ANTARCTIC CLIMATE & ECOSYSTEMS
COOPERATIVE RESEARCH CENTRE

2014/15 Annual Report

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Australian Government
Department of the Environment
Australian Antarctic Division

Australian Government
Bureau of Meteorology

CSIRO

UNIVERSITY of TASMANIA

Australian Government
Department of the Environment

NIWA
Taihoro Nukurangi

Australian Government
Department of Industry and Science

Business Cooperative Research Centres Programme

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1 Executive Summary

The ACE CRC has had a very successful and productive year in 2014/15. This was the first year of a new 5-year funding period for the CRC, with a key highlight being the recruitment of a new team of scientists and support staff to deliver on our new research milestones, and manage the organisation.

The ACE CRC recruited 17 new staff in 2014/15 bringing the total number of ACE-funded staff to 36. Of our new recruits, five came from overseas and four from interstate. Nine are women giving the CRC an overall gender balance of exactly 50:50. One of our new staff is a joint appointment with the University of Tasmania's Institute of Marine and Antarctic Studies (IMAS), further cementing the strong relationship between our two institutions.

We celebrated the new funding for the CRC with an official launch on 10th March 2015, which was attended by approximately 150 partners, stakeholders, staff and guests. Senator David Bushby spoke at the launch on behalf of the Government, and emphasised the importance of the work we do in Antarctica and the Southern Ocean, and the value of the sector to Tasmania's economy. A celebratory function was also held at Government House, hosted by Her Excellency Professor The Honorable Kate Warner, Governor of Tasmania.

At the end of our first year of renewed funding, the ACE CRC has made excellent progress against our seven project milestones, as well as our education, communication and research utilisation milestones. In particular, our fieldwork activities in Antarctica and the Southern Ocean in 2014/15 were very successful as discussed in detail throughout this report. The RSV Aurora Australis became the first ship ever to reach the front of the Totten Ice Shelf and conducted oceanographic measurements there that will help us understand the interactions between the ice shelf and the warming Southern Ocean. The year also saw ACE CRC research at the Southern Ocean Time Series site, south of Tasmania, undertaken during the maiden research voyage of Australia's new marine national facility, RV Investigator.

Our move to the University of Tasmania's Waterfront Building and co-location with the Institute of Marine and Antarctic Science and the Integrated Marine Observing System, is paying strong dividends. The close collaboration between ACE CRC researchers, including those contributed through our partnership with the Australian Antarctic Division and new IMAS staff funded through the Antarctic Gateway Partnership, has been significantly enhanced through the co-location of our institutions. Notwithstanding some teething problems with the new laboratories, the facilities in the new building are excellent and provide the world-class capability we need to deliver on our research projects.

The year also saw two new relationships formalised with Chinese institutions through the development of MoUs with the National Marine Environmental Forecasting Centre in Beijing, and Shanghai Ocean University. The Tokyo University of Marine Science and Technology also committed to becoming a formal participant in the ACE CRC, which will be formalised in 2015/16, and which includes substantial non-staff in-kind support in the form of berths on their vessel Umitaka Maru.

We have continued to focus on the needs of our end-users through the year, particularly the federal government, through the publication of Position Analyses and by hosting Research User Forums in Canberra. The ACE CRC, in collaboration with the Antarctic Gateway Partnership, funded by the Australian Research Council,

also developed the Antarctic Gateway Sea Ice Service, which provides near-real time satellite imagery and expert interpretation to vessels operating in the Antarctic sea ice zone. In 2014/15, we provided services to seven vessels from five different countries on 22 voyages, and plans are underway to continue and expand the service in 2015/16.

1.1 Achievements

Awards and Special Commendations

The CEO has instituted an annual "CEO Award for Excellence". There were two recipients in November 2014: Associate Professor Andrew Bowie and the ACE CRC Administration Manager Wenneke ten Hout. Special acknowledgement of staff is also made at staff meetings and staff forums for outstanding work.

Dr Rowan Trebilco was awarded the RJL Hawke Postdoctoral Fellowship based on research proposal and his early-career track record assessed on his publication record and academic referee reports.

Dr Tony Press was awarded a SCAR Visiting Professor award during November 2014. Dr Press was appointed Chair on the project review committee for the National Climate Change Adaptation Research Facility in February 2015 and Chair of the Tasmania Antarctic Gateway Working Group in June 2015.

Dr Catia Domingues was elected a scientific steering member for the International CLIVAR Research Foci CONCEPT-HEAT and elected co-leader for the "Causes for contemporary regional sea level variability, change and extremes" project (Work Package 3), and the WCRP Grand Challenge on "Regional Sea Level Change and Coastal Impacts" early 2015.

Dr Tas van Ommen continued his role as Chair of the National Committee for Earth System Science with the Australian Academy of Science and became a member for the steering committee for a Future Earth Australian Strategic Plan from the Australian Academy of Science.

Dr Ben Galton-Fenzi became a member of the World Climate Research Program/Cryosphere and Climate/Scientific Committee on Antarctic Research (WCRP/CliC/SCAR) Southern Ocean Regional Panel in May 2015.

In June 2015, Prof Ian Allison was conferred as a Fellow of the International Union of Geodesy and Geophysics (IUGG) for his service to IUGG and international scientific collaboration.

Staff appointments
During the reporting period the ACE CRC recruited the following people:

Name	Position	Start Date	Project
Clarke, Laurence	Molecular Ecologist	12/01/2015	2.2 & 2.3
Cook, Sue	Ice Shelf Glaciologist	05/01/2015	1.2
Downes, Stephanie	Southern Ocean Dynamics Postdoctoral Fellow	27/04/2015	1.1
East, Melanie	Trace Element Marine Analytical Chemist	12/03/2015	2.1

Name	Position	Start Date	Project
Fourquez, Marion	Marine Molecular Physiologist	01/05/2015	2.2
Hobbs, Will	Physical Oceanographer – Detection & Attribution	01/03/2015	1.1
Karsh, Kristen	Microbial Physiologist	17/11/2015	2.2
Kelleher, Mark	Deputy CEO	06/10/2014	Admin
Kusahara, Kazuya	Sea Ice Physicist Postdoctoral Fellow	23/02/2015	1.3
Quayle, Pamela	Laboratory Manager	02/06/2015	Admin
Reilly, David	Public Affairs Manager	09/09/2014	Admin
Remenyi, Tomas	Research Delivery Manager	25/08/2014	Climate Futures
Swadling, Kerrie	Zooplankton & Sea Ice Ecologist	01/10/2014	2.2 & 2.3
Tozer, Carly	Palaeohydrologist	11/03/2015	1.4
Trebilco, Rowan	Ecological Statistician	17/11/2014	2.2 & 2.3
Worby, Tony	CEO	07/07/2014	Admin
Wuttig, Kathrin	Micronutrient Biogeochemist	16/03/2015	2.1

One of our technical staff, Dr Pier van der Merwe, was promoted to an academic position, Micronutrient Biogeochemist, in January 2015.

One staff member, Mr Stephen Bray, left the ACE CRC in April 2015 after serving the organisation for 19 years. He will pursue a career in teaching.

Major purchases for the year
There were no major capital costs for this reporting period.

Internal/External reviews
There were no internal or external reviews during the reporting period.

1.2 Risks and Impediments

The ACE CRC management team has developed an organisational risk register to capture the different risks to the ACE CRC and to the delivery of the ACE CRC milestones. The ACE CRC identified the inherent risks associated with business continuity, finances, reputation, governance, people and safety, environment and community, and project delivery, as well as mitigation measures and specific actions to reduce our risk profile.

The risk register was updated and discussed at Board meetings during the reporting period, with more detailed consideration and tracking of risks undertaken by the Budget, Audit and Risk Committee. The purpose of the register is to ensure careful management of risks throughout the life of the ACE CRC. Over the reporting period, the overall risk profile of the ACE CRC improved.

The ability of the ACE CRC to meet its milestones because of funding pressures on ACE CRC's core partners remains a risk. Budget cuts to Government agencies have reduced their ability to carry out some functions and this saw a small reduction in in-kind support from one partner. The ACE CRC has taken steps to minimise the impact of this risk on ACE CRC activities, particularly those associated with providing ship capacity for fieldwork.

1.3 End-user Environment

The ACE CRC continues to engage closely with key end-users, with a number of major events and current activities.

We delivered against a key utilisation milestone on 29th of July when we held a very successful Research User Forum in Canberra that attracted more than 60 staff from DoE, DIS, BoM, DFAT, AFMA, GA, ASPI, Defence, Navy, Agriculture, Murray Darling Basin Authority, Chief Scientists Office, ONA, NCCARF and the CRCA. The forum was structured around the recently published "Ice Cores and Climate" Position Analysis and the highly topical "Sea Ice Variability and Change" Position Analysis published in late 2014. We have had follow up requests from four agencies for further information and briefings.

At the local level, consulting company SGS remains a formal Other Participant in the ACE CRC and we continue to provide support to their sea level rise consulting activities, through attendance at a community/local government coastal planning workshop. The ACE CRC also continues to be an active contributor to the Tasmanian Polar Network, most recently attending their strategy workshop, as well as engaging regularly in their stakeholder communication activities. The ACE CRC Public Affairs Manager has helped the TPN develop their communication strategy.

On another front, the ACE CRC is discussing with the Queensland Government (Department of Science, Information Technology and Innovation) a collaborative project to investigate the application of Antarctic ice core data to develop a palaeo-climate record for Queensland.

ACE CRC's previous work on the Canute/Sea Level Rise tool and Climate Futures Tasmania has been successfully transitioned to other organisations for ongoing management. The Tasmanian Partnership for Advanced Computing now hosts the 'Canute' online sea level rise tool on an ongoing basis, and the Tasmanian Government Climate Change Office hosts the data for the Climate Futures Tasmania program. Canute currently has 490 active users.

Our recently appointed Board member, Mr Gordon Hagart, is helping to develop an engagement strategy with major companies interested in understanding and managing multi-decadal risk to capital from climate change. The representation of these key stakeholders on the ACE CRC Board ensures that our strategic direction is in alignment with our end-users.

Finally, the ACE CRC remains a very significant contributor to the IPCC Assessment Reports. The ACE CRC contributed 18 co-authors to the Fifth Assessment Report, which is the most authoritative basis for climate change information used by governments and industry around the world. ACE CRC scientists are engaged in discussions on the timing and process for the Sixth Assessment Report.

1.4 Outcomes (round 10 CRCs only)

Not applicable.

1.5 Impacts (round 11 CRCs only)

No significant change has occurred during the reporting period that would require adjustment to the Impact Tool.

2 Research

The ACE CRC has delivered all of its 2014/15 research goals despite some reduction in in-kind support from the Australian Antarctic Division for ship time. ACE CRC scientists had a particularly successful Antarctic field season in 2014/15, including participation in major field campaigns funded through other national Antarctic programs. Some highlights of the 2014/15 field season in Antarctica include:

- The very successful marine science voyage on Aurora Australis in January 2015 to the Totten and Mertz Glacier regions. The first ever oceanographic measurements were taken near the front of the Totten ice shelf. Until this voyage no ship had been able to get within 50 km of the ice shelf. Six oceanographic moorings co-funded by the ACE CRC were recovered, as well as other moorings deployed as part of our collaboration with the French program.
- ACE CRC science projects were the main component of the maiden science voyage of the new Marine National Facility, *RV Investigator*. This ten day voyage serviced moorings south of Tasmania that are measuring carbon uptake by the Southern Ocean.
- ACE CRC staff participated in a successful Australia-New Zealand field campaign at New Zealand's Scott Base. This focused on Antarctic fast ice and ocean/ice shelf interaction. The ACE CRC is proactively building links with the New Zealand Antarctic program and this field program was a major part of that effort.
- Instruments were deployed on the Amery Ice Shelf as part of an ongoing ACE CRC project to look at ocean/ice shelf processes. This work was also expanded to include several radar systems funded by the Antarctic Gateway Special Research Initiative.
- In April-May 2015, ACE CRC staff and students joined the US icebreaker *Nathaniel B. Palmer* as part of an ongoing collaboration with Woods Hole Oceanographic Institution in physical oceanography and sea ice research. Future voyages are planned, with ACE CRC participation already confirmed for 2016 and 2017 as part of this collaboration.

In 2014/15, our researchers published a total of 12 book chapters and 98 articles in scholarly refereed journals. A further 23 articles were submitted to scholarly refereed journals or are in press at the time of reporting. This shows the ACE CRC continues to deliver its intended research outputs. The publications are listed in Appendix 1.

The ACE CRC project portfolio is managed at the level of seven discrete projects within two programs: 'Oceans and Cryosphere' and 'Carbon and Ecosystems'. The overall 'Oceans and Cryosphere' program targets key gaps in our understanding of ocean and cryosphere processes in the Southern Ocean and Antarctica, with the aim of informing an effective national response to the challenges of climate change. The overall 'Carbon and Ecosystems' program aims to deliver knowledge of drivers and changes in the Southern Ocean carbon cycle and ocean chemistry (iron and acidification), the critical responses of biota to environmental change (primary producers, krill, seabirds, Antarctic seals, whales), and assessments of current status, and future trends and impacts on key species and the ecosystem as a whole. As many of the critical knowledge gaps are found at the interface between domains (atmosphere, ocean, cryosphere, biogeochemical cycles and

biosphere), all seven projects are designed to be well-integrated with each other. A detailed summary of the research activities at the project level is given below. Information on involvement with end-users and evidence that the research is meeting their needs is also provided below.

During the reporting period, the ACE CRC also completed work towards a number of project milestones that were carried forward from the previous funding period (2010 – 14). We received formal notification from the Department of Industry and Science on 24th September 2015 that this work was now completed to the satisfaction of the Department.

2.1 Performance against activities

2.1.1.1 The Southern Ocean in a Changing Climate

Project Summary

Project 1.1 is motivated by several recent discoveries and open questions. The Southern Ocean stores more anthropogenic heat and carbon dioxide than any other latitude band but is changing rapidly: it is warming, freshening, decreasing in oxygen, acidifying, and the Antarctic Bottom Water layer has contracted by 50% since 1970. The ability of the Southern Ocean to continue to take up heat and carbon dioxide and thereby slow the rate of climate change is uncertain. Research shows that heat and carbon uptake is localised in subduction "hot spots" which may be sensitive to climate change. Melt of glacial ice by a warming ocean is more important than recognised previously, but the future response of the Antarctic ice sheet to ocean warming is not known. Many of the changes observed in the Southern Ocean are likely to be caused by human drivers (e.g. ozone, greenhouse), but the scale of human influence is yet to be quantified from attribution studies.

Project 1.1 will tackle these critical issues through a research program focused on three inter-related aims.

Aim 1: Dynamics and structure of the Southern Ocean overturning circulation

Many of the most important open questions regarding the Southern Ocean's role in past, present and future climate involve the overturning circulation, including the future of the ocean carbon cycle, the potential for abrupt change in ocean currents and climate, and the possibility that a warmer ocean may cause increased melting of Antarctica and accelerated rates of sea-level rise. Project 1.1 will use a combination of observations and global climate models to determine the major pathways of the upper and lower limbs of the Southern Ocean overturning circulation. Past studies have often reduced the Southern Ocean overturning to two dimensions by taking zonal averages. Recent work has demonstrated that the zonal average perspective likely misses key aspects of the dynamics. This work shows that both the upwelling and sinking motions associated with the overturning are focused in particular locations, rather than broadly distributed as previously assumed. For example, subduction of intermediate waters occurs in limited areas, with each subduction hotspot associated with a ventilation pathway on a particular density surface. These ventilation pathways are clearly visible in the distribution of potential vorticity and are responsible for the sequestration of anthropogenic carbon dioxide.

Aim 2: Response of the Antarctic Circumpolar Current (ACC) to changes in forcing

The ACC is the primary means of exchange of heat, carbon and nutrients between the ocean basins. However, the response of the ACC to changes in forcing remains a topic of vigorous debate. Linear theory and coarse resolution climate models generally suggest the ACC accelerates in response to an increase in the westerly winds. On theother hand, high resolution models and theories that incorporate the effect of eddies suggest that eddies largely compensate the wind-driven Ekman response, resulting in little change in ACC transport. Resolving this question is critical, because the two scenarios have very different implications for the Southern Ocean response to climate change and for the likelihood of climate feedbacks involving ocean circulation.

Aim 3: Air – ocean – ice interaction and water mass formation

Exchange of heat and freshwater between the ocean, the atmosphere and the cryosphere modifies the temperature, salinity and buoyancy of surface waters. When these modified surface waters sink into the ocean interior, they carry these water mass properties with them. Conversion of water from one density class to another by air-sea fluxes in the Southern Ocean acts to link the upper and lower limbs of the global overturning circulation. Near Antarctica, sea ice formation and melt strongly regulate the stratification and the formation of dense water on the continental shelf, while interaction of the ocean with floating ice shelves and glacier tongues both influences water properties and drives basal melt of the ice. However, despite the importance of water mass formation for setting the property distributions and circulation of the ocean, our understanding is still limited because the process is difficult to observe and model.

The project targets priorities identified in national and international research strategies and assessments, including the Australian Antarctic Science Strategic Plan, Framework for Climate Change Science, World Climate Research Program, and the Intergovernmental Panel for Climate Change 5th Assessment Report. These documents highlight the need for expanded observations of the Southern Ocean.

Research activities will include broad-scale sampling of ocean heat and freshwater content using Argo floats; sampling of the ocean beneath the sea ice using ice-capable floats and moorings; full-depth sampling of changes in physical, biological and biogeochemical properties along the SR3 transect at 140°E; assessment of changes in ventilation and the strength of the overturning circulation using multiple tracers; identification and quantification of physical controls on changes in habitat and changes in ocean carbon uptake; quantitative attribution and detection studies using observations and output from coupled climate models; and an assessment of the sensitivity of the Southern Ocean circulation to changes in forcing, including the role of local dynamics (e.g. eddy fluxes and topographic interactions). The project will explore the role of atmospheric processes in ocean changes, particularly through the use of more sophisticated ozone forcing and improved cloud parameterisations to explore surface radiative balance, wind stress and precipitation changes.

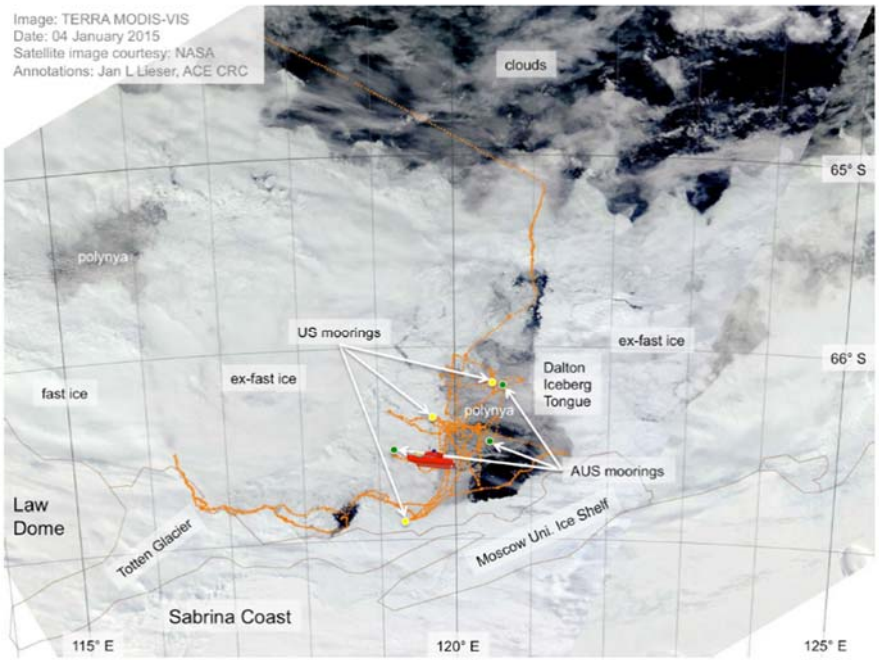
The outcomes of the project will include a more effective national response to climate change, guided by climate projections that include a more faithful representation of Southern Ocean processes and the scale of human influence in the Southern Ocean. The observations of ocean heat content and the earth's

energy balance will provide valuable constraints on climate sensitivity, one of the most controversial and policy-relevant aspects of the IPCC 5th Assessment Report.

