History and Status of the Atmospheric Radiation Measurement Program March 1998

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Introduction

This document contains the summaries of papers presented in poster format at the March 1998 Atmospheric Radiation Measurement (ARM) Program Science Team meeting held in Tucson, Arizona. The status of the ARM Program at the time of meeting helps to put these papers in context.

Although much has been accomplished and specific research objectives have been stated and addressed since 1990, the primary tenet of the program has remained unchanged—to improve the performance of the general circulation models used for climate research and predication by improving how those models deal with radiative energy transfer and the impact of clouds. However, ARM also has evolved from a program dominated by facility implementation to a program wherein the dominate issues are instrument performance, data quality, and specific research objectives related to model improvement. From the beginning, the program has attempted to respond to the most critical scientific issues identified by the United States Global Change Research Program. Consequently, ARM is a continuing collaboration of unprecedented magnitude involving the U.S. Department of Energy (DOE) national laboratories, other federal programs, and international programs under the auspices of the World Climate Research Program (WCRP). International programs such as the WCRP Global Energy and Water Experiment (GEWEX) have used ARM as the basis for regional experiments such as the GEWEX Continental-Scale International Project (GCIP). Expanding the GEWEX collaboration, ARM has been requested to use its experience to coordinate the establishment of the GEWEX Water Vapor (GVap) experiment, a 10-year ground-based observational effort to validate global data bases of satellite remotely sensed water vapor distribution. The ARM sites are the core of the U.S. contribution to the GVap data collection effort. The National Aeronautics and Space Administration's (NASA's) Earth Observing System (EOS) is another program where ground-based ARM measurements are important for validating satellite remote sensing retrievals and where extensive collaborations are under way.

ARM has been aggressive in its implementation activity, in pursuing extensive collaborations, and in developing a strong scientifically based program. These efforts have permitted leveraging the program's existing resources to support a high level of intensive measurement activity while maintaining a steady pace of deployment despite funding that is substantially lower than originally anticipated for this stage of the program. Additionally, the success of the program continues to attract some of the best scientific talent in the climate research community and is, as a result, productive scientifically.

Initial Concept

The initial concept for ARM came out of a series of studies that fell under the auspices of the Intercomparison of Radiation Codes in Climate Models (ICRCCM). ICRCCM pointed to several key issues that are now central to the ARM approach and strategy. First, ICRCCM was based on an assertion that one must understand the quality of the physics inside a climate model if one is to understand the quality of the climate model itself. Second, it is possible, and in fact necessary, to understand the relatively coarse representations of the physical processes in a climate model in terms of higher resolution process models. Finally, the hierarchy of models that leads to needed parameterizations must be built on a sound base of experimental verification.

Concurrently, with the release of the ICRCCM results, it was becoming clear that the radiative transfer of energy in the atmosphere and the impact of clouds was, and remains, one of the greatest sources of error and uncertainty in the current generation of general circulation models (GCM) used for climate research and prediction. With this starting point, DOE proposed a major program targeted at improving the understanding of the role and representation of atmospheric radiative processes and clouds in models of the earth's climate. Initially, the DOE program focused on the radiative aspects of the climate problem. As the scientific issue was studied in more detail, however, it was obvious that a study of radiative processes associated with clouds could not be decoupled from the problem of representing the processes by which clouds form, are maintained, and dissipate in climate models. As a result, the ARM Program was proposed to the then Committee on Earth Sciences of the Federal Coordinating Council on Science Engineering and Technology with two basic objectives:

- to improve the treatment of radiative transfer in climate models under all relevant conditions
- to improve the treatment of clouds in climate models, including the representation of the cloud life cycle and the prognosis of cloud radiative properties.

The "Approved" Plan

The ARM Program Plan was subjected to peer review in the fall of 1989. The key element of the proposed ARM effort was to be the Cloud and Radiation Testbed (CART). This user facility was proposed to consist of four to six semi-permanent observational facilities designed to allow detailed investigations of processes represented in climate research models. These semi-permanent facilities were to be supplemented with a mobile facility that would allow related measurements to be made at other locations on a campaign-oriented basis. The CART facility would include a data management and communications system capable of acquiring and quality-controlling site data; acceptability to acquire data from sources outside the program; and to communicate that data to a Science Team. The Science Team would be selected through a peer review process open to all investigators nationally and internationally.

