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# IMPACT-BASED FORECASTING FOR THE COASTAL ZONE: EAST COAST LOWS

**Annual Project Report 2017/2018**

**Harald Richter, Craig Arthur, Serena Schroeter, Martin Wehner, Jane Sexton, Beth Ebert, Mark Dunford, Jeff Kepert, Shoni Maguire, Russell Hay, Mark Edwards**

Bureau of Meteorology, Geoscience Australia & Bushfire and Natural Hazards CRC



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Cover: Picture illustrating wind & rain hazards (photographer: Harald Richter)



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The project is grateful to Anthony Day and Simon Gethin from the NSW SES for the provision of the BEACON damage assessment data for the 20-22 April 2015 East Coast Low event, and to John Moore from FRNSW for the provision of the EICU dataset for the same event.



## EXECUTIVE SUMMARY

The Bushfire and Natural Hazards CRC project *Impact-based forecasting for the coastal zone: East-Coast Lows* attempts to demonstrate a pilot capability to deliver impact forecasts for residential housing from an ensemble of weather prediction models runs. The project is a collaborative effort between the Australian Bureau of Meteorology and Geoscience Australia.

The project is initially focusing on the wind and rainfall impact from the 20-22 April 2015 east coast low event in New South Wales. The wind and rainfall hazard data are provided by a 24-member ensemble of the Australian Community Climate Earth System Simulator (ACCESS) model on a 1.3 km grid, with damage data provided by NSW State Emergency Services (SES) and the Emergency Information Coordination Unit (EICU) for the 2015 event. Exposure data are sourced from the National EXposure Information System (NEXIS) at Geoscience Australia.

The multi-hazard nature of the east coast low event, the relatively low wind speeds and the available information in the damage assessment data makes attributing the observed building damage to a single hazard such as wind or rain difficult. Wind damage to residential housing in this case is largely due to tree fall, as opposed to structural failure, while the most severe damage was due to flood inundation. To increase the utility of the damage assessment data we recommend that the SES/EICU damage survey templates record multiple damage states and linkages between damage and the associate hazard(s). Such expanded recording practices would lead to improvements in the development of the hazard-damage relationships. Additional uncertainty arises through the NEXIS exposure data which are statistically inferred at the Dungog township and are therefore merely indicative of the actual building attributes.

During the second year the project will set up the end-to-end workflow from hazard to spatial impact. More robust vulnerability relations will be derived from a range of larger-scale severe weather cases, and spatial impact outputs will be delivered into the Visual Weather system at the Bureau of Meteorology.



## END-USER STATEMENT

**Simon Louis**, *NSW Regional Office, Bureau of Meteorology*

A core pillar of the mission of the Bureau of Meteorology and our partners in emergency services 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 Impact Based Forecasting BNHCRC 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 ground work for potential future operational impact based forecasting systems. A key challenge in designing a system of this type lies in gathering disparate sources of data and making sure that existing procedures for collecting impact data are fit for purpose. An important output from the project may include recommendations on how impact data are collected in future.

It is likely that explicit impact forecasting systems will become a key part of the tool kit for operational meteorologists and emergency services in the future. I look forward to the continued work of the BNHCRC team exploring the possibilities in this area.



## INTRODUCTION

Strong surface wind gusts and heavy rain are meteorological hazards that are predominantly produced by storms such as east coast lows, tropical cyclones or thunderstorms. Interest in these hazards from a response agency point of view lies in their impact on the natural and built environment. At present, weather forecast models still predict mostly 'raw' meteorological output such as surface wind speeds at certain times, or rain accumulations over a specified period. This model output needs to be combined with exposure and vulnerability information to translate the forecast hazard into predicted impact.

Weather Services around the world have gradually been shifting their focus from the delivery of weather and hazard information to value-added information that better characterises the impacts that such hazards can have. Weather impact forecasts have matured or are maturing to the point of operational delivery. One such example is the impact and likelihood matrix employed by the Met Office Severe Weather Warning Service in the UK (Neal et al. 2014).

The prediction of weather impacts can be accomplished on many levels. A simple approach to estimate impacts is to recast weather variables produced by a numerical weather prediction model in terms of how unusual a specific forecast is relative to a reference climatology (Perry 2017). The implication is that the more unusual an event the more likely it is that the event has an appreciable impact. The other end of the spectrum is marked by impact prediction models where the effect of a hazard (or interacting hazards) is quantified. Examples of impact models are the Vehicle Overtaking Model (Hemingway and Gunawan 2018) or the Surface Water Flooding Model (Aldridge et al. 2016). Both impact models are at a pre-operational stage of development at the UK Met Office as of April 2018. In-between these two types of impact estimation approaches are various levels of hazard, exposure and vulnerability specifications that, to a varying extent, invites the user to subjectively integrate the various impact drivers (hazards, exposure, vulnerability) in an attempt to estimate the resulting impact.

As part of the three-year Bushfire and Natural Hazards CRC Project "Impact forecasting in the coastal zone: East coast lows", we integrate the wind and heavy rain hazards with information on vulnerability and exposure to estimate the impact on residential properties. The study aims to produce a proof-of-concept system to demonstrate that high-resolution weather forecast models, exposure data and vulnerability relationship estimates have reached a stage of maturity that allows for the production of meaningful spatial impact estimates for residential buildings. The project is developing these impact forecasts in the first instance for Bureau weather forecasters as they work alongside and provide advice to emergency response agencies.

