Climate Systems

National Environmental Science Program

National Environmental Science Program

Climate Systems Hub annual progress report 1 January to 31 December 2022

Version	Date of issue	Author	Comments
1.0	14/02/2023	Hub Program Management Team	First draft
2.0	20/02/2023	Program Manager - Jeff	Second draft
3.0	02/03/2023	Hub Program Management Team	Third draft
4.0	06/03/2023	Hub Program Management Team	Draft to Hub Steering Committee
5.0	06/04/2023	Hub Program Management Team	Draft submission to DCCEEW
6.0	19/05/2023	Hub Program Management Team	Response to DCCEEW assessment summary of draft submission

Acknowledgement of Country **1**
Letter from the Hub Leader **2**
Management **4**
Research **6**
Progress towards research delivery 9
Research projects 10
Cross-cutting initiatives 11
Emerging priorities 12
Performance against milestones **13**
Performance against funding agreement milestones 13
Measuring success **14**
Hub outcomes and outputs 14
Collaboration and partnerships **23**
Knowledge brokering 23
Communication 24
Indigenous partnerships 26
Data management 27
Hub-level risk management **28**
NESP impact stories **29**

Acknowledgement of Country

The Climate Systems Hub recognises and acknowledges First Nations people across the length and breadth of Australia land and sea Country and their ongoing connection to Country.

The Climate Systems Hub pays respect and acknowledgement to Elders past and present, as knowledge holders and keepers.

The Climate Systems Hub pays respect and acknowledgement to senior community leaders of their Country and communities.

Letter from the Hub Leader

In our 2022 annual progress report the Climate Systems Hub is delighted to celebrate our first full calendar year. The year presented both challenges and opportunities, along with much cause for celebration. Below I highlight some of the many significant achievements of the hub in 2022.

Our founding 8 research projects (CS1.X) from Research Plan 2021 (RP2021) were successfully completed in June 2022. The co-design process for these initial projects informed an updated value chain for the hub structured around 5 themes; Accessible and Useable; Land and Terrestrial Ecosystems; Monitoring and Modelling; People and Country; Oceans and Coasts.

During 2022, considerable effort went into annual research planning, with RP2022 tranches 1 and 2 submitted in March and June respectively. The commencement of mostly multi-year research projects provided a sense of longer-term stability to our research portfolio, and confidence to our university partners to initiate employment of the hub postdoctoral cohort. RP2023, submitted in September, further refined our ongoing multi-year projects, also renewing the synthesis and communication project (CS3.2). Our annual research plans continue to support the principles of co-design and progress towards co-production of outputs and co-delivery of outcomes.

Indigenous partnerships are a core aspect of the National Environmental Science Program (NESP) and the Climate Systems Hub. Through the leadership of our Indigenous Facilitator we have made great progress both building new and strengthening existing relationships over 2022. Building on the relationships seeded by the successful National First Peoples Gathering on Climate Change (2021) facilitated by the Earth Systems and Climate Change (ESCC) Hub, a new National First Peoples Platform on Climate Change (NFPPCC) steering committee has been established, supported by a hub secretariat. Members of the steering committee and secretariat met for the first time on Kaurareg Country in the Torres Strait Islands (October) in recognition of the climate challenges the Torres Strait Island communities face.

Seventy-three hub community members and key stakeholders came together in our first hub-wide in-person event, our inaugural Science Days. For many this was the first large-scale in-person event since the onset of the pandemic. It provided valuable opportunity to meet with familiar faces from our predecessor ESCC Hub, and to welcome the many new faces in our hub community. Project scientists shared research highlights from the establishment phase of the hub and the co-design of RP2021 with our many research users. There was a great atmosphere at the event with attendees commenting on the positive impact of the in-person gathering and participants acknowledged the importance of bringing researchers together to collaborate and build a sense of community for the hub.

The hub continues to develop collaborative science relationships in the wider national research ecosystem. In October we had a strong presence at the Australian Climate Service (ACS) workshop, alongside the CS2.6 Climate Attribution Workshop, and have worked with ACS to further develop our collaborations. Through project 2.11 we are engaging with the newly formed National Collaborative Research Infrastructure Scheme ACCESS-National Research Infrastructure (ACCESS-NRI) to further develop Australia's national weather and climate model. We participate in the National Partnership for Climate Projections (NPCP) alongside our Cross Jurisdictional Community of Practice for Climate Science (CJ CoP CS) state partners and foster the growing relationship between state and federal participants in planning for nationally comparable and complementary approaches to climate projections work. The hub contributed to increased capacity of scientists and stakeholders through training and participatory workshops. An Australian Community Climate and Earth System Simulator (*ACCESS) modelling* workshop was held at the Australian Meteorological and Oceanographic Society meeting (AMOS 2022) that included training for around 30 scientists, many of whom are early career. In December the hub facilitated well received climate literacy training for stakeholders in sessions in Perth and Canberra. These will continue in other cities in 2023.

The post-doc cohort across our university partners bring substantive research capability to the hub and are the foundation of our early career program supporting the development of the next generation of climate change, climate adaptation and policy interface practitioner community. On-boarding of postdocs has commenced. We will continue to onboard our postdoctoral cohort into 2023, and launch the early career program, NESP Climate College. The NESP Climate College will help empower early career professionals to tackle the interdisciplinary problems posed by our climate future and offer opportunities such as early career days and hub-hosted significant events.

The cross-hub Climate Adaptation Initiative and Climate Systems Hub partnered with AdaptNSW to convene *2030 and beyond: Adaptation for our future* over 2 days in November. This event brought together over 300 interdisciplinary researchers, specialists, and decision makers to inform tangible, real world decisions, and was the first large climate adaptation conference held in Australia since the conclusion of the National Climate Change Adaptation Research Facility series in 2018. The conference was opened by the Assistant Minister for Climate Change and Energy, Senator the Hon. Jenny McAllister. Attendee feedback was very positive, with over 70% strongly agreeing they enjoyed the event, and over 65% strongly agreeing they learned something new at the event. Planning is underway for the next in a series of related National Adaptation conferences, with *Climate Adaptation 2023 Act Together - Act Now* to be convened in Adelaide (July 2023). Already the event is attracting strong interest in terms of sponsorship. The initiative has also fostered discussion to realise the potential of future cross-hub collaborations bringing together the NESP family in a more cohesive way and has led the hub's climate adaptation work through projects CS1.1 and the launching of project CS2.1.

I am particularly grateful to the passion and dedication shown by the hub's leadership team across 2022 as we navigated the challenges of program management, research planning, reporting, communications, knowledge brokering, data wrangling, and managing relationships across the hub partners and our stakeholders, as well as continuing impacts of the COVID pandemic which saw delays in contracting with some partners. By April, we welcomed the second half of our 8 hub partners with signing of contracts by Monash University, the University of Melbourne, the University of New South Wales and the NSW Department of Planning and the Environment on behalf of the CJ CoP CS. It was delightful to formally cement the relationship of the full complement of the hub partnership.

Midyear saw the establishment of the new Department of Climate Change, Energy, the Environment and Water (DCCEEW) and we continue to build strong relationships with the department. The hub Steering Committee has expanded its scope of expertise in 2022 and provided valued guidance. Most importantly, our project teams continue to deliver hub outputs and outcomes, driven by their passion for the science they do and the application of results to informing the response to Australia's national climate challenges.

In early 2023 we will refill the hub knowledge broker role to bring leadership to our state CJ CoP CS knowledge brokering team (March), continue to deliver excellent science, and work with the NFPPCC alongside their new co-chairs (February) to plan for future National Gatherings on climate change and adaptation with First Nations peoples. There remain further challenges ahead in 2023, which will require leadership from hub partners and DCCEEW in bringing the 4 hubs and cross-cutting initiatives together into a more coherent whole of NESP program. We welcome a close involvement in this process, alongside the implementation of the response to the independent review into the transition from NESP phase 1 to phase 2. Overall, I believe it has been a great year for the Climate Systems Hub and I look forward to continuing to join with our partners and stakeholders in 2023.

Dr Simon Marsland
Climate Systems Hub Leader, CSIRO Climate Science Centre

Management

The National Environmental Science Program (NESP) is a long-term commitment by the Australian Government. The program funds environmental and climate research. The second phase of NESP builds on the foundations of past work, and funds 4 research hubs from 2020–21 to 2026–2027.

Partnership structure: The Climate Systems Hub comprises 8 partners. The Cross Jurisdictional Community of Practice for Climate Science (CJ CoP CS) brings highly relevant experience in climate science expertise, knowledge brokering, and climate change adaptation to the hub. The role of the CJ CoP CS in the hub is focused on linking scientists with technical end-users, policy and decision-makers to deliver applied science outcomes at the community level across all regions of the nation. The other 7 partners are well known to DCCEEW through their role in the predecessor NESP Earth Systems and Climate Change (ESCC) Hub. The Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Bureau of Meteorology (BoM) maintain continuity over a long history as national agencies central to Australia's climate science and delivery. The 5 participating universities enhance the depth of research capability within the hub. The Early Career Program engages a new generation of scientists from throughout the hub and is imperative for climate science targeted to user needs. The participation of these partners ensures the hub's prominence as the central go-to place for expertise in Australian climate science. Together, these 8 partners comprise the expertise, capability, and capacity to deliver hub and NESP outcomes.

Strategic direction and endorsement of hub activities is provided through the Hub Steering Committee (**Figure 1**). NESP programmatic cohesion is facilitated by twice yearly cross-hub leadership fora including DCCEEW representation.

