National Environmental Science Program
Earth Systems and Climate Change Hub

ANNUAL PROGRESS REPORT 5
1 January 2019 – 31 December 2019

Hub Name (full activity title): Earth Systems and Climate Change Hub

Host organisation: CSIRO

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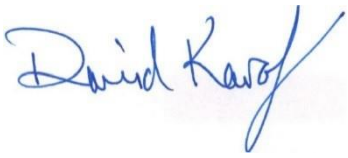
Other consortium partners/subcontractors/research organisations: Bureau of Meteorology, Australian National University, Monash University, University of NSW, University of Melbourne, University of Tasmania

Hub Leader Certification

As Hub Leader, I certify that I have taken adequate steps to reasonably assure myself that:

- each required report component is attached;
- the contents of each component of the report is complete and accurate in all material respects;
- funds have been used for the purpose for which they were provided and all funding conditions have been met, Recipient and Other Contributions have been received, and appropriate oversight has been maintained of Hub projects, their progress, performance and budgets during the reporting period;
- all relevant risks to project delivery have been notified to the Department in this and previous reports and that appropriate steps are being taken to manage those risks;
- the Hub and its sub-contractors have current workers compensation and public liability insurances, as required under the Funding Agreement; and
- any carryover of project funds have been allocated to projects in the next reporting period or financial year in accordance with the approved Research Plan or funds identified for refund to the Department.

Signed:



Hub Leader Name: Professor David Karoly

Date: 08 May 2020

Hub Steering Committee Chair Certification:

As steering committee chair, I certify that any issues of concern or matters raised during steering committee meetings where the draft progress report was discussed have been adequately resolved, amended or incorporated into the final report submitted to the department.

Signed:

Hub Steering Committee Chair Name: Dr Greg Ayers

Date: 04 May 2020

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Letter from the Hub Leader

The Earth Systems and Climate Change (ESCC) Hub has had a busy and successful 2019, with an increased focus on stakeholder engagement, knowledge brokering, synthesis and ensuring our research findings are accessible and useable by a range of decision makers across Australia. Highlights of the Hub's 2019 activities are summarised in this Annual Report.

The Hub's objectives include developing Australia's climate modelling capability; increasing understanding of Australia's climate variability and change, extremes and associated drivers; and developing strong and lasting stakeholder relationships to support decision-making and to facilitate outreach and communication of science products and services to key end-users.

Throughout 2019, the Hub has worked hard to progress each of these objectives. Below is a summary of our key successes:

Key successes

- Submission of more than one thousand years of simulations from the new version of the Australian climate model, ACCESS-CM2, to the sixth phase of the international Coupled Model Intercomparison Project (CMIP6). This makes the simulations available to the international research community and for inclusion in the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).
- Complex research on climate variability, climate change and extremes were transformed into an easy-to-access format as Hub blogs on El Niño and the Indian Ocean Dipole, on unprecedented record high temperatures in Australia, and on the role of climate change in recent observed Australian extreme events. Web statistics show these blogs are continually referred to over the months since publication.
- The Hub played a central role in disseminating information over the period of the 2019 bushfires in Australia, based on the Hub's new brochure in 2019 on bushfires and climate change. This included responding to media requests and writing articles on how climate change and climate variability influence current and future bushfire conditions as well as information on greenhouse gas emissions from bushfires.
- New research on changes in waves and sea level rise on coastal impacts was undertaken by the Hub as part of the international Coordinated Ocean Wave Climate Project (COWCLIP). This is complemented by practical research on natural coastal defences in the Hub through the National Centre for Coasts and Climate (NCCC).
- Stakeholder engagement continued from strength to strength, with a growing awareness of the Hub's research and the utility of climate change science information, advice and data to inform management and adaptation planning and strategies. Examples are included in the impact stories later in this report.
- The Hub's work with Indigenous communities continued with the release of the report on the Hub's first Indigenous National Dialogue on Climate Change. This was used by the Australian Government in the review of the UNFCCC's National Communications on Climate Change process as an example of national-level engagement on climate change with our Indigenous communities.
- The Hub also had a busy year in terms of communication activities and products to showcase our research findings to stakeholders. As well as the on-going popularity of the Hub's science webinars, the Hub took a roadshow to the then Department of the Environment and Energy in Canberra, where Hub researchers joined policy makers from across the Department and other climate change-related agencies to share information, build capacity and develop relationships. This included a popular Indigenous panel, where a group of Indigenous stakeholders who have worked with the Hub talked about their experience of climate change

and how their community has been affected. Feedback from the roadshow was very positive, with the Indigenous panel being described by attendees as ‘insightful and moving’.

- Engagements with new stakeholder groups were established, including with the Australian Sustainable Finance Initiative, the National Disaster Risk Information Services Capability and the Australian Climate Roundtable.

Looking forward – major 2020 activities

As 2020 is the final year of funding for research activities for the Hub, it will be focused on stakeholder engagement and synthesis of Hub research and knowledge brokering activities.

Notably, the Hub will hold activities celebrating the research over the life of the Hub. The Hub had planned to hold the CLIMATE 2020 conference later this year, however with the uncertainty and disruptions resulting from COVID-19, CLIMATE 2020 will not be going ahead in its current format. The Hub is exploring options and opportunities to share the latest climate change science and to bring together our researchers with policy makers, industry and community representatives and First Nations people. These opportunities will focus on the role of climate change science in identifying and managing Australia’s climate challenges.

The Hub’s connections and work with Australia’s First Nations people will continue to be strengthened in 2020. During the restrictions caused by COVID-19, the Hub will continue to maintain strong connections to our First Nations Steering Committee for planning activities for the second First Nations Peoples Dialogue. The Hub will also progress the K’gari (Fraser Island) and Indigenous perspectives of risk projects as much a possible via virtual meeting platforms. The Hub understands that COVID-19 is affecting vulnerable communities in many ways, and so our first priority is to ensure the safety and wellbeing of our colleagues. The Hub’s next steps regarding these Indigenous activities is to consider how we re-engage on Country once COVID-19 restrictions are lifted. As always we will be guided by our Indigenous colleagues as to how this will work.

New case studies, in addition to current on-going RPV5 case studies, have already started as part of RPV6. These include the new World Heritage Area (WHA) case study in K’gari and the review and refresh of the *Climate Change in Australia* (CCiA) website.

We expect that there will be impacts on all our Hub activities, our staff and our researchers associated with the responses to the COVID-19 virus. We are seeking to minimise the risks to the health of everyone in the Hub and to continue our operations and activities as much as possible. For most of our research projects and some case studies, there are likely to be only minor risks and no significant delays are anticipated so far. However, we anticipate major risks and likely delays in meeting milestones and deliverables in several case studies and one research project involving Indigenous engagement, as well as in plans for holding our major synthesis event, the Climate 2020 conference.

We look forward to the new developments and opportunities that 2020 has to offer, as well as trying to meet the challenges that it has brought.

Professor David Karoly

Research

Progress towards outcomes

The Hub's activity outcomes, as reported in the Funding Agreement with the Department of Agriculture, Water and Environment at Schedule 2, Activity 1.3 are:

- building national capacity to understand and predict climate variability and extremes in Australia and their broad implications for the environment and society
- capacity to model past, present and future climate, including understanding and modelling drivers of Australia's climate system to support informed management and decision making
- developing Australia's capacity to model future climate with a particular focus on projections and scenarios that inform coastal impacts and coastal erosion. This includes research into coast and climate interaction through a nationally co-ordinated approach.

In addition, the Hub is committed to effectively deliver and communicate climate information tailored to meet policy, decision-making and management needs.

A summary of progress in 2019 towards these outcomes is provided below:

Building national capacity to understand and predict climate variability and extremes

- The Hub's research continues to contribute to an enhanced understanding of variability in climate drivers of the Australian climate including El Niño–Southern Oscillation (ENSO) and the Southern Annual Mode (SAM). This research has indicated that, while previously there was long-term climate predictability associated with these drivers, in a warmer climate the interconnections between these drivers that provide this predictability will become less reliable, resulting in the future risk that the quality climate information may be less available for planning, decision-making and preparedness.
- New projections for future bushfire risk factors throughout Australia have been prepared, including projections of future changes in weather conditions represented by the Forest Fire Danger Index (FFDI). These show a trend towards more dangerous fire conditions and longer fire seasons in the future under all emission scenarios.

Capacity to model past, present and future climate, including understanding and modelling drivers of Australia's climate system

- The continued development and improvement of ACCESS climate models ensure that climate processes such as land surface-atmosphere interactions and rainfall and weather extremes specific to the Australian region are well represented. This provides the Australian climate research community with powerful tools to conduct experiments focused on Australia's climate drivers to determine future changes to our climate, including researchers in the ESCC Hub projects and in the five universities involved in the ARC Centre of Excellence for Climate Extremes.
- Ocean heat content is one of the key indices of the ongoing energy disequilibrium due to the human influence on the global climate. Ocean heat content was a central part of the IPCC Fifth Assessment report line of evidence that 'global warming is unequivocal…'. One of the key uncertainties in the use of observed heat content data has been its quality, since the instruments were never intended for climate science use. The iQuOD (International Quality Control Ocean Database) was first released in 2018 and continues to be upgraded, with coordination led by ESCC Hub researchers. This has created the underlying quality-controlled observational product for ocean analysis and forecasting, ocean researchers, ocean decision makers and the IPCC assessments (including the recent IPCC Special Report on the Oceans and Cryosphere in a Changing Climate).

- The Hub is improving understanding of carbon sources and sinks in our ecosystems and sectors, both globally and regionally. The annual Global Carbon Budget has continued to be coordinated by the Hub, feeding into international assessments of progress towards meeting the goals of the Paris Agreement. The Hub, through the NCCC, is improving methods for measuring carbon stocks and accumulation rates in blue carbon ecosystems and is developing methods for quantifying sources of carbon in these ecosystems. This may provide an important input into carbon offset schemes.

Developing Australia's capacity to model future climate with a particular focus on projections and scenarios

- Hub researchers have completed investigations into the role topography plays in projected rainfall changes in mid-latitude mountain ranges. The results suggest an enhanced drying on the slopes or tops of mid-latitude mountain ranges in the cool season, including in the Australian Alps, due to increasing greenhouse gases and a warmer climate. This could potentially impact tourism, especially the snow industry, water supply and hydro-power generation.
- A methodology has been produced by the Hub for calculating the multiple contributing factors to sea level extremes, including wind, weather conditions, long-term sea level rise and waves. A tool to make these data accessible has been developed to ensure relevant extreme sea level data is available to coastal engineers, scientists and practitioners to inform coastal planning.

Deliver and communicate climate information tailored to meet end-user needs

- Researchers from the Hub made significant contributions to the IPCC Special Report on the Oceans and Cryosphere in a Changing Climate with over 10 Hub publications cited on sea-level projections and coastal processes, user needs in terms of coastal climate services and marine heatwaves. Hub research into marine heat waves received special attention as a case study feature. Hub researcher Nathan Bindoff (University of Tasmania) was a coordinating lead author on the changing ocean, marine ecosystems and dependent communities chapters of the report, and Kathy McInnes (CSIRO) was a lead author on the chapters around extremes, abrupt changes and managing risks.
- As part of the Hub, researchers in the NCCC have been engaging with communities along the Victorian coast in a citizen science project to map beach erosion and growth.
- Research projects that began in 2016 concluded in 2019, and a number of synthesis products communicating the research findings from these projects have been produced. These include a series of four brochures developed in consultation with stakeholders on tropical cyclones, bushfires, thunderstorms and east coast lows. The brochures summarise the key research findings over the last three years for each of the themes in an accessible way.
- The National Climate Science Advisory Committee (NCSAC) requested that the Hub undertake two studies during 2019-20 on developing a roadmap for a national climate services capability and on planning for the next generation of national and regional climate projections. The climate services study has made good progress and a draft report was provided to the Department early in 2020. Delays have occurred with the climate projections study associated with circumstances outside the control of the project, which have been discussed with the Department. An updated schedule for completion of this study has been agreed by the Department.

Research projects

Attachment A lists the projects funded under the ESCC Hub and provides information on the project status, information on outputs and links to products for all projects (where available). Exceptions to the NESP Data Management and Accessibility Guidelines are also noted here.

Performance against milestones

Performance against Funding Agreement milestones

All milestones for this reporting period and to date have been met as per Funding Agreement Milestones 1-25.

Milestones 1-21 were reported in previous Annual Reports. These milestones have been met and approved by the Department.

Milestones 22-25 are applicable under the current reporting period (Jan-Dec 2019).

Milestone	Description	Due Date	Status
22	Delivery of Annual Progress Report 4 (2018) and Financial Information to the Department	1 April 2019	Met
23	Acceptance of Annual Progress Report 4 and Financial Information by the Department	(date not defined)	Met
24	Delivery of draft Research Plan Version 6 to the Department	16 September 2019	Met
25	Acceptance of the final Research Plan Version 6 by the Department	(date not defined)	Met

Performance against the Research Plan milestones

Information on project progress and performance is provided in Attachment A.

Measuring success

The National Environmental Science Program (NESP) is a long-term commitment to support environmental and climate research. The key objective of the NESP is to improve our understanding of Australia's environment through collaborative research that delivers accessible results and informs decision making. The focus of NESP is on practical and applied research that informs on-ground action and that will yield measurable improvements to the environment.

The Program builds on its predecessors - the National Environmental Research Program and the Australian Climate Change Science Program – in securing for decision makers the best available information to support understanding, managing and conserving Australia's environment.

The NESP is delivered through multi-disciplinary research Hubs or consortia, hosted by Australian research institutions.

The NESP seeks to achieve its objective by supporting research that:

- is practical and applied and informs on-ground action
- addresses the needs of the Australian Government and other stakeholders by supporting and informing evidence-based policy and improving management of the Australian environment
- is innovative and internationally recognised
- enhances Australia's environmental research capacity
- is collaborative and builds critical mass by drawing on multiple disciplines, research institutions and organisations to address challenging research questions
- produces meaningful results accessible to government, industry and the community
- includes synthesis and analysis of existing knowledge
- builds relationships between scientists and policy-makers to encourage collaborative problem solving on environmental issues.

NESP end-users will be a broad range of stakeholders whose decisions may impact on the environment, and include the Australian Government, state governments, industry, business, community groups and Indigenous land managers (or Indigenous Communities).

The intended outcomes of the NESP are:

- Enhanced understanding of, and capacity to manage and conserve Australia's environment.
- Improved climate and weather information for Australia through a greater understanding of the drivers of Australia's climate.
- Timely research that is used by policy and decision-makers to answer questions and provide solutions to problems.
- Research outcomes that are communicated clearly to end-users and the general public, and stored in a manner that is discoverable and accessible.

Table A: Quantitative performance measures

Key Performance Indicator	Hub result for 12-month period (numerical only)	Explanation (if any)
1. Percent of projects (active or completed in the reporting period) for which there is a research-user actively engaged in the project?	**100%**	
2. Percent of projects approved under RPV6 in which research-users were actively involved in project design?	**100%**	
3. Number of research outputs provided to end users **on time**[1] and as identified in the Research Plan	**37 out of 48**	Delays in providing outputs on time were primarily caused by technical issues in accessing data, delays from ACCESS projects having flow on affects to other projects, staff resourcing constraints, or constraints in key stakeholder engagements. Where these delays relate to on-going projects in RPV6, the Hub will work with the Department to prepare a variation for approval by the Department. The Hub is actively managing remaining delayed outputs.
4. Proportion of research outputs provided to end users **on time** and as identified in the Research Plan	**77%**	
5. Number of instances of where the hub has used NESP-generated information from another NESP hub	**0**	The Hub primarily uses climate and weather related data and information, which are not generated by other NESP Hubs. In RPV6 the Hub is participating in the collaborative NESP wide synthesis activity 'Integrated Environmental Assessment for Development Decisions'.
6. Number of peer reviewed NESP-funded publications during the reporting period	**74**	
7. Number of NESP research citations in other researchers' publications during the reporting period	**2,432**	
8. Number of researchers, including PhD and Post-Doc positions, engaged as a result of NESP (total, full-time equivalent) during the reporting period	**98 researchers** **39.25 FTE**	Including 9 PhD, 3 MSc and 12 early career researchers
9. Number of data sets provided to the Hub, or made publicly available, by third parties for the purposes of informing NESP research	**2**	
10. Percentage of data sets made publicly available under open licence by the Hub	**>95%**	Some datasets resulting from Hub research such as blue carbon, coastal erosion and ecological engineering research and ACCESS experiments are raw or draft data and are not suitable for public access. Researchers may make this data available to other researchers on request.

[1] On time – delivered on the date the outputs were expected to be delivered

Key Performance Indicator	Hub result for 12-month period (numerical only)	Explanation (if any)
11. Percentage of NESP research outputs (including publications, data and metadata) that are discoverable and accessible in accordance with NESP data accessibility requirements and the funding agreement	**>95%**	Greater that 95% of the Hub's outputs (as reported in Attachment A) are currently publicly available in accordance with the NESP data accessibility guidelines. Where final publications are not publicly available directly through journals, the Hub has made pre-print versions of the publications available on our website (as allowed by journal archiving and open access policies). Where possible, these will be updated to final publications over the life of the Hub. The Hub continues to work with researchers to ensure all NESP research outputs are made publicly available in accordance with the NESP data accessibility guidelines.
12. Number and FTE of Indigenous people employed in a project (separate into full and part time positions)	**1** **0.2FTE**	
13. Number of Indigenous researchers/graduates/post-graduate/PhD/Post Doc Positions in projects	**1** **0.2FTE**	
14. Number of Indigenous people trained in the use of environmental management tools and techniques	**0**	The Hub continues to engage with representatives of Indigenous communities to identify how the often highly technical data and information produced by Hub research can be tailored for use by these communities in environmental management.
15. The number of management tools for Indigenous waters and land that benefitted from NESP research and outcomes (including but not limited to Plans of Management for IPAs, Co/Joint managed parks, Marine Park Plans of Management, Conservation Agreements)	**0**	The Hub is providing Indigenous stakeholders opportunities to feed their knowledge and experience into the development of potential climate change information tools through: • The First Peoples National Gathering on Climate Change. • The Hub has invited Indigenous stakeholders to participate in the KE4CAP workshop, part of the NCSAC consultancy, to discuss the delivery of climate 'intelligence' platforms for Australia. • The Hub is engaging with Indigenous users of CCiA as part of the review and refresh of the website. • The Hub is providing climate change literacy information to Traditional Owners for use in their communities.
16. Number and type of communication products that have been used to communicate research with Indigenous people	**2**	Workshop Report: National Dialogue on Climate Change. Earth Systems and Climate Change Hub Report No. 11 Communique from the first Interim Steering Committee meeting

Key Performance Indicator	Hub result for 12-month period (numerical only)	Explanation (if any)
17. Number of research, knowledge sharing and communication events held with Indigenous communities	**3**	In engaging with First Nations Peoples the Hub has learned that they have an enormous amount of Traditional Knowledge to share with and inform western science and Australian society in general. The Hub is continuing to engage in two-way knowledge exchange and co-design processes to inform how the Hub can provide tailored climate change information to First Nations Peoples and communities. The Hub has facilitated Traditional Owners to communicate their knowledge and experience of climate change by: • facilitating Traditional Owners to attend and present at the Australian Meteorological and Oceanographic Society (AMOS) Conference in Darwin, 2019. • facilitating Traditional Owners to attend the Hub's Canberra Roadshow in September 2019, and engage with policy makers. • supporting Interim Steering Committee meetings held in 2019 for planning of the 2020 National First Peoples Gathering on Climate Change.
18. Number of public events, conference presentations, jointly authored/published papers with Indigenous participants/contributors.	**7**	The workshop report from the 2018 National Indigenous Dialogue on Climate Change is finalised and includes all 50 Indigenous workshop participants as authors. In June 2019, the Hub supported six First Nations people from around Australia to attend and present at the AMOS 2019 Conference. The presentations received excellent feedback from other conference participants. They served to increase awareness among the climate research community of the climate change impacts being experienced by First Nations people on country, and the potential solutions and adaptation measures.

NESP impact stories

NESP impact stories are provided at Attachment B. These stories showcase the contribution of NESP funded research to the environment, the economy, society, culture, public policy, quality of life, beyond contributions to academia.

The Earth Systems and Climate Change Hub's impact stories for the 2019 Annual Report are:

1. Informing World Heritage Area climate change adaptation planning
2. Understanding climate change impacts on mango production in the Northern Territory
3. Supporting First Nations people to understand climate change impacts and risks to country and communities
4. Building the capacity of key stakeholders to understand and apply climate change information for policy and decision-making
5. Working with industry to develop standards for measuring and reporting physical climate risks
6. Understanding Tasmania's climate information needs for multi-year to decadal climate forecasts

Hub level risk management

All risks identified in the Earth Systems and Climate Change Hub risk register are being actively managed.

Some minor changes or clarifications have been made to a number of risks in the register to either update the explanation of the perceived risk or update the risk rating.

In addition, a significant new risk associated with the COVID-19 virus and potential impacts on the activities of the Hub in 2020 has been identified and included in the Hub's risk register.

A preliminary assessment of the anticipated COVID-19 impacts on the Hub's RPV6 research projects and research facilitation activities has been completed and communicated to the Department on 24 March. We expect that there will be impacts on all Hub activities, staff and researchers. We are seeking to minimise the risks to the health of everyone in the Hub and to continue the operations and activities as much as possible.

The Hub has identified those activities for which we anticipate significant risks and likely delays in meeting milestones and deliverables. This includes delays in planned Indigenous engagement in three Indigenous engagement activities, fieldwork in project 5.9, postponement of the CLIMATE2020 conference, and possible delays in stakeholder meetings planned for two other case studies.

The Hub maintains a register of the currently identified key risks to Hub research projects and research facilitation activities as a result of COVID-19.

Further updates to the COVID-19 risk register will be prepared as new information becomes available. The Hub will consult with the Department on possible variations to RPV6, and to request a no-cost extension for some activities until March or June 2021.

Financial information

Annual financial reporting

The income from NESP funds for this period was as budgeted, and the total funded expenditure was $80,964 greater than income, reducing the carried forward balance of funds. However, the actual expenditure in 2019 was less than the budgeted expenditure in research, communication and knowledge brokering by $412,403. This was partly due to staff changes, delays in activities, delays in financial reporting and a significant mistake in financial reports from a partner organisation that was identified too late to be corrected prior to the preparation of the Audit reports.

The contributions of cash and in-kind expenditure across the Hub in 2019 was $5.4 million in 2019, more than matching the NESP funding.

The Hub is currently considering and planning the use of its unspent funds. Activities that could require additional funding during 2020 and 2021 include the Hub's current suite of Indigenous engagement activities (including facilitation through video conferences), which would require salary support for Indigenous personnel involved in the second First Nation Peoples Climate Change Dialogue, K'gari and Indigenous risk perspectives engagement activities. In addition, the Hub is planning a number of close-out synthesis products and activities, such as a whole-of-Hub publication and a number of products to capture key science findings, achievements and impacts across the Hub, as well as potential communication products on relevant topical matters (for example bushfires and carbon). These activities will require additional resourcing.

It should be noted that there remain significant uncertainties around many of the Hub's engagement activities due to COVID-19 and the associated impacts that will have on the Hub's expenditure. The Hub is in discussion with the Department regarding a no-cost extension for the Hub's activities out to March/June 2021. If this were approved, the Hub would need to consider resourcing for relevant salary costs from unspent funds. The Hub will communicate further plans to use unspent funds with the Department as soon as possible.

The financial budgets for the Hub activities in RPV6 are being updated to reflect the full use in 2020 of the carried-forward balance of funds from 2019. This includes the correction of the mistake in financial reports from the partner organisation and the associated expenditure. We are seeking approval for these budget updates from our Hub Steering Committee and from the Department. We will provide an updated financial report to the Department for the period January to June 2020 as part of the Interim Annual Report for 2020.

Given the uncertain impact of the responses to COVID-19 on some Hub activities and the likely delays in some, as discussed earlier, the Hub will consult with the Department on possible variations to RPV6. After approval from our Steering Committee, we expect to seek a no-cost extension of some Hub activities (primarily Indigenous engagement activities and case studies) until March or June 2021.