The specific aim of this project is to develop a pilot capability to produce useful spatial impact predictions for residential housing due to extreme wind and



rainfall in Australia's coastal regions. Such predictions are expected to improve timely mitigating actions by a wide range of stakeholders, in particular the emergency response agencies. This pilot project will, at least initially, focus on East Coast Low events that often severely impact the subtropical east coast of Australia. These events produce a range of hazards that are relevant to the coastal zone, i.e. high wind, rain, flooding and coastal surge and erosion. The focus of this project is on the wind and rain hazards, which is based on user feedback together with the feasibility of combining relevant hazard forecasts and impact models. Floods are of interest but are not included in this project because Bureau flood warnings are already addressing some of the flood impacts which in turn are translated into more local impacts by individual local councils. More specifically, the project goals include:

- determination of the type of impact information based on the wind/rain hazard that would be most valuable to end-users
- development and testing of an approach to integrate numerical weather forecasts, vulnerability relationships and exposure data at the community level
- development of spatially and temporally varying and meaningful impact information
- testing of the project approach for a small number of previous events
- determination of how data resolution, availability, etc., constrain the impact information that could be provided in a future operational system
- development of a pilot impact-based forecasting system.





## DATA & METHODS

The project aims to demonstrate that standard surface wind and rainfall output fields from a high-resolution (or "convection-allowing") ensemble numerical weather prediction (NWP) model can be processed to provide a useful spatial estimate of wind and rain impact on residential buildings up to several days in advance. This processing chain or *workflow* requires three fundamental input fields: hazard, exposure and vulnerability information. A hazard in the project context can be described as the component / threshold magnitude of one (several) meteorological field(s) that is closely related to the essential causal mechanisms for an impact such as damage to a building. Exposure information describes what assets are acted upon by the hazard or hazards, and vulnerability describes how susceptible an asset is to the actions of a given hazard. This section describes what data the project sources for its hazard, exposure and vulnerability estimates, and how these data are processed to arrive at spatial impact estimates.

### HAZARD DATA

The hazard data used in this project is derived from the output of the "City" series of the Australian Community Climate Earth System Simulator (ACCESS-C; Bureau of Meteorology 2018) NWP model. The operational ACCESS-C model produces hourly outputs on a 1.5 km horizontal grid out to about two days in advance. We also utilised a 24-member ensemble of a 1.3 km version of ACCESS-C for the 2015 Dungoo East Coast Low event (Zovko-Rajak et al. 2018).

The raw model output does not deliver the actual hazards straight away, but some processing is required first. For example, the basic model wind output, such as the mean wind at 10m above ground level ( $U_{10m}$ ), is not the most suitable estimator for wind damage, given wind damage is more closely related to wind gusts rather than mean winds. It is therefore useful to distinguish between raw model output and a related wind hazard specification. A promising model output variable for estimating wind damage is the ACCESS-C wind gust diagnostic,  $U_g$ , derived from the 10 m above ground mean wind speed.  $U_g$  is calibrated to represent a 3 second gust wind speed (P. Clarke, pers. comm.), and corresponds closely to the observed gust wind speed recorded at automatic weather stations.

Apart from the gust diagnostic, other options exist to sensibly define a wind-based damage proxy or hazard. These options include spatiotemporal maxima of the horizontal winds from the native model grid. One such maximum is the hourly maximum field which is an attempt to capture the grid point maximum wind speed across all dynamical model time steps within a given hour (Kain et al. 2010).



As a proxy useful for the prediction of rain ingress, model rainfall accumulations over varying time periods (10 minutes, 30 minutes; 1 hour; 3 hours; 6 hours and 12 hours) are used as the rain hazard fields.

## VULNERABILITY DATA

Vulnerability is a term used to describe the relationship between severity of impact on an asset from a hazard of given magnitude. Vulnerability relationships for the project were originally intended to be derived from two damage assessment datasets, one provided by the State Emergency Services in NSW (the BEACON data), and the other by the Fire and Rescue NSW Emergency Information Coordination Unit (the EICU data). Both damage datasets cover the 20-22 April 2015 East Coast Low impact around the Dungog NSW area. The BEACON dataset was recorded by SES volunteers and covers the area  $35.054^{\circ}\text{S} \leq lat \leq 31.193^{\circ}\text{S}$  and  $150.361^{\circ}\text{E} \leq lon \leq 152.927^{\circ}\text{E}$ , where *lat* and *lon* are the latitude and longitude, respectively. It records a range of attributes such as "property type" or "job received", amongst others. The EICU data was recorded by employees of the Emergency Information Coordination Unit. The data covers an area  $33.3978^{\circ}\text{S} \leq lat \leq 32.3898^{\circ}\text{S}$  and  $151.2658^{\circ}\text{E} \leq lon \leq 151.972^{\circ}\text{E}$ , but unlike the BEACON data, it also recorded five damage categories. Vulnerability relationships are derived by plotting the degree of damage reported for residential buildings against the wind and rain hazard specification based on the ACCESS-C model output. Given our findings that the 2015 Dungog case did not provide sufficient data to derive adequate vulnerability relations, the project also intends to derive vulnerability functions based on multiple tropical and extratropical cyclone events for which high quality damage assessment data are available.

## EXPOSURE DATA

Exposure is a term used, in understanding impact and risk, to describe those assets that will be affected by a particular hazard during an event. Exposure information is sourced from the National EXposure Information System (NEXIS) developed by Geoscience Australia (Nadimpalli 2007). NEXIS contains information on building locations, including structural, economic and demographic attributes at the individual building level.

