7B.2 THE WCRP/GEWEX SURFACE RADIATION BUDGET PROJECT RELEASE 2: FIRST RESULTS AT 1 DEGREE RESOLUTION

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1. INTRODUCTION

The earth's surface radiative budget in the solar wavelengths (i.e., shortwave) and thermal infrared wavelengths (i.e., longwave) is an important component of Earth's global energy balance and climate. As such, it was identified as a priority need by the World Climate Research Programme (WCRP) (Suttles and Ohring, 1986) and thus a program was instituted at NASA to estimate the radiative flux quantities at the surface from space observations. The Surface Radiation Budget (SRB) Project was created and later included as a component of the Global Energy and Water Cycle Experiment (GEWEX) under the auspices of the WCRP.

This paper presents the first results for Release 2 of the WCRP/GEWEX SRB Project data set at 1x1 degree equal angle resolution (hereafter, 1^{o}). The release 2 represents a significant upgrade from the release 1 WCRP SRB Shortwave (SW) 4-year data set (Whitlock *et al.*, 1995). Among many upgrades the most important are: the addition of longwave (LW) flux algorithms, the increase of resolution from the 280 km x 280 km equal area grid system (hereafter, 280 km) to 1^{o}, and the use of reanalysis meteorology from a data assimilation project. This Release 2 data set will provide SW and LW surface and top-of-atmosphere radiative fluxes for at least a 10 year period (1984-1993) on a global 1 degree resolution. The fluxes will be produced at a variety of time scales including 3-hourly, daily, monthly and a monthly averaged 3-hourly.

This paper discusses the upgrades between releases 1 and 2 of the WCRP/GEWEX SRB data sets. First the differences in the inputs are discussed introducing the new 1^{o} gridded cloud products derived from International Satellite Cloud Climatology Project (ISCCP) DX data. Next, the four featured algorithms are described including the two LW algorithms new to this release. Sample results from the new algorithms using the new inputs are given and compared to surface observations.

2. INPUTS AT 1 DEGREE

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2.1 *ISCCP DX*

The release 1 WCRP SRB used the ISCCP C1 level data product which provides radiance, cloud properties, and retrieved meteorological profile information from TOVS gridded to a 280 km resolution, every 3 hours (Rossow *et al.*, 1991). The ISCCP product uses the reflected and emitted radiances from geosynchronous and polar orbiting satellites. The WCRP/GEWEX SRB release 2 data set is based upon the ISCCP "DX" pixel level data set containing radiance and cloud retrieval information sampled to a nominal resolution of 30 km. The ISCCP "D" series data set represents an upgrade from the "C" series including the provision of ice cloud retrievals and better ice/snow determination (Rossow and Schiffer 1999).

To compute fluxes at a 1^{o} resolution, the ISCCP DX is averaged and processed to a specialized intermediate grid that is 1^{o}x1^{o} at the equator, but the longitudinal size of the grid box is increased toward the poles by integer factors of 2. This increase mitigates the severe reduction of sampling that occurs in equal angle grid boxes toward the poles. All 30 km 'DX' pixels that are located within a box on this intermediate grid are averaged analogously to the methods of ISCCP (*e.g.*, Rossow *et al.* 1991) to produce gridded radiance and cloud products. Expanded grid boxes are then replicated to produce a global 1^{o} data set that will be archived at the NASA Langley Distributed Active Archive Center (DAAC).

Some of the differences between the new 1^{o} degree resolution and the 280 km are illustrated in Figs. 1 and 2. Figure 1 shows a difference plot between ISCCP D1 at 280 km and new gridded DX data set for retrieved skin temperature on Oct 11, 1986 at 18Z (both data sets were replicated to a 0.5 degree resolution to allow for the differencing). The differences are largest near significant geographical features like coastlines, mountain ranges, and inner continental lakes. Figure 2 shows an optical depth frequency histograms for both the 280 km and 1^{o} grid systems for October 1986. The distribution of optical depth of the 1^{o} data set is broader with significantly higher frequencies of lower optical depth boxes. These differences are indicative of the decreased samples per grid box of the new grid system relative to the 280 km grid system. The relative sampling decrease reduces the

