

**Call for Proposals under the IMOS (EIF) Five Year Strategy:
Enhancement or extension of IMOS – July 2009 to June 2013**

Satellite Product Infrastructure

Sub Facility Project Plan for 2010-2013

Prepared on 23 October 2009

Proposals should be submitted by 30 October 2009 to:
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Overview:

Proposed Infrastructure Investment:	Investment in the development of satellite marine data product acquisition and processing streams
IMOS Facility:	Satellite Remote Sensing
Operating Institution:	CSIRO Marine and Atmospheric Research
Facility Leader (for this Proposal):	Dr Edward King, and Dr Peter Turner CSIRO MAR Canberra and Hobart Phone: 02 6246 5894 & 03 6232 5094 Edward.King@csiro.au and Peter.Turner@csiro.au
Other(s) key people involved:	Dr Adam Lewis, Geoscience Australia Canberra Dr Peter Fearn, CUT, Perth Craig Steinberg, AIMS
Collaborating Institutions:	CSIRO Marine and Atmospheric Research, Geoscience Australia , Bureau of Meteorology, Curtin University of Technology, AIMS

List of attachments:

- Letter from senior person in Operating Institution, confirming that the proposed infrastructure can be developed and operated within that institution
- Resume of Facility Leader
- Letters received from Collaborating Institutions, detailing their support to the Proposal, and indicative level of co-investment

Nature of Investment:

The activity of the SRS facility (the smallest IMOS facility in terms of investment) has delivered three significant improvements to ocean observing capacity:

1. the establishment of a national data reception, merging and processing system for generating GHRSSST SST products from AVHRR data, feeding directly into global data sets.
2. the development of a data management infrastructure that is well suited to remote sensing data through the AO-DAAC which provides an easy-to-use interface to retrieve remotely sensed marine products in a number of common formats which uniquely meet a number of user requirements (eg. sub-setting and/or aggregated granules).
3. upgrades to the TERSS reception antenna in Hobart and a new X-band reception facility at AIMS in Townsville completing the Australian direct broadcast reception network with stations in the East (AIMS), West (Wastac), North (Darwin), South (TERSS) and at the centre (Alice Springs)

This proposal seeks to capitalise and build on this progress, and exploit opportunities that have emerged in the national research infrastructure environment, namely the:

1. development of the IMOS Portal by the eMII facility,
2. improved networking and storage facilities, and data cataloguing and discovery capabilities arising from the ARCS and ANDS components of NCRIS/PfC
3. commencement of AusCover, the terrestrial remote sensing component of NCRIS/TERN

The over-arching goal is to broaden the range of marine remote sensing available to researchers, to improve their access to it, reduce the cost of utilisation, and put in place the infrastructure needed to sustain those advances over the forthcoming generation of sensors. The principal activities proposed are:

1. Focus the establishment of a sustainable national Ocean Colour production system under the auspices of an agency with both reception facilities and a national and operational focus (GA);
2. Align and unify the AO-DAAC infrastructure and data holdings with the IMOS Portal, and through that, the Australian Research Data Commons;
3. Move the data supply focus from reception facilities to management by improving the efficiency of management and processing of base data sets for remotely sensed products through further development of the information infrastructure in concert with TERN/AusCover, in particular:
 - a. Coordination of data from both reception facilities and overseas data providers
 - b. Compilation and sharing of base sensor data and necessary ancillary data in nationally accessible archives
 - c. Development of distributed processing workflows for spatial time series data sets, with focus on operations in-common with the terrestrial community, such as calibration, geolocation and remapping

Strategically this proposal will develop the relationships, experience and infrastructure that will be required to efficiently manage and exploit the data from forthcoming sensors. It also aligns with IMOS strategic priorities by continuing to build institutional strengths into national capability through development of the role of operational agencies with reception capability (GA) in the support of research, drives down the cost of observations by promoting a national approach to data sharing and partnering for sustained observing, and supports whole of system approaches and data uptake through enabling data interoperability, both within the marine community and with related domains (TERN/AusCover).

