CERES Science Team Meeting

--- Shashi K. Gupta (s.k.gupta@larc.nasa.gov), and Jennifer M. Hubble (j.m.hubble@larc.nasa.gov) NASA Langley Research Center

The 25th Clouds and the Earth's Radiant Energy System (CERES) Science Team meeting was hosted by Steven Dewitte at the Royal Meteorological Institute of Belgium (RMIB) in Brussels, Belgium on January 21-23, 2002. The meeting focused on the status of new TRMM and Terra data products in development and validation planned for Edition 1validated delivery in April and May 2002, Terra long-term calibration stability, and Science Team results. In addition, the CERES meeting was coordinated with a Geostationary Earth Radiation Budget (GERB) meeting at the same venue to encourage interaction between the two teams.

Bruce Wielicki (LaRC), CERES Principal Investigator, gave an Earth Observing System (EOS)/CERES status report. EOS Team recompetitions are expected in the May/June time frame for FY03 funding. Proposal inputs for CERES-heritage instruments on the National Polar Orbiting Environmental Satellite System (NPOESS) are currently being developed. Kory Priestley is leading the LaRC proposal effort. Proposals by both major contractors, Lockheed and TRW, are due to NPOESS by April 2002. TRW will build the instruments. The NPOESS data system will produce top of atmosphere and surface radiation data products within 150 minutes of data acquisition. Currently, only instantaneous accuracies (i.e., weather) are being specified. The next CERES Science Team Meeting is scheduled for May 14-16, 2002 in Williamsburg, VA.

Instrument Status

Bruce Wielicki (LaRC) presented the instrument status report. Terra instruments continue to operate without problems, and Aqua instruments are being readied for launch in April 2002. The sixth CERES instrument (Flight Model 5, FM-5) remains in storage in anticipation of a mission of opportunity to fill the data gap from Aqua (2008 nominal end) to NPOESS (2011 nominal start). For Terra FM-1, all channel gains in orbit were initially within 0.5% of ground values. There has been no detectable gain change in the shortwave (SW) channel (< 0.1%/yr.), in the Total channel (<0.2%/yr.), or in the window (WN) channel. For Terra FM-2, Total and SW channel gains began in orbit within 0.2% of ground values, but the WN channel was higher by 1.3%. There was no detectable gain change in the SW channel (<0.1%/yr.), a Total channel gain change of 0.4%/yr., and no detectable WN channel gain change. While the Mirror Attenuator Mosaic (MAM) performed very well on the Tropical Rainfall Measuring Mission (TRMM), coatings developed by a new vendor for later instruments have experienced degradation. FM-1 MAM performance is marginal (1% changes) and FM-2 performance is poor (3-6% changes). Similar MAM concerns are expected on the Aqua instruments.

Data Production

Bruce Wielicki showed the progress on TRMM and Terra instruments and science data products which was given at the January 7 NASA HQ Terra Data Products Review by Code Y. Science community feedback from Ghassem Asrar indicated that so far CERES was doing the best job of the Terra products in meeting the science community expectations and needs. But all of the Terra data products are behind the idealistic views that Dixon Butler and NASA HQ painted for congress and the science community in the early 1990s. Pressure is on all Terra (and soon Aqua) science teams to reach validated status as soon as possible and to prioritize data products and their deliveries. Efforts will also be made to more clearly indicate planned product delivery dates on team web sites, as well as to hold open workshops on early data products and to confirm to the science community that science team meetings are open to any interested researchers.

This Fall CERES delivered the first of a new generation of validated radiation data products that go well beyond the Earth Radiation Budget Experiment (ERBE) capability for climate analysis and accuracy. The remainder of the full suite of validated CERES TRMM products will appear by Fall 2002. The ERBE-like versions of CERES data, however, have been validated and in the archive since 8 months after launch, and the global record of CERES Terra top-of-atmosphere radiative fluxes is available from March 2000 through November 2001 with new data months delivered within 2 months of acquisition.

Clouds: TRMM and Terra

Patrick Minnis (LaRC) of the Cloud Working Group presented the status of cloud property retrievals from the Visible InfraRed Scanner (VIRS) and Moderate Resolution Imaging Spectroradiometer (MODIS). Beta versions of CERES MODIS cloud properties have been archived. Papers describing VIRS imager calibration have been accepted for publication and a paper describing cloud property comparisons with surface data has been submitted. A comparison of VIRS and MODIS imager calibration showed good agreement for most channels with the exception of a 3% difference at 0.65 µm for bright scenes. Minnis also showed a preliminary comparison of cloud properties derived by the CERES and MODIS groups using MODIS data. Although there was overall consistency between the retrievals, several scene-dependent anomalies were identified for future investigation.

