National Environmental Science Program
Earth Systems and Climate Change Hub

ANNUAL PROGRESS REPORT 4
1 January 2018 – 31 December 2018

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

Host organisation: CSIRO

Key Contact: Professor David Karoly

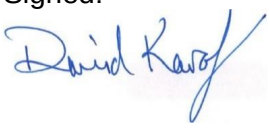
Other consortium partners/subcontractors/research organisations: Bureau of Meteorology, University of Tasmania, University of New South Wales, University of Melbourne, Monash University and the Australian National University

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: 10 May 2019

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: 13 May 2019

Contents

Letter from the Hub Leader

It is my pleasure, at the end of my first year as Leader of the Earth Systems and Climate Change (ESCC) Hub, to report that the Hub has had another very successful year. Some of our many new developments in research, stakeholder and Indigenous engagement and communication are summarised in this Annual Report for 2018.

The objectives of the Hub are to:

- lead further development of the nation's modelling capability and capacity for weather and climate prediction and projections
- achieve greater understanding of Australia's climate variability and change, extremes and associated drivers
- develop and strengthen stakeholder relationships and support informed management and evidence-based decision-making
- facilitate outreach and communication of science products and services to end-users and the general public.

Key successes

The Hub has expanded its engagement and communication of climate change science information with new sectors in 2018, including:

- World Heritage Areas, such as Shark Bay (WA) and Gondwana Rainforests (Qld, NSW)
- the electricity sector, through assisting with the establishment of the Electricity Sector Climate Initiative
- the financial services sector, by working to enable them to better account for exposure to physical climate risks in response to the Task Force on Climate-related Financial Disclosures, and
- Botanical Gardens, by assisting with the formation of the international Botanic Gardens Climate Change Alliance, initially led by the Royal Botanical Gardens Victoria.

There was also a rapid growth in the Hub's subscription list in 2018, almost doubling the numbers of stakeholders who have sought to engage with the Hub. This has helped to raise awareness of the Hub, and also represents a broadening of our stakeholder base with a strong increase in engagement from across a variety of decision-makers, coastal and resource managers and consultants.

The federal Department of the Environment and Energy is one of our key partners and we have substantially increased our engagement with them. Examples include Hub presentations on the Global Carbon Project, on the IPCC Special Report *Global Warming of 1.5 ºC*, and on attribution of climate extremes; research collaboration in World Heritage Areas; and provision of feedback on the draft National Climate Science Strategy.

Indigenous engagement has again been important for the Hub in 2018. Our key activity was the National Indigenous Climate Change Dialogue, held in November on Yorta Yorta country in the Barmah State Forest in Victoria. The organisation of this workshop was led by the Kimberley Land Council, the Yorta Yorta Nation Aboriginal Corporation and Seed, with support from the Hub. The Dialogue was a landmark activity, bringing together more than fifty Traditional Owners from across Australia to discuss recommendations from Indigenous Australians regarding climate change information, their capacity building needs and what form of engagement would be of greatest value to Indigenous communities. Feedback from Indigenous and non-Indigenous participants alike was very positive, with many noting the importance of bringing together traditional and western knowledge on climate change as well as providing a forum for Indigenous communities (who may not usually meet) to discuss shared climate challenges and management practises.

At the initiative of the Hub's researchers, a focused Science Symposium was added to the Hub's Annual Workshop in June. This was a great success, providing an opportunity for our researchers to discuss their different projects through the lens of the national climate change challenges. The Annual Workshop in 2018 was used to discuss research and engagement objectives in preparation

for our new Research Plan Version 5 (RPV5). The approval of our RPV5 at the end of 2018 demonstrated the value of these discussions.

The Hub continued to provide on-going support for PhD students and early career researchers, particularly through a special early career research session prior to the Science Symposium, and through the Young Professionals events that are run jointly with key stakeholders.

The Hub led the organisation of cross-Hub engagement activities at two major stakeholder conferences in 2018, first with the Northern Australia Environmental Resources Hub and the Threatened Species Recovery Hub at the Developing Northern Australia conference in Alice Springs, and then with the Clean Air and Urban Landscapes Hub and the Threatened Species Recovery Hub at the Liveable Cities conference in Melbourne.

There have been many great new research outputs from the Hub in 2018, including new research publications being cited in international climate assessments. Hub researchers continued to play a leadership role in the Global Carbon Project, assessing the latest greenhouse gas emissions across the globe that show a return to global increases in carbon dioxide emissions in 2018. New user-focused research brochures have been prepared on observed trends and future projections first on Northern Australian rainfall and then on Southern Australian rainfall. Research studies on the impacts of climate change on El Niño-Southern Oscillation and its associated rainfall variations in Australia, and on marine heatwaves in Australia and globally have been published in leading international journals.

The biennial 2018 State of the Climate report from the Bureau of Meteorology and CSIRO was released late last year. It draws on the latest monitoring, science and projection information to describe variability and changes in Australia's climate. Hub researchers from six different projects provided significant contributions to the report, which shows ongoing, long-term climate change interacting with underlying natural variability. Hub researcher Dr Michael Grose was one of the two authors of the 2018 report. The State of the Climate report received extensive coverage in print and on radio, including in The Conversation, Sydney Morning Herald, Fairfax media and the ABC News.

2018 saw significant international recognition of the Hub's researchers through their involvement in reports by the Intergovernmental Panel on Climate Change (IPCC). Two Hub researchers, Professor Nathan Bindoff and Dr Kathy McInnes, are Lead Authors in the IPCC *Special Report on the Ocean and Cryosphere in a Changing Climate,* while Professor Jason Evans is a Lead Author in the Special Report *Climate Change and Land*. Both reports will be released later in 2019. In addition, seven Hub researchers have been selected as Lead Authors, Contributing Authors or Review Editors in the IPCC *Sixth Assessment Report*, to be completed in 2021; Dr Pep Canadell, Dr Francis Chiew, Dr Robert Coleman, Dr Pandora Hope, Dr Michael Grose, Professor David Karoly and Dr Simon Marsland.

Looking forward – major 2019 activities

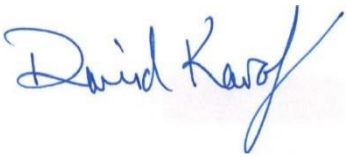
The first three-year phase of the Hub's research projects will close in the middle of 2019, with an evaluation of the research outputs and user outcomes arising from the research. This will be followed in the middle of 2019 by the transition to our new research projects in RPV5, which has a greater emphasis on pathways for research impact among selected users from our Target User Groups.

New case studies with new stakeholders are already starting as part of RPV5. These include evaluation of current and future climate change impacts on growing mangoes in Northern Australia, the value of improved training for state governments and local councils for enhanced understanding of climate change science information, and the TasLab Engage project that will test the value of improved climate change science information for selected stakeholders in Tasmania. Insights gained from the National Indigenous Climate Change Dialogue in 2018 will also be used to build a new level of two-way engagement with identified Indigenous communities.

After three years of development, testing and evaluation, simulations with the new version of the Australian community coupled climate model, ACCESS-CM2, will be run in 2019 and submitted to

the international Coupled Model Intercomparison Project phase (CMIP) 6. The CMIP6 data will be evaluated by many researchers around the world, including Hub researchers, and will feed into the IPCC *Sixth Assessment Report*.

2018 was a very busy and successful year for the Earth Systems and Climate Change Hub. 2019 marks a new stage in the Hub's activities, transitioning to new projects in RPV5 with greater emphasis on research impacts and stronger engagement with targeted research users.



Professor David Karoly

Research

Progress towards outcomes

The Hub's activity outcomes, as reported in the Funding Agreement with the Department of the Environment and Energy 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.

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 2018 towards these outcomes is provided below:

Building national capacity to understand and predict climate variability and extremes

- Significantly enhanced scientific knowledge of climate change, climate variability and climate extremes as shown through the publication of 50 peer-reviewed journal articles, with 10 published in high impact journals. These papers were often developed and delivered in collaboration with other key climate research organisations (i.e. the Centre of Excellence for Climate Extremes (CLEX) and international groups and programs (i.e. the Global Carbon Project (GCP) and the World Climate Research Program (WCRP)).
- Contributed towards national and international research initiatives, programs and global climate assessments, such as the Northern Australia Climate Program, the World Meteorological Organisation global statement and IPCC reports.
- Advanced research into extreme event attribution methodologies to better understand the contribution of climate change to past, current and future extreme events, including initial efforts to provide attribution statements of forecasted near-future events.
- Conducted research into the causes and drivers of changes in ocean heat (particularly in the Southern Ocean) and how this may impact the climate system. Continued contributions were also made to the Argo program to ensure high quality Australian ocean data is included in this important international ocean observing system.
- Increased knowledge on lightning-ignited bushfires, tropical cyclones, east coast lows and other extreme weather which have large social and economic impacts in Australia.
- Undertook initial investigations and developments of a capability to predict decadal scale changes in our climate. This will result in the provision of climate information at timescales most relevant to sectors such as agriculture and horticulture.

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

- Continued development and significant improvement of our national climate model ACCESS to ensure important climate processes in the Australian region are well represented, such as land surface-atmosphere interactions and rainfall and weather extremes.
- Preparation of ACCESS coupled model simulations for inclusion in CMIP6. Involvement in CMIP6 ensures ACCESS simulation data are accessible by the broader international community and can be used to inform global climate assessments, such as the IPCC assessment reports, which inform decision-making and climate policies.
- Continued research into the drivers of Australia's climate system both in the past and how they may change in the future under a warmer climate, including how well climate models represent these drivers. This includes world-class research into the impact of ENSO on rainfall; changes in the frequency of extreme positive Indian Ocean Dipole under future warming; enhanced understanding of climate feedbacks and sensitivity to improve modelling and projections;

investigating the impact of climate change on Australian marine heatwaves; and a better understanding of the drivers and trends of east coast lows.

