Geofile Online

APRIL 2014
709

John Rutter

Update on El Niño, La Niña and the Southern Oscillation

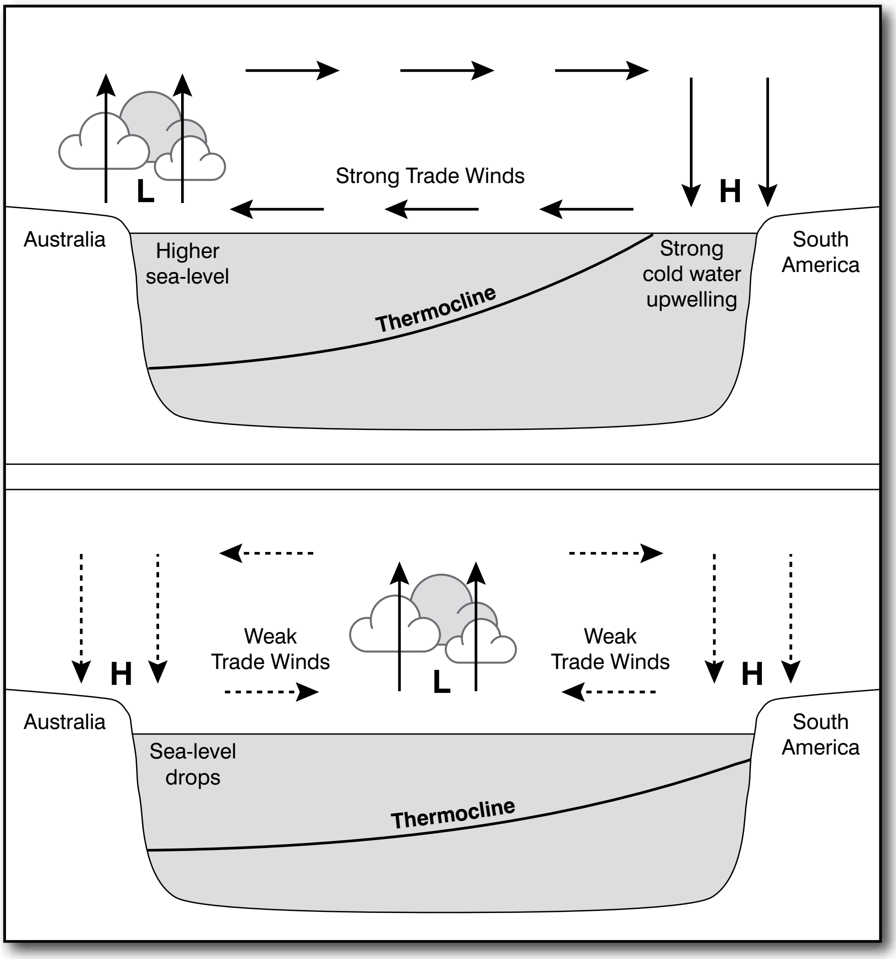
The Atacama Desert, running the length of Peru and into Chile, is one of the driest places on Earth. Yet even here, where people have grown used to a very stable climate, strange conditions are thrown up by the world's weather systems. One of the most unusual occurrences was in 1998 when, without warning, torrential rain led to flood run-off from rivers forming a lake 145km long, 30km wide and 30m deep in the middle of the desert – this temporary water feature becoming Peru's second largest lake.

While initially a boon for local fishermen who stocked the lake, the problems of such a quick influx of water across the region soon became apparent. Rivers bursting their banks caused the deaths of hundreds of people, while newly formed pools provided excellent breeding grounds for mosquitoes and cases of malaria tripled over the following few months.

Meanwhile, across the world, other strange weather was causing havoc. In Sumatra, Borneo and Malaysia, it caused forest fires which gave rise to huge smoke clouds, reducing visibility to a minimum on the roads and shutting down several airports. In Mongolia temperatures soared to 42°C; record flooding in Poland and the Czech Republic killed over 100 people; Madagascar suffered unusual cyclones and typhoons and in parts of Kenya the normal monthly rainfall increased by 100cm. Finally, over in the United States, mudslides and flash floods hit both the east and west coasts.

