23rd CERES Science Team Meeting

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The 23rd Clouds and the Earth's Radiant Energy System (CERES) Science Team meeting was held in Williamsburg, VA, on January 23-25, 2001. The meeting focused on early CERES science results, status of CERES instruments and current data products, status of data products and algorithms in development and validation, cloud properties, anisotropy models, surface/atmosphere fluxes, temporal interpolation using geostationary data, the Cheaspeake Lighthouse and Aircraft Measurements for Satellites (CLAMS) shortwave clear-sky closure experiment, applications of surface radiation data, and educational outreach.

The team welcomed four official new Science Team members: Lin Chambers (educational outreach lead, 3-D radiative modeling); Takmeng Wong (temporal interpolation, decadal variability); Norman Loeb (Chair of the TOA Flux Working Group); and Kory Priestley (Chair of the Instrument Working Group).

Bruce Wielicki (LaRC), CERES Co-Principal Investigator, gave an Earth Observing System (EOS)/CERES status report. The Terra instruments and spacecraft are working well. New Terra products that the team approved at the September meeting are now in production and in the archive. CERES was the first Terra team to get validated Level 1, Level 2, or Level 3 data products to the community. He cautioned users to be aware of several things in the data. Crosstrack switches from FM-1 to FM-2 daily in March 2000 during checkout, then monthly, then every 3 months. Shortwave diurnal sampling bias are large for Terra-only data, but will improve with Aqua, and further with Terra + Aqua + geostationary. SSF has clear-sky fluxes only until we get the new ADMs for SSF Edition 2 in Fall 2001. He stressed the importance of reading the Data Quality Summaries since they are not like the typical software "disclaimers," but are more like micro user manuals. The next major milestones include Tropical Rainfall Measuring Mission (TRMM) ADMs and Single Satellite Footprint (SSF) Edition 2 in September, 2001, and top-of-atmosphere (TOA) and initial surface fluxes and geo-assisted temporal interpolations in the SFCAVG data product in late Fall, 2001. The schedule for Terra SSF Edition 1 products is August 2001, but this will be difficult since we have only gotten clean Moderate Resolution Imaging Spectroradiometer (MODIS) data in the last month.

The next two CERES Science Team Meetings will be May 1-3, 2001 at Langley and September 18-20, 2001 in Belgium.

CERES Terra/Aqua Instrument Status

Kory Priestley (LaRC) presented the instrument status report. The Aqua spacecraft with the CERES Flight Models (FM-3 and FM-4) is preparing for Thermal Vacuum Testing in March 2001. This will provide the first look at the performance of these instruments under vacuum since the original radiometric calibrations in early 1999. Aqua Launch is currently scheduled as no earlier than July 12, 2001 and is likely to slip to the end of the year. Both CERES Terra instruments continue to perform very well on-orbit. Apparent ground to flight change in Window (WN) channel gain of ~1% on the FM-2 instrument has been tracked to insufficient settling time in vacuum during ground calibration. On-board blackbodies will be used to correct the change in Edition 2 data.

There is no evidence of significant instrument drifts from earth-viewing consistency checks, or from the on-board calibration sources for five of the six channels. The sixth channel, FM-2 total, has demonstrated a drift of ~0.5% per year over the first 10 months of nominal mission operations. Two of the four CERES Terra Mirror Attenuated Mosaic (MAM) solar diffusers which are used for stability measurements show drifts that appear to be a problem with the MAM coatings. These MAM coatings were problematic during instrument build. Further studies are underway and should be complete by the May 2000 science team meeting.

Studies are underway to tie the relative (not absolute) calibration and stability of the CERES sensors to less than 0.2% between the TRMM, Terra, and later the Aqua instruments. This is thought to be primarily a problem of demonstrating the cause of the ~0.5% changes in calibration between ground and orbit. Potential for CERES instrument relative calibration and stability is far better than for absolute calibration.

A decision on the Deep Space Offset Calibration maneuver is still pending while we await final word from the Japanese. Technical studies are complete and the risk is very small. MODIS and CERES favor the maneuver while Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) team opposes it.

Data Production Status and Issues

Jim Kibler (LaRC) discussed the status of CERES science data production and archival. EOS Data and Operations System (EDOS) data delivery delays continue to slow production. In particular, the months of June, July, and November 2000 are missing about 15% of the data needed to produce final monthly products. We will delay production since some inputs continue to arrive 8 months after they were acquired. Edition 1 SSF processing for TRMM has given us good measurements of the computer time needed for production. While we can handle the TRMM/VIRS processing, the scaled timing estimates for Terra/MODIS are larger than available computer resources. We are analyzing ways to reduce requirements before Terra archival processing begins with new ADM's this fall. Edition 1 Terra data products (BDS, ES8, ES9, ES4) and Edition 1 TRMM SSF products are now available at ASDC. Orders for CERES products totaled over 1 terabyte in the last 6 weeks, substantially higher than the 30 gigabyte per month average of last year.

Bruce Barkstrom (LaRC), CERES Co-Principal Investigator, presented a brief summary of the interaction between the ESDIS Project, the Science Working Group on Data (SWGD), and NASA HQ regarding funding of the additional hardware capacity need identified by the SWGD over the summer. At present, the needed capacity, which the SWGD estimated as costing $15M/year (and presented by ESDIS to HQ as $28M/year - owing to additional missions needing support and additional work ESDIS felt was needed), has had no support from HQ. The EOS instrument teams have had a request from the EOS Project to identify steps already taken to reduce hardware capacity.

