IMOS Bio-optical working group: Status and next steps
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IMOS Bio-optical Working Group

- Initial funding period 2010 to 2012, extended to 2015
  - BWG a mechanism for addressing the interests and needs of the Australian bio-optical community in relation to the IMOS program

- Meetings generated important discussion on aspects of optical calibration and links between bio-optics and SRS
- Input to IMOS on fluorescence/scattering/turbidity calibration and recommendations for NRS science rationale and sampling regimes
- Informing the wider science community – conference presentations and workshops at AMSA
- Scientific publication evaluating fluorescent standards in the context of ocean observing programs (Earp et. al. 2011)
- IMOS Facilities have begun to implement the recommendations and suggested protocols put forward by the group

- Where has this got us?
Bio-optical observations

Largely support efforts to understand BGC processes including primary production.
New understandings

1. Ocean colour footprints of some NRS are large

Journal of Marine Systems 143: 49-61
New understandings

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New understandings

2. Upper ocean chlorophyll-a dynamics reveal biological ‘domains’

New understandings

2. Upper ocean chlorophyll-a dynamics reveal biological ‘domains’
Satellite product evaluation

<table>
<thead>
<tr>
<th>Region</th>
<th>N</th>
<th>Model II Fit</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>WA_north</td>
<td>47</td>
<td>$Y = 1.14*X + 0.22$</td>
<td>0.82</td>
</tr>
<tr>
<td>WA_south</td>
<td>62</td>
<td>$Y = 0.94*X + -0.03$</td>
<td>0.92</td>
</tr>
<tr>
<td>QLD</td>
<td>29</td>
<td>$Y = 1.70*X + 0.82$</td>
<td>0.79</td>
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<tr>
<td>NSW_in</td>
<td>46</td>
<td>$Y = 1.02*X + 0.09$</td>
<td>0.76</td>
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<tr>
<td>NSW_off</td>
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<td>$Y = 0.75*X + -0.26$</td>
<td>0.78</td>
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<tr>
<td>TAS</td>
<td>24</td>
<td>$Y = 1.10*X + -0.08$</td>
<td>0.92</td>
</tr>
</tbody>
</table>

Match up database (n>500) now available through IMOS portal

Regional performance analysis

Validation of MODIS ocean colour chlorophyll-a for the Australasian region
Submitted to Optics Express

Three improved satellite chlorophyll algorithms for the Southern Ocean
Journal Geophysical Research: Oceans 118, 3694-3703

Plots and table: Dr Virginie van Dongen-Vogels
Chlorophyll-a is easier and cheaper to measure but is not quite what we want to know.

Actually want to understand changes in phytoplankton abundance, composition, physiology and growth/productivity.

Need to relate Chl-a to other biogeochemical parameters we care about and understand why relationships change over space and time.

Remaining challenges

Obtaining parameters we want
Chlorophyll-a is easier and cheaper to measure but is not quite what we want to know. Actually want to understand changes in phytoplankton abundance, composition, physiology and growth/productivity.

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Obtaining parameters we want

Chl-a pigments (NRS surface, WQM, composite)
Phyto abundance (NRS composite, net tow, CPR)
Chl-a fluorescence, turbidity (CTD, NRS, gliders)
CDOM fluorescence (Ecotriplet)
Particulate backscatter, PAR (gliders, Ecopuk)
Transmissometer, beam attenuation meter
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**Remaining challenges**

Obtaining parameters we want

**PP models:**

- **Eppley (1985):** $PP = \sqrt{Chla_0}$
- **VGPM (1997):** $0.66125 \times P_{opt}^B \left(\frac{E_0}{E_0 + 4.1}\right)$
  - $Chla \times Z_u \times DL$
- **Absorption (2003):** $PP = \phi \times a_{ph}^* \times Chla \times Epar$
- **CbPM (1995):** $NPP = \mu \times C_{ph}$

$\rightarrow Chla, Epar, SST, Kd490, MLD$
Remaining challenges

Obtaining parameters we want

Satellite Chl-a (Modis OC3)

In situ Chl-a (IMOS WC)

Phytoplankton abundance (IMOS WC)

Phytoplankton biovolume (IMOS WC)

Pozza, L., Everett, J., Doblin, M.A. 2013 Honours thesis
Remaining challenges

2. Obtaining parameters we want

Chlorophyll-a is easier and cheaper to measure but is not quite what we want to know.

Actually want to understand changes in phytoplankton abundance, composition, physiology and growth/productivity.

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Will require additional measurements to develop bio-optical proxies, and an understanding of the dynamic oceanographic conditions affecting signals.

1. Require vertical resolution in observations;
2. Validation of bio-optical signals with independent measures;
3. Consideration of transport (advective terms) when interpreting time-series → physical circulation models
1. Vertical resolution

Multiple sensor types:
- Gliders
- Vertical profiles from SOOP
- Bio-Argo

Source: Michael Jacox

Source: Mark Baird
2. Lab Validation

Tim Lynch, Lesley Clementson, Robert Kay et al. *Comparison between numerous WQMs and how they responded to different phytoplankton taxa (different size, different pigments)*
2. Field Validation

Using samples collected at Port Hacking NRS to validate satellite-derived Chl-a and applying the best regional NPP model to generate a time-series of primary production.

