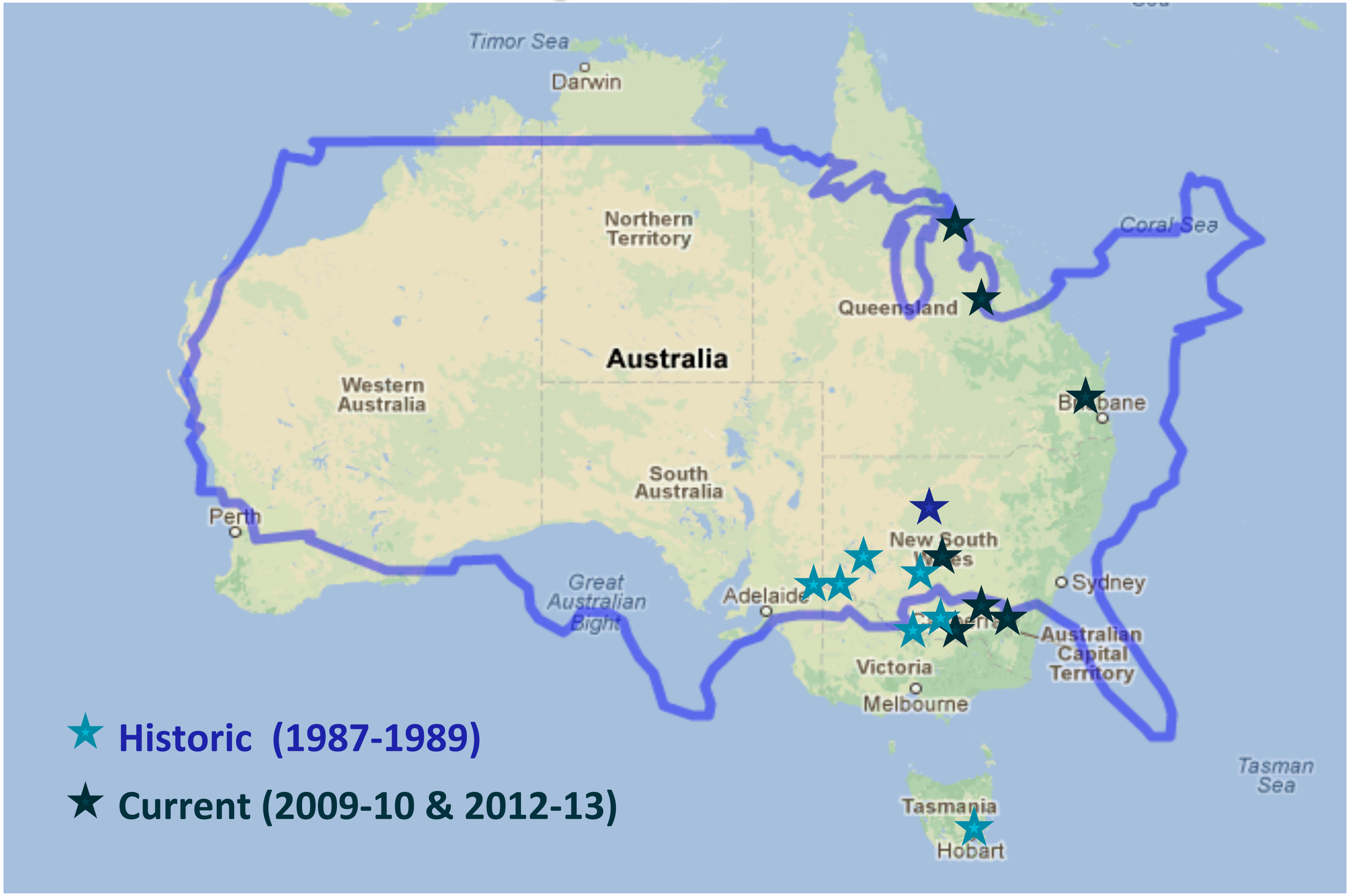
water quality monitoring: the role of HyspIRI

Arnold Dekker, Tim Malthus, Erin Hestir
Earth Observation & Informatics -Transformational Capability Platform

29th May 2013 NASA GSFC

CSIRO

In situ bio-optical observations



Drivers for our EO of water quality research

- Legislation:
  - National Plan for Environmental Information
  - State of Environment
- Algorithms
- New Technologies
- Ecosystem science
  - Climate change and variability
  - Drivers of water quality
  - Resilience
  - Prediction

2013 → **2020**

The Senate

Standing Committee on Economics

Lost in Space? Setting a new direction for Australia's space science and industry sector

Australian Government
Geoscience Australia

A National Space Policy:
Views from the Earth Observation Community

Australian Government
Department of Innovation
Industry, Science and Research

ANALYSIS OF AUSTRALIAN GOVERNMENT SPACE ACTIVITIES

MAY 2010

The economic value of earth observation from space

A review of the value to Australia of Earth observation from space

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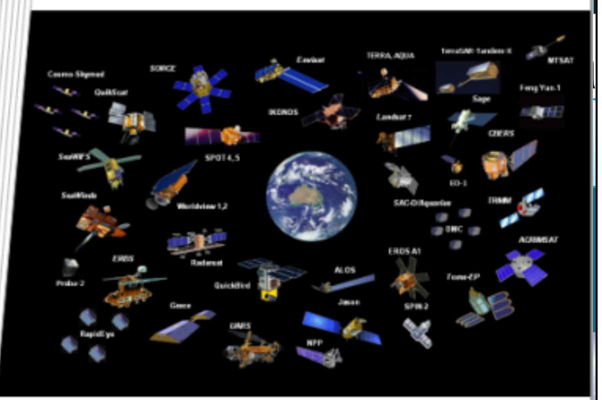


Continuity of Earth Observation Data for Australia: Research and Development Dependencies to 2020

January 2012

Australian Government

"..certainty and strategic direction for satellite technology users"

National Space Policy

"..better domestic co-ordination and focused international engagement"

"...giving priority to Earth observations from space.."

Australian Government

National Earth Observations from Space Infrastructure Plan

"CSIRO is Australia's lead R&D Agency"

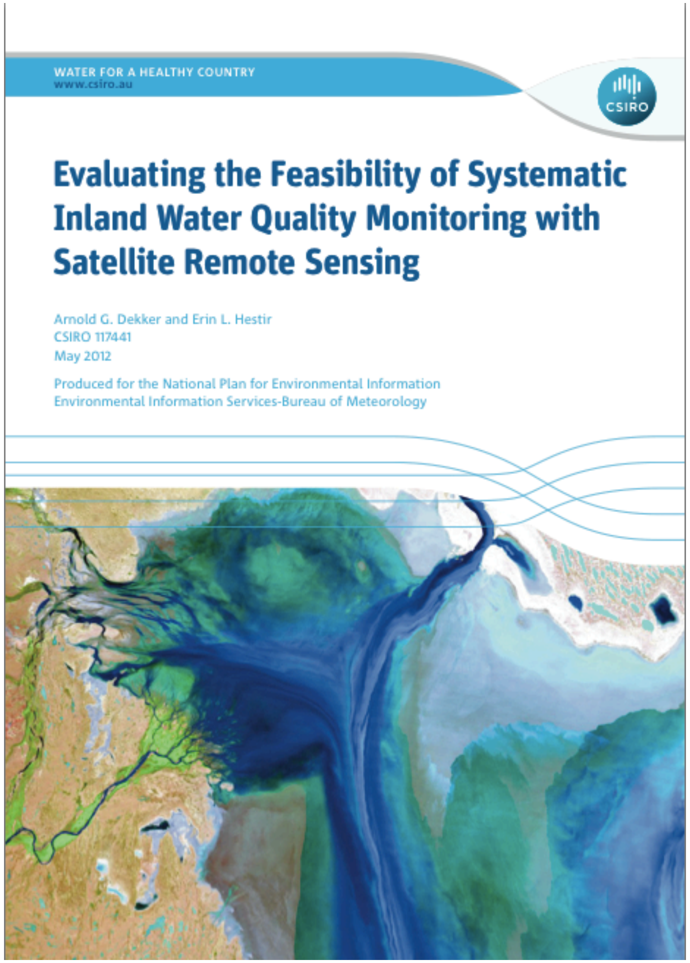
Australian Context for Water Quality

- **The Challenge: Ongoing monitoring of Australia's inland water quality**
- Australia's water quality is poor and is negatively trending
- But water quality data are scarce, potentially declining and with poor temporal coverage
- We need rapid, cost-effective assessments of water quality to assess baseline conditions and study responses to existing and potential environmental stressors
- Such assessments are needed across a range of scales
- Includes from continuous in situ measurements to satellite remote sensing, the latter overcoming some of the costs of remote sampling

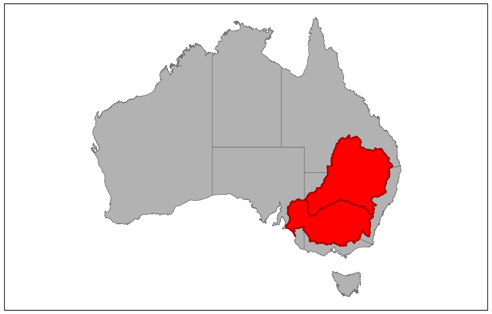
The potential solution

: http://www.clw.csiro.au/publications/waterforahealthycountry/#reports

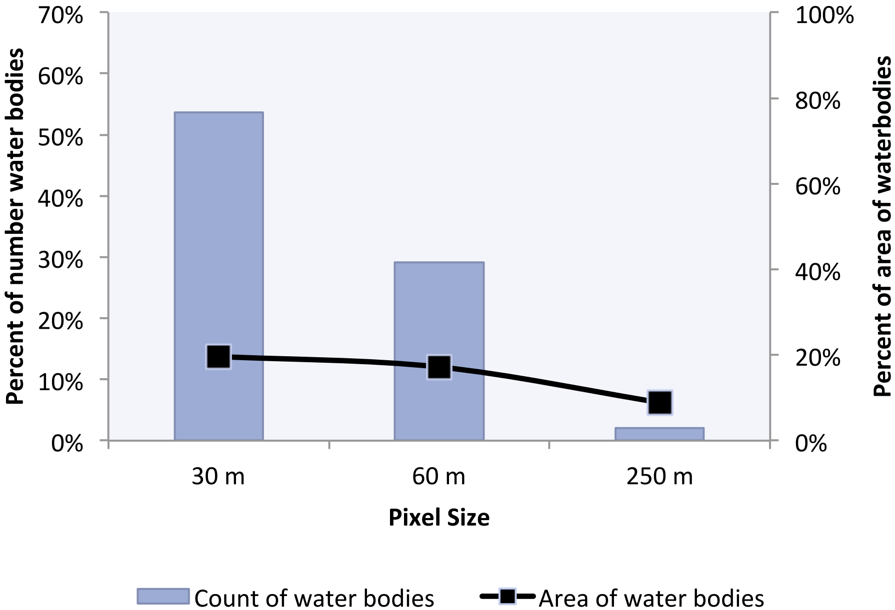
- **Satellite remote sensing**
  - Provides an objective, high frequency and spatially continuous measurement tool to overcome these challenges
  - But for a limited set of water quality parameters
  - Using inversion approaches
  - Will need calibration and validation over low reflecting targets