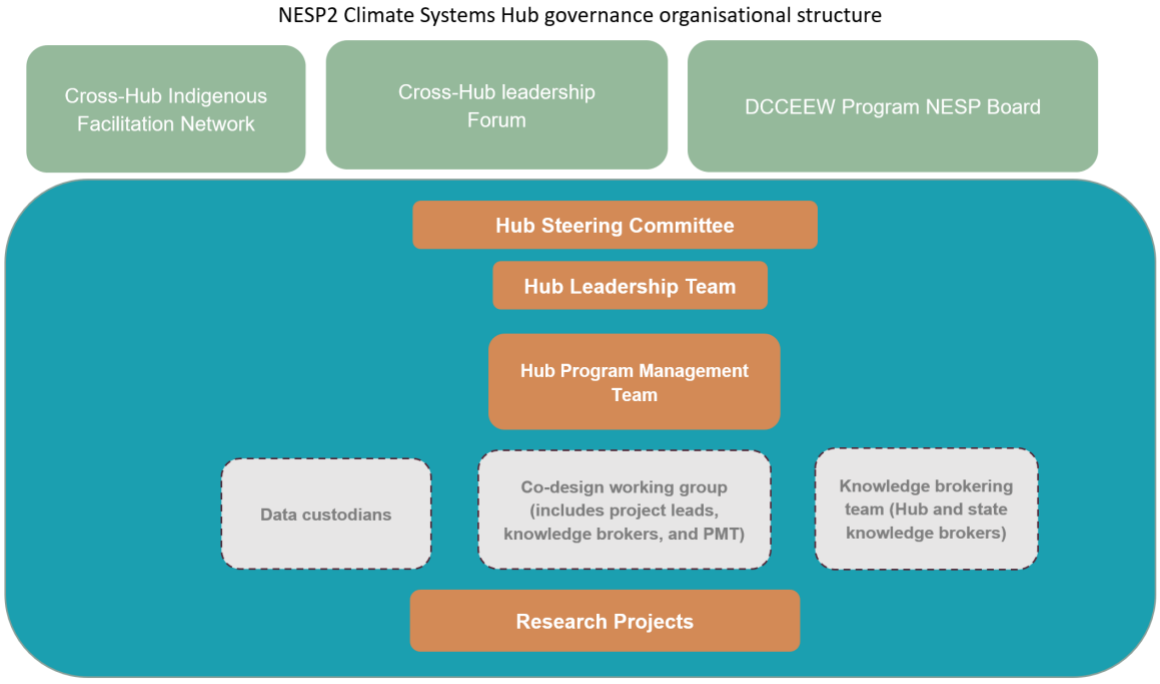


Figure 1: Hub governance structure

Program management: The day-to-day planning and activity is managed by the hub's program management team, including specified personnel (**Table 1**), as per the funding agreement. In addition, there are 4 program managers to support contracting, financial management, reporting, Indigenous engagement and monitoring and evaluation activities across the hub. The hub's knowledge broker resigned in June 2022 and due to recruitment challenges this position remained vacant for the rest of 2022. However, these activities were boosted by the commencement of two full-time state-based

knowledge brokers in Victoria and NSW in November. The hub's knowledge brokering team links the program management team to state partner representatives, ensuring effective coordination of knowledge brokering activities at both the program and project level.

Table 1: Climate Systems Hub specified personnel.

Item	Role	Partner
1	Climate Systems Hub Leader	Simon Marsland, CSIRO
2	Climate Adaptation Initiative Leader	Sarah Boulter, University of Tasmania
3	Indigenous Facilitator	Rowena Bullio, Australian National University
4	Data Wrangler	Brad Murphy, Bureau of Meteorology
5	Knowledge Broker	Rachel Kelly until July 2022, University of Tasmania
6	Communication and media officer	Tahnee Burgess, Monash University

The hub's suite of Indigenous partnerships, communication, data management and knowledge brokering strategies were approved by the steering committee at the December 2022 meeting as living documents. Although the hub had been operating in accordance with draft versions of these strategies, this approval provides confidence in the continued implementation approach.

Research

NESP hubs deliver world-class, practical, evidence-based research to inform decisions. This investment helps build adaptation capacity and resilience in our natural environment and communities.

NESP research has real impact through partnerships and collaboration between researchers and research-users, including policymakers, to deliver proven outcomes. Environmental decision-makers are key partners and are encouraged to articulate their needs to researchers; provide feedback on the quality and usefulness of the research outputs; and be engaged in the communication of how this information has informed policy.

NESP research listens to and prioritises the research needs of Indigenous land and sea managers, weaves together Indigenous and western environmental knowledge systems and celebrates Indigenous-led approaches to strengthening and sharing knowledge.

New and existing NESP research findings are available to use and accessible at Australian Government and hub websites.

During 2022, the hub introduced our strategic approach designed to frame our research program through the life of the hub. Through co-design and analysis of stakeholder needs, we adopted 5 overarching themes (**Figure 2**) to focus our research priorities. At the heart of the NESP program is conservation, protection and sustainable management of Australia's natural areas. It connects us to goals of sustainable communities and care of Country. The hub does this through the lens of climate change science, through understanding and explaining climate processes and supporting adaptation. The five themes reflect this approach. We consider the domain of natural systems across land, ocean and coast; the domain of people and how they live safely and sustainably and the foundations of the climate science from modelled physical understanding to ensuring the best available knowledge is applied to decision making.

The themes also allow us to scaffold our knowledge brokering, communications, data management and Indigenous partnerships strategies. They have been designed to:

- develop clearer pathways to impact
- provide clear entry points to our program for stakeholders
- build strong linkages with the outcomes of the other NESP hubs and initiatives.

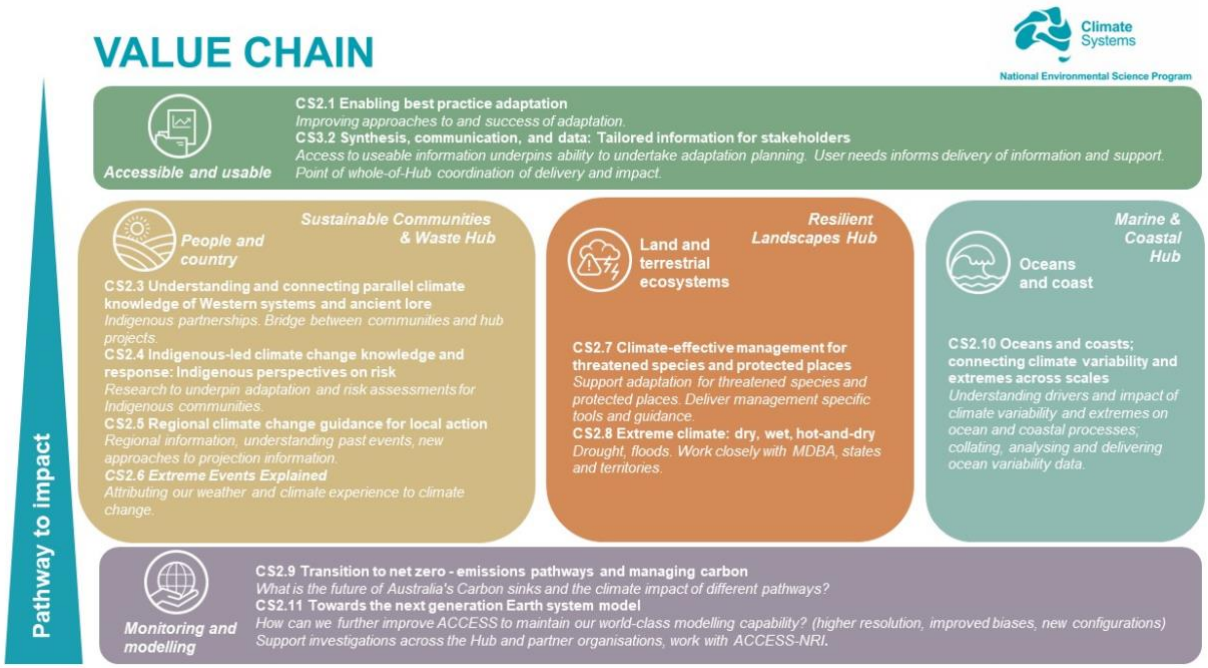


Figure 2: Schematic of 5 overarching hub themes and alignment with project portfolio and other NESP hubs and associated cross-hub initiatives. The modelling and monitoring theme serves as a scientific foundation to the others, with the accessible and usable theme allowing the science to create the greatest impact, creating the hubs pathway to impact.

Eight ongoing projects from RP2021 were completed in June and listed here:

- CS1.1 Adapting to tomorrow's climate
- CS1.2 Indigenous-led knowledge and response to climate change
- CS1.3 Regional knowledge for local action
- CS1.4 Understanding climate variability
- CS1.5 Preparing for emerging climate extremes
- CS1.6 The changing ocean's coastal and climate impacts
- CS1.7 Modelling the future
- CS1.8 Australia's land and ocean carbon and acidification.

RP2022 established 11 new projects (**Table 2**). They represent the breadth of hub expertise and user needs identified through stakeholder engagement and set the broader strategic vision (**Figure 2**) for ongoing research within the hub. On-going co-design is developing enduring partnerships, to shape and co-develop project direction. Built on RP2021 research, the 11 RP2022 projects represent an interconnected research portfolio that strengthens synergies across the hub and the NESP program research priorities assigned to the hub (Table 2).

Table 2: Climate Systems Hub RP2022 projects provide a pathway-to-impact for the NESP priorities assigned to the hub.

