CSIRO

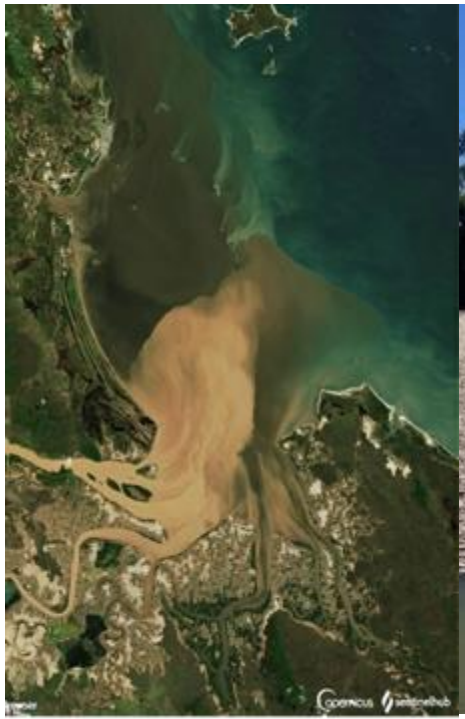
AquaWatch Australia

A ‘weather service’ for water quality

Australia’s National Science Agency

Ambition: Water Quality is a Global Challenge

Sediments & Floods



Fish-kill events

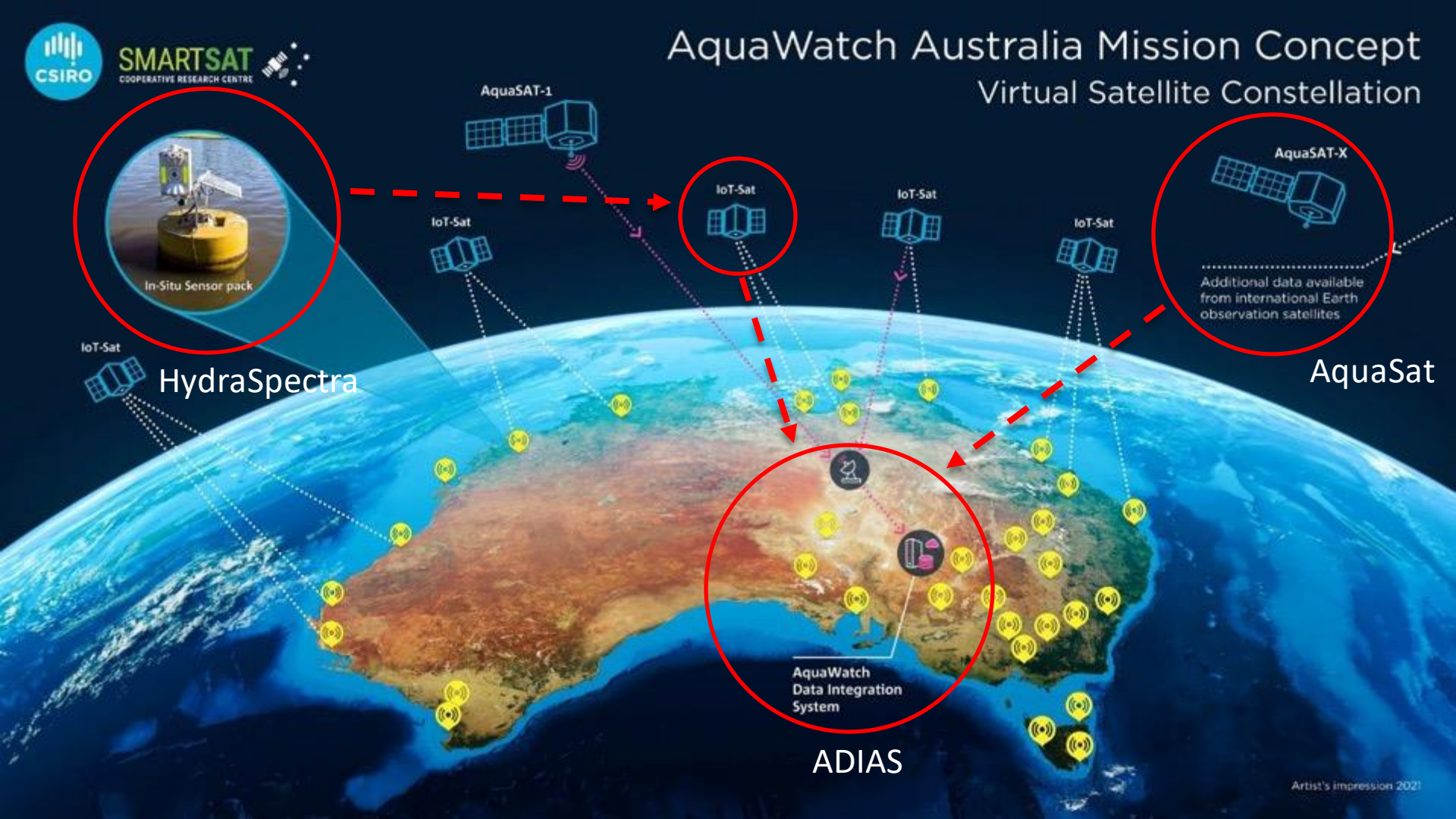
Sewage/Pollution

Harmful Algae Blooms

3 Billion people world-wide don't have access to clean water and sanitation

AquaWatch Mission Launch March 22, 2023

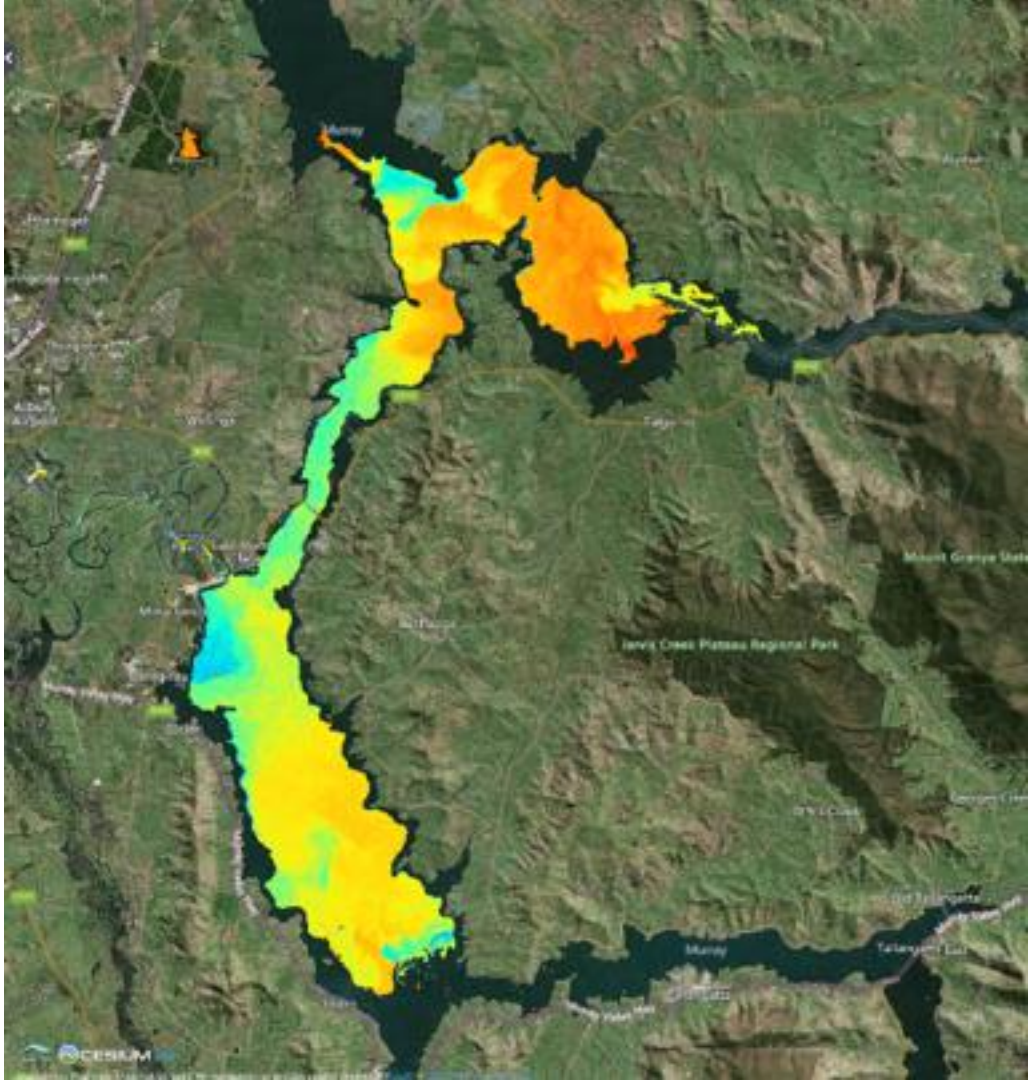
(Canberra & New York)


CSIRO
SMARTSAT
COOPERATIVE RESEARCH CENTRE
AquaWatch Australia Mission Concept
Virtual Satellite Constellation
AquaSAT-1
IoT-Sat
IoT-Sat
IoT-Sat
IoT-Sat
IoT-Sat
AquaSAT-X
In-Situ Sensor pack
Additional data available from international Earth observation satellites
HydraSpectra
AquaSat
AquaWatch Data Integration System
ADIAS
Artist's impression 2021

CSIRO Scope of AquaWatch

- **Technology Element** for space-to-ground water quality monitoring and forecasting, with key milestones in 2026 and 2030.

- **Research program**, for continuous improvement, with aligned R&D and support for growth in the user base.



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Co-Design Pilots

Build new Partnerships
Testing and validating system

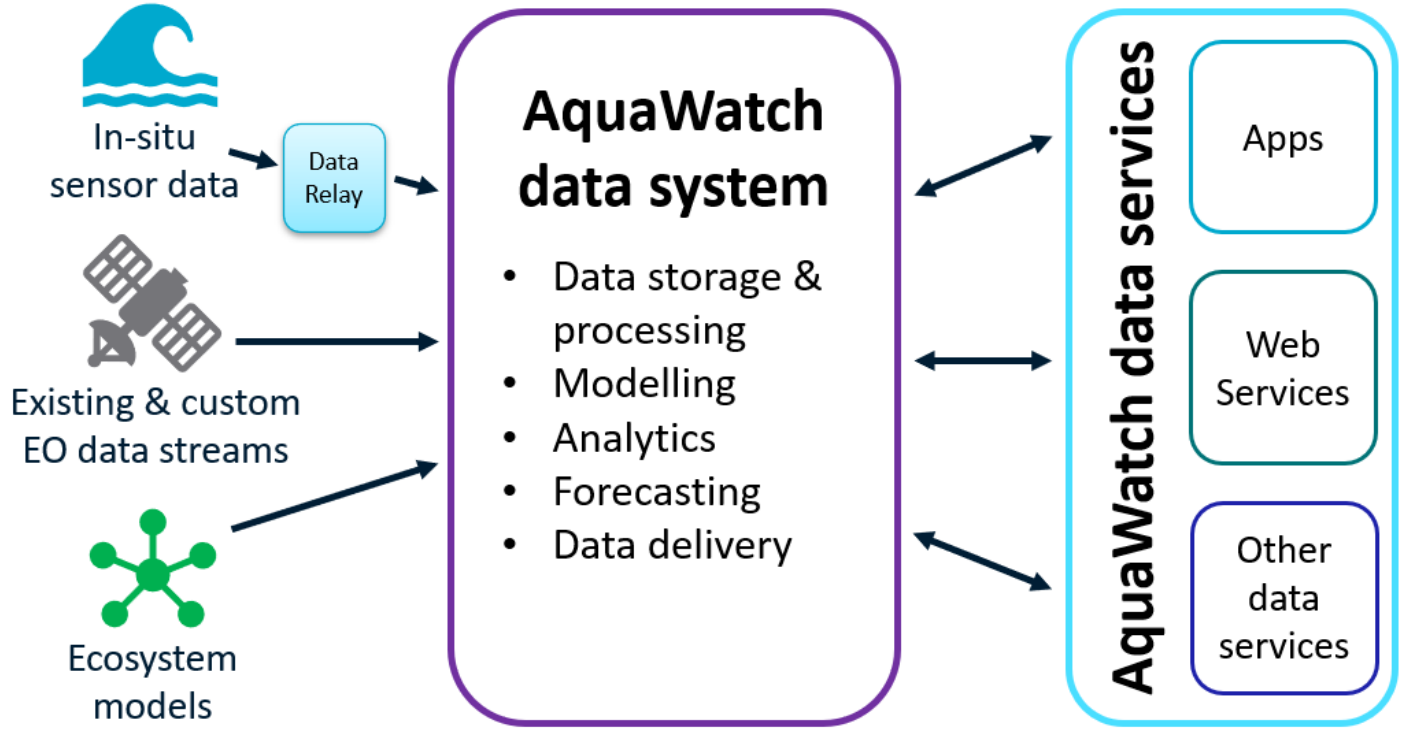
Global Pilot Sites

Sample Pilot Site: Sacramento River Delta California

- Local collaborators: UC Davis, UC Merced, USGS
- Co-Design & Co-funding from partners
- R&D support w. students & technical experts (eg remote sensing, in-situ water quality)
- State government interest (Water Resources agency)
- Indigenous engagement
- Good prospects for sustained operation of pilot by local partners

