HAZARD NOTE

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IMPACT-BASED FORECASTING: A NEW WAY TO PREDICT THE COMMUNITY IMPACT OF EAST COAST LOWS

ABOUT THIS PROJECT

The *Impact-based forecasting for the coastal zone: east coast lows* project began in 2017 as a collaboration between the Bushfire and Natural Hazards CRC, the Bureau of Meteorology and Geoscience Australia.

AUTHORS

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SUMMARY

This project used an existing operational weather prediction model to develop a pilot capability for forecasting the impact or damage to residential housing from east coast lows. Researchers from the Bureau of Meteorology and Geoscience Australia (GA) collaborated to demonstrate the effective use of emergency management data in the validation of wind impact forecasts – an approach that has not been possible until now. The pilot capability combines hazard, exposure and vulnerability data to make useful predictions of impacts of extreme wind in coastal and near-coastal regions of southern Queensland, New South Wales and eastern Victoria. The pilot was based on impact data available after the April 2015 east coast low that caused severe damage in Dungog, NSW. It showed that forecasts of the impact of wind that include the exposure and vulnerability of buildings performed more accurately than a simple wind-only forecast when estimating damage from winds on residential buildings. These impact forecasts can be used by the Bureau, GA and a range of stakeholders, such as emergency response agencies, to improve risk mitigation. GA has implemented a real-time wind impact prediction capability, based on the findings from this project.

▲ **Above:** THIS RESEARCH DEVELOPED A PILOT IMPACT FORECAST CAPABILITY FOR IMPACTS OF EAST COAST LOWS ON HOUSING. PHOTO: CKSYDNEY, FLICKR.

CONTEXT

What is an east coast low?

An east coast low is a type of extratropical cyclone that often severely impacts the subtropical east coast of eastern Australia. Strong winds and heavy rain typical of east coast lows are dangerous and can cause large amounts of damage to infrastructure and agriculture. More widely, east coast lows produce a range of hazards that are relevant to the coastal zone, such as high wind, rain, flooding, coastal storm surge and erosion. An east coast low, rather than a tropical cyclone, was chosen for this project because the larger size of east coast lows allows for more reliable wind field predictions by numerical weather prediction models, as used in the research at hand. The multi-hazard nature of east coast lows means that attributing damage to any single hazard is difficult. The focus of this project was on wind in coastal and near-coastal regions of eastern Australia, which was based on user end-user feedback together with the feasibility of combining relevant hazard forecasts and impact models.

BACKGROUND

The Bureau of Meteorology is responsible for providing severe weather warning information to inform decision making by emergency management organisations, as well as public warnings to help communities take defensive action prior to and during severe weather. In recent years, there has been a shift of focus from delivery of weather and hazard information to more value-added information that better characterises the impacts that such hazards can have on a community.

Currently, hazard forecasts in Australia are based on meteorological analysis and interpretation of observations (satellite and radar observations, for example) or the longer-ranging prediction from numerical weather prediction models. Trained forecasters, through the application of local knowledge and informed by years of experience issuing and verifying forecasts, can add additional value to these hazard forecasts.

But there have been substantial improvements in numerical model and human-based forecast accuracy over the last few decades, and the availability of higher-resolution and ensemble-based models means that the potential for more specific forecasts is increasing. Now, forecasts and warnings that focus on the impact of weather are more of a possibility.

Impact may be qualified and/or quantified by integrating hazard forecasts with data about community vulnerability, exposure to the hazard, and localised damage. Weather services and emergency management agencies can then translate this information into predicted impact and warnings that improve community safety.

Impact forecasting generally requires three fundamental inputs or types of information:

1. **Hazard:** what causes the damage (winds, rainfall, flooding etc) and are there any cascading effects (e.g. landslides)?
2. **Exposure:** what assets might be affected by the hazards (people, buildings, agriculture etc) and how badly?
3. **Vulnerability:** how much damage will be caused by the hazard specified?

These three inputs can then be used to estimate impact and risk, producing an impact-based forecast.

The ability to develop impact assessments has been applied generally within the natural hazard risk modelling community, however the ability to integrate such assessments into a forecasting and warning process currently does not exist in Australia. This project developed and tested an impact forecast capability that integrates existing numerical weather forecasts, exposure data and vulnerability relationships at the community level.

