Global dimming, clouds and aerosols

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Abstract. Recent papers in the international literature on global dimming found a mixed pattern in data from New Zealand. Closer analysis of pyranometer data from four long-term sites shows a downward trend dominated by clear-sky (aerosol or calibration) effects. Lauder data show no comparable nationwide increase in aerosol, suggesting that variation in instrument sensitivity is the cause. A comparison with much longer records of sunshine hours shows that there has nevertheless been a trend of increasing cloudiness to around 1985, and a decline since then, consistent with the global pattern.

Global irradiance

Several recent studies, mostly based on the Global Energy Balance Archive (GEBA), have shown that solar irradiance at Earth's surface declined from 1960 to 1990 (Gilgen *et al.*, 1998; Liepert, 2002; Stanhill and Cohen, 2001). The trend was especially strong in the Americas, parts of the USSR, Israel, sub-Saharan Africa, and some of Asia. The global average trend was about -3 W m^{-2} per decade, for a total of -6 to -9 W m^{-2} up to 1990. Clear sky data show that as much as 1/3 of the decline can be attributed to increasing aerosol optical depth (AOD), with the rest due to increased cloudiness, some of which may be an indirect aerosol effect. The decline in solar surface irradiance has been shown (Roderick and Farquhar, 2002) to be consistent with decreased pan evaporation, and reduced diurnal temperature range (DTR).

Australia and New Zealand show both increases and decreases in GEBA data. New Zealand data are consistent with the global trends in pan evaporation (Roderick and Farquhar, 2005) and DTR (Salinger and Griffiths, 2001).

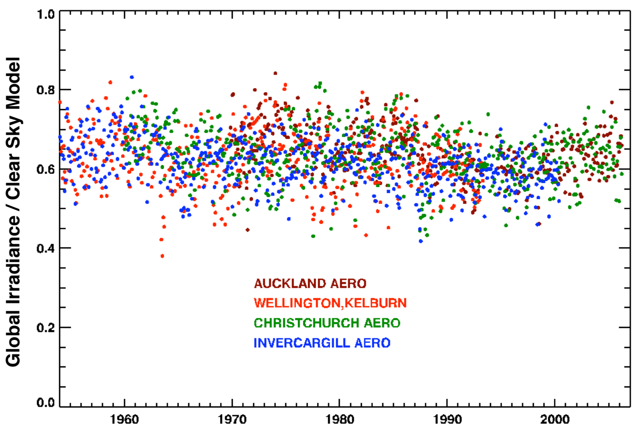

Figure 1. Monthly mean irradiance as a proportion of clear-sky model values, for four long-term NZ records.

New Zealand irradiance

There are few NZ sites with pyranometer data before 1970. Four of them are shown in Figure 1, and they seem to support the global trends up to about 1990. The data in Figure 1 also show the other pattern observed worldwide in recent years: an increase in global irradiance since 1990, reversing the previous trend (Wild *et al.*, 2005) from dimming to brightening.

The data in Figure 1 need to be treated with caution, as there is uncertainty about the stability of pyranometer calibration over decades. This difficulty was the motivation for the Baseline Surface Radiation Network (BSRN), established from 1992 at the initial sites, and at Lauder from 1999.

New Zealand pyranometer data from 1970 to 2002 were carefully quality-controlled for NIWA's UV Atlas project, which requires close alignment of the data with model calculations for clear skies. Any scaling required to align the measurements with the model is then a measure the direct radiative effect of aerosol, or of the drift in instrument sensitivity. Table 1 shows this comparison.

Table 1. Trends in irradiance for four NZ sites, in W m^{-2} per decade. Mean values are ~ 220-270 W m^{-2}.

Location	Years	Year range	Trend Overall	Trend Model	Trend Clear	Trend Cloud
Auckland Aero	23	1970-2002	-7.517	0.054	-4.142	-3.429
Wellington, Kelburn	17	1970-1992	-6.407	1.299	-6.297	-1.410
Christchurch Aero	24	1972-2002	-3.071	0.076	-3.457	0.311
Invercargill Aero	25	1971-1999	-3.039	0.257	-3.685	0.390

'Model' trend is due to water vapour or pressure; 'Clear' is aerosol, or calibration shift; 'Cloud' is residual due to cloud.

Although these data cross the transition from dimming to brightening, they show a marked downward trend. The trend is enhanced somewhat by an increase in clear sky values calculated for the measured pressure and humidity. Restricting the data to just clear skies gives the component due to aerosol extinction or to a drift in calibration of the instruments. In these data, it is the greater part of the decrease in measured irradiance. It might seem plausible that aerosol increased at these urban sites, as it did in the USSR and parts of Asia over the same period, but the magnitude of the change seems unlikely for New Zealand.