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

- On-going delivery of climate change projection data and information to a variety of stakeholders through the *Climate Change in Australia* (CCiA) website. The website receives over 2,500 unique visitors per week and an average of 5 data requests per month in 27 application areas. Multiple training courses and webinars on the climate projections and CCiA website were delivered throughout 2018.
- Improved modelling and projections of terrestrial carbon sources, sinks and changes, including contributing to the development of the 2018 Global Carbon Budget to better understand and track greenhouse gas emissions in Australia and globally.
- Comprehensive reviews were published which highlight the importance of the Southern Ocean and Antarctica on future global and Australian climate and sea levels, dependent on future global emission scenarios.
- Provision of coastal hazards information, including projections, to local councils to assist in coastal adaptation planning and identifying sea level benchmarks for planning decisions.
- Increased understanding of the drivers of ocean surface waves, which can exacerbate storm surge and coincident event impacts on our coastal ecosystems, infrastructure and communities.
- Developed and trialled on-ground coastal defence systems to protect vulnerable coastal ecosystems and to inform local coastal protection plans.

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

- Participation by Hub researchers in over 100 scientific engagement events, including conference presentations, stakeholder meetings and presentations, webinars and seminars.
- Participation at the Hub level (Hub Leader, knowledge brokers, research project leads) in over 50 stakeholder engagement activities, including end-user meetings and events to raise awareness of the utility of Hub research; Hub events at national conferences; Young Professional events; and talks, presentations and panel discussions with sector organisations such as Energy Australia, the Carbon Market Institute and the Reserve Bank of Australia.
- Development of communication products to disseminate Hub research in a relevant and accessible way to stakeholders and the general public, such as brochures, flyers, posters, webinars, reports, newsletters, weblogs and social media posts.
- Undertook a number of stakeholder engagement case studies and activities, in which Hub climate change information was used to inform target stakeholder activities and increase awareness of the utility of climate change science. Activities included (but are not limited to):
    - Engagement with the financial services sector to better understand their climate science data and information needs for physical climate risk and disclosure activities
    - Worked with the Department of the Environment and Energy to understand knowledge gaps around carbon abatement in the land sector and co-develop future Hub research
    - Engagement activities with the WA Department of Water and Environmental Regulation to ensure updated climate change projections are incorporated into their water management tools so that climate change is considered in their water resource management activities
    - Worked with World Heritage Committees and stakeholders to understand the impact of climate change on Shark Bay and Gondwana Rainforest cloud cover to inform future adaptation and management plans for these areas
    - Provided fire weather data, information and advice to rural fire services and the Australasian Fire and Emergency Service Authorities Council (AFAC) to inform emergency response and recovery strategies and policies
    - Engaged with Indigenous stakeholders and communities through the 2018 National Indigenous Climate Change Dialogue to bring Traditional Owners and climate scientists together to discuss Indigenous information needs, share land management practises and determine an agreed on-going engagement approach.

Research projects

Attachment A lists the projects funded under the Earth Systems and Climate Change Hub, as well as the knowledge brokering and communication activities and case studies during the 2018 reporting period. It provides information on the project status and 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 the reporting period, and to date, have been met as per Funding Agreement Milestones 1-21.

Milestones 1-17 were reported in previous Annual Reports. These milestones have been met and approved by the Department.

Milestones 18-21 are applicable under the current reporting period (Jan-Dec 2018).

Milestone	Description	Due Date	Status
18	Delivery of Annual Progress 3 (2017) and Financial Information to the Department	1 April 2018	Met
19	Acceptance of Annual Progress Report 3 and Financial Information by the Department	(date not defined)	Met
20	Delivery of draft Research Plan Version 5 to the Department	1 October 2018	Met
21	Acceptance of the final Research Plan Version 5 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%	All Hub projects and case studies involve the active engagement of research-users.
2. Percent of projects approved under RPV5 in which research-users were actively involved in project design?	100%	Of the 9 new research projects approved under RPV5 (Projects 5.1-5.9) all actively involved research-users in the design of the project. Research users include either next users (other researchers), as for projects 5.1, 5.2, and 5.7; or end users (such as the Hub's Target User Groups), as for projects 5.3, 5.4, 5.5, 5.6, 5.8 and 5.9. Research-users were also actively involved in the design of all stakeholder engagement case studies and activities under the Hub's RPV5 Target User Group activity plans.
3. Number of research outputs provided to end users **on time**[1] and as identified in the Research Plan	27	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. Note that a number of these delays have been identified, varied in RPV5 and approved by the Department. The Hub will actively manage remaining delayed outputs.
4. Proportion of research outputs provided to end users **on time** and as identified in the Research Plan	~70%	
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. However, the Hub is consulting and collaborating closely with other NESP Hubs on case studies and activities.
6. Number of peer reviewed NESP funded publications during the reporting period	50	50 publications, including 10 in high impact journals such as *Nature, Nature Climate Change* and *Bulletin of American Meteorological Society*.
7. Number of NESP research citations in other researchers' publications during the reporting period	1225	Lead Chief Investigator (Project 2.9) Pep Canadell made the Highly Cited List from Clarivate Analytics for the second year running. This captures researchers who place in the top one per cent of the consistently most highly cited researchers in their field.

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

8. Number of researchers, including PhD and Post-Doc positions engaged as a result of NESP (total, Full-time equivalent) during the reporting period	Total: 110 FTE: 32.55	Includes 12 PhD students and postdocs
9. Number of data sets provided to the Hub, or made publicly available, by third parties for the purposes of informing NESP research	>50	The Hub uses a wide variety of climate and weather datasets to inform its research. These include datasets created both within Australia and internationally. The exact number of data sets used by the Hub is hard to calculate, so an estimate has been provided.
10. Percentage of data sets made publically available under open licence by the Hub	~50%	Hub data sets resulting from ACCESS simulations include revision or draft data sets which are research products and not suitable for public access. However, these 'raw' datasets are often available to other researchers through research portals such as NCI. Final data/simulations from ACCESS will be made available through CMIP6 and the Earth Systems Grid. Other datasets, such as those resulting from blue carbon, coastal erosion and ecological engineering research and decadal prediction forecasting are also raw/draft data and not suitable for public access.
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%	About 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 person at 0.25 FTE	
13. Number of Indigenous researchers/graduates/post-graduate/PhD/Post Doc Positions in projects.	N/A	The Hub's strategy on Indigenous engagement aims to foster on-going meaningfully engagement with Traditional Owners to determine their priorities for products, services and tools. However, the Hub is not yet at the stage of engagement with Indigenous stakeholders where management tools can be developed. In part, this is due to the nature of the
14. Number of Indigenous people trained in the use of environmental management tools and techniques.	N/A	
15. The number of management tools for Indigenous waters and land that benefitted	N/A	

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).		Hub's research, which does not easily translate into management tools for Indigenous communities, nor is the Hub's research easily accessible and useable by communities. This is why the Hub held the National Indigenous Climate Change Dialogue in November 2018. The workshop resulted in many good outcomes, including: - development of trusted and respectful relationships with Traditional Owners from a number of regions - the desire of Indigenous stakeholders to keep the dialogue open throughout 2019 and 2020 (a second dialogue workshop will be held in 2020), and - the development of cultural and climate change risk activities which will be undertaken throughout 2019 and 2020, as well as the development of an Indigenous Session at the 2019 Australian Meteorological and Oceanographic Society (AMOS) conference in Darwin.
16. Number and type of communication products that have been used to communicate research with Indigenous people.	1	The National Indigenous Climate Change Dialogue, which involved over 50 Traditional Owners.
17. Number of research, knowledge sharing and communication events held with Indigenous communities.	11	These events include the National Indigenous Climate Change Dialogue and on-going meetings to establish relationship with Yorta Yorta (workshop hosts) and prepare for the Dialogue; the Shark Bay workshop; and continued engagement with Traditional Owners in Cairns.
18. Number of public events, conference presentations, jointly authored/published papers with Indigenous participants/contributors.	1 public event which involved over 50 Traditional Owners	The National Indigenous Climate Change Dialogue, which involved over 50 Traditional Owners over 3 days of discussions.
19. Number of stakeholder engagement activities (such as presentations, workshops, briefings and meetings) participated in by Hub researchers and Hub management staff	~150 stakeholder engagements throughout 2018	Hub researchers participated in over 100 scientific engagement activities, including scientific presentations, workshops, webinars, briefings, conference sessions and panels and meetings. Hub management staff (knowledge brokers and Hub Leader) participated in or led over 50 engagement activities, including stakeholder meetings, expert meetings, case study workshops, business breakfast sessions, presentations and talks.

