FORUM

A Perspective on Global Warming, Dimming, and Brightening

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Heated discussion of climate change is not a new feature of public debate, as *Fleming* [1998] has demonstrated in his studies of the historical perspectives of this topic. Nevertheless, a strong case can be made that the current level of public concern and even apprehension may be unprecedented. The purpose of this article is to draw attention to the challenge that recently reported changes in solar radiation at the Earth's surface, $E_{g\downarrow}$, pose to the consensus explanation of climate change.

Global Dimming and Brightening

There is evidence that changes in $E_{g\downarrow}$ have occurred during the past 50 years. A bibliography of the published literature appears at http://www.greenhouse.crc.org.au/crc/research/c2_bibliog.htm

An example of these changes, based on measurements made in Israel, is presented in Figure 1a. The figure shows that a widespread reduction in solar radiation at the Earth's surface, often referred to as global dimming, lasted from the mid-1950s until the mid-1980s when a recovery, referred to as global brightening, started. An analysis of many reports of global dimming over the land surfaces of the Earth yielded a total reduction of 20 W m^{-2} (watts per square meter) over the 1958–1992 period [*Stanhill and Cohen,* 2001]. This negative shortwave forcing is far greater than the 2.4 W m^{-2} increase in the positive longwave radiative forcing estimated to have occurred since the industrial era as a result of fossil and biofuel combustion [*IPCC,* 2001]. This longwave heating caused by increased concentrations of the so called greenhouse gases is what provides the consensus explanation of global warming.

Records from six widely separated measurement sites (Figure 1b) show that the reversal from global dimming to global brightening occurred almost simultaneously some 20 years ago; this conclusion agrees with the measurements from the World Meteorological Organization's Baseline Surface Radiation Network reported by *Wild et al.* [2005].

The cause of these large changes in $E_{g\downarrow}$ is not known. The one most often suggested—changes in anthropogenic emissions of aerosols [*Stanhill and Cohen,* 2001]—presents a number of difficulties. First, the estimated negative shortwave forcing attributable to aerosol emissions is only one tenth of the measured reduction. Second, the recent widespread reversal of global dimming was measured at sites that have very low concentrations of anthropogenic aerosols as well as in areas such as China where such emissions are high and still increasing [*Che et al.,* 2005]. Third, large changes in $E_{g\downarrow}$ were found in the United States during the first half of the twentieth century, similar in size to those occurring in the second half, despite very different rates of aerosol emission [*Stanhill and Cohen,* 2005].

Reconciling Global Warming and Dimming

Whatever the cause of changes in $E_{g\downarrow}$, the contradiction between global warming and global dimming remains. Theoretically, this paradox was resolved in a model experiment that showed that the direct and indirect effects of anthropogenic aerosols could alter the energy balance at the Earth's surface, reducing evaporation more than net all-wave radiation, and thus lead to an increase in the sensible heat flux and surface air temperature [*Liepert et al.,* 2004]. However, no evidence for a slowing down of the Earth's hydrological cycle has been reported, whereas the many reports of reductions measured in pan evaporation (potential evaporation) can more simply be explained by those measured in $E_{g\downarrow}$. Thus, the paradox remains unsolved.