As part of the CERES team's response, Dr. Barkstrom requested the team to consider appropriate ways of reducing hardware capacities, with particular emphasis on evaluating the scientific impact of moving to retrieving cloud properties from every other scan line and every other pixel of imager data. Preliminary results suggest that this approach would reduce the hardware capacity need by about a factor of four with some degradation in retrieval accuracy.

Clouds and Aerosol

Patrick Minnis (LaRC) presented a summary of the results of the first 6 months of cloud properties derived with the public version of the CERES Edition 1 cloud algorithm. The work represents the culmination of a great group effort by Minnis and Dave Young and contractual personnel at SAIC and AS&M. Although more is yet to come, the initial validations reveal that a very accurate and useful product has been developed and is available for the TRMM satelllite observations taken from January to August 1998.

Minnis showed that incorporation of N_2O gas absorption in modeling of 3.7um channel reflectance and emission has substantially reduced the earlier cloud particle size differences between the Hahn, Coakley, and CERES SSF results. Remaining differences appear to be explained by viewing zenith angle dependencies, and whether both broken and overcast cases are included.

Early comparisons of near simultaneous TRMM VIRS and Terra MODIS cloud property retrievals looked encouraging, although significant differences are found for all cloud properties. The MODIS and CERES teams are planning a workshop at the University of Wisconsin in May for more complete cloud property intercomparisons. MODIS calibration continues to improve.

SSF Edition 1 aerosol retrievals have improved at both 0.6 and 1.6μm wavelengths, but problems are found in the apparent zero level of the 1.6μm VIRS data. Larry Stowe (NOAA/National Environmental Satellite, Data, and Information Service, NESDIS) will work with the VIRS team to resolve this before Edition 2 SSF data are analyzed in September 2001.

Angular Modeling

Early tests of new TRMM angular models shown by Norman Loeb (Hampton University, HU) based on the recently released CERES SSF data product looked very encouraging, and are expected to be ready as scheduled for August, 2001. These models will be used in the SSF Edition 2, a major advance in TOA flux accuracy (factor of 3-4) and in the ability to use TOA flux data for cause/effect studies of cloud, aerosol, and surface properties.

Nitchie Manalo-Smith (AS&M) presented a report on the preliminary set of longwave and window channel angular distribution models (ADMs) generated from the CERES-TRMM dataset. These models are being developed for CERES inversion of satellite radiance measurements to radiant fluxes at top of atmosphere.

The preliminary scene types for these ADMs are stratified by cloud cover (e.g., clear, broken cloud fields, overcast), surface type (e.g., ocean, land, desert) and atmosphere/cloud properties (e.g., precipitable water, surface/cloud temperature differences, IR emissivity, surface emissivity). The method to define ADM scene types uses percentile intervals of PW, cloud emissivity, and surface/cloud temperature differences rather than fixed discrete intervals, thereby ensuring sufficient sampling in these intervals. Preliminary results have shown that for overcast and broken cloud fields, ADMs exhibit a large variation with cloud emissivity and less with PW and surface/cloud temperature differences. For clear scenes, ADMs exhibit more dependence on vertical temperature change [T(sfc)-T(sfc-300mb)] and PW for desert/land scenes than ocean scenes.

Diurnal Sampling

David Young (LaRC) presented preliminary results and initial validation of CERES second-generation monthly mean products. Cloud property retrievals are performed on global 3-hourly geostationary data that are used to provide information between the CERES observation times. Initial results reveal a good agreement between the derived cloud properties with other global data sets. Severe temporal sampling errors due to the TRMM orbit have been reduced by over 50% using this technique. This new product is scheduled for archival in late 2001.

Early tests of the incorporation of geostationary data to eliminate most of the diurnal sampling error for single-satellite time periods like TRMM and current Terra data also looked very encouraging and are on schedule for delivery in Fall, 2001.

CERES Validation Experiment

Bill Smith, Jr. (LaRC) discussed plans for the summer 2001 Chesapeake Lighthouse and Aircraft Measurements for Satellites (CLAMS) mission. CLAMS is a shortwave closure experiment focusing on the validation of Terra data products and specifically to improve Surface and Atmosphere Radiation Budget (SARB) calculations for CERES, and to validate and improve MODIS and Multi-angle Imaging Spectro-Radiometer (MISR) retrieved aerosol properties. The centerpiece of CLAMS is the Chesapeake Lighthouse, also known as COVE (CERES Ocean Validation Experiment), a stable sea platform located 25km east of Virginia Beach, Virginia. COVE provides continuous, long-term broadband, directional and spectral radiation measurements from an ocean platform. It also serves as an official Baseline Surface Radiation Network (BSRN) and Aerosol Robotic Network (AERONET) site. An MPLnet Micro-pulse Lidar will be added to COVE for CLAMS. Three aircraft have been secured for CLAMS and will participate in an intensive measurement campaign during the period July 12-August 1, 2001. The ER-2 will map the horizontal and vertical distribution of aerosol properties with the Cloud Physics Lidar and provide a platform for the airborne versions of MODIS and MISR (MAS and AirMISR). The University of Washington CV-580 will serve as an in-situ profiler of aerosols, profile broadband radiation, and measure ocean surface BRDF. A 14-channel Automated Airborne Tracking Sunphotometer (AATS-14) for passive remote sensing of aerosol properties will also deploy on the CV-580. Upward and downward looking Spectral Solar Flux Radiometers are desired for the CV-580 but have not yet been secured. A third aircraft, the NASA Langley OV-10 will measure and profile upward and downward spectral shortwave fluxes and broadband longwave and shortwave fluxes in the boundary layer. A CLAMS planning workshop is scheduled for February 21-22, 2001 at NASA Langley and will focus on the review and refinement of a strawman operations plan.

