The Mobile CLASS (Cross-Chain Loran Atmospheric Sounding System) for Supporting Energy Related Research at the University of Wisconsin

A Report to the

Department of Energy
University Research Instrumentation Program

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by the

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I. Introduction

This report describes the University of Wisconsin (UW) applications of the mobile Cross-chain Loran Atmospheric Sounding System (CLASS). This mobile CLASS system provides an invaluable augmentation to our research capabilities for the measurement of atmospheric state parameters. We are indebted to the University Research Instrumentation program for the support under grant (DE-FG05-91ER79049) which made the procurement of this system possible.

Two major pieces of equipment make up the mobile system which was acquired under this grant to support ongoing DOE research and student instruction at the University of Wisconsin. The first component was an instrument for the in situ measurement of atmospheric temperature and water vapor using helium filled balloons with attached research grade radiosondes. The Cross-chain Loran Atmospheric Sounding System was originally developed by the National Center for Atmospheric Research (NCAR) in Boulder, Colorado. The UW version of the CLASS was obtained through Radian, Inc. under license to NCAR. The other major component of the mobile system was a vehicle for transport of the CLASS along with other research instruments under development at the UW for the DOE. This vehicle was built by Winnebago Industries to UW specifications.

One of the objectives for this instrumentation is to support ongoing DOE research at the University of Wisconsin - Madison. The University of Wisconsin has been an active participant in the Department of Energy Atmospheric Radiation Measurement (ARM) program. The instrumentation acquired under this grant has directly benefited the advancement of the DOE ARM program by enhancing the capability of the UW for making in-situ measurements of the atmosphere in coordination with instruments currently under development for the ARM program.

A second objective for this instrumentation is to improve facilities for student instruction in the atmospheric sciences. The Cooperative Institute for Meteorological Satellite Studies (CIMSS) has used the CLASS system as part of the Space Grant Consortium summer program for visiting High School students and teachers. The UW department of Atmospheric and Oceanic Sciences has a course in atmospheric instrumentation for which the equipment has been used to provide experience with making atmospheric measurements. The instrumentation has also played an important role in the research of a graduate student in pursuit of a Master's of Science degree.

This report is organized into two sections; (1) a research report which describes the status of the equipment, how it has been used to support projects since delivery and the new projects the equipment makes possible, and (2) a financial report summary which describes the dates on which the equipment was received, the cost breakdown for individual instrument components, and the cost for use of the instrumentation to date.

II. Research Report

The mobile CLASS system is fully functional at the UW and is being used routinely in support of DOE (and other) research as well as university student instruction. This section describes some of the activities for which the CLASS system has played an important role.

A. DOE Research

The University of Wisconsin has been involved in Department of Energy research activities since 1989 beginning with the Spectral Radiation Experiment (SPECTRE) program. This program evolved into the DOE Atmospheric Radiation Measurement (ARM) program which began in 1992 and continues today.

1. DOE ARM Program

The unique role of the UW in the DOE ARM program has been in the development of ground based instrumentation for the measurement of the downwelling infrared spectrum of emitted radiance from the atmosphere and clouds and in the analysis and interpretation of these measurements. The measurements have relevance to the understanding of global warming and of the physics of radiative transfer in the presence of water vapor, liquid water, and water ice.

The instrument system developed by the UW for the ARM program is known as the Atmospheric Emitted Radiance Interferometer (AERI). The instrument uses the spectral resolving capability of a Michelson interferometer combined with state of the art blackbody reference sources to measure the downwelling infrared emission spectrum (3-17 μm) with a spectral resolution of 1 cm^{-1} (apodized). The AERI instrument's high reliability (continuous operation day/night) and relatively compact size have made it a good candidate for inclusion in all the ARM ground sites as well as periodic field measurement programs.

In the development of the AERI instrument it has proven useful to have an independent measurement of the atmospheric state (temperature and water vapor vertical profile) coincident with the downwelling radiance at the surface. High vertical resolution information is provided by the weather balloon with its research grade radiosonde package. These in situ measurements of the atmospheric state are now available at the UW through the acquisition of the Cross-chain Loran Atmospheric Sounding System under this grant. In addition, the acquisition of a vehicle for transport and operation of the CLASS and AERI systems has greatly increased the variety and range of the measurements that can be made with these instruments.

