Curtin's
Remote Sensing & Satellite Research Group (RSSRG)

Activities in the marine space
Vision to 2025

David Antoine,
Research Professor, group leader

Curtin University

http://rssrg.org

RSSRG's marine remote sensing 4 pillars (main activity streams)

From the more fundamental to the rather applied:

- Marine optics, bio-optics, algorithms

  Fundamental research to understand the optical properties of the oceanic and coastal waters, and the physics of the satellite remote sensing signals. Development of the numerical inversion algorithms needed to interpret the satellite observations

- "Satellite oceanography"

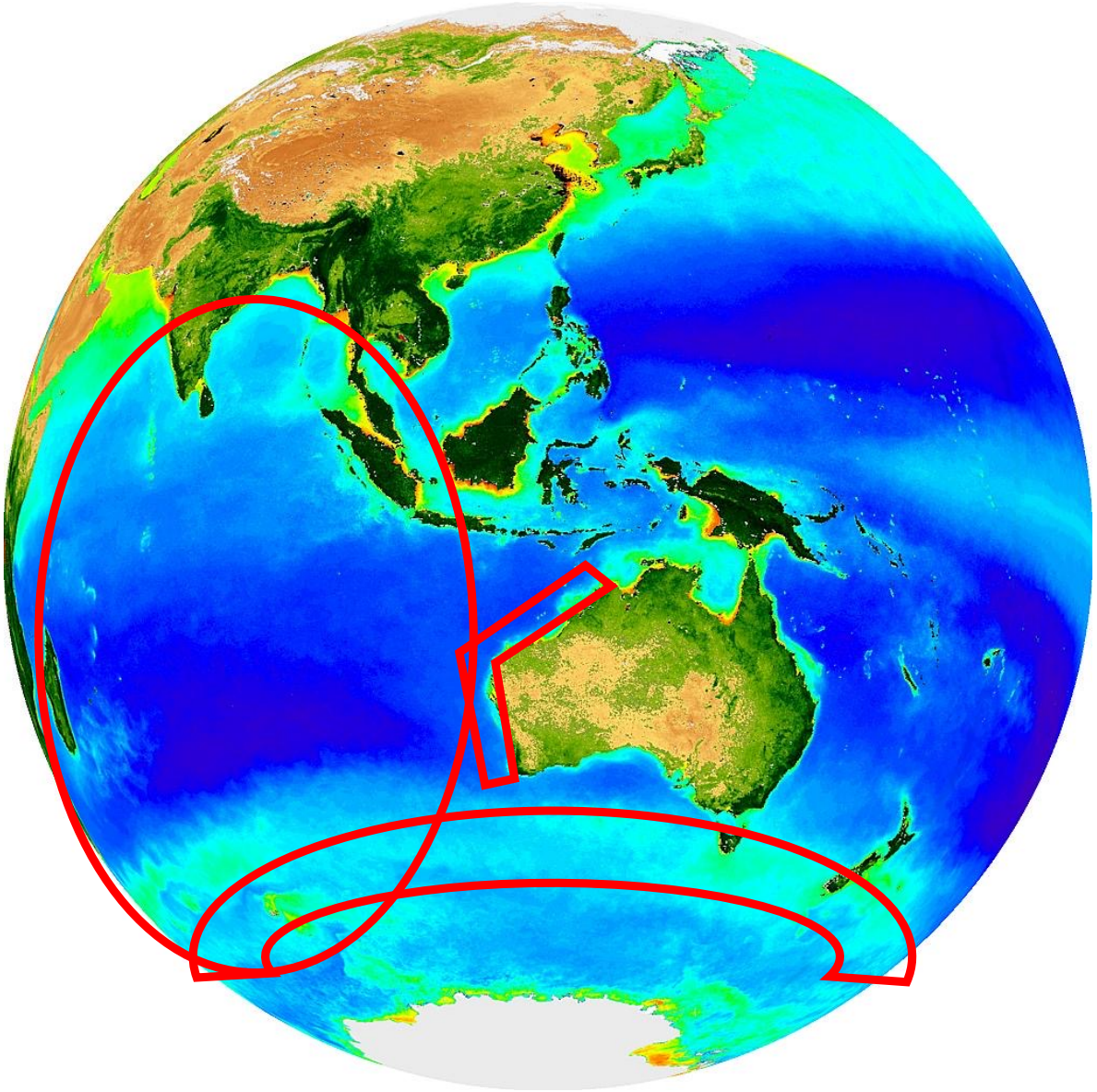
  Using satellite EO to address science questions in oceanography, e.g., long-term changes of phytoplankton and carbon uptake in the oceans

- Calibration / validation activities

  Maintaining field sites providing the high-quality data needed for calibration and validation activities of satellite EO sensors.

- EO-based applications (demand-driven research)

  Developing EO-based applications for e.g., fisheries and aquaculture industries, environmental Agencies, industry.

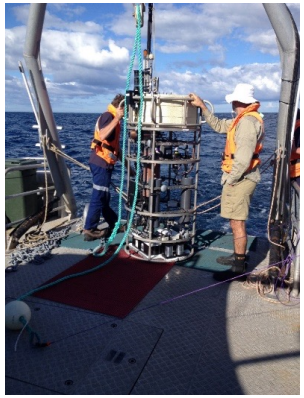


WA coastal areas

Indian ocean

Southern ocean

Our current areas of interest



RITS (Rottnest Island Thetis Station)

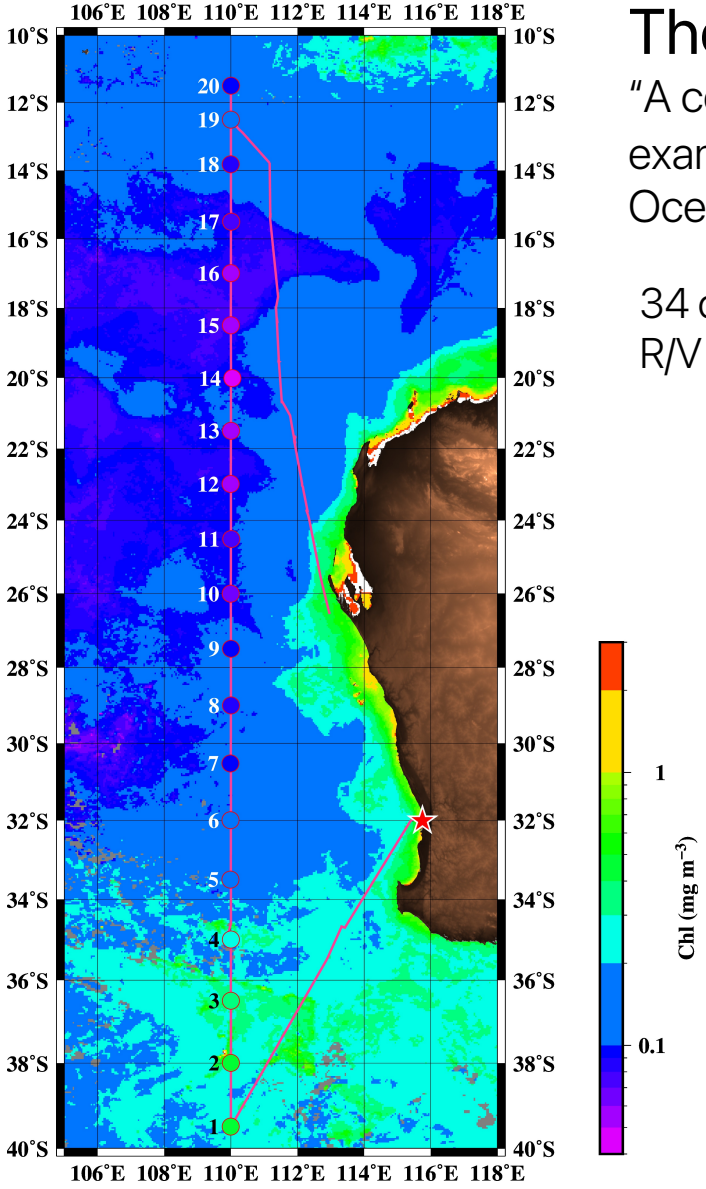
- Regular deployments since 2017 off Rottnest Island (nearby the IMOS NRS)
- A positively buoyant instrument package with an on-board winch, a telemetry system, and the following sensors:

  - Seabird CTD (SBE49 FastCAT) for temperature and salinity, SBE43 for Dissolved Oxygen
  - Satlantic HyperOCR hyperspectral sensors (downward irradiance E_d and upwelling radiance L_u, range: 350-800 nm)
  - WET Labs AC-S hyperspectral spectrophotometer (absorption and attenuation coefficients, range: 400-730nm)
  - WET Labs ECO Triplet BB2FLs for particles backscattering (3 wavelengths) and chlorophyll fluorescence
  - Seabird Turner pCO_2 sensor

- THETIS will be at the IMOS OPEN DAY tomorrow

Initially funded through an ARC LIEF16 grant, and now through the IMOS satellite ocean colour facility

