Evolution of the moisture field during the development of the daytime convective boundary layer

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1 Introduction

The International H_2O Project (IHOP_2002) was designed to sample the three-dimensional time-varying moisture field to better understand convective processes (Weckwerth et al. 2004). Numerous research and operational water vapor measuring systems and retrievals were operated in the U.S. Southern Great Plains in the summer of 2002. This was done in combination with more traditional observations of wind and temperature. Boundary-layer evolution studies were designed to maximize observational overlap from multiple instruments to better understand the moisture distribution during the evolution of the daytime convective boundary layer.

2 Data

Data from 14 June 2002 are used to describe the evolution of the daytime convective boundary layer (CBL) with a focus on the moisture distribution and evolution. Data sets included in this analysis are: S-Pol radar, including refractivity; two Doppler on Wheels (DOW) mobile radars; P-3 aircraft with Leandre II water vapor DIAL; University of Wyoming King Air; tethersonde; Integrated Sounding System (ISS) with a wind profiler, sodar and radio acoustic sounding system; Mobile Integrated Profiling System (MIPS) with a wind profiler and sodar; serial ascents from four nearby radiosondes; Scanning Raman Lidar and AERI interferometer. This day comprises a highly-coordinated data collection period from before sunrise through the development of the CBL.

Preliminary analyses suggest significant horizontal variability in the moisture distribution. The combination of data sets provides a comprehensive description of the development and distribution of the low-level moisture field, in particular, during the early morning hours.

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3 14 June overview

The visible satellite imagery at 1515 UTC (UTC = LT + 5 hr) on 14 June (Fig. 1) illustrates widespread cirrus southwest of the study region during the early hours of the mission. This variation in cloud cover across the domain affects the low-level temperature distribution and may impact the moisture field.

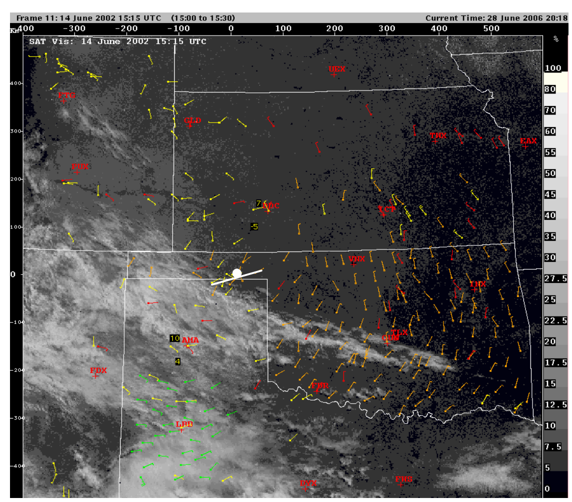

Fig. 1. *Visible satellite image at 1515 UTC on 14 June. Line indicates aircraft track shown in Fig. 4 and dot is Homestead Profiling Site from which data shown in Figs. 2, 3 and 5 were collected.*

High-temporal resolution mobile radar observations show the evolution from no clear-air return, suggesting no convective features, to weak boundary layer clear-air echo return to horizontal convective rolls to open cellular convection 13-19 UTC on 14 June 2002.

The Multi-Antenna Profiler (MAPR) and the wind profiler on MIPS clearly illustrate the commencement of the daytime CBL motions at ~1245 UTC, as well as the depth of the CBL indicated by the maximum in signal-to-noise ratio (Fig. 2). Tops of thermals are suggested 16-18 UTC. This is consistent with the FM-CW radar data which also shows striking examples of thermals with their inverted u-shaped tops (Fig. 3).