2. CLASS System Usage

Since the delivery of the CLASS balloon system in 1993, measurements of the atmospheric state have been made with the system in a variety of field programs, as indicated in Table 1. In each of these experiments, an AERI system has made observations of the atmosphere coincident with the balloon sounding system in order to obtain unique datasets in different geographic areas. In particular, the January 1995 Ocean Temperature Interferometric Survey (OTIS) and GOES-8 calibration experiment featured the CLASS (and AERI) system installed on a research ship during a cruise in the central Gulf of Mexico. In this case, the presence of the CLASS balloon sounding was the only measurement of the atmospheric state within 500 miles of the region of interest and played a critical role in the success of that mission.

Table 1. CLASS system usage.

EXPERIMENT DATE	NAME	LOCATION
August 1993	VOCAR	Pt Mugu, CA
September 1993	CAMEX-I	Wallops Island, VA
January 1995	OTIS / GOES-8 Calibration	RV Pelican, Gulf of Mexico
August 1995	CAMEX-II	Wallops Island, VA

The most recent use of the CLASS system was in coordination with an experiment (CAMEX-II) for the study of atmospheric water vapor and its effect on atmospheric radiation. An example of a measurement from the UW CLASS system is shown in Figure 1.

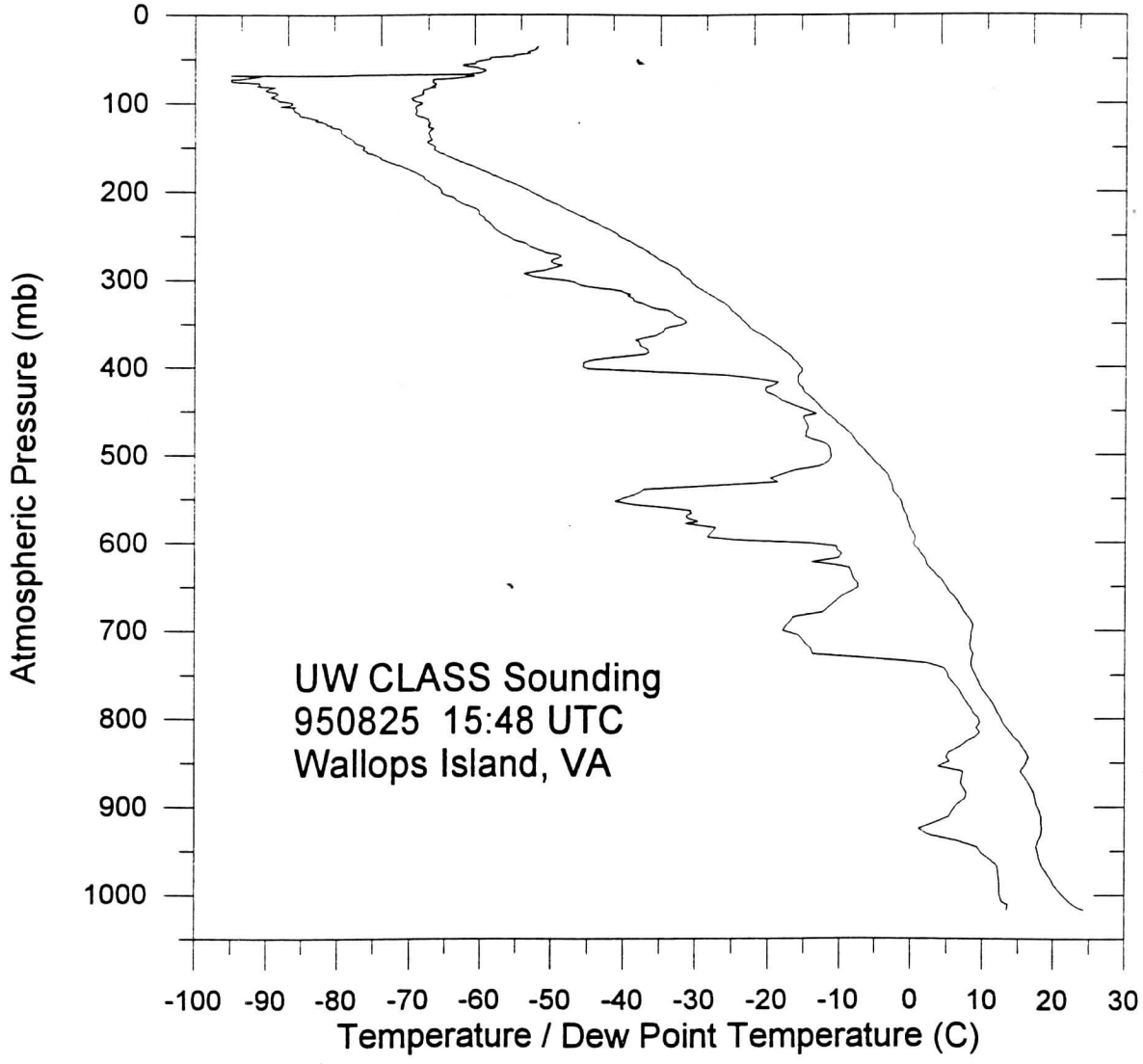

Figure 1 Example from the UW CLASS balloon sounding system obtained October 25, 1995 at Wallops Island, VA during CAMEX-II showing the measurement of atmospheric temperature and water vapor as a function of atmospheric pressure (or altitude).

The CLASS system is normally installed in the rooftop laboratory of the building that contains the Space Science and Engineering Center and the department of Oceanic and Atmospheric Sciences where it is available upon demand for research into atmospheric science and for use in educational activities with student participation. The system is easily transferred as necessary to the mobile research vehicle for transport and operation at field sites anywhere within the continental United States.

3. Vehicle Usage

A vehicle for the transport of the CLASS balloon system was also obtained under this grant. The vehicle acquired was a 30 foot research vehicle built by Winnebago Industries to the specifications provided by the UW. This vehicle has sufficient internal space for the entire CLASS and AERI instrument systems to operate simultaneously along with additional desk-type work areas.