AquaWatch Technical Details – Day 2

AquaWatch Technical Elements



Potential AquaWatch Water Quality 'Measurables' Incl. R&D Needs

VIS-NIR Earth Observation:

*= Hyperspectral Data Required

- Chlorophyll-a
- Phycocyanin, PC *
- Phycoerythrin, PE*
- Species / genus differentiation: Blue-green algae (inland & species levels) * Dinoflagelates (coastal waters) * Phytoplankton Functional Types (PFT) * Peridinin (=dinoflagellates) *
- Total cell counts (phytoplankton abundance)
- Biovolume (may be used with species/types for a HAB index)
- Total Suspended Matter
- Secchi Disk Transparency
- Turbidity
- Coloured Dissolved Organic Matter (CDOM)
- Dissolved Organic Carbon
- Vertical attenuation, Kd
- Forel Ule scale (water colour)
- Water Column Depth (Bathymetry)
- Floating and Submerged Aquatic Vegetation Types*
- Benthic & Coral Reef Habitat*
- Water-related ecosystems & land-use

Extras (satellite and/or in-situ sensors)

- Temperature
- Dissolved Oxygen
- Water Surface Height
- Water surface velocity
- PH

Require more R&D on miniaturization & automation

- Salinity/Conductivity
- Total phosphorous
- Total inorganic Nitrogen (Nitrate-N as surrogate)
- Algal toxins
- Methylisoborneol (MIB)
- Geosmin
- MicroPLastics
- Metals (heavy and other)
- Organic micro pollutants (Pharmaceutical, antibiotics, endocrine disruptors, insecticides, herbicides)
- Pathogens (e-COLI, cholera, water borne...etc)

Composite variables

- Trophic State Index
- TRIX Trophic Index for Coastal Seas
- Trophic State using the Nutrient Colour Paradigm
- Harmful Algal Bloom Index
- CYAN Index
- Chromaticity Index
- Floating Macro-algal Index
- Floating Algal Index
- Toxins Index

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Parameters / feasibility	19-Mar-24				2026				2030				Needs R&D or partners			
	lab sampling	in-situ	EO	WQM	lab sampling	in-situ	EO	WQM	lab sampling	in-situ	EO	WQM	lab sampling	in-situ	EO	WQM
Chlorophyll-a																
Phycocyanin, PC																
Phycoerythrin, PE																
Peridinin (=dinoflagellates)																
Fucoxanthin (=diatoms)																
Total cell counts (phytoplankton abundance)																
Biovolume																
Species / genus differentiation																
Algal toxins																
Secchi Disk Transparency																
Turbidity																
Total Suspended Matter																
Coloured Dissolved Organic Matter																
Dissolved Organic Carbon																
Vertical attenuation, Kd																
Forel Ule scale (water colour)																
Water Column Depth (Bathymetry)																
Submerged and Emergent Aquatic Vegetation																
Coral Reef Habitat																
Benthic Habitat (non-coral)																
Acdom (440 nm)																
S (slope)																
Inherent Optical Properties (IOP)																
Normalized water leaving radiance																
Remote sensing reflectance																
Temperature																
Water Surface Height																
Water surface velocity (flow rate, currents)																
Salinity/Conductivity																
Total phosphorus																
Total Nitrogen																
Nitrate-N																
PH																
Dissolved Oxygen																
Methylisoborneol (MIB)																
Geosmin																
MicroPlastics																
Metals (heavy and other)																
Organic micro pollutants																
Pathogens																

Not Applicable
Not feasible
Yes, feasible (uncertainty TBD)
May be feasible with R&D or partners

AquaWatch Data System for multi-sensor data integration and analytics

Powered by Earth Analytics and Science Innovation Platform (EASI) and Open DataCube Technology

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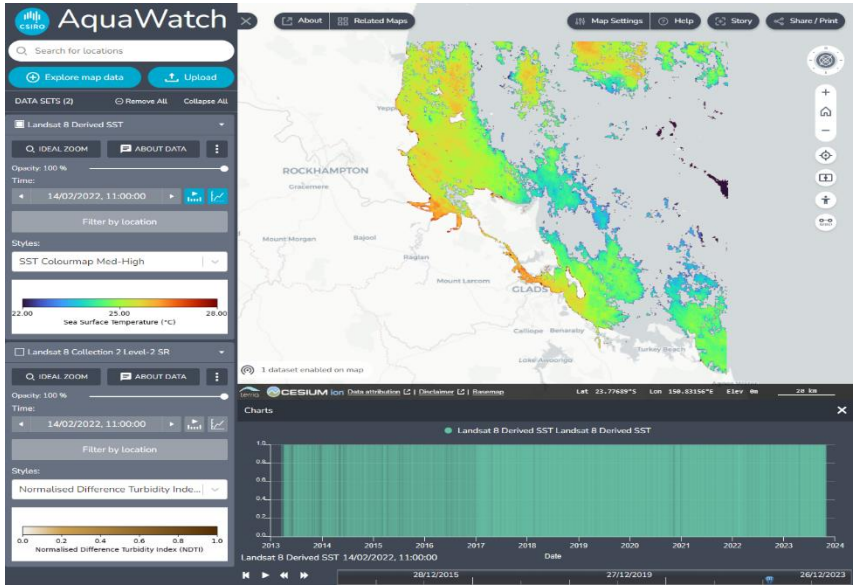
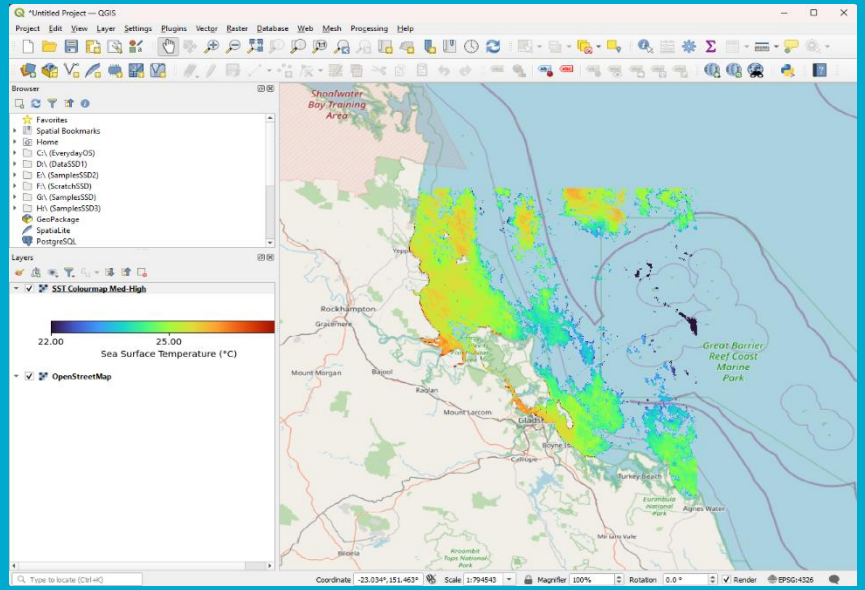
AW Map Portal



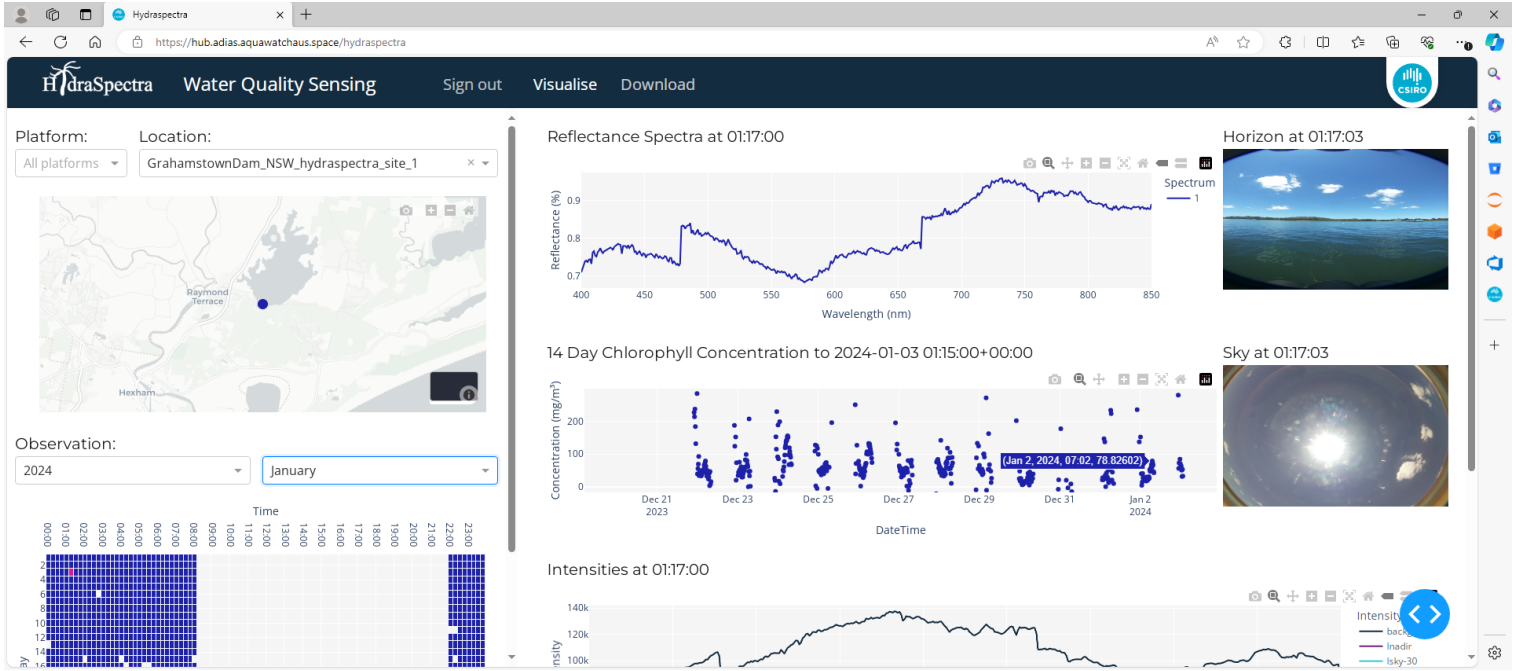
Terria Portal with Open Data Cube WMS serving AquaWatch Sea Surface Temperature derived via ML from Landsat 8

Desktop GIS



QGIS connected to Open Data Cube WMS serving AquaWatch Sea Surface Temperature derived via ML from Landsat 8

