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Site Scientific Mission Plan for the Southern Great Plains CART Site

January-June 1998

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Site Program Manager Office
Environmental Research Division
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NOTATION

ABLE	Argonne Boundary Layer Experiment
ABRFC	Arkansas Basin Red River Forecast Center
AERI	atmospherically emitted radiance interferometer
AGL	above ground level
AMMR	advanced multispectral microwave radar
ANL	Argonne National Laboratory
AOS	aerosol observation system
ARESE	ARM Enhanced Shortwave Experiment
ARM	Atmospheric Radiation Measurement
ASRC	Atmospheric Sciences Research Center
ASTER	air-surface turbulence exchange research
ASTI	absolute solar transmittance interferometer
AVHRR	advanced very-high-resolution radiometer
AWS	automated weather station
BAMS	*Bulletin of the American Meteorological Society*
BBSS	balloon-borne sounding system
BCR	baseline change request
BDRF	bi-directional reflectance functions
BF	boundary facility
BFVceil	boundary facility Vaisala ceilometer
BLC	Belfort laser ceilometer
BLX	Boundary Layer EXperiment
BORCAL	Broadband Outdoor Radiometer CALibration
BRS	broadband radiometer station
BSRN	Baseline Surface Radiation Network
CAR	Corrective Action Report
CART	Cloud and Radiation Testbed
CASES	Cooperative Atmosphere-Surface Exchange Study
CASH	commercial aviation sensing humidity
CN	condensation nuclei
CCN	cloud condensation nuclei
CERES	Clouds and Earth's Radiant Energy System
CIMMS	Cooperative Institute for Mesoscale Meteorological Studies
CIMSS/SSEC	Cooperative Institute for Meteorological Satellite Studies/Space Science and Engineering Center
CIRA	Cooperative Institute for Research in the Atmosphere
CIRES	Cooperative Institute for Research in Environmental Sciences
CLASS	cross-chain loran atmospheric sounding system
CLEX	Cloud Layer EXperiment
CSPHOT	Cimel sunphotometer
CSU	Colorado State University
DIAL	DIfferential Absorption Lidar
DOE	U.S. Department of Energy
DQR	Data Quality Report

NOTATION (Cont.)

DSIT	Data and Science Integration Team
EBBR	energy balance Bowen ratio
ECMWF	European Centre for Medium Range Weather Forecasts
ECOR	eddy correlation
EF	extended facility
EOP	Experimental Operations Plan
ETL	Environmental Technology Laboratory
FDDA	four-dimensional data assimilation
FSBR	fractional solar broadband radiometer
FSL	Forecasts Systems Laboratory
FTP	file transfer protocol
GCIP	GEWEX Continental-Scale International Project
GCM	general circulation model
GEWEX	Global Energy and Water Cycle Experiment
GFGR	Gagarin, Farruggia, Gibisch, Reis, Inc.
GIST	GEWEX Integrated System Test
GOES	geostationary orbiting Earth satellite
GPS	global positioning system
GRAMS	ground-based radiometer autonomous measurement system
GSFC	Goddard Space Flight Center
IDP	Instrument Development Program
IDPC	integrated data processing circuit
IF	intermediate facility
IOP	intensive observation period
IPM	instrument performance model
IR	infrared
IRF	instantaneous radiative flux
IRT	infrared thermometer
ISLSCP	International Satellite Land-Surface Climatology Project
ISM	Integrated Surface Mesonet
ISS	integrated sounding system
IT	Instrument Team
KSU	Kansas State University
LANL	Los Alamos National Laboratory
LBL	line by line
LBLRTM	line-by-line radiative transfer model
LLJ	Low-Level Jet
LMS	Lockheed Missile and Space
MAPS	Mesoscale Analysis and Prediction System
MDS	Meta Data System
MFR	multifilter radiometer
MFRSR	multifilter rotating shadowband radiometer
MIR	microwave imaging radar
MMCR	millimeter cloud radar

NOTATION (Cont.)

MPIR	multispectral pushbroom imaging radiometer
MPL	micropulse lidar
MSU	Millersville State University
MSX	Midcourse Satellite Experiment
MWR	microwave radiometer
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NCSU	North Carolina State University
NEPA	National Environmental Policy Act
NEXRAD	next-generation radar
NFOV	narrow-field-of-view zenith-pointing filtered radiometer
NGM	nested grid model
NIP	normal-incidence pyrheliometer
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NREL	National Renewable Energy Laboratory
NSSL	National Severe Storms Laboratory
NWS	National Weather Service
OCS	Oklahoma Climatological Survey
OKM	Oklahoma Mesonet
ORR	Operational Readiness Review
OU	University of Oklahoma
PAR	photosynthetically active radiometer
PARABOLA	portable appartus for rapid acquisition of bidirectional observations of the land and the atmosphere
PARC	Palo Alto Research Center
PBL	planetary boundary layer
PC	personal computer
PGAMS	portable ground-based atmospheric monitoring
PI	principal investigator
PIF	Problem Identification Form
PNNL	Pacific Northwest National Laboratory
PRB	Problem Review Board
PROF	profile
PRR	Pre-Readiness Review
PSU	Pennsylvania State University
QME	quality measurement experiment
RAMS	radiometer autonomous measurement system
RASS	radio acoustic sounding system
RCF	radiometer calibration facility
RLID	Raman lidar
RSS	rotating shadowband spectrometer
RUC	rapid update cycle

NOTATION (Cont.)

RWP	radar wind profiler
SAC	Site Advisory Committee
SCM	single-column model
SDS	site data system
SGP	Southern Great Plains
SI	International System of Units
SIROS	solar and infrared radiation observing system
SIRS	solar and infrared station
SITAC	Spectral Imagery Technology Applications Center
SMOS	surface meteorological observation station
SNL	Sandia National Laboratories
SORTI	solar radiance transmission interferometer
SSFR	spectral flux radiometer
SST	Site Scientist Team
SUCCESS	Subsonic Aircraft: Contrail and Cloud Effects Special Study
SWATS	soil water and temperature system
SWS	shortwave spectrometer
TBD	to be determined
TDDR	total direct diffuse radiometer
TEMP	temperature
THWAPS	temperature, humidity, wind, and pressure sensor
TLCV	time-lapse cloud video
T/RH	temperature and relative humidity sensor
TSBR	total shortwave broadband radiometer
TWP	Tropical Western Pacific
UAV	unmanned aerospace vehicle
UBC	University of British Columbia
UIR	upwelling infrared radiometer
UM	University of Massachusetts
UNAVCO	University NAVSTAR Consortium
UoM	University of Maryland
URL	universal resource locator
USDA	U.S. Department of Agriculture
USR	upwelling solar radiometer
UTC	universal time coordinated
UU	University of Utah
UV-A	ultraviolet A
UV-B	ultraviolet B
UW	University of Wisconsin
VAP	value-added product
Vceil	Vaisala ceilometer
VORTEX	Verification of the Origins of Rotation in Tornadoes Experiment
WPDN	Wind Profiler Demonstration Network
WPL	Wave Propagation Laboratory

NOTATION (Cont.)

WSI	whole-sky imager
WWW	World Wide Web

SITE SCIENTIFIC MISSION PLAN
FOR THE SOUTHERN GREAT PLAINS CART SITE
JULY-DECEMBER 1997

1 INTRODUCTION

The Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) site is designed to help satisfy the data needs of the Atmospheric Radiation Measurement (ARM) Program Science Team. This document defines the scientific priorities for site activities during the six months beginning on January 1, 1998, and looks forward in lesser detail to subsequent six-month periods. The primary purpose of this *Site Scientific Mission Plan* is to provide guidance for the development of plans for site operations. It also provides information on current plans to the ARM functional teams (Management Team, Data and Science Integration Team [DSIT], Operations Team, and Instrument Team [IT]) and serves to disseminate the plans more generally within the ARM Program and among the members of the Science Team. This document includes a description of the operational status of the site and the primary site activities envisioned, together with information concerning approved and proposed intensive observation periods (IOPs). The primary users of this document are the site operator, the Site Scientist Team (SST), the Science Team through the ARM Program science director, the ARM Program Experiment Center, and the aforementioned ARM Program functional teams. This plan is a living document that is updated and reissued every six months as the observational facilities are developed, tested, and augmented and as priorities are adjusted in response to developments in scientific planning and understanding.

This report (and all previous reports) is available on the SGP CART site World Wide Web (WWW) home page at

http://www.arm.gov/docs/sites/sgp/sgp.html

under the heading "Site Scientific Mission Plan."

A distilled version of this document is being written for publication in the *Bulletin of the American Meteorological Society* targeted for publication during this six-month period.

2 SUMMARY OF SCIENTIFIC GOALS

2.1 Programmatic Goals

The primary goal of the SGP CART site activities is to produce data adequate to support significant research addressing the objectives of the ARM Program. These overall objectives, as paraphrased from the *ARM Program Plan, 1990* (U.S. Department of Energy 1990), are the following:

- To describe the radiative energy flux profile of the clear and cloudy atmosphere

- To understand the processes determining the flux profile

- To parameterize the processes determining the flux profile for incorporation into general circulation models (GCMs)

To address these scientific issues, an empirical data set must be developed that includes observations of the evolution of the radiative state of the column of air over the central facility, as well as the processes that control that radiative state, in sufficient detail and quality to support the investigations proposed by the ARM Science Team. To address the entire 350-km × 400-km SGP CART site, the ARM Program relies on models to compute the processes or properties that affect radiative transfer. This set of data includes measurements of radiative fluxes (solar and infrared [IR]) and the advective and surface fluxes of moisture, heat, and momentum occurring within the column and across its boundaries. Other entities to be described are cloud types, composition, and distribution (depth, fractional coverage, and layering); thermodynamic properties of the columnar air mass (temperature, pressure, and concentrations of all three phases of water); the state and characteristics of the underlying surface (the lower boundary condition); processes within the column that create or modify all of these characteristics (including precipitation, evaporation, and the generation of condensation nuclei); and radiatively significant particles, aerosols, and gases. Basic continuous observations must be made as often as is feasible within budgetary constraints. For limited periods of time, these observations will be supplemented by focused IOPs providing higher-resolution or difficult-to-obtain *in situ* data.

Beyond simply providing the data streams, determining their character and quality as early as possible in the observational program is imperative. This evaluation provides the basic

operational understanding of the data necessary for an ongoing program of such scope. Although both reason and ample opportunity will exist to develop a further understanding of the ARM observations over the course of the program, the task of investigating and ensuring the data quality is extremely important. In this regard, routine instrument mentor and SST data quality assessments, definitive quality measurement experiments (QMEs), and value-added products (VAPs) help establish confidence in the measurements.

The SGP CART site is the first of three global locations chosen and instrumented for data collection. As summarized in the *Science Plan* for the ARM Program (U.S. Department of Energy 1996), the scientific issues to be addressed by using data from a midlatitude continental CART observatory include the following:

- Radiative transfer in cloudless, partly cloudy, and overcast conditions
- Cloud formation, maintenance, and dissipation
- Nonradiative flux parameterizations
- The role of surface physical and vegetative properties in the column energy balance
- Other complications in the radiative balance in the atmosphere, particularly those due to aerosols, cloud condensation nuclei (CCN), and cloud-aerosol radiative interactions
- Feedback processes between different phenomena and different domains

The variety, surface density, and atmospheric volumetric coverage of the SGP instrumentation will be more comprehensive than those at any other ARM site, and the SGP site will experience a wider variety of atmospheric conditions than will any other ARM site. The resulting data will accordingly support a greater range and depth of scientific investigation than data from any other location, making it imperative for the ARM Program to develop and maintain a high-quality, continuous data stream from the SGP site.

The measurements required by Science Team proposals, the DSIT, and the science director are categorized into scientific applications areas/groups within ARM. The DSIT and

other teams coordinate activities to develop these integrated, well-focused data sets for these groups. Focus areas include shortwave radiation, water vapor, longwave radiation, aerosols, clouds, surface fluxes, and the single-column model (SCM). A goal is to facilitate algorithm development that prescribes geophysical phenomena as products of multiple data streams.

2.2 Priorities for Site Activities

Priorities for site activities for January through June 1998 include:

1. Facilitate all data quality assessment efforts, particularly those focused on shortwave radiation and water vapor, including implementation of QMEs and VAPs.

2. Complete establishment and sustain high quality of routine site operations.

3. Plan and implement key IOPs and campaigns.

4. Finish implementation of extended facilities.

5. Support the Instrument Development Program (IDP).

Within this ranking, the differences in relative importance between adjacent items are not large. The categorization is also somewhat artificial because many site activities have multiple purposes. For example, IOP activities can simultaneously support Science Team, IDP, and campaign requirements. Even so, this ranking reflects our scientific assessment of the activities that should receive the most support during this period.

The IOPs focus on providing critical data sets on an episodic basis to the Science Team, as well as field support for instrument development and testing and for collaborative campaigns. The IOPs scheduled for this six-month period are detailed in Section 5.3.

Due to budget restraints, routine radiosonde observations have been reduced to three daily balloon-borne sounding system (BBSS) launches on Monday through Friday (including holidays) at the central facility. There will be no routine launches at any of the four boundary facilities. Funding will be provided for two SCM IOPs, each lasting for three weeks, to be conducted each year. Funding can be made available for a third SCM IOP during a particular year if a strong need can be demonstrated, relative to other scientific tasks. The SCM working

group will provide a recommendation as to when SCM IOPs will take place. Single-column model IOPs are scheduled tentatively for winter (January 16 - February 8, 1998) and late spring (May time frame).

Operation of the radiometer calibration facility (RCF) has matured, with site operations, as trained by staff of the National Renewable Energy Laboratory (NREL), currently performing most of the work. Successful calibration has been carried out in September 1996 and July-September 1997, with the completion of two BORCALS. Optimum use of the facility is an on-going exercise.

The split of the solar and infrared radiation observing system (SIROS) into a solar and infrared station (SIRS) and a multifilter rotating shadowband radiometer (MFRSR) at each of the extended facilities was completed last December with freshly calibrated (e.g., BORCALS at the RCF) broadband radiometers. In addition, the number of radiometers installed at the central facility led to an expansion of the central cluster and the addition of a new area called the optical trailer cluster, which is located just south of the optical trailer and north of the central cluster. Priority instruments recently installed include the time-lapse cloud video (TLCV), the rotating shadowband spectral (RSS) radiometer, and the ground-based radiometer autonomous measurement system (GRAMS) in the optical trailer cluster, and the Cimel sunphotometer (CSPHOT) in the expanded southern area of the central cluster. The permanent shortwave spectrometer (SWS) will be installed in the optical trailer in January 1998.

The phased implementation of the Okmulgee extended facility (the wooded site) is nearly complete. The walk-up tower, shelter, and infrastructure were in place last fall. Instruments are planned for installation in late spring. In addition, a Memorandum of Understanding with the USDA in support of GEWEX studies was signed and allows the costs of installation to be shared with ARM for phased implementation and completion of a fully instrumented extended facility at El Reno. This energy balance Bowen ratio (EBBR) site will be used in support of the GEWEX studies. A solar-powered EBBR and SWATS with cellular phone data communications have been temporarily installed. It is hoped to complete this site during the current six-month period.

The Seminole EF was recently completed by attaching EBBR sensors and completing relevant IDPCs. The installation of four Vaisala 25-km ceilometers and four atmospherically emitted radiance interferometers (AERIs) at boundary facilities have been postponed until FY 1999 due to delivery schedule problems of the AERIs. The disposition of the eddy correlation

(ECOR)-based Ft. Cobb site is yet to be determined. Establishment of one auxiliary facility will be needed to accommodate the installation of a second day-night whole-sky imager (WSI), if needed.

In addition, an administration trailer is currently being installed in the compound area of the central facility, as well as a phased implementation of three trailers at IDP No. 4 for a storage area.

Chad Bahrmann, the on-site scientist, was hired and began residence full time at the central facility this past November. The primary function of his position is to support the SST data-quality-modules development activities and also to provide assistance to site operations functions that may improve the overall quality of the data streams generated at the SGP CART site. Support during IOPs and for education outreach endeavors are also key components of this position.

In summary, our goals for this six-month period continue to be to provide the Science Team with a suite of measurements that will support a wide range of research, to establish solid procedures for instrument calibration and maintenance (particularly for broadband radiometry), to operate the series of VAPs/QMEs, to provide input for the scientific applications groups, and to install required instrumentation and facility support. Quality assessment efforts remain central to the success of the entire program. Section 4 further describes this emphasis.

3 ROUTINE SITE OPERATIONS

3.1 Overview

The overwhelming majority of the measurements with the highest priority, on which the existing experimental designs are based, are regular (i.e., routine) observations, as specified in the *ARM Program Plan, 1990* (U.S. Department of Energy 1990). Scientifically and logistically, routine operations will also serve as the basis and background for all nonroutine operations, including instrument development activities, IOPs, and collaborative campaigns directed toward obtaining difficult-to-gather or expensive *in situ* data. Consequently, development and validation of the basic observations remain high priorities. Site development has progressed sufficiently to support IOPs addressing key scientific areas of study as water vapor.

The SST will continue to work to ensure the scientific productivity of the site by providing guidance to the site operations manager and his staff on scientific matters. This includes monitoring instrument performance via the quality of the data stream, reviewing schedules and procedures for instrument maintenance and calibration, reviewing designs for infrastructure supporting new instruments, contributing to the design of the standard operating procedures, reviewing and developing plans for IOPs, and helping obtain near-real-time data displays for IOPs. The SST, in cooperation with instrument mentors and the DSIT, will continue to lead the data quality assessment effort at the CART site, an ongoing activity that includes monitoring of the CART data streams in collaboration with the staff at the central facility and the development of data quality performance metrics and graphical tools that will address the data originating at the SGP site. The site program manager will help coordinate these activities.

