Status of Instrumentation for the Southern Great Plains Clouds and Radiation Testbed

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Planning for the initial complement of instrumentation at the first Cloud and Radiation Testbed (CART) site has concentrated on obtaining a sufficient level of instrumentation at the central facility for studies of radiative transfer processes in a narrow column above the site. The auxiliary facilities, whose sole purpose is cloud mapping above the central facility, will not be activated as such until provisions are made for all-sky imaging systems. In the meantime, the auxiliary facilities will be instrumented as extended facilities if the locations are suitable, which would be the case if they serve the primary purpose of the extended facilities, i.e., obtaining representative measurements of surface energy exchanges, state variables, precipitation, soil and vegetative conditions, and other factors that must be considered in terms of boundary conditions by single-column and related models.

The National Oceanic and Atmospheric Administration (NOAA) radar wind profiler network is being considered to provide observations of vertical profiles at the boundaries of the CART site. If possible, these locations will be used for boundary facilities. Efforts are proceeding to gain access to the wind profiler network data and to determine if a sufficient number of the profilers can be equipped as Radio Acoustic Sounding Systems (RASS).

Profiles of temperature as well as winds are needed at the boundary facilities for studies with single-column models and four-dimensional data assimilation models. Balloon-borne sounding systems will be used there initially for both temperature and moisture profiles. Infrared spectrometers will eventually be used to infer moisture profiles at these boundary facilities.

Radar Wind Profiler-RASS

One system essential for profiling at the central facility is a radar wind profiler and RASS. Procurement processes are currently taking place to obtain two systems, a 915-MHz boundary layer profiler-RASS and a 50-MHz profiler-RASS. Installation in 1992 is anticipated. This action was planned at a time when 405-MHz systems did not seem available; use of 448-MHz systems might be feasible in the future. The Wave Propagation Laboratory has shown that the 405-MHz (or 448-MHz) system has several advantages, particularly with regard to continuous sensing of temperature between heights of 0.5 and 2.0 km. In any case, it is possible that only a single set of 915-MHz and 50-MHz systems will be obtained for the first CART site and that the NOAA wind profiler network will serve the needs of boundary facilities. The set of profiler-RASS systems currently being obtained for the central facility would be highly complementary to a NOAA 405-MHz system facility that will be located within 15 km of the central facility. Such an arrangement suggests that a powerful capability for profiling of winds and temperature in the general area of the central facility might be available.

Balloon-Borne Sounding System

Adequately observing vertical profiles of water vapor content at the central facility presents greater challenges than does observing wind and temperature profiles. The current

strategy relies on initially observing moisture profiles with balloon-borne instruments and later deploying a Raman lidar being designed and tested by an Instrument Development Program (IDP) project. Infrared spectrometers cannot be used for moisture profiles at the central facility because these same instruments will be used to generate measurements of radiative transfer for developing and testing models of radiative transfer that require data on water vapor profiles. That is, measurements of moisture profiles that are independent of the radiometric observations are required. The procurement process for balloon-borne sounding systems has begun, with the goal of having a system operational at the central facility in 1992. Ideally, deployment at four boundary facilities would be possible then also.

Microwave Radiometer

Microwave radiometry will provide observations useful for several purposes in early operations of the Southern Great Plains (SGP) CART site, provided the current procurement actions are successful in obtaining suitable units. The type of microwave radiometer being obtained can continuously observe integrated columnar amounts of water vapor and liquid. Values sufficiently accurate for several applications can be obtained over averages of one to two minutes. For example, observations at the central facility can be used during intensive radiative transfer experiments to identify when changes in water vapor profiles have probably occurred, which is useful diagnostic information for modeling studies, and can signal when an additional balloon-borne sounding should be made. In other studies, several of the microwave radiometers, which are quite portable, could be used at varying spatial separations at the CART site to study the relationships between temporal and spatial variability of water vapor and clouds as they affect radiative transfer processes.

