Report of the EOS Test Sites Meeting

Held at NASA Goddard Space Flight Center

March 18-19, 1996

David O'C. Starr, Christopher O. Justice, Diane E. Wickland, & John T. Suttles

TABLE OF CONTENTS

INTRODUCTION

The EOS Test Sites Meeting was held on March 18-19, 1996 at NASA Goddard Space Flight Center under the sponsorship of the EOS Project Science Office Validation Program. The meeting focused on land-based test sites involving measurements for land, atmosphere, and vicarious calibration studies and was co-chaired by Diane Wickland, NASA Headquarters, and Chris Justice, University of Maryland/NASA Goddard. Attendees included 57 participants from government and university research organizations and from private industry.

The meeting was motivated by several long-term test site activities underway within the instrument and interdisciplinary science (IDS) teams as part of preparations for EOS AM-1 algorithm development and data product validation. It was deemed appropriate to convene a meeting to allow communication of existing activities between the teams, to communicate other EOS and non-EOS activities to the teams, and to identify areas for coordination, potential collaboration, and cost sharing. Specific objectives of the meeting were to summarize in an informal report the requirements, plans, and timelines for test site development in the early EOS AM-1 time-frame and to build the foundations for coordinated inter-instrument and instrument-IDS test site activities. These foundations will be built upon in subsequent validation planning including the EOS Science Data Validation Workshop in May 1996.

The meeting was conducted in a workshop format. Summary reviews of pre-meeting materials provided by various EOS teams and brief status reports on ongoing community activities were presented and provided a basis for subsequent breakout group sessions. The first round of breakout sessions included discipline groups for Vegetation and Land Cover; Radiation; Aerosols, Chemistry and Meteorology; and Vicarious Calibration. These groups were charged with developing the basis for a test-site measurement implementation plan, including specification of required measurement packages and potential measurement synergy from their discipline viewpoint. A second round of breakout group sessions was designed to develop synergies between the EOS measurement suites identified in the previous breakout group sessions and further develop a strawman implementation plan. For this second round of sessions, six groups were established including: Measurement Package Synergies, Scoping a Test Sites Initiative, Validation and Data Assimilation Activities, Data Management and Standards, Calibration Sites, and Organizing a Test Sites Initiative. Each of these breakout groups reported results of its deliberations in plenary sessions.

This report presents results of the meeting in the form of reports from the four discipline breakout groups followed by the findings of the meeting which incorporate the discipline and synergy group findings. A series of appendices gives the agenda, attendees, information sources for ongoing community activities, and additional team inputs.

RATIONALE FOR EOS TEST SITES PROGRAM

From the beginning of the EOS program, it has been recognized that use of satellite, aircraft, and surface-based observations is essential to achieving the principal scientific objective of increasing the understanding of the Earth as an integrated system. The global nature of Earth system processes dictates a sampling strategy that includes coverage of all important climatological, biogeochemical, and ecological zones of the globe including pristine regions as well as areas impacted by human activities such as biomass burning and industrial production. With satellites, global coverage is relatively straightforward; however, sufficient global sampling with aircraft and surface-based observations presents a major strain on both financial and human resources. In addition to their important role in scientific studies, aircraft and surface-based observations are required to provide correlative measurements and validation for the global satellite observations. Validation of the satellite observations is extremely important since global measurements of high accuracy spanning the full dynamic range of phenomena are required to achieve the program goals.

Aircraft and surface-based observations using both *in situ* and remote sensing techniques play a key role for scientific studies and for satellite data validation. Thus, the EOS Instrument Science Teams (ISTs) and Interdisciplinary Science (IDS) Teams have included such observations as elements of their investigations. Individually, the teams can accomplish limited objectives for their investigations, but the synergies of a coordinated, EOS-wide approach can produce much greater scientific payoff for the program. This is especially true for land-based test sites, since economies of scale and improved coordination with the many existing non-EOS land-based test site programs can be realized. Significant benefits can be realized in the EOS program by coordinating and integrating these activities to establish an EOS-wide, Land Test Sites Program.

CHARGE TO THE BREAKOUT GROUPS

Chris Justice gave the charge to the meeting participants. He began with a proposed definition of EOS Test Sites:

> EOS Test Sites are *Community* sites or locations where *multiple* surface and/or atmosphere measurements are taken for use in calibrating or validating *multiple* EOS sensor data products and models. When the individual sites are combined as a network of sites, they provide an important step toward *global* representation.

The specific charge was:

1) Articulate the rationale for an EOS Test Site activity as part of the EOS Validation Program.

2) Design and scope the required/desired EOS Test Site activity to meet EOS investigator data needs, where possible building on on-going and planned activities.

3) Determine appropriate measurement packages suited to multiple products and instruments, including types, number, distribution, and frequency of measurements.

4) Examine synergy between land and atmosphere measurements.

5) Lay out a process for establishing the measurement protocols, the data system needs, and the interface to EOSDIS.

6) Identify the appropriate approaches and mechanisms for linking the EOS test site activity to: a) the broader U.S. Global Change Research community, and b) international measurement programs.

DISCIPLINE BREAKOUT GROUP REPORTS

Report of the Vegetation and Land Cover Group

Warren B. Cohen and Stephen D. Prince

Introduction

For the EOS program, validation is needed for several vegetation and land cover parameters, including land cover type, land cover change, leaf area index (LAI), fraction of incident photosynthetically active radiation absorbed (FPAR), net primary productivity (NPP), and albedo and directional reflectance. Validation of these parameters may require measurements of additional parameters such as canopy and surface optical properties, digital elevation model (DEM) data, site biogeochemistry, biomass, percent vegetation cover, meteorology, CO_2 fluxes, and emissivity.

The aim of the validation is not to undertake global monitoring, rather it is to validate and calibrate the measurements made by spaceborne sensors on the EOS platforms. As such, the validation site networks must be designed to address the full range of values of each parameter and the full range of measurement conditions including any conditions that can be expected to cause problems with remote sensing of the target parameters.

Land Cover and Cover Change

Land cover mapping is of primary importance, as it is often used to stratify measurement programs and modeling scenarios involving several other parameters. However, our ability to validate EOS land cover products is hampered by several associated problems. The process of land cover classification commonly depends on subjective judgment, which is largely due to the fact that land cover is not measured or estimated, rather labels are subjectively assigned to a complex system of biophysical components. This situation is complicated by the fact that a single classification scheme is insufficient for all purposes. Even if the EOS program were to define a single classification scheme, it is most unlikely that it could achieve its intended purpose, that is, a sampling scheme that maximizes efficiency of field validation of all the target parameters. Moreover, sites for which validation data are sought will utilize a more locally-specific scheme.

To the extent possible, we should minimize qualitative elements of land cover classification. This might involve use of morphological and functional characteristics of vegetation more so than detailed floristic characteristics. Class schemes should be kept simple, as the more complexity involved, the more subjective the process of assigning class labels. Simple regression-tree analysis or some such similar guided statistical or knowledge-based methodology is desirable. This would permit custom-designed class schemes for specific purposes that require them, each of which could trace its lineage directly back to the simpler, common class structure. An important characteristic of the simple class structure is that it should be applicable globally. Those that are more specific should be regionally applicable. We also must recognize certain localized, or widespread but small-scale phenomena that are radiometric problem areas, such as those involving very bright or dark backgrounds that lead to extreme nonlinear reflectance characteristics

for coarse resolution satellite data. Finally, whereas ground observations are often considered
the most reliable for validation, for land cover we must accept that our primary source of reference data is often repetitive aerial photography coupled with ground observations required to develop accurate photointerpretation skills. Because of the 1 km instantaneous field of view of the MODIS sensor, land cover observations for an area of
4-9 km^2 are needed for validation. The only practical means for obtaining such data are from a combination of ground data, aerial photography, and digital aircraft data, and, in many cases, these data used in combination with Landsat data or similar resolution satellite data.

Validation of land cover change will be accomplished by revisiting test sites at some specified sampling frequency and ascertaining their updated land cover classes. For slowly changing landscapes a revisit time of roughly five years or more is probably sufficient. For intensively managed systems more-frequent sampling, e.g., annually, may be desired. Sites having strong seasonal characteristics, when initially evaluated and then at each revisit, must be evaluated across several seasons. Sites should be chosen to represent globally important biomes, significant variations within a biome type, and locally troublesome areas, if these latter areas are likely to cause radiometric calibration problems.

The NASA Landsat Pathfinder Global Land Cover Test Sites Project is compiling consistent datasets of satellite and land cover data for a number of sites representing the world's major biomes. The data products from this project are to provide a resource for the development and testing of algorithms for land-surface characterization. The project is currently working to prioritize the development of these sites from a pool of candidate locations. A project description and the current list of candidate test sites can be found on the World Wide Web at http://dia.maxey.dri.edu/glcts/. This project could provide a basis for the development of an EOS Land Cover Validation activity.

Net Primary Production (NPP)

Methods for estimating NPP include biomass harvest of both above- and below-ground vegetation components, morphological measurements coupled with allometric equations, CO_2 flux measurements, and the use of models. Harvest is expensive, especially for below-ground biomass and forest tree species. Allometric equations, although useful, can have substantial error. As CO_2 flux measurements provide an estimate of net ecosystem productivity, heterotrophic and autotrophic respiration must be isolated to estimate NPP and gross primary production, respectively.

Apart from CO_2 flux measurements made from towers and from aircraft, where advection or the aircraft flight line integrates larger areas, most methods for field estimation of NPP depend on point measurements. Since the aim is to validate the outputs of coarse resolution EOS measurements, these point measurements must be arranged in an explicit sampling design. Extension of point measurements to the larger validation site can be achieved by area-weighting the point measurements according to a stratification scheme, or with the help of models driven by parameters that are either available for the entire validation site or at a higher spatial resolution than the point NPP measurements. The two more-common modeling approaches for estimating NPP are biogeochemical and production efficiency models. These usually require a suite of inputs for parameterization of such parameters as nitrogen concentration, soil moisture, vapor pressure deficit, surface and air temperature, FPAR, structure, species composition, emissivity, and outputs from a radiative transfer model. Care must be taken to avoid the circularity of testing the EOS products, which depend on models, with validation data derived from the same type of model.

The sampling period for NPP estimation is the growing season. Using harvest methods, sampling frequency at test sites will vary considerably by biome type and local characteristics. To minimize measurement errors, the shortest sampling interval should be 7-10 days of production in cropland and grasslands, whereas, for mature evergreen forest, one to several years minimum may be required. CO_2 flux estimates should be made daily, and within 30 minutes of any relevant aircraft and satellite overpasses. Modeling approaches often require hourly or daily parameterization, and thus integrate daily estimates over the growing season. Other models are based on vegetation successional processes, using inputs about composition and structure. These latter models integrate over considerably longer time periods and commonly require much less parameterization.

Sampling NPP at test sites should cover the range of biogeochemical factors controlling it. These include the major global climate regimes with variations in temperature and moisture distribution, seasonality, and nutrients. All major vegetation types should be sampled: perennial, annual, evergreen, deciduous, and those with ephemeral phenologies, differing NPP/biomass ratios, and species with differing adaptive strategies. Ideally, the same sites would be used for land cover, land cover change, NPP, and all other parameters to be validated. There are no field programs designed to measure NPP over a full 4-9 km^2 area. Only tower sites integrate over such areas, and not many of these are in existence globally. Modeling combined with field plot data and high spatial resolution, e.g., TM, data are generally required to estimate NPP over a large area. Intensive field campaigns such as FIFE and BOREAS leave parameterized models that could be reactivated for EOS. The emerging international flux tower network (FLUXNET) of the International Geosphere-Biosphere Program (IGBP) and the IGBP Data and Information Global Primary Production Data Initiative may provide the basis for developing an EOS global NPP validation activity. Information on the IGBP-NPP Data Initiative can be found at: http://www-eosdis.ornl.gov/npp/npp_home.html.

LAI, FPAR, Reflectance, and Albedo

Much of what applies to NPP is equally applicable to this suite of parameters. Methods for estimating LAI at test sites will involve harvest, allometry, and inversion of radiative transfer models. FPAR can be estimated with radiometers, ceptometers, and radiative transfer models, some of which are driven by vegetation indices. Reflectance and albedo require *in situ* measurements and/or radiative transfer modeling. Sampling strategies are generally the same as for NPP, with the addition of considerations of leaf-angle distributions, leaf-to-wood ratios, background reflectance surface properties, and illumination conditions.

Measurement strategies

Vegetation and land cover sampling at test sites for the EOS program must be done at a relatively large number of sites globally. The minimal size of sampled units is 4-9 km^2.

This assures that there is minimal error associated with geographic misregistration between locations sampled in the field and satellite fields of view. As detailed vegetation classification schemes are generally undesirable for global estimation, they should be avoided to the extent possible. Consideration of stratification-free sampling designs, e.g., transects, is important, and wherever a classification is required, it should be as simple as possible, compatible with other schemes, traceable back to a base classification, and based on existing knowledge of model/algorithm sensitivities.

To the extent possible, target test sites should include the least spatially variable vegetation types, or the complex of vegetation types within 4-9 km^2 test sites should consist of types that can be linked to broad areas of homogeneity outside of the test site proper. Although such a sampling consideration eliminates many ecologically interesting areas, it facilitates sampling of a larger number of test sites that are representative of global vegetation. Formal linkages among EOS and various other programs that are more field oriented is essential if the test site program is to be economically feasible.

Two types of measurement strategies are needed to secure the EOS validation measurements considered here:

i. Intensive Validation Sites.

A network of Intensive Validation Sites is needed. At these sites, coordinated radiation, atmospheric chemistry and physical composition, and biological measurements would be made with supporting meteorological monitoring. Measurements would be made continuously for several years so that both the short- and medium-term temporal variations in measurements can be defined and compared with EOS data. In addition to permanent instruments, aircraft platforms should visit these sites for specific campaigns associated with other atmospheric observations. In fact, these sites could become the validation locations for many EOS measurements.