IMOS
Integrated Marine Observing System



The 110E line research voyage

"A coupled bio-physical, ecosystem-scale, examination of Australia's International Indian Ocean Expedition line"

https://mnf.csiro.au

34 days (13th May – 13th June 2019)
R/V Investigator

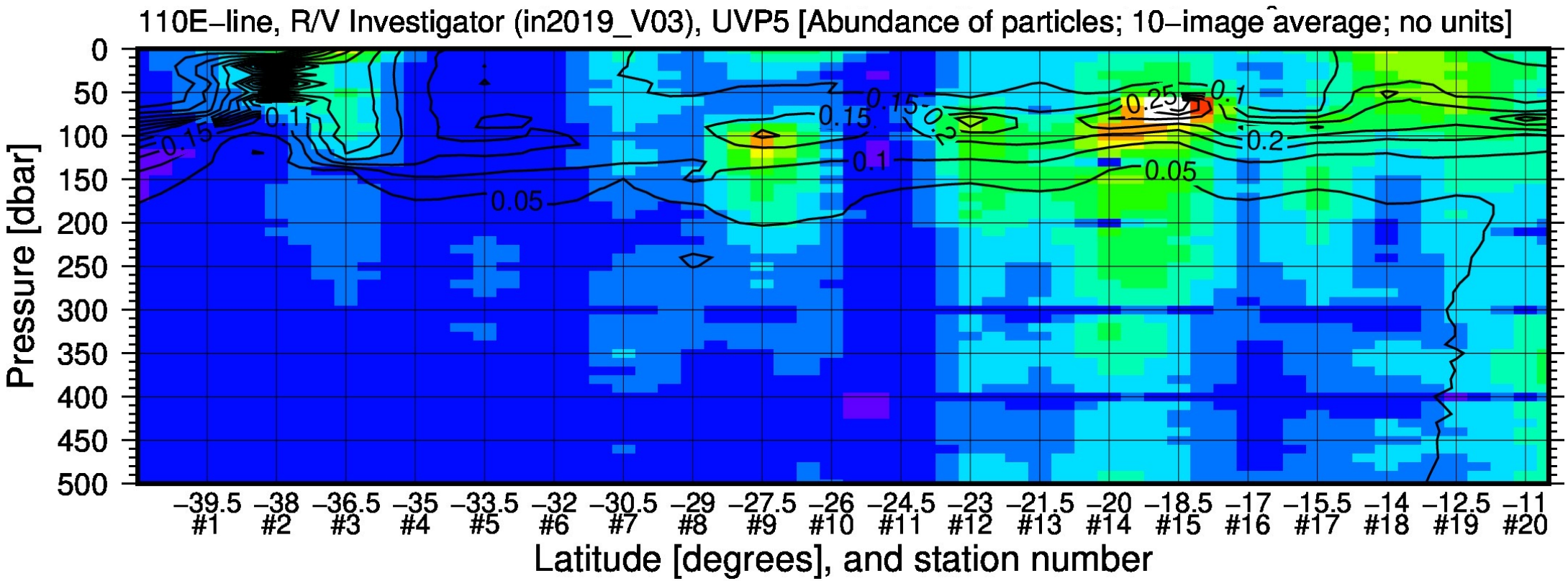
IIOE-2 2nd International Indian Ocean Expedition

General objectives of the research voyage
(Lead scientist: Prof Lynnath Beckley, Murdoch Uni, Perth)

Revisiting the 110E line (last time was 1960s) with these aims:

1. Quantification of multi-decadal, **ecosystem-scale change from the 1960s** benchmark in the **physical, chemical and biological properties** of the water column along 110°E;
2. Characterization of the **physical and biological sources of nitrogen** to the region and their impacts on regional biogeochemistry and ecology;
3. Determination of **trophic relationships** between nitrogen-fuelled primary production and zooplankton, including the larvae of mesopelagic fishes; and
4. **Relating field information on phytoplankton community composition, primary production and carbon export to bio-optical quantities derivable from satellite ocean colour radiometry**.

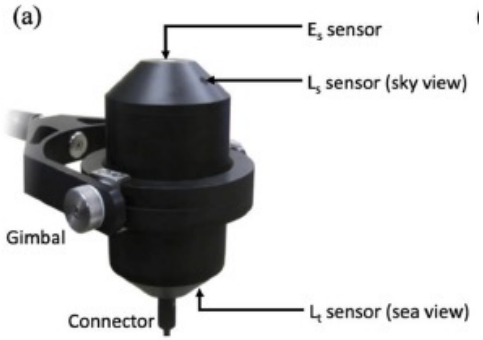
Bio-optical conditions along the transect
Top 500 m

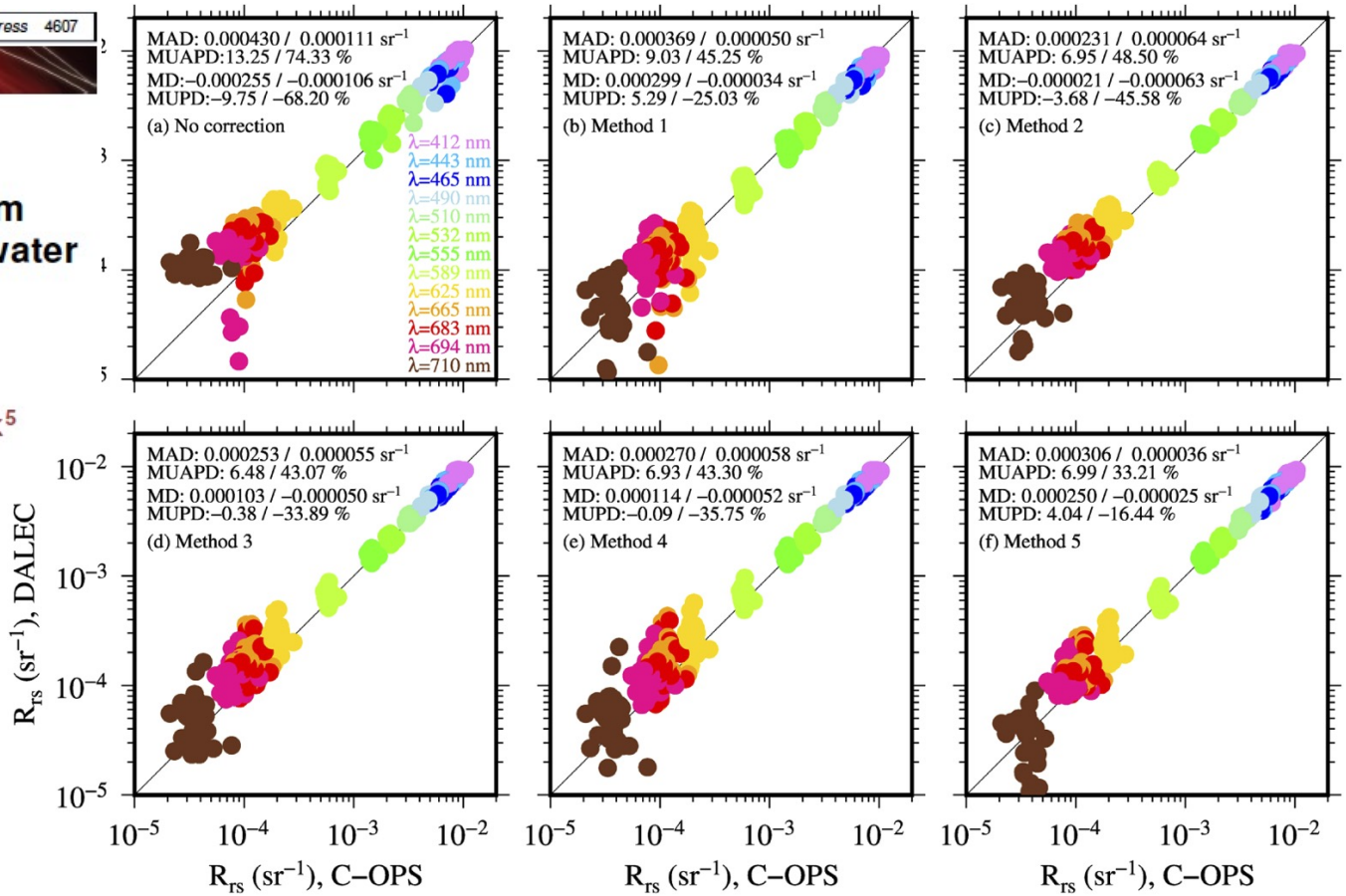


Research Article Vol. 29, No. 3 / 1 February 2021 / Optics Express 4607
Optics EXPRESS

Uncertainty assessment of unattended above-water radiometric data collection from research vessels with the Dynamic Above-water Radiance (L) and Irradiance (E) Collector (DALEC)

DAVID ANTOINE,[1,2,*] MATTHEW SLIVKOFF,[3] WOJCIECH KLONOWSKI,[3] CHARLES KOVACH,[4] AND MICHAEL ONDRUSEK[5]

