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THE EARTH RADIATION BUDGET 15-YEAR DATA SET

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1. INTRODUCTION

The Earth Radiation Budget Satellite (Barkstrom and Smith, 1986) carried a package of non-scanning radiometers (Luther, 1986) which began operation in November 1984 and operated well until October 1999, providing a 15-year data set for outgoing longwave radiation and solar radiation reflected from the Earth. There is an active cavity radiometer for measuring the solar output which has provided a record of 17 years duration with a precision of 0.1% (Lee et al., 1995 1998, 2000). Because of the accuracy of the measurements, the WFOV instrument has been useful as a radiation transfer standard for intercomparing with other broadband radiometers. The Earth-viewing data set has recently been reprocessed to improve its usefulness for research applications, e.g. in climate studies. The present paper briefly describes the instrument, its calibration and the processing of the Earth-viewing data, then discusses some applications of these data.

2. INSTRUMENT AND ORBIT

The non-scanner package, shown in fig. 1, contained 2 wide field-of-view radiometers (WFOV), which view the Earth from limb to limb, and 2 medium field-of-view radiometers, which view a circle of 10^{o} diameter at the Earth's surface. The package also contained a Solar Monitor,

Figure 2 shows the WFOV shortwave radiometer, which is an active cavity radiometer (ACR) with an aperture for limiting the FOV to the Earth with a 2-degree space ring. Earlier WFOV radiometers on the Earth Radiation Budget instrument (W.L. Smith et al., 1977) had used thermopile detectors, during which time ACRs were developed for spacecraft use which were reliable and accurate. The Solar Monitor is also an ACR.

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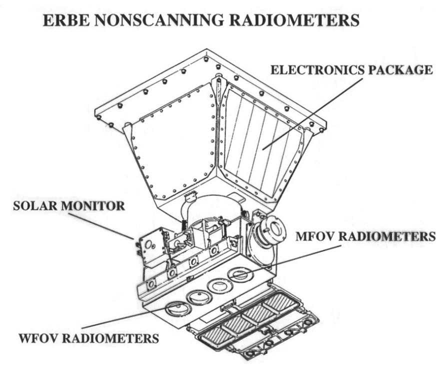

Fig. 1. Non-scanning radiometer instrument.

The spacecraft is in an orbit with an inclination of 57 degrees and an initial altitude of 610 km, so that it precesses around the Earth every 72 days (Harrison et al, 1983), providing measurements at all local times so as to sample the full diurnal cycle over that period.

3. CALIBRATION: GROUND AND IN-FLIGHT

The ERBE nonscanning radiometers were calibrated to the IPTS-68 in a radiometric calibration facility using a blackbody to calibrate the total channel and an integrating sphere for the short-wave channel (Halyo et al., 1989).

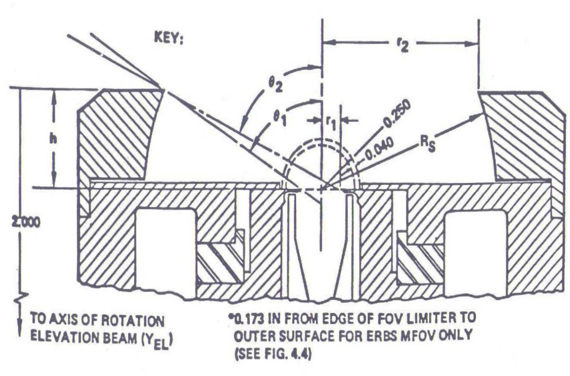

Fig. 2. Wide field-of-view shortwave channel.

The nonscanning instrument was constructed with the Earth-viewing radiometers on a beam which could rotate to view the Sun and an internal blackbody as known sources (by use of the Solar Monitor) in order to determine the gain and zero-flux counts. This in-flight calibration was performed biweekly for the first 15 years (Paden et al., 2000). The Solar and space views showed that the total channel gain did not change significantly over the 15-year period. These calibration also measured the gain of the shortwave channel, which changed due to degradation of the quartz dome which served to stop longwave radiation from entering the detector. These measurements were used to update the zero flux and shortwave gain values which were used in the data processing to compute the longwave and shortwave fluxes from the Earth.