Hub Theme	Project no. & duration	Project	Research priority
Accessible and Usable	CS2.1 (2.5yrs)	Enabling best practice adaptation	Support the Climate Adaptation Initiative
	CS2.2 (6mths)	Synthesis, communication, and data: Tailored information for stakeholders	Applied decision support tools and information
People and Country	CS2.3 (1.5yrs)	Understanding and Connecting Parallel Climate Knowledge of Western Systems and Ancient Lore	Applied decision support tools and information
	CS2.4 (1.5yrs)	Indigenous-led climate change knowledge and response: Indigenous perspectives on risk	Applied decision support tools and information
	CS2.5 (2.5yrs)	Regional climate change guidance for local action	Advance understanding of Australia's climate variability, extremes and associated drivers
	CS2.6 (2.5yrs)	Extreme Events Explained	Advance understanding of Australia's climate variability, extremes and associated drivers
Land and Terrestrial Ecosystems	CS2.7 (2.5yrs)	Climate-effective management for threatened species and protected places	Support Cross Hub Initiative program
	CS2.8 (2.5yrs)	Extreme climate: dry, wet, hot-and-dry	Advance understanding of Australia's climate variability, extremes and associated drivers
Ocean and Coast	CS2.10 (2.5yrs)	Oceans and coasts; connecting climate variability and extremes across scales	Advance understanding of Australia's climate variability, extremes and associated drivers
Monitoring and Modelling	CS2.9 (2.5yrs)	Transition to Net Zero - emissions pathways and managing carbon	Applied decision support tools and information
	CS2.11 (2.5yrs)	Towards the next generation Earth System Model	Maintain world-class capability in multidisciplinary Earth system science and modelling

Progress towards research delivery

Table 3 reports against the Activity Outcomes of Schedule 2 – Activity Particulars of the Climate Systems Hub Funding Agreement, Item 1.3. 2022 includes 8 projects finalised under RP2021 (Jan-Jun; CS1.X), 11 projects commencing under RP2022 (Jul-Dec; CS2.X) and 1 project submitted for RP2023 (CS3.2). CS2.2 finished in 2022 while all other RP2022 projects continue in 2023.

Table 3: Reporting of outcomes (right column) against Activity Outcomes as per Funding agreement.

(a) The Recipient will work with the Department to develop a comprehensive list of Activity Outcomes, reflected in the Research Plans and the Monitoring and Evaluation Plan.	
	• Completed stakeholder engagement plan and co-design guide • 30+ engagement meetings with the department • Activity outcomes listed in RP2022, and RP2023 • Monitoring, evaluation, reporting and improvement (MERI) framework completed and submitted to department August 2022
(b) As stated in the Climate Systems Hub research scope, Activity Outcomes include:	
(i) Leading the further development of Australia's global climate model, ACCESS	• Fund ACCESS projects CS1.7, 2.11 • Future modelling effort priorities workshop in partnership with ACCESS NRI (Oct 2022) • Early career training workshop at AMOS 2022
(ii) Advancing understanding of Australia's climate systems and processes	• Completed CS1.4, CS1.5, CS1.6, CS1.7 and CS1.8 improved understanding of climate systems and processes • Invested in CS2.8 to better understand seasonal and annual extreme events, CS2.6 to help understand why an event occurred and better understand projected future risk profiles
(iii) Contributing to the development of the next generation of climate projections	• Participate in National Partnership for Climate Projections (CS1.3, 2.5) • Co-sponsored: *Regional climate downscaling for Australia within the CORDEX framework* workshop at AMOS 2022
(iv) Progressing the development of national climate services capabilities and systems	• Outreach around data provision via NCRIS Environmental Science Forum • Alignment and engagement with ACS, Climate Services for Agriculture, and Climate Innovation Hub (CSIRO) • Work with the state and territory CJ CoP CS and state knowledge brokers to co-develop research and training program • Training workshop increased confidence in finding and using climate information for participants
(c) The Activity also includes delivering the initiative focused on the climate adaptation theme. As per Climate Systems Hub research scope, the Activity Outcomes for cross-cutting Initiatives include the following	
(i) Supporting integrated research across the program to improve the evidence base for adaptation decision making for climate resilience	• The Climate Adaptation Initiative Activity Outcome is addressed in the Cross-cutting initiatives section below
(ii) Marine and coastal ecosystem management for	• Update original CSIRO sea level reconstruction including sea-level fingerprints and residual vertical land motion • Improves estimation of extreme water levels nationally

sea-level rise and ocean acidification	• Updated satellite altimetry measurements • Progress short-term (~7 days) predictability of marine heatwaves off eastern Tasmania • Completed short technical report on assessment and spatial analysis of ocean acidification in the Coral Sea and Tasman Seas
(iii) Building traditional cultural knowledge into climate understanding and working with indigenous communities to help them adapt to the changing climate	• Partnered with Northern Peninsula Area, K'gari, Malgana, and Arnhem Land Indigenous communities • Established National First Peoples Platform on Climate Change (NFPPCC) and convened first meeting in Torres Strait • NFPPCC and hub members made presentations or convened sessions of the hub at four conferences

Research projects

The projects to be undertaken by the CS Hub are listed (table 7) in the communication section of this document.

Cross-cutting initiatives

Project design specifically targets investment in initiative outcomes as outlined in **Table 4**.

Table 4: Climate systems hub activities and investment in support of cross-hub initiatives.

Initiative	Support identified in the funding agreement	Investment and activities of Climate Systems Hub
Climate adaptation	Support integrated research across the program to improve the evidence base for adaptation decision making for climate resilience Marine and coastal ecosystem management for sea-level rise and ocean acidification Building traditional cultural knowledge into climate understanding and working with Indigenous communities to help them adapt to the changing climate	Implementation of initiative strategy Projects: CS1.1, 2.1, 2.2, 2.3, 2.4, 2.7 CS2.10 coastal and ocean extremes, sea level rise and ocean acidification CS2.3, 2.4 work with Indigenous communities to help them adapt National adaptation forum/conference series CS2.2 synthesis, communication and training to support adaptation
Protected place management	Develop evidence to support decision-making and the development of adaptation measures for Protected places management, including National Parks, National and World Heritage sites and Ramsar listed wetlands.	CS2.7 focuses on protected places and threatened species CS2.2 supporting Indigenous-led adaptation planning process for K'gari World Heritage area
Threatened and migratory species and ecological communities	Develop evidence to support decision-making and the development of adaptation measures for threatened species (including migratory species), and threatened ecosystems management	CS2.7 focuses on protected places and threatened species
Waste impact management	Develop evidence to support decision-making and the development of adaptation measures for Air quality, pollution and waste management	CS2.5 is engaging with the Waste Impact cross-cutting initiative to consider air quality issues.

The Climate Adaptation Initiative strategy, finalised and approved in 2022, outlines 4 key activities to deliver to cross-cutting adaptation outcomes.

KA1 - Integrated adaptation research RP2022 established 2 new projects that support adaptation research - CS2.1 Enabling best practice and CS2.7 Climate-effective management for threatened species and protected places. It also extended the Indigenous Perspectives of Risk project (now CS2.3) that tests Indigenous risk values and approaches to adaptation. Cross-hub projects that deliver to the Climate Adaptation Initiative will be submitted in RP2023 by the Resilient Landscapes Hub focused on the Northern Rivers district (NSW) and Kakadu National Park.

KA2 - Synthesise, communicate, disseminate

Key topics and an approach to developing synthesis and communication products were reported through CS1.1 report *Synthesis and communication options and opportunities for the Climate Systems Hub and Climate Adaptation Initiative*. Project CS2.2 expanded on these findings delivering pilot training and initial synthesis products. This work is ongoing in CS3.2.

KA3 - Planning and decision support

The commencement of CS2.1 brought a focus on identifying best practice and enablers of adaptation. Piloting an Indigenous-led adaptation planning approach for K'gari World Heritage area (CS2.3) built an approach to cultural governance and gathering cultural values. All hubs agreed to scope options for a cross-hub knowledge and adaptation platform to deliver planning and decision support to conservation and other land managers. CS3.2 will commence planning for 'ConservationAdapt' in 2023.

KA4 - Community of practice

The hub organised a highly successful national adaptation forum (Day 1) in partnership with the AdaptNSW annual forum (Day 2). After Senator Jenny McAllister opened day 1, 329 attendees heard from 85 adaptation leaders across 29 breakout, panel and keynote sessions. Feedback was overwhelmingly positive and due to the success of the event the South Australian Government has partnered with the hub to deliver a full 3-day conference Climate Adaptation 2023.

Emerging priorities

Over the 2022 period no emerging priority projects were proposed or undertaken.

Performance against milestones

Performance against funding agreement milestones

All milestones for the reporting period and to date have been met as per the funding agreement (Milestones 1 to 12).

Milestones 1-7 were reported in the previous Annual Report.

Milestones 8-12 are applicable under the current reporting period (Jan-Dec 2022)

Table 5: Performance against funding milestones

Milestone	Description	Due Date	Status
8	Delivery of draft Research Plan 2022 to the Department	10 March 2022	Met
9	Acceptance of final Research Plan 2022 by the Department	(date not defined)	Met
10	Delivery of Annual Progress Report 1 to the Department (Period covered May – 31 December 2021)	1 April 2022	Met
11	Acceptance of Annual Progress Report 1 by the Department	(date not defined)	Met
12	Delivery of draft Research Plan 2023 to the Department	23 September 2022	Met

Measuring success

Hub outcomes and outputs

The hub's program logic (**Figure 3**) was developed by the hub leadership team in consultation with the department. The program logic is a living framework and is reviewed annually in line with the annual research planning process to incorporate any lessons. It represents the hub's expected pathway to outcomes and impact resulting from program delivery and the consolidated portfolio of project level outputs and supporting activities. Our outputs and outcomes for 2022 are summarised against the hub outcomes in the following sections.

