Issue 004

Practice Note

Topics in this edition | Severe weather | Communities | Infrastructure | Exposure | Capability

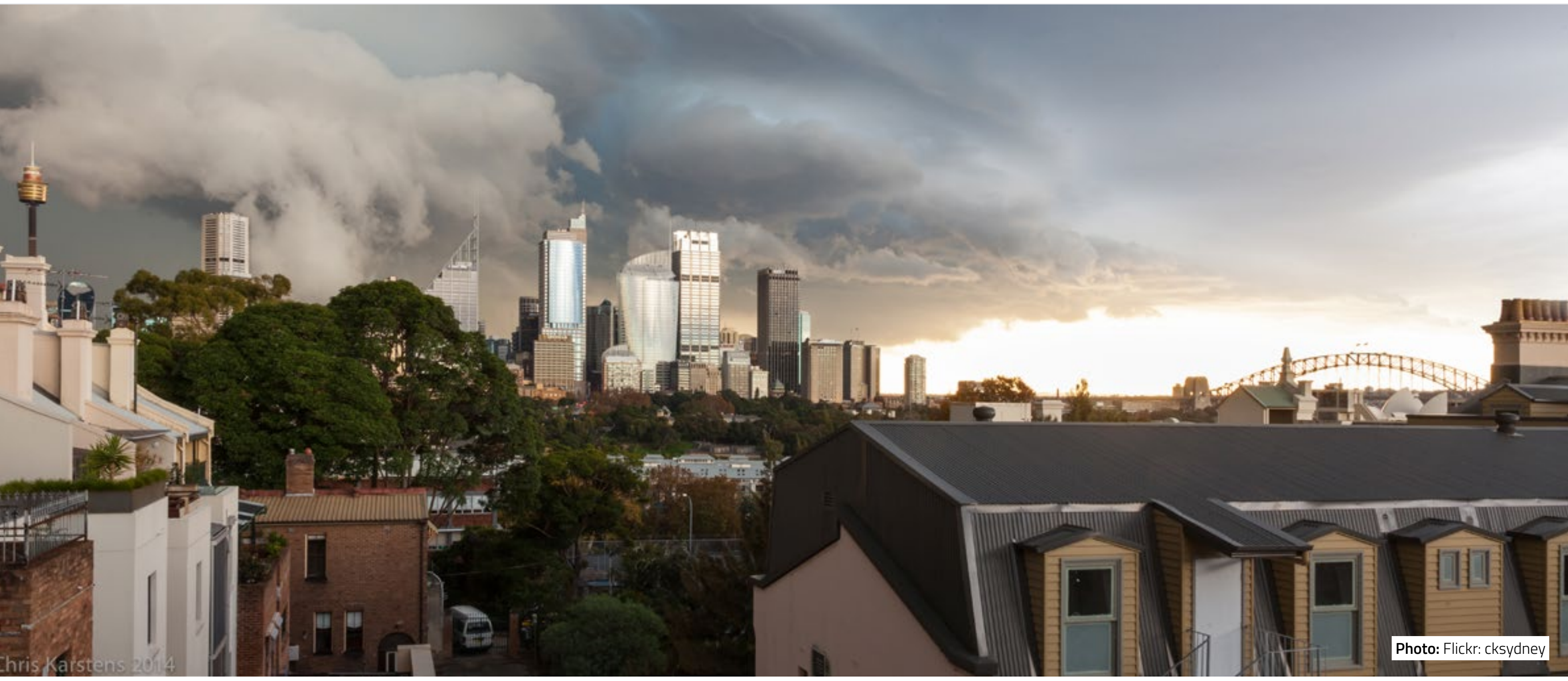

Photo: Flickr: cksydney

MAY 2025

Severe weather impact forecasting: where and how much damage will be caused from imminent severe weather?

Liza Gelt, Rosie Tran, Michael Rumsewicz, Collaborative Consulting Co

Why this matters

The predictive capability for severe weather forecasting, and hazard forecasting more generally, is increasingly moving from a purely hazards-based service to providing information about the resultant impact. In 2015, the World Meteorological Organization (WMO) summarised this direction as the desire to understand not only 'what the weather will be', but 'what the weather will do'. The skill and utility of hazard forecasts and real-time weather monitoring has improved significantly in recent years. What is not being fully realised, however, is the power of incorporating available exposure data (building location and type, broader infrastructure information, demographic information) and vulnerability information (susceptibility to damage from wind, rain, earthquake and other hazards) to add value to the hazard forecasts (temporal, spatial and intensity). Overlaying hazard forecasts with exposure and vulnerability information contextualises the risk to the community and closes the gap to impact-based forecasting and post-event appraisal.