The sites should be 4-9 km^2 located in a larger area of similar land cover. The land cover should be uniform, or have a pattern with a grain finer than that of the EOS measuring instruments. Some measurements will be made on the ground, e.g., vegetation sampling, NPP by biomass increment, and soil respiration; some measurements will be made from towers of sufficient height above the canopy to determine short and longwave radiation up and down with high spectral resolution for downward radiation; and some measurements will be made from towers of sufficient height to determine CO_2, CH_4, CO, and water vapor fluxes and net ecosystem production. The tower height depends on the advection zone to be measured, and should be matched to the site variability; a very uniform site may allow lower towers to measure the gaseous fluxes adequately for the whole validation site, whereas heterogeneous site may need much greater height. Other measurements that cannot be sampled for the whole validation site from a static instrument will be moved around by operators or on aircraft to sample the variability present across the site. These sites will have to be permanently attended and will be visited by validation teams for more-intensive campaigns. The capital costs of high towers means that existing towers should be used where possible. It is envisaged that about ten such intensive sites will be needed.

ii. Extensive Validation Sites.

A larger network of lower-intensity Extensive Validation Sites will be necessary to sample the range of conditions found throughout the Earth's land surface. Whereas the Intensive Validation Sites will provide high accuracy and long-term measurements, the Extensive Validation Sites will provide the required sampling of processes globally. For each parameter, a broad classification of the land surface will be needed. It is likely that some of these classifications will be similar and others will be quite different. Approximately 100 extensive sites will be needed to validate EOS measurements globally. Many of the sites will be in existing study locations where ongoing measurements may be used or supplemented for EOS purposes but existing logistics utilized. By using existing sites some historical information will be available that will assist in interpretation of the measurements. Some of these extensive sites may include measurements using existing tower facilities. At other sites, tower measurements may be obtained for limited periods of time by using portable towers.

The main categories of measurements with an indication of their stratification criteria are: canopy optics (vegetation structural, climatic, and functional types); atmospheric chemistry (ecosystem type, range of productivities, wetlands, and boreal regions); aerosols (dust types, desert, industrial, oceanic, domestic fuel, forest, crop, and savanna burning); biology (range of productivities, seasonality, stress from temperature, moisture, and nutrients, plant type, and canopy structural type); land cover and land cover change (different types and complexity of patterns, areas of slow and rapid change, urban, and rural).

Potential measurement sites

Field measurements are expensive, especially when a global network of sites is required. The Intensive Validation network is aimed at accuracy and multi-temporal measurement. As such this network need not be globally representative, rather existing facilities such as the remaining sites from the Boreal Ecosystem-Atmosphere Study (BOREAS), the NOAA Climate Monitoring and Diagnostics Laboratory (CMDL) tower sampling sites, the Long-Term Ecological Research (LTER) sites, agricultural experiment stations, experimental watersheds, and established physical environment monitoring facilities should be utilized and augmented. The measurement techniques should relate unequivocally to the field of view of the relevant sensors, thus emphasizing large and uniform areas.

The Extensive Validation network should aim to represent the ranges of the globally occurring values of the EOS parameters. The need for cross-calibration of measurement instruments and methods is paramount. Many of these sites will need to be outside the USA and existing networks such as the IGBP Global Change and Terrestrial Ecosystem (GCTE) transects should be used where possible. The creation of an inventory of potential sites and assembly of historical information, maps, and imagery should be undertaken after the pattern of the Landsat Global Land Cover Test Sites program.

Report of the Radiation Group
Thomas P. Charlock and Alan Strahler

Introduction

This group, chaired by Alan Strahler, was charged to develop a strategy for EOS Validation Test Sites serving "Radiation and Fluxes:" radiative, sensible, latent, and chemical fluxes at the surface and within the atmosphere. "Radiation and Fluxes" also represented surface characterization: land type, spectral bidirectional reflectance distribution function (BRDF), description of vegetation canopy, etc. Representatives from MODIS, MISR, CERES, ASTER and the Data Assimilation Office attended this group. Radiative fluxes and surface characterization were represented; however, microwave interests, the ocean, and moist processes were not well represented.

The Radiation Group recommended several classes of continuous surface validation sites:

- Integrated Surface/Tower sites to be constructed by EOS including a full complement of *in situ* observations for validation of EOS data products.
- Remote Sensing Physics sites for measurements of atmosphere parameters to test methods for retrieving atmospheric and surface parameters.
- Regional Climate Trend sites for measurements to differentiate between the effects of changes in surface, aerosol, and cloud properties in producing climate trends.
- Discrete Validation sites that have a limited scope of measurements, but can be used to validate individual (discrete) EOS products.

The group recognized the significant potential offered by many existing programs including: the Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) sites, the World Climate Research Program (WCRP) Baseline Surface Radiation Network (BSRN), the NOAA Surface Radiation Budget (SURFRAD), the Integrated Surface Irradiance Study (ISIS) at NOAA, the surface radiometer sites contributing to the Global Energy Balance Archive (GEBA) in Zurich, Switzerland, and the laser beam ceilometers at airports for cloud base height. Many of these sites are limited in scope; however, the DOE ARM Program supports extensive instrumentation at three sites: the Southern Great Plains (SGP) site in Oklahoma, which is now operating; the Tropical West Pacific (TWP) site, which is expected to begin operation in late 1996; and the North Slope of Alaska (NSA) site, which is planned to begin operation in the EOS AM-1 timeframe. In addition, periodic aircraft campaigns are conducted at the ARM sites.

Group discussions concentrated on the Integrated Surface/Tower sites, which would be constructed by EOS. The group largely approved the description of the Remote Sensing Physics, Regional Climate Trend, and Discrete Validation sites, for which lesser EOS support would be required. Steve Prince, Alan Strahler, Wolfgang Wanner, and Bill Emery from the MODIS and MISR teams were the main architects of the Integrated

Surface/Tower sites. Tom Charlock from CERES team defined and advocated for the Remote Sensing Physics, Regional Climate Trend, and Discrete Validation sites.

Integrated Surface/Tower Sites

Integrated Surface/Tower sites would be centered on towers and cover at least 6 types of surfaces: barren, grassland, brush, broadleaf crop, deciduous forest, and needle-leaf forest. The full group regarded the 6 types as a minimal but sound categorization. The instrument tower would be about 75 meters high, and, for the forests, at least above the canopy. Instrumentation would provide continuous measurements for aerosols, water vapor, clouds, shortwave (SW) and longwave (LW) radiation fluxes, and vegetation. Examples of existing sites, where such towers could be constructed, are the DOE ARM sites, the Harvard Forest - Temperate Deciduous Forest Site, the BOREAS Thompson Site, and the planned Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA) Tower sites. Spectral SW radiation measurements using a high-resolution spectrometer are strongly recommended for both upwelling and downwelling measurements at the Integrated Surface/Tower sites. Spectral downwelling radiation is needed for atmospheric physics studies and spectral upwelling radiation is needed for studies of surface and vegetation physics. A specialized camera is needed at the tower for vegetation measurements.

Most, if not all, of the 6 sites needed for the Integrated Surface/Tower sites could be located in the vicinity of existing sites. Surface measurements at all sites would be continuous. EOS-supported aircraft campaigns at these sites would be needed to determine the spectral BRDF and the spatial homogeneity about the tower and surrounding vegetation. Some of these Integrated Surface/Tower sites could be effectively co-located with the Remote Sensing Physics sites described below.

Remote Sensing Physics Sites

Remote Sensing Physics sites would be used to hone greater absolute accuracy in EOS retrievals of atmospheric and surface parameters. The three DOE ARM sites offer opportunities for these studies. ARM measurements of the temperature, humidity, clouds, and optical characteristics of the atmosphere are comprehensive, especially during Intensive Observing Periods (IOP) when there are aircraft flights. Instruments at the ARM SGP site include the Multispectral Rotating Shadowband Radiometer (MFRSR) for aerosol optical depth, a Raman lidar and microwave radiometer for water vapor, broadband radiometers for SW and LW radiation fluxes at the surface, and a Micro-Pulse Lidar (MPL) and microwave radar for cloud vertical structure. The cloud profiling radar (CPR) is a special requirement of CERES. The CERES/ARM/GEWEX Experiment (CAGEX) for pre-launch validation is already underway at the Oklahoma SGP site, and is described on the internet at http://snowdog.larc.nasa.gov:8081/cagex.html/.

EOS support for aircraft measurement of spectral BRDF, surface albedo, surface LW upwelling, and directional LW radiance at the ARM sites would be valuable. At present, the extensive atmospheric measurements of ARM are valuable resources for the validation of EOS atmospheric parameters. With aircraft measurements of surface properties at the ARM sites, the same sites could serve as ideal locations for the validation of EOS surface sensing as well as atmospheric "subtraction" and the validation of atmospheric sounding.

Regional Climate Trend Sites

Regional Climate Trend sites would capitalize on existing and planned networks such as the WCRP BSRN sites (http://www.geo.umnw.ethz.ch/wrmc/), the NOAA SURFRAD sites (http://www.srrb.noaa.gov/), and the NASA Langley Walker Tower site (c.h.whitlock@larc.nasa.gov). We have selected SURFRAD and BSRN for Regional Climate Trend sites because they meet strict national and international operating protocols for monitoring. Approximately 5 sites currently exist and 40+ are planned through collaboration with the SURFRAD and BSRN projects. The objective is to have co-located radiometers and aerosol sunphotometers at these sites. EOS support will be needed to augment some sites and to allow aircraft campaigns at selected sites.

For Regional Climate Trend sites, the emphasis is on the minimum measurement needed to validate climate trends in a satellite-retrieved surface product. Absolute accuracy will be tested at Integrated Surface/Tower and Remote Sensing Physics sites, but subtle trends (relative accuracy is higher than absolute) will be developed at Regional Climate Trend sites. The critical Regional Climate Trend measurements are: (a) surface broadband radiometric flux and (b) aerosol optical depth. When combined with the satellite, (a) and (b) can validate the identification of clear (cloudless) scenes and aerosols. Regional trends in aerosol and cloudiness are the greatest potential "spoilers" of EOS surface products. Homogeneous surface sites near the approximately 40 existing and planned Regional Climate Trend sites should be selected by EOS. EOS support will be needed to purchase MFRSR aerosol instruments for Regional Climate Trend sites and to take aircraft surveys.

Discrete Validation Sites

Discrete Validation Sites would be target-of-opportunity sites having useful long-term measurements for validation of an individual (discrete) EOS product. Examples would be the laser ceilometers at US airports, which routinely measure the base height of low- and middle-level clouds.

Justification and Specifics for Regional Climate Trend Sites

Due to the unique requirements for studying climate trends, a more-detailed justification and specific applications for the Regional Climate Trend sites are given here.

About 50 Regional Climate Trend sites would be necessary to monitor, at the minimum, surface broadband radiative fluxes and aerosol radiative properties. These sites would permit EOS to confidently "subtract the atmospheric aerosols" and observe regional trends in: (1) aerosol radiative forcing, (2) surface radiative forcing, and (3) a large suite of EOS land products, such as normalized difference vegetation index (NDVI), BRDF, and photosynthetically active radiation (PAR), and some ocean products, too.

If we do not have co-located monitoring of surface radiative flux and aerosol optical properties, our EOS estimates of aerosol forcing will be essentially unvalidated; more importantly, purported regional trends in surface albedo and many other EOS land products would be suspect due to uncertain aerosol contamination. Large regional trends in aerosol loading are anticipated in the next few decades as a result of clean up of industry in the U.S., industrialization of China and Latin America, changing agriculture and biomass burning in South Asia and Africa, etc. It is imperative that a global observing system be able to separate aerosol trends from surface trends.

To generate EOS Land and Ocean products from the remote sensing retrieval process, we must be able to accurately account for the effects of: (a) clouds, (b) the clear-but-IR-active atmosphere, and (c) aerosols. Cloud remote sensing is fairly advanced with respect to screening for cloud or no-cloud conditions and there are several cloud sensors on the cluster of EOS and operational satellites. Therefore, we have good prospects of screening clouds in EOS. The clear-but-IR-active atmosphere (thermal emission by H_2O, etc.) can be screened out, too. Many sensors look in windows where the thermal effect can be accounted for accurately, and the analyzed temperature fields produced by meteorological centers are, in some respects, already sufficient to yield objective corrections to window sensing with radiative transfer calculations. The account or screening of aerosols, however, remains a problem. While MODIS and MISR will make impressive efforts to retrieve aerosols, the atmospheric radiation community anticipates that these groups will produce an advanced, but not a complete solution, to the aerosol problem.

The Regional Climate Trend sites are needed to monitor surface flux and aerosols, in order to improve the EOS screening of aerosol radiative effects. Over these approximately 50 sites, if EOS aerosol sensing matches the surface-based optical depth AND surface-observed radiative forcing, we'll be on firm ground with respect to aerosol radiation. With aerosols screened, we could be more confident in ascribing secular trends in EOS Land products to real changes in the land. This would help the Intergovernmental Panel on Climate Change (IPCC), too. IPCC can readily specify the radiative forcing of trace gases, but it does not have solid numbers for aerosol radiative forcing and surface radiative forcing. The climate community has come to recognize the importance of cloud radiative feedback in General Circulation Models (GCMs), but the large uncertainties from anthropogenic aerosol and surface radiative forcing (and surface albedo feedback) have fallen through the cracks.

The cost to EOS for Regional Climate Trend sites need not be great. Two groups doing broadband surface radiometric monitoring at present are the NOAA SURFRAD (John DeLuisi; deluisi@srrb.noaa.gov; http://www.srrb.noaa.gov/) and the World Climate Research Program BSRN (Ellsworth Dutton; edutton@cmdl.noaa.gov; http://www.geo.umnw.ethz.ch/wrmc/).

SURFRAD and BSRN work through national and international protocols for instrument calibration. SURFRAD and BSRN sites have been carefully dispersed to provide representative (but not full) coverage. SURFRAD has 4 sites that would fit the bill for Regional Climate Trend sites. At some BSRN sites, EOS would have to supplement the broadband radiometers with aerosol instruments. The MultiFilter Rotating Shadowband Radiometer (MFRSR; Harrison *et al.* 1994, *Appl. Opt.*, 5118-5132) would suffice and is available commercially. BSRN will expand to cover about 50 sites globally (see Table 1 below); some already have aerosol instruments.

