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The reduction of global radiation in south-eastern Norway during the last 50 years

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With 2 Figures

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Summary

At the Norwegian University of Life Sciences (previously known as the Agricultural University of Norway), measurements of global radiation have been performed since 1949. Rurally located, 35 km south of Oslo (59°40′N, 10°46′E), the local climate is not affected by industry or heavy traffic. The recent focus on global dimming in the scientific literature, and the impact a reduction of solar radiation on the Earth's surface would have on agriculture and the biosphere in general, motivated us to collect and analyze the global radiation data. On a monthly basis, the reduction in radiation varied between more than 4% per decade in April and June to less than 2% per decade in January and May. The analyses show a reduction in the annual sum of global radiation by 2.5% or 3.1% per decade, depending on whether analyses were restricted to years with reliable and complete data sets (31 years from 1950 to 2003) or included all individual months with reliable data (545 months) were used.

1. Introduction

Evidence is gathering from all over the world (Stanhill and Cohen, 2001) which indicates that global radiation, which is the sum of direct solar radiation and the radiation diffusely scattered by the atmosphere, has been reduced over the last few decades. As a consequence, observations show that the rate of evaporation from open pans of water has been steadily decreasing over the past 50 years (Peterson et al., 1995). This reduction must be due to changes in the atmosphere, the most obvious candidates being clouds and aerosols (Stanhill and Cohen, 2001). There are several factors involved in this process which complicate the analyses. Not only must total cloud cover and aerosol loading be taken into account, but also the height distribution of clouds and the size distribution and composition of the aerosols (Roderick and Farquhar, 2001; Liepert, 2002). The changes in the atmosphere are at least partly related to the burning of fossil fuels, which links the reduction of global radiation to the observed global warming (Liepert et al., 2004). Global dimming could therefore be seen as a negative feedback to the process of global warming.

The data series from the Norwegian University of Life Sciences at Ås represents the longest time series of global radiation in Norway, and an analysis of these data could fill a gap in the overall global picture.

2. Data quality

Monthly means of global radiation for Ås for the period 1950–1959 are published in a university report (Heldal and Kvifte, 1963). A Moll-Gorczynski pyranometer (Kipp and Zonen, Delft, Holland) was used, and the data registered by a Cambridge recorder (Cambridge Instruments Co. LTD, London, UK). Calibration was performed in 1949 and 1958 through comparison with a factory calibrated instrument. No age effect was observed. Some days were missing in the original recordings due to malfunctions, run-out of recorder paper during weekends etc. Missing hours in the analog pen recordings were corrected by using observations from a Bellani spherical pyranometer (manufactured and calibrated by Physikalisch-Meteorologisches Observatorium, Davos, Switzerland) and observations of cloud cover. In this report, we exclude months with data where entire days are estimated from Bellani and cloud cover recordings, but we include those months where only fractions of days were estimated. In total, 15 of the 120 months of this period where thus excluded.

Data for the summer months of 1960–64 are published in another report (Heldal, 1966). In 1963, the observation site was moved four hundred meters to another location and a new Kipp and Zonen instrument installed. Parallel measurements performed throughout 1963 gave 11% higher radiation values for the new instrument. The authors concluded that a shift in sensitivity of the old instrument must have occurred during the period 1960–63. All values from the period were adjusted by adding 11%.

In a later report (Heldal, 1970), a small systematic shift in the recordings from the Kipp and Zonen installed in 1963, due to a zero displacement of the original recordings, were announced and accounted for. From 1964, radiation data were published in annual weather reports by the Department of Physics.

A report from 1982 (Olseth and Hegg, 1982) dealt with radiation data for the period 1968–79, with the purpose of comparing the radiation climate at Ås and Bergen. A new Eppley Precision Pyranometer (Eppley Laboratory Inc, USA) was installed in 1975 and operated in parallel with the Kipp and Zonen pyranometer for four years. The new Eppley instrument was calibrated once a year against an Ångstrøm pyrheliometer. As a result of the intercomparison, former readings from the Kipp and Zonen instruments were reduced by 9% for the period 1964–1974. This is explained by systematic errors in the recording system and not due to calibration errors, as a recalibration of the Kipp and Zonen instrument in 1981 produced the same results as previous calibrations. During late autumn, 1992, the pyranometer was struck by lightening and was replaced with a new Eppley instrument on November 4th. During the observation period from 1950 to the present date, the pyrheliometric scale (the reference scale for calibration) has changed. In the statistical analyses (performed using Mini Tab Statistical Software), this is accounted for by adjusting all data to the 1977 scale.

To conclude, the data for the years 1950–59, excluding months with gaps, are believed to be reliable as no instrument drift was observed during this period. Data for the period 1960–63 are questionable due to the 11% shift that was observed in 1963, and not knowing why and when this happened. Data for the period 1964–74 are reliable but with a greater uncertainty due to the 9% correction that was performed as a consequence of the intercomparison with the more accurate Eppley instrument. The data from 1975 until present-day were obtained from pyranometers calibrated on a regular basis (Hegg, 1983).

3. Results

Normalized values of the annual sums of global radiation are shown in Fig. 1. A linear regression curve was fitted through the points. All years missing one or several months of data are omitted, except for five years missing only December or January. (For these five years, 1955, 1958, 1959, 1980 and 1989 the missing value was replaced by the December or January average for all observed months.) The annual sums are normalised by dividing values for each year by the annual average for all observed years.