Routine operations are considered to be the activities related to the operation and maintenance of instruments, the gathering and delivery of the resulting data, and the planning for scientific investigations, including IOPs, campaigns, and VAPs/QMEs. Although the site is essentially complete, instrumentation will be evaluated continuously to assess the need for possible elimination of instruments or replacement with different or new sensors. The process that leads to implementation of CART instruments continues to be the Pre-Readiness Review (PRR). The PRR includes the identification of requirements for instrument design and installation and the development of the documentation, procedures, and training needed to maintain CART instrumentation and integrate data streams into the site data system (SDS). The PRR also provides a forecast of when these instruments will be fully operational (i.e., operational

handoff to site operations via the Operational Readiness Review [ORR]) and delivering data to the Experiment Center and the Archive.

The design expectation for the routine operation of instruments is that they will continue to require servicing by site operators only once every two weeks. The exception to this is the central facility and the boundary facilities, which are staffed. If an instrument fails during a two-week period at an extended facility, data streams could be lost, although every effort is made to ensure adequate data-logging capacity at each remote site. Such loss of data is unfortunate but deemed acceptable to the ARM Program because of manpower and budget constraints. The instruments at all extended, intermediate, and boundary facilities are polled frequently each day by the SDS at the central facility, with data packaged and delivered to the Experiment Center once daily. The Experiment Center generally delivers data to Science Team members and other data requesters once weekly via an Experimental Operations Plan (EOP), and sends data sets to the ARM Data Archive. It is at the Experiment Center where VAPs/QMEs are developed and operated.

Site operations staff conduct instrument triage during IOPs and campaigns. The triage plan calls for IOP scientists to identify instruments, individual sensors, and communication links that are critical to the operation and goals of the IOP so that these instruments will receive more frequent servicing than that prescribed by routine operational requirements mentioned above. The priority of triage efforts is determined by the SST and IOP scientists and the site program manager, who take into consideration the scientific importance of a particular data stream and its expense. The triage plan has been very successful, as demonstrated during the recent IOPs.

Handling of instruments that must be returned to the vendor for calibration and servicing is also part of routine operation. Replacement instruments and sensors will be rotated regularly to meet these requirements. Calibration and maintenance information is compiled in order both to properly operate and maintain site instruments and to provide pertinent information to data users. Changeouts of all sensors and instrumentation are recorded in the site operations log.

The initial checks on data quality after instrument installation are provided by the instrument mentors. After the mentor reviews the data stream to ensure that the acquired instrument is performing properly and that the data are identified accurately by the Experiment Center, the mentor approves a "beta" release of the data. The beta release provides data to selected Science Team members who have requested them and are willing to work with the instrument mentor on data quality issues. Beta releases are established after the instrument

mentor and an appropriate member of the DSIT create a general statement on data quality for the Experiment Center. When the data quality relative to proper instrument functionality is consistently acceptable and well documented, the mentor approves a full release of the data.

3.2 Routine Operations

3.2.1 Functional Instruments and Observational Systems

Figure 1 is a map of the SGP site showing the locations of the developed extended, intermediate, and boundary facilities. The status of the systems and instruments anticipated by June 30, 1998, is summarized in Table 1.

Accomplishments in the area of site development are most evident at the central facility (Table A.1 in the Appendix), with its functioning power, fiber-optic infrastructure, and near-complete array of instruments. Of the 26 planned extended facilities (Table A.2 in the Appendix), 24 (including one at the central facility and one at the Cement location) are operational at the beginning of this period, one (Ft. Cobb) is yet to be identified, and one is a placeholder site for possible expansion, if required.

In addition, ARM has developed a mission critical database (metadata) that will make it possible to provide a common location for all information (other than instrument data streams) that enhances the scientific utility of the individual instrument data streams. Such information is available at the ARM metadata WWW site:

http://www.db.arm.gov/MDS/ .

3.2.2 Launch Schedule for Balloon-Borne Sounding Systems

Until the full suite of remote sensing systems is deployed to perform deep, detailed soundings of the wind, temperature, and moisture of the troposphere under a wide range of conditions, the BBSS will continue to be an expensive workhorse owing to the cost of the expendables and manpower associated with an ambitious schedule of radiosonde launches. Due to budget constraints, the number of BBSS launches sitewide have been reduced to a minimum needed to support routine cross-checks on the remotely sensed measurements. The frequency of routine launches at the central facility have been reduced and elimated at all four boundary facilities just before the beginning of this six-month period.

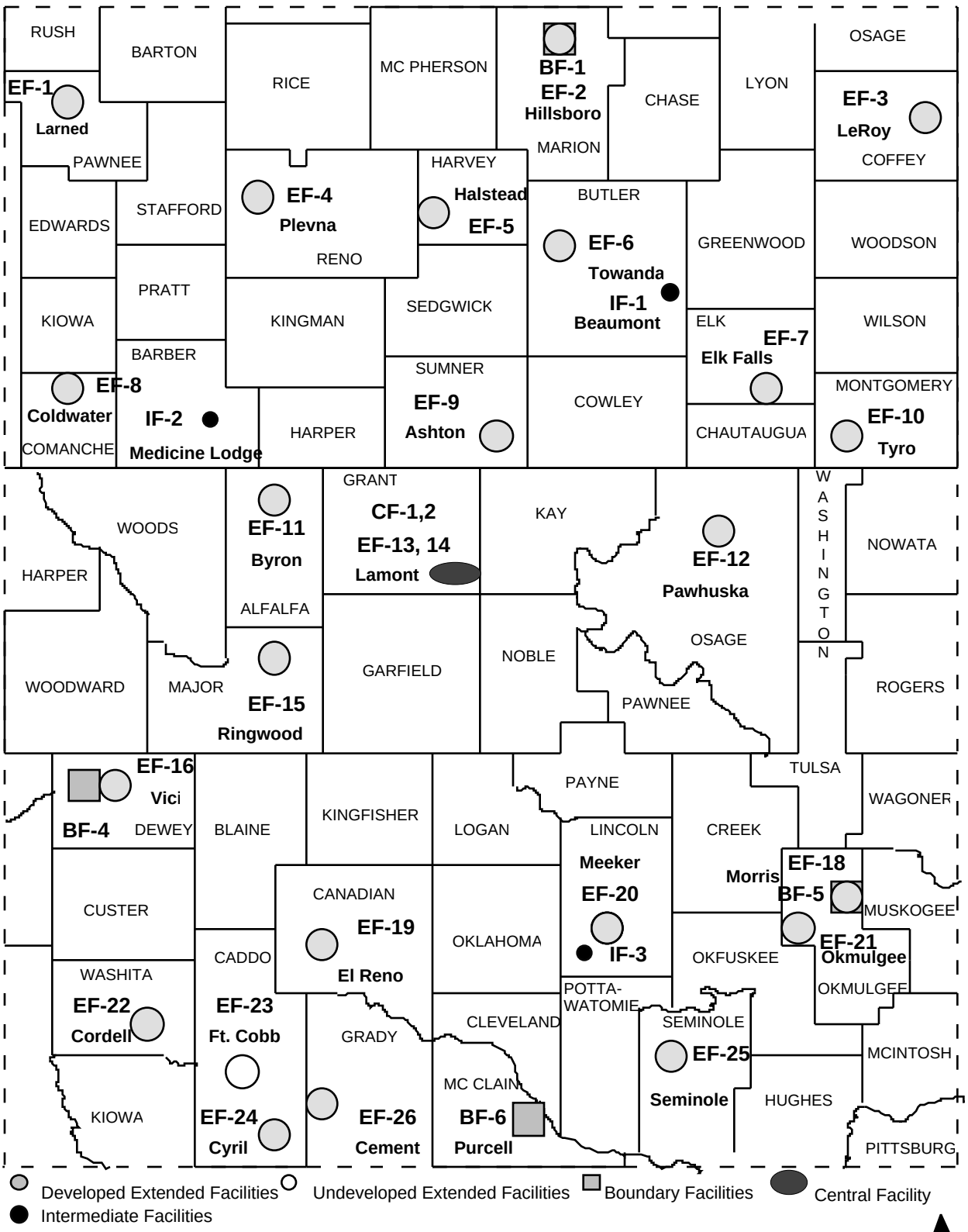

FIGURE 1 Overall View of the SGP CART Site (Approximate Scale: 50 km/in.)

TABLE 1 Instruments and Observational Systems Anticipated at the Central, Boundary, Extended, and Auxiliary Facilities on June 30, 1998[a]

Central Facility

Radiometric Observations

- AERI
- AERI X
- SORTI
- BRS (formally BSRN)
  - Pyranometer (ventilated)
  - Pyranometer (ventilated, shaded)
  - Pyrgeometer (ventilated, shaded)
  - NIP on tracker
  - MFRSR
- SIRS (formally SIROS)
  - Pyranometer (ventilated)
  - Pyranometer (ventilated, shaded)
  - Pyrgeometer (ventilated, shaded)
  - NIP on tracker
  - Pyranometer (upwelling, above pasture at 10 m)
  - Pyrgeometer (upwelling, above pasture at 10 m)
- MFRSR
- MFR (upwelling, above pasture at 10 m)
- Pyranometer (upwelling, above wheat at 25 m on 60-m tower)
- Pyrgeometer (upwelling, above wheat at 25 m on 60-m tower)
- MFR (upwelling, above wheat at 25 m on 60-m tower)
- CSPHOT
- RSS
- NFOV
- GRAMS
- SWS
- RCF instrumentation, including cavity radiometers

Wind, Temperature, and Humidity Sounding Systems

- BBSS
- 915-MHz profiler with RASS
- 50-MHz profiler with RASS
- MWR
- Heimann IR thermometer
- Raman lidar

Cloud Observations

- WSI (daytime/nighttime)
- BLC (interim)
- MPL (IDP) ceilometer
- MPL-HR
- MMCR
- Vceil
- TLCV

TABLE 1 (Cont.)

Others

Temperature and humidity probes at 25-m and 60-m levels on tower
Heat, moisture, and momentum flux at 25-m and 60-m levels on tower
EBBR
ECOR
SMOS
AOS (samples at 10 m)
SWATS

Extended Facility Components

SIRS (formally known as SIROS)
- Pyranometer (ventilated)
- Pyranometer (ventilated, shaded)
- Pyrgeometer (ventilated, shaded)
- NIP on tracker
- Pyranometer (upwelling, at 10 m)
- Pyrgeometer (upwelling, at 10 m)

MFRSR
EBBR or ECOR
SMOS
SWATS

Auxiliary Facilities

None in preparation

Boundary Facilities

BBSS
MWR

Intermediate Facilities

915-MHz profiler and RASS

---

[a] AERI, atmospherically emitted radiance interferometer; AOS, aerosol observation system; BBSS, balloon-borne sounding system; BLC, Belfort laser ceilometer; BRS, broadband radiometer station; BSRN, Baseline Surface Radiation Network; CSPHOT, Cimel sunphotometer; EBBR, energy balance Bowen ratio; ECOR, eddy correlation; GRAMS, ground-based radiometer autonomous measurement system; IDP, Instrument Development Program; IR, infrared; MFR, multifilter radiometer; MFRSR, multifilter rotating shadowband radiometer; MMCR, millimeter cloud radar; MPL, micropulse lidar; MWR, microwave radiometer; NVOV, narrow fild of view zenith-pointing filtered radiometer; NIP, normal-incidence pyrheliometer; RASS, radio acoustic sounding system; RCF, radiometer calibration facility; RSS, rotating shadowband spectrometer; SIROS, solar and infrared radiation observing system; SIRS, solar and infrared station; SMOS, surface meteorological observation station; SORTI, solar radiance transmission interferometer; SWATS, soil water and temperature system; SWS, shortwave spectrometer; TLCV, time-lapse cloud video; Vceil, Vaisala ceilometer; WSI, whole-sky imager.

The new routine operations is provided in Table 2.

The new routine radiosonde launch times at the central facility were chosen to compliment the national Weather Service standard launch times of 0000 UTC and 200 UTC, and to support the daytime satellite (AVHRR on the polar orbiter) overpass at approximately 2030 UTC. The 2100 UTC launch is during maximum daytime boundary conditions and therefore supports instantaneous radiative flux (IRF) and IDP research. Remote sensing of virtual temperature profiles at all boundary facilities is provided by the nearby NOAA profilers, which are being outfitted with ARM-provided RASS units. The RASS units have already been installed at the Purcell, Oklahoma, and at the Haviland, Kansas, NOAA profilers. The Lamont, Oklahoma, NOAA profiler will not receive a RASS unit because it would be located too close to a residence, but the nearby SGP CART site central facility collects a relative abundance of thermodynamic data. In addition, global positioning system (GPS) instruments were recently installed at the Purcell, Vici, Morris, and Hillsboro NOAA profiler locations to provide estimates of precipitable water. This information has become available to the ARM Program as external data, along with the NOAA profiler data.

The routine 1800 UTC radiosonde launch at each of the four boundary facilities has been eliminated. Boundary facilities will be staffed 24 hours per day for 21 consecutive days (including holidays) to facilitate SCM IOP launch schedules of every 3 hours (Table 2).

The central facility will be staffed from 0430 to 1630 and from 2230 to 0230 local time, Monday through Friday (including holidays). During appropriate IOPs, the central facility will be staffed 24 hours per day, 7 days per week (including holidays), to facilitate round-the-clock radiosonde releases every 3 hours.

3.3 Instruments

A CART instrument is any instrument that is approved by the ARM Program and for which the site operations management has accepted responsibility for operation and maintenance. The PRR and ORR forms are requests for information that facilitates the installation and operation of instruments or facilities at the SGP CART site. The purpose of

TABLE 2 Radiosonde Launch Schedule for January-June 1998 (Times in UTC)[a]

Central Facility	Boundary Facilities
Winter SCM IOP Operations, January 19-February 9	
0300	0300
0600	0600
0900	0900
1200	1200
1500	1500
1800	1800
2100	2100
2400	2400
Routine Operations, January 1-18 and February 10-June 30, Monday-Friday[b]	
0600	
1800	
2100	

[a] IOP, intensive observation period; SCM, single-column model; UTC, universal time coordinated. Launch time is 30 min earlier; the stated time represents the approximate midpoint of the flight.

[b] The dates for the late spring SCM IOP have not yet been established.

these reviews is to achieve an efficient handoff of instruments and facilities from instrument mentors to site operators. Figure 2, the SGP CART instrumentation implementation flowchart, contains information obtained from the PRR and ORR documentation. When all procedures, operation manuals, and training pertaining to an instrument have been completed, the instrument is accepted by the site operations management. If sufficient documentation is available to operate an instrument, even though more will ultimately be required for full acceptance, the instrument may be operated in a degraded mode.

Once site operations personnel have accepted instruments, their design and configuration are "locked in" by using a configuration management system that is controlled by site operations. Any modifications to instruments or data systems require a baseline change request (BCR). The BCR process has been upgraded to a secure Web-based system. A BCR submittal form can be found at

http://www.arm.gov/docs/sites/sgp/forms.html .

Such requests usually come from the instrument mentors. The site program manager is the control for the BCR process and assigns infrastructure for review and approval. Those participating in the review and approval process are provided with passwords to gain access to the BCR database.

Instruments recently installed or expected to be installed include the following:

- *Time-Lapse Cloud Video, installed*. Implementation of a video camera and reflector to obtain time-lapse video views of cloud conditions above the central facility has occurred. The instrument in the optical cluster became operational in late summer 1997.

- *Ground-Based Radiometer Autonomous Measurement System, installed*. Two sets of GRAMS sensors were installed at the optical trailer cluster and on the deck of the RCF, in late summer. Each set has a total shortwave broadband radiometer (TSBR), a fractional solar broadband radiometer (FSBR), and a total direct diffuse radiometer (TDDR).

- *Rotating Shadowband Spectrometer, installed.* A RSS radiometer was installed at the SGP central facility during the late summer of 1997 after extensive development and testing at the Atmospheric Sciences Research Center (ASRC) at the State University of New York. It measures the solar spectrum between approximately 350 and 1,050 μm for the direct, diffuse, and global components.

