Final Report on the University of Wisconsin-Madison Participation in the International Water-Vapor Project (IHOP)

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1. INTRODUCTION

This is the final report for NASA grant **NAG-1-02057/University of Wisconsin-Madison/Dr. Henry E. Revercomb, PI**. This grant supported the University of Wisconsin-Madison participation in the International Water-Vapor Project (IHOP) experiment in May-June 2002. The upwelling thermal infrared emission from the surface and atmosphere over the U. S. Southern Great Plains was obtained from the NASA DC-8 with the Scanning High-resolution Interferometer Sounder (S-HIS) instrument. Analysis of the S-HIS radiances were used to obtain atmospheric temperature profiles below the aircraft. In a complementary manner, the downwelling thermal infrared emission at the surface was obtained by the University of Wisconsin Atmophseric Emitted Radiance Interferometer (AERI) instrument from a mobile research vehicle and used to profile the atmospheric boundary layer at the Homestead site. This report summarizes the observations of the S-HIS and AERI instruments during IHOP including validation against in situ observations.

2. SCANNING HIGH-RESOLUTION INTERFEROMETER SOUNDER (S-HIS) MEASUREMENTS DURING THE INTERNATIONAL WATER-VAPOR PROJECT (IHOP)

The University of Wisconsin-Madison Space Science and Engineering Center (UW-SSEC) has extensive experience in the use of infrared sensors for the remote sensing of atmospheric and surface properties. The UW-SSEC has developed advanced instrumentation for ground-based and aircraft platforms that complement the observations made from weather satellites. A network of ground-based advanced infrared sensors was operational during the IHOP campaign that provide near-continuous boundary layer profiling of atmospheric temperature and water vapor at six sites (Feltz et al., 2003a, 2003b). The Scanning High-resolution Interferometer Sounder (S-HIS) is a UW-SSEC aircraft instrument which measures upwelling thermal emission between 3.3 and 18 microns at high spectral resolution. The measured radiance is used to obtain temperature and water vapor profiles of the Earth's atmosphere. The S-HIS serves as an aircraft prototype for future advanced satellite sounder instruments, e.g. the polar orbiting Cross-track InfraRed Sounder (CrIS) and the Geosynchronous Imaging Fourier Transform Spectrometer (GIFTS).

The International H2O Project (IHOP_2002) field experiment took place over the Southern Great Plains (SGP) of the United States from 13 May to 25 June 2002. The chief aim of IHOP_2002 was to improve the characterization of the four-dimensional (4-D) distribution of water vapor and its application to understanding and prediction of convection. The SGP region is an optimal location due to existing experimental and operational facilities, strong variability in moisture, and active convection. Observations of the S-HIS during IHOP_2002 are listed in Table 1.

Table 1. Scanning HIS flights aboard the NASA DC-8 during the IHOP experiment (23 May 2002 – 14 June 2002).

Flight Date	Sortie	Mission	Data Start (UTC)	Data End (UTC)	Flight Length (Hours)
020523	02-0204	Ferry to OKC	17:13	19:40	2.5
020524	02-0205	CI	17:17	22:44	5.5
020530	02-0206	ABL WV	17:22	22:35	5.3
020602	02-0207	LLJ	02:24	06:56	4.4
020603	02-0208	CI	17:40	22:44	5.1
020609	02-0209	LLJ & CI	13:29	21:14	7.8
020611	02-0210	CI	16:40	21:57	5.3
020614	02-0211	ABL Evolution; Ferry	13:07	21:26	8.3
				Total Flt Hours:	**43.1**

[CI=Convective Inititiation; LLJ = Low Level Jet; ABL = Atmospheric Boundary Layer; WV = Water Vapor]

3. OBSERVATIONS AND RESULTS

Observations of the UW-SSEC S-HIS instrument on board the NASA DC-8 aircraft obtained over the IHOP "Homestead" site near Balko in the Oklahoma panhandle on 14 June 2002 were used to study the evolution of the atmospheric boundary layer. Figure 1 shows an observed infrared spectrum collected over the "Homestead" site from an altitude of 7 km. The spectrum contains absorption features due to carbon dioxide, water vapor, and ozone between the aircraft and the surface.

Figure 1. The UW-SSEC nadir cross-track scanning S-HIS instrument (center) was flown on the NASA DC-8 (left) during IHOP_2002. An example observation of the upwelling infrared emission from S-HIS is shown over the range 6.7-17 μm (right).

