
Composite image created from photographs by: Patrick Byrne, Carolyn Conner, Peggy Davis, Daniel Fogg, John Newman, Cyrus Reed, and Gayle Trautman

# Lidar probes the atmosphere

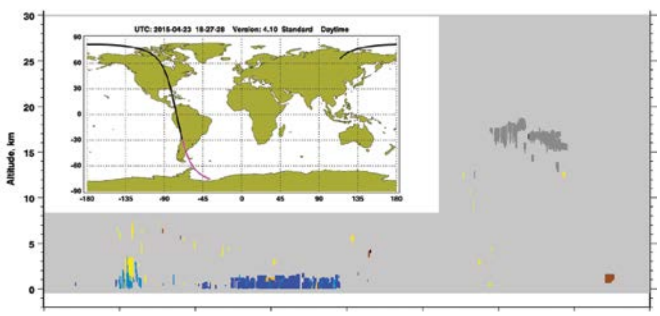
Lidar's potential as a tool for atmospheric studies was recognised soon after the first laser was produced in a laboratory in 1960. A paper on 'The laser and its application to meteorology' in the September 1963 issue of the *Bulletin of the American Meteorological Society* discussed the possible uses of lidar, which was originally coined as a blend of 'laser radar', rather than the current usage as an acronym for 'light detection and ranging'.

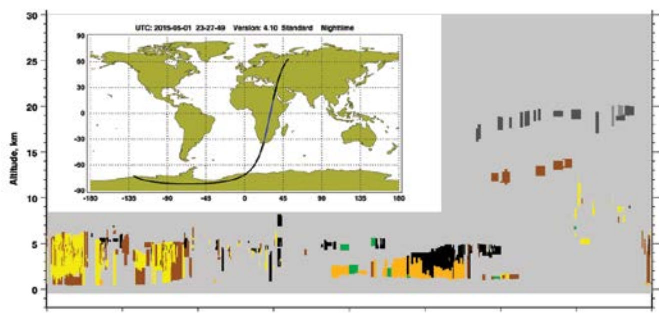
Today, simple 'elastic backscatter' lidar is employed in ground-based, airborne and space-borne instruments to study clouds and aerosols, which are small particles suspended in the atmosphere and made up of things like dust, sea salt, ash and soot from both natural and man-made sources. More advanced Raman lidar and differential absorption lidar (DIAL) even allow atmospheric gases such as ozone, carbon dioxide, methane, sulphur dioxide and nitrogen oxides to be measured, while Doppler lidar is used to measure wind speed.

Dr Lerato Shikwambana, a Senior Scientist: Earth Observation at the South African National Space Agency (SANSA), has considerable experience with ground-based and space-borne elastic backscatter lidar, having used both to study aerosols and clouds over South Africa for his PhD, awarded by the University of KwaZulu-Natal (UKZN) in 2017. The ground-based lidar was a mobile system – mounted in a van – that was originally developed by the Council for Scientific and Industrial Research (CSIR) in 2007 and then modified in 2013. Dr Shikwambana's supervisor at UKZN, Prof. Venkataraman Sivakumar, had played a leading role in the development of the system while previously employed at the CSIR, where Dr Shikwambana too worked as a researcher in the National Laser Centre in the early stages of his PhD.

