Australian Government
Department of the Environment and Heritage
Australian Greenhouse Office

hot topics
in climate change science

IS GLOBAL WARMING PREDOMINANTLY DUE TO SOLAR VARIABILITY?

SUMMARY

The Sun's energy drives the Earth's climate. Solar radiation received by the Earth varies due to changes in the Earth's orbit around the Sun and changes in the Sun's activity. Wobbles in the Earth's orbit have led to major Ice Ages. The amount of energy released by the Sun changes slightly over the years, with some small long-term trends that span centuries, and a well known variation throughout the 11-year sunspot cycle.

Changes in solar radiation during the early 1900s explain much of the global warming that occurred at that time. However, solar changes cannot explain the rapid warming the Earth has experienced since the 1970s. The solar changes account for just a fraction of this recent warming. Rising atmospheric concentrations of greenhouse gases are largely the cause.

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Wobbles in the Earth's orbit occur in cycles of 20,000 years, 40,000 years and 100,000 years. They have led to major Ice Ages.

Sunspots cover one or two per cent of the Sun's surface (Bryant, 1997). Satellite measurements since 1978 show that annual mean total solar energy varies between the minimum and maximum of the 11-year sunspot cycle, by about 0.08 per cent (IPCC, 2001). The radiative forcing, or effect on climate, is 1.1 watts per square metre (Wm^{-2}). Indirect measurements of sunspots over the past millennium show there are also cycles of 80-90 years and 180 years, the latter corresponding to the cyclic alignment of planets (Bryant, 1997). Periods of low sunspot activity correspond with low Earth temperatures, e.g. the Oort Minimum (1010-1050), Wolf Minimum (1280-1340), Spörer Minimum (1420-1530) and Maunder Minimum (1645-1715).

Over the period 1750-2000, the increase in radiative forcing due to changes in solar activity was about 0.3 Wm^{-2}. Over the same period, the increase in radiative forcing was about 2.4 Wm^{-2} from well-mixed greenhouse gases and 0.35 Wm^{-2} from tropospheric ozone (see diagram). Aerosols also contribute small positive and negative forcings, land-use change has reduced forcing by about 0.2 Wm^{-2} and stratospheric ozone depletion has reduced forcing by 0.15 Wm^{-2}.

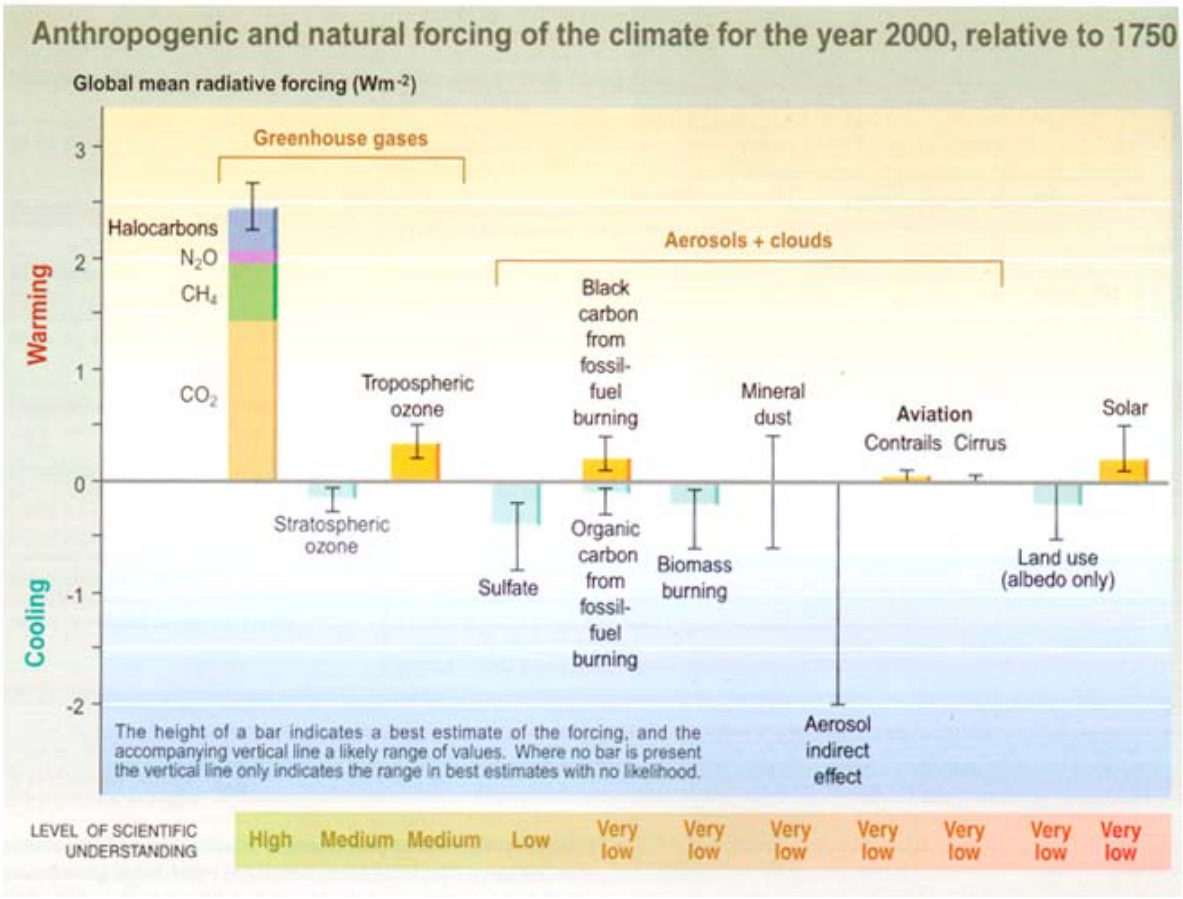

Figure 1: Changes in radiative forcing due to different factors from 1750-2000. Source: IPCC (2001).

