# Water quality

## Satellite technology keeping an eye on South Africa's dams

*Remote sensing technology is being developed to keep a better eye on the quality of South Africa's dams.*

Article by Sue Matthews.

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Persistent algal blooms and dense mats of aquatic weeds are the easily observed signs of nutrient-enrichment of freshwater systems, but more insidious are the secondary impacts of such profuse growth. There's the light limitation due to turbidity and shading that hampers photosynthesis by other primary producers, the resulting habitat alteration that changes the species composition of the animal community, and the oxygen depletion that – at its most extreme – causes fish kills and mass mortalities of bottom-dwelling invertebrates.

Collecting information on the extent and prevalence of the problem is labour-intensive and expensive though. The National Eutrophication Monitoring Programme (NEMP) was launched by the then-Department of Water Affairs (now the Department of Water and Sanitation - DWS) in 2002 following a two-year, Water Research Commission-funded project to develop an implementation plan. Today, NEMP officials coordinate the collection and analysis of water samples from about 160 sites in dams, lakes and rivers countrywide, but it's a logistically challenging undertaking, relying on DWS staff and local stakeholders in far-flung places to take samples and send them in for analysis.

The concentrations of chlorophyll a and total phosphorus are used to assess the trophic status of the waterbodies on a six-monthly (summer and winter) basis, and a number of other physico-chemical parameters are measured too. However, there's only one sampling site in most of the large dams and lakes, which doesn't necessarily coincide with the most likely location of algal blooms, nor give useful information on nutrient inputs.

The frequency of monitoring and logistical challenges also preclude an effective early warning system for cyanobacteria – or blue-green algae – blooms. These cause taste and odour problems in drinking water supplies and may be toxic, resulting in skin and eye irritation on contact, and gastrointestinal illness or even death of people or animals drinking untreated water. Some cyanobacteria species have gas vacuoles that allow them to regulate their buoyancy and form unsightly scums on the water surface, discouraging non-contact recreational activity too.

How much simpler, then, to get a 'snapshot' of phytoplankton biomass for the entire waterbody every few days, with the ability to differentiate cyanobacteria from other phytoplankton blooms, and even locate large patches of aquatic plants – often invasive species such as water hyacinth, red water fern, salvinia or parrot's feather. This is essentially the modus operandi of a WRC project currently underway, except that the snapshots are remote-sensing images from orbiting satellites.

Project Leader, Dr Mark Matthews*, developed a method that allows satellite data to be used in this way during his PhD research at the University of Cape Town (UCT), under the supervision of Dr Stewart Bernard of the CSIR. His research showed that the majority of South Africa's 50 largest waterbodies are hypertrophic, with mean chlorophyll a concentrations exceeding 30 mg.m$^{-3}$, and extensive cyanobacteria blooms are present in at least 10% of them.

Dr Matthews was capped with his PhD in June 2014, and four months later was awarded best business idea in the European Space Agency's Copernicus Masters Competition for CyanoLakes – the company he has set up to provide a public information and warning service for cyanobacteria blooms using satellite data. The service will rely on data from the Ocean and Land Colour Instrument (OLCI) on Sentinel-3, a European Space Agency satellite due to be launched in January 2016.

