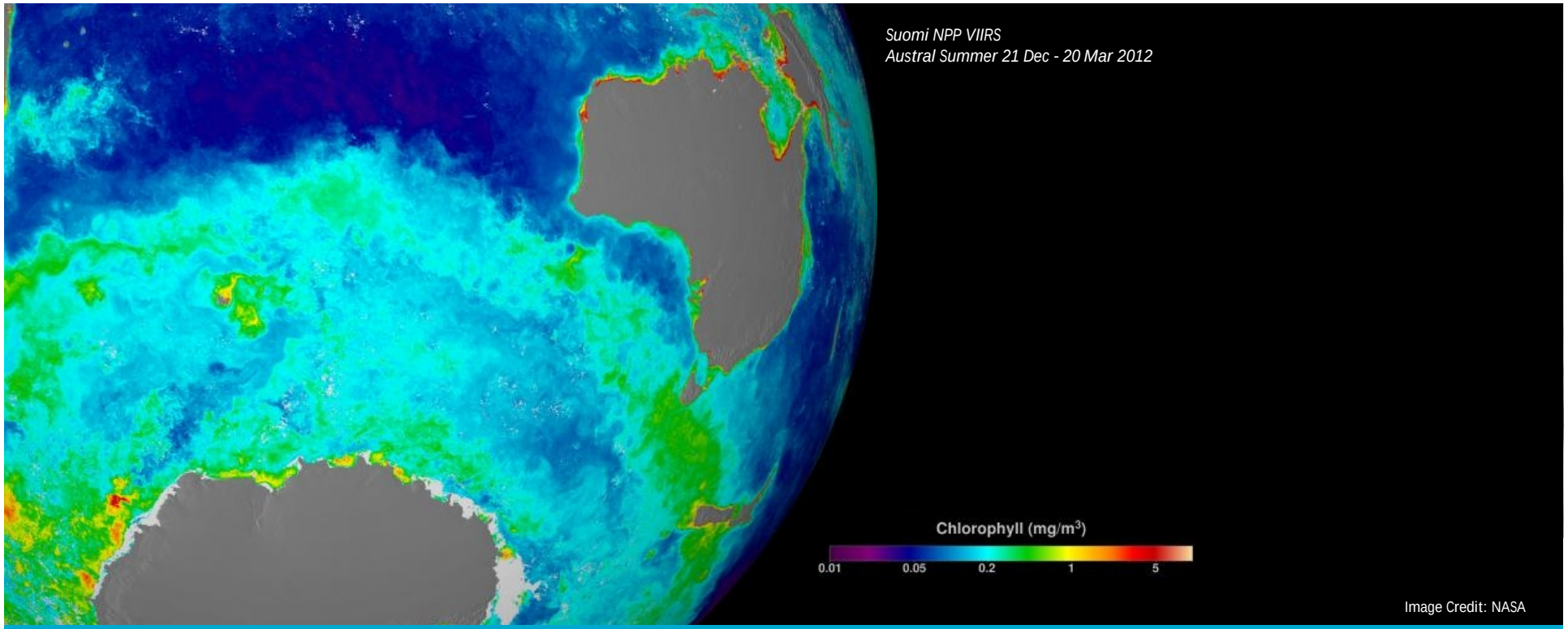


IMOS Ocean Colour Products

Dr Edward King | IMOS Satellite Remote Sensing Facility Leader
and **Dr Thomas Schroeder** | IMOS SRS Ocean Colour Sub-facility co-leader
9 November 2015

CSIRO OCEANS & ATMOSPHERES
www.csiro.au

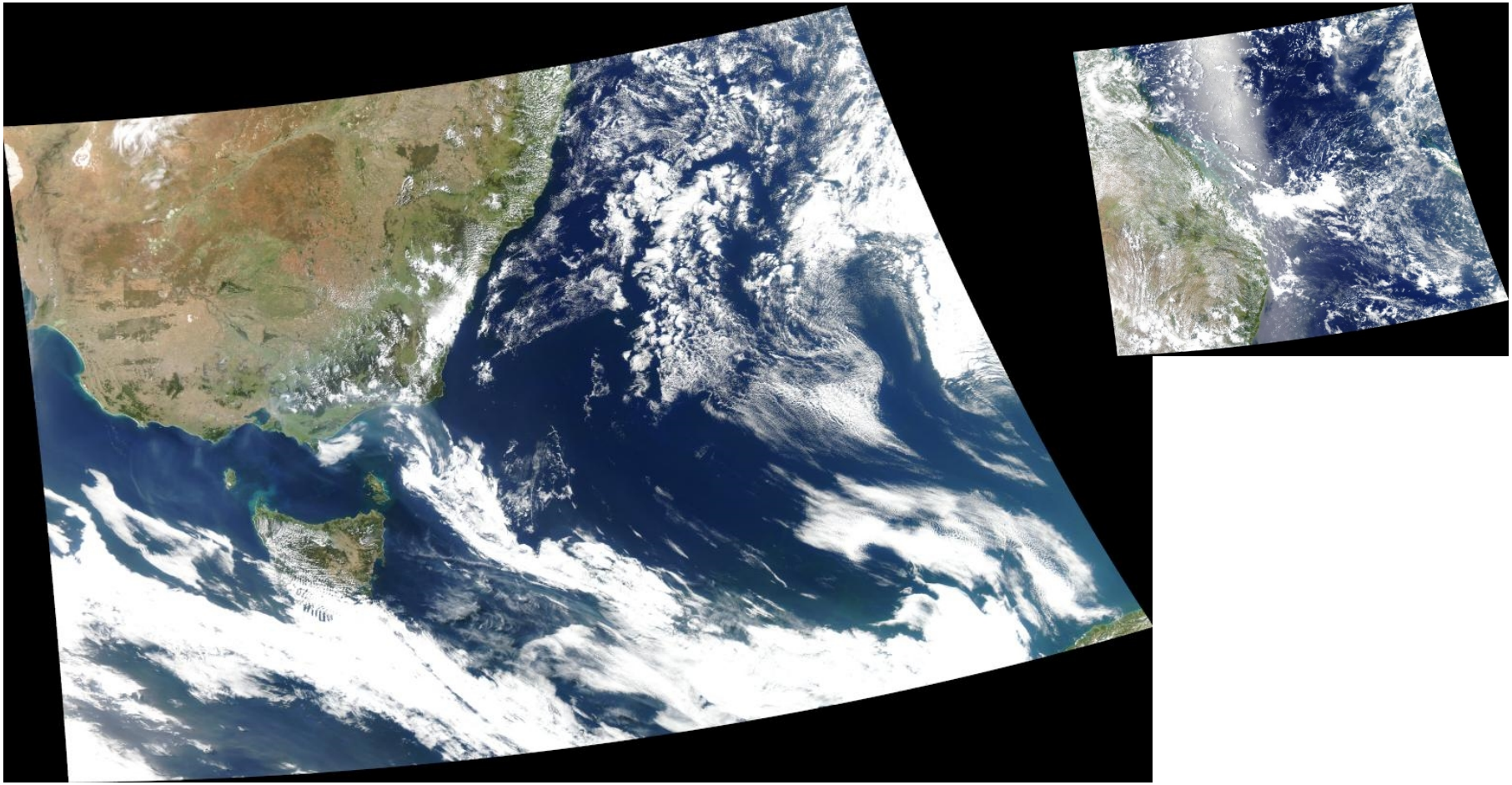
Outline

- Background
  - What is satellite ocean colour
  - Measurements/modelling
- IMOS goals and investments
  - Satellite Data Products
    - Examples using MODIS
    - Other sensors
  - In-situ calibration
    - Bio-Optical Database
    - DALEC
    - Lucinda Jetty

