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Reply to comment by F. A-M. Bender on "A multi-data comparison of shortwave climate forcing changes"

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[1] The manuscript by *Bender* [2006] (hereinafter referred to as *Bender*06), suggests that the conclusions by *Pallé et al.* [2005] (hereinafter referred to as *Palle*05), are undermined by limitations in their data. In particular, they criticize the data for not being global. We agree with *Bender*06 that all the albedo measurements suffer deficiencies at some level, but we do not agree with her interpretation of our results. We show here how, 4 of the 5 data sets used by *Palle*05 can be considered global and that there is plenty of evidence for decadal variability in the shortwave part of the Earth's radiation budget.

[2] Truly global albedo observations from satellite platforms are available during 1985–1989 from ERBE data and 2000-present from CERES. The comparison of these two data sets already shows a large change in albedo of about 2% (about 6 W/m^2). Surprisingly, the same change in global albedo is predicted by estimates based on earthshine data and ISCCP cloud amount [*Pallé et al.*, 2004]. This leaves only two possibilities, either the Earth albedo has changed by this large amount or there is an offset in the albedo estimates of the two data sets. ERBE and CERES use very different instrumentation and their results might not be directly comparable. The only long-term inter-calibration of ERBE and CERES data, available for the tropical regions, shows large decadal variation [*Wielicki et al.*, 2002]. On the contrary, global albedo models do not shown any decadal variability [*Charlson et al.*, 2005].

[3] The earthshine observations cover altogether about 2/3 of the Earth's surface. Based on these measurements and simultaneous cloud properties from the ISCCP data set we reconstructed albedo changes since 1983 [*Pallé et al.*, 2004]. In our reconstruction we used a subsample of the ISCCP data set, that covers the areas and times of our earthshine observations. Based on this fact, *Bender*06 concludes that the reflectance estimates of albedo based on the earthshine methodology cannot be considered global. This is correct but incomplete. *Pallé et al.* [2004] has already explained, although not explicitly shown, that in order to test our results at a global scale we have constructed a large number of mock reconstructions by artificially changing the dates and time of our observations, thus effectively using a large number of ISCCP data subsamples covering the whole data set several times. All the mock reconstructions, and the average, are within the error bars of the reconstruction shown in Figure 3 of *Pallé et al.* [2004]. Thus the earthshine results of decreasing albedo 1985–2000 are effectively global and do not depend on the ISCCP sub-sample used. An update on this work and its interpretation is given by *Pallé et al.* [2006].

[4] *Bender*06 underlines the fact that the GOME temperature studies need further validation. Nevertheless, as reported by *Casadio et al.* [2005], UV-VIS radiance is playing the major role in the temperature variations of the GOME environment. The infrared contribution shows some signatures for Sahara overpasses, but other than that, the contribution seems to be small. S. Casadio (private communication, 2006) has conducted sensitivity tests of GOME temperatures to changes in visible radiation. In Figure 1 the anomalies in the GOME scan mirror temperatures, *T*, and Top-Of-the-Atmosphere (TOA) irradiance measurements from GOME spectra, *S*, are compared during one of its orbits. The TOA estimates are calculated by collapsing the GOME spectra over the 600–800 nm range. These plots clearly show the degree of correlation between visible radiance and temperatures. If an infrared signal is there, then it is very small. More validation work is in progress.

[5] *Bender*06 stated that: "S_{mod} [..] calculations are based on global ISCCP data, and are carried out globally. Still they are actually not an estimate of the global reflectivity, but of how clouds affect the amount of radiation reaching the Earth's surface, although the model used by *Pinker et al.* [2005] does allow for calculation of upward surface fluxes as well as TOA net shortwave fluxes''. The authors can see *Bender*06's point that S_{mod} is not a measure of reflectance, but we have difficulty with her suggestion that it is not global. *Palle*05 used S_{mod} at ground-level because it has been published and analyzed by *Pinker et al.* [2005]. The updated time series of these data now show a decrease in sunlight reaching the ground 2000–2004, following the ISCCP cloud data.

