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CHARACTERIZATION AND VISUALIZATION OF WATER VAPOR AND AEROSOL FIELDS OVER THE SOUTHERN GREAT PLAINS DURING THE IHOP FIELD EXPERIMENT

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1. INTRODUCTION

During the International H_2O Project (IHOP) field mission conducted over the Southern Great Plains during May-June 2002, a large array of state-of-the-art ground-based and airborne remote and in situ sensors provided extensive measurements of water vapor in order to better understand the influence of water vapor variability on the initiation of deep convection and to improve the quantification and prediction of precipitation associated with these storms (Weckwerth and Parsons, 2003). These sensors included the NASA Langley Lidar Atmospheric Sensing Experiment (LASE) airborne DIAL system, which was deployed from the NASA DC-8 aircraft. Water vapor profiles measured by LASE are used to derive distributions of relative humidity, equivalent potential temperature, and stability indices in order to help understand the role of water vapor on convective initiation. Profiles of aerosol scattering ratio, which were also measured by LASE, are used in conjunction with Terra Moderate Resolution Imaging Spectroradiometer (MODIS) retrievals of aerosol optical thickness to examine the distribution of aerosols over the Southern Great Plains (SGP). These datasets show the presence of smoke from forest fires in New Mexico and Colorado. The LASE data and other IHOP datasets are used to create visualizations of the water vapor and aerosol fields in order to gain a better understanding of the three dimensional distributions of water vapor and aerosols over the Southern Great Plains.

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2. INSTRUMENTATION

LASE is an airborne DIAL (Differential Absorption Lidar) system that was developed to measure water vapor, aerosols, and clouds throughout the troposphere (Browell et al., 1995; Moore et al., 1997). This system uses a double-pulsed Ti:sapphire laser, which is pumped by a frequency-doubled flashlamp-pumped Nd:YAG laser, to transmit light in the 815-nm absorption band of water vapor. LASE operates by locking to a strong water vapor line and electronically tuning to any spectral position on the absorption line to choose the suitable absorption cross-section for optimum measurements over a range of water vapor concentrations in the atmosphere. LASE operated using strong and weak water vapor lines, thereby simultaneously acquiring data both 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 300 m, respectively. Comparisons of water vapor measurements made by airborne dew point and frost point hygrometers, NASA/GSFC Raman lidar, and radiosondes showed the LASE water vapor mixing ratio measurements to 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 (cloud+aerosol+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 provided below the DC-8 by the Scanning High-resolution

Interferometer Sounder (S-HIS) (Revercomb et al., 1998). This instrument measures emitted thermal radiation at high spectral resolution between 3.3 and 18 microns. 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 horizontal resolution (at nadir) across a 20-kilometer ground swath from a nominal altitude of 10 kilometers aboard the NASA DC-8 aircraft.

3. IHOP

The main objectives of IHOP are to better understand the influence of water vapor variability on the initiation of deep convection and to improve the quantification and prediction of precipitation associated with these storms. IHOP measurements were acquired during May and June 2002. LASE and S-HIS acquired data during eight DC-8 flights between May 23 and June 14. The LASE data acquired on these flights are being used to investigate convective initiation, boundary layer development, boundary layer heterogeneity, nocturnal low level jets, and morning low level jets (Browell et al., 2003). Here we focus on how these data are being used to visualize the water vapor and aerosol distributions and examine atmospheric stability.

4. MEASUREMENTS

On 9 June 2002, the NASA DC-8 flew a Convective Initiation (CI) flight over the SGP region (Browell et al., 2003). Figure 1 shows a portion of the DC-8 flight track on this day. Figure 2 shows water vapor profiles measured by LASE, and relative humidity and equivalent potential temperature (θ_e) profiles derived from the LASE water vapor and S-HIS temperature profiles measured along the southern east-west leg (leg A) of this pattern. Note the rapid decrease in moisture going from east to west along this line as shown by the water vapor mixing ratios decreasing from about 15 g/kg to 3 g/kg and relative humidities decreasing from 80-90% to less than 10%. The dryline position was estimated to be around 103 W during this leg. The cross section of θ_e indicated that the atmosphere was convectively unstable throughout this region. However, as the dryline moved eastward through the domain during the day, no convection occurred in this region due to the strong capping inversion that was present over the Oklahoma Panhandle region.

