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 Pacific2. The effects are felt worldwide because the tropical Pacific is a powerful source of heat for driving atmospheric circulation. Even slight 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 consequences3.

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 notion is that the El Niño event is due to the impact of a large-scale oceanic current, the warm pool, which moves eastwards. However, the recent El Niño event of 1997–98 suggests that the warm pool may not be enough to sustain the event, and that other factors are involved.

The authors of this study, Cobb et al., have used a combination of data from living corals and proxy archives to reconstruct the past ENSO cycle. They have focused on the period from the mid-twentieth century to the present day. Their approach involves analysing the oxygen isotopic composition of the coral skeletons, which are 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). Their study site, Palmyra Island in the central tropical Pacific, has a long and rich history of ENSO activity.

However, living corals yield only about 100 years of record, so Cobb et al. also analysed cores collected from ancient corals, washed towards lighter (more negative) oxygen isotopic composition. By combining the two datasets, they were able to extend the record back to the mid-twentieth century. The resulting record is much longer than any previous record of ENSO activity, and provides a useful tool for testing the models used in climate prediction.

The authors also note that the recent El Niño event of 1997–98 was particularly strong, but not exceptionally so. The effect of this event on ENSO behavior is still uncertain, and more research is needed to understand how the ENSO cycle might change in the future.

news and views

(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 ago1,2. 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 orbit7. ENSO may come for ENSO in a warmer world, from a cooler conditions of the last glacial period and the present inter-glacial. 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 weakening9,10. Equally, significant strengthening of the cycle, to come close to revealing that principle in action in the macroscopic world.

Uncertain future

Miles Blencowe

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

In 1927, Werner Heisenberg introduced his famous quantum principle, 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 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 Cleland2 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 one-hundredth 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

Closner to the limit. Knobel and Cieland2 have built a device, based on a single-electron transistor, to investigate the effect of Heisenberg’s uncertainty principle on a macroscopic system.

Quantum physics

Miles Blencowe

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

In 1927, Werner Heisenberg introduced his famous quantum principle, 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 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 Cieland2 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 one-hundredth 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

Closner to the limit. Knobel and Cieland2 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. Alternately, 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.