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UAV Fall 1996 Flight Series Mission Summary

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UAV Fall 1996 Flight Series Mission Summary

by R. G. Ellingson, UAV Mission Scientist

Demonstration of the capability of the UAV for extended scientific data gathering operations (24+ consecutive hours on station) near the tropopause was the major emphasis of this three-week deployment. The operations were organized to ramp up to extended operations from short duration flights during which scientific data would be gathered to support a variety of scientific objectives. Successful completion of a 26+ hour UAV flight on October 5, 1996 highlighted the completion of a successful deployment.

Flights during the three week campaign were designed to obtain water vapor profiles in support of the ARM water vapor IOP and to obtain data on the interaction of solar and terrestrial energy with clear and cloudy skies for use in testing and developing new mathematical models of this interaction for application to climate studies. The mission activities centered on four classes of scientific experiments, namely :

1. water vapor profiling, during the aircraft made ascents and descents over the SGP CART site simultaneous to other in situ and remote measurements at the site,
2. radiative fluxes, in which aircraft are used to make high accuracy measurements (~1%) of the solar radiative transport throughout the troposphere under a variety of clear sky, cloud aerosol, and water vapor conditions,
3. cloud properties, in which remote sensing techniques are used to develop and validate techniques for obtaining cloud reflectivity, phase (ice or water), effective droplet size, etc., and
4. satellite calibration and validation, where the high altitude aircraft is used to indirectly calibrate sensors on operational satellites as well as to validate retrieval algorithms for such derived quantities as flux divergence, cloud properties and water vapor profiles.

Briefly, the experiments used a combination of satellite, aircraft, and ground platforms to make highly accurate measurements of up and downwelling terrestrial and solar radiance and flux at different altitudes throughout the atmospheric column. The aircraft used were the Twin Otter and the UAV Altus, and, as in the Spring 1996 deployment, they often flew a "coordinated" pattern with the Otter at low levels and the Altus directly above. The instrumentation on the Altus included a multispectral pushbroom radiometer (MPIR), a cloud detection lidar (CDL), a spectrally scanning polarimeter (SSP), a wide field of view (WFOV) camera, a frost-point hygrometer, and up- and down-looking "Valero" radiometers. The Twin Otter instrumentation included a microwave radiometer (MWR), a frost-point hygrometer, and up- and down-looking "Valero" radiometers identical to those on the Altus. On occasions the aircraft operations were carried out simultaneous to radiance measurements from the GOES and NOAA polar orbiting satellites.

Details concerning the instrumentation, scientific objectives, and flight plans associated with each of the classes are described in the ARM-UAV Science and Experiment Plan.

All aircraft operations were performed in the immediate vicinity of the ARM CART site from September 20 through October 5. During that time eight scientific data flights were flown and data were accumulated under a variety of atmospheric conditions ranging from clear to broken cloud conditions. These flights are detailed in Table 1 below and include: cloud forcing experiments under scattered, broken, and solid overcast conditions including low, mid-, and high-level cloud decks; clear sky column absorption and surface albedo measurements; clear sky flux profiling measurements; and in-flight, co-altitude intercomparisons of flux measurements made from the two aircraft. A summary of the individual missions follows Table 1. The data appear to be of excellent quality and comprise a unique data set for testing our understanding of the transfer of solar radiation in both clear and cloudy atmospheres.

The success of this deployment was the result of the tremendous efforts of a multi-laboratory multiagency team comprised of five DOE Laboratories, three NASA Centers, about a dozen universities and three aircraft companies.

Table 1. - Fall 1996 Science Flights Summary		
Date	Platform	Measurement Conditions and Experiments
09-20	Otter	Broken clouds Water vapor profiling for H ₂ O IOP Short and long wave flux profiles
09-21	Altus and Otter	Clear skies Short and long wave flux profiles Vertical distribution of water vapor for H ₂ O IOP
09-24	Otter	Overcast to broken cirrus and scattered mid-level cover Water vapor profiling for H ₂ O IOP
09-27	Otter	Scattered low-level and cirrus clouds Water vapor profiling for H ₂ O IOP
09-29	Altus and Otter	Clear skies GOES 8 narrow band calibration (Experiment 1) Bi-directional reflectance functions (Experiment 10) Banked turns in support the microwave calibration Radiometer intercomparison level legs