The quality of the NEXIS data is spatially variable; it is reliant on the quality and availability of building specific input data. Where local building survey data is available, the quality of the NEXIS data, at the building level, is better as compared to areas where attributes need to be derived statistically. The statistically derived data areas are representative at an aggregated level but less likely to represent the exact building specific attributes for individual buildings. The NEXIS exposure information for the location of initial interest in this project, Dungog NSW, is statistically derived, which adds uncertainty to any impact prediction for that location.

## THE WORKFLOW

The automated generation of a spatial impact estimates through Geoscience Australia's open source HazImp software requires input information on exposure and vulnerability relationships in addition to the ACCESS-C-based hazard inputs.

The spatial impact estimates are produced by HazImp as part of the workflow chain shown in Fig. 1. They are primarily (but not exclusively) intended to be made available to Bureau of Meteorology forecasters through Visual Weather, their primary operational data display system. In this way, severe weather forecasts and warnings can be augmented with impact information to enhance their utility to a variety of end users, including the emergency response agencies.

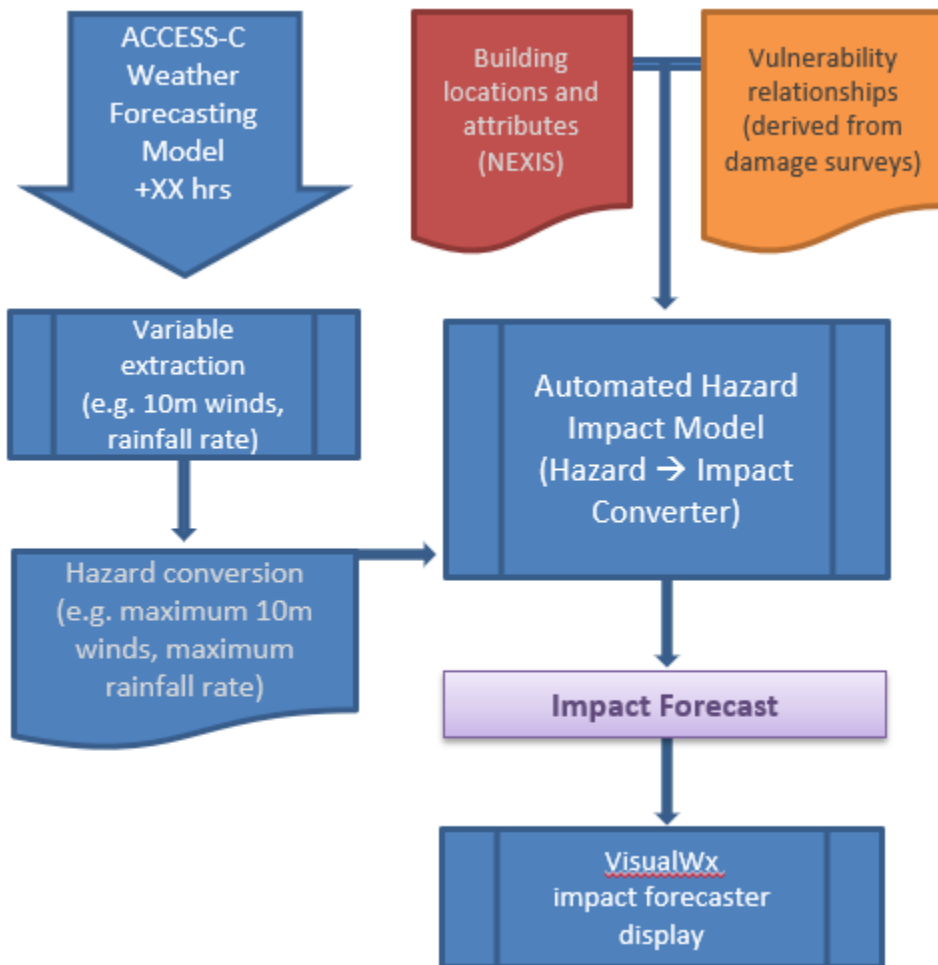


Figure 1: Idealised project workflow from high resolution model output to a spatial display of impacts in the Bureau of Meteorology's operational data display system (Visual Weather).



## KEY MILESTONES

This report covers the first year of this three-year project. Our project team has first been assembled, which involved a lengthy recruitment action. Equally, we compiled a group of end users that have demonstrated commitment to the project. These end users are affiliated with the Bureau of Meteorology, the State Emergency Services (SES), Fire and Rescue New South Wales (FRNSW), the Department for Environment, Water and Natural Resources (DEWNR), the South Australian Country Fire Service (CFS), the Attorney-General's Department's Crisis Coordination Centre (AGCCC), and the Department of Fire and Emergency Services in Western Australia (DFES), and the Queensland Department of Fire and Emergency Services (QFES). A complete overview of all the milestones delivered by the project during its first year is shown in Appendix A.

One year into the three-year project our findings focus on the complexity and usability of the available exposure and vulnerability data in relation to the resolution of the weather forecasts. The properties and limitations of the available datasets largely shape our ability to produce meaningful impact forecasts. However, this knowledge importantly provides the project with the opportunity to showcase how improvements in data collection can improve the quality of impact forecasts and critically, provide the evidence to emergency services to amend damage recording practices for their long-term benefit.

## PROJECT GLOSSARY

The diverse background of our team and end user group, in combination with the multi-disciplinary nature of natural hazard impact assessment necessitated the development of a glossary of terms by the project. Our glossary provides succinct definitions of the terminology used, specific to this project, with the intention of ensuring all participants understand the words and language used throughout reporting and engagement activities.