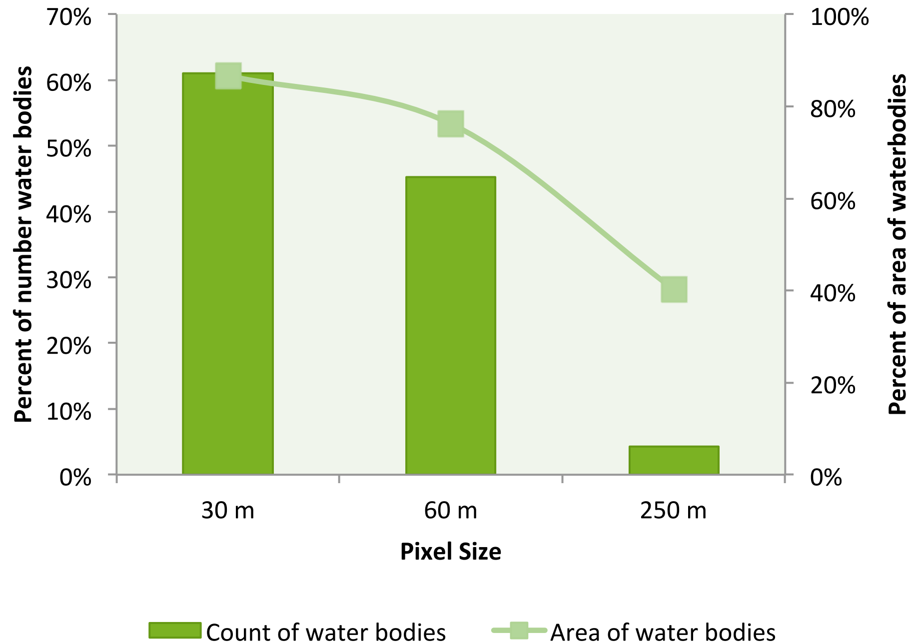
EO-resolvable water bodies in Australia



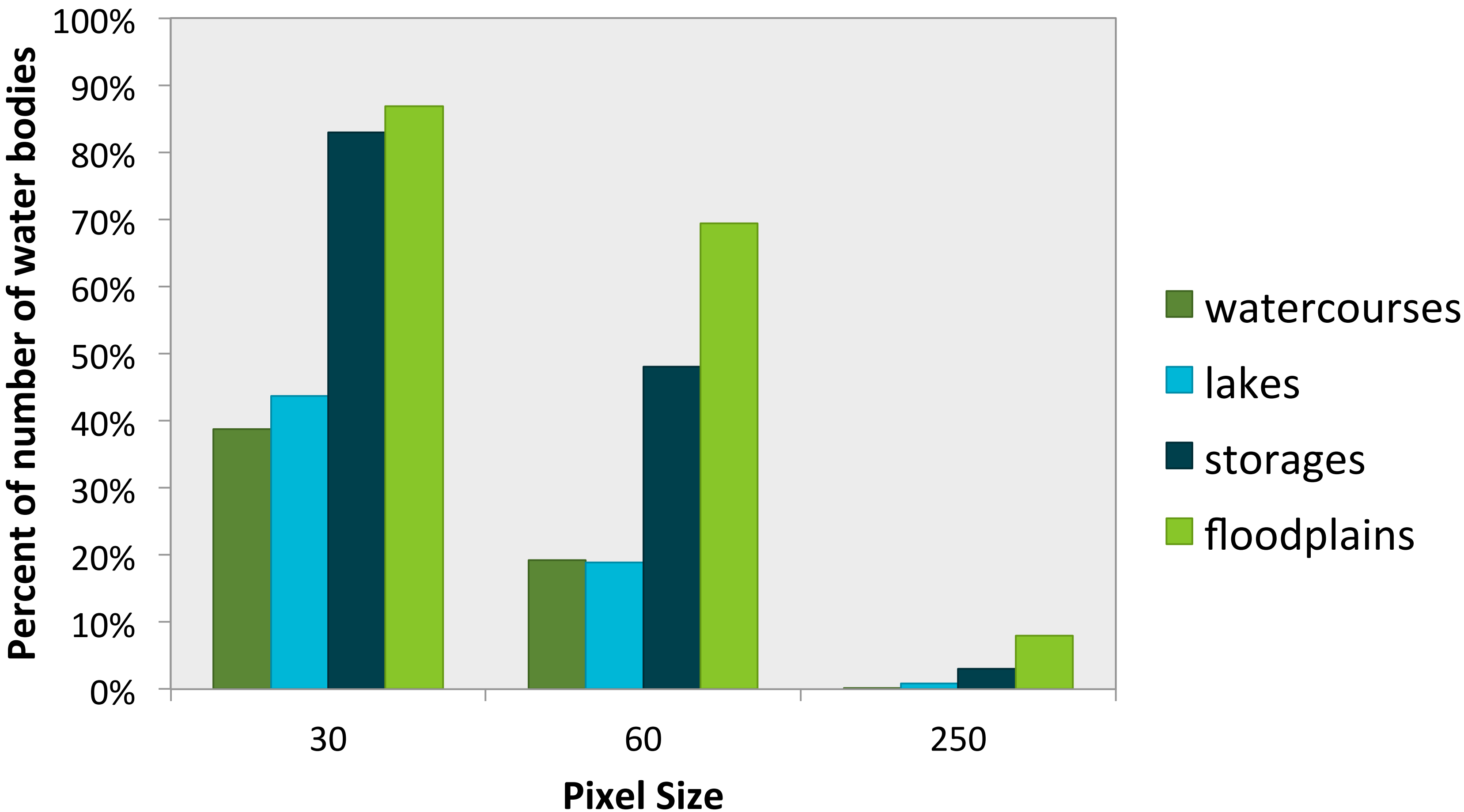
Continental Australia



Murray Darling Basin



EO-resolvable water bodies in Australia



Dekker & Hestir 2012, CSIRO

CSIRO

Relative capability for wq retrieval using free satellite data

	Pixel Size (m)	Bands (400-900 nm)	Revisit cycle	CHL	CYP	TSM	CDOM	SD	K_d
Low res.									
MODIS	1000	9	Daily	Highly suited	Potential	Highly suited	Highly suited	Highly suited	Highly suited
MODIS	500	2	Daily	Not suited	Not suited	Potential	Potential	Potential	Potential
MODIS	250	2	Daily	Not suited	Not suited	Potential	Not suited	Potential	Potential
MERIS	300	15	2-3 days	Highly suited	Highly suited	Highly suited	Highly suited	Highly suited	Highly suited
VIIRS	750	7	2x/day	Suited	Not suited	Suited	Suited	Suited	Suited
Med res.									
Landsat	30	4	16	Potential	Not suited	Suited	Potential	Suited	Suited
Future									
Sentinel-3	300	21	Daily	Highly suited	Highly suited	Highly suited	Highly suited	Highly suited	Highly suited
LDCM	30	5	16	Suited	Not suited	Highly suited	Suited	Highly suited	Highly suited
Sentinel-2	10-60	10	3-5 days	Highly suited	Potential	Highly suited	Suited	Highly suited	Highly suited
HySpIRI	60	60	19 days	Highly suited	Highly suited	Highly suited	Highly suited	Highly suited	Highly suited

● **Highly suited,** ● **Suited,** ● **Potential,** ● **Not suited**

- *Adapted from: Dekker and Hestir (2012). Evaluating the Feasibility of Systematic Inland Water Quality Monitoring with Satellite Remote Sensing, CSIRO*

