EOS PM-1 Science Data Validation Workshop

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The EOS PM-1 Science Data Validation Workshop was held at the University of Maryland Inn & Conference Center during April 1-2, 1998. The purpose of the workshop was to help maximize the value and cost-effectiveness of the validation program for the PM-1 and SeaWinds missions by encouraging and facilitating coordination among the PM-1 and SeaWinds Science Teams. The workshop especially emphasized the new data products associated with AIRS/AMSU/HSB, AMSR-E, and SeaWinds and the potential synergy within and between those teams and with the MODIS and CERES teams as regards data product validation. The Jason-1 (altimeter) team also participated. Approximately 75 scientists attended.

Introduction

The background and programmatic context for the workshop were presented by Pierre Morel and James Dodge of the NASA Headquarters Earth Science Enterprise and by David Starr, EOS Validation Scientist.

The charge to the workshop was to generate information to assist in the development of a more-integrated and effective program by:

a) identifying requirements and planned activities that may be mutually beneficial for multiple teams and/or more than one data product, i.e., seek areas where synergy is likely and cooperative efforts advantageous, and

b) developing specific plans to compare related data products from different instruments.

The workshop began with plenary presentations on the draft PM-1 Instrument Data Validation Plans and several relevant EOS Interdisciplinary Science (IDS) investigations. Invited presentations were also given by community science programs having strong interfaces with the EOS PM-1 science studies. Instrument Validation Plans were presented by the AIRS/AMSU/HSB, AMSR-E, SeaWinds, and Jason-1 teams. Brief Validation Plan updates were later given in panel sessions by the MODIS-Atmosphere, MODIS-Land, and CERES teams. Presentations were given on the validation activities of the Data Assimilation Office and IDS Teams involving Soil Moisture (Thomas Jackson), Hydrology (Eric Wood), Cryosphere (Anne Walker of Goodison's Team), Ocean Surface (Tim Liu), and Clouds (Bryan Baum of Wielicki's Team). Invited presentations were given on the National Centers for Environmental Prediction Re-Analysis program (Glen White), the DOE Atmospheric Radiation Measurement (ARM) program (Ted Cress), the Global Energy and Water Experiment (GEWEX) Continental-Scale International Project (John Leese), GEWEX International Campaigns (Toshio Koike), and Buoy Programs (Peter Niiler).

Subsequent sessions of the workshop were organized into four Discipline Panels covering EOS data products for Meteorology, Hydrology and Snow, Cloud and Radiation, and Ocean and Sea Ice. These panels met during the afternoon of April 1 and morning of April 2 and gave summary reports in plenary session during the afternoon of April 2. This article summarizes the results from the Discipline Panel sessions. More-detailed reports prepared by the session Chairs and Rapporteurs are available from the EOS Project Science Office Validation internet site (http://eospso.gsfc.nasa.gov/validation.html).

Hydrology Products Panel

The Hydrology Products Panel was led by Dennis Lettenmaier, Chair, and Prasad Gogineni, Rapporteur. The panel identified data products to be produced from EOS PM-1 sensors of potential use in hydrologic studies. These are: surface (skin) temperature, surface air temperature, precipitation, surface soil wetness, snow-water equivalent, and snow areal extent. The panel discussions focused on the instruments from which the products will be derived, the anticipated nature of the products, current status of validation plans, opportunities and needs, and potential opportunities for inter-instrument comparisons. The precipitation product (AMSR-E) was not addressed in detail in lieu of the intense validation activity presently occurring with the Tropical Rainfall Measuring Mission (TRMM).

Surface (effective skin) temperature (from AIRS)—Current validation plans involve using surface (point) measurements [via Atmospheric Emitted Radiance Interferometer (AERI)] of radiative temperature and emissivity, and HIS/MAS airborne measurements (to be flown on the ER-2). Pre-launch field observations at the Southern Great Plains (SGP) Cloud and Radiation Testbed (CART)/ARM site are planned for October-November, 1998. Similar post-launch activities are planned. Greater emphasis needs to be placed on ground-based spatial variability studies—there is some doubt that planned surface and airborne validation data will be sufficient to assess the impact of subgrid variability. Coordination with planned soil-moisture validation activities (e.g., SGP follow-on, see below) is apparently absent, notwithstanding that the same or similar sites are planned to be used for both. The possibility of comparisons/evaluations with a MODIS-derived effective temperature should be explored.

