10.1 THE NASA/GEWEX SURFACE RADIATION BUDGET PROJECT: OVERVIEW AND ANALYSIS

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1. INTRODUCTION

The Surface Radiation Budget (SRB) project at NASA is a component of the Global Energy and Water Cycle Experiment (GEWEX), under the auspices of the World Climate Research Programme (WCRP). SRB estimates surface radiative flux quantities using satellite observations, re-analysis meteorology, and ozone measurements as inputs to parameterized radiation models. The current data set, currently being archived for distribution at the NASA Langley Atmospheric Sciences Data Center, now spans the period from July 1983 through December 2004 providing a 21.5 year record of surface and top-of-atmosphere fluxes and components. This release includes a considerable number of improvements over the Release 2.0.

This paper briefly outlines the improvements to several facets of the data set. Various results are presented to give an overview of the validation results from 21.5 years of processing. More detailed results are presented in the following papers also presented at this conference: Zhang et al. (2006) present detailed validation; Mikovitz et al. (2006) present comparisons between SRB fluxes, CERES SRBAVG, ERA-40 and NCEP; Gupta et al. (2006) present initial studies comparing long-term variability to El Nino and NAO signals; and Hinkelman et al. (2006) present time series analysis results between SRB and long-term surface measurements of GEBA and BSRN.

2. GEWEX SRB OVERVIEW

Production of the NASA/GEWEX SRB data set involves the processing of global atmospheric and surface data on a 3-hourly basis. These data are used in radiative transfer based algorithms to estimate the surface fluxes. Ultimately, the data set is aimed to support the validation of data assimilation and climate models, provide radiative boundary conditions for interdisciplinary studies, conduct research on the mean state and variability of the SRB, and applied to many industrial needs.

2.1 *Input Data Sets*

To compute surface fluxes at a 1° spatial and 3-hourly temporal resolution several input data sets are used. Cloud radiance and retrieval information is obtained from the International Satellite Cloud Climatology Project (ISCCP) DX (Rossow et al., 1999). The ISCCP DX pixel level data set contains radiance and cloud retrieval information from geosynchronous and polar orbiting satellites sampled to a nominal resolution of 30 km. All 30 km DX pixels within a grid cell are averaged analogously to the methods of ISCCP (e.g., Rossow *et al.* 1996) to produce gridded radiance and cloud products that are required for the flux algorithms.

To provide the necessary meteorological profile information including temperature and humidity, a global reanalysis is used. A reanalysis provides a better representation of the diurnal cycle of temperature and humidity relative to the Tiros Observational Vertical Sounder (TOVS) data that is mostly just at once per day. The current data set uses the Goddard Earth Observing System (GEOS) v. 4.0.3 reanalysis provided by the Data Assimilation Office (DAO) of NASA's Goddard Space Flight Center (Bloom et al., 2005). In addition to the reanalysis, other new data inputs at higher resolution have been included. The most important is the 1.25° longitude x 1° latitude resolution column ozone from the measurements of the Total Ozone Mapping Spectrometer (TOMS). Since TOMS is a UV based retrieval, it is blended with TOVS data from ISCCP during the polar night. Other higher resolution data sets are being included such as high resolution surface type classification maps.

