JP5.15 INTRASEASONAL VARIATIONS OF EARTH RADIATION BUDGET: CERES EOS/TERRA OBSERVATIONS VERSUS NCEP REANALYSIS 2 DATA

Takmeng Wong* and G. L. Smith
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. 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 of outgoing longwave radiation (OLR) and reflected solar radiation (RSR) from the Earth for over three and half years.

This paper will show preliminary comparisons of the intraseasonal variability, defined as variations with period of 20 to 60 days, of OLR and RSR deduced from the first year of the CERES/Terra observations against those derived from the NOAA/NCEP Reanalysis 2 system. Intraseasonal scale is a important component of the Earth climate system since it fills the gap between the traditional weather scale events and those associated with the longer climatic scale systems. Understanding the distribution of intraseasonal variation will improve both our knowledge of the Earth climate system and our ability to model them using global climate models. Section 2 will provide a general description of the data and analysis method used in this study. Results from regional, zonal, and global mean analyses will be discussed in section 3. Section 4 will give a summary of this work.

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

2. DATA ANALYSIS TECHNIQUE

The global radiation measurements used in this study 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 estimate of top of atmosphere (TOA) OLR and RSR on a 2.5º equal-angle grid and cover all regions on the Earth between North and South Pole. The modeled NCEP/Reanalysis 2 daily mean OLR and RSR data for the same period are obtained by regridding the original 6-hourly NCEP data into the CERES ERBE-like grid and averaging these data into a daily mean estimate.

The technique of Wong and Smith (2002) is used to transform the regional time series of daily mean OLR and RSR over the entire Earth from both the CERES and NCEP data into global maps of intraseasonal variations of OLR and RSR. Specifically, the individual regional time series is first transformed into frequency space using discrete Fourier Transform. The individual regional variance associated with the intraseasonal time scale is then obtained by integrating the resultant power spectrum over the frequency range of interest (i.e., period of 20 to 60 days). This operation is performed independently for every region over the entire globe. The global maps of intraseasonal variations of OLR and RSR are then obtained by recombining the individual regional result together. Regional, zonal, and global mean comparisons using these intraseasonal variability maps are then performed to extract statistical information about the similarity and differences between observations and modeled radiation fields.

3. RESULTS

3.1 *Regional Comparisons*

Figure 1 shows the global map of intraseasonal variability of OLR deduced from both the CERES observations and the NCEP Reanalysis 2 data. Qualitatively, both of these datasets show very similar intraseasonal variability. Both of them show large intraseasonal variability in the tropics over the Indian Ocean, the South China Sea, the area around the maritime Continent, the intertropical convergence zone (ITCZ), the Southwest Pacific convergence zone, the Southwest Atlantic convergence zone, and the Amazon Basin. There is very little intraseasonal variation over the subsidence zone along the Eastern and Central Pacific Ocean and in the stratus regions off the west coast of North and South America and the African Continent. The intraseasonal variability of OLR extends beyond the tropics. However, it becomes very small at latitudes greater than 60º in both hemispheres. There are also some noticeable differences between these two fields as shown in Figure 2. The NCEP Reanalysis 2 data have a smaller dynamics range of intraseasonal variability than the actual data, especially over the tropics. The modeled fields do not capture the highest value over the tropical Indian Ocean and the lowest value over the central and eastern tropical Pacific ocean. Over the extra-tropical regions, the modeled fields tend to overestimate the actual observed intraseasonal variability.

Figure 3 shows the global map of intraseasonal variability of RSR deduced from both the CERES observations and the NCEP Reanalysis 2 data. While there are some similar features in intraseasonal variability between these two data sets, such as the large RSR variability in the tropics, the low RSR variability in the polar regions, the large RSR variability over the Maritime continents of the western Pacific ocean, and the small RSR variability over the North African Desert, most regional patterns between these two datasets disagree with each other. For example, the observed small/large intraseasonal variability of RSR over the central tropical Pacific ocean/mid-latitude continental regions are missing from the NCEP data, respectively. Large intraseasonal variability of RSR is also missing over much of the Southern Ocean in the regions between 30ºS to 60ºS. The RSR intraseasonal variabilities over the Indian ocean, Southwest Pacific Convergence Zone, African Desert are suppressed and less organized in the NCEP data. The NCEP data also seem to have excessive RSR intraseasonal variability over the Southern Ocean just off the coast of Antarctica. Overall, the NCEP data tend to have too little intraseasonal variability over most extra-tropical regions, especially over land, and too much intraseasonal variability over subsidence regions of the central tropical Pacific as shown in Figure 4.

