Review of "A net decrease in the Earth's cloud plus aerosol reflectivity during the past 33 yr (1979-2011) and increased solar heating at the surface," by J. R. Herman, M. T. DeLand, L.-K. Huang, G. Labow, D. Larko, S. A. Lloyd, J. Mao, W. Qin, and C. Weaver

General comments:

This is a well written paper on the development of a 30+ year normalized satellite data set from several SBUV instruments that have flown on several satellites since 1978. I am not familiar with manipulation of satellite data and the special problems that must be overcome to produce a common calibration and usable data set. However, the methods used to normalize the SBUV in sections 2 and 3 are well explained and seem plausible, and a reasonable case is made for using the 340 nm channel for this study. Therefore, I only direct my comments to the data analysis and results presented.

The introduction poses the problem well, however the last part on the satellite data sets that are available is hard to follow. You mention that Norris and Slingo (2009) summarize the problems with the ISCCP data set but you do state what those problems are. In between discussions of ISCCP data, you talk about CERES, AVHRR, and HIRS as alternatives, but the ISCCP website states that they use AVHRR data. This paragraph needs to be rewritten with a more logical, less confusing manner.

Reply: 1) ISCCP does use AVHRR, but that is only part of the ISCCP data set. A large part of the ISCCP data set comes from uncalibrated geostationary satellites that are intercalibrated against low earth orbiting satellites, which have their own calibration problems. Norris and Slingo give a thorough discussion that should not be repeated in our paper. I have modified the paper as follows.

Page 31994 Line 16 Page 3 line 7
tionary). The problems of joining the disparate ISCCP data sets, starting in 1979, to produce an accurately calibrated long-term time series needed to estimate changes in short-wave energy reflected back to space has been reviewed by Norris and Slingo (2009). One of their key points is that ISCCP uses "a long series of weather satellites that were not designed to maintain onboard calibration or interface with other satellites."

I believe that you can do more than attribute the changes in LER to a "combined cloud aerosol effect." Recent papers have documented and quantified a decrease in aerosol optical depth over the oceans and over many land areas of the globe. For example, Zhao, T. X.-P., I. Laszlo, W. Guo, A. Heidinger, C. Cao, A. Jelenak, D. Tarpley, and J. Sullivan (2008), J. Geophys. Res., 113, D07201, doi:10.1029/2007JD009061 document AOD trends over the oceans spatially for a period similar to your analysis period. Chylek et al. (2007), JGR, 112, D24S04, doi: 10.1029/2007JD008740 use ocean AOD data as well as in situ AOD trends measured over various land areas to estimate that global AOD has been recently decreasing at a rate of -0.014/decade. You should be able to use this information to estimate the relative contributions of aerosols and clouds to the documented LER changes at TOA. At least you can estimate the average partitioning for the globe as a whole using Chylek et al's AOD trend. With the AVHRR AOD record, you can do this spatially over the oceans where the satellite AOD measurements are trustworthy. A recent publication by Augustine and Dutton (2013) JGR, 118, doi:10.1029/2012JD018551 partitions the relative contributions of AOD and cloud cover changes over that U.S. to changes in the surface radiation budget from 1996 to 2011. With the availability of global AOD measurements, a similar partitioning for reflected radiation at the TOA (LER) should be possible.

Reply: One could estimate the relative portion of aerosol vs cloud change using the MISR data. Except for special events (volcanic eruptions, biomass burning, dust storms) the UV reflectivity of non-absorbing aerosols over the US and Europe is less than 0.1, and is typically 0.06 based on histograms of reflectivity. If we assume that the aerosol reflectivity is proportional to the aerosol optical depth, then the MISR estimate of –0.0029 per year for the Northern Hemisphere would lead to a change in reflectivity caused by aerosols of –0.00017 per year or about –0.002 per decade. The estimated NH change in LER from clouds and aerosols is approximately –0.01 per decade. This suggests that approximately 20% of the observed LER change is caused by aerosols since 2000, the start of the MISR observations in Chylek et al. (2007).

However, this estimate is based on an assumption that changes in cloud and aerosol seen by MISR are wavelength independent and could be applied to the 340 nm region. Wavelength independence is approximately true for clouds, but not for aerosols. One could use the phase function information derived by other means (e.g., Aeronet) to estimate the wavelength dependence.

Specific comments:

p. 32005-6 When discussing Figs. 3 and 4 it may be clearer to the reader if "higher" and "lower" were used to describe latitude and longitude and "greater" and "smaller" be used to describe variations in LER.

