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LIDAR
Light Detection and Ranging

Shedding light on marine migration

Capturing Kruger in 3D

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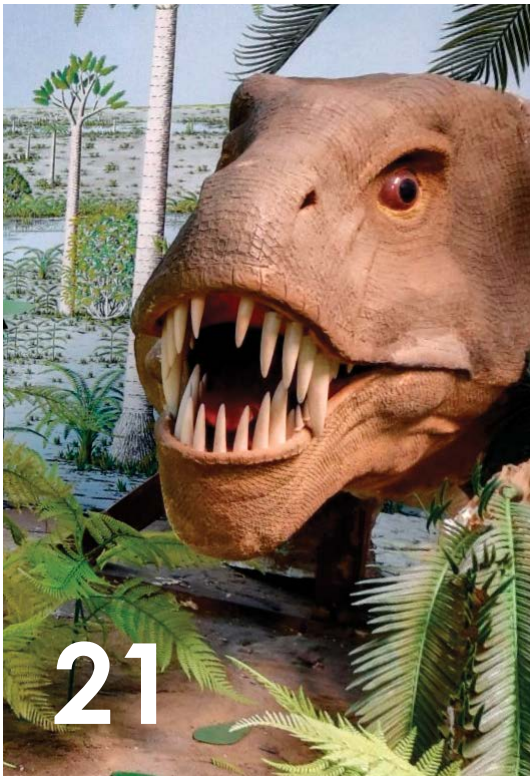

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NASA/Timothy Marvel

Lidar is coming of age

When Apple unveiled the iPhone 12 range in October 2020, one of the major upgrades in the Pro and Pro Max models was the addition of a lidar sensor, initially introduced in the iPad Pro, launched just over six months earlier. Apple says the sensor not only improves focusing for low-light photos and videos, but also creates precise 'depth maps' for image-processing as well as augmented reality (AR) apps that rely on 3D scanning and mapping of objects and rooms.

Lidar stands for Light Detection and Ranging, and while you'll often see it written as LiDAR, most dictionaries treat it in the same way as radar and sonar, which were originally coined as acronyms for Radio Detection and Ranging and Sound Navigation and Ranging, respectively. All are based on the same principle, determining distance to a target from the 'round trip' of a signal that is reflected off the target. While radar uses radio waves and sonar uses sound in much the same way that echolocating bats 'see' obstructions and insect prey in the dark, lidar relies on light from a laser – a word that is itself derived from the acronym for Light Amplification by Stimulated Emission of Radiation.

Most lidar systems use either the time-of-flight or the phase-shift method. In the first, most common for long-distance ranging, distance to the target is calculated from the time taken for a light pulse to return to the sensor (distance = [speed of light x time-of-flight] / 2). Phase-based systems, on the other hand, use a continuous, modulated laser beam and determine distance from the phase difference, or shift, between the sent and received signal.

Lidar serves as an 'eye' in many robotic devices, including those used in some parts of the world during the COVID-19 pandemic to sanitise hospital rooms, deliver supplies, monitor body temperatures and encourage social distancing. It is also a key component of most 'self-driving' autonomous vehicles, although Elon Musk famously called it 'a fool's errand', preferring to use a combination of cameras, radar and ultrasonic sensors in his Tesla cars.

Lidar is increasingly used to measure volume of material on conveyor belts, and has been heavily adopted by the mining industry for this purpose and others. For example, airborne lidar is used to detect and monitor subsidence of the ground surface at local mines, while scientists at the CSIR have combined lidar and ground-penetrating radar on an autonomous robot to find and map faults in rock faces, which pose a safety concern to miners working underground.

Lidar has helped find and map ancient 'lost cities' around the world, and even on the Suikerbosrand hills near Johannesburg (see *Quest* 14:4). South African scientists and resource managers have also used it for mapping natural vegetation and crop-type, assessing biomass, monitoring air quality and predicting flood levels, among other endeavours. In this issue, we explore these and other scientific applications of lidar.

Sue Matthews
Quest Editor

Isihloko saloludaba yi 'lidar', yona esebenzisa ukukhanya ukulinganisa ibanga phakathi kwayo nezinye izinto, ngendlela efanayo amalulwane asebenzisa umsindo 'ukubona' okungaphazamisa endleleni yazo nokuthola izilwanyana ezindiza phambi kwazo. Ngaphandle kokusetshenziswa kwi technology njengezimoto ezizishayelayo, ama robots, ilidar inemisebenzi eminingi kakhulu kweze science njengokwakhiwa kwama map yemihlaba nokuqinisekisa ukuphepha komoya.

Translated by Mbali Nguse

LIGHT DETECTION AND RANGING (LIDAR)

Where did lidar come from, and where's it heading?

It may surprise you to learn that when laser first shot to prominence in the 1960s there was no real use for it. Of course, nowadays, lasers have a place in almost every single piece of technology around – but back then they were more a product of a time of curiosity and imagination than usefulness and application. In fact, scientists from back then would probably be amazed if they saw how we use their invention today.

This is particularly interesting, because although the uses and applications of lasers have developed considerably, the physics have remained almost unchanged since the days of Albert Einstein. And that's because it's impossible to change the rules of physics – although it's great fun to try!

One of the first steps towards laser's myriad applications was its use in the Lunar Laser Ranging experiment, where lasers were employed to measure the distance to the moon. Although scientists and physicists had been able to measure great distances previously using radar, laser made for far greater precision, because it has a much shorter wavelength. This makes it possible to confine a beam to the minimal convergence as defined by physics. To give you an idea of just how much more accurate laser is than radar, consider that if you were to use a radar to measure the same distance, the length of the wavelength means it would be as likely for you to hit the Atlas Mountains than the landing stop of the Apollo 11.

With the success of this experiment, people realised that light was more than something that flashes through the air; it could be a detector too. If it could tell us things about the moon's surface without having to actually travel there, what else could it do?

For a start, it could play a role in measuring the atmosphere. This is primarily where laser was focused during the 1970s, when entities like weather services used laser systems that would be considered enormous by today's standards to gauge features such as clouds and particles. Laser rangefinders also came to be used in surveying work, and for scanning.

These uses point to the versatility of the lidar concept – lidars can have single points, scanned beams and

LightWare Lidar

In mid-2020 LightWare Lidar launched the world's smallest and lightest microlidar, the SF000, which weighs just 8.8 g and is about the size of a Lego piece. It can deliver more than 380 readings per second, allowing for precise measurements of speed and distance.

even collect point clouds, measuring distances without compromising resolution or accuracy. And once people realised that there is literally no limit on the technology's range, they also realised its tremendous scope. Today, lidars are incorporated in everything from the Internet of Things to autonomous cars, to measuring a drone's height above the ground... and the uses keep growing.

As we move to make lidar smaller, more affordable and more readily available, we're set to see the next step in this amazing technology's evolution, an evolution that will be led by one question: what problem would you like to solve next?

This article was originally published as a blog post by Philip Constantine, Executive Vice-President of LightWare Lidar, based in Gauteng. It is a summary of his online discussion with Chief Engineer James Portman, forming the first episode of 'Light Conversations', available on YouTube and the LightWare Lidar blog: https://lightwarelidar.com/blogs/news.

Both the videos and the blog summaries are excellent resources for those wanting a better understanding of lasers and lidar.

Ep01 The evolution of lidar
Ep02 "What, exactly, is a laser?"
Ep03 Power play: choosing the right laser for the job
Ep04 Lasers and rainbows
Ep05 The science of lidar and light amplification
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NASA

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

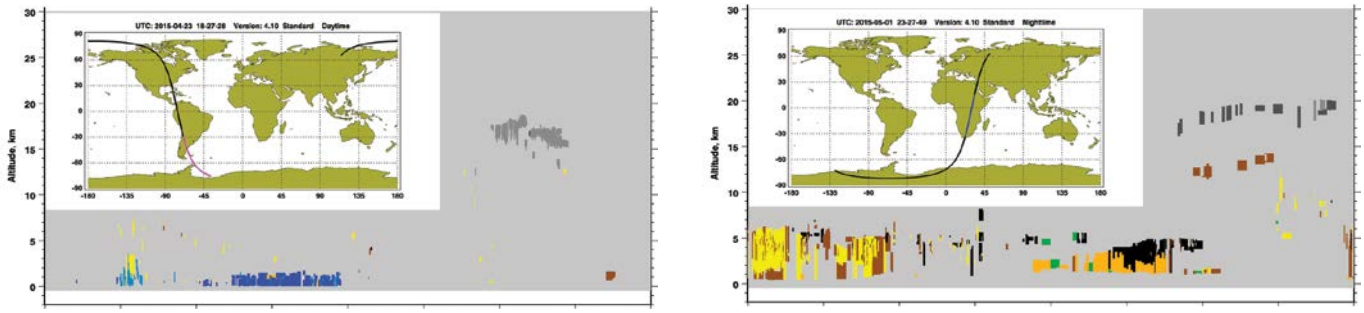
Lidar's potential as a tool for atmospheric studies was recognised soon after the first laser was produced in a laboratory in 1960. A paper on 'The laser and its application to meteorology' in the September 1963 issue of the *Bulletin of the American Meteorological Society* discussed the possible uses 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.

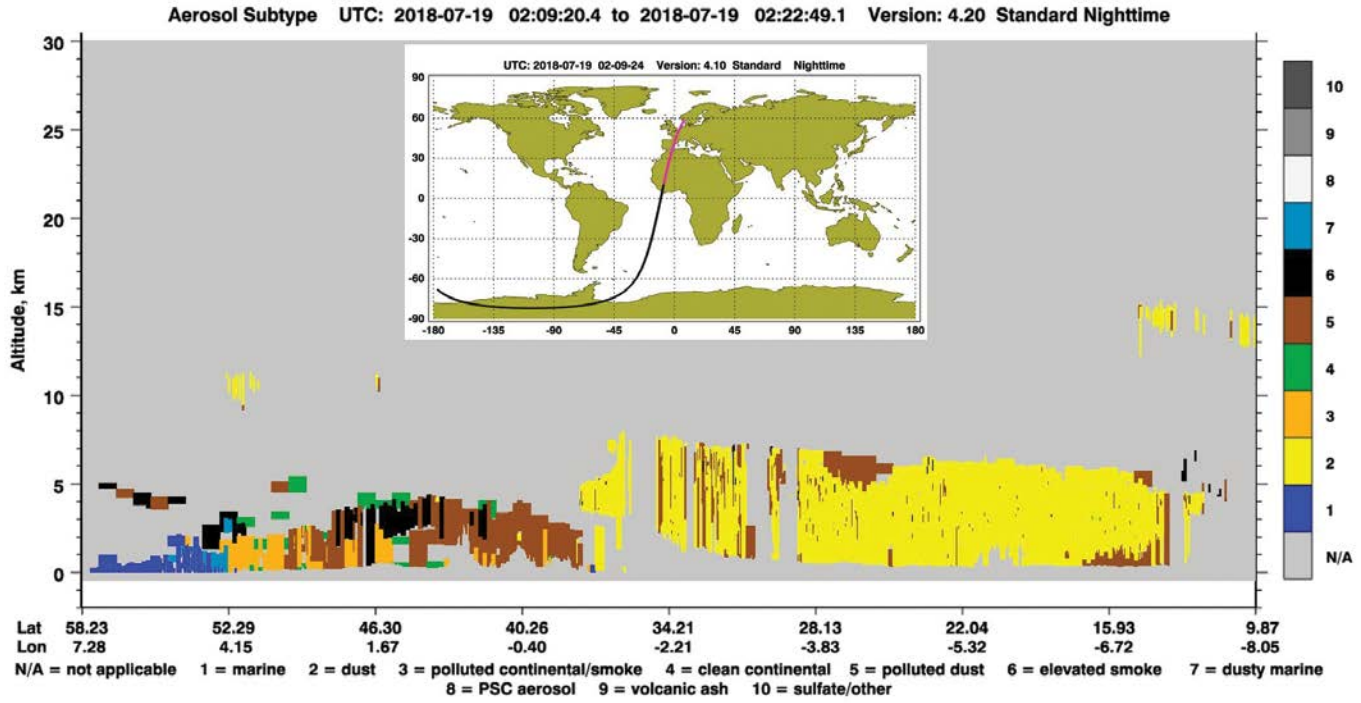
Dr Lerato Shikwambana, a Senior Scientist: Earth Observation at the South African National Space Agency (SANSA), has considerable experience with ground-based and space-borne elastic backscatter lidar, having used both to study aerosols and clouds over South Africa for his PhD, awarded by the University 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/

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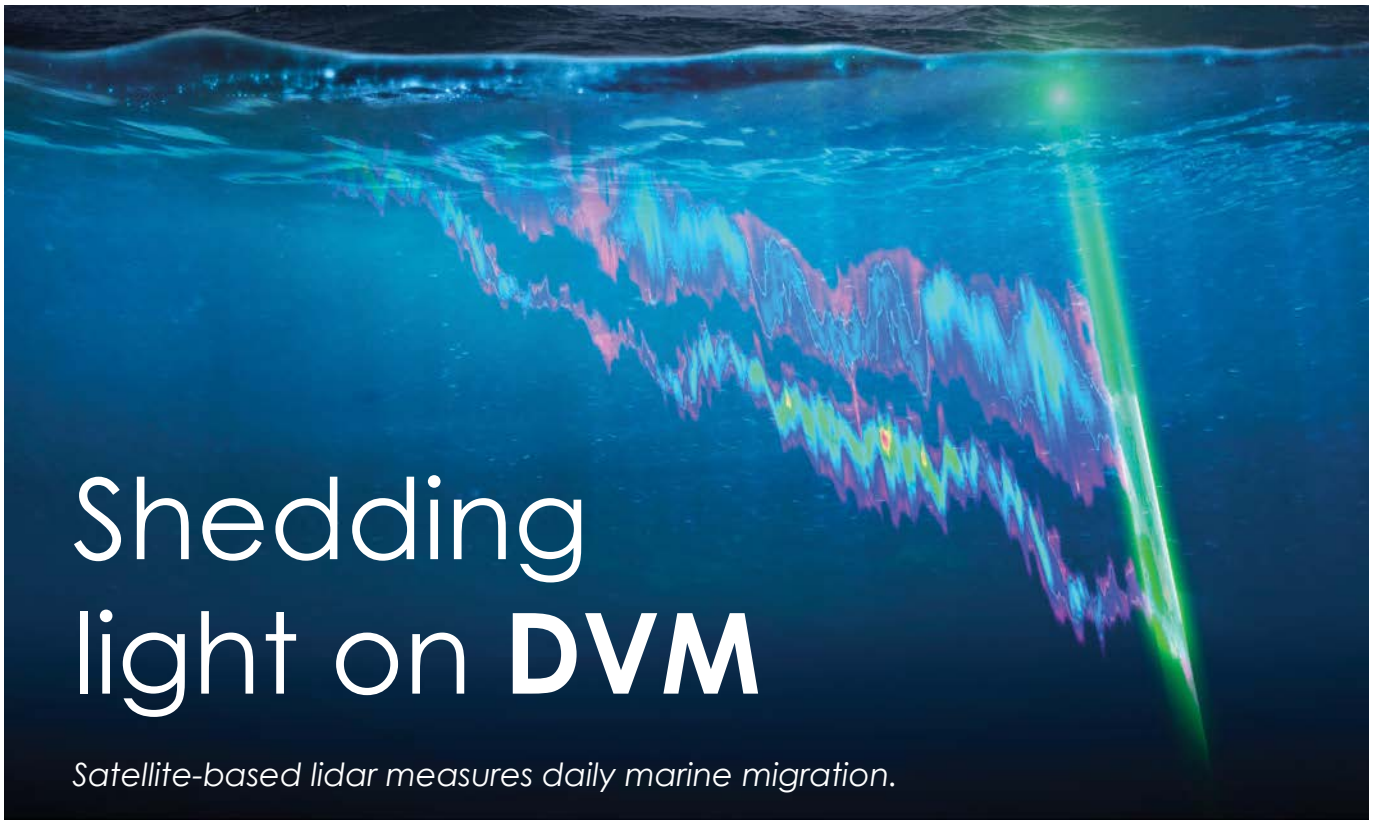


Shedding light on **DVM**

Satellite-based lidar measures daily marine migration.

NASA/Timothy Marvel

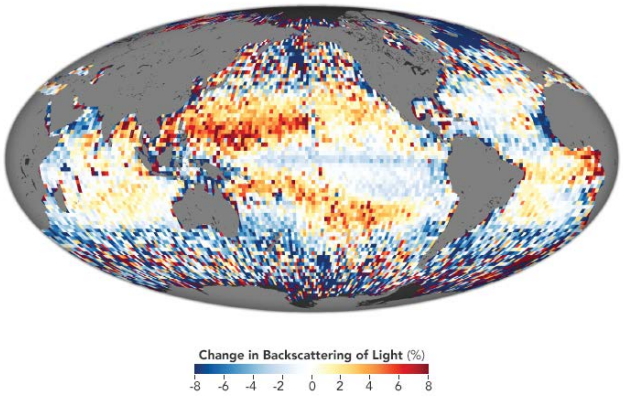
NASA/Timothy Marvel

The CALIPSO satellite's lidar was used to measure diel vertical migration (DVM), the daily movement of small marine organisms into the surface waters at sunset to feed under cover of darkness, before descending back into the depths just before sunrise.

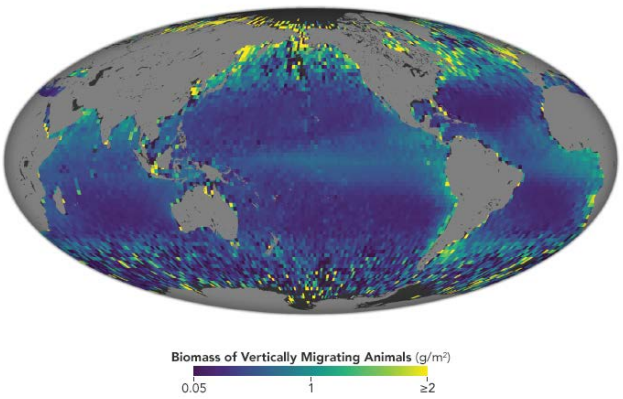
Although CALIPSO was built to study clouds and airborne particles, it has also provided a new perspective on ocean life, allowing researchers to study diel vertical migration (DVM) at a global scale for the first time. The daily movement through the water column of small marine organisms – from planktonic dinoflagellates and crustaceans to fish and squid – has long been studied from ships, but the view from space has yielded insights that improve understanding of the Earth's carbon cycle and can be used to calibrate climate models.

CALIPSO's contribution to marine biological research is rather poignant for those of us old enough to remember that the late Jacques Cousteau's first research vessel in his long-running TV series was named the *Calypso*, after the Greek mythological sea nymph. Two decades before he found fame as a marine explorer and naturalist, Cousteau played a key role in the development of scuba-diving gear, as he co-designed the first safe, twin-hose scuba system, patented in 1945 as the Aqua-Lung. He later co-invented the two-person submarine known as the diving saucer (because it resembled a 'flying saucer' UFO), which allowed him to stay at depths of 350 m for up to five hours.

CALIPSO's laser can only provide remote-sensing data from the upper 20 m of the sea surface, but this is enough to detect the massive migration that takes place on a daily basis. Every night, under the cover of darkness, herbivores that feed on phytoplankton ascend from the depths to the surface layer, where the phytoplankton must remain in order to photosynthesise during the day. Along with the herbivores, which include various kinds of zooplankton and small fish, come the larger animals that prey on them, but just before sunrise they all return to the darker deep water, where they will be harder for predators to see.



CALIPSO's laser pulses are reflected back, or backscattered, by particles and objects in the oceans, influencing the intensity of the signal detected by the satellite's receiver telescope. In this global map of the percentage overnight change in backscattering of light, the red areas had the greatest difference in backscatter between day and night, which indicates a large proportion of animals undertaking DVM.



Joshua Stevens, NASA

Coastal waters have higher nutrient concentrations than open-ocean areas because of river inputs, upwelling and pollution sources, so they are far more productive, supporting an abundance of marine life. This means that even though DVM is most apparent in oceanic waters, the overall biomass of vertically migrating animals is still higher in coastal waters.

This daily movement is the largest migration of animals on Earth in terms of total numbers, and the cumulative effect on global climate is significant. During the day, photosynthesising phytoplankton take up significant amounts of carbon dioxide (CO_2), which contributes to the oceans' ability to absorb this greenhouse gas from the atmosphere. When animals feed on phytoplankton near the surface and then swim back down, they take the phytoplankton carbon with them. Much of this carbon is then defecated at depths where it is effectively trapped, preventing its release back into the atmosphere.