It would be more expensive to add a site (outside of SURFRAD or BSRN), and about 10 such additional sites will be needed. The present aerosol networks on land (AERONET; Brent Holben; brent@kratmos.gsfc.nasa.gov) could serve as Regional Climate Trend sites, IF the AERONET changes to continuous, fixed site operations and adds broadband radiometers. Joe Prospero's (jprospero@rsmas.miami.edu) AEROCE for marine aerosols would be good, too, if it were supplemented with broadband radiometers.

For Land product validation, it is suggested that EOS survey and use fields, forests, crops, etc., in the VICINITY of the Regional Climate Trend sites. Many SURFRAD and BSRN sites already operate. While a BSRN site could not validate cloud and aerosol screening of a field that is 10 km away on an instantaneous basis, on a CLIMATOLOGICAL basis the BSRN screening would be adequate. However, if some large local pollution source were present, a separate Regional Climate Trend site would have to be established.

It is also suggested that at a fraction of the Regional Climate Trend sites, a Micro Pulse Lidar (MPL) be deployed. For a description of the MPL, see the paper by J. Spinhirne, *IEEE Trans. Geosci. and Rem. Sens*., vol. 31, 1993, pp. 48-55, or contact jpin@virl.gsfc.nasa.gov. This instrument gets clouds to altitudes of about 20 km and can profile the aerosols, which is a significant increase in capability over the approximately 4-km altitude capability of the airport ceilometers. MPL would validate cloud screening (contrails and thin cirrus) for a fraction of Regional Climate Trend sites and serve wider EOS cloud applications. MPL would be needed at about 10 sites.

Question: Why approximately 50 sites for Regional Climate Trend monitoring in EOS?

Answer number 1: Other groups, like the World Climate Research Program which established BSRN, have called for about 50 sites to monitor surface radiation. BSRN scientists say we need such coverage to see what comes down through the atmosphere, to the surface. So we need as many to reliably apply “atmospheric correction” methods.

Answer number 2: Aerosols are regional, and we could use twice as many sites. But the approximately 50 BSRN + SURFRAD sites come to us very cheap; only supplementary instruments (about 40 MFRSR and about 10 MPL) are needed.

Pre-CERES validation efforts at NASA Langley are showing that comprehensive sites, like those in the ARM program, are worthwhile for testing the physics of remote sensing (see http://snowdog.larc.nasa.gov:8081/cagex.html). But there will be few truly comprehensive sites; they cost too much. With great economy, Charlie Whitlock has developed a CERES pilot Regional Climate Trend type site called the Walker Tower site, which is in a rural area between Hampton and Richmond in Virginia. He has begun a helicopter survey of the surface optical properties around the Walker Tower site. Such surveys will be needed at other Regional Climate Trend sites.

In summary, at the Regional Climate Trend sites, several parameters must be monitored at the surface. The surface measurements would be combined with satellite data to accurately describe secular change in radiative forcing, i.e., clouds, surface albedo, and aerosols. Surface monitoring MUST include meteorology, broadband SW and LW radiative fluxes, and aerosol optical depth. Strongly desired are measurements of PAR, UV-B radiation, clouds using lidar with 20-km altitude capability, aerosol absorbing properties (physical and chemical), and cloud condensation nuclei (CCN). Cloud profiling microwave radar, passive microwave radiometer, and high-resolution spectral insolation measurements are strongly desired at a significant fraction of the Regional Climate Trend sites.

Candidate Regional Climate Trend sites are:

NASA Langley Walker Tower (Virginia), a 75 meter tower
Surface radiation: Up and down broadband SW and LW radiation fluxes;
Aerosol: Optical depth;
Cloud: Standard (4 km altitude) laser ceilometer;
Contact: c.h.whitlock@larc.nasa.gov

NOAA SURFRAD (Surface Radiation Budget Network)
Surface radiation: Normal Incidence Pyrheliometer (NIP), Precision Spectral Photometer (PSP), Precision Infrared Radiometer (PIR), UV-B Radiometer, Photosynthetically Active Radiation (PAR) Sensor;
Aerosol: Multi-Filter Rotating Shadowband Radiometer (MFRSR);
Sites: Bondville, Illinois
Fort Peck, Montana
Goodwin Creek, Mississippi
Boulder, Colorado (Table Mountain);
Contact: http://www.srrb.noaa.gov/surfrad/surfrad.htm

WCRP BSRN (Baseline Surface Radiation Network)
BSRN sites are given in Table1. Regional Climate Trend sites could be developed by using BSRN sites with their surface SW and LW radiation flux measurements and adding aerosol photometer instruments where they do not already exist.

Table 1. Baseline Surface Radiation Network (BSRN) Sites*.

Station Name	Sponsor	Abbrev.	Lat./Long.	Status
Alice Springs	Australia	ASP	24 S/134 E	s
Manaus	Brazil	MAN	03 S/ 60 W	c
Florianopolis	Brazil	FLO	28 S/ 48 W	Y
Bratt's Lake	Canada	BLA	50 N/104 W	N
Ping Chuan	China	PCH	28 N/102 E	N
Wudaoliang	China	WUD	35 N/ 93 E	N
Aswan	Egypt	ASW	24 N/ 33 E	N
Toravere Observatory	Estonia	TOR	58 N/ 26 E	c
Carpentras	France	CAR	44 N/ 05 E	s
Ny Alesund, Spitsbergen (N)	Germany	NYA	79 N/ 12 E	Y
Lindenberg	Germany	LIN	52 N/ 14 E	s
Georg von Neumayer, Ant.	Germany	GVN	70 S/ 8 W	Y
Budapest-Lorinc	Hungary	BUD	48 N/ 19 E	s
Sede Boker	Israel	SBO	31 N/ 35 E	N
Tateno	Japan	TAT	36 N/140 E	s
Syowa, Antarctica	Japan	SYO	69 S/ 39 E	Y
Tarawa, Kiribati	New Zealand	TAR	02 N/173 E	N
Pukekohe	New Zealand	PUK	37 S/175 E	N
Al Soodah	Saudi Arabia	ALS	18 N/ 42 E	N
Payerne	Switzerland	PAY	46 N/ 07 E	Y
Barrow, Alaska	USA	BAR	71 N/157 W	Y
Boulder, Colorado	USA	BOU	40 N/105 W	Y
Bermuda	USA	BER	32 N/ 64 W	Y
Kwajalein, Marshall Islands	USA	KWA	09 S/167 W	Y
South Pole, Antarctica	USA	SPO	90 S/000 E	s
Franz Josef Land	Russia	FJL	80 N/ 55 E	N
Billings, Oklahoma	USA	BIL	37 N/ 97 W	Y
Colima	Mexico	COL	20 N/104 W	c
Xilinhat	Mongolia	MON	48 N/110 E	c
Fort Peck, Montana	USA	FPE	48 N/105 W	s
Bondville, Illinois	USA	BON	40 N/ 88 W	s
Goodwin Creek, Mississippi	USA	GCR	34 N/ 90 W	s
Boulder SURFRAD, Colo.	USA	BOS	40 N/105 W	s

Status: Is station operating?	Key	Number
Yes:	Y	10
No:	N	9
Soon to be established:	s	10
Candidate:	c	4
Total		33

* Eventually there will be about 30 other sites.
http://www.geo.umnw.ethz.ch/wrmc/ (source of above list of sites)

Report of the Aerosol, Chemistry & Meteorology Group
Jinxue Wang and Eric Vermote

Introduction and Rationale

Members of the MISR, MODIS, MOPITT, and SAGE III teams were represented in the Aerosol, Chemistry & Meteorology group.

Atmospheric chemistry was identified by the National Research Council (NRC) Board on Sustainable Development (BSD) as one of the high-priority scientific areas for the U.S. Global Change Research Program (USGCRP) over the next decade. Within the area of atmospheric chemistry, the BSD recommendations include:

• Enhance USGCRP research and its relationship to tropospheric chemistry;

• Improve estimates of regional and national trends in anthropogenic trace gas emissions;

• Enhance the focus on tropospheric ozone and its precursor through an optimized combination of space-based and *in situ* observations, laboratory studies, and modeling;

• Characterize the global distribution and processes associated with tropospheric aerosols;

• Extend to continental regions the current coastal and island networks monitoring biogenic gases.

Therefore, coordinated measurements of atmospheric trace gases, such as CO, CH_4, O_3, etc.; water vapor; and aerosols at many well-defined and characterized sites across the world are not only essential to ensure the quality of EOS/AM-1 atmospheric chemistry-related products, but also very important as a component of the USGCRP atmospheric chemistry program. By combining AM-1 instruments with existing national/international measurement networks with enhanced measurement capability and products, we will be able to enhance the scientific returns of the AM-1 mission, advance our understanding of atmospheric chemistry, and make a big step in the implementation of the NRC/BSD recommendations.

Requirements for sites, instruments, and measurements for the validation of data processing algorithms and geophysical data products of each instrument were presented and discussed by the Aerosol, Chemistry & Meteorology group. The measurement matrix listed in Table 2 was defined by the group. In addition, existing measurement networks and sites were discussed in terms of their potential for EOS validation measurements. The locations, characteristics, objectives, and measurement requirements appropriate for the DOE/ARM sites, the NOAA/CMDL Cooperative Flask Sampling Network, the Aerosol Sunphotometer Network (AERONET), the Atmosphere/Ocean Chemistry Experiment (AEROCE) sites, and the Network for Detection of Stratospheric Change (NDSC) are discussed in the following sections.

Table 2. - Aerosols, Chemistry, and Meteorology Validation Sites Measurement Matrix.

Parameter	Programs and Instruments	Sampling Frequency	Sampling Period	Existing sites- Areal extent/ distribution	Comments
Aerosol scattering coefficient	AEROCE - Nephelometer & Aethalometer	Daily	Continuous	5 Ocean sites	Need to add more sites
Aerosol scattering coefficient (profile)	Lidars at ARM & NDSC sites	Daily or Weekly	Continuous	3 ARM sites, 10-20 NDSC sites	
Aerosol dry particle size	SMPS/APS 15nm-15µm	Daily or Weekly	Continuous	5 Ocean Sites	Need to add more sites
Aerosol chemical composition	ACN sites / Filter Analysis	Daily or Weekly	Continuous, if possible	34 sites	
Aerosol optical depth (0.38-1.0 µm)	AERONET - CIMEL	5 minutes	Continuous	Global, 60 sites	80 sites desired
Aerosol optical depth (0.38-4.0 µm)	AERONET - CIMEL+	5 minutes	Continuous		20 sites desired, globally distributed
Sky Radiance (0.38-1.0 µm)	AERONET - CIMEL	Hourly	Continuous	Global, 60 sites	80 sites desired
Sky Radiance (0.38-4.0 µm)	AERONET - CIMEL+	Hourly	Continuous		20 sites desired, globally distributed
Sky Radiance (2π steradians)	Instrument like - PARABOLA+	Hourly	Periodic		Periodic in conjunction aerosol sites
Temperature profile	Radiosondes & Lidars at ARM & NDSC sites	Daily or more	Continuous	3 ARM sites, 10-20 NDSC sites	
H_2O profile	Radiosondes & Lidars at ARM & NDSC sites	Daily or more	Continuous	3 ARM sites, 10-20 NDSC sites	

Table 2. - Continued.

Parameter	Programs and Instruments	Sampling Frequency	Sampling Period	Existing sites-Areal extent/ distribution	Comments
CO (surface) CH_4 (surface)	Flask samples at CMDL & collaborator sites	Daily	Continuous	44 Land sites 24 Ocean sites	Existing
CO (profile) CH_4 (profile)	Automated flask system at CMDL & ARM sites Laser heterodyne at NDSC sites	Daily, for campaigns Twice weekly	Continuous	Currently at 2 CMDL sites	Existing, need to add more (~ 50) at CMDL & ARM sites
CO (column) CH_4 (column)	FTIR at ARM & NDSC sites	Daily, for campaigns Twice weekly	Continuous	3 ARM sites 10-20 NDSC sites	Existing, need to get ARM & NDSC data routinely, also need to add more sites at high altitudes
Ozone (profile & column)	Ozondesondes at ARM & NDSC sites Ozone lidar & Dobson at NDSC sites	Daily, for campaigns Weekly	Continuous	3 ARM sites 10-20 NDSC sites	Existing, need coordination with ARM & NDSC
NO_2 (profile)	UV/visible spectrometer at NDSC sites	Daily, for campaigns Weekly	Opportunity	10-20 NDSC sites	Existing, need coordination with NDSC
Clouds (fraction, height, cloud top temperature)	Lidars, radars, all-sky imagers, & AERI at ARM sites	Daily, more often during validation campaigns	Opportunity	3 ARM sites	Existing, also possible opportunities at NDSC sites. Need further discussion with NDSC.

DOE/ARM Sites

DOE/ARM sites with existing aerosol and meteorological capabilities and enhanced measurement capabilities for CO, CH_4, and O_3 by using the CMDL automated flask system and surface trace gas samplers were identified as comprehensive sites for algorithm and geophysical data products validation. Aircraft overflights over ARM sites are very important, and EOS AM-1 coordinated aircraft campaigns should be planned.