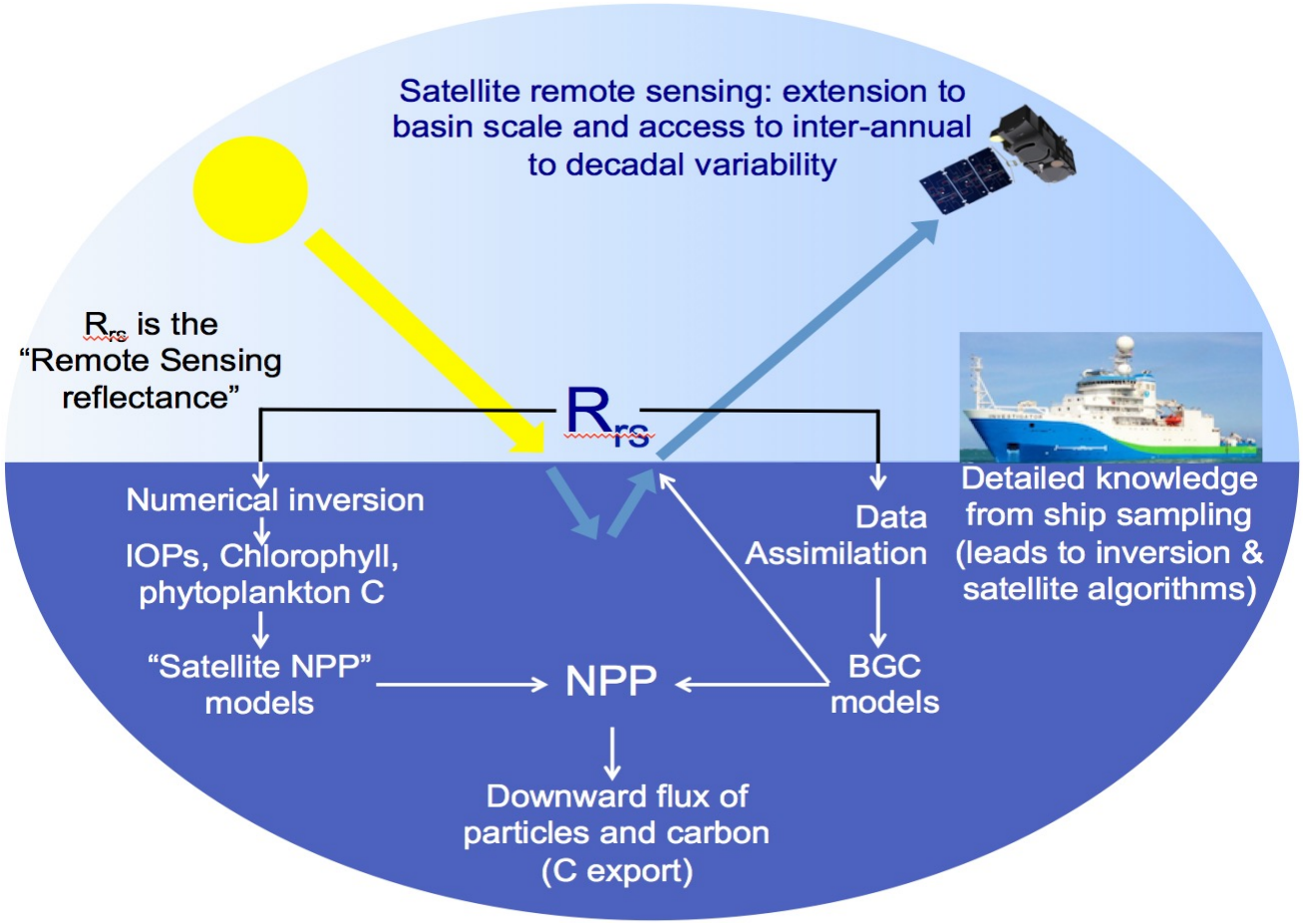




"… Our results show that unattended, carefully quality-controlled, DALEC measurements provide R_{rs} for wavelengths < 600 nm that match those derived from the in-water systems with no bias and a dispersion of about 8%, provided that the appropriate technique is used to quantify the contribution of sky light reflection to the measured signal. The dispersion is larger (25-50%) for red bands, which is expected for clear oligotrophic waters as encountered during the voyage, where ~2 10^{-5} < R_{rs} < ~2 10^{-4} sr^{-1}. For comparison, the two in-water systems provided R_{rs} in agreement within 4% for wavelengths < 600 nm…"

ARC Discovery Project 2021, "Why ocean deserts matter: Phytoplankton carbon and productivity in oligotrophic waters of the Indian Ocean"
Sept 2021 - 2024; Co-Is: Mike Behrenfeld, OSU, Mark Baird, CSIRO

Overall approach, objectives



OBJECTIVE 1: Investigating relationships among Inherent and Apparent optical properties, chlorophyll, phytoplankton carbon, Particulate Organic Carbon, and information on particle characteristics to improve retrieval of phytoplankton carbon from satellite ocean colour

OBJECTIVE 2: Improve modelling of the optical particulate backscattering from phytoplankton and particle state variables in the coupled biogeochemical model currently run by CSIRO

OBJECTIVE 3: Derive NPP from satellite primary productivity models of different kinds, and compare to field determinations and outputs of the coupled BGC model

Bio-optical approach to studying phytoplankton dynamics in the Southern Ocean

Photo credit: SPI & Parafilms

Charlotte M Robinson &
David Antoine

Curtin's Remote Sensing & Satellite Research Group

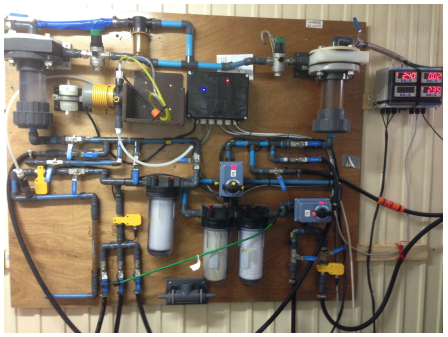
Curtin University

Australian Government
Australian Research Council

Work funded through the ACE Expedition, and ARC discovery project DP160103387

SWISS POLAR INSTITUTE | ACE

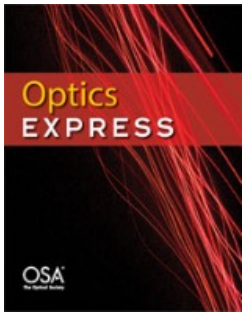
Sampling



Inherent Optical Properties
24 h continuous measurement of light attenuation, absorption, scattering & fluorescence
Data collected autonomously every 2 min by IOP board

Phytoplankton characteristics
3 hourly sampling of pigmentation, biomass, cell size, photophysiology, nutrients

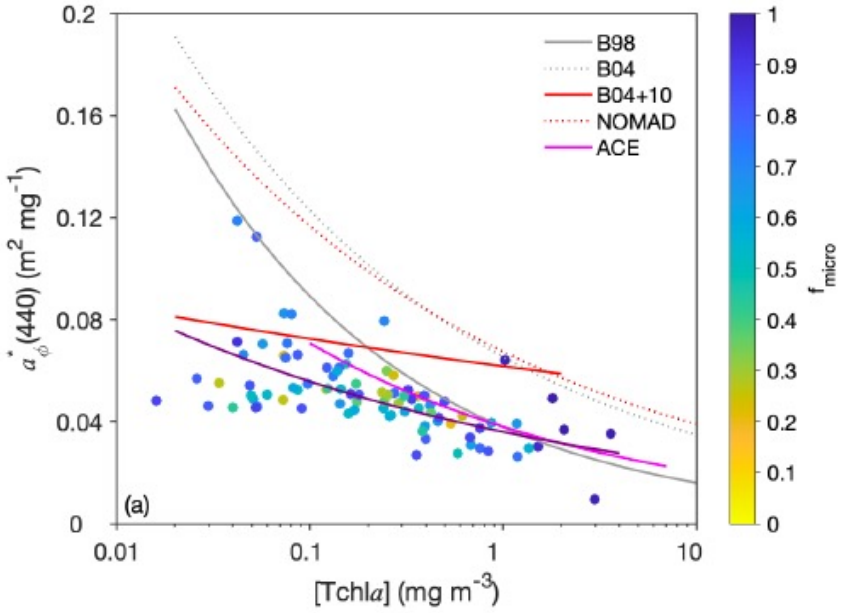
Continuous supply of surface seawater to the blue container laboratory

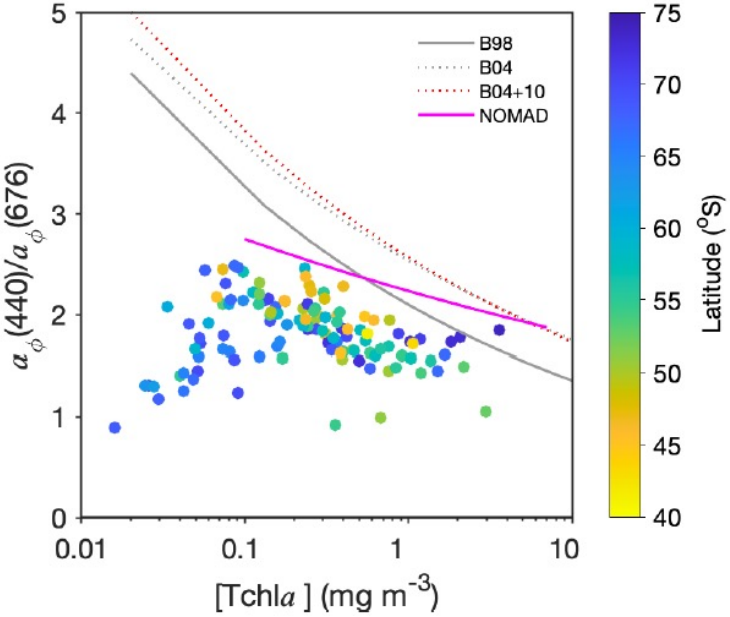


High latitude Southern Ocean phytoplankton have distinctive bio-optical properties.

