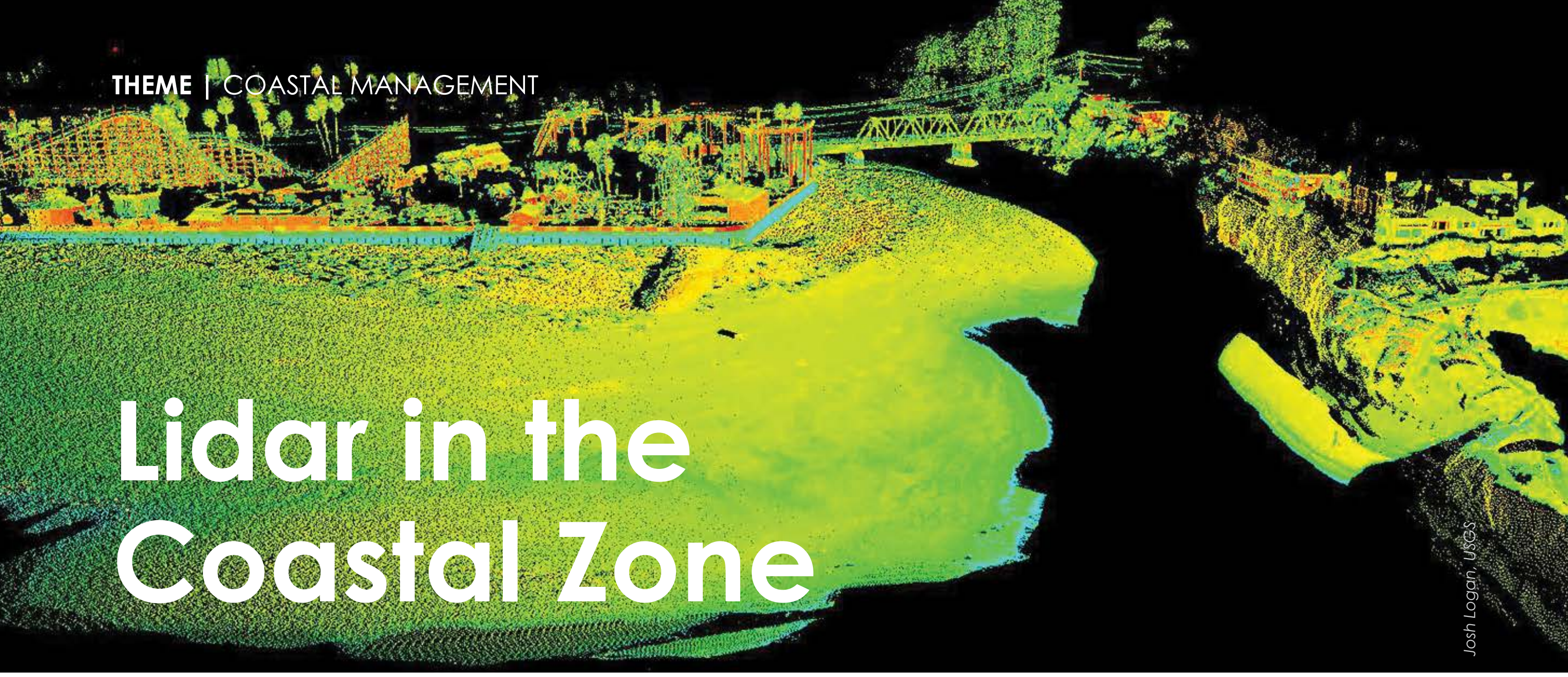


Josh Logan, USGS

Lidar in the Coastal Zone

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.