In-situ dashboard prototype



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MODIS

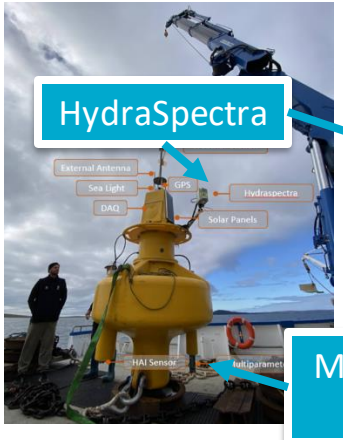
Sentinels

Landsats

Aquatic Reflectance

Sensor time series aggregation

HydraSpectra

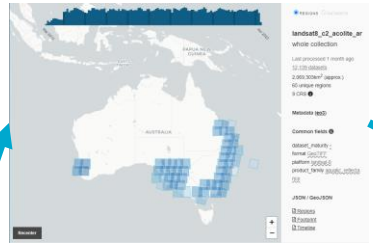


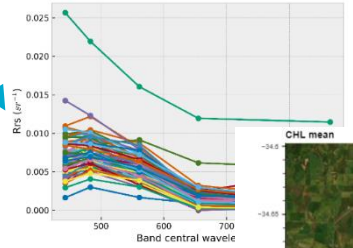
Multiparameter Sonde

Query EO data

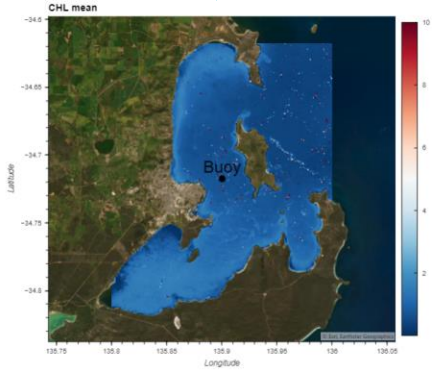
```
buff = 0.1

latitude = lat-buff, lat+buff

#Longitude = (135.85, 136.5)
longitude = long-buff, long+buff

out_crs = "EPSG:3557"


time = ('2013-02', '2023-07')
```

```
ls9 = dc.load(
        product='landsat9_c2_acolite_ar',
        x = longitude,
        y = latitude,
        output_crs=out_crs,
        resolution=(30, -30),
        time = time,
        dask_chunks ={"time":1},
        measurements = ['rrs_443', 'rrs_482', 'rrs_561', 'rrs_654', 'rrs_865']
    )

ls8 = dc.load(
        product='landsat8_c2_acolite_ar',
        x = longitude,
        y = latitude,
        output_crs=out_crs,
        resolution=(30, -30),
        time = time,
        dask_chunks ={"time":1},
        measurements = ['rrs_443', 'rrs_483', 'rrs_561','rrs_655', 'rrs_865' ]
    )
```



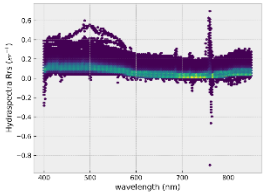


Integrated Analysis

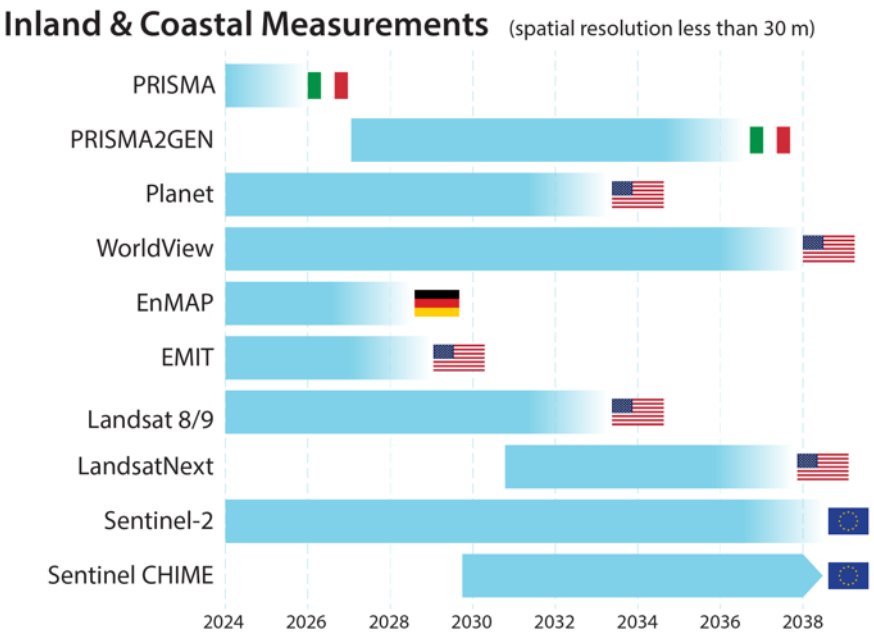


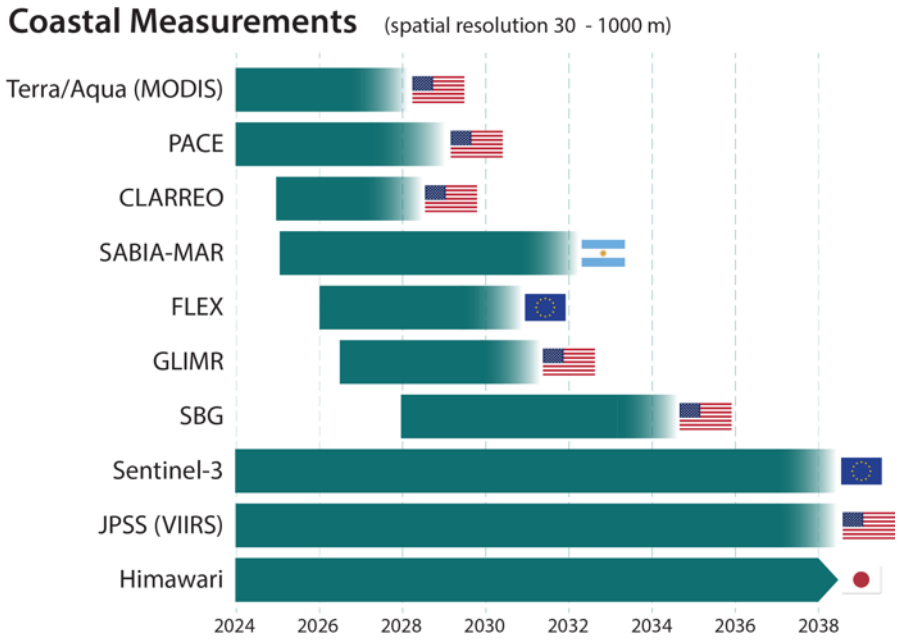
Query time series

```
[4]: cursor = connect(s3_staging_dir="s3://095077079535-mainprod-aw-prod-athena-results",
                      work_group="mainprod-aw-prod-workgroup",
                      region_name="us-west-2",
                      result_reuse_enable=True,
                      result_reuse_minutes=60,
                     cursor_class=PandasCursor).cursor()

[5]: hsres = cursor.execute('SELECT * FROM "mainprod-aw-prod-db"."mainprod-aw-prod-senaps-allvectors-staging"')
```



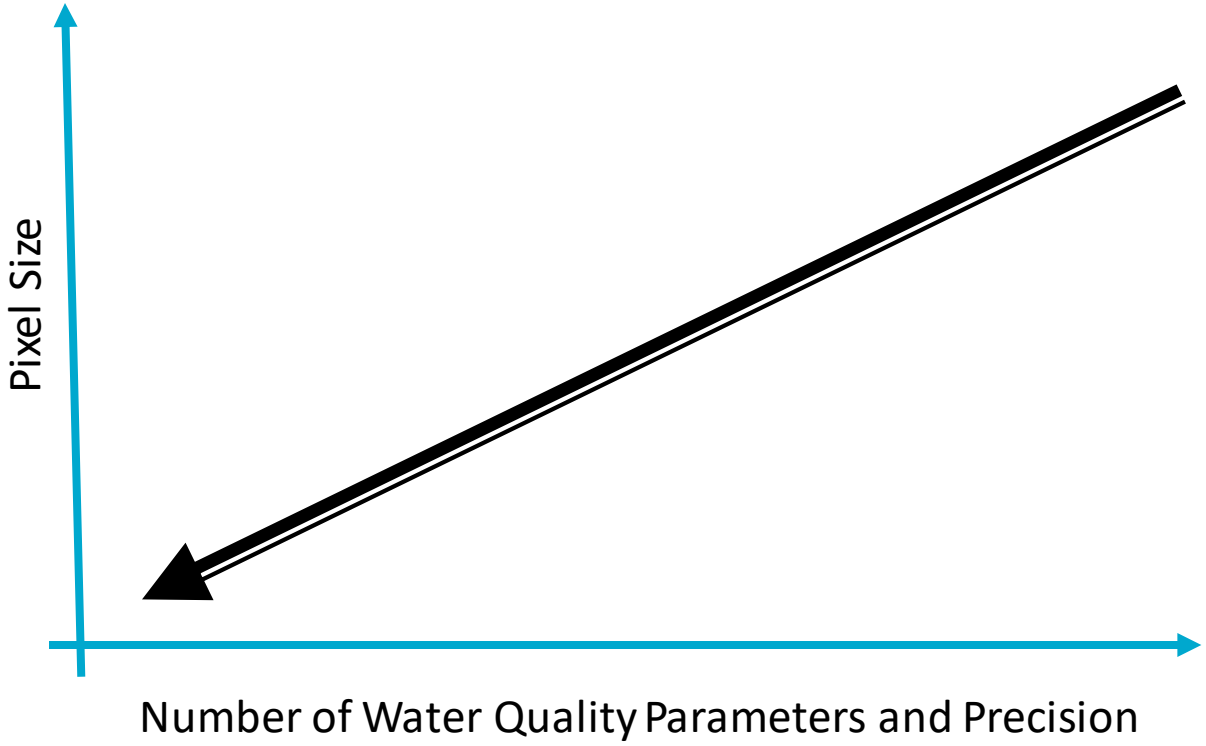
Possible Sources of EO data for AquaWatch



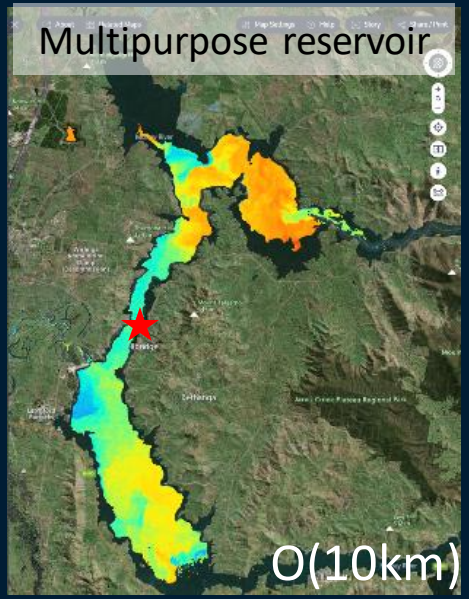


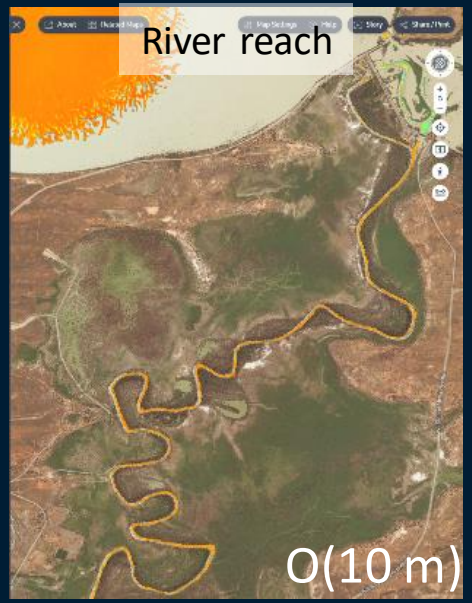
Extra EO Data for Water Quality Modelling: SWOT, Trishna, ..