3.2 *Zonal Mean Comparisons*

Figure 5 shows zonal mean profiles of intraseasonal variability of OLR from both the CERES observation and the NCEP data along with their zonal mean differences. The shape/slope of the observed and modeled zonal mean OLR variabilities reassemble each others; suggesting the NCEP Reanalysis 2 system can reproduce the observed zonal mean intraseasonal variability. The model does have a tendency of overestimating the actual OLR intraseasonal variability in the deep tropics and in the areas poleward of 30º in both hemispheres. At the same time, it tends to underestimate the OLR intraseasonal variability in the regions around 15ºN or 15ºS. The absolute differences in zonal mean variance due to intraseasonal variation between observations and modeled data can be as much as 25 W^2m^{-4}.

Figure 6 shows similar zonal mean comparisons for the corresponding RSR field. In contrast to the OLR field in Figure 5, the shape/slope of the modeled zonal mean profile of RSR intraseasonal variability departs significantly from actual observations, especially in the Northern Hemisphere. The NCEP model significantly underestimates the observed zonal mean RSR intraseasonal variance poleward of 20º in both hemispheres while it overestimates the zonal mean RSR intraseasonal variability in the tropics between 20ºN and 15ºS and in a zone south of 60ºS. The absolute differences in the zonal mean variance is more than three time that of the OLR value.

3.3 *Tropical, Mid-latitudes, and Global Mean Comparisons*

Tables 1 to 4 show the intraseasonal variability of OLR and RSR deduced from both the CERES and NCEP data for the tropics (30ºN to 30ºS), northern mid-latitudes (30ºN to 60ºN), southern mid-latitudes (30ºS to 60ºS), and the entire globe (90ºN to 90ºS). For the tropics as a whole, the NCEP model tends to overestimate the mean intraseasonal variability of both OLR and RSR when compared with CERES observations. In addition, the region-to-region differences of intraseasonal variability are smaller in the NCEP model than the CERES observations. This is due in part to the inability of the model to capture the full dynamic range of the observed variances for both OLR and RSR in the tropics. The NCEP modeled

