FORECASTING THE IMPACT OF TROPICAL CYCLONES USING GLOBAL NUMERICAL WEATHER PREDICTION ENSEMBLE FORECASTS
A Tropical Cyclone Marcia (2015) wind and rainfall case study

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MOTIVATION

Storm surge damage to Texas coast after Hurricane Ike. Photo: NOAA.
1) Use disaster scenario analysis to better understand potential landfalling tropical cyclone impacts to buildings, critical infrastructure and society.

2) Methodology:
   1. Identify historical events to be simulated over a specified region.
SCENARIO SELECTION: TROPICAL CYCLONE MARCIA (2015)

Photo credit: BoM
BNHCRC PROJECT WORKFLOW

1) Use disaster scenario analysis to better understand potential landfalling tropical cyclone impacts to buildings, major lifelines and humans.

2) Methodology:
   1. Identify historical events to be simulated over a specified region.
   2. Acquire exposure (i.e. building type, population density, etc.) information.
NATIONAL EXPOSURE INFORMATION SYSTEM

Physical Location, Size and Shape
Infrastructure
Administrative Area
Land Tenure
Land Use
Construction Period
Structural Characteristics
Demographic or Social Characteristics
Economic Characteristics

Photo credit: Geoscience Australia
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WIND AND RAINFALL HAZARD MODELLING

**Maximum Three-Second Gust (m s$^{-1}$)**

**Rainfall Rate (mm h$^{-1}$)**

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[Images of maps showing wind gusts and rainfall rates]
WIND AND RAINFALL HAZARD MODELLING

Tropical Cyclone Marcia (2015) Maximum 3-Second Gust Wind Speed Comparison
Date: 17/02/15 - 21/02/15

- Black line: Modelled
- Red line: AWS

Graph showing maximum 3-second gust wind speed over time from 00:00 to 00:00 UTC with peaks during the day.
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   3. Simulate hazards (wind, rainfall and storm surge).
   4. Apply vulnerability models to simulate building damage.
VULNERABILITY MODELLING: BUILDING DAMAGE

Mason 2015
VULNERABILITY MODELLING: POPULATION DISPLACEMENT

1) Based on HAZUS methodology and is directly associated with loss of use of residential buildings.

2) Model inputs:
   a) Regional population.
   b) Probability of occurrence of simulated damage state.
   c) Un-inhabitability function.

Photo credit: http://www.weather5280.com/kat-five/
BNHCRC PROJECT WORKFLOW

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   5. Aggregate/extract information within specific regions.
ENSEMBLE PREDICTION SYSTEM FORECASTS

1) The Bureau of Meteorology (BoM) will soon begin releasing ensemble prediction system (EPS) forecasts to emergency services agencies.

2) There is a need to better understand how the uncertainty in EPS forecasts propagates through to expected impacts to the built environment and society at landfall.

Photo credit: Center for Hydrometeorology & Remote Sensing
TROPICAL CYCLONE MARCIA – 72 HR TO LANDFALL

Tropical Cyclone Marcia (2015) - 72 hr to Landfall

- Political boundary
- ECMWF ensemble mean
- GEFS ensemble mean
- BoM best track

Locations:
- Townsville
- Mackay
- Yeppoon
- Rockhampton
- Gladstone
- Bundaberg
TROPICAL CYCLONE MARCIA – 72 HR TO LANDFALL

Uncorrected

Corrected

Minimum Central Pressure (mb)

0 50 100 150 200 250

Time (hours)
MAXIMUM THREE SECOND GUST WIND SPEED EMPIRICAL CUMULATIVE DISTRIBUTION FUNCTION – 72HR

MAXIMUM THREE-SECOND GUST WIND SPEED – 72 HR TO LANDFALL
RESIDENTIAL BUILDING DAMAGE – 72 HR TO LANDFALL
DISPLACED POPULATION – 72 HR FROM LANDFALL
1) The wind hazard model tends to over predict the observed maximum three-second gust wind speed.

2) The rainfall hazard model underestimates inner core rainfall and cannot model rainband rainfall.

3) Global ensemble prediction system intensity forecasts are poor indicators of future storm intensity and expected impacts to buildings and society.

4) Calibrated ensemble forecasts can provide emergency managers with a range of possible scenarios to make more informed decisions depending on one’s risk appetite.
FUTURE WORK

1) Develop an optimization tool to calibrate hazard models.

2) Account for the influence of terrain and topography on wind and rainfall simulations relative to the exposure information.

3) Add storm surge hazard and flood vulnerability models.

4) Simulate wind and flood impacts to Queensland power distribution stations.

“Remember that all models are wrong; the practical question is how wrong do they have to be to not be useful.”

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Photo credit: http://bulletin.imstat.org/2013/07/obituary-george-e-p-box-1919%E2%80%932013/
OPTIMIZATION

\[ N_{\text{iter}} = 5000 - t = 40459 \text{ s} - \text{RMSE}_{\text{end}} = 1.545 \]

1e+04 < \sigma_{\text{max}} [\text{km}] < 1.5e+05

\[ \text{mean} = 1.75e+04 - \sigma = 23.7 \]

0.8 < \beta < 2

\[ \text{mean} = 1.19 - \sigma = 0.74 \]

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