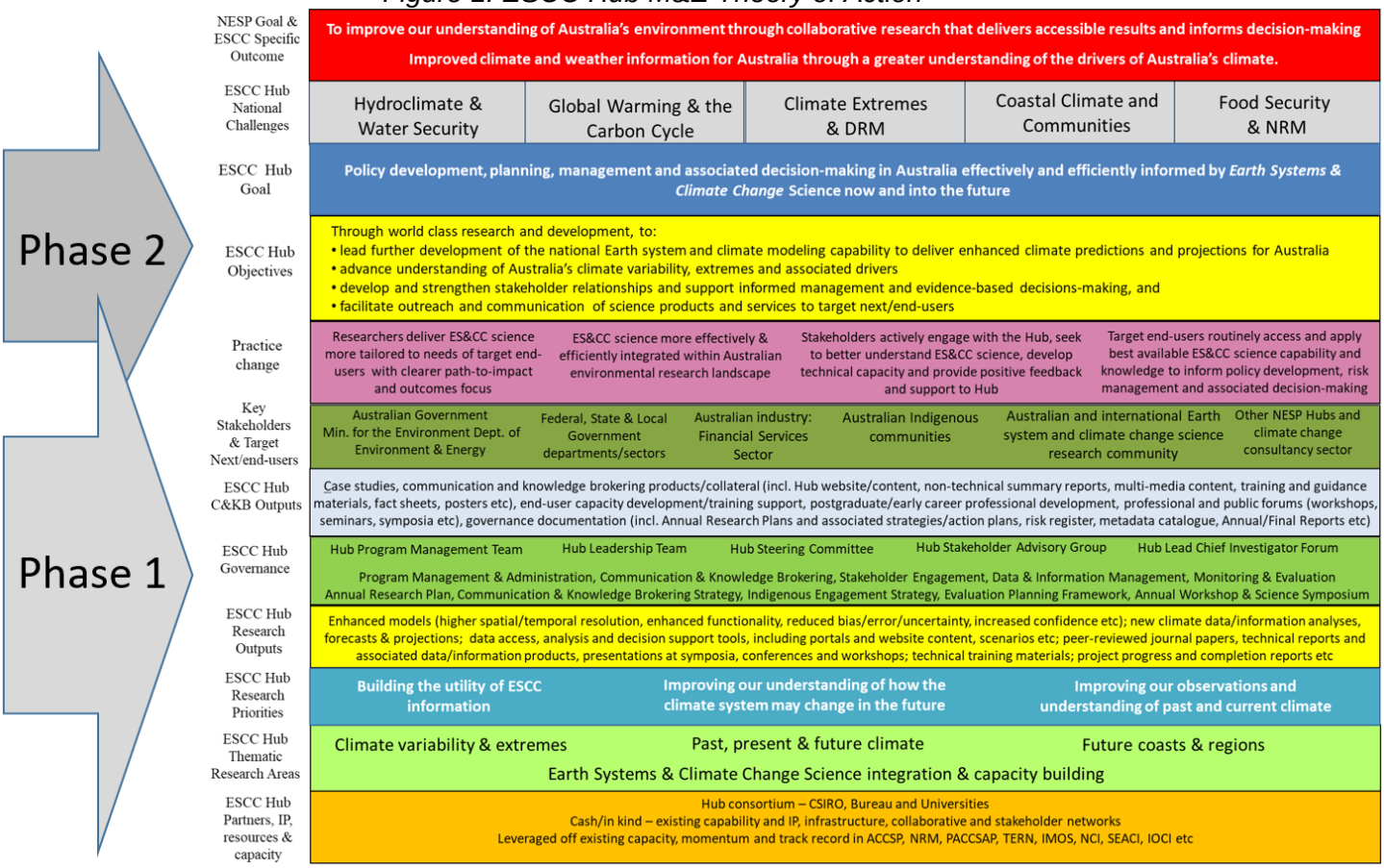
20. Increase in stakeholder engagement through the Hub's subscription list	>300 additional subscribers over 2018	The Hub has grown its subscription list rapidly in 2018, almost doubling the numbers of stakeholders who have sought to engage with the Hub. This has helped to raise awareness of the Hub, and also represents a broadening of our stakeholder base. This stakeholder base has grown over the course of the Hub from one based primarily of next-users within the research community, as well as a limited number of federal and state government stakeholders, to a stakeholder list in 2018 which includes stakeholders from across all levels of government, costal managers and planners and stakeholders from industries such as financial services, agriculture, infrastructure, defence and water resource managers, as well as a wide range of consultants who work in the climate change space.

ESCC Hub Monitoring and Evaluation

The Hub's Evaluation Planning Framework has been updated (V5.1) as part of RPV5 implementation. This version also includes an updated Theory of Action (see Figure 1) based on the Hub's schematically summarised 'climate change science informing services' path-to-impact (Figure 2).

The Framework includes development of the Hub's draft Monitoring and Evaluation (M&E) Action Plan. The Action Plan identifies the target audience for the evaluation as i) the Hub itself, including the Hub Leadership Team (HLT), Hub Program Management Team (HPMT) and Lead Chief Investigators (LCIs) ii) Hub partners and DoEE iii) Hub Steering Committee, Hub Stakeholder Advisory Committee and broader Hub stakeholders.

Figure 1: ESCC Hub M&E Theory of Action



The M&E Action Plan is based on a two-stage approach to M&E:

Phase 1

- Retrospective evaluation based on RPV1-5 projects (projects 2.1-2.11, July 2016 - June 2019) and Hub Central communication, knowledge brokering and stakeholder engagement activities.
- Focus on performance monitoring/governance (systems, procedures, progress reporting and milestone compliance) and next-user (researcher) outputs and outcomes (around peer-reviewed publications).
- Nominal baseline around the Australian Climate Change Science Program (ACCSP) and the Natural Resource Management Planning for Climate Change Fund (climate change projections 2015) closeout and the Hub's mid-term internal review findings (*NESP Earth Systems and Climate Change Hub science and services: Assessment of current capability and future directions*, prepared by Scientell Ltd Pty).

Phase 2

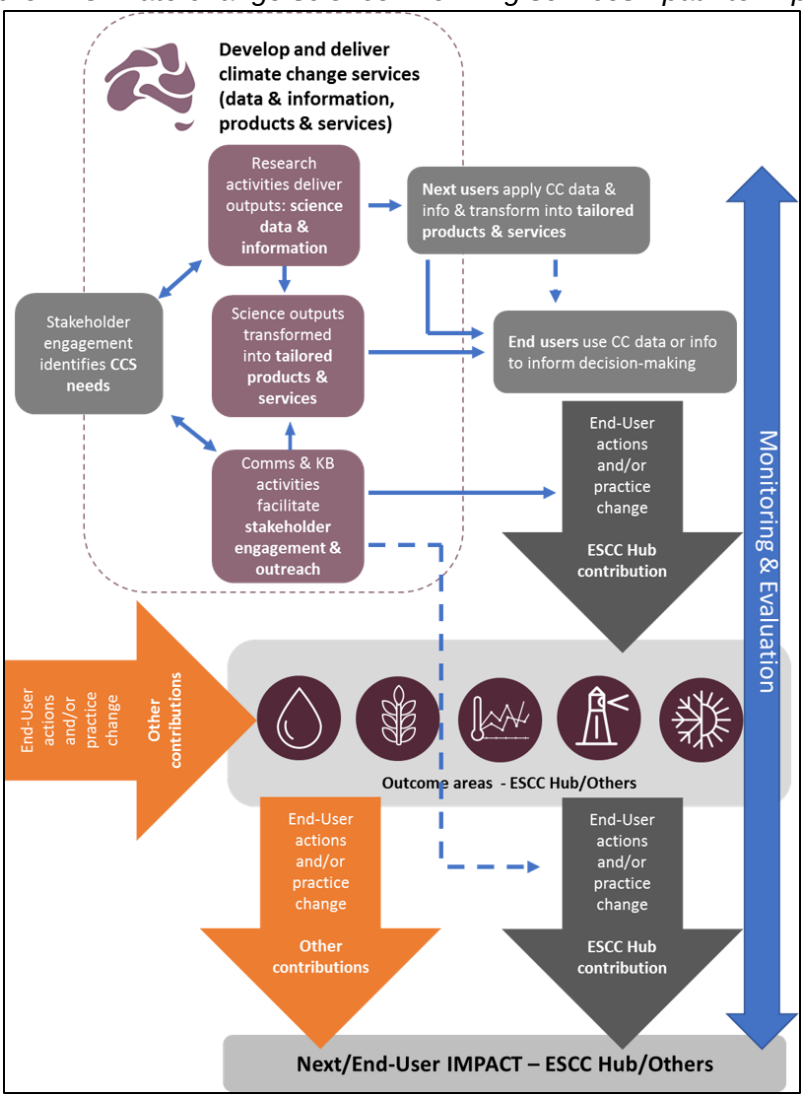
- Real-time evaluation based on RPV5-6 projects (Projects 5.1-5.9, July 2019 – December 2020) and Hub Central Target User Group engagement and activities.
- Focus on performance monitoring/governance (as for Phase 1) and end-user (Target User Groups) outcomes and impacts.
- Emphasis on Target User Groups and case studies.
- Baseline: Phase 1 M&E results.

The M&E Action Plan will leverage off the Theory of Action (Figure 1), with particular emphasis on mapping stakeholder reactions to the Hub's research and outreach across the Hub's line of accountability (i.e. noting the important role and responsibilities of other actors in the climate change science and services value chain in Australia). Monitoring such outcomes and impacts will be benchmarked against relevant baselines (before/after) and the Hub's agreed objectives and associated hierarchy of outcomes.

This latter analysis will allow for realising outcomes and impacts over multiple time scales, including within and beyond the term of the Hub, and will be undertaken using various established M&E methods to generate multiple lines of quantitative and qualitative evidence.

The first results for Phase 1 will be available by June 30 to inform close-out of the RPV2-5 projects.

Figure 2. Climate change science informing services - path to impact



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 System and Climate Change Hub impacts stories included in Attachment B are:

1. Planning for climate change in Shark Bay
2. Developing innovative hybrid coastal protection options for coastal management in Victoria
3. Climate change data and information to inform risk in the financial services sector
4. Novel approaches to making climate change science accessibility and useable
5. Managing water resources in south-west Western Australia under a changing climate
6. Indigenous learnings from the National Indigenous Climate Change Dialogue

Hub level risk management

All risks identified by the Earth Systems and Climate Change Hub are being actively managed. The Hub's Risk Register provides details on the management of these risks. No major new risks have emerged during the reporting period or since the approval of RPV5.

The development and evaluation of improved ACCESS model performance and submission of ACCESS simulations required for CMIP6 remained a challenge for the Hub in 2018, with a number of delays in progress against milestones. These delays were primarily caused by limited availability of resources and personnel, as well as issues with infrastructure availability. These risks are captured in the Hub's Risk Register.

Risk management strategies which were put in place within Projects 2.1 and 2.5 in 2018 and early 2019 to reduce these risks include:

- the employment of a dedicated ACCESS data manager in January 2019 to alleviate resource and personnel pressures
- tasking specific project staff to check the running of model simulations daily to monitor possible infrastructure malfunctions and correct as soon as possible to prevent further time delays.

Production runs of the ACCESS-CM2 model for CMIP6 were started in February 2019 and one of the required simulations was completed in March. This indicates good progress and slight reductions in the risk of meeting the June 2019 milestones.

These risks will continue to be monitored closely over the coming months.

Financial information

Annual financial reporting

The Earth Systems and Climate Change Hub expenditure for the 2018 reporting period is on track and no significant issues have been identified.

All funds for the reporting period have been used for the purpose for which they were provided, and all terms and conditions of the Funding Agreement have been complied with.

