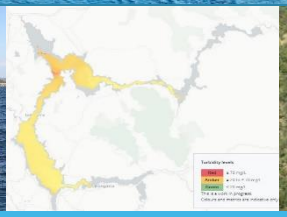
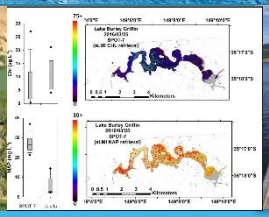
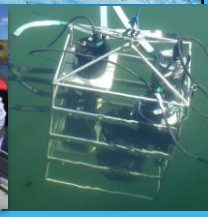








Integration of near-surface and satellite observations for algal bloom detection

Janet Anstee [1], Klaus Joehnk [2], Phillip Ford [1], Tim Malthus [1], Elizabeth Botha [1], Marit van Oostende [1], Eric Lehmann [3], Xavier Ho [3], Stephen Gensemer [4]

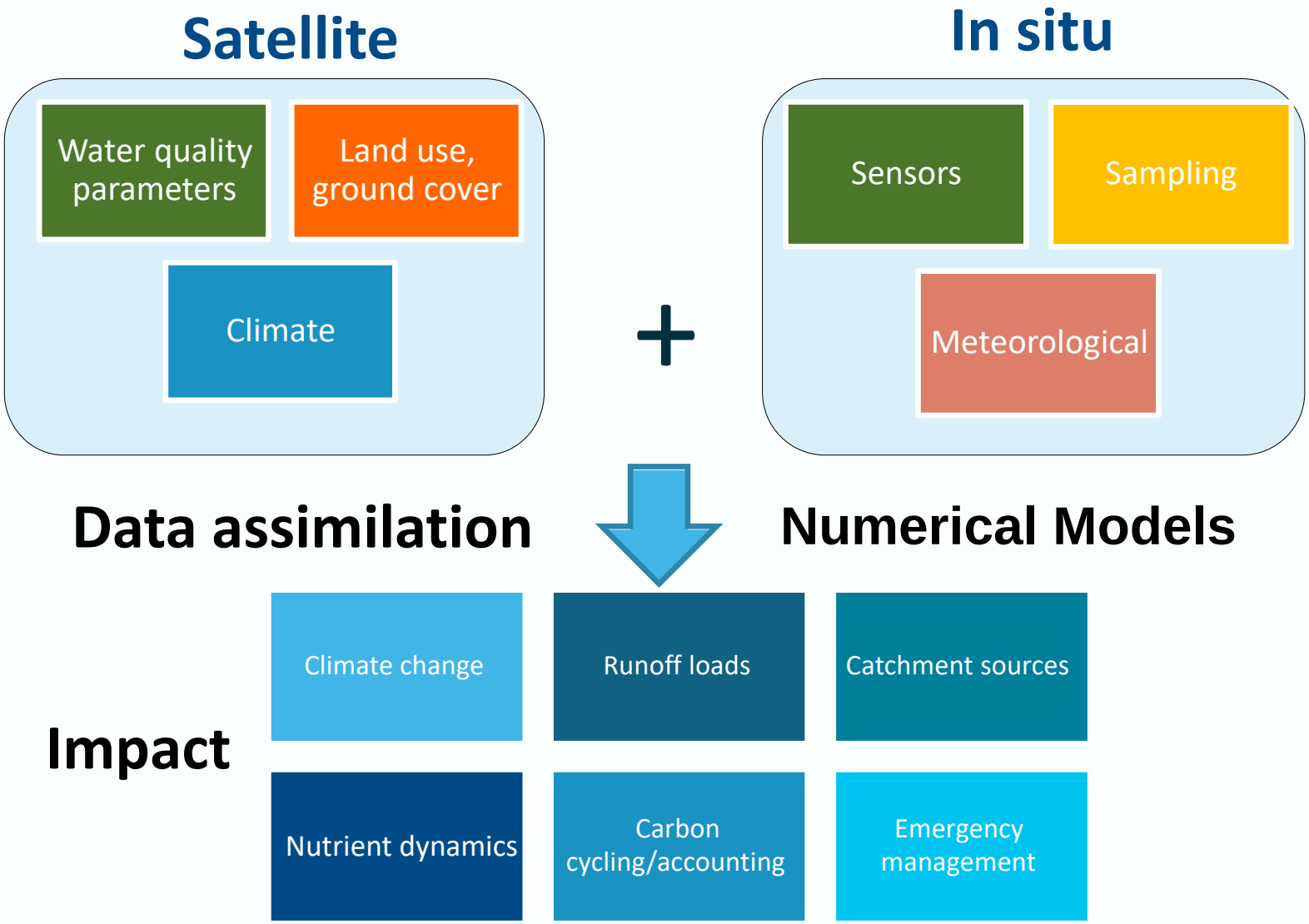
www.csiro.au

[1] CSIRO Oceans and Atmosphere, [2] CSIRO Land and Water, [3]Data61, [4] CSIRO Manufacturing Technology,

Background

- Algal blooms and increased eutrophication is an increasing global problem
- Human and animal health impacts
- AU$180-240 M per annum in bloom impacts (~2006)
- Rapid, cost-effective assessments of water quality are needed to assess baseline conditions and investigate changes in response to existing and potential environmental stressors.