Source: L. Pozza
2. Field Validation

Observations upstream of Port Hacking NRS
External support: ARC, MNF, Environmental Trust, CSIRO, OEH

Everett, J., Doblin, M.A.
Characterising primary productivity across a dynamic western boundary current region
In review: Deep Sea Research I
2. Field Validation

BUT correspondence between observations and satellite-derived estimates of PP are poor.

Everett, J., Doblin, M.A.
Characterising primary productivity measurements across a dynamic western boundary current region
In review: Deep Sea Research I
2. Field Validation

External support: CSIRO Marine and Coastal Carbon Biogeochemistry Cluster and UTS

Alvarez, M., van Dongen-Vogels, V., Doblin, M.A.

unpublished data

External support: CSIRO Marine and Coastal Carbon Biogeochemistry Cluster and UTS
2. Validation

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Need simultaneous optical ($c_p$ and $b_{bp}$) and BGC measurements across time and space.
Proxy development

Converting bio-optical properties to biogeochemical properties in a dynamic framework

Spatial variability

Spatial variability:
- phytoplankton (SPOM)
- inorganic (SPIM)
- detritus (SPOM)

Temporal variability:
- Dry season
- Wet season
Predicting primary production in Australia’s coastal ocean

**Regions of observation (n = 32)**
- Northern Australia **SS2013 (24h $^{13}$C)**
- Great Barrier Reef **eReefs 2013 (4-6h $^{13}$C)**
- East Coast **SS2010 (2h $^{14}$C)** / Port Hacking **NRS (24h $^{14}$C)**
\[ PP(z) = \phi \cdot a^*_{ph} \cdot \text{Chla} \cdot E_{par}(z) \]

Dataset containing all surface stations \( n = 32 \)

- For Chl-a (mg m\(^{-3}\))
  - \( y = 0.0056x + 0.0007 \)
  - \( R^2 = 0.8141 \)
  - Dataset containing all surface stations \( n = 32 \)

- For aph 440 (m\(^{-1}\))
  - \( y = 0.1364x + 0.001 \)
  - \( R^2 = 0.2947 \)
  - Dataset containing all surface stations \( n = 32 \)
Select data points where phytoplankton light absorption > 50% of total light absorption.

Data points where phytoplankton dominate light absorption n=9

Data points where phytoplankton is outcompeted for light by non-algal particulates and CDOM n=23

\[ PP(z) = \phi \cdot a^*_{ph} \cdot Chla \cdot Epar(z) \]
Proxy development

Converting bio-optical properties to biogeochemical properties in a dynamic framework

Measuring optics at NRS to get optical water types
Remote sensing reflectance = ratio of upwelling radiance and downwelling irradiance yields optical type which yields level of uncertainty in satellite products

Examining in situ versus satellite data – vicarious validation has been relatively slow
Models require temporal validation
Some of this work has started at Port Hacking

Validating bio-optical signals from moorings, gliders
Doing appropriate match-ups

Relating bio-optical signals to other useful quantities
Need interest by the research community
3. Physical framework
Fig. 2. Panels (a) and (b) show two satellite images from 1 and 6 January 2005, of euphotic depth-integrated Chl-a scaled to PC using a fixed C-Chl ratio of 60. Panel (c) is the (Eulerian) difference calculated by subtracting panel (a) from panel (b), \( \frac{\partial P}{\partial t} \). Panel (d) shows the difference between the start and end values of PC along water parcel trajectories, i.e., \( \frac{\partial P}{\partial t} + \mathbf{u} \times \mathbf{V}(P) \). These trajectories are computed by seeding particles uniformly in the model flow field and advecting them with surface velocities for the time between the satellite images. They thus represent the source/sink of PC in the moving frame, i.e., NCPE. Panel (e) represents the advective component of the change. It is that part of (d) that remains after the Eulerian change shown in (c) is subtracted, i.e., \( \mathbf{u} \times \mathbf{V}(P) \), plotted with a negative sign.
Solutions to challenges

• If bio-optical proxies for biogeochemical properties are to be developed, need focused activity, potentially at the regional node level. May require deployment of instruments to measure IOPs in conjunction with researchers making additional measurements – co-investment model.

• Validation exercises – recent deployment of glider on CTD in NW Australia ANFOG initiative lead by Paul Thomson and Chari P.
Glider validation activity

- ANFOG initiative lead by Paul Thomson and Chari Pattiaratchi
- Slocum glider attached to CTD frame on-board AIMS RV Solander on NWS of WA in Jan 2015
- CTD casts simultaneously collected seawater and bio-optical signals
- Aim: to validate/compare bio-optical signals with pigments, microbial community composition (viruses, bacteria, phytoplankton) and conc. inorganic suspended matter

Thanks to AIMS staff and crew of the RV Solander!
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• Satellite products delivered by IMOS should have uncertainty estimates (Moore et al. 2009)
Satellite product uncertainty for MODIS-Aqua Chl-a

Moorings: Surface measurements of Chl-a are now being made
SRS: Produce uncertainty product??? Desired accuracy: ± 35%

Moore, T.S., Campbell, J.W., Dowell, M.D. (2009)
Remote Sensing of Environment 113: 2424-2430
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→ Suggests that the BWG which currently acts as a forum for discussion, may need to change to get focussed on specific tasks revisit variables (platform specific?), IOP vs AOP approaches, data evaluation