IMOS Observations for Ocean Acidification Research

IMOS is supported by the Australian Government through the National Collaborative Research Infrastructure Strategy and the Super Science Initiative. It is led by the University of Tasmania on behalf of the Australian marine & climate science community.
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1. Introduction

Australia’s Integrated Marine Observing System (IMOS) was established in 2007 under the National Collaborative Research Infrastructure Strategy (NCRIS), and extended under the Education Investment Fund (EIF) in 2009. It has successfully deployed a range of observing equipment in the oceans around Australia, 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 ocean-climate science as a whole.

IMOS is guided by a National Science and Implementation Plan that has been developed collaboratively with the open-ocean ‘Bluewater and Climate’ Node, and the five regional Nodes covering Australia’s coastal oceans i.e. NSW-IMOS, QIMOS, WAiMOS, SAIiMOS and TasiMOS.

The National Science Plan addresses five major research themes i.e.
1. Multi-decadal ocean change,
2. Climate variability and weather extremes
3. Major boundary currents and inter-basin flows
4. Continental shelf processes, and
5. Ecosystem responses (productivity, abundance and distribution).

IMOS takes a range of acidification related observations spread across nodes, facilities and at least two of the science themes. The aim of this document is to summarise the observations of relevance to ocean acidification.

2. Existing observations and potential for growth.

2.1. Ships of Opportunity

Ships of opportunity are an effective way of taking broad-scale measurements around Australia’s coast, using research vessels, ferries and commercial ships. They also provide the opportunity to take coincident measurements of physics, biogeochemistry and biology. For instance, RSV l’Astrolabe is the most heavily instrumented SOOP, providing the opportunity for multidisciplinary studies along the transect across the Southern Ocean between Hobart and Dumont D’Urville.

2.1.1. \( \text{pCO}_2 \) (sub-facility leader: Bronte Tilbrook)

Broadscale surface \( \text{pCO}_2 \) measurements are made on research vessels around Australia using an underway flow through system.

Existing investments:
- Instrumentation is currently installed on 3 research vessels; RV Southern Surveyor (broad-scale Australian waters), RSV Aurora Australis (broad-scale Southern Ocean waters), RSV l’Astrolabe (repeat Hobart – Dumont D’Urville, Antarctica)

Future opportunities:
- Instrumenting coastal vessels; the RV Solander (NW Australian shelf) and the RV Cape Fergusson (Great Barrier Reef region) and commercial ships, particularly in WA region.
- Addition of pH and oxygen sensors, and underway(UV) nitrate sensors.

2.1.2. Continuous Plankton Recorder *(sub-facility leader: Anthony Richardson)*
Continuous plankton recorders are towed around the Australian coast and across regional basins to collect phyto and zooplankton assemblage data. Calcareous taxa that are sampled include those that produce the more soluble form of calcium carbonate (aragonite: mussel larvae and pteropods) and those that produce the more resistant form (calcite: coccolithophores, foraminifera, and echinoderm larvae). Echinoderm larvae have magnesium-bearing calcite, which is 30 times more soluble than calcite without magnesium.

Existing investments:
- Shelf observations are collected from Brisbane (QLD) - Adelaide (SA).
- Additional shelf routes have been arranged for the Northwest Shelf and Great Barrier Reef.
- Ocean transects are collected from Burnie (Tas) to Nelson (New Zealand); Hobart (Tas) to Durmont D’Urville (Antarctica) have been collected on l’Astrolabe, but currently on hold (due to changes made during ship refit).
- Broadscale observations are collected throughout the Australian sector of the Southern Ocean on the Aurora Australis on its way to/from the bases.

2.1.3. Fluorometer.
Underway fluorometer data is collected, along with temperature and salinity from a thermo-salinograph, on a range of ships around Australia.

Existing investments:
- Great Barrier Reef on the RV Cape Fergusson
- Northwest Shelf on the RV Solander.
- Melbourne (Vic) to Devonport (Tas) aboard the Spirit of Tasmania II
- Hobart(Tas) to Durmont D’Urville (FRRF) on the l’Astrolabe

2.2. Deepwater Moorings
2.2.1. Air Sea Fluxes Site *(sub-facility leader: Eric Schulz)*
Deep water air-sea fluxes moorings takes core measurements of meteorology and heat and moisture fluxes

Existing investments:
- The Southern Ocean Fluxes mooring (SOFS). The mooring also carries sensors to measure pCO2, and dissolved oxygen and is complimentary to the Southern Ocean Timeseries below.

Future opportunities:
- A Flux Mooring in the eastern Indian Ocean (15°S, 115°E) as contribution to the international RAMA array (part of the Indian Ocean Observing System, IndOOS).

2.2.2. Southern Ocean Timeseries *(sub-facility leader: Tom Trull)*
The Southern Ocean Timeseries site is a set of three (including SOFS) moorings in the southern ocean designed to characterise the uptake of CO2 by the ocean, and its fate within the water column (i.e. the Biological Pump).
Existing investments:
- *The Pulse Biogeochemical Mooring*: In addition to sensors for physical and bio-optical parameters, it also collects water samples at weekly intervals for measurements of nutrients, total dissolved carbon dioxide, alkalinity, plus concentrations and identification of phytoplankton functional groups.
- *The SAZ Sediment Trap Mooring*: Collects samples of sinking particles at several depths in the ocean interior (near 1000m, 2000m, 3500m). Actual samples are available for analysis, and photos/ excel summaries are on the portal.

