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INTERCOMPARISON OF CERES SCANNING AND ERBS WFOV NON-SCANNING RADIOMETERS

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1. INTRODUCTION

Flight Models 1 and 2 (FM-1, FM-2) of the Clouds and Earth's Radiant Energy System (CERES) scanning radiometers (Barkstrom, 1990) are now operating aboard the TERRA spacecraft which was placed in orbit December 18, 1999. The instruments began scanning the Earth in February 2000 and have provided over a year of data thus far. The Proto-Flight Model (PFM) CERES flew aboard the Topical Rainfall Measuring Mission (TRMM) in November 1997 and provided data for eight months. Though operation was curtailed due to a problem (corrected on TERRA) PFM returned to operation for intercomparisons with Terra FM-1 and FM-2 (Haeffelin et al., 2000)

The Earth Radiation Budget Experiment (ERBE) Wide Field-of-View (WFOV) radiometers aboard the Earth Radiation Budget Satellite (Luther et al., 1986; Barkstrom and Smith, 1986) have operated since November 1984 and maintained a high level of precision (Paden et al., 2000). Green et al. (1990) developed a method for comparing nonscanning WFOV radiometer results with scanning radiometer results demonstrating accuracy at the level of 1% to 2% between ERBE scanners and ERBE WFOV radiometers. Bess et al. (1997) applied the Green method and software to compare the Scanner for Radiation Balance (ScaRaB) results (Kandel et al., 1998) with the ERBS WFOV radiometer. Rutan et al. (1999) compared a sample of CERES data with ERBS data. The ERBS WFOV radiometers thus serve as a transfer standard for these scanning radiometers. The present paper makes a more extensive comparison of CERES/TRMM with ERBS.

After 15 years of ERBS operation, in October 1999 following a routine calibration, the elevation drive which rotated the radiometers to look at the Sun failed after returning the radiometer to Earth-viewing position. After this time calibrations could no longer be done. WFOV data after that occurrence are not regarded as well-calibrated. The present work also compares ERBS and CERES FM-2 aboard TERRA as part of an effort to reestablish the calibration of ERBS WFOV after the October 1999 anomaly.

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2. TRMM/ERBS INTERCOMPARISON

The method of comparing scanning and WFOV radiometer results is described by Green et al. (1990). The WFOV measures total and shortwave flux at ERBS altitude. The scanner measures radiances at the TRMM or TERRA spacecraft. Data are used from points where orbits cross and both spacecraft pass this point within ten minutes. Radiances as measured by the scanner are used to compute radiances from all points within the FOV of the WFOV radiometer by use of bidirectional reflectance distribution models for shortwave radiances and limb-darkening models for longwave radiation. These radiances are then integrated to compute the flux as measured by the WFOV radiometer. The computation is done for both shortwave and total radiation.

Nighttime longwave radiation is measured by the total channel for both scanner and WFOV. Figure 1 shows the comparison for nighttime flux. The bias is 1.7 W-m^{-2}(0.8%). The slope difference of 0.04 gives a difference of 2 W-m^{-2} over the measurement range of 50 W-m^{-2}, so that the line of best fit matches at the lower range but differs by 3.7 W-m^{-2} (1.4%) at the top of the range.

Figure 2 shows the comparison for shortwave results. The WFOV has a bias of 2.4 W-m^{-2} (1.5%) higher than the scanner. The slope is 0.97 so that the line of best fit for the two instruments agree at 80 W-m^{-2}, which is the lower end of the measurement range. The scatter for shortwave is significantly greater than that for the longwave. This is attributed to the greater variation of shortwave BRDFs as compared to longwave directional models. During daytime the longwave results for each instrument are given by the difference of total and shortwave results. Figure 3 shows the comparison

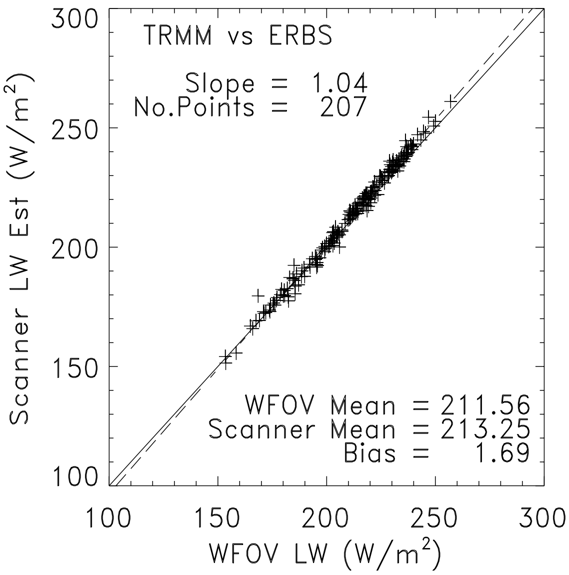

Figure 1: WFOV compared to CERES/TRMM scanner estimate of nighttime longwave radiation.

