, **The device, shown here in an electron micrograph, is only micrometres in size, and although the quantum zero-point detection limit has not yet been reached, the experiment is the best demonstration so far of sensitivity to subatomic-scale displacements of a nanoscale beam.**