P3.2 A COMPARISON OF SURFACE SOLAR FLUXES IN THE NOAA OPERATIONAL GOES SRB PRODUCT WITH THOSE DERIVED FROM THE ISCCP D1 DATA

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1. INTRODUCTION

Surface solar fluxes on a global scale are available from the University of Maryland, Shortwave Radiation Budget (UMD/SRB) Daily and Monthly Data Set (Pinker et al., 2001). Surface solar fluxes for the continental US are also provided in the NOAA/NESDIS GOES Surface and Insolation Products (GSIP) (Tarpley et al., 1996; Pinker et al., 2000). The scheme used for estimating the solar fluxes in these two products is essentially the same; it is the shortwave algorithm developed at the University of Maryland (Pinker and Laszlo, 1992; Laszlo and Pinker, 1997). Over the US, radiances observed by the GOES satellite serve as input for both products; however, the processing of satellite data and their spatial and temporal resolutions are different. GSIP employs visible radiances processed at NESDIS, while the UMD/SRB product uses radiances from the D1 data set of the International Satellite Cloud Climatology (ISCCP) project (Schiffer and Rossow, 1985; Rossow and Schiffer, 1999). Calibration procedures employed at NOAA/NESDIS and those by ISCCP are different; in addition, the GOES radiances in the ISCCP processing are transformed to mimic AVHRR observations. For the flux retrieval, the narrowband radiances are converted to shortwave albedos, and column amount of ozone, precipitable water amount, solar and satellite zenith and relative azimuth angles at every hour (GSIP) and every three hours (UMD/SRB) are appended to the input data stream. The fluxes retrieved at these temporal resolutions are summed over a day to obtain daily values, and over a month to get monthly values. The main characteristics of the two data sets are summarized in Table 1.

Both the GSIP and the UMD/SRB products are thought to be estimates of the same quantity, the true radiation field, and thus ideally they should be the same. In reality, however, due to differences in the data processing, the estimated surface fluxes are not expected to be identical. The question is then: are the two products equivalent representations of the radiation field over the US? Translating it into statistical language: do the two sets of data represent the same distribution function? In this preliminary study, we will try to answer this question by analyzing the monthly mean surface flux fields only, although both products provide data at higher temporal resolutions as well. We will trace back any differences in the surface flux fields to differences in the main input data. These inputs are the top of atmosphere (TOA) shortwave clear-sky, cloudy-sky and clear composite albedos, and cloud fraction. Obviously, establishing the similarity or dissimilarity of the two estimates will not tell us how well they represent the true radiation field, nor will we be able to determine which one is a better estimate.

TABLE 1

	GSIP	**UMD/SRB**
Spatial coverage	25^o N – 50^o N 70^o W – 125^o W	global
Spatial resolution	0.5 x 0.5 degrees	2.5 x 2.5 degrees
Temporal resolution	1 hour	3 hours
Source of satellite radiances	GOES-8 processed at NESDIS	GOES-8 from ISCCP D1 product
Source of water vapor data	ETA model	TOVS (ISCCP)
Source of ozone data	climatology	TOVS (ISCCP)
Source of snow data	US Air Force	US Navy / NOAA Joint Ice Center
Cloud detection	mono-spectral + spatial variability + dynamic threshold	bi-spectral + spatial variability (ISCCP)

2. METHOD

We compare monthly means of the shortwave surface downward fluxes, and corresponding input data in the NOAA/NESDIS GSIP data set with those in the UMD/SRB product for January, April, July and November 1998. The year 1998 was selected because, at the time this study was conducted, data for this year only were available from both products. The top of atmosphere (TOA) broadband albedos in the GSIP and

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UMD/SRB data sets are also compared to those from the Scanner for Radiation Budget (ScaRaB) project (Kandel et al., 1998) for November 1998. No ScaRaB data are available in 1998 prior to this month, hence the selection of November to represent the fall season. To facilitate a direct comparison of the GSIP data with the lower resolution UMD/SRB data, the 0.5 x 0.5 degree GSIP data were remapped to a 2.5 x 2.5 degree grid covering the area bounded by latitudes 25°-50° N and longitudes 70°-125° W. Hereafter, this remapped GSIP data set is referred to as GSIP (2.5). To observe similarities and dissimilarities in the two products we plot the difference fields of GSIP and UMD/SRB surface downward solar flux and main inputs.