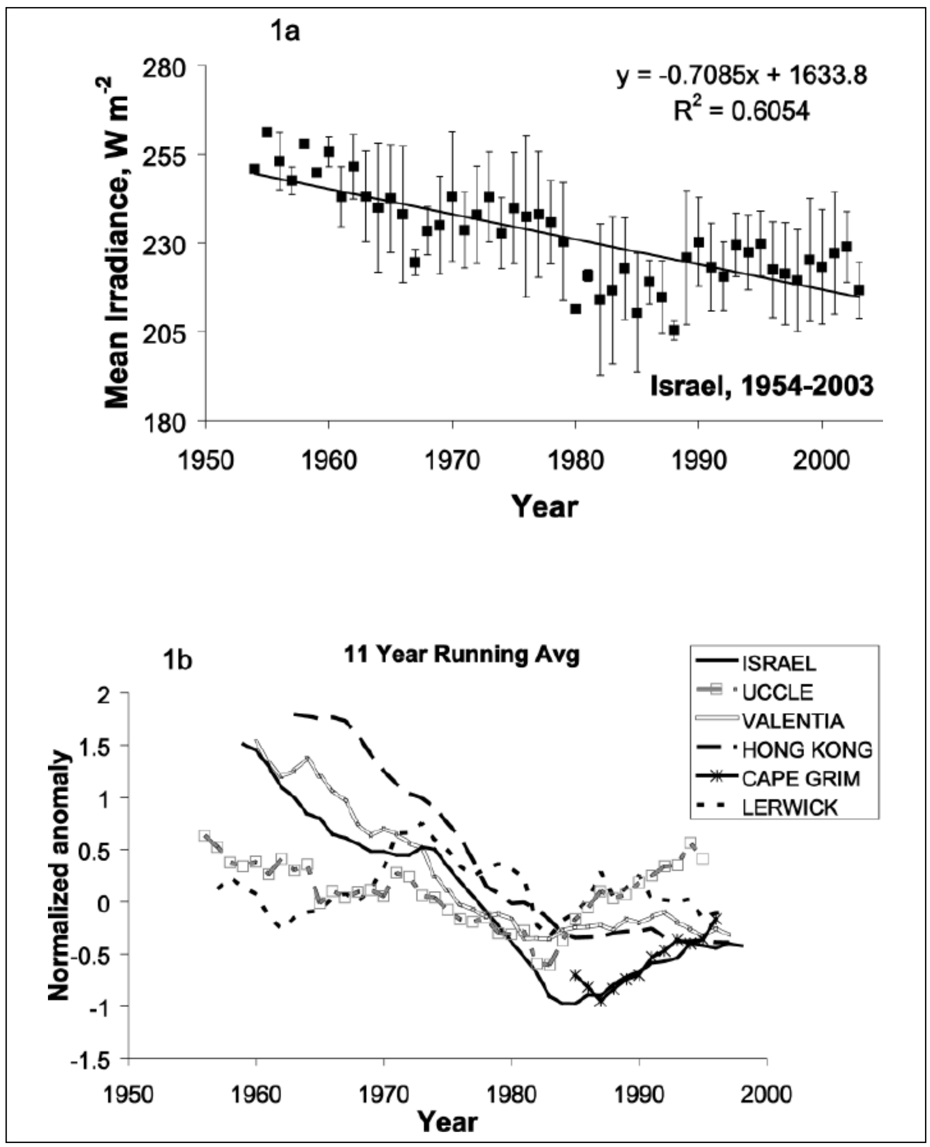

Fig. 1. (a) Fifty years of global radiation measurements in Israel, 1954–2003. Based on 233 mean annual values of $E_{g\downarrow}$ measured with calibrated thermopile pyranometers at 20 sites, the spatial variation around the mean annual values is indicated by vertical bars representing ±1 standard deviation, W m^{-2}. (b) Eleven-year running mean of normalized anomalies of annual means of $E_{g\downarrow}$ measured with calibrated thermopile pyranometers at Israel, 1954–2003; Uccle, Belgium, 1951–2000; Valentia, Ireland, 1955–2002; Hong Kong, China, 1958–2000; Cape Grim, Australia, 1980–2001; and Lerwick, United Kingdom, 1952–2002. Data courtesy of national meteorological services.

In due course, climate change science no doubt will provide an explanation for global dimming and brightening and enable these oscillations to be reconciled with those in global warming. What is difficult to account for is the way in which the Intergovernmental Panel on Climate Change (IPCC), charged with providing the world's governments with an overview of climate change science, has responded to this major challenge to the consensus explanation.

It is now 30 years since the publication of a paper calling attention to a large reduction in shortwave radiation measured over a 40-year interval at an isolated mountaintop desert site [*Suraqui et al.,* 1974]. This finding was followed by the more than 70 others listed in the bibliography previously cited.

No reference to these findings has appeared in the three massive IPCC assessment reports published during the past 15 years. This omission is surprising in view of the important practical consequences of changes in $E_{g\downarrow}$ in addition to their theoretical significance for climate change. These consequences stem from the ubiquitous role of solar energy in powering the Earth's life-sustaining water, carbon, and atmospheric cycles. One such effect of global dimming already noted can be seen in the widespread reports of reductions in potential evaporation listed in the global dimming bibliography site. Another practical consequence, that of global brightening, may have already appeared in the increased net primary production of vegetation monitored from satellites over most of the Northern Hemisphere since the early 1980s [*Brown et al.,* 2004].

