



ANTARCTIC CLIMATE & ECOSYSTEMS COOPERATIVE RESEARCH CENTRE

2015/16 Annual Report



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Annual Report 2015-16

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1 Executive Summary

The ACECRC concluded 2015/16 in a strong position. Throughout the year we finalised the recruitment of four postdoctoral positions, and undertook a number of major field programs in Antarctica and the Southern Ocean. The Kerguelen Axis voyage – a key deliverable for the ACECRC – was successfully completed a year ahead of schedule and as a result the ACECRC is very well positioned to deliver on its milestones over the coming years. Additionally, ACECRC scientists participated on the Heard Island marine science voyage, the recovery and re-deployment of the Southern Ocean Time Series moorings south of Tasmania, the deployment of radar instruments on the Amery ice shelf, a successful suite of experiments on the coastal fast ice near Casey station, ongoing flights in support of the ICECAP airborne geophysics program, and collaboration aboard a number of other international polar expeditions. Each of these field programs generated data that will help the ACECRC's scientists answer important questions about the role of Antarctica and the Southern Ocean in the global climate system, the structure and function of Southern Ocean ecosystems, and the relationships between the physical environment and biological systems.

The very high level of field activity required the ACECRC to recruit additional specialist staff to ensure we had the appropriate level of support on each project. These were mostly short-term contracts and were managed within the scope of each project budget. The field activities also provided an opportunity for many of our new staff to engage deeply with collaborators across our partner agencies, and to engage new students into their project work. At the end of our second year of funding the ACECRC is supporting approximately double the number of PhD students required under our Commonwealth Agreement.

The commitment of the ACECRC's partners remains strong, notwithstanding a considerable drop in support for climate science throughout the year. In February 2016, the CSIRO announced deep cuts to its climate science capability; however, that organisation remains committed to its contractual arrangements with the ACECRC and we are very pleased to report that the projects involving CSIRO staff are unaffected by the changes. On a more positive note, the Australian government released its new Antarctic Strategy and 20 Year Action plan in April 2016, including \$1.9B over 30 years for a new ice breaking research vessel and additional funds for other research infrastructure, such as over-snow traverse capability. These investments are integral to a world-class Antarctic science program and auger well for the future of Antarctic and Southern Ocean science in Australia.

In August 2015, the ACECRC Board approved a two-year trial of a summer intern program. The program provides the opportunity for high calibre students who have finished 3rd year undergraduate studies, or honours, to work full time over a 10-12 week period on an ACECRC project, with a stipend of \$700 per week. The internships were widely publicised and attracted 35 applications nationwide, with the two successful candidates delivering very well against their projects. Further details are provided below.

In terms of outreach, the ACECRC co-hosted three major international conferences in Hobart throughout the year, and conducted two research user forums in Canberra on "Ice cores and climate" and "Iron fertilisation and marine geo-engineering". The research user forums were highly successful in attracting staff from

a broad cross section of government and other agencies including DEE, DIIS, Bo M, DFAT, AFMA, GA, ASPI, Defence, Navy, Agriculture, Murray Darling Basin Authority, Chief Scientists Office, ONA, NCCARF and the CRC Association. During the year the ACECRC also published a publicity booklet titled: “Climate Science for Australia’s Future” which is available on our website and in hard copy.

Throughout the year we have had a very strong focus on Workplace Health and Safety. Improvements over the past year include better staff training prior to field work; better laboratory processes, including chemical purchasing, handling, and the preparation of formal task risk assessments; ongoing regular ergonomic assessments for staff; and improved induction processes building-wide for new staff and visitors. The ACECRC Administration Manager, Wenneken Ho, has taken on formal responsibility as the ACECRC Workplace Health and Safety Representative, and undertaken appropriate training.

Overall, the ACECRC finishes 2015/16 having delivered strongly against all of its contractual milestones, with no actions outstanding, and the actions deferred from the previous year are all now completed. The Centre has a full complement of staff and is very well positioned to deliver strongly against its milestones over the coming year.

1.1 Achievements

Awards and Special Commendations

Prof Philip Boyd was honoured with an Australian Laureate Fellowship from the Australian Research Council (ARC). Prof Boyd will evaluate the feasibility of boosting carbon dioxide removal by Southern Ocean microbes to offset climate change, to provide a framework for future research and inform international policy on the use of geoengineering – large-scale intervention in the Earth’s natural systems - to mitigate against climate change. This is recognition of the value of climate change research and expert peer endorsement of research which links innovative primary science with work on solution-focused mitigation strategies to climate change. The Australian Laureate Fellowship recognises excellence in research along with a researcher’s role in providing significant, sustained leadership and mentoring. Prof Boyd’s contribution to building Australia’s internationally competitive research capacity is recognised in the award of the Laureate Fellowship.

Prof Boyd also received the A.G. Huntsman Award for Excellence in Marine Science from the Royal Society of Canada.

Prof Ian Allison was nominated by the ACECRC for the Australian “Senior Australian of the Year” and won the Tasmanian state category of the award. This recognises Prof Allison’s pioneering role in Australia’s glaciological research program and for his significant contributions to climate science including as a senior author on IPCC Assessment Reports. Prof Allison also became a fellow of the Australian Academy of Science and Australian Meteorological and Oceanographic Society.

Dr Jessica Melbourne-Thomas was awarded the 2015 Tasmanian Tall Poppy Award from the Australian Institute of Policy and Science.

Dr Ben Galton-Fenzi was nominated Australian liaison to the International Association of Cryospheric Sciences (IACS) early 2016.

Dr Rowan Trebilco was awarded a Fellowship by the Scientific Committee on Antarctic Research that supported an extended three-month visit to work with colleagues in France.

The CEO has instituted an annual “CEO Award for Excellence”. There were two recipients of this award in 2015: Mr David Reilly, Public Affairs Manager, and Dr Tessa Vance, Palaeoclimatologist. Special acknowledgement of staff is also made at staff meetings and staff forums for outstanding work.

Staff appointments

During the reporting period, the ACECRC recruited the following people:

Name	Position	Start Date	Project
Paula Conde-Pardo	Marine Carbon Cycle Postdoctoral Fellow	02/07/2015	2.1
Anne Domaradzki	Administration Assistant	01/05/2016	Admin
Hugh Doyle	Biogeochemical Sensor Postdoctoral Research Fellow	01/01/2016	2.1
Alexander Fraser	Remote Sensing Scientist	01/11/2015	1.2 & 1.3
Emmanuel Laurenceau-Comec	Marine Biogeochemistry Postdoctoral Research Fellow	01/11/2015	2.1
Peter Love	Atmospheric Researcher	20/06/2016	CF
Nick Roden	Marine Chemist Technical Officer	04/01/2016	2.1
Claire Rutheford	Administration Officer	09/05/2016	Admin
Christina Schallenberg	Trace Metal Oceanographer	07/09/2015	2.1

During the reporting period, Dr Tessa Vance was promoted to an academic level B and Mrs Claire Rutheford was offered a fixed-term position to replace her casual appointment within the ACECRC administration team.

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 ACECRC management team has developed an organisational risk register to capture the different risks to the ACECRC and to the delivery of the ACECRC milestones. The ACECRC 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 ACECRC. Over the reporting period, the overall risk profile of the ACECRC improved.

1.3 End-user Environment

The ACECRC continues to engage closely with key end-users through a number of major events and current activities.

We delivered against key utilisation milestones at two research user forums in Canberra in 2015. The first research user forum was held in July 2015 at the Canberra Shine Dome. This forum was attended by around 60 representatives from across government and other organisations. Two position analyses were presented, 'Antarctic Sea Ice Climate Change' and 'Understanding Past & Future Climates'. Drs Phil Reid and Rob Massom presented the sea ice position analysis and examined the topical issue of Antarctic sea ice, how it is changing, its impact on shipping operations, and efforts towards an Australian-based sea ice forecasting system. Dr Tasvan Ommen and Dr Tessa Vance presented the palaeoclimate position analysis and examined how ACECRC scientists are using Antarctic ice cores to conduct world-leading research into past Australian and global climates. Of special relevance to Australian policy makers was how the ACECRC is using information from ice cores to gain new insights into extreme drought and flooding events across mainland Australia over the past 1,000 years.

A second research user forum was held on 19 November 2015 at the Canberra Shine Dome, at which a consultation draft of the Ocean Fertilisation position analysis was presented. The purpose of this position analysis was to (i) inform Australian federal and state governments and the broader community about the growing pressure to use the oceans for geoengineering in general and ocean fertilisation specifically; (ii) provide an update on research concerning ocean fertilisation; and (iii) identify issues for consideration in science and policy development. The final document benefited considerably from the discussion at the forum and is now published. All ACECRC position analyses are available electronically from the ACECRC website, and in hard copy on request. Dr Steve Rintoul also provided a detailed update on IPCC AR5 findings, recent science results, and Totten Glacier research outcomes at the November meeting.

At the local level, consulting company SGS Economics and Planning remains a formal Other Participant in the ACECRC. The ACECRC also continues to be an active contributor to the Tasmania Polar Network.

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

Finally, the ACECRC remains a very significant contributor to the IPCC Assessment Reports. The ACECRC 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. ACECRC scientists are engaged in

discussions on the timing and process for the Sixth Assessment Report which is due to be finalised in time for the first UNFCCC global stocktake when countries will review progress towards their goal of keeping global warming to well below 2°C while pursuing efforts to limit it to 1.5°C.

1.4 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 ACECRC has delivered all of its 2015/16 research goals. ACECRC scientists had a successful Antarctic field season in 2015/16, particularly the Kerguelen Axis study. The major research activities of the study were undertaken aboard the *RV Aurora Australis* but there was strong collaboration with other vessels operating in the Kerguelen Axis area doing complementary Southern Ocean science. Some highlights of the 2015/16 field season include:

- The 8-week K-Axis voyage aboard the *RV Aurora Australis* between January-March 2016. The main outcome of this work was to enhance the realism of ecosystem models, to identify methods and technologies that will allow long-term monitoring of the effects of climate change and ocean acidification on Southern Ocean ecosystems in the region, and to provide information for conservation and fisheries management.
- The very successful Heard Earth Ocean Biosphere Interaction (HEOBI) voyage January-March 2016 to Heard Island (northern end of the Kerguelen Axis) on the *RV Investigator*. Great discoveries of hydrothermal vent activity around Heard Island were made, and elevated iron and manganese concentrations and very healthy phytoplankton (identified using the new fluorescence induction and relaxation instrument) were observed.
- The successful deployment of radar instruments on the Amery Ice Shelf to allow us to better understand the properties of the solid Earth and how it changes as ice loading changes occur. The deployment of GPS receivers allows for continuous tracking of bedrock motion over the coming years.
- The successful sea ice fieldwork activities on the fast ice at Davis Station (October-November 2015). This project, led by Dr Meiners, combined a remotely-operated underwater vehicle (ROV) with detailed in situ snow and ice measurements and optical data to the amount of and distribution of algae living in the ice as a function of snow and ice properties. The joint Australia-New Zealand project will combine the ROV measurements with point measurements from ice cores taken within and outside the ROV survey areas. To complement and enhance the ice algae work, Dr Heil operated automated fast ice observatories at Davis. The sea mass balance buoys were deployed to acquire measurements vertically through the snow cover, fast ice and water beneath, enabling estimates of the mass gain and loss of sea ice over time. As such, these buoys provide a unique long-term dataset of sea ice formation and decay.
- The successful experiments into the cycling of iron and carbon in melting fast ice at Davis. Sample analyses will be used to construct iron and carbon budgets for the fast ice in this region. The data collected will also allow the

parameterisation of sea ice primary production in ecosystem and biogeochemical models.

- In October–November 2015, Dr Guy Williams participated in a very successful US-led Arctic marginal ice zone (MIZ) project. Dr Williams was able to collect high-resolution observations of the sea ice thickness and conditions using state-of-the-art drone and automated underwater technology, which will be applied to Antarctic conditions in coming years.

In 2015/16, our researchers published a total of 3 book chapters, 120 articles in scholarly refereed journals, and 1 full written conference paper in refereed proceedings. A further 13 articles were submitted to scholarly refereed journals or are in press at the time of reporting. This shows the ACECRC continues to deliver its intended research outputs. The publications are listed in Appendix 1.

The ACECRC 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.

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. Much of this is known as a result of sustained research by the ACECRC since 1991. The ability of the Southern Ocean to continue to take up heat and carbon dioxide, and thereby slow the rate of climate change on land, 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 to future sea level rise 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.

Research Activities 2015/16

Detection and attribution studies of human-induced changes in the Southern Ocean have been completed, using observations and CMIP5 models. Detection and attribution work in 2015-16 has primarily focused on changes in Antarctic sea ice. A major review of human and natural drivers of change in Antarctic sea ice publication is in press (Hobbs, W., et al., in press, "A review of recent changes in Southern Ocean sea ice, their drivers and forcings." *Global and Planetary Change*). A second paper exploiting proxy data for detection/ attribution studies has been submitted, and a third study led by PhD student Serena Schroeter on drivers of sea ice variability in models and observations will be submitted later this year. A paper published by Dr Catia Domingues and others in the *Journal of Climate* (Boyer, T et al 2016) provides improved understanding of uncertainties in ocean heat content estimates, which is critical information for interpreting trends and their causes.

ACECRC authors contributed to several chapters in the *State of the Climate 2014* and *State of the Climate 2015* volumes published by the American Meteorological Society. These international efforts provide regular annual updates on the state of climate science, an important complement to the more complete but less frequent assessments produced by the Intergovernmental Panel on Climate Change.

A number of papers were published by Dr Stephanie Downes and colleagues exploring the sensitivity of the Antarctic Circumpolar Current, overturning circulation, and Antarctic Bottom Water formation to changes in forcing.

Project 1.1 contributed physical oceanography components to the K-Axis, Heard Island and BSS voyages. Dr Stuart Comey led the physical oceanography program, CTD and float deployments with Dr Ruth Erikson carrying out the hydrochemistry component on the K-Axis voyage. A bio-float as well as 4 SOCCOM biogeochemical floats were successfully deployed. The combined physical oceanography data from all voyages should provide a very useful snapshot of both upper and deep ocean circulation and water mass change in a poorly-sampled region.

Good progress has been made on analysis of results from the 14/15 Totten/Mertz voyage, including quantification of exchange with the sub-ice shelf cavity. The first two papers have been submitted, as well as a review paper on ocean-ice shelf interaction in East Antarctica. Long-term moorings and CTD data are being used to quantify the impact of calving of the Mertz Glacier Tongue on dense shelf water formation and Antarctic Bottom Water.

The high risk/high return experiment of parking profiling Argo floats on the sea floor between profiles has paid off, with profiles covering the full annual cycle obtained from both the Mertz and Totten regions. These observations provide the first full-depth, year-round measurements from these important regions.

Dr Will Hobbs was an invited speaker at an international workshop on Southern Ocean sea ice (National Academy of Sciences Workshop: Antarctic Sea Ice Variability in the Southern Ocean-Climate System).

Dr Steve Rintoul delivered the STLee Lecture in Antarctic Science at Victoria University in Wellington New Zealand, the Malcolm McIntosh lecture in Canberra, and an invited plenary talk at the 11th International Conference on Southern Hemisphere Meteorology and Oceanography in Chile.