Surface and Atmospheric Radiation Budget (SARB)

Early tests of surface radiation algorithms showed mixed results. LW results looked good at all sites tested, but SW looked good at some surface sites and very poor at others. Suspicion of time/space matching errors in combining surface site/satellite data is under investigation.

Tom Charlock (LaRC) updated the team on SARB progress in a number of areas. The Clouds and Radiative Swath (CRS) validation data sets need a surface albedo for input to the Fu-Liou code. For an ice-free ocean footprint, the surface albedo comes from a lookup to the Hu-Cox-Munk table using input wind speed, sun angle, and aerosol/cloud optical depth; CRS iterates Fu-Liou to adjust properties of aerosols or clouds, depending on whether the footprint is clear or cloudy. For clear land, there is a table-lookup to Fu-Liou for surface albedo; CRS then iterates to improve surface albedo. Over cloudy land, surface albedo is not adjusted.

Charlock then outlined the procedure for getting the surface albedo for a cloudy footprint over land. Before integrating a single footprint with the Fu-Liou code, they do a fast Surface Albedo History (SAH) lookup each month. SAH spans the whole domain of clear land footprints for a given month. Using assumed aerosol optical thickness (AOT), the most favorable geometry (i.e., high sun) is selected to determine the default surface albedo. If there are no clear footprints for a particular 10' by 10' tile, the surface albedo from CRS tuning in the previous month is used. There is a hierarchy of selection. The previous year for the same month is the next candidate. Lacking that, David Rutan's maps on the web (which determine the spectral SHAPE of albedo in all cases) give the default broadband land albedo.

Formal mass processing of CERES is presently done through SSF and includes no CRS (SARB). SSF has clear sky TOA fluxes which will succeed the currently archived "ERBE-like" CERES ES8; cloud properties; and AOT. Some have access to the experimental TOA on SSF. Hence, Lisa Coleman (SAIC) is running "subsets" of CRS with the SSF as input. The subsets of CRS cover the CAVE surface observation sites and additional gridboxes (as specified by other WGs) as validation targets. Subset CRS all-sky products are now available for May 1-31, 1998 for comparison with CAVE. While over clear-sky ocean we have access to the VIRS retrievals of AOT, for most footprints we have only monthly mean AOT from GFDL's Chemical Transport Model (CTM). A full spatial CRS for a single day, May 1, 1998 is also complete.

The Cloud, Surface-only, SARB, and TISA WGs are currently using European Center for Medium-Range Weather Forecasts (ECWMF) data. A comparison of ECWMF and Data Assimilation Office (DAO) GEOS (Goddard Earth Observing System) 3.3 has been delayed until March - May because of a 6-week delay in getting test data from DAO. ECMWF data have been ordered through July 2001. Data for November 1, 2000 and on should start coming in soon.

Bill Collins has provided a global, 6-hourly aerosol assimilation covering January-August 1998. This assimilation inputs satellite retrieved aerosol optical thickness (AOT) over the clear ocean; oututs climatological emissions over industrial regions and turns them into aerosols; removes aerosols by cloud processes; lofts dust from deserts, depending on wind speed; and transports the aerosols around the globe with 6-hourly updated NWS meteorological data.

For TRMM, we have no retrievals of aerosol over land; such retrievals over land will be experimental with MODIS. One obvious application of the assimilation is to test is the vertical distribution of heating due to aerosols in SARB. They will try using it as a "dust screen" in the surface albedo retrievals. The clear-sky ADM over land is problematic: the surface itself is often quasi-Lambertian, but the aerosol is both highly directional and variable. A strategy for more effective use of the assimilation may interest different components of CERES.

Seiji Kato (HU) compared the average radiance and irradiance from SSF edition 1, SSF r4, and ES8 edition2 for clear-sky ocean and desert. The average shortwave radiance for clear-sky ocean extracted from ES8 edition 2 using ES8 scene identification is larger than that from SSF edition 1 using SSF scene identification, which is presumably caused by cloud contaminations in the ES8 scene identification. The small difference between the average irradiance from SSF edition 1 and ES8 edition 2 using both SSF edition 1 scene identification indicates that the difference due to angular distribution models is small. The simple arithmetic average of the clear-sky ocean irradiance from ES8 edition 2 using ES8 scene identification is 81.3 W m^-2 while that from SSF edition 1 using SSF scene identification is 73.8 W m^-2. For clear-sky desert, the average irradiance from ES8 edition 2 using ES8 scene identification is less than the average irradiance from SSF edition 1 using SSF scene identification. The difference in the longwave radiance and irradiance from SSF edition 1 and ES8 edition 2 is small. This illustrates the dependence of the irradiance to the scene identification. Therefore, the scene identification method needs to be consistent in order to analyze long term clear-sky irradiance variability.

