INTEGRATED MARINE OBSERVING SYSTEM (IMOS)

IMOS REGIONAL NODES
Information for the 2008/09 Review

Node: **Bluewater & Climate Node**

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Node Science and Implementation Plan (NSIP) – Available to be viewed at http://imos.org.au/fileadmin/user_upload/shared/IMOS%20General/Review_papers/NSIP_Bluewater_Aug08.pdf

1. **Comments on whether the implementation of the IMOS Facilities, as planned for this region, is adequate.**

   The Bluewater and Climate Node, unlike the other regional nodes, is not restricted to a particular region or local area, rather it covers the entire ocean region around Australia. Therefore, in a formal sense, there are 3 Facilities which are directly associated with the Node: Argo Australia, Ship of Opportunity (SOOP) and the Southern Ocean Time Series mooring (SOTS). Additional important contributions come from ANFOG (repeat glider transects may improve the space/time resolution of boundary currents and in regional seas), the SRS (satellite data supplement all other data sources) and the coastal focused facilities of ACORN and ANMN.

   Argo and the XBT network are mature systems which have been enhanced and expanded under IMOS. Progress in these components is therefore very good and the data provide excellent coverage in space and time and serve the Node very well. The remaining programs in SOOP have limited spatial coverage - limited by the staffing resources available - though progress has been generally excellent. For example, the BGC sampling program on Southern Surveyor and L' Astrolabe is now producing real-time, quality-controlled data streams. The CPR component has established new laboratory facilities and recruited and trained new staff. Plankton sampling is about to commence on the L'Astrolabe. Unfortunately, a very promising deployment on an EAC-following track has been vetoed at a late stage by the vessel owners. Such issues need to be addressed within IMOS.

   The SOFS and PULSE platforms of the SOTS facility are developmental and proof of concept projects. As such they are performing adequately. The original SOTS facility proposal called for some regional work using on-going glider missions. These funds were provided to ANFOG, and successful interaction with that facility is required to achieve those missions in 2010-11.

   The SOOP SST Sensors 2c and 2d (Ship fluxes) sub-facilities provide both input and/or validation for regional and global SST and flux products. The roll-out of these two sub-facilities has been impressive. Feasibility of these sensors has been demonstrated but the present spatial coverage is somewhat limited.

Only limited deployments have been completed in ACORN, ANMN and ANFOG and the major contributions to this Node will come in the next 2 years.

2. **Suggestions for filling gaps in the regional observing system and / or suggestions for any enhancements which could be made during July 2009 to June 2011.**
   SOOP SST - 2c: More ship observations (e.g., AIMS research vessels) could be made near real-time and available to eMII and to BoM to place on the GTS. Include calibration of hull-mounted sensors.

   SOOP Air-Sea Flux - 2d: Expand coverage in Southern Ocean by recruiting L'Astrolabe into the sub-facility. The possibility of this expanded coverage is already underway using the existing equipment and systems on the ship, and has been funded from within the current facility budget.

   Argo Iridium float deployments in the Banda/Flores Sea: the original Argo design does not cover the marginal seas, partly due to the high likelihood of grounding due to the long (> 12 hours) surface times associated with transmission via service Argos. This leaves several large 'holes' in the global system, one being the Indonesian and Arafura Seas. There is now a proven application of Iridium satellite communications for Argo, which reduces surface times to a few minutes. This, along with the ability to program floats for nighttime surfacing, would likely result in useful float lifetimes. The Indonesian Seas is one of the key regions that Australian climate is sensitive to. Currently the real-time data stream for this region is sparse, with two low resolution monthly XBT lines transecting the region. A pilot of Banda Sea iridium Argo deployment would bolster the realtime data stream for seasonal climate forecasting, produce unprecedented salinity information (barrier layers) and also allow the study of the modulation of ocean fine-scale (and thus mixing) via the 2db profile resolution achieved. Deployment opportunities are available via the planned transit of the region by a French research vessel in late 2010 or via Indonesian research vessel activity. This work could be achieved with the existing Argo team manpower and expertise. A successful pilot project (subject to float survivability and political clearance) could lead to an enhanced long-term data stream from this key region.

3. **Considering IMOS#2 (i.e., a possible future version of IMOS past July 2011), comment on whether any of the other IMOS facilities (those not mentioned in 1 or 2 above) could be applicable to your region, and / or suggestions for new infrastructure.**
   Boundary Current Monitoring
   One of the great challenges facing IMOS is how to connect the broad-scale offshore variability now monitored by Argo/SOOP facilities and satellites (altimeter, SST, winds, etc) with changes on the inner shelf and at the coasts. On Australia's western, southern and eastern coasts, this interaction is mediated by an energetic and complex boundary current system and coastal wave guide which is not well monitored by IMOS, except at low temporal resolution by the IMOS SOOP Facility, and sparsely by a few shelf and slope moorings, and intermittent glider lines. IMOS does not

resolve the space and time scales in this boundary zone. The ability of ocean data assimilation (ODA) schemes to span this ‘gap’ is one of the key questions that IMOS can address, with the outcomes helping to guide the development of IMOS II. However, for selected transects across major boundary systems (EAC off Brisbane, Tasman Outflow at South Tasman Saddle, Leeuwin Current), an affordable combination of technologies may span this gap and help validate regional ODA products. Current meter moorings are deployed on the slopes and at each end of the transect. In between, the flow is monitored by gliders, thermister strings, Velocity Pressure Inverted Echo Sounders, and other equipment. This configuration should be far cheaper than full transport resolving velocity arrays and provides flexibility in capturing the flow and heat transport of these dynamic and energetic systems. A pilot of this combination of technologies could be planned in one location (possibly under satellite altimeter groundtracks and/or within coastal radar coverage), and be followed by a second array installation in the second half of IMOS II. Such arrays, besides providing great insight into the shelf/slope/offshore interactions, can be combined with Argo and satellite altimeters, to produce ongoing monitoring of the full heat and freshwater fluxes carried by the oceans – an important metric, that to date, has only been measured once by the World Ocean Circulation Experiment.