Dr Steve Rintoul also delivered a public lecture on 16 November 2015 on the future of the Antarctic ice sheet resulting from the ground-breaking Australian marine science voyage in early 2015 which uncovered new evidence of the impact of ocean warming on the Antarctic ice sheet. The lecture is available at: <http://acecrc.org.au/news/a-soft-underbelly-in-east-antarctica/>

Dr Stephanie Downes was successful in her application through AMOS to participate in Science meets Parliament in Canberra in March 2016.

Dr Catia Domingues and Dr Will Hobbs were successful in securing an ARC Discovery Grant looking at sea level and ocean heat content change in the CMIP5 and CMIP6 experiments.

Dr Benoit Legresy from CSIRO joined the ACECRC as a CSIRO in-kind contribution from 1 January 2016. Dr Legresy brings skills and background in oceanography, sea-level rise and glaciology which is a great addition to the R1.1 team.

PhD student Alessandro Silvano, who is working on ocean-ice shelf interaction at the Totten Glacier, received an award from Bank Australia as part of the annual Malcolm McIntosh lecture.

A number of new PhD students commenced on projects in project 1.1. Bella Blanche commenced on a project researching the freshwater budget in climate models and Fabio Dias commenced on a project looking at ocean heat content change in climate models.

Prof Jay McCreary from the University of Hawaii visited during the reporting period to discuss Southern Ocean circulation dynamics.

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 the 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 overdeepened 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 subglacial 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.

Research Activities 2015/16

One new staff member joined this project during the reporting period. Dr Alexander Fraser (Remote Sensing Scientist) started in November 2015. Dr Fraser works both within project R1.2 and R1.3. Elizabeth Russell accepted the ACECRC summer internship project 'Using finite element modelling techniques to assess the distribution of stresses within samples used in laboratory ice-deformation experiments' with Drs Adam Treverrow and Lenneke Jong. The internship commenced early December 2015 and ended March 2016.

Dr Sue Cook participated in the 2015-16 Antarctic summer season from both Casey and Davis stations to deploy ApRES instruments (radar) and GPS receivers which was co-supported with the Australian Research Council (ARC) Special Research Initiative (SRI) for the Antarctic Gateway Partnership. The GPS instruments are tools to better understand the properties of the solid Earth and how it changes as ice loading changes occur. The deployment of GPS receivers allows for continuous tracking of bedrock motion over the coming years. The team was unable to deploy an ApRES instrument on the Sorisdal Glacier to measure strain rates and basal melt rates of the ice shelf component. This work will be continued in the 2016/17 season. Meanwhile, Dr Sue Cook will continue modelling ice shelf processes with collaborators in England, Finland and China.

Dr Jason Roberts and Dr Carly Tozer participated in the ICECAP project with a significant number of ICECAP flights out of Davis station and Casey station, as well as Dome C and Dumont d'Urville, completed. Unfortunately, key targets near Davis station were unable to be achieved due to unforeseen circumstances that affected the Australian Antarctic Science program field season.

Works to resolve building issues in the ice mechanics laboratory were completed, removing the final obstructions to recommissioning the laboratory. Maintenance and modifications to experimental equipment are being finalised with experiments to commence in late 2016. An assessment of numerical ice flow relations led by Dr Adam Treverrow indicates that an ACECRC-developed parameterisation of ice flow physics provides a superior representation of ice dynamics in comparison to other flow relations commonly used in models of the Antarctic ice sheet. Work to implement the ACECRC flow relation in two different ice sheet modelling systems is currently underway with collaborators from the Antarctic Gateway Partnership and the Institute of Low Temperature Science (ILTS), Japan.

Dr Lenneke Jong and Dr Sue Cook together with Antarctic Gateway Partnership researchers published an article in The Conversation on the prediction of when Antarctic's melting ice sheets will lead to a rise in sea levels:

<https://theconversation.com/tipping-point-how-we-predict-when-antarctic-melting-ice-sheets-will-flood-the-seas-56125>.

Coupled modelling activities are underway with Dr Lenneke Jong who attended an Elmer/ice (open source software for ice sheet, glaciers and ice flow modelling) workshop in Grenoble, France, before visiting both Germany and Finland to interact with lead Elmer/ice developers to discuss strategies for initial coupled model experiments in November and December 2015.

This project had a visit from Dr Wolfgang Rack from Canterbury University, New Zealand, who visited Hobart to discuss new work examining grounding line dynamics and possible avenues of collaboration with team members Dr Trevor and Dr Galton-Fenzi.

Dr Natalie Robinson from NIWA visited for one week to collaborate with Dr Ben Galton-Fenzi and Dr David Gwyther on better integrating modelling and observational studies of the sub-ice environment.

Dr Christine Dow from the University of Waterloo (Canada) visited the ACECRC on a SCAR Fellowship for the project 'Antarctic subglacial hydrology and the formation of subglacial lakes'. Dr Dow is looking to apply her modelling techniques to the Aurora Basin, using the data from the ICECAP missions.

Dr Cook made a visit to collaborators in Helsinki to further develop a particle model of the Totten Ice Shelf. Furthermore, several members of R1.2 attended and presented at the International Symposium on Contemporary Ice-Sheet Dynamics: ocean interaction, meltwater and non-linear effects during August 2015 in Cambridge, UK

Both Dr Galton-Fenzi and Dr Jong attended the second workshop on coupled ice sheet/ocean modelling in Abu Dhabi in May 2016, a CiC targeted research activity. The development of the research activity has been presented as an Eos feature article: 'On the rocks: The challenges of predicting sea level rise' Eos, 96, doi:10.1029/2015EO036667.

Several National Computing Infrastructure (NCI) proposals were submitted with an extension of the existing project 'Modelling of the interaction between Antarctica and the Southern Ocean (m68)' granted 1000 kSU for 2016 for HPC researchers at the ACECRC and Antarctic Gateway Project.

ANCI High Performance Computing course on parallel programming and performance was hosted by the ACECRC and IMAS on 29 September 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 Australian-led SIPEX-II voyage, ACECRC 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, the ACECRC shall co-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, ACECRC 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. These voyages present the opportunity to extend the SIPEX-II AUV work to the Marginal Ice Zone (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 and how these vary (and change) over space and time. This research direction represents an important step towards understanding observed changes in Antarctic sea-ice extent and seasonality on time-scales from seasons to centuries, and 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 ACECRC environment, including the Atmosphere group.

The Marginal Sea Ice Zone (MIZ) will remain a major focus of future ACECRC 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 Antarctic'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. ACECRC research will focus on how sea ice processes drive dense shelf-water 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-sal 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 ACECRC 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/a/fin/>

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

Research Activities 2015/16

One new staff member joined this project during the reporting period. Dr Alexander Fraser (Remote Sensing Scientist) started in November 2015. Dr Fraser works both within projects R1.3 and R1.2. The fast ice mapping project that he leads is extending this important time series in time e.g., in support of biology/ecology studies (Adélie/George V Land coast, Mawson coast, Prydz Bay, Ross Sea). Progress was also made on a new high-resolution map of circumpolar fast ice distribution (at 1 km resolution), 2000 - present (and ongoing).

A special volume of *Deep-Sea Research* devoted to results from the 2012 SIPEX-II multi-disciplinary sea ice field experiment was completed and will be available online from September 2016. ACECRC staff member Dr Klaus Meiners, who was Chief Scientist on SIPEX-II, is the lead editor of this volume, which comprises a total of 17 papers and 1 editorial (with strong input from ACECRC scientists).

In addition, the period saw final papers published for the major thematic volume of *Annals of Glaciology* devoted to papers from the ACECRC-sponsored International Glaciological Society International Symposium on Sea Ice in a Changing Environment (10-14 March 2014, chaired by ACECRC staff Drs Massom and Heil). This volume, with Dr Heil as chief editor, contains 48 papers.

The project has benefited greatly from the modelling activities of staff member Dr Kazu Kusahara, with significant progress being made towards attribution of recent Antarctic sea ice and sea surface temperature trends, and in high-resolution modelling of important ocean-cryosphere interactions off the Adélie and George V Land coasts of East Antarctica. Also regarding Antarctic coastal processes and change, a largely satellite data-based study paper published in the *Journal of Geophysical Research-Earth Surface* (Massom et al., 2015) highlighted the importance of external influences on the dynamics of the floating Mertz Glacier Tongue (including landfast sea ice) in the decade leading up to its calving in 2010.

This and other work is indicative of the cross-disciplinary and cross-cutting nature of the work being carried out by the project and within the ACECRC in general.

Project scientists continue to lead the analysis and input of information on an annual Antarctic sea ice conditions for the annual international NOAA/BAMS State of the Climate Report, with publication of the 2014 report (Reid et al., 2015).

New calibration of extended time series of satellite-derived sea ice production rates in East Antarctic coastal polynya has been completed. Three significant papers addressing this deliverable have been published or are in review, including one by Williams et al (2016) in *Nature Climate Change*. The papers use data from sensors attached to seals to determine changes in the salinity of coastal waters during the ice growth season, from which sea ice production rates can be determined and satellite-derived estimates can be calibrated and validated.

In terms of fieldwork activities, members of the Sea Ice Group completed a successful field season on the fast ice at Davis Station (October-November 2015). Led by Dr Meiners and also involving Drs Heil and Massom, this experiment combined a remotely-operated underwater vehicle (ROV) with detailed in situ snow and ice measurements and optical data to the amount of and distribution of algae living in the ice as a function of snow and ice properties. The joint Australia-New Zealand project will combine the ROV measurements with 'point measurements' from ice cores taken within and outside the ROV survey areas. To complement and enhance the ice algae work, Dr Heil operated automated fast ice 'observatories' at Davis. These 'mass balance buoys' were deployed to acquire measurements vertically through the snow cover, fast ice and water beneath, enabling estimates of the mass gain and loss of sea ice over time. As such, these buoys provide a unique long-term dataset of sea ice formation and decay.

In addition, Dr Guy Williams participated in a very successful US-led (ONR - funded) Arctic marginal ice zone (MIZ) project termed 'Sea state' in October/November 2015. He made a significant contribution in gaining remote high-resolution observations of the sea ice thickness and conditions using state-of-the-art drone and automated underwater technology. Also in the Arctic, Dr Massom participated (as an invited snow expert) in a US-led field workshop on fast ice off Barrow (Alaska in May 2015) teaching leading sea ice modellers how snow on sea ice is measured and why it is important; by the same token, the modellers highlighted the issues involved in modelling sea ice and its snow cover. The overall outcome of this cross-disciplinary initiative has been improved parameterisation of snow in global climate models.

Dr Jan Lieser continued to provide regular and widely-appreciated expert sea ice reports and analyses in support of shipping and field operations. Dr Lieser also participated in the 5th International Ice Analyst Workshop, which was held at the US National Ice Center in Suitland MD, during May. This workshop brought together over 20 leading experts in the field of satellite data analysis representing 10 countries, specifically addressing challenges in relation to Antarctic conditions. Topics included the use of Geographic Information Services (GIS) in sea-ice/iceberg analysis, Antarctic iceberg monitoring, operations and needs of vessels operating in Antarctic waters, sea-ice modelling in the Southern Hemisphere and sea-ice analysis in the Southern Hemisphere in general.

Progress has also been made in developing sea ice forecasting capability, by Drs Phil Reid from BoM and Laura Davies from the Antarctic Gateway Partnership. Several ACECRC staff and associates participated at the first COSIMA (Consortium for Ocean Sea Ice Modelling in Australia) workshop (26-27 May 2016) held at IMAS. The goal of the workshop was to formalise a consortium across universities, BoM, AAD and the CSIRO to build global ocean sea ice model configurations that will form the basis for high-resolution forecasting, reanalysis, process modelling and ultimately coupled climate modelling.

In early 2016, the BoM started running hindcasts of a coupled ocean atmosphere sea ice model (ACCESS-S) that will form the basis of its seasonal forecast model in the near future. Analysis of the sea ice component of this model will allow us to experiment with seasonal sea ice forecasting products with the aim of providing early guidance for Antarctic shipping operators and scientists.

Presentations by key sea ice researchers presented at the Council of Managers of National Antarctic Programs (COMNAP) Workshop on Sea Ice Challenges in Hobart (12-13 May 2015) were published in the workshop report (available at: https://comnap.aq/Publications/Comnap%20Publications/COMNAP_Sea_Ice_Challenges_BKLT_Web_Final_Dec2015.pdf).

This project benefited from several international visitors during the reporting period:

- Prof Stephen Ackley (University of Texas San Antonio, USA) visited the ACECRC during March-April 2016 and worked with several ACECRC scientists on the data collected during the ONR Sea State cruise in October-November 2015 and paper publications.
- Dr Ghislain Picard from the University Joseph Fourier & LGGE, France, visited the ACECRC between August 2015 and July 2016 to collaborate with researchers on snow physics and climate in the polar regions. The visit also led to important progress towards improved parameterisation of snow processes in coupled sea ice modelling (with Dr Heil).

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 also 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 CO₂), volcanic forcing (from sulphate), solar forcing (from 10 Be) and climate variability (SAM/ENSO). The Aurora Basin (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, 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 CO₂ and its isotopes will improve our understanding of the hemisphere gradient of CO₂ 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; Mc Morrow et al., 2004). The high resolution continuous flow analysis proposed for this core (see below) will yield an 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 Niño 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 the se 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 Methane sulphonic Acid (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. 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.

Investigate sources and transport pathways: Dust and aerosol pollutant inputs to Antarctica are powerful tracers of atmospheric circulation. Considerable debate exists regarding the 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). This 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 co-investigation 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 CO₂ 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.

Research Activities 2015/16

Aurora Basin ice core analyses have been completed early 2016. Initial results from the Aurora Basin North ice core were recently presented at the IPICS 2016 conference, including the initial dating scale and snow accumulation history for ABN, and an assessment of the ABN temperature record with the regional PAGES 2k record indicating scope for an improved synthesis for the Indian sector of East Antarctica. The project is part of broader international efforts to improve our understanding of how the climate has varied naturally over the past 2000 years in the lead up to the current era. The Aurora Basin Project is providing new results for a large sector of Antarctica where no data was previously available.

Dr Andrew Moy spent two weeks at the Desert Research Institute in the USA analysing Aurora Basin samples. Initial results identify key volcanic markers at expected locations within the core. The record provided by the core is expected to extend back about 2,500 years, a little longer than anticipated.

Dr Jason Roberts and Dr Carly Tözer participated in the ICECAP project with a significant number of ICECAP flights out of Davis station and Casey station, as well as Dome C and Dumont d'Urville, completed.

More than 200 climate scientists from around the world gathered in Hobart in March 2016 to attend a major conference organised by the ACECRC focused on ice core science. The International Partnerships in Ice Core Sciences (IPICS) Second Open Science Conference brought scientists from 22 countries to Tasmania; the home of Australia's Antarctic programme and gateway to Antarctica. The conference was co-hosted by the Australian Antarctic Division and the Antarctic Climate and Ecosystems Cooperative Research Centre with conference chair, Dr Tasvan Ömgen. The conference brought together the world's top experts in ice core science and drilling technology for a week of scientific presentations and planning discussions. One of the major priorities for the conference was progress toward finding and drilling the world's oldest ice. The oldest ice core retrieved from Antarctica to date is about 800,000 years old, which falls just short of a major shift in global ice age cycles that occurred about a million years ago.