Research Activities 2014/15

Two new staff members joined this project during the reporting period. Dr Stephanie Downes (Southern Ocean Dynamics Postdoc Fellow) started in April 2015. Dr Will Hobbs (Physical Oceanographer – Detection & Attribution) started in March 2015. Dr Catia Domingues was awarded an Australian Research Council (ARC) Future Fellowship until 2018 and will continue to provide in-kind support to this project.

The science highlight for Project 1.1 was the successful completion of the marine science voyage to the Totten and Mertz Glaciers during December 2014 – January 2015 (see map below for the voyage track near the Totten). The voyage collected the first measurements near the calving front of the Totten Glacier (as shown on the figure below) and contributes to an Australian-US collaborative study of the Totten Glacier. The observations show that unexpectedly warm water spreads across the continental shelf to the sub-ice shelf cavity, which is counter to the long-held belief that East Antarctic glaciers are isolated from warm ocean waters. Together with satellite observations and model studies, the measurements collected by the project suggest that the East Antarctic Ice Sheet may be more vulnerable to a warming ocean than previously thought. The ship made similar measurements near the Mertz Glacier and recovered nine oceanographic moorings.



In April-May 2015 several ACE CRC staff and students joined the US icebreaker *Nathaniel B. Palmer* as part of an ongoing collaboration with Woods Hole Oceanographic Institution in physical oceanography and sea ice research. There will be subsequent voyages, with ACE CRC participation already confirmed for 2016 and 2017 as part of this collaboration.

Additional scientific highlights in 2014/15 included publications of a number of studies providing new insights into the dynamics of the Antarctic Circumpolar

Current (ACC). For example, Langlais et al (2015) showed that the response of the ACC and its eddy field to changes in wind depends on the location of the wind anomaly, helping to resolve a long-standing debate about the sensitivity of the ACC to changes in forcing. Phillips and Bindoff (2014) and Peña-Molino et al (2014) used novel float observations and a high resolution ocean state estimate, respectively, to investigate the relative contribution of depth-independent ("barotropic") and depth-varying ("baroclinic") flow to ACC transport. In a joint study with ACE core partner NIWA, Rintoul et al (2014) showed how interaction of the ACC with topography can drive a transition to barotropic flow. Chapman et al (2015) explored the dynamics of "storm tracks" in the ACC. Progress has also been made in understanding ocean – ice shelf interaction. Herraiz-Borreguero et al (2015) used unique time series measurements collected through and in front of the Amery Ice Shelf to investigate how ocean circulation influences basal melting of the ice shelf.

Several ACE CRC staff attended an introductory meeting with Department of the Environment representatives to discuss the research agenda for the National Environmental Science Programme (NESP). Prof Bindoff is a Deputy Leader of the NESP Earth System and Climate Change Hub and a co-Project Leader of ACE CRC Project 1.1.

The Southern Ocean Observing System workshop was held in June 2015 to develop an implementation plan for sustained observing in the Southern Ocean. Several ACE CRC staff members attended this workshop.

2.1.1.2. Ocean Forced Evolution of the Antarctic Ice Sheet

Project Summary

Present understanding of the processes governing ice sheet mass loss is poor and the rate of loss under any given future climate scenario is uncertain. Increasingly detailed observations over the last decade have revealed the dynamic nature of ice sheet margins, where rapid changes can be evident on short time scales. A number of external triggers and physical processes have been linked with these changes, with the primary driver thought to be changes in ocean forcing. Ice shelf basal melt rates are controlled by the state of the ocean within the sub-ice-shelf cavities, and ultimately by the transfer of heat within the ocean provided by a complex interplay between the transport of water from the deep ocean and the air-sea fluxes over the continental shelf. The cross-shelf pathways and variability of the oceanic heat supply to the margin of the grounded ice sheet are unknown, and may also be part of interannual variability. Increased melting at the base of ice shelves can lead to a reduction in the thickness and length of ice shelves, potentially reducing their buttressing effect. This increases stresses at the grounding line, causing faster ice flow and thinning in the grounded portion of the marine-terminating glaciers and consequently leading to grounding line retreat. Positive feedbacks associated with bed topography may further enhance shelf-melting driven retreat where grounded ice rests on an over deepened bed, and a slight retreat of the grounding line causes it to move into deeper water.

East Antarctica holds far more sea level potential than West Antarctica and Greenland combined. Estimates indicate that the West Antarctic Ice Sheet holds 3.4 meters of sea level rise in regions grounded below sea level, while the larger East Antarctic Ice Sheet holds 19.2 meters of sea level in regions where the ice sheet is grounded below sea level. The shape of these deep bedrock basins under the ice may make parts of East Antarctica susceptible to runaway grounding retreat

through the same feedback process that has been associated with Pine Island Glacier and numerous Greenland outlet glaciers. Whether and when such a retreat could be triggered is currently unclear, and key datasets (bedrock and bathymetry, water column structure, ice thinning rates and sub glacial context) are sparse and incomplete. These knowledge gaps, and the potential Antarctic input to future sea level, motivate this project and provide the impetus for continued collection of key observations in East Antarctica. They also justify further development of numerical models of the Antarctic ice sheet, and its interaction with the climate system, to improve projections of future sea level rise.

Project 1.2 aims to provide:

- Improved assessment of present and future rates of grounded ice discharge (and sea level contribution) and sensitivity to ice flow across grounding lines due to changes in ice shelves;
- Improved physical understanding of the mechanisms controlling rates of ice loss from ice shelves (basal melting and calving);
- Assessment of the potential for the ocean to melt ice shelves at key East Antarctic glaciers;
- Assessment of the dynamic response of the Antarctic Ice Sheet to changes in climate;
- Identification of regions of potential vulnerability to grounding zone retreat on a range of timescales, and provide estimates of limits to future sea level rise.

The approach is interdisciplinary and relies on ocean, ice and airborne observations (in situ and remotely sensed), interpreted together with laboratory studies of the mechanics of ice. Predictive numerical modelling will be used to consider the dynamic response of the ice sheet occurring as a direct result of changes to the ocean climate.

Key research activities include:

- A coincident/joint land and sea campaign focussed on the Totten and Mertz glacier regions, including ice observing systems of both the grounded and floating portions of the glaciers, and ocean observations of both the sub-ice shelf and open ocean.
- Integrated ice shelf studies that buid on previous studies of ice/ocean interactions and rifting/calving processes through ice deployed instruments, analysis of ice observations, modelling synthesis and laboratory studies of ice rheology.
- Completion of a large-scale survey of East Antarctica (ICECAP) providing improved knowledge of ice sheet/ice shelf geometry and state and rate of change of the ice sheet, together with measurements of velocity change, ice shelf basal melt rates, ice shelf thickness and change, and bedrock uplift.
- Determining the ocean state and longer term variability in oceanic heat transport from offshore to the base of the ice shelves, and basal melt rates using available observations together with numerical modelling.
- Assess the state and rate of change of the Antarctic ice sheet (and hence sea level) for the recent past and future scenarios using coupled modelling.

Research Activities 2014/15

One new staff member joined this project during the reporting period. Dr Sue Cook (Ice Shelf Glaciologist) started in January 2015. Dr Lenneke Jong accepted the position of Cryosphere System Modeller (a joint ACE/Gateway appointment) and commenced in July 2015. Dr Roland Warner made the transition to honorary researcher with ACE, taking early retirement from the AAD in December 2014.

As in Project 1.1, the science highlight for Project 1.2 was the successful completion of the marine science voyage to the Totten Glacier region during December 2014 – January 2015. All six of the oceanographic moorings deployed a few years ago were recovered, including two that were covered by sea ice. A glider was deployed in a small polynya about halfway between the main Dalton Polynya and the Totten Glacier, on a mission to fly north and then east to return to the main polynya.

The Amery Ice Shelf field season was a mixed success with data retrieved from only 1/6 CTD instruments. Distributed temperature sensing equipment was redeployed at AM06 with new radar instruments and summertime data collected and returned. Analysis is presently underway.

There has been considerable delay in getting the ice mechanics laboratory up and running due to construction issues with the freezer room floors. These were finally rectified in September 2015 and a number of experiments that have been delayed by almost a year are now underway.

Papers were published on the following topics during the reporting period:

- Ocean-driven thinning enhances iceberg calving and retreat
- Alternate pathways of water to the Totten
- Amery Ice Shelf flow is in approximate steady state
- External influences on the dynamics of the Mertz Glacier Tongue prior to the major calving event in 2010
- Presence of modified warm water beneath the Amery Ice Shelf

The visit of Marie Curie Fellow, Dr Rupert Gladstone, came to an end in June 2015 after 2 years of collaboration within the ACE CRC. Dr Gladstone has been integral in assisting in further development of approaches to coupling models of ice-shelf and ocean dynamics. In other modelling, he also advanced the understanding of sensitivity of grounding line migration simulations to the physical processes controlling sliding at the base of marine-terminating outlet glaciers.

Project 1.2 has seen several visitors during the reporting period. Dr Ralph Greve, an ice sheet modeller, from the Institute of Low Temperature Science (ILTS), Hokkaido, Japan, visited the ACE CRC for 3 months from September to December 2014. Dr Greve was supported through the UTAS Visiting Fellow program and worked primarily with the ice/ocean team on improving the representation of ice shelf basal melting and on incorporating a description of ice flow physics developed at ACE into ice sheet models. Dr Pippa Whitehouse from Durham University, United Kingdom, visited the ACE CRC on a UTAS Visiting Scholar Program in March 2015. Dr Whitehouse provided input into the ACE CRC coupled modelling effort. Physical oceanographer, Dr Craig Stevens from NIWA, also visited the ACE CRC in March 2015.

Dr Galton-Fenzi gave an invited talk at the Gordon Research Conference on Coastal Ocean Modeling at the University of New England, USA, in June 2015.

2.1.1.3. Sea Ice Processes and Change

Project Summary

A centrepiece of Project 1.3 is a continuation of the 'AUV Under Sea Ice' project, based on extending the floe-scale pack ice work from SIPEX-II across other parts of the sea ice zone. This will build upon the technical and scientific partnership with the Woods Hole Oceanographic Institution (WHOI). Whereas WHOI was previously contracted to provide AUV data collection on the one Australian-led SIPEX-II voyage, ACE CRC scientists will now join WHOI-led projects on multiple international sea ice voyages, by co-funding the AUV equipment pool, contributing personnel and UAV capacity through the ARC funding of Dr Guy Williams. In essence, we shall fund a second SeaBED-125 vehicle, which is the next generation of low-cost, sea-ice specific AUV that has arisen post-SIPEX-II. Co-funding a second vehicle will enhance the research outcomes through increased operational capabilities and decreased risk. To date, ACE CRC researchers have been invited to participate on the ONR-funded Arctic marginal ice zone (MIZ) project termed 'Seastate' in October/November 2015 and the NSF-funded 'PIPERS' voyage to the Ross Sea in April/May 2017. At present, there is another proposal pending for WHOI-led AUV missions on the *RV Polarstern* on the AWI-led 'SC@LES' project in October/November 2017, and there are likely to be others. ACE CRC scientists Drs Heil and Meiners are part of the proposal team for the SC@LES experiment, and wider participation of the sea-ice group is planned on this cruise, including ROV work led by Dr Meiners and buoy/ice dynamics work led by Dr Heil. These three funded voyages, with the others pending, present the opportunity to extend the groundbreaking SIPEX-II AUV work to the MIZ, polynyas and inner pack, across key regions of Antarctic sea ice research. This will enable our participation in world-leading integrated sea ice research voyages and continued access to the state-of-the-art AUV technology. Furthermore, this collaborative work will build our capacity for future Australian-led integrated experiments in the East Antarctic sea ice zone (with some focus on the MIZ).

Focussing on the Antarctic MIZ is important because it forms the highly-dynamic outer part of the circumpolar sea-ice zone where the interaction of atmosphere, ocean and ice is particularly intense. Processes occurring there are thought to play a key role in driving seasonal sea-ice advance and retreat, but we lack even fundamental knowledge of the interactions and feedbacks at work and how these vary (and change) over space and time. This research direction represents a crucial step towards understanding observed changes in Antarctic sea-ice extent and seasonality on time-scales from seasons to centuries, to improve the skill of climate models in more accurately simulating current sea ice conditions. This will in turn give more confidence to model projections of future sea ice change and effects. The Antarctic MIZ is also very important to primary productivity, the krill-based Antarctic marine ecosystem and biogeochemical cycles, and represents an excellent opportunity for multi-disciplinary research across the ACE CRC environment, including the Atmosphere group.

The Marginal Sea Ice Zone (MIZ) will remain a major focus of future ACE CRC sea-ice work, largely through international partnerships and participation on other national research voyages, before an Australian-led Antarctic MIZ when vessel time is available.

Closer to the coast, landfast sea ice (fast ice) and polynyas are two other major elements of the interactive air-ocean-sea ice system that are integral to Antarctica's role in global climate and ocean circulation – one as a narrow yet consolidated interface between the ice-sheet margin and pack ice/ocean, and the other as the site of greatly-enhanced sea-ice production and salt input into the ocean. Both are sensitive to climate change, and are closely related. ACE CRC research will focus on how sea ice processes drive dense shelf formation and ocean-ice shelf interactions. It will also detail the role sea ice plays in ecosystem habitats and carbon cycling. This work will involve remote sensing (analysis of satellite and tagged-seal data) and modelling (high-resolution global ocean/sea ice/ice shelf), and is linked to current and planned external multi-disciplinary fieldwork on fast ice involving strong collaboration between the Australian and New Zealand Antarctic programs (AAS/AAD Project 4298 led by ACE CRC researchers). The overall objective of the latter project is to expand the measurement capability for, and multi-disciplinary observational record and understanding of, Antarctic fast ice characteristics and processes, to assess the impacts of climate change on physical and biological elements of the coastal sea ice zone. Regarding this, Dr Heil is leading the international Antarctic Fast Ice Network, an ongoing programme aimed at encouraging international cooperation and standardisation in fast-ice measurements around the continent (in concert with automatic weather stations and autonomous instrument packages). Details are at: http://seaice.acecrc.org.au/afin/

The Sea Ice Physics and Ecosystem eXperiment II (SIPEX-II, 2012) yielded rich new information about sea ice and snow cover thickness, morphology and evolution in the inner pack ice zone of East Antarctica. Multi-disciplinary synthesis of data from this and the earlier SIPEX I (2007) voyage, and the upscaling of these data to regional scales, will be carried out in this project. This work will be extended to the wider East Antarctic domain in associated work towards i) mapping regional-scale sea ice surface roughness and freeboard using existing airborne data, and ii) providing a first estimate of East Antarctic sea-ice volume through melding of satellite, existing in situ and modelling data (the latter is an AAS Project [4301] led by Dr Heil and involving other CRC researchers). Regarding the key ice dynamics component, Drs Heil and Massom are directly involved in an International Space Science Institute project to improve Antarctic sea-ice motion and high-resolution fast-ice mapping using satellite SAR (synthetic aperture radar) data. Moreover, Dr Heil plays a lead role in the International Antarctic Buoy Programme.

Project 1.3 aims to provide:

- High-resolution, 3D floe-scale maps of sea ice properties and draft from autonomous underwater vehicle (AUV) data and coincident surface measurements from SIPEX-II (Williams).
- New methodologies for integrating nascent technologies (AUV and UAV) towards improved characterisation of key elements of the sea ice zone and the processes responsible (Williams, Fraser, Kusahara, Massom, Alexander [Atmosphere group]).
- The first circumpolar quantification of fast-ice change/variability and characterisation of its coupling with polynyas, ocean-ice shelf processes and the ice sheet margin (Fraser, Kusahara, Massom, Williams), linked with in situ characterization of fast ice physical and biological properties at bases (the

latter being an AAS/AAD Project [4298] involving CRC scientists in collaboration with New Zealand – Meiners, Heil).

- Significant work towards attribution of change and variability in patterns of East Antarctic sea ice seasonality (Kusahara, Massom, with Klekociuk, Hobbs [1.1] and Reid [BoM] plus Australian and international collaborators). This represents key work towards AAS/AAD Project 4116 involving ACE CRC researchers.
- Maps of regional-scale sea ice surface roughness and freeboard (from RAPPLS aerial data) (Lieser, Hyland, Giles, Fraser), as a significant contribution to the cal/val of Antarctic sea-ice thickness estimates from the ESA CryoSat-2 mission; and
- A first estimate of East Antarctic sea-ice volume at maximum extent (the latter being an AAS/AAD Project [4301] involving CRC scientists and partners - Heil, Lieser, Hyland, Fraser, Massom).

Project 1.3 aims to identify and quantify the physical mechanisms responsible for the observed regional and circumpolar patterns of sea ice distribution, production and volume and their change with time. The results will enable improved assessment of the impact of sea ice change on climate, ocean circulation, biological productivity and the carbon cycle. The proposed methodology:

- involves a combination of focused field experiments, remote sensing, sustained observations and numerical models;
- uses a range of in situ, remote sensing, model reanalysis and other atmospheric and oceanic data to derive a first estimate (outlook) of EA sea-ice volume (at annual maximum extent), and its recent variability;
- explores satellite radar backscatter data as a means of gaining proxy large-scale information on regional sea-ice thickness, based on their possible relationship with satellite-derived ice-surface roughness. Melding of coarse-resolution satellite radar backscatter data with accurate in situ and aerial observations will test this new approach;
- conducts circumpolar modelling experiments, with high resolution in areas of interest, to examine sea-ice growth and associated water mass transformation in coastal polynyas around Antarctica, incorporating interaction with fast ice, icebergs and ice shelves to assess the future of dense shelf water formation and oceanic input to ice-shelf processes (link to 1.2 and 1.1); and
- assembles new and historical data on seasonal formation and decay of Antarctic fast ice, using remote sensing and automated observatories, at remote sites in the New Zealand and Australian sectors and in two regions with different environmental conditions.

Research Activities 2014/15

One new staff member joined this project during the reporting period. Dr Kazuya Kusahara (Sea Ice Physicist) started in February 2015, and is already making excellent progress towards modelling and assessing drivers of recent change and variability in patterns of East Antarctic sea ice seasonality (annual advance, retreat and duration). Dr Guy Williams was awarded an ARC Future Fellowship until 2018 and will continue to provide in-kind support to this project. Dr Alex Fraser accepted the remote sensing postdoctoral fellow position and will commence on 1st of November 2015.

Data analysis from the SIPEX-II voyage (September - November 2012) has progressed very well, resulting in two high-profile papers in *Nature* (Williams et al., 2015 and Kohout et al., 2014). The former presents new floe-scale information on thick and deformed sea ice mapped with autonomous underwater vehicles, while the latter highlights the role of storms and ocean waves in Antarctic sea ice breakup. Both are "ground-breaking" results. Nineteen other papers have been submitted to, or are in preparation for, a special volume of Deep-Sea Research devoted to results from SIPEX-II; this will be published in the 2015/16 reporting period. ACE CRC staff member Dr Klaus Meiners, who was Chief Scientist on SIPEX-II, is the lead editor for this volume.