During the 20th century, overall natural forcing (solar and volcanic) probably increased (a warming effect) up to about 1950 due to a period of low volcanism and a small rise in solar radiation (IPCC, 2001, p 706). Recent decades show negative natural forcing (a cooling effect) due to increasing volcanism overwhelming a small rise in solar radiation. All reconstructions of solar variations show that the climatic influence over the 20th century was about 20-25 per cent of the change in forcing due to increasing greenhouse gases (IPCC, 2001, p 706).

Scientists have used climate models to estimate the temperature effect of various factors, such as solar variability, volcanic eruptions, increasing greenhouse gases, aerosols and stratospheric ozone depletion. Simulations of the response to natural forcings alone (that is, solar and volcanic) do not explain the warming in the second half of the 20th century (IPCC, 2001, p.699). However, these natural forcings may have contributed to the observed warming in the first half of the 20th century (IPCC, 2001; Meehl *et al.* 2003). Solar changes *cannot* explain the warming experienced since about 1970.

Researchers must include the effect of rising atmospheric concentrations of greenhouse gases if they are to explain the warming observed over recent decades. The late 20th century warming was due mostly to the increase of greenhouse gases, partially offset by cooling caused by human emissions of aerosols (Meehl *et al.* 2003). Since 1970, when the rate of global warming began to rise, the Sun has been the source of less than a third of the warming (Lean *et al.* 1995).

In 2003, geophysicists in Finland and Germany suggested, through isotopic measurements, that the Sun is more magnetically active now than it has been for over a 1000 years (Usoskin *et al.,* 2003). The link between the magnetic activity of the Sun and the Earth's climate is unclear.

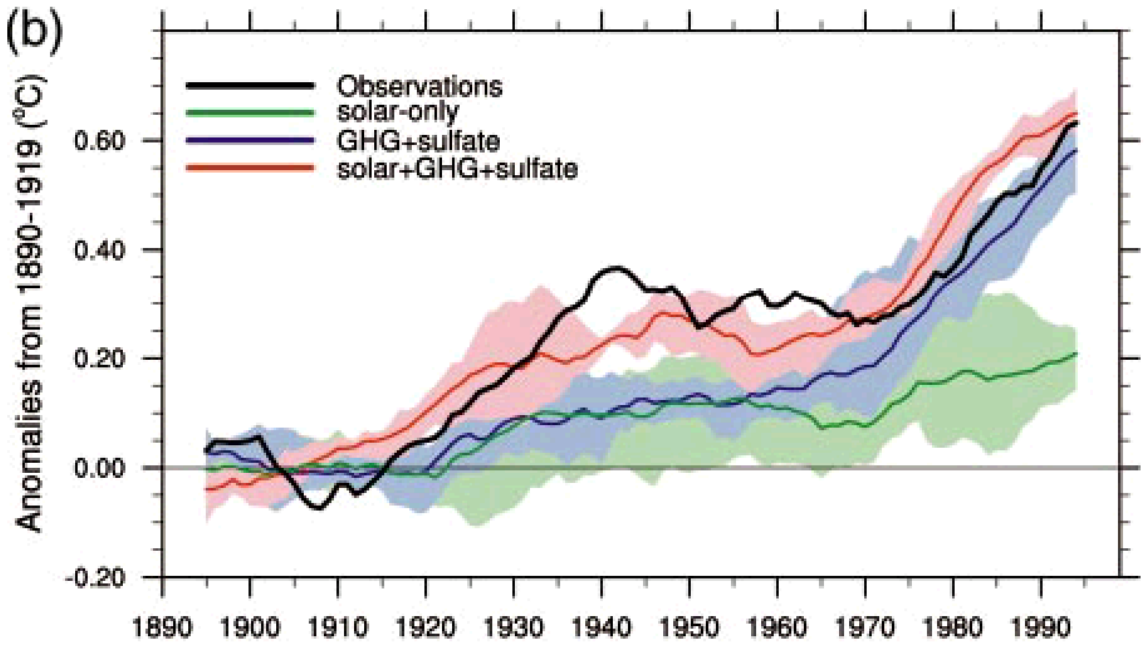

Figure 2: Global annual mean surface air temperature anomalies (11-year running mean) relative to 1890-1919 for observations (black), and for climate model simulations driven by variations in solar radiation (green), greenhouse gases (GHG) and sulfate aerosols (blue), and all three factors (red). The shading indicates the range of uncertainty from an ensemble of four climate model simulations. Source: Meehl *et al.* (2003). The figure shows that including only changes associated with solar radiation cannot explain the observed temperature increases over the past several decades. Incorporating solar changes and those associated with measured increases in greenhouse gases and direct sulfate aerosol effects produces a close fit to the observed global warming over the past century.

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HOT TOPICS IN CLIMATE CHANGE SCIENCE
Prepared by CSIRO for the Australian Greenhouse Office, Department of the Environment and Heritage, 2005

www.greenhouse.gov.au/science/hottopics

Published by the Australian Greenhouse Office, in the Department of the Environment and Heritage