Satellite
Water quality parameters
Land use, ground cover
Climate
+
In situ
Sensors
Sampling
Meteorological
Data assimilation
Numerical Models
Impact
Climate change
Runoff loads
Catchment sources
Nutrient dynamics
Carbon cycling/accounting
Emergency management

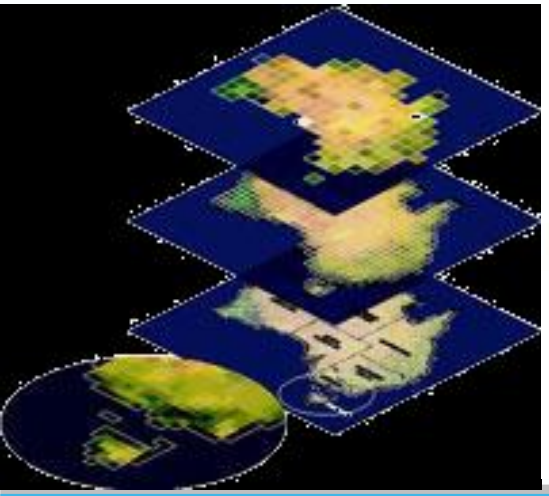
Background

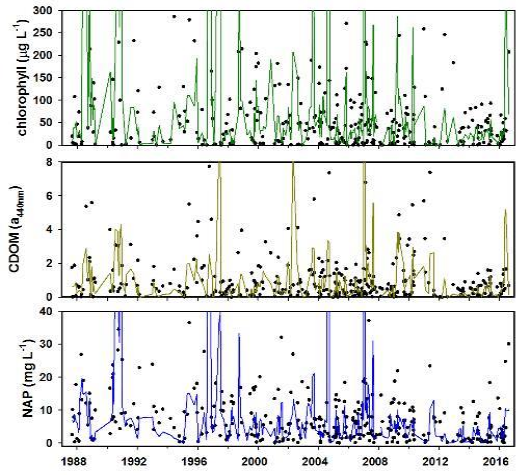
The transformative digital infrastructure - Digital Earth Australia data cube is a:

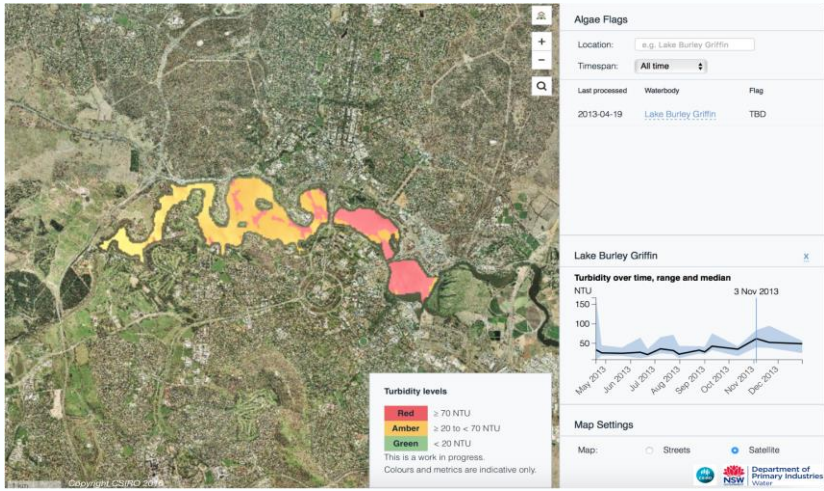
- National Nested Grid
- Surface Reflectance
- All Landsat : TM/ETM/OLCI

Analysis Ready Data (ARD)

In light of the increasing availability of ARD satellite imagery in open datacubes, either on cloud-based services or on high performance computing environments, development of operational monitoring systems is becoming feasible.





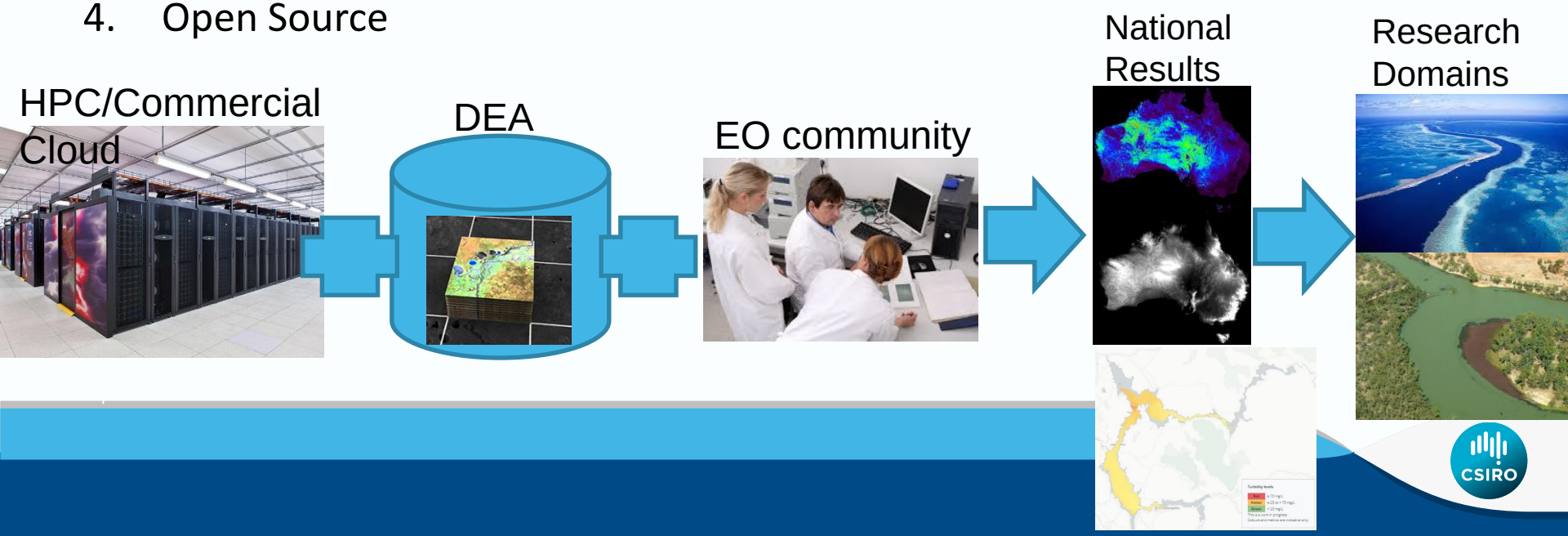


Digital Earth Australia (DEA) Data Cube

To facilitate meeting National objectives in resource management, DEA combines Big data + high performance computing (HPC) or commercial cloud.