Regarding ACE CRC fast ice work, the first component of the collaborative project between the Australian and New Zealand Antarctic programs (AAS/AAD Project 4298 led by ACE CRC researchers) took place with the participation of Dr Meiners in a successdul field experiment at Scott Base (Ross Sea) in Nov-Dec 2014. A follow-up field season will take place on fast ice off Davis Station in late 2015. Excellent progress is also being made with the satellite remote sensing component of the fast ice work, with new results highlighting key relationships between fast ice distribution and sea ice production rates in the globally important Cape Darnley Polynya.

ACE CRC researchers (Drs Reid [BoM], Massom and Lieser) once again contributed sections on annual Antarctic sea ice conditions to annual *NOAA/BAMS State of the Climate* assessment reports, for 2013 (Massom et al., 2014) and 2014 (Reid et al., in press). In addition, Reid et al. (2015) published a detailed case study of the record 2013 Antarctic sea ice extent. This paper appeared in a special volume of Annals of Glaciology devoted to papers from the ACE CRC-sponsored International Glaciological Society International Symposium on Sea Ice in a Changing Environment (10-14 March 2014, chaired by Drs Massom and Heil). This volume, with Dr Heil as chief editor, contains 47 papers and is in preparation (nearing completion).

In other work, a prototype of the new ASPeCt ship-borne sea ice observation software package has been developed by Dr Heil and trialed on 6 recent Antarctic voyages, resulting in very positive feedback and improvements. As a result, the software will be launched in the next few months, and Dr Heil is effectively lobbying for its inclusion and use on all ships traversing the Antarctic sea ice zone (via SCAR etc.). Also, Dr Heil has co-authored papers with German, Chinese and US colleagues on topics including ice shelf influences on fast ice and sea ice density.

The Antarctic Sea Ice Challenges Workshop, convened by the Council of Managers of National Antarctic Programmes (COMNAP), was held in Hobart in May 2015. This workshop brought together the world's Antarctic program managers and scientists to discuss the challenges experienced by a number of national programs in terms of changing sea ice conditions, and the technology available to help vessels navigating through sea ice. There is growing demand for a sea ice forecasting service and the ACE CRC will be leading discussions with partners, nationally and internationally, to explore options for developing this capability. ACE CRC researchers Drs Massom, Heil, Reid (BoM) and Lieser made a strong contribution to the meeting itself by contributing expert information on the Antarctic sea ice environment. The COMNAP workshop was preceded by a public keynote address by Prof Tony Worby on *Antarctic Sea Ice: Trends & Challenges*. In this keynote address, Prof Tony Worby explained the science behind changes in Antarctic sea ice extent and discussed the challenges ahead for operators in the region. The

public lecture was live-streamed and is available as a podcast on the ACE CRC website.

Drs Carpentier (BoM), Massom, Prof Worby and Mr Young also gave presentations and provided expert input on Antarctic sea ice conditions and challenges to the meeting in Chile of the International Ice Chart Working Group (IICWG) on "*Ice Information in the Southern Ocean: Status, challenges and the Future*" (October 2014). Engagement with the IICWG represents a key step towards developing a more effective operational ice analysis, forecasting and seasonal outlook system (sea ice and icebergs) in support of shipping and operations in the high-latitude Southern Ocean around Antarctica.

2.1.1.4. Antarctic Climate Variability of the Past 2,000 Years

Project Summary

Detailed records of past climate improve understanding of global, hemispheric and regional climate dynamics, including responses to natural and anthropogenic forcings. Such records provide improved understanding of natural climate variability on decadal to centennial time scales, and of changes over the anthropogenic era. Ice cores give climate records that mesh with the relatively short instrumental records from Antarctica and high southern latitudes, which are needed for global reconstructions and which allow the role of Antarctica on climate to be better understood. Ice cores are also a unique source of past climate information as they record proxies for both climate responses, and the major forcings (greenhouse gases, solar variability and volcanic aerosols). Project 1.4 is fully aligned with major international ice core and palaeoclimate initiatives, and will produce a range of climate parameters through national and international collaboration.

Temperature and climate forcings: This project will produce a high resolution 2,000 year climate record, the first from an inland East Antarctic site. The 2,000 year record will include information on snow accumulation rate, atmospheric temperatures (from water isotopes), greenhouse gas (GHG) forcing (from highly resolved CO_2), volcanic forcing (from sulphate), solar forcing (from 10 Be) and climate variability (SAM/ENSO). The ABN record will allow a high resolution assessment of the influence of natural solar and volcanic forcings on our climate, and the recent anthropogenic influence of GHG forcing. This assessment is of critical importance to the climate modelling community (projects such as PMIP), and will significantly enhance efforts to understand the dynamics of the climate system over this 2,000 year period, including carbon cycle-climate feedbacks, sea ice feedbacks, and atmospheric dynamics feedbacks. The temperature record will also be used to constrain and evaluate the models used to project future climate change. Also, records of CO_2 and its isotopes will improve our understanding of the hemisphere gradient of CO_2 and gain a better understanding of the carbon cycle.

Snow accumulation rate: Links between rainfall in South West Western Australia and snowfall at Law Dome have been found from our work on the coast (van Ommen and Morgan, 2010), and these links will be further investigated using the ABN accumulation series extending back 2,000 years. The precipitation regime at Law Dome differs significantly from the inland sites, the former being dominated by cyclonic systems, while inland is dominated by clear-sky 'diamond dust' precipitation (e.g. Masson-Delmotte et al., 2000). Probing the transition between the two types of record in conjunction with high resolution data sets should provide for

much better extraction of a common climate signal. At present, it is not well understood if proxy calibration based largely on clear-sky precipitation records can be applied to cyclonic precipitation. Certainly, calibration slopes for water isotopes differ considerably at Law Dome from those in the interior (van Ommen and Morgan, 1997; McMorrow et al., 2004). The high resolution continuous flow analysis proposed for this core (see below) will yield annual resolution at this site. High-resolution records of snow accumulation are required by the modelling community to constrain and evaluate climate system models.

Atmospheric variability: Ice core proxy fingerprints of large scale modes of variability such as the Southern Annular Mode (SAM), El Nino Southern Oscillation (ENSO) and the Interdecadal Pacific Oscillation (IPO), will be derived and compared with meteorological model and reanalysis data for validation. Long term records will provide an understanding of natural variability against which climate change detection and attribution can be assessed, as well as providing a valuable record for the evaluation of climate system models. The high resolution ABN record will be compared to the coastal Law Dome ice core record which has sensitivity to the SAM (Goodwin et al., 2004), ENSO (Vance et al., 2012) and IPO (Vance et al., 2015). This 2,000 year record can also be used to assess decadal-to-centennial scale variability. This research will provide high resolution time-series of raw observables to at least 2000 years, interpreted in terms of variability in large scale atmospheric dynamics: westerly winds, SAM, ENSO, and IPO. Additionally, application of these proxies to reconstruct water catchment variability in Australia through hydrological modelling will be investigated.

Sea ice proxies (MSA and sea salts): Assessing changes in sea ice extent (over the longer perspective) is particularly important to understanding current trends. The Law Dome MSA record has been used as a proxy of sea ice extent in the 80-140°E sector (Curran et al., 2003) as evidence of 20% decline over the last 50 years. Recent data from shallow cores around Antarctica support the use of MSA data as a sea ice extent proxy (Foster et al., 2006; Abram et al. 2007). Data from the more inland Mt Brown site suggests that an inland site (such as ABN), combined with a regional synthesis may provide a more circum-Antarctic sea ice history. The MSA data from ABN will be tested as a proxy and calibrated against satellite data to produce a 2000 year larger scale sea ice history. This work will directly contribute to the new IGBP-PAGES working group on sea ice proxies from ice cores. Conventionally the source of sea salt in the Antarctic was considered to be the ocean surface (e.g. Legrand and Mayewski, 1997). However, this mechanism was challenged and an alternate explanation was proposed involving salt encrustations (frost flowers) on sea ice as the dominant source of sea salt to coastal Antarctica (Rankin et al., 2002), and subsequently inland Antarctica (Wolff et al., 2003). This resulted in a high profile paper concluding sea salts were a measure of sea ice extent, and thereby presenting an Antarctic sea ice extent record over 8 glacial cycles (Wolff et al., 2006). A recent compilation of our data from a number of previous AAS projects (Curran et al., 2011) using records from an iceberg, coastal sites and shallow sites further inland, challenges the findings of Wolff et al. (2006). Our work suggests that frost flowers contribute significantly to the sea salt budget near the source (coast), however as you move inland and to higher elevations, this influence becomes considerably reduced (Curran et al, 2011). A seasonally resolved record at ABN will allow the signature of such encrustations in winter (which present as depleted fractions of sulphate) to be investigated for the first time at an inland site, and will contribute significantly to the frost flower debate through comparisons with records

from EPICA Dome C and Law Dome. This will provide valuable information to the debate on the strength of competing sources and the interpretation of sea salt levels in ice cores, and whether in fact you can use sea salts to reconstruct sea ice history. This work will directly contribute to the new IGBP-PAGES working group on sea ice proxies from ice cores.

Investigate sources and transport pathways: Dust and aerosol pollutant inputs to Antarctica are powerful tracers of atmospheric circulation. Considerable debate exists regarding interpretation of dust records. Some investigators use non sea salt (nss) Calcium as a proxy for dust (e.g. Rothlisberger et al., 2002). However the proportion of nss-Ca is low, producing often noisy, difficult to interpret, records (e.g. Curran et al., 1998). A more direct measure of terrestrial dust is the use of aluminium, iron or rare earth elements such as Cerium (e.g. McConnell et al., 2007), and also the use of particle counts and distributions (e.g. Delmonte et al., 2004). However a multi-tracer approach using a combination of all techniques will be used here for ABN, including a high resolution ice melter with continuous flow analysis to a dual trace element analyser (McConnell et al., 2007), which will be used to produce dust records, fire history, information on trace aerosol sources and atmospheric circulation strength. This information from ABN, combined with existing Law Dome records will be used to improve a regional synthesis of climate records from East Antarctica. Although Patagonia is thought to be the dominant source of dust found in Antarctica (e.g. Rothlisberger et al., 2002; Delmonte et al., 2004, McConnell et al., 2007), Australian dust sources may be important for East Antarctica (e.g. Revel-Rolland et al., 2006). Our multi-tracer approach for ABN may shed some light on the origin of dust in East Antarctica, and influence interpretations of EPICA Dome C and Law Dome dust records, improving an understanding of sources and transport effects.

Very little is known about the past atmospheric variability of carbon monoxide, a trace gas being the main reagent with the hydroxyl radical in the troposphere, and thus key for atmospheric chemistry. In natural conditions, its main sources in the Southern hemisphere are the oxidation of methane, oxidation of non-methane hydrocarbons and biomass burning. Available ice core records of CO changes cover the last few hundred years (Haan et al., GRL 1996 ; Haan and Raynaud, Tellus 1998 ; Wang et al., Science 2010). The coinvestigation of the carbon and oxygen isotopic composition of CO show that most of the observed centennial variability of atmospheric CO can be attributed to biomass burning changes, which may have varied by as much as 40% in the Southern hemisphere between the Medieval Warm episode and the Little Ice Age (Wang et al., Science 2010). A CO record from the Aurora basin would extend this CO history back in time. It's added-value compared with other ice cores would be to enlarge the range of chemical composition of the ice surrounding the CO samples. This will be critical to investigate small but maybe significant artefacts in the ice, which may affect the CO record in Antarctic ice. Such artefacts are known to take place in Greenland ice (Haan and Raynaud, Tellus 1998). The expected output is a reference record of carbon monoxide changes over the last 2000 years. It would be interpreted as reflecting mostly past biomass burning changes in the Southern hemisphere and in particular in Australia.

Ice core records allow climate observations from instruments to be put in a long term context and to reveal climate connections between Australia and Antarctica. Working closely with international partners, a circumpolar assessment will be made using climate history records from both archived and newly collected data.

Project 1.4 will have three principal strands of activity:

1. Capitalise on the Antarctic2k/IPICS connections to develop reconstructions and methodologies using largely existing cores (even shorter centennial records).
2. Derive new primary records from the Aurora Basin ice core, analyse the results and synthesise with others in reconstruction.
3. Recover a new ice core from East Antarctica, using meteorological data and new analysis to guide site selection and seek optimal incremental benefit in coverage.

Project 1.4 has strong cross-cutting research connections with atmospheric sciences that will underpin analyses of ice core data streams with meteorological reanalysis and model outputs as part of the interpretation.

Research Activities 2014/15

One new staff member, Dr Carly Tozer, joined this project during the reporting period (March 2015). Dr Tozer is a Palaeohydrologist and will work on reconstruction of Australian drought records from Antarctic ice cores and is partly funded by the University of Newcastle.

The Aurora Basin (Antarctica, 2013/14) ice core processing has been completed during the reporting period. Issues with laboratories and freezer at the UTAS Waterfront Building have now been largely resolved but have caused some delays. Analysis of samples will be done at the ACE CRC and Curtin University laboratories and some core material has already been analysed at the Desert Research Institute in the USA and AWI in Germany. Records of ice structure and chemistry have been generated. All sample analysis should be completed by February 2016.

An international Aurora Basin (ABN) workshop was convened at a meeting of the European Geophysical Union (Vienna, April 2015) and a follow up national ABN workshop was convened in Melbourne as part of an Australian ice core community meeting at CSIRO (Melbourne, May 2015). We had a very successful ABN workshop at EGU on the 16th April 2015 with 21 attendees from 13 institutions, including 3 new institutions interested in ABN, at least one representative from each of the 5 steering group institutions (AAD, ACE CRC, DRI, LGGE and CIC) and at least one representative from all 6 Australian institutions formally involved in ABN (AAD, ACE CRC, CSIRO, Curtin University, ANSTO, and UNSW). Updates and progess from across the groups were shared and the next round of ice shipment was finalised. The follow up ABN workshop in Melbourne was attended by 22 participants with at least one representative from all 6 Australian institutions formally involved in ABN.

Dr Tessa Vance, Dr Jason Roberts and Dr Mark Curran attended a Queensland State Government workshop and presentation in March 2016 to scope out expanding the hydroclimate work from New South Wales into Queensland. The Queensland government and various authorities were very interested in Dr Vance's work and while the workshop did not reach a formal agreement, there was enough interest to continue to pursue a mutual partnership. Communication is ongoing around the best mechanism to fund this work.

Dr Yaping Liu from CAREERI, China, visited the ACE CRC for a one year placement. Dr Liu provided valuable input on the ice core and samples from the Aurora Basin North Ice Coring project.

The publication of a paper in Nature Geoscience by Greenbaum et al (2015), titled: "Ocean access to a cavity beneath Totten Glacier in East Antarctica" resulted from a long-standing collaboration with the University of Texas to conduct airborne geophysics over Antarctica. The outcomes also link closely with the recent successful voyage of Aurora Australis to the Totten Glacier.

2.1.2.1. Carbon Uptake and Chemical Change

Project Summary

The ocean absorbs CO_2 from the atmosphere, slowing the rate of climate change. The Southern Ocean takes up more atmospheric CO_2 than any other latitude band. This uptake will not continue at current rates if ocean warming reduces the rate at which the surface ocean can absorb atmospheric CO_2, or if decreasing overturning circulation reduces its transfer to the deep ocean, or if biological changes reduce the transformation of CO_2 into organic matter. The pathways of CO_2 uptake are complex, involving that lower limb of the meridional overturning circulation that is influenced by ocean interactions with the cryosphere (modulating the formation of Antarctic Bottom Water) and the upper limb that involves processes in the Subantarctic Zone, including interactions with changing boundary currents such as the East Australian Current. These pathways are further modulated by biological processes that transform CO_2 into organic matter (via photosynthesis) and allow this carbon to reach the deep sea in sinking particles rather than via the circulation. None of these pathways are well quantified, and their relative importance varies with the timescales of interest. The upper limb is dominant on the decadal scale, the lower limb on centennial to millennial scales, and the biological pump on longer timescales. Sustained observations of interannual and interdecadal variations in modern uptake, complimented by process studies for projection of future changes and the testing of these projections against past variations, are required to improve this situation. Improvement of this situation is a key focus for Project 2.1 especially via the Southern Ocean Time Series and SR3 signature projects and the new carbon postdoctoral appointment (see below).

The Southern Ocean and Antarctica host iconic ecosystems of high conservation value, including deep ocean communities that are only now being discovered. These ecosystems are at risk from global changes including physical changes such as loss of sea ice habitat and ocean warming, and chemical changes such as ocean acidification from CO_2 uptake, and changes in the supply of the trace metal iron, which limits phytoplankton growth in the Southern Ocean. This trace element control also affects phytoplankton species composition and physiology and the cycling of other nutrient elements, and thus the structure of the entire marine ecosystem. Production also affects the impacts of ocean acidification, because phytoplankton growth removes CO_2 and thus counters the anthropogenic acidification.

Changing iron supply is the least understood forcing on ocean ecosystems. Since iron is actively taken up into phytoplankton, and transferred throughout the foodweb, including removal by particle settling and remineralisation in deep waters, the assessment of its availability is quite complex and cannot be judged from

dissolved iron levels in surface waters alone. Recent international advances in chemical oceanographic techniques for trace elements now allow the measurement of iron associated with different phases (dissolved and particulate), internal biological recycling and iron export from surface waters. The dominant new iron fluxes may be associated with the particulate phase, and particles thus represent an important transport vector for trace metals in the marine ecosystem, although their bioavailability or transfer into a bioavailable fraction remains uncertain. Surveys of iron distributions and process studies of iron transformations are needed to advance understanding of the potential for significant changes in primary production, and thus impacts on foodwebs and carbon cycling. Improvement of this situation is a key focus for Project 2.1, especially via the SR3, SOTS, and Kerguelen region field projects, and the two new postdoctoral trace element appointments (see below).

Project 2.1 will assess the evolving Southern Ocean carbon dioxide and oxygen uptake, acidification, and iron supply. It will determine the interplay of natural and anthropogenic factors that mediate regional and temporal variability in these changes, as a base for understanding biological responses. The work will contribute to the efforts of the international research community and others on the links between climate change, ocean circulation, biogeochemistry, and primary productivity.

The focus is on observations across all of the ACE CRC signature field programs:

- Totten ice shelf - ocean interactions and their influence on uptake of carbon and nutrients into shelf and bottom waters via the lower limb of the overturning circulation
- Southern Ocean Time Series sustained observations to close annual budgets for carbon, oxygen, nutrients and iron in the upper limb of the overturning circulation, understand modes of interannual variability, and to advance the understanding of the Subantarctic Zone as the dominant location of glacial-interglacial climate change.
- SR3 repeat section to quantify the coupling of heat, gas and nutrient transports, as an essential tool for determining how the climate system works and how Southern Ocean circulation responds to changing forcings.
- Kerguelen axis studies of controls on ecosystem structures, especially the influences of sea-ice and natural iron fertilisation on ecosystem productivity and foodwebs.

Additional effort supports underway observations of carbon uptake, ocean acidification, iron aerosol inputs, and key taxa such as biogenic carbonate forming organisms that are susceptible to acidification impacts. Analytical support will also underpin experiments in the Project 2.2 Biological Responses Project.

Major external investments include:

- IMOS, MNF, and NOAA for SOTS observations ($1.5 million through June 2015; 3 confirmed voyages and another proposal pending), including new work with BoM on climate processes coupling heat and gas exchange, aerosols, and cloud properties.
- French and Belgian University and National Agencies (U Paris, L Arago, LEGOS, IFREMER, IUEM, Villefranche, VUB, CNES-France, BELSPO-Belgium) ship

time and collaborations for iron fertilisation studies (1 voyage awarded, 1 pending) provision of Bio-Argo floats, and a proposal to replicate SOTS over the Kerguelen plateau.
- ACCSP for anthropogenic carbon uptake observations and assessment.