Based on the peer review, the subcommittee on Global Change Research of the Committee on Earth Sciences approved the Plan, noting several key things about how it should be carried out. First, the scope was broadened beyond radiative transfer to include clouds and cloud processes represented in GCMs, a change deemed necessary to adequately address those atmospheric properties important to radiative transfer in the atmosphere and the atmosphere's radiation balance. Next, the Committee recommended that the DOE implementation of this program involve the talents of other federal agencies to the extent possible and that an interagency steering group be formed to assist in that process. Finally, the relevance of ARM to several other climate programs was noted, and DOE agreed to coordinate its deployment of facilities with the schedules of other national and international programs.

The Early Implementation

The implementation of the ARM Program began in January 1990, proceeding on two coupled but parallel tracks. First, a multi-laboratory team was formed to plan the detailed implementation of the ARM facilities. The second track involved the formation of the Science Team. Because the science drivers were important to the design of the ARM facilities, a series of scientific workshops were held in the spring and summer of 1990 to clarify the scientific foundations of the program. In parallel, a solicitation process was initiated to establish the Science Team.

As these two tracks moved forward, features of the program emerged. One of the most significant was a pattern of collaboration with other programs. This collaboration was characterized on one hand by a series of joint field campaigns and, on the other, by involvement in program planning for other major research efforts. In the field collaborations, ARM attempted to bring a value-added contribution to another agency's or group's planned effort, while at the same time trying to gain operational experience necessary to guide its own field deployment.

This strategy resulted in collaborations with the Federal Aviation Administration's Winter Icing and Storms Program (WISP) and First ISCCP (International Satellite Cloud Climatology Project) Regional Experiment (FIRE) activities in Coffeyville, Kansas, and the Azores. In Coffeyville, early ARM concepts were tested in the Spectral Radiance Experiment (SPECTRE), jointly funded by NASA and DOE. It also led to ARM-fostered projects such as the Boardman-ARM Regional Flux Experiment, which tested key aspects of surface and surface flux characterization.

From the standpoint of planning, ARM attempted to gain early involvement in the program planning of other programs that would be evolving in parallel with it. Most notable among these planning collaborations was the GEWEX. One of these joint planning activities culminated in the field deployment of the Pilot Radiation Observation Experiment (PROBE) to Kavieng, Papua New Guinea, as part of the Tropical Ocean Global Atmosphere-Coupled

Ocean Atmosphere Response Experiment (TOGA-COARE), in the winter of 1992-1993. Again, experience gained during TOGA-COARE has been a crucial influence in ARM planning.

A key convergence between science and facility planning tracks was the selection of a siting strategy for the ARM facilities. This process resulted in the identification of five locales in which ARM should locate its semi-permanent facilities and a comparable number of secondary locales in which the program should consider shorter, campaign-like activities. The primary locales in the order of their intended occupation were the Southern Great Plains (SGP) of the United States, the Tropical Western Pacific (TWP), the North Slope of Alaska (NSA), the marine stratus zones of either the Atlantic or Pacific Ocean, and the Gulf Stream.

Budget Realities

While ARM was planned as a decade-long program with a cumulative funding level of almost $500M, it has always been clear that the annual rate of funding would not reach projected levels and that the program's schedule would be changed and/or drawn out. This reality was approached in several ways and recognized several competing concerns: the cost of acquiring equipment, the tradeoff between capital and operating budgets, and the costs of facility design and deployment versus operating costs. More recently, as some of the implementation costs have declined, the cost of providing quality data, contiguously and in near real time, has been becoming an area of concern and tradeoff.

