ANTARCTIC CLIMATE & ECOSYSTEMS
COOPERATIVE RESEARCH CENTRE

2012-2013 Annual Report

Australian Government
Department of Sustainability, Environment, Water, Population and Communities
Australian Antarctic Division

CSIRO

UTAS

Australian Government
Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education

AWI
Alfred Wegener Institute for Polar and Marine Research in the Helmholtz Association

NIWA
Taihoro Nukurangi

Established and supported under the Australian Government's Cooperative Research Centres Program

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Annual Report 2012-2013

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1 Executive Summary

The ACE CRC had a very successful year in 2012 – 2013. The highlight of the period, though was the announcement in May 2013 that the ACE CRC would receive funding of $25M from July 2013 to June 2019. The funding announcement dramatically changed the operating environment for the ACE CRC and allowed it to move from "wind-up" mode to planning future research programs and collaborations between partner institutions in the ACE CRC.

The ACE CRC implemented the recommendations of its mid-term review and made progress against all of its milestones. In reviewing its milestones, the ACE CRC concluded that it was both unnecessary and inefficient to attempt to produce a stand-along "mass-balance" model of the Antarctic ice sheet. Instead, it was determined that this milestone would be best met by contributing specialist data and models to a "community" ice-sheet mass balance model.

At the end of the period, the ACE CRC was confident that it would be able to extend the contracts of research staff to June 2014, and meet all of its contracted milestones.

1.1 Achievements

During the period senior scientists in the ACE CRC contributed significantly to the deliberations of the Intergovernmental Panel on Climate Change (IPCC) as Coordinating Lead Authors, Lead Authors and Contributing Authors. Working Group 1 of the IPCC met in Hobart in January 2013. The ACE CRC was pleased to be able to contribute to the meeting in our home city, but also use the opportunity for discussions and meetings with attending scientists outside of the IPCC's deliberations.

2012 -13 saw the SIPEX-II sea ice voyage as one of ACE CRC's many highlights. On their return in November 2012 the research expeditioners had spent 63 days at sea. Seventy scientists from 14 institutions from 7 countries, and the crew of Aurora Australis spent 49 days in the Antarctic sea ice unravelling the secrets it holds for the global climate system and for Antarctic ecosystems. A wealth of information was gathered from above and below the sea-ice, and an autonomous underwater vehicle (AUV), a remotely operated vehicle (ROV) and the RAPPLS (instrumented) helicopter were successfully deployed. Information from SIPEX-II will be critical to understanding the dynamics of sea ice and the ecology of the sea-ice zone.

The joint ACE CRC-NIWA (Australia/New Zealand) voyage to the Mertz Glacier region aboard *Tangoroa* was also successful, despite the original study sites (and the moorings which it was hoped could be recovered) being covered by persistent sea ice and icebergs during February and March 2013. *Tangaroa* completed a detailed survey of the Antarctic continental slope, including two repeat hydrographic sections along 140°E and 150°E. These transects will extend the time series of changes in Antarctic Bottom Water, including the ongoing freshening and

contraction of the bottom water layer (the densest layers have contracted by more than 50% since 1970).

A new source of Antarctic Bottom Water was discovered when data collected from sensors on seals was analysed. Antarctic Bottom Water is a major driver of global ocean circulation. There had been previous speculation that an undiscovered source of Antarctic Bottom Water existed somewhere in the Prydz Bay region of Antarctica. Through sophisticated satellite data, oceanographic moorings and the data from tagged seals, ACE CRC scientists discovered that a stream of Antarctic Bottom Water is being produced from intense sea ice formation in the Cape Darnley Polynya north-west of the Amery Ice Shelf. It is estimated that this source of Antarctic Bottom Water represents between 6 and 13 per cent of the total circumpolar production of Antarctic Bottom Water.

A 30-metre ice core was recovered from Law Dome on the Antarctic continent (south of Western Australia). This ice core will be used to create a detailed 30-year climate record, supplementing ice core analyses from previous cores collected from Law Dome. These data will be important for reconstruction of past climate records.

Antarctic aero-geophysical data were also collected and analysed through ACE CRC's collaboration in the ICECAP project. These data have played a significant part in the compilation of a new map of the Antarctic continent beneath the ice.

A full year's collection of surface water samples were collected offshore from Australia's Davis Station to examine the interaction between seasonal processes and the progress of ocean acidification in the Antarctic. These samples will be compared to an earlier study done in the mid-1990s.

A significant breakthrough was made in understanding the relationship between past temperature and atmospheric carbon dioxide concentrations. In helping to resolve one of the most important questions in climate science ACE CRC researchers demonstrated that the time lag between changes in temperature and changes in atmospheric CO_2 levels in the past were much shorter than previously thought – no longer than 400 years, and possibly a much shorter, near-synchronous response. All previous work had provided uncertainties on the time lag between temperature and CO_2 in the order of many hundreds to even thousands of years.

ACE CRC research found evidence from ice cores of a long term decline in average annual rainfall in eastern Australia, with records revealing that rainfall since about 1920 is below the average of the past 1000 years. Australia's instrumental climate records extend back only about 100 years and show an apparent decline in eastern Australian rainfall. However, rainfall in eastern Australia is highly variable, and the significance of the decline can only be assessed when compared with a much longer record. ACE CRC glaciologist, Dr Tessa Vance, and her colleagues obtained the 1000-year record from ice core data. The research shows a direct correlation between the eastern Australian instrumental rainfall record and sea salts deposited by winds at Law Dome in East Antarctica over the past 100 years. The 1000-year-old

Law Dome sea salt proxy provides the longest rainfall record yet for eastern Australia. This proxy record shows that the dry period since the 1920s is similar to a dry period from 1000-1260 AD.

The ACE CRC sponsored the Australian and New Zealand Strategic Science in Antarctica Conference which was held in Hobart from 24-26 June 2013. The conference was a joint initiative of the Australian Antarctic Division and Antarctica New Zealand.

The ACE CRC released a Sea-level Rise Report Card that pulls together the past decade of peer-reviewed scientific research into sea-level rise. "Report Card: Sea Level Rise 2012" is a summary of research into past, present and projected future sea-level rise. It focuses in particular on the scientific literature since 2008. This Report Card complements the ACE CRC's series of Position Analyses and Report Cards which present up-to-date scientific information in plain language for policy makers.

The ACE CRC published 5 book chapters, 84 articles in scholarly refereed journals, and 9 full written conference papers in refereed proceedings during the reporting period (Appendix 1). These include publications from the Climate Futures for Tasmania, National Environmental Research Program (NERP) and Natural Disaster Resilience Program (NDRP) projects (see Appendix 1).

Honours and awards

This year ACE CRC staff and honorary staff have been honoured in a wide range of ways.

Prof Nathan Bindoff and the Climate Futures for Tasmania team – Dr Stuart Corney, Dr Michael Grose, Dr Greg Holz, Dr Chris White, Mr James Bennett and Ms Suzie Gaynor – funded by the Australian Government's Commonwealth Environment Research Facilities program – won both the Tasmanian and national 2012 Resilient Australia Awards for Education, Training and Research for generating new future climate information at a level of detail never before provided for Australia. The new information also increased knowledge and understanding of climate change possibilities in Tasmania. The same team was highly commended in the National Climate Change Adaptation Research Facility's Climate Adaptation Champion award.

Dr Rob Massom was appointed a member of the Australian Academy of Sciences National Committee for Antarctic Research in July 2012; a member of the WCRP/SCAR/IASC Climate and Cryosphere (CliC) Project Science Steering Group in January 2013; a member of the International Space Science Institute Working Group on Antarctic Sea Ice Thickness and Volume in February 2013; and awarded a Visiting Professorship at the National Institute of Polar Research, Tachikawa, Japan, from March to November 2013.

Dr Tas van Ommen was appointed Chair of the National Committee for Earth System Science at the Australian Academy of Science in May 2013.

Prof Ian Allison held a Visiting Professorship at the Chinese Academy of Sciences from September to December 2012, a position given to senior international scientists with whom the Academy wishes to collaborate. He also received the Phillip Law Medal in recognition of his outstanding contribution to Antarctic affairs and the Antarctic community.

In September 2012 Dr Andrew Bowie received the Scopus Young Australasian Researcher of the Year award in the Physical Sciences category for his publication and citation record and the impact of his research in the field of chemical oceanography. From May to July 2013, he held a Visiting Professor Fellowship at the Institut Universitaire Européen des Sciences de la Mer, Université de Bretagne Occidentale, in France, and in July 2012 he was elected a member of the GEOTRACES Data Management Committee.

Dr Petra Heil was elected Chair of the International Programme for Antarctic Buoys and a Member of the ASPeCt scientific steering group in July 2012, and a Member of the Council of the International Glaciological Society in 2013.

Prof Tom Trull was elected to the International OceanSITES Scientific Steering Committee in July 2012.

In July 2012, Dr Bronte Tilbrook was elected a Steering Committee Member of the Southern Ocean Observing System, Chair of the Southern Ocean component of Surface Ocean CO_2 Atlas (SOCAT)and Co-chair of the Southern Ocean component of the Regional Carbon Cycle Assessment and Processes (RECCAP).

At the 2nd CLIOTOP (Climate Impacts on Top Predators) Symposium in Noumea, New Caledonia in February 2013, Dr Jessica Melbourne-Thomas won the Prize for the Best CLIOTOP Early Career Researcher Presentation, and at the Strategic Science in Antarctica Conference in Hobart in June 2013 she received the Prize for the Best Overall Plenary Presentation – Early Career Scientist Category.

Dr Donna Roberts was invited lead author of the 'Southern Ocean Pteropods' chapter of the 'SCAR Biogeographic Atlas of the Southern Ocean,' a publication which shared the International Cosmos Prize in June 2013 from the Osaka Expo '90 Commemorative Foundation. Throughout the reporting period, as Australia's invited observer, Dr Roberts was a member of the International Ocean Acidification Reference User Group and Australia's elected expert member of the United Nations Environment Programme's Conservation of Biological Diversity Ocean Acidification Expert Committee.

Dr Klaus Meiners was elected to full membership of the Scientific Committee on Oceanic Research, Working Group – 140: 'Biogeochemcial Exchange Processes at the Sea-Ice Interfaces (BEPSII)' in July 2012.

Dr Stefan Vogel won the CSIRO Prize for best poster by an established scientist at the Strategic Science in Antartica Conference in June 2013.

Dr Alex Fraser won a Japan Society for Promotion of Science Postdoctoral Fellowship in June 2013.

Staff appointments
There were no new appointments during the reporting period.

Major purchases for the year
Major capital costs for this reporting period were:

Item	Amount $	Program
Sediment Drift Array	49,674	Carbon
Mooring	35,012	Ocean
TOTAL	**84,686**	

External reviews
There was no external review during the reporting period. Actions taken in response to the performance review of May 2012 were reported last year.

1.2 Risks and Impediments

The risk register, established at the beginning of this funding period, was updated and discussed at Board meetings during the reporting period. The purpose of the register is to ensure careful management of risks throughout the life of the ACE CRC.

The biggest risk identified in the last annual report was no further funding past June 2014. In May 2013, it was announced that the ACE CRC would be refunded for five years from 1 July 2014 to 30 June 2019. The financial risk previously identified as a 'medium' risk has been downgraded with the annnouncement of 5 additional years of funding amounting to $25 million. In addition, during the period all staff were extended to the end of June 2014. This was possible due to careful management of ACE CRC's cash position. The result of these management actions is that the projected cash position for the end of the ACE CRC's current funding period has improved from last year's forecasted surplus of $379K (excluded staff extensions) to a forecasted surplus of $41K which includes all staff extensions of $1.052M.

Logistic risk continues to be identified as 'medium'. This is because conducting fieldwork in Antarctica and the Southern Ocean is inherently risky due to ocean, ice and weather conditions. The environment is very hard on equipment, and aircraft and shipping delays and rescheduling are not uncommon.

Collaboration and usage are all identified as 'low' risk. Staffing has been revised to a low risk due to renewed funding.

The ability of the ACE CRC to meet its milestones because of funding pressures on ACE CRC's core partners remains a risk. Budget cuts to Government agencies have reduced their ability to carry out some functions. The ACE CRC has identified this as a risk and has taken steps, such as rescheduling payments for logistics, to minimise the impact of this risk on ACE CRC activities.

1.3 End-user Environment

The web tool *Canute* (funded by DIICCSRTE) used to predict sea-level change around the coast of Australia has 329 active users and a further 324 people who have signed up to the website but as yet have not completed all the training.

The ACE CRC actively contributed to the IPCC AR5, (released in 2013) with updated projections of future climate change. The IPCC projections are a major source of information for policy makers.

The fiscal environment remained tight with the Government budget decisions affecting partners in the ACE CRC and the general economic climate affecting the private sector and ACE CRC end-users. This has presented a continuing challenging environment for engaging end-users in long term planning for climate change.

The ACE CRC Board includes representatives from its core research end-users, key government end-users and Small and Medium Enterprise (SME) representatives (as well as independent members). The representation of these end-users on the ACE CRC Board ensures that our strategic direction is in alignment with its existing end-users. The ACE CRC is now working with its core end-users to develop the research plan for the new round of funding from 2014 to 2019.