A team of researchers from the United States, France and Canada published their findings on CALIPSO's revelations about this vast animal migration in the journal *Nature* in November 2019.

"What the lidar from space allowed us to do is sample these migrating animals on a global scale every 16 days for 10 years," said lead author Mike Behrenfeld, who is a senior research scientist and professor at Oregon State University. "We've never had anywhere near that kind of global coverage to allow us to look at the behaviour, distribution and abundance of these animals."

The team found that in tropical and subtropical ocean regions – where the water column is nutrient-poor, supporting low phytoplankton concentrations and hence quite clear – there are fewer vertically migrating animals, but they comprise a greater fraction of the total animal population. This is because visual predators have a greater advantage in clear ocean regions, whereas in murkier, nutrient-rich regions relatively more animals can remain near the surface, night and day.

Matt Wilson, Jay Clark, NOAA NMFS AFSC

Zooplankton such as copepods and euphausiids, or krill, undertake DVM to feed on phytoplankton and smaller zooplankton.

The researchers also observed long-term changes in populations of migrating animals that are probably driven by climate variations. During the study period, between 2008 and 2017, CALIPSO data revealed an increase in the biomass of migrating animals in the subtropical waters of the North and South Pacific, North Atlantic and South Indian oceans. In the tropical regions and North Atlantic, biomass decreased. In all but the tropical Atlantic regions, these changes correlated with changes in phytoplankton production.

Recognising that DVM is an important mechanism in Earth's carbon cycle, scientists are taking the phenomenon into account in their modelling of global climate.

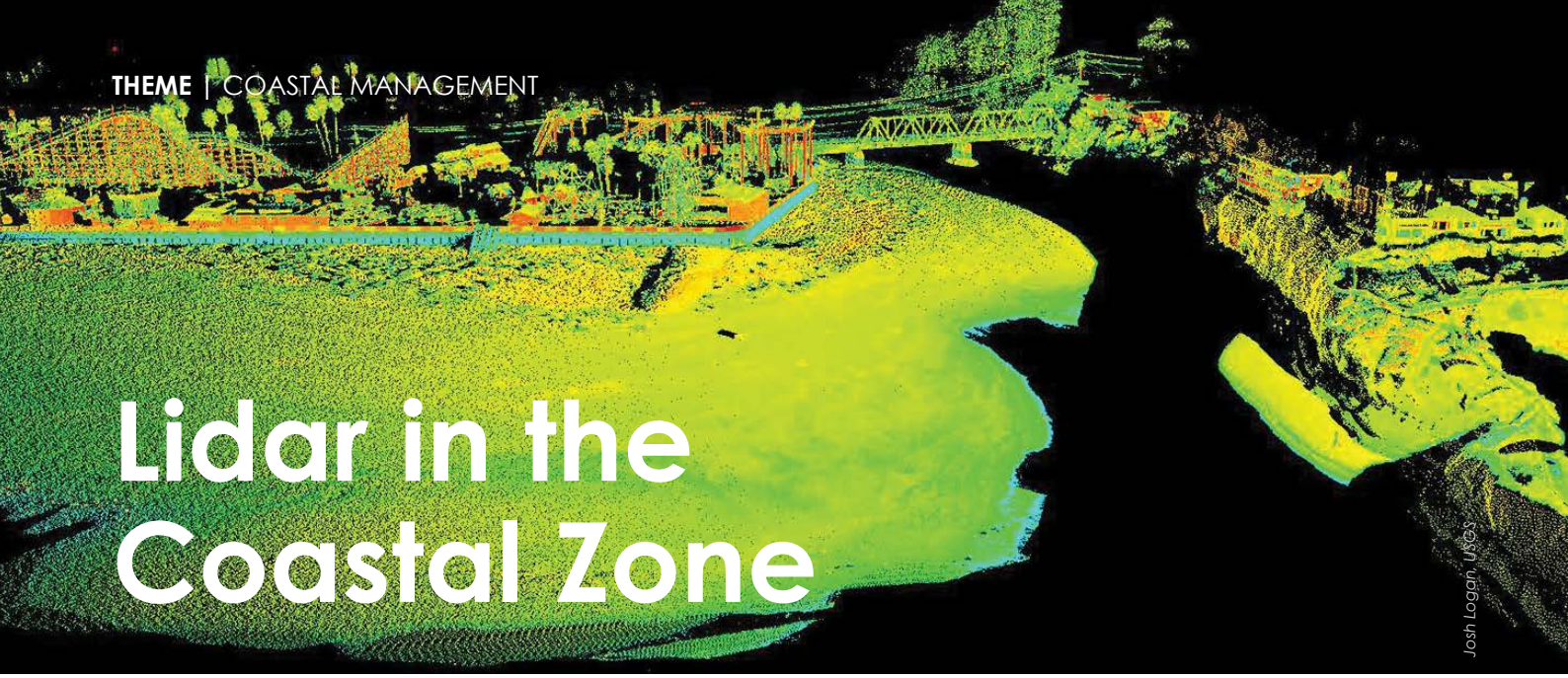
"What these modellers haven't had is a global dataset to calibrate these models with, to tell them where these migrators are most important, where they're most abundant, and how they change over time," said Behrenfeld. "The new satellite data give us an opportunity to combine satellite observations with the models and do a better job quantifying the impact of this enormous animal migration on Earth's carbon cycle."

The CALIPSO outputs are also relevant to global food security, because the migrating animals are an important food source for larger predators that are targeted by commercial fisheries. The larger the DVM signal, the larger the population of fish that can live in the deep sea.

"This is the latest study to demonstrate something that came as a surprise to many: that lidars have the sensitivity to provide scientifically useful ocean measurements from space," said Chris Hostetler, a scientist at NASA's Langley Research Centre and a co-author of the paper. "I think we are just scratching the surface of exciting new ocean science that can be accomplished with lidar."

- Behrenfeld, MJ, Gaube, P, Della Penna, A. et al. 2019. Global satellite-observed daily vertical migrations of ocean animals. *Nature* 576**:** 257–261. https://doi.org/10.1038/s41586-019-1796-9

Lidar in the Coastal Zone



Josh Logan, USGS

The use of airborne lidar for aerial surveying and mapping has been growing since the early 1990s, when the first commercial systems became available. It is particularly valuable in the coastal zone, where land and sea meet. In this highly dynamic environment, sand is continually shifted by wind, waves, currents and freshwater flows. Buildings and other structures impeding this natural movement, or even vegetation that stabilises mobile dunes and estuarine sandbanks, typically result in changes to the terrain – both above and below the water surface – over time, sometimes with disastrous consequences.

Houses built too close to dunes may slowly become swamped by windblown sand, while popular beaches may become rocky and hazardous as layers of sand are stripped away. But changes can also be rapid and catastrophic, as when storm waves erode dunes beneath houses, or floodwaters break open an estuary mouth in a new position, exposing structures on the previously placid lagoon shore to the forces of wave action and strong currents.

These coastal hazards, together with the threats posed by climate change and sea level rise, highlight the benefits of being able to create digital elevation models (DEMs) relatively easily with lidar data. The DEMs can be used to develop setback lines for coastal development, predict the areas that would be inundated by sea level rise or storm surges, or detect both slow and rapid change if regular or before-and-after-event surveys are conducted. Used in combination with aerial photographs or satellite imagery, the lidar-derived elevation information can even assist in mapping vegetation types – such as coastal bush, reedbeds or saltmarshes – and assessing their biomass.

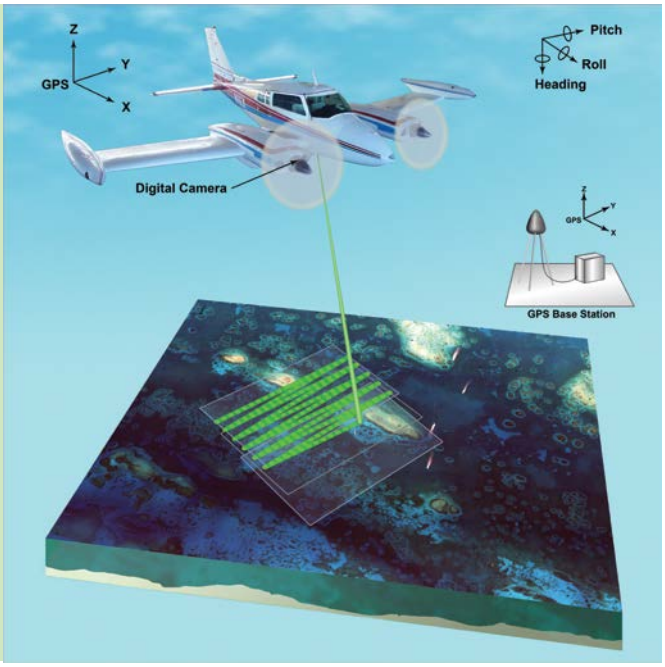
Dr Melanie Lück-Vogel, a senior researcher in remote sensing at the CSIR, was lead author of a paper published in the *South African Journal of Botany* in 2016, reporting on the findings of just such a mapping exercise for the St Lucia estuary on the KwaZulu-Natal coast. She has played an instrumental role in coordinating the application of lidar technology in South Africa's coastal zone, organising three workshops for lidar service providers and stakeholders between March 2014 and December 2017, and co-authoring 'Guidelines for coastal lidar', published in *PositionIT* in May 2018. She explains that lidar surveys of sections of our coast have been commissioned for various purposes by municipal and provincial authorities,

Airborne Lidar

Most airborne lidar systems project the laser beam onto moving mirrors so that light pulses are swept from side to side or in an elliptical pattern. The time taken for reflected pulses to be detected by the aircraft's instrument – called a laser altimeter or laser scanner – is used to calculate the range, or distance, to the object.

The angle of the laser is recorded for each pulse, and the exact position and orientation of the aircraft is determined using an onboard GPS as well as nearby ground stations for geo-referencing, together with an Inertial Navigation System using accelerometers and gyroscopes to measure pitch, roll and heading. In this way, the XYZ coordinates (latitude, longitude and elevation) of each reflection point is computed.

The dataset of points makes up a three-dimensional point cloud that can be used to generate digital elevation models of the scanned surface.



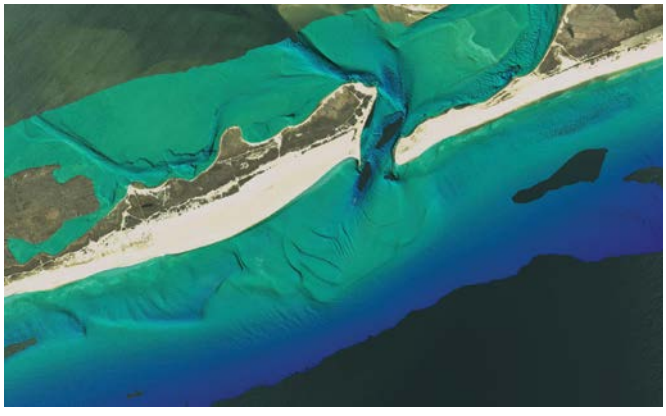
Betsy Boynton, USGS

parastatals and private companies, and so the technical specifications and final datasets differ, making it problematic to compare products and use the data for regional or national coastal studies. Nevertheless, the lidar data was used, after much pre-processing, to develop the Coastal Flood Hazard Tool in OCIMS – the National Oceans and Coastal Information Management System developed by the CSIR for the Department of Environmental Affairs.

During the workshops, the participants identified the need for a central repository for coastal lidar data, which could be curated and distributed by a national custodian. The Chief Directorate: National Geo-Spatial Information (NGI) – previously Surveys and Mapping – in the Department of Agriculture, Land Reform and Rural Development would be the obvious custodian, so it's a positive step that the department recently advertised a tender for an analysis of South Africa's marine and coastal spatial data infrastructure (MCSDI). The terms of reference were essentially to investigate who has what datasets, to review international best practices, and to recommend an approach for integrating the MCSDI into the existing South African Spatial Data Infrastructure (SASDI). Although this includes all kinds of spatial data, it would naturally include lidar data too.

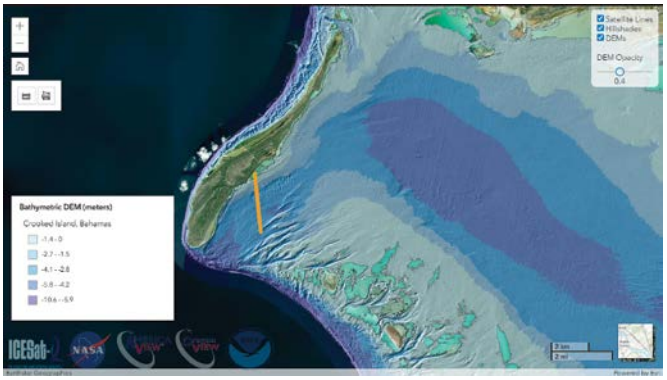
In the United States, the National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management makes lidar and other data available through an online platform called Digital Coast. Its Coastal Topographic Lidar repository contains data gathered by many different organisations using a variety of lidar sensors, and these datasets are easily found and downloaded via a map-based Data Access Viewer. Both point clouds and DEMS are available, and many of these are from 'topobathy' lidar surveys providing both topographic (land) and bathymetric (seafloor) elevation data for the coastal strip.

While bathymetric surveys are normally done from ships, using single-beam sonar or multibeam echosounders, the nearshore areas are too shallow and hazardous for survey ships to operate in. Airborne lidar bathymetry (ALB) now allows these areas to be rapidly surveyed and mapped, and also supports mapping of benthic habitat, such as coral reefs or seagrass beds. The lidar systems use lasers of two different wavelengths – green wavelengths to penetrate water and reflect off the seabed, as well as the near-infrared wavelengths used for topographic lidar to reflect off land and the sea surface. ALB is effective to depths of 50–70 m in the very clear waters typical of tropical regions, but only to 10–30 m in most temperate regions. In very turbid waters – such as the high-energy surf zones of parts of South Africa's coast, or where rivers discharge massive amounts of sediment into the sea – the laser will only penetrate to one to three times the Secchi disc depth, depending on the instrument used. Results can also be affected by sea state and weather conditions.



USGS

Airborne lidar bathymetry was used here to identify features in an estuary and nearshore region.



Ben Babbel

This website demonstrates a method for creating satellite-derived bathymetry (SDB) through fusion of Landsat-8 Operational Land Imager (OLI) and ICESat-2 Advanced Topographic Laser Altimeter System (ATLAS) data. See: http://shallowbathymetryeverywhere.com/

The uptake of ALB is limited by the expense of aerial surveys, but remote-sensing experts have also been able to derive shallow-water bathymetry with reasonable accuracy using ground-truthed algorithms and models applied to freely available multispectral satellite images from the Landsat-8 Operational Land Imager (OLI) and, more recently, the higher-resolution Sentinel-2 Multispectral Instrument (MSI). This is known as satellite-derived bathymetry (SDB), and some exciting developments have taken place in the past year. Lidar data has become available from the Advanced Topographic Laser Altimeter System (ATLAS) on NASA's Ice, Cloud and Land Elevation Satellite (ICESat-2), launched in September 2018, and researchers have started using its point measurements of elevation along the satellite's ground track to calibrate and validate the SDB from Landsat and Sentinel imagery. This paves the way for shallow-water bathymetry of clear coastal seas and estuaries to be derived purely from space in future.

- To launch the OCIMS Coastal Flood Hazard Decision Support Tool, go to: https://www.ocims.gov.za/coastal-flood-hazard-tool/

Shaun Levick/CSIRO

Capturing Kruger in 3D

Izak Smit explains how lidar has been used in the Kruger National Park.

Savannas are particularly interesting in that they contain elements of both grasslands and forests, yet never become either one – they always remain a diverse mixture of trees and grass.

The reason for the coexistence of trees and grass, with neither totally replacing the other, has been one of the most pertinent questions for savanna ecologists over many decades. Why is grass biomass so high and tree cover so low in certain areas, compared to other areas close by? Does it change over time? What drives these patterns and dynamics, and how can management of fire regimes and grazing intensity influence it? What is causing bush encroachment or thickening in certain savannas, resulting in increased woody cover and a reduction in grass biomass, and can it be reversed? How will increasing levels of atmospheric carbon dioxide levels and other drivers of global change influence the tree–grass coexistence? These questions are fundamental to understanding savanna functioning.

One of the key variables that needs to be measured in order to answer some of these questions is the aerial cover of the woody vegetation – the trees and bushes. In recent years, lidar data has proven very useful in this regard, providing valuable insights into subtle patterns and dynamics of woody vegetation at great accuracy and over large scales.

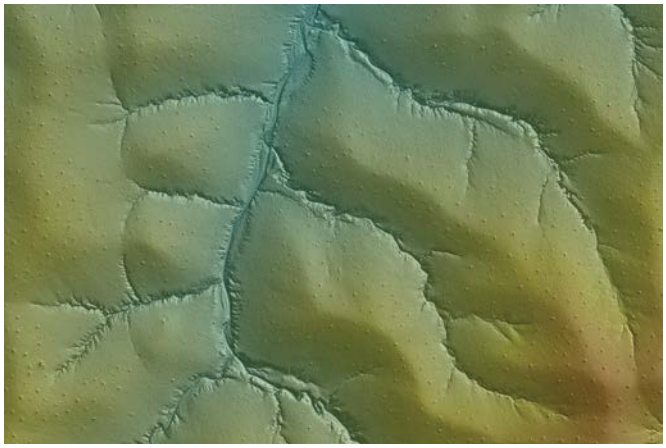
Lidar for landscape mapping

Lidar for large-scale mapping involves measuring the time it takes for laser light pulses – fired from an instrument on an airplane, drone, satellite or mobile platform – to return after reflecting off the ground or from objects on the landscape surface, such as buildings and trees. The data derived from lidar can be used to create two very different types of 3D models. The first, called a digital terrain model (DTM), creates very detailed topographical models by stripping all features off the landscape and only showing the underlying topography. The second type, a digital surface model (DSM), represents the elevation of all the features elevated above the 'bare' ground surface, including trees. By subtracting the DTM from the DSM, one can accurately measure the dimensions of all the features on the landscape, essentially by 'flattening' the underlying landscape and representing the cover and height of objects. Using this type of dataset of the absolute height of features relative to the ground, it is possible to measure the canopy height and dimensions of individual savanna trees over large areas.

Htoni, Wikimedia, CC BY-SA 3.0

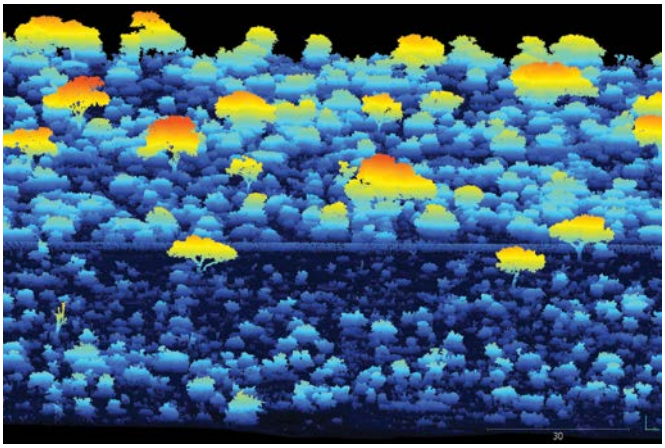
The Kruger National Park encompasses 1.9 million hectares in South Africa's north-eastern extreme.

Collecting lidar-derived tree structure data from specific experimental sites, or overlaying it with other spatio-temporal datasets such as elephant distribution, mean annual rainfall or soil type, can provide valuable insights. In the past decade, scientists from the Kruger National Park (KNP), in collaboration with the Carnegie Airborne Observatory (now the Global Airborne Observatory), Council for Scientific and Industrial Research (CSIR), University of the Witwatersrand and the Friedrich Schiller University



Shaun Levick/GAO

A digital terrain model showing detailed topographic features such as drainage lines and termite mounds, derived from lidar imagery.



Peter Boucher, Davies Lab, Harvard University

A lidar image reveals the contrast in woody vegetation cover and height inside (top half) and outside (bottom half) a fenced herbivore exclosure.

Jena in Germany, have used lidar technology to explore how different abiotic drivers (e.g. landscape positions, fire regimes), biotic drivers (e.g. elephants, termites) and human infrastructure (roads) or human uses (fuelwood harvesting) have influenced woody vegetation cover and height within the KNP and the surrounding communal rangelands.