BUSHFIRE AND NATURAL HAZARDS CRC RESEARCH

This project tested current models and established an end-to-end impact forecast capability. The capability was originally developed using data from the April 2015 east coast low, which resulted in severe and widespread damage to Dungog, New South Wales.

The capability (see workflow in Figure 2) collects hazard, exposure and vulnerability data that combine to create impact estimates for residential properties in coastal zones. Through Geoscience Australia's (GA) open-source Hazard Impact software (HazImp), these estimates can then be made available to the Bureau's forecasters through an internal visual weather system (VisualWx), and then from the Bureau to emergency response agencies and other stakeholders in the emergency management sector.

- **Hazard data** were derived from the Australian Community Climate Earth System Simulator-Suite 3 (ACCESS-C3) weather forecasting model, which produces hourly wind outputs, and the Bureau Atmospheric high-resolution Regional Reanalysis for Australia (BARRA) tool, which provided high-resolution 1.5 km wind gust grids.
- **Exposure data**, including building locations and attributes, were derived from the National Exposure Information System (NEXIS) developed by GA, which provided building locations, as well as structural, economic and demographic attributes at an individual building level.
- **Vulnerability data** from available damage surveys were examined but were not suitable for vulnerability curve development.

Researchers also modified GA's HazImp software to ensure that data from ACCESS-C3 could be entered, and to ensure that the software would produce geospatial data that can be easily used and visualised in programs such as VisualWx. The result is the successful development of a proof-of-concept system that demonstrates

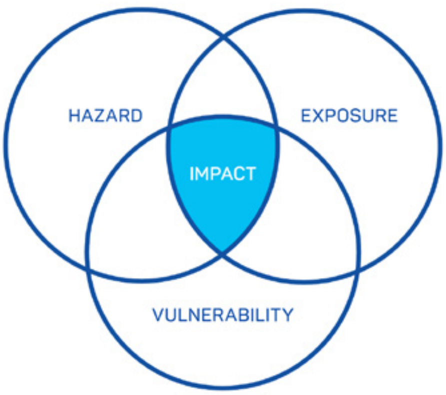


Figure 1: IMPACT IS THE INTERSECTION OF A HAZARD, AND THE VULNERABILITY AND EXPOSURE OF INDIVIDUALS, COMMUNITIES AND ASSETS TO THAT HAZARD. CREDIT: SCHROETER ET AL. (2021).

