CERES Instruments Special Coverage for Field Campaigns

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Abstract – CERES instruments on board the Terra and Aqua satellites can be used to meet variety of science data collection goals. By putting them in a special programmable azimuth plan scanning (PAPS) mode, radiation of a specified Earth target can be measured. Four different field campaigns involving CERES are illustrated in this paper.

I. INTRODUCTION

A Clouds and Earth Radiant Energy System (CERES) instrument is a scanning thermistor bolometer designed to measure reflected solar radiation and outgoing longwave radiation from the Earth for radiation budget studies (Wielicki, 1995). Since 1998, CERES instruments have played an important role in the EOS mission with the launch of the Proto Flight Model (PFM) on board the TRMM satellite. Two CERES instruments, Flight Model 1 and 2 (FM1 and FM2), have been operating on board the Terra satellite since the beginning of 2000. In May, 2002, two additional CERES instruments (FM3 and FM4) were put in service on board the Aqua satellite. Terra and Aqua satellites are in sun-synchronous, polar orbits with equatorial crossings at 10:30AM (descending) and 1:30PM (ascending), respectively. This constellation offers a rare opportunity to provide almost simultaneous observations of some Earth targets in the Northern Hemisphere.

Since their launch, CERES instruments have been used in various field campaigns to provide increased coverage of selected areas to meet research goals. This paper presents an overview of CERES participation in those campaigns rather than science data analysis. A focus is on those field campaigns in which a CERES instrument on each of the satellites is involved. The included are: (a) FM1-FM4 validation campaign, (b) CRYSTAL-FACE or convection clouds campaign, (c) ULDB or ultra-long-duration balloon campaign, and (d) SCALES, or GERB ground validation campaign.

II. CERES OPERATIONS

A CERES scanner has three channels: total (0.3-100 μm), shortwave (0.3-5 μm), and a longwave window (8-12 μm) which measure different parts of the spectrum. A full sweep lasts 6.6 sec., and with a sampling rate of 100[sec^{-1}], it produces 660 samples. There are two basic operational modes of a scanner, namely (i) a cross-track (XT) where the scanning plane is perpendicular to the satellite velocity vector, and (ii) a rotational azimuth plane scan (RAPS) where the scanning plane orientation changes at a constant rate. CERES instruments' special coverage for various field campaigns exploits the RAPS mode by programming the scanning plane orientation.

The programmable azimuth plane scan (PAPS) mode is a variant of the RAPS mode introduced to increase sampling over a target area. In this mode, the instrument head is rotated so that the target lies in the scanning plane for a prescribed number of scans. The head orientation, the instrument relative azimuth, is adjusted as a satellite passes over the target so that the target lies in the scanning plane. In this mode, not only does sampling increase by an order of magnitude, but also directional properties of radiating area are explored better. An instrument returns to one of its normal modes once the target is outside its viewing zone.

CERES special coverage for field campaigns is intended as a free service to the science community. It can be requested on the CERES website at:
http://asd-www.larc.nasa.gov/PAPS/cgi-bin/rygar.cgi.

III. PLANNING AND EXECUTING

Planning tools that make prediction for the PAPS mode reside on the CERES website for special operations. The instrument head orientation is calculated based on a satellite ground track prediction file available for seven days in advance. A satellite location is given in one-minute intervals in this file, and it is interpolated to 6.6 sec, or the duration of a single scan. Once the target location is entered, software checks whether the target is in the CERES field of view. If it is, then the instrument head is rotated to contain the target in the scanning plane. The azimuth relative to the orbital plane can be kept constant for a prescribed number of scans depending upon the requirements as to the width of a swath. All calculations are updated daily, and relative azimuth prediction files are available from the CERES website. However, there is a 48-hour turnaround for commanding a CERES instrument into the PAPS mode, and all activities must be planned accordingly.

IV. CERES COVERAGE CAMPAIGNS

In this section, an overview of four field campaigns involving CERES instruments on Terra and Aqua satellites is presented.

