P1.26 DECADAL VARIABILITY IN TROPICAL BROADBAND RADIATION BUDGET

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1. INTRODUCTION

Continuous monitoring of the earth's radiation field at the top of the atmosphere (TOA) is essential for understanding natural and anthropogenic-induced changes to the earth's climate. To achieve this important science goal, high quality continuous long term broadband radiation datasets are needed. During the past two decades, the National Aeronautics and Space Administration (NASA) has dedicated a number of satellite missions for monitoring the long term broadband radiation environment of the earth system. These missions include the NASA Earth Radiation Budget Experiment (ERBE; Barkstrom 1984) and the NASA Clouds and the Earth's Radiant Energy System (CERES; Wielicki et al. 1996). The ERBE mission, which started on November 1984, contains both a scanner and a nonscanner instrument package. While the scanner instruments, which contained the higher spatial resolution measurements, ceased operating after February 1990, the nonscanner instrument on the Earth Radiation Budget Satellite (ERBS) continues to operate to the present time. This ERBE nonscanner long term dataset, combined with independent datasets from scanner instruments on three other satellites (NASA ERBE/ERBS, French ScaRaB/Meteor, and NASA CERES/TRMM) is used in this paper to examine the decadal variability of the TOA broadband radiation budget in the tropics. Section 2 provides a description of the data used in this study. The results of the data analysis are given in section 3. Section 4 delivers the final summary and discussion.

2. DATA DESCRIPTION

The broadband radiation datasets used in this study are shown in Table 1. These data are from four different independent broadband instruments from three different satellite projects. These radiation datasets can be broken down into two types of data based on their instrument design; the nonscanner and the scanner dataset. The scanner dataset is derived from the scanner instrument, which scans across the orbit plan perpendicular to ground track. The nonscanner dataset is derived from the nonscanner instrument, which looks straight down at the ground track and does not scan across. Both instruments contain active shortwave and longwave calibration source onboard to accurately determine the long term broadband radiation environment of the earth's system. These broadband radiation instruments measure the entire shortwave and longwave spectrum from 0.2 to 5 micron and 5 to 50 micron, respectively. Because of these special broadband features, the outgoing longwave radiation (OLR) data derived from these broadband instruments is more accurate than their National Oceanic and Atmospheric Administration (NOAA) OLR counterpart. The NOAA OLR dataset is derived from narrow-band measurements using model calculations and it does not directly measure the true energy output of the earth system. Since the narrow-band measurements only observe a very narrow longwave spectra of the earth system, physical changes in OLR which are outside the narrow spectrum range may be completely missed by the NOAA OLR data. Due to this reason, the broadband radiation data is scientifically more accurate for monitoring the true energy environment of the earth's climate system. The main broadband radiation dataset used in this study consists of the near-continuous 15 years of ERBE/ERBS noscanner S10N 10-degree shape-factor monthly mean data from January 1985 to June 1999. In addition, this study also utilizes scanner datasets from (1) the five years of ERBE/ERBS S4G 2.5-degree scanner monthly mean data from January 1985 to December 1989, (2) the 11-month ScaRaB/Meteor 2.5-degree scanner monthly mean dataset from March 1994 to February 1995, and (3) the CERES/TRMM ERBE-like ES4G Edition-2 2.5-degree scanner data for first eight months of 1998. While the ERBE/ERBS nonscanner provides a near-continuous dataset between 1985 and 1999, the spatial resolution of the nonscanner data is not as good as the scanner datasets: 10-degree versus 2.5-degree. In addition, the scanner instruments also have better ground calibration characterization than the nonscanner instrument. Therefore, scanner datasets from the four different periods, covering the periods between mid- to late 80's, mid-90's and the late 90's, are also used in this study to validate the ERBE/ERBS nonscanner long term time series.

TABLE 1. Summary of broadband radiation datasets used in this study.

Project	Satellite/ Instrument	Period
ERBE	ERBS/Nonscanner	01/85 - 06/99
ERBE	ERBS/Scanner	01/85 - 12/89
ScaRaB	Meteor/Scanner	03/94 - 02/95
CERES	TRMM/Scanner	01/98 - 08/98

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3. OBSERVATIONAL ANALYSIS

In this section we will examine the observed decadal variability of tropical radiation budget in the ERBE/ERBS nonscanner data period between January 1985 and June 1999. Specifically, we will concentrate on studying the tropical mean TOA radiative energy budget between 20^o N and 20^o S latitude. Figures 1, 2, and 3 show the time series of the tropical mean TOA outgoing longwave radiation (OLR), TOA reflected shortwave radiation (RSR), and TOA net radiation, respectively, for all four broadband radiation datasets during the nonscanner data period. The ERBE/ERBS nonscanner data is shown in solid black line. The ERBE/ERBS scanner is shown in dashed grey line. The ScaRaB/Meteor scanner data is given as solid triangle and the CERES/TRMM scanner data is shown in solid circle.

