



National Environmental Science Program Earth Systems and Climate Change Hub



ANNUAL PROGRESS REPORT 3 1 January 2017 – 31 December 2017

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: 20 April 2018

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: Wendy Craik

Date: 20 April 2018

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Letter from the Hub Leader

It is an honour, as the new Leader of the Earth Systems and Climate Change (ESCC) Hub, to report on the excellent progress that the Hub has made in 2017 in research, communication and stakeholder and Indigenous engagement. 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 decisions-making
- facilitate outreach and communication of science products and services to end-users and the general public.

Commencing in 2017, a suite of new Hub and project level case studies and research activities were implemented that demonstrate the end-user impacts of the Hub's research. These are described in the impact stories which support this report, provided at **Attachment B**.

The Hub has been active in Indigenous engagement in 2017, holding a workshop with the Torres Strait Regional Authority on understanding climate change implications for Torres Strait fisheries and marine ecosystems. In a second workshop, the Hub partnered with the Tiwi Land Council to discuss climate adaptation with local communities, focused on preparing for climate change and coastal erosion in the Tiwi Islands. The Hub also actively engaged with a range of Indigenous communities and stakeholders in 2017 to better understand their climate science information needs, and to understand how traditional knowledge can inform the work of the Hub.

In 2017, the Hub established a Young Professionals Network, in partnership with the Actuaries Institute and other stakeholders. The Network supports both early career climate science researchers and sector-based young professionals to develop technical capacity to deliver and apply climate change information, and to enhance links within and between these two key groups. Two successful workshops for this Network were held in the second half of 2017. This Network is an example of how the Hub is engaging with the finance and banking industries in Australia, as these sectors come to acknowledge their climate risks and start to consider their climate change science information needs.

A cross-Hub research highlight in 2017, in which the ESCC Hub contributed strongly, was the research activity on understanding the drivers of the unprecedented dieback of mangroves in the Gulf of Carpentaria in 2015. This study was conducted in response to a request from the then Minister for the Environment. Hub researchers found that the coincidence of unusually hot and dry conditions with low sea level likely provided a stressful environment for the mangroves, associated with the strong El Niño in 2015. This work has led to interest by the Northern Territory government in investing in more research on this topic.

Major new datasets and web-based apps were developed by the Hub in a number of areas. Hub researchers produced a dataset of weather conditions influencing fire activity that extends back to 1950 and is updated daily. The dataset provides the big picture with regards to fire weather in our changing climate, allowing current extreme conditions to be placed in a historical context. The dataset has been used to directly inform the Australasian Fire and Emergency Service Authorities Council about climate change influences on natural hazards and associated extremes in the future. As a result, climate risks will now be better managed and considered in AFAC policy and practises for emergency management throughout Australia. The Sea Level, Waves & Coastal Extremes web portal was also developed by Hub researchers. The web portal consolidates, updates and extends information on a wide range of coastal hazards, such as sea level change, waves, coastal extremes and ocean energy, increasing the accessibility of this information and data for a range of users. The web portal provides the underpinning science and data on sea level and coastal extremes, which is often incorporated into adaptation tools, such as the sea level rise and allowances data incorporated into CoastAdapt. Building on the vast resources of the *Climate*

Change in Australia website, a prototype climate change projections mobile phone app was developed by Hub researchers in 2017. This is aimed at providing an accessible interface to the climate change projections data and increasing the dissemination and use of the information significantly. Potential users, such as stakeholders from all levels of government and NRM planners and managers, will be surveyed on its usability and accessibility in 2018.

In 2017, the ESCC Hub established its monthly science webinar series, which provides an opportunity to hear about the science being undertaken in the Hub directly from the researchers. The webinars are open to the research community and anyone interested in finding out more about the Hub's research.

2017 saw significant international recognition of the Hub's researchers. Two Hub researchers, Professor Nathan Bindoff and Dr Kathy McInnes, were selected as Lead Authors in the Intergovernmental Panel on Climate Change (IPCC) *Special Report on the Ocean and Cryosphere in a Changing Climate*. Through the Hub's support of the Global Carbon Project, Hub research on trends in anthropogenic carbon emissions and their accumulation in the atmosphere contributes to international research, policies and decision-making, including tracking towards targets under the Paris Agreement.

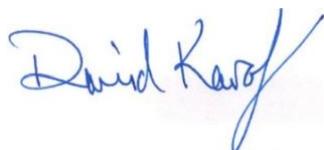
For most of 2017, the success of the Hub was due to the leadership of the acting Hub Leader, Geoff Gooley, and the Hub Project Management Team. In 2017 a thorough search and selection process led to the recruitment of a new Hub Leader. I started as Hub Leader in February 2018.

Major activities in 2018 will include our first Hub Science Symposium in July, bringing together researchers from across the Hub to discuss common research interests, build collaboration and plan the next phase of research projects. Hub research will continue to focus on stakeholder engagement and participation in case studies, which will facilitate path to impact. We will strengthen our engagement and collaboration with other NESP Hubs on case studies and cross-cutting issues. This next phase of the Hub's research will be informed by the external evaluation of Hub activities undertaken by Scientell in 2017. The evaluation assessed the current capabilities and future directions of the Hub, as well as the effectiveness of its communication products and engagement with stakeholders.

In 2018, the Hub will hold the first National Indigenous Workshop on Climate Change, led by the Kimberley Land Council, the Yorta Yorta Nation Aboriginal Corporation and Seed, Australia's first Indigenous youth-led climate network. Hub researchers will partner with the NESP Tropical Water Quality Hub to assess likely impacts of climate change and climate-sensitive management solutions for the Great Barrier Reef, a critical cross-Hub issue. The Hub will continue to provide on-going support for PhD students and early career researchers, building on the success of the Young Professionals workshops started in late 2017.

2018 also marks the start of the preparation of the *Sixth Assessment Report* of the IPCC, which will be released in 2021. Six Hub researchers have been selected as Lead Authors or Review Editors for this Assessment; Dr Pep Canadell, Dr Francis Chiew, Dr Robert Coleman, Dr Pandora Hope, Professor David Karoly and Dr Simon Marsland.

From the excellent research findings produced to the new connections made with key industries and sectors across Australia, 2017 was a very successful year for the Earth Systems and Climate Change Hub. It has set the Hub up for another busy year in 2018, in which world-leading application-focused research will continue to be conducted and the value of our climate change science research will be illustrated more clearly than ever before. I look forward to being a part of this exciting journey.



Professor David Karoly

Research

Progress towards outcomes

The Hub's outcomes as reported in our Research Plan Version 4 are to provide research that:

- enhances our understanding of Australia's environment, climate and weather
- is communicated clearly to relevant stakeholders and the general public
- is discoverable and accessible
- informs decision-making and addresses environmental priorities.

The Hub is delivering these outcomes with a focus on the five identified climate challenges for Australia: future hydroclimate and water resources; food security, ecosystems and NRM; carbon cycle and future warming; future coastal climates; and extremes and disaster risk reduction. The Hub's research portfolio, stakeholder-focused case studies and engagement activities are designed to address these outcomes and challenges.

Significant progress was made during 2017 towards achieving these outcomes and is articulated in a suite of impact stories provided in this Annual Report at **Attachment B**. These impact stories are cross-referenced to one or more Hub projects (2.1 through to 2.11) in terms of deliverables, stakeholder engagement and path-to-impact.

Highlights of the Hub's progress towards its outcomes include:

- The publication of 40 peer-reviewed scientific studies, including 11 in high impact journals such as *Nature Climate Change*, *Science Reports* and *Bulletin of American Meteorological Society*. More publications resulting from 2017 research will be published during 2018. Many Hub publications have been co-authored with researchers from other national or international research organisations, such as the ARC Centre of Excellence for Climate System Science and under the Global Carbon Project. This illustrates the high level of collaboration the Hub is involved in across the research community. These publications and research have increased understanding of Australia's environment, climate and weather.
- Participation of Hub researchers in over 115 stakeholder engagement events, including international and national conferences, presentations, webinars and seminars, and stakeholder meetings. These activities have helped to communicate the work of the Hub to stakeholders and the general public, and to inform decision making processes of key stakeholders.
- On-going development of our national climate model, the Australian Community Climate and Earth System Simulator (ACCESS), including preparation for inclusion of ACCESS in the international Coupled Model Intercomparison Project Phase 6 (CMIP6). Involvement in CMIP6 ensures ACCESS simulation data are discoverable and accessible by the broader international community and can be used to inform global climate assessments, such as the IPCC assessments, which inform decision-making and climate policies.
- Establishment of the National Centre for Coasts and Climate (NCCC) at the University of Melbourne, to provide increased capability to identify feasible solutions for addressing climate change impacts in coastal ecosystems. In Phase 1 of NCCC, it has developed methods to evaluate sensitivity and impacts of climate change, and has trialled solutions for coastal and marine environmental management challenges in Victoria.

During 2018 the Hub's Monitoring and Evaluation Framework will be reviewed, finalised and implemented to facilitate the process of documenting evidence-based path-to-impact progress for the Hub. The Framework will capture and report in detail on the outcomes of the Hub during 2017. Key evaluation data is provided by these 2017 impact stories which will also be supplemented by outcomes from the Hub's RPV4 research projects and associated case studies in 2018.

Research projects

Attachment A lists the projects, activities and case studies funded under the Earth Systems and Climate Change Hub in 2017 and provides information on status, outputs and links to products, where available.

Performance against milestones

Performance against Funding Agreement milestones

All milestones for the period and to date have been met as per Funding Agreement Milestones 1-17.

Milestones 1-13 were reported on in previous Annual Reports. These milestones have been met and approved by the Department.

Milestones 14-17 are applicable under the current reporting period (Jan-Dec 2017).

Milestone	Description	Due Date	Status
14	Delivery of Annual Progress 2 (2016) and Financial Information to the Department	3 April 2017	Met
15	Acceptance of Annual Progress Report 2 and Financial Information by the Department	(date not defined)	Met
16	Delivery of draft Research Plan Version 4 to the Department	18 September 2017	Met
17	Acceptance of the final Research Plan Version 4 by the Department	(date not defined)	Met

Performance against the Research Plan milestones

Detailed information on project progress and performance is provided in **Attachment A**.

Delays to project milestones in 2017 were primarily caused by:

- unavoidable technical issues in accessing relevant data and information
- resource constraints in terms of availability of relevant Hub personnel
- logistical constraints in terms of undertaking key stakeholder consultations.

These delayed milestones are being addressed through agreed variations to due dates as part of RPY4, or are otherwise to be subject to a new RPY4 variation proposal (pending) in 2018. Where appropriate, these variations are also being addressed through relevant Hub and/or project level risk management treatments as specified in the ESCC Hub Risk Register.

These delays and variations are not expected to impact on the Hub's ability to satisfactorily address the relevant project objectives.

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 will build 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 RPV3 in which research-users were actively involved in project design?	100%	While there were no new projects approved in RPV3, new case studies were developed which have an overt end-user focus. Research-users were actively involved in the design of all case studies.
3. Number of research outputs provided to end users on time ¹ and as identified in the Research Plan	45	
4. Proportion of research outputs provided to end users on time and as identified in the Research Plan	82%	The majority of research outputs developed in 2017 were provided to end users on time and as identified in the Research Plan. Delays were primarily caused by technical issues in accessing data, staff resourcing constraints or constraints in key stakeholder engagements.
5. Number of instances of where the hub has used NESP-generated information from another NESP hub.	1	During the development of the mangrove die back activity data and information generated by the NAER and TWQ Hubs were used by ESCC Hub researchers. While the Hub is primarily a research provider rather than a research user, the Hub is consulting and collaborating closely with other NESP Hubs on case studies and activities in RPV4 and beyond.
6. Number of peer-reviewed NESP-funded publications during the reporting period	40	40 publications, including 11 in high impact journals such as <i>Nature Climate Change</i> , <i>Science Reports</i> and <i>Bulletin of American Meteorological Society</i> . Note: 7 publications were produced in 2017 from funding under the Hub's legacy program, the <i>Australian Climate Change Science Program</i> .
7. Number of NESP research citations in other researchers' publications during the reporting period	144	2016 publications: 106 citations from publication date to 7 February 2018. 2017 publications: 38 citations from publication date to 7 February 2018.
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: 106 FTE: 32.07	
9. Number of data sets provided to the Hub, or made publicly available, by third parties for the purposes of informing NESP research	3-5	As this is a new KPI, data was not collected throughout 2017. A more complete response will be available in the next Annual Report. Note that Hub projects run for three years so many datasets are not yet finalised. Once finalised they will be made publicly available.

¹ On time – delivered on the date the outputs were expected to be delivered
May 2018

Key Performance Indicator	Hub Result for 12-month Period (numerical only)	Explanation (if any)
10. Percentage of data sets made publicly available under open licence by the Hub	-	As this is a new KPI, data was not collected throughout 2017. A more complete response will be available in the next Annual Report.
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.	85%	85% of the Hub's outputs are currently publicly available, with the remaining outputs expected to become publicly available in coming months or within 12 months of publication. The Hub is continuously working 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 at 0.25 FTE	Following the outcomes of the national Indigenous workshop in November 2018, this number is likely to increase.
13. Number of Indigenous researchers/graduates/post-graduate/PhD/Post Doc Positions in projects.	2	Indigenous scientists involved in case study 3.1. Following the outcomes of the national Indigenous workshop in November 2018, this number is likely to increase.
14. Number of Indigenous people trained in the use of environmental management tools and techniques.	~10	As this is a new KPI, data was not collected throughout 2017. A more complete response will be available in the 2018 Annual Report.
15. The number of management tools for Indigenous waters and land that benefitted from NESP research and outcomes (including but not limited to Plans of Management for IPAs, Co/Joint managed parks, Marine Park Plans of Management, Conservation Agreements).	-	As this is a new KPI, data was not collected throughout 2017. This will be reported on in the 2018 Annual Report.
16. Number and type of communication products that have been used to communicate research with Indigenous people.	4	Activity 3.1 'Climate 101' information pack Activity 3.3 Torres Strait Island workshop report Activity 3.2 Summary report of the Indigenous steering committee Activity 3.9 Tiwi Island forum report
17. Number of research, knowledge sharing and communication events held with Indigenous communities.	>20	Includes (for example) numerous face to face two-way discussions and information sharing with a variety of Indigenous community representatives; Indigenous Steering Committee meetings; the NESP all-Hub Indigenous Gathering; and meetings with the Torres Strait Regional Authority and other groups under Hub case study's and activities.
18. Number of public events, conference presentations, jointly authored/published papers with Indigenous participants/contributors.	-	As this is a new KPI, data was not collected throughout 2017. This will be reported on in the 2018 Annual Report.
19. Number of stakeholder engagement activities (such as presentations, workshops, briefings and meetings) participated in by Hub researchers	>115	Including stakeholder workshops, meetings, conferences, seminars, presentations and briefings with a wide range of stakeholders.