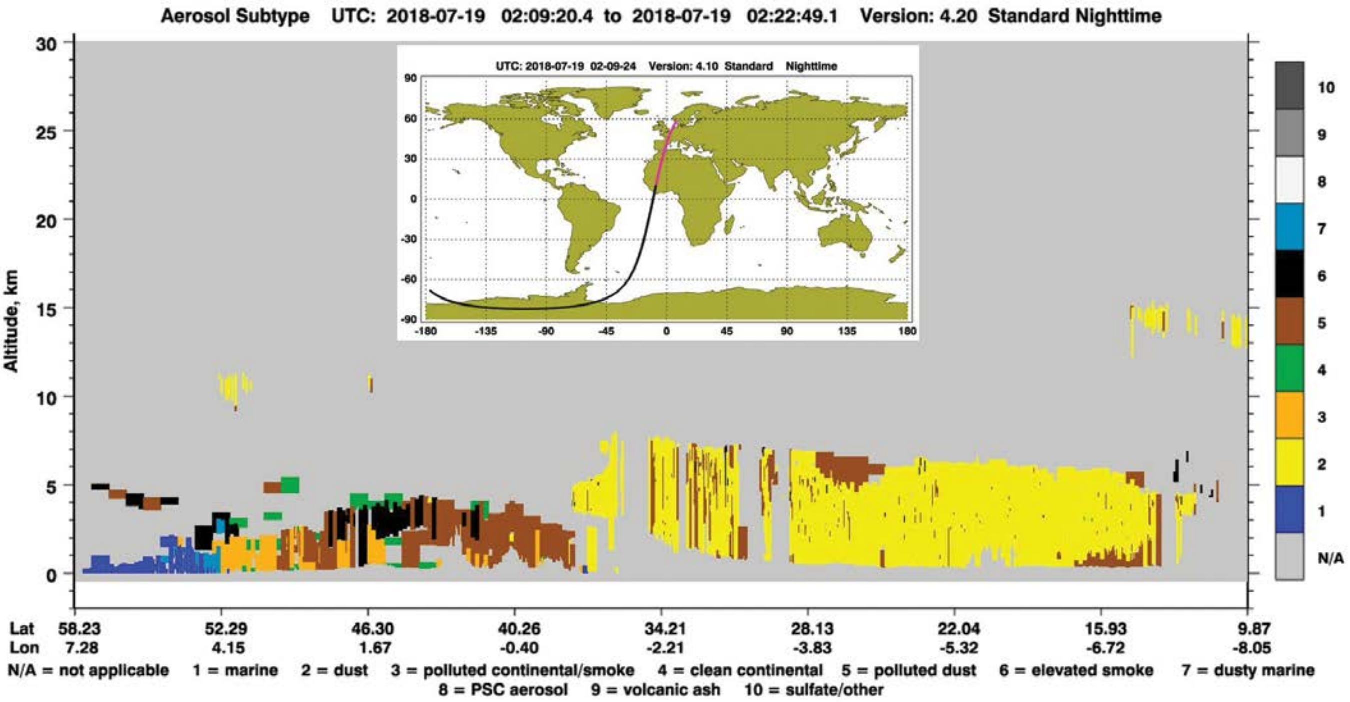
The space-borne lidar system used by Dr Shikwambana was on the satellite known as CALIPSO – short for Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation. Launched in 2006, CALIPSO is a joint venture between NASA and CNES, the French space agency, and its mission is to improve understanding of the role of clouds and aerosols in regulating Earth's weather, climate and air quality. Put simply, its lidar instrument emits pulses of polarised laser light at two wavelengths (532 nm and 1064 nm), and the intensity and state of polarisation of the backscattered radiation that is reflected off clouds and aerosols is measured by a receiver telescope. Automated algorithms then map the atmosphere's structure, with differentiation of clean air, ground surface and various types of clouds and aerosols. For example, stratospheric aerosols are subtyped as polar stratospheric aerosol, smoke, volcanic ash and sulphate/other – sulphate aerosols occur naturally in the stratosphere, but are formed in vast quantities from the sulphur dioxide in volcanic eruptions.