Convective Available Potential Energy (CAPE) and Convective Inhibition (CIN) were computed along the DC-8 flight track using the LASE water vapor and the S-HIS temperature profiles. Figure 3 shows CAPE and CIN along the three east-west legs shown in Figure 1. The southern leg (denoted by A in Figure 1) had high values of CAPE (1500-3000 J/kg) indicative of moderate to high convective instability. The central and northern legs had smaller values indicating that convective instability decreased going northward from Texas into Oklahoma and Kansas. Figure 3 also shows that there were also high values of CIN (50-200 Joules/kg) along the southern leg, with even higher values along the central and northern legs. These CIN values show that, without the presence of a convergence line and associated lifting, no deep convection could be expected in this area. Small cumulus clouds did form but no convection occurred over this area on this day. CAPE, CIN, and θ_e are being computed using the LASE and S-HIS profiles for other DC-8 flights during IHOP to investigate how variations in water vapor distributions impact convective instability.

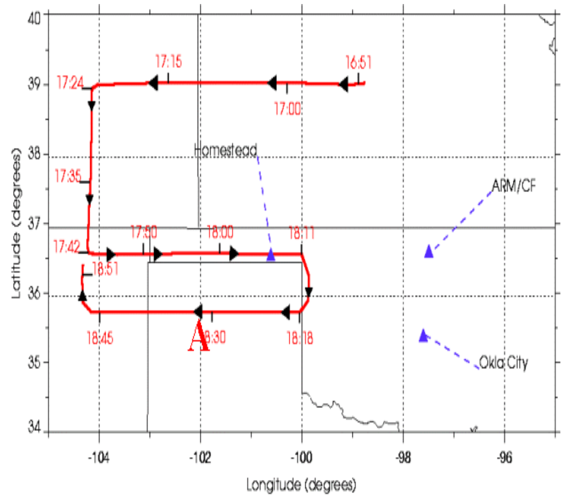

Figure 1. Portion of DC-8 flight track on June 9, 2002 during IHOP. Leg A is the southernmost east-west leg flown between 18:19-18:45 UT.

The aerosol scattering ratio profiles measured by LASE during this flight show an elevated aerosol layer extending to nearly 6 km. An example of this layer is shown in Figure 2. Visual observations, satellite observations, and air parcel back trajectory analyses show these layers to be associated with smoke from forest fires in New Mexico (Browell et al., 2003). Aerosol optical thicknesses (470 nm) derived from Terra MODIS imagery and ground based Sun photometer measurements varied from 0.2 to 0.3 in the regions where the smoke was observed.

5. VISUALIZATIONS

Three-dimensional visualizations of water vapor and aerosols were created by students in NASA's DEVELOP project (http://develop.larc.nasa.gov/) using the LASE measurements and other IHOP datasets. These visualizations provide additional insight into the distributions of water vapor and aerosols over this region, aid in understanding the role of water vapor on convective instability, and provide an opportunity for students to learn about atmospheric processes and become proficient in 3-D modeling and animation software. Datasets used in the visualization include: precipitation derived from the National Weather Service (NWS) radars, cloud field derived from GOES-11 visible and near infrared imagery, surface temperature and