TRMM Angular Modeling and TOA Fluxes

Norman Loeb (Hampton University, HU) reported on the status of TRMM Single Satellite Footprint (SSF) Edition 2 Angular Distribution Models (ADMs) and Top-of-Atmosphere (TOA) flux validation. The main remaining area of concern for the TRMM SSF product is the need to adjust the ADMs and TOA fluxes to a more appropriate reference level. Loeb showed that in order to ensure that all Earth radiation contributions are accounted for when constructing ADMs, the field-of-view (FOV) reference level where the viewing geometry is defined must be well above the Earth's surface (e.g., 100 km). Otherwise, TOA fluxes are systematically underestimated by 1-2 Wm^{-2}. Based on theoretical radiative transfer calculations using a model that accounts for spherical Earth geometry, Loeb also showed that the optimal reference level for defining TOA fluxes in Earth radiation budget studies is approximately 20 km. This level corresponds to the effective radiative "top-of-atmosphere" for the planet.

TRMM SSF Edition 2 Surface Fluxes

Shashi Gupta (Analytical Services & Materials, Inc., AS&M) presented results of the validation studies (with David Kratz of LaRC) of surface-only fluxes. For cases involving SW clear-sky fluxes, the study indicated good agreement between 1-minute surface measurements and the Langley Parameterized Shortwave Algorithm (LPSA) results. It was noted that a document detailing the LPSA was now available as a NASA technical publication (TP-2001-211272). In contrast, the study also indicated a 30 Wm^{-2} bias between surface measurements and the Li-Leighton formulation. This bias was found to be attributable to aerosol forcings. With the addition of the Geophysical Fluid Dynamics Laboratory (GFDL) aerosol climatology into the Li-Leighton formulation, this bias was essentially eliminated. For all-sky conditions, large rms errors were observed. These rms errors were significantly reduced by using 60-minute averaged surface data. The improvement was attributed to better time/space comparison of the 60-minute surface data to the top-of-atmosphere (TOA) CERES measurements for the SW all-sky fluxes. For cases involving longwave (LW) clear-sky fluxes, the study showed good agreement between the surface fluxes and the Inamdar and Ramanathan model, though the number of surface comparisons was very limited. The Langley Parameterized Longwave Algorithm (LPLA) was found to be in good agreement with the surface fluxes for both clear-sky and all-sky conditions. While there were some discrepancies between the LPLA and the surface fluxes, nearly all of those could be attributed to problems with the cloud mask identification at night.

SARB Retrievals

Thomas P. Charlock (LaRC) and Fred G. Rose (AS&M) gave a status report on the retrieval of the vertical profiles of fluxes - the Surface and Atmospheric Radiation Budget (SARB). This component of CERES uses a radiative transfer code to simulate the fluxes observed at TOA. Inputs to the code include imager-based cloud and aerosol properties, as well as European Center for Medium Range Weather Forecasts (ECMWF) temperature and humidity profiles. The SARB algorithm constrains (tunes) key inputs (i.e., cloud optical depth) and observables (i.e., outgoing longwaver radiation, OLR) to achieve a least squares fit based on a priori uncertainties for the key inputs and observables.

Rose covered recent changes to the CERES algorithms to retrieve the SARB profiles. The Langley version of the Fu and Liou radiative transfer code (which provides for a non-black surface and hexagonal ice crystals that scatter in the thermal IR) now has the CKD 2.4 (Clough et al.) water vapor continuum and includes 2200-2850 cm^{-1}. The spectral shape of land surfaces in the near infrared has been modified using MODIS results. Ocean surface spectral albedo is parameterized according to wind speed, sun angle, and aerosol/cloud optical depth. The new ocean albedo is based on look-up tables to a coupled (Jin-Stamnes) radiation code and has a provision for chlorophyll concentration. Earlier bugs to the SARB code, which vexed ice cloud properties and cloud height placement, have been removed.

Constrainment (tuning) uses new sigma (a priori uncertainty) values for TOA fluxes, consistent with the more accurate CERES observations.