DEA Datacube helps meet these challenges by:

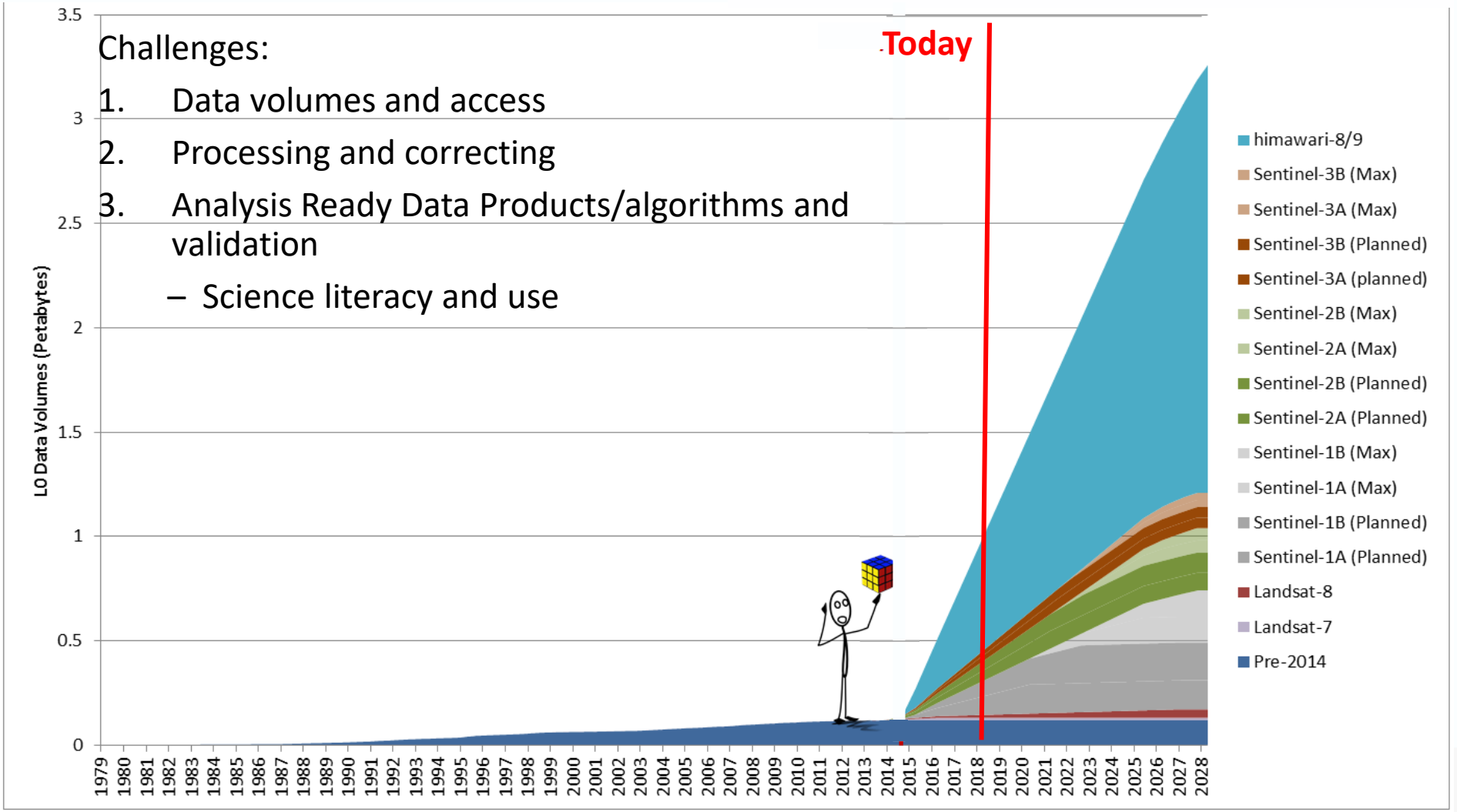
1. Analysis Ready Data (ARD) – process once use multiple time
2. Scalability – scales to large problems. Runs on a number of platforms from desktop, cloud or HPC.
3. Common Python API – rapid development and deployment of application
4. Open Source



Challenges and Opportunities

A step change in EO satellite capability.

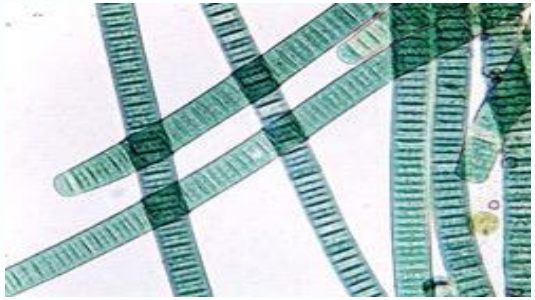
Substantial growth in the EO based digital economy across Industry and Government domestically and internationally