The revamp of the sea-level rise calculator '*Canute*' (www.sealevelrise.info), with enhanced features, presents an opportunity to re-engage with potential new and existing end-users.

1.4 Outcomes

Not applicable to Round 11 CRCs.

1.5 Impacts

The ACE CRC Impact Template was updated in 2011/12 for the mid term review. These changes were reported last year. No significant change has occurred during the year to require adjustment. The ACE CRC is currently preparing an impact template for the new $25 million funding.

2 Governance and Management

The ACE CRC is an unincorporated joint venture comprising 6 essential and 15 other participants. UTAS continues to provide Centre Agent services such as human resource and financial services as in-kind contributions. UTAS signed the

Commonwealth Agreement on behalf of all participants. The six Essential Participants are bound by the Participants Agreement, and the Other Participants Agreements set out the duties and commitments of the remaining 15 parties.

There were no changes in the participants during the reporting period.

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

The Impact Tool (IT) forms the basis of the risk register against which ACE CRC manages its risks. The IT is also used to manage ACE CRC activities and track performances against contracted milestones.

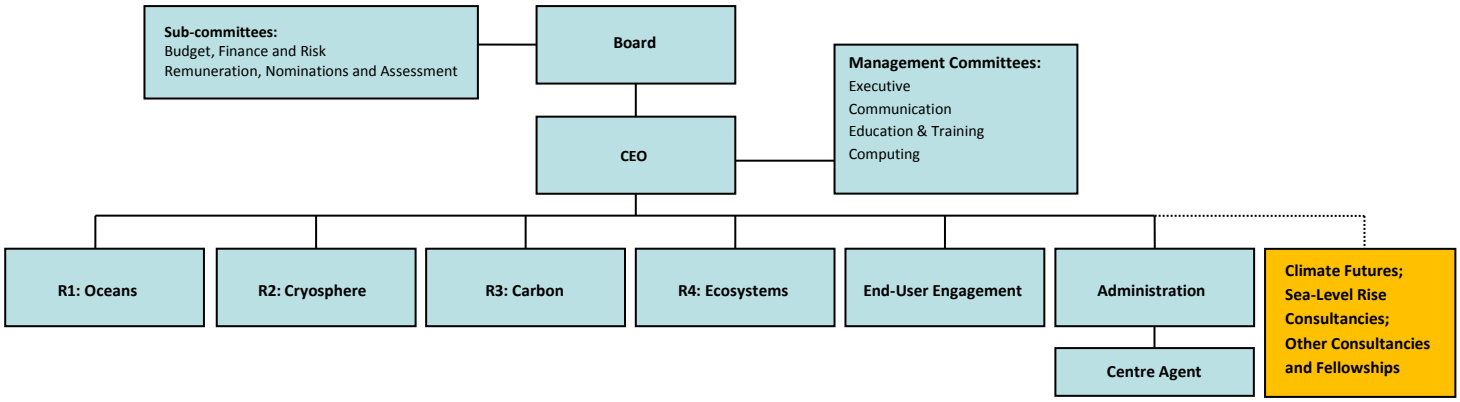
By the close of 2012 no funding had been secured for ACE CRC to remain in its current form beyond the end of its present CRC program funding in June 2014. Considerable effort was therefore directed to securing a whole-of-government approach to ensure continuity of the CRC's scientific work. As a part of this effort, a Science Group composed of representatives of ACE CRC's collaborators met on 20 December 2012 and again on 10 January 2013.

In December 2012, Senator the Hon Christopher Evans, the Minister for Tertiary Education, Skills, Science and Research, requested that a meeting be held to consider post-ACE CRC collaborations in Antarctic, Southern Ocean and climate science. The meeting, chaired by Deputy Secretary Patricia Kelly from DIISRTE, took place in Hobart on 17 January 2013 and was attended by representatives from the Minister's office, DIISRTE, DCCEE, SEWPaC, the Tasmanian Government, AAD, CSIRO, ACE CRC and UTAS. The purpose of the meeting was to determine the level of commitment (cash and in-kind) from participants and to try and identify longer term funding solutions.

On 20 May 2013 the Hon Dr Craig Emerson, Minister Evans's successor in the Innovation portfolio, notified Dr Tony Press, ACE CRC's Chief Executive, that the Centre had been allocated a further $25 million for five years from 1 July 2014. The Minister's letter stated that the funding was made in recognition of "the important role the Antarctic Climate and Ecosystems CRC plays in Australia's Antarctic effort, as well as its ongoing contribution to climate-related research in the Southern Ocean and Antarctic region." The Minister noted the CRC's importance in establishing Hobart as a global hub for Antarctic science and operations and concluded: "The CRC is Australia's largest centre of Antarctic and Southern Ocean climate change research. As such, its work is important not only to Australia, but the global community. The additional funding will keep Australia at the forefront of vital scientific research and provide a stronger foundation for a global response to climate change." Preceding the letter, on 13 May, a joint press release by Dr Emerson and the Environment Minister, the Hon Tony Burke, referred to ACE CRC's "world-leading research into Antarctic climate science and the uncertainties that currently limit the global response to climate change."

This recognition of the importance and quality of the ACE CRC's work and the renewed funding to support it represent major successes. The additional resourcing was achieved more than 12 months in advance of the expiry of the current arrangements.

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



2.1 Governance – Board, Committees and Key Staff

The Board

The Board is constituted with a balance of skills, experience and independence, and operates in accordance with the provisions of the Participants' Agreement. It comprises an independent chairperson, representatives of the CRC's six Essential Participants, two representatives from Other Participants (including one commercial participant), two independent members and two ex-officio members (without voting rights). Board members are governed by an ACE CRC Code of Conduct developed in previous years. There were no changes to the Board membership this year.

Board meetings are held every quarter. During this reporting period meetings were held on 30 July 2012, 5 September 2012 (including AGM), 9 November 2012, 1 March 2013 and 7 June 2013.

End-user organisations, pitt&sherry Pty Ltd and the Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education (DIICCSRTE), were represented on the Board by Mr John Pitt and Ms Jo Mummery respectively.

Board Members

Name	Role	Key Skills	Independent/ Organisation	Number of meetings	% as Board member
Prof Howard Bamsey	Board Member	- High level national and international policy and diplomacy expertise - Federal departmental and university executive managerial expertise - Specialist in climate change, energy security, climate economics and sustainable development	Independent	4/5	80%
Mr Tony Coleman	Board Member	- High level executive management experience in private enterprise - Financial audit, actuarial and risk management expertise - Commercial objectivity and independence from CRC participants	Independent	3/5	60%
Dr Tony Fleming	Board Member	- Broad and extensive experience in development of environmental policy and program delivery - Extensive Federal and State public service experience - Experience with not-for-profit sector - High level policy experience	Australian Antarctic Division (Essential Participant)	3/5	60%

Name	Role	Key Skills	Independent/ Organisation	Number of meetings	% as Board member
Dr Nick Gales	Ex-Officio	- High level national and international experience in science and policy - High level science expertise in applied marine mammal conservation science - Australian Marine Mammal Centre leadership	Australian Antarctic Division (Essential Participant)	3/5	60%
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)	4/5	80%
Dr Bruce Mapstone	Board Member	- Extensive experience in research leadership and management at senior & institutional levels - Experience with CRC establishment, leadership, and governance, including the previous ACE CRC - Broad relevant domain expertise in climate and marine science	Commonwealth Scientific and Industrial Research Organisation (CSIRO) (Essential Participant)	5/5	100%

Name	Role	Key Skills	Independent/ Organisation	Number of meetings	% as Board member
Dr Bettina Meyer	Board Member	- High level Antarctic science expertise - Strong international standing as a scientist - High level administrative experience	Alfred Wegener Institute (Essential Participant)	1/5	20% Granted leave of absence by Board
Ms Jo Mummery	Board Member	- High level executive management experience - Specialist in national and international climate change policy, climate change science policy, assessing climate change impacts and adaptation, Australian biodiversity	Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education (Essential participant)	4/5 appointed 6 July 2012	80%

Name	Role	Key Skills	Independent/ Organisation	Number of meetings	% as Board member
Dr Rob Murdoch	Board Member	- High level executive management experience - Broad experience in the operation of research vessels - Extensive Board experience - High level science expertise in biological oceanography and marine ecology	National Institute for Water and Atmospheric Research, New Zealand (NIWA) (Essential Participant)	1/5	20% Granted leave of absence by Board
Prof Paddy Nixon	Board Member	- Extensive experience in research leadership and management at senior & institutional levels - High level industrial and commercial executive management experience - Broad and extensive expertise in computer science and technology	University of Tasmania (Essential Participant)	1/5	20%
Mr John Pitt	Board Member	- Experienced company director including broad network across private and public sectors - High level private sector executive management (including technology commercialization) experience - Strategic planning expertise in relation to the adaptation of infrastructure assets to climate change	pitt&sherry (Other Participant)	2/5	40%

Name	Role	Key Skills	Independent/ Organisation	Number of meetings	% as Board member
Dr Tony Press	Ex-Officio	- High level leadership and administrative experience - Extensive experience in government and public policy - High level international experience in science and policy	ACE CRC	5/5	100%
Dr Katherine Woodthorpe	Chair	- High level management skills – Chief Executive Officer (CEO) of Australian Private Equity & Venture Capital Association Ltd (AVCAL) - High level Board skills - Broad experience on audit committees - Ventracor, Agenix and chaired the Audit Committee of Australian Cancer Technologies Ltd and Insearch	Independent	5/5	100%

The Board has two sub-committees. The Budget, Finance and Risk sub-committee includes Dr Bruce Mapstone (CSIRO), Prof Paddy Nixon (UTAS) and Mr Tony Coleman as members. The Budget, Finance and Risk sub-committee provided two recommendations to the Board. The sub-committee recommended the acceptance of the audited financial statements in October 2012. This sub-committee also recommended the approval of the ACE CRC annual budget. The annual budget was approved by the Board at the 46th Board meeting on the 7th June 2013.

The Remuneration, Nominations and Assessment sub-committee consists of Dr Katherine Woodthorpe, Dr Tony Fleming and Mr Greg Johannes. They did not meeting during the reporting period.

The Executive Committee

The ACE CRC Executive Committee advises the CEO and Board on a range of matters relating to management of resources, research coordination and research utilisation across the ACE CRC portfolio. The ACE CRC Executive Committee convened on 21 August 2012, 30 October 2012, 10 December 2012, 13 February 2013 and 11 June 2013.

In addition, on 20 December 2012 and 10 January 2013, in view of the transitioning of the CRC, meetings with principal research partners were held to consolidate a whole-of-government proposal for an Antarctic and Southern Ocean Research Partnership. This was refined into a document that was presented to government on 17 January 2013.

Name	Role	Key Skills	Organisation
Prof Nathan Bindoff	Leader, Climate Futures; Director Tasmanian Partnership for Advanced Computing (TPAC)	Computing/research	ACE CRC/TPAC
Ms Wenneke ten Hout	Administration Manager (on leave from 20 December 2012)	Administration	ACE CRC
Dr Andrew Constable	Leader, Ecosystems Program	Research	ACE CRC/AAD
Ms Miranda Harman	Communications Manager	Communications/Media	ACE CRC

Name	Role	Key Skills	Organisation
Prof Marcus Haward	School of Government, UTAS	Research/policy/end-user engagement	ACE CRC/UTAS
Ms Tessa Jakszewicz	Deputy CEO, Business Development (until 19 April 2013)	Business Development/end-user engagement	ACE CRC
Ms Kate Maloney	Business Manager	Finance, administration, governance	ACE CRC
Prof Andrew McMinn	IMAS Representative	Education	IMAS
Dr Kelvin Michael	IMAS Representative	Education	IMAS
Dr Tas van Ommen	Program Leader, Cryosphere Program	Research	ACE CRC/AAD
Dr Tony Press	CEO	Management, governance	ACE CRC
Ms Sarah Ugalde	Student representative	Education	IMAS/ACE CRC
Dr Stephen Rintoul	Program Leader, Oceans Program	Researcher	ACE CRC/CSIRO
Dr Jason Roberts	Researcher, Chair ACE CRC Computing Committee	Research/computing	ACE CRC/AAD
Prof Thomas Trull	Program Leader, Carbon Program	Researcher	ACE CRC/UTAS/CSIRO
Ms Margaret White	Administrative Assistant/Minute Secretary	Administration	ACE CRC

Communications Coordination Committee

The communications coordinating committee met twice during the reporting period, on 1 August 2012 and 25 June 2013. There have been several informal meetings between committee members and regular liaison between the ACE CRC Communications and Media Manager and partner Communications Managers during the reporting period.

Name	Role	Organisation

Name	Role	Organisation
Ms Sally Chambers	General Manager, Corporate Communications	AAD
Mr Peter Cochrane	Media Manager, Communications and Media Office	UTAS
Ms Miranda Harman	Communications and Media Manager	ACE CRC
Mr Craig Macaulay	Communications Officer	CSIRO
Ms Sam East	Communications, Outreach and Marketing Officer	IMAS

Education and Training Committee

The Education and Training committee, composed of representatives from the Institute for Marine and Antarctic Studies (IMAS, based at UTAS) and the ACE CRC, is available to discuss a range of matters relating to education and training. The committee met informally during the reporting period and provided the necessary information through the Executive Committee.