Charlock then described the performance of the older (Beta 1), more recent (Beta 2), and newest (Beta 3) SARB algorithm. Expressed as bias (CERES observed minus model computed) and rms errors at TOA, the untuned Beta 3 algorithm gives bias/rms of -1.78 Wm^{-2}/20.08 Wm^{-2} for reflected SW and 1.45 Wm^{-2}/6.75 Wm^{-2} for broadband OLR. Untuned bias/rms for clear sky were -1.70 Wm^{-2}/6.93 Wm^{-2} for reflected SW and 2.12 Wm^{-2}/5.43 Wm^{-2} for OLR. Constrainment (tuning) reduced these values by roughly one half. Results at the surface were disappointing when compared with Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) data at the surface: For April 1998, the bias in SW surface insolation was -32.5 Wm^{-2} for all sky conditions (and equally bad for clear sky). But the comparison was very favorable for surface downward longwave flux (DLF). Charlock ascribed much of the large bias in insolation (-32.5 Wm^{-2}) to questionable surface observations, rather than to CERES retrievals. It was pointed out that off-line comparisons of the radiation code with recent (year 2000) SGP observations and surface-based (Cimel) inputs for aerosol optical thickness (AOT) resulted in almost no bias for 500 half-hour intervals; that SGP instituted new observing procedures in 1999; and that differences of surface observations (2000-1998) was rather large.

Geostationary Data Enhanced Averaging

David Young presented the status of the temporal interpolation of CERES products using data from imagers aboard geostationary satellites. The first Level 3 results based on Edition 2 CERES TRMM data were shown. A comparison of monthly mean shortwave and longwave fluxes derived with and without geostationary data revealed large corrections in regions of poor temporal sampling near the upper latitude limit of the TRMM orbit. Histograms of monthly mean flux revealed no significant shifts due to the inclusion of the geostationary data. Processing of the geostationary imager data is on schedule. A time series of intercalibrations with the VIRS imager has been produced for each geostationary imager available during the entire CERES TRMM period. Cloud properties derived from the geostationary data were shown to be consistent with VIRS-derived properties.

Surface and Atmospheric Radiation Budget Working Group

The SARB meeting was chaired by Tom Charlock (LaRC). The goal of the meeting was to get recommendations of the Working Group (WG) on several outstanding issues facing the SARB team. Charlock stated that the Beta 2 version of SARB/CRS data for the Jan. – Aug. 1998 period was ready and could be released if recommended by the WG. However, a problem has been identified in the ice-cloud tuning part of the code which results in larger errors for the ice-cloud overcast footprints. A solution for this problem has already been developed and the corrected Beta 3 version of the data can be produced within about 2 months. The WG recommended that the SARB team not release Beta 2 version and release Beta 3 version when ready.

Charlock presented a revised table of a priori uncertainties (tuning sigmas) used in the constrainment process in SARB processing. It was pointed out that sigma of ln(AOD) for land areas was smaller than for ocean areas. The WG recommended that this tuning parameter for land areas should be equal to or greater than for ocean areas. The same change was also recommended by A. Ignatov.

Charlock pointed out that constrainment in the LW region is currently performed on the fluxes, OLR, and WN flux. He asked that since constraining radiances in some instances provided better results, if that should be adopted as standard procedure. In this matter, the WG did not make any specific recommendations.

Charlock pointed out that bulk of the error in SARB products is in the SW fluxes and the SW code currently in use has considerable room for improvement. SARB currently uses the 2-stream version of the Fu-Liou code for SW processing. Better results can be expected if the 4-stream version of the code were to be used but that would require much greater computer resources. The WG recommended that the SARB team conduct extensive objective tests to establish the benefits of 4-stream processing before committing the resources.

Cloud Working Group

The CERES Cloud Working Group, led by Patrick Minnis, held a discussion on recent developments from intercomparisons of VIRS and MODIS imager calibrations. The VIRS 3.7 µm channel calibration used by CERES was found to have a 0.5 K bias for some scenes. This will be corrected in future editions. Jim Coakley of Oregon State University presented a calibration comparison of VIRS and

MODIS 1.6 µm channels based on sunglint scenes and presented results of a simulated surface/satellite cloud property comparison. Alessandro Ipe (RMIB) investigated the normalization of cloud property retrievals from two different imagers. The results will be used to apply CERES-derived angular distribution models based on VIRS cloud property retrievals to GERB data using cloud properties from the Spinning Enhanced Visible and Infrared Imager (SEVIRI) imager.

ADM and TOA Flux Working Group

Norman Loeb led the ADM working group meeting with a general overview of critical ADM/inversion research issues.

David Doelling presented results from several instruments to examine the dependence of daytime LW and WN radiances on relative azimuth angle. He showed that radiances tend to be larger in the backscattering direction and smaller in the forward scattering direction due to differences in temperature between surfaces directly illuminated by the sun (i.e. in the backscattering direction) and surfaces in shadows cast by adjacent topography (i.e., in the forward scattering direction). The relative azimuth dependence was shown to depend upon time of day and surface roughness.