Algal blooms in aquatic systems

Traditional sampling

- Costly, time consuming
- Delayed information
- Poor spatial coverage



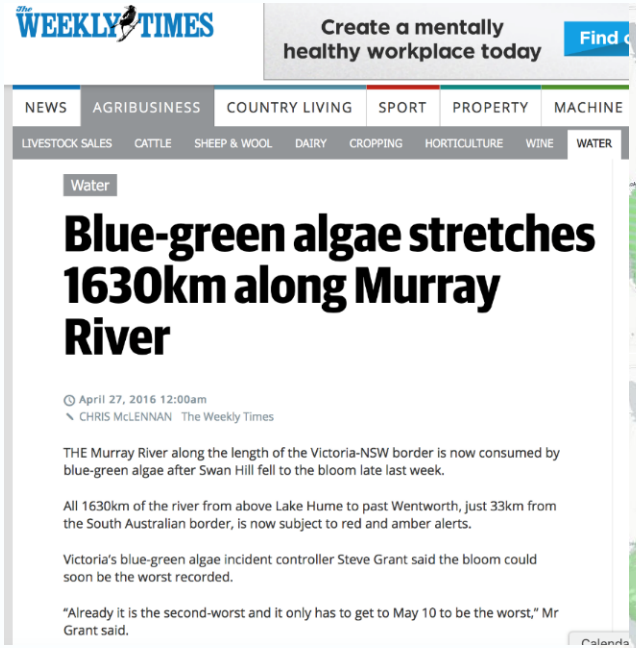
Zamyadi et al. 2015, Trends in Analytical Chemistry, 82:1–14

In situ monitoring

- e.g. fluorometry
- Useful complement, but:
- Bio-fouling, calibration and maintenance, manufacturer differences
- Inaccuracies

2016 Murray River bloom

Initiated in Lake Hume



The Weekly Times

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Water

Blue-green algae stretches 1630km along Murray River

April 27, 2016 12:00am

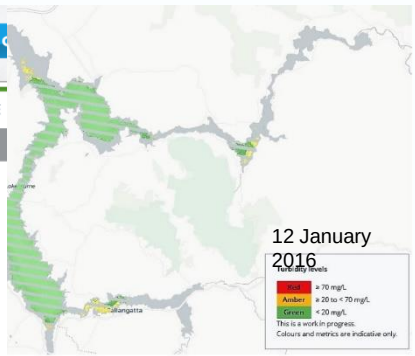
CHRIS McLENNAN The Weekly Times

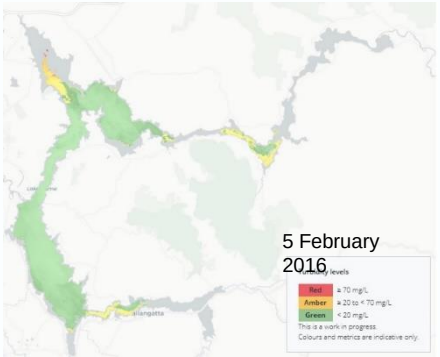
THE Murray River along the length of the Victoria-NSW border is now consumed by blue-green algae after Swan Hill fell to the bloom late last week.

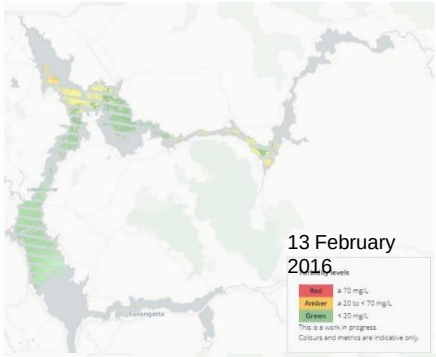
All 1630km of the river from above Lake Hume to past Wentworth, just 33km from the South Australian border, is now subject to red and amber alerts.

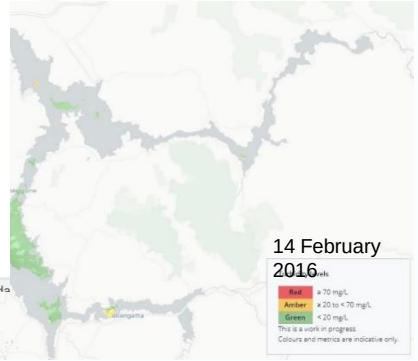
Victoria's blue-green algae incident controller Steve Grant said the bloom could soon be the worst recorded.

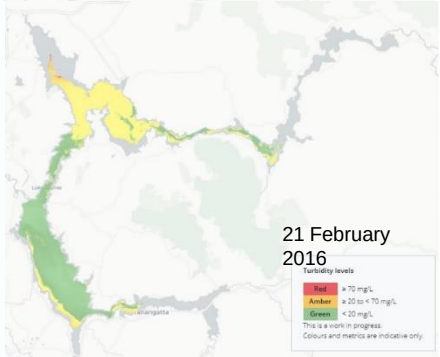
"Already it is the second-worst and it only has to get to May 10 to be the worst," Mr Grant said.

