PROPOSED STUDY SUMMARY	
Title	Sub-hourly extreme precipitation (SHEP)
Abstract *(no more than 500 words and detailing how this proposal addressing the FPS criteria.)*	Many observational studies have found that short duration (hourly and below) precipitation extremes have been increasing in intensity faster than longer duration extremes. In many cases these short duration extremes are increasing much faster than expected based on the Clausius-Clapeyron relationship. In urban environments these short duration extremes are often responsible for flash flood events. A study over Sydney found that 10 minute precipitation extremes have increased in intensity by ~40% over the last 20 years. This is a very large and surprising increase. It is currently unknown whether this increase is unique to Sydney or is occurring in other locations, what mechanisms are responsible for this change, and whether we should expect this trend to continue into the future. This project uses coordinated, convection permitting, regional climate downscaling experiments to investigate how short duration (hourly to sub-hourly) precipitation extremes have been changing over major Australian and New Zealand cities and how are they projected to change due to global warming? (criterion 1). The project will be split into two main activities. The first activity will take an event based approach using reanalysis boundary conditions to investigate model skill when simulating these short duration extremes, evaluating them against observations from automatic weather stations and a network of weather radars, and convective-scale reanalysis (criterion 2). These events will also be simulated within a pseudo-global warming framework to explore how they would develop in a future warmer world. The second activity will focus on long-duration simulations at convection permitting resolutions to investigate the modelled changes in these SHEP events. This activity will include both reanalysis driven and CMIP6 GCM driven simulations. The simulations for activity 2 will take longer and use much more resources than activity 1 but they will also allow a more comprehensive assessment of future changes in these events including changes in their frequency not addressed in activity 1. Stakeholders involved include the Australian Bureau of Meteorology (wants to improve the forecasting of these events and reliability of flash flood warnings), State Emergency Services (who are early responders to flash flood events), as well as the Australian Climate Service and the National Environmental Science Program Climate Systems Hub who work with various stakeholders performing climate change risk assessments (criterion 3) and the National Partnership for Climate Projections (NPCP). The applicant group contains multiple institutional groups within Australia and New Zealand (criterion 4).
Expected study duration	3 years

LEAD INVESTIGATOR DETAILS	
Name	Jason Evans
Affiliation	University of New South Wales
Email address	jason.evans@unsw.edu.au
Address	Climate Change Research Centre, University of New South Wales, Sydney, Australia

PARTICIPATING PARTNERS *Copy and paste partner section as required for further partners*		
Partner 1	**Name**	Giovanni Di Virgilio
	Affiliation	NSW DCCEEW and UNSW
	Email address	giovanni.divirgilio@environment.nsw.gov.au; giovanni@unsw.edu.au
	Address	480 Weeroona Road, Lidcombe NSW 2141, Australia
Partner 2	**Name**	Chun-Hsu Su/Emma Howard
	Affiliation	Bureau of Meteorology
	Email address	chunhsu.su@bom.gov.au, Emma.Howard@bom.gov.au
	Address	Melbourne Office and Brisbane Office, Bureau of Meteorology, Australia
Partner 3	**Name**	Jatin Kala
	Affiliation	Murdoch University
	Email address	J.Kala@murdoch.edu.au
	Address	School of Environmental and Conservation Sciences, Murdoch, University, 6150, Western Australia, Australia
Partner 4	**Name**	Peter B. Gibson
	Affiliation	National Institute of Water and Atmospheric Research (NIWA)
	Email address	peter.gibson@niwa.co.nz