Dr Carly Tözer and others published a paper based on data drawn from an ice core that was used to reconstruct rainfall records for a particular catchment – in this case one in the Hunter Valley called the Williams River. The study found that the extreme weather events of recent years were not extraordinary, but relatively mild compared to the climate patterns of the past millennium. The study, published in Hydrology and

Earth System Science, is a collaboration between Newcastle University, the ACECRC and the Australian Antarctic Division.

Dr Tasvan Ommen and Dr Tessa Vance presented their research at the Greenhouse 2015 – Atmosphere, oceans and ice Conference in Hobart 27-30 October 2015.

Dr Yaping Liu from CAREERI, China, departed after his one-year visit to the ACECRC. Dr Liu provided vital input on the ice core and samples from the Aurora Basin North Ice Coring project.

2.1.2.1. Carbon Uptake and Chemical Change

Project Summary

The ocean absorbs CO₂ from the atmosphere, slowing the rate of climate change on land. The Southern Ocean takes up more atmospheric CO₂ 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 CO₂, or if decreasing overturning circulation reduces its transfer to the deep ocean, or if biological changes reduce the transformation of CO₂ into organic matter. The pathways of CO₂ 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 CO₂ 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, complemented 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 Antarctic 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 CO₂ 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 CO₂ 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 food web, 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 the 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 food webs and carbon cycling. Improvement of this situation is a key focus for Project 2.1, especially via the SR3, Southern Ocean Time Series (SOTS) moorings, 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.

Research Activities 2015/16

Five new staff members joined this project during the reporting period. Dr Paula Conde-Pardo (Marine Carbon Cycle Postdoctoral Fellow) commenced 2 July 2015. Dr Christina Schallenberg (Trace Metal Oceanographer Postdoctoral Fellow) and Dr Emmanuel Laurenceau (Marine Biogeochemistry Postdoctoral Fellow) commenced in September and November 2015 respectively. Mr Hugh Doyle and Mr Nick Roden were appointed in short-term contracts to achieve the HEOBI and K-Axis fieldwork objectives.

Sample analyses have been completed from the summer 2015/16 Totten *RV Aurora Australis* voyage and is helping define end members in calculations of anthropogenic CO₂ in the Southern Ocean. It appears the high salinity shelf waters are important for constraining the amount of CO₂ that has accumulated in bottom waters, which is expected as the shelf waters are a significant end member for bottom water.

The larger scale carbon cycling work based on the multiple repeats of the SR3 hydrographic section also advanced well, with estimates of anthropogenic carbon inventories in the Southern Ocean made using the optimal multi-parametric technique by postdoc Paula Conde-Pardo presented at the Oceans in a High CO₂ World IV conference held in Hobart in May 2016.

The project team working at Davis over the 2015/16 spring/summer conducted a series of very successful experiments into the cycling of iron and carbon in melting fast ice. Sample analyses will be used to construct iron and carbon budgets for the fast ice in this region. This work extends a time series started in 1993 and continued in 2010 that has examined the seasonality of ocean productivity and associated changes in ocean acidification. The data collected will also allow the parameterisation of sea ice primary production in ecosystem and biogeochemical models (strong links to R2.2 and R2.3).

The Heard Earth Ocean Biosphere Interaction (HEOBI) voyage aboard *RV Investigator* investigating the role of volcanic activity in supplying iron to drive phytoplankton production around the central Kerguelen plateau was very successful, despite the early return by approximately one week due to a medical emergency. Elevated iron and manganese concentrations and very healthy phytoplankton (identified using the new fluorescence induction and relaxation instrument) were observed, and laboratory analyses in the coming year will determine the role of hydrothermal activity in their occurrence.

Several members of the biogeochemical team joined the K-Axis voyage onboard *RV Aurora Australis* to the southern Kerguelen plateau, a key habitat area for higher predators in the Southern Ocean. The voyage studied the physical, biological and chemical conditions that drive the krill-based food web in the southern part of the region, and the fish and copepod dominated food web in the north. The biogeochemical teams onboard the *RV Aurora Australis* for K-Axis and *RV Investigator* for HEOBI sampled to identify which iron sources are the most important to primary production in the region.

The Carbon team also successfully turned around the Southern Ocean Time Series moorings south of Tasmania in March-April 2016, wrapping up a huge summer of marine science activities at the ACECRC.

An integrated aerosol sampling program has been implemented at land-based sites and on research vessels examining the role of atmospheric deposition originating from continental land-masses in supplying the limiting trace element iron to Southern Ocean waters.

Work on ocean acidification impacts on Southern Ocean coccolithophore strains continued, with new papers recently published by MAS-ACE postdoc Dr Marius Müller (Müller et al 2015 and Müller, M., Trull, T., and Hallegraeff, G. 2016).

Version 3 of the SOCAT Surface Ocean CO₂ Atlas was released compiling more than 14.5 million measurements for the global ocean, an effort that enables flux quantification at global and regional scales and examination of its response to climate variability.

A high profile paper in *Science* on the Reinvigoration of the Southern Ocean CO₂ sink (Landschutze et al, 2015) was published showing that the Southern Ocean carbon sink is more variable than previously thought and responds sensitively to physical climate variability.

The fourth 'Oceans in a High CO₂ World' Conference was held in Hobart 3-6 May 2016 with the ACECRC as a key sponsor. The conference built on three previous symposia and offered the worldwide community of scientists working to understand ocean acidification an opportunity to share their research results and develop new research collaborations. Over 350 researchers, students and government and industry representatives attended the fourth symposium in the series. The ACECRC Carbon team was well presented with Professors Tom Trull and Phil Boyd and Dr Bronte Tilbrook as committee members.

This project had several visitors during the reporting period:

- Prof Stephane Blain and Dr Ingrid Obemoster visited in October 2015 for preparation for their participation on the HEOBI voyage studying iron-microbial interactions.
- Dr Naoya Kanna visited the ACECRC and IMAS in October 2015 to prepare for the Antarctic fast-ice field work.
- Prof Yue Gao visited during October-December 2015 to develop new DGT (in situ diffusive gradients in thin film) techniques for analysing trace elements in seawater.
- Dr Marius Müller visited in May 2016 to continue ocean acidification collaboration with ACECRC and IMAS scientists.
- Dr Elizabeth Shadwick visited in May 2016 to work on collaborative research on i) the cycling of iron and carbon and the factors controlling the initiation of a spring bloom in the sea-ice environment using data collected by Dr Shadwick and Dr Lannuzel in the 2015/2016 Antarctic field season; ii) the recent changes to the ice escape in the Mertz Polynya and their impacts on long-term trends in primary production and air-sea exchange of CO₂ based on data collected by Dr Tilbrook (ACECRC/CSIRO) and analysis of sea-ice trends by Dr Williams.

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 food web control the flow of energy into food webs 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 food web are likely to be altered by changing oceanic and sea ice conditions. Changing conditions may also directly influence higher levels in the food web, 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.

Research Activities 2015/16

The Ecosystems team had a very busy but successful fieldwork season. Firstly, the 8-week K-Axis voyage departed on 11 January 2016 to a key habitat area in the Southern Ocean. The voyage studied the physical, biological and chemical conditions that drive the krill-based food web in the southern part of the axis, and the fish and copepod dominated food web in the north. ACE CRC Program Leader, Dr Andrew Constable, led this voyage which was a first to study the K-Axis region as a whole. See the full K-Axis research activities in R2.3. Shipboard experiments on *RV Aurora Australis* during K-Axis measuring zooplankton biological rates and CO₂ perturbation were successfully executed.

Experiments on the effects of increased CO₂ on adult krill behaviour as well as on their long-term physiology, are currently being conducted by Dr So Kawaguchi and his team in the AAD krill aquarium. Dr Kristen Karsh and University of Southern California visiting scientists, Prof David Hutchins and Dr Felix Fu successfully completed a suite of temperature and trace metal supply manipulation experiments on a range of polar phytoplankton species over three months in early 2016.

An ongoing suite of laboratory environmental change manipulation experiments (heterotrophic bacteria and phytoplankton species, acidification and/or warming) were complemented by seagoing field work in late 2015 and early 2016. Shipboard zooplankton sampling on the *RV Aurora Australis* as part of K-Axis, and perturbation studies using community mesocosms (microbes to copepods, joint effects of warming, acidification, nutrient depletion and altered light climate) were conducted on the *RV Investigator*. Samples and data are currently being analysed from both lab and linked shipboard studies. A synthesis of the responses of the lower trophic levels to environmental change has been carried out.

Dr Klaus Meiners completed a follow-up field season in late 2015 comprising of fast ice research. This field work was conducted from Davis station, where the team used a remotely operated underwater vehicle (ROV) to measure the under-ice structure, ice thickness, light penetration from above, and the biomass and distribution of algae living in the ice, and was reported in more detail above (1.3).

Progress has been made in understanding the physical drivers of ice algal distribution under sea ice using existing data from a Polarstem 2013 voyage. A publication on this research is in preparation.

The 2.2 project team was also deeply engaged with the fourth 'Oceans in a High CO₂ World' Conference held in Hobart 3-6 May 2016, reported above.

2.1.2.3. Status and Trends in Ecosystems

Project Summary

Marine ecosystems provide a broad and important range of services to people and the environment, from food security to sewage disposal. 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 ACECRC. 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 ACECRC 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.

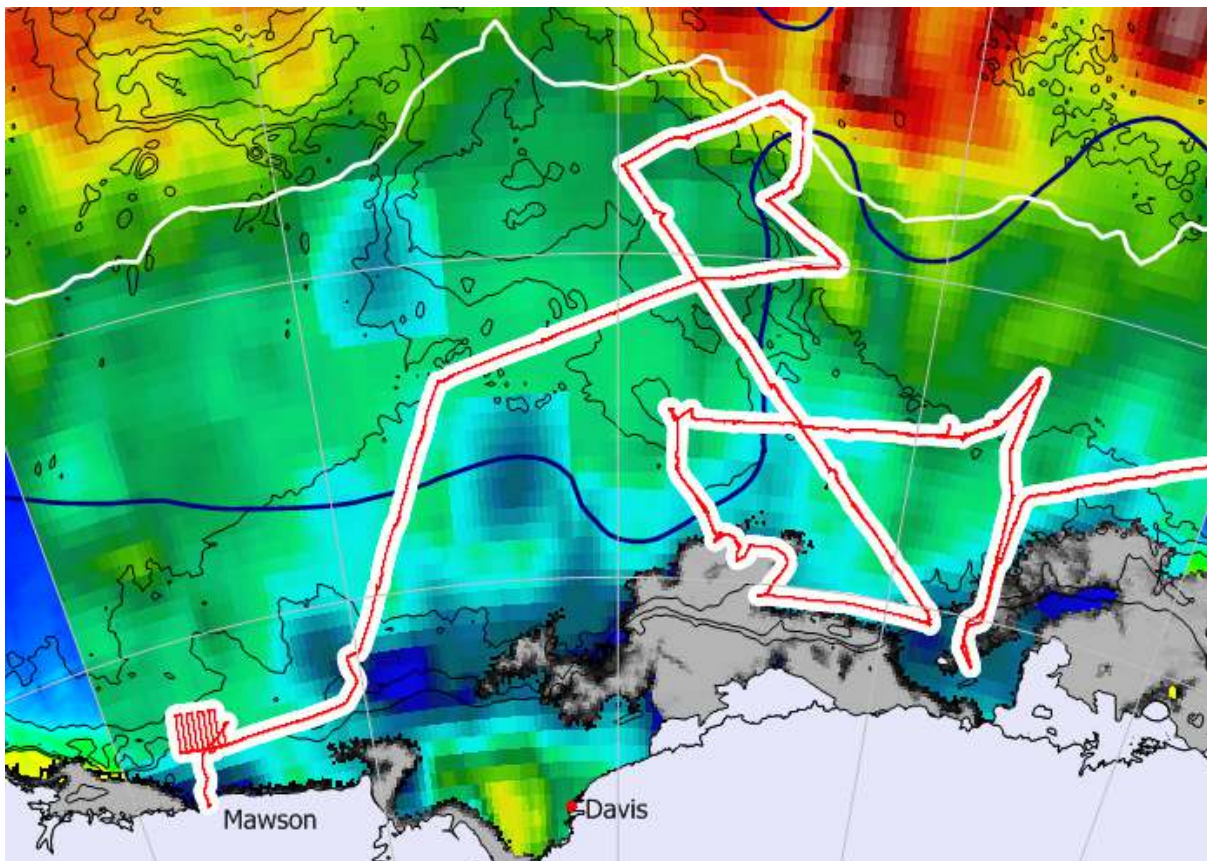
Research Activities 2015/16

The Ecosystems team had a very busy but successful fieldwork season. The 8-week Kerguelen Axis (K-Axis) voyage departed on 11 January 2016 to a key habitat area in the Southern Ocean. The voyage studied the physical, biological and chemical conditions that drive the krill-based food web in the southern part of the axis, and the fish and copepod dominated food web in the north. ACECRC Program Leader, Dr Andrew Constable, led this voyage which was a first to study the K-Axis as a whole. In addition to the *RV Aurora Australis* voyage, another three research vessels conducted complementary research in the region – the French ship Marion Dufresne, the Japanese Umitaka Maru and CSIRO's new national research facility, *RV Investigator*. Further oceanographic input was provided from the US vessel Roger Revelle.

The first research area was to investigate the factors that affect the distribution of Antarctic krill and determine the species' northern limits. This information will be used in ecosystem models of the krill-based food web to understand how the species may be affected by climate change and ocean acidification. The second area of research was to examine the relationships between planktonic species, including phytoplankton, zooplankton and krill, with key habitat characteristics such as temperature, salinity, depth, iron supply and carbonate concentration. A third research area assessed phytoplankton productivity and food web structure in three habitat areas of the K-Axis – close to the Antarctic continent (continental shelf habitat), the BANZARE Bank and adjacent open ocean, and the northern Kerguelen Plateau, near to subantarctic islands. The productivity component of the work focussed primarily on iron sources in each habitat area. For the food web structure analysis, this work was supported by the existing land-based predator monitoring work by France and Australia at Kerguelen Island and Davis station respectively to identify any 'hotspots' of activity by seals, penguins and flying birds in the region. The team also looked at the distribution of small 'mesopelagic' fish. These fish are found in the top 200 to 1,000 metres of the open ocean during the day, and many migrate to shallower water to feed at night. They are a staple food source for seals, penguins and other predators. DNA analysis of the stomach contents of the fish will provide information about their diet – different phytoplankton and zooplankton species which can in turn be related back to the effects of different habitats and ocean chemistry on plankton productivity.

The main outcome of this work will be to enhance the realism of ecosystem models, to identify methods and technologies that will allow long-term monitoring of the effects of climate change and ocean acidification on Southern Ocean ecosystems in the region, and to provide information for conservation and fisheries management.

The first post-voyage K-Axis workshop was held in Hobart to begin the process of working up the results, which is due to be completed in early 2017.



K-axis voyage track overlaid with remotely sensed chlorophyll-a, with sea ice shown in grey.

Substantial progress has also been made on the development and implementation of ecosystem models. The East Antarctic Atlantis model has been implemented and is currently being calibrated.

Dr Rowan Trebilco was awarded a UTAS-REGS grant towards assessing importance of squid in Southern Ocean ecosystem models, and coordinated the implementation of a version of the French SEAPODYM model (a stage-based model for fish-based ecosystems) as part of his 2016 SCAR Fellowship.

