National Environmental Science Program

Earth Systems and Climate Change Hub
2020 INTERIM REPORT

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

Host organisation: CSIRO

Key Contact: Professor David Karoly, Hub Leader

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

Hub Leader Certification

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

Signed: David Karoly

Hub Leader Name: Professor David Karoly

Date: 06 October 2020

Hub Steering Committee Chair Certification

As steering committee chair, I certify that any issues of concern or matters raised during Steering Committee meetings where the Interim Report was discussed have been adequately resolved, amended or incorporated into the Interim Report submitted to the Department.

Signed: G. P. Ayers

Hub Steering Committee Chair Name: Dr Greg Ayers

Date: 06 October 2020

Contents

Letter from the Hub Leader

While 2020 has brought plenty of challenges and uncertainty, it has also provided opportunities. The fires, hailstorms and flooding last summer were tragic for many Australian communities and ecosystems and served to focus national attention on extreme weather events and the possible role of climate change. Earth Systems and Climate Change (ESCC) Hub research, products and expertise were called upon numerous times during and after the 2019/2020 Black Summer bushfires, with our researchers and staff providing input into many national and international media articles, interviews and presentations. Hub researchers also played an important role in providing underpinning climate change science information and data to inform the Royal Commission into Bushfires in May/June this year. This has again demonstrated the importance of the Hub's research in supporting policy advice and contributing to the national conversation on climate change.

The Hub's research continues to be delivered to a world-class standard. Key research successes during 2020 include:

- The Hub's research continues to be regularly published in prestigious scientific journals such as *Nature* and *Science*, including nine papers in recent months. Our science is also regularly communicated by reputable media sources such as ABC News and *The Conversation*. For example, a recent journal paper (Le Quéré et al. 2020) analysing the effects of COVID-19 restrictions on global carbon dioxide emissions, was published in *Nature Climate Change* with a variety of associated media articles (including in *The Conversation*), resulting in a global audience reach of 1.7 million.

- Rapid analysis of changes in carbon dioxide emissions due to the global economic impacts of the COVID-19 restrictions has shown a significant fall in emissions in April primarily due to reductions in fossil fuel emissions from surface transport, air transport and industrial activity. These emissions are expected to grow again as the restrictions are relaxed, and global carbon dioxide concentrations in the atmosphere are still expected to increase over 2020.

- A rapid regional assessment of the additional carbon dioxide emissions from the Australian bushfires in 2019 and early 2020 has indicated that these emissions are comparable in magnitude to the total emissions for Australia from fossil fuel burning from all sectors in one year. However, the additional emissions from the bushfires are not included in the annual Australian emissions reports, as they are not considered as part of human-related emissions.

- Early this year, the ACCESS climate model project was awarded an extra 37 million supercomputer hours under an Australasian Leadership Computing Grants from the National Computational Infrastructure (NCI) in Canberra. This project has now contributed more than 7,000 simulated years of climate data to the latest international archive, phase six of the Coupled Model Intercomparison Project (CMIP6). This ensures ACCESS simulations are available for use by researchers around the world, and for use in global climate assessments such as the Intergovernmental Panel on Climate Change (IPCC).

- Hub analysis of the latest CMIP6 model simulations from more than 30 different international modelling centres has shown improved agreement of the model simulations with observations for the last thirty years. Climate projections for Australia show a higher range of future warming late this century, compared with the earlier CMIP5 simulations, including for some future emission scenarios. Although there are still large uncertainties around future changes to rainfall projections over northern Australia in the monsoon season, there is stronger agreement between the simulations from the different models.

- In 2020, two additional Hub researchers (Mark Hemer, project 5.8, and Michael Grose, project 5.3) were invited to be new Lead Authors for chapters in the IPCC Sixth Assessment Report. This is in addition to the previously approved Hub researchers who are already Lead Authors and Review Editors, illustrating that Hub researchers continue to be recognised as leaders in their field and continue to make significant contributions to the international climate science effort.

Reporting on progress during 2020

The Hub's Research Plan Version 6 (RPV6) is progressing well to date, with most research projects (Research Projects 5.1 - 5.9, see Attachment A) finalising research outcomes and findings and now moving into synthesis and communication of their results. The final months of 2020 will be spent ensuring the Hub's research achievements across these projects are successfully captured, synthesised and communicated to our key stakeholders.

Research project milestones are, on the whole, tracking well with minimal delays due to COVID-19. Milestones which have been delayed are being managed through a contract variation processes and will be delivered using the no-cost extension provided by the Department. This no-cost extension provides the Hub with an additional three months to finalise delayed milestones and ensure research papers are finalised before the end of the Hub. See the below table for further information on research project milestone delays due to COVID-19.

RPV6 also includes a number of research facilitation activities (case studies, engagement activities, Indigenous engagement activities, see Attachment A) which draw on research from across all projects to deliver tailored climate change information, data and products co-designed with stakeholders and to build the capacity of our stakeholders to use climate science information in their decision making processes. Many of these activities are currently being finalised, while others are on track for finalisation by December this year.

Notable progress has been made this year in a number of these activities, including:

- *Understanding the impact of climate change on the Northern Territory mango industry*: The case study final report and a range of associated synthesis products targeted at specific mango growing regions in the Northern Territory are now available, and the case study completed. The case study has generated considerable interest across the horticultural industry and has featured in a number of media articles, including the industry magazine 'Tree Cropper'. An article on this case study was also featured in the Department's Secretary newsletter.

- This year the Hub delivered a Climate Change Literacy workshop to the Office of Northern Australian and the newly formed NT Government's climate change office. This led to a discussion about activities in which the Hub could partner with the office to assist with climate change response strategy. It was agreed the Hub would produce a report on understanding climate change science for the NT Government. A final draft report is complete and is going through final review and revision. The report will be used to inform key areas of the NT Government's climate change response strategy. The Office of Climate Change is hoping to be able to use the report as the introduction to the new climate change response strategy, depending on decisions made after the Territory election in August.

- Over the last nine months, the Hub has conducted intensive stakeholder engagement to inform the report to the National Climate Science Advisory Committee (NCSAC) on a national climate service capability. As part of this engagement, the Hub supported an EU-Australia bi-lateral workshop that brought together experts from Europe, Canada and Australia with policy makers, consultancies, Traditional Owners, NGOs and climate scientists to discuss the challenges and opportunities involved in developing a national climate service capability for Australia. The workshop outcomes will support the stakeholder engagement findings and other efforts to better understand Australia's current capabilities and future needs (such as a Social Analysis Network report conducted by UTS) to inform a final advisory report to the Committee and the Department later this year. This will be delivered in the form of a detailed technical report and a policy relevant summary paper.

- As part of the February 2020 AMOS conference in Fremantle, the Hub convened a workshop to discuss how researchers and First Nations peoples should collaborate. At the workshop, participants identified a series of important considerations for co-designing research projects in climate change and more generally. These co-design principles are being further developed with the Steering Committee of the National First Peoples Gathering on Climate Change with the view of incorporating these in the Gathering. The Gathering has been delayed as a result of COVID-19 and the Steering Committee is meeting regularly via videoconference to maintain momentum and connections with, and between, Traditional Owners. Planning for the Gathering is progressing, including alternative options of holding the Gathering if border closures continue, and how co-design principles will be applied to the Gathering and outputs. Involvement in the Steering Committee has led to opportunities for members to participate more broadly in policy relevant activities, for example as the Indigenous focal point for the climate change chapter of the State of the Environment report.

- The Climate Measurement Standards Initiative (CMSI) represents a first step towards ensuring Australia has a scientifically rigorous approach to standardised scenario analysis as framing for financial disclosures of the physical risks from climate change. The initial focus is on a standardised approach to scenario analysis for reporting under the Task Force on Climate-Related Financial Disclosures (TFCD). The Hub has been instrumental in leading the Science Committee of the initiative. This case study is seen as a forerunner globally in how to integrate the science and business of climate change. The CMSI reports, including the climate science guidance and the financial disclosure guidelines, were publicly released on 14 September, with broad media coverage, with an article in the Australian Financial Review.

Minor delays and updates to milestones have been notified in Attachment A for two projects:

- For project 5.2 – Delays were identified for two milestones, one related to technical issues with simulations caused by different configurations in the new supercomputer Gadi and changes in staff. These milestones are now scheduled to be completed by December 2020.
- For project 5.4 – Collaboration between Hub researchers and the MDBA has led to a minor change in the focus of one milestone based on stakeholder feedback, but no delay in its completion.

Notified delays to research and engagement activities due to COVID19

Some of our case studies and engagement activities have had to be amended or delayed due to COVID-19. In particular, the Hub's Indigenous activities draw heavily on face-to-face engagement with relevant communities and these engagements have been affected significantly. While the Hub is continuing to engage virtually where possible, some activities may not be able to be delivered according to their original project plan, and milestones have been amended to address this.

The Hub's planned CLIMATE 2020 conference has also been delayed due to COVID-19, moving from November 2020 to November 2021 (and renamed to CLIMATE 2021). The Hub will continue to plan and prepare for this conference during 2020 and early 2021, after which the new Climate Systems Hub under NESP2 will take over to finalise planning and delivery of the conference. In this way, the conference will be used to celebrate the success of the current Hub and introduce the new Hub to key stakeholders. Hub research project 5.9, led through the National Centre for Coasts and Climate at the University of Melbourne, has been significantly affected by COVID-19. Travel and social distancing restrictions have resulting in necessary labs and field work being delayed. However, with the use of the no-cost extension and careful management, this project should be able to complete the delayed milestones by the end of the Hub, minimising the impact on the project's objectives and outcomes. The Hub continues to monitor these delays closely as Victoria remains in stage four lockdown and will keep the Department informed of any further delays or challenges.

In addition, project 5.7 reported minor delays in the delivery of some outputs due to COVID19 impacts during March-June in Hobart, leading to the delay of one milestone to November. However, all milestones for this project will be completed by the end of the Hub, and the delay will not affect the overall objectives of the project.

Below is a table of research projects and research facilitation activities that have been delayed by COVID-19, including commentary on changes to milestone or project scope:

Project	Name	Activity delayed
RP 5.7	Tracking ocean change	Minor delays in the delivery of some outputs during March-June. One milestone delayed to November 2020.
RP 5.9	NCCC Phase 2	Major delays in some planned lab and engagement activities. Delays are being monitored closely.
CS 5.1	Impact of climate change on mango flowering	The Foods Futures conference presentation on the case study postponed until March 2021. The case study is otherwise completed.
CS 5.2	Gondwana Rainforest WHA	Presentation at WHP conference (normally in September) and a final face-to-face stakeholder meeting have been delayed until early 2021. The case study is otherwise completed.
IA 5.5	Indigenous perspectives on climate risk	Delays due to COVID-19 related travel restrictions that have impacted consultation with Traditional Owners. The activity is expected to be completed by March 31 2021.
IA 6.1	First Nations People's Gathering on Climate Change	The Gathering dates has been confirmed as March 22-26 2021, in Cairns. The Gathering Steering Committee meets regularly via video conference to progress event planning.
IA 6.3	K'Gari WHA	Planned May workshop postponed until November. Will need at least 6 months after the workshop to complete the study. Discussions around project scope are on-going.
CS 6.5	CLIMATE 2020	Delayed to November 2021 (CLIMATE 2021) – this postponement has been approved by DAWE. Planning is progressing to this timeline.

Tracking Hub finances

The Hub has implemented quarterly financial reporting from all Partners in 2020, to allow more rapid tracking of finances in this final period of Hub activities.

Given the delays of some Hub activities (primarily Indigenous engagement activities and case studies) due to COVID-19 restrictions as outlined above, a no-cost extension until March 2021 was requested from the Department and has been approved. The updated milestones for the affected projects, engagement activities and case studies are included in Attachment A.

The financial budgets for the Hub activities in RPV6 have been updated to reflect the full use in the period to March 2021 of the carried-forward balance of funds from 2019. This includes the correction in the January-June 2020 reports of the mistake in the 2019 financial report from a partner organisation and the associated expenditure, as described in the section on Financial Information in the 2019 Annual Report.

Expenditure of NESP funds in January to June 2020 on Hub activities was $2.704 million, $344 thousand greater than the original RPV6 budget and substantially reducing the carry-forward balance of funds. Over the same period, the cash and in-kind contributions from Partners were $2.733 million, more than matching the NESP funding.

Over the whole life of the Hub to June 2020, total expenditure of NESP funds on Hub activities has been $20.57 million, close to the budget figure of $20.60 million. Over the same period, the contributions of cash and in-kind expenditure from Partners were $22.93 million, more than matching the expenditure of NESP funds.

We have fully allocated the NESP funds on Hub activities to March 2021 and do not expect that the Hub will have a significant amount of unspent NESP funds at the end of the Hub. Implications of COVID-19 restrictions on travel budgets have been emerging, due to the limitation of travel but also the likelihood that the travel and accommodation costs for the National First Peoples Gathering on Climate Change will be higher than previously budgeted for. This is being actively managed and reallocated to synthesis products and delayed Indigenous engagement activities in early 2021.

Managing final outputs for maximum impact

In 2019, the Hub developed a 'close-out communication plan' to capture the outputs and synthesise activities across the whole life of Hub, to be undertaken in the 2020/21 period. This plan has now been updated (to incorporate amendments due to COVID-19) and can be found at Attachment B.

As stated in the plan, the main synthesis product will be a whole-of-Hub publication which captures outcomes and impacts across the life of the Hub. Work is already underway on this product. In addition, the Hub is planning a number of supporting products and activities.

These include:

- Supporting factsheets which sit behind the main publication and provide information to specific target users/stakeholders, as required.
- Various workshops/sessions at the AMOS 2021 conference that has a theme of 'Science for Impact' to showcase the research findings and engagement successes of the Hub.
- A range of project level and case study synthesis products which showcase the science achievements of each of the research projects and case studies.
- Planned Hub synthesis articles in a range of media, possibly including in *The Conversation* and *ECOS* magazine.
- Hub webinar/s to celebrate the life of the Hub, as part of the Hub's usual science webinar series in early 2021.

Note that CLIMATE 2020 was to be one of the showcase events of the Hub. Since it has been postponed due to COVID-19, the Hub is planning a greater than usual presence at the AMOS 2021 national conference and an internal 'Science Symposium' for Hub researchers and key stakeholders. The dates of 8-9 December 2020 have been set for this event, and planning is underway for a multi-site virtual event.

Research

Attachment A lists the projects funded under the Earth Systems and Climate Change Hub and provides detailed information on the project status, information on outputs and links to products for all projects (where available) as at 30 July 2020. Exceptions to the NESP Data Management and Accessibility Guidelines are also noted here.

Attachments

Attachment A: Project information
Attachment B: ESCC Hub close out communication plan, updated 2020

Earth Systems and Climate Change Hub 2020 Interim Report - Attachment A												
Project Number/ID	**Project Name/Title**	**Project Summary**	**Project Leader**	**Lead Organisation**	**Approved Funding Research Plan Versions 1-6**			**Start Date**	**Completion Date**	**Status**	**Outputs**	
					NESP Funding* $	**Total Other Contributions* $**	**Total Budget* $**				**Outputs**	**Link to output**
COMPLETE RESEARCH PROJECTS												
1.1	Current Capability and Future Directions Assessment	This project has informed the development of the ESCC Hub's long-term research delivery through an assessment of current capability and future directions for the Earth Systems and Climate Change Hub science and services. The assessment examined current research and outreach capability and future directions, with an emphasis on how the Hub's key partners can best respond to target stakeholder gaps, needs and associated national priorities. The assessment was conducted by Scientell Ltd Pty.	Geoff Gooley	CSIRO	72,453	72,640	**145,093**	01.07.2015	31.12.2017	Completed	Assessment report conducted and compiled by Scientell Ltd Pty which outlines the current capability and future directions of Earth Systems and Climate Change research and provides feedback on Hub activities, and suggested future directions.	http://nespclimate.com.au/current-capability-and-future-directions-assessment/
1.2	Project 1.2 - Stakeholder and Indigenous Engagement	Communication and Knowledge Brokering budget	Helen Cleugh	CSIRO	80,200	80,200	**160,400**	01.01.2016	31.12.2016	Completed	N/A	N/A
1.3	Low coast abatement options: scoping workshop and report	Low cost abatement options: Scoping Workshop and Report	Helen Cleugh	CSIRO	18,262	18,262	**36,524**	1/07/2015	31/12/2016	Completed	N/A	N/A
2.12 & 1.4	Sea Level Projections for NCCARF	This project provided NCCARF with the latest projections of sea-level rise for each coastal local government area in Australia, including all mainland and Tasmanian Councils and the Torres Strait Islands. Information was communicated through guidance material and stakeholder workshops. The project ensured current knowledge was delivered to the community, particularly coastal planners and managers, in a coherent and efficient manner to aid in decision making and planning for future coastal change. The project did this by using the latest regional climate projections for Australia and, working with NCCARF, included these projections in NCCARF's new coastal tool, CoastAdapt. This tool is an excellent information delivery tool, and has been shown to be used extensively by coastal councils and other coastal planners, managers and relevant governments. Inclusion of project information into CoastAdapt has greatly increased uptake of Hub research across the community.	Kathleen McInnes	CSIRO	25,044	25,044	**50,088**	1/09/2015	30/12/2016	Completed	Updated sea level rise projections incorporated into the NCCARF coastal planning tool, CoastAdapt	https://coastadapt.com.au/tools/coastadapt-datasets
N/A	PhD's and Vacation Scholarships (outside Projects; includes SO)	This is not an actual project but contributes to salaries/costs of PhD students outside project funding.			33,287	205,850	239,137	01.07.2016	30.06.2019	Completed	Supports PhDs within the Hub to participate in Hub run or supported events, particularly those with a stakeholder focus. Provides capacity building and stakeholder engagement experience for PhDs.	N/A

Project Number/ID	Project Name/Title	Project Summary	Project Leader	Lead Organisation	Approved Funding Research Plan Versions 1-6			Start Date	Completion Date	Status	Outputs	
					NESP Funding* $	Total Other Contributions* $	Total Budget* $				Outputs	Link to output
2.1	Preparing ACCESS for CMIP6	ACCESS is Australia's global climate model, which provides climate simulations for the Intergovernmental Panel on Climate Change assessment reports, including the upcoming sixth assessment report. Given its importance to Australia's climate preparedness and resilience, ACCESS needs to be an internationally benchmarked, world-class global climate modelling capability that is significantly more accurate than other global climate models for the Australasian and Southern Hemisphere region. Participation in the Climate Model Intercomparison Project (CMIP) provides this benchmarking. It also supports Australia's effective management of climate risks and opportunities, and engagement with future climate assessments. This project has achieved these outcomes by preparing and submitting ACCESS model simulations into CMIP6 to benchmark ACCESS's performance and suitability for application across the NESP ESCC Hub and the broader climate change science research community. Submission of ACCESS simulations into CMIP6 also allows them to be included in IPCC assessment reports for used by governments across the world.	Simon Marsland	CSIRO	975,000	994,750	**1,969,750**	01.07.2016	30.06.2019	Completed	Kiss AE, Hogg AMcC, Hanna Nh, Dias FB, Brassington G, Chamberlain MA, Chapman C, Dobrohotoff P, Domingues CM, Duran ER, England MH, Fiedler R, Griffies SM, Heerdegen A, Heil P, Holmes RM, Klocker A, Marsland SJ, Morrison AK, Munroe J, Oke PR, Nikurashin M, Pilo GS, Richet O, Savita A, Spence P, Stewart KD, Ward ML, Wu F, Zhang X. 2019. ACCESS-OM2: A Global Ocean-Sea Ice Model at Three Resolutions, Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2019-106, Geosci. Model Dev	https://doi.org/10.5194/gmd-2019-106
											ACCESS Post Processor (APP) software from CMIP5 ACCESS1.0 and 1.3 submissions, for use in ACCESS-CM2 and ACCESS-ESM1.5 CMIP6 submissions	
											Science webinar: Ensuring Australian climate model simulations inform global climate assessments	http://nespclimate.com.au/ensuring-australian-climate-model-simulations-inform-global-assessments/
											Dix M, Bi D, Dobrohotoff P, Fiedler R, Harman I, Law R, Mackallah C, Marsland S, O'Farrell S, Rashid H, Srbinovsky J, Sullivan A, Trenham C, Vohralik P, Watterson I, Williams G, Woodhouse M, Bodman R, Dias F, Domingues C, Hannah N, Heerdegen A, Savita A, Wales S, Allen C, Druken K, Evans B, Richards C, Ridzwan SM, Roberts D, Smillie J, Snow K, Ward M, Yang R, 2019. CSIRO-ARCCSS ACCESS-CM2 model output prepared for CMIP6 CMIP. Version YYYYMMDD[1].Earth System Grid Federation. https://doi.org/10.22033/ESGF/CMIP6.2281	https://doi.org/10.22033/ESGF/CMIP6.2281
											Dix M, Bi D, Dobrohotoff P, Fiedler R, Harman I, Law R, Mackallah C, Marsland S, O'Farrell S, Rashid H, Srbinovsky J, Sullivan A, Trenham C, Vohralik P, Watterson I, Williams G, Woodhouse M, Bodman R, Dias FB, Domingues C, Hannah N, Heerdegen A, Savita A, Wales S, Allen C, Druken K, Evans B, Richards C, Ridzwan SM, Roberts D, Smillie J, Snow K, Ward M, Yang R, 2019. CSIRO-ARCCSS ACCESS-CM2 model output prepared for CMIP6 ScenarioMIP. Version YYYYMMDD[1]. Earth System Grid Federation.	https://doi.org/10.22033/ESGF/CMIP6.2285

