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Title:

ATMOSPHERIC AEROSOL AND DOPPLER LIDAR STUDIES

Investigators:

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Significant Accomplishments in the Past Year:

The Aerosol/Lidar Science Group of the Remote Sensing Branch, Marshall Space Flight Center (MSFC), engages in experimental and theoretical studies of atmospheric aerosol backscatter and atmospheric dynamics with 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 backscatter is the GLObal Backscatter Experiment (GLOBE) program. GLOBE was initiated by NASA in 1986 to support engineering design and performance studies of the NASA Laser Atmospheric Wind Sounder (LAWS), an Earth Observing System (EOS) facility instrument managed by MSFC. GLOBE is a multi-element, multi-institutional effort designed and scientifically directed by MSFC toward developing a global aerosol model to describe tropospheric "clean background" 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. Two survey missions were designed and 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 consisted of pulsed and continuous-wave (CW) carbon dioxide gas 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. MSFC personnel from the Optical Systems and Remote Sensing Branches and supporting contractors were responsible for obtaining backscatter measurements at close range using CW lidars 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 package and survey missions were carefully planned to achieve complementary measurements under clean background backscatter conditions. Special flight maneuvers were made periodically throughout the GLOBE survey missions to allow intercomparisons 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 who developed and operated the instrument. Periodic meetings of the GLOBE scientific working group have been convened to identify data processing priorities and case studies, assess instrument performance, present preliminary findings, and assess overall progress. The most important GLOBE result to date has been the identification of a persistent statistical background CO_2 backscatter distribution, with a surprisingly uniform backscatter mixing ratio throughout a deep tropospheric layer.

Focus of Current Research and Plans for Next Year:

The MSFC Aerosol/Lidar Science Group has begun the task of synthesizing into a global aerosol backscatter model the GLOBE DC-8 and supporting measurements of physical, chemi-

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cal, and optical properties covering *ten* different wavelengths. Processed data sets that have been quality-controlled and validated will be incorporated into the GLOBE data base at MSFC. The model will be applicable to the primary LAWS design wavelength of 9.1 micrometers as well as secondary design wavelengths. A primary analysis technique involves synthesis of the various GLOBE measurements through careful application of 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. Measured size distributions and chemical composition along with established values of refractive index are used to calculate aerosol backscatter coefficient at a desired wavelength. Key checks of the Mie theory calculations are made by comparing calculated aerosol properties with direct measurements.

Mie theory has been successfully applied to both pre-GLOBE calibration and atmospheric measurements with the MSFC continuous-wave (CW) focused Doppler lidars. Aerosol particles with known size, shape and refractive index were generated under controlled laboratory conditions and used as calibration targets. Calibration factors were obtained by comparing measured backscatter signals with those calculated from Mie theory using the known properties of the generated particles. Work is currently focused on intercomparing the CW lidar backscatter observations with backscatter calculated from near-real-time measurements of size-segregated aerosol chemical composition using a preconditioned laser optical particle counter (LOPC). When the operating characteristics of the LOPC are properly taken into account as well as the ambient relative humidity levels, agreement is found to within a factor three or better for the case studies identified to date. MSFC researchers will attempt to quantify the life cycles and the vertical, areal, temporal, and microphysical variability of the background feature. Detailed studies of satellite imagery and supporting meteorological data are expected to lend insight into the relationship between atmospheric dynamic and thermodynamic features, and aerosol backscatter distribution. Specific future in-house tasks will include: (1) completion of processing of the MSFC CW lidar measurements, (2) studies of the optical properties of aerosols generated under controlled conditions in the MSFC Aerosol Optical Properties Laboratory, (3) use of aerosol size distribution and chemistry measurements to extend theoretical backscatter predictions to wavelengths at which no direct measurements were made, (4) incorporation of GLOBE findings into simulation studies to assess impacts of measured and modeled backscatter levels on LAWS performance, (5) continued development and refinement of the global tropospheric backscatter model at LAWS primary and secondary design wavelengths through synthesis of the GLOBE program data sets, and (6) modifications to the CW lidar systems to enhance sensitivity and operating capabilities both in the laboratory and in the field.

The current focus of lidar studies of atmospheric dynamics is on the development of an improved airborne scanning Doppler wind measurement system. The motivation is to understand specific mesoscale processes that are incompletely resolved or are beyond the capability of existing ground-based and airborne research and operational sensors. The GEWEX Continental-Scale International Project (GCIP) and US Weather Research Program Stormscale Operational and Research Meteorology (STORM) program have been identified as opportunities in which MACAWS could make unique and synergistic measurements. Proposed fundamental mesoscale observations will contribute to a greater understanding of the role of the mesoscale, helping to improve predictive capabilities for mesoscale phenomena as well as parameterizations of sub-grid scale processes in global circulation models. A collaborative development effort is planned among the atmospheric lidar groups of MSFC (Optical Systems and Remote Sensing Branches), Jet Propulsion Laboratory, and NOAA Wave Propagation Laboratory. Instrument development and integration is planned for FY92-4, with first flights on the NASA DC-8 in early spring 1994. Existing lidar components, some already flight-qualified, will be exploited to minimize costs. Systems of similar design but with more modest capability were built and demonstrated by MSFC researchers in the early 1980's.

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