Fostering science-industry connections in Australia’s severe-storm science community

Timothy H. Raupach, a,b Joshua S. Soderholm, c and Joanna Aldridge, e

a UNSW Sydney Climate Change Research Centre, Sydney, New South Wales, Australia
b ARC Centre of Excellence for Climate Extremes, Sydney, New South Wales, Australia
c Science and Innovation Group, Bureau of Meteorology, Melbourne, Victoria, Australia
d School of Geosciences, University of Sydney, Sydney, New South Wales, Australia
e QBE Australia, Sydney, New South Wales, Australia

Corresponding author: Timothy H. Raupach, timothy.h.raupach@gmail.com

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The science-industry workshop on severe convective storms

What: About 80 attendees from the research sector, weather services, insurance, utilities, disaster management, and risk analysis sectors met in Sydney, Australia, to bring together researchers and industry representatives working on severe convective storms.

When: 3-4 August, 2023

Where: Sydney, Australia

In Australia, severe convective storms cause significant damage through their associated hazards of hail, extreme wind gusts, extreme rain, lightning, and tornadoes (Allen and Allen 2016). Convective storms can kill or injure people, impact the built environment, and damage crops (Allen and Allen 2016) and disrupt utilities such as power generation (Earl et al. 2019). Hailstorms are a primary contributor to insured losses, with the costliest catastrophe on record in terms of normalized insured losses being the April 1999 Sydney hailstorm (ICA 2023b). Wind and rain produced by convective storms also cause damages that can extend into millions of dollars per event (ICA 2023a). Despite this high damage potential, there remain knowledge gaps in the physical understanding of severe storms, and around changes in their distribution, frequency, and intensity with climate change (Allen 2018; Allen and Allen 2016; Raupach et al. 2023b; Raupach et al. 2021; Seneviratne et al. 2021). With a community working across industry and academia, the severe storms space is one in which collaborative and cross-disciplinary research will be key to closing these gaps. In August 2023, about 80 researchers and practitioners from academia and industry assembled in Sydney, Australia, for the inaugural Science-Industry Workshop on Severe Convective Storms. The focus of the workshop was to bring together the research and industry severe storm communities in Australia, to discuss the latest scientific developments in the field, foster connections and collaborations, and through open discussion to identify shared challenges and plan for the future.

Attendees from academic institutions included representatives from Australian universities, two Australian Research Council Centres of Excellence, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Bureau of Meteorology (the Bureau). Attendees from industry included representatives from insurance and reinsurance firms, risk-analysis companies, utility services, Government and private weather services, the finance and agricultural sectors, a State Emergency Service, and government departments from the Australian Federal Government and state-level New South Wales Government. The depth of
experience and wide variety of sectors present allowed for a broad range of ideas and approaches to be discussed.

**Key topics**

The two-day workshop comprised 25 talks, including two keynotes, two panel discussions, and a networking event (full program available at [https://conference.unsw.edu.au/en/science-industry-workshop-on-severe-convective-storms](https://conference.unsw.edu.au/en/science-industry-workshop-on-severe-convective-storms)). The workshop was opened by Professor Andy Pitman, director of the Australian Research Council (ARC) Centre of Excellence for Climate Extremes. The first keynote was given by an international guest speaker, Dr Julian Brimelow from the University of Western Ontario, Canada. Dr Brimelow introduced the Canadian Northern Hail Project (Brimelow et al. 2023) and Northern Tornado Project (Sills et al. 2020), and outlined the resources and investment required for such dedicated and impactful field campaigns. The second keynote was given by Kylie Macfarlane, Chief Operating Officer of the Insurance Council of Australia (ICA), who spoke about the role of general insurers in Australia and the role of the ICA in facilitating research with industry impact. The two panel discussions were respectively for early-career researchers (ECRs) and more experienced colleagues. The ECR panel discussed community, challenges for junior researchers, and how they viewed industry connections and opportunities. The second panel discussed workshop outcomes and possible future directions for the Australian severe convective storm community.