Shashi Gupta (AS&M) presented results from the validation of surface SW and LW fluxes derived in CERES with the surface-only algorithms. These algorithms are based on fast parameterizations and TOA-to-surface transfer schemes. Two SW and two LW algorithms are currently in use; results were presented for both SW and one LW algoritms. Both SW and one LW algorithms currently provide only clear-sky fluxes; the other LW provides all-sky fluxes. Validation data were obtained from SGP ARM central facility and its extended sites, three CMDL sites, and one BSRN site. LW results for all sites showed low biases, and r.m.s. in the range of 20-25 Wm^{-2} for instantaneous fluxes. SW results compared well for the ARM sites but showed large differences over CMDL and BSRN sites. The causes of these large differences are under investigation.

Invited Presentation

William Collins (National Center for Atmospheric Research, NCAR) gave an invited presentation on the results of aerosol assimilation in a chemical transport model. The model is initialized with global meteorological fields and aerosol emission source data. Satellite retrieved aerosol optical depths (AOD) are assimilated into the model. Sources of sulfates, soil-dust, sea salt, and black and organic carbon are taken into account. The model provides analyses and forecasts of AOD and was used to study aerosols over the Indian Ocean Experiment (INDOEX region. Fields derived by the model showed AOD values of 0.4 or larger over India and China. Comparisons of model results with surface data from Kaashidhoo Climate Observatory (KCO) and NOAA RV Ron Brown showed good agreement. Maps of AOD partitioned by aerosol species were also shown. Aerosol radiative forcing (ARF) was computed with the NCAR column radiation model (CRM) which is a part of NCAR/CCM3. Predicted single scattering albedo, ω, was found to be about 0.90 near the coast of India and increased away from the coast over open ocean. This indicated the presence of highly absorbing carbon aerosols near the coast. ARF sensitivity was estimated to be about –22 Wm^{-2}/AOD at the TOA and about –73 Wm^{-2} at the surface in good agreement with other observations. Over some parts of India, ARF at the surface was found to exceed the cloud radiative forcing. Collins suggested that such large radiative forcings at the surface and in the atmosphere are likely to have a large effect on the atmospheric circulation in the region.

Investigator Presentation Highlights

Larry Stowe and Alexander Ignatov (NESDIS/NOAA) presented a report on the third generation aerosol algorithm which was developed and tested with SSF Edition-1 data for February and April 1998. VIRS data were colocated with AVHRR data and three products, namely, the AOD for VIRS channels 1 and 2, and the λ parameter were derived. Distribution of channel 1 AOD was good (less than 0.4), but channel 2 AOD distribution showed a small negative bias. AOD distributions were found to be about lognormal. Distribution for λ deviated some from the expected gaussian. Relationship between λ and AOD was shown. Ignatov presented a comparison of results obtained with the Dave and 6S radiation models as a check of consistency between the models. Global distribution of the Angstrom exponent (α) was also shown. Values as high as 4 were found for some regions. The negative bias in Channel 2 AOD was linked to dark albedo in the 1.6 μm channel. Future plans call for simultaneous retrieval of aerosol properties from both channels.

V. Ramanathan (Scripps Institution of Oceanography) presented results of an investigation of atmospheric greenhouse effect, G_a, based on TRMM ES8, TRMM SSF, and Terra ES8 data sets. He compared weighting functions of window and non-window radiation emerging at the TOA, and showed that while window radiation comes from near the surface, the non-window radiation comes from the upper troposphere. Comparison of G_a derived form TRMM ES8 (July 1998) and Terra ES8 (July 2000) data sets showed the values from TRMM period to be considerably higher. Comparison of TRMM ES8 and SSF data sets showed both SST and G_a to be higher for the SSF data set. Ramanathan showed further that the differences of SST and G_a between the two data sets were spatially correlated.

Robert Cess (State University of New York at Stony Brook) revisited his earlier work on the impact of 1997-98 El Nino on cloud radiative forcing (CRF) over tropical Pacific ocean. He examined SWCRF, LWCRF, and the ratio N = SWCRF/LWCRF based on TRMM ES8 data for the period Jan.-Apr. 1998, and compared the results with those for the ERBE period. He found that the ratio N, which he used as a diagnostic of the cloud vertical structure, increased from 1.12 in 1987 to 1.54 in 1998. He also found that wind changes in 1998 caused the Walker circulation between west and east Pacific to weaken while Hadley circulation strengthened. Cess also looked at the SAGE-II cloud data for Dec. 1997-April 1998 and found a decrease in high clouds over the western Pacific/warm pool region, in agreement with the work of Wang and Wielicki. He concluded that TRMM ES8 CRF results and SAGE-II results were consistent, and both showed a decrease in high clouds over the western Pacific and an increase over the eastern Pacific during the 1997-98 El Nino.