Name	Role	Organisation
Prof Mike Coffin	Executive Director IMAS	IMAS
Dr Julia Jabour	IMAS Representative	IMAS
Prof Gustaaf Hallegraeff	IMAS Representative	IMAS
Dr Kelvin Michael	IMAS Representative	IMAS
Dr Tony Press	CEO	ACE CRC

Computing Committee

The ACE CRC Computing Committee supports the science, education and policy programs of the ACE CRC by providing advice on information technology, infrastructure and management. The ACE CRC Computing Committee advises the ACE CRC Executive Committee and CEO. The ACE CRC Computing Committee did not formally meet during the reporting period.

Member	Role	Organisation
Ms Wenneke ten Hout	Administration Manager	ACE CRC
Mr Colin Broadbent	Information Technology Resources	UTAS
Mr Antony Cave	Information Technology Resources	UTAS

Member	Role	Organisation
Mr James Harrison	Information Technology Resources	UTAS
Mr Iain Sheppard	Information Technology Resources	UTAS
Dr Jan Lieser	Researcher	ACE CRC
Ms Kate Maloney	Business Manager	ACE CRC
Dr Tony Press	Chief Executive Officer	ACE CRC
Dr Jason Roberts (Chair)	Researcher	AAD
Dr Roland Warner	Researcher	AAD

Key Staff

Staff Member	Role	Organisation	% Time
Dr Tony Press	CEO	ACE CRC	100%
Dr Stephen Rintoul	Program Leader - Oceans	ACE CRC/CSIRO	50%
Dr Tas van Ommen	Program Leader - Cryosphere	ACE CRC/AAD	80%
Prof Tom Trull	Program Leader - Carbon	ACE CRC/CSIRO	75%
Dr Andrew Constable	Program Leader - Ecosystems	ACE CRC/AAD	60%
Prof Nathan Bindoff	IPCC AR5 – coordinating lead author and Deputy Program Leader – Oceans	ACE CRC/IMAS	50%
Prof Ian Allison*	IPCC AR5 – lead author	ACE CRC	50%
Ms Tessa Jakszewicz (until 19 April 2013)	Deputy CEO	ACE CRC	80%
Ms Kate Maloney	Business Manager	ACE CRC	100%
Ms Miranda Harman	Communications Manager	ACE CRC	60%
Ms Wenneke ten Hout (on leave from 20 December 2012)	Administration Manager	ACE CRC	50%

*Prof Ian Allison is an Honorary Research Professor

2.2 Participants

CRC participants during the reporting period

Participant's name	Participant type	ABN or ACN	Organisation type
Alfred Wegener Institute of Polar and Marine Research (AWI), Germany	Essential	NA	Government research institute
Australian Antarctic Division (AAD)	Essential	56 428 630 676	Government
CSIRO Division of Marine and Atmospheric Research (CMAR)	Essential	41 687 119 230	Government
Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education (DIICCSRTE)	Essential	74 599 608 295	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

Participant's name	Participant type	ABN or ACN	Organisation type
Chinese Academy of Meteorological Science (CAMS)	Other	NA	Government research institute
Department of Sustainability, Environment, Water, Population and Communities (SEWPaC)	Other	34 190 894 983	Government
First Institute of Oceanography (FIO), China	Other	NA	Government research institute
Institute of Low Temperature Science (ILTS), Hokkaido University, Japan	Other	NA	Research institute
Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS), France	Other	NA	Research institute
Myriax Software Pty Ltd	Other	95 009 587 848	Industry
National Institute of Polar Research (NIPR), Japan	Other	NA	Government research institute
pitt&sherry	Other	88 234 540 094	Industry
RPS MetOcean Pty Ltd	Other	42 107 962 872	Industry
SGS Economics and Planning Pty Ltd	Other	25 007 437 729	Industry

Participant's name	Participant type	ABN or ACN	Organisation type
Tasmanian Government	Other	84 531 577 304	Government
University of Texas at Austin, USA	Other	NA	University
University of Texas at San Antonio, USA	Other	NA	University

Changes to participants

There were no changes in the reporting period.

2.3 Financial Management

The ACE CRC continued to make considerable efforts balancing its budget following the shortfall in funding from the CRC Program. The result of these management efforts over the reporting period has seen the projected cash position for end of the ACE CRC's current funding period changed from a forecasted surplus of $379K (June 2012 approved budget) to a forecasted surplus of $41K (June 2013 approved budget).

Staff appointments were made based on three-year contracts with most appointments due to expire at the end of 2013. This was done to manage costs and to reduce the projected end-of-contract deficit. The concerted cost management over the first three years of the ACE CRC has result in 2014 forecasted surplus funds. With this surplus the ACE CRC is extending all staff contracts to ensure the delivery of the milestones and outputs, amounting to an additional cost of $1.052M.

The other major factor that assisted in producing the surplus in the budget included:

- Two participants deferred part of logistics payments into the 2013/14 year thereby improving the cashflow position and the interest earned. Interest of $131,639 was earned on the ACE CRC account during this reporting period (shown as 'Other Firm Cash' in the ACE CRC financial tables).

In terms of in-kind contributions, the unfavourable difference of 24% to the agreement budget in the prior report has been reversed and now shows an overall favourable variance of 9%. This resulted from the two voyages reported last year being completed in the current year.

The online 'Expenses' table for the ACE CRC over the year shows major variances to the agreement.

Table 1 Excerpt from the online 'Expenses' table 3, 2012/13

	Actual	Agr'mt	Diff	% Diff
Employee Expenses	3,553	3,540	13	0
Supplier Expenses	2,347	1,418	929	66
Capital	85	0	85	0
Other Expenses	0	0	0	0
TOTAL EXPENSES	5,985	4,958	1,027	21

The difference in supplier expenses arose due to a number of factors:

- The change of the timing of the SIPEX-II cruise (departed September 2012), meant that some of the final preparation cost for this cruise was carried forward into this next financial year, resulting in the predicted reversal of last

year's underspend. The major contributor is the contract with WHOI for the AUV for $270K.

- As reported in previous annual reports the calculation of variances needs to be amended in the agreement column for the carried forward cash when evaluating the totals to date and the forecasted position to the end of the ACE CRC. The expected use of these additional funds and the years in which the expenditure was budgeted was advised to the CRC Program in June 2010. In this year's table 3, the unadjusted totals show the following variances:

Table 2 Excerpt from the online 'Expenses' table 3 Totals

	Totals to 2012-13				Totals for 5 years			
	Actual	**Agr'mt**	**Diff**	**%Diff**	**Actual/Proj**	**Agr'mt**	**Diff**	**%Diff**
Employee Expenses	3,553	3,540	13	0	14,108	12,273	1,835	15
Supplier Expenses	2,347	1,418	929	66	8,071	5,798	2,273	39
Capital	85	0	85	0	1,579	807	772	96
Other Expenses	0	0	0	0	225	612	-387	-63
TOTAL EXPENSES	5,985	4,958	1,027	21	23,983	19,490	4,493	23

These variances change with the inclusion of the carried forward cash as per the below:

Table 3 Adjusted online 'Expense' table 3 Totals for carried forward cash

	Totals to 2012-13				Totals for 5 years			
	Actual	**Agr'mt**	**Diff**	**%Diff**	**Actual/Proj**	**Agr'mt**	**Diff**	**%Diff**
Employee Expenses	3,553	3,540	13	0	14,108	13,094	1,014	8
Supplier Expenses	2,347	1,418	929	66	8,071	6,885	1,186	17
Capital	85	0	85	0	1,579	1,696	-117	-7
Other Expenses	0	0	0	0	225	612	-387	-63
TOTAL EXPENSES	5,985	4,958	1,027	21	23,983	22,287	1,696	8

During the current financial year, additional financial information was obtained in relation to balances and transactions that occurred during the previous financial years. The results and impact of this information has been to require adjustments to the 2012 financial year comparatives included in the financial statements for the 2013 financial year. This was the non accrual of a salary of $120,000 in the 2011/12 year. This makes no difference to the totals of the CRC financial table as it is a timing

difference between the two years. In addition, a correction for CSIRO was made totalling $79,000 which was mainly over-reported salaries which has been adjusted to agree with the remaining cash held by CSIRO.

2.4 Communications

The ACE CRC is concerned to ensure effective communication within the organisation, among its partners, with external users and the wider community and to provide up-to-date information on its research results and their implications for the future. This section provides details of the various means by which this is achieved. Further information about communication with end-users is given in section 3.3.

Communication with ACE CRC partners

The ACE CRC Board is composed of a mixture of independent and partner representatives. All partners are invited to the Annual General meetings and their organisations are provided with copies of all newsletters, annual reports and other ACE CRC publications. Regular one-on-one meetings occur between partner staff in Australia and overseas.

Internal communication

- **Staff forums** were held in September and December 2012 and March and June 2013. These provide staff with administrative information and updates on the ACE CRC's strategic direction as required by the mid-term review.
- **Staff Intranet** is provided through acecrc.org.au
- **Internal email:** Several lists are maintained and used to disseminate information on a day-to-day basis.
- **ACE CRC executive meetings** were held in August, October and December 2012 and February and June 2013.

External communication

- **ACE CRC website** (www.acecrc.org.au): Together with the media releases and e-newsletter referred to below, this website is one of the main means by which the ACE CRC communicates its successes to a wide audience. The website is regularly updated, and 26 new stories were added in the reporting period. Metrics gathered using Google Analytics showed there were 24,267 visits to the site during the reporting period. Other statistics were: unique visitors (15,426), pages per visit (2.21), average duration of visits (2 min, 39 sec), percentage of new visits (61.8%) and returning visitors (38.2%).
- ***Canute***, the Sea Level Calculator (www.sealevelrise.info) is a free online support tool for calculating sea level rise allowance. It was launched in Melbourne on 23 October 2012 with approximately 50 guests attending. Approximately 329 people have since completed the online training and registered to use the tool; a further 324 have signed up but have not yet completed the training.

- **E-Newsletter:** ACE News was produced and distributed in January 2013 and in May 2013 to about 700 subscribers – members of the Australian climate change research community, policy makers, advisors and the media. The newsletter contains a message from the CEO, updates on research, newsworthy developments within the organisation and notice of significant upcoming events.
- **Media**: Nine media releases were sent out by the ACE CRC and an additional three jointly with the Australian Antarctic Division. The Meltwater Media Monitoring service recorded 436 online mentions of the ACE CRC on Australian media sites and 106 on international online sites. Statistics are indicative and only include media stories that were published online.
- **Social media**: The ACE CRC has a Facebook page and Twitter account, @acecrcscience. There were 128 Twitter followers in the reporting period, of whom 56 were new. There were 31 tweets and 95 LinkedIn connections.
- **Position Analyses:** These provide synopses in plain English of the latest research in their particular fields. Their aim is to inform Government policy makers and planners and the wider community about our current state of knowledge and what this suggests for the future. Work was begun on four position analyses (sea ice, palaeoclimate, ecosystems impacts, ocean fertilisation).
- **Report Cards:** Report Card Sea-Level Rise 2012 was published in July 2012. It was mailed out to end-users (the Australian climate change research community, policy makers and advisors, media) in hard copy and is also available online.
- **Year in Review**: A 48-page, A4-size promotional booklet written in non-technical language was produced as a companion to the annual report. The publication introduces the ACE CRC, its partnerships, programs and aims, explains the importance of its research activities, and gives highlights of these and of associated publications. It was widely distributed by mail and online in October 2012.
- **Technical Reports**: The report titled 'Generic Design Coastal Erosion Volumes and Setbacks for Australia' was released in 2012, and Sea Ice Reports Volume 2 for the Season 2012-13 was released in 2013.
- **Face-to-face meetings/briefings:** Senior staff participated in Science Meets Parliament information sessions for MPs, organised by the CRC Association (August 2012). A Roundtable briefing summarising the latest work in all programs was held in Canberra on 5 December 2012 for approximately 35 end-users. An Antarctic policy discussion was held in Hobart involving 16 policy makers (April 2013). Approximately 35 end-users were briefed on the content of Position Analysis: Ecosystems Impacts and Position Analysis: Antarctic Palaeoclimate (Canberra, 3 May 2013). Various meetings were held with Ministers and other individual MPs from across the political spectrum.
- **Sponsorship:** The ACE CRC sponsorship of the Strategic Science in Antarctica conference in June 2013 allowed branding opportunities and the distribution of marketing material, technical reports, position analyses and report cards.

The ACE CRC also provided sponsorshop support for the WGOMD/SOP Workshop on Sea Level Rise, Ocean/Ice Shelf Interactions and Ice Sheets in Hobart in February 2013, the 18th Australasian Fluid Mechanics Society in Launceston in December 2012, the Second Australian Earth System Outlook Conference at Shine Dome, AAS, Canberra in November 2012, and the Australian Marine Sciences Association – New Zealand Marine Science Society 2012 Conference in Hobart in July 2012.

- **Community Briefings:** The ACE CRC opened its research facilities for 20 Year-10 students from the Calvin Christian School, Kingston, on 28 August 2012. The visit included tours of the ice core lab and the ice mechnics lab. The students took part in an ocean convection experiment and attended an ocean acidification presentation. Furthermore, several ACE CRC staff presented their research to schools around Tasmania, including Windermere Primary School, Taroona Primary School, South Hobart Primary School, Friends School, the Hutchins School, and St James Catholic College.