Early in the program, capital equipment resources were inadequate to acquire the instrumentation necessary for the first site and the development of the associated data system. As a result, the deployment to the first site was phased, supporting one aspect of the program, the radiative transfer segment, over the cloud life-cycle segment. Similarly, the program sought opportunities to take advantage of existing equipment and data. This approach led, in no small way, to the decision to deploy the first site in the North Central Oklahoma/South Central Kansas area to take advantage of the existing National Oceanic and Atmospheric Administration's (NOAA's) profiler and radar facilities and the then-developing Oklahoma Mesonet.

The operational budgets also lagged, leading to a series of joint development activities. For example, rather than building a new system for field data acquisition, the program instead developed a collaboration with the National Center for Atmospheric Research (NCAR) to build the data system around their campaign data management system, now known as Zebra.

Finally, the program has been rescoped annually. This rescoping has resulted in substantive changes including the cancellation of the planned mobile facility, the reduction of planned permanent field sites from five to three, the slowing of development and deployment of instruments and facilities, fewer than anticipated campaign activities, and delayed the implementation of the ARM Data Archive.

Despite budgetary limitations, development of the central facility for the SGP site began in May 1992, only one month later than originally planned. The initial deployment was meager, a single portable meteorological station borrowed from NCAR. By that fall, however, most of the infrastructure for the instrumentation was in place, and the major equipment was being delivered. Originally planned for completion in about one year, some aspects of the originally planned SGP facility development continued into 1998.

In other areas, the initial deployment to the second permanent locale, the TWP, was delayed to 1996. TWP has been subsequently limited to three island sites instead of the five recommended ones pending clarification of future budget and operating costs for remote sites. The deployment to the third permanent locale, the NSA, was delayed into 1998. This schedule reflects the impact of the limited budgets allocated to the program. The originally planned deployment schedule called for one site to be completed each year, implying a full deployment of five sites by mid-1997. Full deployment of the three currently planned sites will not be achieved until the year 2000.

The implementation of the program has been reviewed annually by external reviewers at the request of DOE. In the last major review of the program before the 1998 meeting, the Washington Advisory Group included in its recommendations that ARM move from being largely driven by "discovery" based field efforts to being soundly anchored on the principles of "hypothesis testing," especially for its key intensive operational periods (IOPs) at the various sites.

Project Status at the Time of the 1998 Tucson Meeting

Continuing the rapid pace of activity that started in 1996, the period between the 1997 San Antonio meeting and the 1998 Tucson meeting saw significant gains in facility development, data quality, and the use of data in model development and improvement. These areas of effort are apparent in the posters presented at the 1998 meeting. The program is rapidly achieving the multi-climate observational capability that was envisioned when the ARM Program was proposed. Each of the long-term sites, while evolving in commonality, have their unique features and stage of development. Data quality, the availability of data quality information, and the emphasis on key scientific issues is the focus of activity at the SGP site and the conduct of measurement programs and field experiments there. The Atmospheric Radiation and Cloud Station (ARCS) at Manus Island, Papua New Guinea, continues to function reliably with routine data recorded and returned on tape while health-of-station data are reported hourly via satellite relay. Integration of the second ARCS, intended for deployment to Nauru at the end of FY 1998, is under way, but slightly behind its original schedule, in part due to an unfortunate lightning strike at the integration facility. The deployment of a limited, relocatable instrument and data system to the Surface Heat Budget of the Arctic (SHEBA) sea ice camp, an icebreaker, was completed and deployed on schedule. The NSA site at Barrow, Alaska, was largely in place at the time of the meeting and was being checked out in anticipation of its first collaborative measurements in conjunction with the NASA FIRE III aircraft flights to be conducted over the SHEBA and Barrow sites in the spring and summer of 1998. With the completion of the Nauru and Barrow sites, only the deployment of the facility and instruments to Christmas Island and the relocation of the SHEBA instrument suite to an inland site on the North Slope, the village of Atqasuk, remained to be completed as goals of the long-term deployment strategy of ARM. With these deployments, to be completed in FY 2000, ARM will complete its foundation goal of data acquisition in key climatic regimes worldwide and the establishment of ARM as a premier data source for the development of globally representative cloud and radiation models. While necessary to meet the goals of ARM, these sites also serve a valuable serendipitous role as the foundation for a wide range of atmospheric research efforts including weather and severe storm analysis and prediction.