IMOS Contribution to the CLIVAR Repeat Carbon/Hydrographic lines
Currently CLIVAR lines are not supported by IMOS – such activity fits the IMOS mission and could be part of it, removing uncertainty in maintaining time series from individual PI and funding agendas.

Improving the Mapping of Nutrient distributions
Better coverage of nutrients (both macro-N, P & Si, and micro-trace elements and vitamins) in Australasian regional seas and further afield are in demand for biogeochemical and ecological modelling, oceanic climatologies and enhanced understanding of marine ecosystems. This proposal will bring this about by miniaturising flow analysis instruments into ruggedised and more autonomous systems so that they might be routinely deployed on SOOP/VOS vessels, ferries, fishing boats and even fixed marine structures (such as oil and gas rigs, navigational and weather buoys, etc.). On vessels underway, ship's intake or small towed bodies will deliver the surface seawater stream to the analysers. Another option to be developed, subject to a successful pilot project, will be the 'SmartFish' concept. This involves an autonomous, programmable towed fish that swims to one side of the ship's wake, operating over a shallow depth range if required, to collect a sequence of discrete measurements, uncontaminated for subsequent analysis in a shipboard or land-based laboratory. Finally, a more ambitious, long-term goal of this proposal will be an even greater miniaturising of flow analysers, loosely based on the evolving 'Lab-on-a-Chip' technology, to provide very compact and lightweight devices that might be deployed in Argo floats or gliders. This project would be concordant with the decade-long, SCOR-sponsored 'GEOTRACES' program <www.geotraces.org>, particularly in regard to micronutrient trace elements.

Enhanced Biogeochemical Time Series
The present suite of biogeochemical observations being collected on the l'Astrolabe is summarized below.

These first 3 observation sets are IMOS funded: 1. pCO2 (Tilbrook); 2. FRRF (Tilbrook); 3. CPR (Richardson). Additional observations being collected include: (i) From discrete bottle samples from the underway water - nutrients, pigments; (ii) Total alkalinity and total carbon.

Additional measurements that could be included in future IMOS-II work include:
(i) Oxygen/argon (O_2/Ar) ratio measurements to determine productivity (made from underway water using a Quadra pole mass spectrometer - Tilbrook)
(ii) Expanded bio-optical measurements (which would require expertise from outside of CMAR)

In next phase of IMOS, we may want to consider pCO2 and bioptical/chemical sensors at the moored coastal sites. Acidification and ocean CO2 flux issues are making these integrated sensor package very useful. The technology now exists. NOAA have moorings with CO2 sensors working for up to 14 months on the TAO array and more recently on smaller PICO moorings like those used for the Tsunami warning network. These systems report data every day, although it could be more frequent. Provided these sensors are well prepared and calibrated they have proven to be robust with close to 100% data returns. Bronte Tilbrook, CSIRO has been to Seattle to discuss deployments with NOAA. CSIRO expects to purchase one complete mooring for work on the GBR to develop our capability and target acidification work. They also expect to deploy CO2 sensors on two of the TAO moorings at 8S as part of the PCCSP program.

It is not certain the sensor packages will fit the existing buoys used for coastal sites in IMOS, although the people who designed them thought is was possible. One other alternative is to have a few reference sites with PICO or similar moorings that can be serviced from a ship. Bronte observed one PICO mooring being towed to a site in Kaneohe Bay. A small truck crane was used to drop the mooring in the water and it was towed out by dinghy a few kilometers for deployment. For a site like Maria Island or Port Hacking it would be best to have a boat with a crane. Rottnest Island and GBR may also be good sites with potential for a ship servicing. These do not seem to be too difficult to overcome and he expects all the reference sites could be reporting these parameters in near real time.

Argo floats
Depending on outcomes of trials using the oxygen-sensor equipped Argo floats and the Argo oxygen white paper (see http://www.ioccg.org/groups/argo.html), IMOS-II would need to invest in more iridium satellite transmission and be involved in future planned activities. Other future IMOS-II related activities would be alternatives to using Argo in the sea-ice, and in shallow seas (eg Coral and Solomon seas); and

experimentation to better understand the use of gliders in seas where Argo use is marginal.

SOFS/SOTS
The SOFS platform will need to be completed with a second and possibly third (replacement mooring) as well as ongoing operating costs. IMOS-II could fund the addition of a deeper-ocean physical oceanographic component on SOFS.

The SOTS proposal outlined additional instruments to be deployed on the PULSE platform in future years for which funding was not requested under IMOS-I, including video and acoustic plankton recorders. This is still a high priority.

Air-Sea Flux Measurements
An autonomous, routinely deployed, skin sea surface temperature radiometric sensor (either developed within Australia or purchased overseas) to be trialed on the Marine National Facility: Southern Surveyor.

An autonomous, routinely deployed, radiometric sea surface salinity sensor for deployment on the Southern Surveyor, to be used to validate satellite sea surface salinity measurements.

The coverage in the Southern Ocean would be improved by installing the appropriate meteorological systems on vessels, such as L'Astrolabe and the Oceanic Viking. This would probably require the installation of completely new meteorological packages and telemetry systems.

