Summary

22nd CERES Science Team Meeting

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The 22nd Clouds and the Earth's Radiant Energy System (CERES) Science Team meeting was hosted by Ron Welch at the Bevill Conference Center, University of Alabama-Huntsville (UA-H), on September 20-22, 2000. The Science Team approved release of validated Terra CERES level 1 radiance data products as well as the global ERBE-Like TOA fluxes. Early "Beta" products were already available at the Langley Atmospheric Sciences Data Center (ASDC), and the new CERES data will be the first validated Level 1-3 Terra Data Product available to the science community for research and publication. Data Quality Summaries will be completed in October and the Edition 1 data products will appear at the ASDC starting early November. The merged Tropical Rainfall Measuring Mission (TRMM) cloud property/radiation data product (Single Scanner Footprint, SSF) was also approved for Edition 1 pending some final minor changes. This also will become available starting early November. Validation plans are nearly updated, and will be peer reviewed with other Terra/Aqua plans this fall. The next Science Team meeting is scheduled for January 23-25, 2001 at NASA Langley. The next meeting will focus on science team results, TISA with geostationary diurnal corrections, early angular distribution model (ADM) results from SSF data products, Surface and Atmospheric Radiation Budget (SARB) Chesapeake Lighthouse & Aircraft Measurements for Satellites (CLAMS) plans for Summer 2001, instrument deep space determined offsets, and improved spectral corrections.

Bruce Wielicki (LaRC), CERES Co-Principal Investigator, opened the meeting with an Earth Observing System (EOS) program status report. The Aqua launch date has slipped until July 2001. The recompetition of the CERES Science Team will likely take place next summer. Wielicki is continuing to work with the science community, including modelers, to evolve the Earth Observing System (EOS) science strategy.

Bruce Barkstrom (LaRC), CERES Co-Principal Investigator, discussed the science impact of Earth Science Data and Information System (ESDIS) hardware capacities. If the Terra Science Teams do not get additional hardware, we can expect a 2 to 3 year delay in producing validated data products.

CERES Instrument Status

Kory Priestley (LaRC) presented the instrument status report. The Aqua instruments were delivered on schedule and have completed mechanical and electrical integration on the spacecraft. While no instrument problems have been encountered there are outstanding spacecraft interface issues including suspect traceability of spacecraft supplied bolts to mount the instruments as well as spacecraft supplied deployment drives that continue to leak penzane oil. Priestley gave a 'post mortem' report on the CERES instrument on TRMM. The prospect of restoring nominal operations on this instrument is believed to be extremely thin. The likely culprit for the demise of this instrument is the failed Interpoint voltage converter. The Terra instruments have continued to function flawlessly since their launch in December 1999. These two instruments are currently in an opposing 3-month operational cycle of rotating azimuthal plane and fixed azimuthal plane scanning. We expect that in early 2001 the Terra spacecraft will perform a Deep Space Calibration maneuver such that final measurements of the scan angle dependent offsets can be made.

Terra Radiometric Validation

Kory Priestley (LaRC) led the session which reported results of eleven studies which quantify the radiometric performance of the CERES/Terra Flight Model 1 (FM1) and Flight Model 2 (FM2) instruments as well as their relative relationship with the CERES/TRMM and ERBE scanner instruments. These studies utilize data products spanning the range from instantaneous raw counts to temporally and spatially averaged TOA fluxes and are statistically robust at the sub 1% confidence level. Priestley reported that the ground-to-flight traceability of the radiometric calibration was better than 0.3% for the total (TOT) and shortwave (SW) channels. The window channel calibrations both shifted by about 0.5%, but in opposite directions. Pointing accuracy has been established via coastline detection techniques to be better than 1.8 and 2.4 km at nadir for the FM1 and FM2 instruments, respectively. Tropical Deep Convective Cloud (DCC) investigations were used to establish both a 3-channel intercomparison and SW albedo metric. The Three

Channel Intercomparison suggests an inconsistency between the FM1 SW channel and SW portion of the TOT channel at the 1.1% level while the FM2 instrument had no significant inconsistencies in the SW region. The DCC albedo metric demonstrates that the SW channels on all three CERES instruments agree to within 0.5%, suggesting the inconsistency in FM1 resides in the SW portion of the total channel. David Kratz (LaRC) provided the line-by-line radiative transfer calculations for Terra.

Richard Green (LaRC) conducted a direct comparison of the FM1 and FM2 instruments on Terra. All nadir radiances for each of the three channels were averaged over the Tropics and over 3 months. The results showed that for the SW channels FM1<FM2 by 0.2%. At night for the TOT channels (or the LW portion of the TOT channel) he showed that FM1>FM2 by 0.6%. From the LW comparison during the day and the other comparisons, he determined that for the SW portion of the TOT channels FM1<FM2 by 1.0%. And finally, for the window channels FM1<FM2 by 0.9%. These results were in general agreement with the other studies.