By the end of 1997, the SGP CART site was complete except for installation of the last instruments at a forested extended facility and the installation of several remote sensors at the boundary facilities. To understand the size of this site, the site was composed of 29 facilities spread over an area of approximately 55,000 square miles (200 e-w, 215 n-s) and, nominally, 240 instrument systems representing over 930 separate sensors and instruments, producing 280 distinct data streams. Substantial efforts have been made or are under way to improve instrument performance. The new radiometric calibration facility completed two additional cycles of broadband radiometer calibrations, calibrating a total of 152 pyranometers and pyrheliometers. Symptomatic of the distinctly different focuses of the scientific Working Groups of the Science Team, yet highlighting the complementary nature of the data needs of each of those groups, the largest event at the SGP site was the execution of a single IOP comprised of seven distinct areas of research involving between 70 to 100 scientists and colleagues of the Science Team and collaborating programs.

SGP instrumentation is now relatively stable, but some new instruments were installed during the last year and a few are still to be installed. Improvement of instrument performance is a major concern and the focus of a number of instrument related evaluation efforts. The delivery and installation of Vaisala ceilometers and atmospheric emitted radiance interferometers (AERIs) at the four boundary facilities was anticipated to be completed late in FY 1998, but will now be completed early in FY 1999. This will complete the boundary facilities and permit studies to compare driving single-column model (SCM) research using remote sensors and satellite data in comparison to driving these models solely with radiosonde data. Two shortwave spectrometers were installed during the year, with both still being “checked-out” and validated at the end of the year. A reconfiguration of the broadband radiometric suite has proven to make that suite of instruments more robust and amenable to real-time monitoring and management. A zenith pointing narrow-field-of-view radiometer, based on the multi-filter rotating shadowband radiometer (MFRSR) sensor body, was developed and installed. The Raman lidar and 50-MHz radar wind profiler (RWP) radio acoustic sounding system (RASS) both suffered hardware and software problems that affected data quality. The RWP RASS problems were successfully corrected with a substantial performance improvement in its temperature profiling capability. The Raman lidar was anticipated to be repaired in the spring of 1998 before the Spring 1998 IOP. Additional instruments introduced during the year included a sky video for time lapse documentation of sky condition and two radiometer suites using radiometers developed by Francisco Valero. These radiometers were intended to operate continuously alongside the epply radiometers used generally by ARM, but it was anticipated that some components would not be durable enough for this style of operation. Once established, these instruments will prove to be a valuable check point for radiometric measurements made at all sites using epply radiometers.

The new 35-GHz cloud radar, installed in the previous year, was tested and evaluated during intercomparisons to NOAA’s Ka-band radar and the University of Massachusetts’ 35- to 95-GHz dual channel radar. The new radar has proven to be as sensitive as the design desired, and validation activity has corrected several problems detected from data analyses and the intercomparison activity. At the time of the Science Team meeting, several issues were still being investigated and flying insects were suspected as contributing to low-altitude background noise. Since its installation, the radar has proven to be extremely reliable, checking in at about 98% of the potential operating time. The radar was built by NOAA's Environmental Technology Laboratory (ETL) for ARM. Additional radars are being built for the NSA and TWP sites.

The balloon-borne sounding system (BBSS) continued to be the focus of efforts to evaluate apparent differences in water vapor measurements between the BBSS and other observational tools such as the AERI, the Raman lidar, and the microwave radiometer (MWR). Data intercomparisons and analysis following the two water vapor IOPs at the SGP suggested lot-to-lot variability in the calibration of sondes purchased from Vaisala. Since this was the first problem detected following the 1996 IOP, ARM has worked closely with Vaisala to ensure the highest quality sonde data. The differences noted are small enough to be of little consequence to routine meteorological applications, but are significant in the intercomparison of sonde water vapor data to other high sensitivity measurements. The observed lot-to-lot variability was found to be apparently related to the periodicity of the recalibration of the Vaisala water vapor calibration facility. Vaisala has modified their calibration procedures for the sondes purchased by ARM to reduce lot-to-lot variability. An apparent dry bias at higher altitudes remains to be resolved.