Surface air temperature (from AIRS)—Surface air temperature is used in hydrologic models for computation of evapotranspiration and (somewhat less commonly) for estimation of surface sensible heat flux. It is also useful as a surrogate for estimation of downward longwave radiation. Little information was available to the group about this product. However, there is an extensive global surface air temperature network, which presumably would be used for validation. Comparisons between the AIRS surface air temperature data product and similar products derived from the NOAA Polar-orbiting Operational Environmental Satellite (POES) sounders should be done.

Surface soil wetness (from AMSR-E)—Some pre-launch evaluation is possible via retrospective analysis of SMMR, which had an appropriate spectral band (currently operating SSM/I does not). More-effective C-band tests are expected to be possible once a C-band instrument is available for aircraft-based testing (expected within the next year). Completion of the simulator development and conduct of appropriate field observations are a high priority. Post-launch validation is planned via a SGP field campaign, perhaps similar to SGP-97, tentatively planned for 2001 or 2002. In addition, validation possibilities may exist with the GEWEX Hydrometeorology Panel transferability studies planned for the GEWEX Asian Monsoon Experiment (GAME) Tibet, where the current plan is to fly a Japanese AMSR simulator.

There is a need to develop a global stratification of areas with vegetation mass less than the apparent upper limit for C-band surface moisture estimation. Tom Jackson (USDA) has produced a map which could be a starting point for such a classification. Analysis of the vegetation data, along with other relevant factors (i.e., precipitation climatology, topography, and soil characteristics) could form the basis for identification of global "end points" for validation studies. Comparisons with data from a similar instrument to be flown on ADEOS-II should be conducted. Opportunities for comparison with other more-independent satellite measurements do not presently exist.

Snow areal extent (from MODIS and AMSR-E)—MODIS will be flown on EOS-AM as well as PM, and validation plans have been developed in connection with EOS-AM. Field campaigns will include intensive observations (primarily using aerial photography) over New England and the Midwestern U.S. Target test sites have been selected to provide contrast in subpixel vegetation characteristics, which are important at the MODIS resolution (approximately 0.5 km for snow products). Current plans for AMSR-E validation of snow-extent products are to use MODIS product intercomparisons.

There is some question as to whether validation using MODIS products will be sufficient for evaluation of AMSR-E snow extent, particularly given the differences in footprints. Such a validation approach is subject to any uncertainties associated with the MODIS product. In any event, there is a need for a well-thought-out AMSR-E snow-extent validation strategy. There is an opportunity for AMSR-E-MODIS product intercomparisons. An opportunity also exists for pre-launch comparisons for AVHRR and SSM/I snow-extent products.

Snow-water equivalent (from AMSR-E)—During the pre-launch period, the primary validation sets are snow water equivalent derived from SSM/I, NOAA aircraft transects (primarily Midwestern U.S.) using gamma radiation sensors, and point observations from such sources as the National Resources Conservation Service (NRCS) Snow-water-equivalent Telemetered data (SNOTEL) network (western U.S. only) and Russian observations. In the post-launch period, the main validation data sets are expected to be derived from NOAA gamma flights, and perhaps, as yet unspecified, field campaigns.

There is a strong need for development of a comprehensive post-launch validation plan. This could be based on global stratification of areas where passive microwave sensing is expected to be most useful (e.g., absence of wet snow). It is essential that the relatively large footprint be taken into account. This probably means manual transects, e.g., following the lead of the Canadians in collecting data for testing and validation of SSM/I algorithms. Coordination with other ongoing, large-scale hydrological activities, such as the Coordinated Extended Observing Periods (CEOPs) of the relevant GEWEX continental scale experiments [Mackenzie GEWEX Study (MAGS), GAME-Siberia, GEWEX Continental-scale International Project (GCIP), Baltic Sea Experiment (BALTEX)] should be undertaken. Comparisons with data from a similar instrument to be flown on ADEOS-II should be conducted. Opportunities for comparison with other more-independent satellite measurements do not presently exist.