Attachments

Attachment A: ESCC Hub Research Project Information

Attachment B: ESCC Hub Impact Stories

Attachment A

Attachment A: Earth Systems and Climate Change Hub 2018 Annual Progress Report 4											
				Approved Funding Research Plan Versions 1-5			Start Date	End Date	Status	Outputs	
No.	Project Name	Project Summary	Lead Org.	NESP Funding $	Total Other Contributions $	Total Budget $				Outputs	Link to output
Completed projects											
1.1	Current Capability and Future Directions Assessment	This project will inform 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 been conducted by Scientell Ltd Pty.	CSIRO	72,453	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/
1.2	Project 1.2 - Stakeholder and Indigenous Engagement	Communication and Knowledge Brokering budget	CSIRO	80,200	80,200	**160,400**	01.01.2016	31.12.2016	Completed	N/A	N/A

Attachment A

1.3	Low coast abatement options: scoping workshop and report	Low cost abatement options: Scoping Workshop and Report	CSIRO	18,262	18,262	**36,524**	1/07/2015	31/12/2016	Completed	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.	CSIRO	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
N/A	PhD's and Vacation Scholarships (outside Projects; includes SO)			33,287	206,007	239,294	01.07.2016	30.06.2019	Ongoing	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

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No.	Project Name	Project Summary	Lead Org.	Approved Funding Research Plan Versions 1-5			Start Date	End Date	Status	Outputs	
				NESP Funding $	Total Other Contributions $	Total Budget $				Outputs	Link to output
Continuing three-year projects, approved in RPV2 (July 2016-June2019)											
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 addresses these outcomes by preparing the current ACCESS model for participation in the CMIP (CMIP6) to benchmark ACCESS's performance and suitability for application across the NESP ESCC Hub and the broader climate change science research community.	CSIRO	975,000	975,000	**1,950,000**	01.07.2016	30.06.2019	Ongoing	Fiddes 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 weblog: Something in the air	http://nespclimate.com.au/something-in-the-air/
2.2	Enhancing Australia's capacity to manage climate variability and climate extremes in a	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	Bureau of Meteorology	1,833,000	1,826,520	**3,659,520**	01.07.2016	30.06.2019	Ongoing	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	https://link.springer.com/article/10.1007%2Fs00382-017-4007-0

	changing climate	change now and into the future. This project will analyse past climate variability and extremes to significantly enhance our understanding of the underpinning mechanisms and processes. Its focus is 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.								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
										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	https://link.springer.com/article/10.1007%2Fs00382-018-4113-7
										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
										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-world/

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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. Australia currently has severely limited predictive capability at these timescales due to the challenges of innovative, multi-year-focussed ocean data assimilation and prediction methods. This project develops forecasting capability specific to filling the critical gap between seasonal climate predictions and multi-decadal climate projections, within ACCESS. The project will advance the development of a forecast capability on the decadal scale and will improve understanding and simulation of Southern hemisphere climate drivers. The project will, as an example and tester, focus on delivering targeted stakeholder products to inform marine and agriculture policy and adaptive management strategies, including an assessment of marine temperature extremes which have large impacts on marine life and fisheries.	UTAS	411,980	554,539	**966,519**	01.07.2016	30.06.2019	Ongoing	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.	https://www.sciencedirect.com/science/article/pii/S0079661117303336
										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

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										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-extremes/
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 will use observations and models to provide these improvements; underpinning a more resilient Australia.	CSIRO	1,102,500	1,253,461	**2,355,961**	01.07.2016	30.06.2019	Ongoing	Updated Argo Australia profiles	www.imos.org.au; www.argo.net
										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
										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

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										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/

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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 will enhance ACCESS's accuracy by improving its simulation of critically important climate processes in the Australasian region, focussing on rainfall and weather extremes. It will facilitate the robust predictions needed for adaptation and emissions policies and deliver an enhanced system to the Hub and broader community.	CSIRO	1,616,181	1,723,241	**3,339,422**	01.07.2016	30.06.2019	Ongoing	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
										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	CSIRO	1,668,750	1,691,576	**3,360,326**	01.07.2016	30.06.2019	Ongoing	NextGen Projections workshop summary report	http://nespclimate.com.au/wp-content/uploads/2018/06/ESCC-R005-NextGen-projections-180629.pdf

		uptake has been limited. Furthermore, a new set of climate simulations are due in 2018-19, so we need to begin development of new projections that maintain credibility and salience. This project addresses these issues by: (1) enhancing uptake of information through improved products and services for targeted stakeholders; (2) constraining uncertainty and improving confidence in projections; and (3) laying the groundwork for the next generation of regional projections.								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: How will rainfall change in Northern Australia over this century?	Our changing climate: How will rainfall change in Northern Australia over this 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/

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										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
										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 will improve 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 will engage 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.	CSIRO	599,981	1,200,019	**1,800,000**	01.07.2016	30.06.2019	Ongoing	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
										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	Bureau of Meteorology and CSIRO	1,527,529	1,560,429	**3,087,958**	01.07.2016	30.06.2019	Ongoing	Fire weather dataset products i.e. maps etc.	http://www.bom.gov.au/
										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_etal_mwr_2018.pdf

		making all require information about how these extreme events will change in the future. This research will fill knowledge gaps and improve understanding of existing and projected characteristics of these extreme events. We will use this knowledge to improve simulations and projected changes in these extreme events and, through ongoing and effective stakeholder engagement, transform our research into targeted, useful and application-ready information.								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
										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

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										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 will investigate and assess 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 will deliver 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 will be delivered in stakeholder-relevant formats, suitable for use by government agencies, business and enterprises, and the broader community.	CSIRO	900,000	900,000	**1,800,000**	01.07.2016	30.06.2019	Ongoing	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
										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

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										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: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

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										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
										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: 10.1088/1748-9326/aaf303	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
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 will improve 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, our products and outputs will be tailored and delivered	CSIRO	1,294,366	1,306,057	**2,600,423**	01.07.2016	30.06.2019	Ongoing	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
										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

		in ways that ensure Australians can plan effectively for coastal change.								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
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 will establish the National Centre for Coasts and Climate (NCCC), and initiate 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.	University of Melbourne	1,050,000	1,142,325	**2,192,325**	01.07.2016	30.06.2019	Ongoing	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://www.sciencedirect.com/science/article/pii/S0031018217312579
										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

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										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/

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No.	Project Name	Project Summary	Lead Org.	Approved Funding Research Plan Versions 1-5			Start Date	End Date	Status	Outputs	
				NESP Funding $	Total Other Contributions $	Total Budget $				Outputs	Link to output
CASE STUDIES											
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 has 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.	CSIRO	15,000	0	**15,000**	1/01/2017	31/12/2018	Completed	Draft Climate Change 101 package (Power point slide) for use by the traditional owners of the Mackay region	N/A

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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.	CSIRO	130,000	0	**130,000**	1/01/2017	30/06/2019	Completed	Workshop report is currently being drafted by the workshop steering committee	-
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.	CSIRO	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

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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 an 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.	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
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 several 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.	CSIRO	5,000	0	**5,000**	1/01/2017	31/12/2017	Completed	WA Government Stakeholder Engagement and Research Planning/Outreach Workshop	N/A
										Workshop report from the 2017 meeting in Perth	http://nespclimate.com.au/wp-content/uploads/2016/03/NESP-ESCC-Hub-SWWA-workshop-report-July-2018.pdf

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3.6	Climate Change in Australia mobile website (a prototype)	Stakeholders and everyday Australians are used to accessing information on the go and in the' here and now'. The current suite of climate change projections provides 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.	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
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.	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

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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 will be 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	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
3.9	Practical and empowering responses to coastal erosion in the Tiwi Islands	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 working 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.	Uni 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

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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 will test 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 will provide a starting point for a process of partnering and delivering information for this growing need. This case study will demonstrate the path to impact of Hub research from Projects 2.6 (regional projections) and 2.8 (extremes projections).	Bureau of Meteorology and CSIRO	15,000	20,000	**35,000**	1/01/2018	31/12/2018	Completed	Case study report	http://nespclimate.com.au/understanding-finance-sector-climate-change-information-needs/
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 will 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 will leverage primarily off activities and outputs (key data and information) being delivered through Project 2.9.	CSIRO	10,000	10,000	**20,000**	1/01/2018	31/12/2018	Completed	Internal report only	N/A

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4.3	Communicat-ing projected changes in hydroclimate affecting water supply in South-West Western Australia (SWWA)	This case study will develop 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.	CSIRO	5,000	5,000	**10,000**	1/01/2018	31/12/2018	Completed	Case study impact story	http://nespclimate.com.au/wp-content/uploads/2019/05/A4-2p-impact-SWWA-WEB.pdf
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 will demonstrate 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 is partnering 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.	Bureau of Meteorology and CSIRO	20,000	20,000	**40,000**	1/01/2018	31/12/2018	Completed	Gondwana rainforest section - fact sheet and workshop report	http://nespclimate.com.au/wp-content/uploads/2019/03/Gondwana-CC-workshop-report.pdf

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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 will develop 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 may also demonstrate 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 key stakeholders. It will also propose a strategic process for further developing and implementing the framework over the life of the Hub as part of the overarching Evaluation Planning Framework for the Hub.	CSIRO on behalf of the ESCC Hub partners	65,000	65,000	**130,000**	1/01/2018	31/12/2018	Completed	Case story report	http://nespclimate.com.au/determining-the-return-on-investment-of-earth-systems-and-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 will 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 will also determine the best and most accessible way to present and make this information available to stakeholders.	CSIRO	25,000	25,000	**50,000**	1/01/2018	31/06/2019	Ongoing	Case study report	N/A

Attachment B

NESP Impact Story

Hub

Earth Systems and Climate Change Hub

Title

Planning for climate change in Shark Bay

Project number and project title

Hub level activity

Short version

Climate change has the potential to tip the balance of the biological and physical systems in Western Australia's Shark Bay World Heritage Area. Australia has an international commitment to protect and conserve the values of its World Heritage areas. Understanding the climate change impacts and risks to Shark Bay is therefore critical to the future management and resilience of the area under a changing climate. Climate change science from the Earth System and Climate Change Hub is informing the development of a climate change adaptation strategy and action plan for the region. The adaptation strategy and action plan will be relevant to a number of environmental decision makers who work together to manage the area, including the Western Australia state government, relevant local governments, the Australian Government and the Shark Bay World Heritage Advisory Committee. Hub research and advice in this process will help to ensure climate risks in Shark Bay are better understood, planned for and managed, and that Australia continues to meet its international obligations.

