ARM-UAV: The Next Phase

J. Vitko, Jr. and T. P. Tooman
Sandia National Laboratories
Livermore, California

R. G. Ellingson
University of Maryland
College Park, Maryland

Introduction

The Atmospheric Radiation Measurement-Unmanned Aerospace Vehicle (ARM-UAV) Program was initiated in 1993 to develop a capability to provide radiation and cloud measurements at the top of the troposphere, thereby capping the top of the grid cell above ARM sites. To date, ARM-UAV has developed the necessary payloads and measurement techniques for radiative flux measurements at mid-latitudes. The upcoming Kauai mission completes the original vision by extending these capabilities to cloud measurements and tropical altitudes. Beyond Kauai, with development largely though not completely done, we will begin transitioning to an operational phase to better support ARM's emphasis on sustained measurements, as well as continued support of special campaigns such as the past ARM Enhanced Shortwave Experiment (ARESE).

Kauai '99

Kauai '99 is a joint ARM-UAV and National Aeronautics and Space Administration (NASA) Environmental Research Aircraft and Sensor Technology (ERAST) mission to demonstrate UAV flight in excess of 50 k ft and to provide unique data on the radiative, optical, and microphysical properties of sub-tropical cirrus clouds. Kauai '99 is scheduled for April to May 1999 and involves the stacked flight of a UAV over the cirrus clouds with a Twin Otter below the cirrus clouds. NASA ERAST is providing the UAV, a two-stage, turbo-charged, General Atomics Altus II (see Figure 1). ARM-UAV is providing the Twin Otter, the UAV and Otter payloads, and the scientific mission. The payloads are summarized in Table 1 and consist of identical up- and down-looking broadband flux and spectral radiance measurements on both aircraft, as well as a downward looking lidar on the Otter, and upward looking 95-GHz radar on the Altus. The radar and lidar will provide cloud structure information, and when combined with the passive spectral measurements will enable improved retrievals of cloud microphysical properties, e.g., optical depth, ice water content, ice particle effective size, and number density. Optical properties predicted on the basis of these microphysical and structural properties will be compared to the measured broadband radiative fluxes.

Figure 1. The high altitude Altus-II developed by General Atomics under the NASA ERAST Program.

Table 1. ARM-UAV payloads on-board the unmanned Altus and the manned Twin Otter.

	Altus	Twin Otter
Flux radiometers (Scripps)		
Broadband solar	↑ ↓	↑ ↓
Filtered solar (TDDR)	↑ ↓	↑ ↓
Broadband IR	↑ ↓	↑ ↓
Spectral radiometers/imagers		
SSFRs (NASA Ames)	↑ ↓	↑ ↓
SSP2 (CSU)	↓	↑
MPIR (Sandia)	↓	
Radars/lidars		
Cloud detection lidar (LLNL)	↓	
95 GHz cloud radar (UMass/JPL)		↑

CSU	Colorado State University
IR	infrared
LLNL	Lawrence Livermore National Laboratory
MPIR	Multispectral Pushbroom Imaging Radiometer
SSP	Spectrally Scanning Polarimeter
SSFR	Solar Spectral Flux Radiometer
TDDR	Total, Direct, Diffuse Radiometer
UMass/JPL	University of Massachusetts/Jet Propulsion Laboratory

Note Added in Preparation

The Kauai '99 mission was conducted April 28 to May 18, 1999, and was highly successful. Operationally, we demonstrated sustained operation at 50-k ft or greater, penetration and transit of ice clouds, and operations out of a semi-remote locale. Scientifically, we acquired excellent data on a range of cirrus clouds and performed a calibration intercomparison with the Clouds and Earth's Radiant Energy System experiment (CERES) flux radiometer on-board the Tropical Rainfall Monitoring Mission (TRMM) satellite. Additional information on this mission can be found on the ARM-UAV home page at http://armuav.atmos.colostate.edu/armuav.html.

ARESE Follow-on

The original ARESE conducted in October 1995 has been extensively analyzed, especially the heavy stratocumulus case of October 30. On this latter day, the broadband flux measurements showed strong enhanced absorption (up to 130 W/m^2), while the spectrally resolved measurements did not. Therefore, the focus of the ARESE Follow-on is to address these unresolved issues by 1) significantly increasing the number of heavily overcast days studied, and 2) greatly increasing the shortwave measurement capability on-board the aircraft and on the ground, and where possible, having multiple independent instruments making the same measurements. Based on the original ARESE experience, we will focus on heavy stratus cases—both because the observed effect was the largest and because such clouds minimize the role of three-dimensional (3-D) effects, i.e. photon leakage. Measurements will be made at the Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) site because of the extensive ground-based instrumentation there for characterizing the atmospheric column. The proposed measurement strategy uses a Twin Otter repeatedly overflying the CART central facility (CF) to provide the top-of-the cloud fluxes and combines these with surface-based measurements at the CF to determine both broadband and spectrally resolved vertical flux divergences. The ARESE Follow-on is currently scheduled for February to March 2000 in conjunction with the Cloud Intensive Operational Period (IOP), which will provide extensive radar, lidar, and in situ characterization of the measured cloud fields.

ARM-UAV: the Next Phase

With Kauai '99 marking the culmination of the original ARM-UAV goals—i.e., the development of a UAV capability for 'capping the ARM grid-box' at all latitudes—the next phase will emphasize transition to an operational capability. Key near-, mid-, and long-term elements to actualizing this transition are summarized below.

- Near-term (2000) will focus on increased dependability and simplified operations. The Fall 2000 mission will have as its key goal to fly for 75% of the weather allowable days, including at least three to four consecutive days so as to provide effective support of the Single-Column Modeling IOP that is also scheduled for this time. Simplified flight patterns, an experienced-based spare parts strategy, a ruggedized payload with a 'hot spares,' and a return to engineering flight tests will all contribute to these more robust operations.

- Mid-term (2001/03) will transition this more robust operations into the tropics, including participation in a major campaign. A promising focal point is the planned multi-agency First International Satellite Cloud Climatology Program Regional Experiment (FIRE) IVCRYSTAL mission, including an ARM suggestion to do ‘station keeping’ over a surface ship (an activity for which the UAV is ideally suited). The NASA ERAST desire to develop an over the horizon capability and a more robust unmanned, a transition to on-board recording rather than real-time transmission of the data, and the addition of a cloud radar and ice particle sampler to the UAV payload will all contribute to this evolution.

- Long-term (2004/05) will seek to take advantage of the solar-powered UAVs (Pathfinder, Centurion, Helios) currently being developed by NASA ERAST to create a true “geostationary satellite” above the tropopause. These solar powered aircraft, once developed, should be able to stay on station continuously for 30 days or more. ARM-UAV will develop the more compact and more robust payloads required by the reduced payload capacity (<100 kg) and by the much longer times on station.