Australian Government
Australian Research Council

climate extremes
ARC centre of excellence

Annual Report 2022

ARC Centre of Excellence for Climate Extremes

Australian Government
Australian Research Council

climate extremes
ARC centre of excellence

The ARC Centre of Excellence for Climate Extremes reduces Australia's economic, social and environmental vulnerability to climate extremes.

We do this by

- developing and leading fundamental climate science;
- improving the predictions of extreme weather and climate events;
- fostering collaborative science between five of Australia's leading universities and our Partner Organisations;
- training and investing in the climate science leaders of the future; and
- sharing our knowledge with governments, policymakers, industry and the community.

The ARC Centre of Excellence for Climate Extremes is financially supported via a Major Investment Grant (CE170100023) from the Australian Research Council (ARC). The Centre is financed and hosted by the University of New South Wales.

Collaborating Institutions are Monash University, the University of Melbourne, the Australian National University and the University of Tasmania. They provide significant financial and in-kind support. The Centre also receives financial support from the NSW Research Attraction and Acceleration Program, the NSW Department of Planning and Environment and the Bureau of Meteorology.

The ARC Centre of Excellence for Climate Extremes acknowledges the Traditional Owners of Country throughout Australia. We pay our respects to Elders past and present.

Photo Credits
Jonathan Brown, supplied or stock

Report
Stephen Gray, Jonathan Brown, Angela Kaplish, Ellen Hooper, Andy Pitman, Melissa Hart, Vilia Co, Chief Investigators

Sub-editor
Kathy Murfitt

Design
Georgina Harmer

UNSW SYDNEY · MONASH University · THE UNIVERSITY OF MELBOURNE · Australian National University · UNIVERSITY of TASMANIA

Contents

Who we are 1

2022 in Review 3
From the Director 5
From the Chair of the Advisory Board 7
Strategic Plan 9
Organisational Chart 10
Governance, Management and our Commitment to Equity, Diversity and Inclusion 11
Centre Advisory Board 11
Centre Executive 13
Centre Committees 13
Leadership Development 15
Equity Diversity and Inclusion 15
Chief Investigators 17
Our Staff and Students 28
Our Partners 34

Climate science leaders of the future 35

Researcher Development Program 36
Winter School 2022
Ocean and Atmosphere Dynamics 37
Postdoctoral Development 38
Science Fundamentals Lectures 38
Celebrating Graduate Director Associate Professor Melissa Hart 39

Climate extremes research in 2022 41

Weather and Climate Interactions Research Program 42
Attribution and Risk Research Program 47
Drought Research Program 53
Ocean Extremes Research Program 58
Modelling Research Program 63
Computational Modelling Systems 67

Connecting climate science to Australians & beyond 70

What is Engagement and Impact at the ARC Centre of Excellence for Climate Extremes? 71
Case Study: Rapid Rain Bursts in Sydney 73
How we Connected with the Community and Decision-Makers in 2022 75
Case Study: The State of Weather and Climate Extremes Report 77
Case Study: Climate Science in Schools 79
What's Ahead 80
Case Study: Finance Sector and Financial risk 81
2023 - Providing Skills and Support for the Future of Climate Science 83

Outputs & performance 85

Publications 86
Impact, Engagement, Awards and Service 97
2022 KPIs 102
2022 Financial Statement 105
Finance Tables 109

ARC Centre of Excellence for Climate Extremes Annual Report 2022

Who we are

The Australian Research Council **Centre of Excellence for Climate Extremes** is the world's first fully integrated centre focused explicitly on the understanding and prediction of climate extremes.

We research the processes causing climate extremes and build this understanding into the Australian prediction systems, thereby improving our capability to predict extremes into the future.

Climate extremes are high-impact events that can range in time scales from minutes to centuries.

They are estimated to have cost the global economy **US$2.4 trillion** between 1979 and 2012 alone.

By improving our capability to predict these extremes we will inform strategies and policies to minimise these huge sums and **reduce national and global vulnerability to climate extremes** and their potential costs.

Our unique focus is a response to the **World Climate Research Programme's identification of climate extremes as a Grand Challenge.**

This reflects the importance of climate extremes to society, the scientific challenges associated with the understanding and prediction thereof and the lack of major, coordinated activities worldwide to address them.

Thanks to a 30-million-dollar investment from the Australian Research Council (ARC) and collaboration between leading Australian and international research partners, the ARC Centre of Excellence for Climate Extremes accepts the challenge set by the World Climate Research Programme and leads the charge on this globally significant problem.

2022 in Review

World Class Research

207
Papers Published

71%
of papers in journals with impact factor >4

32%
of our publications are in top 10% most cited worldwide

Outstanding Environment

19
PhD completions

84%
of PhD students attended a science or PD workshop

16
in person workshops

48%
of members are women

Exceptional Research Infrastructure

24.1
million SU of supercomputing time used at NCI

300+
CMS tickets actioned

30+
Computational modelling support drop-in sessions and presentations open to everyone in the centre

Transforming Collaboration

27
Our students come from over 27 countries

290+
hours of zoom meetings

25
in person weeks spent at nodes/partner orgs

85%
of papers are cross institutional

Strong Engagement Beyond Academia

26+
articles published at TheConversation.com.au by Centre Researchers

40+
policy discussions and briefings to government and industry

100,000
New website launched with over 100,000 page views

7600+
media mentions by Centre Researchers

Winners of ARC Centre of Excellence for Climate Extremes Prizes in 2022

Director's Prize:
Kim Reid

Best paper by a student:
Maurice Huguenin

Best paper by an Early Career Researcher:
Stacey Hitchcock

Outreach Prize:
Shukla Poddar

From the Director

Two years ago I began my Director's Report with comments focused on a summer of bushfires, drought, extreme rainfall, hail and dust storms all in one day. I write this report in the context of some of the worst flooding in Australia's history, some quite phenomenal rainfall statistics in Queensland, but with a waning La Niña. The climate is truly remarkable.

This annual report explores activities within the Australian Research Council (ARC) Centre of Excellence for Climate Extremes through 2022 and highlights major progress in all elements of the Centre's agenda. Amongst the major highlights, many relate to external impact and engagement. Our The **State of Weather and Climate Extremes 2021 report** was widely read and referenced, including by the federal Department of Climate Change, Energy, the Environment and Water and by the Government of New South Wales. The Climate Change Authority sought input from the Centre to expand on this report, which was provided to and ultimately acknowledged by the Honourable Chris Bowen, Minister for Climate Change and Energy. I want to thank the Centre's research fellows who led virtually all the writing around the State of Extremes report.

We contributed to Australia's 8th National Communication on Climate Change to the United Nations Framework Convention on Climate Change. Centre research was widely reported to the United Nations via this Commonwealth activity. The Centre made multiple submissions to inquiries and was instrumental in the 2022 NSW Independent Flood Inquiry, providing targeted analyses of the causes of the flooding. Our researchers also made submissions to the Environmental Protection and Biodiversity Conservation Amendment (Climate Trigger) Bill 2022. We have provided multiple briefings to parliamentarians, to the Department of Prime Minister and Cabinet, the Department of Foreign Affairs and Trade, the Office of National Security and various state departments.

We have also been active in supporting the use of climate science by institutions and industry. This includes work on Christmas and Norfolk Islands and multiple initiatives across the Pacific and the **Australian agricultural industry**. We are also engaging with the federal government's efforts around the National Partnership for Climate Projections, which is an ongoing effort to better connect those working in climate modelling and climate futures.

In 2022 we have advised the business community on how to manage climate risk, including briefings to the US Securities Exchange Commission, the Australian Prudential Regulation Authority, the US Federal Reserve, the Monetary Authority of Singapore, UBS and many others. Meetings with Treasury have highlighted the types of modelling available to assess financial risk. Our Engagement and Impact team led a sustained communications strategy coincident with COP27 via tweets and LinkedIn posts, further raising our profile with the business community.

Our science continues to be published in elite international journals. The Centre published 207 papers in 2022, including 20 papers in Nature or Science family journals. Overall, 17.6 percent of our papers in 2022 are among the 10 percent of most-cited papers in the world, according to SciVal. The number and quality of our publications is not by chance: It reflects well on the training provided through our Graduate Program. Choosing highlights from such a large number of papers is not appropriate in my report – after all, how does one choose one or two papers from more than 200. However, our courageous research program leads have been braver and have selected particularly interesting or impactful papers, which are reported on later.

What I can celebrate here is an impressive collection of awards and prizes, including Professor Julie Arblaster being elected Fellow of the Australian Meteorological and Oceanographic Society (AMOS), Chiara Holgate being named as a 2022 Superstar of STEM by Science and Technology Australia, Ariaan Purich winning the AMOS Meyers Medal and Josue Martinez Moreno winning the AMOS Uwe Radok award for the best PhD thesis of 2022. Congratulations to all.

The ARC Centre of Excellence for Climate Extremes has been highly effective through 2022, in part as a consequence of guidance from the mid-term review. We have pivoted more toward impact and engagement, led by our knowledge brokerage, communications/media and design teams. Our Graduate Program has provided more opportunity for our researchers to develop skills of value to industry while maintaining training in core skills required within the research community. Our Computational Modelling Systems team has maintained an outstanding level of technical support and has begun to develop strategies to collaborate with the now-established ACCESS National Research Infrastructure, which provides a long-term solution to many major challenges in weather and climate science.

Our achievements through 2022 occurred with Covid-19 still being very much front and centre. Many Centre researchers and members of its leadership, management and administration teams caught Covid, and many events were seriously affected by attendance or had to be cancelled due to illness. The Centre has navigated these challenges well, and in the last three months of 2022 travel really began to ramp up again; workshops in particular began to be more viable and helped re-establish new levels of energy. I hope this leaves us in good stead for 2023.

One reason we navigated major challenges over the last few years well is outstanding contributions from key individuals. One of those key individuals is Todd Lane who has been Deputy Director and has provided me outstanding advice and support. Todd is stepping down as Deputy Director and I wanted to thank him for everything he has done in support of the Centre. Todd stepping down was not unexpected – he is Head of School now - and that is a very challenging role. The Centre appointed Julie Arblaster as a second Deputy Director in early 2022 and she will continue in that role; another major contribution that I am very grateful for.

Finally, as most of you know, the ARC Centre of Excellence for the Weather of the 21st Century was funded by the ARC in late 2022. Congratulations to Professor Christian Jakob and his leadership team. Plans to ensure a smooth transition are currently in preparation, but the impact on our Centre in 2023 is likely very minor.

I hope you will find details, projects, vignettes and so on, in this report that surprise you or at least interest you. As always, we welcome comments and suggestions on areas we might enhance in 2023.

Best wishes,

Professor Andy Pitman
Director, ARC Centre of Excellence for Climate Extremes

From the Chair of the Advisory Board

The year 2022 was one of vigour and renewal for the Australian Research Council (ARC) Centre of Excellence for Climate Extremes. While Covid-19 is still with us, the end of lockdowns and restrictions on travel saw a return to face-to-face meetings, science workshops, in-person professional development activities and serendipitous corridor conversations.

The Centre of Excellence for Climate Extremes has become a cornerstone of Australia's climate research efforts. The ARC's investment in the Centre enables the university sector to work on long-term, foundational science projects that require critical mass, which can only be achieved by collaboration across institutions and disciplines. This report highlights just a small sample of the exceptional scientific advances that would otherwise have been unimaginable without this Centre.

The Centre of Excellence is not only focused on cutting-edge science: 2022 saw a concerted effort to increase the visibility of the Centre and its impact beyond academia. There was a significant increase in the number of briefings provided to parliamentarians and senior policymakers. The Centre made several formal submissions to inquiries, and staff and students engaged in a wide range of activities that are listed in this report. Much of this effort was ably coordinated by the Centre's new Engagement and Impact team members.

Early in the year the Centre released its first **State of Weather and Climate Extremes report** for the preceding year (2021). This report, produced primarily by early career researchers and collated by the Centre's exceptional Engagement and Impact team, outlined notable extreme weather and climate events that affected Australia in 2021. It cited research undertaken by Centre scientists and elsewhere that explain these phenomena.

Examples included research on record-breaking heatwaves in Western Australia, the highly unusual Tropical Cyclone Seroja and significant storms in south-east Australia associated with East Coast Lows. The report was distributed widely among state and federal government departments and industry partners and received very positive feedback. The 2022 report will no doubt be an equally insightful - though sobering - read after another year of record-breaking rains and other extremes for Australia's continent and marine environments.

Without a doubt, the ARC Centre of Excellence for Climate Extremes offers its researchers and PhD scholars an unparalleled environment in which to conduct science and grow their careers. I once again this year congratulate the ambition and dedication of the Centre's leadership team in realising this vision and in making such a strong and positive mark on the Australian research landscape.

Dr Tony Press AO
Chair, ARC Centre of Excellence for Climate Extremes Advisory Board

Strategic Plan

Our Vision: Our Centre will transform the understanding and modelling of climate extremes, including their dependence on climate change and variability, to advance scientific understanding and assist decision-makers.

Our Research
We will be a world-leading research centre contributing a significant advancement of knowledge

Our Influence and Outreach
We will have influence and impact beyond academia to have a lasting legacy

Our People
We will demonstrate a commitment to diversity, excellence and community

Strategic Objectives	Success strategy	Strategic foci	
World class research focused on climate extremes	Our research program's success will be measured and reported via the quantity and quality of our publications	1.1	Focus on four key programs: • Weather and Climate interactions • Attribution and Risk • Drought • Ocean Extremes
		1.2	An uncompromising focus on excellence
		1.3	Leadership in national model development and collaboration
		1.4	Fundamental research into climate variability and change
An outstanding environment for all Centre activities	We will measure and report our effectiveness in achieving an exemplar environment for all students and staff	2.1	Enhanced Researcher Development Program to mentor and train the next generation
		2.2	Proactive Equity, Diversity and wellbeing initiatives
		2.3	Ensure early career representation at all levels of Centre activities
		2.4	Foster a culture of community and belonging across the Centre
		2.5	Post-Covid accelerated recovery strategies
Transform collaboration at all scales	We will measure and report the breadth and depth of our collaboration	4.1	Maintain structures that avoid silos
		4.2	Conduct national workshops and training programs
		4.3	Strategic cross-institutional research team
		4.4	Interact with our Advisory Board on key strategic issues
		4.5	Post-Covid accelerated recovery strategies
Exceptional research infrastructure	We will measure and report our effectiveness at maintaining research infrastructure	3.1	The Computational Modelling Systems Team provides advise on modelling and data systems
		3.2	Secure and collaborative relationships with NCI and the ACCESS NRI
		3.3	Be an exemplar for data delivery
		3.4	Develop tools for research that are sustainable beyond the Centre's lifetime
		3.5	Lead collaboration to build the next generation climate model
Research that engages and has impact	We will measure and report our effectiveness in influence and outreach	5.1	Maintain a knowledge brokerage team to facilitate stakeholder engagement
		5.2	Be an influential and dominant voice in key areas of climate extremes
		5.3	Plan and communicate for influence and impact
		5.4	Promote climate science in secondary school STEM subjects
		5.5	Post-Covid accelerated recovery strategies
Identify gaps in our research, training, infrastructure, influence and outreach and seek additional funding to resolve them			

Organisational Chart

Governance

ADVISORY BOARD
Chair Dr Tony Press

Executive Management

DIRECTOR
Andy Pitman

DEPUTY DIRECTORS
Todd Lane, Julie Arblaster

GRADUATE DIRECTOR
Melissa Hart

CHIEF OPERATING OFFICER
Stephen Gray

COMPUTATIONAL MODELLING SYSTEMS LEADER
Paola Petrelli

ENGAGEMENT & IMPACT LEADERS
Angela Kaplish
Jonathan Brown

Research Programs

5 RESEARCH PROGRAMS

- Weather & Climate Interactions
- Attribution & Risk
- Drought
- Ocean Extremes
- Modelling

Workgroups And Committies

OPERATIONS

COMPUTATIONAL MODELLING SUPPORT

KNOWLEDGE BROKERAGE TEAM

COMMITTEES & ECR REPRESENTATION

MEDIA

Governance, Management and our Commitment to Equity, Diversity and Inclusion

The Australian Research Council (ARC) Centre of Excellence for Climate Extremes has a robust and efficient governance structure, as illustrated on our organisational chart on page 10. Our governance model ensures participative decision-making by all Centre members, via our committees – for early career researchers, infrastructure, diversity and culture; seminars; and engagement and impact. Each committee presents recommendations to the Centre Executive and provides updates to monthly Chief Investigator meetings. In addition to these internal structures, the Centre receives guidance and strategic advice from its Advisory Board.

Centre Advisory Board

The ARC Centre of Excellence for Climate Extremes is overseen by an Advisory Board, which is chaired by distinguished scientific leader Dr Tony Press. The Centre's Advisory Board provides strategic oversight and advice to the Centre of Excellence, as well as monitoring the Centre's performance against its stated Key Performance Indicators. The Advisory Board met once in 2022, on 28 October.

Advisory Board Members in 2022

Dr Tony Press, Adjunct Professor, UTAS, Antarctic Climate and Ecosystems Cooperative Research Centre (Chair)

Dr Tony Press is an Adjunct Professor at the Antarctic Climate and Ecosystems Cooperative Research Centre, where he served as its chief executive officer from 2009 to 2014. Dr Press has had a long career in science, natural resource management, public administration and international policy.

Dr Press chaired the Antarctic Treaty's Committee for Environmental Protection (CEP) from 2002 to 2006. He was Australia's representative to the CEP and alternative representative to the Antarctic Treaty Consultative Meetings from 1999 to 2008. He was Australia's Commissioner for the Convention on the Conservation of Antarctic Marine Living Resources from 1998 to 2008.

Dr Jaci Brown, Research Director, CSIRO Climate Science Centre

Dr Jaci Brown is the Research Director for the Climate Science Centre in CSIRO's Ocean and Atmosphere Business Unit. Dr Brown's research has spanned tropical oceanography, climate projections, fisheries, high-resolution ocean defence tools and seasonal atmospheric processes in Australia. Her previous role was as a team leader in CSIRO's Agriculture and Food Business Unit. There, Dr Brown led the Weather and Climate Decisions team. This team focused on delivering actionable weather and climate knowledge to stakeholders.

Ian T. Dunlop, Independent Advisor & Commentator, Climate Change & Energy

Ian Dunlop is a Cambridge-educated engineer, formerly a senior executive in the international oil, gas and coal industries. He chaired the Australian Coal Association in 1987-88. From 1998 to 2000 he chaired the Australian Greenhouse Office Experts Group on Emissions Trading, which developed the first emissions trading system design for Australia. From 1997 to 2001 Ian was chief executive officer of the Australian Institute of Company Directors. He has a particular interest in the interaction of corporate governance, corporate responsibility and sustainability.

Ian is a director of Australia 21, a fellow of the Centre for Policy Development and a member of The Club of Rome. He advises and writes extensively on governance, climate change, energy and sustainability.

Danielle Francis, Manager Liveable Communities, Water Services Australia

In her 20 years in the Australian water industry, Danielle has led communications, regulatory, pricing, stakeholder and strategy portfolios to help the industry deliver valued services to the community.

Today, as Water Services Australia's Manager Liveable Communities, Danielle oversees national and regional collaboration, learning and advocacy on water security, integrated water cycle management and climate change. She also develops initiatives to promote understanding and adoption of circular-economy principles in the water industry. In addition, Danielle leads work to promote recognition and integration of Indigenous water values and knowledge in water management and water services.

Dr Greg Holland, Willis Senior Scientist Emeritus, National Center for Atmospheric Research, Boulder, USA

Dr Greg Holland is Willis Senior Scientist Emeritus at the US National Center for Atmospheric Research (NCAR). He is also a member of the Zurich Insurance Advisory Council for Catastrophes and a key stakeholder for the European ISIpedia. Dr Holland was previously director of NCAR's Earth System Laboratory and the Capacity Center for Climate and Weather Extremes. He has served on a number of committees and review boards for the National Oceanic and Atmospheric Administration, the US National Academies and NASA – and he chaired the Tropical Meteorological Program of the World Meteorological Organization for 12 years.

Dr Holland's current research focuses on climate variability and change and its effect on weather and climate extremes. He holds a PhD in Atmospheric Science from Colorado State University. He is a fellow of both the American Meteorological Society and the Australian Meteorological and Oceanographic Society.

Professor Dane McCamey, Pro Vice-Chancellor (Research), UNSW

Professor Dane McCamey is Pro Vice-Chancellor (Research) at the University of New South Wales, Sydney. His research interest is in condensed-matter physics, in particular the role that spin (a quantum property of subatomic particles) plays in the function of optoelectronic materials and devices. His research spans from fundamental investigation of quantum properties through to applications in photovoltaics and quantum technologies. Prior to his current role, Prof McCamey was deputy dean of Research and Enterprise for UNSW Science and also served as deputy director of the ARC Centre of Excellence in Exciton Science.

Dr Jon Petch, UK Meteorological Office

As the head of UK Meteorological Office Science Partnerships, Dr Jon Petch is responsible for the UK Met Office's national and international relationships with other science organisations. He has worked on physical modelling and parameterizations since joining the UK Met Office in 1997. From 2009, in parallel with his science research, Dr Petch has also managed various science collaborations on behalf of the UK Met Office. He continues to carry out research in areas related to atmospheric processes and parameterizations, and he leads the Global Atmospheric System Studies project.

Matthew Riley, Director, Climate and Atmospheric Science, NSW Office of Environment and Heritage – Department of Primary Industries and the Environment

Matthew Riley is Director of Climate and Atmospheric Science at the NSW Office of Environment and Heritage (OeH). He is also the Director for the NSW and ACT Regional Climate Modelling Project (NARCliM), and leads OEH's Climate Change Impacts research program. In addition, he is responsible for the operation of the 43 monitoring stations of the NSW Air Quality Monitoring Network and leads the NSW Government's air quality research program. Matthew has over two decades of experience in urban meteorology, climatology and air-quality measurement.

Anthony Swirepek, Acting Director, Geological and Bioregional Assessments, Department of the Environment and Energy

Anthony Swirepek is a highly experienced public servant, having held numerous senior roles in the federal Department of Environment over many years. His previous positions in that department have included director of the Climate Science team, director of the Research program and director of Bioregional Assessments. Anthony has represented the Department on the advisory boards of multiple scientific research organisations and brings a wealth of experience to help facilitate collaboration between science and policy.

Dr Bertrand Timbal, Head of Research, Bureau of Meteorology

Dr Bertrand Timbal moved to Australia and the Bureau of Meteorology in 1996, after completing his PhD at the French National Met Service (Meteo-France) in 1994. After a three-year stint leading the Climate branch in the Centre for Climate Research Singapore, Dr Timbal re-joined the Bureau of Meteorology in 2020 as the General Manager for the research program, Science and Innovation Group. In this role, he leads a program of 130 scientists, support scientists and science managers delivering along the four objectives of the Bureau of Meteorology's Research and Development Plan.

Centre Executive

The Centre Executive is composed of the Centre Director, who carries overall responsibility for day-to-day leadership of the ARC Centre of Excellence for Climate Extremes and its research; the Deputy Director; the Chief Operating Officer; the Graduate Director; the Manager of the Computational Modelling Systems team; and the leaders of the Engagement and Impact team.

Each of the Centre's research programs has a pair of co-leaders who set and monitor yearly and longer-term research priorities. All Chief Investigators meet monthly to discuss Centre business and cross-nodal research activity and initiatives.

Centre Committees

To maximise the Centre's effectiveness as a cohesive entity, we have established three key committees that report to the Centre Executive, each with an important and specific remit to enhance collaboration across the Centre and drive focus in key areas of our Centre strategy; namely, equity and diversity, outreach and pathways-to-impact and infrastructure and technology.

Diversity and Culture Committee

Chairs: Melissa Hart (UNSW) and Stephen Gray (UNSW)

2022 Members: Hooman Ayat (UniMelb), Hakase Hayashida (UTAS), Christian Jakob (Monash), Stephy Libera (UTAS), Andrea Taschetto (UNSW), Claire Vincent (UniMelb)

The Centre of Excellence is committed to providing an unrivalled working environment for its students and staff. Consequently, we're implementing measures that enhance the diversity of our staff and student populations and proactively ensuring we build and maintain an equitable culture.

The Diversity and Culture Committee provides advice and recommendations to the Centre Director and Centre Executive on matters pertaining to equity, diversity and Centre culture, including mental health and wellbeing. The committee leads Centre-wide initiatives and drafts policies and procedures within its sphere of influence. The committee's activities are based on research and on benchmarking of best practice in the equity, diversity and culture landscape in Science, Technology, Engineering and Mathematics and in higher education generally.

Infrastructure Committee

Chair: Paola Petreli (UTAS)

Members: Gab Abramowitz (UNSW), Dietmar Dommenget (Monash), Jason Evans (UNSW), Andy Hogg (ANU), Neil Holbrook (UTAS)

The Infrastructure Committee's primary role is to aid the Computational Modelling Systems team in the prioritisation and delivery of the services it provides. This includes facilitating discussion and decision-making around which modelling systems and data sets should be considered in or out of scope, as well as identifying emerging modelling systems or data sets that offer new opportunities for the Centre. The committee is also tasked with helping the Computational Modelling Systems (CMS) team allocate, compute and store resources in respect to Centre research programs - particularly where there are competing requests - as well as liaise with National Computational Infrastructure and other relevant national infrastructure bodies.

These roles are intended to help maintain strong communication between Centre researchers and the CMS team, as well as support the latter in prioritising competing requests for its time.

Engagement and Impact Committee

Chairs: Angela Kaplish and Jonathan Brown (UNSW)

Members: Nerilie Abram (ANU), Ailie Gallant (Monash), Amelie Meyer (UTAS), Kim Reid (Monash), Zoe Gillett (UNSW), Alice Wilson (Monash)

The Engagement and Impact Committee at the Centre of Excellence brings together some of Australia's most talented policymakers, media and communications specialists, science communicators, content makers and designers, and more, to ensure that the essential science of climate extremes is heard by the people who need to know.

The committee advises and collaborates with the Centre's Engagement and Impact team to deliver training, resources and opportunities for Centre researchers to share their work and expertise with government, industry and the community.

Centre Operations Team

The transformative research that the Centre of Excellence continues to deliver is supported by a dedicated team of professional staff.

Stephen Gray is the Centre's Chief Operations Officer and brings extensive ARC Centres of Excellence management experience to the role. He is supported by Vilia Co in the role of Finance and Resources Manager. The operations team is further comprised of Project Officers and Executive Assistants Ellen Hooper (UNSW), Sook Chor (Monash), Christine Fury (UTAS) Carmen Tucker (ANU) and Simon Parsons (UniMelb).

Leadership Development

We are strongly committed to providing leadership training, mentorship, guidance and opportunities for all ARC Centre of Excellence for Climate Extremes researchers, including our students and early career researchers (ECRs) and our professional and technical staff.

Our Centre is unique among Australian Centres of Excellence in appointing a dedicated, full-time senior Graduate Director to build a fully integrated leadership and professional development program for our staff and students.

What our Centre offers far exceeds a typical 'mentoring program' in both scale and ambition. We provide bespoke, end-to-end support for our graduate students and ECRs via the following: individual training-needs analyses; support for internships; a curated calendar of annual workshops, addressing both scientific and professional skills; and access to funding to support research visits to nodes and Partner Organisations, summer schools and other career-enhancing opportunities.

Furthermore, our students and ECRs are represented via our Early Career Researcher Committee, with an ECR representative attending Chief Investigator meetings. The committee also organises professional development and training events, including dedicated events at the national Australian Meteorological and Oceanographic Society annual meetings. It helps facilitate dedicated ECR funding applications that enable our researchers to lead small projects that expand beyond the scope of their research programs.

Our Engagement and Impact team delivers training and creates opportunities for Centre researchers and students to boost their skills in government relations, policymaking, industry engagement, science communications, media commentary, public speaking and more. The team focuses on fostering the next generation of leaders in engagement and impact through long-term skill building.

Equity Diversity and Inclusion

Our Centre fosters a culture of diversity and inclusion.

Our goal is to make the Centre a forward-thinking organisation that enables all staff and students, regardless of background, to do their best work in a professional and compassionate environment. Our equity plan is an ambitious document to guide the Centre's efforts to fulfil our aim of being an exemplar in this space. We are serious about creating a respectful research environment for our diverse population of researchers, to ensure our staff and students can reach their full potential; and about making a meaningful contribution to addressing historical prejudices and inequality in Science, Technology, Engineering and Mathematics disciplines.

Research Ethics and Intellectual Property

The ARC Centre of Excellence for Climate Extremes is committed to uncompromisingly high standards of professional conduct and rigour in all activities, including all aspects of our research.

Arguably, few disciplines receive as much public scrutiny as climate science. Accordingly, climate scientists have long embraced openness, accountability and an open-source approach to their work. This ensures originality and reproducibility of research, adherence to proven methodological frameworks and rigorous data management practices. Adherence to Findability, Accessibility, Interoperability and Reusability (FAIR) is normal practice in our field; indeed we have been influential in driving this agenda, including in the production of recent Academy of Science reports. All new staff and students at Centre receive information on the ethical conduct of research as part of their Centre induction, and reminders of this responsibility are periodically circulated.

Intellectual property customarily relates to inventions as opposed to discoveries. Research in our Centre is driven by our overarching goal to better understand the physical processes in the global climate system that contribute to extremes across scales of time and space. In other words, we are a Centre focused primarily on discovery.

Globally, the climate science community has always worked from a foundational premise that all our work is open source and shared such that others may build on work that has preceded their own, without restriction beyond the norms of attribution. Thus, code, data, models and so on are openly shared, and we benefit from this by having access to data and models that would be impossible for Australia to develop independently. By returning our contributions into that system, we provide the rationale for the rest of the world maintaining, in turn, open access to their data and models. Accordingly we place greater emphasis on proper data management – including publishing data and code – than on traditional notions of intellectual property.

This approach to open-source development of our models and tools that assist us in interrogating model output is made explicit in the Centre's inter-institutional agreement. The agreement also offers an intellectual property framework to follow if at any point the Centre developed an invention or product that meets the standard definitions of intellectual property.

Consequently, intellectual property is a low priority in climate science – to raise this priority would break our capacity to engage internationally and access data and models developed by the community. However, we recognise that around half of our graduates leave academia and research to take positions in government or industry where intellectual property considerations may be material. We are therefore developing an internal training module on intellectual property that is specific to the uniquely open-source approach taken by researchers in our field.

Chief Investigators

Director
Professor Andy Pitman AO

Professor Andy Pitman was born in Bristol and was awarded a bachelor's degree with honours in physical geography and a PhD in Atmospheric Science by the University of Liverpool, UK. He also holds a Postgraduate Certificate in Educational Leadership from Macquarie University. He has been at the University of New South Wales since 2007. He was the director of the Australian Research Council (ARC) Centre of Excellence for Climate System Science (2011-2017) and is now Director of the ARC Centre of Excellence for Climate Extremes.

Prof Pitman's research focus is on terrestrial processes in global and regional climate modelling, model evaluation and earth systems approaches to understanding climate change. His leadership, collaboration and research experience is extensive both nationally and internationally. Between 2004 and 2010 he convened the ARC Research Network for Earth System Science, which facilitated interaction between individuals and groups involved in climate system science.

He is a member of the Australian Community Climate and Earth System Simulator (ACCESS) initiative, the Academy of Science's National Committee for Earth System Science and the NSW Minister for Climate Change's Science Advisory Committee. He is also heavily engaged in e-research, including most recently on the taskforce assessing the roadmap for national research infrastructure.

Internationally, Prof Pitman is closely affiliated with the World Climate Research Programme (WCRP). He was a long-term member and former chair of the WCRP's Land Committee for the Global Land Atmosphere System Study. As co-chair, he jointly led one of the first major international intercomparison exercises: the Project for the Intercomparison of Land Surface Parameterization Schemes, which is supported by the WCRP and the International Geosphere Biosphere Programme. He also sat on the Science Steering Committee of the Integrated Land Ecosystem-Atmosphere Processes Study and is currently co-coordinator of the Land Use Change: Identification of Robust Impacts project.

Prof Pitman is a regular invitee for keynote presentations and is a passionate communicator about science, contributing regularly to the media on the science of climate change. He was a Lead Author for the Intergovernmental Panel on Climate Change (IPCC) 3rd and 4th Assessment Reports, contributing to the award of the Nobel Peace Prize to the IPCC in 2007.

He was review editor of the 2013 IPCC report. He has also contributed to the Copenhagen Diagnosis, an Australia-led update of the science of climate change. Prof Pitman has held editorial positions with the Journal of Climate and the Annals of the Association of American Geographers' Journal of Geophysical Research-Atmospheres, and he is currently an associate editor for the International Journal of Climatology.

Prof Pitman was appointed an Officer of the Order of Australia in 2019. Other awards and accolades he has received include: The Royal Society of Victoria's Medal for Excellence in Scientific Research (2019), NSW Scientist of the Year Award (2010), the Australian Meteorological and Oceanographic Society (AMOS) Medal (2009), the Dean's Award for Science Leadership at Macquarie University (2005), the Priestley Medal for Excellence in Atmospheric Science Research (2004) and the Geoff Conolly Memorial Award (2004).
Prof Pitman jointly won the International Justice Prize for the Copenhagen Diagnosis (2010) and was among Sydney Magazine's list of the 100 most influential people (2010). He is a fellow of AMOS and of the American Meteorological Society.

Prof Pitman has a long track record of nurturing early career researchers and has supervised multiple PhD students through to successful completion. He has published over 200 papers in peer-reviewed journals and has authored 20 book chapters.

Deputy Director
Professor Todd Lane

Professor Todd Lane was awarded his PhD in Applied Mathematics from Monash University in 2000, having completed his bachelor's degree in 1997. He was a postdoctoral fellow with the National Center for Atmospheric Research (USA) from 2000 to 2002 and a staff scientist there from 2003 to 2005.

He joined the University of Melbourne in 2005, where he is now a professor and Head of the School of Geography, Earth, and Atmospheric Sciences. Between 2010 and 2014 he was an Australian Research Council Future Fellow.

Prof Lane's primary research focus is on atmospheric processes. He is internationally recognised as an expert on tropical thunderstorms, atmospheric waves and turbulence. He has made important contributions to many aspects of mesoscale meteorology, convective cloud dynamics and high-resolution atmospheric modelling. Prof Lane's research at the Centre is within the Weather and Climate Interactions program, where he conducts research on extreme rainfall and fronts. He uses high-resolution regional atmospheric models to determine the mesoscale processes controlling extremes to help better understand and predict them.

Prof Lane has held numerous leadership positions, including president of the Australian Meteorological and Oceanographic Society (AMOS) (2014-2015), chair of the American Meteorological Society's (AMS) Committee on Mesoscale Processes (2012-2015) and editor of Monthly Weather Review (2016-2018). He has received awards from AMS, the Australian Academy of Science and NASA and is a fellow of AMOS.

Deputy Director
Professor Julie Arblaster

Julie Arblaster is a professor in the School of Earth, Atmosphere and Environment at Monash University, having moved there in 2016 after many years at the Bureau of Meteorology, and before that, the National Center for Atmospheric Research (NCAR), USA.

