A Systematic approach to maintaining high quality bio-optical data streams in a coastal observing system.

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What is IMOS (http://imos.org.au)

Australia’s Integrated Marine Observing System (IMOS) was established in 2007 under the National Collaborative Research Infrastructure Strategy (NCRIS), with initial funding of $50M and co-investment of $44M from partners.

It has successfully deployed a range of observing equipment in the oceans around Australia, and is making all of the data freely and openly available through the IMOS Ocean Portal – http://imos.aodn.org.au/webportal/ - for the benefit of Australian marine and climate science as a whole.

With the injection of an additional $52M from the Education Investment Fund (EIF) in 2009, and up to $66M in further co-investment, IMOS will be extended out to mid-2013 and enhance its monitoring in the Southern Ocean and northern Australian waters.

IMOS is designed to be a fully-integrated, national system, observing at ocean-basin and regional scales, and covering physical, chemical and biological variables.
IMOS Facilities

IMOS Facilities, operated by ten different institutions within the National Innovation System, are funded to deploy equipment and deliver data streams for use by the entire Australian marine and climate science community and its international collaborators.

Argo Floats
Ships of Opportunity
Deep-water Moorings
Ocean Gliders
Autonomous Underwater Vehicles
National Mooring Network
Ocean Radar
Animal Tagging and Monitoring
Wireless Sensor Networks
Marine Information (eMII)
Satellite Remote Sensing (SRS)
Australian Ocean Data Network
Bio-optical Working Group
National Reference Stations – time series data
Sensors and Sampling

Key
* - long term site
# - infrastructure deployed
+ - Telemetry
^ BGC sampling

Ocean Observatory Workshop, Glasgow, Scotland, UK, October 2012.
NRS design—Many FLNTUs

Ocean Observatory Workshop, Glasgow, Scotland, UK, October 2012.
QC sensors vs biogeochemical water sampling
- Combine for cross validation

Sensors (T, S, Fl NTU)
9 QC tests
Scientist per site
Matlab toolbox
Methods papers
NATA calibration laboratory

BGC (pigments, nutrients, TSS, flow cytometry, phytoplankton and zooplankton counts)
4 central processing laboratories
Scientist per laboratory
Annual training
Sampling/lab manuals
Taxonomic guides
Lesson Learnt – Bio-fouling of sensors after 6 months - Detected by users via telemetry

Photos of sensors upon retrieval are taken and kept with the sensor history.
Key lesson learnt for sustained observing QC – inter sensor comparability

Spiking – physicists vs biologists
Cross validation of sensor to monthly BGC samples – Chlorophyll (20m) Maria Island NRS

Data from other NRS have shown a similar or slightly better regression.
Back to the laboratory

NATA Certified Calibration lab

Australian National Algae Culture Collection (ANACC)

Many FLNTUs available

Highly skilled staff
Key lesson learnt for sustained observing QC – inter sensor comparability

*Nannochloropsis oculata* Wetlabs

WQM 127 did not give reproducible results

Ocean Observatory Workshop, Glasgow, Scotland, UK, October 2012.
Ratio adjustment with ref samples
Fluoroscein calibration

WQM (41) Chl-a Calibration Curve Using Fluorescein:

\[
y = 0.0243x - 0.8938 \\
R^2 = 0.99986
\]
Remove the bogus instruments
– start to get repeatable results

*Nannochloropsis oculata* CMAR remove WQM 127 and 96

Note: change in scale factor
Algal culture calibration?

HPLC chl-a (mg m⁻³) vs WQM chl-a (all cultures)

- Thalassiosira (1)
- Tetraselmis (2)
- Heterocapsa (3)
- Synechococcus (4)
- Ditylum (5)
- Nannochloropsis (6)
Characterize against the HPLC standard and now both precise and accurate across 3 algal species.
### Procedures for CTD / WQM on moorings

