IMOS Integrated Marine Observing System

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

Facility Project Plan

Proposals submission to:
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Overview:

Proposed Infrastructure Investment:	Integrated coastal fast ice monitoring sites in Antarctica
IMOS Facility:	New Facility – Antarctic Fast Ice Monitoring [AFIM]
Operating Institution:	Australian Antarctic Division and ACE CRC
Facility Leader (for this Proposal):	Dr Petra Heil, AAD and ACE CRC, petra.heil@utas.edu.au 03 6226 7243
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Collaborating Institutions:	AAD, ACE CRC, NIWA, and international partners listed below

Attachments:

- Letters from Drs. John Gunn (Chief Scientist, AAD) and Tony Press (CEO, ACE CRC), confirming institutional support for the proposed infrastructure.
- Resume for Dr. Petra Heil (AAD and ACE CRC), facility leader.
- Letter of support from Dr. R. Murdoch (General Manager, Research, National Institute for Water and Atmosphere, NZ), detailing their support to the proposal, and indicative level of co-investment**.**

Nature of Investment

Summary

The sea ice cover plays a major role in governing the exchange of energy between the ocean and atmosphere in the polar regions. Changes in the thickness and extent of the Antarctic sea ice cover may be harbingers of climate change. Results of global climate change models indicate that there is still much to be learned about the details of the complex atmosphere-ice-ocean interaction. Key to improving this understanding is the collection of field measurements pertinent to the development of physically based parameterizations of sea ice thermodynamic processes. A basic element in studies focused on thermodynamics is the mass balance of the ice cover, which is a great thermodynamic integrator. In simple terms, if there is net warming over time, then there will be thinning of the ice, and, conversely, net cooling leads to thicker ice. Over the past several decades we have witnessed a very significant change in the distribution of sea ice around the Antarctic continent, with a reduction in the west Antarctic Peninsula region during summer that is on par with the much publicised decline in Arctic sea ice extent [Maslanik et al., 2007]. This has resulted in significant habitat changes for species in that region, e.g., a southward movement of both Antarctic and sub-Antarctic species of penguins.

Direct measurements of the mass balance are relatively simple. An array of stakes and thickness gauges is used to measure ablation and accumulation of ice and snow at the top and base of the ice cover. Coupled with ice temperature measurements, the mass balance measurements provide valuable information on the heat exchange between the air, ice and ocean. In spite of the importance of mass balance measurements and the relatively straight foreward equipment involved in constructing them, there are few observational results, and hardly any from the Antarctic. This is due, in large part, to the expense involved in operating long-term field camps in the drifting pack ice to serve as the base for these studies. The mass balance of sea ice can also be inferred autonomously using acoustic position and auxiliary sensors. The coastal fast ice adjacent to Antarctic stations can provide cost-effective deployment locations that provide valuable data. These fast ice monitoring sites use acoustic sensors to determine the position of the ice surface and base, and to monitor snow accumulation [Heil, 2007]. An integrated automatic weather station monitors wind speed, direction, air temperature and pressure, and additional instruments can be added into the water column. A similar setup is proposed for an Arctic coastal sea-ice observatory [Druckenmiller et al., 2009].

In addition to the existing climatological fast-ice mass-balance station, the proposed monitoring set-up will also include instruments to measure biological parameters at the underside of the ice and in the water column. Ice algae can contribute between 5-25 % of the overall primary production in ice-covered waters of the Southern Ocean [Arrigo and Thomas, 2004]. However, these are crude estimates as the sea ice algal biomass and production cannot be monitored on large scales [Mundy et al., 2007]. Despite recent advances in our understanding of the spatial dynamics of ice algal biomass distribution [Raymond et al., 2009], the current models used to estimate ice algal productivity remain highly uncertain due to the paucity of *in situ* biomass data. Knowledge of the processes on how microalgal communities integrate within the ocean-fast ice-atmosphere system is important not only to understand carbon production within the coastal food chain, but is also integral for the validation of ice algal production models that will be used over the entire Southern Ocean. Robust ice algal primary production models, calibrated against *in situ* ice algal biomass data, are a key element for further development of ecosystem models needed to predict the impacts of climate change on Antarctic marine ecosystems.