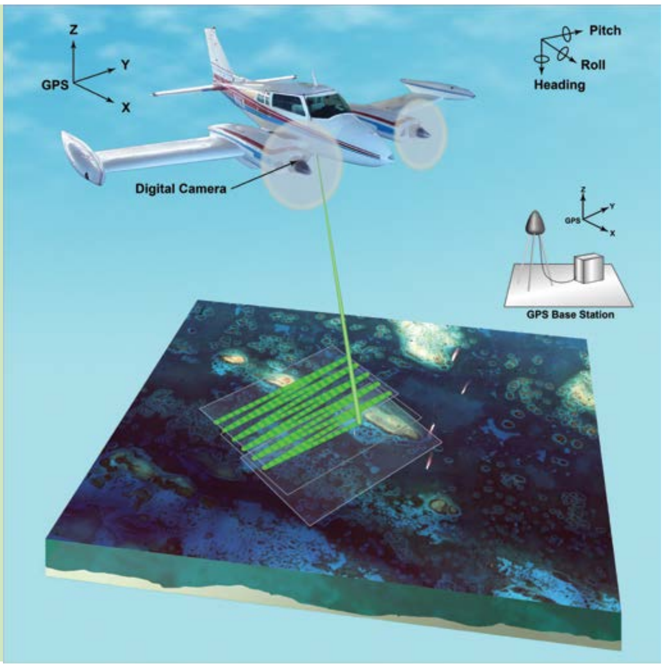
Dr Melanie Lück-Vogel, a senior researcher in remote sensing at the CSIR, was lead author of a paper published in the *South African Journal of Botany* in 2016, reporting on the findings of just such a mapping exercise for the St Lucia estuary on the KwaZulu-Natal coast. She has played an instrumental 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.



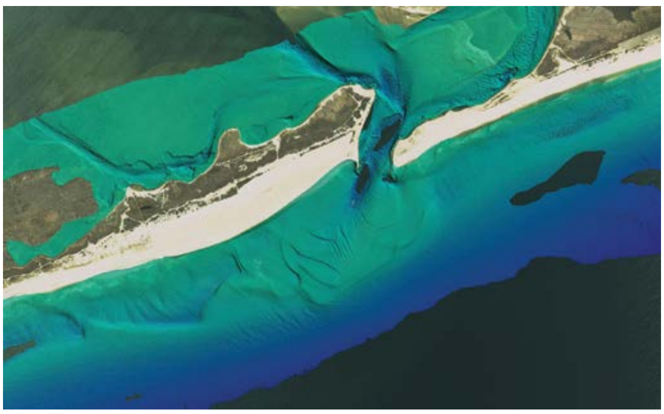
Betsy Boynton, USGS

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.

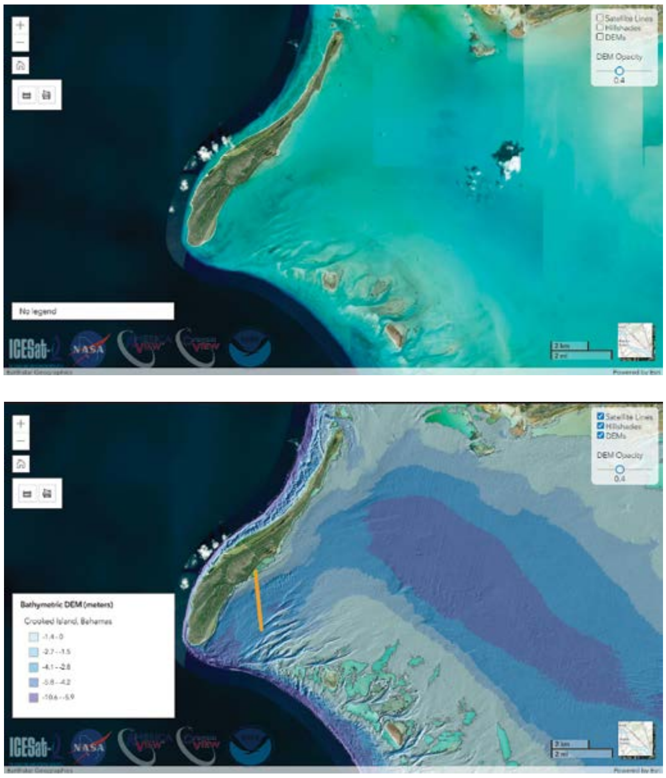
In the United States, the National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management makes lidar and other data available through an online platform called Digital Coast. Its Coastal Topographic Lidar repository contains data gathered by many different organisations using a 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



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/

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.

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/

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