Innovative uses of microwave radiometers in concert with other observation systems should be developed for experiments. For some experiments, locating the units at boundary facilities might provide a useful supplement to balloon-borne sounding systems if observations of vertical profiles of water content are particularly valuable.

Central Facility Solar and Infrared Radiometers

A set of conventional broadband infrared (IR) and broadband and filtered radiometers must be operational at the first CART site in 1992. The set for the central facility is being designed by NOAA's Climate Monitoring and Diagnostics Laboratory and will include the sensors planned for Baseline Solar Radiation Network (BSRN) sites. In addition, a commercially available solar spectroradiometer and an ultraviolet spectral radiometer made by SUNY Albany will be incorporated into routine operations at the central facility. Observations with commercial radiometers of upwelling broadband infrared radiation and filtered solar radiation from the 60-m tower are being considered for the Central Facility, partly to provide a modicum of "ground truth" for optical observations from satellites. The various instruments that are commercially available are currently being identified for procurement. Several special radiometric instruments provided by IDP projects will also be incorporated into the central facility.

Extended Facility Solar and Infrared Radiometers

A set of solar and infrared radiometers has been identified for use at extended facilities; procurement has not yet been initiated. These observations are designed to provide coverage of radiative fluxes and surface optical properties at locations throughout the CART site, so that modeling of radiative transfer can be extended from the central facility to the entire CART site. A complete set of extended facility radiometers will also be located at the central facility. The Climate Monitoring and Diagnostics Laboratory leads this planning effort as well as the planning for conventional radiometric observations at the central facility.

The extended facility instrumentation includes two pyranometers and two pyrgeometers, to allow broadband observations of downwelling and upwelling solar and infrared radiation. The upwelling flux measurements will

be made from near the top of a 10-m tower used for local meteorological observations. Arrangements have been made to have one multispectral rotating shadowband radiometer at each extended facility. A radiometric surface temperature in the infrared window might be observed separately from pyrgeometer observations of upwelling infrared radiation, particularly if the radiometric temperature is a highly influential parameter in surface energy exchange modeling.

Radiometric Calibration Facilities

Calibration facilities and procedures for radiometers of various types at the SGP CART site are currently being planned by the National Renewable Energy Laboratory. In keeping with BSRN practice, two absolute (active cavity) radiometers will be maintained, one for continuous operation and one for a "shelf" reference. Comparisons of conventional radiometers with these and other reference instruments will be conducted routinely at the CART site on an outdoor platform. An indoor facility will be used for routine evaluation of instrument response. These facilities ideally should be in place, either at the central facility or somewhere fairly centrally located in the CART site, at the beginning of CART operations. Some highly detailed calibrations, such as thorough evaluation of the cosine response of some sensors, will be done mostly offsite.

Whole-Sky Imaging System

Many discussions have been held on finding a suitable whole-sky imaging system. Such systems do not appear to be available "off the shelf" commercially. Because of the fairly urgent need to carry out cloud mapping at the central and auxiliary facilities with whole-sky imaging systems, options such as a special competitive action or directed development are being considered. At least one system should be installed early at the central facility to record local cloud conditions.

Ceilometer

Ceilometers are needed for routine observation of cloud base height. Used in conjunction with one whole-sky imaging system, a ceilometer would provide information essential for some long-term experiments involving radiative transfer in cloudy conditions. Such observations would provide a starting point for such studies at the SGP CART site. More sophisticated systems, such as scanning lidars and cloud radars produced by IDP projects or from their spinoffs, will be needed for detailed modeling of radiative transfer in cloudy conditions. Currently, however, commercially available ceilometers do not appear to be capable of routinely reaching high clouds such as cirrus. A new IDP project will be addressing this need.

IDP Projects

The role of IDP projects in producing needed instruments has been noted several times in this summary, particularly IR interferometers, Raman lidar, and sophisticated lidar and radar systems. Considering the length of time before some of these instruments can be operated routinely at the SGP CART site, creative use of the available CART instruments as interim means of observation is required.

