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FIRST YEAR OF CERES/TERRA ERBE-LIKE GLOBAL RADIATION BUDGET OBSERVATIONS

Takmeng Wong*, David F. Young, and Bruce A. Wielicki
NASA Langley Research Center, Hampton, VA

1. INTRODUCTION

Continuous monitoring of the Earth's radiation field at the top of the atmosphere (TOA) is essential for understanding climate and climate variability on Earth. To achieve this important science goal, the National Aeronautic and Space Administration (NASA) has begun the Clouds and the Earth's Radiant Energy System (CERES) project (Wielicki, et al., 1996), which consists of Earth radiation budget instrument packages flying on three different satellites, beginning with Tropical Rainfall Measuring Mission (TRMM) satellite in November 1997, the Earth Observing System (EOS) Terra spacecraft in December 1999, and the EOS Aqua satellite in May 2002. Building on the successful Earth Radiation Budget Experiment (ERBE) project (Barkstrom, 1984), this multi-satellite Earth Radiation budget mission will provide the scientific community with necessary information for monitoring and understanding the Earth's radiation environment well into the 21th century.

After two months of initial routine checkup, the two CERES instruments (FM-1 and FM-2) installed aboard the NASA EOS Terra spacecraft begin taking scientific observations on February 26, 2000. They have since provided global broadband radiation measurements for over 25 months. This paper will show preliminary results of radiation budget analyses from the first year of the CERES/Terra operation. Results will include regional and global analyses of outgoing longwave radiation, reflected solar radiation, net radiation, and cloud radiative forcings over various time scales. In addition, tropical mean outgoing longwave radiation will be shown along with results from other broadband datasets to illustrate the long-term variability of the tropical mean longwave radiation budget.

2. DATA DESCRIPTION

The main radiation data used in this paper are extracted from the first full year of CERES/Terra ERBE-like Edition-1 ES-9 FM-1 and FM-2 combined dataset and cover the period between March 1, 2000 and February 28, 2001. Specifically, these data include regional daily mean and monthly mean estimate of top of atmosphere (TOA) outgoing longwave radiation (OLR), reflected solar radiation (RSR), and net radiation (NET) for the whole globe on a 2.5-degree equal-angle grid and cover all regions between the North and South Pole. Other datasets used in this paper include the CERES/TRMM ERBE-like Edition2 dataset, ERBE/ERBS S9 scanner dataset, ERBE/ERBS/S10 nonscanner dataset, ScaRaB/Meteor and ScaRaB/Resurs monthly mean scanner dataset, and Nimbus-7 nonscanner dataset. Examples of preliminary results from our analyses are given below in the order of increasing time scale.

3. RESULTS

3.1 *Daily Time Scale*

Daily mean TOA radiation budget records are an important data source for the validation of global numerical weather model. In addition, radiation data at this time scale are also very useful in many observational climate studies, ranging from studies on climate variability on time scale less than a month to studies on identifying abrupt transitions in the dataset. Figure 1 shows an example of the regional map of daily mean OLR on March 1, 2000. Areas of low OLR are visible in both the tropics and higher latitudes. These include areas associated with both tropical deep convection, mid-latitude synoptic storm systems, and the extreme cold polar regions near both Poles. Regions of high OLR include areas of major deserts and subtropical subsidence zones across the 30º latitudes. Figure 2 shows time series of daily mean OLR from two regions. The Equatorial Indian Ocean time series shows high frequency peaks and valleys that are imbedded within OLR features of longer time scales. The time series for the Eastern Pacific Ocean, however, shows a relatively constant OLR field through most of the year with a transitional period that is marked by high OLR variability.

Corresponding author address: Dr. Takmeng Wong, NASA Langley Research Center, Mail Stop 420, Hampton, VA 23681-2199; e-mail address: takmeng.wong@larc.nasa.gov.

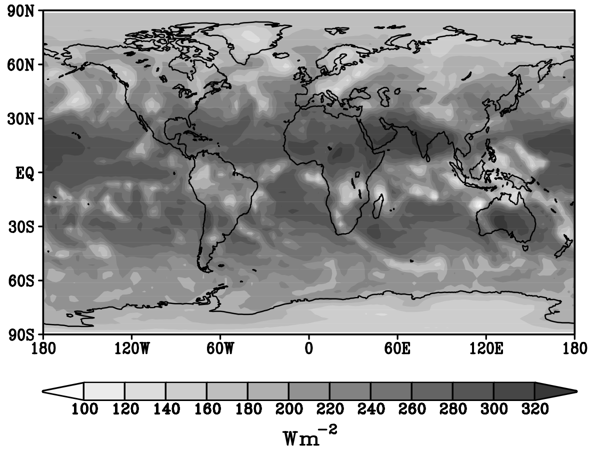

FIG. 1. Daily mean map of regional CERES/Terra OLR for March 1, 2000.