A. FM1-FM4 validation campaign

Validation of CERES instruments on board Terra and Aqua was a very important effort to ensure consistency of the Earth decades-long, radiation budget data set. The goal was accomplished by designing a new scanning experiment for FM1 and FM4. The main purpose of this experiment was to provide operating conditions in which both instruments could measure fairly uniform scenes simultaneously. The experiment was implemented just after one month into the service of Aqua instruments. The validation data acquisition took place between July 4 and August 22, 2002. During the validation experiment, both CERES instruments, FM1 and FM4, were scanning in the same plane in the vicinity of nodes, 70°N and 70°S, of their sun-synchronous orbits. Both satellites were at the northern crossing over the Arctic and the southern crossing over the Antarctic about 15 minutes apart.

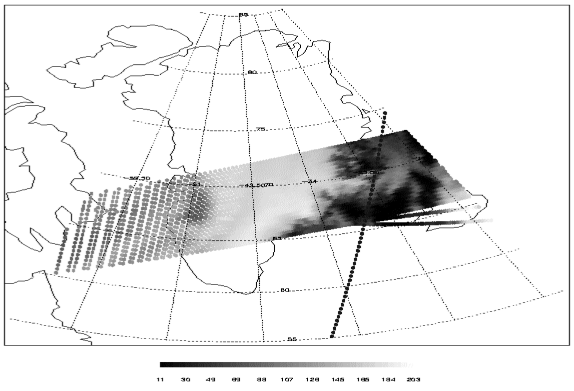

Figure 1

The best comparison scene location, particularly for the shortwave radiances, is Greenland which is covered by an ice sheet two miles thick. This provides to most uniform scene available for measurements. The best comparison viewing direction is in the plane normal to the principal (solar) plane. There are far fewer features in this plane for the plane parallel radiative transfer, as forward or backward scatter occur in the principal plane. Effects of shadowing can also be reduced by scanning in that plane.

The scanners on Terra and on Aqua were rotated to have the scan axes in the principal plane as the spacecrafts crossed the orbital plane intersection at noon. The scanning plane was kept constant for about 90 seconds of the data collection. The same procedure was followed for both intersections. In the Antarctic nighttime data for longwave and window were obtained. Details of this campaign can be found in Szewczyk, Smith, and Priestley (2003).

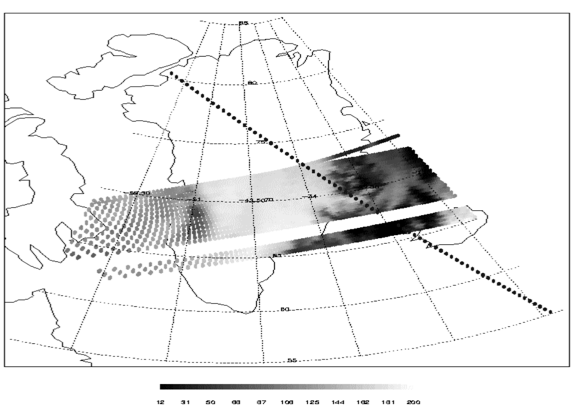

Figure 2

Figure 1 and Figure 2 show unfiltered shortwave radiances measured by FM1 and FM4, respectively. Plots clearly show that the scans are lined up for both instruments. Instruments return to the crosstrack mode after completion of the special scan. It is worth mentioning that the CERES measuring consistency is within 1% for all the data collected in the campaign.

B. CRYSTAL-FACE campaign

The Cirrus Regional Study of Tropical Anvils and Cirrus Layers - Florida Area Cirrus Experiment (CRYSTAL-FACE) united seven NASA centers, NOAA, National Science Foundation, Department of Energy, Office of Naval Research, U.S. Weather Research Program, universities and other government weather researchers in an extensive study of cirrus clouds. The detailed measurements from the CRYSTAL-FACE mission were collected to assist in improving climate models.