The workshop was divided into the following thematic sections:

A) Convective storm hazards and impacts

Speakers discussed hail, heavy rain, and damaging winds caused by convective storms, and their impacts. In southern Australia, heavy rain days (25 mm or more) are usually associated with thunderstorms (Pepler et al. 2020). Impacts from convective storms are often coupled and do not occur in isolation. Mitigation of storm impacts requires both better understanding of physical hazards and an increased effort to implement known strategies to lessen impacts. It is well acknowledged that observations of storms in Australia are limited, particularly away from population centers, which complicates analysis of hazards and impacts. Severe storms near population centers can be monitored using the radar network, which is especially useful for rain rate retrieval but can also be used for other hazards. For example, radars can indicate hail occurrence (e.g. Brook et al. 2023a), and the mismatch between radar-based hail swaths and damage on the ground can be improved.
using hail trajectory models (Brook et al. 2021). The full 3D wind field can be retrieved using Doppler information, although care must be taken with spatial interpolation (Brook et al. 2023b). Further, a new operational radar-based 3D wind retrieval and nowcasting technique named SWIRL (Synthetic Winds from Radar or Lidar) has been developed by the Bureau for this purpose (Louf and Protat 2023). Increasing urban resilience to storm impacts is challenging. For example, in Australia there is no explicit requirement for structures to be hail resistant, nor are there publicly available data on building material resilience to hail. Convective winds also differ from larger-scale (cyclone) winds and there are knowledge gaps in understanding these winds and their impacts on built structures. Estimates of extreme convective rainfall and its climatic changes – important for sub-daily rainfall extremes – feed into design flood estimation, a cornerstone of flood planning (e.g. DCCEEW 2023; Wasko et al. 2023).

B) Convective storm prediction

Forecasting convective storms is difficult and requires years of experience. The Bureau’s new thunderstorm and heavy rain forecasting team provides a continually improving national service for Australia, which was presented in this section. The Bureau has recently updated its operational guidance for severe storms to include new ensemble-model output, convection diagnostic parameters and storm attribute information (Warren et al. 2023). Specialized private weather services, represented at this meeting, complement government services by providing bespoke weather advice for businesses and assisting in filtering weather threat warning information for their clients.

C) Assessing convective storm risk

Unlike many other more location-specific perils, severe storms affect most general insurance customers in Australia, and storm risks contribute an appreciable amount to total insurance premiums and contribute the largest proportion of all natural perils. The insurance industry uses stochastic catastrophe models to determine the level of risk that perils pose to exposed assets, for risk pricing, reinsurance requirements and event response. Catastrophe models require observational datasets, process understanding, and climate change understanding to accurately assess risk. Risk, meanwhile, is made up of hazard, exposure and vulnerability (e.g. IPCC 2022), and each of these components has associated uncertainties. Given the availability of industry expertise and experience on peril exposure, vulnerability, and catastrophe modelling on the one hand, and academic study of hazard
changes and process understanding on the other, risk assessment is an area ripe for cross-disciplinary collaboration. The availability of radar data in Australia has enabled new hail-risk modelling for the insurance industry, and the insurance and research sectors are already collaborating on estimating hail damage using insurance claims and machine learning (Ackermann et al. 2023).

D) Community readiness and recovery

Storm impacts are the reason for a large proportion of callouts for State Emergency Services (e.g. VICSES 2023), and these services publish community guidelines on storm safety. Accurate forecasting with effectively communicated uncertainties is crucial for the ability of emergency services to properly allocate resources and respond to requests for assistance during severe convective events. Effective communication via warnings and notifications to affected communities is also key when attempting to mitigate extreme weather impacts. It was noted that communities can become desensitized to frequent warnings and that communicating a threat level with uncertainty is challenging. Valuable understanding of event impacts and of possible solutions comes from engaging local communities and emergency managers and hearing their experiences and views, for example through surveys and interviews (e.g. Taylor et al. 2023). Social vulnerability and adaptation capacity are important factors when considering community resilience.