Water quality variables from remote sensing e.g. WV-2

Chlorophyll

Colored dissolved organic matter

Cyano-pigments

Total suspended matter

Water column optically active components

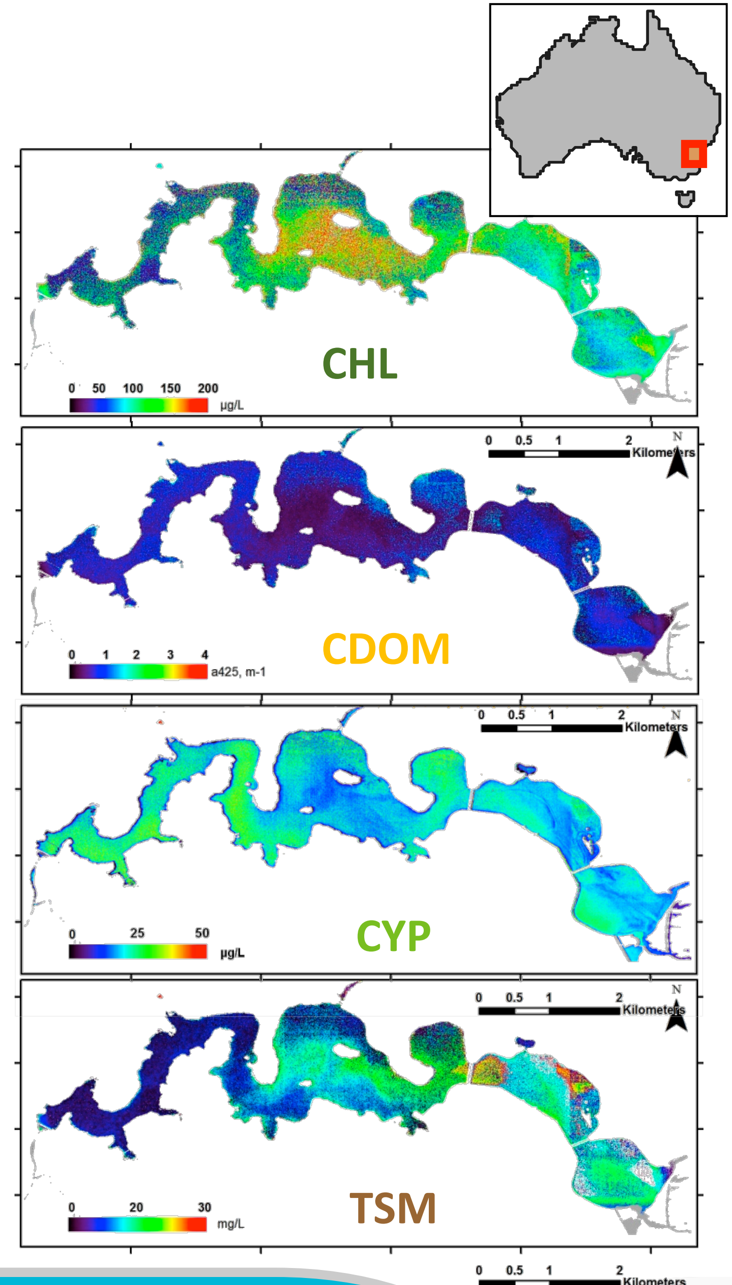
Vertical attenuation of light

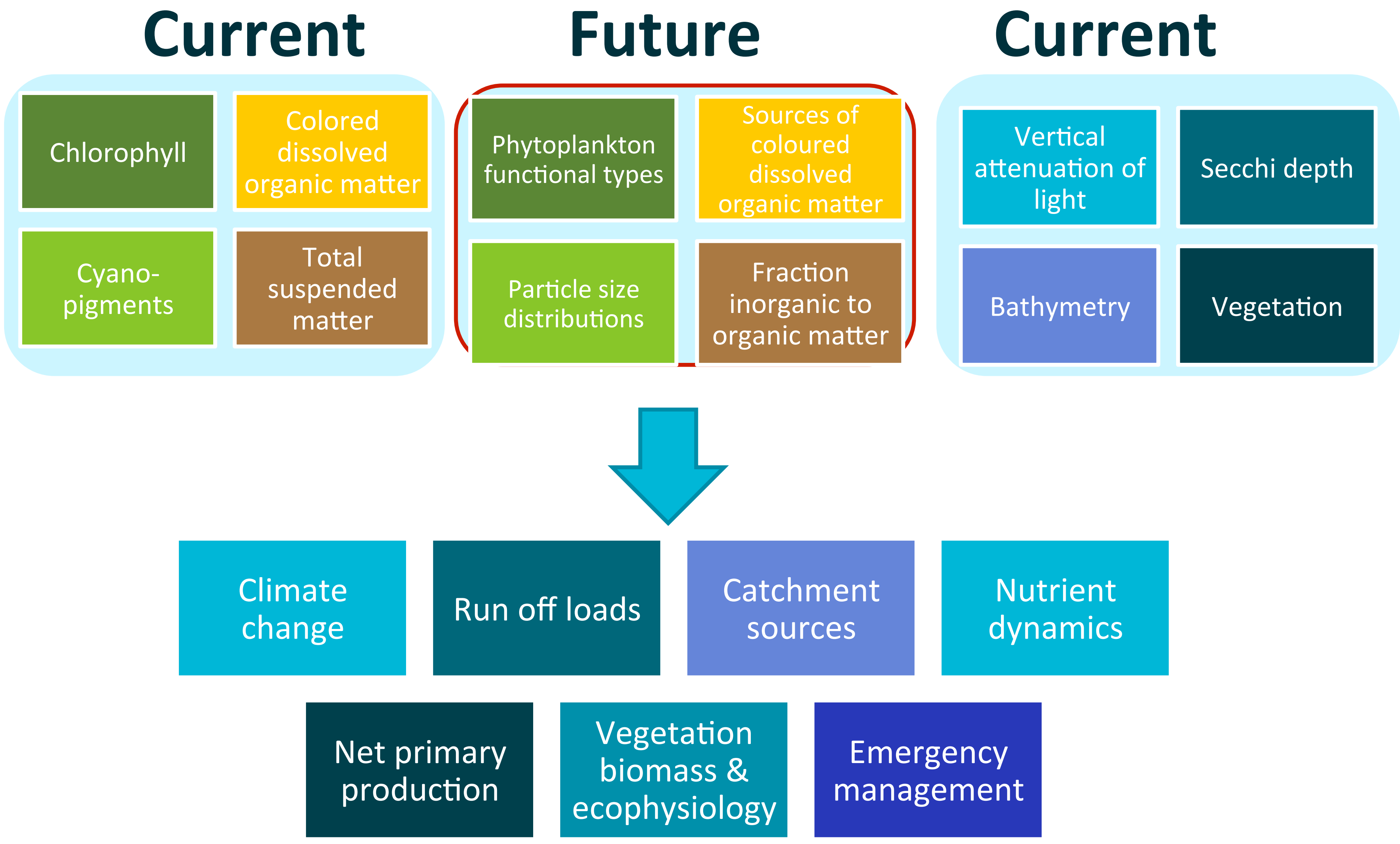
Secchi depth

Bathymetry

Vegetation

Estimated from water column properties





Current
Future
Current
Chlorophyll
Colored dissolved organic matter
Cyano-pigments
Total suspended matter
Phytoplankton functional types
Sources of coloured dissolved organic matter
Particle size distributions
Fraction inorganic to organic matter
Vertical attenuation of light
Secchi depth
Bathymetry
Vegetation
Climate change
Run off loads
Catchment sources
Nutrient dynamics
Net primary production
Vegetation biomass & ecophysiology
Emergency management

Current

Chlorophyll

Coloured dissolved organic matter

Cyano-pigments

Total suspended matter

CURRENT & FUTURE MSS

Future

Phytoplankton functional types

Sources of coloured dissolved organic matter

Particle size distributions

Fraction inorganic to organic matter

HYSPIRI

Current

Vertical attenuation of light

Secchi depth

Bathymetry

Vegetation

CURRENT & FUTURE MSS

Climate change

Run off loads

Catchment sources

Nutrient dynamics

Net primary production

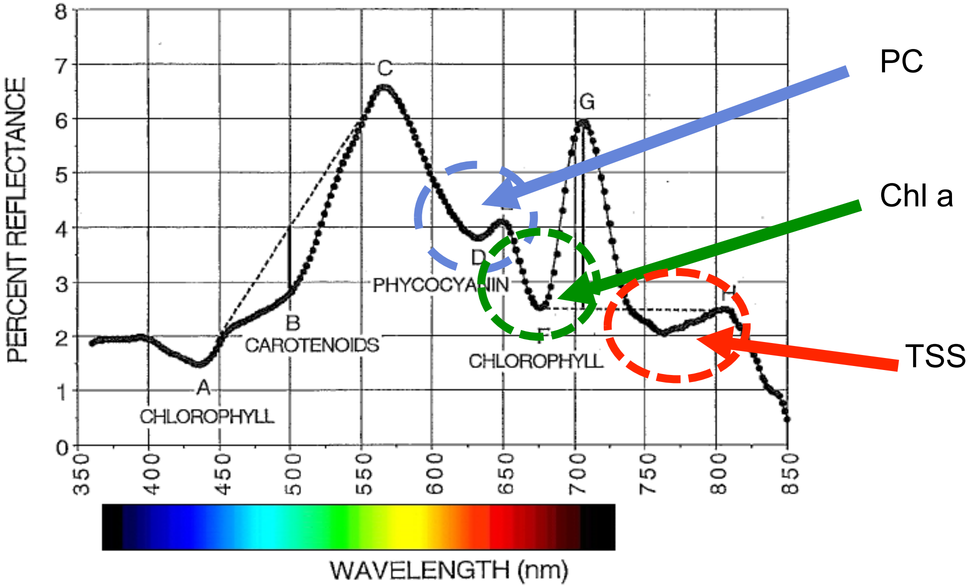
Vegetation biomass & ecophysiology

Emergency management

Pigment signals in spectral reflectance

Spectral resolution:

- Detect significant spectral features
- Discriminate different wq parameter signals



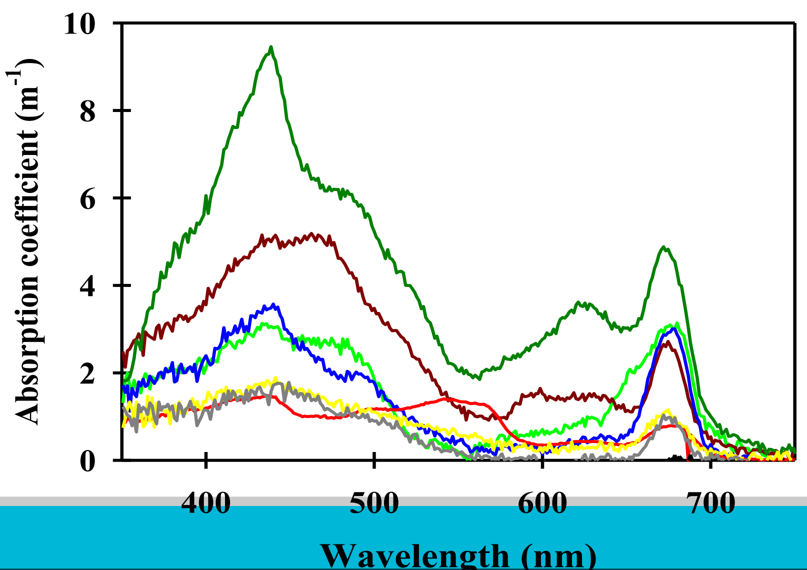
Schalles a

Colouring Material:Pigments in phytoplankton cultures: their light absorption and scattering

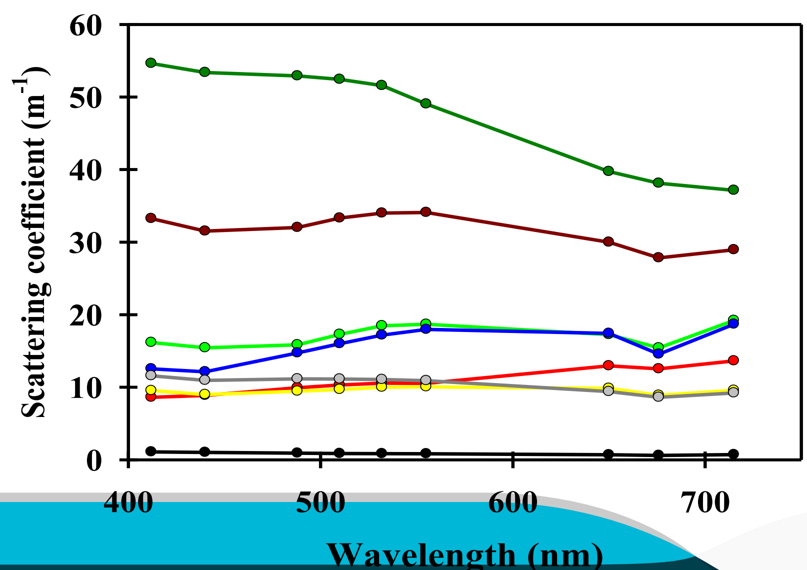
From left to right on the photo:

- Dunaliella tertiolecta
- Emiliania huxleyi
- Pavlova lutheri
- Porphyridium cruentum
- Synechococcus sp.
- Gymnodinium catenatum
- Thalassiosira pseudonana
- Chaetoceros socialis