The NASA LASE team reported that water vapor gradients near the top of the boundary layer over the "Homestead" site increased in altitude from about 1.9 km at 15:14 UT to 2.3 km at 18:45 UT. Preliminary analysis of the observations from the UW S-HIS instrument are generally consistent with these and ground-based observations of the planetary boundary layer (PBL). Figure 2 shows the PBL time evolution derived from the UW ground-based AERI instrument (Feltz et al., 2003b). Figure 3 shows the S-HIS retrieved temperature and water vapor profile obtained during an overpass of the "Homestead" site by the NASA DC-8. The S-HIS retrieval methodology follows that of Zhou et al., 2002. Validation of the S-HIS temperature and water vapor retrieval is provided by a coincident ground-based AERI retrieval and a radiosonde. The AERI and radiosonde observations are at 17:31 UTC on 14 June 2002. The S-HIS profile selected for comparison is the one closest to the "Homestead" site (within 1 km) which occurred at 17:38:44 UTC.

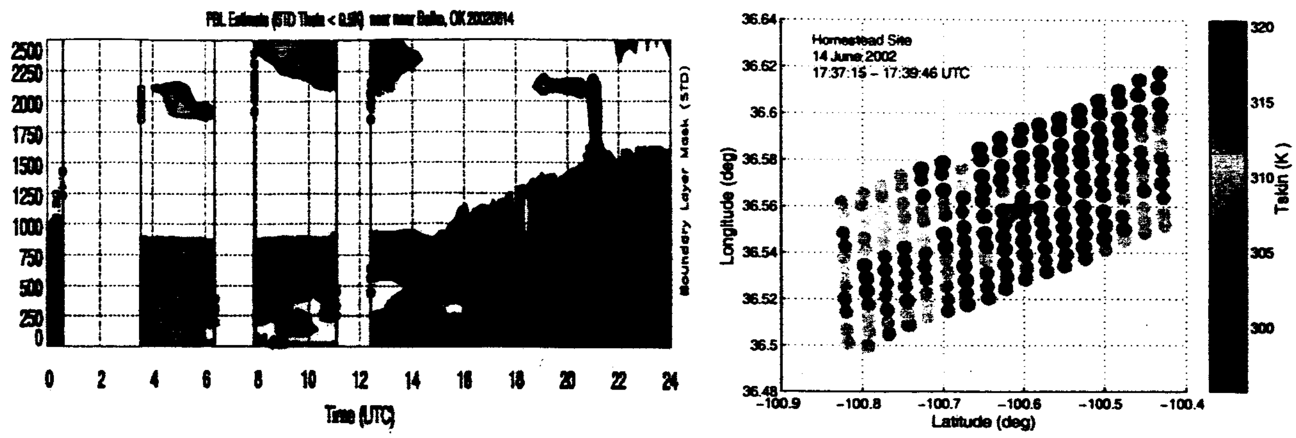

Figure 2. Time-height cross-section (left) of the vertical variation of potential temperature on 14 June 2002 derived from the UW-SSEC ground-based AERI measurements from the IHOP "Homestead" site near Balko in the Oklahoma panhandle. The time is in hours and the height is in meters above ground level. The colored regions indicate where the potential temperature varies by less than 0.5 K, effectively mapping out the evolution of the planetary boundary layer. The UW S-HIS retrieved skin temperature is shown in the right-hand panel from the 17:30 UTC overpass. The star symbol marks the Homestead site location (elevation 862 meters).