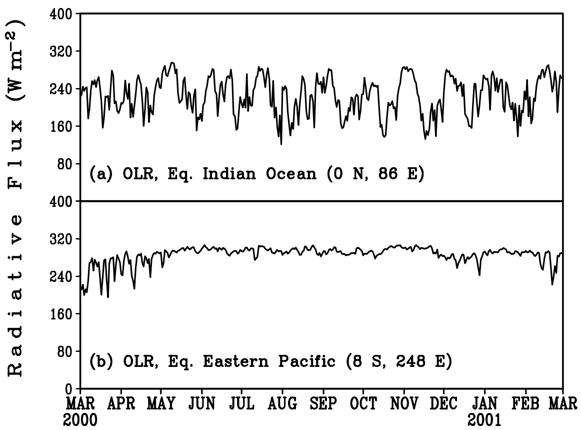

FIG. 2. Variation of daily CERES/Terra OLR with time for (a) a point in the Equatorial Indian Ocean and (b) a point in the Eastern Pacific Ocean.

3.2 ***Monthly Time Scale***

Monthly mean data have been use in the climate community to form the basis of climate statistics. For example, global climate models are routinely outputting their monthly mean data and using this information for generating statistics for climate prediction. The ERBE-like monthly mean radiation data can be used to generate similar statistics for validation of these global climate models. In addition, these monthly mean data can be used to (1) monitor the radiative budget of the Earth system on a global or regional scale and (2) examine the cloud radiative forcing effects on the climate system. Figures 3 and 4 show the regional map of net radiation for March 2000 and their corresponding time series of global mean net radiation during the first 12 months of the Terra observations. The regional map shows a positive net energy surplus into the Earth system for much of the tropical and subtropical regions and a negative net energy deficit for the rest of the Earth, with the polar regions being the largest source of energy deficit on Earth during this month. Areas of energy deficit also appear over the north African desert. The global mean OLR, RSR, and NET for March 2000 are 238.1 Wm^{-2}, 97.9 Wm^{-2}, and 8.6 Wm^{-2}, respectively. The corresponding global mean cloud forcing for longwave, shortwave, and net radiation are 26.9 Wm^{-2}, -46.4 Wm^{-2}, and -19.5 Wm^{-2}, respectively. The net effects of clouds are to cool the Earth system, relative to the clear-sky conditions, by reducing NET energy into the system. The time series of global mean NET radiation shows an energy surplus into the Earth system from March to mid-April and from late August through February. Energy deficit dominates the net radiation for the rest of the year from mid-April to late August.

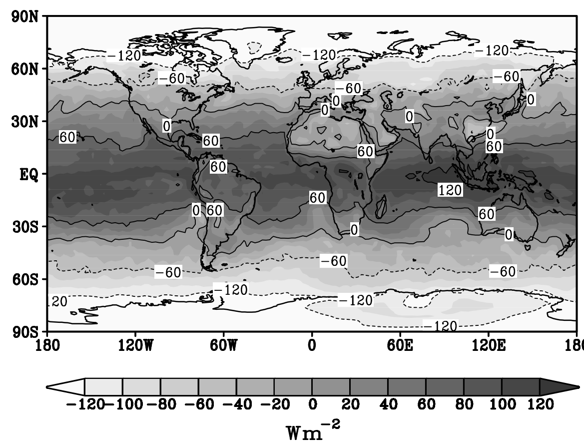

FIG. 3. Monthly mean map of regional CERES/Terra NET radiation for March 2000.

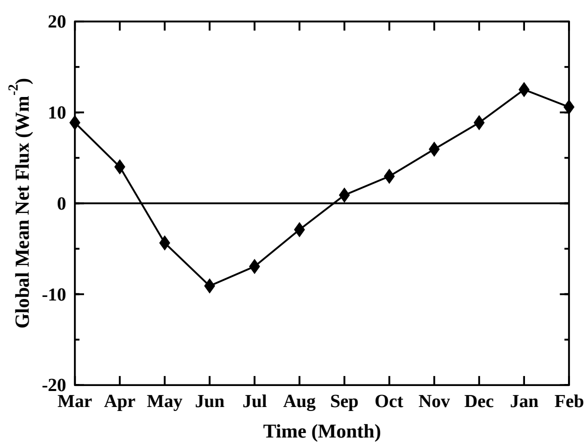

FIG. 4. Time series of global averaged monthly mean NET radiation during the first year of CERES/Terra observations.