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:

Impact story topic	Short description
Climate change science for a safer Australia: providing fire weather data to ensure emergency services policies and practices incorporate climate change	Australia has experienced a sequence of severe fire seasons in recent years, leading to the loss of many lives and properties. The seasons have stretched the capabilities of fire services and communities. Understanding how weather conditions that influence fire activity have changed and how future risks may need to be managed will help with planning to minimise future losses. Earth Systems and Climate Change Hub researchers produced a dataset of fire weather conditions that extends back to 1950 and is updated daily. The Bureau of Meteorology Climate Information Services group is using this dataset to provide weather warnings, maps and planning information to emergency services. The dataset has also been used to inform the Australasian Fire and Emergency Services Authorities Council (AFAC). As a result, climate risks will be better managed and considered in future AFAC policy and practices for emergency management throughout Australia.
Understanding climate change implications for Torres Strait fisheries and marine ecosystems	Fisheries and marine ecosystems in the Torres Strait are economically and culturally important but are vulnerable to the changing climate. Helping Torres Strait islanders understand their climate risks requires careful relationship fostering between islanders and knowledge providers. It also requires the communication of this information in a manner which is accessible and relevant to islanders. The Earth Systems and Climate Change Hub partnered with the Torres Strait Regional Authority to gather together climate change, marine and fisheries scientists, fisheries managers and traditional owners to discuss the implications of climate change on fisheries and marine ecosystems in the region. The relationships built and information needs and priorities identified through this activity provided a new level of understanding around the climate risks to Torres Strait fisheries and marine ecosystems. This understanding and the new relationships built will form the basis of ongoing activities to ensure traditional owners in the Torres Strait have the best available information and tools to help manage climate change impacts on their businesses, communities and country.
Improving access to data and information on sea level, waves and coastal extremes for better coastal planning and practices	Prior to the development of the new Sea Level, Waves & Coastal Extremes website, sea-level rise information from science leaders had a technical focus and was delivered on an old website maintained by the CSIRO and the Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC). The new website developed by the Earth System and Climate Change Hub consolidates this information and brings in additional material on a wide range of coastal hazards, including waves, coastal extremes and ocean energy. The new website also improves accessibility and readability of this information and data. The information is delivered in ways that are appropriate for a range of users and stakeholders including the research community (through datasets and scientific papers), and governments, businesses and school students (through high level summary information and figures). The improved accessibility of this information enhances its uptake and the ability of this information to be used by stakeholders, such as the Australian wave energy industry, the CoastAdapt website and local councils.
Understanding the climate drivers of the 2015 Gulf of Carpentaria mangrove dieback	In late 2015 more than 7000 hectares of mangroves died along the south-west coastline of the Gulf of Carpentaria. This event appears to be unprecedented. Initial investigations into the dieback suggested that climate factors played a role in the dieback. After an all-Hub discussion, researchers from the Northern Australia Environmental Resources, Tropical Water Quality and Earth Systems and Climate Change Hubs took a closer look to determine how this might have occurred. Researchers from the ESCC Hub discovered that the coincidence of unusually hot and dry conditions with low sea level likely provided a stressful environment for the mangroves. This cumulative stress during most of 2015 almost certainly contributed to the major dieback near the end of 2015. Understanding why this dieback happened is important for ongoing management of the mangroves to ensure the critical environmental services they provide are not compromised in the future. This work has initiated a larger study that is currently underway to assess the extent of dieback across the Gulf.

<p>Identifying Indigenous climate change information priorities</p>	<p>Indigenous communities across Australia are vulnerable to the impacts of climate change. Strong and lasting relationships and relevant communication methods are required to help Indigenous stakeholders understand and manage these impacts. They are also necessary to help the ESCC Hub understand the climate change information that is most useful and relevant to Indigenous communities, and to explore ways that traditional knowledge can inform the Hub's research. By engaging constantly and meaningfully with Indigenous stakeholders the ESCC Hub has developed strong relationships and has begun to enhance the capacity and understanding of both the Hub researchers and Indigenous communities. To further this, and to increase the Hub's understanding of the climate change priorities for Indigenous stakeholders, a national Indigenous workshop is currently being developed and will be held in November 2018. This workshop will identify the climate change information and capacity building requirements of Indigenous stakeholders. The recommendations from the workshop, which is Indigenous led, will inform the Hub's ongoing engagement with Indigenous communities.</p>
<p>Preparing for climate change and coastal erosion in the Tiwi Islands</p>	<p>Climate change will have significant social, environmental and financial impacts on the communities of the Tiwi Islands, which are largely coastal and remote. Coastal erosion will be a particular issue. However, it is often difficult for the people of the Tiwi Islands to relate the big scales of climate change impacts science to the local, social and environmental processes that are important and relevant to them. Previous engagement with the Tiwi around climate change has alarmed local residents and escalated feelings of powerlessness. So the Hub, working with the Tiwi Land Council, undertook engagement and knowledge brokering activities to discuss climate adaptation with local communities. Trust and respect were required to build relationships and understand the concerns and priorities of the local communities. The information, discussions and relationships built during these engagement activities provide a foundation for potential future work with the Tiwi to develop practical and guidelines for adaptive management of coastal erosion.</p>
<p>Supporting communication of climate challenges for water resources management in Western Australia</p>	<p>With variable rainfall against the backdrop of an extended drying trend, managing climate risk to water security in south-west Western Australia is a critical climate challenge. The Earth System and Climate Change Hub worked with the Western Australian Government to prepare communication materials for the Government to convey the latest climate change science, with a focus on rainfall in south-west Western Australia. These materials make the latest climate change science accessible to water suppliers and users in the region so it can be used to inform and support decisions about water security. The communication materials developed by the Hub will be incorporated into the WA Department of Water and Environmental Regulation website and used by the Department when communicating with water users and water related stakeholders.</p>
<p>Supporting the next generation of knowledge providers and decision-makers within the Australian climate change science and services landscape</p>	<p>While the realities of climate change are already apparent, the impacts and risks are likely to continue and increase. This means the responsibility for developing and applying new scientific knowledge to inform adaptation and climate-related risk management policy and planning will increasingly fall on the shoulders of future generations of scientists and decision-makers within government and the private sector. The Earth Systems and Climate Change Hub established a Young Professionals Network to support both early career climate science researchers and sector based young professionals to develop technical capacity to deliver and apply climate change science, and to enhance links within and between these two key groups. New professional relationships are being created through this network which will facilitate ongoing engagements and relationships that will be advantageous in the process of addressing climate risks for Australia.</p>
<p>Tracking carbon sources and sinks in support of the Paris Agreement</p>	<p>The Australian Government and the international community cannot respond to climate change without adequate information on climate change science, impacts and human caused carbon emissions. In particular, understanding how the Australian and global carbon budget is tracking is vital for understanding the likelihood of meeting or exceeding the Paris Agreement targets of 1.5°C and 2°C. The maximum amount of carbon that humans can emit into the atmosphere and still keep global average temperatures below an increase of 2°C is referred to as the 'carbon budget'. To assist in tracking the Australian and global carbon budgets, the Earth Systems and Climate Change Hub supports the Global Carbon Project (GCP). The GCP is an international collaboration which provides an authoritative assessment of human caused carbon sources and sinks. The GCP's annual Global Carbon Budget provides information, data and communication products to inform and raise awareness about how the world is tracking against the carbon budget. This information is provided directly to policy and decision makers from across the globe through its annual release at the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC). Through this high-profile global initiative and the Hub's own carbon tracking research which feeds into the Budget, the Hub's research informs both Australian and international climate policies.</p>

Hub level risk management

All risks identified in the Earth Systems and Climate Change Hub Risk Register are being actively managed. No new risks have emerged during the reporting period or since the approval of RPV4. The Hub's Risk Register provides details on the management of these risks.

An overarching risk to Hub activities during 2017 was the on-going availability and future funding of computational resources provided by the National Computational Infrastructure (NCI). These resources are particularly important for the Hub's modelling activities and ACCESS development.

During 2017, the Hub worked with other research agencies across Australia to address this risk by supporting a proposal for funding for new high-performance computing capability and mass data storage at NCI. This resulted in the recent announcement in 2018 of future funding for NCI under the Australian Government's National Collaborative Research Infrastructure Strategy (NCRIS). The Hub will continue to be involved in discussions and decisions around NCI resources for use by the Australian climate change science research community.

Financial information

Earth Systems and Climate Change Hub expenditure for the 2017 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: Earth Systems and Climate Change Hub Research Project Information (RPV4)

Project Number	Project Title	Project Summary	Lead Organisation and Project Leader	Approved Funding		
				NESP Funding \$'s	Total Other Contributions \$'s	Total Budget
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 Hub's science and services. The assessment examined current research and outreach capabilities and future directions, with an emphasis on how the Hub and its key partners can best respond to target stakeholder gaps, needs and associated national priorities. The assessment, undertaken by Scientell Pty Ltd, consulted widely with academic and policy stakeholders.	CSIRO, Geoff Gooley	72,453.00	72,640.00	145,093.00
2.1	Preparing ACCESS for CMIP6	ACCESS is Australia's global climate model. It 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 CMIP6 to benchmark ACCESS's performance and suitability for application across the NESP ESCC Hub and the broader climate change science research community.	CSIRO, Simon Marsland	975,000.00	975,000.00	1,950,000.00
2.2	Enhancing Australia's capacity to manage climate variability and climate extremes in a changing climate	Climate extremes such as heatwaves, floods and droughts cause high economic, agricultural and human costs in Australia. Managing the risks and reducing the costs associated with climate variability and extremes requires a transformation in our current understanding of the influence of climate change now and into the future. This project 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. The project aims to inform the development of robust projections that will help Australia prepare for and respond to climate variability, extremes and change in the future.	Bureau of Meteorology, Pandora Hope	1,833,000.00	1,833,097.00	3,666,097.00

Project Number	Start Date	Completion Date	Status	Outputs		Outcomes
				Outputs	Link to output	Project Outcomes
1.1	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, including the challenges and opportunities for future strategic planning.	Soon to be available at www.nespcclimate.com.au	The output from this project (assessment report) provides valuable stakeholder feedback to the Hub, in particular relating to the outcomes and impacts achieved by the Hub thus far, as well as a clearer understanding of stakeholder expectations of the Hub's ongoing research. All such findings will be appropriately factored into the Hub's strategic planning for RPV5 and beyond, including directions of post-NESP Earth systems and climate change science. The assessment also provides insights into the challenges which exist across the whole Australian climate change science community, such as a lack of long term funding and the need for better coordination and collaboration across all organisations within the Australian climate science landscape. These findings add to and support previous assessments and reviews on the status of Australian climate science research, such as the Australian Academy of Science's capability review and the Australian Climate Change Science Program close out review.
2.1	01.07.2016	30.06.2019	Ongoing	Zhou, X., O. Alves, S.J. Marsland, D. Bi, and A.C. Hirst, 2017: Multi-decadal variations of the South Indian Ocean subsurface temperature influenced by Pacific Decadal Oscillation, Tellus A, 69:1, 13pp,	https://www.tandfonline.com/doi/full/10.1080/16000870.2017.1308055?scroll=top&needAccess=true	The outputs from this project will result in the update of ACCESS so it can participate in the Climate Model Intercomparison Project (CMIP) phase 6, which will inform the IPCC sixth assessment report. These simulations will be used by researchers around the world to produce peer review publications which will be used as input into the IPCC AR6 report, thus ensuring the Australian region is included in global assessments on the climate. The IPCC assessment reports and other global climate assessments provide government's around the world with scientific information on climate change, it's likely impact and mitigation strategies. When the updates to ACCESS are complete, climate simulations will be submitted to the global CMIP database. ACCESS simulations will also be benchmarked against simulations from other global climate models, allowing us to rate the capability and performance of ACCESS on a global scale and also it's ability to simulate the Australian region climate compared to other models. The inclusion of ACCESS model simulations in CMIP is helpful in ensuring Australia's climate is considered in global assessments which inform international and national policies and decisions.
				Dave Bi presentation to the Working Group on Coupled Modelling (WGCM)	https://www.wcrp-climate.org/images/modelling/WGCM/WGCM21/10oct/02-10-ACCESS-WCRP-WGCM21.pdf	
2.2	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	https://link.springer.com/article/10.1007%2Fs00382-017-4007-0	The ability to project the future climate rests partially on our ability to explain the past. Australia's ability to explain our past climate - its variability, extremes and associated trends - is therefore important for the development of climate projections and in understanding the future climate risks Australia may face . Outputs from this project will further our understanding of the drivers and processes of past climates. This will result in better projections of future climates and as a result higher public confidence in those projections. As prudent decision making relating to climate change relies on the willingness of the broader community to use climate change projections, outputs which allow for more accurate projections and therefore more uptake and use of projections by decisions makers and planners will greatly benefit Australia. In particular it is important to understand and quantify the extend to which humans have contributed to past extreme events, improve projections of changes in intensity, duration and
				Chung C, Power SB. 2017. The non-linear impact of El Niño, La Niña and the Southern Oscillation on seasonal and regional Australian precipitation. Journal of Southern Hemisphere Earth Systems Science, 67(1), 25–45, doi:10.22499/3.6701.003	http://www.bom.gov.au/jshess/docs/2017/Chung.pdf	

Project Number	Project Title	Project Summary	Lead Organisation and Project Leader	Approved Funding		
				NESP Funding \$'s	Total Other Contributions \$'s	Total Budget