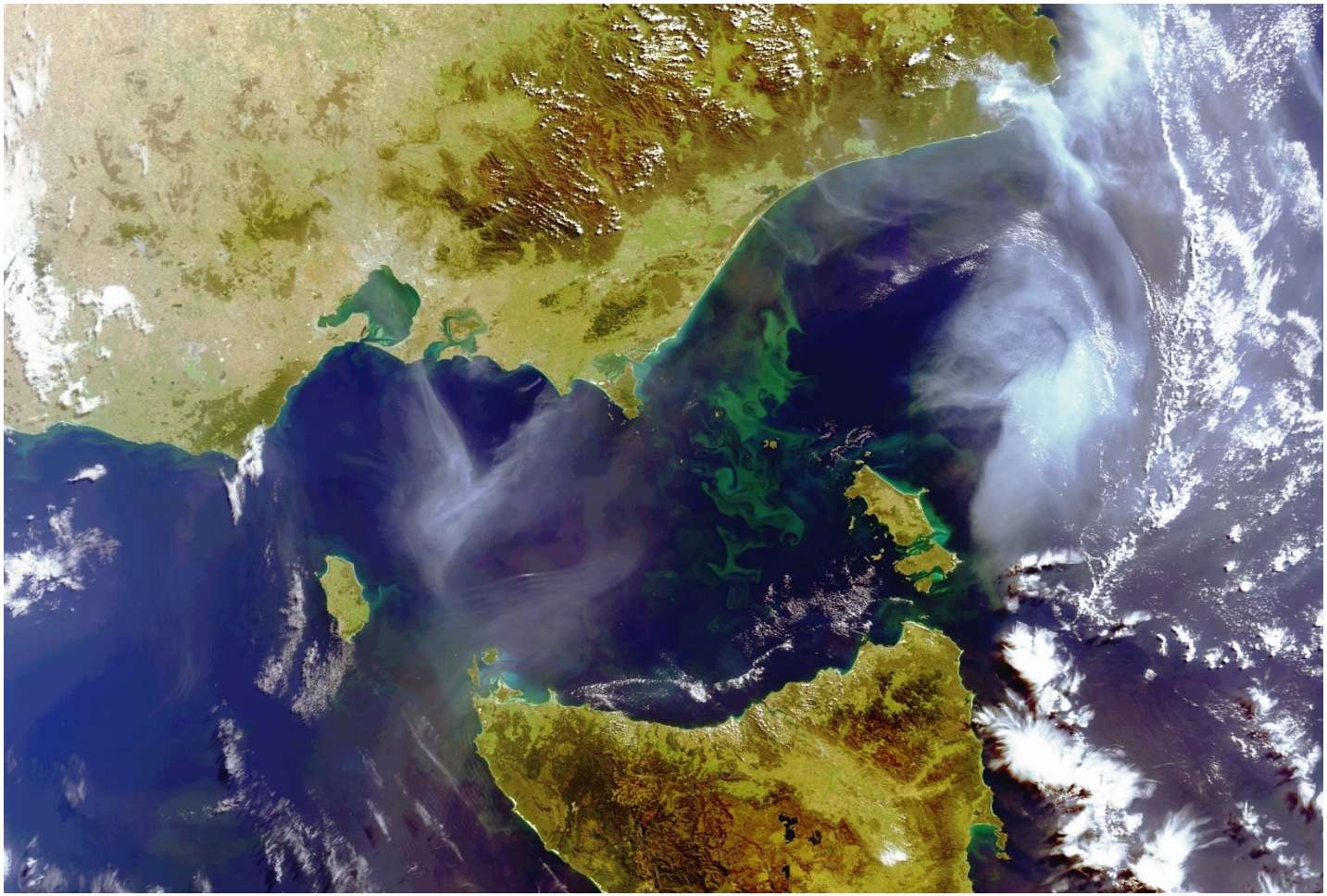
Ocean Colour Background

- **This is a USER workshop**

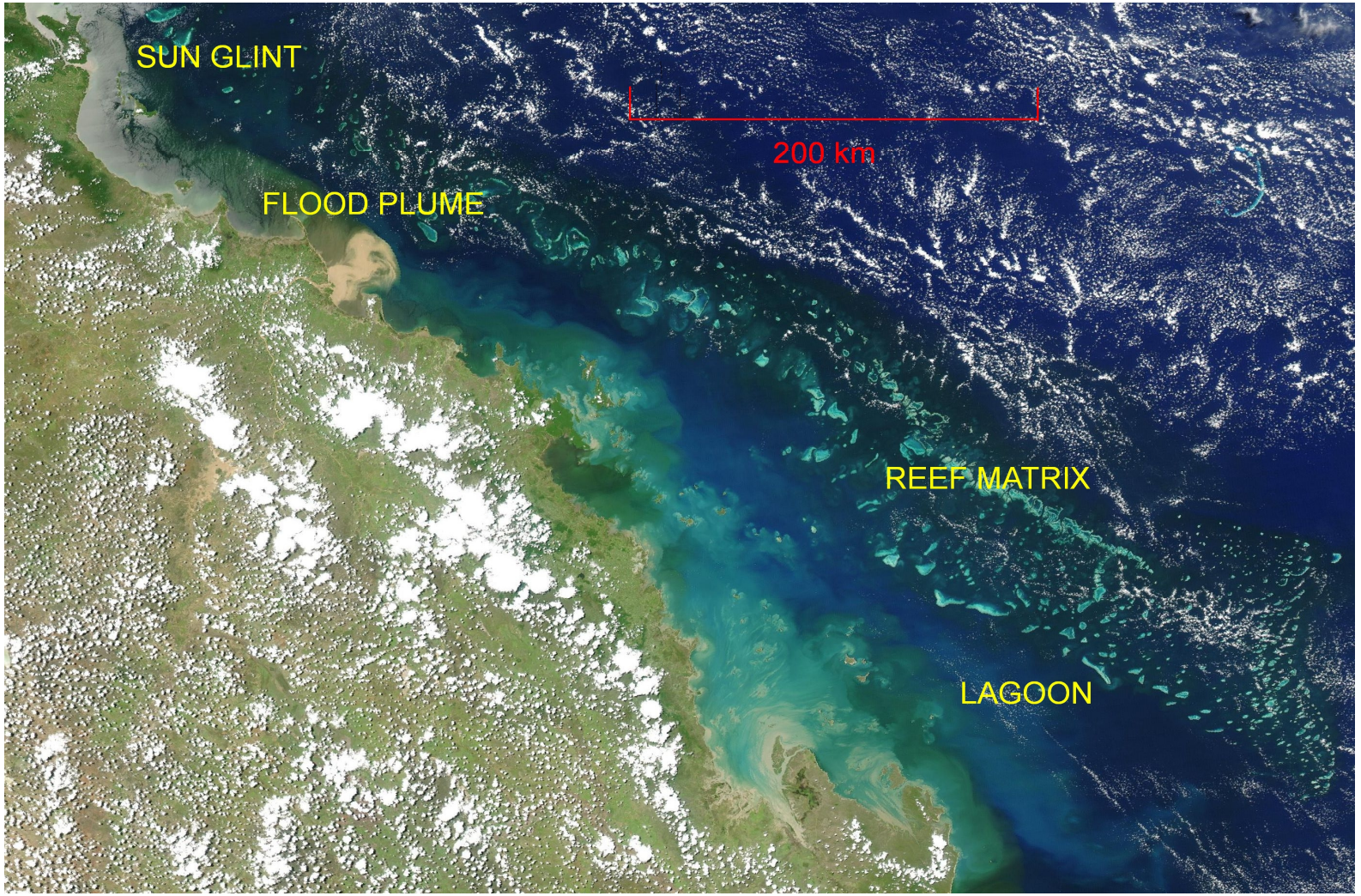
Imaging from space, sunlight reflected from the upper layer of the ocean (NOT the surface)



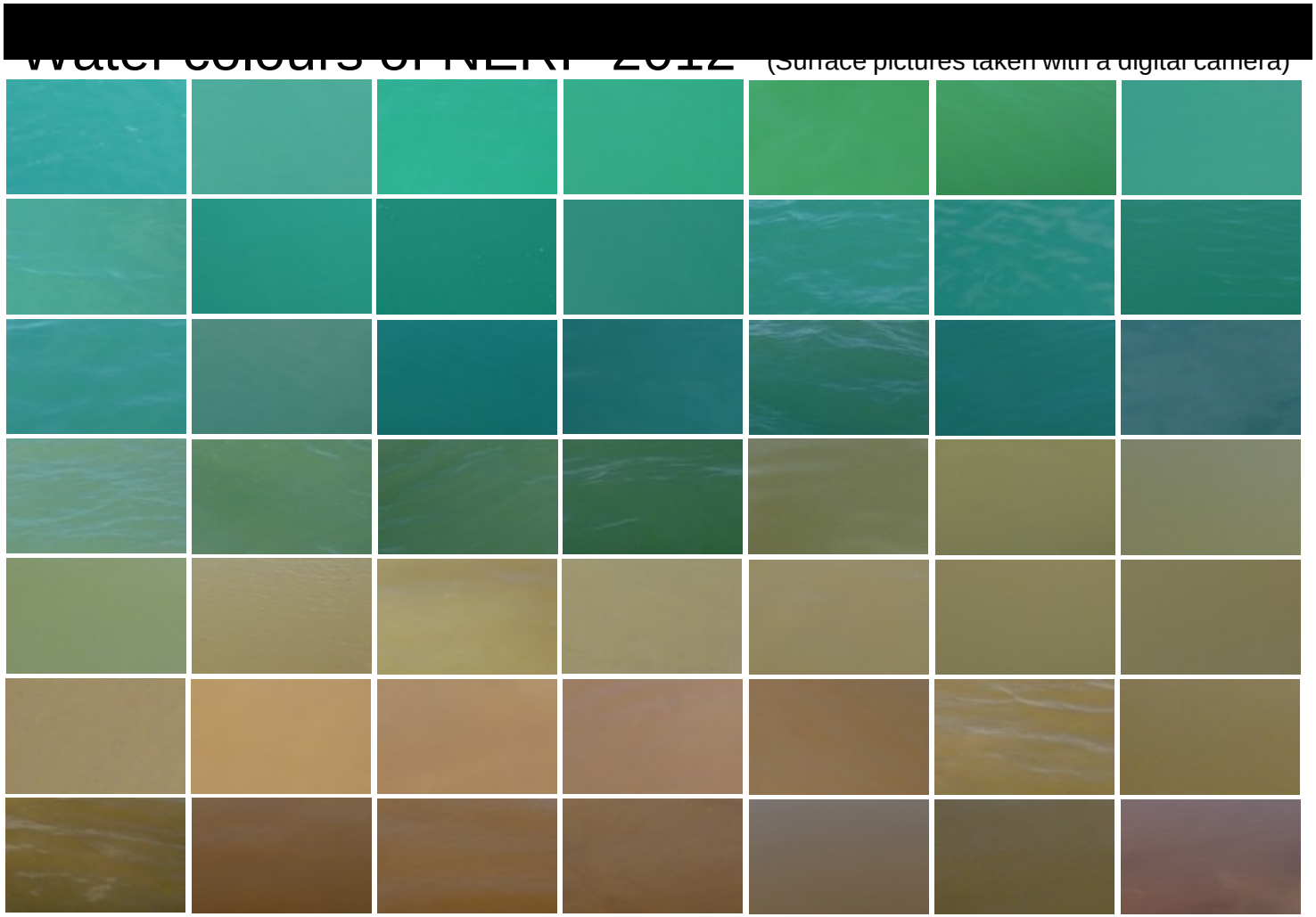
Looking more closely in the ocean...



...and in the coastal zone

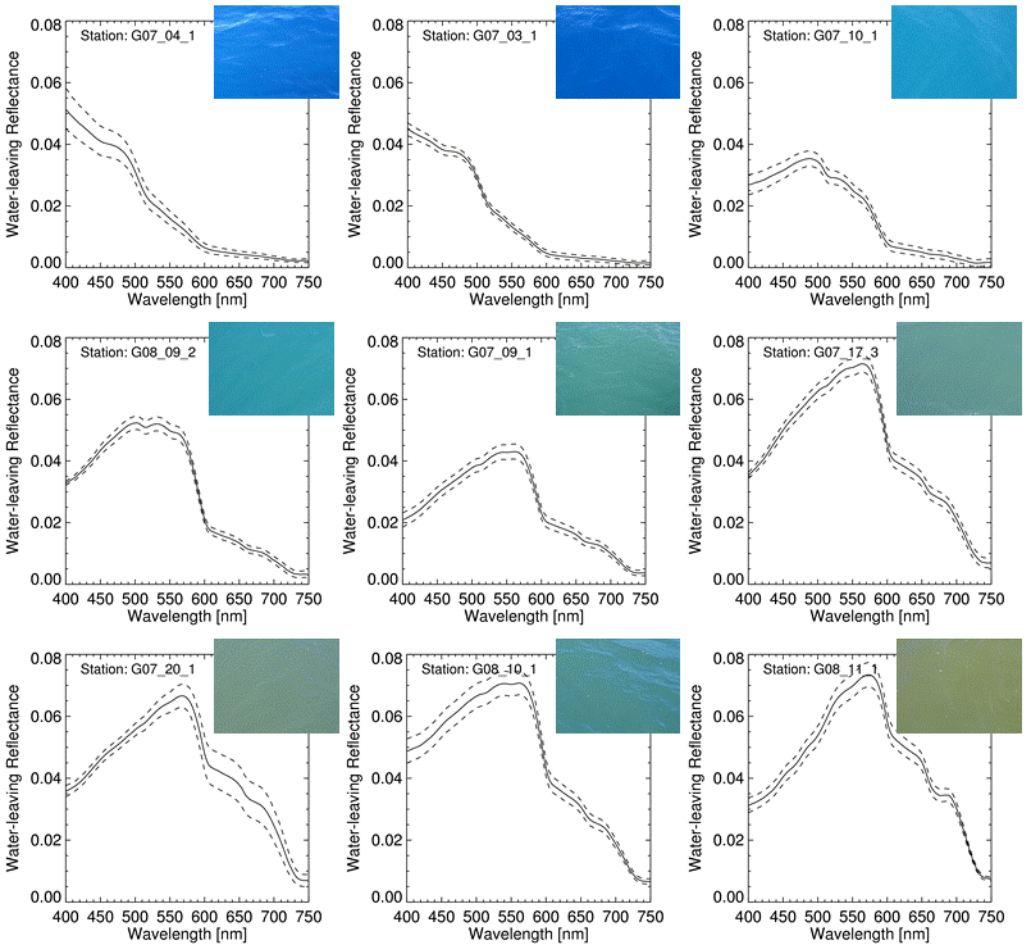


More systematically...