In October 1999 a biweekly calibration was performed in which the beam carrying the Earth-viewing channels was rotated to look at the Sun as a known source. Afterwards the beam did not return to its Earth-viewing position, i.e. the WFOV radiometer is not oriented exactly along a vertical axis. Furthermore, the beam cannot be rotated for calibrations. A pitch-over maneuver of the spacecraft is planned which will provide a zero flux measurement so that the measurements since October 1999 can be processed. They are not included in the high quality 15-year data set from the ERBS WFOV radiometers which has been calibrated and archived.

4. MEASUREMENTS AND DATA PROCESSING

The measurement is simply the vertical component of flux at the spacecraft (Smith et al.,1986). The radiance in each direction is related to the flux M(r) at TOA by the bidirectional reflectance distribution function for shortwave and the limb-darkening function for longwave. These functions vary with the scene type and view angles and are denoted here as R(r,u), where u denotes the unit vector from r to r_S. The measurement equation can thus be written as

$$m(r_S) = \pi^{-1} \int_{FOV} M(r) R(r, u) \cos\alpha \, d\Omega$$

For the shortwave case, the TOA flux is given in terms of albedo $a(r)$, so that the measurement equation for the shortwave case becomes

$$m_S(r_S) = \pi^{-1} S \int_{FOV} a(r) R(r, u) \cos\varsigma \cos\alpha \, d\Omega$$

Two approaches are used for retrieving the TOA longwave flux and albedo.

4.1 Shape Factor Method

The shape factor method assumes that M(r) is constant over the FOV for the longwave case and that $a(r)$ is constant for the shortwave case. For the longwave case, the measurement equation simplifies to

$$m_L(r_s) = \mathbf{SF_{LW}} M(r_s)$$

where $\mathbf{SF_{LW}}$ is the longwave shape factor and is simply the square of the Earth radius divided by the orbit radius. The albedo is computed by use of a shape factor, which is computed using the bidirectional reflectance distribution function for mostly cloudy over ocean (Suttles et al., 1988).

4.2 Numerical Filter Method

The longwave and shortwave fluxes are also computed by a technique which treats the measurement equation as an integral equation to be solved for the longwave flux or albedo as a function of distance alongtrack. The purpose of this method is to enhance the resolution of the WOFV radiometers so as to produce monthly-mean radiant flux or albedo maps at 5-degree resolution. This is accomplished by means of a numerical filter.

4.3 Monthly-Mean Fluxes and Albedos

A comparison of monthly mean fluxes from the WFOV with results from the ScaRaB showed that for high latitudes during some months there were not enough measurements to compute accurate shortwave or longwave monthly-mean fluxes. Quality checking algorithms were developed for evaluating the temporal sampling errors in monthly-mean longwave flux (Smith, 1997) and albedo (Smith, 1998) and tested (Spangenberg et al., 1999). The data were reprocessed with this check and monthly-mean values are not reported for regions for which the computed temporal sampling error exceeds 12 W-m^{-2}.

The instantaneous longwave and shortwave fluxes at the instrument and as computed at TOA are available on the S-7 data product. The measurements are averaged in a 10-degree longitude-latitude Earth grid for the shape factor results and a 5-degree grid for the numerical filter results in the S-10 data product. The monthly means are available in the S-4 and S-4G data products. The S-4 has data listed with all parameters in a file for a given region. The S-4G lists a given parameter. e.g. monthly-mean longwave flux, for all regions in a given file and is more useful for mapping parameters.