Project Number	Start Date	Completion Date	Status	Outputs		Outcomes
				Outputs	Link to output	Project Outcomes
				Chung C, Power S, Santoso A, Wang G. 2017. Multi-year variability in the Tasman sea and impacts on Southern Hemisphere climate in CMIP5 models. Journal of Climate, doi:10.1175/jcli-d-16-0862.1	http://journals.ametsoc.org/doi/abs/10.1175/JCLI-D-16-0862.1	frequency of future extremes, and that this information is provided to next users, end users and stakeholders.
				Grose MR, Black M, Risbey JS, Uhe P, Hope PK, Haustein K, Mitchell D. 2017. Severe frosts in Western Australia in September 2016. Bulletin of the American Meteorological Society, doi:10.1175/bams-D-17-0088.1	http://www.ametsoc.net/eee/2016/ch29.pdf	
				Herold N, Santoso A. 2017. Indian Ocean warming during peak El Nino cools surrounding land masses. Climate Dynamics, 1-16, doi:10.1007/s00382-017-4001-6	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017GL075635	
				Hope P, Lim E-P, Hendon H, Wang G. 2017. The effects of increasing CO2 on the extreme September 2016 rainfall across South Eastern Australia. Bulletin of the American Meteorological Society, doi:10.1175/bams-D-17-0094.1	http://www.ametsoc.net/eee/2016/ch26.pdf	
				Power SB, Delage FPD, Chung CTY, Ye H and Murphy BF. 2017. Humans have already increased the risk of major disruptions to Pacific rainfall. Nature Communications, 8, 14368, doi:10.1038/ncomms14368 Full paper	https://www.nature.com/articles/ncomms14368	
				Power SB, Delage FPD, Wang GM, Smith I, Kociuba G. 2017. Apparent limitations in the ability of CMIP5 climate models to simulate recent multi-decadal change in surface temperature: implications for global temperature projections. Climate Dynamics, 49, 53-69, doi:10.1007/s00382-016-3326-x	https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1002/2017RG000560	
				Santoso A, McPhaden MJ, Cai W. 2017. The Defining Characteristics of ENSO Extremes and the Strong 2015/2016 El Niño. Reviews of Geophysics, 55(4), 1079-1129, doi:10.1002/2017rg000560	http://onlinelibrary.wiley.com/doi/10.1002/2017RG000560/epdf	
				Wang G, Cai W, Gan B, Wu L, Santoso A, Lin X, Chen Z, McPhaden MJ. 2017. Continued increase of extreme El Niño frequency long after 1.5°C warming stabilisation. Nature Climate Change, doi:10.1038/nclimate3351	https://www.nature.com/articles/nclimate3351	

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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.	CSIRO, Terence O'Kane	410,000.00	552,559.00	962,559.00
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, Steve Rintoul	1,102,500.00	1,102,500.00	2,205,000.00

Project Number	Start Date	Completion Date	Status	Outputs		Outcomes
				Outputs	Link to output	Project Outcomes
				Presentation of new method to establish the causes of changes in the climatology of the explosive growth of high impact weather systems at ANZIAM. Conference Proceedings published in ANZIAM Journal: S.L. Osbrough, J.S. Frederiksen, "Computation of changes in explosive weather systems during the 20th century"	https://doi.org/10.21914/anziamj.v58i0.11784	
2.3	01.07.2016	30.06.2019	Ongoing	O'Kane TJ, Monselesan DP, Risbey JS, Horenko I, Franzke CLE. 2017. On memory, dimension, and atmospheric teleconnections. Mathematics of Climate and Weather Forecasting, 3(1), 1–27, doi:10.1515/mcwf-2017-0001 Full paper	https://research.csiro.au/dfp/wp-content/uploads/sites/148/2017/03/OKane_mcwf2017.pdf	There is currently a critical gap in Australia's forecasting ability between seasonal prediction and longer term multi-decadal climate projections. This decadal time scale is often the time scale at which planners and decision makers in such sectors as agriculture and fisheries need climate information into order to inform future planning and activities. This project aims to start to fill this critical gap by gaining better insight into the feasibility of decadal prediction. The project will cover key interim steps in the longer term vision of a decadal prediction system that could eventually become operational to routinely inform policies and adaptive management strategies. The importance of developing a decadal forecasting capability for Australia was highlighted in 2016 by the then Minister for the Environment's announcement for additional Government funding to develop a decadal forecasting capability. The Minister cited the need for this data by decision-makers in agriculture, energy, water, health, finance and other sectors to manage risks and opportunities resulting from climate variability and change. The ocean temperature extremes pilot will enable improved marine and coastal planning and response decisions informed by knowledge of changing ocean temperature extremes in the 1-10 year time scale.
				Oliver ECJ, Perkins-Kirkpatrick SE, Holbrook NJ, Bindoff NL. 2017. Anthropogenic and natural influences on record 2016 marine heatwaves. Bulletin of the American Meteorological Society, doi:10.1175/BAMS-D-17-0093.1 Full paper	http://www.ametsoc.net/eee/2016/ch9.pdf	
2.4	01.07.2016	30.06.2019	Ongoing	Updated Argo Australia profiles	www.imos.org.au and	To better simulate changes in the climate and interpret past changes we need to understand how the ocean takes up heat, and how ocean heat uptake may change as a result of climate change. This information is required to inform national and international mitigation policies. With the oceans playing such an important role in regulating the Earth's temperature, if ocean heat uptake were to decrease (for example) under a changing climate, our ability to meet the international targets set in the UN Paris Agreement (1.5C to 2C) would be affected. Better representation of ocean processes in climate models will allow us to gain insights into how our oceans and the heat uptake mechanisms of oceans may change and the influence this will have of global temperatures. This information will assist countries and the international community to therefore determine what actions and policies may be needed to ensure global temperature targets set under the Paris Agreement are met. In addition, outputs from this project, such as contributions to the global compilation of ocean data through the Argo program, ensure Southern Hemisphere ocean data is considered as part of global assessments of the oceans.
				GO-SHIP P15 data finalised and submitted to data centres	www.go-ship.org	
				New version of iQuOD global ocean historical data set with new bias corrections completed	http://www.iquod.org/	
				Ocean Model equilibration period and runs and climate change scenarios complete at 1° and 0.25° resolution and stored in NCI Research Data Collection (Hogg/Stewart)	https://doi.org/10.4225/41/5a2dc8543105a	
				Langlais C, Lenton A, Matear R, Monselesan D, Legresy B, Cougnon E, Rintoul SR. 2017. Stationary Rossby waves dominate subduction of anthropogenic carbon in the Southern Ocean. Scientific Reports, 7, 17076. doi:10.1038/s41598-017-17292-3	https://www.nature.com/articles/s41598-017-17292-3	

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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, Harun Rashid	1,635,000.00	1,704,422.00	3,339,422.00
2.6	Regional Climate Projection Science, Information and Services	Key stakeholders have indicated that they want credible and salient projections to underpin adaptation. However, there are a few areas where uncertainties remain, data are inadequate for impact assessment and uptake has been limited. Furthermore, a new set of climate simulations are due in the 2020's, so we need to begin development of	CSIRO, Michael Grose	1,668,750.00	1,691,576.00	3,360,326.00

Project Number	Start Date	Completion Date	Status	Outputs		Outcomes
				Outputs	Link to output	Project Outcomes
				Silvano A, Rintoul SR, Peña-Molino B, Williams GD. 2017. Distribution of water masses and glacial meltwater on the continental shelf near the Totten Glacier. Journal of Geophysical Research – Oceans, 122, 2050–2068, doi:10.1002/2016JC012115.	http://nespclimate.com.au/publications/	
				Pardo PC, Tilbrook B, Langlais C, Trull TW, Rintoul SR. 2017. Carbon uptake and biogeochemical change in the Southern Ocean, south of Tasmania. Biogeosciences.	https://www.biogeosciences.net/14/5217/2017/	
2.5	01.07.2016	30.06.2019	Ongoing	Rashid H, Zhu H and Sun Z (2017) Initial documentation of key systematic errors in a high resolution (60 km grid) version of the current ACCESS atmospheric model. Earth Systems and Climate Change Hub Technical Report No. 1, NESP Earth Systems and Climate Change Hub, Australia.	http://nespclimate.com.au/publications/	To be prepared for the climatic risks Australia faces as a national and to prepare for these risks, Australian industries, businesses and governments first need accurate and credible information on what the likely changes to our climate will be in the future. This information and data is then able to underpin and inform changes and adaptations in policies and management and planning decisions for the future. The Australian Community Climate and Earth System Simulator (ACCESS) equips Australia with a global climate modelling capability that focusses on the weather and climate of the Australasian and Southern Hemisphere region. There is no other climate model which uniquely focusses on our region. This ensures model simulations and outputs from ACCESS are as accurate for our region as possible. The continual improvement of ACCESS is important in ensuring ACCESS's simulations of important climate processes in our region – focusing on rainfall, extremes, climate variability and change over multiple timescales – are as robust as possible. This ensures policies and decisions are based on the best possible evidence. Outputs from this project will allow inform other projects undertaken by the Hub (Projects 2.1, 2.2 2.3, 2.4, 2.6, 2.9) thereby ensuring information, data and outputs produced in those projects are also as accurate as possible. Outputs form this project align strongly with the ESCC Hub research priorities Building the utility of earth systems and climate change information and Improving our understanding of how the climate system may change in the future by enhancing ACCESS so model simulations and projections for the Australian region.
				Version 1 of the diagnostic toolkit	https://accessdev.nci.org.au/trac/wiki/access/access_DiagnosticToolsV	
				Zhou XB, Alves O, Marsland SJ, Bi DH, Hirst AC. 2017. Multi-decadal variations of the South Indian Ocean subsurface temperature influenced by Pacific Decadal Oscillation. Tellus Series a-Dynamic Meteorology and Oceanography 69. doi:10.1080/16000870.2017.1308055	https://www.tandfonline.com/doi/full/10.1080/16000870.2017.1308055	
				Zhu HY, Maloney E, Hendon H, Stratton R. 2017. Effects of the changing heating profile associated with melting layers in a climate model. Quarterly Journal of the Royal Meteorological Society 143, 3110-3121. doi: 10.1002/qj.3166	https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/qj.3166	
				Zhu H, Jacob C, Ma Y, Warren R, Santra A, Yorgun S, Sun Z. 2017. A comprehensive report of model systematic errors in the latest ACCESS climate models, NESP Technical Report.	http://nespclimate.com.au/publications/	
2.6	01.07.2016	30.06.2019	Ongoing	Brochure 'Our changing climate: Using climate change information to 2030'	http://nespclimate.com.au/publications/	The current suite of climate change projections have continued to used widely by researchers and stakeholders, including industries, governments and communities, to better understand and plan for climate risks. Project outputs will ensure improved confidence in the current projections, particularly rainfall projections. The project will deliver and explain the projections to stakeholders through
				Brochure 'Our changing climate: How will rainfall change in Northern Australia over the coming century?'	http://nespclimate.com.au/publications/	

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		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 climate change projections.				
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, Dewi Kirono	600,000.00	1,200,000.00	1,800,000.00
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,	Bureau of Meteorology, Andrew Dowdy	1,526,250.00	1,534,898.00	3,061,148.00

Project Number	Start Date	Completion Date	Status	Outputs		Outcomes
				Outputs	Link to output	Project Outcomes
				Brown JR, Moise AF, Colman RA. 2017. Projected increases in daily to decadal variability of Asian-Australian monsoon rainfall. Geophysical Research Letters, 44, 5683–5690. doi:10.1002/2017GL073217	http://nespclimate.com.au/regional-projections/	training, workshops and presentations. These activities will help to identify user information needs and make the projections more accessible and increase uptake of the projections for use in impact assessments and adaptation planning in Australia. However, the landscape of climate change projections has evolved. The science and datasets which underpin projections have advanced, and the way end users and stakeholders use projections and for what purpose has also changed. It is therefore timely to start planning for how the next generation of climate projections can be enhanced and focused on end user requirements. If funded in the future, the next generation of updated climate projections will position Australia to produce updated, credible and relevant information in a timely way for use by policy makers and planning managers across the Australian community. The project aligns with ESCC Hub research priorities Building the utility of Earth Systems and climate change information and Improving our understanding of how the climate system may change in the future by progressing projections science, engaging with stakeholders to ensure climate information supports decision making and meets the needs of end users, and delivers future climate simulations into CMIP6.
			Risbey JS, Grose MR, Monselesan DP, O’Kane TJ, Lewandowsky S. 2017. Transient response of the global mean warming rate and its spatial variation. Weather and Climate Extremes, doi:10.1016/j.wace.2017.11.002	https://www.sciencedirect.com/science/article/pii/S2212094716300494		
			Zhang H., Y. Zhao, A. Moise, H. Ye, R. Colman, G. Roff, M. Zhao 2017. On the influence of SST warming intensity/patterns for uncertainties in CMIP5 model rainfall projections: An AGCM study. Climate Dynamics.	http://nespclimate.com.au/wp-content/uploads/2016/03/Post-print-Zhang-et-al-2017.-accessSST.pdf		
			NextGen Climate Projections workshop summary report	http://nespclimate.com.au/wp-content/uploads/2018/06/ESCC-R005-NextGen-projections-		
2.7	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	Water impacts all sectors of Australia's economy. A sustainable future water provision demanded by many of these sectors could be achieved through effective water resources planning, management and infrastructure investment. These activities all require robust knowledge about water futures, both on the demand and supply sides. It is critical to have consistent projections and interpretations of relevant hydroclimate variables and the associated likelihood and uncertainty. Project outputs will provide essential inputs to climate change impact assessments and adaptation actions. Outputs will further develop the nation’s capability and capacity for hydroclimate projections. Working closely with key stakeholders will ensure that the importance and use of project outputs are demonstrated to users and are therefore used to inform water resource planning and management in Australia. The project aligns to ESCC Hub research priorities Building the utility of Earth Systems and climate change information and Improving our understanding of how the climate system may change in the future by engaging with stakeholders to ensure uptake and use of climate information and improving understanding and simulation of Southern Hemisphere climate drivers in our climate models to provide regional information on future climate.
			Kirono DGC, Grose MR, Hennessy KJ. 2017. Increasing risk of months with low rainfall and high temperature in southeast Australia for the past 150 years. Climate Risk Management, 16, 10–21, doi:10.1016/j.crm.2017.04.001	https://www.sciencedirect.com/science/article/pii/S2212096316300717		
			Haverd, V., Smith, B., Nieradzic, L., Briggs, P., Woodgate, W., Trudinger, C. M., and Canadell, J.: 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-discuss.net/gmd-2017-265/		
2.8	01.07.2016	30.06.2019	Ongoing	Fire weather dataset products	Soon to be available at http://www.bom.gov.au/ and http://nespclimate.com.au/	Extreme weather events such as tropical cyclones, east coast lows, thunderstorms, and extreme fire weather incur economic costs associated with property, environmental and human impacts. These events, and the costs associated with