Ice algae present an early season food source for pelagic herbivores and these in turn provide food for higher trophic levels like seals and penguins [Arrigo et al., 1997]. The fast ice is also the breeding and birthing ground for species such as Emperor penguins [Massom et al., 2009] and seals [Lake et al., 1997]. For example, the breeding cycle of Emperor penguins lasting 9 months, and this species is very vulnerable to a reduction in the seasonal fast-ice duration or its thickness. Fast ice makes up 16 to

20% by volume of the East Antarctic sea ice at its maximum extent [Fedotov et al.,1998] and provides a stable platform to study ocean, ice, and atmosphere interactions that contribute to thermodynamic processes. Predictions of changes in the polar climate depend on our ability to accurately simulate sea ice and its role within the climate system, and knowledge of these thermodynamic processes is especially important in context of a changing environment, i.e. as expressed by the polar amplification of global warming, changes in trajectories of polar cyclones and associated redistribution of precipitation patterns. Sea ice is a key driver in Antarctic ecosystems and understanding the physical forcing of ice algal production is pivotal to understand the impact of climate change on ecosystem processes.

We propose to build upon an international network of fast ice monitoring sites established in Antarctica during the International Polar Year, 2007-09. The Australian Antarctic program has already established fast ice mass balance stations at two sites and has taken a leadership role internationally in the development and expansion of the Antarctic Fast Ice Network [AFIN]. International partners in the AFIN network are: Australia[#], China[#], France, Germany, Japan[#], Malaysia, New Zealand[#], Norway[#], and Russia, with active partners indicated by [#]. Other countries have indicated strong interest to be involved in the program, contingent on securing funding.

The key scientific questions to be addressed by this program are:

1. Is Antarctic sea-ice thickness changing, and if so, what is the spatio-temporal variability of these changes?
2. How are changes in Antarctic ice thickness linked to the changes observed in the surrounding ocean and atmosphere?
3. How is ice algal biomass coupled to physical sea ice properties and local oceanographic and atmospheric conditions?
4. How does the fast-ice extent respond to changed atmospheric (and oceanographic) conditions?

An extended AFIM is crucial to fill existing gaps in the observational record of IMOS, which has been charged to undertake sustained observing to improve our understanding of the oceans' role in the global climate system, how the system is changing and the potential impacts of change, by providing data on the polar ocean-ice-atmosphere system. Data from this facility will be highly relevant to a wide range of scientific disciplines, including physical oceanography, climate and ecosystem modelling, ecosystems research (primary production, predator habitat), and air-sea fluxes in ice covered regions. In detail, AFIM data will be digested into the ACCESS initiative and will also play a pivotal role for the further development of ecosystem models (e.g., an algal primary productivity model (ACE CRC) and ecosystem model development at the AAD and CSIRO (Atlantis).

The principles of such a mass-balance station have been verified on the fast ice off Davis Station, East Antarctica over the last three seasons, and a coastal observatory (including a digital camera system and weather station) has operated near Davis Station since early 2009. Stand-alone underwater radiometers and fluorometers are already operated by AAD and ACE CRC. These sensors can be integrated into the AFIM system using the existing design. As such, the proposed system builds largely on existing expertise within the AAD and the ACE CRC to the benefit of the proposed national facility.

The proposed fast-ice observatories will include a (physical) mass-balance station, which consists of the following basic components:

- downward looking ultrasound pinger (to measure height of fast-ice surface including any ablation, or, in case of a snow cover, snow accumulation);
- upward looking ultrasound pinger (to measure depth of the fast-ice base and to estimate the volume of platelet ice);
- thermistor string for sampling of the ocean underneath the ice (5 m vertical resolution);
- 2 m air temperature sensor;

- 2 m air pressure sensor;
- upward and downward looking radiometers.

The mass-balance station allows the integration of additional sensors.

