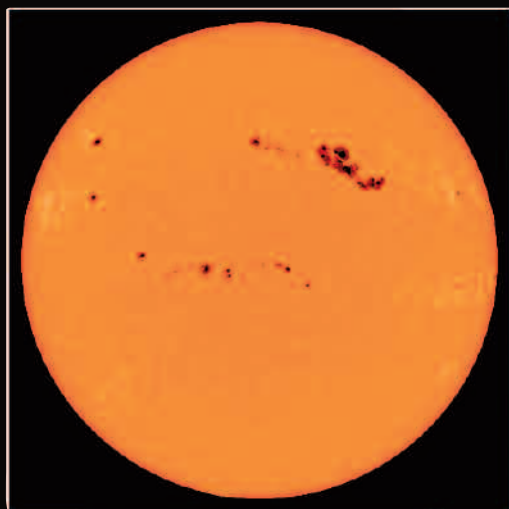


# SOLAR POWER

Some people have pointed to the sun as the cause of recent climate change here on Earth. **Jo Haigh** explains how variations in the sun may affect climate in unusual and subtle ways.



Approximate size of the Earth → ●

**D**o changes in the sun affect the Earth's climate? Variations in sun-Earth geometry clearly have a major effect, controlling daily and seasonal cycles as well as the onset of ice ages. But what about the impact on climate of variability within the sun itself? Our research is suggesting that small changes in the sun's heat output may affect the Earth's climate in ways we might not expect.

The clearest indication that the sun is varying is given by the presence of sunspots which come and go approximately every 11 years. The first sunspot records date back to 200BC when Chinese astronomers made naked-eye observations, probably filtered through sandstorms. Since then people have often speculated that weather is related to sunspot numbers.

In 1801, William Herschel, who discovered the planet Uranus and infrared radiation, claimed to have found a relationship between solar activity and wheat prices on the London Stock Exchange. These results are not easy to verify and over the nineteenth century scientists made other serious attempts to establish similar links. However, the evidence was far from convincing and when 'sunspottery' became popular and was adopted by various astro-meteorologists (who predicted the weather based on the sun and the planets), the embryonic UK Met Office distanced itself from such supposed quackery. This distance remained until probably the 1980s when scientists started focusing on long-term changes in climate. Nowadays the

effort to quantify and understand solar influences has acquired a particular urgency. A better appreciation of how natural factors, such as the sun and explosive volcanic eruptions, affect climate makes the detection of human influences much more reliable.

In the past half century, what has really helped to identify the causes of climate variability are global gridded meteorological datasets such as those produced by the European Centre for Medium-Range Weather Forecasting and the US National Center for Environmental Prediction. These and other datasets have provided statistically robust connections between solar activity and various meteorological parameters. For example, we have found that the paths of storms at mid-latitudes shift slightly further towards the poles when the sun is more active and that the mid-latitude jet-stream winds are slightly weaker.

Interestingly, the temperature patterns that emerge are not the uniform warming we might anticipate as a response to a higher input of solar energy. Thus finding a solar signal in the meteorological records is only part of the story: the other, and arguably more difficult part is to understand how the apparent responses arise.

A first step towards this is to establish the variation in solar output. Traditionally scientists believed that when the sun had more spots it must emit less radiation, the spots being darker than the remaining surface. But even very careful attempts to measure solar radiant energy at the Earth's surface were unable to

Joanna Haigh is Professor of Atmospheric Physics in the Space and Atmospheric Physics Group, Blackett Laboratory, Imperial College London. Tel: 020 7594 7671, email: j.haigh@imperial.ac.uk

Jo Haigh was awarded the Institute of Physics Chree Medal and Prize in 2004 for her work on solar variability and its effects on climate.

The SOLCLI consortium, led by Imperial College with partners at the universities of Cambridge, Leeds and Reading and the British Antarctic Survey and with collaborators in Germany, Japan, the USA and the UK Met Office, is studying many of the topics outlined below. For more information see [www.sp.ph.ic.ac.uk/~ssparrow/Solcli\\_web/solcli\\_home.htm](http://www.sp.ph.ic.ac.uk/~ssparrow/Solcli_web/solcli_home.htm)

SOHO (ESA & NASA)

“There is likely to be a decline in the sun’s activity over the next century.”

The sun at the peak of the most recent solar activity cycle, showing lots of sunspots, seen from NASA’s SOHO satellite 29 March 2001. The next sunspot minimum is predicted for March 2008 and maximum around the end of 2011.

detect systematic variations so scientists referred to the value they measured as the ‘solar constant’. However, since the late 1970s and the launch of satellites carrying instruments called radiometers which measure electromagnetic radiation, researchers have shown that higher sunspot numbers coincide with greater solar radiative flux – the total power emitted by the sun. This extra energy comes from the brighter patches, less apparent to the naked eye, which occur between the sunspots. Solar physicists are now beginning to understand how sunspot numbers and solar irradiance are related and this is enabling us to deduce (or reconstruct) how solar energy output must have varied in the past. Predicting the future is even more difficult but many scientists consider that there is likely to be an overall decline in the sun’s activity over the next century or so.

Over the 11-year cycle, total solar power varies by only about 0.1 percent but satellite measurements have shown that this varies hugely across the spectrum of radiation, from ultraviolet (UV) light, through to visible light and infrared. In particular, the changes at higher wavelengths, in the UV region of the spectrum, are much larger than those in the visible region. This means that the solar impact is felt more strongly higher in the atmosphere. Importantly, at altitudes of around 20-50km (the stratosphere) UV radiation from the sun breaks up oxygen molecules causing ozone to form. So, when the sun is more active, stratospheric ozone concentrations increase.

Measurements show that the total amount of stratospheric ozone varies by 2-3 percent over the solar cycle but quite how this is distributed is not well known. We have found that in climate models where we include ozone changes in the upper atmosphere caused by the sun, the models are much better at simulating the observed effects of solar variability on climate lower down. This intriguing result suggests that other factors which affect the temperature higher in the atmosphere, such as major volcanic eruptions or ozone depletion, might influence the climate of the lower atmosphere by similar means. Researchers are now looking at the mechanisms involved and this is leading to a new understanding of climate variability. For example, it is possible that knowing the state of the stratosphere might help improve seasonal weather predictions.

NERC is funding our Solar Variability and Climate (SOLCLI) consortium, a coordinated study of the influences of solar variability on climate. Currently we are working out the variability in solar output across all wavelengths over the last 150 years and refining our ability to detect solar signals throughout the lower and middle atmosphere. We also want to see the response of stratospheric composition to varying UV and to identify the links between the stratosphere and the troposphere beneath. All of this will lead to a better representation of solar effects in global climate models. ❖