Attachments

Attachment A: ESCC Hub Project Information

Attachment B: ESCC Hub NESP Impact Stories

Earth Systems and Climate Change Hub 2019 Annual Progress Report 5 - Attachment A

Project Number/ID	Project Name/Title	Project Summary	Project Leader	Lead Organisation	Approved Funding Research Plan Versions 1-6					Start Date	Completion Date	Status	Outputs		Outcomes
					NESP Funding* $	Other Cash Contributions* $	Other In-Kind Contributions* $	Total Other Contributions* $	Total Budget* $				Outputs	Link to output	
COMPLETE RESEARCH PROJECTS															
1.1	Current Capability and Future Directions Assessment	This project has informed the development of the ESCC Hub's long-term research delivery through an assessment of current capability and future directions for the Earth Systems and Climate Change Hub science and services. The assessment examined current research and outreach capability and future directions, with an emphasis on how the Hub's key partners can best respond to target stakeholder gaps, needs and associated national priorities. The assessment was conducted by Scientell Ltd Pty.	Geoff Gooley	CSIRO	72,453	0	72,640	72,640	**145,093**	01.07.2015	31.12.2017	Completed	Assessment report conducted and compiled by Scientell Ltd Pty which outlines the current capability and future directions of Earth Systems and Climate Change research and provides feedback on Hub activities, and suggested future directions.	http://nespclimate.com.au/current-capability-and-future-directions-assessment/	The output from this project (assessment report) provides valuable stakeholder feedback to the Hub, in particular relating to the outcomes and impacts achieved by the Hub thus far, as well as a clearer understanding of stakeholder expectations of the Hub's ongoing research. All such findings will be appropriately factored into the Hub's strategic planning for RPV5 and beyond, including directions of post-NESP Earth systems and climate change science. The assessment also provides insights into the challenges which exist across the whole Australian climate change science community, such as a lack of long term funding and the need for better coordination and collaboration across all organisations within the Australian climate science landscape. These findings add to and support previous assessments and reviews on the status of Australian climate science research, such as the Australian Academy of Science's capability review and the Australian Climate Change Science Program close out review.
1.2	Project 1.2 - Stakeholder and Indigenous Engagement	Incorporated into the communication and knowledge brokering budget after 2015.	Helen Cleugh	CSIRO	80,200	0	80,200	80,200	**160,400**	01.01.2016	31.12.2016	Completed	N/A	N/A	N/A
1.3	Low coast abatement options: scoping workshop and report	In agreement with the Department, this project was closed and funding invested into RPV3 case studies and Indigenous engagament activities.	Helen Cleugh	CSIRO	18,262	0	18,262	18,262	**36,524**	1/07/2015	31/12/2016	Completed	N/A	N/A	N/A
2.12 & 1.4	Sea Level Projections for NCCARF	This project provided NCCARF with the latest projections of sea-level rise for each coastal local government area in Australia, including all mainland and Tasmanian Councils and the Torres Strait Islands. Information was communicated through guidance material and stakeholder workshops. The project ensured current knowledge was delivered to the community, particularly coastal planners and managers, in a coherent and efficient manner to aid in decision making and planning for future coastal change. The project did this by using the latest regional climate projections for Australia and, working with NCCARF, included these projections in NCCARF's new coastal tool, CoastAdapt. This tool is an excellent information delivery tool, and has been shown to be used extensively by coastal councils and other coastal planners, managers and relevant governments. Inclusion of project information into CoastAdapt has greatly increased uptake of Hub research across the community.	Kathleen McInnes	CSIRO	25,044	0	25,044	25,044	**50,088**	1/09/2015	30/12/2016	Completed	Updated sea level rise projections incorporated into the NCCARF coastal planning tool, CoastAdapt	https://coastadapt.com.au/tools/coastadapt-datasets	Australian coastal communities are vulnerable to sea level rise and extreme sea levels in the future. Updated sea level rise projections were development following the IPCC Fifth Assessment Report and the release of the Climate Change in Australia climate projections in 2015. These updated projections needed to be made available to coastal managers and planners to ensure they had the most up to date information on future sea levels and sea level allowances. Project outcomes included the inclusion of sea level rise projections in the new NCCARF coastal management tool, CoastAdapt. Project outputs included the latest projections of sea-level rise for each coastal local government area in Australia, including all mainland and Tasmanian Councils and the Torres Strait Islands. CoastAdapt also co-locates the sea-level data outputs developed by the project with other relevant tools for coastal managers, such as the Australian inundation tool and Smartline (CRC for Spatial Information) which provides guidance on the potential for coastal erosion. This combination of tools on the one platform makes relevant, up-to-date information readily accessible, saving time. The level of detail provided in the sea-level information is unprecedented for Australian councils, so planning decisions can be made on a more informed basis. CoastAdapt is an excellent information delivery tool, and has been shown to be used extensively by coastal councils and other coastal planners, managers and relevant governments. Inclusion of project information into CoastAdapt has greatly increased uptake of Hub research across the community.
N/A	PhD's and Vacation Scholarships (outside Projects; includes SO)	This is not an actual project but contributes to salaries/costs of PhD students outside project funding.			33,287		205,850	205,850	239,137	01.07.2016	30.06.2019	Completed	Supports PhDs within the Hub to participate in Hub run or supported events, particularly those with a stakeholder focus. Provides capacity building and stakeholder engagement experience for PhDs.	N/A	The ESCC Hub is committed to supporting research training for PhD students as part of the original NESP application to the Department of the Environment and Energy. Relative to some existing university programs, this initiative by the ESCC Hub is modest in terms of actual financial investment, and aims to provide targeted support for developing capacity of a select number of PhD students over the lifetime of the Hub. However, this support also has potential for developing some unique climate research collaborations not found anywhere in Australia.
2.1	Preparing ACCESS for CMIP6	ACCESS is Australia's global climate model, which provides climate simulations for the Intergovernmental Panel on Climate Change assessment reports, including the upcoming sixth assessment report. Given its importance to Australia's climate preparedness and resilience, ACCESS needs to be an internationally benchmarked, world-class global climate modelling capability that is significantly more accurate than other global climate models for the Australasian and Southern Hemisphere region. Participation in the Climate Model Intercomparison Project (CMIP) provides this benchmarking. It also supports Australia's effective management of climate risks and opportunities, and engagement with future climate assessments. This project has achieved these outcomes by preparing and submitting ACCESS model simulations into CMIP6 to benchmark ACCESS's performance and suitability for application across the NESP ESCC Hub and the broader climate change science research community. Submission of ACCESS simulations into CMIP6 also allows them to be included in IPCC assessment reports for used by governments across the world.	Simon Marsland	CSIRO	975,000	0	994,750	994,750	**1,969,750**	01.07.2016	30.06.2019	Completed	Kiss AE, Hogg AMcC, Hanna Nh, Dias FB, Brassington G, Chamberlain MA, Chapman C, Dobrohotoff P, Domingues CM, Duran ER, England MH, Fiedler R, Griffies SM, Heerdegen A, Heil P, Holmes RM, Klocker A, Marsland SJ, Morrison AK, Munroe J, Oke PR, Nikurashin M, Pilo GS, Richet O, Savita A, Spence P, Stewart KD, Ward ML, Wu F, Zhang X. 2019. ACCESS-OM2: A Global Ocean-Sea Ice Model at Three Resolutions, Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2019-106, Geosci. Model Dev	https://doi.org/10.5194/gmd-2019-106	This project has delivered an updated version of the Australia's national climate model, the Australian Community Climate and Earth System Simulator (ACCESS). The outputs from this project have underpinned the submission of ACCESS CM2 model simulations into the Climate Model Intercomparison Project (CMIP) phase 6. These simulations will be used by researchers around the world to produce peer review publications that will inform the IPCC Sixth Assessment Report, due for release in 2021/22. IPCC assessment reports and other global climate assessments provide governments around the world with scientific information on climate change, it's likely impact and mitigation strategies. Through the CMIP process, ACCESS simulations will also be benchmarked against simulations from other global climate models, allowing us to rate the capability and performance of ACCESS on a global scale and also its ability to simulate the Australian region climate compared to other models. The inclusion of ACCESS model simulations in CMIP is helpful in ensuring Australia's climate is considered in global assessments which inform international and national policies and decisions.
													ACCESS Post Processor (APP) software from CMIP5 ACCESS1.0 and 1.3 submissions, for use in ACCESS-CM2 and ACCESS-ESM1.5 CMIP6 submissions	N/A	
													Science webinar: Ensuring Australian climate model simulations inform global climate assessments	http://nespclimate.com.au/ensuring-australian-climate-model-simulations-inform-global-assessments/	
													Dix M, Bi D, Dobrohotoff P, Fiedler R, Harman I, Law R, Mackallah C, Marsland S, O'Farrell S, Rashid H, Srbinovsky J, Sullivan A, Trenham C, Vohralik P, Watterson I, Williams G, Woodhouse M, Bodman R, Dias F, Domingues C, Hannah N, Heerdegen A, Savita A, Wales S, Allen C, Druken K, Evans B, Richards C, Ridzwan SM, Roberts D, Smillie J, Snow K, Ward M, Yang R, 2019. CSIRO-ARCCSS ACCESS-CM2 model output prepared for CMIP6 CMIP. Version YYYYMMDD[1].Earth System Grid Federation. https://doi.org/10.22033/ESGF/CMIP6.2281	https://doi.org/10.22033/ESGF/CMIP6.2281	

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													Prototype ACCESS-CM2 modelling system using JULES land scheme	N/A	
													Ziehn T, Chamberlain M, Lenton A, Law R, Bodman R, Dix M, Wang YP, Dobrohotoff P, Srbinovsky J, Stevens L, Vohralik P, Mackallah C, Sullivan A, O'Farrell S, Druken K, 2019. CSIRO ACCESS-ESM1.5 model output prepared for CMIP6 CMIP. Version YYYYMMDD[1].Earth System Grid Federation.	https://doi.org/10.22033/ESGF/CMIP6.2288	
													Ziehn T, Chamberlain M, Lenton A, Law R, Bodman R, Dix M, Wang YP, Dobrohotoff P, Srbinovsky J, Stevens L, Vohralik P, Mackallah C, Sullivan A, O'Farrell S, Druken K, 2019. CSIRO ACCESS-ESM1.5 model output prepared for CMIP6 ScenarioMIP. Version YYYYMMDD[1]. Earth System Grid Federation.	https://doi.org/10.22033/ESGF/CMIP6.2291	
													Fiddles SL, Woodhouse MT, Nicholls Z, Lane TP, Schofield R. 2018. Cloud, precipitation and radiation responses to large perturbations in global dimethyl sulfide. *Atmospheric Chemistry and Physics* , 18	https://www.atmos-chem-phys.net/18/10177/2018/acp-18-10177-2018.html	
													ESCC Hub webinar: Atmosphere, aerosols and ACCESS	http://nespclimate.com.au/webinar-atmosphere-aerosols-access/	
													ESCC Hub blog: Something in the air	http://nespclimate.com.au/something-in-the-air/	
													Zhou, X., O. Alves, S.J. Marsland, D. Bi, and A.C. Hirst, 2017: Multi-decadal variations of the South Indian Ocean subsurface temperature influenced by Pacific Decadal Oscillation, Tellus A, 69:1, 13pp,	https://www.tandfonline.com/doi/full/10.1080/16000870.2017.1308055?scroll=top&needAccess=true	
													Dave Bi presentation to the Working Group on Coupled Modelling (WGCM)	https://www.wcrp-climate.org/images/modelling/WGCM/WGCM21/10oct/02-10-ACCESS-WCRP-WGCM21.pdf	
2.2	Enhancing Australia's capacity to manage climate variability and climate extremes in a changing climate	Climate extremes such as heatwaves, floods and droughts in Australia cause high economic, agricultural and human costs. Managing the risks – and reducing the costs – associated with climate variability and extremes requires a transformation in our current understanding of the influence of climate change now and into the future. This project has analysed past climate variability and extremes to significantly enhance our understanding of the underpinning mechanisms and processes. It has focused on longer timescale extremes such as extended heatwaves, floods and droughts and the historical record of tropical cyclones; with the aim of informing the development of robust projections that will help Australia prepare for and respond to climate variability, extremes and change in the future.	Pandora Hope	Bureau of Meteorology	1,838,475	0	2,075,394	2,075,394	**3,913,869**	01.07.2016	30.06.2019	Completed	Chung CTY, Power SB, Sullivan A, Delage F, 2019. The role of the South Pacific in modulating Tropical Pacific Variability, Scientific Reports, doi:10.1038/s41598-019-52805-2	https://www.nature.com/articles/s41598-019-52805-2	The ability to project the future climate rests partially on our ability to explain the past. Australia's ability to explain our past climate - its variability, extremes and associated trends - is therefore important for the development of climate projections and in understanding the future climate risks Australia may face. Outputs from this project have furthered our understanding of the drivers and processes of past climates by using climate models to examine how key climate drivers in the Australian and Pacific regions are changing as the global climate changes. The research focus has been on climate variability driven from the oceans (including El Niño, La Niña and the Indian Ocean Dipole), and longer timescale extremes such as extended heatwaves, floods and droughts. This analysis has provided greater clarity on what causes extreme events. It has helped to identify trends and variations in large-scale climate features and extreme events and has shed light on the extent to which these extreme events are influenced by human activities. This information can now be integrated into Australia's climate change projections, allowing for more accurate projections, and enabling us to better plan for and respond to drought, heatwaves and floods. end users and stakeholders.
													Science webinar: Understanding past and future extreme events and their causes	http://nespclimate.com.au/understanding-past-and-future-extreme-events-and-their-cause/	
													Lim EP, Hendon HH, Hope P, Chung CC, McPhaden MJ, 2019. Continuation of tropical Pacific Ocean temperature trend will weaken linkage of Southern Annular Mode and extreme El Niño, Science Reports, doi: 10.1038/s41598-019-53371-3	https://www.nature.com/articles/s41598-019-53371-3	
													Abhik S, Hendon HH, Wheeler MC, 2019. On the Sensitivity of Convectively Coupled Equatorial Waves to the Quasi-Biennial Oscillation, J. Climate, 32, 5833–5847, doi: 10.1175/JCLI-D-19-0010.1	https://journals.ametsoc.org/doi/full/10.1175/JCLI-D-19-0010.1?mobileUi=0	
													Abhik S, Hendon HH. 2019. Influence of the QBO on the MJO during coupled model multiweek forecasts, Geophysical Research Letters, 46, 9213– 9221.	http://nespclimate.com.au/wp-content/uploads/2019/05/2.2_Abhik-2019_GRL_2019GL083152.pdf	
													Bordbar MH, England MH, Sen Gupta A, Santoso A, Taschetto AS, Martin T, Park W, Latif M. 2019. Uncertainty in near-term global surface warming linked to tropical Pacific climate variability. Nature Communications, 10, doi: 10.1038/s41467-019-09761-2	https://www.nature.com/articles/s41467-019-09761-2	

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													Cai WJ, Wu L, Lengaigne M, Li T, McGregor S, Kun JS, Stuecker MF, Santoso A, Li X, Ham YG, Chikamoro Y, Ng B, McPhaden MJ, Du Y, Dommenget D, Jia F, Kajtar JB, Keenlyside N, Lin X, Luo JJ, Martin-Rey M, Ruprich-Robert Y, Wang GJ, Xie SP, Yang Y, Kang SM, Choi JY, Gan B, Kim GI, Kim CE, KiM SY, Kim, JH, Chang P. 2019. Pantropical climate interactions, Science, 363(6430), doi: 10.1126/science.aav4236	https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=4&cad=rja&uact=8&ved=2ahUKEwju46Wq9u3mAhUBzjgGHZsBDuAQFjADegQIAxAB&url=https%3A%2F%2Fwww.researchgate.net%2Fpublication%2F331435229_Pantropical_climate_interactions&usg=AOvVaw0tF9m9odbPUNUEqFkl-TpS	
													Dowdy AJ, Pepler A, Di Luca A, Cavicchia L, Mills, G, Evans JP, Louis S, McInnes KL, Walsh K. 2019. Review of Australian east coast low pressure systems and associated extremes, Climate Dynamics, 1-24, doi: 10.1007/s00382-019-04836-8	https://link.springer.com/article/10.1007%2Fs00382-019-04836-8	
													Fact sheet: Earth Systems and Climate Change Hub. 2019. What role does climate change play in extreme events?	http://nespclimate.com.au/wp-content/uploads/2016/02/A4-2p-ccs-brief-extremes.pdf	
													Freund MB, Henley BJ, Karoly DJ, McGregor HV, Abram NJ, Dietmar D. 2019. Higher frequency of Central Pacific El Niño events in recent decades relative to past centuries, *Nature Geoscienc* e, doi: 10.1038/s41561-019-0353-3	https://findanexpert.unimelb.edu.au/scholarlywork/1394138-higher-frequency-of-central-pacific-el-nino-events-in-recent-decades-relative-to-past-centuries	
													Hope P, Black MT, Lim E-P, Dowdy A, Wang, Pepler A and Fawcett RJB. 2019. On determining the impact of increasing atmospheric CO2 on the record fire weather in eastern Australia in February 2017, *Bulletin of the American Meteorological Society* , doi:10.1175/BAMS-D-18-0135.1	https://doi.org/10.1175/BAMS-D-18-0135.1	
													Jia F, Cai WJ, Gan BL, Wang GJ, Kucharski F, Chang P, Keenlyside, 2019. Weakening Atlantic Niño–Pacific connection under greenhouse warming, *Science Advances* , doi:10.1126/sciadv.aax4111	https://advances.sciencemag.org/content/5/8/eaax4111?rss=1	
													Lim E-P, Hendon HH, Hope P, Chung C, Delage F, McPhaden MJ. 2019. Continuation of tropical Pacific Ocean temperature trend may weaken extreme El Nino and its linkage to the Southern Annular Mode, Scientific Reports, 9(17044), doi: 10.1038/s41598-019-53371-3	https://www.nature.com/articles/s41598-019-53371-3	
													Power SB, Delage FPD. 2019. Setting and smashing extreme temperature records over the coming century. *Nature Climate Change*, doi:10.1038/s41558-019-0498-5	https://www.nature.com/articles/s41558-019-0498-5	
													Wang G, Hendon H, Arblaster J, Lim E, Abhik S and van Rensch P. 2019. Compounding Tropical and Stratospheric Forcing of the Record Low Antarctic Sea-Ice in 2016. *Nature Communications* , 10, doi: 10.1038/s41467-018-07689-7	https://www.nature.com/articles/s41467-018-07689-7	
													Kirk-Patrick et al. 2018. The role of natural variability and anthropogenic climate change in the 2017/18 Tasman Sea Marine Heatwave, Bulletin of the American Meteorological Society.	http://www.ametsoc.net/eee/2017a/ch20_EEEof2017_Perkins.pdf	
													Power SB and Delage FPD. 2018a. El Niño–Southern Oscillation and Associated Climatic Conditions around the World during the Latter Half of the Twenty-First Century. Journal of Climate. doi:10.1175/JCLI-D-18-0138.1	https://journals.ametsoc.org/doi/full/10.1175/JCLI-D-18-0138.1	
													Cai et al. 2018, Stabilised frequency of extreme positive Indian Ocean Dipole under 1.5°C warming target. Nature Communications	https://www.nature.com/articles/s41467-018-03789-6	
													Cai W et al. 2018. Increased variability of eastern Pacific El Niño under greenhouse warming. Nature. 564, 201–206.	https://www.nature.com/articles/s41586-018-0776-9	
													Pepler AS, Hope P. 2018. Orography Drives the Semistationary West Australian Summer Trough, *Geophysical Research Letters* , doi.org/10.1029/2018GL079312	http://nespclimate.com.au/wp-content/uploads/2019/03/Pepler-Hope-2018-Orography-drives-the-semi-stationary-West-Australi....pdf	

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													Santoso A, et al. 2018. Dynamics and predictability of the El Niño-Southern Oscillation: An Australian perspective on progress and challenges. Bulletin of the American Meteorological Society, doi: 10.1175/bams-d-18-0057.1	https://journals.ametsoc.org/doi/abs/10.1175/BAMS-D-18-0057.1	
													ESCC Hub science webinar: ENSO and rainfall	http://nespclimate.com.au/the-impact-of-enso-on-rainfall-in-a-warming-	
													Abellán E, McGregor S, England M, Santoso A. 2017. Distinctive role of ocean advection anomalies in the development of the extreme 2015-16 El Nino. Climate Dynamics, 1-18. doi: 10.1007/s00382-017-4007-0 | Abstract	http://web.science.unsw.edu.au/~matthew/Abellan_et_al_2018_Climate_Dynamics.pdf	
													Herold N, Santoso A. 2017. Indian Ocean warming during peak El Nino cools surrounding land masses. Climate Dynamics, 1-16, doi:10.1007/s00382-017-4001-6	http://onlinelibrary.wiley.com/doi/10.1002/2017GL075635/full	
													Hope P, Lim E-P, Hendon H, Wang G. 2017. The effects of increasing CO2 on the extreme September 2016 rainfall across South Eastern Australia. Bulletin of the American Meteorological Society, doi:10.1175/bams-D-17-0094.1	http://www.ametsoc.net/eee/2016/ch26.pdf	
													Power SB, Delage FPD, Chung CTY, Ye H and Murphy BF. 2017. Humans have already increased the risk of major disruptions to Pacific rainfall. Nature Communications, 8, 14368, doi:10.1038/ncomms14368	https://www.nature.com/articles/ncomms14368	
													Power SB, Delage FPD, Wang GM, Smith I, Kociuba G. 2017. Apparent limitations in the ability of CMIP5 climate models to simulate recent multi-decadal change in surface temperature: implications for global temperature projections. Climate Dynamics, 49, 53-69, doi:10.1007/s00382-016-3326-x	http://onlinelibrary.wiley.com/doi/10.1002/2017RG000560/epdf	
													Santoso A, McPhaden MJ, Cai W. 2017. The Defining Characteristics of ENSO Extremes and the Strong 2015/2016 El Niño. Reviews of Geophysics, 55(4), 1079-1129, doi:10.1002/2017rg000560	http://onlinelibrary.wiley.com/doi/10.1002/2017RG000560/epdf	
													Chung C, Power SB. 2017. The non-linear impact of El Niño, La Niña and the Southern Oscillation on seasonal and regional Australian precipitation. Journal of Southern Hemisphere Earth Systems Science, 67(1), 25–45, doi:10.22499/3.6701.003	http://www.bom.gov.au/jshess/docs/2017/Chung.pdf	
													Chung C, Power S, Santoso A, Wang G. 2017. Multi-year variability in the Tasman sea and impacts on Southern Hemisphere climate in CMIP5 models. Journal of Climate, doi:10.1175/jcli-d-16-0862.1	http://journals.ametsoc.org/doi/abs/10.1175/JCLI-D-16-0862.1	
													Grose MR, Black M, Risbey JS, Uhe P, Hope PK, Haustein K, Mitchell D. 2017. Severe frosts in Western Australia in September 2016. Bulletin of the American Meteorological Society, doi:10.1175/bams-D-17-0088.1	http://www.ametsoc.net/eee/2016/ch29.pdf	
													Wang G, Cai W, Gan B, Wu L, Santoso A, Lin X, Chen Z, McPhaden MJ. 2017. Continued increase of extreme El Niño frequency long after 1.5°C warming stabilisation. Nature Climate Change, doi:10.1038/nclimate3351	https://www.nature.com/articles/nclimate3351	
													Presentation of new method to establish the causes of changes in the climatology of the explosive growth of high impact weather systems at ANZIAM. Conference Proceedings published in ANZIAM Journal: S.L. Osbrough, J.S. Frederiksen, "Computation of changes in explosive weather systems during the 20th century"	https://doi.org/10.21914/anziamj.v58i0.11784	
													Colman R, Power SB. 2018. What can decadal variability tell us about climate feedbacks and sensitivity? *Climate Dynamics*. doi: 10.1007/s00382-018-4113-7	http://nespclimate.com.au/wp-content/uploads/2019/05/Colman-and-Power-2018.-Decadal_Jan_2018_revised.pdf	
2.3	Towards an ACCESS decadal prediction system	The marine, agriculture, energy and water sectors have consistently requested climate information at multi-year to decadal timescales. However, Australia capability is only just being developed in our predictive capability at these timescales. This project developed forecasting capability specific to filling the critical gap between seasonal climate predictions and multi-	Neil Holbrook	UTAS	410,000	0	673,633	637,633	**1,047,633**	01.07.2016	30.06.2019	Completed	Factsheet: Earth Systems and Climate Change Hub. 2019. Understanding marine heatwaves	http://nespclimate.com.au/wp-content/uploads/2019/05/A4-2p-ccs-brief_marineheatwaves_web.pdf	This project contributed significantly to initial steps towards developing a decadal forecasting system and capability in Australia to fill the critical gap between seasonal climate predictions and multi-decadal climate projections. Outcomes from the decadal forecasting work under this project is now being further developed by the CSIRO's Decadal Climate Forecasting Project. The project also investigated and characterised the decadal-scale predictability of ocean temperature extremes (often call marine heatwaves), leading to improved understanding
													Science webinar: What causes marine heatwaves and how are they changing?	http://nespclimate.com.au/what-causes-marine-heatwaves-and-how-are-they-changing/	

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		decadal climate projections, within ACCESS. The project advanced the initial steps in developing Australia's forecast capability on the decadal scale, and has improved understanding and simulation of Southern hemisphere climate drivers. The project has, as an example and tester, focused on delivering targeted stakeholder products to inform marine and agriculture policy and adaptive management strategies, through assessment of marine temperature extremes which have large impacts on marine life and fisheries.											Lou J, NJ Holbrook and TJ O'Kane, 2019. South Pacific decadal climate variability and potential predictability. Journal of Climate, doi:10.1175/JCLI-D-18-0189.1	https://journals.ametsoc.org/doi/full/10.1175/JCLI-D-18-0249.1	of marine heat wave trends and the predictability of ocean temperature extremes over multi-year to decadal timescales. Marine heat waves can have devastating consequences for marine life, fisheries, and aquaculture, making them environmentally and economically significant events. Tracking and predicting changes in marine extremes are key to managing and reducing their impacts in these sectors. Outcomes from this marine ocean temperature prediction work has also been used in the IPCC Special Report on the Oceans and Cryosphere in a Changing Climate. Data from this project will also feed into ACCESS, Australia's global climate model. The enhanced projections developed through this research will better inform marine and coastal planning decisions, as well as fisheries and aquaculture.
													O'Kane T, et al. 2019. Coupled data assimilation and ensemble initialisation with application to multi-year ENSO prediction. Journal of Climate, doi:10.1175/JCLI-D-18-0249.1	https://journals.ametsoc.org/doi/full/10.1175/JCLI-D-18-0249.1	
													Kushnir et al. 2019. Towards operational predictions of the near-term climate, Nature Climate Change, 9, 94–101	https://www.nature.com/articles/s41558-018-0359-7	
													Smale DA, T Wernberg, ECJ Oliver, M Thomsen, BP Harvey, SC Straub, MT Burrows, LV Alexander, JA Benthuysen, MG Donat, M Feng, AJ Hobday, NJ Holbrook, SE Perkins-Kirkpatrick, H Scannell, A Sen Gupta, B Payne, PJ Moore, 2019. Marine heatwaves threaten global biodiversity and the provision of ecosystem services, doi:10.1515/mcwf-2017-0001	https://www.nature.com/articles/s41558-019-0412-1	
													O'Kane TJ, Monselesan DP, Risbey JS, Horenko I, Franzke CLE. 2017. On memory, dimension, and atmospheric teleconnections. Mathematics of Climate and Weather Forecasting, 3(1), 1–27, doi:10.1515/mcwf-2017-0001	https://research.csiro.au/dfp/wp-content/uploads/sites/148/2017/03/OKane_mcwf2017.pdf	
													Oliver ECJ, Lago V, Hobday AJ, Holbrook NJ, Ling SD, Mundy CN. 2018. Marine heatwaves off eastern Tasmania: Trends, interannual variability, and predictability. *Progress in Oceanography* 161, 116-130.	http://nespclimate.com.au/wp-content/uploads/2019/05/Oliver_2018_PIO_MHWsEasternTasmania.pdf	
													Oliver ECJ, Perkins-Kirkpatrick SE, Holbrook NJ, Bindoff NL. 2017. Anthropogenic and natural influences on record 2016 marine heatwaves. Bulletin of the American Meteorological Society, doi:10.1175/BAMS-D-17-0093.1	https://www.nature.com/articles/ncomm	
													Risbey, J. S., O'Kane, T. J., Monselesan, D. P., Franzke, C. L. E., & Horenko, I. 2018. On the dynamics of Austral heat waves. Journal of Geophysical Research: Atmospheres, 123, 38–57.	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017JD027222	
													Oliver ECJ, MG Donat, MT Burrows, PJ Moore, DA Smale, LV Alexander, JA Benthuysen, M Feng, A Sen Gupta, AJ Hobday, NJ Holbrook, SE Perkins-Kirkpatrick, HA Scannell, SC Straub and T Wernberg, 2018: Ocean warming brings longer and more frequent marine heatwaves. Nature Communications.	https://www.nature.com/articles/s41467-018-03732-9	
													Hobday, A.J., E.C.J. Oliver, A. Sen Gupta, J.A. Benthuysen, M.T. Burrows, M.G. Donat, N.J. Holbrook, P.J. Moore, M.S. Thomsen, T. Wernberg, and D.A. Smale. 2018. Categorizing and naming marine heatwaves. Oceanography 31(2):162–173.	https://tos.org/oceanography/article/categorizing-and-naming-marine-heatwaves	
													Oliver ECJ, Donat MG, Burrows MT, Moore PJ, Smale DA, Alexander LV, Benthuysen JA, Feng M, Sen Gupta A, Hobday AJ, Holbrook NJ, Perkins-Kirkpatrick SE, Scannell HA, Straub SC, Wernberg T. 2018. Longer and more frequent marine heatwaves over the past century. Nature Communications, 9, doi:10.1038/s41467-018-03732-9	https://www.nature.com/articles/s41467-018-03732-9	
													Oliver ECJ & Holbrook NJ. 2018. Variability and Long-Term Trends in the Shelf Circulation Off Eastern Tasmania. *Journal of Geophysical Research: Oceans* . doi:10.1029/2018JC013994	http://nespclimate.com.au/wp-content/uploads/2019/03/Oliver_et_al-2018-Journal_of_Geophysical_Research__Oceans.pdf	
													ESCC Hub science webinar: Ocean temperature extremes	http://nespclimate.com.au/towards-predicting-ocean-temperature-	
2.4	Changing oceans and Australia's future climate	Global warming is ocean warming: over 93% of the extra heat stored by the Earth over the past 50 years is found in the ocean. To interpret past changes and better predict changes in the climate we need to understand how the ocean takes up heat, and how ocean heat uptake may change as the planet warms. Projections of future warming, sea level rise and water availability for Australia and our region can be improved by ensuring that ocean heat uptake is well represented in climate models. This project used	Steve Rintoul	CSIRO	1,050,146	0	1,209,970	1,209,970	**2,260,116**	01.07.2016	30.06.2019	Completed	Updated Argo Australia profiles	https://data.nodc.noaa.gov/cgi-bin/iso?id=gov.noaa.nodc:0170893	Ocean heat uptake is one of the primary rate-setters of global warming. Over 93% of the extra heat stored by the Earth over the past 50 years is found in the ocean. To date this has not been well integrated into Australia's climate models. This project analysed data collected from international ocean monitoring initiatives (historical archives, Argo floats and research vessels) to interpret and improve our understanding of past and future changes in ocean temperature and salinity. These analyses have helped identify sources of bias in ocean heat update efficiency in climate models, as well as to examine the connection between ocean salinity changes and water balance over Australia. This research has been used to better represent ocean processes in climate models, which will improve projections of future warming, sea-level rise and water availability for
													Cyriac A, McPhaden MJ, Phillips HE, Bindoff NL, Feng M. 2019 Seasonal Evolution of the Surface Layer Heat Balance in the Eastern Subtropical Indian Ocean. Journal of Geographic Research – Oceans. 10.1029/2018JC014559	https://eprints.utas.edu.au/31743/1/134365%20-%20Seasonal%20evolution%20of%20the%20surface%20layer%20heat%20balance%20_accepted%20manuscript.pdf	