So, what was the cause of all this destruction? Everything stemmed from the global climatic phenomenon known as El Niño. Part of the Southern Oscillation, El Niño and its companion La Niña (which brings similarly unexpected weather conditions), were responsible for the deaths of over 2000 people and damage valued at around £9 bn worldwide between 1997 and 1998. Since then, El Niño events have been much milder in nature but there are concerns they could increase in both frequency and magnitude as a result of long-term global climate change. Increasingly well researched but still little understood, it seems

Figure 1: Climatic conditions over the Pacific Ocean and the beginnings of El Niño. The upper diagram shows the normal atmospheric and oceanic conditions in the equatorial Pacific. The lower diagram illustrates the beginnings of El Niño, with high pressure causing drought over Australia and rainfall moving east towards South America



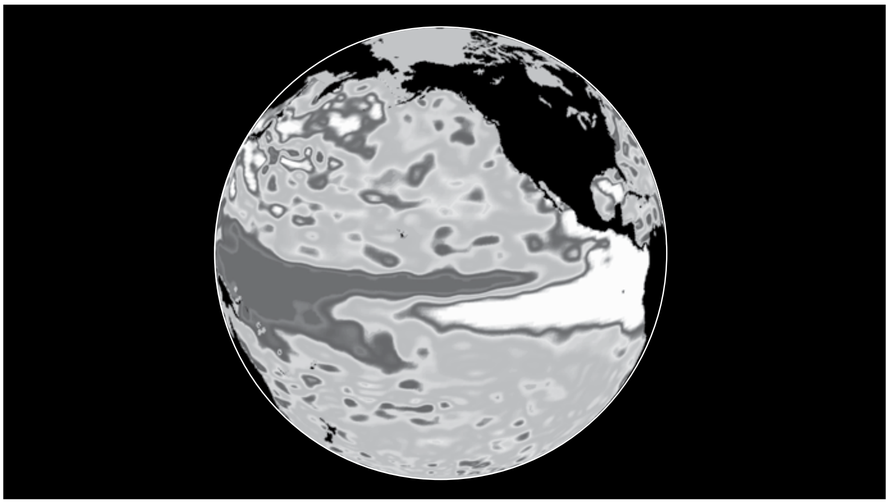
an ideal time to look at more recent events, current scientific knowledge and predictions for the future.

El Niño Southern Oscillation (ENSO)

Named El Niño – the 'Christ Child' in Spanish – because it occurs just after Christmas, the more scientifically known El Niño-Southern Oscillation (ENSO) is the occasional switch in the direction and intensity of ocean currents and winds over the Pacific Ocean (Figure 1). ENSO occurs (very roughly) every three to seven years, can last for anything from several months to more than a year and is a switching (an oscillation) between three different types of climate: the normal situation, El Niño and La Niña. As we have seen, ENSO is linked to changes in meteorological conditions including storm patterns, hurricanes, monsoon and instances of drought. These changes, while originating in the Pacific Ocean, can happen all over the world.