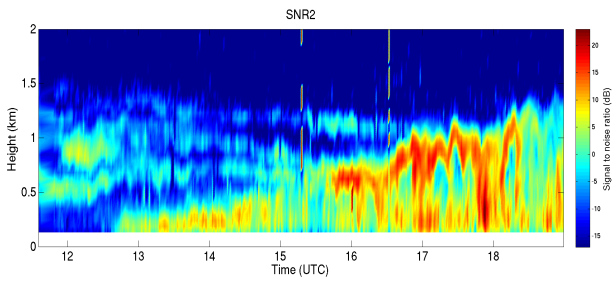

Fig. 2. *Time series of MIPS signal-to-noise ratio. MIPS was located near the dot shown in Fig. 1.*

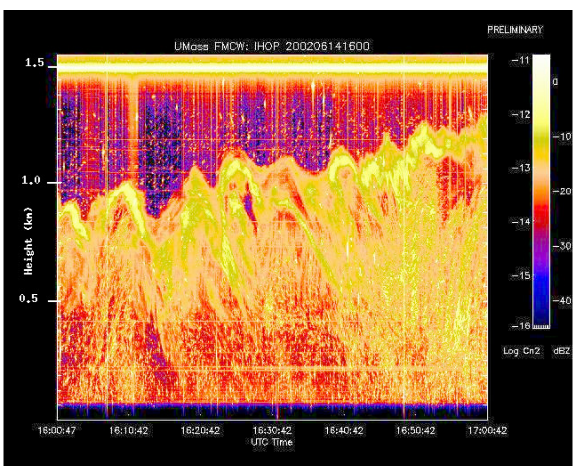

Fig. 3. *Turbulence structure parameter from FM-CW radar 1600-1700 UTC on 14 June 2002.FM-CW radar was located at the dot in Fig. 1.*

4 Horizontal moisture variations

The in situ aircraft measurements from 14 June 2002 highlight the east-west moisture variations in the early morning hours (Fig. 4), as well as the temporal variability. The early morning legs at ~1200 UTC at ~350 m AGL most clearly illustrate the enhanced moisture toward the west beneath the cirrus cloud shield. While the cloud field is dissipating throughout the day, this east-west moisture gradient is surprisingly strengthened by 1712 UTC. This moist region to the west is mirrored in the radar refractivity data (not shown).

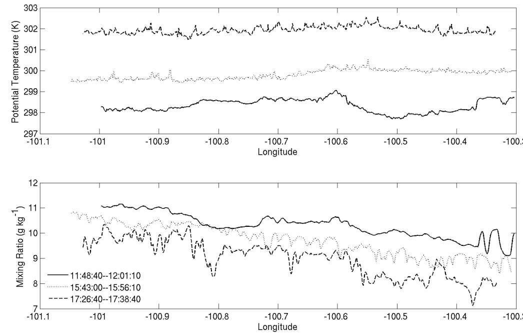

Fig. 4. *U. of Wyoming King Air in situ aircraft measurements at ~350 m AGL at various times throughout the development of the CBL. The flight track is shown in Fig. 1.*

5 Vertical moisture distribution

Scanning Raman Lidar (SRL) profiles of water vapour are presented in Figure 5. Note the early morning high low-level moisture content. This time period (10-15 UTC) is also consistent with the existence of wave motions atop the stable layer. These waves may help to trap the moisture in the low-levels during the nighttime and early morning hours.

The SRL at 1545 UTC shows the growth of the convective motions above the stable layer and into the previous day's residual layer at 600 m. Other datasets, such as aircraft, MIPS (Fig. 2) and radiosondes, suggest that convective motions commenced as early as 1245 UTC at lower levels. In the SRL data, this early development of boundary-layer convective motions was masked by the strong low-level moisture.

The depth of the CBL from various instruments, illustrated by lines in Fig. 5, show that the depth of the surface-based moist layer is slightly lower than the depth of the well-mixed CBL. This may be due to horizontal mixing of thermals during their ascent through the CBL or to intense vertical mixing in the entrainment zone at the top of the CBL.

6 Summary and conclusions

Multiple datasets observed on 14 June 2002 illustrate the development of the moisture field during the evolution of the CBL. The CBL grows up from the surface several hours after sunrise and penetrates into and dominates the wave motions within the previous evenings' stable layer. The CBL continues its growth into the previous days' residual layer and becomes the dominant surface-based layer by 1815 UTC.