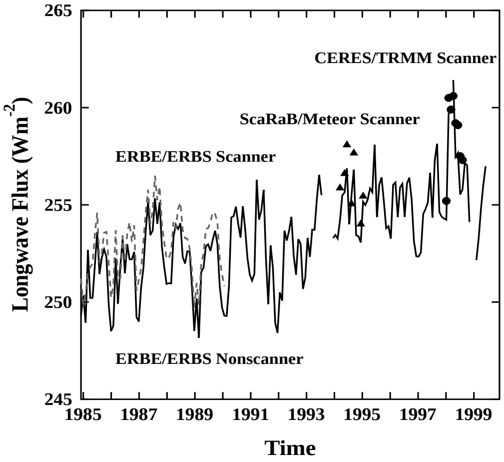

FIG 1. Time series of tropical mean outgoing longwave radiation for the period between January 1985 and June 1999.

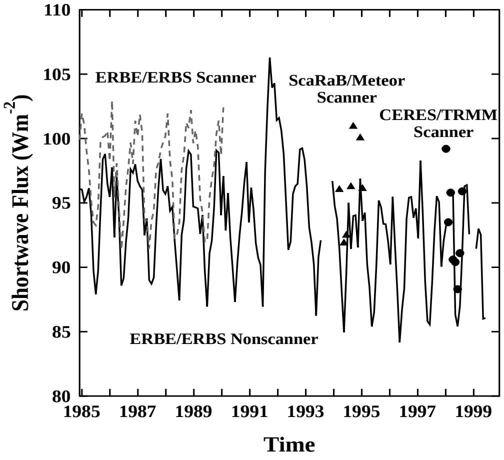

FIG 2. Time series of tropical mean reflected shortwave radiation for the period between January 1985 and June 1999.

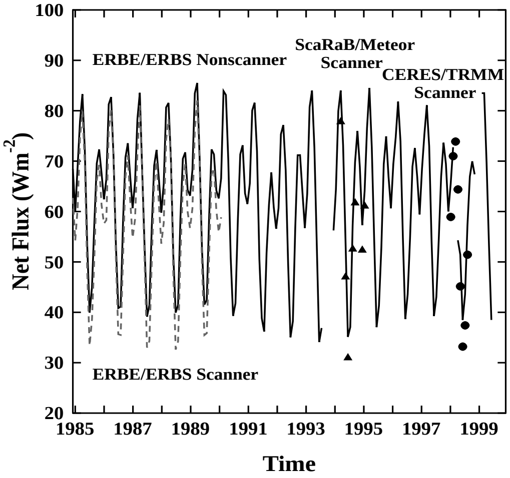

FIG 3. Time series of tropical mean net radiation for the period between January 1985 and June 1999.

Three major findings can be deduced from these figures. First, the long term broadband nonscanner data agree remarkably well with the three independent broadband scanner datasets. The differences between scanner and nonscanner monthly mean values are well within the estimated temporal sampling uncertainty (given in Table 2 below) caused by the differences in orbital sampling pattern between these satellites. This suggests that the quality of the long term nonscanner dataset is comparable to those of the scanner datasets for tropical mean monitoring.

TABLE 2. Estimated monthly mean tropical mean temporal sampling errors in Wm^{-2} for OLR, RSR and Net radiation due solely to orbital sampling for ERBS/scanner data, ERBS/nonscanner data, and CERES scanner data.

Satellite/Instrument	OLR	RSR	Net
ERBS/Scanner	0.24	1.61	1.58
ERBS/Nonscanner	0.37	1.72	1.48
TRMM/Scanner	0.14	0.91	0.95