Martial Haeffelin (Virginia Tech) presented results of a direct comparison between the CERES instruments on the TRMM and Terra Platforms. Unfiltered radiances measured by FM1 and FM2 on Terra and PFM on TRMM are matched in time, space and viewing geometry to provide comparisons independent of angular and diurnal models. Comparisons of SW radiances require both the zenith and the relative azimuth angles to be matched. This is obtained by rotating the scanning plane of one of the instruments to scan parallel to the other instrument. For LW and nighttime WN comparisons we match the zenith angles only. Daytime WN radiances are compared for matched zenith and relative azimuth because heating of land surfaces can vary with azimuth. Observations from the two instruments are considered coincident if made within ±15 minutes of each other. Spatial resolution discrepancy between FM1/FM2 and PFM is reduced by averaging the radiances on a 1-deg grid. Zenith angles are matched to ±5 deg and relative azimuth angles are required to be within ±10 deg. Any differences found between FM1/FM2 and PFM can be attributed to uncertainties in either radiometric calibration or spectral unfiltering process. Unfiltered FM1/FM2 SW radiances were found to be 0.4% less than PFM radiances; however, the 95% confidence interval on this comparison is ±0.4%. The uncertainty is dominated by spatial noise. The FM1-PFM differences of unfiltered LW radiances are -0.5% and +0.1% for daytime and nighttime, respectively. The daytime and nighttime FM2 minus PFM differences of unfiltered LW radiances are consistent: -0.5% and -0.4%, respectively. The uncertainty in the LW comparisons is ±0.1% (95% confidence interval). The difference between FM1 and PFM WN radiances are +0.1% and +0.5% for daytime and nighttime, respectively. For FM2-PFM, the differences are greater: +1.0% and +1.5% for daytime and nighttime, respectively. Again the 95% confidence interval is ±0.1%. These results show no statistically significant dependence on scene type.

David Kratz put forth a proposal to use the CERES/Terra instruments to observe the totally eclipsed moon on January 9, 2001. The moon, having virtually no atmosphere, is an excellent calibration source and, indeed, is the only naturally occurring source of thermal energy which is sufficiently large and bright to be useful for CERES/Terra calibration studies involving the intercomparison of the window channel and the longwave portion of the total channel. Nevertheless, most of the time, the moon is either too near the direction of the sun to safely observe or the lunar surface is bathed in sunlight during which time the energy measured by the total channel instrument is dominated by reflected solar energy. A total lunar eclipse, however, provides that somewhat rare opportunity to measure the thermal energy emitted by the moon in the absence of the reflected sunlight. After the January, 2001 event, the next opportunity to take measurements during a total lunar eclipse occurs on May 16, 2003. The results from this endeavor, along with the internal calibration efforts should provide even greater confidence in the long-term stability of the CERES/Terra instruments.

Terra ERBE-Like TOA Fluxes

Norman Loeb (Hampton University, HU) conducted theoretical tests which showed that unfiltering algorithms are more robust for Terra SW compared to TRMM. Larger relative errors (about 1%) in unfiltered radiances were found for deep convective cloud scenes for Terra. Unfiltered SW and LW radiance differences between FM-1 and FM-2 are small (less than 0.5%) and show no evidence for any systematic dependence on scene type or solar angle.

David Young (LaRC) updated the status of ERBE-like product validation for TRMM and Terra. Tropical Means are used to minimize temporal sampling errors. Young compared Tropical Means from 1998 CERES data with ERBS scanner 5-year (1985-89) averages. Comparison of Terra results

with the ERBE climatology was consistent with a similar comparison using TRMM results for total-sky LW, clear-sky LW, and clear-sky SW. Total-sky SW flux differences were explained by the Terra temporal sampling. The Terra March-May means are consistent. Multiple satellite products are now ready. A comparison of results from the crosstrack and rotating azimuth plane scan modes showed zonal mean differences less than 2 Wm^{-2} except at the Poles. Regional monthly mean differences were primarily caused by the temporal sampling patterns. Clear-sky SW differences were noted due to the MLE over snow surfaces. Clear-sky LW differences were less than 0.5% and appear to be instrument based.

TRMM/Terra Data Production

Erika Geier (LaRC) updated the team on CERES data product status, major SSF changes, subsetting data products (Langley ASDC can subset SSF, CRS, and ES8 products), and CERES data distributed from the Langley ASDC. There have been some problems in receiving Terra data. Most data sources are available for March-May 2000, but June-August data are only available sporadically. Terra count conversion offsets previously set to zero have been updated to the ground-determined values. The second time constant coefficients and algorithm have been updated. Reprocessing will be completed this Fall.

TRMM SSF Edition 1 Status and Early MODIS/TRMM comparisons

Patrick Minnis (LaRC) summarized recent improvements to the cloud algorithm. The 1.6-µm calibration was changed throughout the code, sub-pixel cloud contamination was minimized with a spatial variability test for AOD retrievals, a 10' land/water mask was incorporated to allow more AOD retrievals, 3 new parameters were added to SSF (fraction of pixels, and the mean 0.6 µm and 1.6 µm reflectances used for AOD retrievals, and 3.7-µm reflectance models from Minnis, Han, and Coakley were compared to help explain differences in particle size. Preliminary cloud retrievals from Moderate-Resolution Imaging Spectroradiometer (MODIS) were completed and compared to Visible Infrared Scanner (VIRS) results. VIRS and MODIS calibrations for 0.65, 1.6, and 10.8 µm are very close. The MODIS 3.7-µm channel averages about 2K greater than VIRS, partly due to spectral differences and part likely due to calibration. The 11-µm data have a possible scan angle variation of 1-2K. The 12-µm results are about 0.5K greater than VIRS. MODIS channels at 1.38, 8.55, and 13.9 µm look very promising. VIRS and MODIS retrievals are generally consistent. Biases in cloud amount and particle size are likely due to calibration differences.