Termites and trees

Lidar data proved very useful for identifying mounds built by termites from the genus *Macrotermes*. Mapping thousands of termite mounds across tens of thousands of hectares in the KNP allowed researchers to study the distribution, spacing and height of the mounds. This revealed that termites build their mounds at different topographic positions and make them different sizes depending on the long-term rainfall patterns in the specific landscape. This can be attributed to the fact that the rainfall regime determines the availability and distribution of clay particles in the landscape – and termites need adequate clay to build their mounds, of course.

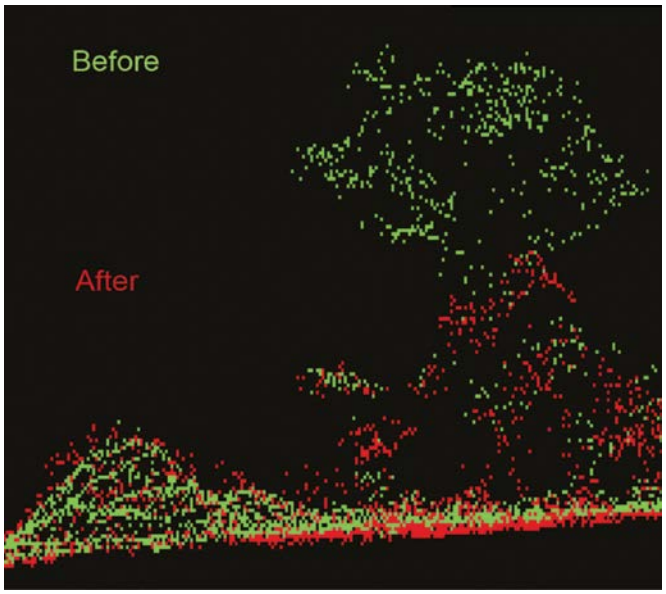
A further interesting finding emerged when comparing the size of trees at different distances from termite mounds. Trees within a 20 m radius of termite mounds were found to be taller than trees further away. In addition, by fencing trees in an exclosure to exclude large mammalian herbivores, it was revealed that trees closer to termite mounds seem to be more heavily browsed than those further away. This confirms the importance of termite mounds as nutrient hotspots for animals in the landscape. Considering the density of termite mounds in KNP, this 20 m zone of influence around termite mounds may affect as much as 20% of some landscapes. The role of these important insects in shaping the African savannas should therefore not be underestimated.

Elephants and treefall

The KNP has various experimental sites where the fire regime or the herbivore composition or density are manipulated, in order to tease apart and quantify the influence of fires and herbivores on vegetation structure.

Tim Ellis, CC BY-NC 2.0

Elephants have a major impact on vegetation structure, and account for the high rate of treefall in some areas of the park.



Shaun Levick/GAO

Lidar data collected over time allows detection of fallen trees. This lidar point cloud shows a tree before (green) and after (red) it toppled over.

Using lidar-derived data on woody structure inside and outside of these experimental sites, it is possible to compare the patterns and dynamics of woody vegetation under these different fire and herbivore regimes.

As such, lidar data was used to determine the location and height of trees in exclosures where all mammalian herbivore species larger than a hare have been excluded (using meshed and electric cable fence), as well as exclosures where only giraffe and elephant have been excluded (two high strands of electric cable fence allow free movement of other animals). The vegetation patterns were then compared between these two herbivore exclosure areas and the control areas outside the exclosures. Two years later, lidar data was collected from exactly the same areas, allowing researchers to determine the fate of the same trees and identify which trees were missing or had toppled over. Using this approach, it was estimated that the rate of treefall was about six times faster in areas where elephants and giraffes have access to the trees, compared to areas protected from elephants. Since giraffes do not topple trees, this study suggested that elephants have a significant effect on vegetation structure within an area next to a permanent river that is frequented by elephants.

This study was expanded to larger landscapes of the park outside of the exclosures, linking the fate of more than 10 million individual trees over hundreds of thousands of hectares over time with a range of spatial data layers, such as mean annual rainfall, soil type, landscape position, fire frequency, time since last fire, and elephant density. From the results, it was again apparent that elephants are a big driver of change in vegetation structure. But what was noticeable from the landscape-scale study, as opposed to the exclosure study, was that bull elephants are seemingly having a larger impact on woody vegetation structure than breeding herds, as the rate of treefall was higher for areas frequented by bulls rather than mixed herds. In addition, it was evident that the rate of treefall across the landscape was highly variable, with elephant–tree interaction a spatially heterogeneous process.

Fire intensity and tall trees

Similar to the studies exploring the effect of elephants on vegetation structure, we have also explored how fire influences vegetation structure under different experimental fire regimes. We found that if similar adjacent landscapes are burned at different times of the year, and under different climatic and grass-curing conditions, the difference in fire intensity results in very different vegetation structure outcomes. Very high-intensity fires – typically occurring late in the dry season – tend to reduce woody cover, at least in the short term, but also result in the toppling of significantly more tall trees (> 10 m height and > 6 m crown diameter). For example, it was found that two very high-intensity fires over a four-year period opened up a landscape in the short term by reducing overall woody cover, but at the same time toppled about one-third of all the tall trees, whereas two low-intensity fires over the same four-year period did not reduce woody cover, and a tree-toppling rate of only 3% was recorded.

Recently, additional lidar data was collected in order to determine what has happened to the vegetation structure in these landscapes since the experimental fires of variable intensity. Some observational data suggests that although these high-intensity fires may have reduced the

Izak Smit

High-intensity fires on hot, dry days towards the end of the dry season can open a landscape of woody cover, at least in the short term, but with high collateral damage to tall trees.

woody cover in the short term, they may increase woody cover in the long term by stimulating trees to grow back as multi-stemmed individuals, coppicing from roots and resprouting from the main stem. This is an ongoing project and the results will have implications for how fires of different intensities can or cannot be used in an attempt to address woody encroachment – a concern in savannas across many continents.

Roads and trees

Another interesting insight from the lidar data was that tree cover is higher for trees growing closer to roads. This effect is seen up to about 10–15 m from roads, extending furthest from the road in areas with higher average rainfall conditions. It is expected that this 'hedging' effect alongside the roads may be due to roads 'harvesting' rainfall for the surrounding landscapes, via runoff from the hardened road surfaces. The hedging displays a typical distance-decay function, with the biggest increase in woody cover closest to the road (within 5 m) and then decreasing at increasing distance from the road, until background tree cover is achieved around 10–15 m from the road. Although these findings were consistent and very noticeable when analysing the lidar data across various soil and rainfall environments in the KNP, the effects are too subtle to see with the naked eye, and would have been very hard to detect with field-based surveys.

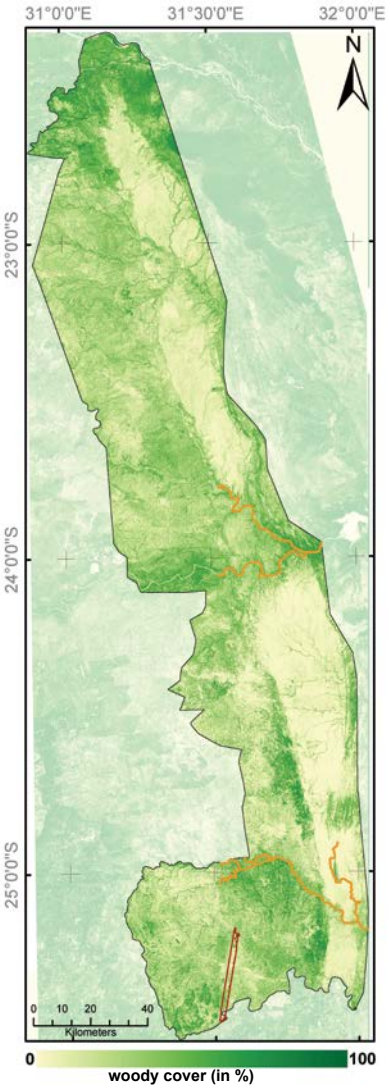
Lidar and satellite upscaling

Although lidar has many advantages and can provide detailed vegetation structural data over large scales, as illustrated by some of the case studies provided above, it can be costly to collect such data over very large landscapes, such as the KNP's entire 1.9 million hectares. In these cases, satellite imagery may be a more suitable remote-sensing product to use. Over large scales, satellite imagery is cheaper, or even free, and can be collected more frequently, although aerial lidar may still have an important role to play in focusing in on smaller areas. For example, lidar data was used in a recent study to calibrate and validate random forest models to estimate woody cover from the radar data collected by the European Space Agency's Sentinel-1 satellite sensor. The lidar calibration and validation imagery played an important role in creating a wall-to-wall woody cover map at 10 m spatial resolution for the entire KNP.

Allan Watt, CC BY-NC

Lidar data has revealed higher tree cover alongside KNP roads, creating a 'hedging' effect that is not apparent to the naked eye.

There may also be potential for using space-based lidar data in future, but this has not yet been explored for the KNP. For example, NASA's Ice, Cloud and land Elevation Satellite-2 (ICESat-2) and its Global Ecosystem Dynamics Investigation (GEDI) mission on the International Space Station – both launched in late 2018 – provide lidar data that may be useful for monitoring changes in canopy height and cover.



Urban et al. 2020, Koedoe, https://doi.org/10.4102/koedoe.v62i1.1621

Lidar data collected at the red and orange strips was used to calibrate and validate models to estimate woody cover across the entire KNP at a 10 m resolution, using radar time series from the Sentinel-1 satellite mission.

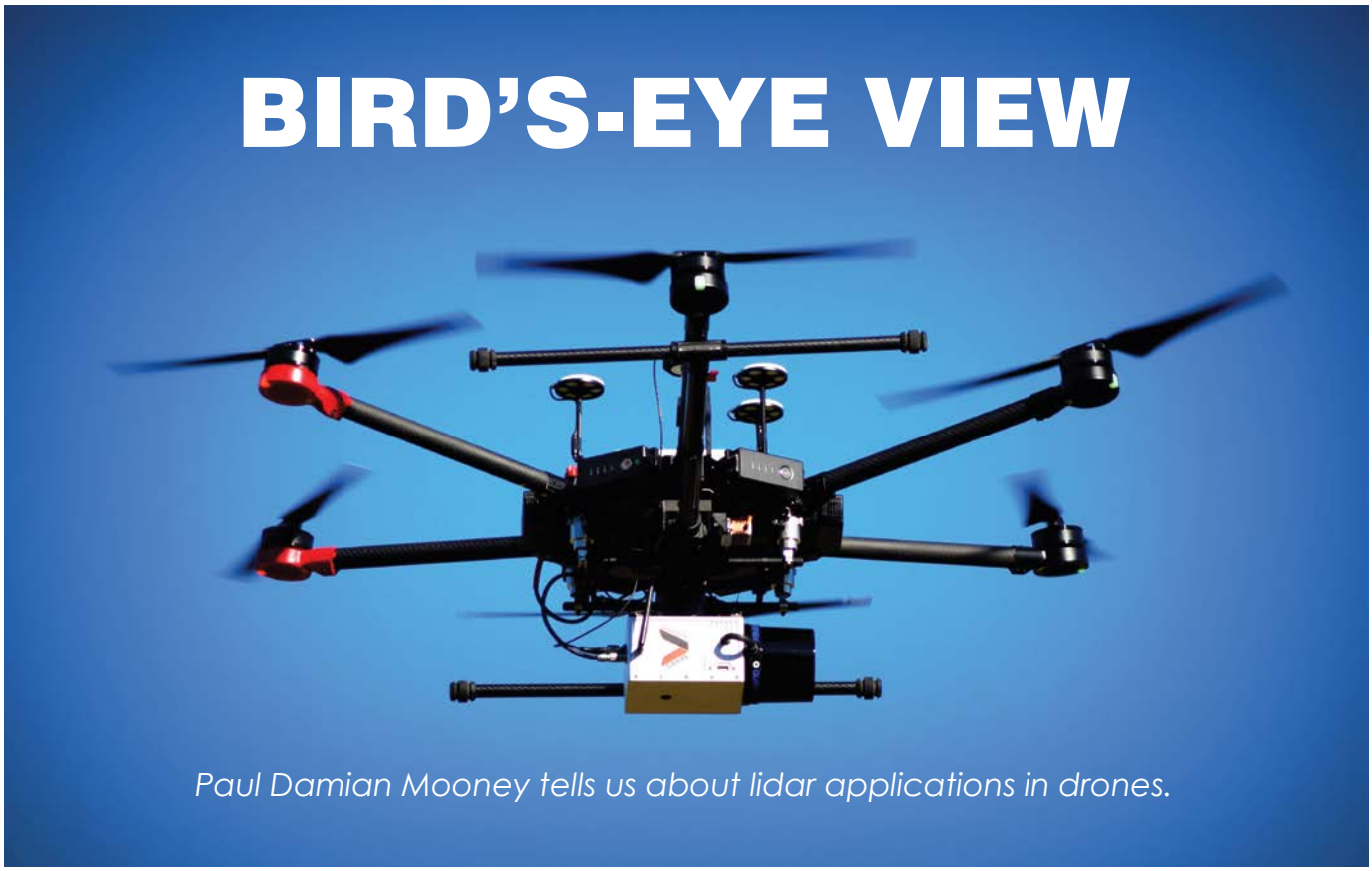
Lidar will never replace field-based studies, but has become an incredibly powerful tool in the toolbox of ecologists working in the KNP. Lidar has allowed small-scale patterns (e.g. location and height of individual termite mounds) and small-scale dynamics (e.g. fate of individual trees) in the KNP to be studied over large scales (thousands of termite mounds; tens of kilometres of road verges; >10 million trees; hundreds of thousands of hectares), and in many different and contrasting environmental contexts (different soils, rainfall, fire and herbivore conditions).

The KNP has become a popular lidar 'research destination', the most recent addition being a collaborative project by Harvard University and SANParks. The project explores what new insights can be gained from combining ultra-high resolution lidar data before and after fires with thermal imagery collected during active fires by means of a state-of-the-art drone system. Lidar is helping KNP scientists and collaborators better understand vegetation patterns and processes in order to inform management approaches to various ecological challenges.

Dr Izak Smit is Science Manager: Systems Ecology, GIS and Remote Sensing at SANParks, based at Skukuza in the Kruger National Park. He works at the interface of science and management and focuses on applied research to inform conservation management.

Lidar images by Shaun Levick created using data from the Global Airborne Observatory (GAO), Arizona State University (formerly Carnegie Airborne Observatory) unless otherwise indicated.

BIRD'S-EYE VIEW



Paul Damian Mooney tells us about lidar applications in drones.

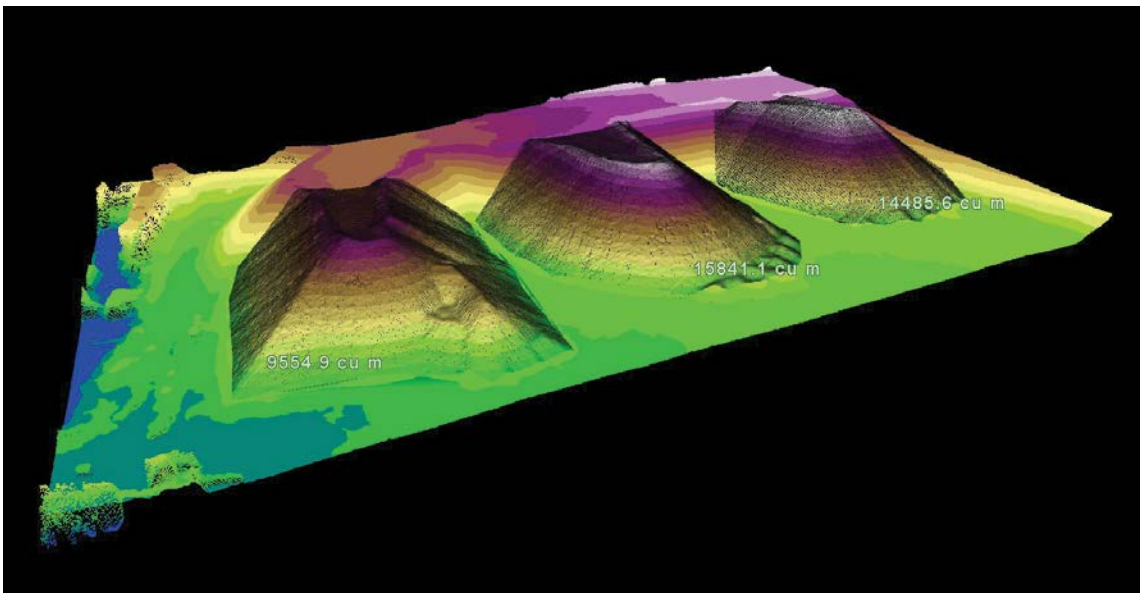
LiDARUSA Snoopy120, CC BY-SA 4.0

In stark contrast to 15 years ago when they were associated mainly with high-end military equipment, drones have now become readily available must-have gadgets that we might find in our Christmas stocking. Most of these drones are used as flying toys, and their ability to be easily controlled and make users feel like a professional helicopter pilot is their main aim and appeal.

The commercial drone, on the other hand, has an entirely different purpose in life. Once people realised that drones could carry some form of payload, even if only a few grams in early models, the drone itself was no longer the main point of interest. Instead, it was relegated to a tool that could carry other items with the potential to generate revenue, once in the air.

Although many commercial operators refer to drones as UAVs – an acronym for unmanned aerial vehicles – they are now officially classified in terms of the International Civil Aviation Organisation as remotely piloted aircraft systems, or RPAS.

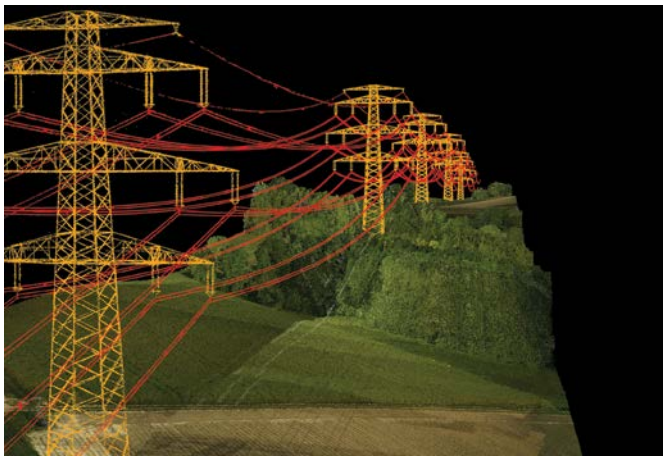
The list of airborne equipment mated to an RPAS is very long, and growing every day. Cameras with RGB, thermal and multispectral sensors, sonar, lidar, air-samplers, loudhailers, floodlights, emergency Wi-Fi and GSM repeaters, receivers for tracking radio-tagged wildlife, weapons and – conversely – cargo bays for life-saving blood deliveries are just a few of the items that are airborne on thousands of RPAS around the world daily.



LandScope Engineers

Drone-based lidar is widely used in the mining industry for volumetric measurements of ore stockpiles.

Cameras are by far the most common sensor on an RPAS, not only for the obvious benefit of having a bird's-eye



Siemens AG

Inspection of power lines has been taken to a new level with the Siemens SIEAERO service, which relies on drones equipped with highly sensitive lidar sensors, together with smart analytics software that uses artificial intelligence (AI) and machine learning. The service allows for rapid and precise automated detection and assessment of faults and issues along the lines.

view of a feature on the ground, but also for their use in photogrammetry – the science of making measurements from photographs, particularly useful for mapping and 3D surveying. If numerous images of an object of interest are taken from various angles as an RPAS traverses overhead, the different views of the object can be interpolated to determine both its horizontal and vertical dimensions, in a similar way to how human eyes determine depth of view by having two slightly different views. A high-quality camera can attain 1 cm horizontal accuracy and 2–3 cm vertical accuracy, which is very sought-after in the mining industries for volumetric analysis of ore stacks.

Recently, as technology has improved and sensor size has been miniaturised, lidar has become the new method of choice for high-accuracy airborne surveying. By recording the time taken for a laser pulse emitted from a lidar sensor on the RPAS to be reflected back, the distance that the pulse has travelled can be calculated to sub-centimetre accuracy. When the lidar is used in conjunction with tiny oscillating mirrors, the laser pulses leave the sensor in many directions per second, generating a line of data points across the ground as the RPAS moves forward. The high-speed mirrors give the lidar sensor up to 500 accurate point readings per square metre as the RPAS performs its survey. The resultant high-resolution data is capable of showing not only the structure of electrical power pylons but the thin power cables between them.

Mechatronics master's student Jacques Welgemoed was awarded joint second place at the online BRICS Future Skills Drone Operating Challenge 2020, which involved 85 participants from 12 countries.