A joint project between the ACECRC, AAD, IMAS, CSIRO and the EU – the MESOPP (Mesopelagic Southern Ocean Predators and Prey) project – is now up and running and will fund several post-doctoral positions, including one at the ACECRC.

Planning and coordination of the planned ACECRC conference in 2018 on Marine Ecosystem Assessment for the Southern Ocean and subsequent Southern Ocean ecosystem benchmarking in 2022 has started in earnest. There will be a workshop on this topic at the SCAR Biology symposium next year in early July 2017.

Key publications for project R2.3 have included a paper on ecosystem Essential Ocean Variables in the Journal of Marine Systems (Constable et al 2016) and a series of student-led papers on the development of ecological models (Ratnarajah et al 2016, Subramaniam et al 2016).

2.2 Education and Training

Education

The ACECRC 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 ACECRC also supports a small number of students at other tertiary institutions.

ACECRC staff teach PhD students and 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, 69 (FTE) students were involved in PhD studies related to the ACECRC, including 31 commencing students. There were also 8 completions. Of the 8 PhD students that graduated during the reporting period, Dr Sjoerd Groeskamp, Dr Fabien Queroue and Dr Malcolm O'Toole are in post-doctoral positions overseas. Dr Emmanuel Laurenceau-Comec and Dr Christina Schallenberg are employed at the ACECRC as a Marine Biogeochemistry Postdoctoral Fellow and Trace Metal Oceanographer respectively. Dr Felicity Graham is employed at the Antarctic Gateway Partnership and Dr Sarah Ugaldé is working at the Institute for Marine and Antarctic Studies.

The ACECRC currently provides financial support to 13 PhD students through top-up scholarships, which are awarded on a competitive basis. Seven of these were awarded during the reporting period.

In total, 37 UTAS staff and 57 non-university staff including in-kind contributed staff were involved in PhD supervision.

Interest in the IMAS undergraduate Bachelors of Antarctic and Marine Science has been growing during the reporting period. Nine students were enrolled in the Bachelor of Antarctic Science with 3 due to complete in 2016 and 15 in the Bachelor of Marine Science with 4 due to complete. IMAS also enrolled 156 students in the Bachelor of Marine and Antarctic Science with 5 due to complete, which will eventually supersede both of the existing undergraduate courses. A significant number of these undergraduate students are expected to go on to higher degrees at UTAS, with good potential for the ACECRC to attract them into research projects relevant to Antarctica and the Southern Ocean.

Five Honours students commenced since July 2015 with 1 continuing Honours student. Four Honours students graduated during the reporting period (Callum Knight, Amy Lewitzka, Andrew Gunn and Jane Moran).

These figures indicate a resurgence in interest in Honours programs, which augurs well for future recruitment into PhD programs within the ACECRC. There have been strong employment outcomes for this year's PhD graduates, who continue to develop outstanding professional careers.

As per the Deed of Variation in March 2016, the Masters educational milestones have been removed from the Education and Utilisation Milestones.

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

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

Student Lavenia Ratnarajah received the University of Tasmania's inaugural Peter W Smith CSL Postgraduate Prize and student Ben Arthur was awarded best oral student presentation at the Cliotop 3 meeting 'Future of oceanic animals in a changing ocean'.

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 many 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 ACECRC) present the course. As of 22 September 2016, 13,456 students have taken the course; 65,969 videos have been watched; and 4,091 classroom posts have been made.

The ACECRC has several structures in place for interaction with and between students. The 'ACECHit Chat' series has been up and running since 7 June 2012 and has been managed by ACECRC PhD students since September 2013. The 'ACECHit 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 facilitate interaction with colleagues and students from different organisations. A special student poster session was organised for 27 November 2015 with 21 students presenting their research on a poster with Mao Mori winning first prize for her poster titled 'Modelling the oceanic transport of planktonic species in the Southern Ocean'.

In addition, DaSH (Data Science Hobart) fortnightly sessions have been organised by ACECRC students and researchers to build a community of researchers to discuss data, concepts, tools, methods and to solve problems. The weekly IMAS and AAD seminars also allow for students and researchers to have discussions and improve collaborations.

Summer Internship Program

The ACECRC summer internship program was established in December 2015 with two internships offered each year, providing students with the opportunity to undertake an 8-12 week project alongside some of the world's leading scientists. The projects will be focused on Antarctic and Southern Ocean research and will be available on a competitive basis to undergraduate students interested in pursuing a career in Antarctic and/or marine science. The two projects available during the reporting period were:

- Using finite element modelling techniques to assess the distribution of stresses within samples used in laboratory ice deformation experiments; and
- Ventilation of Law Dome over the 20th century.

The two successful applicants for the ACECRC inaugural internship round 15/16 were Elizabeth Russell and Imogen Wadlow.



Elizabeth Russell



Imogen Wadlow

Elizabeth Russell worked with Dr Adam Tveit and Dr Lenneke Jong on the project titled: “Using finite element modelling techniques to assess the distribution of stresses within samples used in laboratory ice deformation experiments”. Imogen Wadlow joined us from Macquarie University and worked with Dr Andrew Klekocuk on project titled “Ventilation of Law Dome over the 20th Century”. They presented their results at a seminar on Thursday 18 February 2016.

The internship program allows for undergraduate students the opportunity to attend seminars, planning meetings, and gain experience working in a supportive, collegiate research environment. The 16/17 internship round is currently advertised.

In addition to the above internships, Ben Hendricks was also successful in getting a 'Dean's Summer Research Scholarship' and worked with Dr Damian Murphy and the atmospheric group for 6-8 weeks over the summer from 30 November 2015.

Work experience

The ACECRC hosted two work experience participants during the reporting period. Nina Koenig from Germany participated in a 2 week long placement and was shown all aspects of Antarctic and Marine research including laboratory work. Finn Ledger participated in a week long placement in June 2016 with the aim to further develop a better understanding of future career options within the Antarctic and Marine science field.

Workshops for end-users

During the reporting period, the ACECRC hosted several workshops for end-users, attended by a total of 207 delegates.

The two ACECRC-led research user forums in Canberra in July 2015 and November 2015 attracted a total 104 government and non-government end-users. More detail on these research user forums can be found in the Utilisation and Commercialisation section below.

During May and June 2016, the ACECRC hosted a 4-part lecture series open to science teachers, those involved in science education, and those with a general interest in climate science. The lectures were held over four consecutive Monday evenings at the Aurora Lecture Theatre in the UTAS IMAS waterfront building. The

lectures are still available online via UTM Live stream (<http://livestream.com/UniversityofTasmania/climate101>). The lecture series attracted 78 registrants from multiple educational institutions.

The speakers were Prof Nathan Bindoff, “How do we know the climate is changing and the role of humans”; Dr Andrew Lenton, “The global carbon cycle: changes and impacts”; Dr Stephanie Downes, “Observing and modelling the ocean and atmosphere”; and Dr Mark Curran, “Reconstructing our climate history from ice cores”.

Sea ice view tool training

During the reporting period, services were provided utilising the Sea Ice View Tool for operational use on-board Antarctic-bound vessels, including *RSV Aurora Australis*, *l’Astrolabe*, *RV Xue Long* and a commercial fishing operator. 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 Japan Maritime Self-Defence Force (*Shirase*) and the Australian Marine National Facility (*RV Investigator*). A collation of all these reports is available in the fifth edition of the Season’s Sea Ice Report edited by Dr Jan Lieser and produced in June 2016.

2.3 SME Engagement

There was active engagement with the consulting company SGS Economics and Planning, who are a formal Other Participant in the ACECRC.

The ACECRC also continues to be an active contributor to the Tasmanian Polar Network, most recently (2016/17) with Prof Tony Worby being elected to the TPN committee.

During the reporting period, services were provided utilising the Sea Ice View Tool for operational use on-board Antarctic-bound vessels, including *RSV Aurora Australis*, *l’Astrolabe*, *RV Xue Long* and a commercial fishing operator. 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 Communications and Utilisation

The ACECRC undertook a wide variety of activities to communicate our research outcomes to maximise awareness and uptake of our scientific work. Outreach activities have taken place with elected representatives, policy makers and the public, as well as within the science community. These included:

- Briefings to politicians and representatives across all levels of government;
- Public lectures, school visits, and science festivals;

- Regular review with key government departments such as Department of Environment and Energy, and Department of Industry, Innovation and Science, commercial participants, and ACECRC's essential and other research participants; and
- The Annual General meeting was held on 17 November 2015 with a BoM representative and the Tasmania Polar Network Chair present.

Strategies for ensuring uptake by end-users included:

- Media releases and briefings to journalists
- 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 ACECRC 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;
- An ACECRC consultative draft of the Ocean Fertilisation position analysis was presented at a second research user forum on 19 November 2015 at the Canberra Shine Dome;
- 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 policy makers nationally and internationally);
- Implementing strategies to measure uptake (for example downloads of reports).

Key Events

Canberra Research User Forum: The ACECRC held its second Canberra Research User Forum for 2015 on 19 November at Shine Dome. The event, held in the weeks leading up to the COP21 meeting in Paris, was attended by around 45 departmental representatives. During the morning session, researchers presented a consultation draft of the ACECRC's *Ocean Fertilisation Position Analysis*. In the afternoon session, Dr Steve Rintoul presented an overview of what climate scientists have learned since the IPCC's AR5 was finalised in 2013, including an overview of recent Australian research on thinning of the Totten Glacier.

Climate 101: In May and June 2016, ACECRC hosted a 4-part lecture series entitled *Climate 101* open to science teachers and those involved in science education and communication. The speakers were Prof Nathan Bindoff, Dr Andrew Lenton, Dr Stephanie Downes, and Dr Mark Curran. More details:

<http://acecrc.org.au/climate101/>

ACECRC Symposium: Preparations were well underway toward the end of the reporting period for the ACECRC's 2016 Symposium in Hobart on August 4 and 5. The objectives of the Symposium were:

- To strengthen connections between fundamental climate science and user needs
- To discuss the ACECRC's latest climate and ecosystems research in Antarctica and the Southern Ocean
- To highlight important scientific questions for the future
- To foster greater collaboration across the ACECRC's research programs

More details at: <http://www.acecrc.org.au/2016-ace-crc-symposium>

Key Publications

Position Analysis: Ice Cores and Climate: In September 2015, the ACECRC released a 44-page Position Analysis entitled *Ice Cores and Climate*. The publication was produced under the supervision of Dr Tasvan Ommen and other palaeoclimate scientists at the ACECRC, the Australian Antarctic Division and the Institute for Marine and Antarctic Studies. The booklet explores several recent discoveries in ice core climate science as well as future objectives, with a special focus on Australian-led palaeoclimate initiatives through the ACECRC. The analysis aims to inform Australian government and the community about the current knowledge of ice core science in Antarctica and to identify issues for consideration in policy development. It is available from the publications section of the ACECRC website.

Position Analysis: Ocean Fertilisation

In February 2016, the ACECRC released its *Ocean Fertilisation Position Analysis*. Produced under the supervision of Assoc Professor Andrew Bowie and Prof Tom Trull, the purpose of the booklet was to inform Australian federal and state governments and the broader community about the growing pressure to use the oceans for geoengineering in general and ocean fertilisation specifically; to provide an update on research concerning ocean fertilisation; and to identify issues for consideration in science and policy development. It is available from the publications section of the ACECRC website.

ACECRC Science Highlights: Preparations were underway during the reporting period for a 24-page *Science Highlights* publication for release at the ACECRC Symposium in August 2016. The document is intended to serve as a broad overview of the ACECRC's key scientific milestones during its 25-year history.

Future Fire Danger Report: The Climate Futures group released its future bushfire risk for the state of Tasmania to 2100 in mid-December. The report, prepared for the State Emergency Service and Tasmanian Fire Service, presented the first fine resolution climate projections (~10km) for Tasmania from global-scale climate models. Among its key findings were that Tasmania could expect roughly double the fire danger over twice the area of land by the end of the century. The report is available on the ACECRC and Climate Futures websites under "Publications".

Potential Impacts of Climate Change on the Victorian Alpine Resorts: This report examines 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. It was completed and presented to the Alpine Resorts Coordinating Council during the reporting period.

Media Highlights

The ACECRC achieved a historically high Australian media profile during 2015/16, a year that offered a variety of opportunities for public engagement on topical and newsworthy issues. Working closely with our partners, the ACECRC worked to maximise news coverage opportunities in line with approaches outlined in the communications strategy. The following is a summary of key news stories during the period.

Future Fire Danger Report: The launch of this report, which coincided with the beginning of the fire season, received strong coverage in the Australian media, including a front page story in The Mercury.

- [Climate report says Tasmanian fire danger days set to soar](#), The Mercury, 14 December 2015
- [Tasmanian bushfire risk 'double' by 2100 if climate emissions continue at current rate: report](#), ABC News, 14 December 2015

HEOBI Voyage: CSIRO's RV *Investigator* departed Fremantle in January research the link between active volcanoes on the seafloor and the mobilisation of iron. The ACECRC worked with staff from MNF and IMAS on publicity coordination. ACECRC voyage co-chief scientist, Assoc Prof Andrew Bowie appeared in stories across a number of media outlets. The voyage also received considerable international attention when the videographer on board, Pete Harmesen, captured first-ever footage of the Big Ben volcano on Heard Island erupting.

- [Investigator voyage to explore the iron-deficient Southern Ocean](#), Fairfax Media, 07 January 2016
- [Volcanoes may play role in ocean's health](#), News.com.au (AAP), 07 January 2016
- [Major IMAS Investigator voyage to study impact of submarine volcanoes on ocean ecosystems](#), CSIRO Blog, 07 January
- [Video interview with Assoc Prof Andrew Bowie on board RV Investigator](#)
- [Rare glimpse of erupting Australian sub-Antarctic volcano](#), BBC News Online, 02 February 2016
- [Dramatic Australian volcanic eruption captured on film](#), Fairfax Media, 04 February 2016
- [IMAS Investigator voyage seeking link between submarine volcanoes and ocean life](#), IMAS Media Release, 07 January 2016

Kerguelen Axis Marine Science Voyage: The Kerguelen Axis Marine Science Voyage departed in January 2015, with publicity efforts coordinated jointly by personnel from ACECRC, AAD and IMAS. The voyage received satisfactory national news coverage, however publicity efforts faced an additional challenge due to simultaneous publicity activities for the HEOBI voyage. A website was set up at <http://k-axis.voyage> where ACECRC scientists posted regular blog updates from the ship.

- [Video of Andrew Constable](#), Youtube, 06 January 2016
- [Australian scientists embark on wildlife mission](#), Sydney Morning Herald, January 10, 2016
- [Antarctic scientists head to biological hotspot studying climate change in Southern Ocean](#), January 10, 2016

IPICS 2016: The ACECRC and AAD jointly hosted the International Partnerships in Ice Core Sciences conference from 7-11 March 2016, with the ACECRC leading communications. Communications activities were especially successful in building awareness and support for the million-year ice core drilling project.