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		represented in climate models. This project uses observations and models to provide these improvements; underpinning a more resilient Australia.											Stammer D, Bracco A, AchutaRao K, Beal L, Bindoff NL, Braconnot P, Cai WJ, Chen D, Collins M, Danabasoglu G, Dewitte B, Farneti R, Fox-Kemper B, Fyfe J, Griffies SM, Jayne SR, Lazar A, Lengaigne M, Lin XP, Marsland SJ, Minobe S, Monteiro PMS, Robinson W, Roxy MK, Rykaczewski RR, Speich S, Smith EIJ, Solomon A, Storto A, Takahashi K, Toniazzo T, Vialard J. 2019. Ocean climate observing requirements in support of Climate Research and Climate Information, Frontiers of Marine Science, doi: 10.3389/fmars.2019.00444	https://www.frontiersin.org/articles/10.3389/fmars.2019.00444/full	will improve projections of future warming, sea level rise and water availability for Australia. This work has also informed international efforts to enhance strategies and policies which aim to improve globally co-ordinated ocean monitoring initiatives.
													Zhang Y, Feng M, Du Y, Phillips HE, Bindoff NL, McPhaden MJ. 2018. Strengthened Indonesian throughflow drives decadal warming in the Southern Indian Ocean. Geographical Research Letters, doi:10.1029/2018GL078265	nespclimate.com.au/wp-content/uploads/2016/03/Zhang_et_al-2018-Geophysical_Research_Letters.pdf	
													Mao H, Feng M, Phillips HE, Lian S, 2018. Mesoscale eddy characteristics in the interior subtropical southeast Indian Ocean, tracked from the Leeuwin Current system, Deep-Sea Research II	https://www.sciencedirect.com/science/article/pii/S0967064517303892?via%3Dihub	
													Stewart KD and Hogg A Mc. 2019. Southern Ocean heat and momentum uptake are sensitive to the vertical resolution at the ocean surface, Ocean Modelling,	https://www.sciencedirect.com/science/article/abs/pii/S1463500319300897	
													Sprintall J, Gordon AL, Wijffels SE, Feng M, Hu SJ, Koch-Larrouy A, Phillips HE, Nugroho D, Napitu A, Pujiana K, Susanto RD, Sloyan BM, Pena-Molino B, Yuan D, Florida Riama N, Siswanto S, Kuswardani A, Arifin Z, Wahyudi AJ, Zhou H, Nagai T, Ansong JK, Bourdalle-Badié R, Chanut J, Lyard F, Arbic BK, Ramdhani A, Setiawan A, 2019. Detecting Change in the Indonesian Seas, OceanObs'19 white paper, Frontiers in Marine Science, 10.3389/fmars.2019.00257	https://www.frontiersin.org/articles/10.3389/fmars.2019.00257/full	
													Sloyan BM, Wilkin J, Hill KL, Chidichimo MP, Cronin MF, Johannessen JA, Karstensen J, Krug M, Lee T, Oka E, Palmer MD, Rabe B, Speich S, von Schuckmann K, Weller RA, Yu WD, 2019. Evolving the Physical Global Ocean Observing System for Research Application Services Through International Coordination, Frontiers of Marine Science, 10.3389/fmars.2019.00449	https://www.frontiersin.org/articles/10.3389/fmars.2019.00449/full	
													Sloyan BM, Wilkin J, Hill KL, Chidichimo MP, Cronin MF, Johannessen JA, Karstensen J, Krug M, Lee T, Oka E, Palmer MD, Rabe B, Speich S, von Schuckmann K, Weller RA, Yu WD, 2019. Evolving the Physical Global Ocean Observing System for Research Application Services Through International Coordination, Frontiers of Marine Science, doi:10.3389/fmars.2019.00449	https://www.frontiersin.org/articles/10.3389/fmars.2019.00449/full	
													Sloyan BM, Wanninkhof R, Kramp M, Johson GC, Talley LD, Tanhua T, McDonagh E, Cusack C, O'Rouke E, McGovern E, Katsumata K, Diggs S, Hummon J, Ishii M, Azetsu-Scott K, Boss E, Ansorge I, Perez FF, Mercier H, Williams MJM, Anderson L, Lee JH, Murata A, Kouketsu S, Jeansson E, Hoppema M, Campos E, 2019. The Global Ocean Ship-Based Hydrographic Investigations Program (GO-SHIP): A Platform for Integrated Multidisciplinary Ocean Science, Frontiers of Marine Science. doi:10.3389/fmars.2019.00445	https://www.frontiersin.org/articles/10.3389/fmars.2019.00445/full	
													Silvano A, Rintoul SR, Kusahara K, Pena-Molino B, van Wijk E, Gwyther DE, Willimas GD. 2019. Seasonality of warm water intrusions onto the continental shelf near the Totten Glacier, Journal of Geophysical Research - Oceans, doi:10.1029/2018JC014634	https://eprints.utas.edu.au/30939/	

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													Castagno, P. V. Capozzi, G. R. DiTullio, P. Falco, G. Fusco, S. R. Rintoul, and G. Budillon, 2019. Rebound of shelf water salinity in the Ross Sea, Nature Communications, doi: 10.1038/s41467-019-13083-8	https://www.nature.com/articles/s41467-019-13083-8	
													Carter BR, Feely RA, Wanninkhof R, Kouketsu S, Sonnerup RE, Pardo PC, Sabine CL, Johnson GC, Sloyan BM, Murata A, Mecking S, Tilbrook B, Speer K, Talley LD, Millero FJ, Wijffels, Macdonald AM, Gruber N, Bullister JL. 2019. Pacific Anthropogenic Carbon between 1991 and 2017. Global Biogeochemical Cycles, doi: 10.1029/2018GB006154	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018GB006154	
													Patel RS, Phillips HE, Strutton P, Lenton A, Llort J. 2019. Meridional Heat and Salt Transport Across the Subantarctic Front by Cold-Core Eddies. Journal of Geographical Research: Oceans, 124(2), doi:10.1029/2018JC014655	https://eprints.utas.edu.au/29700/	
													Szuts ZB, Bower AS, Donohue KA, Girton JB, Hummon JM, Katsumata K, Lumpkin R, Ortner PB, Phillips HE, Rossby T, Shay LK, Todd RE. 2019. The scientific and societal uses of global measurements of subsurface velocity, Frontiers of Marine Science, Doi: 10.3389/fmars.2019.00358	https://www.frontiersin.org/articles/10.3389/fmars.2019.00358/full	
													Purkey SG, Johnson GC, Talley DL, Sloyan B M, Wijffels SE, Smethie W, Mecking S, Katsumata K. 2018. Unabated Bottom Water Warming and Freshening in the South Pacific Ocean. Journal of Geophysical Research, Doi:10.1029/2018JC014775	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018JC014775	
													Buchanan PJ, Matear RJ, Chase Z, Phipps SJ, Bindoff NL. 2018. Marine nitrogen fixers mediate a low latitude pathway for atmoshperic CO2 drawdown, Nature Communications, 10(4611), doi: 10.1038/s41467-019-12549-z	https://www.nature.com/articles/s41467-019-12549-z	
													Ocean observations along GO-SHIP P15S section	https://cchdo.ucsd.edu/cruise/096U20160426	
													New version of iQuOD global ocean historical data set with new bias corrections completed		
													Ocean Model equilibration period and runs and climate change scenarios complete at 1° and 0.25° resolution and stored in NCI Research Data Collection (Hogg/Stewart)	https://doi.org/10.4225/41/5a2dc8543105a	
													Langlais C, Lenton A, Matear R, Monselesan D, Legresy B, Cougnon E, Rintoul SR. 2017. Stationary Rossby waves dominate subduction of anthropogenic carbon in the Southern Ocean. Scientific Reports, 7, 17076. doi:10.1038/s41598-017-17292-3	https://www.nature.com/articles/s41598-017-17292-3	
													Silvano A, Rintoul SR, Peña-Molino B, Williams GD. 2017. Distribution of water masses and glacial meltwater on the continental shelf near the Totten Glacier. Journal of Geophysical Research – Oceans, 122, 2050–2068, doi:10.1002/2016JC012115.	http://nespclimate.com.au/wp-content/uploads/2016/03/Silvano_et_al-2017-Journal_of_Geophysical_Research__Oceans2.pdf	
													Rintoul, S. R., 2018. Global influence of localized dynamics in the Southern Ocean. Nature, 558, 209-218. Doi: 10.1038/s41586-018-0182-3	http://nespclimate.com.au/wp-content/uploads/2016/03/rintoul_nature2018_pre-print-1.pdf	
													SSTAARS: A very high spatial resolution (2 km) atlas of sea surface temperature of Australian regional seas	https://portal.aodn.org.au	
													Rintoul SR, Chown SL, DeConto RM, England MH, Fricker HA, Masson-Delmotte V, Naish TR, Siegert MJ, Xavier JC. 2018. Choosing the future of Antarctica. Nature, 558, 233-241, doi: 10.1038/s41586-018-0173-4	http://nespclimate.com.au/wp-content/uploads/2016/03/rintoul_nature2018_pre-print.pdf	

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													Silvano A, Rintoul SR , Peña-Molino B, Hobbs WR, Aoki S, Orsi AH and Williams GD. 2018. Freshening by glacial meltwater enhances melting of ice shelves and reduces formation of Antarctic Bottom Water. Science Advances, Vol. 4, doi: 10.1126/sciadv.aap9467	http://advances.sciencemag.org/content/4/4/eaap9467/tab-pdf	
													Snow K, Rintoul SR, Sloyan BM & Hogg AM. 2018. Change in Dense Shelf Water and Adelie Land Bottom Water precipitated by iceberg calving. *Geophysical Research Letters* , 45, 2380-2387, doi:10.1002/2017gl076195	http://nespclimate.com.au/wp-content/uploads/2016/03/Snow_et_al-2018-Geophysical_Research_Letters.pdf	
													Lambelet, M., van de Flierdt, T., Butler, E.C. V., Bowie, A. R., Rintoul, S. R., Watson, R. J., et al. (2018). The neodymium isotope fingerprint of Adélie Coast Bottom Water. Geophysical Research Letters, 45	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018GL080074	
													IQuOD database products	http://iquod.github.io/	
													Palmer, M.D., Boyer, T., Cowley, R., Kizu, S., Reseghetti, F., Suzuki, T.Thresher, A., 2018. An algorithm for classifying unknown expendable bathythermograph (XBT) instruments based on existing metadata. J. Atmos. Ocean. Technol. 35, 429–440.	https://journals.ametsoc.org/doi/full/10.1175/JTECH-D-17-0129.1	
													Zhang Y, Feng M, Du Y, Phillips HE, Bindoff NL, McPhaden MJ. 2018. Strengthened Indonesian throughflow drives decadal warming in the Southern Indian Ocean. Geographical Research Letters, doi: 10.1029/2018GL078265	https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2018GL078265	
													ESCC Hub science webinar: IPCC and our changing oceans	http://nespclimate.com.au/the-ipcc-process-and-our-changing-oceans/	
													ESCC Hub science webinar: ocean heat uptake	http://nespclimate.com.au/webinar-ocean-heat-content/	
													Pardo PC, Tilbrook B, Langlais C, Trull TW, Rintoul SR. 2017. Carbon uptake and biogeochemical change in the Southern Ocean, south of Tasmania. Bio geosciences.	https://www.biogeosciences.net/14/5217/2017/	
2.5	Improving Australia's Climate Model (ACCESS)	ACCESS equips Australia with a global climate modelling capability that is uniquely concerned with the weather and climate of the Australasian and Southern Hemisphere region. The key outcome is a national preparedness that enables Australia to better manage weather and climate impacts, including future risks and opportunities; saving lives, resources and money. This project has significantly enhance ACCESS's accuracy by improving its simulation of critically important climate processes in the Australasian region, focussing on rainfall and weather extremes. It has facilitated the robust predictions needed for adaptation and emissions policies, and delivered an enhanced modelling system to the Hub and broader community.	Harun Rashid	CSIRO	1,494,551	0	1,635,511	1,635,511	**3,130,062**	01.07.2016	30.06.2019	Completed	Colman RA, Brown JR, Franklin C, Hanson L, Ye H, Zelinka MD, 2019, Evaluating cloud feedbacks and rapid responses in the ACCESS model. Journal of Geophysical Research, doi:10.1029/2018jd029189	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018JD029189	To be prepared for the climate risks Australia faces as a nation, our industries, businesses and governments first need accurate and credible information on what the likely changes to our climate will be in the future. The Australian Community Climate and Earth System Simulator (ACCESS) equips Australia with a global climate modelling capability that is uniquely concerned with the weather and climate of the Australasian and Southern Hemisphere region. This project provided solutions to improve ACCESS simulations of important climate processes in the Australasian region, focusing on rainfall and weather extremes, as well as climate variability and change. The model improvements to ACCESS enhance our confidence in Australian rainfall simulations in current and future climates. More reliable ACCESS model projections will help to better inform policy development and decision-making outcomes for the Australian Government and other stakeholders. The improved ACCESS model simulations and diagnostic tools will also be used by other Australian and international researchers (including other Hub projects) to progress their own climate research. ACCESS model improvements in the atmospheric component of the model have also been adoption by the UK Met Office for use in their climate model.
													Singh MS, Warren RA, Jakob C, 2019. A Steady-State Model for the Relationship Between Humidity, Instability, and Precipitation in the Tropics, Journal of Advances in Modelling Earth Systems, doi:10.1029/2019MS001686	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019MS001686	
													Protat A, Klepp C, Louf V, Petersen WA, Alexander SP, Barros A, Leinonen J, Mace GG, 2019. The Latitudinal Variability of Oceanic Rainfall Properties and Its Implication for Satellite Retrievals: 1. Drop Size Distribution Properties, Journal of Geophysical Research - Atmospheres, doi:10.1029/2019JD031011	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019JD031010	
													An improved version of ACCESS with significant reduction in tropical rainfall errors and improved simulations of the Madden-Julian Oscillation	https://trac.nci.org.au/svn/access_tools/NESP_diagnostics/trunk	
													Timmermann A, et al. 2018. El Niño–Southern Oscillation complexity. Nature, 559, 535-545, doi: 10.1038/s41586-018-0252-6	http://nespclimate.com.au/wp-content/uploads/2016/03/Timmermannetal_ENSO-Complexity_Nature18_Preprint.pdf	
													Version 1 of the diagnostic toolkit	https://accessdev.nci.org.au/trac/wiki/access/access_DiagnosticToolsV1	
													Zhou XB, Alves O, Marsland SJ, Bi DH, Hirst AC. 2017. Multi-decadal variations of the South Indian Ocean subsurface temperature influenced by Pacific Decadal Oscillation. Tellus Series a-Dynamic Meteorology and Oceanography 69. doi:10.1080/16000870.2017.1308055	https://www.tandfonline.com/doi/full/10.1080/16000870.2017.1308055	
													Zhu HY, Maloney E, Hendon H, Stratton R. 2017. Effects of the changing heating profile associated with melting layers in a climate model. Quarterly Journal of the Royal Meteorological Society 143, 3110-3121. doi: 10.1002/qj.3166	https://rmets.onlinelibrary.wiley.com/doi/abs/10.1002/qj.3166	

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													Rashid H, Zhu H and Sun Z (2017) Initial documentation of key systematic errors in a high resolution (60 km grid) version of the current ACCESS atmospheric model. Earth Systems and Climate Change Hub Technical Report No. 1, NESP Earth Systems and Climate Change Hub, Australia.	http://nespclimate.com.au/wp-content/uploads/2018/05/ESCC-R001-ACCESS-1705.pdf	
													Zhu H, Jakob C, Ma Y, Warren R, Santra A, Yorgen S and Sun Z. 2018. A comprehensive report of model systematic errors in the latest ACCESS climate models. Earth Systems and Climate Change Hub Report No. 3, NESP Earth Systems and Climate Change Hub, Australia	http://nespclimate.com.au/wp-content/uploads/2016/03/ESCC-R003-ACCESS-1806.pdf	
													Weblog on improving ACCESS	http://nespclimate.com.au/improving-tropical-rainfall-simulations-in-our-national-climate-model/	
													ESCC Hub science webinar: Australia's national climate model	http://nespclimate.com.au/australias-national-climate-model-access-development-and-application/	
													Model code for improved ACCESS version 1 is available through CWSLab	http://nci.org.au/services/nci-national-research-data-collection/climate-change-and-earth-system-science/	
2.6	Regional Climate Projection Science, Information and Services	Key stakeholders have indicated that they want credible and salient projections to underpin adaptation. However, there are a few areas where uncertainties remain, data are inadequate for impact assessment, and uptake has been limited. This project has begun initial steps for planning and development of new projections that maintain credibility and salience. This project has enhanced uptake of climate projections information through improved products and services for targeted stakeholders. Research has also constrained uncertainty and improving confidence in projections, and the project has begun to lay the groundwork for the next generation of regional projections.	Michael Grose	CSIRO	1,668,750	32,625	1,339,096	1,371,721	**3,040,471**	01.07.2016	30.06.2019	Completed	Grose MR, Syktus J, Thatcher M, Evans JP, Ji F, Rafter T, Remenyi T. 2019. The role of topography on projected rainfall change in mid-latitude mountain regions. Climate Dynamics, 1-16, doi:10.1007/s00382-019-04736-x	http://nespclimate.com.au/wp-content/uploads/2019/05/10.1007_s00382-019-04736-x.pdf	The current suite of climate change projections has continued to be used widely by researchers and stakeholders, including industries, governments and communities to better understand and plan for climate risks. The project engaged with stakeholders to improve stakeholder understanding of the climate change information and projections available on the Climate Change in Australia website through training, guidance, workshops and presentations. This engagement helped identify user information needs including the need to update and improve climate projection products and services with new data and lessons learned to make the projections more accessible. This has increased the uptake of climate change information provided in the website for use in impact assessments and adaptation planning in Australia. Outputs from this project have also progressed the science behind climate change projections, increasing confidence in the current projections, particularly rainfall projections. The landscape of climate change projections is continually evolving. The science and datasets which underpin projections have advanced, and the way end users and stakeholders use projections and for what purpose has also changed. This project initiated and led planning for how the next generation of climate projections could be enhanced and focused on end user requirements. If funded in the future, the next generation of updated climate projections will position Australia to produce updated, credible ad relevant information in a timely way for use by policy makers and planning managers across the Australian community.
													Our changing climate: how will rainfall change in Northern Australia over this century?	http://nespclimate.com.au/wp-content/uploads/2018/06/Northern-Australia-6pp_WEB.pdf	
													Brown JR, Moise AF, Colman RA. 2017. Projected increases in daily to decadal variability of Asian-Australian monsoon rainfall. Geophysical Research Letters, 44, 5683–5690. doi:10.1002/2017GL073217	http://nespclimate.com.au/wp-content/uploads/2016/03/Brown_et_al-2017-Geophysical_Research_Letters.pdf	
													Risbey JS, Grose MR, Monselesan DP, O'Kane TJ, Lewandowsky S. 2017. Transient response of the global mean warming rate and its spatial variation. Weather and Climate Extremes, doi:10.1016/j.wace.2017.11.002	https://www.sciencedirect.com/science/article/pii/S2212094716300494	
													Zhang H., Y. Zhao, A. Moise, H. Ye, R. Colman, G. Roff, M. Zhao 2017. On the influence of SST warming intensity/patterns for uncertainties in CMIP5 model rainfall projections: An AGCM study. Climate Dynamics.	http://nespclimate.com.au/wp-content/uploads/2016/03/Post-print-Zhang-et-al-2017.-accessSST.pdf	
													Brochure 'Our changing climate: Using climate change information to 2030'	http://nespclimate.com.au/wp-content/uploads/2017/10/Using-climate-change-information-to-	
													Grose MR, Colman RA, Andrews T. 2018. What climate sensitivity index is most useful for projections? Geophysical Research Letters. 45(3), 1559-1566.	http://nespclimate.com.au/wp-content/uploads/2016/03/Grose_et_al-2018-Geophysical_Research_Letters.pdf	
													ESCC Hub Science Webinar: Northern Australian rainfall change	http://nespclimate.com.au/how-will-rainfall-change-in-northern-australia-over-the-coming-century/	
													Brochure: Our changing climate: Southern Australia rainfall – long-term trends and future projections	Our changing climate: Southern Australia rainfall – long-term trends and future projections	
													ESCC Hub weblog: Northern Australia rainfall changes	http://nespclimate.com.au/how-will-rainfall-change-in-northern-australia-over-this-century/	
													ESCC Hub weblog: Long term trends and future projections of rainfall in Southern Australia	http://nespclimate.com.au/long-term-trends-and-future-projections-of-rainfall-in-southern-australia/	
													ESCC Hub weblog: State of the Climate Report 2018	http://nespclimate.com.au/state-of-the-climate-2018-bureau-of-meteorology-and-csiro/	
													ESCC Hub science webinar: regional projections	http://nespclimate.com.au/the-why-how-and-when-of-producing-climate-projections-in-australia/	
													Climate Change in Australia (climate projections website)	www.climatechangeinaustralia.gov.au	
													Training sessions on the Climate Change in Australia website with end-users	N/A	
													The Conversation' article: Grose M, Bettio L. 2018. State of the Climate 2018: Bureau of Meteorology and CSIRO.	https://theconversation.com/state-of-the-climate-2018-bureau-of-meteorology-and-csiro-109001	
													Brochure: Towards the next generation of climate change projections for Australia – summary of a proposed approach and timeline for a new future suite of climate change projections.	http://nespclimate.com.au/wp-content/uploads/2019/07/ESCC-NetGen-4pp_web.pdf	