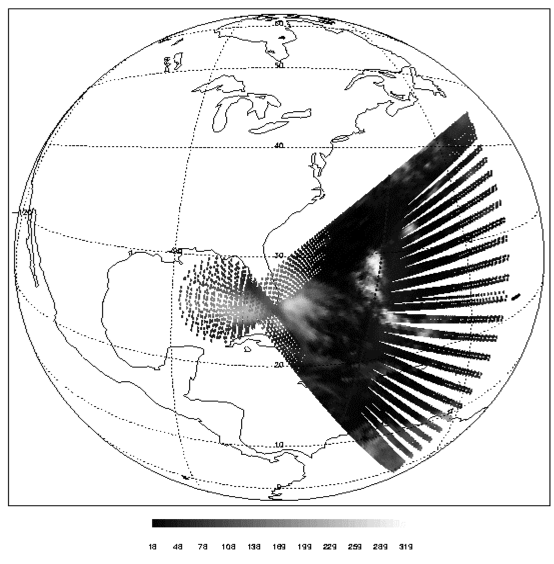

Figure 3

Carbon dioxide and other greenhouse gases from human activities warm our climate. Two effects of this warming are the increase of clouds and the rise of water vapor in the atmosphere. Both of these in turn influence the impacts of man-made gases on global warming. Clouds can reflect solar rays away from the surface, cooling the climate, but they also act as a "blanket," trapping solar radiative heat. These various interactions are complex and not fully understood.

The CRYSTAL-FACE campaign involved six aircrafts equipped with state-of-the-art instruments to measure characteristics of clouds and how clouds alter the atmosphere's temperature. These measurements were compared with ground- based radars and also CERES radiance measurements. CERES instruments on board Terra (FM2) and Aqua (FM3) were put into the PAPS mode to scan over a ground station located just outside Miami. Each satellite pass provided about 5 minutes of data, and there were up to two passes per day when the site was in the CERES field of view. Measurements of FM3 were particularly important as Aqua flyovers took place in the afternoon when the cloud cover increased. The campaign took place from July 6 to July 29, 2002. While in the PAPS mode, the CERES relative azimuth was kept constant for two full scans or about 13sec., so that the width of a swath was approximately 50km. Details of this experiment can be found at: http://cloud1.arc.nasa.gov/crystalface/.

Figure 3 and Figure 4 show unfiltered shortwave radiances measured by FM2 and FM3, respectively. All scans intersect at the Miami site providing increased sampling and also directional dependencies. Plots show about 5 minutes of data which corresponds to 45 scans.

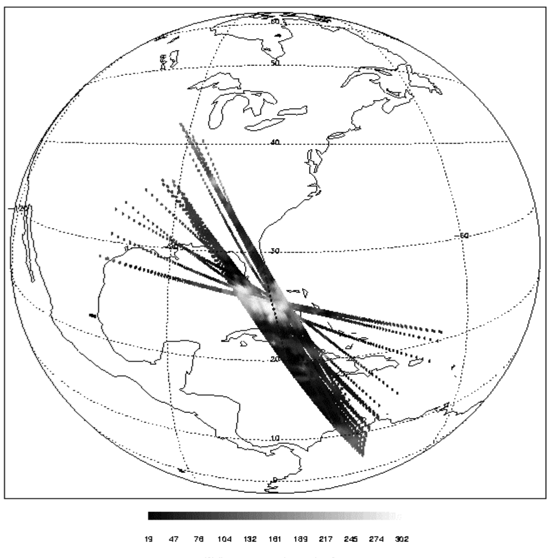

Figure 4

C. ULDB campaign

The objective of the NASA LaRC ultra-long-duration-balloon project was to develop a system to measure shortwave and longwave radiant fluxes at the top of the atmosphere to characterize calibrated hemispherical radiometers at the 1% level. The balloon was developed by NASA Goddard's Wallops Flight Facility (Virginia, USA) and was capable of providing scientific measurements above 99% of the atmosphere for 100-day missions with floating altitude close to 35km. It could travel at 30 m/s propelled by stratospheric winds, and circumvent the Earth in about 2 weeks. The balloon was 120 meters in diameter and carried a set of pyranometer and pyrgeometer instruments to monitor the shortwave and longwave radiation incident upon the balloon. It was to be launched from Alice Springs, Australia, in February of 2003.

