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Lidar research in South Africa

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Two laser-radar systems in South Africa offer great potential to characterize the region's atmospheric particulate matter and pollutants.

Lasers offer great advantages over conventional light sources in terms of peak power and narrow spectral bandwidth. Advancements in both laser and detector technology along with improvements in data-acquisition and analysis techniques have made laser radar or 'lidar' (for light detection and ranging) a very reliable tool for active atmospheric remote sensing.[1]

Although ground-based lidar systems are routinely used in many developed countries, the techique is still novel for South Africa (and other African countries). Two lidar configurations are currently available in South Africa, located in Pretoria and Durban. They are similar in operation and specifications, thus permitting simultaneous measurements. The Durban device is operated at the University of KwaZulu-Natal, as a collaborative project with Reunion University and the Service d'Aéronomie of the Centre National de la Recherche Scientifique (CNRS)/Institut Pierre Simon Laplace (France) for climate-research studies. The second device is a mobile lidar system aimed at contributing to atmospheric research in southern Africa, which was recently designed and developed by the National Laser Centre of the Council for Scientific and Industrial Research (CSIR) in South Africa.[2]

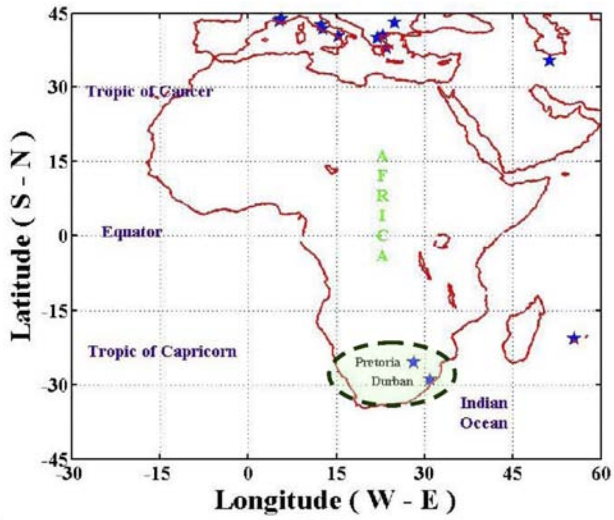

Figure 1. Geographical locations of the lidar sites in Pretoria and Durban. Other operational systems are also shown (stars).

Pretoria lidar

The CSIR system is ideally placed to obtain measurements in the southern hemisphere, which will encourage further collaboration with other partners employing spaceborne and/or ground-based lidar facilities. This mobile lidar system,[3] developed at 25°5′ South, 28°2′ East, was primarily designed to measure trace gases and pollutants in the troposphere, particularly aimed at characterizing atmospheric backscatter. The complete system is custom-fitted into a van using a shock-absorber frame. Hydraulic stabilizer feet were added to the vehicle's suspension to ensure stability during measurements. The system uses an Nd:YAG laser operating at the second harmonic (532nm) at a repetition rate of 10Hz. The receiver system is based on a Newtonian-telescope design with a 16in. primary mirror. A multimode optical fiber couples the backscattered optical signal from the telescope to a Hamamatsu R7400-U20 photomultiplier tube, which operates from 300–900nm with a fast rise-time response of 0.78ns. A lidar computing-and-electronics (LICEL) transient digitizer was procured for data acquisition. It communicates with a host computer for storage and offline data processing. The data-acquisition system has been optimized for detection of fast repetitive photomultiplier-lidar signals in the analog voltage range of 0–500mV. The system is capable of simultaneous analog and photon-counting measurements across a large dynamic range, which makes it highly suited for lidar applications.

Initial results show that aerosol and cloud backscatter can be measured from the ground up to an altitude of 35km with a vertical resolution of 10m. The lidar can quantify and characterize the aerosol concentration, optical depth, cloud position, thickness, and other general cloud properties, which are important for an improved understanding of the earth-radiation budget, global climate change, and turbulence. Future plans include qualitative industrial-pollutant and ozone measurements, 3D characterization of the atmosphere using an *XY*-plane (horizontal) scanner, a two-channel lidar system, water-

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Figure 2. CSIR/National Laser Centre mobile lidar system at Pretoria.