Professor Arblaster's research interests lie in using climate models as tools to investigate mechanisms of recent and future climate change, with a focus on shifts in the Southern Hemisphere atmospheric circulation, tropical variability and climate extremes. She is particularly interested in the interplay between the predicted recovery of the Antarctic ozone hole over coming decades and greenhouse gas increases in future climate projections, with its potential impacts on the surface, ocean circulation and sea ice. Her recent work has also focused on explaining extreme events in Australia, such as record-breaking temperatures and rainfall, in terms of both the role of human influences on climate and the diagnosis of the climate drivers. Prof Arblaster's research incorporates the use of observations, multi-model data sets and sensitivity experiments with a single model. Her strong collaboration with NCAR and participation in various international committees and reports enhances her engagement with the latest advances in climate research internationally.

Prof Arblaster was awarded the 2014 Australian Academy of Science Anton Hales Medal for research in earth sciences and the 2018 Priestley Medal from the Australian Meteorological and Oceanographic Society. She served as a Lead Author of the Intergovernmental Panel on Climate Change 5th Assessment Report and is currently on the scientific steering committee for the 2022 World Meteorological Organization/United Nations Environment Programme Scientific Assessment of Ozone Depletion. She is also a member of the World Climate Research Programme Coupled Model Intercomparison Project panel and the Australian Academy of Science's National Committee on Earth System Science.

Graduate Director Associate Professor Melissa Hart

Associate Professor Melissa Hart has led and developed a national, cross-institutional graduate program which has reimagined the traditional Australian PhD. With a vital combination of breadth, depth, support and collaboration, the program has provided over 180 graduate students with the skills, knowledge and experience fundamental to developing the next generation of adaptable climate science leaders equipped for employment across a range of sectors.

Associate Prof Hart completed her Bachelor of Science (Hons) in 2001 and her PhD in Atmospheric Science in 2006, at Macquarie University. During her PhD studies she worked part-time in industry. She then spent two years as a postdoctoral researcher at Portland State University, Oregon, working on the National Science Foundation-funded FUSE (Feedback between Urban Systems and the Environment) project.

This was followed by five years in a faculty position in the Department of Geography, the University of Hong Kong, China.

Associate Prof Hart's research looks at the impact of cities on climate and climate on cities, as well as the meteorological controls on air pollution. A strong advocate for gender equity in science, she is a past chair of the Australian Meteorological and Oceanographic Society's Equity and Diversity Committee and a proud participant of the 2018 Homeward Bound Women in STEMM leadership initiative.

Professor Nerilie Abram

Professor Nerilie Abram uses palaeoclimate records to study how Earth's climate has behaved in the past in order to provide a long-term perspective on recent climate change. She has a particular focus on reconstructing climate variability in the tropical Indian Ocean and Antarctica and how this impacts Australia's rainfall patterns.

Prof Abram's work also involves proxy-model comparisons to assess forcing mechanisms behind natural and anthropogenic climate changes and to help test climate model performance in historical and last-millennium experiments.

Prof Abram holds an Australian Research Council Future Fellowship. In 2015 she received the Dorothy Hill Award from the Australian Academy of Science for her research achievements. She was a Coordinating Lead Author of the Intergovernmental Panel on Climate Change Special Report on the Ocean and Cryosphere in a Changing Climate, released in September 2019.

Associate Professor Gab Abramowitz

Associate Professor Gab Abramowitz's primary research interest is in evaluating computational models in climate science, ecology and hydrology.

Currently his research focuses on two main areas: defining and accounting for model dependence in multi-model ensemble climate prediction and standardising model evaluation in land surface research.

Climate research teams share literature, data sets and even sections of model code. To what extent, then, do different climate models constitute independent estimates of a climate prediction problem? What is the most appropriate statistical framework with which to define model independence? What are the implications of ignoring model dependence for future climate projection?

Associate Prof Abramowitz is also leading the development of **modelevaluation.org**, a web application that provides automated land surface, hydrological and ecological model evaluation tools as well as observational data sets. He is a member of the Global Energy and Water Cycle Experiment (GEWEX) Global Land-Atmosphere System Study panel.

Professor Lisa Alexander

Professor Lisa Alexander holds a BSc (Hons) and MSc in Applied Mathematics from Queens University Belfast and a PhD in Climate Science from Monash University. She previously worked as a research scientist at the UK Meteorological Office Hadley Centre, including a year on secondment at Australia's Bureau of Meteorology.

Prof Alexander's primary research focuses on understanding the variability and driving mechanisms of climate extremes. Of particular significance is her ongoing work assessing global changes in temperature and rainfall extremes, which has contributed significantly to the Intergovernmental Panel on Climate Change (IPCC) assessments.

Prof Alexander was awarded the 2011 Priestley Medal by the Australian Meteorological and Oceanographic Society (AMOS) and the 2013 Australian Academy of Science Dorothy Hill Award for her contribution to this field of research. In 2020 she became a fellow of AMOS.

She has contributed to IPCC assessments in 2001, 2007 and 2021 and to the 2012 Special Report on Extremes and was a Lead Author of the IPCC's 5th Assessment Report. Prof Alexander also chairs a World Meteorological Organization expert team, is a member of the International Association of Meteorology and Atmospheric Sciences Executive Committee and sits on the Joint Scientific Committee of the World Climate Research Programme.

Professor Craig Bishop

Professor Craig Bishop completed his PhD in Applied Mathematics at Monash University. His innovative ensemble-based data assimilation and ensemble forecasting techniques are now widely used by leading environmental forecasting agencies in several countries.

Prof Bishop has held positions at the University of Reading, the NASA Goddard Space Flight Center, Pennsylvania State University's prestigious Department of Meteorology and the Marine Meteorology Division of the Naval Research Laboratory (NRL) in Monterey, California. There he garnered six outstanding-contribution awards, three NRL Alan Berman publication awards and an NRL Edison Patent Award. He returned to Australia as Professor of Weather Prediction at the University of Melbourne, in June 2018.

Prof Bishop has held numerous notable leadership positions, including founding co-chair of the World Meteorological Organization's Working Group on Predictability, Dynamics and Ensemble Forecasting; associate editor of the Quarterly Journal of the Royal Meteorological Society; and chair of the Science Steering Committee of the Joint (NASA, NOAA, US Navy, US Air-Force, National Science Foundation) Center for Satellite Data Assimilation. He was elected to the International Commission on Dynamical Meteorology in 2010 and a fellow of the American Meteorological Society in 2012.

Professor Dietmar Dommenget

Professor Dietmar Dommenget completed his Diploma (MSc) in Physics at the University of Hamburg. He was awarded a PhD by the Max-Planck Institute for Meteorology in 2000. He joined the ECCO (Estimating the Circulation and Climate of the Ocean) project in a postdoctoral position at the Scripps Institution of Oceanography in La Jolla, California, to study the predictability of El Niño with an adjoint data- assimilation scheme.

After three years in California he returned to Germany in 2003 for a fixed-term faculty position as a junior professor (lecturer) in the Meteorology department at the Helmholtz Centre for Ocean Research Kiel. Since 2010, Prof Dommenget has been at Monash University in the atmospheric and climate science group of the School of Earth, Atmosphere and Environment.

Prof Dommenget's research focuses on large-scale climate dynamics and climate modelling. He works with climate models at all levels of complexity. Most of his work centres on the development, conducting and analysis of coupled general-circulation models, but he has also developed simple conceptual models of natural climate variability. Most of his work focuses on sea surface temperature variability in the tropical and extratropical oceans.

Prof Dommenget is most widely known for his work on the interpretation of patterns and modes of climate variability. His most recent projects focus on El Niño, climate model developments and climate change. He developed a new type of climate model for the conceptual understanding of the climate response to external forcing, which is a fast and simple tool for researchers, students and the public to understand the interactions in the climate system. An outreach program based on this is called the Monash Simple Climate Model.

Professor Jason Evans

Professor Jason Evans completed his undergraduate degrees in physics and mathematics at Newcastle University in 1996 and earned his PhD in Environmental Management from the Australian National University in 2001.

He then spent six years as a postdoctoral and then research fellow at Yale University in the USA. In 2007 he returned to Australia to take up a position in the Climate Change Research Centre at UNSW, where he remains today.

Prof Evans' expertise is in the area of regional climate, land-atmosphere interactions, the water cycle and climate change. His focus is on regional climate change and its impacts. His research program brings together advanced modelling tools with extensive observational data sets, with an emphasis on satellite based, remotely sensed earth observations.

Prof Evans was a Lead Author on the Intergovernmental Panel on Climate Change (IPCC) Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems. He has also been an editor of the Journal of Climate since 2016. In 2020 Prof Evans was elected a fellow of the Modelling and Simulation Society of Australia and New Zealand and in 2021 he received their Biennial Medal for outstanding contributions to modelling and simulation over a sustained period. He was also elected a fellow of the Royal Society of New South Wales, in 2021.

Dr Ailie Gallant

Dr Ailie Gallant completed her PhD at Monash University in 2009 in the School of Mathematical Sciences. She is currently an Australian Research Council Discover Early Career Researcher Award fellow in the School of Earth, Atmosphere and Environment in the Faculty of Science, Monash University.

Dr Gallant's work seeks to characterise and understand climate variability and change on multiple time and spatial scales, primarily for the Australasian and Antarctic regions. Most of her research relates to examining climate extremes, particularly extremes of the hydroclimate such as drought. Her current research interests include identifying and understanding variations and trends in Australian climate extremes; investigating the role of multi-decadal scale climate variability in the Australian region; and characterising pre-instrumental climate variations in Australia and Antarctica, using paleoclimate data.

Professor Andy Hogg

Professor Andy Hogg completed his undergraduate degree in physics at the Australian National University in 1996 and was awarded his PhD in Geophysical Fluid Dynamics from the University of Western Australia in 2002.

He then spent three years as a postdoctoral fellow at the Southampton Oceanography Centre, where he developed a new high-resolution coupled ocean-atmosphere model. In 2004 he returned to ANU to take up a position as an Australian Research Council (ARC) postdoctoral fellow. He is currently based at ANU's Research School of Earth Sciences.

Prof Hogg's research interests centre on physical processes governing the ocean and climate. His work within the ARC Centre of Excellence for Climate Extremes is focused on understanding ocean-atmosphere interactions in the Southern Ocean, particularly the exchange of heat, momentum and carbon between different components of the climate system.

He plays a key role in developing tools to understand the climate system at progressively finer scales.

Due to his unique contributions to understanding of the Southern Ocean, Prof Hogg was awarded the Frederick White Prize from the Australian Academy of Science, in 2012; the Nicholas P. Fofonoff Award from the American Meteorological Society; and the Australian Meteorological and Oceanographic Society Priestly Award, in 2015.

Professor Neil Holbrook

Professor Neil Holbrook completed his undergraduate degree in applied mathematics and physical oceanography at the University of Sydney with a Bachelor of Science (Honours Class I) in 1990. He was awarded his PhD in applied mathematics/physical oceanography, also at the University of Sydney, in 1995, and he is one of Australia's original National Greenhouse Advisory Committee PhD scholars. Following a brief postdoctoral fellowship at Macquarie University in the Climatic Impacts Centre, he was appointed a lecturer in Atmospheric Science in 1996 at Macquarie University.

He left Macquarie University as a senior lecturer in 2007 and commenced at the University of Tasmania in 2008 as an associate professor in Climatology and Climate Change. He was promoted to Professor of Ocean and Climate Dynamics in 2018 and is currently Head of the Centre for Oceans and Cryosphere within the Institute for Marine and Antarctic Studies at UTAS.

Prof Holbrook uses his expertise in ocean and climate dynamics on sub-seasonal to multi-centennial time scales to better diagnose the important mechanisms underpinning climate variability and extremes, as well as climate change. His current research focuses on understanding the causes and predictability of marine heatwaves, based on the analysis of observations and a hierarchy of model complexities and experiments. He has published extensively in the international literature on the ocean's role in climate, climate variability, climate extremes and climate change.

Prof Holbrook is an elected fellow of the Australian Meteorological and Oceanographic Society and an associate editor of the Journal of Southern Hemisphere Earth Systems Science. He previously served as president of the International Commission on Climate of the International Association of Meteorology and Atmospheric Science/International Union of Geodesy and Geophysics (2011-2019) and was an associate editor of the Journal of Climate (2006-2008). Prof Holbrook also led Australia's National Climate Change Adaptation Research Network for Marine Biodiversity and Resources (2009-2013).

Professor Christian Jakob

Professor Christian Jakob was awarded his PhD in Meteorology from the Ludwig Maximilians University, Munich, in 2001. As a research and senior research scientist for the European Centre for Medium-Range Weather Forecasts from 1993 to 2001, he worked on the development and evaluation of the model representation of clouds, convection and precipitation.

From 2002 to 2007 he was senior and principal research scientist at the Bureau of Meteorology and since 2007 he has been a professor at Monash University. Currently he is the Chair of climate modelling at Monash's School of Earth, Atmosphere and Environment.

Prof Jakob's current interests are in the development and evaluation of the processes crucial to the energy and water cycles in global atmospheric models. Internationally, he is engaged in many scientific and collaborative activities. He is the current Co-chair of the World Climate Research Programme's (WCRP) Digital Earths Lighthouse Activity.
Before that, he co-chaired the WCRP Modelling Advisory Council (2012-2017) and led the prestigious Working Group on Numerical Experimentation (2008-2012).

He was chair of the WCRP's Global Energy and Water Cycle Experiment (GEWEX) Modelling and Prediction Panel from 2007 to 2010.

As recognition of his prominent position in the climate science field, Prof Jakob was a Lead Author for the Intergovernmental Panel on Climate Change 5th Assessment Report, Working Group 1. In 2016 his research was recognised via the Ascent Award of the American Geophysical Union's Atmospheric Sciences Section, and in 2018 he was elected a fellow of the Australian Meteorological and Oceanographic Society (AMOS). He was awarded the AMOS Morton Medal in 2019.

Dr Amelie Meyer

Dr Amelie Meyer completed her PhD in 2014 at the University of Tasmania. Collaborating on her thesis with CSIRO, she focused on circulation, mixing and internal waves in the Southern Ocean. Between 2014 and 2018 Dr Meyer worked as a postdoctoral fellow at the Norwegian Polar Institute in Tromsø (Norway), on ocean-ice interactions in the changing Arctic.

She is currently a research fellow at the University of Tasmania, where she has been granted an Australian Research Council (ARC) Discover Early Career Researcher Award.

Dr Meyer is passionate about climate variability, polar science and ocean circulation. Her work looks at how and why polar regions influence, and are influenced by, climate.
To understand polar oceans, Dr Meyer collects scientific observations in the Arctic and Antarctic. This work has taken her to remote places where she has spent a total of 180-plus days working both on research ships and on the ice.

Dr Meyer is a strong advocate for science communication and outreach. In 2019 she was awarded the Tasmanian Young Tall Poppy Science Award and the ARC Centre of Excellence for Climate Extremes Director's Prize.

Dr Sarah Perkins-Kirkpatrick

Dr Sarah Perkins-Kirkpatrick completed her PhD at the University of New South Wales in 2010. She is currently an Australian Research Council (ARC) Future Fellowship awardee and a senior lecturer at UNSW Canberra at ADFA.

Dr Perkins-Kirkpatrick's work investigates trends in heatwaves globally and in Australia, as well as exploring the role of human activity behind such trends. She is currently focusing on comprehensive methods of attributing heatwaves to climate change, and how we might be able to attribute the health impacts of heatwaves to climate change.

Dr Perkins-Kirkpatrick was the recipient of the 2013 Young Tall Poppy Award, the 2014 Director's Prize from the ARC Centre of Excellence for Climate System Science and the 2016 Australian Meteorological and Oceanographic Society Early Career Researcher Award. In 2016 she was named one of 'UNSW's 20 rising stars who will change the world'.

Professor Michael Reeder

Professor Michael Reeder completed a PhD in Applied Mathematics at Monash University, before holding postdoctoral positions at the University of Munich (Germany) and the NASA Goddard Space Flight Center (USA). He subsequently returned to Monash University as a member of staff, rising through the ranks to professor.

Prof Reeder's research is focused principally on the dynamics of weather-producing systems. He has published on a wide variety of topics, including fronts, tropopause folding, extratropical cyclones, Rossby waves, heat waves, tropical cyclones, gravity waves, solitary waves, convection, boundary layers, the Hadley and Walker circulations, the Madden-Julian Oscillation and bushfires. He has been the principal supervisor for more than 50 graduate students.

Prof Reeder is a fellow and past president of the Australian Meteorological and Oceanographic Society (AMOS). He is a winner of the AMOS Zillman Medal and the Loewe Prize (Royal Meteorological Society, Australian Branch), and he has given the AMOS Clarke Lecture.

Dr Callum Shakespeare

Dr Callum Shakespeare was awarded his PhD from the Department of Applied Mathematics and Theoretical Physics at the University of Cambridge, in 2015. Since that time he has worked at the Australian National University, first as a postdoctoral fellow, then as an Australian Research Council Discovery Early Career Researcher Award fellow, and since 2018 as a tenure track fellow. Dr Shakespeare currently leads the Climate and Fluid Physics research group and the Geophysical Fluid Dynamics Laboratory at the ANU.

Dr Shakespeare's research spans oceanography, atmospheric science and air-sea interactions, using a combination of mathematical theory, numerical modelling and laboratory experiments. He is particularly well known for his theoretical work on fine-scale ocean processes such as submesoscale eddies, fronts and internal waves. Dr Shakespeare also teaches ANU's core Fundamentals of Climate Science course and convenes the ANU Research School of Earth Sciences honours program.

Professor Steven Sherwood

Professor Steven Sherwood was awarded his PhD in Oceanography from the Scripps Institute of Oceanography, University of California, in 1995. He carried out postdoctoral research at Victoria University of Wellington (NZ) from 1996 to 1997 and was a research scientist at the NASA-Goddard Earth Sciences and Technology Centre from 1998 to 2000.

In 2001 he joined the faculty of Yale University, where he later rose to the rank of professor. At the beginning of 2009 he moved to Australia, where he is a professor at – and former director of – the Climate Change Research Centre at the University of New South Wales.

Prof Sherwood has made significant contributions to the understanding of moisture-related processes in the atmosphere. His areas of study include atmospheric humidity; convective systems; interactions between clouds, air circulation and climate; remote sensing of storms; and observed warming trends.

Prof Sherwood was a Lead Author of the chapter on Clouds and Aerosols in the 2013 Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report, Working Group I, and a Contributing Author to the IPCC's previous report in 2007. He currently serves on the review board of the journal Science and co-chairs the World Climate Research Programme's Lighthouse Activity on Safe Landing Climates.

Professor Peter Strutton

Professor Peter Strutton received his bachelor's degree with honours in marine science from Flinders University of South Australia, in 1993. He went on to complete his PhD in Marine Science in 1998. He then left Australia to take up a postdoctoral research position with the Monterey Bay Aquarium Research Institute in California, a post he held until 2002. From 2002 to 2004 he was assistant professor with the State University of New York's Marine Sciences Research Centre, and from 2004 to 2010 he was assistant, then associate professor at Oregon State University's College of Oceanic and Atmospheric Sciences. In 2010 he returned to Australia on an Australian Research Council (ARC) Future Fellowship and since then has been associate professor then Professor at the Institute for Marine and Antarctic Studies, University of Tasmania.

Prof Strutton's research focuses on biological oceanography and his standing as an Antarctic and Southern Ocean scientist is recognised internationally. He has considerable expertise on how modes of variability – such as El Niño and internal ocean waves – affect nutrients in the ocean, biological productivity and carbon cycling. In the ARC Centre of Excellence for Climate Extremes, Prof Strutton contributes to the Ocean Extremes research program. He is contributing to projects in the area of ocean variability – physical, biological and chemical.

He concentrates on the drivers of observed changes in biogeochemical cycles, including oxygen, carbon and nutrients, with a recent and continuing focus on eddies.

Prof Strutton is an experienced supervisor and mentor of early career researchers. He currently oversees two postdoctoral researchers and several PhD and honours students. He has an extensive publication record that spans Antarctica to the tropical Pacific and the Labrador Sea. He is a past editor for the journal Geophysical Research Letters and a former leader of the Bluewater and Climate Node for Australia's Integrated Marine Observing System. Prof Strutton has also served on the scientific steering committee and biogeochemistry task team for the redesign of the Tropical Pacific Observing System **(tpos2020.org).**

Associate Professor Andrea Taschetto

Associate Professor Andrea Taschetto is based at the Climate Change Research Centre, University of New South Wales.

She investigates the mechanisms by which the oceans affect global and regional climate, using observations and numerical models. Her work looks at the impact of sea surface temperature variability on precipitation over Australia and elsewhere. She is particularly interested in the mechanisms of the different types of El Niño Southern Oscillation; specifically, how these influence atmospheric circulation, interact with other oceanic basins and affect extreme events such as droughts and heavy rainfall.

Associate Prof Taschetto was awarded the Australian Academy of Science Dorothy Hill Award in 2016 for her contribution to the climate science field. She was awarded an Australian Research Council (ARC) postdoctoral fellowship in 2010 and an ARC Future Fellowship in 2016. She was a council member of the Australian Meteorological and Oceanographic Society. She is currently a member of the Climate Variability and Predictability Pacific Regional Panel and Tropical Basin Interactions Research Foci.

Dr Claire Vincent

Dr Claire Vincent completed her PhD in mesoscale wind variability at the Technical University of Denmark in 2010. Prior to this, Dr Vincent worked at Australia's Bureau of Meteorology, first as a forecaster and then on a project to verify near-surface winds from mesoscale modelling.

Presently, Dr Vincent is a lecturer in atmospheric science at the School of Earth Sciences, the University of Melbourne.

Dr Vincent"s research interests include tropical variability, clouds and precipitation and mesoscale meteorology and modelling. She is particularly interested in the interactions between different scales of variability in the atmosphere and how these interactions influence regional weather and climate.

Our Staff and Students

Director
Professor Andy Pitman
University of New South Wales

Deputy Directors
Professor Julie Arblaster
Monash University

Professor Todd Lane
University of Melbourne

Graduate Director
Associate Professor Melissa Hart
University of New South Wales

Chief Operations Officer
Stephen Gray
University of New South Wales

Chief Investigators
Professor Nerilie Abram
Australian National University

Dr Gab Abramowitz
University of New South Wales

Professor Lisa Alexander
University of New South Wales

Professor Craig Bishop
University of Melbourne

Associate Professor Dietmar Dommenget
Monash University

Professor Jason Evans
University of New South Wales

Professor Andy Hogg
Australian National University

Professor Neil Holbrook
University of Tasmania

Dr Ailie Gallant
Monash University

Professor Christian Jakob
Monash University

Dr Amelie Meyer
University of Tasmania

Dr Sarah Perkins-Kirkpatrick
University of New South Wales Canberra

Professor Michael Reeder
Monash University

Dr Callum Shakespeare
Australian National University

Professor Steven Sherwood
University of New South Wales

Professor Peter Strutton
University of Tasmania

Dr Andrea Taschetto
University of New South Wales

Dr Claire Vincent
University of Melbourne

Partner Investigators
Associate Professor Ali Behrangi
University of Arizona (USA)

Dr Martin Best
Met Office (UK)

Dr Sandrine Bony
LMD/CNRS (France)

Dr Elizabeth Ebert
Bureau of Meteorology

Dr Wojciech Grabowski
NCAR (USA)

Dr Stephen Griffies
GFDL – NOAA (USA)

Professor Nicolas Gruber
ETH Zurich (Switzerland)

Professor Hoshin Gupta
University of Arizona (USA)

Dr Robert Hallberg
GFDL – NOAA (USA)

Dr Cathy Hohenegger
Max Plank Institute for Meteorology (Germany)

Dr Reto Knutti
ETH Zurich (Switzerland)

Dr Rachel Law
CSIRO

Dr Andrew Marshall
Bureau of Meteorology

Dr Simon Marsland
CSIRO

Dr Richard Matear
CSIRO

Dr Gerald Meehl
NCAR (USA)

Mr Sean Milton
Met Office (UK)

Dr Nathalie de Noblet
LMD/CNRS (France)

Dr Christa Peters-Lidard
NASA – GFSC (USA)

Dr Alain Protat
Bureau of Meteorology

Professor Joellen Russell
University of Arizona (USA)

Dr Joe Santanello
NASA - GFSC (USA)

Professor Sonia Seneviratne
ETH Zurich (Switzerland)

Professor Bjorn Stevens
MPI for Meteorology (Germany)

Dr Peter Stott
Met Office (UK)

Dr Ying Ping Wang
CSIRO

Dr Matthew Wheeler
Bureau of Meteorology

Associate Investigators
Dr Daniel Argueso Barriga
UIB (Spain)

Dr Linden Ashcroft
University of Melbourne

Dr Kathleen Beyer
NSW OEH

Dr Ghyslaine Boschat
Bureau of Meteorology

Dr Josephine Brown
University of Melbourne

Dr Jennifer Catto
Exeter University (UK)

Dr Christine Chung
Bureau of Meteorology

Dr Navid Constantinou
Australian National University

Dr Ajitha Cyriac
University of Tasmania

Dr Randall Donohue
CSIRO

Dr Stephanie Downes
NSW DPIE

Dr Nick Earl
University of Tasmania

Professor Graham Farquhar
Australian National University

Dr Sonya Fiddes
University of Tasmania

Dr Bishakhdatta Gayen
Australian National University

Dr Joëlle Gergis
University of Melbourne

Dr Rishav Goyal
University of New South Wales

Associate Professor Donna Green
University of New South Wales

Dr Harry Hendon
Monash University

Dr Benjamin Henley
University of Melbourne

Dr Will Hobbs
University of Tasmania

Dr Ryan Holmes
University of Sydney

Dr Pandora Hope
Bureau of Meteorology

Dr Yi Huang
University of Melbourne

Dr Debbie Hudson
Bureau of Meteorology

Dr Fei Ji
NSW DPIE

Dr Martin Jucker
University of New South Wales

Dr Jatin Kala
Murdoch University

Dr Andrew King
University of Melbourne

Dr Andrew Kiss
Australian National University

Professor Trevor McDougall
University of New South Wales

Dr Shayne McGregor
Monash University

Dr Tim McVicar
CSIRO

Professor Patrick Meir
Australian National University

Professor Katrin Meissner
University of New South Wales

Dr Adele Morrison
Australian National University

Dr Negin Nazarian
University of New South Wales

Dr Maxim Nikurashin
University of Tasmania

Dr Terrance (Terry) O'Kane
University of Tasmania/CSIRO

Dr Eric Oliver
Dalhousie University (Canada)

Professor Jonathon Overpeck
University of Michigan

Dr Acacia Pepler
Bureau of Meteorology

Dr Helen Phillips
University of Tasmania

Dr Scott Power
Bureau of Meteorology

Dr Ariaan Purich
Monash University

Dr Tim Raupach
University of New South Wales

Professor Peter Rayner
University of Melbourne

Professor Moninya Roughan
University of New South Wales

Dr Agus Santoso
University of New South Wales

Associate Professor Robyn Schofield University of Melbourne

Dr Alexander Sen Gupta
University of New South Wales

Professor Jason Sharples
University of New South Wales

A/Professor Steven Siems
Monash University

Dr Martin Singh
Monash University

Professor Scott Sisson
University of New South Wales

Dr Claire Spillmann
Bureau of Meteorology

Dr Andrea Taschetto
University of New South Wales

Dr Anna Ukkola
University of New South Wales

Dr Caroline Ummenhofer
WHOI (USA)

Dr Elisabeth Vogel
University of New South Wales

Professor Kevin Walsh
University of Melbourne

Dr Bethan White
Monash University

Dr Jan Zika
University of New South Wales

Research Associates

Dr Hooman Ayat
University of Melbourne

Dr Michael Barnes
Monash University

Dr Hien Bui
Monash University

Dr Diego Saul Carrio Carrio
University of Melbourne

Dr Anjana Devanand
University of New South Wales

Dr Georgy Falster
Australian National University

Dr Zoe Gillett
University of New South Wales

Dr Hakase Hayashida
University of Tasmania

Dr Stacey Hitchcock
University of Melbourne

Dr Sanaa Hobeichi
University of New South Wales

Dr Chiara Holgate
Australian National University

Dr Wilma Huneke
Australian National University

Dr Jules Kajtar
University of Tasmania

Dr Malcolm King
Monash University

Dr Chen Li
Monash University

Dr Nidhi Nishant
University of New South Wales

Dr Tess Parker
Monash University

Dr Ramkrushnbhai Patel
University of Tasmania

Dr Kimberley Reid
Monash University

Dr Nina Ridder
University of New South Wales

Dr Sami Rifai
University of New South Wales

Dr Yawen Shao
University of Melbourne

Dr DongXia Yang
University of Melbourne

PhD Students

Tahereh Alinejadtabrizi
Monash University

Arathy Aneeshkumar Kurup
Monash University

Larry Ger Aragon
University of Melbourne

Eliza Arias
University of New South Wales Canberra

Natasha Ballis
University of Melbourne

Ashley Barnes
Australian National University

Ankit Bhadouriya
University of Melbourne

Dhruv Bhagtani
Australian National University

Ce Bian
University of Tasmania

Alexander Borowiak
University of Melbourne

Annabel Bowden
Monash University

Andrew Brown
University of Melbourne

Liam Cassidy
University of Melbourne

Camilla Crockart
University of Tasmania

Felipe Da Silva
University of Tasmania

Thi Lan Dao
University of Melbourne

Hannah Dawson
University of New South Wales

Xu Deng
University of New South Wales Canberra

Michael Eabry
University of New South Wales

Nathan Eizenberg
University of Melbourne

Elizabeth Elwell
University of Melbourne

Xinyang Fan
University of Melbourne

Chen-shuo Fan
Monash University

Denisse Fierro Arcos
University of Tasmania

Pia Freisen
Monash University

Maheshinderjeet Garg
University of Melbourne

Bahman Ghasemi
University of Melbourne

Nicholas Grosfeld
University of New South Wales

Jessica Hargreaves
Australian National University

Matthew Heislers
Monash University

Qinuo Huang
Monash University

Maurice Huguenin-Virchaux
University of New South Wales

Alejandra Isaza
University of New South Wales

Rachael Isphording
University of New South Wales

Maya Jakes
University of Tasmania

Chenhui Jin
Monash University

Tom Lemaitre
Monash University

Zeya Li
University of Tasmania

Darren Li Shing Hiung
University of Tasmania

Stephy Libera
University of Tasmania

Ruby Lieber
University of Melbourne

Guillaume Liniger
University of Tasmania

Franciscus Liqui Lung
Monash University

Ying Lung Liu
University of New South Wales

Clemente Lopez-Bravo
University of Melbourne

Jiachen Lu
University of New South Wales

Yuxuan Lyu
University of Tasmania

Davide Marchegiani
Monash University

Maxime Marin
University of Tasmania

Sebastian McKenna
University of New South Wales

Jan Jaap Meijer
University of Tasmania

Sarthak Mohanty
Monash University

Estefania Montoya Duque
University of Melbourne

Fadhlil Rizki Muhammad
University of Melbourne

Rajashree Naha
Monash University

Marzie Naserikia
University of New South Wales

Julia Neme
University of New South Wales

Phuong Loan Nguyen
University of New South Wales

Justin Oogjes
University of Melbourne

Valentina Ortiz Guzman
University of New South Wales

Jon Page
University of New South Wales

Chengyuan Pang
University of Tasmania

Mahya Parchami
University of New South Wales

Kishor Kumar Paul
University of New South Wales

Zhangcheng Pei
University of Tasmania

Nicholas Pittman
University of Tasmania

Shukla Poddar
University of New South Wales

Priyamvada Priya
Monash University

Katie Quail
University of New South Wales

Clara R. Vives
University of Tasmania

Tony Rafter
University of Melbourne

Jemima Rama
Australian National University

John Reilly
University of Tasmania

Elona Rey-Costa
University of New South Wales

Sandra Richard
University of Melbourne

Lara Richards
Monash University

Daniel Robbins
Monash University

Fiona Robinson
University of New South Wales

Corey Robinson
Monash University

Raina Roy
Monash University

Manon Sabot
University of New South Wales

Emmanuel Sarbeng
Monash University

Francesco Sardelli
University of Melbourne

Christina Schmidt
University of New South Wales

Nasimeh Shahrokhi
University of Melbourne

Jiaxin Shi
University of Tasmania

Polina Sholeninova
Australian National University

Ewan Short
University of Melbourne

Tanya Singh
University of New South Wales

Annette Stellema
University of New South Wales

Jiaoyang Su
University of Tasmania

Arnold Sullivan
Monash University

James Sweetman
Australian National University

Isaac Tan
Monash University

Lina Teckentrup
University of New South Wales

Son (Sonny) Truong
Monash University

Danielle Udy
University of Tasmania

Nick Velzeboer
Australian National University

Robert Vicari
University of Melbourne

Yuxin Wang
University of Tasmania

Yu (Sulla) Wang
University of Tasmania

Lingfei Wang
University of New South Wales

Jakob Weis
University of Tasmania

James Wyatt
University of Tasmania

Zhiang Xie
Monash University

Xiang Yang
University of Tasmania

Kai Yang
University of Tasmania

Claire Yung
Australian National University

Shujing Zhang
University of Tasmania

Xihan Zhang
University of Tasmania

Xinyue Zhang
University of New South Wales

Wenhui Zhao
Monash University

Zijie Zhao
University of Melbourne

Masters Students

Michael Fitzpatrick
University of Melbourne

Isabelle Greco
University of New South Wales

Xuehan Kang
Australian National University

Hangyu Meng
Australian National University

Adam Nahar
University of Melbourne

Jarrad Rowe
University of Melbourne

Dillon Sherlock
University of Melbourne

Joshua Sibbing
University of Melbourne

Priya Singh
University of Melbourne

Nicholas Thorne
University of Melbourne

Christal Xie
University of Melbourne

Fan Zhang
Australian National University

Honours Students

Meng Han
University of Tasmania

Brendan Healy
Monash University

Jemma Jeffree
Australian National University

Tea Jones
University of Melbourne

Xinlong Liu
University of Tasmania

Greta Paget
University of New South Wales

Elise Palethorpe
Australian National University

Lucinda Palmer
Monash University

Mathilde Ritman
Monash University

Kathleen Shalini Rome
University of New South Wales

Helen Shea
Monash University

Ellie Traill
Monash University

Illaria Visentin
Monash University

Xinhui Wang
University of Tasmania

Fengmin Xing
University of Tasmania

Heng Xu
University of Tasmania

Xin Ye
University of Tasmania

Professional Staff

Sook Chor
Monash University

Vilia Co
University of New South Wales

Christine Fury
University of Tasmania

Ellen Hooper
University of New South Wales

Silvana Katragadda
Monash University

Simon Parsons
University of Melbourne

Jenny Rislund
University of New South Wales

Carmen Tucker
Australian National University

Computational Modelling Support Team

Samuel Green
University of New South Wales

Aidan Heerdegen
Australian National University

Ramzi Kutteh
University of New South Wales

Paola Petrelli
University of Tasmania

Dale Roberts
University of Melbourne

Scott Wales
University of Melbourne

Carl Holger Wolff
Monash University

Engagement and Impact Team

Jonathan (JB) Brown
University of New South Wales

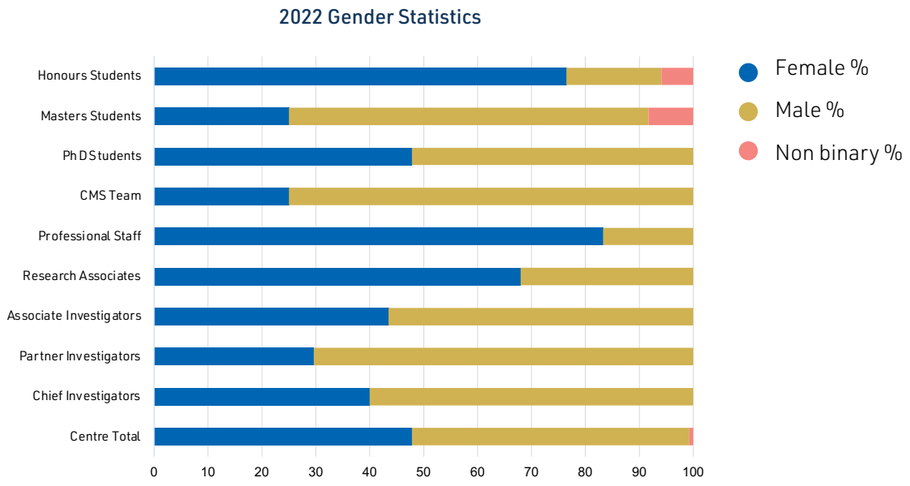
Georgina Harmer
Monash University

Allyson Crimp

Monash University

Angela Kaplish
University of New South Wales

Alice Wilson
Monash University



The ARC Centre of Excellence for Climate Extremes is committed to creating a diverse and equitable working environment. Since the commencement of the Centre, we have increased the proportion of women Chief Investigators from 22% to 40%. This is a notable achievement in the physical climate sciences. We are training the next generation of research associates (68% women) in a wide range of scientific, professional and leadership skills to provide them a strong foundation to become the leaders of tomorrow in whatever sector they choose for their future careers.