Project Number/ID	Project Name/Title	Project Summary	Project Leader	Lead Organisation	Approved Funding Research Plan Versions 1-6 NESP Funding* $	Total Other Contributions* $	Total Budget* $	Start Date	Completion Date	Status	Outputs	Link to output
											Prototype ACCESS-CM2 modelling system using JULES land scheme	
											Ziehn T, Chamberlain M, Lenton A, Law R, Bodman R, Dix M, Wang YP, Dobrohotoff P, Srbinovsky J, Stevens L, Vohralik P, Mackallah C, Sullivan A, O'Farrell S, Druken K, 2019. CSIRO ACCESS-ESM1.5 model output prepared for CMIP6 CMIP. Version YYYYMMDD[1].Earth System Grid Federation.	https://doi.org/10.22033/ESGF/CMIP6.2288
											Ziehn T, Chamberlain M, Lenton A, Law R, Bodman R, Dix M, Wang YP, Dobrohotoff P, Srbinovsky J, Stevens L, Vohralik P, Mackallah C, Sullivan A, O'Farrell S, Druken K, 2019. CSIRO ACCESS-ESM1.5 model output prepared for CMIP6 ScenarioMIP. Version YYYYMMDD[1]. Earth System Grid Federation.	https://doi.org/10.22033/ESGF/CMIP6.2291
											Fiddles SL, Woodhouse MT, Nicholls Z, Lane TP, Schofield R. 2018. Cloud, precipitation and radiation responses to large perturbations in global dimethyl sulfide. *Atmospheric Chemistry and Physics*, 18	https://www.atmos-chem-phys.net/18/10177/2018/acp-18-10177-2018.html
											ESCC Hub webinar: Atmosphere, aerosols and ACCESS	http://nespclimate.com.au/webinar-atmosphere-aerosols-access/
											ESCC Hub blog: Something in the air	http://nespclimate.com.au/something-in-the-air/
											Ziehn T, Chamberlain M, Lenton A, Law R, Bodman R, Dix M, Wang YP, Dobrohotoff P, Srbinovsky J, Stevens L, Vohralik P, Mackallah C, Sullivan A, O'Farrell S, Druken K. 2019. CSIRO ACCESS-ESM1.5 model output prepared for CMIP6 CMIP. Version YYYYMMDD[1].Earth System Grid Federation. https://doi.org/10.22033/ESGF/CMIP6.2288	https://doi.org/10.22033/ESGF/CMIP6.2288
											Ziehn T, Chamberlain M, Lenton A, Law R, Bodman R, Dix M, Wang YP, Dobrohotoff P, Srbinovsky J, Stevens L, Vohralik P, Mackallah C, Sullivan A, O'Farrell S, Druken K. 2019. CSIRO ACCESS-ESM1.5 model output prepared for CMIP6 ScenarioMIP. Version YYYYMMDD[1].Earth System Grid Federation. https://doi.org/10.22033/ESGF/CMIP6.2291	https://doi.org/10.22033/ESGF/CMIP6.2291

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					NESP Funding* $	Total Other Contributions* $	Total Budget* $				Outputs	Link to output
											Ziehn T, Chamberlain M, Lenton A, Law R, Bodman R, Dix M, Mackallah Chloe, Druken K, Ridzwan SM. 2019. CSIRO ACCESS-ESM1.5 model output prepared for CMIP6 C4MIP. Version YYYYMMDD[1].Earth System Grid Federation. https://doi.org/10.22033/ESGF/CMIP6.2286	https://doi.org/10.22033/ESGF/CMIP6.2281
											Dix M, Bi D, Dobrohotoff P, Fiedler R, Harman I, Law R, Mackallah C, Marsland S, O'Farrell S, Rashid H, Srbinovsky J, Sullivan A, Trenham C, Vohralik P, Watterson I, Williams G, Woodhouse M, Bodman R, Dias F, Domingues C, Hannah N, Heerdegen A, Savita A, Wales S, Allen C, Druken K, Evans B, Richards C, Ridzwan SM, Roberts D, Smillie J, Snow K, Ward M, Yang R. 2019. CSIRO-ARCCSS ACCESS-CM2 model output prepared for CMIP6 CMIP. Version YYYYMMDD[1].Earth System Grid Federation. https://doi.org/10.22033/ESGF/CMIP6.2281	https://doi.org/10.22033/ESGF/CMIP6.2281
											Ziehn T, Chamberlain M, Lenton A, Law R, Bodman R, Dix M, Mackallah Chloe, Druken K, Ridzwan SM. 2019. CSIRO ACCESS-ESM1.5 model output prepared for CMIP6 CDRMIP. Version YYYYMMDD[1].Earth System Grid Federation. https://doi.org/10.22033/ESGF/CMIP6.2287	https://doi.org/10.22033/ESGF/CMIP6.2287
											Ziehn T, Chamberlain M, Lenton A, Law R, Bodman R, Dix M, Mackallah Chloe, Druken K, Ridzwan SM. 2019. CSIRO ACCESS-ESM1.5 model output prepared for CMIP6 CDRMIP. Version YYYYMMDD[1].Earth System Grid Federation. https://doi.org/10.22033/ESGF/CMIP6.2287	https://doi.org/10.22033/ESGF/CMIP6.2287
											Zhou, X., O. Alves, S.J. Marsland, D. Bi, and A.C. Hirst, 2017: Multi-decadal variations of the South Indian Ocean subsurface temperature influenced by Pacific Decadal Oscillation, Tellus A, 69:1, 13pp,	https://www.tandfonline.com/doi/full/10.1080/16000870.2017.1308055?scroll=top&needAccess=true
											Dave Bi presentation to the Working Group on Coupled Modelling (WGCM)	https://www.wcrp-climate.org/images/modelling/WGCM/WGCM21/10oct/02-10-ACCESS-WCRP-WGCM21.pdf

Project Number/ID	Project Name/Title	Project Summary	Project Leader	Lead Organisation	Approved Funding Research Plan Versions 1-6			Start Date	Completion Date	Status	Outputs	
					NESP Funding* $	Total Other Contributions* $	Total Budget* $				Outputs	Link to output
2.2	Enhancing Australia's capacity to manage climate variability and climate extremes in a changing climate	Climate extremes such as heatwaves, floods and droughts in Australia cause high economic, agricultural and human costs. Managing the risks – and reducing the costs – associated with climate variability and extremes requires a transformation in our current understanding of the influence of climate change now and into the future. This project has analysed past climate variability and extremes to significantly enhance our understanding of the underpinning mechanisms and processes. It has focused on longer timescale extremes such as extended heatwaves, floods and droughts and the historical record of tropical cyclones; with the aim of informing the development of robust projections that will help Australia prepare for and respond to climate variability, extremes and change in the future.	Pandora Hope	Bureau of Meteorology	1,838,475	2,075,394	**3,913,869**	01.07.2016	30.06.2019	Completed	Chung CTY, Power SB, Sullivan A, Delage F, 2019. The role of the South Pacific in modulating Tropical Pacific Variability, Scientific Reports, doi:10.1038/s41598-019-52805-2	https://www.nature.com/articles/s41598-019-52805-2
											Science webinar: Understanding past and future extreme events and their causes	http://nespclimate.com.au/understanding-past-and-future-extreme-events-and-their-cause/
											Lim EP, Hendon HH, Hope P, Chung CC, McPhaden MJ, 2019. Continuation of tropical Pacific Ocean temperature trend will weaken linkage of Southern Annular Mode and extreme El Niño, Science Reports, doi: 10.1038/s41598-019-53371-3	https://www.nature.com/articles/s41598-019-53371-3
											Abhik S, Hendon HH, Wheeler MC, 2019. On the Sensitivity of Convectively Coupled Equatorial Waves to the Quasi-Biennial Oscillation, J. Climate, 32, 5833–5847, doi: 10.1175/JCLI-D-19-0010.1	https://journals.ametsoc.org/doi/full/10.1175/JCLI-D-19-0010.1?mobileUi=0
											Abhik S, Hendon HH. 2019. Influence of the QBO on the MJO during coupled model multiweek forecasts, Geophysical Research Letters, 46, 9213– 9221.	http://nespclimate.com.au/wp-content/uploads/2019/05/2.2_Abhik-2019_GRL_2019GL083152.pdf
											Bordbar MH, England MH, Sen Gupta A, Santoso A, Taschetto AS, Martin T, Park W, Latif M. 2019. Uncertainty in near-term global surface warming linked to tropical Pacific climate variability. Nature Communications, 10, doi: 10.1038/s41467-019-09761-2	https://www.nature.com/articles/s41467-019-09761-2
											Cai WJ, Wu L, Lengaigne M, Li T, McGregor S, Kun JS, Stuecker MF, Santoso A, Li X, Ham YG, Chikamoro Y, Ng B, McPhaden MJ, Du Y, Dommenget D, Jia F, Kajtar JB, Keenlyside N, Lin X, Luo JJ, Martin-Rey M, Ruprich-Robert Y, Wang GJ, Xie SP, Yang Y, Kang SM, Choi JY, Gan B, Kim GI, Kim CE, KiM SY, Kim, JH, Chang P. 2019. Pantropical climate interactions, Science, 363(6430), doi: 10.1126/science.aav4236	https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=4&cad=rja&uact=8&ved=2ahUKEwju46Wq9u3mAhUBzjgGHZsBDuAQFjADegQIAxAB&url=https%3A%2F%2Fwww.researchgate.net%2Fpublication%2F331435229_Pantropical_climate_interactions&usg=AOvVaw0tF9m9odbPUNUEqFkl-TpS

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					NESP Funding* $	Total Other Contributions* $	Total Budget* $				Outputs	Link to output
											Dowdy AJ, Pepler A, Di Luca A, Cavicchia L, Mills, G, Evans JP, Louis S, McInnes KL, Walsh K. 2019. Review of Australian east coast low pressure systems and associated extremes, Climate Dynamics, 1-24, doi: 10.1007/s00382-019-04836-8	https://link.springer.com/article/10.1007%2Fs00382-019-04836-8
											Fact sheet: Earth Systems and Climate Change Hub. 2019. What role does climate change play in extreme events?	http://nespclimate.com.au/wp-content/uploads/2016/02/A4-2p-ccs-brief-extremes.pdf
											Freund MB, Henley BJ, Karoly DJ, McGregor HV, Abram NJ, Dietmar D. 2019. Higher frequency of Central Pacific El Niño events in recent decades relative to past centuries, *Nature Geoscience*, doi: 10.1038/s41561-019-0353-3	https://findanexpert.unimelb.edu.au/scholarlywork/1394138-higher-frequency-of-central-pacific-el-nino-events-in-recent-decades-relative-to-past-centuries
											Hope P, Black MT, Lim E-P, Dowdy A, Wang, Pepler A and Fawcett RJB. 2019. On determining the impact of increasing atmospheric CO2 on the record fire weather in eastern Australia in February 2017, *Bulletin of the American Meteorological Society*, doi:10.1175/BAMS-D-18-0135.1	https://doi.org/10.1175/BAMS-D-18-0135.1
											Jia F, Cai WJ, Gan BL, Wang GJ, Kucharski F, Chang P, Keenlyside, 2019. Weakening Atlantic Niño–Pacific connection under greenhouse warming, *Science Advances*, doi:10.1126/sciadv.aax4111	https://advances.sciencemag.org/content/5/8/eaax4111?rss=1
											Lim E-P, Hendon HH, Hope P, Chung C, Delage F, McPhaden MJ. 2019. Continuation of tropical Pacific Ocean temperature trend may weaken extreme El Nino and its linkage to the Southern Annular Mode, Scientific Reports, 9(17044), doi: 10.1038/s41598-019-53371-3	https://www.nature.com/articles/s41598-019-53371-3
											Power SB, Delage FPD. 2019. Setting and smashing extreme temperature records over the coming century. *Nature Climate Change*, doi:10.1038/s41558-019-0498-5	https://www.nature.com/articles/s41558-019-0498-5

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											Wang G, Hendon H, Arblaster J, Lim E, Abhik S and van Rensch P. 2019. Compounding Tropical and Stratospheric Forcing of the Record Low Antarctic Sea-Ice in 2016. *Nature Communications* , 10, doi: 10.1038/s41467-018-07689-7	https://www.nature.com/articles/s41467-018-07689-7
											Kirk-Patrick et al. 2018. The role of natural variability and anthropogenic climate change in the 2017/18 Tasman Sea Marine Heatwave, Bulletin of the American Meteorological Society.	http://www.ametsoc.net/eee/2017a/ch20_EEEof2017_Perkins.pdf
											Power SB and Delage FPD. 2018a. El Niño–Southern Oscillation and Associated Climatic Conditions around the World during the Latter Half of the Twenty-First Century. Journal of Climate. doi:10.1175/JCLI-D-18-0138.1	https://journals.ametsoc.org/doi/full/10.1175/JCLI-D-18-0138.1
											Cai et al. 2018, Stabilised frequency of extreme positive Indian Ocean Dipole under 1.5°C warming target. Nature Communications	https://www.nature.com/articles/s41467-018-03789-6
											Cai W et al. 2018. Increased variability of eastern Pacific El Niño under greenhouse warming. Nature. 564, 201–206.	https://www.nature.com/articles/s41586-018-0776-9
											Pepler AS, Hope P. 2018. Orography Drives the Semistationary West Australian Summer Trough, *Geophysical Research Letters* , doi.org/10.1029/2018GL079312	http://nespclimate.com.au/wp-content/uploads/2019/03/Pepler-Hope-2018-Orography-drives-the-semi-stationary-West-Australi....pdf
											Santoso A, et al. 2018. Dynamics and predictability of the El Niño-Southern Oscillation: An Australian perspective on progress and challenges. Bulletin of the American Meteorological Society, doi: 10.1175/bams-d-18-0057.1	https://journals.ametsoc.org/doi/abs/10.1175/BAMS-D-18-0057.1
											ESCC Hub science webinar: ENSO and rainfall	http://nespclimate.com.au/the-impact-of-enso-on-rainfall-in-a-warming-world/
											Abellán E, McGregor S, England M, Santoso A. 2017. Distinctive role of ocean advection anomalies in the development of the extreme 2015-16 El Nino. Climate Dynamics, 1-18. doi: 10.1007/s00382-017-4007-0 | Abstract	http://web.science.unsw.edu.au/~matthew/Abellan_et_al_2018_Climate_Dynamics.pdf

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											Herold N, Santoso A. 2017. Indian Ocean warming during peak El Nino cools surrounding land masses. Climate Dynamics, 1-16, doi:10.1007/s00382-017-4001-6	http://onlinelibrary.wiley.com/doi/10.1002/2017GL075635/full
											Hope P, Lim E-P, Hendon H, Wang G. 2017. The effects of increasing CO2 on the extreme September 2016 rainfall across South Eastern Australia. Bulletin of the American Meteorological Society, doi:10.1175/bams-D-17-0094.1	http://www.ametsoc.net/eee/2016/ch26.pdf
											Power SB, Delage FPD, Chung CTY, Ye H and Murphy BF. 2017. Humans have already increased the risk of major disruptions to Pacific rainfall. Nature Communications, 8, 14368, doi:10.1038/ncomms14368	https://www.nature.com/articles/ncomms14368
											Power SB, Delage FPD, Wang GM, Smith I, Kociuba G. 2017. Apparent limitations in the ability of CMIP5 climate models to simulate recent multi-decadal change in surface temperature: implications for global temperature projections. Climate Dynamics, 49, 53-69, doi:10.1007/s00382-016-3326-x	http://onlinelibrary.wiley.com/doi/10.1002/2017RG000560/epdf
											Santoso A, McPhaden MJ, Cai W. 2017. The Defining Characteristics of ENSO Extremes and the Strong 2015/2016 El Niño. Reviews of Geophysics, 55(4), 1079-1129, doi:10.1002/2017rg000560	http://onlinelibrary.wiley.com/doi/10.1002/2017RG000560/epdf
											Chung C, Power SB. 2017. The non-linear impact of El Niño, La Niña and the Southern Oscillation on seasonal and regional Australian precipitation. Journal of Southern Hemisphere Earth Systems Science, 67(1), 25–45, doi:10.22499/3.6701.003	http://www.bom.gov.au/jshess/docs/2017/Chung.pdf
											Chung C, Power S, Santoso A, Wang G. 2017. Multi-year variability in the Tasman sea and impacts on Southern Hemisphere climate in CMIP5 models. Journal of Climate, doi:10.1175/jcli-d-16-0862.1	http://journals.ametsoc.org/doi/abs/10.1175/JCLI-D-16-0862.1
											Grose MR, Black M, Risbey JS, Uhe P, Hope PK, Haustein K, Mitchell D. 2017. Severe frosts in Western Australia in September 2016. Bulletin of the American Meteorological Society, doi:10.1175/bams-D-17-0088.1	http://www.ametsoc.net/eee/2016/ch29.pdf

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					NESP Funding* $	Total Other Contributions* $	Total Budget* $				Outputs	Link to output
											Wang G, Cai W, Gan B, Wu L, Santoso A, Lin X, Chen Z, McPhaden MJ. 2017. Continued increase of extreme El Niño frequency long after 1.5°C warming stabilisation. Nature Climate Change, doi:10.1038/nclimate3351	https://www.nature.com/articles/nclimate3351
											Presentation of new method to establish the causes of changes in the climatology of the explosive growth of high impact weather systems at ANZIAM. Conference Proceedings published in ANZIAM Journal: S.L. Osbrough, J.S. Frederiksen, "Computation of changes in explosive weather systems during the 20th century"	https://doi.org/10.21914/anziamj.v58i0.11784
											Colman R, Power SB. 2018. What can decadal variability tell us about climate feedbacks and sensitivity? *Climate Dynamics*. doi: 10.1007/s00382-018-4113-7	http://nespclimate.com.au/wp-content/uploads/2019/05/Colman-and-Power-2018.-Decadal_Jan_2018_revised.pdf
2.3	Towards an ACCESS decadal prediction system	The marine, agriculture, energy and water sectors have consistently requested climate information at multi-year to decadal timescales. However, Australia capability is only just being developed in our predictive capability at these timescales. This project developed forecasting capability specific to filling the critical gap between seasonal climate predictions and multi-decadal climate projections, within ACCESS. The project advanced the initial steps in developing Australia's forecast capability on the decadal scale, and has improved understanding and simulation of Southern hemisphere climate drivers. The project has, as an example and tester, focused on delivering targeted stakeholder products to inform marine and agriculture policy and adaptive management strategies, through assessment of marine temperature extremes which have large impacts on marine life and fisheries.	Neil Holbrook	UTAS	410,000	637,633	**1,047,633**	01.07.2016	30.06.2019	Completed	Factsheet: Earth Systems and Climate Change Hub. 2019. Understanding marine heatwaves	http://nespclimate.com.au/wp-content/uploads/2019/05/A4-2p-ccs-brief_marineheatwaves_web.pdf
											Science webinar: What causes marine heatwaves and how are they changing?	http://nespclimate.com.au/what-causes-marine-heatwaves-and-how-are-they-changing/
											Lou J, NJ Holbrook and TJ O'Kane, 2019. South Pacific decadal climate variability and potential predictability. Journal of Climate, doi:10.1175/JCLI-D-18-0189.1	https://eprints.utas.edu.au/32367/
											O'Kane T, et al. 2019. Coupled data assimilation and ensemble initialisation with application to multi-year ENSO prediction. Journal of Climate, doi:10.1175/JCLI-D-18-0249.1	https://journals.ametsoc.org/doi/full/10.1175/JCLI-D-18-0249.1
											Kushnir et al. 2019. Towards operational predictions of the near-term climate, Nature Climate Change, 9, 94–101	https://www.nature.com/articles/s41558-018-0359-7
											Smale DA, T Wernberg, ECJ Oliver, M Thomsen, BP Harvey, SC Straub, MT Burrows, LV Alexander, JA Benthuysen, MG Donat, M Feng, AJ Hobday, NJ Holbrook, SE Perkins-Kirkpatrick, H Scannell, A Sen Gupta, B Payne, PJ Moore, 2019. Marine heatwaves threaten global biodiversity and the provision of ecosystem services, doi:10.1515/mcwf-2017-0001	https://www.nature.com/articles/s41558-019-0412-1