- [Interview with IPICS Co-Chair Ed Brook](#), ABC Radio National Breakfast, 11 March 2016
- [Drilling for history where no-one has stood: the act of science in Antarctica](#), Adam Morton, The Sunday Age, 6 March, 2016

- [*Ancient Ice Could Help Explain Why Earth's Climate Is Warming*](#), Brian K Sullivan, Bloomberg, 14 March 2016
- [*Million-year-old ice the 'holy grail' of climate research in Antarctica*](#), Peter Carlyon [ABC News Online](#), 7 March 2016
- [*Three million euro laser machine brought in to search for world's oldest ice in Antarctica*](#), Felicity Ogilvie, [ABC PM](#), 7 March 2016
- [*Chasing ice: how ice cores shape our understanding of the ancient climate*](#), [Tas van Ommen](#), The Conversation, 7 March 2016
- [*Climate scientists step up search for 'holy grail' of million-year-old ice*](#), Michael Slezaik, The Guardian, 9 March 2016
- [*Three decades of ice core science with Dorthe Dahl-Jensen*](#), Michael White, ForecastPod, 26 February 2016
- [*Tasmania big player in Antarctic science*](#), Michelle Wisbey, The Examiner, 12 March 2016

Williams River catchment reconstruction: The ACECRC was active in promoting the findings of a [paper](#) in Hydrology and Earth System Sciences in May. The study uses climate data from Antarctic ice cores to reconstruct a 1,000-year rainfall history of the Williams River catchment, which is a major source of water for the Newcastle region in NSW. The paper, which builds on the East Australian drought reconstruction work of Dr Tessa Vance from 2014, is the world's first study to use data obtained from Antarctic ice cores to provide catchment specific climate information for use by water resource managers – and suggests that Newcastle's exposure to drought and flood risk is higher than previously estimated. Publicity activities were jointly coordinated by the ACECRC and Newcastle University, with assistance from the AAD's communications team.

- [*Antarctic ice cores reveal risks for water supply*](#), ACECRC Media Release
- [*Scientists use Antarctic ice to find 1000-year-old climate record for Newcastle region*](#), Felicity Ogilvie, ABC PM
- [*Researchers use 1000-year-old Antarctic ice sample to study Williams River weather patterns*](#), Amy De Lore, Newcastle Herald

Early 2016 sea ice retreat: Sea ice remained a major area of interest for the national and international media during the reporting period. The ACECRC's sea ice team led national coverage of the unusually early breakup and retreat of Antarctic sea ice. The ACECRC's Dr Tessa Vance was also cited on a paper in Nature Climate Change reviewing the longer-term trends in Antarctic sea ice distribution, along with an associated piece for The Conversation.

- [*Sea ice record retreat has Antarctic scientists worried for wildlife*](#), climate, Ted O'Connor and Elise Fantin, ABC News
- [*Antarctic sea ice at record low two years after record high*](#), Matthew Denholm, The Australian

Other notable articles:

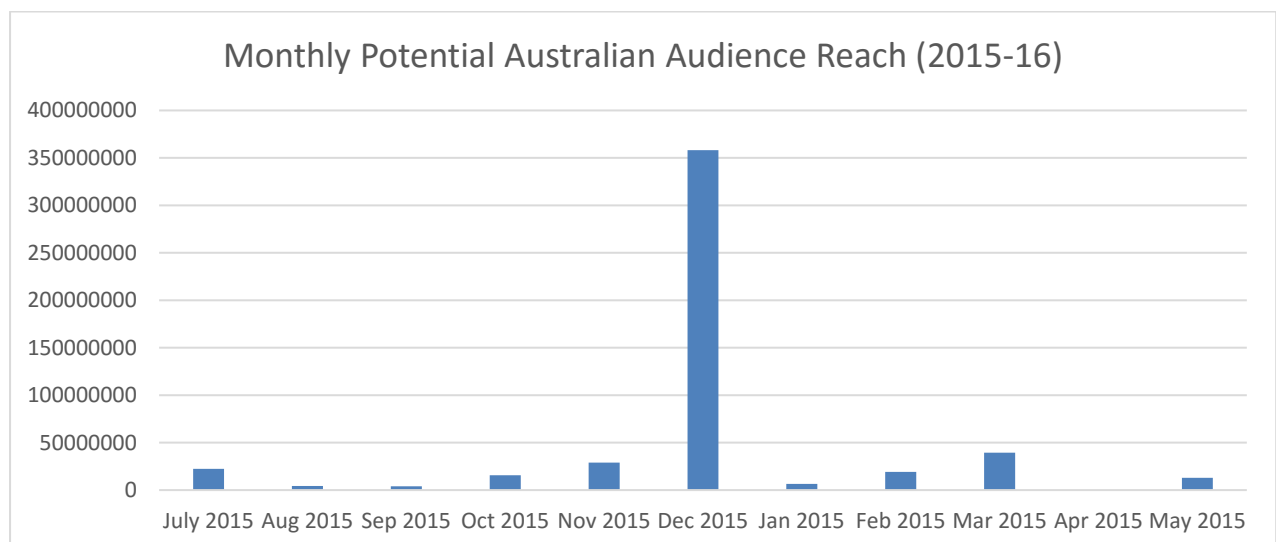
- [*China and Australia to share Antarctic research to better forecast sea ice conditions*](#), ABC News, 9 Nov 2015
- [*Understanding Future Fire Danger*](#), Tom Remenyi and Rebecca Harris, Asia Pacific Fire Magazine
- [*China shows intentions to be key Antarctic player - for science or resource?*](#) Michael Atkin, ABC 7:30, 20 January 2015

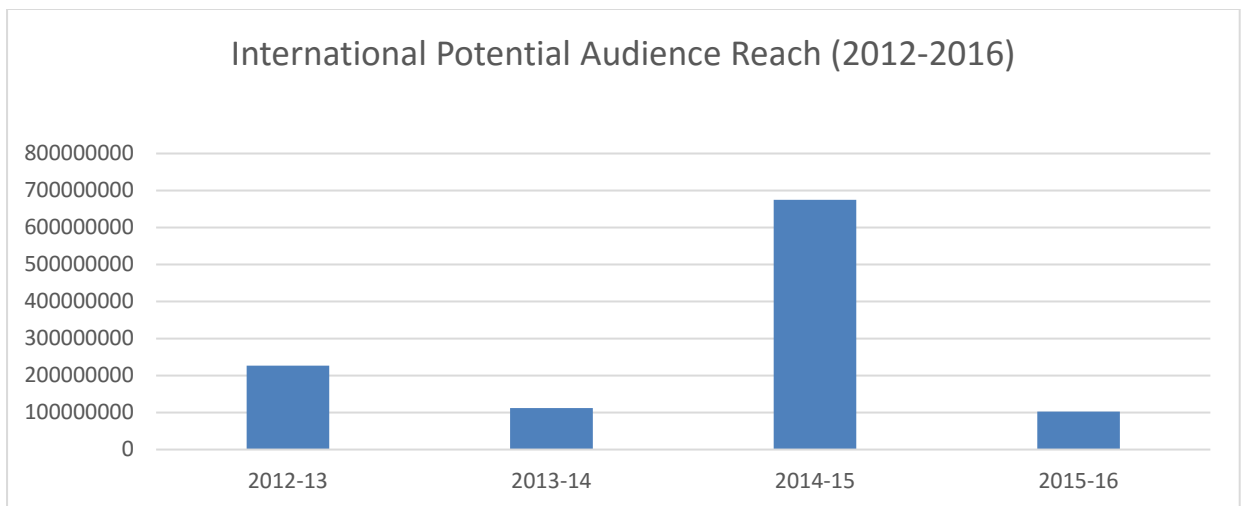
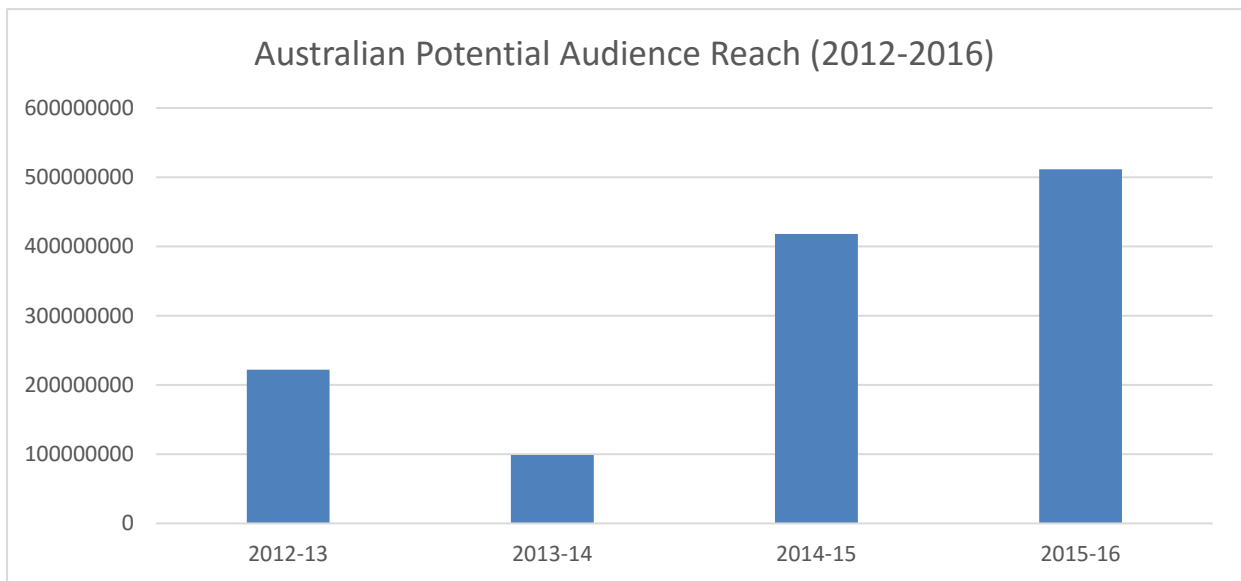
- [Seals help show how melting ice shelves in East Antarctica affect deep ocean.](#) Genele Weule, ABC News, 24 August 2016
- [What lies beneath Antarctica's ice? Lakes, life and the grandest of canyons.](#) Christine Dow, Felicity Graham and Sue Cook, The Conversation, 18 July 2016
- [#TalkAboutIt: Climate change sceptics versus the scientists.](#) Clara Tan, ABC Radio Australia
- [Australian Antarctic expeditions prepare to journey south for fast ice project.](#) Bruce Munster, The Mercury, 22 October 2015
- [NASA says Antarctica has enough new snow to counteract ice loss in other parts of continent.](#) news.com.au, 6 November 2015

Media Profile

The ACECRC's Australian media profile grew strongly during the reporting period, in large part through interest in research activities linked to the work of the Climate Futures and palaeoclimate groups. Coverage of the ACECRC's work spiked significantly in December 2015, when reporting on the Future Fire Danger Report set a new record monthly audience reach for the ACECRC. Estimated audience reach for this story in the national media almost doubled the ACECRC's previous record, set in May 2015 during the COMNAP Sea Ice Workshop in Hobart. Another smaller spike in audience reach was achieved in May 2016, linked to coverage around the search for the world's oldest ice core, as part of the IPICS Second Open Science Conference. The IPICS conference delivered the ACECRC its highest spike in international audience reach during the reporting period, however overall international news reach was below the previous period.

The audience reach figures provided below from the Meltwater media monitoring service, are an estimate of the total potential audience for stories mentioning the ACECRC and/or its staff members. Figures are calculated using an industry standard model based on publicly available circulation data, and are generally considered a more reliable measure of impact than total story mentions.





Online communications

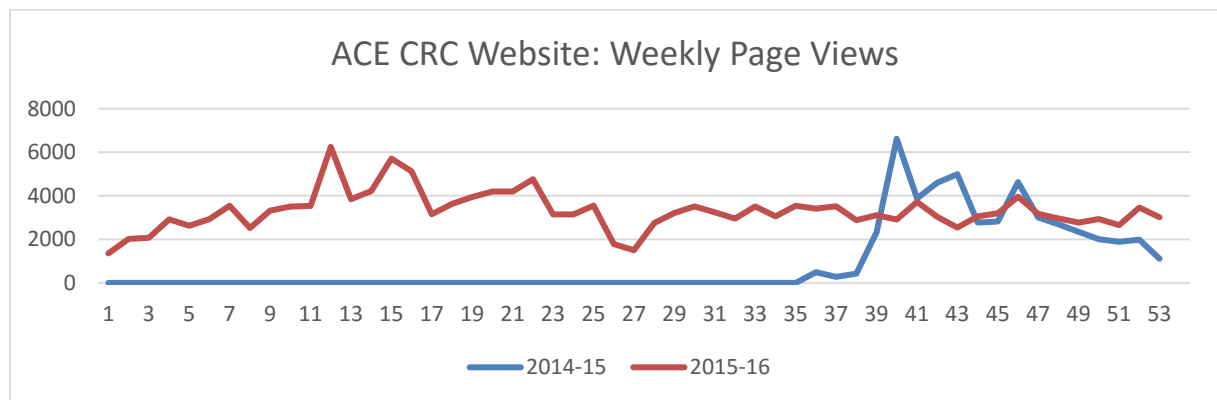
The ACECRC was actively managing, or developing, the following web domains during the reporting period:

- <http://www.acecrc.org.au>
- <http://www.climatefuture.org.au>
- <http://www.ipics2016.org>
- <http://k-axis.voyage>
- <http://www.measo2018.aq>

ACECRC Website: Attracting repeat visitors by regularly renewing and updating content was a key focus during the reporting period, with satisfactory traffic results that have met or exceeded targets. The ACECRC communications strategy sets out a target of 20% year on year growth in visitor volume for the website. Whilst web traffic statistics performed strongly over the reporting period, there is insufficient data to perform a satisfactory comparison with 2014-15 since the new site had only been in operation for 3 months of the previous reporting period.

Site metrics show that job and internship advertisements remained the single greatest generator of site visitation. The site experienced its largest influxes of visitors

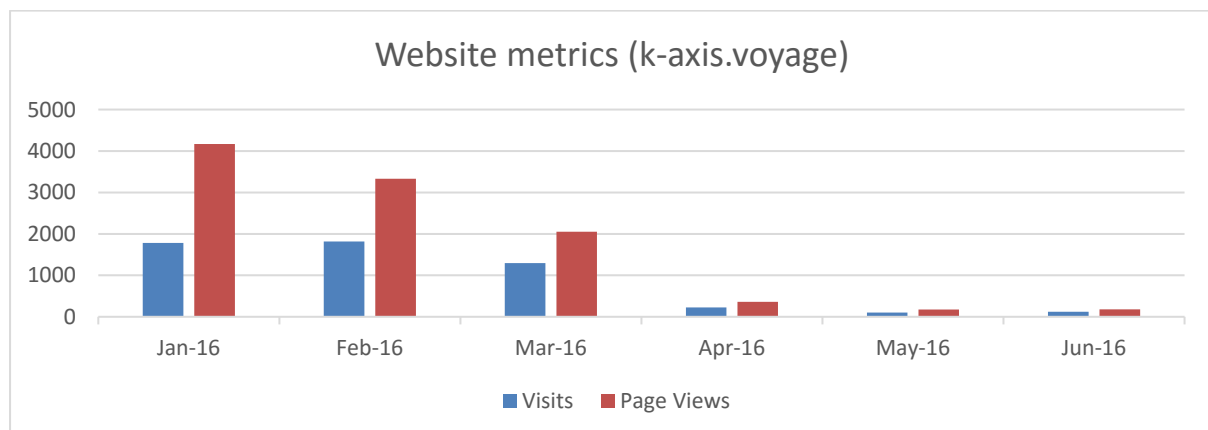
during September and October 2015, coinciding with a campaign to promote the inaugural ACECRC Internship Program. The internships page recorded the highest daily page views since the site's launch, totalling 1,131 on 17 September 2015, with a total number of views at 5,989.