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													Di Virgilio G, Evans JP, Di Luca A, Olson R, Argüeso D, Kala J, Andrys J, Hoffmann P, Katzfey JJ, Rockel B. 2019. Evaluating reanalysis-driven CORDEX regional climate models over Australia: model performance and errors, Climate Dynamics, doi: 10.1007/s00382-019-04672-w	http://nespclimate.com.au/wp-content/uploads/2019/05/2.6_DiVirgilio_et_al_8Feb2019_preprint.pdf	
													Grose MR, Foster S, Risbey JS, Osbrough S, Wilson L. 2019. Using indices of atmospheric circulation to refine southern Australian winter rainfall climate projections, Climate Dynamics, pp1-13, doi: 10.1007/s00382-019-04880-4	https://link.springer.com/article/10.1007%2Fs00382-019-04880-4	
													Science webinar: Climate Thresholds – an easy way to explore future climate extremes	http://nespclimate.com.au/climate-thresholds-an-easy-way-to-explore-future-climate-extremes/	
													NextGen Projections workshop summary report	http://nespclimate.com.au/wp-content/uploads/2018/06/ESCC-R005-NextGen-projections-180629.pdf	
													ESCC Hub science webinar: Climate Analogues Tool	http://nespclimate.com.au/climate-analogues-a-way-to-experience-the-future-climate/	
2.7	Refining Australia's Water Futures	Information about, and analyses of, future water availability are critical for water resources planning and investment decisions. However credible and consistent projections for a range of hydroclimate variables are not currently available. This project has improved our national modelling capability to simulate how changes in climate and land-use will affect Australia's hydroclimates and water resources into the future. As part of this activity the project team engaged with stakeholders to ensure that the projections are both relevant and useful to sectors that are significantly affected by climate and water, such as (but not limited to) agriculture.	Dewi Kirono	CSIRO	600,000	0	1,201,467	1,201,467	**1,801,467**	01.07.2016	30.06.2019	Completed	Chiew FHS, Zheng H, Potter NJ, Ekstrom M, Grose MR, Kirono DGC, Zhang L, Vaze J. 2017. Future runoff projections for Australia and science challenges in producing next generation projections. Proceedings of the 22nd International Congress on Modelling and Simulation, Hobart, December 2017, pp. 1745–1751.	http://www.mssanz.org.au/modsim2017/L16/chiew.pdf	Water impacts all sectors of Australia's economy. A sustainable future water provision demanded by many of these sectors could be achieved through effective water resources planning, management and infrastructure investment. These activities all require robust knowledge about water futures, both on the demand and supply sides. It is critical to have consistent projections and interpretations of relevant hydroclimate variables and the associated likelihood and uncertainty. This project worked with state and federal government and water managers to identify gaps in hydroclimate metrics and improve climate-water modelling. Building on existing science, the project developed methods to deliver next generation projections of future water availability and hydrologic variables or metrics important to the water and related sectors. Project outputs will provide essential inputs to climate change impact assessments and adaptation actions.
													Cernusak LA, Haverd V, Brendel O, Thiec DL, Guehl JM, Cuntz M. 2019. Robust response of terrestrial plants to rising CO2, Trends in Plant Science, 24(7), pp. 578-586, 10.1016/j.tplants.2019.04.003	http://nespclimate.com.au/wp-content/uploads/2019/05/2.7_Cernusak_etal_2019_Accepted-version.pdf	
													Kirono DGC, Grose MR, Hennessy KJ. 2017. Increasing risk of months with low rainfall and high temperature in southeast Australia for the past 150 years. Climate Risk Management, 16, 10–21, doi:10.1016/j.crm.2017.04.001	https://www.sciencedirect.com/science/article/pii/S2212096316300717	
													Ekström M, Gutmann ED, Wilby RL, Tye MR, Kirono DGC. 2018. Robustness of hydroclimate metrics for climate change impact research. Wiley Interdisciplinary Reviews: Water, doi:10.1002/wat2.1288	https://onlinelibrary.wiley.com/doi/epdf/10.1002/wat2.1288	
													ESCC Hub science webinar: water futures under climate change	http://nespclimate.com.au/water-futures-under-climate-change-science-applications-and-challenges/	
2.8	Extreme Weather Projections	Extreme weather events such as tropical cyclones, east coast lows, thunderstorms, and extreme fire weather incur economic costs associated with property, environmental and human impacts (injury, displacement and death). Effective disaster risk reduction, emergency response, infrastructure design/operation, planning and policy making all require information about how these extreme events will change in the future. Research under the project filled critical knowledge gaps around extremes, and improve understanding of existing and projected characteristics of these extreme events. The projected used this new knowledge to improve simulations and projected changes in these extreme events and, through ongoing and effective stakeholder engagement, transform the research into targeted, useful and application-ready information.	Andrew Dowdy	Bureau of Meteorology and CSIRO	1,526,250	152,625	1,665,540	1,818,165	**3,344,415**	01.07.2016	30.06.2019	Completed	Fire weather dataset products, i.e. maps etc.	http://www.bom.gov.au/jsp/ncc/climate_averages/ffdi/index.jsp	Extreme weather events such as tropical cyclones, east coast lows, thunderstorms, and extreme fire weather incur economic costs associated with property, environmental and human impacts. These events, and the costs associated with their impact, are likely to change in a changing climate. Evidence of this change is already becoming clear. Robust scientific information about the influence of climate change on these extreme events is essential for improving the resilience and wellbeing of Australian communities in the future and to ensure effective disaster risk reduction, emergency response, infrastructure design/operation and policy making. Outputs from this project have provided: information on how, when and where extreme weather events occur; an assessment of the ability of climate models to simulate extreme weather events; and projections of extreme weather events in the future. An example of the policy outcomes of this project's outputs is shown through the production of an extreme fire weather dataset that extends back to 1950 and is updated daily. This dataset has already been used by (for example) the Bureau of Meteorology to provide more comprehensive fire weather information to clients including state fire agencies, emergency services and government groups, and fire agencies and emergency services to place fire weather conditions – which, due to climate change are different from what has been experienced in the past – in the context of events that they have dealt with previously. This helps with planning emergency responses and disaster risk reduction activities, which ultimately results in a reduction in the costs and other impacts on people and property. A set of extremes brochure has provided stakeholders and the media with timely and easy to understand information about extremes, in particular on bushfire weather conditions in Australia.
													Chand SS, Dowdy AJ, Ramsay HA, Walsh KJE, Tory KJ, Power SB, Bell SS, Lavender SL, Ye H, Kuleshov Y, 2019. Review of tropical cyclones in the Australian region: Climatology, variability, predictability, and trends, Advanced Review, doi: 10.1002/wcc.602	https://onlinelibrary.wiley.com/doi/full/10.1002/wcc.602	
													Ashcroft L, Dowdy AJ, Karoly DJ, 2019. Historical extreme rainfall events in south-eastern Australia, Weather and Climate Extremes, doi:10.1016/j.wace.2019.100210	https://www.sciencedirect.com/science/article/pii/S221209471930009X	
													Dowdy AJ, Ye H, Pepler A, Thatcher M, Osbourgh SL, Evans JP, Di Virgilio G, McCarthy N. 2019. Future changes in extreme weather and pyroconvection risk factors for Australian wildfires. Nature Scientific Reports, 9:10073, doi:10.1038/s41598-019-46362-x	https://www.nature.com/articles/s41598-019-46362-x	
													Terrasson A, McCarthy N, Guyot A, Dowdy A and McGowan H. 2019. Wildfire and Weather Radar: A Review. Journal of Geophysical Research – Atmospheres, doi: 10.1029/2018JD029285	http://nespclimate.com.au/wp-content/uploads/2019/05/2.8_Terrasson_et_al-2019-Journal_of_Geophysical_Research__Atmospheres.pdf	
													Earth Systems and Climate Change Hub. 2019. Bushfires and climate change in Australia.	http://nespclimate.com.au/wp-content/uploads/2019/11/A4_4pp_brochure_NESP_ESCC_Bushfires_FINAL_Nov11_2019_WEB.pdf	
													Earth Systems and Climate Change Hub. 2019. Thunderstorms and climate change in Australia.	http://nespclimate.com.au/wp-content/uploads/2019/11/A4_4pp_brochure_NESP_ESCC_Thunderstorms_Nov11_2019_WEB.pdf	
													Earth Systems and Climate Change Hub. 2019. East coast lows and climate change in Australia.	http://nespclimate.com.au/wp-content/uploads/2019/11/A4_4pp_brochure_NESP_ESCC_East_Coast_Lows_Nov11_2019_WEB.pdf	
													Earth Systems and Climate Change Hub. 2019. Tropical cyclones and climate change in Australia.	http://nespclimate.com.au/wp-content/uploads/2019/11/A4_4pp_brochure_NESP_ESCC_Tropical_Cyclones_FINAL_Nov11_2019_WEB.pdf	

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					NESP Funding* $	Other Cash Contributions* $	Other In-Kind Contributions* $	Total Other Contributions* $	Total Budget* $				Outputs	Link to output	
													Cavicchia L, et al. 2019. A physically-based climatology of Australian east coast lows occurrence and intensification. Journal of Climate, doi:10.1175/JCLI-D-18-0549	https://journals.ametsoc.org/doi/abs/10.1175/JCLI-D-18-0549.1	
													Bell SS, Chand SS, Tory KJ, Turville C, Ye H. 2019. Eastern North Pacific tropical cyclone activity in historical and future CMIP5 experiments: assessment with a model-independent tracking scheme, Climate Dynamics, doi: 10.1175/JCLI-D-18-0549	https://journals.ametsoc.org/doi/abs/10.1175/JCLI-D-18-0549.1	
													Tropical Cyclone Portal	https://shiny.csiro.au/Tropical-Cyclone-Projections-Portal/	
													Bell SS, Chand SS, Camargo SJ, Tory KJ, Turville C. 2019. Western North Pacific Tropical Cyclone Tracks in CMIP5 Models: Statistical Assessment Using a Model-Independent Detection and Tracking Scheme, Journal of Climate.	https://doi.org/10.1175/JCLI-D-18-0785.1	
													Science webinar: Tropical cyclones in the Australian region – past, present and future	http://nespclimate.com.au/tropical-cyclones-in-the-australian-region/	
													Bates B, Dowdy AJ, Chandler R, 2017. Lightning Prediction for Australia Using Multivariate Analyses of Large-Scale Atmospheric Variables, Journal of Applied Meteorology and Climatology, 57, 525-534. doi: 10.1175/jamc-d-17-0214.1	http://journals.ametsoc.org/doi/abs/10.1175/JAMC-D-17-0214.1	
													Dowdy A. 2017. Climatological variability of fire weather in Australia. Journal of Applied Meteorology and Climatology, doi:10.1175/JAMC-D-17-0167.1.	http://journals.ametsoc.org/doi/10.1175/JAMC-D-17-0167.1	
													Dowdy AJ, Catto JL. 2017. Extreme weather caused by concurrent cyclone, front and thunderstorm occurrences. Scientific Reports, 7, doi:10.1038/srep40359	https://www.nature.com/articles/srep40359	
													Dowdy AJ, Fromm MD, McCarthy N. 2017. Pyrocumulonimbus lightning and fire ignition on Black Saturday in southeast Australia. Journal of Geophysical Research—Atmospheres, 122(14), 7342-7354, doi: 10.1002/2017JD026577	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017JD026577	
													McCarthy N, McGowan H, Guyot A, Dowdy A. 2017. Mobile X-Pol radar: A new tool for investigating pyroconvection and associated wildfire meteorology. Bulletin of the American Meteorological Society. doi: 10.1175/bams-d-16-0118.1	https://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-16-0118.1	
													Pepler AS, Di Luca A, Evans JP. 2017. Independently assessing the representation of midlatitude cyclones in high-resolution reanalyses using satellite observed winds. International Journal of Climatology, doi:10.1002/joc.5245	http://web.science.unsw.edu.au/~jasone/publications/peplereta2017a.pdf	
													Dowdy, A., Ye, H., Tory, K., Jones, D., Evans, A., Lavender, S., Thatcher, M., Rafter, T., Osbrough, S., Walsh, K., Cavicchia, L., Evans, J., Catto, J., 2017: Extreme weather: improved data products on bushfires, thunderstorms, tropical cyclones and east coast lows, Peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference, 4-6 September 2017, 269.2017.	https://www.bnhcrc.com.au/node/3874	
													Tory KJ, Ye H, Dare RA. 2017. Understanding the geographic distribution of tropical cyclone formation for applications in climate models. Climate Dynamics, doi:10.1007/s00382-017-3752-4	https://link.springer.com/article/10.1007/s00382-017-3752-4	
													Cavicchia L, Dowdy A, Walsh K. 2018. Energetics and dynamics of subtropical Australian east coast cyclones: Two contrasting cases. *Monthly Weather Review*, doi:10.1175/MWR-D-17-0316.1	http://nespclimate.com.au/wp-content/uploads/2019/03/cavicchia_et al_mwr_2018.pdf	
													Sharmila, S. and K.J.E. Walsh. 2018. Recent poleward shift of tropical cyclone formation and its link to tropical expansion. *Nature Climate Change* , 8, 730-736, doi: 10.1038/s41558-018-0227-5	http://nespclimate.com.au/wp-content/uploads/2018/11/Walsh_poleward-shift-in-TC_NCC.pdf	

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													Pepler AS, Dowdy AJ, Hope P. 2018. A global climatology of surface anticyclones, their variability, associated drivers and long-term trends, Climate Dynamics, doi.org/10.1007/s00382-018-4451-5	https://link.springer.com/article/10.1007%2Fs00382-018-4451-5	
													Ramsay H, Chand S & Camargo S, 2018. A statistical assessment of Southern Hemisphere tropical cyclone tracks in climate models. Journal of Climate, Vol 13, 24:10081-10104.	http://nespclimate.com.au/wp-content/uploads/2019/01/Ramsay_jcli-d-18-0377.1_early-online-release.pdf	
													Bates B, McCaw L, Dowdy A, 2018. Exploratory analysis of lightning-ignited wildfires in the Warren Region, Western Australia, Journal of Environmental Management, doi: 10.1016/j.jenvman.2018.07.097	http://nespclimate.com.au/wp-content/uploads/2016/03/Bates-etal-Exploratory-Analysis-JoEM-V2.2.pdf	
													Bell SS, Chand SS, Tory KJ, Turville C. 2018. Statistical assessment of the OWZ tropical cyclone tracking scheme in ERA-Interim. Journal of Climate, doi:10.1175/JCLI-D-17-0548.1	https://journals.ametsoc.org/doi/abs/10.1175/JCLI-D-17-0548.1	
													Bell SS, Chand SS, Tory KJ, Dowdy AJ, Turville C, Ye H. 2018. Projections of southern hemisphere tropical cyclone track density using CMIP5 models, Climate Dynamics doi:10.1007/s00382-018-4497-4	http://nespclimate.com.au/wp-content/uploads/2019/03/CLDY-D-18-00393-1-pages-deleted.pdf	
													von Storch H, Cavicchia L, Feser F, Li D. 2018. The Concept of Large-Scale Conditioning of Climate Model Simulations of Atmospheric Coastal Dynamics: Current State and Perspectives. *Atmosphere* 9, 337, doi:10.3390/atmos9090337.	https://www.mdpi.com/2073-4433/9/9/337	
													Dowdy A, Pepler P, Ashcroft L, Jones D, Braganza K, Bettio L, 2018. Climate Change Influences on Natural Hazards, Proceedings of AFAC 2018 Conference, Perth, WA	http://nespclimate.com.au/wp-content/uploads/2019/05/climate-change-impacts-on-natural-hazards.pdf	
													Lavender SL, Walsh KJE, Caron L-P, King M, Monkiewicz S, Guishard M, Zhang Q, Hunt B. 2018. Estimation of the maximum annual number of North Atlantic tropical cyclones using climate models. Sci. Adv. 4, doi:10.1126/sciadv.aat6509.	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6105296/	
													ESCC Hub weblog: Conditions more conducive for pyroconvection	http://nespclimate.com.au/conditions-more-conducive-for-pyroconvection/	
													Lavender SL, Hoeke RK, Abbs DJ. 2018. The influence of sea surface temperature on the intensity and associated storm surge of tropical cyclone Yasi: a sensitivity study. Natural Hazards and Earth System Sciences, 18, 795-805, doi:10.5194/nhess-18-795-2018	https://www.nat-hazards-earth-syst-sci.net/18/795/2018/	
2.9	Risk assessment of future carbon sources and sinks	This project has investigated and assessed the potential for current carbon abatement by revegetation and conservation in Australia, with an emphasis on their potential vulnerability under future climate change, and long-term carbon-climate feedbacks. The project delivered data products showing national and global carbon budget trajectories (CO2 and CH4), and how these track the pathways needed for global climate stabilisation by the end of the 21st century. These products were delivered in stakeholder-relevant formats, suitable for use by government agencies, business and enterprises, and the broader community.	Pep Canadell	CSIRO	900,000		1,028,751	1,028,751	**1,928,751**	01.07.2016	30.06.2019	Completed	Fleischer K, Rammig A, De Kauwe MG, Walker AP, Domingues TF, Fuchslueger L, Garcia, Daniel S Goll, Adriana Grandis, Mingkai Jiang, Vanessa Haverd, Bernard Pak, Yingping Wang, et al. Amazon forest response to CO2 fertilization dependent on plant phosphorus acquisition, Nature Geoscience 12 (9), 736-741, doi:10.1038/s41561-019-0404-9	https://www.nature.com/articles/s41561-019-0404-9	Policy makers need information on carbon and greenhouse gases to develop successful national climate change policies, as well as international engagement to achieve global climate mitigation targets. They also need accurate and credible evidence to help identify effective carbon mitigation options. While climate policies seek to manage the net emissions of greenhouse gas emissions, large uncertainties remain on how the carbon budget can be best managed to reduce emissions, increase sinks and protect existing carbon stocks. Outputs from this project have helped to determine the potential for land-based mitigation options in Australia, and the vulnerability of the land sector in a changing climate. This information can now be used to inform environmental and climate change policies in Australia. Outputs include both national and global carbon budget data products that show how carbon dioxide and methane levels are tracking on the pathways needed for global climate stabilisation by the end of the 21st century. Outputs also include an enhanced ability of ACCESS to estimate global carbon-climate feedbacks of future land use and climate scenarios, and enhancement of data delivery systems to make data accessible and discoverable. In addition, this project supported Australia's involvement in the Global Carbon Project (GCP), with the project lead chief investigator (Dr Pep Canadell) participating as Director of the GCP. The GCP is the most authorative and up-to-date assessment of global anthropogenic carbon sources and sinks, providing the international community with annual 'Global Carbon Budgets'. Australia has benefited from involvement in the GCP through both ensuring Australian and Southern Hemisphere science and results are incorporated into the global assessment and by receiving access to credible and robust carbon budget information relevant to our region.
													Zhang XZ, Peng SS, Wang YP, Silver JD, Piao SL, Rayner PJ. 2019. Greenhouse gas concentration and volcanic eruption dominated the variability of terrestrial carbon fluxes uptake over the last millennium. Journal of Advances in Modelling Earth Systems. doi:10.1029/2018MS001566	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018MS001566	
													Pugh TAM, Lindeskog M, Smith B, Poulter B, Arneth A, Haverd V, Calle L. 2019. Role of forest regrowth in global carbon sink dynamics, Proceedings of the National Academy of Sciences, 116, 4382-4387, doi: 10.1073/pnas.1810512116	https://www.pnas.org/content/116/10/4382	
													Jackson RB, Solomon EI, Canadell JG, Cargnello M, Field CB. 2019. Methane removal and atmospheric restoration. Nature Sustainability, doi:10.1038/s41893-019-0299-x	https://www.nature.com/articles/s41893-019-0299-x	
													Canadell JG & Jackson RB. 2019. Turning methane into carbon dioxide could help us fight climate change. The Conversation.	https://theconversation.com/turning-methane-into-carbon-dioxide-could-help-us-fight-climate-change-117317	

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													Corinne Le Quéré, Robbie M. Andrew, Pierre Friedlingstein, Stephen Sitch, Julia Pongratz, Andrew C. Manning, Jan Ivar Korsbakken, Glen P. Peters, Josep G. Canadell, et al (2018) Global Carbon Budget 2017. Earth System Science Data 10: 405–448	https://www.earth-syst-sci-data.net/10/405/2018/essd-10-405-2018-discussion.html Data sets: https://www.icos-cp.eu/GCP/2017	
													Cheng L, Zhang L, Wang Y-P, Canadell JG, Chiew FHS, Beringer J, Li L, Miralles DG, Piao S, Zhang Y. 2017. Recent increases in terrestrial carbon uptake at little cost to the water cycle. Nature Communications, 8, doi:10.1038/s41467-017-00114-5	https://www.nature.com/articles/s41467-017-00114-5	
													Global Carbon Budget 2017 dataset	https://www.icos-cp.eu/GCP/2017	
													ESCC Hub webinar - The Global Carbon Budget 2017 and COP23	http://nespclimate.com.au/webinar-the-global-carbon-budget-2017-and-cop23/	
													Jackson RB, Le Quéré C, Andrew RM, Canadell JG, Peters GP, Roy J, Wu L. 2017. Warning signs for stabilizing global CO2 emissions. Environmental Research Letters 12. doi: 10.1088/1748-9326/aa9662	http://iopscience.iop.org/article/10.1088/1748-9326/aa9662/meta	
													Peters GP, Andrew RM, Canadell JG, Fuss S, Jackson RB, Korsbakken JI, Le Quéré C, Nakicenovic N. 2017. Key indicators to track current progress and future ambition of the Paris Agreement. Nature Climate Change, 7, 118–122, doi:10.1038/nclimate3202	http://www.nature.com/nclimate/journal/v7/n2/full/nclimate3202.html	
													Poulter B, et al. 2017. Global wetland contribution to 2000–2012 atmospheric methane growth rate dynamics. Environmental Research Letters, 12(9), doi:10.1088/1748-9326/aa8391 | Full paper	http://iopscience.iop.org/article/10.1088/1748-9326/aa8391/pdf	
													Saunois M, et al. 2017. Variability and quasi-decadal changes in the methane budget over the period 2000–2012, Atmospheric Chemistry and Physics, 17, 11135-11161, doi:10.5194/acp-17-11135-2017	https://www.atmos-chem-phys.net/17/11135/2017/acp-17-11135-2017.pdf	
													Buermann et al. 2018. Widespread seasonal compensation effects of spring warming on northern plant productivity, Nature 562, 110-114 doi:10.1038/s41586-018-0555-7	http://nespclimate.com.au/wp-content/uploads/2016/03/Buermann_Nature_2018.pdf	
													Kim et al. 2018. A protocol for an intercomparison of biodiversity and ecosystem services models using harmonized land-use and climate scenarios. Geoscientific Model Development Discussions, 1-37, doi: 10.5194/gmd-2018-115	https://www.geosci-model-dev.net/11/4537/2018/gmd-11-4537-2018-discussion.html	
													Bastos et al. 2018. Impact of the 2015/2016 El Nino on the terrestrial carbon cycle constrained by bottom-up and top-down approaches, Philosophical Transactions of the Royal Society B, doi: 10.1098/rstb.2017.0304	https://royalsocietypublishing.org/doi/full/10.1098/rstb.2017.0304	
													Houlton, BZ, Wang, YP, Warlind, D, Dass, Pawlok, Houlton, Benjamin Z. 2018. Grasslands may be more reliable carbon sinks than forests in California, Environmental Research Letters 13.	https://iopscience.iop.org/article/10.1088/1748-9326/aacb39/meta	
													Canadell P, Le Quere C, Peters G, Andrews R, Jackson R. 2018. Carbon emissions will reach 37 billion tonnes in 2018, a record high. The Conversation.	https://theconversation.com/carbon-emissions-will-reach-37-billion-tonnes-in-2018-a-record-high-108041	
													Le Quere et al. 2018. Global Carbon Budget 2018, earth systems science Data, 10, 2141-2194	https://www.earth-syst-sci-data.net/10/2141/2018/	
													Jackson et al, 2018. Global energy growth is outpacing decarbonisation, Environ. Res. Letters, 13, doi: https://doi.org/10.1088/1748-9326/aaf303	https://iopscience.iop.org/article/10.1088/1748-9326/aaf303/meta	
													Haverd, V., et al. 2018. A new version of the CABLE land surface model (Subversion revision r4546), incorporating land use and land cover change, woody vegetation demography and a novel optimisation-based approach to plant coordination of electron transport and carboxylation capacity-limited photosynthesis., Geosci. Model Dev.	https://www.geosci-model-dev.net/11/2995/2018/gmd-11-2995-2018.pdf	
													C Trudinger, V Haverd, P Canadell, P Briggs, B Smith. 2018. Model-data fusion framework to assess the vulnerability of Australian carbon stocks and water resources. Geophysical Research Abstracts, Volume 20, https://meetingorganizer.copernicus.org/EGU2018/EGU2018-18757.pdf	https://meetingorganizer.copernicus.org/EGU2018/EGU2018-18757.pdf	

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													Jackson RB, Le Quéré C, Andrew RM, Canadell JG, Korsbakken JI, Liu Z, Peters GP, Roy J, Wu L, 2018, Global energy growth is outpacing decarbonisation, *Environmental Research Letters* , 13, doi:	https://iopscience.iop.org/article/10.1088/1748-9326/aaf303	
													ESCC Hub weblog - record high carbon emissions in 2018	http://nespclimate.com.au/carbon-emissions-will-reach-37-billion-tonnes-in-2018-a-record-high/	
													Cuntz M, Haverd V. 2018. Physically Accurate Soil Freeze-Thaw Processes in a Global Land Surface Scheme. Journal of Advances in Modelling Earth Systems, 10(1), 54-77, doi:10.1002/2017ms001100	http://onlinelibrary.wiley.com/doi/10.1002/2017MS001100/full	
													Data are the submission of CABLE results to the 'Trends in net land-atmosphere carbon exchange' (TRENDY) global terrestrial biosphere simulation experiment.	Data: http://hpc.csiro.au/users/70496/TRENDYv6_CABLE_Aug2017/ Documents: http://hpc.csiro.au/users/70496/TRENDYv6_CABLE_Aug2017/documents/	
2.10	Coastal Hazards in a Variable and Changing Climate	Coastal erosion and inundation will be influenced by changes in sea levels and waves. Over $226 billion in Australian assets could be at risk from a 1.1 m increase in sea level (a high-end projection for 2100). However, the projected changes and their coastal impacts remain uncertain and controversial. This project has improved understanding of past, and develop projections for future, changes to coastal stressors (sea level, storm surges and waves) and their physical impact. Through engagement with end-users in government and industry, the project has tailored and delivered it's outputs in ways that ensure Australians can plan effectively for coastal change.	Kathleen McInnes	CSIRO	1,240,000	36,625	1,470,372	1,506,997	**2,746,997**	01.07.2016	30.06.2019	Completed	Morim, Hemer et al., 2019. Skill and uncertainty in surface wind fields from general circulation models: Intercomparison of bias between AGCM, AOGCM and ESM global simulations, International Journal of Climatology, doi: 10.1002/joc.6357	https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/joc.6357	As sea levels rise under the changing climate, coastal areas are likely to experience increased erosion and inundation. The effects of storm surge and waves will amplify these impacts, and pose risks to coastal communities, infrastructure and ecosystems. Local coastal councils and state governments are increasingly considering their climate risks. Planning and preparing for current and future coastal hazards depend on the availability of regional data linking coastal extreme events to their impacts. However, this data is not always readily available. This project has provided new information about how extreme sea levels are changing, and improved sea level rise and coastal extremes projections to support national coastal planning, coastal protection activities and coastal investment and development decisions. The data and information developed by this project has helped to bridge the gap between scientific knowledge and stakeholder understanding of climate risks – leading to more informed adaptation and resilience on-ground actions and decisions. The project has also developed tools to provide coastal hazards information to next and end users in an accessible manner which will enhance uptake of the information for impact assessment and adaptation activities.
													O'Grady JO, McInnes KL, Hemer MA, Hoeke RK, Stephenso A, Colberg F, 2019. Extreme water levels for Australian beaches using empirical equations for shoreline wave setup. Journal of Geophysical Research- Oceans	https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2018JC014871	
													Echevarria ER, Hemer MA, Holbrook NJ. 2019. Seasonal Variability of the Global Spectral Wind Wave Climate, JGR Oceans, doi:10.1029/2018JC014620	https://eprints.utas.edu.au/30262/	
													CAWCR Wave Hindcast 1979-2010	https://data.csiro.au/collections/#collection/CIcsiro:6616v8/Ditrue	
													Science webinar: Understanding future extreme sea levels – tools and information to support coastal management	http://nespclimate.com.au/understanding-future-extreme-sea-levels-tools-and-information-to-support-coastal-management/	
													Hinkel J, Church JA, Gregory JM, Lambert E, Le Cozannet G, Lowe J, McInnes KL, Nicholls RJ, van der Pol T, van de Wal R. 2019. Meeting User Needs for Sea Level Rise Information: A Decision Analysis Perspective, Earth's Future, doi: 10.1029/2018EF001071	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018EF001071	
													Colberg F, McInnes KL, O'Grady J, Hoeke R. 2019. Atmospheric circulation changes and their impact on extreme sea levels around Australia. J. Nat. Hazards Earth Syst. Sci., 19, 1067–1086, doi:10.5194/nhess-19-1067-2019	https://www.nat-hazards-earth-syst-sci.net/19/1067/2019/	
													Morim J, Hemer, M, Wang XL, Cartwright N, Trenham C, Semedo A, Young I, Bricheno L, Camus P, Casas-Prat M, Erikson L, Mentaschi L, Mori N, Shimura T, Timmermans B, Aarnes O, Breivik O, Behrens A, Dobrynin M, Menendez M, Staneva J, Wehner M, Wolf J, Kamranzad B, Webb A, Stopa J, Andutta F. 2019. Robustness and uncertainties in multivariate wind-wave climate projections, Nature Climate Change, doi:10.1038/s41558-019-0542-5	https://www.researchgate.net/publication/335250596_Robustness_and_uncertainties_in_global_multivariate_wind-wave_climate_projections	
													Mark Hemer, Ian Young, Joao Morim Nascimento and Nobuhito Mori, 2019. Climate change may change the way ocean waves impact 50% of the world's coastlines. The Conversation	https://theconversation.com/climate-change-may-change-the-way-ocean-waves-impact-50-of-the-worlds-coastlines-121239	
													CSIRO Australia Coastal Sealevel Simulations	https://data.csiro.au/collections/#collection/CIcsiro:29013v1	
													Le Cozannet G, Nicholls RJ, Hinkel J, Sweet WV, McInnes KL, Van de Wal RSW, Slangen ABA, Lowe JA, White KD. 2017. Sea level change and coastal climate services: the way forward. Journal of Marine Science and Engineering. 5(4), 49; doi:10.3390/jmse5040049	http://www.mdpi.com/2077-1312/5/4/49	
													Chen X, Zhang X, Church JA, King MA, Watson CS, Monselesan D, Legresy B, Harig C. 2017. The increasing rate of global mean sea-level rise during 1993–2014. Nature Climate Change, doi:10.1038/nclimate3325	http://nespclimate.com.au/wp-content/uploads/2016/03/Preprint-Chen_etal_NCC_2017.pdf	