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											O'Kane TJ, Monselesan DP, Risbey JS, Horenko I, Franzke CLE. 2017. On memory, dimension, and atmospheric teleconnections. Mathematics of Climate and Weather Forecasting, 3(1), 1–27, doi:10.1515/mcwf-2017-0001	https://research.csiro.au/dfp/wp-content/uploads/sites/148/2017/03/OKane_mcwf2017.pdf
											Oliver ECJ, Lago V, Hobday AJ, Holbrook NJ, Ling SD, Mundy CN. 2018. Marine heatwaves off eastern Tasmania: Trends, interannual variability, and predictability. *Progress in Oceanography* 161, 116-130	http://nespclimate.com.au/wp-content/uploads/2019/05/Oliver_2018_PIO_MHWsEasternTasmania.pdf
											Oliver ECJ, Perkins-Kirkpatrick SE, Holbrook NJ, Bindoff NL. 2017. Anthropogenic and natural influences on record 2016 marine heatwaves. Bulletin of the American Meteorological Society, doi:10.1175/BAMS-D-17-0093.1	https://www.nature.com/articles/ncomms16101
											Risbey, J. S., O'Kane, T. J., Monselesan, D. P., Franzke, C. L. E., & Horenko, I. 2018. On the dynamics of Austral heat waves. Journal of Geophysical Research: Atmospheres, 123, 38–57.	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017JD027222
											Oliver ECJ, MG Donat, MT Burrows, PJ Moore, DA Smale, LV Alexander, JA Benthuysen, M Feng, A Sen Gupta, AJ Hobday, NJ Holbrook, SE Perkins-Kirkpatrick, HA Scannell, SC Straub and T Wernberg, 2018: Ocean warming brings longer and more frequent marine heatwaves. Nature Communications.	https://www.nature.com/articles/s41467-018-03732-9
											Hobday, A.J., E.C.J. Oliver, A. Sen Gupta, J.A. Benthuysen, M.T. Burrows, M.G. Donat, N.J. Holbrook, P.J. Moore, M.S. Thomsen, T. Wernberg, and D.A. Smale. 2018. Categorizing and naming marine heatwaves. Oceanography 31(2):162–173.	https://tos.org/oceanography/article/categorizing-and-naming-marine-heatwaves
											Oliver ECJ, Donat MG, Burrows MT, Moore PJ, Smale DA, Alexander LV, Benthuysen JA, Feng M, Sen Gupta A, Hobday AJ, Holbrook NJ, Perkins-Kirkpatrick SE, Scannell HA, Straub SC, Wernberg T. 2018. Longer and more frequent marine heatwaves over the past century. Nature Communications, 9, doi:10.1038/s41467-018-03732-9	https://www.nature.com/articles/s41467-018-03732-9

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											Oliver ECJ & Holbrook NJ. 2018. Variability and Long-Term Trends in the Shelf Circulation Off Eastern Tasmania. *Journal of Geophysical Research: Oceans*. doi:10.1029/2018JC013994	http://nespclimate.com.au/wp-content/uploads/2019/03/Oliver_et_al-2018-Journal_of_Geophysical_Research__Oceans.pdf
											ESCC Hub science webinar: Ocean temperature extremes	http://nespclimate.com.au/towards-predicting-ocean-temperature-extremes/
2.4	Changing oceans and Australia's future climate	Global warming is ocean warming: over 93% of the extra heat stored by the Earth over the past 50 years is found in the ocean. To interpret past changes and better predict changes in the climate we need to understand how the ocean takes up heat, and how ocean heat uptake may change as the planet warms. Projections of future warming, sea level rise and water availability for Australia and our region can be improved by ensuring that ocean heat uptake is well represented in climate models. This project used observations and models to provide these improvements; underpinning a more resilient Australia.	Steve Rintoul	CSIRO	1,050,146	1,209,970	**2,260,116**	01.07.2016	30.06.2019	Completed	Updated Argo Australia profiles	National Centers for Environmental Information, NESDIS, NOAA https://data.nodc.noaa.gov/cgi-
											Cyriac A, McPhaden MJ, Phillips HE, Bindoff NL, Feng M. 2019 Seasonal Evolution of the Surface Layer Heat Balance in the Eastern Subtropical Indian Ocean. Journal of Geographic Research – Oceans. 10.1029/2018JC014559	https://eprints.utas.edu.au/31743/1/134365%20-%20Seasonal%20evolution%20of%20the%20surface%20layer%20heat%20balance%20_accepted%20manuscript.pdf
											Stammer D, Bracco A, AchutaRao K, Beal L, Bindoff NL, Braconnot P, Cai WJ, Chen D, Collins M, Danabasoglu G, Dewitte B, Farneti R, Fox-Kemper B, Fyfe J, Griffies SM, Jayne SR, Lazar A, Lengaigne M, Lin XP, Marsland SJ, Minobe S, Monteiro PMS, Robinson W, Roxy MK, Rykaczewski RR, Speich S, Smith EIJ, Solomon A, Storto A, Takahashi K, Toniazzo T, Vialard J. 2019. Ocean climate observing requirements in support of Climate Research and Climate Information, Frontiers of Marine Science, doi: 10.3389/fmars.2019.00444	https://www.frontiersin.org/articles/10.3389/fmars.2019.00444/full
											Zhang Y, Feng M, Du Y, Phillips HE, Bindoff NL, McPhaden MJ. 2018. Strengthened Indonesian throughflow drives decadal warming in the Southern Indian Ocean. Geographical Research Letters, doi:10.1029/2018GL078265	nespclimate.com.au/wp-content/uploads/2016/03/Zhang_et_al-2018-Geophysical_Research_Letters.pdf
											Mao H, Feng M, Phillips HE, Lian S, 2018. Mesoscale eddy characteristics in the interior subtropical southeast Indian Ocean, tracked from the Leeuwin Current system, Deep-Sea Research II	https://www.sciencedirect.com/science/article/pii/S0967064517303892?via%3Dihub
											Stewart KD and Hogg A Mc. 2019. Southern Ocean heat and momentum uptake are sensitive to the vertical resolution at the ocean surface, Ocean Modelling,	https://www.sciencedirect.com/science/article/abs/pii/S1463500319300897

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											Sprintall J, Gordon AL, Wijffels SE, Feng M, Hu SJ, Koch-Larrouy A, Phillips HE, Nugroho D, Napitu A, Pujiana K, Susanto RD, Sloyan BM, Pena-Molino B, Yuan D, Florida Riama N, Siswanto S, Kuswardani A, Arifin Z, Wahyudi AJ, Zhou H, Nagai T, Ansong JK, Bourdalle-Badié R, Chanut J, Lyard F, Arbic BK, Ramdhani A, Setiawan A, 2019. Detecting Change in the Indonesian Seas, OceanObs'19 white paper, Frontiers in Marine Science, 10.3389/fmars.2019.00257	https://www.frontiersin.org/articles/10.3389/fmars.2019.00257/full
											Sloyan BM, Wilkin J, Hill KL, Chidichimo MP, Cronin MF, Johannessen JA, Karstensen J, Krug M, Lee T, Oka E, Palmer MD, Rabe B, Speich S, von Schuckmann K, Weller RA, Yu WD, 2019. Evolving the Physical Global Ocean Observing System for Research Application Services Through International Coordination, Frontiers of Marine Science, 10.3389/fmars.2019.00449	https://www.frontiersin.org/articles/10.3389/fmars.2019.00449/full
											Sloyan BM, Wilkin J, Hill KL, Chidichimo MP, Cronin MF, Johannessen JA, Karstensen J, Krug M, Lee T, Oka E, Palmer MD, Rabe B, Speich S, von Schuckmann K, Weller RA, Yu WD, 2019. Evolving the Physical Global Ocean Observing System for Research Application Services Through International Coordination, Frontiers of Marine Science, doi:10.3389/fmars.2019.00449	https://www.frontiersin.org/articles/10.3389/fmars.2019.00449/full
											Sloyan BM, Wanninkhof R, Kramp M, Johson GC, Talley LD, Tanhua T, McDonagh E, Cusack C, O'Rouke E, McGovern E, Katsumata K, Diggs S, Hummon J, Ishii M, Azetsu-Scott K, Boss E, Ansorge I, Perez FF, Mercier H, Williams MJM, Anderson L, Lee JH, Murata A, Kouketsu S, Jeansson E, Hoppema M, Campos E, 2019. The Global Ocean Ship-Based Hydrographic Investigations Program (GO-SHIP): A Platform for Integrated Multidisciplinary Ocean Science, Frontiers of Marine Science. doi:10.3389/fmars.2019.00445	https://www.frontiersin.org/articles/10.3389/fmars.2019.00445/full

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											Silvano A, Rintoul SR, Kusahara K, Pena-Molino B, van Wijk E, Gwyther DE, Willimas GD. 2019. Seasonality of warm water intrusions onto the continental shelf near the Totten Glacier, Journal of Geophysical Research - Oceans, doi:10.1029/2018JC014634	https://eprints.utas.edu.au/30939/
											Castagno, P. V. Capozzi, G. R. DiTullio, P. Falco, G. Fusco, S. R. Rintoul, and G. Budillon, 2019. Rebound of shelf water salinity in the Ross Sea, Nature Communications, doi: 10.1038/s41467-019-13083-8	https://www.nature.com/articles/s41467-019-13083-8
											Carter BR, Feely RA, Wanninkhof R, Kouketsu S, Sonnerup RE, Pardo PC, Sabine CL, Johnson GC, Sloyan BM, Murata A, Mecking S, Tilbrook B, Speer K, Talley LD, Millero FJ, Wijffels, Macdonald AM, Gruber N, Bullister JL. 2019. Pacific Anthropogenic Carbon between 1991 and 2017. Global Biogeochemical Cycles, doi: 10.1029/2018GB006154	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018GB006154
											Patel RS, Phillips HE, Strutton P, Lenton A, Llort J. 2019. Meridional Heat and Salt Transport Across the Subantarctic Front by Cold-Core Eddies. Journal of Geographical Research: Oceans, 124(2), doi:10.1029/2018JC014655	https://eprints.utas.edu.au/29700/
											Szuts ZB, Bower AS, Donohue KA, Girton JB, Hummon JM, Katsumata K, Lumpkin R, Ortner PB, Phillips HE, Rossby T, Shay LK, Todd RE. 2019. The scientific and societal uses of global measurements of subsurface velocity, Frontiers of Marine Science, Doi: 10.3389/fmars.2019.00358	https://www.frontiersin.org/articles/10.3389/fmars.2019.00358/full
											Purkey SG, Johnson GC, Talley DL, Sloyan B M, Wijffels SE, Smethie W, Mecking S, Katsumata K. 2018. Unabated Bottom Water Warming and Freshening in the South Pacific Ocean. Journal of Geophysical Research, Doi:10.1029/2018JC014775	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018JC014775
											Buchanan PJ, Matear RJ, Chase Z, Phipps SJ, Bindoff NL. 2018. Marine nitrogen fixers mediate a low latitude pathway for atmospheric CO2 drawdown, Nature Communications, 10(4611), doi: 10.1038/s41467-019-12549-z	https://www.nature.com/articles/s41467-019-12549-z
											Ocean observations along GO-SHIP P15S section	https://cchdo.ucsd.edu/cruise/096U20160426

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											New version of iQuOD global ocean historical data set with new bias corrections completed	
											Ocean Model equilibration period and runs and climate change scenarios complete at 1° and 0.25° resolution and stored in NCI Research Data Collection (Hogg/Stewart)	https://doi.org/10.4225/41/5a2dc8543105a
											Langlais C, Lenton A, Matear R, Monselesan D, Legresy B, Cougnon E, Rintoul SR. 2017. Stationary Rossby waves dominate subduction of anthropogenic carbon in the Southern Ocean. Scientific Reports, 7, 17076. doi:10.1038/s41598-017-17292-3	https://www.nature.com/articles/s41598-017-17292-3
											Silvano A, Rintoul SR, Peña-Molino B, Williams GD. 2017. Distribution of water masses and glacial meltwater on the continental shelf near the Totten Glacier. Journal of Geophysical Research – Oceans, 122, 2050–2068, doi:10.1002/2016JC012115.	http://nespclimate.com.au/wp-content/uploads/2016/03/Silvano_et_al-2017-Journal_of_Geophysical_Research__Oceans2.pdf
											Rintoul, S. R., 2018. Global influence of localized dynamics in the Southern Ocean. Nature, 558, 209-218. Doi: 10.1038/s41586-018-0182-3	http://nespclimate.com.au/wp-content/uploads/2016/03/rintoul_nature2018_pre-print-1.pdf
											SSTAARS: A very high spatial resolution (2 km) atlas of sea surface temperature of Australian regional seas	https://portal.aodn.org.au
											Rintoul SR, Chown SL, DeConto RM, England MH, Fricker HA, Masson-Delmotte V, Naish TR, Siegert MJ, Xavier JC. 2018. Choosing the future of Antarctica. Nature, 558, 233-241, doi: 10.1038/s41586-018-0173-4	http://nespclimate.com.au/wp-content/uploads/2016/03/rintoul_nature2018_pre-print.pdf
											Silvano A, Rintoul SR , Peña-Molino B, Hobbs WR, Aoki S, Orsi AH and Williams GD. 2018. Freshening by glacial meltwater enhances melting of ice shelves and reduces formation of Antarctic Bottom Water. Science Advances, Vol. 4, doi: 10.1126/sciadv.aap9467	http://advances.sciencemag.org/content/4/4/eaap9467/tab-pdf
											Snow K, Rintoul SR, Sloyan BM & Hogg AM. 2018. Change in Dense Shelf Water and Adelie Land Bottom Water precipitated by iceberg calving. *Geophysical Research Letters*, 45, 2380-2387, doi:10.1002/2017gl076195	http://nespclimate.com.au/wp-content/uploads/2016/03/Snow_et_al-2018-Geophysical_Research_Letters.pdf

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											Lambelet, M., van de Flierdt, T., Butler, E.C. V., Bowie, A. R., Rintoul, S. R., Watson, R. J., et al. (2018). The neodymium isotope fingerprint of Adélie Coast Bottom Water. Geophysical Research Letters, 45	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018GL080074
											IQuOD database products	http://iquod.github.io/
											Palmer, M.D., Boyer, T., Cowley, R., Kizu, S., Reseghetti, F., Suzuki, T.Thresher, A., 2018. An algorithm for classifying unknown expendable bathythermograph (XBT) instruments based on existing metadata. J. Atmos. Ocean. Technol. 35, 429–440.	https://journals.ametsoc.org/doi/full/10.1175/JTECH-D-17-0129.1
											Zhang Y, Feng M, Du Y, Phillips HE, Bindoff NL, McPhaden MJ. 2018. Strengthened Indonesian throughflow drives decadal warming in the Southern Indian Ocean. Geographical Research Letters, doi: 10.1029/2018GL078265	https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2018GL078265
											ESCC Hub science webinar: IPCC and our changing oceans	http://nespclimate.com.au/the-ipcc-process-and-our-changing-oceans/
											ESCC Hub science webinar: ocean heat uptake	http://nespclimate.com.au/webinar-ocean-heat-content/
											Pardo PC, Tilbrook B, Langlais C, Trull TW, Rintoul SR. 2017. Carbon uptake and biogeochemical change in the Southern Ocean, south of Tasmania. Bio geosciences.	https://www.biogeosciences.net/14/5217/2017/
2.5	Improving Australia's Climate Model (ACCESS)	ACCESS equips Australia with a global climate modelling capability that is uniquely concerned with the weather and climate of the Australasian and Southern Hemisphere region. The key outcome is a national preparedness that enables Australia to better manage weather and climate impacts, including future risks and opportunities; saving lives, resources and money. This project has significantly enhance ACCESS's accuracy by improving its simulation of critically important climate processes in the Australasian region, focussing on rainfall and weather extremes. It has facilitated the robust predictions needed for adaptation and emissions policies, and delivered an enhanced modelling system to the Hub and broader community.	Harun Rashid	CSIRO	1,494,551	1,635,511	**3,130,062**	01.07.2016	30.06.2019	Completed	Colman RA, Brown JR, Franklin C, Hanson L, Ye H, Zelinka MD, 2019, Evaluating cloud feedbacks and rapid responses in the ACCESS model. Journal of Geophysical Research, doi:10.1029/2018jd029189	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018JD029189
											Singh MS, Warren RA, Jakob C, 2019. A Steady-State Model for the Relationship Between Humidity, Instability, and Precipitation in the Tropics, Journal of Advances in Modelling Earth Systems, doi:10.1029/2019MS001686	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019MS001686
											Warren RA,Singh MS, Jakob C. 2020. Simulations of Radiative-Convective-Dynamical Equilibrium. Journal of Advances in Modeling Earth Systems, 12(3) DOI: 10.1029/2019MS001734	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019MS001734

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											Protat A, Klepp C, Louf V, Petersen WA, Alexander SP, Barros A, Leinonen J, Mace GG, 2019. The Latitudinal Variability of Oceanic Rainfall Properties and Its Implication for Satellite Retrievals: 1. Drop Size Distribution Properties, Journal of Geophysical Research -Atmospheres, doi:10.1029/2019JD031011	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019JD031010
											An improved version of ACCESS with significant reduction in tropical rainfall errors and improved simulations of the Madden-Julian Oscillation	https://trac.nci.org.au/svn/access_tools/NESP_diagnostics/trunk
											Timmermann A, et al. 2018. El Niño–Southern Oscillation complexity. Nature, 559, 535-545, doi: 10.1038/s41586-018-0252-6	http://nespclimate.com.au/wp-content/uploads/2016/03/Timmermannetal_ENSO-Complexity_Nature18_Preprint.pdf
											Version 1 of the diagnostic toolkit	https://accessdev.nci.org.au/trac/wiki/access/access_DiagnosticToolsV1
											Zhou XB, Alves O, Marsland SJ, Bi DH, Hirst AC. 2017. Multi-decadal variations of the South Indian Ocean subsurface temperature influenced by Pacific Decadal Oscillation. Tellus Series a-Dynamic Meteorology and Oceanography 69. doi:10.1080/16000870.2017.1308055	https://www.tandfonline.com/doi/full/10.1080/16000870.2017.1308055
											Zhu HY, Maloney E, Hendon H, Stratton R. 2017. Effects of the changing heating profile associated with melting layers in a climate model. Quarterly Journal of the Royal Meteorological Society 143, 3110-3121. doi: 10.1002/qj.3166	https://rmets.onlinelibrary.wiley.com/doi/abs/10.1002/qj.3166
											Rashid H, Zhu H and Sun Z (2017) Initial documentation of key systematic errors in a high resolution (60 km grid) version of the current ACCESS atmospheric model. Earth Systems and Climate Change Hub Technical Report No. 1, NESP Earth Systems and Climate Change Hub, Australia.	http://nespclimate.com.au/wp-content/uploads/2018/05/ESCC-R001-ACCESS-1705.pdf
											Zhu H, Jakob C, Ma Y, Warren R, Santra A, Yorgen S and Sun Z. 2018. A comprehensive report of model systematic errors in the latest ACCESS climate models. Earth Systems and Climate Change Hub Report No. 3, NESP Earth Systems and Climate Change Hub, Australia	http://nespclimate.com.au/wp-content/uploads/2016/03/ESCC-R003-ACCESS-1806.pdf
											Weblog on improving ACCESS	http://nespclimate.com.au/improving-tropical-rainfall-simulations-in-our-national-climate-model/