Our Partners

Administering Institution

The University of New South Wales

Collaborating Institutions

The Australian National University

Monash University

The University of Melbourne

The University of Tasmania

Australian Partner Organisations

Bureau of Meteorology

CSIRO

Managing Climate Variability Program

National Computational Infrastructure

NSW Department of Planning, Industry and Environment (formerly OEH)

Risk Frontiers

Sydney Water

International Partner Organisations and Collaborators

ETH Zurich

Geophysical Fluid Dynamics Laboratory (USA)

LMD – Centre National de la Recherche Scientifique (France)

Max-Planck Institute for Meteorology (Germany)

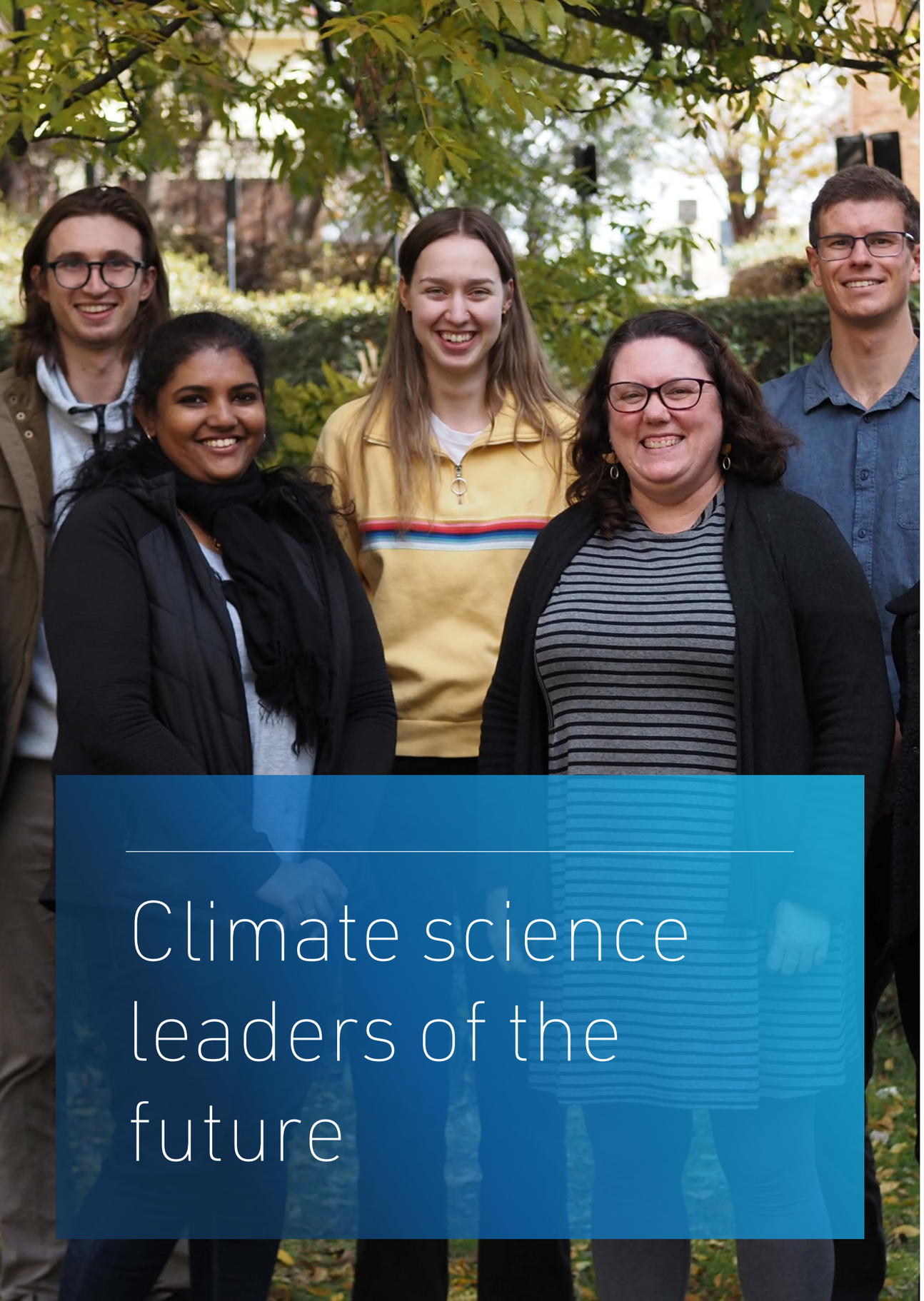
NASA-Goddard Space Flight Center (USA) N

National Center for Atmospheric Research (USA)

UK Meteorological Office (UK)

The University of Arizona (USA)

The ARC Centre of Excellence for Climate Extremes has a large network of partner organisations, both in Australia and overseas. Each of our partners was carefully chosen for the expertise and resources they contribute to the overall research and outreach objectives of the Centre and the climate research community at large. Our partners enable us to collaborate on cutting-edge science and model development and to advance our engagement and impact ambitions.



Climate science leaders of the future

Researcher Development Program

The Researcher Development Program at the Australian Research Council Centre of Excellence for Climate Extremes develops national capacity in climate science by training and mentoring the next generation of researchers. It equips them with the intellectual and technical capacity required to take on the research challenges of the future. The program, which involves all Centre researchers, covers fundamental research and communications skills, professional development, mentoring and leadership opportunities.

In 2022 we welcomed 20 new honours and masters students and 23 PhD students to the Centre. All have been actively involved in our graduate activities.

We had 39 students submit this year (21 PhD and 18 honours/masters) and they are working in a variety of sectors. Of our graduating PhD students, half have moved on to positions in universities, 30 percent have taken up positions in research institutions, and the remainder are split between government and industry, including data sciences, insurance companies and environmental consultancies.

Our Researcher Development Program recognises that climate scientists come from a variety of undergraduate backgrounds and come to us with a varying range of skills and knowledge. Therefore, the program offers important breadth and depth of climate science knowledge, technical and communications training and professional development. In 2022 we packaged our bespoke training and development opportunities into a personalised training needs analysis and training plan. The latter was developed in consultation with all facets of the Centre. This included workshops co-designed by students and early career researchers (ECRs) and implementation of feedback from Centre researchers, Partner Organisations and Centre alumni and their employers.

Each commencing ECR is tasked with undertaking personal training needs analysis to assess their skills and knowledge base. This analysis reveals the skills and knowledge they may need to develop or acquire for successful completion of their project and to prepare for their next career step. Once this analysis is complete, students develop their individualised training in consultation with their supervisors. This training plan then becomes a living document – revisited throughout their time with the Centre – and is revisited at least annually.

After two years online, our popular and successful scientific paper writing workshops moved back to three-day, in-person events. The workshops provide participants with the skills and confidence to write scientific papers for successful publication in leading scientific journals.The success of our writing workshops can be seen in our publication numbers, with 75 papers published by Centre students this year 62 as first author).

Included in this impressive publication list was a first-author paper in Science, by Hooman Ayat, on rapid rain bursts over Sydney, along with groundbreaking work led by student Zoe Gillett in The Journal of Atmospheric Sciences on Indian Ocean Teleconnections and a noteworthy paper by Danielle Udy in Nature-family journal Communications Earth and Environment.

In collaboration with our Computational Modelling Systems team, technical training opportunities this year have included weekly technical training sessions delivered via our videoconferencing system. This includes regular "code break" sessions, offered both online and on a drop-in basis, to replace lost in-person interactions due to Covid-19.

Our students and ECRs are represented in the Centre via our Early Career Researcher Committee. The committee provides formal and informal communication channels between ECR members and the Centre Executive Committee. The committee's mission is to facilitate, encourage and contribute to the development of all Centre ECRs. This year, our Early Career Researcher Committee led efforts to advocate for increases to PhD stipends and student financial support.

Climate science students come from a range of quantitative undergraduate degree backgrounds. To ensure undergraduate students are aware of the opportunities within the climate sciences, we offer highly competitive undergraduate scholarships. In 2022 we welcomed 16 undergraduate students to work with us on research projects. The scholarships provide the students with an introduction to cutting-edge climate science research at one of the Centre's five member universities or one of our national Partner Organisations. Undergraduate students are supervised by our ECRs, giving them vital supervisory experience.

Winter School 2022
Ocean and Atmosphere Dynamics

Our winter schools are the cornerstone of our graduate program. We want to have graduate students who not only have highly specialised knowledge in their own area of research, but also a broad understanding of the discipline as a whole. The winter school provides this opportunity. The theme of the winter school changes each year and shifts from broader, relevant-to-everyone topics to more focused topics requiring prerequisite knowledge.

In 2022 our winter school covered atmosphere and ocean dynamics – with the help of the ANU Research School of Earth Sciences Geophysical Fluid Dynamics lab. Participants also visited the National Computational Infrastructure (NCI) to learn more about the supercomputer Gadi and the data visualisation support that NCI provides.

As our first in-person event since Covid-19 lockdowns, the winter school week started with a large cheer. This excitement continued throughout the week as graduate students had the opportunity to learn from leaders in the field and to engage with their peers.

Postdoctoral Development

Our postdoctoral researchers were provided targeted development opportunities in 2022 via a postdoc workshop focusing on collaboration and communications skills, as well as monthly postdoctoral development sessions covering topics from networking to training to become a supervisor.

Science Fundamentals Lectures

In 2022 the Centre of Excellence also started a series of online science fundamentals lectures. The objective of these lectures was to provide additional breadth of knowledge for our graduate students and postdoctoral researchers. Interestingly, their reach extended well beyond our ECRs, with lectures often including many Chief Investigators and Partner Organisation members coming along to brush up on their fundamentals. Given the success of these lectures, they will continue on for the remainder of the Centre's existence.

Finally, we celebrate the success of our students in winning a wide range of prizes and awards.
The 2022 recipients included:

Chiara Holgate - named as a 2022 STA Superstar of STEM
Ariaan Purich - winner of the AMOS Meyers Medal
Josue Martinez Moreno - winner of the AMOS Uwe Radok Award for best PhD thesis

See page 97 for a full list of 2022 prize and award winners.

Celebrating Graduate Director Associate Professor Melissa Hart

Associate Professor Melissa Hart has been the heart of the Researcher Development Program since the inception of the ARC Centre of Excellence for Climate Extremes, in 2017. Before that, she held the position of Graduate Director in the ARC Centre of Excellence for Climate System Science, from 2011 to 2017.

Associate Prof Hart has overseen the development of more than 300 researchers at our Centre and has delivered more than 30 workshops and training opportunities so far. She has done this work while also still making important contributions to research on urban environments and working with schools through projects like the **Schools Weather and Air Quality** project.

We thank Associate Prof Melissa Hart for her hard work and success supporting hundreds of Australia's current and future climate scientists.

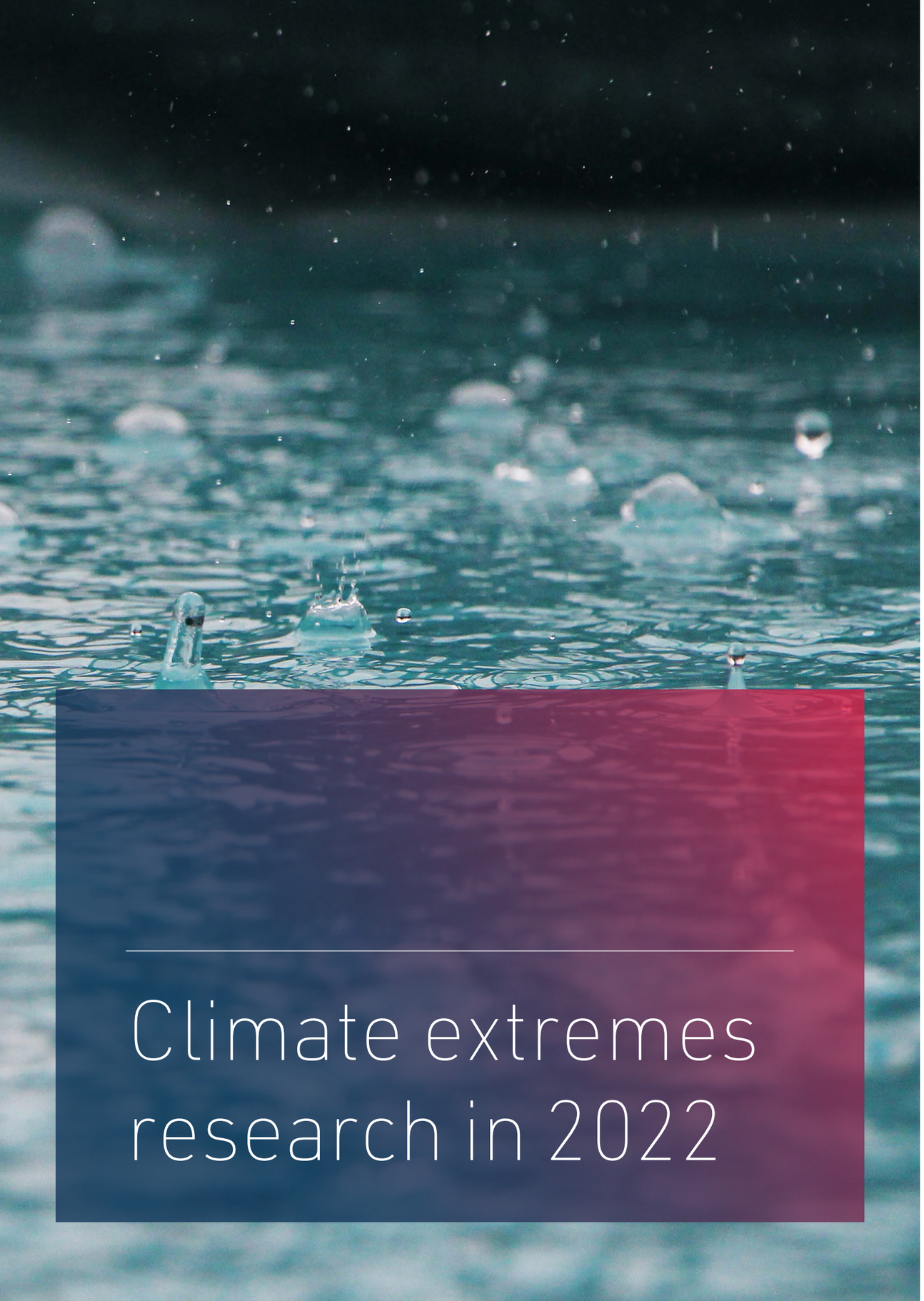
'Throughout my Masters, PhD and postdoc, Melissa has been a foundation for me. Her optimistic, unfaltering support has provided me with a constancy throughout the ups and downs of academic life that I am incredibly grateful for.'
- Dr Chiara Holgate

'Leadership is not about titles, it's about the impact you have on others. In my experience as a former student and current postdoctoral researcher at the Centre, Melissa has been a true champion of my career growth and development. I see her as an example of a leader who leads with integrity and compassion.'
- Dr Sanaa Hobeichi

'When I think about Melissa, I think of happiness, kindness, intelligence, helpful, hard working... when I realised that she also supervises students and is doing all the activities of a professor, I was even more amazed by her. I think we are glad to have someone like her in the Centre, being so dedicated and so human.'
- Estefania Montoya Duque

'I had a great experience supporting Melissa in aspects of the Researcher Development Program. She is an extremely pleasant and fun person to work with, and I think the ECRs in the Centre are very lucky to have her!'
- Dr Jules Kajtar

'Melissa brings enthusiasm and boundless passion into developing the next generation of climate scientists, while also being a leading researcher in urban climate science.'
- Dr Kimberley Reid



Climate extremes research in 2022

The following chapters outline just a fraction of the exceptional research undertaken by scientists at the Australian Research Council Centre of Excellence for Climate Extremes.

Weather and Climate Interactions Research Program

Weather systems are the building blocks of the climate, as it is the aggregate of these weather systems that defines the climate. Of course, the connection is not one way, since the frequency and amplitude of various weather systems are themselves modulated by climate.

The Weather and Climate Interactions research program investigates climate, and especially climate extremes, through a weather lens. In this pursuit, our work focuses on the physical mechanisms responsible for extreme weather in the tropics and extratropics – and the effect of climate change on these mechanisms. Understanding how the weather changes as the world warms, and especially how extreme weather changes, is an important part of how climate change affects people, the economy and the environment.

The Weather and Climate Interactions research program was added to the Centre's research portfolio last year and is now in full swing. We have appointed our full complement of postdoctoral research associates, we have a strong cohort of graduate students, and we are making significant contributions to the science of weather and climate extremes.

Project 1

Fronts are perhaps the only weather systems implicated in heat, wind and precipitation extremes. To illustrate this point, consider the following: the most catastrophic fires in recent history in southern Australia have been associated with extreme but shallow dry cold fronts that form along the southern coastline; Melbourne's record maximum temperature preceded the passage of the extreme cold front on Black Saturday; and frontal systems commonly provide the uplift needed to produce extreme precipitation. Our research into extratropical extremes is guided by the overarching question:

What controls the strength, frequency and path of fronts in the Australian extratropics, and how do these factors affect extremes?

In a project led by Dr Hooman Ayat, a version of the Australian Community Climate Earth System Science model has been configured and run over the Australian region with approximately two-kilometre horizontal grid spacing. This is a real technical achievement. It is also a real scientific achievement, as Dr Ayat has used the model to explore the weather conditions that made the 2020 New Year's Eve fires in south-eastern Victoria so extreme. In particular, Dr Ayat has investigated the source of the extremely dry but localised air ahead of the approaching cold front, which is thought to have been an important contributor to the severity of the conditions.

In a project led by Dr Malcolm King, we investigated strong cold fronts in Australian station data, as defined by daily maximum temperatures decreasing by at least 10°C between two consecutive days. These strong cold fronts occur most often during spring and summer and are more common along the southern regions of Australia. Although no widespread trend in the frequency of strong fronts was detected during the 110-plus-year record, relationships between increased strong-front frequency and El Niño, positive Indian Ocean Dipole and negative Southern Annular Mode patterns were found for many stations in the south-eastern parts of Australia. This result suggests a link between dryer conditions and increased occurrence of strong fronts. Exploring this link more fully is one of the future directions of this project.

Project 2

Tropical lows are among the most important rain-bearing weather systems in the northern half of the continent. For example, in north-western Australia, around half of all summertime rainfall is associated with them. Moreover, tropical lows are commonly implicated in rainfall extremes. These considerations motivate our second overarching research question:

What causes the long-lived, heavy rains in tropical and subtropical Australia?

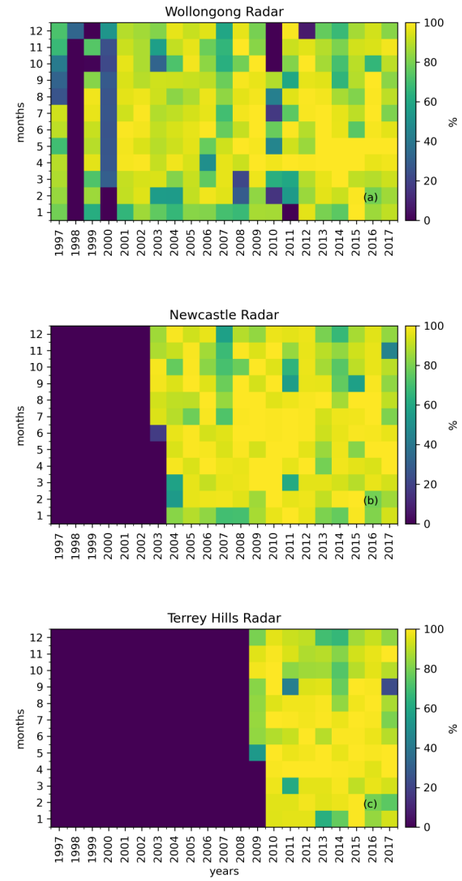
This research question could hardly have been more timely! In the last year, the eastern seaboard of Australia has been inundated. Research led by Dr Michael Barnes has shown that this kind of inundation is due to slow-moving vortices in the upper atmosphere. The rainfall is copious because these vortices linger over eastern Australia and force air upward on their eastern flank. In 2022 these vortices inextricably linked to a surface anticyclone over the Tasman Sea, which directed moist easterlies onshore. Rossby wave breaking near the end of the jet stream is the physical process responsible for slow-moving upper-level vortices and the associated surface weather pattern. Our research emphasises that the upper levels of the atmosphere is the key to understanding and predicting the kind of heavy rain and inundation we've experienced in 2022.

Another important contribution to our science is that led by Dr Dawn Yang. It has been widely publicised that 2022 was a La Niña year. Dr Yang's work is also extremely timely, as it is focused on how the rainfall associated with the various phases of the Madden-Julian Oscillation (MJO) change between El Niño and La Niña conditions. In comparison to El Niño conditions, the rainfall maximum propagates as a focused region from west to east across northern Australia. One result of particular relevance is that the rain is highly focused on the eastern seaboard in the later stages (MJO Phases 6 and 7).

Research Snapshot

Although previous studies of extreme precipitation have focused mainly on extreme daily rainfall, brief but heavy rain can cause flash flooding, severe damage and dangerous conditions. These sub-daily extremes are often confined to small areas that can be missed by rain gauge networks or satellites, and they are very far from being resolved by climate models. In this study, we find a robust positive trend of at least 20% per decade in sub-hourly extreme rainfall near Sydney, Australia, over 20 years, despite no evidence of trends at hourly or daily scales. This trend is seen consistently in storms tracked using multiple independent ground radars, is consistent with rain-gauge data and does not appear to be associated with known natural variations. This finding suggests that sub-hourly rainfall extremes may be increasing substantially faster than those on more widely reported time scales.

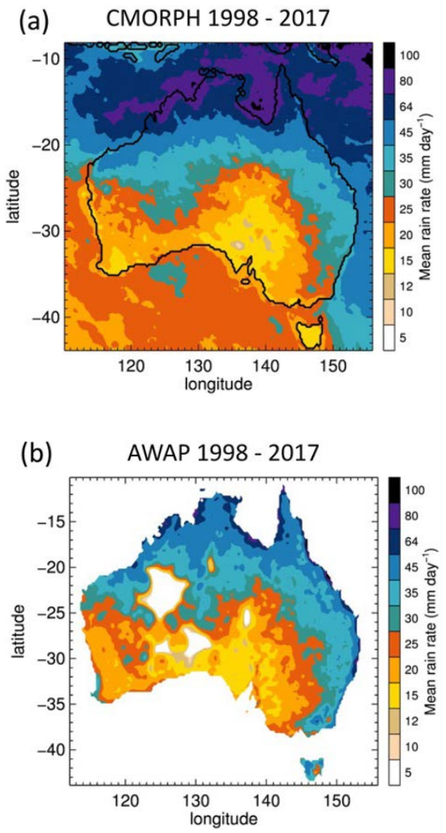
Ayat, H., Evans, J.P., Sherwood, S.C., Soderholm, J., 2022. Intensification of sub-hourly heavy rainfall. Science 378, 655–659. https://doi.org/10.1126/science.abn8657



Research Snapshot

This study reports on the atmospheric conditions that are necessary to produce rainfall extremes in three different regions of Australia. It finds that it takes two to tango. In all regions, the ingredients are very high moisture content and strong upward vertical motion. Either of them alone is not sufficient for extreme rainfall. This result highlights the important interplay between the dynamics and thermodynamics of weather systems in making rainfall extremes. In other words, how and where weather systems force ascent, along with how and where they tap into moist air, are crucial. Understanding how extreme rainfall will change with climate change therefore requires us to understand how both moisture and vertical motion change as the planet warms.

White, B.A., Jakob, C., Reeder, M.J., 2022. Fundamental Ingredients of Australian Rainfall Extremes. Journal of Geophysical Research: Atmospheres 127, e2021JD036076. https://doi.org/10.1029/2021JD036076



'I went to a summer school about clouds and I was like, "this is so interesting!". I like the fact that we can be connected, potentially collaborating with other people and learning from everyone.'

Early career researcher
Estefania Montoya Duque - University of Melbourne

Weather and Climate Interactions 2023 Statement of Intent	
Whole-of-research program activities	• Coordinate a paper documenting the heavy rainfall across eastern Australia in 2022 and review what is known about the physical processes responsible.
Project 1 activities What controls the strength, frequency and path of fronts in the Australian extratropics, and how do these factors affect extremes?	• Evaluate recent and future changes in extreme fronts in ERA5 and various CMIP6 models • Determine the relationship between surface conditions (especially surface moisture) and the development of extreme fronts, the degree to which this relationship is linked to local and remote SSTs, and the implications for fire weather • Complete the regional 2.2 km (Aus2200) case-study simulation(s) from summer 2019/2020. Evaluate the simulation • Implement a trajectory code and use it to evaluate the source of extreme mesoscale drying in the summertime wildfire-front case studies • Evaluate how SST anomalies in the neighbourhood of Australia affect the Walker circulations and evaluate how this affects seasonal dryness • Investigate how the various modes of variability affect wildfire conditions in Australia.
Project 2 activities What causes the long-lived, heavy rains in tropical and subtropical Australia?	• Extreme rainfall in eastern Australia is connected to breaking Rossby waves. Determine where the precursor Rossby waves are generated, and how, and determine the pathways by which they propagate to eastern Australia. Investigate how wave-breaking weakens the background steering flow leading to slow-moving systems • Investigate how well these processes are captured in CMIP6 models. What should we expect in a warmer world? • Establish variability/co-variability of ENSO/IOD and MJO in long historical data sets and examine composite large-scale variability over tropical Australia • Is MJO-ENSO-heavy rainfall relationship represented in CMIP6 models and does it persist in future projections? • Examine the statistics and physical processes behind the heavy rainfall across Eastern Australia in 2022.
Engagement activities	• Apply stakeholder indices to QLD mean and extreme rainfall and variability with ENSO / MJO / IOD • Present stakeholder analysis at stakeholder-relevant forums • Write a briefing note on MJO-ENSO impact on extreme rainfall • Write a briefing note on slow-moving vortices and extreme rainfall.

Attribution and Risk Research Program

The Attribution and Risk research program had a busy start to the year, organising and participating in a number of seminars and meetings around the February and March extreme rainfall events in Queensland and NSW and associated floods. This included substantial outreach through media interviews and briefing notes on extreme rainfall, atmospheric rivers, compound events and the triple-dip La Niña, as well as contributions to the 2022 NSW Flood Inquiry. The extent to which climate change played a role in these events was a frequent question and we plan to extend our work on these extraordinary extremes throughout 2023, with a number of workshops, model simulations and research articles planned.

ARC Centre of Excellence for Climate Extremes postdoctoral researchers, Yawen Shao and Zoe Gillett, coordinated regular monthly meetings of the research program throughout the year, including speakers from industry (for example, Valentina Koschatzky from Risk Frontiers on catastrophe modelling), Partner Organisations (for example, John Fasullo from the National Center for Atmospheric Research on the climate impacts of the Australian bushfires) as well as research updates from across the Centre of Excellence community.

We continued to build relationships with industry, through webinars and discussions with the agriculture, adaptation and finance sectors. Our researchers also returned to international travel for the first time since 2019, contributing and presenting our research at forums such as the **International Symposium on Data Assimilation**, **Stratospheric-Tropospheric Processes and their Role in Climate General Assembly** and the World Meteorological Organization-United Nations Environment Programme's Scientific Assessment of Ozone Depletion Panel final review meeting, as well as others, both in-person and virtually.

We outline progress against our two main goals, below.

Project 1

How do the relative roles of large-scale, regional and local-scale processes and their interactions shape Australian extremes and govern their changes?

Extremes in temperature and rainfall often occur during excursions of tropical Indian and Pacific variability; for example, La Niña. This was evident in 2022, which saw a rare triple-dip La Niña and a wetter-than-average year across most of Australia, particularly in the south-east.

However, the mechanisms of these interactions between the tropics and extratropics – and between processes at different scales – are not fully understood. In a paper published in the Journal of Atmospheric Sciences, Dr Zoe Gillett and co-authors used a novel modelling framework to simulate the time-evolving response to a sudden switch-on of heating in the tropical Indian Ocean. It revealed a new pathway for Rossby wave propagation below the subtropical jet stream, which is prominent across subtropical latitudes of Australia in winter and has long been recognised to act as a barrier to the propagation of Rossby waves, which are important for teleconnections to south-eastern Australia. These results have implications for forecasting the Australian climate response to the Indian Ocean Dipole, as it relies on a good simulation of the subtropical jet. To explore the impacts of tropical variability on Australian extremes further, Dr Gillett has been coordinating pacemaker experiments with the Australian Community Climate and Earth System Simulator–Coupled Model 2 (ACCESS-CM2) as part of an international coordinated tropical basin interaction project.

Other studies explored the fidelity of extremes in models and observations, including a study led by Dr Dr Nidhi Nishant which examined the impact of spatial resolution on means and extremes in precipitation. They compared precipitation in high-resolution dynamically downscaled data against the driving lower-resolution reanalysis over Australia, finding that high-resolution data were less accurate than lower-resolution data for standard statistics of precipitation. They also showed that the extra detail resolved by higher resolution is of negligible importance compared to the overall uncertainties. These results highlighted that increasing the horizontal resolution alone may not help address problems with precipitation. Significant model developments and data assimilation techniques are also required to reap the benefits of high horizontal resolution.

Project 2

Can machine learning/ statistical approaches be used to improve the representation of scale interactions, processes and projection of the risk of extremes?

We continued to make substantial progress in the application of advanced statistics and machine-learning techniques in 2022.

Focusing more on the risk component of Attribution and Risk, Associate Investigator Dr Tim Raupach developed and published an improved hail proxy for Australia, which predicts whether an atmospheric environment is prone to hailstorm formation. This proxy has been applied to reanalysis data and will form a basis for upcoming work on machine-learning-based techniques for characterising local-scale hailstorm environments. Separately, Centre of Excellence for Climate Extremes Masters student Isabelle Greco is leading the development of a Bayesian model to explore links between radar hail detection, reports of hailstorms and population density, with the goal of producing a probabilistic hail climatology for Australia.

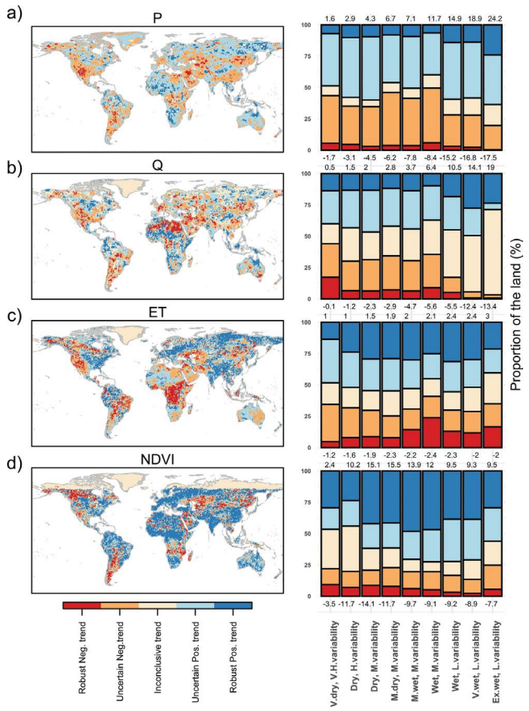
Centre PhD student Rachael Isphording is leading work on developing a standardised benchmarking framework to assess the veracity of rainfall simulations from regional climate models. The framework, which will allow for the standardised intercomparison of statistics and precipitation processes across any downscaled simulation, has so far been applied to CORDEX-Australasia output. The framework has been built to be flexible so that it can be applied to simulations from any region and, once finalised, will be able to assess the 'added value' of any given regional precipitation simulation. The ultimate goal is to help stakeholders better utilise ensemble projections from a variety of different sources.

Postdoctoral researcher Dr Yawen Shao and Chief Investigator Professor Craig Bishop have continued to make important refinements to their new, multiplicative correction approach, in order to create a set of CMIP-based projections that have much more realistic variances across a range of time scales. Further, by applying ensemble weighting, they can more accurately project and attribute climate extremes such as heatwaves.

Research Snapshot

A critical question in hydrology is the extent to which climate change is affecting changes in rainfall, evapotranspiration and runoff over land and how this might impact human activity. We demonstrate that >50% of the land surface has experienced robust changes in these hydrological cycle components since 1980. Of particular concern is increasing water resource stresses in key breadbasket regions including Australia, and some densely populated areas. Using a diverse range of observations in combination with data assimilation approaches and machine learning, our results support the general conclusion that over land "wet gets wetter but dry does not get drier".

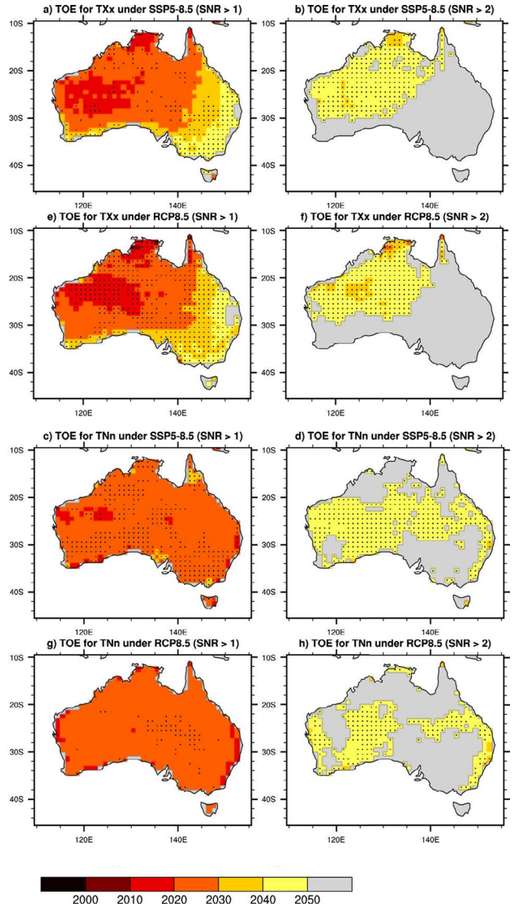
Hobeichi, S., Abramowitz, G., Ukkola, A.M., De Kauwe, M., Pitman, A., Evans, J.P., Beck, H., 2022. Reconciling historical changes in the hydrological cycle over land. npj Clim Atmos Sci 5, 17. https://doi.org/10.1038/s41612-022-00240-y



Research Snapshot

Time of emergence is a concept showing when the trend in a climate variable emerges above the "noise" of natural climate variability. A study led by ARC Centre of Excellence for Climate Extremes PhD student Xu (Pete) Deng used large ensembles of the latest state-of-the-art climate models and a range of future scenarios to understand this concept for temperature extremes over Australia. The strongest warming levels, and therefore earlier time of emergence, are projected under the highest future scenario with tropical Australia usually showing the highest warming. However, emergence patterns differ greatly for different extreme indices and there is large inter-model uncertainty in time of emergence with internally generated variations influencing the noise.