- *Improved Solar and Infrared Radiation Observing System Data Logging at Central Facility and Extended Facilities, installed*. New data loggers and associated data equipment have been installed to provide an independent data logger for the non-MFRSR components of SIROSs and for the central facility Baseline Surface Radiation Network (BSRN). The new platforms are named SIRS and broadband radiometer station (BRS) for "solar and infrared station" and "broadband radiometer station," and the MFRSRs now have independent "MFRSR" platform names. The conversion of all SIROS to SIRS + MFRSR was completed in December 1997. The new SIRS platform is expected to have considerably greater reliability than that achieved with the MFRSR-

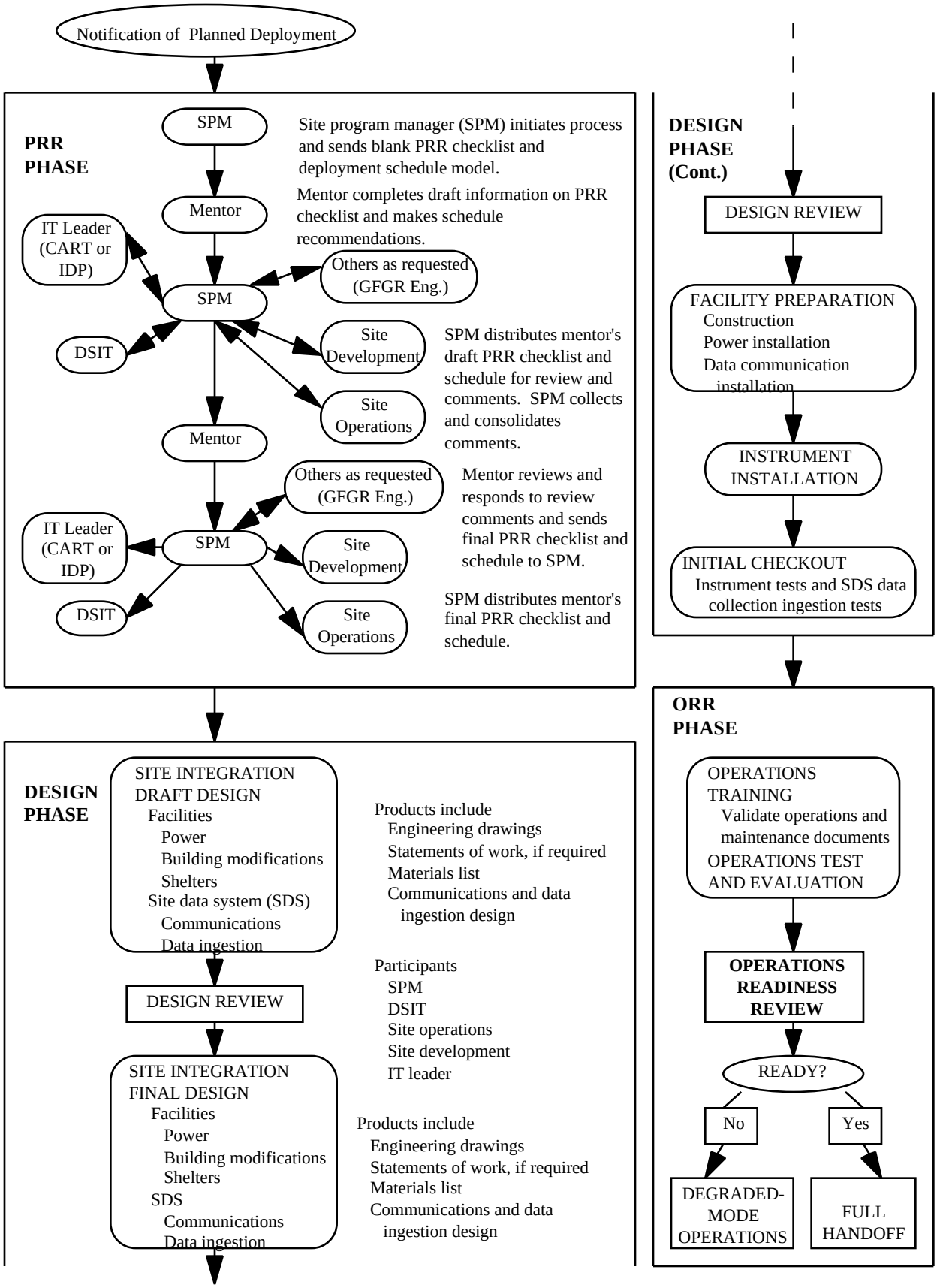

FIGURE 2 SGP CART Instrumentation Implementation Flowchart

logger-based platform, and the computations will allow data capture that meets international standards.

- *Cimel Sunphotometer at the Central Facility, installed.* A CSPHOT was acquired for installation at the central facility. The CSPHOT will provide measurements of aerosol optical depth to supplement the MFRSR and to tie in with a global network of sunphotometers supported in part by NASA. In addition to measuring optical depths, the system is used to observe the sky radiance along the solar almucantar and along the solar principal plane, including the solar aureole. The resulting data can be used for research on inferring aerosol size distribution and the scattering phase function. A prototype instrument was installed in the expanded central cluster in late summer 1997 for the Fall 1997 Integrated IOP. The permanent instrument was installed in December 1997.

- *Shortwave Spectrometer, in Progress.* A field spectroradiometer system for wavelength ranges of 350-2,500 nm in three wave bands has been acquired. Initially, only global radiation will be detected. A prototype was operated during the Fall 1997 Integrated IOP. The permanent version is anticipated to be installed in January 1998.

- *Establishment of Instruments at an Extended Facility at a Forested Site, in Progress.* A walk-up scaffolding tower (approximately 55 ft) for supporting an ECOR system, a surface meteorological observation station (SMOS), and a SIRS above the forest canopy at the Okmulgee extended facility was erected in summer 1997. Phased implementation of instrumentation continues. This site may not be fully operational until spring 1998.

- *Ceilometers and AERIs at Boundary Facilities, in Progress.* Four Vaisala ceilometers have been acquired for installation at the boundary facilities this year. These ceilometers are capable of detecting cloud base to a height of about 2.5 km. They are intended primarily to provide data for algorithms to retrieve temperature and humidity profiles in the lower troposphere from AERI data. Installation of the AERIs have been delayed until all four units are in hand. Budget considerations resulted in delayed ceilometers and AERIs

until FY 1999. At that time, when all instruments are in hand, installations will take place.

- *Occasional Tethersonde and Kite Measurements of Humidity Profiles at the Central Facility, in Progress*. A tethersonde system and a kite system outfitted with a high-quality humidity sensor have made measurements of temperature and relative humidity profiles in the lower 1 km of the atmosphere above the central facility during both the Water Vapor IOP in September 1996 and the Fall 1997 integrated IOP. These systems will be used in future IOPs.

- *Upgrades of the Radiosonde System, installed*. Steps have been taken to upgrade the CART BBSSs to use GPS-based rather than loran-based tracking for determining position, which will be necessary during the next few years as Loran-C transmitters are phased out. In addition, a new type of Vaisala radiosonde, which uses the RS-90 sonde instead of the RS-80 version presently used, is expected to become available within a year. The humidity sensor on the RS-90 sondes is reported to have a faster response and to recover more quickly after emerging from clouds. The temperature sensors are smaller and thus probably considerably faster in response and less susceptible to the effects of heating by solar radiation. In addition, reference temperature, humidity, wind, and pressure sensors (THWAPSs) were installed at the balloon launch site at the central facility to provide surface reference values. A THWAPS will be installed during this six-month period at each of the boundary facilities as well.

- *Narrow-Field-of-View Zenith Sky Radiance in the Near Infrared, in Progress.* An uplooking near-IR shortwave radiance instrument with a field of view overlapping or nearly coincident with the MWR and possibly the cloud radar is being developed. The wavelengths detected are in a fairly narrow band near 0.9 μm. Such a device is needed to improve understanding of the relationships between the liquid water path and shortwave radiation.

- *Optical Transmissometer, in Progress*. A commercially available transmissometer will be acquired to detect fog, dust, and drizzle too light to be recorded by rain gauges. Such phenomena are best detected by open-path

devices rather than through a large sampling stack such that as being used with the aerosol observation system (AOS). The data will be useful for evaluation of signals from radars, lidars, and the MWR.

Measurement issues currently being considered but unresolved by the ARM infrastructure include the following:

- *Continuous Direct-Beam Solar Irradiance Measurements with a Cavity Radiometer*. Documentation for the BSRN specifies that an all-weather windowless cavity radiometer be operated at a BSRN site. This task is not feasible at the SGP CART site central facility because of dust conditions. Operation of a windowed cavity radiometer, one of which has already been purchased for this purpose, might be possible at the RCF, but considerable effort would be necessary for continuous operation. Some compromise for part-time or discontinuous operation might have to be developed. Cavity radiometers were operated during the Fall 1997 Integrated IOP, and during BORCAL operations.

- *Absolute Solar Transmittance Interferometer and Solar Radiance Transmission Interferometer*. Operation of the absolute solar transmittance interferometer (ASTI) is occurred in IOP mode for the shortwave portion of the Fall 1997 Integrated IOP. Solar radiance transmission interferometer (SORTI) implementation at the central facility also occurred for the IOP. Data are being collected, but ingest has not been achieved.

- *Local Observations of Surface Vegetative Conditions at Extended Facilities*. The interpretation of data on, and the modeling of, surface latent and sensible heat fluxes at extended facilities would be assisted with routine observation of leaf area index and surface optical reflectance properties represented by the nondimensional vegetative index. Local leaf area index measurements might be too variable to be of much use, but local measures of nondimensional vegetative index were believed to be particularly important for interpretation of nondimensional vegetative index values derived from remote sensing data from satellites. The satellite could then be used to help infer the values and variability of surface heat fluxes for the overall SGP CART site. Relatively

simple devices that obtain a measure of nondimensional vegetative index can be obtained at a modest cost and are currently being investigated.

- *Additional Extended Facilities at the SGP CART Site*. Some concern has been expressed that the spatial coverage of extended facilities for measuring air-surface exchange rates of heat and moisture seems to be incomplete, particularly to the south and southeast of the central facility. A review of the current site distribution needs to be carried out.

- *Surface Bidirectional Reflectance*. Measurements of surface bidirectional reflectance have been suggested at times for the SGP CART site, and a commercial source of the portable apparatus for rapid acquisition of bidirectional observations of the land and the atmosphere (PARABOLA) is available. Such an observation would be quite useful in the interpretation of solar reflectances seen from satellites. A commercial system is available but is not suitable for routine observations. Currently, a Science Team project is addressing this observational need.

- *Profiling with Passive Microwave Systems*. A passive MWR for obtaining profiles of temperature through clouds could augment or supplant profile measurements made with the AERI at the boundary facilities. The primary advantage of microwave profiling is that it penetrates through clouds, which is not accomplished with any of the water vapor remote sensing systems currently in operation at the SGP CART site. Radiometrics has been developing such a system. Vertical resolution appears to be about 100 m near the surface and increases gradually to over 2 km at a height of about 10 km near its maximum range. A less expensive Russian system with slightly greater vertical resolution and a maximum range of about 600 m is currently being evaluated. If funding were provided, a passive system for water vapor profiling might also be successfully developed.

3.4 Observations, Measurements, and External Data

The ARM observations being delivered to the Experiment Center from the SGP CART site as of June 30, 1997, can be found on the WWW at

http://www.ec.arm.gov/data/sgpmeasurement.html .

External data being delivered to the ARM Program can be found on the WWW at

http://www.xdc.arm.gov/ .

The availability of data from a particular platform on any given day is a function of quality control, with some segments temporarily unavailable during evaluation or correction of problems.

A summary that includes both the measurements derived from the SGP CART data and data streams from sources external to ARM (e.g., the gridded data from the National Centers for Environmental Prediction model [ETA]) can be found on the WWW at

http://www.ec.arm.gov/data/sgpavailability.html .

3.5 Site Development Activities

3.5.1 Facilities

Full implementation of the El Reno extended facility may take place in 1998 with the signing of the Memorandum of Understanding between Argonne National Laboratory and the USDA. A temporary setup of a solar-powered EBBR and SWATS with cellular phone data communications is currently in place.

Implementation of the Okmulgee extended facility is taking place in five phases. The first was access roadway and power. The second was the installation of the walk-up tower. The third phase was the installation of the infrastructure (cement pads, data communication lines, gravel, etc.). The fourth phase was the installation of the shelter and security fence. All four phases were completed by late 1997. The fifth phase will be installation of the instruments. Full implementation is not expected until near the end of this six-month period.

The number of radiometers to be deployed at the central cluster has required expansion and an additional area designated as the optical trailer cluster. Instruments critical to the Fall 1997 Integrated IOP were be installed and operational there by August 1997. They include the GRAMS, TLCV, RSS, and CSPHOT. A narrow-field-of-view zenith-pointing filtered

radiometer (NFOV) may be deployed near the EBBR. The shortwave spectrometer (SWS) will be installed in the optical trailer, and the ASTI will be considered for installation in the optical trailer. Each of the cluster areas has been upgraded relative to electronics and communications to allow for expansion of yet unspecified instruments.

In anticipation of additional IDP area facilities, IDP No. 4 is being implemented. This 150-ft × 175-ft graveled area is located at the site formerly occupied by the farmhouse at the extreme southeast corner of the central facility. This area will have a double-wide trailer (24 ft × 55 ft) for storage and a 12-ft × 50-ft office trailer. Finally, an administration trailer has been situated at the north end of the central facility, parallel to the conference trailer.

3.5.2 Development of the Site Data System

Several of the installed instruments and all new instruments require creation of software to transfer the data from the instrument platforms to the SDS via a pathway referred to as the integrated data processing circuit (IDPC). The IDPC includes communications between the instrument and data loggers, as well as data ingest (described more fully in Section 4.1), instrument status to site operations and others, and, finally, transmission of data to the Experiment Center and the Data Archive. Usually, transfer of data is accomplished by coded switches at the extended facilities and intermediate facilities or by T-1 lines at the boundary facilities. Most of the ARM SGP instruments have their data collected (or delivered) to the SDS regularly, with data processed through the IDPC and passed on to the Experiment Center and the ARM Archive. Some exceptions to this pattern will continue to occur during the next six months.

The IDPC development schedule and status for instruments can be found at the WWW site:

http://kombo.dis.anl.gov/armtrack .

To access this database, log in as "guest"; and type in "guest" for the password, and specify "IDPC" as type. Further work is being undertaken to facilitate routine operations and particularly to assess instrument performance, by including a broader suite of data display capabilities. Once the SDS is near completion, procedures for system management and maintenance need to be written and transferred to site operations staff.

In addition, the SDS continues to address the ongoing need to make near-real-time data available for selected scientists during IOPs and campaigns and for educational outreach efforts in conjunction with the Oklahoma Climatological Survey's outreach projects. A successful prototype system for delivering near-real-time data to scientists was used during the Water Vapor IOP of September 1996, and was greatly expanded upon and enhanced during the Fall 1997 Integrated IOP. This Web-based system, known as the R1 or Research System, played a key role in the success of the Fall 1997 experiment.

3.6 Limiting Factors

The most basic of limiting factors is the amount of resources available to continue site development, expand operations, and provide necessary support for the IT and DSIT. Shortfalls result in delays in implementation. Shortfalls in vendor supplies, delays in obtaining information for PRRs, and budgeting problems have also been hindrances. Another significant limiting factor is the time lag inherent in the procurement process.

All systems awaiting construction or installation go through a formal design review of structural and mechanical systems. These reviews frequently identify deficiencies in plans and drawings related to engineering requirements, procurement details, safety, and quality control. This review activity was expanded to include large or complex IOPs (e.g., the 1997 Fall Integrated IOP in September-October 1997) in an effort to integrate the exceptionally wide variety of IDP instrument support requirements for cost-effective and safe implementation. Neither construction nor installation can begin until the design review process has been successfully completed.

The costs associated with BBSS launches (primarily expendables) will continue to be a burden on the operations budget until these systems are replaced by continuous, unmanned remote sensing systems (if ever). These expenses are a strong constraint on the total number and frequency of launches, making impossible the routine provision of all of the requested launches (eight per day at the central and boundary facilities), defined as the optimal sounding strategy for SCM requirements by the DSIT (M. Bradley and R. Cederwall, unpublished information).

4 DATA QUALITY

Data quality issues are addressed at several levels within the ARM Program and at the SGP CART site. One of the goals of the ARM Program is to provide data streams of known and reasonable quality. Maintaining data quality for a program of this size and complexity is a significant challenge. Data quality assurance within the ARM Program infrastructure has matured over the past few years and will continue to evolve, with the SST continuing to play a strong role. Data flagging issues and addressing the data quality of newer instruments are a prime focus for this six-month period.

4.1 Instrument Mentors

Instrument mentors are charged with developing the technical specifications for instruments procured for the ARM Program. The instrument mentor then tests and operates the instrument system (either at his or her location or at the SGP CART site). In addition, the mentor works with SDS personnel on ingestion software requirements as part of the IDPC. Data ingestion involves the conversion of data streams to the International System of Units (SI), as well as the acquisition of parameters that can be used to monitor instrument performance (e.g., monitoring an instrument's output voltage for a 5-V power supply or the continuity of the wire in a hot-wire anemometer). Data collection and ingestion, then, are the focus of the first level of data quality assurance. Quality at this level is monitored routinely by site operators and instrument mentors.

The next level of data quality assurance involves beta release of data streams from individual instruments. The mentor receives the data from the instrument to determine whether the technical specifications of the instrument are being met. When the mentor is satisfied that the instrument is functioning properly and that the technical specifications have been met, the data are formally released to the Science Team and other data users. After this release, the instrument mentor is also charged with reviewing the instrument data streams at least once every two weeks, an action monitored at the Experiment Center. This information is forwarded to the SST.

Instrument mentors also provide all calibrations, operations and maintenance documents and lists of spare parts to site operations. Typically, the mentor provides additional detailed documentation and hands-on training so that appropriate support can be provided by site operators. This activity is part of the ORR process.

4.2 Site Scientist Team

The SST helps to ensure that the scientific productivity of the SGP CART site is maximized by both the routine and special (IOP) operations at the site. The SST acts as a resource for the site operations manager and his staff on scientific matters by doing the following:

- Working with site operations personnel and instrument mentors on potential instrument problems

- Reviewing proposed instrument siting and deployment strategies, including the needs of the instrument mentors and instrument requirements for IOPs and campaigns

- Reviewing schedules and procedures for instrument calibration and maintenance

- Providing an early assessment of suspected instrument and/or data problems through the use of performance metrics, graphic display techniques, and data quality research investigations, and distributing their findings so that corrective actions can be taken

- Planning and conducting IOPs and campaigns

These activities require constant communication with site operations staff, including routine visits to the central facility and occasional trips to extended, intermediate, and boundary facilities. These activities are also highly coordinated with the site program manager and, when appropriate, with instrument mentors and DSIT personnel. Ongoing focus activities of the SST will contribute to the goals of data quality assessment for the SGP CART site and ensure that the operation of the site meets, as nearly as possible, the overall scientific goals of the ARM Program.

In the past, data quality assessment efforts of the SST largely involved evaluation of individual and multiple sets of data streams as needed, on an exploratory or developmental basis (data quality investigations); participation in QMEs; and participation in the creation and workings of the VAP Working Group.

Now that operational activities have shifted from deployment to support of ongoing, continuous operation of a wide variety of instrumentation at many locations, a more comprehensive, systematic data quality assessment effort has been undertaken by the SST. This effort is manifested in several ways, including the evaluation of the calibration and maintenance information, the development and use of automated, graphic display techniques for use by the SST in daily monitoring of data quality (work began in October 1995), and the development of performance metrics that systematically determine what percentage of the collected data falls within given quality tolerances (work began in February 1996).