## WORKFLOW SETUP

We have made substantial progress in setting up an end-to-end (weather model output to spatial impact) workflow across two agencies, the Bureau of Meteorology and Geoscience Australia. For now, we use pre-existing vulnerability relations based on damage assessments from Queensland tropical cyclone case studies to establish the workflow. During the second year of the project, data-derived vulnerability will be inserted into the data chain.

## CASE-SPECIFIC VULNERABILITY RELATIONSHIPS FOR DUNGOG NSW: DAMAGE ASSESSMENT DATA

Two damage assessment datasets for the 20-22 April 2015 East Coast Low event were sourced and analysed to reveal that the relationship between residential



building damage and the driving hazards is complex with a need for the damage reporting to be modified. Through some of our project end users, these modifications are now being undertaken, which is progress in itself and will, in time, enable new vulnerability relationships for residential housing to be developed for some locations affected by severe weather.

Vulnerability refers to the relationship between severity of impact on an asset from a hazard of given magnitude. Quantitative vulnerability relationships are essential in the estimation of quantitative impact predictions. The key impediments to the derivation of vulnerability relationships for the Dungog event were twofold. First, only the EICU data contained a categorical degree of damage (none, minor, major, severe and destroyed). Such a categorisation is needed to relate the damage severity to the magnitude of the associated hazard. Second, the wind speeds produced by the Dungog event mostly stayed well below the design wind speeds for newer housing in the Hunter area ( $34\text{-}40\text{ m s}^{-1}$ ) and therefore cannot be expected to define the full wind vulnerability relationship. In addition, whilst damage was reported in the BEACON and EICU data, it was not possible to determine which hazard(s) caused the damage, i.e. wind or rain or other hazards. The wind-related damage that did occur was mostly due to tree fall, rather than direct wind impact on buildings. This 'damage by intermediary' causality chain greatly complicates the derivation of vulnerability relations given tree response to strong winds depends on a multitude of other factors.

An outcome from these findings has been a recommendation to the NSW SES (via the project's end user, Anthony Day) to amend the damage reporting detail in the BEACON data. We asked for the inclusion of damage categories and for a linkage for all reported damage to the underlying hazard(s).

### **CASE-SPECIFIC VULNERABILITY RELATIONSHIPS FOR DUNGOG NSW: MULTI-HAZARD IMPACTS**

Detailed examination of the damage data for the Dungog event also confirmed a well-established view that most impacts are multi-hazard in nature. Fig. 2 demonstrates that the reported total damage in the EICU dataset is not sensibly related to the model-derived wind speed alone, but is the aggregated product of interacting hazards including wind, heavy rain and overland flooding. Particularly the damage reports in the 76-100% (destroyed) category are related to flooding as a nearby creek rose beyond its banks (Wehner et al. 2015).

Fig. 3 shows the relationship between the EICU damage categories as a function of the 48-hour instantaneous rain rate rainfall maximum. Again, the most severe damage in the 76-100% category occurred at rain rates that were at most intermediate.

The derivation of vulnerability relationships from damage assessment data either requires an unambiguous link between the reported damage and a single underlying hazard that caused the damage (as is typically the case for tropical



cyclone damage), or it will be necessary to explore the use of multi-hazard predictors to estimate the spatial event-integrated damage pattern in a more statistical sense.

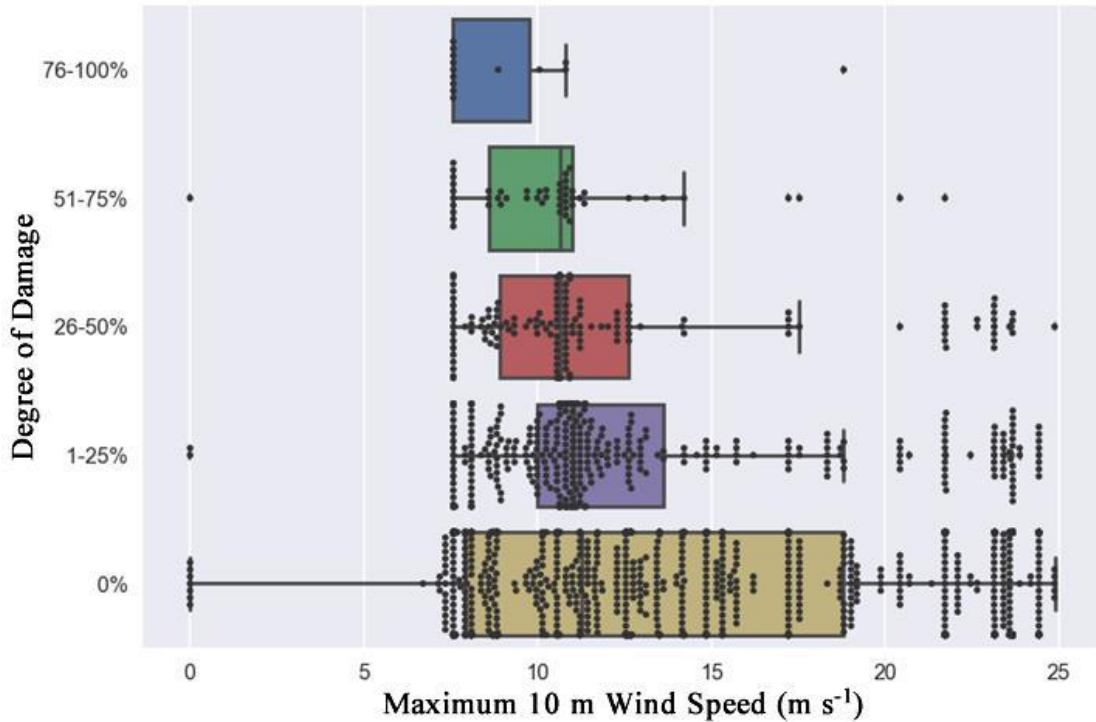


Figure 2: 20-22 April 2015 EICU damage data for the town of Dungog (NSW). The recorded building damage, categorised into five classes (none, minor, major, severe, destroyed), is shown in relation to the matching 48-hour maximum 10 m mean wind speed from one individual ensemble member (member 12) of a 24-member high resolution model run on a 1.3 km grid. The coloured boxes show the inner two quartiles of the model wind distribution for each damage category.