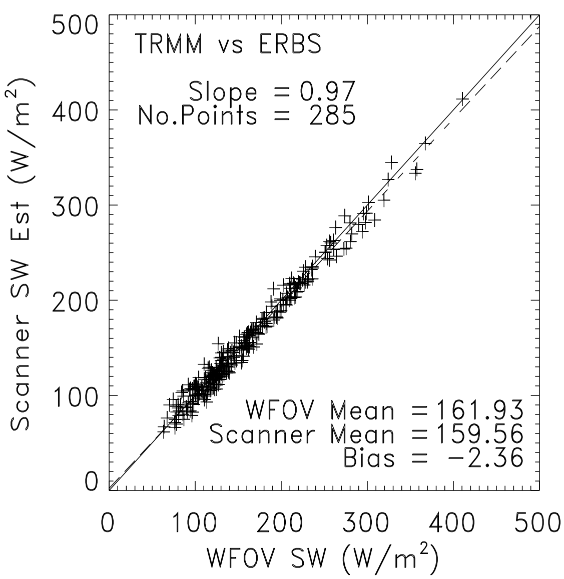

Figure 2: WFOV compared to CERES/TRMM scanner estimate of shortwave radiation.

of CERES/TRMM results with ERBS measurements for daytime. The bias of 4 W-m^{-2} (1.8%) is consistent with the shortwave and night longwave biases. The slope is 1.03, so that the line of best fit agrees at the lower range of the measurements as for the shortwave and nighttime longwave results. The differences of results as function of solar zenith angle of the subsatellite point of ERBS are a useful diagnostic and are shown by fig. 4 for short wave measurements. As ERBS approaches the

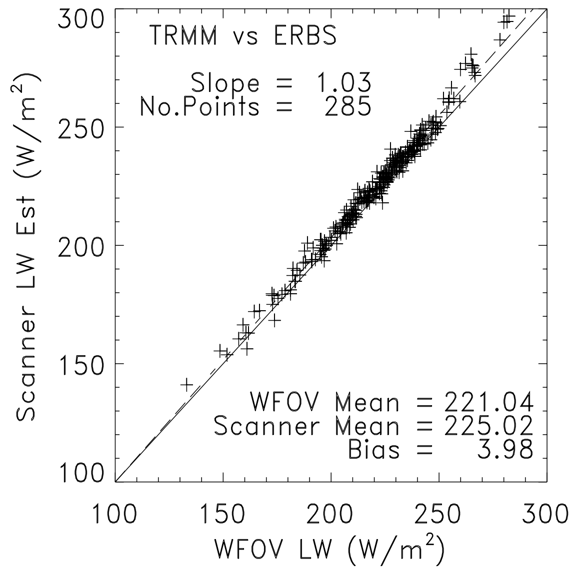

Figure 3: WFOV compared to CERES/TRMM scanner estimate of daytime longwave radiation.

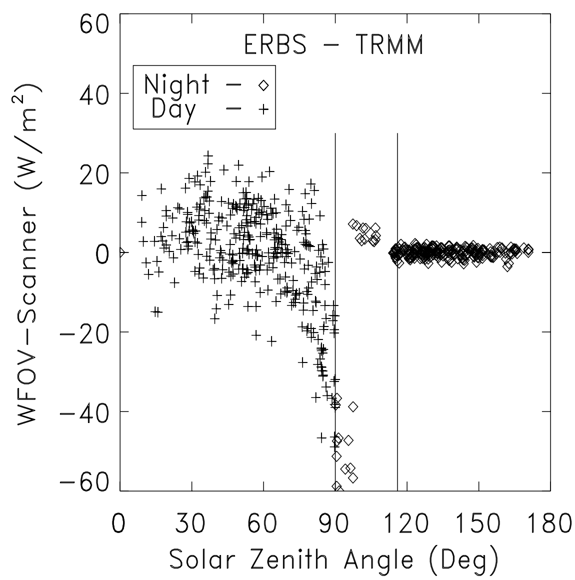

Figure 4: Shortwave WFOV minus CERES/TRMM estimate as a function of solar zenith angle.

terminator (solar zenith angle of 90^o) scanner results increasingly exceed WFOV measurements because the BRDFs are not accurate for large solar zenith angles. Thus, results are not used for solar zenith angles greater than 80^o. This limitation is unfortunate as it reduces the range available for comparison.