<table>
<thead>
<tr>
<th>QC procedure</th>
<th>Variables checked (* can be tuned by user)</th>
<th>Parameterized</th>
<th>Pass flag</th>
<th>Fail flag</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impossible date</td>
<td>TIME</td>
<td>Yes</td>
<td>Good</td>
<td>Bad potentially correctable</td>
</tr>
<tr>
<td>Impossible location</td>
<td>LATITUDE, LONGITUDE</td>
<td>Yes, and per site</td>
<td>Good</td>
<td>Bad potentially correctable</td>
</tr>
<tr>
<td>In/out water</td>
<td>All</td>
<td>No</td>
<td>Non QC’d</td>
<td>Bad potentially correctable</td>
</tr>
<tr>
<td>Global range</td>
<td>TEMP, PSAL, PRES/DEPTH, DO, CHL-A *</td>
<td>Yes</td>
<td>Good</td>
<td>Bad</td>
</tr>
<tr>
<td>Regional range</td>
<td>TEMP, PSAL, DO *</td>
<td>Yes, and per site</td>
<td>Good</td>
<td>Bad</td>
</tr>
<tr>
<td>Impossible depth</td>
<td>PRES/DEPTH</td>
<td>Yes</td>
<td>Good</td>
<td>Bad</td>
</tr>
<tr>
<td>Spike</td>
<td>TEMP, PSAL, PRES/DEPTH, DO, CHL-A *</td>
<td>Yes</td>
<td>Good</td>
<td>Bad</td>
</tr>
<tr>
<td>Gradient / Rate of change</td>
<td>TEMP, PSAL, PRES/DEPTH, DO, CHL-A *</td>
<td>Yes</td>
<td>Good</td>
<td>Bad potentially correctable</td>
</tr>
<tr>
<td>Stationarity</td>
<td>TEMP, PSAL, PRES/DEPTH, DO, CHL-A *</td>
<td>No</td>
<td>Good</td>
<td>Bad</td>
</tr>
<tr>
<td>Climatology</td>
<td>TEMP, PSAL, DO (when possible?)</td>
<td>Yes</td>
<td>Good</td>
<td>Bad</td>
</tr>
</tbody>
</table>
## 4 – Global range

Each listed parameter has its values compared to global upper and lower valid values:

<table>
<thead>
<tr>
<th>IMOS parameter</th>
<th>CF title</th>
<th>Unit</th>
<th>Valid min</th>
<th>Valid max</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEMP</td>
<td>Sea water temperature</td>
<td>Celsius</td>
<td>-2.5</td>
<td>40</td>
<td>ARGO Quality control manual v2.7 (Jan. 2012)</td>
</tr>
<tr>
<td>PSAL</td>
<td>Sea water salinity</td>
<td>PSU</td>
<td>2.0</td>
<td>41</td>
<td>ARGO Quality control manual v2.7 (Jan. 2012)</td>
</tr>
<tr>
<td>PRES</td>
<td>Sea water pressure</td>
<td>dbar</td>
<td>5</td>
<td>12 010</td>
<td>ARGO Quality control manual v2.7 (Jan. 2012)</td>
</tr>
<tr>
<td>PRES_REL</td>
<td>Sea water relative pressure</td>
<td>dbar</td>
<td>-5</td>
<td>12 000</td>
<td>ARGO Quality control manual v2.7 (Jan. 2012)</td>
</tr>
<tr>
<td>DEPTH</td>
<td>Depth</td>
<td>m</td>
<td>-5</td>
<td>12 000</td>
<td>ARGO Quality control manual v2.7 (Jan. 2012)</td>
</tr>
<tr>
<td>DOX1</td>
<td>Mole concentration of dissolved molecular oxygen in sea water</td>
<td>umol/l</td>
<td>0</td>
<td>900 000</td>
<td>MyOcean - Real Time Quality Control of biogeochemical measurements v1.0 (Jan. 2011)</td>
</tr>
<tr>
<td>DOX2</td>
<td>Moles of oxygen per unit mass in sea water</td>
<td>umol/kg</td>
<td>0</td>
<td>880 000</td>
<td>MyOcean - Real Time Quality Control of biogeochemical measurements v1.0 (Jan. 2011)</td>
</tr>
<tr>
<td>CPHL, CHLU, CHLF</td>
<td>Mass concentration of chlorophyll in sea water</td>
<td>mg/m3</td>
<td>0</td>
<td>100</td>
<td>MyOcean - Real Time Quality Control of biogeochemical measurements v1.0 (Jan. 2011)</td>
</tr>
</tbody>
</table>

...
## 5 – Regional range

Each listed Site and parameter has its values compared to regional upper and lower valid values:

<table>
<thead>
<tr>
<th>Site</th>
<th>IMOS parameter</th>
<th>CF title</th>
<th>Unit</th>
<th>Valid min</th>
<th>Valid max</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRSPHB</td>
<td>TEMP</td>
<td>Sea water temperature</td>
<td>Celsius</td>
<td>10</td>
<td>28</td>
<td>Port Hacking historical water samples.</td>
</tr>
<tr>
<td>NRSPHB</td>
<td>PSAL</td>
<td>Sea water salinity</td>
<td>PSU</td>
<td>31</td>
<td>37</td>
<td>Port Hacking historical water samples.</td>
</tr>
<tr>
<td>NRSPHB</td>
<td>DOX2</td>
<td>Moles of oxygen per unit mass in sea water</td>
<td>umol/kg</td>
<td>50</td>
<td>400</td>
<td>Port Hacking historical water samples.</td>
</tr>
<tr>
<td>NRSMAI</td>
<td>TEMP</td>
<td>Sea water temperature</td>
<td>Celsius</td>
<td>8</td>
<td>21</td>
<td>Maria Island historical water samples.</td>
</tr>
<tr>
<td>NRSMAI</td>
<td>PSAL</td>
<td>Sea water salinity</td>
<td>PSU</td>
<td>33</td>
<td>37</td>
<td>Maria Island historical water samples.</td>
</tr>
<tr>
<td>NRSMAI</td>
<td>DOX2</td>
<td>Moles of oxygen per unit mass in sea water</td>
<td>umol/kg</td>
<td>100</td>
<td>400</td>
<td>Maria Island historical water samples.</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
7 – Spike test