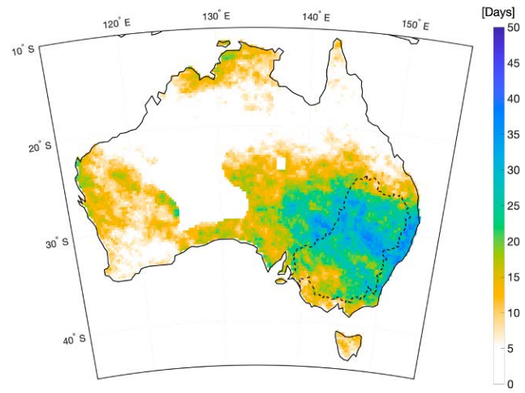
Deng, X., Perkins-Kirkpatrick, S.E., Alexander, L.V., Stark, C., 2022. Projected Changes and Time of Emergence of Temperature Extremes Over Australia in CMIP5 and CMIP6. Earth's Future 10, e2021EF002645. https://doi.org/10.1029/2021EF002645

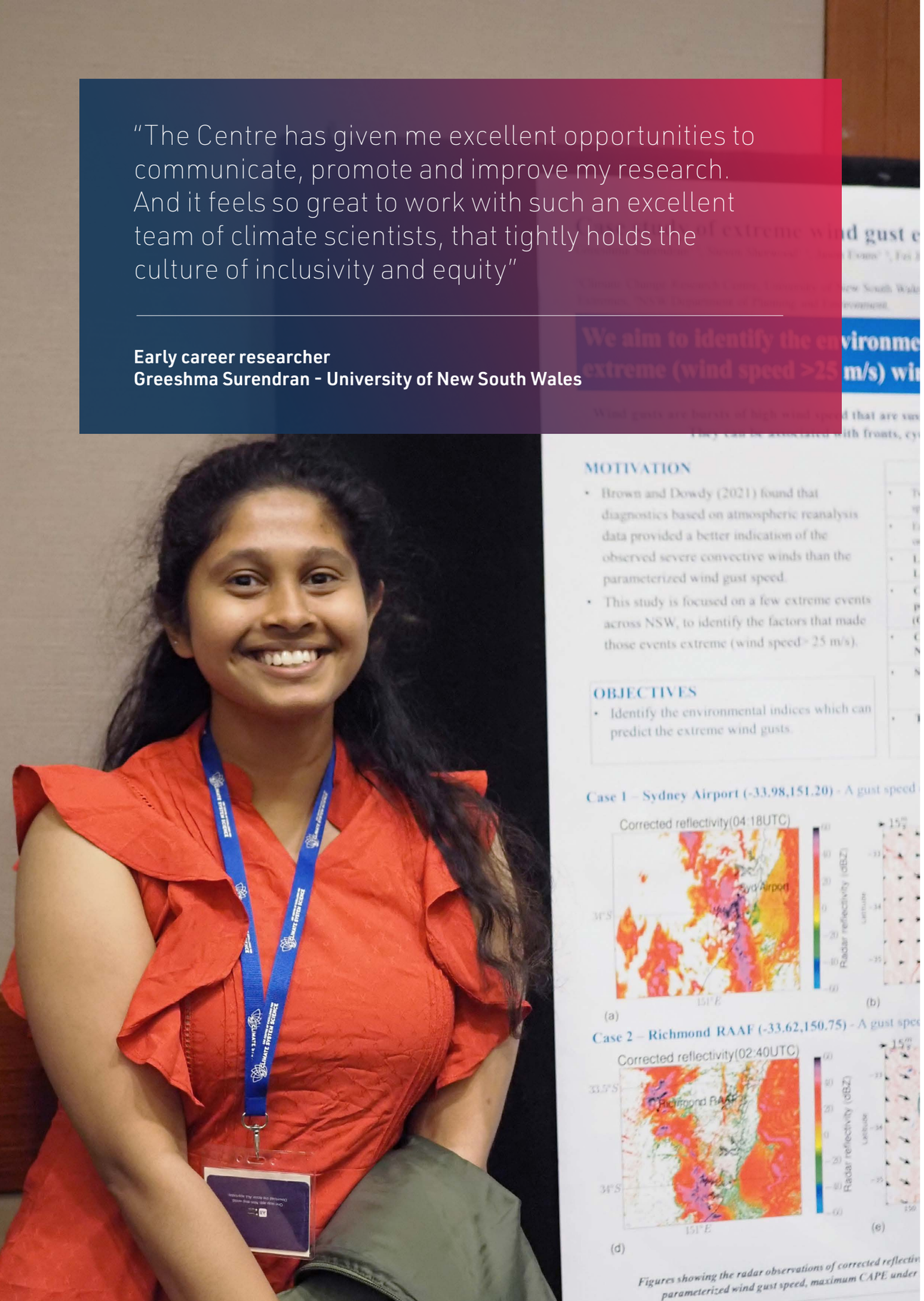


Research Snapshot

Atmospheric Rivers are narrow regions of strong moisture transport in the lower atmosphere. They can cause beneficial rainfall, and on average, atmospheric rivers contribute 20-35% of southeast Australia's and 10-20% of southwest Australia's annual rainfall. However, they can also be disastrous with 20-30% of the heaviest rainfall days in the Northern Murray-Darling Basin occurring during Atmospheric Rivers including the devastating Feb-Mar floods in 2022. In 2022, Dr Kim Reid and co-authors published the first study to quantify the effects of Atmospheric Rivers over all of Australia. Current ARC Centre of Excellence for Climate Extremes research is exploring how we can better predict these systems and their future behaviour.

Reid, K.J., King, A.D., Lane, T.P., Hudson, D., 2022. Tropical, Subtropical and Extratropical Atmospheric Rivers in the Australian Region. Journal of Climate 35, 2697–2708. https://doi.org/10.1175/JCLI-D-21-0606.1





"The Centre has given me excellent opportunities to communicate, promote and improve my research. And it feels so great to work with such an excellent team of climate scientists, that tightly holds the culture of inclusivity and equity"

Early career researcher
Greeshma Surendran - University of New South Wales

Attribution and Risk 2023 Statement of Intent	
Whole-of-research-program activities	• Hold 2023 Workshop • Hold extreme rainfall workshop together with Weather and Climate Interactions + 2022 rainfall paper writing workshop • Conduct benchmarking extremes in CORDEX.
Project 1 activities How do the relative roles of large-scale, regional and local-scale processes and their interactions shape Australian extremes and govern their changes?	• Explore the use of ACCESS global AMIP simulations and/or AUS2200 regional model for understanding the 2022 extreme rainfall events • Investigate dynamical downscaling of extreme events by idealised model tests • Examine ENSO teleconnections via observed synoptic patterns related to heavy rainfall events • Finalise running of first set of ACCESS pacemaker experiments • Investigate role of ENSO and IOD on Australian rainfall extremes using Pacemaker experiments with CCAM • Contrast rainfall from fronts and atmospheric rivers over Australia • Review article on the attribution of extreme events to climate change in the Australian region.
Project 2 Activities Can machine learning/statistical approaches be used to improve the representation of scale interactions, processes and projection of the risk of extremes?	• Investigate the possibility of exploiting machine-learning-based downscaling and its uncertainty estimates for risk quantification • Conduct time-series correction of future projections (e.g. robust warm spell duration index).
Engagement activities	• Develop set of briefing notes on detection & attribution, including explainer • Interact further with AON and the Australian Climate Service • Develop a 'climate dashboard' with a focus on Australia and extremes indicators • Potential roundtable with agriculture community e.g. Agriculture Victoria in Bendigo (joint with Weather and Climate Interactions).

Drought Research Program

The ARC Centre of Excellence for Climate Extremes' Drought research program has had a very productive year, including building momentum through two in-person workshops of the research team.

In March 2022 the program's Chief Investigators and postdoctoral researchers met and developed a plan to draw together the diverse expertise of the team around a case study to understand the intense drought that impacted south-east Australia between 2017 and early 2020 - a drought which we have termed the Tinderbox Drought.

In August the research program team met in-person again to discuss progress on this case study, resulting in the development of a comprehensive review paper on the characteristics, drivers and predictability of this intense drought.

Dr Anjana Devanand gave an invited talk on this Tinderbox Drought review at the Centre's annual workshop in November, and work is now under way to finalise the paper for publication. The Drought program team is also coordinating a special issue on the Tinderbox Drought in Weather and Climate Extremes. It has already received its first submissions and will be open to more until late 2023.

Project 1

What determines the onset, persistence and termination of drought?

Large-scale climate modes, such as El Niño and positive Indian Ocean Dipole events, are often linked to increased drought risk in parts of eastern Australia. However, the weather processes connecting these broad-scale, distant features to local rainfall are unclear.

Dr Chiara Holgate and co-authors have shown, in research **published in Journal of Climate,** that East Australia is wetter during La Niña because more moisture is transported into the region and is more easily turned into rainfall when it arrives, whereas drier conditions during El Niño are because local conditions inhibit the conversion of moisture into rainfall. Distant atmospheric changes over the Indian and Southern Oceans can intensify these changes. These results can be used to better understand and predict the regional impact of long-term changes in these modes of climate variability, which are potentially altered under climate change.

Dr Holgate was also recognised as a **Superstar of STEM** in 2022. She will spend the next two years developing her communications skills to help Australians better understand and prepare for future extreme events – and to show rural kids what it's like to be an engineer and scientist.

Our drought research is also being applied to help the agricultural industry better understand and predict climate extremes. Our Chief Investigators **contributed to research** exploring time-series yield and crop production from cotton sites in Australia and related them to climatic variations. This study found that dryland lint yield gains during average-to-moderate rain/temperature years, while irrigated lint yields have improved during more-frequent average rain/hot growing seasons. The work also discovered that climate in central cotton-growing areas is affected by Central Pacific and Western Pacific Nino indices.

These findings translate into meaningful actions for industry adaptation and in turn provide a valuable step in accounting for climate variability and yield-related inputs such as fertiliser and water resources.

Additionally, our research contributed to work looking at the impact of large-scale climate modes on wheat production in Australia. The research, **published in Nature Food**, found that the influence of the tropical Pacific has decreased since the 1990s, while the impact of the Indian Ocean Dipole on Australian wheat yields has strengthened. These findings are critical for ensuring that seasonal forecasting adapts to the changing effects of climate variability on Australian agricultural yields.

Project 2

Why did the 2017 to 2020 drought in eastern Australia develop and what made it so impactful?

This case study has focused the combined efforts of the Drought research program with a diversity of research being done to define the characteristics, the small and large-scale drivers and the predictability of the Tinderbox Drought. For example, did interactions between the land and the atmosphere intensify the hot and dry extremes towards the end of the Tinderbox Drought and also during Australia's Black Summer fire disaster that punctuated the end of this severe drought?

Research led by Dr Mengyan Mu, **published in Weather and Climate Extremes** ,has found that groundwater plays an integral role in land-atmosphere interactions by connecting the sub-surface storage of water to transpiration via interactions with the root zone. The role of groundwater in moderating heatwave intensity has rarely been examined in coupled climate simulations, as many models overlook this key component of the water cycle. Dr Mu used a coupled land-atmosphere model with an explicit representation of groundwater dynamics to analyse three major heatwave events in south-east Australia.

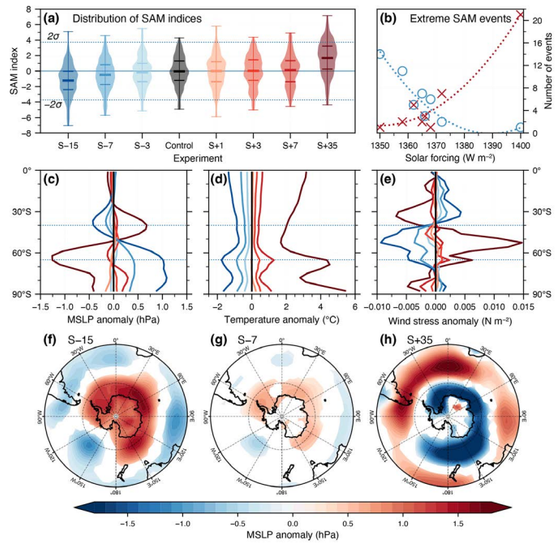
Groundwater moistens and cools the land surface, with impacts extending to the top of the atmospheric boundary layer during heatwaves. Associated with this cooling, there occurred an increase of net radiation and a reduction in the atmospheric boundary-layer height, primarily over areas with a shallow water-table depth and woody vegetation. The maximum air temperatures were reduced by up to 3 °C at the surface and up to 1 °C through the atmospheric boundary layer. The results point to an important influence of groundwater on heatwave intensity, implying the necessity of considering groundwater dynamics in climate models for future heatwave predictions.

Jon Cranko Page **also led Centre research** examining the time scales of carbon and water fluxes across Australian ecosystems. Although vegetation responds to climate at a wide range of time scales, models of the land-carbon sink often ignore responses that do not occur instantly. In this study, our researchers identified that carbon and water fluxes can be modelled more accurately if we include environmental drivers from up to a year in the past. The importance of antecedent conditions is related to ecosystem aridity but is also influenced by other factors.

Undergraduate summer scholar, Dejun Cai, published his research project in **Environmental Research Letters**. This work looked at cold fronts and identified a significant connection between cold fronts passing over south-east Australia and days of large fires burning across Australia's Black Summer. This type of connection has been demonstrated for individual fire days before, but this is the first time it has been demonstrated across an entire fire season. The work showed that the extreme cold-front conditions during the Black Summer were part of a long-term increase in the number and intensity of strong cold fronts passing over south-east Australia and that, if these trends continue, then fire-promoting weather conditions such as these will imminently move outside of the range of historical experience.

Research Snapshot

The Southern Annular Mode is a major mode of climate variability that influences climate extremes across the southern hemisphere, including drought in southern Australia. Proxy-based Southern Annular Mode reconstructions show large changes during the last millennium that current climate simulations don't reproduce. **Research led by Dr Nicky Wright** tested the Southern Annular Mode's sensitivity to solar forcing by using simulations with a range of constant solar values, and transient last millennium simulations with large amplitude solar variations. The work found that solar forcing can alter the Southern Annular Mode, and that transient simulations forced with a large amplitude option for solar forcing during the last millennium better match proxy-based reconstructions. The findings suggest that the effects of solar forcing on high-latitude climate may not be adequately incorporated in most last millennium simulations, due to solar irradiance changes that are too small and/or the absence of interactive atmospheric chemistry in global climate models.



Wright, N.M., Krause, C.E., Phipps, S.J., Boschat, G., Abram, N.J., 2022. Influence of long-term changes in solar irradiance forcing on the Southern Annular Mode. Climate of the Past 18, 1509–1528. https://doi.org/10.5194/cp-18-1509-2022

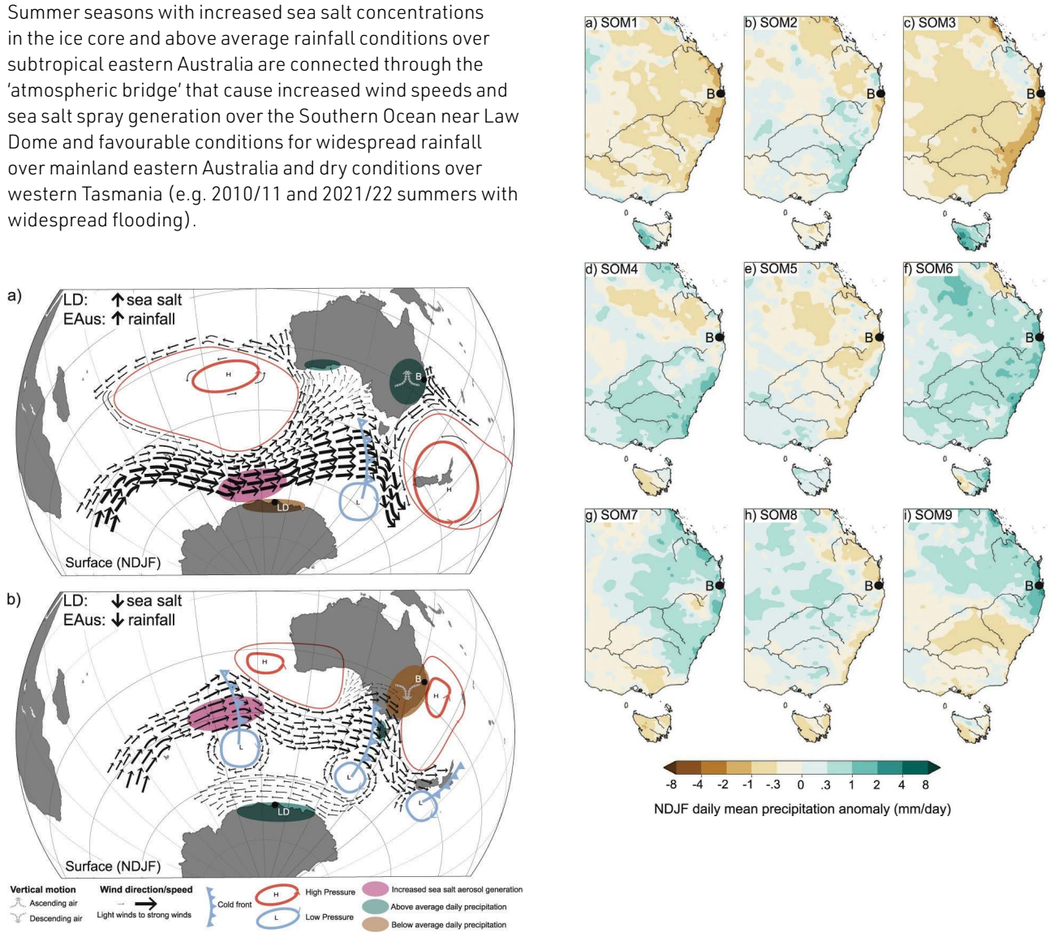
Research Snapshot

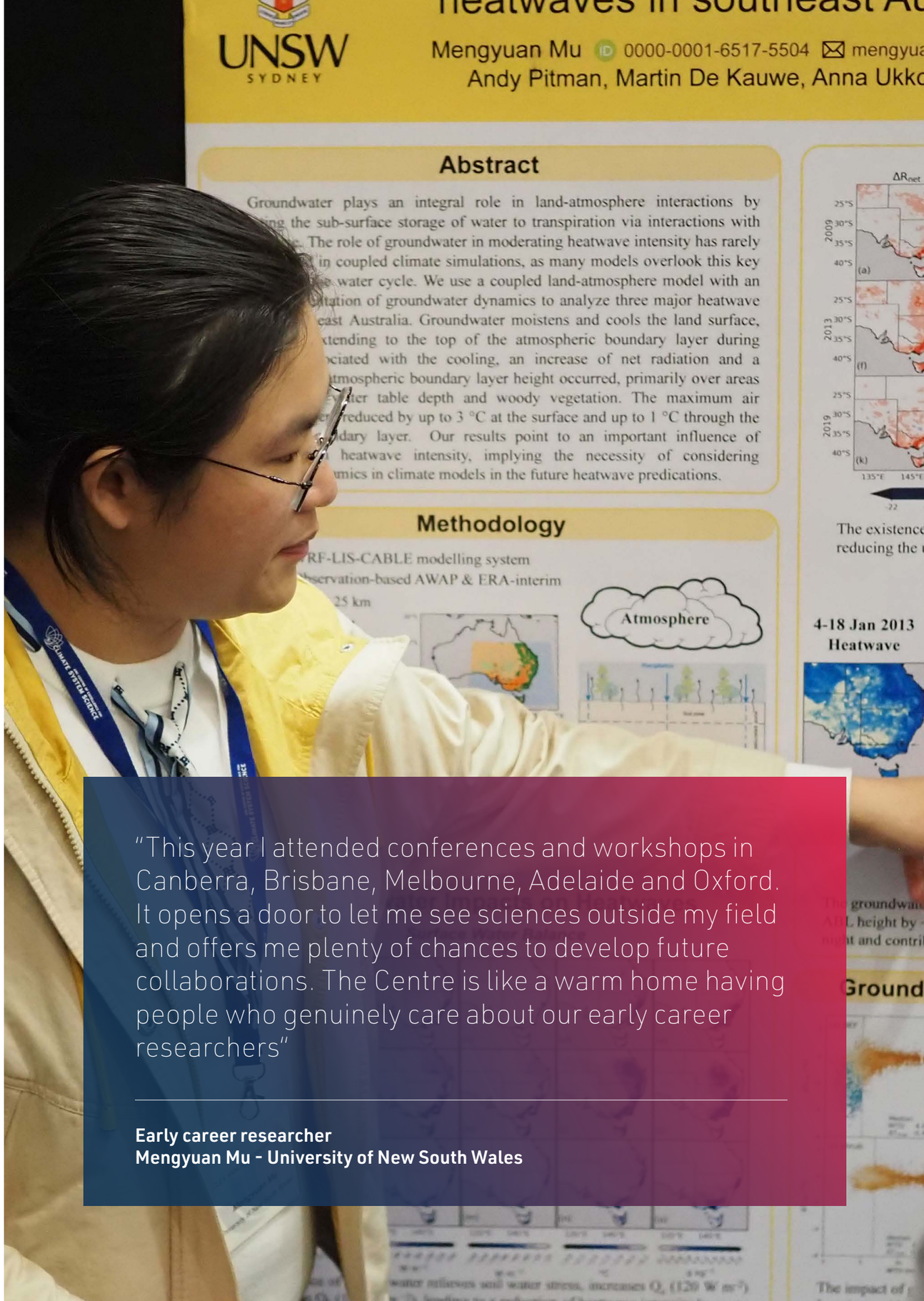
Australia's rainfall is highly variable and long-term (>100 years) observational records from rain gauges are limited, making it difficult to develop robust water policies and infrastructure that mitigates and adapts to future rainfall extremes. Relying solely on the severity of droughts and floods experienced since observations and meteorological record keeping began in Australia for water resource management decisions leaves communities, agriculture and industry vulnerable to infrastructure failure when the magnitude of future droughts or floods exceed previously experienced extremes.

In this paper **Danielle Udy led research** that uses a method called 'synoptic typing' to group combinations of synoptic-scale weather systems (e.g. high and low pressure systems) together to show that ice cores in East Antarctica and rainfall in Australia are connected by an 'atmospheric bridge'. Summer seasons with increased sea salt concentrations in the ice core and above average rainfall conditions over subtropical eastern Australia are connected through the 'atmospheric bridge' that cause increased wind speeds and sea salt spray generation over the Southern Ocean near Law Dome and favourable conditions for widespread rainfall over mainland eastern Australia and dry conditions over western Tasmania (e.g. 2010/11 and 2021/22 summers with widespread flooding).

In contrast, low sea salt concentrations in the ice core are associated with synoptic-scale weather systems that cause hot and dry conditions over mainland eastern Australia and cool and wet conditions over Tasmania (e.g. 2019/20 summer with severe bushfires). This study improves the understanding of the weather-scale processes linking the Law Dome ice core record to East Australian rainfall, which is vital for advancing how drought and flooding challenges are managed both currently and in the future.

Udy, D.G., Vance, T.R., Kiem, A.S., Holbrook, N.J., 2022. A synoptic bridge linking sea salt aerosol concentrations in East Antarctic snowfall to Australian rainfall. Commun Earth Environ 3, 175. https://doi.org/10.1038/s43247-022-00502-w





"This year I attended conferences and workshops in Canberra, Brisbane, Melbourne, Adelaide and Oxford. It opens a door to let me see sciences outside my field and offers me plenty of chances to develop future collaborations. The Centre is like a warm home having people who genuinely care about our early career researchers"

Early career researcher
Mengyuan Mu - University of New South Wales

Drought research program 2023 Statement of Intent	
Whole-of-research-program activities	• Publish a comprehensive assessment of the characteristics, drivers and predictability of the Tinderbox Drought • Conduct Pacemaker experiments to test the role of ocean variability on Australian climate risks • Improve the land surface model (CABLE) to alleviate biases during extended dry periods • Develop downscaling methods using deep learning approaches.
Project 1 activities What determines the onset, persistence and termination of drought?	• Determine how severe droughts in Australia could be, even without any climate change influence • Examine the processes and probability of drought-breaking rains in Australia • Establish the characteristics and predictability of multi-year drought in Australia.
Project 2 activities Why did the 2017 to 2020 drought in eastern Australia develop and what made it so impactful?	• Coordinate a special issue in Weather and Climate Extremes on the Tinderbox Drought • Assess changes in sources of moisture during the Tinderbox Drought • Complete a thorough analysis of observed characteristics of the Tinderbox Drought.
Engagement activities	• Prepare an industry and government symposium on the Tinderbox Drought • Write a series of briefing notes on drought • Continue industry engagement in Drought program meetings.

Ocean Extremes Research Program

The ARC Centre of Excellence for Climate Extremes' Ocean Extremes research program published a range of groundbreaking research keenly focused on our three research projects and the program continued significant interactions with policymakers and industry in 2022.

We have had a number of striking papers published. Some, like the paper that explored a massive phytoplankton bloom in the South Pacific, generated significant media coverage, while others had smaller media impact but a profound impact on our understanding of ocean processes. For example, research published in Geophysical Research Letters elaborated on our 2021 'bushfires and blooms' paper to explain how the recycling of dissolved iron, delivered by 2019-20 bushfire aerosols, helped to sustain a massive phytoplankton bloom in the Pacific sector of the Southern Ocean

On October 31 and November 1, 2022, students, researchers and stakeholders of the program gathered in Hobart and over Zoom to hold the second Ocean Extremes program workshop. The main objectives of the workshop were to get the Ocean Extremes team together; share current research and outline where it is going; facilitate collaborations in and around the Centre of Excellence; and foster dialogue with key marine stakeholders, to better understand their concerns and needs.

The workshop consisted of four key components: science sessions on observations, modelling and prediction, as well as presentations by colleagues with expertise in stakeholder engagement – namely, Richard Eccleston, Director of the Tasmanian Policy Exchange and Kathleen Beyer, from Climate Futures Tasmania.

Project 1

Marine heatwaves: How can we best model and predict marine heatwaves?

Ocean Extremes program researchers have developed a new catalogue of marine heatwave metrics and trends for the Australian region as well as a global multi-product of coastal marine heatwaves, which will provide valuable data sets against which to test model hindcasts (back predictions). Program researchers have also analysed modelled climate change projections of marine heatwaves across the tropical western and central Pacific Islands region, to better understand potential impacts on communities in the future.

New insights have been gained into the processes that produce shallow marine heatwaves, such as those that led to bleaching events over the Great Barrier Reef during cool La Niña periods. These insights will help forecast such events in the short term. Looking to the longer term, a high-resolution model investigation of marine heatwaves around Australia and New Zealand has revealed how climate change will alter local hotspots, showing warming impacts by the East Australian Current, around Tasmania and in waters close to New Zealand.

Project 2

Mesoscale ocean processes: How do marine heatwaves interact with other climate extremes?

There have been significant advances in this project. Highlights from 2022 include a comprehensive review of Indian Ocean systems and interactions, which is foundational to understanding the processes that generate ocean extremes; a paper highlighting the future impacts of warmer oceans on Antarctica; and another paper examining the processes in a warmer world that lead to amplification effects in certain areas that create marine heatwave hotspots here in Australia and around the world.

Project 3

Biogeochemistry: What are the current and future roles of mesoscale physics and biogeochemistry in the climate system?

Student publications were again the engine room of this project's achievements in 2022. Land-ocean connections were further explored, with more detailed analysis of the way in which the 2019-20 south-east Australia fires impacted ocean productivity. Deposition of fire aerosols onto the ocean surface, thousands of kilometres from the fires themselves, stimulated a phytoplankton bloom that was visible from space for months. Other student projects combined ship observations with autonomous platforms (satellites and floats) to look at the interaction of physics and ocean productivity in the sea ice zone and the Antarctic Circumpolar Current south of Tasmania.

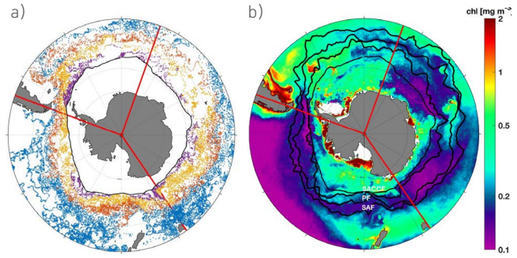
In the Antarctic Circumpolar Current, eddies were implicated as drivers of nutrient inputs to the surface from below. Close to the Antarctic continent, careful experiments quantified the importance of iron and light as regulators of productivity. And from several different approaches, mostly using data from biogeochemical Argo floats, large-scale analyses have contributed to an ongoing debate about the amount of productivity and carbon uptake occurring in the Southern Ocean, with implications for global carbon budgets.

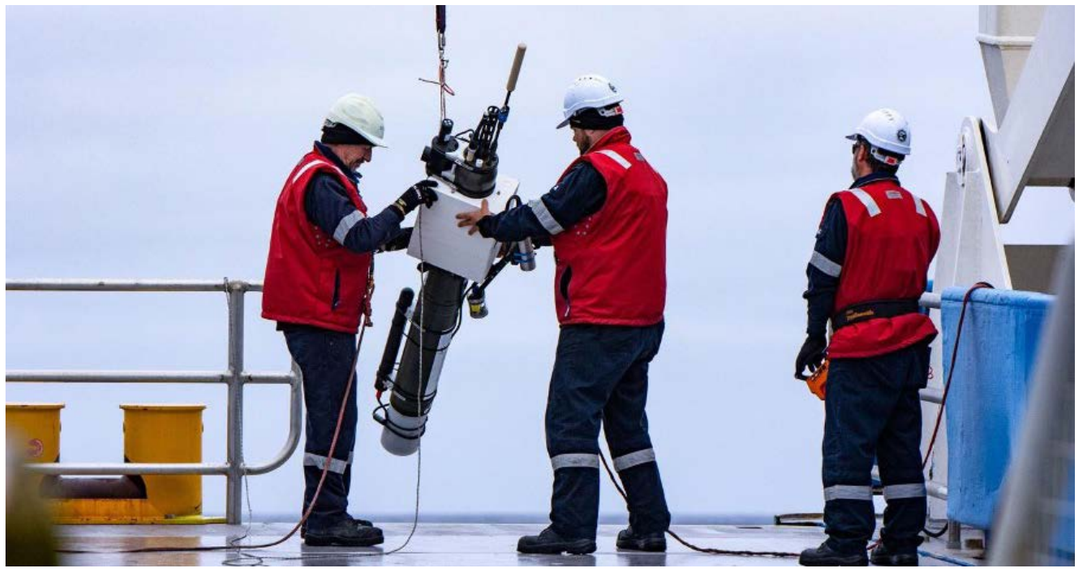
Research Snapshot

Annual net community production is the amount of biologically produced carbon available for export to the deep ocean. Ocean Extremes program researchers developed a novel approach to estimate annual net community production in the Southern Ocean, using robotic biogeochemical Argo (BGC-Argo) floats.

Using our improved method, we calculated total Southern Ocean annual net community production to be 3.89 billion tonnes of carbon per year. This estimate is much larger than previous estimates, which suggests a more important role than previously thought for the Southern Ocean in regulating oceanic carbon storage, atmospheric CO2 exchange and climate.

Su, J., Schallenberg, C., Rohr, T., Strutton, P.G., Phillips, H.E., 2022. New estimates of Southern Ocean annual net community production revealed by BGC-Argo floats. Geophysical Research Letters 49, e2021GL097372. https://doi.org/10.1029/2021GL097372





A BGC-Argo float is deployed from RV Investigator in January 2021. Credit: Jakob Weis.

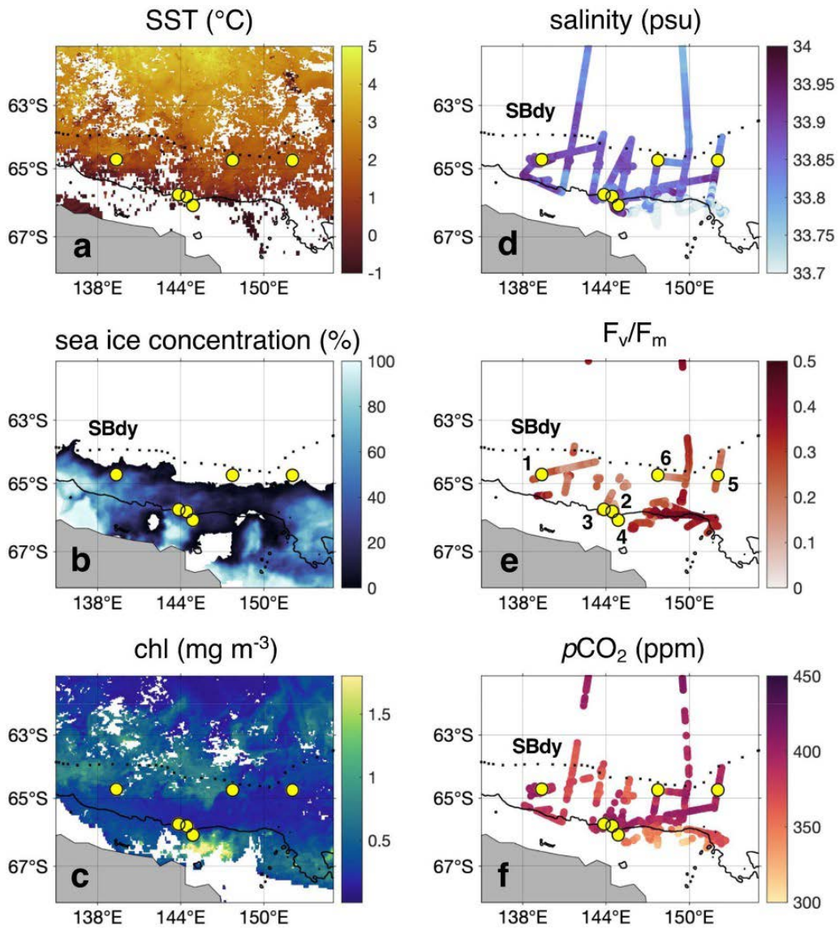
Research Snapshot

Phytoplankton, microscopic marine algae that photosynthesize, facilitate the sequestration of carbon dioxide from the atmosphere into the ocean, thus contributing to the regulation of global climate. In the Southern Ocean, phytoplankton productivity is limited by micronutrients, including iron.