Narrative

The Shark Bay World Heritage Area in Western Australia is one of 19 listed World Heritage properties in Australia. Among other plants and animals, it is home to one of the world's largest seagrass meadows, nearly 10 percent of the world's population of dugongs and four mammal species that are found nowhere else in the wild. Sea-level rise, reduced rainfall, intense storms, higher air and sea temperatures and coincident events all have the potential to tip the balance of biological and physical systems in this region.

The Australian Government has obligations and commitments under the international World Heritage Convention. These include ensuring that the values of a World Heritage area are protected and conserved.
Management of the Shark Bay World Heritage Area involves a number of key environmental decision makers who each play an important role in developing and implementing management and adaptation plans and relevant policies. These include:

- the Western Australia government, primarily through its Parks and Wildlife services, who manage the day-to-day on-ground activities
- Relevant local governments, who work with state agencies to maintain the values of the area
- the Australian Government, who set national level World Heritage policy, and
- the Shark Bay World Heritage Advisory Committee, who provide advice to government and assist in the development of management plans.

Climate change has been recognised as a risk to the future resilience of the Shark Bay World Heritage area.

Highlighting vulnerability to climate change

In September 2018, the Shark Bay World Heritage Advisory Committee convened a workshop to lay the foundations of a climate adaptation strategy and action plan for the area. The Hub presented climate change projections for Shark Bay that informed a rapid risk assessment undertaken at the workshop, which confirmed Shark Bay's high vulnerability to climate change. The climate projections and risk assessment are documented in a workshop report (and two-page summary) that has been circulated among agencies responsible for Shark Bay's management. The engagement was reported in a news post on the Hub's website. The workshop was also the basis of an article that appeared in *The Conversation* in February 2019.

Understanding climate change impact on seagrass

Through the course of the workshop, the critical role played by Shark Bay's seagrass beds became apparent. They are the foundation of the Shark Bay's marine ecosystem, providing food, shelter and nursery areas for many marine animals, including dugongs, turtles, and commercial fishery species. The seagrass beds and underlying sandbanks contribute to the hypersalinity of Hamelin Pool, and so to the existence of the stromatolites.

The Hub is working with the Shark Bay World Heritage Advisory Committee and the University of Western Australia in 2019 to assess the impact of climate change on Shark Bay's seagrass beds. Understanding these climate impacts will be critical for maintaining the ongoing integrity of the seagrass beds in Shark Bay.

2018 workshop participants, Shark Bay, WA

Informing management for the future of Shark Bay (and other World Heritage properties)

The Hub's climate change science and participation in the Shark Bay workshop facilitated the rapid risk assessment that identified Shark Bay's high vulnerability to climate change. It also identified the need for a climate impact assessment on Shark Bay's seagrass beds, which led to a case study examining this issue in 2019.

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The use of climate change science in assessing impacts and vulnerability at Shark Bay has led to similar work with the Gondwana Rainforests World Heritage Area and preliminary discussions with Ningaloo Coast World Heritage Area about climate change science to inform their management decisions. These engagements and outputs show how World Heritage Areas can benefit from using climate change science and are paving the way for these properties to use it more frequently and for other properties to incorporate climate change science into their planning.
Research outputs NESP Earth Systems and Climate Change Hub. 2018. *Climate change and the Shark Bay World Heritage Area: foundations for a climate change adaptation strategy and action plan*, Earth Systems and Climate Change Hub Report No. 7, NESP Earth Systems and Climate Change Hub, Australia. Full report | Summary
Attributions • Mandy Hopkins – ESCC Hub knowledge broker • Vanessa Hernaman – ESCC Hub researcher, Project 2.6 • Karen Pearce – ESCC Hub communication advisor • Cheryl Cowell, Phil Scott, Diana Walker – Shark Bay World Heritage Advisory Committee

NESP Impact Story

Hub

Earth Systems and Climate Change Hub

Title

Developing innovative hybrid coastal protection options for coastal management in Victoria

Project number and project title

Project 2.11 - Establishment of the National Centre for Coasts and Climate

Short version

Australia's coastal communities and infrastructure are threatened by hazards such as erosion and flooding. The severity of these coastal hazards is predicted to increase with rising sea levels and more frequent storm events caused by climate change. Earth System and Climate Change Hub researchers, through the National Centre for Coasts and Climate, are working 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. Planning and development of these trials included collaboration between researchers and coastal decision makers, such as state and local governments, community groups and engineers. This collaboration is vital in ensuring coastal protection solutions are location appropriate, meet stakeholders needs and will result in beneficial adaptation activities to protect the region's coasts under a changing climate.

Narrative

Australia's coastal communities and infrastructure are threatened by hazards such as erosion and flooding. The severity of these coastal hazards is predicted to increase with rising sea levels and more frequent storm events caused by climate change. Coastal managers, such as state and local governments, engineers and infrastructure designers, are frequently faced with decisions on what management options are most appropriate to implement in response to such challenges. The use of traditional protection methods, such as seawalls, are most common, yet these structures are often environmentally and economically unsustainable, especially under future climate change scenarios. Novel approaches to coastal protection are therefore required. Earth System and Climate Change Hub researchers, through the National Centre for Coasts and Climate (NCCC), are working with state and local coastal managers in Victoria to trial a number of innovative approaches that combine natural, created or restored habitats to provide coastal protection.

3D printed mangrove pots

Hub researchers have designed 3D-printed concrete pots to plant mangroves for erosion control. The pots protect the mangroves from wave energy as they establish and grow, resulting in more successful mangrove restoration efforts and an enhancement in the natural coastal protection services mangroves provide against waves and in stabilising sediment. This activity involves a large collaborative team of local and state government bodies, community engagement specialists and an

industry partner. Sites within Port Phillip and Western Port Bay have been identified for implementation of mangrove planters, and implementation will be finalised in 2019.

Mangrove planters used to protect mangroves against wave energy

Artificial shell fish reef/breakwater

The design and development of an offshore artificial reef/breakwater consisting of steel cages filled with local rock and recycled scallop shell is another example of an innovative hybrid approach to coastal protection. The breakwater has been constructed in Portarlington in Port Phillip Bay to protect the foreshore and adjacent residential properties from persistent erosion and flooding. A number of different methods have been trialled to seed the breakwater with native mussels, with the aim of creating an entire mussel reef for coastal protection. Mussel reefs have suffered a significant decline in the Port Philip Bay region, and so this breakwater provides the additional benefit of habitat restoration.

Ongoing monitoring of the artificial reef/breakwater by the NCCC, in partnership with the City of Greater Geelong, in 2019 will measure its success in reducing wave height, promoting accretion of sand with the aim of addressing erosion of the foreshore, while realising co-benefits such as increased biodiversity and improved water quality. The design, construction and implementation of the artificial reef/breakwater was undertaken by the City of Greater Geelong Council, with a co-contribution from the Victorian Department of Environment, Land, Water and Planning for design and monitoring.

Attachment B

Development and seeding of the mussel breakwater in Portarlington, Port Phillip Bay

Innovative approaches such as those described above provide decision makers and coastal planners with new, sustainable and economical means to protect shorelines and reduce coastal erosion. The trials will assist in determining which habitats are effective at providing coastal protection, the types of environments in which they work best, and the best designs for achieving long term sustainable protection. This is only possible though collaboration and engagement between researchers and coastal managers, such as state and local governments, engineers and infrastructure designers. By working with these stakeholders, the Hub and NCCC have ensured the development and trialing of these solutions meet stakeholders' needs and are appropriate for implementation at site-specific locations. This collaborative approach also provides a useful framework for the development of future on-ground adaptation and coastal protection activities, including on coastal erosion and habitat restoration.

Research outputs

Morris et al. 2018. From grey to green: Efficacy of eco-engineering solutions for nature-based coastal defense, *Global Change Biology*, https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.14063

Attributions

Project 2.11 researchers: Stephen Swearer, David Kennedy, Teresa Konlechner, Ben Fest, Beth Strain, Rebecca Morris and Ralph Roob.

Attachment B

NESP Impact Story

Hub

Earth Systems and Climate Change Hub

Title

Climate change data and information to inform risk in the financial services sector

Project numbers and project titles or Hub activity

Project 2.6 – Regional climate projections science, information and services
Project 2.8 – Extreme weather projections
Case study 4.1 – Test case for datasets and information for managing climate risk in the Australian banking and finance sector

Short version

There is a large and growing industry need for science-based data and information to inform physical climate change risk for the Australian financial services sector. The information needs to be technically credible and consistent (based on peer-reviewed knowledge with institutional authority), salient and relevant, readily accessible and tailored for end-user applications. The Earth Systems and Climate Change Hub has increasingly engaged with this emerging new user group to build relationships and raise awareness of the utility of climate change science. In addition, this engagement has benefited the Hub by highlighting the information needs of the sector and how climate change science can be used in the private sector. Engagement activities which bring together financial sector professionals and climate change researchers help to bridge the gap in culture, language and understanding and respect for each profession and their expertise. It has provided Hub researchers with insights into how decisions within the financial services sector are made, the terminology used by the sector and how data and information is used to support and change policies. These new learnings will be used to inform the future direction of the Hub's research.

Narrative

The Australian economy is influenced by changes to the average climate (e.g. increases in the mean temperature and sea level) as well as by long-term changes to extreme weather conditions which have the potential to cause more rapid economic impacts, such as those associated with phenomena such as bushfires, cyclones and floods. Managing these changes within the economy involves a range of financial risks, 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. In particular, there is a large and growing industry need for science-based data and information that is credible, consistent, relevant and tailored for end-user applications to inform physical climate change risk for the Australian financial services sector.

