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CHARACTERIZATION AND VISUALIZATION OF WATER VAPOR AND ATMOSPHERIC STABLITY DURING THE IHOP FIELD EXPERIMENT

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1. INTRODUCTION

The International H_2O Project (IHOP) investigated the three-dimensional distribution of water vapor over the Southern Great Plains region from May 13 to June 25 of 2002, by employing technologically advanced airborne and in situ water vapor sensors. IHOP's objective was to create an improved characterization of water vapor and determine how current forecasting capabilities could benefit from this research. Of particular interest was the influence of water vapor and atmospheric stability upon deep convection (Weckworth and Parsons, 2003). As part of IHOP, NASA Langley Research Center's Lidar Atmospheric Sensing Experiment (LASE) collected data concerning the water vapor, clouds, and aerosols along fronts and drylines during convective initiation events by utilizing Differential Absorption Lidar (DIAL) technology aboard the NASA DC-8 aircraft (Browell et al., 2003). From the data, vertical profiles of equivalent potential temperature and water vapor mixing ratio were derived and compiled with surface observations from the National Weather Service's Automated Surface Observing System (ASOS) to create three-dimensional visualizations. The visuals help characterize convective initiation in the vicinity of fronts and drylines and provide additional insight into the distribution of water vapor. Additionally the visuals were compared to Rapid Update Cycle (RUC) model analyses.

2. INSTRUMENTATION

LASE is an airborne DIAL system that measures water vapor, aerosols, and clouds throughout the troposphere (Browell and Ismail, 1995; Moore et al., 1997). LASE operates using strong and weak water vapor absorption cross sections in the 815-nm absorption band of water vapor, thereby enabling simultaneous measurements above and below the aircraft. LASE simultaneously measures aerosol backscattering profiles at the off-line wavelength near 815 nm. Typical horizontal and vertical resolutions for water vapor profiles are 14 km (1 min) and 330 m, respectively. LASE water vapor mixing ratio measurements have an accuracy of better than 6% or 0.01 g/kg, whichever is larger, across the troposphere (Browell et al., 1997). Profiles of the total scattering ratio, defined as the ratio of total (aerosol and molecular) scattering to molecular scattering, are determined by normalizing the scattering in the region containing enhanced aerosol scattering to the expected scattering by the "clean" atmosphere at that altitude. These aerosol measurements typically have horizontal and vertical resolutions of 45 m and 30 m, respectively.

During IHOP, temperature profiles were derived from infrared radiances measured by the University of Wisconsin Scanning High-resolution Interferometer Sounder (S-HIS), which was also deployed on the DC-8 (Revercomb et al., 1998). This instrument measures emitted thermal radiation at high spectral resolution between 3.3 and 18 μm. The measured emitted radiance is used to obtain temperature and water vapor profiles of the Earth's atmosphere. S-HIS produces sounding data with 2 kilometer resolution (at nadir) across a 20 km ground swath from a nominal altitude of 10 km aboard the NASA DC-8 aircraft. Dropsondes deployed from the Flight International Learjet also provided periodic profiles of pressure, temperature, humidity, and winds.

3. MEASUREMENTS

Convective initiation flights were flown by the DC-8 aircraft on May 24 and June 9, 2002. For May 24, a north-south oriented dryline associated with very dry conditions to the west and very moist conditions to the east was detected over the Texas panhandle. Unstable conditions indicative of deep convection existed within the moist sector; rapid decreases of equivalent potential temperature (θ_e) with height, high values of Convective Available Potential Energy (CAPE), and low values of Convective Inhibition (CIN). The flight path of the DC-8 traversed the northern Texas panhandle and then into western Oklahoma as it flew from west to east between 18:28 and 18:53 UTC (Browell et al., 2003). The flight

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was concluded when convection initiated along and in front of the dryline in southwest Oklahoma (Ferrare et al., 2004b).

For June 9, the atmospheric conditions were similar to that on May 24 in that a dryline was present with strong moisture gradients. Seeing that conditions appeared conducive for convection, the DC-8 aircraft flew over the Texas and Oklahoma panhandles to collect data (Browell et al., 2003). Cross-sections of θ_e revealed unstable conditions and high values of CAPE (1500 to 3000 J/kg) were derived from the LASE water vapor profiles. However, the occurrence of deep convection was prevented on this day by high values of CIN (200 J/kg) associated with a strong capping inversion in Oklahoma (Ferrare et al., 2004b).

4. VISUALIZATIONS

Three-dimensional visualizations of LASE measurements and other IHOP datasets were created by students in NASA's DEVELOP program (http://develop.larc.nasa.gov/) to depict the water vapor distribution and atmospheric stability on May 24 and June 9, 2002 (Ferrare et al., 2004a). For each day, two visuals were created. One depicted water vapor mixing ratio, and the other displayed equivalent potential temperature. All of the visuals were created in the same manner and resembled one another to ease the comparison process. The visuals begin by showing the flight path of the DC-8 aircraft on a map of the Southern Great Plains. Surface data from ASOS then begins to fade between 15:00 UTC to 23:00 UTC to show the evolution of the distribution of water vapor and stability before and after the flight of the LASE instrument. Additionally, to further aid in the understanding of the development of convective initiation, the cold front and drylines, as well as an array of wind barbs, are superimposed upon the ASOS data. Once the visual fades to 18:00 UTC, near the time of flight for the DC-8 for both days, the vertical profiles derived from the LASE data are revealed. Moreover, values for CAPE and CIN, also computed from the LASE data, are graphically represented within the visuals by red and blue columns respectively.