The lidar sensor is only one part of the system needed for a high-accuracy survey. In order for the lidar to pinpoint a reference point on the ground, the sensor must also have extremely accurate readings as to its own position in space. This positioning data is obtained from high-precision satellite positioning systems in conjunction with inertial measurement units to determine the inclination of the lidar at any given microsecond as the RPAS 'bounces' through the air. The combination of lidar and supporting positioning systems can make lidar nearly double the price of a photogrammetry system, in the region of R500 000.

In the teaching and research arena, the high cost makes it difficult to provide students with lidar systems for individual projects, and we often have to use entry-level versions in the form of laser rangefinders. These units – weighing just a few grams – have recently become available for as little as R500. The VL53L1X is a state-of-the-art, time-of-flight (ToF), laser-ranging sensor, with accurate ranging up to 4 m and a fast ranging frequency up to 50 Hz. By combining a number of these sensors at various angles underneath an RPAS, students are able to mimic the line of points that high-end oscillating mirror lidar sensors generate, at a fraction of the cost although at a much lower resolution per square metre.

With the low costs of small RPAS, laser rangefinders and small-factor computers like the Raspberry Pi or Odroid, students from all over the world are competing in events to see what they can achieve with an RPAS and lidar system. Events include hackathons where students are given free rein to develop any project they feel will benefit humanity. An example of this is an RPAS that autonomously uses its lidar to keep a safe distance from a human while spiralling around the subject, in order to generate an accurate 3D model for clothes sizing.

Other events are structured competitions where students have to use lidar to navigate their drone through an indoor factory environment with no access to GPS, while measuring the size and shapes of containers to simulate an automated stock-taking sequence in a factory. Due to COVID restrictions, one of the events in 2020 became an online remote-controlling demonstration. Competitors were tasked with writing code in their home country that was then uploaded to physical drones waiting in a warehouse in Russia to perform the tasked flights. Competitors had the surreal experience of watching live YouTube footage of their drones flying autonomously on the other side of the world, using lidar sensors and the code they had just written. The South African team from Nelson Mandela University, consisting of Jacques Welgemoed with me as his mentor, achieved the silver medal at the event.

Paul Damian Mooney is an RPAS technician with the MandelaUni Autonomous Operations group at Nelson Mandela University, Port Elizabeth. He has had an aviation career spanning 20 years as an airline transport pilot and instructor in the South African Airforce and the commercial sector.

3D scanning the 'New Jerusalem'

and other ancient monuments

The Zamani Project uses lidar to document heritage sites in Africa and further afield.

The spectacular Biet Ghiorgis, or House of St George, is one of 11 churches carved or constructed from the soft volcanic rock at Lalibela, in the mountainous heart of Ethiopia. Legend has it that King Lalibela, emperor of Ethiopia in the 12th century AD, ordered the churches to be built as a 'New Jerusalem' for Christian pilgrimage, after the holy city of Jerusalem in the Middle East was captured by Muslims. Today their true history is debated, but the Lalibela rock-hewn churches were among the first dozen World Heritage Sites to be designated by UNESCO in 1978.

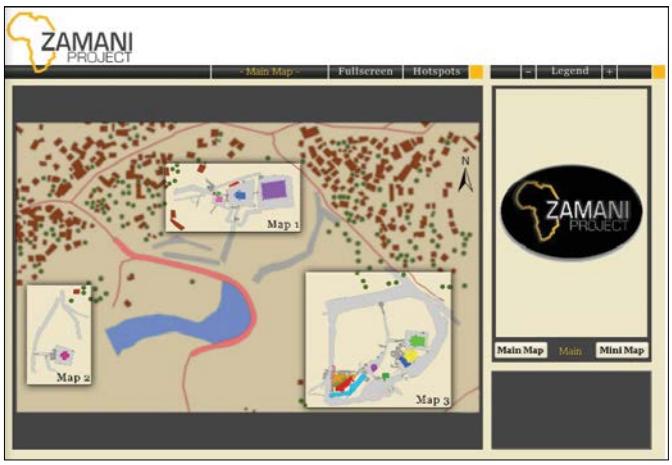
Now one of Ethiopia's main tourist attractions, the site is still used for daily worship and special ceremonies during Christian festivals, including Christmas and Easter. But there have long been concerns about the deteriorating state of the churches, and a variety of interventions have been implemented over the years. In 2006 the World Monuments Fund (WMF) and UNESCO funded research into the decay processes affecting the Lalibela rock in order to define a long-term conservation strategy, and three years later the WMF partnered with the Zamani Project to 'digitally preserve' the entire site with lidar scanning. The team returned in 2017 for a follow-up survey of two of the churches, during which they were invited to scan an inner sanctum – off-limits to all but a few priests – where King Lalibela was buried.

The Zamani Project is a research group in the geomatics division of the University of Cape Town's Faculty of Engineering and the Built Environment. It was conceptualised in 2001 by (now Emeritus) Professor Heinz Rüther – still the project's principal investigator – but the first expedition only took place three years later. Since then, the Zamani team has documented more than 250 structures and features at some 65 sites in 18 countries of Africa, the Middle East and South East Asia.

The work is important because the ravages of time naturally take their toll on these ancient architectural treasures and heritage sites. Some of those surveyed by the team had also been damaged during wars or natural disasters, such as earthquakes and floods, or – even more sadly – had been subject to theft and vandalism. Looking forward, the threat of climate change, with the predicted rise in sea level and increase in extreme weather events, puts coastal and floodplain sites at particular risk.

The Zamani Project doesn't only digitally preserve the sites for posterity though – it also transforms the data into formats that allow armchair travellers to view the sites on their own screens at home. These include 3D models, animated and virtual 'tours', as well as photos, maps and architectural plans from various perspectives.

The process begins with terrestrial lidar, using a laser scanner on a tripod. The scanner records an object by



The Lalibela rock-hewn churches can be explored using an online panoramic tour.

The Zamani Project team with their laser scanner at the Meroë Pyramids in Sudan.

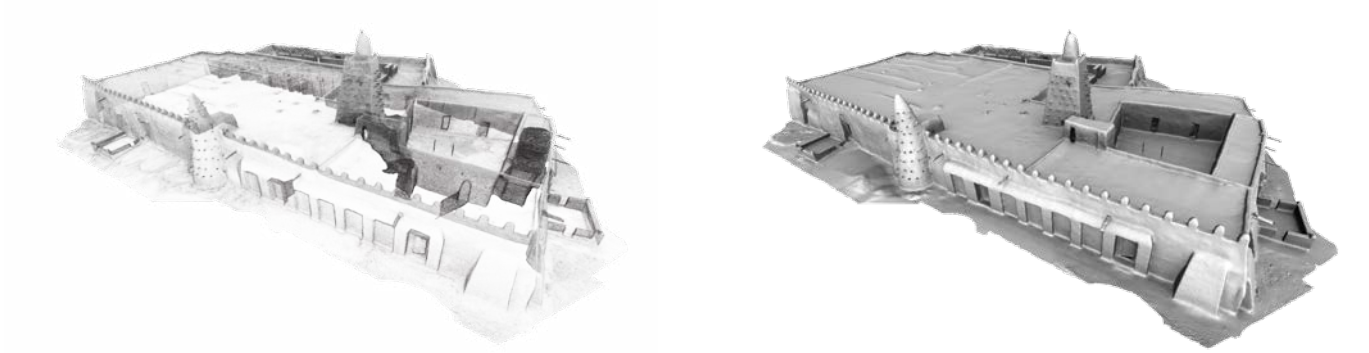
The 3D model of the Hill Complex at the Great Zimbabwe National Monument was created by the Zamani Project team in 2020. The stone structures at this World Heritage Site were built by ancestors of the Shona people in the 11th century.

determining the XYZ position of millions of points on the object surface, creating a three-dimensional 'point cloud'. To determine these XYZ coordinates, the distance, vertical angle and horizontal angle must be measured. The Zamani team's Zoller & Fröhlich phase-based scanner emits a constant laser beam – rather than short pulses as in slower pulse-based systems – and measures the phase difference between the transmitted and the return signal received by the scanner to calculate the distance between the scanner and the object. The two angles to the point are measured in the same way that a traditional theodolite measures angles.

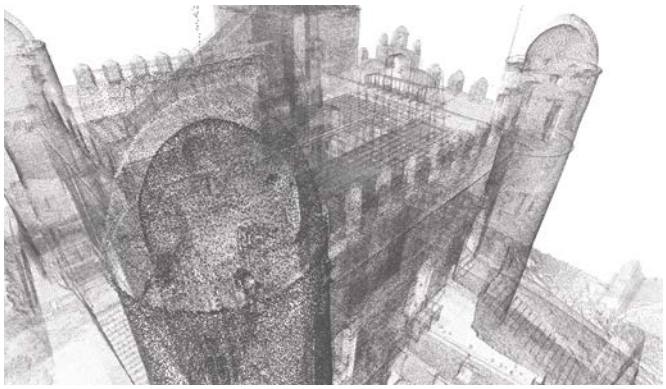
Scans are taken from numerous positions to cover as much of the object, be it a building or physical feature, as possible. Then, to fill in any data gaps in areas where the laser scanner cannot reach, photographs are taken with handheld and drone-borne cameras. Photogrammetry is used to generate additional point clouds for these gaps, and all the individual point clouds are combined and processed. Subsequently, a mesh representing the object surface is created, and photographic texture is 'draped' over the surface to give the 3D model a realistic appearance. Surfaces of models created during the early years of laser scanning have a somewhat metallic appearance – almost like they're tiny physical models made by a metal 3D printer – because software for the creation of coloured meshes was not then sufficiently advanced.

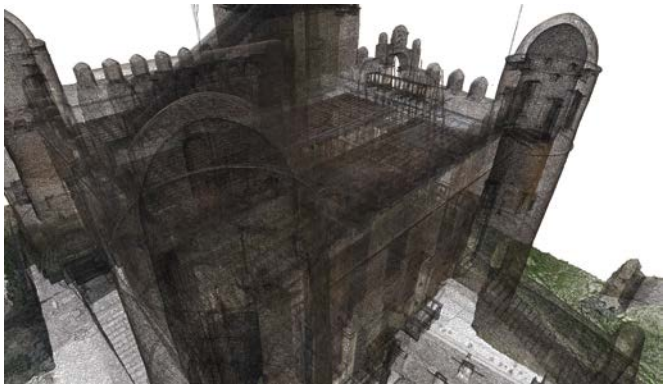
The end result is a metrically correct, mathematical representation of the object that can be viewed, navigated and even explored in virtual reality by those who have the necessary VR equipment. Accurate dimensional information can also be extracted. This means that architects and conservators can accurately plan the conservation and preservation of heritage buildings, as well as identify possible deformations and structural weaknesses.

The interactive panoramic tours are undoubtedly the best digital product to get an overall impression of a site within its surroundings. These don't use lidar but are



The Zamani Project team documented the Djingareyber Mosque in Timbuktu, Mali, in 2005. Surfaces of 3D models created during the early years lacked the photorealistic appearance of recent models because the software for such rendering was not yet sufficiently advanced.





From lidar point cloud to final 3D model of Fasil's Castle, the palace of Emperor Fasilidas, in the Fasil Ghebbi fortress in Ethiopia. Once the Zamani Project team have completed the laser scanning, photography and other survey work on site, an enormous amount of post-processing is required to create the 3D models and other digital products, including plans, sections, panoramic tours and video animations.

purely photographic depictions. Wide-angle photos are stitched together to create 360-degree images, which are in turn merged into a panoramic tour. Viewers can look in all directions from one vantage point using their mouse, trackpad or touchscreen, or move through the scene by clicking on arrows or other icons, or even leapfrog to another area by clicking on a dot on the embedded map. Some of these maps use an aerial or satellite image of the site to give a better idea of the landscape.

The tour of Petra – the 2 000-year-old sandstone city in Jordan – allows viewers to feel almost like the tourists seen wandering through the 264 000 m^2 archaeological park, but putting this tour together was just one component of a mammoth task. As part of a UNESCO project, the Zamani team spatially documented Petra during eight field campaigns between 2011 and 2014, completing over 2 000 scans that yielded a point cloud of some 12 billion surface points. These were used to create 3D models of the individual monuments as well as the Siq, the access route through a narrow canyon.

In addition, the team compiled a comprehensive Geographical Information System (GIS) and database for the site. The position of the models depicted in the GIS was accurately established by surveying control points using conventional survey methods and GPS/GNNS technology – something that is done for all sites.

Some of the sites documented are not yet available online, but the information is securely stored in a digital repository, and data requests for research and education purposes can be made. Although the majority of the sites documented to date are in Africa, the team has ventured as far afield as Myanmar in South East Asia to 'capture' the Buddhist temples and pagodas of Bagan. Close to home, the South African sites that can be explored on the Zamani Project website include Wonderwerk Cave near Kuruman in the Northern Cape, the Castle of Good Hope in Cape Town, and three rock art sites on the banks of the Clanwilliam Dam. Prior to the raising of the dam wall, due to be completed by March 2023, the rock art was scanned pending its removal – with the provincial heritage agency's permission – to a safe location. It is anticipated that the Zamani Project's 3D models and other outputs for the site will form part of a permanent exhibition in Clanwilliam.

By providing opportunities for both current and future generations to view spatially accurate depictions of heritage sites that they might otherwise never get to see, the Zamani Project helps share the insights such sites provide into past cultural practices and societal developments.

- Visit the Zamani Project's website to view the 3D models, animations, interactive panoramic tours and other digital products: https://www.zamaniproject.org/

  Animations of the 3D models and additional videos are also available on the Zamani Project's YouTube channel: https://www.youtube.com/user/zamaniproject

  Follow the Zamani Project on Facebook to stay up to date with new releases.

DIGITISING DIORAMAS

Technology and planning help museums manage outdated exhibitions.
By Claire Browning, Heinz Rüther, Stephen Wessels and Wendy Black.

Museum exhibitions are all about the 'Wow!', 'What?' and 'Why?' as they showcase beauty and wonder, spark curiosity, and share some of the important lessons museum scientists have learnt through detailed study of these objects.

But what happens when exhibitions no longer reflect our current understanding of how life on Earth evolved? Science advances all the time and new discoveries are constantly being made. At what point should older exhibitions be dismantled – and what should they be replaced with, given how rapidly knowledge is moving?

These are questions we've recently had to mull at the Iziko South African Museum in Cape Town. As curators and members of the museum's Research and Exhibitions team, we had to decide on the future of an iconic exhibition that first opened in 1959. It was the first diorama-style exhibition in South Africa that showcased the fossil discoveries made in the country's Karoo region. Dioramas are three-dimensional scenes with models and a painted backdrop.

The Boonstra Dioramas were named for Dr Lieuwe Dirk Boonstra, a curator and researcher at the South African Museum who dedicated his life to understanding the mysteries of ancient pre-mammalian relatives that looked a lot like modern-day reptiles and dinosaurs, but are actually much older. The dioramas he and his colleagues created represented the best available scientific knowledge about how extinct plants and animals interacted with each other and the Karoo ecosystem around 270 million years ago.

Building on the efforts of science education pioneers like Boonstra, modern scientists now have an even better understanding of Karoo fossils. That has rendered many of the models in the Boonstra Dioramas scientifically inaccurate. But should it remain as a testament to its place in history, to teach us about the process of knowledge generation and the evolution of scientific discovery, or be dismantled to maintain a scientifically accurate and relevant museum?

Museums around the world have been grappling with the issue of diorama removal. Some museums have opted to remove these old dioramas; the Smithsonian National Museum of Natural History in the US has, since 2003, substituted old animal displays with more scientific and modern exhibitions (often digital) emphasising what is currently known of their evolution.

We decided to remove the dioramas. But they're not lost forever. Thanks to technological advances, we've been able to preserve the exhibition digitally. We can do the same with other soon-to-be-retired museum exhibitions – and

make space for more up-to-date exhibitions that reflect the best-available science.

A big moving job

Before we could turn the dioramas over to technological wizards, we had to decide which objects from the Boonstra Dioramas should be archived for perpetuity and what to do with objects that didn't make the cut.

A careful de-installation plan was negotiated between museum professionals and building contractors, who oversaw the physical de-installation process. Most of the models were built in place and were too big to fit through the museum doors. As with most dioramas that are only ever viewed from the front, the wall-facing sides of the models didn't need to be complete.

Many of the wall-facing sides in the Boonstra Diorama models showed a grotesque mesh of wire and plaster that would make it difficult to display them in future historical exhibitions without extensive conservation efforts. Most of these larger models had to be dismantled on site and removed in pieces. Models that were small enough to fit through the door were carefully removed intact.

We were able to salvage and carefully relocate a few scientifically accurate models. Most of the real fossils (not models or casts) could be carried back into the collections by hand, with one exception. The *Bradysaurus*, a kind of Pareiasaur, was a remarkably complete showcase fossil that had been built into the display. To our surprise, we found this fossil was encased in concrete. Today, plaster of Paris, which is much lighter and less brittle than concrete, is used to consolidate the rocks surrounding fossils in the field and to protect the encased fossil during transport to the museum.

Thanks to 10 strong construction workers and a customised movable dolly, the *Bradysaurus* specimen was safely removed. It is now in the museum's behind-the-scenes collection, accessible to researchers for further study.

Some of the painted backdrops, separated into panels, have found new homes at regional museums. Others will be temporarily housed at Iziko South African Museum until suitable homes can be found.

With the exhibition space cleared, a large blank canvas remains. It will be used for a new permanent exhibition on human evolution, a collaboration between Iziko's Archaeology Unit and the Human Evolution Research Institute at the University of Cape Town.

A Zamani Project team member in action, digitising fossil replicas using a 3D laser scanner.

Sibusiso Mthungata, a technical assistant, prepares the *Bradysaurus* fossil for transport.

The *Bradysaurus* is displayed in the diorama as it may have appeared shortly before fossilisation within layers of hardened mud and clay.

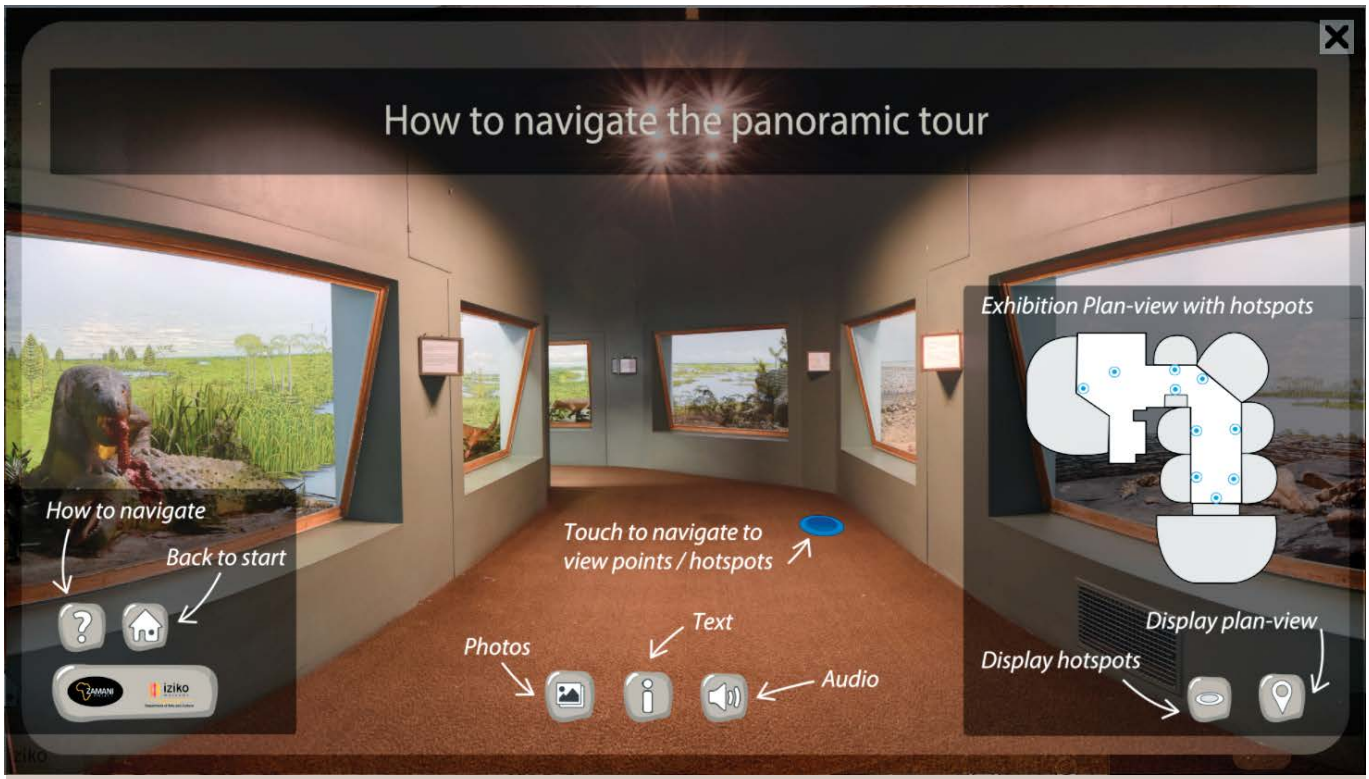
A digital approach

Several digital technologies have recently emerged to help preserve brick-and-mortar exhibitions. These include lidar (3D laser scanning) and photogrammetry to create high-resolution, colour 3D models that are accurate digital replicas.