2.5 Intellectual Property Management

The Intellectual Property (IP) management arrangements are outlined in the ACE CRC IP Assignment Deed and the Participants Agreement. The IP clauses within the Agreement were established in accordance with the National Principles of IP Management.

As a 'public good' CRC, the ACE CRC aims to make its research outputs widely and freely available. It does this by publishing its results in formal journals, public-ready documents, via its website and by providing data via means such as the sea-level rise webtool (www.sealevelrise.info). Much of the scientific data collected is available through the Australian Antarctic Data Centre at the AAD, the Integrated Marine Observing System (IMOS) and the TPAC.

If ACE CRC licenses use of its Centre IP to a third party that party can only use the IP on the basis that it does not prejudice ACE CRC's ability to maximise the commercial return from the Centre IP. This ensures that benefits are maximised for Australia.

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

3 Performance against Activities

3.1 Progress against the Key Challenge/Outcomes

1. Oceans: The Southern Ocean and Sea-Level Rise (SLR)

How is the Southern Ocean changing, and the implications that this will have for Australian and global climate now and in the future?

The Southern Ocean and Antarctica are vital elements of the climate system. Antarctica is melting, primarily through the intrusion of warming Southern Ocean waters into the cavities below the ice sheet. This melt is causing the deep Antarctic

Bottom Water (AABW), to become fresher. Salinity is also changing in surface waters and Antarctic Intermediate waters, implying changes in the water cycle (changes in rain and evaporation). Some of the most reliable evidence for this is provided by observed changes in the salinity of waters originating in the Southern Ocean.

AABW, commonly defined as water below 0°C, is the coldest and densest water in the global ocean. It feeds the deep ocean basins, spreading beyond the equator into the northern Pacific, Indian and Atlantic oceans. It is also an important element of the Southern Ocean overturning circulation, a major system of surface and deep currents. While the Southern Ocean and AABW occupy a relatively small fraction of the global ocean, the warming of the water column surrounding Antarctica could account for up to a quarter of the approximately 180-trillion-watt heat gain by the climate system during the late 20th century. Evidence has already emerged that AABW is becoming much less saline in the Australian Antarctic basin, and it is estimated that overall the AABW is storing about half of the total melt of the Antarctic ice mass. The warming also results in a rise in the level of the Southern Ocean of between one and two metres per year. The accompanying fresher AABW also contributes a weak signal to sea-level rise.

Several matters remain to be investigated. Surface waters around Antarctica are also freshening, and it seems likely that a significant fraction of the Antarctic melt ends up in these waters. Surface freshening allows sea ice to form more easily and may help explain observed increases in Antarctic sea-ice cover. Fully accounting for the role of freshwater in the Antarctic region, including changes in rainfall, will help us to predict the future accumulation and melt of Antarctic ice sheet – and thereby Antarctica's contribution to sea-level rise. While the freshening of AABW is very likely linked to the faster flow and thinning of the West Antarctic ice sheet, there are significant potential sources of melt in East Antarctica which need to be assessed. Finally, the amount of AABW freshening, changes in surface salinity and the warming of the Southern Ocean which are attributable to human influences and to the internal variability of the climate system have yet to be clearly established.

To increase its capacity to answer these questions, the ACE CRC is exploiting the revolution in ocean observation technology. We are using profiling floats which drift with the ocean currents and periodically rise to the surface to transmit temperature and salinity measurements. Seals travel far through the ocean and even beneath the winter sea ice, and miniaturised oceanographic sensors attached to the animals are providing information on the oceanic environment and on seal biology. Fixed moorings, ships and satellites are also being used to measure the physical and chemical properties of the Southern Ocean.

ACE CRC researchers are repeating previous tests in order to calibrate changes in ocean characteristics. We are using satellite altimetry to determine how the Antarctic Circumpolar Current (ACC) distributes surface chlorophyll and sea ice, and monitoring regional variations in the height of the Southern Ocean's surface. This research allows global, IPCC-class models to be tested against observations in

order to improve the models and deliver more reliable climate predictions. We also use detection and attribution methods to determine the extent to which observed changes in the composition of the atmosphere can be attributed to human influences or to natural variations such as solar and volcanic eruptions – crucial information for decision-makers. In these endeavours, the ACE CRC collaborates in the Antarctic with partners from the United States of America, England, France, Germany, China, New Zealand and Japan.

One of the most significant impacts of climate change will be caused by a rise in sea level. Recent research has shown that sea levels are rising at rates near the highest of previous predictions, that the rate of the rise is accelerating, and that the Antarctic ice-sheet contributes more to this than was understood less than a decade ago.

ACE CRC's Sea-Level Rise Impacts project focuses on providing decision-makers with targeted assessments of the risks of sea-level rise. This work is incorporating the effects of storm surges and the recession of the coastline as sea levels rise. The ACE CRC is helping Australia plan and prepare for future sea-level changes by providing specialised technical consulting, specialised vocational training for governments and industry, and a sea-level rise calculator tool called *Canute* (www.sealevelrise.info). *Canute* provides a wide range of stakeholders with an understanding of how to assess risks to existing assets, plan adaptation, and set appropriate design codes and planning strategies for future development.

2. Cryosphere: Impacts of Changing Snow and Ice Cover

How will sea ice and the Antarctic ice sheet respond to changes in climate and what impact will changes in the cryosphere have on climate and sea level?

The ACE CRC's Cryosphere Program is divided into three main research projects: the dynamic role polar ice sheets play in determining future sea levels; the role of Antarctic sea ice in the climate system; and the records and dynamics of past and present climate.

The great ice sheets of Antarctica and Greenland hold the largest potential for substantial and prolonged contributions to sea-level rise in a warming climate, but our present ability to predict these changes is limited. Recent observations suggest that the contribution to sea-level rise from both these great ice sheets is increasing, and that this is due to increasing discharge of ice by glaciers, rather than simply to more melt. Current computer models which simulate ice sheet dynamics and their links within the climate system are inadequate for quantifying the nature, rapidity and extent of the response of the ice sheets to climate change, and this gives rise to the principal uncertainty in sea-level predictions over time scales of a century and longer.

The project, 'The dynamic role of polar ice sheets in future sea level,' aims to improve the computer models of ice-flow dynamics, basal processes (occurring

underneath ice sheets, where they interact with land) and interactions with the atmosphere and ocean. The ACE CRC is collaborating with international efforts in model development, in particular through building on our expertise in the properties of ice flow and the interactions between ice shelves and the ocean. The models now take account of stresses to the ice that were previously neglected, and the ACE CRC's contributions include improved treatment of basal conditions, particularly the melting under ice shelves, and a better understanding of conditions at the surface of and beneath ice sheets. Modelling of the transition of glaciers from grounded ice flow to floating ice shelves is also being refined, so that the effects of changes occurring at the ocean margins on the flow in the ice-sheet interior are also accounted for.

The ACE CRC is involved in a major collaboration with international partners in the aerogeophysical survey of unexplored sectors of East Antarctica. This project is called 'Investigating Cryospheric Evolution through Collaborative Aerogeophysical Profiling' (ICECAP). The suite of instruments used in these surveys is producing vital knowledge of bedrock topography, basal rock, sediment and water conditions. These data will ensure that ice-sheet models are enhanced by real-world boundary data. The ICECAP survey targets deep sub-glacial basins and major outlet glaciers, which hold the greatest potential for dynamic ice sheet changes, and consequently for potential sea-level rise.

The Cryosphere Program's second project, 'The role of Antarctic sea ice in the climate system,' revolves around the fact that sea ice is a key component of Earth's climate system: the annual change in Antarctica from the maximum extent of sea ice in winter to the minimum in summer is one of the largest natural physical changes on the planet. Through a variety of feedback mechanisms, sea ice acts as both an agent and an indicator of climate change. It is also an important structure with respect to marine ecosystems. Over recent decades, the extent of sea ice and its thickness have decreased in the Arctic; a reduction in extent has also occurred in the Antarctic Peninsula region, but it is not known how the thickness of Antarctic sea ice is changing.

The ACE CRC is conducting field research, including the deployment of an Autonomous Underwater Vehicle, equipped with an upward-looking sonar to measure the drift of sea ice. To validate and calibrate satellite remote sensing, in situ observations and airborne laser altimetry will be conducted. Sea-ice mass balance stations equipped with biological sensors and sea-ice drifting buoy arrays will also be deployed.

The third project in the Cryosphere Program is 'Past and present climate: records and dynamics'. Climate records from the Antarctic region, Southern Hemisphere and even Australia are relatively sparse and of short duration. The previous IPCC reports have underscored the need for more palaeoclimate records from the Southern Hemisphere. These records are needed to support climate reconstructions and process studies and to test models. The project is producing additional high-

resolution climate records for the Antarctic. The team is developing existing records and using these to investigate regional and hemispheric climate processes, with emphasis on connections to Australian climate.

In order to do this, we are expanding the spatial extent and the timespan of the network of high-resolution ice-core records from East Antarctica. ACE CRC researchers are calibrating high-resolution ice-core records against modern meteorological data, and using these to probe climate dynamics over timescales beyond the period of human records. Finally, we are investigating longer-term processes related to natural climate forcing variations over the last glacial cycle, and the manner in which these processes influence the progression of global climate change and abrupt climate events.

3. Carbon: Southern Ocean Uptake

Will the Southern Ocean continue to remove CO_2 from the atmosphere and how rapidly will this increase the acidity of the ocean?

Currently one quarter of humankind's annual emissions of the fossil-fuel derived greenhouse gas, CO_2, are absorbed by the oceans – the Southern Ocean accounting for about 40% of that total. The oceans act as a reservoir for carbon, called a carbon sink, which accumulates and stores carbon via the ocean's physiochemical and biological processes.

Increased absorption of CO_2, however, comes at a cost – a decrease in the alkalinity of the ocean (often called ocean acidification). In the 21st century this change will have potentially serious impacts on the sustainability and management of many marine and coastal ecosystems and fisheries. Upwelling of sea water rich in CO_2 occurs more strongly in polar seas, and it is there that acidification will cross geochemical thresholds first, producing, for example, an undersaturation of the carbonate minerals which form the skeletons or shells of many marine organisms. This is a clear reason for giving the Southern Ocean special attention.

The ACE CRC collaborates with many organisations and countries around the world to understand the ability of the Southern Ocean to draw down atmospheric carbon. This understanding is vital for our environmental future and, as emphasised by the IPCC, is of crucial importance for the setting of efficient emissions reductions in order to limit climate warming. The ACE CRC Carbon Program has the overall goal of quantifying the role of the Southern Ocean in the global carbon cycle via three main projects.

The first of these projects involves measuring the magnitude of the uptake of atmospheric CO_2, the processes that control this uptake, and their propensity for change. The Southern Ocean's ability to take up CO_2 will not continue at current rates if global climate change reduces the rate of the ocean's normal mixing processes and therefore hampers their effectiveness. Changes in sea-ice cover, ocean warming and stratification, and a lack of supply of the limiting trace nutrient

iron all potentially have negative effects on the effectiveness of the 'biological pump' (those biologically-mediated processes, viewed as a whole, which transfer carbon from the surface region of the ocean to its interior) to lock CO_2 in the Southern Ocean carbon sink.

Determining the extent of ocean acidification caused by the uptake of CO_2, and its biogeochemical ramifications, is the second project in the Carbon Program. The overall goal is to determine how the progress of acidification depends on both the uptake of human-produced CO_2 and its interaction with naturally varying processes that control the distributions of alkalinity, dissolved inorganic carbon, and nutrients. Using samples from Antarctic voyages, the Carbon Program is mapping the progress of acidification and measuring the abundance of carbonate-forming organisms that may be affected by ocean acidification.

The final Carbon Program project examines potential carbon sequestration benefits and associated ecological risks of increasing the Southern Ocean's uptake of CO_2 by iron fertilisation of the ocean. The ACE CRC focuses its efforts on the study of natural iron fertilisation – most of which is wind-borne iron from rocks and soils – in order to investigate the associated extent of carbon uptake and ecosystem health and to compare these results to artificial fertilisations.

The ACE CRC Carbon Program collaborates with national and international bodies including DIICCRSTE, SEWPaC, the Australian Computational Earth Systems Simulator (ACCESS), the Australian Climate Change Science program, CSIRO, AAD, International Ocean Carbon Coordination Project (IOCCP), CO_2/Climate Variability and Predictability Program (CLIVAR), GEOTRACES, the Global Carbon Project and the IPCC. Impacts of ACE CRC's research include cost savings by governments and industry as a result of more accurate carbon-cycle models and more informed carbon-management strategies.

4. Ecosystems: Impacts of Climate Change on Antarctic Marine Life

What will be the impact of Southern Ocean and sea-ice changes on Antarctic ecosystems and fisheries?