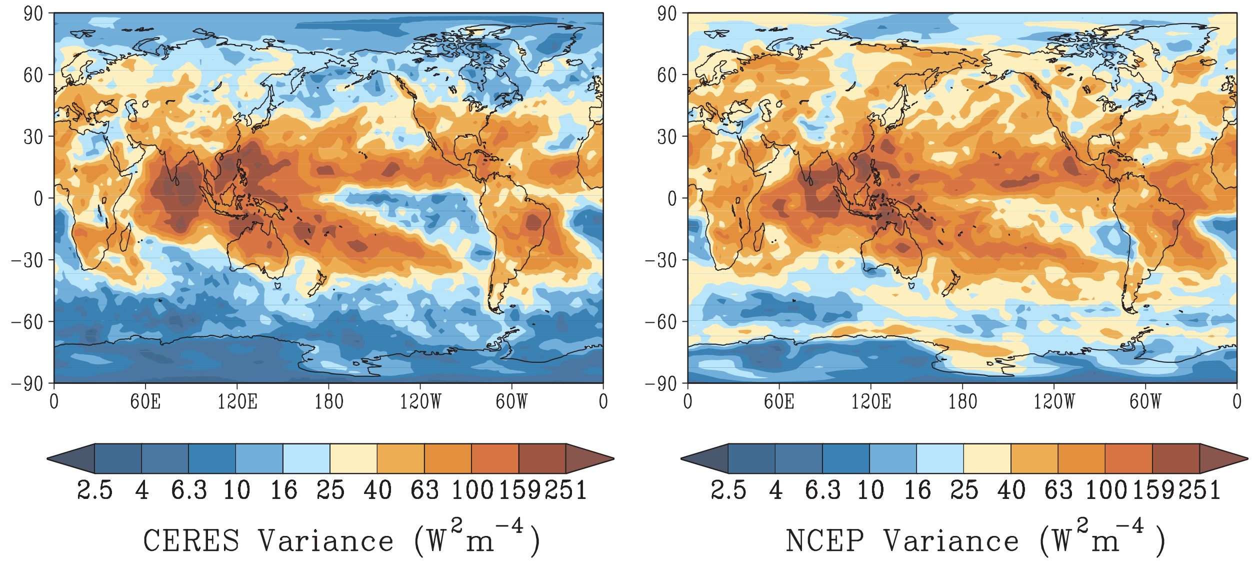

FIG. 1. Regional map of intraseasonal variability of OLR constructed using first year of CERES/Terra data (left) and NCEP Reanalysis 2 data during the same period (right).

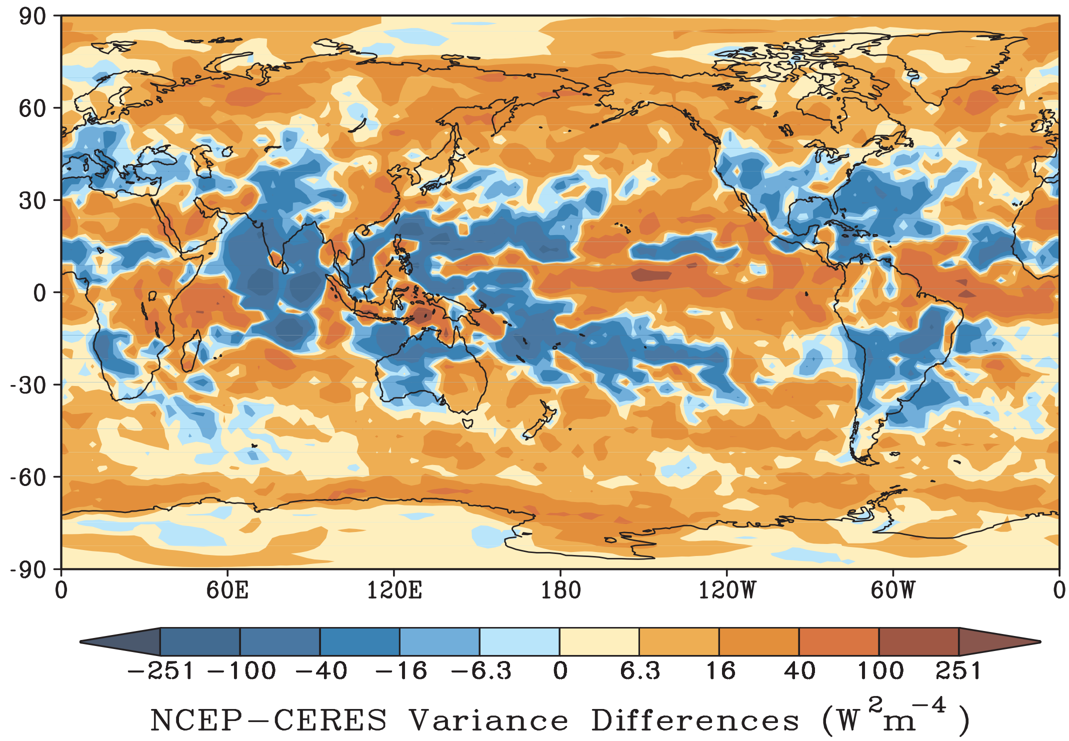

FIG. 2. Regional map of differences in intraseasonal variability of OLR between NCEP Reanalysis 2 data and CERES/Terra observations during the first year of EOS/Terra operation.

