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12 JUNE 2002 RAPID WATER VAPOR TRANSITIONS DURING THE IHOP FIELD PROGRAM

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1. INTRODUCTION

The International H2O Project (IHOP) was conducted in the Southern Great Plains (SGP) region of the United States from 13 May – 25 June 2002. Three of the primary goals for the program were to measure water vapor variability at high temporal/spatial resolution to improve numerical model quantitative precipitation forecasting (QPF), understand the evolution of the atmospheric boundary layer (ABL), and to study the mechanisms for convective initiation (CI) within the Southern Great Plains region. Satellite, aircraft, and ground based instrument suites were deployed to measure meteorological parameters at relatively high temporal and vertical resolution. A fixed suite of ground based instruments composed of radars, lidars, an interferometer, and in situ meteorological instrumentation were installed at a location called the Homestead Profiling site. The site was located at an abandoned homestead near Balko, Oklahoma to provide near realtime measurement of the atmospheric boundary layer and tropospheric atmospheric state.

On 12 June 2002, a rapid oscillation within the boundary layer water vapor field was measured by several instruments deployed at the homestead site. The meteorological mesoscale water vapor variation occurred within a ten-hour period of time. The total precipitable water amount fluctuated by greater than 30% (1 cm) as measured by a Global Positioning System (GPS) receiver. An Atmospheric Emitted Radiance Interferometer (AERI) temperature and moisture profiling system indicated several drying and moistening water vapor transition events within the lower boundary layer with no reflection of this feature within the surface moisture observations. This oscillation provides a unique water vapor signal from which various remote sensing instrument comparisons can be conducted. Data will be presented indicating the magnitude and time scale of the water fluctuation, with a hypothesis provided regarding the genesis of this mesoscale water vapor feature.

2. HOMESTEAD PROFILING SITE DESCRIPTION AND INSTRUMENTATION

A suite of meteorological instruments from several federal and university organizations were deployed in the Oklahoma panhandle (Fig. 1 and Fig. 2 near Balko, Oklahoma) to measure high temporal variations of atmospheric state in support of the IHOP field campaign.

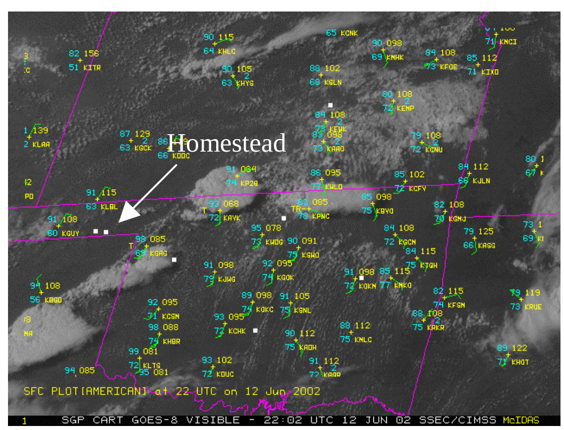

Figure 1: A GOES-8 visible satellite image of the IHOP field experiment domain. The white dots indicate locations of fixed ground based instrumentation supported by the DOE ARM (Stokes et al. 1994) program or IHOP. The location of the IHOP Homestead site is indicated.

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The instrument suite consisted of an interferometer (U of Wisconsin AERI, Fig. 3), several lidars (NASA GSFC SRL, HARLIE, and GLOW), a wind profiler (NCAR ATD MAPR), a radiosonde launch capability (NCAR ATD ISS), a boundary layer profiler (U Mass FMCW), a GPS total precipitable water system (NASA Goddard), and mobile profiling vehicles (U of Alabama MIPS and DRI MMR). The purpose of the ground based instrumentation site was to provide a fixed location for gathering high temporal resolution boundary layer and tropospheric data in support of IHOP ABL and CI research in a location where dryline development was favored. A variety of exciting data sets were obtained measuring dryline structure, bore events, convective initiation, boundary layer evolution, and rapid air mass transitions.

Figure 2: A picture of the instrumentation vehicles at the Homestead site.