Air-sea fluxes off the North West Australia region are important to the development of tropical cyclones, Madden-Julian Oscillation (MJO) (intraseasonal oscillation), and Indian Ocean Dipole (IOD). It is also the key pathway that ENSO influences the oceanography off the west and south Australian coast. Long term (mooring) monitoring of the air-sea fluxes in that region has already attracted international attention (LOCEAN and PMEL). A collaborative project with such international groups would be worthy of investigation.

New, operational, real-time, satellite ocean products over the Australian region
Such products would also be extremely valuable, including:

i. Sea surface skin temperature from existing and new geostationary satellites;
ii. Sea surface temperature from new polar-orbiting satellites;
iii. Ocean colour products.

Gulf of Carpentaria Mooring
Enhance tropical cyclone and air/sea interaction research by establishing a mooring(s) in the Gulf of Carpentaria. This region demonstrates an interesting correlation with the Leeuwin Current variability.

Infrastructure for observations in the Southern Ocean.
IMOS 1 has not had a large focus on the Southern Ocean. This was largely because infrastructure for Southern Ocean observations (eg Argo floats, repeat hydrography/carbon, underway observation from Astrolabe (XBT, pCO2, phytoplankton pigments), moorings, animal-borne sensors) was being provided already by the ACE CRC and partners. IMOS 1 has invested, of course, in the Southern Ocean Time Series site and in CPR work across the Southern Ocean.

The future of observing infrastructure in the Southern Ocean is uncertain. The ACE CRC term comes to an end in 2010. The CRC has already deployed all the Argo floats it purchased and completed all of the repeat hydrography planned and mooring deployments planned for the centre. In this sense, the Australian Southern Ocean observing system is already in steep decline. The partners in the ACE CRC are keen to find a way to continue the partnership, but it is not known whether a new bid will be successful.

The National Framework for Climate Change Science identifies Southern Ocean observations as very high priority, but the level of investment to be made in observing infrastructure through this mechanism (in the Southern Ocean or elsewhere) is not known. Given past experience (eg with the Australian Climate Change Science Program), it will likely be difficult to find support for observation infrastructure through this mechanism.

The concern is that there is a significant risk that Australia will no longer have the capacity to make the observations of the Southern Ocean that are required to underpin improved climate predictions and to inform adaptation decisions. This comes at a time when the need is more urgent than ever. Some of the greatest uncertainties in climate change science involve Southern Ocean processes. These include poorly known but potentially large feedbacks involving changes in ocean circulation, carbon uptake and sea ice. Existing observations have begun to track the rate of change in the Southern Ocean and show that the region is warming faster than the global ocean average, the salinity of near-surface and abyssal water masses is decreasing, and the rate of basal melt of floating ice is increasing, with implications for the rate of sea-level rise. Ecosystem changes have also been observed, including a decline in krill numbers in some regions, poleward expansion of the distribution of warm-water species, and changes in higher predators. Carbon dioxide stored in the Southern Ocean is slowing the rate of climate change but increasing the acidity of ocean waters, placing many species at risk but with completely unknown consequences for the ecosystem as a whole.

While observations over the last decade have provided growing evidence of changes underway in the Southern Ocean, the lack of sustained observations is a critical gap limiting our ability to detect, interpret and respond to change. To meet this need, the Southern Ocean community has since 2006 been working on a strategy for a sustained Southern Ocean Observing System (SOOS). SOOS aims to deliver sustained, integrated observations of the physical, chemical and ecological state of the

Southern Ocean. These observations are essential to provide the climate information needed by a wide range of stakeholders, including government, industry and the community.

Australia has been leading the development of SOOS. A commitment by IMOS 2 to support an Australian contribution to SOOS would have a large impact both in Australia and overseas, helping to leverage further investment from other countries in regions of direct interest to Australia.

4. Comments on how the Nodes activities fit into the National IMOS; for example describe factor(s) which unify this Node's activities at the National level

The output from these facilities will provide data of national significance, contribute to international networks of physical and biogeochemical observations for the global ocean, and provide the first regular broad-scale lower trophic level data for the Australian region. While the data streams are valuable in their own right, for example, process studies using output from the SOTS mooring, much of the impact of the observations collected in this node will be via a range of re-analysis products. As seen in atmospheric sciences over many years, re-analysis products tend to produce a greater uptake in the scientific community than 'raw' data streams, and result in a step up in scientific productivity and understanding resulting from such data sets. The data from the IMOS Bluewater Node has a clear synthesis pathway through two major funded projects in ocean re-analysis: the BlueLink Project and ACCESS.

The BLUELink project will assimilate data from IMOS into a global model but with 10km resolution in the Australasian region from 1992 to the present. This product will be suitable for detailed ocean circulation/dynamical studies, forcing coastal models, ecosystem studies and many other applications. While BLUELink's short temporal duration (some 16 years) limits its utility for climate studies, it will form the basis for the spatial downscaling of results from output from climate models. The ACCESS reanalysis will produce a global 50 year data set including IMOS and historical data, which will be of great utility in ocean, marine and climate studies. The synergy, then, between IMOS and these reanalysis efforts is a great strength.

There is a large community of users at universities and other research organisations waiting for lower trophic level information to integrate into ecosystem models. These data will provide the springboard for Australian Research Council and other research grants.

The SOTS and PULSE platforms will carry similar bio-optical instruments to the National Reference Stations, providing an off-shore comparison for those coastal sites.