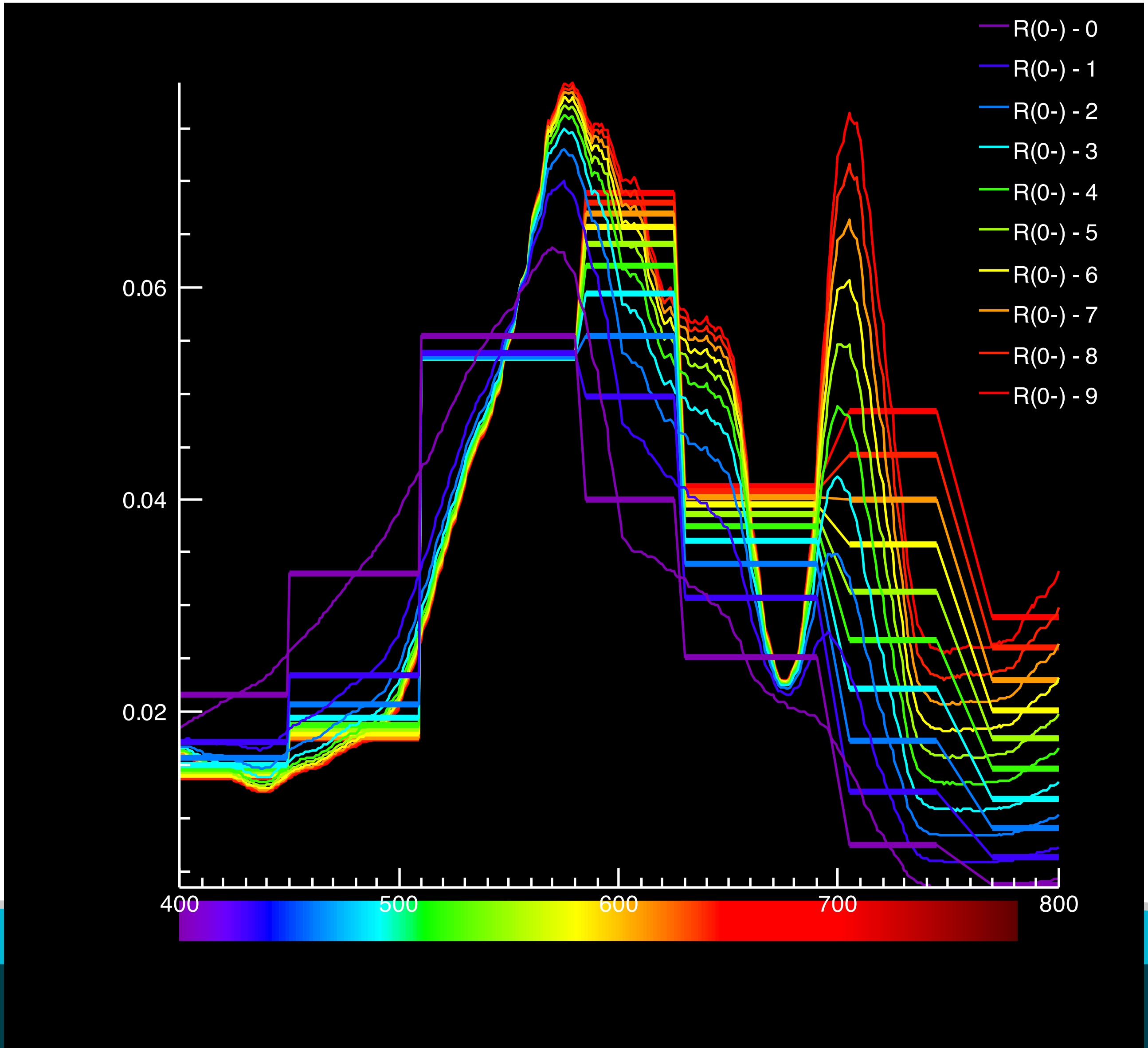
Phytoplankton absorption



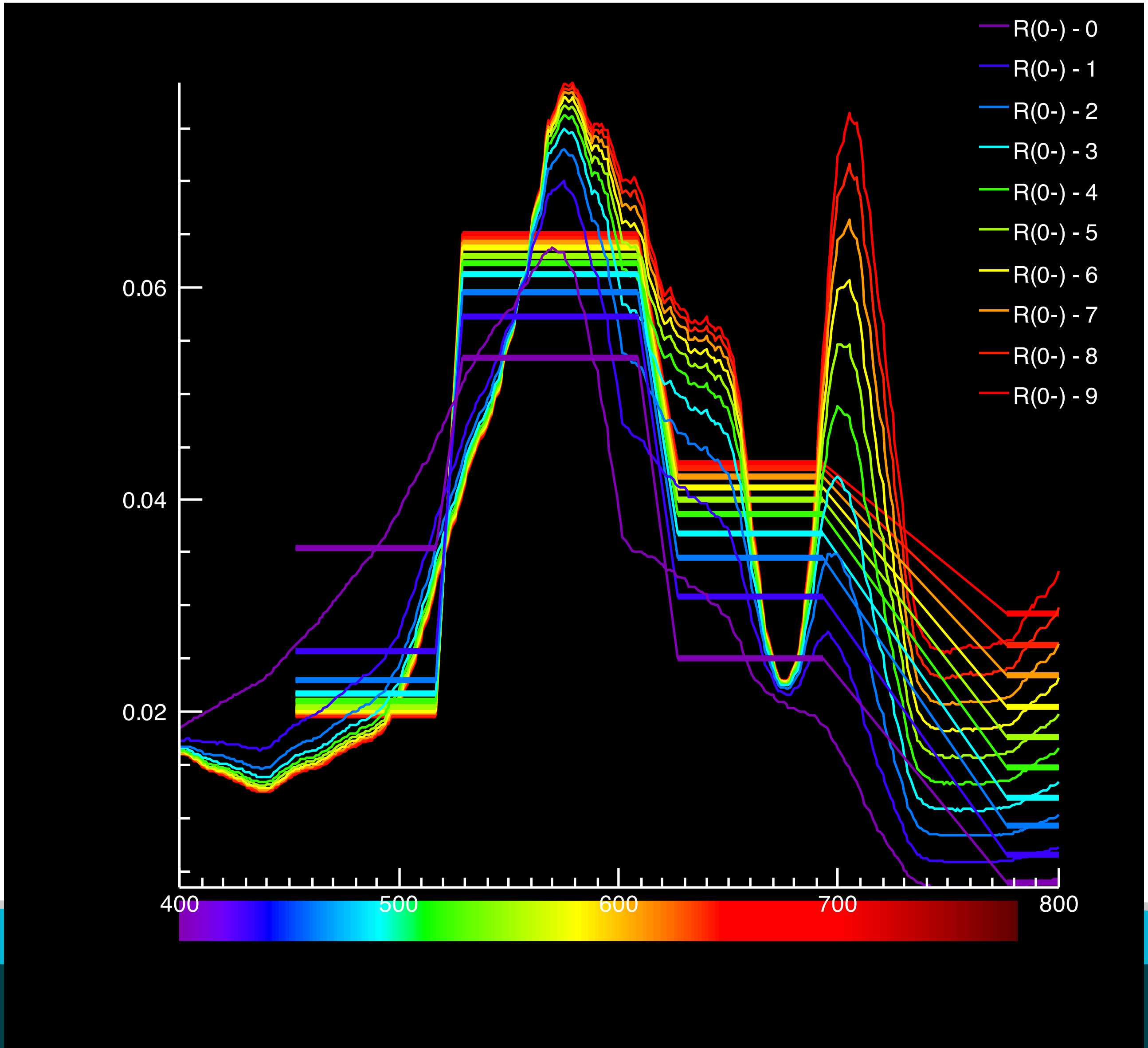
Phytoplankton scattering



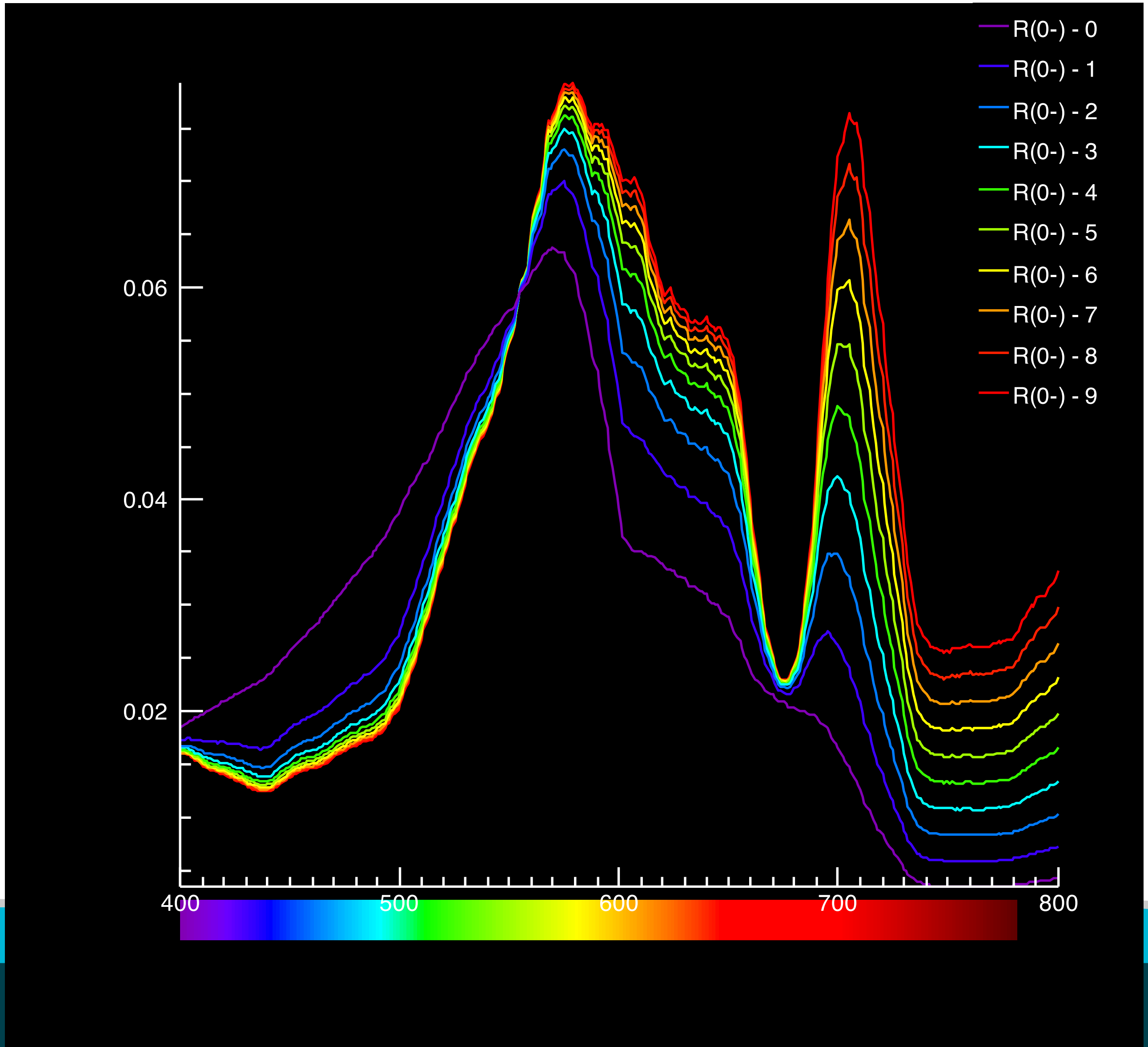
Algal bloom as seen by WorldView-2   2m



Algal bloom as seen by Landsat 30 m