A time-height cross section summary of AERI retrieved ten minute resolution boundary layer temperature and moisture profiles (Feltz et al. 1998, Feltz et al. 2002) for the IHOP campaign period (13 May – 25 June 2002) is shown in Fig. 4. Rapid air mass transitions were common at the Homestead site location. Rapid variations in thermodynamic state due to dryline passages, return flow from the Gulf of Mexico, or the low-level jet moisture advection were a regular occurrence. Some of the water vapor transitions occurred on time scales of less than six hours. One of the most dramatic of these examples occurred on 12 June 2002.

Figure 3: A picture of the University of Wisconsin – Madison AERIbago on deployment at the Homestead site. The AERIbago contains an uplooking AERI instrument and surface station.

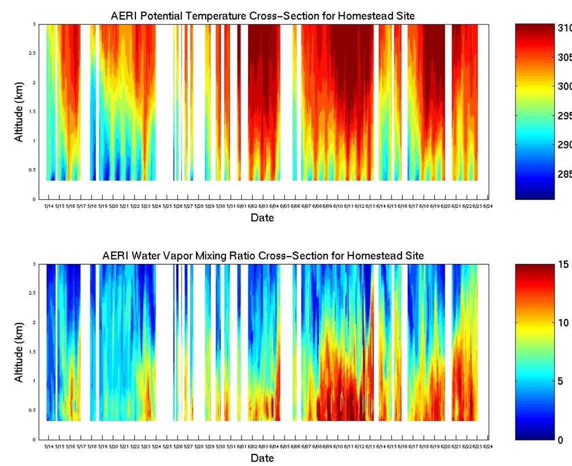

Figure 4: A time-height cross section of all AERI retrieved potential temperature and moisture profiles from 13 May – 25 June 2002 at the Homestead site. Data gaps are mainly due to precipitation and fog.

3. 12 JUNE 2002 WATER VAPOR OSCILLATION

On 12 June, a rapid oscillation within the boundary water vapor field between 0600 and 1600 UTC was measured at the IHOP Homestead site with AERIplus retrieval (Feltz et al. 2002) and GPS total precipitable water measurements (Bevis et al. 1994). Figure 5 demonstrates the rapid change within AERI derived boundary layer water vapor mixing ratio on 12 June. The water vapor mixing ratio field dries rapidly in time at approximately 0700 UTC, then moistens between 0900 –

1000 UTC and dries again between 1200 – 1300 UTC. It is interesting to note that without a profiling capability the surface water vapor mixing ratio observations gave no indication of this rapid change in water vapor amount (Fig. 6) within the ABL. Figure 6 (top panel) indicates a relatively steady state surface mixing ratio of approximately 15 g kg^{-1}. Without a high temporal resolution profiling capability, no indication of the magnitude of the boundary water vapor field transitions were reflected at the surface. If radiosondes had been launched from this location an standard synoptic times (0000 and 1200 UTC) the moisture perturbations would have also been missed altogether.

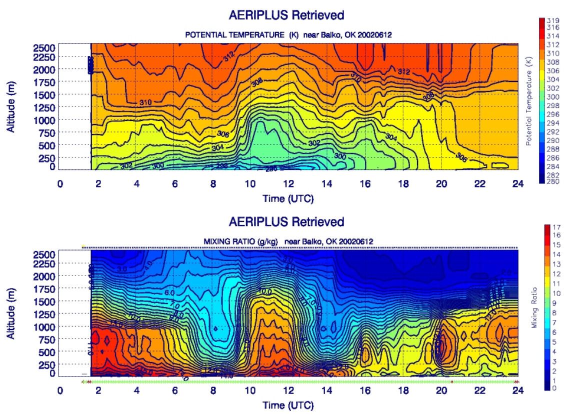

Figure 5: A time-height cross section of AERI derived potential temperature and water vapor mixing ratio from 12 June. A rapid water vapor fluctuation is apparent between 0600 and 1400 UTC.