More detail on each activity is provided immediately below, however it should be noted that this proposal is merging a number of synergistic sub-proposals which are at varying stages of development and, because of the timeframes involved in this process, require further work to fully integrate. For this reason, for the Ocean Colour element, additional detail can be found in an appendix at the end of this document.

1. National ocean colour production has not yet been achieved in Australia for a number of reasons; either because it has been attempted by an agency without a strong national mandate, or because processing has been undertaken by a number of research algorithm developers with a particular local focus who therefore failed to achieve critical-mass, or simply because of the difficulty of compiling sufficiently comprehensive national base data sets. Geoscience Australia, as a National operational agency with reception capability and a track record of processing MODIS data at continental scale, is well placed to lead the addressing of this problem. By establishing a standardised processing stream, based on the SEADAS system, and utilising both existing network of reception facilities and GA's own historical archive of MODIS data, it will be possible to produce not only standard high resolution products in near real time, but a consistently processed historical archive. The appropriateness of this approach (a lead agency with supporting data providers) has been well demonstrated by the success of the BoM in sub-facility 11a of providing the backbone for SST processing in Australia. Through GA providing leadership in creating a processing framework for the base data, the system can be evolved by progressively adding regionally validated algorithms. This permits the immediate needs of blue water users to be met, whilst enabling a staged approach to refining the data streams for coastal and case 2 waters nationally. An advisory group comprising active researchers and end-users can provide guidance on how this process should be implemented. A natural by-product of the SEADAS processing of the entire Australian MODIS data set could be the provision of a regional MODIS SST for use by the GHRSSST sub-facility.

2. The AO-DAAC and IMOS portals both deliver data successfully to end users. The AO-DAAC is more than just a portal, and is built upon a data system that is well suited to delivery of gridded remote sensing data. In contrast, the IMOS Portal interface allows more sophisticated visualisation including "merging" with other datasets, but permits bulk data access only at a less convenient coarse granular level. The IMOS portal, however, includes middleware that supports metadata conventions that enable discovery of data via standardised protocols. Integrating the AO-DAAC functionality into the IMOS portal, by interfacing the IMOS portal to the AO-DAAC data system, would immediately make the AO-DAAC data discoverable and accessible by a much larger community of users, and it would enhance the capability of the IMOS portal to deliver large gridded data sets beyond satellite-derived SST and Ocean Colour, such as model output fields for example. It has always been the goal of the AO-DAAC to develop the capability to support swath-format data (*ie.* non-remapped). This activity would include enhancement of the system to achieve that by generalising the underlying metadata model.

3. The nature of remotely sensed earth observation data means that sensors collect data over both marine and terrestrial environments, and that multiple swaths or observations are required to form a view at continental scale. These characteristics mean that there are significant opportunities to reduce the cost and difficulties in working with these data sets by sharing acquisition, storage, management, and any processing that is in common (either spatially or across domains). The establishment of ARCS-managed national research computing infrastructure, openly accessible outside institutional firewalls, has for the first time made it possible to easily share large data sets with the whole research community, and such sharing has an immediate impact on the requirements for the storage of multiple copies. The efficiency improvements are going to be critical as the next generation of satellite sensors comes on line and data volumes increase. To achieve these savings however, some considerable effort needs to be made to establish the relationships between the participating communities, be they locally based or research domain based. Some of this cooperation is already going on between reception stations with both AVHRR and MODIS data, but the establishment of TERN/AusCover means that there has never been a better opportunity to do it across domains. Moreover, a substantial fraction of the base processing of remotely sensed data, including geolocation, remapping and calibration, is in common regardless of location or domain, and the implementation of a standardised processing workflow for these data would represent a second major advance in reducing time and effort to

utilisation of these data by scientists. The tools developed in this activity can be immediately demonstrated naturally in the Ocean Colour processing stream activity and through the development of a remapping system within the AO-DAAC infrastructure. There is a pressing need to prepare for a single national archive of data from the NPOESS forerunner mission NPP (due 2011) which this activity proposes to do in conjunction with TERN/AusCover and the Members of ARCS.