The relationship between TOA albedo and surface downward flux characterizes the retrieval process. Because the downward flux-transmittance can be substituted for the surface downward flux, this relationship is also indicative of the atmospheric absorption. Comparison of these relationships from the GSIP and the UMD/SRB data sets is also useful to reveal similarities or differences. Most comparison studies give only the mean and the standard deviation; these however, sufficient to fully characterize a distribution only if it is known to be normal. Therefore, to quantify any differences in the two products, we apply the two-dimensional Kolmogorov-Smirnov (2D K-S) test to the distributions of albedo-flux pairs. A large value of the Kolmogorov-Smirnov statistic *d* and a small probability *p* will indicate that the two distributions are significantly different.

Histograms of the main inputs (clear- and all-sky TOA shortwave albedo, and cloud cover) in the GSIP and the UMD/SRB data sets are compared to diagnose the sources of differences observed in the shortwave surface downward flux. To quantify the differences in these inputs we use the one-dimensional Kolmogorov-Smirnov (1D K-S) test. Similarly to the 2D K-S statistic, a large value of the K-S statistic *d* and a small probability *p* will indicate statistically significant differences between the two distributions.

Both the GSIP and the UMD/SRB processing estimate the TOA albedo from the narrowband radiance using approximate angular and spectral transformations. These introduce uncertainties in the TOA albedo. We quantify these differences by comparing the TOA shortwave albedos to albedos from the ScaRaB data. The ScaRaB data provide an independent and more direct estimate of the TOA shortwave albedo. To express the differences in the TOA albedos from the two products relative to the ScaRaB albedo, we again apply the 1D K-S test to the TOA clear- and all-sky shortwave albedos from ScaRaB, paired with the corresponding quantities in the GSIP and the UMD/SRB data, respectively.

3. RESULTS

In November 1998, spatial GCIP (2.5)-UMD/SRB differences in the monthly mean surface downward flux range from about –10 W m^{-2} to 35 W m^{-2}. The largest negative values occur at low latitudes, while the largest positive difference is at the border of Idaho and Wyoming. For the same time, GSIP (2.5) all-sky TOA albedo is generally smaller than that in UMD/SRB; spatial differences (GSIP (2.5)-UMD/SRB) range from -0.12 to 0.02; positive values occurring predominately in the eastern part of the US. Clear-sky TOA albedo, on the other hand, is significantly larger for most part of the US in the GSIP (2.5) data; spatial differences range between -0.08 and 0.12; negative values found mostly over Mexico, southern California and Arizona. The largest spatial differences are observed in the cloud fraction; the GSIP (2.5)-UMD/SRB spatial differences range from -0.55 to 0.1. Cloud cover in the GSIP (2.5) data tends to be somewhat larger over snow covered surface. The results for the albedos for the other months are somewhat variable. For example, for January 1998, both all-sky and clear-sky average TOA albedos are larger in the GSIP (2.5) data, while for April 1998 the difference in the average clear-sky TOA albedo is small. Only the cloud fraction and the surface flux show a systematic difference for all four months examined; the cloud fraction is always larger in the UMD/SRB data, while the surface downward flux is always larger in the GSIP (2.5) data.

An example of albedo-flux pairs, describing the retrieval process and atmospheric absorption as mentioned above, is shown in Figure 1 for November 1998. UMD/SRB data tend to show larger scatter at small albedos (large fluxes), while the spread in the GSIP (2.5) data appears larger at large values of the TOA albedo (small fluxes).