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													Lyu K, Zhang X, Church JA, Hu J, Yu J-Y. 2017. Distinguishing basin-scale modes of the quasi-decadal and multi-decadal sea level variations in the Pacific, Journal of Climate, doi:10.1175/JCLI-D-17-	http://journals.ametsoc.org/doi/full/10.1175/JCLI-D-17-0004.1	
													Wu Q, Zhang X, Church JA, Hu J. 2017. Changes and variability of sea level and its components in the Indo-Pacific during the altimeter era, Journal of Geophysical Research, doi:10.1002/2016JC012345	http://nespclimate.com.au/wp-content/uploads/2016/03/Wu_et_al-2017-Journal_of_Geophysical_Research__Oceans.pdf	
													Progress of digitalisation of imaged charges presented at AMOS. Digitisation of registers back to 1900, QC of all digitised data and preliminary analysis of extremes	http://nespclimate.com.au/breathing-new-life-into-old-tide-records/	
													Marshall AG, Hemer MA, Hendon HH, McInnes KL. 2018. Southern annular mode impacts on global ocean surface waves. *Ocean Modelling* , 129, 58-74. doi: 10.1016/j.ocemod.2018.07.007	https://doi.org/10.1016/j.ocemod.2018.07.007	
													Wu, Q., X. Zhang, J. A. Church and J. Hu. 2018. ENSO-related Global Ocean Heat Content Variations, Journal of Climate, doi: 10.1175/JCLI-D-17-0861.1	https://journals.ametsoc.org/doi/full/10.1175/JCLI-D-17-0861.1	
													Wu W, McInnes KL, O'Grady J, Hoeke RK, Leonard M, Westra S. 2018. Mapping dependence between extreme rainfall and storm surge, Geophysical Research Letters, doi:10.1002/2017JC013472	https://doi.org/10.1002/2017JC013472	
													CAWCR Wave Hind cast 1979-2010	https://data.csiro.au/dap/landingpage?pid=csiro:6616	
2.11	Establishment of the National Centre for Coasts and Climate – Phase 1	The growing economic and population concentration in Australia's coastal areas, and their increasing exposure to flooding and inundation due to climate change, are leading to emerging challenges for coastal development. This project has established the National Centre for Coasts and Climate (NCCC), and initiated its mission to deliver outcomes-focussed research, by identifying: (1) the value of blue carbon in mitigating climate change, (2) the dynamic responses of coastal landform systems to waves and inundation and improve predictions of the impacts of sea-level rise, and (3) the approaches needed to integrate ecological engineering into planning decisions to improve the adaptive capacity of coastal and marine ecosystems to respond to climate change.	Stephen Swearer	University of Melbourne	1,050,000	265,327	1,899,587	2,164,914	**3,214,914**	01.07.2016	30.06.2019	Completed	Morris RL, Strain EMA, Konlechner TM, Fest BJ, Kennedy DM, Arndt SK, Swearer SE. 2019. Developing a nature-based coastal defence strategy for Australia, Australian Jounal of Civil Engineering, doi: 10.1080/14488353.2019.1661062	https://www.tandfonline.com/doi/full/10.1080/14488353.2019.1661062	Local governments who are responsible for coastal management do not always have the resources or means to easily access science-based information on the scale they require. In addition the existing modes of science focus on impacts and not solutions, which are often less effective at encouraging social action. This project has continually engaged with Victorian state and local coastal managers to develop and trial a number of novel and innovative approaches which combine natural, created or restored habitats to provide coastal protection. Two such approaches include using 3D printed concrete pots to plant and protect mangroves for enhanced restoration efforts, and the construction of an artificial reef/breakwater to protect against coastal erosion in Portarlington in Port Phillip Bay. These trials will provide coastal managers with more sustainable, economic and environmentally beneficial options for coastal protection in response to climate change impacts in the region. The project has also developed methodologies for assessing carbon stock in blue carbon ecosystems. This will improve our ability to assess and manage how blue carbon ecosystems can contribute towards mitigation of climate change, including better understanding challenges in its inclusion in an emission trading scheme. Coastal erosion research conducted under the project has also resulted in better understanding of historical shoreline change along the Victorian coastline, the changes in beach and dune morphology when eroded, and the role of vegetated systems (coastal dunes) in mitigating erosion.
													Science webinar: The causes of coastal erosion	http://nespclimate.com.au/the-causes-of-coastal-erosion/	
													Konlechner TM, Kennedy DM, Cousens RD and Woods JL. 2019. Patterns of early-colonising species on eroding to prograding coasts; implications for foredune plant communities on retreating coastlines. Geomorphology, 327, 404-416, doi:10.1016/j.geomorph.2018.11.013	http://nespclimate.com.au/wp-content/uploads/2019/01/Konlechner_GEOMOR_6579.pdf	
													Morris RL, Bilkovic DM, Boswell MK, Bushek B, Cebrian J, Goff J, Kibler KM, La Peyre MK, McGlenachan G, Moody J, Sacks P, Shinn JP, Sparks EL, Temple NA, Wlaters LJ, Webb BM, Swearer SE. 2019. The application of oyster reefs in shoreline protection: are we over-engineering for an ecosystem engineer? Journal of Applied Ecology, doi: 10.1111/1365-2664.13390	https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/1365-2664.13390 AB228:AB229AB231AB227:AB228AB228:AB232AB231AAB228:AB234+AB227:AB228	
													Kennedy DM, McInnes K, and Ierodiaconou D. 2019. Understanding Coastal Erosion on Beaches: A guide for managers, policy makers and citizen scientists. National Centre for Coasts & Climate, The University of Melbourne	http://nespclimate.com.au/wp-content/uploads/2019/08/Understanding-Coastal-Erosion-on-Beaches-Web.pdf	
													Earth Systems and Climate Change Hub. 2019. Eco-engineering and restoration of coastal habitats in Australia.	http://nespclimate.com.au/wp-content/uploads/2019/05/2.11-1_A4_4pp_Brochure_Eco-Engineering_NCCC_ESCC_Feb26_2020_WEB.pdf	
													Earth Systems and Climate Change Hub. 2019. Coastal erosion under a changing climate	http://nespclimate.com.au/wp-content/uploads/2019/05/2.11_1_A4_4pp_Brochure_Coastal_Erosion_NCCC_ESCC_Feb26_2020_WEB.pdf	
													Earth Systems and Climate Change Hub. 2019. Climate change and blue carbon in Australia	http://nespclimate.com.au/wp-content/uploads/2019/05/2.11-1_A4_4pp_Brochure_Blue_Carbon_in_Australia_NCCC_ESCC_Feb26_2020_WEB.pdf	
													Understanding coastal erosion on beaches: A guide for managers, policy makers and citizen scientists	http://nespclimate.com.au/wp-content/uploads/2019/11/Understanding-Coastal-Erosion-on-Beaches_updatedNov19.pdf	

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													Ecological Engineering Data Collection - Meta-analysis data for nature-based coastal defence studies; Wave attenuation for kelp, mangroves, seagrass, saltmarsh and mussel reefs; Sediment accumulation using rSETs, sediment traps, pins, beach profiling and drone surveys for mangroves seagrass, saltmarsh and mussel reefs; ecological data (vegetation and biodiversity characteristics) for kelp, seagrass, saltmarsh, mangroves.	N/A	
													Oliver TSN, Kennedy DM, Tamura T, Murray-Wallace CV, Konlechner TM, Augustinus PC, Woodroffe CD. 2018. Interglacial-glacial climatic signatures preserved in a regressive coastal barrier, south-eastern Australia. *Palaeogeography, Palaeoclimatology, Palaeoecology* , 501, 124 – 135, doi:10.1016/j.palaeo.2018.04.011	https://ro.uow.edu.au/smhpapers/5390/	
													Kennedy DM, Konlechner T, Zavadil E, Mariani M, Wong V, Ierodiaconou D, Macreadie P. 2017. Invasive cordgrass (Spartina spp.) in south-eastern Australia induces island formation, salt marsh development, and carbon storage. Geographical Research, 56(1), 80-91, doi: 10.1111/1745-5871.12265	http://onlinelibrary.wiley.com/doi/10.1111/1745-5871.12265/full	
													Morris RL, Konlechner TM, Ghisalberti M, Swearer SE. 2018. From grey to green: Efficacy of eco-engineering solutions for nature-based coastal defence. Global Change Biology, 1-16, doi: 10.1111/gcb.14063	http://nespclimate.com.au/wp-content/uploads/2016/02/Morris-From-grey-to-green -efficacy-of-eco-eng.pdf	
													Coastal Erosion Data Collection - Georectified aerial photos, digitised shorelines, EPR of change of shoreline position; UAV derived pointclouds, digital surface models and orthophotos of sites; RTK-GPS derived cross-shore profiles; GPS co-ordinates of sampling locations; ecological data (vegetation cover, species richness) for foredunes; database of past erosion events, Victoria Coast; database of known erosion sites, Victoria Coast.	N/A	
													Blue Carbon Data Collection - Collection comprises of: Literature database for systematic literature reviews and meta data extraction. Raw field sediment core profile data to determine carbon stocks, carbon accumulation rates, organic matter composition from py-GC-MS, sedimentation data from rSET, sediment traps and sediment pins; raw greenhouse gas flux data from chamber and tower measurements; Images, areal images for monitoring and digital elevation models of sites, photo points, photo quadrants, Rhizotron images for root growth analysis.	N/A	
													ESCC Hub science webinar: nature based opportunities for adaptation in the coastal zone	http://nespclimate.com.au/nature-based-opportunities-for-climate-adaptation-in-the-coastal-zone/	
CURRENT RESEARCH PROJETCS															
5.1	ACCESS evaluation and application	Climate and Earth system models are important tools for understanding and predicting climate variability and change. This project will use ensemble simulations with different ACCESS model versions to demonstrate how the ACCESS model developments and CMIP6 benchmarking undertaken in previous Hub projects can be applied for next and end users. The project will use various simulations to support other Hub projects under RPV5. It will also support these projects by providing multi-decadal simulations of the ACCESS atmospheric model at relatively high spatial resolution (useful for regional applications). The project will highlight the application of ACCESS model versions by quantify the biophysical and biogeochemical effects and socio-economic cost of various land management strategies for Australia and regionally under low and high emissions scenarios. This information could be used by land managers when developing cost effective strategies to reduce greenhouse gas emissions and/or store carbon on the land.	Harun Rashid	CSIRO	951,563	0	951,563	951,563	**1,903,126**	01.07.2019	31.12.2020	Ongoing	Products not yet availble, future products can be found on the project webpage	http://nespclimate.com.au/access-evaluation-and-application-5-1/	Australia's national climate model, the Australian Community Climate and Earth Systems Simulator (ACCESS), has been developed by the Australian climate research community and provides us with a modelling capability that focuses on the Australian and Southern Hemisphere region. This project is delivering multiple model runs (ensembles) of past and future climates, using the coupled and atmospheric model versions of ACCESS (ACCESS-CM and ACCESS-AM). Combined with the ACCESS simulations submitted to the World Climate Research Program (WCRP) Coupled Model Intercomparison Project (CMIP) phase 6, this ensemble will provide better estimates of changes in future extreme rainfall and temperature over Australia.

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5.2	Understanding climate variability and change - past, present and future	Australians have managed in a variable climate for thousands of years, but opportunities exist to further apply our scientific understanding of climate variability and change to help water, ecosystem, food resource and disaster managers understand and act on their climate risks. This project will undertake the underpinning climate science research to provide information and data on Australia's variable and changing climate and how climate drivers are expected to change in the future. This information can then be used in targeted tools, guidance and communication products to inform and advise relevant stakeholders. The project will also build on previous Hub research to further develop attribution of extreme events methods and systems, and will provide attribution statements for forecasted events as they occur. This will allow better understanding of the role climate change plays in individual extreme events, and how these events are likely to change as the climate continues to warm.	Christine Chung	BoM	992,250	0	992,250	992,250	**1,984,500**	01.07.2019	31.12.2020	Ongoing	Wang GW, Cai WJ, Santoso A, 2019. Stronger increase in the frequency of extreme convective El Nino than extreme warm El Nino under greenhouse warming, *Journal of Climate* , doi:10.1175/JCLI-D-19-0376.1	https://journals.ametsoc.org/doi/full/10.1175/JCLI-D-19-0376.1?mobileUi=0	Australia has a variable climate which is affected by large-scale features in the global climate system, including the El Nino-Southern Oscillation, Indian Ocean Dipole and the Southern Annular Mode. This project is using the latest available observations and model outputs (as well as our own model simulations from ACCESS) to better understand the drivers of Australia's large-scale variability, their impacts on Australia's climate and how these impacts may change in the future. This increased understanding of how climate drivers vary and interact, as well as more accurate simulations of these drivers in climate models, will provide reliable and relevant information for input into climate projections and planning and management activities. This project is also developing and applying methods to better distinguish the influence and contribution of climate change on extreme weather events such as heatwaves and drought. This will allow important information on the role of climate change in extreme events to be provided to governments, industries and businesses to assist them to better manage their current and future climate risks.
													Li SJ, WuLX, Yang Y, Geng T, Cai WJ, Gan BL, Chen ZH, Jing Z, Wang GJ, Ma XH. 2019. The Pacific Decadal Oscillation less predictable under greenhouse warming, Nature Climate Change, doi: 10.1038/s41558-019-0663-x	https://www.nature.com/articles/s41558-019-0663-x	
5.3	Regional climate change projections science and delivery	To make evidence-based decisions about climate change and to manage climate risks Australia needs access to credible, up-to-date and relevant information and data on future climate change. This project will enhance the functionality of the current suite of national climate change projections (delivered through the Climate Change in Australia website) to improve the accessibility and scope of the projections for existing next- and end-users of climate projections in several key fields. The project will also allow new and emerging users (e.g. the finance sector) to better integrate climate projections into their area of interest through the provision of guidance, training and tailored information and datasets to meet their specific needs. In addition, the project will build the underpinning projections science and modelling to support and build towards a future major release/update of national projections, setting up future and ongoing success in this arena.	Michael Grose	CSIRO	730,078	13,322	716,757	730,079	**1,460,157**	01.07.2019	31.12.2020	Ongoing	Moise, A.F., I.N. Smith, J.R. Brown, R.A. Colman and S. Narsey, 2019: Observed and projected intra-seasonal variability of Australian monsoon rainfall. International Journal of Climatology, doi: 10.1002/joc.6334	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019GL085160	This project is enhancing the functionality of the current suite of national climate change projections for existing and new users, including new analysis, communication products and updates to tools and guidance materials found on the 'Climate Change in Australia' projections website. The useability of the current projections will be supported through the provision of enhanced training and outreach activities, and tailored information and datasets to meet the needs of decision makers and stakeholders. This will ensure users are better able to integrate climate change projections into their decision-making processes, leading to enhanced climate-resilience and sustainable development across Australia. The project is also enhancing the underpinning projections science and modelling capability required for a future major release of new national projections. This includes applying new methods and addressing knowledge gaps to advance the science and modelling capability for the future next-generation of climate change projections for Australia. Additionally, the project will facilitate and contribute to the coordination and development of plans for the delivery of a future major release of national climate change projections, bringing together key research agencies, funders and users to ensure future national projections are salient, relevant and accessible.
													Michael Grose and Pandora Hope. 2019. Climate change and extreme events – quantifying the changing odds, ECOS	https://ecos.csiro.au/climate-change-and-extreme-events-quantifying-the-changing-odds/	
5.4	Water futures under climate change	Robust projections of water futures are important for impact assessments and developing adaptation options in the water and related sectors. This project will develop a framework that integrates climate and hydrological science and modelling to deliver the next generation of water projections. This will be based on outputs from previous Hub research as well as research and initiatives across Australia (e.g. Victorian Water and Climate Initiative, Bureau of Meteorology Hydrological Projections initiative). Guidance tailored to different uses and different sectors will be provided for developing projections of a range of hydrological characteristics/metrics, including long-term averages, low flow, high flow, and drought indices. The project will engage closely with stakeholders (focussing on the MDBA and WA DWER) to ensure that the framework and the knowledge produced are directly adopted by the end-users.	Dewi Kirono	CSIRO	262,500	0	525,000	525,000	**787,500**	01.07.2019	31.12.2020	Ongoing	Science webinar: Assessing future climate risks and adaptation options for Australian water systems	http://nespclimate.com.au/assessing-future-climate-risks-and-adaptation-options-for-australian-water-systems/	Water resource management in Australia will be affected by future changes in rainfall, temperature, evaporation and runoff so robust projections of water futures are important for impact assessments and developing adaptation options. This project is developing a framework that will integrate climate and hydrological science and modelling to deliver next generation national projections of key surface water metrics. The project is working with state government and government authority agencies to assess the resilience of water systems and adaptation options, and trial how the framework and knowledge produced under this project can be directly adopted by end-users.
													Zheng H, Chiew FHS, Potter NJ and Kirono DGC. 2019. Projections of water futures for Australia: an update. Proceedings of the 23nd International Congress on Modelling and Simulation, Canberra, December 2019, pp. 1000 –1006,	https://doi.org/10.36334/modsim.2019.K7.zhengH	
5.5	Extreme weather hazards in a changing climate	Many of the earliest and most significant effects of a changing climate are experienced through changes in hazardous weather events. However there are considerable scientific knowledge gaps around this, with a clear need for enhanced guidance and products to enable effective evidence-based planning. This project will deliver knowledge products addressing identified needs around four key types of hazards: tropical cyclones; bushfire hazards; east coast lows hazards; and thunderstorm hazards. The project will deliver science translation outputs which build on previous Hub research, as well as new analysis, to develop and deliver (in direct consultation with primarily existing stakeholder networks) a range of targeted communication tools and research synthesis products.	Andrew Dowdy	BoM	667,735	40,268	627,466	667,734	**1,335,469**	01.07.2019	31.12.2020	Ongoing	Warren RA, Ramsay HA, Siems ST, et al. Radar-based climatology of damaging hailstorms in Brisbane and Sydney, Australia. QJR Meteorol Soc. 2020;1–26. https://doi.org/10.1002/qj.3693	https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/qj.3693	Changes in the intensity and frequency of extreme and hazardous weather events are visible impacts of climate change currently experienced across much of Australia. These events often have important consequences for infrastructure, energy, health and ecosystems. The costs associated with extreme weather hazards and disasters are likely to change in the future as the climate continues to warm. This project is using observational data, climate models and statistical approaches to improve our understanding of current and future changes to extreme weather hazards and to deliver nationally significant knowledge products on current and future natural hazards focussed specifically on tropical cyclones, bush fires, thunderstorms, east coast lows and the extreme weather hazards they can produce. The project is consulting directly with stakeholders to ensure our information and knowledge products are incorporated and used to inform effective disaster risk policies and management activities. The improved understanding, information and tools on extreme weather hazards will be provided in formats that are relevant for reducing risks to human health, property and the environment in a changing climate.
													Giovanni Di Virgilio, Andrew Dowdy, Jason Evans, Jason Sharples, and Rick McRae. 2019, Climate change will make fire storms more likely in south-eastern Australia. The Conversation	https://theconversation.com/climate-change-will-make-fire-storms-more-likely-in-southeastern-australia-127225	
													Di Virgilio G, Evans JP, Blake SAP, Armstrong M, Dowdy AJ, Sharples J, McRae R. 2019. Climate change increases the potential for extreme wildfires, Geophysical Research Letters, 46, 8517–8526.	http://nespclimate.com.au/wp-content/uploads/2019/05/2019GL083699.pdf	
5.6	The carbon budget of continental Australia and possible future trajectories	While climate change policies seek to manage the net emissions of greenhouse gases, large uncertainties remain on how the carbon budget can be best managed to reduce emissions, increase carbon sinks and protect existing carbon stock. This project will provide the most internally consistent carbon budget for Australia to date, enabling reported emissions to be put in the context of a century-long assessment of Australian carbon stocks and fluxes, including legacy fluxes from past land-clearing and disturbance by wildfire. The project will also provide projections of how Australia's carbon budget may change under a range of climate and land-use scenarios. The projections will be consistent with the Australian National Outlook integrated assessment modelling for Australia.	Pep Canadell	CSIRO	393,750	0	393,750	393,750	**787,500**	01.07.2019	31.12.2020	Ongoing	Peters et al. 2019. Carbon dioxide emissions continue to grow amidst slowly emerging climate policies, Nature Climate Change. 10.1038/s41558-019-0659-6	https://www.nature.com/articles/s41558-019-0659-6	Tracking changes in global and Australian greenhouse gas emissions is vital for understanding our commitments under the Paris Agreement. This project continues to track Australia's carbon sources and sinks and develop a comprehensive carbon budget for Australia for the most recent decade. The project is estimating how the carbon budget may change in the future using climate scenarios and socio-economic pathways. The projections will be consistent with the Australian National Outlook integrated assessment modelling for Australia. The project is also supporting the development of an enhanced global carbon budget, through the international Global Carbon Project, to support the global policy call to better estimate and track the path towards global zero net greenhouse gas emissions. This will provide a clearer picture on the national and global mitigation efforts required under the Paris Agreement, and will inform national and international climate change policy decision-making.
													Friedlingstein et al. 2019. Global Carbon Budget 2019, Earth Systems Science Data, 11, 1-56. doi:10.5194/essd-11-1-2019	https://www.earth-syst-sci-data.net/11/1783/2019/	
													Science webinar: Disentangling environmental and human drivers of carbon dioxide uptake and release on land	http://nespclimate.com.au/disentanglin	
													Pep Canadell, Corinne Le Quéré, Glen Peters, Pierre Friedlingstein, Robbie Andrew, Rob Jackson, and Vanessa Haverd. 2019. Global emissions to hit 36.8 billion tonnes, beating last year's record high. The Conversation	https://theconversation.com/global-emissions-to-hit-36-8-billion-tonnes-beating-last-years-record-high-128113	

