What are ARM and ARM/CART?

Overview

The U.S. Department of Energy's Atmospheric Radiation Measurement (ARM) Program is a long-term, worldwide research effort designed to assess the role that clouds play in Earth's radiative energy balance. In addition, ARM seeks to improve the measurement of radiation within the earth-atmosphere system.

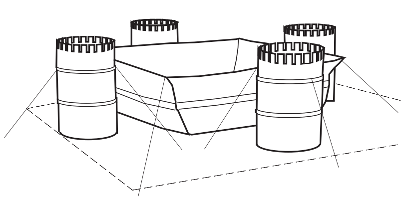
ARM implements its measurement goal by establishing and maintaining field sites in various climate regions of the world. Each of these heavily instrumented sites is an ARM Cloud and Radiation Testbed (CART). The first ARM/CART site to be installed is located in a portion of the Southern Great Plains of the United States (Master #1D).

Why is ARM/CART in the Southern Plains?

The ARM Program was designed to conduct research in the global climate. Thus, specific climate regimes were selected as representative of much of Earth's environment. These regimes are:

- mid-latitude continental (e.g., U.S. Southern Great Plains)
- high-latitude continental (e.g., North Slopes of Alaska)
- low-latitude oceanic (e.g., Tropical Western Pacific)

Considerations that affected the choice of the Kansas/Oklahoma area included (1) the wide range of atmospheric conditions that occurs across this region over short periods of time, (2) the existence of the Oklahoma Mesonet in most of this region and (3) the substantial coverage of Doppler radar and wind profilers by the National Oceanic and Atmospheric Administration. ARM administrators found that the coupling of ARM's efforts with those of other agencies was the most efficient use of resources.



The Southern Great Plains CART site covers hundreds of thousands of square kilometers. The size of this region allows scientists to correlate measurements with the output of global climate computer models, as the area represents the standard size of a "grid box."

The focus of activity within the Southern Great Plains ARM/CART is the Central Facility. Located on the rural landscape near Lamont, Oklahoma, the Central Facility consists of many advanced instruments and the infrastructure necessary to keep the instruments operational (Master #1E).

In addition to the Central Facility, the Southern Great Plains ARM/CART contains many other instrumented sites, called Boundary, Intermediate and Extended facilities. The program is able to use data from various other sources, including the NEXRAD radar network and the Oklahoma Mesonet, to supplement its own observations.

The ARM/CART region is in an *ecotone*– a zone of distinct change over distance. The change primarily is evident in the east-west direction. To the ARM program, this location is of great value because it allows for the measurement of a wide variety of land and atmospheric conditions.

Overall, the Southern Great Plains ARM/CART is one of the best outdoor laboratories in the world.

Fun Fact

The normal yearly temperature at the Central Facility is 15° Celsius (59° Fahrenheit) and the mean precipitation is 823 millimeters (32.4 inches).

Geography of the SGP ARM/CART Region

Located on a region about 350 kilometers from east to west and 400 kilometers from north to south, the Southern Great Plains (SGP) ARM/CART spans a significant portion of Oklahoma and southern Kansas. On the western border of the region, elevations are roughly 450 meters above sea level. The land slopes downward to the east, with the eastern border of ARM/CART rising to only about 300 meters above sea level. Gently sloping hills, streams and rivers dominate the landscape of the region.

The SGP ARM/CART is within an east-west climatic transition zone, with a semi-arid climate typical of the western U.S. to the west and a more precipitation-rich climate typical of the eastern U.S. to the east. In addition, significant differences on both daily and yearly times scales are *normal* in this area.

The influence of the climate change across this ARM/CART is evident in its vegetation. To the west are short grasses, typical of the original short-grass prairie of the western Great Plains. Moving eastward, the native grasses become taller or mixed, changing to a region that once was tall-grass prairie. Most of these native grasses have been replaced by farm or range land. On the far eastern side of ARM/CART, trees become more common and soon become prominent.

Fun Fact

The Southern Great Plains ARM/CART site contains the world's largest collection of advanced remote sensing instruments.