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		<p>displacement and death). Effective disaster risk reduction, emergency response, infrastructure design/operation, planning and policy making all require information about how these extreme events will change in the future. 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.</p>				

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				Outputs	Link to output	Project Outcomes
				Bates B, Dowdy AJ, Chandler R, 2017. Lightning Prediction for Australia Using Multivariate Analyses of Large-Scale Atmospheric Variables, Journal of Applied Meteorology and Climatology, 57, 525-534. doi: 10.1175/jamc-d-17-0214.1	Abstract - http://journals.ametsoc.org/doi/abs/10.1175/JAMC-D-17-0214.1	<p>their impact, are likely to change in a changing climate. Evidence of this change is already becoming clear. In the World Meteorological Organization's Statement on the Status on the Global Climate in 2017 report, they assessed 2017 as the most expensive year on record for severe weather and climate events. Robust scientific information about the influence of climate change on these extreme events is essential for improving the resilience and wellbeing of Australian communities in the future and to ensure effective disaster risk reduction, emergency response, infrastructure design/operation and policy making. Outputs from this project will provide: information on how, when and where extreme weather events occur; an assessment of the ability of climate models to simulate extreme weather events and projections of extreme weather events in the future. Project outputs will also include the development of information and tools in formats that are relevant for making infrastructure more resilient to extreme weather events with lower operating and maintenance/replacement costs in the intermediate to long term, and reduce risks to human health, property and the environment.</p> <p>An example of the policy outcomes of this project's outputs is shown through the production of an extreme fire weather dataset that extends back to 1950 and is updated daily. This dataset has already been used by (for example) the Bureau of Meteorology to provide more comprehensive fire weather information to clients including state fire agencies, emergency services and government groups, and fire agencies and emergency services to place fire weather conditions – which, due to climate change are different from what has been experienced in the past – in the context of events that they have dealt with previously. This helps with planning emergency responses and disaster risk reduction activities, which ultimately results in a reduction in the costs and other impacts on people and property. This project aligns with all of the ESCC Hub research priorities by enhancing Australia's climate modelling capability, better understanding of past extreme weather events and through provision of useable and accessible climate data to key stakeholders to ensure uptake.</p>
				Dowdy A. 2017. Climatological variability of fire weather in Australia. Journal of Applied Meteorology and Climatology, doi:10.1175/JAMC-D-17-0167.1.	Abstract - http://journals.ametsoc.org/doi/10.1175/JAMC-D-17-0167.1	
				Dowdy AJ, Catto JL. 2017. Extreme weather caused by concurrent cyclone, front and thunderstorm occurrences. Scientific Reports, 7, doi:10.1038/srep40359	https://www.nature.com/articles/srep40359	
				Dowdy AJ, Fromm MD, McCarthy N. 2017. Pyrocumulonimbus lightning and fire ignition on Black Saturday in southeast Australia. Journal of Geophysical Research—Atmospheres, 122(14), 7342-7354, doi: 10.1002/2017JD026577	http://nesplclimate.com.au/publications/	
				McCarthy N, McGowan H, Guyot A, Dowdy A. 2017. Mobile X-Pol radar: A new tool for investigating pyroconvection and associated wildfire meteorology. Bulletin of the American Meteorological Society. doi: 10.1175/bams-d-16-0118.1	https://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-16-0118.1	
				Pepler AS, Di Luca A, Evans JP. 2017. Independently assessing the representation of midlatitude cyclones in high-resolution reanalyses using satellite observed winds. International Journal of Climatology, doi:10.1002/joc.5245	http://nesplclimate.com.au/publications/	
				Dowdy, A., Ye, H., Tory, K., Jones, D., Evans, A., Lavender, S., Thatcher, M., Rafter, T., Osbrough, S., Walsh, K., Cavicchia, L., Evans, J., Catto, J., 2017: Extreme weather: improved data products on bushfires, thunderstorms, tropical cyclones and east coast lows, Peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference, 4-6 September 2017, 269.2017.	https://www.bnhcrc.com.au/node/3874	

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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, Pep Canadell	900,000.00	900,000.00	1,800,000.00

Project Number	Start Date	Completion Date	Status	Outputs		Outcomes
				Outputs	Link to output	Project Outcomes
				Tory KJ, Ye H, Dare RA. 2017. Understanding the geographic distribution of tropical cyclone formation for applications in climate models. Climate Dynamics, doi:10.1007/s00382-017-3752-4	Abstract - https://link.springer.com/article/10.1007/s00382-017-3752-4	
2.9	01.07.2016	30.06.2019	Ongoing	<p>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</p> <p>Cheng L, Zhang L, Wang Y-P, Canadell JG, Chiew FHS, Beringer J, Li L, Miralles DG, Piao S, Zhang Y. 2017. Recent increases in terrestrial carbon uptake at little cost to the water cycle. Nature Communications, 8, doi:10.1038/s41467-017-00114-5</p> <p>Global Carbon Budget 2017 dataset</p> <p>ESCC Hub webinar - The Global Carbon Budget 2017 and COP23</p> <p>Jackson RB, Le Quéré C, Andrew RM, Canadell JG, Peters GP, Roy J, Wu L. 2017. Warning signs for stabilizing global CO2 emissions. Environmental Research Letters 12. doi: 10.1088/1748-9326/aa9662</p> <p>Peters GP, Andrew RM, Canadell JG, Fuss S, Jackson RB, Korsbakken JI, Le Quéré C, Nakicenovic N. 2017. Key indicators to track current progress and future ambition of the Paris Agreement. Nature Climate Change, 7, 118–122, doi:10.1038/nclimate3202</p> <p>Poulter B, et al. 2017. Global wetland contribution to 2000–2012 atmospheric methane growth rate dynamics. Environmental Research Letters, 12(9), doi:10.1088/1748-9326/aa8391 Full paper</p> <p>Saunois M, et al. 2017. Variability and quasi-decadal changes in the methane budget over the period 2000–2012, Atmospheric Chemistry and Physics, 17, 11135-11161, doi:10.5194/acp-17-11135-2017</p> <p>Data are the submission of CABLE results to the 'Trends in net land-atmosphere carbon exchange' (TRENDY) global terrestrial biosphere simulation experiment.</p>	<p>https://www.earth-syst-sci-data.net/10/405/2018/essd-10-405-2018-discussion.html</p> <p>Data sets: https://www.icos-cp.eu/GCP/2017</p> <p>https://www.nature.com/articles/s41467-017-00114-5</p> <p>https://www.icos-cp.eu/GCP/2017</p> <p>http://nespclimate.com.au/webinar-the-global-carbon-budget-2017-</p> <p>http://iopscience.iop.org/article/10.1088/1748-9326/aa9662/meta</p> <p>http://www.nature.com/nclimate/journal/v7/n2/full/nclimate3202.html</p> <p>http://iopscience.iop.org/article/10.1088/1748-9326/aa8391/pdf</p> <p>https://www.atmos-chem-phys.net/17/11135/2017/acp-17-11135-2017.pdf</p> <p>Data: http://hpc.csiro.au/users/70496/TR-ENDYv6_CABLE_Aug2017/ Documents: http://hpc.csiro.au/users/70496/TR-ENDYv6_CABLE_Aug2017/documen</p>	<p>Policy makers need information on carbon and greenhouse gases to develop successful national policies and international engagement to achieve climate mitigation targets. They also need accurate and credible evidence to help identify effective carbon mitigation options. While climate policies seek to manage the net emissions of greenhouse gas emissions, large uncertainties remain on how the carbon budget can be best managed to reduce emissions, increase sinks and protect existing carbon stocks. Outputs from this project will help determine the potential for land-based mitigation options in Australia, and the vulnerability of the land sector in a changing climate. This information can then be used to inform environmental and climate change policies in Australia. Outputs include both national and global carbon budget data products that show how carbon dioxide and methane levels are tracking on the pathways needed for global climate stabilisation by the end of the 21st century. Outputs also include the enhancement of ACCESS to estimate global carbon-climate feedbacks of future land use and climate scenarios and enhancement of data delivery systems to make data accessible and discoverable.</p> <p>Support for Australia's involvement in the Global Carbon Project (GCP) also falls under this project, with the project lead chief investigator (Dr Pep Canadell) participating as Director of the GCP. The GCP is the most authoritative and up-to-date assessment of global anthropogenic carbon sources and sinks, and its 2017 carbon budget was announced at the UN COP23 in Bonn, German in 2017. Australia benefits from involvement in the project through both ensuring Australian and Southern Hemisphere science and results are incorporated into the global assessment and by receiving access to credible and robust carbon budget information relevant to our region. This project aligns with ESCC research priorities Building the utility of Earth Systems and climate change information and Improving our understanding of how the climate system may change in the future by enhancing our national climate modelling capability, engaging with stakeholders to ensure information is useable and investigating the impact of human activities on our climate system.</p>

Project Number	Project Title	Project Summary	Lead Organisation and Project Leader	Approved Funding		
				NESP Funding \$'s	Total Other Contributions \$'s	Total Budget
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 in ways that ensure Australians can plan effectively for coastal change.	CSIRO, Kathleen McInnes	1,290,000.00	1,289,027.00	2,579,027.00
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, Stephen Swearer	1,050,000.00	1,142,325.00	2,192,325.00

Project Number	Start Date	Completion Date	Status	Outputs		Outcomes
				Outputs	Link to output	Project Outcomes
2.10	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	As sea levels rise under the changing climate, coastal areas are likely to experience increased erosion and inundation. The effects of storm surge and waves will amplify these impacts, and pose risks to communities, infrastructure and ecosystems on the coast. Local coastal councils and state governments are increasingly considering their climate risks, with many focusing on risks to coastal communities, assets and infrastructures and ecosystems. Planning and preparing for current and future coastal erosion and flooding depends on the availability of regional data linking coastal extreme events to their impacts. However this data is not always readily available. The outputs of this project, which include new information about how extreme sea levels are changing and improved sea level rise and coastal extremes projections, will support national coastal planning, coastal protection activities and coastal investment and development decisions. The provision of data and information under this project, supported the accompanying stakeholder engagement and information sharing activities undertaken, will bridge the gap between scientific knowledge and stakeholder understanding of climate risks – leading to more informed adaptation and resilience on-ground actions and decisions. This project aligns with all of the ESCC Hub research priorities through better understanding of past, current and future sea level rise and coastal hazards, and engagement with stakeholders to ensure information is discoverable and useable.
				Chen X, Zhang X, Church JA, King MA, Watson CS, Monselesan D, Legresy B, Harig C. 2017. The increasing rate of global mean sea-level rise during 1993–2014. Nature Climate Change, doi:10.1038/nclimate3325	http://nespclimate.com.au/wp-content/uploads/2016/03/Preprint-Chen_etal_NCC_2017.pdf	
				Lyu K, Zhang X, Church JA, Hu J, Yu J-Y. 2017. Distinguishing basin-scale modes of the quasi-decadal and multi-decadal sea level variations in the Pacific, Journal of Climate, doi:10.1175/JCLI-D-17-0004.1 Full paper	http://journals.ametsoc.org/doi/full/10.1175/JCLI-D-17-0004.1	
				Wu Q, Zhang X, Church JA, Hu J. 2017. Changes and variability of sea level and its components in the Indo-Pacific during the altimeter era, Journal of Geophysical Research, doi:10.1002/2016JC012345 Abstract	http://nespclimate.com.au/wp-content/uploads/2016/03/Preprint-Wu_etal_JGR_2017.pdf	
				Progress of digitalisation of imaged charges presented at AMOS. Digitisation of registers back to 1900, QC of all digitised data and preliminary analysis of extremes	http://nespclimate.com.au/breathing-new-life-into-old-tide-records/	
				CAWCR Wave Hind cast 1979-2010	https://data.csiro.au/dap/landingpage?pid=csiro:6616	
2.11	01.07.2016	30.06.2019	Ongoing	Kennedy DM, Konlechner T, Zavadil E, Mariani M, Wong V, Ierodiaconou D, Macreadie P. 2017. Invasive cordgrass (Spartina spp.) in south-eastern Australia induces island formation, salt marsh development, and carbon storage. Geographical Research, 56(1), 80-91, doi: 10.1111/1745-5871.12265	http://onlinelibrary.wiley.com/doi/10.1111/1745-5871.12265/full	Local governments who are responsible for coastal management do not always have the resources or means to easily access science-based information on the scale they require. In addition the existing modes of science focus on impacts and not solutions, which are often less effective at encouraging social action. Identifying the best solutions for addressing climate change impacts in coastal ecosystems is currently hampered by (among other things) the multifaceted nature of the complex challenges which requires interdisciplinary research; an incomplete understanding of the processes that influence carbon accumulation rates in coastal vegetation; and a lack of understanding of the value and feasibility of ecological engineering solutions to adaptation to the impacts of coastal climate change impacts. The project outputs include establishment of the NCCC, engagement with stakeholders to define problems, identify research needs and produce solutions, and build capacity in delivering on-ground, solutions-focused and engaged science

Project Number	Project Title	Project Summary	Lead Organisation and Project Leader	Approved Funding		
				NESP Funding \$'s	Total Other Contributions \$'s	Total Budget
2.12	Sea Level Projections for NCCARF	The 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; and communicated the information through guidance material and stakeholder workshops. A goal was to ensure that the 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 has done this by using the latest regional climate projections for Australia, and by working with NCCARF who are delivering this information via their coastal tool CoastAdapt.	CSIRO, Kathleen McInnes	25,000.00	115,000.00	140,000.00
CASE STUDIES						