Algal bloom reflectance simulation~ HyspIRI 60m



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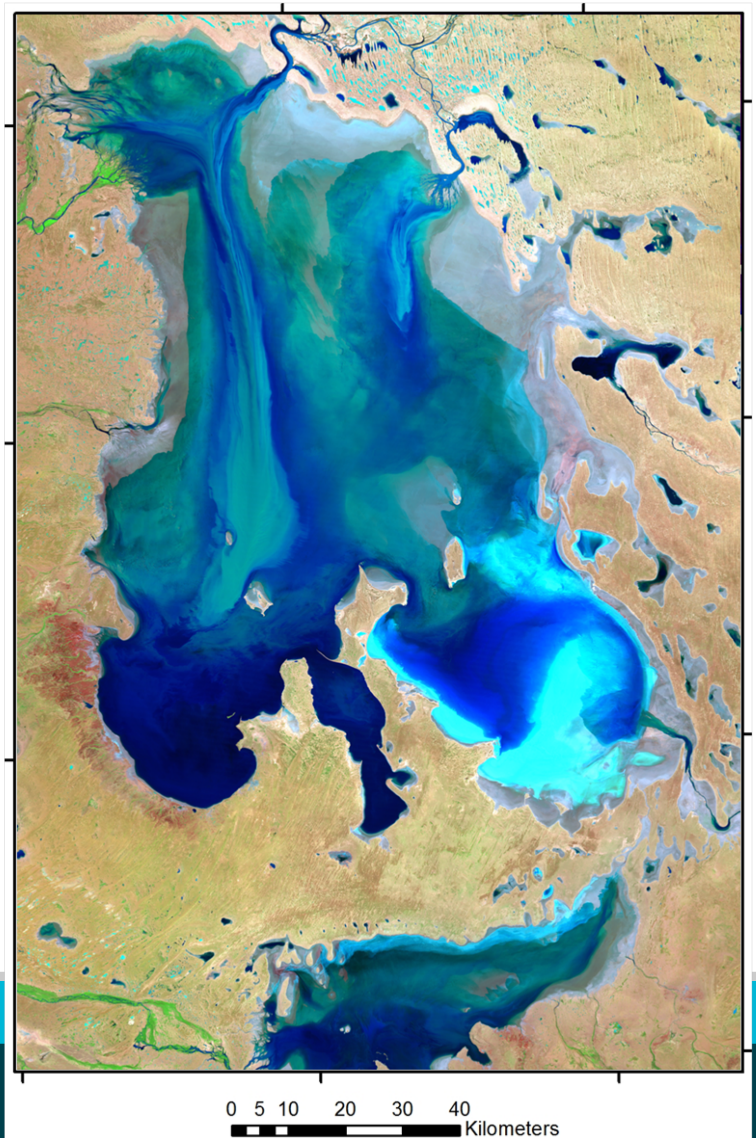
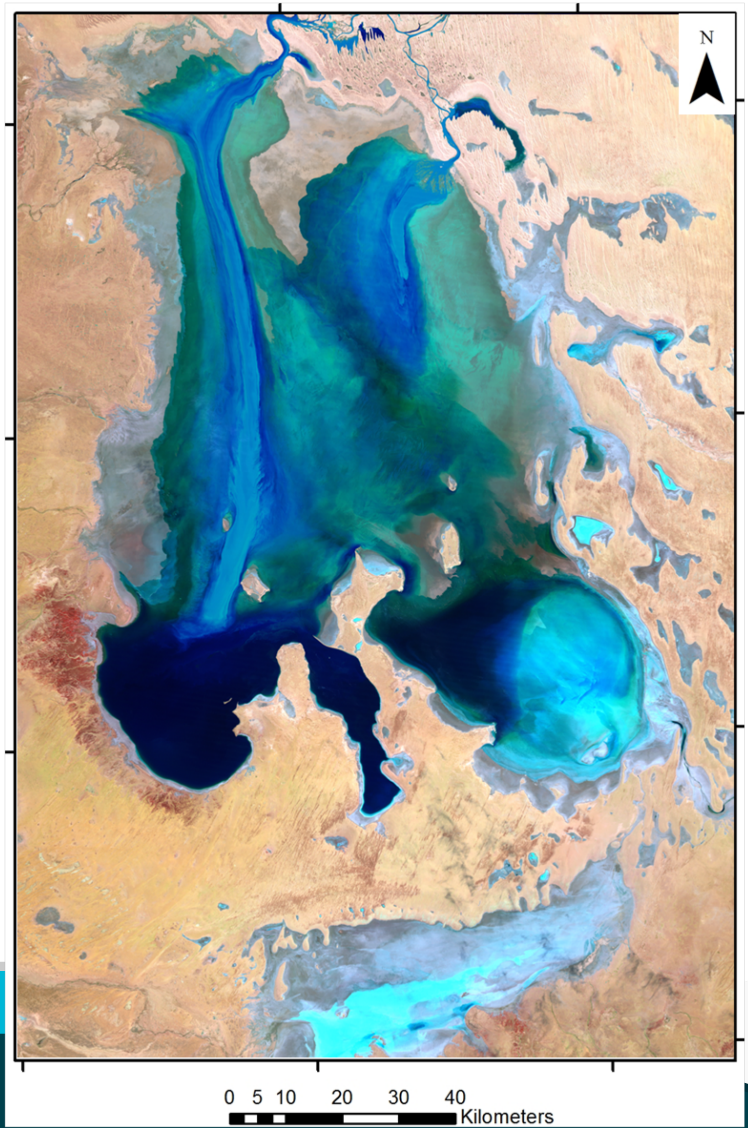
Needs bio-optical parameterisation of algorithm to estimate water quality or hyperspectral from space

