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Title: Airborne Watar Vapor DIAL System and Measurements of Water Vapor and Aerosol Profiles

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The Lidar Applications Group at the NASA Langley Research Center has developed a differential absorption lidar (DIAL) system for the remote measurement of atmospheric water vapor (H_2O) and aerosols from an aircraft. The airborne H_2O DIAL system is designed for extended flights to perform mesoscale investigations of H_2O and aerosol distributions. This DIAL system utilizes a Nd:YAG-laser-pumped dye laser as the off-line transmitter and a narrowband, tunable Alexandrite laser as the on-line transmitter. The dye laser has an oscillator/amplifier configuration which incorporates a grating and prism in the oscillator cavity to narrow the output linewidth to approximately 15 pm. This linewidth can be maintained over the wavelength range of 725-730 nm, and it is sufficiently narrow to satisfy the off-line spectral requirements. In the Alexandrite laser, three intracavity tuning elements combine to produce an output linewidth of 1.1 pm. These spectral devices include a five-plate birefringent tuner, a 1-mm thick solid etalon and a 1-cm air-spaced etalon. A wavelength stability of ±0.35 pm is achieved by active feedback control of the two Fabry-Perot etalons using a frequency stabilized He-Ne laser as a wavelength reference. The three tuning elements can be synchronously scanned over a 150 pm range with microprocessor-based scanning electronics.

For accurately positioning the on-line laser to the center of the H_2O line, we utilize a 1-meter monochromator and a multipass absorption cell. The monochromator incorporates an optical multichannel analyzer to achieve a measurement resolution of 20 pm. This system is used to set the output wavelength close to the H_2O absorption line of interest. The absorption cell is heated to 60°C and filled with approximately 40 torr of pure H_2O. With these environmental conditions and a 100 m pathlength, there is sufficient optical depth to accurately center the wavelength on any H_2O line with a line strength greater than 10^{-24} $cm^{-1}(cm^2/molecule)$. An energy ratiometer is then used to measure the amount of absorption through the multipass cell as the laser wavelength is scanned across the line. When the maximum absorption is reached, the laser is locked on the line by the active wavelength control.

The receiver system has a 14-inch-diameter, f/7 Celestron telescope to collect the backscattered laser light and focus it into the detector optics. An adjustable field stop is placed in the focal plane of the telescope to provide a variable field-of-view. The detector optics consist of a collimating lens, a beamsplitter, and an interference filter, which has a bandwidth of 0.38 nm (FWHM) and a transmission of 32 percent. After transmission through the filter, the return signals are directed to the detector, which can be either a photomultiplier (PMT) tube or an avalanche photodiode.

After the return signals are converted to electrical signals by the optical detector, they are sent to the digitizers contained in the data acquisition system (DAS). The signals are then digitized to 12 bits at 10 MHz over 4096 words and stored on magnetic tape. The HV power supply for the PMT is housed in the DAS so that the dynamic range of the measurement can be controlled from there. In addition, the DAS has computers and monitors for signal processing and data display, which facilitate real-time experiment control. The aerosol and H_2O distributions derived by the DAS are plotted in real time on color printers.

The airborne H_2O DIAL system was flight tested in July 1989 on board the Electra aircraft at the NASA Wallops Flight Facility. Preliminary H_2O distributions were obtained during these flight tests, and comparison in situ H_2O measurements were in good agreement with the DIAL H_2O measurements.

The first extensive observations of H_2O and aerosols in the lower troposphere were made during March and April 1990 with the DIAL system operating in a nadir mode from the NASA Wallops Electra aircraft. Water vapor measurements were made on flights at night over the ocean, during the day over land and ocean, and across a cold front. Daytime DIAL measurements clearly showed the decrease in the mixed layer depth from about 1.7 km over land to less than 500 m over the Atlantic. The dry atmospheric conditions above the moist mixed layers were readily apparent in the DIAL H_2O data. Regions with enhanced H_2O concentrations were also found to have higher aerosol backscattering. The airborne DIAL measurements showed for the first time the detailed H_2O and aerosol structure that occurs in the free troposphere and in the mixed layer over different land and marine regimes. In addition, the first high-spatial resolution distribution of H_2O was obtained across a cold front. The transition from the very dry conditions behind the front to the very moist conditions ahead of the front was seen in detail. These experiments have provided new insights into atmospheric processes involving H_2O, and they will serve as a basis for future H_2O investigations, including studies of cloud formation and the effect of H_2O on the Earth's climate system.