Scafetta and West's discussion of glacial and interglacial cycles does not support their assertion that climate is exceptionally sensitive to solar variations. As is well established, glacial and interglacial temperature differences result from extremely large changes—not "small" ones as Scafetta and West claim—in the spatial and seasonal patterns of incoming solar radiation, which trigger two powerful but slow feedbacks: changes in atmospheric carbon dioxide and changes in surface reflectivity resulting from the advance and retreat of land ice sheets. Certainly, neither feedback can be responsible for late-20th-century warming.

Although this is irrelevant to the main point of contention, climate models do not assume that "only humans can modify greenhouse gas concentrations." Naturally occurring CO_2 variations are included either by prescription or through modeling of climate and carbon-cycle feedbacks.

Finally, a recent paper[2] explains in detail the serious flaws in the work of Scafetta and West. Primarily, multicollinearity between different climate forcing agents makes it impossible to unravel their relative effects by considering only a single forcing, as Scafetta and West attempt. Reference 2 further shows that the statistical method they used leads to grossly incorrect results; when applied to a situation with a known solar contribution, it gives a greatly and unrealistically enhanced solar effect.

In response to Benjamin Jordan, we note that observed temperatures reflect both natural variability and the effects of forcings such as greenhouse gases and solar variability. So in an era of increasing greenhouse gases, each year need not be warmer than the previous, even as temperatures trend generally upward. Climate models correctly predict that phenomenon.[3] However, because climate simulations are not initialized from observations in the same way that weather forecasts are, they are not expected to predict the *timing* of natural variations, including cooling episodes. Hence, the lack of any warming trend since 1998 is not cause for concern about climate models.

In summary, we do not claim that the climate is insensitive to solar forcing, only that the sensitivities to different types of forcing appear to be very similar. We are open to the possibility that unknown feedbacks might amplify solar forcing; however, Scafetta and West have provided no evidence of such and no reason to discard an explanation of late-20th-century warming that is consistent with theory, models, and observations—namely, increased greenhouse gases.

References

1. See, for example, M. Lockwood, C. Fröhlich, *Proc. R. Soc. A* **464**, 1367 (2008).
2. R. E. Benestad, G. A. Schmidt, *J. Geophys. Res. D* **114**, 14101 (2009), doi:10.1029/2008JD011639.
3. See, for example, D. R. Easterling, M. F. Wehner, *Geophys. Res. Lett.* **36**, L08706 (2009), doi:10.1029/2009GL037810.

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Other climate-change inputs

A vigorous round of correspondence appeared in Physics Today (October 2008, page 10) regarding the Opinion piece "Is Climate Sensitive to Solar Variability?" by Nicola Scafetta and Bruce West (Physics Today, March 2008, page 50). One letter writer, Peter Foukal, pointed out that neither total nor UV solar irradiance can account for most of the climate variance that correlates with solar activity. In view of the quantitative problems in using irradiance to account for the correlated climate variations, the question can be asked, Are the cosmic-ray variations, which are mostly due to solar activity, themselves drivers of climate change, or are they—as generally assumed—merely proxies for irradiance variations?

Not mentioned in the discussion was observational evidence for greater long-term and short-term climate sensitivity to solar activity than irradiance can account for. Proxies for climate change on the centennial and millennial time scales—proxies such as glacier-carried debris and the oxygen-18 isotope—show strong correlations with the cosmic-ray-generated cosmogenic isotopes carbon-14 and beryllium-10 in stratified geological repositories.[1]

One little-known mechanism coupling solar activity to the atmosphere has been shown to respond to cosmic-ray changes as well as to other inputs, as documented and reviewed in recent publications.[2,3] Clear evidence of meteorological responses, including changes in cloud cover, has been reported for five disparate short-term solar or terrestrial inputs that modulate the flow of the downward electric current density J_z of the global electric circuit through the atmosphere. For example, recent analysis of measurements in both the Antarctic and Arctic high-magnetic-latitude regions shows correlations between surface pressure and the north–south component of the interplanetary electric field. Changes in J_z due to low-latitude thunderstorms produce a similar effect on polar surface pressure.[2] There are other consistent, statistically significant atmospheric responses to the effects of cosmic-ray, solar-proton, and relativistic-electron precipitation on J_z.[3]

The J_z flow deposits electric charge on droplets and aerosol particles in gradients of droplet concentration, humidity, and, therefore, resistivity in clouds in accordance with Ohm's law and Gauss's law. Such charges could affect clouds through the scavenging rates for cloud-condensation and ice-forming nuclei. Consequent changes in the concentration of such nuclei and in ice-nucleation rates can affect droplet concentration, precipitation rate, and cloud cover and can potentially explain the observations. But to model the effects of the cloud changes on global mean temperature on the century time scale, it will be necessary to separately evaluate the effects of solar-induced J_z changes on clouds at low and high altitudes, at high and low latitudes, over ocean and land, by day and night, and for stratus versus cumulus clouds. Such work has not been done, but uncertainties appear much larger than those shown for the solar irradiance effect in the reports of the Intergovernmental Panel on Climate Change, and can thus accommodate the observed changes in global temperature that correlate with solar activity.

References

1. G. Bond et al., *Science* **294**, 2130 (2001), and references therein.
2. G. B. Burns et al., *J. Geophys. Res.* **113**, D15112 (2008), doi:10.1029/2007JD009618.
3. B. A. Tinsley, *Rep. Prog. Phys.* **71**, 066801 (2008).

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Complexities of cell differentiation

In his Reference Frame (Physics Today, March 2009, page 8), Leo Kadanoff discussed how the function of biological