10.4 NCAR INTEGRATED SOUNDING SYSTEM OBSERVATIONS AT IHOP

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1. INTRODUCTION

The International H_2O Project (IHOP) was a large experiment conducted in May and June 2002 to study water vapor. Over 200 researchers from 18 agencies and universities in five countries participated in the campaign which was centered in the Kansas and Oklahoma region. (IHOP will be the topic of a special session at the AMS conference in the Symposium on Observing and Understanding the Variability of Water in Weather and Climate). The IHOP home page is www.atd.ucar.edu/dir_off/projects/2002/IHOP.html

NCAR deployed an Integrated Sounding System (ISS) at the so-called "Homestead" or profiling site in the Oklahoma panhandle. The site was 17 km east of the NCAR S-Pol scanning weather radar.

Additional instrumentation at the Homestead site were operated by NASA (the Raman, GLOW, and HARLIE lidars); the University of Wisconsin (AERIBAGO - Atmospheric Emitted Radiance Interferometer), and the University of Massachusetts (FM-CW radar). Mobile systems such as the University of Oklahoma/NCAR DOWs (Doppler radar on Wheels), NCAR Mobile GLASS (radiosondes), University of Alabama MIPS (Mobile Integrated Profiling System), DRI mobile microwave radiometer, and various other facilities were often operated near the Homestead site.

2. INSTRUMENTATION

The basic NCAR ISS is described by Parsons et al (1994) and includes a wind profiler radar with RASS, a GPS radiosonde sounding system, and surface meteorology instruments. For IHOP, the system was enhanced by including a sodar, an advanced wind profiler radar, and nearby, a tethered blimp supporting in-situ instruments. Radiosondes were launched routinely at 18UT (1pm local), and at 2-3 hour intervals during IOPs.

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The wind profiler used was MAPR (Multiple Antenna Profiler Radar), which is based on a highly modified NOAA/AL Radian 915 MHz boundary layer wind profiler. It uses the spaced antenna technique, making it capable of making wind measurements at 1 – 5 minute intervals (much faster than the 30 minute sampling rate typical of the more common Doppler Beam Swinging or DBS wind profilers). The basic vertical resolution is 100 meters, however as described below, this is being improved using advanced interferometry techniques. The radar is described in Cohn et al (2001).

The sodar used was a Metek DSDPA.90-24 mini-sodar. Engelbart, et al (1999) described the similar, but larger, DSDPA.90-64. For IHOP the sodar was used with a frequency of 1600 Hz, 25m vertical resolution, and 15 minute time resolution. The sodar provided winds up to 200 - 400 meters, depending on conditions.

The tethered blimp, TAOS (Tethered Atmospheric Observing System), had 6 sensor packages measuring wind, temperature, relative humidity, and pressure suspended along a 600 m line. TAOS was operated about 1.5 km east of MAPR.

3. EXAMPLES OF OBSERVATIONS

3.1 Bore-like Event

Several bore or bore-like events were observed during the project. These phenomena can be generated by the outflow from storms and sometimes travel considerable distances before meeting unstable air and triggering further storms. One goal of the project was to detect and examine these events to learn more about their characteristics.

An example of a bore-like event is shown in figure 1. The figure shows MAPR observations of reflectivity, vertical motion, and winds. The vertical motion panel clearly shows three upward pulses, peaking at almost 2 m/s in the first updraft (6:40UT). Reflectivity layers in the top panel are undulating with the pulses with gradually increasing amplitude. The surface meteorological observations of the event are shown in figure 2. A pressure surge, along with fluctuations in temperature, relative humidity and wind can be clearly seen. The southerly flow appears to have lifted during the event, and returns to the surface as the wave passes.

On S-Pol, three bands were visible at approx. 10 km separation, traveling at about 8 m/s towards the southeast, partially into the prevailing southerly wind. The event appeared to originate from a line of storms to the northwest and new convection did appear downstream.