		Vertical profile of radiative fluxes (Otter)
09-30	Altus and Otter	Clear skies Coordinated flying for vertical profile of radiative fluxes (2 legs) Radiometer intercomparison level legs
10-03	Altus and Otter	Clear skies to scattered low-level clouds Coordinated flying for vertical profile of radiative fluxes (fixed Altus, variable Otter altitudes) GOES 8 narrow band calibration (Experiment 1) Bi-directional reflectance functions (Experiment 10) Banked turns in support the microwave calibration
10-04	Altus and Otter	Scattered cirrus, middle level and low-level clouds at different times during the 26+ hr flight Coordinated flying for vertical profile of radiative fluxes (fixed Altus, variable Otter altitudes) Diurnal radiation budget (Experiment 11) GOES 8 and NOAA 12 calibrations (Experiment 1) Bi-directional reflectance functions (Experiment 10) Radiometer intercomparison level legs

The remaining portions of the document contain individual Mission Summaries.

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F96-S1-04, Fri Sep 20,1996: Flt.960920.18

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Mission Summary

Today's mission was scheduled to be a set of vertical profiles to obtain temperature and humidity profiles for use in the ARM-H2O IOP. In all, three profiles were obtained - two ascending, one descending with constant level legs. Comparisons with the aircraft data with earlier radiosonde profiles showed similar magnitude and shaped humidity profiles. Nevertheless, there was an apparent moistening of the layers during the mission. The aircraft met package appeared to have operated properly throughout the flight.

During the mission, the sky remained mostly cloudy, although not overcast (i.e., broken clouds). The clouds had variable bases and thicknesses, although the clouds were generally confined to the same layers throughout the flight. It appears as if the radiometers on the aircraft operated correctly throughout the mission.

Overall, the mission appeared to have met its goals.

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F96-S1-05, Sat Sep 21,1996: Flt.960921.15

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Mission Summary

Today's mission was aborted shortly after the Altus reached 24000 ft msl. Despite the early termination of the data taking session, during the time the Altus was in the air, it appeared that there was very good stability during wings-level flight (i.e., the roll was very stable despite 50 kft winds).

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F96-S1-06, Tue Sep 24,1996: Flt.960924.19

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Mission Summary

Today's flight was scheduled to provide water vapor profiles over the CART site in conjunction with the ARM Water Vapor IOP. The Twin Otter ascended to approximately 5000 ft agl in the vicinity of the CART site and performed a stair step profile with 6 km legs at roughly 2000 ft intervals to 1000 ft agl. The Otter then ascended over the same path to about 5000 ft and repeated the descent stair step before returning to Ponca City.

During the flight we compared an Otter ascent dew point profile with one measured by a radiosonde launched at 1230 CDT. The Otter sounding showed a mixed layer to about 870 mb, whereas mixed layer measured by the earlier sonde extended to 910 mb. Despite the difference in time with an obvious deepening of the mixed layer, the comparison showed agreement to within 0.5 C over the lowest 110 mb.

A radiosonde was launched at the CART site during the Otter flight. However, those data were not received at the UAV center by the end of the flight. A comparison will be performed with those data when they are received.

In summary, the Otter apparently provided excellent water vapor data for use in the ARM Water Vapor IOP.

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F96-S1-07, Fri Sep 27,1996: Flt.960927.22

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Mission Summary

Tonight's flight was designed to be a set of stair step profiles over the CART site in support of the ARM water vapor IOP. After the first three legs over the CART site, a broken cloud layer moved over the region. The Otter ascended through the cloud to 10000 ft. This was followed by a descent to 7000 ft, and the aircraft descended in a stair step mode to 2000 ft msl. After an ascent to 4000 ft, the flight plan was changed to a zigzag pattern with constant rates of ascent between the two ends of the flight legs. The aircraft ascended to 16000 ft, and then followed a zigzag pattern back to 2000 ft before returning to base.

Overall, the aircraft obtained very good water vapor data during the flight, and reports from the CART site showed that they obtained excellent lidar data as well.

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F96-S1-09, Fri Sep 29,1996: Flt.960929.15

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Mission Summary

SUBJECT: Post-Flight - R. G. Ellingson
Today's mission completed the following:

One profile of radiative fluxes with the Otter (17, 10, and 2.5 kft),

Two Goes 8 satellite calibration runs by the Altus,
BDRF runs by the Altus at altitude,
Bank turns in support the microwave calibration, and
radiometer intercomparison level legs.

Overall, this was the longest, and highest science mission yet accomplished with a UAV. Overall, the mission must be regarded as highly successful.