Metric	Total	Daily
Page views	174,483	473
Sessions	8,069	89
Average Session Duration	1:38	N/A
Pages/Session	5.33n	N/A

Climate Futures: During the reporting period, the ACECRC commenced development for a new standalone website for the Climate Futures group. The site, containing details of Climate Futures projects, media releases and other materials, was planned for launch at the ACECRC Symposium. See <http://www.climatefutures.org.au>.

Kerguelen Axis Marine Science Voyage: Communications staff from the ACECRC and Antarctic Division collaborated on a website to promote the Kerguelen Axis Marine Science Voyage on board *RV Aurora Australis* in January. The site includes media releases and blog updates from staff on board, and attracted strong traffic in January-February during the voyage. See: <http://k-axis.voyage>



Marine Ecosystem Assessment for the Southern Ocean (MEASO 2018): The ACECRC has established a website to act as a central information point for the planned MEASO 2018 conference hosted by the ACECRC. The site development remains in the early stages. See: <http://www.measo2018.aq>

International Partnerships in Ice Core Sciences IPICS 2016: The ACECRC was responsible for establishing and maintaining the website for the IPICS 2016 conference in March. The site is no longer actively managed, and will be archived after March 2017. See <http://www.ipics2016.org.au>

Performance Against Communications Goals

The ACECRC developed a new *Communications Strategy* in 2014-15 to provide a framework for internal and external communication activities. The document outlines a comprehensive set of 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). The ACECRC is meeting or exceeding most key goals set out in the strategy.

3.2 Intellectual Property Management

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

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

In particular, the ACECRC 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 ACECRC 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 ACECRC remains a very significant contributor to the IPCC Assessment process. The ACECRC 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. ACECRC scientists are engaged in discussions on the timing and process for the Sixth Assessment Report which is due to be finalised in time for the first UNFCCC global stocktake when countries will review progress towards their goal of keeping global warming to well below 2°C while pursuing efforts to limit it to 1.5°C.

Two areas of ACECRC 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 ACECRC 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 reports are being utilised by a wide variety of users, including State and local government, and private businesses including consulting firms.

The ACECRC 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 ACECRC.

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

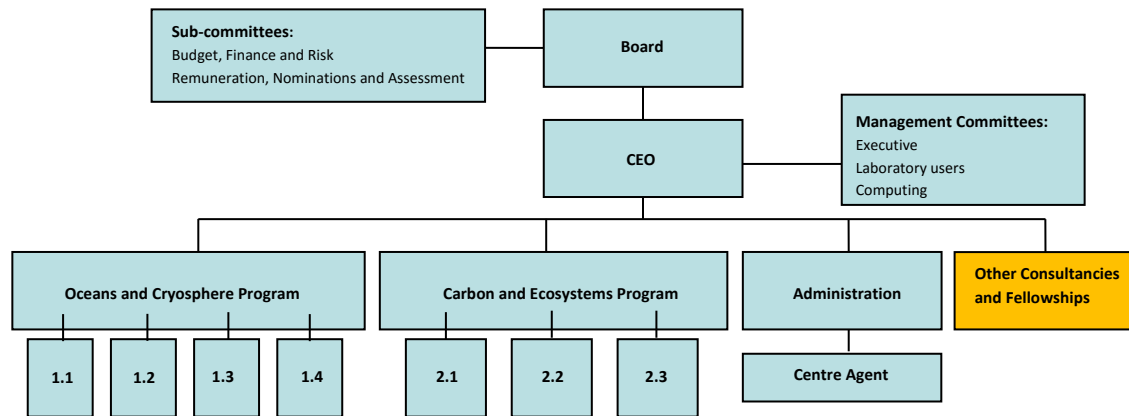
The ACECRC does not hold any patents in Australia or overseas.

4 Resources

4.1 Governance – board, committees and key staff

The ACECRC is an unincorporated joint venture comprising of 7 core and 14 supporting partners, or 'other participants'. The participating organisations have a Centre Agent agreement with UTAS which provides that UTAS acts as the legal entity for the ACECRC in respect of such matters as contracts, financial transactions and taxation. The seven Essential Participants are bound by the Participants Agreement, and the Other Participants Agreements set out the duties and commitments of the remaining 14 parties.

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



BOARD #
 Katherine Woodthorpe – Chair
 Tony Coleman – Independent
 Gordon Hagart – Independent
 Nick Gales – AAD
 Graham Hawke – BoM
 Ken Lee – CSIRO
 Brigid Heywood – UTAS
 Andrew Wells – UTAS**
 Steven Kennedy – Dept. of Environment **
 Tony Worby – Ex officio
 Gwen Fenton – Ex officio
 Mark Kelleher – Board Secretary
 ** Resigned from Board
 October 2015

MANAGEMENT TEAM ~
 Tony Worby – CEO (Chair)
 Mark Kelleher – Deputy CEO
 David Reilly – Public Affairs Mgr
 Wenneke ten Hout (0.8) – Admin Mgr
 Claire Rutherford (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)
 Nils Jansen – 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
 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) one representative of the Australian Department of Environment and Energy, (v) two persons independent of the Participants and (iv) the CEO and the AAD Chief Scientist who are ex-officio members.

During the reporting period, Prof Brigid Heywood commenced on the Board in November 2015 after Prof Andrew Wells acted as Board representative for the University of Tasmania. Dr Tony Fleming retired as Director of the Australian Antarctic Division and Dr Nick Gale was appointed as Director of the Australian Antarctic Division in July 2015. Dr Gwen Fenton was appointed as the new AAD Chief Scientist and ex-officio member on the ACECRC Board. The Department of the Environment and Energy was represented by Mr Steven Kennedy at the August 2015 meeting; however he subsequently moved into another position in the Department of Industry, Innovation and Science. The Department of the Environment and Energy did not have a representative on the Board for the remainder of the 2015/16 reporting period; however that situation has been resolved in 2016/17 with the appointment of Mr Malcolm Thompson.

Board meetings are held every quarter. During this reporting period, meetings were held on 18 August 2015, 17 November 2015 (including Annual General Meeting), 24 February 2016 and 13 May 2016.

Board Members (in alphabetical order)

Name	Role	Key Skills	Independent/ Organisation	Number of meetings
Mr Tony Coleman	Board Member	<ul style="list-style-type: none"> - 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 Gwen Fenton	Ex-Officio	<ul style="list-style-type: none"> - High level science planning and coordination experience - High level national and international experience in science and policy - High level science expertise in stable isotope analysis of marine food webs 	Australian Antarctic Division (Essential Participant)	4/4
Dr Nick Giles	Board Member	<ul style="list-style-type: none"> - 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 Hagar	Board Member	<ul style="list-style-type: none"> - Extensive experience in financial services including investment - Extensive experience in leadership and management at senior levels 	Independent	4/4
Mr Graham Hawke	Board Member	<ul style="list-style-type: none"> - 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
Prof Brigid Heywood	Board Member	- Extensive experience in research leadership and management at senior & institutional levels - Broad and extensive expertise in biological sciences	University of Tasmania (Essential Participant)	3/4 (commenced November 2015)
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)	4/4
Mr Steven Kennedy	Board Member	- High level management skills - Extensive experience in government and public policy	Department of Environment (Essential Participant)	1/4 (resigned September 2015)
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

Name	Role	Key Skills	Independent/ Organisation	Number of meetings
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)	1/4 (until October 2015)
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	ACECRC	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 2 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 21 October 2015 and 6 April 2016. 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 ACECRC Board Chair, and has a majority of independent members. The primary objective of the Nominations, 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 July 2015 to review the CEO's KPIs.

The Executive Committee

The ACECRC 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 4 August 2015, 3 November 2015, 10 December 2015, and 5 April 2015. At the Executive meeting of 10 December 2015, it was decided to invite project leaders to future Executive meetings, these have not been included in the table below.

Name	Role	Key Skills	Organisation
Prof Nathan Bindoff	Project Leader 1.1, Climate Futures; Director Tasmania 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	ACECRC
Dr Kevin Michael	IMAS Representative	Education	IMAS
Mr David Reilly	Public Affairs Manager (from September 2014)	Communications/Media	ACECRC
Dr Stephen Rintoul	Program Leader, Oceans and Cryosphere Program	Researcher	ACE CRC/CSIRO
Dr Jason Roberts	Researcher, Co-chair ACECRC Computing Committee	Research/computing	ACE CRC/AAD

Name	Role	Key Skills	Organisation
Ms Wenneke ten Hout	Administration Manager	Administration	ACECRC
Prof Thomas Trull	Program Leader, Carbon and Ecosystems Program	Researcher	ACE CRC/C SIRO
Dr Tasvan Ommen	Program Leader, Oceans and Cryosphere Program	Research	ACE CRC/AAD
Dr Tony Worby	CEO	Management/Governance	ACECRC

Laboratory Users Committee

The Laboratory Users Committee represents the ACECRC laboratory's broad multidisciplinary user community and advises management on all issues affecting users of the facilities. Ms Pamela Quayle is Chair for this committee. During the reporting period, the laboratory users' committee met on 6 July 2015 and 13 October 2015 but due to a busy field season with key staff away no further meetings were held in early 2016. At least one person of each research group attends the meetings with any students that work in the laboratories also invited.

Name	Role	Organisation
Mr Toby Bolton	Laboratory Manager	IMAS
Mr Nils Janse	Laboratory technician – lab 304	IMAS
Dr Diana Davies	Researcher – lab 308	ACECRC
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	ACECRC
Dr Adam Tverrow	Researcher – lab 310	ACECRC
Dr Piervander Merwe	Researcher – lab 306	ACECRC

Computing Committee

The ACECRC Computing Committee supports the science and education programs of the ACECRC by providing advice on information technology, infrastructure and management. The ACECRC Computing Committee advises the ACECRC Executive Committee and CEO. The ACECRC Computing Committee will meet every quarter two weeks prior to the scheduled ACECRC Executive meetings or more frequently as necessary.

Member	Role	Organisation
Mr Antony Cave / Mr Tze Feng Low	UTIAS II representative	UTIAS
Dr Stuart Comey	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	UTIAS

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%
Mr David Reilly	Public Affairs Manager (from September 2014)	ACE CRC	100%
Dr Stephen Rintoul	Program Leader – Oceans and Cryosphere	ACE CRC / CSIRO	50%

Staff Member	Role	Organisation	% Time
Ms Wenneke ten Hout	Administration Manager	ACECRC	80%
Prof Tom Trull	Program Leader – Carbon and Ecosystems	ACECRC/CSIRO	50%
Dr Tas van Ommen	Program Leader – Oceans and Cryosphere	ACECRC/AAD	60%
Dr Guy Williams	Project Leader – project 1.3	ACECRC/IMAS	50%
Dr Tony Worby	CEO	ACECRC	100%
*Prof Ian Allison is an Honorary Research Professor			

4.2 Participants

The commitment of the seven core partners to the ACECRC remains strong.

The ACECRC has formal partnership agreements with two Chinese institutions and a Memorandum of Understanding with Shanghai Ocean University, and the Chinese National Marine Environmental Forecasting Centre (NMEFC) in Beijing. This agreement with NMEFC is a first step in building complementary arrangements for sea ice forecasting – an important and growing part of the logistics associated with scientific voyages conducting our research programs as well as station resupply. This agreement demonstrates the benefits of the collaboration approach that is at the heart of the CRC model.

Our two international core partners, NIWA and AWI, are closely engaged with the ACECRC. A new ACECRC/AWI visitor exchange program is being developed and will commence next reporting period. A NIWA representative participated in the ACECRC Symposium in August 2016.

ACECRC 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
Bureau of Meteorology (BoM)	Essential	92 637 533 532	Government
CSIRO Oceans and Atmosphere Flagship (O&A)	Essential	41 687 119 230	Government

Participant's name	Participant type	ABN or ACN	Organisation type
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 (ILIS), Hokkaido University, Japan	Other	NA	Research institute
Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (IEGOS), France	Other	NA	Research institute
National Institute of Polar Research (NIPR), Japan	Other	NA	Government research institute
Old Dominion University	Other	NA	University

Participant's name	Participant type	ABN or ACN	Organisation type
SGS Economics and Planning Pty Ltd	Other	25 007 437 729	Industry
Tokyo University of Marine Science and Technology (TUMSAT)	Other	NA	University
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

The ACECRC signed an agreement with the Tokyo University of Marine Science and Technology (TUMSAT) taking effect July 2016. This “Other Participant” has research interests that align with the ACECRC in the areas of marine biology, physical oceanography, ocean acoustics and marine biogeochemistry. TUMSAT owns the 93m training and research vessel *Umitsuka-maru*, which has been used by the Japanese National Institute for Polar Research for marine research in the Southern Ocean in recent years. This formal partnership will create opportunities for ACECRC researchers to participate on these voyages, bringing valuable marine science capacity to our program.

4.3 Collaboration

Currently, the ACECRC collaborates with 100 domestic and international organisations. Of these, there are 27 Australian, 3 New Zealand, 9 Asian, 24 North American, 1 South American, and 36 European.

Of the 27 domestic collaborations, there are 6 Australian Government Institutions, 5 State Government Institutions, 12 universities, 1 industry/private sector, and 3 others.

Of the 73 international collaborators, there are 36 universities, 2 from industry/private sector, and 35 research institutions/organisations.

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

Hobart has been the centre of collaboration activities with three major conferences held during the reporting period. Each one had major involvement by the ACECRC as a sponsor and/or organiser.

The 'Species on the Move – Detection, Impacts, Predictions & Adaptation Conference' was held at the Hotel Grand Chancellor from 9-12 February 2016. The conference attracted scientists of multiple fields to better understand how a changing climate is affecting natural ecosystems. The ACECRC sponsored this conference which was attended by 277 Australian and international delegates.

More than 200 climate scientists from around the world gathered in Hobart to attend a major conference focusing on ice core science 7-11 March 2016. The International Partnerships in Ice Core Sciences (IPICS) Second Open Science Conference brought scientists from 22 countries to Tasmania; the home of Australia's Antarctic programme and gateway to Antarctica. The conference was co-hosted by the Australian Antarctic Division and the Antarctic Climate and Ecosystems Cooperative Research Centre with conference chair, Dr Tasvan Ommen.

The conference brought together the world's top experts in ice core science and drilling technology for a week of scientific presentations and planning discussions. One of the major priorities for the conference was progress toward finding and drilling the world's oldest ice. The oldest ice core retrieved from Antarctica to date is about 800,000 years old, which falls just short of a major shift in global ice age cycles that occurred about a million years ago.

The fourth 'Oceans in a High CO₂ World' Conference was held in Hobart 3-6 May 2016 with the ACECRC as a key sponsor. The conference built on three previous symposia and offered the worldwide community of scientists working to understand ocean acidification an opportunity to share their research results and develop new research collaborations. Over 350 researchers, students and government and industry representatives attended the fourth symposium in the series. The ACECRC Carbon team was well presented with Professors Tom Trull and Phil Boyd and Dr Bronte Tilbrook as committee members.