The Ecosystems program addresses the challenging question of the impact of changes in the Southern Ocean and sea ice on Antarctic ecosystems and fisheries. The current expectation is that the 'keystone' nature of krill will remain the same but that the productivity of the ecosystem will generally decline with the loss of sea ice. However, emerging science is showing that the productivity of the system is uncertain and that a pelagic system without sea ice may develop, with the food web structure shifting from being centred on krill to one centred on fish, like that seen on the Kerguelen Plateau of the Southern Ocean. Such a change could seriously affect the region's fisheries and the conservation of whales and other higher predators. The ACE CRC is using a combination of field and analytical studies, along with qualitative and quantitative modelling to determine what may happen

to the Antarctic marine ecosystem, based on prognoses of change from the IPCC AR5 analyses.

The Ecosystems program is researching possible changes to Antarctic ecosystems and the consequences for fisheries through four main projects. The first of these is identifying the risks to key species of Southern Ocean marine ecosystems from the effects of climate change, such as temperature changes and ocean acidification. Literature and expert opinion are being used in a risk-assessment framework to evaluate the responses of species to climate-change scenarios. This work includes the development of conceptual models of the impacts on the physical environment and on food webs. Spatial modelling will identify major environmental drivers for species, and IPCC AR5 results will be used to ascertain change in those drivers and the likely consequences to species distributions and dynamics.

The second project aims to contribute to determining the impacts on ecosystems of predicted changes in Antarctic sea ice through evaluating the linkages between ocean productivity and the spatial and temporal dynamics of the sea-ice zone, including physical and biological parameters of sea ice. A sea-ice 'emulator' is being developed to improve models of the productivity of algae in sea ice until a full physical model for sea ice is completed. The international dataset of the biological and biogeochemical parameters of sea ice from ice cores is being further developed. In situ measurements of the biomass and production of ice algae and an understanding of how these relate to the physical attributes of sea ice and the water column are essential for developing the spatial models and the dynamic simulation models. Field programs in winter and autumn will help identify these relationships.

Identification of food-web processes which could be impacted by changes in the physical and biogeochemical environments in eastern Antarctica is the third project of the Ecosystems program and is split into two parts. Part 1 includes regular sampling on the SR3 oceanographic transect, combined with spatial statistical analyses of available data to evaluate the types of changes in phytoplankton and zooplankton assemblages that could arise as a result of a changing climate, and the mechanisms that could cause those changes. Part 2 of this project is to develop the foundations for an integrated ship- and land-based program to evaluate the primary food-web linkages from phytoplankton to top predators in eastern Antarctica. A multidisciplinary approach, which aims to develop collaborations amongst agencies in Australia and internationally is being adopted in order to sustain this program in the long term.

The fourth project draws on the results of the other ACE CRC Ecosystems projects to create a second-generation model of marine ecosystems which will be used to assess historical and future climate change impacts on Antarctic marine ecosystems, and to evaluate the types of objectives that could be appropriate for the conservation of Southern Ocean species. Models currently under development include the Ecosystem Productivity Ocean Climate (EPOC) modelling framework, a

regional ocean model (using the Regional Ocean Modelling System - ROMS) of eastern Antarctica and the Kerguelen Plateau, and the Australian Earth-system model through ACCESS. Development of a further ecosystem model using 'Atlantis' is also being undertaken to model effects on biodiversity and to support other modelling efforts in the program. This work is employing the latest cross-program knowledge of different components of the ecosystem in order to represent them appropriately in the modelling environment. These enhanced ecosystem models will be coupled to an ocean-ice-atmosphere model through the ROMS, in partnership with the modelling group at Old Dominion University, USA. Once developed, experiments can be undertaken which are based on plausible scenarios for climate change impacts, as developed in the other three projects in the ACE CRC Ecosystems program.

3.2 Research

The ACE CRC is on track to achieve its research goals. A detailed summary of research activities at the program level – Oceans, Cryosphere, Carbon and Ecosystems – is given below. Information on involvement with end-users and evidence that the research is meeting their needs are provided in section 3.3.

In 2012-2013, our researchers published a total of 5 book chapters, 84 articles in scholarly refereed journals, and 9 fully written conference papers in refereed proceedings. A further 35 articles were submitted to scholarly refereed journals or were in press during the reporting period. This shows the ACE CRC continues to deliver its intended research outputs. The publications are listed in Appendix 1.

1. Oceans

The ACE CRC and NIWA completed a joint Antarctic voyage on *RV Tangaroa* in February – March 2013. *Tangaroa* made a detailed survey of the Antarctic continental slope, including repeat investigations of two hydrographic sections along 140°E and 150°E. These latest surveys will extend the time series of changes in Antarctic Bottom Water, including the ongoing freshening and contraction of the bottom water layer (the densest layers have contracted by more than 50% since 1970).

ACE CRC researchers, with help of seals, have solved a 30-year mystery surrounding the formation of the global ocean's coldest, deepest waters (Ohshima et al. 2013). Through the use of sophisticated satellite data, oceanographic moorings and tagged seals researchers have discovered that Antarctic Bottom Water is being produced from intense sea ice formation in the Cape Darnley Polynya, north-west of the Amery Ice Shelf. Its significance is underlined by the fact that Antarctic Bottom Water is a key driver of the global ocean circulation and therefore of the earth's climate (for the full media release, see page 38).

ACE CRC scientists observed for the first time how and where human-produced carbon dioxide enters the Southern Ocean and published these findings in a paper

in Nature Geoscience (Sallée et al., 2012). Surprisingly, anthropogenic carbon enters the ocean through narrow 'ventilation windows', and the processes identified are responsible for the sequestration of carbon and are likely to be sensitive to climate change.

Studies of the changes in ocean temperatures (Gleckler et al., 2013) and oxygen concentrations (Andrews et al., 2012) provide further evidence of a human influence on climate. The work on ocean temperature concludes that it is virtually certain (that is, 99% certain) that humans have influenced the warming of the oceans. While an earlier study had established that the decline of oxygen concentrations was most pronounced in the Southern Ocean, the new evaluation with climate models shows formally that these oxygen decreases are caused by the changing composition of the atmosphere as a consequence of human activities.

The Climate Futures, an externally-funded project, continues to analyse the outputs of simulations over Tasmania and to make the connections between the evolving states of the Southern Ocean and Tasman Sea on the future rainfall and meteorological conditions over Tasmania.

A paper published in Geophysical Research Letters (Shadwick et al., 2013), and authored by scientists in the Oceans and Carbon programs, describes the oceanographic consequences of the calving of the Mertz Glacier Tongue. Comparison of data collected before and after calving shows that the loss of the glacier tongue dramatically reduced the salinity of the dense shelf water that contributes to the formation of Antarctic Bottom Water, and also significantly enhanced biological productivity and ocean carbon uptake. A second paper, in collaboration with Japanese partners in the ACE CRC, helped explain the causes of changes observed in Antarctic Bottom Water in the Australian Antarctic Basin (Shimada et al., 2013).

Analyses of genetic material from samples collected directly on ACE CRC voyages have provided new insights into how ocean circulation influences the biogeography of microorganisms in the global ocean and Southern Ocean (Brown et al., 2012; Wilkins et al., 2013).

ACE CRC scientists led an international workshop 'Seeing Below the Ice: Developing a strategy for sustained observations in the sea ice zone of the Southern Ocean' in Hobart from 22-25 October, 2012. The aim of the workshop was to develop a strategy for filling in the largest 'blind spot' in the global ocean observing system: the ocean beneath the Antarctic sea ice and ice shelves. The workshop made substantial progress in identifying how new technologies and established techniques can be combined to meet the significant challenges of observing this part of the ocean.

Recognising that the quality of ocean observations is a key element of understanding heat content changes in the ocean, ACE CRC scientists played a leading role in organising the "International Quality controlled Ocean Database". This

is a coordinated, international effort to 'clean up' the ocean temperature profile database and is a formal part of the international Climate Variability and Predictability program (CLIVAR). The first meeting was held in Hobart in June 2013.

The Sea-level Rise Impacts team launched a completely new version of the web-based decision support tool, '*Canute*: the sea-level-calculator', at a public event at River's Edge in Melbourne on 23 October 2012. The tool provides estimates of the likelihood of present and future flooding at approximately 12,000 simulated-tide-gauge locations; previously, data from only 29 physical gauges were available. Therefore, *Canute* delivers an effective resolution of 2.5 km along the entire length of the Australian coastline. This allows a prospective builder, for example, to make an initial estimate of the expected future storm-surge characteristics of a particular region before proceeding to a site-specific survey. Similarly, assessments can be made of the exposure of existing assets to the possible increased risk of flooding.

A further enhancement of the website has seen the introduction of a 'beach-recession' tool. Combining the output of *Canute* with modelled, regionally-specific beach characteristics, estimates are provided of expected soft shoreline retreat. In association with Water Research Laboratories (WRL) at UNSW, beach evolution was simulated using the internationally recognised 'XBeach' modelling framework. XBeach provides a 2-D model of sediment transport and beach erosion under prescribed conditions, which are derived from our *Canute* storm-tide modelling data. The Australian coastline has been divided into 30 regions, each having a sub-set of beach types. A user selects a region, a beach type, a year, a low-, medium- or high-level IPCC scenario and then receives a predicted recession.

We are working closely with the Spatial CRC (CRCSI) to translate the output from the calculator into high-resolution maps of predicted flood inundation. CRCSI has built a subset of our data into their new, web-based GIS, which is presently in testing mode. When their system is in production mode, we will be able to link into their server to create flood maps on-the-fly from within the *Canute* website.

The new website has a simple tool to calculate the additional effect waves have on sea-level: for example, to show how far they will run up the beach. This requires the user to have some knowledge of the offshore wave climatology. A new version is in development that uses the output of the NOAA WAVEWATCH III model to provide offshore wave data for the whole Australian coastline. We are also working closely with CSIRO to incorporate higher-resolution wave data into the tool in the future.

Financial impact tools are also under development and are presently on the test server. These implement a 'damage function' to calculate the financial impact of predicted flood levels. Pre-defined damage functions, sourced from industry, are provided, with the additional feature of allowing a user-defined array. This work is being conducted in association with SGS Economics and Planning.

SCIENTISTS SOLVE 30-YEAR MYSTERY OF THE DEEP

Scientists, with the help of seals, have solved a 30-year mystery surrounding the formation of the global ocean's coldest, deepest waters.

Until now they had known that the cold, dense bottom waters of the global ocean originated at three different locations in Antarctica - the Weddell Sea, the Ross Sea and the Adélie Coast of East Antarctica. Thirty years ago, a fourth source was speculated to exist somewhere in the Prydz Bay region, but until now scientists have been unable to confirm if, where and how it is being formed.

Now, through sophisticated satellite data, oceanographic moorings and tagged seals, they have discovered that a fourth stream of so-called 'Antarctic bottom water' is being produced from intense sea ice formation in the Cape Darnley Polynya, north-west of the Amery Ice Shelf. Scientists estimate that this source of Antarctic bottom water represents between six and 13 per cent of the circumpolar total.

The research is published today in the journal Nature Geoscience. Its significance is underlined by the fact that Antarctic bottom water is a key driver of the global ocean circulation and therefore of the earth's climate.
Co-lead author Dr Guy Williams, sea-ice specialist at the Antarctic Climate & Ecosystems CRC in Hobart, said the search for the fourth source of the Antarctic Bottom Water dated back to the discovery in 1977 of recently formed bottom water offshore of Mac Robertson Land (60 – 70ºE).

"So since then we have had a smoking gun – we suspected there was a source of Antarctic bottom water in the area, but the inaccessibility of the area has meant that it has taken another 30 years to locate and observe how it is being formed."
In 2008-9, as part of the International Polar Year, Japanese scientists from the Institute of Low Temperature Science, Hokkaido University and the Tokyo University of Marine Technology deployed moorings in the Daly and Wild canyons off the continental shelf at Cape Darnley. Data from these moorings is now being examined in conjunction with data provided by southern elephant seals.

"The seals went to an area of the coastline that no ship was ever going to get to, particularly in the middle of winter, and measured the most extreme dense shelf water anywhere around Antarctica," Dr Williams said. "Additionally several of the seals foraged on the continental slope as far down as 1800 metres, punching through into a layer of this dense water cascading down to the abyss. They gave us very rare and valuable wintertime measurements of this process."

The oceanographic data being collected by the seals is part of a larger ecological project at Institute for Marine and Antarctic Studies to study their behaviour. When the seals surface, their tags relay information (via satellite) back to land, where it is collected by the Integrated Marine Observing System (IMOS), also based in Hobart.

By chance, the data from these seals allowed scientists to pinpoint the path of the dense salty water and therefore identify the area from which it originates.

The newly identified source is different from the other three sources. Its existence demonstrates that polynyas (areas of open water surrounded by sea ice) are capable of forming sufficiently dense shelf water over a narrow section of continental shelf without the traditional assistance of a large ice shelf or coastal storage volume. This opens the door for further discoveries of Antarctic bottom water production from the other polynya regions around the Antarctic coastline.

Dr Williams said the discovery was the missing piece of a 30-year old puzzle. “This redraws the map of large-scale Antarctic oceanography in the Atlantic sector. It is now vital that this new information be incorporated into the assessment of Antarctic bottom water variability and change, and its input to the global overturning circulation. This will improve numerical modelling efforts to predict its response to long-term climate change. “

ACE CRC media release 25 February 2013

2. Cryosphere

The ACE CRC's Cryosphere Program continued to be very productive this year, with significant field activities and detailed preparations for future fieldwork. Important publications resulting from this work are referred to below and, once again, significant effort was directed towards contributing to the forthcoming IPCC AR5 Report, in which Cryosphere staff are involved as both authors and reviewers. Details of ACE CRC's contribution to IPCC are provided in section 3.3 below.

