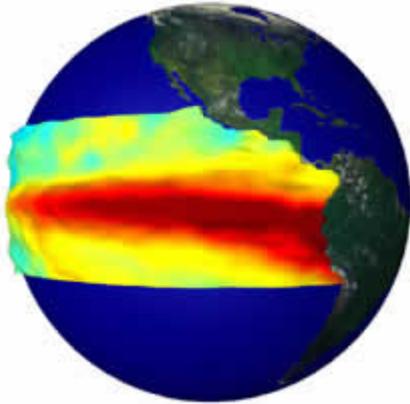


## The El Niño Southern Oscillation



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Mat Collins, Exeter Climate Systems, College of Engineering Mathematics and Physical Science, University of Exeter <sup>[1]</sup>

The temperature of the sea surface in the Eastern Tropical Pacific is usually around 27°C – pretty balmy by UK standards but reasonably cold for the tropics. Cooler waters from deeper in the ocean rise up in the Eastern Pacific, bringing nutrients that feed a thriving ecosystem. Every so often these cooler sea surface temperatures (SSTs) are replaced by warmer waters and this has a profound influence, not only on the number of fish that S. American fishermen can catch, but also on the atmospheric circulation above and the oceanic circulation below.

Normally the cold SSTs in the East go along with warm SSTs in the west, which underlie a large area of moist atmospheric convection. This ‘warm pool’ convection is accompanied by strong easterly trade winds forming an atmospheric circulation named after the 19th Century scientist Sir Gilbert Walker – a past president of the Society. Below the surface of the ocean, the trade winds cause upwelling of cold ocean water from below in a process known as Ekman pumping. When this climatological situation is disturbed, this sets in a chain of events. If the trade winds weaken, then the warm SSTs in the west can move towards the east, bringing with them the atmospheric convection and further weakening the trade winds (a feedback first described by Jacob Bjerknes). The weakened trades also lead to reduced upwelling of cold water in the ocean, further enhancing the warm SSTs in the east and causing the ocean thermocline, a sharp vertical gradient of temperature around a few hundred meters below the surface, to become more horizontal in comparison to its normal state of being deeper in the west compared to the east. This is what we now call an El Niño event. The Walker Circulation in the atmosphere is weakened and displaced and, if we measure this by examining the surface pressure across the Pacific, traditionally by differencing the pressure records from Tahiti and Darwin, we see what Walker called the Southern Oscillation. Together they form the El Niño Southern Oscillation (ENSO).

The study of ENSO has evolved along four prongs; observations, theory, numerical modelling and prediction:

### **Observations:**

We now have a network of ocean bouys – the Tropical Atmosphere Ocean Array or TAO Array – which constantly measure the state of the upper-ocean and surface meteorological conditions. Combined with satellites, this gives us the ability to monitor ENSO in real-time. Since the last big El Niño in 1997/98 we have measured a succession of smaller warm and, sometimes protracted cold events, often known as La Niña. There is also some indication that recent El Niño events have had their SST signature concentrated in the central Pacific rather than extending all the way to the east coast of South America.

### **Theory:**

Early theories of ENSO invoked ideas of eastward and westward propagating ocean waves carrying signals along the ocean thermocline. Later, such theories were refined to highlight the role of the recharge of heat content in the west as a pre-cursor to ENSO events. Theory has evolved to take into account other ocean and atmosphere processes to describe different types of ENSO events in which different processes dominate the initiation. For example, the difference between a 'classical' ENSO event in which the thermocline feedback is the dominant amplifier of SST anomalies, contrasted with a central Pacific or 'Modoki' event in which zonal advection of SST anomalies plays a dominant role (as has been seen in recent observations).

### **Modelling:**

The first numerical models of ENSO used simplified ocean dynamics and 'static' or thermodynamic atmospheres, but were able to capture the essential physics of the phenomena. As three-dimensional coupled atmosphere-ocean models were developed, they were initially very poor at generating spontaneous ENSO events. The balance of amplifying and damping processes in the ENSO cycle presents a considerable challenge for numerical models. More recently, coupled models have improved and can now generate ENSO variability that is similar to, if not exactly like, that which we observe. Evaluating and improving the ability of coupled models to simulate ENSO is now one of the high-priority areas for modelling centres.

### **Prediction:**

While much of the research into ENSO has been driven by a desire to understand the atmosphere-ocean system, ENSO also represents a source of potential predictive skill on seasonal and interannual time scales. Prediction schemes use a variety of tools from statistical models, through intermediate or simplified dynamical models to fully coupled models. Prediction integrates understanding, observation and modelling and we now have predictive skill for many areas that are 'teleconnected' to ENSO, many months in advance. Those predictions are regularly used by governments and individuals in future planning and provide an excellent example of the positive impact that science can have on society.

My own interest in ENSO was motivated by wanting to understand how climate change might have an impact on the phenomena. We are now beginning to see some robust responses of

climate models in turns of the mean climate of the tropical Pacific; reduced trade winds, a local maxima in warming along the equator, reduced upwelling and a rising but strengthening thermocline. However, these changes are challenged by recent observations and there is no consensus on how the changes in mean climate will affect the characteristics of ENSO variability in terms of changes in amplitude, frequency or spatial pattern. There is still plenty of research to do.

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