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CO_2 LIDAR BACKSCATTER EXPERIMENT

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Background of the Investigation:

The Aerosol/Lidar Science Group of the Remote Sensing Branch engages in experimental and theoretical studies of atmospheric aerosol scattering and atmospheric dynamics, emphasizing Doppler lidar as a primary tool. Activities include field and laboratory measurement and analysis efforts by in-house personnel, coordinated with similar efforts by university and government institutional researchers. The primary focus of activities related to understanding aerosol scattering is the GLObal Backscatter Experiment (GLOBE) program. GLOBE was initiated by NASA in 1986 to support the engineering design, performance simulation, and science planning for the prospective NASA Laser Atmospheric Wind Sounder (LAWS) managed by MSFC. Designed and scientifically directed by MSFC, GLOBE is a multi-element multi-institutional effort to develop a global aerosol model to describe the "background" tropospheric backscatter conditions that LAWS is likely to encounter. The accuracy of LAWS wind estimates will depend on the strength of the backscattered signals, which in turn will depend on the spatial distribution and physicochemical and optical properties of aerosols. Survey missions were flown in the NASA DC-8 in November 1989 and May-June 1990 over the remote Pacific Ocean, a region where backscatter values are low and where LAWS wind measurements could make a major contribution. The instrument complement included: pulsed and continuous-wave (CW) carbon dioxide gas lidars and solid state lidars measuring aerosol backscatter in the 0.53-10.6 micrometer range; optical particle counters measuring aerosol concentration, size distribution and chemical composition in the 0.1-43 micrometer range; a filter/impactor system collecting aerosol samples for subsequent analysis; and integrating nephelometers measuring visible scattering coefficients in the 0.45-0.7 micrometer range. Personnel from the MSFC Remote Sensing and Optical Systems Branches and supporting contractors obtained backscatter measurements at close range using MSFC-developed CW lidars operating at 9.1 and 10.6 micrometers, the former being the primary design wavelength for LAWS. Supporting measurements included satellite observations of tropospheric extinction profiles in the near-infrared, surface observations of aerosols and dust transport, coordinated observations by airborne and ground-based lidars and aerosol samplers, and visible and infrared satellite imagery. The GLOBE instrument configuration and survey missions were carefully planned to achieve complementary measurements under background backscatter conditions. Special flight maneuvers were made periodically throughout the GLOBE survey missions to allow inter-comparisons between the *in situ* and remote sensing instruments. Measurements of backscatter at 9.1 and 10.6 micrometers and aerosol physicochemical and optical properties were made routinely at flight level. The airborne measurements were coordinated with ground-based aerosol samplers and satellite based extinction profilers in order to relate the airborne observations to these long-term, global-scale climatologies of physicochemical and optical properties. The processing of each measurement set has been the responsibility of the investigators or institutions which developed and operated the instrument. MSFC has responsibility for synthesizing the various measurements into a wavelength-dependent global tropsphere backscatter model for LAWS design, simulation, and science planning. Periodic meetings of the GLOBE Science Working Group have been convened to identify data processing priorities and case studies, assess instrument performance, present preliminary findings, and assess overall progress.

Significant Accomplishments in the Past Year:

The most important GLOBE scientific result has been identification of a background aerosol mode with a surprisingly uniform backscatter mixing ratio (backscatter normalized by air density) throughout a deep tropospheric layer. The backscatter magnitude of the background mode evident from the MSFC CW lidar measurements is remarkably similar to that evident from ground-based backscatter profile climatologies obtained by JPL in Pasadena CA, NOAA/WPL in Boulder CO, and by the Royal Signals and Radar Establishment in the United Kingdom. Similar values for the background mode have been inferred from the conversion of *in situ* aerosol microphysical measurements to backscatter using Mie theory. Little seasonal or hemispheric variation is evident in the survey mission data, as opposed to large variation for clouds, aerosol plumes, and the marine boundary layer. Additional features include: localized aerosol residues from dissipated clouds, occasional regions having mass concentrations of nanograms per cubic meter and very low backscatter, and aerosol plumes extending thousands of kilometers and several kilometers deep. Preliminary comparisons with meteorological observations thus far indicate correlation between backscatter and water vapor under high humidity conditions. Limited intercomparisons with the Stratospheric Aerosol and Gas Experiment (SAGE) limb extinction sounder shows differences in the troposphere, however, it should be noted that in general SAGE measurements have not yet been validated in the troposphere.