Bruce Wielicki showed that the TRMM CERES (Cess et al., 2001) and ERBS SAGE II (Wang et al.) data confirm that the large 1998 El Nino changes in cloud radiative forcing ratio (the ratio of solar reflectance to thermal emission effects of clouds) were caused by cloud height distribution changes dramatically larger than those seen in the 1987 El Nino. The dramatic changes occur in both the western and eastern Pacific oceans. The changes appear to be a result of the normal East/West Walker Cell circulation almost shutting down in Jan-April 1998, while the north/south Hadley circulation increases in strength. Current climate models do not appear to predict these changes.

Takmeng Wong (LaRC) updated intercomparisons between CERES/Terra monthly mean FM-1 and FM-

2 ERBE-like TOA fluxes using three additional data months from August to October 2000. Most of the differences between CERES/Terra FM-1 and FM-2 ERBE-like monthly mean fluxes can again be explained by the differences in sampling pattern of the two CERES instruments (i.e., RAP vs. cross-track scan mode sampling). In terms of tropical mean TOA longwave/shortwave radiation, the CERES/Terra cross-track monthly mean ERBE-like data are always running higher/darker than the corresponding RAP data. Due to the 3-month scan mode cycling of the two CERES/Terra instruments, it is recommended that data users should exercise cautions when using CERES/Terra ERBE-like monthly-mean TOA fluxes for climate study. Specifically, users should (1) separate CERES/Terra monthly mean data based on instrument scan mode operation, (2) use only CERES/Terra cross-track scan mode monthly mean data for climate study and long-term comparison with ERBE monthly mean data sets, and (3) avoid mixing CERES/Terra monthly mean data from different scan mode operations.

Elizabeth Weatherhead (University of Colorado) presented results of her work with a time-series analysis technique developed for detecting trends in environmental data. The technique was developed primarily for trend detection in ozone data. The desirable characteristics for a data set to be suitable for trend detection were, a stable instrument, a representative site, a trend signal large relative to the noise, and a long enough data record. The main objective of the work was to determine the number of years required to detect a trend objectively. She presented a statistical model of a time series consisting of a mean, a trend, an explanatory part, and the noise. The explanatory part which results from autocorrelation in the data, can be minimized by using only independent observations in the analysis. Results from a case study showed that it took 7-35 years to detect a trend depending on the magnitude of the trend and the level of noise. Weatherhead cautioned that it is very easy to detect false trends.

Q. Han (University of Alabama - Huntsville) presented his work on the effect of viewing geometry on droplet size (r_e) retrievals in water clouds. The motivation of the study was to identify the causes of the differences between r_e retrieved from CERES and ISCCP data sets. He noted that CERES retrievals were for all view zenith angles (VZA) while ISCCP (International Satellite Cloud Climatology Project) retrievals were mostly for near-nadir viewing. Han presented histograms showing an increase in retrieved r_e with increasing VZA. The dependence of r_e on solar zenith angle showed no consistent trend. He also showed small differences between r_e retrieved from forward and backward viewing, though both were larger than r_e from near-nadir viewing. Optical depth (τ) retrievals for a range VZA showed that forward viewing yielded lower τ, and backward viewing higher τ, than near-nadir viewing. Han concluded that off-nadir viewing yielded larger r_e because r_e is larger near the top of the clouds than near the bottom, and top part is preferentially viewed in off-nadir viewing. Cloud shadowing effect also contributes to larger r_e values in the forward viewing retrievals.

Gerald (Jay) Mace (University of Utah) summarized ongoing cloud property validation opportunities at the University of Utah using surface data. They have made considerable progress in continuous product creation with ARM data from all four sites and have collected many exciting data sets at Utah complete with in-situ data. He presented data obtained at the Facility for Atmospheric Remote Sensing (FARS) located at the University of Utah in Salt Lake City. The main objective of FARS is to derive a broad suite of cloud properties from ground-based observations at satellite overpass times. These results can be used to validate coincident satellite retrievals of the same cloud properties. The same methodology is also applied to the ground-based measurements from the Department of Energy's ARM sites for all satellite overpasses. The suite of derived parameters includes cloud layer temperature, LWC, IWC, mean droplet radius, and particle number density. The entire database is made available to the satellite cloud scientists from a web site. Similar data sets obtained during IOPs at the ARM Southern Great Plains (SGP) and Tropical Western Pacific (TWP; Nauru) sites are also available.

Xiquan Dong (University of Utah) presented Arctic stratus cloud properties deduced from ground-based measurements. The Arctic plays a major role in global climate change and has considerable influence on the middle latitude belt. The Arctic affects the global climate directly through interactions between its atmosphere, ice cover, land surface and ocean, and through complex coupled feedbacks. To provide a much needed source of validation data for model results and for improving model parameterizations over the Arctic region, the DOE Atmospheric Radiation Measurement (ARM) program established the high-latitude Cloud and Radiation Testbed (CART) site on the North Slope of Alaska (NSA) in 1997. The ultimate goal of the ARM program is to improve the representation and parameterization of clouds and radiation in the general circulation models

(GCMs) so that these models can produce more accurate climate change simulations.