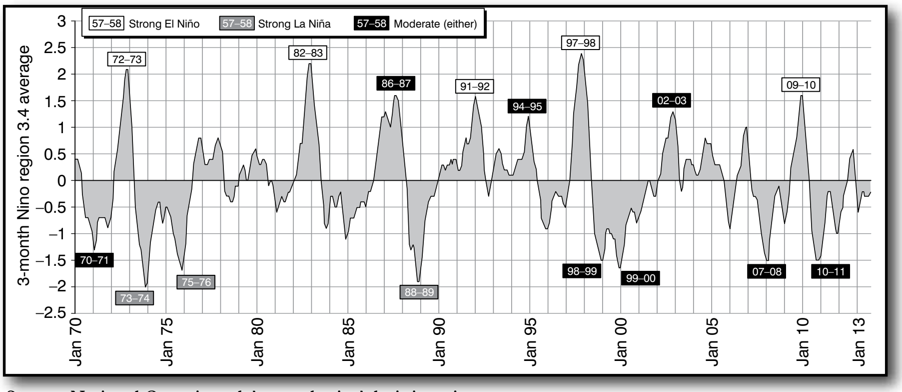
The normal situation is when the (Trade) winds blow from east to west along the Pacific equator. The strength of the wind is such that the water piles up (to a depth of about half a metre) in the western part of the Pacific. Meanwhile, in the eastern Pacific, cold water is drawn up from deep under the surface to replace the water which has been pushed west. This gives a difference in the surface temperature of the water of around 8°C from the west (where it averages 30°) to the east (about 22°C).

Figure 2: An El Niño year (1997). Sea surface height measurements (related to temperature) over the Pacific Ocean collected using the TOPEX/Poseidon satellite. The large white area on the right shows a sea surface between 14 and 32 cms above normal – indicative of an El Niño event



Source: NASA

Figure 3: NOAA's Oceanic Niño Index (ONI)



Source: National Oceanic and Atmospheric Administration

In an El Niño year (Figure 2) the winds are weaker and the water is pushed around less. With less water piled up in the west, more remains in the east and not so much cold water gets pulled up from the depths of the ocean. The result is that the eastern Pacific is warmer and the normally strong trade winds weaken. This weakening means the eastern ocean continues to increase in temperature and the winds weaken even more – a positive feedback loop which makes El Niño grow even stronger.

The huge changes resulting from El Niño have both economic and environmental effects around the world, including:

- a reduction in the amount of cold, nutrient-rich water upwelling off the western coast of South America with a consequent loss of productivity in local fishing
- rising air over the eastern Pacific with much wetter conditions than expected in areas that normally experience a desert climate
- descending air over South East Asia and Australia, with much drier conditions and occasional drought
- further afield, the huge shift in ocean currents and the position of the rising warm air alters the direction of the jet stream and changes the weather in North America, Africa and the rest of the world.

El Niño events are often followed by La Niña (the 'little girl' in Spanish) when climatic conditions are reversed and a more extreme version of the normal situation takes place – in general, in areas where El Niño is warm, La Niña is cool and where El Niño is wet, La Niña is dry. Low pressure over the western Pacific deepens further and the high pressure over the east increases. In contrast to El Niño there is an extreme upwelling of cold water off the coast of South America leading to a huge increase in nutrient-rich waters and fantastic fishing for the local people. With the greater temperature difference between the Pacific east and west the strength of the trade winds increases. This can lead to an increase in rainfall over South East Asia, consequent drought conditions in South America and higher sea-levels and coastal flooding in Indonesia and the Philippines, as large amounts of water are pushed westwards. Changes on a global scale are often quite difficult to quantify and predict as the jet stream is weakened and storm tracks become more irregular.

A recent history of ENSO events

History suggests El Niño events occur every three to seven years – a variation that makes prediction very difficult indeed. Figure 3 shows what has happened over the past 30 years as measured by the Oceanic Niño Index (ONI). This index has become the standard measure used by NOAA (the United States National Oceanic and Atmospheric Administration) to identify warm and cool periods in the tropical Pacific Ocean and is the three-month mean sea surface temperature (SST) variation for one of the main ENSO areas (between latitude 5° north and south of the equator and 120° and 170° west in longitude). ENSO events are defined as five consecutive months at 0.5°C above the mean, for El Niño, and 0.5°C below the mean, for La Niña.