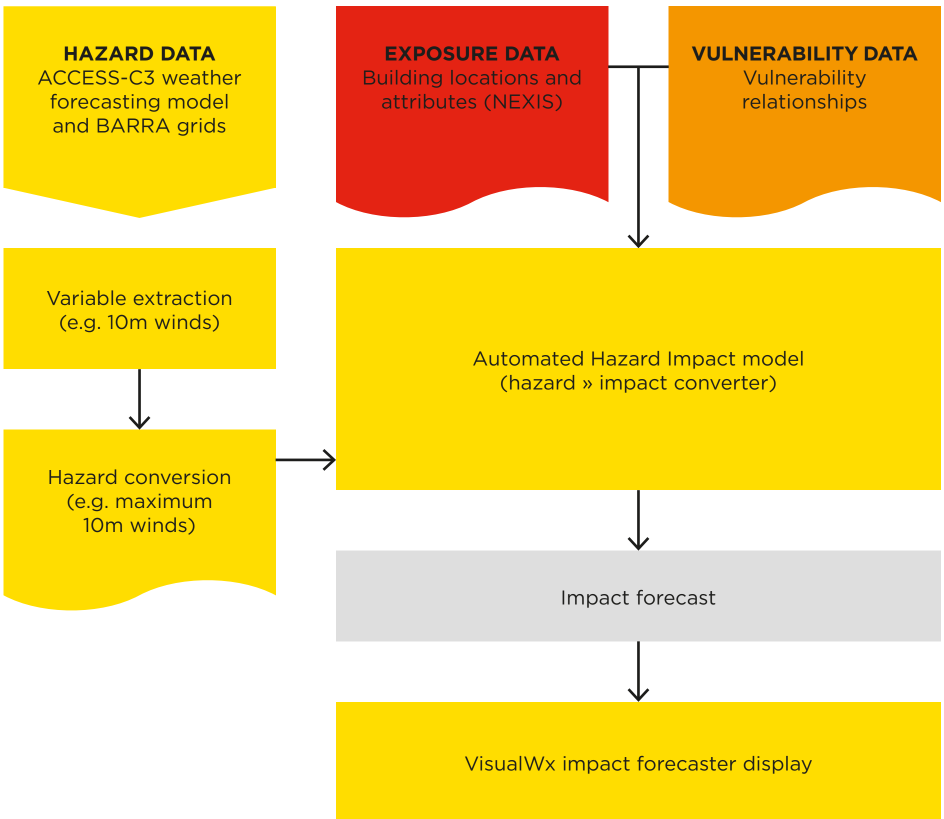
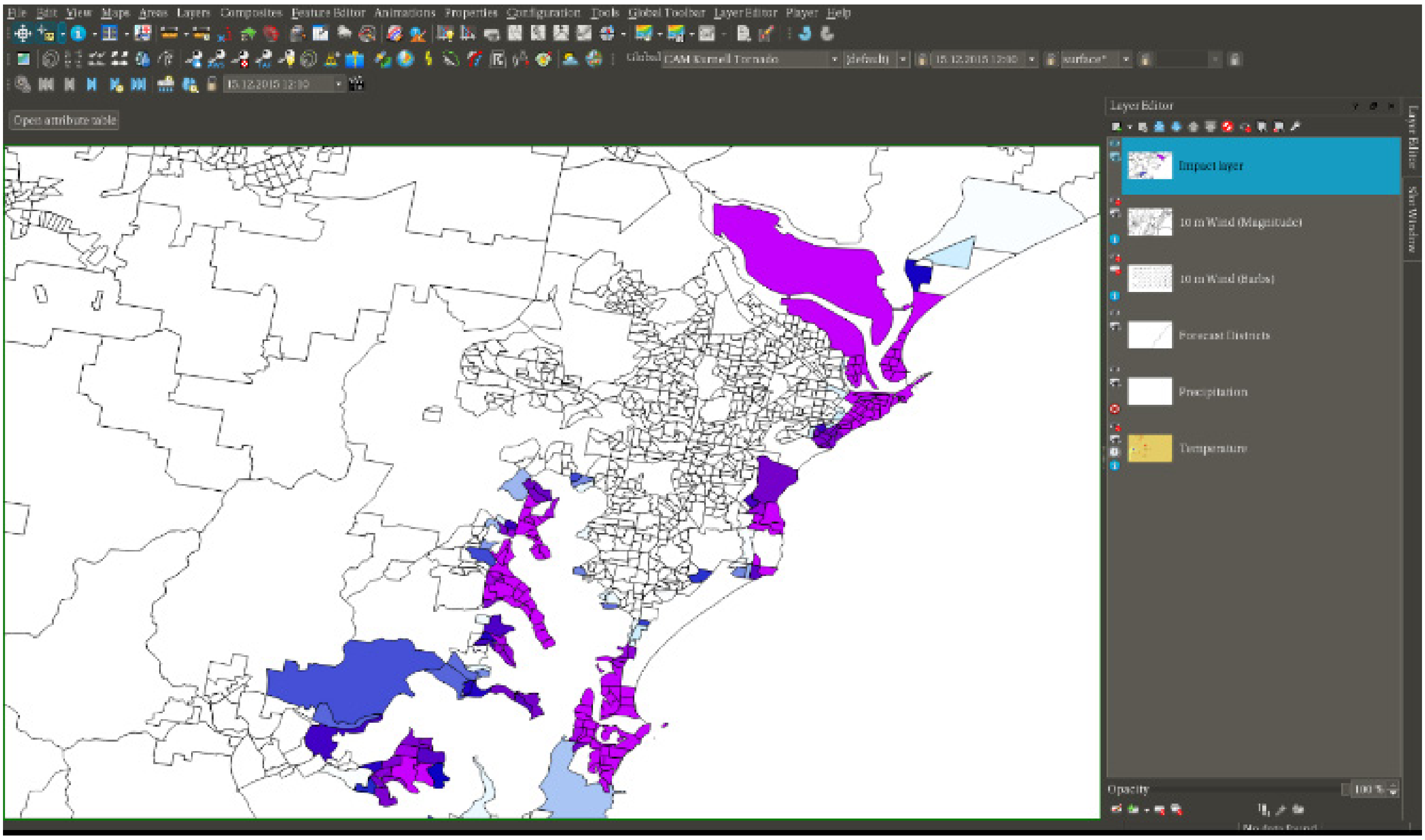


Figure 2: THE IMPACT FORECAST CAPABILITY WORKFLOW, WHICH COLLECTS HIGH-RESOLUTION HAZARD, EXPOSURE AND VULNERABILITY DATA TO PRODUCE A SPATIAL DISPLAY OF IMPACTS IN THE BUREAU'S DATA DISPLAY SYSTEM, VISUAL WEATHER (VISUALWX).