The hub has also developed a monitoring, evaluation, reporting and improvement (MERI) framework to guide monitoring and reporting progress of outcomes and outputs at the project and hub level. Internal evaluation will inform annual research plans, while external evaluation will help identify progress toward outcomes.

Outcome 1. Increased understanding and improved modelling of climate systems across all timescales and relevant spatial scales to improve decision making and planning

Ongoing research targets an improved understanding of climate systems and approaches to modelling this understanding. NESP and ESCC Hub research informed the IPCC's Sixth Assessment Report. The Climate Systems Hub continues to build on the related ACCESS modelling contributions in the Coupled Model Intercomparison Project (CMIP) framework, through the building of larger ensembles of experiments and by providing new simulations that explore possible future scenarios of climate including mitigation pathways towards net-zero emissions and beyond (CS1.8 and CS2.11). To ensure policymakers and practitioners understood the changes in global model projections and findings, the hub summarised IPCC report findings in a webinar series, with 560 registering to attend, and a series of short video explainers, which received positive feedback and was shared within state government departments., which received positive feedback and was shared within state government departments.

Project CS2.9 completed the first comprehensive carbon budget for Australia (and first ever carbon budget for Australasia and New Zealand) and contributes to the Global Carbon Budget, a comprehensive annual account of global emissions. These budgets are essential to inform policies to get Australia and the world to net zero emissions. The Australian Government is already using this information to inform Australia's policy pathway to net zero emissions.

Projects CS2.6 and CS2.8 continue to build on our knowledge of climate drivers and extremes with wide-ranging applications to flood and drought. Project CS2.5 is delivering new science to inform the development of better next-generation climate downscaling simulations, for example through very high-resolution modelling of pyrocumulus convection and tropical cyclones. Marine heat waves and the coastal impacts of sea-level change are under investigation in Project CS2.10.

Engagement at scientific conferences such as Illuminate, the National Adaptation Conference and the Australian Oceanographic and Meteorological Society annual conference, allowed collaboration and awareness of hub outputs to be spread with the broader scientific community across Australia.

Outcome 2. Best practice climate adaptation and risk assessments are informed by fit-for-purpose climate science for decision making and planning

Improved risk assessment approaches are informed by both climate science and adaptation research for a diversity of users. The hub's research is made available to technical users for modelling risks for specific systems. Project CS2.6 worked with water planners in Western Australia to consider climate risk. Information is also delivered to users undertaking first pass risk assessments via training and literacy workshops (CS1.1, 2.2). Simple presentation of information and approaches for adaptation planning are being co-developed with Indigenous partners to support adaptation planning (K'gari) and

inform risk awareness and assessment (Northern Peninsula Area (NPA) and Shark Bay). This outcome is likely to be delivered later in the hub's life due to the time lag between development and uptake. We expect case studies of implementation projects to be available in 2023 – 2024.

Outcome 3. Fit-for-purpose tools and information to support conservation, protection and sustainable management of biodiversity, ecosystems, environment and heritage are accessed and used

A database typology of adaptation options and climate interactions is under development to help conservation and land managers consider management interventions to adapt to climate change. Resources that will help these managers understand near term and long-term climate risk include regionally specific summaries of historical, short-term and long-term forecast (CS2.7 'situational' reports, CS2.5 downscaled projections). Early drafts of these outputs are being tested with central stakeholders, but once published will be of value to conservation and land managers, Natural Resource Management (NRM) groups, policymakers, listing of threatened species and regional planners.

Project CS2.7 developed a calendar highlighting adaptation challenges and solutions for species across Australia to foster sharing of intervention approaches in response to climate change. 100 copies of the calendar were distributed to key stakeholders and policymakers, with additional demand met by an on-line version.

Outcome 4. Decision makers and planners in government, industry and community have increased capacity to use climate and adaptation information, including data rich information, to assess climate risk and undertake adaptation planning

This year the hub's projects have produced more than 60 publicly available outputs including 29 peer reviewed articles, 13 media articles, 9 reports and briefing notes, and 13 workshops and training sessions. Projects worked directly with the communication and media officer, knowledge broker and state government partners to develop outputs that meet stakeholder needs and made information accessible and usable in line with best practise. For example, Project 2.6 Extreme events explained collaborated with stakeholders across Western Australia to co-design their report on Rainfall in the Pilbara, and then worked with the communication officer to further refine this work into an accessible fact sheet for non-technical users. This ensures this work is relevant and accessible to decision makers across the Pilbara, with the storylines themselves also giving context to water availability in future climate scenarios. The hub received feedback from our stakeholders that this was beneficial to various stakeholders working in water management across Western Australia and addressed uncertainty around precipitation in the region in a way that is understandable to those of varying climate literacy. Beyond the technical report, this work is being summarised into a fact sheet and webinar to reach further stakeholders.

Two pilot in person training sessions (CS2.2) in Perth and Canberra increased the confidence of decision makers in accessing and interpreting climate information for their decision-making needs. Of the 49 participants, almost 70% reported increased confidence in finding and using climate projections than before the training. One attendee commented it was an "informative and well-structured workshop that should be mandatory for all climate policy officers". All participants gave positive feedback and 39% of participants, unprompted, expressed that they had found the training helpful. 18% would like additional future training.

Outcome 5. Greater connection between climate science communities and Indigenous communities to support increased capacity of Indigenous communities to respond to climate change impacts

The NFPPCC has been established and commenced its work on building partnerships between climate science communities and Indigenous communities, including planning for the next Gathering on Climate Change event in 2024. Projects are also partnering with individual Indigenous communities

to support Indigenous research, processes and planning. Outputs are in development that guide Indigenous engagement, adaptation planning and understanding cultural values and risks to those values. Once published, we expect these outputs to provide guidance and examples for Australia's broader Indigenous community to learn from and implement.

Outcome 6. Next generation of environmental, climate and adaptation scientists have capability to deliver advancements in environmental research to undertake adaptation planning

The hub's projects will employ post-doctoral and early career researchers. We are also beginning to formalise an early career professionals' network, with an initial call for members made at the National Adaptation Forum and AMOS. A calendar of events and opportunities is planned for 2023.

NESP goals	**Conserve, protect and sustainably manage Australia's biodiversity, ecosystems, environment and heritage through research, information management, supporting natural resource management, establishing & managing Commonwealth protected areas, and reducing and regulating the use of pollutants and hazardous substances, and coordination of climate change adaptation strategy and climate change science activities.**					
NESP Outcomes	Credible peer reviewed, timely research that is used by decision-makers to answer questions and develop solutions to problems.	Research findings and practical guidance for decision-makers, stored in a manner that is discoverable and accessible, and where appropriate integrated into end-users' databases and decision support tools.			Enhanced environmental science and research capability amongst researchers, end-users, and Indigenous Australians.	
Initiative Outcomes	**Threatened species** Policy, investment and on-ground action to halt the loss of and recover Australia's threatened and migratory species and threatened ecological communities is better informed by scientific and Indigenous knowledges as a result of this Initiative.	**Protected places** Management of Australia's protected places is supported by building capacity of Indigenous communities and organisations to determine, lead and disseminate indigenous knowledge and science to support protected place management. Adaptive management of protected places supported by building the evidence base. Governance of Australia's protected places improved by identifying effective interventions.	**Waste impact management** The science informs business decision and communal approaches that reduce primary material requirements, increase secondary content in products and infrastructure, and workable cycles arrangements leading to tangible reduction in material use, waste to landfill and emission and reduced environmental impacts (climate change, natural resource depletion, biodiversity loss, toxic waste issues) related to natural resource use creating significant and measurable environmental benefits.	**Climate Adaptation Initiative** Adaptation focused research and outputs are produced across the NESP Hubs Strong end-user capacity, uptake and application of evidence-based adaptation information Decision support tools are delivered that enable application of climate change adaptation on the ground Adaptation decision-makers and researchers are supported to shared learnings and build relationships	
Climate Adaptation Initiative goal	**Improve Australia's adaptive capacity and resilience to climate change**					
Climate Systems Hub goal	**Empower Australian government and communities to use climate science for good practice adaption for the intergenerational benefit of Australia's people and environment**					
Hub Outcomes	Increased understanding and improved modelling of climate systems across all timescales and relevant spatial scales to improve decision making and planning	Best practice climate adaptation and risk assessments are informed by fit-for-purpose climate science for decision making and planning	Fit-for-purpose tools and information to support conservation, protection and sustainable management of biodiversity, ecosystems, environment and heritage are accessed and used	Decision makers and planners in government, industry and community have increased capacity to use climate and adaptation information, including data rich information, to assess climate risk and undertake adaptation planning	Greater connection between climate science communities and Indigenous communities to support increased capacity of Indigenous communities to respond to climate change impacts	Next generation of environmental, climate and adaptation scientists have capability to deliver advancements in environmental research undertake adaptation planning
Hub themes	Modelling and monitoring	Accessible and useable		Oceans and coasts	Land and terrestrial ecosystems	People and Country
Outputs	Guidance, framework and case studies to support best practice adaptation for conservation management and Indigenous communities (CS2.1, 2.3, 2.4, 2.7) Synthesis and communication materials delivered through an accessible gateway (all projects co-ordinated through CS2.2) Spatial layers (data or maps) of climate information (CS2.2, 2.5, 2.7, 2.8, 2.9, 2.10, 2.11) Scenarios/projections of future climate scenarios (CS2.11, 2.5) Increased understanding of climate processes and drivers (CS2.6, 2.9, 2.8) Implementation and delivery of an Early Career program (all projects) Deliver major climate change and adaptation conferences/ events including supporting the National Gathering World class, peer reviewed science publications (all projects) Governance documents (Annual Research Plans, Annual Reports, strategies, risk register, reporting on strategic progress and delivery, MERI Framework)					
Activities	Climate Adaptation Initiative (foster the community of practice, synthesise and communicate climate and adaptation research and information, support for adaptation planning and decision-making, integrated adaptation research)				Indigenous Partnerships including supporting the First People's Platform on Climate Change	
	Communications	Data wrangling	Knowledge brokering		Program management	Monitoring and evaluation

Figure 3: Climate Systems Hub program logic provides indicative hub outcomes and outputs.