The corresponding AERIplus potential temperature field indicates that the relatively more moist air mass between 0900 – 1200 UTC had different thermodynamic characteristics than the boundary layer air mass before or after this feature was apparent. There is also a rapid 3 C rise (Fig. 6 bottom panel) in surface temperature between 0900 – 1000 UTC which corresponds to the rapid transition in the AERIplus derived ABL potential temperature field (Fig. 5) at approximately the same time. The unique characteristics of the AERIplus potential temperature field between 1000 and 1200 UTC differing from any other period during the 24 hour time series suggests that the air mass originated from a different geographical area. A wind data set from the NCAR ATD MAPR instrument will be examined to provide further evidence of advection tendency throughout this period.

The only other local water vapor remote sensing capability that was active the night of 12 June was a GPS receiver mounted on top of the NASA GSFC Scanning Raman Lidar (the SRL is capable of high resolution water vapor profiling but was not operating this night). The GPS antenna measures wet path delay between the ground-based receiver and GPS satellite within field of view. The delay of the signal is related to the total precipitable water (TPW) vapor amount and can be used to extract the water vapor column. Since most of the water vapor variation occurred within the local ABL and most of the column water vapor exists within the ABL, the GPS TPW should corroborate the water vapor transitions indicated by the AERI system. Figure 7 (lowest panel) shows a time series of TPW from the AERIplus retrievals (black), GPS (red), and radiosondes (blue symbols). No radiosondes were launched during the event, however radiosonde measurements from the afternoon of 12 June were plotted for reference. Although there are differences in the absolute TPW measurements, the correlation of tendency of AERIplus and GPS TPW amounts was very high. The TPW variation pattern between 0500 and 1500 UTC indicates nearly a 1 cm decrease, a 1 cm increase, and finally a 1.5 cm decrease within both the AERIplus and GPS data sets. Note the effect the variability of water vapor has on the stability indices in Figure 7; the convective available potential energy is nearly 0 Jkg^{-1} at 0900 UTC, but rapidly increases to 2000 Jkg^{-1} at 1100 UTC due to the rapid water vapor mixing ratio increase. Similarly the lifted index, commonly used to quantify stability, oscillates between –5 and 0 C depending on the amount of moisture present.

Collocated hourly 20 km spatial resolution operational RUC-2 analysis (Benjamin et al 1994, 1995) profile calculations for TPW and average lowest 100 hPa parcel equivalent potential temperature (θ_e) are plotted respectively on the lower and upper panels on Figure 7. Notice that the RUC-2 TPW variation is out of phase with the observed TPW amounts and the average RUC-2 parcel θ_e is fairly flat compared to the structure observed by the AERI retrievals. The RUC-2 model assimilates hourly in situ and remote sensing observations to provide a twelve hour forecast. The model is most likely not resolving these mesoscale water vapor fluctuations because of the lack of temporal and spatial resolution within the observations used within the analysis between non-synoptic times.

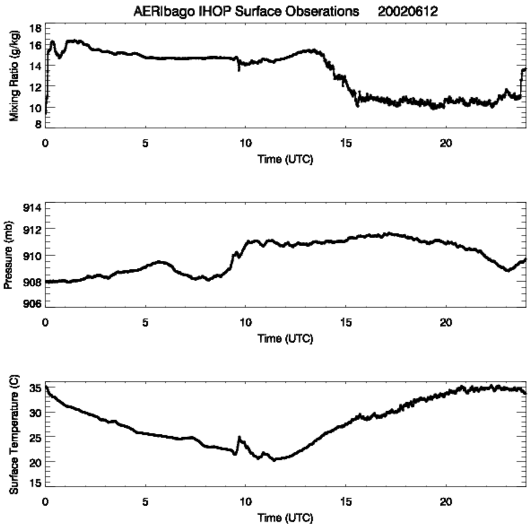

Figure 6: Time series of water vapor mixing ratio, atmospheric pressure, and temperature surface observation at the Homestead profiling site from 12 June.

