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Evaluation and Improvement of Earth Radiation Budget Data Sets

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To
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(1) Advanced scan patterns for enhanced spatial and angular sampling of ground targets:
Surface observations are very important to the validation of surface and atmospheric fluxes derived from satellite measurements. We developed a protocol for scanning radiometers with azimuth rotation capability to provide extensive spatial and angular coverage of a field campaign area. Each time the satellite orbits the Earth in the vicinity of the target, the instrument is aimed and rotated progressively to keep the target in the instrument field of view for several minutes. We applied this protocol to the CERES instrument onboard the Terra spacecraft during the CLAMS intensive observation campaign at the Chesapeake Lighthouse in July 2001. We obtained an average of 500 measurements per overpass in an area within 50 km of the target compared to 35 for the CERES instrument in cross-track (fixed-azimuth) mode. At each overpass the target was observed with a variety of viewing geometries. These types of measurements provide unprecedented information on the error introduced by angular distribution models used to convert radiances into fluxes. The data collected during CLAMS 2001 are still being analyzed. The protocols were presented at the May 2001 CERES science team meeting held in Newport News, VA.

(2) Inter-calibration of polar orbiter in low Earth orbits (LEO) and geostationary (GEO) broadband radiance measurements:
Polar orbiters provide global data at limited times of observation while GEO satellites provide complete temporal sampling over a limited geographical area with fixed viewing geometry. The LEO/GEO combination provides very complete spatial and temporal sampling of the radiative field of the Earth, given that their radiometric calibrations are consistent. We developed a protocol for LEO scanning radiometers with azimuth rotation capability to match continuously the GEO viewing geometry. In this manner it is expected that the radiometric calibrations of the LEO and GEO instruments can be compared with a 0.5% (0.1%) uncertainty with 30 days of matched SW (LW) observations. This protocol will be applied to the inter-calibration of CERES and GERB flying on-board Terra and Meteosat Second Generation, respectively in the mid-2002 time frame.
A presentation of the inter-calibration protocols was prepared for the September 2001 CERES science team meeting (Brussels, Belgium) that has been postponed to a later date.

(3) Synergism between CERES on TRMM and Terra:

Scanning radiometers of the Clouds and the Earth's Radiant Energy System (CERES) program operate independently on the TRMM and Terra platforms. The quantitative consistency of their products was evaluated by comparing collocated unfiltered radiance data derived from the CERES Proto-flight Model (PFM) on TRMM and Flight Models 1 and 2 (FM1/2) on Terra. The comparisons reveal a consistency between PFM and FM1/2 radiance measurements better than 0.5% for both longwave and shortwave products. The uncertainty in the comparison at the 95% confidence level is 0.1% for longwave and 0.4% for shortwave. The radiance comparisons contribute significantly to the complete radiometric validation process and are consistent with results from other validation tests.

These results were published in the proceedings of the July 2000 International Radiation Symposium (St Petersburg, Russia): Haeffelin, M. B. Wielicki, K. Priestley, J-P. Duvel, and M. Viollier. Direct comparisons of radiances measured by independent contemporary ERB instruments, A Deepak Publishing, Hampton VA, 2001 (paper included).

(4) Improved surface solar irradiance measurements:

A significant discrepancy has been reported between measured and modeled solar irradiance at the surface of the Earth, which compromises the validation process of the measurements made from satellites. Solar irradiance measurements performed with an Eppley precision spectral pyranometers (PSP) contain an offset related to the thermal state of the instrument that varies in time and ranges from 0 to $-15Wm^{-2}$. Thermistors were installed in a PSP to monitor the temperature gradient between its filter dome and detector. A protocol was developed to predict the thermal offset from the temperature measurements and remove the offset from the instrument signal. Another protocol was developed that uses the output signal of a pyrgeometer as a surrogate of the pyranometer thermal offset. A third protocol was developed to relate the cloud cover fraction to the pyranometer thermal offset. The second and third protocols can be used to correct historical data where pyrgeometer or cloud cover data are available.

These results were published in the February 01, 2001 issue of Applied Optics: Haeffelin, M., S. Kato, A. M. Smith, C. K. Rutledge, T. P. Charlock, and J. R. Mahan, Determination of the thermal offset of the Eppley precision spectral pyranometer. *Applied Optics*, **40**, 472-484, 2001 (paper included).

(5) SW flux observations from Ultra Long Duration Balloons at 35-km altitude:

Currently, radiant fluxes are derived from radiance measurements from low Earth orbit satellites. Significant uncertainties are introduced by the radiance-to-flux conversion process. We investigate the possibility to measure top-of-the-atmosphere (TOA) radiant fluxes directly using pyranometers and pyrgeometers on-board high-altitude ultra-long-duration balloons. These measurements would provide unprecedented validation data for orbital satellite estimates of TOA radiant fluxes. A modified pyranometer (see paragraph 4) was tested in a thermal vacuum chamber at 5mbars and –70C to simulate conditions at TOA. The same instrument was later flown on-board a long-duration balloon for 28 hours at 30-km altitude. Further tests and development are required to develop a calibrated measurement system capable of producing TOA radiant fluxes with 1% accuracy goals.

The initial stage of this project was presented at the January 2001 CERES science team meeting held in Williamsburg, VA.

(6) Nighttime cloud property retrieval algorithm:
The algorithm used to retrieve the cloud optical and microphysical properties based on nighttime narrowband radiance measurements was significantly improved resulting in a 50% shorter run time. This allowed many more retrievals to be performed for analysis. A new parametrization which can handle temperature inversions was developed, extending the algorithm beyond its current capability of $Tc > Ts-4$, where Tc and Ts are the cloud and surface temperatures, respectively.
This algorithm is described in a paper to be submitted to *Geophysical Research Letters*. This paper is currently under internal review (paper included in its current state).

(7) Retrievals of overlapped and mixed-phase clouds:
The detection of multi-layer clouds is very important to improve the quality of satellite products. Two approaches are proposed: (1) Use of brightness temperature difference (BTD) between 11 and 12-micron channels. The basic principle is that if the cloud is a single layer, BTD will be small (nearly equal 0) when the cloud is thick enough, because the cloud emissivity approaches unity. A large BTD indicates the presence of thin clouds over lower clouds. (2) Use of retrieved parameters such as the optical depth and particle size. Statistical differences in particle size exist between single and multi-layer clouds. A cloud property retrieval algorithm assumes that the cloud is a single layer, so departure from expected retrievals indicates the presence of multiple layers. We analyzed one year of GOES data in combination with 35 GHz radar data for reference. We found that our procedure is promising when the two approaches described above are combined. Retrieval algorithms are still under development.
These techniques were presented at the March 2001 ARM science team meeting (proceeding included), held in Atlanta, GA, and at the May 2001 CERES science team meeting in Newport News, VA.

Tasks (1) through (5) were performed by Dr. M. Haeffelin and tasks (6) and (7) by Dr. K. Kawamoto.