Short- to medium-term outcomes – quantitative measures

Table 6: Quantitative performance measures (short- to medium-term outcomes). Reporting period means the calendar year preceding the Annual Progress Report. For the first year of NESP 2 hubs, the reporting period is May to December 2021. Unless specified otherwise, the term 'research-user' refers to departmental and/or external users.

No.	Performance measure	Result for reporting period (numerical only)	Explanation, if any
1	Proportion of projects (active or completed in the reporting period) for which there is a research-user actively engaged in the project: a) co-design b) research delivery c) use and research uptake	a) 19/19 b) 19/19 c) 19/19	
2	Research outputs in the reporting period provided to research-users on time and as identified in the approved research plans: d) total number e) proportion	d) 62 e) 62/62	All outputs provided to the Department.
3	Proportion of completed research projects that are confirmed to meet the needs of departmental research-users as identified at project co-design stage	8/8	CS1.1 through CS1.8 completed June 2022.
4	Number of projects that: • are Indigenous-led • meet research and management priorities of Indigenous stakeholders • are Indigenous-led projects that also meet research and management priorities of Indigenous stakeholders.	3	CS1.2. CS2.3, CS2.4
5	Number of peer-reviewed, NESP-funded publications during the reporting period	29	Including 8 publications in prestige journals such as *Nature, Nature Climate Change, Scientific Data* and *Bulletin of the American Meteorological Society*.
6	Number of NESP research citations in other researchers' publications during the reporting period	193	

No.	Performance measure	Result for reporting period (numerical only)	Explanation, if any
7	Percentage of completed NESP products, research publications, datasets and metadata that are discoverable and accessible in accordance with *NESP data and information guidelines* and the funding agreement	100%	
8	The number of datasets and management tools that benefitted from hub research and outcomes (including but not limited to web-based decision support systems; environmental management tools for Indigenous communities, waters and land management; plans of management for Indigenous Protected Areas (IPAs), co/jointly managed parks, marine park plans of management, conservation agreements)	10 published datasets, accessible by stakeholders	Many projects have data outputs planned that are still in development.
9	Number (full-time equivalents) during the reporting period of: • PhD students • post-doc and early-career researchers • mid-career researchers • Indigenous researchers • volunteers (total) • Indigenous volunteers • Indigenous sub-contractors	PhD: 2 Post doc: 2 Mid-career researchers: 60 Indigenous researchers: 2 Volunteers: 0 Indigenous volunteers: 0 Indigenous sub-contractors: 4	Onboarding of early career (postdoctoral and PhD) researchers was delayed due to later than anticipated contracting with university partners, with many candidates anticipated to commence in early 2023. The Climate Systems Hub supports the 9 member Indigenous-led Steering Committee for the National First Peoples Platform on Climate Change. Although not formal sub-contractors, the steering committee members and secretariate roles and responsibilities are outlined in the Terms of Reference drafted at the Inaugural Steering Committee meeting 28-30 October 2022. Indigenous sub-contractors supported Northern Peninsula Area work (project CS2.3).
10	Number of knowledge-sharing and communication events and activities held or shared: • with on-ground managers (general) • jointly with Indigenous researchers and Traditional Custodians • that are Indigenous-led	3	Indigenous-led: On-Country visit by hub scientists, hub leader and Indigenous facilitator to Northern Peninsula Area.

No.	Performance measure	Result for reporting period (numerical only)	Explanation, if any
			Initial meetings of the National First Peoples Platform on Climate Change including the Inaugural Steering Committee meeting on Ngurupai (Horn Island). In conjunction, the Steering Committee member from Torres Strait Islands assisting in setting up a meeting with community members on Waiben (Thursday Island).
11	Proportion of hub staff and researchers who have completed: • Indigenous cultural capability training • Indigenous cultural and intellectual property training • both Indigenous cultural capability training and Indigenous cultural and intellectual property training	5/63	Note that these proportions are for training during life of Climate Systems Hub only. 5 people from the hub attended the DCCEEW facilitated Indigenous Cultural Intellectual Property training. We are considering expanding the number of hub staff engaging in True Tracks training in future, along with other opportunities for Indigenous cultural capability training.
12	Proportion of hub projects overall that fall within the categories of the Three-category approach: • Category 1 • Category 2 • Category 3	Cat 1: 3/19 Cat 2: 1/19 Cat 3: 15/19	Projects CS1.2, CS2.3, CS2.4 are Category 1.
13	Proportion of hub projects that have been developed in consultation with the hub Indigenous Facilitator or the Indigenous Facilitators Network	3/19	CS1.2, CS2.3, CS2.4
14	Number of guidelines about best-practice that the hub has produced or co-produced in the reporting period, for:	0	

No.	Performance measure	Result for reporting period (numerical only)	Explanation, if any
	• knowledge brokering (e.g. https://www.nespthreatenedspecies.edu.au/publications-and-tools/connecting-research-with-policy-guide-to-writing-for-policy-makers) • Indigenous partnerships and products (including design of flagship engagement activities (e.g. Our Knowledge Our Way; Three Category Approach) • environment and climate management within the scope of the hub's research (e.g. *Guidelines for the translocation of threatened plants in Australia, Third Edition;* https://www.nespmarine.edu.au/project/project-d2-standard-operating-procedures-survey-design-condition-assessment-and-trend		

Longer-term outcomes – qualitative measures

Although early in the life of hub research projects, we are already building capacities that can enable longer-term impacts through improved interest and understanding of most recent adaptation practice and thinking, uptake of climate literacy training and application of climate information in several case studies.

Several of our projects have provided input to media enquiries in response to extreme weather events and climate processes. For example, CS2.6 fielded more than 15 media interactions around the on-going La Nina and east-coast flooding. This interest has helped guide research around what drives multi-La Nina events; and when large-scale modes of variability combine to drive wet conditions.

There's continuing demand for climate literacy training and the learnings from the 2 training sessions so far will assist the hub to shape and adapt training to user needs. The next phase of training will help guide use of climate change information and data. We collected evidence of improved climate literacy through the climate literacy training (CS2.2), with attendees showing an increased confidence as follows:

- 69% of participants said they were more confident "Finding information on observed/historic weather and climate" than before the training
- 65% of participants said they were more confident "Finding and using models to simulate climate" than before the training
- 67% of participants said they were more confident "Finding and using climate projections" than before the training
- 63% of participants said they were more confident "Finding the right climate information for the spatial scale you need" than before the training
- 63% of participants said they were more confident "Understanding what an acceptable level of uncertainty in climate projections is" than before the training.

The success of the *2030 and beyond: Adaptation for our future* and the interest in *Climate Adaptation 2023 Act Together - Act Now* demonstrated by strong sponsorship commitments, show there's an ongoing demand for adaptation focused events where adaptation practitioners and scientists can share knowledge and experiences to improve the adaptation practices.

Finally, partnering with our state and territory partners is changing the way the hub and its research projects do business. We are building on relationships with state and territory partners to embed a more user-centred, co-design approach to the NESP research program.

Collaboration and partnerships

NESP encourages a collaborative, multi-disciplinary approach to environmental and climate research. Key to the success of the hub will be the capacity to foster partnerships across hubs and with a wide range of decision-makers across the Australian community, including Indigenous communities, to achieve positive environmental, social, and economic outcomes.

The Climate Systems Hub and Climate Adaptation Initiative have continued building collaborative partnerships to inform our program. In 2021 we designed and initiated a 4-step co-design process which we continued into 2022:

1. **Explore (Sep-Oct 2021)**: Identify user needs the hub and initiative might meet. Established a co-design working group to coordinate and support engagement and develop a co-design guide. This step generated over 200 user-needs.
2. **Analyse (Oct-Nov 2021)**: Analysis and synthesis of communicated and known user needs into five strategic themes. Theme-focused groups delved deeper into associated user needs.
3. **Co-plan (Nov – Dec 2021)**: Build options for research, activities and products that could be delivered within themes. Tested with stakeholders to prioritise project options.
4. **Co-design (Nov 2021 – Mar 2022):** Refined and developed project proposals to ensure possible/identified projects address research themes, deliver to cross-hub initiatives and provide outcomes that meet stakeholder and end-user needs and priorities.

In 2022 we have continued to incorporate co-design into our research design, including a fifth step in the co-design process: to co-develop and co-produce projects. This step helps project teams think about how they establish, plan, and conduct their projects in a way that considers stakeholder needs, input and up-take. The process is ongoing and evolving in partnership with research teams and the knowledge brokering team.

The Indigenous facilitator has continued to build and strengthen relationships with Indigenous groups and supporting them to safeguard their ICIP and ensure engagement with projects and partners is done so with Free, Prior and Informed Consent.

