1.1 AN OVERVIEW OF THE INTERNATIONAL H_2O PROJECT (IHOP_2002)

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1. INTRODUCTION

The International H_2O Project (IHOP_2002) was one of the largest North American weather field experiments in history. From 13 May to 25 June 2002, over 200 researchers from the U.S., France, Germany and Canada converged on the Southern Great Plains to measure water vapor and other atmospheric parameters. The principle objective of IHOP_2002 is obtaining an improved characterization of the time-varying three-dimensional water vapor field and evaluating its utility in improving the understanding and prediction of convective processes. Toward this goal, IHOP_2002 brought together many of the existing operational and state-of-the-art water vapor sensors and numerical models.

The focus of IHOP_2002 is on four coordinated and overlapping research components: i) The Quantitative Precipitation Forecasting (QPF) research component seeks to determine the degree of improvement in forecast skill that occurs through improved characterization of the water vapor field. This work includes a variety of research and operational numerical modeling, data assimilation and expert systems. ii) The Convection Initiation (CI) research component seeks to further understand and eventually predict the processes that determine where and when convection forms. iii) The Atmospheric Boundary Layer (ABL) Processes research component seeks to improve understanding of the relationship between atmospheric water vapor and surface and boundary layer processes and their impact on convective development; and iv) The Instrumentation research component seeks to determine the optimal mix of future operational water vapor measurement strategies to better predict warm season rainfall. This group will also work toward better quantification of measurement accuracy, precision and performance limitations as they relate to using water vapor measurements in warm season forecasts and data assimilation systems.

This paper presents a brief summary of the motivation, goals and experimental design of the project and shows some preliminary data collected.

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2. MOTIVATION

An accurate prediction of warm season precipitation amounts has remained an elusive goal for the atmospheric sciences despite steady advances in the ability of numerical weather prediction models to forecast many other atmospheric variables (e.g., Emanuel et al. 1995; Dabberdt and Schlatter 1996). One necessary condition for an accurate prediction of convective rainfall is a good forecast of where and when convection will initially develop. Currently both the prediction and understanding of convection initiation processes are impeded by a lack of high-resolution, high-accuracy water vapor measurements.

For example, existing observational techniques for mapping the three-dimensional distribution of water vapor are lacking. Radiosondes, the traditional means of obtaining water vapor measurements, are insufficient because they provide only vertical profile information, are only available twice a day at most locations and have significant errors and biases (Guichard et al. 2000; Wang et al. 2002).

Additionally, there is a general absence of operational ground-based water vapor remote sensing systems and many satellite techniques have relative

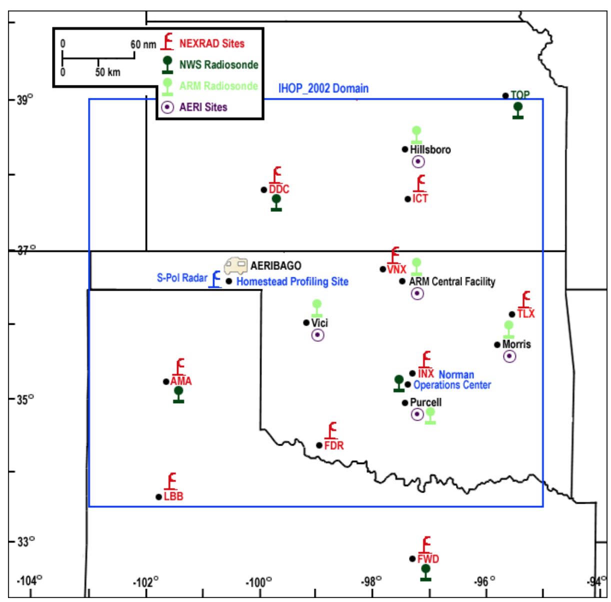

Fig. 1. Map of IHOP_2002 domain with subset of operational instruments, including NEXRAD radars, NWS and ARM sounding sites and AERI locations.

difficulty in obtaining high-resolution and high-accuracy water vapor measurements in the lower troposphere. Thus, while water vapor measurements are critically linked to convective processes, measurements are simply not available to derive high quality initial conditions for the next generation of numerical weather prediction models or to provide guidance for bench forecasters seeking to nowcast convective development and evolution. Adequate means for measuring water vapor are only now beginning to emerge.