Spatial Resolution vs. Number of Variables & Precision



Monitoring across scale – space





Characteristic target and feature scale
determine necessary **spatial resolution**

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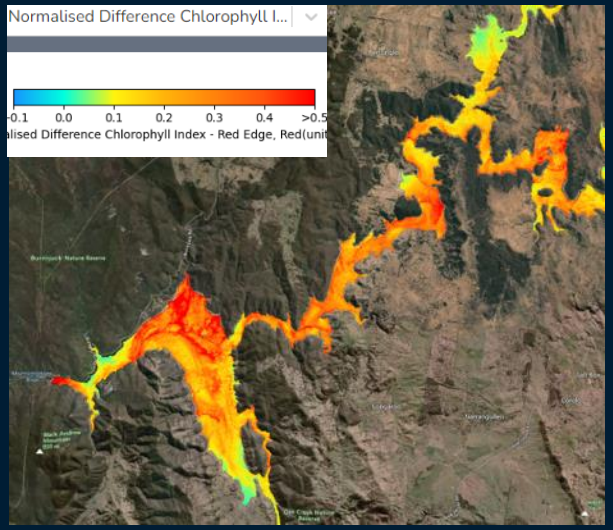
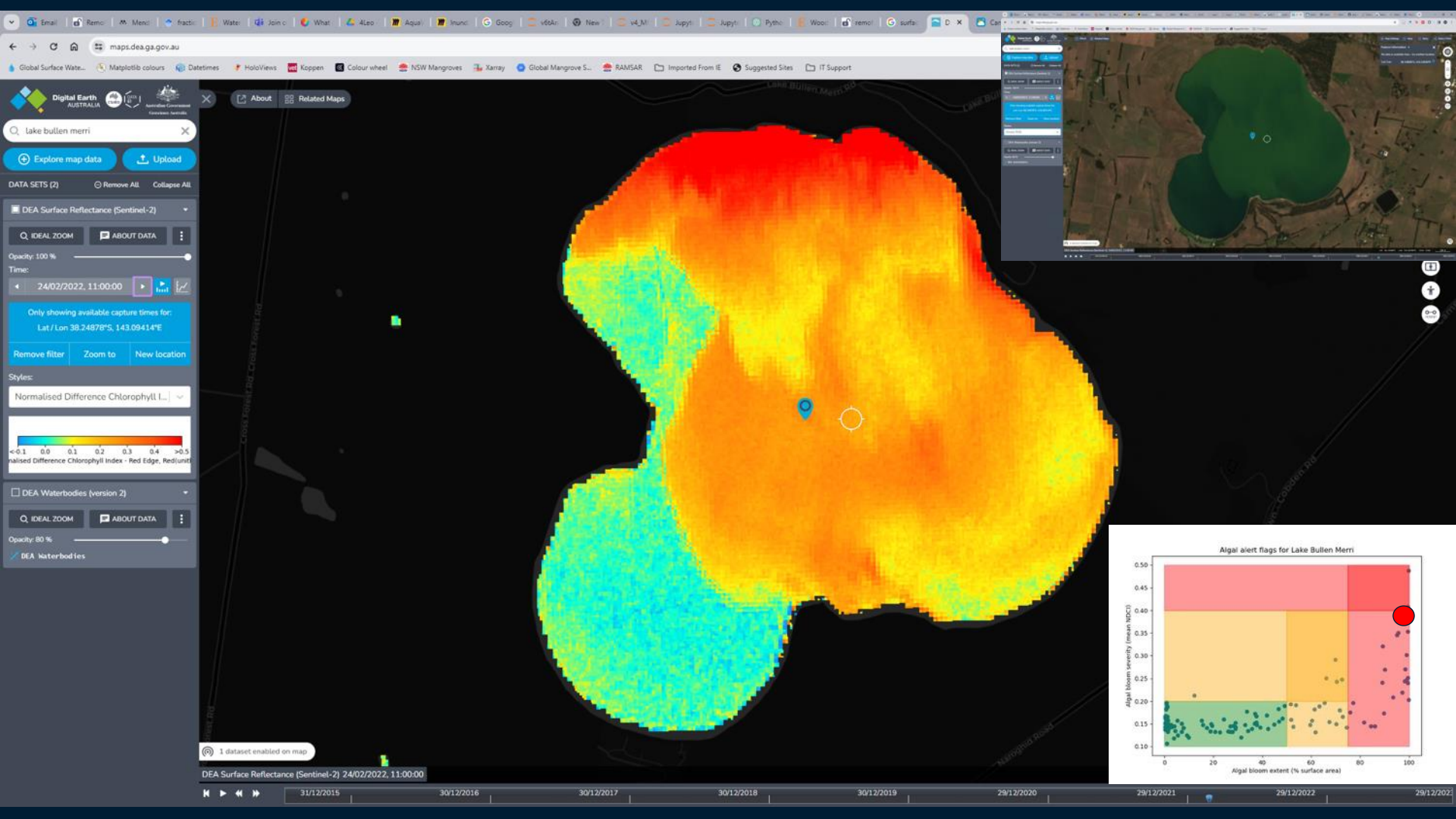
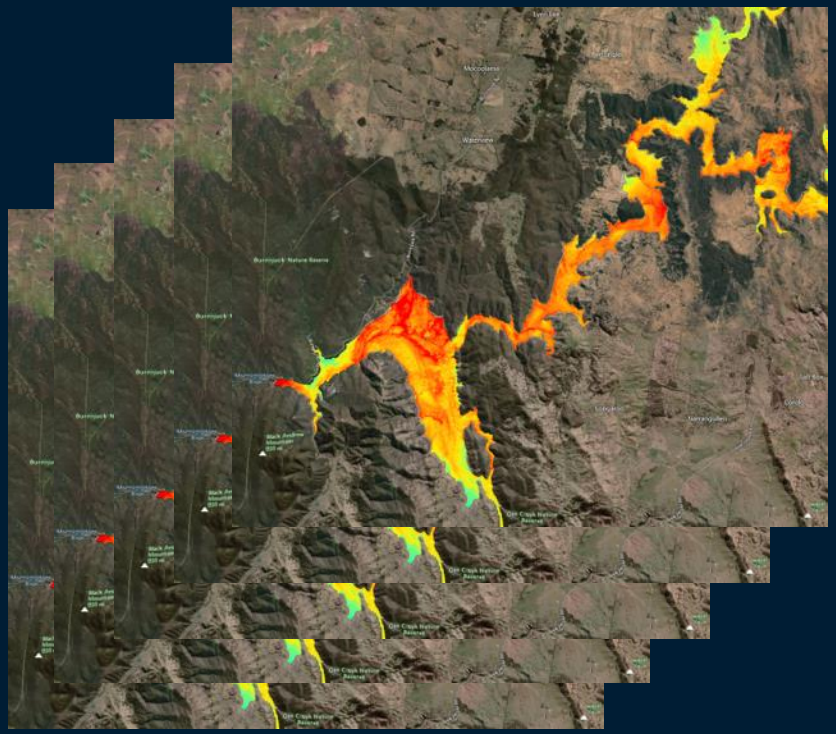
Sentinel 2 based algal alerts

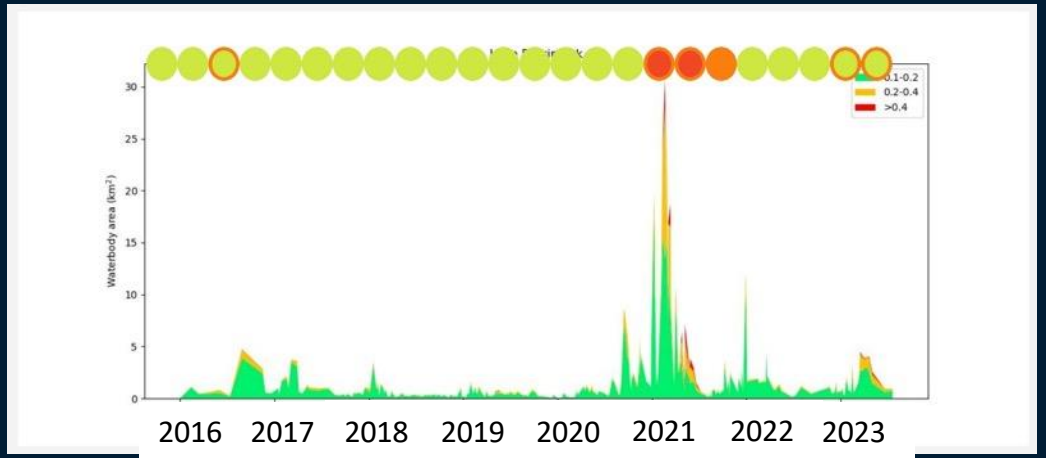
- The Sentinel 2 series of satellites include spectral bands that allow the calculation of an index which provides a qualitative estimate of algal concentration

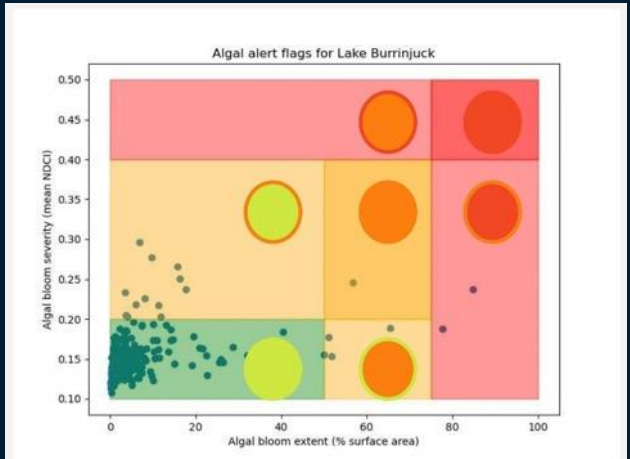



maps.dea.ga.gov.au
Digital Earth AUSTRALIA
lake bullen merri
Explore map data
Upload
DATA SETS (2)
Remove All
Collapse All
DEA Surface Reflectance (Sentinel-2)
IDEAL ZOOM
ABOUT DATA
Opacity: 100 %
Time:
24/02/2022, 11:00:00
Only showing available capture times for:
Lat / Lon 38.24878°S, 143.09414°E
Remove filter
Zoom to
New location
Styles:
Normalised Difference Chlorophyll I...
<-0.1 0.0 0.1 0.2 0.3 0.4 >0.5
DEA Waterbodies (version 2)
IDEAL ZOOM
ABOUT DATA
Opacity: 80 %
DEA Waterbodies
About
Related Maps
1 dataset enabled on map
DEA Surface Reflectance (Sentinel-2) 24/02/2022, 11:00:00
31/12/2015
30/12/2016
30/12/2017
30/12/2018
30/12/2019
29/12/2020
29/12/2021
29/12/2022
Algal alert flags for Lake Bullen Merri
Algal bloom severity (mean NDCI)
Algal bloom extent (% surface area)

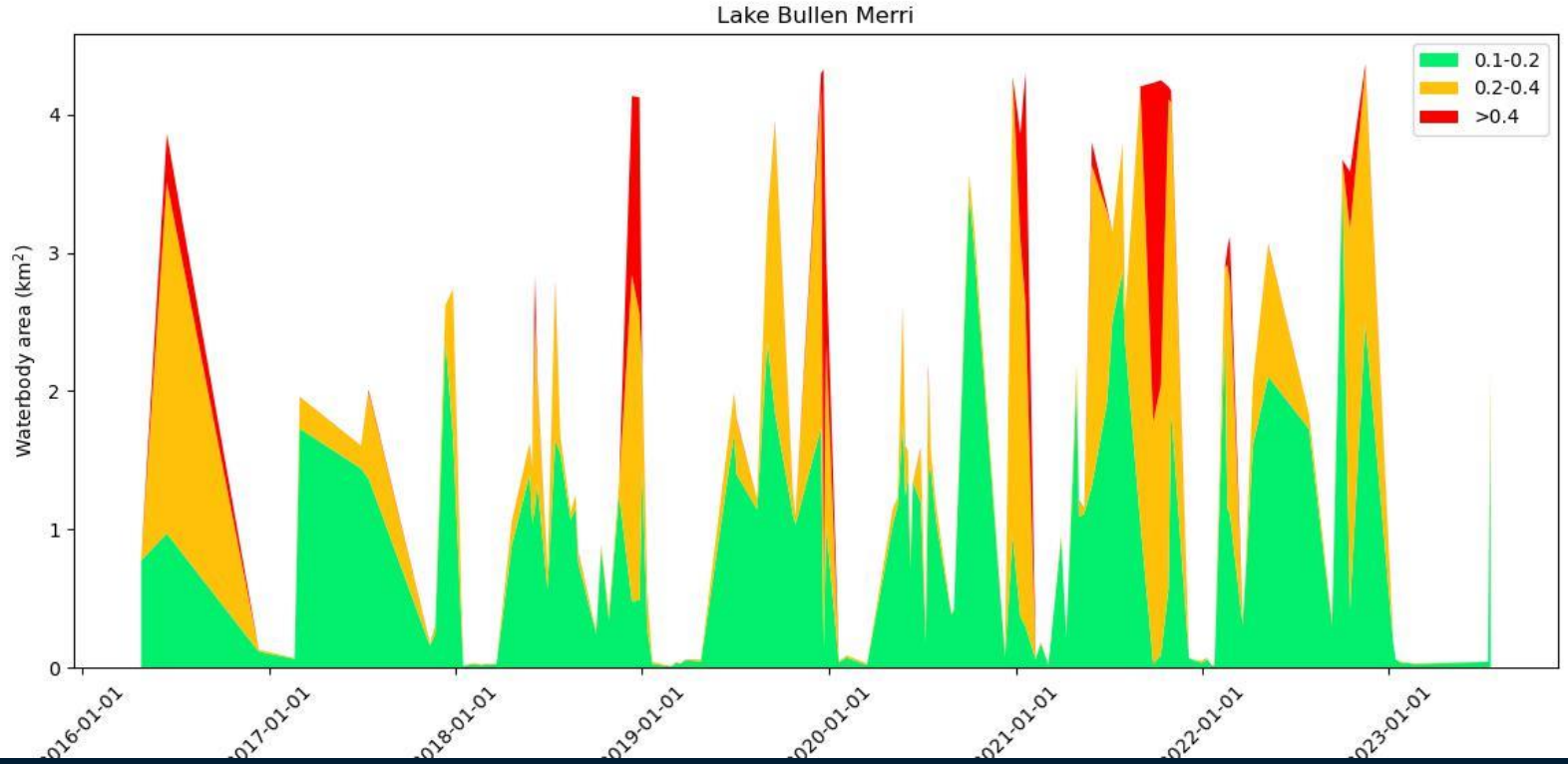
Traffic lights provide qualitative flags of extent and severity