The National First Peoples Platform on Climate Change was formalised in 2022, with the inaugural meeting of the platform held in the Torres Strait Islands in October 2022.

The hub reviewed it's 5 strategies in the second half of the year. The Hub Steering Committee endorsed them on 8 December 2022.

Knowledge brokering

The hub's knowledge brokering strategy was refined in 2022 and guides the work of the hub knowledge brokering team. The success of the hub hinges on the ability of decision-makers to articulate their needs to researchers; the quality and usefulness of the outcome-focused research outputs produced; as well as how effectively these outputs are communicated to their intended end-users.

The role of the knowledge brokering team is to support and realise this engagement and knowledge transfer. The ongoing co-design process has been central to achieving these goals. Co-led by the Climate Adaptation Initiative lead and the knowledge brokering team, this process created a platform for the effective integration of state and territory government stakeholders into project planning and development. A co-design guide was developed, and several stakeholder workshops completed. A co-design working group bringing together the knowledge brokers and project teams has helped foster greater connection and sharing of co-design approaches.

The knowledge brokering team was to include 3.75FTE staff and additional in-kinds support from our state and territory partners, as well as a full-time co-ordinating knowledge broker. The coordinating

hub knowledge broker role has been vacant since July 2022. Two full-time state-based knowledge brokers commenced with the hub late in 2022, having been vacant prior to that while contracting arrangements were finalised. Despite limited capacity, the knowledge brokering team have met weekly to progress co-design activities, first under the guidance of the then coordinating knowledge broker (January-July 2022), and then the Climate Adaptation Initiative leader. A recruitment process has been completed and the new staff member is due to start in March 2023.

Overall, 2022 has cemented effective working relationships, across all participating organisations and relevant staff and experts. These relationships have helped to (co-) create a strong direction for research delivery over the lifetime of the hub. Working collaboratively with users through co-design and co-production processes is necessarily iterative and time-consuming – but the strength of this work is evident, and the hub aims to embed these approaches into decision-making and achieve practice change.

Communication

The hub's communication strategy is structured to enable our stakeholders to understand the best available science for their decision-making needs. This year has seen communications increase awareness, build support, and highlight key information for our stakeholders. This has come from a range of outputs including webinars, blogs and social media posts, reports, fact sheets and explainer videos- all aimed at ensuring hub science is understood, accessible and usable.

Website engagement

The hub's website has continued to be updated regularly to include breakdowns of updated projects, governance documents and information about events. Over the course of 2022 more than 16,000 users visited the site more than 38,000 times – a tenfold increase in engagement compared to the previous year.

Events run in collaboration with CJ CoP CS members generated significant website traffic, demonstrating the benefits of collaboration to develop specialised events. The page Climate projections: what's happening to rainfall in Western Australia, a webinar run jointly by Western Australia's Department of Water and Environmental Regulation, had more than 1,500 views and was the second most visited page on the website after the home page. Other pages of note were the 2030 and beyond Adaptation for our future, with the event run in collaboration with AdaptNSW. This, as well as ongoing discussions within the knowledge brokering team, indicated the need for communications and information targeted at a local and state-based level.

Google analytics indicate that more than 70% of these website users were within Australia. The main referrals that drove traffic to the site were google, social media websites, the department's site, and CSIRO. Through the course of the year, 11 blog posts and 30 resources were added to the site with other pages updated and added to continue to drive this engagement- these were then promoted through hub news email updates and social media.

Hub promotions

Ongoing outreach from the hub also came in the form of hub news email updates and social media posts. Google analytics indicates almost 70% of website traffic came from the direct sharing of hub news and updates. 35% of hub email subscribers are considered "highly engages". The hubs audience for its regular hub news and adaptation updates has grown substantially to 824 contacts. The hub regularly updated its Twitter, Youtube, Facebook and Linkdin through the year. The most engagement came from the hubs Twitter, driving website traffic. Through frequent tweets and sharing of hub news, the hubs tweets gained more than 31,000 impressions through the year and the account gained 87 new followers (a 14% increase since the previous year).

Hub events

The hub ran 7 webinars in 2022 to a collective audience of more than 1800 people. These webinars have been developed to address key knowledge gaps or areas of interest identified by stakeholders through co-design and ongoing knowledge brokering activities. The highest attendance was Answering your questions about the IPCC Working Group II report, planned in collaboration with the knowledge broker team to answer hub stakeholder questions about the latest IPCC report.

The hub also received positive feedback about its October webinar "Australia's Indigenous Peoples- the big picture and climate change" with stakeholders reaching out to speak to the importance of the content discussed and the relatability of the round table discussion format of the webinar, facilitated by the hubs Indigenous Facilitator.

For the first time, the hub also held in person events. In October the National First Peoples Platform on Climate Change held its first in person meeting in the Torres Strait. While in November the hub hosted the 2022 National Adaptation Forum, with more than 329 people registered to attend this event brought together adaptation practitioners from across Australia to discuss good practise and included an opening by The Hon. Senator Jenny McAllister, the Assistant Minister for Climate Change. This event also included a pre-event roundtable with key experts from across the hub, its partners and industry leaders to further the discussion of adaptation and what it means across Australia.

Internally, the Science Days in June brought together more than 100 hub scientists from across Australia and partnership agencies to collaborate and discuss new and emerging scientific priorities, advancements, opportunities for collaboration and larger questions around modelling and our understanding of the climate.

Table 7: The hub hosted webinars, events and workshops with positive audience responses and impacts listed in the table below. For hub outputs and media appearances, see Appendix A.

Project	Event	Audience and Impact
All Projects	Science Days	This event brought together almost 100 scientists from across the hub
CS2.1	2030 and beyond: Adaptation for our future forum	2-day event for more than 300 interdisciplinary attendees, based on very positive feedback this will be continued with a series of National Adaptation Forums
CS2.2	Training for policy makers in Perth and Canberra	49 attendees all indicated increased conferences, based on positive feedback this will be continued as a training series in 2023
CS2.2	Answering your questions about the IPCC Working Group II report webinar series	560 registered with supplementary fact sheet shared among CJ CoP CS partners and positive feedback reported
CS2.3	Australia's Indigenous Peoples- the big picture and climate change webinar	184 registered with the series ongoing in 2023 after positive feedback
CS2.3	Illuminate festival presentation and engagement	The hub engaged with Traditional Owners through the festival on Gimuy Country (Cairns)
CS2.5 and CS2.6	Climate projections: what's happening to rainfall in Western Australia? webinar	363 registered with feedback from the West Australian government the webinar was helpful, and the recording was shared widely internally

CS2.6	Attribution workshop	27 key stakeholders attended to contribute to ongoing co-design
CS2.6	There and back again: the impacts of back-to-back El Niño and La Niña webinar	115 registered
CS2.6	Developing a 'storylines' approach for regional climate change information webinar	309 registered with a storyline approach applied to case studies in the Pilbara. Read more in Appendix B.
CS2.8	Understanding Australia's future climate webinar	250 registered
CS2.10	Internal CANUTE workshop	30 key stakeholders attended who were able to contribute to ongoing co-design
CS2.11	Australian Community Climate and Earth System Simulator (ACCESS) modelling workshop (AMOS 2022 conference)	30 scientists and experts workshopped the ongoing development of ACCESS

Indigenous partnerships

Every Indigenous community in Australia is different. The Climate Systems Hub is committed to Informed partnership processes that reflect responsible and transparent engagement underpinned by Indigenous people having the right to their Indigenous Cultural and Intellectual Property, and Free, Prior and Informed Consent.

At the NESP program level the hub Indigenous Facilitator engages through the Indigenous Facilitators Network. Additionally, there are several key areas where the Climate Systems Hub is making progress towards implementing its Indigenous partnerships strategy:

- Maintenance of existing relationships with the Indigenous led Steering Committee group of the National First Peoples Gathering on Climate Change (NFPGCC) facilitated by the predecessor Earth Systems and Climate Change Hub (CS1.2).
- Early stages of formation of a new National First Peoples Platform on Climate Change. This will build on the NFPGCC Steering Committee above, with further incorporation of members representing each State and Territory, along with 2 additional members, an Indigenous youth member, and a member representing the Indigenous Deserts Alliance. The Torres Strait Regional Authority continues to be a valued member going forward. Key members of the hub provide secretariat support to this Indigenous led body.
- On-going project work with the Malgana (Shark Bay) Traditional Owners through the Indigenous Perspectives of Climate Risk component of project CS1.2 and project CS2.4.
- Initial engagement extended to key organisations such as the Indigenous Land and Sea Corporation, and the Great Barrier Reef Foundation – Traditional Owner Partnership, introducing the hub in NESP phase 2. Partnership with Butchulla Aboriginal Corporation of K'gari (Fraser Island) incorporated early collaborations with the Queensland Department of Environment and Science World Heritage Team. Hub engagement also extended to Gur A Baradharaw Kod (GBK) Torres Strait Sea and Land Council Torres Strait Islander Corporation.
- Scoping of future project work for RP2022 with several Traditional Owner groups in the NPA. Ipima Ikaya Aboriginal Corporation, Registered Native Title Body Corporate is the principal partner of the hub, that incorporates members of the Apudthama Land Trust and Gudang Yadhaykenu Aboriginal Corporation into their governance structure. The Northern Peninsula

Area Regional Council is also a stakeholder through ongoing discussions with the NPA Traditional Owners.