The cost of digital preservation, and particularly lidar scanning, is often prohibitive for publicly funded museums. Iziko partnered with the Zamani Project, a non-profit heritage documentation organisation based at the University of Cape Town. Through this collaborative effort the Boonstra Dioramas, including the exquisitely painted backdrops, are now digitally archived.

A 360-degree panoramic tour is available online, allowing visitors an immersive experience of the dioramas. This is a valuable way for museums to connect with a wide range of visitors in a virtual environment during the global COVID-19 pandemic and hopefully beyond. There are also plans to create augmented and virtual reality applications from the digitised exhibition. Additionally, the digital models could be 3D printed to create scaled-down versions of the fossil models.

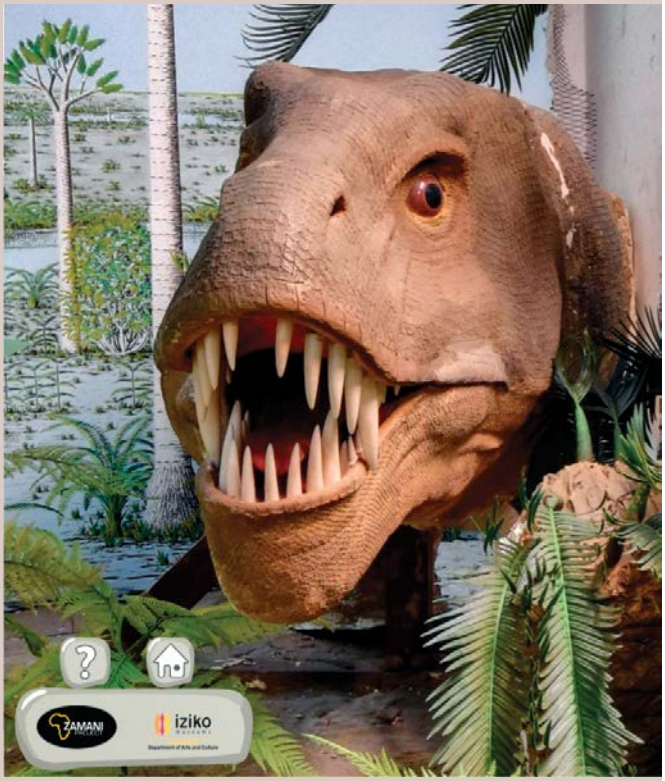
Claire Browning is the Curator of Karoo Palaeontology at Iziko Museums of South Africa,
Prof. Heinz Rüther is Professor Emeritus of Geomatics and Principal Investigator of the Zamani Research Group at the University of Cape Town (UCT),
Stephen Wessels is a PhD candidate at UCT,
Dr Wendy Black is Curator of Archaeology at Iziko Museums of South Africa.



On 18 September, Claire Browning presented an online seminar on the Boonstra Diorama Digital Reconstruction Project for the Geological Society of South Africa. During her presentation, she gave a demonstration of the 3D panoramic tour, which allows viewers to zoom in on the models and pan around from a number of different positions, including some from inside the display cases. This means that viewers can in some instances see more of the dioramas than visitors to the museum could in the past, from behind the glass windows.

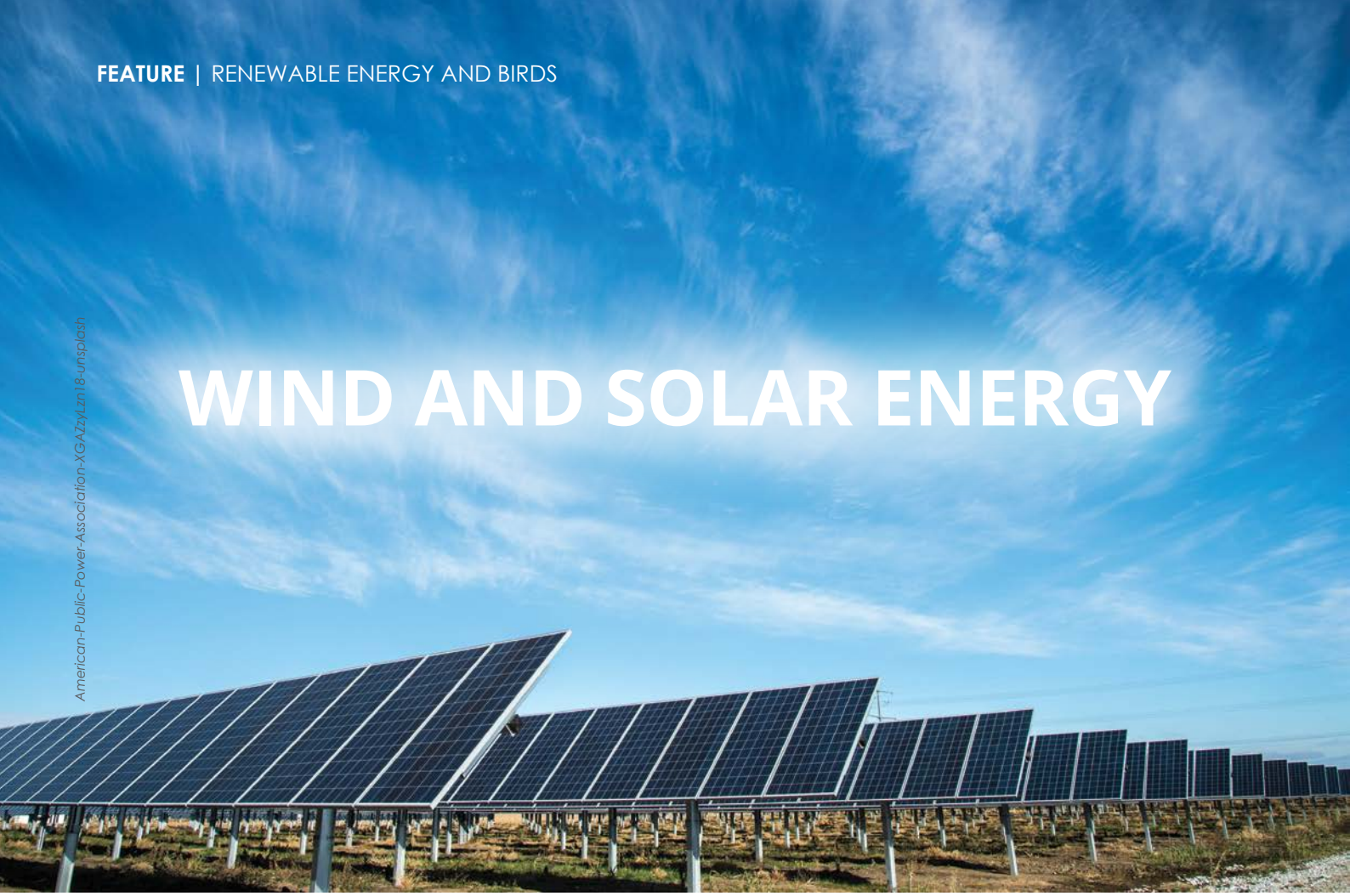
Viewers have the option of reading text from the original information panels, or listening to it, and they can also access a set of photos showing details of each diorama's backdrop. Claire explained that preserving the exquisitely painted backdrops was something she felt passionate about, so she had photographed these herself using a Hasselblad medium-format camera for archival quality images.

Apart from being available online, the panoramic tour has been installed on a touchscreen next to the *Bradysaurus*



model and fossil, which have been relocated to another part of the museum's exhibits. The future plans to create a virtual reality application from the digitised dioramas would allow visitors to have an immersive experience, wandering amongst the ancient animals of the Karoo, while 3D printing would allow visitors to print a souvenir of their favourite diorama model.

- View the panoramic tour at: https://boonstra360panoramas.zamaniproject.org/



American-Public-Power-Association-XGAZzyLzn18-unsplash

WIND AND SOLAR ENERGY

More facilities on the way, but what about the impacts on birds? Quest reports on some recent research.

On 25 September 2020, the Minister of Mineral Resources and Energy, Gwede Mantashe, gazetted the determination in accordance with the Electricity Regulation Act (2006) to procure new generation capacity amounting to 11 800 megawatts (MW). This is needed to contribute towards South Africa's energy security, and will be procured from Independent Power Producers (IPPs).

Of this total, 6 800 MW will be from renewable energy sources – specifically wind and solar photovoltaic (PV) – and the rest from gas, coal and storage. In line with the Integrated Resource Plan (IRP2019) published in October 2019, the renewable energy sources will be split into 4 800 MW from wind and 2 000 MW from solar PV. The new capacity will be procured through Bid Window 5 of the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP). During the first four bid windows between 2011 and 2018, more than 100 projects with capacity to produce a total of 6 400 MW were approved.

In July, Minister of Environment, Forestry and Fisheries, Barbara Creecy, called for public input on the geographical areas identified as renewable energy development zones (REDZ) for large-scale wind and solar PV. These zones were determined through three strategic environmental assessments (SEA) undertaken between 2016 and 2019. Public input was also requested on the identification of procedures to be followed when applying for, and deciding on, environmental authorisation applications for REDZ activities.

May et al. 2020, Ecology and Evolution, https://doi.org/10.1002/ece3.6592

A study in Norway showed that the annual fatality rate at wind turbines with one blade painted black was reduced by more than 70% compared to neighbouring turbines.

One of the main concerns raised in environmental impact assessment (EIA) processes for wind and solar energy facilities is the effect on birds. Here, *Quest* explores the issue, drawing on local and international research.

Wind energy

BirdLife South Africa published its position statement 'The effect of wind energy facilities on birds' in January 2019, and over the past few years has produced a number of guideline documents relating to wind energy. Most recently, in July 2020, Samantha Ralston-Paton – the organisation's Manager: Birds and Renewable Energy – co-authored a paper with Vonica Perold and Prof. Peter Ryan of UCT's FitzPatrick Institute of African Ornithology titled 'On a collision course? The large diversity of birds killed by wind turbines in South Africa'.

The paper, published in *Ostrich: Journal of African Ornithology*, reported on the results of monitoring conducted at 20 'wind farms' in the south-western parts of South Africa. Between 2014 and 2018, 848 bird carcasses of 130 different species were found during this monitoring. This translated to about one bird per turbine per year at the 16 facilities that had at least a year of post-construction monitoring. However, once the figures had been adjusted to take into account the carcasses that might not have been detected or had already been eaten by scavenging animals, the mortality estimate increased to 4.6 birds per turbine per year. Calculated according to the megawatt capacity of the facilities, this translates to 2.0 fatalities/MW/year. Raptors (birds of prey) that hunt during the day were the bird group most frequently killed, making up 36% of carcasses, closely followed by passerines (perching birds).

ZX Lidars

Lidar on wind farms

Doppler lidar is increasingly being used by wind farms, from the planning stages to optimise the siting of turbines, to post-installation for turbine rotation (yaw adjustment) that takes wake flows from neighbouring turbines into account, and even during ongoing operation for activating the turbines or adjusting rotor speed or blade angle (pitch adjustment). The aim is to ensure efficient performance that maximises energy output while also controlling the load on the turbines, to minimise maintenance costs and extend the lifetime of the components.

Initial systems were mostly ground-based, but nacelle-mounted systems are gaining in popularity. The most recent models can measure wind speed, direction and turbulence intensity from as much as 700 m in front of the blades.

Derek Keats, CC BY 2.0

Wind farms sited along rocky ridges and escarpment edges may put the Verreaux's Eagle, previously known as the Black Eagle, at risk.

At around the same time, a team from the Norwegian Institute for Nature Research published their paper in *Ecology and Evolution*, detailing an experiment conducted at a wind farm in Norway. They selected four of the Smøla facility's 68 wind turbines, and arranged for one of their three rotor blades to be painted black. This simple measure decreased annual bird mortality by 70% overall, with raptor fatalities being most reduced. They also painted the lower half of 10 turbines black, and this reduced the mortality for willow ptarmigan – a ground-dwelling grouse that is prone to flying into the turbine towers rather than the higher blades – by almost 50% compared to unpainted turbines in the same area.

The Norwegian researchers also noted that wind energy facilities can be made more bird-friendly by avoiding installation of the wind turbines within strong updraft areas. Soaring raptors are naturally attracted to such areas, which include ridges with high orographic uplift or flat terrain with high thermal uplift, and the collision rate is known to be higher there.

This recommendation is similar to one made in Birdlife South Africa's 2017 document 'Verreaux's Eagle and wind farms: Guidelines for impact assessment, monitoring, and mitigation', which states that siting wind turbines along escarpment edges, ridge tops, cliffs, steep slopes and particularly slopes that are perpendicular to the prevailing wind direction should be avoided. Previously known as the Black Eagle, this distinctive raptor is found mainly in mountainous, rocky habitat and is already considered regionally vulnerable, so poorly planned wind farms could pose a threat to local populations of the species.

Solar PV

Bird mortality at photovoltaic solar energy facilities has not been as well studied as that at wind farms. Indeed, an open-access paper published in *PLoS ONE* in April 2020 by Kosciuch and co-authors notes that only one paper in the peer-reviewed literature provides fatality information from a monitoring study at such a facility – and that was another by a team from the Birdlife South Africa–UCT Fitzpatrick Institute collaboration.

However, mortality data can also be found in the 'grey literature' of organisation reports, so the *PLoS ONE* paper, 'A summary of bird mortality at photovoltaic utility scale solar facilities in the Southwestern U.S.', synthesised results from

SolarReserve

The Jasper solar PV facility near Postmasburg in the Northern Cape consists of more than 325 000 photovoltaic panels. According to the 'lake effect' hypothesis, birds may collide with photovoltaic panels when they mistake large areas of them for waterbodies.

fatality monitoring studies at 10 solar PV facilities across 13 site-years in California and Nevada. About 54% of the 'carcasses' reported in those earlier studies were only 'feather spots', which can be any of the following: at least five tail feathers, or two primary feathers, or a total of at least 10 feathers with no attached bone or tissue, within five metres of each other. This clearly introduces some uncertainty into the interpretation of fatality estimates. Nevertheless, the authors calculated the average annual fatality estimate for known and unknown cause to be 2.49 fatalities/MW/year.

Addressing the 'lake-effect' hypothesis, which suggests that collisions may occur because birds are confused by polarised light pollution from the rows of PV panels and mistake them for waterbodies on which they can land, the authors note that the earlier studies had not collected data to investigate causal mechanisms. But the synthesised results did show that fatalities of water-obligate birds, which rely on water for take-off and landing, occurred at 90% of site-years at facilities in the Sonoran and Mojave Deserts Bird Conservation Region. The Salton Sea in this region is an important stopover and winter habitat for an abundance of water obligates, such as loons and grebes.

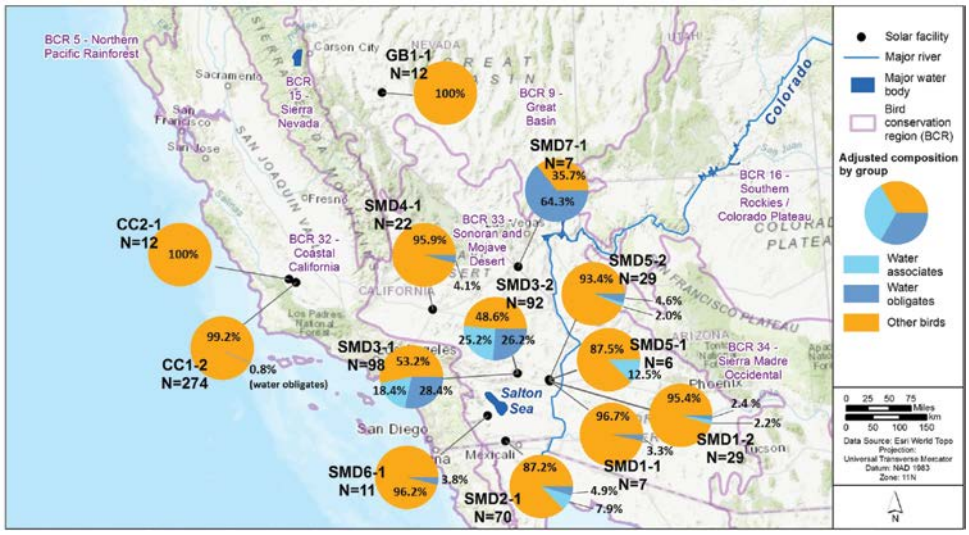
The South African paper, 'Assessing the impacts of a utility-scale photovoltaic solar energy facility on birds in the Northern Cape, South Africa', was published in the journal *Renewable Energy* in 2019. Lead author, Elke Visser, conducted the study for her Conservation Biology MSc degree, the Fitzpatrick Institute's intensive coursework programme that includes a six-month research project. As such, the study involved only three months of surveys – from September to December 2015 – at the 96 MW Jasper PV facility near Postmasburg. Apart from searching for carcasses and feather spots, the solar panels were checked for smudge marks and feathers, both considered evidence of collisions. Only eight fatalities were detected from these methods, which the authors extrapolated to an annual mortality of 435 birds for the entire facility, or 4.5 fatalities/MW/year.

The paper also discusses the facility's impact on the avian community through habitat loss, since bird species richness and density within the facility were found to be lower than areas in its boundary zone or in the adjacent veld. As noted in BirdLife South Africa's 'Best Practice Guidelines: Birds & Solar Energy', the removal of vegetation from the development footprint of solar PV facilities – and the resulting loss, degradation or fragmentation of habitat – has generally been considered the most significant impact of such facilities on birds.

Solar tower CSP

Concentrated solar power (CSP) systems have highly reflective mirrors that concentrate the sun's light energy, so that the heat created can be used to drive a steam turbine coupled to a generator, which produces electricity. In CSP tower systems, the mirrors are flat panels called heliostats, which track the sun's movement and focus the reflected sunlight onto a receiver at the top of a tower.

Birds may get potentially fatal burn injuries or feather singeing when flying through this concentrated reflected sunlight, known as the solar flux, and may also collide with the mirrors and other infrastructure on the site. CSP facilities are therefore considered more detrimental to birds than solar PV facilities. In its position statement 'The



An analysis of bird mortality data from solar PV facilities in California and Nevada, USA, showed that there was a greater proportion of fatalities of water associates and water obligates at facilities close to inland waterbodies. Water associates are species that rely on water for foraging, reproduction, and/or roosting, while water obligates are species that cannot take flight from land. N = total number of detections for each site-year (e.g. CC2-1) represented on the map.

Kosciuch et al. 2020, PLos ONE, https://doi.org/10.1371/journal.pone.0232034.g004

Abengoa

The 50 MW Khi Solar One near Upington is South Africa's only concentrated solar power (CSP) tower facility, operational since late 2016. Unlike most CSP tower facilities that use molten salt as the heat transfer fluid, Khi Solar One relies on superheated steam technology.

effect of concentrated solar power (CSP) tower facilities on birds', dated January 2019, Birdlife South Africa supports the responsible development of CSP facilities, but acknowledges that they could be hazardous to birds and their habitats. It recommends that the impacts of operational CSP tower facilities on birds should be monitored according to BirdLife South Africa's 'Best Practice Guidelines: Birds & Solar Energy', published in 2017.

An earlier version of the guidelines was used by HP van Heerden, who studied Khi Solar One's effects on birdlife for his MSc in Conservation Ecology, recently awarded by Stellenbosch University. Van Heerden began his monitoring in mid-2015, initially conducting short surveys in both winter and summer to get an idea of the area's bird community. Overall, he counted 2 380 birds from 57 different species, with only one being of conservation importance – the lanner falcon, which is listed as a vulnerable species. Most of the species were recorded from the surrounding Nama Karoo veld, rather than the solar tower site itself, but development of the facility did influence the composition of bird species typically found in the area. Its evaporation ponds attracted waterbirds such as flamingos, which had not previously been found on the farm where the facility was built, and species usually found in urban areas are nowadays found in greater numbers around the tower area.