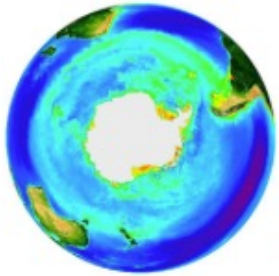
CHARLOTTE M. ROBINSON,[1,*] YANNICK HUOT,[2] NINA SCHUBACK,[1,3,4] THOMAS J. RYAN-KEOGH,[5] SANDY J. THOMALLA,[5,6] AND DAVID ANTOINE[1,7]

Applied Optics, 2021 https://doi.org/10.1364/OE.426737





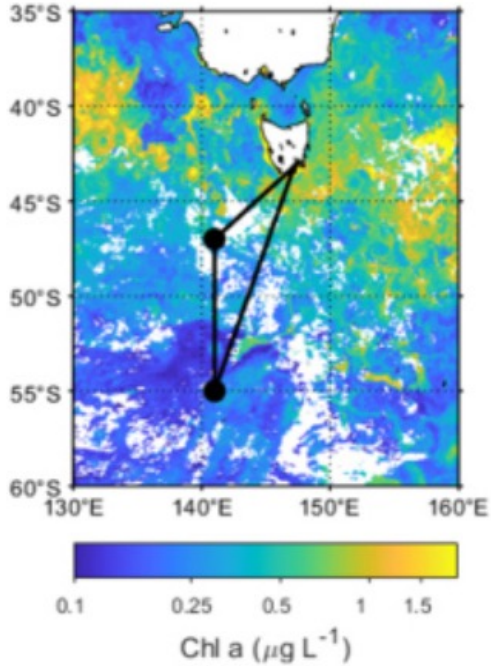
chlorophyll-specific phytoplankton absorption coefficient is significantly lower than in other oceans at comparable chlorophyll concentrations



SOLACE

Southern Ocean Large Area Carbon Extent

Images/photos credit: Charlotte Robinson, Anabelle Erskine and Jake Weiss. Also from https://solace2020.net, © 2021 SOLACE and from https://mnf.csiro.au

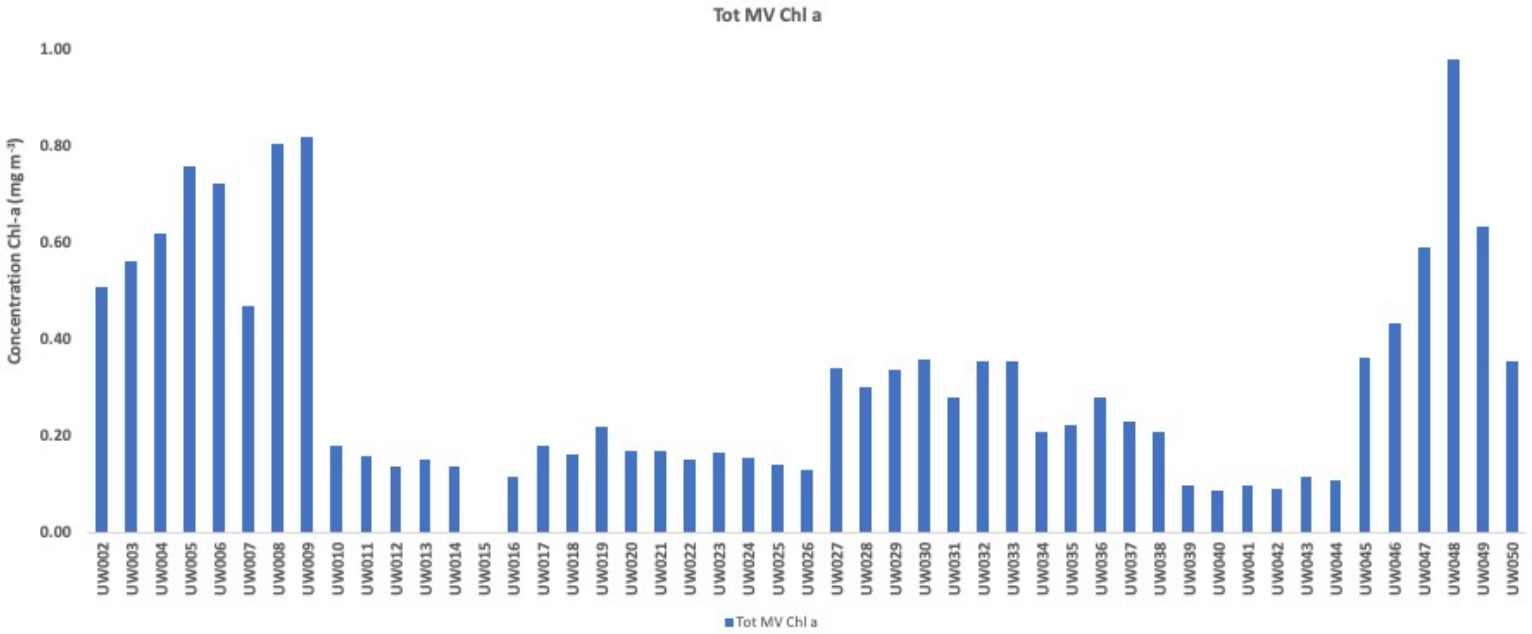


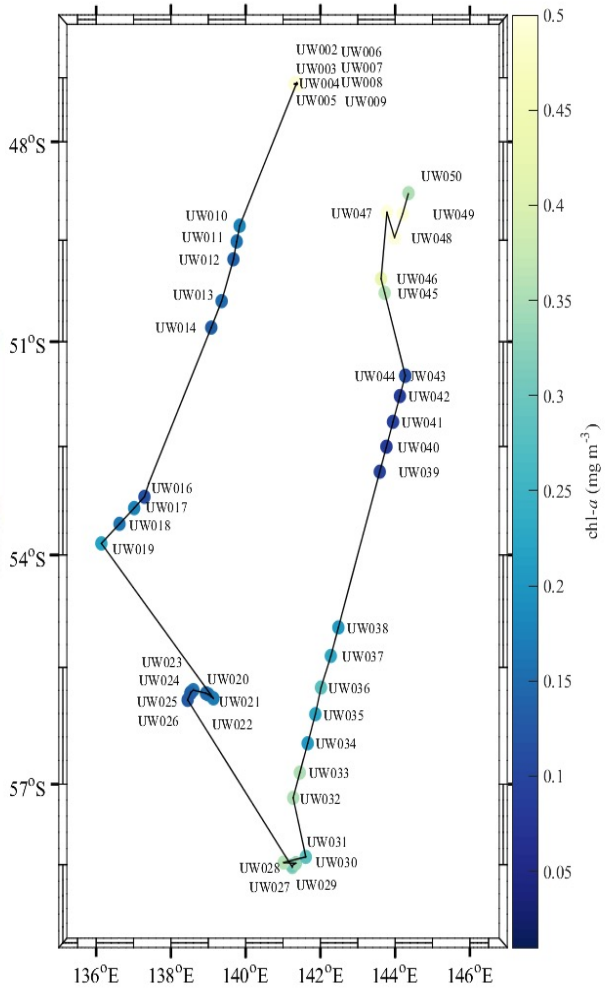
https://solace2020.net

- 5-week research voyage in the Southern Ocean, Dec 2020-January 2021
- Led by Phil Boyd, Univ. Tasmania
- Curtin RSSRG in charge of the IOPs, radiometry, pigments and UVP measurements

From the SOLACE proposal: *"SOLACE will compare and contrast downward particle export flux at low and high export sites, thus placing bounds on Southern Ocean export and the many processes that drive it. We will undertake a suite of transdisciplinary measurements, involving overseas collaborators, to target the many characteristics of the biological pump in both surface and subsurface waters. These datasets will be used for both validation of satellite, bio-float and acoustic remote-sensing and model parameterisation. The former will provide the means to extrapolate the biological pump regionally, and the latter will probe* ***how the regional biological pump is likely to change in a future Southern Ocean, in response to projected increases in productivity****. "*

Preliminary results; pigments
(figures from Bozena Wojtasiewicz, CSIRO, Hobart)





AUSTRALIAN CENTRE FOR EXCELLENCE IN ANTARCTIC SCIENCE

Australian **C**entre *for* **E**xcellence in **A**ntarctic **S**cience

A Special Research Initiative of the Australian Research Council

https://www.utas.edu.au/aceas

Australian Research Council (ARC)
funding under the Special Research Initiative for Excellence in Antarctic Science.
Lead UTAS (Director Matt King; about 50 CIs/PIs)

The centre got **$20M** for 4 years,
and will officially start **January 2022**

Our role in the centre

" improved use of satellite remote sensing, of ocean colour in particular, in view of better understanding long-term changes in the southern ocean ecosystem in response to physical and climate drivers"