Repeated high chlorophyll events in late spring – early summer



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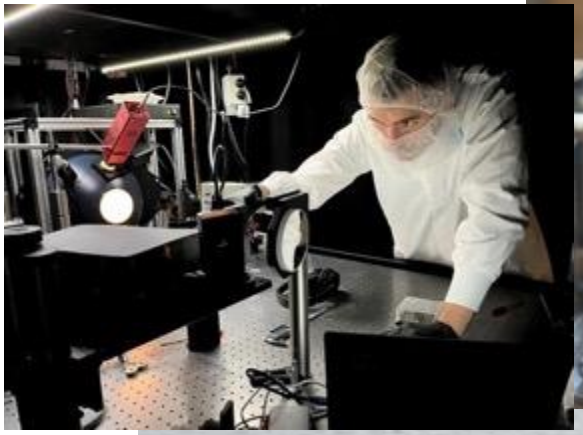
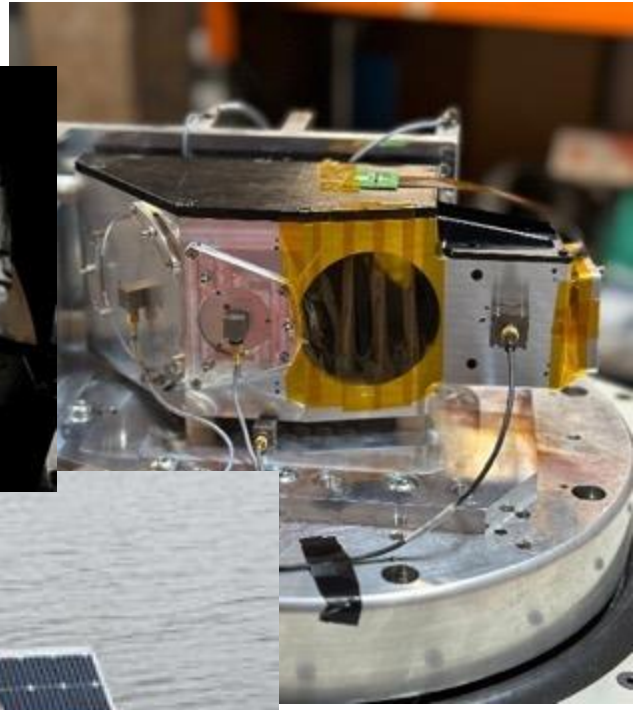
Technologies





HydraSpectra Mk IV

Pilot Site Instrumentation Stations for In-situ Water Quality Measurement and Satellite Data Validation

HydraSpectra Mk IV

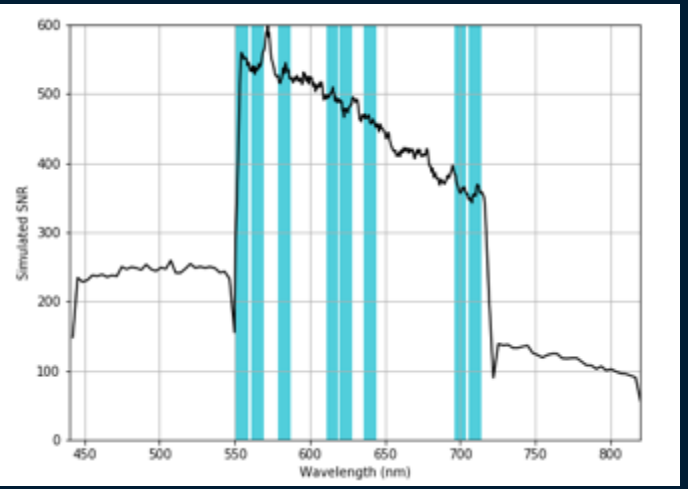
Instruments include:

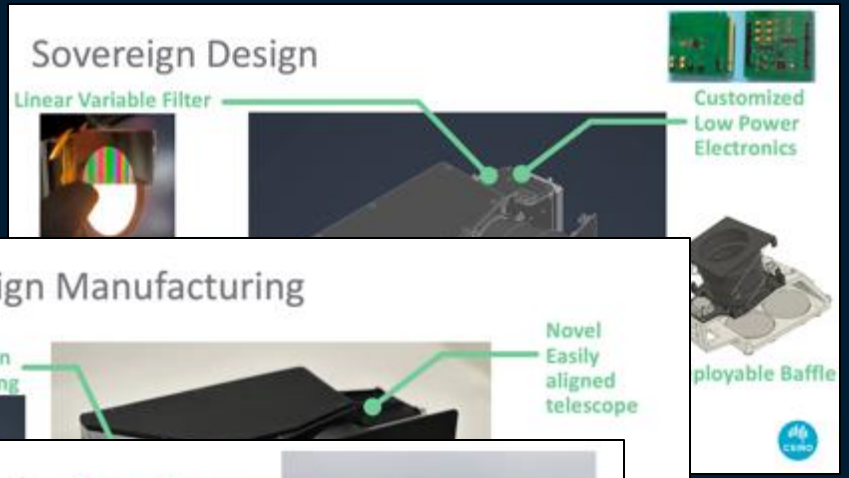
- CSIRO Hydraspectra
- TriOS Ramses E_d, L_{sky} and L_w
- Pan/tilt unit
- Weather station
- Cameras horizontal and forward-looking
- Water temperature (below surface & 2 depths (4/8m)

Deployments @ national pilots

CSIRO Cyanosat-1

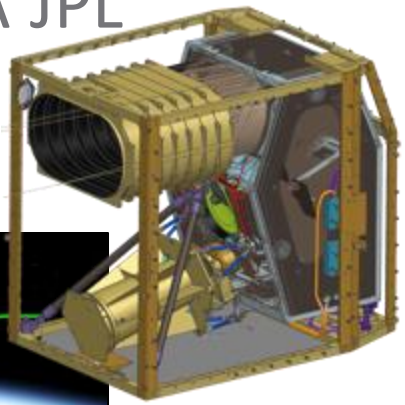
- Aquawatch Pathfinder
- CSIRO Satellite Optics Lab, Adelaide
- Launched – June 12th on Skykraft payload
- Communication with payload, under commissioning
- Cyanosat-2 in development

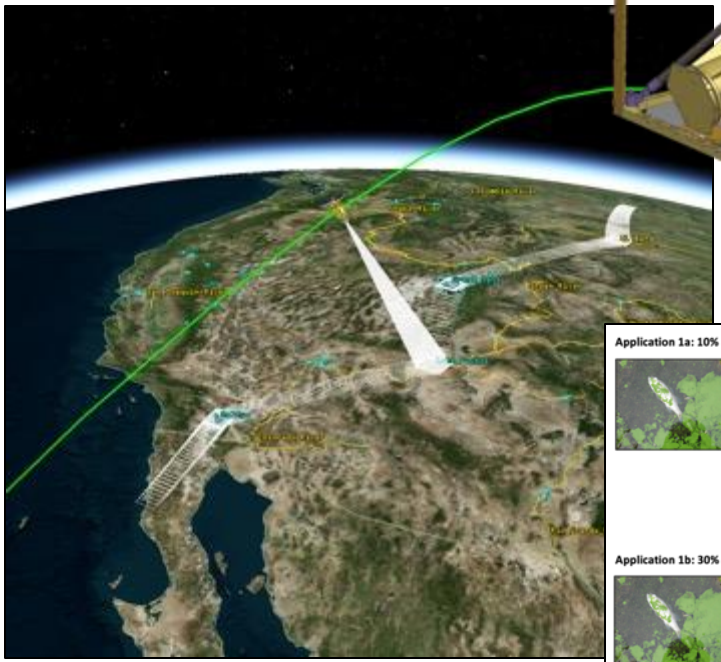


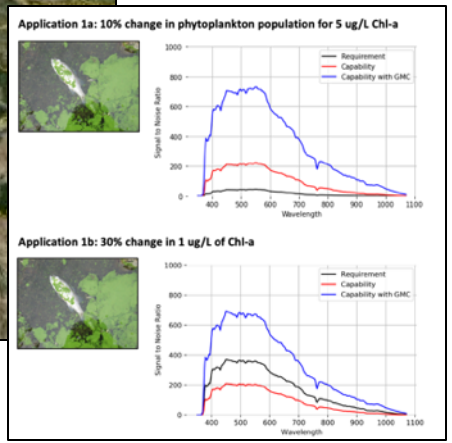


CSIRO AquaSAT-1 Feasibility study, with NASA JPL

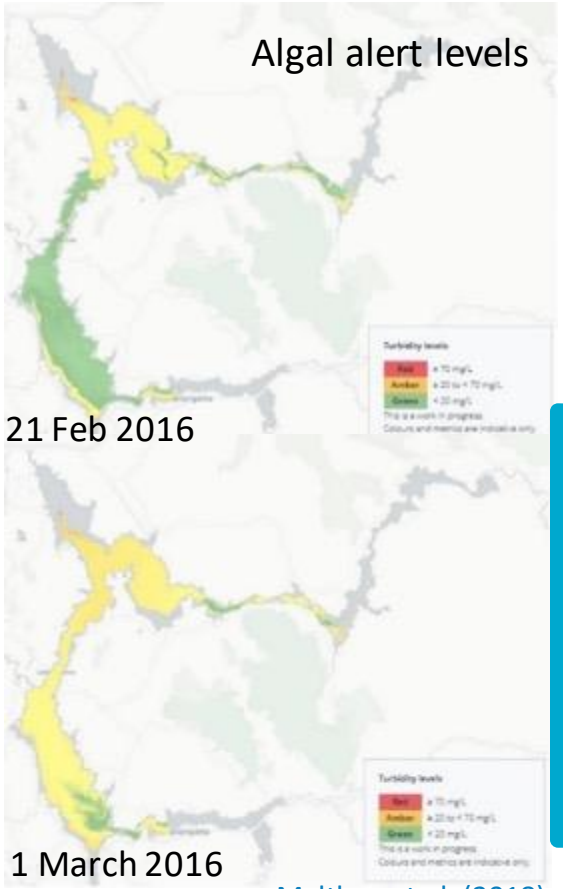
- **Orbit:** sun-synchronous, ~noon crossing time, ~400 km altitude (trade study: 600 km altitude)
- **GSD:** 18 m
- **Imaging coverage:** target sites (key lakes, rivers, estuaries, coral reefs in Australia and the US West)
- **Revisit:** 5 days with +/- 30 deg cross-track slew (not accounting for cloud cover, sunglint, target site conflicts, etc.)
- Dyson imaging spectrometer (350 to 1050 nm, 9.6 nm FWHM)







Water Quality Modelling – Remote Sensing Data Assimilation



Malthus et al. (2018)