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					NESP Funding* $	Other Cash Contributions* $	Other In-Kind Contributions* $	Total Other Contributions* $	Total Budget* $				Outputs	Link to output	
5.7	Tracking ocean change: ocean observations and models	Changes in ocean heat and salinity affect the modes of climate variability that dominate Australia's climate, and impact on the frequency and magnitude of extreme events. To understand how the oceans may impact Australia's climate, it is important to understand how and why oceans are changing and how we can better project future changes. This project will improve, extend and deliver high quality ocean data which is vital for assessing ocean change. Analysis of ocean temperatures and salinity will be undertaken using ocean observations and model experiments to track and understand observed changes, and to identify and understand the key mechanisms of ocean heat uptake in our oceans. Model improvements will also be provided under the project to improve how ocean heat uptake is represented in ACCESS and other climate models, thereby improving climate change projections.	Bernadette Sloyan	CSIRO	482,344	0	482,344	482,344	**964,688**	01.07.2019	31.12.2020	Ongoing	Kennicutt MC, Bromwich, Liggett D, Njastad B, Peck L, Rintoul SR, Ritz C, Siegert MJ, Brooks CM, Cassano J, Chaturvedi S, Chen D, Dodds K, Golledge NR, Le Bohec C, Leppe M, Murray A, Chandrika Nath P, Raphael MN, Rogan-Rinnemore M, Schroeder DM, Talley L, Travouillon T, Vaughan DG, Wang L, Weatherwax AT, Yang H Chown SL. 2019. Sustained Antarctic Research: A 21st Century Imperative, One Earth Review, doi: 10.1016/j.oneear.2019.08.014	https://www.sciencedirect.com/science/article/pii/S2590332219300020X?via%3Dihub	The ocean impacts Australia's climate and the frequency and magnitude of extreme events. As the climate continues to change, it's important to assess how the oceans are changing and the impact these changes may in turn have on Australia's climate, now and into the future. This project is improving and delivering high quality ocean data vital for continued assessments of ocean change. Ocean observations and model experiments will be analysed to track and understand ocean changes, and to identify the key mechanisms of ocean heat uptake and changes in ocean salinity. The project is also improving the representation of ocean heat uptake in Australia's climate model, ACCESS, and other climate models by identifying sources of bias in the models and provide solutions to reduce them. This research will ensure high quality ocean datasets required for assessing change in our oceans are accessible for use by researchers around the world. The improved model simulations of ocean change will result in improved climate change projections. Data sets and analysis produced under the project will also inform global climate assessments such as the Intergovernmental Panel on Climate Change assessment reports.
5.8	Marine and coastal climate services for extremes information	Coastal and marine managers, engineers, industries and finance organisations have a keen interest in sea level rise and extreme sea levels. Information on marine heat waves is of key importance to fisheries and aquaculture industries. Relevant information targeted towards these end-users will deliver tangible benefits to the nation as climate risks become better understood and managed. This project will investigate and analyse a range of coastal and near-shore variables, such as sea level trends, current and future marine heat waves, extreme sea level, waves, estimates of ocean mass increases and the effects of wind, waves, sea level rise and storm surge on sediment compartments. The project will consolidate this information and previous information developed under previous Hub research and deliver the information through a platform that hosts a range of tools and data delivery mechanisms. Project researchers will work closely with key stakeholders in the development of the platform to ensure the information is readily available and other coastal tools are adequately linked in to enhance end-user understanding of past variability and future changes in events that cause extreme impacts in the coastal zone.	Kathleen McInnes	CSIRO	656,250	19,031	637,219	656,250	**1,312,500**	01.07.2019	31.12.2020	Ongoing	Marshall AG, Hemer MA, McInnes KL, 2019. Australian blocking impacts on ocean surface waves, *Climate Dynamics* , doi:10.1007/s00382-019-05058-8	https://link.springer.com/article/10.1007/s00382-019-05058-8	Changes in our coastal climate, through sea-level, waves, marine heatwaves and coastal extremes, have broad implications for a range of coastal stakeholders such as coastal councils, environmental managers, engineers, infrastructure designers and aquaculture and fisheries industries. This project is improving understanding of how marine and coastal extremes are changing by investigating and analysing a range of coastal and near-shore variables, including sea-level trends, current and future marine heat waves, extreme sea-levels, waves, estimates of ocean mass increases and the effects of wind, waves, sea-level rise and storm surges on sediment compartments. The project is also developing a suite of science-based data and information services tailored to the priority needs of coastal managers and decision-makers. To do this, project researchers are working closely with stakeholders to ensure our research is appropriately consolidated and delivered via a readily available, co-produced range of tools and data-delivery mechanisms. This research will inform the next generation of coastal climate projections for Australia. It will also lead to a more aware coastal population, armed with the tools and improved knowledge to better assess climate risks and improve coastal planning and management decisions and activities.
													Science webinar: Impacts of climate change and variability on ocean waves	http://nespclimate.com.au/impacts-of-climate-change-and-variability-on-ocean-waves/	
5.9	Natural habitats for coastal protection and carbon sequestration (NCCC - Phase 2)	Living shorelines have the potential to play important roles in climate mitigation and adaptation because of their ability to sequester carbon and/or reduce the threats of coastal erosion and flooding. However knowledge gaps remain around the value of natural habitats for coastal protection and carbon sequestration. This project will investigate the amount of carbon fixed by these natural habitats and ecosystems (blue carbon) and evaluation the potential for these ecosystems to contribute to national carbon accounting. To better understand the response of dune vegetation to event-scale extremes and the resulting consequences to coastal erosion, project researchers will undertake high resolution field surveying . The project also aims to develop the first national assessment of sediment accumulation, shoreline changes and wave attenuation from soft, hybrid and hard engineering solutions to provide local governments with the knowledge needed to inform coastal planning.	Stephen Swearer	University of Melbourne	525,000	132,663	438,500	571,163	**1,096,163**	01.07.2019	31.12.2020	Ongoing	O'Connor JJ, Fest, BJ, Sievers, M, Swearer, SE. Impacts of land management practices on blue carbon stocks and greenhouse gas fluxes in coastal ecosystems—A meta-analysis. Glob Change Biol. 2020; 00: 1– 13, doi: 10.1111/gcb.14946	http://nespclimate.com.au/wp-content/uploads/2019/05/5.9_BCR-ms_GCB_v5_pre_print.pdf	Natural, created or restored habitats such as oyster reefs, mangroves and saltmarshes have the potential to provide coastal protection as well as enhance biodiversity and other ecosystem services, including food provision and improved water quality. These 'living shorelines' also have the potential to play an important role in climate mitigation and adaptation due to their ability to sequester carbon and reduce the threats of coastal erosion and flooding. However, many of these habitats have been lost or degraded throughout Australia. While restoration is a clear national priority for biodiversity conservation, there are still key uncertainties regarding the use of natural habitats for coastal protection and carbon sequestration. This project will is conducting research on blue carbon, coastal erosion and eco-engineering research to: • develop a standard method for assessing changes in carbon stocks due to coastal ecosystem management activities • develop an ecological and geomorphological index of dune resilience to coastal erosion, and •assess the effectiveness of a hybrid living shoreline approach for habitat restoration and coastal protection. In collaboration with key stakeholders, such as state and local governments and conservation groups, this research will be synthesised into a road map that identifies the next steps towards developing national guidelines for coastal habitat restoration and eco-engineering to inform on-ground coastal management actions.
CURRENT RESEARCH FACILITATION ACTIVITIES															
CASE STUDIES AND INDIGENOUS ACTIVITIES															
CS 5.1	Understanding the impact of climate change on flowering induction in mango in the Northern Territory	Rising minimum and maximum temperatures will affect flower induction of current commercially produced mango cultivars and those from the National Mango Breeding Program . This case study will provide and support the application of climate change information to the NT mango industry so the precise effects of minimum and maximum temperatures for these cultivars can be determined. This will allow the industry to consider an appropriate management response. To ensure the maximum value is realised from the impact assessment, a climate literacy intervention will also be included based on a workshop and supporting explainer products.	Mandy Hopkins	CSIRO	40,000	0	0	0	**40,000**	1/01/2019	31/12/2020	Ongoing	Workshop report: Impact of climate change on mango production in the Northern Territory	http://nespclimate.com.au/wp-content/uploads/2019/05/NT-mango-expert-meeting-report-WEB.pdf	Mango flowering is sensitive to minimum and maximum temperature thresholds at particular times in the growing season. The Hub is working with the Northern Territory Department of Primary Industry and Resources and Australian Mango Industry Association to determine changes to the occurrence of these thresholds in Northern Territory growing regions, and how these changes would impact on commercial mango cultivars and those in development. The results of this assessment will help both individual producers and the mango industry ensure sustainable mango production into the future.
													Workshop summary: Impact of climate change on mango production in the Northern Territory	http://nespclimate.com.au/wp-content/uploads/2019/05/A4-2p-workshop-summary-NT-mangoes-WEB.pdf	
													Case study fact sheet: Understanding the impact of climate change on the Northern Territory mango industry	http://nespclimate.com.au/wp-content/uploads/2019/05/A4-2p-cs-factsheet-NT-mangoes-WEB.pdf	
													Case study technical scope summary	http://nespclimate.com.au/wp-content/uploads/2019/05/Mango-CS-scope-summary.pdf	
CS 5.2	Using climate change information in a Gondwana Rainforest WHA climate change adaptation plan	There are gaps in the scientific understanding of projected climate change impacts on the Gondwana Rainforest World Heritage Area, particularly changes to cloud cover. Cloud cover is an important environmental variable for the property because cloud and fog provide up to half of the annual vegetation water requirements in high elevation forests. This case study will develop lifting condensation level projections, to provide information about changes to the cloud base in a changing climate, to complement existing temperature and rainfall projections. This information can be used to inform the development of a climate change adaptation plan for the Gondwana Rainforests WHA.	Mandy Hopkins	CSIRO	35,500	0	0	0	**35,500**	1/01/2019	31/12/2020	Ongoing	Not yet available	Future products will be available from: http://nespclimate.com.au/informing-world-heritage-area-climate-change-adaptation-planning/	There are gaps in the scientific understanding of the impact of climate change on the Gondwana Rainforests WHA, particularly changes to cloud cover. This is an important environmental variable for the property because cloud and fog provide up to half of the annual vegetation water requirements in high elevation forests. The Hub is working with the Gondwana Rainforests of Australia World Heritage Area to provide climate change projections to help with planning for the future. The new data is being used to model future changes in habitats for and distribution of key species in the forests.

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CS 5.3	TasLab Engage	Extreme climate events impact a number of sectors across Tasmania, including water, agriculture, aquaculture and emergency response. These events are costly and difficult to plan for. Information on the form these extremes might take over the coming years, their past variability and guidance on the use of relevant climate information would assist with planning for these events. TasLab Engage facilitates engagement between industry groups and scientists to understand industry-specific climate sensitivities and identify the relevant climate information required - at the multi-year to decadal timescales. It has the potential to assist with better management of climate sensitive systems and increase resilience to climate extremes in Tasmania. The findings from this case study will directly inform the CSIRO's Decadal Forecast Project to ensure climate information and predictions resulting from this large project are aimed at stakeholder needs.	Sonia Bluhm	CSIRO	50,000	0	50,000	50,000	**100,000**	1/01/2019	31/04/2020	Completed	Case study final report	http://nespclimate.com.au/understanding-tasmanias-climate-sensitivities-and-information-needs/	Extreme climate events impact a number of sectors across Tasmania, including water, agriculture, aquaculture and emergency response. These events are costly and difficult to plan for. To better understand the climate information needs in Tasmania, the Hub is working with CSIRO's Decadal Climate Predictions project to collected and analyse valuable stakeholder information that will drive the development of multi-year to decadal predictions for Australia. This will give many industries much more useful climate information at operational timescales, allowing for better risk identification and decision making.
CS 5.4	Climate Change Literacy (climate change 101) (State Government/ Local Government)	Stakeholder feedback over the past three years of the Hub indicates that there is still a lot of stakeholder uncertainty about how the climate system works, how the climate is changing and what climate change projections actually tell us. Existing climate change information (e.g. Climate Change in Australia) is not readily accessed, understood and applied to inform decision and policy making. This case study is preparing a climate change capability development package that will consist of a half-day training session and supplementary information materials. The package will provide participants/users with a better understanding of the climate system, an appreciation of climate change science, and the confidence to find and use climate change information to inform decisions. The package includes guidelines for a rapid climate change impact assessment methodology that can be applied across all sectors to co-produce climate change information and facilitate its use in decision making.	Mandy Hopkins	CSIRO	71,250	0	0	0	**71,250**	1/01/2019	31/12/2020	Ongoing	Methodology has been adapted and simplified from a 8-step process to a 'health-check' 5 step process that fits within a risk assessment	The methodology is being finalised, and, as part of this process the Hub plans to hold Climate literacy sessions for Australian Government depts prior to public release of the methodology. The timing will be dependent on the COVID-19 situation.	Science-based climate change data and information provides a solid basis for developing 'climate-smart' policies and decisions. However, without a fundamental understanding of climate change and how climate change science can be used, the benefits of using this information are not realised. The Hub is developing a climate literacy workshop to increase understanding of and ability to use climate change science that is applicable across sectors and stakeholders. This workshop is being rolled out across selected stakeholders and industries to ensure it is fit for purpose.
													Climate Change Literacy sessions have been held with a range of stakeholders including the mango industry, DEWLP, with Australian Government representatives during the Hub's Road Show 23-24 September 2019	http://nespclimate.com.au/training/	
IA 5.5	Indigenous perspectives on climate risk (Indigenous Communities)	Indigenous peoples in Australia form the majority of populations in many remote highly vulnerable environments where climate change impacts on their country are already evident, including extreme weather events, climate variability and sea level change. For all Indigenous peoples in Australia, and most globally, climate change compounds over-arching issues of socio-economic disadvantage, chronic poor health, and the burdens of the colonial history of dispossession and hostile policy settings. Indigenous peoples bring a particular perspective of climate risk related to their particular socio-economic, historical, political, cultural and environmental circumstances. This results in perceptions that are often specific to communities and their cultures, places and regions with distinctive community values, resource and policy circumstances. Understanding these risk perceptions can potentially set the foundation for new pathways of research collaboration to better tailor climate science and information to meet Indigenous communities. This is a Indigenous-led project based on two case studies, (Shark Bay World Heritage Site and Central Land Council Ranger Groups community) which will work with Indigenous peoples on two-way sharing of climate risk that will contribute to place-based risk reduction strategies.	Mandy Hopkins and Marian Sheppard	CSIRO	133,803	0	0	0	**133,803**	1/01/2019	31/12/2020	Ongoing	Not yet available	http://nespclimate.com.au/understanding-indigenous-perspectives-of-climate-risk/	Indigenous peoples in Australia form the majority of populations in many remote highly vulnerable environments where climate change impacts on their country are already evident, including extreme weather events, climate variability and sea level change. For all Indigenous peoples in Australia, and most globally, climate change compounds over-arching issues of socio-economic disadvantage, chronic poor health, and the burdens of the colonial history of dispossession and hostile policy settings, which often are of more immediate concern in Indigenous peoples' lives. Indigenous peoples bring a particular perspective of climate risk related to their particular socio-economic, historical, political, cultural and environmental circumstances. This results in perceptions that are often specific to communities and their cultures, places and regions with distinctive community values, resource and policy circumstances. Understanding these risk perceptions can potentially set the foundation for new pathways of research collaboration to better tailor climate science and information to meet Indigenous communities. This Indigenous-led project, based on two case studies, one in the Shark Bay World Heritage Site and another with Central Land Council Ranger Groups community, will work with Indigenous peoples on two-way sharing of climate risk that will contribute to place-based risk reduction strategies.
CS 5.6	Climate measurement standards initiative	In response to the Recommendations of the Task Force on Climate-related Financial Disclosures many organisations in the Australian financial services sector are now beginning to explore the use of science-based scenario analysis of the physical impacts of climate change as part of their strategic planning, risk management processes and financial disclosures. There are however no agreed standards in place to underpin industry efforts and reporting to date is fragmented and inconsistent in scope and quality with respect to use of relevant peer-reviewed science. To support the use of high-quality, science-based climate change data and information to inform such analysis and related decision-making and reporting, the industry-led Climate Measurement Standards Initiative (CMSI) has been formed. The Hub will provide scientific expertise and advise to this initiative to ensure standards and outputs developed under this case study are based on credible and up-to-date climate change science and knowledge.	Geoff Gooley	CSIRO	150,000	0	0	0	**150,000**	1/01/2019	31/12/2020	Ongoing	Not yet available	http://nespclimate.com.au/designing-climate-change-risk-information-standards-for-the-financial-services-sector/	While recognition of corporate climate-related financial risks continues to increase, there are no agreed standards in place in Australia for measuring and reporting physical climate change risks in the financial services sector. The Hub is providing climate change science expertise to the industry-led Climate Measurement Standards Initiative, which aims to address this gap by developing best-available, open-source, science-based standards for physical climate-related financial risk disclosure. The standards will allow for better reporting of physical risks, providing better risk information – and so, better decisions – for investors.
CS 5.7	National Disaster Risk Information Services Capability (NDRISC) Pilot Project (Federal Government)	Increased information on changes in natural disaster risks due to climate change is needed by all sectors of Australian society, business and government to inform their decision-making and planning. The ESCC Hub is participating in a pilot project through the National Resilience Taskforce in the Department of Home Affairs to demonstrate the benefits of considering climate change in a national disaster risk information services capability, using the Australian freight and supply chain network as the example. The goal of the study is to support a business case for longer term funding of NDRISC.	David Karoly	CSIRO	5,000	0	0	0	**5,000**	1/01/2019	31/12/2019	Ongoing	Not yet available	Not yet available	Increased information on changes in natural disaster risks due to climate change is needed by all sectors of Australian society, business and government to inform their decision-making and planning. The ESCC Hub is participating in a pilot project through the National Resilience Taskforce in the Department of Home Affairs to demonstrate the benefits of considering climate change in a national disaster risk information services capability, using the Australian freight and supply chain network as the example. The role of the Hub will be to provide timely climate science information and communication products for incorporation into government policies, briefings and activities around NDRIS, and to provide advice and input into strategic climate change science and adaptation policy activities.

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IA 6.1	Second national Indigenous gathering on climate change - pathway to sustainable relationships (Indigenous Communities)	The 2018 National Indigenous Climate Change Dialogue received positive feedback from Indigenous and non-Indigenous attendees alike. It was agreed that this Dialogue was an important start to the conversation between Indigenous communities, the Hub and climate researchers. To continue this conversation and build on the relationships developed through the 2018 Dialogue and other Hub related Indigenous activities, the Hub has committed to supporting a second gathering in June 2020. In developing the second gathering, important findings from the first event will be considered, including greater representation of Indigenous communities across Australia. To this end, this gathering will be led by an expanded Indigenous Steering Committee who will facilitate the co-development of the gathering in 2020 with Indigenous peoples, scientists and relevant stakeholders, with support from the Hub	Mandy Hopkins and Marian Sheppard	CSIRO	300000	0	0	0	**300,000**	1/07/2019	31/12/2020	Ongoing	Communique from the first Interim Steering Committee meeting: http://nespclimate.com.au/wp-content/uploads/2019/11/NFPDCCSC_communique01_191121.pdf Communique from the second Steering Committee meeting: http://nespclimate.com.au/wp-content/uploads/2019/11/NFPGCC-SC-communique-2-200130.pdf	http://nespclimate.com.au/wp-content/uploads/2019/11/NFPDCCSC_communique01_191121.pdf	Indigenous communities across Australia are experiencing the effects of our changing climate, with changes in seasonal weather patterns, increasing temperatures, rising sea levels and changing water availability already impacting on country and people. The 2018 National Indigenous Dialogue on Climate Change demonstrated an overwhelming interest by Australia's First Peoples in better understanding our changing climate and what the future holds. It also highlighted the importance of an ongoing dialogue and made clear that First Peoples want to set their own agenda on climate knowledge and action. Following on from the 2018 dialogue, the Hub is supporting the organisation and delivery of the National First Peoples Gathering on Climate Change to be held in 2020. This Gathering will celebrate, learn from and enhance First Peoples-led climate change action and will include: •sharing tools and approaches •presentations from selected Indigenous-led case studies •western science learnings about climate change, both in the case studies and through climate change literacy presentations •a proposal for governance of a First Peoples-led climate action plan •a session on the NESP ESCC Hub's role going forward •identification of opportunities to deliver joint presentations through roadshows to government departments and others.
IA 6.2	Supporting Indigenous participation at AMOS 2020 conference (Indigenous Communities)	The first ever Indigenous session was held at the 2019 Australian Meteorological and Oceanographic Society (AMOS) conference in Darwin. Traditional Owners were invited to present on their perspective of climate change and risks to their country, as well as community led solutions contributing to climate change mitigation while generating income for communities. This activity will support another Indigenous session to be convened at the next AMOS, February 2020 in Fremantle. The Indigenous discussion and workshop session at the 2020 AMOS conference is entitled Cross-cultural communication and climate change. At the workshop and discussions within this session, Indigenous people, their partners and science communication practitioners will share experiences in climate science communication. The strengths and weaknesses of the different approaches, such as peer-to-peer exchanges, national and local dialogues, Indigenous-led fact sheets and other approaches will be discussed, with an aim to identify and report on key insights about what works and why.	Mandy Hopkins and Marian Sheppard	CSIRO	36,500	0	0	0	**36,500**	1/07/2019	31/12/2020	Completed	Workshop summary	http://nespclimate.com.au/wp-content/uploads/2020/03/A4-2p-AMOS-TO-workshop-summary.pdf	There are many benefits for western science by incorporating traditional knowledge in efforts to understand the past and current changes. At the same time, First Nations peoples can benefit from incorporating the understanding of climate change from western science in planning for the future. While the benefits of bringing these two knowledge systems together are obvious, the steps to do so are not. The Hub developed and convened a workshop to discuss collaboration between researchers and First Nations peoples as part of the February 2020 AMOS conference in Freemantle. At the workshop, participants identified a series of important considerations for co-designing research projects in climate change and more generally. Some examples of these considerations include understand that there are many peoples, many cultures; include Traditional Owners from the start (and all the way through); appreciate different timelines; and ensure you are giving as well as taking. The Hub has prepared a summary of these considerations, available in the workshop summary.
CS 6.3	Adapting to climate change and building resilience in Australian World Heritage properties: using climate change science information and traditional knowledge to inform risk and vulnerability assessments and adaptation planning	The continued protection of World Heritage properties across Australia (and indeed, the world) requires improved understanding about the current and future impacts of climate change on their Outstanding Universal Values, and credible information and risk assessment processes to respond effectively to likely changes and build resilience. World Heritage properties are important assets, with natural sites providing ecosystem benefits, such as water and climate regulation and carbon storage in forested sites. Additionally, their inter-connected cultural heritage values can convey traditional knowledge that builds ecological and social resilience for change. This case study will develop a methodology for using science-based climate change information to inform the development of a climate change risk or vulnerability assessment that can then form the basis for preparation of adaptation plans to build the resilience of World Heritage properties to climate change.	Mandy Hopkin	CSIRO	150,000	0	0	0	**150,000**	1/01/2020	31/12/2020	New	Not yet available	http://nespclimate.com.au/integrating-western-science-and-traditional-knowledge-world-heritage/	The continued protection of World Heritage properties across Australia (and indeed, the world) requires improved understanding about the current and future impacts of climate change on their Outstanding Universal Values, and credible information and risk assessment processes to respond effectively. Natural sites provide ecosystem benefits, such as water and climate regulation and carbon storage in forested sites. Additionally, their inter-connected cultural heritage values can convey traditional knowledge that builds ecological resilience for change. In this way, World Heritage properties can serve as climate change laboratories to gather and share information on applied and tested monitoring, mitigation and adaptation practices. This case study will develop a methodology for using science-based climate change information to inform the development a climate change risk or vulnerability assessment that can then form the basis for preparation of climate change adaptation plans. This work will be based on previous case studies in the Shark Bay and Gondwana Rainforest WHAs.
CS 6.4	Integrated Environmental Assessment for Development Decisions (cross-NESP Hub)	Lack of knowledge can hinder decision-making when new opportunities for economic development are being explored. It also leaves industries, financiers and communities uncertain and risk-averse about investment and, importantly, places our environment at risk due to poorly informed decision-making. Integrated environmental assessment (IEA) is an interdisciplinary approach to combine, interpret and communicate information from diverse scientific disciplines and knowledge systems, to support decision making. This collaborative project between all NESP Hubs will develop and demonstrate the value of a holistic approach to providing information for strategic decision-making for sustainable development. It will provide clear guidance to government and stakeholders about the existing information available, data needs, analysis approaches, and governance settings to support Integrated Environmental Assessment for northern Australia.	David Karoly	CSIRO	39,593	0	0	0	**39,593**	1/01/2020	31/12/2020	New	Not yet available	http://nespclimate.com.au/supporting-integrated-environmental-assessment-for-northern-australia/	Lack of knowledge can hinder decision-making when new opportunities for economic development are being explored. It also leaves industries, financiers and communities uncertain and risk-averse about investment and, importantly, places our environment at risk due to poorly informed decision-making. Integrated environmental assessment is an interdisciplinary approach to assessment based on combining, interpreting and communicating knowledge from diverse scientific disciplines and knowledge systems. The main task of any integrated assessment is to provide useful information to policy makers. This is a cross-NESP project, led by the Threatened Species Recovery Hub. The ESCC Hub will provide climate change data, information and advice into this project as required.
Total research facilitation costs					**1,011,646**	**0**	**50,000**	**50,000**	**1,061,646**						
TOTAL RESEARCH COSTS					**19,655,534**	**692,486**	**21,410,916**	**22,067,402**	**41,722,936**						
ENGAGEMENT ACTIVITIES Funded from the Comms & KB component of the budget															