2.2 *SW Flux Algorithms*

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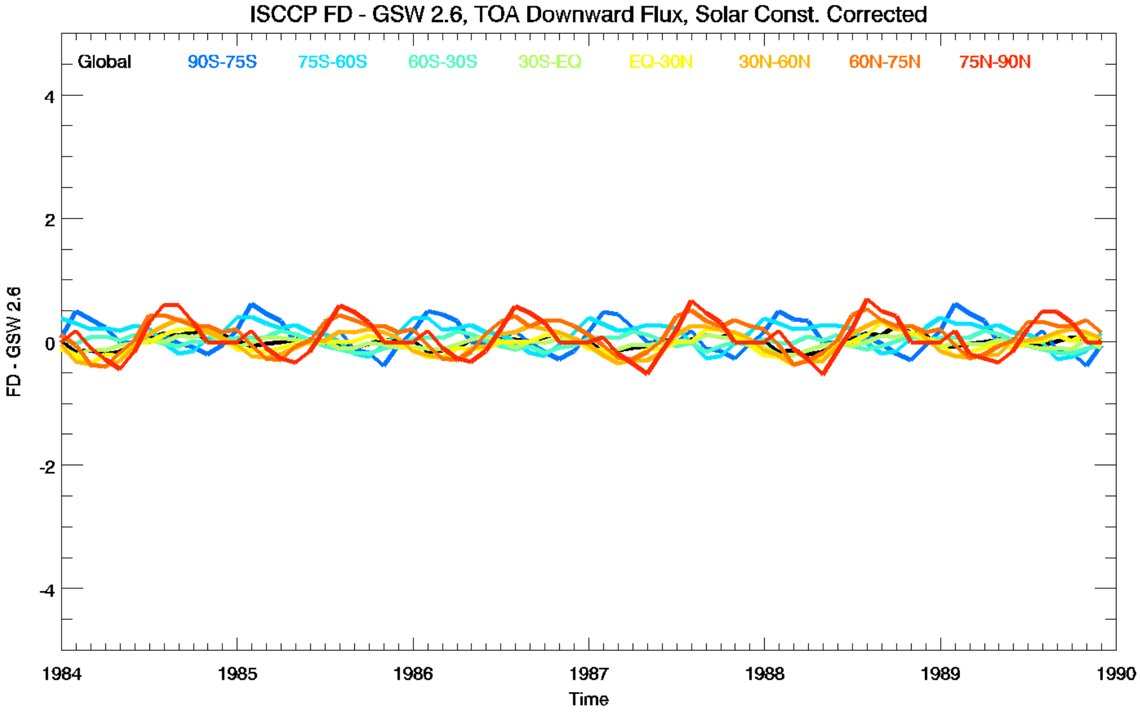


Figure 1: Differences between ISCCP FD and GEWEX SRB Release 2.6 TOA Downward Shortwave Flux, in Wm^{-2} for various zonal bands, after fluxes are corrected for the different values of solar constant used by the two algorithms. GEWEX SW cuts off calculation at 4.0µm so has an effective solar constant of 1358.8 Wm^{-2}, whereas ISCCP FD goes out to 5µm with a solar constant of 1367 Wm^{-2}.

The GEWEX SRB data products are computed using two shortwave (SW) and two longwave (LW) algorithms. The shortwave data results from an upgraded version of Pinker and Laszlo (1992). This algorithm computes a broadband solar flux for each time stamp. The algorithm uses a two-stream delta-Eddington model to map broadband reflected fluxes at the Top-of-Atmosphere (TOA) to transmitted fluxes at the surface. The reflected fluxes at TOA are computed using narrow band to broadband relationships on the visible radiances and angular distribution models (ADMs) from the Earth Radiation Budget Experiment (ERBE). This algorithm has now been significantly altered since Release 2.0. In this version, Release 2.6, the following changes have been made:

1) Radiative transfer lookup tables were expanded to include larger solar zenith angles; the previous version was found to extrapolate the tables under those conditions.
2) A new procedure to fill gaps was implemented to eliminate the gaps in the polar twilight regions; SW calculations are now made using IR based cloud fractions.
3) A new TOA insolation parameterization was installed to more accurately account for the variation in the days of the year.

Improvements 2 and 3 address the issues identified in Raschke et al. (2006). This paper improperly concludes that polar zonal TOA flux differences (as high as 50 W m^{-2} in some months) between SRB and ISCCP-FD data sets (Zhang et al., 2004) were due to the old TOA insolation parameterization. This problem was mostly due to the issue of SW data gaps at polar twilight that existed in the SRB SW Rel. 2.0 fluxes, which we believe were handled improperly by Raschke et al. However, the results do illustrate the dangers of computing zonal averages over areas containing data gaps. The actual real differences due to the older TOA insolation parameters are 8-10 W m^{-2} for polar twilight zones during seasonal transition months. The improved insolation treatment brings the differences down to a maximum of 3 W m^{-2} Much of the remaining difference is due to the simple matter of SRB and ISCCP-FD using different effective solar constants, as SRB calculates only out to 4 µm, whereas ISCCP-FD goes to 5 µm, which is a difference in method rather than an error, and which can be properly accounted for by a simple scaling. Normalizing the fluxes confines the maximum differences to +/- 0.5 W m^{-2}, as shown in Figure 1.