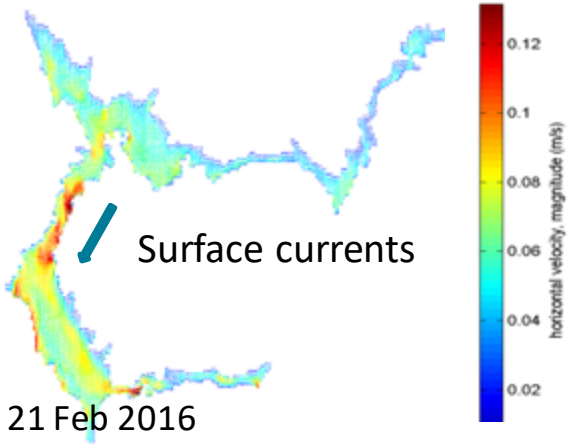
satellite derived
Algal Alert Levels

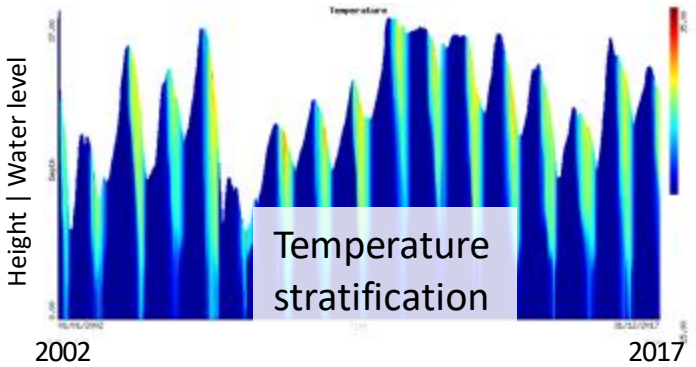
drivers
Meteorology
Bathymetry - In/Outflow

hydrodynamics 3D | 1D
Currents
Mixing/Stratification

algal growth
Cyanobacteria species
Physiology

satellite derived
Algal Alert Levels



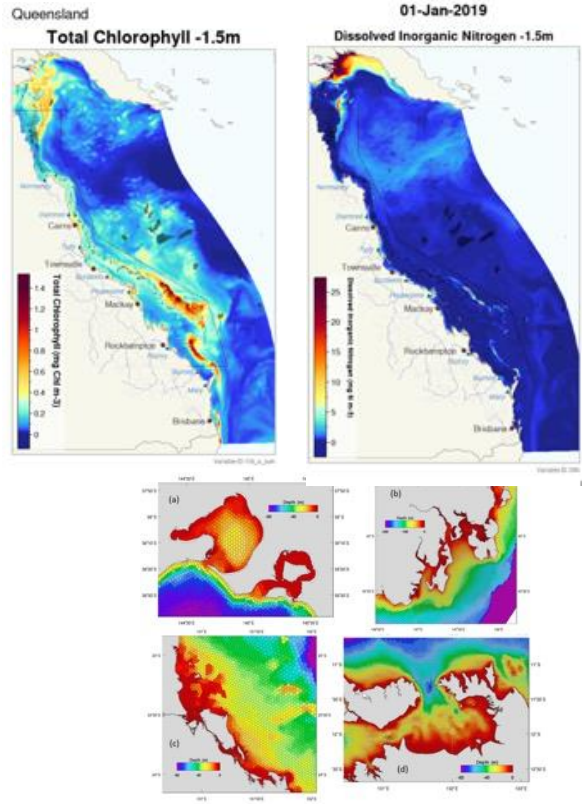


Joehnk et al. (2018a)

Coastal Dynamic Water Quality Modelling

National Scale (coarse)

Regional/Local Scales of Special Interest (fine)



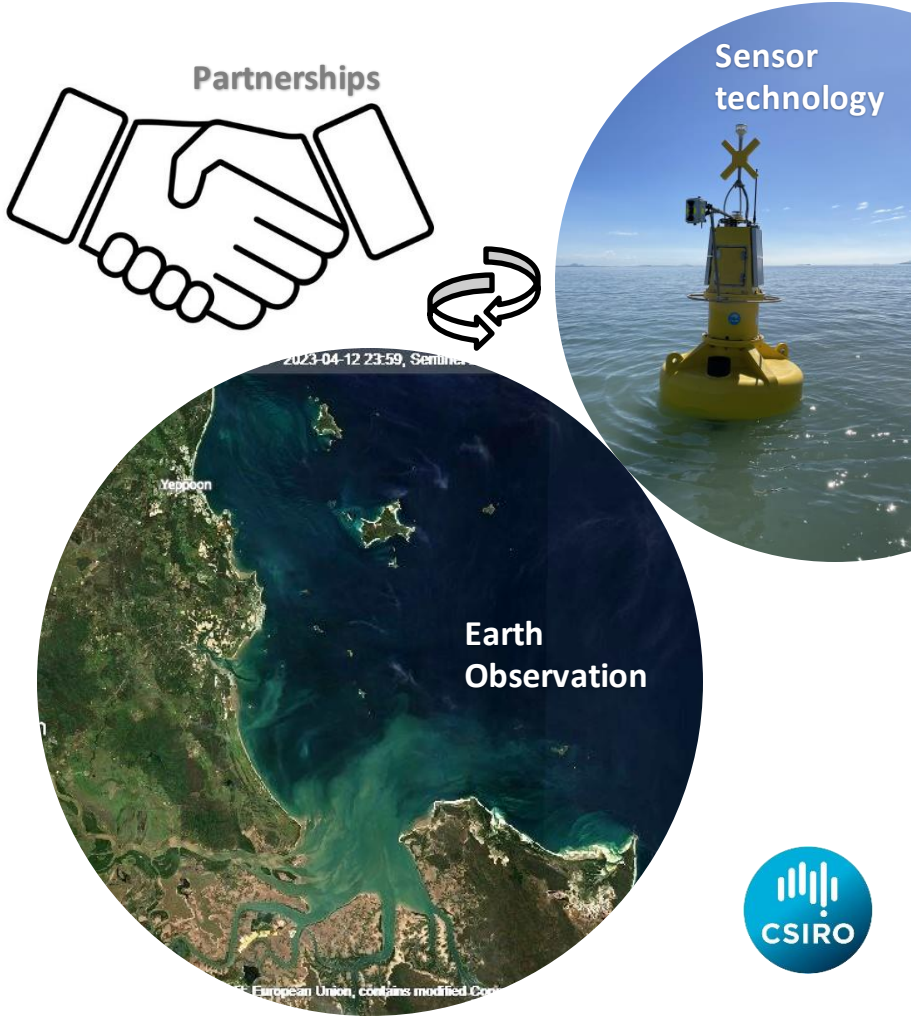
AquaWatch Australia Mission: GBR Pilot Project

Nagur Cherukuru,, Gemma Kerrisk, Tim Malthus Eric Lehmann, Yiqing Guo, Xiubin Xi, Tim Bolton, Tish Dhar, Rob Woodcock, Erin Kenna,Geoff Carlin

Pilot project objectives

- Establish a significant new pilot site (Fitzroy Estuary and Keppel Bay –FEKB), generating water quality information that will demonstrate the impact of AquaWatch for monitoring and managing estuarine and coastal ecosystems in Great Barrier Reef (GBR) region.

- Partnerships: To create high-impact partnerships around Queensland coastal waters and the Great Barrier Reef.



CSIRO

Successful installation of insitu

Continuous observations from Fitzroy River Observatory

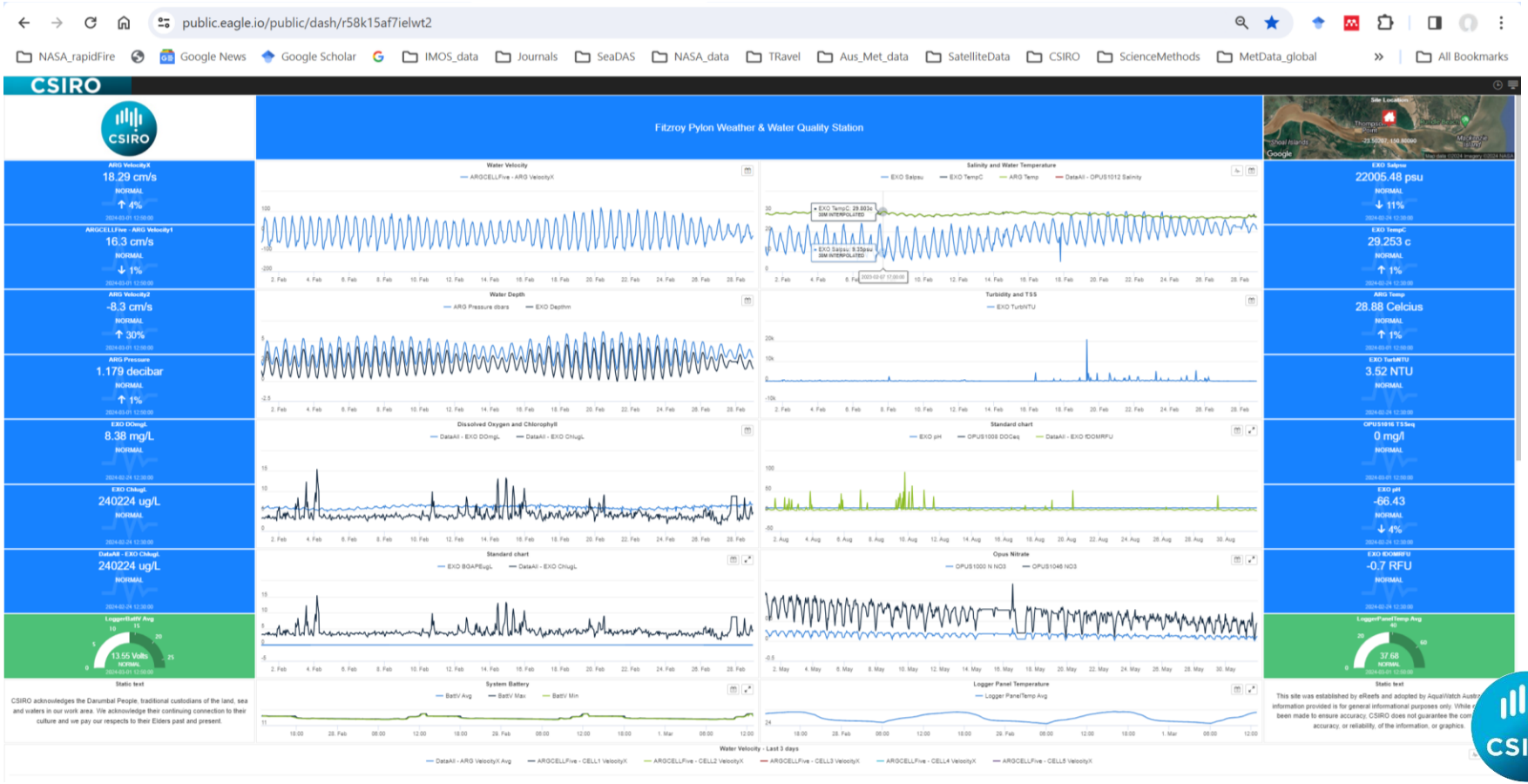
CSIRO HydraSpectra optical sensor to measure reflectance

Underwater sensors measure:
- Salinity
- Temperature
- Turbidity
- Chlorophyll
- dissolved organic matter
- dissolved oxygen
- nitrate