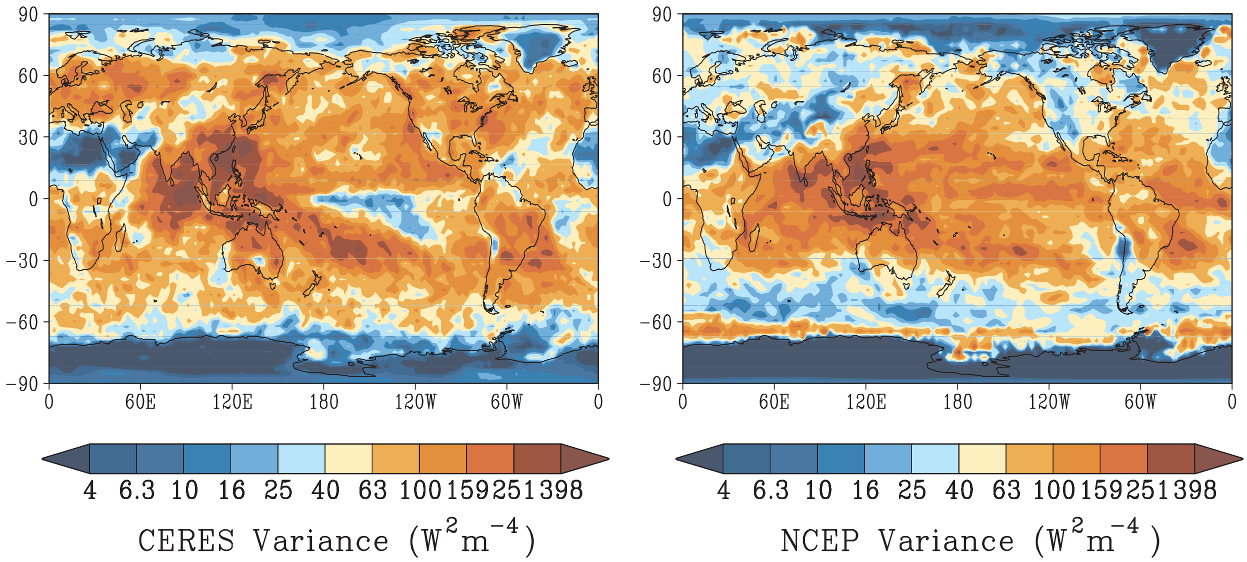

FIG. 3. Regional map of intraseasonal variability of RSR constructed using first year of CERES/Terra data (left) and NCEP Reanalysis 2 data during the same period (right).