Implementation Strategy: Summary

1. Ocean Colour

- A science advisory working group drawn from the Nodes will be convened to provide guidance on priority of algorithm implementation and direct links to cal/val activity
- Implement the SeaDAS processing chain in-house within GA to process GA-sourced data (both near real time and historical archive).
- Make resulting data (standard OC, possibly MODIS SST) visible via AO-DAAC and IMOS Portal.
- Deploy SeaDAS chain in ARCS environment, to support regional reception facilities, in conjunction with activity 3.
- Add regionalised OC algorithms to processing chain based on advice from science advisory working group.

2. AO-DAAC/IMOS Portal

- Engage directly with eMII IMOS/Portal team to develop strategy for accessing underpinning AO-DAAC infrastructure from IMOS Portal
- Ensure AO-DAAC harvester can access data served through eMII THREDDS servers (common data platform for both AO-DAAC and IMOS Portal)
- Move AO-DAAC infrastructure (harvester, spatial database and web-query service) to ARCS-supported environment (in common with IMOS Portal).
- Extend AO-DAAC metadata model to support swath-format gridded data

3. Data Management and Processing

- Formally arrange with ARCS to provide storage for national long-time series data sets and consolidate existing holdings online in this environment. Make these holdings visible via the IMOS Portal/AO-DAAC.
- Prepare for launch of NPP (est. 2011) by deploying NASA processing software in ARCS environment and arranging for storage for single national archive
- Develop, with AusCover+NeAT, workflows that are able to access these data repositories
- Implement some standard processing streams in these environments, including the OC SeaDAS process, remapping of MODIS swath format data (served by the merged AO-DAAC/IMOS Portal), and NPP product streams.

Objectives

The Blue Water node lists four major areas driving the observing system:

- Tracking multidecadal ocean change, understanding its role in setting the global response rates to increasing anthropogenic forcing and projecting regional coastal and marine impacts.

- Understanding and predicting the major modes **and drivers** of climate variability in the Australian region
- Improving the understanding and prediction of ocean currents and the links between large-scale offshore variability and the response of the Australian shelf/slope boundary current systems.
- Discovering and understanding the links between ocean and climate variability, marine chemical cycling and ecosystems from multidecadal through to monthly timescales.

To address these science challenges time series of sea surface temperature and ocean colour products will be essential. It is not clear as what priority should be given to particular products and this needs to be determined by a flexible process that can adapt to the availability of resources and the needs sought from and articulated by the nodes. The prime objective is to make critical datasets available as soon as possible to node communities needing them for scientific application. The sub facility needs to engage firmly with the IMOS community and also engage with international satellite agencies and product development efforts such as GHRSSST-PP. The sub facility will develop infrastructure by implementing product production streams for specific products with a generic management structure. If there are multiple product generation streams running in different organisations a central management system is needed so that the integrity of the system can be maintained. Processing errors will need to be managed and systems restarted. Table 1 shows a list of sensors both current and future. It will be critical to be able to manage data from a large number of these sensors both via standard processing packages and by using locally developed algorithms. Part of the work of this sub facility will be to take “scientific code” and make it into operational infrastructure. The work to do this is significant and should not be underestimated. This sub-facility is building software infrastructure to ensure a continual supply of data, costs are all salary related with a travel component to ensure international and local contacts are maintained.

Table 1: Current Satellite Sensors for which the assessment of accuracy is planned.