Angular Modeling Status

Norman Loeb updated the team on ADM-related activities. His paper on spectral corrections was accepted for the Journal of Applied Meteorology. LW ADMs were developed for clear and overcast scenes stratified by cloud properties. Progress was made on validating cloud property averaging over CERES footprints. A new method was developed for reducing angle-dependent biases in satellite cloud optical depth retrievals. The largest corrections occur for thick clouds at large solar zenith angles. The main strength of the method is that it removes optical depth dependence on satellite viewing geometry. The primary weakness is that reference optical depth distribution does not account for diurnal variations. The approach will be used to develop CERES ADM optical depth classes, but will require more than the 8 months of VIRS data.

CERES Ocean Validation Experiment (COVE)

Ken Rutledge (Analytical Services & Materials, Inc., AS&M) briefed the team on the status of the COVE site. Chesapeake Lighthouse is an ocean platform located 25 km from Virginia Beach, Virginia. This location is a primary validation site for the CERES project. The site was chosen primarily because of the homogeneity of the surrounding scene type and because the ocean (which covers approximately 70% of the Earth's surface) has precious few radiometric measurement stations. COVE measures insolation, albedo, net longwave flux, and aerosol optical depth. The basic radiometric instrumentation has been installed using the recommendations of the WMO's Baseline Surface Radiation Network (BSRN) program. Insolation is obtained by separate measurements of the direct solar beam and shortwave diffuse flux. The direct beam is measured with a tracking pyrheliometer and the diffuse flux with a shaded pyranometer. Shortwave and longwave downwelling flux (from an uplooking pyranometer and pyrgeometer), air temperature, pressure, and relative humidity complete the basic BSRN radiation requirements. Additionally, total column aerosol optical thickness is monitored with a multifilter rotating shadowband radiometer (MFRSR). An aerosol robotic network (AERONET) automatic sun-sky scanning spectral radiometer is located on the platform, enabling retrieval of aerosol size distributions and refractive index (from almucantar scans) that is publicly available on the AERONET webpage. A downlooking pyranometer allows the

calculation of sea surface albedo. The submission of data to BSRN for archive began with July 1998 data.

SARB Status: Plans for CLAMS 2001

Tom Charlock (LaRC) discussed plans and objectives for the upcoming CLAMS mission. CLAMS targets clear skies (cloud free conditions). The core Terra validation during summer 2001 includes aerosols; SW broadband fluxes and spectral radiances at the sea surface and within the atmosphere. The potential second CLAMS (2002) includes Aqua validation; humidity sounding and the vertical profile of LW radiation. Two weeks is regarded as the minimum deployment to meet the needs of CERES, MODIS-Atmospheres, and GACP. A full six weeks (July to mid-August) is needed for basic MISR requirements and as an enhancement for CERES and MODIS on Terra.

The centerpiece of CLAMS is COVE, the Chesapeake Lighthouse sea platform at which NASA and NOAA make continuous, long-term measurements of radiation, meteorology, and ocean waves. The core summer CLAMS will include a low-level aircraft to measure radiation at the sea surface, a mid-level aircraft to profile aerosol properties in situ, and a high-level aircraft to measure radiation and sense aerosols remotely with lidar. William L. Smith, Jr. (LaRC) is the CLAMS scientist and primary point of contact for the mission.

Temporal Interpolation Using Geostationary Data: An Update

Dave Young reviewed the status of data sets and algorithms for incorporating 3-hourly visible and infrared data from four geostationary satellites into the CERES temporal interpolation process to account for meteorological variability at times not sampled by the satellite. The method involves normalizing the narrowband calibration to VIRS or MODIS measurements, and narrowband-to-broadband conversions based on ERBE/GOES relationships. Preliminary results show a significant improvement in daily and monthly mean fluxes in many regions. In addition, Young showed that using geostationary data to interpolate cloud properties further reduced the instantaneous shortwave flux interpolation errors. Geostationary-enhanced monthly mean products will be produced before the next science team meeting. Cloud property interpolation issues include the lack of nighttime optical depth retrievals and the lack of particle size/phase information.

CERES/ERBE Decadal Variability

Bruce Wielicki showed an update on the decadal variability of tropical broadband LW radiation budget using both observations and general circulation model results. Observational analysis using data from five totally independent broadband radiation instruments, including ERBE/ERBS nonscanner, ERBE/ERBS scanner, ScaRAB/Meteor scanner, CERES/TRMM scanner, and CERES/Terra scanner, over the period from 1985 and 2000 shows that (1) there is remarkably good agreement among measurements from all five instruments, and (2) there is a significant variability in the tropical broadband radiation budget during this 15-year period. This decadal variability in tropical broadband radiation budget, however, is not captured by the current general circulation models (GCMs). These models tend to underpredict the tropical mean interannual variability in both radiation and precipitation. This suggests that further improvements in GCM cloud parameterization schemes are needed. While the magnitude and the sign of this observed decadal variability is found to be consistent with the observed SAGE II decadal cloud frequency variability and the observed steepening of tropical lapse rate, the decadal LW anomalies do not agree with the HIRS simulated decadal broadband LW anomalies. Further analyses are needed to understand these differences.

Cloud Working Group

Patrick Minnis led discussions of cloud retrieval, archival, and validation issues. The group agreed that trying 8 by 16 tiles should be tested to see if the discontinuities in retrieved optical depths could be avoided. Minnis, Jim Coakley (Oregon State University, OSU), and David Young will continue conducting comparisons of particle size and optical depth over ocean to isolate the differences in retrieval techniques. Other action items included fixing a problem in the optical depth interpolation routine and adding the mean viewing zenith angle of imager aerosol optical depth retrieval pixels. The working group reminded the team that SSF Edition 1 has cloud properties, aerosols, and clear-sky fluxes, but cloudy sky fluxes will not be available until used by ADM group to generate new ADMs. A telecon to discuss the status of Edition 1 SSF will be held later this year.