Summary

When provided with impact and exposure forecasts regarding severe weather events, emergency service agencies may have a greater ability to mitigate adverse impacts and better inform, prepare and protect the community. This may be through better public information and warnings, timely securing of structures, safe evacuation or the appropriate pre-positioning of resources, including evacuation or relief centres, to minimise disruption to the community.

Learn more about this project online
naturalhazards.com.au/research/research-projects/sector-partner-engagement-enhance-severe-weather-impact-predictions

Project purpose

Strengthening the emergency management sector's capability to predict the impact of severe weather events could help better inform its preparedness and response activities, and consequently save lives, minimise injury and reduce damage to property.

The predictive capability for severe weather forecasting, and hazard forecasting more generally, is increasingly moving from a purely hazard-based service to providing information about the resultant impact. Such impact-based forecasting, however, is complex, and the information required to understand 'what the weather will do' depends on the user. For example, a community member looking to protect their property and an emergency manager making resourcing decisions or providing warnings to the community might want different impact-based information.

Though a relatively new field, hazard forecasting and real-time weather monitoring have improved significantly in recent years. What is not being fully realised, however, is the power of incorporating available exposure data (building locations and types, broader infrastructure information, demographic information) and available vulnerability information to add value to the hazard forecasts (temporal, spatial and intensity).

Overlaying hazard forecasts with exposure and vulnerability information contextualises the risk to the community and closes the gap to impact-based forecasting and post-event appraisal.

There is a clear opportunity for emergency service agencies and decision makers to access more detailed and tailored information to better inform preparedness and response activities, and consequently save lives, reduce damage to properties and support early relief and recovery decisions.

This project engaged with the emergency management sector and industry stakeholders (collectively referred to as sector partners) to better understand their information requirements when making decisions before and during a forecast severe weather event, to understand how existing impact prediction capability should be developed and the types of information required by different user groups. This research project provided the opportunity to explore the current national picture and inform the future development path for impact-based forecasting products and services.

The outcomes of this research will contribute to strengthening the capability to provide clear fit for purpose information, which in turn will build agency confidence in using impact information to improve community resilience to severe weather.

Engagement approach

This project engaged emergency service sector partners and industry stakeholders to better understand their information requirements when making decisions before and during forecast severe weather. This increased understanding of how existing impact prediction capability should be developed and the types of information required by different user groups.

The project approach was designed to provide practical guidance for the Bureau of Meteorology (the Bureau), Geoscience Australia (GA) and/or other industry providers to improve and further develop prediction modeling and diagnostic capabilities. Extensive engagement was undertaken with sector partners to understand the perspectives of all Australian states and territories and various decision-making roles within the planning, preparedness and response phases of an event. This involved identifying key sector partner 'user types', the most common 'use cases' or decision-making scenarios and, from those use cases, identifying information needs for severe weather impact forecasting.

The Australasian Fire and Emergency Service Authorities Council (AFAC) Flood and Severe Weather Intelligence Services Technical Group provided project guidance as the Project Reference Group. Also, several national sector partner engagement opportunities were undertaken, including three workshops, an online survey, targeted consultations, a presentation and follow-on discussions at the AFAC2023 Conference. In all, over 250 people from the sector contributed their experience to the project.

The Impact Triangle

For the purposes of this Practice Note, impact describes a wide range of consequences from a hazard including physical damage to buildings and property, as well as disruption to services. The impact of a hazard can be understood as the intersection of the likelihood of the hazard, and the vulnerability and exposure of an individual, community or asset to that hazard. *Figure 1. The Impact Triangle* highlights information sources available from the Bureau and Geoscience Australia.

The Impact Triangle considers information regarding the hazard, exposure and vulnerability:

- **Hazard** – large-scale winds and severe thunderstorm forecasts from the Bureau
- **Exposure** – location-based asset information provided by Geoscience Australia in the Australian Exposure Information Platform (AEIP)
- **Vulnerability** – asset vulnerability, including the location and structural, economic and demographic characteristics.