Aerosol optical depth

A 4-5 % reduction in irradiance would require an increase of about 0.05 in purely absorptive AOD (across the visible spectrum, due to soot for example. For the predominant aerosols that mostly scatter rather than absorb, energy removed from the direct beam, as measured by AOD, largely reappears as diffuse radiation in global irradiance. For aerosols with high single-scatter albedo, AOD would have to be much larger (e.g., 0.2) to account for the 4-5% reduction in irradiance. This did occur in the year after the June 1991 eruption of Mt Pinatubo, contributing to a cold NZ winter in 1992, but there has been no long-term increase of this size for the country. Measurements at Lauder in 1996/7 showed monthly average AOD to be 0.02 – 0.05 at a wavelength of 500 nm (Fig. 2). A decade of data since then confirms this range, well below the values needed to account for the measured decline in clear-sky irradiance across New Zealand as a whole. This implies that the latter is largely a calibration artifact.

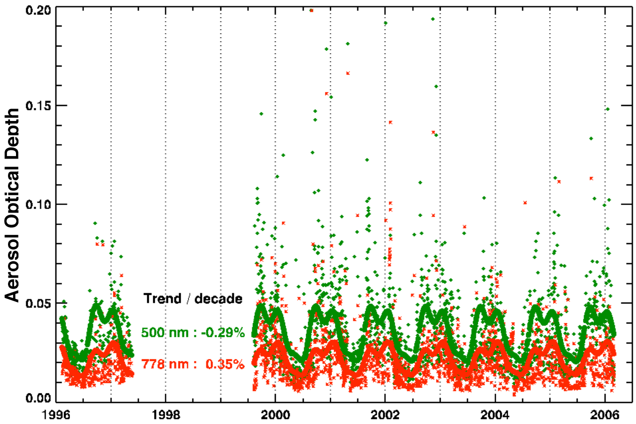

Figure 2. Aerosol optical depth (AOD) at 500 nm and 778 nm over Lauder, Central Otago.

Sunshine hours

The difference between total and clear-sky trends is due to cloud. Though Figure 1 shows data from 1954, there are few stations in the NZ climate network with pyranometer data from before 1970. An alternative and independent measure of the change in cloud can be found in the record of sunshine hours at 207 sites around NZ and the South Pacific, providing over 61,000 monthly totals as shown in Figure 3.

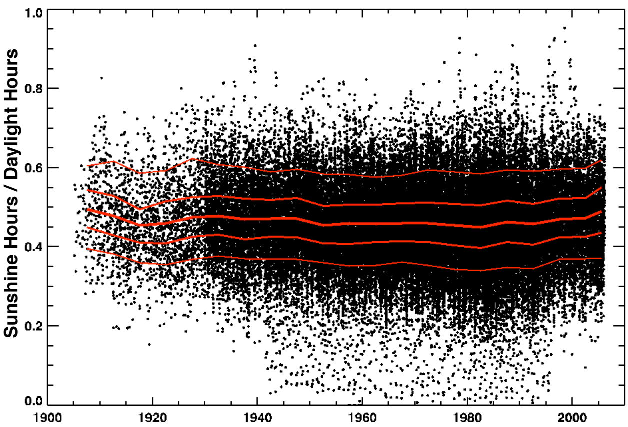

Figure 3. Monthly mean sunshine hour fraction. Lines show deciles 1, 3, 5, 7, 9 for 5-year intervals.

Though measurements at a few sites started as early as 1905, many stations have been repositioned or replaced by a nearby station over the century. Linking all sites within 8 km of each other, and within 125 m altitude, gave groups with smooth transitions between the time-series for each station in the group. Global trends, as cited earlier, suggested a spline fit, allowing one trend up to 1985, and another thereafter. Fitting the 60 site groups (54 within NZ) with the longest series gave mostly negative trends to 1985, and positive trends thereafter, as shown in Figure 4.

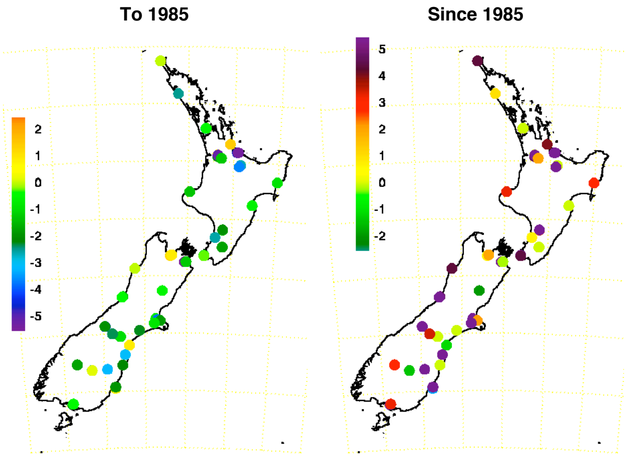

Figure 4. Trends in sunshine hours, expressed as the decadal change in percentage of maximum possible hours.

The mean and its 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, using a regression of irradiance fraction on sunshine hour fraction for 22 sites with enough simultaneous data.

Table 2. Mean decadal trends in sunshine hour percentage, for the site groups with the longest records.

Period	No of sites	% / decade		W m^{-2} / decade
		Mean ± s.e.m.	S.D.	
1905-1985	54	−1.62 ± 0.22	1.65	−2.23 ± 0.31
1986-2006	52	3.34 ± 1.07	7.73	+4.61 ± 1.48

These figures are consistent with GEBA- and BSRN-derived global trends as described above. Further work will focus on a site-by-site comparison of radiation, cloud, and climate records, using the extended UV Atlas data set.

References

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