Sensor	Agency	Satellite	Launch date	Swath (km)	Resolution (m)	Bands	Spectral range	orbit
SeaWiFS	NASA	OrbView-2	1 Aug. 1997	2806	1100	8	402-885	Polar
MODIS-Terra	NASA	Terra	18 Dec. 1999	2330	1000	36	405-14,385	Polar
MODIS-Aqua	NASA	Aqua	4-May-02	2330	1000	36	405-14,385	Polar
MERIS	ESA	ENVISAT	1 Mar. 2002	1150	300/1200	15	412-1050	Polar
OCM-2	ISRO	Oceansat-2	23 Sep. 2009	1420	360/4000	8	400 - 900	Polar

HICO - Hyperspectral Imager for the Coastal Ocean	ONR & DOD Space Test Programme	JEM-EF on Int. Space Stn.	18 Sep. 2009	50 km (selected coastal scenes)	100	124	380 - 1000	51.60, 15.8 orbits p/d
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Table 2: Forthcoming Satellite Sensors for which the assessment of accuracy is planned.

Sensor	Agency	Satellite	Launch date	Swath (km)	Resolution (m)	Bands	Spectral range	Orbit
VIIRS	NOAA / IPO (USA)	NPP	Early 2011	3000	370 / 740	22	402 - 11,800	Polar
HSI	DLR (Germany)	EnMAP	2012	30	30	~200	420 - 2450	Polar
OLCI	ESA	GMES-Sentinel 3A	Oct/Nov 2012	1265	260	21	390 - 1040	Polar
VIIRS	NOAA / IPO	NPOESS C-1	2013 / 2014	3000	370 / 740	22	402 - 11,800	Polar

Preliminary costing

Costing of A, B, C and D

The work to be done under this proposal will be shared between CSIRO, Geoscience Australia, and Curtin University. The balance of funding between institutions will vary over time depending on the state of the development. The overall staff requirements, given experience with the Bureau of Meteorology GHRSSST SST sub-facility, peak at 5 FTE in the Ocean Colour production system startup year. Given the varying overheads and nature of coinvestment between CSIRO, the Bureau, Curtin and GA this implies an average figure <\$400K pa over the life of the funding. There will be a limited requirement for equipment assuming that ARCS will provide access to computing resources, though they may require some support in order to do this (albeit at a discount rate though economies of scale). There will be a need for a travel budget for attending local (within Australia) coordination and collaboration meetings, and possibly to support international collaboration (e.g. NPP/NPOESS and Ocean Colour standard products). This will diminish in the later years of the project.

In round figures, funding of \$500-\$550K pa will be required. Note that until June 2011 the AO-DAAC activity is funded at 200K pa.

Salary: 1.5 FTE 09/10, 5.05 FTE 10/11, 3.6FTE 11/12 3.0 FTE 12/13
Operating \$30k/yr first two years, \$15k/yr second two years

Total requested is \$1485k, of which \$355k is already committed NCRIS funding. The total cost of the proposal to EIF funding over three years is therefore \$1130k. As a comparison, the AO-DAAC and reception station upgrades, which this sub-facility extends, were funded at \$1.420M over four years, so this proposal represents a small increase on present investment from \$355K pa to \$375K

pa, in line with the larger number of EFTs versus capital costs associated with building information infrastructure rather than reception facilities.

It should be noted that this proposal leverages co-investment by NeAT in the IMOS-related MACDAP project (AO-DAAC), and NeAT2 in AusCover/Grid Workflows (Data infrastructure).

List of major activities – including major party(s) involved, duration, start, finish

Activity	Parties	Duration	Start	Finish
Natl Ocean Colour Production system – creation of in-house system followed by rollout on ARCS infrastructure	GA+ (in advisory roles) CMAR & CLW, CUT, UQ	36 mo.	2010/07	2013/06
AO-DAAC, integration with IMOS portal, extension of metadata model to support swath grids	CMAR + eMII (TPAC?)	48 mo.	2009/07	2013/06
Data infrastructure (provision of storage, workflows, NPP preparation, OC production integration)	CMAR CUT (TERN/AusCover),	36 mo.	2010/07	2013/06

List of major equipment to be purchased / developed

Initial investment (~\$30K in local compute+storage) for GA Ocean colour processing system. Provision for up to \$100K of storage to be hosted by Members of ARCS in national data centres in years 2 and 3. It is not presently clear what the investment model for storage within the ARCS infrastructure will be in the EIF regime, but the provision here is made on the assumption that some co-investment by the user domain will be both necessary and the most cost effective.

