BIODIVERSITY

In living colour – South African aquatic scientists make a splash in biodiversity campaign

A new age of satellite remote sensing is upon us. High-tech sensors capable of imaging the earth at over 100 spectral wavebands are now a reality. These sensors, known as hyperspectral radiometers, capture very fine spectral features of the colours emitted from the surface of the earth and its water bodies, offering opportunities for improved satellite-based environmental monitoring. South African researchers are primed and ready to make use of these new technologies to derive water quality parameters from hyperspectral radiometric measurements by applying it towards monitoring our diverse estuaries, dams and oceans. So writes Lisl Lain and Marie Smith of CSIR.

Bradclin Photography / Flickr

Famous for its biodiversity, South Africa displays corresponding diversity in ecosystems, as well as extraordinary dynamism within the aquatic realms. Water bodies can change dramatically overnight or during the course of a few days – for example when a coastal embayment turns green, brown or red when microscopic algal blooms, or 'red tides', are present. Pressure on the healthy ecosystem functioning of our coastal and inland waters is undoubtedly rising, with difficult challenges arising for governing and management agencies as South Africa experiences the impacts of extreme weather events, as well as increased drinking water demands by a growing population. The routine acquisition of satellite data, and the ability to retrieve water quality parameters from these data, provide the grounding for a far better understanding of our unique geophysical and ecological systems and their dynamics.

Aquatic remote sensing relies on the principle that the colour of any water body is determined by the type and amount of the

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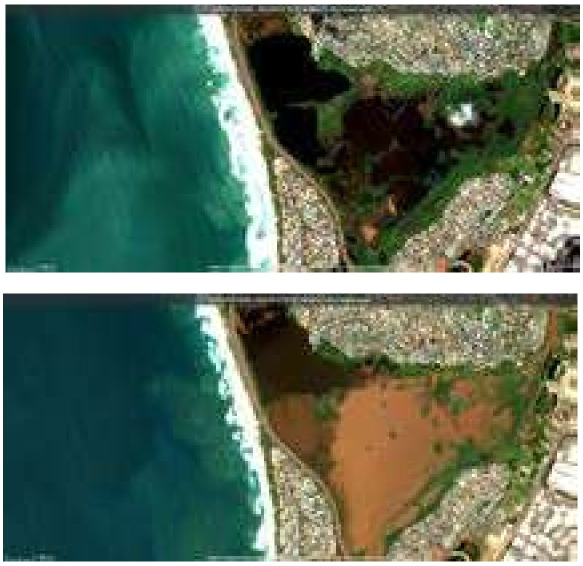
particles that are present inside of it, and results from the way that these particles interact with light. These particles usually consist of things like sediments, plant matter, algae, or dissolved substances, all of which differ in the way that they scatter and absorb light in the visible range observed by the naked eye. Any variation in the presence or concentrations of these particles, or if the bottom substrate is visible in shallow waters, can affect the colour of the water. Hyperspectral radiometers are able to capture the very fine spectral features of the water's appearance, providing unprecedented detail of water colour and facilitating huge potential for improving the retrieval of water quality parameters and constituent concentrations.

The water colour signal is best understood using ***in situ*** measurements in combination with theory or modelling, and most valuable of all, coincident in-water measurements of individual parameters with surface, airborne and/or satellite radiometry. This allows the radiometric signal, or light spectrum, to be decomposed into its different parts, i.e. the concentrations and types of water constituents, which in turn supports the development of algorithms that are capable of reliably and routinely deriving these information from future radiometric measurements.