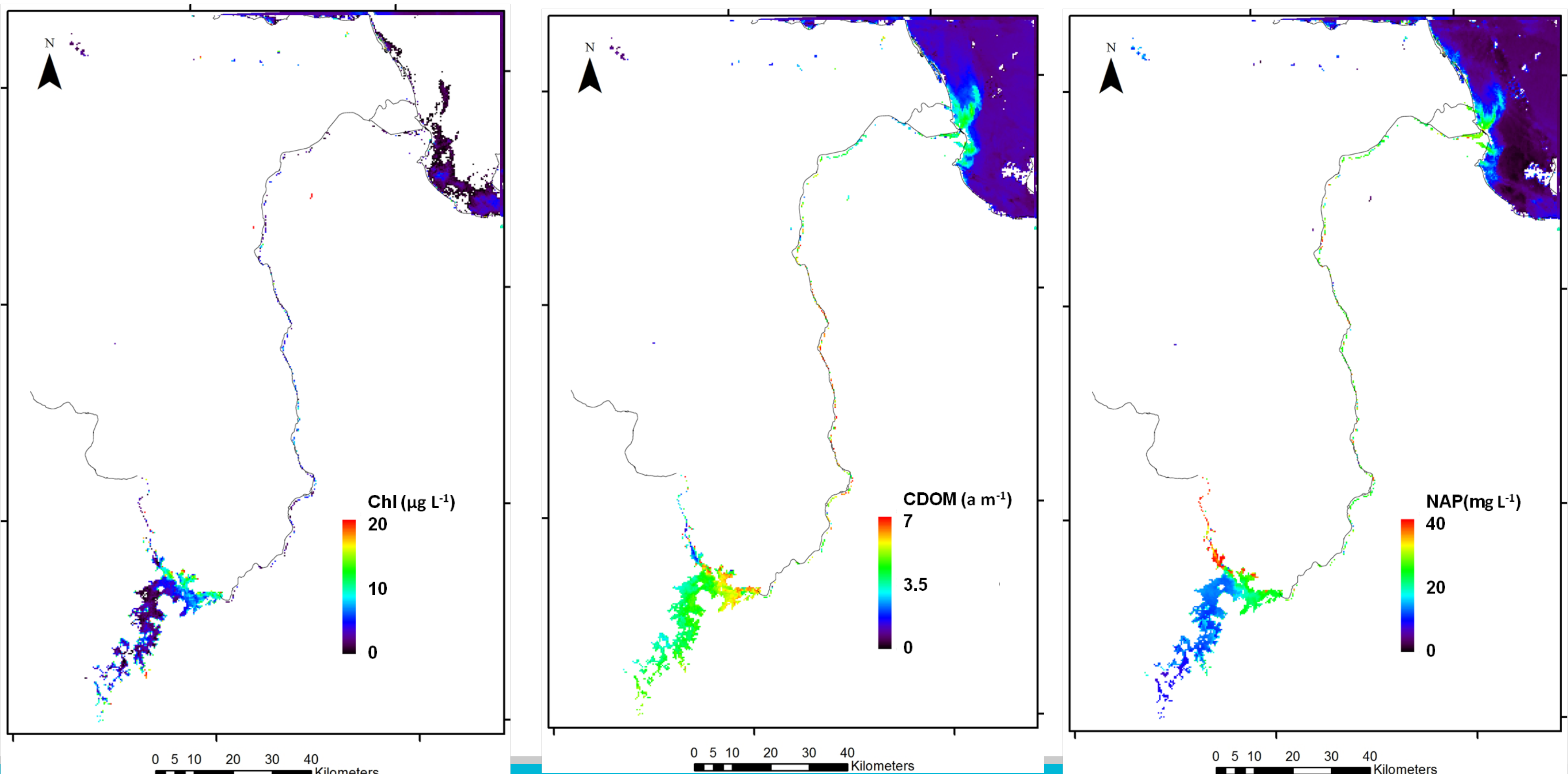
9th May 2009

28th March 2011

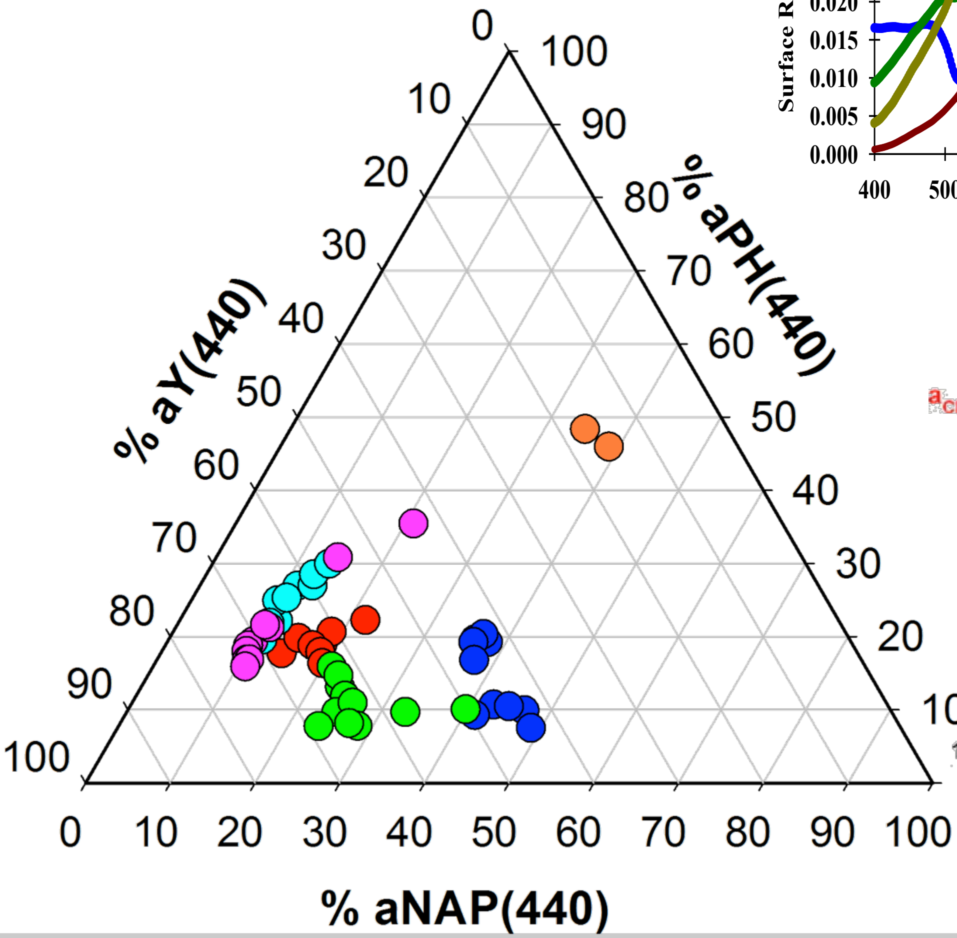


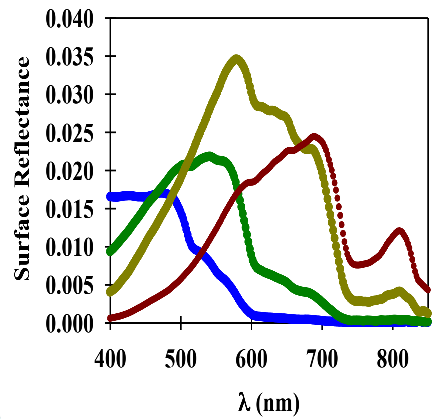


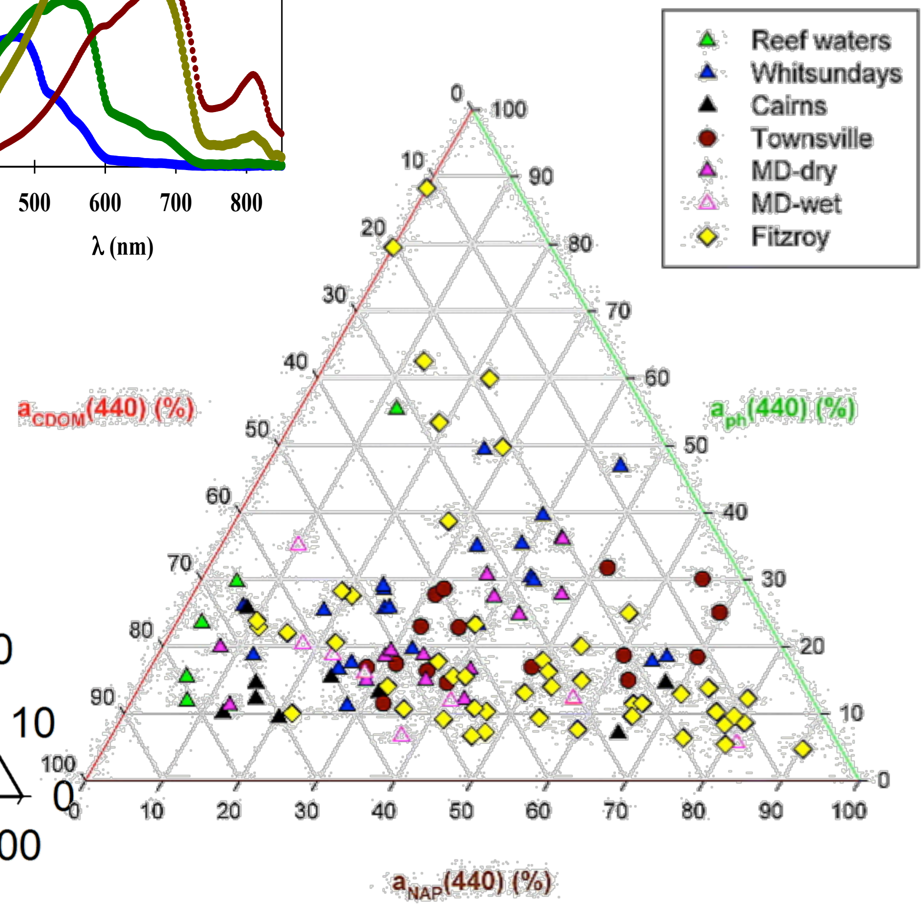
MERIS inland –coastal water example (from G. Campbell USQ)
Burdekin Falls Dam and Burdekin to GBR
MERIS : every two days a scene @ 300 m resolution

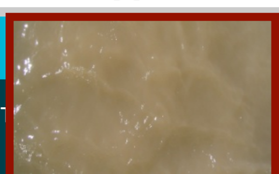


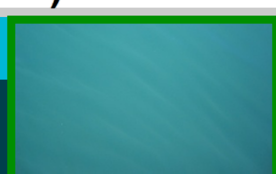
Inland waters->->->->->->->Coastal Waters

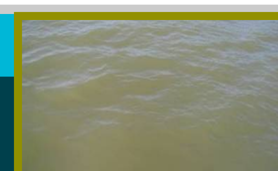


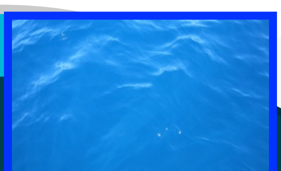












Semi-analytical approaches: the forward problem

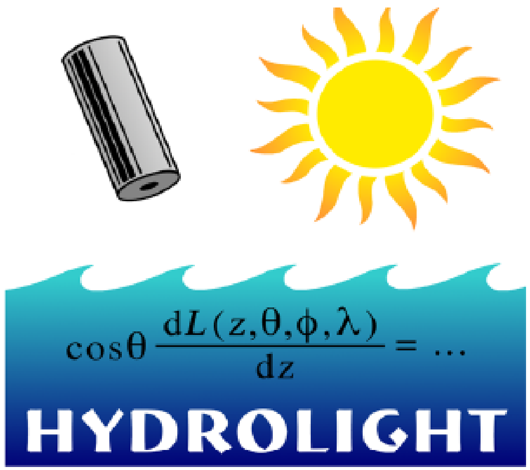
Index of refraction, distribution, particle size and properties of all constituents

→

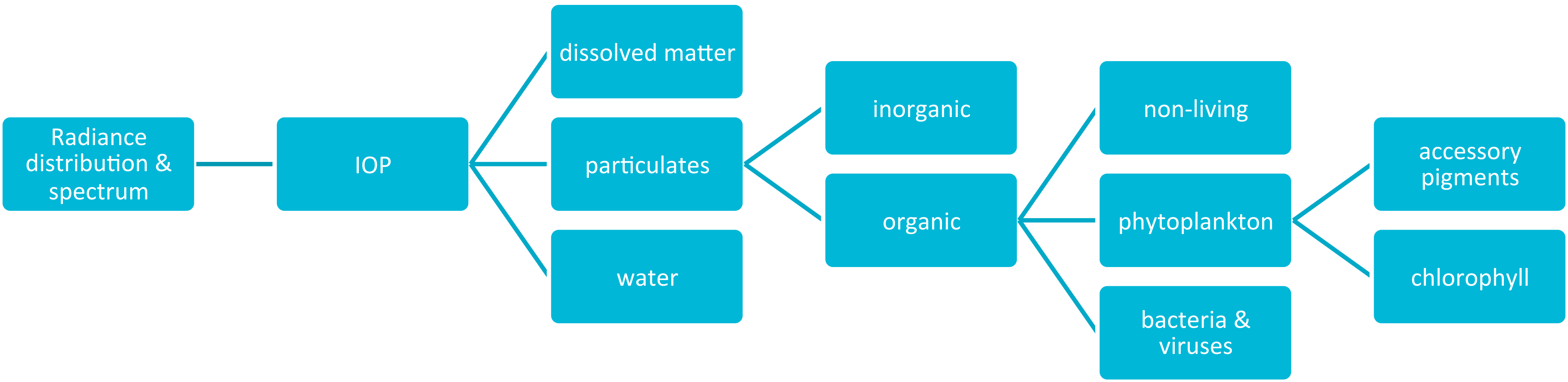
Inherent Optical Properties (IOPs)

→

Remote Sensing Reflectance



Semi-analytical approaches: the inverse problem



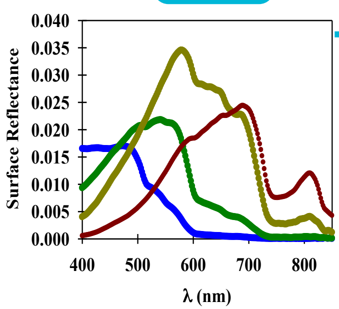
$$R_{rs}(\lambda)=f\,[a(\lambda),b_b(\lambda),\rho(\lambda),H,\Theta_w,\Theta_v,\psi]$$

IOCCG Report Number 5 (2006): *Remote Sensing of Inherent Optical Properties: Fundamentals, Tests of Algorithms, and Applications.*