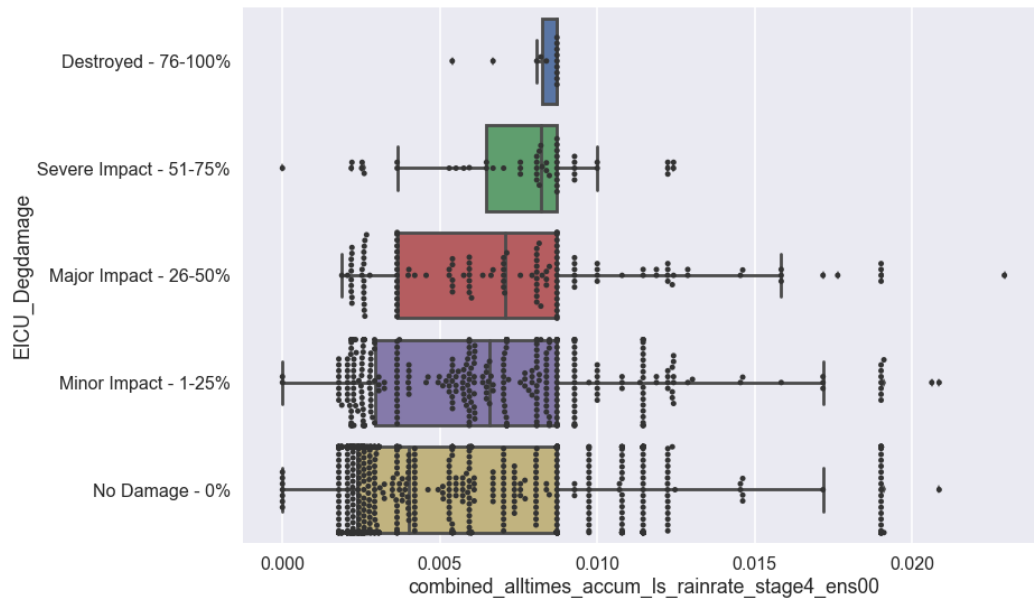




Figure 3: As in Fig. 2, but in relation to the matching 48-hour maximum of the instantaneous rain rate ( $\text{kg m}^2 \text{s}^{-1}$ ) from ensemble member 0 (the control run) of a 24-member high resolution model run on a 1.3 km grid. The rain rate is output by the model every 30 minutes during the period 00 UTC 20 April 2015 to 00 UTC 22 April 2015. A constant rain rate of  $0.01 \text{ kg m}^2 \text{ s}^{-1}$  would equate to an hourly rain accumulation of 36 mm.





## **CASE-SPECIFIC EXPOSURE DATA FOR DUNGOG NSW: STATISTICALLY DERIVED DATA**

The project has also explored the quality of available exposure information for residential buildings in the Dungog (NSW) area, where such information is derived from surveyed data in neighbouring towns. We gained some important insights into the uncertainties that derived exposure information possesses. Ultimately, the uncertainties of exposure information, of vulnerability relationships and of the hazard predictions generated by the weather prediction models combine into the uncertainty of the final impact outputs.

Akin to the vulnerability relationships, the available exposure information has also been tested for its level of uncertainty. For the township of Dungog, the NEXIS information is statistically derived from known point source data in equivalent nearby towns. The building attributes "wall material" and "roof material" in NEXIS for houses in Dungog are derived from exposure survey results in Newcastle (Dhu and Jones 2002) and Alexandria (Maqsood et al. 2013). The "age" attribute for houses built pre-1982 are sourced from NSW cadastral parcel registration date. The "age" attribute for houses built 1982 and onwards is sourced 75% from NSW median suburb year and 25% from cadastral parcel registration date.

We examined all 856 dwellings in Dungog in a desktop exposure survey (using Google Streetview, aerial and other imagery) and compared the surveyed (actual) wall and roof types to the statistically derived attributes within NEXIS. Fig. 4 shows the degree of agreement between the surveyed and statistically derived house types (a house type is defined as a specific combination of one of ten possible roof types and one of six possible wall types).

Fig. 4 implies that the statistically derived residential building attributes for Dungog do not agree well with the actual attributes on the town scale. This suggests that in areas where residential building attributes need to be derived statistically due to lack of in-situ survey data, wind and rain impacts on such housing can only be meaningfully considered on scales larger than the town scale. This observation is well understood by the NEXIS data custodians. Implementation of an impact forecasting system nationally will require a nationally consistent exposure system which in turn relies on what data each jurisdiction collects and the quality of that data. This decision will become a cost-benefit analysis for each government.



