Global dimming and brightening in New Zealand

Ben Liley

National Institute of Water & Atmospheric Research (NIWA), Lauder, Central Otago, New Zealand

Abstract. Global irradiance in New Zealand declined from 1960 to 1990, and increased thereafter. These changes are attributable to decadal variation in cloud cover rather than to aerosol.

Background

Several studies, mostly using the Global Energy Balance Archive (WMO/ICSU World Climate Programme), show solar irradiance at Earth's surface declined from 1960 to 1990 (e.g., Figure 1).

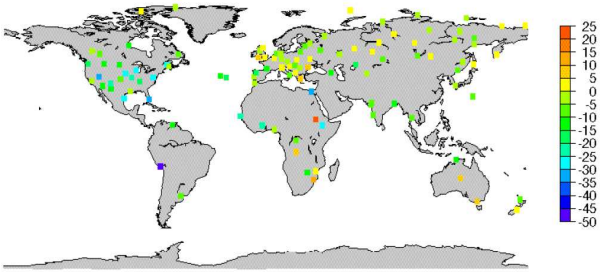

Figure 1. Difference in surface solar radiation from 1961-1970 to 1981-1990, in W m^{-2} (Liepert 2002).

Subsequent GEBA and BSRN data show an increase after 1990. Worldwide, approximately one third of this effect has been attributed to change in aerosol optical depth (AOD) and two thirds to change in cloud cover. New Zealand data show similar trends in irradiance, but there is too little aerosol to explain any of the change (Liley 2009). The analysis is updated here with data to the end of 2013.

New Zealand irradiance data

Four sites in New Zealand have global irradiance time series of relevant length. Monthly means and trends (zeroth-order spline, knot at 1990) are shown in Figure 2.

A decline in global irradiance could be from:

- increased absorption or scattering by cloud
- increased absorption by aerosol
- drift in instrument calibration.

In particular, the proximity of the knot (turning point) to the Pinatubo eruption in June 1991 is suspicious. However, Pinatubo aerosol strongly scattered direct radiation but had only a small effect on global irradiance, as shown in Figure 3.

Clear-sky trend

From hourly data, as recorded more recently, clear-sky days can be distinguished. They correspond closely to the 10% of days with highest total irradiance, a criterion then applicable before hourly records. Trends are shown in Table 1. A real change in clear-sky irradiance would result from increase in aerosol extinction, but especially absorption. The difference between all-sky and clear-sky results is attributable to changes in cloud cover.

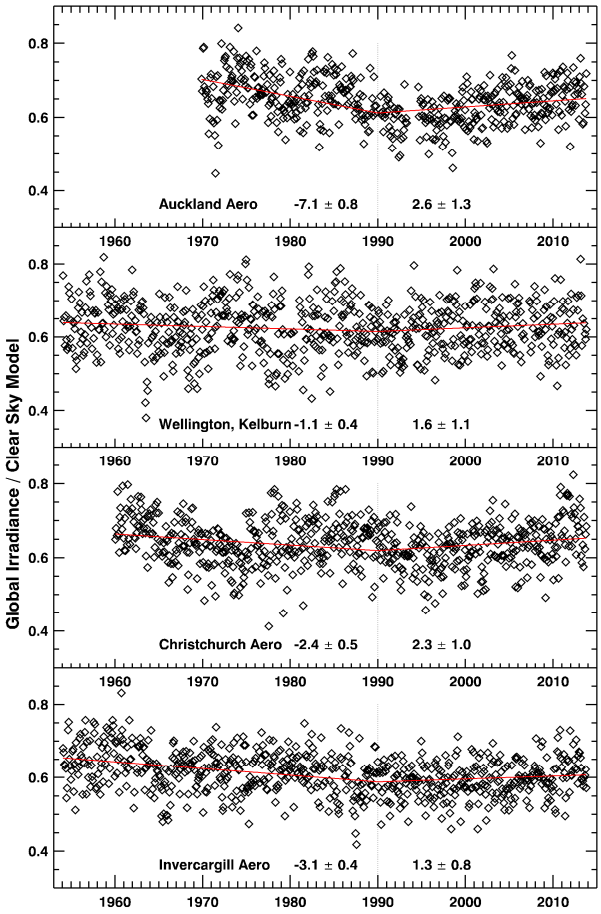

Figure 2. Monthly total global irradiance at four NZ sites as a fraction of clear sky, with trends per decade for 1960-1990 and for 1991-2013.

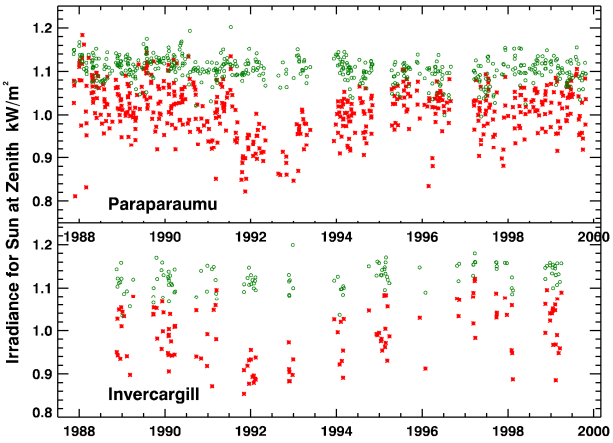

Figure 3. Global (green) and direct (red) irradiance for putative zenith sun, extrapolated from data for Paraparaumu (41° S) and Invercargill (46° S).

Table 1. Decadal trends for all days, and the 90th percentile 'clear-sky' days. Figures are given in W m^{-2} per decade. Mean irradiance is ~ 220-270 W m^{-2}.