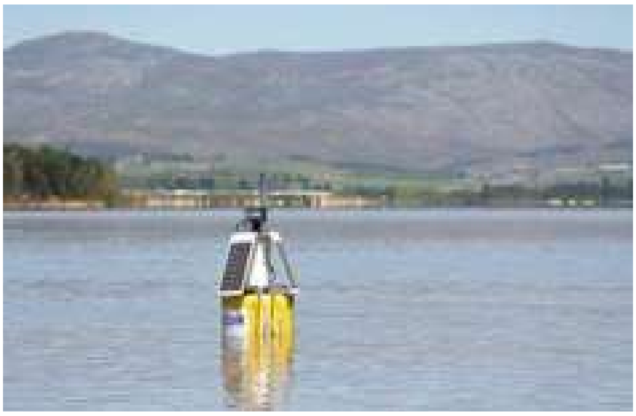
NASA's BioSCape hyperspectral airborne campaign (Western Cape Greater Floristic Region, October and November 2023) provided the ideal springboard from which to launch a comprehensive field campaign covering a variety of very different aquatic sites, in pursuit of these coincident measurements. Integrated teams of USA and RSA researchers provided instrumentation and expertise, with 'Gizmo', the CSIR's hyperspectral radiometric buoy, as the star of the show. Gizmo – the only buoy with these measurement capabilities in Africa – was deployed in Theewaterskloof Dam for the duration of the campaign, making continuous measurements of water colour and providing surface validation data for the airborne sensors and atmospheric correction processes.



Sentinel 2 colour images of Rietvlei, Milnerton (Cape Town) taken on the 22nd and 27th of September 2023, before and after a significant rainfall event. Credit: European Union Copernicus data processed with EO Browser.

The routine acquisition of satellite data, and the ability to retrieve water quality parameters from these data, provide the grounding for a far better understanding of our unique geophysical and ecological systems and their dynamics. Internationally funded environmental satellite missions offer such routine and freely available space-based data. However, due to the highly absorbing nature of water, it can be very challenging to accurately measure the colour of aquatic targets from space. Since water bodies are much darker than land and plants, satellite sensors need to be specifically designed to be sensitive enough to detect even the smallest variations in the colour of the water.

In addition, the water signal detected by the satellite can also be contaminated by sun glint or light signals reflecting off of the surrounding land, clouds and atmosphere, and need to be removed or corrected before it can be useful. One of the most highly anticipated satellites due for launch in early 2024 is the hyperspectral Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission from the National Aeronautics and Space Administration (NASA). PACE is specifically designed to provide detailed information of the global ocean and will provide daily coverage of the globe at spatial resolution, or pixel size, of one kilometer. The PACE satellite also consists of different sensors that help to correct the water-leaving signal for influences from the atmosphere.

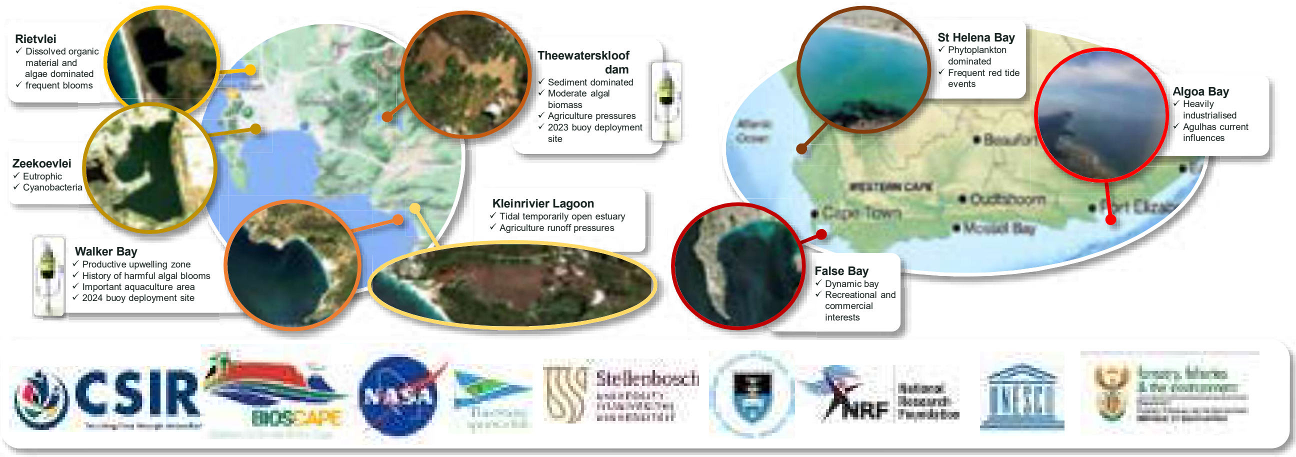


Michael Walker

Gizmo, Africa's only hyperspectral radiometric buoy, deployed in Theewaterskloof Dam.