Access, pricing regimes:

- How will data access be provided?
 - Via AO-DAAC integrated with IMPOS Portal
- How will data and products be managed?
 - On infrastructure managed by ARCS, hosted by Members of ARCS, and co-funded in some cases by TERN/AusCover
- What are the dependencies on external / other facilities (national and international)?
 - eMII engagement to ensure proper integration of AO-DAAC into IMOS Portal
 - TERN/AusCover implementation plan to complement IMOS investments for shared base data sets.
 - NeAT Workflows project to contribute to generic infrastructure applicable to marine data
- Collaborative structures for allocation of priorities
 - Ocean Colour science advisory group to provide guidance on base implementation and prioritisation of implementation of regional products
 - TERN/AusCover liaison to ensure opportunities for co-investment in key common data sets are realised

Governance

- Performance indicators
 -
- Describe key risks and risk management strategies
-

- For existing Facilities, respond to any issues raised in the 2008 IMOS Review
 1. SST now available, Ocean Colour production facility under auspices of GA now proposed
 2. Integration with eMII/IMOS Portal now explicit in plan and eMII plan
 3. Extension to support gridded but not remapped (swath) format data now proposed
 4. Linkage with TERN/AusCover (and related NeAT project) now proposed.

Budget: Please complete the spreadsheet provided, and detail here any further information you have available on the background to the Budget:

- EIF Funds
 - Extension of existing Facility
 - Expansion of existing Facility / New Facility
- Co-investments – source and nature
- CSIRO Salary overheads
- Staffing details
-
- Description of proposed new infrastructure for Nodes – please complete the Table on the next page, referring to Attachment 1 to the Guidelines for further information

TABLE: Observations required by the Nodes in relation to this Facility

Facility	Observations required by the Node		
	NCRIS Funded (already allocated to Jun11)	EIF first \$8M funded (already allocated to Jun10)	Extension of existing facility infrastructure out to 2013.
	(see Appendix 1 of the Guidelines)		
Bluewater & Climate			
WAIMOS			
GBROOS			
NSW-IMOS			
SAIMOS			
Other <enter name>			

Appendix 1

An Ocean Colour Data System for the Australian Maritime Jurisdiction (AMJ)

Project overview

This project will deliver ocean colour and water quality data, for the entire Australian Marine Jurisdiction in near real time. The input data source will be the MODIS sensor. MODIS data are already routinely captured by Geoscience Australia using facilities at Alice Springs and the TERSS and provided as raw data feeds to CSIRO, the BoM, the WASTAC and the wider remote sensing community. This project will provide a national facility for processing these data to produce OC products using the SEADAS algorithms. The data products would be distributed via the EMII and the AODAAC.

The project will provide the marine science community with:

1. Standard data ocean colour data for the AMJ, and;
2. A core facility for on-going improvements such as:
 - Systematic and staged incorporation of validated regional algorithms;
 - Adoption of other data sources (future sensors, and preparedness for the end of life of the MODIS sensors)
 - Development of value-added products: seasonal averages, time-series parameters, anomalies, etc

The project involves Geoscience Australia's National Earth Observation Group and Marine Environment Group; and CSIRO

Relevance to IMOS 5 year strategic plan

The role of the IMOS satellite remote sensing facility (SRS)

The role of the SRS is to provide calibrated science data streams from remote sensing sources to the marine science research community. In a recent workshop in Melbourne it was identified that these data streams fall into several sets:

- Sea Surface Temperature (SST)
- Ocean Colour (OC)
- Ocean Surface Topography (OST);
- Other (e.g., surface salinity)

In discussions, it was also identified that OC and SST datasets have multiple applications. For instance patterns of change of SST provide indirect, fine-scale observations of surface currents that cannot be matched by topography measures. It is also clear that visualisation of the ocean surface through OC products is an important process in the development of marine science.