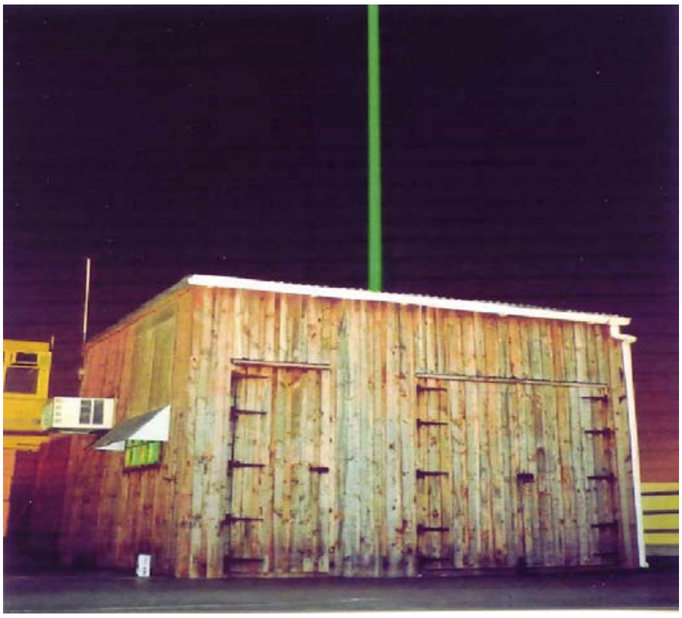

Figure 3. Lidar system in Durban.

vapor measurements, and the implementation of differential-absorption lidar.

Durban lidar

The first operational measurements with the Durban lidar took place in 1999. It has since been used for specific field campaigns. The device consists of a Rayleigh-Mie system which can measure the vertical profiles of relative density, temperature, and aerosol scatter.[4] A pulsed Nd:YAG laser is used with a repetition rate of 30Hz and a fundamental wavelength of 1064nm. The light source is a frequency-doubled laser emitting at 532nm, with a power of ∼500mJ per pulse. The receiving system has three operational channels. In its current form it can run as many as six channels (four channels in photon-count and two channels in analog mode).

Two telescopes with diameters of 445 and 200mm, designed to cover a wide dynamic range, are integrated with the lidar. The larger telescope covers the upper atmospheric levels while its smaller counterpart is optimized for lower-atmosphere measurements. The incoming photons are collected at the telescope focus and transmitted by optical fibers to a detection box consisting of filters, a lens, and a photomultiplier. The two-channel photon-counting system (driven by the laser pulse) converts the scattered photons into a numerical signal as a function of altitude, using 1μs integrations, which corresponds to a vertical resolution of 150m. This can be inverted to obtain temperature profiles from 10 to 70km altitude by combining the Rayleigh and Raman–N_2 channels, while aerosol profiles can be retrieved in the 10–38km range.

Future research plans include characterizing the structure and dynamics of the middle atmosphere, the implementation of a water-vapor channel, and studies related to tropospheric-aerosol content and cirrus-cloud morphology.

Projects

Research projects undertaken with these two South African lidars include the Lidar for Atmosphere Research over Africa (LARA), the South African-French lidar (SAFiR) network for the study of upper-troposphere and lower-stratosphere aerosol distributions and dynamics, PROTEA (French-South African scientific cooperation program), Atmospheric Research in Southern Africa and the Indian Ocean (ARSAIO), and the Groupement de Recherche International (GDRI), a collaboration between South Africa and France.

In addition to the CSIR and the University of KwaZulu-Natal in Durban, our research partners and collaborators include the South African Department of Science and Technology, the South African National Research Foundation, the African Laser Centre (South Africa), CNRS (France), and the French embassy in South Africa.

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