Furthermore, two-dimensional visualizations of CAPE were created for June 9 and May 24 using RUC model analyses to compare the actual CAPE values (the LASE derived values) to those that were predicted by the model. These visuals show the progression of CAPE from 15:00 UTC to 23:00 UTC. All visualizations were created with commercial software packages.

5. RESULTS

The three-dimensional visualizations for May 24 and June 9 show general agreement between the LASE and ASOS data by reporting matching water vapor mixing ratios and equivalent potential temperatures at the point of intersection between the surface and vertical profiles. This attests to the precision and accuracy of the high resolution measurements produced by the LASE instrument.

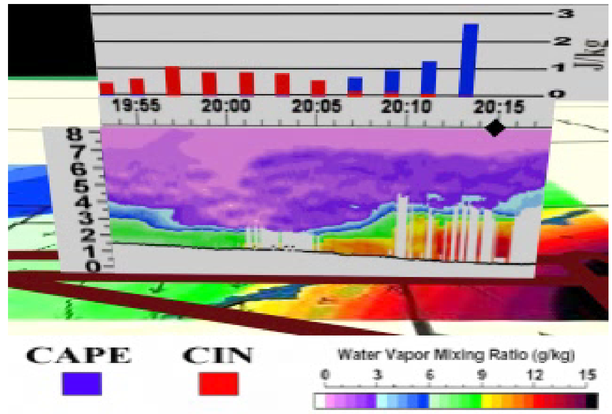

Figure 1. Water vapor mixing ratio from ASOS and LASE combined with CAPE and CIN measurements, in thousands of J/kg, on May 24, 2002.

The May 24 visuals of water vapor mixing ratio and equivalent potential temperature show prime conditions for convective initiation: unstable air, atmospheric lift, and high amounts of water vapor within the atmosphere. A dryline is located to the southeast of a cold front at 15:00 UTC, but the systems converge at 19:00 UTC and provide a mechanism for atmospheric lift. Additional evidence of rising air near the cold front is the convergence of the winds in this region. The ASOS data on the equivalent potential temperature visual show that the values of θ_e increase to the east of the cold front, and the gradient tightens as time progresses. The vertical profile of θ_e depicts unstable air associated with both the dryline and cold front. The water vapor mixing ratio visual shows a tight gradient of moisture ahead of the dryline, and the vertical profile reveals the extent at which the moisture extends upward. Lastly, the values derived from the LASE instrument for CAPE are high, and the derived values of CIN are low. Thus, all elements for convection were met on May 24, and storms were produced.

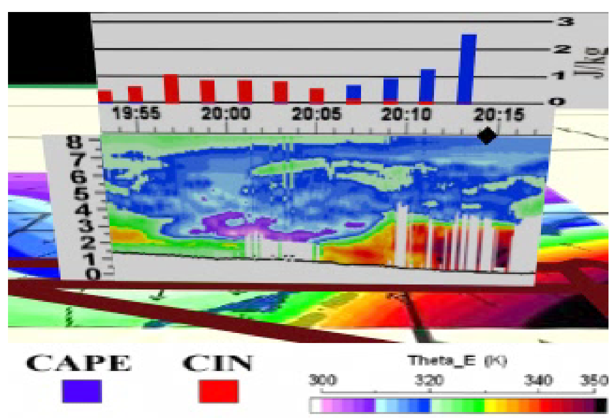

Figure 2. θ_e from ASOS and LASE on May 24, 2002 combined with CAPE and CIN measurements in thousands of J/kg.

For June 9, the atmosphere was more unstable than that on May 24, but convection did not initiate. A dryline was oriented north-south over the Texas and

Oklahoma panhandles. East of the dryline, θ_e rapidly increases with height, as seen in the equivalent potential temperature visual, and sufficient moisture is present according to the data presented in the water vapor mixing ratio visual. CAPE values are also indicative of convection. However, the strong convergence in the wind field, and thus the rising motion, is not as prominent as it was on May 24. Additionally, and more notably, a strong capping inversion that produced high CIN values was present in Oklahoma and prevented convection from initiating.

CAPE and CIN values derived from the LASE measurements and computed by the RUC model for both May 24 and June 9 were compared. The comparisons showed generally excellent agreement, as the differences that occurred were not statistically significant. Comparisons were also made for the regions where the CAPE values were above and below 1000 J/kg. At the lower values of CAPE, large differences occurred with the CAPE derived from the LASE measurements being much greater than the corresponding values from the RUC model. At these lower measurements, the difference was found to be statistically significant. Where the values of CAPE exceed 1000 J/kg, the CAPE values represented by the RUC model were consistently higher than the CAPE derived from the LASE data. However, the overall analysis concluded that the differences between the CAPE values computed from the LASE data and RUC model were not significant.

6. SUMMARY

Three dimensional visualizations of equivalent potential temperature and water vapor mixing ratio, which combine data from the LASE instrument and ASOS, were produced. The visuals were integral in a comparison of the variability of water vapor during a convective (May 24) and a non-convective (June 9) case. Visuals of the progression of CAPE and CIN using RUC model analyses for the same cases were also produced. The thermodynamic stability as represented by the RUC model was compared to the actual values of CAPE as derived by LASE through the use of a statistical analysis. This analysis revealed no significant difference between the two sets of values.

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