Towards measurement

Reflectance Spectra Fieldwork GBR 2007/08

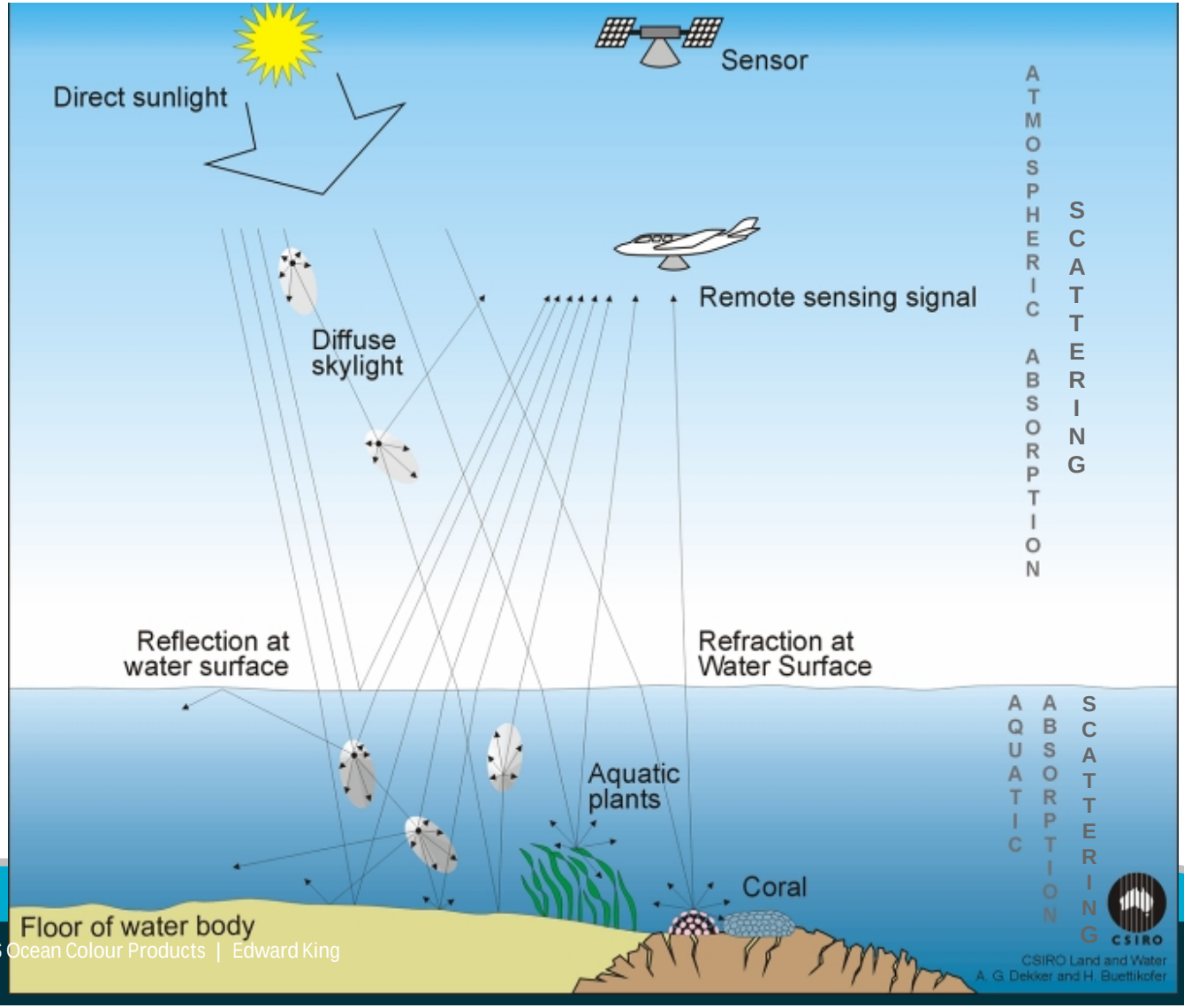


CSIRO

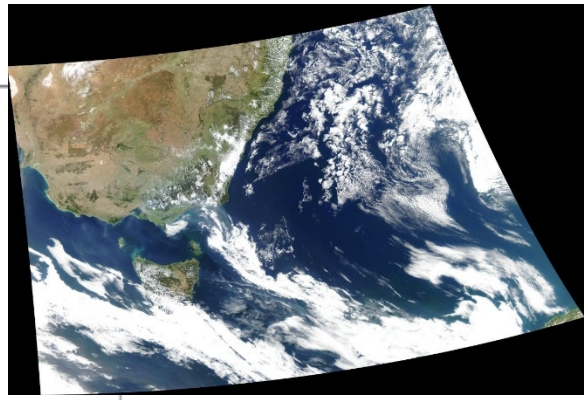
CSIRO

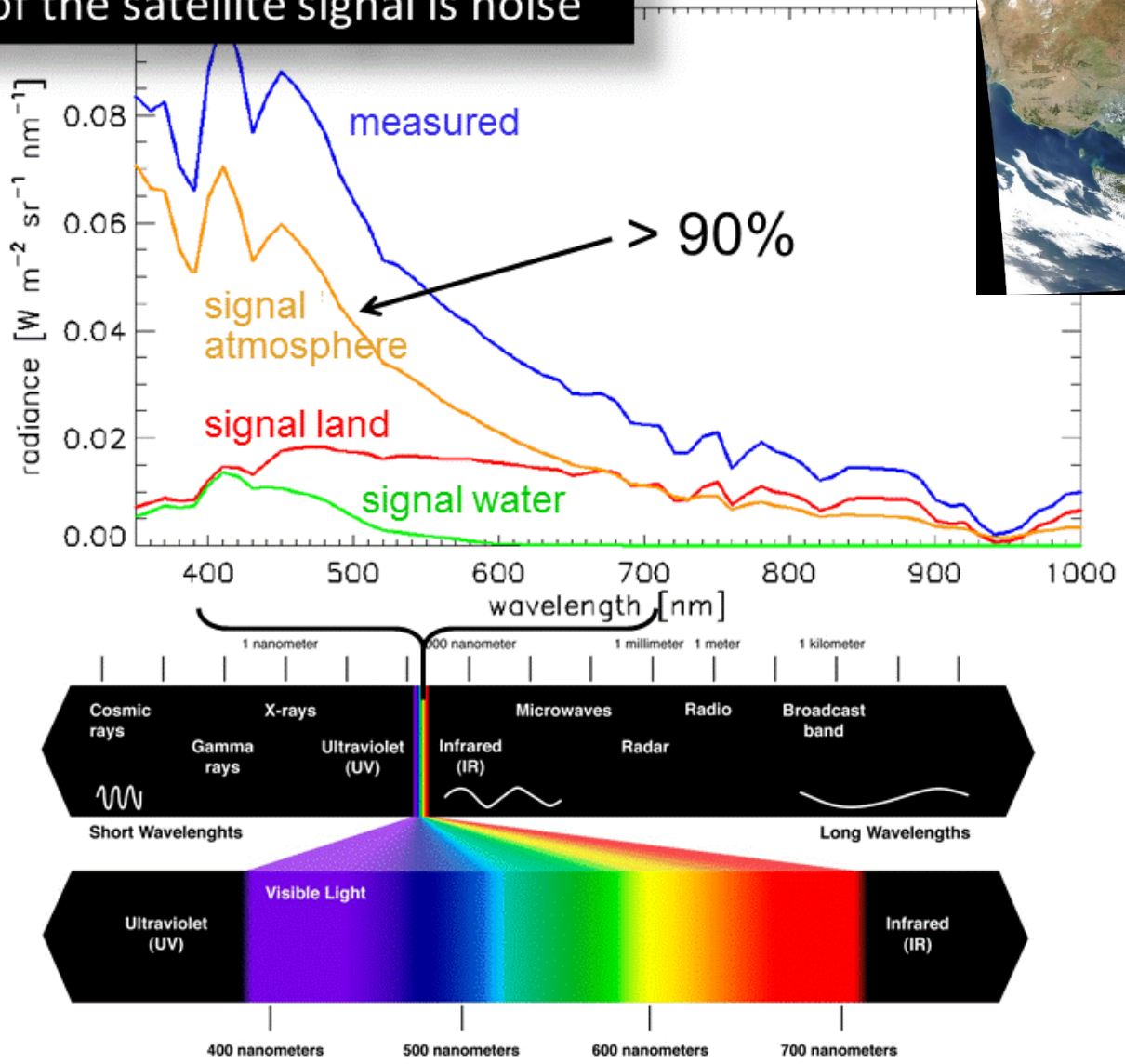
And quantitatively

$$L_{\mathrm{TOA}}(\lambda) = L_{\mathrm{Rayleigh}}(\lambda) + L_{\mathrm{Aerosol}}(\lambda) + L_{\mathrm{Rayleigh+Aerosol}}(\lambda) + t(\lambda)\, L_{\mathrm{Water}}(\lambda)$$



Most of the satellite signal is noise

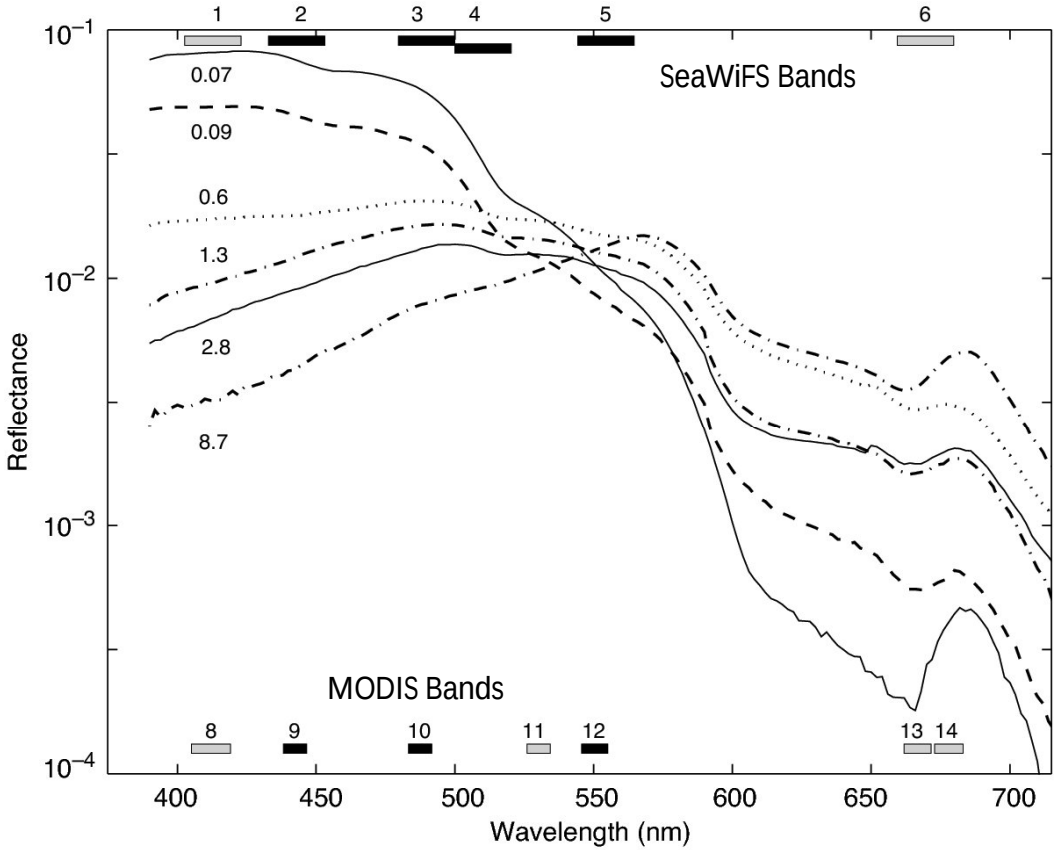




Top of atmosphere (with)

Bottom of atmosphere (without)

Chlorophyll only – “Case 1 Waters”



1. Accuracy goal in the “Blue ocean” ~35%.

2. There is no “chlorophyll sensor” – just a model that uses a measured spectrum.

Image Credits: Martin 2014, Introduction to Ocean Remote Sensing, Plate 6.1 and Figure 6.20

Case 2 subtlety: CDOM (Coloured Dissolved Organic Matter, aka "yellow substance")