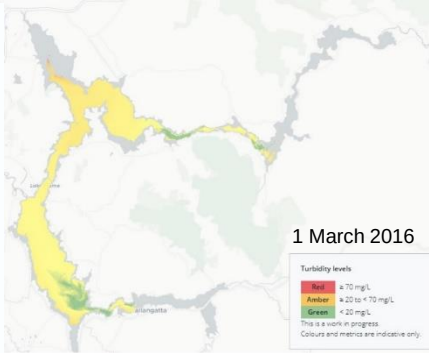


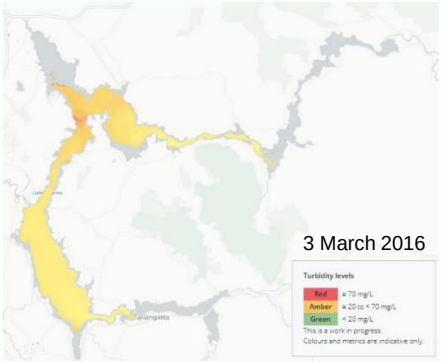


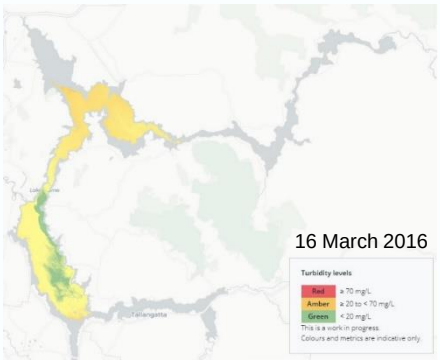


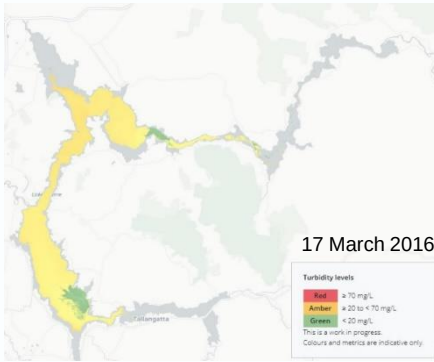






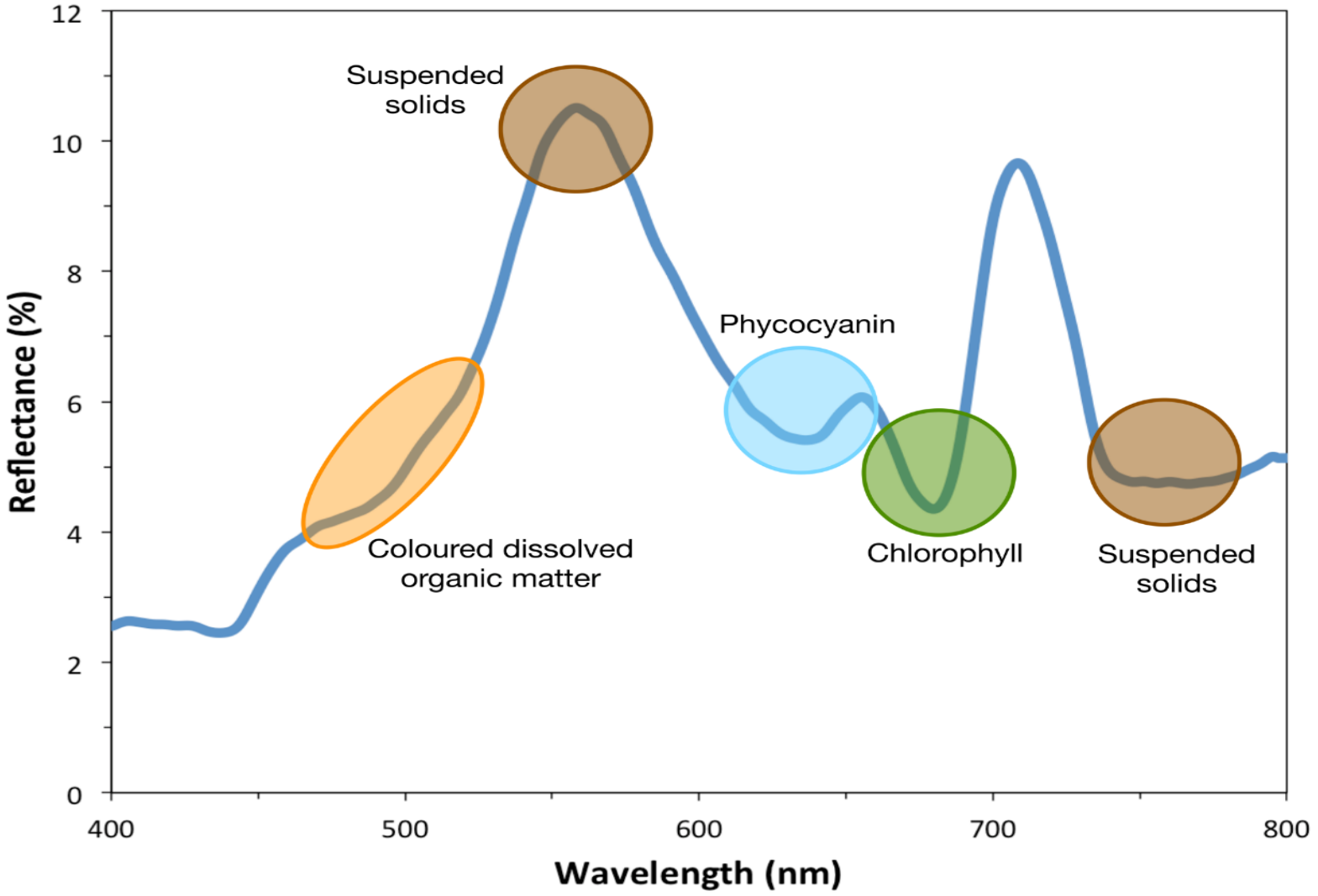




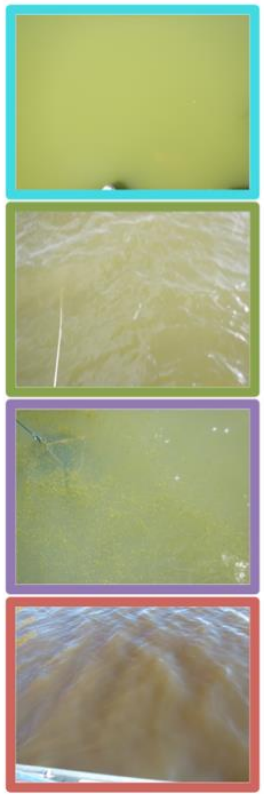


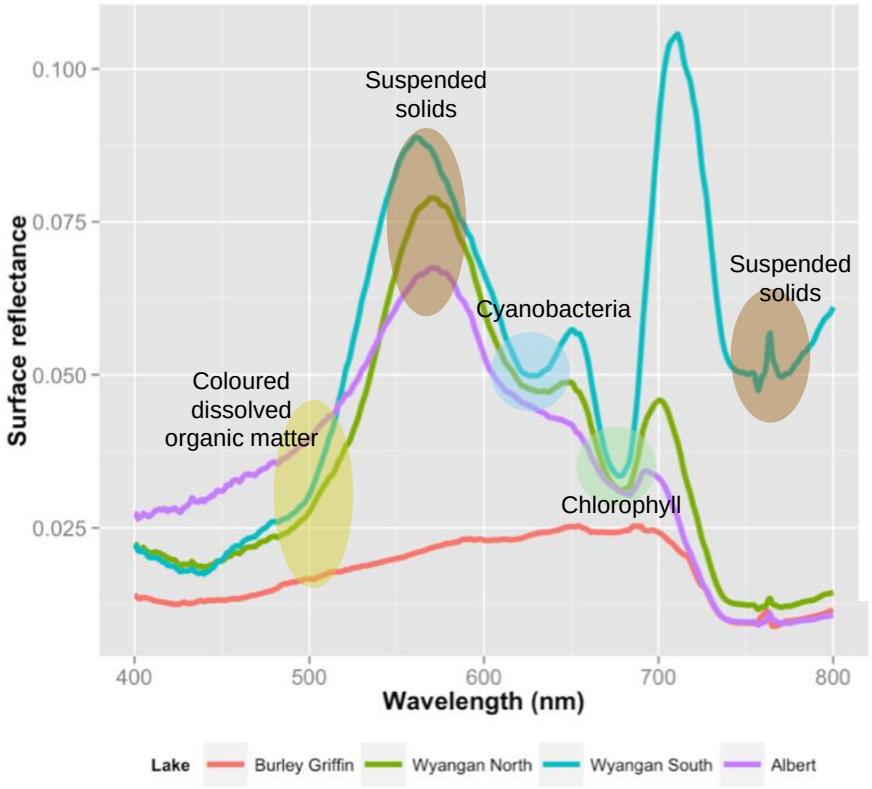
The main blue-green alga in 2016 was *Chrysosporium ovalisporum*, previously reported in very low numbers. This species flourishes in tropical areas.