The vehicle was received considerably later than the CLASS system so that our experience with the use of the vehicle begins only in January of this year. Table 2 gives a list of the field programs that the research vehicle has contributed to during this period. Figure 2 is a picture of the research vehicle shown from the starboard side.

Table 2. CLASS vehicle usage.

DATE	NAME	LOCATION
January 1995	OTIS	Cocodrie, LA
April 1995	ARM CART	Ponca City, OK
August 1995	CAMEX-II	Wallops Island, VA
September 1995	WMO Intercomparison	Wallops Island, VA

Figure 2 The research vehicle acquired under this grant is a 30 foot mobile laboratory custom built by Winnebago Industries of Waterloo, Iowa.

4. New Projects

The capabilities of the mobile CLASS system have already been taken advantage of in several projects as indicated in the previous sections. However, there are at least two new project areas that will take advantage of the unique features of the mobile CLASS system in the near future.

A project for the measurement of land surface emissivity (an important but largely unknown quantity in the surface energy budget) will make use of a totally unique feature of the mobile CLASS system. That feature is the ability to lift the AERI instrument (using a hydraulic lift) through a hatch in the roof of the vehicle in order that the AERI can view down to the ground at an angle in addition to its normal vertical sky view. Simultaneously the CLASS balloon sounding system will be able to record the local meteorological conditions as well as a vertical profile of temperature and water vapor. All of these quantities are required for an accurate determination of the land surface emissivity. In addition, the mobile nature of the research vehicle will mean that we can easily move from one measurement site to another, thereby sampling a range of soil and vegetative conditions.

Another project that is in the proposal stage is for use of the mobile CLASS system in studying the meteorological conditions that lead to dangerously high levels of atmospheric ozone in the

atmospheric boundary layer. This project would make use of the rapid deployment capability of the mobile CLASS system to move quickly to regions suffering from poor air quality and make measurements that would lead to improvements in the modeling of air pollution. These measurements would be coincident with stations that routinely monitor ozone levels and would provide data that could be used to understand the vertical dimension of this important problem.