Why Measure Clouds and Radiation?

The primary goal of ARM is to obtain a decade-long database of measurements related to radiation. These measurements will be used by scientists for years to come as they conduct climate research.

The importance of these measurements cannot be overstated. Life exists on the earth because of radiation and atmospheric effects on radiation. Without radiation from the sun, Earth would be a ball of ice. Without the atmosphere's "greenhouse effect," the sun's rays would not keep Earth warm enough for life.

In recent years, radiation has received more public attention, as nuclear power plants now provide energy to our society, microwave ovens are commonplace, skin cancer is on the rise and questions about the ozone hole and global warming spark heated debates. However, even the scientific community cannot agree on how humans impact their environment nor how the environment affects itself.

One of the greatest questions left unanswered is "how do clouds affect the earth's climate"? Clouds influence radiation in a number of ways. First, they absorb radiation from both the sun and the earth. Second, they reflect a portion of incoming radiation, especially solar radiation (radiation from the sun). Third, the molecules within clouds can scatter solar radiation, causing the radiation to change direction to *any* direction. Finally, clouds emit their own radiation, adding to that emitted by the atmosphere, sun and Earth.

These interactions alone are complicated and poorly measured, but it is also true that different *types* of clouds interact with radiation in different ways. For example, cumulonimbus clouds reflect significantly more solar radiation than do cirrus clouds. However, they also produce (emit) more radiation than cirrus clouds. Thus, if the earth warms as a result of "global warming" and the seas evaporate more water, will more thunderstorms (cumulonimbus clouds) be produced? And will this lead to less solar radiation entering the earth's atmosphere? If so, perhaps the atmosphere will cool to its original temperature.

Knowledge of the interactions, or feedbacks, between the earth-atmosphere system is crucial if scientists are ever to obtain accurate predictions of climate change.

The Central Facility

A few miles southeast of Lamont, Oklahoma, on a site which was originally a prairie of mixed grasses, resides the ARM/CART Southern Great Plains Central Facility. The site contains equipment designed to make sophisticated measurements of clouds and radiation.

The Central Facility is one of the best-equipped outdoor laboratories in the world. It occupies a quarter-section (65 hectares) of land. The terrain rises to a broad hilltop with a crest approximately 320 meters (1040 feet) above sea level. On this hilltop sits a cluster of radiation-measuring equipment.

The site is wired with underground fiber optic cable, allowing for data to be sent to the various buildings nearby where ARM staff analyze the data. Shortly after the measurements are taken, the data are shipped electronically to ARM scientists around the world.

The backbone of the network is represented by the continuous observations made by the instrumentation permanently installed at the ARM sites. These observations create the climatic record needed to perform the research necessary to attain ARM's goals.

Another key part of the program is represented by three or four three-week periods throughout a calendar year called "Intensive Observation Periods," or IOPs. The IOPs are crucial for evaluating specific scientific hypotheses or for testing new sensors. Scientists from around the world are allowed to bring their own instruments to the Central Facility during these periods to aid in comparative analyses. The IOPs have allowed the U. S. Department of Energy (DOE) to develop strong collaborations with other groups, such as the National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), the U.S. Department of Agriculture (USDA) and the Oklahoma Mesonet.

The Central Facility is perfect for testing new instruments. Instruments brought in for testing are hooked up to an Instrument Development Pad which includes connections for power and communication.

Fun Fact

The Southern Great Plains ARM/CART site collects 146 gigabytes of routine weather data each year. During intensive observation periods, the site may collect more than one gigabyte of data each day!

Fun Fact

Data-gathering balloons released from the Lamont Central Facility routinely float 50 miles from the site. Many have been found over 100 miles away and one was found in northeastern Nebraska, about 400 miles away!

The Central Facility's permanent instruments include the following:

- **Balloon-Borne Sounding System (BBSS)**—A large, helium balloon carries a lightweight package of instruments into the atmosphere three times each day. The sensors measure temperature, relative humidity, pressure, wind speed and wind direction. Data are radioed back from the balloon-borne package to the ground site.