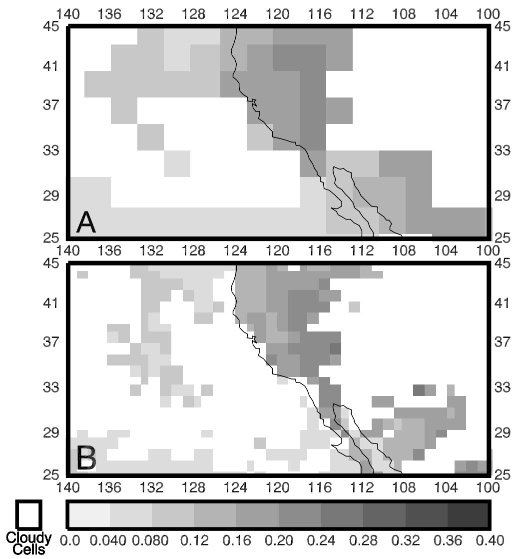

Figure 1: Maps of clear-sky reflectances (relative units) from the 280 km ISCCP D1 data set (A) and the ISCCP DX data set gridded to a 1^o resolution (B) for the west coast of the United States on 11 Oct., 1986 at 18Z. The pure white areas represent grid boxes with no clear pixels. The higher resolution more clearly resolves the coastal regions and horizontal cloud distribution.

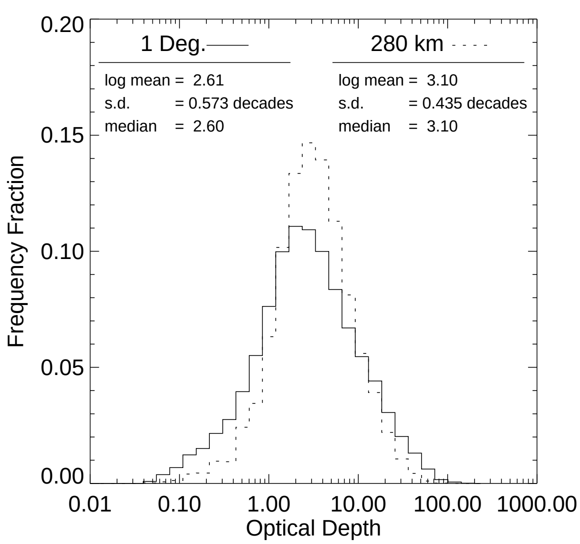

Figure 2: Grid box averaged optical depth histograms from both the 280 km ISCCP D1 and the newly derived 1^o resolutions. The frequencies are given in terms of the fraction of total cloudy grid boxes and standard deviations (s.d.) are given in powers of ten (decades) to correspond to the log coordinates of the abscissa.

number of values averaged together, broadening the distribution.

2.2 *Reanalysis Meteorology*

Unlike 280 km ISCCP C1 and D1 data sets, the TIROS Operational Vertical Sounder (TOVS) meteorology is not included in the ISCCP DX pixel data sets. 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 TOVS soundings which are mainly given at once per day. Presently, the Goddard Earth Observing System (GEOS) v.1 reanalysis provided by the Data Assimilation Office (DAO) of NASA's Goddard Space Flight Center is used to provide this information. The feasibility of using the European Center for Medium-Range Wearther Forecasting reanalysis (ERA-15) is currently being evaluated.

2.3 *Ancillary Inputs*

In addition to the reanalysis, other new data inputs at higher resolution have been include. The most important of which is the 1.25^o longitude x 1^o latitude resolution column ozone from the measurements of the Total Ozone Mapping Spectrometer (TOMS). Other higher resolution data sets are being included such as high resolution surface type classification maps.

3. SURFACE FLUX ALGORITHMS AND RESULTS

3.1 *SW Algorithms*

The shortwave algorithms included in the SRB release 2 at 1 degree resolution are essentially the same as documented in Whitlock *et. al.* (1995). The official GEWEX SW algorithm is that 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). The model has been updated with new water vapor parameterizations and averaging schemes.