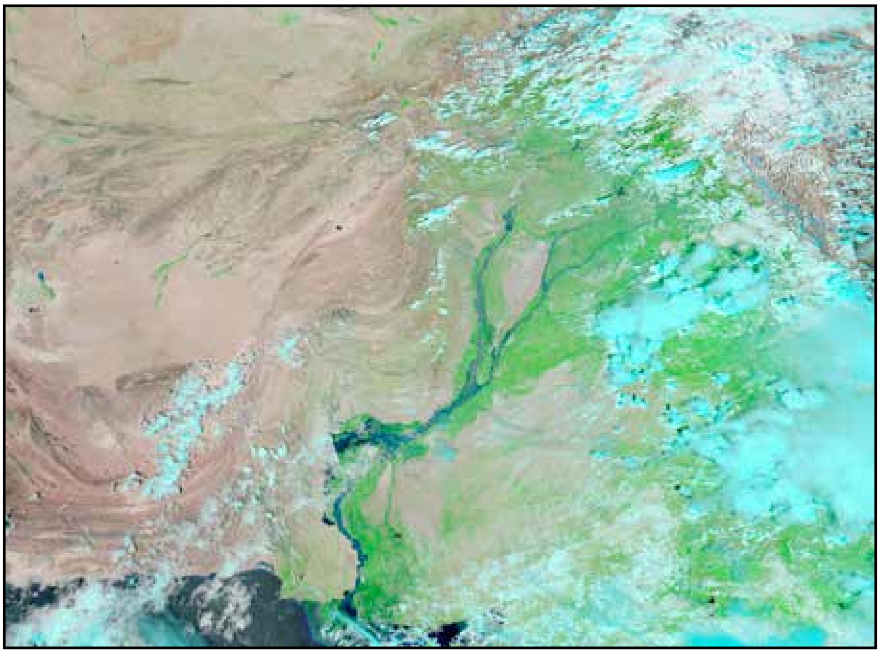
As can be seen from the graph in Figure 3, El Niño has been relatively quiet since the major events of 1997 and 1998 outlined at the beginning of this article. Twelve years passed until the moderate to strong event of 2009 and 2010, but this was still nowhere near the previous level. Although relatively weak, effects felt across the world included a weakening of the monsoon in India, increased rainfall in California and other coastal regions of the western United States and reduced precipitation in Australia. In contrast with the lack of major El Niño events, the graph does show an increase in the intensity and frequency of La Niña, culminating in the 2010 event which maintained a moderate increase in SSTs throughout 2011.

Case study: the effects of La Niña 2010 and 2011

The La Niña event of 2010 coincided with record high ocean temperatures in the northeast Indian Ocean and brought a number of devastating and unexpected effects to countries bordering the Pacific Ocean:

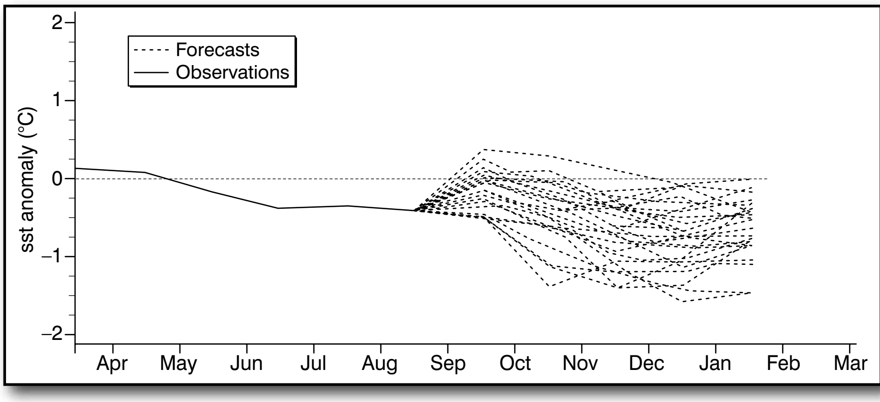
- **Pakistan**: floods began in late July 2010 following exceptionally high monsoon rains (the second highest in the last 50 years) which increased river levels throughout the Indus basin (Figure 4). An estimated 20 per cent of the country was under water, 20 million people were affected by damage to property and infrastructure and 2000 lost their lives. The total estimated cost of the floods lay at around £27 billion.
- **Australia**: flooding came later to the Queensland area of Australia, arriving in December 2010. Thousands of people were evacuated from towns and cities – around 70 settlements and 200,000 individuals ultimately being affected. An estimated 38 people died with around £1.5 bn worth of property damage. There were huge knock-on effects for the Australian economy with disruption to the coal industry in particular playing a part in a total budget reduction of around £18 bn.
- **United States**: while parts of Australia suffered under the deluge, the eastern USA was afflicted by a blizzard of historic proportions. On Boxing Day, from northern Florida through to Maine and into southern Canada, between 30 and 80cm of snow fell in just over 24 hours. In total, six states declared a state of emergency, with major road closures and disruption to services and local infrastructure.
- **East Africa**: by far the most devastating effects of the 2010 La Niña event were in the Horn of Africa (Somalia, Djibouti, Kenya and Ethiopia) which suffered the worst drought in over 60 years. Precipitation rates across many parts of the region decreased to around 70 per cent of the long-term average leading to major crop loss, death of livestock (between 40 and 60 per cent of some herds) and reduced milk production. In some of the poorest countries of the world, cereal prices rose beyond what local people (whose livelihoods had been adversely affected by loss of income) could afford.

Figure 4: Flooding in the Indus River basin, Pakistan



Source: NASA

Figure 5: Tropical Pacific sea surface temperature forecasts September 2013



The examples above show how global weather systems can have major impacts on the lives of people and cause widespread suffering on an individual basis. Countries such as Australia and the United States are well able to cope with the disruption caused but the case of the Horn of Africa is particularly tragic. As the drought set in, a refugee and humanitarian crisis developed as millions of people abandoned their homes and fled to surrounding countries such as Sudan – recently recovering from civil war and having little ability to cope with such an influx of people. As with similar situations involving large numbers of refugees, an increase in malnutrition, sexual violence and diseases such as malaria and HIV/AIDS were the inevitable result.

Prediction of ENSO events

As the above case study example shows, there is a need for more efficient monitoring and prediction of El Niño/La Niña events, so that action can be taken to prevent the worst effects. Over the last 30 years a lot of work has been done to try to understand the climate system better. A major development has been the installation of a large network of oceanic and satellite monitoring systems concentrated on measuring SSTs across the Pacific. As can be seen from the ONI (Oceanic Nino Index), this has become the main indicator of the state of ENSO events. The climatic data gathered is then fed into increasingly complex computer models for predicting oceanic and atmospheric circulation patterns.

Despite these advances in monitoring and modelling, it is still difficult enough to predict what may happen in the next six months without looking further ahead. Figure 5, for instance, shows there is a long way to go before accurate predictions are produced. The lines on the graph, produced by the UK Met Office, display accurate measurements of SSTs from the previous six months followed by predictions for the next six months based on different computer models. It is obvious from the spread of figures (which show anything from a return to the average to a decrease of one degree below and, therefore, a fairly major La Niña event) that basing anything on these forecasts is a little ambitious at this stage. In October 2013 a new prediction method produced by Glessen University was announced that appeared to be accurate two-thirds of the time and only resulted in false alarms once in every ten cases. Other researchers have been sceptical of the accuracy of the new model and it remains untested for future ENSO events. One thing without doubt is that, as computer models and data collection models improve over the coming years, predictions will likely become more accurate.

ENSO and climate change – the past and the future

With such a huge influence over the global climate and especially extreme weather in many vulnerable countries, there has understandably been a lot of concern over how climate change will affect the frequency and intensity of ENSO events. To look to the future, scientists often need a better knowledge of what has happened in the past and, in relation to ENSO, details have been rather sparse. Reconstruction of past climate in the western Pacific region has been possible by looking at coral reef growth but this record only goes back around 150 years. It shows a shift in ENSO events at the beginning of the 20th century from a 10- to 15-year cycle to a three to five year cycle. This was followed by a second shift in 1976 to more intense and more frequent events. More recent data, over the last few decades, is too variable to show any real pattern.