3. IHOP_2002

The U.S. Southern Great Plains was chosen for IHOP_2002 due to the extensive array of operational and experimental instruments. An overview map of the IHOP_2002 domain is shown in Fig. 1. IHOP_2002 is taking advantage of the WSR-88D radars, the NWS soundings with which numerous special soundings were launched for IHOP_2002, the ARM soundings, the wind profiler demonstration network and the Atmospheric Emitted Radiance Interferometer (AERI) sites. The passive AERI provides continuous profiles of temperature and moisture (e.g., Feltz et al. 2002).

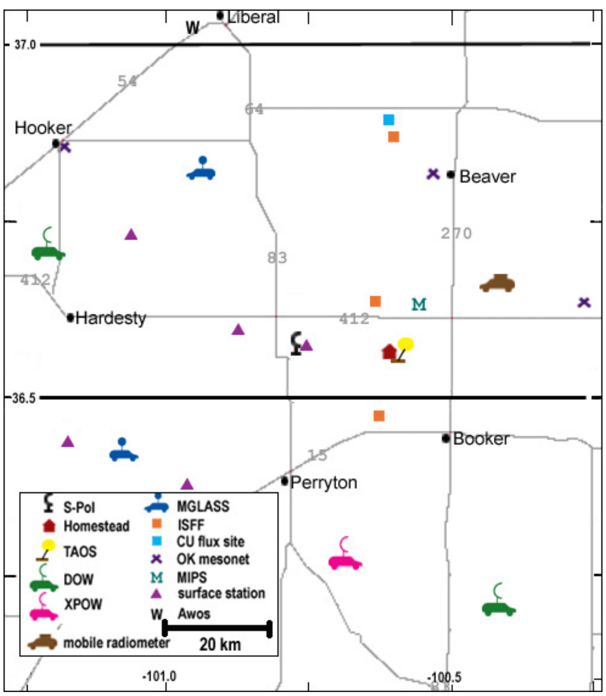

Fig. 2. Subset of field sites deployed for IHOP_2002, including S-Pol, TAOS, surface stations and Homestead Profiling site. The Profiling Site included three NASA lidars (SRL, GLOW and HARLIE), AERIBAGO, FMCW radar and ISS with MAPR. Also shown are mobile instruments based in Liberal area including DOWs, X-Pol, MIPS and the DRI Mobile Microwave Radiometer.

A concentration of IHOP_2002 research instruments was placed in the Oklahoma panhandle. Figure 2 shows the extensive array of instruments including NCAR's S-Pol radar, numerous surface stations, some of which measure surface fluxes, a tethersonde and a multitude of instruments based at the Homestead Profiling Site.

The densely-instrumented Homestead site includes the NASA Scanning Raman Lidar (SRL) providing profiles of water vapor measurements, the NASA Goddard Lidar Observatory for Winds (GLOW) lidar providing Doppler wind measurements, the NASA Holographic Airborne Rotating Lidar Instrument Experiment (HARLIE) lidar providing backscatter profiles, the U-Mass FMCW radar, UW-Madison AERIBAGO, which is an AERI in a Winnebago and an NCAR Integrated Sounding System (ISS) with an advanced wind profiler called MAPR, sodar, RASS and soundings. The project also had a wealth of mobile systems, some of which are shown in Fig. 2. Mobile instruments based in the Liberal, KS area included 2 University of Oklahoma/NCAR Doppler on Wheels (DOW) radars, 2 NCAR mobile GLASS sounding systems, University of Connecticut's X-Pol radar, University of Alabama-Huntsville Mobile Integrated Profiling System (MIPS) and DRI's Mobile Microwave Radiometer. An NSSL mobile armada of instruments based in Norman, OK were directed from a mobile Field Control (FC) van with wireless data links to the mobile instruments, including a Shared Mobile Atmospheric Research and Teaching Radar (SMART-Radar), 9 mobile mesonets, a field camera vehicle and a mobile CLASS sounding system.

