Future Flight Opportunities and Calibration protocols for CERES : Continuation of the Earth Radiation Budget Climate Data Record

Kory J. Priestley, Norman G. Loeb, Susan S. Thomas,
G. Lou Smith
NASA Langley Research Center
kory.j.priestley@nasa.gov

Abstract

The goal of the Clouds and the Earth's Radiant Energy System (CERES) project is to provide a long-term record of radiation budget at the top-of-atmosphere (TOA), within the atmosphere, and at the surface with consistent cloud and aerosol properties at climate accuracy (Wielicki et al., 1996). CERES consists of an integrated instrument-algorithm-validation science team that provides development of higher-level products (Levels 1-3) and investigations. It involves a high level of data fusion, merging inputs from 25 unique input data sources to produce 18 CERES data products. Over 90% of the CERES data product volume involves two or more instruments.

Continuation of the Earth Radiation Budget (ERB) Climate Data Record (CDR) has been identified as critical in the 2007 NRC Decadal Survey, the Global Climate Observing System WCRP report, and in an assessment titled 'Impacts of NPOESS Nunn-McCurdy Certification on Joint NASA-NOAA Climate Goals'. To date, five CERES instruments (PFM, FM1-FM4) have flown on three different spacecraft: TRMM, EOS-Terra and EOS-Aqua. In response, NASA, NOAA and NPOESS have agreed to fly the final existing CERES Flight Model (FM-5) on the NPP spacecraft for launch in 2011 and to procure an additional CERES Sensor with modest performance upgrades for flight on the NPOESS C1 spacecraft in 2014, followed by a new CERES follow-on sensor for flight in 2018 on the NPOESS C3 spacecraft.

Each CERES instrument is a scanning broadband radiometer that measures filtered radiances in the SW (wavelengths between 0.3-5 μm), total (TOT) (wavelengths between 0.3-200 μm) and WN (wavelengths between 8-12 μm) regions. Rigorous pre-launch ground calibration is performed on each CERES Flight Model to meet an accuracy goal of 1% for SW and 0.5% for outgoing LW radiance observations. Any ground to flight or

in-flight changes in radiometer response is monitored using a protocol employing both onboard and vicarious calibration sources and experiments. Recent studies of FM-1 through FM-4 data have shown that the SW response of space based broadband radiometers can change dramatically due to optical contamination. With these changes having most impact on optical response to blue-to UV radiance, where tungsten lamps are largely devoid of output, such changes are hard to monitor accurately using existing on-board sources. To correct for the imperfect spectral response of the instrument, the filtered radiances are converted to unfiltered reflected solar, unfiltered emitted terrestrial LW and WN radiances (Loeb et al., 2001). On Terra and Aqua, CERES has a spatial resolution of approximately 20 km (equivalent diameter).

While science goals remain unchanged for the long-term ERB Climate Data Record, it is now understood that the task of achieving these goals is more difficult for two reasons. The first is an increased understanding of the dynamics of the Earth/atmosphere system which demonstrates that rigorous separation of natural variability from anthropogenic change on decadal time scales requires observations with higher accuracy and stability than originally envisioned. (Ohring, et. al, 2005, 2007) Secondly, future implementation scenarios involve less redundancy in flight hardware (1 vs. 2 orbits and operational sensors) resulting in higher risk of loss of continuity and reduced number of independent observations to characterize performance of individual sensors. Although the EOS CERES observations realize a factor of 2 to 4 improvement in accuracy and stability over previous ERBE Climate Data Records, future sensors will require an additional factor of 2 improvement to answer rigorously the science questions moving forward. Modest investments, defined through the CERES Science Team's 30-year operational history of the EOS CERES sensors, in onboard calibration hardware and pre-flight calibration and test program will ensure meeting these goals while reducing costs in re-processing scientific datasets.

The CERES FM-5, and future, pre-flight radiometric characterization programs will benefit from the operational experience of the CERES EOS sensors, including stronger emphasis of radiometric characterization in the Statement of Work with the sensor

provider. Improvements to the pre-flight program include increased spectral, spatial, and temporal sampling under vacuum conditions as well as additional tests to characterize the primary and transfer standards in the calibration facility. Future work will include collaboration with NIST to further enhance the understanding of the radiometric performance of this equipment prior to flight. The current effort summarizes proposed improvements to the CERES pre-flight sensor characterization program , as well as the in-flight radiometric calibration and validation subsystems and analysis protocol and operational tasking to ensure that science requirements continue to be met in the new operational environment. In addition, an estimate of the impacts to the system level accuracy and traceability is presented.

References

Haeffelin, M.P.A., J. R. Mahan, and K. J. Priestley, 1997: Predicted dynamic electrothermal performance of thermistor bolometer radiometers for Earth radiation budget applications, *Applied Optics, 36*, 7129-7142.

Loeb, N.G., K.J. Priestley, D.P. Kratz, E.B. Geier, R.N. Green, B.A. Wielicki, P. O'R. Hinton, and S.K. Nolan, 2001: Determination of unfiltered radiances from the Clouds and the Earth's Ra-diant Energy System (CERES) instrument. J. Appl. Meteor., 40, 822-835.

Ohring, G, B. Wielicki, R. Spencer, B. Emery, and R. Datla, 2005 : Satellite Instrument Calibration for Measuring Global Climate Change Report of a Workshop. Bull. Amer. Meteor. Soc., 86, 1303-1313.

Ohring, G, editor 2007 : Achieving Satellite Instrument Calibration for Climate Change (ASIC3), Report of a Workshop Organized by : National Oceanic and Atmospheric Administration, National Institute of Standards and Technology, National Aeronautics and Space Administration, National Polar-orbiting Operational Environmental Satellite System-Integrated Program Office, Space Dynamics Laboratory of Utah State University, At the National Conference Center, Lansdowne, VA, May 16-18, 2006

Pandey, P. L. Spence, and G. L. Smith, 2000: "Post-launch radiometric performance validation of CERES Flight Models 1 and 2 located on NASA's Terra Spacecraft," *Proc. SPIE, 4135-04*.

Priestley, Kory J., G. Louis Smith, Susan Thomas , Denise Cooper, Robert B. Lee, III , Dale Walikainen, Phil Hess, Z. Peter Szewczyk and Robert Wilson, 2007:Radiometric performance of the CERES Earth Radiation Budget climate record sensors on the EOS Aqua and Terra Spacecraft, *Conf. SPIE*.

Priestley, K. J., R. B. Lee III, B. R. Barkstrom, S. Thomas, R. S. Wilson, A. Al-Hajjah, J. Paden, D. K. Pandey, P. L. Spence, and G. L. Smith, 2000: "Post-launch radiometric performance validation of CERES Flight Models 1 and 2 located on NASA's Terra Spacecraft," *Proc. SPIE, 4135-04*.

Szewczyk, Z. P., G. L. Smith, K. J. Priestley, 2005: "Comparison of CERES instruments aboard the Terra and Aqua satellites," J. Geophys. Res., 110, D02103, doi:10.1029/2004JD004776.

Wielicki, B. A., B. R. Barkstrom, E. F. Harrison, R. B. Lee, 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.