5. APPLCATIONS OF DATA

Figure 3 shows a time line with the various broadband radiation budget radiometers. The ERB WFOV radiometers of Nimbus 6 and 7 provided a

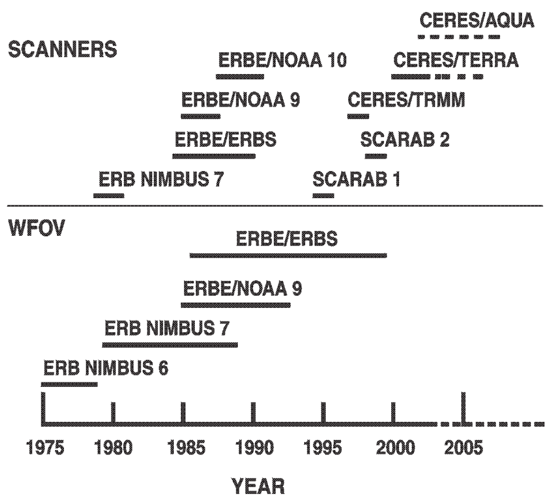

Fig. 3. Time line of radiation data sets

data set from 1975 though 1987, giving 2 years of overlapping data with the ERBS WFOV. The total period covered by the ERB and ERBS together is from 1975 to 1999.

The monthly-mean data products are the most important results of the WFOV radiometers for most climate applications. These products for ERBS cover the Earth from 60^{o}S to 60^{o}N, except for regions for which the sampling is inadequate to compute a monthly-mean value for a longwave or shortwave flux. The spatial resolution is nominally 500 km, but realistically is somewhat larger. Figure 4 shows the space-time scales of the WFOV data. The processes which take place at these scales are also shown. Most intraseasonal variations are not well resolved with monthly means, so that WFOV are not well-suited for studying these processes. However, scanning radiometer data sets are long enough for those studies. Interannual variations of climate (and longer) typically have large spatial scales and WFOV data are well-suited investigating these processes. The 15-year data record of the ERBS WFOV can be used to do initial studies of decadal scale variations. There are 2 decadal cycles in the combined ERB/ERBS WFOV data set.

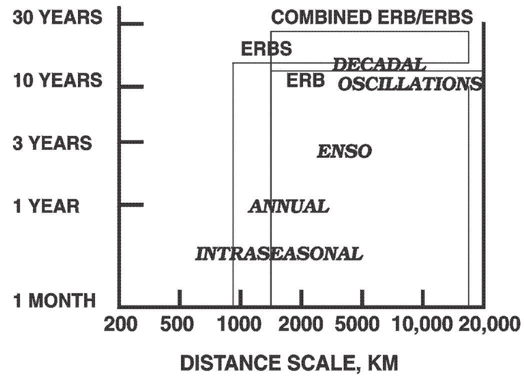

Fig. 4. Radiation data sets and climate processes

A second major application of the ERBS WFOV data has been as an in-orbit radiometric standard for the scanning radiometers which flew during that time period. Green et al. (1990) developed the technique for computing the shortwave and longwave fluxes at a WFOV orbital location and applied it to compare the results of the scanning radiometers aboard the ERBS and NOAA 9 and 10 spacecraft. Bess et al., (1999) used the Green software to compare the ScaRaB-1 radiances with the ERBS WFOV. Finally, Rutan et al. (1999) used the technique to compare the Clouds and Earth Radiant Energy System (CERES) scanner with the ERBS WFOV. Thus, the ERBS WFOV served as a calibration source for the radiation budget scanners which flew during its 15-year data period, providing a link between them.

6. CONCLUDING REMARKS

The Earth Radiation Budget Satellite is nearing the end of its mission and End-of-Life planning is under way. It is hoped that a pitch-over maneuver can be done, whereby the spacecraft will be rotated so that the nonscanner will view space with neither the Earth nor Sun in field of view of the radiometers, thus giving final zero-flux measurements. A decision can then be made about processing the last 3 years of data.

7. ACKNOWLEDGEMENTS

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