The development of performance metrics is aimed at systematically determining the data "health" of the site via time series (numerical and graphic) of the metrics. In late 1996, the SST began issuing SIROS data assessments with the goal of attaining quicker resolution of instrument and data quality problems. In spring 1997, this weekly data quality assessment was expanded to all instruments, currently available on the WWW at

http://www.arm.gov/docs/sites/sgp/sgp.html .

Once at this site, go to the “Site Scientist Team Data Quality Overviews” link. These weekly data quality assessments include input not only from the SST, site operations, and instrument mentors, but also from DSIT staff, who look at VAP and QME performance and data existence. Plans for this six-month period and beyond include development of graphic display technique scripts for more data streams, the development of explicit guidance materials to allow site operations staff to use the display techniques effectively, continued development and display of performance metrics, and continued evaluation of the calibration and maintenance information, with an eye on developing presentation formats for use by different groups such as site operations and actual data users. Thus, with the assistance of the site operations staff and instrument mentors, the SST will be able to serve the ARM Program goals better by laying a foundation for improving data credibility. Please see *Peppler and Splitt* (1998) for more detail about ARM SGP data quality strategies.

4.3 Value-Added Products and Quality Measurement Experiments

Unlike many other scientific projects, ARM collects data in an ongoing, continuous manner. Because of the volume of these perpetual data streams, traditional case study methods for analyzing these data are not very effective. To fit the need for an automatic analytical approach, the concept of a VAP (value-added product) has been defined. A VAP creates a

"second-generation" data stream by using existing ARM data streams and inputs and applying algorithms or models to them. A VAP is run continuously in the ARM Experiment Center, and the output generated is treated as a new ARM data stream.

Many of the scientific needs of the ARM project are met through VAPs. Physical models that use ARM instrument data as inputs are implemented as VAPs and can help fill some of the unmet measurement needs of the program. A special class of VAPs called QMEs compare different data streams for consistency and allow for continuous assessment of the quality of the ARM data streams. These data streams may come from direct measurements, measurements derived from instrument observations via other VAPs, or model output that is currently created by other VAPs.

New VAPs or suggestions of improvements or modifications to existing VAPs come from all aspects of the ARM program: the Science Team, instrument mentors, the DSIT, the Archive, the SST, etc. However, because of the limited resources available, VAP development must be prioritized in a meaningful manner. To this end, the VAP Working Group was established. This group consists of members of the infrastructure that crosscut the program, with representatives from each of the major scientific areas of ARM. This group discusses the scientific objectives of each VAP in the development queue, looks for common threads among them, assigns priorities, estimates completion dates, and assists in the development of the VAPs. The SST is represented on the VAP Working Group. Value-added products currently available are given in Table 3. More information is available on the WWW at

http://www.arm.gov/docs/research/vap_homepage/vap.html .

In September 1997, DSIT Experiment Center staff announced, in beta release, the Shortwave Radiation Best Estimate data product for the central facility. The goal of this product is to create one data stream that holds all (or most) of the data products of interest to the shortwave community for the central facility. Multiple measurements of the same parameter (e.g., SIRS and BRS broadband sensors) are handled by designating one as the primary measure and using the other(s) to fill in any gaps. Also, some data quality comparisons between like measurements are included. Components of this tracking system cover 10 measurement components: downward hemispheric flux, direct broadband component, diffuse broadband component, direct spectral component, diffuse spectral component, optical depth, net shortwave surface radiation, broadband albedo, spectral albedo, and calculated quantities (zenith angle, effective top of atmosphere horizontal flux). This data product remains under development as

more of the 10 measurement areas are added. This shortwave product will be followed by one of four water vapor, then by ones for other key ARM geophysical parameters listed in Section 2.1. Contact the ARM Experiment Center to receive such products.

4.4 Data Quality Indicators

One focus for this six-month period will be to incorporate what is known about data quality and link it directly to individual data streams in an easily identifiable method for data users, such as by data flagging. Generally, there are four levels of data quality inspection. The first level is part of the ingest routine, where min/max and delta limits, if exceeded, are stamped. The second level of data quality inspection is provided by the instrument mentors. Although each may have a unique methodology for data inspection, it is their expert view that provides information on suspect data points for their particular instrument. The third level of review looks for consistency of data between instruments using data quality metrics and data stream comparisons between instruments. This is provided by the SST. The fourth level of data quality inspection are the VAPs and QMEs, which have been driven by the Science Team.

The concept of data quality indicators would be to flag individual data streams, where the flags refer simply to each of the four levels of data quality inspection outlined above. Then, there would be pointers developed that would direct the data user to details of the particular level of data quality inspection methodology for each instrument. The Meta Data System (MDS) captures all information that comes from all functional areas of the program and can be searched to determine potential reasons for data points being flagged. The flags must be included with the data, probably requiring data reprocessing. Discussions are on-going.

4.5 Problem Review Board

For a large data collection program, procedures must be in place to facilitate the documentation of problems and their associated resolutions. The ARM Program is tasked with creating data of "known and reasonable" quality. To achieve this quality, the Problem Review Board (PRB) facilitates the resolution of problems identified by anyone involved in the ARM data pipeline. The Problem Identification Form (PIF) and Corrective Action Report (CAR) are reports that allow a formal mechanism for capturing information about potential problems, the potential impact on the quality of the data, and the correction action needed to resolve the problem.

TABLE 3 Value-Added Products in Place at the SGP CART Site[a]

Value-Added Product	Description
LBLRTM	Line-by-line radiative transfer model; used for longwave and microwave radiance calculations
QME AERI/LBL	Comparisons of observed (AERI) vs. calculated (LBLRTM) longwave downwelling radiation
QME MWR/LBL	Comparisons of observed (MWR) vs. calculated (LBLRTM) microwave radiance at two frequencies
QME AERI/LBL CLOUDS	State-of-the-atmosphere data to facilitate QME AERI/LBLRTM analysis
RWP TEMP	Merged and quality-controlled RASS virtual temperature profiles
MWR PROF	Retrievals of water vapor, liquid water, and temperature profiles from a suite of ground-based instruments
QME MWR PROF	Comparisons of retrieved water vapor and temperature profiles from MWR PROF with BBSS profiles
AERI PROF	Retrievals of temperature and water vapor from the AERI data
QME AERI PROF	Comparisons of retrieved water vapor and temperature profiles from AERI PROF with *in situ* measurements
QME MWR COL	Comparisons of the MWR with an instrument performance model

TABLE 3 (Cont.)

Value-Added Product	Description
RLPROF	Profiles of water vapor mixing ration, aerosol scattering ratio, and depolarization ration from the Raman lidar

[a] AERI, atmospherically emitted radiance interferometer; BBSS, balloon-borne sounding system; LBL, line by line; LBLRTM, line-by-line radiative transfer model; MWR, microwave radiometer; PROF, profile; QME, quality measurement experiment; RASS, radio acoustic sounding system; RWP, radar wind profiler; RL, Raman lidar; TEMP, temperature.

The goal of the PIF/CAR system is to provide "end-to-end" problem management. No single person has the expertise to correctly resolve all classes of problems that might be identified in the ARM Program. The PRB technically reviews all incoming PIFs for their immediate impact on data connection and quality and assigns responsibilities for their correction and response (i.e., CAR).

The PRB is a small multilaboratory team with a broad base of membership. It is composed of a chairman, an oversight individual, and a representative from each of three teams: the IT, the Site Operation Team, and the DSIT. The PRB oversees the assignment of problem-solving actions as triggered by PIFs and the resolution of the problems as documented in CARs.

A PIF should document anything that impacts the data system or that more than one person needs to know or learn from. Not every PIF will identify a real problem. In some cases, the PIF will identify a misunderstanding or someone's need for more information. Some problems will have an obvious solution, but the timing of the corrective action may need to be coordinated with other subsystems within the project. Some problems will require further analysis to be understood, and some problems may just require documentation because no clear solution can be identified at the time. A review of the PIF is required before the PIF is accepted as a problem and before it is actually scheduled for resolution. The CAR documents the details of the resolving action. The corrective action required is an end-to-end problem solution, not just a fix in a software module.

In addition, a Data Quality Report (DQR) may be required. A DQR is a statement about the quality of data from a particular instrument. Usually, a DQR is generated by an instrument

mentor. If not generated by the mentor, it must be reviewed by the mentor. The DQR information could be quite simple (e.g., stating that an instrument system was turned off during certain time periods because of unexpected hardware problems), but it could also be quite complex, giving detailed analysis and equations that should be used to adjust the instrument's observational data. One advantage of the DQR in comparison with a PIF is that the DQR form is simpler. It is easier to fill out and less cumbersome to incorporate into a data stream. If a large amount of processing of data is implied or requested in the DQR, reprocessing could be delayed for a long time. Hence, the description of the problem and the fix must be complete, so that someone can accurately reprocess the data several months after the date of the DQR submission, if required.

The PIFs should continue to be used to request action by others, or oneself, to find a solution to a problem or generate information on it. A borderline case might be to state that data should be flagged during data ingest as a result of quality control algorithms provided as part of the form submitted. In this case, a PIF rather than a DQR is favored because a specific type of implementation is being requested. On the other hand, application of data quality control algorithms to data already collected and resident in the Experiment Center or the Archive would be best handled with a DQR. DQRs tend to be retrospective.

In case of doubt on whether to use a PIF or a DQR, using a PIF is better because it will automatically be examined by the PRB to see if the PIF should be converted to a DQR. If data flagging of an algorithm needs to be implemented both retrospectively and on the current data ingest, consider splitting the request into two parts: a PIF and a DQR.

The PIF/CAR/DQR database can be found at

http://www.db.arm.gov/PIFCARDQR/ .

5 SCIENTIFIC INVESTIGATIONS AND OPPORTUNITIES

In 1994, the ARM Program identified a need for the creation of a Site Advisory Committee (SAC) to provide assistance to the ARM Program Science Team, the SGP CART SST, and the SGP CART site program manager. The SAC's charter is to

- Evaluate the SGP CART site scientific mission,
- Provide scientific mission guidance for SGP CART site operations,
- Evaluate the research program of the site scientist,
- Evaluate the potential for collaboration with other research programs, and
- Provide recommendations for the SGP CART site educational outreach program.

The seven-member SAC is composed of ARM and non-ARM Program scientists who meet formally at least once per year. The first such meeting was held in November 1995 at the University of Oklahoma (OU), and a second follow-up meeting was held in June 1996. Written reports summarizing the SAC's recommendations on the basis of these two meetings were distributed to the ARM Management Team, the SST, the site operations manager, and the site program manager, and were responded to in writing by the SST. Individual committee memberships last for three years.

5.1 Intensive Observation Periods

The SGP CART site operates a vast suite of instrumentation that routinely provides continuous data streams at a prescribed rate. These rates, however, can be changed upon request. Requests from inside and outside the ARM Program can be made through the SGP CART site program manager's office either (1) to operate an ARM instrument or instruments at a different data collection rate or mode of operation or (2) to support and compare non-ARM instruments with ARM instruments. Those periods are referred to as IOPs.

The requests can be made by the ARM Science Team, ARM Program infrastructure, or the scientific community at large. Preference for IOPs is given to the ARM Science Team and

infrastructure. The ARM Program has a limited budget for IOP support. However, funding from sources other than the ARM Program can be accepted to support IOPs or campaigns.

The BBSS is the instrument most frequently requested to operate in an accelerated data collection rate and is the primary driver for the timing of IOP requests. The SGP CART site has five locations where BBSS instruments are operated routinely. When operated in an accelerated data-rate mode, simultaneous radiosonde launches can be made every three hours at all five locations for a 21-day period or longer.

The ARM Program provides funding for a total of 2-3 three-week-long, accelerated BBSS launch periods per year, which are referred to as SCM IOPs. Two SCM IOPs are held at fixed time periods, one in spring and one in summer. The third SCM IOP alternates between winter and fall. Although the ARM Program supports and encourages multiple, concurrent IOPs during SCM IOP periods, IOPs involving accelerated BBSS launches at other times of the year will be considered as the budget allows.

Requests for IOPs come through the SGP CART site program manager's office. The initial requests can be made informally, but an abstract of the goal(s) of the experiment(s) being requested, a list of the potential instruments and platforms involved, and the time period of the experiment(s) must be provided for approval. Requester coordination points of contacts are identified.

Approval of an IOP is an external process that requires (1) review for resources and relevancy and (2) approval by the ARM Program Technical Director, the SGP CART site program manager, the SST, and site operations. Once approved, the management of the detailed operational planning, setup, conduct, and shutdown of the IOP is the responsibility of the site program manager.

An IOP is given a title and assigned a DSIT representative. The DSIT representative has the responsibility to obtain the relevant scientific information about the proposed activity, which is typically obtained in a science plan. The DSIT representative has the responsibility to inform ARM Science Team members of the proposed activity for the purpose of potential collaboration. The SST has taken an increasingly greater leadership role in this activity, beginning with the fall 1996 Water Vapor IOP.

The site program manager obtains a list of potential principal investigators (PIs) and the instrument or systems that are intended to be located at the SGP CART site from the DSIT representative. The site program manager then sends an IOP Questionnaire to the PIs to collect information critical to the operation, safety, and data requirements for the IOP. The IOP questionnaire is returned to the site program manager's office and distributed to the appropriate ARM infrastructure for review. The IOP questionnaire can now be entered directly by a PI at the WWW site:

http://www.arm.gov/stdocs/internal/iop_form.html .

The ARM infrastructure groups include the SGP CART site program manager, the SGP CART site SDS team, the DSIT representative, the SST, and site operations. Each of the ARM infrastructure groups has a specific role in the planning and implementation of the IOP.

The SDS representative assesses the data requirements: those requested by the participating PI from ARM and those to be provided to ARM by the PI. A schedule of data delivery is determined. The DSIT will maintain a Web site that provides information about IOP planning and status, as well as day-to-day operations activities during the IOP, which are provided by the SST. The main elements of the IOP Web site include a science plan, each PI's IOP questionnaire, the IOP operations plan, and a daily log during the IOP that identifies and discusses each day's scientific mission.

The SGP CART site SDS team assists PIs that have requested Internet connections at the SGP CART site central facility. The SDS team assists with the actual interface, as well as establishing limitations to the size of data files and the actual time of data file transfers so that the PI data transfers do not impact the SGP CART site data transfer schedule.

The SST has the overall responsibility for coordinating scientific interactions at the SGP CART site. The SST personnel work with the DSIT representative to identify IOP scientists. The SST assists the site program manager and site operations in locating instrumentation at the SGP CART site. The SST personnel assist in identifying real-time display requirements during IOP operations and identify mission-critical data streams that must be maintained during the IOP. The SST also assists in the creation of a Science Plan for the IOP.

Site operations personnel provide IOP safety oversight and support installation of all guest instruments in accordance with requirements identified in the IOP questionnaire. The site

operations personnel maintain the operational status of SGP CART site instrumentation and provide triage (quick-response maintenance) for those instruments with data that have been identified as critical to the IOP. The operations staff provide PIs with additional logistical support (e.g., liquid nitrogen supplies, phone lines, safety briefings, and power) in accordance with requirements identified in the IOP questionnaire.

The site program manager's office manages the coordination of all activities associated with the IOP. The site program manager's office produces an IOP operations plan that will identify all of the activities associated with IOPs, including roles and responsibilities, identification of mission-critical instruments and an instrument triage plan, the locations of instruments and use of SGP CART site facilities, safety and emergency actions, IOP termination and start-up procedures, and a list of participants.

The progress of IOP planning activities is monitored via the weekly SST coordination conference call that takes place on Tuesdays at 11:00 a.m. central time and through other as-needed conference calls with IOP participants and ARM infrastructure personnel. The IOP Web interface page functions as a tool to facilitate the coordination and flow of information during all phases of IOP planning, implementation, and operation. The site program manager will provide monthly updates in his internal monthly reports. Past, present, and known future IOPs are listed in Table 4. The URL for the large fall 1997 Integrated IOP is

http://www.arm.gov/docs/iops/1997/sep_integrated/index.html .

5.2 Preliminary Results of IOPs during the Past Six-Month Period

5.2.1 Overview

ARM's largest IOP to date was conducted from September 15-October 5, 1997, at and near the SGP Central Facility. The Integrated IOP consisted of six separate but interrelated IOPs: Water Vapor, Cloud, Aerosol, Shortwave Radiation, UAV, and SCM.

There were three bases of operation for the IOP. The Central Facility housed ground-based instrumentation and most computer operations. The Blackwell-Tonkawa Airport was the headquarters for UAV operations and housed the Altus UAV. The Ponca City Airport housed the PNNL Gulfstream-1, North Dakota Citation, Wyoming King Air, and the UAV Twin Otter aircraft, and was the home of the IOP's weather briefing operations. At the Central Facility,

some 40 guest instruments were brought to participate in the various IOPs, and on some days, over 70 participants were registered in the log book as being on-site. UAV operations saw attendance of 40-50 people during some pre-flight and coordination meetings. Weather briefings at the Ponca City Airport were sometimes attended by as many as 15-20 participants.

Coordination meetings, including the weather briefings were held every day during the IOP at 7 a.m. and 1 p.m. Central time. The 7 a.m. meetings were held at the Ponca City Airport, while most of the 1 p.m. meetings were held via phone and video conference, with participants distributed at the three bases of operation. The Water Vapor IOP additionally held scientific meetings each day at the Central Facility at 2 p.m., while the Shortwave IOP held meetings most days at the same location at 4 or 5 p.m. The Cloud IOP held a large coordination meeting at the Ponca City Airport on September 15. UAV pre-flight and scientific coordination meetings were held at the Blackwell/Tonkawa Airport at various times, as required.