Seiji Kato (HU) presented results from a sensitivity study to determine the uncertainty in TOA flux caused by using the MODTRAN radiative transfer model to approximate the flux contribution of radiances emerging from above the Earth's tangent point. MODTRAN calculations were compared with 8 months of SW and LW radiance measurements under all-sky conditions from the CERES/TRMM ES8 product. Differences between MODTRAN and ES8 fluxes due to differences in radiance at angles beyond the Earth's tangent point are found to be less than 0.2 Wm^{-2}, a factor of 5 reduction in bias compared to that obtained when radiance contributions from these very oblique viewing zenith angles are neglected.

Nicolas Clerbaux (RMIB) described the methodology used in GERB to convert measured radiances to LW fluxes. The method uses the correlation between the angular and spectral dependence of LW radiation to derive a theoretical regression function that converts SEVIRI spectral radiances to LW fluxes. GERB broadband radiances are used to adjust the SEVIRI-based fluxes. He showed that the use of spectral signatures reduces the radiance-to-flux error by approximately 50% compared to methods that ignore the spectral dependence in the radiances. Compared to CERES LW ADMs, the regression method shows a 2% bias in nadir anisotropic factors for clear scenes.

Norman Loeb (presenting for Konstantin Loukachine) showed results from a validation study of TOA LW and WN fluxes from CERES TRMM SSF Edition2A ADMs. Compared to TOA flux estimates from the ERBE-Like product, the new CERES SSF ADMs show a reduction in bias with viewing geometry by up to a factor of 5 for all-sky conditions. To examine the flux biases with viewing geometry for specific scene types (e.g., overcast, broken clouds), Loeb showed the importance of using a constant field-of-view (FOV) size at all angles (obtained by spatially averaging adjacent FOVs). Again, the reduction in TOA flux bias with viewing geometry relative to ERBE was approximately a factor of 5. When LW TOA flux biases from CERES SSF ADMs are compared with those for a theoretical limb darkening model, results are similar for clear scenes, whereas the model overestimates fluxes for overcast conditions by up to 5 Wm^{-2}. Instantaneous TOA flux uncertainties for clear ocean scenes are $< 0.5\%$ ($< 2\ Wm^{-2}$) based on multi-angle consistency tests using CERES alongtrack observations.

Nitchie Manalo-Smith (AS&M) presented an overview of current plans for development of Terra LW and window ADMs. Based upon lessons learned from TRMM, she point out several areas where improvements can be made. Examples include scene identification (selection of scene type parameters), geometry (potential need to stratify clear land ADMs by relative azimuth angle), angular resolution, selection of an improved theoretical model for estimating radiances in under-sampled angular bins, and the need for LW and WN models over snow surfaces.

TISA Working Group

The Temporal Interpolation and Spatial Averaging (TISA) Group, led by David Young, discussed recent progress in the development of monthly mean CERES products. New models of diurnal albedo variability are being developed from 8 months of Edition 2 fluxes. Initial comparisons show general consistency between these empirical models with theory. Testing is underway to compare interpolations using these new models to the previously used models based on ERBE data. A discussion was held on the validation strategy for calibration of the narrowband geostationary imager data. Comparisons with VIRS and possibly ISCCP data are planned. Deep convective cloud albedos will be used to monitor imager gain consistency.

Invited Presentations

John Harries (Imperial College, London, U.K.) presented an overview of the activities of the Geostationary Earth Radiation Budget (GERB) project, a joint project between U.K., Belgium, and Italy. GERB was designed for measuring broadband SW and LW radiation budget of the Earth from a geostationary platform. GERB instrument will be flown onboard the first METEOSAT Second Generation (MSG-1) spacecraft, currently scheduled for launch in July 2002. The instrument was built and tested at the Rutherford Appleton Laboratory in U.K. and its characterization was done at the Imperial College. Harries presented results from the characterization of the gains of SW and total channels, filter transmission, spectral response, and point-spread function. He showed that the results were reproducible and the instrument was stable. GERB instrument will provide radiation budget parameters over the METEOSAT domain, on a 15-minute time resolution with expected r.m.s. errors of 10 Wm^{-2} in SW and 5 Wm^{-2} in LW. Results will be used for validation of the GCMs and a variety of meteorological and Earth science applications. GERB processing system will use a number of models and methods developed for CERES processing.