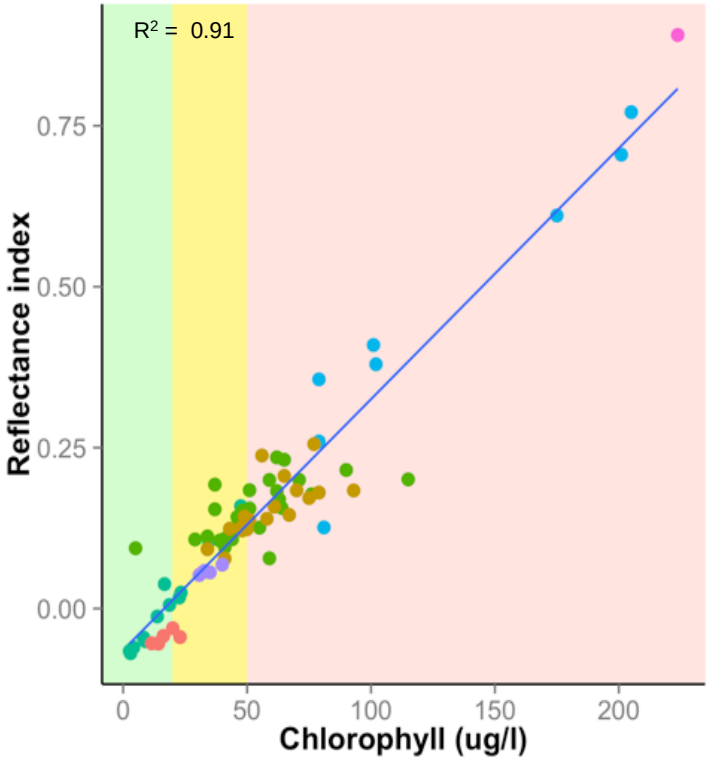
Information in spectral reflectance



Information in spectral reflectance







Alert level	Chlorophyll level
Green	<20 ug Chl l^{-1}
Amber	>20-50 ug Chl l^{-1}
Red	>50 ug Chl l^{-1}

NHMRC/WHO – Guidelines for recreational use

Satellites approaches

Systematic, repeatable, wide coverage

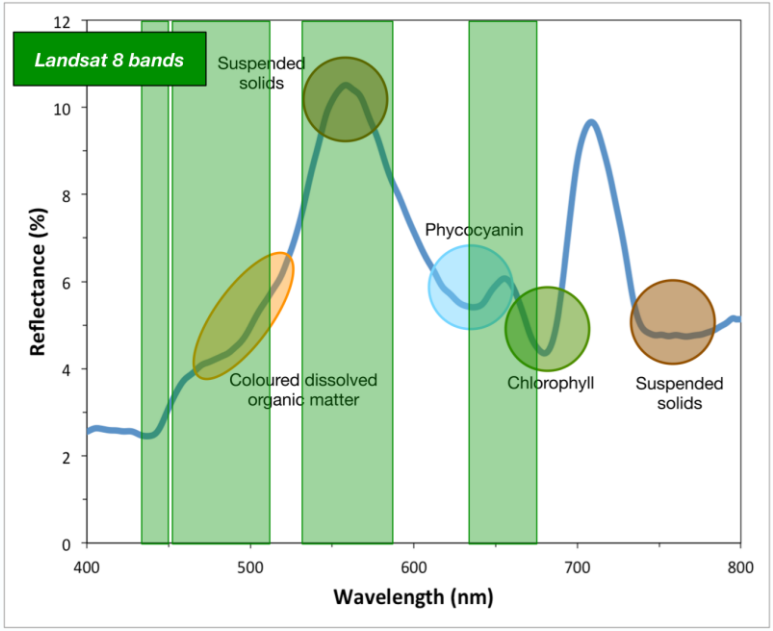
Helps fill the gaps in existing *in situ* programs and sensor networks