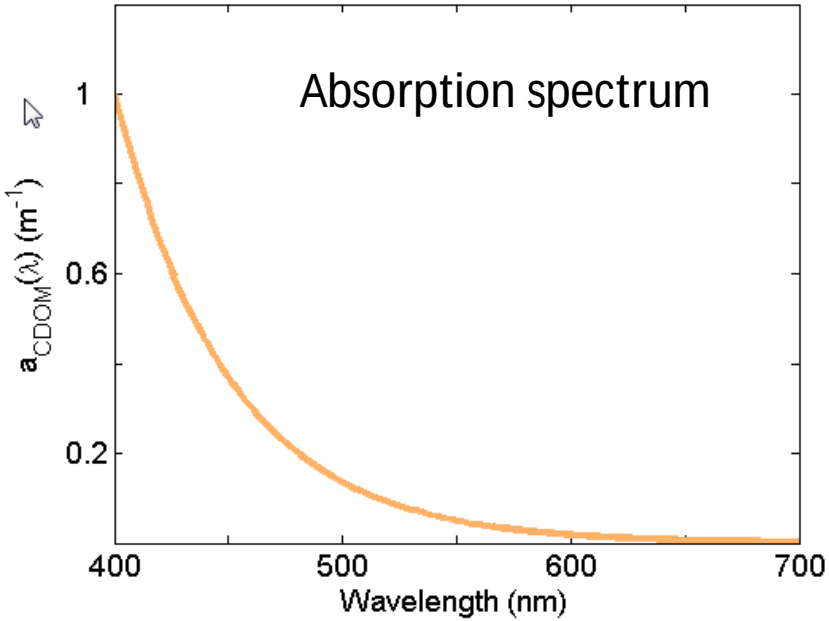
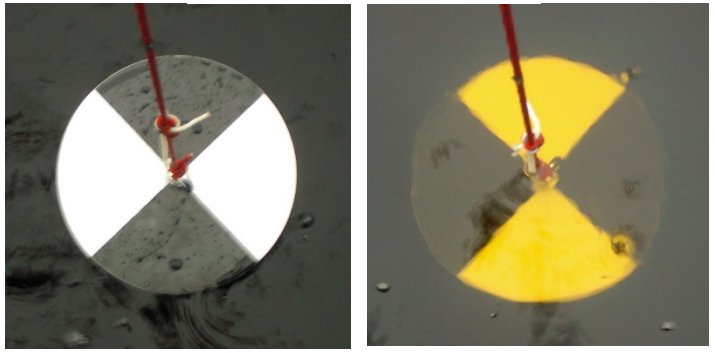
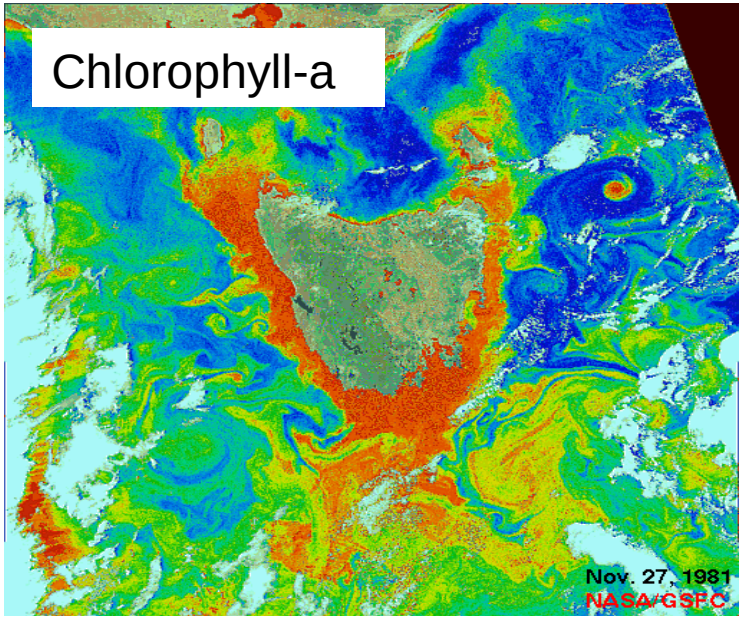


Figure: Fig. 4. Generic colored dissolved organic matter (CDOM) absorption spectrum for mixed composition.

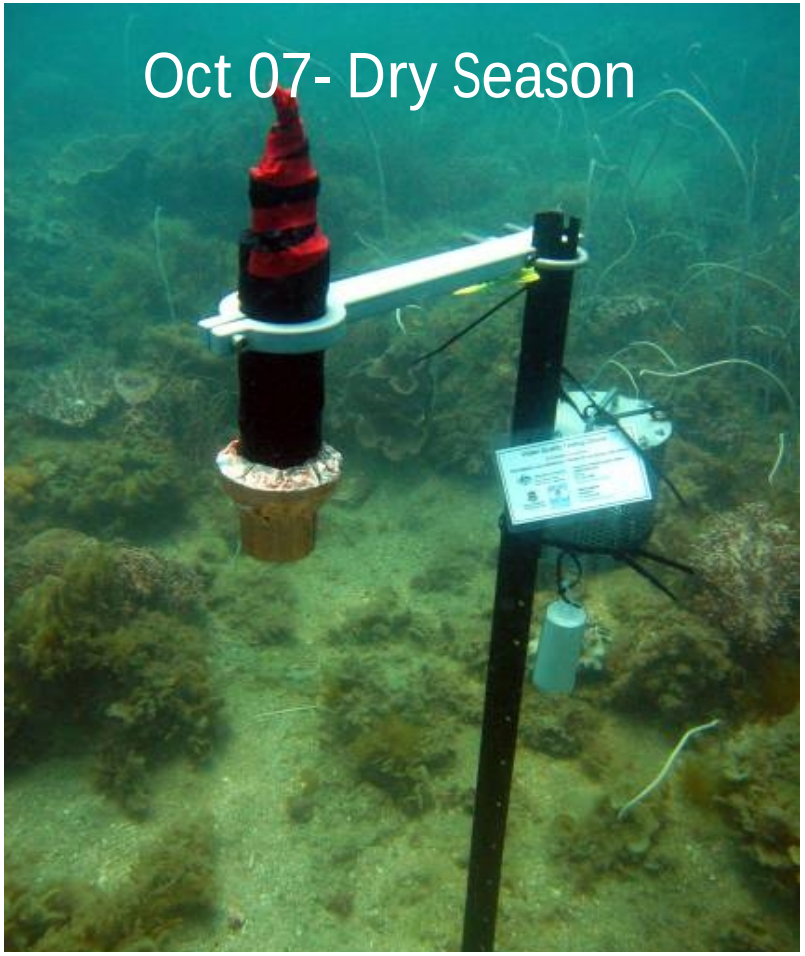
http://www.oceanopticsbook.info/view/absorption/definitions

Secchi Disk





Case 2 unsubtlety: Coastal waters of the Great Barrier Reef: Optical complexity and seasonal differences



WET Labs Eco FLNTU (Fluorometer and Turbidity Sensor) at Barren Island

Photos courtesy of Britta Schaffelke, AIMS

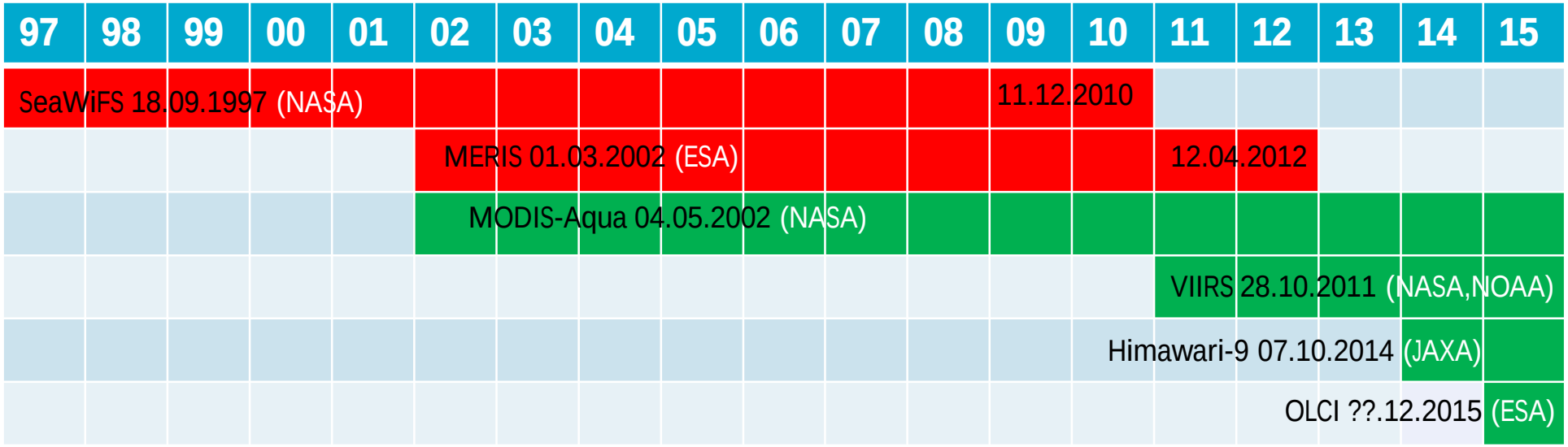
IMOS Ocean Colour Goals and Context

- Provide data as infrastructure to support research
- Data can be:
  - Satellite products not elsewhere available
  - Ancillary data for calibration and/or validation
- Users can be
  - Direct (local Australian researchers)
  - Indirect (foreign space agencies and RS algorithm developers)
- Satellite products are focussed on the National scale, rather than products tuned regionally (for node-based reasons)
- IMOS provides a backbone of base data sets that underpin regional algorithm development and delivery
- IMOS seeks to make data production “routine” (not 24x7)
- Data access is via IMOS Portal (subset), or from NCI (everything)

Satellite data sets

Data Sources and Availability

- Routine observing since late 1997, with a variety of instruments
- SeaWIFS was the pathfinder, 1km
- MERIS and MODIS, 250m-1km (note also MODIS-Terra)
- VIIRS “operational”, 750m
- Himawari – less spectrally capable, 500m/1km, high time res.
- OLCI (Sentinal-3), 300m, not yet launched



Processing Flow/Levels

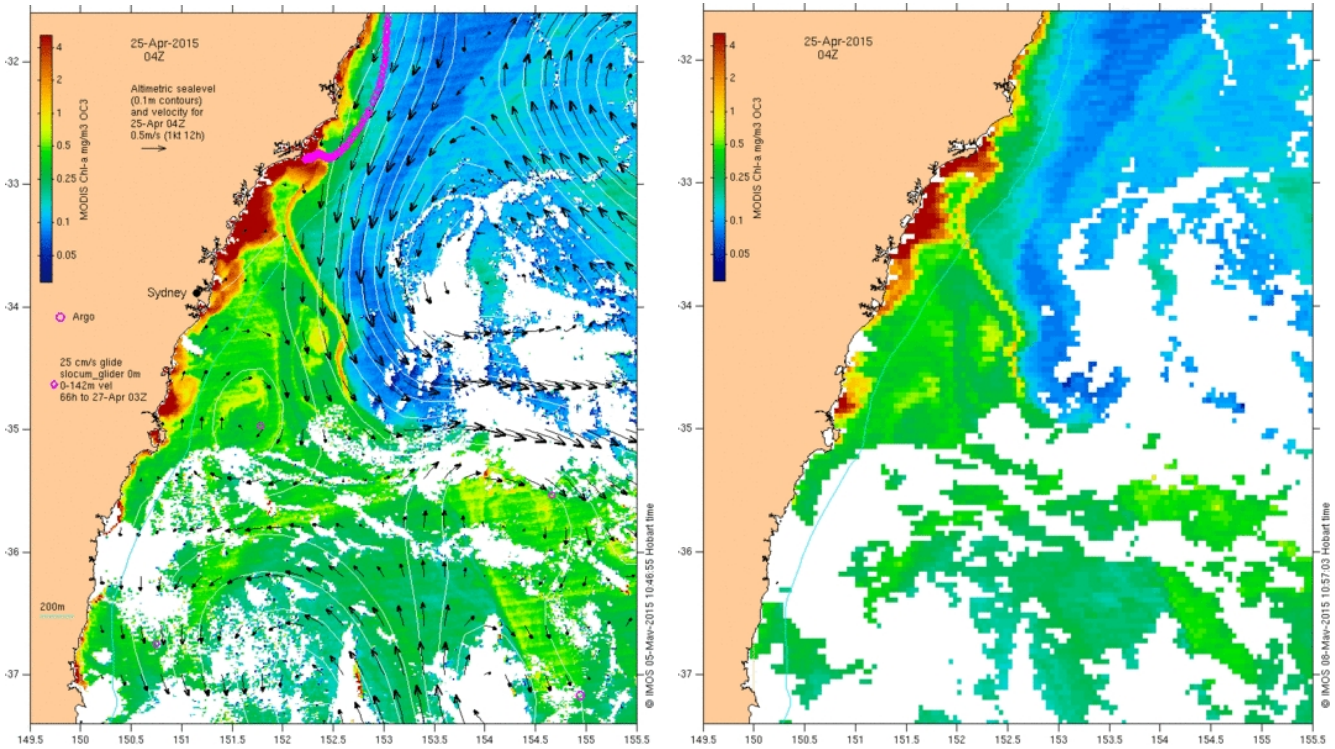
- Raw data from Satellite, instrument counts (PDS, Level-0 or “Raw Data Records”)
- Calibrate and geolocate, radiances at top of atmosphere (Level-1B, “Science Data Records”)
- Geophysical products (Level-2 or “Environmental Data Records”)
  - Atmospheric correction (bottom of atmosphere radiances/reflectances)
  - In water modelling outputs (Chl_X, K_490, absorption etc)
- Mapped products (Level-3)
  - Gridded onto a map and binned (averaged)