E) Impacts on utilities and agriculture

Convective storms affect water services (e.g. dam safety and flood operations), the power grid, and agriculture in Australia. Sub-daily rainfall data is crucial for water services but requires substantial quality assurance and control, and possible changes in sub-daily rainfall amounts in a warming climate affect engineering decisions (e.g. Wasko et al. 2023). The power grid is a highly interdependent system susceptible to outages caused by storm events (e.g. Ausgrid 2023). Solar panels are notably at risk from convective storm impacts, especially hail. Engagement with affected communities, for example via workshops to discuss solutions, is helpful in determining how utility providers can support investment for resilience. Novel insurance models are being used to help the agricultural sector deal with storm risk. For example, parametric insurance is a model in which a predefined insurance payout is “triggered” by data showing an impact threshold has been reached, without the usual requirement for damage to be proven and assessed. The model is designed
to provide rapid disaster relief and is being trialed in some Australian agricultural areas affected by severe convective storms (QFF 2023).

F) Changing convective storm hazards

Changes to thunderstorm hazards are difficult to assess from observations because the required temporal and spatial coverage is often lacking. Changes can, however, be assessed by examining the evolution of larger-scale atmospheric environments and linking those changes to hazards (e.g. Brown and Dowdy 2021; Pepler et al. 2020; Raupach et al. 2023a), or using high-resolution models that can resolve storms, although convection-permitting modelling studies are few in Australia (Raupach et al. 2021). While uncertainty on observed and projected changes in convective storm hazards remains high, some recent progress has been made. Hail hazard has changed over the last four decades across Australia, with decreases in annual hail-prone days across much of the country but increases in some heavily populated regions (Raupach et al. 2023b). Over 1979-2016, thunderstorm environment frequency in Australia decreased while rainfall totals from thunderstorms increased (Dowdy 2020). Rainfall from thunderstorms was greater in 1997-2015 compared to 1979-1996 in much of southern Australia, especially in the warm season (Pepler et al. 2021). Also for southern Australia, future projections show increases with global warming in the frequency of days with heavy rain (exceeding the 99.7th percentile) but without an associated cyclone (Pepler and Dowdy 2022). Such rainfall likely relates to thunderstorm activity (Pepler et al. 2020). Environments conducive to severe convective winds are projected to increase in future Australian summers (2081-2100 compared to 1979-2005, Brown and Dowdy 2021).

G) Data for convective storm understanding

In Australia, thunderstorm data availability is concentrated around the more populated regions. There is very limited ground-truth data available, particularly for hail, incomplete radar coverage, and sparse in-situ wind observations. However, there has been progress on the publishing, quality control and organization of available storm data. Convective storm data for Australia is made publicly available by the Bureau and hosted on the National Computational Infrastructure (NCI). These data include quality-controlled and gridded radar observations (Soderholm et al. 2019), satellite observations (Bureau of Meteorology 2022), archived forecast model data (Bureau of Meteorology 2021), and convective parameters from reanalysis and projection outputs. The Australian community makes heavy
use of satellite data provided by international partners, and the Australian Space Agency has proposed a pathway to national Earth observation capability (Australian Space Agency 2021).

**H) Building connections for the future**

A new Australian Research Council Centre of Excellence for Weather of the 21st Century, led by Professor Christian Jakob, will launch in 2024 (https://www.arc.gov.au/funding-research/discovery-linkage/linkage-program/arc-centres-excellence/arc-centre-excellence-weather-21st-century). This new center, funded for seven years, is designed to determine how weather, including severe convective storms, is and will continue to be shaped by climate change. The development of weather-scale climate models will be a core feature of this research program, allowing for development of more accurate representation of many localized processes relevant to severe convective storms.

**Key outcomes**

We identified four primary outcomes from the workshop, relating to the Australian severe storm community, supporting early career academics, data sharing, and knowledge gaps.