Solution: The adaptive Linear Matrix inversion (a-LMI) hyperspectral parameterisation-EO sensor agnostic

Loop RTE inversion over candidate model parameter sets

r_{rs}



$SIOP_k$ = Candidate model parameter set k

$[a^*_{phy}(\lambda), S_{CDOM}, a^*_{NAP}(440), S_{NAP}, b^*_{bphy}(555), Y_{phy}, b^*_{NAP}(555), Y_{NAP}]_k$

$[C_{CHL}, C_{CDOM}, C_{NAP}]_k = f(r_{rs}^{input}, SIOP_k)$

$\Delta k = \Delta(r_{rs}^{input}, r_{rs}^{model}{}_k)$

C_{CHL}
C_{CDOM}
C_{NAP}

a_{phy}
a_{CDOM}
a_{NAP}
b_{bphy}
b_{bNAP}

Brando et al, 2012, Applied Optics

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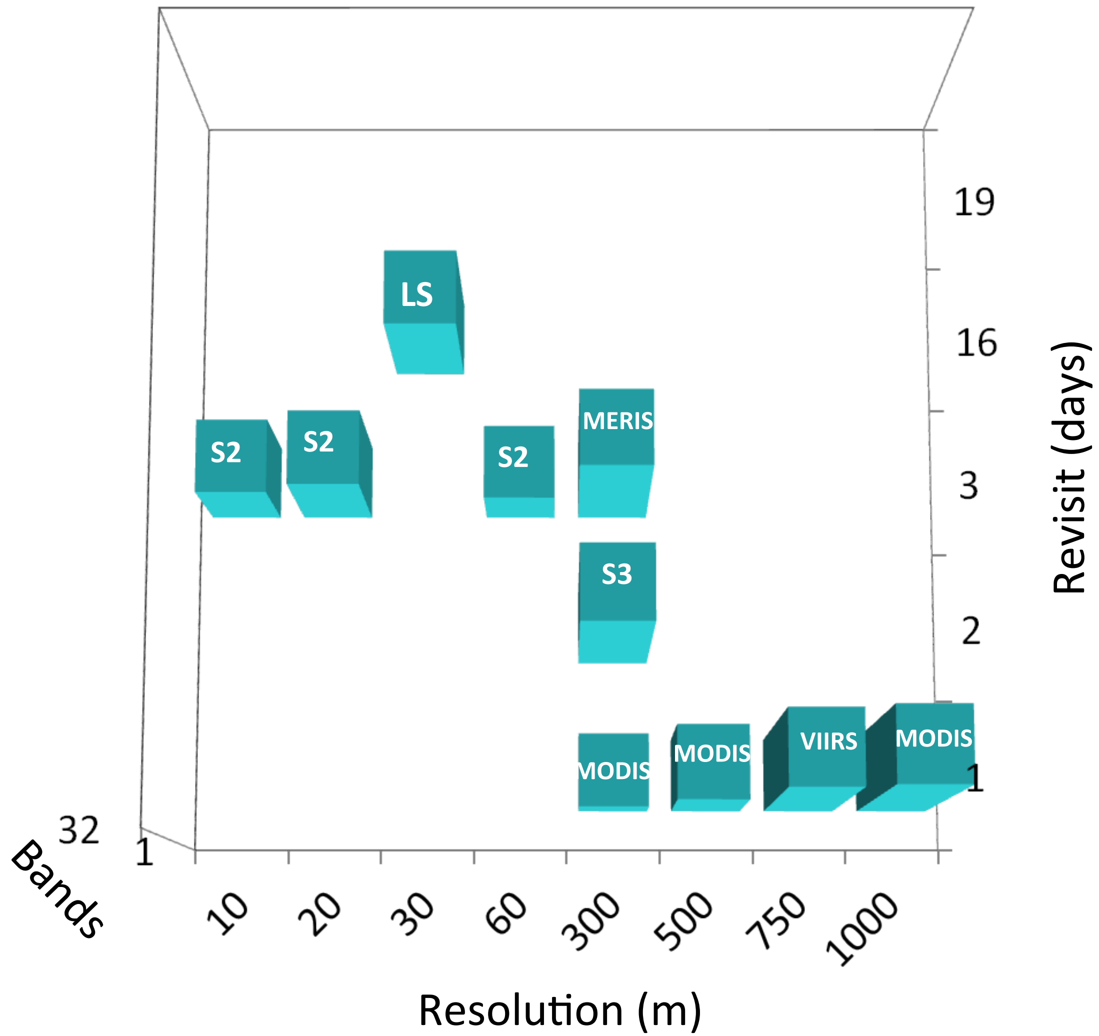
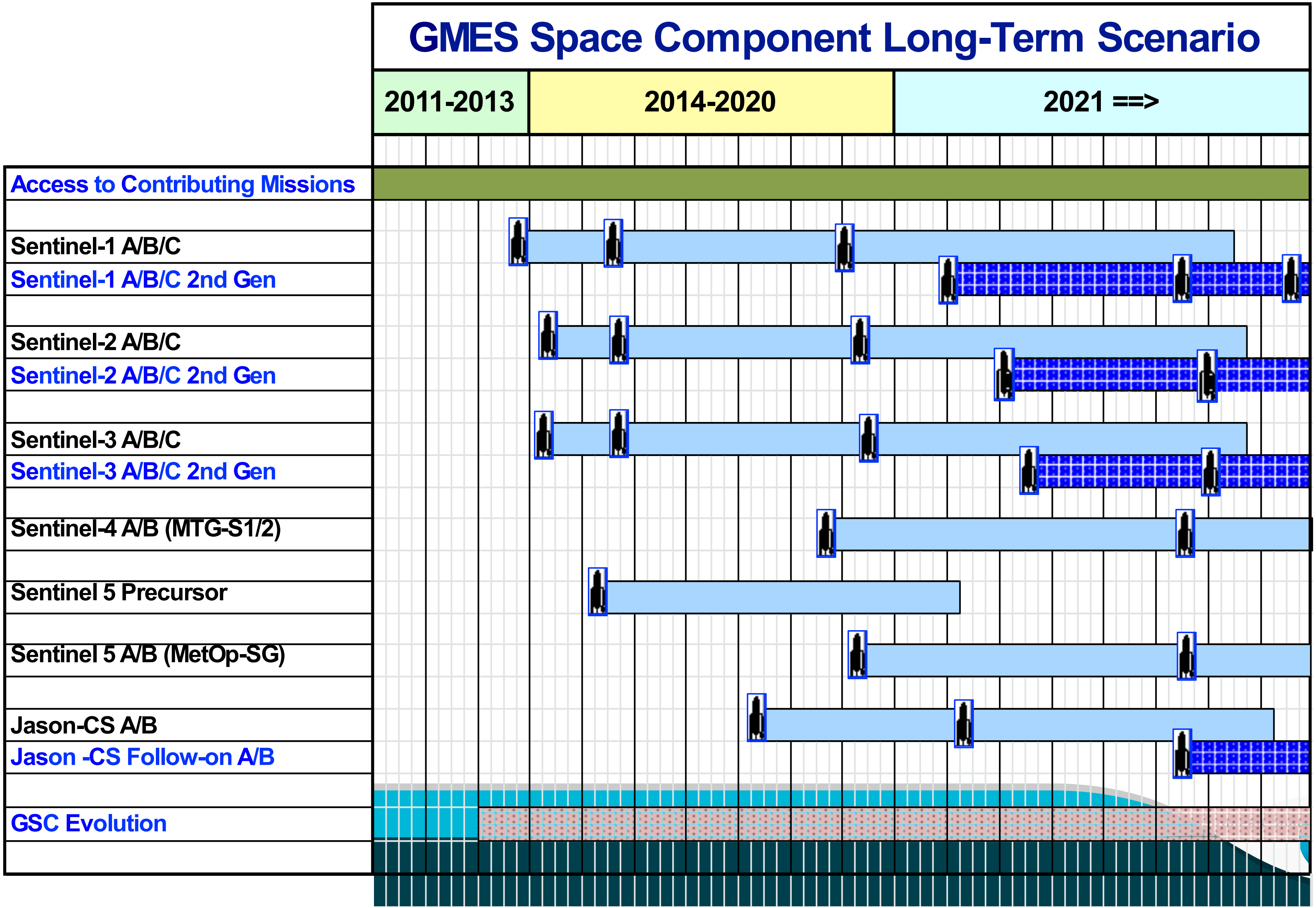
Current & pending global mapping capabilities



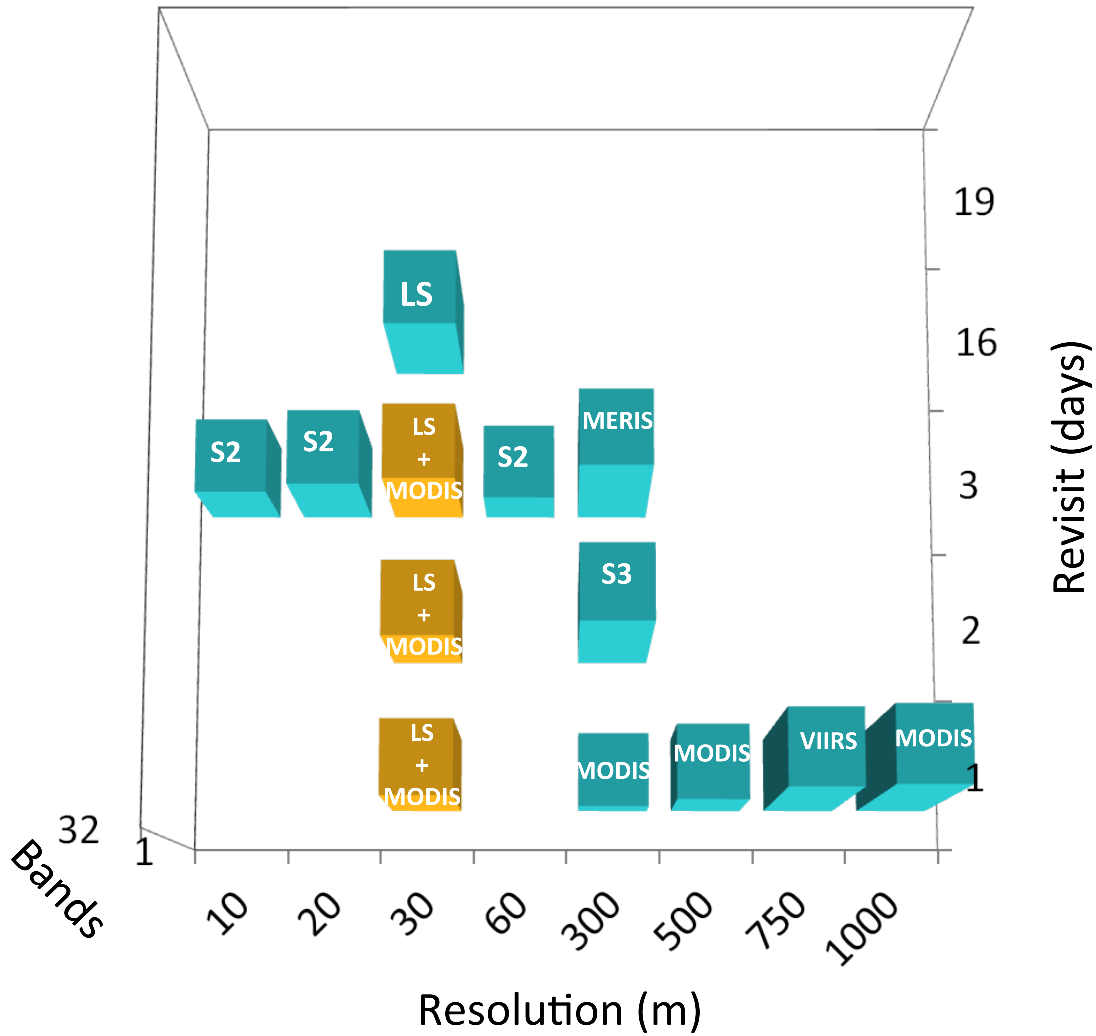
Sentinel-2 as an Optically Deep Water Sensor