Polar POD

A unique multi-year expedition around the Southern Ocean

Imagined and made possible by Jean-Louis Etienne

https://www.oceanpolaire.org/en/polar-pod/

- 100m-tall drifting platform
  - Inspired from the US navy "Flip", and adapted to SO conditions. Crew: 3+5 onboard, rotation every 2 months (supply vessel). Silent, "green"
  - Allow collecting data all-year long. Minimal perturbation of interface
- 4 main research themes
  - 1 – Energy and gas exchange at the air-sea interface,
  - 2 – Improving satellite observation of the SO (Calibration/validation, algorithms)
  - 3 – biodiversity and structure of SO marine ecosystems,
  - 4 – human impacts.
  - + a transverse activity specifically considering what underwater acoustics can bring to the overall science programme
- An ambitious outreach programme
- Public/private partnership
- Science programme coordinated by D. Antoine
- Expedition will start Q1 2024

	2021				2022				2023				2024				2025				2026			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
bid procedures																								
Finalising the full funding structure																								
Finalising the science plan																								
Applying to research funding (European entities)																								
Construction and testing																								
Transfer to South Africa →																								
Expedition …																								
Science exploitation …																								

Polar Pod

International Oceanographic Station

Exploring the Southern Ocean

Climate - Biodiversity – Satellite observations - pollution

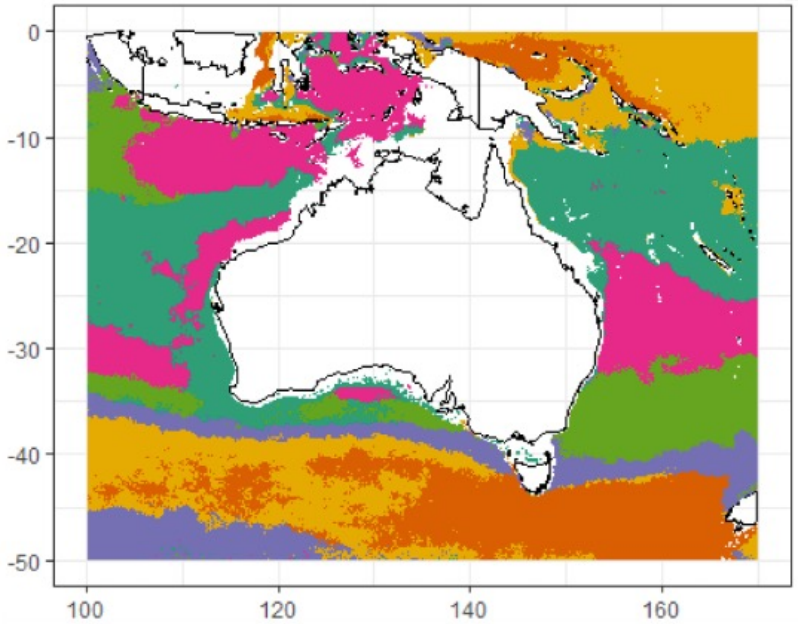
A unique 3-year expedition around the Southern Ocean

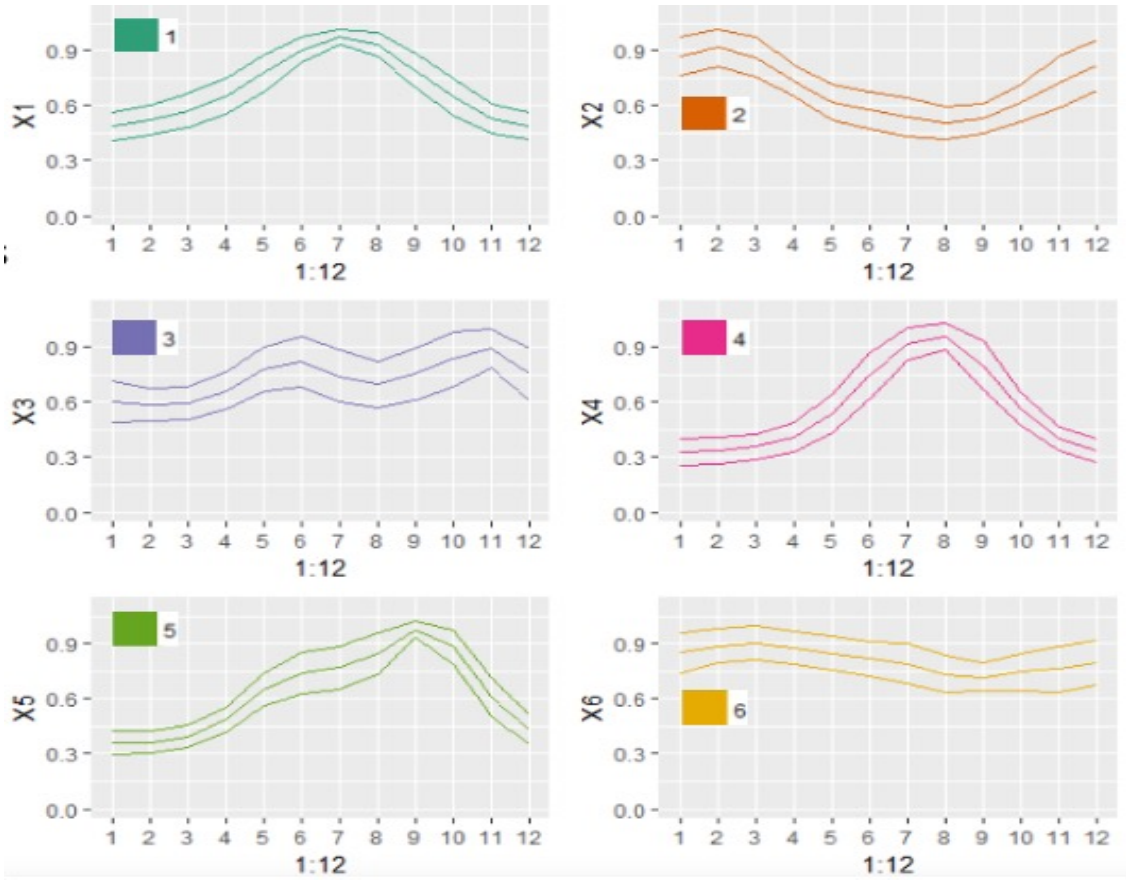
2.4 The seasons of phytoplankton around Australia

David Antoine[1], Nicolas Mayot[2] and Edward King[3]

Data and methods:

- Sixteen years [2003-2018] of satellite ocean colour observations from the NASA Aqua-MODIS sensor combined into a monthly climatology
- A k-means-based cluster analysis [D'Ortenzio and Ribera d'Alcalà, Biogeo-sciences 2009] was applied after the data were normalized by their maximum.
- The average within each cluster is then computed and provides the typical seasonal cycle representative of the group.





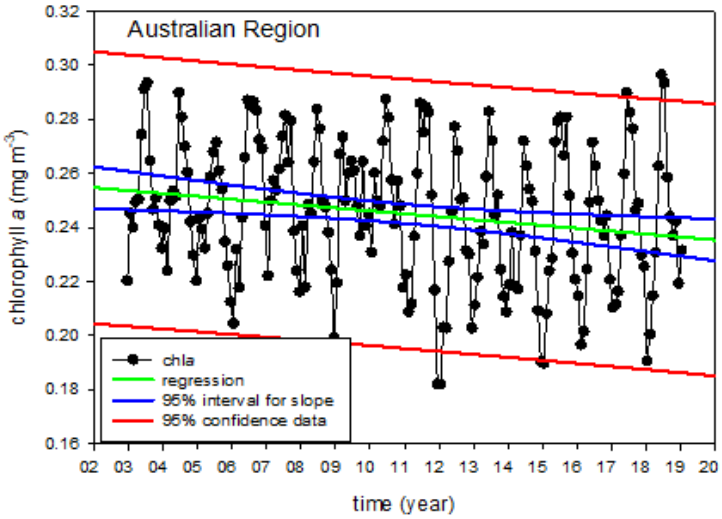
Antoine D, Mayot N, King E. (2020) The seasons of phytoplankton around Australia. In Richardson A.J, Eriksen R, Moltmann T, Hodgson-Johnston I, Wallis J.R. (Eds). State and Trends of Australia's Ocean Report. doi: 10.26198/5e16a91249e7c

2.1 Spatial and seasonal trends in Chlorophyll *a*

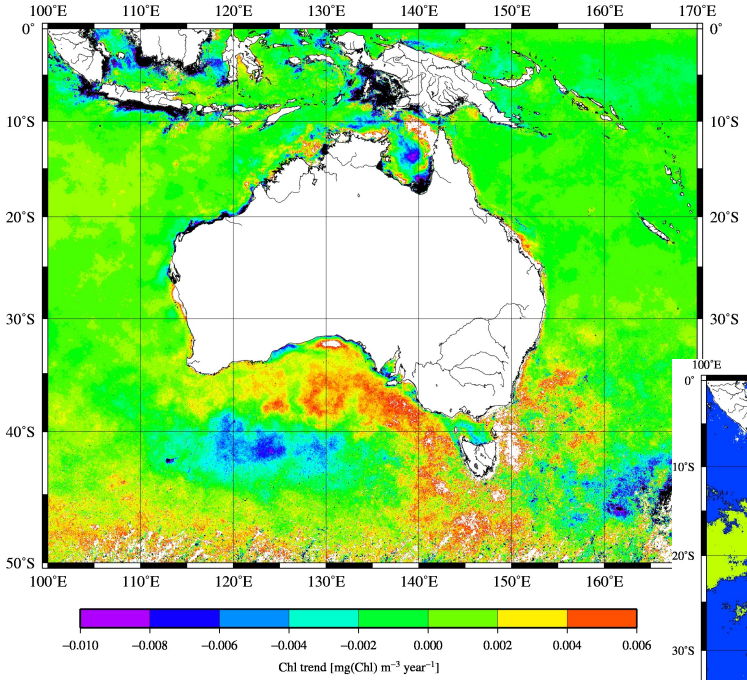
Peter Thompson[1], David Antoine[2] and Edward King[1]