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EA6.5	CLIMATE 2020 – a resilient and sustainable Australia	With the Hub's research program concluding in December 2020, it has been decided that a conference would serve as a fitting final showcase of the Hub's research and research impact from 2015–2020. The CLIMATE2020 conference will provide an opportunity for attendees across government, industry and sectors to be provided with a synthesis of research under the Hub and across the climate change science community as a whole to build the capacity of attendees and to be used to inform decisions, policies and products. It will also provide multiple opportunities for networking between researchers, policy-makers, managers and planners, practitioners and communicators to build lasting relationships and partnerships. The conference will bring together researchers and policy makers from across multiple disciplines and may lead to the development of new projects, initiatives, communication products, and help to drive the climate change research agenda.	Mandy Hopkins and Marian Sheppard	CSIRO	150000	0	0	0	**150,000**	1/07/2019	31/12/2020	New	Conference delayed due to COVID-19. New date yet to be determined.	http://nespclimate.com.au/climate2020	The Climate 2020 conference will provide an opportunity for attendees across government, industry and sectors to be provided with a synthesis of research under the Hub and across the climate change science community as a whole to build the capacity of attendees and to be used to inform decisions, policies and products. It will also provide multiple opportunities for networking between researchers, policy-makers, managers and planners, practitioners and communicators to build lasting relationships and partnerships. The conference will bring together researchers and policy makers from across multiple disciplines and may lead to the development of new projects, initiatives, communication products, and help to drive the climate change research agenda. The conference is also likely to inform future opportunities and programs related to climate change research and science application.
EA6.6	Improving the functionality, utility and accessibility of information on the Climate Change in Australia (CCiA) website	The Climate Change in Australia (CCiA) website was developed in 2015/16 in consultation with NRM planners to address their climate change information needs. However, almost 5 years later it is clear that the needs of some climate change projections users have changed and grown, with new users emerging with different requirements that were not considered at the time of development. As a result, a refresh to the navigation functions of the website and improved accessibility of key information and data is required. This activity will conduct a user needs survey to determine ways to improve the accessibility of information in the website and will be informed by a user reference group of key stakeholders to test and advise on planned improvements to the website. This activity will also look at partnering with the Electricity Sector Climate Information (ESCI) project to share resources and ensure the needs of the energy sector, as well as other existing user needs, are met. Improving the user experience of the CCiA website and the functionality, utility and accessibility of information, data and tools within the website. This will assist in ensuring that climate change projections information is better able to be applied by target user groups to inform policy development, management planning, and risk assessments.	Sonia Bluhm and Mandy Hopkins	CSIRO	15,000	0	0	0	**15,000**	1/09/2019	31/12/2020	New	Not yet available	http://nespclimate.com.au/making-climate-change-projections-information-more-accessible/	The Climate Change in Australia projections website was launched in 2016, at which time it represented a world-class climate change tool. However, since this time new users of climate change information have emerged, and the needs of existing users have changed. This activity will conduct a user needs survey to determine ways to improve the accessibility of information in the website and will be informed by a user reference group of key stakeholders to test and advise on planned improvements to the website. This activity will also look at partnering with the Electricity Sector Climate Information (ESCI) project to share resources and ensure the needs of the energy sector, as well as other existing user needs, are met.
EA6.7	Synthesising research outcomes and impacts under the Earth Systems and Climate Change Hub	The Hub has undertaken world leading climate change science and has engaged with a variety of target user groups and stakeholders over its life time. Synthesising and communicating the outcomes and impacts of these research and knowledge brokering activities is important to show the value of the Hub and the investment provided through both the government and partner organisations. This research facilitation activity will deliver a range of synthesis products and activities across three levels during 2020 and 2021 to showcase the achievements, successes and research findings across the life of the ESCC Hub.	Sonia Bluhm	CSIRO	65,000	0	0	0	**65,000**	1/01/2020	30/03/2021	New	Not yet available	N/A	The Hub has undertaken world leading climate change science and has engaged with a variety of target user groups and stakeholders over its lifetime. Synthesising and communicating the outcomes and impacts of these research and knowledge brokering activities is important to show the value of the Hub and the investment provided through both the government and partner organisations. This engagement activity will deliver a range of synthesis products and activities across three levels during 2020 and 2021: project level; research facilitation level and Hub level. The synthesise activities will be guided by a Hub Close-out Communication Plan and will be consistent with and informed by the Hub's Communication and Knowledge Brokering Strategy and Evaluation Planning Framework and associated actions and outputs. The path-to-impact storylines from projects developed as part of the Hub's M&E will also be used to inform the synthesis products. A Synthesis Working Group will be formed with membership from Hub Central and representatives from across all Hub projects to ensure synthesis products and activities draw on the latest Hub research findings and accurately portray outcomes and impacts across the Hub.
TOTAL HUB FUNDED ENGAGEMENT ACTIVITIES					**230000**	**0**	**0**	**0**	**230000**						
ENGAGEMENT ACTIVITIES (funded externally to NESP by DAWE)															
EA6.8	Towards a National Climate Service: a report to the National Climate Science Advisory Committee (Federal Government)	The National Climate Science Advisory Committee (NCSAC) has asked that the National Environmental Science Program (NESP) Earth Systems and Climate Change (ESCC) Hub to prepare a report on a proposed development and implementation approach for a national climate service capability for Australia. This engagement activity will report on a climate services capability that could provide end-users with science-based data and information tailored to the needs of their respective organisations and sectors for purposes of assessing physical climate risk and informing policy development, management planning, investment and associated decision-making.	Geoff Gooley	CSIRO	0	75000	0	75,000	**75,000**	1/07/2019	30/09/2020	New	Not yet available	http://nespclimate.com.au/informing-the-strategic-direction-of-australias-climate-science-research/	The National Climate Science Advisory Committee (NCSAC) has asked that the ESCC Hub to prepare a report on a proposed development and implementation approach for a national climate service capability for Australia. This capability would provide end-users with science-based data and information tailored to the needs of their respective organisations and sectors for purposes of assessing physical climate risk and informing policy development, management planning, investment and associated decision-making. The proposed approach will incorporate input from key partners in the Bureau of Meteorology, CSIRO and the university sector, with emphasis on their critical role in provision of comprehensive knowledge brokering and climate services needed by industry, government and the community to manage the physical and financial risks and opportunities of a variable and changing climate, both now and into the future.
EA6.9	Australia's Next Generation Climate Projections: a report to the National Climate Science Advisory Committee (Federal Government)	The National Climate Science Advisory Committee (NCSAC) has contracted the NESP Earth Systems and Climate Change (ESCC) Hub to prepare a report on a proposed development and implementation approach for the next generation of national and regional climate change projections for Australia. The proposed approach will incorporate input from key partners in the Bureau of Meteorology, CSIRO and the university sector, with emphasis on their key role in provision of past climate change projections for Australia.	David Karoly	CSIRO	0	75000	0	75,000	**75,000**	1/07/2019	30/09/2020	New	Not yet available	http://nespclimate.com.au/informing-plar	The National Climate Science Advisory Committee (NCSAC) has asked the ESCC Hub to prepare a report on a proposed development and implementation approach for the next generation of national and regional climate change projections for Australia. The proposed approach will incorporate input from key partners in the Bureau of Meteorology, CSIRO and the university sector, with emphasis on their key role in provision of past climate change projections for Australia.
TOTAL ENGAGEMENT ACTIVITY COSTS (EXTERNALLY FUNDED ACTIVITIES NOT INCLUDED IN ATTACH C)					**0**	**150,000**	**0**	**150,000**	**150,000**						
COMPLETED CASE STUDIES RPV 2-4 *Funded from the Comms & KB component of the budget*															

Project Number/ID	Project Name/Title	Project Summary	Project Leader	Lead Organisation	Approved Funding Research Plan Versions 1-6					Start Date	Completion Date	Status	Outputs		Outcomes
					NESP Funding* $	Other Cash Contributions* $	Other In-Kind Contributions* $	Total Other Contributions* $	Total Budget* $				Outputs	Link to output	
3.1	Climate change information products for Indigenous communities	In collaboration with the traditional owners of the Mackay region this case study continues to develop a package of 'Climate Change 101' information from across the Hub's research portfolio, for use by champion traditional owners in their outreach activities with the Traditional Owners group. The package includes a PowerPoint slide pack, technical written information and a video. The package as been developed in collaboration with traditional owners to ensure the information is relevant and accessible, and can be communicated by traditional owners to traditional owners. This scientific information, in combination with traditional knowledge from the region, is being used to help Indigenous communities prepare for the impacts of climate change on country.	Mandy Hopkins	CSIRO	15,000			0	**15,000**	1/01/2017	31/12/2018	Completed	Climate Change 101 package (Power point slide) for use by the traditional owners of the Mackay region	N/A	Climate change threatens the social, cultural and economic wellbeing of many Indigenous communities. Traditional owners are aware of changes to country, but do not necessarily know much about the science explaining the changes. Without understanding the context of the changes, it is difficult to prepare for a future that is very different from the past. The project outputs (climate change 101 package) where developed in collaboration with traditional owners of the Mackay region, and provide information on why climate change is different from other cycles and past changes and what it means for Indigenous communities in the region. The combination of ESCC Hub research and traditional knowledge provides a unique and appropriate tool for communicating and starting discussions with indigenous communities and traditional owners on how climate change will impact their communities.
3.2	Meeting Indigenous priorities for climate change information, capacity building and engagement	Discussing and understanding the climate science information needs of Indigenous communities will enable the Hub to better engage and be useful to these communities now and into the future. In partnership with CSIRO Land and Water's Collaborative and Indigenous Science team, Kimberley Land Council (KLC) and Seed (the Indigenous branch of the Australian Youth Climate Coalition, and Australia's first Indigenous youth-led climate network), the Hub is working to identify Indigenous priorities for climate-change focussed information, capacity building and forms of engagement. A national workshop on this topic will be held in November 2018. Outputs from this workshop will provide input into future plans to meet the Hub's Indigenous engagement goal. This activity builds on previous Hub work with Indigenous communities to reach common understanding about priority needs.	Mandy Hopkins	CSIRO	130,000			0	**130,000**	1/01/2017	30/06/2019	Completed	Morgan M, Morgan-Bulled D, Hopkins M, Hill R, Talbot L, Lyons P, Sheppard M, Gorring A, Johnston S, Baldwin L, Karoly D, Bullio R, Bolzenius J, Brady L, Bux J, Clubb K, Clubb R, Clubb Z, Cooper S, Cushion A, Neal DP, Flugge K, Fourmile J, Gilbert J, Gilbert R, Gilbert Z, Gudju Gudju, Jakobi C, James L, Joseph J, Kerr B, Kulka A, Lawerence M, Liezenga K, Locke J, McNeair B, Martin J, Morgan G, Mumbulla M, Pattison A, Pattison M, Power A, Romagnoli Z, Steffensen K, Stuart H, Thompson S, Turpin G, Walker C, Wason S, Watkins S, Willis K, Wilson J, Whyman D, Chung C, Dobrohotoff P, Marsland S, Moise A, Ramsay H, Trenham C, Wilson B. 2019. Workshop Report: National Dialogue on Climate Change. Earth Systems and Climate Change Hub Report No. 11, NESP Earth Systems and Climate Change Hub, Australia.	http://nespclimate.com.au/wp-content/uploads/2019/05/191209-NICCD-report-final.pdf	The Earth Systems and Climate Change Hub is one of the first Australian climate change science research organisations to actively and continually engage with, and consider the climate change information needs of, Indigenous communities. Conversations with Indigenous stakeholders have highlighted the importance of first gathering information on what science and information Indigenous communities actually want and need, rather than making assumptions about this. To ensure Indigenous communities are able to provide the Hub with this knowledge and information, the Hub is supporting a national workshop to identify the climate change information and capacity building requirements of our Indigenous stakeholders. The workshop, which is driven and run by Indigenous members, will provide the forum for Indigenous peoples to come together to provide recommendations regarding what climate change information, capacity building and forms of engagement they see as being of greatest value. A workshop report will be developed which will capture the information identified in the workshop by participants and the communities they represent. These recommendations will guide the Hub in the development and delivery of climate change knowledge products that draw on both the Hub's science and traditional knowledge. The workshop will be held in November 2018.
3.3	Climate change impacts on inshore aquatic ecosystems and coastal communities in the Torres Strait Islands: A Workshop	Torres Strait Islander stakeholders want to learn more about the interdependencies between climate change and impacts on inshore fisheries, coral reefs, seagrass beds, mangroves and indigenous coastal communities. The Hub is working in partnership with the Torres Strait Regional Authority (TSRA) and Australian Fisheries Management Authority (AFMA) to explore the impact of climate change on marine ecosystems, fisheries and livelihoods in the Torres Strait Island area. Such knowledge would be based on the latest (CMIP5) regional projections for sea-level rise, sea surface temperature and ocean acidification, amongst other variables.	Mandy Hopkins	CSIRO	5,000	5,000		5,000	**10,000**	1/01/2017	31/12/2018	Completed	Workshop report	http://nespclimate.com.au/wp-content/uploads/2016/03/ESCC-R004-TS-CC-fisheries-workshop-180601.pdf	Fisheries and marine ecosystems in the Torres Strait are economically and culturally important but are vulnerable to the changing climate. The Earth Systems and Climate Change Hub partnered with the Torres Strait Regional Authority to gather together climate change, marine and fisheries scientists, fisheries managers and traditional owners to discuss the implications of climate change on fisheries and marine ecosystems in the region. The information needs and research priorities identified at this workshop will form the basis of ongoing activities to ensure that traditional owners in the Torres Strait have the best available information and tools to help manage climate change impacts on their businesses, communities and country.
3.4	Coastal climate adaptation with City of Greater Geelong	The City of Greater Geelong have expressed a need for additional interpretation and guidance on the selection of extreme sea level and sea-level rise scenarios for use by their coastal managers when using the SWIFT hydrodynamic model. The SWIFT model offers a innovative solution to investigating and mitigating urban flooding under climate change. Data61 have previously engaged with the City of Greater Geelong to investigate future flooding hotspots under extreme events and sea level rise using SWIFT. In this case study the Hub will work with Data61 and the City of Greater Geelong to design appropriate guidance material for the usage of SWIFT.	Mandy Hopkins	CSIRO	5,000			0	**5,000**	1/01/2017	31/12/2018	Completed	Impact story	http://nespclimate.com.au/wp-content/uploads/2019/05/A4-2p-impact-CFAST-WEB.pdf	Improving and communicating coastal climate process information will provide coastal planners, developers and decision makers with the information they need to minimise risks now and into the future. This will result in an enhanced ability to respond to the unavoidable impacts of climate change. Previous engagement by the Hub with the Greater City of Geelong resulted in the identification of an area where the Hub could assist coastal managers and planners better assess the risks from extreme sea levels and sea level rise. The Hub will work with the City of Greater Geelong and Data61 to design and communicate guidance material around the selection of extreme sea level and sea-level rise scenarios for use by coastal managers using the SWIFT hydrodynamic model. This model provides next generation solutions to investigating and mitigating urban flooding under climate change. The case study will result in City of Greater Geelong coastal planners and managers being better able to use the SWIFT model to understand risks from sea level to their coast line and coastal infrastructure. This is an on-ground example of how the Hub is helping stakeholders to understand and manage climate risks.
3.5	Climate variability and change in Western Australia	The Western Australian Government is working to secure the water supply for Perth and the south-west of the state through a number of initiatives, including reducing water use, increasing water recycling and identifying new water sources (including desalination plants). The Government regularly engages with water users to support these initiatives and to educate and update their stakeholders about the outlook for water availability. Climate change information is an important component of these engagements. The Earth Systems and Climate Change Hub has prepared communication materials to help the Western Australian Government convey information about climate change to their users.	Michael Grose	CSIRO	5,000			0	**5,000**	1/01/2017	31/12/2017	Completed	WA Government Stakeholder Engagement and Research Planning/Outreach Workshop Workshop report from the 2017 meeting in Perth	N/A http://nespclimate.com.au/wp-content/uploads/2016/03/NESP-ESCC-Hub-SWWA-workshop-report-July-2018.pdf	With variable rainfall against the backdrop of an extended drying trend, managing climate risk to water security in south-west Western Australia is a critical climate challenge. The Hub prepared communication materials for the Western Australian Government to convey the latest climate change science, with a focus on rainfall in south-west Western Australia. An animated map of rainfall over south-west Western Australia was provided by the Hub which clearly showed that since 1900 cool season rainfall has decreased over the region, particularly since the 1950s, even though there is variability from year to year and decade to decade. Extending the animation into the future shows the drying will continue, with the extent depending on whether we follow a high or lower emissions scenario. These materials make the latest climate change science accessible to water suppliers and users in the region, so it can be used to inform and support decisions about water security.
3.6	Climate Change in Australia mobile website (a prototype)	Stakeholders and everyday Australians are use to accessing information on the go and in the' here and now'. The current suite of climate change projections provide a wealth of state of the art climate change projection information, including maps, tools and educational products. The development of a prototype of a mobile website for these climate change projections would mean that this information could be accessed at any time in any place, and would greatly extend the uptake and use of the climate change projections and research undertaken by the Hub.	Aurel Moise	Bureau of Meteorology	15,000			0	**15,000**	1/01/2017	31/12/2017	Completed	Development of a prototype mobile website/app	http://climate-data.it.csiro.au/webapp/index.shtml	The current suite of climate change projections produced under the Regional NRM Planning for Climate Change Fund resulted in a wealth of state of the art climate change projections information, data, maps, tools and educational products. The prevalent use of smart phones within Australia has resulted in an expectation that information be available 'now and here'. The development of a mobile website would allow quick and easy access to climate change projections on the go, in the field or just at a BBQ - without the need for a desktop computer or lap top. Building on the vast resources of the Climate Change in Australia website, this first of its kind climate change projections phone app would provide an accessible interface to the projections data and therefore potentially increase the dissemination and use of the information significantly. Hub researchers have developed a prototype of such a mobile website.

Project Number/ID	Project Name/Title	Project Summary	Project Leader	Lead Organisation	Approved Funding Research Plan Versions 1-6					Start Date	Completion Date	Status	Outputs		Outcomes
					NESP Funding* $	Other Cash Contributions* $	Other In-Kind Contributions* $	Total Other Contributions* $	Total Budget* $				Outputs	Link to output	
3.7	Climate Change for Councils (pilot)	Many climate change impacts will be experienced at regional and local levels, so councils may often be best placed to manage these risks. The ESCC Hub is well positioned, both as a producer and curator of the latest climate change science, to empower local councils with the confidence and understanding to use climate change science products to inform their decision making. The Hub will work with one or two regional Victorian councils to develop useful knowledge brokering and communication resources that package climate information for the councils in a way that is useful and accessible for their needs and audiences. These knowledge products will be drawn from across all the Hub's research portfolio.	Mandy Hopkins	CSIRO	7,228			0	**7,228**	1/01/2017	31/12/2017	Completed	Council Roadshow - meetings and discussions were had with 6 councils around how the Hub could engage with them and their climate change information needs	http://nespclimate.com.au/wp-content/uploads/2018/08/A4-2p-impact-LG-CC-info-needs-web.pdf	Many climate change impacts will be experienced at regional and local levels, so councils may often be best placed to manage these risks. Climate change has the potential to damage council assets, cause serious disruptions to the delivery of council services, generate unbudgeted financial impacts and affect the wellbeing of the community, particularly those vulnerable to weather extremes. It is therefore important that local and regional councils are provided with the information and guidance they need to prepare for the unavoidable impacts of climate change. The Hub will work with a small number of regional Victorian councils to develop useful knowledge brokering and communication resources that package climate information in a way that is useful and accessible for these councils. These knowledge products will be drawn from across the Hub research portfolio. The case study will build the capacity of local councils to identify, use and apply climate information, and will increase the use and uptake of Earth Systems and Climate Change Hub research.
3.8	Web delivery portal for coastal hazards information	The CSIRO and ACE CRC web page, http://www.cmar.csiro.au/sealevel/ has been the primary vehicle for communicating sea level science and delivering key data sets to the broader scientific community that were developed as part of the former *Australian Climate Change Science Programme.* This case study significantly upgraded the sea-level web page to a more secure and user-friendly platform and at the same time enhance its utility. This has been done by providing existing extreme sea level information requested by the broader community, providing additional information on coastal hazards, enhancing its user base and creating an effective platform for the delivery of new information that is planned through Project 2.10.	Kathleen McInnes	CSIRO	10,000			0	**10,000**	1/01/2017	31/12/2017	Completed	Web delivery portal for engaging with the coastal community	Sea Level, Waves & Coastal Extremes website	Prior to the development of the Sea Level, Waves & Coastal Extremes web delivery portal, limited information on sea level rise was provided in a less accessible and user friendly manner. The new web portal developed by the Earth System and Climate Change Hub consolidates information on a wider range of coastal hazards (such as sea level change, waves, coastal extremes and ocean energy) and improves access to this information and data. The new web portal presents information and data in an accessible, clear and well communicated manner appropriate for a range of users and stakeholders including the research community, governments, businesses, school students and the community. The web portal describes processes driving coastal impacts across a range of time and space scales, presenting the most up-to-date research in this area. The portal is an important tool for communicating and providing access to Hub research in this area, thereby increasing the uptake and use of this research across the community.
3.9	Practical and empowering responses to coastal erosion	Local Tiwi Islander people often struggle to relate the big scales of climate impacts science to the local, social and environmental processes that are important and relevant to them. Solutions to climate change impacts in the coastal zone require solutions focused science that co-produces knowledge and practices with relevant stakeholders to inspire and enable local communities to act on their values and goals for the future. Previous engagement with the Tiwi around climate change alarmed local residents and escalated feelings of powerlessness. This case study is worked to educate local communities about climate adaptation and provide practical guidance for what actions can be implemented to help address coastal erosion in the Islands.	David Kennedy and Jon Barnett	University of Melbourne	5,000			0	**5,000**	1/01/2017	31/12/2017	Completed	Tiwi Island workshop report	http://nespclimate.com.au/wp-content/uploads/2016/03/Workshop-report-Tiwi-Islands_Climate-Change-Adaptation-Report.pdf	Local Tiwi Island people often struggle to relate the big scales of climate impacts science to the local, social and environmental processes that are important and relevant to them. Previous engagement with the Tiwi around climate change alarmed local residents and escalated feelings of powerlessness. Solutions to climate change impacts in the coastal zone require solutions focussed science that co-produces knowledge and practices with relevant stakeholders to inspire and enable local communities to act on their values and goals for the future. Working with the Tiwi Land Council a workshop was held to educate local communities about climate adaptation. The outcome of the workshop was a report that provides a foundation for working with the Tiwi to develop practical guidelines for monitoring and adaptive management of coastal erosion in the Islands.
4.1	Test case for datasets and information for managing climate risk in the Australian banking and finance sector	There has recently been a new focus and awareness of climate risks for corporate Australia. The finance and banking industries in particular have begun to engage in this area and have expressed a pressing need to assess what climate change risk means for their business. However existing climate change projections information and data are not tailored to their specific needs. This case study tests the utility of climate change projections for the banking and finance sector to demonstrate how climate change projections information can be readily applied to decision-making in these sectors. The case study provides a starting point for a process of partnering and delivering information for this growing need. This case study demonstrates the path to impact of Hub research from Projects 2.6 (regional projections) and 2.8 (extremes projections).	Dr Michael Grose/ Dr Andrew Dowdy	Bureau of Meteorology and CSIRO	15,000		20,000	20,000	**35,000**	1/01/2018	31/12/2018	Completed	Case study report	http://nespclimate.com.au/wp-content/uploads/2019/07/ESCC-R010-case-study-4.1-report.pdf	The Australian economy is influenced by changes to the average climate (e.g., increases in the mean temperature and mean sea level) as well as by long-term climatological changes to extreme weather conditions which have the potential to cause more rapid economic impacts (e.g., as can be associated with phenomena such as bushfires, cyclones and floods). Managing these changes within the economy involves a range of financial risks and opportunities, including questions of liability and indemnity for the financial services sector as well as presenting opportunities to optimise investment and facilitate ongoing prosperity for stakeholders more broadly. To achieve this goal, there is a large and growing need for climate information for the financial services sector that is scientifically credible, salient and relevant, tailored for financial applications. This case study represents an initial effort to provide improved information for managing climate risk in the Australia finance sector. The outcomes of the case study include both an increase in engagement with the financial services sector and in the development of a report. The report provides details of key climate risks, intended for practical applications in the finance sector in relation to the influence of climate change on weather and ocean conditions. It is noted that significant changes have already occurred to a number of physical risks relevant to the finance sector, and that further changes will continue to occur in the future due to ongoing climate change.
4.2	Potential for carbon abatement by revegetation and conservation in Australia - Stakeholder engagement and status report	Revegetation and conservation in Australia may have great potential to contribute to achieving the mitigation targets of the Paris Agreement. Current estimates of this potential are limited to a few studies, none of which have been able to adequately address the opportunities and limitations of the biophysical and socio-economic worlds. This case study aimed to identify existing vegetation/carbon information and tools available to policy makers, and identify gaps and needs that will inform future research directions. The case study aimed to leverage primarily off activities and outputs (key data and information) being delivered through Project 2.9.	Dr Pep Canadell	CSIRO	10,000		10,000	10,000	**20,000**	1/01/2018	31/12/2018	Completed	N/A - case study closed. More information available at: http://nespclimate.com.au/understanding-information-needs-for-carbon-policy/		Previously Hub engagements with certain areas of the Department of the Environment and Energy (working on emission reduction policies in the land sector) had highlighted that gaps in policy and information needs exist in the Department around the role of revegetation and conservation in carbon abatement in Australia. Case study 4.2 therefore aimed to build a community of stakeholders and researchers in order to identify and improve the alignment between policy needs and research on the potential of revegetation and conservation for climate mitigation. However, it become clear during scoping engagements with DoEE that there are approved protocols and methodologies for land based mitigation strategies and measurements established at the federal level by which state governments, businesses and private landowners need to comply, and it would therefore be difficult in this already very formalized framework to gain a wide range of stakeholders interested in engaging. The case study was therefore closed, however scoping engagements with DoEE resulted in multiple benefits, including building relationships and trust between the Hub and DoEE and better understanding of DoEE information needs, which was used to shape research under the Hub's RPV5 project 5.6.