<u>Site Locations:</u> Southern Great Plains (SGP) site in Oklahoma (mid-latitude, continental)
Tropical Western Pacific (TWP) site (tropical)
North Slope of Alaska (NSA) site (polar)

<u>Site Types:</u> Comprehensive sites

<u>Objectives:</u>
(1) Algorithm validation
- MOPITT CO and CH_4 retrieval algorithm validation
- MOPITT cloud clearing algorithm validation
- MODIS aerosol retrieval algorithm validation
- MODIS total ozone retrieval algorithm validation

(2) Geophysical Products Validation
- MOPITT CO profile
- MOPITT CO column
- MOPITT CH_4 column
- MODIS & MISR aerosol optical depth
- MODIS water vapor total column
- MODIS cloud height and cloud top temperature
- SAGE III upper troposphere H_2O profile
- SAGE III upper troposphere aerosol
- SAGE III upper troposphere O_3

<u>Measurement Requirements:</u>
(1) Aerosol optical depth (MODIS, MISR, MOPITT)
(2) Temperature profile (MODIS, MISR, MOPITT, SAGE III)
(3) H_2O profile (MODIS, MISR, MOPITT, SAGE III)
(4) O_3 profile (MODIS, MOPITT, SAGE III)
(5) Cloud fraction & height (MODIS, MOPITT, MISR, SAGE III)
(6) CO, CH_4, CO_2 profiles (MODIS, MOPITT, SAGE III)
(7) Spectral sky radiance
(8) Aerosol scattering coefficient
(9) Dry particle size

<u>Instrument Requirements:</u>
(1) Radiosonde, microwave radiometer, Raman lidar for temperature and H_2O profiles.
(2) Ozonesondes for O_3 profiles.
(3) AERONET & AEROCE extension for aerosols.
(4) NOAA/CMDL surface and automated flask system for CO, CH_4 , CO_2 profiles (NOAA/CMDL extension).
(5) Cloud lidar and all-sky imager for cloud fraction and cloud heights.

(6) PARABOLA-like instrument (2 π steradian).
(7) At ARM sites - AERI (Atmospheric Emitted Radiance Interferometer) and SORTI (Solar Radiance Transmittance Interferometer) instruments for CO, CH_4, O_3, H_2O total column retrieval.

NOAA/CMDL Cooperative Flask Sample Network

The NOAA/CMDL Cooperative Flask Sampling Network, about 60 sites worldwide, with profiling capability at most, if not all sites, by using the automated flask sampling system and small airplanes were identified as long-term sites for geophysical products validation and correlative measurements. We strongly encourage the early implementation of the trace gas measurement program with automated flasks and small airplanes proposed by the Carbon Cycle Group of the NOAA/CMDL.

Site Locations: There is a total of 44 land sites and 24 sites on commercial ships. The exact locations of these sites and the cooperating agencies are listed in Table 3. Some explanations are needed for the sites on commercial ships. In the Pacific Ocean, samples are taken on two ships every five degrees in latitude from nominally 45 N to 40 S, therefore the Pacific Ocean ships are counted as 16 sites. In the South China Sea, a third ship acquires samples every 3 degrees in latitude from 3 N to 21 N, which is accounted for as 7 sites. The Baltic Sea site is an ocean site. Therefore, the ocean sites add up to 24 (Michael Trolier, *personal communication*, 1996).

Site Types: Long-term sites

Objectives: (1) Geophysical Products Validation
MOPITT CO profile
MOPITT CO column
MOPITT CH_4 column
MODIS & ASTER CO_2 profile (at least 2 levels)
MODIS & MISR CO, CO_2 for correlation with aerosols

Measurement Requirements:
(1) Temperature profile measurements (MODIS, MOPITT, SAGE III).
(2) H_2O profile measurements(MODIS, MOPITT, SAGE III).
(3) CO, CH_4, CO_2 profile measurements (MODIS, MOPITT).
(4) Surface CO, CH_4, CO_2, measurements (MODIS, MOPITT).

Instrument Requirements:
(1) Radiosondes for temperature and H_2O profiles measurement.
(2) Surface flask sample for CO, CH_4 , CO_2 measurement.
(3) CMDL automated flask system on small airplanes for CO, CH_4, CO_2 profiles measurement. Currently there is profiling capability at only two sites. We need to expand this capability to more sites as part of the AM-1 validation activities. The small airplanes can also be equipped with aerosol measurement instruments for MODIS and MISR aerosol validation.

Table 3. - NOAA/CMDL Cooperative Flask Sampling Network.

Location (country)	Lat/Long	Cooperating organization	Operational date
Albert, N.W. T. (Canada)	82.45 N / 62.52 W	Environmental Canada/ Atmospheric Environment Service	JUN 1985
Ascension Island, Atlantic Ocean (U. K.)	7.92 S / 14.42 W	DOD/USAF and Pan American World Airways	AUG 1979
Assekrem, Algeria (Algeria)	23.18 N / 5.42 E	Tamanrasset GAW Observatory	SEP 1995
Terceira Island, Azores (Portugal)	38.77 N / 27.38 W	Instituto Nacional de Meteorologia e Geofisica	OCT 1994
Baltic Sea (Poland)	55.50 N / 16. 67 E	MIR, Sea Fisheries Institute	SEP 1992
St. David's Head, Bermuda (U. K.)	32.37 N / 64.65 W	Bermuda Biological Station	FEB 1989
Southhampton, Bermuda (U.K.)	32.27 N / 64.88 W	Bermuda Biological Station (AEROCE)	May 1989
Barrow, Alaska (U.S.A.)	71.32 N / 156.60 W	NOAA/Environmental Research Laboratory (CMDL Observatory)	APR 1971
Black Sea, Constanta (Romania)	44.17 N / 28.68 E	Romania Marine Research Institute	OCT 1994
Cold Bay, Alaska (U.S.A.)	55.20 N / 162.72 W	NOAA/ National Weather Service	AUG 1978
Cape Grim, Tasmania (Australia)	40.68 S / 144.68 E	CSIRO, Division of Atmospheric Research	APR 1984
Christmas Island, Pacific Ocean (Kiribati)	1.70 N / 157.17 W	Scripps Institution of Oceanography	MAR 1984
Cape Meares, Oregon (U.S.A.)	45.48 N / 123.97 W	Oregon Graduate Institute of Science and Technology	MAR 1982
Crozet, Indian Ocean (France)	46.45 S / 51.85 E	Centre des Faibles Radioactivities/TAAF	MAR 1991
Easter Island, PacificOcean (Chile)	29.15 S / 109.43 W	Direccion Meteorologica de Chile	JAN 1994

Table 3. - NOAA/CMDL Cooperative Flask Sampling Network. CONTINUED

Location (country)	Lat/Long	Cooperating organization	Operational date
Guam, Mariana Islands (U. S. A.)	13.43 N / 144.78 W	University of Guam/ Marine Laboratory	SEP 1978
Dwejra Point, Gozo (Malta)	36.05 N / 14.18 E	Ministry of Environment, PCCU	OCT 1993
Halley Bay, Antarctica (U.K.)	75.67 S / 25.50 W	British Antarctic Survey	JAN 1983
Hegyhatsal (Hungary)	46.97 N / 16.38 E	Hungarian Meteorological Service	MAR 1993
Storhofdi, Heimaey, Vestmannaeyjar (Iceland)	63.25 N / 20.15 W	Iceland Meteorological Service	OCT 1992
Grifton, North Carolina (U. S. A.)	35.35 N / 77.38 W	WITN Television	JUL 1992
Tenerife, Canary Islands (Spain)	28.30 N / 16.48 W	Izana Observatory	NOV 1991
Key Biscayne, Florida (U. S. A.)	25.67 N / 80.20 W	NOAA/ Environmental Research Laboratory	DEC 1972
Cape Kumukahi, Hawaii (U. S. A.)	19.52 N / 154.82 W	NOAA/Environmetal Research Laboratory	JAN 1971
Park Falls, Wisconsin (U. S. A.)	45.93 N / 90.27 W	Wisconsin Educational Communications Board	NOV 1994
Mould Bay, N.W.T. (Canada)	76.25 N / 119.35 W	Environmental Canada/ Atmospheric Environment Service	APR 1980
Mace Head, County Galway (Ireland)	53.33 N / 9.9 W	University College Atmospheric Research Station (AEROCE)	JUN 1991
Sand Island, Midway (U. S. A.)	28.22 N / 177.37 W	DOD/ U. S. N.	MAY 1985
Mauna Loa, Hawaii (U. S. A.)	19.53 N / 155.58 W	NOAA /Environmental Research Laboratory (CMDL Observatory)	AUG 1969
NIWOT Ridge, Colorado (U. S. A.)	40.05 N / 105.58 W	University of Colorado/ INSTAAR	MAY 1967

Table 3. - NOAA/CMDL Cooperative Flask Sampling Network CONTINUED

Location (country)	Lat/Long	Cooperating organization	Operational date
Palmer Station, Antarctica (U. S. A.)	64.92 S / 64.00 W	National Science Foundation	JAN 1978
Qinghai Province (China)	36.27 N / 100.92 E	Chinese Academy of Meteorological Sciences	AUG 1990
Ragged Point, St. Phillips Parish (Barbados)	13.17 N / 59.43 W	University of Bristol (P. Simmonds)	NOV 1987
Mahe Island (Seychelles)	4.67 S / 55.17 E	DOD/USAF	JAN 1980
Bird Island, S. Georgia, Atlantic Ocean (U. K.)	54.00 S / 38.05 W	British Antarctic Survey	FEB 1989
Shemya Island, Alaska (U. S. A.)	52.72 N / 174.10 E	DOD/USAF	SEP 1985
Tutuila, American Samoa (U. S. A.)	14.25 S / 170.57 W	NOAA/Environmental Research Laboratory	JAN 1972
South Pole, Antarctica (U. S. A.)	89.98 S / 24.80 W	(CMDL Observatory)/ NSF	JAN 1975
Atlantic Ocean (Polarfront) (Norway)	66.00 N / 2.00 E	Norway Meteorological Institute (Ocean Station "M")	MAR 1981
Syowa Station, Antarctica (Japan)	69.00 S / 39.58 E	Upper Atmospheric and Space Laboratory, Tohoku University	JAN 1986
Tae-ahn Peninsula (Korea)	36.73 N / 126.13 E	Korea National University of Education	NOV 1990
Tierra Del Fuego, La Redonda Isla (Argentina)	54.87 S / 68.48 W	Servicio Meteorologico Nacional	SEP 1994
Wendover, Utah (U. S. A.)	39.90 N / 113.72 W	National Weather Service	MAY 1993
Ulaan Uul (Mongolia)	44.45 N / 111.10 E	Mongolian Hydrometeorological Research Institute	JAN 1992
Sede Boker (Negev Desert) (Israel)	31.13 N / 34.88 E	Weizmann Institute of Science	NOV 1995

Table 3. - NOAA/CMDL Cooperative Flask Sampling Network. CONTINUED

Location (country)	Lat/Long	Cooperating organization	Operational date
Ny-Alesund, Svalbard (Norway/Sweden)	78.90 N / 11.88 E	Zeepelin Station/Univ.of Stockholm Meteorological Institute	FEB 1994
Pacific Ocean ships	40 S to 45 N	Blue Star Line, Ltd.	DEC 1986
SCS South China Sea ships	3 N to 21 N	Chevron	JUL 1991

AERONET & University of Miami Aerosol Network

The AERONET (Aerosol Sunphotometer Network) and University of Miami Aerosol Network sites, with enhanced measurement capability by including instruments to measure the upward and downward angular distribution of radiance at the surface, were identified as long-term sites for geophysical products validation and correlative measurements. The University of Miami conducts aerosol measurements at two types of networks: the Aerosol Chemistry Network (ACN) and the Atmosphere/Ocean Chemistry Experiment (AEROCE).

<u>Site Locations:</u> AERONET has about 60 sites, and the University of Miami has about 56 sites. Locations and status of these sites are listed in Tables 4.1-4.3 for AERONET and Tables 5.1-5.2 for the University of Miami ACN and AEROCE sites. Measurements at the ACN sites consist of high-volume filter samples, with filters changed daily or weekly. The AEROCE sites have a more-comprehensive data set including continuous measurement of some gases, e.g., CO and O_3; a wide range of species in the aerosol and precipitation phases (non-sea-salt $SO_4^{=}$, NO_3^{-}, NH_4^{+}, sea-salt components, and several sources tracers); and aerosol physical properties including aerosol size, aerosol light scattering (nephelometer) and aerosol light absorption (aethalometer).

<u>Site Types:</u> Long-term/limited focus sites

<u>Objectives:</u> (1) Algorithm validation

MODIS particle size retrieval algorithm validation

MODIS & MISR dry aerosol size distribution (3 nm - 15 μm) retrieval algorithm

MODIS & MISR aerosol scattering/extinction ω_0 retrieval algorithm

(2) Geophysical products

MISR aerosol optical depth

MODIS aerosol optical depth (0.3 - 1.0 μm)

MODIS aerosol chemical composition

MODIS H_2O total column

<u>Measurement requirements:</u>

(1) Aerosol optical depth (0.3-1.0 μm) & dry particle size (MODIS, MISR)
(2) Aerosol optical depth (0.3-4.0 μm) & dry particle size (MODIS)
(3) Aerosol optical composition (MODIS)
(4) H_2O total column (MODIS)
(5) Dry aerosol size distribution (MODIS, MISR)
(6) Aerosol scattering/extinction (MODIS, MISR)
(7) Spectral sky radiance

<u>Instrument Requirements:</u>

(1) multi-wavelength sunphotometer with shadowband for aerosol optical depth & sky radiance
(2) multi-wavelength sunphotometer for H_2O total column
(3) High volume filter for aerosol chemical composition

(4) SMPS-APS for dry aerosol size distribution
(5) Nephelometer/aethalometer for aerosol scattering/extinction
(6) Need to extend AEROCE to other aerosol and chemistry networks, such as the NOAA/CMDL Cooperative Flask Sample Network
(7) multi-spectral sunphotometers for extended spectral range optical depth & sky radiance

Table 4. - AERONET Sites.

Table 4.1 - Permanent AERONET sites.

