1.6 LARGE-SCALE WATER VAPOR, AEROSOL, AND CLOUD DISTRIBUTIONS DETERMINED FROM AIRBORNE LIDAR (LASE) MEASUREMENTS DURING THE IHOP FIELD EXPERIMENT

Edward V. Browell*, S. Ismail, R. A. Ferrare
NASA Langley Research Center, Hampton, Virginia

S. A. Kooi, A. Notari, and C. F. Butler
SAIC/NASA Langley Research Center, Hampton, Virginia

1.0 INTRODUCTION

The Lidar Atmospheric Sensing Experiment (LASE) was flown on the NASA DC-8 aircraft to investigate large-scale variations in water vapor, aerosols, and clouds during the International H2O Project (IHOP) conducted over the Southern Great Plains during May-June 2002. During IHOP, LASE data were used on several missions to examine the spatial and temporal characteristics of the dry line and fronts and the onset of convection along them, as well as to map the gradients in the boundary layer water vapor field. This paper describes the LASE system and presents measurements of water vapor, aerosols, and clouds from the IHOP field experiment.

2. LASE SYSTEM

LASE is an airborne DIAL (Differential Absorption Lidar) system that was developed to measure water vapor, aerosols, and clouds throughout the troposphere. 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. For the IHOP mission, LASE operated from the NASA DC-8 aircraft, and used strong and weak water vapor lines in both the nadir and zenith modes, thereby simultaneously acquiring data both below and above the aircraft. Comparisons of water vapor measurements made by airborne dew point and frost point hygrometers; the 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). LASE also simultaneously measures aerosol backscattering profiles at the off-line wavelength near 815 nm. Profiles of the aerosol scattering ratio, defined as the ratio of aerosol scattering (including clouds) to molecular scattering, are determined by ratioing the scattering in the region containing enhanced aerosol scattering to the expected scattering by the "clean" atmosphere at that altitude. The vertical resolution of the LASE water vapor measurements is adjustable from 100 to 300 m in post-mission processing with a horizontal resolution of about 13 km (1-minute running average). The aerosol and cloud backscatter measurements were made with a vertical and horizontal resolution of 30 and 45 m, respectively.

3. IHOP FIELD EXPERIMENT

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 brought together a large array of airborne and ground-based remote sensors to investigate a set of related atmospheric processes, including convective initiation (CI), boundary layer development, boundary layer heterogeneity, nocturnal low-level jets, and morning low-level jets. All of these targeted investigations, which were the subject of individual flight missions, contribute to a better understanding of the basic atmospheric processes associated with convective initiation and precipitation quantification.

Will Rogers World Airport in Oklahoma City, Oklahoma (35.39N, 97.60W) was the base of aircraft operations during IHOP. LASE participated in eight DC-8 flight missions between 23 May and 14 June 2002. Four CI flights and one flight each of the other types of investigations were made with LASE during IHOP under widely varying atmospheric conditions. LASE measured nadir and zenith water vapor, aerosol, and cloud profiles along the flight track of the DC-8, which was nominally flown at an altitude of 7.3 km (24 kft).

4. LASE MEASUREMENTS

During IHOP, the data from LASE were used on several missions to examine the spatial and temporal characteristics of the dry line and fronts and the onset of convection along them. A classic case of CI was observed on 24 May when LASE was flown on a large-scale mapping mission over the region of intensive aircraft and ground observations in the western panhandle of Oklahoma and northern panhandle of Texas. LASE observed strong gradients of water vapor across the front to the north and very dry conditions on the west side of the north-south dry line and very moist conditions on its east side. Figure 1 shows water vapor,

**Corresponding author address:* Dr. Edward V. Browell, NASA Langley Research Center, Mail Stop 401A, Hampton, Virginia, 23681

aerosol, and cloud distributions as the DC-8 flew from west to east over the Texas Panhandle and western Oklahoma between 19:53 and 20:17 UT on May 24. Data were taken until thunderstorms developed in the southeast region of the observation area and rapidly propagated in the northwest direction. Several more CI missions were flown under varying atmospheric conditions, and as expected, it was difficult for the forecasters to predict where and when CI would start. LASE data were obtained on each of the other investigations mentioned above, and extensive intercomparisons opportunities were available in each flight mission between the various airborne and ground-based lidar systems. The complementarity of measurements made from the different aircraft and ground sites makes this a unique data set for studying convective initiation and precipitation.

Figure 2 shows another example of water vapor and aerosol distributions measured by LASE when the DC-8 flew from west to east over eastern Colorado and western Kansas on June 9. The LASE water vapor image clearly shows the large increase in water vapor along this track as surface mixing ratios increased from 3 to 15 g/kg over a horizontal distance of about 350 km. LASE data also show an elevated aerosol layer extending to nearly 6 km over much of this track. Visual observations and satellite data show this elevated layer to be associated with a smoke plume generated by forest fires in eastern Colorado. Relative humidity profiles were generated from LASE water vapor profiles and temperature profiles from radiosondes launched from nearby Department of Energy Atmospheric Radiation Measurement (ARM) sites. Figure 2 shows that the enhanced backscattering in this elevated layer was also associated with high relative humidity and was likely due in part to hygroscopic growth of aerosol particles. These LASE data, along with additional