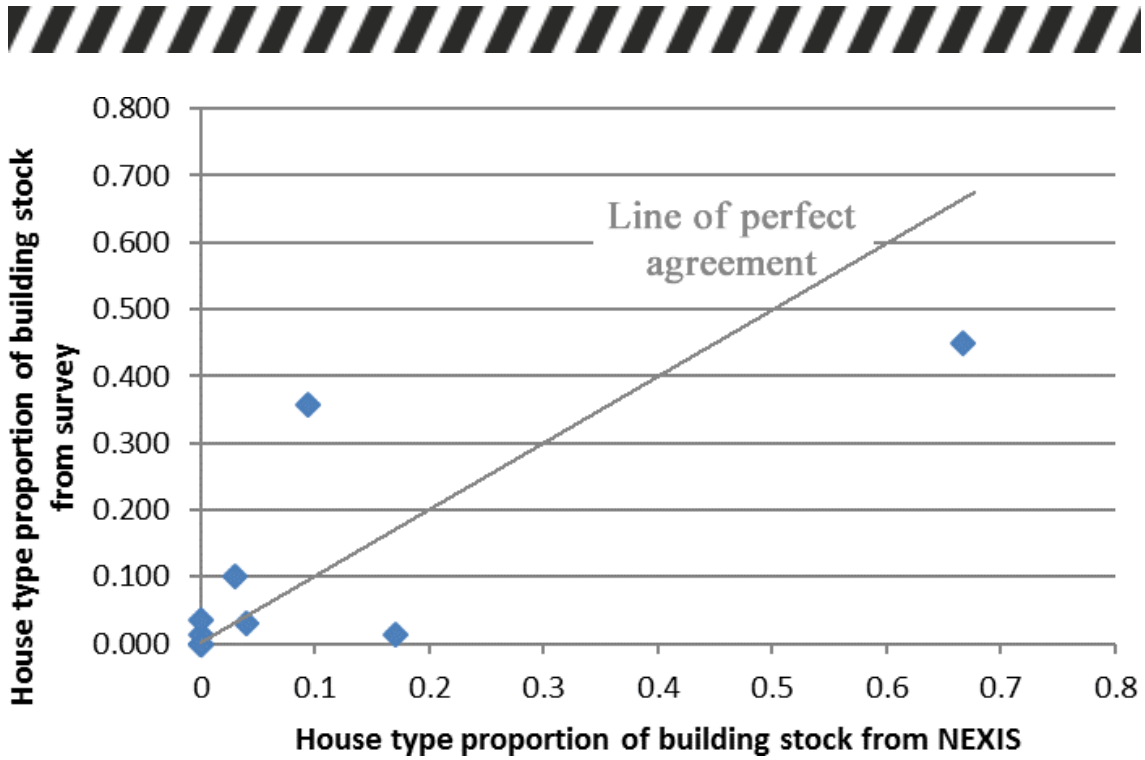


Figure 4: Relationship of statistically derived NEXIS and surveyed house types for all post-1982 houses in the town of Dungog NSW. A "house type" is defined as a combination of wall material (10 categories) and roof material (6 categories). Note that only a small number out of all 60 possible house types is actually present in Dungog.



## SUMMARY

This study ultimately aims at deriving useful multi-day spatial impact forecasts for residential buildings based on wind and rain forecasts from high-resolution numerical models. Damage assessment data for the 20-22 April 2015 Dungog NSW east coast low event was sourced and its relationship to the wind strength and rainfall rate explored.

We found that the available damage data were lacking some critical information needed to establish vulnerability relationships of residential houses with respect to wind and rain. The reported damage needs to be categorised and linked to the hazard or hazards that caused it. The observed damage was often due to more than one hazard, raising the prospects that vulnerability relations might have to be crafted based on multiple interacting hazards. As part of an extensive literature review into impact modelling undertaken by this project it has become clear that the literature on multi-hazard impact modelling is very sparse. In regard to the available exposure data, areas where local building attributes need to be derived from surveyed housing attributes elsewhere (e.g., Dungog NSW) have significant errors in their exposure data. Currently this does not allow meaningful impact estimates at town scales or smaller.

The project plans to extend our severe weather data collection to multiple tropical and extra-tropical cyclone cases for which high-resolution model data and high quality damage assessment data are jointly available. These datasets will be used to derive statistically more robust vulnerability relationships that will employ multi-hazard predictors for the impact on residential buildings. However, starting this project using the Dungog example as a case study is highly instructive as it allows many of the data issues to be identified and highlights the reality in the varied quality and extent of damage and exposure data. Without this example, the impact forecast user community may see this as a trivial problem, when it simply is not.

In the meantime, we will employ existing vulnerability relations that have been used by Geoscience Australia for scenario impact assessments for emergency management planning purposes to demonstrate the full end-to-end workflow in a pseudo-operational environment – from high-resolution weather model output to spatial impact data.



## PUBLICATIONS LIST

### JOURNAL PUBLICATIONS

Schroeter, S., H. Richter, S. Panchuk and C. Arthur: Forecasting the Impacts of Severe Weather. (In preparation)

### CONFERENCE PROCEEDINGS - PAPERS

Richter, H., 2018: Severe local windstorms – a meteorologist's perspective. *Proceedings of the 19<sup>th</sup> Australasian Wind Engineering Society Workshop*, Torquay, Victoria, 4-6 April 2018.

Richter, H, C. Arthur, S. Schroeter, M. Wehner, J. Sexton, E. Ebert, M. Dunford, J. Kepert, S. Maguire, R. Hay, and M. Edwards, 2018: Impact-based forecasting for the coastal zone. *Proceedings of the research forum at the Bushfire and Natural Hazards CRC & AFAC conference*, Perth, Western Australia. September 2018 (accepted).

### BNHCRC EXTERNAL REPORTS

None.