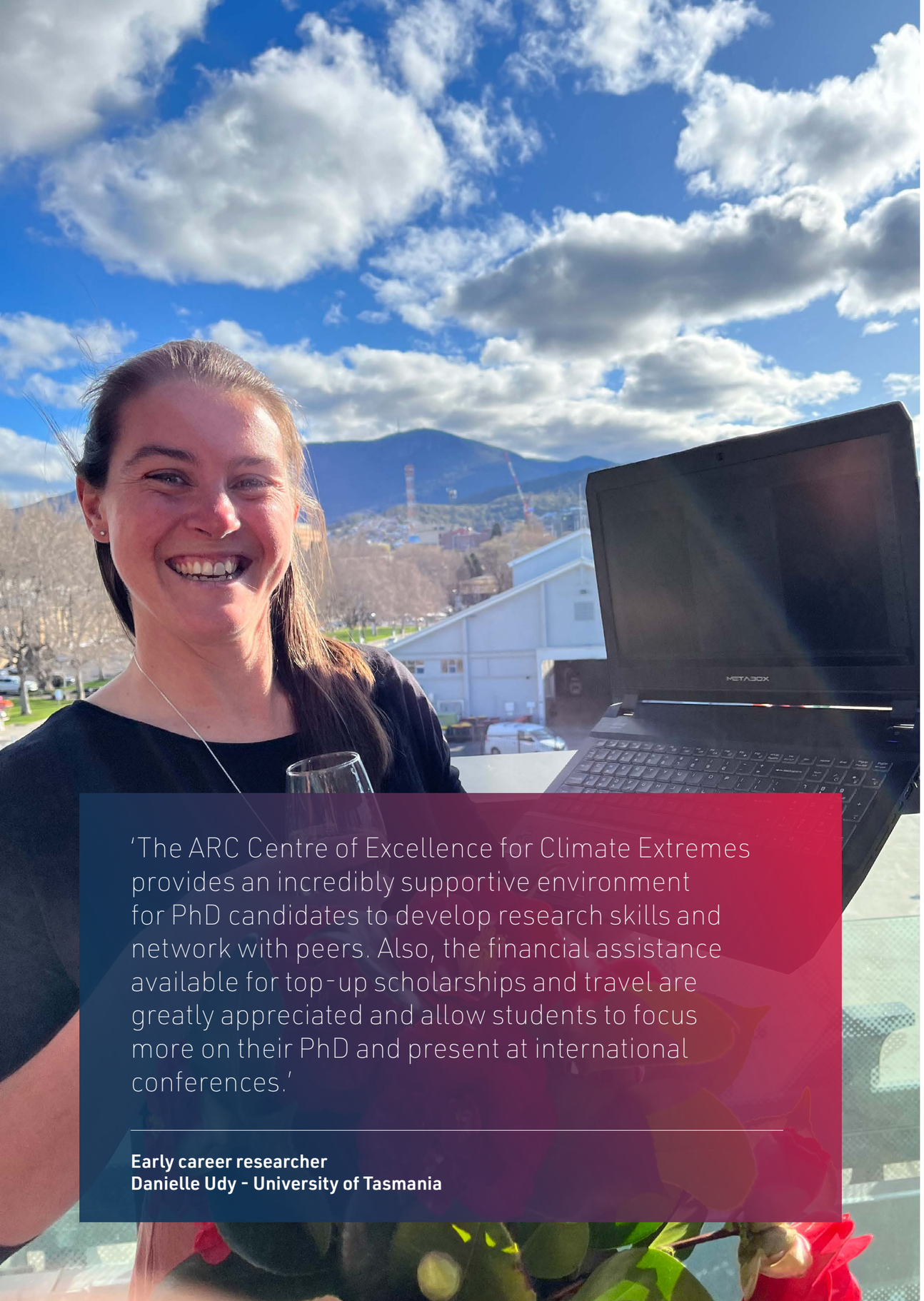
Light is also important, because it undergoes such strong seasonal extremes. The relative dominance of iron and light limitation on phytoplankton growth is important to our understanding of how primary production, and the sequestration of carbon dioxide, will change in a future warming ocean. Program researchers conducted a series of incubation experiments during a research voyage off East Antarctica to investigate iron and light limitation in the austral summer. Our results show that, while light was the primary limiting factor of phytoplankton growth, iron favoured growth only under high light conditions.

Our results provide new insight into these processes from a poorly sampled area of the Southern Ocean, improving our understanding of how phytoplankton production will change in the future.

Vives, C.R., Schallenberg, C., Strutton, P.G., Westwood, K.J., 2022. Iron and light limitation of phytoplankton growth off East Antarctica. Journal of Marine Systems 234, 103774. https://doi.org/10.1016/j.jmarsys.2022.103774



Ocean Extremes 2023 Statement of Intent	
Whole-of-research-program activities	• Improve understanding of marine heatwave dynamics and processes • Broaden the use of models and new observational data sets to address coupled physical-biogeochemical processes in the Southern Ocean and East Australian Current.
Project 1 activities How can we best model and predict marine heatwaves?	• Processes to predictability: Improve understanding of marine heatwave drivers and processes to inform predictability • Limiting extreme temperatures: Improve understanding of evaporation physics and its role in limiting ocean surface temperatures • Coastal and subsurface marine heatwaves: Improve understanding of structure, drivers and impacts of coastal and subsurface marine heatwaves, from model simulations and observations • Hazard and risk profiles: Develop hazard and risk profiles for marine heatwaves.
Project 2 activities What are the current and future roles of ocean physics and biogeochemistry in the climate system?	• Mesoscale physics and biogeochemistry: Characterise Southern Ocean eddies, fronts, meanders and internal waves to better understand impacts on heat and carbon fluxes, productivity and marine ecosystems • Large-scale physics and biogeochemistry: Improve understanding of heat and freshwater fluxes, Antarctic sea ice and water mass variability, multiscale dynamics, large-scale ocean/ice productivity, air-sea CO2 exchange and C export • Modelling: Conduct validation with observations, investigate spin-up properties, implement improvements needed for future runs, consider applications to understanding mostly Southern Ocean physics and biogeochemistry.
Engagement activities	• Hold marine heat waves-focused workshop in May-June 2023 • Hold Hackathon for ACCESS-OM2-01-BGC evaluation and analysis in February 2023 • Produce briefing note on ocean biogeochemistry, February 2023 • Contribute to the State of Weather and Climate Extremes report 2022 • Contribute to The Conversation articles and media releases associated with research papers and projects.



'The ARC Centre of Excellence for Climate Extremes provides an incredibly supportive environment for PhD candidates to develop research skills and network with peers. Also, the financial assistance available for top-up scholarships and travel are greatly appreciated and allow students to focus more on their PhD and present at international conferences.'

Early career researcher
Danielle Udy - University of Tasmania

Modelling Research Program

Numerical models of the weather and climate system are key research tools in gaining a deeper understanding of the mechanisms that generate climate extremes. They are also our primary tool in assessing how these extremes may be affected as our planet warms. The Modelling research program at the ARC Centre of Excellence for Climate Extremes is therefore an underpinning and enabling activity that develops improved simulations, tools and procedures for use in all research programs across the Centre.

Project 1

Global Coupled Modelling

in collaboration with our partners at CSIRO, the Modelling program has completed a 500-year present-day simulation of the Australian Community Climate and Earth System Simulator–Coupled Model 2 (ACCESS-CM2) climate model with an ocean component at a higher lateral resolution (0.25°) that allows eddies to be resolved across most of the globe. Work continues towards improving the eddy parameterization at high latitudes, where eddies are poorly resolved. Wilma Huneke commenced in a postdoctoral researcher role in 2022 to evaluate the new model and to investigate the effect of ocean resolution on decadal climate variability.

Project 2

Regional Atmospheric Modelling

In a project led by Dr Hooman Ayat, the ACCESS regional model has been run with the most up-to-date configurations over the Australian region, with approximately two-kilometre horizontal grid spacing (the Aus2200 project). Extensive testing has been performed to optimise the model configuration and setup. Initial simulations for the 2019/2020 megafire event have also been completed and evaluated. This is a real technical achievement.

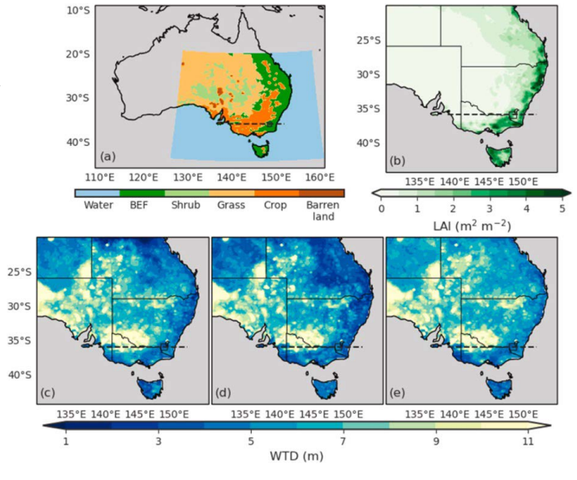
Dr Ayat has been using the simulations to explore the weather conditions that made the 2020 New Year's Eve fires in south-eastern Victoria so extreme. In particular, Dr Ayat has investigated the source of the extremely dry but localised air ahead of the approaching cold front, which is thought to have been an important contributor to the severity of the conditions. A paper on this is planned for 2023.

Project 3

Land-surface Modelling

The merging of new science undertaken by the Centre into the newest version of CABLE has continued. At the end of 2022 this version of CABLE was being evaluated against multiple sets of observations. In parallel, research has been published using key elements of this new version, which is focused on how groundwater influences the expression of drought and heatwaves in high-resolution regional climate simulations. This work demonstrated that groundwater could cool temperature extremes by up to 3 °C at the surface, which was not unexpected. However, because these simulations were conducted using a coupled land surface-atmospheric modelling system, the impact on temperature extremes could be evaluated within the atmosphere. Results showed changes of up to 1 °C through the atmospheric boundary layer. These results point to an important influence of groundwater on heatwave intensity, implying the necessity of considering groundwater dynamics in climate models in future heatwave predictions.

Mu, M., Pitman, A.J., De Kauwe, M.G., Ukkola, A.M., Ge, J., 2022. How do groundwater dynamics influence heatwaves in southeast Australia? Weather and Climate Extremes 37, 100479.
https://doi.org/10.1016/j.wace.2022.100479



Research Snapshot

In a world first, Centre postdoctoral researcher Dr Mat Lipson and colleagues partnered with Australian companies AURIN and Geoscape to transform the way cities can be integrated in weather and climate models. The research was enabled by a new generation of sub-metre urban morphology data sets covering entire continents and powered by machine learning, satellite imagery and remote sensing. From these new data sets they could, for the first time, configure our urban climate models across large geographical extents with unparalleled accuracy, from the 'bottom-up'. AURIN and Geoscape are the developers of the only continental-scale building-resolving data set available in the world, which includes the shape and height of every building in Australia larger than nine square metres (a small bedroom), as well as the land cover of all Australian urban areas at two-metre resolution.

From this valuable Geoscape data the collaborators derived new data sets for Sydney and Melbourne, with 25 parameters used to configure slab, canyon or block-array urban land surface models. We negotiated with Geoscape to make the derived Sydney data openly available at 300-metre resolution, which makes it suitable for high-resolution urban climate modelling.

This bottom-up approach is in stark contrast to the top-down or class-based methods traditionally used to configure urban models since the beginning of the field 50 years ago. The authors compare the latest top-down methods (for example, the 10-class Local Climate Zones) with their bottom-up approach, and they provide tables of adjusted parameter values that are more appropriate for modelling, using classes in Australian cities. They discuss the future of top-down versus bottom-up methods of configuring urban models and predict that bottom-up will come to replace top-down as consistent building-resolving data sets become more widely available globally in coming years.

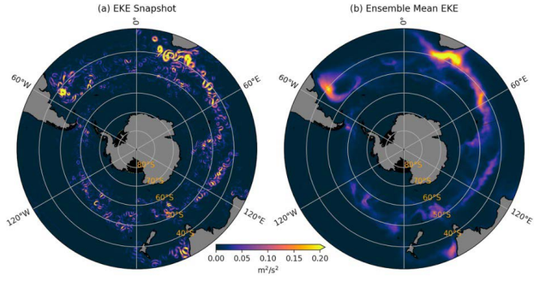
Lipson, M.J., Nazarian, N., Hart, M.A., Nice, K.A., Conroy, B., 2022. A Transformation in City-Descriptive Input Data for Urban Climate Models. Frontiers in Environmental Science 10, 866398.
https://doi.org/10.3389/fenvs.2022.866398

Research Snapshot

The Southern Ocean is the most turbulent part of the world's oceans. This turbulence, often referred to as eddies, is critical to the evolution of the Southern Ocean under climate change. But it's hard to get information about these eddies, because they occur on small scales in a large ocean basin that is poorly observed. In addition, the observational record is quite short, which makes it more difficult to use these observations to study what controls variations of these eddies. For this reason, Centre Chief Investigator Professor Andy Hogg and colleagues used an eddy-permitting ocean model and ran it 50 times with the same prescribed surface winds but slightly different initial states.

The chaotic nature of the turbulent ocean means that these model runs exhibit different evolutions. So the simulations were used to study which eddy processes occur as a consequence of the chaotic nature of turbulence and which are forced by the external factors that are common to all model runs, such as the winds. The collaborators concluded that monthly-to-interannual fluctuations of the Southern Ocean eddy field are dominated by chaotic processes, but that the forced variability responds to wind on particular time scales that are controlled by the mechanisms that generate ocean turbulence.

Hogg, A.McC., Penduff, T., Close, S.E., Dewar, W.K., Constantinou, N.C., Martínez-Moreno, J., 2022. Circumpolar Variations in the Chaotic Nature of Southern Ocean Eddy Dynamics. Journal of Geophysical Research: Oceans 127, e2022JC018440.
https://doi.org/10.1029/2022JC018440



'I'm really grateful for the way that the Centre puts so much emphasis on building a skill set that would be applicable not only to academia, if one wanted to continue in science, but also to apply your science in industry in other ways that are going to contribute. I'm really grateful for just how much support the Centre has given us young early career researchers.'

Early career researcher
Ashley Barnes - Australian National University

Modelling 2023 Statement of Intent	
Whole-of-research-program activities	• Provide modelling and model-analysis tools • Provide bespoke model experiments to support the research activities throughout the Centre community.
Project 1 activities Global Coupled Modelling	• Run a new 500-year simulation with ACCESS-CM2 at 0.25° ocean resolution with improved eddy at high latitudes • Run an Antarctic freshwater forcing experiment with ACCESS-CM2 at 1° ocean resolution as a contribution to the international Southern Ocean Freshwater Release Model Experiments Initiative.
Project 2 activities Atmospheric Regional Modelling	• Continue to improve the Aus2200 modelling suite, with progress towards greater flexibility and efficiency • Develop the ability to choose boundary conditions from ERA5, ERA5LAND and/or BARRA(-2) with flexible domain size and time frame • Document the model and experiment set-up • Run the model for key 2019/2020 weather events and possibly for the full year of 2019 (with support from the CMS team and ACCESS-NRI) • Develop a platform/system to capture, advertise, document and evaluate available cases through engagement with the wider community.
Project 3 activities Land Surface Modelling	• Continue joint development of JULES-and-CABLE modelling framework and benchmarking platform (modelevaluation.org) with the UK Met Office.
Engagement activities	• Deepen the collaboration between the ACCESS-NRI initiative and the Centre • Produce a series of briefing notes on climate models and their applications.

Computational Modelling Systems

The year 2022 has been a big one for the Computational Modelling Systems (CMS) team. We have seen some of our colleagues leave, after many years of working together; Paola Petrelli stepped up as the new CMS team leader; and we welcomed three new members: Ramzi Kutteh, Sam Green and Dale Roberts.

A year has passed that has felt busy and intense; but at the end of it, what have we done? When you are in a support role – as our team is – it is hard to quantify your work. We facilitate other people's research outcomes, with contributions which are sometimes small and sometimes big.

During this period of transition in team members we still worked on specific projects, whose outcomes are detailed below. However, our biggest outcome was the continuous support we offered the researchers and students at the Australian Research Council (ARC) Centre of Excellence for Climate Extremes..

In the last calendar year we resolved more than 300 requests for help on the National Computational Infrastructure Climate and Weather helpdesk. The helpdesk requests cover a vast range of tasks: Someone might be looking for guidance, troubleshooting an analysis code, solving an issue with a model configuration, downloading or publishing a data set – and much more. While some of the answers to these questions might be quick, they all help someone in progressing with their research project.

We also offer hands-on help via one-on-one meetings and weekly Code Break sessions. Anyone can come to a Code Break session to ask a question or get help with a code. These sessions allow us not only to solve the specific issue the researchers came for, but also to offer them some personalised advice. For the last few months, we used the Code Break sessions to offer short, focused training at the start. Every week we cover a different topic, and we allow time for questions.

Both the helpdesk and the Code Break sessions give us an important insight into the research work which is happening at the Centre. They are our main contact with the researchers and students and a source of inspiration to decide future goals and longer-term projects. They help us identify areas for improvements in the available infrastructure and documentation. We can react quickly by offering new or improved code, documenting new model configurations and other processes and providing new data sets and services.

Some of the projects described below, such as the machine learning and the FrontDetection code collaborations, were identified and developed in this way. In particular, the use of machine learning in climate-related projects is growing across our research community and the international community, so the team is also training to support more of these projects in the future.

This year the Australian Community Climate and Earth System Simulator National Research Infrastructure (ACCESS-NRI), a computer modelling framework to support research with the ACCESS model was established. As the NRI's modelling partly overlaps with ours, the CMS team has started meeting with them to identify areas of common interest as well as collaboration opportunities. In some cases, as with the Community Atmosphere Biosphere Land Exchange (CABLE) model, we are already working in partnership. Some of the services we maintain are of interest to the NRI and we are reviewing and consolidating them. They include the conda environments, the analytics database and our wiki-based documentation.

In fact, the reorganisation of our services, in view of the ARC Centre of Excellence for Climate Extremes moving towards the end of its funding period, has been a major focus for this year. It is important for us to have a long-term strategy so that the services and documentation we built for the last decade will survive, and wherever possible, to move to a community-based model.

We are trying to achieve this by relocating our documentation to new community- and/or project-based platforms and out of the current CMS wiki, which is UNSW based.

This is giving us a chance to also review and update content and to augment its relevance by making it more relevant to any researcher in the climate science community. Part of this work is happening in collaboration with other experts from CSIRO and the Bureau of Meteorology, as the documentation aims to build a best practice for the entire climate community.

Highlights

CABLE Groundwater Module

Dr Mengyuan Mu made some contributions to the CABLE model groundwater module. Dr Ramzi Kutteh was given the task of integrating these into the official version of the model code, as a two-phase project. The first phase involved implementing Dr Mu's work into the last version of CABLE, preceding a significant recent refactoring of the code.

This is now completed and the code has been successfully compiled and run for a simple test. Currently, more testing and validation is under way and, once this is completed, the second phase will involve the final integration into the latest refactored version of CABLE.

Alongside this task, Dr Kutteh is also participating in the CABLE model documentation project. This is led by the ACCESS-NRI CABLE team and it is an important and significant effort to improve the usability and provenance of this model.

Australian Community Reference Climate Data Collection @ the National Computational Infrastructure

In July 2022 the new **Australian Community Reference Climate Data Collection @ the National Computational Infrastructure (NCI**) was launched in collaboration with the Australian Climate Service, to reestablish and maintain a reference climate data set collection at NCI. Currently, the collection contains precipitation data sets, climate indices and some sea-surface temperature data sets. The data is hosted in the NCI **project ia39** and can be accessed directly or programmatically using a Python **Intake catalogue** developed by Paola and Sam.

While some of these data sets were already available in one of the ARC Centre of Excellence for Climate Extremes projects, moving them to a longer-term project and sharing their maintenance with others in the climate community is an important step to ensure that the data will be available to the research community past the Centre's life. It also gave us a chance to review our processes, making them more robust and transparent.

FrontDetection Code

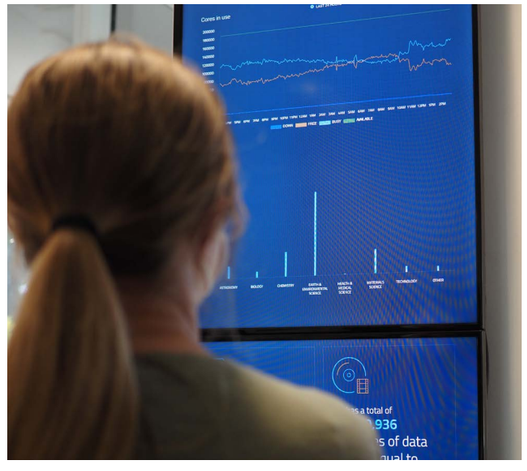
The FrontDetection is a Python-based module to detect atmospheric fronts, initially developed by Dr Malcom King. Various members of the team collaborated with Dr King to improve the code, and this year a new, improved version was released by Sam Green. The refactored code is now faster and more robust, and tests have been added so future changes that might affect the code reliability will be picked up and solved more easily.

Sam also improved the code documentation and added a tutorial explaining how to run a test case and produce plots. This code is now published on Zenodo and on part of the Centre of Excellence for Climate Extremes code collection.

Optimisation of a Machine-Learning Downscaling Climate Model

Sam Green helped Dr Sanaa Hobeichi and her UNSW group to speed up a downscaling climate model using a GPU-enabled machine learning algorithm. Dr Hobeichi developed the original code, but this was using only one GPU, so she needed some help to parallelise it.

Sam hadn't used machine learning himself before this task, so he learned on the job through an online course and documentation. He also attended a NVIDIA-organised hackathon with Dr Hoebeichi. Sam improved the way the data was loaded by the code, so the data is now loaded only on GPUs, which was necessary to effectively scale the code. At the hackathon, Sam and Dr Hoebeichi learned how to profile the code, identifying other bottlenecks, which brought them to refactor the code to remove repetition and to run four instead of only one process per GPU. The next step will be to make the code run on multiple GPUs. The pair will also collaborate to produce a climate change machine learning tutorial for the NCI machine learning course series in 2023.



New Improved Documentation Resources

Paola Petrelli has been working on two collaborative projects to create new resources for the Australian climate community, both built using JupyterBook. This Python-based software allows anyone to build online books from a simple GitHUb repository. It is easy to contribute and there is no need to host a website.

The first of these projects, a handbook titled **Climate Dataset Guidelines**, provides guidelines for creating, managing, sharing and publishing climate data. With a focus on Australian climate research, this handbook has been designed to enable a common approach across the community. The handbook also includes a lot of practical tips on technical aspects of data management. The second project, a report titled **Working with Big and Challenging Data Collections**, focuses on solving challenges posed by analysing climate data which is ever-increasing in size and complexity. It covers topics from the basic knowledge necessary to understand how the data is structured and how this affects analysis, to useful analysis techniques and software, including a review of all platforms and tools available in an Australian context.

A One-stop Catalogue to Discover Climate Data in Australia

In 2021 Paola Petrelli co-hosted a climate-data-related workshop at the Australian Meteorological and Oceanographic Society conference. One of the main findings was that the climate science community struggled with finding data sets and other resources, as each organisation involved in the science uses different portals to share their data, and lots of data (as replicated data sets) are not even listed anywhere. A collaborative working group was then established to explore solutions to this problem.

This is how the **Australian Climate Data Guide Catalogue** was born. The portal is open to anyone looking for climate data sets and other resources (such as software, online resources and training) available in Australia. The portal lists information on the resources, with links to their official documentation where it exists. The portal is based on the Invenio Research Data Management package, but Paola configured it and adapted it to introduce climate-related search capabilities. We are currently **seeking feedback** before finalising the portal for production. While the portal's main aim is to list resources for climate researchers, it has the potential to be expanded to also include resources useful to stakeholders.

Connecting climate science to Australians & beyond

What is Engagement and Impact at the ARC Centre of Excellence for Climate Extremes?

Climate science is a fundamental part of protecting and preparing communities from the extremes of climate change. Floods, fires, heatwaves, storms, rising oceans - extreme events - need to be understood as part of a bigger picture.

Climate scientists are being asked to provide projections and advice to help governments, industry and decision-makers prepare for the decades to come. We need to be able to look ahead and plan for the future.

The Engagement and Impact team at the ARC Centre of Excellence for Climate Extremes brings together some of Australia's most talented policymakers, media and communications specialists, science communicators, content makers, designers and more, to ensure that the essential science of climate extremes is heard by the people who need to know.

We train researchers in engagement and impact skills so they can be recognised by decision-makers as: Trusted, Respected, Legitimate, Credible,Reputable

Researchers gain this by:

- Providing expert comment to international and Australian media.
- Making submissions to government inquiries and processes
- Producing and appearing in web and social media content
- Meeting with decision-makers directly, to educate them about climate science
- Producing resources for school teachers to incorporate climate science.

The Engagement and Impact team provides the training, structure and support that enables Centre researchers to undertake these activities now and well into the future.

Case Study: Rapid Rain Bursts in Sydney

When researchers at the ARC Centre of Excellence for Climate Extremes discovered that rapid rain bursts in Sydney had intensified by 40 percent in two decades, it caught the attention of the prestigious journal *Science*.

With Science's publication impending, the Centre's Engagement and Impact team snapped into action, working with the researchers to do as follows:

- Brainstorm ways to simplify the scientific concepts for public audiences, such as defining the term "rapid rain bursts" for easier public understanding
- Produce **video and photographic content** to explain the research and its implications for media and social media use
- Write an opinion piece for **The Conversation**
- Collaborate with the Australian Science Media Centre
- Produce a briefing for politicians and policymakers in local, state and federal governments explaining the implications of the research
- Practice and conduct media training on presenting the research
- Create two targeted media releases – one explaining the research for international audiences and the other for Sydney audiences.

The Results

The rapid rain bursts media story received over 370 media mentions from Australian and international media, reaching a potential audience of more than 13 million people.

The importance of the research was recognised by the Hon Steph Cooke, New South Wales Minister for Emergency Services, who said:

'Rapid rain bursts can happen in just 10 minutes and overwhelm roads and drainage systems. I'm sure we can all recall a time this year when we've been driving through Sydney and seen such unexpected flash flooding. These researchers developed a new technique which used weather radar data from overlapping radar to track trends in rainfall extremes. According to co-author Professor Steven Sherwood, governments, councils, city planners and communities need to prepare more for the possibility that rapid rain bursts will get more and more extreme and I'd encourage you to do just that.'

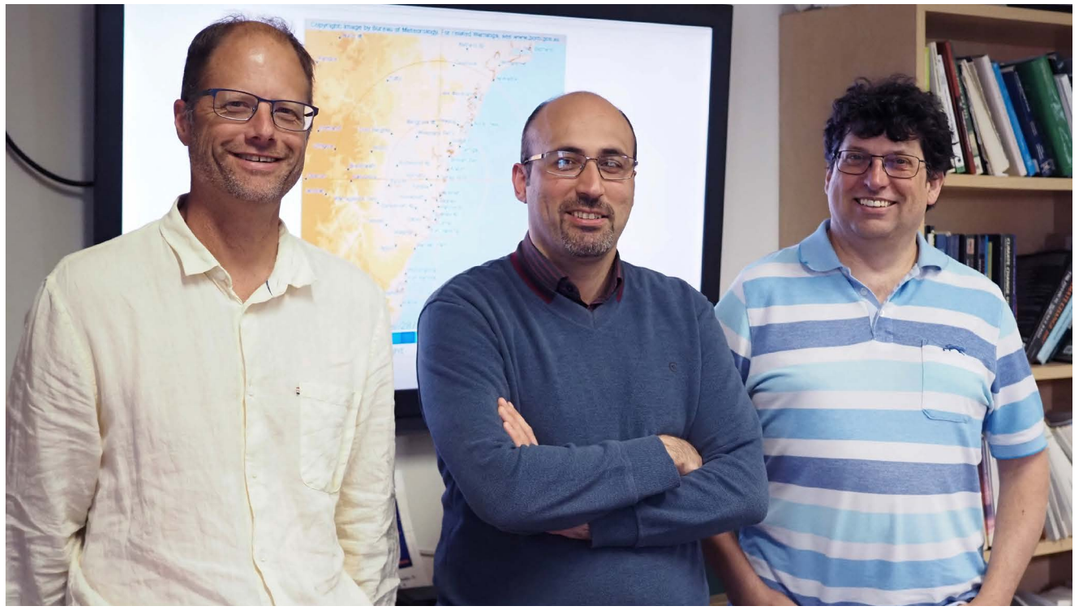
– The Hon Steph Cooke, New South Wales Minister for Emergency Services

The research was also highlighted at the 2022 annual lecture of the Peter Cullen Trust, a foundation which works with scientists, policymakers and political leaders to bridge science, people and the environment via funding and facilitating programs that contribute to improved rural and urban water management in Australia. The lecture was given by Rachel Connell, Division Head, Water Reform Taskforce, federal Department of Climate Change, Energy, the Environment and Water.

'For me, clear, trusted science, modelling and monitoring will be critical to guiding and implementing water reform. There is some great science being done in Australia, and we need it to continue to push the boundaries. Last week researchers at the ARC Centre of Excellence for Climate Extremes had research published in the journal Science which pioneers a new technique using weather radar data to identify rapid rain bursts. Rain bursts are destructive short bursts of rain that overwhelm roads, gutters and drainage systems in as little as 10 minutes. Until now, it has been difficult for climate scientists to identify changes in rapid rain bursts due to limitations in rain gauges, satellite data and climate models. The researchers identified thousands of rapid rain bursts over Sydney using weather radar data over two decades. They found that the most severe rapid rain bursts had intensified by 40 percent over Sydney during this period – a phenomenon not explained by regular climate processes.'

– Rachel Connell, Division Head, Water Reform Taskforce, federal Department of Climate Change, Energy, the Environment and Water.

The researchers are now encouraging other researchers around the world to adopt their pioneering technique using weather radar data to help their communities plan for the future.



How we Connected with the Community and Decision-Makers in 2022

January

As Australia's east coast experienced heavy wind and rains and the Northern Hemisphere faced some of the most extreme heatwaves ever seen, Dr Andrew King provided an **important summary of what happened with climate extremes in 2021** and of what was set to come in 2022, for The Conversation.

February

Dr Nina Ridder explained the role that La Niña and climate change played in Australia's ongoing flooding situation for **international audiences in The New Scientist.**

March

The inaugural **State of Weather and Climate Extremes report** was released, drawing on the Centre's experts across floods, droughts, oceans, climate modelling and more, to help decision-makers understand the science of Australia's climate extremes in 2021.

April

The Centre's climate scientists worked with school teachers on Climate Classrooms - **producing free resources** to help teachers incorporate climate science into their classrooms and the curriculum.

May

Dr Tess Parker and Dr Michael Barnes **explained what caused Australia's extreme rainfall in early 2022** in The Conversation.

June

Dr Zoe Gillett collaborated on a **briefing note** for decision-makers on the implications of multi-year La Niña events. Dr Gillett **then shared those findings with the community** through a wide range of media outlets, becoming one of Australia's "go-to" commentators on La Niña events.

July

The Centre's researchers hosted a **live stream Q&A for the agriculture industry**, answering the industry's most pressing questions about climate science.

August

Centre experts made a submission to the Climate Change Bill 2022 and Climate Change (Consequential) Amendments Bill 2022 in Federal Parliament, leading to Professor Nerilie Abram appearing in the Australian Senate as an expert witness for the **Australian Senate Environment and Communications Committee.**

September

The Centre led global discussions regarding the role of compound events (multiple extreme climate/weather events that influence each other), releasing the briefing note, **High-impact compound events in Australia.**

October

Members of the Centre's Drought research program learned about federal water policy in the Murray-Darling Basin – and the issues policymakers are grappling with – from a former director of Environmental Water Policy.

November

The Engagement and Impact team worked with Year 9 students at Camberwell High, in Melbourne's east, to teach students about science communication skills.

December

The Engagement and Impact Team supported our early career researchers to make a submission to the Australian Higher Education review, focusing on financial support for students.

Case Study: The State of Weather and Climate Extremes Report

The inaugural State of Weather and Climate Extremes report released by the ARC Centre of Excellence for Climate Extremes in March 2022 was a vital summary of the science behind Australia's extremes in the year prior.

Importantly, **the report** was a collaborative work between 12 of the Centre's key researchers and experts, among them early career researchers who are leading many of the new discoveries vital to Australia's scientific understanding of weather and climate extremes.

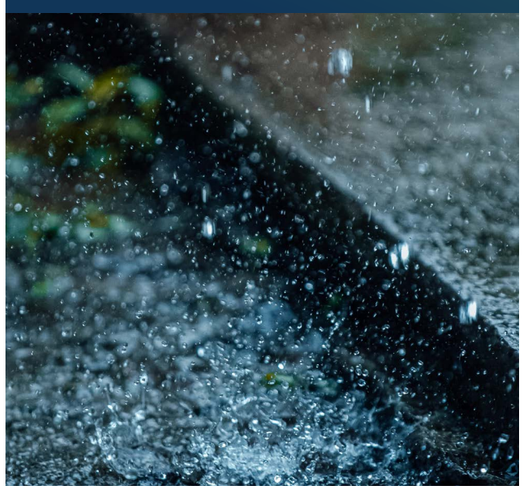
With a new federal government in mid 2022, there was a greater focus on climate change issues and strengthening the role of the Climate Change Authority. It was apparent that an annual progress report was required to provide advice to the Minister for Climate Change and Energy.

We provided an updated report, giving vital scientific backing to the **Climate Change Authority report** which was subsequently tabled to the Federal Parliament.

'The synthesis of weather and climate extremes for the financial year 2021-2022 was timely and comprehensive. Having that synthesis to refer to in our Annual Progress Report to the Government helped ensure our advice on climate change was based on the most rigorous and up-to-date science available. The Centre was responsive and flexible in preparing the report. We hope we can continue to work together to shape evidence-based advice to Government on climate change.'

– Brad Archer, CEO,
Climate Change Authority

The Centre's provision of information forms the basis of an ongoing relationship with the Climate Change Authority to provide annual advice on the physical impacts of climate change.



Research Snapshot: Frontiers for Young Minds

In an article for Frontiers for Young Minds, an open-access journal written by scientists and reviewed by kids and teens, Centre Chief Investigators Dr Amelie Meyer and Associate Professor Sarah Perkins-Kirkpatrick joined forces with colleagues around the world to explain weather and climate extremes to young readers. The article highlights that extreme climate and weather events are unusual and rare events that often cause a lot of damage both to nature and to people.

Meyer, A., Bresson, H., Gorodetskaya, I., Harris, R., Perkins-Kirkpatrick, S., 2022. Extreme Climate and Weather Events in a Warmer World. Frontiers for Young Minds 10, 682759. https://doi.org/10.3389/frym.2022.682759

Credit: Frontiers for Young Minds

Case Study: Climate Science in Schools

The Centre of Excellence delivered a free Climate Classrooms workshop in April 2022 for teachers in Sydney as part of its commitment to empower high school teachers to bring the science of climate change – and its extremes – into the classroom.

The Centre's PhD students worked closely with teachers and curriculum advisors to develop teaching resources that use the latest climate research and data to teach areas of the Science, Technology, Engineering and Mathematics curriculum.

We **developed and published** a digital technology lesson plan, Climate data visualisation in R, for Years 9-10, and a maths lesson plan, Data representation and interpretation of our future climate, for Years 11-12, in line with the Australian Curriculum. We led these efforts in collaboration with the Monash Climate Change Communication Research Hub.