2.3. **National Reference Stations** (*sub-facility leader: David Hughes*)
National reference stations are a combination of a mooring taking water quality measurements at two depths (temperature, salinity, dissolved oxygen, chlorophyll a, and turbidity every 15 minutes), and a hydrochemistry sampling regime which provides monthly biogeochemical data including total alkalinity and total dissolved carbon dioxide, as well as phyto- and zooplankton tows; from which calcareous taxa (e.g. forams, echinoderm larvae, pteropods) are collected.

Existing investments:
- 9 national reference stations are located around the coast of Australia at Yongala (QLD), Stradbroke Island (QLD), Port Hacking (NSW), Maria Island (Tas), Kangaroo Island (SA), Esperance (WA), Rottnest Island (WA), Ningaloo (WA) and Darwin (NT).

2.4. **Coastal CO₂/acidification moorings** (*sub-facility leader: Bronte Tilbrook*)
CO₂ moorings are co-located with some National Reference Stations. They deliver pCO₂, as well as dissolved oxygen, temperature and salinity. When combined with the monthly sampling, a complete determination of the carbonate system and pH can be derived.

Existing investments:
- CO₂ moorings have been deployed at Yongala (QLD), Maria Island (Tas) and Kangaroo Island (SA), with additional moorings at Heron Island (funded by CSIRO).

Future opportunities
- pCO₂ moorings could be deployed at other reference sites depending on sea conditions (North Stradbroke Island (QLD), Port Hacking (NSW), Esperance (WA), Rottnest (WA), Ningaloo (WA) and Darwin (NT)).
- Incorporate pH sensors onto moorings.

2.5. **Sensor Networks on the Great Barrier Reef (FAIMMS)** (*Facility leader: Scott Bainbridge*).
The sensor network on the Great Barrier Reef is being used to collect dense biophysical data; particularly around the island research stations. There are “Nodes” at Lizard Island, Orpheus Island, Davies Reef, Heron Island and One Tree Island. IMOS has developed the wireless communications system and a core set of instruments, and P.I.’s can “plug and play” instruments into the system, which delivers their data in real time.

Existing investments:
- In addition to core temperature and salinity sensors, collaborative projects involving AIMS, University of Queensland, and CSIRO are spinning up; particularly around Heron Island, to deploy new smaller pCO₂ sensors short term to complement the more sophisticated pCO₂ moorings giving some information on spatial variability.
2.6. **Ocean Gliders** *(Facility leader: Chari Pattiaratchi)*
IMOS deploys both Slocum shelf gliders, which operate to 200m and Seaglider deep water gliders which can go up to 1000m, at sites around Australia. Core glider data streams include temperature, salinity, fluorescence, oxygen, turbidity and surface currents.

Existing investments:
*Slocum gliders* are used to take measurements across the continental shelf at sites including:
- Two rocks transect/Perth Canyon, WA.
- Kangaroo Island/Eyre peninsular (entrance to Spencer Gulf), SA.
- Storm Bay, Tas.
- Coffs Harbour to Port Stephens, NSW.
- Pilbara transect, WA.
- Kimberly transect, WA.

*Seagliders* are primarily used to take measurements of boundary currents and are deployed at:
- Kalibari to Perth, WA (Leeuwin Current)
- Sydney, NSW (East Australian Current, EAC).
- Hobart to the Southern Ocean Timeseries, Tas (Tasman Outflow).
- Bicheno and St Helens, Tas (EAC Extension)
- Bonney Coast, SA (Flinders/Leeuwin Current).
- Coral Sea (North Queensland Current)

2.7. **Autonomous Underwater Vehicle (AUV).** *(Facility leader: Stefan Williams)*
The AUV takes high resolution geo-referenced stereo imagery of the sea floor annually at reference sites around Australia, to monitor changes in benthic habitats and assemblages. These are a combination of high resolution, fine scale surveys, and broader scale grids and transects along depth gradients.

Existing investments:
- The reference sites are occupied in Western Australia (tropical and temperate), Queensland (southeast), New South Wales and Tasmania (east coast).

Future opportunities:
- Reference sites on the Great Barrier Reef (Queensland), and Southern Australia.

2.8. **Satellite Remote Sensing - Ocean Colour** *(Facility leader: Edward King)*
IMOS aims to delivery nationally consistent ocean colour data of known quality. As part of this, IMOS is collecting a range of bio-optical data and has also funded the development of a national bio-optical dataset (through the AODN) to deliver data for validation of satellite ocean colour.

Existing investments:
- A nationally consistent ocean colour product of known quality for Case 1 waters.
- A national database of high quality bio-optical data for research into the bio-optical qualities of case 1 and case 2 waters.
- Deliver bio-optical data to NASA (SeaBASS) and ESA (Globcolour) for the validation of global products in the Australian region.
3. Future opportunities

3.1. Wavegliders.

Wavegliders, which are satellite controlled and get their propulsion energy from the wave action and solar power, are promising new technology for collecting surface measurements of the ocean. Wavegliders show potential as a platform for collecting surface pCO$_2$ measurements, pH, T, S, dissolved oxygen and bioptics; both at station and along transects.

3.2. Integration of observations.

Where feasible, integration of the CO$_2$ observing system with biological and physical observations that utilises emerging biological and chemical sensor technology for moored and underway observations will be sought. A showcase of this potential is the Astrolabe SOOP line and NRS sites.