A secondary algorithm is that described in Gupta *et al*., (1999). This model is referred to as the Langley Parameterized Shortwave Algorithm (LPSA) since it employs several empirical and parametric relationships to account for various scattering and absorptive processes in the atmosphere. This model was also significantly upgraded from SRB release 2.5. The upgrades are:

1) A climatology of MATCH aerosol distributions and optical depths were installed into the model.
2) A climatology of Terra spherical albedo were adapted for use in the model.

The results of the upgrades are given below.

2.3 *LW Flux Algorithms*

In the longwave, the GEWEX SRB LW algorithm uses a model based on the Fu *et al*. (1997) infrared radiative transfer model. This radiative transfer model is nearly the same model used in the Surface and Atmospheric Radiative Budget (SARB) flux computations that are part of the Clouds and the Earth's Radiant Energy Systems (CERES) processing system. The main difference between CERES and SRB versions of the code center on the use of the random-maximum cloud overlap scheme to better estimate cloud undercast conditions. The model requires complete temperature and water vapor profiles and surface skin temperatures. The temperature and water vapor profiles come directly from GEOS 4.0.3. The surface skin temperature is taken from GEOS over the open ocean and in grid boxes with a cloud fraction greater than 50%. ISCCP skin temperature brightness temperatures modified by the surface emissivity are used for cloud fractions less than 50%. The spectral surface emissivity is required and is taken from the CERES Surface and Atmospheric Budget (SARB).

LW Quality Check algorithm is a slightly upgraded version of Gupta *et al*. (1999). This algorithm uses broadband parameterizations of narrow band (10 cm^{-1}) radiative transfer calculations as a function of water vapor and temperature to compute a clear-sky flux given the meteorological profile of the grid box. The model uses cloud fraction and the cloud top temperatures to prescribe the effects of clouds on the clear-sky flux using the same assumptions about cloud thickness mentioned above. TOA fluxes are currently not computed with this algorithm, but the model does allow for nonblack surface emittances.

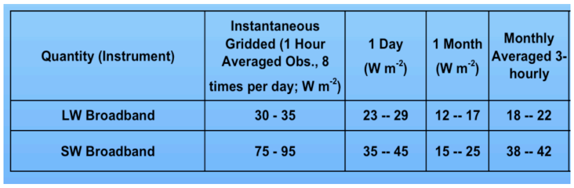
2.4 *Processing Status and Currently*

To date all 21.5 years of data have been processed for all 4 algorithms. The data are being prepared for archival at the NASA Langley Research Center Atmospheric Science Data Center (ASDC) for public distribution. Portions of the data sets processed so far are available and can be obtained by contacting the author.

3. MONTHLY AVERAGED FLUX VALIDATION

Accompanying the processing of the SRB data is a concerted effort to validate the fluxes in time. Table 1 shows a comparison of the flux estimates for the four algorithms used here versus measurements from the Baseline Surface Radiation Network (BSRN) for all sites and all months from 1992 to 2004. Monthly averaged biases vary depending upon the length records and the number of sites. Typical GEWEX SW range in the -5 to -15 W m^{-2} while the SWQC biases vary between 0 and 10 W m^{-2}. The LW baises vary from -5 to 5 W m^{-2}. For additional information on validation please see Zhang et al. 2006).

Table 1: Magnitudes of SW and LW errors as a function of time scale based on comparison to BSRN data.



Quantity (Instrument)	Instantaneous Gridded (1 Hour Averaged Obs., 8 times per day; W m^{-2})	1 Day (W m^{-2})	1 Month (W m^{-2})	Monthly Averaged 3-hourly
LW Broadband	30 - 35	23 -- 29	12 -- 17	18 -- 22
SW Broadband	75 - 95	35 -- 45	15 -- 25	38 -- 42

4. SAMPLE RESULTS

For the study here, we present samples of results obtained through analysis of the entire 21.5 year data set.