60-m Tower

A standard meteorological 60-m tower will be obtained for the central facility. These tower systems are commercially available and come equipped with an elevator with platforms that can be set at heights of 10 m and 60 m. At the CART site, radiative, heat, and moisture transfer will be observed at two levels, at 60 m and 25 m. The latter height is preferable to 10 m because observations at greater heights provide a larger "footprint" and more effectively supplement observations at lower levels at the central facility. As already noted, observations of surface optical properties provide the opportunity for ground truthing of satellite data and eddy flux observations, which are described in the next entry.

Water Vapor and Heat Flux Observations on 60-m Tower

Eddy correlation observations of water vapor, heat, and moisture fluxes will be taken at two levels on the 60-m tower. Such observations are valuable in determining the surface boundary conditions important in single-column modeling and in supporting small-scale modeling. The upper level is particularly useful as a reference point and as a basis of comparing flux observations from aircraft that are attempting to get an areal average of the fluxes over

the CART site. Flux observations at two levels provide a means of evaluating the variability of the air-surface exchange rates in the area. The instrumentation for these flux observations is currently being identified.

Surface Flux Stations

Several energy balance Bowen ratio stations are currently being procured. These stations observe air-surface exchange rates of moisture and heat and several other quantities that must be known as boundary conditions for single-column and related models over the entire CART site. The stations will be deployed at extended facilities and the central facility, where they will provide a third point of flux profiles when data from the 60-m tower are included. Routine eddy correlation observations at extended facilities are being considered because of the considerable difficulty of maintaining the energy balance Bowen ratio stations at locations where the surface must be frequently disturbed, such as in fields subjected to intensive agricultural management.

Surface Flux Benchmarking Facility

A moveable surface flux station is needed to evaluate the performance of flux stations at the extended facilities. Use of a moveable station using eddy correlation gear is more practical than moving energy balance Bowen ratio stations. The configuration of the benchmarking facility will be designed in late 1991.

Surface Meteorological Observation Stations

These stations are used to observe wind speed and direction at a height of 10 m, temperature and humidity typically at 2 m, as well as precipitation and barometric pressure. They serve as the primary sources of such data for single-column and related models. A mixture of different types of these stations will be used at the SGP CART site. Access to data from, and possibly augmentation of, the Oklahoma Mesonet currently being designed should provide most of the needs for the State of Oklahoma. For both Kansas and Oklahoma, arrangements have been initiated to have long-term use of approximately twelve PAM-II systems supplied by the National Center for Atmospheric Research.

Gas and Particle Observations

Ozone concentrations will be ovserved in situ at a height of several meters at the central facility. We have requested that a Raman lidar being developed by an IDP project observe tropospheric ozone profiles in addition to water vapor. We are considering other methods of routinely measuring ozone profiles, which is particularly desirable at night, when the vertical gradients of ozone can be large in the lower atmosphere. For estimates of other greenhouse gases, no local observations have been planned.

Observations of the concentrations and optical properties of aerosols near the surface at the central facility will consist of some in situ sensing at a height near 10 m, which should be sufficiently high to avoid much of the effects of local particle resuspension. An integrating nephelometer will observe bscat; particle size distributions will be observed with a combination of optical and other types of sensors; chemical composition will be observed occasionally in at least two size ranges to determine if the aerosol air mass type has been identified properly; and some simple measure of chemical composition as it affects optical absorption will be made. All these observations together should allow estimates of the radiative properties of the aerosol important in modeling radiative transfer. Plans are currently being made to specify the needed instruments so that procurement can begin.

The ceilometer mentioned earlier will also provide some mapping of the distribution of aerosol particles in the atmospheric boundary layer. Observations of solar radiation with optically filtered instruments that will be used routinely throughout the CART site at the surface can also provide some measure of the scattering and absorption by aerosol when investigated in conjunction with appropriate numerical models.