Data management

The hub data management strategy was refined during 2022, and applied at the project level to ensure projects are producing data following the FAIR data principles, that is, Findable, Accessible, Interoperable and Reusable. Each project has a data lead who liaises with the data wrangler on matters relating to data management. Many of the activities of the data wrangler have been delivered through project CS2.2. This has been built on the stakeholder engagement work of RP2021. User needs for data have been clarified through this process and documented in detail. This is informing future work in CS3.2 that will develop solutions for enabling users to find the data they need, make it more accessible and useable, and help them apply it to decision making, thereby making data FAIR (hub produced and other existing data).

DCCEEW facilitated meetings between data wranglers from all four NESP hubs, and other informal discussions between data wranglers have begun sharing of challenges and solutions for making data FAIR. As cross-hub collaboration develops this engagement will become more important, particularly where data needs to be shared between researchers across hubs.

Collaboration between the data wrangler and the ACS has grown and strengthened. The data wrangler attended and presented at the ACS Improve Climate and Natural Hazard Science workshop in Hobart on 5 October. This opportunity allowed the hub to share its vision for a climate information gateway (led through project CS2.2) and hear from ACS and other partners on their plans for data portals relevant to their stakeholders. The data wrangler reviewed and provided advice on an ACS review of existing portals. The ensuing and ongoing discussions are aligning the approaches of the two programs to provide complementary portals and gateways, using common data sources and delivery mechanisms where possible, but targeted at the specific needs of their respective stakeholders.

The data wrangler has also been closely involved in several collaborative data working groups with aims that will deliver benefits to hub stakeholders. One of these is developing common guidelines to enable cross-institutional sharing of data, particularly that used by scientists to carry out their research. Another is developing a platform to capture the metadata and provide a catalogue for users to search for and discover available climate data, thus facilitating sharing and access of data to stakeholders. The data wrangler is also a member of working group 2 of the National Partnership for Climate Projections, which is focusing on the data standards for climate projections; this will help deliver data to stakeholders that adhere to the FAIR data standards.

Hub-level risk management

All risks identified in the hub’s risk management plan are being actively managed.

NESP impact stories

Theme title

Bridging science and policy: partnerships for climate science

Theme description

Mitigation and adaptation to avoid or reduce the risks of climate change is undeniably necessary. This requires responses at all levels of decision making, informed by world-class science. The science must meet the needs of decision-makers and be trusted by them, making long-term partnerships between researchers and decision-makers a vital piece of the puzzle.

The Climate Systems Hub is a trusted adviser and its broad reach means it has a unique convening power. It brings together the powerhouses of climate science in Australia; from fundamental science to applied science to decision support tools; and expertise from science to knowledge brokering to policy-makers. By partnering with both research institutions and the state and territory governments the hub has considerable opportunity to translate research findings and expertise into decision making at both the national and state level.

The hub is realising this potential by convening, resourcing and building lasting connections across the research spectrum and between scientists, decision-makers and Indigenous communities.

Impact snapshots

Strengthening the ACCESS community

The importance of the Australian Community Climate and Earth System Simulator (ACCESS) as a critical modelling and research tool, developed for Australia's unique climate, has been recognised in a recent significant investment by the Australian Government into the ACCESS National Research Infrastructure (NRI). The hub is building on this investment by convening strong connections between the ACCESS-NRI and policymakers, helping guide the sustainable development of this critical research infrastructure and maximise this long-term investment for Australia. This ongoing work will include articulating the particular value ACCESS brings to Australian decision makers.

Building a national approach to climate projections through trusted partnerships

Decision-makers need robust, fit-for-purpose regional and local scale climate information to prepare for climate change impacts, especially climate related hazards. Although climate projections information has been available for decades, a consistent national approach has been lacking. The hub worked with the Australian Government to establish the National Partnership for Climate Projections (NPCP). The aim of the partnership is to collaborate with state and territory governments, Australian government science agencies (such as CSIRO and the Bureau of Meteorology) and universities, to come to consistent approaches to providing future climate data that is comparable, fit-for-purpose, credible, authoritative, robust and useable to enable a wide range of users to assess their climate risks and plan for the future. The hub's networks of state and territory governments, and research institutions, readily link the Australian government with decision-makers and the best scientists on this important initiative. Through continued involvement in the NPCP the hub can help to provide the user needs perspective through demonstrated applications to shape the development of fit-for-purpose projections and information for users.

Partnering with decision-makers to test new ways of delivering complex information

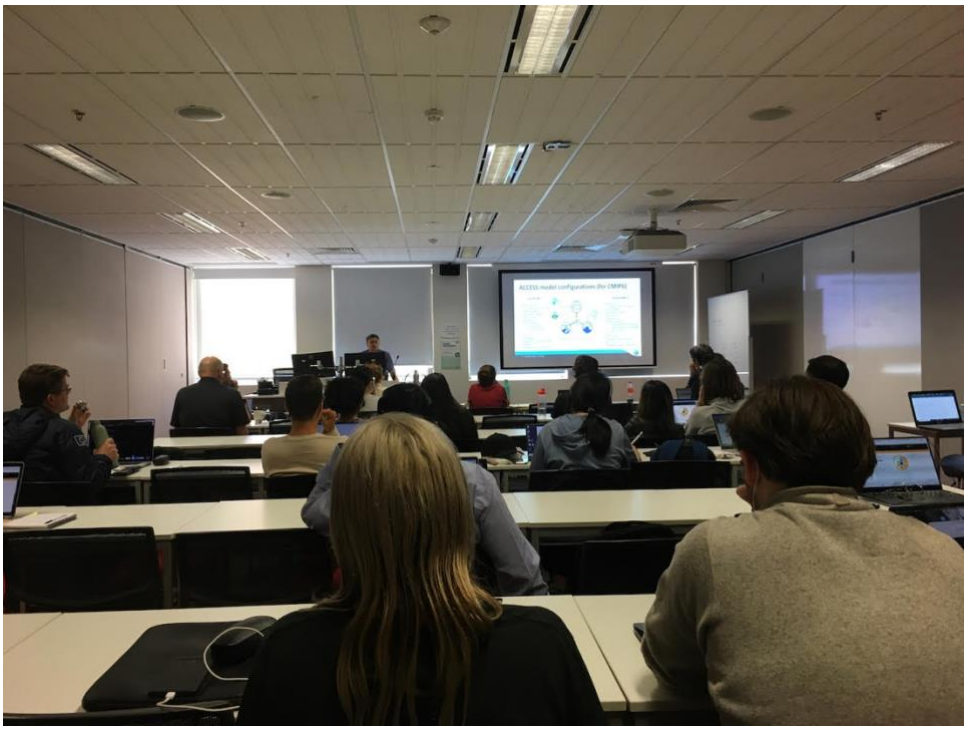
Climate projections may not always provide information and data that local planners and decision-makers can use. A storyline approach uses narratives to explore the implications of climate change on particular decisions. In partnership with the Western Australian Department of Water and Environment Regulation, hub researchers explored three climate projection storylines for two Western Pilbara catchments. The project has demonstrated that this approach can provide reliable and relevant storylines for planning future water resources for western Pilbara catchments. Given the success of this storyline approach, we will seek other opportunities to apply this approach with other stakeholders to refine and further develop it.

Research outputs and attributions

Storylines report and fact sheet

Images and video

The hub had a strong presence at AMOS 2022, including the Australian Community Climate and Earth System Simulator (ACCESS) modelling workshop



Participants in the ACCESS workshop at AMOS November 2022 (Credit: Climate Systems Hub)

NESP scientists from project CS2.6 present at AMOS 2022 (Credit: Climate Systems Hub)

Theme title

Building capacity for climate adaptation

Theme description

Climate change impacts all Australians. Effective responses and adaptation will be complex, and at times difficult choices will need to be made. It is essential relevant stakeholders have the knowledge, skills and capacity to be part of the conversation.

The Climate Systems Hub has developed a co-design approach to ensure we are delivering information and research that fills real world and emerging knowledge needs.

Hear from adaptation practitioners and policymakers sharing their experience and knowledge at the first National Adaptation Forum in Sydney.

Through the piloting and development of climate science and adaptation literacy training, the Climate Systems Hub is building a training program to meet the knowledge needs of local councils, all levels of government, small business, industry and land managers.

By applying the protocols for Indigenous partnerships and Free Prior and Informed Consent developed and endorsed by the National First Peoples Platform on Climate Change, the hub is showing how government and researchers can support Indigenous-led adaptation planning projects.

Impact snapshots

Co-design approach to build a research program

To build a research program that meets user needs, the Climate Systems Hub and its knowledge broker partners - the state and territory Cross Jurisdictional Community of Practice for Climate Science (CJ CoP CS), developed a 5-step process to co-design. Hub members have access to a step-by-step guidance document developed by the team.

A national forum for adaptation learning

A two-day conference '2030 and Beyond: Adaptation for our future' brought together Australia's most prominent climate change leaders. Speakers and participants explored the challenges and opportunities of climate change adaptation in NSW and across Australia. Over 300 participants came from government, industry, academia, consulting, and the not-for-profit sectors. The event was the first time the Climate Adaptation Initiative had partnered with the NSW government to deliver an adaptation forum. The success of this forum has led to another forum to be held in Adelaide 27-28 July 2023, partnering with the South Australian Government.

Improving climate literacy among policymakers

Decision makers want to be confident in applying climate information to complex problems. The Climate Systems Hub piloted the delivery of full-day training courses in Perth and Canberra. Over 50 attendees learnt more about the basics of climate change. Covering topics such as observations, base periods, climate models, scenarios and uncertainty, places to find climate information, as well as risk assessment and adaptation planning. The workshops focused on getting started in finding the most relevant and up to date information. Participants provided feedback and priorities for further training which will be developed and delivered in 2023. An example of typical feedback was "...such an informative and well-structured workshop. Should be mandatory for all climate policy officers."