Anthony Slingo (Hadley Center, UKMO) presented an overview of the climate research underway at the Hadley Center. He gave a brief description of the model currently in use at the Hadley Center for climate studies, namely, the HadCM3. This model has a varying horizontal resolution over land and ocean areas, 19 vertical levels, and uses the Edwards and Slingo radiation code. Slingo showed a time-series of the observed surface temperature for the 1860-2000 period and stated that HadCM3 is being used to determine whether the observed temperature changes were caused by natural or anthropogenic factors. He showed the projections from the latest IPCC assessment which predict anthropogenic forcing of 2.5 - 4.5 K for the year 2100. He also presented results of a model simulation which showed precipitation decreasing in the absence of a CO_2 sink, and a positive feedback. Comparisons of LW and SW cloud forcing were presented between the 40-year ECMWF Reanalysis (ERA40) which uses HadCM3 and ERBE observations. Good agreement was found for LWCF but not for SWCF. It was suggested that cloud forcing was strongly affected by highly interactive dynamical processes.

Investigator Presentation Highlights

Jeff Boghosian (Science Applications International Corporation, SAIC) presented results on new directional models developed for CERES which represent the variation of albedo with solar zenith angle (SZA). Most satellites provide measurements for a few values of SZA. Directional models are essential for estimating albedos for other values. ERBE-like processing uses only 12 different scene-types but CERES processing systems use more than 500 because cloudy scenes are classified by cloud amount, optical depth, and phase. Boghosian presented many examples showing strong dependence of the directional model on cloud properties. Directional models can also be generated by integration of angular dependence models (ADMs). Results from these methods were compared and the errors of the methods were quantified.

Tom Charlock (LaRC) discussed early results from the Chesapeake Lighthouse and Aircraft Measurements for Satellites (CLAMS) flights and summarized the new measurement capabilities at the CERES Ocean Validation Experiment (COVE) site. At COVE, the long-term Baseline Surface Radiation Network (BSRN), Aerosol Robotic Network (AERONET), and Multi-Filter Rotating Shadowband Radiometer (MFRSR) measurements continued. Wind speed/direction and temperature/humidity measurements at 10m will start in February/March. Wenying Su (HU) is initiating a study of ocean foam using data from a second SP1A spectral photometer (radiance) which is being mounted looking down. The Analytical Spectral Devices (ASD) FieldSpec spectroradiometer (SW flux) will be mounted looking down. OV-10 broadband and spectral flux measurements are planned to cover conditions with high winds and clouds. The National Data Buoy Center (NDBC) is considering deployment of a wave direction sensor to augment current measurements of wave height and period. Advances in modeling include the Jin and Stames coupled air-sea radiative transfer code which generates look up tables for SARB ocean surface albedo as a function of sun zenith angle, wind speed, aerosol optical thickness, and chlorophyll. Given the high accuracy of CERES at TOA, surface albedo is now regarded as the primary uncertainty to assessments of TOA aerosol radiative forcing in clear conditions. With the best CLAMS inputs (including measurements of chlorophyll and in-situ spectral absorption of sea water), Zhonghai Jin's sophisticated coupled radiative transfer code still produces a surface albedo over COVE that is slightly smaller (~0.005) than the observations.

James Coakley (Oregon State University) presented estimates of direct aerosol radiative forcing (ARF) derived from CERES TOA radiances and aerosol optical depth (AOD) data from AERONET stations. This work represented an extension to other sites of the earlier work by Satheesh and Ramanathan which provided estimates of ARF over Kaashidhoo Climate Observatory (KCO). Cloud-free CERES footprints were matched with several ocean AERONET sites to within ±50 km and ±1 hour. Different aerosol models were utilized for deriving AOD and ARF from the measurements. Derived ARF values were generally independent of the aerosol model used but varied greatly from site to site. Values ranged from 22 to 57 Wm^{-2}/unit AOD. Low sensitivity was associated with sites with highly absorbing aerosols. Sites with non-absorbing aerosols showed high sensitivity. Current results from KCO agreed well with those of Satheesh and Ramanathan.

Steven DeWitte (Royal Meteorological Institute of Belgium) presented results of homogenization (smooth blending) of GERB-like fluxes derived from METEOSAT-7 data and corresponding fluxes from CERES. Comparison of a pre-homogenized OLR dataset for July-August 1998 showed a rms error of 8.4 Wm^{-2}. Differences were found to be dependent on view zenith angle (VZA). A factor developed to correct for VZA effects was found to be dependent on surface scene type. Homogenization reduced the rms error to 7.0 Wm^{-2}. Corresponding effort for SW fluxes is now underway and has been found to be much more difficult because of the complex angular models and surface classifications involved.