Jay Mace, of the University of Utah, presided as the Integrated IOP scientific coordinator, and was also the chief scientist for the Cloud IOP. Other IOP chief scientists included Hank Revercomb of the University of Wisconsin (Water Vapor), Pete Daum of BNL (Aerosol), Bob Ellingson of the University of Maryland (UAV), Warren Wiscombe of NASA/GSFC and Graeme Stephens of Colorado State University (Shortwave Radiation), and Dave Randall of Colorado State University (SCM). Mike Splitt of the SGP Site Scientist Team was in charge of daily weather forecasting and briefings. Randy Peppler, also of the Site Scientist Team, was in charge of general coordination during the IOP and prepared daily WWW IOP updates. Pete Daum also coordinated non-UAV aircraft activity for the IOP and coordinated flight plans with UAV operations. Jim Teske, the SGP Site Operations Manager, coordinated ground logistics. PNNL's SDS staff handled all computer, network, and data storage/display logistics at the Central Facility and Ponca City Airport. Doug Sisterson, SGP Site Program Manager, and Ted Cress, ARM Technical Director, provided IOP oversight.

The following sections describe activities that occurred during the IOP, with areas of interaction noted.

For more detailed information about all aspects of the fall 1997 Integrated IOP, visit:

http://www.arm.gov/docs/iops/1997/sep_integrated/index.html .

5.2.2 Water Vapor IOP

The fall 1997 Water Vapor IOP was conducted as a follow-up to a predecessor IOP on water vapor held in September 1996. This IOP relied heavily on both ground-based guest and CART instrumentation and *in-situ* aircraft and tethered sonde/kite measurements. Primary operational hours were from 6 p.m. CST until at least midnight, with aircraft support normally from about 9 p.m. until midnight when available. However, many daytime measurements were made to support this IOP.

The first Water Vapor IOP primarily concentrated on the atmosphere's lowest kilometer. This IOP concentrated not only on that layer but also on atmospheric layers up to 12 kilometers. A key goal of both IOPs was to reduce the uncertainties in water vapor observations integral to ARM spectroscopic analyses that contribute to better radiative transfer calculations for climate models. A key component of both IOPs was the assemblage of a wide array of both remote and *in situ* sampling platforms for observing water vapor profiles and precipitable water to learn how to best measure and characterize water vapor. Establishment of absolute calibration techniques and stability characterization for the CART Raman lidar was another prime goal of these IOPs.

Specific IOP objectives for fall 1997 included 1) evaluation of absolute calibration standards, 2) characterization of the accuracy of the routine CART water vapor measurements, 3) calibration of the CART Raman lidar independent of the BBSS, and 4) evaluation of methodologies for synthesizing more accurate measurements.

Guest ground-based instrumentation included:

- NASA/GSFC scanning Raman lidar
- NOAA/CIRES microwave and infrared radiometers
- LANL tethered balloon system with chilled mirror hygrometers
- NOAA/CIRES tethered kite and balloon system with chilled mirror hygrometers
- Chilled mirror hygrometers at the 25- and 60-m levels on the 60-m tower, and at the THWAPS (adjacent to BBSS launch station)
- NOAA/FSL GPS, capable of inferring integrated precipitable water vapor
- University of Wisconsin AERI-00 and AERIbago
- NASA/Ames 6-channel tracking sunphotometer and two hand-held sunphotometers

Critical ARM instrumentation included:

- BBSS, with dual-package sonde launches in a prescribed schedule
- Raman lidar
- MWR
- 60-m tower sensors
- AERI
- SMOS
- MFRSR
- MPL

All five Integrated IOP aircraft platforms were important for this IOP because each carried either a chilled mirror hygrometer (Citation, King Air, Gulfstream, and Twin Otter) and/or a frost-point hygrometer (Citation, Altus). Thus, every aircraft flight made during the Integrated IOP should have been of benefit to the Water Vapor IOP. In addition, the DOE 7-channel microwave radiometer (DoER) and the 5-channel millimeter-wave imaging radiometer (MIR), both flown on the Twin Otter, supported microwave radiometer comparisons.

In particular, the Citation and King Air flew special nighttime missions in support of the Water Vapor IOP. These flights, carrying the highly precise hygrometers, were coordinated particularly with operations of the Raman lidars, tethered systems, and dual package BBSS launches. In all, the Citation made five such nighttime missions (September 17, 25, 30; October 1, 3), while the King Air participated in two (September 27; October 3). The evening of October 3 saw both aircraft flying in support of this IOP.

A special wingtip-to-wingtip flight mission involving the King Air and Gulfstream on September 29 afforded comparison of both the chilled mirror and wind sensors on those aircraft. Also, the joint flights of the Citation and King Air on the evening of October 3 allowed similar comparisons to be made for those two aircraft.

A substantial 2:00 p.m. Central meeting was held each day at the Central Facility to discuss/display results from the previous day/night and to make plans for the upcoming evening. A good deal of decision making was made based on which instruments were/were not performing as anticipated. Some recommendations, based on this IOP, will be forthcoming concerning issues such as 60-m tower moisture sensors and Raman lidar operation. Data will be analyzed by focus groups throughout the rest of 1997 and early 1998 in anticipation of water

vapor breakout sessions at both the IRF Workshop in Maryland in January 1998 and the ARM Science Team Meeting in March 1998. Decisions will then likely be made as to when and how to conduct a third Water Vapor IOP.

For more details about the science and operations of the second Water Vapor IOP, please see:

http://www.res.sgp.arm.gov/iop/fall97/wvap/ .

5.2.3 Cloud IOP

The primary objective of the fall 1997 SGP Cloud IOP was to generate a multi-platform data set that could be used as validation for cloud property retrieval algorithms that are being implemented on the operational CART data stream. Within this primary objective, secondary objectives included: 1) quantification of the uncertainty associated with the various algorithms, 2) provide absolute calibration and intercalibration for the millimeter radars used in cloud research (including the CART MMCR), and 3) provide guidance on the operational modes of the CART MMCR. All of these objectives were addressed with varying degrees of success during the course of the IOP.

It appears that all the critical CART instruments (listed below) performed well during this IOP. The MMCR was operated in a number of new operational modes, including the collection of Doppler spectra, with no identifiable negative impact on data quality. The new set of operational modes was devised to maximize the scientific utility of the full data stream. A mode was added to provide high vertical resolution with sufficient sensitivity for lower and middle tropospheric water clouds. A mode was also added for identification of certain ambiguities in the other modes. The guest instruments (listed below) performed with somewhat less success. The Utah polar diversity lidar experienced an outage early in the experiment for approximately three days, while the PSU radar was down for several days. Other visiting instruments performed as expected. Initial analyses of the aircraft data are encouraging; no major failures were evident aside from occasional problems with the microphysical probes on the Citation and King Air.

To meet the primary objective of the IOP, a full spectrum of cloud types and meteorological conditions needed to be sampled *in situ* and by the surface instruments. The cloud types include single-layer liquid phase, ice-phase, and mixed-phase clouds, as well as

multi-layered conditions. To some degree, all of these cloud types were sampled. The weather pattern during the first half of the IOP was very conducive to high-based mixed-phase clouds below cirrus. The Citation and the King Air flew several missions in these situations. Dual aircraft missions were also conducted in which the Citation sampled cirrus while the King Air worked the mixed phase clouds. The King Air also conducted several flights in liquid phase stratocumulus clouds near the middle of the IOP. A diversity of microphysical characteristics in stratocumulus clouds was observed. The Gulfstream also performed cloud-related missions in several stratocumulus situations. The opportunity to sample single layer cirrus was limited to a single case associated with the remains of Hurricane Nora. While this was the only cirrus case, it did appear to be exceptional with extraordinary optical displays in a persistent overcast layer. Our stated goal was to expend approximately 20 aircraft hours in cirrus. This goal was not met.

Given the diversity of cloud types sampled during the IOP, the analysis of this data set will continue for some time. Initial plans are to develop WWW pages summarizing each aircraft flight having a significant data collection period. An example can be found at

http://www.res.sgp.arm/iop/fall97/clouds/ .

Development of these summaries will facilitate the use of the data by the wider community. Beyond the web pages the data will be used for their intended purpose of validating retrieval algorithms as they are implemented. Basic scientific research will also be conducted since several of the cases were unique and very well sampled by the surface and ground-based instruments. We intend to maintain a close collaboration with the Shortwave Radiation IOP group as well since the synergy between the two groups was evident during the IOP.

While analysis of the data collected during the IOP will dictate the need for future Cloud IOPs, we are certain that this exercise will need to be repeated in the future with an emphasis on cirrus clouds. It is also evident that conducting a Cloud IOP during late September is not advisable in the future. This IOP succeeded largely due to anomalously abundant moisture in the eastern Pacific.

Guest ground-based instrumentation included:

- University of Utah 95 GHz Doppler radar system
- Penn State University millimeter cloud radar
- University of Massachusetts dual 35/95 GHz scanning cloud radar

- University of Utah Polarization diversity lidar
- Penn State University lidar
- Penn State University sunphotometer
- Penn State University NFOV infrared radiometer
- Colorado State University beam filter infrared radiometer
- University of Utah time lapse video
- NCAR balloon-borne Formvar ice particle replicator

Critical ARM instrumentation included:

- MMCR
- MPL
- BLC and VCEIL
- AERI
- MWR
- BBSS

All three aircraft carried standard meteorological sensors, along with devices to measure cloud droplet number concentration and size distribution, cloud liquid water content, and cloud condensation nuclei number. The Citation and King Air carried additional sensors to measure cloud and large particles, super cooled liquid water content, and radiometric properties. The Citation was equipped with a time lapse camera and video, while the King Air's payload included the Wyoming 95 GHz cloud radar. In addition, the Twin Otter carried the DOE 7-channel microwave radiometer (DoER) and the 5-channel millimeter-wave imaging radiometer (MIR). Data from these devices should complement those of the cloud radars, especially in the correction path attenuation due to clouds and water vapor near 90 GHz. These data should also help develop cloud and water vapor retrievals using passive microwave/millimeter-wave frequencies from 20-325 GHz.

Citation flights, mainly into cirrus and higher mid-level clouds, occurred during the day on September 16, 17, 19, 26, and during some of its Water Vapor IOP nighttime missions. King Air flights, primarily into mid and lower level cloud layers, were made on September 16, 19, 20, 23, 24, and also during parts of its Water Vapor IOP nighttime missions. The Gulfstream flew cloudy air missions, from 500-17,000 ft. above ground level (AGL), on September 21, 24, and 25.

One NCAR ice replicator sonde flight was made into an interesting cirrus field on September 26. This particular day produced some unusual optics that were of interest to all of the IOPs. This flight was seen as an augmentation to the Citation *in situ* cirrus missions since ice water contents derived from the standard probes are generally uncertain by a factor of two. Additionally, the microphysical information to be gleaned from an aircraft mounted replicator is often obscured by the destruction of the crystal habits on impact. The replicator radiosondes bypass these difficulties. Although the launch that occurred provided only a single profile through a cirrus system, the data should provide an important check on the reliability of the microphysical data collected that day by the *in situ* aircraft.

5.2.4 Aerosol IOP

The Aerosol IOP was highlighted by the Gulfstream aircraft flying clear-sky aerosol missions over the Central Facility to study the effect of aerosol loading on clear sky radiation fields, with weather particularly favorable for these flights during the first and third weeks of the IOP. A secondary but important goal of this IOP was to fly cloudy-sky missions over the Central Facility to study the effect of aerosol loading on cloud microphysics, and the effect of the microphysics on cloud optical properties. The Gulfstream obtained aerosol data in support of some of the UAV IOP clear-sky missions, the LANDSAT overpass of September 27, and *in situ* cloud microphysical data in support of the UAV IOP under cloudy sky conditions. The aerosol data collected by the Gulfstream is also of critical importance to the Shortwave IOP's radiometric measurements. Another key IOP priority was to use the collected aerosol data to support algorithm development for MPL and Raman lidar aerosol profiles.

The clear-sky experiment examined the effect of aerosol loading on clear sky radiation fields, and involved obtaining vertical profiles of aerosol microphysical and optical properties under clear sky conditions. Flights in support of this experiment involved passes over the Central Facility as low as 500 ft. AGL, with stepped legs up to about 17,000 ft. and spirals back down to 500 ft. Flights for this experiment were centered approximately on solar noon. Optimal conditions for this experiment were either clear skies or skies with minimal cloud cover (e.g., fair weather cumulus). Flights were made directly over the Central Facility for best coincidence with surface aerosol (AOS) and radiometric (variety of platforms) measurements.

The overcast-sky experiment addressed the issue of aerosol loading on cloud microphysics and the effect of variations of the microphysics on cloud optical properties. Flights measured the vertical distribution of cloud microphysical properties (e.g., droplet number

density, size distribution, and liquid water content). The objective was to examine the relationship between the pre- or below cloud aerosol number concentrations, CCN spectra and the cloud droplet number concentration. Optimal clouds for these experiments were warm (liquid water) stratus or stratus with imbedded stratocumulus. Flights were conducted during daylight hours, centered on mid-day, and were coupled with UAV IOP flights to obtain cloud radiative properties whenever possible. Flight tracks consisted of vertical soundings through cloud layers and extended legs above, below, and in clouds.

The Gulfstream payload for aerosols included instruments for measuring aerosol number concentrations and size distributions, aerosol light scattering coefficient at three wavelengths, aerosol backscatter, aerosol absorption, CN concentrations and the CCN activation spectra.

Clear-sky Gulfstream flights were conducted on September 15, 18, 21, 25, 27 (in support of LANDSAT), 28, 29 (coordinated with the Altus/Twin Otter clear-flux profiling), 30 (wingtip-to-wingtip flight with the King Air for wind and water vapor sensor calibrations), and October 1 and 4 (both coordinated with the Altus and/or Twin Otter clear-sky flux profiling). Cloudy sky flights were conducted on September 21, 24, and 25. The cloudy sky flights were coordinated with flights of the UAV IOP aircraft as possible.

Critical ARM ground-based instrumentation included:

- AOS
- Raman lidar
- MPL
- RSS
- MFRSR
- Cimel sunphotometer

The AOS data provided the local microphysical environment at the surface, while the MFRSR, RSS, and Cimel sunphotometer provided column-integrated optical depths. Vertical profiles of microphysical properties were specified by the Raman lidar and MPL, and by the Gulfstream aircraft.

Information about ARM's Aerosol IOP series can be found at

http://www.archive.arm.gov/research/aerosols/Spring97aerosoliop.html .

5.2.5 Shortwave Radiation IOP

The Shortwave Radiation IOP, the first in a series of three such IOPs, was devoted to exploring the measurement of broadband and spectral radiation with an array of ground-based ARM and guest instrumentation, including the RCF suite, and with airborne radiometric sensors on all of the IOP aircraft.

Whereas much of the debate on solar radiative transfer has centered on the topic of clouds, there are also a significant number of issues related to clear sky transfer that this IOP hoped to address. Two key aspects of the underlying problem relate to the baseline measurement of solar radiation and the atmospheric composition through which the transfer occurs. Programs like ARESE provided motivation to compare the performance of different instruments both on the ground and in aircraft to assess methodologies for measuring fluxes. Atmospheric composition parameters such as aerosol optical depth, column integrated water vapor and liquid water, and lidar and radar backscatter, when compared with measured radiometric fluxes, will provide an important opportunity to test out transfer calculations. Spectral fluxes will offer insight, in identifying key absorption bands and will allow more rigorous testing of transport calculations.

The main objectives of this IOP were to 1) compare measurements of fluxes from a variety of ARM and guest spectral and broadband radiometers, 2) contrast spectral and broadband fluxes to determine their level of consistency, 3) characterize measurements in terms of other parameters from other sensors, and 4) promote development of a baseline spectral solar transfer model and compare it to measurements.

In order to mitigate time synchronization issues between the various ground-based sensors, the IOP concentrated on three 10-minute periods each day for comparison of shortwave spectra: 11:20-11:30 a.m. Central, 1:20-1:30 p.m. (solar noon), and 3:20-3:30 p.m., rain or shine. Aircraft flights augmented these measurement periods. Scientific coordination meetings were held at the Central Facility each day at 4:00 p.m. to intercompare results from the previous day and make any future plans, if necessary. Jim Barnard of PNNL made SBDART model output available on a daily basis to the IOP for comparison with observations.

Guest ground-based instrumentation included:

- NASA/Ames solar spectral flux radiometer (SSFR)

- Colorado State University scanning spectral polarimeter
- Colorado State University visible Michelson interferometer
- South Dakota State PGAMS (Portable Ground-based Atmospheric Monitoring System
- NOAA/CIRES hemispheric sky imager
- Two MICROTOPS ozonometers
- University of Denver ASTI
- NASA/Ames 6-channel tracking sunphotometer and two MICROTOPS hand-held sunphotometers
- NREL absolute cavity radiometers, pyranometers, pyrheliometers. pyrgeometers, UV-A, UV-B, and PAR sensors
- NOAA/ARL/SRRB absolute cavity radiometer, pyranometers, and pyrgeometers
- ASD shortwave spectrometer
- O2 A-band spectrometer

Critical ARM instruments included:

- RCF suite
- GRAMS
- RSS
- MFRSR
- SIRS and SIRS testbed
- Cimel sunphotometer
- Raman lidar
- MWR
- MMCR
- MPL
- TLVC and WSI
- BBSS

Operations were generally independent of aircraft overflights, but scientifically this IOP will be extremely dependent on the aircraft data collected. As mentioned above, all of the aircraft made some sort of radiometric measurements. And, the aerosol measurements described above, made by the Gulfstream, are of vital importance. Notable other critical aircraft measurements made in support of this IOP included

- RAMS (Altus and Twin Otter)
- Scanning spectral polarimeter (Twin Otter)

- Scanning spectral polarimeter (Altus)
- Cloud detection lidar (Altus)
- MPIR (multispectral pushbroom imaging radiometer - Altus)

Much data analysis and intercomparison will occur before the ARM Science Team Meeting in March 1998, where it is planned to have a breakout session. Some discussion has already occurred concerning when to hold the next Shortwave Radiation IOP. It may be desirable to link it with the next Cloud IOP. One scientific mystery hoped to be solved concerns the multi-layer stratus event observed on September 24. The SSFR showed a reappearing hump at the 1.6-micron band, which appeared and disappeared, sometimes in a matter of minutes. There were no visible cloud changes when this was noted. However, the Penn State University cloud radar was able to detect a very thin (100 m thick) layer at about 3-km that alternately appeared and disappeared. More data analysis, and modeling, will be done to further analyze this interesting situation.