Data and methods:

- Sixteen years [2003-2018] of satellite ocean colour observations from the NASA Aqua-MODIS, monthly resolution
- Linear trends assessed for each of the 4x4-km2 bins
- Significance of the trend also assessed

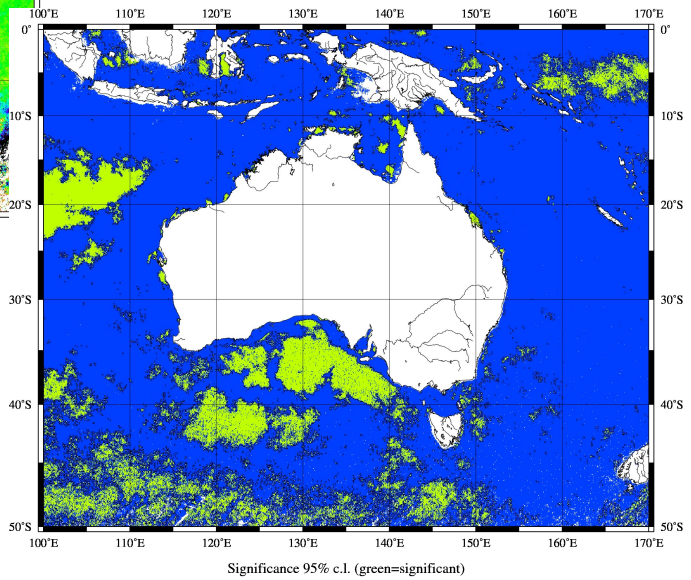


On average over the 0-50S / 100E-170E box



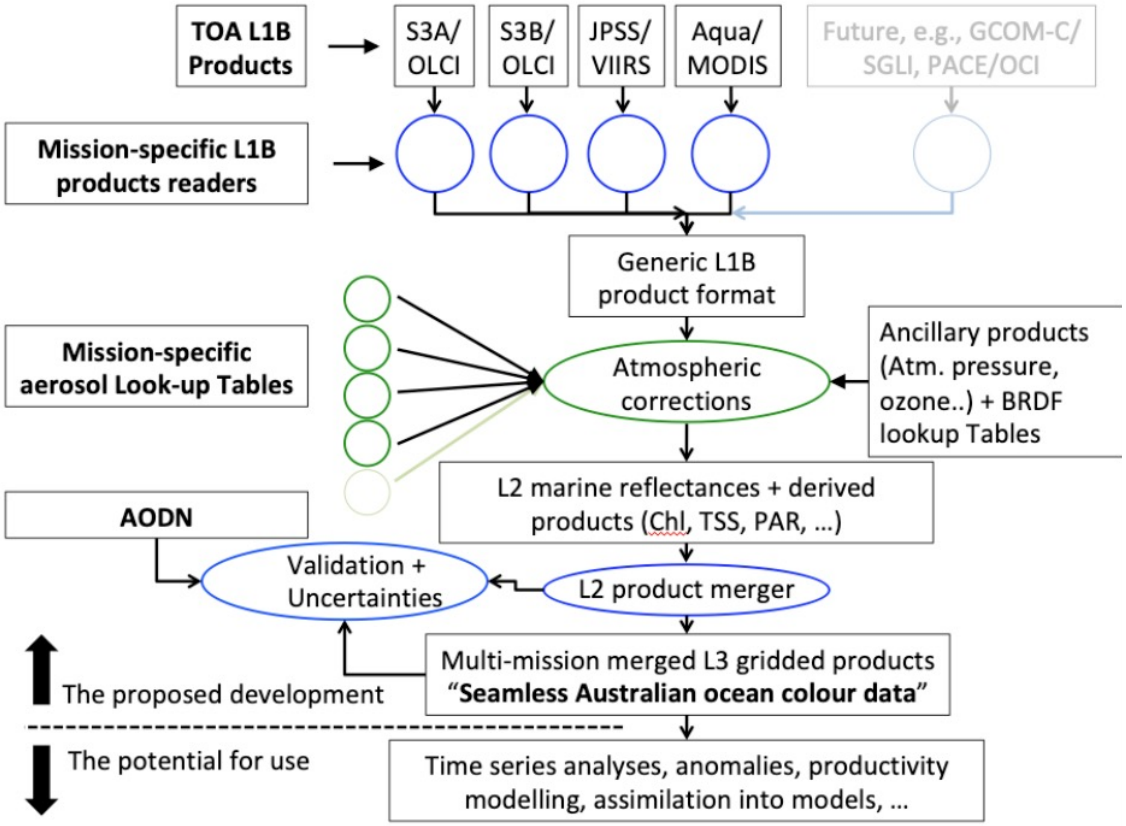
16-year trend

Significance



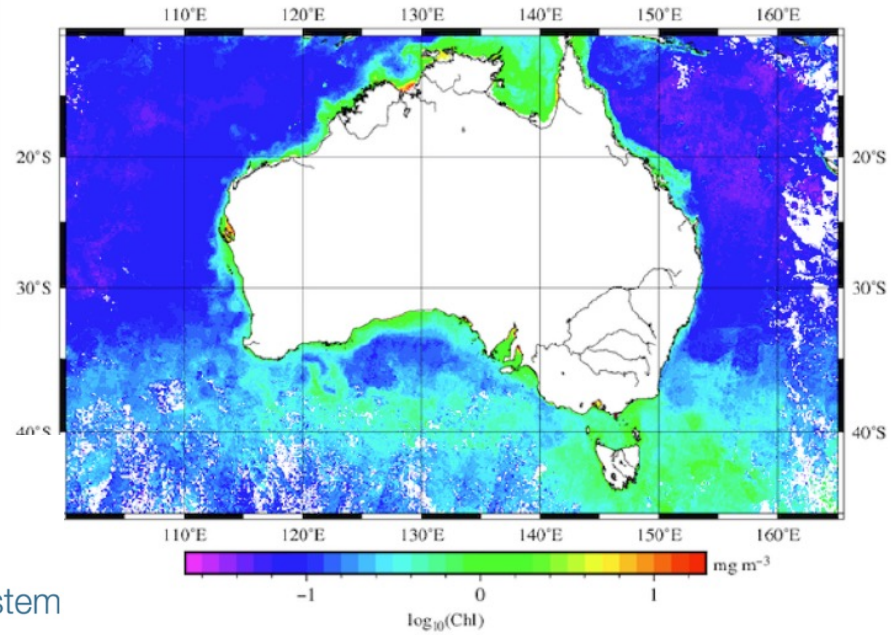
Thompson P, Antoine D, King E. (2020) Spatial and seasonal trends in Chlorophyll a. In Richardson A.J, Eriksen R, Moltmann T, Hodgson-Johnston I, Wallis J.R. (Eds). State and Trends of Australia's Ocean Report. doi: 10.26198/5e16a44a49e79

Improving coverage and quality of satellite products



- Homogenising the processing of observations from several satellite missions, so as to improve consistency of the final merged product.
- Adding uncertainties to the final product

Collaboration with **CSIRO**, and with contribution from the **Curtin Institute of Computation**



Activity carried out in the frame of the Australia Integrated Marine Observing System "**New Technology Proving**" programme

IMOS Integrated **Marine Observing** System

Demand-driven applied science

"A Pilot Study In Improving The Health of At-Risk Western Australian Estuaries: Assessing The Relationship Between On-Land Water Use and Estuarine Health."

Funded by: Western Australian Satellite Technology and Applications Consortium (WASTAC) Small Grants Scheme; started Nov 2020
Partner: WA DWER

Looking at relationships between LULC and water quality in Estuaries using Sentinel2 & 3 observations in particular

OYSTERQUAL (funded by the "**SmartSAT**" CRC); To start 1st June 2021
Partners: *WA DPIRD, Maxima Rock Oyster Company, GA, Myriota, Geoplex, Frontier SI*

"A Proof of Concept and feasibility study utilising space technologies to advance the aquaculture markets in Western Australia remote and regional areas."

Using Sentinel2 and 3, plus in-situ monitoring, to help the WA aquaculture industry.
As a preliminary step the project will investigate the feasibility of jointly using satellite remote sensing Earth Observation (EO) and in-situ data to ultimately assist with identification of suitable shellfish growing sites. The aim is to apply novel remote sensing technology to minimise the need for in-situ data in remote sites that would be too costly to assess.