In addition to the sensor package for climatological measurements outlined above, we plan to incorporate the following sensors to study the relation between the physical system and the ecosystem to expand observations to the “whole-of-fast-ice-system”:

- hyperspectral radiometer (to determine ice algal biomass dynamics);
- fluorometer (to determine under-ice water phytoplankton dynamics);
- underwater camera (for physical-biological observation of the sea-ice subsurface).

Each integrated observation platform would be deployed on fast ice with sensors distributed across a 20 m footprint. The observatories will be deployed as soon there is safe access to the fast ice, typically from mid April, will be recovered around early November to prevent loss of the instrumentation. Observation platforms will be maintained, calibrated and maintained over several fast-ice seasons, hence driving down the cost per observation. To determine interannual variability and identify long-term trends, a minimum 10 year deployment program is required, with longer-term deployments clearly the preferred goal. The (relatively small) infrastructure costs, however, are all up front and with a relatively small maintenance budget the stations can be re-established each year to ensure continuity of the data. Thus a sustained observing program at a number of sites can be established for relatively little money and maintained for a significant period of time with minimal resources, thus driving down the cost per observation within the IMOS program. The development costs have largely been borne by the Australian Antarctic Division over the past three years, and have been modelled on the experience of the US Cold Regions Research and Engineering Laboratory (CRREL).

In addition, changes in the horizontal fast-ice extent will be monitored using a digital camera system. These stations consist of an autonomous digital camera plus a (mini) Automatic Weather Station [AWS]. These stations will provide near year-round imagery of the fast-ice edge and its translocation during the season, mainly in response to atmospheric forcing. The sensor package includes:

- digital camera (wide angle lense; to derive the horizontal fast-ice extent and open-water ratio);
- 2 m air temperature sensor;
- 2 m air pressure sensor;
- surface wind velocity;
- radiometers (to measure incoming/outgoing short-wave radiation);
- precipitation sensor (to be confirmed).

Concurrent surface meteorological observations are used to assess how atmospheric processes drive the formation and breakout of fast ice. The intra-seasonal loss of fast ice is often associated with regions where the ice growth rate is high, with the cumulative annual sea-ice production exceeding that of most parts of the Southern Ocean. Consequently these areas are significant drivers of regional thermohaline circulation and therefore globally important as a key driver of the ocean circulation.

To study the physical and ecological fast-ice system, the variability of processes involved and how it responds to environmental change, it is proposed to establish observatories at Davis (two sites) and Mawson stations, and at Scott Base (New Zealand). In addition, the deployment of such a station at a suitable site near Casey Station, where the fast ice is known to break out multiple times during the ice season, would provide invaluable information on a system with an interrupted ice-growth regime. The observatories will be reused over several years, allowing for maintenance and calibration during the austral summer. The first “whole-of-system” AFIM observatory is to be deployed off Davis Station in austral winter 2010, with further deployments (Vestfold Hills (supported from Davis station), Mawson Station and Scotts Base in austral winter 2011 and off Casey Station in austral winter 2012). The coastal observatories are to be deployed near the AFIM sites beginning 2011/12. The expected lifetime of each AFIM station is 4-6 years. We plan to keep up the AFIM observatories for at least 10 years, and to extend the observations using second generation instruments to replace failed observatories. Furthermore, it is expected that AFIN collaborators will deploy similar observatories (i.e., at Dumont D'Urville (France), Atka Bay (Germany), Fimbul Ice Shelf (Norway), Syowa Base (Japan)).

The deployment of this component of the coastal observatory has been timed to ensure cost-savings in the initial investment, by bundeling all observatories in a single order and by submitting it as a bulk order together with other partners.

Data

- *Data will be provided as delayed-mode time series data to the IMOS eMII facility and the Australian Antarctic Data Centre [AADC]. Management of the expanded AFIM data will be via the AADC, which will also provide long-term data archives. The AADC will integrate these data into their data discovery, display and download tool, the Data Navigator.*
- *There are no identified dependencies on external / other facilities for the investment under IMOS. Scheduling of the deployments of the digital camera and AWS system has taken the manufacturing queue into account.*
- *AFIN is an international collaboration that will benefit from the combined (near) circum-Antarctic data collection effort, carried out between Australian and international collaborators. As especially the international contributions to AFIN are currently ramping up, it is crucial to expand the Australian effort to the near full coverage stipulated under AFIN.*

Fully equipped AFIM sites would provide the following data streams. These would not be available in real time, but through downloads about every 6 to 8 weeks. However, several parameters require post-deployment calibration, so that data would be uploaded once per year from each site following retrieval of the instrumentation in austral spring, and calibration of sensors.