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											ESCC Hub science webinar: Australia's national climate model	http://nespclimate.com.au/australias-national-climate-model-access-development-and-application/
											Rashid HA, 2020. Delving deeper into Australia's national climate model: the Australian Community Climate and Earth System Simulator (ACCESS), NESP Earth Systems and Climate Change Hub Report No. 12, NESP Earth Systems and Climate Change Hub, Australia.	http://nespclimate.com.au/wp-content/uploads/2020/03/ESCC_R012_March-2020.pdf
											Model code for improved ACCESS version 1 is available through CWSLab	http://nci.org.au/services/nci-national-research-data-collection/climate-change-and-earth-system-science/
2.6	Regional Climate Projection Science, Information and Services	Key stakeholders have indicated that they want credible and salient projections to underpin adaptation. However, there are a few areas where uncertainties remain, data are inadequate for impact assessment, and uptake has been limited. This project has begun initial steps for planning and development of new projections that maintain credibility and salience. This project has enhanced uptake of climate projections information through improved products and services for targeted stakeholders. Research has also constrained uncertainty and improving confidence in projections, and the project has begun to lay the groundwork for the next generation of regional projections.	Michael Grose	CSIRO	1,668,750	1,371,721	**3,040,471**	01.07.2016	30.06.2019	Completed	Grose MR, Syktus J, Thatcher M, Evans JP, Ji F, Rafter T, Remenyi T. 2019. The role of topography on projected rainfall change in mid-latitude mountain regions. Climate Dynamics, 1-16, doi:10.1007/s00382-019-04736-x	http://nespclimate.com.au/wp-content/uploads/2019/05/10.1007_s00382-019-04736-x.pdf
											Our changing climate: how will rainfall change in Northern Australia over this century?	http://nespclimate.com.au/wp-content/uploads/2018/06/Northern-Australia-6pp_WEB.pdf
											Brown JR, Moise AF, Colman RA. 2017. Projected increases in daily to decadal variability of Asian-Australian monsoon rainfall. Geophysical Research Letters, 44, 5683–5690. doi:10.1002/2017GL073217	http://nespclimate.com.au/wp-content/uploads/2016/03/Brown_et_al-2017-Geophysical_Research_Letters.pdf
											Risbey JS, Grose MR, Monselesan DP, O'Kane TJ, Lewandowsky S. 2017. Transient response of the global mean warming rate and its spatial variation. Weather and Climate Extremes, doi:10.1016/j.wace.2017.11.002	https://www.sciencedirect.com/science/article/pii/S2212094716300494
											Zhang H., Y. Zhao, A. Moise, H. Ye, R. Colman, G. Roff, M. Zhao 2017. On the influence of SST warming intensity/patterns for uncertainties in CMIP5 model rainfall projections: An AGCM study. Climate Dynamics.	http://nespclimate.com.au/wp-content/uploads/2016/03/Post-print-Zhang-et-al-2017.-accessSST.pdf
											Brochure 'Our changing climate: Using climate change information to 2030'	http://nespclimate.com.au/wp-content/uploads/2017/10/Using-climate-change-information-to-2030.pdf
											Grose MR, Colman RA, Andrews T. 2018. What climate sensitivity index is most useful for projections? Geophysical Research Letters. 45(3), 1559-1566.	http://nespclimate.com.au/wp-content/uploads/2016/03/Grose_et_al-2018-Geophysical_Research_Letters.pdf
											ESCC Hub Science Webinar: Northern Australian rainfall change	http://nespclimate.com.au/how-will-rainfall-change-in-northern-australia-over-the-coming-century/

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											Brochure: Our changing climate: Southern Australia rainfall – long-term trends and future projections	Our changing climate: Southern Australia rainfall – long-term trends and future projections
											ESCC Hub weblog: Northern Australia rainfall changes	http://nespclimate.com.au/how-will-rainfall-change-in-northern-australia-over-this-century/
											ESCC Hub weblog: Long term trends and future projections of rainfall in Southern Australia	http://nespclimate.com.au/long-term-trends-and-future-projections-of-rainfall-in-southern-australia/
											ESCC Hub weblog: State of the Climate Report 2018	http://nespclimate.com.au/state-of-the-climate-2018-bureau-of-meteorology-and-csiro/
											ESCC Hub science webinar: regional projections	http://nespclimate.com.au/the-why-how-and-when-of-producing-climate-projections-in-australia/
											Climate Change in Australia (climate projections website)	www.climatechangeinaustralia.gov.au
											Training sessions on the Climate Change in Australia website with end-users	N/A
											The Conversation' article: Grose M, Bettio L. 2018. State of the Climate 2018: Bureau of Meteorology and CSIRO.	https://theconversation.com/state-of-the-climate-2018-bureau-of-meteorology-and-csiro-109001
											Brochure: Towards the next generation of climate change projections for Australia – summary of a proposed approach and timeline for a new future suite of climate change projections.	http://nespclimate.com.au/wp-content/uploads/2019/07/ESCC-NetGen-4pp_web.pdf
											Di Virgilio G, Evans JP, Di Luca A, Olson R, Argüeso D, Kala J, Andrys J, Hoffmann P, Katzfey JJ, Rockel B. 2019. Evaluating reanalysis-driven CORDEX regional climate models over Australia: model performance and errors, Climate Dynamics, doi: 10.1007/s00382-019-04672-w	http://nespclimate.com.au/wp-content/uploads/2019/05/2.6_DiVirgilio_et_al_8Feb2019_preprint.pdf
											Grose MR, Foster S, Risbey JS, Osbrough S, Wilson L. 2019. Using indices of atmospheric circulation to refine southern Australian winter rainfall climate projections, Climate Dynamics, pp1-13, doi: 10.1007/s00382-019-04880-4	https://link.springer.com/article/10.1007%2Fs00382-019-04880-4
											Science webinar: Climate Thresholds – an easy way to explore future climate extremes	http://nespclimate.com.au/climate-thresholds-an-easy-way-to-explore-future-climate-extremes/
											NextGen Projections workshop summary report	http://nespclimate.com.au/wp-content/uploads/2018/06/ESCC-R005-NextGen-projections-180629.pdf
											ESCC Hub science webinar: Climate Analogues Tool	http://nespclimate.com.au/climate-analogues-a-way-to-experience-the-future-climate/

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2.7	Refining Australia's Water Futures	Information about, and analyses of, future water availability are critical for water resources planning and investment decisions. However credible and consistent projections for a range of hydroclimate variables are not currently available. This project has improved our national modelling capability to simulate how changes in climate and land-use will affect Australia's hydroclimates and water resources into the future. As part of this activity the project team engaged with stakeholders to ensure that the projections are both relevant and useful to sectors that are significantly affected by climate and water, such as (but not limited to) agriculture.	Dewi Kirono	CSIRO	600,000	1,201,467	**1,801,467**	01.07.2016	30.06.2019	Completed	Chiew FHS, Zheng H, Potter NJ, Ekstrom M, Grose MR, Kirono DGC, Zhang L, Vaze J. 2017. Future runoff projections for Australia and science challenges in producing next generation projections. Proceedings of the 22nd International Congress on Modelling and Simulation, Hobart, December 2017, pp. 1745–1751.	http://www.mssanz.org.au/modsim2017/L16/chiew.pdf
											Cernusak LA, Haverd V, Brendel O, Thiec DL, Guehl JM, Cuntz M. 2019. Robust response of terrestrial plants to rising CO2, Trends in Plant Science, 24(7), pp. 578-586, 10.1016/j.tplants.2019.04.003	http://nespclimate.com.au/wp-content/uploads/2019/05/2.7_Cernusak_etal_2019_Accepted-version.pdf
											Kirono DGC, Grose MR, Hennessy KJ. 2017. Increasing risk of months with low rainfall and high temperature in southeast Australia for the past 150 years. Climate Risk Management, 16, 10–21, doi:10.1016/j.crm.2017.04.001	https://www.sciencedirect.com/science/article/pii/S2212096316300717
											Ekström M, Gutmann ED, Wilby RL, Tye MR, Kirono DGC. 2018. Robustness of hydroclimate metrics for climate change impact research. Wiley Interdisciplinary Reviews: Water, doi:10.1002/wat2.1288	https://onlinelibrary.wiley.com/doi/epdf/10.1002/wat2.1288
											ESCC Hub science webinar: water futures under climate change	http://nespclimate.com.au/water-futures-under-climate-change-science-applications-and-challenges/
2.8	Extreme Weather Projections	Extreme weather events such as tropical cyclones, east coast lows, thunderstorms, and extreme fire weather incur economic costs associated with property, environmental and human impacts (injury, displacement and death). Effective disaster risk reduction, emergency response, infrastructure design/operation, planning and policy making all require information about how these extreme events will change in the future. Research under the project filled critical knowledge gaps around extremes, and improve understanding of existing and projected characteristics of these extreme events. The projected used this new knowledge to improve simulations and projected changes in these extreme events and, through ongoing and effective stakeholder engagement, transform the research into targeted, useful and application-ready information.	Andrew Dowdy	Bureau of Meteorology and CSIRO	1,526,250	1,818,165	**3,344,415**	01.07.2016	30.06.2019	Completed	Fire weather dataset products, i.e. maps etc.	http://www.bom.gov.au/jsp/ncc/climate_averages/ffdi/index.jsp
											Chand SS, Dowdy AJ, Ramsay HA, Walsh KJE, Tory KJ, Power SB, Bell SS, Lavender SL, Ye H, Kuleshov Y, 2019. Review of tropical cyclones in the Australian region: Climatology, variability, predictability, and trends, Advanced Review, doi: 10.1002/wcc.602	https://onlinelibrary.wiley.com/doi/full/10.1002/wcc.602
											Ashcroft L, Dowdy AJ, Karoly DJ, 2019. Historical extreme rainfall events in south-eastern Australia, Weather and Climate Extremes, doi:10.1016/j.wace.2019.100210	https://www.sciencedirect.com/science/article/pii/S221209471930009X
											Dowdy AJ, Ye H, Pepler A, Thatcher M, Osbourgh SL, Evans JP, Di Virgilio G, McCarthy N. 2019. Future changes in extreme weather and pyroconvection risk factors for Australian wildfires. Nature Scientific Reports, 9:10073, doi:10.1038/s41598-019-46362-x	https://www.nature.com/articles/s41598-019-46362-x

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											Terrasson A, McCarthy N, Guyot A, Dowdy A and McGowan H. 2019. Wildfire and Weather Radar: A Review. Journal of Geophysical Research – Atmospheres, doi: 10.1029/2018JD029285	http://nespclimate.com.au/wp-content/uploads/2019/05/2.8_Terrasson_et_al-2019-Journal_of_Geophysical_Research__Atmospheres.pdf
											Earth Systems and Climate Change Hub. 2019. Bushfires and climate change in Australia.	http://nespclimate.com.au/wp-content/uploads/2019/11/A4_4pp_brochure_NESP_ESCC_Bushfires_FINAL_Nov11_2019_WEB.pdf
											Earth Systems and Climate Change Hub. 2019. Thunderstorms and climate change in Australia.	http://nespclimate.com.au/wp-content/uploads/2019/11/A4_4pp_brochure_NESP_ESCC_Thunderstorms_Nov11_2019_WEB.pdf
											Earth Systems and Climate Change Hub. 2019. East coast lows and climate change in Australia.	http://nespclimate.com.au/wp-content/uploads/2019/11/A4_4pp_brochure_NESP_ESCC_East_Coast_Lows_Nov11_2019_WEB.pdf
											Earth Systems and Climate Change Hub. 2019. Tropical cyclones and climate change in Australia.	http://nespclimate.com.au/wp-content/uploads/2019/11/A4_4pp_brochure_NESP_ESCC_Tropical_Cyclones_FINAL_Nov11_2019_WEB.pdf
											Cavicchia L, et al. 2019. A physically-based climatology of Australian east coast lows occurrence and intensification. Journal of Climate, doi:10.1175/JCLI-D-18-0549	https://journals.ametsoc.org/doi/abs/10.1175/JCLI-D-18-0549.1
											Bell SS, Chand SS, Tory KJ, Turville C, Ye H. 2019. Eastern North Pacific tropical cyclone activity in historical and future CMIP5 experiments: assessment with a model-independent tracking scheme, Climate Dynamics, doi: 10.1175/JCLI-D-18-0549	https://journals.ametsoc.org/doi/abs/10.1175/JCLI-D-18-0549.1
											Tropical Cyclone Portal	https://shiny.csiro.au/Tropical-Cyclone-Projections-Portal/
											Bell SS, Chand SS, Camargo SJ, Tory KJ, Turville C. 2019. Western North Pacific Tropical Cyclone Tracks in CMIP5 Models: Statistical Assessment Using a Model-Independent Detection and Tracking Scheme, Journal of Climate.	https://doi.org/10.1175/JCLI-D-18-0785.1
											Science webinar: Tropical cyclones in the Australian region – past, present and future	http://nespclimate.com.au/tropical-cyclones-in-the-australian-region/
											Raavi PH and Walsh KJE. 2020. Sensitivity of tropical cyclone formation to resolution-dependent and independent tracking schemes in high-resolution climate model simulations. Earth and Space Science Journal, Vol 7, Issue 3, doi: 10.1029/2019EA000906	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019EA000906

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											Bates B, Dowdy AJ, Chandler R, 2017. Lightning Prediction for Australia Using Multivariate Analyses of Large-Scale Atmospheric Variables, Journal of Applied Meteorology and Climatology, 57, 525-534. doi: 10.1175/jamc-d-17-0214.1	http://journals.ametsoc.org/doi/abs/10.1175/JAMC-D-17-0214.1
											Dowdy A. 2017. Climatological variability of fire weather in Australia. Journal of Applied Meteorology and Climatology, doi:10.1175/JAMC-D-17-0167.1.	http://journals.ametsoc.org/doi/10.1175/JAMC-D-17-0167.1
											Dowdy AJ, Catto JL. 2017. Extreme weather caused by concurrent cyclone, front and thunderstorm occurrences. Scientific Reports, 7, doi:10.1038/srep40359	https://www.nature.com/articles/srep40359
											Dowdy AJ, Fromm MD, McCarthy N. 2017. Pyrocumulonimbus lightning and fire ignition on Black Saturday in southeast Australia. Journal of Geophysical Research—Atmospheres, 122(14), 7342-7354, doi: 10.1002/2017JD026577	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017JD026577
											McCarthy N, McGowan H, Guyot A, Dowdy A. 2017. Mobile X-Pol radar: A new tool for investigating pyroconvection and associated wildfire meteorology. Bulletin of the American Meteorological Society. doi: 10.1175/bams-d-16-0118.1	https://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-16-0118.1
											Pepler AS, Di Luca A, Evans JP. 2017. Independently assessing the representation of midlatitude cyclones in high-resolution reanalyses using satellite observed winds. International Journal of Climatology, doi:10.1002/joc.5245	http://web.science.unsw.edu.au/~jasone/publications/pepleretal2017a.pdf
											Dowdy, A., Ye, H., Tory, K., Jones, D., Evans, A., Lavender, S., Thatcher, M., Rafter, T., Osbrough, S., Walsh, K., Cavicchia, L., Evans, J., Catto, J., 2017: Extreme weather: improved data products on bushfires, thunderstorms, tropical cyclones and east coast lows, Peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference, 4-6 September 2017, 269.2017.	https://www.bnhcrc.com.au/node/3874

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											Tory KJ, Ye H, Dare RA. 2017. Understanding the geographic distribution of tropical cyclone formation for applications in climate models. Climate Dynamics, doi:10.1007/s00382-017-3752-4	https://link.springer.com/article/10.1007/s00382-017-3752-4
											Cavicchia L, Dowdy A, Walsh K. 2018. Energetics and dynamics of subtropical Australian east coast cyclones: Two contrasting cases. *Monthly Weather Review*, doi:10.1175/MWR-D-17-0316.1	http://nespclimate.com.au/wp-content/uploads/2019/03/cavicchia_etal_mwr_2018.pdf
											Sharmila, S. and K.J.E. Walsh. 2018. Recent poleward shift of tropical cyclone formation and its link to tropical expansion. *Nature Climate Change*, 8, 730-736, doi: 10.1038/s41558-018-0227-5	http://nespclimate.com.au/wp-content/uploads/2018/11/Walsh_poleward-shift-in-TC_NCC.pdf
											Pepler AS, Dowdy AJ, Hope P. 2018. A global climatology of surface anticyclones, their variability, associated drivers and long-term trends, Climate Dynamics, doi.org/10.1007/s00382-018-4451-5	https://link.springer.com/article/10.1007%2Fs00382-018-4451-5
											Ramsay H, Chand S & Camargo S, 2018. A statistical assessment of Southern Hemisphere tropical cyclone tracks in climate models. Journal of Climate, Vol 13, 24:10081-10104.	http://nespclimate.com.au/wp-content/uploads/2019/01/Ramsay_jcli-d-18-0377.1_early-online-release.pdf
											Bates B, McCaw L, Dowdy A, 2018. Exploratory analysis of lightning-ignited wildfires in the Warren Region, Western Australia, Journal of Environmental Management, doi: 10.1016/j.jenvman.2018.07.097	http://nespclimate.com.au/wp-content/uploads/2016/03/Bates-etal-Exploratory-Analysis-JoEM-V2.2.pdf
											Bell SS, Chand SS, Tory KJ, Turville C. 2018. Statistical assessment of the OWZ tropical cyclone tracking scheme in ERA-Interim. Journal of Climate, doi:10.1175/JCLI-D-17-0548.1	https://journals.ametsoc.org/doi/abs/10.1175/JCLI-D-17-0548.1
											Bell SS, Chand SS, Tory KJ, Dowdy AJ, Turville C, Ye H. 2018. Projections of southern hemisphere tropical cyclone track density using CMIP5 models, Climate Dynamics doi:10.1007/s00382-018-4497-4	http://nespclimate.com.au/wp-content/uploads/2019/03/CLDY-D-18-00393-1-pages-deleted.pdf