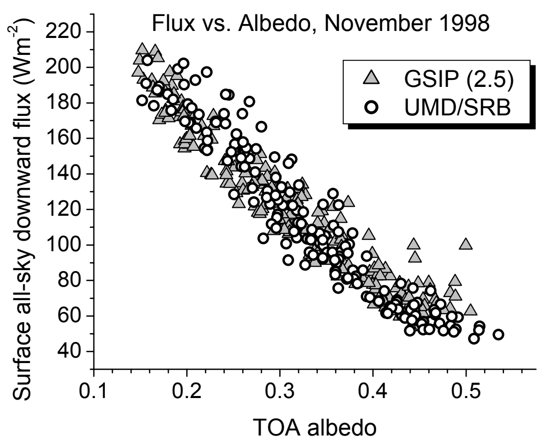

Figure 1. Distribution of GSIP and UMD/SRB flux retrievals in flux-albedo space for November 1998 for the continental US.

Table 2 summarizes the results of the 2-D Kolmogorov-Smirnov test applied to the flux-albedo pairs from the GSIP (2.5) and the UMD/SRB data. As seen, according to the K-S test, the flux-albedo distributions in the two data sets are significantly different for all four months.

TABLE 2

Month of 1998	K-S statistic *d*	Probability *p*	Are the distributions different?
Jan	0.296	1E-07	yes
Apr	0.234	8E-05	yes
Jul	0.329	2E-09	yes
Nov	0.162	1E-02	yes

TABLE 3

'98		GSIP (2.5)		UMD/SRB	
		mean	sd	mean	sd
Jan	All-sky albedo	0.397	0.121	0.380	0.097
	Clear-sky albedo	0.246	0.110	0.219	0.090
	Cloud fraction	0.604	0.253	0.704	0.150
	Surface flux	106	34	98	41
Apr	All-sky albedo	0.253	0.065	0.276	0.062
	Clear-sky albedo	0.150	0.034	0.149	0.035
	Cloud fraction	0.324	0.151	0.609	0.150
	Surface flux	246	37	235	41
Jul	All-sky albedo	0.217	0.040	0.249	0.044
	Clear-sky albedo	0.134	0.019	0.144	0.028
	Cloud fraction	0.253	0.118	0.571	0.122
	Surface flux	283	25	267	27
Nov	All-sky albedo	0.318	0.093	0.342	0.093
	Clear-sky albedo	0.189	0.051	0.176	0.053
	Cloud fraction	0.469	0.237	0.649	0.175
	Surface flux	119	40	109	44

Histograms (frequency distributions) of monthly mean shortwave surface downward flux, clear-sky and all-sky TOA albedos, and cloud cover are examined for all four months. The shapes of the histograms vary from month to month within one data set, and they are different when the two sets of data are compared to each other for the same month. The mean and standard deviation (sd) of all four distributions are given in Table 3. As an illustration, histograms for November 1998 are plotted in Figure 2. For this month, histograms of TOA albedos from the ScaRaB data are also shown. The

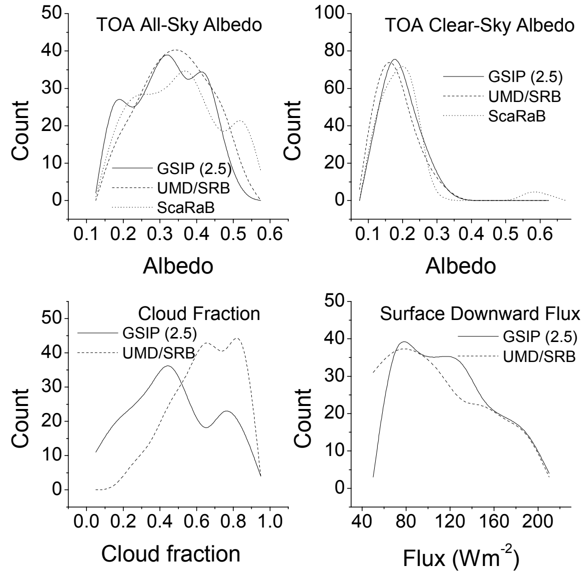

Figure 2. Histograms of the main inputs to the UMD algorithm and distribution of the surface downward flux for November 1998 for the continental US.

