ARM Fall 1997 Integrated IOP - A Look Back

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Introduction

The Atmospheric Radiation Measurement (ARM) Program's largest intensive observation period (IOP) to date was conducted from September 15 to October 5, 1997, at and near the Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) Central Facility. The Integrated IOP consisted of six separate but interrelated experimental efforts, including water vapor, clouds, aerosols, shortwave radiation, the Unmanned Aerospace Vehicle (UAV), and Single-Column Model (SCM). This paper briefly describes IOP operations and the scientific issues investigated.

Operations

The IOP was conducted from three bases of operation. The SGP 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 was the base for operations of the Battelle Gulfstream-1, University of North Dakota Citation, University of Wyoming King Air, and the UAV Twin Otter aircraft. The Ponca City Airport was the location of the IOP's weather briefing operations. At the Central Facility, around 40 guest instruments were positioned to participate in the various IOPs, and on some days, as many as 75 scientists and engineers were on hand. UAV operations saw attendance of 40 to 50 people during some pre-flight and coordination meetings. Weather briefings at the Ponca City Airport were sometimes attended by as many as 15 to 20 participants.

Coordination meetings, including the weather briefings, were held each day of the IOP at 7:00 a.m. and 1:00 p.m. central standard time (CST). The 7:00 a.m. meetings were held at the Ponca City Airport, while most of the 1:00 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 2:00 p.m., while the Shortwave IOP held meetings most days at the same location at 4:00 p.m. or 5:00 p.m. The Cloud IOP held a large coordination meeting at the Ponca City Airport at the beginning of the IOP 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 scientific coordinator of the integrated effort, 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 Brookhaven National Laboratory (Aerosol), Bob Ellingson of the University of Maryland (UAV), Warren Wiscombe of the National Aeronautics and Space Administration (NASA)/Goddard Space Flight Center (GSFC), 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 logistical coordination during the IOP and prepared daily web updates. Pete Daum also coordinated non-UAV aircraft activity for the IOP and coordinated those flight plans with those of the UAV operations. Jim Teske, the SGP Site Operations Manager, coordinated ground logistics. Site Data System 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. Ted Cress coordinated flight information before the IOP with Vance Air Force Base and the Federal Aviation Administration (FAA).

Detailed information about IOP operations can be found at *http://www.arm.gov/docs/iops/1997/sep_integrated/index.html*.

Water Vapor IOP

The Water Vapor IOP was conducted as a follow-up to a previous 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 6:00 p.m. CST until at least midnight, with aircraft support normally from about 9:00 p.m. CST 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 there but also on atmospheric layers up to 12 km. A key goal of each Water Vapor IOP was to reduce the uncertainties in water vapor observations integral to ARM spectroscopic analyses that contribute to better radiative transfer calculations for climate models. Each saw an assemblage of a wide array of both remote and in situ sampling platforms for observing water vapor profiles and precipitable water to ultimately 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 during 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 balloon-borne sounding system (BBSS), and 4) evaluation of methodologies for synthesizing more accurate measurements.

Guest ground-based instrumentation included the NASA/GSFC scanning Raman lidar, National Oceanic and Atmospheric Administration (NOAA)/Cooperative Institute for Research in Environmental Sciences (CIRES) microwave and infrared radiometers, Los Alamos National Laboratory (LANL) tethered balloon system with chilled-mirror hygrometers, NOAA tethered kite and balloon system with chilled-mirror hygrometers, ARM chilled-mirror hygrometers at the 25-m and 60-m levels on the 60-m tower and at the Temperature, Humidity, Winds and Pressure System (THWAPS) (adjacent to BBSS launch station), NOAA Global Positioning System (GPS), capable of inferring integrated precipitable water vapor, University of Wisconsin atmospheric emitted radiance interferometer (AERI)-00 and AERIbago, and NASA/Ames Research Center 6-channel tracking sunphotometer and two MICROTOPS hand-held sunphotometers. Critical ARM instrumentation for this IOP included the BBSS with dual sonde capability, Raman lidar, microwave radiometer (MWR), 60-m tower sensors, AERI, surface meteorological observing station (SMOS), multifilter rotating shadowband and radiometer (MFRSR), and micropulse lidar (MPL).