4.4 Financial Management

The ACECRC completed the 2015-16 financial year with a cash balance of \$4,322k. This reflects the advance of Commonwealth funds of \$2,500k from 2016-17 financial year as well as the \$495k carried forward from the previous funding round. The remaining amount of just over \$1 million relates mainly to changes in profile of expenses as a result of timing of voyages and impacts of these on related field trip and post-voyage expenditure. The overall five-year program remains on track.

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

<i>Participants</i>	<i>Table 1(a) Number (FTE) of Staff in-kind Contributions</i>	
	<i>Amount Contributed (FTE)</i>	<i>Amount Committed (FTE)</i>
Australian Antarctic Division	24.0	28.6
University of Tasmania	6.1	6.9
Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS)	0.7	1.2
SGS Economics and Planning Pty Ltd	-	0.2

<i>Participants</i>	<i>Table 1(b) Non-staff in-kind Contributions</i>	
	<i>Amount Contributed (\$'000)</i>	<i>Amount Committed (\$'000)</i>
Australian Antarctic Division	4,712	6,350
Institute of Low Temperature Science (ILTS), Hokkaido University	340	345
Chinese Academy of Meteorological Science (CAMS)	12	13

Shortfalls in staff in-kind contributions were relatively minor, and did not impact the program or delivery of the ACECRC.

The main variance in non-staff contributions was associated with lower station support requirements from Australian Antarctic Division for the ICECAP project. This was more than offset by the value of higher levels of ship-time (\$2,057k) for the K-Axis voyage and HEOBI research project provided by the CSIRO (on the *RV Investigator*) and other ocean activity by the First Institute of Oceanography (\$900k).

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

Table 1

	Totals for 2015-16				Projected Totals for 5 years			
	Actual	Agr'mt	Diff	%Diff	Actual/Proj	Agr'mt	Diff	%Diff
Employee Expenses	3,534	3,467	67	2	17,828	16,642	1,186	7
Supplier Expenses	1,204	2,144	-940	-44	5,900	7,680	-1,780	-23
Capital	301	512	-211	-41	1,821	973	848	87
Other Expenses	0	0	0	0	200	753	-553	-73
TOTAL EXPENSES	5,039	6,123	-1,084	-18	25,749	26,048	-299	-1

The variations in expenses in 2015-16 arose due to the following factors:

- The underspend in supplier and capital expenses reflects the impact of deferral of post-voyage analytical activity and associated equipment purchases until the 2016-17 financial year, due to changes in timing of the K-Axis voyage.
- Expenditure on capital items for the five years is projected to be higher than that in the Commonwealth Agreement due to 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 approximately \$1,000k from supplier expenses to capital over the five-year term.

Expenses for the 5 year term are now forecast to be \$299k below the agreement level. This is offset by an equivalent reduction in other firm income – associated with no longer requiring the use of an overdrift facility to cover previously forecast deficits in the middle years of this term.

Additional external and interest income totalling \$254k, along with \$932k 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 \$1,186k.

5 Other activities

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

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. During the

reporting period, stage 2 of this project was finalised and a final report was submitted in combination with stage 1.

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

An Assessment of the Viability of Prescribed Burning as a Management Tool under a Changing Climate: This project is funded by the Department of Police and Emergency Management under the State Emergency Service. This project will identify the future viability of prescribed burning as a management tool for mitigating bushfire risk under climate change.

High Resolution Reanalysis for Tasmania Project: This project is funded through the Department of Police and Emergency Management. This project will generate a reanalysis dataset for Tasmania at 1.5km grid spacing with hourly time steps for a 25-year period, producing a high-resolution meteorological and climatological dataset to inform emergency management and disaster risk activities in Tasmania. The Bureau of Meteorology (BoM) has agreed to produce the reanalysis for Tasmania for ACECRC, forming part of a wider project that will generate a nationwide Australian reanalysis product at a lower 12 km resolution. In the first phase of the project (Stage 1), the Bureau of Meteorology will provide a 5-year high-resolution NWP climatology for Tasmania at a spatial resolution of about 5 km and at an hourly time step. Both ACECRC and the Bureau of Meteorology have declared their intention to provide the 25-year high-resolution reanalysis at 1.5 km resolution for Tasmania (Stage 2) if the Tasmania State Emergency Service provides the required additional funding in 2016. Project partners will evaluate the dataset, both at the broad scale and for specific sub-regions and time periods in considerable detail to ensure the quality of the data, with the resulting approximately 70 terabytes of data stored by TPAC. Partners will engage with stakeholders to highlight the implications of the results for emergency management in Tasmania. On completion, project and technical reports will be presented, and peer-review journal articles prepared.

Tasmanian State Natural Disaster Risk Assessment: The 2016 Tasmanian State Natural Disaster Risk Assessment (TSNDRA) report provides a revised assessment of the state-level risks associated with bushfires, floods and coastal inundation, severe storms, heatwaves, earthquakes, landslides and human influenza pandemics in Tasmania. Building on the previous TSNDRA report published in 2012, and utilising up-to-date research and information from the Climate Futures program, the report reassesses Tasmania's current risk from natural hazards, and provides a series of new risk treatment options for how the State can treat and reduce risk, produced in collaboration with the emergency management sector, Government agencies and departments, and industry partners. The overall aim of the TSNDRA is to contribute to disaster resilience by delivering an increased understanding and awareness of emergency risks affecting the state of Tasmania, and provides a basis to inform decision-making across the Tasmanian emergency management sector, particularly in relation to risk reduction and mitigation activity priorities. The 2016 TSNDRA report has been endorsed by the Tasmanian State Emergency Management Committee (SEMC) as the authoritative state-level natural disaster risk assessment that

Tasmanian Government agencies use to inform the management of state-level risks posed by natural disasters in Tasmania.

Updating Hobart City Council Climate Change Guidelines: This project is funded by the City of Hobart. This project reviewed and provided additional details for the draft technical Climate Change guidelines that give effect to the Council's Climate Change Strategy. The draft guidelines are based on the ACECRC's Climate Future of Tasmania municipal profiles. Two reports were produced detailing the necessary climate variables at suitable intervals up to 2100 using CMIP5 and a background report outlining the methodology behind the climate variables.

During the reporting period, these projects published 9 articles in scholarly refereed journals and 4 technical reports (see below).

Articles in scholarly refereed journals

- Fox-Hughes, P. (2015). "Characteristics of some days involving abrupt increases in fire danger." *Journal of Applied Meteorology and Climatology* 54(12): 2353-2363.
- Harris, R. M. B. (2016). "Adapting to an Uncertain Climate: Lessons from Practice edited by Tago Capela Lourenço, Ana Rovisco, Anne-marie Groot, Carin Nilsson, Hans-Martin Füssel, Leender van Breë, and Roger B. Street." *The Quarterly Review of Biology* 91(1): 79-79.
- Johnson, F., C. J. White, A. van Dijk, M. Ekstrom, J. P. Evans, D. Jakob, A. S. Kiem, M. Leonard, A. Rouillard and S. Westra (2016). "Natural hazards in Australia: floods." *Climatic Change*: 1-15.
- Lechner, A. M., R. M. B. Harris, V. Doerr, E. Doerr, M. Drielsma and E. C. LeFroy (2015). "From static connectivity modelling to scenario-based planning at local and regional scales." *Journal for Nature Conservation* 28: 78-88.
- McDonald, J., P. C. McCormack, A. J. Fleming, R. M. B. Harris and M. Lockwood (2016). "Rethinking legal objectives for climate-adaptive conservation." *Ecology and Society* 21(2).
- McInnes, K L, C. J. White, I D. Haigh, M. A. Hemer, R. K. Hoek, N. J. Holbrook, A. S. Kiem, E. C. J. Oliver, R. Ranasinghe, K. J. E. Walsh, S. Westra and R. Cox (2016). "Natural hazards in Australia: sea level and coastal extremes." *Climatic Change*: 1-15.
- Perkins-Kirkpatrick, S. E., C. J. White, L. V. Alexander, D. Argüeso, G. Boschhat, T. Cowan, J. P. Evans, M. Ekström, E. C. J. Oliver, A. Phatak and A. Purich (2016). "Natural hazards in Australia: heatwaves." *Climatic Change*: 1-14.
- Porfiro, L L, R. M. B. Harris, D. Stojanovic, M. H. Webb and B. Mackey (2016). "Projected direct and indirect effects of climate change on the Swift Parrot, an endangered migratory species." *Emu* 116(3): 273-283.
- Raymond, C. M., A. M. Lechner, M. Lockwood, O. Carter, R. M. B. Harris and L. Gilfedder (2015). "Private land manager capacity to conserve threatened communities under climate change." *Journal of Environmental Management* 159: 235-244.

Technical reports

- Harris, R.M.B. and T Remenyi (2015) A report for Hobart City Council. Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, Australia.
- Harris, R.M.B., T Remenyi, and N.L Bindoff (2016) The Potential Impacts of Climate Change on Victorian Alpine Resorts. A Report to the Alpine Resorts Co-ordinating Council. Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, Australia.
- Fox-Hughes, P., R.M.B. Harris, G. Lee, J. Jabor, M.R. Grose, T.A. Remenyi and N.L Bindoff (2015) Climate Futures for Tasmania future fire danger: the summary and the technical report, Antarctic Climate & Ecosystems Cooperative Research Centre, Hobart, Tasmania.
- White, C.J., T Remenyi, D. McEvoy, A. Tundle, and S.P. Comey (2016) Tasmania State

6 Additional requirements

6.1 Performance review

The Chair of the Board, Dr Katherine Woodthorpe and Prof Tony Worby attended the CRC Advisory Committee Review of the ACECRC on 8 December 2015 in Sydney. The CRC Advisory Committee noted that the ACECRC is meeting all its obligations against the Commonwealth Agreement and is on track to achieve its stated outcome. The Committee also noted that the ACECRC has no known alignment with any of the Industry Growth Centres and requested the ACECRC to provide an update on the ACECRC transition plan.

In July 2016, we received advice from the CRC Programme that revised Programme Guidelines for the CRC Programme were released. In line with the Department's efforts to streamline administrative processes, and in accordance with Part Nine of the revised guidelines, CRC Performance Reviews are no longer required. The Department may commission a review of the ACECRC's performance as necessary and in accordance with the new Reporting and Compliance framework for the CRC Programme.

7 Glossary of Terms & Acronyms

A	
AAD	Australian Antarctic Division
AAS	Australian Antarctic Science Program
ABN	Aurora Basin North
ACECRC	Antarctic Climate & Ecosystems Cooperative Research Centre
AFMA	Australian Fisheries Management Authority
AMOS	Australian Meteorological & Oceanographic Society
ARC	Australian Research Council
ASPI	Australian Strategic Policy Institute
AUV	Autonomous Underwater Vehicle
AWI	Alfred Wegener Institute for Polar Research (Germany)
B	
BoM	Bureau of Meteorology
BAR	Budget, Audit, and Risk Committee
C	
CAMS	Chinese Academy of Meteorological Science (China)
CAREERI	Cold and Arid Regions Environmental and Engineering Research Institute (Chinese Academy of Sciences)
CCAMLR	Convention for the Conservation of Antarctic Marine Living Resources
CO	Carbon Monoxide
CO₂	Carbon Dioxide
COMNAP	Council of Managers of National Antarctic Programmes
COSIMA	Consortium for Ocean Sea Ice Modelling in Australia
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	
DEE	Department of Environment and Energy
DFAT	Department of Foreign Affairs and Trade
DIIS	Department of Industry, Innovation and Science
E	
ENSO	El Niño Southern Oscillation
EPICA	European Project for Ice Coring in Antarctica
F	
FIO	First Institute of Oceanography (China)
G	

GA	Geoscience Australia
GHG	Greenhouse gases
GIS	Geographic information system
GPS	Global Positioning System
H	
HEOBI	Heard Earth Ocean Biosphere Interaction
HPC	High Performance Computing
I	
IACS	International Association of Cryospheric Sciences
ICECAP	Investigating Cryospheric Evolution through Collaborative Aerogeophysical Profiling
IGBP-PAGES	International Geosphere-Biosphere Programme – Past Global Changes
ILIS	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
IP	Intellectual Property
IPO	Interdecadal Pacific Oscillation
IPCC	Intergovernmental Panel on Climate Change
IPICS	International Partnership in Ice Core Sciences
IWC	International Whaling Commission
L	
LEGOS	Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (France)
LGGE	Laboratoire de Glaciologie et Géophysique de l'Environnement
M	
MEASO	Marine Ecosystem Assessment for the Southern Ocean
MESOPP	Mesopelagic Southern Ocean Prey and Predators
MIZ	Marginal Ice Zone
MNF	Marine National Facility
MODIS	Moderate Resolution Imaging Spectroradiometer
MSA	Methane sulfonic acid
N	
NCCARF	National Climate Change Adaptation Research Facility
NCI	National Computational Infrastructure
NIPR	National Institute of Polar Research (Japan)
NIWA	National Institute for Water and Atmospheric Research (New Zealand)
NMEFC	National Marine Environmental Forecasting Centre (China)
NRA	Nomination, Remuneration and Assessment Committee

O	
ONA	Office of National Assessments
ONR	Office of Naval Research
R	
REGS	Research Enhancement Grants Scheme
ROV	Remotely Operated Vehicle
S	
SAM	Southern Annular Mode
SCAR	Scientific Committee on Antarctic Research
SCOR	Scientific Committee on Oceanic Research
SEAPODYM	Spatial Ecosystem and Population Dynamics Model
SGS	SGS Economics & Planning Pty Ltd
SIPEX-II	Sea-ice Physics & Ecosystem Experiment
SME	Small and Medium Enterprises
SOCAT	Surface Ocean Carbon Atlas
SOCOM	Southern Ocean Carbon and Climate Observations and Modeling Project
SOTS	Southern Ocean Time Series
SRI	Special Research Initiative
T	
TPAC	Tasmanian Partnership for Advanced Computing
TSANDRA	Tasmanian State Natural Disaster Risk Assessment
TUMSAT	Tokyo University of Marine Science and Technology
U	
UNFCCC	United Nations Framework Convention on Climate Change
UTAS	University of Tasmania
V	
VUB	Vrije Universiteit Brussel
W	
WHOI	Woods Hole Oceanographic Institution

Appendix 1– list of publications

Book Chapters

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Tozer, C., A. S. Kiem and D. Verdon-Kidd (2015). Establishing the hierarchy of influence of drivers of seasonal rainfall variability in South Australia to inform seasonal rainfall forecasting. The Art and Science of Water - 36th Hydrology and Water Resources Symposium, HWRS 2015, Hobart, Australia, 7-10 December 2015.