One set of observations which has the spatial and temporal resolution to improve the initial analysis is hourly Geostationary Operational Environmental Satellite (GOES) sounder derived TPW (Ma et al. 1999, Menzel et al. 1998, Schmit et al 2002). Figure 8 indicates GOES-11 (green diamond) and GOES-8 (light blue diamond) single field of view (10 km x 10 km) TPW during 12 June. Notice that even though the GOES satellite sounder TPW is retrieved over a relatively large spatial domain for the mesoscale water features, the water vapor amount tendency is consistent with the AERIplus and GPS TPW until 1100 UTC when the TPW amounts fail to capture the increase and decrease. The RUC-2 model uses GOES sounder TPW but primarily over the oceanic regions within the model domain. In this case the GOES sounder TPW would have provided useful integrated water vapor horizontal structure to the RUC-2 initial analysis (purple line).

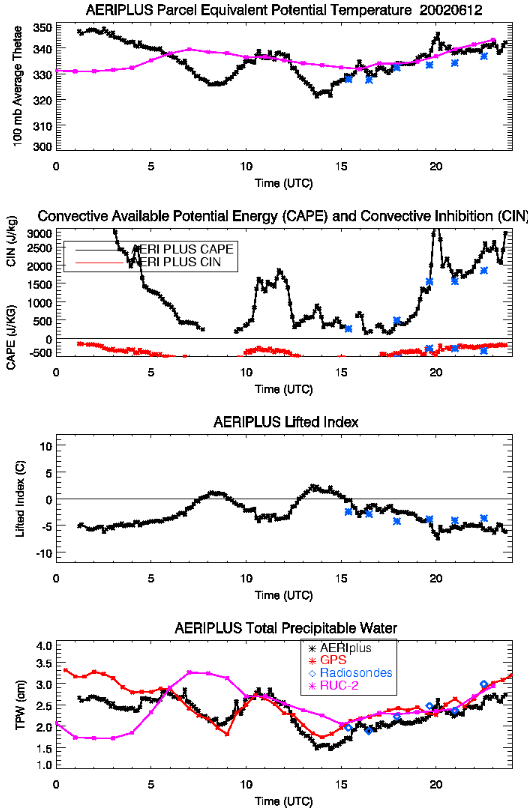

Figure 7: Time series of AERI derived parcel equivalent potential temperature, CAPE, CIN, LI, and TPW for 12 June. Coincident radiosonde (blue diamond), GPS TPW (red), and RUC2 analysis (magenta) data are plotted in conjunction with the AERIplus data for comparison. Notice the RUC-2 analysis is out of phase with the water vapor oscillation apparent in the AERIplus and GPS TPW data.

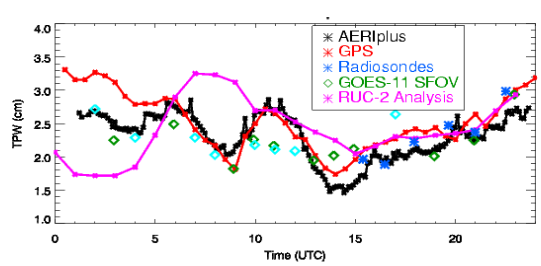

Figure 8: A time series comparison of all possible Homestead site TPW measurements on 12 June: AERIplus (black), GPS (red), radiosondes (dark blue), and GOES 11 (green)/ GOES-8 (light blue) SFOV. The RUC-2 20 km analysis profiles collocated with the Homestead site are also shown.