To address this need, a case study was undertaken by the Hub during 2018 which provided a synopsis of existing and available science-based climate change data and information relevant for application by the financial services sector. Information gathered and summarised in the case study report includes:

- information on the influence of climate change on Australia's mean weather and ocean conditions as well as on relevant weather and ocean hazards

- existing science-based climate data and information resources, including tools to explore and use climate change projections
- further relevant resources, such as those produced for the financial services sector by national and international bodies, and
- identified gaps and needs in data and information for the sector.

The Hub engaged with a number of financial services sector stakeholders, with representation by individuals and groups from across banking, insurance and fund managers, and various professional entities mostly across the private sector.

Through these engagement activities the Hub learnt that the influence of climate change on extreme weather events was consistently identified by stakeholders as acutely relevant to financial risks. Direct and indirect impacts from extreme events can have both an immediate and longer-term influence on the economy, and so have large implications for the financial services sector in terms of managing risk.

Extreme phenomena of the greatest interest to stakeholders include heatwaves, bushfires, hail, extreme rainfall, floods, droughts and coastal inundation. Storms, particularly tropical cyclones, east coast lows and thunderstorms, are responsible for many of the most costly and destructive natural hazards and disasters influencing Australia. In addition, compound events (multiple interacting factors that can exacerbate the resultant impacts) were also identified as important. It was recognised that physically plausible 'worst case' scenarios based on multiple extreme events are therefore needed to 'stress test' systems and management models.

Engagement with the financial services sector has resulted in an enhanced awareness by the sector of the existing availability and utility of climate change data and information to inform risk and associated decision-making, and of the Hub's research capability and future strategic directions. It has also led to the development of potential new collaborative partnerships to inform and facilitate meaningful engagement between the Hub and the sector going forward.

Engagement activities which bring together financial sector professionals and climate change researchers help to bridge the gap in culture, language and understanding and respect for each profession and their expertise. It has provided Hub researchers with insights into how decisions within the financial services sector are made, the terminology used by the sector and how data and information is used to support and change policies.

There are a number of potential ways for the Hub to address the identified climate risk priority gaps and needs for the financial services sector. Existing data and information can be provided in the short term by the Hub and partner agencies, including through climate change services based on agreed sector priorities. In the medium term, some new climate change data and information products and services (such more tailored guidance, training, protocols and content) can be added to the national climate projections. More detailed data products and guidance information will also continue to be made available through the Hub's research.

However, further detailed needs assessments are required to inform new work, particularly on the specific tools, analysis methods and data that are most commonly used by financial analysts and risk managers for climate-related risk assessments and financial disclosures.

Attachment B

Research outputs Case study 4.1 report - Test case for datasets and information for managing climate risk in the Australian banking and finance sector (currenlty going through internal review, will be made available on the Hub's website)
Attributions • Hub researchers: Michael Grose and Aurel Moise (Project 2.6), Andrew Dowdy (Project 2.8) and David Newth (Case Study 4.5) • Hub Stakeholder Advisory Group representatives: Nick Wood and Kate Mackenzie • Hub staff: David Karoly and Geoff Gooley

Attachment B

NESP Impact Story

Hub

Earth Systems and Climate Change Hub

Title

Novel approaches to making climate change science accessible and useable

Project numbers and titles

Project 2.10 – Coastal hazards in a variable and changing climate
Project 2.1 – Preparing ACCESS for CMIP6
Project 2.8 – Extreme weather projections

Short version

Climate change science research results in a wealth of big and complex data which can be difficult to identify, access and use. The Earth Systems and Climate Change Hub is supporting a number of novel approaches to enhance the accessibility of climate change data, including utilising volunteer students to digitise historic tide gauge records from old books and charts so that more accurate information on past and future changes can be provided to coastal managers, engineers and consultants; submitting Australian climate model runs to the international World Climate Research Programme Coupled Model Intercomparison Project (WCRP/CMIP) for use by international and Australian researchers; and converting fire weather data into visual and accessible maps for use by emergency managers, such as regional fire services and emergency management peak bodies. By enhancing the accessibility and useability of climate change information, the Hub is increasing the evidence base available to support decisions and management activities in response to our changing climate.

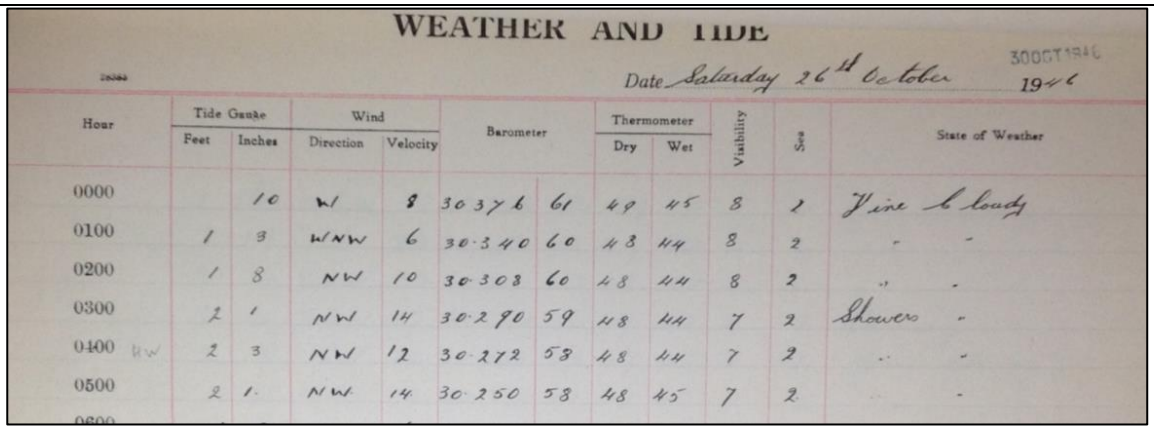
Narrative

Climate change science research results in a wealth of data from model outputs, observations and process studies. This data is large and complex, and is often spread across a number of formats, organisations, websites and publications. This can make finding and accessing relevant data challenging, and can act as a barrier to the utility and uptake of climate change science. The Hub is supporting a number of novel approaches to enhance the accessibility of climate change data so it can be found and used by researchers and users, both nationally and internationally. By enhancing the accessibility and useability of climate change information, the Hub is increasing the evidence base available to support decisions and management activities in response to our changing climate by a range of environmental managers such as coastal managers, emergency service managers and climate change decision-makers.

Digitising Australia's long term tide and weather records

Under the Hub's coastal hazards project (Project 2.10), researchers are working with volunteer and work experience students to digitise hard-copy historic tide records from old books and charts. This data dates back to the late 19th century and in its current hard-copy format is not accessible to other researchers or coastal managers, and is therefore unavailable for modelling and analysis.

Attachment B



WEATHER AND TIDE

Date Saturday 26th October 1946

Hour	Tide Gauge Feet	Tide Gauge Inches	Wind Direction	Wind Velocity	Barometer		Thermometer Dry	Thermometer Wet	Visibility	Sky	State of Weather
0000		10	W	8	30.376	61	49	45	8	2	Fine & cloudy
0100	1	9	WNW	6	30.340	60	48	44	8	2	- -
0200	1	8	NW	10	30.303	60	48	44	8	2	" -
0300	2	1	NW	14	30.290	59	48	44	7	2	Showers -
0400 HW	2	3	NW	12	30.272	58	48	44	7	2	" -
0500	2	1	NW	14	30.250	58	48	45	7	2	" -
0600											

Hand written weather and tide data dating from the 1940's

Past records on sea levels, tides and extreme events are used by engineers, infrastructure planners and consultants to understand the past range of changes to consider when determining development locations and designs. These stakeholders are increasingly aware that the past is no longer a reliable indicator of future change, and so projections of future sea level are beginning to also be considered when planning long-term developments or assets. These historical records are therefore important as they allow us to better understand how mean sea level and extreme events, such as storm surges, have changed. Building a greater understanding of past change also builds confidence in projections of future change.

Making Australian climate model data accessible for international assessments

Climate model data is important for understanding the past, current and future climate, but is often very large and complex. By submitting data from Australia's national climate model, ACCESS, to the World Climate Research Programme Couple Model Intercomparison Project (WCRP/CMIP) through Project 2.1, data on Australia's climate is made available to researchers across the world for use in research and global assessments, such as IPCC assessment reports. The IPCC reports are used to support climate change policies and decisions by governments and decision makers around the world, including Australia.

Inclusion of ACCESS into CMIP6 also enhances the useability of the data, as all data submitted to CMIP must comply with common data standards, formatting and documentation. This consistency of model data within CMIP allows our data to be combined and compared with other model outputs from around the world and used in a number of applications, such as climate projections and tracking changes in our climate.