An example of the fluxes produced from this algorithm at both the new high resolution and the 280 km resolution is shown in Fig. 3. The figure shows the fluxes resulting from gridding the radiance and cloud products at 18Z on Oct. 11, 1986. Only the United States is shown to emphasize the finer structure at 1^o. Figure 4 shows the difference histograms of the monthly averaged SW algorithm compared to monthly averaged fluxes from 472 surface sites for the month of October 1986. The difference histograms and statistics are shown from ISCCP C1, ISCCP D1, and at the new resolution. The difference between the C1 and D1 is due primarily to the changes in calibration by ISCCP. The difference between the fluxes using D1 and the new cloud products are indicative of the differences in averaging over smaller areas. Although the mean difference is essentially zero for this month, the difference distribution at the new resolution is skewed slightly toward an underestimation of the surface fluxes relative to the surface observations. The RMS difference at 1^{o} is reduced slightly compared to the differences using D1 and C1 inputs. Error analysis like this will be performed on a daily and regional basis to identify problem areas for further analysis.

The GEWEX SW Quality Check (QC) algorithm is that described in Darnell *et. al.*, (1992). This model is referred to as a physical-empirical surface insolation model since it employs several empirical and parametric relationships to account for various scattering and absorptive processes in the atmosphere. The central feature of the scheme is an empirical fit between a cloud transmittance and fractional radiance between brightest and darknest pixels in the box during a given day. This provides a method of estimating cloud transmittance independently from the absolute satellite calibration. The algorithm was primarily designed to give daily averaged solar insolations and uses surface albedos derived from corrected ERBE measurements. TOA fluxes are not computed with this scheme.

3.2 *LW Algorithms*

In the longwave, a new GEWEX LW algorithm is introduced. This algorithm uses the Fu et al., (1997) infrared radiative transfer model. This radiative transfer model is 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 model uses correlated-k distributions in 12 wavelength bands to account for gaseous absorption. The model treats longwave scattering which requires the specification of cloud and aerosol optical properties. The model also treats nonblack surfaces and will use as input surface emissivity maps derived for CERES-SARB (Wilber *et al.* 1999). Cloud bases are prescribed by using cloud top temperatures to infer atmospheric levels and then assuming a constant pressure thickness that depends on latitude and height. Random cloud overlap is assumed to better estimate the distribution of cloud base in a particular grid box. The algorithm will be used to estimate both TOA and surface fluxes.

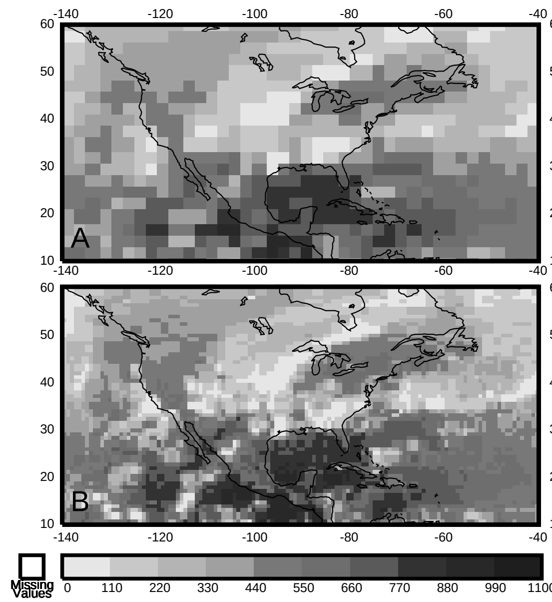

Figure 3: Surface insolation in W m^{-2} from v2.1 of the GEWEX SW algorithm (Pinker and Laszlo, 1992) at 18Z 11 Oct. 1986 using (A) the radiance, cloud and surface properties from the ISCCP D1 280 km equal area data set and (B) the newly derived properties from the ISCCP DX data set averaged to a 1^{o} based grid (B). The higher resolution more clearly resolves cloud systems like the stratocumulus field off the coast the California, the subtropical jet streaming from southwest over Mexico and the southern US and the frontal system located over the central US.