The PULSE and Tethered profiler platforms will carry similar physical (temperature, salinity) and chemical (oxygen) instruments to the extended ARGO floats, allowing lagrangian-eulerian comparisons.

APPENDIX –

OceanObs'09
Community White Paper Proposal

A global sea surface carbon observing system: assessment of sea surface CO_2 and air-sea CO_2 fluxes.

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Description

The oceans currently take up 25 to 30% of the annual anthropogenic CO_2 emissions (Sabine et al., 2004; Canadell et al., 2007). Yet, global air-sea flux estimates on seasonal to interannual timescales remain uncertain, with strong indications that at regional scales at least, the variability of the annual fluxes is a substantial fraction of the mean. Additionally, recent indications of changes in the partitioning of the anthropogenic carbon between the atmosphere, terrestrial biosphere, and ocean (Canadell et al 2007), have heightened the need to independently constrain the global air-sea exchange of CO_2.The underlying mechanisms driving this observed variability, and therefore the implications for future trends of the air-sea flux, are not fully resolved (e.g. SOLAS, 2004).

Sea surface carbon measurements started approximately 50 years ago (e.g. Keeling, 1963, Takahashi, 1961), and the prevalent measurement techniques have remained fundamentally unchanged. In the last decade the number of routine sea surface pCO_2 measurements on commercial ships, as well as on research vessels and autonomous platforms, has increased significantly in response to concerns about the uncertain impacts of rapidly rising atmospheric CO_2 levels on global warming, climate, and ocean acidification. To build upon this work and move into the future, a co-ordinated strategy for global CO_2 observations is required.

The main goals of a global network of sea surface carbon measurements on commercial ships (Ships of Opportunity, SOOP) are:

a) to reduce the uncertainty of CO_2 air-sea fluxes on regional and ocean basin scales, and ultimately on a global scale to better than ± 0.2 Pg C yr^{-1} (~ 10%),
b) to create a sustained observation system to monitor trends and variability in sea surface partial pressures of carbon dioxide (pCO_2) in response to climate variability and increasing atmospheric CO_2 burden, and to determine the drivers of regional variability, the sensitivity of these drivers to climate change, and
c) to provide observations to constrain and validate hindcast and forecast numerical models, including those used to constrain the ocean-land partitioning of carbon.

The overall need and design of a global surface carbon observing network has been outlined in several planning and program documents (e.g Bender et al., 2002). These have recommended a combination of fixed platforms and ships covering the global ocean at spatial and temporal scales of $\approx 10^3$ km and $\approx$ 30- 60 days, respectively. The initial systematic implementation was concentrated in the North Atlantic, and North and Equatorial Pacific Oceans, utilising existing mooring infrastructure such as the TAO array and commercial shipping lanes. In the North Atlantic, the measurements and innovative spatial and temporal interpolation techniques have shown that the target to constrain the regional air-sea flux to below 15 % can be achieved (e.g. Watson et al., 2009). If the current observing network is expanded, similar targets maybe reached in the North and Equatorial Pacific Ocean, whilst other basins will require significant augmentation of the existing effort to achieve this level.

Significant advances are being made by the international community to unify sampling protocols, data quality control, data archiving and access. The comparability of measurements is also being improved by commercialisation of instruments, sensor advancements, inter-comparison activities, traceable reference gases, and by homogenising measurements according to the updated Guide to Best Practice (Dickson et al., 2007).Takahashi and colleagues (1997, 2008) have assembled the first global surface CO_2 dataset to quantify a climatological global air-sea CO_2 flux. A new community based effort is now underway to establish a Surface Ocean Carbon ATlas (SOCAT, an IOCCP/UNESCO initiative), which will be routinely updated and archived centrally at the Carbon Dioxide Information Analysis Centre (CDIAC).

Over the next decade, a co-ordinated strategy for global CO_2 observations is needed to detect changes in surface CO_2 levels relevant to the global carbon budget, and to reduce the uncertainty of the global air-sea flux estimates to approx ± 0.2 PgC yr^{-1}, Carbon cycle models are now starting to be utilised to optimise the network design (e.g. Lenton et al., 2006), but cannot fully capture the biological, physical, and chemical drivers of the observed interannual to decadal variability, nor all of the feedbacks due to increasing CO_2 levels (cf ocean acidification). To resolve and quantify these – drivers and climate feedbacks - a strengthening of the existing activities is required to measure sea surface pCO_2, as well as parameters influencing the marine carbon cycle such as basic hydrography, alkalinity, dissolved inorganic carbon, nutrients, oxygen, and carbon isotopes. Our ship-based network will need to be augmented with further development of sensors, and increased deployments of autonomous platforms such as gliders, floats, buoys and moorings. These platforms will be particularly important in regions that are insufficiently covered by shipping routes (e.g. the Arctic, the South East Pacific and Southern Ocean), and regions with high variability such as the coastal oceans.

This white paper will summarise the advances in the last decade and provide a roadmap to meet the objectives including the scale and observational requirements needed to achieve the proposed reductions in uncertainties in air - sea CO_2 flux estimates in the global ocean and coastal systems.