Project Number	Start Date	Completion Date	Status	Outputs		Outcomes
				Outputs	Link to output	Project Outcomes
				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.	Abstract - https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.14063	and build capacity in delivering on-ground, solutions-focused and engaged science to inform marine and terrestrial coastal management practises. Blue carbon has also become a focus for many levels of government as potentially part of broader climate change mitigation solutions and policies. The NCCC consists of a Blue Carbon theme which improve understanding of how managing Blue Carbon in Australia can contribute to climate mitigation. Outputs will include reduced uncertainty in regional estimates of carbon accumulation rates in coastal vegetation and demonstrated and evaluated feasibility of on-ground activities for increasing carbon storage in coastal vegetation to increase Australia's Blue Carbon storage. This project aligns with all ESCC research priorities as well as the National Marine Science Plan (2015-2055) produced by the National Marine Science Committee in 2015.
2.12	1/9/15	30/12/16	Completed	Updated sea level rise projections incorporated into the NCCARF coastal planning tool, CoastAdapt	https://coastadapt.com.au/tools/coastadapt-datasets	Australian coastal communities are vulnerable to sea level rise and extreme sea levels in the future. Updated sea level rise projections were development following the IPCC Fifth Assessment Report and the release of the Climate Change in Australia climate projections in 2015. These updated projections needed to be made available to coastal managers and planners to ensure they had the most up to date information on future sea levels and sea level allowances. Project outcomes included the inclusion of sea level rise projections in the new NCCARF coastal management tool, CoastAdapt. Project outputs included the latest projections of sea-level rise for each coastal local government area in Australia, including all mainland and Tasmanian Councils and the Torres Strait Islands. CoastAdapt also co-locates the sea-level data outputs developed by the project with other relevant tools for coastal managers, such as the Australian inundation tool and Smartline (CRC for Spatial Information) which provides guidance on the potential for coastal erosion. This combination of tools on the one platform makes relevant, up-to-date information readily accessible, saving time. The level of detail provided in the sea-level information is unprecedented for Australian councils, so planning decisions can be made on a more informed basis. CoastAdapt is an excellent information delivery tool, and has been shown to be used extensively by coastal councils and other coastal planners, managers and relevant governments. Inclusion of project information into CoastAdapt has greatly increased uptake of Hub research across the community.

Project Number	Project Title	Project Summary	Lead Organisation and Project Leader	Approved Funding		
				NESP Funding \$'s	Total Other Contributions \$'s	Total Budget
3.1	Climate change information products for Indigenous communities	In collaboration with the Reef and Rainforest Traditional Owners this pilot is developing a package of 'Climate Change 101' information from across the Hub's research portfolio. The information will be used by an Indigenous climate change champion in outreach activities with the Reef & Rainforest Traditional Owners group. The provision of this climate information will be through a package which includes a PowerPoint presentation, information sheets and a video. The package as been developed in collaboration with traditional owners to ensure the information is relevant and accessible, and can be communicated by traditional owners to traditional owners.	CSIRO on behalf of the ESCC Hub partners, Mandy Hopkins	15,000.00	15,000.00	30,000.00
3.2	Meeting Indigenous priorities for climate change information, capacity building and engagement	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 identifying Indigenous priorities for climate change focussed information, capacity building and forms of engagement. This will contribute to future plans to meet the Hub's Indigenous engagement goal. A national Indigenous engagement workshop will be held in November 2018 to gain common understanding about capabilities of the Hub and the most valuable approaches to respond to Indigenous community needs for climate change information, capacity building and forms of engagement.	CSIRO on behalf of the ESCC Hub partners, Mandy Hopkins	130,000.00	130,000.00	260,000.00
3.3	Climate change impacts on inshore aquatic ecosystems and coastal communities in the Torres Strait Islands: A Workshop	In partnership with the Torres Strait Regional Authority (TSRA) and Australian Fisheries Management Authority (AFMA), this case study explored the impact of climate change on marine ecosystems, fisheries and livelihoods in the Torres Strait Island area. These stakeholders were keen to learn more about the interdependencies between climate change and impacts on inshore fisheries, coral reefs, seagrass beds, mangroves and indigenous coastal communities. A stakeholder workshop was held by the Hub, TSR and AFMA to facilitate outreach, identify key information gaps and needs, generate tailored communication products and identify strategic future options. The workshop report was produced which captures the key discussions and findings from the workshop.	CSIRO on behalf of the ESCC Hub partners, Mandy Hopkins	5,000.00	5,000.00	10,000.00

Project Number	Start Date	Completion Date	Status	Outputs		Outcomes
				Outputs	Link to output	Project Outcomes
3.1	1/1/17	31/12/18	Ongoing	Draft Climate Change 101 package (Power point slide) for use by the traditional owners of the Mackay region	N/A - still in progress.	Climate change threatens the social, cultural and economic wellbeing of many Indigenous communities. Traditional owners are aware of changes to country, but do not necessarily know much about the science explaining the changes. Without understanding the context of the changes, it is difficult to prepare for a future that is very different from the past. The project outputs (climate change 101 package) were developed in collaboration with traditional owners of the Mackay region, and provide information on why climate change is different from other cycles and past changes and what it means for Indigenous communities in the region. The combination of ESCC Hub research and traditional knowledge provides a unique and appropriate tool for communicating and starting discussions with indigenous communities and traditional owners on how climate change will impact their communities.
3.2	1/1/17	31/12/18	Ongoing	Development and planning for the November 2018 National Indigenous Workshop	N/A - still in progress. Indigenous workshop report will be published on the ESCC Hub website later in 2018.	The Earth Systems and Climate Change Hub is one of the first Australian climate change science research organisations to actively and continually engage with, and consider the information needs of, Indigenous communities. Conversations with Indigenous stakeholders have highlighted the importance of first gathering information on what science and information Indigenous communities actually want and need, rather than making assumptions about this. To ensure Indigenous communities are able to provide the Hub with this knowledge and information, the Hub is supporting a national workshop to identify the climate change information and capacity building requirements of our Indigenous stakeholders. The workshop, which is driven and run by Indigenous members, will provide a forum for Indigenous peoples to come together to provide recommendations regarding what climate change information, capacity building and forms of engagement they see as being of greatest value. A workshop report will be developed which will capture the information identified in the workshop by participants and the communities they represent. These recommendations will guide the Hub in the development and delivery of climate change knowledge products that draw on both the Hub's science and traditional knowledge. The workshop will be held in November 2018.
3.3	1/1/17	31/12/18	Completed	Workshop report	http://nespclimate.com.au/wp-content/uploads/2016/03/ESCC-R004-TS-CC-fisheries-workshop-180601.pdf	Fisheries and marine ecosystems in the Torres Strait are economically and culturally important but are vulnerable to the changing climate. The Earth Systems and Climate Change Hub partnered with the Torres Strait Regional Authority to gather together climate change, marine and fisheries scientists, fisheries managers and traditional owners to discuss the implications of climate change on fisheries and marine ecosystems in the region. The information needs and research priorities identified at this workshop will form the basis of ongoing activities to ensure that traditional owners in the Torres Strait have the best available information and tools to help manage climate change impacts on their businesses, communities and country.

Project Number	Project Title	Project Summary	Lead Organisation and Project Leader	Approved Funding		
				NESP Funding \$'s	Total Other Contributions \$'s	Total Budget
3.4	Coastal climate adaptation with City of Greater Geelong	The City of Greater Geelong have expressed a need for additional interpretation material around the selection of extreme sea level and sea level rise scenarios for use by coastal managers in the running of the SWIFT hydrodynamic model. The SWIFT model offers a innovative solution to investigating and mitigating urban flooding under climate change. This case study will work with CSIRO's Data61 and the City of great Geelong to design appropriate guidance material for the use of SWIFT by coastal managers. This will leverage work done under the Hub, Data61 and NCCARF.	CSIRO on behalf of the ESCC Hub partners, Mandy Hopkins and Kathleen McInnes	5,000.00		5,000.00
3.5	Climate variability and change in Western Australia	The Western Australian Government is working to secure the water supply for Perth and the south-west of the state through a number of initiatives, including reducing water use, increasing water recycling and identifying new water sources. A workshop was held in Perth in 2017 which identified and built a shared understanding of immediate (3–5 year) climate research and communication needs and opportunities, and associated priorities for water management in south-west WA. It also built a shared understanding of the ESCC Hub research projects most relevant for southwest WA, and identified opportunities for tailoring and adding value to projects to address climate-related water management needs for the south west of WA. The Hub prepared communication materials to help the Western Australian Government convey information about climate change to their water user stakeholders.	CSIRO on behalf of the ESCC Hub partners, Kevin Hennessy	5,000.00	5,000.00	10,000.00
3.6	Climate Change in Australia mobile website (a prototype)	The climate change projections produced by the NRM Planning for Climate Change project resulted in a wealth of state of the art climate change projection information, including maps, tools and educational products. It encompasses a very large range of regionally important information on how our climate might evolve and associated uncertainties. This work has already been very successful at ground level (Natural Resource Management community) as well as in the impact community. The development of this prototype provides 'on the go' or 'here and now' access to climate change projections. To date, feedback on the prototype has been very positive. This is the first mobile website of it's kind and, if developed further in the future, will further extend the outreach and communications of the climate change projections.	Bureau of Meteorology on behalf of the ESCC Hub partners, Aurel Moise	15,000.00		15,000.00

Project Number	Start Date	Completion Date	Status	Outputs		Outcomes
				Outputs	Link to output	Project Outcomes
3.4	1/1/17	31/12/18	Ongoing	Guidance material for the City of Greater Geelong	N/A - still in progress. Report or impact story will be published on the Hub's website on completion of the case study.	Improving and communicating coastal climate process information will provide coastal planners, developers and decision makers with the information they need to minimise risks now and into the future. This will result in an enhanced ability to respond to the unavoidable impacts of climate change. Previous engagement by the Hub with the Greater City of Geelong resulted in the identification of an area where the Hub could assist coastal managers and planners better assess the risks from extreme sea levels and sea level rise. The Hub will work with the City of Greater Geelong and Data61 to design and communicate guidance material around the selection of extreme sea level and sea-level rise scenarios for use by coastal managers using the SWIFT hydrodynamic model. This model provides next generation solutions to investigating and mitigating urban flooding under climate change. The case study will result in City of Greater Geelong coastal planners and managers being better able to use the SWIFT model to understand risks from sea level to their coast line and coastal infrastructure. This is an on-ground example of how the Hub is helping stakeholders to understand and manage climate risks.
3.5	1/1/17	31/12/17	Completed	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	With variable rainfall against the backdrop of an extended drying trend, managing climate risk to water security in south-west Western Australia is a critical climate challenge. The Hub prepared communication materials for the Western Australian Government to convey the latest climate change science, with a focus on rainfall in south-west Western Australia. An animated map of rainfall over south-west Western Australia was provided by the Hub which clearly showed that since 1900 cool season rainfall has decreased over the region, particularly since the 1950s, even though there is variability from year to year and decade to decade. Extending the animation into the future shows the drying will continue, with the extent depending on whether we follow a high or lower emissions scenario. These materials make the latest climate change science accessible to water suppliers and users in the region, so it can be used to inform and support decisions about water security.
3.6	1/1/17	31/12/17	Completed	Development of a prototype mobile website/app	N/A - prototype only	The current suite of climate change projections produced under the Regional NRM Planning for Climate Change Fund resulted in a wealth of state of the art climate change projections information, data, maps, tools and educational products. The prevalent use of smart phones within Australia has resulted in an expectation that information be available 'now and here'. The development of a mobile website would allow quick and easy access to climate change projections on the go, in the field or just at a BBQ - without the need for a desktop computer or lap top. Building on the vast resources of the Climate Change in Australia website, this first of its kind climate change projections phone app would provide an accessible interface to the projections data and therefore potentially increase the dissemination and use of the information significantly. Hub researchers have developed a prototype of such a mobile website, and have surveyed potential users on its usability and accessibility.

Project Number	Project Title	Project Summary	Lead Organisation and Project Leader	Approved Funding		
				NESP Funding \$'s	Total Other Contributions \$'s	Total Budget
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. In this case study the Hub conducted a roadshow to local Victorian councils and provided a survey to capture the climate science information needs of interested councils.	CSIRO on behalf of the ESCC Hub partners, Mandy Hopkins	7,228.00		7,228.00
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. This case study supported an upgrade to the sea-level web page to a more secure platform and at the same time enhance its utility. The website now provides a much broader range of coastal hazards information than the old website, as requested by the broader community. This has enhanced the user base of the website and created an effective platform for the delivery of new information that is planned through Project 2.10.	CSIRO on behalf of the ESCC Hub partners, Kathleen McInnes	10,000.00		10,000.00
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 worked with Tiwi stakeholders 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.	Melbourne University on behalf of the ESCC Hub partners, David Kennedy and Jon Barnett	5,000.00	5,000.00	10,000.00
				13,285,181.00	14,273,044.00	27,558,225.00

Project Number	Start Date	Completion Date	Status	Outputs		Outcomes
				Outputs	Link to output	Project Outcomes
3.7	1/1/17	31/12/17	Completed	Hub impact story based on discussions with 4 Victorian local councils on their climate change information needs, and barriers to the incorporation of climate change information into councils decisions and plans.	http://nespclimate.com.au/publications/	Many climate change impacts will be experienced at regional and local levels, so councils may often be best placed to manage these risks. Climate change has the potential to damage council assets, cause serious disruptions to the delivery of council services, generate unbudgeted financial impacts and affect the wellbeing of the community, particularly those vulnerable to weather extremes. It is therefore important that local and regional councils are provided with the information and guidance they need to prepare for the unavoidable impacts of climate change. The Hub will work with a small number of regional Victorian councils to develop useful knowledge brokering and communication resources that package climate information in a way that is useful and accessible for these councils. These knowledge products will be drawn from across the Hub research portfolio. The case study will build the capacity of local councils to identify, use and apply climate information, and will increase the use and uptake of Earth Systems and Climate Change Hub research.
3.8	1/1/17	31/12/17	Completed	Web delivery portal for engaging with the coastal community	Sea Level, Waves & Coastal Extremes website	Prior to the development of the Sea Level, Waves & Coastal Extremes web delivery portal, limited information on sea level rise was provided in a less accessible and user friendly manner. The new web portal developed by the Earth System and Climate Change Hub consolidates information on a wider range of coastal hazards (such as sea level change, waves, coastal extremes and ocean energy) and improves access to this information and data. The new web portal presents information and data in an accessible, clear and well communicated manner appropriate for a range of users and stakeholders including the research community, governments, businesses, school students and the community. The web portal describes processes driving coastal impacts across a range of time and space scales, presenting the most up-to-date research in this area. The portal is an important tool for communicating and providing access to Hub research in this area, thereby increasing the uptake and use of this research across the community.
3.9	1/1/17	31/12/17	Completed	Tiwi Island workshop report	http://nespclimate.com.au/wp-content/uploads/2016/03/Workshop-report-Tiwi-Islands_Climate-Change-Adaptation-Report.pdf	Local Tiwi Island people often struggle to relate the big scales of climate impacts science to the local, social and environmental processes that are important and relevant to them. Previous engagement with the Tiwi around climate change alarmed local residents and escalated feelings of powerlessness. Solutions to climate change impacts in the coastal zone require solutions focussed science that co-produces knowledge and practices with relevant stakeholders to inspire and enable local communities to act on their values and goals for the future. Working with the Tiwi Land Council a workshop was held to educate local communities about climate adaptation. The outcome of the workshop was a report that provides a foundation for working with the Tiwi to develop practical guidelines for monitoring and adaptive management of coastal erosion in the Islands.