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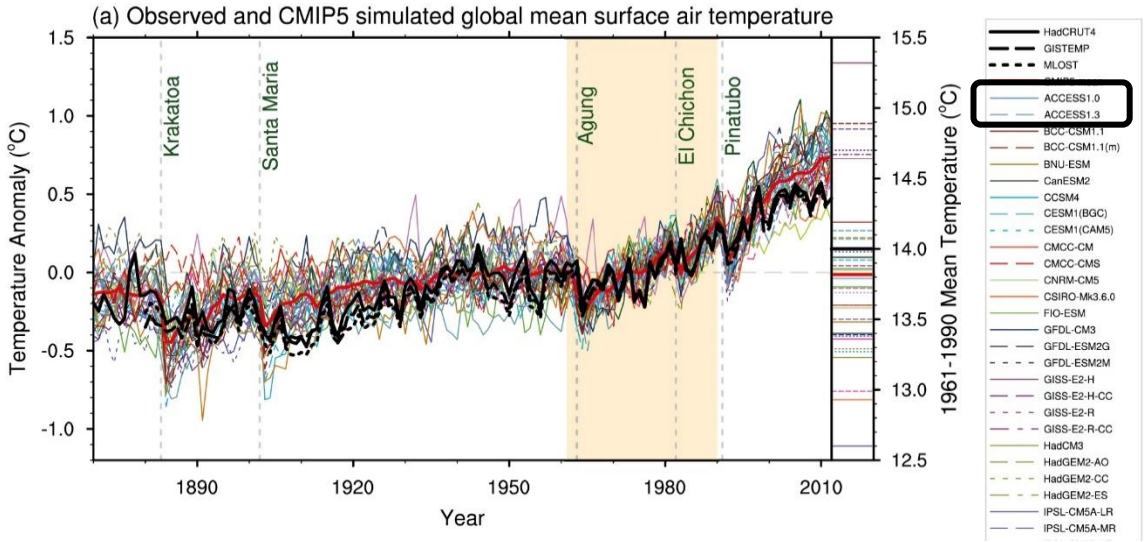
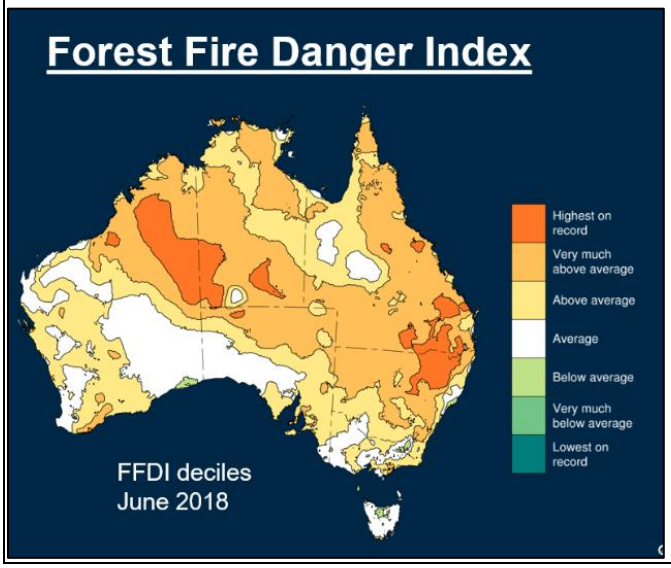


ACCESS model outputs were used in the last IPCC Assessment Report: Figure 9.8 from the IPCC Fifth Assessment Report, Chapter 9: Evaluation of climate models.

Providing fire weather data through stakeholder-friendly maps

Researchers under Project 2.8 have developed fire weather datasets of mean Forest Fire Danger Index (FFDI) values and the change in the number of extreme fire weather days since the 1950's. While the data itself is a useful output for research within Australia, it is not in a digestible format for many stakeholders, such as emergency managers. Hub researchers have worked with stakeholders to determine the best way to present the data to ensure it is accessible, visual and easy to understand. For example, fire weather maps have been developed - much like those used by the Bureau of Meteorology for their temperature and rainfall maps. This is a format which is familiar to many stakeholders, and provides a quick and visual representation of the data. The maps, data and information resulting from Hub research has also been provided to regional fire services (such as the Victorian Country Fire Authority) and the Australasian Fire and Emergency Service Authorities Council (AFAC). AFAC is the peak body responsible for representing fire, emergency services and land management agencies in the Australasian region. Ensuring climate change science informs their emergency planning and response policies and activities results in a trickle-down effect into regional fire services activities and management plans.



Example of a fire weather map based on Hub data

Attachment B

Research outputs

Tide Gauge Digitisation

- More information at: http://nespclimate.com.au/breathing-new-life-into-old-tide-records/
- On completion, tide gauge information will be available on the Global Extreme Sea Level Analysis portal: https://gesla.org/
- The data will also be provided to the Bureau of Meteorology's National Tidal Centre: http://www.bom.gov.au/oceanography/projects/ntc/ntc.shtml

Climate model data through CMIP:

- More information at: http://nespclimate.com.au/access-all-areas-a-closer-look-at-australias-national-climate-model/
- ACCESS climate simulations will be made available to scientists around the word through the Earth Systems Grid website: https://esgf-node.llnl.gov/projects/esgf-llnl/

Fire weather data:

- More information at: http://nespclimate.com.au/wp-content/uploads/2016/03/A4-2p-impact-fire-dataset-180604-web.pdf
- Journal article on the fire weather dataset: https://journals.ametsoc.org/doi/full/10.1175/JAMC-D-17-0167.1

Attributions

Researchers from across Hub projects 2.1, 2.10 and 2.8.

NESP Impact Story

Hub

Earth Systems and Climate Change Hub

Title

Managing water resources in south-west Western Australia under a changing climate

Project/ activity

Case study 4.3 – Hydroclimate and water resource management in W.A
Project 2.7 – Refining Australia's water

Short version

Climate change poses a range of challenges for water resource management in the south-west region of Western Australia (SWWA). This region has been drying since the 1960s and has experienced a 20% decline in rainfall since 2000. This drying is expected to continue under a changing climate. Water resource management and planning in the SWWA region has previously been informed by climate change science under the Indian Ocean Climate Initiative. This science helped to inform such decisions as the implementation of two desalination plants and plans to use recycled water as part of Perth's water supply. The Earth Systems and Climate Change Hub has been engaging with the WA Department of Water and Environmental Regulation (DWER) since 2016 to continue the provision of relevant, updated and useful climate change science. A small case study was conducted in 2018 to determine their priority climate change information needs and how this information can best be incorporated into the Department's water resource management tools and frameworks. The case study led to the co-development of a research plan for the Hub to conduct priority research as identified by the Department. These activities have led to multiple benefits including raising awareness of the utility of the Hub's research, providing Hub researchers with insights into how DWER use climate data in their water management activities and what their priority data needs are, and strengthening relationships between our researchers and DWER to pave the way for continued future engagement.

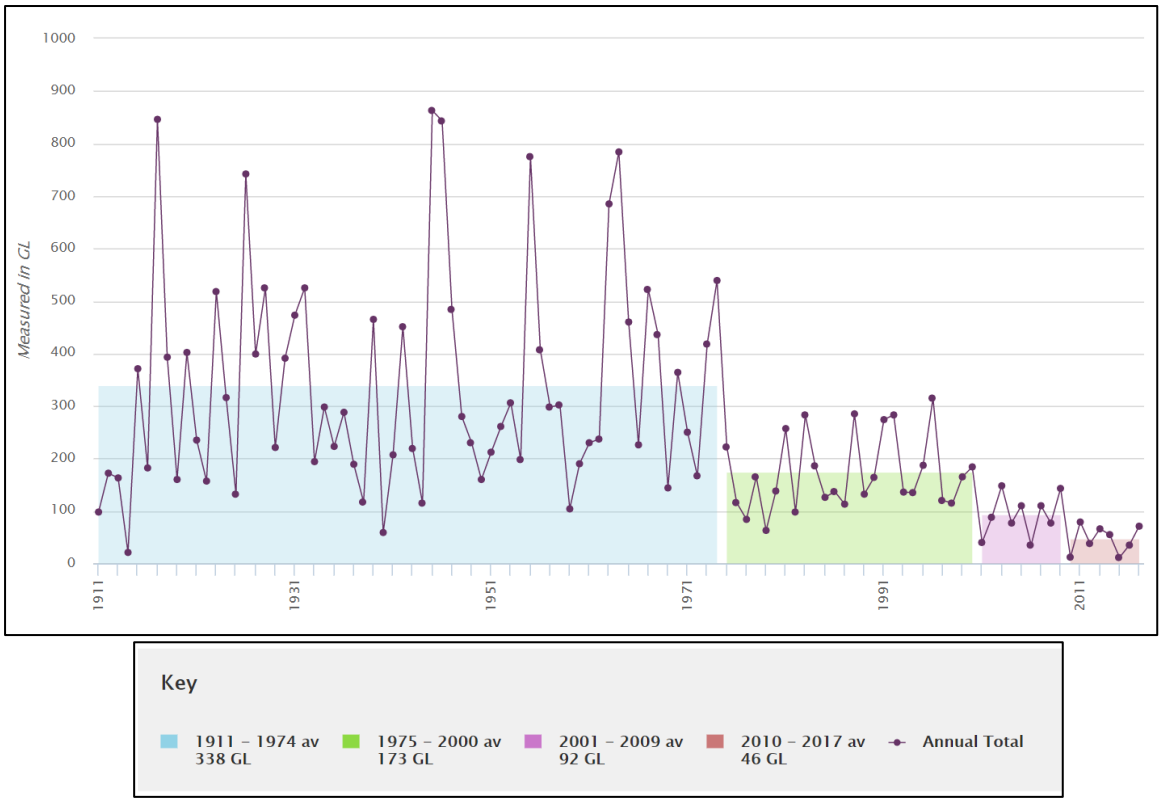
Narrative

Climate change poses a range of challenges for water resource management in Western Australia, including rising temperatures and changing weather and rainfall trends. The climate in the south-west region of Western Australia (SWWA[2]) is particularly vulnerable to climate change and has been drying since the 1960s. Since 2000, rainfall totals in SWWA have continued to be low and this drying has also expanded in geographic extent. Total rainfall decline in autumn and winter in SWWA is approximately 20%, with some of the largest rainfall decreases in the month of July.

There is significant evidence that climate change has contributed to this drying trend[3]. The drying trend is expected to continue into the future and will have serious implications for environmental water flow, urban water supplies and agriculture. Long-term planning of water supplies for all water users and for the environment is

[2] SWWA – south-west Western Australia
[3] Indian ocean Climate Initiative 3 Synthesis report: Summary for Policy Makers, page 10: http://www.ioci.org.au/publications/ioci-stage-3/cat_view/17-ioci-stage-3/23-reports.html?limit=20&limitstart=0&order=name&dir=ASC

therefore required to ensure the sustainability of water resources for SWWA under a changing climate.



Historic streamflow in Perth – a declining trend (source: [Water Corporation of WA](#))

Declining rainfall means Perth's dams receive much less streamflow than in years past

Water resource managers in Western Australia, such as state and local governments and water companies, have previously considered climate change science provided through the Indian Ocean Climate Initiative (IOCI - a partnership between the state government, CSIRO and Bureau which finished in 2012). They used the data and information produced by IOCI to understand their climate risks and to help inform such decision as the implementation of two desalination plants in

the Perth region to provide almost 50% of Perth's water supply[4] and plans for a significant proportion of Perth's future water supply to be sourced from recycled water[5].