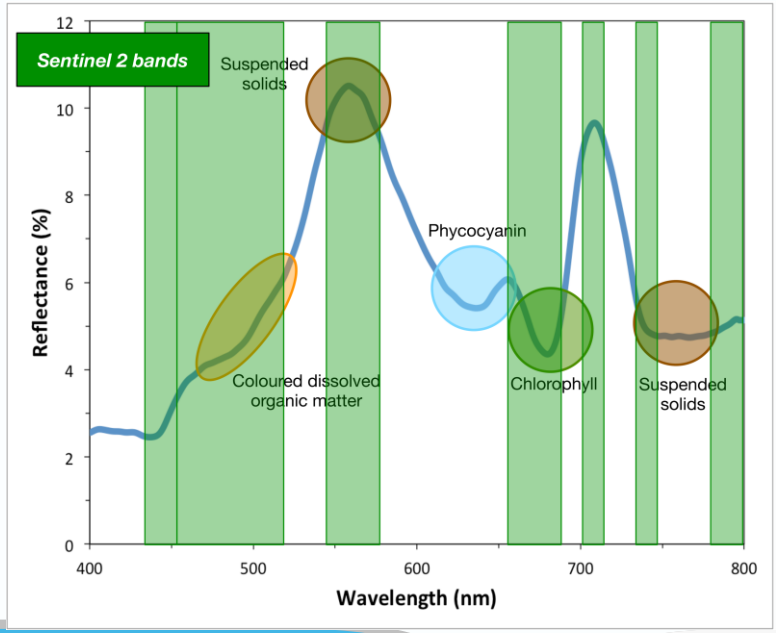
Spectral resolution can be limiting

Spatial resolution may not give sufficient information in smaller water bodies (e.g. river reaches)

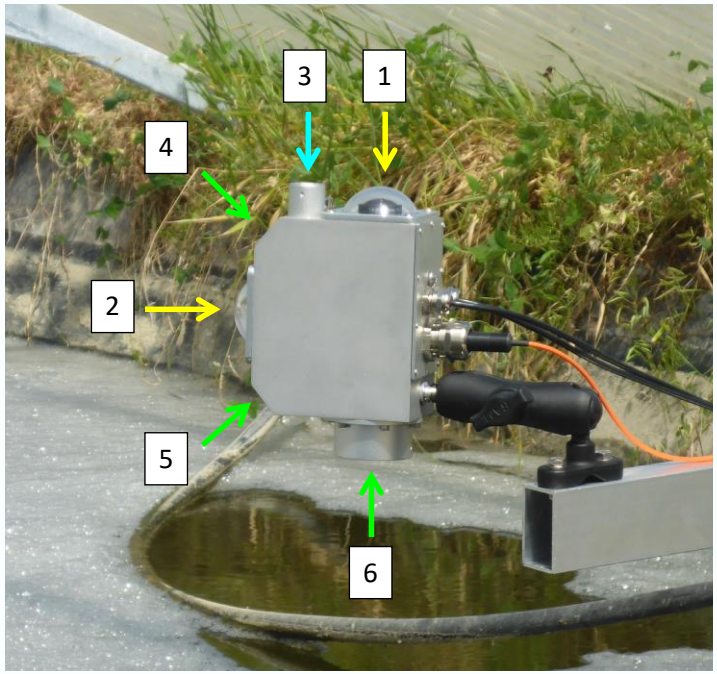
Timeliness:

- Not a high temporal resolution system (but S2/L8 ~2.9 day revisit)
- Overpasses may be obscured by cloud issues
- Latency issues in upload to data cubes





Rationale low cost spectral sensor - HydraSpectra



Total Cost: ~$AUD 5000

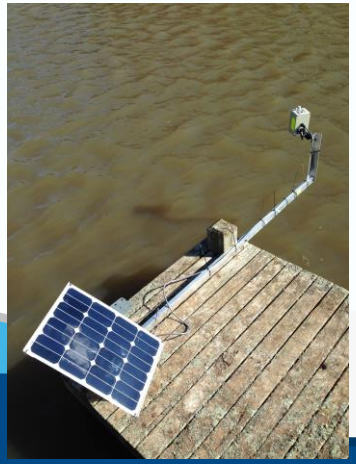
- Overcomes challenges of the satellite approach
- Complements satellite approach
- Same principles as satellite sensing
- Much cheaper than existing systems (the lower the cost the more we can have)

Key characteristics:

- Measures in the 400 to 900 nm spectral range at high resolution
- Above surface sensor with three fields of view
- Much cheaper than existing systems (the lower the cost the more we can have)
- Networks of such sensors allow for early detection of water quality issues, such as algal blooms, turbidity events

New model Mk III

- 8 apertures all through a single spectrometer, 2 hemispherical cameras



Patent pending – Gensemer et al. 2017

Example deployments

Temporary installation on Brisbane River.