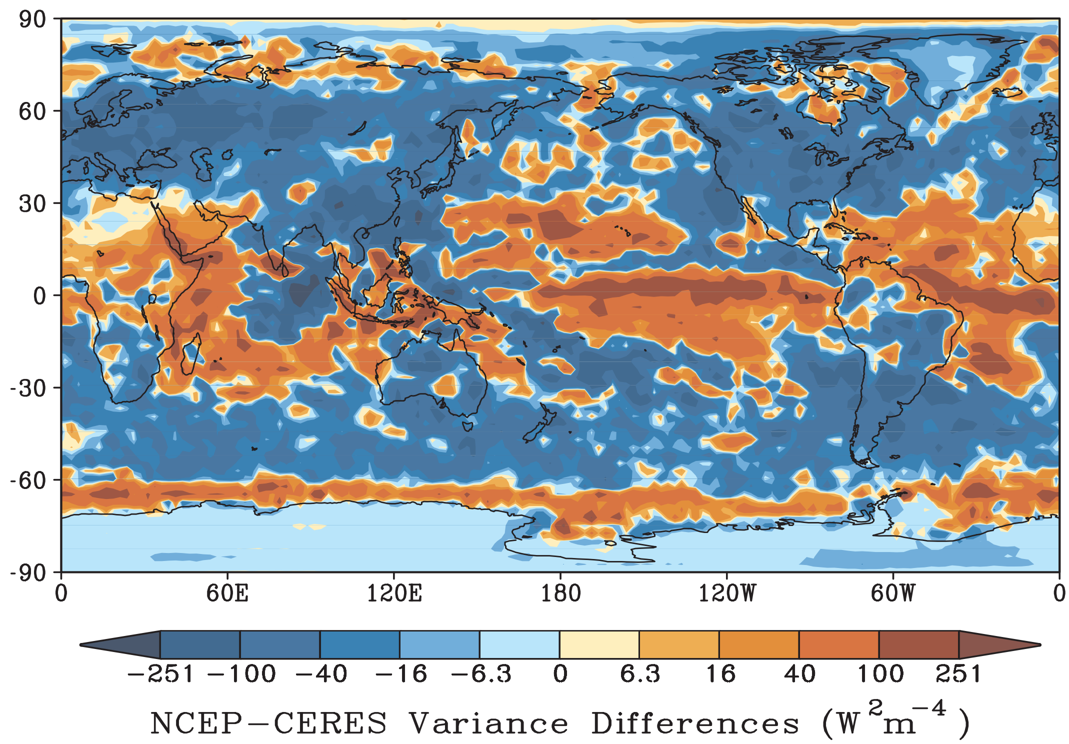

FIG. 4. Regional map of differences in intraseasonal variability of RSR between NCEP Reanalysis 2 data and CERES/Terra observations during the first year of EOS/Terra operation.

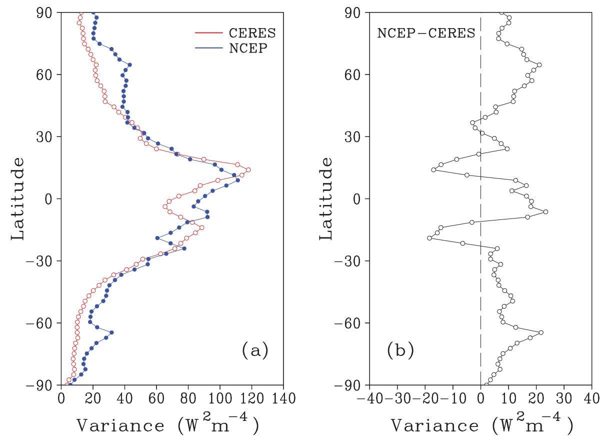

FIG. 5. Zonal mean profile of intraseasonal variability of OLR from (a) CERES observations and NCEP Reanalysis 2 modeled data and (b) their zonal mean differences.

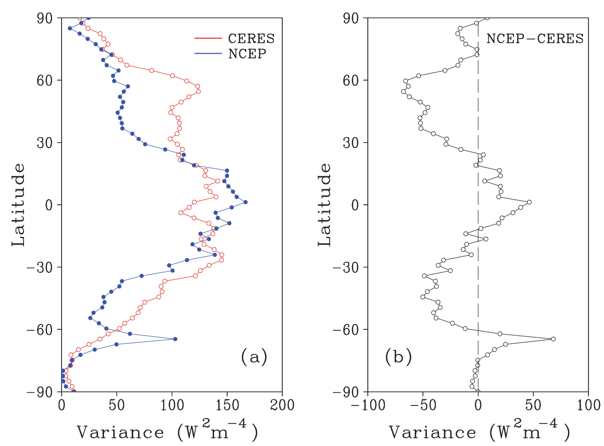

FIG. 6. Zonal mean profile of intraseasonal variability of RSR from (a) CERES observations and NCEP Reanalysis 2 modeled data and (b) their zonal mean differences.

mean and regional sigma of intraseasonal variability for OLR, however, are much closer to the CERES observations than those of the RSR. While the NCEP Reanalysis 2 system again overestimates the actual mean OLR variance in the mid-latitudes, it underestimates the actual RSR variance when compared to CERES observations. The region-to-region variability of the intraseasonal variance is similar between model and observations for the OLR field. For the RSR field, the model again underestimates the region-to-region variability in intraseasonal variance. For the globe as a whole, the model overestimates the mean OLR intraseasonal variability by a 7 W^2m^{-4} in variance and underestimates the RSR intraseasonal variability by a 14 W^2m^{-4} in variance.

TABLE 1. Variance (W^2m^{-4}) of tropical mean (30ºN to 30ºS) OLR and RSR intraseasonal variability (mean/sigma) from CERES and NCEP.

	CERES	NCEP	NCEP-CERES
OLR	77.6 / 58.0	81.3 / 48.0	2.69 / 40.6
RSR	127.0 / 99.3	132.0 / 76.3	5.1 / 81.3

TABLE 2. Variance (W^2m^{-4}) of northern mid-latitude mean (30ºN to 60ºN) OLR and RSR intraseasonal variability (mean/sigma) from CERES and NCEP.