Cloud and Radiation Products Panel

The Cloud and Radiation Products Panel was led by Robert Curran, Chair, and Ming-Dah Chou, Rapporteur. The cloud and radiation products to be produced by the relevant PM-1 instrument teams are:

CERES: Upward, downward, and net longwave and shortwave fluxes at the top of the atmosphere, in the atmosphere, and at the surface; cloud cover, cloud top height, cloud top temperature, visible optical thickness, 11-μm emissivity, liquid or ice water path, and effective particle size.

MODIS: cloud cover, cloud top height, cloud top temperature, visible optical thickness, 11-μm emissivity, cloud liquid or ice water path, and effective particle size for multiple cloud layers.

AIRS/AMSU/HSB: cloud cover, cloud top height, cloud top temperature, cloud liquid water path, and spectral longwave emissivity.

AMSR-E: cloud liquid water path.

The panel identified four areas as critical for validating the PM-1 global cloud and radiation products:

1. Validation using long-term intercomparisons of products retrieved from measurements made on PM-1 and measurements made at a growing number of surface sites;
2. Use of measurements from intensive field campaigns to provide physical process tests, characterize surface measurements and establish the validation linkage between individual satellite observations and measurements made at individual surface sites;
3. Intercomparison of products common to two or more PM-1 instrument teams; and
4. Validation using new active and passive satellite remote sensing systems potentially available during the time frame of PM-1.

Long-term intercomparisons using surface sites—The surface radiation and cloud/aerosol measurement networks important for PM-1 validation include: DOE's Atmospheric Radiation Measurement (ARM) sites, the Aerosol Robotic Network (AERONET), World Climate Research Program's (WCRP's) Baseline Surface Radiation Network (BSRN) and Global Energy Balance Archive (GEBA), and NOAA's Surface Radiation (SURFRAD) network. NASA EOS is a major funding source for AERONET and contributes to BSRN and SURFRAD. In addition, Flux Networks for Validating EOS Terrestrial Carbon, Water, and Energy Budgets (FLUXNET), Long-Term CO_2 Flux Measurements of the Americas (AMERIFLUX) and other surface characterization sites with appropriate radiometric capability also provide useful data, some with NASA EOS funding support. CERES and other EOS teams also maintain other validation sites with very useful observations.

The panel recommends an increased number of sites, enhancements in the capabilities of existing sites, and operation of the sites to include all PM-1 satellite overpasses to greatly improve the validation of the cloud and radiation products. The lidar, cloud radar, and shortwave and longwave radiometers at the 3 existing ARM sites provide an excellent basis for validation. Similar sites in unrepresented climate regimes would significantly augment the present validation capability. This could be at least partially accomplished by the judicious enhancement of several AERONET sites to include the lidar, cloud radar, and irradiance measurements. Additional surface sites are required, especially in subtropical, mid- and high-latitude oceanic regimes. These additional sites might also be achieved by inviting the involvement of NOAA research ships and through international cooperation.

Intensive field campaigns—There are several near-term field experiments important to cloud and radiation validations prior to the launch of PM-1, which include: The First ISCCP Regional Experiment (FIRE) Arctic Cloud Experiment (May-June 1998)—collocated and concomitant with the Surface Heat Budget in the Arctic (SHEBA) experiment sponsored by NSF, and the GEWEX Asian Monsoon Experiment (GAME) in May 1998. Similar GAME experiments are planned for the 2001-2005 time period and the FIRE-Cirrus Regional Study of Tropical Anvils and Layers (CRYSTAL) experiment is planned for the summer of 2001. Both the FIRE III Arctic Cloud Experiment and the CRYSTAL experiment are conducted in collaboration with DOE ARM sites, and the ARM program has planned a continuing series of intensive field observation experiments (IOPs) related to clouds and radiation. In the case of CRYSTAL, current plans also call for deployment of a floating ARM site, NOAA's R/V Ron Brown. MODIS and other EOS AM-1 teams plan a series of validation field experiments over the ARM site in Oklahoma that will likely continue into the PM-1 time period. These will typically be coordinated with ARM IOPs as with the recent MOPITT activity at the SGP site.

The panel recommends continued strong collaboration with field experiments to validate cloud profile information to be obtained by lidar, radar, and radiometers at the ARM and other sites which have these measurement capabilities.