Site Name	Longitude	Latitude	Elevation
Tucson, Arizona	-110.95	32.23	779
NASA GSFC, MD	-76.88	39.03	50
NASA Wallops, VA	-75.47	37.94	10
Waskesiu, Canada	-106.08	53.92	550
Sevilleta, New Mexico	-106.89	34.35	1477
ARM SGP Site, Okla.	-97.41	36.61	315
Mauna Loa, Hawaii	-155.58	19.54	3397
Bondoukoui, Africa	-3.75	11.85	0
Bibi Bahn, Africa	-2.45	14.06	0
Lille, France	3.14	50.61	60
Cape Verde	-22.94	16.73	60
Quagadougou, Africa	-1.40	12.20	0
Sede Boker, Israel	34.47	30.52	0
El Refugio, Bolivia	-62.03	-14.77	225
Banizoumbou, Niger	2.66	13.54	0
Lanai, Hawaii	-156.98	20.25	80
Bermuda	-64.70	32.37	10
Dry Tortugas, Florida	-82.80	24.60	0
Ascension Island	-14.41	-7.98	30
Barbados	-60.00	13.00	0
La Reunion Island	55.50	-20.00	0
Catalina Island	-119.00	34.00	0
Guadeloupe Island	-58.50	16.00	0
Lampedusa Island	12.62	35.52	0
Aire Adour, France	-0.25	43.70	0

Table 4.2 - AERONET seasonal sites.

Site Name	Longitude	Latitude	Elevation
Cuiaba, Brazil	-56.00	-15.50	250
Alta Floresta, Brazil	-56.02	-9.92	175
Brasilia, Brazil	-47.90	-15.92	1100
BOREAS NSA YJP	-98.29	55.90	290
Flin Flon, Canada	-101.69	54.67	305
BOREAS SSA YJP	-104.65	53.67	490
Prince Albert, Canada	-105.70	53.20	425
Bonanza Creek, AK	-148.32	64.74	150
HJ Andres, Oregon	-122.22	44.24	830
Wisconsin	-89.65	46.05	463
McMurdo, Antarctica	162.88	-77.63	75
Mongu, Africa	23.00	-15.50	500

Table 4.3 - AERONET future sites.

Site Name	Longitude	Latitude	Elevation
Lamto, Africa	-5.03	6.21	0
Falkand Islands	-58.00	-51.75	0
Tahiti	-149.00	-17.00	20
Male, Maldives	74.00	5.00	20
New Caledonia	165.00	-21.00	0
Barrow, AK	-156.50	71.20	0
Manus Is., Papua New Guinea	147.00	-2.00	0
Galapagos Island	-90.00	-0.80	0
Tromelin Island	54.50	-16.00	0
Eddy Stone Island	-4.00	50.00	0
Tenerife, Canary Is.	-16.00	28.00	0
Dakar, Africa	-17.00	15.00	0
Niigata, Japan	139.00	38.00	0
Okinawa, Japan	128.00	25.50	0
Crete	25.00	35.00	0
Taipei, Taiwan	121.50	24.00	0
Nagasaki, Japan	130.00	32.50	0

Table 5. University of Miami Aerosol Network Sites for the Aerosol Chemistry Network (ACN) and the Atmosphere/Ocean Chemistry Experiment (AEROCE).

Table 5.1 - ACN and AEROCE Sites in the Northern Hemisphere.

Lat	Long	Station	State	Country	Status	Start	Stop	ACN Daily Filter (D) Weekly Filter(W)	AEROCE shown as * All Daily
63.77	-171.75	Gambell	Alaska	USA	Inactive	1986	1989	W	
63.40	-20.30	Heimaey		Iceland	OK	1991	Present	D	*
53.32	-9.85	MaceHead		Ireland	OK	1988	1994	D	*
52.92	174.06	Shemya	Alaska	USA	OK	1986	Present	W	
42.80	-109.80	Pindale	Wyoming	USA	OK	1995	Present	W	
39.50	-31.22	Flores	Azores	Portugal	Pending				
38.75	-27.31	Terceira	Azores	Portugal	Pending				
37.67	58.33	Geokoha		Turkmanistan	OK	1994	Present	W	
33.52	126.48	Cheju		Korea	OK	1991	Present	W	
32.35	-64.65	David's Head		Bermuda	OK	1992	Present	D	*
32.27	-64.87	Tudor Hill		Bermuda	OK	1988	Present	D	*
30.16	119.43	Lin'an	Jiangsu	China	OK	1994	Present	W	
28.57	-16.30	Pta Hidalgo	Tenerife	Canary Is Spain	OK	1995	Present	D	*
28.30	-16.50	Izana	Tenerife	Canary Is Spain	OK	1975	Present	D	*
28.22	-177.35	Midway		USA	OK	1981	Present	W	
26.92	128.25	Hedo	Okinawa	Japan	OK	1991	1994	W	
25.75	-80.25	Miami	Florida	USA	OK	1974	Present	D	*
23.39	120.93	Yu Shan	Jade Mtn	Taiwan	Pending				
21.87	120.87	O-luan-pi		Taiwan	Inactive				
21.33	-157.70	Oahu	Hawaii	USA	OK	1981	Present	W	
21.06	121.32	Lanyu	Hung t'ou Hsu	Taiwan	OK	1991	Present	W	
17.48	144.80	Guam		USA	Inactive	1981	1982		
16.78	-22.90	Sal		Cape Verde ls	Pending	1996			
13.17	-59.43	Ragged Point		Barbados	OK	1972	Present	D	
11.33	162.33	Eniwetak		USA	Inactive	1981	1987		
7.33	134.48	Belau		Palau Islands	Inactive	1981	1983		
4.92	-52.30	Cayenne	Fr. Guiana	France	Inactive	1977	1979	W	
4.00	73.47	Male		Maldives	Pending	1996			
3.92	-159.33	Fanning		Fanning	Inactive	1981	1986		

Table 5.2 - ACN and AEROCE Sites in the Southern Hemisphere.

Lat	Long	Station	State	Country	Status	Start	Stop	ACN Daily Filter (D) Weekly Filter (W)	AEROCE shown as * all Daily
-0.50	-90.50	Galapagos		Ecuador	Approved				
-0.52	166.93	Nauru		Nauru	Inactive	1983	1988		
-8.50	179.20	Funafuti	Tuvalu	Kiribati	Inactive	1983	1987		
-14.25	-170.58	Am.Samoa		USA	OK	1983	Present	W	
-17.97	122.23	Broome		Australia	Inactive	1979	1984		
-21.17	55.83	Reunion		France	OK	1990	Present	W	
-21.25	-159.75	Rarotonga		Cook Is	OK	1983	1994	W	
-22.15	167.00	Yate		New Caledonia	Inactive	1983	1985		
-26.22	27.75	Pretoria		South Africa	OK	1990	Present	W	
-29.08	167.98	Norfolk (inland)		Australia	OK	1983	Present	W	
-29.08	167.98	Norfolk (coast)		Australia	OK	1983	Present	W	
-31.93	115.83	Rollystone		Australia	Inactive	1983	1987	W	
-31.93	115.83	Perth		Australia	OK	1987	Present	W	
-33.80	18.47	CapeTown		South Africa	OK	1992	Present	W	
-40.68	144.68	Cape Grim		Australia	OK	1983	Present	W	
-41.25	172.12	Karamea		New Zealand	Inactive	1986	1990	W	
-41.28	174.78	Wellington	Lower Hutt	New Zealand	Inactive	1987	1993	W	
-41.42	174.87	Baring Head		New Zealand	OK	1993	Present	W	
-43.60	37.95	Prince Edward Is		South Africa	OK	1992	Present	W	
-43.92	-176.5	Chatham Is		New Zealand	OK	1983	Present	W	
-46.43	168.35	Invercargill		New Zealand	OK	1983	Present	W	
-51.75	-60.00	Mt. Pleasant	Falklands	Great Britain	OK	1987	Present	W	
-52.50	169.03	Campbell Is		New Zealand	Approved				
-54.48	158.97	Macquarie		New Zealand	Approved				
-62.18	-58.30	King George	Antarctica	Argentina	OK	1990	Present	W	
-64.77	-64.05	Palmer	Antarctica	USA	OK	1990	Present	W	
-67.60	62.50	Mawson	Antarctica	Australia	OK	1987	Present	W	

NDSC

The NDSC (Network for Detection of Stratospheric Change) sites with Fourier Transform Infrared spectrometers (FTIR), microwave radiometers, laser heterodyne spectrometers, UV/visible spectrometers, and lidars were identified as long-term sites for geophysical products validation and correlative measurements. (http://climon.wwb.noaa.gov/)

Site Locations: There are currently 14 sites with FTIR instruments, some of which also have lidars. The site locations, instruments, and operation status are listed in Tables 6.1-6.2 (William Mankin, *personal communication*, 1996).

Site Types: Long-term sites

Objectives: (1) Geophysical products validation

- MOPITT total column CO
- MOPITT total column CH_4
- MODIS total column O_3
- MODIS total column H_2O
- MODIS aerosol extinction
- SAGE III upper troposphere and stratosphere temperature
- SAGE III upper troposphere and stratosphere H_2O
- SAGE III upper troposphere and stratosphere O_3
- SAGE III upper troposphere and stratosphere NO_2
- SAGE III upper troposphere and stratosphere aerosol

Measurement requirements:

(1) CO total column (MOPITT)
(2) CH_4 total column (MOPITT)
(3) O_3 profile (MODIS, SAGE III)
(4) Temperature profile (MODIS, SAGE III, MOPITT)
(5) H_2O profile (MODIS, SAGE III, MOPITT)
(6) NO_2 profile (SAGE III)
(7) Aerosol profile

Instrument requirements:

(1) FTIR for CO, CH_4, O_3, total column retrieval
(2) Laser heterodyne system for vertical profiles of O_3, NO_2 , and CH_4
(3) Ozone lidar for O_3 profile
(4) Aerosol lidar
(5) Lidar for temperature
(6) Radiosondes & Ozonesondes for temperature, H_2O, and O_3 profile

Table 6. - Network for Detection of Stratospheric Change (NDSC) Sites with Fourier Transform Infrared (FTIR) Spectrometers.

Table 6.1 - Primary NDSC Sites with FTIR Instruments.

Site Name	Lat. / Long.	Instruments & Status	MOPITT Validation Activities
Eureka, Canada	80.0 N / 86.4 W (Arctic station)	Bomem DA8 FTIR Deployed at Eureka in February 1993. Ozone and aerosol lidars.	CO and CH_4 total column from FTIR measurements
Ny Alesund, Spitsbergen	78.5 N / 11.9 E (Arctic station)	Bruker 120M FTIR with 0.0035 cm^{-1} resolution. Solar & lunar (polar night) obs. Also, ozone and aerosol/ temperature lidars.	CO and CH_4 total column from FTIR measurements
Thule, Greenland	76.05 N / 68.8 W (Arctic station)	Bomem 120M FTIR to be installed by late summer 1996. Also, aerosol/temperature lidar.	CO and CH_4 total column from FTIR measurements
Jungfraujoch	47.0 N / 8.0 E (Alpine station)	Mobile Bruker FTIR instrument used primarily for intercomparisons and campaigns.	CO and CH_4 total column from FTIR measurements
Jungfraujoch	47.0 N / 8.0 E (Alpine station)	Two FTIR instruments since 1984 (0.0025 cm^{-1}) and 1990 (0.001 cm^{-1}). Limited database extends back to 1977.	CO and CH_4 total column from FTIR measurements
Mauna Loa/ Mauna Kea	19.0 N / 115.6 W (Hawaii station)	Automated Bruker FTIR installed in August 1995. Also, ozone & aerosol/ temperature lidars.	CO and CH_4 total column from FTIR measurements
Lauder, New Zealand	45.05 S / 169.7 W	Bruker 120M with 0.0035 cm^{-1} resolution since Sept.1990. Also, ozone & aerosol lidars.	CO and CH_4 total column from FTIR measurements
Arrival Heights	78.0 S / 166.0 E (Antarctic station)	A permanent FTIR (Econ with 0.03 cm^{-1} resolution) was installed in early 1991 and will be upgraded to a Bruker 2 in October 1996.	CO and CH_4 total column from FTIR measurements

Table 6.2 - Secondary NDSC Sites with FTIR Instruments.

Site Name	Lat. / Long.	Instruments & Status	MOPITT Validation Activities
Harestau, Sweden	60.0 N / 10.0 E	Bruker 120M FTIR. Intercompared with NPL mobile unit in September /October 1994.	CO and CH_4 total column from FTIR measurements
Zugspitze	47.48 N / 11.06 E	Bruker FTIR (0.002 cm^{-1}) operating from in 1993 as part of Environmental High Altitude Observatory. Also, aerosol/temperature lidar.	CO and CH_4 total column from FTIR measurements
Table Mountain	37.6 N / 118.2 W	MkIV interferometer beginning in late 1996 or early 1997. Also, O_3 and aerosol/temp. lidars.	CO and CH_4 total column from FTIR measurements
Toyokawa, Japan	35.0 N / 137.0 E	Bruker 120M (0.0035 cm^{-1}) FTIR. Operating from December 1994 to April 1995. Moved to Rikubetsu in July 1995.	CO and CH_4 total column from FTIR measurements
Kitt Peak Observatory	32.0 N / 111.5 W	Continuous record of IR solar spectra using FTIR (0.005 cm^{-1} resolution) from 1976.	CO and CH_4 total column from FTIR measurements
University of Wollongong	34.4 S / 150.9 E	Bomem DA3 spectrometer at the University of Wollongong since December 1994.	CO and CH_4 total column from FTIR measurements

Report of the Vicarious Calibration Group
Jim Butler and Phil Slater

Introduction

The meetings of the Calibration Breakout Group occurred during the afternoon of Monday, March 18 and the morning of Tuesday, March 19. The meeting discussions for each day are outlined below.

Meeting Discussions on March 18:

This first meeting immediately followed the morning's plenary session at which Chris Justice instructed the breakout group to address the following charges:

1. Design and scope the required/desired EOS Test Site activity to meet EOS investigator data needs (where possible building on on-going and planned activities);

2. Determine appropriate measurement packages suited to multiple products and instruments (types and frequency of measurements, instrumentation, and number and distribution of measurement sites).