ARM's cloud observational capability was substantially strengthened with the reconfiguration of the whole sky imager (WSI) to achieve both improved data transfer and availability as well as more reliable instrument operation. WSI imagery and products will be routinely available from all sites in 1998. Although the imagery certainly captures observable cloud cover, the cloud fraction calculations available early in 1998 are still limited to the analysis of "dense" or "thick" clouds during the day. Algorithms to account for visible thin cloud and to calculate cloud fraction for day and night were in development and expected to be operational during 1998.

Aerosol data taken at ARM sites is being strengthened by adding CIMEL sunphotometers to the instrument suite as extensions of the CIMEL network supported by NASA. Unlike other ARM data from these sites, the CIMEL data will be collected and sent to the NASA processing site with all other CIMEL data. ARM will get the data from the NASA center, with distribution to interested Science Team members. As of the beginning of 1998, the SGP and NSA CIMELs were installed, but the TWP instruments were planned to be added to Nauru and Manus as upgrades.

IOPs in support of Science Team research objectives are significant elements of the operations of the SGP CART site. Regularly scheduled IOPs continued in support of SCM activity, aiming towards a significantly representative data set for each season of the year. Additional IOPs, focused largely on instrumentation at the central facility, were scheduled in conjunction with the SCM IOPs to take advantage of the complementary data being acquired at other locations across the site. Through 1997, the SGP site had supported 47 IOPs of varying size and intensity. The table below includes the IOPs conducted at the SGP and NSA sites between the 1997 and 1998 Science Team meetings.

Period of IOP	Site	IOP Type
April 1997	SGP	Multiple IOP period • SCM IOP • Cloud Radar Validation IOP • First Aerosol IOP
June 1997	SGP	Second Spectral Imagery Technology Applications Center (SITAC) IOP [collaboration with the U.S. Department of Defense (DOD)]
June-July 1997	SGP	Multiple IOP period • SCM IOP • SGP-97 Hydrology IOP [collaboration with NASA and the U.S. Department of Agriculture (USDA)]
September-October 1997	SGP	Multiple IOP period • SCM IOP • ARM Unmanned Aerospace Vehicle (UAV) Deployment • Second Water Vapor IOP • First Shortwave Radiation IOP • First Cloud IOP • Second Aerosol IOP
October 1997-October 1998	NSA	SHEBA Ice Camp deployment [collaboration with the National Science Foundation (NSF), Office of Naval Research (ONR), and NASA]

Between the San Antonio and Tucson meetings, 12 IOPs were supported at the SGP site. The April IOP saw the first attempts to validate the performance of the newly installed 35-GHz cloud radar by comparison to similar systems and against theoretical performance expectations. During this period, the first airborne vertical profiles of aerosol particulates were obtained in an effort to understand the vertical structure of aerosols in this area as a function of height above ground, as contrasted to what is measured directly at the ground-based aerosol facility.

The Fall IOP was comprised of six distinct efforts listed in the table. This "Integrated IOP" activity involved three primary bases of operation—the central facility, the Blackwell-Tonkawa airport, and the Ponca City airport. At the central facility, 40 temporary instruments were installed, and on some days, up to 70 additional people were onsite. Five aircraft, including the UAV and its chase aircraft, operated out of the two airports. Although interrelated and complementary, the major thrusts of each of the IOPs, outside of the SCM IOP, which was a continuation of the statistical series of seasonal IOPs, were:

- Water Vapor: To reduce uncertainties in water vapor measurements through improved calibration and accuracy of the various instruments, and to provide improved characterization of the CART Raman lidar.
- Clouds: To acquire a multi-sensor data set that could be used to validate cloud property retrieval algorithms for the new cloud radar and to improve the calibration of the radar itself.
- Aerosol: To understand the impact of the aerosol vertical profile on shortwave radiation reaching the ground and to begin to address the impact of aerosols on cloud albedo.
- Shortwave Radiation: To conduct the first comparison of a large number of spectral and broad-band radiation sensors to achieve improved agreement and accuracy of the instruments.
- UAV: Using recently developed instruments, support the objective of each of the scientifically oriented IOPs and acquire data appropriate to understand the vertical structure of the radiation budget of the atmosphere and the impact of clouds.