The omission of reference to changes in $E_{g\downarrow}$ in the IPCC assessments brings into question the confidence that can be placed in a top-down, 'consensus' science system that ignores such a major and significant element of climate change.

A separate and more fundamental question is whether scientific understanding of climate change is now sufficient to produce a useful consensus view. Is climate change a science or is it a trans-science, asking questions that can be stated in the language of science but that are currently beyond its ability to answer?

The cautionary note global dimming and brightening sounds for climate change scientists is not a new one; rather it strikingly vindicates the two rules of climate change set out by Peter Wright 30 years ago [*Wright,* 1971]. The first rule states that some feature of the atmosphere can always be found that will oscillate in accordance with your hypothesis; the second states that shortly after its discovery, the oscillation will disappear.

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New Madrid GPS: Much Ado About Nothing?

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Two articles in this issue address the surprising and intriguing negative result that high-precision geodetic measurements find no compelling evidence for crustal motions in the New Madrid Seismic Zone of the central Unites States.

The geodetic measurements have drawn great interest because they add another puzzle to the many surrounding New Madrid. This area is the best known case of large earthquakes within the interior of the plates, in continental lithosphere. Such earthquakes are much rarer and release much less seismic energy than those at plate boundaries. Because idealized plates are perfectly rigid, these earthquakes demonstrate that deformation occurs within plates and provide a lower bound on their rigidity. Moreover, precisely because such earthquakes are rare, they pose a hazard to areas that are less well prepared for earthquakes than areas with more active ones. Assessing the hazard is further complicated by a growing sense that earthquakes within plates migrate among seismic zones that 'turn on,' remain active for some time, and then 'turn off.'

The potential hazard is illustrated by the large (magnitude 7) earthquakes that occurred in 1811 and 1812, causing shaking across much of the area. Houses collapsed in the tiny Mississippi River town of New Madrid, Mo., and minor damage occurred in St. Louis, Mo., Louisville, Ky., and Nashville, Tenn. The smaller earthquakes that continue today, which may be aftershocks of the 1811–1812 events, are more of a nuisance than a catastrophe. For example, the largest earthquake in the past century, the 1968 (magnitude 5.5) southern Illinois earthquake, was widely felt and caused damage but no fatalities. However, large earthquakes like those of 1811–1812 would be much more destructive. Paleoseismic data suggest that these have occurred about 500 years apart in the past 1000 years and hence may recur.

Surprisingly little is known about these earthquakes. It is not clear why they occur, when they started, when, if ever, they will recur, and how large a hazard they pose. As a result, researchers looked to the new tool of GPS geodesy for new insights and were surprised by the results [*Newman et al*., 1999].

A GPS measurement yields a site's position to a precision of millimeters, so a series of measurements over time gives its velocity. This is typically plotted as a velocity vector from the site's position, with an error ellipse about the vector's head showing the uncertainty in velocity. Ideally, the ellipse is a small region about the vector's head, showing that the velocity is well constrained. This is far from the case for sites in the New Madrid zone (Figure 1, top). The site velocities shown, which are motions with respect to the rigid North American plate, are small—less than 2 millimeters per year—and generally within their error ellipses. Hence most sites show no motion significantly different from zero. In other words, the GPS data do not require that they be moving at all, and restrict any motion to being very slow. Moreover, the vectors do not show the spatially coherent pattern typically seen in deforming seismic zones.

The results are gratifying from the view of plate tectonics, in that they and sites elsewhere in eastern North America show that the plate is quite rigid, with the major deviation being vertical motion due to postglacial adjustment. Beyond this motion, there is no clear case for tectonic effects, in that the small motions could be a combination of observational and analysis errors, and small motions of the geodetic monuments. However, much faster motion had been expected because of the earthquakes. It had been suggested that the earthquakes of 1811–1812 were magnitude 8 events and occurred about every 500 years. If so, more than 5 millimeters per year of average motion during the interval between earthquakes would be needed to store up the slip for a future large earthquake (Figure 1, middle). Hence, the first inference from the slow motions was that typical large earthquakes in the area are smaller, magnitude 7, in accord with recent analysis of historic records of the intensity of shaking