To begin the process of evaluating cloud parameterizations against observed data, Dong generated a database of stratus cloud properties, including the 10-day means, standard deviations, and frequency distributions from June through September 2000 at the ARM NSA site (71.32N, 156.61W) using the surface-based data. The data base includes two parts: measurements and retrievals. The former consists of cloud amount, base/top heights and temperatures, LWP, solar transmission, surface albedo, as well as SW, LW, and net cloud forcing at surface. Net CRF at the surface was found to be positive during the June-September period and negative during October-April. The retrievals include the cloud-droplet effective radius and number concentration, broadband shortwave optical depth, and cloud/TOA albedos. Dong compared several of the above measurements with corresponding MODIS retrievals and found good agreement. Low cloud amounts ranged from 40 to 70% and total cloud amounts from 60 to 100%. Typical cloud thickness was estimated to be about 700 m.

Andy Heymsfield (NCAR) presented results based on the observations of microphysical properties of tropical and mid-latitude ice clouds obtained during ARM IOP 2000 and a TRMM-related tropical program. Instruments were flown on the aircraft 'Citation' that started at the top and descended along spiral paths known as Lagrangian spirals. Probes mounted on the aircraft measured temperature, particle size distribution and habits, and number densitites during the descent. Observations were also made with the 2 cm precipitation radar. Heymsfield showed that particle sizes were smaller near the top of the clouds and larger near the bottom. The particle size growth was driven by aggregation. Particle shapes in the tropical clouds were found to be highly variable. More common type shapes were predominant in the mid-latitude clouds.

Bryan Baum (LaRC) presented results of cloud phase retrievals using MODIS data for day and night times for 4 days in September, 2000. He examined the correation between cloud temperature and its phase, and the effect of spatial resolution on the results. Phase retrievals were based on a trispectral technique which used the 8.5, 11, and 12 μm channels on a spatial scale of 5x5 1-km pixels. Cloud height and temperature were retrieved by the CO_2 slicing method. Baum presented results of a global analysis and found a correlation between cloud temperature and phase. Clouds with $T < 243K$ were mostly ice clouds during day or night; those with $243K < T < 273K$ water or mixed-phase clouds. Some exceptions to the above rules found over S. America and S. Africa are being investigated further. Baum presented comparisons between MODIS retrievals and corresponding ground-based results obtained at the SGP ARM site on 18 November 2000, and reported good agreement. The main focus is now involved with the analysis of supercooled water phase clouds which tend to occur primarily in the high-latitude storm tracks. A direct broadcast system for bringing these data to the science community is still being developed.

Michael Friedman (Oregon State University, OSU) presented results of an investigation of the differences found in the values of cloud mean droplet radius, r_e, derived from the operational CERES algorithm and the OSU algorithm. Comparisons led to the inclusion of N_2O absorption at 3.7 μm in the CERES algorithm and resulted in better agreement for the r_e values. He also presented comparisons of cloud properties derived from partly cloudy pixels with those from the overcast pixels. Friedman showed that r_e is smaller for the partly cloudy pixels and increases with the increasing pixel cloud fraction. Optical depths for partly cloudy pixels are also smaller and remain constant for pixel cloud fractions from 20 to 80%. For pixel cloud fractions above 80%, the optical depths quickly approach those for the overcast pixels.

James Coakley (OSU) presented estimates of the direct aerosol radiative forcing (ARF) derived from CERES/TRMM broadband radiative fluxes and AOD measurements at the surface over AERONET sites. He used CERES data from January to June 1998 and AOD measurements for the same period from the AERONET site at KCO. CERES and AERONET observations were matched to within ±50 km in space and ±1 hr in time. Very few matches were found in the SSF Edition-1 data for any AERONET site; only nine over the KCO site. AERONET AOD values were derived from the 0.55μm radiance measurements. Direct ARF at the TOA for the KCO site was determined to be about –32 Wm^{-2}/AOD, which is considerably larger in magnitude than the –23 Wm^{-2} determined by Satheesh and Ramanathan from Indian Ocean Experiment (INDOEX) observations. Direct ARF at the surface was about three times larger than at the TOA.

Bing Lin (LaRC) estimated vertically averaged cloud water temperature using Humidity Sounder for Brazil (HSB) data. Cloud vertical structure (e.g., cloud top and base temperatures) is extremely important for atmospheric longwave radiation. The HSB on the

Aqua spacecraft will have measurements at frequencies of 150 and 183 GHz, microwave window and vapor absorption bands, which will provide useful information on cloud water temperature, especially at channels 1 (150 GHz), 3 (183+/-3 GHz) and 4 (183+/-7 GHz). For a U.S. standard atmospheric profile and clouds with small-to-moderate water amounts (0.1mm), the brightness temperature, Tb, differences at the 3 HSB channels between warm (281K) and cold (241K) clouds are about 10, 5, and 5K for channels 1, 3, and 4, respectively. These values are significantly larger than the noise levels of the HSB (~0.7K). The greater the cloud water amounts, the larger the Tb differences. These Tb differences generally have very small variations (within 1K - 2K) with cloud physical thickness if the vertically averaged cloud temperature is a constant. This study suggests that cloud base temperature can be estimated by combining thermal infrared (IR) satellite measurements to determine cloud top temperature and HSB microwave data to obtain the average cloud temperature. Simulations using global NOAA 1988 radiosonde data show that simple linear empirical methods could retrieve the cloud average or base temperature with errors of 9 to 13K when the uncertainties in sea surface temperature, wind speed, water vapor, and instrumental noise are taken into account, even if the actual atmospheric profiles are unknown. Using two-channel lookup tables, similar accuracy on the temperature is obtained. A reasonable a priori estimate of the temperature and humidity profiles would reduce the errors significantly.