3.3 *Intraseasonal Time Scale*

Variability on Intraseasonal time scales is an important feature of the Earth climate system. Understanding the physical causes of this variability can have the potential benefit of improving future climate forecasts. Figure 5 shows the results from a recent study (Wong and Smith, 2002) on the intraseasonal variability of OLR using data from the first full year of CERES/Terra observations. This figure shows a large intraseasonal variability in the tropics over the west Indian Ocean, the area around the maritime continent, the Inter-Tropical Convergence Zone (ITCZ), and the Southwest Pacific Convergence Zone. These features may be related to MJO activities. Large variabilities are also found in the Atlantic Ocean, off the coast of North Africa and over the Amazon region. There is very little intraseasonal variation over the subsidence zone along the Eastern Pacific Ocean. The intraseasonal variability of OLR extends beyond the tropics. However, it becomes very small at latitudes greater than 50° in both hemispheres.

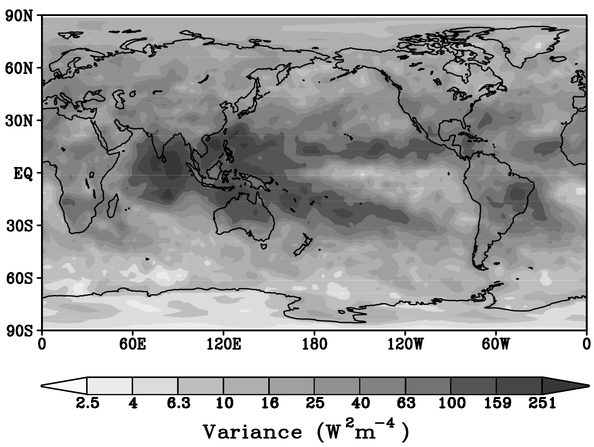

FIG. 5. Regional map of Intraseasonal variability of OLR constructed using first year of CERES/Terra data.

3.4 *Annual Time Scale*

The radiation data at annual time scale are important for climate diagnostic study because the annual mean energy storage into the Earth system is close to zero and the radiation results represent a clear and complete picture of Earth energy balance over a year. Figure 6 shows the regional map of annual mean OLR, RSR, and NET from the first full year of CERES/Terra observations. The OLR map shows high values over the subtropical regions of both hemispheres. The ITCZ is visible in the picture as a narrow band of lower values, sandwiched between the two higher OLR subtropical regions. OLR decreases poleward from the subtropics. While the highest OLR values are located over the major deserts and subsidence zones, the lowest OLR value occurs over the South Pole. The RSR map shows many features. Low RSR is found over the subtropical oceans and high RSR is located over areas of tropical deep convections, mid-latitude storm tracks, polar snow caps, and major deserts. Areas of stratus cloud, off the west cost of most major continents, also give higher values of RSR. The NET radiation map looks similar to Fig. 3, but is much smoother. Overall, the tropics and the subtropics are gaining energy while the rest of the Earth is losing energy. The annual averaged global mean OLR, RSR, NET, and albedo for the first year of CERES/Terra data are 240.1 Wm^{-2}, 98.6 Wm^{-2}, 2.6 Wm^{-2}, and 28.9%, respectively.