In the TWP, the first ARCS, installed on Manus Island, Papua New Guinea, proved to be remarkably robust. From November 1996 through early 1998, operations were continuous with only occasional instrument problems and/or failures. The facility itself had few problems. The ARCS facility is a ruggedized, semi-autonomous system designed for use in such remote locations. Health-of-station data are transmitted daily to the TWP program office enabling the instruments and data system to be managed remotely. The bulk of the data is stored on tape and returned by mail periodically. The first ARCS installation was complete with the exception of two major instruments, the whole sky imager and the cloud radar. Both are anticipated to be retrofitted as upgrades to the site during 1998, but likely following the deployment of the second ARCS facility to Nauru in late summer. Data returned on tape is quality controlled by the site scientist before release and transmission to Science Team members.

Discussions relative to the third of the currently planned three TWP sites (a change in the deployment plan from last year) is also under way. The deployment plan for the TWP was modified following an out-year budget review to place the last two of the originally planned five TWP sites "on hold" pending clarification of the actual costs to keep systems operating in remote locations. It is feared that the high cost of remote location operations will preclude deploying and operating five such sites at one time. The third site is planned to be on Christmas Island, also located on the equator but at 157.33 degrees west longitude.

Collaboration continued, as in previous years, with the "Schools of the Pacific Rainfall Climate Experiment" and the "South Pacific Regional Environmental Program." SPREP has been a valuable source of help in talking to the governments of the island nations as well as planning and coordinating logistical support in the area.

At the NSA site, two major activities were undertaken in the last year. The first was completion of cold weather testing of the instruments for SHEBA and deploying those instruments to a Canadian icebreaker for deployment on the ice in the Beaufort Sea as part of the collaborative project. This was successfully done and by the time of the Science Team meeting, the ice camp had been operating for several months and had experienced many of the vagaries of working on the ice, including unannounced lead openings and polar bears. The deployment, overall, was being highly successful, and valuable data were being acquired. For ARM, the data are returned on tape and quality controlled by the NSA Site Scientist prior to release and transmission to ARM Science Team members. At Barrow, the shelter and platforms had been put in place and instrumentation and data system installed. Planning was proceeding for full operational capability by the time of a planned collaboration with the NASA FIRE field program starting in April. Significantly, the extended range AERI (ER-AERI) was installed and operating at both the SHEBA ice camp and at Barrow. The ER-AERI was built specifically for the high latitudes where low water vapor concentrations are common. The ER-AERI operates using a stirling cooler and is sensitive for wave numbers out to 420 cm^{-1} (wavelength of 23.9 micrometers). One of the new 35-GHz cloud radars was installed and operating, but the WSI planned for Barrow was delayed pending upgrades and the deployment of WSIs to other locations. An instrument unique to the NSA is a 60-GHz temperature profiler. Testing confirmed that reliable, high vertical-resolution temperature profiles to as high as 600 meters were possible with this instrument.

The instrument was retested at Barrow and deployed to SHEBA, but unfortunately failed on the ice and returned to Barrow for repair.

Collaboration with the agencies and programs is a fundamental philosophy of ARM. Major collaborations included participation in the SHEBA effort, but also included efforts to support the NASA-USDA summer hydrology experiment at the SGP site. In December 1997, DOE committed ARM to support the GEWEX Water Vapor Program (GVap) by coordinating the establishment of the GVap ground-based validation network. This network will be comprised of up to 20 sites world wide that will acquire, at a minimum, water vapor profile data using advanced radiosondes. A half dozen of the sites are anticipated to be "high level" sites with instruments that include a Raman or dial lidar, AERI-like Fourier transform infrared radiometers (FTIRs), microwave radiometers (MWRs), and a Global Positioning System (GPS) receiver for water vapor measurements. The ARM sites will be the "backbone" of the network and provide GVap with a "quick start." In an additional major collaboration, planning is under way for an international effort in the area of Nauru in the summer of 1999, following the installation of the Nauru ARCS.