Xuepeng Zhao (NOAA/NESDIS) reported on efforts to validate VIRS-derived aerosol optical depths using surface data collected at Aerosol Robotic Network (AERONET) sites. Larry Stowe (NOAA NESDIS) discussed the effect of recent changes in VIRS

calibration on retrieved aerosol optical depths. The 0.63 μm optical depths obtained with the version of the algorithm that was delivered in August, 2000, were unchanged when the September, 2000, delivery was used. However, the 1.6 μm optical depths had increased by 0.08. After discussion, it was agreed that the 1.6 μm channel calibration was still unsettled.

Bryan Baum (LaRC) gave a summary of the wavelengths that are available on MODIS. He reported that the shortwave IR to microwave IR channels from 1.23 to 4.55 μm were having potentially fatal problems due to electronic cross talk between channels. He then presented a comparison of MAS-derived ice crystal habits and size distributions with those calculated with the Takano and Liou models. He presented initial results from a new effort to derive ice crystal properties using new MODIS wavelengths.

Alexander Ignatov (NESDIS) summarized the aerosol optical depth retrievals including a discussion of the optical depths' dependence on scattering, solar zenith, and viewing zenith angles. He also discussed the effect of ocean surface winds on the magnitude of sunglint. He estimated the effect of calibration errors on aerosol optical depth at both 0.63 and 1.6 μm. The 1.6 μm optical depths are extremely sensitive to calibration errors.

Jim Coakley summarized an ongoing comparison of cloud properties derived using his cloud retrieval algorithm and the CERES cloud algorithm. The radiative transfer calculations from both algorithms seemed to agree, but a remaining difference of about 2.0 μm in retrieved effective water droplet radii remained. It was agreed that he and Pat Minnis would continue these comparisons for large optical depth cases in order to isolate the cause of the differences.

Mike Friedman (OSU) gave an update on his work with Jim Coakley on retrievals of cloud properties from partly cloudy pixels.

Xiquan Dong (University of Utah) presented comparisons of VIRS- and MODIS-derived cloud properties with surface-derived cloud properties from the ARM North Slope of Alaska (NSA), Southern Great Plains (SGP), and Tropical Western Pacific (TWP) sites as well as from surface sites at Penn State and Utah.

Ron Welch (UA-H) demonstrated a new version of their MODIS cloud classifier and presented results from an improved polar cloud classifier. He gave a demonstration of a new version of the Satellite Imagery Visualization System (SIVIS) that ingests VIRS and MODIS data as well as CERES VIRS retrievals for validation purposes.

Ben Ho (AS&M) presented a summary of seasonal variations of liquid water path and cloud frequency as determined from both the TRMM Microwave Imager (TMI) and VIRS. He discussed cloud overlap frequency over oceans derived from both TMI and VIRS.

Surface and Atmospheric Radiation Budget (SARB) Working Group

The meeting was jointly chaired by Thomas Charlock and David Kratz. The working group action items included: continue CLAMS field experiment planning, determine DAO/ECMWF status by January 2001 (Man-Li Wu will visit LaRC to discuss DAO 4-D results), and conduct early CRS data product testing with new SSF data products.

David Rutan (AS&M) presented an update on the status of the CERES ARM Validation Experiment (CAVE) database. This database was developed to facilitate the validation of CERES-derived surface fluxes. It consists of flux measurements from ARM, Baseline Surface Radiation Network (BSRN), SURFRAD, and other surface sites from around the world which are matched in space and time with CERES retrievals over the sites. Meteorological data for the sites necessary for making radiative transfer calculations are also included in the database. Site measurements are presented in a standardized format as 30-min. averages. Rutan informed that new data from the Saudi Solar Village, the COVE site, and the AERONET have been acquired and added to the database. The database is available to science community from the CAVE web site at http://www-cave.larc.nasa.gov/cave.

Ellsworth Dutton (NOAA/CMDL) presented the status of surface radiometric observations at the sites operated by the CMDL and the BSRN. Spectral aerosol optical depth (AOD) measurements are now being made at several CMDL sites with MFRSR instruments. Results for the March – May 2000 period from these sites are already available. He outlined the steps being taken to assess and correct for the errors incurred in the measurements of diffuse solar flux because of the thermal offsets of the pyranometers. The new black and white pyranometers now available from Eppley Labs will provide diffuse fluxes free of thermal offsets. With

the addition of 6 new stations within the last year, BSRN now has a total of 23 stations online. An intercomparison of sunphotometers and pyrgeometers is underway at the World Radiation Center in Davos, Switzerland.

Martial Haeffelin (Virginia Tech) presented results of a recent study of thermal offsets in PSPs (pyranometers) conducted at NASA/LaRC. Thermal offsets which are caused by temperature differences between the body and the dome of the pyranometers affect both the shaded and the unshaded instruments. These offsets are not eliminated in the calibration process and generally result in an overestimation of the responsivity of the instrument. The resulting underestimation of the measured irradiance can be up to 15-20% of the diffuse flux. Haeffelin presented a procedure by which these errors can be monitored and eliminated. Efficient ventilation of the instruments also minimizes the temperature difference between the body and the dome of the instrument and thus minimizes the thermal offsets.