Vortex Sensor – measures water quantity

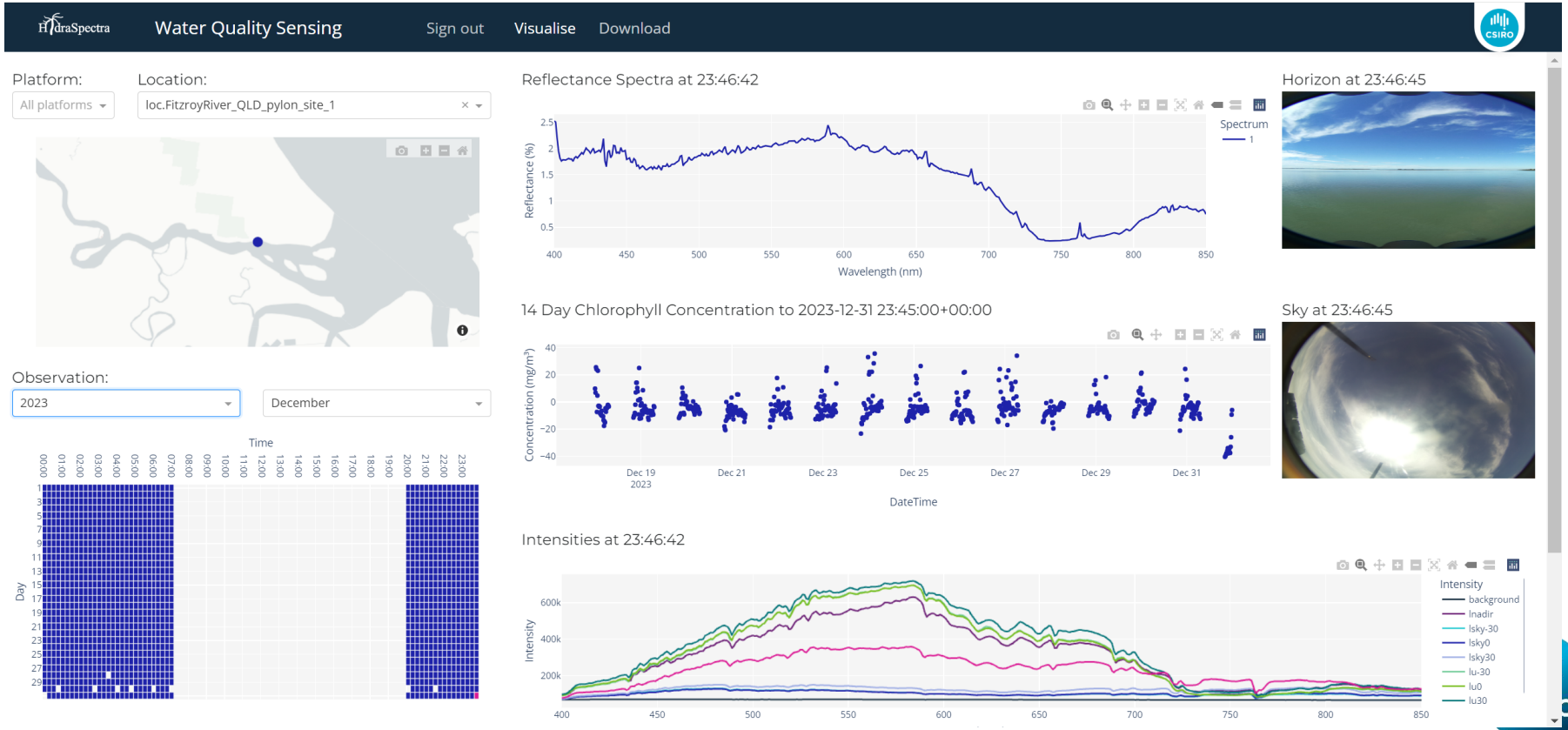
Partners:
University of Queensland
CSIRO Envi. BU
Xylem
AquaWatch Mission

Live data available on AquaWatch dashboard



Live data: https://public.eagle.io/public/dash/r58k15af7ielwt2

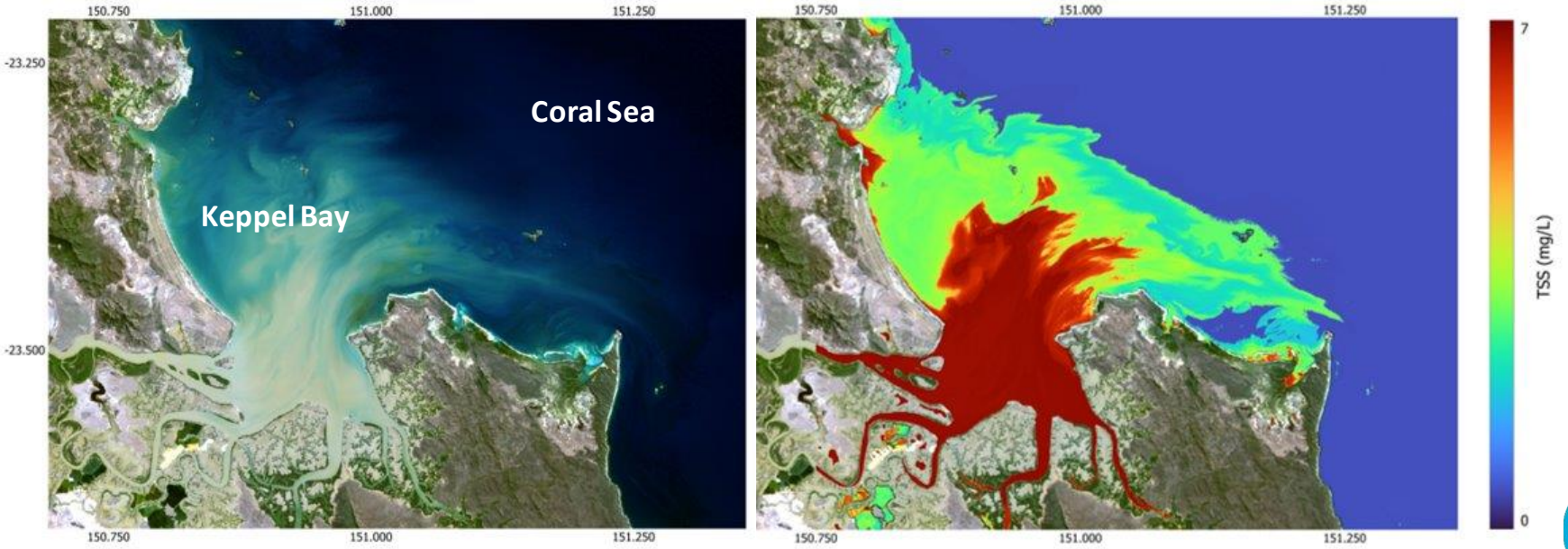
Insitu data generation - HydraSpectra



Remote sensing and machine learning – Suspended sediment maps

LandSat-8 (30 m pixel resolution)

AquaWatch Machine Learning model derived map of suspended sediment

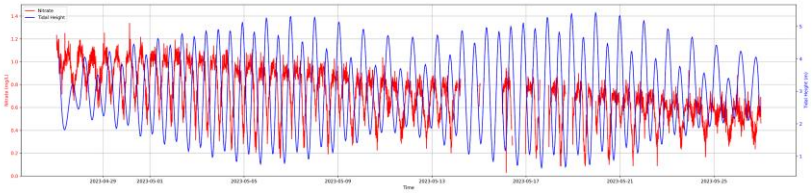


New remote sensing products– Nitrate maps

Mapping nitrate at Fitzroy River Estuary from Landsat-8 Observations

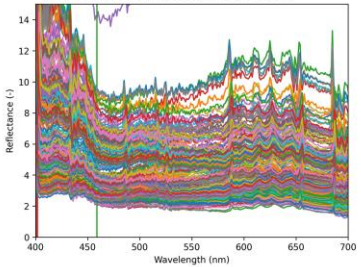
Modelling the relationship between nitrate and spectral reflectance

In-situ Nitrate measurements

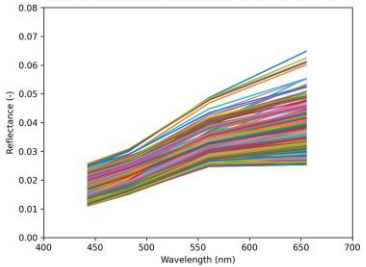


Multilayer Perceptron (MLP) Model

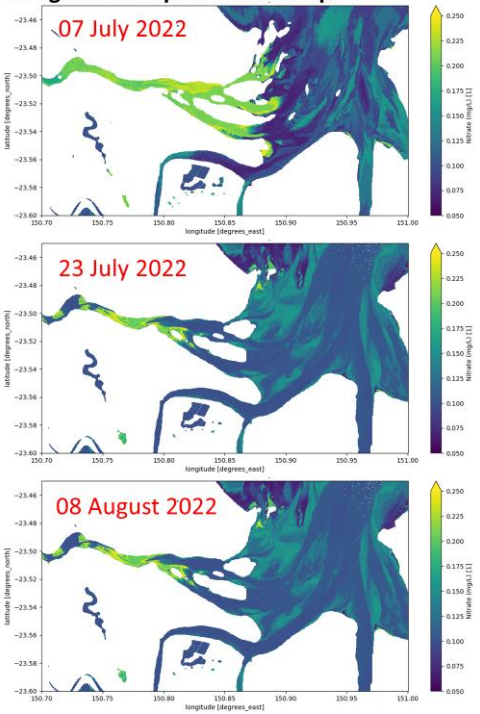
In-situ spectral reflectance
(Original hyperspectral measurements)



In-situ spectral reflectance
(Convoluted to Landsat-8 spectral responses)

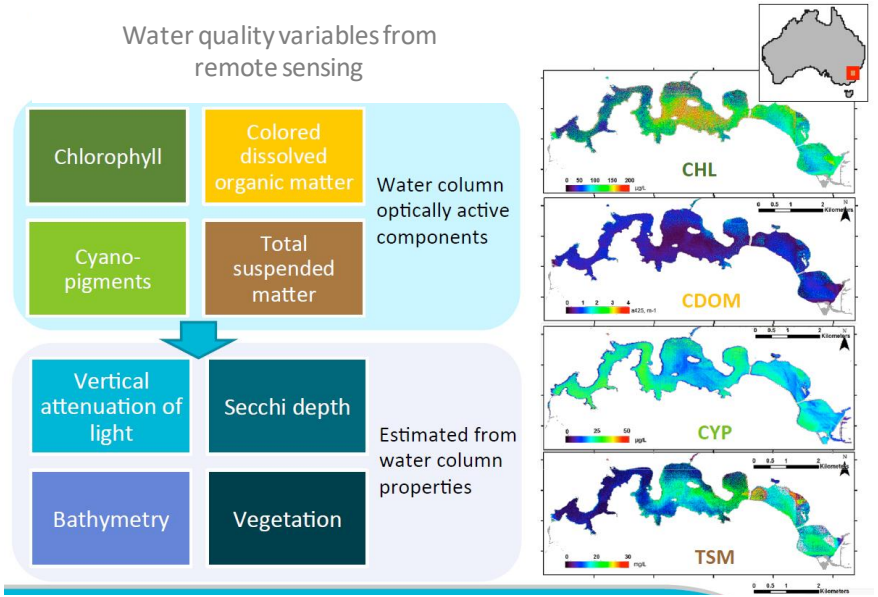


Applying the model to time-series Landsat-8 images to compile nitrate maps



Insitu data streams from this project are now helping AquaWatch teams to develop **new data-driven machine learning models** to map important water quality parameters in GBR coastal regions

Information Delivery: Water Quality Products

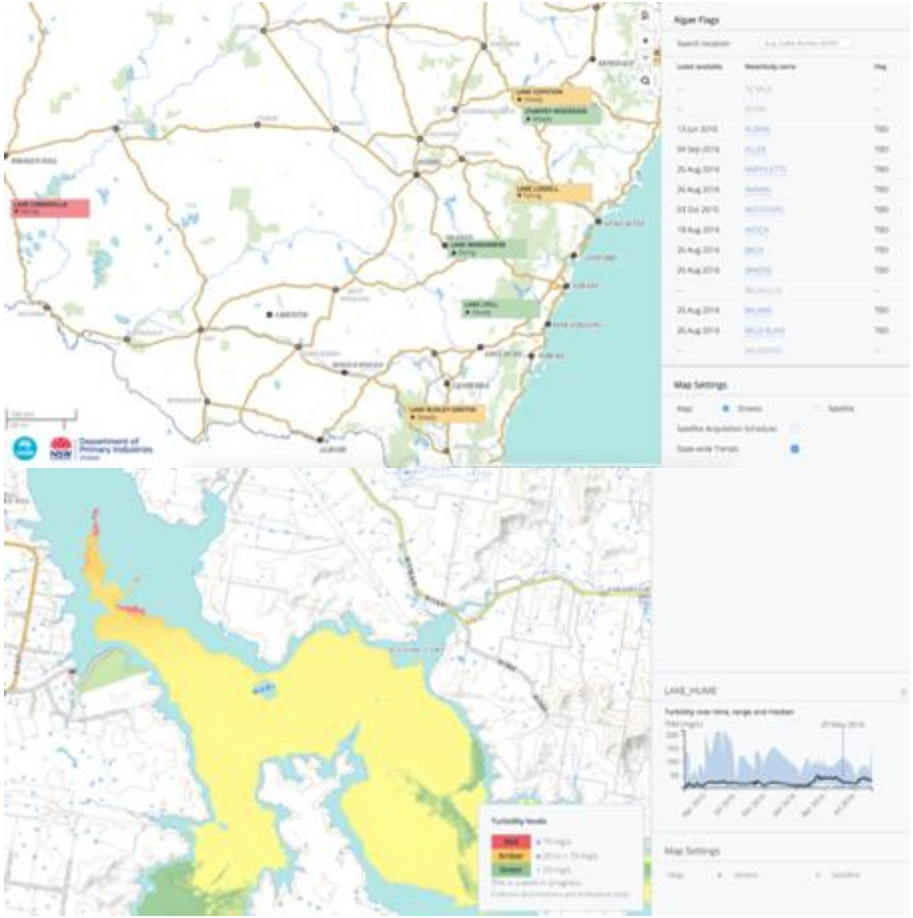


Canberra, ACT

Source: Imagery copyright 2019 Google.
Map data copyright 2019 Google

Dekker, Malthus and Hestir (2013)