More information on the Shortwave Radiation IOP can be found at:

http://optical.atmos.colostate.edu/swiop/swiop.html .

5.2.6 UAV IOP

The UAV IOP operated both the Altus UAV and the Twin Otter chase aircraft during the IOP period. As can be seen in the previous sections, the IOPs on water vapor, clouds, aerosols, and shortwave radiation were all dependent to various degrees on UAV operations. UAV headquarters were at the Blackwell/Tonkawa Airport.

The advantage of a UAV such as the Altus is that it offers high altitude, long endurance, and unmanned observation of the atmosphere. These are important features when studying evolving cloud fields and their effect on solar and thermal radiation balance. The high-altitude capability of the Altus also provides measurements to calibrate satellite radiance products and validate their associated retrieval algorithms. Indeed, during this IOP, it was possible to coordinate a UAV operation with a LANDSAT overpass.

This particular UAV IOP contained four experimental areas as a focus. These are described briefly below. For a complete look at the science and operational plans of this IOP, see:

http://www.arm.gov/uav/docs/uav_scie.pdf .

Experimental Group I, termed "Geostationary Satellite over the SGP Central Facility", attempted to:

- Characterize the sunset to sunrise radiation budget of the atmospheric column from the surface of the central facility to the Altus' service ceiling (approximately 35,000-37,000 ft.) in aerosol-laden clear skies and single-layer extensive cloudy conditions

- Measure the solar noon radiation field above an extensive single solid cloud layer or a broken cloud field, with the Twin Otter near cloud top and the Altus at various cloud altitudes

- Measure the solar noon radiation field above an extensive single solid cloud layer or a broken cloud field, with the Twin Otter and Altus 1-2 km below and above cloud base and top, respectively

- Characterize the sunrise to sunset correlation of microphysics to absorption, with the Altus at its service ceiling and in situ sampling by another aircraft (such as the Gulfstream)

Missions in support of Experiment Group I were flown on September 17, 24, 27, 29, October 1 and 4.

Experiment Group II, "Surface Characterization", measured the effects of surface properties on the solar and infrared radiation budgets in the atmospheric column. Special objectives included building databases of spectrally resolved BDRF (bi-directional reflectance functions) viewed from the tropopause and spectrally-resolved and broadband directional albedo models viewed from near the surface, and to determine the response of skin temperature to cloud shading. These were to be carried out using the following measurements:

- MPIR measurements, with the Altus at its service ceiling over the central facility and other diverse sites in northern Oklahoma (grass, soil, forest) for all solar zenith angles; this assesses BDRF versus time of day

- RAMS albedos over the central facility, and also soil, grass, forest, water, and salt, with the Twin Otter near the surface under clear, broken, and thin cloud skies for all solar zenith angles

- RAMS infrared measurements, with the Twin Otter flying near the surface when cloud conditions produced large sunlit and shaded areas

Missions in support of Experiment Group II were flown on September 21 (albedos), and September 25 and October 1 (surface characterization).

Experiment Group III, termed "ARESE Re-Reprise", was designed to fill in gaps in the ARESE 1995 IOP data set. The ARESE experiment produced data from 12 scientific flights that have been analyzed and presented at various conferences and in several manuscripts. Results have supported the hypothesis that absorption of shortwave radiation by clouds is more than that predicted by models, but the results have been challenged in their details. This issue is important, because small errors in absorption might have large consequences regarding tropical atmospheric dynamics. Inadequacy in this understanding can lead to the misinterpretation of remote sensing data used to infer cloud microphysical properties. The main objective of the re-reprise was to further determine if cloudy atmospheres absorb more shortwave radiation than predicted by state of the art climate models. Two objectives embedded within this were

- The direct measurement of the absorption of solar radiation by clear and cloudy atmospheres and the placement of bounds on these measurements

- The investigation of the possible causes of absorption in excess of model predictions

To achieve these objectives, the Altus was to fly at its service ceiling while the Twin Otter was to fly directly below it, closer to the surface and underneath clouds, on long legs over four Extended Facilities to the west of the Central Facility (Vici, Byron, Ringwood, Coldwater). Unfortunately, it was not possible to fly Experiment Group III missions during the IOP.

Experiment Group IV, "Diurnal Radiation Budget Quantities", sought to intensively study the effect of diurnal cycles on the radiation budget, specifically assessing the variation of shortwave and longwave radiation in the vicinity of the Central Facility. A successful test of the Altus' ability to fly continuously for a 24-hour or longer period occurred in October 1996 over the Central Facility. For this experiment, the Altus was to fly at its service ceiling for an extended period of time. Planning for this exercise occurred during the third week of the IOP,

and was planned for execution, sometime during October 3-5, but windy conditions did not allow it to happen.

Formal UAV scientific missions occurred on nine days:

- September 17: Altus/Otter clear-sky mission (Altus was forced down early, but the Twin Otter continued with microwave radiometer calibrations
- September 21: Otter surface albedo measurements with diffuse illumination to support satellite interpretation
- September 24: Otter cloverleaf patters 1,000 ft. above the central facility, over uniform overcast consisting of several layers, in order to make radiometric measurements
- September 25: Otter surface characterization mission over a variety of land surfaces, including plowed soil, grasslands, forest, water, and the central facility
- September 26: Altus/Otter joint water vapor profiling mission in generally clear skies, with cirrus above 35,000 ft.
- September 27: Altus/Otter joint clear-sky calibration mission support of a LANDSAT overpass, with the Altus in a cloverleaf pattern over the central facility at 35,000 ft. and another Altus/Otter cloverleaf at 12,500 ft.; the Otter also performed microwave radiometer calibration turns at 1,000 ft. The Gulfstream provided clear-sky aerosol support
- September 29: Altus/Otter clear-sky flux profiling with complementary Gulfstream aerosol profiling; Altus/Otter comparisons occurred at 10,000 ft., then the Altus climbed to 37,000 ft. and remained aloft for 6.5 hours.
- October 1: Otter clear-sky surface characterization mission similar to September 25 mission, carried out at three solar elevation angles (10,30,50 degrees) and three altitudes (500, 3,000, 7,000 ft. AGL); it was accompanied by the Gulfstream profiling aerosols both in the morning and afternoon.
- October 4: Altus/Otter clear-sky mission, with instrument intercomparison at 15,000 ft. AGL. The Altus subsequently performer clear-sky radiation measurements at 35,000 ft., with the Otter profiling radiative flux from 500 to 10,000 ft. above the central facility. The Gulfstream performed complementary aerosol profiling in conjunction with the Otter.

For more information about operations during this UAV IOP, please visit

http://optical/atmos.colostate.edu/uavf97/uavf97.html .

5.2.7 SCM IOP

The fall 1997 SCM IOP was conducted from 1500 UTC on September 15, 1997, to 0300 UTC October 6, 1997. During this time, 817 soundings were launched that reported data. This represents 99.0 percent of the potential 825 soundings (165 3-hourly launch opportunities at five sites) during the IOP. Of the successful launches, 799 soundings (or 96.8 percent) of the maximum possible) ascended above 10 km.

The statistics of soundings by launch site were as follows:

Launch Site	Successful Launches	Ascents above 10 km	Missing Soundings
CF	159 (96.3%)	154 (93.3%)	6 **
B1	165 (100%)	161 (97.6%)	0
B4	164 (99.4%)	159 (96.3%)	1
B5	164 (99.4%)	161 (97.6%)	1
B6	165 (100%)	164 (99.4%)	0

** Note: One missing sounding due to ice replicator sonde launch.

The percentage of successful launches and soundings ascending above 10 km was outstanding, and provides a high level of sampling that characterizes the atmospheric state in the column. These data will be used in objective analyses to provide atmospheric forcing terms for SCMs.

Of particular interest to the ARM SCM researchers is the wealth of supporting data from the other IOPs conducted during this time, especially the Cloud IOP. The detailed data sets will

provide an unprecedented opportunity to evaluate details of the GCM parameterizations being tested.

5.3 Intensive Observation Periods or Campaigns for this Six-Month Period

IOPs of key scientific interest planned for 1998 are discussed in the following paragraphs (also see Table 4).

The Winter 1998 Single-Column Model IOPs. As SCM is a physical parameterization package extracted from a GCM or other large-scale model. The SCM is a primary test of our current understanding of clouds and radiative transfer. The SCM IOPs are designed to provide, as boundary conditions, the advective tendencies and vertical velocities that are the dynamic forcing normally calculated with a GCM. The BBSS is the only technology currently capable of providing the range and resolution of observations of winds and thermodynamic quantities necessary to estimate these boundary conditions. Because derivatives are needed in both horizontal directions, BBSS data from the central facility and the four boundary facilities are the minimum required for reliable estimates. The winter SCM IOP is tentatively scheduled for January 19-February 8, 1998. Another SCM IOP is tentatively planned for late spring.

The Measurements Of Pollution In The Troposphere Campaign. This MOPITT Campaign is tentatively scheduled for February 21-28, 1998. The MOPITT is new instrument that measures CO and CH4 and will rely on validation information from a number of ground-based instruments, including AERI (analysis of data by Wallace McMillan, University of Maryland, SORTI (analysis by Frank Murcray, University of Denver), a grating spectrometer (instrument and analysis by Leonid Yurganov, University of Toronto), and the MOPITT, a light aircraft to do sampling up to 30,000 feet by Paul Novelli, NOAA/CMDL Boulder. Jinxue Wang, NCAR, is coordinating the MOPITT validation effort.

The Bi-Directional Reflectance Function Campaign. This BDRF Campaign is tentatively scheduled for June 29-July 19, 1998. Don Cahoon replaces the recently retired Charlie Whitlock as the principle investigator for the CERES validation exercises that involve the NASA helicopter. As part of the CERES validation exercises, a field campaign will be conducted to make BDRF measurements over several of the major scene types in and around facilities within the SGP CART Site. In addition to the helicopter crew, they will be bringing a ground support team to make surface measurements, instruments on the order of an active cavity radiometer.

TABLE 4 Intensive Observation Periods and Campaigns

Date	Name	Science Team Membera[1]	DSIT Contact[b]	Description	Status
11/92	Field Test of NCAR Flux Profiler	D. Parsons (NCAR)	R. Cederwall	Enhanced soundings at the central facility and profiler site were made 11/10-11/19; boundary layer flights were also conducted on a few days.	Completed; data available
4/93	AERI Field Test	H. Revercomb (UW)	J. Liljegren	Enhanced soundings at the central facility were requested during the field acceptance test of the AERI instrument.	Completed 4/29/93
5/93-6/93	Using the GPS for the Measurement of Atmospheric Water Vapor	Collaborative (UNAVCO and NCSU)	J. Liljegren	The purpose was to test the investigators' technique for inferring total precipitable water vapor in the atmosphere column by using GPS signals.	Completed 6/8/93; data available

6/93	Warm-Season Data Assimilation and ISS Test	D. Parsons (NCAR)	R. Cederwall	This test was an enhanced sampling (in time and space) of the SGP domain for a 10-d period with profilers and sondes. The primary goals of the IOP were (1) to study the performance of FDDA under thermodynamic conditions typical of the continental warm season and (2) to evaluate the estimates of divergence and vorticity from the prototype NCAR ISS with interferometric techniques, the triangle of three 915-MHz profilers, and the results of FDDA.	Completed; all data available at the Experiment Center except for FDDA, which is available upon request at NCAR
1/94; 4/94; 7/94; 10/94; 4/95; 7/95; 9/95; 4/96; 7/96; 4/97; 6/97; 9/97-10/97; 1/98-2/98	Seasonal SCM IOP	D. Randall (CSU)	R. Cederwall	Seasonal IOP with enhanced frequency of observations, particularly vertical soundings of temperature, water vapor, and winds at central facility and boundary facilities for periods of 21 d; the required sounding frequency is 8/d. The data are required for quantifying boundary forcing and column response.	IOPs being planned for spring and winter 1998

4/94; 9/95-10/95; 4/96; 9/96; 9/97-10/97	ARM UAV	B. Ellingson (UoM)	D. Rodriguez	Measurements of clear-sky flux profiles acquired by a UAV and surface support data are to be used to understand clear-sky heating rates and the ability of models to reproduce the observations.	First IOP conducted successfully in 4/94; flight for ARESE IOP in 9/95-10/95; first 24-h UAV flight in 10/96
4/94-5/94; 4/95-5/95	Remote Cloud Sensing Field Evaluation	R. McIntosh (UM); B. Kropfli (NOAA); T. Ackerman (PSU); K. Sassen (UU); A. Heymsfield (NCAR); J. Goldsmith (SNL); and others	C. Flynn	The primary purpose was the field evaluation and calibration of several remote sensing cloud-observing instruments (some from the IDP project). *In situ* cloud observations were critical to the success of this IOP. Enhanced soundings were required at the central facility.	Completed; data analysis in progress
5/94	WB-57 Overflight for the Measurement of Atmospheric Water Vapor at High Altitude	Collaborative (Visidyne and Lockheed PARC)	J. Liljegren	The purpose was to attempt to infer the vertical distribution of water vapor at high altitudes from solar transmission spectra.	Completed; preliminary transmission spectra delivered to ARM
5/94	VORTEX IOP	E. Rasmussen (NSSL)	D. Slater	Special launches were made in support of VORTEX, testing hypotheses on the development and dissipation of severe storms.	Completed 5/31/94

8/94	GEWEX/GCIP/ GIST IOP	Collaborative	T. Cress	Special launches were made in support of the GCIP and GIST as part of an effort to improve climate models by improving parameterizations of hydrologic and energy cycles.	Successfully conducted in 8/94
9/94-10/94; 6/95-7/95	Sampling of Coherent Structures with the 915-MHz Profiler	R. Coulter (ANL)	R. Cederwall	Fluctuations in the vertical wind and index of refraction were observed by operating the 915-MHz profiler with RASS in a special mode during the afternoon hours to sample convective plume structures.	Completed
4/95-5/95	Simultaneous Ground-Based, Airborne, and Satellite-Borne Microwave Radiometric and *In Situ* Observations of Cloud Optical Properties and Surface Emissivities	W. Wiscombe (NASA-GSFC); E. Westwater (NOAA-ETL)	D. Slater	Observations of cloud optical properties were obtained over the CART site simultaneously from ground-based, *in situ*, and satellite-borne sensors; spatial variability of surface emissivities was assessed to attempt retrieval of total precipitable water and cloud liquid water from the special sensor microwave imager.	Completed; involved collaboration between Wiscombe and L. Fedor at NOAA

4/95-5/95	VORTEX-ARM	E. Westwater (NOAA-WPL); W. Wiscombe (NASA-GSFC); G. Stephens and P. Gabriel (CSU); J. Schneider (CIMMS/NSSL)	D. Slater	A joint VORTEX-ARM proposal was approved for 45 h of P-3 aircraft time to study stratocumulus clouds. Work was coordinated with Remote Cloud Sensing IOP.	Data exchange completed 12/95
6/95-7/95	Surface Energy Exchange IOP	C. Doran (PNNL); R. Coulter (ANL); R. Stull (UBC)	R. Cederwall	Detailed observations of the temperature and moisture profiles in the PBL obtained within a radius of 75-125 km of the central facility by using airsondes and profilers to evaluate the variations of the PBL structure in relation to underlying surface fluxes.	Completed; airsonde data available as beta release from C. Doran
9/95-10/95	ARESE	Collaborative	T. Cress	The purpose was to study the anomalous absorption of solar radiation by clouds. The phenomenon was first noticed when satellite measurements of solar radiation absorbed by the surface atmosphere were compared with solar radiation measured at collocated surface sites.	Completed; data are available
4/96-5/96	SUCCESS	Collaborative	R. Peppler	The purpose is to determine the impact of the current and the future subsonic aircraft fleet on Earth's radiation budget and climate.	Completed

6/96	MSX Satellite Overflights	Collaborative	H. Foote	The purpose is to provide ground truth support for the MSX satellite. Nine MSX sensors operate in the range of 0.12-0.9 µm. A spectral IR imaging telescope also operates.	Launched on 4/24/96; SGP CART site flyovers on 6/17, 7/15, 8/12, and 9/9, and TWP CART site flyover on 10/13/96; data exchange in process
6/96-7/96	CLEX IOP	G. Stephens (CSU/CIRA); J. Davis (CSU/CIRA)	R. Cederwall	Intensified satellite data collection (by CSU), airborne cloud radar and *in situ* microphysical observations, and an array of ground-based measurements will be carried out for better understanding of the nature and role of middle-level, nonprecipitating cloud systems.	Completed; data exchange in process
7/96-8/96	BLX IOP	R. Stull (UBC)	R.Cederwall	Remote sensing surface fluxes with instrumentation on the University of Wyoming King Air; CASES site and NCAR mobile profiler involved; in conjunction with 7/96-8/96 SCM IOP.	Completed; aircraft data to be available in 1997; BAMS article published June 1997

7/96-8/96	LLJ IOP	D. Whiteman (PNNL)	R. Cederwall	The purpose is to investigate oscillations in the characteristics of the LLJ over the SGP.	Completed; data from 915-MHz profiler run in modified mode will be ingested in 1997 (available now from R. Coulter at ANL); Wyoming King Air data, in collaboration with R. Clark (MSU), will be available in 1997
9/96; 9/97-10/97	Water Vapor IOP	H. Revercomb (UW)	D. Turner/ R. Peppler/ M. Splitt	Series of IOPs to take measurements of water vapor profiles using many instrument systems to attempt to define water vapor profile of the site in support of IRF research efforts. First in series focused on lowest kilometer; second in series focused up to 4-12 km.	Completed; data analysis in progress
12/96; 6/97	LMS/SITAC IOP	B. Dillman (Lockheed)	D. Slater	To analyze approaches to atmospheric compensation on hyperspectral and ultraspectral image data obtained from satellite platforms.	Completed