NESP ESCC Hub 2017 Impact Story

Climate change science for a safer Australia: providing fire weather data to ensure emergency services policies and practices incorporate climate change

Project

Project 2.8 – Extreme weather projections

Summary

Australia has experienced a sequence of severe fire seasons in recent years, leading to the loss of many lives and properties. The seasons have stretched the capabilities of fire services and communities. Understanding how weather conditions that influence fire activity have changed and how future risks may need to be managed will help with planning to minimise future losses. Earth Systems and Climate Change Hub researchers produced a dataset of fire weather conditions that extends back to 1950 and is updated daily. The Bureau of Meteorology Climate Information Services group is using this dataset to provide weather warnings, maps and planning information to emergency services. The dataset has also been used to inform the Australasian Fire and Emergency Services Authorities Council (AFAC). As a result, climate risks will be better managed and considered in future AFAC policy and practices for emergency management throughout Australia.

Narrative

In the past, fire weather studies and datasets have been based on information about single locations. While this helps us understand the fire weather at a given point, it does not provide information about how fire weather varies across a region. Earth Systems and Climate Change Hub researchers developed a dataset that uses observations of fire weather conditions throughout Australia to identify regions with exceptionally dangerous fire weather. This dataset covers a longer period than earlier datasets – from 1950 onwards – so we now have more confidence in assessing longer fire weather patterns.

The dataset clearly shows that the severity of fire weather conditions has increased in recent decades in many parts of Australia. Fire weather conditions we have experienced in recent years (including for Victoria's Black Saturday bushfires in 2009 and the February 2017 conditions in New South Wales and Queensland) are more dangerous than conditions that fire managers would have previously faced in those regions. This means that pre-existing procedures for managing bushfires will need to be modified based on the global warming that has occurred to date and will continue to occur this century.

The fire weather dataset was initially developed for the Bureau of Meteorology's Climate Information Services group, which prepares information and guidance used by fire agencies, emergency services and government groups to plan for potential bushfire conditions. The Bureau are using the dataset to produce warnings and maps that show fire weather for a given month in terms of average and record fire weather, as well as map how often (on average) conditions of a particular severity occur at a given location.

With this dataset, the Bureau's Climate Information Services group are now providing an additional dimension of information to fire agencies, emergency services, and local councils and planning authorities. This will lead to better informed planning for emergency responses and disaster risk reduction activities, which not only may result in more efficient resourcing and response capabilities, but ultimately a reduction in the costs and other impacts on people and property.

Along with this 'on-the-ground' application, the dataset and underpinning research are informing emergency management policy and planning. The Australasian Fire and Emergency Services Authorities Council (AFAC) is the peak body for public sector fire, land management and emergency services organisations in Australia and New Zealand. AFAC drew on information from this dataset in their Climate Change Discussion Paper, developed to provide guidance on planning in relation to the risks of climate change on natural hazards. AFAC's incorporation of climate change impacts into their policies and practices is likely to influence a range of fire and emergency services organisations and practices across Australia.

The research community also benefits from access to information products derived from the dataset, which can be used for a range of applications, including examining long-term trends and the influence of climate change and the influence of the El Nino-Southern Oscillation. For example, CSIRO and UNSW scientists recently used the dataset to assess how well models represent spatial and seasonal variations in gridded fire weather conditions for the current climate. This work will also help to improve confidence in projections of future changes in fire weather extremes.

Hub researchers will continue to work closely with the fire and emergency services sector, state governments and the research community to ensure current and future impacts of climate change are considered in relevant policies and practices.

Research outputs

Fire weather dataset – www.nesplclimate.com.au.

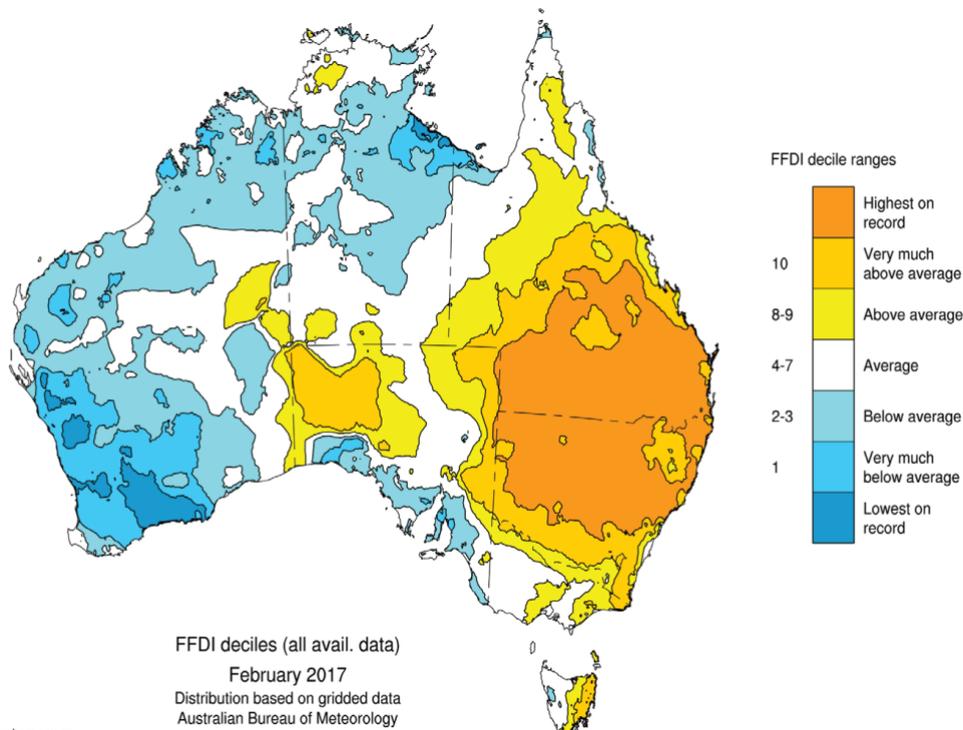
Dowdy, A., 2017: Climatological Variability of Fire Weather on Australia. *Journal of Applied Meteorology and Climatology*, **57**, 221-234.

Dowdy, A., Ye, H., Tory, K., Jones, D., Evans, A., Lavender, S., Thatcher, M., Rafter, T., Osbrough, S., Walsh, K., Cavicchia, L., Evans, J., Catto, J., 2017: Extreme weather: improved data products on bushfires, thunderstorms, tropical cyclones and east coast lows, *Peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference*, 4-6 September 2017, **269.2017**.

Attributions

This research was led by ESCC Hub Project 2.8 team members (Lead Chief Investigator Dr Andrew Dowdy), in collaboration with members of the Bureau of Meteorology Climate Information Services group.

The Hub and the Bureau produced the data, and Climate Information Services staff within the Bureau helped ensure it was in a format compatible with their existing analysis tools.



This map is an example of the information generated using the dataset. It shows that the Forest Fire Danger Index (FFDI) values in February 2017 were above average for most of eastern Australia, with large regions experiencing the highest FFDI values on record.

NESP ESCC Hub 2017 Impact Story

Understanding climate change implications for Torres Strait fisheries and marine ecosystems

Project

Case study 3.3 – Climate change impacts on inshore aquatic ecosystems and coastal communities in the Torres Strait Islands

Summary

Fisheries and marine ecosystems in the Torres Strait are economically and culturally important but are vulnerable to the changing climate. Helping Torres Strait islanders understand their climate risks requires careful relationship fostering between islanders and knowledge providers. It also requires the communication of this information in a manner which is accessible and relevant to islanders. The Earth Systems and Climate Change Hub partnered with the Torres Strait Regional Authority to gather together climate change, marine and fisheries scientists, fisheries managers and traditional owners to discuss the implications of climate change on fisheries and marine ecosystems in the region. The relationships built and information needs and priorities identified through this activity provided a new level of understanding around the climate risks to Torres Strait fisheries and marine ecosystems. This understanding and the new relationships built will form the basis of ongoing activities to ensure traditional owners in the Torres Strait have the best available information and tools to help manage climate change impacts on their businesses, communities and country.

Narrative

Fisheries and marine ecosystems in the Torres Strait are economically and culturally important. They are also vulnerable to the changing climate.

Marine impacts from climate change in the Western and Central Torres Strait will include coastal erosion, declines in reef health and diversity, loss of critical inshore habitat, increased sea temperatures and sea levels and changes to currents and water quality; all of which will have a variety of direct and indirect impacts on fish stocks and marine ecosystems. Climate change will affect fisheries productivity, species distributions and seasonality, so subsistence and commercial fishery practices will need to be able to adapt to shifting circumstances.

Helping Torres Strait islanders understand their climate risks requires careful relationship fostering between islanders and knowledge providers. It also requires the communication of this information in a manner which is accessible and

relevant to islanders. It is important that all relevant parties are engaged in conversations about what climate change means for fisheries and marine ecosystems in order to prepare for the changes. Local traditional knowledge and scientific knowledge from the research community are important tools which can and should be integrated to help understand and prepare for future changes.

The ESCC Hub partnered with the Torres Strait Regional Authority (TSRA) to bring together, for the first time, climate change, marine and fisheries scientists, fisheries managers and traditional owners to review the current state of relevant local and scientific knowledge about climate change impacts on Torres Strait inshore fisheries and marine ecosystems. This allowed a meaningful dialogue and relationships to be built between research providers and traditional owners.

During this activity representatives from the ESCC Hub, TSRA, CSIRO, the NESP Tropical Water Quality Hub, Australian Fisheries Management Authority, Australian Institute of Marine Science, Great Barrier Reef Marine Park Authority and traditional owners discussed research and on-country observations that show that climate change impacts are already occurring: research provides the evidence of this, communities see it on country (land and sea) and fishers see it in the changing state of natural resources.

The key message from this activity was that ongoing research into both the biological and physical components of the ecosystem is crucial to understand the changes, as is building the capacity of local communities to adapt to them. The research priorities identified, along with the information needs to support management and adaptation, will serve as a key reference for ongoing work to ensure that traditional owners in the Torres Strait have the best available information and tools to help manage climate change impacts.

By bringing together traditional owners and knowledge providers, the ESCC Hub has helped to foster and build valuable relationships which will enhance the success of future climate change research and adaptation activities in the area.

Research outputs

The findings and outcomes of this engagement activity have been recorded in the report *Climate change in the Torres Strait: Implications for fisheries and marine ecosystems*, available on the ESCC Hub [Publications](#) web page.

Attributions

This activity was a collaboration between the ESCC Hub and the TSRA. Members of the workshop committee were Mandy Hopkins, Geoff Gooley and Karen Pearce (ESCC Hub), John Rainbird and Mariana Nahas (TSRA), Selina Stoute and Ian Butler (AFMA) and Johanna Johnson (TWQ Hub).

NESP ESCC Hub 2017 Impact Story

Improving access to data and information on sea level, waves and coastal extremes for better coastal planning and practices

Projects

Case study 3.8 – Web delivery portal for coastal hazards information

Project 2.10 – Coastal hazards in a variable and changing climate

Summary

Prior to the development of the new [Sea Level, Waves & Coastal Extremes website](#), sea-level rise information from science leaders had a technical focus and was delivered on an old website maintained by the CSIRO and the Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC). The new website developed by the Earth System and Climate Change Hub consolidates this information and brings in additional material on a wide range of coastal hazards, including waves, coastal extremes and ocean energy. The new website also improves accessibility and readability of this information and data. The information is delivered in ways that are appropriate for a range of users and stakeholders including the research community (through datasets and scientific papers), and governments, businesses and school students (through high level summary information and figures). The improved accessibility of this information enhances its uptake and the ability of this information to be used by stakeholders, such as the Australian wave energy industry, the CoastAdapt website and local councils.

Narrative

Technical science output from sea-level rise researchers across Australia has, for a long time, been delivered through an old website maintained by CSIRO and the Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC). While popular with researchers and research users, the website was very old and in need of a refresh to both update scientific content and make it more accessible and appealing to a wider audience.

The Earth Systems and Climate Change Hub has developed a new website that consolidates information on an expanded range of coastal hazards – sea-level change, waves, coastal extremes and ocean energy – in formats and at technical levels suitable for a range of website visitors. It contains and presents information about physical coastal process and sea-level rise in ways that are accessible to non-

scientific audiences (such as high school students) while also providing access to research papers and data relevant to university students through to researchers.

For example, the website provides researchers with access to research papers and a range of data, both directly and through links to relevant sites in the CSIRO Data Access Portal, and national and international data facilities such as CoastAdapt. The website also contains sea level and coastal hazard information, including papers and literature reviews, suitable for senior secondary and university students.

Coastal engineers and managers can access the latest figures on global averaged sea-level rise and schematic figures for their reports that explain contributions to coastal sea levels. There is also a tool that replicates the functionality of Canute 2.0, (a University of Tasmania sea-level tool no longer being developed) that provides extreme sea level information and sea-level allowances for use in planning now and into the future.