CSIRO Visualization – Eg. Statewide and local overviews



Lake Hume, time series, January to March 2016

In-situ Dashboard

2.7.5 Visualisation Dashboard for Cyanobacteria (Chlorophyll-a concentration as an indicator)

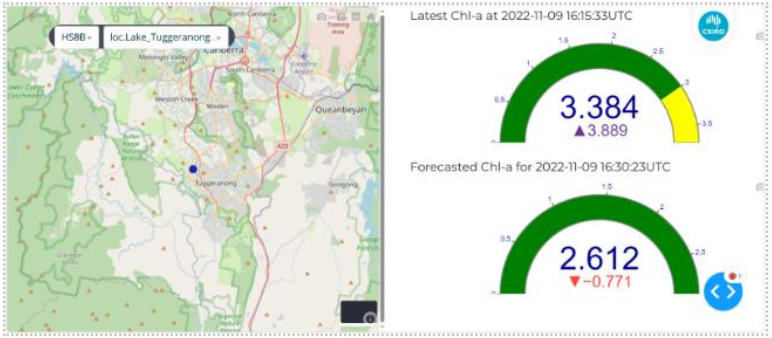
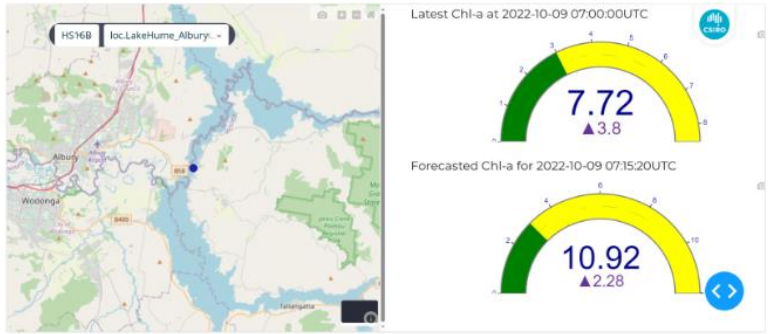
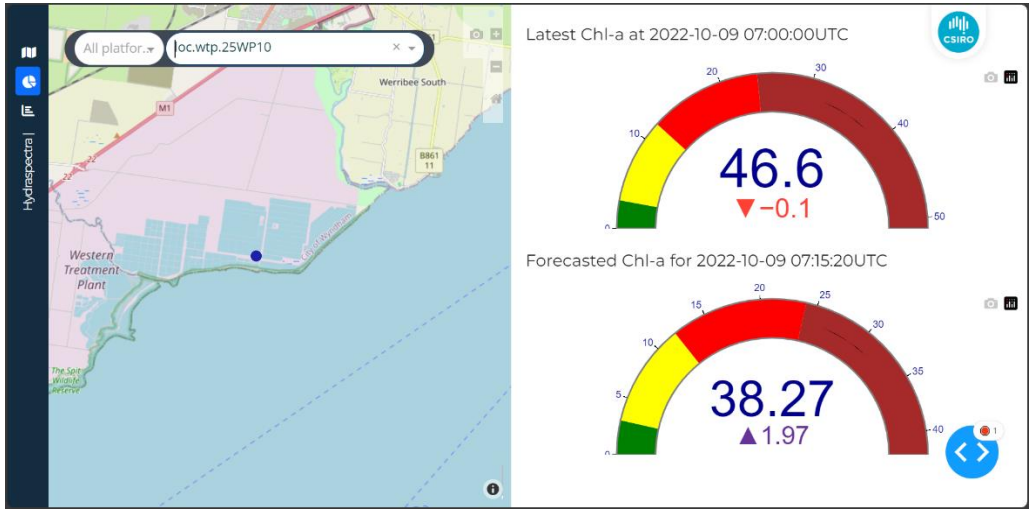


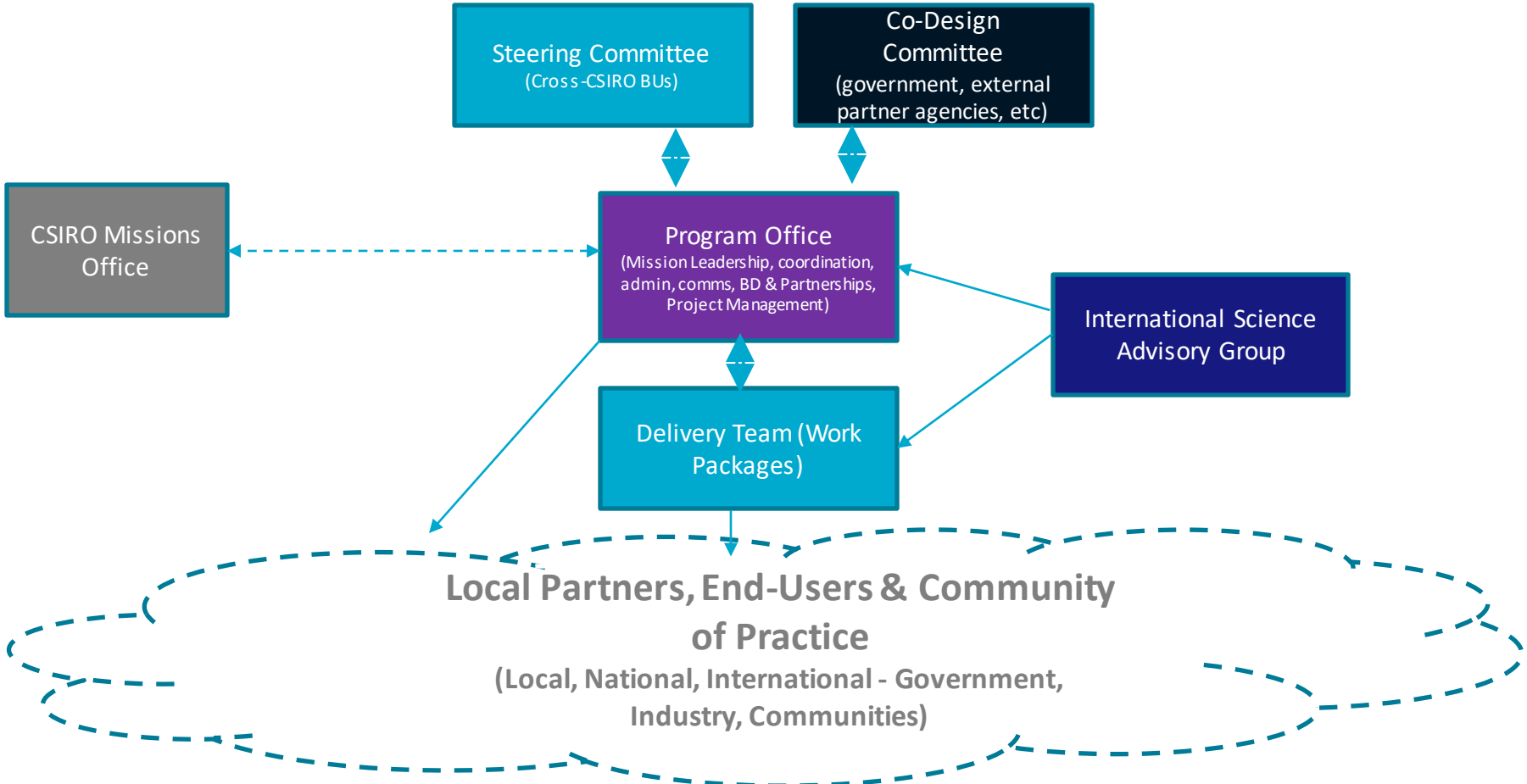
Figure 1xx: Lake Tuggeranong visualisation screen shot.



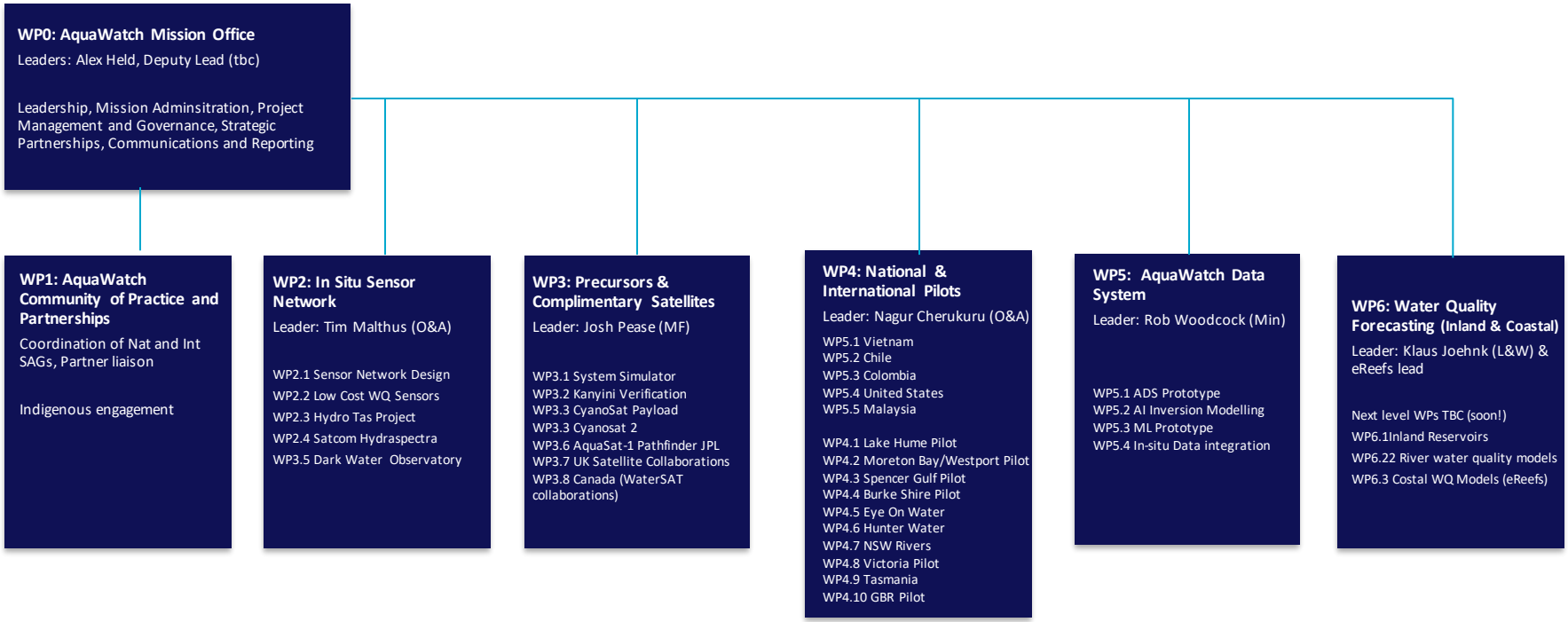


CSIRO

AquaWatch Australia Governance Structure (Sept. 2023)



AquaWatch Implementation Work Structure (Interim)



Key Science Challenges and Opportunities

1. Water Quality Forecasting Models
   a. Linking catchment to coast ecohydrology & water quality models w. eReefs modelling capability
   b. Testing full physics/biogeochemical- based vs. AI approaches
2. In-situ Sensing
   a. Sensor Networks (existing sensors by other agencies and new deployments)
   b. New Sensor Technologies (pesticides, toxic algae, bacteria, sewage detection, etc.)
   c. Remote-area data relay, miniaturisation and automation
   d. Data assimilation w. satellite data
   e. Citizen-science applications
3. Petabyte-scale Multi-sensor data assimilation, cloud-computing and visualization
4. Integrating First Nations' cultural water indicators w. western science approached for water quality monitoring
5. Bespoke satellite sensors and algorithms
   a. Distinguishing different types of algae and phytoplankton types (eg toxic algae)
   b. Discriminate benthic cover types (algae, coral, rocks, etc.)
   c. Atmospheric correction over water

Opportunities for Collaboration

1. Establish one or more “pilot sites’” with co-investment & operation by local partners
2. Collaborate with international space agencies (e.g. CNES) to bring relevant EO satellite data into the AquaWatch Data System (eg Trishna, SWOT, etc.)
3. Ground-Segment with downlink station and high-performance data analytics capacity to develop integrated AquaWatch data service

CSIRO

Thank you

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Director, Earth Observation Infrastructure

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csiro.au/en/about/challenges-missions/AquaWatch