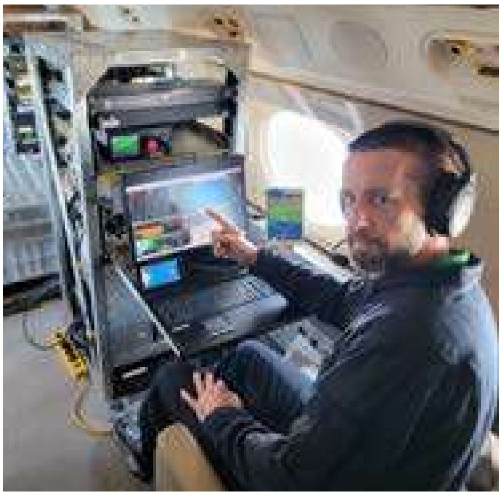
BioSCape is a collaborative research project focusing on the assessment of biodiversity in the Greater Cape Floristic Region, built on deep scientific engagement between South Africa and the United States. The project is funded by NASA, the South African government's National Research Foundation (NRF) and South African Environmental Observation Network (SAEON), as well as the United Nations Educational, Scientific and Cultural Organization (UNESCO). The aquatics teams, comprising both inland and coastal sites, persisted through temperamental Cape weather and very challenging logistics to ensure sampling took place at a minimum of 8 different sites, culminating in the achievement of an enormously valuable dataset encompassing a wide variety of in-water parameter measurements coincident with overflight data, as well as opportunistically satellite overpasses.

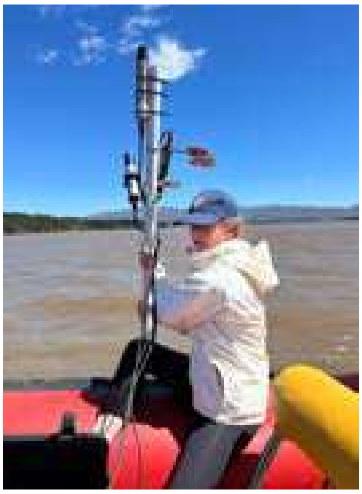
The unusual diversity in water types and constituent composition make this a very exciting and useful dataset. The teams measured



The BioSCape Aquatic sites represent an extraordinary diversity of environments, from algal bloom-vulnerable coastal areas to dynamic estuaries and inland freshwater bodies, both natural and man-made. Measurements made represent an unusually wide spectrum of conditions for one campaign, providing data which will ultimately support a range of applications including algal bloom monitoring and management, drinking water quality assessment, and ecosystem vulnerability mapping.

Photo by Rob Switzer





This photo and one to the left by Samantha Sharp

In-air measurements are taken over the water body by the NASA aircraft (left), while simultaneous radiometric measurements and water samples are collected by boat (middle), which are subsequently analysed in the lab (right).

clear, coastal waters with a fascinating array of algal types in a variety of marine environments; sediment-dominated Theewaterskloof dam waters, cyanobacteria-dominated urban vlei waters and the dark clear waters of the Klein River Estuary typified by high concentrations of dissolved tannins.

The full suite of measurements includes phytoplankton pigments and type, suspended solids, dissolved substances, particulate absorption and backscatter over a range of different water types, providing both validation data for existing satellite water quality retrieval algorithms, as well as parameterisation for new models and algorithms under development by South African scientists.

By leveraging the biodiversity focus of BioScape, the aquatics teams were able to go above and beyond the stated science objectives and collect optical data of a wide range of both living and non-living in-water constituents. This comprehensive approach to characterizing the full spectrum of water colour components is of enormous value to the international "optically complex waters" research community as well. All data from the BioSCape campaign will be made publicly available.

To learn more about the BioScape campaign, visit: https://www.bioscape.io/science

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