All five IOP aircraft platforms were important for the Water Vapor 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 had benefit for the Water Vapor IOP. In addition, the U.S. Department of Energy (DOE) 7-channel microwave radiometer (DoER) and the 5-channel millimeter-wave imaging radiometer (MIR) were flown on the Twin Otter to support MWR comparisons.

The Citation and King Air flew special nighttime missions in direct support of the Water Vapor IOP. These flights, carrying highly precise hygrometers, were coordinated especially with operations of the two Raman lidars, tethered systems, and dual package BBSS launches. In all, the Citation performed five such nighttime missions (September 17, 25, and 30, and October 1 and 3), while the King Air participated in two (September 27 and 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-1 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 between sensors on those two aircraft.

A substantial 2:00 p.m. CST 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 instrument(s) were/were not performing as anticipated. Data was analyzed by the IOP's scientific focus groups throughout the remainder of 1997 and early 1998 in anticipation of water vapor meetings at both the Instantaneous Radiative Flux (IRF) Workshop in January 1998 and the ARM Science Team Meeting in March 1998. Decisions will then be made as to when and how to conduct a third Water Vapor IOP.

More details about the science and operations of the second Water Vapor IOP can be found at *http://www.res.sgp.arm.gov/iop/fall97/wvap/*.

Cloud IOP

The primary objective of the Cloud IOP was to generate a multiplatform data set that can be used as validation for cloud property retrieval algorithms that are being implemented on the operational millimeter wave cloud radar (MMCR) data stream. Within this primary objective, secondary objectives included 1) quantifying the uncertainty associated with the various algorithms, 2) providing absolute calibration and intercalibration for the millimeter radars used in cloud research (including the CART MMCR), and 3) providing 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.

The MMCR was operated in a number of new operational modes, including the collection of Doppler spectra, with no identifiable negative impact on general MMCR data quality. A 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.

It was desired to sample a full spectrum of cloud types and meteorological conditions both in situ and with surface instruments. Cloud types of interest included 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 and 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-1 also performed cloud-related missions in several stratocumulus events. 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.

Given the diversity of cloud types sampled during the IOP, the analysis of this data set will continue for some time. Web pages are being developed that summarize each aircraft flight having a significant data collection period. An example web site can be found at *http://www.res.sgp.arm.gov/iop/fall97/clouds/flight1/flight1.htm*

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 because several of the cases were unique and very well sampled by the surface and ground-based instruments. The Cloud Working Group intends to maintain a close collaboration with the Shortwave Radiation IOP group because 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, it is 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 particular IOP succeeded largely due to anomalously abundant moisture in the eastern Pacific.

Guest ground-based instrumentation included the University of Utah 95 GHz Doppler radar system polarization diversity lidar and time lapse video, The Pennsylvania State University MMCR, lidar, sunphotometer, and narrow field of view (NFOV) infrared radiometer, University of Massachusetts dual 35/95-GHz scanning cloud radar, University of Utah polarization diversity lidar, Colorado State University beam filter infrared radiometer, and NCAR balloon-borne Formvar ice particle replicator. Critical ARM instrumentation included the MMCR, MPL, Belfort laser ceilometer (BLC), Vaisala ceilometer (VCEIL), AERI, MWR, and 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, supercooled 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 DoER and the 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 GHz to 325 GHz.

Citation flights, mainly into cirrus and higher mid-level clouds, occurred during the day on September 16, 17, 19, and 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, and 24, and also during parts of its Water Vapor IOP night-time missions. The Gulfstream-1 flew cloudy air missions from 500 ft. to 17,000 ft. above ground level (AGL) on September 21, 24, and 25. One National Center for Atmospheric Research (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 because 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.

