

## 2: The Causes of Climatic Change

*Mick Kelly*



*The character of the Earth's climate system is shaped by the general circulation of the atmosphere and oceans, the winds and currents that move heat and moisture around the planet. The main source of the energy that drives these circulations is the Sun.*

*So, to identify the reasons why climate varies, we must first look to the Sun...*

### **Variations in the Sun's output**

Change in the amount of energy emitted by the Sun is a prime candidate as a cause of climate variability. And there is no doubt that on the longest timescales of Earth's geological history, trends in solar output have played a major role in shaping the Earth's climate – and will continue to do so in the future.

Within our lifetime, though, of more concern are variations on the 10- to 100-year timescales. It has been known for many centuries that the face of the sun exhibits dark patches, 'sunspots', and that the number of sunspots varies with a fairly regular cycle of around 11 years.

Is this sunspot cycle an indicator of processes within the sun that might also affect the solar output and, hence, Earth's climate? Despite many studies, the evidence is still controversial. Sunspot cycles have been found in climate parameters, but the fluctuations are weak and tend to appear and disappear without reason.

The 11-year sunspot cycle itself varies in strength on timescale of 80 years and longer, and these longer-term fluctuations have also been linked to climatic change. In the early 1600s, the sunspot cycle almost disappeared and this phenomenon, the so-called Maunder Minimum, has been associated with the height of the Little Ice Age. It has also been claimed that the warming of the 20th century was largely due to trends in sunspot activity, for example, in the length of the sunspot cycle.

But, again, the evidence for these apparent correlations is not strong. Moreover, the fluctuations in solar output that likely accompanied these sunspot trends were not really sufficient to generate the observed climate changes, without some amplifying mechanism.

*As the stream of solar energy – heat and light – reaches our planet, the character of the Earth's orbit and of its rotation plays a major role in causing long-term climate change...*

### **Milankovitch cycles**

On time scales of a thousand years and longer, changes in the character of the Earth's orbit around the Sun and in its rotation can significantly affect the way in which the energy from the Sun is distributed by season and by latitude. This is known as the 'Milankovitch Effect,' and it generates changes which are cyclic in nature.

Comparison of the changes predicted by astronomical calculations with the observed climate record suggests that this mechanism has played a part in inducing the shift from ice age to interglacial conditions on time scales of 10,000 to 100,000 years.

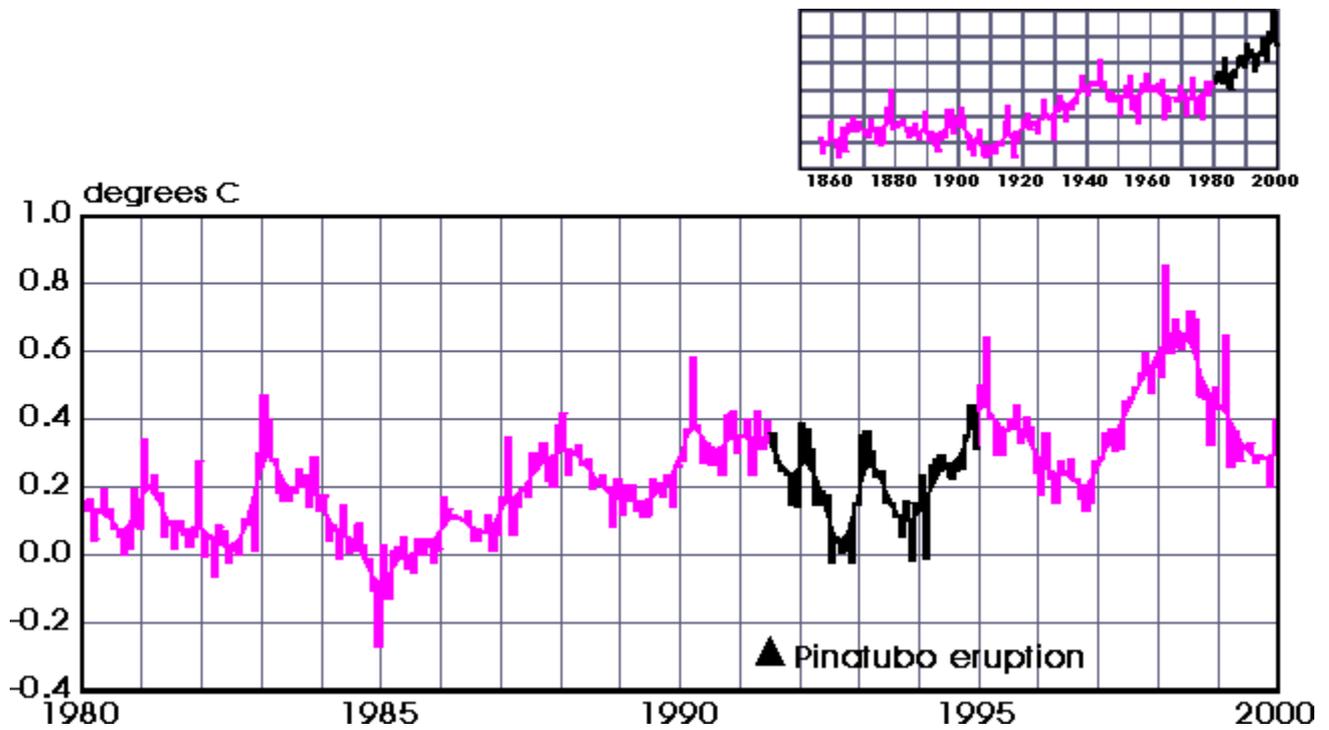
But in order to explain the scale of the observed variations, it is necessary to invoke other factors. One possibility is that the basic effect is magnified by the release and uptake of carbon dioxide as climate alters.