The Hub has engaged with the Western Australian state government Department of Water and Environmental Regulations (DWER) since 2016 to better understand their on-going climate change information needs, During 2018, the Hub worked directly with DWER water resource managers on a small case study to determine the best way to provide them with priority new and updated climate change data and information for incorporation into existing DWER water management tools and frameworks. In particular the case study focused on DWER's information needs regarding the impact of climate change on the reliability of water supply to farm dams and environmental flow.

Working together, Hub researchers and DWER shared knowledge on how the most up-to-date climate change science could continue to effectively inform water resource management and planning activities, especially regarding projected changes into the future. Under this case study a co-designed research plan was developed to deliver to the needs of DWER. The research plan aims to:

- identify the critical rainfall metrics that drive the reliability of supply to farm dams and resulting environmental flow in Wilyabrup Brook, WA
- assess how these critical rainfall metrics are represented in the latest future climate change information
- assess how future climate, including both changes in rainfall and temperature, could impact the reliability of water supply to farm dams and environmental flows
- develop an approach that can be applied to other and more complex applications.

The first stages of the research plan will be conducted by Hub research during 2019 and 2020, in close conjunction with DWER. While the Hub may not currently be able to conduct all of the above aims, these should be viewed as a research roadmap for a future stage-based research process. This co-designed research plan represents the needs of on-ground water resource managers and therefore ensures the research conducted by the Hub will be relevant, useable and accessible. Engagement activities conducted under this case study has resulted in other benefits including:

- providing the Hub with a better understand of 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. This knowledge will be valuable to inform future Hub research plans and will result in an increase in the accessibility and usability of climate change information and data.
- DWER has gained a better understanding of the utility of climate change information and data produced by the Hub in informing management and planning activities.
- Existing and new relationships have been further enhanced and strengthened between Hub researchers and DWER policymakers/ managers to encourage

[4] Water Corporation for WA: https://www.watercorporation.com.au/water-supply/our-water-sources/desalination
[5] Water Corporation of WA: https://www.watercorporation.com.au/water-supply/our-water-sources/recycled-water

collaborative problem solving on environmental and climate change issues. This is a key objective of the National Environmental Science Program and the ESCC Hub.

The long-term benefit of these engagement activities will be that through the co-design of tailored and stakeholder driven research, DWER has the information and science-based evidence required to better inform their management and planning for the current and future impacts of climate change on the water resources of south-west Western Australia.

Research outputs

Case Study 4.3 and Project 2.7

Case study 4.3 Fact Sheet: http://nespclimate.com.au/wp-content/uploads/2019/05/A4-2p-impact-SWWA-WEB.pdf

Related background material: Workshop report resulting from Hub level engagement with WA stakeholders during 2016-17 - *Climate challenges for water resources management in Western Australia*: http://nespclimate.com.au/wp-content/uploads/2016/03/NESP-ESCC-Hub-SWWA-workshop-report-July-2018.pdf

Attributions

Case Study 4.3 and Project 2.7

- Hub researchers: Steve Charles, Dewi Kirono and Francis Chiew
- Key DWER stakeholders: Jacqui Durrant and Artemis Kitsios

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NESP Impact Story

Hub

Earth Systems and Climate Change Hub

Title

Indigenous learnings from the National Indigenous Climate Change Dialogue

Project title/activity

Indigenous activity 3.2 – Meeting Indigenous priorities for climate change information, capacity building and engagement

Short version

Climate change presents a risk to the livelihoods of many Aboriginal and Torres Strait Islanders. Indigenous peoples have noticed changes to country that haven't been seen before, and at rates of change much faster than previously experienced. To discuss and share knowledge about these changes and how they may impact Indigenous communities and land, the Earth Systems and Climate Change Hub enabled a National Indigenous Climate Change Dialogue to be held in November 2018. The Dialogue brought together over 50 Traditional Owners to hold powerful two-way conversations about how Traditional Knowledge and western science can provide relevant information on the climate risks faced by Indigenous communities. Key impacts from the Dialogue included better understanding of Indigenous knowledge and information needs, the development of trusted and on-going relationships between researchers and Indigenous communities, and building the capacity of hub researchers to understand the challenges faced by Indigenous communities and their Traditional Knowledge on climate change. While the Dialogue is just the beginning of a longer and broader conversation between the Hub and Indigenous communities, it provides an open and honest forum for the development of future engagements and partnerships.

Narrative

Climate change presents a risk to the livelihoods of many Aboriginal and Torres Strait Islanders. Indigenous peoples are noticing changes to country that haven't been seen before. While they have lived in a sustainable and adaptable environment for many centuries, the rate of change being seen at present is a concern. As coastal and island communities confront rising sea levels, rainfall and heat extremes, and hotter, drier climates, Aboriginal and Torres Strait Islanders face the potential loss and degradation of the lands, waters and the natural resources they have relied upon for generations. Climate change also poses a major threat to the physical health of Indigenous communities and their ability to sustain traditional life, languages, knowledge and cultural heritage.

To discuss these risks and impacts, the ESCC Hub worked with a steering committee of Indigenous representatives to bring together more than 50 Traditional Owners from across Australia with Hub scientists and staff for the inaugural National Indigenous Dialogue on Climate Change, which was held on Yorta Yorta country in November 2018.

The Dialogue, which built on the 2012 National Workshop on Indigenous Knowledge for Climate Change Adaptation, enabled powerful two-way conversations on climate risks and impacts, Indigenous climate observations and stories and how Traditional

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Knowledge and western science can provide relevant information and knowledge about the current and future risks faced by Indigenous communities.

The two-way dialogue between researchers and Traditional Owners helped improve the understanding of mutual goals and potential benefits from working together to support the community's climate information needs. It allowed Traditional Owners from across Australia to discuss their management practices and hear from the Hub researchers about how and why the climate and its extremes will continue to occur into the future.

Discussions at the Dialogue centered around developing future opportunities for knowledge sharing between Indigenous communities in Australia; increasing Indigenous access to credible and relevant information and research; and how to build the capacity and skills of Indigenous peoples within their communities to understand what climate change means for them. The Dialogue also presented Hub researchers with an important opportunity to build their understanding of the climate challenges and risks faced by Indigenous communities, as well as insights into Traditional Knowledge on how the climate has changes in the past and is changing currently.

It was clear that Indigenous participants valued the opportunity to speak with representatives from other Indigenous communities across Australia (from regions they may not normally connect with) about the changes they are experiencing on country and their land management practices. Developing further opportunities for knowledge sharing between Indigenous communities about the changes they are experiencing and the management practices that could be considered was a key finding from the Dialogue.

The Dialogue also provided a forum for open and honest discussions, which was appreciated by participants and resulted in positive feedback on the value of the workshop.

The Dialogue is just the beginning of a longer and broader conversation between the Hub and Indigenous communities about climate change impacts and information needs. There was overwhelming support to continue these conversations into the future and to grow the relationships built at this workshop. The ESCC Hub has therefore committed to holding another Dialogue in 2020, which will include a broader representation of Indigenous communities, to continue the dialogue and two-way knowledge exchange.

Indigenous participants felt that the Dialogue provided the following benefits:

- "Good representation of nations and climate change issues - what other mobs are doing. Interactive approaches. Cultural connections and interactions. Going out on country, food, hospitality etc."
- "Group activities; joint conversations; 2 way talk; agencies responding to needs."
- "Meeting everybody and sharing our thoughts and culture and knowledge with our brothers and sisters."

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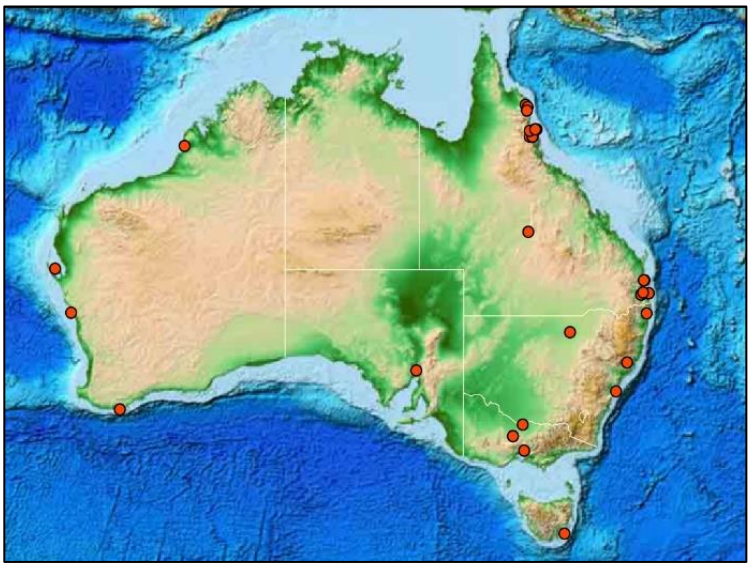
- "Engagement & conversations with scientists; meeting & listening to other mobs; meeting on country; grassroots focus; good forum for Indigenous Australian input."

- "Networking, partnership development with scientific community."



This map shows the locations that Indigenous participants came from to attend the National Indigenous Dialogue on Climate Change

Images from Yorta Yorta country, Barmah Forest Victoria

Attachment B

Research outputs A workshop report is currently being developed by the Dialogue Steering Committee, which will be circulated to all participants and may (pending Indigenous participant's approval) be publicly available. The Hub is continuing to progress case studies with Indigenous communities based on existing work, including providing climate change information for seagrass species in Shark Bay, and for climate adaptation strategies with the Central Land Council Rangers.
Attribution The Dialogue was planned with assistance from an Indigenous-led Steering Committee including Yorta Yorta Nation Aboriginal Corporation (YYNAC), Kimberley Land Council, and SEED (Indigenous Youth Climate Network), and co-hosted by YYNAC on country at the Dharnya Cultural Centre, Barmah. The workshop participants greatly appreciated the hospitality and warm welcome to country by Yorta Yorta, and their sharing of song, story and ceremony throughout the event.