Research Activities 2014/15

Three new staff members joined this project during the reporting period. Dr Pier van der Merwe (Trace Elements Biogeochemist Postdoctoral Fellow) moved from a technical role into an academic role in January 2015. Dr Kathrin Wuttig (Micronutrient Biogeochemist Postdoctoral Fellow) started in March 2015. Dr Melanie East (Trace Element Marine Analytical Chemist) started in March 2015 and will provide technical support to research projects examining trace element biogeochemistry in the marine and sea ice environment. A/Prof Andrew Bowie was awarded an ARC Future Fellowship until 2018, and Prof Tom Trull and Dr Zanna Chase received an ARC Discovery grant to support the Heard Island Southern Ocean fieldwork. Dr Paula Conde-Pardo (Marine Carbon Cycle Postdoctoral Fellow) accepted her offer during the reporting period and commenced in July 2015. One staff member departed in April 2015 to pursue a career in teaching. This will cause a slight delay in sample analysis of the SAZ-16 mooring.

The new Marine National Facility, *RV Investigator*, headed south in March 2015 to re-deploy the Southern Ocean Time Series moorings. This was the first science voyage for the new vessel and included a long-standing ACE CRC science project looking at ocean-atmosphere exchanges of heat and carbon and the impacts on ocean biology. Prof Tom Trull led this voyage which successfully redeployed the IMOS SOTS Facility moorings and recovered the SAZ-16 mooring with full sample collection after two years in the ocean. New work during the voyage with ACE CRC BoM staff members Dr Eric Schulz and Dr Alain Protat on Southern Ocean clouds was featured in the ACE Newsletter. Results using data from prior seasons from the Pulse and SOFS moorings at SOTS were used to quantify the seasonality of air-sea CO_2 fluxes and associated physical and biological influences (Shadwick et al., 2015).

A/Prof Andrew Bowie led a science team from Project 2.1 for the 'Trace element and micronutrient' trials voyage on *RV Investigator* in April 2015, with the goal of testing 5 key pieces of new Marine National Facility (MNF) equipment/facilities for trace metal oceanography. One test station southeast of Tasmania (43° 25'S, 148° 25'E) was occupied for 3 days. The team successfully tested the trace metal rosette, in situ pumps, trace metal aerosol sampler, and new clean containerised laboratory. Some issues were identified with the trace metal clean underway supply on the *RV Investigator*, and solutions to this are under discussion with the MNF.

A special issue for the journal *Biogeosciences,* reporting results from the Kerguelen: Ocean Plateau compared Study 2 (KEOPS-2) project - a natural iron fertilisation study around the Kerguelen Islands in the Southern Ocean – was finalised. Thirty-two papers have been published in volumes 11-12 of the journal. The work confirms that natural Fe inputs stimulate phytoplankton blooms, and further reveals that bloom community structures are strongly modulated by mesoscale circulation features. This work is an outcome of the strong collaboration with European scientists within Project 2.1, especially with LEGOS (Toulouse), UParis (Banyuls and Paris), VUB (Brussels), and LEMAR (Brest).

The Totten Glacier cruise was completed successfully from December 2014 - January 2015 on *RV Aurora Australis* with a suite of CO_2 system measurements now undergoing quality control and finalisation. The CO_2 system measurements on the voyage complement the physical oceanographic program and provide the first information on carbon cycling in the region and the potential for change in carbon uptake in this rapidly changing environment.

Dr Bronte Tilbrook co-chaired the group quality controlling all Southern Ocean data for the next release of the Surface Ocean Carbon Atlas (SOCAT). Version 3 quality control was completed in May 2015, with a release planned for September 2015. SOCAT contains most measurements of surface CO_2 collected by the global community and is the main database used to detect change in ocean carbon uptake and for testing ocean carbon cycle models. Papers co-authored by program staff that utilise the database include yearly updates of the global carbon budget (Lequere et al 2014a and LeQuere et al 2014b), and a new assessment of carbon uptake in the sea-ice zone with Belgium colleagues (DeLille et al, 2014).

Results from the 2012 SIPEX-II sea ice voyage will be published in a single special issue of Deep-Sea Research II. In this volume, which is scheduled for publication in mid 2016, our team will showcase the first under-ice seawater DFe profiles, indicating a clear enrichment compared to Southern Ocean background concentrations (Schallenberg et al., 2015). Dissolved iron sources include melting icebergs, shelf sediment process and melting sea ice. SIPEX-II data indicate that particles released from melting sea ice may be effective in supplying bio-available Fe (Lannuzel et al., 2014). Dr Naoya Kanna, from ILTS, visited scientists from this project on a UTAS Tsuneichi Fuji Scholarship and worked with Dr Delphine Lannuzel and Dr Pier van der Merwe on the dissolution of iron particles in the sea ice environment.

The first data on the organic complexation of Fe in sea ice, brine and under-ice seawater samples collected in fast ice near Casey were reported by our group, showing that dissolved Fe concentrations in sea ice are controlled by organic ligands (Lannuzel et al., 2015). Analysis of archived pack ice samples from the Western Weddell Sea (AWECS) and East Antarctic sector (SIPEX-II) are currently underway with our collaborator in Italy (Dr Marco Grotti, University of Genoa).

Analysis of iron (Fe) in rare ice cores collected in the Amery Ice Shelf (AIS) provide the first evidence of a rich supply of Fe from marine ice in front of the AIS (Herraiz-Borreguero et al., submitted). Under current acceleration in ice shelf basal melt this fertilisation pathway is likely to increase, with important implications for ocean productivity and CO_2 drawdown around Antarctica.

Finally, our bid to host the fourth 'Oceans in a High CO_2 World' conference was successful, and it will be held in Hobart 3-6 May 2016. This is a very high profile conference and will attract approximately 400 delegates to Hobart from all around the world.

2.1.2.2. Biological Responses to Environmental Change

Project Summary

Climate change and ocean acidification are considered to be major threats to Southern Ocean ecosystem structure and function. Potential impacts identified in the Fifth Assessment Report published by the Intergovernmental Panel on Climate Change in 2014 include poleward shifts in geographical distributions, population

collapses or local extinctions, failure of large-scale animal migrations, changes in the seasonal timing of biological events, and changes in food availability and food web structure.

Microbes at the base of the foodweb control the flow of energy into foodwebs and the biological pump (through phytoplankton primary production), and mediate the recycling of key plant nutrients such as nitrate and iron (through heterotrophic bacteria). Studies at high latitudes have already identified that the community composition of the species and groups that comprise the base of the foodweb are likely to be altered by changing oceanic and sea ice conditions. Changing conditions may also directly influence higher levels in the foodweb, which can create not just bottom up, but also top-down pressures. The potential for many consequential pressures may alter the predator-prey relationships, which may in turn cause changes in the relative importance of different energy pathways. At present, energy transfer to higher trophic levels is primarily through Antarctic krill (*Euphausia superba*). Change may give rise to a copepod-fish pathway becoming more important in some areas.

Sea ice is a major driver of Southern Ocean food webs. From studies in the West Antarctic Peninsula region, recruitment and abundance of krill is hypothesised to be dependent on the extent of winter sea ice. The mechanisms proposed for this relationship hinge on the reliance of krill (particularly krill larvae) on the microbial communities that grow on the underside of sea ice. Krill feed on these communities during times when food in the water column is scarce. Whether this relationship holds true for the different sectors around Antarctica remains unclear. Understanding regional differences in the dependency of pelagic food webs on sea ice conditions is critical for a proper assessment of the impacts of changing sea ice conditions on Antarctic marine ecosystems.

Experimental studies in controlled environments of the physiology of keystone species or groups, particularly at lower trophic levels (bacteria, phytoplankton, zooplankton and Antarctic krill) will enable an assessment of the responses of species – to both individual and multiple environmental stressors – to changing environmental conditions are more likely to occur. These studies will also be used to characterise their life history and population dynamics in models which will be used to predict the fate of phytoplankton, zooplankton and krill in the Southern Ocean under various IPCC scenarios and fishing regimes.

Project 2.2 will utilise outputs from other ACE projects to help prioritise the key biological responses and physiological tipping points to be resolved for understanding (i) the consequences to biota and foodwebs of changes in ocean state and chemistry, sea ice, and carbon, and (ii) the uncertainties to resolve for assessing status and trends of the ecosystem as a whole (Project 2.3).

Project 2.2 will utilise a combination of perturbation experiments (laboratory and field), field studies, data synthesis and modelling (habitat and autecological) to:

- fill important gaps in representing lower trophic levels in ecosystem models
- determine physiological tipping points, from microbes to krill, to both individual and multiple environmental stressors (such as temperature, acidification, light, iron and food);
- in conjunction with Project 2.3, the ecological ramifications (energetics, restructuring) of such tipping points for polar foodwebs will be projected using simulation models to assess early warnings of change; and

- assess functional relationships between phytoplankton, krill and krill predators in sea-ice habitats, and how they might change in the coming decades.

Work on this project will focus on the following tasks:

1. Perturbation experiments – laboratory experiments (microbes to krill) will be undertaken at the AAD and IMAS.
2. Field program – use the Kerguelen Axis study (Project 2.3) and other international studies including collaborations with Japan, France and Germany to investigate habitat dependencies of key taxa (microbes to whales).
3. Modelling – the relative impacts of processes (individually or in concert with others) on the autecology of key taxa will be investigated using models.
4. Using analyses of existing (SIPEX-2012, Polarstern-2013) and newly collected datasets (Polarstern-2017) this project will provide a field-based assessment of sea ice physical and biological habitat qualities and the dependency of (larval and juvenile) krill on different sea ice types.

Research Activities 2014/15

Dr Kristen Karsh (Microbial Physiologist) commenced November 2014 and Dr Marion Fourquez joined this project on a short-term contract in May 2015. Several other new staff members joined this project (jointly with Project 2.3) during the reporting period. Dr Kerrie Swadling (Zooplankton and Sea Ice Ecologist) commenced October 2014. Dr Rowan Trebilco started in November 2014 and was recently awarded the Hawke Fellowship. Dr Laurence Clarke (Molecular Ecologist) started in January 2015. Acoustic analyses have begun in conjunction with Dr Martin Cox (AAD). An acoustics position will soon be filled in the ACE CRC to support this work.

Measurements of key biological rates and physiological metrics of lower trophic levels in response to ocean acidification have begun. Recent submitted work (Muller et al, 2014) has shown that the three main Southern Ocean morphotypes of the globally important *Emiliania Huxleyi* (*a* calcifying coccolithophore phytoplankton species) have varying vulnerabilities to ocean acidification; the most polar morphotype is particularly at risk of being unable to form its shells under elevated CO_2 levels expected this century. The field experiment on the Umitaka-Maru voyage (January - February 2015) was successful. All sampling was completed and analysis is currently ongoing and a first manuscript from this voyage is currently in review. Design of the ocean acidification laboratory manipulation system has been finalised and fabrication started in February 2015. Delay in staff appointments and fabrication of the state-of-the-art laboratory system has meant that laboratory work has been slightly delayed.

In early 2015, an opportunity to undertake 17 days of marine science on the Aurora Australis (voyage 3) along the shelf break off Enderby and MacRobertson lands was successfully used to undertake fine-scale surveys (5 fine-scale areas) of krill distribution and abundance in relation to summertime penguin foraging areas. A total of 53 target and regular RMT-8 tows along with acoustic observations within the fine-scale boxes were undertaken, and a total of 131 filtered phytoplankton samples were collected using underway equipment during these trawls. Species identificatyion and demographic measurements were completed for krill and zooplankton samples. These data will be used to assess localised influence of

oceanographic factors on krill distributions and how the fine scale patterns of krill may influence the foraging of penguins in the region.

Planning is well underway for the signature Kerguelen Axis program to be undertaken in January - February 2016. Planning is also underway to host the 4th meeting of *Oceans in a high CO_2 world*.

Project 2.2 had three visitors from ACE CRC core partner, AWI, Germany, during January and March 2015. Dr Mathias Teschke, Mr Fabio Piccolin, and Mr Felix Muller visited to work together with ACE CRC scientists on the collaborative study on climate change effects on the krill biological clock at the AAD krill aquarium. Ms Nopparat Nauschon from Nagasaki University, Japan, visited during December 2014 and March 2015 and worked with ACE CRC scientists on the collaborative study on CO_2 effects on behaviour of krill early life stages.

2.1.2.3. Status and Trends in Ecosystems

Project Summary

Marine ecosystems provide important services to people for food, sewage disposal, and environmental quality. They are also significant in the global carbon cycle, playing an important role in sequestering carbon from the atmosphere. These ecosystems are changing and will continue to change over at least the next 100 years as the ozone layer recovers and as climate change and ocean acidification continue to modify ocean habitats. Minimising such impacts on ecosystem services is one challenge for governments and administrators. But, most importantly, another challenge is to provide policy and regulatory frameworks that can respond to these impacts in a timely manner without causing rapid upheavals in how we use marine ecosystems and adequately conserve those services. For example, an important challenge will be how to manage the rapidly expanding krill fishery within a changing ecosystem, including changes as a result of the recovery of whale and seal populations from past exploitation.

Climate change poses greater difficulties for policy makers and managers than the usual forms of environmental management. This is because the effects of actions are not seen immediately; increased concentration of greenhouse gases will likely result in changes to ecosystems only after many decades, as demonstrated by the 50-year time frame expected for the recovery of the ozone hole after cessation of emissions of ozone-depleting substances.

In order to ensure ecosystem services are sustained in the face of future change, the following capabilities are required:

- robust early-warning indicators of change;
- robust assessments of the likelihood of different future states of ecosystem services given different management options or scenarios; and
- mechanisms for adjusting management options to take account of new information.

These capabilities are required for the Southern Ocean and, when met, will provide important foundations for adaptation to climate change impacts elsewhere in the world.

The recent Fifth Assessment Review of the Intergovernmental Panel on Climate Change describes how these capabilities are essential for the Southern Ocean but currently poorly developed. Initiatives in SCAR, SCOR and IMBER provide important forums for coordinating and achieving these capabilities by 2020. Project 2.3 will play an integral and leading role in these initiatives, particularly in delivering these capabilities for the Indian Sector of the Southern Ocean.

The sequence of work for Project 2.3 integrates the main tasks below with other projects in the ACE CRC. A quantitative framework will be developed to undertake ecosystem assessments. A preliminary assessment in the first year, with an emphasis on the Indian Sector of the Southern Ocean, will use existing models, data sets and scenarios of future environmental change. It will identify key gaps and uncertainties to guide priorities for this project and Project 2.2. Existing models and data will also be used to design a cost-effective field program to obtain new data required for helping resolve uncertainties in status and trends and to improve model performance. This project will combine work across the ACE CRC and international programs to deliver up-to-date, quantitative assessments for use by the Australian Government, IPCC, CCAMLR, IWC and other bodies as a basis for management in the region.

Work on Project 2.3 will focus on the following tasks:

1. Modelling and assessment – in collaboration with international modelling efforts through the IMBER program Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED), refine and utilise the ACE CRC end-to-end ecosystem model, and other species-specific models, along with existing field and model data, to undertake assessments of status and trends of key species (phytoplankton, krill, icefish, toothfish, marine mammals and birds) and the ecosystem as a whole.
2. Observing system design – in conjunction with ICED (Southern Ocean Sentinel) and the Southern Ocean Observing System (SOOS), develop a set of essential ecosystem variables and design a cost-effective field observation program to measure these variables in the Indian Sector of the Southern Ocean that will facilitate:
    i. ecosystem assessments; and
    ii. validation and updating of end-to-end ecosystem models. This will include analyses of existing data sets, simulations, field trials, collection of underway data, and the development of automated processing techniques, particularly using genetic and chemical methods.
3. Field program – undertake a study on the Kerguelen Axis, in conjunction with Japan and France, co-ordinated with ICED and SOOS, and in collaboration with other ACE CRC projects, to identify:
    i. the relationships of the different food webs (primary and secondary producers and nekton) to environmental (ocean and sea ice) and biogeochemical (iron, micronutrients, primary production) drivers;
    ii. where the transition between the northern fish-centric food web and the southern krill-centric food web might occur; and
    iii. whether the transition zone is fixed in its location or will migrate south with the frontal systems.

    This study will also trial different underway measurement systems for use in a longer-term observing system.

4. Habitat reconstruction - with the palaeo-environmental Project 1.4 - initiate a habitat reconstruction in order to examine (i) what Southern Ocean ecosystems might have looked like prior to the industrial revolution, and (ii) what consequences there might be for current population trajectories of historically harvested species.
5. International Conference 2018 - International collaboration to deliver these outcomes will be enhanced through an international conference in Hobart in 2018 on Assessing Status and Trends of Key Habitats, Species and Food Webs in the Southern Ocean. Working groups will help deliver products to this conference, which aims to consolidate results and set the stage for research priorities from 2020 to 2025.

Research Activities 2014/15

Several new staff members joined this project and Project 2.2 during the reporting period. Dr Kerrie Swadling (Zooplankton and Sea Ice Ecologist) commenced October 2014. Dr Rowan Trebilco started in November 2014 and was recently awarded the Hawke Fellowship. Dr Laurence Clarke (Molecular Ecologist) started in January 2015. An acoustics capability will soon be filled in the ACE CRC to support this project.

Assessments of habitat and biological changes are underway. Use of CMIP5 model output to define scenarios for habitat change and biological responses is progressing through work within the ICED program. A community paper, led by Dr Andrew Constable, was published online on 30 June 2014 and October 2014 in hard print (Constable et al., 2014 – reported in 2013/14 publication list), with another two other papers near submission.

Progress has been made on the development of a circumpolar ROMS model to 40 degrees South and the use of sea-ice model outputs to assess change in habitat suitability for larval krill (work currenlty in review). Assessment methodologies have been developed for habitats and are complemented by regional-scale foodweb modellling (work currently in preparation for publication). The development of an end-to-end ecosytem model for the Indian Sector of the Southern Ocean is ongoing, with the successful completion of a ‘cartoon’ model that established methods for configuring the more complex Atlantis model for the region.

Work on ecosystem Essential Ocean Variables is ready for submission – this work was presented to a recent international SOOS workshop, which was held in Hobart in June 2015 and supported by the ACE CRC through this project. This work will form an important part of regional and capabilty working groups in SOOS. Progress has been made on the engagement of partners and other nations working in the Indian Sector, particularly in relation to planning of the voyage to the Kerguelen Plateau region in the upcoming 2015/16 season and in developing interest in the 2018 international conference in Hobart, which has been endorsed by SCAR and its working groups, SOOS and ICED (IMBER). Work through IMBER on model integration will also contribute to this project through upcoming, ACE CRC-led workshops and conference sessions in August (Hobart) and October (Italy) 2015.

2.2 Education and Training

Education

The ACE CRC education program continues to be supported by, and provided through, the University of Tasmania's Institute for Marine and Antarctic Studies (IMAS). Students study a range of topics relevant to Antarctica and the Southern Ocean. The ACE CRC also supports a small number of students at other tertiary institutions.

ACE CRC staff teach PhD, Masters by Research and Masters by Coursework students. They also teach Honours programs and units in undergraduate courses, mostly to students taking science degrees, although a few undergraduates from other backgrounds (e.g., Arts) do enrol in first-year Antarctic studies units taught by IMAS.

During the reporting period, 50.5 (FTE) students were involved in PhD studies related to the ACE CRC, including 12 commencing students. There were also 8 completions and 1 withdrawal. Of the 8 PhD students that graduated during the reporting period, Dr Amelie Meyer, Dr Jose Mauro Vargas-Hernandez, Dr Christopher Roach, and Dr Fabien Queroue are in post-doctoral positions overseas. Dr Kristen Karsh is employed at the ACE CRC as a Microbial Physiologist, Dr Andrea Walters is employed at the Antarctic Gateway and Cathryn Wynn-Edwards is working at the AAD. Dr Kirrily Moore is working for the Marine Biodiversity Hub in Hobart.