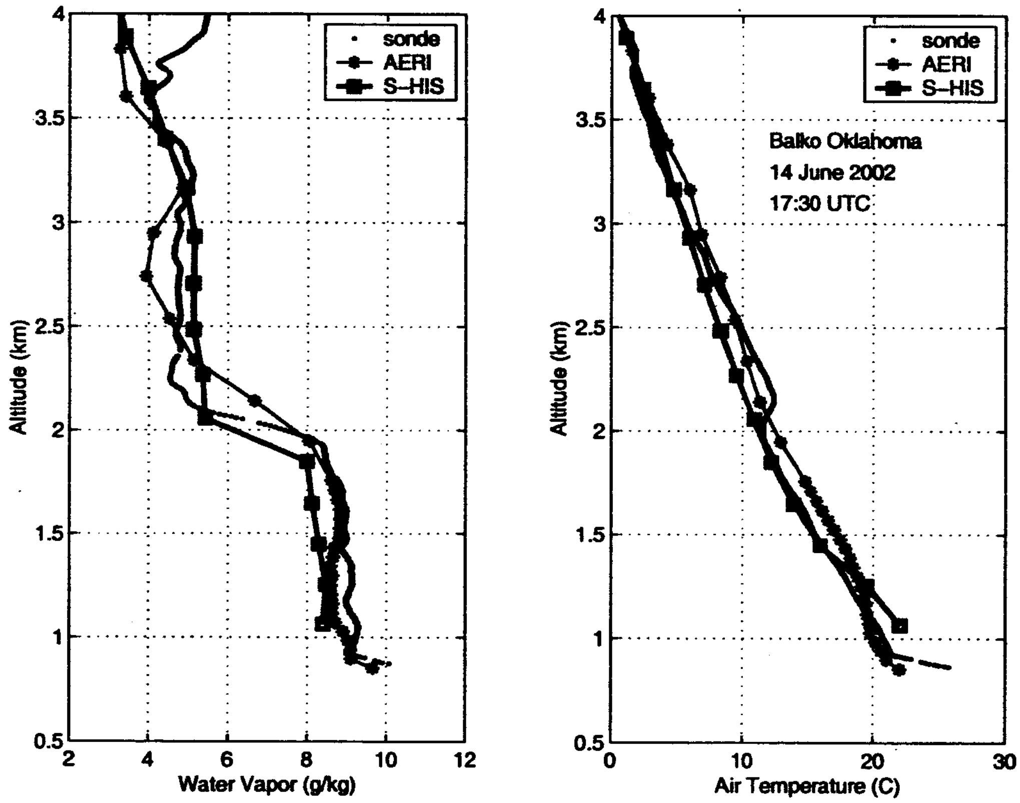

Figure 3. Preliminary comparison of the boundary layer temperature and water vapor profile derived from the downlooking UW S-HIS instrument on the NASA DC-8 aircraft (7 km altitude) to uplooking measurements from the UW AERI instrument and a co-located radiosonde (GLASS) at the IHOP "Homestead" site in the Oklahoma panhandle. The S-HIS was used to map out the boundary layer thermodynamic structure in the vicinity of the ground site over a period of about four hours on the morning of 14 June 2002.

4. AERI BOUNDARY LAYER THERMODYNAMIC PROFILING: IMPROVEMENTS IN VERTICAL AND TEMPORAL RESOLUTION DURING IHOP

The United States Department of Energy's Atmospheric Radiation Measurement (ARM) program has funded the development of the Atmospheric Emitted Radiance Interferometer (AERI). This has led to a hardened, autonomous system that measures downwelling infrared (IR) radiance at high-spectral resolution, and seven AERI systems have been deployed around the world as part of the ARM program. The initial goal of these instruments was to characterize the clear-sky IR emission from the atmosphere and thermodynamic profiling (Feltz et al. 2003b), thus a temporal sampling was chosen (8-10 min per spectrum) to minimize random noise in the AERI observations. Research emphasis has been placed on the improvement of vertical resolution and temporal sampling on AERI derived atmospheric boundary layer thermodynamic profiles and cloud property retrievals. Results indicate that the AERI derived temperature profiles more accurately represent strong surface based temperature inversions common through noctural radiational cooling and in the polar regions. AERI retrieval results from the International H20 Program (IHOP) demonstrate improved vertical resolution of temperature within the lowest one kilometer of atmosphere has been achieved (Feltz et al. 2003a). Boundary layer profiles were obtained continuously with the AERI instrument for the duration of the IHOP experiment at the Homestead site in the Oklahoma panhandle.

5. CONCLUSIONS

The Scanning High-resolution Interferometer Sounder is a valuable tool for the characterization of the atmospheric boundary layer and surface thermal emission. The UW-SSEC is using S-HIS data from the NASA DC-8 aircraft to characterize the atmospheric boundary layer thermodynamic structure in the IHOP domain. Preliminary validation against ground-based and in situ observations shows good agreement in boundary layer structure. The S-HIS measurements of atmospheric temperature and water vapor profiles are being used with those of other sensors (e.g. the NASA LASE) to characterize the four dimensional distribution of water vapor during IHOP. The ground-based AERI instrument also provided a valuable dataset of atmospheric temperature profiles to complement the other ground-based sensors at the IHOP Homestead site in the panhandle of Oklahoma. Several aircraft missions over-flew this site which was used for ground-truth validation as well as for providing a continuous time series of observations from a fixed site.

6. REFERENCES

1. Knuteson, R., P. Antonelli, F. Best, S. Dutcher, W. Feltz, and H. Revercomb: "Scanning High-resolution Interferometer Sounder (S-HIS) measurements during the International Water-Vapor Project (IHOP)", 2003: Proceedings of the 6th International Symposium on Tropospheric Profiling: Needs and Technologies, September 14-20, 2003, Leipzig, Germany.
2. Feltz, W. F., H. B. Howell, H. Woolf, and R. O. Knuteson, 2003a: "AERI Boundary Layer Thermodynamic Profiling: Improvements in Vertical and Temporal Resolution During IHOP and TEXAS 2002," Proceedings of the 6th International Symposium on Tropospheric Profiling: Needs and Technologies, September 14-20, 2003a, Leipzig, Germany.
3. Feltz, W. F., W. L. Smith, H. Ben Howell, R. O. Knuteson, H. M. Woolf, and H. E. Revercomb, 2003b: "Near-Continuous Profiling of Temperature, Moisture, and Atmospheric Stability Using the Atmospheric Emitted Radiance Interferometer (AERI)," *J. of Appl. Meteor.*, 42, 584-597.