Leo Donner (Geophysical Fluid dynamics Laboratory) presented results from a study of convective mass fluxes and tracer transport in a new parameterization of cumulus convection. Most existing cumulus parameterizations model only the deep convective aspects of the systems. In the new parameterization under development at the GFDL, mesoscale circulation is also accounted for. The latter simulation was named 'cell-meso,' to distinguish it from the usual simulation named 'cell.' Donner presented detailed comparisons of results from the two simulations. Large-scale flows in the two simulations were quite different but heating was similar. Tracer transport in cell-meso was much lower. This result is very significant with regard to atmospheric chemical composition when chemistry is included in the general circulation models.

Xiquan Dong (University of Utah) presented comparisons of CERES/MODIS retrievals of macro- and microphysical cloud properties with those measured at the ARM/SGP site. Satellite retrievals were performed by the CERES team using MODIS data for the November 2000 to June 2001 period, and were screened to provide 57 daytime and an equal number of nighttime cases for comparison. Surface data taken with the mm-wave cloud radar provided reflectivity profiles. For thin clouds ($\tau < 5$), cloud height and temperature showed good agreement during the day; not so good during the night. Similar comparisons for thick clouds ($\tau > 5$) showed better agreement. He also showed comparisons of effective radius (r_e) for daytime stratus clouds. Dong concluded that MODIS retrievals overestimate cloud height during the night and underestimate r_e during both, day and night. LWP retrievals showed better agreement.

Alexander Ignatov (NESDIS/NOAA) presented comparisons of aerosol optical depths (AOD/τ) retrieved from TRMM/VIRS and Advanced Very High Resolution Radiometer (AVHRR) data. It was shown that VIRS channel 2 (1.61 μm) yielded negative values for AOD in up to 8% of retrievals. This problem was attributed to the instability of VIRS ch. 2, and rendered corresponding AOD (τ_2) values as unreliable. VIRS ch. 1 retrievals (τ_1) were found to be reliable and were compared with corresponding results from AVHRR for about a 10-day period in April 1998. Average τ_1 values from VIRS were found to be higher than from AVHRR (0.18 vs. 0.14). The agreement was regarded as good because the geographical areas of the two retrievals were slightly different. AOD from both sources also showed some dependence on cloud amounts and the wind speed. Because of the persistent problem with VIRS channel 2, Ignatov recommended that the team should use only the AOD retrievals from VIRS channel 1.

Seiji Kato (HU) estimated the absorption by atmosphere and tropical ocean from CERES and ARM data taken at Manus Island. The results indicated that clouds over Manus Island present between January and August 1998 had a cooling effect to the column and a warming effect to the atmosphere compared to clear-sky conditions. The top-of-atmosphere shortwave irradiance reflected by the earth after sunset at the surface was also estimated. The irradiance is small and can be neglected in estimating regional radiation balance. However, the irradiance might not be negligible in analyzing global radiation balance between shortwave and longwave radiation.

Robert B. Lee III briefed the team on the long-term precision of ERBE nonscanner data products. For the October 1984 through September 1999 level 1 data products, the ERBS/ERBE nonscanner active cavity radiometer (ACR) measurements of earth-reflected solar irradiances and earth-emitted longwave irradiances were found to be stable at precision levels approaching 1 Wm^{-2}. Using direct observations of the incoming total solar irradiance ("Solar Constant"), the ERBE wide field-of-view (WFOV) total and shortwave nonscanner responses were found to drift 0.1% and 8.7 %, respectively. The observed instrumental drifts were removed from the final data products. During special maneuvers of the ERBS spacecraft, observations of cold deep space, representative of a zero irradiance source, were used to validate the measurement precisions of the final level 1 data products near the 1 Wm^{-2} level. After September 1999, in-flight calibrations could not be conducted because the calibration positioning mechanism failed. A 2002 end-of-mission, special ERBS Spacecraft maneuver is being planned to observe deep space and the sun to provide the calibrations which are required to determine the final ERBE nonscanner ACR gains and zero-irradiance offsets, and to process the October 1999 through 2002 measurements at the 1 Wm^{-2} level.

Bing Lin (LaRC) reported on using CERES SSF data to test the Iris hypothesis proposed by Lindzen et al. The study (with Lin Chambers, LaRC) tested the Iris hypothesis using CERES ERBE-like and SSF data to detect high clouds and to estimate the radiative properties of tropical dry, clear-moist, and cloudy-moist regions of the 3.5 box climate model. They found that no matter what thresholds of IR brightness temperature and actual cloud temperature were used to classify tropical high clouds (i.e., cloudy-moist regions), the net radiative forcing between cloudy-moist and clear-moist regions was generally an order of magnitude smaller than that of Lindzen et al. The results were also supported by the CERES measurements when SSF water/ice phase of high clouds was considered. Using the CERES observed radiative properties, the climate feedback calculated from the 3.5 box model was about a factor of 5-10 smaller than the Iris hypothesis, which is consistent with the conclusions of a previous study by Lin et al.