Building partner capacity to support Indigenous-led adaptation planning

As the Traditional Owners of the World Heritage listed K'gari, Fraser Island, the Butchulla Traditional Owners want to understand how climate change will impact their Country. The Butchulla Aboriginal Corporation (BAC) have partnered with the Queensland Government and the Climate Systems Hub to pilot implementing the Australian Government's 'Climate Change Toolkit for World Heritage Properties' to assess climate risk and consider adaptation options. The partners are committed to an Indigenous-led process. The Climate Systems Hub has

worked with the Queensland Government to build staff capacity to understand and implement Free Prior and Informed Consent and engagement protocols through to Indigenous Cultural Intellectual Property – which were developed and endorsed by the National First Peoples Platform on Climate Change.

Research outputs and attributions

2030 and beyond: Adaptation for our future: https://nesp2climate.com.au/national-adaptation-forum-22/

National First Peoples Platform on Climate Change:

Images and video

Looking back at the National Adaptation Forum

The Hon Jenny McAllister, Assistant Minister for Climate Change opens 2023 and beyond: Adaptation for our future (Credit: Climate Systems Hub)

Adaptation Initiative lead Sarah Boulter introducing Day 1 2030 and beyond: Adaptation for our future (Credit: Climate Systems Hub)

Indigenous Facilitator Rowena Bullio presents at 2030 and beyond: Adaptation for our future (Credit: Climate Systems Hub)

John Clarke presents on climate change to decision makers in Canberra, 2022 (Credit: Climate Systems Hub).

Theme title

Building Australia's climate science excellence

Theme description

Foundational science understanding underpins the confidence with which we attribute climate impacts, including climate extremes, to climate change. It gives insights into how the changing climate will evolve under potential lower and higher-emission future scenarios - which allows us to better understand and adapt to our climate future.

The Climate Systems Hub continued to deliver to our foundational understanding of climate science, allowing our decision making to be underpinned by world class modelling of science products. In 2022, hub scientists continued to work with the Intergovernmental Panel on Climate Change (IPCC), World Climate Research Programme (WCRP), and the Global Carbon Project (GCP) - global coalitions of scientists to inform adaptation and mitigation activities.

Hub scientists work directly with knowledge broker partners from the Cross Jurisdictional Community of Practice for Climate Science to deliver directly to state and territory needs. In 2022 this led to better understanding of Western Australian rainfall and how it might change under future climate to provide critical information for decision makers e.g., water security planning.

Impact snapshots

Preparing for a net-zero world

Modelling is critical to understanding our current and future climate risk. Hub scientists have been working with the Australian Community Climate and Earth System Simulator (ACCESS) and other international modelling and research tools, to better simulate Australia's future climate risk. This allowed hub scientists to model a cooling planet as well as further understand the impacts of our changing climate on Australia's climate drivers.

Utilisation of ACCESS CMIP datasets

Our ACCESS modelers vastly built upon the WCRP Coupled Model Intercomparison Project (CMIP6) submission of our predecessor NESP Earth Systems and Climate Change Hub. Larger ensembles of simulations increase confidence in our understanding of both natural variability and extremes. Together, the two ACCESS submissions to CMIP6 have accumulated over 100 million dataset downloads, placing these models in the top 10 of over 140 CMIP models internationally for uptake. These datasets are being used for many applications, including by Australian groups undertaking regional downscaling to inform societal climate information needs at local scales. Articulating the particular value ACCESS brings to Australian decision makers, especially through regional downscaled information is the focus of future work.

Hub science on the world stage

Contributing to international carbon budgets, the hub's science has featured on the world stage. Feeding into the IPCC's Sixth Assessment Report released this year, thereport and carbon budgets are summarised in this webinar series and a series of short video explainers. Hub science also fed into the Global Carbon Budget, a comprehensive account of global emissions that allows us to know the world is not on track to meet global emission reduction goals in line with the Paris Agreement, and inform global mitigation and adaptation.

Understanding west Australia's rainfall

This year the hub worked with the Western Australian Department of Water and Environment Regulation to better understand rainfall across the state. Hub scientists are working to understand future precipitation trends, and the potential implications for decision makers, for example, water security planning, flooding and agriculture. The hub worked with key stakeholders within WA to run a webinar attended by over 100 participants from across WA government agencies. The hub used a storylines approach to explore the best available information of future precipitation in the Pilbara - which allows decision makers to contextualise the likelihood and impacts of different wet or dry projection scenarios. The questions raised identified opportunities to continue to work with key

stakeholders to translate the projections into decision-ready information to inform decisions on the potential impacts of storms and flooding, and water supply in the future.

Research outputs and attributions

King, A.D., Peel, J., Ziehn, T. et al. Preparing for a post-net-zero world. Nat. Clim. Chang. (2022). https://doi.org/10.1038/s41558-022-01446-x

Friedlingstein et. al, (2022). Global Carbon Budget 2022, Earth Syst. Sci. Data, 14, 4811–4900, https://doi.org/10.5194/essd-14-4811-2022

Storylines report and factsheet

Images and video

Answering your questions about adaptation and the upcoming IPCC report: https://nesp2climate.com.au/answering-your-questions-about-adaptation-and-the-upcoming-ipcc-report/

What's changed in the latest IPCC report: https://www.youtube.com/watch?v=93_-AWKcIJo&list=PLS7M1Ll5Xnx5uAgLXFnpu_UVzfhiagCdF&index=5

Climate projections: what's happening to rainfall in Western Australia?: https://www.youtube.com/watch?v=-eiy5bAmXYA&t=380s

Theme title

Connecting with Indigenous communities

Theme description

Indigenous people across Australia have held knowledge of their climate and environment for millennia. This knowledge is deeply tied to culture and spiritual beliefs and land management practises. Now climate change threatens Country and is causing environmental changes.

The Climate Systems Hub is bringing together Traditional Owners and scientists to better understand these impacts and work together to address them.

Watch the hub's Indigenous facilitator explain the importance of bringing together these knowledge systems and the hubs webinar on Australia's Indigenous people- the big picture and climate change.

These activities have been guided by NESP tools like the Indigenous-led Three-Category Approach and Our Knowledge Our Way Guidelines, and is showing how researchers and practitioners can build relationships with Indigenous experts. Read more in Indigenous collaboration for Australia's environmental science.

Impact snapshot

National First Peoples Platform on Climate Change's first in-person meeting

The establishment and first meeting of the National First Peoples Platform on Climate Change (NFPPCC) on Kaurareg Country in the Torres Strait Islands marks a significant step in Indigenous-led responses to climate change. This work is based on the connections and application of Indigenous-led governance, bi-lateral co-design principles and Terms of Reference from the Earth Systems and Climate Change Hub National First Peoples Gathering on Climate Change. This consistent practice of Indigenous Partnership has embedded confidence with Traditional Owners and hub scientists operating in this space. The meeting on Ngurupai (Horn) Island in the Torres Strait Islands produced key outcomes on the governance, function and secretariat support for the NFPPCC members. This is an exciting development that will continue to grow in line with the vision of platform members, and towards the first National First Peoples Gathering on Climate Change in NESP phase 2.

Ongoing collaboration with Indigenous Communities

The hub's Indigenous facilitator has worked to build trust with the hub and has implemented ongoing cultural awareness and development. This has allowed hub scientists to be invited onto Country by Traditional Owners in the Northern Peninsula Area, and soon on K'gari, which has allowed learning for both groups. These engagement activities have allowed scientists and Traditional Owners to scope areas to bring together traditional and western knowledge to address cultural adaptation activities - a first in Australia.

All First Nations communities are different and maintain their respective cultural and social protocols (norms). Changes in local Indigenous communities, such as the Board of Directors, staffing and sorry business impacted on project timelines. The overarching NESP Indigenous Partnership Principles and True Tracks training has ensured a clear process of communication and engagement framework with Indigenous project partners, building confidence and trust with ongoing re-engagement dialogue, project planning and key outputs aspiration for all partners. This is the case with both K'gari and the Northern Peninsula Area.

There is significant work ongoing with Indigenous project partners, such as the development of communication products, that are to be endorsed by the Indigenous project partner through free prior and informed consent (FPIC).

Engaging with our next generation of Adaptation leaders

On 18-20 August, the hub was invited to participate in Illuminate Festival which brought together First Nations and western scientists from across Australia. The hub's Indigenous Facilitator spoke on the importance of empowering Indigenous communities through FPIC. The hub also worked with the next generation of scientists and students from across Irukandji and Gimuy Walubara Yidinji Country (Cairns) to help them understand

climate impacts, and give them the chance to draw their vision for a well-adapted future and have this shared with some of Australia's leading climate scientists.

Research outputs and attributions

N/A

Images and video

Why was the National First Gathering on Climate Change important?: https://www.youtube.com/watch?v=_bVhGbHq51E

The National First People's platform on Climate Change meets on Thursday Island, October 2022 (Credit: Climate Systems Hub).

Project CS2.3 works with traditional owners in the Northern Penisula Area, Pajinka, September 2022 (Credit: Climate Systems Hub).

Hub scientists work with Traditional Owners to look at changes to Pajinka Beach, September 2022 (Credit: Climate Systems Hub)

Hub scientists work with Traditional Owners to look at changes to Pajinka Beach, September 2022 (Credit: Climate Systems Hub)