In April 2010, CALIPSO's outputs made media headlines when NASA released a map graphic showing the plume of drifting ash that caused a seven-day shutdown of much of Europe's air traffic following the eruption of Iceland's Eyjafjallajokull volcano. As part of his PhD research, Dr Shikwambana did a similar exercise, using CALIPSO data





**Volcanic aerosols (mid-grey) at heights of up to ~18 km were observed by CALIPSO as it passed over the erupting Calbuco volcano in Chile on 23 April 2015. These aerosols moved eastward and by 1 May 2015 were observed over South Africa as low concentrations of volcanic ash and sulphate (darker grey).**




**This CALIPSO image depicts types of aerosols observed as the satellite passed over the Sahara Desert on 19 July 2018. A low density of dust aerosols up to heights of ~15 km is seen in the 9.87°N and 8.05°W region, which corresponds to the country Guinea. Higher densities of dust aerosols up to ~6 km height are seen in Sahara Desert countries such as Algeria, Morocco, Mali and Mauritania. In Europe the most abundant types of aerosol are polluted dust (soot), smoke, marine and polluted continental/smoke aerosols, and these occur below 5 km height.**

to track volcanic aerosols emanating from Chile's Calbuco volcano, which erupted on the evening of 22 April 2015. By the beginning of May, the volcanic aerosols were detectable above South Africa, at an altitude of 18 km.

CALIPSO has featured in international news a few times during 2020, particularly when it was used to observe an unusually large plume of Saharan dust that crossed the Atlantic to the Caribbean and the south-eastern USA in June. Although such dust events are common at that time of year, this plume was so massive that it was nicknamed 'Godzilla'. CALIPSO was also used to study smoke distribution from the devastating wildfires that occurred in south-eastern Australia in the 2019–2020 summer and on the West Coast of the United States in September 2020.

South Africa had its own large-scale fire disaster in June 2017, when wildfires in the Knysna-Plettenberg Bay area burned 15 000 hectares, including 5 000 hectares of forestry plantations and more than 800 buildings, and claimed the lives of seven people. Dr Shikwambana was lead author of a paper published in the *International Journal of Remote Sensing* in early 2019, exploring the possibility of using various satellite and model data to characterise the aerosol emissions from the fires. By using CALIPSO data he was able to distinguish aerosols and smoke from cloud cover, and also establish that the fires created higher pyrocumulus clouds. These are formed when the intense heat from wildfires or volcanic eruptions causes a rising column of hot air, which cools at higher altitudes and condenses into clouds, providing there's sufficient moisture in the air.

Dr Shikwambana says CALIPSO is one of the best satellites to use in order to study clouds, being able to differentiate between the content of the clouds, such as water clouds, ice clouds or a mixture of the two, as well as types of clouds, such as cumulus, altocumulus and cirrus. It can also determine the heights, thickness and shapes of the clouds. During his PhD, he compared CALIPSO cloud observations for a two-day period over Durban with those of the CSIR mobile unit and found that the two systems complemented one another, because in cloudy conditions the ground-based lidar was better for detecting clouds in the lower parts of the troposphere.

- Another space-borne lidar that has been used to study aerosols in southern Africa is the Cloud-Aerosol Transport System (CATS) on the International Space Station. It ceased functioning in October 2017, but its data forms the basis of a paper in the March/April 2020 edition of the *South African Journal of Science* by McGill and co-authors, revealing the outflow of aerosols from biomass burning in Africa towards Australia.

*CALIPSO images, including attenuated backscatter and other products, are available at: https://www-calipso.larc.nasa.gov/products/lidar/browse_images/production/*

## CURRICULUM CORNER

**GEOGRAPHY: GRADE 10**
Composition and structure of the atmosphere

**LIFE SCIENCES: GRADE 11**
The atmosphere and climate change

**PHYSICAL SCIENCES: GRADE 10**
Electromagnetic radiation

**Academy of Science of South Africa (ASSAf)**

| **ASSAf Research Repository** | **http://research.assaf.org.za/** |
|---|---|
| A. Academy of Science of South Africa (ASSAf) Publications | D. Quest: Science for South Africa |

2020-11-30

# Quest Volume 16 Number 4 2020

## Academy of Science of South Africa (ASSAf)

Academy of Science of South Africa (ASSAf)

http://hdl.handle.net/20.500.11911/169

*Downloaded from ASSAf Research Repository, Academy of Science of South Africa (ASSAf)*