Information provided through the website has fed into a number of guidelines and adaptation web portals. For example, the data on sea level rise and allowances was used to inform the [CoastAdapt](#) website developed by the National Climate Change Adaptation Research Facility. CoastAdapt is used by a variety of local and state level coastal planners and managers to assess and manage climate risks to coastal ecosystems, communities and assets.

Information provided on the website on tides, waves, currents and thermal energy conversion was used to provide wave energy projections and assess the potential of wave energy to be included in the future energy mix for Australia. This information has supported the wave energy industry in Australia to develop best practice guidance for assessing impacts of wave energy extraction on the marine and coastal environment.

The new website acts as an information and data repository for the fundamental climate change science which underpins coastal hazards. It also provides links to websites, projects and information relevant to coastal climate risks. In this way the web site provides the information and data needed by various stakeholders to understand climate risks, and links users to a variety of adaptation and risk assessment websites to assist stakeholders in using climate change science information in coastal guidelines and practices.

Research outputs

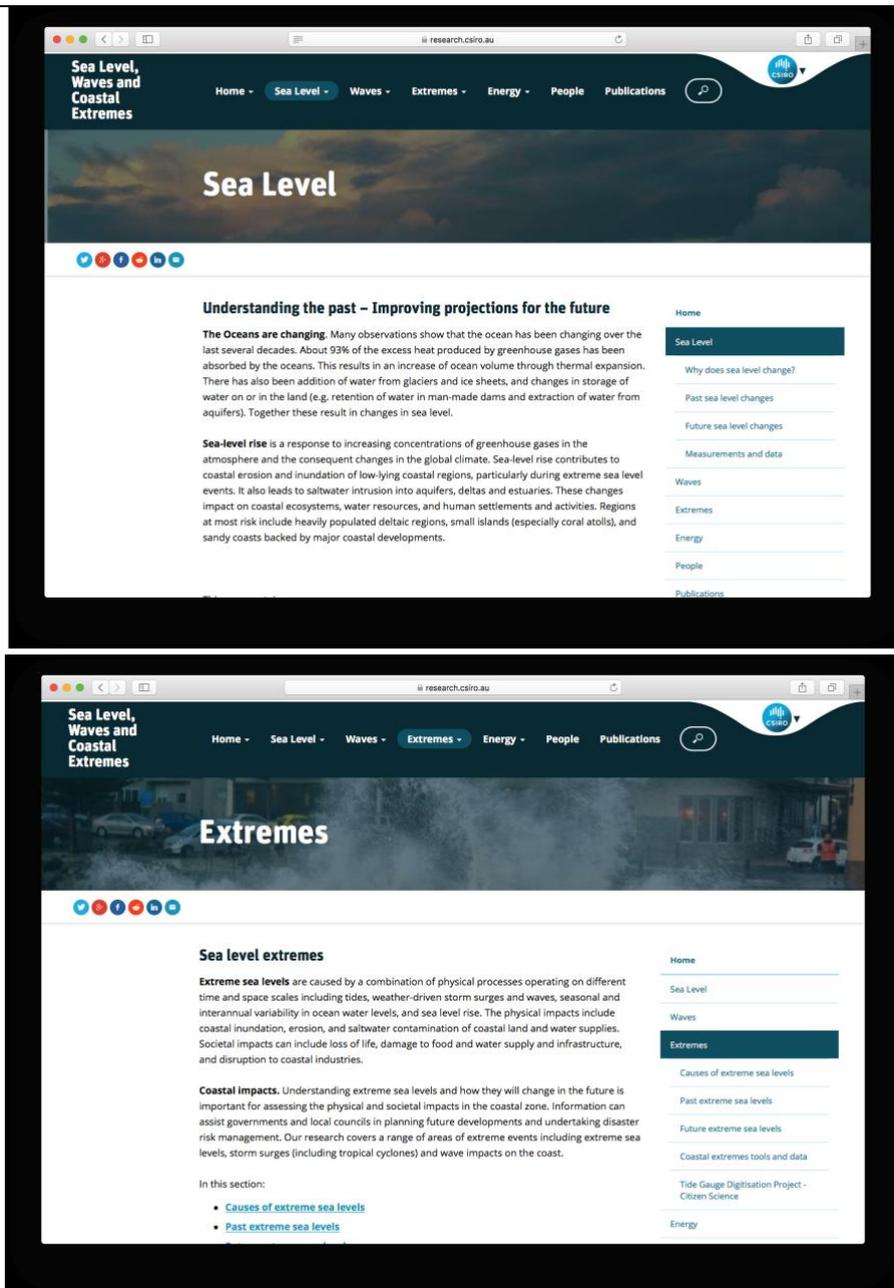
The Sea Level, Waves & Coastal Extremes web portal is available at <https://research.csiro.au/slrwavescoast/>.

Attributions

Contributing ESCC Hub researchers: Kathy McInnes, Mark Hemer, Ron Hoeke and Julian O'Grady.

Raw data used from NASA, NOAA, CNES, EUMETSAT, NTC, PSMSL, ECMWF and the ESGF. Computational work is performed on resources operated by CSIRO, the Bureau of Meteorology, TPAC and NCI.

World leading sea level rise research by Dr John Church and Dr Xuebin Zhang is also an important component of the web portal.



Example of web pages from the Sea Level, Waves & Coastal Extremes web portal

NESP ESCC Hub 2017 Impact Story

Understanding the climate drivers of the 2015 Gulf of Carpentaria mangrove dieback

Projects

Project 2.2 – Enhancing Australia’s capacity to manage climate variability and climate extremes in a changing climate

Project 2.3 – Towards an ACCESS decadal prediction system

Summary

In late 2015 more than 7000 hectares of mangroves died along the south-west coastline of the Gulf of Carpentaria. This event appears to be unprecedented. Initial investigations into the dieback suggested that climate factors played a role in the dieback. After an all-Hub discussion, researchers from the Northern Australia Environmental Resources, Tropical Water Quality and Earth Systems and Climate Change Hubs took a closer look to determine how this might have occurred. Researchers from the ESCC Hub discovered that the coincidence of unusually hot and dry conditions with low sea level likely provided a stressful environment for the mangroves. This cumulative stress during most of 2015 almost certainly contributed to the major dieback near the end of 2015. Understanding why this dieback happened is important for ongoing management of the mangroves to ensure the critical environmental services they provide are not compromised in the future. This work has initiated a larger study that is currently underway to assess the extent of dieback across the Gulf.

Narrative

Mangroves are a vitally important part of the local ecosystem, providing homes and nurseries for an array of aquatic life, protecting coastlines from extreme weather and erosion, filtering out sediment from river run-off to protect coral reefs and seagrass, as well as absorbing and storing large amounts of carbon dioxide.

In late 2015, more than 7000 hectares of mangroves died along the 700 km south-west coastline of the Gulf of Carpentaria. Understanding why this dieback happened is important for ongoing management of the mangroves to ensure that the critical environmental services they provide are not compromised in the future.

In 2016 the Minister of the Environment and Energy identified the event as a priority for the National Environmental Science Program (NESP), requesting cross-Hub collaboration to investigate the causes. After an all-Hub discussion, researchers

from the Northern Australia Environmental Resources, Tropical Water Quality and Earth Systems and Climate Change Hubs took a closer look to determine how this might have occurred.

ESCC Hub researchers investigated the oceanic and atmospheric conditions leading up to the major mangrove dieback in late 2015 to identify the climate drivers that contributed to the tree deaths. They found that the dieback event was preceded by a combination of relatively dry conditions, unusually low local sea levels due to the strong El Niño in 2015/16, and high air temperatures (November 2015 was the warmest on record for much of the affected coastline). In fact, the combination of dry and warm conditions in the six to nine months preceding the dieback has likely not been experienced since records began in 1971, however further work is required to confirm this preliminary result. This cumulative stress during most of 2015 almost certainly contributed to the major dieback near the end of 2015.

Better understanding of why this large mangrove dieback event occurred is important when considering ways to manage or prevent future mass dieback events, including how the ecosystem can be better managed or protected as our climate continues to change. This work has provided the catalyst for a larger study that is currently underway to assess the extent of dieback across the Gulf. Further analysis of this issue may lead to a better understanding of how the ecosystem should be managed and protected into the future.

Research outputs

Harris T, Hope P, Oliver E, Smalley R, Arblaster J, Holbrook N, Duke N, Pearce K, Braganza, K and Bindoff N. 2017. Climate drivers of the 2015 Gulf of Carpentaria mangrove dieback. Earth Systems and Climate Change Hub Technical Report No. 2, NESP Earth Systems and Climate Change Hub, Australia. Available on the Hub [Publications](#) web page.

Attributions

ESCC Hub researchers worked closely with researchers from the Northern Australia Environmental Resources and Tropical Water Quality Hubs, in particular Damien Maher, Damien Burrows and Lindsay Hutley. Ruth Reef, Cath Lovelock and Marilyn Ball provided guidance on mangroves and their stressors. Thanks also to Stephen Swearer (ESCC Hub, NCCC) and Todd Harris, who was a summer student through the ARC Centre of Excellence for Climate System Science.

NESP ESCC Hub 2017 Impact Story

Identifying Indigenous climate change information priorities

Project

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

Summary

Indigenous communities across Australia are vulnerable to the impacts of climate change. Strong and lasting relationships and relevant communication methods are required to help Indigenous stakeholders understand and manage these impacts. They are also necessary to help the ESCC Hub understand the climate change information that is most useful and relevant to Indigenous communities, and to explore ways that traditional knowledge can inform the Hub's research. By engaging constantly and meaningfully with Indigenous stakeholders the ESCC Hub has developed strong relationships and has begun to enhance the capacity and understanding of both the Hub researchers and Indigenous communities. To further this, and to increase the Hub's understanding of the climate change priorities for Indigenous stakeholders, a national Indigenous workshop is currently being developed and will be held in November 2018. This workshop will identify the climate change information and capacity building requirements of Indigenous stakeholders. The recommendations from the workshop, which is Indigenous led, will inform the Hub's ongoing engagement with Indigenous communities.

Narrative

Indigenous communities are vulnerable to many climate-related risks. As coastal and island communities confront rising sea levels, rainfall and heat extremes, and many inland regions become hotter and drier, Aboriginal and Torres Strait Islander people face the potential loss and degradation of the lands, waters and 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 their traditional life, languages, knowledge and cultural heritage.

At the same time, Indigenous communities are custodians of a wealth of knowledge about Australia's weather and climate, which underpins their adaptive capacity and strategies in response to climate change.

Strong and lasting relationships and relevant communication methods are required to help Indigenous stakeholders understand the impacts of climate change. They are

also necessary to help the Earth Systems and Climate Change Hub and its researchers understand the climate change information that is useful and relevant to the Indigenous communities, and to explore ways that traditional knowledge can inform the Hub's research. By engaging constantly and meaningfully with Indigenous stakeholders the ESCC Hub has developed strong relationships and has begun to enhance the capacity and understanding of both its researchers and Indigenous communities.

The ESCC Hub is currently working with Indigenous stakeholders to identify the climate change information that is useful and relevant to their communities, and to explore ways that traditional knowledge can inform the Hub's research.

A key activity in this will be the national Indigenous workshop (November 2018) that will provide the forum for Indigenous peoples to come together to provide recommendations regarding what climate change information, capacity building and forms of engagement they see as being of greatest value.

While the Hub is providing resources via an Organising Committee to support the Steering Committee, the workshop and its agenda is largely driven by Indigenous stakeholders, ensuring the workshop will deliver useable and relevant information and outcomes to their communities. The development of the workshop agenda is driven by the priorities identified by the workshop Steering Committee. The Steering Committee comprises of representatives from the Kimberley Land Council, the Yorta Yorta Nation Aboriginal Corporation and Seed, Australia's first Indigenous youth-led climate network, as well as the University of Melbourne.

The workshop outcomes and recommendations will guide the Hub in the development and delivery of climate change knowledge products that draw on both the Hub's science and traditional knowledge, and will inform the Hub's ongoing engagement with Indigenous communities.

Research outputs

A report summarising the outcomes and findings from the November 2018 national Indigenous workshop will be posted on the ESCC Hub website by the end of 2018.

Attributions

The Steering Committee members are; Larissa Baldwin (Seed), Sam Johnson (University of Melbourne), Damian Morgan-Bulled (YYNAC) and Peter Murray (KLC). This committee is supported by the Organising Committee comprising Hub advisors and staff (Ro Hill, Leah Talbot, Mandy Hopkins and Marian Sheppard).

NESP ESCC Hub 2017 Impact Story

Preparing for climate change and coastal erosion in the Tiwi Islands

Project

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

Summary

Climate change will have significant social, environmental and financial impacts on the communities of the Tiwi Islands, which are largely coastal and remote. Coastal erosion will be a particular issue. However, it is often difficult for the people of the Tiwi Islands to relate the big scales of climate change impacts science to the local, social and environmental processes that are important and relevant to them. Previous engagement with the Tiwi around climate change has alarmed local residents and escalated feelings of powerlessness. So the Hub, working with the Tiwi Land Council, undertook engagement and knowledge brokering activities to discuss climate adaptation with local communities. Trust and respect were required to build relationships and understand the concerns and priorities of the local communities. The information, discussions and relationships built during these engagement activities provide a foundation for potential future work with the Tiwi to develop practical and guidelines for adaptive management of coastal erosion.

Narrative

The Tiwi Islands are at risk of social, environmental and financial damages from climate change impacts, particularly coastal erosion. The majority of Tiwi Island communities are along the coastline and are remote, with many accessible only by boat or plane. Future changes in climate and sea level are unavoidable and will affect the people on the Tiwi Islands and the places and practices they value.

It is critical that communities begin planning for the inevitable impacts of climate change. Early implementation of a no-regrets adaptation strategy and a longer-term staged approach will help mitigate the impacts of climate change through preparedness and preventative action. By developing a climate change strategy and adapting management practices, the Tiwi Islands can become a national leader in climate change responses, and act as an example of best practice for climate change adaptation.