Attendees of the initial meeting of the Calibration Breakout Group included:

Phil Slater, U. of Arizona - Group Chair
Jim Butler, NASA/GSFC - Rapporteur
Richard Barbieri, GSC/MCST
Jim Conel, JPL/MISR
Bruce Guenther, NASA GSFC/MCST
Brian Markham, NASA GSFC/Landsat
Frank Palluconi, JPL/ASTER
Jim Storey, Landsat

The discussion of the first charge began with a clear statement of the goal of vicarious calibration at calibration test sites, namely to predict top of the atmosphere (TOA) radiances in the spectral bands of sensors and to validate the geometric registration of sensor radiometric scenes. A list of some candidate calibration test sites for predicting TOA radiances was presented by Phil Slater. Each test site was examined with respect to its use by EOS instruments and its calibration benefits and liabilities. Table 7 summarizes the test sites and the discussions on each.

It was noted that the sites in Table 7 have no permanently operating instrumentation. Test sites with permanently operating instrumentation were briefly considered, for example, the DOE/ARM SGP site in Oklahoma. However, the spatial heterogeneity of the test site land would make it very difficult to perform meaningful ground reflectance measurements. A proposal was made to examine the possibility of placing some permanent instrumentation at the vicarious calibration sites of Table 7. Candidate instrumentation could include sunphotometers and a radiometer measuring ground spectral reflectance relative to a diffuse panel with known reflectance. The group believed that this could be accomplished at a modest cost, i.e. approximately $100 K.

Table 7. Candidate Radiometric Sites.

Radiometric Test Site	EOS Instruments	Advantages	Disadvantages
Lunar Lake, NV	ASTER Landsat MODIS (250 & 500 m) MISR	-elevation -spatially and spectrally uniform in the VNIR/SWIR -good site for small footprint sensors	-untested in the TIR
Railroad Valley, NV	ASTER Landsat MODIS MISR	-good site for cal. and cross-cal. -spectrally uniform -good site for large footprint sensors	-unproven for sensor calibration particularly of 1km GIFOV, for which it may be best suited
Lake Tahoe, CA & NV	ASTER MODIS Landsat	-good site for TIR cal. and cross-cal. -could provide low rad. cal. in the VNIR/SWIR -site of interest to ATSR	-as yet unproven but calibration campaigns are planned for 1996-1997
White Sands, NM	ASTER Landsat	-good Lambertian site for VNIR	-questionable source for SWIR because of gypsum surface -untested in TIR - spatial uniformity over 1km GIFOV questionable -accessibility problems
Edwards A.F.B., CA		-spatially and spectrally uniform in the VNIR/SWIR -good site for small- footprint sensors	-accessibility problem -small and non-uniform site over 1 km GIFOV -low elevation -close to Los Angeles
Ivanpah Playa, CA		-spatially and spectrally uniform in the VNIR/SWIR -good site for small footprint sensors	-lower elevation than Lunar Lake and smaller in size

VNIR = Visible and near infrared
SWIR = Shortwave infrared
TIR = Thermal infrared
GIFOV = Ground instantaneous field of view
ATSR = Along-Track Scanning Radiometer

In accordance with Justice's first charge, the Calibration Breakout Group decided to use the upcoming May/June vicarious calibration comparison campaign at Railroad Playa and Lunar Lake, the first of its kind, as a guide to designing and scoping calibration test site activities. In accordance with Justice's second charge, the upcoming comparison campaign was also used by the group as a guide to determining the measurement types, number, distribution, and frequency, and the necessary instrumentation for future calibration test site activities. Regarding measurement packages, it was suggested that vicarious calibrations be performed with sun angles equivalent to a 10:30 a.m. equatorial crossing and at the times of both solstices and one equinox. This would enable comparisons to be made between radiance and reflectance-based methods for the range of incident solar angles to be encountered by the AM-1 platform instruments. The goal of the vicarious calibration campaigns is to produce three measurement data sets per day.

The frequency of field campaigns would be higher during the activation and evaluation (A&E) phases of the EOS AM-1 instruments, with an exact frequency determined by the behavior of the instruments and their on-board calibration systems.

Critical to the overall success of the vicarious calibration campaigns are the coordination of pre-campaign meetings to: (1) examine the calculation methods of the participating groups, e.g. radiometric bandpass calculations/corrections, atmospheric correction codes, etc.; (2) establish protocols for the measurement and reporting of results; and (3) perform laboratory calibration of participating instruments using common, well-characterized sources. It is expected that the need for such steps will be better understood as a result of the joint campaign in May/June 1996. The use of the sun for pre-comparison, in-field relative calibration of participating instruments was also proposed.

Frank Palluconi presented information on his plans for making thermal IR (TIR) measurements during the upcoming campaign at Railroad Valley and Lunar Lake. For the spring comparison, Simon Hook plans to make emissivity measurements of Railroad Valley in the 8-to-12 micron wavelength region at a spatial resolution of 100 m by 100 m. Hook hopes to determine the emissivity variation of the site in the TIR spectral range. Palluconi pointed out that Railroad Valley has been partially covered by the Thermal Infrared Multispectral Scanner (TIMS) instrument and completely covered by the MODIS Airborne Simulator. Palluconi stated that he will use these data to determine where they will make measurements during the comparison. It was stated that TIMS will overfly the site during the comparison.

The Calibration Breakout Group ended the session with a listing of instrumentation and measurements required for vicarious calibration campaigns. Table 8 outlines these instruments and the needed measurements.

Meeting Discussions on March 19:

The second meeting of the Calibration Breakout Group was held in the morning of March 19. The charge to the group was delivered by Chris Justice and included examining geometric calibration test sites, coordinating international participation in vicarious calibration, and examining test sites for thermal infrared calibration. Because of time limitations this last topic was not discussed.

Attendees of the second meeting of the Calibration Breakout Group included:

Phil Slater, U. of Arizona - Group Chair
Jim Butler, NASA GSFC - Rapporteur
Richard Barbieri, GSC/MCST
Jim Conel, JPL/MISR
Bruce Guenther, NASA GSFC/MCST
Brian Markham, NASA GSFC/Landsat
Hank Reichle, North Carolina State Uni./MOPITT
Jim Storey, Landsat

Geometric test sites were discussed with regards to the calibration of EOS AM-1 instrument footprints. In the case of the ASTER instrument, Hugh Kieffer was identified as the point of contact for details on ASTER geometric calibration. Candidate ASTER sites include Iowa road/field patterns and linear features such as bridges. In the case of the MODIS instrument, the MODIS Science Data Support Team was identified as the contact for details. Possible use of the edges of playas and lakes by MODIS was postulated. MODIS plans to characterize the instrument Modulation Transfer Function using its on-board radiometric calibrators and the Moon. The MISR instrument will possibly use playas/lakes/rivers and the Moon for geometric calibration. In the case of the Landsat instrument, the single point of contact is Jim Storey. Storey submitted a summary of Landsat geometrical test sites. Landsat characterizes its test sites into two types. Type I are high accuracy, dense control, i.e. Global Positioning System (GPS), test sites that are few in number. An example is the Iowa test site. Type I test sites are used to perform the following geometric calibration functions:

-characterize and calibrate the sensor alignment to the spacecraft attitude control system navigation base using ground control points;
-assess along-scan, i.e. scan-mirror profile, and across-scan, i.e. scan-line corrector-mirror profile, performance;
-assess band-to-band registration using high-frequency image content, i.e. road/field networks;
-assess detector-placement accuracy using strong edges in images.

Type II tests sites are of moderate accuracy and have less dense control, i.e., GPS or large-scale maps. These sites are distributed across the satellite central travel angles and exhibit strong edge content. Type II test sites are used to perform the following geometric calibration functions:

-characterize sensor alignment sensitivity to the time of exposure to the sun, i.e., temperature effects;
-monitor navigation/pointing-accuracy performance;
-monitor band-to-band registration using high-contrast edges.

The final topic addressed by the Calibration Breakout Group was the coordination of international groups interested in the vicarious calibration of satellite sensors. It was generally agreed by the group that CEOS and its working groups and subgroups in calibration and validation offer an opportunity to promote coordinated international comparison campaigns. Bruce Guenther offered a scenario for accomplishing these campaigns involving the initial establishment of a series of bilateral agreements for comparisons. Success in these bilateral comparisons potentially will lead to larger scale comparisons, provided that there is a shared, strong scientific interest among the international groups.

Table 8. Campaign Instruments[1] and Measurements.

Parameter	Instrumentation	Frequency per morning	Active Measurement Period per Calibration	Areal Extent
Radiance				
Top of atmosphere	Predicted by measurements & rad. trans. calcs	3	N/A	N/A
Surface	Aircraft[2] & surface	3	15 min.	center pixel of 2x2 or 3x3 uniform pixel area
Surface Properties				
Spectral reflectance	A/C & surface radiometer	3	15 to 45 min.	center pixel of 2x2 or 3x3 uniform pixel area
Spectral BRDF	BRDF radio-meter & camera	3	20 min.	2 or 3 areas?
Spectral emissivity	μFTIR			
Temperature	Thermocouple in buoys	3	10 min.	?
Atmospheric Properties				N/A
Spec. opt. dep. H_2O vapor, O_3 Aero. opt. dep., size dist., & Angstrom coef.	Solar radiometer (Reagan, CIMEL 3-band, SWIR)	Frequent repetitions during the morning of the campaign		
Phase Func. & Complex Index of Refraction	Diffuse/global Aureole camera almucantar scans			
General				
Tot. downward irradiance	Pyranometer all-sky camera			
Loss of signal angle	Narrow-field portable radiometer	3	15 min.	
Atmos. density, temperature, & rel. humidity	Met. station radiosonde	continuous 3	continuous	

[1] Not all the instruments listed will be available for the first campaign. However, most if not all will be available by the proposed second joint campaign in 1997 or the AM-1 launch in mid-1998.

[2] Aircraft: ASTER Airborne Simulator, AVIRIS, Cessna, TIMS
First campaigns May 30 to June 15, 1996. Repeat in 1997 but modified according to lessons learned in 1996. Results of campaigns should be reported in a timely fashion.

FINDINGS OF THE MEETING

The findings of the meeting incorporate results of both the discipline and the synergy breakout groups in terms of consensus on test site characteristics, measurement groups, test site classifications, measurement suites, and data management and standards.

Consensus on Test Sites Characteristics

The meeting revealed considerable overlap between the needs and approaches identified by different disciplines for test site characteristics in terms of homogeneity, diversity, synergy, ramp-up strategy, and locations.

Homogeneity: Measurements are needed from sites that are homogeneous over areas larger than the footprints of instruments to be validated; 4-9 km^2 appears minimal.

Diversity: Measurement streams should be acquired from a diversity of global land surface cover types and atmospheric conditions, paying special attention to vegetation structure and seasonality and encompassing the 6-10 basic surface types (biomes).

Synergy: Data acquisition will be most effective with respect to both cost and scientific value if data are acquired in synergy with other measurements and measurement programs.

Ramp-up Strategy: Instrument costs are substantial and there needs to be a balance struck between the amount and cost of instrumentation and the number of sites. The most costly (but most valuable) sites need to be expanded on an incremental basis as appropriate.

Locations: Some existing and planned measurement locations and instruments have already been identified at this meeting, including BOREAS tower sites, proposed LBA tower sites in Brazil, ARM sites, etc. and existing networks, such as AERONET, AEROCE, BSRN, SURFRAD, LTER, NDSC, Flask Sampling Network, IGBP Transects, IGBP-FLUXNET, etc. These capabilities should be utilized and enhanced by adding value wherever appropriate to provide new data streams with proper characteristics. Other well- instrumented, long-term monitoring sites that are well distributed in the primary climatic zones within the U.S. are the U.S. Department of Agriculture-Agricultural Research Service (USDA-ARS) Experimental Watersheds and the U.S. Geological Survey - WEBB (Water Energy and Biogeochemical Balance) sites.

Measurement Groups

The principal measurement groups are: Atmospheric Measurements, Radiation (including BRDF Radiometry), Chemistry, Vegetation Characteristics, and Hydrology.

Very little discussion was devoted to hydrology or existing watershed monitoring systems at this meeting. It was generally agreed that, in the future, additional emphasis will be needed to clarify the *in situ* data requirements for the hydrological aspects of the EOS platforms and program.

EOS Integrated Test Site Classifications

Discussions of classes of test sites were developed from existing concepts formulated by the Global Terrestrial Observing System (GTOS) and the MODIS and CERES Instrument Teams. The concept of a hierarchical system (in terms of tiers) was developed for EOS Test Sites based on the required functionality, distribution, and level of instrumentation. It was recognized that individual measurement programs will continue and will be of use to the EOS community. Emphasis here was given to integration of land and atmosphere measurements for EOS Validation with an emphasis on EOS products. In their deliberations, the breakout groups generated different categories of test sites that have been reorganized into the tier structure given below.

Tier 1 - Intensive Field Campaign Sites. These sites are developed as part of the International Intensive Field Campaign Program supported in part by NASA such as the International Satellite Land-Surface Climatology Project (ISLSCP) - First ISLSCP Field Experiment (FIFE), the Boreal Ecosystem-Atmosphere Study (BOREAS), the Global Tropospheric Experiment (GTE) - Transport and Chemistry near the Equator in the Atlantic (TRACE-A) experiment, the International Satellite Cloud Climatology Project (ISCCP) - First ISCCP Regional Experiment (FIRE), MONSOON'90 Walnut Gulch Campaign in the Semi-Arid Southwest U.S., and the planned Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA). The sites have comprehensive multi-disciplinary ground-based instrumentation and repeated aircraft and satellite coverage. The field campaigns are intensive, lasting a month to a season and sometimes spanning successive years. The campaigns have an experimental focus and there is a large cost to supporting the field activities. They have been located in major biomes or climate regions. The multidisciplinary nature of the research is usually stressed. Such campaigns will be very useful for EOS Validation. In the context of long-term measurements and time series analysis, it may be desirable to maintain one or two of these Tier 1 test sites as Tier 3 sites, as described below. The Tier 3 site would be established by extending certain measurements beyond the duration of the intensive field campaigns, taking advantage of the capital investment in the site infrastructure and providing the possibility of long-term monitoring. There will probably be around ten of these international campaigns during the entire life of the EOS program.