	Address	301 Evans Bay Parade, Hataitai, Wellington 6021
Partner 5	**Name**	Neelesh Rampal
	Affiliation	National Institute of Water and Atmospheric Research (NIWA)
	Email address	neelesh.rampal@niwa.co.nz
	Address	82 Wyndham St, Auckland, 1010, New Zealand.
Partner 6	**Name**	Jozef Syktus
	Affiliation	University of Queensland.
	Email address	j.syktus@uq.edu.au
	Address	The University of Queensland, St Lucia, QLD, 4072, Australia
Partner 7	**Name**	Sarah Chapman
	Affiliation	Department of Energy and Climate, Queensland Government
	Email address	sarah.chapman@des.qld.gov.au
	Address	EcoSciences Precinct, 41 Boggo Rd. Dutton Park QLD 4102, Australia
Partner 8	**Name**	Muhammad Omer Mughal
	Affiliation	Department of Water and Environmental Regulation
	Email address	omer.mughal@dwer.wa.gov.au
	Address	Prime House, 8 Davidson Terrace, JOONDALUP WA 6027, Australia
Partner 9	**Name**	Marcus Thatcher / Sonny Truong
	Affiliation	CSIRO Environment
	Email address	Marcus.Thatcher@csiro.au , Sonny.Truong@csiro.au
	Address	107 Station Street Aspendale,Victoria, Australia
Partner 10	**Name**	Ben Evans
	Affiliation	National Computational Infrastructure (NCI) Australia
	Email address	Ben.Evans@anu.edu.au .
	Address	Leonard Huxley Bldg, 56 Mills Road, ANU, ACTON, Australia

Partner 11	**Name**	Stephen Stuart
	Affiliation	National Institute of Water and Atmospheric Research (NIWA)
	Email address	stephen.stuart@niwa.co.nz
	Address	301 Evans Bay Parade, Hataitai, Wellington 6021, New Zealand
Partner 12	**Name**	Click here to enter text.
	Affiliation	Click here to enter text.
	Email address	Click here to enter text.
	Address	Click here to enter text.
Partner 13	**Name**	Click here to enter text.
	Affiliation	Click here to enter text.
	Email address	Click here to enter text.
	Address	Click here to enter text.

PROPOSAL ***Maximum of 750 words for this section with all headings to be addressed***	
Objectives	• Quantify observed changes in short duration (hourly to sub-hourly) precipitation extremes over major Australian cities. • Evaluate the ability of convection permitting Regional Climate Models to simulate these short duration precipitation extremes. • Simulate changes in these short duration precipitation extremes due to climate change.
Relevance to CORDEX vision	This project addresses CORDEX Scientific challenges related to cities and convective systems by targeting short duration extreme precipitation over major cities. The project aims to improve our understanding of the processes important in producing these extremes and how they will change with climate change using very high resolution convection permitting models. Machine Learning/Artificial Intelligence approaches to expand the CP

	ensemble to better span the range of plausible future climates will also be explored. The outcomes of this project will also be connected to climate change risk assessments performed with the State Emergency Services.
Science aims	This project aims to answer the questions: ● How have short duration (hourly to sub-hourly) precipitation extremes been changing over major Australian cities? ● How well can convection permitting Regional Climate Models simulate these short duration precipitation extremes? ● How are these short duration precipitation extremes projected to change due to global warming? In the process of addressing the above questions we will perform experiments that could also be used to investigate: ● Investigate the sensitivity of the results to experiment design choices (e.g. spectral nudging, bias correction,...) ● What mechanisms/processes contribute to the production of short duration extreme precipitation? Do different RCMs agree on the processes/contributions? ● How well can convection permitting Regional Climate Models simulate hail and/or thunderstorm related extreme wind gust events? ● What mechanisms/processes contribute to the production of hail? Do different RCMs and/or parameterisations within individual RCMs agree on the processes/contributions? ● What mechanisms/processes contribute to the production of extreme wind gusts? Do different RCMs agree on the processes/contributions? ● Intensification of Short-Duration Rainfall Events Attributable to Urbanization and the Shifting of Precipitation Patterns Away from Urban Centers ● How much of the changes in thunderstorm, hail events and convective wind gusts can be inferred from large-scale environmental proxies or diagnostics (e.g., SHIP, CAPE)? What are the uncertainty and biases in these large-scale diagnostics? Do these differ from what we can infer from the existing 10-20 km CORDEX experiments? ● Can trained ML approaches accurately emulate short-duration extreme precipitation and the related physical processes as simulated within convection-permitting RCMs?