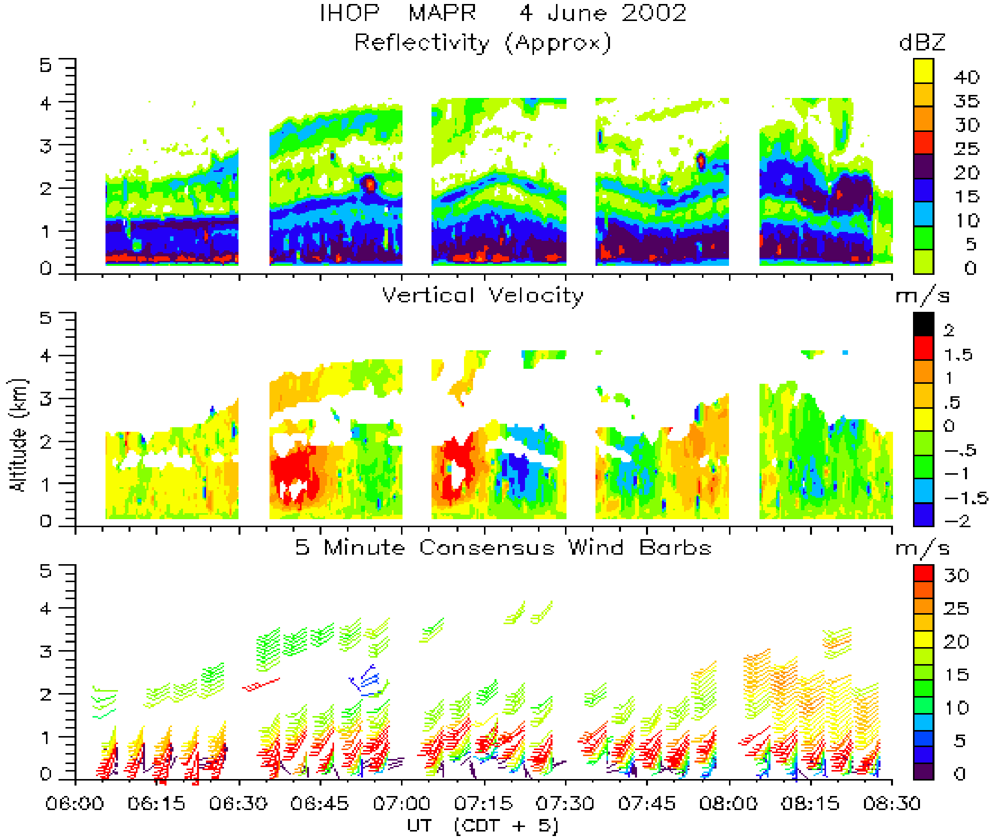

Figure 1 : MAPR observations of a bore-like event on 4 June 2002.

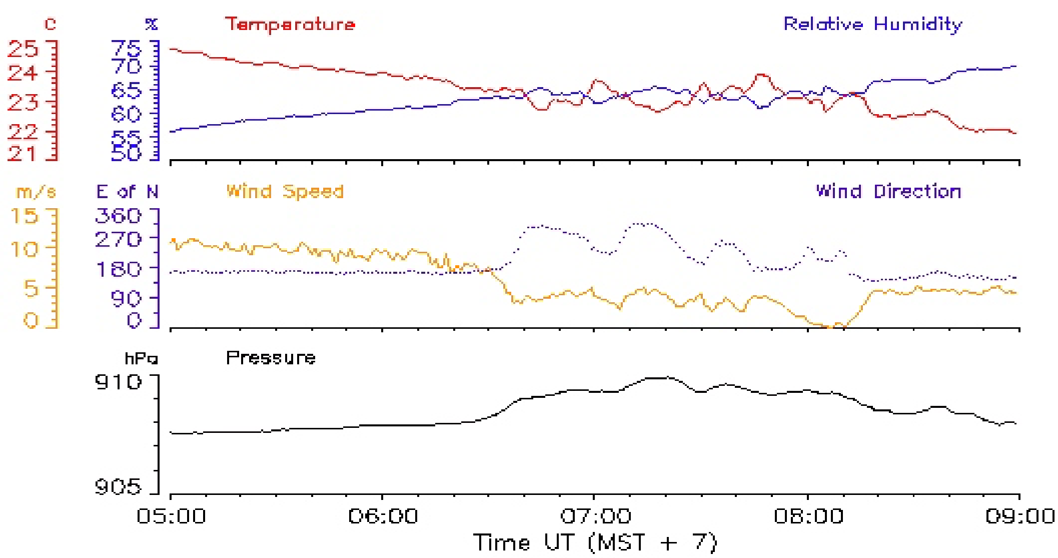

Figure 2: ISS surface meteorology observations of the event in figure 1 (note that this figure starts an hour earlier and extends half an hour longer than figure 1 to show context)