Ongoing work includes comparing and contrasting these observations with two other IHOP boundary layer evolution study days: 21 June and 25 June 2002.

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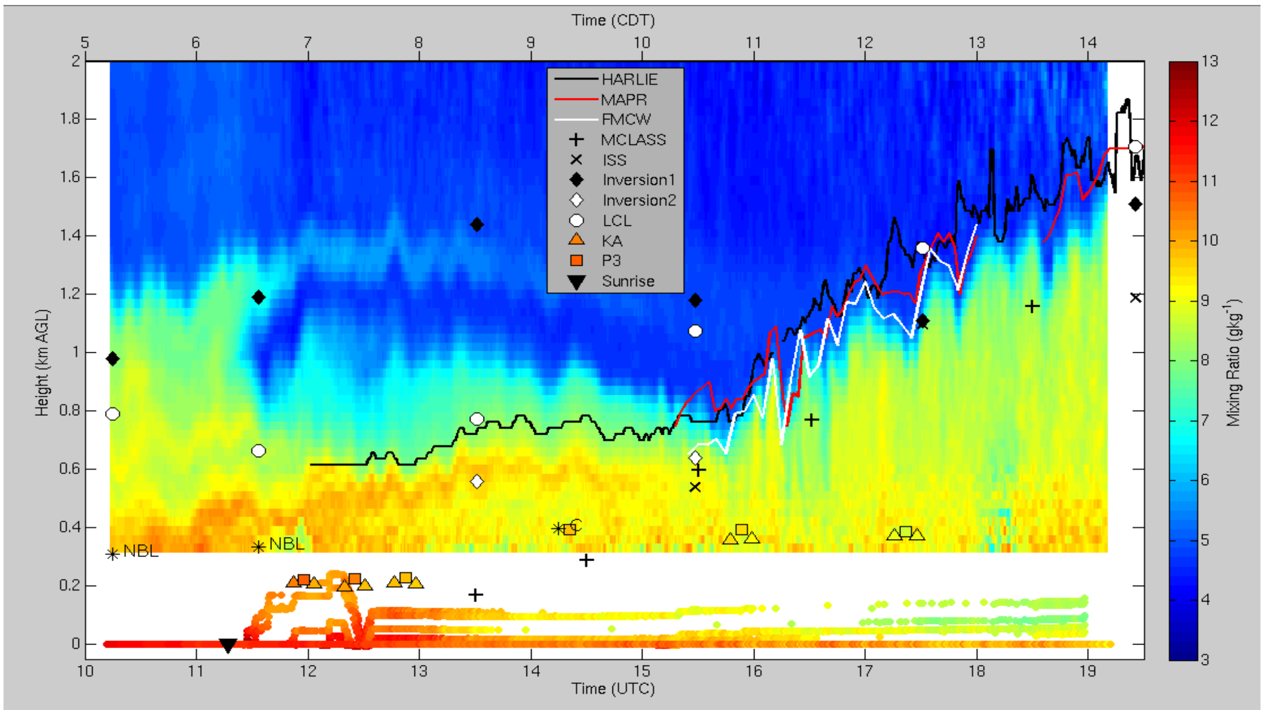

Fig. 5. *Time series of SRL moisture field obtained from Homestead Profiling Site location shown by dot in Fig. 1. Overlaid are CBL height determined from wind profiler, FM/CW radar and soundings. Sunrise is shown by an inverted triangle. Tethersonde and surface station data are shown beneath the lowest SRL gates.*

References

Weckwerth, T. M., D. B. Parsons, S. E. Koch, J. A. Moore, M. A. LeMone, B. B. Demoz, C. Flamant, B. Geerts, J. Wang and W. F. Feltz, 2004: An overview of the International H_2O Project (IHOP_2002) and some preliminary highlights. *Bull. Amer. Meteor. Soc*., **85**, 253-277.