The concept of the Impact Triangle reflects the Risk Triangle as applied by the emergency services sector. In this context, where the risk is certain (that is, likelihood approaches 1.0), risk equates to impact.

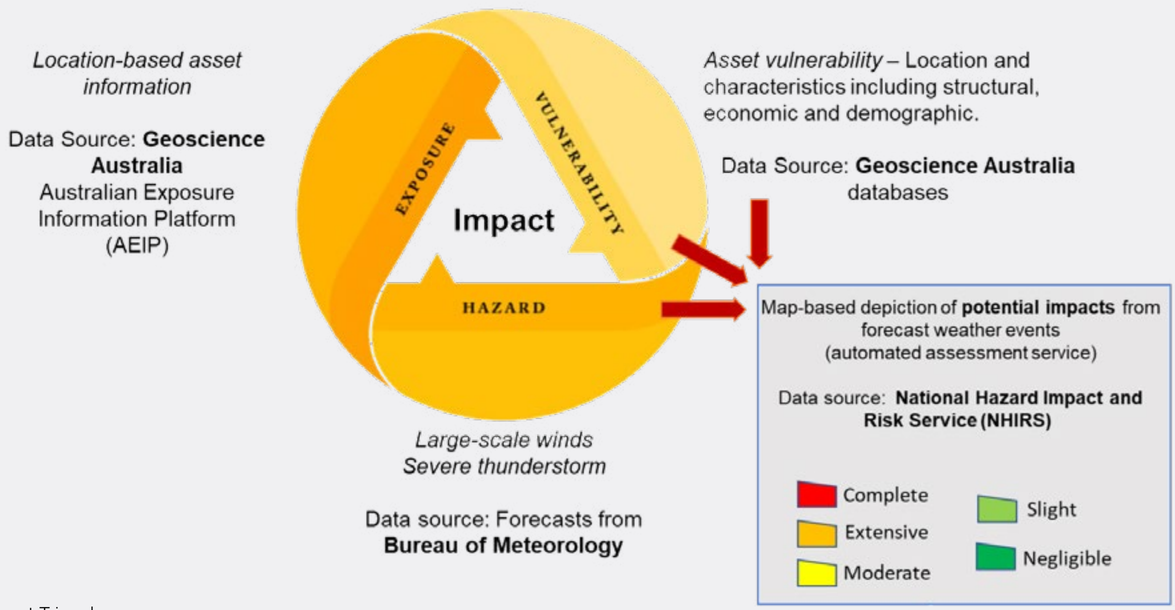

Figure 1. The Impact Triangle

Key findings

The research identified three key user types and 10 use cases that drive sector partner needs relevant to exposure and impact forecasting.

The key user types were:

- Emergency management agency decision-makers in the intelligence function of an Incident Management Team in the response phase.
- Relief and recovery functions in local, state and Commonwealth agencies.
- Essential services and critical infrastructure providers.

The 10 use cases identified were:

- Activating emergency response teams.
- Resourcing allocation and rostering response teams.
- Communicating ongoing risks and impacts to government, stakeholders and the community.
- Issuing information and warnings.
- Coordinating with other agencies, essential services and critical infrastructure providers.
- Identifying and establishing evacuation centres and routes.
- Planning and setting up relief centres, providing accommodation and logistics coordination.
- Assessing damage/length of disruption to homes, critical infrastructure, community facilities and access routes.
- Planning to support vulnerable cohorts.
- Planning for the recovery phase.

Following analysis of sector partner contributions, eight key information decision-making information needs were validated with the national reference group, and eight key findings were identified. These findings support a combination of high-level and scientific and technical capability implications.

Eight priority information needs relevant to forecasting were identified, with four of these focused on meteorological and environmental forecasting, one that can be applied to all three information types, two on exposure forecasting and one on impact forecasting (see Figure 2, below). We propose that the large proportion of information needs that are meteorologically focused results, at least in part, may be from the familiarity of agencies with such products and the relatively small leap required to see how their information content can be enhanced to support decision making.