Bernardo Carnicero-Dominguez (Virginia Tech) presented another method to correct for the thermal offsets in pyranometer measurements. He showed that there is a linear relationship between the net LW flux measured by a PIR (pyrgeometer) and the thermal offset of a PSP. When the two instruments are operated together, the PIR measurement can be used to correct for the PSP offset. Carnicero-Dominguez showed that this relationship is different for day and night, and also for clear-sky and cloudy conditions. He showed that the daytime clear-sky relationship can be used for clear and partly cloudy conditions. For daytime overcast conditions, the nighttime relationship was found to work better. This procedure allows the PSP offsets to be determined within about 1 Wm^{-2}.

David Kratz (LaRC) presented an update of the ongoing validation efforts of CERES surface-only radiation budget algorithms. The downward surface fluxes derived by the Langley Parameterized Longwave Algorithm (LPLA; see ATBD 4.6.3), which are a part of the CERES/TRMM SSF data products, compared favorably with corresponding surface measurements obtained from several locations. The comparisons yielded an RMS of approximately 25 Wm^{-2} and biases of less than 5 Wm^{-2} for all four subsets (ARM/CART Central Facility, ARM/CART Extended Facilities, CMDL sites, and BSRN sites) of the eight-month (January to August, 1998) CERES/TRMM data. In contrast, the surface-only downward SW fluxes derived with the algorithms presented in ATBD 4.6.1 yielded much larger RMS and biases when compared with corresponding surface measurements. Several potential sources of error (e.g., temporal averaging, surface measurement problems, and misidentification of cloud conditions) were identified.

Anand Inamdar (Scripps; representing V. Ramanathan) presented results of an application of CERES ES-8 OLR data. He found good agreement between model OLR results and monthly average ES-8 OLR values. He also showed the seasonal variation of ocean surface temperature and the normalized atmospheric greenhouse parameter, G_a, derived from ES-8 data. Comparison of G_a derived from CERES data (1998) with corresponding values from the ERBE period (1985-89) showed that G_a was lower in 1998 than in 1985-89. Inamdar stated that his results were different when the process was repeated with the CERES/SRBAVG product. He attributed these discrepancies to ES-8 and SRBAVG processing system differences (scene ID, ADMs etc.).

Fred Rose (AS&M) presented a study of the effects of using SST and column water vapor (PW) retrieved from TRMM Microwave Imager (TMI) measurements on SARB results. Standard SARB processing in CERES uses meteorological inputs from MOA which currently gets data from ECMWF global analyses. The MOA/ECMWF PW was higher than the TMI PW by about 4% on a monthly average basis. Rose compared CERES broadband LW and filtered window radiance measurements with SARB results and found that SARB radiances were lower. The differences (CERES measurement – SARB computation) were correlated with MOA PW. Use of TMI PW in SARB computations provided better agreement with CERES measurements. There were still some differences between window radiances, which were attributed to a small error in the window response function.

Ken Rutledge (AS&M) presented results of an effort underway for retrieving optical properties of the ocean surface. Radiances were measured at 0.5 μm with a Schulz sunphotometer which was mounted on automatic scanning platform. The photometer scans 180° in azimuth, starting at about 2° below the horizon and changes the view zenith angle in steps of 10°. These data will be used to examine the relationships between sunglint condition and the wave state of the ocean surface.

Wenying Su (HU) presented the LW radiation budget of the Tibetan plateau derived from radiances measured by instruments on board the GMS-5 satellite launched in 1995. A water vapor band

channel (6.5 – 7.0 μm) and the split window channels (10.5 – 11.5, and 11.5 – 12.5 μm, respectively) were used. Model computations with a 4-stream DISORT radiative transfer model were used to establish a linear regression relationship between narrowband and broadband fluxes. Satellite radiances were converted to broadband OLR using these relationships. Results showed a correlation of 0.85 with NOAA-12 OLR retrievals. Results for July 1998 were validated with CERES TOA measurements. High spatial and temporal resolution of the geostationary satellites provides a much better description of corresponding variabilities.

Qingyuan Han (UA-H) presented a study designed to help develop a strategy for monitoring indirect aerosol radiative forcing from satellites. He started with the recommendations made by the NRC in 1996 based on the evidence available at that time. He also examined the new information that has since become available from various field and regional experiments. While earlier work focussed only on aerosol effects on cloud albedo, new information also shows effects on cloud fraction and precipitation rate. Han suggested that two different approaches can be used to monitor these effects. The first, called the snapshot method, uses cloud properties from a region and correlates them with aerosol properties from adjacent regions. The other, called the one-month regression method, correlates cloud and aerosol properties acquired from the same region over the course of a month.

Pete Robertson (NASA/MSFC) presented results of an analysis involving the Langley 8-year SRB dataset. He compared SST anomalies over the tropics derived from ISCCP clear-sky composite surface temperature with those from Reynold's SSTs, and found ISCCP-derived anomalies to be much larger. Robertson suggested that the large surface net LW signal over the tropics shown by B. Soden (derived from the Langley SRB dataset) may not be real but an artifact of the large anomalies in ISCCP-derived surface temperatures.

TOA Fluxes/Angular Distribution Model (ADM) Working Group

Norman Loeb led the working group meeting with a general overview of critical ADM/Inversion research issues. The group concluded that we should avoid screening out "no cloud property retrieval cases" or flux biases will occur. In addition, optical depth frequency distribution normalization should help minimize flux retrieval biases.

Nitchie Manalo-Smith (AS&M) presented longwave and window limb darkening functions obtained from CERES measurements under overcast conditions. She examined how various stratifications of the measurements based on scene parameters, such as precipitable water, cloud-surface temperature difference, and cloud emissivity, influence the anisotropy of the scene.