Looking further back researchers have found no evidence for the existence of El Niño in the early Holocene period (beginning around 10,000 BC) and it is now thought ENSO started between four and five thousand years ago. The most interesting recent research has used 2,222 tree-ring chronologies to reconstruct parts of the climate record of the past 700 years. Very sensitive to changes in the weather, these tree rings show accurately that there has been an increase in ENSO events since the beginning of the 20th century, chiming with the coral reef record and, perhaps more importantly, reflecting changes brought about by global warming. In particular the study found a big increase in events over the last 50 years coinciding with the major concerns over man-made changes to the Earth's climate. Many scientists now believe that, as ENSO events are driven by increased warming of the Pacific Ocean, future changes in SSTs related to global warming will result in an increase in their intensity and frequency.

Following the recent report by the Intergovernmental Panel on Climate Change (September 2013), which said scientists were now 95 per cent sure global climate change was a result of man's activities, research published in the highly respected journal, Nature, reported the most robust evidence yet that (based on computer modelling) future ENSO events would lead to more drought in the countries bordering the western Pacific Ocean and rainfall increases in the central and eastern equatorial Pacific. As well as these direct impacts on the global climate, there will be additional effects on, for instance, the number, intensity and pathways of hurricanes and cyclones and the strength and timing of the monsoon over Asia.

An unpredictable world

The study of El Niño and La Niña brings home to us just how little we still know about the climate system of our planet and how our activities are affecting it. While it is likely we will become increasingly adept at predicting how ENSO will operate in the future, at the moment we have little opportunity (considering we have little idea of the ultimate effects) to prepare for the events as they occur. What is not in doubt is that this is a great worry to people who live in the countries affected. Recent reports by the World Health Organisation have, for instance, shown how much El Niño affects outbreaks of a range of diseases in humans (including malaria, dengue fever and rift valley fever) and in animals (hantavirus) and fish (ciguatera poisoning). Other indirect effects include pollution hazes and forest fires associated with the increase in temperatures in countries including Indonesia and Australia.

In the meantime, with most computer models looking at predicting ENSO over the next 100 years being inconclusive, scientists, researchers and, most importantly, the people affected by unpredictable changes in weather just have to cope as best they can with this most fascinating of climatic conditions.

References

Maslin, M. (2004) *Global Warming*. Oxford University Press.
Maslin, M. (2013) *Climate*. Oxford University Press.
Power, S., et al. (2013) 'Robust twenty-first century projections of El Niño and related precipitation variability'. *www.nature.com*.
Waugh, D. (2009) *Geography: an integrated approach* 4th edition. Nelson Thornes.

There is a huge amount of information on the internet about ENSO, although not all of it is reliable. The best information comes from the USA's National Oceanic and Atmospheric Administration (www.noaa.gov). The UK Met Office (www.metoffice.gov.uk) and Australian Weather Bureau (www.bom.gov.au) also have plenty of information. The Intergovernmental Panel on Climate Change (www.ipcc.ch) publishes up-to-date scientific research on the state of affairs and, for a detailed analysis of what future ENSO events may mean for world health issues, see the World Health Organisation's detailed report at www.who.int/globalchange/publications/en/elnino.pdf.

Focus Questions

1. Describe the formation of ENSO events over the Pacific Ocean and how they differ from the normal climatic conditions.

2. Use case study examples to show the social, economic and environmental effects of ENSO events on specific countries.

3. Explain how scientific research methods have contributed to development in the understanding of past ENSO events since the beginning of the Holocene period.

4. What is the current understanding of the relationship between ENSO and global climate change? How are predictions for the future being refined and modified with the intention of providing greater accuracy?