Zhonghai Jin (AS&M) reported on early steps to improve the SARB ocean surface spectral albedo with an advanced model that treats scattering and absorption in both the ocean and the atmosphere explicitly. The current SARB input for surface spectral reflectance over ice-free ocean uses the Hu-Cox-Munk parameterization for Fresnel reflection (dependent on wind speed, cloud/aerosol optical depth, and sun angle); constant underlight (volume scattering from water below the surface); and foam (wind-speed dependent but spectrally flat). The advanced coupled model includes phytoplankton pigment concentration, dissolved organic matter (DOM), sediments, and an ocean bottom of finite depth, in addition to aerosols and clouds in the atmosphere. Ocean spectral albedos from the advanced model show the importance of including these components. The goal is to parameterize the ocean surface albedo using data (e.g., concentrations of chlorophyl and DOM) which can be obtained from new sources like SeaWIFS, and thereby improve fluxes and optical depths retrieved in SARB. The new model will be verified with field observations from COVE, CLAMS, and the ACE-Asia cruise.

Wenying Su (Hampton University) compared COVE observations of upwelling SW spectral radiances with theory. The SP1A Spectralphotometer at COVE has observed reflected radiances at 500 nm since May 2000. The record for 9 elevation angles (2, 12, 22, 32, 42, 52, 62, 72, and 90 degrees) spans 180 degrees of azimuth. Measured radiance distributions were compared with the model "6S" (Second Simulation of Satellite Signal in the Solar Spectrum). As elevation angle increases, the field of view decreases, and the temporal signature of ocean waves then becomes obvious. In order to reduce the influence of transient facets on the radiance distribution, a new measurement scheme was used, which took measurements every 5 minutes. The first six measurements were averaged to give out the first half-hour results and the last six measurements to give out the second half-hour results. The measured sun glint is more intense and covers a larger area than the Cox and Munk statistical results. When apart from the sunglint region at low sun, the measured radiance is often smaller than that of the 6S; this is probably caused by the strong absorption of coastal water. The differences between 6S and measurements could be explained by the inadequate theory and/or different water type. Dr. Su plans to participate in the upcoming ACE-Asia cruise in the mid Pacific which will provide an opportunity to resolve this issue.

Shi-Keng Yang (NOAA/National Centers for Environmental Prediction, NCEP) presented results of an analysis of the downtrend observed in water vapor and LWCRF in the NCEP Reanalysis II data set. The magnitude of this downtrend, first observed by G. Potter, is about 3 Wm^{-2} (or about 10%) over a 30 year period. Analysis of clouds from the same data set shows a downtrend in the mid-level clouds which is related to a similar trend in mid-tropospheric relative humidity (RH). The causes of the RH downtrend were examined in great detail, including the changes in the instruments and the reporting procedures. It was determined that both have changed greatly over the years, and were never uniform geographically. The new instruments are very different than the older ones, especially those used before the International Geophysical Year (IGY). The number of reporting stations has also been increasing steadily. Changes in the response time of the hygristors used in the radiosondes could give rise to small trends. Yang concluded that the LWCRF and water vapor trends could be artifacts of changes in RH measurements and cautioned regarding the use of pre-IGY RH data in trend analyses. Yang also made a short presentation on the activities of the S'COOL program in China. One school in Beijing and six schools in Taiwan are currently paritipating in the program. The Chinese Central Weather Bureau has adopted S'COOL as a model for enhancing student interest in atmospheric sciences.

Kathryn Bush (SAIC, representing Lou Smith) used the 15-year data set of radiative fluxes from the Earth Radiation Budget Experiment (ERBE) nonscanner to investigate the interannual variability of top-of-atmosphere (TOA) outgoing longwave radiation (OLR) and reflected solar (shortwave) radiation (SWR). Monthly variance maps of OLR and SWR and an empirical orthogonal function (EOF) analysis of the monthly mean flux anomalies both show that most of the variability is in the tropics and is associated with ENSO events. Variability over the Indian Ocean is likely associated with interannual variations in the Indonesian Throughflow. An EOF analysis of sea surface temperature (SST) monthly mean anomalies derived from the NCEP monthly optimum interpolation data set shows patterns similar to those seen in the flux data. In addition, the SST third EOF map shows high variability in the northern Pacific Ocean, which is likely an expression of the North Pacific Decadal Oscillation.

Xin Lin (CSU, representing David Randall) reported the results of a theoretical study designed to determine the capabilities and limitatations of satellite sampling in fully observing the behavior of the nature. He asked the question: Could satellite sampling introduce spurious signals in the data? The study was performed by simulating satellite observations of meteorological fields produced by a GCM. The GCM used in this study had a grid of hexagonal regions and the simulated satellite was the TRMM. Sampling patterns of VIRS and CERES satellite were used. Aggregation of data over a 3-month period evened out the frequency of coverage over most of the globe. Lin compared global fields and zonal averages of OLR from the GCM (unsampled) with those obtained after satellite sampling and found significant differences. He stated that differences of the type recently reported by B. Soden between GCM simulations and satellite retrievals could arise from satellite sampling. He also stated that in some cases, spurious low frequency signals generated by satellite sampling can be comparable in magnitude to the real climate signals, and that can create a problem for climate monitoring.