Processing Flow/Levels Users

- Raw data from Satellite, instrument counts (Level-0 or “Raw Data Records”) Engineers, nerds
- Calibrate and geolocate, radiances at top of atmosphere (Level-1B, “Science Data Records”) Instrument QA/QC, Calibration and atmospheric correction people
- Geophysical products (Level-2 or “Environmental Data Records”)
  - Atmos corr.(bottom of atmos. radiances/reflectances) Algorithm developers
  - In water modelling outputs (Chl_X, K_490, absorption etc) Advanced science applications and algorithm validation
- Mapped products (Level-3)
  - Gridded onto a map and binned (averaged) Most science applications

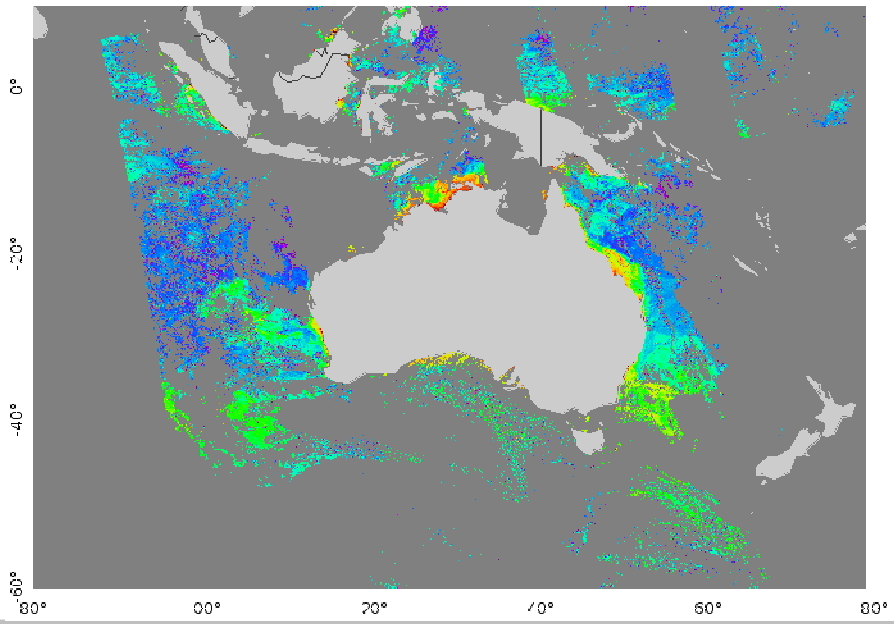
L3 Data products – MODIS examples 1

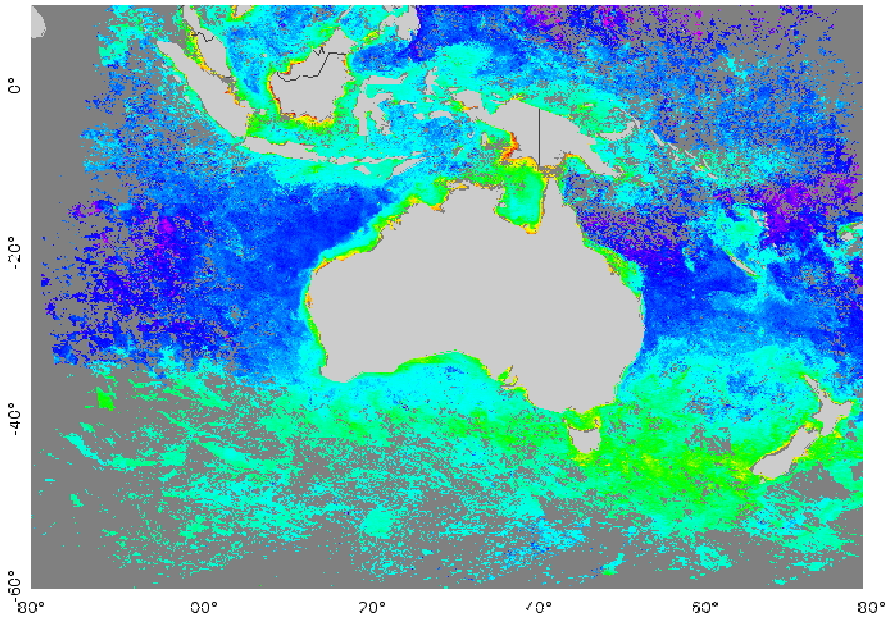
- Standard (NASA algorithm) products, mapped, netCDF-CF
- 1km resolution daily data (cf NASA best ~4km)
- Up-to-date calibration



L3 Data products – MODIS examples 2

- Products: Chlorophyll (OC3 & GSM), K_490, PAR, NPP (& SST)
- National images at 1km resolution:
  - Daily – simple mosaic
  - Monthly – min/max/mean/median/stdev
- Access via IMOS Portal, CSIRO (THREDDS/OPENDAP, ERDDAP, WWW), or NCI (Linux filesystem)





L2 Products – MODIS examples 3

- Lots of products (>100)
- In SWATH format (not mapped)
- Can be mapped if requested
- Useful for algorithm development/testing/validation
- Match-up tools available
- Access from NCI Linux filesystem

Current MODIS Aqua products

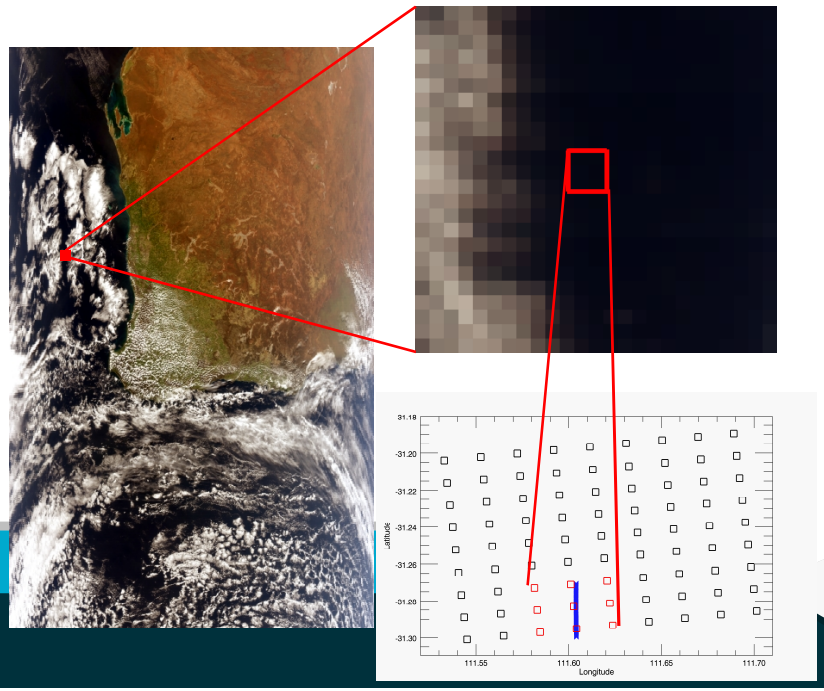
See http://oceancolor.gsfc.nasa.gov/DOCS/MSL12/MSl12_prod.html for more detail and references.

Nnn = 412,443,469,488,531,547,555,645,667,678,748,859,869,1240,1640,2130nm

NASA (SeaDAS) Products	L2 (Swath)	Gridded	
		Daily	Monthly
chl_oc3 - Chl Conc. OC3 Alg.	Yes	Yes	Yes
chl_gsm - Chl Conc. GSM model	Yes	Yes	Yes
chl_carder- Chl Conc. Carder model	Yes		
K_490 - Diffuse atten. coeff. at 490 nm	Yes	Yes	Yes
par - Photosynthetically Available Radiation,	Yes	Yes	Yes
ipar - Instantaneous Photosynthetically Avail. Rad.	Yes	Yes	Yes
sst - Sea Surface Temperature	Yes	Yes	Yes
bias_sst - SST Bias	Yes		
stdv_sst - SST Standard Deviation	Yes		
qual_sst - Quality Levels, SST	Yes		
9 x Lt_nnn - Calibrated TOA radiance at wavelength nnn	Yes		
9 x Es_nnn - Solar Irradiance at Surface at 412,443,488,531,547,667,678,748,869nm	Yes		
9 x Lw_nnn - Water-leaving radiance at 412,443,488,531,547,667,678,748,869nm	Yes		
9 x nLw_nnn - Normalized water-leaving radiance at 412,443,488,531,547,667,678,748,869nm	Yes		
9 x Rrs_nnn - Remote sensing refl. at 412,443,488,531,547,667,678,748,869nm	Yes		
Zeu_lee - Euphotic depth, Lee algorithm	Yes		
Zsd_gbr - Secchi depth, GBR algorithm	Yes		
Zsd_lee - Secchi depth, Lee algorithm	Yes		
adg_443_qaa adg_443_carder adg_443_gsm - Abs. due to gelbstoff and detrital material at 443nm, QAA/Carder/GSM models	Yes		
bbp_547_qaa bbp_547_carder bbp_547_gsm - Particulate backscattering at 547 nm, QAA/Carder/GSM models	Yes		
l2_flags - Level-2 Processing Flags	Yes		
flags_carder - Product flags, Carder model	Yes		
Longitude, Latitude - Pixel Lons & Lats	Yes		
pressure ozone k_oz Tau_r - Surface Pressure, Ozone Conc., Ozone Abs., Rayleigh Optical Thickness	Yes		
Solz, sola - Solar Angles	Yes		
Senz, sena - Sensor Angles	Yes		
windspeed, windangle, zwind, mwind - Wind Speed/Angle/Zonal/Merid at 10m	Yes		
F0 - Mean Solar Flux	Yes		
Experimental Derived Products			
Eppley_npp_chl_gsm - VGPM-based NPP using chl_gsm	Yes	Yes	Yes
Eppley_npp_chl_oc3 – VGPM-based NPP using chl_oc3	Yes	Yes	Yes
pftBrewin2010at – Phytoplankton types (Brewin et al 2010 alg.)	Yes	Yes	
pftBrewin2012in – Phytoplankton types (Brewin et al 2012 alg.)	Yes	Yes	

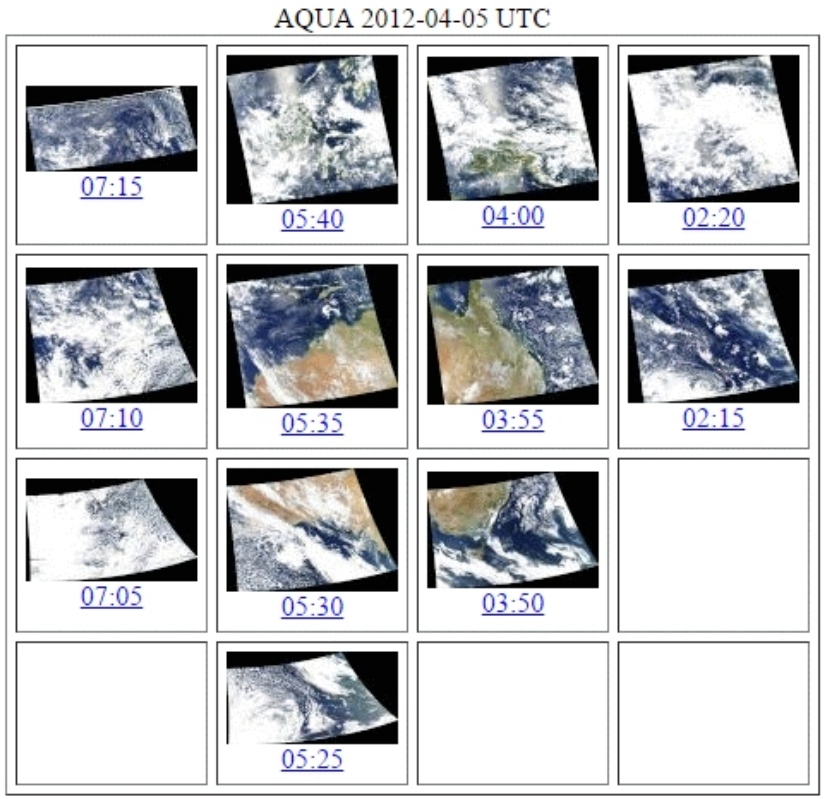
Notes:

1. Swath products only accessible via NCI
2. Any swath product can be gridded and promoted to daily mosaic or monthly average
3. Temporal averages computed on equal-angle grid. Equal-area averaging grids still under development.