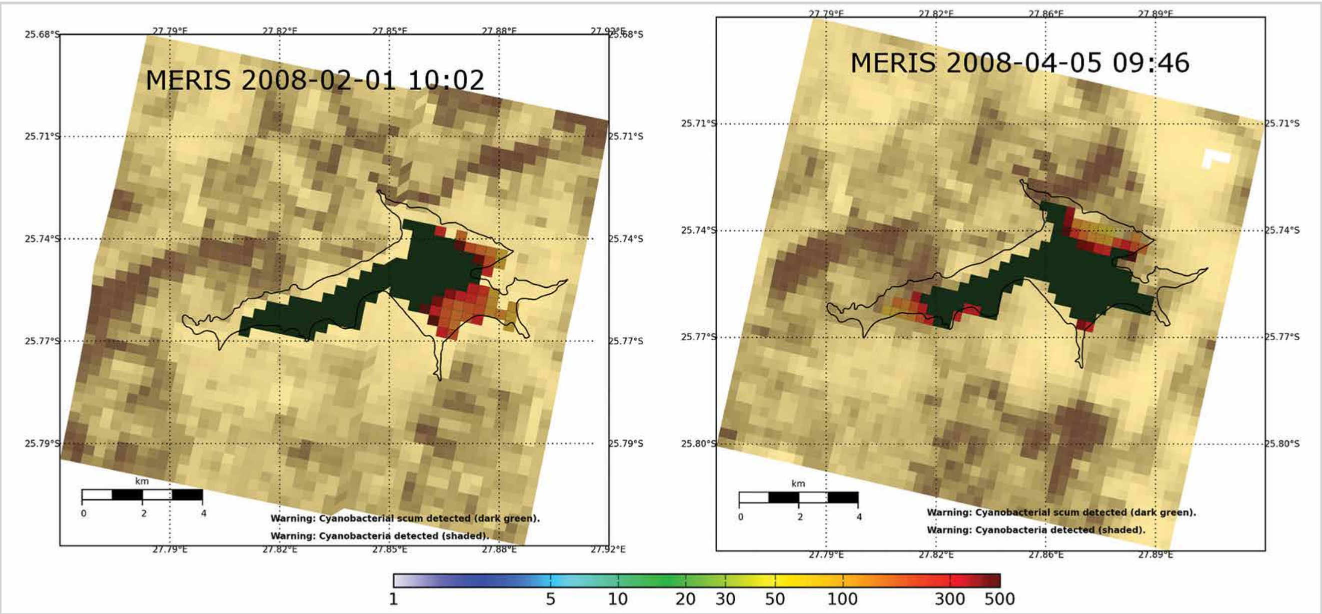
The WRC project, officially titled 'The integration of Earth Observation into the National Eutrophication Monitoring Programme' but generally referred to by the acronym EONEMP, will also make use of this data once it becomes available.

In the meantime, the focus has been on getting the most out of retrospective data from MERIS – the Medium Resolution Imaging Spectrometer on the European Space Agency's Envisat satellite. Launched in March 2002, Envisat's mission ended unexpectedly in April 2012 when communication with the satellite was suddenly lost. Nevertheless, MERIS provided a decade's worth of data at a spatial resolution of 260 m by 290 m every two to three days, and it's all available free of charge.

"The satellite scene is very large, but for each overpass we can subset the data out for the large waterbodies and do an analysis to calculate the chlorophyll average for the entire lake or dam," explains Dr Matthews. "There's more than a thousand images for some waterbodies, so we have a really good record and can resolve monthly and seasonal changes."

The added benefit of being able to determine how much of that chlorophyll is due to cyanobacteria blooms is the particularly novel feature of the MPH algorithm developed by Dr Matthews during his PhD research. The algorithm uses a spectral shape approach, relying on the 'maximum peak height' in the MERIS red bands at 681, 709 and 753 nm.

"Essentially, the algorithm separates the spectral features of cyanobacteria from those of algae, and then applies specific chlorophyll algorithms to that data," he explains. "So now you can get quantitative estimates of the biomass of cyanobacteria and algae respectively. This was the first algorithm in the world to distinguish cyanobacteria and algae in a quantitative way, so it was quite cutting edge in that respect, and was very well received by the remote-sensing community."




*Time series of MERIS-derived chlorophyll a in Hartbeespoort Dam closely compares to that measured in situ by the National Eutrophication Monitoring Programme. The high chlorophyll concentrations are likely due to blooms of cyanobacteria and the associated surface scums, which are visible as bright green slicks on true colour Landsat images and as dark-green pixels on corresponding MERIS images.*

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In fact, the MPH algorithm was one of several tested for 300 large lakes and reservoirs around the world by the Diversity II Project, a European initiative contributing to the assessment and monitoring of the Convention of Biological Diversity's targets for 2020. It was found to be the best-performing algorithm for eutrophic systems and so – following some tweaks to improve performance in oligotrophic waters – it was included as a plug-in for BEAM, the European Space Agency's open-source toolbox for viewing, analysing and processing MERIS data. The improved algorithm also allows identification of clear water affected by sun glint and stray light, and enhances detection of floating aquatic vegetation.