### INVITED CONFERENCE PRESENTATIONS

Richter, H, C. Arthur, S. Schroeter, M. Wehner, J. Sexton, E. Ebert, M. Dunford, J. Kepert, S. Maguire, R. Hay, and M. Edwards, 2018: *Impact forecasting*. Invited presentation at BNHCRC NT Emergency Services Workshop in Darwin, October 2017.

Richter, H, C. Arthur, S. Schroeter, M. Wehner, J. Sexton, E. Ebert, M. Dunford, J. Kepert, S. Maguire, R. Hay, and M. Edwards, 2018: *Impact-based forecasting for the coastal zone: East coast lows*. Invited "ignite talk" at the Engineering for Climate Extremes Partnership (ECEP) workshop, Sydney, February 2018.

Richter, H.: *Severe local windstorms – a meteorologist's perspective*. Invited keynote presentation at the 19<sup>th</sup> Australasian Wind Engineering Society Workshop, Torquay, Victoria, 4-6 April 2018.

Richter, H, C. Arthur, S. Schroeter, M. Wehner, J. Sexton, E. Ebert, M. Dunford, J. Kepert, S. Maguire, R. Hay, and M. Edwards, 2018: *Impact-based forecasting for the coastal zone: East coast lows*. Invited presentation at the RFSA triennial conference, Sydney, July 2018.

Richter, H, C. Arthur, S. Schroeter, M. Wehner, J. Sexton, E. Ebert, M. Dunford, J. Kepert, S. Maguire, R. Hay, and M. Edwards, 2018: *Impact-based forecasting for the coastal zone*. Invited presentation for the BNHCRC & AFAC Conference, September 2018.

### EUROPEAN GEOPHYSICAL UNION (EGU) ANNUAL ASSEMBLY, VIENNA, APRIL 2018

Richter, H., G. Collocutt, and A. Treloar, 2018: *New developments in the Bureau's thunderstorm prediction system – Calibrated Thunder*.

### AUSTRALIAN METEOROLOGICAL AND OCEANOGRAPHIC SOCIETY (AMOS) ANNUAL CONFERENCE

Richter, H, C. Arthur, S. Schroeter, M. Wehner, J. Sexton, E. Ebert, M. Dunford, J. Kepert, S. Maguire, R. Hay, and M. Edwards, 2018: *Impact-based forecasting for the coastal zone: East coast lows*. AMOS Conference, Sydney, February 2018.

Soderholm, J., H. McGowan, M. Mason, A. Dowdy, T. Wedd, A. Protat, and H. Richter, 2018: *South East Queensland hazard analysis and verification testbed – operations and preliminary results*.



AMOS Conference, Sydney, February 2018.

Turner, K., J. Soderholm, T. Wedd, J. Callaghan, D. Grant, and H. Richter, 2018: *High-impact severe thunderstorm events in southeast Queensland*. AMOS Conference, Sydney, February 2018.

Walsh, K., C. J. White, K. McInnes, J. Holmes, S. Schuster, H. Richter, J. P. Evans, A. Di Luca, and R. A. Warren, 2018: *Natural hazards in Australia and east coast lows*. AMOS Conference, Sydney, February 2018.

Richter, H., G. Collecutt, and A. Treloar, 2018: *New developments in the Bureau's thunderstorm prediction system – Calibrated Thunder*. AMOS Conference, Sydney, February 2018.

Allen, J. T., E. R. Allen, and H. Richter, 2018: *Australian tornadoes in 2013: Implications for climatology and the warning process*. AMOS Conference, Sydney, February 2018.

### **BNHCRC & AFAC CONFERENCE, SYDNEY, SEPTEMBER 2017**

Richter, H., E. Ebert, J. Kepert, R. Stringer, C. Arthur, M. Wehner, C. Krause, M. Dunford, M. Edwards, J. Sexton, and R. Hay, 2017: *Impact forecasting – what does the forecast mean?*

### **CAWCR ANNUAL MODELLING WORKSHOP, NOVEMBER 2017**

Richter, H., G. Collecutt, and A. Treloar, 2018: *New developments in the Bureau's thunderstorm prediction system – Calibrated Thunder*.

### **BOM SCIENCE TO SERVICES SEMINAR SERIES**

None.



## TEAM MEMBERS

Harald Richter: Project leader. Severe convective weather, thunderstorms and its hazards (hail, wind, tornado, heavy rain), convection-allowing modelling of severe convective weather.

Craig Arthur: Project co-leader. Tropical cyclone hazards, impact modelling

Serena Schroeter: Coupled climate modelling, Antarctic sea ice, physical oceanography, climate interactions, severe weather.

Martin Wehner: Vulnerability and exposure

Jane Sexton: Hazard

Beth Ebert: Verification, ensemble prediction

Mark Dunford: NEXIS

Jeff Kepert: Tropical cyclones, atmospheric dynamics, fire weather, turbulence.

Shoni Maguire: Warning policy

Russell Hay: Exposure Lead

Mark Edwards: Vulnerability lead



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## APPENDIX A: SUMMARY OF DELIVERED MILESTONES DURING YEAR 1

Code	Item	Status	Comments
1.1.1	End-user panel is established and priorities agreed on exposure assets, impacts considered, and visualisation outputs to be produced	End-user panel established, first meeting 12 September 2017	Assets: Agreement to focus on residential property (and possibly power distribution assets down the track) Hazards: Focus on damaging winds ; rain ingress down the track if damage data permits this Visualisation outputs: more appropriate to develop the detailed outputs in collaboration with end users as results are produced
1.1.2	Detailed project plan completed and agreed between parties	Completed	Final allocation of individual researchers against milestones on 12 December 2017
1.1.3	Poster for BNHCRC Conference completed	Completed	Was showcased at the Showcase in Adelaide in July 2017
1.1.4	Glossary of project terminology developed	Completed	Circulated to end users 22 September, to be finalised in October.
1.1.5	Quarterly Report	Completed	
1.2.1	Review of international impact forecasting approaches completed (CM 2.2.12)	Completed	A draft was completed in May 2018 and is currently being circulated within the project team for comment. Some additional impact-related studies not currently contained in the draft will be added to it as part of this review. The next step after that is the approval process within GA / BoM. This process includes an additional internal review.