Expected impact *(e.g scientific, end user, policy)*	● Improved understanding of processes causing changes in SHEP potentially leading to improvements in the model representation of these events. ● Projected future changes in SHEP to inform climate change risk assessments. End users include insurance, national/state risk assessment, infrastructure design, and others. ● Produce new body of knowledge on SHEP changes due to climate change to inform future IPCC reports. ● Prepare/improve models and inform experiment design for high resolution downscaling of CMIP7
Project timeline *Detail the key milestones and responsibilities throughout project duration*	**Activity 1: Event based analysis** ● Co-develop guidelines for coordinated experiments including selection of target events. ● Collect a variety of observation-based datasets including automatic weather stations, weather radars, lightning data, radiosondes, regional reanalysis, State Emergency Services damage reports, etc. ● Perform reanalysis driven simulations and evaluate against observation-based data. ● Analysis of simulations to identify key processes in the production of SHEP. ● Perform pseudo-global warming experiments and analyse to identify how the events and their contributing processes change. ● Explore the added value of ~1km resolution compared to ~10-20km resolution. ● **Activity 2: Climate length simulations** ● Identify CORDEX-CMIP6 Australasia simulations to downscale from. Simulations within this ensemble are currently being evaluated and the chosen simulations will provide the boundary conditions for the convection permitting experiments. ● Perform coordinated simulation experiments of the recent past and future. ● Analyse the projected future climate outcomes in various ways including the simulations of changes in SHEP events. ● Examine the ability of AI/ML techniques to expand the Convection Permitting ensemble. ● Work with stakeholders to quantify the implications for their climate change risk assessments. ● Compare the future changes simulated with a pseudo-global warming approach with those obtained from climate length simulations.

CRITERIA ADDRESSED

How does your proposal address the following criteria (maximum 200 words per criteria)	
1. Targeting fine scale processes and clear scientific questions of interest	This proposal is targeting fine scale processes involved in the production of sub-hourly extreme precipitation (SHEP). Convection permitting resolutions are required to capture the intense, short-lived, convection driven events that produce SHEP. A range of scientific questions are being addressed, starting with questions around the model capability to simulate SHEP accurately, the key processes involved and the likely future changes in SHEP. Complementing this, the same model experiments will be used to explore similar questions for other phenomena that occur on small time and space scales including hail and convective wind gusts.
2. Use of observational data including not only meteorological but also derived data (e.g. soil moisture, streamflow etc.)	As well as standard meteorological data, largely from automated weather stations, this project will use weather radar, lightning data, radiosonde data. We will also use stakeholder collected data such as the State Emergency Services damage data which compiles observed instances of flash flood damage, extreme wind and extreme rain damage.
3. End-to-end perspective and potential to support demonstrated local/regional needs	This project is supported by the Australian National Computational Infrastructure (NCI) high performance computing facility who will provide compute resources and data curation and distribution. Also in this project the Australian Climate Service (ACS) and the National Environmental Science Program Climate Systems Hub work with stakeholders to provide the necessary climate change information to perform climate change risk assessments. This project will provide future change data on a family of extremes that is currently missing from these risk assessments. In addition, the State Emergency Services are very interested in understanding future changes in SHEP events and are sharing data from their past event damage database.
4. Applicant group	The applicant covers participants from many organisations in Australia and New Zealand: University of New South Wales (UNSW), Murdoch University, NSW Department of Climate Change, Energy, the Environment and Water (DCCEEW), Bureau of Meteorology, National Institute of Water and Atmospheric Research (NIWA) New Zealand, University of Queensland, Queensland government Department of Energy and Climate, WA Department of Water and Environmental Regulation (DWER), the Commonwealth Scientific and Industrial Research Organisation (CSIRO), and the National Computational Infrastructure (NCI) high performance computing facility.

SUGGESTIONS FOR POTENTIAL REVIEWERS		
Reviewer 1	**Name**	Andreas Prein

	Position	Professor
	Affiliation	ETH Zurich (formerly NCAR)
	Email address	prein@ucar.edu
	Expertise	Convection permitting modelling
Reviewer 2	**Name**	Elizabeth Kendon
	Position	Met Office Science Fellow
	Affiliation	UK Met Office
	Email address	elizabeth.kendon@metoffice.gov.uk
	Expertise	Convection permitting modelling
Reviewer 3	**Name**	Stefan Sobolowski
	Position	Research Professor
	Affiliation	NORCE, Norway
	Email address	stso@norceresearch.no
	Expertise	Convection permitting modelling