Fixed

p. 31994, l. 21 Awkward sentence. Begin this sentence with "Evan et al. (2007)", and remove "An analysis"

Fixed

p. 31997, l. 26 The sentence beginning with "As a result, many factors…" should be moved to be the 2nd sentence of the paragraph that it resides, before the discussion of the diffuser-related problems.

Fixed

p. 32006, l. 12-15 The sentence beginning with In the NH is awkward and should be divided into two sentences.

The sentence has beren rewritten

During the NH winter (December to February) LER is higher than in the summer (June to August) from 25^{O}N to 80^{O}N, and has a larger difference than in the SH winter (June to August) compared to the SH summer (December to February).

Fig. 5 The two frames of Figure 5 should be labeled (a) and (b) and in the caption they should not be referred to as “upper” and “lower”. In the text they are referred to as 5a and 5b.

Fixed

p. 32006, l. 29 Why not just include the 2010–2011 in the list of major ENSO events and leave off the superfluous phrase beginning with “, and for most other…”

Fixed

p. 32008, l. 12-17 The two sentences beginning with “The largest change, …” are badly worded and should be rewritten.

This has been changed to read:

The largest NH change, ΔR = -0.9 RU per decade, is near 50^{O}N followed by the change at 30^{O}N-40^{O}N of ΔR = -0.7 RU per decade. An important contribution to the change in energy reflected back to space comes from the equatorial band between 0^{O} and 15^{O}S (ΔR = -0.5 RU).

p. 32010, l. 7 The entire term (λ < 4000 nm, 99% of the solar spectrum) should be in parentheses. The way you have it is very awkward.

Fixed

p. 32011 You refer to Fig. 10 in these two paragraphs, but I think you meant to refer to Fig. 11.

Fixed

p. 32012, l. 2 Figure 2 only represents one day. What is your point here?

Reply:

The description of Figure 2 has been changed to read,

“LER represents the *combined* cloud, aerosol (including haze) and surface scene reflectivity as observed from space. Changes in LER are mostly caused by clouds and, to a lesser extent, aerosols, except in regions covered by snow/ice (e.g., Greenland). While the local details vary from day to day, the global patterns of cloud cover are present every day. Most of the regional cloud patterns repeat seasonally, but with small shifts in latitude and longitude. An example of LER from a single day, 10 September 2008, is shown in Figure 2 using the daily imaging capabilities of OMI. The LER in Figure 2 is scaled from 0 to 80 RU showing some bright high clouds in the equatorial region, a bright hurricane cloud in the Gulf of Mexico (a category 4 hurricane named Ike), and the geographic distribution of cloud cover. The main patterns are from cloud cover showing higher area averaged LER towards the polar regions, an equatorial band of clouds at about 5^{O}N, and local minima (more cloud-free) at about 20^{O}N and

$20^{O}S$. Some of the smaller features are frequently recurring, such as the cloud plumes going south-eastward from Argentina, southern Africa, and Australia. Significant sulfate aerosols, which typically rise to an altitude of 3-5 km when well away from their sources, can sometimes increase the nadir-viewing LER of a scene up to 15 RU relative to a clear-sky background. Soot, smoke, desert dust, volcanic ash, black carbon and organic aerosols absorb in the NUV and can decrease the scene reflectivity.

p. 32012, l. 5 The sentence beginning with "The percent distribution…" should be the first sentence of the paragraph it resides, not the second sentence.

Fixed as follows:

The percent distribution of solar insolation with latitude is shown in Figure 12. Most of the estimated change in solar insolation comes from the latitude bands between $15^{O}S$ to 0^{O} (31%) and between $25^{O}N$ to $60^{O}N$ (36.3%).

p. 32012, l. 20 Perhaps Figure 17 should be introduced here so that the reader can see the locations of the boxes you average over for the subsections of sections 7 and 8.

The reference to the map has been introduced as follows.

LER trends from additional specific sites (Fig. 17) selected from regions with significant change shown in Figure 10 are shown in Figs. 14 to 16 and Table 2 along with maps Figs. 14-16 taken from Google Earth.

p. 32013, l. 4-6 Figures 11 and 13 say nothing about ocean currents, but they do show that the intensity of ENSO events has decreased. You should first comment on the trend in ENSO events, then suggest that that change may imply long-term changes in underlying ocean currents.

A change has been made as follows:

The 33-year decreasing reflectivity trend associated with the ENSO events (Figures 11 and 13) suggest that there may be a long-term change in the underlying ocean currents in the equatorial region. Since 2000 the LER and MEI suggest a decrease in the frequency of major ENSO events.