*The Australian severe storm community*

The workshop highlighted the vibrant and enthusiastic community of severe storm researchers in Australia, which is spread across academia and industry and extends well beyond the community typically represented at more general scientific conferences in this country. With the importance of community engagement highlighted here, it is useful that our scientific community includes those in contact with affected communities through industry and social sciences. This type of engagement should be strengthened and expanded in future. There is a high level of industry interest in further understanding severe storm forecasts, risks, impacts, and changes with climate change. The people affected by severe storms are often in more direct contact with industry than academia, making industry well positioned to understand affected people’s needs, be they for knowledge, risk mitigation, or adaptation. An overview of stakeholder needs and community engagement should allow industry to act as a conduit to real-world impact for those in academia. Funding and data provision are often requirements for impactful research, both of which industry can support via academic collaborations. This
workshop established communication channels for an ongoing and sustainable severe storm science community in Australia.

**Support for early-career researchers**

There are currently relatively few ECRs in the Australian severe storm community, while there is an ongoing need across industry and government for individuals with a strong background in this topic. To increase the number of ECRs, new research projects are required and there is a corresponding need for funding and supervision. More regular exchanges between industry and universities will help foster such new cooperative projects. In a relatively small research community, ongoing effort is required to ensure new ECRs join the community to contribute new ideas and continue the work of the current generation, and for this it is important to emphasize training and education of a new generation of researchers.

**Data availability and sharing**

There is limited storm data availability outside of highly populated regions in Australia, including in many agricultural regions where storm hazards pose a risk. Data sharing between industry and academia was noted as being critical but not always simple, given commercial constraints. It also remains a challenge to get the right information to people “on the ground” – such as emergency services – in a timely and useful manner. Continuing collaboration should increase the possibilities for data sharing when possible. Open data should be prioritized, and there is a need for common data-sharing fora across research, forecasting and industry, as exist today in various projects enabled by the National Collaborative Research Infrastructure (NCRIS, see [https://www.education.gov.au/national-research-infrastructure](https://www.education.gov.au/national-research-infrastructure)). There remains the need for investment in convective-storm-specific data collection campaigns in Australia, like those being run internationally (e.g. Brimelow et al. 2023; Sills et al. 2020). When sharing data it is important that the audience is kept in mind, since there are industry-specific uses of information and formats for data dissemination that may require translational effort. Take heavy convective rainfall under climate change as an example: climate scientists may have information as an expected percentage change in hourly rain amount per degree of warming, but a water engineer may need to know that change in mm for a given future year and scenario to make a design decision.

**Knowledge gaps in Australian storm science**
Knowledge gaps identified at this workshop include those in understanding the effects of large-scale climate drivers on severe storms and their hazards in Australia, measuring and understanding hail size distributions, coincidence of sub-perils in severe convective storms leading to compound hazards, the interannual and annual variability of hazards, detection and monitoring of storms, damage impacts across the full range of property and infrastructure types, and trend analysis and climate change projections of severe storm hazards. Most of these knowledge gaps are the subject of ongoing work in the Australian community. It was noted that impacts and long-range return periods of severe storms are best understood by process understanding, in which the driving physical forces are better understood, rather than statistical representation or data extrapolation.

Conclusions and next steps

The 2023 science-industry workshop on severe convective storms was held in August 2023 in Sydney, Australia. It was the first such event specifically for the Australian severe storm community in more than twenty years, and it brought together a diverse range of scientists and industry representatives to discuss the latest science, industry perspectives, shared challenges, and a path forward. A goal of the workshop was to identify next steps to ensure that this new momentum continues to grow. Regular engagement is now maintained through a new LinkedIn group, as well as fortnightly virtual meetings with invited domestic and international speakers on storm-related science and industry topics. New industry-academia collaborations, partly fueled by this workshop, will help to foster ECR engagement, provide training and career pathways for a new generation of researchers and practitioners, and nurture new research projects in the severe storm community.

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QFF, cited 2023: Queensland Farmers’ Federation, Queensland farmers should revisit their risk management practices as the disaster season continues. [Available online at https://www.qff.org.au/presidents-column/queensland-farmers-should-revisit-their-risk-management-practices-as-the-disaster-season-continues/.]


Warren, R., H. Richter, I. Blockley, and D. Sgarbossa, 2023: New convective guidance at the Australian Bureau of Meteorology. 11th European Conference on Severe Local Storms, Copernicus Meetings