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					NESP Funding* $	Other Cash Contributions* $	Other In-Kind Contributions* $	Total Other Contributions* $	Total Budget* $				Outputs	Link to output	
4.3	Communicating projected changes in hydroclimate affecting water supply in South-West Western Australia (SWWA)	This case study develops useful communication products for the Western Australian water sector to facilitate the application of science to water management. In particular, the case study addresses two priority needs 1) demonstration of 'science to management' as an exemplar of the use of existing climate science to inform WA water resource planning and management, and 2) communication products for key stakeholders on climate variability, extremes and reliability of water supply in a changing climate.	Dr Dewi Kirono and Dr Francis Chiew	CSIRO	5,000		5,000	5,000	**10,000**	1/01/2018	31/12/2018	Completed	Case study report	http://nespclimate.com.au/wp-content/uploads/2019/05/A4-2p-impact-SWWA-WEB.pdf	The climate in south-west Western Australia (SWWA) has been drying since the 1960's, and this drying trend is expected to continue into the future. Long-term planning of water supplies for all water users and for the environment is therefore required to ensure the sustainability of water resources for SWA under a changing climate. During 2018 the Earth Systems and Climate Change Hub undertook a small case study with the Department of Water and Environmental Regulation (DWER) which, building on previous engagement activities, identified research to inform their water resource management and planning activities. It also led to the co-design of a research plan to ensure current and future research by the Hub is tailored to the needs of DWER, and that the resulting knowledge and information is easily incorporated into their water management tools and frameworks. The engagement activities under this case study updated DWER with the latest climate projection information, and provided the Hub with a valuable opportunity to better understand the approaches and tools used by DWER in their water resource planning activities. This has allowed Hub researchers to consider the type and format of hydroclimate data most appropriate for incorporation into these tools. Armed with a better understanding of the climate change information needs of DWER and how best to prepare the data for ease of use in water resource management tools, Hub researchers and DWER stakeholders co-designed a tailored and stakeholder driven research plan. Under this preliminary project plan, researchers will investigate the reliability of water supply to SWA farms dams and environmental flow under climate change in the Willyabrup Brook catchment. This will be conducted through modelling design and the provision and incorporation of climate change scenarios into DWER water management tools and frameworks, and will be undertaken within Hub projects 2.7 and 5.4 during 2019 and 2020.
4.4	Climate change impacts on threatened species and ecosystems – preliminary review and scoping	There is a growing body of work on the impact of climate change on threatened species and ecosystems/ecosystem services. However ecological analysis and weather and climate research are often not well connected. This case study demonstrates how the application of the Hub's research in improving understanding of climate feedbacks and key climate processes (including clouds) can be used to assess climate change impacts on threatened species and ecosystems. The Hub partnered with the World Heritage Australia, the NESP Threatened Species Recovery Hub and key agencies (i.e. Qld Herbarium) to bring together complementary skills and expertise in climate change, micro- and meso-scale meteorology, land surface feedback and ecology to address information gaps and needs in two specific areas of interest to key stakeholders: 1) climatic change, cloud caps and cloud forest ecosystems affecting threatened plant communities in the Lamington National Park World heritage Area of SE Qld, and 2) climatic change and the conditions impacting distribution and abundance and critical habitat for the Greater Glider in SE Australia. This case study raises awareness of the importance of factoring in climate change as a key environmental stressor for threatened species.	Dr Rob Colman and Rachel Morgain (TSR Hub)	Bureau of Meteorology and CSIRO	20,000		20,000	20,000	**40,000**	1/01/2018	30/10/2019	Completed	Gondwana rainforest section - fact sheet and workshop report	http://nespclimate.com.au/wp-content/uploads/2019/03/Gondwana-CC-workshop-report.pdf	The Gondwana Rainforests of Australia World Heritage Area is one of 19 listed World Heritage properties in Australia. The changing climate poses a threat to the unique habitats in the WHA and to the species that live there. Under this case study the Hub worked with the people responsible for managing the reserves to understand how climate change will impact the World Heritage Area. In October 2018, a workshop was convened in Brisbane at the University of Queensland to bring experts from key agencies together to discuss available climate change projections for the Gondwana Rainforests of Australia World Heritage Area (Gondwana Rainforests WHA) and identify specific data needs for ongoing climate change adaptation planning. The Hub provided advice and relevant climate projections for the region to inform adaptation options and planning, assess the impact of climate change on cloud cover in the region covered by the Border Ranges Rainforest Biodiversity Management Plan. This work will continue under RPV5 during 2019 and 2020 to ensure managers of this WHA have the climate information they need to assess current and future risks and plan accordingly.
4.5	Framework for determining the net socio-economic benefits of Earth systems and climate change science and services	The ESCC Hub supports a diverse portfolio of scientific research and service delivery to address stakeholder needs and to realise outcomes relevant to Australia's national interest. This case study developed a preliminary/ conceptual cost-benefit framework designed to measure the short to long-term value of the Hub's research outputs to the Australian economy and society more generally. It also demonstrates the practical application of this framework as part of a virtual analysis designed to quantify the net social and economic value of the investment into selected areas of ESCC Hub science of direct relevance to selected key stakeholders.	Dr David Newth	CSIRO on behalf of the ESCC Hub partners	65,000		65,000	65,000	**130,000**	1/01/2018	31/12/2018	Completed	Report: What are climate change science and services worth?	http://nespclimate.com.au/wp-content/uploads/2020/04/ESCC-Hub_CS4.5-summary-report.pdf	Quantifying the net social and economic value of investment in climate change science will highlight the importance of such research and it's benefit to our economy and stakeholders. This case study has developed a preliminary/conceptual cost-benefit framework designed to measure the short to long term value of climate change science outputs conducted under the Hub to the Australian economy and society in general. In showing the value of science, this analysis will help to inform future research planning an government planning, and will demonstrate the value of the Government's investment in climate change science.
4.6	Multi-disciplinary approach to understanding climate change impacts and exploring climate sensitive management solutions for the Great Barrier Reef	Carbon dioxide absorbed into the oceans is driving ocean acidification, which poses a threat to marine ecosystems, particularly reefs. Better regional data on the likely impacts of climate change on the Great Barrier Reef will be important for management and decision making and can be applied to the management of other Ramsar areas. This case study aimed to undertake a multi-disciplinary approach to build consensus amongst stakeholders on how we can move from near-term understanding of climate impacts, to exploring the projected climate future of the Great Barrier Reef under different emissions pathways. The case study aimed to determine the best and most accessible way to present and make this information available to stakeholders.	Dr Andrew Lenton and Dr Mark Baird	CSIRO	25,000		25,000	25,000	**50,000**	1/01/2018	30/06/2019	Completed	N/A	N/A	Climate change is a major threat to the long-term health of the Great Barrier Reef (GBR). However regional scale impacts are yet to be well quantified in the context of the global scale carbon cycle and associated atmospheric and oceanic climate drivers. This case study aimed to conduct a literature review of the existing information on this topic to synthesis current understanding and to potentially identify information gaps and needs for more informed, climate sensitive risk management by stakeholders in the process of improving the resilience and health of the GBR. This case study has been closed. It is superseded by the GBRMPA climate change position statement released in 2019: http://www.gbrmpa.gov.au/our-work/threats-to-the-reef/climate-change
TOTAL CASE STUDY/TARGET USER GROUP ACTIVITIES COSTS (RPV1-5)					**337,228**	**5,000**	**145,000**	**150,000**	**487,228**						

NESP Impact Stories
Earth Systems and Climate Change Hub

Impact story #1

Hub
Earth Systems and Climate Change

Title
Informing World Heritage Area climate change adaptation planning

Project numbers and project titles/or Hub activity
Case study 5.2: Using climate change information in a Gondwana Rainforests of Australia World Heritage Area climate change adaptation plan

Short version
The Gondwana Rainforests World Heritage Area (WHA) are biodiversity hotspots, home to many rare and threatened species. Climate change will add pressure to these already vulnerable species. The Earth Systems and Climate Change Hub worked with managers of the Gondwana Rainforests WHA to provide climate change projections to help with planning for the future. Projections of cloud base height were particularly important, given the upland forests receive up to half of their annual vegetation water requirements from cloud and fog, however, these projections were unavailable prior to this project. The new data are being used to model future changes in habitats for, and distribution of, key species in the forests.

Narrative
The Gondwana Rainforests of Australia World Heritage Area (WHA) extends across 40 reserves on Australia's east coast. The rainforests are biodiversity hotspots and are home to many rare and threatened plants and animals, and unique habitats. The high-elevation forests are one such habitat: they receive up to half of their annual vegetation water requirements from cloud and fog. However, there are gaps in the scientific understanding of the impact of climate change on cloud cover in the property.

As a result of collaboration with the Earth Systems and Climate Change Hub, the Gondwana Rainforests WHA now has climate change projection data for temperature, rainfall and lifting condensation level (a proxy for cloud base height) for 2030 (2020–2039), 2050 (2040–2059) and 2070 (2060–2079) under high (RCP8.5) and lower (RCP4.5) emissions scenarios. The data are being used by ecologists to help understand possible future changes in distributions of key species in these forests, including the black-tailed antechinus (*Antechinus arktos*) and Antarctic beech (*Nothofagus moorei*).

The collaboration grew out of an initial meeting convened by the Gondwana Rainforests Technical and Scientific Advisory Committee to discuss available climate change projections for the Gondwana Rainforests WHA and identify specific data needs for ongoing climate change adaptation planning. Representatives from the ESCC Hub, Gondwana WHA, Queensland Herbarium and University of Queensland attended.

Discussions at the workshop made it clear that managers want information about how cloud base height and moisture transport associated with horizontal rainfall will change

in the future, as this is crucial to the diversity of flora and fauna in the upland rainforests. The Hub was able to identify existing rainfall and temperature climate projections data that could be used to explore climate change impacts on the upland forests, as well as derive projections for lifting condensation level.

Delivery of these data in application-ready datasets allowed for the refinement of species and community level modelling to account for cloud water inputs. This in turn has allowed ecologists to develop predictions of future habitat and conservation requirements under a changing climate. Using this information, managers have been able to understand possible impacts on the property's Outstanding Universal Value, and factor in appropriate management responses. This will lead to adaptation activities that will improve the resilience of this World Heritage property and ensure it is prepared for the changes to come.

This project demonstrated how climate change projections can be incorporated into risk assessments, strategic and adaptation planning of World Heritage and other protected areas to inform applied management strategies. For example, the climate change information provided to ecologists working in the Tweed Caldera area of the property has allowed them to use lifting condensation level data in their spatial models. They have not had the required data to do this before and are now able to better understand the moisture changes in their area. This will help them better understand possible future changes in the climate which may impact on the distribution of key species in the property. This will assist them in making better informed priority management decisions and leading to more sustainable outcomes for specific key species, as well as the ecosystem as a whole.

This project was successful because of the close collaboration between the Hub's climate scientists and the WHA's ecologist. By co-designing the research, the outputs were readily accessible and applicable to the population modelling that was necessary to inform ongoing property management and adaptation planning. The experience of the Gondwana Rainforests WHA shows how climate change information can be incorporated into WHA management planning and can be readily applied to any WHA property.

> "Collaboration with the Earth Systems and Climate Change Hub has greatly improved our understanding of how high elevation rainforest species and ecosystems within the Gondwana Rainforests of Australia World Heritage Area may be impacted by a changing climate. Novel spatial products developed as a result of the Gondwana Rainforest Case Study confirm predictions that cloud base height (lifting condensation level/LCL) is likely to rise as a result of climate change, leading to increased moisture stress at high elevation. Incorporation of LCL into habitat modelling will, for the first time, allow species threatened by a rising cloud base to be identified and prioritised for adaptation planning."
> *Dr Melinda Laidlaw, Senior Ecologist, Queensland Herbarium*

Image: Cloud and fog provides up to half of the annual water requirements of the high-elevation forest in the Gondwana Rainforest World Heritage Area

Research outputs

Final products are not yet available. On completion, case study outputs will be provided on the Hub's website at: http://nespclimate.com.au/informing-world-heritage-area-climate-change-adaptation-planning/.

Attributions

The project was led by ESCC Hub Knowledge Broker Mandy Hopkins, with science provided by Dr Rob Colman and Dr Sugata Narsey (both Bureau of Meteorology). They worked closely with ecologist Dr Melinda Laidlaw (Queensland Herbarium). Tricia Waters (Gondwana Rainforests WHA Executive Officer) was also involved in the project.

Impact story #2

Hub
Earth Systems and Climate Change

Title
Understanding climate change impacts on mango production in the Northern Territory

Project numbers and project titles/or Hub activity
Case study 5.1: Understanding the impact of climate change on the Northern Territory mango industry

Short version
Mango flowering is sensitive to minimum and maximum temperature thresholds at particular times in the growing season. The Earth Systems and Climate Change Hub worked with the Northern Territory Department of Primary Industry and Resources and Australian Mango Industry Association to determine changes to the occurrence of these thresholds in Northern Territory growing regions, and how these changes would impact on commercial mango cultivars and those in development. The results of this assessment will help both individual producers and the mango industry ensure sustainable mango production into the future by providing climate change information to inform current and future decisions around viable mango varieties and growing regions, and by outlining future risks and questions around adaptation and management practises.

Narrative
Mangoes are the Northern Territory's largest horticultural product, and the Territory is Australia's largest grower of mangoes. In 2017/18, the Northern Territory produced almost half of the national mango crop, worth around A$90 million.

In the Northern Territory, mango flowering is promoted by low night-time (minimum) temperatures and can be inhibited by high daytime (maximum) temperatures. Changes in absolute maximum and minimum temperatures and the frequency of these events will affect flowering and fruit production in northern Australian mango production regions.

Image: Mango flowering and fruit production in northern Australia are sensitive to absolute maximum and minimum temperatures and the frequency of these events.

The Hub collaborated with the Northern Territory Department of Primary Industry and Resources (NT DPIR) to develop a better understanding of how and when these important temperature thresholds may change. With this information, individual producers and the industry as a whole can plan ahead to ensure the ongoing sustainability of mango production in the Territory.

This work was developed in response to an enquiry to CSIRO from NT DPIR for information about temperature thresholds in the Northern Territory. While the data existed as part of the national climate projections, it was not readily available through the Climate Change in Australia website. To determine the requirements of the NT DPIR, the Hub convened an expert workshop attended by NT DPIR horticulture and extension experts, Northern Territory mango producers, representatives from NT Farmers, and climate and knowledge brokering specialists from the ESCC Hub.

Discussions at this workshop identified that the NT DPIR horticulture team needed projections for the number of days under minimum threshold temperatures and over maximum threshold temperatures for two emissions scenarios (RCP4.5 and RCP8.5) for four 20-year time periods centered on 2030 (relevant to the current planting), 2050 (relevant for the next planting), 2070 and 2090 (both relevant to breeding programs).

Projections were provided for 13 growing regions. These data were combined with biophysical data for six mango cultivars to determine which would be most suitable in the different growing regions into the future.

The project has been supported by an ongoing communication and engagement campaign to inform growers about the project. An important component has been workshops and materials to increase the climate literacy of growers, to enhance the uptake of the project results when they are available.

As a result of this project, Northern Territory mango growers will have access to information that will help them ensure the ongoing sustainability of their businesses. Decisions about which varieties to plant and maintain, investment in equipment and trees, and which production practices may have to change can all benefit from this information. This project has also highlighted issues of interest to the industry as a whole, such as availability of popular varieties, possible timing and geographic shifts in production, the need to support growers with adaptation advice and options.

This project demonstrates the utility of climate change information for primary production systems and has the potential to encourage producers of other commodities to seek similar information to ensure the resilience of their enterprises and industries.

Research outputs

Current workshop and case study reports and factsheets can be found on the ESCC Hub website on: http://nespclimate.com.au/climate-change-impacts-in-the-northern-territory-mango-industry/. While final products are not available yet, once the case study is completed all outputs will be provided on the webpage listed above.

ECOS article featuring this case study (published April 2020): https://ecos.csiro.au/climate-change-nt-mangoes/

Attributions

The project was led by ESCC Hub Knowledge Broker Mandy Hopkins, with science provided by Dr Vanessa Hernaman (CSIRO) and communication and engagement support from Karen Pearce (Bloom Communication). They worked closely with horticulturalists Maddison Clonan and Dr Cameron McConchie (NT DPIR). Sarah Hain (Australian Mango Industry Association) represented industry on the project team.

Impact story #3
Hub Earth Systems and Climate Change
Title Supporting First Nations people to understand climate change impacts and risks to country and communities
Project numbers and project titles/or Hub activity Case study 3.2: Meeting Indigenous priorities for climate change information, capacity building and engagement Indigenous engagement activity 6.1: Second national Indigenous gathering on climate change – pathway to sustainable relationships Indigenous engagement activity 6.2: Supporting Indigenous participation at the AMOS 2020 conference
Short version Australia's First Nations people are already feeling the impacts of the changing climate. The Earth Systems and Climate Change Hub's work with Indigenous stakeholders over the past four years resulted in the first national Indigenous engagement with climate change science. This in turn has provided many opportunities for our Indigenous collaborators to engage with each other and with western science, not only to share information but also to drive an Indigenous-led agenda on climate change knowledge and action.
Narrative First Nations people have a relationship with country that extends back for millennia and is integral to cultural and community wellbeing. The changing climate is impacting on country in a way that is beyond the experience of the Traditional Owners. To maintain the health of country and communities, First Nations people need access to climate change information as well as traditional knowledge; however, opportunities to participate in national conversations about climate change and share information have been limited. The Earth Systems and Climate Change Hub is providing opportunities for First Nations people to engage with each other and with western science, not only to share information but also to drive an Indigenous-led agenda on climate change knowledge and action. For the past four years, the Hub has been actively building relationships with Indigenous stakeholders to facilitate a two-way exchange of information. This resulted in the first ever national engagement on climate change science at the National Indigenous Dialogue on Climate Change in 2018, where Traditional Owners from across the country had the opportunity to discuss climate change with each other and to engage with the Hub's climate change researchers.

Image: Barmah Forest National Park, Victoria. Yorta Yorta country.

This experience and engagement opened up other opportunities for First Nations people to engage with climate change science in a broader forum. In 2019, the Australian Meteorological and Oceanographic Society (AMOS) devoted time in the main program of their annual conference for Traditional Owners to speak about climate change on country. This session, facilitated by the Hub, was the first time an Indigenous knowledge featured on the AMOS conference program to this extent, and it paved the way for an extended session at the 2020 event. At the Hub's roadshow for Canberra policy makers in 2019, Indigenous collaborators had the opportunity to participate in a panel session highlighting the issues climate change is causing on country.

The Hub's work with Indigenous communities featured in Australia's report for the (7th) UNFCCC National Communication on Climate Change by the government, where it was the only example of national-level engagement with Indigenous communities on climate change science. This report prompted interest and follow-up questions from Canada. The Hub's Indigenous engagement has raised awareness in government and prompted World Heritage Areas to include Indigenous cultural heritage in assessments of cultural heritage.

Australia's First Nations people are already feeling the impacts of the changing climate. The physical impacts make some areas difficult to live in, with extreme heat and prolonged heat causing health and other problems. Moving from country is problematic due to social and cultural ties. Understanding the changes to come is essential for communities to prepare for these changes and those still to come, so ongoing engagement with climate change science is critical. The Hub continues to work with its Indigenous collaborators and facilitate opportunities for access to essential information.

Research outputs

Indigenous engagement activity 6.1 workshop report - National Indigenous Dialogue on Climate Change: http://nespclimate.com.au/wp-content/uploads/2019/05/191209-NICCD-report-final.pdf

Indigenous engagement activity 6.2 workshop report: http://nespclimate.com.au/wp-content/uploads/2020/03/A4-2p-AMOS-TO-workshop-summary.pdf

Attributions

The Hub's Indigenous engagement is led by ESCC Hub Knowledge Broker and Indigenous Engagement Coordinator, Mandy Hopkins.

Impact story #4

Hub
Earth Systems and Climate Change

Title
Building the capacity of key stakeholders to understand and apply climate change information for policy and decision-making

Project numbers and project titles/or Hub activity
Case study 5.4: Climate change 101 toolkit: an introduction to climate change and understanding climate change information

Short version
Science-based climate change data and information provides a solid basis for developing 'climate-smart' policies and decisions. However, without a fundamental understanding of climate change and how climate change science can be used, the benefits of using this information are not realised. The Earth Systems and Climate Change Hub developed a climate literacy workshop to increase understanding of and ability to use climate change science that is applicable across sectors and stakeholders. Participants of pilot workshops provided to date have noted their increased confidence in understanding and applying climate change information in their decision-making activities. Further workshops will be provided in 2020 to a range of stakeholders, including the electricity sector and Indigenous Communities.

Narrative
While we now have more science-based climate change information available than ever before, there is still a lot of stakeholder uncertainty about how the climate system works, how the climate is changing and what climate change projections actually tell us. Further, there is limited understanding about how to use this information to inform policy and decisions.

The Earth Systems and Climate Change Hub has developed a climate change literacy workshop that seeks to address this. The workshop provides participants with an introduction to understanding the climate system and climate change science and understanding climate change modelling and projections. It then goes on to provide advice on choosing and using climate change information before stepping through a Hub-developed process to use climate change information to understand climate change impacts. This 'climate change health check' is a simple, five-step guide to quickly identifying climate change impacts. The health check may be all that is required for some purposes (e.g. awareness raising) but also provides a starting point for more detailed impact, risk and vulnerability assessments.

A pilot workshop was delivered to Northern Territory mango growers and industry representatives in May 2019, followed by five workshops for Victorian Department of Environment, Water, Land and Planning stakeholders in November and December 2019. Content from the workshop was also delivered to Department of the Environment and Energy staff and to participants at the World Heritage Area forum in Canberra in September 2019.

> *The workshop demystified a lot of things and I feel more confident when talking about projections – Participant, DELWP Melbourne workshop, 3/12/19*

The best thing about the workshop was making sense of the information available and how this can practically be applied in our decision-making – Participant, DELWP Melbourne workshop, 3/12/19

Feedback from the pilot workshops has been extremely positive and has helped shape the content and format of the workshop and climate change health check process. The ESCC Hub is now developing a final guideline and training package that can be easily delivered to audiences across sectors. The package will provide participants with a better understanding of the climate system, an appreciation of climate change science, and the confidence to find and use climate change information to inform decisions. This will facilitate the incorporation of relevant and credible climate change science and information in risk assessments and adaptation plans and encourage stakeholders to routinely factor climate change projections and associated scenarios into long-term strategic business planning.

Image: Hub researcher Vanessa Round explains climate modelling at a Hub climate literacy workshop

Research outputs

Final products are not yet available. At the end of the case study all products will be available from the ESCC Hub website.

Attributions

The workshop was developed by ESCC Hub Knowledge Broker Mandy Hopkins and communication and engagement specialist Karen Pearce (Bloom Communication).

Impact story #5

Hub
Earth Systems and Climate Change

Title
Working with industry to develop standards for measuring and reporting physical climate risks

Project numbers and project title/or Hub activity
Case study 5.6: Climate Measurement Standards Initiative (CMSI)

Short version
While recognition of corporate climate-related financial risks continues to increase, there are no agreed standards in place in Australia for measuring and reporting physical climate change risks in the financial services sector. The Earth Systems and Climate Change Hub is providing climate change science expertise to the Climate Measurement Standards Initiative, which aims to address this by developing best-available, open-source, science-based standards for physical climate-related financial risk disclosure. The standards will allow for better reporting of physical risks, providing better risk information – and so, better decisions – for investors.

Narrative
As the potential economic impacts of climate change become more apparent, corporates around the world are increasingly being asked to identify and report on physical climate-related risks to regulators and investors. The application of standardised, scientifically robust scenario analysis has been recommended as a key component of climate-related financial risk disclosures for use by companies in providing information to investors, lenders, insurers and other financial sector stakeholders. However, there remain challenges in mapping the outcomes from climate modelling into economic modelling then using that information for decision-making.

In Australia, the financial services sector is seeking to address these challenges through the Climate Measurement Standards Initiative (CMSI). This initiative aims to develop 'best-available', open-source, science-based standards for physical climate-related financial risk disclosure under the recommendations of the Financial Stability Board's Taskforce on climate-related financial disclosure (TCFD). The standards will inform risk and reporting as part of a strategic endeavour to build climate resilience more broadly within the Australian economy.

The standards will be used by companies with financial interests in physical assets, including residential and commercial buildings or other infrastructure in Australia. These companies will include banks (who use those assets to provide security), insurers (who provide insurance on those assets), and asset owners (who derive income from those assets).

The Earth Systems and Climate Change Hub is a partner in this industry-led initiative and has direct responsibility for contributing to strategic planning, governance and service delivery, including primary responsibility for implementing the science committee. This committee will provide guidelines on approaches, methods, assumptions and data for estimating future costs that are disclosed and will consider what are the appropriate climate scenarios to use.

The CMSI will provide the financial services sector with tools and advice for using science-based climate change information to develop disclosures on physical risk.

Application of the standards will reduce the risk of any individual company adopting an approach to climate-related financial disclosure that unintentionally differs widely from others in the industry. It will also increase confidence in disclosures by users including market analysts and regulators, as the standards will be supported by independent, peer-reviewed and internationally benchmarked scientific advice from Australia's leading climate experts.

In addition, through bringing together leading industry, scientific and financial experts, the CMSI will raise the collective capability for Australia to address climate change by enabling companies to make informed, scientifically robust, decisions.

Ultimately, better reporting of physical climate-related risks will give investors better information about the risks to their investment, allowing them to make better-informed decisions about where to invest their money.

Research outputs

Products are not yet available. At the end of the case study, final products will be provided on the ESCC Hub website at: http://nespclimate.com.au/designing-climate-change-risk-information-standards-for-the-financial-services-sector/.

Attributions

- CMSI/ESCC Hub industry focal point: Sharanjit Paddam, QBE Insurance Group
- ESCC Hub Program Manager: Geoff Gooley (CMSI Secretariat/Steering Committee)
- ESCC Hub technical advisor: Nick Wood (CMSI Secretariat)
- ESCC Hub science leads (CMSI Science Committee):
  - Kevin Hennessy (Chair)
  - Andrew Dowdy (Bureau of Meteorology)
  - Michael Grose (CSIRO)
  - Jason Evans (UNSW)

Impact story #6

Hub
Earth Systems and Climate Change

Title
Understanding Tasmania's climate information needs for multi-year to decadal climate forecasts

Project numbers and project title/or Hub activity
Case study 5.3: TasLab Engage

Project 2.3: Towards an ACCESS decadal prediction system

Short version
While long term climate change projections (i.e. for 2050, 2070, 2090) provide valuable information to inform strategic planning and management of climate risks, many Australian sectors are making decisions at multi-year to decadal timescales. Climate information and forecasts at these timescales would therefore benefit many Australian sectors and industries, including agriculture, horticulture and water management. However this is still an emerging area of global and Australian science capability. Working with CSIRO's Decadal Climate Forecasting Project, the Earth Systems and Climate Change Hub has collected valuable stakeholder information that will contribute to the development of multi-year to decadal forecasts for Australia. Climate information on these timescales will assist many industries with long-term operational planning, allowing for better risk identification and decision making.

Narrative
Climate conditions influence the operations and subsequent profitability of many Australian industries. Advance knowledge of the climate, on timescales relevant to operational decisions, may assist in planning and management activities for these industries, potentially providing the ability to identify periods of increased profitability or risk.

Daily to ~10-day weather forecasts, monthly to seasonal climate forecasts and climate change projections (~100 years into the future) are currently available to users. Bridging the gap between seasonal forecasts and climate change projections are forecasts on the yearly, multi-year and decadal timescales. Many Australian sectors and industries – including agriculture, horticulture, aquaculture and water resources management – would potentially benefit from forecasts at these timescales to inform adaptation, management and operational activities. Forecasting on these timescales is an emerging area of global research. The CSIRO's Decadal Climate Forecasting Project (DCFP) is building Australia's capability in this area.

The Earth Systems and Climate Change Hub, in collaboration with the DCFP, engaged industry stakeholders in Tasmania to determine the types of operational decisions they make on the multi-year to decadal timescale and therefore the scope for using forecasts on these timescales in their industries. Tasmanian-based stakeholders were engaged because of the broad range of industries based in the region and the highly variable climate across the State.

They found that some historical climate information and anecdotes related to past extreme events/years currently guide many practices and decisions. The activity found that all of the interviewed stakeholders have a set of decisions they make, or

have the potential to make, on yearly to multi-year timescales, indicating the potential utility of multi-year forecasts for these industries. This activity also determined that industries are more likely to use multi-year to decadal climate forecasts if the information is provided in a format they are familiar with, and if they are confident they can trust the forecasts.

The activity also sought to shine a light on which climate variables would be most useful to stakeholders. These varied from sector to sector and included sea ice extent and thickness for the Australian Antarctic Division's shipping operations; extreme rainfall events for flooding and therefore emergency response for the Tasmanian State Emergency Service; changes in maximum temperatures for crop growth and grape sweetening for the wine industry; and extreme wet and dry periods due to their influence on water storage levels in water catchments managed by Hydro Tasmania.

Image: The wine industry is impacted by changes in maximum temperatures, which affect crop growth and grape sweetening.

This activity not only collected critical information to inform the development of both useful and useable decadal climate forecasts in Australia, but also raised awareness among the stakeholders of the potential utility of this information. Stakeholders who are better able to utilise this information will be better placed to consider climate in their mid to longer term business operations and risk assessment planning tools. This may ultimately lead to Australian industries which are better prepared to manage the risks and impacts of a variable and changing climate.

Research outputs

Tas Lab Engage final case study report, available from the ESCC Hub website at: http://nespclimate.com.au/understanding-tasmanias-climate-sensitivities-and-information-needs/.

Attributions

TasLab Engage Project team:

- Carly Tozer (Project lead) and James Rigby, CSIRO DCFP
- Sonia Bluhm (ESCC Hub Knowledge Broker)
- Tom Remenyi (University of Tasmania)

Industry bodies interviewed – Australian Antarctic Division, Tasmanian State Emergency Service (Flood Policy Unit), Tasmanian Institute of Agriculture (wine industry) and Hydro Tasmania.