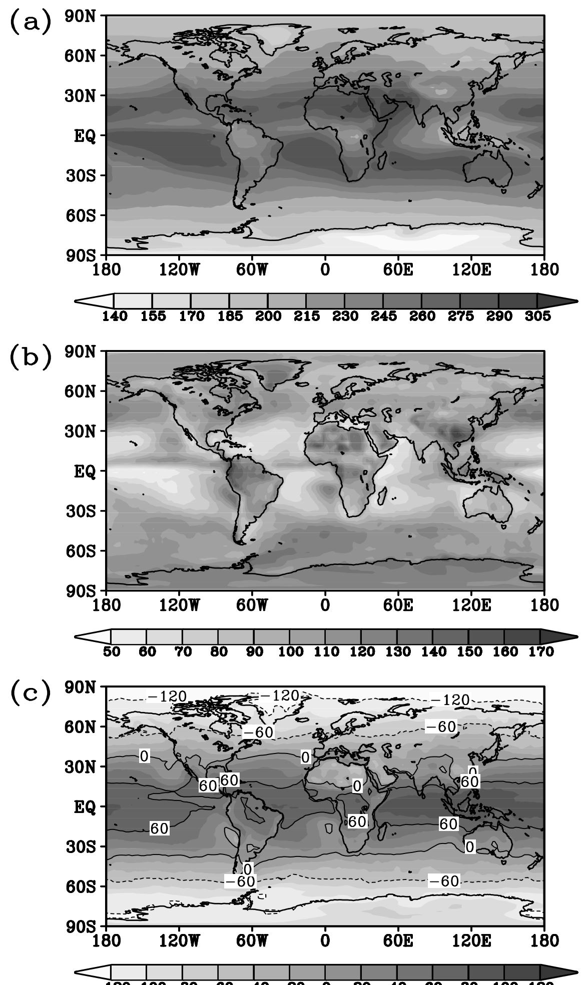

FIG. 6. Regional map of annual mean (a) OLR, (b) RSR, and (c) NET radiation during the first year of CERES/Terra observations.

3.5 *Decadal Time Scale*

Monitoring the long-term Earth radiative balance at TOA is essential for understanding climate changes and for improving current global climate models. Figure 7 shows results from a recent study (Wielicki et al. 2002) on decadal variations in the tropical mean (20º N to 20º S) radiative energy budget. Using data records from seven independent instruments, on six different satellites, including Nimbus-7 nonscanner, ERBE/ERBS scanner, ERBE/ERBS nonscanner, ScaRaB/Meteor scanner, ScaRaB/Resurs scanner, CERES/TRMM scanner, and CERES/Terra scanners, over a 22-year time span from 1979 to 2001, Wielicki et al. (2002) shows observational evidence for a large decadal variation of tropical broadband OLR. Specifically, there is an apparent drop of about 2 Wm^{-2} in OLR from the late 1970s to the mid-1980s, followed by a rise of about 4 Wm^{-2} from the late 1980s to the mid to late 1990s. In addition to these large decadal changes, there are also significant short term variability in tropical OLR associated with El Nino/La Nina events and two major volcanic eruptions. Since the radiative impact for doubling of CO_2 is about 4 Wm^{-2}, large natural decadal variation of tropical OLR such as this is considered a major change. These observed changes in tropical OLR have been linked to the strengthening of the tropical general circulation in the 1990's (Chen et al., 2002).

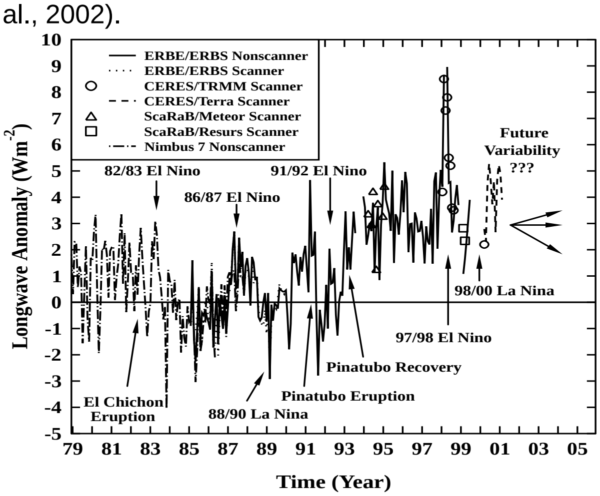

FIG. 7. Decadal variation of tropical mean OLR for a 22-year period from 1979 to 2001. Results are from 7 independent instruments on 6 satellites.

4. SUMMARY

Using the first full year of CERES/Terra broadband radiation dataset, this paper illustrates some examples of the Earth radiative energy budget study on various temporal (i.e., daily, monthly, intraseasonal, annual, and decadal) and spatial (such as regional and global) scale. While it is not possible to give a full detailed account on each of these results in the limited space given here, we hope that the specific information shown in this paper will be helpful to climate researchers in assessing the many possible uses of this high quality climate radiation dataset. The ultimate goal of the CERES mission is to improve human understanding of global climate and climate variability on Earth. CERES/Terra ERBE-like data is making the first effort in achieving this goal. Additional CERES/Terra global climate datasets (i.e., CERES/Terra SRBAVG product) with higher monthly mean accuracy will be available in the near future. These new datasets with improved diurnal radiation information from geostationary satellites will further enhance our current knowledge of Earth's climate.

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