4.1 *Global Annual Average*

Table 2 compares the global 21.5 year mean surface fluxes from SRB with previous products. The most notable difference between SRB and Ohmura and Gilgen (1993) appear in the shortwave with SRB 17 Wm^{-2} higher. Zhang and Rossow (2004) is also based on ISCCP data and show general agreement with SRB. Kiehl and Trenberth (1997) made calculations based on ERBE results and climate model radiation algorithms and gave a SW surface flux higher higher still, indicating there is still a substantial uncertainty in the community for this fundamental parameter.

4.2 *Time Series Anomalies*

The 21.5-year anomaly time series for the global and tropical fluxes are shown in Figure 2. The top two panels give the variability of the TOA upward fluxes over the time period while the bottom two panels show the surface downward fluxes. The anomalies are plotted relative to the monthly average fluxes obtained during the period of 1985 through 1988, the ERBE time period. The time series show the variability of the fluxes over this time period. The OLR and SW reflected time series correspond to variability observed through normalization of the ERBE data set. The largest SW anomalies are caused by the Pinatubo volcanic eruption in June 1991. Note that the increase in the reflected SW flux corresponds to the decrease in the observed surface flux at this time. Note also that the tropical radiative anomaly is nearly 10 W m^{-2}, agreeing well with ERBE results. Gupta et al (2006) describe this in more detail and also illustrate the correspondence of LW anomalies to El Nino processes. The LW fluxes also show much less variability than the SW fluxes from month-to-month.

Table 2: Global Annual averages for each of the 5 years processed and two previous SRB data sets.

Parameter	**Ohmura & Gilgen (1993)** ***GEBA Surf. Obs.***		**Kiehl and Trenberth (1997) ERBE/ CCM3**		**Zhang & Rossow (2004)** ***21-Year Mean (1984-2004)***		**NASA/GEWEX SRB Rel. 2.5* (NASA LaRC)** ***21-Year Mean (1984-2004)***			
							SW, LW		**SW, LW QC**	
	Flux	**% F_0**	**Flux**	**% F_0**	**Flux**	**% F_0**	**Flux**	**% F_0**	**Flux**	**% F_0**
SW Down	169.0	49.4	198	57.9	189.2	55.4	187.3	54.8	183.7	53.8
SW Net	142.0	41.6	168	49.2	165.9	48.5	164.9	48.3	161.0	47.1
LW Down	345	100.9	324	94.8	343.8	100.6	343.1	100.4	348.7	102.0
LW Net	-40.0	-11.7	-66	-19.3	-49.6	-14.5	-53.0	-15.5	-50.0	-14.6
Total Net	102.0	29.8	102	29.8	116.3	34.0	111.9	32.7	111.0	32.5
SW CRF	--	--	--	--	-53.0	-15.5	-56.2	-16.4	-59.2	-17.3
LW CRF	--	--	46	13.5	29.5	8.6	35.3	10.3	34.3	10.0
Total CRF	--	--	--	--	-23.5	-6.9	-20.9	-6.1	-24.9	-7.3