Additional airborne validation measurements would enhance the veracity of the measurements made at these surface sites. Future EOS/ARM field campaigns need to be planned to add to the validation data base.

Intercomparison of PM-1 instrument team products—There are many cloud parameters which are produced by one or more of the PM-1 instruments. Since all of the instruments are on the same spacecraft, spatial and temporal matching of the common products should be relatively straightforward. The panel recommends that it is absolutely essential that the products from the various EOS teams be intercompared for accuracy, consistency, spatial resolution, and temporal resolution. The investigations to be conducted should include statistics of discrepancy among the products from different teams, nature of the discrepancy, and sources of discrepancy for various temporal and spatial scales. The scales should include daily, monthly, seasonal, interannual, regional, zonal, climatic regimes, and global.

Use of new active and passive satellite remote sensing—The best global sampling of cloud top height, cloud overlap, physical thickness, and ice water path (IWP) will come from new active and passive remote sensing technologies as part of future Earth System Science Pathfinder (ESSP) and other, international, programs. Examples are improved measurements of cloud overlap using cloud lidar and radar, as well as improved measurements of ice cloud properties (IWP, effective particle radius). The panel recommends that, to the greatest extent possible, comparisons of spatially and temporally coincident measurements made by these new satellite systems should be made with appropriate PM-1 cloud and radiation products.

Ocean and Sea Ice Products Panel

The Ocean and Sea Ice Products Panel split into an Ocean section, led by Chet Koblinsky, Chair, and Michael Freilich, Rapporteur, and a Sea Ice section led by Claire Parkinson. Discussions were held on ocean data products from AMSR-E, MODIS, AIRS/AMSU/HSB, SeaWinds, and Jason-1. Also, ocean-related EOS IDS investigations were represented by Tim Liu, Peter Niiler, and Mike Freilich. Sea-ice related EOS IDS investigations were represented by Anne Walker. Specific data products discussed were sea surface temperature, surface vector winds, sea surface height, and sea ice concentration, sea ice temperature, and snow depth on ice.

Sea Surface Temperature (MODIS, AIRS, AMSR-E)—Several complementary data sets are needed to provide an adequate sampling of the marine atmospheric conditions, principally water vapor, and sea-surface temperature (SST) for validating the MODIS and AIRS infrared channel measurements and derived SST fields. The validation strategy is two-fold: 1) highly-focused field expeditions using state-of-the-art calibrated spectral radiometers supported by extensive instrument suites to determine the state of the atmosphere to understand the atmospheric and oceanic processes that limit the accuracy of the derived SST, and 2) long-time-period, global-scale data sets to provide a monitoring capability that would reveal calibration drift and the consequences of sudden or extreme atmospheric events, such as volcanic eruptions, transoceanic transport of terrestrial aerosols, cold-air outbreaks, etc., on the global SST product.

Advantage will be taken of field programs occurring in the pre-launch and post-launch periods. In particular, the DOE ARM sites in the Tropical Western Pacific Ocean (TWP) and North Slope of Alaska and Adjacent Arctic Ocean (NSA-AAO) provide a valuable framework for MODIS validation. In addition to these long-term sites, use will be made of supplementary oceanic ARM sites that are intended to be operated on a short-term basis, or intermittently for specific research campaigns. Sites include the eastern North Pacific or Atlantic Oceans (probably the Azores), the Gulf Stream off the eastern U.S.A., and the Bering or Greenland Seas. Opportunities with other oceanic and marine atmospheric campaigns using ships, buoys, fixed platforms, aircraft, and island stations should be grasped as funding and resources allow. In particular, initialization cruises for ocean color (biology) conducted by MODIS-Ocean will provide excellent opportunities for SST validation.

Suitable EOS instruments for intercomparisons are ASTER, AMSR-E, and AIRS. Preliminary discussions have started with the ASTER team about cross-validation on the AM-1 platform. Coordinated validation of SST measurements needs to be worked with the AMSR-E and AIRS teams. Many other opportunities exist for cross-platform validation. For example, the Advanced Very High Resolution Radiometer (AVHRR) on the NOAA satellites, the Along-Track Scanning Radiometer (ATSR) on the ERS-2 satellite, the Advanced ATSR on the European Polar Platform of the Envisat-1 Mission, and the Global Imager (GLI) on the ADEOS-II satellite should all provide SST observations during the AM/PM missions.