Flux measurements from the balloon can be used to validate the radiant fluxes derived from satellite-based radiance measurements using bi-directional reflectance functions. The radiance-to-flux conversion process is the principal source of uncertainty in instantaneous (not time averaged) fluxes estimated from radiance measurements. For CERES data, it is estimated that this process introduces a 4% uncertainty in the flux, whereas the calibration uncertainty of the instrumentation is less than 1%. Solar and terrestrial flux measurements from a stratospheric balloon at 35 km altitude can be made with a spatial resolution on the order of 70 km. The uncertainty of measurements made from 35 km is

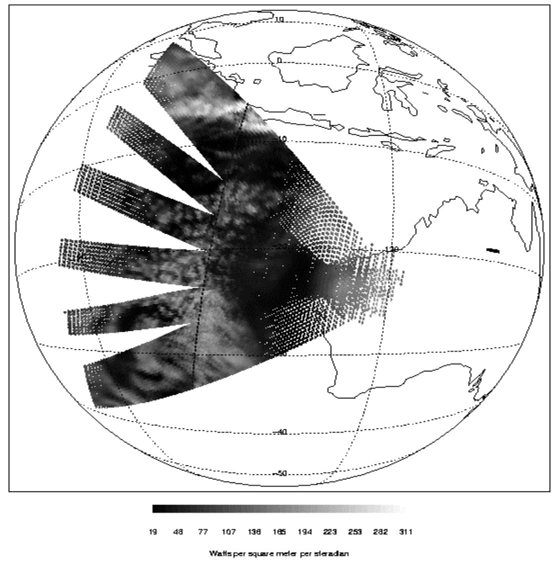

Figure 5

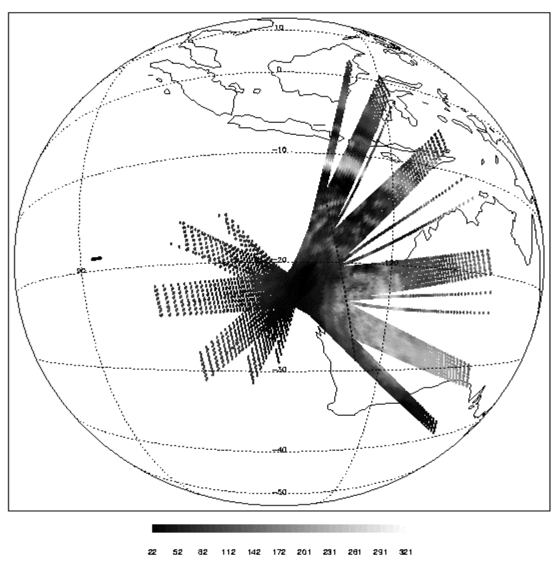

Figure 6

limited only by the accuracy of the instruments. Additional information about the ULDB project can be found at: http://www.wff.nasa.gov/~uldb.

CERES instruments, FM2 and FM4, were designated to be put in the PAPS mode to measure radiances over the swath of about 70 km wide. Due to uncertainty in predicting the balloon geolocation in 48 hours, it was decided to update the CERES azimuth orientation every eight scans (~ every 52 seconds) as the spacecrafts were flying over in the vicinity of the balloon geolocation. Command uploads for Terra and Aqua were to be performed daily to increase chances of obtaining matching measurements. The balloon was eventually launched on March 17, but due to a leak, it came down after just 12 hours in the air.

Figure 5 and Figure 6 show the scanning pattern with unfiltered shortwave radiance for FM2 and FM4, respectively, executed during the trial runs on January 26 and 27. The balloon geolocation is predicted for 3:20 GMT for the FM2 overpass, and for 6:00 GMT for the FM4 overpass.