The regression equation is given by

$$y = 5.9\ (\pm 1.5) - 0.0025\ (\pm 0.0008) \cdot x \qquad (1)$$

x is the year, and the numbers in parenthesis the standard errors based on the 95% significance level. The mean reduction $\Delta G/G$ of the annual sum of global radiation per decade is 2.5%.

Figure 2 shows the reduction of global radiation on a monthly basis. Error bars represent the standard error. The reduction varies from more than 4% in April and June to less than 2% in January and May. For the months January and December, the reduction of global radiation is not statistically significant.

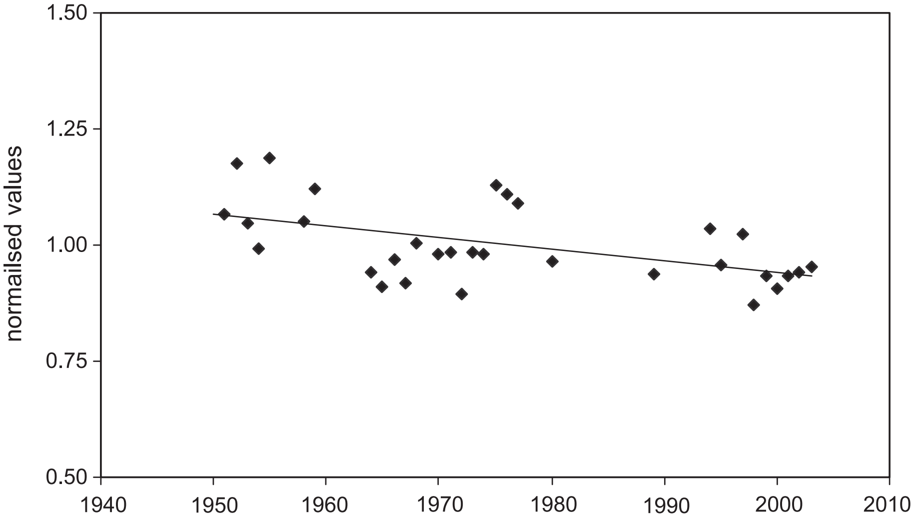

Fig. 1. Normalized annual sums of global radiation from 1950 to 2003 for Ås, Norway

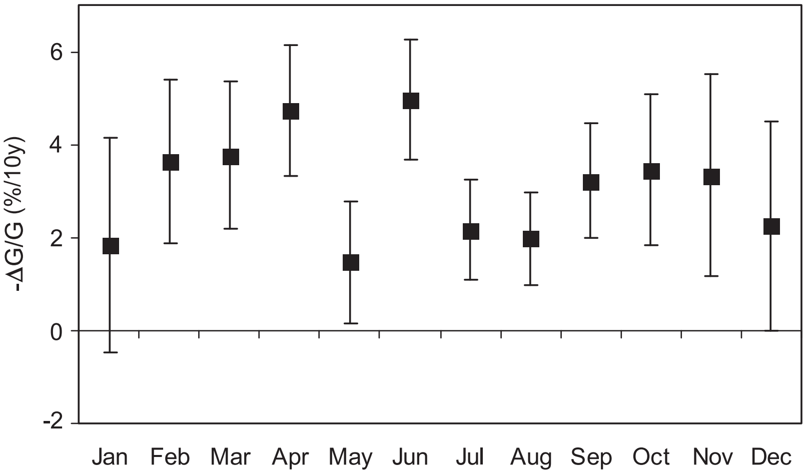

Fig. 2. Mean monthly reduction in the global radiation per decade from 1950 to 2003 for Ås, Norway

If the mean reduction $\Delta G/G$ of the annual sum of global radiation per decade is calculated from the *monthly* changes by weighting each month with the monthly average G, the annual reduction $\Delta G/G$ per decade is 3.1%. This is a more realistic value for the reduction as it is based on a total of 545 monthly values, an equivalent of 45 years – whereas the reduction of 2.5% is based on only 31 years due to omitted years with missing months.

4. Discussion

In their review article, Stanhill and Cohen (2001) conclude that the globally averaged reduction of global radiation equals 2.7% per decade. However, the scatter is large. For example, stations in China show approximately 10% reduction per decade (Li et al., 1995; Stanhill and Kalma, 1995); stations situated between 40° N and 60° N in the former Soviet Union and in the Baltic, show a reduction between 3% to 5% (Abakumova et al., 1996; Russak, 1990); and Arctic stations in the Northern Hemisphere show reductions between 0.6% and 5% (Stanhill, 1995). The significant decrease in zonally averaged global radiation found between 25° N an 45° N is closely related to the increase of anthropogenic carbon emissions (Stanhill and Cohen, 2001). The maximum rate of decrease (1.2% per year) was centered around 35° N, close to the zone with the largest industrial activities and fossil fuel energy consumption.

5. Conclusions

The Norwegian University of Life Sciences is situated in a rural location 30 km away from any industrial activity. A change in atmospheric transmittance caused by increased aerosol content from the burning of fossil fuel must be explained by large scale transport and not by local sources. A reduction in global radiation between 2.5% and 3.1% per decade found in this study agrees with the overall picture presented by Stanhill et al. (2001). Future investigations should go into greater detail regarding the trajectories of large scale transports and investigate the relationship between trajectories and the annual patterns shown in Fig. 2.

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