* *Normalized to* $S_0 = 1367\ W\ m^{-2}$; $(F_0 = S_0/4)$

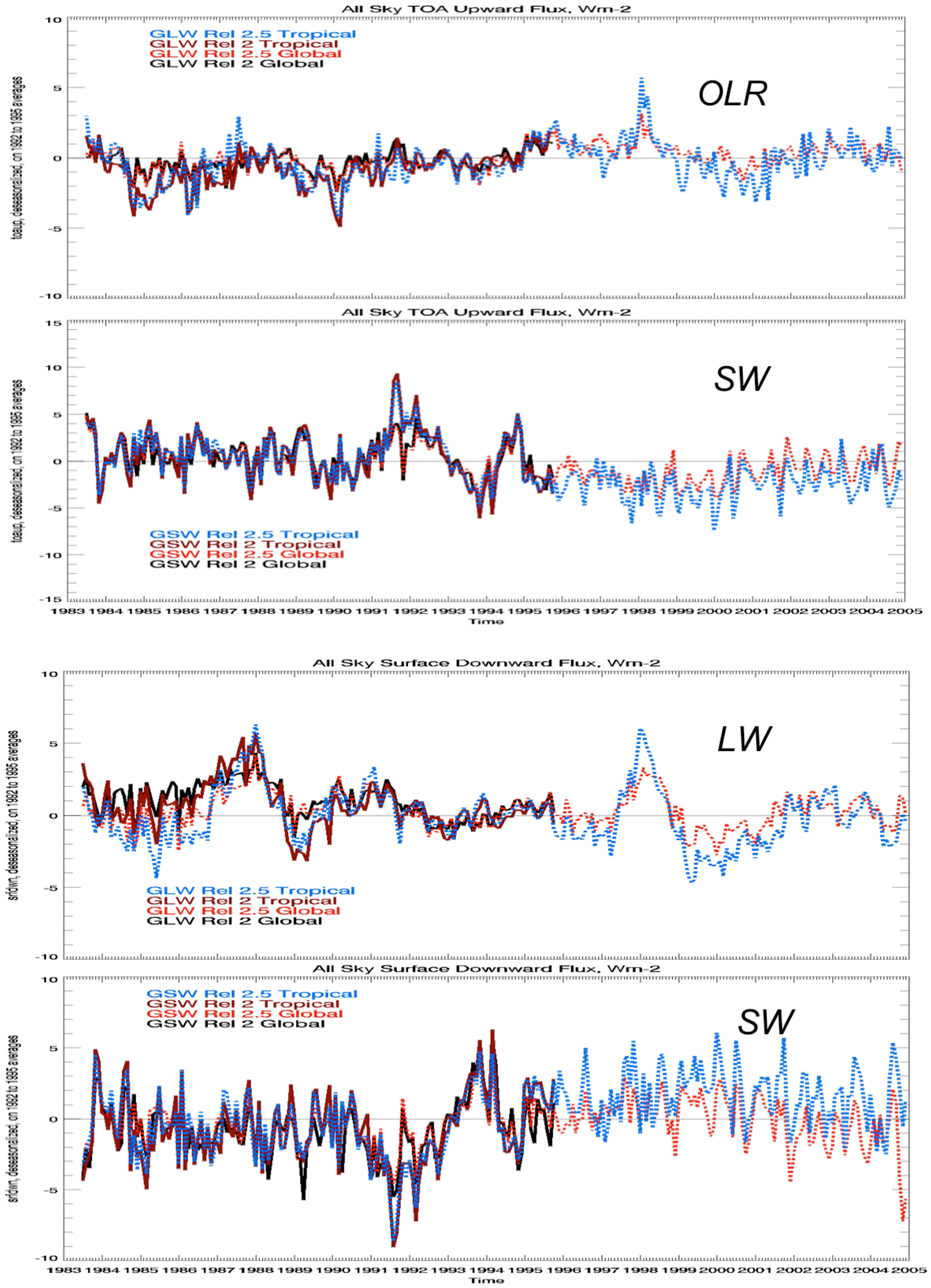


Figure 2: 21.5-year zonal anomalies top-of-atmospheric upward (top two panels) and surface downward fluxes.

5. CONCLUSIONS

The NASA/GEWEX SRB is finalizing the documentation for the lastest version of the GEWEX SRB flux data sets. This version, Release 2.5/2.6 (SW-only) spans 21.5 years from June 1983 through December 2004. Several issues were addressed in SW algorithms for this latest version. However, the largest difference is the incorporation of the GEOS 4.0.3 assimilation. The validation of the surface fluxes relative to surface measurements gives RMS and bias errors that are improved relative to version 2.0. The long-term global averages and time series show results consistent with current understanding.

Further study of the time series, validation, and comparison against other surface flux estimates including CERES are under way and addressed in more detail in the companion papers referenced here. The data should be available for public distribution within one month of the completion of this abstract and certainty for the conference.

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