Working with the Tiwi Land Council, the Hub (through the National Centre for Coasts and Climate) developed strong and trusted relationships with Tiwi islanders and

undertook engagement activities, including a workshop, to discuss opportunities and challenges associated with adapting to climate change in the Tiwi Islands.

Tiwi participants shared their concerns for how climate change may affect their communities, which included impacts of climate change on:

- wet and dry seasons, the timing and strength of the monsoon and frequency of cyclones
- physical processes such as coastal erosion and flooding, king tides, storm surges and inundation
- ecologically important habitats such as seagrasses, corals, mangroves and beaches
- infrastructure such as the power grid, roads and bridges, and health facilities.

There were also discussions about how to adapt management practices to reduce these impacts, including changes to disaster management plans and fire management practices, and implementing new monitoring projects.

A number of follow up actions were agreed at the conclusion of the workshop, which included engaging with the Office of Township Leasing, the Tiwi Leaders forum and the Tiwi Land Council; finding and incorporating climate change information into planning strategies and management plans; the formation of a climate change working group; and immediate planning for roads at risk of flooding. Delivering on these actions is expected to lead to longer-term benefits to climate change awareness and adaptation planning in the Tiwi Islands.

The success of the engagement activities and the relationships built between researchers and Tiwi Islanders is shown through the request that the research team return to the islands in the wet season to observe the seasonal impacts of climate change firsthand. Plans will be developed in 2018, pending available resources, for the research team to return to the islands for follow up activities.

Research outputs

Barnett J, Head L, Konlechner T, Swearer S, Leitch A (2017). *Adapting to Climate Change in the Tiwi Islands*. Report on the Climate Change Adaptation workshop for the Tiwi Land Council (November 2017). This report can be found on the ESCC Hub [Publications](#) web page.

NESP ESCC Hub 2017 Impact Story

Supporting communication of climate challenges for water resources management in Western Australia

Project

Case study 3.5 – Climate variability and change in Western Australia

Summary

With variable rainfall against the backdrop of an extended drying trend, managing climate risk to water security in south-west Western Australia is a critical climate challenge. The Earth System and Climate Change Hub worked with the Western Australian Government to prepare communication materials for the Government to convey the latest climate change science, with a focus on rainfall in south-west Western Australia. These materials make the latest climate change science accessible to water suppliers and users in the region so it can be used to inform and support decisions about water security. The communication materials developed by the Hub will be incorporated into the WA Department of Water and Environmental Regulation website and used by the Department when communicating with water users and water related stakeholders.

Narrative

Rainfall in south-west Western Australia varies from season to season, year to year and decade to decade, with both drier than usual periods and wetter than usual periods. However in south-west Western Australia, this variability is occurring on top of an extended period of drying, particularly in autumn and early winter. This drying is projected to continue in the future and extend into spring. The combination of climate variability and climate change has serious consequences for water security in the region.

Through the Department of Water and Environmental Regulation and WA Water Corporation, the Western Australian Government is working to secure the water supply for Perth and the south-west of the state through a number of initiatives, such as 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 worked with the Western Australian Government to prepare communication materials to convey information about climate change to their users.

An animated map of rainfall over south-west Western Australia was provided by the Hub which clearly showed that since 1900 cool season rainfall has decreased over the region, particularly since the 1950s, even though there is variability from year to year and decade to decade. Extending the animation into the future shows the drying will continue, with the extent depending on whether we follow a high or lower emissions scenario.

A short publication produced by Hub researchers explaining how to account for both climate variability and climate change when managing climate risks was also provided to the government as part of the communication package. *Our changing climate: Using climate change information to 2030* includes a case study examining how the combination of climate variability and climate change could combine to influence rainfall in south-west Western Australia in the years to 2030.

The WA Department of Water and Environmental Regulation is in the process of incorporating these materials into their website and communication materials to make the latest climate change science accessible to water suppliers and water related stakeholders in south-west Western Australia. This information can then be used to inform and support decisions about water security in the region.

Research outputs

Our changing climate: Using climate change information to 2030 is available on the ESCC Hub [Publications](#) web page.

The animation rainfall map was delivered to the Western Australian Government in a PowerPoint slide pack, and will be made publicly available on both the Hub and the WA Government's website once approval is gained from the Government.

Attributions

Products were developed by Hub researchers in Project 2.2 Enhancing Australia's capacity to manage climate variability and extremes in a changing climate; Project 2.6 Regional climate projection science, information and services; and Project 2.7 Refining Australia's water futures.

NESP ESCC Hub 2017 Impact Story

Supporting the next generation of knowledge providers and decision-makers within the Australian climate change science and services landscape

Project

A cross-cutting Hub activity

Summary

While the realities of climate change are already apparent, the impacts and risks are likely to continue and increase. This means the responsibility for developing and applying new scientific knowledge to inform adaptation and climate-related risk management policy and planning will increasingly fall on the shoulders of future generations of scientists and decision-makers within government and the private sector. The Earth Systems and Climate Change Hub established a Young Professionals Network to support both early career climate science researchers and sector based young professionals to develop technical capacity to deliver and apply climate change science, and to enhance links within and between these two key groups. New professional relationships are being created through this network which will facilitate ongoing engagements and relationships that will be advantageous in the process of addressing long-term climate risks for Australia.

Narrative

With the ever-increasing reality of direct impacts from climate change on Australia's people, resources and infrastructure comes a heightened national need to better manage long-term climate risks. Many of these risks will play out over long (multi-decadal) timescales, and so the responsibility for developing and applying new scientific knowledge to inform adaptation and climate-related disaster risk management policy and planning will increasingly fall on the shoulders of future generations of scientists and decision-makers within government and the private sector.

The Hub established a Young Professionals (YP) Network to develop capacity and facilitate networking and awareness raising between sector-based young professionals and Hub early career researchers in relation to the practical, mainstream application of climate change science and services in Australia. The Hub Stakeholder Advisory Group (HSAG) plays an active role in facilitating stakeholder engagement as part of the development and delivery of the Hub's annual Research Plans. More recently, the HSAG has also been active in promoting links between YPs and early career researchers through the establishment of the Young Professional's Network, which has an initial focus on the banking, finance and insurance sectors.

The YP Network currently comprises of early career researchers, including PhD students and post-docs, and young sector professionals. The network consists of representatives drawn from Hub partner organisations (representing the main climate change research institutions in Australia), other NESP Hubs and from private and public organisations from across the Australian economy and political landscape. The network members form part of the science/services-based climate change knowledge value chain.

The YP Network comes together at organised 'climathon' events hosted by the Hub's sectoral collaborators. These dynamic events are delivered around problem-solving exercises based on hypothetical, business-related climate change scenarios. The events are designed to provide a creative space for innovative problem solving, with an emphasis on what climate change science can do rather than what it can't when it comes to informing financial-based risk assessment, management and decision-making in the private sector. Potential 'solutions' and issues raised in these events are expected to feature in the Hub's strategic planning and prioritisation for future research.

Reflecting on the success of one of these events, Sharanjit Paddam from the Actuaries Institute Climate Change Working Group, stated: "Young people are far more willing to engage in multi-disciplinary approaches to problem solving. The answers provided clearly reflected deep engagement between the scientists and the actuaries to bring their respective skill sets to resolving the problem." This sentiment was echoed by participant Lisa Yap, a young actuary from Suncorp, who said: "I really enjoyed the discussion with the scientists around the table, then having everyone feedback their thoughts. It was valuable for me to see the breadth of the discussion, learn about how other people currently deal with climate change at their work, and understand that there's actually a lot of practical thought being put into climate change from all areas, it's just not always widely visible."

The new professional relationships being created through these events will facilitate long-term inter-generational engagement. These engagements and relationships will be advantageous in the process of addressing long-term climate change risks for Australia.



Working through the issues at a YPN event with the National Australia Bank



Reporting back at a YPN event held with the Actuarial Institute

Research outputs

2017 Young Professionals Network events:

1. [Manly Island](#): *if, when and how could an extreme weather event (i.e. coincident extreme rainfall and sea level events) cause the City of Manly to be cut off from the mainland by floodwaters, and what would be the social and financial impact?*
Hosted by KPMG, Sydney, 12 Oct 2017
2. *Project Kumbh (the Water Carrier): Understanding the risk factors when lending to water sensitive intensive agriculture in the Murray-Darling Basin.* Hosted the National Australia Bank, Melbourne, 18 Dec 2017

Attributions

The Young Professionals Network is an initiative led by the Hub Stakeholder Advisory Group, chaired by Dr Nick Wood.

NESP ESCC Hub 2017 Impact Story

Tracking carbon sources and sinks in support of the Paris Agreement

Projects

Project 2.9 – Risk assessment of future carbon sources and sinks

Global Carbon Project - 2017 Carbon Budget and its publication at the 2018 UN Conference of Parties (COP23) in Bonn, Germany

Summary

The Australian Government and the international community cannot respond to climate change without adequate information on climate change science, impacts and human caused carbon emissions. In particular, understanding how the Australian and global carbon budget is tracking is vital for understanding the likelihood of meeting or exceeding the Paris Agreement targets of 1.5°C and 2°C. The maximum amount of carbon that humans can emit into the atmosphere and still keep global average temperatures below an increase of 2°C is referred to as the 'carbon budget'. To assist in tracking the Australian and global carbon budgets, the Earth Systems and Climate Change Hub supports the [Global Carbon Project](#) (GCP). The GCP is an international collaboration which provides an authoritative assessment of human caused carbon sources and sinks. The GCP's annual Global Carbon Budget provides information, data and communication products to inform and raise awareness about how the world is tracking against the carbon budget. This information is provided directly to policy and decision makers from across the globe through its annual release at the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC). Through this high-profile global initiative and the Hub's own carbon tracking research which feeds into the Budget, the Hub's research informs both Australian and international climate policies.

Narrative

The Australian Government and the international community cannot respond to climate change without adequate information on climate change science, impacts and human caused carbon emissions. In particular, understanding how the Australian and global carbon emissions are changing is vital for understanding the likelihood of meeting or exceeding the Paris Agreement targets of 1.5°C and 2°C. The implementation of the Paris Agreement and its five-year global stocktaking cycle requires the capacity to analyse long- and short-term trends in human caused carbon emissions and their concentration in the atmosphere.

To assist in tracking the Australian and global human caused carbon emissions and trends, the Earth Systems and Climate Change Hub supports the [Global Carbon Project](#) (GCP). The GCP is an international collaboration which provides an authoritative assessment of human caused carbon sources and sinks, including how the international community is tracking against the carbon budget. The term 'carbon budget' is used to refer to the maximum amount of carbon that humans can emit into the atmosphere and still keep global average temperatures below an increase of 2 °C.

The Global Carbon Project's annual Global Carbon Budget has become the most authoritative and up-to-date assessment of global human caused carbon emissions and how the world is tracking against the carbon budget. The Hub supports Australia's participation in the Global Carbon Project and Hub researcher Dr Pep Canadell is the executive director of the Project. Working with two other leaders from the UK and Norway, he leads the coordination of international science data and information (including from the ESCC Hub) into the Global Carbon Budget from 77 scientists from 57 institutions around the world.

The release of the 2017 Global Carbon Budget at the 23rd Conference of the Parties (COP23) to the UNFCCC in Germany in November 2017 generated significant media coverage across the world and much interest from policy and decision makers. Its release was covered by over 3,000 media items (print and online) in 99 countries and 27 different languages. The Budget was immediately picked up by COP23 organisers, with the UN Secretary General Antonio Guterres using the new data from the Budget in his opening address to the world leaders (see <https://youtu.be/J821sZPGkY4?t=14>). The World Meteorological Organization [Statement of the State of the Global Climate in 2017](#) (released March 2018) also incorporated information from the Budget. This statement is the single most authoritative update on global climate trends and is translated into multiple languages for maximum global reach.

The [Carbon Atlas](#) web page of the Global Carbon Budget provides interactive games and tools for exploring the international data and information in a visual and engaging manner. These communication products show how the world is tracking against the carbon budget and when (depending on global mitigation efforts) we are likely to meet or exceed the Paris Agreement targets. This information is used by governments across the world in considering their country's national emission targets, and how these feed into the Paris Agreement targets.

Through its ongoing support of the Global Carbon Project, the Hub continues to contribute to international climate change policy and initiatives, and the Hub's research on carbon sinks and sources not only informs Australian policy but also these international climate change initiatives.

Research outputs

Data:

Global Carbon Budget 2017: <https://www.icos-cp.eu/GCP/2017>

Global Carbon Project datasets and interpretation:

www.globalcarbonproject.org/carbonbudget

Country emissions - Global Carbon Atlas: <http://www.globalcarbonatlas.org/en/CO2-emissions>

Research papers:

Le Quéré C, Andrew RM, Friedlingstein P, Sitch S, Pongratz J, Manning AC, Korsbakken JI, Peters GP, Canadell JG, et al (2018) Global Carbon Budget 2017. Earth System Science Data, 10: 405–448.

Peters GP, Le Quéré C, Andrew RM, Canadell JG, Friedlingstein P, Ilyina T, Jackson R, Joos F, Korsbakken JI, McKinley GA, Sitch S, Tans P (2017) Towards real-time verification of carbon dioxide emissions. Nature Climate Change, 7: 848–852.

Jackson RB, Le Quéré C, Andrew RM, Canadell JG, Peters GP, Roy J, Wu L (2017) Warning signs for stabilization global CO₂ emissions. Environmental Research Letters, DOI: 10.1088/1748-9326/aa9662.

Outreach materials:

Presentations: www-test.globalcarbonproject.org/carbonbudget/17/presentation.htm

Infographics: www-test.globalcarbonproject.org/carbonbudget/17/infographics.htm

Videos: www-test.globalcarbonproject.org/carbonbudget/17/visualisations.htm

Attributions

Dr Pep Canadell (Project 2.9) is the executive director of the Global Carbon Project and one of the three leaders of the Global Carbon Budget activity. His role is to ensure the continued improvement of the scientific effort and the coordination of delivery of data by the multiple organisations. He also provides interpretation of results and papers and coordinates the Australian and global outreach effort.

Dr Vanessa Haverd (Project 2.9) led the model data contribution of the ESCC Hub to the Carbon Budget 2017 based on the CABLE-land surface model. Cathy Trudinger and Peter Briggs (Project 2.9) also contributed to that effort.