- **60-Meter Tower**—The tower is located in a wheat field and holds devices to measure temperature, relative humidity, wind (blowing either horizontally or vertically), solar radiation reflected off the ground and terrestrial radiation emitted from the ground.

- **Wind Profilers and Acoustic Sounders**—The two wind profilers are upward-directed Doppler radars that measure the speed and direction of winds at various altitudes. Unlike standard Doppler radars, they use frequencies of radiation (915 Megahertz for one and 50 Megahertz for the other) that do not require clouds to be present. The acoustic sounding system enhances the profilers by providing the ability to measure temperature at various altitudes.

- **Energy-Balance Bowen Ratio (EBBR)**—The EBBR takes several vital measurements to estimate energy and moisture exchanges, or fluxes, between the ground and the atmosphere directly above it. These measurements include moisture, latent heat and sensible heat fluxes and whether they are transported upward from the ground or downward to the ground. Measurements of the soil moisture and soil temperature are made nearby the EBBR. All of these measurements are used to compute the "Bowen ratio," an important quantity for modeling the atmosphere.

- **Pyrheliometer**—The pyrheliometer measures the amount of solar radiation from the sun that follows a path directly from the sun to the instrument without being absorbed, scattered or reflected. It tracks with the sun during the day such that it always points directly at the sun and looks only at the solar disk.

- **Pyranometer**—The pyranometer measures the total amount of solar radiation (whole sky) near the surface, including that which has been scattered or reflected by the atmosphere.

- **Multi-Frequency Rotating Shadow Band Radiometer**—As implied by the name, this instrument can block direct rays from the sun (hence, a shadow is produced where the sun would be directly measured). When the shadow arm rotates off of the sun's disk, this radiometer measures the sun's direct radiation in six specific wavelength channels of the visible spectrum.

World Wide Web addresses:

Arm Home Page
http://www.arm.gov/

ARM Southern Great Plains Outreach Home Page
http://outreach.ocs.ou.edu/arm/

- **Laser Ceilometer**—The ceilometer measures the altitudes of the bottoms of any clouds overhead by sending a laser beam upward and waiting for a return of energy. The amount and timing of the returned energy determines whether clouds are above the instrument. The ceilometer can sense up to three levels of clouds.

- **Surface Meteorological Observation Station**—The automated station measures air temperature, wind speed and direction, relative humidity, barometric pressure, rainfall and snow depth.

- **Microwave Radiometer**—This radiometer passively measures water vapor and liquid water in the air using two specific bands of the microwave spectrum.

- **Whole Sky Imager**—The imager uses a solar tracker to block the sun so that it can take images of the sky to map cloud coverage and type.

- **Raman Lidar**—This instrument sends laser beams into the sky to continuously observe the amount of water vapor in the lower atmosphere.

ARM Scientists and Engineers

Scientists and engineers from all over the world have served the ARM Program during its planning, implementation, maintenance and research phases. Many of these people work at several of the U.S. Department of Energy's laboratories, including Argonne, Pacific Northwest, Sandia, Livermore, Brookhaven and Los Alamos.

Acknowledgments

These materials have been prepared by scientists at the Oklahoma Climatological Survey and Oklahoma State University.

Each instrument has its own "instrument mentor" who is responsible for analyzing the data gathered by the instrument to verify their quality. These mentors are scientists from universities or agencies across the world. They work with the Site Operations Team and the Site Scientist Team, located at the ARM Central and Extended Facilities and the University of Oklahoma, respectively.

The Site Operations Team includes the Site Manager, Site Safety Officer and a host of technicians and engineers who oversee the operations of the instruments, computers and telecommunications at the Central Facility and Boundary, Intermediate, and Extended Facilities in Oklahoma and Kansas. Some of the surface observing sites in Oklahoma are part of the Oklahoma Mesonet and are maintained by the Oklahoma Climatological Survey.

The Site Scientist Team is located at the Cooperative Institute for Mesoscale Meteorological Studies at the University of Oklahoma. This group conducts data quality and assurance procedures, interfaces with instrument mentors and other scientists and promotes the scientific and educational use of the data. The Site Scientist Team tries to ensure that the ARM sites are operated to maximize their scientific potential.

