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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Trends of solar ultraviolet irradiance at Barrow, Alaska, and the effect of measurement uncertainties on trend detection" *by* G. Bernhard

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I thank Robert Stone for his thoughtful suggestions. His comments are repeated below, followed by my response.

Comment 1: I suggest inclusion of another analysis and revision of Fig. 6. Actually cross-correlate the UV parameters with the date of snow onset and plot this on Fig. 6 to show the anti-correlation more clearly. This will bolster the conclusions graphically and you can present the correlation coefficients as well.

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Response: Fig. 6 was revised and now also includes the monthly mean irradiance at 345 nm (E345) for October (see the new figure at the end of this comment). E345 is referenced to the right y-axis, which is inverted (small values are on top). The red and blue lines of the new figure correlate well between 1995 and 2009. The coefficient of determination for this period is R^2=0.73. (The good correlation indicated graphically is in fact an anti-correlation because of the inverted right y-axis). The good correlation corroborates the original conclusion of the paper that the trend in E345 can be explained by changes in snow cover. As the day of permanent snow-cover is getting progressively later, the fraction of the month with high surface albedo is decreasing. As described in the paper, reduced surface albedo leads to a decrease in UV radiation and this is confirmed by the E345 dataset. There is no good correlation for the years 1991-1994. This may have several reasons. First, the period 1991-1993 was affected by aerosols from the Mt. Pinatubo eruption, which has lowered the surface irradiance by a few percent (e.g., Bernhard et al., 2007). Second, during the early years, the day of the start of persistent snow cover already occurred in September. It therefore can be expected that there is not a good correlation between that day and irradiance for October. Third, factors other than albedo such as cloud cover contribute to the variability.

New caption for Fig. 6, shown at the end of this comment: Comparison of onset of snow cover and irradiance at Barrow. Blue symbols, left axis: Day of year when surface albedo becomes larger than 0.6 and stays above 0.6 for the rest of the winter. Heavy blue line: Linear regression to this dataset. The date of persistent snow cover was not well defined in 2006, and the associated data point is missing (broken blue line). Red symbols, right axis: Monthly mean irradiance at 345 nm for October. Note that the right axis is reversed. No data are available for 2009 (broken red line). The broken black line indicates 1 October.

The following text will be added to the Discussion: “I determined the first day of fall when albedo becomes larger than 0.6 and remains above 0.6 for the rest of the winter.

ACPD
11, C10952–C10957, 2011

Interactive Comment

Results shown in Fig. 6 indicate that this day has advanced considerably during the last 20 years with a statistically significant trend of 13.6±9.7 days per decade (blue dataset in Fig 6). Note that the date of persistent snow cover was not well defined in 2006 because of a melting period in mid-October; the data point for 2006 is therefore missing. For the period 1995–2008, the day of the start of persistent snow cover anti-correlates well with the monthly mean irradiance at 345 nm for October (red dataset in Fig. 6). The coefficient of determination R^2 is 0.73. As the day of permanent snow-cover is getting progressively later, the fraction of the month with high surface albedo is decreasing. Reduced surface albedo leads to less UV radiation. The good anti-correlation between the start of persistent snow cover and E345 suggests that the dominant fraction of the trend in E345 is caused by changes in snow cover. There is no good correlation for the years 1991–1994. This may have several reasons. First, the period 1991–1993 was affected by aerosols from the Mt. Pinatubo eruption, which has lowered the surface irradiance by a few percent (e.g., Bernhard et al., 2007). Second, during this period, the day of the start of persistent snow cover already occurred in September and a good correlation with E345 for October cannot be expected. Third, factors other than albedo such as cloud cover contribute to the variability."

Comment 2: It should also be pointed out that the period of record discussed is rather short and such trends are not representative of the longer term and have not, nor cannot be sustained. Caveats should be included in the conclusions or discussion of this phenomenon. Such a trend, 13.6+/-9.7 days per decade, cannot be sustained, nor is it historically sustained in the longer time series. Fig. 6 begins in 1992 and ends in 2009, with 2006 missing. In the longer time series you find this choice might result in "end-point" issues when performing the regression because 1992 was the second earliest onset and 2009 the latest in the time series under consideration. I have gauged this against the 1974-2010 record I have at my disposal, although my analysis is preliminary and unpublished. Further, I understand why 2006 was omitted

ACPD

11, C10952–C10957, 2011

due to ambiguity. It should be stated why somewhere. A more sophisticated algorithm is probably required to determine "onset" for years when the signal is ambiguous; that is, albedo exceeds 60% for a day or more but then the snow melts and it drops to < 60%. Refinement of the criteria for these ambiguous years I realize is beyond the scope of this study, however. The interested reader can access yearly time series of daily average albedo at Barrow at: http://cmdl1.cmdl.noaa.gov:8000/www/albedo/ that will illustrate the value and also pitfalls of determining onset of snow definitively.