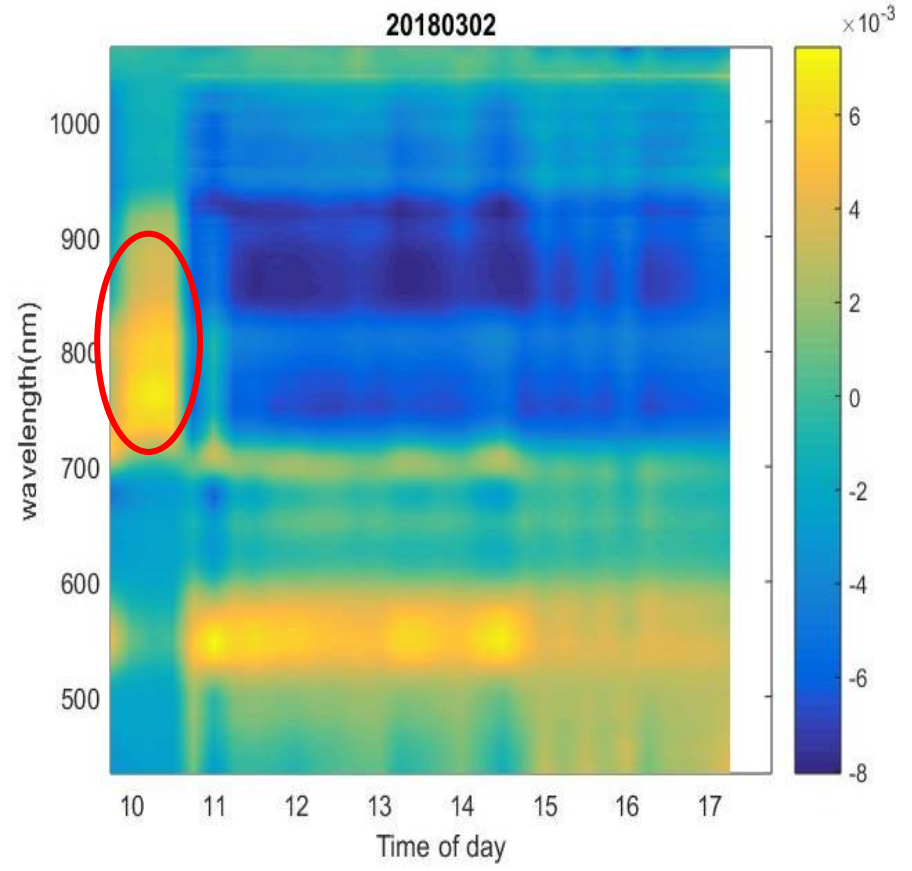
The sensor needs an unobstructed and unshaded view of the water surface. The sensor can be mounted at any height over the water surface, on fixed structures or on buoys. The solar panel is sufficient to power the system.

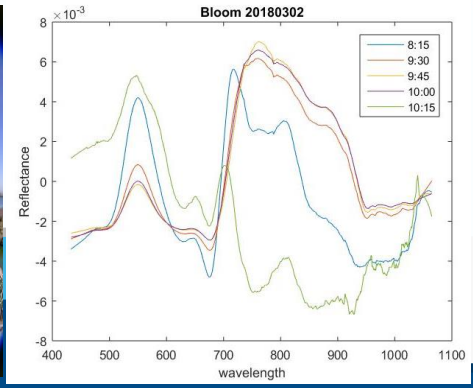
Melbourne Water Treatment Ponds, Werribee

Applications of high temporal data

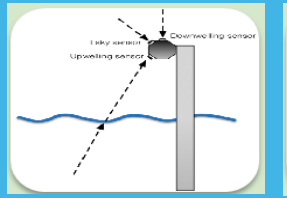
Process studies

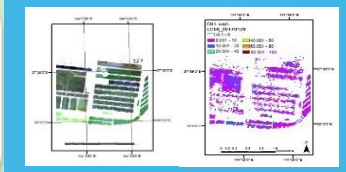
- particle and phytoplankton temporal dynamics (e.g. assessing diurnal to seasonal variability),
- modeling of the underwater light climate for primary production,
- identifying optical proxies linking optical observations to biogeochemical properties,
- radiative transfer modeling studies to derive optical closure between inherent and apparent optical properties.

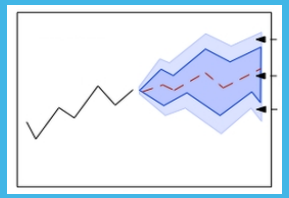




Temporal distribution of algal blooms – waste water ponds







Surface sampling ➔ in-situ camera ➔ satellite imagery ➔ early warning ➔ forecast

The potential outcomes

- The application of these spatial analysis techniques to time-series mapping may provide a way to explore the imagery more fully and monitor the change in the characteristics of aquatic systems through improved visualisation.
- Maps produced as an integrated approach for implementing earth observation-derived water quality relevant data into numerical models for forecasting.
- High resolution *in situ* monitoring enables *in situ* surveys to be put into temporal and spatial context and explain the spectral variability and patterns seen in the broad-scale satellite imagery.

Future work

The installation of the HydraSpectra was designed to advance an early warning system for algal blooms, and the results have demonstrated that potential. However, automation of the end-to-end data to information flow is required for realisation of this system. To achieve this, CSIRO is currently developing:

- Senaps Sensor cloud software (https://research.csiro.au/dss/research/sensor-data-models-managament/) which will ingest and store the images and data.
- Python code to build the workflows, calculate reflectance and finally to implement some simple water quality algorithms.

Further to this CSIRO could develop a Melbourne Water WTP tailored dashboard to visualise the data and send out alerts or flag particular days.

Conclusions

- HydraSpectra closely matches hyperspectral performance of a commercial radiometer.
- Purely spectral ratio methods provide realistic estimates of in situ Chlorophyll and Phycocyanin concentrations - additional parametrization will improve these estimates.
- High temporal resolution (we used 15 minute averages but can be shorter) and horizontal camera provides valuable visual confirmation of bloom formation.
- Simple spectral criterion identifies bloom formation.
- Quantitative, temporal, non-perturbing, and economic characteristics make possible new approaches to investigating limnological behaviour of highly concentrated cyanobacterial systems.

Thank you

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Team leader, Aquatic remote sensing
e Janet.Anstee@csiro.au

CSIRO OCEANS AND ATMOSPHERE