Band Nr	Spatial Resolution (m)	Spectral width (nm)	From λ	To λ	Optically Deep Water
1	60	20	433	453	Chlorophyll, CDOM, NAP, Kd + Turb + SD
2	10	65	458	523	Carotenoids, zeaxanthine, CDOM, TSM,Kd + Turb + SD
3	10	35	543	578	Cyanophyco-erythrin, TSM, CDOM, Kd + Turb + SD
4	10	30	650	680	Chlorophylls, TSM, Kd + Turb + SD
5	20	15	698	713	TSM, Kd + Turb + SD, floating algal layers & macro-algae
6	20	15	733	748	TSM, Sunglint,floating algal layers & macro-algae
7	20	20	773	793	TSM, Sunglint,floating algal layers & macro-algae
8	10	115	785	900	TSM, Sunglint
8a	20	20	855	875	ATCOR, Sunglint
9	60	20	935	955	ATCOR, Sunglint
10	60	30	1360	1390	ATCOR
11	20	90	1565	1655	
12	20	180	2100	2280	

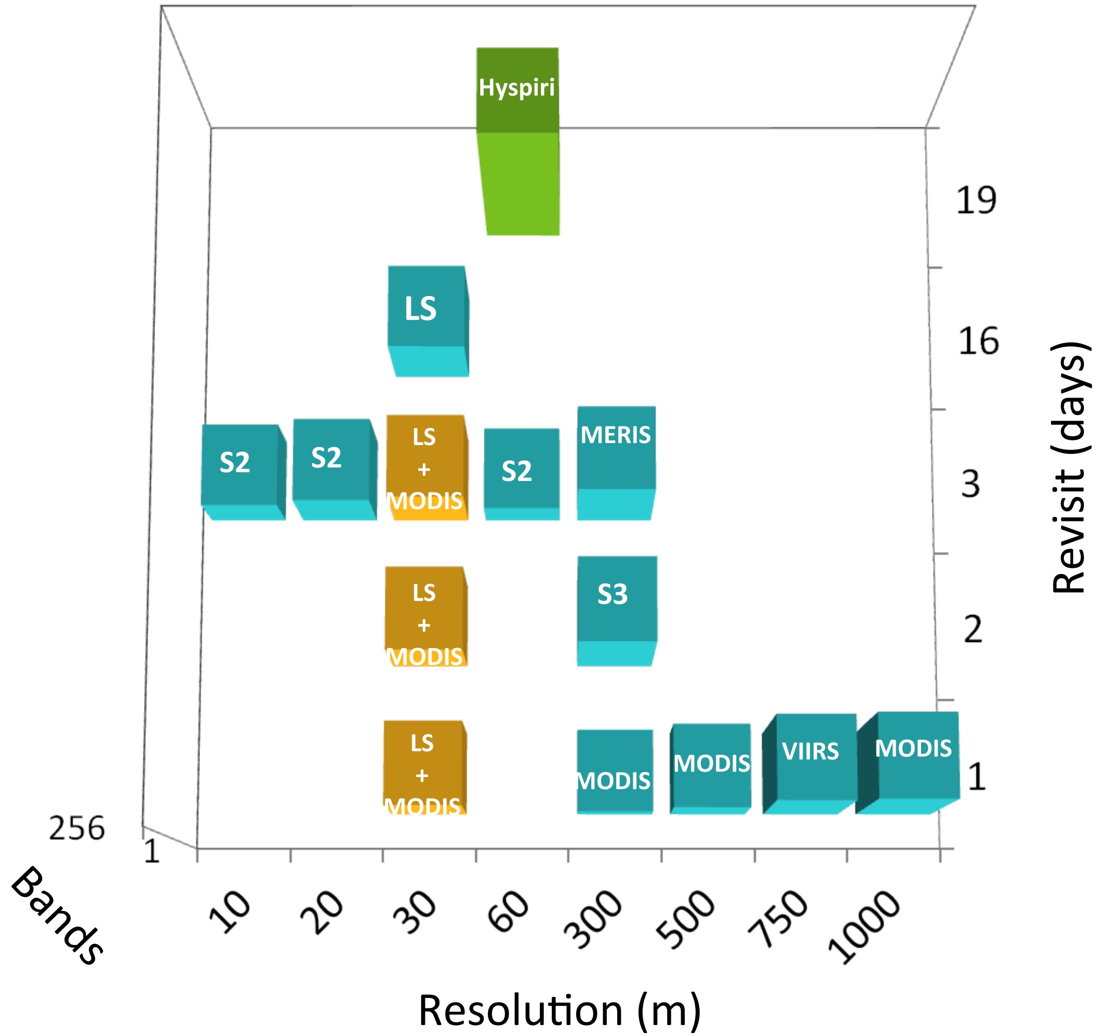
Users need decade-long term perspectives



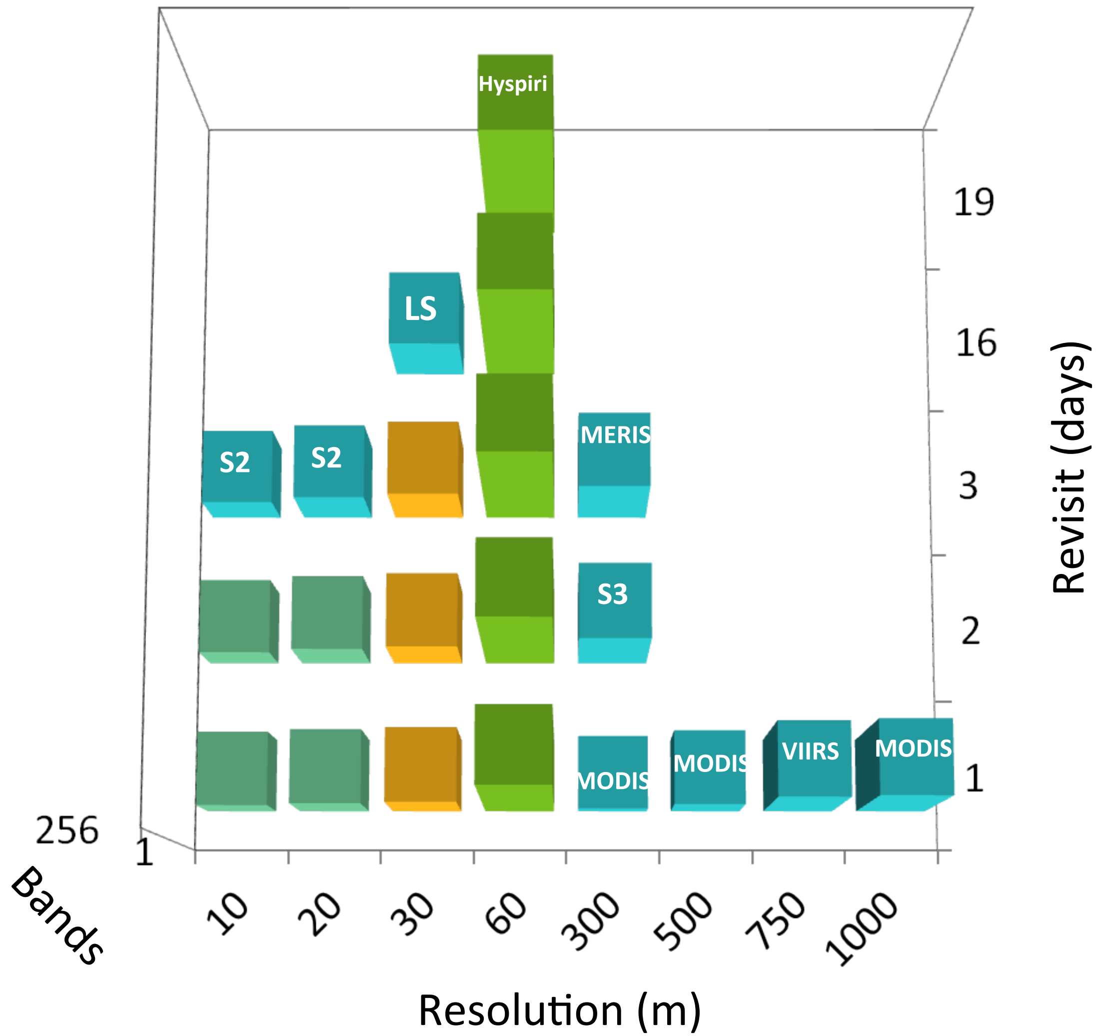
Current blending opportunities



Hyspiri's contribution to global mapping



Future blending potential



Towards an Aquatic Earth Observation System: using tools such as hydrodynamic and biogeochemical models, in situ observations and multi-and hyperspectral earth observation to:

- Eutrophication- Nutrients Fluxes & Budgets
  - Inland waters, bays and estuaries: water quality, macrophytes & habitat
- Carbon Fluxes & Budgets
  - Land to inland water body to sea: fluxes and reservoirs
- Climate Change
  - Retrospective time series analyses for trend and anomaly detection (including areas in Australia where nothing has been measured previously)
- Shoreline erosion and flooding
  - Effect of land-use changes on run-off
  - Riparian and flood plain
  - Bathymetry and DEM
- National Environmental Accounts
  - Habitat status, State of Environment reporting
- Emergency management
  - Potentially harmful algal blooms
  - Oil & Chemical Spill Response;