▲ **Figure 3:** FIRST SAMPLE OF SPATIAL IMPACT OUTPUT FROM HAZIMP, DISPLAYED THROUGH THE BUREAU'S OPERATIONAL DISPLAY SYSTEM, VISUALWX. THE MAP SHOWS THE IMPACT TO THE NEWCASTLE AND LAKE MACQUARIE AREA IN NSW, DURING THE EAST COAST LOW IN APRIL 2015, WHILE ENDURING STRONG WIND SPEEDS. THE COLOURS SHOW THE AVERAGE DAMAGE RATING FOR RESIDENTIAL BUILDINGS WITHIN THE AREA , WITH DARKER COLOURS SHOWING MORE DAMAGE. THE DAMAGE RATING IS CALCULATED ON A BUILDING-BY-BUILDING BASIS BEFORE THE AVERAGE IS CALCULATED.

that high-resolution weather forecast models, exposure data and vulnerability relationship estimates have reached a stage of technological maturity that allows for the production of more meaningful wind impact estimates for residential buildings. The first ever spatial impact output using GA's HazImp software, displayed through the Bureau's VisualWx, can be seen in Figure 3.

KEY FINDINGS

This project successfully demonstrated a wind impact forecast capability, applicable to residential buildings in coastal zones. Other key findings or developments from this project include:

Refining accuracy of vulnerability data

Researchers found that the wind-related damage that occurred at Dungog in April 2015 was mostly due to falling trees, rather than structural building damage caused by wind itself. This intermediary damage complicates the way that vulnerability is calculated, and affects the subsequent calculations in the impact forecast, given that falling trees are the result of multiple other factors aside from just strong winds. Researchers provided a recommendation to the NSW State Emergency Service to amend the damage accuracy in their data, to improve the overall accuracy of vulnerability data being fed into the capability by categorising and linking the damage to the hazard that caused it.

Improving wind impact assessments

To evaluate the performance of the wind impact forecasts, researchers processed all the available damage data for the Dungog event to remove damage reports due to fallen trees, rain ingress and flood inundation. Such filtering leaves only those damage reports that are due to direct wind damage to residential buildings. Results showed that the inclusion of exposure and vulnerability information can successfully outperform a forecast that only uses a plain wind hazard prediction. In other words, the Dungog case study suggests that the extra effort needed for the inclusion of exposure and vulnerability information is a promising approach in the pursuit of more accurate forecasts of wind impact or damage in Australia. To gain a better understanding of how other agencies have approached the wind impact prediction problem, researchers also conducted an extensive literature search which resulted in a selective summary of meteorological hazard impact prediction systems (see Schroeter et al. 2021, Further Reading, page 4).

Assessing available exposure information in towns like Dungog

Researchers explored the quality of available exposure information for residential buildings in Dungog. For this specific location, exposure information was statistically derived from surveyed exposure data available from neighbouring towns, such as Newcastle or Alexandria, and not from buildings in Dungog itself. Using a desktop exposure survey, researchers compared the actual buildings in Dungog with the data provided from NEXIS and found that the data did not accurately reflect Dungog's buildings on a building-by-building basis. This highlights the need for a national impact forecasting system that uses accurate and nationally consistent exposure data for each specific area.

HOW COULD THIS RESEARCH BE USED?

The impact forecast capability is still in pilot mode and is therefore not yet widely available for use.

However, researchers conducted two workshops in 2019 and 2020, with emergency management agencies and Bureau meteorologists, to demonstrate the use of the capability. In the workshops, researchers demonstrated that wind impact forecasts performed better than a simple wind-only forecast when estimating damage from winds on residential houses during the 2015 Dungog east coast low. Feedback from end-users indicated a strong appetite for forecast impact products in the emergency management sector, especially regarding the incorporation of the capability into existing forecast products, and the increased collaboration with human experts in operations centres that can interpret the outputs and can deal with variations in presented scenarios. Feedback also suggested that the quantitative impact forecasts will be useful for the Bureau under its Future Warning Framework, and to emergency response agencies. GA has also extended this project's pilot capability developed to produce wind impacts based on the Bureau's ACCESS-C3 NWP model data.

