SOLAR FORCING

Solar forcing is the hypothesis that variations in solar emissivity can bring about global climate changes. This hypothesis is undeniable in principle, since virtually all of the Earth's heat comes eventually from the Sun. The problems come in finding episodes in the Earth's climatic history where this has actually occurred.

This requires that we first document changes in solar emissivity over time, and then document that the Earth's climate actually changed in response to those changes in emissivity. This is not easy to do.

First of all, we have only recently been able to measure actual solar emissivity at the outside of the Earth's atmosphere. Since 1977, we have had the benefit of measurements taken by earth-orbiting satellites. These satellites are able to measure both incoming solar radiation and outgoing terrestrial radiation at the top of the atmosphere.

It should be noted, however, that these measurements are still short-term by conventional climatic standards. Moreover, these measurements are neither as precise nor as comprehensive as we might wish them to be. Therefore, judgments based on these measurements must still be considered to be somewhat tentative.

Variations in Solar Emissivity

Variations in solar emissivity are due to processes and occurrences taking place within the Sun itself, and affect the Sun's emissivity from its photosphere. Before the advent of direct measurements of solar emissivity by artificial satellites in 1977, variations in solar emissivity were estimated from surface measurements. Estimates for the more distant past were derived from proxies, specifically observations of sunspot numbers and groupings, and from concentrations of cosmogenic isotopes[1] in sediments and organic materials.

Period of direct measurement – We have been using satellite measurements of solar emissivity only since 1977. During this period of measurement, the variation in solar emissivity has been slight—once the eccentricity of the Earth's orbit has been factored out. This non-orbital variation has been on the order of 0.1%; but it must be borne in mind that the period of record is still small.

Period of surface measurements – Before satellite measurements were available, the intensity of solar radiation was measured at the surface—usually in deserts or at higher mountain elevations. Such records date back to the seminal work of Abbot at the Smithsonian from 1902 to 1954. These measurements are limited in their value by the natural variability of insolation from place to place and time to time over the face of the Earth due to non-solar factors, and by significant variations in the measurement instruments themselves.

Sunspot activity and solar emissivity – There is a strong positive correlation between sunspot activity and solar emissivity. Although the first recorded mention of sunspots dates to China some 2800 years ago, systematic observations and recordings date only to the invention and spread of telescopes in the seventeenth century. Even then, data were sketchy and comparisons unreliable. Only in the last three-hundred years has data been gathered that meet even the most rudimentary standards of scientific acceptance.

Proxy measurements – It should be noted that values for insolation based on sunspot activity and other related phenomena are derived measurements, not actual ones. They are usually termed "proxy" measurements. The most commonly used proxies are concentrations of cosmogenic isotopes.

Cosmogenic isotopes and solar emissivity – There is also believed to be a strong inverse correlation between solar emissivity and the concentration of cosmogenic isotopes. Both the concentration of beryllium-ten[2] in ice cores and sediments and the concentration of carbon-fourteen[3] in tree rings are thought to be inversely

[1] Cosmogenic isotopes are isotopes that are generated by radiation from outer space.
[2] The standard isotope of beryllium is beryllium-nine.
[3] The standard isotope of carbon is carbon-twelve.

related to emissivity. Measurements of these isotopes allow us to hypothecate solar emissivity back through periods when neither direct measurements of insolation were available nor sunspot activity accurately observed. Using these measurements, we have been able to hypothecate sunspot activity (and, by derivation, solar emissivity) back some 11,400 years [Solanki et al, 2004].

Solar emissivity and climate change – The correlation between these various proxy estimates of past solar emissivity and historic climatic changes is strong but not conclusive. There is measurable correlation between increased sunspot activity and the *Medieval Warm Period* (900 to 1350); and a very strong correlation between decreased sunspot activity (especially the Maunder Minimum) and the *Little Ice Age* (1350 to 1880).

Students of climate change should note that the present period of sunspot activity (since 1950) is outstanding in both its magnitude and its duration [Solanki et al., 2004].

Time lag of insolation forcing – It should be noted that although local temperatures are strongly forced by variations in insolation (witness the temperature changes from day to night), global temperatures respond much more slowly due to the enormous heat capacity and thermal inertia of the world ocean. It may take several years for any significant change to be observed. This, in turn, depends upon the magnitude of the variation and in which part of the solar spectrum the variation is concentrated.

Emissivity variations and the solar spectrum – Most variations in solar emissivity have been recorded in the ultraviolet portion of the solar spectrum. The observed variations in the visible portion have shown a much lesser magnitude, and the variations in the infrared portion have had the least variance of all.

Long term changes – The consensus of informed opinion is that there has been an increase in solar emissivity over the past two centuries. The magnitude of this increase and the magnitude of its effects on global temperatures are both the subject of strong scholarly argument.

Very long term changes – The Sun is gradually expanding and getting hotter. Astronomers estimate that the emissivity of the Sun is increasing by some 10% over each billion years.

SOLAR EMISSIVITY AND CLIMATE CHANGE

The role of solar emissivity in climate change – Scholars have advanced a large number of hypotheses as to the role of solar emissivity in climate change. Simple thermodynamics tells us that there is a role. Scholars debate as to its magnitude and application. Most of the proponents of solar forcing use it to explain the medium-term fluctuations on the backs of the long-term orbital forcing cycles.

A recent study [Perry & Hsu, 2000] uses a thirteen-hundred year cycle of diminutions in solar output to explain much of the climatic record of the past forty-thousand years, dating back to the last interglacial. The correlation with the paleoclimatological record is quite strong, especially for the more recent Dark Ages Cold Era and the Little Ice Age.

More recently [Scarfetta & West, 2006], have suggested that solar emissivity increases account for as much as 45% to 50% of the 1900-2000 global warming, although only 25% to 35% of the 1980-2000 period.

The IPCC scoffs at all attempts to show that the warming trend since 1750 has any cause other than carbon-forcing.

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