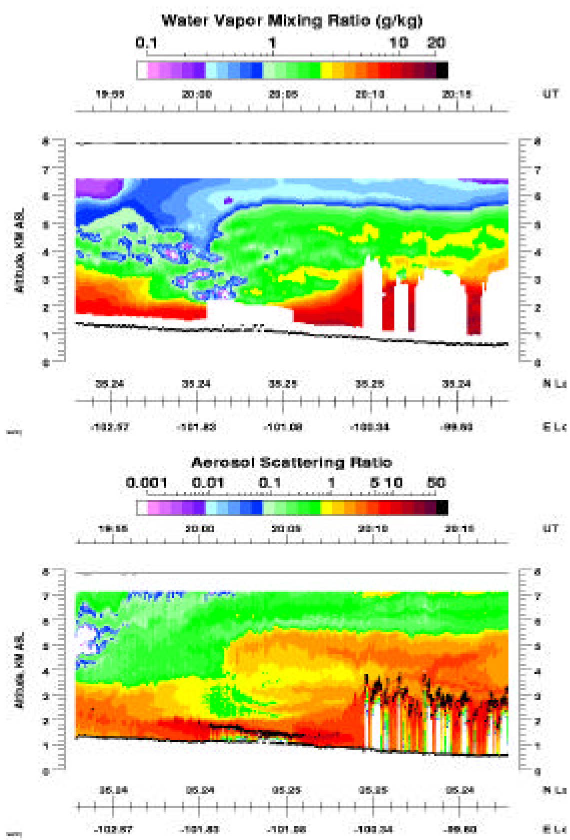

Figure 1. LASE water vapor (top) and aerosol scattering ratio (bottom) profiles measured during DC-8 flight 5 on May 24, 2002 during IHOP.

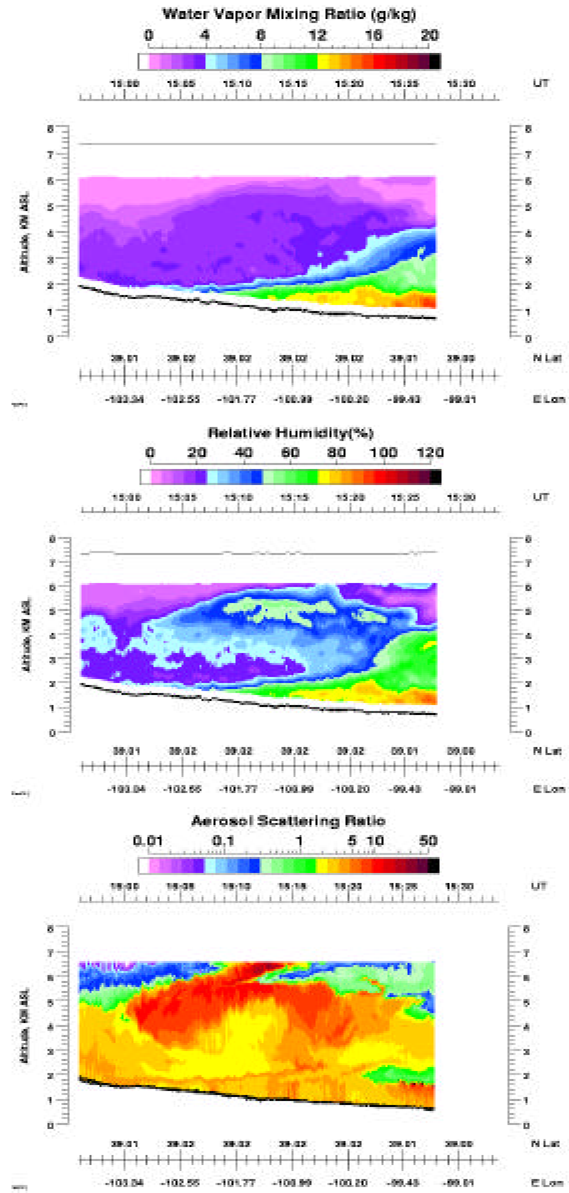

Figure 2. LASE water vapor (top), relative humidity (middle), and aerosol scattering ratio (bottom) profiles measured during DC-8 flight 9 on June 9, 2002 during IHOP. Relative humidity profiles were constructed using LASE water vapor profiles and temperature profiles from nearby radiosondes.

surface and satellite based measurements, provide a valuable dataset for studying the optical properties of smoke from these fires.

5. SUMMARY

LASE provided detailed water vapor measurements during several DC-8 flights during IHOP. These data provide a unique perspective into the role of water vapor in convective initiation and severe storm development. LASE also measured aerosol distributions associated with smoke from forest fires in Colorado. Work is underway to combine the LASE measurements with other IHOP airborne and ground-based measurements to assess the impact of high resolution water vapor profiles on investigations of the development of the convective boundary layer, forecasts of convective initiation, and relationships between surface and boundary layer processes.

6. ACKNOWLEDGEMENTS

We thank George Insley, Jerry Williams, and Nick Kepics for their support of LASE in IHOP. Dr. Jim Dodge, NASA Headquarters, provided financial support for the deployment of LASE during this mission. Radiosonde data were provided by the Department of Energy Atmospheric Radiation Measurement (ARM) Program.

7. REFERENCES

Browell, E., et al. 1997: LASE validation experiment, in Advances in Atmospheric Remote Sensing with Lidar, A. Ansmann, R. Neuber, P. Rairoux, and U. Wandinger, eds., Springer-Verlag, Berlin, 289-295.