Focus of Current Research and Plans for Next Year:

1. Aerosol data analysis activities. processed GLOBE data sets continue to be incorporated into the GLOBE data base at MSFC. Measured size distributions and chemical composition long with established valued of refractive index are being used to calculate aerosol backscatter coefficients at desired wavelengths using Mie theory, taking into account instrument limitations. Conversion functions are being developed to relate one aerosol property to another, for example, 1.06 micrometer extinction to 9.1 micrometer backscatter. Key checks of the Mie theory calculations are being made by comparing calculated aerosol properties with direct measurements. In support of GLOBE aerosol analyses, laboratory studies continue to characterize scattering features of aerosols generated in the MSFC Aerosol Optical Properties Laboratory (AOPL) using the MSFC CW lidars. Aerosol particles with known size, shape and refractive index are generated under controlled laboratory conditions. Chemical compositions are selected for analysis which reflect what was encountered in several locations during the survey missions. Meteorological model outputs from the European Center for Medium-range Weather Forecasting (ECMWF) continue to be compared to composite backscatter profile measurements from the pulsed lidars to better classify the conditions under which a correlation may exist between backscatter and one or more meteorological variables, e.g., water vapor, and to quantify the degrees of correlation. Progress in this area will greatly benefit Observing System Simulation

Experiments (OSSEs), which rely heavily on global meteorological datasets--and which represent the principal means thus far--to assess LAWS performance. Specific future in-house tasks include: 1) completion of GLOBE MSFC CW lidar data processing, 2) study of optical properties of aerosols generated in the MSFC AOPL and transfer of findings to interpretation of GLOBE results, 3) use of GLOBE aerosol size distribution and chemistry measurements to extend theoretical backscatter predictions to wavelengths at which no direct measurements have as yet been made, 4) incorporation of GLOBE findings into simulation studies to assess impacts of measured and modeled backscatter levels on LAWS performance, 5) refinement of global tropospheric backscatter model at LAWS primary and alternate design wavelengths using GLOBE program data sets, 6) modifications to CW lidar systems to enhance sensitivity and operating capabilities both in the laboratory and in the field, 7) intercomparison of backscatter and meteorological measurements for the remainder of the GLOBE survey mission flights, 8) development and initiation of research plan to address discrepancies between SAGE extinction and GLOBE survey mission measurements, and 9) development of science rationale for future GLOBE missions.

Publications:

Bowdle, D.A., J. Rothermel and J.E. Arnold, "GLObal Backscatter Experiment (GLOBE) research and results," Amer. Geophys U. 1990 Fall Meeting, San Francisco, Dec. 3-7 *Eos*, 71, 1252-1253 (1990).

Bowdle, D.A., J. Rothermel, J.M. Vaughan, D.W. Brown and M.J. Post, "Aerosol backscatter measurements at 10.6 micrometers with airborne and ground-based CO_2 Doppler lidars over the Colorado High Plains, 1, Lidar intercomparison," *J. Geophys Res.*, **96** 5327-5336 (1991).

Bowdle, D.A., J. Rothermel, J.M. Vaughan and M.J. Post, "Aerosol backscatter measurement at 10.6 micrometers with airborne and ground-based CO_2 Doppler lidars over the Colorado High Plains, 2, Backscatter structure, " *J. Geophys. Res.*, **96**, 5337-5344 (1991).

Jones, W.D., "Calibrating a continuous-wave (CW) focused CO_2 lidar for single particle mode (SPM) backscatter measurements," *Proceedings, Fifth Conf. Coherent Laser Radar*, 215, Munich, Germany, June 5-9 , sponsored by Opt. Soc. Amer. (1989).

Rothermel, J., D.A. Bowdle, J.M. Vaughan, D.W. Brown and A.A. Woodfield, "Calculation of aerosol backscatter from airborne continuous wave focused CO_2 Doppler lidar measurements 1. Algorithm description," *J. Geophys. Res.* **96**, 5293-5298 (1991).

Rothermel, J., D.A. Bowdle, and J.M. Vaughan, "Calculation of aerosol backscatter from airborne continuous wave focused CO_2 Doppler lidar measurements 2. Algorithm performance," *J. Geophys. Res.* **96**, 5299-5305 (1991).

Rothermel, J., W.D. Jones, D. Hampton, V. Srivastava, M. Jarzembski, "Airborne coherent continuos wave CO_2 Doppler lidars for aerosol backscatter measurements," *preprints 4th Airborne Geoscience Workshop,* Jan. 29-Feb. 1, LaJolla, Hosted by NASA, 235-236 (1991).

Rothermel, J., W.D. Jones, V. Srivastava, M. Jarzembski and D. Hampton, "In situ backscatter measurements over Pacific Ocean using two coherent focused CO_2 lidars." *Preprints, 7th Symposium Meteor Observation Instrum.*, Jan. 14-18, New Orleans, sponsored by Amer. Meteor. Soc., J257-260 (1991).

Srivastava, V., A.D. Clarke, J. Porter, M. Jarzembski and D.A. Bowdle, "Comparison of CO_2 backscatter using Mie theory from aerosol measurements over Pacific Basin with lidar data," *Preprints, 7th Symposium Meteor Observation Instrum.*, Jan. 14-18, New Orleans, sponsored by Amer. Meteor. Soc., J268-271 (1991).

Srivastava, V., M.A. Jarzembski, and D.A. Bowdle, "Comparison of Calculated aerosol backscatter at 9.1 and 2.1 mm wavelengths," *Appl. Opt.*, **31**, 1904-1906 (1992).