*As the stream of solar energy reaches the Earth's atmosphere, the constituents of the atmosphere – gases and particles, clouds and pollution – interfere with the energy stream, reflecting some heat and light back to space, trapping then releasing a proportion...*

### **Volcanic pollution**

Explosive volcanic eruptions can inject large quantities of dust and the gas, sulphur dioxide, high into the atmosphere. Whereas volcanic debris in the lower atmosphere falls out or is rained out within days, the veil of pollution in the upper atmosphere is above the weather and may remain for several years, gradually spreading to cover much of the globe.

The volcanic pollution results in a substantial reduction in the stream of solar energy as it passes through the upper layers of the atmosphere, reflecting a significant amount back out to space.



Global-mean monthly temperature for the period 1980-1999, showing the effects of the eruption of Pinatubo in 1991. The upper graph shows the complete global-mean temperature record as context.

Observational and modelling studies of the likely effect of recent volcanic eruptions suggest that an individual eruption may generate global cooling amounting to two or three tenths of a degree Celsius. The effect lasts for a year or two.

Major eruptions have not been common this century, occurring once every ten to twenty years, so the long-term influence has been slight. The influence on climate has been on the year-to-year time scale.

*Other forms of pollution can affect the passage of heat and light through the air – dust thrown up by windstorms or human activity, for example – but the most significant factor at this time is believed to be the rising amount of greenhouse gases, such as carbon dioxide and methane, in the atmosphere...*



## **The greenhouse effect**

Greenhouse gases do not interfere to any great extent with the incoming solar energy. But once that energy reaches the Earth's surface, it is absorbed, warms the land and ocean surface of the planet, and then is re-emitted. The amount of heat re-emitted and eventually lost to space must equal the amount gained from the Sun if the temperature of the planet is to remain constant.

But the so-called terrestrial energy stream is different in character – it is longer in wavelength than the incoming solar energy as the Earth is cooler than the Sun – and the greenhouse gases interfere with it strongly before it can escape to space.

The greenhouse gases absorb the outgoing terrestrial energy, trapping it near the Earth's surface, and causing even more warming. This is the 'greenhouse effect.' Without it the planet would be too cold to support life as we know it.

Unfortunately, humanity, through energy generation, changing land use and other processes, has produced a substantial increase in the amount of greenhouse gases in the atmosphere, enhancing the natural greenhouse effect, and it is feared that this continuing change will lead to a major shift in global climate.

*Climate variability can also be generated by smaller-scale changes in the energy balance – the balance between heat received and heat lost. Many processes can lead to disruption of regional climate. The North Atlantic Oscillation, for example, has a major effect on the winter climate of the Atlantic-European sector. But the related phenomena of El Niño, La Niña and the Southern Oscillation have the greatest societal impact...*

## **El Niño and La Niña**

The El Niño Southern Oscillation (ENSO) phenomenon is one of the best-defined modes of so-called internal climate variability. It has an oceanic - El Niño and La Niña – and an atmospheric – the Southern Oscillation – component.