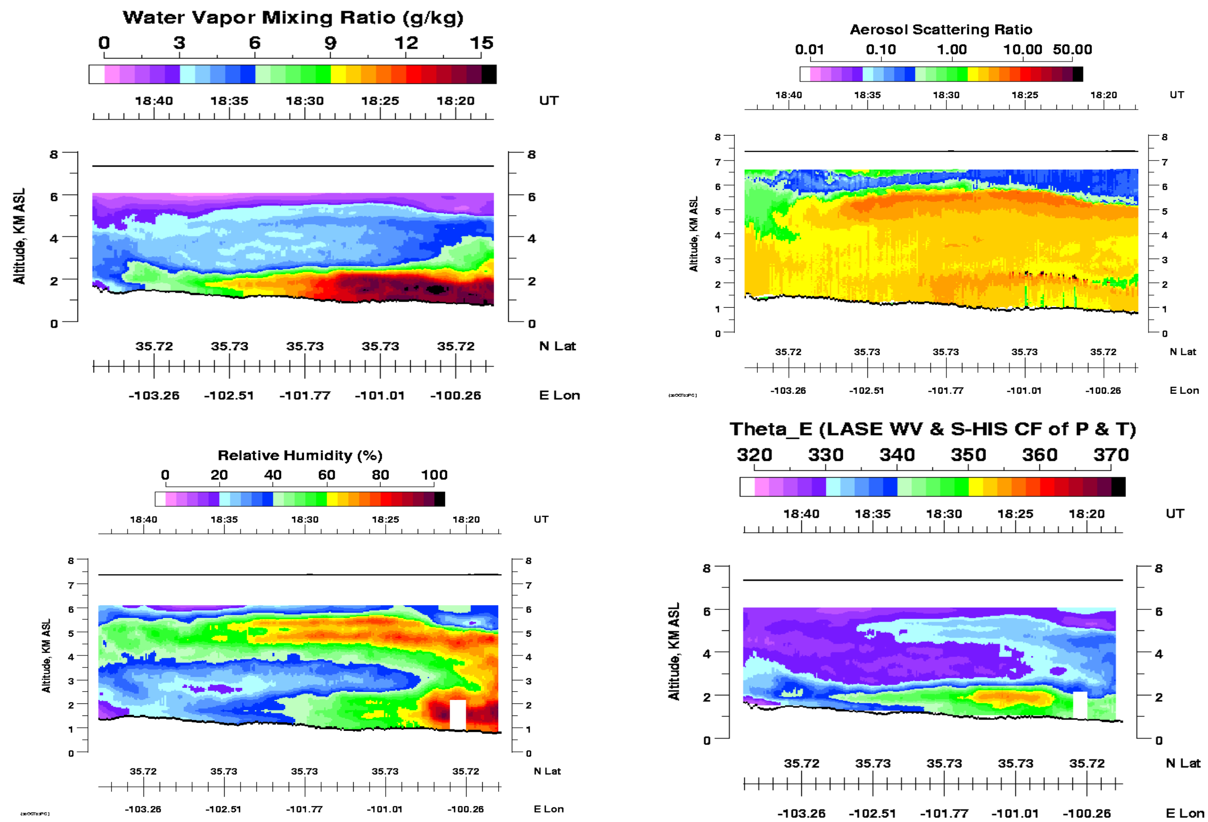

Figure 2. Water vapor mixing ratio (top left) and aerosol scattering ratio (top right) profiles measured by LASE on June 9, 2002 along flight leg A shown in Figure 1. The DC-8 flew from east (right) to west (left) on this leg. Relative humidity (bottom left) and θ_e profiles (bottom right) derived from LASE water vapor and SHIS temperature profiles along this same track.

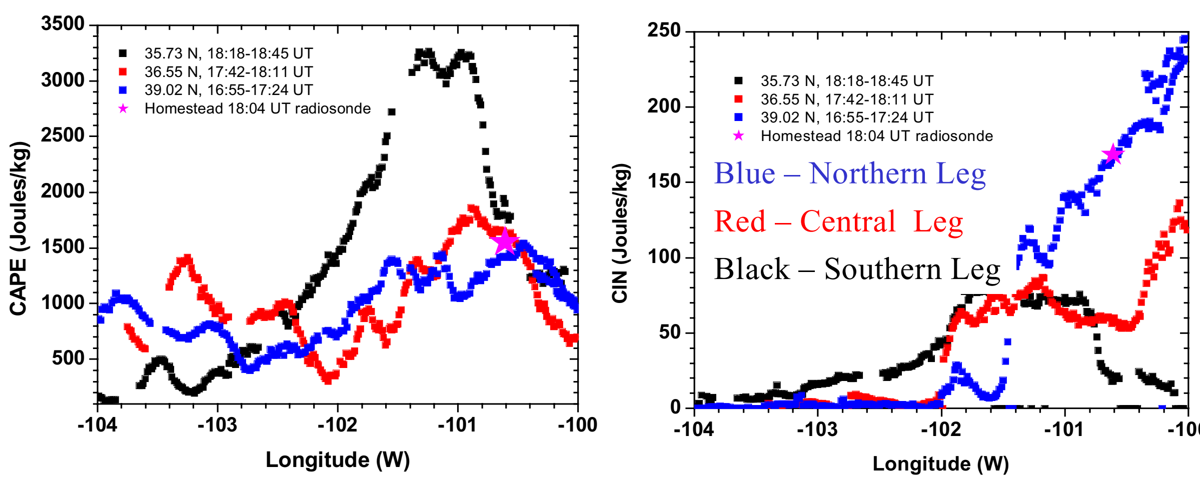

Figure 3. CAPE (left) and CIN (right) derived from LASE water vapor and SHIS temperature profiles measured on June 9, 2002 along DC-8 flight track shown in Figure 1. Leg A shown in Figures 1 and 2 is denoted by the Southern Leg (black) in this figure.

moisture fields measured by the Oklahoma Mesonet, and precipitable water vapor and aerosol optical thickness derived from the Terra MODIS sensor. Commercially available software packages were used to transform the datasets in standardized formats, produce three-dimensional "fly-through" animations, and edit the video excerpts. We will present examples of these visualizations.

6. SUMMARY

LASE water vapor profiles collected during the IHOP campaign have been used to derive distributions of relative humidity, equivalent potential temperature, and stability indices in order to help understand the role of water vapor on convective initiation. LASE profiles of aerosol scattering ratio have been used in conjunction with Terra MODIS retrievals of aerosol optical thickness to study the three-dimensional distribution of aerosols over the region. These and other datasets have been combined to form three-dimensional visualizations of water vapor and aerosols over the Southern Great Plains.

7. ACKNOWLEDGEMENTS

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