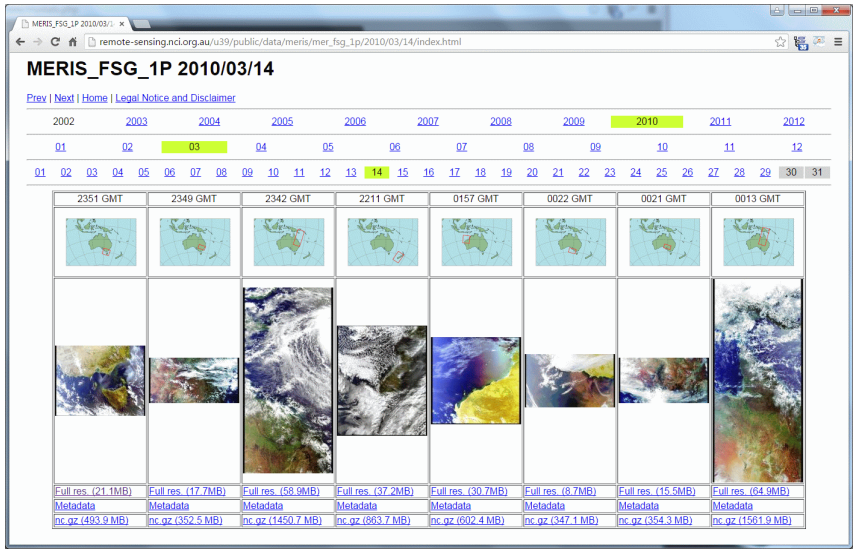
L1 Data products – MODIS examples 4

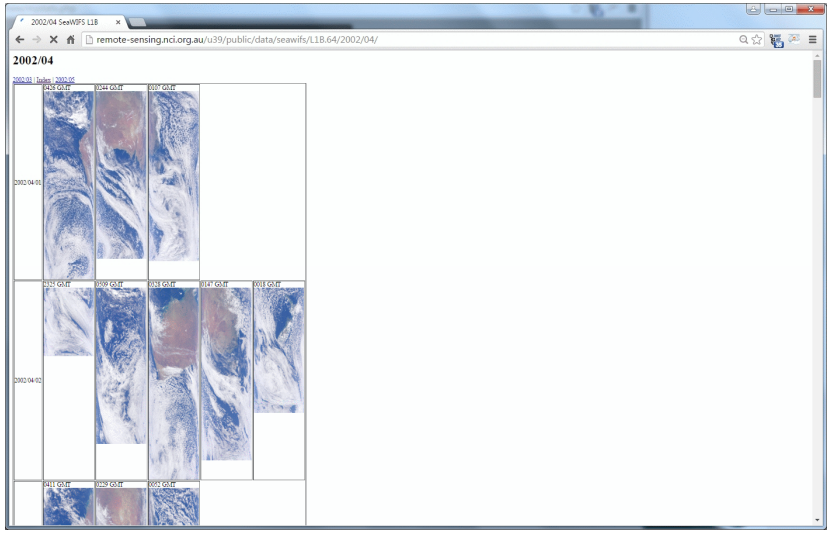
- Access to top of atmosphere radiances
- 250m and 500m channels (not “ocean colour” quality)
- Night time imagery also (SST)
- “RGB” imagery at 250m res.
- Access via NCI (Linux file system and www server)



Other Sensors

- SeaWiFS & VIIRS:
  - Complete Australian archives of exist at L1B and L2.
  - Trialling L3 products for both to go to IMOS Portal
  - Content/products organised following MODIS
- MERIS:
  - L2 full res. Australian imagery available (c/o CSIRO/ESA). Not yet an IMOS responsibility but being managed consistently
- Himawari-8: experimental only
  - Process insight
- OLCI: not yet launched

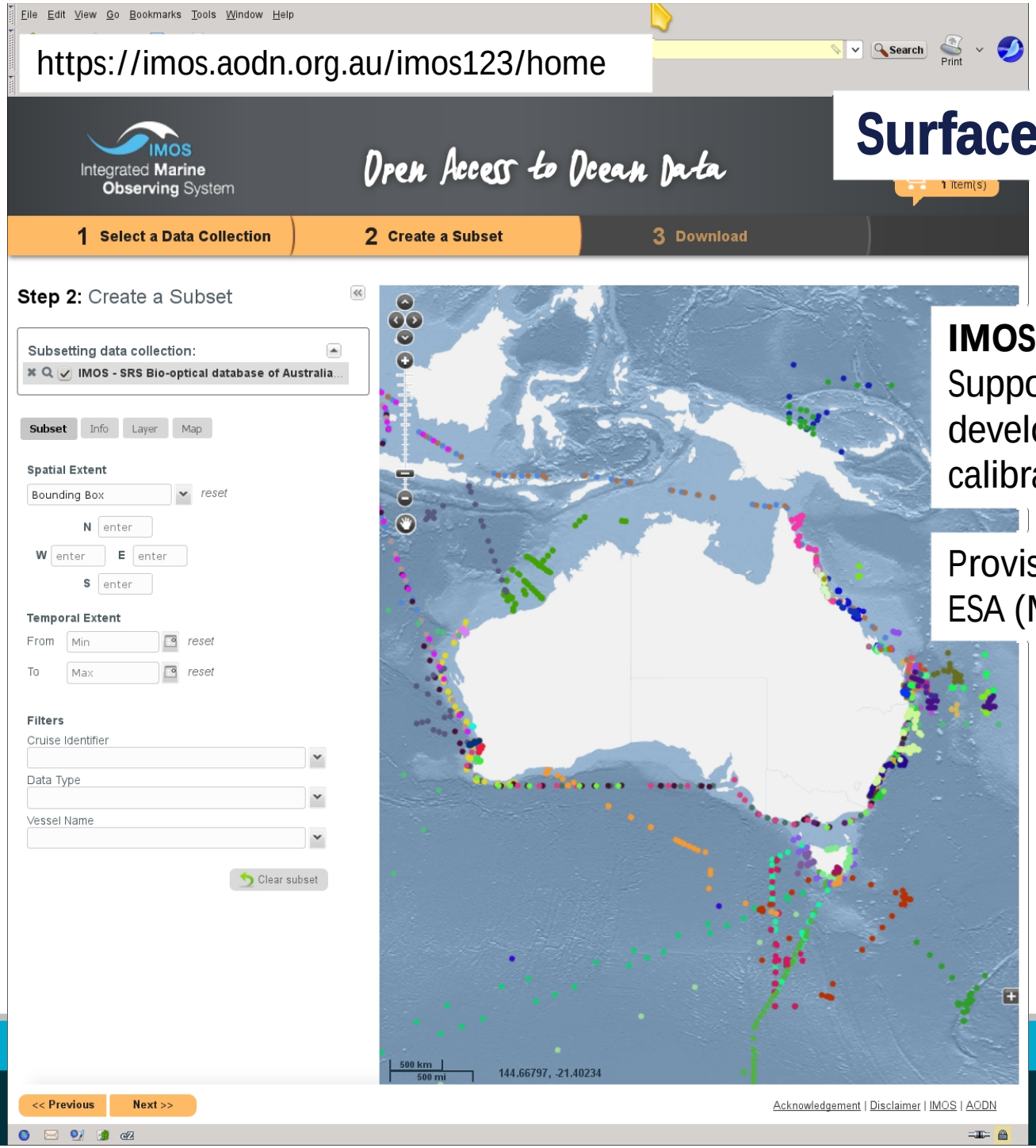




In-situ data sets

- Bio-optical database
- DALEC Radiometers
- Lucinda Jetty Coastal Observatory

Surface observations



IMOS bio-optical data base
Support algorithm validation, development and model calibration

Provision to NASA (SeaBASS), ESA (Mermaid)

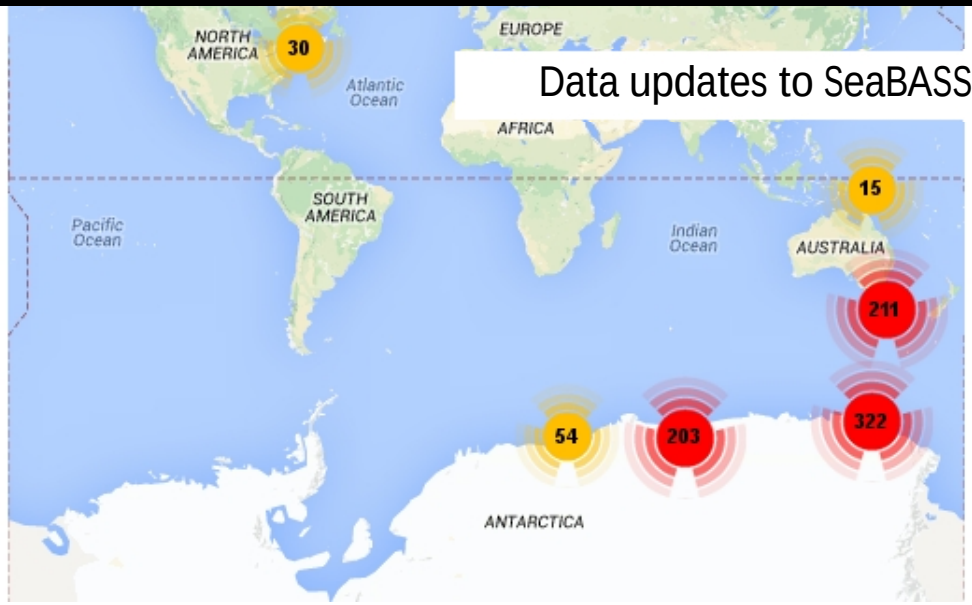
also
http://aesop.csiro.au

IMOS bio-optical data base

Continued acquisition of bio-optical data from the Australian research community into the IMOS bio-optical data base and data provision to NASA (SeaBASS) and ESA (Mermaid) as well as ESA's Ocean Colour Climate Change Initiative (OC-CCI).

Focus 2015/16

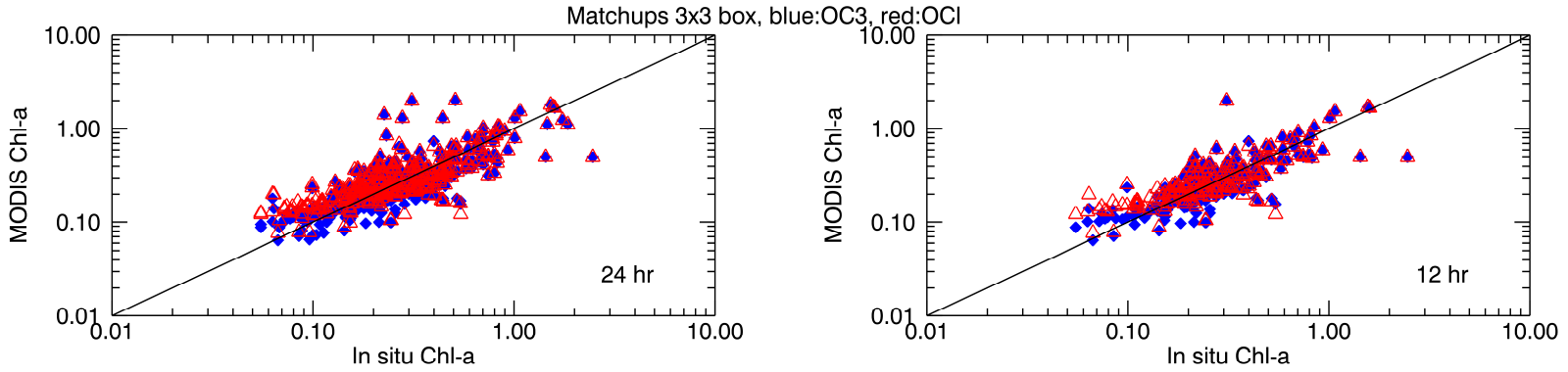
Inclusion of AIMS & JCU data sets



Data updates to SeaBASS (Jan-June 2014)