Figure 5 shows the longwave flux as measured by ERBS WFOV radiometers minus the flux at ERBS computed from the CERES/TRMM scanner

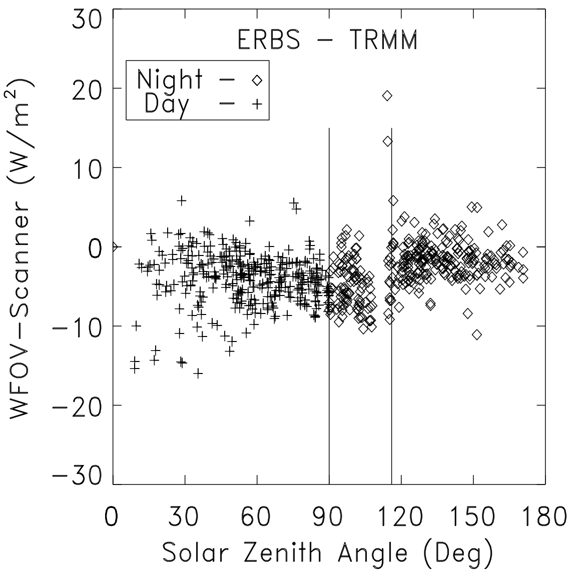

Figure 5: Longwave WFOV minus CERES/TRMM estimate as a function of solar zenith angle.

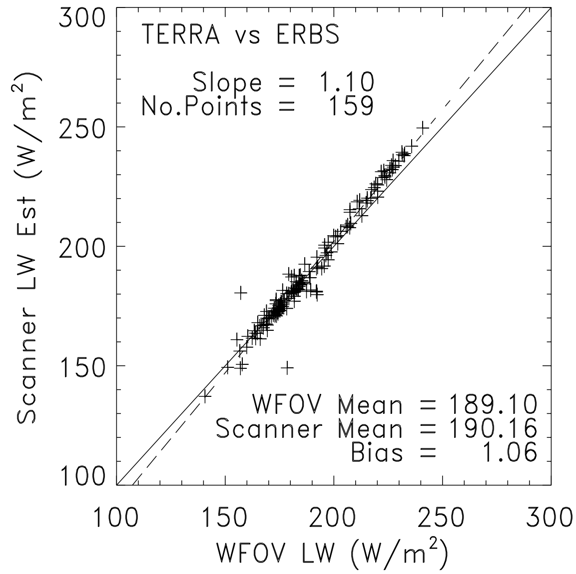

Figure 6: WFOV compared to CERES/Terra estimate of nighttime longwave radiation.

as a function of solar zenith angle. During the day there is a slight downward trend with solar zenith angle, but otherwise the results are as expected.

3. TERRA/ERBS INTERCOMPARISON

Terra is in a Sun-synchronous orbit crossing the Equator at 10:30 AM going south, so that the orbits of ERBS and Terra intersect with local times between 9:00 and 12:00 and over a latitude range between 57^{o} north and south. Comparisons are shown here for March through July 2000 using edition 1 CERES/Terra data. Figure 6 shows the comparison of fluxes at the ERBS spacecraft computed using CERES FM-2 data with WFOV measurements for longwave radiation at night. The WFOV mean is 190.2 W-m^{-2} and FM-2 has a relative bias of 1.06 W-m^{-2}(<1%). Although the means compare quite well, the slope is 1.10 W-m^{-2} resulting in a difference of 3 W-m^{-2} at the lower limit but 7 W-m^{-2} at the upper limit of measurements. Figure 7 shows the comparison for shortwave radiation. The slope is 1.00, but the bias of the shortwave FM-2 relative to ERBS is 20 W-m^{-2}(9%). The daytime longwave comparison is shown in fig. 8. The scanner mean is higher than the WFOV mean by 6.2 W-m^{-2}(3%) and the slope is 1.08. The ERBE WFOV does not agree with Terra as well as any of the other comparisons made before the October 1999 drive failure. Figure 9 shows the differences between the ERBS/WFOV and FM-2 as a function of solar zenith angle. The difference is mostly random, without a noticeable dependence on solar zenith angle and is not understood now.