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INTEGRATED MARINE OBSERVING SYSTEM (IMOS)

IMOS REGIONAL NODES
Information for the 2009 Review

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Node Science and Implementation Plan (NSIP) – Available to be viewed at http://imos.org.au/fileadmin/user_upload/shared/IMOS%20General/Review_papers/NSIP_GBROOS_Sep_08.pdf

1. Scope and feasibility of science and implementation plans

A comprehensive Science and Implementation Plan has been developed for the GBROOS Node with a focus on the start up phase of the project. Progress to date has tracked well against the plan and all components are on track or within the anticipated time table with all milestones being met. The project is actively deploying infrastructure, and so far all potential major risks have been dealt with. The status of the components of GBROOS is given below:

- Remote Sensing Upgrade – this has been completed and the data are now flowing to BoM;
- GBR Mooring array – array fully deployed and third service / data visit planned for October / November 2008;
- Reference Stations – the Townsville station has been deployed although in a limited fashion, the Darwin station will be deployed by mid 2009 with the upgraded Townsville one due in the first half of 2009;
- Underway Sampling – equipment has been fitted to the two AIMS research vessels and the Whitsundays ferry, the Heron Island ferry should be completed by early 2009;
- Sensor networks (FAIMMS) – three of the seven sites have been deployed with three more to be completed by mid 2009 leaving Lizard Island to be done in late 2009.
- Radar – has been operational since November 2007 and has been performing well

There have been some delays in getting equipment and this has resulted in some components being late. This is being managed and as the project moves forward any delayed deployments will be caught up. The main area of risk still lies with the data management component due to the late start of the eMII facility and the lack of progress on some of the higher level data management components. This has delayed us being able to get data to users and to more pro-actively engage with the user and research community.

As the project moves past the initial deployment phase, the need to get data out to users in a form that is usable to them will become more critical. The need to do this as a marine community means that this has to be done at a coordinated higher level than just at the agency or node level and so the emphasis is again on the eMII project to provide the leadership and frameworks to support this.

2. **Level of researcher participation / demonstrated user community**

The GBROOS node consists of significantly differing data types and these are being taken up differently by the user community. The Remote Sensing data is flowing routinely to BoM and so the use and uptake of this data is more measured by the Bureau rather than directly by AIMS. There remain some minor issues in order to get the remote sensing data flowing to the formal data repository, AO-DAAC. In the same way the validation data is also going directly to BoM for use in the generation of their products. It will also be supplied to the GTS enabling operational use of the data and access internationally. The management of the underway data is still in progress so it has not been possible to make this available to users in a form that they can easily use and so we have some way to go in order to make this data available.

The moorings data is more complex. There are obvious synergies with the mooring data collected by AIMS and that collected by CMAR, SIMS and other partners; to utilise these synergies a community of practice has been formed around the management of the mooring data. The community is working on developing common processing and presentation standards and tools and while this will result in better products and management of the data it is slowing the release of this data. A proposal has been developed to speed this up but this is yet to go to IMOS. As a result the uptake of this data is also slow but it is hoped that once the data is available this will change. At present data deployment summaries are made available on the IMOS web page and data is made available upon request. The expectation is that raw data will be downloadable in the next upgrade of the web page.

The development of the two NRS has required the formation of two local user community groups. Planning for Darwin is still in the preliminary stages however a small Reference Mooring Group within the Ecosystems Research Group (ERG) that reports to the Darwin Harbor Advisory Committee was formed in order to ensure local input. The Yongala station off Townsville is working collaboratively with DEWHA, Museum of Tropical Queensland, Australian Maritime Systems and diving tourist operators. Mooring designs have been altered in order to utilise a planned IALA isolated danger buoy at this location.

The sensor data from the FAIMMS facility is starting to become available via a range of products and so we are now in a position to make this available to the user community. Again we need to have in place web sites and data streams and the current issues with how this can best be done are slowing this down. We hope to have these resolved by late 2008 so that we are able to advertise this and start the development of user products.

The current level of user and researcher participation is low due to the inability to make the data available and to advertise this. The GBROOS data is diverse and so we need to develop targeted integrated data products rather than having an existing community that is able to immediately use all of the data generated by the Node. For this reason we need to move forward on the management of the data and to more visibly advertise the data. Some of this can be done within the Node but some needs to come from IMOS or from the various communities of interest.

3. **Scope for growth in science community engagement**

There is considerable scope for growth in engaging the science and user communities with the GBROOS data and in fact this will be the main focus of the Node once the initial deployments are completed. A number of proposals are underway with the various user communities in developing data products targeted at those communities. Some examples of these include:

- Development of bleaching predictions based on the sensor network and mooring real time data and the work of Dr. Ray Berkelmans for the Great Barrier Reef Marine Park Authority;
- Development of coral spawning predictions using temperature, tides and winds, to better determine what spawns and when on the reef in collaboration with researchers from James Cook University and AIMS;
- Validation of models of physiological stress in corals in conjunction with the University of Queensland (Dr. Ken Anthony) looking at real time predictions of coral stress and 'health' from models seeded with real time temperature, light and sea state measurements, this has the potential to become a predictive tool for general coral health and environmental conditions;
- Input of mooring and remote sensing data into work being undertaken by Drs. Ove Hoegh Guldberg and Scarla Weeks at the University of Queensland to look at the small scale dynamics of the southern GBR in conjunction with MTSRF and NOAA ARC Linkage at UQ;
- Utilising data to calibrate and validate hydrodynamic modelling studies in conjunction with Dr Schiller CAWCR, CSIRO.
- Integration of the underway sampling water data into the AIMS water quality project to extend the work currently underway;
- Deployment of a radiance reference station at Heron Island in conjunction with NOAA to look at the development of validated satellite products;
- Work underway with the CREON international network to deploy a standardized set of sites in a number of international locations with the data being commonly available;
- Work underway with the University of Queensland via the SEMAT project to develop new sensor designs and underwater wireless communications;
- Cross facility collaboration with experimental design to validate ACORN currents with in situ observation from the GBROOS Moorings array.
- Deployment and validation of Acidification/pCO2 sensors with CSIRO/UQ (Dr. Ken Anthony) looking at natural cycles of alkalinity on reefs and how commercial grade sensors work under test deployments;
- Expansion of the current GBRMPA/AIMS Water Quality and Temperature monitoring program to include the GBROOS data and in particular delivering a number of real-time data products.