Six research aircraft participated in IHOP_2002, many of them with unique instrumentation. The NRL P-3 had a unique combination of sensors, including NCAR's airborne Doppler radar (ELDORA) and Leandre II (CNRS/France's airborne water vapor DIAL). Leandre II was pointed downward for boundary layer and QPF missions and in a horizontal-pointing mode during CI missions. This combination of sensors during CI flights allowed for the horizontal mapping of the moisture field in the context of clear-air dual-Doppler winds from ELDORA. The DC-8 with downward-pointing LASE water vapor DIAL was used to map out the large-scale moisture distribution. The Falcon had downward-pointing water vapor DIAL which also provided curtains of water vapor measurements above and within the boundary. Additionally the Falcon launched numerous dropsondes and housed NOAA's High-Resolution Doppler Lidar (HRDL) providing high-resolution wind measurements. The Flight International Learjet was utilized as a dedicated dropsonde aircraft for IHOP_2002. The University of Wyoming King Air (UWKA) was a critical platform for both ABL and CI missions. The UWKA housed the Wyoming Cloud Radar (WCR) which obtained high-resolution Doppler and backscatter measurements of boundary layer motions in clear air and within clouds.

Numerous numerical models were run in real-time during IHOP_2002. Some of these were used to assist in forecasting decisions (e.g., LAPS, local ETA, ARPS) while others were run to evaluate the impact of new data assimilation products (e.g., MM5 with AERI data). A multitude of models will be run in research and analysis mode to evaluate the impact of various datasets on improving the models' QPF performance (e.g., WRF, MM5, ARPS).

4. PRELIMINARY ANALYSIS

4.1 *Undular bores*

One of the exciting surprises during IHOP was the multitude of bore events in the region. These occurred numerous evenings in association with cold fronts, outflow boundaries and low-level jets. Their impact on convection initiation and the maintenance of convection will be studied. A couple case studies of bores impacting convection initiation were performed by Carbone et al. (1990) and Koch and Clark (1999). The downward-pointing Leandre II water vapor DIAL onboard the P-3 aircraft obtained an impressive image of the water vapor structure in association with an undular bore on 20 June 2002 (Fig. 3).

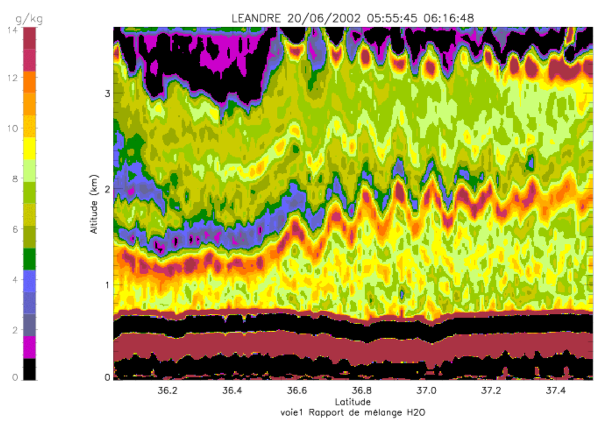

Fig. 3. Leandre II downward-pointing water vapor DIAL field from NRL P-3 at 0616 UTC on 20 June 2002. The wave-like structure in the moisture field depicts an undular bore propagating beneath the aircraft. Figure courtesy Cyrille Flamant (CNRS/France).

4.2 *Radar refractivity retrieval*

An excellent example of a new product with a great deal of potential is the radar refractivity retrieval. It has been implemented on McGill's radar for some time (Fabry et al. 1997) but has only recently been utilized on NCAR's S-Pol radar. Fabry et al. (1997) use an ingenious technique to retrieve surface-layer refractivity measurements (closely related to moisture measurements) from ground clutter. The technique takes advantage of the stationarity of the ground targets and therefore relates variations in Doppler signal delay to variations in the intervening atmospheric refractivity field. The refractivity field often identifies boundaries corresponding to the traditional reflectivity fine lines and velocity convergence zones (Figs. 4 and 5). At times, the refractivity field illustrated boundaries prior to the appearance of boundaries in the other more-traditional radar fields. Additionally the refractivity field often showed blobs of moisture or pockets of dry air approaching and receding from S-Pol. These boundaries and other features apparent from the refractivity field will be examined to evaluate their impact

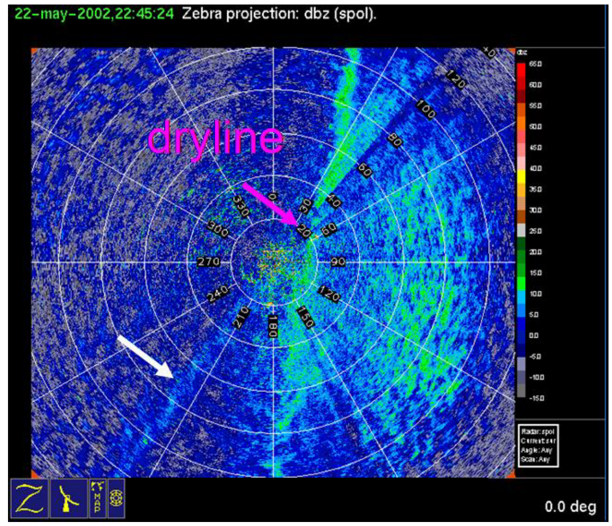

Fig. 4. S-Pol radar reflectivity field at 2245 UTC on 22 May 2002 with arrows showing two well-defined boundaries: a dryline and an unidentified boundary.