			Publication will take place through a peer-reviewed journal and through the BNHCRC website (for easier access by the emergency management community and other end users).
1.2.2	Collection of 20 April 2015 datasets	Completed	<p>The project requires damage assessment survey data to relate building damage to the magnitude of the underlying hazard(s). Two such datasets were sourced by the project:</p> <p>[1] NSW SES BEACON data were sourced through one of the project's end users, Tony Day.</p> <p>[2] The second damage assessment dataset, the Emergency Information Coordination Unit or EICU dataset, was provided by Fire and Rescue NSW.</p>
1.2.3	Quarterly Report	Completed	
1.3.1	Split SES callout data for the 20 April 2015 event into new event-specific wind damage categories	Completed	<p>At this point the project made an impactful discovery regarding the available damage assessment datasets.</p> <ul style="list-style-type: none"> <li>• Only the Emergency Information Coordination Unit (EICU) dataset contained any classification of the damage to buildings into categories, the BEACON data did not</li> <li>• Neither</li> </ul>





			<p>dataset consistently linked the documented damage to the hazard(s) that caused the damage</p> <p>The information gaps in the available damage datasets affect the project milestones 1.3.1, 1.3.2 and 1.4.1. It also put the project into a position of needing to adjust its deliverables to account for the nature of the damage assessment datasets. A new project deliverable was identified as a consequence. We approached the NSW SES with a request to include damage categories and hazard-damage link information into the BEACON damage assessment reporting template. Tony Day, after consultation with a BEACON developer, communicated that he supported this request and that the changes to implement it are relatively minor.</p>
1.3.2	Split SES callout data for the 20 April 2015 event into rain damage categories.	Completed	<p>As a work-around, the project decided on the following adaptations:</p> <ul style="list-style-type: none"> <li>• We will continue to construct the data workflow from ACCESS-C model output through to a spatial impact display using simple existing or <i>interim</i> fragility</li> </ul>



			<p>relationships for wind (Fig. 2 below) and rain</p> <ul style="list-style-type: none"> <li>• In parallel, we will develop more basic fragility relationships for the wind and rain hazards that will be based on multiple severe wind and rain weather events, not just the 20-22 April 2015 Dungog event. Multiple events will allow us to be more selective on which components of the damage assessment data we choose to use in the construction of fragility relationships without dealing with too small a sample size.</li> </ul> <p>In the meantime, we also seek to develop a more basic fragility curve, where we identify a threshold above which damage occurs. The probability of damage is based on a simple count of damaged buildings in each region. Currently we have mapped damage onset to wind speed (see Figs. 3 and 4 below), but not yet to rainfall rate/accumulation.</p>
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1.3.3	Presentation/Poster for AMOS 2018 conference.	Completed	An oral presentation focusing on the current project findings and status was delivered by Harald Richter at AMOS 2018 in session 4.2B on Thursday 8 February 2018.
1.3.4	Quarterly Report	Completed	
1.4.1	Determine wind speed thresholds for each of the event wind damage categories	Interim solution completed; problem will be re-visited downstream for quality improvements	<p>The damage assessment data available to the project thus far do not allow for an attribution of reported damage to a specific hazard (BEACON and EICU data – see previous quarterly report for acronyms). The BEACON data also don't categorise the damage by damage state or degree of damage.</p> <p>The project needed to find a workaround to address this milestone. Two more immediate pathways have been found:</p> <ol style="list-style-type: none"> <li>1. To complete the construction of the end-to-end data workflow, from ACCESS model output to spatial impact, an interim generic fragility relationship will be used (see Fig. 2 in the Y1/Q3 report showing that relationship)</li> </ol> <p>A second option is the construction of a simplified fragility relationship that</p>



			<p>simply determines a single model wind speed threshold that separates no house damage from house damage. This approach can be applied in the absence of any degree of damage information. Again, the Y1/Q3 report shows the results of this exploration in Figs. 3 and 4.</p>
1.4.2	<p>Reformat ACCESS wind and rain outputs for compatibility with GA systems</p>	<p>Manual solution only</p>	<p>A key software component on the project workflow is GA's "HazImp" code which ingests a hazard grid and produces impact output. The Bureau's ACCESS models produce NetCDF output. Currently, the project has managed to manually convert the NetCDF output to GeoTiff format which is the native input format of HazImp. To automate this capability, we are considering the approach of modifying HazImp to directly ingest NetCDF output. This is work in progress. A second modification of HazImp, although not part of this milestone, is the addition of shapefile outputs to HazImp, so that the Bureau's primary operational data display system, Visual Weather or VW, can easily display the impact information.</p>
1.4.3	<p>Draft for a short article on impact forecasting approaches written</p>	<p>Completed</p>	<p>A near-final draft of the article on impact forecasting approaches has been circulated for review</p>



			by the project team on 8 June 2018. We are expecting the manuscript to be ready for formal peer review in July 2018. Publication is intended through the BNHCRC website (easy access by stakeholders) and in the peer-reviewed literature (as a quality control assurance measure).
1.4.4	Quarterly Report	Completed	