The Cryosphere Program continues its evolving approach to delivering outcomes from ice sheet and associated ocean modelling. As noted in section 3.1, the program's particular strength is its ability to improve ice-sheet/ice-ocean modelling by better specification of boundary conditions and of processes. This has led to a shift towards adopting and adapting ice sheet models from the wider international community, and strengthening, informing and testing these, rather than devoting resources to extensive ice-sheet model development at the ACE CRC. From July 2013 the ACE CRC is hosting a British Marie Curie Fellow, Dr Rupert Gladstone, who will assist in further development of approaches to coupling ice-shelf ocean models.

The ICECAP airborne survey has continued to provide important data and publications from the observational side of the ice-sheet work. In the 2012/13 season, ICECAP conducted 16 flights, adding more than 24,600 line kilometres to the number surveyed and bringing the project's total to 320,000 km. This work has provided fundamental data on ice-sheet boundary conditions, which is incorporated into the 'BEDMAP2' Antarctic bedrock reconstruction. BEDMAP2 is the definitive product of its kind and was published during this reporting period. This season ICECAP completed its targets of filling major survey gaps along the grounding zone from Casey to Davis stations, and surveying a critical junction in the subglacial hydrology in the Aurora Basin.

Experimental studies continue to develop the understanding of ice-mechanical properties and how these relate to ice flow under different conditions. A major advance in this work was the publication of a comprehensive synthesis of existing experimental results to provide a description that can be incorporated into ice-sheet models.

The Cryosphere Program has made significant progress in applying models and developing modelling techniques for ice-ocean interaction. Work has continued with the recovery and interpretation of data from instruments under the Amery Ice Shelf through the Amery Ice Shelf Ocean Research (AMISOR) project, and there have been advances in the calibration and interpretation of data from fibre-optic distributed temperature sensing in the ocean cavity below the ice shelf. Several papers resulting from this work are in various stages of preparation, including some in review or published.

The sea-ice team has had a very big season, with the major SIPEX-II (Sea Ice Physics and Ecosystems Experiment II) voyage off East Antarctica (100-120°E) in September-

November 2012. This multi-disciplinary study, using RSV Aurora Australis, was specifically designed to address major gaps in the knowledge of Antarctic sea-ice zone processes as identified by national and international end-users. Researchers measured the physical and biological properties of sea ice on small-to-regional scales using classical methods and state-of-the-art technology which included: ice coring surveys, remotely-operated and autonomous underwater vehicles, drifting buoys and instrumented helicopters. Data currently being processed will enhance our understanding of the role of sea ice in Antarctic climate and ecosystem processes. These data will also be utilised for the validation of satellite-derived products and the parameterisation of sea ice processes for climate and ecosystem models (see page 45 for ACE CRC media release on SIPEX-II).

Ice-core research has produced a number of important results. One notable published paper (Vance, et al. 2013) identifies a connection between the El-Niño Southern Oscillation (ENSO) and summer wind speeds in the Southern Ocean. This connection is seen in the form of links between wind-induced sea salt levels in the Law Dome ice core and ENSO, which, in turn, provide a proxy for ENSO-related rainfall in Eastern Australia. The highlight for palaeoclimate outputs was the publication of a global region-by-region synthesis of temperature over the past 2000 years, in Nature Geoscience (PAGES2k Consortium, 2013). The Antarctic regional reconstruction was led by ACE CRC researchers. The work is an important initial product for characterising natural climate variability over Antarctica as a whole, but it also illustrates the sparsity of detailed climate information and inherent limits to understanding regional variations in Antarctic climate. ACE CRC researchers also provided commentary for Nature Geoscience on Antarctic climate responses more generally (van Ommen, 2013).

A major activity for the ACE CRC ice-core research project has been the planning and advance deployment of equipment towards the large Aurora Basin North ice-coring project which is scheduled for December-January 2013-2014. This involved positioning several tonnes of cargo at the French Dumont d'Urville station in 2012 for early-season deployment by traverse. The Aurora Basin North project will provide a vital new climate record from East Antarctica.

3. Carbon

This year the Carbon Program's focus was on assembling data and synthesizing results. In addition, the Carbon Program carried out two voyages to service the Integrated Marine Observatory Southern Ocean Time Series facility, recovering and deploying new air-sea flux, surface biogeochemistry, and deep sediment trap moorings each time. Important results this year from the three Carbon Projects are discussed below.

Ocean Uptake

Using measurements taken from Antarctic resupply vessels, surface waters were demonstrated to be tracking the atmospheric CO_2 increase over large regions of

the Southern Ocean. These results were assembled into global databases, with over 10 million data points released in 2013. ACE CRC scientists led the Southern Ocean group of the Surface Ocean CO_2 Atlas (SOCAT) (Pfeil et al., 2013 and Bakker et al., in press). This work is essential for evaluating inter-annual variations and their links to climate modes such as the Southern Annular Mode, ENSO, and other still-to-be-discovered aspects of ocean-atmosphere interactions.

Southern Ocean CO_2 uptake over the past 20 years was evaluated by combining the SOCAT surface ocean results and additional deep ocean data with ocean and atmospheric models. This work was done as part of the Regional Carbon Cycle Analysis and Processes project (RECCAP; Lenton et al., 2013). The Southern Ocean CO_2 uptake continues to be large compared to other ocean areas, but the efficiency of Southern Ocean carbon uptake in response to the intensification of high latitude westerly winds remains uncertain. Oceanic models suggest that uptake has increased along with emissions, but atmospheric models suggest there is less of an increase for the period 1990-2009. The processes controlling the uptake are not yet well understood, and no global model is able to successfully simulate the total annual uptake and also the seasonal and regional patterns of uptake. This calls into question the ability of current models to predict long term changes in the efficiency of the Southern Ocean sink. These results emphasise the need to continue to map pCO_2 every year and to carry out full hydrographic sections every 5 years for the purpose of completing global carbon budgets including verifying emissions, and quantifiying the evolving relationships between CO_2 emissions and climate responses.

The Carbon Program demonstrated the ability at the Southern Ocean Time Series facility to estimate the net production of oxygen and consumption of CO_2 by an ecosystem at hourly resolution from moored sensors. This revealed unexpectedly high levels of production in deep, mixed layers in spring (Weeding and Trull, 2013, in review), and differs from the parameterisations used in almost all global models of the biological carbon pump, which predict low net community production. This work is essential to advancing the understanding of seasonal productivity in the Subantarctic Southern Ocean – the key region for changes in ocean carbon cycling over the Holocene and this century – and for properly including it in global carbon models.

Ocean Acidification

The progress of acidification has been shown to be regionally and temporally variable as a result of concomitant changes in natural carbon cycling. One such change is the demonstration that the collapse of the Mertz Ice-Shelf Tongue led to large increases in the biological removal of dissolved inorganic carbon, thereby countering the effect of human-produced acidification (Shadwick et al., 2013). Another significant finding is that reduced activity of the biological pump in coastal waters near Davis Station has had the opposite effect of approximately doubling the change over the period 1994-2011 predicted from the uptake of atmospheric CO_2 alone (Roden et al., in press). This ability of Antarctic waters to affect the progress of acidification via changes in the biological pump is one reason that Antarctic waters

appear to be less vulnerable than Arctic waters (Shadwick et al., submitted). These studies are the launching pad for the development of greater monitoring of coastal Antarctic biogeochemistry as a gauge for vulnerability. Collaborations with biologists to investigate vulnerability also advanced, including work on echinoderms and pteropods (Byrne et al., 2013; Roberts et al., submitted).

Ocean Fertilisation

The rapid release of dissolved iron from sea-ice, sufficient to fertilise surrounding waters, has been demonstrated from SIPEX-II observations, (Lannuzel et al., in press), and a deep mid-ocean ridge south of Australia has been recognised as a source of hydrothermal iron (Tagliabue et al., 2011; Bowie et al., in prep). The possibility of new or rapidly changing sources of iron holds the largest potential for possible surprises in the control of primary production and thus the health of all Southern Ocean and Antarctic ecosystems in the coming century.

The complex interaction of iron sources with mesoscale and sub-mesoscale flows is also emerging as a key determinant of biological responses. Work illustrating these interactions from the 2012 KEOPS-2 France-Australia collaboration is currently being assembled into a special volume of papers for the journal Biogeosciences. These studies are first steps towards further evaluating new sources of iron in our sector, determining their bio-availability, and examining how ecosystems are structured in response to changing iron inputs.

These evolving perspectives on the interactions of iron fertilisation with the characteristics and health of ecosystems continue to inform collaborations with SEWPaC to promote an amendment to the International Maritime Organisations London Protocol to improve the regulation of ocean fertilisation and extend this to broader forms of marine geo-engineering.

4. Ecosystems

The Ecosystems Program's modelling group has now established a methodology for coupling ocean and ecosystem models. An ocean model for the Indian Sector of the Southern Ocean was developed using ROMS. And a sea-ice 'emulator' – to approximate sea-ice dynamics until a full physical sea-ice model is completed – has been included in an ecosystem model for the region, based on CSIRO's Atlantis model and being developed in conjunction with CSIRO. Delays in developing the Atlantis model have arisen due to the need to further test components relating to higher predators and to refine the responses of populations to changes in sea ice. This should be completed later in 2013. Testing of the coupled model is now expected to begin later in 2013, and the first experiments in early 2014. In the interim, a strategy has been developed for using IPCC model outputs (CMIP5) to drive models of species and food webs in order to provide assessments of their vulnerabilities in the future. The last mentioned work, which is ongoing, has resulted in a publication in Nature Climate Change on the potential negative impacts of ocean acidification on krill populations by 2100 (Kawaguchi et al., in press).

The SIPEX-II voyage, led by the Ecosystems Program's Dr Klaus Meiners, took place in September-October 2012. It revisited a study area off Wilkes Land to build on the information and observations collected in 2007. The overall aim of the voyage was to gather data during spring to help assess the impacts of climate change on the physical and biological elements of the East Antarctic sea ice zone. Planning and preparations are well underway for participation in the AWI *Polarstern* winter-spring voyage in the Weddell Sea and the South Atlantic.

Methods have been developed for conducting rapid qualitative assessments of the impacts of climate change on Southern Ocean food webs, and training workshops promoting their very effective use have been conducted, including at the Australia-New Zealand Strategic Science in Antarctica Conference in Hobart in June 2013. As a result, this methodology is becoming rapidly accepted. Further publications are well advanced in utilising these methods in a circumpolar risk assessment and are expected to be published in the next reporting period.

A series of papers arising from the second international workshop on the Southern Ocean Sentinel are nearing completion for submission. These summarise circumpolar changes to Antarctic and Southern Ocean biota and a risk assessment of current and future change to these ecosystems. Considerable progress has been made in the international coordination of a circumpolar program to measure change in Southern Ocean ecosystems. The Ecosystems Program has contributed to workshops and planning in ICED, the Southern Ocean Observing System and the Council of Managers of National Antarctic Programs. The Ecosystems Program also facilitated a grant from the International Council of Scientific Unions (ICSU) for the further coordination and standardisation of marine ecosystem observations.

During the reporting period, the Ecosystems Program continued to contribute to the Working Group 2 of the IPCC AR5. The Program Leader, Dr Andrew Constable, was appointed as a Lead Author in Chapter 28 on the Polar Regions with responsibility for leading the development of text on Antarctic marine, freshwater and terrestrial ecosystems. The review work described above has formed the foundation for these contributions to Chapter 28. In addition, the Ecosystems Program has established the Southern Ocean Knowledge and Information (SOKI) wiki, which provides a scientific community forum for standardising methods and information and for promoting coordination of research programs. An international Steering Committee for SOKI has been formed and an editorial process established.

ANTARCTIC VOYAGE BRINGS HOME RARE GLIMPSE UNDER THE SEA ICE

An international sea ice voyage returned to Hobart with spectacular images of the world beneath the East Antarctic sea ice.

Researchers on board Australia's icebreaker, Aurora Australis, spent two months in Antarctica studying the link between sea ice and Southern Ocean ecosystems as part of the Sea Ice Physics and Ecosystem eXperiment-II (SIPEX-II). This significant voyage was jointly conducted by the Australian Antarctic Division (AAD) and the Antarctic Climate and Ecosystems CRC (ACE CRC).

Science Leader, Dr Klaus Meiners, said an underwater robot (Remotely Operated Vehicle or ROV) captured almost 40 hours of vision of jumbled giant ice blocks, sea ice algae and krill under the sea ice.

The robot was deployed through a hole in the ice and engineers used a joystick to operate and monitor its progress via four high-definition stereo-vision cameras.

"The ROV's icy dives transported us into a different world. The subsurface of the ice was like a badly eroded mountain range, with Antarctic krill and patchy areas of algae," Dr Meiners said.