		Priority information needs
Meteorological and environmental	I	**Antecedent conditions** Potential impacts of severe weather events are significantly affected by the antecedent environmental conditions, such as soil moisture content and vegetation.
	II	**Relative intensity for a geographic location** Information about whether the severe weather is atypical for the location, taking into account topography and wind direction.
	III	**Range of meteorological event severity** The range of meteorological conditions that might be experienced within the forecast period, including the best case, most likely case and worst case scenarios.
	IV	**Relevant historical meteorological events** Historical events with similar meteorological forecasts may be useful to support decision making (i.e. historical analogues).
All	V	**Observations versus forecast** Real-time verification of currently valid forecasts against the latest observations.
Exposure	VI	**Location of specific cohorts, including vulnerable cohorts** Information regarding structures supporting vulnerable cohorts such as aged care, health services and schools.
	VII	**Dynamic human considerations** Information regarding people movement arising from seasonal and routine period (e.g. peak tourism for the location, school times).
Impact	VIII	**Disruption to essential services and critical infrastructure** This includes exposure and time to restoration in each location, for energy, water, transport and roads, telecommunications, food and supply chains.

Figure 2: Priority information needs

Implications

High-level and scientific and technical capability implications were identified from the research finding. A summary of these fundings is outlined immediately below, with greater detail provided in the following section.

High-level implications:

1. Timely access to a range of appropriately presented information, spanning meteorological, exposure and impact forecasts, would support real-time decision making for emergency services sector partners. To achieve this goal, continue collaborating with the emergency management sector to build awareness of exposure and impact forecasting, and better understand the sector's operational needs
2. Extend scientific and technical capability in line with sector partner information needs
3. Consider a phased approach to providing enhanced information for decision-making, focusing initially on exposure forecasting, then followed by impact forecasting

Scientific and technical capability implications include:

1. Expanding the meteorological features and functionality.
2. Expanding the features and functionality capability.
3. Develop and implement a communication and engagement approach with sector partners to support the communication and interpretation of detailed technical information in accessible formats during an incident.

Detail of implications

While the Bureau and GA are national bodies with statutory obligations, responsibility for managing and mitigating the impact of severe weather is the responsibility of states and territories. And recently, perhaps as a consequence of complex and compounding severe weather events of the last few years, strong inter-jurisdictional and national forums for addressing how to better predict the impacts of severe weather have emerged in the emergency management sector. As maturity grows across the emergency management sector, the language and capability around severe weather forecasting (or hazard forecasting) will develop into exposure forecasting and impact forecasting.

It is in this context that high level and scientific and technical capability implications have been identified from the research findings and outlined below. Only those implications considered to have high impact for sector partners have been provided in this Practice Note.

Photo: Flickr: Rob and Stephanie Levy

High level implications

Implication	
Implication H1 Timely access to a range of appropriately presented information, spanning meteorological, exposure and impact forecasts, would support real-time decision making for emergeny management sector partners. To achieve this goal, continue collaborating with the emergency management sector to build awareness of exposure and impact forecasting, and better understand the sector's operational needs.	H1.1 **Build emergency management sector awareness** of existing tools and capability, and the potential benefit of applying exposure and impact forecasting in their decision making.
	H1.2 **Share information with the emergency management sector.** This includes progress and outcomes of impact-based forecasting research activities.
	H1.3 **Engage with other industry stakeholders.** This includes energy, water, food supply chain and insurance stakeholders.
Implication H2 Extend scientific and technical capability in line with sector partner information needs.	H2.1 **Engage with the cross-section of sector partners and industry stakeholders** who have registered interest to contribute to the development roadmaps of the Bureau, GA and other providers. This may include developing detailed and agreed business requirements for the eight information gaps identified, user testing of tools or development of other functionality.
	H2.2 **Identify high-value prospects** for implementation, based on outcomes of H2.1, noting that a number of high-value prospects have been identified and are detailed below.
Implication H3 Consider a phased approach to providing enhanced information for decision-making, focusing initially on exposure forecasting, then followed by impact forecasting.	H3.1 **Continue developing and engaging on exposure forecasting** as a step change that progresses sector partners to using impact-based forecasts.
	H3.2 **In partnership with sector partners, develop an agreed vocabulary and terminology with respect to meteorological, exposure and impact forecasting**, consistent where possible, across hazards and across community and physical assets. Embed this terminology within existing training and information resources, such as the Australian Disaster Resilience Glossary[1].
	H3.3 **Explore benefits and appetite for operationalising existing decision-making support systems** such as Natural Hazard Impact and Risk Service impact reports, including identifying any information access and security issues that may arise, for example, with the sharing of information concerning critical infrastructure.
	H3.4 **Develop the business case for the development of an enhanced exposure and impact forecasting system**, including what would be required to reach the threshold for initiating development of the system.