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											von Storch H, Cavicchia L, Feser F, Li D. 2018. The Concept of Large-Scale Conditioning of Climate Model Simulations of Atmospheric Coastal Dynamics: Current State and Perspectives. *Atmosphere* 9, 337, doi:10.3390/atmos9090337.	https://www.mdpi.com/2073-4433/9/9/337
											Dowdy A, Pepler P, Ashcroft L, Jones D, Braganza K, Bettio L, 2018. Climate Change Influences on Natural Hazards, Proceedings of AFAC 2018 Conference, Perth, WA	http://nespclimate.com.au/wp-content/uploads/2019/05/climate-change-impacts-on-natural-hazards.pdf
											Lavender SL, Walsh KJE, Caron L-P, King M, Monkiewicz S, Guishard M, Zhang Q, Hunt B. 2018. Estimation of the maximum annual number of North Atlantic tropical cyclones using climate models. Sci. Adv. 4, doi:10.1126/sciadv.aat6509.	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6105296/
											ESCC Hub weblog: Conditions more conducive for pyroconvection	http://nespclimate.com.au/conditions-more-conducive-for-pyroconvection/
											Lavender SL, Hoeke RK, Abbs DJ. 2018. The influence of sea surface temperature on the intensity and associated storm surge of tropical cyclone Yasi: a sensitivity study. Natural Hazards and Earth System Sciences, 18, 795-805, doi:10.5194/nhess-18-795-2018	https://www.nat-hazards-earth-syst-sci.net/18/795/2018/
2.9	Risk assessment of future carbon sources and sinks	This project has investigated and assessed the potential for current carbon abatement by revegetation and conservation in Australia, with an emphasis on their potential vulnerability under future climate change, and long-term carbon-climate feedbacks. The project delivered data products showing national and global carbon budget trajectories (CO_2 and CH_4), and how these track the pathways needed for global climate stabilisation by the end of the 21st century. These products were delivered in stakeholder-relevant formats, suitable for use by government agencies, business and enterprises, and the broader community.	Pep Canadell	CSIRO	900,000	1,028,751	**1,928,751**	01.07.2016	30.06.2019	Completed	Zhang XZ, Peng SS, Wang YP, Silver JD, Piao SL, Rayner PJ. 2019. Greenhouse gas concentration and volcanic eruption dominated the variability of terrestrial carbon fluxes uptake over the last millennium. Journal of Advances in Modelling Earth Systems. doi:10.1029/2018MS001566	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018MS001566
											Fleischer K, Rammig A, De Kauwe MG, Walker AP, Domingues TF, Fuchslueger L, Garcia, Daniel S Goll, Adriana Grandis, Mingkai Jiang, Vanessa Haverd, Bernard Pak, Yingping Wang, et al. Amazon forest response to CO2 fertilization dependent on plant phosphorus acquisition, Nature Geoscience 12 (9), 736-741, doi:10.1038/s41561-019-0404-9	https://www.nature.com/articles/s41561-019-0404-9

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											Pugh TAM, Lindeskog M, Smith B, Poulter B, Arneth A, Haverd V, Calle L. 2019. Role of forest regrowth in global carbon sink dynamics, Proceedings of the National Academy of Sciences, 116, 4382-4387, doi: 10.1073/pnas.1810512116	https://www.pnas.org/content/116/10/4382
											Jackson RB, Solomon EI, Canadell JG, Cargnello M, Field CB. 2019. Methane removal and atmospheric restoration. Nature Sustainability, doi:10.1038/s41893-019-0299-x	https://www.nature.com/articles/s41893-019-0299-x
											Canadell JG & Jackson RB. 2019. Turning methane into carbon dioxide could help us fight climate change. The Conversation.	https://theconversation.com/turning-methane-into-carbon-dioxide-could-help-us-fight-climate-change-117317
											Corinne Le Quéré, Robbie M. Andrew, Pierre Friedlingstein, Stephen Sitch, Julia Pongratz, Andrew C. Manning, Jan Ivar Korsbakken, Glen P. Peters, Josep G. Canadell, et al (2018) Global Carbon Budget 2017. Earth System Science Data 10: 405–448	https://www.earth-syst-sci-data.net/10/405/2018/essd-10-405-2018-discussion.html Data sets: https://www.icos-cp.eu/GCP/2017
											Cheng L, Zhang L, Wang Y-P, Canadell JG, Chiew FHS, Beringer J, Li L, Miralles DG, Piao S, Zhang Y. 2017. Recent increases in terrestrial carbon uptake at little cost to the water cycle. Nature Communications, 8, doi:10.1038/s41467-017-00114-5	https://www.nature.com/articles/s41467-017-00114-5
											Global Carbon Budget 2017 dataset	https://www.icos-cp.eu/GCP/2017
											ESCC Hub webinar - The Global Carbon Budget 2017 and COP23	http://nespclimate.com.au/webinar-the-global-carbon-budget-2017-and-cop23/
											Jackson RB, Le Quéré C, Andrew RM, Canadell JG, Peters GP, Roy J, Wu L. 2017. Warning signs for stabilizing global CO2 emissions. Environmental Research Letters 12. doi: 10.1088/1748-9326/aa9662	http://iopscience.iop.org/article/10.1088/1748-9326/aa9662/meta
											Peters GP, Andrew RM, Canadell JG, Fuss S, Jackson RB, Korsbakken JI, Le Quéré C, Nakicenovic N. 2017. Key indicators to track current progress and future ambition of the Paris Agreement. Nature Climate Change, 7, 118–122, doi:10.1038/nclimate3202	http://www.nature.com/nclimate/journal/v7/n2/full/nclimate3202.html

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											Poulter B, et al. 2017. Global wetland contribution to 2000–2012 atmospheric methane growth rate dynamics. Environmental Research Letters, 12(9), doi:10.1088/1748-9326/aa8391 | Full paper	http://iopscience.iop.org/article/10.1088/1748-9326/aa8391/pdf
											Saunois M, et al. 2017. Variability and quasi-decadal changes in the methane budget over the period 2000–2012, Atmospheric Chemistry and Physics, 17, 11135-11161, doi:10.5194/acp-17-11135-2017	https://www.atmos-chem-phys.net/17/11135/2017/acp-17-11135-2017.pdf
											Buermann et al. 2018. Widespread seasonal compensation effects of spring warming on northern plant productivity, Nature 562, 110-114 doi:10.1038/s41586-018-0555-7	http://nespclimate.com.au/wp-content/uploads/2016/03/Buermann_Nature_2018.pdf
											Kim et al. 2018. A protocol for an intercomparison of biodiversity and ecosystem services models using harmonized land-use and climate scenarios. Geoscientific Model Development Discussions, 1-37, doi: 10.5194/gmd-2018-115	https://www.geosci-model-dev.net/11/4537/2018/gmd-11-4537-2018-discussion.html
											Bastos et al. 2018. Impact of the 2015/2016 El Nino on the terrestrial carbon cycle constrained by bottom-up and top-down approaches, Philosophical Transactions of the Royal Society B, doi: 10.1098/rstb.2017.0304	https://royalsocietypublishing.org/doi/full/10.1098/rstb.2017.0304
											Houlton, BZ, Wang, YP, Warlind, D, Dass, Pawlok, Houlton, Benjamin Z. 2018. Grasslands may be more reliable carbon sinks than forests in California, Environmental Research Letters 13.	https://iopscience.iop.org/article/10.1088/1748-9326/aacb39/meta
											Canadell P, Le Quere C, Peters G, Andrews R, Jackson R. 2018. Carbon emissions will reach 37 billion tonnes in 2018, a record high. The Conversation.	https://theconversation.com/carbon-emissions-will-reach-37-billion-tonnes-in-2018-a-record-high-108041
											Le Quere et al. 2018. Global Carbon Budget 2018, earth systems science Data, 10, 2141-2194	https://www.earth-syst-sci-data.net/10/2141/2018/
											Jackson et al, 2018. Global energy growth is outpacing decarbonisation, Environ. Res. Letters, 13, doi: https://doi.org/10.1088/1748-9326/aaf303	https://iopscience.iop.org/article/10.1088/1748-9326/aaf303/meta

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											Haverd, V., et al. 2018. A new version of the CABLE land surface model (Subversion revision r4546), incorporating land use and land cover change, woody vegetation demography and a novel optimisation-based approach to plant coordination of electron transport and carboxylation capacity-limited photosynthesis., Geosci. Model Dev.	https://www.geosci-model-dev.net/11/2995/2018/gmd-11-2995-2018.pdf
											C Trudinger, V Haverd, P Canadell, P Briggs, B Smith. 2018. Model-data fusion framework to assess the vulnerability of Australian carbon stocks and water resources. Geophysical Research Abstracts, Volume 20, https://meetingorganizer.copernicus.org/EGU2018/EGU2018-18757.pdf	https://meetingorganizer.copernicus.org/EGU2018/EGU2018-18757.pdf
											Jackson RB, Le Quéré C, Andrew RM, Canadell JG, Korsbakken JI, Liu Z, Peters GP, Roy J, Wu L, 2018, Global energy growth is outpacing decarbonisation, *Environmental Research Letters* , 13, doi: 10.1088/1748-9326/aaf303	https://iopscience.iop.org/article/10.1088/1748-9326/aaf303
											ESCC Hub weblog - record high carbon emissions in 2018	http://nespclimate.com.au/carbon-emissions-will-reach-37-billion-tonnes-in-2018-a-record-high/
											Cuntz M, Haverd V. 2018. Physically Accurate Soil Freeze-Thaw Processes in a Global Land Surface Scheme. Journal of Advances in Modelling Earth Systems, 10(1), 54-77, doi:10.1002/2017ms001100	http://onlinelibrary.wiley.com/doi/10.1002/2017MS001100/full
											Data are the submission of CABLE results to the 'Trends in net land-atmosphere carbon exchange' (TRENDY) global terrestrial biosphere simulation experiment.	http://hpc.csiro.au/users/70496/TRENDYv6_CABLE_Aug2017/ Documents: http://hpc.csiro.au/users/70496/TRENDYv6_CABLE_Aug2017/documents/
											Morim, Hemer et al., 2019. Skill and uncertainty in surface wind fields from general circulation models: Intercomparison of bias between AGCM, AOGCM and ESM global simulations, International Journal of Climatology, doi: 10.1002/joc.6357	https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/joc.6357
2.10	Coastal Hazards in a Variable and Changing Climate	Coastal erosion and inundation will be influenced by changes in sea levels and waves. Over $226 billion in Australian assets could be at risk from a 1.1 m increase in sea level (a high-end projection for 2100). However, the projected changes and their coastal impacts remain uncertain and controversial. This project has improved understanding of past, and develop projections for future, changes to coastal stressors (sea level, storm surges and waves) and their physical impact. Through	Kathleen McInnes	CSIRO	1,240,000	1,506,997	**2,746,997**	01.07.2016	30.06.2019	Completed	O'Grady JO, McInnes KL, Hemer MA, Hoeke RK, Stephenso A, Colberg F, 2019. Extreme water levels for Australian beaches using empirical equations for shoreline wave setup. Journal of Geophysical Research- Oceans	https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2018JC014871

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		waves) and their physical impact. Through engagement with end-users in government and industry, the project has tailored and delivered it's outputs in ways that ensure Australians can plan effectively for coastal change.									Echevarria ER, Hemer MA, Holbrook NJ. 2019. Seasonal Variability of the Global Spectral Wind Wave Climate, JGR Oceans, doi:10.1029/2018JC014620	https://eprints.utas.edu.au/30262/
											CAWCR Wave Hindcast 1979-2010	https://data.csiro.au/collections/#collection/CIcsiro:6616v8/Ditrue
											Science webinar: Understanding future extreme sea levels – tools and information to support coastal management	http://nespclimate.com.au/understanding-future-extreme-sea-levels-tools-and-information-to-support-coastal-management/
											Hinkel J, Church JA, Gregory JM, Lambert E, Le Cozannet G, Lowe J, McInnes KL, Nicholls RJ, van der Pol T, van de Wal R. 2019. Meeting User Needs for Sea Level Rise Information: A Decision Analysis Perspective, Earth's Future, doi: 10.1029/2018EF001071	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018EF001071
											Colberg F, McInnes KL, O'Grady J, Hoeke R. 2019. Atmospheric circulation changes and their impact on extreme sea levels around Australia. J. Nat. Hazards Earth Syst. Sci., 19, 1067–1086, doi:10.5194/nhess-19-1067-2019	https://www.nat-hazards-earth-syst-sci.net/19/1067/2019/
											Morim J, Hemer, M, Wang XL, Cartwright N, Trenham C, Semedo A, Young I, Bricheno L, Camus P, Casas-Prat M, Erikson L, Mentaschi L, Mori N, Shimura T, Timmermans B, Aarnes O, Breivik O, Behrens A, Dobrynin M, Menendez M, Staneva J, Wehner M, Wolf J, Kamranzad B, Webb A, Stopa J, Andutta F. 2019. Robustness and uncertainties in multivariate wind-wave climate projections, Nature Climate Change, doi:10.1038/s41558-019-0542-5	https://www.researchgate.net/publication/335250596_Robustness_and_uncertainties_in_global_multivariate_wind-wave_climate_projections
											Mark Hemer, Ian Young, Joao Morim Nascimento and Nobuhito Mori, 2019. Climate change may change the way ocean waves impact 50% of the world's coastlines. The Conversation	https://theconversation.com/climate-change-may-change-the-way-ocean-waves-impact-50-of-the-worlds-coastlines-121239
											CSIRO Australia Coastal Sea level Simulations	https://data.csiro.au/collections/#collection/CIcsiro:29013v1
											Le Cozannet G, Nicholls RJ, Hinkel J, Sweet WV, McInnes KL, Van de Wal RSW, Slangen ABA, Lowe JA, White KD. 2017. Sea level change and coastal climate services: the way forward. Journal of Marine Science and Engineering. 5(4), 49; doi:10.3390/jmse5040049	http://www.mdpi.com/2077-1312/5/4/49

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											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/Wu_et_al-2017-Journal_of_Geophysical_Research__Oceans.pdf
											Progress of digitalisation of imaged charges presented at AMOS. Digitisation of registers back to 1900, QC of all digitised data and preliminary analysis of extremes	https://theconversation.com/climate-change-may-change-the-way-ocean-waves-impact-50-of-the-worlds-coastlines-121239
											Marshall AG, Hemer MA, Hendon HH, McInnes KL. 2018. Southern annular mode impacts on global ocean surface waves. *Ocean Modelling*, 129, 58-74. doi: 10.1016/j.ocemod.2018.07.007	https://doi.org/10.1016/j.ocemod.2018.07.007
											Wu, Q., X. Zhang, J. A. Church and J. Hu. 2018. ENSO-related Global Ocean Heat Content Variations, Journal of Climate, doi: 10.1175/JCLI-D-17-0861.1	https://journals.ametsoc.org/doi/full/10.1175/JCLI-D-17-0861.1
											Wu W, McInnes KL, O'Grady J, Hoeke RK, Leonard M, Westra S. 2018. Mapping dependence between extreme rainfall and storm surge, Geophysical Research Letters, doi:10.1002/2017JC013472	https://doi.org/10.1002/2017JC013472
											CAWCR Wave Hind cast 1979-2010	https://data.csiro.au/dap/landingpage?pid=csiro:6616
											Morris RL, Strain EMA, Konlechner TM, Fest BJ, Kennedy DM, Arndt SK, Swearer SE. 2019. Developing a nature-based coastal defence strategy for Australia, Australian Journal of Civil Engineering, doi: 10.1080/14488353.2019.1661062	https://www.tandfonline.com/doi/full/10.1080/14488353.2019.1661062
2.11	Establishment of the National Centre for Coasts and Climate –	The growing economic and population concentration in Australia's coastal areas,	Stephen Swearer	University of Melbourne	1,050,000	2,164,914	**3,214,914**	01.07.2016	30.06.2019	Completed	Science webinar: The causes of coastal erosion	http://nespclimate.com.au/the-causes-of-coastal-erosion/

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	Phase 1	and their increasing exposure to flooding and inundation due to climate change, are leading to emerging challenges for coastal development. This project has established the National Centre for Coasts and Climate (NCCC), and initiated its mission to deliver outcomes-focussed research, by identifying: (1) the value of blue carbon in mitigating climate change, (2) the dynamic responses of coastal landform systems to waves and inundation and improve predictions of the impacts of sea-level rise, and (3) the approaches needed to integrate ecological engineering into planning decisions to improve the adaptive capacity of coastal and marine ecosystems to respond to climate change.									Konlechner TM, Kennedy DM, Cousens RD and Woods JL. 2019. Patterns of early-colonising species on eroding to prograding coasts; implications for foredune plant communities on retreating coastlines. Geomorphology, 327, 404-416, doi:10.1016/j.geomorph.2018.11.013	http://nespclimate.com.au/wp-content/uploads/2019/01/Konlechner_GEOMOR_6579.pdf
											Morris RL, Bilkovic DM, Boswell MK, Bushek B, Cebrian J, Goff J, Kibler KM, La Peyre MK, McGlenachan G, Moody J, Sacks P, Shinn JP, Sparks EL, Temple NA, Wlaters LJ, Webb BM, Swearer SE. 2019. The application of oyster reefs in shoreline protection: are we over-engineering for an ecosystem engineer? Journal of Applied Ecology, doi: 10.1111/1365-2664.13390	https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/1365-2664.13390 AB228:AB229AB231AB227:AB228AB228:AB232AB231AAB228:AB234+AB227:AB228
											Kennedy DM, McInnes K, and Ierodiaconou D. 2019. Understanding Coastal Erosion on Beaches: A guide for managers, policy makers and citizen scientists. National Centre for Coasts & Climate, The University of Melbourne	http://nespclimate.com.au/wp-content/uploads/2019/08/Understanding-Coastal-Erosion-on-Beaches-Web.pdf
											Earth Systems and Climate Change Hub. 2019. Eco-engineering and restoration of coastal habitats in Australia.	http://nespclimate.com.au/wp-content/uploads/2019/05/2.11-1_A4_4pp_Brochure_Eco-Engineering_NCCC_ESCC_Feb26_2020_WEB.pdf
											Earth Systems and Climate Change Hub. 2019. Coastal erosion under a changing climate	http://nespclimate.com.au/wp-content/uploads/2019/05/2.11_1_A4_4pp_Brochure_Coastal_Erosion_NCCC_ESCC_Feb26_2020_WEB.pdf
											Earth Systems and Climate Change Hub. 2019. Climate change and blue carbon in Australia	http://nespclimate.com.au/wp-content/uploads/2019/05/2.11-1_A4_4pp_Brochure_Blue_Carbon_in_Australia_NCCC_ESCC_Feb26_2020_WEB.pdf
											Understanding coastal erosion on beaches: A guide for managers, policy makers and citizen scientists	http://nespclimate.com.au/wp-content/uploads/2019/11/Understanding-Coastal-Erosion-on-Beaches_updatedNov19.pdf
											Ecological Engineering Data Collection - Meta-analysis data for nature-based coastal defence studies; Wave attenuation for kelp, mangroves, seagrass, saltmarsh and mussel reefs; Sediment accumulation using rSETs, sediment traps, pins, beach profiling and drone surveys for mangroves seagrass, saltmarsh and mussel reefs; ecological data (vegetation and biodiversity characteristics) for kelp, seagrass, saltmarsh, mangroves.	N/A

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											Oliver TSN, Kennedy DM, Tamura T, Murray-Wallace CV, Konlechner TM, Augustinus PC, Woodroffe CD. 2018. Interglacial-glacial climatic signatures preserved in a regressive coastal barrier, south-eastern Australia. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 501, 124 – 135, doi:10.1016/j.palaeo.2018.04.011	https://ro.uow.edu.au/smhpapers/5390/
											Kennedy DM, Konlechner T, Zavadil E, Mariani M, Wong V, Ierodiaconou D, Macreadie P. 2017. Invasive cordgrass (Spartina spp.) in south-eastern Australia induces island formation, salt marsh development, and carbon storage. Geographical Research, 56(1), 80-91, doi: 10.1111/1745-5871.12265	http://onlinelibrary.wiley.com/doi/10.1111/1745-5871.12265/full
											Morris RL, Konlechner TM, Ghisalberti M, Swearer SE. 2018. From grey to green: Efficacy of eco-engineering solutions for nature-based coastal defence. Global Change Biology, 1-16, doi: 10.1111/gcb.14063	http://nespclimate.com.au/wp-content/uploads/2016/02/Morris-From-grey-to-green_-efficacy-of-eco-eng.pdf
											Coastal Erosion Data Collection - Georectified aerial photos, digitised shorelines, EPR of change of shoreline position; UAV derived pointclouds, digital surface models and orthophotos of sites; RTK-GPS derived cross-shore profiles; GPS co-ordinates of sampling locations; ecological data (vegetation cover, species richness) for foredunes; database of past erosion events, Victoria Coast; database of known erosion sites, Victoria Coast.	N/A