Tier 2 - Super Sites. These sites are designed for long-term monitoring with a central focus on establishing a full suite of radiation and flux measurements, including broadband and spectral radiation flux, continuous carbon dioxide, temperature/moisture sounding, cloud observations, aerosol optical thickness and absorbing property measurements, meteorological data, and surface characteristics data. Tall-tower measurements and the collocation of ground-based radar and cloud-lidar measurements are highly desirable at these sites. Aircraft data will also need to be acquired periodically at these sites. An example of this type of site is the DOE ARM SGP site. Given the full suite of measurements, it is unlikely that there will be more than 5 of these fully instrumented sites globally during the EOS timeframe. Currently, two additional sites are planned as part of this DOE ARM network (NSA and TWP). Interagency collaboration will be necessary to provide the full suite of instruments. International programs and participation may provide the means to increase the number of such sites.

Tier 3 - Biome Tower Sites. These sites will provide long-term monitoring using instrumented towers at locations representing major biomes. These sites will be less well instrumented than the Tier 2 Sites, but will be at a larger number of locations. The sites could include eddy-correlation tower measurements of carbon dioxide and water vapor fluxes, selected radiation measurements, aerosol optical thickness, vegetation structure and phenology, biomass, land-cover and land-use characterization, soil fluxes, and meteorology. Flask sampling of stable carbon isotopes will be a useful synergistic addition to these measurements. Site locations will represent major ecosystems and climatic regions. Emphasis will be given to process studies at these sites. An example is the Harvard Forest - Temperate Deciduous Forest Site. The BOREAS Thompson Site may also be continued to provide a long-term monitoring site in this category. The planned LBA Tower sites might also fall within this category. At present these sites have a strong bias towards the land community needs. The EOS Validation Program would benefit from the synergism resulting from collecting radiation and atmospheric data at these sites. Interagency coordination will be needed to increase the distribution of such sites. Internationally, there are already strong indications that a global network could be established, for example, through IGBP coordination. The IGBP FLUXNET will be an important step in this direction. With international participation there could be as many as 20-30 of these long-term sites in the EOS time frame.

Tier 4 - Globally Distributed Test Sites. These sites provide an extensive site network aimed at a broader and more global representation of surface land cover, radiation, and atmospheric conditions. The sites will be permanent, for example, the LTER network, the NOAA CMDL Flask Network, the BSRN/SURFRAD network, and the USDA-ARS Experimental Watersheds. These different networks are each currently focusing on specific measurement sets and communities. *Emphasis for EOS Validation will be to strengthen such networks by building multi-measurement components and to broaden the global extent of the sites.* Emphasis at these sites will be on surface and atmospheric characterization for a limited number of parameters, such as land cover, LAI, vegetation structure, surface radiation, and aerosol optical thickness**.** The primary purpose of these test sites for EOS will be global data product validation, e.g., land aerosols, atmospheric correction, land cover, LAI, and surface radiation data products. Of particular importance will be sites where a broad range of parameters will be addressed. Measurements may be continuous or may be taken at various intervals during the year and extend over a number of years. The sites will be used to capture seasonal and interannual variability and develop climatologies for the location. The instrumentation complement is likely to be less than at the Tier 2 and 3 sites; however, this will likely allow a greater number and much wider distribution of these sites. Occasional portable flux tower measurements may be possible. It may be that regional teams can be developed to provide consistent measurement and monitoring between these sites, which may, for example, fall along the IGBP Transects addressing ecology, hydrology, and atmospheric chemistry. Interagency and international cooperation will be needed to secure the network. However, interaction will be primarily between PIs. It is envisioned that there may be as many as 60 of these distributed, multi-instrument sites globally.

Tier 5 - Instrument Calibration Sites. A separate category of test sites is needed by EOS for instrument calibration. These sites will require unique properties of reflectance and emittance, with an emphasis on uniformity and, typically, a lack of vegetation. Examples of this category in the U.S. are the White Sands and Railroad Playa sites. There will be few test sites in this category (less than 5), and these sites will be well instrumented for vicarious calibration. It is recommended that international coordination between the various space agencies provide a network of these sites for use by multiple space-based platforms and instruments. Characterization of the atmosphere as well as the surface is critical. Aircraft overflights will be needed in association with the vicarious calibration campaigns. Geometric calibration sites were not discussed in any detail at this meeting, although it was recognized that an additional type of site may be needed for vicarious geometric calibration.

The role of EOS in the above activities will be to develop a network of sites to focus the EOS validation activities. *Emphasis will be given to augmenting existing networks with measurements needed to validate EOS data products rather than developing new networks.* Interagency and international coordination will be essential to developing the necessary global representation. The large number of *in situ* data collection programs currently in place and the apparent overlap with EOS objectives makes coordination a high priority. The spatial scale of the satellite data will place stringent needs for spatial sampling at the sites, and considerable emphasis will be needed in developing the appropriate methodologies. Coordination of aircraft overflights at the sites is needed.

Measurement Suites

Individual measurements identified for different instruments and disciplines were grouped into the following examples of measurement suites which indicate synergy between measurements.

"A" Measurements: Baseline, long term

- Aerosol characteristics -- Sunphotometers, e.g., the French CIMEL+ instrument or Multi-Filter Rotating Shadowband Radiometer (MFRSR)
- Broadband radiant fluxes, up and down, shortwave and longwave
- Spectral radiant fluxes, up and down, shortwave and longwave (Cost-limited)
- Tropospheric CO profile
- O_3, CO, and CH_4 in column
- Simple meteorological and precipitation data
- Uncalibrated TV cameras looking up and down to show site and sky conditions.
- Basic site characteristics (DEM, etc.)

"B" Measurements: Baseline, episodic

- Vegetation Index, LAI, FPAR, cover fractions, canopy structure, phenology, etc.

"C" Measurements: Enhancements, episodic (specific focus, rotating from site to site, and acquiring data for 3-6 month periods at a site)

- Temperature sounder
- Water sounder
- Directional radiance/reflectance measurements in SW and LW bands (Cost-limited)
- Tropospheric CO, CH_4, O_3 profile
- O_3, CO, and CH_4 in column
- Aerosol size distribution
- Cloud lidar
- Cloud radar

"D" Measurements: Aircraft measurements

Directional reflectance -- e.g., ASAS (Advanced Solid-State Array Spectrometer), MISR airborne simulator, and TIMS for boundary conditions
CO, CH_4, CO_2, O_3, etc., profiles
Aerosols, fluxes, etc.
Tropospheric CO profile

"E" Measurements: Desirable enhancements
Sensible and latent heat fluxes
Gas fluxes
NPP

These measurement suites provide an example of how different measurements might be grouped. Further work will be needed to develop the appropriate combined-measurement packages and measurement frequencies associated with the previously defined site tier structure.

Data Management and Standards

EOS test site data will need careful management to ensure open and timely availability, ease of accessibility, and archiving. Within the EOS Data and Information System (EOSDIS) Distributed Active Archive Center (DAAC) system, the Oak Ridge DAAC is currently responsible for field data and, for example, the DOE-funded ARM Data Archive is located at Oak Ridge. Test site data are also well suited to Principal Investigator (PI)-generated data systems using internet or CD-ROM distribution. The federated system currently being developed for EOSDIS might be well suited to validation data management and distribution. As part of the EOS Validation program, PIs will be responsible for managing their data effectively and in keeping with EOS data policy. Questions of test site data management and associated costs have yet to be addressed but are clearly fundamental issues for EOS.

It will be important to ensure that measurements at different sites are made following set standards and guidelines. Specific findings and recommendations are:

Standards

- intermediate standards traceable to NIST (National Institute of Standards and Technology)
- baseline instrument calibration twice per year
- intercalibrate every 6 months (at a few sites)
- calibration teams using same sampling methods and processing techniques
- standards for geolocation data

Data Formats

- guidelines needed for data formats and metadata for ingest into EOSDIS

- the data systems must accept multiple data types (spatial, point, tabular)
- need to clarify the support that EOSDIS can provide and the role of DAACs

Quality Assurance/Quality Control

- done by test site scientist prior to submission to the data system
- DAAC does general checks for consistency and completeness
- PIs will need to adhere to documentation guidelines

Data Integration and Packaging

- need to develop integrated EOS satellite, aircraft, and *in situ* validation data sets
- integrate different data types into readily usable datasets for the scientists
- integrate data from different sites and link to relevant data from non-EOS sites
- clarify integration and packaging responsibilities including the role of the DAACs
- need georeferencing
- need processing history

User feedback

- test site coordinating group needed for contact point, evaluation, coordination, etc.

RECOMMENDATIONS

Recommendations from the meeting are:

1. The group recommended that there should be an EOS Test Sites Program.
   - There is a strong scientific rationale.
   - There is a strong desire to develop the integrated test site approach, including the EOS and broader scientific communities.

2. An EOS Test Sites Program should be developed to embrace four communities:
   - EOS Instrument and IDS Teams,
   - the larger USGCRP science community,
   - Interagency test site network partners,
   - International test site partners.

3. A small EOS Test Sites Steering Group should be established to develop and guide the integrated EOS Test Sites Program, with representatives from:
   - Instrument Teams,
   - IDS Teams,
   - EOSDIS,
   - U.S. Agency Partners,
   - International Partners.

4. EOS scientists will certainly participate in the Tier 1 campaigns, and the EOS Validation Program may wish to enhance the Tier 2 monitoring sites. However, it is recommended that the emphasis for the EOS Test Sites Program should be to build the capacity for Tier 3 and 4 activities. The development of multi-instrument, multi-product, and multi-discipline test site validation will be an essential component of the EOS program.

5. The EOS Validation and Calibration Programs should support a small number of vicarious calibration sites and work through CEOS to establish international cooperation for selecting, instrumenting, and supporting these sites for the benefit of EOS and its international partners.

6. EOSDIS (EOSDIS Core System or Federated System) should ensure the sound management, archiving, and distribution of EOS test site data to the EOS science community.

7. An EOS Pathfinder data activity should be undertaken to prototype the management and integration of test site data and satellite data in support of the EOS Validation Program.

APPENDICES

A. Agenda
B. Attendees and Participation
C. Information Sources for Ongoing Community Activities
D. Additional Team Inputs

APPENDIX A - Agenda

EOS Test Sites Meeting

Goddard Space Flight Center
Building 32, Room 103/109
March 18-19, 1996

Monday, March 18, 1996

8:30	Welcome & Charge	Wickland & Justice
8:40	EOS Validation Perspective	Starr
8:45	Synthesis of EOS Test Site Submissions from Instruments & IDS Teams	
	Land	Justice
	Atmosphere	Suttles
	Ocean	Esaias
	Calibration	Butler
10:00	Break	
10:15	Ongoing Community Activities (10 min. status reports)	
	DOE ARM/CART	Cress
	AERONET-Aerosol Network	Holben
	AEROCE-Aerosol Network	Prospero
	CEOS Cal/Val Sites	Reber
	LTER	Vande Castle/Cohen/Vermote
	Landsat Pathfinder/GLCTS	McGwire
	IGBP Land Cover Core Sampling Strategy	Strahler
	CO2 Flask Network	Trolier
	Global Fiducials	Dreves
	NASA R&A Campaigns	Wickland
	GCIP	Lawford
	GTOS Concept	Justice
	EVAC/Oklahoma Mesonet	Morrissey
12:30	Lunch	
1:30	EOS, Interagency, and International Test Site Implementation Concepts	Running

2:00	Breakout Groups (to develop desired measurement suites)	
	Vegetation & Land Cover	-e.g., LAI, FPAR, structure, NPP, Land Cover (inc. snow & ice), etc.
	Radiation	- e.g., Shortwave & longwave fluxes, surf. temp., emissivity, albedo, BRDF, etc.
	Aerosols, Chemistry & Meteorology	- e.g., Aerosols, trace gases (ozone, etc.), atmos. temp. & humidity profiles, etc.
	Calibration	- e.g., Vicarious calibration activities, underflights, etc.

Groups develop basis for a test site measurement implementation plan, including specification of required measurement packages and potential measurement synergy, as input to the validation workshop in May 1996.

4:30 Preliminary Group Reports

Informal evening discussions as required

Tuesday, March 19, 1996

8:30	Group Reports & Open Discussion	Group Rapporteurs
10:30	Break	
11:00	Approaches for Further Development of Synergistic Site Measurements	Open Discussion, Chair - Justice
12:00	Lunch	
1:00	Synergistic Discussions	Breakout Groups

Purpose: To develop synergies between the EOS measurement suites identified in the previous breakout group sessions and further develop a strawman implementation plan. Breakout Groups TBD in real time for these sessions.