[6] *Bender*06 further writes: "Also, measuring shortwave radiation incident at the surface differs from measuring reflected radiation at the top of the atmosphere in that no surface effects can be taken into account, and that no distinction can be made between reflection and absorption in the atmosphere''. Distinguishing between reflection and absorption is not necessary in terms of TOA albedo calculations, although it might affect the S_{mod} simulations if the calculations are based solely on cloud data and aerosols are not properly accounted for. But there are other estimates of TOA albedo based on the ISCCP data. The GEWEX Surface Radiation Budget (SRB) project provides estimates of long wavelength and short wavelength radiation at the

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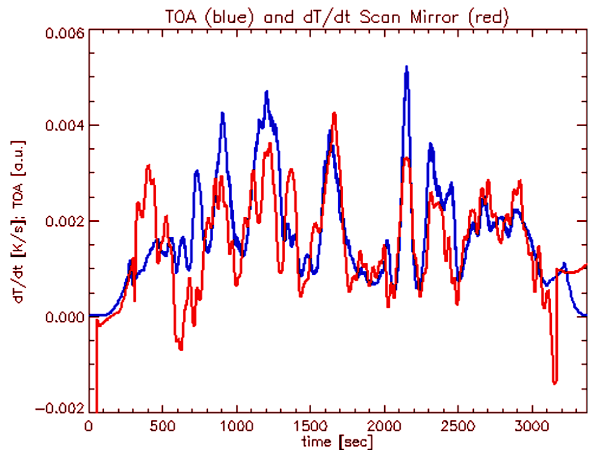

Figure 1. Top of the atmosphere anomalies in the short wavelength irradiance estimated from GOME spectra (red) and in the GOME scan mirror temperatures (blue). The temporal axis, in seconds, covers one random GOME orbit. Figure provided by Stefano Casadio.

Earth's surface and TOA since 1983. Inputs include water vapor and meteorology from the Goddard Earth Observing System, Total Ozone Mapping Spectrometer (TOMS) ozone, and ISCCP cloud and radiance information. These data show a maintained decrease in TOA reflectance 1985–2000, and an increase over the period 2000–2004 of about 2 W/m^2 [*Cox et al.*, 2005].

[7] BSRN data [*Wild et al.*, 2005] are indeed local in nature. *Palle*05 already notes that "although a simple average from only 8 stations is a crude approximation, it is the best available representation of a global observed mean surface solar radiation, at least over land areas". It was not our intention to draw conclusions at global scales from these data, but the fact remains that the most precise data set on the ground is consistent with the available global data, and with large decadal variability in reflectance, at least at local scales.

[8] Comparisons between different narrowband (ES, BSRN, GOME) and broadband (CERES) measurements will probably lead to different estimates of the magnitude of the reflectance changes, but they cannot lead to trends with opposite signs. GOME data are measured in units of degrees *K*, whereas the anomalies for the rest of the data sets are measured in W/m^2, but we do not see the relevance of this comment by *Bender*06, as an absolute reflectance change in W/m^2 was not attempted by *Palle*05. Instead, we wrote that "OBT_{GOME} anomalies are in °K and they may or may not correspond to the same forcing amplitude in W/m^2, but this evolution is highly consistent with ES observations". Finally, we note that, opposite to the absolute measurements of current satellite and ground-based instrumentation, earthshine observations are the only true reflectance measurements, and that they are absolutely calibrated because they measure relative intensities [*Qiu et al.*, 2003; *Pallé et al.*, 2003].

[9] Thus we have shown here how, except from *BSRN* data, all the data set used by *Palle*05, while not ideal, are representative of global averages, with the *BSRN* data being consistent with the former data sets over the period in which they are available. To establish unequivocally decadal trends in Earth albedo from any of these data sets alone is a difficult task. However, the overall agreement in the sign of the albedo changes among the different data sets is sufficient to conclude that albedo changes have occurred, especially over the period 1985 to 2000. Unfortunately, we have to agree that the magnitude of such changes at decadal time scales has yet to be determined with any confidence.

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