Sergei Matrosov (University of Colorado) presented multi-year datasets of the properties of Arctic clouds collected at the ARM/North Slope of Alaska (NSA) site and during the Surface Heat Budget of the Arctic (SHEBA) experiment. These properties were derived from measurements made by cloud radars, microwave (MW) radiometers, depolarization lidars, and Atmospheric Emitted Radiance Interferometer (AERI) instruments. Radar reflectivity measurements provided the data on liquid water content (LWC), ice water content (IWC), r_e, D_e, and τ (for visible absorption). MW radiometer measurements provided the liquid water path (LWP) and ice water path (IWP) data. Cloud amounts, heights of cloud boundaries, and a number of other properties were also retrieved. Matrosov showed τ measurements from MW radiometer obtained over a 6-month period. He showed comparisons of satellite retrievals and ground measurements for IWC, D_e, and τ for March 20, 2001. Satellite retrievals of τ were found to be slightly higher. These datasets are available to the science community and can be used for validation of CERES and MODIS cloud retrieval algorithms.

V. Ramanathan (Scripps Institution of Oceanography) presented results of a validation of spatio-temporal properties of tropical convective clouds simulated in the GCMs using geostationary satellite images from METEOSAT-5. A Lagrangian analysis scheme was used to identify biases in cloud sizes and precipitation rates. It was found that the winter monsoon cloud systems are dominated by giant size clouds, as large as 10^7 km^2. The probability of cloud precipitation increased with increasing cloud size. He stated that most GCMs do not simulate the above features too well. For example, CCM3 simulated this behavior qualitatively but did not diagnose the intense mesoscale systems seen in TRMM/TMI observations. A diagnostic cloud scheme based on relative humidity simulated this behavior better. However, the small- and mid-sized clouds in this scheme precipitated too frequently.

David Randall (Colorado State University) presented results from a modeling study of mesoscale convective systems. The shapes, orientation, and propagation speed of these systems are their most important observed features, yet they are not well simulated in the large-scale models. The study was motivated by the fact that mesoscale convective systems or thunderstorms have widespread effects on human activities. In this study, latent heating was included as a forcing factor and linearized 3-dimensional equations of momentum, continuity, and thermodynamics were solved for the system. Model simulations were compared with observations for several cases. Of the two simulations over Oklahoma ARM site, one showed good agreement and the other did not. Comparisons for all three simulations over TOGA-COARE region showed good agreement. The formulation developed in this work can be incorporated into large scale models used for numerical weather prediction and general circulation studies for improved representation of mesoscale convective systems.

G. Louis Smith (Virginia Tech) described a study done in collaboration with Anne Wilber (AS&M) in which the annual cycle of surface radiation budget was described in terms of empirical orthogonal functions, a method by which maps and time histories of basic patterns in the data are computed. These patterns were then related to the climate classification of each region. Smith also presented a study done with Takmeng Wong (LaRC) to examine temporal variations with periods between 10 days and a year, using the first year of CERES/Terra data. The data show variations which have a lifetime beyond the usual 10-day limit of predictability. The equatorial eastern Indian Ocean has especially strong variations in the 20 to 60 day range, which could be due to Madden-Julian oscillations, but the variations extend to higher latitudes. Studies of these variations are ongoing.

Petra Udelhofen (State University of New York at Stony Brook) presented results from a study exploring relationships between cloud amount variability and variables like the galactic cosmic ray flux or the sunspot number over the U. S. Cloud data came from ground-based observations. Time series of cloud amount averaged over the U. S. for the period 1900 to 1997 showed a variability of about ±2%. Both, galactic cosmic ray flux and sunspot number showed negative correlation with cloud amount. Anomalies in the time series were found to agree well even though the signal was always weak. North Atlantic Oscillation was also examined as possible link to the cloud variability.

Francisco Valero (Scripps Institution of Oceanography) presented an update on the Triana mission, the first deep space climate observatory, to be launched at some future date. This spacecraft will be located at the first Lagrangian point (L1) between the Sun and the Earth. From this location, it will provide a synoptic view of the entire sunlit side of the Earth from sunrise to sunset. The spatial resolution of the instrument is 8 km. It will be able to use Moon as a calibration reference and intercalibrate with instruments on other satellites. A 10-channel instrument from Scripps, the NISTAR, will be used to monitor radiation budget, ozone, aerosols, cloud phase, and ultraviolet radiation at the surface. Radiometers on NISTAR are already calibrated. The expected lifetime of this spacecraft is about 10 years.