1 https://knowledge.aidr.org.au/glossary/

Scientific and technical capability implications

The following implications relate to the extension of scientific and technical capabilities, building on the functionality of the existing National Hazard Impact and Risk Service (NHIRS) platform. The implications consider readily adapted existing capability or propose the development of new exposure and impact services by information providers, as appropriate. The following scientific and technical capability implications are intended to apply on a multi-hazard basis (that is, for large scale winds, severe thunderstorms, flood, cyclone and/or bushfire) as funding and resourcing allows.

Scientific and technical capability implications (STC)

Implication STC1: Expand the meteorological features and functionality supported by the Bureau to include:

i. **Antecedent environmental conditions** relevant to emergency sector partners.

ii. Information on the **relative intensity and atypicality** of forecast conditions for affected localities.

iii. Information on the **range of conditions** (from most likely to reasonable worst case) that may be expected during an event, for example, detailed information from ensemble forecasts.

iv. Information on **relevant historical meteorological events** that might assist emergency sector partners in planning response activities.

Implication STC2: Consider expanding on the features and functionality contained within Bureau and GA's information products to include:

i. **Real-time verification** indicating accuracy of most current forecasts against observations.

ii. Ensemble exposure and impact forecasting capability.

iii. Identification, quantification and location of vulnerable cohorts, including but not limited to aged care centres, schools, mass gatherings and transient communities.

iv. Identification and location of community buildings and critical infrastructure, and where possible, the development of applicable vulnerability models for those assets.

v. Development of proxy indicators for exposure and impact, methodology to be further validated with sector partners, for example,

- Number of calls for assistance
- Tree fall forecasts (number, location)
- Flood mapping (noting that this information may be already available to some segments of the emergency community through locally available products and services)
- Seasonal booking numbers for national parks (e.g., campsites, park passes).

vi. A longer-term research question should explore the link between forecasts of physical impact and subsequent social impacts, with a view to rapid estimation of impacts informing response, early relief and recovery decision-making.

Implication STC3: Develop and implement a communication and engagement approach with sector partners to support the communication and interpretation of detailed technical information in accessible formats during an incident, including:

i. Data provided by the Bureau and Geoscience Australia, and the limitations of the models underpinning the outputs.

ii. Methods for communicating uncertainty and/or the limitations of meteorological, exposure and impact forecast information products.

iii. Methods for consolidating, synthesising and simplifying the presentation of information from a range of sources, including, for example, connection of services in ArcGIS Online (AGOL) or similar platforms.

iv. Appropriate materials to raise user awareness and support the understanding of terminology, interpretation of forecast data, and understanding of potential limitations of data sets and models.

How to use these research findings/implications

The outcomes of this research will contribute to strengthening the capability to provide clear fit for purpose information, which in turn will build agency confidence in using impact information to improve community resilience to severe weather events.

Strengths and limitations

Strengths of this research include:

- the broad multi-jurisdictional nature of the sector partner engagement, which included federal, state and local government agencies and dedicated emergency service authorities.
- engaging with the private and essential services sector to support the requirements gathering process.
- drawing on the senior executive experience and expertise of the AFAC Flood and Severe Weather Intelligence Services Technical Group through project design, communications and in validating the findings.
- opportune timing of the sector engagement for this research project meant that sector partners were attuned to the information needs required for decision making before and during severe weather events.

Limitations of this research include:

- lack of consistent baseline technology and language for the national sectors' experience regarding hazard, exposure and impact forecasting is reflected in the high-level nature of development opportunities for this area of forecasting
- while the project enjoyed strong sector engagement, the AFAC Conference in Brisbane coincided with the Australasian earthquake disaster exercise (also in Brisbane), which prevented some Participants from severe weather response agencies from participating.

Acknowledgements

We would like to acknowledge the Traditional Owners of the lands on which we meet and work throughout Australia. We pay our respects to their Elders past, present and emerging and acknowledge that sovereignty was never ceded.