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											Blue Carbon Data Collection - Collection comprises of: Literature database for systematic literature reviews and meta data extraction. Raw field sediment core profile data to determine carbon stocks, carbon accumulation rates, organic matter composition from py-GC-MS, sedimentation data from rSET, sediment traps and sediment pins; raw greenhouse gas flux data from chamber and tower measurements; Images, areal images for monitoring and digital elevation models of sites, photo points, photo quadrants, Rhizotron images for root growth analysis.	N/A
											ESCC Hub science webinar: nature based opportunities for adaptation in the coastal zone	http://nespclimate.com.au/nature-based-opportunities-for-climate-adaptation-in-the-coastal-zone/

CONTINUING RESEARCH PROJECTS

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5.1	ACCESS evaluation and application	Climate and Earth system models are important tools for understanding and predicting climate variability and change. This project will use ensemble simulations with different ACCESS model versions to demonstrate how the ACCESS model developments and CMIP6 benchmarking undertaken in previous Hub projects can be applied for next and end users. The project will use various simulations to support other Hub projects under RPV5. It will also support these projects by providing multi-decadal simulations of the ACCESS atmospheric model at relatively high spatial resolution (useful for regional applications). The project will highlight the application of ACCESS model versions by quantify the biophysical and biogeochemical effects and socio-economic cost of various land management strategies for Australia and regionally under low and high emissions scenarios. This information could be used by land managers when developing cost effective strategies to reduce greenhouse gas emissions and/or store carbon on the land.	Harun Rashid	CSIRO	951,563	951,563	**1,903,126**	01.07.2019	31.12.2020	Ongoing	Yeung N, Menviel L, Meissner K, Ziehn T, Chamberlain M, Mackallah C, Druken K, Ridzwan SM. 2019. CSIRO ACCESS-ESM1.5 model output prepared for CMIP6 PMIP. Version YYYYMMDD[1].Earth System Grid Federation. https://doi.org/10.22033/ESGF/CMIP6.13701	https://doi.org/10.22033/ESGF/CMIP6.13701
											Ziehn T, Dix M, Mackallah C, Chamberlain M, Lenton A, Law R, Druken K, Ridzwan SM. 2020. CSIRO ACCESS-ESM1.5 model output prepared for CMIP6 DAMIP. Version YYYYMMDD[1].Earth System Grid Federation. https://doi.org/10.22033/ESGF/CMIP6.14362	https://doi.org/10.22033/ESGF/CMIP6.14362
											Zhu HY, Smith RK. 2020. A case-study of a tropical low over northern Australia. Quarterly Journal of the Royal Meteorological Society.	https://rmets.onlinelibrary.wiley.com/doi/abs/10.1002/qj.3762
											Rashid HA, Dix M, Sullivan A, Bodman R, Zhu HY. 2020. ACCESS climate model simulations for the Coupled Model Intercomparison Project (CMIP6) Earth Systems and Climate Change Hub Report No. 14. Earth Systems and Climate Change Hub, Australia.	http://nespclimate.com.au/wp-content/uploads/2019/05/Rashidetal_InitialReport-ACCESS-climate-model-simulations-for-CMIP6_ESCCHubReport14_FINAL.pdf

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					NESP Funding* $	Total Other Contributions* $	Total Budget* $				Outputs	Link to output
											Rashid HA. 2020. Factors affecting ENSO predictability in a linear empirical model of tropical air-sea interactions. Science Reports. 10(1), 3931, doi: 10.1038/s41598-020-60371-1	https://doi.org/10.1038/s41598-020-60371-1
5.2	Understanding climate variability and change - past, present and future	Australians have managed in a variable climate for thousands of years, but opportunities exist to further apply our scientific understanding of climate variability and change to help water, ecosystem, food resource and disaster managers understand and act on their climate risks. This project will undertake the underpinning climate science research to provide information and data on Australia's variable and changing climate and how climate drivers are expected to change in the future. This information can then be used in targeted tools, guidance and communication products to inform and advise relevant stakeholders. The project will also build on previous Hub research to further develop attribution of extreme events methods and systems, and will provide attribution statements for forecasted events as they occur. This will allow better understanding of the role climate change plays in individual extreme events, and how these events are likely to change as the climate continues to warm.	Christine Chung	BoM	992,250	992,250	**1,984,500**	01.07.2019	31.12.2020	Ongoing	Holmes RM, Zika JD, Ferrari R, Thompson AF, Newsom ER, England MH. 2019. Atlantic Ocean Heat Transport Enabled by Indo-Pacific Heat Uptake and Mixing. Geophysical Research Letters, doi: 10.1029/2019GL085160	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019GL085160
											Cai et al. 2020. Climate impacts of the El Niño–Southern Oscillation on South America. Nature Reviews Earth & Environment, doi: 10.1038/s43017-020-0040-3	https://www.nature.com/articles/s43017-020-0040-3
											Grose MR, Black MT, Wang G, King AD, Hope P, Karoly DJ. 2020. The warm and extremely dry spring in 2015 in Tasmania contained the fingerprint of human influence on the climate. J. South. Hemisph. Earth Syst. Sci. doi: 10.22499/3.6901.011	https://www.publish.csiro.au/ES/ES19011
											Santoso A, Bordbar MH, England M, Sen Gupta A, Taschetto A, Martin T, Park W, Latif M. 2020. Uncertainty in Near-term Global Surface Warming Linked to Tropical Pacific Climate Variability. Nature Communications, 10	https://www.nature.com/articles/s41467-019-09761-2
											Delage FPD and Power SB. 2020. The impact of global warming and the El Niño-Southern Oscillation on seasonal precipitation extremes in Australia. Climate Dynamics, doi: 10.1007/s00382-020-05235-0	https://link.springer.com/article/10.1007/s00382-020-05235-0
											Wang GW, Cai WJ, Santoso A, 2019. Stronger increase in the frequency of extreme convective El Nino than extreme warm El Nino under greenhouse warming, *Journal of Climate* , doi:10.1175/JCLI-D-19-0376.1	https://journals.ametsoc.org/doi/full/10.1175/JCLI-D-19-0376.1?mobileUi=0
											Wang GJ, Cai WJ, Yang K, Santoso A, Yamagata T. 2020. A unique feature of the 2019 extreme positive Indian Ocean Dipole event. Geophysical Research Letters,	https://doi.org/10.1029/2020GL088615
											Li SJ, WuLX, Yang Y, Geng T, Cai WJ, Gan BL, Chen ZH, Jing Z, Wang GJ, Ma XH. 2019. The Pacific Decadal Oscillation less predictable under greenhouse warming, Nature Climate Change, doi: 10.1038/s41558-019-0663-x	https://www.nature.com/articles/s41558-019-0663-x

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											Freund MB, Brown JR, Henley BJ, Karoly DJ, Brown JN. 2020. Warming patterns affect El Nino diversity in CMIP5 and CMIP6 models, Journal of Climate	https://journals.ametsoc.org/jcli/article/doi/10.1175/JCLI-D-19-0890.1/348584/Warming-patterns-affect-El-Nino-diversity-in-CMIP5
											Moise, A.F., I.N. Smith, J.R. Brown, R.A. Colman and S. Narsey, 2019: Observed and projected intra-seasonal variability of Australian monsoon rainfall. International Journal of Climatology, doi: 10.1002/joc.6334	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019GL085160
5.3	Regional climate change projections science and delivery	To make evidence-based decisions about climate change and to manage climate risks Australia needs access to credible, up-to-date and relevant information and data on future climate change. This project will enhance the functionality of the current suite of national climate change projections (delivered through the Climate Change in Australia website) to improve the accessibility and scope of the projections for existing next- and end-users of climate projections in several key fields. The project will also allow new and emerging users (e.g. the finance sector) to better integrate climate projections into their area of interest through the provision of guidance, training and tailored information and datasets to meet their specific needs. In addition, the project will build the underpinning projections science and modelling to support and build towards a future major release/update of national projections, setting up future and ongoing success in this arena.	Michael Grose	CSIRO	730,078	730,079	**1,460,157**	01.07.2019	31.12.2020	Ongoing	Colman RA, Soldatenko S. 2020. Understanding the links between climate feedbacks, variability and change using a two-layer energy balance model. Climate Dynamics, 54, 3441–3459.	https://link.springer.com/article/10.1007/s00382-020-05189-3
											Narsey SY, Brown JR, Colman R, Delage F, Power S, Moise A and Zhang H. 2020. Climate change projections for the Australian monsoon from CMIP6 models. Geophysical Research Letters, doi: 10.1029/2019GL086816	https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2019GL086816
											Grose MR et al. 2020. Insights from CMIP6 for Australia's Future Climate. Earth's Future, Vol 8. Issue 5.	https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2019EF001469
											Grose MR. 2019. Just how hot will it get this century? Latest climate models suggest it could be worse than we thought. The Conversation	https://theconversation.com/just-how-hot-will-it-get-this-century-latest-climate-models-suggest-it-could-be-worse-than-we-thought-137281
											Di Virgilio, G., Evans, J.P., Di Luca, A., Grose M.R., Round V., Thatcher M. 2020. Realised added value in dynamical downscaling of Australian climate change. Climate Dynamics.	https://doi.org/10.1007/s00382-020-05250-1
											Michael Grose and Pandora Hope. 2019. Climate change and extreme events – quantifying the changing odds, ECOS	https://ecos.csiro.au/climate-change-and-extreme-events-quantifying-the-changing-odds/
											Brown JR, Colman RA, Narsey S, Moise AF. 2020. Sensitivity of Australian Monsoon Rainfall to Aerosol Direct and Indirect Effects under a Range of Emission Scenarios, Bureau Research Report No 44, Australian Bureau of Meteorology, Melbourne.	http://www.bom.gov.au/research/publications/researchreports/BRR-044.pdf

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5.4	Water futures under climate change	Robust projections of water futures are important for impact assessments and developing adaptation options in the water and related sectors. This project will develop a framework that integrates climate and hydrological science and modelling to deliver the next generation of water projections. This will be based on outputs from previous Hub research as well as research and initiatives across Australia (e.g. Victorian Water and Climate Initiative, Bureau of Meteorology Hydrological Projections initiative). Guidance tailored to different uses and different sectors will be provided for developing projections of a range of hydrological characteristics/metrics, including long-term averages, low flow, high flow, and drought indices. The project will engage closely with stakeholders (focussing on the MDBA and WA DWER) to ensure that the framework and the knowledge produced are directly adopted by the end-users.	Dewi Kirono	CSIRO	262,500	525,000	**787,500**	01.07.2019	31.12.2020	Ongoing	Zheng H, Chiew FHS, Potter NJ and Kirono DGC. 2019. Projections of water futures for Australia: an update. Proceedings of the 23nd International Congress on Modelling and Simulation, Canberra, December 2019, pp. 1000 –1006,	https://doi.org/10.36334/modsim.2019.K7.zhengH
											Science webinar: Assessing future climate risks and adaptation options for Australian water systems	http://nespclimate.com.au/assessing-future-climate-risks-and-adaptation-options-for-australian-water-systems/
5.5	Extreme weather hazards in a changing climate	Many of the earliest and most significant effects of a changing climate are experienced through changes in hazardous weather events. However there are considerable scientific knowledge gaps around this, with a clear need for enhanced guidance and products to enable effective evidence-based planning. This project will deliver knowledge products addressing identified needs around four key types of hazards: tropical cyclones; bushfire hazards; east coast lows hazards; and thunderstorm hazards. The project will deliver science translation outputs which build on previous Hub research, as well as new analysis, to develop and deliver (in direct consultation with primarily existing stakeholder networks) a range of targeted communication tools and research synthesis products.	Andrew Dowdy	BoM	667,735	667,734	**1,335,469**	01.07.2019	31.12.2020	Ongoing	Giovanni Di Virgilio, Andrew Dowdy, Jason Evans, Jason Sharples, and Rick McRae. 2019, Climate change will make fire storms more likely in south-eastern Australia. The Conversation	https://theconversation.com/climate-change-will-make-fire-storms-more-likely-in-southeastern-australia-127225
											Warren RA, Ramsay HA, Siems ST, et al. Radar-based climatology of damaging hailstorms in Brisbane and Sydney, Australia. QJR Meteorol Soc. 2020;1–26. https://doi.org/10.1002/qj.3693	https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/qj.3693
											Chand SS, Dowdy AJ, Bell SS, Tory Kevin. 2020. A Review of South Pacific Tropical Cyclones: Impacts of Natural Climate Variability and Climate Change. Climate Change and Impacts in the Pacific. Springer Nature Switzerland, pp 251-273, doi: 10.1007/978-3-030-32878-8_6	https://doi.org/10.1007/978-3-030-32878-8_6
											Bell, S.S., S.S. Chand, K. J. Tory, H. Ye, C. Turville, 2020: North Indian Ocean tropical cyclone activity in CMIP5 experiments: Future projections using a model-independent detection and tracking scheme, https://doi.org/10.1002/joc.6594	https://doi.org/10.1002/joc.6594
											Chand SS. 2020. Climate Change Scenarios and Projections for the Pacific. In Climate Change and Impacts. Springer Nature Switzerland, pp 171-199, doi: 10.1007/978-3-030-32878-8_3	10.1007/978-3-030-32878-8_3

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											Lewis et al. 2019. Deconstructing factors contributing to the 2018 fire weather in Queensland, Australia, BAMS, doi: 10.1175/BAMS-D-19-0144.1	https://journals.ametsoc.org/bams/article/101/1/S115/346377/Deconstructing-Factors-Contributing-to-the-2018
											Dowdy AJ, 2020. Climatology of thunderstorms, convective rainfall and dry lightning environments in Australia, Climate Dynamics. doi:10.1007/s00382-020-05167-9	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2020GL088488
											Pepler A and Dowdy A. 2020. A Three-Dimensional Perspective on Extratropical Cyclone Impacts. Journal of Climate, Vol 33. doi:10.1175/JCLI-D-19-0445.1	https://journals.ametsoc.org/jcli/article/33/13/5635/345271/A-Three-Dimensional-Perspective-on-Extratropical
											Pepler A. 2020. Record lack of cyclones in southern Australia during 2019. Geophysical Research Letters, 47, doi: 10.1029/2020GL088488	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2020GL088488
											Bell SS, Chand SS, Turville C. 2019. Projected changes in ENSO driven regional tropical cyclone tracks, Climate Dynamics, doi: 10.1007/s00382-020-05129-1	http://nespclimate.com.au/wp-content/uploads/2019/03/CLDY-D-18-00393-1-pages-deleted.pdf
											Convective available potential energy (CAPE): 6-hourly global values based on historical CMIP5 simulations for 1979-2005 and on the RCP8.5 scenario CMIP5 simulations for 2006-2100	
											Di Virgilio G, Evans JP, Blake SAP, Armstrong M, Dowdy AJ, Sharples J, McRae R. 2019. Climate change increases the potential for extreme wildfires, Geophysical Research Letters, 46, 8517–8526	http://nespclimate.com.au/wp-content/uploads/2019/05/2019GL083699.pdf
5.6	The carbon budget of continental Australia and possible future trajectories	While climate change policies seek to manage the net emissions of greenhouse gases, large uncertainties remain on how the carbon budget can be best managed to reduce emissions, increase carbon sinks and protect existing carbon stock. This project will provide the most internally consistent carbon budget for Australia to date, enabling reported emissions to be put in the context of a century-long assessment of Australian carbon stocks and fluxes, including legacy fluxes from past land-clearing and disturbance by wildfire. The project will also provide projections of how Australia's carbon budget may change under a range of climate and land-use scenarios. The projections will be consistent with the Australian National Outlook integrated assessment modelling for Australia.	Pep Canadell	CSIRO	393,750	393,750	**787,500**	01.07.2019	31.12.2020	Ongoing	Peters et al. 2019. Carbon dioxide emissions continue to grow amidst slowly emerging climate policies, Nature Climate Change. 10.1038/s41558-019-0659-6	https://www.nature.com/articles/s41558-019-0659-6
											Friedlingstein et al. 2019. Global Carbon Budget 2019, Earth Systems Science Data, 11, 1-56. doi:10.5194/essd-11-1-2019	https://www.earth-syst-sci-data.net/11/1783/2019/
											Science webinar: Disentangling environmental and human drivers of carbon dioxide uptake and release on land	http://nespclimate.com.au/disentangling-environmental-and-human-drivers-of-carbon-dioxide-uptake-and-release-on-land/
											Saunois et al. 2020. Global Methane Budget 2000-1017. Earth Syst. Sci. Data, 12, 1561–1623,	https://essd.copernicus.org/articles/12/1561/2020/essd-12-1561-2020-discussion.html

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											Pep Canadell, Ann Stavert, Ben Poulter, Marielle Saunois, Paul Krummel, Rob Jackson. 2020. Emissions of methane – a greenhouse gas far more potent than carbon dioxide – are rising dangerously. The Conversation	https://theconversation.com/emissions-of-methane-a-greenhouse-gas-far-more-potent-than-carbon-dioxide-are-rising-dangerously-142522
											Jackson et al. 2020. Increasing anthropogenic methane emissions arise equally from agricultural and fossil fuel sources. Environmental Research Letters. 15(7): doi:10.1088/1748-9326/ab9ed2	https://iopscience.iop.org/article/10.1088/1748-9326/ab9ed2
											Pep Canadell, Corinne Le Quéré, Glen Peters, Pierre Friedlingstein, Robbie Andrew, Rob Jackson, and Vanessa Haverd. 2019. Global emissions to hit 36.8 billion tonnes, beating last year's record high. The Conversation	https://theconversation.com/global-emissions-to-hit-36-8-billion-tonnes-beating-last-years-record-high-128113
5.7	Tracking ocean change: ocean observations and models	Changes in ocean heat and salinity affect the modes of climate variability that dominate Australia's climate, and impact on the frequency and magnitude of extreme events. To understand how the oceans may impact Australia's climate, it is important to understand how and why oceans are changing and how we can better project future changes. This project will improve, extend and deliver high quality ocean data which is vital for assessing ocean change. Analysis of ocean temperatures and salinity will be undertaken using ocean observations and model experiments to track and understand observed changes, and to identify and understand the key mechanisms of ocean heat uptake in our oceans. Model improvements will also be provided under the project to improve how ocean heat uptake is represented in ACCESS and other climate models, thereby improving climate change projections.	Bernadette Sloyan	CSIRO	482,344	482,344	**964,688**	01.07.2019	31.12.2020	Ongoing	Kennicutt MC, Bromwich, Liggett D, Njastad B, Peck L, Rintoul SR, Ritz C, Siegert MJ, Brooks CM, Cassano J, Chaturvedi S, Chen D, Dodds K, Golledge NR, Le Bohec C, Leppe M, Murray A, Chandrika Nath P, Raphael MN, Rogan-Rinnemore M, Schroeder DM, Talley L, Travouillon T, Vaughan DG, Wang L, Weatherwax AT, Yang H Chown SL. 2019. Sustained Antarctic Research: A 21st Century Imperative, One Earth Review, doi: 10.1016/j.oneear.2019.08.014	https://www.sciencedirect.com/science/article/pii/S259033221930020X?via%3Dihub
											Pellichero V, Boutin J, Claustre H, Merlivat L, Sallée JB, Blain S. 2020. Relaxation of wind stress drives the abrupt onset of biological carbon uptake in the Kerguelen Bloom: a multisensor approach. Geophysical Research Letters, doi: 10.1029/2019GL085992	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019GL085992
											Rathore S, Bindoff NL, Ummenhofer CC, Phillips HE, Feng M. 2020. Near-Surface Salinity Reveals the Oceanic Sources of Moisture for Australian Precipitation through Atmospheric Moisture Transport, Journal of Climate, doi:10.1175/JCLI-D-19-0579.1	https://doi.org/10.1175/JCLI-D-19-0579.1
											Science webinar: Overview of the IPCC Special Report on the Oceans and Cryosphere in a Changing Climate	http://nespclimate.com.au/overview-of-the-ipcc-special-report-on-the-oceans-and-cryosphere-in-a-changing-climate/