Richard Green (LaRC) showed a comparison of SW reflectances and albedos between ERBS and CERES-TRMM. His results demonstrate how the difference in footprint size between these two instruments causes large differences in scene type frequency-of-occurrence. If the same ADMs are used to estimate albedo from both instruments, the differences in scene type frequency-of-occurrence lead to large biases in the all-sky mean albedo despite the fact that the mean reflectivities are consistent. His main conclusion is that separate ADMs are needed for ERBS and CERES-TRMM to account for the differences in footprint size.

Brian Killough (LaRC) outlined the motivation and plans for a study on the development of empirical angular distribution models in the presence of biomass burning aerosols. His approach will be to first test the reliability of the CERES cloud mask for identifying biomass burning regions and to then develop a set of ADMs specifically for these cases. Theoretical modeling using realistic single scattering properties for smoke will be used to supplement the data as appropriate.

Lin Chambers (LaRC) demonstrated the diurnal variability in cloud optical depth retrievals from three months of ground-based radar over the SGP and Tropical Western Pacific ARM sites. She found a much smaller diurnal trend than is suggested by satellite retrievals (e.g., VIRS). She also performed theoretical simulations to determine under what viewing conditions 1D-derived cloud optical depth retrievals show the least bias. Her "truth" field consisted of 2D SHDOM overcast and broken cloud fields based on Landsat scenes. For small solar zenith angles, she found reasonable results. However, as the solar zenith angle increased beyond 45°, the 1D cloud optical depth retrievals showed considerable bias.

Invited Presentations

Pete Robertson (Marshal Space Flight Cemter, MSFC) presented a comparison of decadal variability of tropical-mean OLR in the ERBE/CERES dataset, and the TOVS Path-A dataset derived from the

HIRS-2/MSU measurements. ERBE/CERES data showed a much stronger variability than Path-A, though the differences for corresponding clear-sky fluxes were smaller. He showed differences between OLR anomalies for CERES and Path-A data for JJA 1998. These differences (CERES – Path-A) showed a very noisy pattern but were about 10 Wm^{-2} over regions with low clouds. Also, these differences correlated well with corresponding differences between 850 mb NCEP reanalysis temperatures and Reynold's SSTs. Robertson suggested several possible explanations for these differences between the OLR records, such as SST errors, cloud retrieval errors, O_3 data differences, and CO_2 increase.

Roy Spencer (UA-H) made a presentation on the retrieval of cloud LWP and rain rates from passive microwave measurements obtained from satellites. He pointed out the close relationship between these two variables, and that areas of high LWP are often indistinguishable form those of light rain. He discussed the advantages and disadvantages of microwave techniques for retrieving these variables over ocean and land. Important advantages were that ice clouds are transparent to microwaves and the absorption is insensitive to drop size distribution. Notable disadvantages are the large footprint of microwave instruments, and that the absorption is temperature dependent. Analysis of ocean data showed that rain rate was correlated with SST. TRMM precipitation radar data is anticorrelated with DCI. Spencer showed Wentz's LWP retrievals (SSM/I) for a 4-year period and compared them with Greenwald's results.

John Christy (UA-H) presented a 20-year time-series of atmospheric temperatures derived from the microwave sounding unit (MSU) on NOAA satellites. This instrument senses O_2 microwave emission to retrieve atmospheric temperatures. The data record was corrected for instrument drifts related to the orbit decay, and offsets related to the temperature of the satellite itself. This record was compared with balloon measurements from 30 highly reliable stations within the U.S., and found to be in good agreement. Christy also presented the work done recently for the IPCC2000 where long time-series of many atmospheric variables (e.g., temperature, precipitation etc.) were examined to look for long-term trends. He found that contrary to what appears in the popular press, the data showed no trends. There was no evidence of extreme events in 2000. Tropical temperatures did not show any increase. There was no increase in the frequency of tornados in the U.S. or of cyclones in the Australian basin. In summary, he found no evidence of global warming and related effects in the datasets which were examined.

Investigator Presentation Highlights

Baijun Tian (Scripps, representing V. Ramanathan) presented a study examining the role of tropical cloud radiative forcing (CRF) in maintaining Hadley and Walker circulations. While GCM studies performed with ECHAM3 show that Hadley and Walker circulations are maintained by tropical CRF, the observational basis of this hypothesis is still missing. He examined the energetics of the tropical atmosphere from an observational perspective and determined that under clear skies radiative and latent heat processes do not provide the necessary energy gradients. He showed further that longwave CRF of the atmosphere establishes the necessary energy gradients for maintaining these circulations.

Leo Donner (GFDL) presented results of a GCM study examining the effects of the treatment of convective shields and cumulus-scale vertical velocities on general circulation. He used results from several model integration schemes (e.g., cell meso, cell, and fixed humidity) to examine these effects. He took into account the total mass flux in the convective shields, cumulus parameterization heat source, cell temperature , and cell mixing ratio. He determined that Walker circulation was much stronger when convective shields were operating, and noted the differences between the results of cell and cell meso integrations. Donner also found that when cumulus-scale vertical velocities are not allowed to vary, and not allowed to interact with model microphysics, the resulting cumulus activity and circulation are much weaker. He concluded that when convective shields are included and vertical velocities are allowed to vary in cumulus parameterizations, the convective systems are much larger and model results match better with observations.