The ACE CRC currently provides financial support to 7 PhD students through top-up scholarships, which are awarded on a competitive basis. Four of these were awarded in January 2015.

In total, 35 UTAS staff and 53 non-university staff including in-kind contributing staff were involved in PhD supervision.

Also in the reporting period, 1 Masters by Research student and 1 Masters by Coursework and Research commenced their studies. This student's supervision involves 2 UTAS staff and 2 non-UTAS staff. These figures fall short for our Masters students milestones. This is likely to be a recurrent trend throughout the life of the ACE CRC given that Masters degrees are not preferred in most environmental science programs. The ACE CRC has discussed this with the Department of Industry and Science and reached in principle agreement to renegotiate the relevant milestones. The ACE CRC expects to exceed PhD enrolments to make up for the shortfall in Masters students.

A total of 326 students were enrolled in IMAS undergraduate units during 2014/15. Of these, 18 were enrolled in the Bachelor of Antarctic Science and 45 in the Bachelor of Marine Science. IMAS also enrolled 89 students in the Bachelor of Marine and Antarctic Science, which will eventually supersede both of the existing undergraduate courses. We expect a signficant number of these undergraduate students to go on to higher degrees at UTAS, with good potential for the ACE CRC to attract them into research projects relevant to Antarctica and the Southern Ocean.

Three Honours students commenced in February 2015 with 2 continuing Honours students. Three Honours students graduated during the reporting period (Rebecca Dunn, Dale Maschette and Penny Pascoe).

These figures indicate a resurgence in interest in Honours programs, which augurs well for future recruitment into PhD programs within the ACE CRC. There have been strong employment outcomes for this year's PhD graduates, who continue to develop outstanding professional careers. Out of the 8 PhD students that graduated during the reporting period, 4 are in post-doctoral positions overseas and 4 are employed in local Hobart Antarctic/Marine organisations, including the ACE CRC.

The ACE CRC will continue to work closely with IMAS to improve visibility of projects and enhance student recruitment.

Furthermore, the free online marine and Antarctic science course which is run through the Open2Study program of Open Universities Australia, consisting of 37 short videos and four modules, attracted 7,926 students during the reporting period. Subject material covers the full spectrum of activity undertaken by IMAS. Prof Craig Johnson (IMAS) and Dr Jessica Melbourne-Thomas (AAD and ACE CRC) present the course. As of 9 September 2015, 7,926 students have taken the course; 36,386 videos have been watched; and 2,293 classroom posts have been made.

The ACE CRC has several structures in place for interaction with and between students. The 'ACE Chit Chat' series has been up and running since 7 June 2012 and has been managed by ACE CRC PhD students since September 2013. The 'ACE Chit Chat' sessions are held fortnightly and update staff and students on what other colleagues or students are currently working on, promote discussion, feedback and collaboration, and faciliate interaction with colleagues and students from different organisations. In addition, DaSH (Data Science Hobart) fortnightly sessions have been organised by ACE CRC students and researchers to build a community of researchers to discuss data, concepts, tools, methods and to solve problems. The weekly IMAS seminars also allow for students and researchers to have discussions and improve collaborations.

Furthermore, the Science Communication Workshop for PhD students on 26-27 February 2015 was well attended by 30 ACE CRC PhD students. The workshop aimed to equip students with basic skills for communicating their research to the public, including interview techniques, media release preparation and interaction with the media. The workshop was organised and hosted by the ACE CRC and IMAS communications managers, with assistance from the Australian Science Media Centre.

A list of all ACE CRC PhD students, including commencement date, research program, project title, research organisation, country and expected completion date, is provided in Appendix 2.

Training courses for end-users/professional development

During the reporting period, the ACE CRC hosted several workshops for end-users, attended by a total of 105 delegates.

COMNAP

The Antarctic Sea Ice Challenges Workshop, convened by the Council of Managers of National Antarctic Programmes (COMNAP), was held in Hobart in May 2015. This workshop brought together 65 of the world's Antarctic program managers and scientists to discuss challenges experienced by a number of national programs caused by changing sea ice conditions, and the technology available to help

vessels navigating through sea ice. There is growing demand for a sea ice forecasting service and the ACE CRC will be leading discussions with partners, nationally and internationally to explore options for developing this capability. A number of ACE CRC researchers contributed expert knowledge on the Antarctic sea ice environment. The workshop was preceded by a public keynote address by ACE CEO, Prof Tony Worby, on *Antarctic Sea Ice: Trends & Challenges*. In this presentation, Prof Worby explained the science behind changes in Antarctic sea ice extent and discussed the challenges ahead for operators in the region. The public lecture was live-streamed and is available on the ACE website as a podcast.

Sea ice view tool training
The Sea Ice View Tool is a software package that provides satellite data products to vessels operating in the Antarctic sea ice zone, to assist with navigation. Dr Lieser provided this service to 7 Antarctic-bound vessels, including Australia's two research vesels *RSV Aurora Australis* and *RV Investigator*. This service included providing the software, its installation, provision of images suitable for use with the software (MODIS images and sea ice concentration maps) and further training/support as required.

In addition, weekly sea ice reports (with sub-weekly updates where requested) were provided to AAD Operations, as well as to the Chinese National Antarctic Research Expeditions (*RV Xue Long*), the Royal New Zealand Navy, the New Zealand National Institute of Water and Atmospheric Research (*RV Tangaroa*), the Australian Marine National Facility (*RV Investigator*) and the US Antarctic Program (*RVIB Nathaniel B Palmer* voyage 15-03). The reports were collated by Dr Jan Liser in a single volume entitled Season's Sea Ice Report (Volume 4) available on the ACE CRC website.

In total, the ACE CRC supported 16 voyages of 7 institutions from 5 nations. The service will be provided again in the 2015/16 Antarctic shipping season.

Icesheet and Ocean Modelling Workshop
The icesheet and ocean modelling workshop was held on 10-11 November 2014. This workshop was attended by 40 researchers. Twenty-one speakers participated in this workshop followed by an afternoon discussion.

2.3 SME Engagement

There was active engagement with the consulting company SGS who are a formal Other Participant in the ACE CRC. The ACE CRC provided support to their sea level rise consulting activities through attendance at a recent community/local government coastal planning workshop.

The ACE CRC also continues to be an active contributor to the Tasmanian Polar Network, most recently attending their strategy workshop, as well as engaging regularly in their stakeholder communication activities.

Our recently appointed new Board member, Mr Gordon Hagart, is helping the ACE CRC develop an engagement strategy with major companies interested in understanding and managing multi-decadal risk to capital from climate change.

During the reporting period, services were provided utilising the Sea Ice View tool for operational use on-board Antarctica-bound vessels, including *RSV Aurora Australis*, *l'Astrolabe* and *RSV Xue Long*. As described above, this service included providing the software, its installation, provision of images suitable for use with the software

(MODIS images and sea ice concentration maps) and further training/support as required.

3 Results

3.1 Utilisation and Commercialisation

The ACE CRC continues to seek innovative ways to communicate our research outcomes to maximise the uptake of our scientific work. This section begins by outlining important activities that have involved staff from across the ACE CRC.

The ACE CRC's position analysis publications provide plain English summaries of the latest research in their particular fields. Their aim is to inform Government policy makers and planners, and the wider community, about the current state of knowledge on particular topics. The *Ice Cores and Climate* position analysis was completed during the reporting period and presented at a Research User Forum in Canberra on 29 July 2015, together with the *Antarctic Sea Ice and Climate Change* Position Analysis produced in 2014. Over 60 departmental representatives attended the briefing from a broad range of government agencies and other end-users. Both publications are available in the publications section of the ACE CRC website.

A two-day Southern Ocean Observing System (SOOS) workshop was held on 11 and 12 June 2015 to develop an implementation plan for the coming two years. This included understanding and Implementing the vision for SOOS, establishing Regional Working Groups, and identifying key capabilities needing development/refinement.

Canute, the publically available sea level calculator, enables end users to assess the likelihood of coastal flooding under different sea level rise scenarios. A major co-funder of this project was the Australian Government's (then) Department of Climate Change and Energy Efficiency. A requirement of this funding was that the web-tool be placed in the public domain, with any end-user or consulting firm able to freely generate outputs from it. The Tasmanian Partnership for Advanced Computing now hosts the 'Canute' online sea level rise tool on an ongoing basis. Canute currently has 490 active users.

A wide range of outreach activities have taken place with politicians, policy makers and the public, as well as within the science community. These are listed below:

- Briefings to politicians and representatives across all levels of government;
- Public lectures and school visits;
- Regular review with key government departments such as Department of Environment and Department of Industry, commercial participants, and ACE CRC's essential and other research participants; and
- The Annual General meeting was held on 17 November 2014 with a BoM representative, and commercial participant SGS present.

Strategies for ensuring uptake by end-users include:

- Regular reviews with end-users to understand needs and transfer knowledge;
- Production of Position Analyses, Report Cards and Technical Reports, including mail-out to an established database of users;
- An ACE CRC Position Analysis on Ice Cores and Climate was published in June 2015, followed by a briefing with end-users at a workshop in Canberra on 29 July 2015;

- E-newsletters and Twitter to keep users updated on the latest science;
- Presentations at conferences and symposiums;
- Direct involvement in the IPCC reporting process (as a major conduit to policymakers nationally and internationally);
- Media releases and briefings to journalists, including through the Australian Media Science Centre;
- Implementing strategies to measure uptake (for example downloads of reports).

3.2 Intellectual Property Management

The ACE CRC is a "public good" research centre focussed on the important role of Antarctica and the Southern Ocean in the global climate system, and on climate change and its impacts in the Antarctic, Australia and the world.

The value of the ACE CRC's IP can be measured by its social and environmental impact. As a public good CRC, the ACE CRC aims to make its research outputs widely and freely available. The ACE CRC does not seek commercial returns from its IP, consistent with the terms of the Antarctic Treaty System to which Australia is a signatory.

The ACE CRC IP comprises research outputs documented and published in peer-reviewed journals and public-ready documents such as position analyses and report cards. Data sets include those collected as part of Antarctic fieldwork as well as the outputs of climate models, such as sea-ice and ice-sheet models (and the sea-ice web-tool now with TPAC). These are all publicly available through repositories such as the Australian Antarctic Data Centre, Tasmanian Partnership for Advanced Computing, and the Integrated Marine Observing System. These data sets provide invaluable public-good assets for researchers now and in the future.

The value of the ACE CRC's IP is derived from the products and services developed by the ACE CRC, which wrap around ACE CRC's core research outputs. These products and services have evolved over the ACE CRC's history in close consultation with end-users to ensure that they are relevant to end-users.

In particular, the ACE CRC is playing an important role in improving the parameters that feed into climate change and sea level rise projections and underpin any adaptation response. The ACE CRC has pioneered ways to provide its information in a user-friendly format. This information has informed government policies and industry strategy in many areas.

For example, the ACE CRC remains a very significant contributor to the IPCC Assessment process. The ACE CRC contributed 18 co-authors to the Fifth Assessment Report, which is the most authoritative basis for climate change information used by governments and industries around the world.

Two areas of ACE CRC activity have attracted a level of commercial interest. These are the impacts of sea-level rise on the Australian coastline and fine-scale climate change modelling.

- The ACE CRC sea-level rise impacts project delivered a web-based tool, *Canute* that enables end users to assess the likelihood of coastal flooding under different sea level rise scenarios.

- The Climate Futures for Tasmania project was developed via a funding model, which sits outside the CRC program. It was a requirement of the funding model that the data and outputs be placed in the public domain. The Climate Futures Tasmania Report is being utilised by a wide variety of users, including State and local government, and private businesses including consulting firms.

The ACE CRC did not envisage securing any commercial return on either of these projects, both of which have now been successfully transitioned to other organisations for ongoing management. Any further development of the products would require substantial additional funding and should the private sector pursue such a strategy, there is no expected return to the ACE CRC.

The ACE CRC presently archives its data and Meta data with the Australian Antarctic Data Centre. This is a requirement of any project receiving support through the Australian Antarctic Science proposal process.

The ACE CRC does not hold any patents in Australia or overseas.

3.3 Communications

The ACE CRC is committed to effective communication within the organisation, among its partners, with external users and the wider community. This section details the various means by which this was achieved during the reporting period.

Communications Strategy
The ACE CRC developed a new Communications Strategy during the reporting period to provide a framework for internal and external communication activities. The document outlines the objectives, actions and timeframes for delivering an effective communications program and acts as a long-term work plan for the Public Affairs Manager (and other staff in some cases). This document builds on the work of three previous ACE CRC communications strategic plans implemented in 2004, 2010 and 2012 and is aimed at building the CRC's public profile, fostering collaboration with partner agencies, building internal cohesion, attracting leading research talent, strengthening engagement with key influencers and communicating research outputs. A key element of improved communications through 2014/15 was a redevelopment of the ACE CRC website, which is described in more detail below.

Major Launch Event
On 10 March 2015, the ACE CRC held its official launch event for the 2014/19 funding period. The launch was an important opportunity for the CRC to celebrate its renewed funding, to present an overview of its research agenda for the coming years and to acknowledge, thank and engage directly with our participants, stakeholders and supporters. The launch was originally scheduled during the last half of 2014, but delayed due the sudden death of the Tasmanian Governor, His Excellency Peter Underwood. It was held on the ground floor of the UTAS Waterfront Building, and later at Government House where Her Excellency Professor the Honourable Kate Warner, Governor of Tasmania, hosted a reception for staff and guests.

Internal Communications
Staff events
On 17 Nov 2014, staff and members of the ACE CRC Board met at an informal

gathering in the staff galley on Level 3 of the UTAS Waterfront Building. The event was an opportunity for new staff and board members to become acquainted.

On 10 March 2015, the ACE CRC held a Staff Forum on the ground floor of the UTAS Waterfront Building. The forum was an opportunity for the ACE CRC management team and the Program Leaders to provide staff with updates on important matters relating to ACE, along with short science presentations to help ensure staff are up-to-date on the latest activities in each of our research programs.

Email Communications
The ACE CRC's administrative staff maintain a number of internal distribution lists to disseminate information on a day-to-day basis. The CEO issues a regular informal 'ACE Update' to staff by email with details of research milestones, staff changes, events and publications. The CEO issued 18 staff news updates during the reporting period.

Online Resources
Staff and students have access to a new protected online resources page, which includes document templates, policies, project plans, and design assets.

ACE Chit Chat and DaSH
Regular 'ACE Chit Chat' and 'DaSH' sessions were held throughout the year to discuss research amongst staff and students. These sessions are held fortnightly.

Mainstream Media
The ACE CRC achieved a historically high media profile during 2014/15, a year that offered a variety of opportunities for public engagement on topical and newsworthy issues. Working closely with our partners, the ACE CRC worked to maximise news coverage opportunities in line with approaches outlined in the communications strategy. The following is a month-by-month summary of key news stories during the period.

<u>July 2014</u>
No news coverage

<u>August 2014</u>
An article published in The Conversation on 'How whale poop helps feed the ocean' by PhD students Lavenia Ratnarajah and Indi Hodgson-Johnston and A/Prof Andrew Bowie received considerable interest from local and mainstream media.

<u>September 2014</u>
In September 2014, the ACE CRC received widespread coverage with news that Antarctic sea ice extent was on track to reach its highest recorded annual extent for the third consecutive year. The story received considerable worldwide attention, with an ABC Online story quoting Professor Tony Worby and Dr Jan Lieser becoming the most read news article on the ABC website during the month of September. For the ACE CRC, it was a valuable opportunity to proactively engage in the public dialogue over climate and provide an informed scientific perspective on a topical issue.

Earlier in the month, a story on research using satellite-tagged elephant seals to collect oceanographic data also received considerable media interest.

October 2014

The Federal Government's 20 Year Antarctic Strategic Plan was released in October 2014 and attracted significant national media attention. A number of scientists and legal experts from the ACE CRC provided comment and analysis following the report's release, including its lead author and former CEO of the ACE CRC Dr Tony Press. Professor Tony Worby published a response in The Conversation and made a number of media appearances.

November 2014

A visit by the Chinese President Xi Jinping provided a valuable opportunity to highlight scientific links with Chinese polar research agencies. The ACE CRC used the opportunity to host a media event at the UTAS Waterfront Building with Chinese polar researchers that was widely covered by local and national media.

December 2014

In mid-December 2014, Dr Tessa Vance from the ACE CRC published a groundbreaking article in the journal Geophysical Research Letters that gave unprecedented new insights into eastern Australia's long-term historic drought patterns. We expect the findings – from the analysis of ice cores drilled in East Antarctica – will help improve catchment management strategies in drought-affected areas of Queensland and New South Wales.

January 2015

The *Aurora Australis* returned in early January from a highly successful voyage to the front of the Totten Glacier to collect moorings and take measurements to determine the rate of glacial melting. Working closely with partners at the Australian Antarctic Division, the ACE CRC helped drive strong national news coverage of the voyage. Voyage leader and ACE CRC Program Leader, Dr Steve Rintoul, made a number of media appearances to discuss the observations.

February 2015

Researchers from the ACE CRC co-authored an important publication in the journal Nature Geoscience identifying a previously unknown gateway to the ocean underneath the largest glacier in East Antarctica. The paper identified the potential for warm seawater to reach the base of the glacier, causing melt and potentially raising sea levels. The story received worldwide news coverage, with communications teams at the Australian Antarctic Division, the ACE CRC and the University of Texas at Austin working in close cooperation.

March 2015

In March, the ACE CRC led the first science voyage of Australia's new research vessel, *RV Investigator*. The voyage was also the first major scientific collaboration with the Bureau of Meteorology since Australia's weather agency re-joined the partnership in 2014. The voyage received publicity in local and national media.

April 2015

April was a quiet month for news coverage, with communications efforts mostly focused toward internal planning activities for the coming period.

In late April, Dr Tas van Ommen authored a notable travelogue-style piece for The Conversation about the ACE CRC's recent research on the Totten Glacier.

May 2015

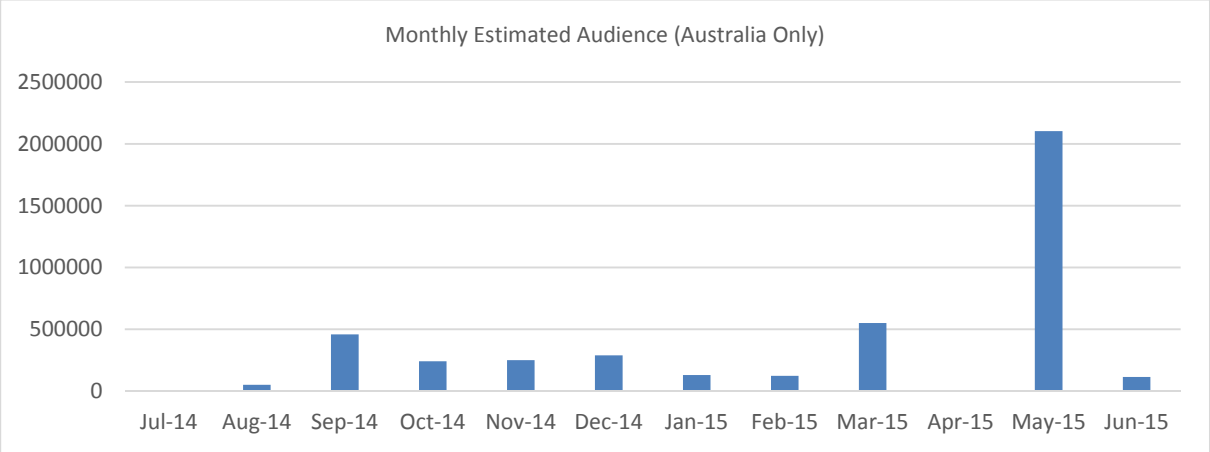
News coverage around the COMNAP Sea Ice Challenges Workshop in May generated the ACE CRC's largest spike in viewership in the past five years. A significant effort was made prior to the meeting to identify and target journalists worldwide with an interest in sea ice and climate. Much of the local and international news coverage focused on difficulties with Antarctic resupply and the need for improved sea ice forecasting systems. Professor Worby's public lecture prior to the conference attracted a large audience of approx. 180 people and the live stream attracted the largest single spike in website visitation since the website was re-launched (around 800 sessions in the space of an hour). A video of the lecture has since been viewed well over 200 times on Youtube: https://www.youtube.com/watch?v=H0-n1DVGEfM.