We also worked with Pymble Ladies' College to design learning material for Australia's first school Data Science course. We contributed tutorials, assessments, project ideas and data sets for the course.

Climate Classrooms is a joint initiative of the ARC Centre of Excellence for Climate Extremes and the Monash Climate Change Communication Research Hub. It aims to help teachers to teach concepts in climate science along with the core Australian secondary curriculum in Science, Technology, Engineering and Mathematics (STEM).

What's Ahead

Engagement and Impact Strategy 2022-2024

In 2022 the Engagement and Impact team at the ARC Centre of Excellence changed significantly, with four new engagement and impact experts coming into the organisation and the previous team departing for new opportunities. Building on the previous team's strategy, the new team refocused the Centre's activities to build a long-lasting legacy for the Centre and its experts.

Engagement and Impact Team 2022-2024

Purpose

- **Invest in long term skills.** We can provide access to and support the development of skills in engagement and impact through practical actions and examples.
- **Create opportunities.** We will create platforms, publications and opportunities for Centre experts to showcase their research and be recognised for their engagement and impact skills.
- **Boost confidence.** We will help Centre researchers to feel confident engaging with Government, policy makers, media and industry and how they can do small actions to make their communications more impactful.
- **Celebrate the Centre and our people**. As the Centre comes to a close we will make sure our people and their research is celebrated and recognised.

Our Support

- We will refine the previous Engagement and Impact team's priorities, meeting our promises to our funders, partners and community, while re-focusing on the most effective use of our skills and resources.
- Researchers will have increased their confidence in how to engage in their work and make an impact with stakeholders so that they can continue to show the impact of their research well into the future.
- Researchers can take forward a body of engagement activities and material which exhibits and highlights their skills at the end of the Centre.
- We will provide and prioritise activities that cement the Centre's long term legacy.

Priorities 2022-2024

Influential Voices	Creating a profile for the Centre and its researchers to be known as: Trusted, Respected, Legitimate, Credible, Reputable.
Research Engagement	Build ties and connections with Government, Industry and policy makers. Create writing skills opportunities through evergreen content, reactive content and media skills.
Schools Engagement	Climate classrooms workshops + educational resources.

Case Study: Finance Sector and Financial Risk

The Centre of Excellence has a long-term strategy to support an uplift in the understanding within the finance sector of climate risk.

In this context, "finance sector" includes regulators, banks, Treasury (federal and state) reinsurers and insurers. However, as recognition of climate risk and business grows, and as regulators encourage business to consider climate risk, the breadth of interested organisations grows.

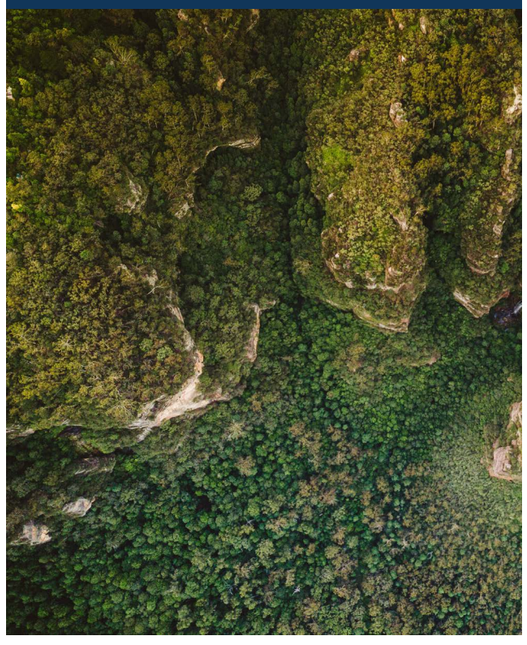
The Centre's engagement in this area has been led by Professor Andy Pitman, supported by several Chief Investigators, including Professor Christian Jakob, Associate Professor Gab Abramowitz and Associate Professor Sarah Perkins-Kirkpatrick. Strong collaboration with colleagues at the University of Sydney, in particular Dr Tanya Fiedler, has been instrumental.

To build a profile and support our engagement in this area, two academic papers with very high impact have been published:

- Fiedler, T., Pitman, A.J., Mackenzie, K., Wood, N., Jakob, C., and Perkins-Kirkpatrick, S.E., 2021. Business risk and the emergence of climate analytics. Nature Climate Change, 11, 87–94, doi: **https://doi.org/10.1038/s41558-020-00984-6**
- Pitman, A.J., Fiedler, T., Ranger, N., Jakob, C., Ridder, N., Perkins-Kirkpatrick, S.E., Wood, N., and Abramowitz, G., 2022. Acute climate risks in the financial system: examining the utility of climate model projections. Environmental Research: Climate, **https://doi.org/10.1088/2752-5295/ac856f**

The first of these papers has already been cited 76 times and downloaded over 9,000 times. It is in the 99th percentile of tracked articles of a similar age in all journals (Altmetric).

The second paper was downloaded over 2,000 times in the first 30 days following publication.



More importantly, in the context of engaging with regulators, these papers have been central in briefings with the US Securities Exchange Commission, the Australian Prudential Regulation Authority, the US Federal Reserve, the Monetary Authority of Singapore, UBS and many others. A growing Linkedin profile has helped us communicate this work directly to business. We included our perspective on financial risk in tweets and Linkedin posts associated with the 27th Conference of the Parties (COP27).

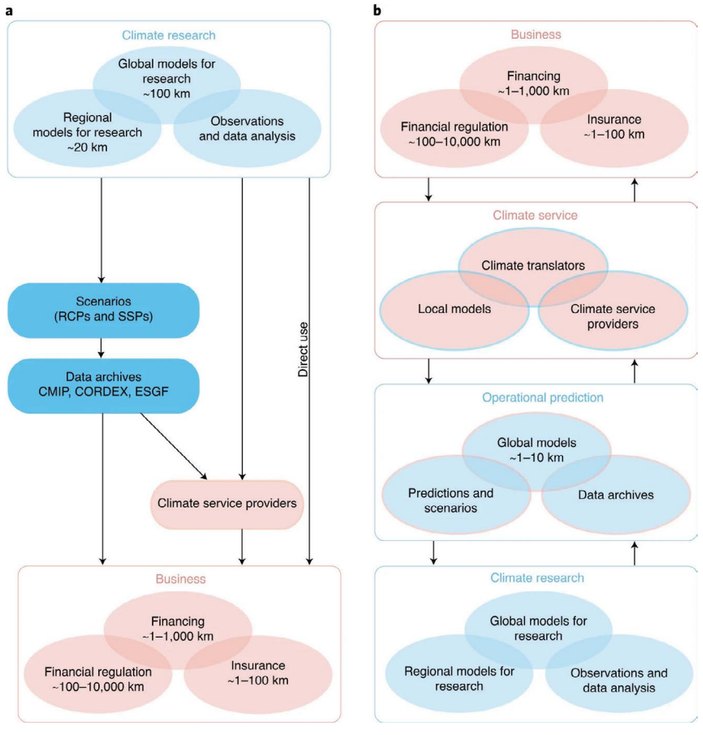
Our approach to helping communicate climate risk to the financial sector has received widespread coverage, including in the Sydney Morning Herald and The Australian.

Our work has also been picked up by **industry blogs**, and formed the basis of **industry briefings** (including by **Yale**), the **Governance Institute of Australia** and many more.

An emerging strategy to become a contributor to "thought leadership" across industry is particularly important, as business will tend to listen to those within the sector rather than academics. Our initial engagement here has included the following report:

- Wood, N., Pui, A., Pitman, A.J., Evans, J., Aellen, N., Auestad, H., 2022. Treating Climate Uncertainties as Knowable Risks – a Recipe for Greenwash? Joint report by Energetics, Swiss Re and ARC Centre of Excellence for Climate Extremes, **https://www.energetics.com.au/insights/thought-leadership/experts-warn-current-approaches-to-assessing-physical-climate-impacts-are-flawed**

Supporting a general uplift is one thing, but actually changing how climate risk is managed by business is different, given pressures from regulators, investors and so on. It is far easier for a business to undertake a superficial or misleading risk assessment that satisfies the regulators, than to invest in a proper assessment. In short, the Centre's role here is ongoing.



2023 - Providing Skills and Support for the Future of Climate Science

To leave a long-term and lasting legacy for the ARC Centre of Excellence for Climate Extremes, the new Engagement and Impact team is focusing on long-term skills and support for researchers in 2023.

Engaging in the policy process

Under the Centre's new Knowledge Brokerage team lead Angela Kaplish, Centre researchers have been and will continue to submit to Government and industry inquiries – learning about policy processes and translating science for decision-makers. The team will also continue producing the Centre's highly regarded briefing notes and reports to assist policymakers in understanding the science of climate extremes.

Highlighting early career researchers

New Knowledge Broker Alice Wilson will support early career researchers (ECRs) by highlighting their research on social media and elsewhere online. The Centre will continue to publish a range of written and video profiles of ECRs, teaching them how to be interviewed, promote themselves and prepare for media opportunities as their careers develop.

Long-term media skills and opportunities

The Centre's new Media and Communications Advisor Jonathan Brown has embarked on an ongoing media training program focused on boosting new voices. The Centre has partnered with the Australian Science Media Centre and Science Media Exchange to provide ongoing media opportunities – often leading to multiple Centre researchers appearing in stories together, providing diverse perspectives on climate science. Fifteen Centre experts provided regular media commentary through the Australian Science Media Centre in 2022, with more being trained in 2023.

Training workshops and one-on-one support

The Engagement and Impact team has delivered training in scientific poster presentations, media training, career development and more. The team has also provided one-on-one support to Centre researchers at all levels, doing everything from assisting senior researchers to prepare for high-level Government consultations, through to holding coaching sessions for students doing their first-ever media appearances. In 2023, the team will build on these training workshops and one-on-one support.

Design, imagery and boosting climate science

The Centre's new graphic designer Georgina Harmer is assisting researchers in communicating their research through effective design principles. This will be achieved through the development of a range of templates – for posters, Powerpoint presentations and social media as well as for the Centre's bigger publications, such as the annual report. The team will continue to assist the Centre in communicating scientific concepts through design.

Teaching climate science in schools

The Centre's highly successful Climate Classrooms program will continue in 2023, led by Dr Sanaa Hobeichi (a former maths teacher and now one of the Centre's most valued researchers) and the Monash Climate Change Communication Research Hub. The partnership will also host a summit on climate change education and training in 2023.

Outputs & performance

Publications

Journal Articles

Abram, N. J., Wright, N. M., Ellis, B., Dixon, B. C., Wurtzel, J. B., England, M. H., et al. (2022). Author Correction: Coupling of Indo-Pacific climate variability over the last millennium. Nature, 602(7896), E20–E20. **https://doi.org/10.1038/s41586-021-04318-0**

Adamu, M., Gallant, A. J. E., & McGregor, S. (2022). Decadal-scale variations in extreme precipitation and implications for seasonal scale drought. Climate Dynamics, 58(5), 1845–1860. **https://doi.org/10.1007/s00382-021-05995-3**

Ahn, M.-S., Gleckler, P. J., Lee, J., Pendergrass, A. G., & Jakob, C. (2022). Benchmarking Simulated Precipitation Variability Amplitude across Timescales. Journal of Climate, 35(20), 3173–3196. **https://doi.org/10.1175/JCLI-D-21-0542.1**

Ali, S. M., Röthlisberger, M., Parker, T., Kornhuber, K., & Martius, O. (2022). Recurrent Rossby waves and south-eastern Australian heatwaves. Weather and Climate Dynamics, 3(4), 1139–1156. **https://doi.org/10.5194/wcd-3-1139-2022**

Amarathunga, U., Hogg, A. M., Rohling, E. J., Roberts, A. P., Grant, K. M., Heslop, D., et al. (2022). Sill-controlled salinity contrasts followed post-Messinian flooding of the Mediterranean. Nature Geoscience, 15(9), 720–725. **https://doi.org/10.1038/s41561-022-00998-z**

Argüeso, D., Di Luca, A., Jourdain, N. C., Romero, R., & Homar, V. (2022). Mechanisms for Extreme Precipitation Changes in a Tropical Archipelago. Journal of Climate, 35(17), 5519–5536. **https://doi.org/10.1175/JCLI-D-21-0224.1**

Ashcroft, L., Trewin, B., Benoy, M., Ray, D., & Courtney, C. (2022). The world's longest known parallel temperature dataset: A comparison between daily Glaisher and Stevenson screen temperature data at Adelaide, Australia, 1887–1947. International Journal of Climatology, 42(5), 2670–2687. **https://doi.org/10.1002/joc.7385**

Ayat, H., Evans, J. P., Sherwood, S. C., & Soderholm, J. (2022a). An object-based climatology of precipitation systems in Sydney, Australia. Climate Dynamics. **https://doi.org/10.1007/s00382-022-06404-z**

Ayat, H., Evans, J. P., Sherwood, S. C., & Soderholm, J. (2022b). Intensification of subhourly heavy rainfall. Science, 378(6620), 655–659. **https://doi.org/10.1126/science.abn8657**

Barthel, A., Hogg, A. M., Waterman, S., & Keating, S. (2022). Baroclinic Control of Southern Ocean Eddy Upwelling Near Topography. Geophysical Research Letters, 49(7), e2021GL097491. **https://doi.org/10.1029/2021GL097491**

Battula, S. B., Siems, S., & Mondal, A. (2022). Dynamical and thermodynamical interactions in daily precipitation regimes in the Western Himalayas. International Journal of Climatology, 42(9), 4909–4924. **https://doi.org/10.1002/joc.7511**

Bauman, D., Fortunel, C., Cernusak, L. A., Bentley, L. P., McMahon, S. M., Rifai, S. W., et al. (2022). Tropical tree growth sensitivity to climate is driven by species intrinsic growth rate and leaf traits. Global Change Biology, 28(4), 1414–1432. **https://doi.org/10.1111/gcb.15982**

Bauman, D., Fortunel, C., Delhaye, G., Malhi, Y., Cernusak, L. A., Bentley, L. P., et al. (2022). Tropical tree mortality has increased with rising atmospheric water stress. Nature, 608, 528–533. **https://doi.org/10.1038/s41586-022-04737-7**

Beck, H. E., Dijk, A. I. J. M. van, Larraondo, P. R., McVicar, T. R., Pan, M., Dutra, E., & Miralles, D. G. (2022). MSWX: Global 3-Hourly 0.1° Bias-Corrected Meteorological Data Including Near-Real-Time Updates and Forecast Ensembles. Bulletin of the American Meteorological Society, 103(3), E710–E732. **https://doi.org/10.1175/BAMS-D-21-0145.1**

Bergemann, M., Lane, T. P., Wales, S., Narsey, S., & Louf, V. (2022). High-resolution simulations of tropical island thunderstorms: Does an increase in resolution improve the representation of extreme rainfall? Quarterly Journal of the Royal Meteorological Society, 148(748), 3303–3318. **https://doi.org/10.1002/qj.4360**

Beringer, J., Moore, C. E., Cleverly, J., Campbell, D. I., Cleugh, H., De Kauwe, M. G., et al. (2022). Bridge to the future: Important lessons from 20 years of ecosystem observations made by the OzFlux network. Global Change Biology, 28(11), 3489–3514. **https://doi.org/10.1111/gcb.16141**

Bhattacharyya, S., Sreekesh, S., & King, A. (2022). Characteristics of extreme rainfall in different gridded datasets over India during 1983–2015. Atmospheric Research, 267, 105930. **https://doi.org/10.1016/j.atmosres.2021.105930**

Bi, D., Wang, G., Cai, W., Santoso, A., Sullivan, A., Ng, B., & Jia, F. (2022). Improved Simulation of ENSO Variability Through Feedback From the Equatorial Atlantic in a Pacemaker Experiment. Geophysical Research Letters, 49(2), e2021GL096887. **https://doi.org/10.1029/2021GL096887**

Bishop, C. H., & Eizenberg, N. W. (2022). Implicit ensemble tangent linear models (IETLMs) for model differentiation. Quarterly Journal of the Royal Meteorological Society, 148(748), 3319–3342. **https://doi.org/10.1002/qj.4363**

Bläckberg, C. P. O., & Singh, M. S. (2022). Increased Large-Scale Convective Aggregation in CMIP5 Projections: Implications for Tropical Precipitation Extremes. Geophysical Research Letters, 49(9), e2021GL097295. **https://doi.org/10.1029/2021GL097295**

Blunn, L. P., Coceal, O., Nazarian, N., Barlow, J. F., Plant, R. S., Bohnenstengel, S. I., & Lean, H. W. (2022). Turbulence Characteristics Across a Range of Idealized Urban Canopy Geometries. Boundary-Layer Meteorology, 182(2), 275–307. **https://doi.org/10.1007/s10546-021-00658-6**

Brown, A., Dowdy, A., Lane, T. P., & Hitchcock, S. (2022). Types of Severe Convective Wind Events in Eastern Australia. Monthly Weather Review, 1(aop). **https://doi.org/10.1175/MWR-D-22-0096.1**

Bui, H. X., Timmermann, A., Lee, J.-Y., Maloney, E. D., Li, Y.-X., Kim, J.-E., et al. (2022). Summer midlatitude stationary wave patterns synchronize Northern Hemisphere wildfire occurrence. Geophysical Research Letters, 49(18), e2022GL099017. **https://doi.org/10.1029/2022GL099017**

Cai, D., Abram, N. J., Sharples, J. J., & Perkins-Kirkpatrick, S. E. (2022). Increasing intensity and frequency of cold fronts contributed to Australia's 2019–2020 Black Summer fire disaster. Environmental Research Letters, 17(9), 094044. **https://doi.org/10.1088/1748-9326/ac8e88**

Cai, W., Ng, B., Wang, G., Santoso, A., Wu, L., & Yang, K. (2022). Increased ENSO sea surface temperature variability under four IPCC emission scenarios. Nature Climate Change, 12, 228–231. **https://doi.org/10.1038/s41558-022-01282-z**

Carrió, D. S., Jansà, A., Homar, V., Romero, R., Rigo, T., Ramis, C., et al. (2022). Exploring the benefits of a Hi-EnKF system to forecast an extreme weather event. The 9th October 2018 catastrophic flash flood in Mallorca. Atmospheric Research, 265, 105917. **https://doi.org/10.1016/j.atmosres.2021.105917**

Choudhury, D., Menviel, L., Meissner, K. J., Yeung, N. K. H., Chamberlain, M., & Ziehn, T. (2022). Marine carbon cycle response to a warmer Southern Ocean: the case of the last interglacial. Climate of the Past, 18(3), 507–523. **https://doi.org/10.5194/cp-18-507-2022**

Churakova-Sidorova, O. V., Myglan, V. S., Fonti, M. V., Naumova, O. V., Kirdyanov, A. V., Kalugin, I. A., et al. (2022). Modern aridity in the Altai-Sayan mountain range derived from multiple millennial proxies. Scientific Reports, 12(1), 7752. **https://doi.org/10.1038/s41598-022-11299-1**

Collow, A. B. M., Shields, C. A., Guan, B., Kim, S., Lora, J. M., McClenny, E. E., et al. (2022). An Overview of ARTMIP's Tier 2 Reanalysis Intercomparison: Uncertainty in the Detection of Atmospheric Rivers and Their Associated Precipitation. Journal of Geophysical Research: Atmospheres, 127(8), e2021JD036155. **https://doi.org/10.1029/2021JD036155**

Couldrey, M. P., Gregory, J. M., Dong, X., Garuba, O., Haak, H., Hu, A., et al. (2022). Greenhouse-gas forced changes in the Atlantic meridional overturning circulation and related worldwide sea-level change. Climate Dynamics. **https://doi.org/10.1007/s00382-022-06386-y**

Cranko Page, J., De Kauwe, M. G., Abramowitz, G., Cleverly, J., Hinko-Najera, N., Hovenden, M. J., et al. (2022). Examining the role of environmental memory in the predictability of carbon and water fluxes across Australian ecosystems. Biogeosciences, 19(7), 1913–1932. **https://doi.org/10.5194/bg-19-1913-2022**

Crespo, L. R., Rodríguez-Fonseca, M. B., Polo, I., Keenlyside, N., & Dommenget, D. (2022). Multidecadal variability of ENSO in a recharge oscillator framework. Environmental Research Letters, 17(7), 074008. **https://doi.org/10.1088/1748-9326/ac72a3**

Crosta, X., Kohfeld, K. E., Bostock, H. C., Chadwick, M., Du Vivier, A., Esper, O., et al. (2022). Antarctic sea ice over the past 130 000 years - Part 1: a review of what proxy records tell us. Climate of the Past, 18(8), 1729–1756. **https://doi.org/10.5194/cp-18-1729-2022**

Cyriac, A., Phillips, H. E., Bindoff, N. L., & Feng, M. (2022). Characteristics of Wind-Generated Near-Inertial Waves in the Southeast Indian Ocean. Journal of Physical Oceanography, 52(4), 557–578. **https://doi.org/10.1175/JPO-D-21-0046.1**

Cyriac, A., Phillips, H. E., Bindoff, N. L., & Polzin, K. (2022). Turbulent Mixing Variability in an Energetic Standing Meander of the Southern Ocean. Journal of Physical Oceanography, 52(8), 1593–1611. **https://doi.org/10.1175/JPO-D-21-0180.1**

De Kauwe, M. G., Sabot, M. E. B., Medlyn, B. E., Pitman, A. J., Meir, P., Cernusak, L. A., et al. (2022). Towards species-level forecasts of drought-induced tree mortality risk. New Phytologist, 235(1), 94–110. **https://doi.org/10.1111/nph.18129**

Della Penna, A., Llort, J., Moreau, S., Patel, R., Kloser, R., Gaube, P., et al. (2022). The Impact of a Southern Ocean Cyclonic Eddy on Mesopelagic Micronekton. Journal of Geophysical Research: Oceans, 127(11), e2022JC018893. **https://doi.org/10.1029/2022JC018893**

Denes, M. C., Froyland, G., & Keating, S. R. (2022). Persistence and material coherence of a mesoscale ocean eddy. Physical Review Fluids, 7(3), 034501. **https://doi.org/10.1103/PhysRevFluids.7.034501**

Deng, X., Perkins-Kirkpatrick, S. E., Alexander, L. V., & Stark, C. (2022). Projected Changes and Time of Emergence of Temperature Extremes Over Australia in CMIP5 and CMIP6. Earth's Future, 10(9), e2021EF002645. **https://doi.org/10.1029/2021EF002645**

Denissen, J. M. C., Teuling, A. J., Pitman, A. J., Koirala, S., Migliavacca, M., Li, W., et al. (2022). Widespread shift from ecosystem energy to water limitation with climate change. Nature Climate Change, 12(7), 677–684. **https://doi.org/10.1038/s41558-022-01403-8**

Deo, A., Chand, S. S., McIntosh, R. D., Prakash, B., Holbrook, N. J., Magee, A., et al. (2022). Severe tropical cyclones over southwest Pacific Islands: economic impacts and implications for disaster risk management. Climatic Change, 172(3), 38. **https://doi.org/10.1007/s10584-022-03391-2**

Deo, K., & Prasad, A. A. (2022). Exploring Climate Change Adaptation, Mitigation and Marketing Connections. Sustainability, 14(7), 4255. **https://doi.org/10.3390/su14074255**

Dommenget, B. D., & Al-Ansari, M. (2022). Asymmetries in the ENSO phase space. Climate Dynamics. **https://doi.org/10.1007/s00382-022-06392-0**

Du, H., Donat, M. G., Zong, S., Alexander, L. V., Manzanas, R., Kruger, A., et al. (2022). Extreme Precipitation on Consecutive Days Occurs More Often in a Warming Climate. Bulletin of the American Meteorological Society, 103(4), E1130–E1145. **https://doi.org/10.1175/BAMS-D-21-0140.1**

Dunn, R. J. H., Donat, M. G., & Alexander, L. V. (2022). Comparing extremes indices in recent observational and reanalysis products. Frontiers in Climate, 4, 989505. **https://doi.org/10.3389/fclim.2022.989505**

Eabry, M. D., Holmes, R. M., & Sen Gupta, A. (2022). The impact of Indonesian Throughflow constrictions on eastern Pacific upwelling and water-mass transformation. Journal of Geophysical Research: Oceans, 127(5), e2022JC018509. **https://doi.org/10.1029/2022JC018509**

Erhardt, T., Bigler, M., Federer, U., Gfeller, G., Leuenberger, D., Stowasser, O., et al. (2022). High-resolution aerosol concentration data from the Greenland NorthGRIP and NEEM deep ice cores. Earth System Science Data, 14(3), 1215–1231. **https://doi.org/10.5194/essd-14-1215-2022**

Everingham, S. E., Blick, R. A. J., Sabot, M. E. B., Slavich, E., & Moles, A. T. (2022). Southern hemisphere plants show more delays than advances in flowering phenology. Journal of Ecology. **https://doi.org/10.1111/1365-2745.13828**

Feng, P., Wang, B., Macadam, I., Taschetto, A. S., Abram, N. J., Luo, J.-J., et al. (2022). Increasing dominance of Indian Ocean variability impacts Australian wheat yields. Nature Food, 3(10), 862–870. **https://doi.org/10.1038/s43016-022-00613-9**

Fiddes, S.L., Protat, A., Mallet, M. D., Alexander, S. P., & Woodhouse, M. T. (2022). Southern Ocean cloud and shortwave radiation biases in a nudged climate model simulation: does the model ever get it right? Atmospheric Chemistry and Physics, 22(22), 14603–14630. **https://doi.org/10.5194/acp-22-14603-2022**

Fiddes, Sonya L., Woodhouse, M. T., Utembe, S., Schofield, R., Alexander, S. P., Alroe, J., et al. (2022). The contribution of coral-reef-derived dimethyl sulfide to aerosol burden over the Great Barrier Reef: a modelling study. Atmospheric Chemistry and Physics, 22(4), 2419–2445. **https://doi.org/10.5194/acp-22-2419-2022**

Fowler, K., Peel, M., Saft, M., Peterson, T. J., Western, A., Band, L., et al. (2022). Explaining changes in rainfall–runoff relationships during and after Australia's Millennium Drought: a community perspective. Hydrology and Earth System Sciences, 26(23), 6073–6120. **https://doi.org/10.5194/hess-26-6073-2022**

Fox-Hughes, P., Su, C.-H., Eizenberg, N., White, C., Steinle, P., Jakob, D., et al. (2022). A review of early severe weather applications of high-resolution regional reanalysis in Australia. Meteorological Applications, 29(4), e2087. **https://doi.org/10.1002/met.2087**

Freisen, P. F., Arblaster, J. M., Jakob, C., & Rodríguez, J. M. (2022). Investigating Tropical Versus Extratropical Influences on the Southern Hemisphere Tropical Edge in the Unified Model. Journal of Geophysical Research: Atmospheres, 127(7), e2021JD036106. **https://doi.org/10.1029/2021JD036106**

Garfinkel, C. I., Gerber, E. P., Shamir, O., Rao, J., Jucker, M., White, I., & Paldor, N. (2022). A QBO Cookbook: Sensitivity of the Quasi-Biennial Oscillation to Resolution, Resolved Waves, and Parameterized Gravity Waves. Journal of Advances in Modeling Earth Systems, 14(3), e2021MS002568. **https://doi.org/10.1029/2021MS002568**

Garg, M., Silver, J. D., Schofield, R., & Ryan, R. G. (2022). Hourly emission inventories for air toxic emissions for eastern Australian electricity generators derived from energy distribution data. International Journal of Environmental Science and Technology, 19, 2973–2992. **https://doi.org/10.1007/s13762-021-03429-5**

Gayen, B., & Griffiths, R. W. (2022). Rotating Horizontal Convection. Annual Review of Fluid Mechanics, 54(1), 105–132. **https://doi.org/10.1146/annurev-fluid-030121-115729**

Geng, T., Cai, W., Wu, L., Santoso, A., Wang, G., Jing, Z., et al. (2022). Emergence of changing Central-Pacific and Eastern-Pacific El Niño-Southern Oscillation in a warming climate. Nature Communications, 13(1), 6616. **https://doi.org/10.1038/s41467-022-33930-5**

Gevorgyan, A., Ackermann, L., Huang, Y., Siems, S., & Manton, M. (2022). Simulation of Heavy Precipitation and the Production of Graupel Related to the Passage of a Cold Front Over the Australian Snowy Mountains. Monthly Weather Review, 150(12), 3229–3249. **https://doi.org/10.1175/MWR-D-21-0080.1**

Gillett, Z. E., Hendon, H. H., Arblaster, J. M., Lin, H., & Fuchs, D. (2022). On the Dynamics of Indian Ocean Teleconnections into the Southern Hemisphere during Austral Winter. Journal of the Atmospheric Sciences, 79(9), 2453–2469. **https://doi.org/10.1175/JAS-D-21-0206.1**

Gillett, Z. E., Hendon, H. H., Arblaster, J. M., & Lin, H. (2022). Sensitivity of the Southern Hemisphere Wintertime Teleconnection to the Location of ENSO Heating. Journal of Climate, (aop). **https://doi.org/10.1175/JCLI-D-22-0159.1**

Goosse, H., Barriat, P.-Y., Brovkin, V., Klein, F., Meissner, K. J., Menviel, L., & Mouchet, A. (2022). Changes in atmospheric CO2 concentration over the past two millennia: contribution of climate variability, land-use and Southern Ocean dynamics. Climate Dynamics, 58(11), 2957–2979. **https://doi.org/10.1007/s00382-021-06078-z**

Gormley-Gallagher, A. M., Sterl, S., Hirsch, A. L., Seneviratne, S. I., Davin, E. L., & Thiery, W. (2022). Agricultural management effects on mean and extreme temperature trends. Earth System Dynamics, 13(1), 419–438. **https://doi.org/10.5194/esd-13-419-2022**

Goyal, R., Jucker, M., Sen Gupta, A., & England, M. H. (2022). A new zonal wave 3 index for the Southern Hemisphere. Journal of Climate, 35(15), 5137–5149. **https://doi.org/10.1175/JCLI-D-21-0927.1**

Green, R. A., Menviel, L., Meissner, K. J., Crosta, X., Chandan, D., Lohmann, G., et al. (2022). Evaluating seasonal sea-ice cover over the Southern Ocean at the Last Glacial Maximum. Climate of the Past, 18(4), 845–862. **https://doi.org/10.5194/cp-18-845-2022**

Hawkins, E., Alexander, L. V., & Allan, R. J. (2022). Millions of digitized historical sea-level pressure observations rediscovered. Geoscience Data Journal. **https://doi.org/10.1002/gdj3.163**

Hitchcock, S. M., & Lane, T. P. (2022). Two Quasi-Linear Convective Systems, their Mesoscale Structure and Moisture Sources. Monthly Weather Review. **https://doi.org/10.1175/MWR-D-22-0030.1**

Hobeichi, S., Abramowitz, G., Ukkola, A. M., De Kauwe, M., Pitman, A., Evans, J. P., & Beck, H. (2022). Reconciling historical changes in the hydrological cycle over land. Npj Climate and Atmospheric Science, 5, 17. **https://doi.org/10.1038/s41612-022-00240-y**

Hobeichi, S., Abramowitz, G., Evans, J. P., & Ukkola, A. (2022). Toward a Robust, Impact-Based, Predictive Drought Metric. Water Resources Research, 58(2), e2021WR031829. **https://doi.org/10.1029/2021WR031829**

Hogg, A. McC., Penduff, T., Close, S. E., Dewar, W. K., Constantinou, N. C., & Martínez-Moreno, J. (2022). Circumpolar Variations in the Chaotic Nature of Southern Ocean Eddy Dynamics. Journal of Geophysical Research: Oceans, 127(5), e2022JC018440. **https://doi.org/10.1029/2022JC018440**

Holbrook, N. J., Hernaman, V., Koshiba, S., Lako, J., Kajtar, J. B., Amosa, P., & Singh, A. (2022). Impacts of marine heatwaves on tropical western and central Pacific Island nations and their communities. Global and Planetary Change, 208, 103680. **https://doi.org/10.1016/j.gloplacha.2021.103680**

Holgate, C., Evans, J. P., Taschetto, A. S., Sen Gupta, A., & Santoso, A. (2022). The Impact of Interacting Climate Modes on East Australian Precipitation Moisture Sources. Journal of Climate, 35(10), 3147–3159. **https://doi.org/10.1175/JCLI-D-21-0750.1**

Holmes, R. M., Sohail, T., & Zika, J. D. (2022). Adiabatic and Diabatic Signatures of Ocean Temperature Variability. Journal of Climate, 35(5), 1459–1477. **https://doi.org/10.1175/JCLI-D-21-0695.1**

Holmes, R. M., Groeskamp, S., Stewart, K. D., & McDougall, T. J. (2022). Sensitivity of a Coarse-Resolution Global Ocean Model to a Spatially Variable Neutral Diffusivity. Journal of Advances in Modeling Earth Systems, 14(3), e2021MS002914. **https://doi.org/10.1029/2021MS002914**

Huguenin, M. F., Holmes, R. M., & England, M. H. (2022). Drivers and distribution of global ocean heat uptake over the last half century. Nature Communications, 13(1), 4921. **https://doi.org/10.1038/s41467-022-32540-5**

Huneke, W. G. C., Morrison, A. K., & Hogg, A. M. (2022). Spatial and Subannual Variability of the Antarctic Slope Current in an Eddying Ocean–Sea Ice Model. Journal of Physical Oceanography, 52(3), 347–361. **https://doi.org/10.1175/JPO-D-21-0143.1**

Hwong, Y.-L., Sherwood, S. C., & Fuchs, D. (2022). Can We Use 1D Models to Predict 3D Model Response to Forcing in an Idealized Framework? Journal of Advances in Modeling Earth Systems, 14(4), e2021MS002785. **https://doi.org/10.1029/2021MS002785**

Jacques-Coper, M., Ortiz-Guzmán, V., & Zanelli, J. (2022). Simplified two-dimensional model for global atmospheric dynamics. Physics of Fluids, 34(11), 116610. **https://doi.org/10.1063/5.0119855**

Jeong, Y.-C., Yeh, S.-W., Lim, Y.-K., Santoso, A., & Wang, G. (2022). Indian Ocean warming as key driver of long-term positive trend of Arctic Oscillation. Npj Climate and Atmospheric Science, 5(56). **https://doi.org/10.1038/s41612-022-00279-x**

Jha, R., Mondal, A., Devanand, A., Roxy, M. K., & Ghosh, S. (2022). Limited influence of irrigation on pre-monsoon heat stress in the Indo-Gangetic Plain. Nature Communications, 13(1), 4275. **https://doi.org/10.1038/s41467-022-31962-5**

Ji, F., Nishant, N., Evans, J. P., Di Virgilio, G., Cheung, K. K. W., Tam, E., et al. (2022). Introducing NARCliM1.5: Evaluation and projection of climate extremes for southeast Australia. Weather and Climate Extremes, 38, 100526. **https://doi.org/10.1016/j.wace.2022.100526**

Jucker, M., & Goyal, R. (2022). Ozone-forced Southern Annular Mode during Antarctic Stratospheric Warming Events. Geophysical Research Letters, 49(4), e2021GL095270. **https://doi.org/10.1029/2021GL095270**

Jucker, Martin, & Reichler, T. (2022). Lifecycle of Major Sudden Stratospheric Warmings in the Southern Hemisphere from a Multi-Millennial GCM Simulation. Journal of Climate, 36(2), 643–661. **https://doi.org/10.1175/JCLI-D-22-0425.1**