4/97	Cloud Radar IOP	B. Martner (ETL); P. Daum (BNL)	D. Rodriguez/ M.-D. Cheng	Designed to validate retrieval of cloud microphysics on the basis of newly installed ARM zenith-pointing MMCR (developed by NOAA/ETL); ETL to operate collocated scanning NOAA/K-band cloud radar; high-altitude and low-altitude sampling to be done by two aircraft; aerosol components to be flown in clear-sky conditions by low-altitude aircraft.	Completed
6/97-7/97	SGP '97 (Hydrology) IOP	T. Jackson (USDA); M.-Y. Wei (NASA)	R. Cederwall	Conducted as part of USDA and NASA campaign to study 3 "recharge" events; additional ARM instruments will be installed at USDA El Reno extended facility; non-ARM aircraft with microwave radiometry will be sensing soil moisture.	Completed; data analysis in progress; meeting to be held 3/98

9/97-10/97	Cloud IOP	G. Mace (UU)	D. Rodriguez/ P. Daum (aircraft coordinator)	Obtain on-site measurements of cloud and aerosol properties in cloudy and clear-sky conditions; single microphysics aircraft to be flown in conjunction with ARM UAV high/low set of airborne platforms measuring radiometric properties; unprecedented opportunity to quantify cloud/aerosol/radiation interactions.	Completed; data analysis in progress
9/97-10/97	Aerosol IOP	P. Daum (BNL)/ S. Schwartz (BNL)	M.-D. Cheng/ P. Daum (aircraft coordinator)	See above for Cloud IOP.	Completed; data analysis in progress
9/97-10/97	Shortwave Radiation IOP	W. Wiscombe (NASA/GSFC)/ G. Stephens (CSU)	D. Slater/ B. McCoy	To focus on both broadband and spectrally resolved shortwave measurements, including emphasis on instrument calibration and intercomparison; will also evaluate GRAMS and have UAV/aircraft component.	Completed; data analysis in progress
9/97-10/97	Fall 1997 Integrated IOP	G. Mace (UU)	R. Peppler	Name for the ensemble UAV, SCM, Water Vapor, Cloud, Aerosol, and Shortwave Radiation IOPs.	Completed; data analysis in progress

10/98	CO_2 DIAL IOP	J. Jolin (LANL)	D. Turner/ D. Slater	CO_2 DIAL on aircraft will overfly the site; has potential benefit for water vapor and aerosols measurements.	Site visit complete; planning underway
2/98	MOPITT Campaign	J. Wang (NCAR)	D. Slater	Validation of an airborne instrument that measures tropospheric CO and CH4.	Planning underway
6/98-7/98	BDRF Campaign	D. Cahoon (NASA Langley)	D. Slater	Bi-directional reflectance function measurements will be made over the major scene types in and around the central facility.	Planning underway
Summer 1998 or 1999	Soil Sampling Campaign	J. Happell	R. Cederwall	A study that proposes to test that soils are a significant global sink of atmospheric CC114 and CH3CC13.	Planning underway

[a] Affiliations: ANL, Argonne National Laboratory; BNL, Brookhaven National Laboratory; CIMMS, Cooperative Institute for Mesoscale Meteorological Studies; CIRA, Cooperative Institute for Research in the Atmosphere; CSU, Colorado State University; ETL, Environmental Technology Laboratory; GSFC, Goddard Space Flight Center; LANL, Los Alamos National Laboratory; MSU, Millersville State University; NASA, National Aeronautics and Space Administration; NCAR, National Center for Atmospheric Research; NCSU, North Carolina State University; NOAA, National Oceanic and Atmospheric Administration; NSSL, National Severe Storms Laboratory; PARC, Palo Alto Research Center; PNNL, Pacific Northwest National Laboratory; PSU, Pennsylvania State University; SNL, Sandia National Laboratories; UBC, University of British Columbia; UM, University of Massachusetts; UoM, University of Maryland; UNAVCO, University NAVSTAR Consortium; USDA, U.S. Department of Agriculture; UU, University of Utah; UW, University of Wisconsin; and WPL, Wave Propagation Laboratory.

[b] Other definitions: AERI, atmospherically emitted radiance interferometer; ARESE, ARM Enhanced Shortwave Experiment; ARM, Atmospheric Radiation Measurement (Program); BAMS, *Bulletin of the American Meteorological Society*; BDRF, Bi-Directional Reflectances Function; BLX, Boundary Layer EXperiment; CART, Cloud and Radiation Testbed; CASES, Cooperative Atmosphere-Surface Exchange Study; CLEX, Cloud Layer EXperiment; DIAL, DIfferential Absorption Lidar; DSIT, Data and Science Integration Team; EBBR, energy balance Bowen ratio; ECOR, eddy correlation; FDDA, four-dimensional data assimilation; GCIP, GEWEX Continental-Scale International Project; GEWEX, Global Energy and Water Cycle Experiment; GIST, GEWEX Integrated System Test; GPS, global positioning system; GRAMS, ground radiation measurement system; IDP, Instrument Development Program; IOP, intensive observation period; IR, infrared; IRF, instantaneous radiative flux; ISS, integrated sounding system; LLJ, Low-Level Jet; LMS, Lockheed Missile and Space; MOPITT, Measurements of Pollution in the Troposphere; MSX, Midcourse Satellite Experiment; PBL, planetary boundary layer; RASS, radio acoustic sounding system; SCM, single-column model; SGP, Southern Great Plains; SITAC, Spectral Imagery Technology Applications Center; SUCCESS, Subsonic Aircraft: Contrail and Cloud Effects Special Study; TBD, to be determined; TWP, Tropical Western Pacific; UAV, unmanned aerospace vehicle; VORTEX, Verification of the Origins of Rotation in Tornadoes Experiment.

The Soil Sampling Campaign. The Soil Sampling Campaign is proposed for the summer of 1998 or 1999. This yet unfunded study proposes to investigate the possibility that soils are a significant global sink of atmospheric CCl14 and CH3CCl3. Sampling would involve taking soil gas samples over the top 50 cm of soil with a small probe and analyzed at the central facility by gas chromatography over a two week period.

The CO_2 Differential Absorption Lidar Campaign. John Jolin, Los Alamos National Laboratory (LANL), anticipates conducting a DOE-funded experiment at the SGP CART site. His experiment uses a 10-kHz tunable-frequency lidar system for the 9- to 11-μm wavelength region of interest. The CO_2 DIfferential Absorption Lidar (DIAL) system can be mounted in aircraft or be ground-based. Currently, the aircraft system is being considered. The CO_2 DIAL system will be used to identify trace chemical species, as well as to measure water vapor. The system on board a U.S. Air Force KC-135 aircraft can be used to make spectrally resolved albedo measurements. This IOP has been scheduled tentatively for October 1998.

5.4 Collaborative Investigations

Argonne National Laboratory has developed a new research facility within the existing boundaries of the SGP CART site to be devoted to studies of the planetary boundary layer (PBL). The Argonne Boundary Layer Experiment (ABLE) cover an area approximately 50 km × 50 km within the Walnut River watershed in Butler County, Kansas, about 50 km (30 mi) east of Wichita and near the Towanda extended facility. New techniques of observation and data fusion will be developed and used to study the nocturnal low-level wind maximum and its relation to the synoptic jet features; to develop methods for spatial integration of air-surface exchange of heat, gases, and momentum; and to study horizontal and vertical dispersion in the PBL. The initial set of instrumentation currently available at ABLE includes two 915-MHz profilers with RASS, three minisodars, one surface ECOR flux station, one soil moisture and temperature station, three automated weather stations (AWSs), and one satellite data receiver processor. One central location will house data collection equipment and instrumentation and will provide accommodations for visiting scientists. The data obtained are being provided in real time to a user community of atmospheric scientists and ecologists.

The 915-MHz profilers with RASS and the minisodars have been installed at Oxford and Whitewater, Kansas. A minisodar and an AWS have been added to the ARM Program's Beaumont, Kansas, intermediate facility, which is shared by and provides data streams for both the ARM Program and ABLE. In addition, an extensive automated high-spatial-resolution soil

moisture and temperature network will be installed and remain in place, located in the Towanda subbasin. A second network (not automated) with larger spacing may also remain in place. All are within the footprint of the Wichita next-generation radar (NEXRAD).

The Cooperative Atmosphere-Surface Exchange Study (CASES) is a collaborative effort to obtain measurements over the entire Walnut River watershed (approximately 100 km × 100 km) in and around Butler County, Kansas, about 50 km (30 mi) east of Wichita. The CASES initiative will obtain measurements over a somewhat larger domain than ABLE. CASES will include hydrologic, ecological, and atmospheric chemistry studies, in addition to ABLE research. The principal contacts for CASES are Peggy LeMone, National Center for Atmospheric Research (NCAR), and Bob Grossman, University of Colorado. Several proposals have been submitted to the NASA Land Surface Hydrology Program to conduct experiments over the CASES/ABLE domain.

5.5 Geophysically Significant Phenomena

The ARM Program is concentrating on the study of geophysically significant phenomena (e.g., water vapor profiles, aerosols, clouds, temperature profiles, and radiation). Algorithm development that describes these phenomena is a current primary focus.

The algorithm products represent a merging of appropriate instrument measurements into a cohesive product defining a particular geophysical state, for use by the Science Team. These products specifically address problems posed in the *Science Plan* and by various working groups. A product example currently under construction is one prescribing water vapor over the SGP CART site sought by the IRF Working Group. As noted above, such an effort involves three IOPs obtaining multiple water vapor measurements at the central facility (e.g., additional measurements on the 60-m tower; use of tethered systems; use of guest instruments and additional instruments, such as chilled mirrors and frost-point hygrometers), use of aircraft, and comparison of these measurements with routine BBSS, Raman lidar, MWR, and 915- and 50-MHz RASS water vapor profiles. The end result of such comparisons will be the generation of an ensemble, site-representative water vapor profile for use in GCMs. Section 4.3 describes a recently-constructed product for shortwave radiation at the central facility.

5.6 Educational Outreach

The educational outreach program for the SGP CART site, coordinated by Dr. Ken Crawford, Director of the Oklahoma Climatological Survey (OCS), combines a range of resources available at OU. Outreach efforts are focused at the precollege, undergraduate, and graduate levels. Efforts in this six-month period will be focused on professional development activities, staff support for teacher participants, scientific mentorship of students, development of data analysis tools for students and teachers, and application of data in the classroom (Melvin and McPherson 1998; McPherson and Crawford 1996). A two-week workshop involving five Kansas and two Oklahoma teachers was held at OU in July 1997. Instruction was given on how to use ARM data and related software, along with lessons on atmospheric radiation, energy transfer, meteorological data, telecommunications, data visualization, the WWW, and the ARM Program. Six EARTHSTORM teachers attended the workshop as the "Storm Team", helping teach participants and offering insight into how to modify existing lessons and materials to incorporate ARM data. The five Kansas teachers were provided a Power Macintosh 5400 computer for their classrooms. Schools can access ARM data on the WWW from the OCS home page at

http://www.ocs.ou.edu/lessons/lessons.html .

6 DISTRIBUTION OF DATA

Most of the data being requested are received from the SGP CART site or external data sources and are then repackaged for daily and weekly distribution to individual users. In some cases, users can log into the Experiment Center or the R1 System at the central facility and extract data by anonymous file transfer protocol (FTP). All data are sent to the Data Archive, where they are accessible to anyone at the WWW site:

http://www.archive.arm.gov .

The current status of CART and external data streams can be accessed at the uniform resource locators (URLs) provided in Sections 3.4 and 3.5.2 of this report.

The status of data streams from CART instruments or external sources has been classified as releasable (released upon request for the data stream), developmental (released only to SDS personnel for development of ingestion programs), under evaluation (released to an investigator for an initial data quality check), beta release (for releasable data of known and reasonable quality), collecting (when raw data are being collected for future processing and distribution), mentor only (when the data stream is provided only to the instrument mentor at the request of the mentor), analysis (if the data stream is released for further processing and/or analysis, such as for graphic display), or defunct (due to replacement of a prototype instrument data stream with the CART instrument data stream).

7 LOOKING AHEAD

The nearly mature SGP CART site now provides the full range of data streams needed to support the DSIT's "building block" algorithm development effort and a broad spectrum of Science Team research. These activities, in turn, are increasingly drawing on multiple SGP data streams to focus strongly on geophysically significant phenomena (water vapor profiles, clouds, aerosols, temperature profiles, radiation, surface fluxes). The operational challenges that will be of greatest importance during 1998 and beyond will therefore include maintaining the performance of the basic instrumentation suite at the highest possible level, improving that performance where possible, enhancing the original CART design through the permanent addition of new instruments, and mounting focused IOPs involving temporary additional instrumentation. Through this mix of activities, the evolving scientific requirements, challenges, and opportunities for the SGP CART will be met. The present chapter outlines the path ahead, to the extent that it can be identified in late 1997.

The key developments that are expected to occur at the central facility during the present six-month period and the following 18 months include the achievement stable operation of the Raman lidar; full use of the RCF; upgrading of the Vaisala BBSS sondes (see below); and the possible installation of several new instruments (UV-B sensor, PAR, optical transmissometer and a solar spectral radiometer). The solar spectral radiometer will provide solar spectral observations at the central facility that are needed for the testing and improving of solar radiation models. A narrow-field-of-view zenith sky radiance sensor in the near IR has also been suggested for that location. The sensor would have the advantage of a field of view that overlaps or nearly coincides with that of the MWR and possibly MMCR. Another central facility measurement issue now under consideration includes the possibility of acquiring continuous direct-beam solar irradiance measurements with a cavity radiometer. Cavity measurements were made under close supervision during the fall 1997 Shortwave IOP.

The utility of the Raman lidar to characterize the lower half of the troposphere (e.g., water vapor, clouds, aerosols) more accurately and with a finer vertical resolution than is possible with the original suite of instruments (BBSSs, MWRs) has been strongly advocated by the IRF Working Group. The routine, unattended, continuous operation of the Raman lidar remains an ongoing goal, following the installation in spring 1997 of a permanent hail shield. However, the operation of the Raman lidar and its measurement strategies are being closely monitored. Also, the 1997 installation of the MMCR is already enhancing the algorithm development efforts of the VAP Working Group to improve the definition of cloud

characteristics (fractional coverage, as well as base and top heights) above the central facility, in coordination with key Science Team members. The MMCR is equipped to map the vertical extent of cloud boundaries up to a height of approximately 20 km. Coincident measurements of vertical wind speed will be obtained from Doppler analysis. The system will operate only in the vertically pointing position. Results from the fall 1997 Cloud IOP will be instrumental in determining the best operational strategies for the MMCR.

Improved specifications of the water vapor, temperature, and cloud conditions above the boundary facilities are expected to result from several observational enhancements and additions during 1998 and 1999. First, the addition of ceilometers is primarily intended to provide data for algorithms that will retrieve lower tropospheric temperature and humidity profiles from the output of new, planned AERI instruments. Second, higher quality BBSS soundings should result from a planned upgrade of the Vaisala sensors being used (from RS-80 to RS-90). The RS-90 humidity sensor has a faster response time and thus recovers more quickly than its predecessor after emerging from clouds. Its temperature counterpart is also smaller and has a faster response time than the RS-80 and, in addition, is less susceptible to solar heating. An identical BBSS upgrade will occur at the central facility. Under consideration for the boundary facilities is a capability to profile with passive microwave systems, which would augment the AERI measurements.

The anticipated completion of extended facilities at El Reno (pasture) and at a wooded Okmulgee site will provide the basis for the spatial integration of the turbulent and radiative fluxes over the entire SGP CART site. A key feature of that upgrading is the existence of SWATS at all extended facilities. The SWATS data will contribute significantly to completing the characterization of the land surface and subsurface that is essential for investigating surface heat and moisture exchanges. In a closely related development, approximately 40 additional identical SWATSs have been installed at OKM sites within the SGP CART site domain during a two-year period that began in mid-1996. The SWATSs that existed in midsummer 1997 (approximately 40) were the centerpiece of the ARM/USDA/NASA Hydrology IOP conducted in June and July 1997, which also made use of satellite and aircraft data and focused in particular on soil moisture. The first half of 1998 will see the completion of improved SIROS data logging at the central and extended facilities. This improvement is involving both (1) the introduction of independent data logging systems for the SIROS broadband sensors, which will henceforth be known as SIRS (solar and infrared station), and (2) the MFRSRs becoming the sole users of the original systems that were previously shared with the SIROS instrument suites. Improved reliability via SIRS data gathering should result. A similar logging system was introduced for

the central facility BSRN (to be renamed BRS [broadband radiometer station]). Measurement issues under consideration at the extended facilities include local observations of surface vegetative conditions and measurements of surface bidirectional reflectance.

The capability for monitoring land-atmosphere interactions recently was enhanced further with the establishment and operation of three ARM intermediate facilities containing 915-MHz profilers with RASS, which are being used to quantify structures and processes in the PBL. Stabilization of these systems should occur during 1998 after a vendor-recommended upgrade, and significant scientific dividends will begin to accrue in 1998 and 1999.

The SGP CART site activities during 1998 will continue to capitalize on the 1996 installation of the aerosol instrumentation and the RCF at the central facility. The data from the aerosol instruments are filling a significant gap in the specification of the radiative state of the near-surface atmosphere. In-situ measurements during the fall 1997 Aerosol IOP will greatly increase our understanding of clear-sky aerosols in the layer from 500-17,000 ft. Indeed, the importance for ARM of aerosol effects is likely to grow in the next two years. The establishment of the RCF was a key element in the total quality control effort addressing the wide variety of radiometers at the central facility and the more limited SIROS/SIRS radiometer suites at the extended facilities. Establishment of the RCF was accomplished during the latter half of 1996 and will be augmented by the development and implementation of a comprehensive integrated RCF Operations Plan as the SGP CART site moves from the establishment of routine operations to the maintenance of routine operations, with inherent instrument-aging problems. BORCALs were conducted throughout summer 1997.