D. SCALES campaign

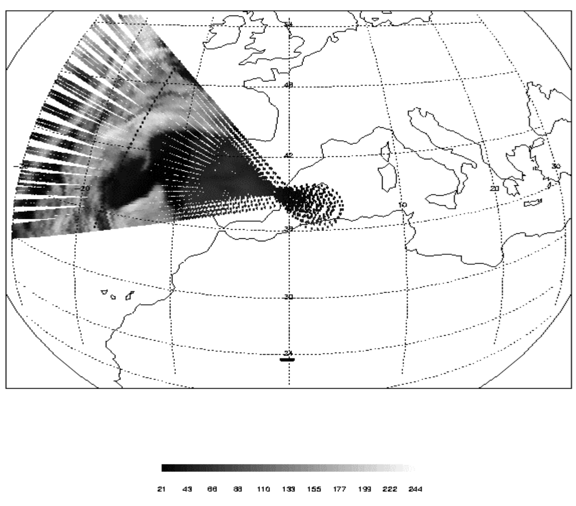

Figure 7

SEVIRI & GERB Calibration-validation Area for Large-scale field ExperimentS (SCALES) is located near Valencia, Spain, and is the first GERB (Geostationary Earth Radiation Budget) ground validation site. The area of the anchor station is approximately the GERB pixel size (50 by 50 km), and its surface is reasonably homogeneous. The station is equipped with several ground instruments including lidar and sun-photometers, and it operates within the GIST (GERB International Science Team) framework. More information about the GERB experiment can be found at: http://www.sp.ph.ic.ac.uk/gerb.

The first validation activity was scheduled for June 18-24, 2003. CERES shortwave and longwave radiance measurements were intended as a cross-reference for the GERB instrument and ground measurements. Therefore, CERES instruments (FM2 and FM4) were targeting the Valencia anchor station located at 39.51°N and 1.21°W as the satellites passed over the site. In the PAPS mode, each instrument could scan the site for about five minutes once or twice a day. The data were collected for seven consecutive days. Since satellite flyovers were known up to seven days in advance, ground activities were synchronized for more complete data sets.

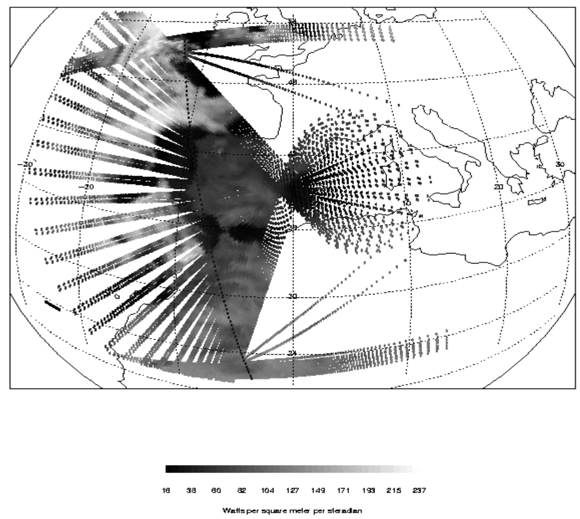

Figure 8

Figure 7 and Figure 8 show scanning patterns of FM2 and FM4 at noon and 1:35 GMT on 06/20/2003 using unfiltered shortwave radiances. Both instruments approach the site in the crosstrack mode. There are two transient relative azimuth angles executed by FM4 due to wide angle rotation.

V. CLOSING REMARKS

The paper demonstrates the flexibility and efficiency of CERES instruments and their operation team. The instruments have been extensively used in various research projects, and full list of their activities since launches can be found at: http://asd-www.larc.nasa.gov/ceres/ASDceres.html. Readers are encouraged to check the listed websites for information about the impact of CERES data on results and outcome of specific experiments described in this paper.

VI. REFERENCES

B.A. Wielicki et al., “Clouds and the Earth's Radiant Energy System (CERES): an Earth observing system experiment”, Bul. Amer. Met. Soc. Vol. 77, pp. 853--868, 1996.

Z. Peter Szewczyk, G. Luis Smith, Kory J. Priestley, “Validation of CERES instruments on board the Terra and Aqua satellites”, Remote Sensing of Clouds and the Atmosphere VII, SPIE paper No.5231-22.