Within six months of the start of the WRC project – a collaborative initiative involving UCT, CSIR, DWS and the South African National Space Agency (SANSA) – in April 2015, the MPH algorithm had been applied to MERIS data for more than 100 waterbodies around the country. Most of these are dams, but there are also some natural systems such as Barberspan, Chrissiemeer, Lake Sibaya and Groenvlei, the proviso being that the waterbodies should be at least 600 m wide to reduce error caused by shoreline effects, and should not experience prolonged dry periods. The resulting database, covering the entire decade from 2002 to 2012, was provided to DWS for ingestion into the computerised Water Management System maintained by Resource Quality Information Services.

By February, Dr Matthews will have completed an analysis of that data in terms of trends, means and seasonality for each waterbody, and submitted a report "essentially saying this is the trophic status of our dams, this is the variability we're seeing, these are the worse affected by cyanobacteria. A website will also be set up to display this data in a very user-friendly way for the public."

An MSc student is focusing on time-series analysis for selected systems in the Vaal catchment and starting to compare the MERIS-derived data to that of NEMP, while another MSc or PhD student will be taken on for OLCI-related work early this year. Fortunately, OLCI will have the same bands as MERIS plus some additional ones, so the MPH algorithm should still be applicable in future, but validation will nevertheless be necessary. This will be done using bio-optical data from dedicated fieldwork and laboratory analyses, as well as data from routine NEMP sampling.

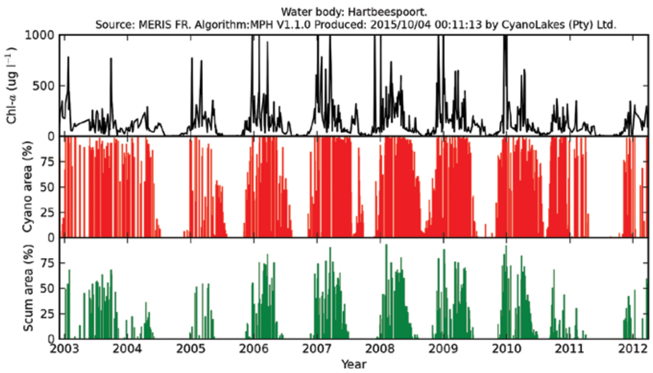
There is also much work to be done on setting up the processing chains to acquire OLCI data and make it available in near real time to provide an operational monitoring system for estimating phytoplankton biomass, detecting cyanobacteria blooms and managing invasive aquatic plants. Data from OLCI will be available within three hours of the satellite overpass, but this will need to be converted to usable products, and products to value-added information, such as tables with weekly averages and graphs showing seasonal and yearly changes.

Programme Manager for NEMP, Elijah Mogakabe, is excited by the opportunities presented by this eye-in-the-sky approach to monitoring eutrophication, and recognises how the two programmes complement one another.

"We'll be able to get an idea of the water quality in waterbodies not currently being monitored by NEMP, while our monitoring data can be used for further calibration and improvement of the algorithm," he says. "The remote-sensing information will allow us to optimise our monitoring network and streamline our activities, which is going to save money in the long term."

Hopefully, some of those cost savings can be used for remedial measures to mitigate eutrophication, as well as preventive management. Ironically, though, in this day and age it is far harder to achieve results 'on the ground' than it is to view the problem from space.

*Dr Mark Matthews analyses a water sample during a field trip on the Hartbeespoort Dam in October 2010 to collect in situ bio-optical data, which he used during his PhD research to develop and validate the MPH algorithm.*




*Time series for MERIS-derived chlorophyll a concentration and area coverage for cyanobacteria and surface scum at Hartbeespoort Dam for the period 2003-2012.*