Michel Viollier (Laboratoire de Meteorologie Dynamique, France) presented correlations between narrowband (NB) fluxes from METEOSAT and broadband (BB) fluxes from the Scanner for Radiation Budget (ScaRaB) instrument over the region of INDOEX-1999. LW correlation worked well for the entire region. SW correlation also worked well except for some regions over the Bay of Bengal which were affected by sunglint. These NB-BB correlations can be used to derive broadband SW and LW fluxes using METEOSAT narrowband measurements. Similar correlations between METEOSAT narrowband counts and CERES ERBE-like broadband fluxes were also shown. LW correlation worked well and was used to produce the diurnal cycle of OLR over the METEOSAT region. Comparisons for March 2, 2000 OLR data showed differences to be within ±10 Wm^{-2}. Development of a corresponding SW correlation presented some problems which are being addressed. Viollier stated that another ScaRaB launch is scheduled for 2007.

Betsy Weatherhead (University of Colorado) presented results from a trend detection study on regionally averaged ERBE data. Trend detection studies are successful only when the signal is stronger than the background noise. It was found that from a trend detection point of view, cloud and radiation data sets are not very well behaved and do not provide unambiguous results. These data sets were not normally distributed and did not show strong spatial or temporal correlations. Trends in such cases, if they can be detected at all, have a low confidence associated with them. For comparison, Weatherhead presented a data set of MSU derived temperatures which showed a strong trend signal. She also showed correlations between SW and LW flux fields. Spatial correlations between the two were mostly negative as expected, but non-existent and even positive over some areas. Overall, regional trends in ERBE data were not strong.

Bruce Wielicki (LaRC) summarized his recent *Science* paper on the tropical decadal variability seen in 22 years of overlapping broadband radiation data including El Chichon, Pinatubo, the 1983, 1987, and 1998 El Nino events, and what appears to be a shift of 3 Wm^{-2} in the tropical mean SW and LW fluxes from the late-1980s (85-89 baseline) to the mid-1990s (94-97 period between Pinatubo and the strong 97/98 El Nino). The decadal variations also appear to show a shift in the seasonal variations in tropical albedo in spring and fall seasons. Comparisons were made to the major current climate models forced with observed SSTs, but the climate models failed to reproduce the radiation field variations, including the large 1998 El Nino tropical mean anomalies in February through April of 1998. These are the same climate models that given SSTs do a very good job of simulating the spatial anomaly patterns of SW and LW flux anomalies during the 1998 El Nino. These tropical radiation signals appear to be excellent candidates to test improved cloud models used in climate simulations.

Wielicki also discussed a companion paper by Chen et al. Which shows a new method to compare upper tropospheric humidity, vertical velocities, and International Satellite Cloud Climatology Project (ISCCP) cloud fraction to the radiative anomalies shown in Wielicki et al. This paper showed that the anomalies appear to be explained by fluctuations in the strength of the Hadley and Walker circulations. The analysis is particularly innovative in that it applies Empirical Orthogonal Function (EOF) analysis to SW/LW joint probability density space rather than the traditional latitude/longitude space. As a result, simple spatial shifts in cloudiness which dominate the traditional latitude/longitude EOFs, have no effect on the EOF of the pdfs. Instead, these patterns respond only to tropical wide changes in the distribution of cloudiness in SW/LW pdfs. In the simplest sense, these pdfs cluster cloud types in different portions of the 2-D pdf and monitor the relative frequency of occurrence of these cloud types.

Shi-Keng Yang (NOAA/National Centers for Environmental Prediction) presented results from validation of the Medium Range Forecast (MRF) model using CERES data. He described many improvements made to the MRF recently, especially those to the radiation scheme. A scatterplot comparison between CERES OLR and AVHRR-derived OLR from NOAA showed good agreement in the middle of the range, but not at the low and high ends of the range. Comparison between results from the global data assimilation system (GDAS) and AVHRR showed similar characteristics. Comparison between GDAS and CERES OLR, on the other hand, showed consistent agreement throughout the range. Yang also examined the model-derived Arctic Oscillation (AO) index using ERBE wide field of view OLR data. He showed that the monthly AO index correlated well with the OLR composite for latitudes with strong vertical motions.

Education and Outreach

David Young presented an update on the CERES Students' Cloud Observations On-Line (S'COOL) educational outreach program. During the past 6 months, S'COOL signed up its 1000th participant and logged its 10,000th observation. S'COOL now has over 1000 schools in all 50 states and in 57 other countries. NASA recognized the success of the program in 2001 with the presentation of a NASA Group Achievement Award.