Location	Years *from*	Before 1990		After 1990	
		Total	Clear sky	Total	Clear sky
Auckland Airport	44 *1970*	-11.8±0.9	-4.3±0.3	3.7±0.8	1.5±0.3
Wellington, Kelburn	60 *1954*	-1.5±0.5	-1.2±0.1	2.2±0.8	-0.3±0.2
Christchurch Airport	54 *1960*	-3.6±0.5	-2.3±0.1	2.8±0.7	2.2±0.2
Invercargill Airport	60 *1954*	-3.8±0.4	-1.4±0.1	1.3±0.6	0.6±0.2

Aerosol optical depth (AOD)

A 5% reduction in clear-sky global irradiance requires a change of 0.05 in purely absorbing AOD (e.g., soot), or a change of at least 0.2 in AOD of typically scattering aerosol. For most of New Zealand, this is contradicted by observations of visibility, and especially by AOD measurements at Lauder shown in Figure 4.

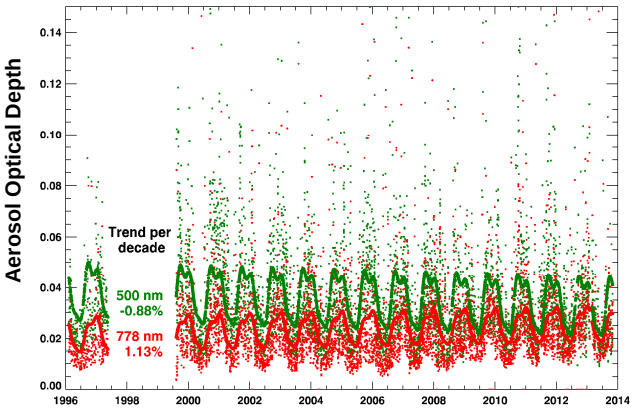

Figure 4. Aerosol optical depth (AOD) at Lauder (45° S).

Instrumentation

To detect decadal trends of this order reliably, long-term stability is essential. Pyranometers, and especially silicon photodiodes, as widely used for measuring global irradiance, lack such stability. Any change in clear-sky irradiance is confounded with instrument drift.

A separate measure of changes in cloud is available from sunshine hour records, originally with Campbell-Stokes recorders that burned a track on paper tape, and subsequently from electronic detectors. Though their radiometric calibration is less reliable than a good pyranometer, the binary detection of direct radiation as more or less than 120 W m^{-2} seems to be a more stable measurement.

Sunshine hours have been measured at more than 200 sites around New Zealand and the South Pacific, from as early as the 1900s (Figure 5). Data from adjacent sites have been merged in the analysis to yield longer records for individual spline fits.

The mean and standard error of the trends in each period are shown in Table 2 (excluding two outliers from the latter period). The trends are also expressed in W m^{-2}, from comparison at sites that measure both.

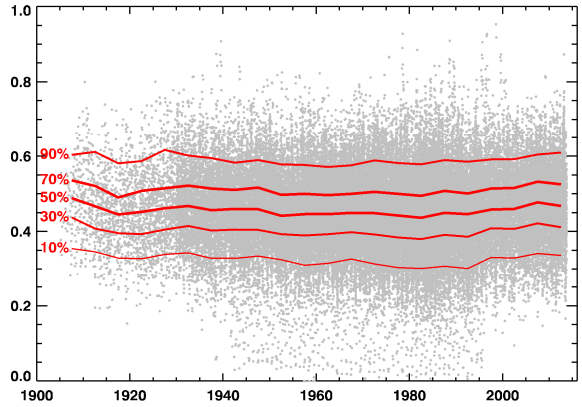

Figure 5. Sunshine hours as a fraction of total available, and 5-year percentiles, for over 200 sites in New Zealand.

The additional data from 2008 to 2013 confirm the brightening trend found in the earlier study, with a slightly smaller trend (5.42 to 4.85 W m^{-2} /decade) but narrower confidence interval. The trends, due to changing cloud cover across New Zealand, are shown in Figure 6.

Table 2. Decadal trends for all days, and the 90th percentile 'clear-sky' days. Figures are given in W m^{-2} per decade. Mean irradiance is ~ 220-270 W m^{-2}.

Period	Number of sites	% / decade		W m^{-2} / decade
		Mean ± s.e.m	S.D.	
1950 - 1990	86	-1.55 ± 0.41	3.80	-2.14 ± 0.57
1991 - 2013	53	3.52 ± 0.63	4.60	+4.85 ± 0.87

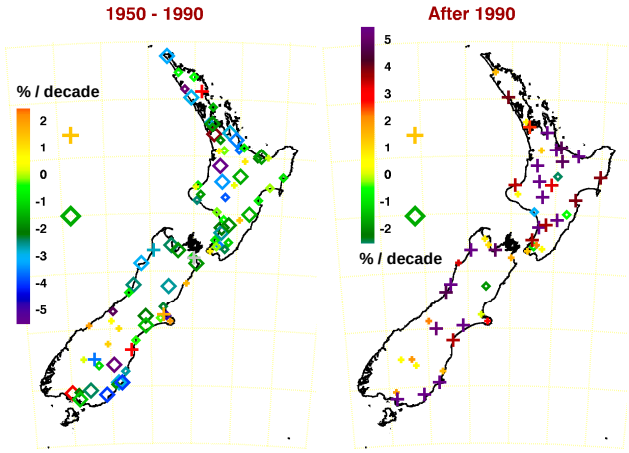

Figure 6. Trends in sunshine hours as a fraction of maximum possible. Larger symbols denote trends significant at 2-σ level from fitted error.

References

Liepert, B.J. 2002. Observed reductions of surface solar radiation at sites in the United States and worldwide from 1961 to 1990. Geophysical Research Letters 29(10): 10.1029/2002GL014910.

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