Aerosol IOP

The Aerosol IOP was highlighted by the Gulfstream-1 aircraft flying clear-sky aerosol missions over the Central Facility to study the effect of aerosol loading on clear-sky radiation fields. Weather was 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-1 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-1 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 [aerosol observing system (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, cloud condensation nuclei (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-1 payload for aerosols included instruments for measuring aerosol number concentrations and size distributions, aerosol light scattering coefficient at three wavelengths, aerosol backscatter, aerosol absorption, condensation nuclei (CN) concentrations and the CCN activation spectra.

Clear-sky Gulfstream-1 flights were conducted on September 15, 18, 21, 25, and 27 (in support of LANDSAT), 28 and 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 the AOS, Raman lidar, MPL, rotating shadowband radiometer (RSS), MFRSR, and a guest Cimel sunphotometer. The AOS data provided the local microphysical environment at the surface, while the MFRSR, rotating shadowband spectroradiometer (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-1 aircraft.

Information about ARM's Aerosol IOP series can be found at *http://www.archive.arm.gov/research/aerosols/Spring97 aerosoliop.html*

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 Radiometer Calibration Facility (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 the ARM Enhanced Shortwave Experiment (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 into 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 a.m to 11:30 a.m. CST, 1:20 p.m. to 1:30 p.m. (solar noon), and 3:20 p.m. to 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 Pacific Northwest National Laboratory (PNNL) made SBDART model output available on a daily basis to the IOP for comparison with observations.

Guest ground-based instrumentation included the NASA/Ames solar spectral flux radiometer (SSFR), Colorado State University scanning spectral polarimeter and visible Michelson interferometer, South Dakota State PGAMS (Portable Ground-based Atmospheric Monitoring System), NOAA hemispheric sky imager, two MICROTOPS ozonometers, University of Denver Absolute Solar Transmission Interferometer (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 photosynthetically active radiation (PAR) sensors, NOAA absolute cavity radiometer, pyranometers, and pyrgeometers, Analytical Spectral Devices, Inc. (ASD) shortwave spectrometer, and an O2 A-band spectrometer.

Critical ARM instruments included the suite of instruments on the RCF, Ground Radiation Measurement System (GRAMS), RSS, MFRSR, Solar Infrared Radiation Stations (SIRS) and SIRS testbed, Cimel sunphotometer, Raman lidar, MWR, MMCR, MPL, time lapse video camera (TLVC), whole sky imager (WSI), and 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. Also, the aerosol measurements described above, made by the Gulfstream-1, are of vital importance. Other notable critical aircraft measurements made in support of this IOP included the Regional Atmospheric Modeling System (RAMS) (Altus and Twin Otter), scanning spectral polarimeter (Twin Otter), Scanning spectral polarimeter (Altus), Cloud detection lidar (Altus), and MPIR (multispectral pushbroom imaging radiometer - Altus).

Some discussions have 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 multilayer 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 Pennsylvania 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.

UAV IOP

The UAV Program 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.

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 ft to 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 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 km to 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, and 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 (bidirectional 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 achieved 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. However, time did not allow for any flights in support of this experiment. A similar fate befell Experiment Group IV, "Diurnal Radiation Budget Quantities." It 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 during the October 3 to 5 window, but unusually windy conditions prevented this from happening.

Formal UAV scientific missions occurred on the following nine days:

- September 17: Altus/Otter clear-sky mission (Altus was forced down early, but the Otter continued with microwave radiometer calibrations)

- September 21: Otter surface albedo flights with diffuse illumination to support satellite interpretation

- September 24: Otter cloverleaf pattern 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 in 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°, and 50°) and three altitudes (500 ft., 3,000 ft., and 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 performed clear-sky radiation measurements at 35,000 ft., with the Otter profiling radiative flux from 500 ft. to 10,000 ft. above the Central Facility. The Gulfstream performed complementary aerosol profiling in conjunction with the Otter.

More information about operations during the UAV IOP can be found at *http://optical.atmos.colostate.edu/uavf97/uavf97.html*

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% of the potential 825 soundings flown (165 3-hour launch opportunities at five sites) during the IOP. Of the successful launches, 799 soundings (or 96.8%) 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 NCAR Formvar ice replicator sonde launch on September 26.

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.

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