David Randall (CSU) presented a comparative study of convective and stratiform precipitation with particular emphasis on the tropics. He stressed the fact that distinctions made between convective clouds and precipitation are not at all natural; they are artificially made, very likely for the convenience of description in the GCMs. He presented TRMM data which show that precipitation types are not limited to convective and stratiform; there are other types in between. He discussed the partition of precipitation in the GCMs and compared GCM results with TRMM data. Comparisons showed large differences in the Southern Atlantic, and model results showed no convective precipitation over the mid-latitude

storm tracks. Randall also showed results of a GCM simulation for 1999 and 2000, and compared them with TRMM data. Both showed that total precipitation changed little from 1999 to 2000. He stressed the need to develop and use similar parameterizations for convective and stratiform precipitation. Randall's final conclusion: "A cloud is a cloud."

Shi-Keng Yang (NOAA/National Centers for Environmental Prediction, NCEP) presented an investigation of the downward trend in LW CRF in the NCEP/NCAR reanalysis dataset first discovered by Potter and coworkers. The dataset used was the new 50-year reanalysis. The downward trend was confirmed; LW CRF was found to decrease from 34 Wm^{-2} to 31 Wm^{-2} over the period. The purpose of the investigation was to identify the causes of this downtrend. Global data was analyzed separately in three parts; the tropical (30° N – 30° S), and 30° – pole in each hemisphere. The trend was found to be slightly weaker in the tropics than in the higher latitudes. An examination of the clear-sky and all-sky OLR anomalies confirmed the downtrend in LW CRF. Examination of the anomalies of globally averaged low, middle, and high clouds showed a strong downtrend for the middle clouds. Middle cloud anomalies were similar to the anomalies in 500 mb RH. There was no trend in surface temperature anomalies. Yang concluded that the LW CRF trend is caused by changes in mid-tropospheric RH.

Helene Chepfer (Laboratoire de Meteorologie Dynamique, France) presented results of a study of ice-particle shapes in cirrus clouds when the same cloud is observed from two different directions. Cirrus clouds are about 20% of the total cloud cover and have a large impact on the radiation budget. The radiative impact of cirrus clouds is closely linked with their microphysical properties, such as the ice-particle shapes. She presented results of a simulation in which scattering phase function and particle shapes were determined from observations from two different directions. GOES and TRIANA can be suitable platforms for such observations. Results from this study can be used to validate the phase functions for CERES and MODIS processing and to improve IWC determinations. This method can also be used to develop maps of ice-crystal shapes at high spatial and temporal resolution.

Michel Viollier (Laboratoire de Meteorologie Dynamique, France) presented results of a new procedure developed for interpolating reflected SW fluxes between times of observation to fill all local hours of the day to get a better estimate of the diurnal cycle. For this procedure, monthly climatological diurnal albedo curves were developed for each region by compositing five years of ERBS data. These curves were then applied to fill all local hours for March 2000 CERES/Terra data. Results were compared with corresponding values obtained from the standard ERBE-type interpolation procedure. Differences of upto 10 Wm^{-2} were noted for some regions, though tropical and global averages did not show significant differences. The procedure was also applied to ERBE and ScaRaB 1 data. Viollier also presented time series of clear-sky and all-sky SW and LW fluxes from mid-eighties to late-nineties constructed from ERBE, ScaRaB 1 & 2, and CERES TRMM and Terra data. He noted that while all-sky fluxes showed differences between eighties and nineties, clear-sky fluxes held steady. He also showed that March 2000 Terra data confirmed the low values of reflected SW fluxes observed by ScaRaB 2 in 1999.

Nicolas Clerbaux (Royal Meteorological Institute of Belgium) presented a comparison of the Geostationary Earth Radiation Budget (GERB) Spinning Enhanced Visible and Infrared Imager (SEVIRI) scene identification algorithm with the corresponding CERES algorithm. This comparison was necessary because GERB processing will use ADMs developed by CERES and the choice of ADM is dependent on scene identification. Scene identification involves retrieval of cloud optical depth, cloud fraction, and phase. Cloud optical depth and phase will be retrieved at the imager (SEVIRI) pixel resolution. Cloud fraction will be derived at GERB resolution from reflectances obtained from the imager, and then convoluted with the point spread function. Comparison of cloud optical depths retrieved by GERB processing from VIRS data with VINT retrievals showed large differences for some regions. Comparisons are also being made between CERES SSF cloud property retrievals and GERB retrievals from Meteosat-7 data. Cloud fraction comparisons showed good agreement but optical depth differences were significant.

Bryan Baum (LaRC) presented results from MODIS cloud property retrievals for 29 August 2000. Retrieved properties included cloud fraction, optical depth, height, and phase. Phase retrievals were based on a trispectral method using 8.5, 11, and 12 μm channels. Phase retrievals from an orbit swath near the coast of India showed clouds in ice, water, mixed, and uncertain phase categories. Another orbit swath over Southern Hemisphere storm tracks also showed large areas with uncertain phase category. He showed a global cloud fraction chart composited from

all orbital swaths for the whole day. Comparison of day and night cloud fractions showed significant differences. Comparison of cloud-top heights between day and night showed more cirrus during the night. Baum showed extensive comparisons with corresponding retrievals from other satellite instruments/algorithms (GOES, HIRS-2 CO_2 slicing etc.) and field experiments (SAFARI, COVE etc.).