The Ocean Colour data gap

Despite the importance of OC data, and the availability of standard global datasets on a daily time-step at 4km resolution, OC data are (still) not available for the entire Australian EEZ at appropriate spatial and temporal resolution (e.g., 1 km resolution and up to twice daily, from the MODIS sensor). More than this, there is no operational facility providing OC data in general. This is a clear gap, which IMOS can fill.

The proposed Ocean Colour Data System (OCDS) will significantly enhance our capacity to monitor oceanographic and associated biological phenomena at a relatively fine spatial scale across the entire Australian Marine Jurisdiction. This is especially important for the 2.5 million square kilometres of the new AMJ and IMOS priority areas such as the Southern Ocean and Northern Australia. The system represents a significant enhancement of the IMOS SRS Facility, with new co-investment from CSIRO and GA in its implementation and maintenance.

Benefits

The Ocean Colour system will significantly improve our knowledge of the spatial and temporal variations of impacts of ocean boundary currents on continental shelf ecosystems by identifying the spatial and temporal shifts in optical characteristics of shelf waters. These reliable water-quality parameters delivered by the system will provide key indicators of marine ecosystem condition. An important outcome of the project will be an enhanced capacity to characterise pelagic ecosystems across the AMJ, which will be especially useful for pelagic bioregionalisations. Outputs of this system will also provide essential data for the characterisation of the high seas adjacent to the AMJ, and inform the ongoing study of these areas for marine conservation management.

In addition, this project will:

- strengthen the backbone of the IMOS coastal component
- enable the monitoring of the surface water expression of the major boundary currents across and within Nodes
- address the pressing issue of more reliable maps of coastal/inner-shelf water quality parameters

Users

There will be immediate uptake of the new datasets delivered by the system by a range of marine and coastal research groups, including the CERF Marine Biodiversity Hub (UTAS), Wealth from Oceans Flagship projects (CSIRO) and the Marine and Coastal Environment Group (GA), etc..

Project Description

Work has already been done in both the development of water quality products, notably by the Inland & Coastal Water Remote Sensing Group at CSIRO Land and Water (see for example <http://www.elmow.csiro.au>). In this project we propose a unified approach, combining the operational remote sensing data infrastructure of Geoscience Australia with the scientific expertise of CSIRO to deliver a national, operational system.

The water quality products will be comprised of AMJ-wide maps of water column concentrations of chlorophyll and suspended sediment. These products will be derived from remote sensing data using standard concentration assessment algorithms implemented by the scientific collaborators on this project, the Inland & Coastal Water Remote Sensing Group of CSIRO Land and Water, led by

Dr. Arnold Dekker. On-going research to refine the concentration-estimating algorithms for regional applications is not part of this proposal, however improved algorithms could be included in the system in future. Other IMOS data streams are expected to provide validation data which will improve the marine science community's understanding of the applications of the Ocean Colour datasets. Again, this validation research is not part of this proposal.

The data processing systems would be implemented in Geoscience Australia using expertise from GA and CSIRO. GA has demonstrated competence in delivering operational data streams from the MODIS sensor. In 2005 implemented the Sentinel hot-spot detection system developed at CSIRO, and in 2008 GA began producing a continental land surface reflectance dataset extracted from MODIS observations. These are produced every 4 days, using data gathered over a 16 day period. Furthermore, Geoscience Australia has a successful track record of maintaining data streams (data continuity through uptake & implementation of new sources of satellite data) and is already fully operational in down-linking and maintaining remote sensing data flow.