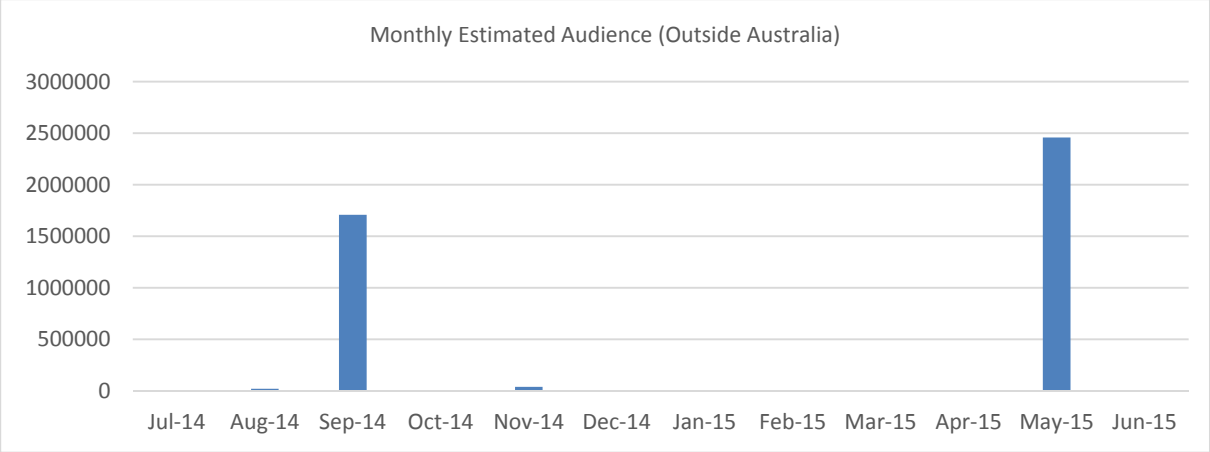
June 2015

The Southern Ocean Observing System's Planning Workshop (11-12 June 2015) attracted moderate levels of media coverage. The ACE CRC and IMAS provided assistance with publicity for the event. SOOS Vice-Chair and ACE CRC Program Leader Andrew Constable appeared in a widely syndicated News Ltd piece promoting the conference.

Estimated Audience Reach (2014/15)

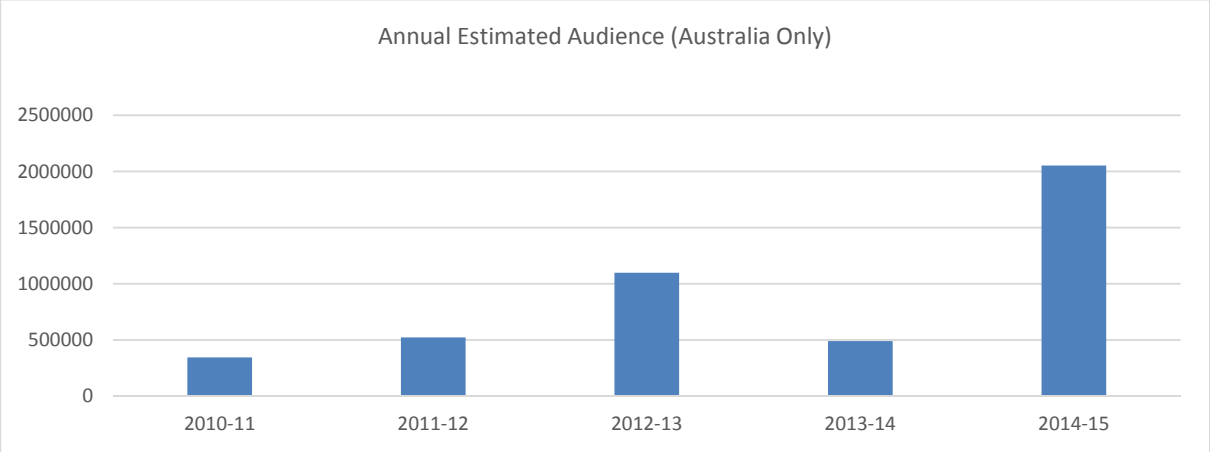
The figures below, provided by the Meltwater media monitoring service, are an estimate of the total audience for stories mentioning the ACE CRC and its staff members. Figures are calculated using an industry standard model based on publicly available circulation data. The ACE CRC was particularly prominent in global media coverage on Antarctic sea ice extent during the period, with the two largest spikes in news coverage achieved in September 2014 (coinciding with a new record annual sea ice extent) and May 2015 (coinciding with the COMNAP Sea Ice Workshop in Hobart).

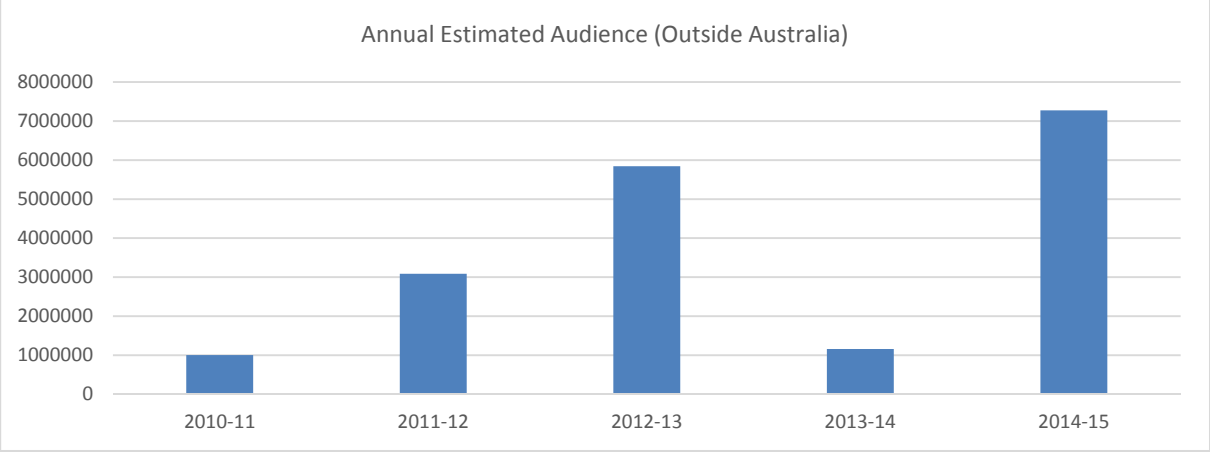




Long Term Audience Trend (2010/11 to 2014/15)

The figures below illustrate the five year trend in estimated audience. Metrics indicate that the Australian audience for stories mentioning the ACE CRC and its staff in 2014/15 were roughly double the previous maximum in 2012/13, highlighting the success of collaborative publicity efforts with partner agencies.





Website

The ACE CRC website was re-launched on 02 April 2015 after a four-month consultation, design and development period. The site was re-designed from the

ground up with a WordPress content management system and a stronger focus on simple navigation, visual appeal and easy access to information. The site includes the following content:

PAGE	CONTENT
About Us	Information on the history, laboratory facilities, governance structure and study/employment opportunities at the ACE CRC.
Research	A succinct overview of the ACE CRC's project structure and summaries of individual research projects.
Services	Information and links to tools produced by the ACE CRC to assist governments and other end-users to understand future climate scenarios and make decisions that take account of the risks posed by climate change.
Our People	Profile pages for all ACE CRC staff members, including photo, biographical details, research projects, key publications and contact information.
Publications	A comprehensive archive page containing links to position analyses, refereed publications, annual reports, online publications and external publications with contributions by ACE CRC staff members.
Events	A calendar of upcoming major events involving the ACE CRC including conferences and seminars.
News	A list of recent ACE CRC media releases and links to online published articles featuring ACE CRC research.
Contact	Contact information for the ACE CRC.

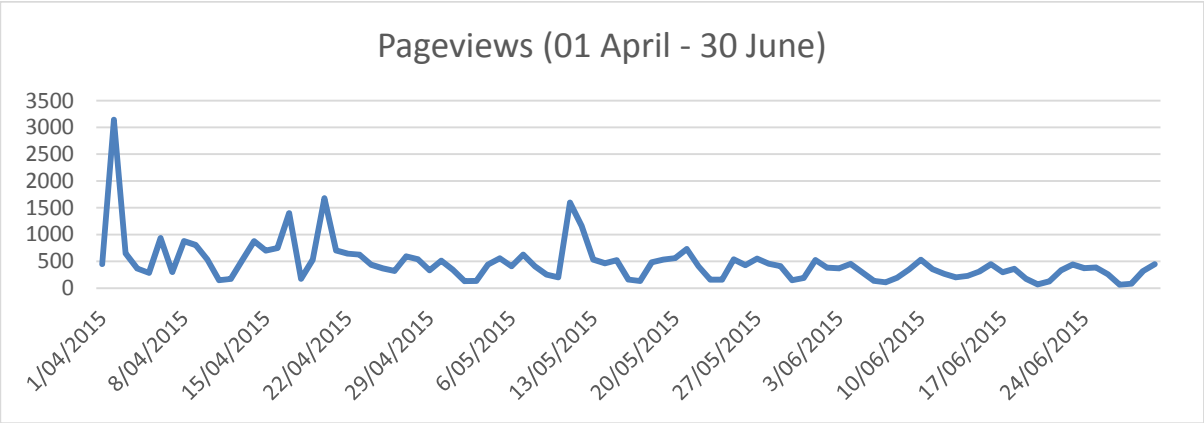
Website Metrics

The website metrics below cover only the three-month period from its launch on 2 April 2015 to the conclusion of the reporting period. Metrics for the new website and the old website are not directly comparable, because the content management systems use different algorithms for measuring, categorising and authenticating site traffic.

The site experienced a large influx of visitors during the first month, peaking at 3139 daily views when the site was launched on 2 April. Traffic peaked again at 1677 views following the circulation of the ACE News email bulletin, and a third peak of 1595 views was recorded on 11 May coinciding with Professor Tony Worby's keynote lecture for the COMNAP Sea Ice Workshop.

Page views reached a plateau of approximately 300-400 views per day – which is roughly equivalent (or slightly above) the best available estimate for traffic to the old website. Attracting repeat visitors by regularly renewing and updating content will be a key focus in the coming year.

Metric	Total (3 Months)	Daily
Page views	43,048	473
Sessions	8,069	89
Average Session Duration	3:01	N/A
Pages/Session	5.33n	N/A



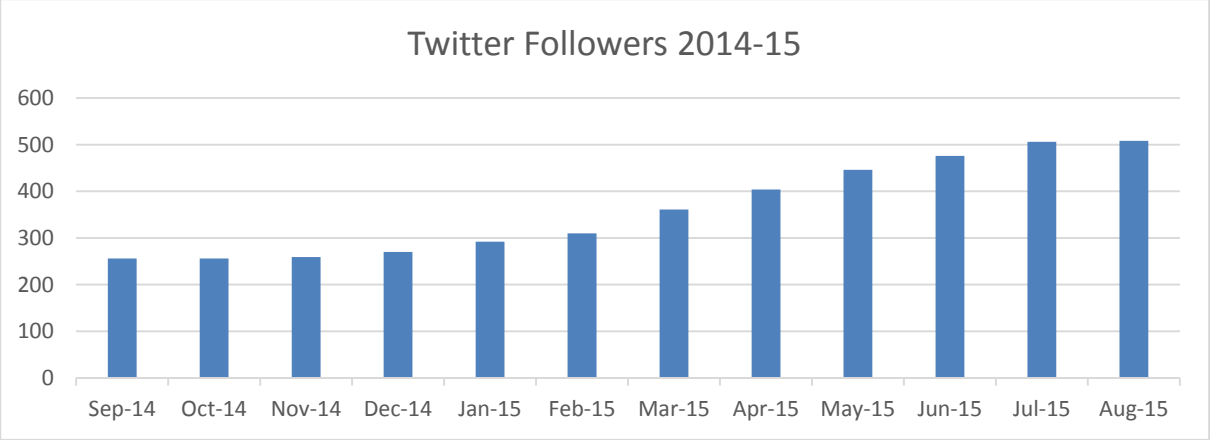
IPICS 2016 Website

A website was set up early 2015 for the International Partnerships in Ice Core Sciences Second Open Science Conference at www.ipics2016.org. The IPICS 2016 conference is being held in Hobart in March 2016, and is jointly hosted by the Australian Antarctic Division and the ACE CRC.

Social media

The ACE CRC's primary platform for social media engagement is Twitter (along with a less active presence on LinkedIn). In line with the objectives set out in the communications strategy, the ACE CRC's Facebook account has been suspended (although not deleted) due to the excessive workload required and limited derived benefit. Twitter remains a very useful tool both for promoting the work of the ACE CRC to a broader audience and for strengthening cross-institutional relationships. During the period, ACE CRC PhD student Indiah Hodgson-Johnston, was brought on as a casual contractor to provide 1-2 hours of social media support per fortnight.

Twitter engagement has steadily ramped up over the first half of 2015, with the number of followers doubling during the reporting period. This is in line with targets set out in the communications strategy.



ACE Newsletter

The ACE CRC distributed two editions of its stakeholder circular ACE News during the reporting period, on 31 October 2014 and 17 April 2015. Engagement with the newsletter was strong, with growth in 'open' and 'click-through' rates remaining within the target range in the communications strategy, and well above the industry benchmark averages for equivalent institutions.

Date Sent	Open %	Click %	Recipients
19 Sept 2013 (previous reporting period – for comparison only)	33.01%	8.34%	789
31 October 2014	33.92%	22.76%	790
17 April 2015	38.13%	28.44%	947
Industry average	22.49%	3.42%	N/A

Publications

Position Analysis: Ice Cores and Climate

The ACE CRC's position analysis publications are plain English summaries of the latest research in particular fields of Antarctic and Southern Ocean research. Their aim is to inform Government policy makers and planners, and the wider community, about the current state of knowledge and what this suggests for the future. The *Ice Cores and Climate* position analysis was completed and presented at a Research User Forum in Canberra on 29 July 2015 along with the *Antarctic Sea Ice and Climate Change* Position Analysis (produced in 2014). Both are available in the publications section of the ACE CRC website.

The Science of Climate Change: Questions and Answers

This publication from the Australian Academy of Science addresses some of the confusion created by contradictory information in the public domain regarding climate change. Co-authored by ACE CRC Honorary Professor Ian Allison, it sets out the current situation in climate science, including where there is consensus in the scientific community and where uncertainties exist.

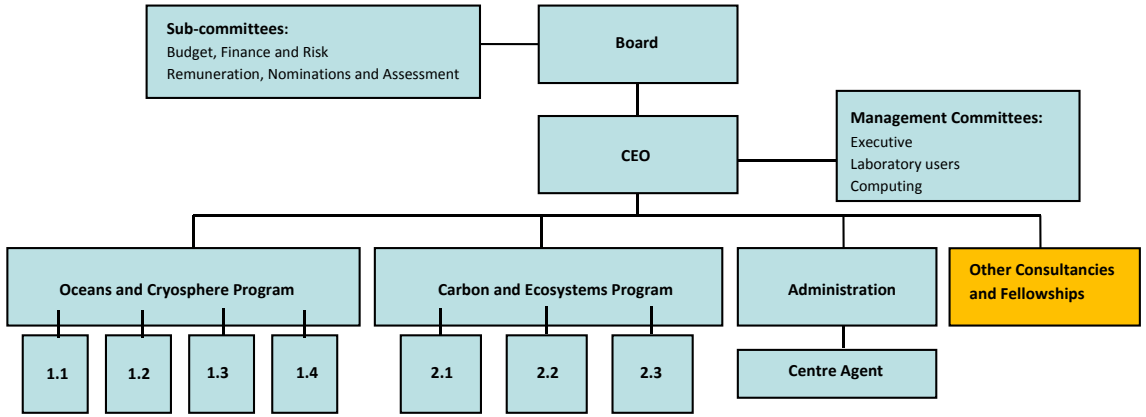
4 Resources

4.1 Governance – board, committees and key staff

The ACE CRC is an unincorporated joint venture comprising 7 core and 13 supporting partners. UTAS continues to provide Centre Agent services such as human resource support and financial services as in-kind contributions. UTAS signed the Commonwealth Agreement on behalf of all participants. The seven Essential Participants are bound by the Participants Agreement, and the Other Participants Agreements set out the duties and commitments of the remaining 13 parties.

The ACE CRC is registered for GST and classified as a government partnership for taxation purposes.

The governance and management structure of ACE CRC has been established as follows:



BOARD #

Katherine Woodthorpe – Chair
Tony Coleman – Independent
Gordon Hagart – Independent
Tony Fleming – AAD **
Graham Hawke – BoM
Ken Lee – CSIRO
Paddy Nixon – UTAS **
Steven Kennedy – Dept. of Environment **
Tony Worby – Ex officio
Nick Gales – Ex officio
Mark Kelleher – Board Secretary

** Resigned from Board at the end of the 2014/15 reporting period.

MANAGEMENT TEAM ~

Tony Worby – CEO (Chair)
Mark Kelleher – Deputy CEO
David Reilly – Public Affairs Mgr
Wen ten Hout (0.8) – Admin Mgr
Kathleen Kelly (0.4) – Admin

EXECUTIVE COMMITTEE #

Tony Worby – CEO (Chair)
Mark Kelleher – Deputy CEO
David Reilly – Public Affairs Manager
Wenneke ten Hout – Exec Secretary
Steve Rintoul – Program Leader
Tas van Ommen – Program Leader
Tom Trull – Program Leader
Andrew Constable – Program Leader
Kelvin Michael – Education
Nathan Bindoff – University liaison
Jason Roberts – Co-chair, Computing Committee

LAB USERS COMMITTEE #

Pamela Quayle – ACE Lab Mgr (Chair)
Zanna Chase – Lab 304
Pier v/d Merwe – Lab 306
Diana Davies – Lab 308
Adam Treverrow – Lab 310
Andrew Moy – Lab 312D
Meredith Nation – Lab 312
Toby Bolton – IMAS Lab Mgr

COMPUTING COMMITTEE #

Jason Roberts – Co-Chair
Ben Galton-Fenzi – Co-Chair
Wenneke ten Hout – ACE Admin
Stuart Corney – Staff Rep
Antony Cave – UTAS IT Rep
Brendon Davey – NECTAR Rep/Unix
Chen Zhao – Student rep

~ Meets weekly
^ Meets monthly
# Meets quarterly

The Board

The Board is constituted with a view to balancing the skills and experience of its members, and operates in accordance with the provisions of the Participants' Agreement.

The Board comprises (i) an independent Chairman, (ii) one representative from each Australian Essential Participant, (iii) one representative of the Tasmanian Government, (iv) two persons independent of the Participants and (v) the CEO and the AAD Chief Scientist who are ex-officio members. There is currently one vacancy on the ACE CRC Board.

A new Board Governance Charter was put in place by the Board at its November 2014 meeting. The Terms of Reference for the Budget, Audit and Risk (BAR) Committee and the Nomination, Remuneration and Assessment (NRA) Committee have been updated during the reporting period.