The aim is to develop a number of targeted 'operational' data products and for these to be routinely used by a number of agencies and so the focus will be on selecting particular user communities and then developing knowledge products for them using the full set of integrated GBROOS data. The data will be made available via IMOS and so this in no way precludes engaging with a wider range of users but a number of high priority users have been identified and the Node will work with these to grow the level of engagement within these selected communities.

INTEGRATED MARINE OBSERVING SYSTEM (IMOS)

IMOS REGIONAL NODES
Information for the 2008/09 Review

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Node Science and Implementation Plan (NSIP) – Available to be viewed at
http://imos.org.au/fileadmin/user_upload/shared/IMOS%20General/Review_papers/NSIP_SAIMOS_Sep08.pdf

1. **Comments on whether the implementation of the IMOS Facilities, as planned for your region, is adequate.**
   The implementation of the IMOS Facilities, namely Enhanced Measurements from Ships of Opportunity (SOOP), Australian National Facility for Ocean Gliders (ANFOG), Autonomous Underwater Vehicle Facility (AUV) and Australian Tagging and Monitoring System (AATAMS) is adequate and underway. Delays have been experienced with the glider deployments as ANFOG gains capability. The implementation of the Australian Coastal Ocean radar Network (ACORN) has been delayed due to problems in obtaining licences. However, in principal approavals have now been obtained and we are expediting the purchase of the WERA RADAR system.

2. **Suggestions for filling gaps in the regional observing system and / or suggestions for any enhancements which could be made during July 2009 to June 2011.**
   Gaps in the regional observing system as originally planned relate to the understanding of biophysical couplings. In particular, beside the basic information provided by the ADCPs and WQM devices fitted on the moorings (i.e. vertical current structure, temperature, salinity, dissolved oxygen, chlorophyll fluorescence and turbidity), no information would have been made available on the biological and ecological structure of the pelagic ecosystem that underpin the vertical fluxes between the photic zone and the deep-ocean and the ocean-atmosphere fluxes, thus the response of marine waters to local and global hydroclimatic variability. We then initiated a biological oceanography program that involved in 2008 the identification of the main planktonic player of the pelagic ecosystems (i.e. viruses, bacteria and phytoplankton), and this effort will be continued from January 2009 to July 2011 through a careful assessment of the main processes affecting plankton organisms. This includes assessment of the related processes (respiration, production and grazing rates as well as viral infection rates) that will be systematically investigated in parallel to the vertical structure of the water column. This will considerably enhanced the information provided by our mooring network, and complement the information coming from our reference station.

Further improvements in our understanding of the nature of the ocean to hydroclimatic forcing are suggested and described in the next section.

SARDI has a pilot program in remotely sensed CTD data obtained from seals and sea lions. Five CTD/GPS tags ($15K each, including satellite time) could be added to SAIMOS so as to provide real-time data on feeding hot-spots that are most likely driven by important local upwellings: this data would complement that from gliders and ship-based surveys.

3. Considering IMOS#2 (ie a possible future version of IMOS past July 2011), comment on whether any of the other IMOS facilities (those not mentioned in 1 or 2 above) could be applicable to your region, and / or suggestions for new infrastructure.

IMOS#2 could provide considerable improvements to the actual IMOS following several ways not yet considered:

- implementation of a national biogeochemical component to IMOS to assess the level of production of Australian waters and the fate of that production (i.e. recycled locally, exported to the depth)
- assessment of the ocean-atmosphere fluxes; this includes CO_2 fluxes but also an assessment of the enrichment of the surface waters through atmospheric particulate matter
- assessment of the vertical fluxes between the photic layer and the deep-ocean (particularly relevant for SAIMOS, NSW-IMOS and WAIMOS) to assess the fate of organic matter production
- adoption of several CTD/GPS tags for seals and sea lions.

Finally the growing area represented by metagenomics could be encompassed in IMOS#2 in the form of a new infrastructure (a genome sequencer) that could be used at the national level to assess hot issues such as (i) genetic divergence of plankton populations advected by large scale oceanographic features such as the Leuwin/Flinders Current the East Australian Current, the South Equatorial Current and the Tasman Outflow, (ii) population connectivity at the regional scale (intra-node) and the national scale (inter-node) and (iii) more generally geographical distribution of microbial and planktonic taxa.

4. Comments on how the Nodes activities fit into the National IMOS; for example describe factor(s) which unify this Node's activities at the National level

SAIMOS activities fit into the National IMOS through the monitoring of the shelf-slope Flinders Current and shelf currents. The Flinders Current forms part of Australia's important boundary current system, being related to currents off both the east and west coasts of Australia. In the east, the Flinders Current is driven in part by the Tasman Outflow, that is dependent on the strength of the East Australian Current and wind-stress curl in the South Pacific. In the west, the Flinders Current forms the undercurrent of the Leeuwin Current where it is important to the upwelling in canyons off Perth and thus local ecosystems. As the Flinders Current is also driven by wind-stress curl in the Southern Ocean it responds to large-scale changes in the equatorward Sverdrup transport. The shelf currents off southern Australia are driven by the Leeuwin Current during winter as well as by local winds. In the context of the latter, the wind-forced Coastal Trapped Wave (CTW) field generated along the southern shelves is important to the circulation within Bass Strait and also to driving the CTWs on the east Australian shelf. In summary, the boundary and shelf currents along the southern shelves that are being monitored by SAIMOS represent a vital link between currents on both the east and western shelves.