Kajtar, J. B., Bachman, S. D., Holbrook, N. J., & Pilo, G. S. (2022). Drivers, Dynamics, and Persistence of the 2017/2018 Tasman Sea Marine Heatwave. Journal of Geophysical Research: Oceans, 127(8), e2022JC018931. **https://doi.org/10.1029/2022JC018931**

Kajtar, J. B., Hernaman, V., Holbrook, N. J., & Petrelli, P. (2022). Tropical western and central Pacific marine heatwave data calculated from gridded sea surface temperature observations and CMIP6. Data in Brief, 40, 107694. **https://doi.org/10.1016/j.dib.2021.107694**

Kala, J., Hirsch, A. L., Ziehn, T., Perkins-Kirkpatrick, S. E., De Kauwe, M. G., & Pitman, A. (2022). Assessing the potential for crop albedo enhancement in reducing heatwave frequency, duration, and intensity under future climate change. Weather and Climate Extremes, 35, 100415. **https://doi.org/10.1016/j.wace.2022.100415**

Kelly, R., Evans, K., Alexander, K., Bettiol, S., Corney, S., Cullen-Knox, C., et al. (2022). Connecting to the oceans: supporting ocean literacy and public engagement. Reviews in Fish Biology and Fisheries, 32, 123–143. **https://doi.org/10.1007/s11160-020-09625-9**

King, A. D., Peel, J., Ziehn, T., Bowen, K. J., McClelland, H. L. O., McMichael, C., et al. (2022). Preparing for a post-net-zero world. Nature Climate Change, 12, 775–777. **https://doi.org/10.1038/s41558-022-01446-x**

Koenig, Z., Meyer, A., Provost, C., Sennéchael, N., Sundfjord, A., & Gascard, J.-C. (2022). Atlantic Water Circulation and Properties Northwest of Svalbard During Anomalous Southerly Winds. Journal of Geophysical Research: Oceans, 127(6), e2021JC018357. **https://doi.org/10.1029/2021JC018357**

Kotsuki, S., & Bishop, C. H. (2022). Implementing Hybrid Background Error Covariance into the LETKF with Attenuation-Based Localization: Experiments with a Simplified AGCM. Monthly Weather Review, 150(1), 283–302. **https://doi.org/10.1175/MWR-D-21-0174.1**

Lang, F., Ackermann, L., Huang, Y., Truong, S. C. H., Siems, S. T., & Manton, M. J. (2022). A climatology of open and closed mesoscale cellular convection over the Southern Ocean derived from Himawari-8 observations. Atmospheric Chemistry and Physics, 22(3), 2135–2152. **https://doi.org/10.5194/acp-22-2135-2022**

Lawrence, Z. D., Abalos, M., Ayarzagüena, B., Barriopedro, D., Butler, A. H., Calvo, N., et al. (2022). Quantifying stratospheric biases and identifying their potential sources in subseasonal forecast systems. Weather and Climate Dynamics, 3(3), 977–1001. **https://doi.org/10.5194/wcd-3-977-2022**

Layton, C., Vermont, H., Beggs, H., Brassington, G. B., Burke, A. D., Hepburn, L., et al. (2022). Giant kelp rafts wash ashore 450 km from the nearest populations and against the dominant ocean current. Ecology, e3795. **https://doi.org/10.1002/ecy.3795**

Lestari, S., Protat, A., Louf, V., King, A., Vincent, C., & Mori, S. (2022). Subdaily Rain-Rate Properties in Western Java Analyzed Using C-Band Doppler Radar. Journal of Applied Meteorology and Climatology, 61(9), 1179–1199. **https://doi.org/10.1175/JAMC-D-21-0041.1**

Lestari, S., King, A., Vincent, C., Protat, A., Karoly, D., & Mori, S. (2022). Variability of Jakarta Rain-Rate Characteristics Associated with the Madden–Julian Oscillation and Topography. Monthly Weather Review, 150(8), 1953–1975. **https://doi.org/10.1175/MWR-D-21-0112.1**

Li, S., Rifai, S., Anderson, L. O., & Sparrow, S. (2022). Identifying local-scale meteorological conditions favorable to large fires in Brazil. Climate Resilience and Sustainability, 1(1), e11. **https://doi.org/10.1002/cli2.11**

Libera, S., Hobbs, W., Klocker, A., Meyer, A., & Matear, R. (2022). Ocean-Sea Ice Processes and Their Role in Multi-Month Predictability of Antarctic Sea Ice. Geophysical Research Letters, 49(8), e2021GL097047. **https://doi.org/10.1029/2021GL097047**

Lieber, R., King, A., Brown, J., Ashcroft, L., Freund, M., & McMichael, C. (2022). ENSO Teleconnections More Uncertain in Regions of Lower Socioeconomic Development. Geophysical Research Letters, 49(21), e2022GL100553. **https://doi.org/10.1029/2022GL100553**

Liguori, G., McGregor, S., Singh, M., Arblaster, J., & Di Lorenzo, E. (2022). Revisiting ENSO and IOD Contributions to Australian Precipitation. Geophysical Research Letters, 49(1), e2021GL094295. **https://doi.org/10.1029/2021GL094295**

Lipson, M., Grimmond, S., Best, M., Chow, W. T. L., Christen, A., Chrysoulakis, N., et al. (2022). Harmonized gap-filled datasets from 20 urban flux tower sites. Earth System Science Data, 14(11), 5157–5178. **https://doi.org/10.5194/essd-14-5157-2022**

Lipson, M. J., Nazarian, N., Hart, M. A., Nice, K. A., & Conroy, B. (2022). A Transformation in City-Descriptive Input Data for Urban Climate Models. Frontiers in Environmental Science, 10, 866398. **https://doi.org/10.3389/fenvs.2022.866398**

Lopez-Bravo, C., Vincent, C. L., Huang, Y., & Lane, T. P. (2022). A case study of a West Sumatra squall line using satellite observations. Monthly Weather Review. **https://doi.org/10.1175/MWR-D-21-0194.1**

Lu, P., Xia, G., Zhao, Q., Green, D., Lim, Y.-H., Li, S., & Guo, Y. (2022). Attributable risks of hospitalizations for urologic diseases due to heat exposure in Queensland, Australia, 1995–2016. International Journal of Epidemiology, 51(1), 144–154. **https://doi.org/10.1093/ije/dyab189**

Malan, N., Roughan, M., Stanley, G. J., Holmes, R., & Li, J. (2022). Quantifying Cross-Shelf Transport in the East Australian Current System: A Budget-Based Approach. Journal of Physical Oceanography, 52(10), 2555–2572. **https://doi.org/10.1175/JPO-D-21-0193.1**

Mao, Y., Zou, Y., Alves, L. M., Macau, E. E. N., Taschetto, A. S., Santoso, A., & Kurths, J. (2022). Phase Coherence Between Surrounding Oceans Enhances Precipitation Shortages in Northeast Brazil. Geophysical Research Letters, 49(9), e2021GL097647. **https://doi.org/10.1029/2021GL097647**

Marin, M., Feng, M., Bindoff, N. L., & Phillips, H. E. (2022). Local Drivers of Extreme Upper Ocean Marine Heatwaves Assessed Using a Global Ocean Circulation Model. Frontiers in Climate, 4, 788390. **https://doi.org/10.3389/fclim.2022.788390**

Marshall, A. G., Wheeler, M. C., & Cowan, T. (2022). Madden–Julian Oscillation Impacts on Australian Temperatures and Extremes. Journal of Climate, 36(2), 335–357. **https://doi.org/10.1175/JCLI-D-22-0413.1**

Marshall, A. G., Wang, G., Hendon, H. H., & Lin, H. (2022). Madden–Julian Oscillation teleconnections to Australian springtime temperature extremes and their prediction in ACCESS-S1. Climate Dynamics. **https://doi.org/10.1007/s00382-022-06586-6**

Martínez-Moreno, J., Hogg, A., & England, M. H. (2022). Climatology, seasonality, and trends of spatially coherent ocean eddies. Journal of Geophysical Research: Oceans, 127(7), e2021JC017453. **https://doi.org/10.1029/2021JC017453**

May, P. T., Trewin, B., Nairn, J. R., Ostendorf, B., Su, C.-H., & Moise, A. (2022). Diurnal and seasonal variability of near surface temperature and humidity in the Maritime Continent. Journal of Applied Meteorology and Climatology, 61(11), 1819–1834. **https://doi.org/10.1175/JAMC-D-22-0032.1**

McGregor, S., Dommenget, D., & Neske, S. (2022). Distinct Off-Equatorial Zonal Wind Stress and Oceanic Responses for EP- and CP-Type ENSO Events. Journal of Climate, 35(5), 1423–1440. **https://doi.org/10.1175/JCLI-D-21-0473.1**

McGregor, S., Cassou, C., Kosaka, Y., & Phillips, A. S. (2022). Projected ENSO Teleconnection Changes in CMIP6. Geophysical Research Letters, 49(11), e2021GL097511. **https://doi.org/10.1029/2021GL097511**

McKay, R. C., Arblaster, J. M., & Hope, P. (2022). Tropical influence on heat-generating atmospheric circulation over Australia strengthens through spring. Weather and Climate Dynamics, 3(2), 413–428. **https://doi.org/10.5194/wcd-3-413-2022**

Meijer, J. J., Phillips, H. E., Bindoff, N. L., Rintoul, S. R., & Foppert, A. (2022). Dynamics of a Standing Meander of the Subantarctic Front Diagnosed from Satellite Altimetry and Along-Stream Anomalies of Temperature and Salinity. Journal of Physical Oceanography, 52(6), 1073–1089. **https://doi.org/10.1175/JPO-D-21-0049.1**

Meng, H., Hayashida, H., Norazmi-Lokman, N. H., & Strutton, P. G. (2022). Benefits and detrimental effects of ocean warming for Tasmanian salmon aquaculture. Continental Shelf Research, 246, 104829. **https://doi.org/10.1016/j.csr.2022.104829**

Meyer, A., Bresson, H., Gorodetskaya, I., Harris, R., & Perkins-Kirkpatrick, S. (2022). Extreme Climate and Weather Events in a Warmer World. Frontiers for Young Minds, 10, 682759. **https://doi.org/10.3389/frym.2022.682759**

Montoya Duque, E., Huang, Y., Siems, S. T., May, P. T., Protat, A., & McFarquhar, G. M. (2022). A Characterization of Clouds and Precipitation Over the Southern Ocean From Synoptic to Micro Scales During the CAPRICORN Field Campaigns. Journal of Geophysical Research: Atmospheres, 127(17), e2022JD036796. **https://doi.org/10.1029/2022JD036796**

Morrison, A. K., Waugh, D. W., Hogg, A. McC., Jones, D. C., & Abernathey, R. P. (2022). Ventilation of the Southern Ocean Pycnocline. Annual Review of Marine Science, 14(1), 405–430. **https://doi.org/10.1146/annurev-marine-010419-011012**

Mu, M., Pitman, A. J., De Kauwe, M. G., Ukkola, A. M., & Ge, J. (2022). How do groundwater dynamics influence heatwaves in southeast Australia? Weather and Climate Extremes, 37, 100479. **https://doi.org/10.1016/j.wace.2022.100479**

Muller, C., Yang, D., Craig, G., Cronin, T., Fildier, B., Haerter, J. O., et al. (2022). Spontaneous Aggregation of Convective Storms. Annual Review of Fluid Mechanics, 54(1), 133–157. **https://doi.org/10.1146/annurev-fluid-022421-011319**

Narsey, S., Brown, J. R., Delage, F., Boschat, G., Grose, M., Colman, R., & Power, S. (2022). Storylines of South Pacific Convergence Zone changes in a warmer world. Journal of Climate, 35(20), 2949–2967. **https://doi.org/10.1175/JCLI-D-21-0433.1**

Naserikia, M., Hart, M. A., Nazarian, N., & Bechtel, B. (2022). Background climate modulates the impact of land cover on urban surface temperature. Scientific Reports, 12(1), 15433. **https://doi.org/10.1038/s41598-022-19431-x**

Neme, J., England, M. H., & Hogg, A. M. (2022). Projected changes of surface winds over the Antarctic continental margin. Geophysical Research Letters, 49(16), e2022GL098820. **https://doi.org/10.1029/2022GL098820**

Neogi, S., & Singh, M. S. (2022). Understanding changes in the tropical circulation under global warming using a cloud resolving model and a conceptual model. Journal of Climate, 35(18), 5855–5868. **https://doi.org/10.1175/JCLI-D-21-0854.1**

Nguyen, P.-L., Bador, M., Alexander, L. V., Lane, T. P., & Ngo-Duc, T. (2022). More intense daily precipitation in CORDEX-SEA regional climate models than their forcing global climate models over Southeast Asia. International Journal of Climatology, 42(12), 6537–6561. **https://doi.org/10.1002/joc.7619**

Nice, K. A., Nazarian, N., Lipson, M. J., Hart, M. A., Seneviratne, S., Thompson, J., et al. (2022). Isolating the impacts of urban form and fabric from geography on urban heat and human thermal comfort. Building and Environment, 224, 109502. **https://doi.org/10.1016/j.buildenv.2022.109502**

Nishant, N., Ji, F., Guo, Y., Herold, N., Green, D., Virgilio, G. D., et al. (2022). Future population exposure to Australian heatwaves. Environmental Research Letters, 17(6), 064030. **https://doi.org/10.1088/1748-9326/ac6dfa**

Orihuela-Pinto, B., England, M. H., & Taschetto, A. S. (2022). Interbasin and interhemispheric impacts of a collapsed Atlantic Overturning Circulation. Nature Climate Change, 12, 558–565. **https://doi.org/10.1038/s41558-022-01380-y**

Orihuela-Pinto, B., Santoso, A., England, M. H., & Taschetto, A. S. (2022). Reduced ENSO Variability due to a Collapsed Atlantic Meridional Overturning Circulation. Journal of Climate, 35(16), 5307–5320. **https://doi.org/10.1175/JCLI-D-21-0293.1**

Pang, C., Nikurashin, M., Pena-Molino, B., & Sloyan, B. M. (2022). Remote energy sources for mixing in the Indonesian Seas. Nature Communications, 13(1), 6535. **https://doi.org/10.1038/s41467-022-34046-6**

Parker, T., & Gallant, A. J. E. (2022). The role of heavy rainfall in drought in Australia. Weather and Climate Extremes, 38, 100528. **https://doi.org/10.1016/j.wace.2022.100528**

Pathmeswaran, C., Sen Gupta, A., Perkins-Kirkpatrick, S. E., & Hart, M. A. (2022). Exploring Potential Links Between Co-occurring Coastal Terrestrial and Marine Heatwaves in Australia. Frontiers in Climate, 4, 792730. **https://doi.org/10.3389/fclim.2022.792730**

Perkins-Kirkpatrick, S. E., Stone, D. A., Mitchell, D. M., Rosier, S., King, A. D., Lo, Y. T. E., et al. (2022). On the attribution of the impacts of extreme weather events to anthropogenic climate change. Environmental Research Letters, 17(2), 024009. **https://doi.org/10.1088/1748-9326/ac44c8**

Phillips, H. E., Patel, R. S., Benthuysen, J. A., Duran, E. R., & Marin, M. (2022). Watermass characteristics and circulation near 110°E in the southeast Indian Ocean. Deep Sea Research Part II: Topical Studies in Oceanography, 202, 105149. **https://doi.org/10.1016/j.dsr2.2022.105149**

Pichault, M., Vincent, C., Skidmore, G., & Monty, J. (2022). LiDAR-based detection of wind gusts: An experimental study of gust propagation speed and impact on wind power ramps. Journal of Wind Engineering and Industrial Aerodynamics, 220, 104864. **https://doi.org/10.1016/j.jweia.2021.104864**

Pitman, A. J., Fiedler, T., Ranger, N., Jakob, C., Ridder, N. N., Perkins-Kirkpatrick, S. E., et al. (2022). Acute climate risks in the financial system: examining the utility of climate model projections. Environmental Research: Climate, 1, 025002. **https://doi.org/10.1088/2752-5295/ac856f**

Pittman, N. A., Strutton, P. G., Johnson, R., Matear, R. J., & Sutton, A. J. (2022). Relationships Between Air-Sea CO2 Flux and New Production in the Equatorial Pacific. Global Biogeochemical Cycles, 36(4), e2021GB007121. **https://doi.org/10.1029/2021GB007121**

Pontes, G. M., Taschetto, A. S., Sen Gupta, A., Santoso, A., Wainer, I., Haywood, A. M., et al. (2022). Mid-Pliocene El Niño/Southern Oscillation suppressed by Pacific intertropical convergence zone shift. Nature Geoscience, 15, 726–734. **https://doi.org/10.1038/s41561-022-00999-y**

Prasad, A. A., Nishant, N., & Kay, M. (2022). Dust cycle and soiling issues affecting solar energy reductions in Australia using multiple datasets. Applied Energy, 310, 118626. **https://doi.org/10.1016/j.apenergy.2022.118626**

Rama, J., Shakespeare, C. J., & Hogg, A. McC. (2022a). Importance of Background Vorticity Effect and Doppler Shift in Defining Near-Inertial Internal Waves. Geophysical Research Letters, 49(22), e2022GL099498. **https://doi.org/10.1029/2022GL099498**

Rama, J., Shakespeare, C. J., & Hogg, A. M. (2022b). The Wavelength Dependence of the Propagation of Near-Inertial Internal Waves. Journal of Physical Oceanography, 52(10), 2493–2514. **https://doi.org/10.1175/JPO-D-21-0266.1**

Rathore, S., Goyal, R., Jangir, B., Ummenhofer, C. C., Feng, M., & Mishra, M. (2022). Interactions Between a Marine Heatwave and Tropical Cyclone Amphan in the Bay of Bengal in 2020. Frontiers in Climate, 4. **https://doi.org/10.3389/fclim.2022.861477**

Raupach, T. H., Soderholm, J., Protat, A., & Sherwood, S. C. (2022). An improved instability–shear hail proxy for Australia. Monthly Weather Review. **https://doi.org/10.1175/MWR-D-22-0127.1**

Reddy, P. J., Perkins-Kirkpatrick, S. E., Ridder, N. N., & Sharples, J. J. (2022). Combined role of ENSO and IOD on compound drought and heatwaves in Australia using two CMIP6 large ensembles. Weather and Climate Extremes, 37, 100469. **https://doi.org/10.1016/j.wace.2022.100469**

Reichler, T., & Jucker, M. (2022). Stratospheric wave driving events as an alternative to sudden stratospheric warmings. Weather and Climate Dynamics, 3(2), 659–677. **https://doi.org/10.5194/wcd-3-659-2022**

Reid, K. J., King, A. D., Lane, T. P., & Hudson, D. (2022). Tropical, Subtropical and Extratropical Atmospheric Rivers in the Australian Region. Journal of Climate, 35(9), 2697–2708. **https://doi.org/10.1175/JCLI-D-21-0606.1**

van Rensch, P., McGregor, S., & Dommenget, D. (2022). Exploration of Atmosphere-Only Model Deficiencies in Reproducing the 1992–2011 Pacific Trade Wind Acceleration. Geophysical Research Letters, 49(17), e2022GL099981. **https://doi.org/10.1029/2022GL099981**

Retsch, M. H., Jakob, C., & Singh, M. S. (2022). Identifying Relations Between Deep Convection and the Large-Scale Atmosphere Using Explainable Artificial Intelligence. Journal of Geophysical Research: Atmospheres, 127(3), e2021JD035388. **https://doi.org/10.1029/2021JD035388**

Ridder, N. N., Ukkola, A. M., Pitman, A. J., & Perkins-Kirkpatrick, S. E. (2022). Increased occurrence of high impact compound events under climate change. Npj Climate and Atmospheric Science, 5, 3. **https://doi.org/10.1038/s41612-021-00224-4**

Ridder, Nina N., Pitman, A. J., & Ukkola, A. M. (2022). High impact compound events in Australia. Weather and Climate Extremes, 36, 100457. **https://doi.org/10.1016/j.wace.2022.100457**

Rifai, S. W., De Kauwe, M. G., Ukkola, A. M., Cernusak, L. A., Meir, P., Medlyn, B. E., & Pitman, A. J. (2022). Thirty-eight years of CO2 fertilization has outpaced growing aridity to drive greening of Australian woody ecosystems. Biogeosciences, 19(2), 491–515. **https://doi.org/10.5194/bg-19-491-2022**

Robbins, D., Poulsen, C., Siems, S., & Proud, S. (2022). Improving discrimination between clouds and optically thick aerosol plumes in geostationary satellite data. Atmospheric Measurement Techniques, 15(9), 3031–3051. **https://doi.org/10.5194/amt-15-3031-2022**

Sabot, M. E. B., De Kauwe, M. G., Pitman, A. J., Medlyn, B. E., Ellsworth, D. S., Martin-StPaul, N. K., et al. (2022). One Stomatal Model to Rule Them All? Toward Improved Representation of Carbon and Water Exchange in Global Models. Journal of Advances in Modeling Earth Systems, 14(4), e2021MS002761. **https://doi.org/10.1029/2021MS002761**

Sabot, M. E. B., De Kauwe, M. G., Pitman, A. J., Ellsworth, D. S., Medlyn, B. E., Caldararu, S., et al. (2022). Predicting resilience through the lens of competing adjustments to vegetation function. Plant, Cell & Environment, 45(9), 2744–2761. **https://doi.org/10.1111/pce.14376**

Samuels, L., Nakstad, B., Roos, N., Bonell, A., Chersich, M., Havenith, G., et al. (2022). Physiological mechanisms of the impact of heat during pregnancy and the clinical implications: review of the evidence from an expert group meeting. International Journal of Biometeorology, 66(8), 1505–1513. **https://doi.org/10.1007/s00484-022-02301-6**

Santoso, A., England, M. H., Kajtar, J. B., & Cai, W. (2022). Indonesian Throughflow Variability and Linkage to ENSO and IOD in an Ensemble of CMIP5 Models. Journal of Climate, 35(10), 3161–3178. **https://doi.org/10.1175/JCLI-D-21-0485.1**

Savita, A., Domingues, C. M., Boyer, T., Gouretski, V., Ishii, M., Johnson, G. C., et al. (2022). Quantifying Spread in Spatiotemporal Changes of Upper-Ocean Heat Content Estimates: An Internationally Coordinated Comparison. Journal of Climate, 35(2), 851–875. **https://doi.org/10.1175/JCLI-D-20-0603.1**

Scalon, M. C., Oliveras Menor, I., Freitag, R., Peixoto, K. S., Rifai, S. W., Marimon, B. S., et al. (2022). Contrasting strategies of nutrient demand and use between savanna and forest ecosystems in a neotropical transition zone. Biogeosciences, 19(15), 3649–3661. **https://doi.org/10.5194/bg-19-3649-2022**

Schroeter, B. J. E., Bindoff, N. L., Reid, P., & Alexander, S. P. (2022). An Intercomparison of Antarctic NWP during the Austral Summer Special Observing Period for the Year of Polar Prediction. Weather and Forecasting, 37(6), 833–852. **https://doi.org/10.1175/WAF-D-21-0088.1**

Shahrokhishahraki, N., Rayner, P. J., Silver, J. D., Thomas, S., & Schofield, R. (2022). High-resolution modeling of gaseous air pollutants over Tehran and validation with surface and satellite data. Atmospheric Environment, 270, 118881. **https://doi.org/10.1016/j.atmosenv.2021.118881**

Shakespeare, C. J., & Roderick, M. L. (2022). Diagnosing Instantaneous Forcing and Feedbacks of Downwelling Longwave Radiation at the Surface: A Simple Methodology and Its Application to CMIP5 Models. Journal of Climate, 35(12), 3785–3801. **https://doi.org/10.1175/JCLI-D-21-0865.1**

Sharples, J. J. (2022). A note on fire weather indices. International Journal of Wildland Fire, 31(7), 728–734. **https://doi.org/10.1071/WF21134**

Sherwood, S. C., Sen Gupta, A., & Schwartz, S. E. (2022). Probability of committed warming exceeding 1.5C and 2.0C Paris targets. Environmental Research Letters, 17, 064022. **https://doi.org/10.1088/1748-9326/ac6ff6**

Short, E., Lane, T. P., & Vincent, C. L. (2022). Objectively Diagnosing Characteristics of Mesoscale Organization from Radar Reflectivity and Ambient Winds. Monthly Weather Review. **https://doi.org/10.1175/MWR-D-22-0146.1**

Sieber, R., Slonosky, V., Ashcroft, L., & Pudmenzky, C. (2022). Formalizing Trust in Historical Weather Data. Weather, Climate, and Society, 14(3), 993–1007. **https://doi.org/10.1175/WCAS-D-21-0077.1**

Siems, S. T., Huang, Y., & Manton, M. J. (2022). Southern Ocean precipitation: Toward a process-level understanding. WIREs Climate Change, 13(6), e800. **https://doi.org/10.1002/wcc.800**

Singh, M. S., & Neogi, S. (2022). On the interaction between moist convection and large-scale ascent in the tropics. Journal of Climate, 35(14), 4417–4435. **https://doi.org/10.1175/JCLI-D-21-0717.1**

Singh, M. S., & O'Neill, M. E. (2022). The climate system and the second law of thermodynamics. Reviews of Modern Physics, 94(1), 015001. **https://doi.org/10.1103/RevModPhys.94.015001**

Sohail, T., Zika, J. D., Irving, D. B., & Church, J. A. (2022). Observed poleward freshwater transport since 1970. Nature, 602(7898), 617–622. **https://doi.org/10.1038/s41586-021-04370-w**

Solodoch, A., Stewart, A. L., Hogg, A. McC., Morrison, A. K., Kiss, A. E., Thompson, A. F., et al. (2022). How Does Antarctic Bottom Water Cross the Southern Ocean? Geophysical Research Letters, 49(7), e2021GL097211. **https://doi.org/10.1029/2021GL097211**

Stellema, A., Sen Gupta, A., Taschetto, A. S., & Feng, M. (2022). Pacific Equatorial Undercurrent: Mean state, sources, and future changes across models. Frontiers in Climate, 4. **https://doi.org/10.3389/fclim.2022.933091**

Stokes, C. R., Abram, N. J., Bentley, M. J., Edwards, T. L., England, M. H., Foppert, A., et al. (2022). Response of the East Antarctic Ice Sheet to past and future climate change. Nature, 608(7922), 275–286. **https://doi.org/10.1038/s41586-022-04946-0**

Su, J., Schallenberg, C., Rohr, T., Strutton, P. G., & Phillips, H. E. (2022). New estimates of Southern Ocean annual net community production revealed by BGC-Argo floats. Geophysical Research Letters, 49(15), e2021GL097372. **https://doi.org/10.1029/2021GL097372**

Tasgaonkar, P., Zade, D., Ehsan, S., Gorti, G., Mamnun, N., Siderius, C., & Singh, T. (2022). Indoor heat measurement data from low-income households in rural and urban South Asia. Scientific Data, 9(1), 285. **https://doi.org/10.1038/s41597-022-01314-5**

Traill, C. D., Weis, J., Wynn-Edwards, C., Perron, M. M. G., Chase, Z., & Bowie, A. R. (2022). Lithogenic Particle Flux to the Subantarctic Southern Ocean: A Multi-Tracer Estimate Using Sediment Trap Samples. Global Biogeochemical Cycles, 36(9), e2022GB007391. **https://doi.org/10.1029/2022GB007391**

Tran, T. L., Ritchie, E. A., & Perkins-Kirkpatrick, S. E. (2022). A 50-Year Tropical Cyclone Exposure Climatology in Southeast Asia. Journal of Geophysical Research: Atmospheres, 127(4), e2021JD036301. **https://doi.org/10.1029/2021JD036301**

Trebilco, R., Fleming, A., Hobday, A. J., Melbourne-Thomas, J., Meyer, A., McDonald, J., et al. (2022). Warming world, changing ocean: mitigation and adaptation to support resilient marine systems. Reviews in Fish Biology and Fisheries, 32, 39–63. **https://doi.org/10.1007/s11160-021-09678-4**

Treble, P. C., Baker, A., Abram, N. J., Hellstrom, J. C., Crawford, J., Gagan, M. K., et al. (2022). Ubiquitous karst hydrological control on speleothem oxygen isotope variability in a global study. Communications Earth & Environment, 3, 29. **https://doi.org/10.1038/s43247-022-00347-3**

Truong, S. C. H., Huang, Y., Siems, S. T., Manton, M. J., & Lang, F. (2022). Biases in the thermodynamic structure over the Southern Ocean in ERA5 and their radiative implications. International Journal of Climatology, 42(15), 7685–7702. **https://doi.org/10.1002/joc.7672**

Udy, D. G., Vance, T. R., Kiem, A. S., & Holbrook, N. J. (2022). A synoptic bridge linking sea salt aerosol concentrations in East Antarctic snowfall to Australian rainfall. Communications Earth & Environment, 3, 175. **https://doi.org/10.1038/s43247-022-00502-w**

Ukkola, A. M., Abramowitz, G., & De Kauwe, M. G. (2022). A flux tower dataset tailored for land model evaluation. Earth System Science Data, 14(2), 449–461. **https://doi.org/10.5194/essd-14-449-2022**

Ulpiani, G., Hart, M. A., Di Virgilio, G., Maharaj, A. M., Lipson, M. J., & Potgieter, J. (2022). A citizen centred urban network for weather and air quality in Australian schools. Scientific Data, 9(1), 129. **https://doi.org/10.1038/s41597-022-01205-9**

Ulpiani, G., Duhirwe, P. N., Yun, G. Y., & Lipson, M. J. (2022). Meteorological influence on forecasting urban pollutants: Long-term predictability versus extreme events in a spatially heterogeneous urban ecosystem. Science of The Total Environment, 814, 152537. **https://doi.org/10.1016/j.scitotenv.2021.152537**

Ulpiani, G., Hart, M. A., Di Virgilio, G., & Maharaj, A. M. (2022). Urban meteorology and air quality in a rapidly growing city: Inter-parameter associations and intra-urban heterogeneity. Sustainable Cities and Society, 77, 103553. **https://doi.org/10.1016/j.scs.2021.103553**

Villalobos, Y., Rayner, P. J., Silver, J. D., Thomas, S., Haverd, V., Knauer, J., et al. (2022). Interannual variability in the Australian carbon cycle over 2015–2019, based on assimilation of Orbiting Carbon Observatory-2 (OCO-2) satellite data. Atmospheric Chemistry and Physics, 22(13), 8897–8934. **https://doi.org/10.5194/acp-22-8897-2022**

Vincent, C. L., & Huang, Y. (2022). Meso- and microscale response to variation in cloudiness at three forested sites in the Maritime Continent. Quarterly Journal of the Royal Meteorological Society, 148(742), 418–433. **https://doi.org/10.1002/qj.4212**

Vives, C. R., Schallenberg, C., Strutton, P. G., & Westwood, K. J. (2022). Iron and light limitation of phytoplankton growth off East Antarctica. Journal of Marine Systems, 234, 103774. **https://doi.org/10.1016/j.jmarsys.2022.103774**

Wang, G., Cai, W., Santoso, A., Wu, L., Fyfe, J. C., Yeh, S.-W., et al. (2022). Future Southern Ocean warming linked to projected ENSO variability. Nature Climate Change, 12(7), 649–654. **https://doi.org/10.1038/s41558-022-01398-2**

Wang, L.-C., Dao, T. L., & Yu, J.-Y. (2022). Continued weakening of the equatorial Pacific upwelling annual cycle in CMIP5 future projections. Scientific Reports, 12, 15595. **https://doi.org/10.1038/s41598-022-19874-2**

Wang, Y., Kajtar, J. B., Alexander, L. V., Pilo, G. S., & Holbrook, N. J. (2022). Understanding the Changing Nature of Marine Cold-Spells. Geophysical Research Letters, 49(6), e2021GL097002. **https://doi.org/10.1029/2021GL097002**

Webb, D. J., Holmes, R. M., Spence, P., & England, M. H. (2022). Propagation of barotropic Kelvin waves around Antarctica. Ocean Dynamics, 72(6), 405–419. **https://doi.org/10.1007/s10236-022-01506-y**

Weis, J., Schallenberg, C., Chase, Z., Bowie, A. R., Wojtasiewicz, B., Perron, M. M. G., et al. (2022). Southern Ocean Phytoplankton Stimulated by Wildfire Emissions and Sustained by Iron Recycling. Geophysical Research Letters, 49(11), e2021GL097538. **https://doi.org/10.1029/2021GL097538**

Welsh, J. M., Taschetto, A. S., & Quinn, J. P. (2022). Climate and agricultural risk: Assessing the impacts of major climate drivers on Australian cotton production. European Journal of Agronomy, 140, 126604. **https://doi.org/10.1016/j.eja.2022.126604**

White, B. A., Jakob, C., & Reeder, M. J. (2022). Fundamental Ingredients of Australian Rainfall Extremes. Journal of Geophysical Research: Atmospheres, 127(17), e2021JD036076. **https://doi.org/10.1029/2021JD036076**

Whitt, D. B., Cherian, D. A., Holmes, R. M., Bachman, S. D., Lien, R.-C., Large, W. G., & Moum, J. N. (2022). Simulation and scaling of the turbulent vertical heat transport and deep-cycle turbulence across the equatorial Pacific cold tongue. Journal of Physical Oceanography, 52(5), 981–1014. **https://doi.org/10.1175/JPO-D-21-0153.1**

Wright, N. M., Krause, C. E., Phipps, S. J., Boschat, G., & Abram, N. J. (2022). Influence of long-term changes in solar irradiance forcing on the Southern Annular Mode. Climate of the Past, 18(6), 1509–1528. **https://doi.org/10.5194/cp-18-1509-2022**

Xie, Z., Dommenget, D., McCormack, F. S., & Mackintosh, A. N. (2022). GREB-ISM v1.0: A coupled ice sheet model for the Globally Resolved Energy Balance model for global simulations on timescales of 100 kyr. Geoscientific Model Development, 15(9), 3691–3719. **https://doi.org/10.5194/gmd-15-3691-2022**

Xu, Y., Lin, L., Diao, C., Wang, Z., Bates, S., & Arblaster, J. (2022). The Response of Precipitation Extremes to the Twentieth- and Twenty-First-Century Global Temperature Change in a Comprehensive Suite of CESM1 Large Ensemble Simulation: Revisiting the Role of Forcing Agents Vs. the Role of Forcing Magnitudes. Earth and Space Science, 9(1), e2021EA002010. **https://doi.org/10.1029/2021EA002010**

Yang, X., Strutton, P. G., Cyriac, A., Phillips, H. E., Pittman, N. A., & Vives, C. R. (2022). Physical drivers of biogeochemical variability in the Polar Front meander. Journal of Geophysical Research: Oceans, 127(6), e2021JC017863. **https://doi.org/10.1029/2021JC017863**

Yung, C. K., Morrison, A. K., & Hogg, A. McC. (2022). Topographic Hotspots of Southern Ocean Eddy Upwelling. Frontiers in Marine Science, 9. **https://doi.org/10.3389/fmars.2022.855785**

Zhang, G., Azorin-Molina, C., Wang, X., Chen, D., McVicar, T. R., Guijarro, J. A., et al. (2022). Rapid urbanization induced daily maximum wind speed decline in metropolitan areas: A case study in the Yangtze River Delta (China). Urban Climate, 43, 101147. **https://doi.org/10.1016/j.uclim.2022.101147**