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											Hub Science Webinar: Australia's boundary current pathways to the deep ocean.	http://nespclimate.com.au/australias-boundary-current-pathways-to-the-deep-ocean/
											Bestley S, van Wijk E, Rosenberg M, Eriksen R, Corney S, Tattersall K, Rintoul S. 2020. Ocean circulation and frontal structure near the southern Kerguelen Plateau: The physical context for the Kerguelen Axis ecosystem study. Deep Sea Research Part II, doi: 10.1016/j.dsr2.2018.07.013	https://www.sciencedirect.com/science/article/pii/S0967064518300663
											Chapman CC, Lea M, Meyer A. et al. 2020. Defining Southern Ocean fronts and their influence on biological and physical processes in a changing climate. Nature Climate Change,10, 209–219, doi:10.1038/s41558-020-0705-4	https://www.researchgate.net/publication/339464542_Defining_Southern_Ocean_fronts_and_their_influence_on_biological_and_physical_processes_in_a_changing_climate
											Stewart et al. 2020. JRA55-do-based repeat year forcing datasets for driving ocean–sea-ice models, Ocean Modelling, Vol 147, doi: 10.1016/j.ocemod.2019.101557	https://www.sciencedirect.com/science/article/pii/S1463500319302768
											Wallace LO, van Wijk EM, Rintoul SR, Hally B. 2020. Bathymetry-constrained navigation of Argo floats under sea ice on the Antarctic continental shelf. Geophysical Research Letters, 47, doi: https://doi.org/10.1029/2020GL087019	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2020GL087019
5.8	Marine and coastal climate services for extremes information	Coastal and marine managers, engineers, industries and finance organisations have a keen interest in sea level rise and extreme sea levels. Information on marine heat waves is of key importance to fisheries and aquaculture industries. Relevant information targeted towards these end-users will deliver tangible benefits to the nation as climate risks become better understood and managed. This project will investigate and analyse a range of coastal and near-shore variables, such as sea level trends, current and future marine heat waves, extreme sea level, waves, estimates of ocean mass increases and the effects of wind, waves, sea level rise and storm surge on sediment compartments. The project will consolidate this information and previous information developed under previous Hub research and deliver the information through a platform that hosts a range of tools and data delivery mechanisms. Project researchers will work closely with key stakeholders in the development of the platform to ensure the information is readily available and other coastal tools are adequately linked in to enhance end-user understanding of past variability and future changes in events that cause extreme impacts in the coastal zone.	Kathleen McInnes	CSIRO	656,250	656,250	**1,312,500**	01.07.2019	31.12.2020	Ongoing	Marshall AG, Hemer MA, McInnes KL, 2019. Australian blocking impacts on ocean surface waves, *Climate Dynamics*, doi:10.1007/s00382-019-05058-8	https://link.springer.com/article/10.1007/s00382-019-05058-8
											Holbrook NJ, et al. 2020: Keeping pace with marine heatwaves. Nature Reviews Earth and Environment. doi: 10.1038/s43017-020-0068-4	https://www.researchgate.net/publication/343261891_Keeping_pace_with_marine_heatwaves
											Morim J, Trenham C, Hemer M. et al. 2020. A global ensemble of ocean wave climate projections from CMIP5-driven models. Scientific Data 7, 105, https://doi.org/10.1038/s41597-020-0446-2	https://doi.org/10.1038/s41597-020-0446-2
											Mark Hemer, Ian Young, Joao Morim Nascimento and Nobuhito Mori, 2019. Climate change may change the way ocean waves impact 50% of the world's coastlines. The Conversation	https://theconversation.com/climate-change-may-change-the-way-ocean-waves-impact-50-of-the-worlds-coastlines-121239

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											Meucci A, Young IR, Hemer M, Kirezci E, Ranasinghe Roshanka. 2020. Projected 21st century changes in extreme wind-wave events, Science Advances, 6(24), doi:10.1126/sciadv.aaz7295	https://advances.sciencemag.org/content/6/24/eaaz7295
											Updated sea level rise calculator tool, Canute3.0.	https://shiny.csiro.au/Canute3_0/
											Science webinar: Impacts of climate change and variability on ocean waves	http://nespclimate.com.au/impacts-of-climate-change-and-variability-on-ocean-waves/
5.9	Natural habitats for coastal protection and carbon sequestration (NCCC - Phase 2)	Living shorelines have the potential to play important roles in climate mitigation and adaptation because of their ability to sequester carbon and/or reduce the threats of coastal erosion and flooding. However knowledge gaps remain around the value of natural habitats for coastal protection and carbon sequestration. This project will investigate the amount of carbon fixed by these natural habitats and ecosystems (blue carbon) and evaluation the potential for these ecosystems to contribute to national carbon accounting. To better understand the response of dune vegetation to event-scale extremes and the resulting consequences to coastal erosion, project researchers will undertake high resolution field surveying . The project also aims to develop the first national assessment of sediment accumulation, shoreline changes and wave attenuation from soft, hybrid and hard engineering solutions to provide local governments with the knowledge needed to inform coastal planning.	Stephen Swearer	University of Melbourne	525,000	571,163	**1,096,163**	01.07.2019	31.03.2021	Ongoing	O'Connor JJ, Fest, BJ, Sievers, M, Swearer, SE. Impacts of land management practices on blue carbon stocks and greenhouse gas fluxes in coastal ecosystems—A meta-analysis. Glob Change Biol. 2020; 00: 1– 13, doi: 10.1111/gcb.14946	http://nespclimate.com.au/wp-content/uploads/2019/05/5.9_BCR-ms_GCB_v5_pre_print.pdf
											ESCC Hub/NCCC. 2020. Understanding shoreline change on the Victorian coast: Apollo Bay, Great Ocean Road	http://nespclimate.com.au/wp-content/uploads/2020/07/A4-2p-NCCC-ApolloBay_WEB.pdf
											ESCC Hub/NCCC. 2020. Understanding shoreline change on the Victorian coast: Cowes, South Gippsland	http://nespclimate.com.au/wp-content/uploads/2020/07/A4-2p-NCCC-cowes_WEB.pdf
											ESCC Hub/NCCC. 2020. Understanding shoreline change on the Victorian coast: Inverloch, South Gippsland	http://nespclimate.com.au/wp-content/uploads/2020/07/A4-2p-NCCC-Inverloch_WEB.pdf
											ESCC Hub/NCCC. 2020. Understanding shoreline change on the Victorian coast: Mounts Bay, Great Ocean Road	http://nespclimate.com.au/wp-content/uploads/2020/07/A4-2p-NCCC-MountsBay_WEB.pdf
											ESCC Hub/NCCC. 2020. Understanding shoreline change on the Victorian coast: Ocean Grove, Barwon Coast	http://nespclimate.com.au/wp-content/uploads/2020/07/A4-2p-NCCC-OceanGrove_WEB.pdf
											ESCC Hub/NCCC. 2020. Understanding shoreline change on the Victorian coast: Port Fairy	http://nespclimate.com.au/wp-content/uploads/2020/07/A4-2p-NCCC-PortFairy_WEB.pdf
											ESCC Hub/NCCC. 2020. Understanding shoreline change on the Victorian coast: Lady Bay, Warrnambool	http://nespclimate.com.au/wp-content/uploads/2020/07/A4-2p-NCCC-warrnambool_WEB.pdf
											ESCC Hub/NCCC. 2020. Understanding shoreline change on the Victorian coast: Anglesea, Great Ocean Road	http://nespclimate.com.au/wp-content/uploads/2020/07/A4-2p-NCCC-anglesea_WEB.pdf
											ESCC Hub/NCCC. 2020. Understanding shoreline change on the Victorian coast: Seaspray, East Gippsland	http://nespclimate.com.au/wp-content/uploads/2020/07/A4-2p-NCCC-seaspray_WEB.pdf

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											Morris RL, Graham TDJ, Kelvin J, Ghisalberti M, Swearer SS. 2020. Kelp beds as coastal protection: wave attenuation of Ecklonia radiata in a shallow coastal bay, Annals of Botany, Volume 125 (2), 235–246, doi:10.1093/aob/mcz127	https://academic.oup.com/aob/article/125/2/235/5551380
											Morris RL, Hale R, Strain EMA, Reeves SE, Vergés A, Marzinelli EM, Layton C, Shelamoff V, Graham TDJ, Chevalier M, Swearer SE. 2020. Key Principles for Managing Recovery of Kelp Forests through Restoration, BioScience, biaa058, https://doi.org/10.1093/biosci/biaa058	https://academic.oup.com/bioscience/article/doi/10.1093/biosci/biaa058/5864934
											Morris RL, Boxshall A, Swearer SE. 2020. Climate-resilient coasts require diverse defence solutions. Nat. Clim. Chang. 10, 485–487, doi: https://doi.org/10.1038/s41558-020-0798-9	https://doi.org/10.1038/s41558-020-0798-9
CURRENT RESEARCH FACILITATION ACTIVITIES - RPV5-6												
CASE STUDIES AND INDIGENOUS ACTIVITIES												
CS 5.1	Understanding the impact of climate change on flowering induction in mango in the Northern Territory	Rising minimum and maximum temperatures will affect flower induction of current commercially produced mango cultivars and those from the National Mango Breeding Program . This case study will provide and support the application of climate change information to the NT mango industry so the precise effects of minimum and maximum temperatures for these cultivars can be determined. This will allow the industry to consider an appropriate management response. To ensure the maximum value is realised from the impact assessment, a climate literacy intervention will also be included based on a workshop and supporting explainer products.	Mandy Hopkins	CSIRO	40,000	0	**40,000**	1/01/2019	31/12/2020	Completed	Workshop report: Impact of climate change on mango production in the Northern Territory	http://nespclimate.com.au/wp-content/uploads/2019/05/NT-mango-expert-meeting-report-WEB.pdf
											Workshop summary: Impact of climate change on mango production in the Northern Territory	http://nespclimate.com.au/wp-content/uploads/2019/05/A4-2p-workshop-summary-NT-mangoes-WEB.pdf
											Case study fact sheet: Understanding the impact of climate change on the Northern Territory mango industry	http://nespclimate.com.au/wp-content/uploads/2019/05/A4-2p-cs-factsheet-NT-mangoes-WEB.pdf
											Final report: Impact of climate change on flowering induction in mangoes in the Northern Territory	http://nespclimate.com.au/wp-content/uploads/2019/05/CC-NT-mango-flowering-TR-final.pdf
											Fact sheet: Conducting a climate change health check on temperature thresholds for mango production in the Northern Territory	http://nespclimate.com.au/wp-content/uploads/2019/05/A4-2p-IA-process-NT-mangoes_web.pdf
											Fact sheet: Changing number of suitable days for initiating mango flowering in the Northern Territory	http://nespclimate.com.au/wp-content/uploads/2019/05/A4-2p-IA-results-NT-mangoes_web.pdf
											Fact sheets: What do fewer inductive days mean for mango cultivars in Katherine	http://nespclimate.com.au/wp-content/uploads/2019/05/A4-2p-mango-IA-results-factsheet-Katherine_web.pdf
											Fact sheets: What do fewer inductive days mean for mango cultivars in Kununurra	http://nespclimate.com.au/wp-content/uploads/2019/05/A4-2p-mango-IA-results-factsheet-Kununurra_web.pdf
											Fact sheets: What do fewer inductive days mean for mango cultivars in Darwin	http://nespclimate.com.au/wp-content/uploads/2019/05/A4-2p-mango-IA-results-factsheet-Darwin_web.pdf

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											Clonan M, Hernaman V, Pearce K, Hopkins M, Moise A and McConchie C. 2020. Impact of climate change on flowering induction in mangoes in the Northern Territory, Earth Systems and Climate Change Hub Report No. 16, NESP Earth Systems and Climate Change Hub, Australia.	http://nespclimate.com.au/wp-content/uploads/2019/05/CC-NT-mango-flowering-TR-final.pdf
											Science webinar: Understanding the impact of climate change on the Northern Territory mango industry	http://nespclimate.com.au/science-webinar-understanding-the-impact-of-climate-change-on-the-nt-mango-industry/
											ECOS article: Understanding climate change impacts on mangoes in the Northern Territory	https://ecos.csiro.au/climate-change-nt-mangoes/
											Case study technical scope summary	http://nespclimate.com.au/wp-content/uploads/2019/05/Mango-CS-scope-summary.pdf
CS 5.2	Using climate change information in a Gondwana Rainforest WHA climate change adaptation plan	There are gaps in the scientific understanding of projected climate change impacts on the Gondwana Rainforest World Heritage Area, particularly changes to cloud cover. Cloud cover is an important environmental variable for the property because cloud and fog provide up to half of the annual vegetation water requirements in high elevation forests. This case study will develop lifting condensation level projections, to provide information about changes to the cloud base in a changing climate, to complement existing temperature and rainfall projections. This information can be used to inform the development of a climate change adaptation plan for the Gondwana Rainforests WHA.	Mandy Hopkins	CSIRO	35,500	0	**35,500**	1/01/2019	31/12/2020	Completed	Case study report	http://nespclimate.com.au/informing-world-heritage-area-climate-change-adaptation-planning/
CS 5.4	Climate Change Literacy (climate change 101) (State Government/ Local Government)	Stakeholder feedback over the past three years of the Hub indicates that there is still a lot of stakeholder uncertainty about how the climate system works, how the climate is changing and what climate change projections actually tell us. Existing climate change information (e.g. Climate Change in Australia) is not readily accessed, understood and applied to inform decision and policy making. This case study is preparing a climate change capability development package that will consist of a half-day training session and supplementary information materials. The package will provide participants/users with a better understanding of the climate system, an appreciation of climate change science, and the confidence to find and use climate change information to inform decisions. The package includes guidelines for a rapid climate change impact assessment methodology that can be applied across all sectors to co-produce climate change information and facilitate its use in decision making.	Mandy Hopkins	CSIRO	71,250	0	**71,250**	1/01/2019	31/12/2020	Completed	Methodology has been adapted and simplified from a 8-step process to a 'health-check' 5 step process that fits within a risk assessment	http://nespclimate.com.au/building-capacity-to-use-climate-change-information/
											Climate Change Literacy sessions have been held with a range of stakeholders including the mango industry, DEWLP, with Australian Government representatives during the Hub's Road Show 23-24 September 2019	http://nespclimate.com.au/training/

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IA 5.5	Indigenous perspectives on climate risk (Indigenous Communities)	Indigenous peoples in Australia form the majority of populations in many remote highly vulnerable environments where climate change impacts on their country are already evident, including extreme weather events, climate variability and sea level change. For all Indigenous peoples in Australia, and most globally, climate change compounds over-arching issues of socio-economic disadvantage, chronic poor health, and the burdens of the colonial history of dispossession and hostile policy settings. Indigenous peoples bring a particular perspective of climate risk related to their particular socio-economic, historical, political, cultural and environmental circumstances. This results in perceptions that are often specific to communities and their cultures, places and regions with distinctive community values, resource and policy circumstances. Understanding these risk perceptions can potentially set the foundation for new pathways of research collaboration to better tailor climate science and information to meet Indigenous communities. This is a Indigenous-led project based on two case studies, (Shark Bay World Heritage Site and Central Land Council Ranger Groups community) which will work with Indigenous peoples on two-	Mandy Hopkins and Marian Sheppard	CSIRO	133,803	0	**133,803**	1/01/2019	31/03/2021	Ongoing	Not yet available	
CS 5.6	Climate measurement standards initiative	In response to the Recommendations of the Task Force on Climate-related Financial Disclosures many organisations in the Australian financial services sector are now beginning to explore the use of science-based scenario analysis of the physical impacts of climate change as part of their strategic planning, risk management processes and financial disclosures. There are however no agreed standards in place to underpin industry efforts and reporting to date is fragmented and inconsistent in scope and quality with respect to use of relevant peer-reviewed science. To support the use of high-quality, science-based climate change data and information to inform such analysis and related decision-making and reporting, the industry-led Climate Measurement Standards Initiative (CMSI) has been formed. The Hub will provide scientific expertise and advise to this initiative to ensure standards and outputs developed under this case study are based on credible and up-to-date climate	Geoff Gooley	CSIRO	150,000	0	**150,000**	1/01/2019	31/12/2020	Completed	Earth Systems and Climate Change Hub. 2020. Scenario analysis of climate-related physical risk for buildings and infrastructure: climate science guidance. Technical report by the National Environmental Science Program (NESP) Earth Systems and Climate Change Science (ESCC) Hub for the Climate Measurement Standards Initiative, ESCC Hub Report No.21.	Access the climate science guidance report at: https://www.cmsi.org.au/reports ESCC Hub science webinar: http://nespclimate.com.au/science-webinar-scenario-analysis-of-climate-related-physical-risk-2/
CS 5.7	National Disaster Risk Information Services Capability (NDRISC) Pilot Project (Federal Government)	Increased information on changes in natural disaster risks due to climate change is needed by all sectors of Australian society, business and government to inform their decision-making and planning. The ESCC Hub is participating in a pilot project through the National Resilience Taskforce in the Department of Home Affairs to demonstrate the benefits of considering climate change in a national disaster risk information services capability, using the Australian freight and supply chain network as the example. The goal of the study is to support a business case for longer term funding of NDRISC.	David Karoly	CSIRO	5,000	0	**5,000**	1/01/2019	31/12/2019	Completed	Not yet available	Outputs will be made available on the Hub's website at: http://nespclimate.com.au/outreach-publications/

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IA 6.1	Second national Indigenous gathering on climate change - pathway to sustainable relationships (Indigenous Communities)	The 2018 National Indigenous Climate Change Dialogue received positive feedback from Indigenous and non-Indigenous attendees alike. It was agreed that this Dialogue was an important start to the conversation between Indigenous communities, the Hub and climate researchers. To continue this conversation and build on the relationships developed through the 2018 Dialogue and other Hub related Indigenous activities, the Hub has committed to supporting a second gathering in June 2020. In developing the second gathering, important findings from the first event will be considered, including greater representation of Indigenous communities across Australia. To this end, this gathering will be led by an expanded Indigenous Steering Committee who will facilitate the co-development of the gathering in 2020 with Indigenous peoples, scientists and relevant stakeholders, with support from the Hub	Mandy Hopkins and Marian Sheppard	CSIRO	300000	0	**300,000**	1/07/2019	31/03/2021	Ongoing	Communiques from monthly Steering Committee meetings are available on case study webpage	http://nespclimate.com.au/supporting-the-development-of-an-indigenous-led-agenda-on-climate-change-knowledge-and-action/
IA 6.2	Supporting Indigenous participation at AMOS 2020 conference (Indigenous Communities)	The first ever Indigenous session was held at the 2019 Australian Meteorological and Oceanographic Society (AMOS) conference in Darwin. Traditional Owners were invited to present on their perspective of climate change and risks to their country, as well as community led solutions contributing to climate change mitigation while generating income for communities. This activity will support another Indigenous session to be convened at the next AMOS, February 2020 in Fremantle. The Indigenous discussion and workshop session is entitled 'Cross-cultural communication and climate will enable Indigenous people, their partners and science communication practitioners to share experiences in climate science communication. A workshop report will identify and report on key insights from the session.	Mandy Hopkins and Marian Sheppard	CSIRO	36,500	0	**36,500**	1/07/2019	31/12/2020	Completed	Workshop summary	http://nespclimate.com.au/wp-content/uploads/2020/03/A4-2p-AMOS-TO-workshop-summary.pdf
											Blog 'Co-design, cross-cultural communication and climate change'	http://nespclimate.com.au/co-design-cross-cultural-communication-and-climate-change/
CS 6.3	Adapting to climate change and building resilience in Australian World Heritage properties: using climate change science information and traditional knowledge to inform risk and vulnerability assessments and adaptation planning	The continued protection of World Heritage properties across Australia (and indeed, the world) requires improved understanding about the current and future impacts of climate change on their Outstanding Universal Values, and credible information and risk assessment processes to respond effectively to likely changes and build resilience. World Heritage properties are important assets, with natural sites providing ecosystem benefits, such as water and climate regulation and carbon storage in forested sites. Additionally, their inter-connected cultural heritage values can convey traditional knowledge that builds ecological and social resilience for change. This case study will develop a methodology for using science-based climate change information to inform the development of a climate change risk or vulnerability assessment that can then form the basis for preparation of adaptation plans to build the resilience of World Heritage properties to	Mandy Hopkin	CSIRO	150,000	0	**150,000**	1/01/2020	31/03/2021	Ongoing	Not yet available	