Ocean Colour Validation

- New in 2014/15 sub-facility will start providing annual validation reports
- Based on bio-optical data base – match-up analysis
- Provision of extracted satellite data & associated match-ups
- Possible – ocean colour time series from “virtual buoys”

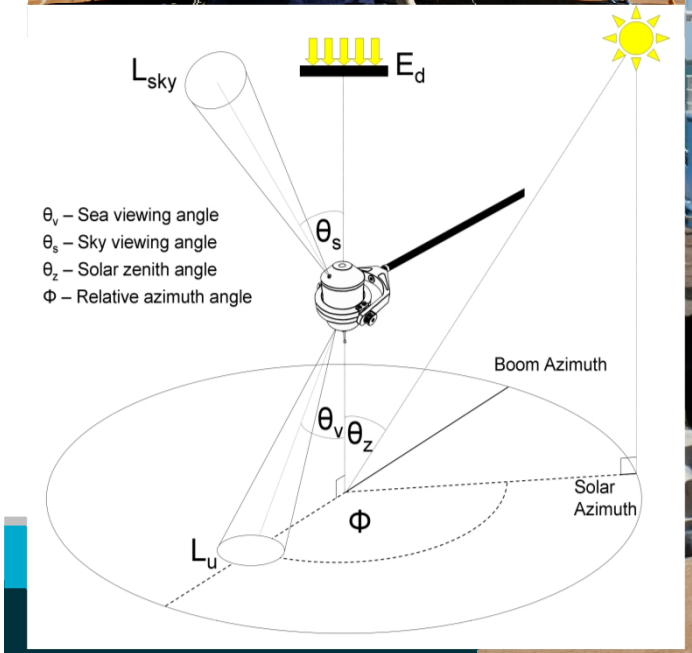


(Image credit J. Lovell)

Continuous above-water radiometry

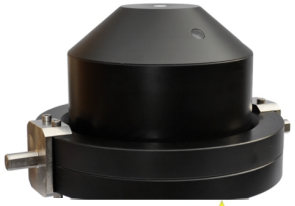
In collaboration with AIMS

3 x Zeiss MMS1 UV-VIS NIR
10 nm spectral resolution
16 bit ADC
NIST traceable calibration 400-900 nm
Manufacturer: In-situ Marine Optics, Australia