2:30	EOS Project Office Support for Validation	Starr
2:40	Action Items and Wrap Up	Wickland/Justice
3:00	Meeting Ends	

****

APPENDIX B - Attendees (Participation & Alphabetic Listing)

EOS Test Sites Meeting

NASA/Goddard Space Flight Center
March 18-19, 1996

INSTRUMENT TEAM PARTICIPANTS

ASTER	Kahle, Palluconi, Slater, Hook
CERES	Charlock
MISR	Conel, Ledeboer
MODIS	Justice, Running, Esaias, Slater, Strahler, Kaufman, Vermote, Leeuwen, Wan
MOPITT	Wang, Reichle
SAGE III	Woods, Trepte
Landsat	Storey

IDS PARTICIPANTS

SELLERS	Justice
DICKINSON	Emery
LAU	Engman
BARRON	Miller
KERR/SOROOSHIAN	submitted CESBIO report
WIELICKI	Charlock
ROOD (DAO)	Bloom

EOSDIS PARTICIPANTS

Oak Ridge National Lab	Dick Olson/DOE
EROS Data Center	Grant Mah

PROGRAM PARTICIPANTS

NASA R&A	Wickland, Connors/ NASA HQ
NASA EOS	Starr/Butler/EOS PSO
EOS PDQ	Freilich
ARM	Cress/DOE, Splitt/U. Okla. Norman
GCIP	Lawford/NOAA
Landsat Pathfinder/GLCTS	McGwire
Global Fiducials	Dreves/CIA/NOAA
CEOS	Reber
IGBP	Strahler
GTOS	Justice

NETWORK PARTICIPANTS

LTER	Vande Castle/U. Wash., Cohen/USDA FS
AERONET	Holben/NASA GSFC
AEROCE	Prospero/U. Miami
CO_2 Flask Network	Trolier/NOAA CMDL

Oklahoma Mesonet	Morrissey/U. Oklahoma

ALPHABETIC LISTING

Bill Bandeen
Hughes STX
7701 Greenbelt Rd, Suite 400
Suite 400
Greenbelt, MD 20771
301-441-4038
301-441-1853 fax
wbandeen@ltpmail.gsfc.nasa.gov

Richard Barbieri
SAIC/GSC
7501 Forbes Blvd.
Seabrook, MD
301-352-2131
barbieri@highwire.gsfc.nasa.gov

Jim Butler
NASA/Goddard Space Flight Center
Code 923
Greenbelt, MD 20771
butler@highwire.gsfc.nasa.gov

Thomas Charlock
NASA/Langley Research Center
M/S 420
Hampton, VA 23681-0001
804-864-7996
804-864-5687 fax

Warren Cohen
USDA Forest Service
cohenw@ccmail.orst.edu

Jim Conel
NASA/Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109
818-354-4516
jconel@jord.jpl.nasa.gov

Ted Cress
Pacific Northwest Lab
DOE ARM Program
509-375-6964
ts_cress@pnl.gov

Don Dreves
Global Fiducials Program
703-351-2143
703-527-6139 fax

Robert Ellingson
University of Maryland
Dept. of Meterology
College, MD 20742
301-405-5386
301-314-9482 fax
bobe@atmos.umd.edu

Bill Emery
University of Colorado
Boulder, CO
emery@frodo.colorado.edu

Ted Engman
NASA/Goddard Space Flight Center
Code 974
Greenbelt, MD 20771
301-286-5355
301-286-1758 fax
tengman@neptune.gsfc.nasa.gov

Wayne Esaias
NASA/Goddard Space Flight Center
wayne.esaias@gsfc.nasa.gov

Mike Freilich
OSU
Corvallis, OR 97331-5503
541-737-2748
541-737-2064 fax
mhf@oce.orst.edu

Renny Greenstone
Hughes STX
7701 Greenbelt Rd
Greenbelt, MD 20770
301-441-4037
301-441-1853 fax
renny@ltpmail.gsfc.nasa.gov

Brent Holben

NASA/Goddard Space Flight Center
Code 923
Greenbelt, MD 20771
301-286-2975
brent@kratmos.gsfc.nasa.gov

Simon Hook
NASA/Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109
818-354-0974
818-354-0966 fax
simon@lithos.jpl.nasa.gov

Chris Justice
NASA/Goddard Space Flight Center
Code 923
Greenbelt, MD 20771
301-286-7372
301-286-1775 fax

Anne Kahle
JPL, MS 183-504
4800 Oak Grove Drive
Pasadena, CA 91109
anne@lithos.jpl.nasa.gov

Yoram Kaufman
NASA/Goddard Space Flight Center
Code 913
Greenbelt, MD 20771
301-286-4866
301-286-1759 fax
kaufman@climate.gsfc.nasa.gov

Michael King
NASA/Goddard Space Flight Center
Code 900
Greenbelt, MD 20771
301-286-8228
301-286-1738 fax
king@climate.gsfc.nasa.gov

Rick Lawford
NOAA Office of Global Programs
301-427-2089, x40
lawford@ogp.noaa.gov

William Ledeboer
NASA/Jet Propulsion Laboratory
4800 Oak Grove Dr.
Pasadena, CA 91109
818-354-9603
bill.ledeboer@jpl.nasa.gov

Grant Mah
EROS Data Center
Grant R. Mah
Sioux Falls, SD
mah@edcserver1.cr.usgs.gov

Brian Markham
NASA/Goddard Space Flight Center
Code 923
Greenbelt, MD 20771
301-286-5240
301-286-1757 fax
markham@highwire.gsfc.nasa.gov

Kenneth McGwire
DRI Biological Sciences Center
7010 Dandini Blvd.
Reno, NV 89512
702-673-7324
702-673-7397 fax
kenm@maxey.unr.edu

Doug Miller
The Pennsylvania State University
Earth System Science Center
248 Deike Bldg.
University Park, PA 16802
Phone: 814-863-7207
FAX: 814-865-3191
miller@essc.psu.edu

Mark Morrissey
Oklahoma Climatological Survey
Norman, OK 73019
405-325-2541
405-325-2550 fax
mmorriss@uoknor.edu

Doug Muchoney

Boston University
Department of Geography
675 Commonwealth Ave
Boston, MA 02215
617-353-5984

Dick (R.J.) Olson
Oak Ridge National Laboratory
Environmental Sciences Division
P.O. Box 2008, Bldg. 1507, MS 6407
Oak Ridge, TN 37831-6407
Phone: 423-574-7819 (new area code)
FAX: 423-574-4665 (new area code)
rjo@ornl.gov

Hassan Ouaidrabi
University of Maryland
College Park, MD 20740
301-286-0683
hassan@kratmos.gsfc.nasa.gov

Frank Palluconi
NASA/Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109
818-354-
frank.d.palluconi@jpl.nasa.gov

Stephen Prince
University of Maryland
Department of Geography
College Park, MD 20742-8225
301-405-4062
301-314-9299 fax
sp43@umail.umd.edu

Jeff Privette
NASA/Goddard Space Flight Center
Code 923
Greenbelt, MD 20771
301-286-5340

Joseph Prospero
University of Miami
RSMAS
305-361-4789
305-361-4891 fax
jprospero@rsmas.miami.edu

Skip Reber
NASA/Goddard Space Flight Center
Code 170
Greenbelt, MD 20771
301-286-6534
reber@cdhf2.gsfc.nasa.gov

Hank Reichle
North Carolina State University
Box 8208
Raleigh , NC 27695-8208
919-515-5100
919-515-7802 fax
HENRY_REICHLE@NCSU.EDU

Steve Running
University of Montana
406-243-6311
swr@ntsg.umt.edu

Mark D. Schwartz
Department of Geography, Bolton 474
P.O. Box 413
University of Wisconsin-Milwaukee
Milwaukee, WI 53201
Phone: (414) 229-3740 or 4866
Fax: (414) 229-3981
mds@csd.uwm.edu

Piers Sellers
NASA/Goddard Space Flight Center
Code 923
Greenbelt, MD 20771
301-286-4173
piers@imogen.gsfc.nasa.gov

Dave Short
NASA/Goddard Space Flight Center
Code 910
Greenbelt, MD 20771
301-286-7048
short@trmm.gsfc.nasa.gov

Phillip Slater
University of Arizona
Remote Sensing Group, Optical Sciences
Center
Tucson, AZ 85721
520-621-4242

520-621-8292 fax
pslater@opt-sci.arizona.edu

James Smoot
LMSO
Stennis Space Center, MS 37259
601-658-1951
601-688-3838 fax
jsmoot@ssc.nasa.gov

Mike Splitt
University of Oklahoma Norman
msplitt@manatee.gcn.uoknor.edu

David Starr
NASA/Goddard Space Flight Center
Code 913
Greenbelt, MD 20771
301-286-9129
301-286-1759 fax
starr@climate.gsfc.nasa.gov

James Storey
Hughes STX
11723A Summerchen Circle
Reston, VA 22094
703-648-4175

Alan Strahler
Boston University
Department of Geography
675 Commonwealth Ave
Boston, MA 02215
617-353-5984

Tim Suttles
Hughes STX, Ste 400
7701 Greenbelt Road
Greenbelt, MD 20770
301-441-4028
301-441-1853 fax
suttles@ltpmail.gsfc.nasa.gov

Chip Trepte
Science Applications Intl. Corp.
1 Enterprise Pkwy, Suite 250
Hampton,VA 23693
804-864-5836
804-864-2671 fax
chip@mirage.larc.nasa.gov

Michael Trolier
NOAA CMDL
Boulder, CO
303-405-5386
mtrolier@cmdl.noaa.gov

Wim J. D. Van Leeuwen
University of Arizona
429 Shantz Bldg, #38
Tucson, AZ 85721
520-621-8514
520-621-5401 fax
leeuw@ag.arizona.edu

John Vande Castle
University of Washington
Long-Term Ecological Research (LTER)
- Network Office
Winkenwerder 205, Box 352100
Seattle, WA 98195-2100
206-543-6249
206-543-7295 fax
jvc@LTERnet.edu

Eric Vermote
University of Maryland
Dept. of Geography
College Park, MD 20740
301-286-6232
301-286-1775 fax
eric@kratmos.gsfc.nasa.gov

Ed Walser
NASA/Stennis Space Center
Stennis Space Center, MS 39529
ewalser@ssc.nasa.gov

Zheugwing Wan
University of California at Santa Barbara
ICESS
Santa Barbara, CA 93106
805-893-4541

wan@icess.ucsb.edu

Jinxue Wang
National Center for Atmospheric Research
Atmospheric Chemistry Division
P.O. Box 3000
Boulder, CO 80307-3000
Phone: (303)497-1436
Fax: (303)497-1492
jwang@eos.acd.ucar.edu

Wolfgang Wanner
Boston University
Department of Geography
675 Commonwealth Ave
Boston, MA 02215
617-353-5984

Diane Wickland
NASA Headquarters
Code YS
Washington, DC 20546
202-358-0245
diane.wickland@hq.nasa.gov

Dave Woods
NASA/Langley Research Center
Hampton, VA 23681-0001
804-864-2672
dave_woods@qmgate.larc.nasa.gov

APPENDIX C - Ongoing Community Activities

EOS Test Sites Meeting

Goddard Space Flight Center
Building 32, Room 103/109
March 18-19, 1996

The EOS Test Sites Meeting included brief status reports on the Ongoing Community Activities listed below. Information on these programs can be obtained from the contact persons given or, in some cases, by visiting the homepage URL address on the Internet.

DOE Atmospheric Radiation Measurement (ARM) Program

Contact : Ted Cress
Pacific Northwest Lab
DOE ARM Program
509-375-6964
ts_cress@pnl.gov

URL: http://info.arm.gov

AERONET - Aerosol Network

Contact: Brent Holben
NASA Goddard Space Flight Center
Code 923
Greenbelt, MD 20771
301-286-2975
brent@kratmos.gsfc.nasa.gov

University of Miami Aerosol Network -
Atmosphere/Ocean Chemistry Experiment (AEROCE)

Contact: Joseph Prospero
University of Miami
RSMAS
305-361-4789
305-361-4891 fax
jprospero@rsmas.miami.edu

Committee on Earth Observation Satellites (CEOS) Cal/Val Sites

Contact: Jim Butler
NASA Goddard Space Flight Center
Code 923
Greenbelt, MD 20771
butler@highwire.gsfc.nasa.gov

Long-Term Ecological Research (LTER)

Contact: John Vande Castle
University of Washington
LTER - Network Office
Winkenwerder 205, Box 352100
Seattle, WA 98195-2100
206-543-6249
206-543-7295 fax
jvc@LTERnet.edu

or

Warren Cohen
USDA Forest Service
cohenw@ccmail.orst.edu

URL: http://www.lternet.edu/

Landsat Pathfinder / Global Land-cover Test Sites

Contact: Kenneth McGwire
DRI Biological Sciences Center
7010 Dandini Blvd.
Reno, NV 89512
702-673-7324
702-673-7397 fax
kenm@maxey.unr.edu

URL: http://dia.maxey.dri.edu/glcts/

IGBP Land Cover Core Sampling Strategy

Contact: Alan Strahler
Boston University
Department of Geography
675 Commonwealth Ave
Boston, MA 02215
617-353-5984

CO2 Flask Network

Contact: Mike Trolier
NOAA CMDL
Boulder, CO
303-405-5386

URL: http://ccg1.cmdl.noaa.gov/co2/co2insitu.html

Global Fiducials

Contact: Don Dreves
Global Fiducials Program
703-351-2143
703-527-6139 fax

NASA Research & Analysis Program - Field Campaigns

Contact: Diane Wickland
NASA Headquarters
Code YS
Washington, DC 20546
202-358-0245
diane.wickland@hq.nasa.gov

URL: http://www.hq.nasa.gov/office/mtpe/

GEWEX Continental-scale International Project (GCIP)

Contact: Rick Lawford
NOAA Office of Global Programs
301-427-2089, x40
lawford@ogp.noaa.gov

URL: http://www.cais.net/gewex//gcip.html

Global Terrestrial Observing System (GTOS) Concept

Contact: Chris Justice
NASA/Goddard Space Flight Center
Code 923
Greenbelt, MD 20771
301-286-7372
301-286-1775 fax

Environmental Verification and Analysis Center / Oklahoma Mesonet

Contact: Mark Morrissey
Oklahoma Climatological Survey
Norman, OK 73019
405-325-2541
405-325-2550 fax
mmorriss@uoknor.edu

URL: http://geowww.gcn.uoknor.edu/WWW/Mesonet/Mesonet.html

The Semi-Arid Land-Surface-Atmosphere (SALSA) Program

Contact: David C. Goodrich
USDA-ARS-SWRC
2000 E. Allen Rd.
Tucson, AZ 85719
goodrich@tucson.ars.ag.gov

URL: http://www.hwr.arizona.edu/salsa/salsa_1.html

APPENDIX D - Additional EOS Team Inputs

Appendix D.1 - PREVIOUS, CURRENT, AND PLANNED EOS CALIBRATION AND
VALIDATION ACTIVITIES FOR THE UA-CESBIO IDS TEAM.
See http://spso.gsfc.nasa.gov/validation/docs.html

Appendix D.2 - ASTER CALIBRATION/VALIDATION TEST SITES
See http://spso.gsfc.nasa.gov/validation/test.html

Appendix D.3 - SUMMARY AND OVERVIEW OF MISR PRE-LAUNCH ALGORITHM
AND POST-LAUNCH PRODUCT VALIDATION ACTIVITIES