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CS 6.4	Integrated Environmental Assessment for Development Decisions (cross-NESP Hub)	Lack of knowledge can hinder decision-making when new opportunities for economic development are being explored. It also leaves industries, financiers and communities uncertain and risk-averse about investment and, importantly, places our environment at risk due to poorly informed decision-making. Integrated environmental assessment (IEA) is an interdisciplinary approach to combine, interpret and communicate information from diverse scientific disciplines and knowledge systems, to support decision making. This collaborative project between all NESP Hubs will develop and demonstrate the value of a holistic approach to providing information for strategic decision-making for sustainable development. It will provide clear guidance to government and stakeholders about the existing information available, data needs, analysis approaches, and governance settings to support Integrated Environmental Assessment for northern Australia.	David Karoly	CSIRO	39,593	0	**39,593**	1/01/2020	31/12/2020	Ongoing	Not yet available	
Total research facilitation costs					**961,646**	**0**	**961,646**					
TOTAL RESEARCH COSTS					**19,605,534**	**22,017,402**	**41,622,936**					
ENGAGEMENT ACTIVITIES												
EA6.5	CLIMATE 2021 – a resilient and sustainable Australia	The CLIMATE2021 conference will provide an opportunity for attendees across government, industry and sectors to be provided with a synthesis of research across the climate change science community as a whole to build the capacity of attendees and to be used to inform decisions, policies and products. It will also provide multiple opportunities for networking between researchers, policy-makers, managers and planners, practitioners and communicators to build lasting relationships and partnerships. The conference will bring together researchers and policy makers from across multiple disciplines and may lead to the development of new projects, initiatives, communication products, and help to drive the climate change research agenda.	Mandy Hopkins and Marian Sheppard	CSIRO	150000	0	**150,000**	1/07/2019	31/12/2020	Ongoing	N/A	http://nespclimate.com.au/climate2021/
EA6.6	Improving the functionality, utility and accessibility of information on the Climate Change in Australia (CCiA) website	The Climate Change in Australia (CCiA) website was developed in 2015/16 in consultation with NRM planners to address their climate change information needs. However, almost 5 years later it is clear that the needs of some climate change projections users have changed and grown, with new users emerging with different requirements that were not considered at the time of development. As a result, a refresh to the navigation functions of the website and improved accessibility of key information and data is required. This activity will conduct a user needs survey to determine ways to improve the accessibility of information in the website and will be informed by a user reference group of key stakeholders to test and advise on planned improvements to the website. This activity will also look at partnering with the Electricity Sector Climate Information (ESCI) project to share resources and ensure the needs of the energy sector, as well as other existing user needs, are met. Improving the user experience of the CCiA website and the functionality, utility and accessibility of information, data and tools within the website. This will assist in ensuring that climate change projections information is better able to be applied by target user	Sonia Bluhm and Mandy Hopkins	CSIRO	15,000	0	**15,000**	1/09/2019	31/12/2020	Ongoing	Not yet available	

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EA6.7	Synthesising research outcomes and impacts under the Earth Systems and Climate Change Hub	The Hub has undertaken world leading climate change science and has engaged with a variety of target user groups and stakeholders over its life time. Synthesising and communicating the outcomes and impacts of these research and knowledge brokering activities is important to show the value of the Hub and the investment provided through both the government and partner organisations. This research facilitation activity will deliver a range of synthesis products and activities across three levels during 2020 and 2021 to showcase the achievements, successes and research findings across the life of the ESCC Hub.	Sonia Bluhm	CSIRO	65,000	0	**65,000**	1/01/2020	30/03/2021	Ongoing	Not yet available	
TOTAL HUB FUNDED ENGAGEMENT ACTIVITIES					**230000**	**0**	**230000**					
ENGAGEMENT ACTIVITIES (funded externally to NESP by DAWE)												
EA6.8	Towards a National Climate Service: a report to the National Climate Science Advisory Committee (Federal Government)	The National Climate Science Advisory Committee (NCSAC) has asked that the National Environmental Science Program (NESP) Earth Systems and Climate Change (ESCC) Hub to prepare a report on a proposed development and implementation approach for a national climate service capability for Australia. This engagement activity will report on a climate services capability that could provide end-users with science-based data and information tailored to the needs of their respective organisations and sectors for purposes of assessing physical climate risk and informing policy development, management planning, investment and associated decision-making.	Geoff Gooley	CSIRO	0	75,000	**75,000**	1/07/2019	30/09/2020	Ongoing	NESP ESCC Hub. 2020. Platform-based science and services supporting climate action. Proceedings of an EU-Australia bilateral knowledge exchange workshop on developing and using web-based resources to enhance climate intelligence and support climate action. National Environmental Science Program, Earth Systems and Climate Change Hub Report No. 17.	http://nespclimate.com.au/wp-content/uploads/2020/05/NESP-ESCC-Hub-report-17_KE4CAP-workshop-report_final.pdf
											Cunningham R. 2020. Mapping Climate Services Capability in Australia, UTS-ISF, Sydney	http://nespclimate.com.au/wp-content/uploads/2020/06/Mapping-Climate-Services-in-Australia_updated-Final-Report.pdf
EA6.9	Australia's Next Generation Climate Projections: a report to the National Climate Science Advisory Committee (Federal Government)	The National Climate Science Advisory Committee (NCSAC) has contracted the NESP Earth Systems and Climate Change (ESCC) Hub to prepare a report on a proposed development and implementation approach for the next generation of national and regional climate change projections for Australia. The proposed approach will incorporate input from key partners in the Bureau of Meteorology, CSIRO and the university sector, with emphasis on their key role in provision of past climate change projections for Australia.	David Karoly	CSIRO	0	75,000	**75,000**	1/07/2019	30/09/2020	Ongoing	Not yet available	
TOTAL ENGAGEMENT ACTIVITY COSTS (EXTERNALLY FUNDED ACTIVITIES NOT INCLUDED IN ATTACHMENT C)					**0**	**150,000**	**150,000**					
PAST CASE STUDIES RPV 2-4												
3.1	Climate change information products for Indigenous communities	In collaboration with the traditional owners of the Mackay region this case study continues to develop a package of 'Climate Change 101' information from across the Hub's research portfolio, for use by champion traditional owners in their outreach activities with the Traditional Owners group. The package includes a PowerPoint slide pack, technical written information and a video. The package has been developed in collaboration with traditional owners to ensure the information is relevant and accessible, and can be communicated by traditional owners to traditional owners. This scientific information, in combination with traditional knowledge from the region, is being used to help Indigenous communities prepare for the impacts of climate change on country.	Mandy Hopkins	CSIRO	15,000	0	**15,000**	1/01/2017	31/12/2018	Completed	Draft Climate Change 101 package (Power point slide) for use by the traditional owners of the Mackay region	N/A

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3.2	Meeting Indigenous priorities for climate change information, capacity building and engagement	Discussing and understanding the climate science information needs of Indigenous communities will enable the Hub to better engage and be useful to these communities now and into the future. In partnership with CSIRO Land and Water's Collaborative and Indigenous Science team, Kimberley Land Council (KLC) and Seed (the Indigenous branch of the Australian Youth Climate Coalition, and Australia's first Indigenous youth-led climate network), the Hub is working to identify Indigenous priorities for climate-change focused information, capacity building and forms of engagement. A national workshop on this topic will be held in November 2018. Outputs from this workshop will provide input into future plans to meet the Hub's Indigenous engagement goal. This activity builds on previous Hub work with Indigenous communities to reach common understanding about priority needs.	Mandy Hopkins	CSIRO	130,000	0	**130,000**	1/01/2017	30/06/2019	Completed	Morgan M et al. 2019. Workshop Report: National Dialogue on Climate Change. Earth Systems and Climate Change Hub Report No. 11, NESP Earth Systems and Climate Change Hub, Australia.	http://nespclimate.com.au/wp-content/uploads/2019/05/191209-NICCD-report-final.pdf
3.3	Climate change impacts on inshore aquatic ecosystems and coastal communities in the Torres Strait Islands: A Workshop	Torres Strait Islander stakeholders want to learn more about the interdependencies between climate change and impacts on inshore fisheries, coral reefs, seagrass beds, mangroves and indigenous coastal communities. The Hub is working in partnership with the Torres Strait Regional Authority (TSRA) and Australian Fisheries Management Authority (AFMA) to explore the impact of climate change on marine ecosystems, fisheries and livelihoods in the Torres Strait Island area. Such knowledge would be based on the latest (CMIP5) regional projections for sea-level rise, sea surface temperature and ocean acidification, amongst other variables.	Mandy Hopkins	CSIRO	5,000	5,000	**10,000**	1/01/2017	31/12/2018	Completed	Workshop report	http://nespclimate.com.au/wp-content/uploads/2016/03/ESCC-R004-TS-CC-fisheries-workshop-180601.pdf
3.4	Coastal climate adaptation with City of Greater Geelong	The City of Greater Geelong have expressed a need for additional interpretation and guidance on the selection of extreme sea level and sea-level rise scenarios for use by their coastal managers when using the SWIFT hydrodynamic model. The SWIFT model offers a innovative solution to investigating and mitigating urban flooding under climate change. Data61 have previously engaged with the City of Greater Geelong to investigate future flooding hotspots under extreme events and sea level rise using SWIFT. In this case study the Hub will work with Data61 and the City of Greater Geelong to design appropriate guidance material for the usage of SWIFT.	Mandy Hopkins	CSIRO	5,000	0	**5,000**	1/01/2017	31/12/2018	Completed	Impact story	http://nespclimate.com.au/wp-content/uploads/2019/05/A4-2p-impact-CFAST-WEB.pdf
3.5	Climate variability and change in Western Australia	The Western Australian Government is working to secure the water supply for Perth and the south-west of the state through a number of initiatives, including reducing water use, increasing water recycling and identifying new water sources (including desalination plants). The Government regularly engages with water users to support these initiatives and to educate and update their stakeholders about the outlook for water availability. Climate change information is an important component of these engagements. The Earth Systems and Climate Change Hub has prepared communication materials to help the Western Australian Government convey information about climate change to their users.	Michael Grose	CSIRO	5,000	0	**5,000**	1/01/2017	31/12/2017	Completed	WA Government Stakeholder Engagement and Research Planning/Outreach Workshop	N/A
											Workshop report from the 2017 meeting in Perth	http://nespclimate.com.au/wp-content/uploads/2016/03/NESP-ESCC-Hub-SWWA-workshop-report-July-2018.pdf

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3.6	Climate Change in Australia mobile website (a prototype)	Stakeholders and everyday Australians are use to accessing information on the go and in the' here and now'. The current suite of climate change projections provide a wealth of state of the art climate change projection information, including maps, tools and educational products. The development of a prototype of a mobile website for these climate change projections would mean that this information could be accessed at any time in any place, and would greatly extend the uptake and use of the climate change projections and research undertaken by the Hub.	Aurel Moise	Bureau of Meteorology	15,000	0	**15,000**	1/01/2017	31/12/2017	Completed	Development of a prototype mobile website/app	http://climate-data.it.csiro.au/webapp/index.shtml
3.7	Climate Change for Councils (pilot)	Many climate change impacts will be experienced at regional and local levels, so councils may often be best placed to manage these risks. The ESCC Hub is well positioned, both as a producer and curator of the latest climate change science, to empower local councils with the confidence and understanding to use climate change science products to inform their decision making. The Hub will work with one or two regional Victorian councils to develop useful knowledge brokering and communication resources that package climate information for the councils in a way that is useful and accessible for their needs and audiences. These knowledge products will be drawn from across all the Hub's research portfolio.	Mandy Hopkins	CSIRO	7,228	0	**7,228**	1/01/2017	31/12/2017	Completed	Council Roadshow - meetings and discussions were had with 6 councils around how the Hub could engage with them and their climate change information needs	http://nespclimate.com.au/wp-content/uploads/2018/08/A4-2p-impact-LG-CC-info-needs-web.pdf
3.8	Web delivery portal for coastal hazards information	The CSIRO and ACE CRC web page, http://www.cmar.csiro.au/sealevel/ has been the primary vehicle for communicating sea level science and delivering key data sets to the broader scientific community that were developed as part of the former *Australian Climate Change Science Programme.* This case study significantly upgraded the sea-level web page to a more secure and user-friendly platform and at the same time enhance its utility. This has been done by providing existing extreme sea level information requested by the broader community, providing additional information on coastal hazards, enhancing its user base and creating an effective platform for the delivery of new information that is planned through Project 2.10.	Kathleen McInnes	CSIRO	10,000	0	**10,000**	1/01/2017	31/12/2017	Completed	Web delivery portal for engaging with the coastal community	Sea Level, Waves & Coastal Extremes website
3.9	Practical and empowering responses to coastal erosion	Local Tiwi Islander people often struggle to relate the big scales of climate impacts science to the local, social and environmental processes that are important and relevant to them. Solutions to climate change impacts in the coastal zone require solutions focused science that co-produces knowledge and practices with relevant stakeholders to inspire and enable local communities to act on their values and goals for the future. Previous engagement with the Tiwi around climate change alarmed local residents and escalated feelings of powerlessness. This case study is worked to educate local communities about climate adaptation and provide practical guidance for what actions can be implemented to help address coastal erosion in the Islands.	David Kennedy and Jon Barnett	University of Melbourne	5,000	0	**5,000**	1/01/2017	31/12/2017	Completed	Tiwi Island workshop report	http://nespclimate.com.au/wp-content/uploads/2016/03/Workshop-report-Tiwi-Islands_Climate-Change-Adaptation-Report.pdf

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4.1	Test case for datasets and information for managing climate risk in the Australian banking and finance sector	There has recently been a new focus and awareness of climate risks for corporate Australia. The finance and banking industries in particular have begun to engage in this area and have expressed a pressing need to assess what climate change risk means for their business. However existing climate change projections information and data are not tailored to their specific needs. This case study tests the utility of climate change projections for the banking and finance sector to demonstrate how climate change projections information can be readily applied to decision-making in these sectors. The case study provides a starting point for a process of partnering and delivering information for this growing need. This case study demonstrates the path to impact of Hub research from Projects 2.6 (regional projections) and 2.8 (extremes projections).	Dr Michael Grose/ Dr Andrew Dowdy	Bureau of Meteorology and CSIRO	15,000	20,000	**35,000**	1/01/2018	31/12/2018	Completed	Case study report	http://nespclimate.com.au/wp-content/uploads/2019/07/ESCC-R010-case-study-4.1-report.pdf
4.2	Potential for carbon abatement by revegetation and conservation in Australia - Stakeholder engagement and status report	Revegetation and conservation in Australia may have great potential to contribute to achieving the mitigation targets of the Paris Agreement. Current estimates of this potential are limited to a few studies, none of which have been able to adequately address the opportunities and limitations of the biophysical and socio-economic worlds. This case study aimed to identify existing vegetation/carbon information and tools available to policy makers, and identify gaps and needs that will inform future research directions. The case study aimed to leverage primarily off activities and outputs (key data and information) being delivered through Project 2.9.	Dr Pep Canadell	CSIRO	10,000	10,000	**20,000**	1/01/2018	31/12/2018	Completed	N/A - case study closed. More information available at: http://nespclimate.com.au/understanding-information-needs-for-carbon-policy/	
4.3	Communicating projected changes in hydroclimate affecting water supply in South-West Western Australia (SWWA)	This case study develops useful communication products for the Western Australian water sector to facilitate the application of science to water management. In particular, the case study addresses two priority needs 1) demonstration of 'science to management' as an exemplar of the use of existing climate science to inform WA water resource planning and management, and 2) communication products for key stakeholders on climate variability, extremes and reliability of water supply in a changing climate.	Dr Dewi Kirono and Dr Francis Chiew	CSIRO	5,000	5,000	**10,000**	1/01/2018	31/12/2018	Completed	Case study report	http://nespclimate.com.au/wp-content/uploads/2019/05/A4-2p-impact-SWWA-WEB.pdf
4.5	Framework for determining the net socio-economic benefits of Earth systems and climate change science and services	The ESCC Hub supports a diverse portfolio of scientific research and service delivery to address stakeholder needs and to realise outcomes relevant to Australia's national interest. This case study developed a preliminary/ conceptual cost-benefit framework designed to measure the short to long-term value of the Hub's research outputs to the Australian economy and society more generally. It also demonstrates the practical application of this framework as part of a virtual analysis designed to quantify the net social and economic value of the investment into selected areas of ESCC Hub science of direct relevance to selected key stakeholders.	Dr David Newth	CSIRO on behalf of the ESCC Hub partners	65,000	65,000	**130,000**	1/01/2018	31/12/2018	Completed	Case study report	http://nespclimate.com.au/wp-content/uploads/2020/04/ESCC-Hub_CS4.5-summary-report.pdf

Project Number/ID	Project Name/Title	Project Summary	Project Leader	Lead Organisation	Approved Funding Research Plan Versions 1-6			Start Date	Completion Date	Status	Outputs	
					NESP Funding* $	Total Other Contributions* $	Total Budget* $				Outputs	Link to output
4.6	Multi-disciplinary approach to understanding climate change impacts and exploring climate sensitive management solutions for the Great Barrier Reef	Carbon dioxide absorbed into the oceans is driving ocean acidification, which poses a threat to marine ecosystems, particularly reefs. Better regional data on the likely impacts of climate change on the Great Barrier Reef will be important for management and decision making and can be applied to the management of other Ramsar areas. This case study aimed to undertake a multi-disciplinary approach to build consensus amongst stakeholders on how we can move from near-term understanding of climate impacts, to exploring the projected climate future of the Great Barrier Reef under different emissions pathways. The case study aimed to determine the best and most accessible way to present and make this information available to stakeholders.	Dr Andrew Lenton and Dr Mark Baird	CSIRO	25,000	25,000	**50,000**	1/01/2018	30/06/2019	Completed	N/A	N/A
4.4	Climate change impacts on threatened species and ecosystems – preliminary review and scoping	There is a growing body of work on the impact of climate change on threatened species and ecosystems/ecosystem services. However ecological analysis and weather and climate research are often not well connected. This case study demonstrates how the application of the Hub's research in improving understanding of climate feedbacks and key climate processes (including clouds) can be used to assess climate change impacts on threatened species and ecosystems. The Hub partnered with the World Heritage Australia, the NESP Threatened Species Recovery Hub and key agencies (i.e. Qld Herbarium) to bring together complementary skills and expertise in climate change, micro- and meso-scale meteorology, land surface feedback and ecology to address information gaps and needs in two specific areas of interest to key stakeholders: 1) climatic change, cloud caps and cloud forest ecosystems affecting threatened plant communities in the Lamington National Park World heritage Area of SE Qld, and 2) climatic change and the conditions impacting distribution and abundance and critical habitat for the Greater Glider in SE Australia. This case study raises awareness of the importance of factoring in climate	Dr Rob Colman and Rachel Morgain (TSR Hub)	Bureau of Meteorology and CSIRO	20,000	20,000	**40,000**	1/01/2018	30/10/2019	Completed	Gondwana rainforest section - fact sheet and workshop report	http://nespclimate.com.au/wp-content/uploads/2019/03/Gondwana-CC-workshop-report.pdf
CS 5.3	TasLab Engage	Extreme climate events impact a number of sectors across Tasmania, including water, agriculture, aquaculture and emergency response. These events are costly and difficult to plan for. Information on the form these extremes might take over the coming years, their past variability and guidance on the use of relevant climate information would assist with planning for these events. TasLab Engage facilitates engagement between industry groups and scientists to understand industry-specific climate sensitivities and identify the relevant climate information required - at the multi-year to decadal timescales. It has the potential to assist with better management of climate sensitive systems and increase resilience to climate extremes in Tasmania. The findings from this case study will directly inform the CSIRO's Decadal Forecast Project to ensure climate information and predictions resulting from this large project are aimed at stakeholder needs.	Sonia Bluhm	CSIRO	50,000	50,000	**100,000**	1/01/2019	31/04/2020	Completed	Case study report	http://nespclimate.com.au/understanding-tasmanias-climate-sensitivities-and-information-needs/
TOTAL CASE STUDY/TARGET USER GROUP					**317,228**	**130,000**	**447,228**					