There has been signficant turn over on the Board in the past year. Professor Howard Bamsey and Mr John Pitt resigned at the end of the 2013/14 financial year. CEO, Dr Tony Press, was replaced by Professor Tony Worby in early July 2014. Dr Bruce Mapstone was replaced by Dr Kenneth Lee for CSIRO in August 2014. Professor Paddy Nixon left the University of Tasmania at the end of May 2015 and Professor Andrew Wells has acted as Board representative for the university until the new DVC-R, Prof Brigid Heywood commences. Prof Heywood will commence on the Board in November 2015. Mr Graham Hawke from the Bureau of Meteorology joined the ACE CRC Board in May 2014. During the reporting period the Department of the Environment did not have a representative on the Board; however this will be addressed in 2015/16. Under the new Participants Agreement it was determined that the two international participants, AWI and NIWA, would no longer have representatives on the Board.

The newest member of the ACE CRC Board, Mr Gordon Hagart, comes from the finance sector and brings new skills and a different perspective to Board discussions. Mr Hagart joined the ACE CRC Board in March 2015.

Board meetings are held every quarter. During this reporting period meetings were held on 8 September 2014, 17 November 2014 (including Annual General Meeting), 24-25 February 2015 and 18 May 2015. The two-day meeting in February 2015 included a half-day strategy discussion of funding options beyond 2019.

Board Members (in alphabetical order)

Name	Role	Key Skills	Independent/ Organisation	Number of meetings
Mr Tony Coleman	Board Member	- High level executive management experience in private enterprise - Financial audit, actuarial and risk management expertise - Commercial objectivity and independence from CRC participants	Independent	3/4
Dr Tony Fleming	Board Member	- Broad and extensive experience in development of environmental policy and program delivery - Extensive Federal and State public service experience - Experience with not-for-profit sector - High level policy experience	Australian Antarctic Division (Essential Participant)	3/4
Dr Nick Gales	Ex-Officio	- High level national and international experience in science and policy - High level science expertise in applied marine mammal conservation science - Australian Marine Mammal Centre leadership	Australian Antarctic Division (Essential Participant)	3/4
Mr Gordon Hagart	Board Member	- Extensive experience in financial services including investment - Extensive experience in leadership and management at senior levels	Independent	2/2 (joined February 2015)
Mr Graham Hawke	Board Member	- Extensive experience in research leadership and management at senior & institutional levels - Broad relevant domain expertise in climate and atmospheric science	Bureau of Meteorology	4/4

Name	Role	Key Skills	Independent/ Organisation	Number of meetings
Mr Greg Johannes	Board Member	- High level executive management experience in both policy and operational roles in the public and private sector - Substantial and wide ranging Board experience in both the research and community sector - Lead State Government representative in national negotiations under Council of Australian Governments (COAG) on climate change policy, legislation and regulation	Tasmanian Government (Other Participant)	2/4
Dr Kenneth Lee	Board Member	- Extensive experience in research leadership and management at senior & institutional levels - Broad relevant domain expertise in climate and marine science, in particular development and application of emerging technologies in ocean sciences	Commonwealth Scientific and Industrial Research Organisation (CSIRO) (Essential Participant)	3/4
Prof Paddy Nixon	Board Member	- Extensive experience in research leadership and management at senior & institutional levels - High level industrial and commercial executive management experience - Broad and extensive expertise in computer science and technology	University of Tasmania (Essential Participant)	3/3 (left Board after Feb 2015)
Prof Andrew Wells	Board Members	- Extensive experience in research leadership and management at senior & institutional levels - Extensive experience in government and public policy	University of Tasmania (Essential Participant)	1/1 (joined May 2015)

Name	Role	Key Skills	Independent/ Organisation	Number of meetings
Dr Tony Worby	Ex-Officio	- High level leadership and administrative experience - Extensive experience in government and public policy - High relevant domain expertise in climate and marine science and policy	ACE CRC	4/4
Dr Katherine Woodthorpe	Chair	- High level management skills - High level Board skills - Broad experience on audit committees - Ventracor, Agenix and chaired the Audit Committee of Australian Cancer Technologies Ltd and Insearch	Independent	4/4

The Board has two sub-committees. The Budget, Audit and Risk (BAR) sub-committee includes 3 Board directors and an independent director as chair of the committee. The primary objective of the Budget Audit and Risk committee is to monitor and provide effective supervision of management's financial and risk reporting processes, and review the adequacy of internal control systems to ensure accurate, timely and proper financial and risk reporting. The BAR committee met on 29 April 2015 to review the risk register and to sign off on the 2015/16 budget. The committee reports to the Board as appropriate, through its Chair.

The Nominations, Remuneration and Assessment committee includes four members. It is Chaired by the ACE CRC Board Chair, and has a majority of independent members. The primary objective of the Nomination, Remuneration and Assessment Committee is to assist the Board in fulfilling its responsibilities by reviewing, advising and making recommendations to the Board on the matters pertaining to CEO and Board member remuneration, recruitment, performance appraisal, and succession planning. This committee met in September 2014 to set the CEO's KPIs and reviewed the remuneration of the Chair and independent Board members in late 2014. Adjustments to remuneration were recommended to the Board and approved at its February 2015 meeting.

The Executive Committee

The ACE CRC executive brings together senior administrative staff and program leaders on a quarterly basis to report on progress against milestones and discuss priority activities. Meetings were held on 1 September 2014, 12 November 2014, 3 February 2015, and 30 April 2015.

Name	Role	Key Skills	Organisation
Prof Nathan Bindoff	Project Leader 1.1, Climate Futures; Director Tasmanian Partnership for Advanced Computing (TPAC)	Computing/research	ACE CRC/TPAC
Dr Andrew Constable	Program Leader, Carbon and Ecosystems Program	Research	ACE CRC/AAD
Mr Mark Kelleher	Deputy CEO (from October 2014)	Finance/Governance	ACE CRC
Dr Kelvin Michael	IMAS Representative	Education	IMAS
Mr David Reilly	Public Affairs Manager (from September 2014)	Communications/Media	ACE CRC
Dr Stephen Rintoul	Program Leader, Oceans and Cryosphere Program	Researcher	ACE CRC/CSIRO

Name	Role	Key Skills	Organisation
Dr Jason Roberts	Researcher, Co-chair ACE CRC Computing Committee	Research/computing	ACE CRC/AAD
Ms Wenneke ten Hout	Administration Manager	Administration	ACE CRC
Prof Thomas Trull	Program Leader, Carbon and Ecosystems Program	Researcher	ACE CRC/CSIRO
Dr Tas van Ommen	Program Leader, Oceans and Cryosphere Program	Research	ACE CRC/AAD
Dr Tony Worby	CEO	Management/Governance	ACE CRC

Laboratory Users Committee

The Laboratory Users Committee represents the ACE CRC laboratory's broad multidisciplinary user community and advises management on all issues affecting users of the facilities. Ms Pamela Quayle was appointed as the ACE CRC Laboratory Manager in June 2015 and manages the ACE CRC laboratories in close collaboration with the IMAS laboratory manager. During the reporting period, the laboratory users committee met on 25 February 2015, 23 March 2015 and 16 June 2015.

Name	Role	Organisation
Mr Toby Bolton	Laboratory Manager	IMAS
Dr Zanna Chase	Researcher – lab 304	IMAS
Dr Diana Davies	Researcher – lab 308	ACE CRC
Dr Andrew Moy	Researcher – lab 312	AAD
Ms Meredith Nation	Laboratory assistant – ice core group – lab 312	AAD
Ms Pamela Quayle	Laboratory Manager (from June 2015) – Chair	ACE CRC
Ms Wenneke ten Hout	Administration Manager/Lab Manager (Chair until June 2015)	ACE CRC
Dr Adam Treverrow	Researcher – lab 310	ACE CRC
Dr Pier van der Merwe	Researcher – lab 306	ACE CRC

Computing Committee

The ACE CRC Computing Committee supports the science and education programs of the ACE CRC by providing advice on information technology, infrastructure and

management. The ACE CRC Computing Committee advises the ACE CRC Executive Committee and CEO. The ACE CRC Computing Committee will meet every quarter two weeks prior to the scheduled ACE CRC Executive meetings or more frequently as necessary.

Member	Role	Organisation
Mr Antony Cave	UTAS IT representative	UTAS
Dr Stuart Corney	Researcher	ACE CRC
Brendon Davey	NECTAR representative/Unix	TPAC
Dr Ben Galton-Fenzi (co-chair)	Researcher	AAD
Dr Jason Roberts (co-chair)	Researcher	AAD
Ms Wenneke ten Hout	Administration Manager - secretary	ACE CRC
Ms Chen Zhao	PhD student representative	UTAS

Key Staff

Staff Member	Role	Organisation	% Time
Prof Ian Allison*	IPCC AR5 – lead author	ACE CRC	50%
Prof Nathan Bindoff	IPCC AR5 – coordinating lead author and Project Leader – 1.1	ACE CRC/IMAS	50%
Dr Phillip Boyd	Project Leader – project 2.2	ACE CRC/IMAS	20%
A/Prof Andrew Bowie	Project Leader – project 2.1	ACE CRC/IMAS	50%
Prof Richard Coleman	Project Leader – project 1.2	ACE CRC/IMAS	20%
Dr Andrew Constable	Program Leader – Carbon and Ecosystems	ACE CRC/AAD	65%
Dr Mark Curran	Project Leader – project 1.4	ACE CRC/AAD	80%
Dr Ben Galton-Fenzi	Project Leader – project 1.2	ACE CRC/AAD	80%
Dr So Kawaguchi	Project Leader – project 2.2	ACE CRC/AAD	60%
Mr Mark Kelleher	Deputy CEO (from October 2014)	ACE CRC	100%
Dr Rob Massom	Project Leader – project 1.3	ACE CRC/AAD	80%
Dr Jessica Melbourne-Thomas	Project Leader – project 2.3	ACE CRC/AAD	70%
Dr Klaus Meiners	Project Leader – project 2.2	ACE CRC/AAD	80%

Staff Member	Role	Organisation	% Time
Mr David Reilly	Public Affairs Manager (from September 2014)	ACE CRC	100%
Dr Stephen Rintoul	Program Leader – Oceans and Cryosphere	ACE CRC/CSIRO	50%
Ms Wenneke ten Hout	Administration Manager	ACE CRC	80%
Prof Tom Trull	Program Leader – Carbon and Ecosystems	ACE CRC/CSIRO	50%
Dr Tas van Ommen	Program Leader – Oceans and Cryosphere	ACE CRC/AAD	60%
Dr Guy Williams	Project Leader – project 1.3	ACE CRC/IMAS	50%
Dr Tony Worby	CEO	ACE CRC	100%
*Prof Ian Allison is an Honorary Research Professor			

4.2 Participants

The commitment of the seven core partners to the ACE CRC remains strong, despite the challenging operating environment. At the February Board "future directions" strategy workshop, all core participants reaffirmed their commitment to the ACE CRC collaborative model, confirming that this delivers considerable benefits to all parties.

The ACE CRC has formal partnership agreements with two Chinese institutions; however, there is potential for much stronger engagement with China, particularly on the back of President Xi's visit to Tasmania in November 2014. The ACE CRC has negotiated two new MOUs – with the Chinese National Marine Environmental Forecasting Centre in Beijing and Shanghai Ocean University.

Our two international core partners, NIWA and AWI, are closely engaged with the ACE CRC. The CEO has primary carriage of these two institutional relationships, and visited NIWA in New Zealand in July 2014 and visited AWI in Germany in June 2015. The ACE CRC is exploring options for a closer collaboration with AWI through more formal visitor exchange and teaching programs.

ACE CRC participants during the reporting period

Participant's name	Participant type	ABN or ACN	Organisation type
Alfred Wegener Institute of Polar and Marine Research (AWI), Germany	Essential	NA	Government research institute
Australian Antarctic Division (AAD)	Essential	56 428 630 676	Government

Participant's name	Participant type	ABN or ACN	Organisation type
Bureau of Meteorology (BoM)	Essential	92 637 533 532	Government
CSIRO Division of Marine and Atmospheric Research (CMAR)	Essential	41 687 119 230	Government
Department of Environment	Essential	34 190 894 983	Government
National Institute of Water and Atmospheric Research Ltd (NIWA), New Zealand	Essential	NA	Government research institute
University of Tasmania (UTAS)	Essential	30 764 374 782	University
Centre for Polar Oceanography and Modelling (CPOM), University College London, UK	Other	NA	Research institute
Chinese Academy of Meteorological Science (CAMS)	Other	NA	Government research institute
Curtin University	Other	99 143 842 569	University
First Institute of Oceanography (FIO), China	Other	NA	Government research institute
Institute of Low Temperature Science (ILTS), Hokkaido University, Japan	Other	NA	Research institute
Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS), France	Other	NA	Research institute

Participant's name	Participant type	ABN or ACN	Organisation type
National Institute of Polar Research (NIPR), Japan	Other	NA	Government research institute
Old Dominion University	Other	NA	University
SGS Economics and Planning Pty Ltd	Other	25 007 437 729	Industry
Tasmanian Government	Other	84 531 577 304	Government
Vrije Universiteit Brussels (VUB)	Other	NA	University
University of Texas at Austin, USA	Other	NA	University
University of Texas at San Antonio, USA	Other	NA	University

Changes to participants

There were no changes in the reporting period. However, the ACE CRC is currently negotiating a formal "Other Participant" agreement with the Tokyo University of Marine Science and Technology (TUMSAT). This university has research interests that align with the ACE CRC in the areas of marine biology, physical oceanography, ocean acoustics and marine biogeochemistry. TUMSAT owns the 93m training and research vessel *Umitaka-maru*, which has been used by the Japanese National Institute for Polar Research for marine research in the Southern Ocean in recent years. A formal partnership will create opportunities for ACE CRC researchers to participate on these voyages, bringing valuable marine science capacity to our program. The agreement was approved by the ACE CRC Board and the TUMSAT President and will come into effect in early 2016.

4.3 Collaboration

Currently, the ACE CRC collaborates with 82 domestic and international organisations. Of these, there are 17Australian, 4 New Zealand, 7 Asian, 22 North American, 1 South American, and 31 European.

Of the 17 domestic collaborations, there are 4 Australian Government Institutions, 2 State Government Institutions, 10 universities, and 1 industry/private sector.

Of the 65 international collaborators, there are 32 universities, 1 from industry/private sector, and 32 research institutions/organisations.

The ACE CRC entered into a formal Collaboration Agreement with the National Computational Infrastructure (NCI) in April 2015. This formalises access by ACE CRC researchers to 4 million CPU hours per year.

During the reporting period, the ACE CRC had several overseas visitors. Project 2.2 had three visitors from ACE CRC core partner, AWI, Germany, during January and March 2015. Dr Mathias Teschke, Mr Fabio Piccolin, and Mr Felix Muller visited to work together with ACE CRC scientists on the collaborative study on climate change effects on the krill biological clock at the AAD krill aquarium.

Ms Nopparat Nauschon from Nagasaki University, Japan, visited during December 2014 and March 2015 and worked with ACE CRC scientists on the collaborative study on CO_2 effects on behaviour of krill early life stages.

Dr Ralph Greve from Institute of Low Temperature Science (ILTS) in Hokkaido, Japan, visited the ACE CRC for 3 months in late 2014 on a UTAS Visiting Fellow Scholarship. Dr Greve, an ice sheet modeller, worked with a number of ACE researchers in our ice/ocean team, primarily focussed on improving the representation of ice shelf basal melting and ice flow physics in ice sheet models.

Dr Pippa Whitehouse from Durham University visited the ACE CRC in March 2015 on a UTAS Visiting Fellow Scholarship. Dr Whitehouse worked with researchers on the ACE CRC coupled modelling Project 1.2. Dr Craig Stevens from NIWA also visited the ACE CRC in March 2015 to work with researchers in Project 1.2 on under-ice shelf boundary layers.

Dr Naoya Kanna, from ILTS, visited the ACE CRC on a UTAS Tsuneichi Fuji Scholarship and worked with Dr Delphine Lannuzel and Dr Pier van der Merwe on the dissolution of iron particles in the sea ice environment.

In June 2015, the ACE CRC said good-bye to British Marie Curie Fellow, Dr Rupert Gladstone, who was hosted at the ACE CRC for approximately 2 years. Dr Gladstone assisted with the further development of coupled ice-shelf ocean models.

The ACE CRC also said farewell to Dr Liu Yaping from the 'State Key Laboratory of Cryospheric Sciences' at the Cold and Arid Regions Environmental and Engineering Research Institute Chinese Academy of Sciences (CAREEI). Dr Yaping worked with the Ice Core Group at the ACE CRC for 12 months on a 'Visiting Scholar Program' funded by the China Scholarship Council's Postdoctoral Program. Dr Yaping made a significant contribution towards preparing the Aurora Basin ice core.

4.4 Financial Management

The ACE CRC completed the 2014-15 financial year with a cash balance of $3,791k. This includes $495k carried forward from the previous incarnation of the CRC and $1,789k associated with receipt of Commonwealth Grant Funds originally profiled for the 2015-16 financial year. Remaining funds represent the impact of ramp up of expenditure on the Program; given the 2014-15 financial year is the first year of the five-year program.

Staff and non-staff contributions from participants were on track, apart from the following:

Participants	***Table 1(a) Number (FTE) of Staff in-kind Contributions***	
	Amount Contributed (FTE)	***Amount Committed (FTE)***
Australian Antarctic Division	25.10	28.60
National Institute of Water and Atmospheric Research	0.80	1.00
University of Tasmania	6.15	6.90
Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS)	0.45	1.20
SGS Economics and Planning Pty Ltd	-	0.20
Institute of Low Temperature Science (ILTS), Hokkaido University	1.15	1.20

Participants	***Table 1(b) Non-staff in-kind Contributions***	
	Amount Contributed ($'000)	***Amount Committed ($'000)***
Australian Antarctic Division	2,792	8,700
Bureau of Meteorology	-	63

Shortfalls in staff in-kind contributions were relatively minor, and did not impact the program or objectives of the ACE CRC.

The main variance in non-staff contributions was associated with the Australian Antarctic Division. The original level of commitment was based on including a "Free Ocean CO_2 Enrichment ("FOCE") Project which did not proceed in the finalised program. Furthermore, weather conditions prevented the 2014-15 season ICECAP activity from proceeding; this will be picked up in future season activities.

Overall, the variations in contributions is not expected to affect achievement of current or future milestones.

Table 1

	Totals to 2014-15				Projected Totals for 5 years			
	Actual	**Agr'mt**	**Diff**	**%Diff**	**Actual/Proj**	**Agr'mt**	**Diff**	**%Diff**
Employee Expenses	2,596	2,420	176	7	17,261	16,642	619	4
Supplier Expenses	808	1,609	-801	-50	6,253	7,680	-1,427	-19
Capital	310	187	123	66	1,971	973	998	103
Other Expenses	0	0	0	0	300	753	-453	-60
TOTAL EXPENSES	3,714	4,216	-502	-12	25,785	26,048	-263	-1

The variations in expenses in 2014-15 arose due to the following factors:

- Employee expenses were slightly higher than forecast due to the impact of some external income sources enabling the employment of additional staff.
- The underspend in supplier expenses reflects some deferral of equipment purchases into the 2015-16 financial year.
- Expenditure on capital items is above forecast due to a number of equipment purchases previously included as supplier expenses now being properly categorised as capital items. This will have no net impact but will result in a shift of $1,000k from supplier expenses to capital over the five-year term.

Expenses for the 5 year term are now forecast to be $263k below the agreement level. This is offset by an equivalent reduction in other firm income.