	CERES	NCEP	NCEP-CERES
OLR	33.8 / 17.4	41.7 / 15.2	7.9 / 15.3
RSR	108.8 / 53.9	56.2 / 32.4	-52.6 / 51.0

TABLE 3. Variance (W^2m^{-4}) of southern mid-latitude mean (30ºS to 60ºS) OLR and RSR intraseasonal variability (mean/sigma) from CERES and NCEP.

	CERES	NCEP	NCEP-CERES
OLR	22.7 / 16.5	30.4 / 16.2	7.6 / 9.7
RSR	83.3 / 41.7	47.4 / 31.3	-35.9 / 36.4

TABLE 4. Variance (W^2m^{-4}) of global mean (90ºN to 90ºS) OLR and RSR intraseasonal variability (mean/ sigma) from CERES and NCEP.

	CERES	NCEP	NCEP-CERES
OLR	39.6 / 45.2	46.7 / 39.4	7.1 / 25.4
RSR	84.5 / 78.0	70.7 / 68.7	-13.8 / 62.0

4. SUMMARY AND DISCUSSIONS

This paper compares the intraseasonal variability of OLR and RSR deduced from the first full year of CERES/Terra broadband radiation dataset and the radiation dataset from the NCEP Reanalysis 2 system during the same period using technique of Wong and Smith (2002). While the intraseasonal variations of OLR from the NCEP Reanalysis 2 system show good spatial agreements with observations, the dynamic range of the modeled variability in the tropics is smaller than those of the CERES/Terra observations. In addition the NCEP Reanalysis 2 system also overestimates the actual OLR intraseasonal variability in the extra-tropics; suggesting some deficiencies in modeling the intraseasonal processes that generated these OLR fields. The modeled intraseasonal variations of RSR, in general, do not agree with observations; indicating additional works are needed for improving the physical processes that generated these RSR fields. For example, the lack of RSR intraseasonal variability over the Southern Ocean, in the major stratus regions off the coasts of North and South America and Africa, and in the northern mid-latitude continental areas suggests that the NCEP Reanalysis 2 system's mid- and low-level boundary clouds are not modeled correctly at the intraseasonal time scale. In addition, the excessive RSR intraseasonal variability over the tropical central Pacific and in the regions of the southern ocean just off the coast of the Antarctica also points to a similar problem, but in an opposite sense, with the model representation of mid- and low-level clouds at the intraseasonal time scale. Since low-level boundary clouds are coupled to the surface through the planetary boundary layer, the lack of RSR intraseasonal variability in the NCEP Reanalysis 2 system may suggest deficiencies in both the current model surface physics and the model representation of intraseasonal variation of surface temperature field. For the globe as a whole, the model overestimates the actual global mean OLR intraseasonal variability by a 7 W^2m^{-4} in variance and underestimates the actual global mean RSR intraseasonal variability by a 14 W^2m^{-4} in variance. In addition, the global regional sigma (i.e., region-to-region variability) of intraseasonal variability are smaller in the NCEP model than the CERES observations.

Acknowledgments. This work was supported by NASA Earth Science Enterprise through the CERES project at NASA Langley Research Center at Hampton, Virginia. G. L. Smith is supported by the CERES project through a task to the National Institute of Aerospace at Hampton, Virginia. CERES/Terra data were provided by NASA Langley Atmospheric Sciences Data Center at Hampton, Virginia. The NCEP Reanalysis 2 data were obtained on-line from the NOAA/NCEP website at http://wesley.wwb.noaa.gov.

REFERENCES

Wielicki, B. A., B. R. Barkstrom, E. F. Harrison, R. B. Lee III, G. L. Smith, and J. E. Cooper, 1996: Clouds and the Earth's Radiant Energy System (CERES): An Earth Observing System Experiment. *Bull. Amer. Meteor. Soc.*, **77**, 853-868.

Wong, T., and G. L. Smith, 2002: Temporal Spectra of Earth Radiation Budget Components. *16th Conference on Probability and Statistics in the Atmospheric Sciences*, 13-17 January 2002, Orlando Florida, American Meteorological Society, 66-69.