Bringing a NASA cal/val site to our shores. From end of 2022

https://pace.oceansciences.org

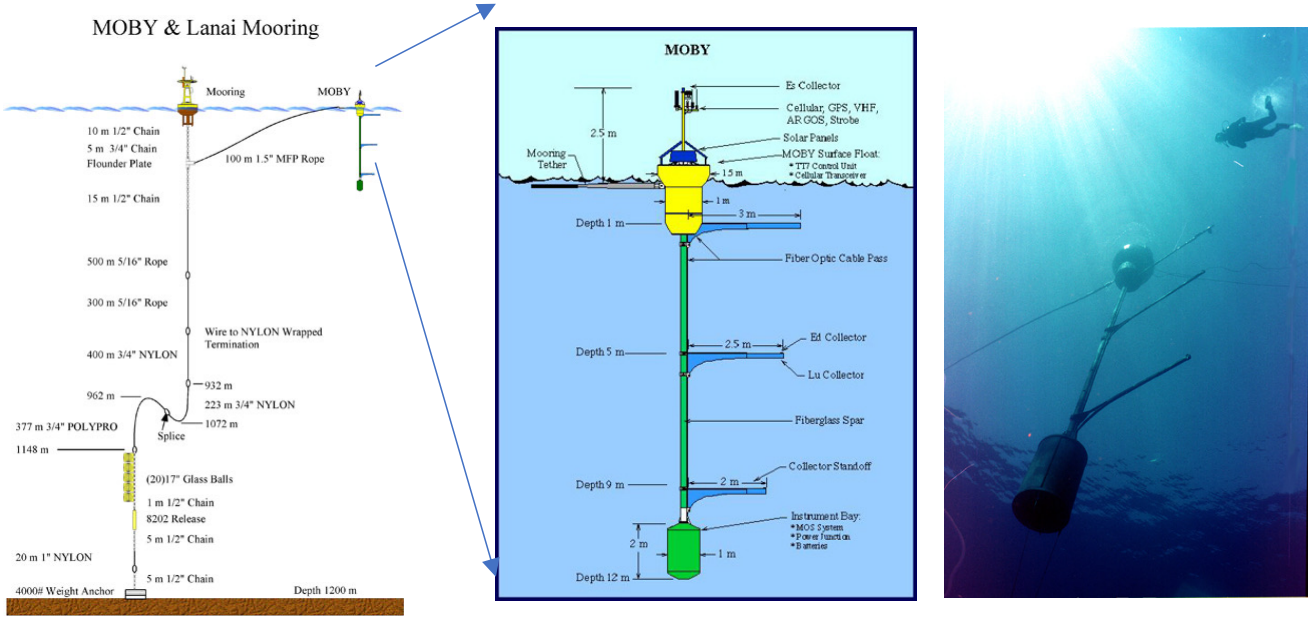
National Aeronautics and Space Administration

We will host one element of the "Marine Optical Network" (**MarONet**). To be deployed off Perth, in deep clear waters. The other one is deployed in Hawaii

This unique equipment is the new generation "vicarious calibration" system that NASA is going to use for their PACE mission (Plankton, Aerosols, Clouds, Ocean Ecosystem).

PACE is the first global hyperspectral ocean colour mission

The former system ("MOBY") has been used for 25 years, and has served not only NASA missions but virtually all ocean colour missions (ESA, JAXA, ISRO)



Images form: https://mlml.sjsu.edu/moby/moby-photo-gallery/

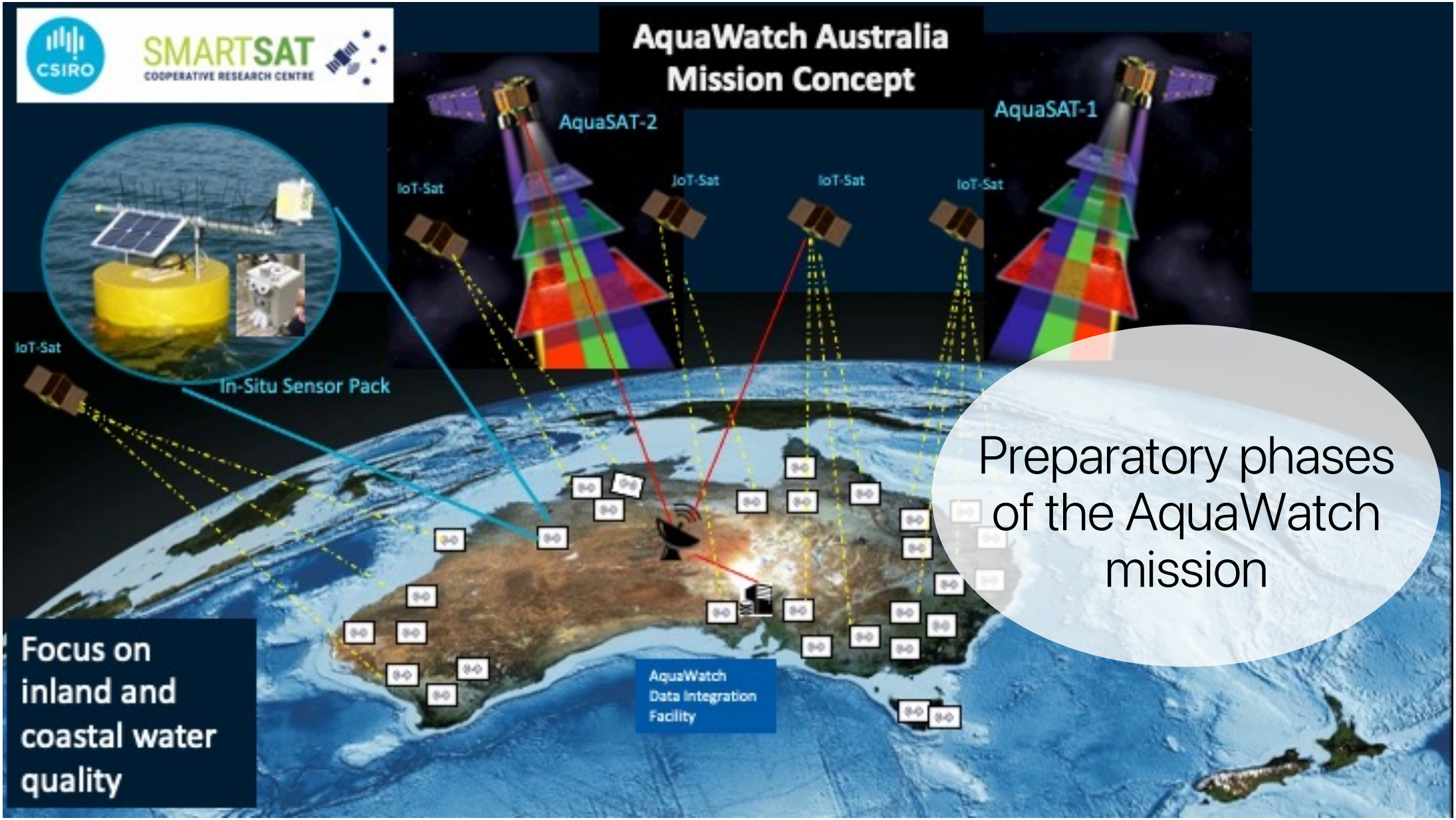
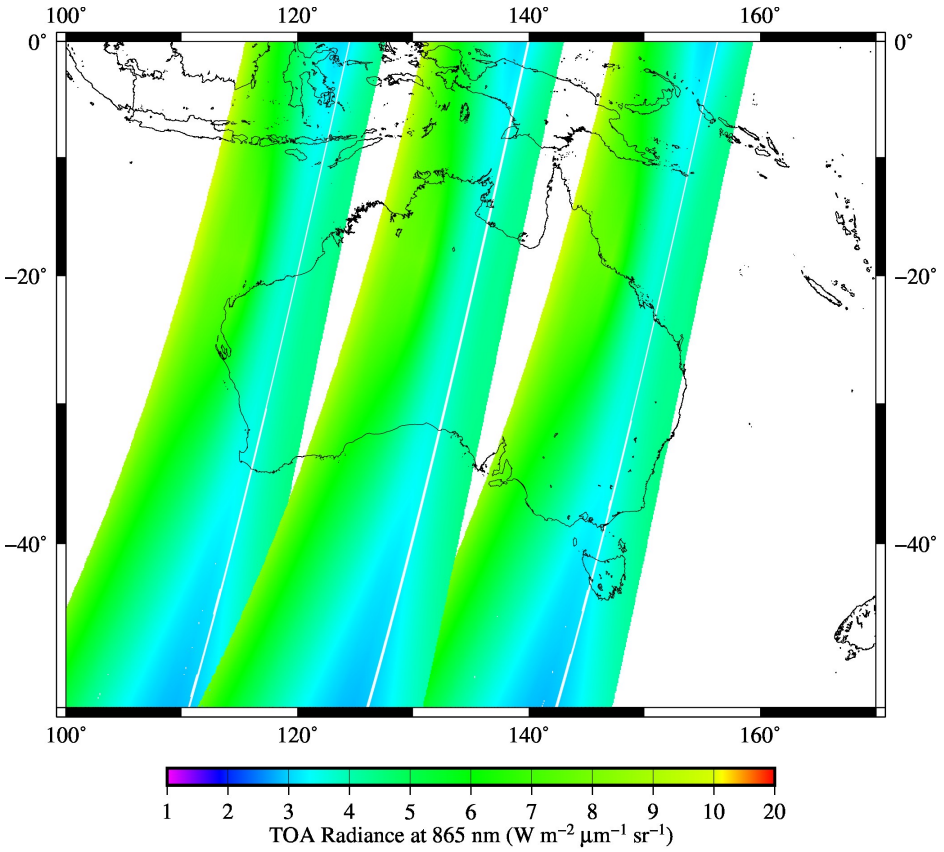
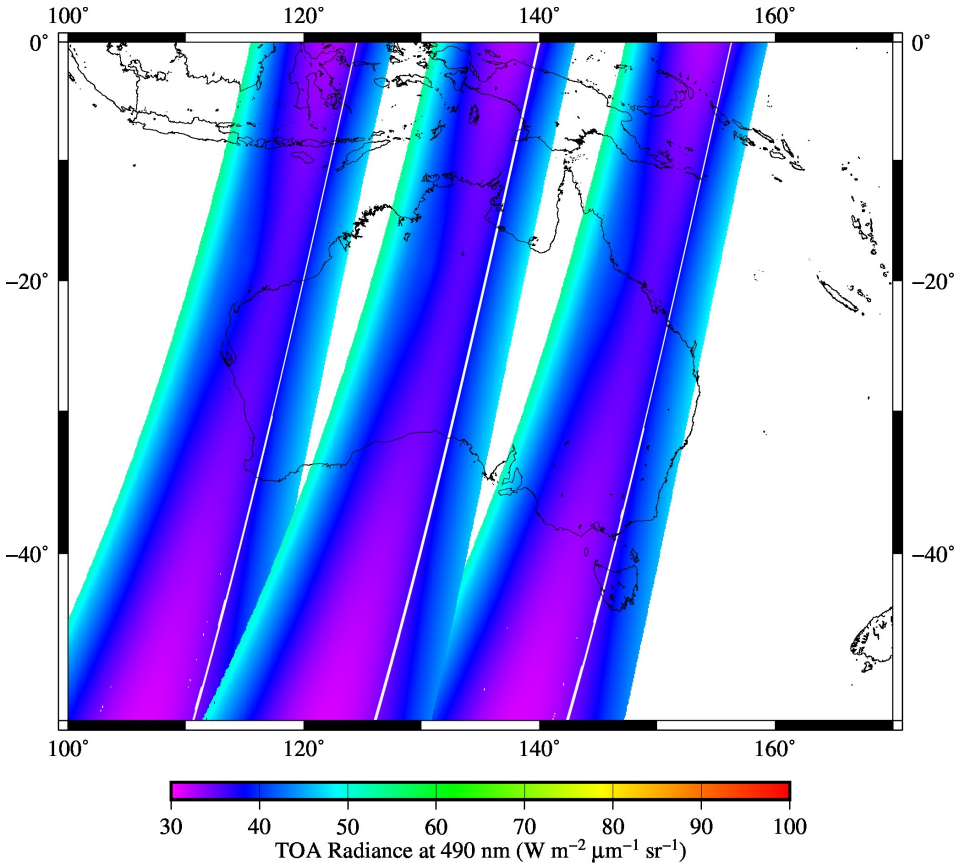