Zhao, W., Huang, Y., Siems, S., & Manton, M. (2022). A characterization of clouds over the Great Barrier Reef and the role of local forcing. International Journal of Climatology, 42(12), 6647–6664. **https://doi.org/10.1002/joc.7660**

Zhao, Y., Sun, R., Xie, Z., & Duan, A. (2022). Upper-Troposphere Saddle-Like Response to Springtime Surface Sensible Heating Over the Tibetan Plateau: Combined Effect From Baroclinic and Barotropic Process. Journal of Geophysical Research: Atmospheres, 127(11), e2021JD036002. **https://doi.org/10.1029/2021JD036002**

Zhao, Z., Holbrook, N. J., & Oliver, E. C. J. (2022). An eddy pathway to marine heatwave predictability off eastern Tasmania. Frontiers in Climate, 4. **https://doi.org/10.3389/fclim.2022.907828**

Zhao, Z., Han, M., Yang, K., & Holbrook, N. J. (2022). Signatures of midsummer droughts over Central America and Mexico. Climate Dynamics. **https://doi.org/10.1007/s00382-022-06505-9**

Zheng, F., Chen, J., Maier, H. R., & Gupta, H. (2022). Achieving Robust and Transferable Performance for Conservation-Based Models of Dynamical Physical Systems. Water Resources Research, 58(5), e2021WR031818. **https://doi.org/10.1029/2021WR031818**

Zscheischler, J., Sillmann, J., & Alexander, L. (2022). Introduction to the special issue: Compound weather and climate events. Weather and Climate Extremes, 35, 100381. **https://doi.org/10.1016/j.wace.2021.100381**

Published Data Sets

Holmes, R. M., Groeskamp, S., Stewart, K., & McDougall, T. (2022). Sensitivity of a Coarse-Resolution Global Ocean Model to a Spatially Variable Neutral Diffusivity - ACCESS-OM2 data and plotting routines [Data set] Zenodo. **https://doi.org/10.5281/zenodo.6253779**

King, M., Green, S., Heerdegen, A., Carouge, C., Wales, S., & Wolff, H. (2022, November 30). FrontDetection: A python module to detect fronts in xarray data (v2.0.0). Zenodo. **https://doi.org/10.5281/zenodo.7379134**

Lipson, M., Grimmond, S., Best, M., Chow, W., Christen, A., Chrysoulakis, N., et al. (2022). Site data archive for "Harmonized gap-filled dataset from 20 urban flux tower sites" for the Urban-PLUMBER project (v0.92) [Data set]. Zenodo. **https://doi.org/10.5281/zenodo.6590886**

Lipson, M., Nazarian, N., Hart, M. A., Nice, K. A., & Conroy, B. (2022). Urban form data for climate modelling: Sydney at 300 m resolution derived from building-resolving and 2 m land cover datasets [Data set]. Zenodo. **https://doi.org/10.5281/zenodo.6579061**

Lu, J., Nazarian, N., & Hart, M. A. (2022, May 20). OSM2LES - A python-based tool to prepare realistic urban geometry for LES simulation from OpenStreetMap (0.1.0). Zenodo. **https://doi.org/10.5281/zenodo.6566346**

Petrelli, P. (2022a, February 25). XMHW: Xarray based code to identify Marine HeatWave events and their characteristics (0.8.0). Zenodo. **https://doi.org/10.5281/zenodo.6270280**

Petrelli, P. (2022b, July 25). cds_etccdi: CDS API python wrapper to download the Climate extreme indices and heat stress indicators derived from CMIP6 global climate projections. (1.0.0). Zenodo. **https://doi.org/10.5281/zenodo.6897993**

Ridder, N. N. (2022). Compound hot and dry and wet and windy events in CMIP6 models (Version v1) [Data set]. Zenodo. Retrieved from **https://zenodo.org/record/6622392#.YqfUiOcRU2x**

Tran, T. L. (2022, February 9). Southeast Asia Tropical cyclone landfall database. https://doi.org/10.26190/unsworks/1987. Retrieved from **https://doi.org/10.26190/unsworks/1987**

Wales, S., & Petrelli, P. (2022, August 25). CleF - Climate Finder - A python based command line tool to query ESGF dataset hosted at NCI (1.4.1). Zenodo. **https://doi.org/10.5281/zenodo.7020691**

Impact, Engagement, Awards and Service

Prizes and Awards

Arblaster, Julie: Nominated Fellow of the Australian Meteorological and Oceanographic Society

Constantinou, Navid:
COSIMA 2022 most selfless contributor award

Eizenberg, Nathan:
Bureau of Meteorology PhD top-up scholarship

Falster, Georgy:
AINSE early career researcher grant

Fan, Xinyang: EGU outstanding student and PhD candidate presentation award

Gillett, Zoe:
2022 CLEX prize for best paper by a student

Hitchcock, Stacey:
2022 CLEX prize for best paper by an ECR

Holgate, Chiara: STA 2022 Superstar of STEM

Martinez Moreno, Josue:
AMOS Uwe Radok Award for best PhD thesis of 2021

Montoya Duque, Estefania: UniMelb Faculty of Science 3 minute thesis competition, runner-up

Naserikia, Marzie: UNSW Climate Change Research Centre prize for best paper

Ong, Qing Yee Ellie: UNSW Climate Change Research Centre best student presentation

Poddar, Shukla: UNSW Faculty of Engineering Teaching Excellence and Innovation Award

Poddar, Shukla: UNSW Faculty of Engineering Outstanding HDR Student Award

Poddar, Shukla: CLEX media engagement prize by an early career researcher

Purich, Ariaan: AMOS Meyers Medal for high-quality and innovative contributions by early career researchers

Reid, Kimberley: 2022 CLEX director's award

Taschetto, Andrea: Journal of Southern Hemisphere Earth Systems Science Outstanding Associate Editor Award

Vincent, Claire: University of Melbourne Faculty of Science Deans Award for Excellence in Teaching

Engagement with Industry and Government

Abram, Nerilie:
Bespoke advice to Senator David Pocock

Abram, Nerilie: Expert witness advice to hearings on the Climate Change Bill 2022 and the Climate Change (Consequential Amendments) Bill 2022

Alexander, Lisa: Isphording, Rachael: WMO/GCF Climate Science Information for Climate Action Regional Workshop in Johannesburg

Ashcroft, Linden: Work with Mornington Peninsula Council to develop climate emergency training program

Brown, Jonathan (JB); Evans, Jason; Shao, Yawen; Wilson, Alice: Live stream for the agricultural industry, hosted by Lee Constable

Evans, Jason: Presented at the Pacific Climate Change Centre Virtual Climate Innovative Exhibition

Evans, Jason: Online Panel Event for the Australian Water School: Australian Rainfall and Runoff – to the extreme!

Hobeichi, Sanaa; Nishant, Nidhi; Hobeichi, Sanaa: Presentation to Risk Frontiers "How can machine learning aid dynamical downscaling?"

Jakob, Christian: Presentation at the COP-27 WCRP Pavillon Event entitled: "Observing and Modelling the climate for a net-zero emissions future"

Kaplish, Angela: Discussion with Department of foreign Affairs and Trade regarding the Centre's work and overlapping opportunities.

Kaplish, Angela: Meeting with Climate Resiliance and Finance Branch, DFAT for water related effects of climate change

Kaplish, Angela: Submission of Climate Extremes report to Senior Advisor for Climate at the Dept of Prime Minister and Cabinet. Asked to be included on future Clex publications list.

Kaplish, Angela; Abram, Nerilie; Pitman, Andy: Submission to Environment and Communications Legislation Committee regarding the Climate Change Bill 2022 and the Climate Change (Consequential Amendments) Bill 2022

Kaplish, Angela; Evans, Jason; Pitman, Andy: Discussion with Transport NSW on policy response to extreme events. Further follow up with Jason Evans.

Kaplish, Angela; Gallant, Ailie: Meyer, Amelie; Pitman, Andy; Wilson, Alice: Submission to Environmental Protection and Biodiversity Conservation Amendment, Climate Trigger Bill 2022.

Kaplish, Angela; Jakob, Christian: Evans, Jason: Meeting with Windlab company regarding high resolution windmapping and wind droughts

Kaplish, Angela; Pitman, Andy: Report by Climate Change Authority with significant Centre input tabled to parliament

Meyer, Amelie: Hosted visit of the Ambassador of France to IMAS at UTAS

Pitman, Andy: Advice on scenarios for Christmas and Norfolk Island climate future.

Pitman, Andy:
Meeting with the Office of National Security

Pitman, Andy:
Meeting with Treasury on modelling extreme events.

Pitman, Andy: Discussion on Federal project on National Partnerships for Climate Projections

Pitman, Andy: Meeting with Australian Institute of Disaster Research (AIDR) on compound events

Pitman, Andy: Briefing to NSW Minister for Emergency Services and Resilience

Pitman, Andy: Briefing to NSW Minister minister for environment and heritage

Pitman, Andy; Macadam, Ian; Taschetto, Andrea; King, Andrew; Barnes, Michael: Written CLEX submission to the NSW Flood Inquiry

Pitman, Andy; Ukkola, Anna; Evans, Jason: Participation at NSW Government's 2030 and beyond Adaption for our Future conference

Raupach, Tim: Briefing regarding hail risk and climate change to the scientific committee of the European Union Aviation Safety Agency (EASA).

Raupach, Tim; Alexander, Lisa; Jucker, Martin; Pitman, Andy: Meeting with AON to discuss compound events and hazard correlations.

Raupach, Tim; Greco, Isabelle: Contributions to "Thunderstorm Friday" meetings to discuss thunderstorm science with other researchers and industry representatives

Reid, Kimberley: Discussions with Riparian, a water and agriculture investment firm

Reid, Kimberley; Abram, Nerilie; Holgate, Chiara; Pitman, Andy; Parker, Tess; Wilson, Alice: Update of Weather and Climate extremes report to climate Change Authority contribution to Annual Climate Statement

Santoso, Agus: Delivered a webinar for Swiss Re Climate TEDs series, titled: "The rise of the 3 headed dog"

Sherwood, Steven: Participated in UNSW and LaTrobe delegation to Suva, Fiji for presentation to UN Joint Country Team

Short, Ewan; Lane, Todd; Vincent, Claire: Presentation to the Bureau of Meteorology's Thunderstorm group

Strutton, Peter: Presentation on ocean observations to representatives from ConocoPhillips.

Wilson, Alice:
Meeting with Risk Frontiers on future collaboration

Wilson, Alice: Meeting with AgEcon on collaboration with the cotton industry.

Wilson, Alice:
Meeting with Deloitte on future collaboration

Wilson, Alice:
Meeting with the policy hub at ARC CoE CABAH

Yang, DongXia: Discussions with an asset management company on Environmental, Social, and Governance (ESG)

Public Talks and School Outreach

Ashcroft, Linden: Presentation on weather and climate science at the Swinburne LabRats Science Club for Grade 5 to Year 8 students at the Synchrotron

Ashcroft, Linden: Spoke to Casey Fields Primary School Grade 2 class about weather

Brown, Jonathan (JB): Judged three minute thesis talks for UNSW Science students and gave advice on presentation skills

Falster, Georgy: Interviewed by Year 5 students at Rivercrest Christian College about environmental and societal aspects of climate change

Greco, Isabelle; Isphording, Rachael: Supplied a dataset and presentation to the UNSW Data Science Hub's Year 10 Work Experience Program

Greco, Isabelle: Invited to share my research at an event run by AMOS and the UNSW Ocean and Atmosphere Systems Integrated Society

Greco, Isabelle: Participated in National Youth Science Forum UNSW Hub event

Greco, Isabelle: Volunteer and panelist at the Girls Do The Maths event

Greco, Isabelle: Invited panelist at the Queer Students in Science Society 'Pride in Science' Networking event

Greco, Isabelle: Mini three minute thesis event to fellow students at International House Residential College.

Hobbs, Will; Meyer, Amelie; Libera, Stephy: Presented at 'Pint of Science 2022' in Hobart, on Antarctic climate extremes

Hobeichi, Sanaa: Developed high school teaching resources with Pymble's Ladies College

Hobeichi, Sanaa: Delivered the 2022 Climate Classrooms teachers' workshop at UNSW in collaboration with the Monash Climate Change Communication Research Hub

Hobeichi, Sanaa: Represented UNSW at the launch of Australia's first school data science course at Pymble Ladies' College

Hogg, Andy: Guest Scientist Presentation to Junior Science Olympiad Spring School

Isphording, Rachael: Presented a high-level overview of climate science to Year 12 students at Cherrybrook Technology High School

Jakob, Christian: Second climate masterclass for EarthEd Victoria (Primary schools across Victoria), joint with Deadly Science

Jakob, Christian: Talk to the Melbourne Chapter U3A Current Affairs group entitled: "Weather and Climate Prediction: Science or Science Fiction?"

Jakob, Christian: Delivered Climate Masterclass online to 400 year 4-7 students across Victoria

Kajtar, Jules: Presentation to Waverley Council community group on climate change and social justice

Meyer, Amelie: Presentation to Tasmanian Science Meets Parliament Dinner

Meyer, Amelie: Presentation to grade 3-4 at Goulburn Street Primary School (Hobart) about 'What climate scientists do and dealing with the challenges of dyslexia'

Patel, Ramkrushnbhai: Curious Climate Experts - fielding questions regarding climate change asked by students

Petrelli, Paola: Panelist for Women in Data Science event organised by DataTAS UTAS

Petrelli, Paola: Weekly visit to Albuera st primary, Hobart, TAS to present a python coding course with grade5-6 students

Raupach, Tim: Attended the UNSW Open Day

Ridder, Nina: Presentation to the Australian Women in Emergency Services' Climate Action Group

Strutton, Peter: Presentation on climate change and biogeochemical Argo observations to grade 5/6s at Princes St Primary School

Taschetto, Andrea: Public talk about climate extremes to the Climate Action Network Australia

Wilson, Alice: Presented to year 9 students at Camberwell High School about science communications and knowledge brokering

Wyatt, James: Ran a Geophysical Fluid Dynamic station at the University of Tasmania open day

Wyatt, James: Operated a Geophysical Fluid Dynamic station at the Australian Antarctic Festival

Xie, Christal: Scouts Victoria STEM Camp: activity leader

Xie, Christal: Helper for Year 10 Work Experience at Uni.Melb and ran a session on weather forecasting

Xie, Christal: Presentation on aviation meteorology at VicJam Scout Event

Scientific Leadership and Editorships

Abram, Nerilie: Member, National Committee for Antarctic Science

Abram, Nerilie: Member, advisory board ANU Institute for Climate Change

Abram, Nerilie: Co-editor in Chief, Climate of the Past

Abram, Nerilie: Member, Australian Antarctic Science Council

Abram, Nerilie: Member, Climate Crisis Advisory Group

Abram, Nerilie: Member, External Advisory Board European DEEPICE project

Abram, Nerilie: Member, International Liason Committee Oldest Ice project

Abram, Nerilie: Australian Delegate to Scientific Committee for Antarctic Research

Abram, Nerilie: Editor, Climate of the Past

Abramowitz, Gab: Member, Australian Museum Climate Solutions Centre Advisory Group

Abramowitz, Gab: Member, Scientific Reference Panel for private company XDI / Climate Risk Engines

Abramowitz, Gab: Member, GEWEX Global Land/ Atmosphere System Study (GLASS) Panel

Alexander, Lisa: Co-chair, WMO Expert Team on Climate Information for Decision-making

Alexander, Lisa: Member, WCRP Joint Steering Committee

Alexander, Lisa: Member at Large, International Association of Meteorology and Atmospheric Science Executive Council

Alexander, Lisa: Editor in Chief, Weather and Climate Extremes

Arblaster, Julie: Member, Scientific Steering Committee 2022 WMO/UNEP Scientific Assessment of Ozone Depletion

Arblaster, Julie: Member, National Committee for Earth System Science

Arblaster, Julie: Member, Coupled Modelling Intercomparison Project (CMIP) panel

Ashcroft, Linden: Ordinary member, AMOS National Council

Brown, Josephine: Chair, Australian Meteorological and Oceanographic Society Expert Group on Climate Variability

Evans, Jason: Member, WCRP CORDEX Science Advisory Team

Hart, Melissa: Board member, International Association of Urban Climate

Hart, Melissa: Elected board member, International Association of Urban Climate

Hart, Melissa: Member, Australian Museum Climate Solutions Centre Advisory Group

Hart, Melissa: Co-chair, WCRP Academy Steering Group

Henley, Benjamin: Executive Domain Editor, WIREs Climate Change

Hogg, Andy: Chair, American Meteorological Society Oceanographic Research Awards Committee

Jakob, Christian: Member, GEWEX Scientific Steering Group

Meyer, Amelie: Member, International SCOR working group 'Analysing ocean turbulence observations to quantify mixing (ATOMIX)'

Meyer, Amelie: Member, Antarctic Women's Network

Perkins-Kirkpatrick, Sarah: Editor, Weather and Climate Extremes

Perkins-Kirkpatrick, Sarah: Co-Chair, Early Career Scientist Committee, International Association of Meteorology and Atmospheric Sciences

Pitman, Andy: Member, International J. Climatology International Editorial Board

Pitman, Andy: Member, National Committee for Earth System Science

Pitman, Andy: Member, TERN Science Advisory Committee

Ridder, Nina: Executive committee member, Young Earth System Scientists Community

Ridder, Nina: Member, WCRP Home Regional Information for Society Interim Coordinating Committee

Santoso, Agus: Editior, special issue in journal Frontiers in Climate

Santoso, Agus: Editor, Journal of Climate

Sen Gupta, Alexander: Member, National Committee for Earth System Science

Sherwood, Steven: Co-Chair, WCRP Safe Landing Climates Lighthouse

Sherwood, Steven: Member, WCRP Grand Challenge on Climate Sensitivity steering committee

Sherwood, Steven: Review editor, Science

Strutton, Peter: Member, Tropical Pacific Observing System Scientific Advisory Committee

Strutton, Peter: Member, International Biogeochemical Argo Mission Team

Taschetto, Andrea: Guest Associate Editor, Frontiers in Climate – Dynamics and Impacts of Tropical Climate Variability: Understanding Trends and Future Projections

Taschetto, Andrea: Member, CLIVAR Pacific Region Panel

Taschetto, Andrea: Member, CLIVAR Tropical Basin Interactions Working Group

Taschetto, Andrea: Associate Editor, Journal of Southern Hemisphere Earth System Science

Taschetto, Andrea: Review Editor, Frontiers in Climate – Predictions and Projections

Taschetto, Andrea: Associate Editor, Journal of the Southern Hemisphere Earth System Science

Vincent, Claire: Member, American Meteorological Society Mesoscale Processes Committee

Vincent, Claire: Member, ACCESS-NRI Scientific Advisory Committee

2022 KPIs

Performance measure		Target 2022	Achieved 2022
1. Number of research outputs	Annually		
Journal articles		100	207
Book chapters		5	0
Software modules published		2	11
Data sets published		2	20
Facebook posts		52	153
Centre website updates		25	129
LinkedIn posts		15	181
Science explainer videos		2	15
2. Quality of research outputs	Annually		
Percentage of publications in journals with impact factors greater than 2.0		80	97
Percentage of publications in journals with impact factors greater than 4.0		60	71
Percentage of publications in journals with impact factors greater than 10		10	15
3. Number of conferences held/offered by the Centre	Annually		
National workshop		1	1
International conference/workshop		1	1
Topical/Research program workshops		3	5
Teacher workshop with training material kit		1	1
4. Number of training courses held/offered by the Centre	Annually		
Professional development training in gender equity and diversity		1	1
Professional training for ECRs in engaging with government and decision makers		2	3
Computational skills workshops/tutorials		3	29
Science fundamentals workshops		1	6
Leadership and professional development workshops		1	4
Communications/writing workshops		1	3
Number of centre-wide virtual lectures/seminars		5	22
Percentage of students/ECRs attending researcher development activities		90%	84%
5. Number of additional researchers working on Centre research	Annually		
Postdoctoral researchers		5	10
Honours students		10	13
HDR students		20	24
Associate investigators		5	5
6. Student Completions	Annually		
Number of PhD completions		14	21
Number of Masters by Research completions		4	2
Number of Honours student completions		10	8
Percentage completing PhD students submitting within 4 years (FTE)		100%	71%[1]

Performance measure		Target 2022	Achieved 2022
7. Number of mentoring programs offered by the Centre	Annually		
We have an integrated researcher development program for HDR students and early-mid career researchers. It includes a personalised skills needs assessment and induction, an annual calendar of workshops and training opportunities, an annual winter school covering science fundamentals, cross-node and partner organisation supervision, and a mentoring circle initiative involving all centre researchers and students allowing a range of mentoring and networking opportunities.		1	1
Percentage of ECRs and HDR students with a completed training needs analysis template		90%	n/a[2]
8. Number of presentations/briefings	Annually		
To the public		10	12
To government		10	23
To industry/business/end users		5	16
To non-government organisations		5	7
To professional organisations and bodies		5	2
9. Number of new organisations collaborating with, or involved in, the Centre	Annually	0	
10. Gender profile by cohort (female/male/any gender)	Annually	F:M:Any	
Graduate students		40:40:20	48:52
Research fellows		40:40:20	68:32
Senior research fellows		40:40:20	N/A[3]
Centre leaders		40:40:20	50:50
Administration team		40:40:20	83:17
Advisory board members		40:40:20	30:70
Keynote speakers at workshops and conferences		40:40:20	50:50

1. Covid had a marked effect on many student's duration of candidature
2. Accurate data not collected in 2022. Process implemented for 2023
3. No senior RAs currently employed

Performance measure		Target 2022	Achieved 2022
CLEX Specific KPIs			
11. Computational Modelling Support	Annually		
Supported climate models served to the community		15	20
New/updated/supported environment for data analysis served to the community		5	9
New/refined/updated data sets served to the community.		8	12
Monthly bulletin to all researchers on CMS-related updates		11	11
Training material produced and delivered		15	20
Percentage of compute time allocation used		95%	96%
12. Researcher Development Program	Annually		
Percentage of students with cross node and/or partner organisation support and project input		80	35%
Student / ECR internships in industry/government		2	2
Percentage of students/ECRs making a research visit to other nodes and/or Australian partner organisations		25	14%
Percentage of students/ECRs making a research visit to international partner organisations or organisation with a collaborative relationship		30	4%
Number of undergraduate summer scholarships offered		15	16
Regular Research Program videoconference meetings p/a		10	88
Media KPIs	**Annually**		
Media releases		15	20
Website – unique hits		40000	34974
Website – page views		50000	113,736
CLEX media mentions		300	7615
Social media – Twitter (new followers)		500	552
Social media – Facebook (new followers)		300	67
Social media - LinkedIn (new followers)		50	717
Additional pathways to impact	**Annually**		
Establishment of significant partnerships			
Data sets provided to or updated for stakeholders		3	3
Briefing notes published		8	10
Number of research program meetings with stakeholder focus		8	6
Tailored advice provided to stakeholders		5	12
Demonstrated examples of model improvements available for use in national modelling systems		2	2

2022 Financial Statement

Executive Summary

The Australian Research Council Centre of Excellence for Climate Extremes formally commenced operations on 4 August 2017. The Centre's financial affairs are conducted within the established procedures, controls and delegations of the relevant universities, and as set out by the Australian Research Council (ARC). This statement provides an analysis of the income and expenditure of the Centre of Excellence.

In 2022, the Centre received $6,028,704 (100%) income compared to the full-year budget of $6,023,934.
In terms of the Centre's expenditure, $5,477,702 (96%) was spent compared to the full-year budget of $5,682,352.

In 2022, personnel accounted for the highest proportion of expenditure of $3,845,045 (70%),
followed by travel expenditure of $682,935 (12%). Overall, the Centre's cash balance in 2022 is $551,003.

Financial Management and Performance

Quarterly financial reporting monitors institutional income and expenditure against the Centre-wide budget.
The Centre's Finance Manager prepares consolidated financial statements for review by the Director.
The Centre-wide finances are discussed at Centre Executive meetings, and financial statements are tabled at Centre Board meetings.

The Centre meets its annual reporting requirements to the ARC and meets all other reporting obligations set by partner organisations that provide financial support.

2022 Income

Cash income totalled $6,028,704 from all sources. The Centre derived its income from the ARC, participating universities, the Bureau of Meteorology (BoM), the NSW Department of Planning and Environment (DPE), the NSW Department of Industry Research Attraction and Acceleration Program (RAAP) and the Department of Agriculture, Fisheries and Forestry. Income is summarised by the source in detail in the tables that follow.

1: Australian Research Council Funding

The Centre received indexed income from the ARC of $4,720,210. This was distributed to the institutions following the inter-institutional agreement and was used for payroll, scholarships, consumables and events, equipment and maintenance and travel.

2: Government Funding

2.1 Bureau of Meteorology

BoM committed $20,000. This cash contribution was targeted at PhD top-up scholarships for students working collaboratively with BoM.

2.2 NSW Department of Planning and Environment

The cash investment from DPE is specifically intended to support pathways-to-impact by supporting an improved understanding of climate extremes in NSW and by making this knowledge available to the community and decision-makers in the form that they need. The Centre received 3 years (2021-2023) of funding totalling $300,000 in 2021. An additional $25,000 was received in 2022.

2.3 NSW Department of Industry RAAP

RAAP funding invests in appointing a Research Fellow to focus on high-resolution modelling of processes relating to climate extremes (e.g. hail, drought processes, vegetation-climate extremes, etc.). The Centre received $143,000 in 2022.

2.4 Department of Agriculture, Fisheries and Forestry

Funds of $4,000 were provided to deliver one annual Ozone Science Summer Scholarship in 2022.

3: Collaborating Organisation Funding

Cash contributions to the Centre of Excellence from the Administering Organisation and the Collaborating Organisations amounted to $1,111,724, as follows:

UNSW	$510,974
ANU	$216,095
University of Melbourne	$131,965
University of Tasmania	$0*
Monash University	$252,690

*UTAS provided $314,432 in 2021, covering 2021 and 2022.

4: In-kind Contributions

In-kind support totalled $7,812,357 in 2022. The Centre is grateful for $5,604,270 of in-kind contributions, provided by the administering organisation and the collaborating organisations. The contributions are primarily personnel-related and consist of the apportioned salary, on-costs and burdens of faculty members and other university staff members who contribute towards the Centre. Partner organisations provided additional in-kind contributions of $2,208,087.
Again, this was mainly personnel time.

Organisation	In Kind Budget	In Kind Actual
ANU	736,869	743,058
BOM	154,878	154,878
CSIRO	356,000	302,177
LATMOS CNRS/INSU/IPSL	13,400	13,400
Max Planck Inst. For Meteorology	20,000	20,000
Met Office UK	150,000	150,000
Monash	855,431	1,077,992
NASA Goddard Space Flight Center	43,666	43,666
NCAR	123,355	123,355
NCI	892,000	892,000
NOAA	30,000	30,000
DPIE	312,785	312,785
Risk Frontiers Grp	45,000	45,000
Swiss Federal Inst of Tech	64,036	64,036
UMEL	967,564	1,141,091
Uni of Arizona, USA	56,790	56,790
UNSW	1,931,552	2,056,615
UTAS	462,828	585,515
TOTAL	7,216,153	7,812,357

2022 Leverage

The Centre's 2022 cash income of $6,028,704 and in-kind support of $7,812,357 total $13,841,061 with ARC funding accounting for $4,720,210 of the total income. The Centre's leverage of $9,120,851 equates to $1.93 of external funding and in-kind contributions for each $1.00 received from the ARC.

2022 Expenditure

In 2022 the Centre expended $5,477,702, analysed below:

Personnel (including on-costs)	$3,845,045	70%
Scholarships	$531,680	10%
Equipment and Maintenance	$33,256	1.0%
Consumables and Events	$384,785	7.0%
Travel	$682,935	12%

2022 Income Vs Expenditure

Income and Expenditure are based on cash and is derived from the institutions' general ledgers. The collaborating organisations certify income and expenditure by formally acquitting all grants as of 31 December 2022.

The Centre's cash expenditure of $5,477,702 was below income of $6,028,704 by $551,003.

The Centre will carry over a balance of $551,003 to 2023. The carry-over by institution is as follows:

University of New South Wales	$718,052	surplus
Australian National University	$40,146	surplus
University of Melbourne	$58,397	deficit
University of Tasmania	$196,517	deficit
Monash University	$47,719	surplus

In summary, as at 31 December, 2022, the financial position for the life of the ARC Centre of Excellence for Climate Extremes after its sixth year of operation is as follows:

Total Cash Income	$6,028,704
Total Expenditure	$5,477,702
Surplus carried forward to 2023	$551,003

Finance Tables

COECX Cash Income & Expenditure

	Actual			Actual			Budget/ Forecast		
1. Cash Income	2017	2018	2019	2020	2021	2022	2023	2024	TOTAL
Australian Research Council- Centre of Excellence	4,350,000	4,250,000	4,250,001	4,300,000	4,300,000	4,300,000	4,231,751	68,250	30,050,000
Australian Research Council- Centres of Excellence Indexation	65,250	128,456	211,645	295,388	378,106	420,210	585,419	0	2,084,474
Bureau of Meteorology	10,000	20,000	30,000	30,000	30,000	20,000	20,000	0	160,000
NSW Department of Planning and Environment	100,000	100,000	100,000	165,000	300,000	25,000	0	0	790,000
NSW Department of Industry/ RAAP	143,000	143,000	142,857	143,000	143,000	143,000	142,143	0	1,000,000
University Node Cash Contributions	1,103,142	1,285,737	1,253,234	1,236,647	1,600,020	1,111,724	993,559	0	8,584,063
Other (Interest Distribution)	0	15,871	19,146	3,087	696	4,770	0	0	43,570
Department of Agriculture, Water and the Environment	0	0	4,523	0	4,000	4,000		0	12,523
Sydney Water Corporation	0	200,000	0	0	0	0	0	0	200,000
Total	5,771,392	6,143,064	6,011,406	6,173,122	6,755,822	6,028,704	5,972,871	68,250	42,924,630

2. ARC Expenditure	2017	2018	2019	2020	2021	2022	2023	2024	TOTAL
Personnel	114,662	1,941,921	3,354,377	3,350,987	2,992,974	3,418,564	5,062,732	6,557,175	26,793,392
Scholarship	6,358	90,723	158,714	191,388	217,551	311,788	403,297	275,085	1,654,903
Equipment and Maintenance	0	5,105	33,216	12,814	3,500	4,202	4,950	83,750	147,538
Consumables and Events	16,369	165,632	160,379	110,198	128,817	297,141	224,909	278,190	1,381,633
Travel - Conference, workshops and meetings (Staff, AI)	12,634	133,395	210,647	48,557	10,454	142,930	227,938	190,525	977,079
Travel - Conference, workshops and meetings (Postdocs and Students)	0	40,497	178,653	49,316	26,531	208,137	108,712	74,239	686,085
Travel - Visitor travel to the Centre and other	1,336	38,236	31,324	22,335	0	5,966	73,557	56,594	229,349
Travel - New staff relocation expenses	0	0	0	0	0	0	0	0	-
Travel - Research Visits (Staff, AI)	0	9,585	34,451	7,153	-2,004	12,647	49,987	27,786	139,606
Travel - Research Visits (Postdocs and Students)	1,341	380	3,484	1,802	0	5,783	61,787	50,310	124,888
Total	152,701	2,425,476	4,165,244	3,794,550	3,377,822	4,407,159	6,217,869	7,593,654	32,134,474

3. Nodes Expenditure	2017	2018	2019	2020	2021	2022	2023	2024	TOTAL
Personnel	65	311,556	615,789	475,725	603,844	92,194	382,193	1,973,341	4,454,707
Scholarship	10,706	61,092	132,039	120,983	105,712	185,892	458,583	408,962	1,483,969
Equipment and Maintenance	6,182	48,972	46,325	17,274	41,776	29,054	36,353	28,798	254,735
Consumables and Events	4,575	43,568	53,831	48,424	43,636	87,644	111,260	125,251	518,188
Travel - Conference, workshops and meetings (Staff, AI)	12,901	49,055	67,758	21,570	14,943	84,552	118,500	118,927	488,206
Travel - Conference, workshops and meetings (Postdocs and Students)	2,969	60,341	104,294	18,986	13,011	178,416	238,500	222,162	838,679
Travel - Visitor travel to the Centre and other	0	9,570	41,971	9,881	0	0	43,000	43,000	147,422
Travel - New staff relocation expenses	7,354	55,163	22,719	2,193	37,490	29,628	40,882	0	195,430
Travel - Research Visits (Staff, AI)	5,132	8,979	22,952	4,320	-2,677	11,965	32,500	31,024	114,195
Travel - Research Visits (Postdocs and Students)	0	10,981	13,860	8,446	1,296	-4,750	34,500	24,200	88,533
Total	49,885	659,276	1,121,538	727,802	859,030	694,595	1,496,272	2,975,666	8,584,063

	Actual		
4. Others	2017	2018	2019
Personnel	61,192	192,341	272,939
Scholarship	0	10,000	14,000
Equipment and Maintenance	0	0	0
Consumables and Events	0	0	0
Travel - Conference, workshops and meetings (Staff, AI)	0	0	0
Travel - Conference, workshops and meetings (Postdocs and Students)	0	0	523
Travel - Visitor travel to the Centre and other	0	0	0
Travel - New staff relocation expenses	0	0	0
Travel - Research Visits (Staff, AI)	0	0	0
Travel - Research Visits (Postdocs and Students)	0	0	0
Total	61,192	202,341	287,462

5. Summary Income Vs. Expenditure / Carry Over	2017	2018	2019
ARC			
Total Income	4,415,250	4,378,456	4,461,646
Total Expenditure	152,701	2,425,476	4,165,244
Income less Expenditure	4,262,549	1,952,980	296,402
Nodes			
Total Income	1,103,142	1,285,737	1,253,234
Total Expenditure	49,885	659,276	1,121,538
Income less Expenditure	1,053,257	626,461	131,696
Other			
Total Income	253,000	478,871	296,526
Total Expenditure	61,192	202,341	287,462
Income less Expenditure	191,808	276,530	9,064
Carry over surplus / deficit	5,507,614	2,855,971	437,162

Actual			Budget		
2020	2021	2022	2023	2024	TOTAL
338,433	260,881	334,287	348,666	197,169	2,005,909
10,000	79,000	34,000	10,000	35,000	192,000
0	0	0	0	0	-
0	0	0	0	0	-
0	0	0	0	0	-
0	0	7,661	0	0	8,184
0	0	0	0	0	-
0	0	0	0	0	-
0	0	0	0	0	-
0	0	0	0	0	-
348,433	339,881	375,948	358,666	232,169	2,206,093

2020	2021	2022	2023	2024	TOTAL
4,595,388	4,678,106	4,720,210	4,817,169	68,250	32,134,474
3,794,550	3,377,822	4,407,159	6,217,869	7,593,654	32,134,474
800,838	1,300,284	313,051	-1,400,699	-7,525,404	0
1,236,647	1,600,020	1,111,724	993,559	0	8,584,063
727,802	859,030	694,595	1,496,272	2,975,666	8,584,063
508,845	740,990	417,129	-502,713	-2,975,666	0
341,087	477,696	196,770	162,143	0	2,206,093
348,433	339,881	375,948	358,666	232,169	2,206,093
-7,346	137,815	-179,178	-196,523	-232,169	-0
1,302,337	2,179,088	551,003	-2,099,936	-10,733,239	0

Australian Government
Australian Research Council

climate extremes
ARC centre of excellence

climateextremes.org.au