Appendix 2– ACECRC PhD students 2015-2016

Commenced in 2015/16

Name	Start Date	Status	Research Program	Project Title	Research Organisation	Country	Expected Completion Date
1. Afleizer, Helene	18/04/2016	FT	Carbon & Ecosystems	Impact of ocean acidification on the availability and toxicity of trace elements and nutrients	UTAS	Australia	October 2019
2. Blanche, Bella	08/02/2016	FT	Oceans & Cryosphere	Detecting human influence in global ocean salinity patterns	UTAS	Australia	August 2019
3. Cimoli, Emilia no	31/03/2016	FT	Oceans & Cryosphere	Hyperspectral remote sensing of Antarctic sea ice algae and benthos using AUV	UTAS	Australia	September 2019
4. Craneburgh, Andrea	01/03/2016	FT	Oceans & Cryosphere	How do standing meanders break the ACC?	UTAS	Australia	September 2019
5. Cyriac, Ajitha	18/11/2015	FT	Oceans & Cryosphere	Eastward flows, ocean mixing and air-sea interaction in the Southeast Indian Ocean	UTAS	Australia	June 2019
6. Dias, Fabio	24/08/2015	FT	Oceans & Cryosphere	Testing of Climate Models and Sea Level Rise Projections using Observations of Ocean Heat Uptake	UTAS	Australia	February 2019
7. Ericson, Jessica	15/10/2015	FT	Carbon & Ecosystems	Using Signature Lipid Analysis to Understand the Biology and Ecology of Antarctic Krill (<i>Euphausia superba</i>)	UTAS	Australia	April 2019
8. Evans, Eleri	08/07/2015	FT	Oceans & Cryosphere	Processes Controlling Iceberg Calving Rates Around Antarctic Margins	UTAS	Australia	January 2019
9. Freyer, Julie n	01/03/2016	FT	Carbon & Ecosystems	Comparative diving physiology and ecology across the Southern Ocean marine predators	UTAS	Australia	September 2019

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

Name	Start Date	Status	Research Program	Project Title	Research Organisation	Country	Expected Completion Date
10. Gamble Rosevear, Madeline	01/02/2016	FT	Oceans & Cryosphere	Fine scale ocean processes driving the basal melting of ice shelves	UTAS	Australia	August 2019
11. Hancock, Alice	1/1/2016	FT	Carbon & Ecosystems	Effects of ocean acidification on associations among Antarctic and SO marine microbes	UTAS	Australia	July 2019
12. Hellesey, Nicole	01/11/2015	FT	Carbon & Ecosystems	Seasonal lipid changes in Antarctic krill in relation to Climate Change	UTAS	Australia	June 2019
13. Huneke, Wilma	19/10/2015	FT	Oceans & Cryosphere	Quantifying Key Physical Processes Responsible for Ocean Warming under Antarctic Ice Shelves	UTAS	Australia	January 2019
14. Kelly, Paige	01/08/2015	FT	Carbon & Ecosystems	Climate Change and Sea Ice Habitats: Modelling effects from plankton to penguins	UTAS	Australia	February 2019
15. Kennedy, Fraser	18/08/2015	FT	Carbon & Ecosystems	Using experimental sea ice tanks and micro sensors to investigate sea ice microbial ecology	UTAS	Australia	February 2019
16. Libaros, Damien	28/08/2015	FT	Oceans & Cryosphere	Determining changes in sea level around Antarctica	UTAS	Australia	February 2019
17. McCormack, Stacey	22/07/2015	FT	Carbon & Ecosystems	Energy Flow in Southern Ocean Ecosystems: Comparing mass balance and size-based approaches	UTAS	Australia	January 2019
18. Patel, Ramkrushnbhai	02/03/2016	FT	Oceans & Cryosphere	The physical and bio-optical structure of Southern Ocean eddies in observations and models	UTAS	Australia	September 2019
19. Perez-Tribouillier, Habacuc	07/10/2015	FT	Carbon & Ecosystems	Quantifying Protactinium, Thorium and Neodymium Isotopes in Southwest Pacific Waters: Elucidating the Oceanographic Controls on these Tracers of	UTAS	Australia	January 2019

Name	Start Date	Status	Research Program	Project Title	Research Organisation	Country	Expected Completion Date
				Circulation, Productivity and Dust Input			
20. Perron, Morgane	02/05/2016	FT	Carbon & Ecosystems	Natural iron fertilisation of oceans around Australia linking terrestrial aerosols to marine biogeochemistry	UTAS	Australia	November 2019
21. Richter, Ole	02/05/2016	FT	Oceans & Cryosphere	Tidal melting of Antarctic Ice Shelves since last glacial maximum	UTAS	Australia	November 2019
22. Schroeter, Ben	01/02/2016	FT	Oceans & Cryosphere	Towards improved modelling of the high southern latitudes	UTAS	Australia	August 2019
23. Sellers, Ben	31/07/2015	FT	Carbon & Ecosystems	Determining Predator Prey Relationships of Killer Whales Within Distinct Areas of the Southern Ocean Using Biochemical Analytical Tools (Signature Fatty Acids and Stable Isotopes)	UTAS	Australia	January 2019
24. Sow, Swan	20/09/2015	FT	Carbon & Ecosystems	Microbial Oceanography of the Different Water Masses of the Southern Ocean	UTAS	Australia	March 2019
25. Streletz, Michal	31/05/2016	FT	Carbon & Ecosystems	Source characterisation of atmospheric trace metal deposition around Australia	UTAS	Australia	September 2019
26. Thomson, David	10/08/2015	PT	Oceans & Cryosphere	Evidence of carbon cycle changes from trace gas indicators in polar ice	UTAS	Australia	August 2020
27. Tonnard, Manon	01/10/2014	FT	Carbon & Ecosystems	The biogeochemical cycles of trace metals: distributions and speciation in the ocean and co-impact on the phytoplankton (GEOVIDE)	UTAS/ University of Bretagne - cote lle	France/ Australia	April 2018

Name	Start Date	Status	Research Program	Project Title	Research Organisation	Country	Expected Completion Date
28. Wallis, Jake	31/03/2016	FT	Carbon & Ecosystems	Impacts of ocean acidification on Southern Ocean lower-trophic food pathways	UTAS	Australia	September 2019
29. Wariji, Doreen	1/1/2016	FT	Oceans & Cryosphere	High resolution modelling of the retreat of the East Antarctic ice sheet since last glacial maximum	UTAS	Australia	July 2019
30. Weldrick, Christine	1/12/2015	FT	Carbon & Ecosystems	Mapping Planktonic Trophic Pathways Through the Sea Ice Zone	UTAS	Australia	June 2019
31. Yang, Luwei	14/10/2015	FT	Oceans & Cryosphere	Internal Waves and Mixing in the Southern Ocean	UTAS	Australia	April 2019

Completed

Name	Start Date	Status	Research Program	Project Title	Research Organisation	Country	Expected Completion Date
1. Graham, Felicity	18/07/2011	FT	Oceans & Cryosphere	Understanding the Dynamics of ENSO and How They Might Change with Global Warming	UTAS	Australia	Graduated August 2015
2. Groeskamp, Sjoerd	27/06/2011	FT	Oceans & Cryosphere	Estimating Diffusion Coefficients from Ocean Hydrography	UTAS	Australia	Graduated August 2015
3. Laurenceau-Comec, Emmanuel	01/10/2011	FT	Carbon & Ecosystems	Controls on Organic Carbon Sequestration from the Naturally Iron-fertilised Phytoplankton Bloom over the Kerguelen Plateau	UTAS	Australia	Graduated December 2015
4. O'Toole, Malcolm	07/11/2011	FT	Carbon & Ecosystems	Top Marine Predator Foraging Behaviour in Relation to Primary Productivity in the Southern Ocean	UTAS	Australia	Graduated August 2015
5. Queroue, Fabien	1/10/2010	FT	Carbon & Ecosystems	Manganese Distributions in the Southern Ocean and the Co-impact Mn-Fe-Cu on Phytoplankton	UTAS	Australia	Graduated August 2015

Name	Start Date	Status	Research Program	Project Title	Research Organisation	Country	Expected Completion Date
6. Ugalde, Sarah	15/02/2010	FT	Carbon & Ecosystems	Primary Production and Fate of Antarctic Sea Ice Algae	UTAS	Australia	Graduated December 2015
7. Vasconcelos de Menezes, Viviane	20/02/2012	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	Graduated December 2015
8. 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	Graduated Oct 2015

Continuing (enrolled prior to 2015/16)

Name	Start 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 21 st century projections of climate change	University of New South Wales	Australia	September 2018
2. Arthur, Benjamin	31/10/2011	FT	Carbon & Ecosystems	Winter Habitat Usage and Trophic Links for Antarctic Fur Seal Populations in the Southern Ocean	UTAS	Australia	April 2016
3. Baird-Bower, Debbie	08/04/2013	FT	Carbon & Ecosystems	Demographic Responses of Antarctic Fur Seals to Environmental Variability	UTAS	Australia	October 2016
4. Baker, Barry	31/07/2002	PT	Carbon & Ecosystems	Demography and Conservation of Shy Albatross (<i>Thalassarche cauta</i>)	UTAS	Australia	July 2015
5. Bedford, Merel	01/03/2014	FT	Carbon & Ecosystems	Representing Southern Ocean predators in end-to-end ecosystem models using individual-based modelling	UTAS	Australia	September 2017

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6. Black, James	28/08/2014	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	February 2018
7. Buchanan, Pearse	01/11/2014	FT	Oceans & Cryosphere	Ocean Deoxygenation: A paleo-modelling perspective	UTAS	Australia	May 2018
8. Cleeland, Jaimie	20/05/2013	FT	Carbon & Ecosystems	Macquarie Island's Albatrosses: A comprehensive assessment of population and demographic status and trends and the environmental and anthropogenic	UTAS	Australia	November 2016
9. Cougnon, Eva	08/10/2012	FT	Oceans & Cryosphere	Quantifying the Impact of Glacial Melt Water on Antarctic Bottom Water	UTAS	Australia	May 2016
10. Della Penna, Alice	19/11/2012	FX	Carbon & Ecosystems	Living in a fluid dynamic system: how do marine predators respond to turbulence?	UTAS	Australia	January 2016
11. Deppeler, Stacy	15/10/2013	FT	Carbon & Ecosystems	Effects of Elevated pCO ₂ on the Productivity of Marine Microbes and the Remineralisation of Nutrients in Coastal Antarctic Waters	UTAS	Australia	April 2017
12. Durand, Axel	03/04/2013	FT	Carbon & Ecosystems	Ocean Deoxygenation, a Paleo Proxy Perspective	UTAS	Australia	April 2017
13. Gwyther, David	05/03/2012	FT	Oceans & Cryosphere	Investigating the Impact of Ocean Warming on Antarctic Ice Shelves	UTAS	Australia	August 2015
14. Hamilton, Vicki	24/07/2012	FT	Carbon & Ecosystems	Energetic Variability in Sperm Whales and Relationships with the Marine Environment	UTAS	Australia	May 2016
15. Hodgson-Johnston, Indiah	21/10/2013	FT	Carbon & Ecosystems	Beyond the Bases? Applying Contemporary Principles of	UTAS	Australia	April 2017

Name	Start Date	Status	Research Program	Project Title	Research Organisation	Country	Expected Completion Date
				International Law to Australian Sovereignty in Antarctica			
16. Holmes, Thomas	01/04/2014	FT	Carbon & Ecosystems	The impact of hydrothermal vents on trace metal biogeochemistry in the Southern Ocean	UTAS	Australia	October 2017
17. Inoue, Mana	04/04/2011	FT	Oceans & Cryosphere	Glacioc hemical Study of Mill Island Ice Core Records	UTAS	Australia	August 2015
18. Jackson, Andrew	01/03/2015	FT	Carbon & Ecosystems	Who Saved Antarctica?	UTAS	Australia	September 2018
19. Jackson, Christine	15/01/2006	PX	Carbon & Ecosystems	Determining Cetacean - Cephalopod Trophic Interactions - A Qualitative and Quantitative Approach	UTAS	Australia	April 2016
20. Janse n, Jan	01/10/2014	FT	Carbon & Ecosystems	Modelling biodiversity in the Southern Ocean and Antarctica using sparse data	UTAS	Australia	April 2019
21. Jansse ns, Julie	06/09/2012	FT	Carbon & Ecosystems	Incorporation Mechanisms of Organic Matter and Iron into Sea Ice	UTAS	Australia	March 2016
22. Jia, Zhongnan	02/05/2011	FT	Carbon & Ecosystems	Diet and Energy Budget of Antarctic Krill (<i>Euphausia superba</i>) - Relationship between Krill and Winter Sea Ice	UTAS	Australia	July 2015
23. Johnson, Rob	07/02/2011	PT	Carbon & Ecosystems	Effects of Climate Change on Phytoplankton Primary Production and Chemotaxonomy in Southern Ocean and Antarctic Ecosystems	UTAS	Australia	December 2015
24. Labrousse, Sara	02/09/2014	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 - Cote lle	Australia	March 2018

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25. Lago, Veronique	06/04/2011	FT	Oceans & Cryosphere	Testing of climate models and sea level rise projections using observations of ocean heat uptake	UTAS	Australia	September 2015
26. Lee, Shi Hong	15/12/2012	FT	Carbon & Ecosystems	Impact of Climate Change on Physiological and Behavioral Responses of Coastal Microphytobenthos	UTAS	Australia	September 2016
27. Michael, Pam	04/02/2013	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	March 2016
28. Mori, Mao	01/12/2014	FT	Carbon & Ecosystems	Modelling ocean transport of key species in the Indian sector of the Southern Ocean	UTAS	Australia	June 2018
29. Peel, Samantha	27/01/2015	FT	Carbon & Ecosystems	Statistical Issues for Mapping Biodiversity in the Southern Ocean	UTAS	Australia	July 2018
30. Pittard, Mark	30/04/2012	FT	Oceans & Cryosphere	Ice Sheet Response to Enhanced Ice Shelf Basal Melt	UTAS	Australia	April 2016
31. Plummer, Christopher	01/05/2010	FT	Oceans & Cryosphere	Holocene Climate and Environmental Indicators from Trace Chemistry of Law Dome Ice Core, Antarctica	UTAS	Australia	October 2016
32. Polanowski, Andrea	03/10/2011	PT	Carbon & Ecosystems	Mechanisms for Sex Determination in Antarctic Krill	UTAS	Australia	April 2021
33. Ratnarajah, Lavania	01/12/2013	FT	Carbon & Ecosystems	Effect of natural iron fertilisation by krill and whales on the Southern Ocean carbon cycle	UTAS	Australia	June 2017
34. Roden, Nick	14/03/2011	PT	Carbon & Ecosystems	Acidification and Carbonate Chemistry of Shelf Waters in the Australian Antarctic Territory	UTAS	Australia	November 2016

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35. 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	September 2018
36. Semolini Pilo, Gabriela	15/12/2013	FT	Oceans & Cryosphere	Eddies Tidimensional Structure and their Role in Oceanic Mass and Heat Distribution	UTAS	Australia	June 2017
37. Silvano, Alessandro	05/05/2015	FT	Oceans & Cryosphere	Observations of Ocean - Ice Shelf Interaction at the Totten Glacier	UTAS	Australia	November 2018
38. Steer, Adam	01/10/2009	FT	Oceans & Cryosphere	Optimising Airborne LiDAR Positioning for Remote Area Geophysical Surveys	UTAS	Australia	May 2016
39. Ward, Delphine	01/10/2014	FT	Carbon & Ecosystems	Evaluating the likelihood of critical transitions in Southern Ocean ecosystems	UTAS	Australia	April 2018
40. Winton, Holly	September 2012	FT	Carbon & Ecosystems	Impact of biomass burning emissions and dust on soluble iron deposition to Australian waters, the Southern Ocean and Antarctica	Curtin University	Australia	December 2015
41. Younger, Jane	06/06/2011	FT	Carbon & Ecosystems	Glacial Refugia of Antarctic Ice Breeding Species	UTAS	Australia	June 2015
42. Zhao, Chen	13/10/2014	FT	Oceans & Cryosphere	Ice mass unloading and bedrock response in the southern Antarctic Peninsula	UTAS	Australia	April 2018