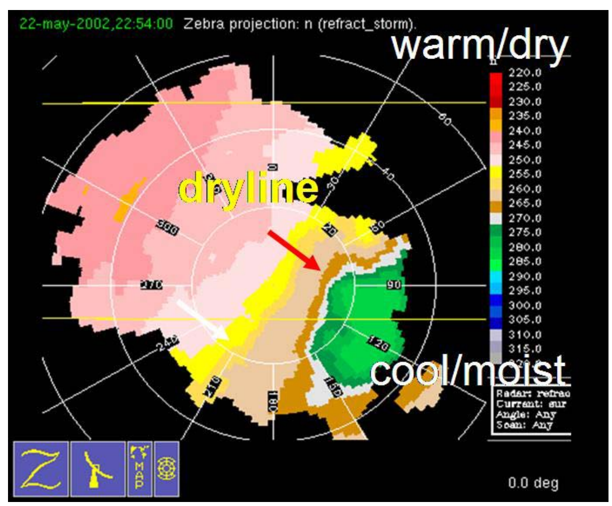

Fig. 5. S-Pol radar refractivity retrieval at 2254 UTC on 22 May 2002 corresponding to Fig. 4. Note the strong refractivity gradients at the locations of the arrows indicative of boundary features.

of better understanding boundary layer evolution, boundary layer heterogeneity and convection initiation processes.

4.3 *Reference radiosonde*

Some preliminary results which will have significant impact on both operational and research sounding datasets were obtained from the reference radiosonde system. This state-of-the-art sounding package can be flown on the same balloon as traditional sounding packages. An intercomparison of the Snow White moisture sensor, which is the reference value, with the carbon hygristor and the Vaisala sensor is shown in Fig. 6. A paper in this volume (Wang et al. 2003) nicely describes the system and these preliminary results. Briefly, however, it is apparent that substantial variations exist between the reference and the standard sounding packages. At extremely cold temperatures (i.e., high levels), in particular, there is alarmingly little response in the hygristor and Vaisala sensors.

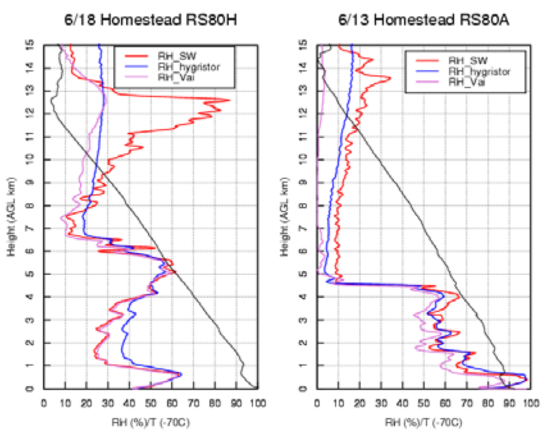

Fig. 6. Relative humidity intercomparisons between Snow White reference sensor (red), carbon hygristor (blue) and Vaisala RS80 (pink) on 18 June (left) and 13 June (right). The temperature profile (+70 deg C; black) is also shown. Taken from Wang et al. (this conference; 2003).

Further examples of datasets collected during IHOP_2002 may be viewed at: http://www.joss.ucar.edu/ihop/catalog/.

5. SUMMARY

The wealth of data collected during IHOP_2002 will be studied by teams of international investigators for years to come. These datasets will allow for detailed comprehensive studies of the moisture fields along with temperature and wind fields with the aim of i) assimilating these data into numerical models to ascertain the level of improvement in quantitative precipitation forecasting; ii) better understanding and pinpointing exactly why and when storms form; iii) evaluating the relationship between land surface heterogeneities and boundary layer moisture distribution and iv) determining the future optimal mix of operational ground-based and satellite-borne moisture sensing instruments for forecasting convective rainfall.

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