Van Heerden then began monitoring more intensively from mid-2016, conducting weekly surveys of areas within the development footprint for an entire year. During this time, he recorded 324 injured or dead birds from 34 different species. Some 61% of these injuries and mortalities could be attributed to collisions with structures, and 14% to being singed.

Most of the dead birds were seedeaters such as the red-billed quelea and lark-like bunting, which are quite common in the area. The only casualties of conservation importance were one lanner falcon and one white pelican.

Van Heerden found that collisions were primarily against the lower part of structures in the heliostat area, within a few metres of the ground, corresponding to the normal flight height of the seedeaters. The majority of incidents occurred around sunrise or sunset, when birds are most active, but this is also when the heliostats stand at a 90° vertical position, creating an almost continuous mirror image. This may confuse the birds into thinking they are flying through an unbroken landscape, with no obstacles.

Arthur Chapman, CC BY-NC 2.0

Derek Keats-CC BY 2.0

Seedeaters such as the red-billed quelea and lark-like bunting made up most of the bird mortalities at Khi Solar One.

In the case of singeing, migrating birds and species that hunt their prey in the air accounted for most of the mortalities. The bright light radiating from the tower's mirrors attracts insects, which in turn attract insect-eating birds.

Based on these findings, Van Heerden recommended that heliostats should not be positioned at exactly 90° during early mornings and late afternoons, when birds are most active, and should preferably be set in a horizontal position when solar power is not being generated by the facility. In this way, the intensity of the solar flux would be reduced when the heliostats are in standby position.

- Although many birds are killed by wind and solar energy facilities, this needs to be considered in context of the thousands that are killed countrywide through collisions with buildings and vehicles or through encounters with pets, particularly cats. Electricity generation by these facilities also does not result in emissions of greenhouse gases and other pollutants associated with coal-fired power stations.

CURRICULUM CORNER

GEOGRAPHY: GRADE 11
Non-conventional energy sources

NATURAL SCIENCES: GRADE 7
Renewable sources of energy

NATURAL SCIENCES: GRADE 9
Energy and the national electricity grid

Theo Busschau

SNAKES ALIVE!

Forest biodiversity study reveals 10 'cryptic' species in one.

Herpetologists involved in the Eastern Cape Forests Project – a Foundational Biodiversity Information Programme (FBIP) study that aims to document the diversity of these ancient forests – have uncovered a treasure trove of snake biodiversity. Lead author of a paper published on the research in the *Journal of Zoological Systematics and Evolutionary Research*, MSc graduate Theo Busschau, explains that the number of forest thread snake species has increased from two to 10, a fivefold increase in diversity.

The forest thread snake, *Leptotyphlops sylvicolus,* is the only thread snake restricted to the forested regions of South Africa. Unlike many other snakes, *L. sylvicolus* does not have well-developed eyes, spends most of its life underground, and is a very picky eater, feeding exclusively on the larvae of ants and termites.

In its bid to stay nourished on its very specific diet, evolution has seemingly blessed *L. sylvicolus* with an 'invisible cloak' – studies have shown that the snake is able to produce a chemical that mimics its prey's scent and allows it to enter ant nests and termite mounds without being attacked.

An earlier study in 2009 showed that there were possibly two 'cryptic' thread snake species. Cryptic species are those that are morphologically similar, looking nearly identical to each other in physical features, but at the level of DNA have diverged to the point where scientists can classify them as different species. For the 2009 study, sample sizes were low and further investigation was needed. But Busschau says the findings of his study raise more questions than answers. He describes his analyses of how many species are found under the forest thread snake 'umbrella' as conservative, meaning more than 10 species are likely.

"There are varying degrees of morphological differences among these various species, but more work remains

Theo Busschau

The forest thread snake, *Leptotyphlops sylvicolus*, is typically only about 10 cm long and is sometimes mistaken for a worm, as both have the rounded head and poorly developed eyes that are adaptations to a burrowing lifestyle.

before we can describe them," he adds. Species description is the formal process whereby a newly discovered species is described, usually in the form of a scientific paper. To do this, many more samples will be needed to see what distinguishes one species from another and how they differ from known species.

Genetic diversity

The analyses on the DNA sequence data allowed Busschau and the team to identify how isolated the various populations were, and which populations possibly represented undescribed species.

"We were also able to estimate when these populations became isolated. Our estimates point towards the late Miocene, 11 to five million years ago, when the global climate became cooler and drier, resulting in the fragmentation of forest habitats in South Africa," he says.

Busschau notes that this and similar studies are important because we need to know what is out there so we can conserve it.

"Unfortunately, conservation management plans don't often recognise genetic diversity, focusing only on the diversity of described species. Therefore, future research is important to quantify the true diversity and describe the cryptic species in *L. sylvicolus*, so we can conserve them and the habitats in which they occur."

Although genetic diversity is often a neglected aspect of conservation, Busschau says it is important when species need to adapt to changing environments. *L. sylvicolus* likely shows patterns of genetic diversity that would be shared by other forest-living species, so future work is important not only for *L. sylvicolus* but also for other species that share its habitat.

Forest biodiversity

Forests form the smallest biome in South Africa, yet they support a large proportion of the country's biodiversity and are of high conservation value. The study shows that forests possibly have much higher reptile diversity than currently recognised, emphasising the importance of forest conservation – especially since many of these cryptic species occur in small forest fragments.

Busschau says that the presence of multiple cryptic species with small distributions have consequences for their conservation status once they are described. At present, *L. sylvicolus* is listed as 'Least Concern' in the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species. In future, the description of multiple species means that each could occupy a smaller area than the 'umbrella species', leading to higher conservation threat status, such as 'Vulnerable' or 'Endangered'.

The Eastern Cape is home to 46% of South Africa's remaining natural forest cover, including many of the country's most threatened forest types. The area also forms part of the Maputuland-Pondoland-Albany Hotspot for biodiversity. Challenges facing the Eastern Cape forests represent a crucial test case for the nexus between human survival needs and the importance of keeping indigenous forests intact.

Theo Busschau handling a Natal black snake, *Macrelaps microlepidotus*, during a field trip.

According to Stellenbosch University biodiversity expert and ECFP project leader, Prof. Michael Cherry, forests are important in terms of the bio-economy. Although they have traditionally been harvested by local rural communities, they have experienced increased pressure post-democracy due to collection of timber for building material as well as bark for medicinal use. Furthermore, the region has been earmarked for economic development, including dry gas exploration, titanium mining, dam construction and major road infrastructure.

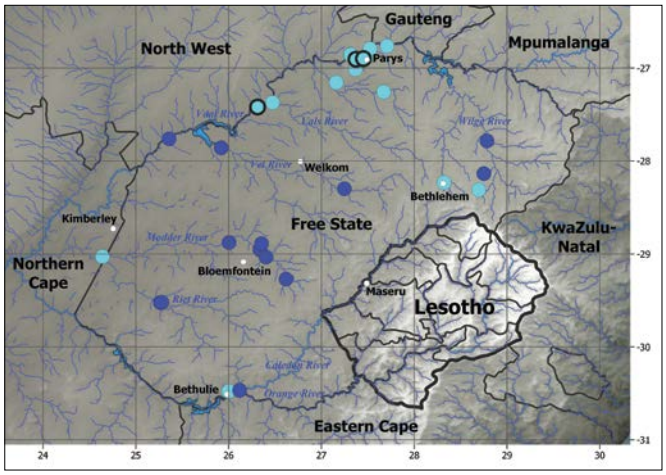
Written by Dane McDonald, Science Communicator for the Foundational Biodiversity Information Programme (FBIP).
The FBIP aims to generate, manage and disseminate foundational biodiversity information and knowledge to improve decision-making and service delivery, and to create new economic opportunities. It is funded by the Department of Science and Innovation (DSI) under the Global Change Programme, and is jointly managed by the National Research Foundation (NRF) and the South African National Biodiversity Institute (SANBI).

Citizen Science
Using Facebook records of reptiles and amphibians

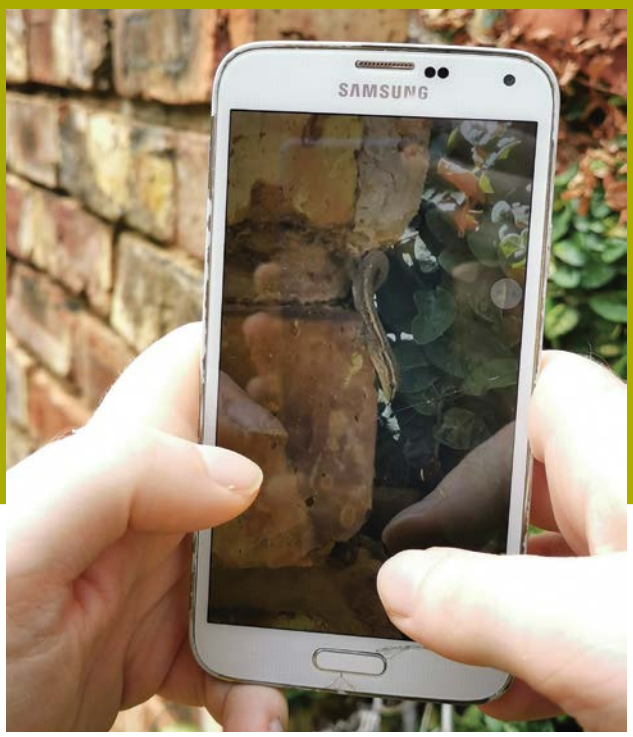
By Cora Stobie and Michael Bates

In this age of social media, Facebook has become a hub for people to upload and share information. There is probably a Facebook group for almost every conceivable topic! For example, there are several groups serving those interested in getting help identifying reptiles or amphibians, all the while providing educational information to their members. One such group based in South Africa has upwards of 170 000 members. Many of these groups receive dozens of photographs or videos on a daily basis, and represent huge virtual archives of natural history information that can be used to aid various scientific investigations, including studies on species distribution ranges.

Tyrone Ping



The water monitor *Varanus niloticus*, also known as a water leguaan or *waterlikkewaan*, can grow up to 2.2 m long. On this map of its distribution in Free State Province, literature records are shown in dark blue, while new records are shown in pale blue and are separated into Facebook records (no edge) and other online records from iNaturalist and Flickr (black edge).



Zoe Yannikarkis

Some citizen science platforms, like iNaturalist and ReptileMap, are popular in South Africa, and the observations reported there are often used in scientific publications. However, the numbers of people actively using these platforms are much lower than those posting observations to Facebook. What makes Facebook so appealing for this purpose is its ease-of-use, the quick reaction of members in identifying the subject in photographs and videos ('expert crowdsourcing'), and the opportunity via the comments section to contact observers directly regarding their observations.

In December 2019 we set up a Facebook group, initially to collect photographs and video evidence of reptiles and amphibians from Bloemfontein, the capital city of the Free State. It soon became apparent that we were attracting records for the entire province, and so we changed the group's name. We were collecting so much valuable distribution information that the group essentially became a research project on the distribution of reptiles and amphibians in the Free State. The province was comprehensively sampled for these animals in the 1970s, with later distribution updates published in the mid-1990s. However, much has happened in the area since then, such as farming activities and urbanisation, which may have altered the current-day distributions of species. We then realised that it made sense to include areas immediately adjacent to the Free State, as well as Lesotho – a very poorly known area for reptiles and amphibians – so the group is now called 'Free State Reptiles and Amphibians (including adjacent areas and Lesotho)'. This project represents the first attempt to investigate reptile and amphibian distributions in southern Africa using Facebook as a primary source of records.

Our group is still growing, but already over a thousand photographic and video records of 83 species have been posted. The majority of these observations were shared from other established groups, but as participation

increases we are seeing more and more posts made directly to our group. Each of these records is recorded in a database where the species name is listed, together with date, locality, observer, and any other relevant information. This locality information is used to assess the current distribution ranges of certain species across central South Africa and Lesotho.

Tyrone Ping

The colour pattern of this rinkhals, *Hemachatus haemachatus*, photographed in the Eastern Cape, is typical of individuals from much of the Free State and Lesotho.

An example of a distribution map resulting from our project is that of the largely aquatic water monitor *Varanus niloticus*, a huge lizard that grows to a length of 2.2 m. This species is generally common in rivers and other permanent waterbodies in South Africa, though sightings in the Free State are relatively infrequent. There are currently 15 published records for the Free State, to which we have added another 19 records from Facebook and a few other sources. There is little overlap between previously published and new records, but we cannot say much about the significance of this at the moment.

The rinkhals or ring-necked spitting cobra, *Hemachatus haemachatus,* is another excellent example of how Facebook records have aided scientific research. Posts to our Facebook group have yielded 156 new rinkhals distribution records in the Free State and Lesotho, representing 63% of all known (including literature) records for the species in this region.

For both the water monitor and rinkhals, Facebook records greatly surpass the number of records supplied by citizen science platforms such as ReptileMap and iNaturalist, which are designed specifically for collecting distribution data. Furthermore, we used Facebook Messenger to contact 110 of the 126 people who posted the original rinkhals records, to ask for clarification of the locality, or further details. Approximately 46% of those approached for additional information responded, which allowed us to refine or confirm 68 localities. The information we have collected to date emphasises how valuable citizen science observations sourced from Facebook groups can be for scientific research.

Michael F. Bates

This juvenile giant bullfrog, *Pyxicephalus adspersus*, was found in moist grassland near a dam in Bloemfontein.

Every day there are hundreds of photographs and videos of reptiles and amphibians posted on various Facebook groups and pages. Many of these posts represent valuable data that researchers can use when investigating the distribution of species. We have had much success in running our relatively new Facebook group, and would like to encourage anybody and everybody with photographic or video records of reptiles and amphibians to share these with us. The records are a lot more valuable when accompanied by accurate locality information. Every contribution adds to our citizen science initiative!

- Find the Facebook group at https://www.facebook.com/groups/FreeStateHerps/.

Dr Cora Stobie is a Senior Museum Scientist in the Department of Herpetology at the National Museum in Bloemfontein. Her focus is on phylogenetics, systematics and population genetics of southern African reptiles and amphibians.

Dr Michael Bates is a Specialist Scientist and head of the Department of Herpetology at the National Museum in Bloemfontein. His focus is systematic studies on African snakes and lizards, and he also has an interest in biogeography and conservation of reptiles and amphibians.

The map was produced using QGIS (QGIS Development Team, 2020) and Natural Earth (free vector and raster map data @ naturalearthdata.com). The Rivers of Africa project from the Food and Agriculture Organisation of the United Nations (FAO) (http://www.fao.org/geonetwork/srv/en/metadata.show?id=37333&currTab=simple) was used to add additional rivers to the map. The Global Multi-resolution Terrain Elevation Data 2010 (GMTED2010) (Danielson & Gesch, 2020) was added to provide an elevation layer.

Ososayensi eBloemfontein bakwazile ukufunda kabanzi ngezilwane nemigudu yohambo lwazo, emuva kokuvula iFacebook group yabantu emphakathini uukuba bafake izithombe nama-video ooxamu, namaxoxo abawathwebule kwizindawo zabo.

Translated by Mbali Nguse

2020 NOBEL PRIZE: CHEMISTRY

Emmanuelle Charpentier from the Max Planck Unit for the Science of Pathogens in Berlin, Germany, and Jennifer A. Doudna from the University of California in Berkeley, USA, were awarded the Nobel Prize in Chemistry 2020 "for the development of a method for genome editing". In the announcement on 7 October, the Royal Swedish Academy of Sciences said that each would be awarded an equal share of the prize money of 10 million Swedish kronor.

Genetic scissors: a tool for rewriting the code of life

Emmanuelle Charpentier and Jennifer A. Doudna have discovered one of gene technology's sharpest tools: the CRISPR/Cas9 genetic scissors. Using these, researchers can change the DNA of animals, plants and microorganisms with extremely high precision. This technology has had a revolutionary impact on the life sciences, is contributing to new cancer therapies and may make the dream of curing inherited diseases come true.

Researchers need to modify genes in cells if they are to find out about life's inner workings. This used to be time-consuming, difficult and sometimes impossible work. Using the CRISPR/Cas9 genetic scissors, it is now possible to change the code of life over the course of a few weeks.

"There is enormous power in this genetic tool, which affects us all. It has not only revolutionised basic science, but also resulted in innovative crops and will lead to groundbreaking new medical treatments," says Claes Gustafsson, chair of the Nobel Committee for Chemistry.

Niklas Elmehed, Nobel Media

Emmanuelle Charpentier and Jennifer A. Doudna

As so often in science, the discovery of these genetic scissors was unexpected. During Emmanuelle Charpentier's studies of *Streptococcus pyogenes*, one of the bacteria that cause the most harm to humanity, she discovered a previously unknown molecule, tracrRNA. Her work showed that tracrRNA is part of bacteria's ancient immune system, CRISPR/Cas, which disarms viruses by cleaving their DNA.

Charpentier published her discovery in 2011. The same year, she initiated a collaboration with Jennifer Doudna, an experienced biochemist with vast knowledge of RNA. Together, they succeeded in recreating the bacteria's genetic scissors in a test tube and simplifying the scissors' molecular components so they were easier to use.

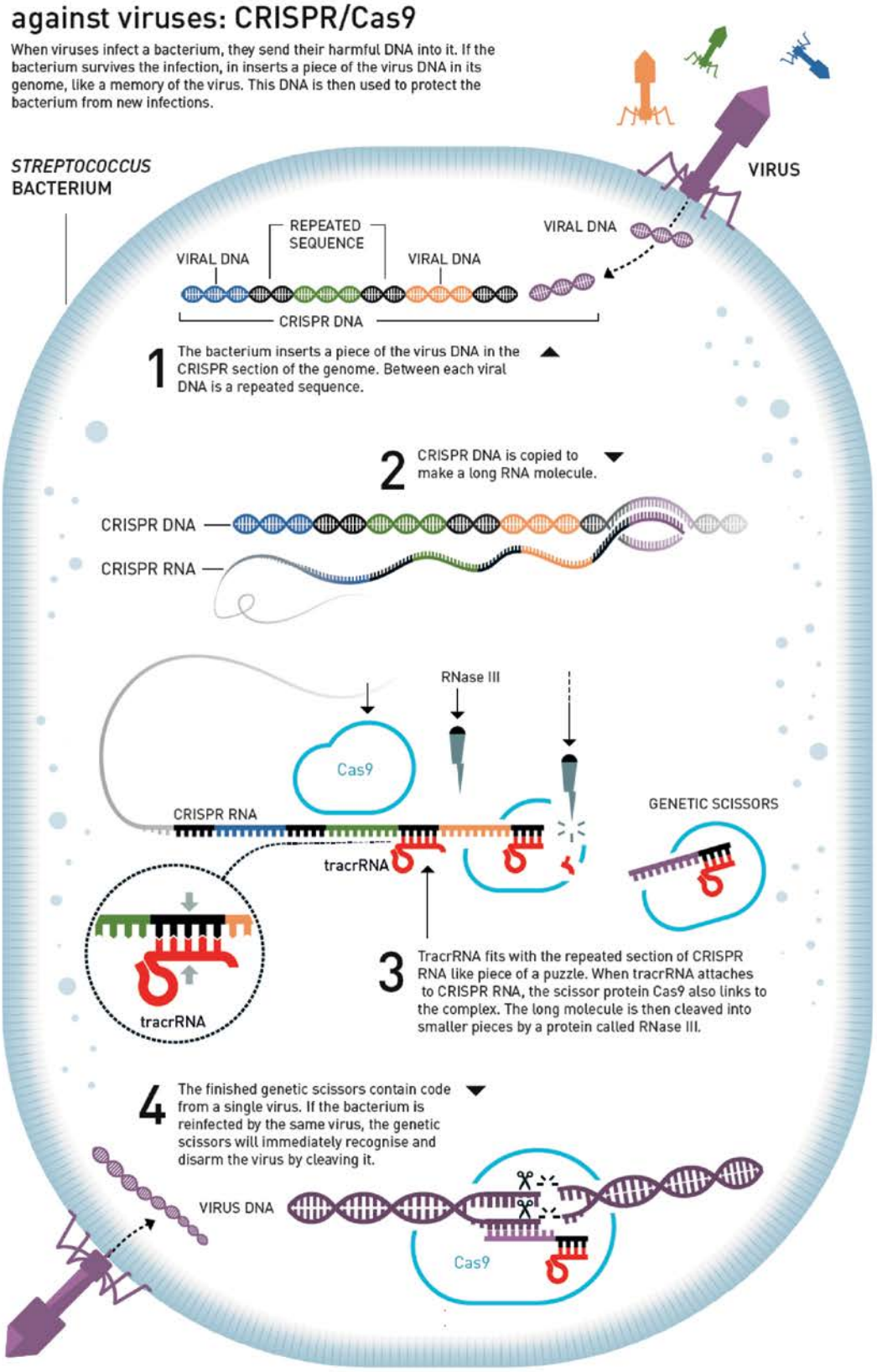
In an epoch-making experiment, they then reprogrammed the genetic scissors. In their natural form, the scissors recognise DNA from viruses, but Charpentier and Doudna proved that they could be controlled so that they can cut any DNA molecule at a predetermined site. Where the DNA is cut it is then easy to rewrite the code of life.