5. Any other comments

The number of IMOS salaried positions (1.3 FTE) needed to implement SAIMOS was underestimated. Additional support has been obtained through:

1) the secondment of Louise Renfrey (from Flinders) to be the SAIMOS Executive Officer.
2) the use of SARDI/Flinders funds to support the glider deployments. Unfortunately, these funds will cease in early 2009 and other funds will be needed to continue the glider program.

Finally, SAIMOS of all the coastal nodes is unique in that the reference station and shelf region of study is far from our base in Adelaide (200 km or 12 hrs steaming). SAIMOS cruises and glider deployment cruises are therefore longer than those for other nodes so that additional support is required for salaries (and glider deployments). We request that some capital ($100k) allocated to SAIMOS Moorings be made available for salaries so as to support the mooring program.

INTEGRATED MARINE OBSERVING SYSTEM (IMOS)

IMOS REGIONAL NODES
Information for the 2008/09 Review

Node: **South East Australian-Marine Observing System (SEA-MOS, was NSW-IMOS)**
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Node Science and Implementation Plan (NSIP) – Available to be viewed at http://imos.org.au/fileadmin/user_upload/shared/IMOS%20General/Review_papers/NSIP_NSWIMOS_Aug08.pdf

1. **Comment on whether the implementation of the IMOS Facilities, as planned for your region, is adequate.**
   Implementation of the three facilities that SIMS hosts through SEA-MOS has been very good. The two Sydney moorings (SYD100, SYD140) deployed and operated through Oceanographic Field Services (OFS) has been most satisfactory. We are delighted with the professionalism of OFS and they satisfy our goal of building oceanographic capacity in the region. OFS also services the Ocean Reference Station off Bondi (ORS-65 m). One significant hurdle has been the re-location of these moorings from the historic Port Hacking transect (PH50, PH100, where 70 years of data has been collected), due to the risk of trawling activity (the two SYD moorings are in the cable exclusion zones, along with the proposed AATAMS line). Finally, we await the testing of the water quality meters (WQM) in Hobart with anticipation.

   We are examining the budget implications of a trial mooring at PH110 m, to compare with SYD100. To assess the past 70 years of monthly data, we hope to deploy a WQM at this mooring to examine how the sub-monthly scale variation influences the annual trends.

   The Jervis Bay mooring maintained and operated by ADFA was a bonus, along with DSTO's WaMos deployment. We look forward to MHL beginning the Coffs Harbour moorings (early 2009), which will complement the Coffs Radar and Coffs AATAMS transect. We will then consider our budget for a coastal mooring along the southern NSW coast off Eden.

   The AUV facility operates from SIMS and has been a star attraction at our annual open days. The facility is active nationally and has reliably delivered. SIMS will use it to survey the fauna on deep reefs and wrecks off Sydney, and await an MOU with the navy's DMS for vessel support.

   SEA-MOS has not engaged well with SOOP, nor with Tasmanian researchers. However the proposed CPR line from Brisbane-Portland and interaction with Anthony Richardson from the SE Queensland region is a welcome addition. This confirms opportunities with eastern Victoria and Randall Lee Vic-EPA: the Spirit ferry box, the de-salination mooring off Wonthaggi; the AATAMS transects off Gabo Island. Victoria has directly analogous organizations and issues as NSW.

2. **Suggestions for filling gaps in the regional observing system and / or suggestions for any enhancements which could be made during July 2009 to June 2011.**
   1) The second coastal radar, located near the separation zone off Newcastle is a high priority for SEA-MOS;
   2) SIMS wishes to link with Tasmania in the deployment of a third radar off Eden or in the Bass Strait area, possibly with an ARC-LEIF grant leveraging on the IMOS investments.

South East Australia is a consistently problematic area for BlueLink, especially over the continental shelf. Observational data is needed. We wish to discuss with BlueLink the potential for these radar fields to be linked.

3) The Coffs moorings should be up-graded to National Reference Mooring status. The mooring data could be in real time - the benefit to the public and marine community would make the project worthwhile.
4) SEAMOS needs of a node project leader funded through IMOS, much the way that GBROOS has a full time lead scientist.

3. Considering IMOS#2 (ie a possible future version of IMOS past July 2011), comment on whether any of the other IMOS facilities (those not mentioned in 1 or 2 above) could be applicable to your region, and / or suggestions for new infrastructure (brief details only).

Nearshore, biological and estuarine research should be the hallmark of IMOS-2. We need to ensure complementary state funding before signing any federal agreement.

1) Further short range high resolution coastal radar (WERA) and shorter range WaMOS systems for beach erosion, storm surge and marine park planning; estuarine or park connectivity. For example, the NSW government does not see the East Australian Current as a state priority, but beach erosion and storm surge definitely is a concern for them.
2) Maintenance of national reference moorings; further development of water colour assessments and tailoring algorithms;
3) A Marine Microbial Observatory – a first for the southern hemisphere.
4) Aerial surveys of the eastern and southern coasts to monitor kelp abundance and the spread of urchin-dominated barrens. Also, surveys for precise land elevation (L-band radar).