"The ROV's main role was to measure the amount and distribution of sea ice algae using a smart light sensor. This instrument measures the reduction in the blue and green wavelengths of light beneath the sea ice, allowing us to estimate the overall amount of algae."

Sea ice algae live within and attached to the bottom of the sea ice and are a key food source for Antarctic krill, which in turn are the primary food for larger animals such as penguins, seals and whales.

"Climate models predict sea ice in Antarctica could decline by 35% in volume by the end of the century, so understanding the distribution of sea ice algae will enable us to assess the impacts of climate change on the Antarctic marine ecosystems into the future," Dr Meiners said.

The ROV scientists will spend the coming months analysing their data sets to understand relationships between sea ice thickness and algal biomass. Also on the voyage scientists, including AAD krill aquarium manager, Rob King, investigated how Antarctic larval and juvenile krill survive the winter months beneath the sea ice. Krill have 12 larval stages before they become juveniles and then sexually mature adults.

"Most krill research has been conducted on adult krill during the Antarctic summer and only a few studies have focused on the larval stages during winter," Rob King said.
"On this trip we were able to use a high-volume water pumping system off the side of the Aurora Australis, to capture live larval and juvenile krill under the ice and look at their metabolism, growth rate and diet."

The krill pump uses a large, insulated pipe to suck 400 litres of water per minute into a filter system housed in the ship's oceanographic instrument room. The captured krill are then gently washed into a holding tank for transfer to the ship's laboratories.

"There have been suggestions that the krill population around West Antarctica has already declined significantly as a result of changes caused by the decline in sea ice," Mr King said.

"By bringing together under sea ice information available from the ROV and physiological studies on krill larvae we want to understand how climate change alters sea ice conditions in East Antarctica and what impact this will have on the dynamics of krill larval and adult populations in this area."

SIPEX-II was a continuation and extension of the first SIPEX voyage which took place in 2007. More than 50 scientists from Australia, Belgium, Canada, France, Germany, Japan, New Zealand and the United States took part in the voyage.

A range of multi-disciplinary projects looking at the physical and biological elements of the Antarctic sea-ice zone were undertaken on this internationally collaborative voyage.
From the air researchers used laser and radar-equipped helicopters to determine sea ice and snow cover properties. On the ice floes others worked on ice algae physiology and sea ice biogeochemistry. Under the ice, instruments measured water properties including salinity, oxygen and temperature.

All of this information contributes to scientists' greater understanding of how sea ice might be affected by climate change, enabling them to assess its impacts on the function of ecosystems in the ice-covered Southern Ocean.

ACE CRC media release 16 November 2012

3.3 Utilisation and Commercialisation

The ACE CRC continues to seek innovative ways of communicating its research outcomes so as to maximise the uptake of its scientific work. This section begins by outlining important activities which have involved staff from across the ACE CRC, most notably contributions to the forthcoming Intergovernmental Panel on Climate Change's Fifth Assessment Report (IPCC AR5). Additional details are then provided for individual programs.

IPCC

The contributions of ACE CRC staff over several years to the preparation of the forthcoming IPCC AR5 represent a major commitment to end-users nationally and globally. The IPCC is the international body responsible for providing governments with the largest and most comprehensive summary of the latest scientific information on climate change. This work depends on voluntary input from scientists around the world and ACE CRC researchers have been involved as coordinating lead authors, lead authors, contributing authors and as reviewing editors or reviewers of the first, second and final drafts of chapters, both as scientific expert reviewers and on behalf of the Australian Government. As an indication of the amount of time invested by some staff, one of the Coordinating Lead Authors calculates that in the course of his work for IPCC AR5 he has written and received 10,000 emails.

Eight ACE CRC staff have held senior roles during the IPCC AR5's preparation:

- Prof Nathan Bindoff (Coordinating Lead Author, Working Group 1, Chapter 10 - Detection and attribution of climate change: from global to regional; Contributing Author, Summary for Policy Makers; Technical Summary)
- Dr Steve Rintoul (Coordinating Lead Author, Working Group 1, Chapter 3 - Observations: Oceans; Contributing Author, Summary for Policy Makers; Technical Summary)
- Dr Andrew Constable (Lead Author, Working Group 2, Chapter 28: Polar Regions)
- Dr Ian Allison, Honorary Research Professor, (Lead Author, Working Group 1, Chapter 4 - Observations: Cryosphere)
- Dr John Church, Honorary ACE CRC Fellow, (Coordinating Lead Author, Working Group 1, Chapter 13 - Sea Level Change; Contributing Author, Summary for Policy Makers; Technical Summary)
- Dr Shigeru Aoki, ILTS, Japan (Lead Author, Working Group 1, Chapter 3 - Observations: Oceans)
- Prof Phil Boyd (Lead Author, Working Group 2, Chapter 6 – Ocean systems)
- Prof Kurt Lambeck, formerly ACE CRC (Lead Author, Working Group 1, Chapter 5 - Information from Paleoclimate Archives)

In addition, the following ACE CRC personnel were Contributing Authors, Reviewers or both:

- Dr John Hunter (Contributing Author and Reviewer, Working Group 1, Chapter 13 - Sea Level Change; Contributing Author, Working Group 2, Chapter 5 – Coastal Systems and Low-Lying Areas; Contributing Author, Technical Summary)

- Dr Catia Domingues (Contributing Author, Working Group 1, Chapter 3 – Observations: Oceans; Chapter 10 - Detection and attribution of climate change. Reviewer, Working Group 1, Chapter 3 – Observations: Oceans Oceans; Chapter 13 - Sea Level Change)

- Dr Tas van Ommen (Reviewer, Working Group 1, Chapter 2 - Observations: atmosphere and surface; Chapter 4 - Observations: Cryosphere; Chapter 5 - Information from Paleoclimate Archives. Government Reviewer, Working Group 1, Chapter 4 - Observations: Cryosphere)

- Dr Rob Massom (Contributing Author, Working Group 1, Chapter 4 - Observations: Cryosphere)

- Dr Roland Warner (Government Reviewer, Working Group 1, Chapter 4 - Observations: Cryosphere)
- Dr Stuart Corney (Reviewer, Working Group 1, Chapter 10 – Detection and Attribution of climate change: from global to regional; Working Group 2, Chapter 28: Polar Regions)
- Prof Richard Coleman (Reviewer – Working Group 1, Chapter 4 - Observations: Cryosphere; Chapter 13 – Sea Level Change)
- Prof Peter Lemke, AWI, Germany (Reviewing Editor, Working Group 1, Chapter 4 - Observations: Cryosphere)

- Dr Xiao Cunde, CAMS, China (Reviewing Editor, Working Group 1, Chapter 13 - Sea Level Change)

- Dr Joel Pedro (Reviewer, Working Group 1, Chapter 5 - Information from Paleoclimate Archives)Ms Viviane Vasconcellos de Menezes (Contributing Author, Working Group 1, Chapter 10 - Detection and attribution of climate change: from global to regional; Contributing Author, Summary for Policy Makers; Technical Summary)

- Dr Paul Durack (Contributing Author, Working Group 1, Chapter 3 – Observations: Oceans)

The Intergovernmental Panel on Climate Change (IPCC) Working Group I Fourth Lead Authors meeting was held in Hobart, Tasmania, 13-19 January 2013. Several ACE CRC staff were invited to attend the Opening Plenary and ACE CRC researchers Prof Nathan Bindoff, Dr John Church and Dr Stephen Rintoul spoke at the media briefing preceeding the plenary.

The ACE CRC was visited by the Chief Scientist for Australia, Professor Ian Chubb, on 7 August 2012. Professor Chubb had a tour of the ACE CRC research facilities and attended a roundtable with Hobart-based research institutional leaders, scientists, and PhD students from the ACE CRC, AAD, CSIRO, IMAS and IMOS.

In November 2012, ACE CRC scientists featured prominently in a briefing on Australian Antarctic science provided for HRH Prince Charles, The Prince of Wales. Among the topics covered were SIPEX-II, Argo and Ocean research, ecosystem studies and ice core research.

The following month, ACE CRC researchers were also involved in Antarctic familiarisation activities organised and hosted by AAD for a range of other VIPs. Guests included Her Excellency the Governor-General (who, accompanied by Cryosphere Program Leader Dr Tas van Ommen among others, became the first Australian Governor-General to travel to Antarctica), The Honourable Bob Hawke, and a delegation of parliamentarians. All these guests were briefed on research conducted by AAD within the ACE CRC and many were also able to visit the AAD warehouse to tour a trial camp-setup for the Aurora Basin North expedition of 2013-14.

A wide range of outreach activities have taken place with politicians, policy makers and the public, as well as within the science community. In the last category was the first Strategic Science in Antarctica conference, organised by the Australian Antarctic Division and Antarctic New Zealand. This event, sponsored by the ACE CRC and held on the campus of the University of Tasmania prominently featured research of the ACE CRC and its collaborators.

Oceans

As detailed above, ACE CRC scientists have played a leading role in the 5th Assessment Report of the Intergovernmental Panel on Climate Change. Dr Stephen Rintoul and Prof Nathan Bindoff of the Oceans Program served as Coordinating Lead Authors of the Oceans and the Detection and Attribution chapters of the report, and led the development of the Technical Summary and Summary for Policy Makers, which summarise the headline results from all the chapters. Other program members also made important contributions to the report, which will be concluded on 27 September, 2013.

During the reporting period, the following utilisation milestones were achieved:

- Briefings to politicians across all three levels of government, public lectures, school visits and contributions to blogs like www.skepticalscience.org.
- Regular review with key government departments such as DIICCSRTE and SEWPaC, commercial participants, and ACE CRC's essential and other research participants.
- The Annual General meeting was held on 5 September 2012 in the Royal Botanical Gardens, Queen's Domain, Hobart, with key government

departments (DIICCSRTE, SEWPaC), research partners (NIWA, AAD) and commercial participants (pitt&sherry, SGS and Myriax).
- The Oceans Program also maintained important links with the international scientific community via collaborations, such as the SOOS and the Global Ocean Observing System (GOOS). Through these collaborations, the Oceans Program research outputs are utilised by the global scientific community.

Sea-level Rise

- The ACE CRC sea-level calculator '*Canute*' (www.sealevelrise.info) was officially launched at River's Edge in Melbourne on 23 October 2012. Subsequently, the website has evolved and additional components have been added.
- Uptake is measured by new registrations and active users of the website. There are currently 329 active users and a further 324 people who have signed up to the website but not yet completed all the online training needed to gain access to the calculator.
- Regular reviews were held with key commercial participants, and we are jointly expanding the tool's functionality.
- The sea-level rise team also offered consultancy services to a number of Governments.

Cryosphere

The Cryosphere Program had excellent media coverage, supported by the AAD and ACE CRC media teams, as well as by many scientists communicating various aspects of the SIPEX-II project to the general public through media interviews, public presentations and webpage contributions.

During the reporting period progress was made with several utilisation milestones:

- Position analyses for sea-ice and ice-core research were largely completed, with only the final production work remaining.
- An ACE CRC Position Analysis Briefing: Ice Cores, Climate and Australia's Antarctic Research for end-users was held in Canberra on 3 May 2013. A similar function for a sea-ice Position Analysis update is scheduled for 29 August 2013.
- A Position Analysis update for ice sheets and sea level is in preparation.

The Australian Academy of Science National Committee for Earth System Science held a two-day Earth System Outlook Conference, *Ticking time bombs in the human earth system,* in Canberra from 26-27 November, 2012. The focus was on four themes with the potential to become planetary tipping-points and which involved climate change and biodiversity. Dr Tas van Ommen was co-convenor and a number of other ACE CRC researchers took part, in particular in the session on Polar deglaciation and sea-level rise. Drs van Ommen and Hunter were both speakers and discussion panellists and Drs Galton-Fenzi and Herraiz-Borreguero were members

of the discussion panel. The proceedings were broadcast online nationally and internationally, which can be found here: http://www.igbp.net/multimedia/multimedia/tickingtimebombsinthehumanearthsystem.5.561163a13d60576e12292.html

Carbon

During the reporting period, the following utilisation milestones were achieved:

- Regular review with key government departments such as DIICCSRTE and SEWPaC, commercial participants, and ACE CRC's essential and other research participants.
- The Annual General meeting was held on 5 September 2012 in the Royal Botanical Gardens, Queen's Domain, Hobart, with key government departments (DIICCSRTE, SEWPaC), research partners (NIWA, AAD) and commercial participants (pitt&sherry, SGS and Myriax)
- Many presentations were held over 2012-2013, including to politicians, SEWPaC, DIICCSRTE, DAFF, DFAT and the Climate Institute.

The Carbon Program communicates directly with SEWPaC on policy matters such as

providing a scientific basis for the evaluation of the potential risks of proposed marine geo-engineering activities, including ocean fertilisation. Research uptake is also reflected by incorporation of outputs into IPCC reports, as discussed at the start of this section.

Dr Donna Roberts, senior ocean acidification research fellow, represented the ACE CRC at the ocean science dinner with the USA Ambassador to Australia at the USA Embassy in Canberra on 6 July 2012. Dr Roberts also represented the ACE CRC at the ocean science lunch with HSH Prince Albert II of Monaco at the Blue Ocean-Google VIP lunch in Monterey, California, USA, on 27 September 2012.