Since Charpentier and Doudna discovered the CRISPR/Cas9 genetic scissors in 2012, their use has exploded. This tool has contributed to many important discoveries in basic research, and plant researchers have been able to develop crops that withstand mould, pests and drought. In medicine, clinical trials of new cancer therapies are under way, and the dream of being able to cure inherited diseases is about to come true. These genetic scissors have taken the life sciences into a new epoch and, in many ways, are bringing the greatest benefit to humankind.

- https://www.nobelprize.org/prizes/chemistry/2020/press-release/
  See the popular science background at:
  https://www.nobelprize.org/uploads/2020/10/popular-chemistryprize2020.pdf
  or the scientific background at:
  https://www.nobelprize.org/uploads/2020/10/advanced-chemistryprize2020.pdf

Streptococcus' natural immune system against viruses: CRISPR/Cas9

When viruses infect a bacterium, they send their harmful DNA into it. If the bacterium survives the infection, in inserts a piece of the virus DNA in its genome, like a memory of the virus. This DNA is then used to protect the bacterium from new infections.



2020 NOBEL PRIZE: PHYSICS

On 6 October, the Royal Swedish Academy of Sciences announced the decision to award the Nobel Prize in Physics 2020 to Roger Penrose "for the discovery that black hole formation is a robust prediction of the general theory of relativity" and to Reinhard Genzel and Andrea Ghez "for the discovery of a supermassive compact object at the centre of our galaxy". One half of the prize money of 10 million Swedish kronor went to Roger Penrose and the other half jointly to Reinhard Genzel and Andrea Ghez.

Black holes and the Milky Way's darkest secret

Roger Penrose (University of Oxford, United Kingdom) used ingenious mathematical methods in his proof that black holes are a direct consequence of Albert Einstein's general theory of relativity. Einstein did not himself believe in the existence of black holes, which capture everything that enters them – nothing can escape, not even light.

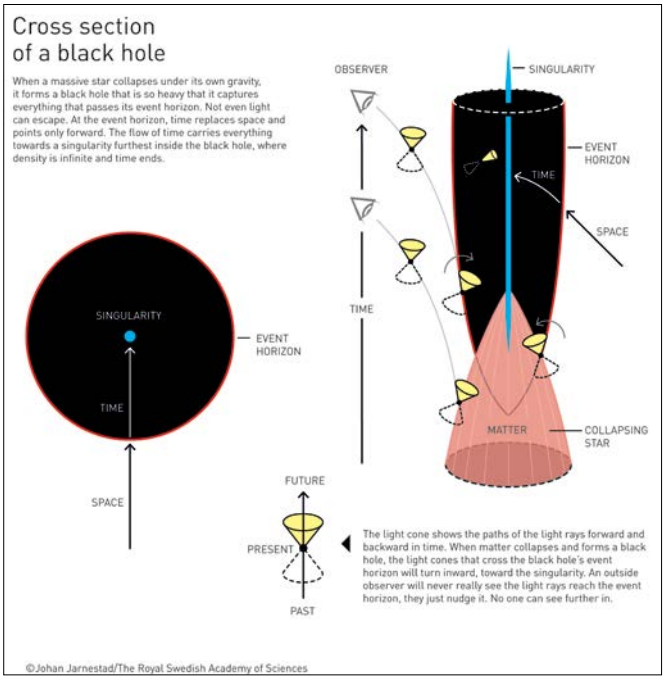
In January 1965, 10 years after Einstein's death, Roger Penrose proved that black holes really can form, and described them in detail. At their heart, black holes hide a singularity in which all the known laws of nature cease. Penrose's groundbreaking article is still regarded as the most important contribution to the general theory of relativity since Einstein.

Reinhard Genzel (Max Planck Institute for Extraterrestrial Physics in Germany and University of California, Berkeley, USA) and Andrea Ghez (University of California, Los Angeles, USA) discovered that an invisible and extremely heavy object governs the orbits of stars at the centre of our galaxy. A supermassive black hole is the only currently known explanation.

The two scientists each lead a group of astronomers who, since the early 1990s, have focused on a region called Sagittarius A* at the centre of our galaxy. The orbits of the brightest stars closest to the middle of the Milky Way have been mapped with increasing precision. The measurements of these two groups agree, with both finding an extremely heavy, invisible object that pulls on the jumble of stars, causing them to rush around at dizzying speeds. Around four million solar masses are packed together in a region no larger than our solar system.

Niklas Elmehed, Nobel Media

Roger Penrose, Reinhard Genzel and Andrea Ghez



Using the world's largest telescopes, Genzel and Ghez developed methods to see through the huge clouds of interstellar gas and dust to the centre of the Milky Way. Stretching the limits of technology, they refined new techniques to compensate for distortions caused by the Earth's atmosphere, building unique instruments and committing themselves to long-term research. Their pioneering work has given us the most convincing evidence to date of a supermassive black hole at the centre of the Milky Way.

"The discoveries of this year's Laureates have broken new ground in the study of compact and supermassive objects. But these exotic objects still pose many questions that beg for answers and motivate future research. Not only questions about their inner structure, but also questions about how to test our theory of gravity under the extreme conditions in the immediate vicinity of a black hole," says David Haviland, chair of the Nobel Committee for Physics.

- https://www.nobelprize.org/prizes/physics/2020/press-release/
  See the popular science background at:
  https://www.nobelprize.org/uploads/2020/10/popular-physicsprize2020-1.pdf
  or the scientific background at:
  https://www.nobelprize.org/uploads/2020/10/advanced-physicsprize2020.pdf

SAAO ASTRONOMER DISCOVERS COMET

Dr Nic Erasmus, an astronomer from the South African Astronomical Observatory (SAAO), discovered a new comet in September, while monitoring the output of the ATLAS telescopes in Hawaii. ATLAS is the Asteroid Terrestrial-impact Last Alert System, an early warning system for asteroid impacts developed by the University of Hawaii and funded by NASA. It consists of two 0.5-metre telescopes situated 160 kilometres apart at the Haleakala (ATLAS-HKO) and Mauna Loa (ATLAS-MLO) observatories on the islands of Maui and Hawaii, or 'Big Island', respectively. The two telescopes automatically scan the observable sky for asteroids that might pose a threat to Earth, while their CCD cameras capture images that are processed by software optimised to detect fast-moving objects.

Dr Erasmus made the discovery from four 30-second exposures taken by ATLAS-MLO. Working remotely from Cape Town, he does a stint on 'ATLAS duty' every three weeks. This entails vetting the images posted by the software on the nightly discovery page if its algorithms flag any potential near-Earth objects (NEOs). These NEOs include any asteroids or comets whose orbits around the Sun bring them within about 45 million kilometres of Earth's orbit.

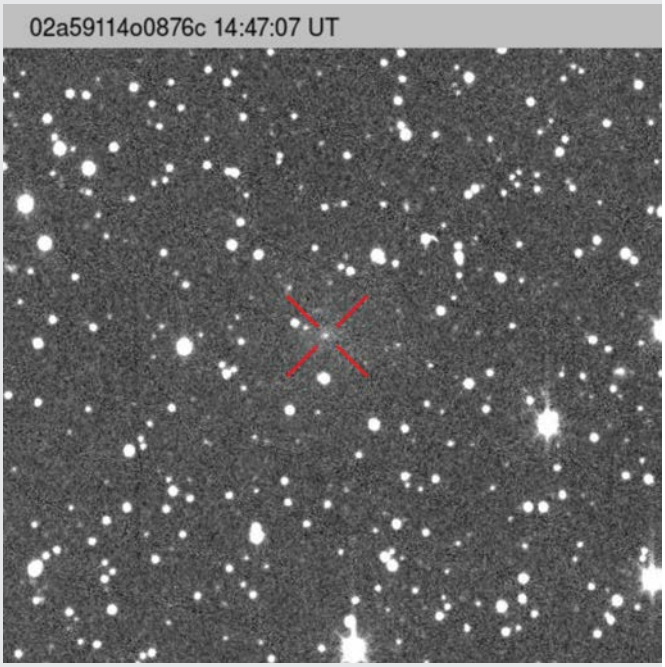
The algorithms generate many false-positives every night, so three astronomers monitor the observations before making the final submissions to the Minor Planet Centre (MPC). The MPC notifies observers worldwide about NEOs so that follow-up observations can be collected for identification and orbit computation.

Dr Erasmus noticed that the object in the discovery images had a faint coma – a fuzzy halo of gas and dust around a comet's icy centre, or nucleus. According to procedure, he double-checked with his two ATLAS colleagues that they could also see a coma before notifying the MPC. A few days later, on 20 September, the MPC confirmed that this was a new comet, named 'C/2020 S3 (Erasmus)' after its discoverer, as is customary.

The comet will reach perihelion – the closest approach to the Sun – around 12 December 2020, and will be at its brightest at that point. How bright it becomes will depend on how much it starts outgassing as it approaches the Sun, but it will most likely not be visible to the naked eye.

Prior to this discovery, more than 50 comets had been discovered by ATLAS since it began operating in 2015, along with over 500 asteroids. But the system has a 'blind spot' in the skies of the southern hemisphere, so in 2018 NASA agreed to fund two additional ATLAS telescopes. One of these will be installed at the SAAO field station in Sutherland in early 2021.

ATLAS is just one of the NEO survey projects funded by NASA through its Near-Earth Object Observation Programme. Other major ones include the University of Arizona's Catalina Sky Survey, the MIT Lincoln Laboratory's



ATLAS

Lincoln Near-Earth Asteroid Research (LINEAR), and the University of Hawaii's Panoramic Survey Telescope and Rapid Response System (Pan-STARRS).

NASA established the programme in 1998. In 2005, the United States Congress set NASA the target of finding 90% of NEOs that are 140 metres or larger in size, because these would pose a significant risk to Earth. They can be detected much further away from Earth than smaller NEOs because they are brighter. Most NEOs are asteroids, and Potentially Hazardous Asteroids (PHAs) are those that come within about 7.5 million kilometres of Earth and have an absolute magnitude (H) of 22.0 or brighter. By the beginning of October 2020, the programme's funded projects had identified 2 122 PHAs, of which 157 were asteroids larger than a kilometre in diameter.

- An animation of comet C/2020 S3 (Erasmus) is available at: https://www.saao.ac.za/2020/09/23/saao-astronomer-discovers-new-comet-c-2020-s3-erasmus/

Asteroids are small rocky objects that orbit the Sun. Comets also orbit the Sun, but they are made of ice and dust rather than rock. As a comet's orbit takes it towards the Sun, the ice and dust begin to vaporise, forming the comet's tail.

Sometimes small pieces of asteroids or comets break off, and these are called meteoroids. If a meteoroid comes close enough to Earth, it burns up as it enters Earth's atmosphere, creating a streak of light in the sky known as a meteor, but sometimes called a 'shooting star' or 'fireball'. Sometimes meteoroids don't burn up completely in the atmosphere, and land on the Earth's surface, at which point they are called meteorites.

https://spaceplace.nasa.gov/

Bridging the GAP

The government-funded New Generation of Academics Programme (nGAP) includes a three-year development programme followed by three years of induction for new academics. Here, we meet an nGAP appointee at the University of Johannesburg's Zoology Department.

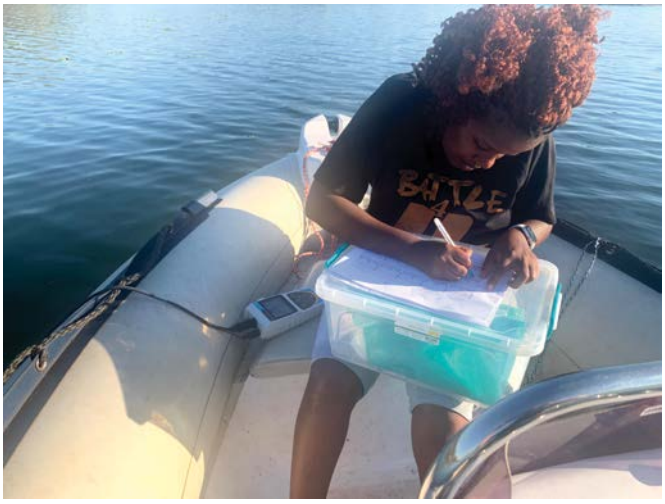
Refilwe Lukhwareni is originally from a small town called Tweeling in the Free State Province, where she matriculated. She is married and has a five-year-old son. She obtained her BSc in Biochemistry and Human Physiology, followed by her BSc Honours in Biochemistry at the University of Johannesburg (UJ). After graduation, her work experience during 2010–2012 included being a DST/NRF intern at Mintek, a sales rep at Sandoz, and a medical enablement specialist at Healthbridge. In September 2012 she rejoined UJ as a senior technician at the Department of Zoology, where she also got an opportunity to pursue her MSc in Aquatic Health (part-time), which she completed in September 2018.

Can you briefly describe your current role?

I was awarded an amazing opportunity to be part of the nGAP in UJ's Department of Zoology in 2019. This role came after I completed my MSc *cum laude* in 2018, while working full-time as a senior technician for all the physiology modules in the same department. This role allows me to complete my PhD while gaining experience as an emerging academic, and I am currently lecturing the Physiology 2A module.

What is nGAP?

According to the Department of Higher Education and Training (DHET), its prestigious nGAP programme "involves the recruitment of highly capable scholars as new



academics. The recruitment of these academics is based on carefully designed and balanced equity considerations and in light of the disciplinary areas of greatest need in the higher education system. The nGAP is currently the biggest programme within the Staffing South Africa's Universities Framework (SSAUF), a university staff development component under the University Capacity Development Programme (UCDP)."

DHET also has other programmes such as the Nurturing Emerging Scholars Programme (NESP). "Emerging scholars are students in their final year of undergraduate study, or are honours or master's students or graduates, whose academic performance is strong. The NESP recognises the potential of this group of students or graduates and seeks to actively direct some of that potential towards a career in academia, through making structured, attractive prospects and opportunities visible and available to them."

What advice do you have for emerging researchers and aspiring scientists?

Firstly, always prepare yourself for your future, and rest assured that you are the only person responsible for how it turns out. No one owes you anything. Always be ready for an opportunity when it presents itself, so that you are in a position to grasp it with both hands. You need to work hard in every step, or milestone, of your career. I have seen that no matter where you are, hard work always pays off. Therefore, equip yourself with relevant information for the field you want to pursue, surround yourself with people with like minds, and what matters is how you stand after that fall, not how many falls you have encountered along the way.

- For more information about nGAP and NESP, see:
  http://www.ssauf.dhet.gov.za/ngap.html
  http://www.ssauf.dhet.gov.za/nesp.html

This profile of Refilwe Lukhwareni was originally published on UJ Zoology's Twitter feed, @UjZoology, as part of Women's Month celebrations in August.

Girls4Tech, the science, technology, engineering and mathematics (STEM) programme launched by Mastercard in 2014, reached its initial goal of educating one million girls in mid-October. The programme now aims to reach five million girls by 2025.

The Girls4Tech programme offers activities and curriculum built on global standards in science and mathematics. It incorporates Mastercard's expertise in technology and innovation, enabling students to discover a range of STEM careers, such as fraud detective, data scientist and software engineer.

Originally a hands-on, in-person session run by employee volunteers, the programme has expanded into new topics such as artificial intelligence and cybersecurity, and has also enhanced access to its STEM curriculum through a digital learning experience, called Girls4Tech Connect. This provides interactive worksheets that can be downloaded and printed for home use, as well as teacher guides for online lessons.

To access these, visit Girls4Tech Connect at: https://www.girls4tech.com/

4IR progress

In October, Minister Stella Ndabeni-Abrahams reported on progress made by the Department of Communications and Digital Technologies with regard to the Fourth Industrial Revolution, known as 4IR. The Department was delegated a coordination role, which included overseeing the Presidential Commission tasked with developing a programme of action around 4IR.

The Commission's completed 4IR Report, which has been approved by Cabinet, consists of the following eight recommendations:

- Investment in human capital
- The establishment of an artificial intelligence (AI) institute
- The establishment of a platform for advanced manufacturing
- To secure and avail data to enable innovation
- Incentivise future industries, platforms and applications of 4IR technologies
- Build 4IR infrastructure
- The review and amendment (or creation) of appropriate policies and legislation
- The establishment of a 4IR Strategic Implementation Coordination Council.

Speaking about the need to provide the public with the tools required to take advantage of the outcomes, the Minister said that the Department had designed a framework for implementing the Digital Skills Strategy. The strategy focuses on developing skills in data science, software development, cybersecurity, 3D printing, drone piloting and the production of digital content.

In parallel, a pilot programme had been started by NEMISA, one of the entities under the Department's custodianship. NEMISA appointed Coursera to undertake training and development of over 700 learners on the skills and competencies required to take advantage of the 4IR outcomes. An additional 50 000 young people will be trained specifically on data science and related competencies.

Maths boffs represent Mzansi

The South African IMO team, from left to right: Phil Labuschagne (deputy team leader), Jean Weight, Andi Qu, Juliette Roux, Kerry Porrill (holding the IMO team mascot), Kgoagelo Bopape, Emmanual Rassou and Liam Baker (team leader).

In September, six high school learners from South Africa participated in the 61st International Mathematical Olympiad (IMO). The team walked away with three bronze medals and three honourable mentions.

Bronze medals were awarded to Andi Qu (Grade 12) from St John's College in Gauteng, Kgaogelo Bopape (Grade 12) from Horizon International School in Gauteng, and Jean Weight (Grade 12) from Curro Hermanus in the Western Cape, while Kerry Porrill (Grade 11) from Cannons Creek Independent School in the Western Cape, Emmanuel Rassou (Grade 10) from South African College Schools in the Western Cape, and Juliette Roux (Grade 10) from Herschel Girls' High School in the Western Cape received honourable mentions.

"South Africa has been taking part in the IMO since 1992," says Prof. Kerstin Jordaan, the executive director at the South African Mathematics Foundation (SAMF). "Over the years, learners achieved one gold medal, nine silver medals, 46 bronze medals and 63 honourable mentions. We are very proud of the team's achievements this year, and would like to congratulate them on their successes."

The overall winning country of the 2020 IMO was China, followed by Russia and then the United States of America. South Africa finished with a ranking of 61st out of 105 participating countries. In previous years South Africa ranked 46th (2019), 62nd (2018), 60th (2017), 58th (2016) and as high as 27th in 1992, 1999 and 2000.

Each country selects a team of six learners. This year's South African team was selected based on the results of last year's South African Mathematics Olympiad (SAMO). The SAMO, including the South African team's training camps, is sponsored by Old Mutual and co-sponsored by the South African Institute of Chartered Accountants (SAICA). Old Mutual also sponsors the Pan African Mathematics Olympiad, as well as the training of mathematics teachers in partnership with the African Institute for Mathematical Sciences Schools Enrichment Centre (AIMSSEC).

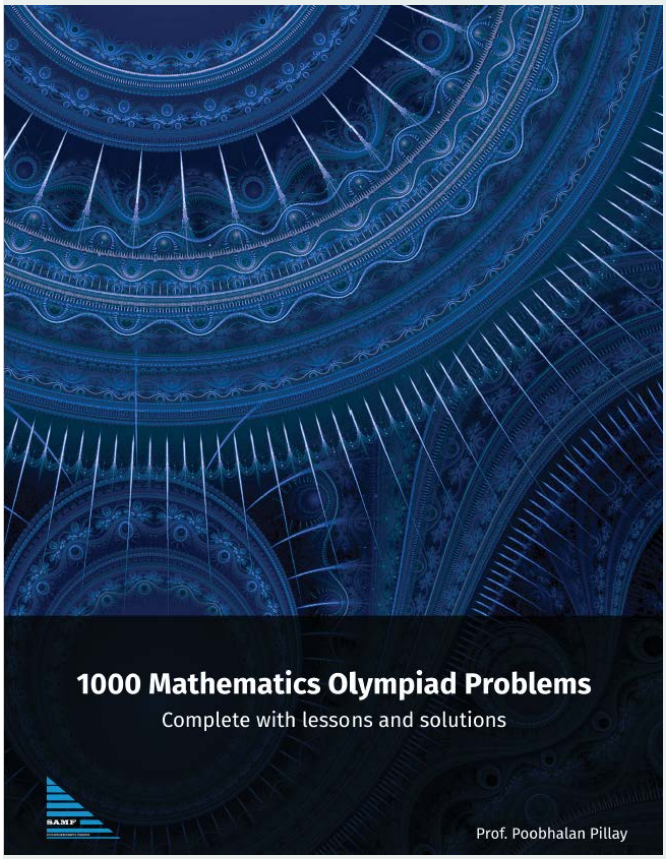
Dr Liam Baker, a lecturer in mathematics at the University of Stellenbosch, participated in the IMO in 2008 and 2009, and served as team leader for this year's participants, helping them to prepare for the event. "The IMO was due to take place in St Petersburg in Russia in July. But because of the COVID-19 pandemic, it was postponed to 21 and 22 September and changed into a virtual event," he says.