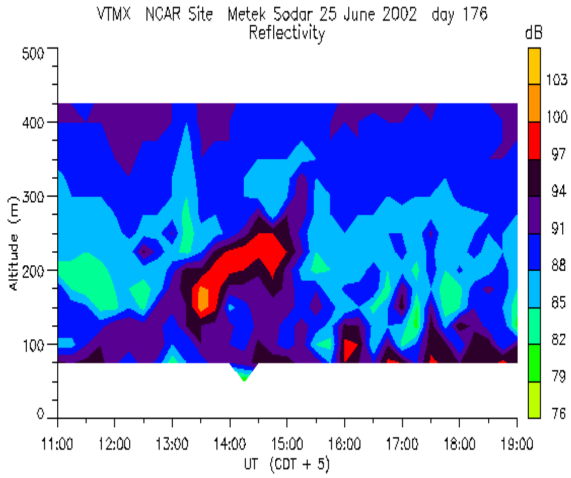

Figure 3: Sodar reflectivity, 15 minute mean.

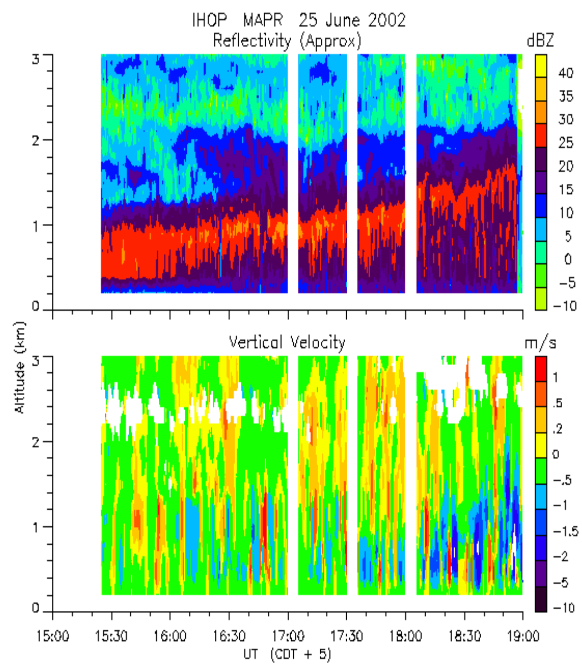

Figure 4: MAPR reflectivity & vertical velocity. Reflectivity approximately calibrated.

3.2 Boundary Layer Growth

Another aspect of the campaign was the study of boundary layer development. The sodar and MAPR made complementary observations of the growth of the boundary layer. The mini-sodar, designed to observe up to about 400 meters, captured the initial growth, (e.g. figure 3). MAPR, which was often affected by ground clutter below about 400 m because of the generally windy conditions, was well suited to provide observations from mid-morning on (figure 4). The boundary layer top corresponds to the peak in reflectivity in these figures. However, there was often a disconnect between the initial growth seen by the sodar and the later growth seen by MAPR. For example in figure 3, the sodar shows gradual growth up to around 200m at about 1430 UT, but the observations from MAPR indicate a depth of about 700m at 1530 UT, gradually deepening. (Unfortunately MAPR wasn't operating prior to 1525 on this day).

Nearby in-situ measurements do indicate a period of rapid growth. The tethered balloon, TAOS, was operated in profiling mode on this day, and observations of potential temperature are shown in figure 5. The dashed line shows an estimate of boundary layer top, and as can be seen, is consistent with the gradual build up to around 1430, followed by much faster growth. Soundings taken at 13, 15, 17, and 19 UT are shown in figure 6 and display similar early behavior and also show the deeper boundary layer later. MAPR observations seem to be consistent with these sounding data.

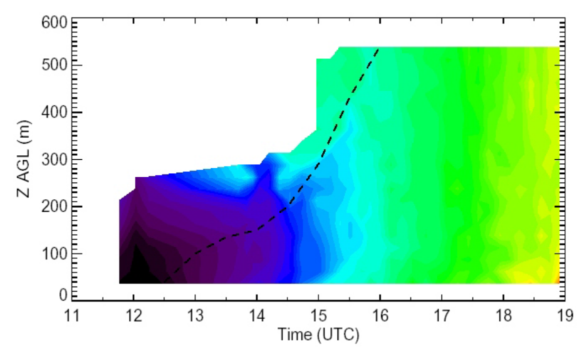

Figure 5: TAOS Potential Temperature 25 June 2002, 1.5 km east of MAPR. Approx. boundary layer top marked by dashed line.