Notably, the broad range of implementation activity characteristic of ARM up to the present time continues to give way to an increasing concentration on critical issues concerning radiation propagation in the atmosphere, the impact of clouds, and how the important variables can be measured and modeled. Much of what is being attempted in ARM is being done for the first time, at least in some context. ARM is measuring critical variables at unprecedented accuracy and precision for prolonged periods of time under the full range of atmospheric conditions. Many of the instruments in use are field hardened for the first time and are derivatives of instruments previously found only in laboratories or in the field under carefully controlled circumstances. The attention to seemingly minor inconsistencies between similar measurements from different instruments is a first, and leading to improvement in instrument performance and precision. We have found that it is often possible to understand the difference between instruments and that understanding those differences is often a key to a slightly different view of the physical parameter being measured.

The flow of data to the user is symptomatic of the approach that ARM has been taking relative to instruments and research objectives. Figure 1 shows a first order metric of

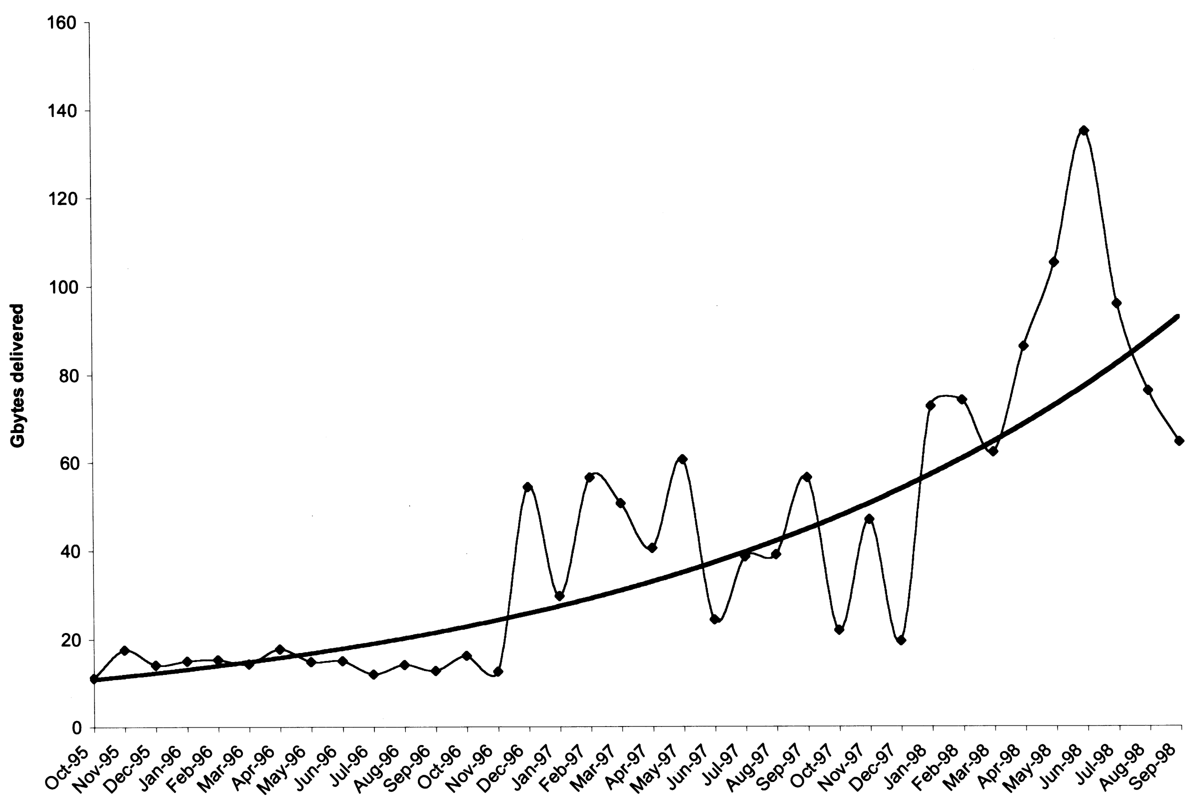

Figure 1. Data flow volume by year.