 Image courtesy, Alex Held, CSIRO

Quantification of the top-of-atmosphere (TOA) total radiance



MAR70 aerosol for AOT(550)=0.10, Acquisition Dec21st, average θ_S=33.5 degrees



MAR70 aerosol for AOT(550)=0.10, Acquisition Dec21st, average θ_S=33.5 degrees

Report of the 2020/21 “CDF” sessions

Aquawatch Technical Report 1

Preliminary Concept Study for the Satellite Segment of AquaWatch Australia

August 2021

ISBN:

This report should be cited as:
SmartSat 2021, Preliminary Concept Study for the Satellite Segment of AquaWatch Australia, SmartSat Aquawatch Technical Report no. 1, SmartSat, Adelaide, Australia.

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Acknowledgement:
SmartSat acknowledges the contribution made by CSIRO towards the AquaWatch Program. AquaWatch is a joint initiative between SmartSat and CSIRO.

SmartSat acknowledges the contribution made by UNSW Canberra Space in the facilitation of the study with the Australian National Concurrent Design Facility and towards the writing and compilation of this technical report.

CSIRO SMARTSAT COOPERATIVE RESEARCH CENTRE

UNSW CANBERRA Curtin University Sat Dek pty ltd space UNSW CANBERRA

Table of Contents

"Cyanosat" – Cubesat precursor to AquaWatch

- Partnership to be consolidated
  CSIRO (Payload),
  Curtin (platform SSTC, mission
  SmartSAT CRC ($'s)
  WA Government ($'s)

- Mission would be a 3 to 6U Cubesat, hosting a multi- or hyperspectral payload dedicated to Cyanobacteria blooms, and more generally inland and coastal water quality

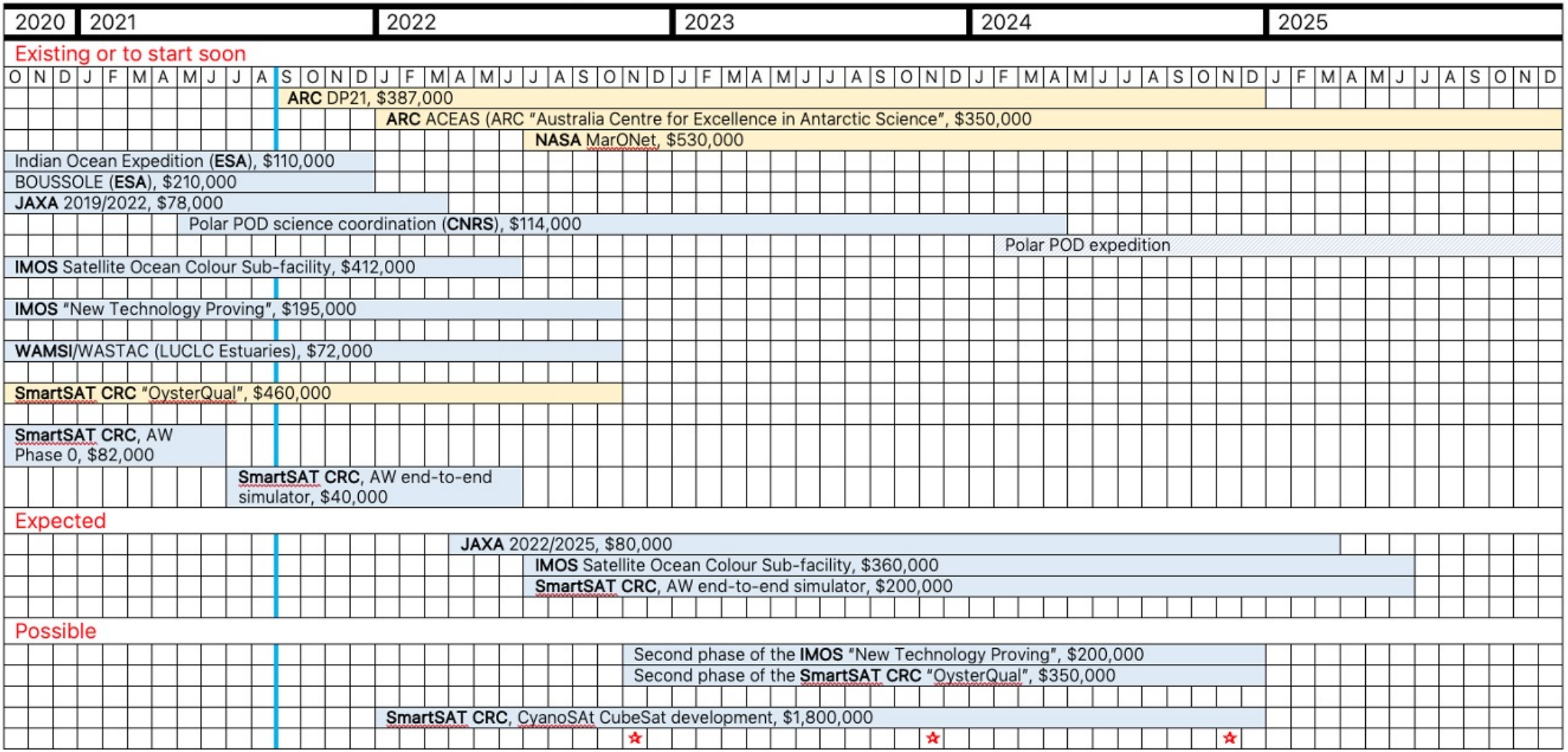
- ... Stay tuned..

Ocean Color Feature

SeaHawk/HawkEye Begins Routine Operations

https://oceancolor.gsfc.nasa.gov

Time line / RSSRG projects schedule



Research grants with NO salary support for D. Antoine

Research grants WITH salary support for D. Antoine

Research grants for which salary support for D. Antoine is not yet defined

☆ Submissions to ARC ITTC and/or Laureate

Under consideration for the future:

- Fellowships to attract high quality Academics (Forrest, ARC DECRA, ARC FUTURE)
- ARC DP, ITTC, Laureate (D. Antoine)

In conclusion

- We have built a highly successful track record of attracting: 4 ARC grants over 5 years (1 LIEF, 2 DPs, 1 SRI), Grants from SmartSAT CRC, Int'l space agencies, NCRIS IMOS, plus co-investment by State Departments and Industry

  Total is close to $5M (without including the research block grant that comes to Curtin on top of this)

- RSSRG will grow to about 20/25 staff at the end of 2022 ("permanent", PDRAs and students)
- Still need to consolidate this for a more sustainable future
- We are well positioned at the national level
- A 5-year plan is in the making, to be discussed with the Faculty in September 2021


Thank you
Image from https://oceancolor.gsfc.nasa.gov