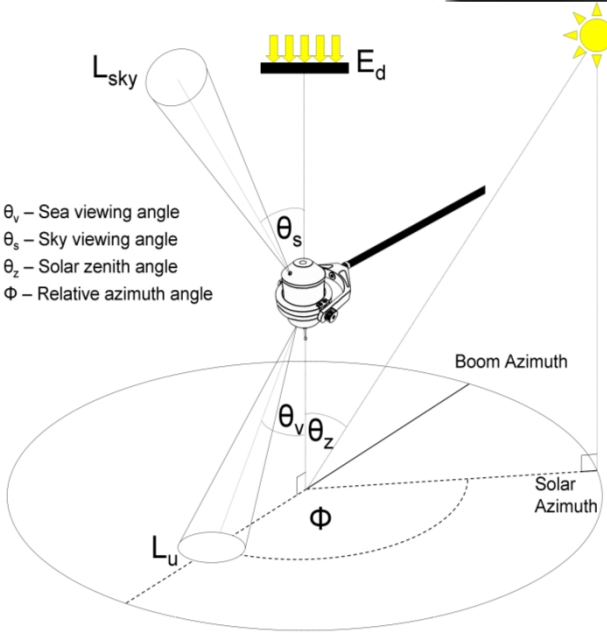


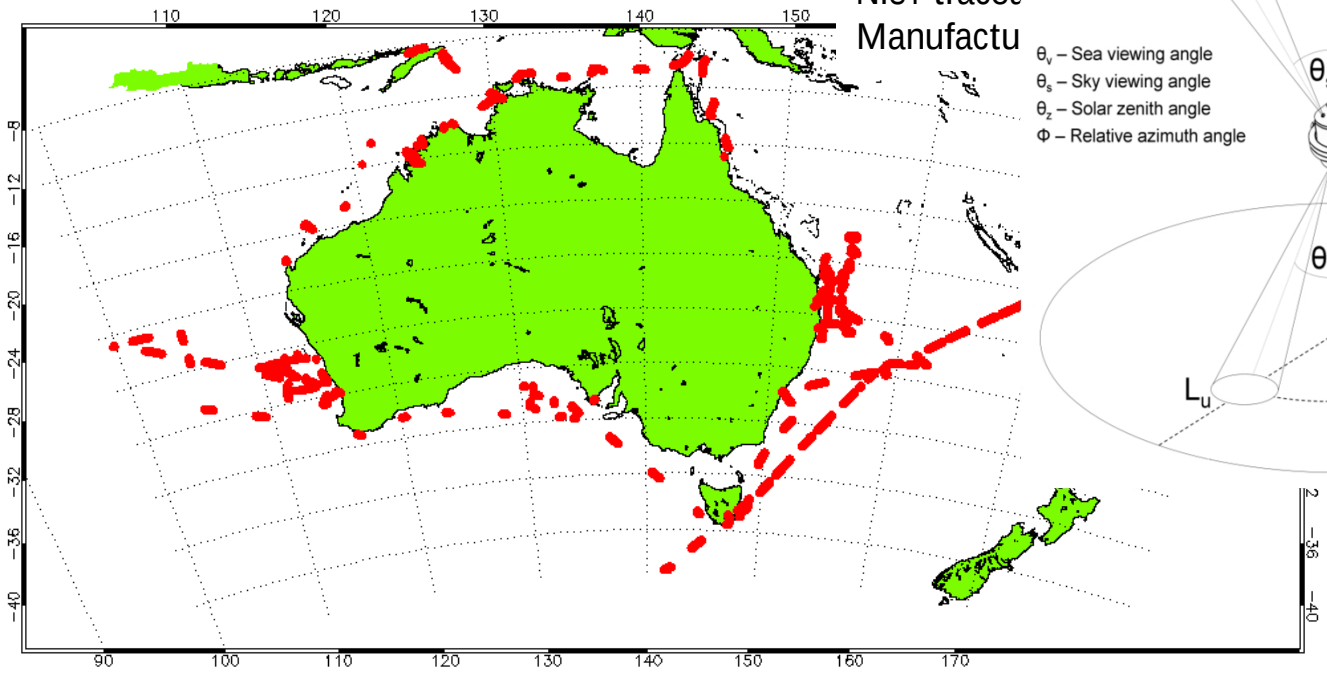
Continuous above-water radiometry

All DALEC data since 2011



3 x Zeiss M
10 nm spec
16 bit ADC
NIST tracea
Manufactu

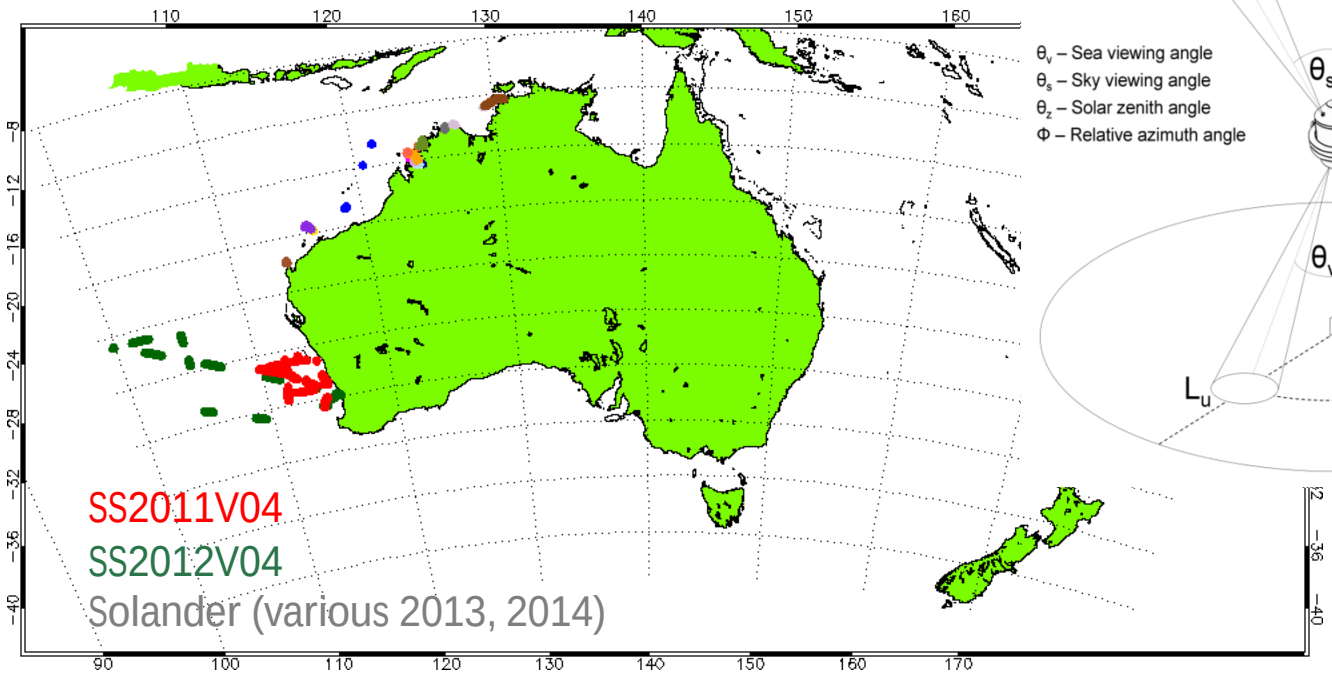


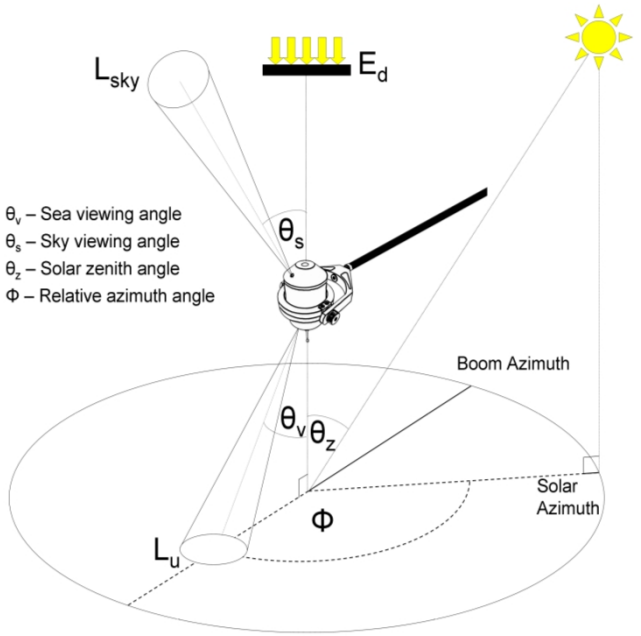


Transects of above water radiance and irradiance → objective reflectance

Continuous above-water radiometry

Quality controlled DALEC data

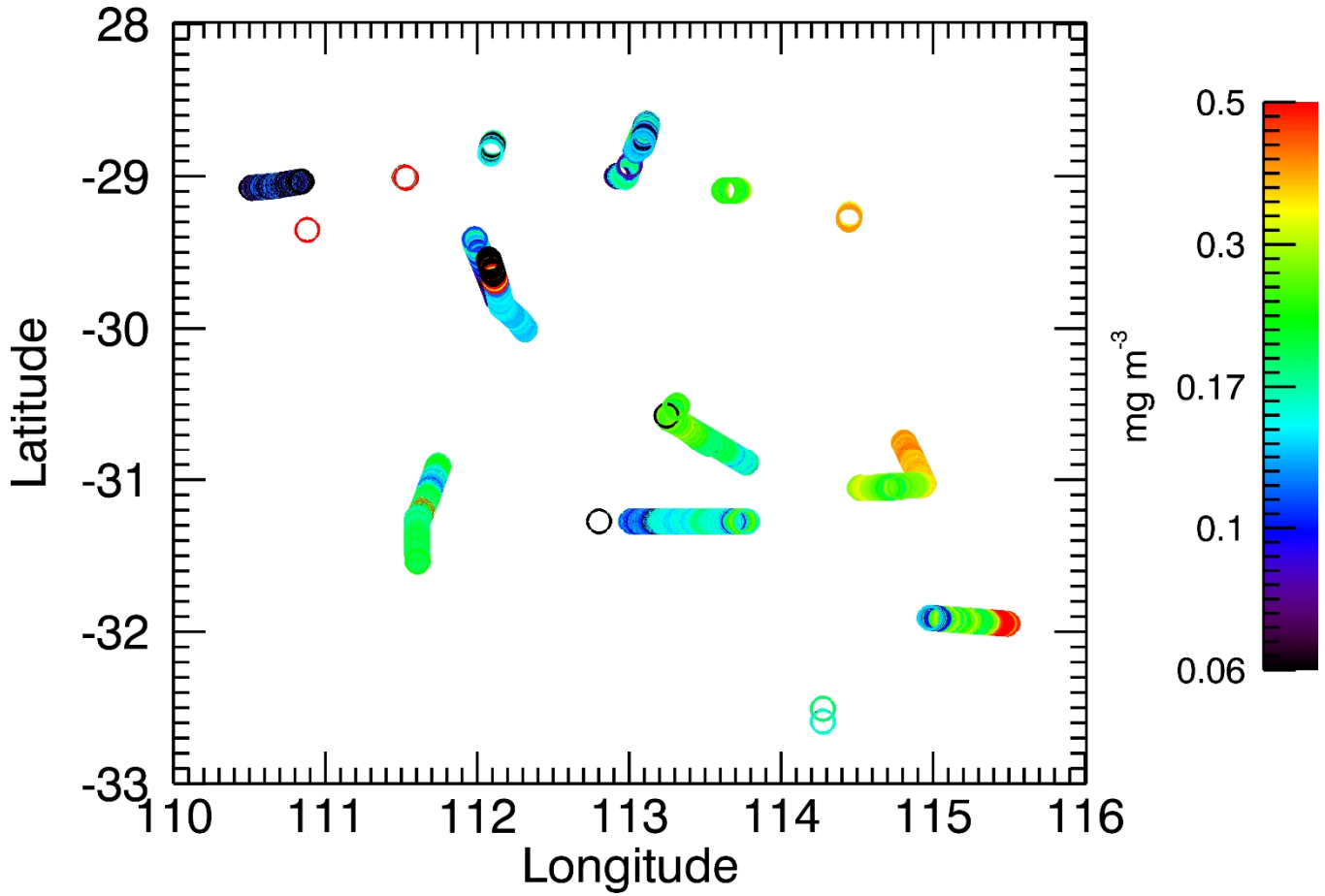




Reflectance conversion possible for above transects

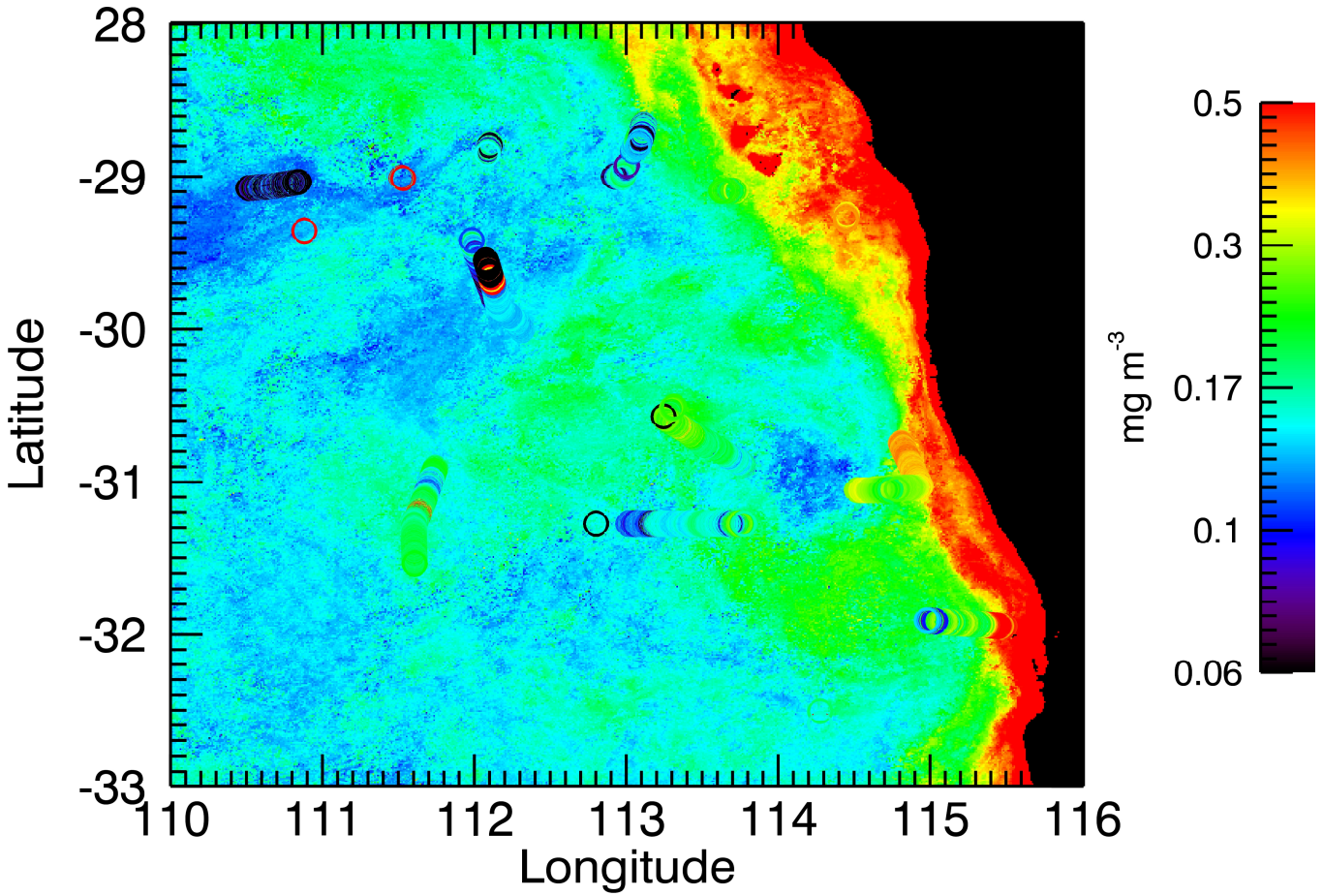
OC3 inverted DALEC reflectance spectra off WA

Southern Surveyor 21 Aug – 11 Sep 2011



OC3 inverted DALEC reflectance spectra off WA

Southern Surveyor 21 Aug – 11 Sep 2011 + MODIS median composite overlay



Lucinda Jetty Coastal Observatory

- Complex waters
- Permanently instrumented
- 5km from shore
- Fortnightly water sampling
- Continuous optical observations both above & below water
- Contributes data to international cal/val
- Algorithm development and validation

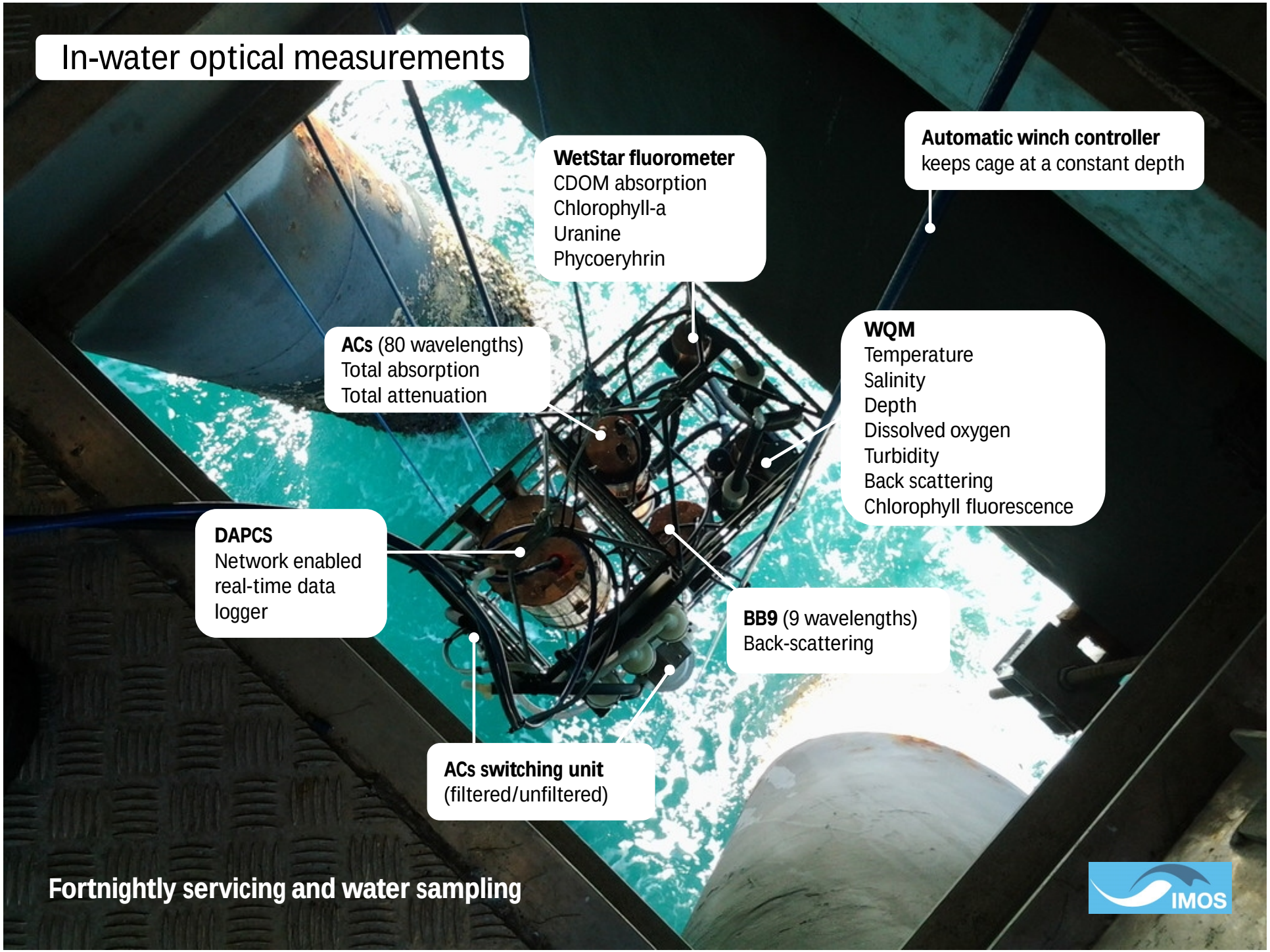
Above-water measurements

Weather Station
Temperature
Pressure
Humidity
Dew point
Wind speed etc

Satlantic
Spectral irradiance

Webcams
Sky and Sea

SeaPRISM (7 wavelengths)
Water-leaving radiance
Aerosol optical thickness
Aerosol absorption
Aerosol size distribution
Refractive index
Single scattering albedo
Phasefunction
Water vapor
Spectral flux
Radiative forcing


In-water optical measurements
WetStar fluorometer
CDOM absorption
Chlorophyll-a
Uranine
Phycoeryhrin
Automatic winch controller
keeps cage at a constant depth
ACs (80 wavelengths)
Total absorption
Total attenuation
WQM
Temperature
Salinity
Depth
Dissolved oxygen
Turbidity
Back scattering
Chlorophyll fluorescence
DAPCS
Network enabled
real-time data
logger
BB9 (9 wavelengths)
Back-scattering
ACs switching unit
(filtered/unfiltered)
Fortnightly servicing and water sampling
IMOS

Conclusions

- Datasets with an Australian focus
- The most useful data sets are on the IMOS portal
- Many others are on the NCI
- Users come and talk to us about what they need
  - We will try to help
- Get involved in your local IMOS Node to influence direction

Thank you

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