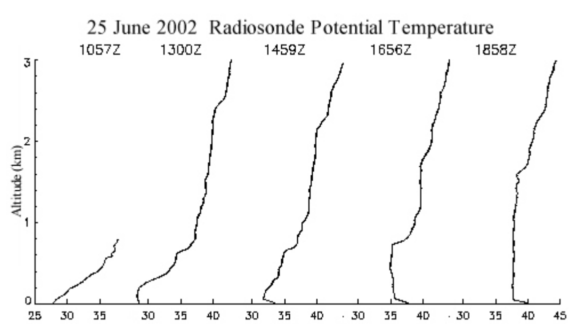

Figure 6: Sounding potential temperatures.

3.3 RIM

Instrumentation development was another IHOP focus. RIM (Range IMaging) is a technique that can greatly improve the range resolution of a profiler (Palmer et.al., 1999). The frequency of the profiler is shifted from 915 MHz from pulse to pulse by about 1 - 2 MHz. As the wavelength changes, the phase of echoes change in a manner that can be precisely related to range using frequency domain interferometry techniques. Depending on the application, the range resolution can improve from 100 meters down to around 10-20 meters.

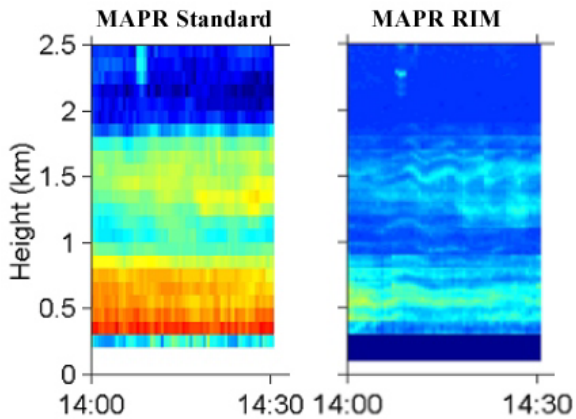

Figure 7: MAPR Standard and RIM reflectivity from June 6, 2002.

RIM observations were made on MAPR from May 23 to June 11. Figure 7 shows reflectivity using standard processing (with a resolution of 100 m) and RIM processing for the same period. As can be seen, the RIM processing appears to resolve billow like structures. A later sounding does show a jet with significant shear at around this level (figure 8) and Richardson numbers near the critical level. Similar wave-like structures were seen on the nearby University of Massachusetts FM-CW radar.

In addition to improving the range resolution of reflectivity images, RIM can be used to improve the resolution of wind measurements. An example of preliminary results is shown in the right hand panel of figure 8. (The central panel shows standard resolution winds). Oscillatory behavior is seen in both the sounding and RIM eastward winds, although the RIM winds are nosier and have shorter wavelength. RIM processing for winds does require stronger signals than standard processing, and so here the RIM winds only go up to about 1km, and do not show the jet above that. Standard processing gave winds to 1700 m, however at lower levels the standard winds appear to be more strongly affected by ground clutter (and thus biased towards zero) than the RIM winds.

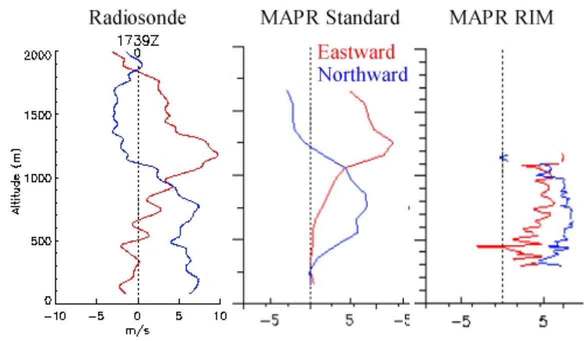

Figure 8: June 6, 2002, Sounding and MAPR Standard and RIM wind profiles. The MAPR profiles are 5-minute averages from 1740 at 100 m resolution for the standard and 30 m resolution for RIM processing.

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