Surface Vector Winds (QuikSCAT, SeaWinds)—The QuikSCAT and ADEOS-II SeaWinds scatterometers acquire direct measurements of global backscatter (ocean, ice, and land) from which near-surface vector winds over the ice-free oceans are calculated. Validation plans were discussed in the context of NSCAT experience, which included calibration and validation of backscatter and vector winds for the Seasat, ERS-1/2, and NSCAT scatterometer data sets. Initial SeaWinds validation will follow the NSCAT model. In this approach, measurements are quantified independently by analyses of data from distributed stable (isotropic) land targets, analyses of open-ocean data (i.e., buoy and ship data) in conjunction with operational surface wind products from the European Centre for Medium-range Weather Forecasts (ECMWF) and the National Centers for Environmental Prediction (NCEP), and directly by measurements from one or two specially deployed calibration surface stations.

Although microwave scatterometers are presently the only instruments that can accurately measure vector winds from space, multichannel microwave radiometers such as AMSR-E and altimeters such as Jason-1 can measure near-surface wind speed. Both the radiometers and altimeters also acquire additional environmental information (such as integrated atmospheric water vapor and surface wave height) that is useful for complete validation of the scatterometer velocity data over the full range of parameters. The presence of AMSR and SeaWinds on the ADEOS-II spacecraft will allow direct intercomparison opportunities.

In addition to the planned QuikSCAT and ADEOS-II SeaWinds validation, three scientifically important validation-related activities must be addressed:

(1) Quantification of the accuracy of spatially and temporally gridded products (Level 3) developed from swath scatterometer (and other instrument) measurements;

(2) Validation of algorithms and multi-instrument backscatter corrections and wind data, especially for joint scatterometer/microwave radiometer retrievals; and

(3) Determination of the effects of subsidiary geophysical quantities (such as non-equilibrium long waves, surface films, and atmospheric surface layer stratification) on the accuracy of the scatterometer measurements.

Of these, validation of the Level-3 products is by far the most important and scientifically challenging. The participation of IDS teams and other non-instrument scientists in the development of proper Level 3 requirements is essential. The development and validation of low-cost drifting buoys, and their dense deployment during initial satellite post-launch validation periods, may allow issues related to small-scale spatial variability to be addressed directly. In addition, acquisition and interpretation of comparison data for extreme wind conditions, both high (> 20 m/s) and low (< 3 m/s) wind speeds, is very important for the validation of the satellite measurements over the full range of climatically important conditions.

Sea Ice (AMSR-E and MODIS)—AMSR-E passive-microwave measurements will allow daily calculation of sea ice coverage under most weather conditions at a horizontal resolution of about 20 km. Planned standard AMSR-E products include sea ice concentration and temperature and snow depth on sea ice. MODIS visible and infrared measurements will allow a much finer (1 km) resolution than the AMSR-E products, but will be hindered by clouds, thereby limiting determination of the sea ice coverage to cloud-free locations. The MODIS sea ice product will be an indication of the presence or absence of ice in each 1-km cloud-free polar-ocean pixel.

Validation of the sea ice products will include in situ, aircraft, and especially inter-satellite comparisons. Pre-launch algorithm validation will use SSM/I data and take advantage of two major field expeditions, including the 1998 FIRE-III Arctic Cloud Experiment and the 1999 Antarctic Zonal Experiment (ANZONE). Pre-launch inter-satellite comparisons for validating the derived SSM/I sea-ice concentrations will be made with NOAA Advanced Very High Resolution Radiometer (AVHRR) and Canadian Radarsat measurements. In the case of MODIS, the plan is to validate EOS AM-1 MODIS sea-ice measurements with in situ measurements in the Southern Ocean in January and February 1999 in conjunction with a National Science Foundation (NSF)-sponsored cruise. Due to the delay in AM-1 launch, this effort will necessarily rely on validation transfer via AVHRR on NOAA POES. Additional post-launch opportunities will be sought. Comparisons will also be made with observations from the Landsat-7 Enhanced Thematic Mapper Plus (ETM+), the European ERS-2 Synthetic Aperture Radar (SAR), and the Canadian Radarsat.