The SST will continue to assist in the calibration and maintenance areas during 1998, when it will also contribute further to the quality control and assurance of the ever-expanding SGP CART data bank through the further development and use of graphic data quality display modules and performance metrics. As noted in earlier chapters, the graphic displays, which plot actual data against modeled expectations, are intended for use by site operations staff (and the SST) to aid in their efforts to perform "first-line-of-defense" near-real-time quality assurance relative to instrument operation. The performance metrics are intended to give a broader view of instrument performance and data quality over the CART site relative to how data fall within or outside of specified quality tolerances, such as range and consistency checks, and already include platform intercomparisons. Both efforts represent a major step forward toward achieving a comprehensive end-to-end quality control system for instrument performance and data. Further

in that regard, in spring 1997, the SST began issuing weekly data quality assessments on the WWW, using input from other groups within ARM as well as its own assessment tools.

During 1998, the SGP CART site observational capabilities are expected to continue to benefit from ongoing interactions between the ARM Program and several other federal and state research programs having an interest in the SGP in general. The federal agency interactions, which until now have particularly involved the GCIP component of GEWEX, were broadened through the leadership of NASA and the USDA in the aforementioned midsummer 1997 Hydrology IOP. These interactions are also currently manifest in the approximately biannual meeting of a joint ARM-GCIP-ISLSCP Working Group (on which ARM is represented by J.C. Doran, R.G. Ellingson, and P.J. Lamb); the aforementioned implementation of the SWATS at the ARM extended facilities, with significant financial support from GCIP; and the USDA's facilitation and partial funding of the above El Reno extended facility. The Joint Working Group will be concerned not only with fostering the most cost-effective and efficient observational strategies for the SGP CART site for 1998 and subsequent years, but also with formulating the best possible scientific use of the resulting data among their programs. Consistent with this latter goal, the Working Group's May 1997 meeting focused on "Value-Added Science," which will likely be a continuing theme of that forum. Interactions with the OKM, which has been an important source of external data for the SGP for several years, increased with the OKM’s aforementioned parallel deployment of approximately 40 SWATSs. Finally, a joint effort between the NWS and ARM resulted in ARM radiosonde data being made available to the meteorological community at large via the Global Telecommunications System. This availability will be especially valuable for the NWS short-range prediction efforts during the tornado seasons of the next few years.

The integration of ARM UAV operations into the SGP CART site scientific mission was initiated successfully during the April 1994 IOP, which used a small UAV (GNAT) that could ascend only to 6.7 km (about 22,000 ft). However, delays in developing, testing, and gaining operational approval for the larger UAVs needed for radiation measurements at higher elevations precluded their subsequent use over the SGP CART site for the next two years. Manned aircraft were used instead, as during the 1995 ARESE IOP. Fortunately, this situation was rectified with the deployment of the Altus UAV during the September 1996 Water Vapor IOP, which permitted the valuable operation of highly stable UAV-mounted radiation and other instruments over the SGP CART site. Indeed, this operation constituted a great step forward for the use of UAVs in scientific research in general, because it included a record-breaking 26-hour mission.

The use of the Altus and Twin Otter was also an essential ingredient of the Fall 1997 Integrated IOP and presumably other follow-ups.

Throughout 1998, the scientific operation of the SGP CART site should benefit significantly from guidance provided by the SAC. The fundamental role of the SAC is to ensure that the operation of the site addresses the goals and objectives of the ARM Program (published in the 1996 *Science Plan*) to the fullest possible extent, including through successful adaptation to changing circumstances and opportunities. Such performance will ensure that the flows of data to the Science Team members are appropriate to their needs, of consistently high quality, and as continuous as possible. For example, the recent redoubling of efforts by the SST to help ensure the quality of SGP data is consistent with the strong encouragement offered by the November 1995 SAC Review. Because the membership of the SAC is divided approximately equally between ARM Science Team members and nonmembers, its guidance reflects both the inherently more parochial concerns of the ARM Science Team and the broader global-change perspective of the others. The recommendations from the November 1995 and June 1996 SAC meetings are now being acted upon by the SST and will be reflected in the scientific capability of the site during 1998 and beyond. Those recommendations included the aforementioned need for increased attention to quality assurance and quality control of the SGP instruments and data streams, the necessity of making midcourse corrections (including those of personnel assignments and funding priorities) to ensure that the configuration and operation of the SGP CART site are in full consonance with the ARM *Science Plan* priorities, the desirability of converting the *Site Scientific Mission Plan* into an article for publication in the *Bulletin of the American Meteorological Society* that would publicize the scientific potential of the site (to be completed during the present six-month period); and the inauguration of an SST "Visitor Program" that would particularly involve cloud and radiation data analyses and simulations with the goal of enhancing the site's observational capabilities in those crucial areas. Thus, from now onward, the SAC guidance will have a continuing effect on the scientific mission of the SGP CART site. This fact, coupled with the recent maturation of the site, should result in optimal operation of this ARM locale with respect to the goals and objectives of the overall ARM Program during 1998 and subsequent years.

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APPENDIX:

STATUS AND LOCATIONS OF INSTRUMENTS

TABLE A.1 Actual and Planned Locations of Instruments at the Central Facility[a]

Instrument	Latitude, Longitude (deg)	Surface Type	Location	Comments
AERI	36.967 N 97.528 W	Pasture	Optical trailer	—
AERI X	36.967 N 97.528 W	Pasture	Optical trailer	—
SORTI	36.967 N 97.528 W	Pasture	Optical trailer	—
BSRN	36.993 N 97.708 W	Pasture	Central cluster	—
MFRSR	36.993 N 97.708 W	Pasture	Central cluster	—
SIRS	36.993 N 97.708 W	Pasture	Central cluster	—
10-m MFR	36.785 N 97.665 W	Pasture	Central cluster	—
25-m USR	36.932 N 97.916 W	Wheat	60-m tower	—
25-m UIR	36.932 N 97.916 W	Wheat	60-m tower	—
25-m MFR	36.932 N 97.916 W	Wheat	60-m tower	—
CSPHOT	—	Pasture	Central cluster	—
BBSS	37.012 N 98.120 W	Grass	Central compound	—
915-MHz RWP	36.677 N 97.686 W	Shale, pasture	Profiler trailer	—
50-MHz RWP	36.630 N 97.706 W	Shale, pasture	Profiler trailer	—
MWR	37.105 N 97.765 W	Pasture	Optical trailer	—

TABLE A.1 (Cont.)

Instrument	Latitude, Longitude (deg)	Surface Type	Location	Comments
RLID	38.052 N 97.741 W	Pasture, wheat	IDP 3	—
WSI	36.842 N 97.608 W	Pasture	Optical trailer	—
BLC	36.697 N 97.528 W	Pasture	Optical trailer	—
MPL	36.967 N 97.528 W	Pasture	Optical trailer	—
MMCR	36.885 N 97.591 W	Pasture, wheat	IDP 2	—
TLCV	—	Pasture	Optical trailer cluster	—
25-m T/RH	36.932 N 97.916 W	Wheat	60-m tower	—
60-m T/RH	36.932 N 97.916 W	Wheat	60-m tower	—
ECOR	36.857 N 97.631 W	Wheat, pasture	Aerosol trailer	—
25-m ECOR	36.932 N 97.916 W	Wheat	60-m tower	—
60-m ECOR	36.932 N 97.916 W	Wheat	60-m tower	—
EBBR	36.887 N 97.531 W	Pasture	Central cluster	—
SMOS	36.785 N 97.665 W	Pasture	Central cluster	—
AOS	36.927 N 97.828 W	Pasture, wheat	Aerosol trailer	—
RCF	36.958 N 97.653 W	Pasture, wheat	Calibration trailer	—

TABLE A.1 (Cont.)

Instrument	Latitude, Longitude (deg)	Surface Type	Location	Comments
RSS	—	Pasture	Optical trailer cluster	—
SWS	—	Pasture	Optical trailer	Not installed
GRAMS	—	Pasture	Optical trailer cluster	—
SWATS	—	Pasture	Central cluster	—

[a] AERI, atmospherically emitted radiance interferometer; AOS, aerosol observation system; BBSS, balloon-borne sounding system; BLC, Belfort laser ceilometer; BSRN, Baseline Surface Radiation Network; CSPHOT, Cimel sunphotometer; EBBR, energy balance Bowen ratio; ECOR, eddy correlation; GRAMS, ground-based radiometer autonomous measurement system; IDP, Instrument Development Program; MFR, multifilter radiometer; MMCR, millimeter cloud radar; MPL, micropulse lidar; MWR, microwave radiometer; RCF, radiometer calibration facility; RLID, Raman lidar; RSS, rotating shadowband spectrometer; RWP, radar wind profiler; SIROS, solar and infrared radiation observing system; SIRS, solar and infrared station; SMOS, surface meteorological observation station; SORTI, solar radiance transmission interferometer; SWATS, soil water and temperature system; SWS, shortwave spectrometer; TLCV, time-lapse cloud video; T/RH, temperature and relative humidity sensor; UIR, upwelling infrared radiometer; USR, upwelling solar radiometer; Vceil, Vaisala ceilometer; WSI, whole-sky imager.

TABLE A.2 Locations and Status of Extended Facilities[a]

Site	Elev b (m)	Latitude, Longitude (deg)	Surface Type	Flux Station[c]	SWATS[c]	SMOS[c]	SIROS/ SIRS[c]	Comment
Larned, KS EF-1	632	38.202 N 99.316 W	Wheat	ECOR 9/1/95	Yes 6/96	Yes 9/1/95	Yes 9/1/95	Power and communication center installed 10/95
Hillsboro, KS EF-2	450	38.306 N 97.301 W	Pasture	EBBR 10/96	Yes 6/96	No	Yes 9/7/95	Power and communication center installed 8/95
LeRoy, KS EF-3	338	38.201 N 95.597 W	Wheat and soybeans (rotated)	ECOR 12/7/95	Yes 9/96	Yes 12/7/95	Yes 12/7/95	Power and communication center installed 9/95
Plevna, KS EF-4	513	37.953 N 98.329 W	Rangeland (ungrazed)	EBBR 4/3/93	Yes 3/5/96	Yes 3/28/95	Yes 3/28/95	Power and communication center installed 3/95
Halstead, KS EF-5	440	38.114 N 97.513 W	Wheat	ECOR 1997	Yes 9/96	Yes 5/31/96	Yes; broad-band only 5/31/96	Power and communication center installed 11/95
Towanda, KS EF-6	409	37.842 N 97.020 W	Alfalfa	ECOR 12/14/95	Yes 9/96	Yes 12/14/95	Yes 12/14/95	Power and communication center installed 8/95
Elk Falls, KS EF-7	283	37.383 N 96.180 W	Pasture	EBBR 8/29/93	Yes 3/12/96	Yes 3/9/95	Yes 3/9/95	Power and communication center installed 2/95
Coldwater, KS EF-8	664	37.333 N 99.309 W	Rangeland (grazed)	EBBR 12/8/92	Yes 6/96	Yes 3/4/93	Yes 5/9/95	Power and communication center installed 5/95

Ashton, KS EF-9	386	37.133 N 97.266 W	Pasture	EBBR 12/10/92	Yes 2/27/96	Yes 3/13/90	Yes 10/5/93	Power and communication center installed 10/93
Tyro, KS EF-10	248	37.068 N 95.788 W	Wheat	ECOR 7/21/95	Yes 7/96	No	Yes 7/21/95	Power and communication center installed 6/95
Byron, OK EF-11	360	36.881 N 98.285 W	Alfalfa	ECOR 6/26/95	Yes 6/96	Yes 6/26/95	Yes 6/26/95	Power and communication center installed 6/95
Pawhuska, OK EF-12	331	36.841 N 96.427 W	Native prairie	EBBR 8/29/93	Yes 9/97	No	Yes 6/30/95	Power and communication center installed 6/95
Lamont, OK EF-13, 14	318	36.605 N 97.485 W	Pasture, wheat	EBBR 9/14/92 ECOR 5/30/95	Yes 2/5/96	Yes 4/9/93	Yes 10/15/93 BSRN 5/15/92	Power and communication center installed 6/93
Ringwood, OK EF-15	418	36.431 N 98.284 W	Pasture	EBBR 9/16/92	Yes 2/21/96	Yes 3/29/93	Yes 10/12/93	Power and communication center installed 10/93
Vici, OK EF-16	602	36.061 N 99.134 W	Wheat	ECOR 5/30/95	Yes 7/96	No	Yes 5/30/95	Power and communication center installed 5/95
EF-17[d]	—	—	—	—	—	—	—	—
Morris, OK EF-18	217	35.687 N 97.856 W	Pasture (ungrazed)	EBBR 7/97	Yes 9/96	No	Yes; broad-band only 5/24/96	Power and communication center installed 10/95

El Reno, OK EF-19	—	—	Pasture (ungrazed)	EBBR	Yes	No	Yes	Implementation began in 5/97
Meeker, OK EF-20	309	35.564 N 96.988 W	Pasture	EBBR 4/5/93	Yes 2/8/96	Yes 4/2/93	Yes	Power and communication center installed 10/94
Okmulgee, OK EF-21	—	Location identified	Forest	ECOR 4/97	Yes 4/97	Yes 4/97	Yes 4/97	Lease signed 2/97; installation to begin in 1997
Cordell, OK EF-22	465	35.354 N 98.977 W	Rangeland (grazed)	EBBR 4/5/93	Yes 2/15/96	No	Yes 4/26/95	Power and communication center installed 3/95
Ft. Cobb, OK EF-23	415	35.153 N 98.461 W	Peanuts (irrigated)	ECOR 12/96	Yes 12/96	No	Yes 12/96	No lease agreement
Cyril, OK EF-24	409	34.883 N 98.205 W	Wheat (gypsum hill)	ECOR 8/25/95	Yes 7/96	Yes 8/25/95	Yes 8/25/95	Power and communication center installed 7/95
Seminole, OK EF-25	277	35.245 N 96.736 W	Pasture	EBBR 12/97	Yes 12/97	Yes 12/97	Yes 12/97	Power and communication center installed 11/96
Cement, OK EF-26	400	34.957 N 98.076 W	Pasture	EBBR 6/10/92	—	No	No	Phone line (only) installed 10/92

[a] BSRN, Baseline Surface Radiation Network; EBBR, energy balance Bowen ratio; ECOR, eddy correlation; EF, extended facility; NEPA, National Environmental Policy Act; SIROS, solar and infrared radiation observing system; SIRS, solar and infrared station; SMOS, surface meteorological observation station; SWATS, soil water and temperature system.

[b] Above sea level.

[c] Date indicates actual or scheduled installation date.

[d] This extended facility is a placeholder site, for possible expansion, if required.

TABLE A.3 Locations and Status of Intermediate Facilities[a]

Site	Elev[b] (m)	Latitude, Longitude (deg)	Surface Type	915-MHz Profiler and RASS[c]	Comment
Beaumont, KS IF-1	525	37.626 N 96.538 W	Rangeland	Yes 9/96	Power and communication installed 9/96
Medicine Lodge, KS IF-2	585	37.280 N 98.933 W	Rangeland	Yes 9/96	Power and communication installed 9/96
Meeker, OK IF-3	300	35.550 N 96.920 W	Grass	Yes 9/96	Power and communication installed 9/96

[a] IF, intermediate facility; RASS, radio acoustic sounding system.

[b] Above sea level.

[c] Date indicates actual installation date.

TABLE A.4 Locations and Status of Boundary Facilities[a]

Site	Elev[b] (m)	Latitude, Longitude (deg)	Surface Type	BBSS[c]	MWR[c]	Vceil	AERI	Comment
Hillsboro, KS BF-1	441	36.071 N 99.218 W	Grass	Yes 1/18/94	Yes 1/18/94	—	No	Temporary power and communication installed 12/93
Hillsboro, KS BF-1	447	38.305 N 97.301 W	Grass	Yes 9/28/94	Yes 9/28/94	No	No	Relocation and temporary power and communication installed 9/94; permanent power, communication, and grounding mat installed 3/96; T-1 line installed 4/96
BF-2	—	Unspecified	—	—	—	—	No	—
BF-3	—	Unspecified	—	—	—	—	No	—
Vici, OK BF-4	648	36.071 N 99.218 W	Grass	Yes 1/18/94	Yes 1/18/94	—	No	Temporary power and communication installed 12/93
Vici, OK BF-4	622	36.071 N 99.204 W	Grass	Yes 10/3/94	Yes 10/3/94	No	No	Relocation and temporary power and communication installed 9/94; permanent power, communication, and grounding mat installed 3/96; T-1 line installed 4/96
Morris, OK BF-5	18	35.682 N 95.862 W	Grass	Yes 1/18/94	Yes 1/18/94	—	No	Temporary power and communication installed 12/93

Morris, OK BF-5	217	35.688 N 95.856 W	Grass	Yes 10/6/94	Yes 10/6/94	No	No	Relocation and temporary power and communication installed 9/94; permanent power, communication, and grounding mat installed 3/96; T-1 line installed 4/96
Purcell, OK BF-6	344	34.969 N 97.415 W	Grass	Yes 9/23/94	Yes 9/23/94	No	No	Permanent power, communication, and grounding mat installed 3/96; T-1 line installed 4/96

[a] AERI, atmospherically emitted radiance interferometer; BBSS, balloon-borne sounding system; BF, boundary facility; MWR, microwave radiometer; Vceil, Vaisala ceilometer.

[b] Above sea level.

[c] Date indicates actual installation date.