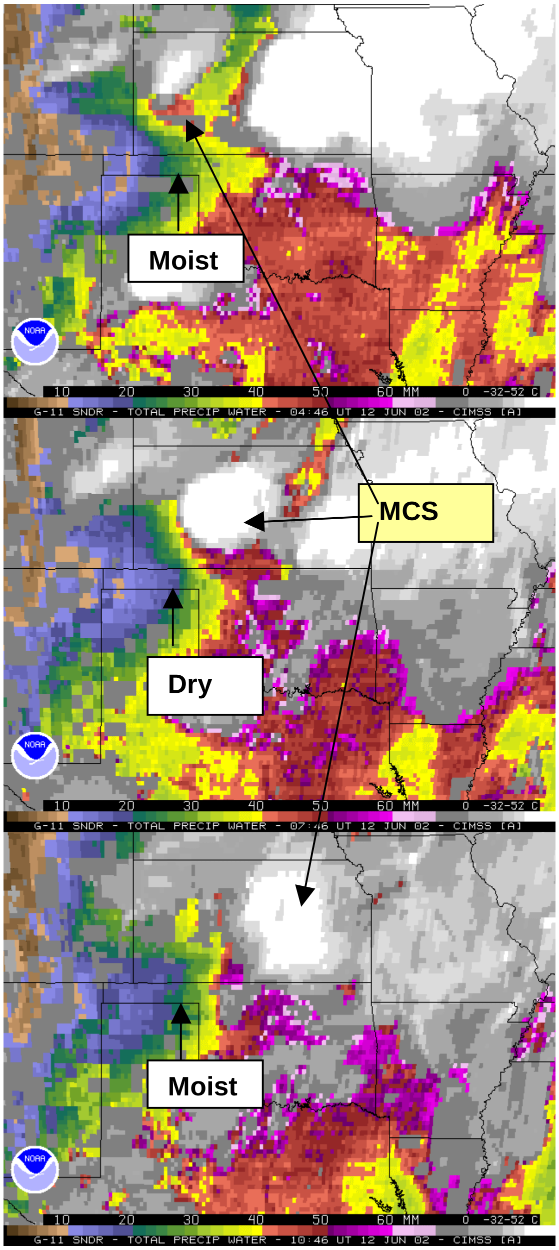

Figure 9: A series of GOES-11 sounder derived total precipitable water on 12 June for 0446, 0746, and 1046 UTC (top to bottom). The approximate location of the IHOP Homestead site is indicated by the arrows labeled moist and dry.

Preliminary analysis of the cause of the meteorological events described within this paper indicates that a Mesoscale Convective System (MCS) to the north-northeast of the Homestead site may have played a role. Figure 9 contains a series of three GOES-11 sounder derived TPW images selected at times correlated to the water vapor variations in Figure 5. The TPW data within the imagery contains the extracted site specific GOES-11 TPW data in Figure 8. A strong water vapor gradient is evident throughout the time period across the panhandle domain. To the north-northeast of the site, a MCS moves from northwest to southeast through the period. The oscillation, though somewhat subtle within static imagery, is readily apparent within an animation. It is speculated that the MCS directly or indirectly caused the water vapor transitions over the Homestead site. Satellite imagery indicates that another possible mechanism for the water vapor oscillation was a mesoscale vortex, which rotated through the Homestead site domain. An MM-5 Numerical Weather Prediction (NWP) model run, initialized with IHOP data, may provide trajectory evidence as well as MAPR boundary layer wind profiler data will also be analyzed to better understand the advection tendencies at the over the Homestead site.

4. CONCLUSIONS

A rapid variation of water vapor within the planetary boundary layer was detected by an AERI profiling instrument and GPS receiver measurements at the IHOP Homestead profiling site on 12 June. The water vapor amount varied by over 1 cm of total precipitable water (greater than 30%) three times within a period of ten hours. These water vapor amount transitions were not detectable by surface moisture observations and could only be resolved with high temporal remote sensing capability. This oscillation provides a unique water vapor signal from which various remote sensing instrument comparisons can be conducted. The water vapor oscillations, though large in magnitude were not present in the operational hourly RUC-2 initial analysis profiles collocated with the Homestead site. In situ and remotely sensed IHOP data sets will be used to improve the initial analysis for the Penn State MM5 version 3.5 NWP model specifically for this case study. Future work includes the analysis of Penn State MM5 version 3.5 NWP model data and wind profiler data to understand the origin and interaction of the water vapor features observed over the Homestead site and the MCC complex.

5. ACKNOWLEDGEMENTS

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