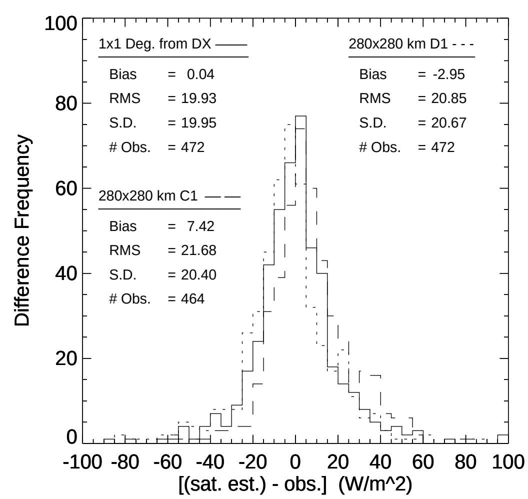

Figure 4: The difference histograms and statistics between monthly averaged solar flux measurements (W m^{-2}) and the flux computed with the GEWEX SW algorithm using ISCCP C1, D1 and the newly derived radiance/surface/cloud properties at 1^{o} from ISCCP DX. The radiometer sites are globally distributed.

The GEWEX LW QC algorithm is the same as described in Gupta *et. al*., (1992). 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. Figure 5 presents an example of the downward LW flux at the surface from this algorithm at both the 280 km and 1^o resolutions.

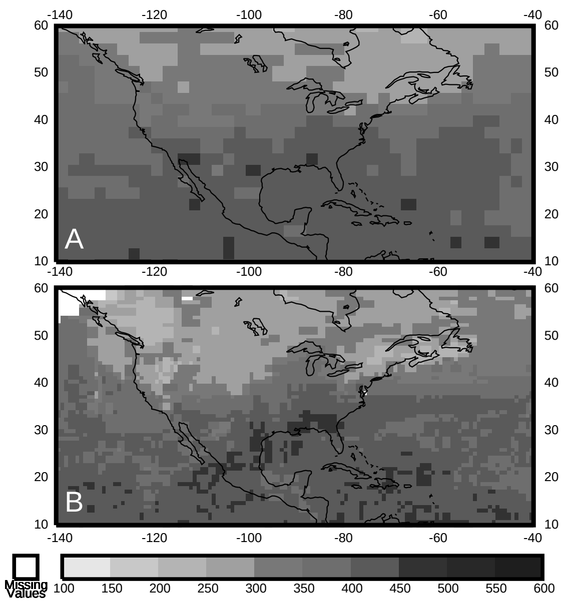

Figure 5. The downward LW flux incident to the surface at 18Z 11 Oct. 1986 with the GEWEX QC algorithm using (A) the ISCCP D1 280 km cloud properties and (B) the newly derived 1^o based data set from ISCCP DX. The meteorological profiles are taken from the DAO GEOS-1 reanalysis. The maximum fluxes in the southeastern US occur due to the high temperatures, humidities and the low clouds in this area.

4. SUMMARY AND SCHEDULE

This paper briefly described the inputs and algorithms that are being used to generate release 2 of the WCRP/GEWEX SRB data set. The validation of the cloud and flux properties are currently being analyzed and compared to other satellite and surface based data sets to eliminate major errors in the analysis. Reanalysis products are being compared in preparation of full processing. Finally, a new background aerosol data set is being studied for possible inclusion as input.

The quality of the preliminary results puts the project on a schedule to begin processing and archiving both the 1^o gridded cloud and flux properties by the end of 1999. It is expected that limited amounts of the data will become available in the first quarter of the year 2000. All the data will be made available through the Langley DAAC. Also, Web pages are being developed to describe the availability and quality of the products. These will be accessible through the GEWEX homepage at URL:

http://www.cais.com/gewex/gewex.html.

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