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DEVELOPMENT OF TROPOSPHERIC OZONE LIDAR

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Introduction

Ozone is considered to be the single most important trace species in the atmosphere. It initiates photochemistry, it is a key non-CO_2 "greenhouse" molecule, and it can damage vegetation and human health. There are indications that ozone is increasing in the global troposphere, perhaps 20% over the past two decades. However, the data sets available for this period are too limited in global and temporal coverage and their long-term relative accuracy has been seriously questioned. Ozone measurements are also of value as a tracer in the dynamical processes of exchange between the stratosphere and troposphere. A high resolution ground-based instrument with a short measurement time and reliable long-term precision would help fill some of these needs. To this end, the lidar technique seems particularly well suited.

Objective

Our goal in the NOAA Aeronomy Lab is to optimize the differential absorption lidar (DIAL) technique for rural tropospheric ozone measurements. Although the prototype version is being built as a research instrument with maximum flexibility, it will be used to determine a suitable design for a long-term tropospheric ozone monitoring network. We anticipate that the prototype lidar will be capable of providing an ozone profile up to 12 km once every 60 seconds with an altitude resolution of 1 km or less. Better resolution and higher altitudes will result from longer integration times. The wavelength range that we have chosen will minimize solar interference, thereby allowing 24 hours-per-day observations in clear skies. When clouds are present, measurements can be made in those portions of the sky that are clear for the 60-second integration time required. The precision of the measurements should be 5% and their accuracy 10%.

Approach

From previous work of J. Pelon and G. Megie (J. Geophys. Res., 87, 4947, 1982), the wavelength range of 280 to 300 nm was chosen for the tropospheric ozone measurements. This optimized the sensitivity of the DIAL measurement for the rather low tropospheric ozone concentrations and allowed for the 24 hours-per-day observations. A careful survey of possible molecular interferents for both the rural boundary layer and the free troposphere (searching for worst-case differential cross sections and abundances) yielded the result that SO_2, NO_2, and formaldehyde could, under adverse conditions, contribute a few percent to the uncertainty of the ozone measurements. Therefore, it was decided that a scanning of the wavelengths was necessary to search for the interfering species. Computer modeling of the important atmospheric parameters indicated that the uncertainty in the aerosol scattering could introduce unacceptable errors in the ozone calculation. Therefore, aerosols will be monitored simultaneously with ozone using the longer-wavelength aerosol lidar technique. With these requirements, we decided that two identical laser systems consisting of a doubled Nd/YAG laser pumping a dye laser, which is again doubled, would provide the necessary wavelengths (280-300 nm, 560-600 nm, 532 nm, and 1.06 micron) and the necessary power (1 watt from 280-300 nm) for the experiment. With experience, we should be able to select the optimal fixed wavelengths for a simpler laser system.

Progress

After completing the search for molecular interferents, an atmospheric model was made to predict the uncertainties that we would likely encounter in ozone calculations using this DIAL lidar technique. It was concluded that the two laser systems described above would fulfill our requirements. The laser systems have been purchased and are now installed at the Aeronomy Lab's mountain observatory at Fritz Peak, west of Boulder. Although these are not off-the-shelf laser systems, their components are. Our initial testing has shown that the energy and wavelength requirements have all been met. We are continuing with other tests and expect these systems to be quite satisfactory. We anticipate that our model predictions for photon returns (detected signal) will be verified in the next few months. Then other critical components can be selected and ordered or, if necessary, built. Critical to the success of the experiment is a proper match between the different components. In particular, the detector and the waveform digitizer must be suitable for the wide dynamic range of signal intensity expected. Also a computer will be interfaced for control of the experiment and for real-time data analysis.