I have verified independently the trend of onset date stated in the paper for the same period of time. I also have performed an analysis (unpublished) of the 1974-2010 time series and find the following: the overall "trend" is 2.7 (+/-3.3) d/dec, and broken at 1991. I find a distinct negative trend from '74-'91 and positive trend from '91-2010 of -6.7(+/-9.0) and +10.3(+/-7.6), respectively; noting that my value for the recent decades is lower than that reported by the author (by 3 d/dec) but I also include my best for 2006 and 2010. This illustrates the issue of endpoint influence and selection of a rather short time series for this sort of analysis, although does not negate the value of correlation with the UV parameters in any way in my opinion.

My concern is that caveats be made pertaining to the record of snow onset at Barrow (as presented), with recognition the trends are not sustainable and past records suggest a more cyclical behavior. In turn, it might be speculated that these variations occur in response to dynamical forcing due to changes in both atmospheric circulation and also the distribution of sea ice in the Beaufort Sea at the time of snow onset. If the sea remains open as is the case for large retreat in recent years, the snow may come later than earlier?

Response: The following text will be added to the Conclusions: "This large trend [referring to 13.6±9.7 days per decade] was derived from a relatively short period (18 years) and cannot be sustained indefinitely. Trend estimates are sensitive to the first and last point of the time series under consideration. The magnitude of the observed trend may be exaggerated by the fact that the first year of the time series (1992) was the year with the second-earliest onset of snow cover while the last year (2009) was the year with the latest arrival of snow. Trend estimates for longer periods are quite different. For example, the trend for the period 1974–2010 is +2.7±3.3 days per decade and trends for the sub-periods 1974–1991 and 1991–2010 are -6.7±9.0 and +10.3±7.6 days per decade, respectively (pers. comm., Robert Stone, NOAA GMD, based on unpublished data). While it is possible that the timing of persistent snow cover will remain delayed for the foreseeable future as a consequence of climate change, the observed trend could also be a part of a decadal cycle linked to periodic atmospheric circulations (Stone et al., 2005). It can be expected that the large changes in sea ice observed during the last decade will also have a profound influence on precipitation, including timing and amount snow fall."

Interactive comment on Atmos. Chem. Phys. Discuss., 11, 26617, 2011.

ACPD

11, C10952–C10957, 2011

Interactive Comment

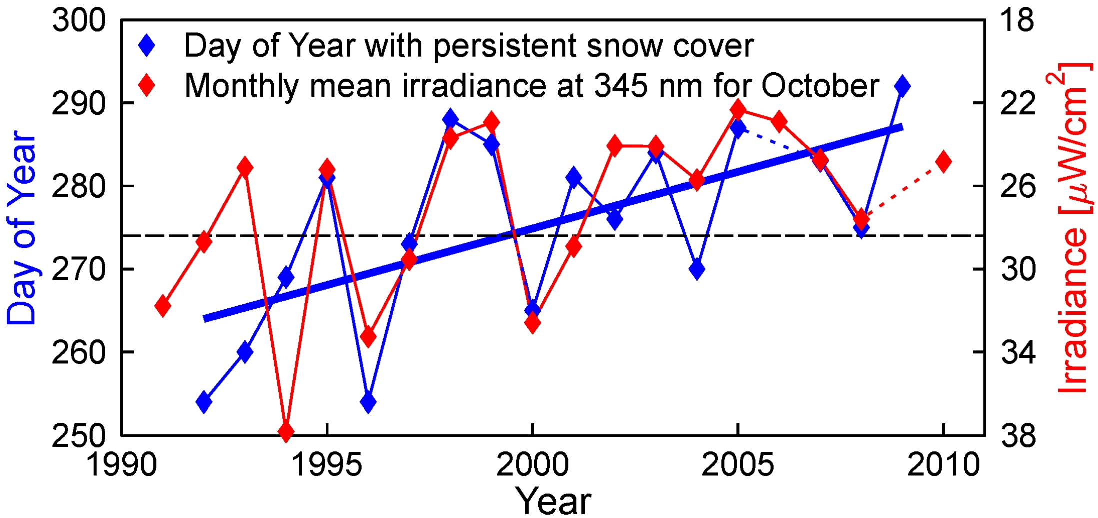

Fig. 1. Comparison of onset of snow cover and irradiance at Barrow. (See complete caption in text above).

ACPD
11, C10952–C10957, 2011

Interactive Comment