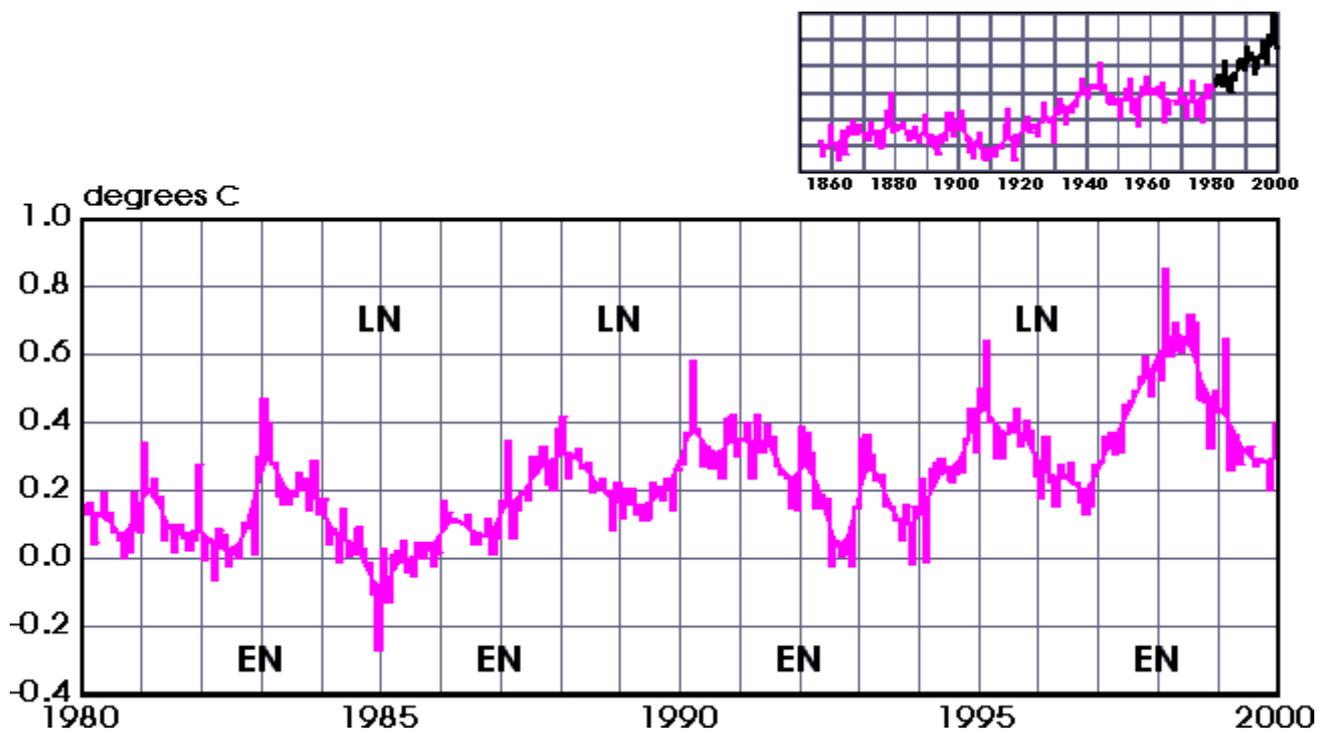
The oceanic component consists of a marked warming (or cooling in the opposite, La Niña phase) of the waters of the central and eastern Pacific. The temperature change is strongest in a zone ten degrees latitude either side of the equator. It affects the regional energy balance, disrupting the atmospheric circulation and climate of much of the low-latitude zone, with effects extending well into middle latitudes during strong ‘warm’ or ‘cold’ events.

The atmospheric component – the Southern Oscillation – is a see-saw in pressure between the eastern and western Pacific, accompanied by a change in the strength of the winds over the equatorial Pacific Ocean.

During a warm ENSO event, sea-level pressure drops in the eastern Pacific and rises in the west and the dominant easterly trade winds weaken.

Drought is experienced over Australasia and parts of southeast Asia and South America while heavy rains occur in the nations neighbouring the warmer waters off South America (e.g. Peru and Ecuador). A poor Indian monsoon is expected.

The duration of warm and cold events is about a year and the switch between El Niño and La Niña conditions occurs every four to seven years.



Global-mean monthly temperature for the period 1980-1999, showing the effects of El Niño (EN) and La Niña (LN). At the global scale, the effects of the Pinatubo eruption masked the warming induced by the 1991/92 El Niño event, although the regional impacts of that El Niño event did occur. The upper graph shows the complete global-mean temperature record as context.

The change in tropical temperatures is sufficient to affect global-mean temperature, creating a rise and fall of a couple of tenths of a degree Celsius every few years.

The El Niño Southern Oscillation phenomenon is “the most important cause of climate extremes lasting from a season to a year or more in the tropics and subtropics,” according to participants

at the workshop *The Impact of El Niño and La Niña on Southeast Asia*, held in Hanoi, Vietnam, in February 2000.

For many of the world's population, El Niño and La Niña present a far more tangible threat than the possibility of long-term global warming.

## On the Web

Other information sheets in this series present more detailed information about the [El Niño Southern Oscillation phenomenon](#), the [North Atlantic Oscillation](#), [volcanic activity and climate](#), and [global warming](#).

Links to other web sites are also available:

- Basics of weather, climate and climate change
- Global climate change and solar variability
- Volcanoes and climate change
- Global warming
- El Niño and the Southern Oscillation
- Seasonal climate forecasts — El Niño and Africa

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