Major equipment

1. *Mass-balance site (per station):*
    - *Atmospheric surface data:*
        - 2~m air temperature*
        - 2~m air pressure*
        - upward and downwards short-wave radiation

    - *Fast-ice data:*
        - Ice thickness*
        - snow thickness*
        - estimated volume of platelet ice*
        - fast-ice light attenuation (PAR range 400-700 nm)
        - bio-mass of ice algae (estimated from under-ice irradiance data [Mundy et al., 2007])

    - *Oceanic surface data:*
        - vertical temperature profile of surface ocean
        - under-ice light field (hyperspectral 350-950 nm)
        - phytoplankton biomass

Note: Data stream of the AFIN station operating at Davis Station are marked with *. The additional sensors are off-the-shelf and can be readily integrated into the design and structure of existing stations, with additional onboard data logging.

2. *Coastal monitoring network site (per station):*
    - *Atmospheric surface data:*
        - 2 m air temperature
        - 2 m air pressure
        - surface wind speed

- upward and downwards short-wave radiation

- *Fast-ice data:*
  - Fast-ice extent
  - (Shore) lead width and direction

Budget

The cost for one integrated physical-biological fast-ice station is $75,000, including the underwater digital camera. During the first three years of this project we aim to deploy five fast-ice observatories at a total cost of $375,000.

The cost for one coastal monitoring network station is $36,000. We seek to deploy at least one coastal station with each mass-balance station, bringing the total to five coastal monitoring stations. These are budgeted in the second year, and it is proposed they are all built at the same time in order to generate cost savings in capitalised labour.

Co-investment will be from the operating institutions (AAD, ACE CRC and NIWA), who will provide salary for staff to manage the network, develop data management protocols, provide logistics support and install and maintain the equipment.

For further details, please refer to the attached spreadsheet (Sheet 2: New Facility).

Summary IMOS budget information:

IMOS Program	**2010/11**	**2011/12**	**2012/13**
Fast-ice mass-balance station	75k	150k	150k
Coastal network	-	180k	-
Total	75k	330k	150k

Governance

Performance indicators:

- Identification of suitable deployment sites and likely deployment/recovery dates, from historical data (largely known).
- Integration of multi-disciplinary sensor packages.
- Submission of high quality data and data products to IMOS eMII and data uptake from there.
- Uptake of AFIM data in climate and ecosystem analysis research, and by modelling communities.

Identified risks and risk management strategies

A risk of the mass balance station deployments on fast ice is that the ice breaks up and is blown out, thereby resulting in the loss of the station. This risk is mitigated by establishing the station on the fast ice early in the growth season, but only once the ice has reached 30 cm thick and is relatively stable. The stations will not be deployed at locations where there is a record of intra-seasonal breakout, or where access is difficult during the year. Typically the stations would be accessible during the year from coastal Antarctic bases and would be visited semi-regularly. Historical data on the spring breakout date is used to determine the time of station recovery. It is essential that the stations are recovered before the ice breaks out. Again, this is a risk, but the ice is carefully monitored, and the station would be recovered prior to a major storm event in spring that might be expected to blow the ice out. The coastal monitoring sites are established on the rocky coastline, so the fast ice breakout does not affect their recovery.

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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.	Enhancements of existing Facilities / new infrastructure required 2010-2013
	(see Appendix 1 of the Guidelines)			
Bluewater & Climate				Observations of: • Antarctic sea-ice thickness and volume, and spatio-temporal changes thereof; • ocean-ice-atmosphere exchanges, including data for flux estimates.
WAIMOS				
GBROOS				
NSW-IMOS				
SAIMOS				
Other <enter name>				