4. CONCLUDING REMARKS

Comparisons of CERES/TRMM with ERBS WFOV measurements are consistent to better than 1% for nighttime longwave fluxes, 1.5% for shortwave fluxes and 2% for daytime longwave fluxes. Whereas the ERBS WFOV compares well with ERBE scanners, ScaRaB and CERES/TRMM scanners, after the drive failure of October 1999 calibration checks have not been made for the WFOV. Thus, information is not available to account for degradation of the dome of the shortwave channel. It is hoped than in late 2001 a pitchover maneuver can be made with the ERBS spacecraft so that offsets and gains can be determined for the WFOV radiometer channels.

5. ACKNOWLEDGEMENTS

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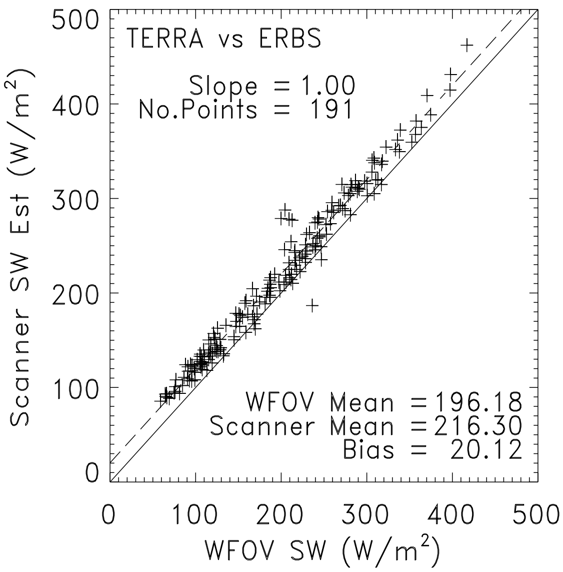

Figure 7: WFOV compared to CERES/Terra estimate of shortwave radiation.

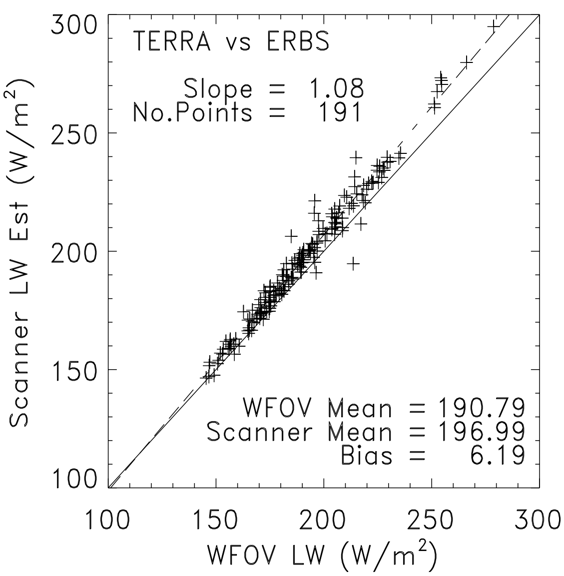

Figure 8: WFOV compared to CERES/Terra estimate of daytime longwave radiation.

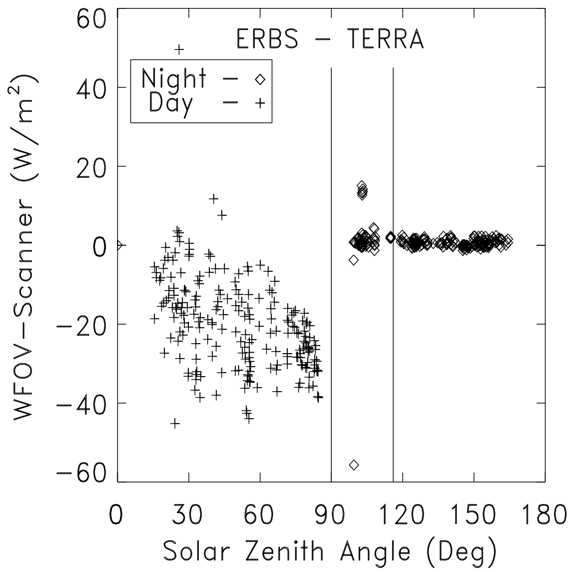

Figure 9: Shortwave WFOV minus CERES/ Terra estimate as a function of solar zenith angle.

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