Lin Chambers (LaRC) presented a brief update on her theoretical simulation of the CERES flux retrieval process, using realistic inhomogeneous clouds based on Landsat scenes. She showed a consistent trend in flux bias error from Equator to pole which needs to be considered in future analyses of CERES data.

Mamoudou Ba (University of Maryland) presented comparisons of CERES ERBE-like OLR from both TRMM and Terra with OLR derived from Geostationary Operational Environmental Satellite (GOES) sounding channels. The GOES technique is similar to that based on High Resolution Infrared Radiation Sounder (HIRS) radiances, where OLR is estimated from a regression relation using radiances in five sounding channels. He showed comparisons for July 1998 for TRMM data and April 2000 for Terra. GOES OLR was derived on a 10 km x 10 km resolution covering TRMM and Terra swaths. GOES Infrared Sounder estimates of LW fluxes, which showed large disagreements with CERES TRMM measured data, now appear to be in good agreement after NOAA corrections to the GOES calibrations and improvements in radiative models used to make the inferences. The CERES data showed some evidence of SW contamination.

Robert B. Lee III (LaRC) reported on the status of CERES measurements of the moon-reflected solar shortwave and moon-emitted longwave radiances. The CERES sensors are being used to place lunar radiances on an absolute radiometric scale based upon the International Temperature Scale of 1990 (ITS-90). The CERES sensor responses are tied to an ITS-90 radiometric scale with uncertainties approaching 0.2 Watts per square meter per steradian (Wm-2sr-1). He presented 1998 TRMM/CERES total, shortwave, and window sensor measurements which yielded lunar filtered radiances of 26.0, 4.5, and 4.9 Wm-2sr-1 at phase angles near 7 degrees. Phase angle is the angle formed at the moon between directions to the sun and to the spacecraft-borne CERES sensors. The TRMM/CERES measurements were obtained over the 5 to 100 phase angle range. In addition, he reported that the Terra/CERES sensors were used successfully to measure lunar radiances during the January 9, 2001, total lunar eclipse.

Nicolas Clerbaux (Royal Meteorological Institute of Belgium, RMIB) presented a progress report on the data processing system being developed at the RMIB for the Geostationary Earth Radiation Budget (GERB) instrument. This instrumrnt is scheduled to fly on board the Meteosat Second Generation (MSG), which in turn, is scheduled for a launch in July 2002. RMIB is responsible for the inversion of GERB radiances to TOA fluxes and is developing its procedures based on CERES methods. Clerbaux presented comparisons of GERB and CERES scene identification algorithms. He also presented a detailed description of the efforts underway at RMIB for developing thermal ADMs. A parameterization was developed for thermal ADMs using SBDART radiative transfer model and atmospheric soundings from the TIGR database. A data set of clouds with randomly distributed radiative properties was also used. Flux errors were analyzed and found to be largest for high-thin cirrus clouds and large view zenith angles. Clerbaux showed scatterplots of flux error as a function of radiances, and a table of bias and r.m.s. errors for differnet scene types. He stated that efforts are underway to devise methods for reducing the errors for high clouds.

Martial Haeffelin (Virginia Tech) discussed how ultra-long duration high-altitude balloon flights (ULDB) can provide a new opportunity to measure radiative fluxes from the top of the atmosphere (TOA) with a spatial resolution comparable to radiance measurements by CERES. The conversion from CERES radiances to flux uses angular dependence models. Comparisons between the CERES flux estimates and the balloon-based flux measurements will provide useful information about the validity of these angular models. He installed thermistor sondes in the body and dome of an Eppley Precision Spectral Pyranometer (PSP) to allow continuous temperature monitoring. The measurement uncertainty is greatly reduced by accounting for temperature gradients in the instrument. The modified instrument was delivered to NASA Wallops for the engineering test flight of the ballooncraft scheduled for April 2001. A pyranometer and a pyrgeometer by Kipp & Zonen will also be delivered for the 100-day ULDB science flights scheduled to launch in December 2001 and December 2002. Each balloon flight will provide several hundred independent matching opportunities with each CERES instrument in orbit. Most scene types and viewing geometries will be sampled, but the solar zenith angle range will be limited because the Terra and Aqua spacecrafts are in sunsynchronous orbits.

Education and Outreach

Charlie Whitlock (SAIC) described the commercial outreach effort which uses estimates of surface solar insolation to guide solar power plant, solar power, and architectural applications. This effort is being used internationally, by the U.N., and has led to a joint U.S./Canada collaboration and data base for international solar industry use. From June 1999 to Sept 2000, there were 551 U.S. customer data orders, and 1388 international customer orders. Customers includes the major U.S. energy companies. This has been a great success story of changing science data into the alternative forms which commercial groups need, and keeping the data set simple enough to use. An improved recent version of the web site is getting even larger use.

The CERES Students' Cloud Observations On-Line (S'COOL) educational outreach is now up to 46 countries and over 700 schools participating. Dave Young showed the first quantitative comparisons between students' cloud observations and CERES data. Through one of the CERES science team members (Shi-Keng Yang) education officials and high schools in Taiwan have become involved, along with a group of Taiwanese scientists in the D.C. area. They will be holding a week-long workshop in the DC area for high school students as a spin off of the S'COOL project.