Larry Stowe and Alexander Ignatov (NOAA/NESDIS) presented results of SSF Edition 1 data testing. Stowe presented results of the consistency checks and comparisons of edition 1 data relative to the earlier versions of SSF and found it to be much improved. Edition 1 data showed less cloud contamination, provided more samples for better statistics, and mostly positive values of Angstrom exponent (α). Ignatov outlined the steps underway for developing the third generation aerosol retrieval algorithm. A new bimodal size distribution will be used in place of the old monomodal distribution. An additional parameter, η, representing the proportion of smaller to larger particles will be introduced, and iterated upon to achieve agreement with observations. The 6S forward radiative transfer model will replace the Dave model, and will be used to evaluate the relationship between α and the phase function.

Thomas P. Charlock (LaRC) discussed the aerosol effect in the residual clear-sky insolation discrepancy. The "clear-sky insolation discrepancy" surfaced a few years ago: several well-regarded theoretical simulations (sound radiative transfer codes and carefully measured inputs for them) produced values for clear-sky shortwave insolation that exceeded measurements by 20-30 Wm^{-2}. By both carefully screening the radiometer observations and adjusting them with sound physical principles, the group now finds theory exceeding observations by a mean of 5 to 10 Wm^{-2} for 1999-2000 at the ARM SGP Central Facility. They also find that for moderate values of aerosol optical thickness (AOT), the aerosol forcing to surface insolation is considerably greater than the (now reduced) discrepancy of theory and observations. In other words, the aerosol radiative forcing inferred from theory and ground-based spectral AOT observations appears to be fairly reliable.

Seiji Kato (HU) presented a radiative transfer algorithm that can treat horizontal inhomogeneities of cloud optical thickness in a CERES footprint. The algorithm assumes that the optical thickness follows a gamma distribution and uses the discrete ordinate method to compute the irradiance averaged over a footprint. The distribution of optical thickness in a CERES footprint can be estimated from VIRS/MODIS derived cloud properties. Kato will continue developing the algorithm to handle multiple layer clouds. Combining the algorithm with cloud radar derived cloud top and base height statistics and cloud particle size distributions, computed irradiances at ARM validation sites can be compared with those in CRS files.

James Coakley (Oregon State University, OSU) presented estimates of direct aerosol radiative forcing (DARF) over ocean regions derived from CERES/TRMM ES8 data. Broadband SW reflectances over cloud-free ocean scenes were used with models of aerosol optical depth (AOD) to derive DARF. Analyses of INDOEX data suggested that model AOD values provided reasonable results. He used AOD measurements available from the AERONET site at Kaashidhoo Climate Observatory to derive DARF over that site. Coakley derived (DARF =) 25 Wm^{-2}/AOD (per unit AOD), which is considerably lower than the 36 Wm^{-2} obtained by Ramanathan for the same site. He indicated plans to conduct similar analyses for other AERONET sites. Coakley also compared cloud property retrievals form the OSU method with corresponding VINT retrievals and found effective droplet radii from the two methods to be significantly different.

Robert Cess (State University of New York at Stony Brook) presented algorithm development strategies for retrieving downward LW flux (DLF) at the surface. Column radiation model from NCAR/CCM3 and MODTRAN 3.7 were used to produce the model results which were compared with ground measurements from a number of Intensive Operations Periods (IOPs) at the ARM SGP and TWP sites. Model results showed that even for clear skies, the relationship between DLF and OLR was not good. Clear-sky DLF was represented by a regression relation in terms of the upward LW flux and column water vapor. For overcast skies, inclusion of the cloud-base height was also necessary. Cess suggested that averaging cloud-base height over a grid box is inappropriate, and that cloud LWP could be used in the regression as a surrogate for cloud-base height. Also, cloud LWP can be averaged over a grid box. Cess showed several comparisons of his model results with ARM IOP data.

Lou Smith (Virginia Tech) presented the methodology and results for limb-darkening functions (LDF) derived using along-track radiances from the window channel of CERES instrument on the TRMM satellite. Along-track radiances are

ideally suited for deriving LDF because the instrument sees every spot on the ground at many viewing zenith angles (vza) in a single pass. Temporal compositing of radiances for constructing LDF becomes unnecessary. The ground track was divided into 50 km segments, and vza vs. radiance dataset was plotted for each segment. Curve fitting for each dataset reduced the noise and provided a smooth LDF. Smith also applied the same methodology to broadband LW radiances to derive broadband LDF.

Bing Lin (LaRC) presented a comparison study of cloud liquid water path (LWP) derived from in situ and microwave radiometer data taken during the Surface Heat Budget of the Arctic (SHEBA) experiment. Mean cloud LWP derived using the standard ARM retrieval technique is nearly twice as large as coincident *in situ* aircraft data taken over the SHEBA ice camp during the First ISCCP Regional Experiment (FIRE) Arctic Cloud Experiment (ACE). A new algorithm is developed that accounts for atmospheric gas and cloud water absorption at the MWR wavelengths using the microwave radiative transfer model of Lin et al. [1998]. This method results in a 25 to 45% reduction in LWP values relative to the standard ARM estimates. If possible precipitation cases are excluded, the mean results from the new technique differ by only 3% from the *in situ* data. The correlation between the two techniques is statistically significant above the 95% significant level. Larger differences for heavier clouds may be the result of difficulties with the *in situ* probes. The primary reason for the improvement is use of different absorption coefficients for the supercooled clouds often found in the Arctic. This new method has excellent potential for ground-based cloud and atmosphere remote sensing.

Educational Outreach

Lin Chambers (LaRC) reported that over 600 schools from all 50 states and over 44 nations are now participating in the Students' Cloud Observations On-Line (S'COOL) program. More than 4500 observations have been reported to date. Planning is underway for the July 2001 S'COOL Teachers Workshop which will be open to educators from all 50 states.