Additional external and interest income totalling $190k, along with $429k in net savings in supplier/capital expenses will underpin a number of contract extensions for research staff, which is reflected in the forecast employee expenses variance of $619k.

5 Other activities

The ACE CRC continued to undertake a number of externally funded research, primarily in the area of fine-scale climate modelling and analysis.

National Environmental Research Program (NERP): Project 3 – Climate Futures – is a project within the Landscapes and Policy (LAP) hub funded through the NERP. This project extends and builds upon the successful Climate Futures for Tasmania project. This project coordinates with seven national projects within the LAP hub to provide climate change information and datasets for research into ecosystems and landscapes in a changing climate. This project was finalised in March 2015.

Potential Impacts of Climate Change on the Victorian Alpine Resorts: This project is

funded by the Alpine Resorts Co-ordinating Council in Victoria, Australia. This project will report on the economic viability and impact of investing in snow making in the Victorian alpine resorts in the context of the potential impacts of climate change outlined by the Climate Futures for the Australian Alps projections. A final report was submitted June 2015.

Projecting Volunteer Resources Under Extreme Climate Futures: This project is funded by the Department of Police and Emercency Management under the Emergency Volunteer Fund. This project will report on the expected workload or pressure on the Tasmanian volunteer workforce in the future, and compile and present results and anticipated outcomes of the project.

During the reporting period, these projects published 5 articles in scholarly refereed journals and 1 technical report (see below).

Articles in scholarly refereed journals

Gould, S. F., N. J. Beeton, R. M. B. Harris, M. F. Hutchinson, A. M. Lechner, L. L. Porfirio and B. G. Mackey (2014). "A tool for simulating and communicating uncertainty when modelling species distributions under future climates." Ecology and Evolution 4(24): 4798-4811.

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Porfirio, L. L., R. M. B. Harris, E. C. Lefroy, S. Hugh, S. F. Gould, G. Lee, N. L. Bindoff and B. Mackey (2014). "Improving the Use of Species Distribution Models in Conservation Planning and Management under Climate Change." PLoS ONE 9(11): e113749.

Technical reports

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6 Additional requirements

6.1 Performance review

The performance review was delayed due to CRC Programme review conducted by David Miles. At the time of writing this report the first year review was rescheduled to November 2015.

7 Glossary of Terms & Acronyms

A	
ABN	Aurora Basin North
AAD	Australian Antarctic Division
AAS	Australian Antarctic Science Program
ACC	Antarctic Circumpolar Current
ACCSP	Australian Climate Change Science Programme
ACE CRC	Antarctic Climate & Ecosystems Cooperative Research Centre
AIS	Amery Ice Shelf
ANSTO	Australian Nuclear Science and Technology Organisation
ARC	Australian Research Council
AUV	Autonomous Underwater Vehicle
AWECS	Airborne Wind Energy Conversion System
AWI	Alfred Wegener Institute for Polar Research (Germany)
B	
BoM	Bureau of Meteorology
BAMS	Bulletin of the American Meteorological Society
BAR	Budget, Audit, and Risk Committee
C	
CAMS	Chinese Academy of Meteorological Science (China)
CAREERI	Cold and Arid Regions Environmental and Engineering Research Institute (Chineses Academy of Sciences)
CCAMLR	Convention for the Conservaton of Antarctic Marine Living Resources
CEO	Chief Executive Officer
CLiC	Climate and Cryosphere Project
CLIVAR	Climate Variability and Predictability Program
CMAR	CSIRO Division of Marine & Atmospheric Research
CO_2	Carbon Dioxide
COMNAP	Council of Managers of National Antarctic Programmes
CPOM	Centre for Polar Oceanography and Modelling (United Kingdom)
CRC	Cooperative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTD	Conductivity, Temperature and Depth instrument
D	
E	
EGU	European Geosciences Union
ENSO	El Nino Southern Oscillation
F	

FIO	First Institute of Oceanography (China)
G	
H	
I	
ICECAP	Investigating Cryospheric Evolution through Collaborative Aerogeophysical Profiling
ICED	Integrating Climate and Ecosystem Dynamics
IICWG	International Ice Chart Working Group
ILTS	Institute of Low Temperature Science, Hokkaido University (Japan)
IMAS	Institute for Marine and Antarctic Studies, University of Tasmania
IMBER	Integrated Marine Biogeochemistry and Ecosystem Research project
IMOS	Integrated Marine Observing System
IP	Intellectual Property
IPO	Interdecadal Pacific Oscillation
IPCC AR5	Intergovernmental Panel on Climate Change Fifth Assessment Report
IPICS	International Partnership in Ice Core Sciences
IUGG	International Union of Geodesy and Geophysics
IWC	International Whaling Commission
J	
K	
KEOPS-2	Kerguelen compared study of Ocean and Plateau in Surface waters (2nd study)
L	
LAP	Landscapes and Policy
LEGOS	Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (France)
M	
MIZ	Marginal Ice Zone
MNF	Marine National Facility
MSA	Methanesulfonic acid
N	
NCI	National Computational Infrastructure
NERP	National Environmental Research Program
NESP	National Environmental Science Programme
NIPR	National Institute of Polar Research (Japan)
NIWA	National Institute for Water and Atmospheric Research (New Zealand)
NOAA	National Oceanic and Atmospheric Administration
NRA	Nomination, Remuneration and Assessment Committee
NSF	National Science Foundation

O	
P	
PMIP	Paleoclimate Modelling Intercomparison Project
Q	
R	
ROMS	Regional Ocean Modelling System
ROV	Remotely Operated Vehicle
S	
SAM	Southern Annular Mode
SAR	Synthetic Aperture Radar
SAZ	Sub-Antarctic Zone
SCAR	Scientific Committee on Antarctic Research
SCOR	Scientific Committee on Oceanic Research
SGS	SGS Economics & Planning Pty Ltd
SIPEX-II	Sea-ice Physics & Ecosystem Experiment
SME	Small and Medium Enterprises
SOCAT	Surface Ocean Carbon Atlas
SOFS	Southern Ocean Flux Series
SOOS	Southern Ocean Observing System
SOTS	Southern Ocean Time Series
SWWA	South-West Western Australia
T	
TPAC	Tasmanian Partnership for Advanced Computing
TUMSAT	Tokyo University of Marine Science and Technology
U	
UAV	Unmanned Aerial Vehicles
UNSW	University of New South Wales
UTAS	University of Tasmania
V	
VUB	Vrije Universiteit Brussel
W	
WCRP	World Climate Research Programme
WHOI	Woods Hole Oceanographic Institution
X	
Y	
Z	

Appendix 1– list of publications

Book Chapters

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Appendix 2– ACE CRC PhD students 2014-2015

Commenced in 2014/15

Name	Commencement Date	Status	Research Program	Project Title	Research Organisation	Country	Expected Completion Date
1. Black, James	28/08/14	FT	Carbon & Ecosystems	Measuring impacts of ocean acidification on biological communities in Antarctica: an in-situ experiment and laboratory exploration of the mechanisms of community	UTAS	Australia	August 2018
2. Buchanan, Pearse	1/11/2014	FT	Oceans & Cryosphere	Ocean Deoxygenation: A paleo-modelling perspective	UTAS	Australia	November 2018
3. Jackson, Andrew	1/3/15	FT	Carbon & Ecosystems	Who Saved Antarctica?	UTAS	Australia	March 2019
4. Jansen, Jan	1/10/14	FT	Carbon & Ecosystems	Modelling biodiversity in the Southern Ocean and Antarctica using sparse data	UTAS	Australia	October 2019
5. Labrousse, Sara	2/9/14	FT	Carbon & Ecosystems	Foraging Ecology of Male and Female Elephant Seals in the Sea-Ice Zone: Role of the physiography, hydrological factors, and sea-ice condition	UTAS - Cotutelle	Australia	September 2018
6. Mori, Mao	1/12/14	FT	Carbon & Ecosystems	Modelling ocean transport of key species in the Indian sector of the Southern Ocean	UTAS	Australia	
7. Peel, Samantha	27/01/15	FT	Carbon & Ecosystems	Statistical Issues for Mapping Biodiversity in the Southern Ocean	UTAS	Australia	January 2019

***FT – full-time internal; FX – full-time external; PT – part-time internal; PX – part-time external**

Name	Commencement Date	Status	Research Program	Project Title	Research Organisation	Country	Expected Completion Date
8. Roman, Lauren	23/2/15	FT	Carbon & Ecosystems	Population Level Effects of the Ingestion of Marine Debris by Seabirds	UTAS	Australia	February 2019
9. Schroeter, Serena	30/03/2015	FT	Oceans & Cryosphere	The response of Antarctic sea ice to anthropogenic climate change, from model and satellite observations	UTAS	Australia	March 2019
10. Silvano, Allessandro	5/05/15	FT	Oceans & Cryosphere	Observations of Ocean - Ice Shelf Interaction at the Totten Glacier	UTAS	Australia	May 2019
11. Ward, Delphine	1/10/14	FT	Carbon & Ecosystems	Evaluating the likelihood of critical transitions in Southern Ocean ecosystems	UTAS	Australia	October 2018
12. Zhao, Chen	13/10/14	FT	Oceans & Cryosphere	Ice mass unloading and bedrock response in the southern Antarctic Peninsula	UTAS	Australia	October 2018

Graduated in 2014/15

Name	Commencement Date	Status	Research Program	Project Title	Research Organisation	Country	Expected Completion Date
1. Karsh, Kristen	1/07/05	PT	Carbon & Ecosystems	Environmental controls on nitrogen isotopic fractionation by subantarctic and Antarctic phytoplankton	UTAS	Australia	August 2014
2. Meyer, Amelie	22/09/08	PT	Oceans & Cryosphere	On the Role of Diapycnal Mixing in the Antarctic Circumpolar Current on the Meridional Overturning Circulation	UTAS	Australia	August 2014

Name	Commencement Date	Status	Research Program	Project Title	Research Organisation	Country	Expected Completion Date
3. Moore, Kirrily	1/04/09	FT	Carbon & Ecosystems	Biodiversity of the Southern Ocean: An Assessment of Morphological and Molecular Diversity in Key Octocorallia Groups	UTAS	Australia	December 2014
4. Queroue, Fabien	1/10/10	FT	Carbon & Ecosystems	Manganese Distributions in the Southern Ocean and the Co-impact Mn-Fe-Cu on Phytoplankton	UTAS	Australia	August 2014
5. Roach, Christopher	8/03/10	FT	Oceans & Cryosphere	Ekamn Currents in the Antarctic Circumpolar Current	UTAS	Australia	December 2014
6. Vargas-Hernandez, Jose Mauro	22/03/10	FT	Oceans & Cryosphere	The Signature of Global Warming in the Indo-Pacific Ocean: Investigation of the Subsurface Dynamics	UTAS	Australia	August 2014
7. Walters, Andrea	1/12/07	FT	Carbon & Ecosystems	Marine Mammal Biology in Tasmanian Waters/Southern Ocean	UTAS	Australia	August 2014
8. Wynn Edwards, Cathryn	1/03/09	FT	Carbon & Ecosystems	Impacts of Ocean Acidification on the Bottom of the Antarctic Food Web: Quantification of Changes in Nutritional Quality of Phytoplankton and Bottom Sea Ice Algae and the Effect on Juvenile Krill	UTAS	Australia	December 2014

Current

Name	Commencement Date	Status	Research Program	Project Title	Research Organisation	Country	Expected Completion Date
1. Alexander, Kaitlin	September 2014	FT	Oceans & Cryosphere	Response of sub-ice shelf circulation to 21st century projections of climate change	University of New South Wales	Australia	September 2018
2. Arthur, Benjamin	31/10/11	FT	Carbon & Ecosystems	Winter Habitat Usage and Trophic Links for Antarctic Fur Seal Populations in the Southern Ocean	UTAS	Australia	October 2015
3. Baird-Bower, Debbie	8/04/13	FT	Carbon & Ecosystems	Demographic Responses of Antarctic Fur Seals to Environmental Variability	UTAS	Australia	April 2017
4. Baker, Barry	31/07/02	PT	Carbon & Ecosystems	Demography and Conservation of Shy Albatross (Thalassarche cauta)	UTAS	Australia	July 2015
5. Bedford, Merel	1/03/14	FT	Carbon & Ecosystems	Representing Southern Ocean predators in end-to-end ecosystem models using individual-based modelling	UTAS	Australia	March 2018
6. Cleeland, Jaimie	20/05/13	FT	Carbon & Ecosystems	Macquarie Island's Albatrosses: A comprehensive assessment of population and demographic status and trends and the environmental and anthropogenic	UTAS	Australia	May 2017
7. Cougnon, Eva	8/10/12	FT	Oceans & Cryosphere	Quantifying the Impact of Glacial Melt Water on Antarctic Bottom Water	UTAS	Australia	October 2016

Name	Commencement Date	Status	Research Program	Project Title	Research Organisation	Country	Expected Completion Date
8. Della Penna, Alice	19/11/12	FX	Carbon & Ecosystems	Living in a fluid dynamical system: how do marine predator respond to turbulence?	UTAS	Australia	November 2016
9. Deppeler, Stacy	15/10/13	FT	Carbon & Ecosystems	Effects of Elevated pCO2 on the Productivity of Marine Microbes and the Remineralisation of Nutrients in Coastal Antarctic Waters	UTAS	Australia	October 2017
10. Durand, Axel	3/04/13	FT	Carbon & Ecosystems	Ocean Deoxygenation, a Paleo Proxy Perspective	UTAS	Australia	April 2017
11. Graham, Felicity	18/07/11	FT	Oceans & Cryosphere	Understanding the Dynamics of ENSO and How They Might Change with Global Warming	UTAS	Australia	August 2015
12. Groeskamp, Sjoerd	27/06/11	FT	Oceans & Cryosphere	Estimating Diffusion Coefficients from Ocean Hydrography	UTAS	Australia	June 2015
13. Gwyther, David	5/03/12	FT	Oceans & Cryosphere	Investigating the Impact of Ocean Warming on Antarctic Ice Shelves	UTAS	Australia	July 2015
14. Hamilton, Vicki	24/07/12	FT	Carbon & Ecosystems	Energetic Variability in Sperm Whales and Relationships with the Marine Environment	UTAS	Australia	July 2016
15. Hodgson-Johnston, Indiah	21/10/13	FT	Carbon & Ecosystems	Beyond the Bases? Applying Contemporary Principles of International Law to Australian Sovereignty in Antarctica	UTAS	Australia	October 2017
16. Holmes, Thomas	1/04/14	FT	Carbon & Ecosystems	Tracing the source of iron inputs to the Southern	UTAS	Australia	April 2018

Name	Commencement Date	Status	Research Program	Project Title	Research Organisation	Country	Expected Completion Date
				Ocean using radiogenic isotopes			
17. Inoue, Mana	4/04/11	FT	Oceans & Cryosphere	Glaciochemical Study of Mill Island Ice Core Records	UTAS	Australia	July 2015
18. Jackson, Christine	15/01/06	PX	Carbon & Ecosystems	Determining Cetacean - Cephalopod Trophic Interactions - A Qualitative and Quantitative Approach	UTAS	Australia	December 2015
19. Janssens, Julie	6/09/12	FT	Carbon & Ecosystems	Incorporation Mechanisms of Organic Matter and Iron into Sea Ice	UTAS	Australia	September 2016
20. Jia, Zhongnan	2/05/11	FT	Carbon & Ecosystems	Diet and Energy Budget of Antarctic Krill (Euphausia superba) - Relationship between Krill and Winter Sea Ice	UTAS	Australia	July 2015
21. Johnson, Rob	7/02/11	FT	Carbon & Ecosystems	Effects of Climate Change on Phytoplankton Primary Production and Chemotaxonomy in Southern Ocean and Antarctic Ecosystems	UTAS	Australia	July 2015
22. Lago, Veronique	6/04/11	FT	Oceans & Cryosphere	Testing of climate models and sea level rise projections using observations of ocean heat uptake	UTAS	Australia	April 2015
23. Laurenceau, Emmanuel	1/10/11	FT	Carbon & Ecosystems	Controls on Organic Carbon Sequestration from the Naturally Iron-fertilised Phytoplankton Bloom over the Kerguelen Plateau	UTAS	Australia	October 2015
24. Lee, Shi Hong	15/12/12	FT	Carbon & Ecosystems	Impact of Climate Change on Physiological and	UTAS	Australia	December 2016

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				Behavioural Responses of Coastal Microphytobenthos			
25. McInnes, Julie	20/11/13	FT	Carbon & Ecosystems	Using Non Invasive Faecal DNA Methodologies to Investigate Albatross Diet	UTAS	Australia	November 2017
26. Michael, Pam	4/02/13	FT	Carbon & Ecosystems	Potential impacts of climate change on the dynamics and distribution of tuna, major industrial pelagic longline fleets and consequent interactions with threatened albatrosses: a first application to the Indian Ocean	UTAS	Australia	February 2017
27. O'Toole, Malcolm	7/11/11	FT	Carbon & Ecosystems	Top Marine Predator Foraging Behaviour in Relation to Primary Productivity in the Southern Ocean	UTAS	Australia	November 2015
28. Pittard, Mark	30/04/12	FT	Oceans & Cryosphere	Ice Sheet Response to Enhanced Ice Shelf Basal Melt	UTAS	Australia	April 2016
29. Plummer, Christopher	1/05/10	FT	Oceans & Cryosphere	Holocene Climate and Environmental Indicators from Trace Chemistry of Law Dome Ice Core, Antarctica	UTAS	Australia	May 2016
30. Polanowski, Andrea	3/10/11	PT	Carbon & Ecosystems	Mechanisms for Sex Determination in Antarctic Krill	UTAS	Australia	October 2019
31. Quiroz Espinosa, Juan	1/03/14	FT	Carbon & Ecosystems	A consistent approach to the estimation of sustainable harvests of Patagonian	UTAS	Australia	March 2018

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				Toothfish in Chilean, France and Australian Jurisdictions			
32. Ratnarajah, Lavenia	1/12/13	FT	Carbon & Ecosystems	Effect of natural iron fertilisation by krill and whales on the Southern Ocean carbon cycle	UTAS	Australia	December 2017
33. Roden, Nick	14/03/11	FT	Carbon & Ecosystems	Acidification and Carbonate Chemistry of Shelf Waters in the Australian Antarctic Territory	UTAS	Australia	November 2015
34. Schallenberg, Christina	September 2009	FT	Carbon & Ecosystems	An investigation into the sources of iron and iron(II) in HNLC high-latitude oceans	University of Victoria	Canada	July 2015
35. Semolini Pilo, Gabriela	15/12/2013	FT	Oceans & Cryosphere	Eddies Tridimensional Structure and their Role in Oceanic Mass and Heat Distribution	UTAS	Australia	December 2017
36. Steer, Adam	1/10/09	FT	Oceans & Cryosphere	Optimising Airborne LiDAR Positioning for Remote Area Geophysical Surveys	UTAS	Australia	November 2015
37. Ugalde, Sarah	15/02/10	FT	Carbon & Ecosystems	Primary Production and Fate of Antarctic Sea Ice Algae	UTAS	Australia	July 2015
38. Vasconcellos de Menezes, Viviane	20/02/12	FT	Oceans & Cryosphere	Remarkable Near-surface Eastward Flows in the South Indian Ocean: Understanding the Dynamical Links between the Indian Ocean Subtropical Gyre, Indonesian	UTAS	Australia	February 2016
39. Winton, Holly	September 2012	FT	Carbon & Ecosystems	Impact of biomass burning emissions and dust on soluble iron deposition to Australian waters, the	Curtin University	Australia	December 2015

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				Southern Ocean and Antarctica			
40. Younger, Jane	6/06/11	FT	Carbon & Ecosystems	Glacial Refugia of Antarctic Ice Breeding Species	UTAS	Australia	July 2015