4. Comments on how the Nodes activities fit into the National IMOS; for example describe factor(s) which unify this Node's activities at the National level

The IMOS infrastructure off Sydney and especially Coffs Harbour addresses a major national concern about the activity of the East Australian Current, and its affect on the region's climate for over 50% of Australians. The Tasman Sea is a consistent anomaly in BlueLink due in part to the considerable mesoscale variability. Observational data is needed. The two AATAMS transects will be of direct benefit for east coast scientists on the migration of fish and sharks from the Spencer Gulf to the GBR. The proposed AUV surveys of deep reefs will benchmark deepwater communities. The SEA-MOS glider deployments will be facilitated by SIMS for any interested and collaborative scientists in the EAC-Tasman Sea region.

5. Any other comments

Much of the IMOS scientific infrastructure has no dedicated science based funding. For many cases (e.g. AATAMS, AUV) the equipment nicely complements existing scientific activity. However the management tasks of SEA-MOS and the additional scientific effort to deploy and analyse data is considerable and unfunded (especially the coastal radar and ocean gliders). These management duties are done on top of existing workloads as a service to the marine community. SEA-MOS is acutely aware of the importance of attracting scientists and attracting/supervising students to succeed with IMOS-2, but together the task is too large for too few, to be a success. The NSW state government has been unable to assist SEA-MOS, although negotiations to support SIMS are still on-going over the past 2 years. This issue was raised at the February 2008 Glenelg meeting, and has not been resolved. A strong node on the urbanized eastern seaboard is essential for a successful IMOS. To this end:

1) The AUV facility will assist with glider deployments – we need east coast radar and glider capability (not a facility, just a capability to troubleshoot).
2) SEA-MOS is about to appoint a mooring technician to facilitate communication and data QA-QC amongst OFS, MHL, ADFA and eMII;

3) SEA-MOS has already suggested to IMOS some creative ways to foster students and attract researchers to the field and the data-sets for IMOS-2.
4) SEA-MOS must employ a node Project Scientist dedicated to the implementation and promotion of the various IMOS activities. Recently, the coordinator from UNSW of the SEA-MOS radar and moorings, and the node deputy chair, has not been re-appointed as lecturer at UNSW and is a serious concern for us all. Moninya Roughan brings essential skills and publications in coastal modeling and radar to SEAMOS.

INTEGRATED MARINE OBSERVING SYSTEM (IMOS)

IMOS REGIONAL NODES
Information for the 2008/09 Review

Node: **West Australian Marine Observation System (WAIMOS)**
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Node Science and Implementation Plan (NSIP) – Available to be viewed at http://imos.org.au/fileadmin/user_upload/shared/IMOS%20General/Review_papers/NSIP_WAIMOS_Nov08.pdf

1. **Comments on whether the implementation of the IMOS Facilities, as planned for your region, is adequate.**
At present, given the current resources, we believe that the planned implementation of the IMOS facilities is adequate. However, it should be noted at the time of writing (early November) only a few facilities in Western Australia are currently delivering data streams. These include AATAMS mooring array in Ningaloo, the Rottnest ferry sea surface temperature and a logger deployed in the Perth canyons as part of the passive acoustic laboratory. However, in the next 2-3 months, the HF Radar systems should be implemented as we all as the ocean gliders should be deployed on a regular basis. The national reference stations at Rottnest Island and Esperance are scheduled to be deployed in November and the shelf mooring over the next few months.

   As a scientific community we look forward to the above data streams to come on board over the next 2-3 months.

2. **Suggestions for filling gaps in the regional observing system and / or suggestions for any enhancements which could be made during July 2009 to June 2011.**
Support sediment trap measurement off Two-rocks – Peter Thompson

   A National reference station in the Kimberley region would be appropriate. We consider that this is essential as part of IMOS#2, but is also included here as if implemented during current IMOS – data streams will be available earlier and thus would be very useful prior to a series of major development in the region.

   Consideration for the inclusion of ADCP with wave options at the National reference stations.

3. **Considering IMOS#2 (ie a possible future version of IMOS past July 2011), comment on whether any of the other IMOS facilities (those not mentioned in 1 or 2 above) could be applicable to your region, and / or suggestions for new infrastructure (brief details only).**
   There is unanimous support for the establishment of an IMOS node in the Kimberley region of Western Australia. This should include (1) North Head, north of Broome; (2) Camden Sound; (3) Adele Island; and, (3) Scott Reef regions. The facilities should include a National Reference station, HF Radar installations, ocean glider tracks and shelf moorings, including passive acoustics. In additional AATAMS and FAIMMS could also be established in the region. The WA marine community believes that a very high priority should be given to this region which is one of the major 'unexplored' regions in the country with very contrasting environment when compared to other regions of Australia. For example, the region has a very high tidal range which is not experienced in other regions of Australia and is also subject to the action of tropical cyclones. There is a major whale aggregation in Camden Sound and considerable amount of activity in the offshore regions by oil and gas industry. Also the Government of Western Australia has identified North Head region to the north of Broome as a location for an onshore LNG hub to service the offshore industry.

   WAIMOS will also support the maintenance of a proposed international air-sea flux/upper ocean mooring off NW Australia, which is a key area for tropical cyclone modeling/forecast, Leeuwin Current and seasonal climate forecast, and climate change monitoring.

4. **Comments on how the Nodes activities fit into the National IMOS; for example describe factor(s) which unify this Node's activities at the National level**
   Majority of data streams from WAIMOS will be available from the region between Guilderton and Fremantle and extending offshore. These include HF Radar, ocean glider and shelf moorings. These data streams has been designed to monitor the physical and ecological influences associated with the two major currents systems within the study region: the Leeuwin and Capes Currents and their interaction. The Leeuwin Current is the major boundary current along the western and southern regions of Australia. This is consistent with the overall aim of IMOS which is to monitor the boundary currents around the Australian continent.