Opportunities also exist through the project's connections to the Weather Impact Team at the UK Met Office, as well as with the World Meteorological Organisation's Human Impacts, Vulnerability and Risks task, which is part of the World Weather Research Programme. Through both relationships, this project has forged connections with international experts who work on impacts of meteorological hazards, and thus have the potential to play a role in the quality assurance of future meteorological hazard impact prediction work in Australia.

Finally, National Hydro-Meteorological Centres around the globe have stated that impact forecasts are a major new strategic direction. As such, the pilot capability is well placed to meet an emerging need for ways to transition from hazard to impact forecasts.

This project was a collaboration between the Bushfire and Natural Hazards CRC; the Bureau of Meteorology; Geoscience Australia; the State Emergency Services in Victoria, New South Wales and South Australia; Fire and Rescue New South Wales; the Department for Environment and Water in South Australia; the South Australian Country Fire Service; the Attorney-General's Department's Crisis Coordination Centre; the Department of Fire and Emergency Services in Western Australia; and the Queensland Fire and Emergency Services. During its second year, the project also joined the World Meteorological Organisation's Task Team on Human Impacts, Vulnerability and Risks (at the time chaired by Brian Mills from Environment and Climate Change Canada).

FUTURE DIRECTIONS

Analysis of the Dungog data confirmed a well-established view that most impacts are multi-hazard in nature – meaning that damage is likely the result of combining factors such as wind and heavy rain. Any future attempts to assess accurate vulnerability will need to include either a clear link between reported damage and a single underlying hazard, or an exploration of multi-hazard predictors that, in combination, result in the reported damage.

Future quantitative impact models should also include tree fall potential when assessing residential building damage due to strong winds as trees are responsible for a considerable proportion of 'wind damage' for these buildings. This would require a range of additional datasets on tree heights, density, species, rooting depths, soil type and many more.

A final example of useful future research relates to the sensitivity of wind impact output to the initial accuracy of the input data (hazard, exposure, vulnerability). The maturity of the capability developed in this project does not lend itself yet for such sensitivity studies, as more testing is required to determine the accuracy and comprehensiveness of the processes captured by the initial model.

END-USER STATEMENT

"A core pillar of the mission of the Bureau of Meteorology is to reduce the loss of life and damage to property in extreme weather events. Critical to this mission is the ability to provide forecasts and warnings of weather conditions in a way that facilitates effective decision making by officials and members of the public. These decisions can range from the type of language used in public messaging, to pre-positioning of emergency response teams, to tactical decisions made by on-the-ground responders. Fundamental to this decision-making process is the ability to match up intelligence about likely weather conditions with knowledge about risks and vulnerabilities in the community. The work of the CRC's *Impact-based forecasting* project team is a critical first step in bridging this gap between hazards associated with weather conditions and the vulnerability of the community to the hazards. By establishing a proof-of-concept approach to combining these two pieces of the puzzle to produce explicit forecasts of impacts from extreme weather events, this work will lay the groundwork for potential future operational impact-based forecasting systems."
Simon Louis, Manager of Weather Services, Bureau of Meteorology

FURTHER READING

Richter H, Arthur C, Wilke D, Dunford M, Wehner M & Ebert E (2021) Impact-based forecasting for the coastal zone: east coast lows – final project report, Bushfire and Natural Hazards CRC, accessible at www.bnhcrc.com.au/publications/biblio/bnh-7868.

Schroeter S, Richter H, Arthur C, Wilke D, Dunford M, Wehner M & Ebert E (2021) Forecasting the impacts of severe weather, Australian Journal of Emergency Management, 36(1), pp.76–83, accessible at https://knowledge.aidr.org.au/resources/ajem-january-2021-forecasting-the-impacts-of-severe-weather/.

The Bushfire and Natural Hazards CRC is a national research centre funded by the Australian Government Cooperative Research Centre Program. It was formed in 2013 for an eight-year program to undertake end-user focused research for Australia and New Zealand.