Post launch, the primary initial validation of the AMSR-E sea-ice products will be through comparisons with the continuing SSM/I measurements. There will also be comparisons with the ADEOS-II AMSR, expected to be launched in the same time frame as the PM-1 AMSR-E, and with the ADEOS-II Global Imager (GLI). Validation of the PM-1 MODIS sea-ice measurements will begin with comparisons to the AM-1 MODIS measurements and the corresponding Landsat ETM+, SAR, and Radarsat measurements. During this workshop, an important coordinated activity was initiated between the MODIS and AMSR-E sea-ice teams. A MODIS Airborne Simulator image, developed by the MODIS team, immediately suggested to the passive-microwave team the possibility of using the MODIS sea-ice product as validation for the AMSR-E sea-ice concentrations.

The present plan concentrates on validating the sea-ice concentration product. The AMSR-E sea-ice temperature and snow depth on sea-ice products must also be validated. In the case of snow depths, the working-group consensus was that the best means of validating snow depths would be through aircraft flights with as-yet-undeveloped step-frequency radars and laser altimeters, in conjunction with in-situ surface measurements. In the case of AMSR-E-derived ice temperatures, comparisons should also be made with in situ surface measurements and with AVHRR- and MODIS-derived surface temperatures, although these will require the development of appropriate functional relationships between these satellite-derived surface temperatures and the actual ice temperatures. In view of the current emphasis of the AMSR-E team members on the validation of the ice-concentration product, it is felt that the validation of sea-ice temperatures and snow depth on sea ice would be particularly relevant for the planned PM-1 Validation NASA Research Announcement.

Sea Surface Height—Studies have shown that the mean surface height from TOPEX/ Poseidon (T/P) and Jason-1 can be validated at the cm level using data from a fully instrumented oil platform (Harvest) located directly in the path of the repeating satellite ground track off the coast of central California. Using data from the Harvest facility, studies have successfully explained bias and drift in the T/P sea-height measurements as being associated with the on-board radiometer data which are used to correct the altimeter range for the effects of wet tropospheric path delay. Thus, a coordinated effort at calibration and validation of water vapor measurements during the EOS PM era is needed. A focused cross-instrument sub-team should meet within the next year to outline a strategy for meeting the needs of all instruments. A secondary issue is the potential for measuring surface currents by combining geostrophic flow estimates from Jason-1 with winds derived from QuikSCAT and ADEOS-II SeaWinds. A combined group of Jason-1 and SeaWinds investigators will be working on this problem. Validation of this effort should be addressed in the EOS PM Validation NASA Research Announcement.

A primary concern is the longevity of the primary verification site at Harvest, data from which have been collected continuously since 1992. The Jason-1 project will work on this issue, and will explore alternative means for maintaining a permanent validation presence at or near this location. In addition, the impact on validation of the differences between in situ point measurements (e.g., tide gauges) vs. satellite spot averages (e.g., altimeter footprint) requires attention. Ensuring adequate funding for this validation component within the Jason-1 instrument team is a concern.

Recent comparisons of surface-height estimates from ocean circulation models, including assimilated temperature data, with T/P for the tropical Pacific show that model-based and altimetric measurements are quite comparable. Typical differences of monthly averaged values over 100-to-200 km squares are within 3 cm rms, whereas altimeter validation with tide gauges is at 2-to-3 cm rms in this region. Clearly, an accurate representation of the gridded field is required, as well as its error covariance, in order to provide added value to assimilation systems or to use independently to assess the accuracy in ocean estimates. Efforts to validate and assess the accuracy of Level-3 altimeter products have been limited.

Conclusion

The participants agreed that the workshop was very fruitful and had already stimulated new collaborative activities among the EOS Instrument Teams. David Starr, EOS Validation Scientist, and Claire Parkinson, PM-1 Platform Scientist, were very pleased with results of the workshop and expressed their gratitude for the excellent contributions of the attendees.

Complete Panel Reports from the PM-1 Science Data Validation Workshop are available at:

http://eospso.gsfc.nasa.gov/validation/valinfo.html

under the heading of “PM-1 Information.”