data flow and represents the volume of data in bytes that has been delivered from either the Archive or from the experiment center. It shows a significantly increasing mean volume with time. The sharp increases in Dec 96, Jan 98, and Apr-June 98 are associated with new satellite data deliveries. The use of this data by Science Team research efforts is reflected in the approximately 200 posters presented at the 1998 Science Team meeting, most of which are represented by the extended abstracts in this volume. These efforts focus on a wide range of topics from instrument performance to large-scale modeling impacts. Science Team feedback on data quality, either observational or derived, continues to be a valuable stimulus to improving the overall quality and robustness of existing and planned data streams.

Science Team research efforts largely fall into the two fundamental strategies through which ARM seeks to achieve its programmatic objectives and to focus its scientific efforts. These strategies are also the basic organizing principle behind defining the requirements for individual IOPs and determining what additional measurement capabilities are required. The first strategy, and the one that was at the heart of the priorities that led to the initial focus on the implementation of the SGP central facility, is the “instantaneous radiative flux” measurement and modeling effort. The second is single-column modeling to evaluate the cloud and radiative process models either used in, or being developed for, GCMs being used for climate studies. A third focused area of activity, related to establishing the lower boundary condition for both SCM evaluations and instantaneous radiative flux (IRF) calculations, is the effort to characterize surface fluxes, surface radiative properties, and planetary boundary layer behavior on scales appropriate to GCMs.

In the IRF strategy, the effort consists of collecting data on radiative transfer, the distribution of radiatively active constituents, and the radiative properties of the lower boundary. The radiative properties of the atmosphere and the lower boundary are used as input to radiative transfer models, including both detailed models with high spectral and angular resolution and simplified models suitable for use as parameterizations in climate models. The results produced by the models can then be compared with the radiation measurements as depicted in Figure 2.

The IRF approach is crucial to ARM, but it is not sufficient. Specifically, it does not address the large-scale processes that lead to cloud distribution and structure and the resultant cloud radiative properties that are important to understanding the instantaneous radiative fluxes. Using an SCM approach allows the testing of models and parameterizations intended to represent cloud property life cycles in GCM grid cells. Thus the fundamental idea of the SCM is to measure the external forces at work on a column of the atmosphere that corresponds to a single GCM grid column, to use transfer processes inside the column, and to evaluate the results produced by the models by comparing them with additional observations, in much the same manner as the IRF example in Figure 2.

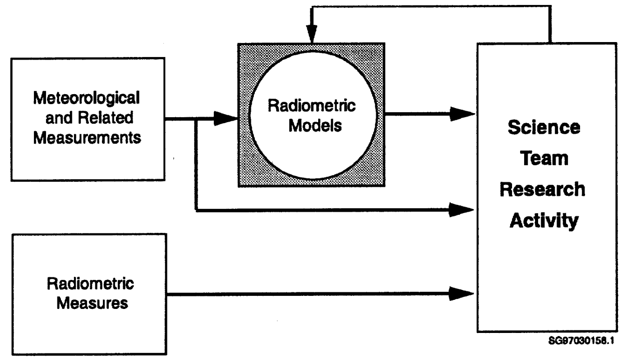

Figure 2. Experiment-based radiative model test scheme.

Science Team efforts focusing on the evolving nature and use of the measurement and modeling capabilities represented by the sites, their instruments, and the routinely running algorithms of the Experiment Center, is largely centered in the activities of various working groups. At the time of the 1997 meeting, the IRF working group had held its annual meeting and had made a number of recommendations to changes and additions to ARM’s measurement capabilities including the necessity for a new observational capability for the NSA site. As a result, an evaluation of a rotational Raman lidar was scheduled for the spring of 1998 and an evaluation of a 183-GHz microwave sensor in the spring of 1999, both at the Barrow site. Likewise, the SCM working group had held its second meeting, focusing on an SCM intercomparison, which was initiated following its first meeting. The cloud and aerosol working groups had each conducted their first meetings and focused on measurement capabilities and data needs.

Reference

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