IMOS has invested in the AO-DAAC and the EMII, and these would be the basis for discover and access to the data streams. Geoscience Australia would maintain a copy of the data, thus ensuring a back-up independent of the AO-DAAC and EMII data management processes.

Outcomes

1. AMJ-wide maps of water column concentrations of chlorophyll and suspended sediment, delivered to the AO-DAAC and the EMII on a daily basis (to include binned products where appropriate).
2. A new component of a the National Collaborative Research Infrastructure in an operational agency with both remote sensing capabilities and a mandate for marine data.
3. Potential development of time series products for aquatic application such as anomaly and trend analysis (e.g. long-term seasonal averages and high magnitude/low frequency events in primary productivity) in collaboration with key partners
4. A significant enhancement of the IMOS SRS Facility

Other considerations

Standard v. locally tailored algorithms

It is recognised that standard international algorithms may not apply for regional scale and coastal applications, for example where parameterisation of the local-scale optical water properties may be necessary in order to extract sufficiently accurate results. However, it is equally contended that standard international algorithms do apply in off-shore and deeper water environments and that standard products have a key role to play. Pursuit of 'ideal' products corrected for Australian environments can be counter-productive if not tempered with recognition of the value of the standard data products.

Beyond MODIS. Preparedness for future satellite sensors

With this facility in place, Australia will be better positioned to plan for future satellite based OC sensors. MODIS is the dominant satellite sensor for OC work at present, and can be expected to continue for several years more, given the projected operational life of the sensors. However the Aqua and Terra satellites (which house the MODIS sensors) are already beyond their initial design life, illustrating the importance of planning ahead for future data streams. This project will establish

an operational OC data stream and associated 'down-stream' uses, which will better position the marine science community to plan and advocate for future OC capabilities.

Future work

Maps of chlorophyll a and suspended sediment derived from remote sensing can be used derive synoptic, broad-scale ecological indicators (taken from Platt and Sathyendranath, 2008). In the case of chlorophyll, examples may include:

- initiation, amplitude, duration, and total production of Spring bloom
- timing of Spring maximum
- annual phytoplankton production
- integrated phytoplankton loss
- spatial variance in biomass and production field
- phytoplankton functional types
- delineation of biogeochemical provinces

The proposal will encourage the development of algorithms for time series-based value add products (such as listed above) and will provide an environment in which such value added products, once developed, can be deployed to the wider marine science community.

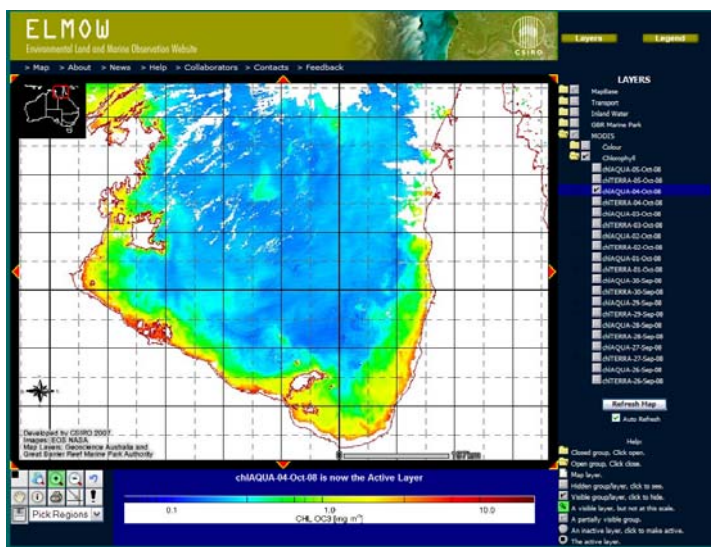


Figure: Screenshot of ELMOW prototype system over Gulf of Carpentaria, CSIRO Land and Water.