Each listed parameter has its own threshold value to be used in the ARGO spike test:

$$|V_n-(V_{n+1} + V_{n-1})/2| - |(V_{n+1} - V_{n-1})/2| \leq \text{threshold}$$

<table>
<thead>
<tr>
<th>IMOS parameter</th>
<th>CF title</th>
<th>Unit</th>
<th>Threshold</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEMP</td>
<td>Sea water temperature</td>
<td>Celsius</td>
<td>6</td>
<td>ARGO Quality control manual v2.7 (Jan. 2012)</td>
</tr>
<tr>
<td>PSAL</td>
<td>Sea water salinity</td>
<td>PSU</td>
<td>0.9</td>
<td>ARGO Quality control manual v2.7 (Jan. 2012)</td>
</tr>
<tr>
<td>PRES, PRES_REL, DEPTH</td>
<td>Sea water pressure, Sea water relative pressure, Depth</td>
<td>dbar, m</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>DOX1, DOX2</td>
<td>Mole concentration of dissolved molecular oxygen in sea water, Moles of oxygen per unit mass in sea water</td>
<td>umol/l, umol/kg</td>
<td>PABIM</td>
<td>MyOcean - Real Time Quality Control of biogeochemical measurements v1.0 (Jan. 2011)</td>
</tr>
<tr>
<td>CPHL, CHLU, CHLF</td>
<td>Mass concentration of chlorophyll in sea water</td>
<td>mg/m3</td>
<td>PABIM</td>
<td>MyOcean - Real Time Quality Control of biogeochemical measurements v1.0 (Jan. 2011)</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

PABIM white book v1.3 (Feb. 2010) threshold:

$$|\text{median}(V_n-2,V_n-1,V_n,V_n+1,V_n+2)| + |\text{stDev}(V_n-2,V_n-1,V_n,V_n+1,V_n+2)|$$
# 8 – Gradient Vs Rate of change

## Gradient
Each listed parameter has its own threshold value to be used in the ARGO gradient test:

\[
|V_n - (V_{n+1} + V_{n-1})/2| \leq \text{threshold}
\]

## Rate of change
Each listed parameter has its own threshold value to be used in the MyOcean rate of change test:

\[
|V_n - V_{n-1}| + |V_n - V_{n+1}| \leq 2\times\text{threshold}
\]

<table>
<thead>
<tr>
<th>IMOS parameter</th>
<th>CF title</th>
<th>Unit</th>
<th>Gradient threshold</th>
<th>Rate of change threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEMP</td>
<td>Sea water temperature</td>
<td>Celsius</td>
<td>9</td>
<td>2*stDev(first month)</td>
</tr>
<tr>
<td>PSAL</td>
<td>Sea water salinity</td>
<td>PSU</td>
<td>1.5</td>
<td>2*stDev(first month)</td>
</tr>
<tr>
<td>PRES, PRES_REL, DEPTH</td>
<td>Sea water pressure, Sea water relative pressure, Depth</td>
<td>dbar, m</td>
<td>3</td>
<td>2*stDev(first month)</td>
</tr>
<tr>
<td>DOX1, DOX2</td>
<td>Mole concentration of dissolved molecular oxygen in sea water, Moles of oxygen per unit mass in sea water</td>
<td>umol/l, umol/kg</td>
<td>90</td>
<td>2*stDev(first month)</td>
</tr>
<tr>
<td>CPHL, CHLU, CHLF</td>
<td>Mass concentration of chlorophyll in sea water</td>
<td>mg/m3</td>
<td>3</td>
<td>2*stDev(first month)</td>
</tr>
</tbody>
</table>

- Points with more than 1h apart are not considered as neighbours and current point is flagged as “Non QC’d”.
- Tests only flag current point Vn.
8 – Gradient Vs Rate of change

**Gradient**

\[ |V_n - (V_{n+1} + V_{n-1})/2| <= \text{constant} \]

**Rate of change**

\[ |V_n - V_{n-1}| + |V_n - V_{n+1}| <= 2 \times 2 \times \text{stDev(first month)} \]

Actual value is “real”
Summary

We have taken a three prong approach to achieving consistent quality controlled data from the moored sensors.

Fieldwork - consistent sensor deployment/retrieval procedures over all sites
- consistent BGC sampling procedures over all sites
- maintain sensor history

Laboratory - consistent one operator analyses for samples from all sites
- routine multi-point calibration of sensors
- extra experimental work to characterize sensors

Data - 9 QC tests applied to sensor data
- manual checks of some flagged data – eg: chl-a

All data is freely available http://imos.aodn.org.au/webportal
Acknowledgements

NRS Teams

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