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F96-S1-10, Mon Sep 30,1996: Flt.960930.14

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Mission Summary

The primary objective of today's flight was to obtain a set of vertical profiles of the up and downwelling short and longwave fluxes. Unfortunately, transponder problems with the Altus kept us from completing the mission as planned. However, we did complete two coordinated legs at about 17 and 12 kft. Furthermore, we did complete a radiometer intercalibration by flying the usual four intercomparison flight legs (i.e., one into, one away and two abeam of the solar direction).

After the intercomparison legs, John Vitko and I used the wings level data to determine if the fluxes measured into and away from the solar direction were consistent with the changes in the solar zenith angles. We determined that the measured flux differences agreed with what we calculated. This gives us considerably more confidence in the relative accuracy of the Valero shortwave radiometers. Thus, despite the problems encountered on the flight, good data were gathered regarding the accuracy of the radiometers.

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F96-S1-11a, Thu Oct 3,1996: Flt.961003.15

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Mission Summary

Today's flight was scheduled to be a dual aircraft Otter - Altus, clear-sky mission as described in previous flights.

During the ascent to altitude, there were broken clouds that thinned to scattered to clear by the time the aircraft reached 18000 ft. The Otter followed the Altus to 18000 feet, and while the Altus was climbing to 35000 ft, the Otter performed a clear-sky profile to 1500 ft AGL. During this descent, the aircraft flew 5 minute legs at about 17, 10. 5 and 2.5 kft msl. Aerosol layers were noted on

both the ascent and descent. Since there was such extensive cloudiness earlier at the altitudes of the reported haze, it is quite likely that the aerosols were swollen nuclei or very small water droplets.

After reaching 2.5 kft msl, the Otter performed a coordinated ascent with the Altus. That is the Altus and Otter flew the same legs one above the other, with the Otter changing altitudes after flying 5 min legs. After the Otter reached 10 kft, it performed turns for a microwave calibration. Then the Otter returned to Ponca City for refueling.

During the refueling the Altus performed several BDRF turns and a GOES 8 Calibration run. While the Otter was ascending to begin a coordinated ascent, the Altus developed an autopilot problem. This resulted in a curtailment of the science portion of the mission.

The Altus and the Otter both returned safely to base.

In summary, the aircraft obtained excellent radiometric data on ascent over a broken cloud region, and they were able to obtain two clear-sky profiles under moderate haze conditions. Furthermore, the CDL, WFOV and MPIR collected data throughout most of the flight. Despite the shortened nature of the mission, excellent data were obtained under meteorologically important conditions.

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F96-S1-12b, Fri Oct 4,1996: Flt.961004.16
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Mission Summary

The past 26+ hours (24 hours and 46 minutes on station) saw the Altus set a new endurance record for airborne scientific study!!! During the period, the aircraft performed near flawlessly and all personnel associated with the mission retained their professional demeanor throughout this stressful period.

The mission was set to be a 24+ hour endurance flight to test the capability of using a UAV in an extended reconnaissance mode.

After take-off, the Altus and Otter climbed together to 18 kft, after which the Altus climbed to 20 kft. While the Altus was climbing, the Otter descended to about 15 kft, after which the Otter and Altus flew in a coordinated fashion to perform a clear-sky profile with 5 minute legs at 10, 5 and 2.5 kft msl.

Following the profile, the Otter returned to Ponca City while the Altus began to fly its diurnal pattern laps - roughly a square with 20 km sides.

At roughly 1730 local, the Otter began a Altus coordinated clear-sky profile at 2.5 and 5 kft msl. The purpose of this profile was to measure the change of the IR flux profile across sunset.

Following the profile, the Otter returned to Ponca City, and the Altus resumed its diurnal pattern laps throughout the night.

During the early morning daylight hours the Altus performed a NOAA-12 calibration run, centered at 09:05:10 local. That closely followed by a set of BDRF turns at constant bank. These were followed by two GOES calibration runs.

At about 1400, the Otter returned to the area to begin a coordinated clear-sky profile with the Altus. Following the profile, the Otter ascended to 18 kft to join up position with the Altus. During the profile there were scattered low level clouds and occasional cirrus. These data are likely to be of particular use for finite cloud studies, particularly as applies to cloud statistics.

It should be noted that the MPIR, CDL, SSP and the broadband radiometers were operating throughout the flight.

The Otter followed the Altus to 10 kft to perform a radiometer calibration run with legs into away and two abreast of the solar position.

In summary, this was an OUTSTANDING mission. The aircraft, the scientific payload, and the personnel all performed exceptionally well.