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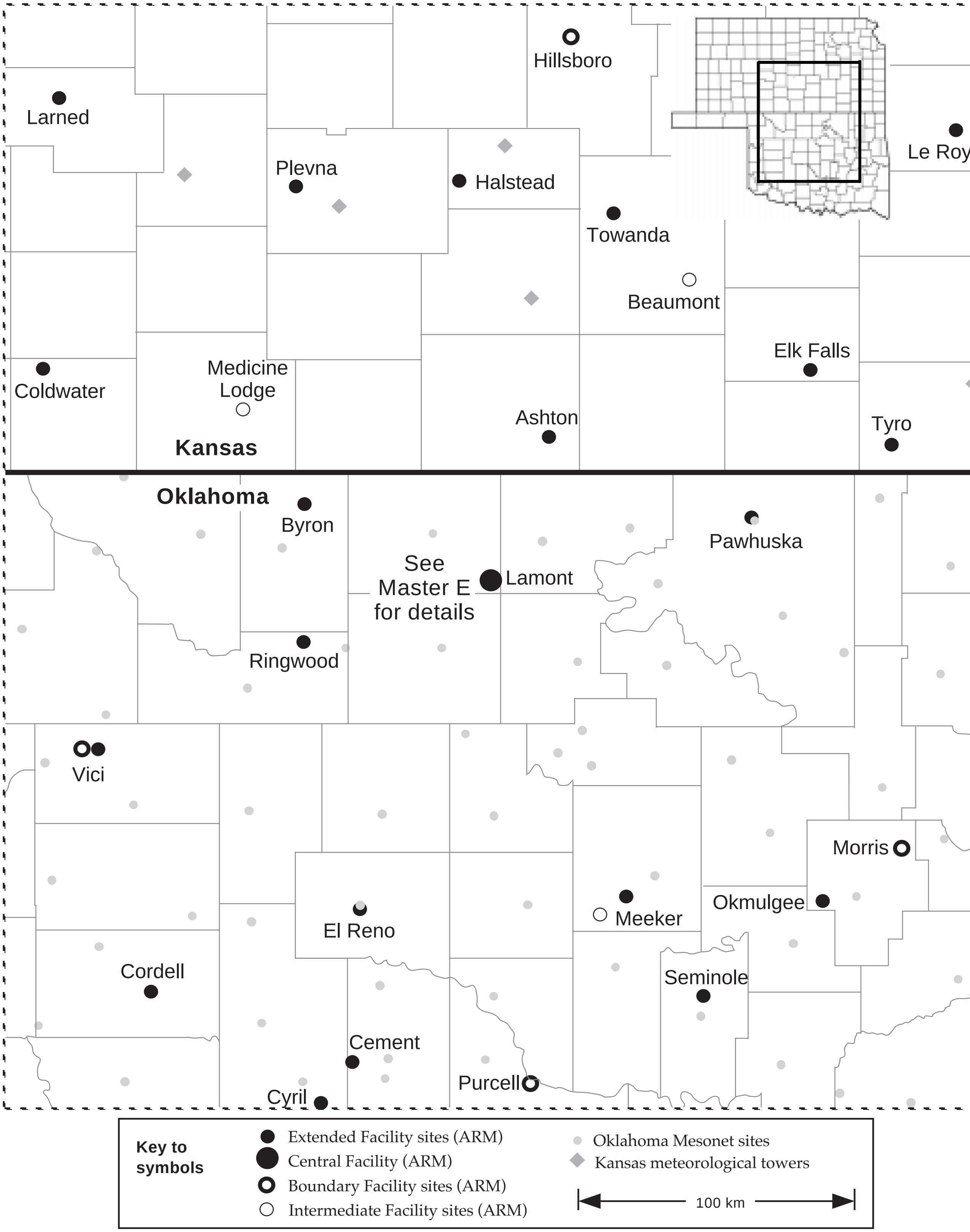
Map of the ARM Study Area

350 km x 400 km



Map of the ARM Central Facility