mean value of the all-sky and clear-sky TOA albedo from the ScaRaB data for this month are 0.354 and 0.200, respectively; both higher than the corresponding albedos in the GSIP (2.5) and UMD/SRB data. The standard deviations of the ScaRaB albedos are also larger, they are 0.114 and 0.091, respectively for all-sky and clear-sky. As evident from Figure 2, the relatively large clear-sky standard deviation in the ScaRaB data is the result of the high albedo values of ~0.6 that are not present in the GSIP nor in the UMD/SRB data.

Table 4 presents the 1D K-S statistics for the four months for the surface downward flux, and for the three major inputs used in the flux retrieval. According to this statistic, with the exception of the clear-sky albedo in April 1998, all distributions are statistically significantly different. An independent analysis of the variances shows that for cloud cover, the variances in the GSIP (2.5) and UMD/SRB data are always statistically significantly different. Whether the variances in the surface flux are different, however, is determined by the difference in the variance of the TOA all-sky albedo.

4. SUMMARY

Monthly mean shortwave surface downward fluxes, and TOA clear-sky and all-sky shortwave albedos, along with cloud fractions from the GSIP and the UMD/SRB data sets are compared. Application of the two-dimensional Kolmogorov-Smirnov test to pairs of surface flux and TOA albedo in the two data sets indicates statistically different distributions. On average, monthly mean shortwave surface downward fluxes in the UMD/SRB data are systematically smaller than the fluxes in the GSIP data by 8-16 W m^{-2}. Based on the one-dimensional Kolmogorov-Smirnov test, these differences are significant, and indicate different distributions of fluxes as a function of space. An examination of the input parameters used to retrieve the surface flux shows that the source of these differences is the statistically significant differences in the TOA shortwave albedos and cloud cover. (The effect of differences in water vapor and ozone was not included in the current, preliminary study.)

TABLE 4

'98		**K-S statistic *d***	**Prob-ability *p***	**Are the distributions different?**
Jan	All-sky albedo	0.198	3E-04	yes
	Clear-sky albedo	0.137	3E-02	yes
	Cloud fraction	0.301	3E-09	yes
	Surface flux	0.275	9E-08	yes
Apr	All-sky albedo	0.191	6E-04	yes
	Clear-sky albedo	0.107	2E-01	no
	Cloud fraction	0.685	0.0	yes
	Surface flux	0.259	6E-07	yes
Jul	All-sky albedo	0.345	6E-12	yes
	Clear-sky albedo	0.308	1E-09	yes
	Cloud fraction	0.844	0.0	yes
	Surface flux	0.252	1E-06	yes
Nov	All-sky albedo	0.109	1E-01	yes
	Clear-sky albedo	0.153	1E-02	yes
	Cloud fraction	0.393	2E-15	yes
	Surface flux	0.171	3E-03	yes

The cloud fraction in the UMD/SRB data set (as obtained from the ISCCP D1 data) is systematically larger than the cloud fraction in the GSIP data by 10-40%. TOA albedos in the GSIP, UMD/SRB and ScaRaB data are also significantly different. The difference of variances in the GSIP and the UMD/SRB surface flux fields is primarily determined by the difference in the variance of the TOA albedo fields.

Despite the common satellite platform and common algorithm used to estimate the surface solar fluxes in the GSIP and the UMD/SRB products, significant differences are introduced by the processing of satellite radiances into shortwave albedos, and by the determination of cloud cover.

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