B. University Education

One of the objectives of this project was to contribute to the education of students by providing access to state of the art instrumentation. This objective has been achieved through the acquisition of the mobile CLASS system at the University of Wisconsin. An important synergism exists between the Space Science and Engineering Center (which acquired the CLASS system) and the UW department of Oceanic and Atmospheric Sciences (formerly Meteorology) starting with the fact that they share the same 16 story building on campus. Since the CLASS system, when not installed in the mobile vehicle, is normally available for use from the rooftop laboratory of this building there are many opportunities to demonstrate the measurement capabilities of the system both to students participating in formal classroom activities and to graduate students in pursuit of Masters or Ph.D. degrees.

1. Instruction

A course is taught in the department of Oceanic and Atmospheric Sciences on instrumentation used in the measurement of the atmosphere. The CLASS system acquired under this grant has become a standard part of the course. Demonstrations of a balloon flight and subsequent data processing are given to the classroom participants. The ability to participate in the activities of a balloon launch and to see for themselves the characteristics of the atmosphere as they are transmitted back to the ground in real time provide insight into the measurement process that would be difficult to convey in any other way.

In addition to these undergraduate and graduate courses, each summer the Cooperative Institute for Meteorological Studies (CIMSS) sponsors a workshop for High School students and their teachers as part of the Space Grant Consortium. The CLASS balloon sounding system is used to show to these participants the true characteristics of the atmosphere in real-time demonstrations of its capabilities.

2. Graduate Research

The UW department of Oceanic and Atmospheric Sciences supports an extensive graduate program of research into the nature of the atmosphere. Graduate students conduct research under the direction of faculty and academic staff in a wide range of theoretical and experimental areas. The UW CLASS system is playing an important role in theoretical investigations of the atmosphere by defining the atmospheric state more accurately than was previously possible. The combination of CLASS measurements with other coincident measurements has also been an important component of experimental investigations at the UW
into the infrared and optical characteristics of clouds. Graduate students participate at all levels with the UW CLASS system from the collection of data during field programs to the high level analyses needed to accurately model atmospheric radiative transfer and dynamics.

III. Financial Report

A. Procurement Summary

As originally proposed, the entire Mobile CLASS System including CLASS Hardware, Vehicle, and Radiosondes (plus balloons), was to be purchased (sole source) from the National Center for Atmospheric Research (NCAR), Atmospheric Technology Division, for a total of $157.2K; with the UW providing cost sharing totaling $31.4K. The NCAR system was to be housed in a 15 passenger van. Between the time when the Mobile CLASS System proposal was submitted to DOE and the time UW received the grant funding, NCAR sold to Radian Corporation of Boulder, an exclusive licensing agreement for Radian to produce CLASS systems. At the time of our proposal, the NCAR system was technologically the best system available, and they had experience building mobile systems. In addition, their software was not proprietary, which was important because the UW had plans for modifying and testing various developmental changes in the code.

Radian Corporation could provide essentially the same CLASS hardware that NCAR had developed (and would provide the software code), but was not interested in the mobile aspect of job. It was decided to split the proposed system and procure the CLASS System, vehicle, and Radiosondes separately. After initial contacts with Radian, it became apparent that the CLASS System could be provided for substantially less cost than if it were procured from NCAR. This allowed us to look at procuring a customized 30 foot Research Vehicle to house the CLASS system and also house the Atmospheric Emitted Radiance Interferometer (AERI) instrument, that was under development for DOE by the UW under the ARM program.

Under overhead funding, the UW-SSEC staff communicated extensively with prospective vendors, wrote specifications for the CLASS System and vehicle, evaluated the bids for these procurements and made the selection of Radian Corporation for the CLASS and Winnebago for the research vehicle. The Radiosondes were procured from Vaisala. During the fabrication of the CLASS System and the research vehicle numerous technical meetings were held over the phone to ensure that the hardware to be provided by the vendors, properly meet the needs of our Mobile CLASS System. The entire vendor oversight effort was funded by UW-SSEC overhead.