Each participating country had a central exam centre that was monitored via webcams by the Olympiad hosts in Russia. The South African team gathered in Stellenbosch. On each of the two days, the team members had to individually solve three maths problems within the set time of four-and-a-half hours.

This is one of the problems the team members had to solve: "A deck of $n > 1$ cards is given. A positive integer is written on each card. The deck has the property that the arithmetic mean of the numbers on each pair of cards is also the geometric mean of the numbers on some collection of one or more cards. For which n does it follow that the numbers on the cards are all equal?"

- The rest of the maths problems from the 2020 IMO as well as previous years are available at: https://www.imo-official.org/problems.aspx

New e-book for maths enrichment



The South African Mathematics Foundation (SAMF) has launched a new e-book to help learners from Grades 7 to 12 improve their mathematics skills. The e-book, *1 000 Mathematics Olympiad Problems*, was compiled by Prof. Poobhalan Pillay, an Emeritus Professor in the School of Mathematics, Computer Science and Statistics at the University of KwaZulu-Natal. Prof. Pillay was on the South African Mathematics Olympiad (SAMO) Round 3 panel, and acted as national moderator of National Senior Certificate (NSC) Mathematics for 20 years. He is currently the academic coordinator for the Siyanqoba Regional Olympiad Training Programme, which manages 10 training centres across the country.

"The programme, organised by the SAMF and sponsored by the Department of Science and Innovation (DSI), concentrates on developing problem-solving skills," he explains. "Unlike the regular school curricula that focus more on solving routine-type questions, the emphasis of the Siyanqoba programme is on the understanding of mathematical concepts rather than pure memorisation of formulae."

Each problem in the e-book is assigned a difficulty level ranging from Level 2 to Level 10, the higher-level problems being suitable for learners who qualified for the various Olympiad programmes offered by the SAMF.

According to a review by Prof. Michael de Villiers, who chairs SAMO's Senior Problem-Solving Committee R1-R2, most of the problems have their origins in SAMO, the SAMF's Team Competitions or the SAMF's Talent searches, but other resources on problem-solving were also used. Learners are encouraged to first attempt to solve the problems, and if possible to do so, solve them in more than one way. Fully worked solutions to all the problems are provided at the back of the e-book.

He explains that the book also includes 11 lessons and seven appendices. Examples of topics covered include:

- Numbers: from natural numbers to complex numbers
- Sequences and series: arithmetic and geometric sequences and series, triangular numbers, Fibonacci sequences, Farey sequences, sums of the first n squares and cubes, proof by mathematical induction
- Rational and irrational numbers: irrationality proofs, recurring decimals, Farey sequences
- Factorisation: factorisation of sums and difference of integral powers
- Geometry: general polygons, concurrency theorems, Euler's formula and Platonic solids
- Areas: Heron's formula, areas of regular polygons, Pick's Theorem
- Trigonometry: trigonometric ratios of multiples of 18°, sum of sines
- Counting and probability: binomial coefficients, binomial theorem, counting with repetitions.

Topics in elementary number theory include congruence arithmetic, the Euclidean algorithm, the Chinese Remainder Theorem, solutions of Diophantine Equations, Fermat's little theorem, perfect numbers, and Mersenne and Fermat primes.

Advanced topics in geometry include the Euler line, the nine-point circle, the power of a point, Ceva's Theorem, Ptolemy's Theorem, Pick's Theorem, and a detailed treatment of the regular pentagon. New results on Cevian ratios, constructing Pythagorean triples, and constructing 60° triangles with integral sides are presented. Diameters of the inscribed, circumscribed and nine-point circles in terms of the sides of a triangle are determined.

The Cauchy-Schwartz and rearrangement inequalities, as well as the inter-relationships amongst the difference means are discussed. The lesson on polynomials provides an in-depth treatment of quadratic polynomials, while moving onto a general discussion of roots of arbitrary polynomials over complex numbers, and consequences of the Fundamental Theorem of Algebra. The Viete formula, De Moivre's Theorem and roots of unity are also discussed in passing.

The e-book can be purchased for R520 (VAT inclusive) at: https://www.samf.ac.za/en/mathematics-olympiad-problems.
Learners on the Siyanqoba programme will receive the e-book on a flash drive free of charge.

UFS traditional medicine expert heads up WHO Regional Committee

Prof. Motlalepula Matsabisa, Associate Professor in the Department of Pharmacology at the University of the Free State (UFS), will lead Africa's fight against the COVID-19 pandemic with his appointment as chairperson of the World Health Organisation's (WHO) Regional Expert Advisory Committee on Traditional Medicines for COVID-19.

Barend Nagel

Prof. Matsabisa has been chosen over 25 other experts from 27 African countries to head this committee, tasked with setting up research and clinical trials for COVID-19 and beyond. The committee is also supported by the African Union (AU), the Centres for Disease Control and Prevention (CDC – Africa), and the European and Developing Countries Clinical Trials Partnership (EDCTP).

The committee was established by the WHO and CDC – Africa on 22 July with the aim of providing independent scientific advice and support to countries on the safety, efficacy and quality of traditional medicine therapies. It is also an effort to enhance research and development of traditional medicines for COVID-19 in Africa.

"This is a huge continental and global responsibility being laid on my shoulders as a chairperson. I have to keep the committee together and ensure that it delivers on its set mandate and terms of reference. I need to ensure that the committee helps the continent and region to get the scientific and legislative aspects on traditional medicine development on track," says Prof. Matsabisa.

"I have taken this position and responsibility, knowing quite well what it entails. I want to do this for the continent and for the sake of good science of all traditional healers and consumers of traditional medicines on the continent and beyond."

According to Prof. Matsabisa, he is looking forward to working with a team of dedicated experts from 27 countries in the African region, and being of help to countries that need assistance with clinical trials, including preclinical work to move to clinical research. He is also looking forward to countries asking South Africa to be part of their multicentre studies in clinical trials for traditional medicines, and to help set up clinical trial teams that include Western-trained clinicians to get into traditional medicine studies.

Prof. Matsabisa says his new position took effect the same day as his appointment and will run as long as COVID-19 is part of our daily lives, and even beyond. It entails supporting member states to implement the WHO master plan for clinical trial protocols in order to generate credible data for COVID-19 results, based on traditional medicines. The committee will also coordinate support to member states in the African region to collaborate on clinical trials of traditional medicine-based therapies – elevating standards by pooling expertise in multicentre studies, as well as complying with GCP (good clinical practice) and GPP (good participatory practice) guidelines for trials of emerging and re-emerging pathogens.

"The committee will also advise on strengthening the capacity of national medicine regulatory authorities to accelerate the issuance of marketing authorisations for traditional medicine products that have been well researched for safety, efficacy and quality, as well as to expedite the approval of clinical trials on traditional medicines. This will help to meet the national registration criteria and the WHO norms and standards of quality, safety and efficacy for the management of COVID-19 and others."

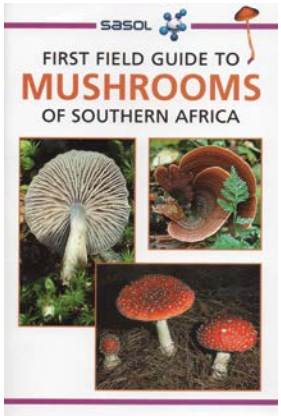
"It will also provide independent scientific advice to the WHO and other partners regarding policies, strategies and plans for integrating traditional medicines into COVID-19 responses and health systems," explains Prof. Matsabisa.

Written by André Damons, Senior Media Relations Officer: Communication and Marketing, UFS

Books

Sasol First Field Guide to Mushrooms of Southern Africa

By Margo Branch. Struik Nature.



This is an updated and redesigned second edition of a book that was originally published in 2001. The text has been revised to address taxonomic changes, new photographs have been included, and the design is simple but attractive. Being a pocket-sized book about the size of a smartphone, it's easy to take along on walks into forests and other damp areas where mushrooms and other fungi can be expected to be found. This is especially useful for those who intend collecting mushrooms to eat, given that some are toxic, and potentially deadly.

The book is not limited to edible species, but rather covers 44 common species or groups of fungi that are most likely to be encountered in southern Africa. These include well-known examples like pine rings, puff balls, ink caps and red stinkhorn, and the even more evocatively named chicken of the woods, bird's nest fungus and turkey tail. An introductory section provides a brief overview of fungi, including the types of fruit bodies, the main identifying features in the form of cap shapes, gill attachment and gill spacing, and the three modes of nutrition – saprophytic, parasitic or symbiotic.

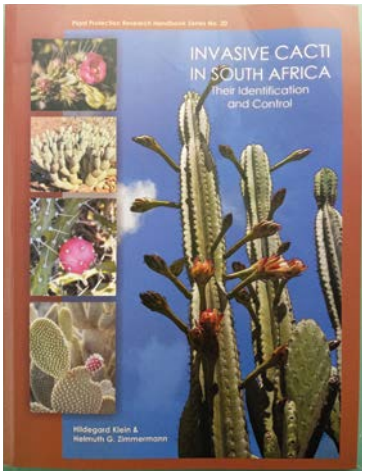
The author, Margo Branch, has written a number of books, including *Living Shores* with her husband, marine biologist Emeritus Professor George Branch, who took the photographs for this field guide. The recommended retail price is R80, and it is also available as an e-book for R55.

Other recent releases by Struik Nature that will appeal to both amateur and professional astronomers and stargazers include the 2021 edition of the *Sky Guide*, published each year by the Astronomical Society of Southern Africa (R150), and *Night Skies of Botswana* by Stephen O'Meara (R240).

While the *Sky Guide* – now in its 75th year of publication – contains more technical detail, with monthly tables, charts and maps, *Night Skies of Botswana* is more attractive and easy-to-digest, with colourful maps and bite-sized bits of information that are conducive to casual browsing by stargazing members of the public. The content of both books will assist in identifying the stars and constellations in southern African skies that are visible to the naked eye, for those without telescopes. Both books also cover some local star lore.

Invasive Cacti in South Africa: Their Identification and Control

By Hildegard Klein and Helmuth Zimmermann. Agricultural Research Council.



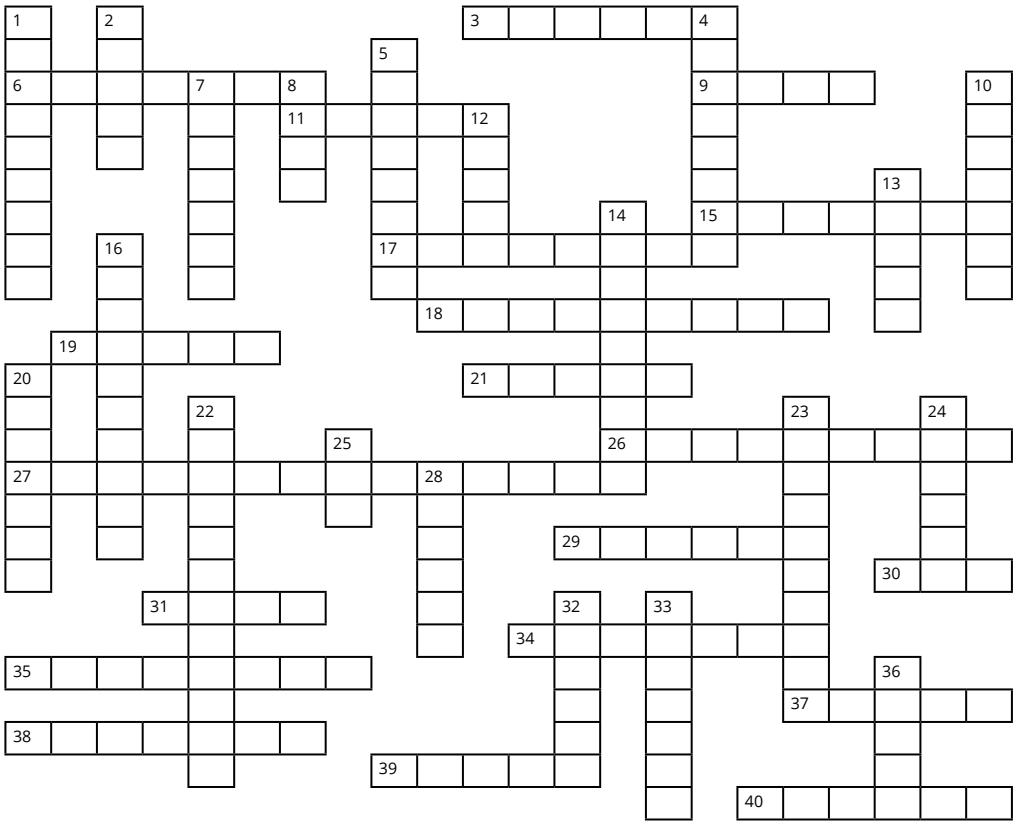
Although cacti are popular in South Africa as garden ornamentals, and in some cases as a fruit crop or source of fodder, they rank among the worst alien invasive plants overrunning agricultural and conservation land.

This book will allow landowners to identify the 33 species covered by the Alien and Invasive Species Regulations of the National Environmental Management: Biodiversity Act (NEM:BA), as well as six other emerging invaders. For each of these species, the authors recommend the best management strategy for various growing conditions. They also explain the science of biological control in simple terms, indicating which biocontrol agents are available for each cactus species, and with enough details to enable landowners to use them successfully against their own cactus weeds.

Before their retirement, the authors were both researchers in the Agricultural Research Council's Plant Protection Research division, spending large parts of their careers on research into the biological control of cactus weeds. The book costs R200 and can be ordered from Hendrieta Moletsane at MoletsaneH@arc.agric.za.

Test your knowledge

All of the answers can be found in this issue of *Quest*



ACROSS

3 South Africa's first national park
6 The 2020 Nobel Prize in Chemistry was awarded for work on ___ scissors
9 A government-funded programme for new academics
11 The lidar instrument on ICESat-2
15 Another name for a water monitor
17 Airborne particles are atmospheric ___
18 A fenced area to exclude grazers
19 Winners of this prize are known as laureates
21 Relating to the moon
26 A mirror that tracks the sun at solar CSP facilities
27 The process of taking measurements from photographs
29 A satellite supporting bathymetry mapping using lidar
30 An acronym for the Fourth Industrial Revolution
31 The gas and dust 'halo' of a comet
34 A satellite using lidar to detect particles in the air and sea
35 This scientist developed the general theory of relativity
37 Another name for a UAV or RPAS
38 An insect that builds large mounds
39 Acronym for light detection and ranging
40 A term used in the scientific name of many lizard-like animals, including dinosaurs

DOWN

1 DVM is an acronym for diel vertical ___
2 Mushrooms are part of this plant group
4 Another name for the ring-necked spitting cobra
5 Our galaxy is called this
7 DTM is an acronym for digital ___ model
8 A lidar instrument on the International Space Station
10 This biome contains elements of grasslands and forests
12 Describes a type of renewable energy
13 Succulent alien invasive plants often associated with deserts
14 Lidar-derived information on both topography and bathymetry
16 Self-driving cars are ___ vehicles
20 Describes species that look similar but have genetic differences distinguishing them as separate species
22 The term for solar panels
23 A set of data points with XYZ coordinates, representing a 3D object
24 This project uses lidar to digitally preserve heritage sites
25 Rotation around a vertical axis, as in a wind turbine
28 Correct name for a shooting star
32 Describes a bird of prey
33 A museum exhibit with three-dimensional models in front of a painted scene
36 Khi Solar One is a solar ___ power plant

BRAINTEASERS

Desmond won the lottery. He spent two-thirds of his winnings on a new car. He spent two-thirds of what he had left renovating his house. Then he spent two-thirds of what he had left on an overseas holiday. He spent his last R20 000 on new clothes. How much did Desmond win on the lottery?

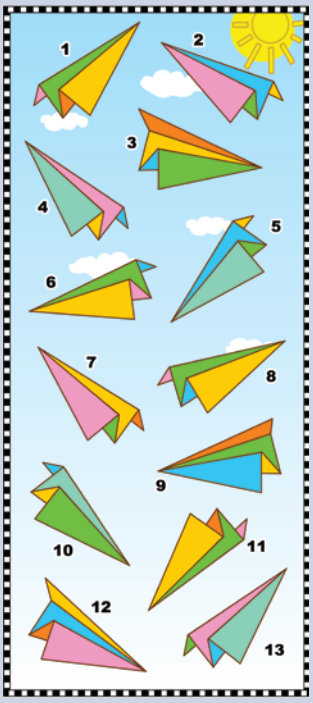
Rose put some 10 cent coins on the table. Half of them were tails up. Rose turned over two of the coins, and then a third of them were tails up. How many coins did Rose put on the table?

Answers to Brainteasers in Vol. 16 No. 3

Lethabo is 9 years old.
Mary is either 48 or 104.

PICTURE PUZZLE

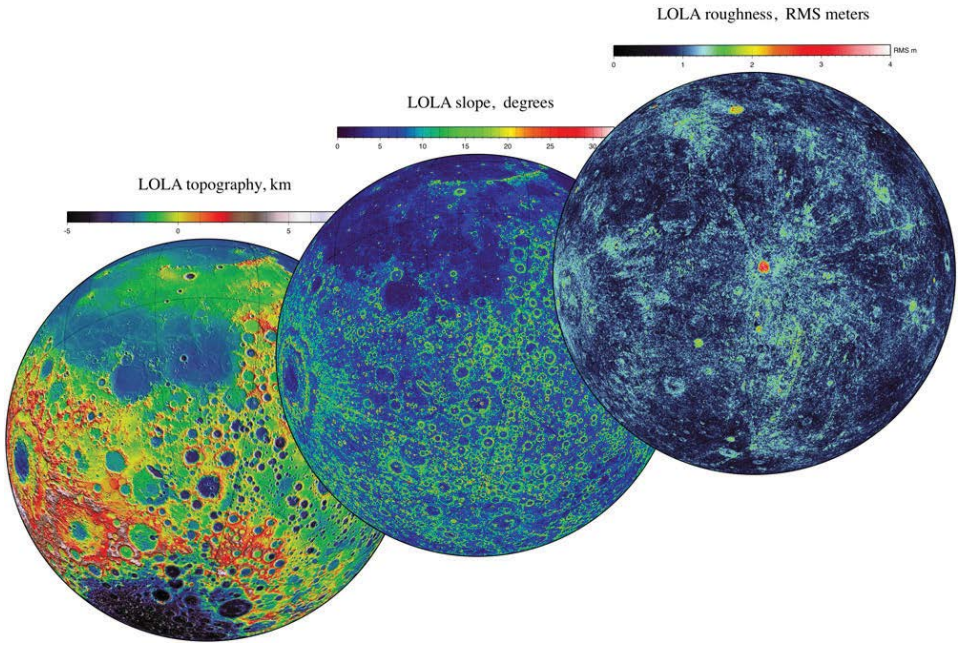
Find the two identical paper plane images (they may be rotated).



MAPPING THE MOON

NASA/GSFC/USGS

In April 2020 the new 'Unified Geologic Map of the Moon' (above) was released by the United States Geological Survey (USGS). It is a synthesis of six Apollo-era regional geologic maps, updated with data from recent satellite missions. Much of the shaded topography was derived from the lidar instrument known as LOLA – for Lunar Orbiter Laser Altimeter – on NASA's Lunar Reconnaissance Orbiter spacecraft, which was launched in June 2009 and is still in orbit today. LOLA's laser, fired 28 times per second, is split into five beams by a diffractive optical element, so 140 pulses are sent to the moon's surface per second. Apart from measuring pulse time-of-flight (range), LOLA measures pulse spreading (surface roughness) and transmit/return energy (surface reflectance). The data is used to map (below) topography, as well as surface slope values and roughness of the topography. The slope magnitude indicates the steepness of terrain, while roughness indicates the presence of large blocks.



NASA/LRO/LOLA Science Team

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