Ecosystems

During the reporting period, the following utilisation milestones were achieved:

- Regular review with key government departments such as DIICCSRTE and SEWPaC, commercial participants, and ACE CRC's essential and other research participants.
- During the reporting period, the Ecosystems Program contributed to the Working Group 2 of the IPCC AR5. The Program's research on impacts of climate change in Polar Regions will contribute to chapter 28 of the report.
- An ACE CRC Position Analysis Briefing: Ecosystems Impacts for end-users was held in Canberra on 3 May 2013.

Strategies for ensuring uptake by end-users include:

- Regular reviews with end-users to understand needs and transfer knowledge.

- Production of Position Analyses, Report Cards and Technical Reports, including mailout to an established database of users.
- A draft ACE CRC Position Analysis Briefing: Impacts of Climate Change on Southern Ocean Ecosystems was presented to end-users at a workshop in Canberra on 3 May 2013.
- E-newsletters and Twitter to keep users updated on the latest science.
- Attendance and presentations at conferences and symposiums.
- Direct involvement in IPCC reporting process (as a major conduit to policymakers nationally and internationally).
- Media releases and briefings to journalists.
- Implementing strategies to measure uptake (for example downloads of reports).

3.4 Education and Training

Education

The ACE CRC Education Program continues to be supported by and provided through the Institute for Marine and Antarctic Studies (IMAS), which is part of the University of Tasmania. Students study a range of topics relevant to Antarctica and the Southern Ocean.

ACE CRC, including IMAS, staff teach PhD, Masters by Research and Masters by Coursework students. They also teach Honours programs and units in undergraduate courses, mostly to students taking science degrees, although a few Arts undergraduates also enrol in IMAS's general Antarctic studies units.

During the reporting period, 37 (FTE) students were involved in PhD studies related to the ACE CRC. There were 8 commencements and 9 completions. The graduates are now working at ACE CRC (1), AAD (1), AWI (1), industry (1), post-doctoral positions at Australian universities (2), started own business (1), and unknown (2). Twenty-two UTAS staff and 28 non-university staff were involved in the PhD supervision.

One student was enrolled in Masters by Research, but there were 18 (FTE) in Masters by Coursework at IMAS. There were no commencements but one completion during the reporting period. Six non-university staff members were involved in the formal teaching of these postgraduate units.

A total of 292 students were enrolled in IMAS undergraduate units during 2012-2013. Forty-eight of these were taking Bachelor of Antarctic Science and 53 Bachelor of Marine Science degrees and there were 3 Honours students. Also included in the total are 17 Professional Honours students. This represents a new arrangement this year, whereby students wishing to undertake a Masters by Coursework will first complete the Professional Honours and then enrol in the Masters for their 6-month thesis projects only.

The combined figures show that Masters by Coursework enrolments, direct and via the Professional Honours, have continued to be very strong. Somewhat reduced recruitment into ACE CRC-related research degrees can be attributed partly to the period of uncertainty about the ACE CRC's future, since students and supervisors were reluctant to commit to projects under those circumstances. However, there have been strong employment outcomes for this year's PhD graduates, who continue to develop strong careers. Total undergraduate numbers (not including the Professional Honours students) represent a 34% increase on the last reporting period– a very encouraging sign, as some of these students can be expected to progress to postgraduate studies in the future.

The ACE CRC sponsorship of the Australian Marine Sciences Association – New Zealand Marine Science Society 2012 Conference in Hobart in July 2012 allowed student recruitment opportunities. IMAS and the ACE CRC shared a booth to display current projects and general scholarship information to potential students. A competition was held to capture the audience at the booth during the conference and a total of 97 people visited the booth of which 58 were students. The majority of these students were from overseas or interstate.

The ACE CRC's involvement as a sponsor of the Strategic Science in Antarctica conference, held on the UTAS campus in June 2013, provided a valuable opportunity for students to attend and take part in discussions and workshops by Australian and New Zealand scientists on the most up-to-date Antarctic research. Eva Cougnon, an ACE CRC PhD student, won First Prize in the category: ACE CRC Prize for Best Concurrent Presentation by a Student at the conference.

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

Training courses for end-users/professional development

During the reporting period, the ACE CRC hosted several workshops for end-users, attended by a total of 98 end-users. *Canute*, the publically available sea level calculator, now has approximately 329 people registered and training with another 324 people registered but are yet to complete the online training. The sea ice view tool training and *Canute* online training are mentioned below.

Sea ice view tool training

The sea ice view tool training is a hands-on training course in the use of the Sea Ice View Tool developed by the ACE CRC. The Sea Ice View Tool allows for clear interpretation of data products to navigate an icebreaker, in this case the Aurora Australis, safely through the sea-ice. Dr Lieser trained 12 employees from P&O Maritime (9/9/12) and Australian Antarctic Division (18/11/12). This training included background about the tool as well as training in setting it up and driving it. Emphasis was placed on interpretation of the data products that were available for the season, and their origin. A manual for the tool as well as a printed copy of Sea Ice

Reports for reference were given to participants. This training will be done annually before the voyage season.

Canute

Canute, the publically available sea level calculator, provides estimates of the likelihood of future flooding from the sea. By combining two uncertainties (the frequency of present storm surges and the uncertainty of future sea-level rise) into a single likelihood, a statistically robust prediction is generated. To use *Canute*, people need to register and complete online training, and then are granted access to *Canute*. Approximately 329 people have since completed the online training and registered to use the tool. Another 324 people have registered but are yet to complete the online training.

3.5 SME Engagement

There was active engagement with the three SME participants in the ACE CRC program. pitt&sherry Managing Director, Mr John Pitt continues to hold an ACE CRC Board position as the representative of the commercial and SME participants.

The Sea-level Rise Impacts project continued developing *Canute* including the additional features of financial damage with SGS Economics , and included datasets from RPS MetOcean.

In conjunction with SMEs, pitt&sherry and SGS Economics and Planning, the ACE CRC completed a number of collaborative consulting projects for governments. These collaborations have assisted in knowledge sharing between the ACE CRC and the SMEs, and with governments.

New products and services

During the reporting period, services were provided utilising the sea ice view tool for an expedition cruise company in the Ross Sea. 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 other training/support as required.

In addition 3 cruise companies and other antarctic entities were provided with free access to fortnightly sea-ice updates from satellite imagery. This has also been made available in the second edition of the Season's Sea-ice report which is a compliation of the fortnightly reports edited by Dr Jan Lieser and produced in May this year.

3.6 Collaboration

Currently, the ACE CRC collaborates with 79 domestic and international organisations. Of these, 24 are Australian, 2 New Zealand, 6 Asian, 18 North American, 1 South American, and the remaining 28 are scattered throughout Europe.

Of the 24 domestic collaborations, 4 are industry/private sector, 8 Australian Government Institutions, 1 State Government Institution, and 11 Universities.

Of the 55 international collaborations, 30 are Universities, 1 industry/private sector, and 24 others.

The Sea-level Rise Impacts team is working in close collaboration with the Spatial CRC (CRCSI) to translate the output from the calculator into high-resolution maps of predicted flood inundation. CRCSI has built a subset of our data into their new, web-based GIS, which is presently in testing mode. When their system is in production mode, we will be able to link into their server to create flood maps on-the-fly from within the *Canute* website. This collaboration is vital to achieve this milestone.

During the reporting period, the ACE CRC had several overseas visitors, including visitors from Participants (NIPR and LEGOS). For further discussions on end-user collaborations, see section 3.3 of this report.

4 Other activities

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

Natural Disaster Resilience Program (NDRP): The work already undertaken in the Climate Futures for Tasmania project is being extended to examine changes to severe weather events likely to cause significant damage (and cost) to Tasmania. This program aims to identify and address disaster risk priorities throughout the State. The ACE CRC has secured 2.5 years of funding from the Program, administered by Tasmanian State Emergency Services, to investigate these weather events using a combination of established and new techniques and indices. These events include increased bushfire risk (encompassing both bushfire meteorology and hazard), and severe storms.

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

During the reporting period, the Climate Futures for Tasmania, encompassing both NDRP and NERP projects, have published 3 articles in scholarly refereed journals (Appendix 1) and 2 articles are in press.

In addition, funding was received to run climate modelling to evaluate the impact of different warming patterns on tropical rainfall which is to be used in particular in the South Pacific Convergence Zone.

5 Additional requirements

5.1 Performance review

The recommendations of the May 2012 mid-term review were made at a time when it was anticipated that the ACE CRC would be wound up at the end of its current cycle in June 2014. Following the refunding arrangements this year, the ACE CRC is no longer in a transition phase but instead is preparing the contract variation and replanning on a continuing basis. Strategies to implement all the recommendations were reported last year: those referring to transition are no longer applicable and any which are ongoing will be incorporated into the research plan for the new ACE CRC.

6 Glossary of Terms & Acronyms

A	
AABW	Antarctic Bottom Water
AAD	Australian Antarctic Division
AAS	Australian Academy of Science
ACC	Antarctic Circumpolar Current
ACCESS	Australian Computational Earth Systems Simulator
ACE CRC	Antarctic Climate & Ecosystems Cooperative Research Centre
AMISOR	Amery Ice Shelf Ocean Research
ASPeCt	Antarctic Sea-ice Processes & Climate
AUV	Autonomous Underwater Vehicle
AVCAL	Australian Private Equity & Venture Capital Association Ltd
AWI	Alfred Wegener Institute for Polar Research (Germany)
B	
BEPSII	Biogeochemical Exchange Processes at the Sea-Ice Interfaces
C	
CAMS	Chinese Academy of Meteorological Science (China)
CEO	Chief Executive Officer
CLiC	Climate and Cryosphere Project
CLIOTOP	Climate Impacts on Oceanic Top Predators
CLIVAR	Climate Variability and Predictability Program
CMAR	CSIRO Division of Marine & Atmospheric Research
CMIP5	Coupled Model Intercomparison Project Phase 5
CO_2	Carbon Dioxide
COAG	Council of Australian Governments
CPOM	Centre for Polar Oceanography and Modelling (United Kingdom)
CRC	Cooperative Research Centre
CRCSI	Cooperative Research Centre for Spatial Information
CSIRO	Commonwealth Scientific and Industrial Research Organisation
D	
DAFF	Department of Agriculture, Fisheries and Forestry
DCCEE	(Former) Department of Climate Change and Energy Efficiency

DFAT	Department of Foreign Affairs and Trade
DIICCSRTE	Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education
DIISRTE	(Former) Department of Industry, Innovation, Science, Research and Tertiary Education
E	
ENSO	El-Niño Southern Oscillation
EPOC	Ecosystem Productivity Ocean Climate
F	
FIO	First Institute of Oceanography (China)
G	
GEOTRACES	An international study of the biogeochemical cycles of Trace Elements and Isotopes in the Arctic and Southern Oceans
GOOS	Global Ocean Observing System
I	
IASC	International Arctic Science Committee
ICECAP	Investigating Cryospheric Evolution through Collaborative Aerogeophysical Profiling
ICED	Integrating Climate and Ecosystem Dynamics
ICSU	International Council for Science (formerly the International Council of Scientific Unions)
ILTS	Institute of Low Temperature Science, Hokkaido University (Japan)
IMAS	Institute for Marine and Antarctic Studies, University of Tasmania
IMOS	Integrated Marine Observing System
IOCCP	International Ocean Carbon Coordination Project
IP	Intellectual Property
IPCC AR5	Intergovernmental Panel on Climate Change Fifth Assessment Report
IT	Impact Tool
ITR	Information Technology Resources
K	
KEOPS	Kerguelen compared study of Ocean and Plateau in Surface waters (KEOPS-1 and KEOPS-2)
L	

LAP	Landscapes and Policy
LEGOS	Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (France)
M	
MODIS	Moderate Resolution Imaging Spectroradiometer
N	
NDRP	Natural Disaster Resilience Program
NERP	National Environmental Research Program
NIPR	National Institute of Polar Research (Japan)
NIWA	National Institute for Water and Atmospheric Research (New Zealand)
NOAA	National Oceanic and Atmospheric Administration
P	
PAGES2k	Past Global Change – 2k Network
R	
RAPPLS	Radar, Aerial Photography, Pyrometer, Laser Scanner
RECCAP	Regional Carbon Cycle Assessment and Processes
ROMS	Regional Ocean Modelling System
ROV	Remotely Operated Vehicle
S	
SCAR	Scientific Committee on Antarctic Research
SEWPaC	Department of Sustainability, Environment, Water, Population and Communities
SGS	SGS Economics & Planning Pty Ltd
SIPEX-II	Sea-ice Physics & Ecosystem Experiment
SLR	Sea-Level Rise
SME	Small and Medium Enterprises
SOCAT	Surface Ocean Carbon Atlas
SOKI	Southern Ocean Knowledge and Information wiki
T	
TPAC	Tasmanian Partnership for Advanced Computing
U	
UNSW	University of New South Wales

USA	United States of America
UTAS	University of Tasmania
W	
WCRP	World Climate Research Programme
WGOMD/SOP	Working Group on Ocean Model Development/Sea Level Rise, Ocean/Ice Shelf Interactions and Ice Sheets
WHOI	Woods Hole Oceanographic Institute (USA)
WRL	Water Research Laboratory

Appendix 1– list of publications

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