Second, there is a notable decadal variability in tropical TOA longwave and shortwave radiation budget during this 15-year period. For example, the values of TOA OLR (given in Fig. 1) during the 90's are higher than their corresponding values during ERBE 85-89 period. The higher OLR values, however, seems to move closer back to those of ERBE 85-89 climatology after the 1997-98 ENSO event. In order to estimate the magnitude of this tropical mean OLR variability, a linear regression analysis is performed for the whole nonscanner data period. The linear regression results are shown in Table 3. According to this analysis, the TOA tropical mean OLR is changing at a rate of about +3.6 Wm^{-2}/decade over the entire nonscanner data period. This positive rate of change in the tropical mean OLR is statistically significant since it lies outside the 2-sigma uncertainty limit estimated from the nonscanner dataset. While a linear regression analysis is used in this study to give a first order estimate of the OLR changes during this data record, the actual decadal variability in OLR, as given in Fig. 1, is far from being linear. For example, there seems to be a transition of OLR in early 1991, before the Pinatubo eruption, when the OLR begins to increase and to move away from its 85-89 baseline climatology. The positive increase in all-sky OLR is consistent with results of an earlier study (Wielicki et al 1999) where they also noted positive differences between 1998 CERES all-sky OLR data and ERBE all-sky OLR 85-89 climatology. In another study, Wong et al (2000) found that the tropical mean clear-sky TOA OLR value was well within the ERBE 85-89 climatological values after the 97-98 ENSO period. The results of these two studies suggested that changes in cloud properties between the ERBE and CERES time periods are responsible for the differences between the observed agreement in clear-sky OLR and disagreement in all-sky OLR. The observed TOA RSR, given in Fig. 2, shows a similar, but opposite effect during this 15-year period. For example, the values of the RSR in the 90's are lower than their corresponding values during the ERBE 85-89 period. A linear regression analysis is used again to quantify the RSR change during this period. The results (given in Table 3) indicates that the RSR is changing at a rate of about -2.4 Wm^{-2}/decade over the entire nonscaner data period. This negative change in tropical mean RSR is again found to be statistically significant since it also lies outside the 2-sigma uncertainty limit estimated from the nonscanner dataset. While a linear regression analysis is used to give a first order estimate of the RSR changes during this data record, the actual decadal variability in RSR, as given in Fig. 2, is again far from being linear. For example, there seems to be a transition of RSR in early 1991, before the Pinatubo eruption, when the RSR begins to decrease and to move away from its 85-89 baseline climatology. These RSR features are consistent with the OLR results and again point to the effect of possible cloud property changes in the tropics during this period.

Third, the TOA net radiation budget (given in Fig. 3), which represents the combined effect of both TOA OLR and TOA RSR, remains relatively unchanged during this 15-year period. The linear regression analysis (shown in Table 3 above) does not show any statistically significant changes in net radiation over the entire nonscanner data period. This feature indicates that the effects of both the OLR change and the RSR change during this period tend to largely cancel each other out and the net effects on the TOA energy budget is near zero over this 15-year period. This decadal variability in tropical mean TOA OLR and RSR field and the near-zero variability in tropical mean TOA net radiation field is again consistent with the radiative effect of cloud property changes over the tropical belt during this 15-year period.

TABLE 3. Linear regression analysis for (1) the rate of change and (2) its associated 2-sigma uncertainty in nonscanner tropical mean OLR, RSR, and net radiation for the period between January 1985 and June 1999. Asterisk indicates that change is statistically different than zero.

	Rate of Change (Wm^{-2}/decade)	Uncertainty (Wm^{-2}/decade)
OLR	+3.6*	0.7
RSR	-2.4*	1.4
Net	-1.5	4.9

4. SUMMARY AND DISCUSSION

Using near-continuous long term broadband radiation data from ERBE/ERBS nonscanner instrument, a study is carried out to examine the decadal variability in tropical broadband radiation budget between January 1985 and June 1999. It is found that the ERBE/ERBS nonscanner instrument can provide a high quality measurement for monitoring the long term tropical mean radiation budget (defined as the mean value between 20^o N and 20^o S latitude). Specifically, remarkable agreements are found between the nonscanner and the scanner datasets when the various scanner datasets are overlaid onto the nonscanner long term time series. While time series analysis of the tropical mean radiation budget indicates a statistically significant decadal variability in TOA broadband OLR and RSR fields over this 15-year period, the time series of the net radiation budget, on the other hand, does not show any statistically significant decadal changes over the same period. Furthermore, the observed variabilities between OLR and RSR during this period are very similar, but in opposite sign. There is a increase/decrease in the tropical mean OLR/RSR, respectively, during the 90's as compared to the ERBE 85-89 climatology. However, both the changes in OLR and RSR seem to reverse their direction after the end of 97-98 ENSO period and are moving closer to their ERBE 85-89 climatological values. Although these decadal variabilities in tropical radiation budget are theoretically consistent with the radiative effects of cloud property changes over the tropics during this 15-year period, additional satellite cloud observations are still needed to fully understand these changes. While long term ISCCP cloud dataset from 1985 to 1999 period is currently not available to examine this issue in more details, preliminary analyses of existing cloud data are very encouraging and they are also pointing in the same direction as the OLR changes. For example, cloud frequency data using SAGE II data from the ERBS satellite does indicate a decrease in high cloud frequency during this period. This decrease in high cloud frequency recorded by the SAGE II instrument is consistent with the increases in OLR recorded by the ERBE/ERBS non-scanner broadband radiation instrument (Personally communization, Wang 2000) over this long time period. Preliminary analysis of ISCCP data between 1985 and 1993 also shows a decrease in total cloud amount in the 90’s relative to the ERBE 85-89 period. While the exact cause of this observed decadal variability in tropical radiative energy budget is still under investigation, it is clear from this study that a continuous, long term observation of TOA broadband OLR and RSR is necessary for detecting and understanding long time scale climate variability and climate change.

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