We sincerely thank Geoscience Australia and the Bureau of Meteorology, especially Craig Arthur (GA), Nicole Allen (GA) and Harald Richter (Bureau), who were so generous with their time and expertise throughout the project. They were an incredible brains' trust and supporter of impact-based forecasting and its current and future potential.

We also thank all the sector partners who participated in our end-user surveys and workshops. All of our Participants provided incredibly valuable insights and unique perspectives from their roles in their respective organisations. Their thoughtful and nuanced feedback provided us with the contextual richness that underpin the insights in this report.

Special thanks to Natural Hazards Research Australia, especially Kat Haynes and George Goddard, for their ongoing support throughout the project.

End-user statement

Steve Muncaster, Principal Advisor, Emergency Management Reform, Victorian State Emergency Service

"SES Victoria greatly values the insights provided by the Severe Weather Impact Prediction report. As a hazard intelligence analyst, I can attest to the critical importance of timely access to severe weather impact forecasting information. This research not only enhances our ability to make informed decisions regarding operational response but also aids in effectively planning for relief and recovery efforts in the face of severe weather events.

The collaboration between AFAC Flood and Severe Weather Intelligence Services Technical Group and the research team enabled access to various views and requirements across all jurisdictions. This project facilitated improved coordination and consultation between response agencies and the Bureau.

I commend the team's efforts in enhancing communication between stakeholders in the emergency management sector. This collaborative effort has undoubtedly strengthened our ability to mitigate the impact of severe weather events on our communities."

References and further reading

Varney, C., & Smith, R., (2023). Rapid damage assessment tools demonstrate value in Turkish earthquake. *Zurich Commercial Insurance Risk Insights.*

Schroeter et al., (2021). Forecasting the Impacts of Severe Weather. *Australian Journal of Emergency Management.*

Schroeter et al., (2022) Forecasting the Impacts of Severe Weather: A Review. *Australian Journal of Emergency Management.*

Krocak et al., (2023). Public Information Priorities across Weather Hazards and Time Scales. *American Meteorological Society.*

Röösli, T., C. Appenzeller, & D. N. Bresch, (2021). Towards operational impact forecasting of building damage from winter windstorms in Switzerland. *Meteorological Applications*, 28, e2035.

Harrison, S. E., S. H. Potter, R. Prasanna, E. E. H. Doyle, & D. Johnston, (2022). Identifying the Impact-Related Data Uses and Gaps for Hydrometeorological Impact Forecasts and Warnings. *Weather, Climate, and Society*, 14, 155–176.

Kaltenberger, R., A. Schaffhauser, & M. Staudinger, (2020). "What the weather will do" – results of a survey on impact-oriented and impact-based warnings in European NMHSs. *Adv. Sci. Res.*, 17, 29–38.

Harrison, S. E., S. H. Potter, R. Prasanna, E. E. H. Doyle, & D. Johnston, (2021). "Where oh where is the data?": Identifying data sources for hydrometeorological impact forecasts and warnings in Aotearoa New Zealand. *International Journal of Disaster Risk Reduction*, 66, 102619.

Geoscience Australia Impact Forecasting Utilisation – End User Workshop Reports (2021).

Suri, D., & Davies, P. A., (2021). A Decade of Impact-Based NSWWS Warnings at the Met Office. *The European Forecaster.*

Kropf, C. M., Ciullo, A., Otth, L., Meiler, S., Rana, A., Schmid, E., McCaughey, J. W., & Bresch D. N., (2022). Uncertainty and sensitivity analysis for probabilistic weather and climate-risk modelling: an implementation in CLIMADA v.3.1.0. *Geoscientific Model Development*, 15, 7177–7201.

Harrison, S. E., Potter, S. H., Prasanna, R., Doyle, E. E. H. & Johnston, D., (2022). "Sharing is caring": a socio-technical analysis of the sharing and governing of hydrometeorological hazard, impact, vulnerability, and exposure data in Aotearoa New Zealand. *Progress in Disaster Science*, 13, 100213.

Merz, B., Kuhlicke, C., Kunz, M., Pittore, M., Babeyko, A., Bresch, D. N., et al. (2020). Impact forecasting to support emergency management of natural hazards. *Reviews of Geophysics*, 58, e2020RG000704.