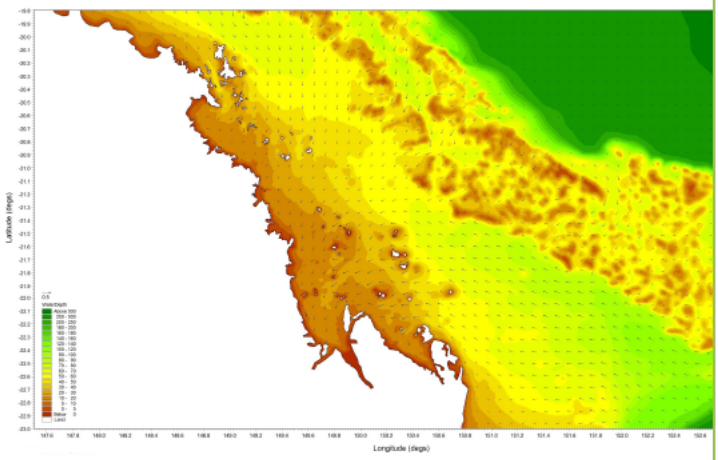
Griffith UNIVERSITY
Centre for Coastal Management

GCCM Submission to Senate Inquiry: "Recent trends in and preparedness for extreme weather events"



January 2013

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Image: Snapshot of timestep showing water depth and direction of flow from a tidal model of the Qld coastline (Dr JM Burston, Griffith University, Jan 2013).

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REVISION/CHECKING HISTORY

REVISION NUMBER	REPORT DATE	CHECKED BY		ISSUED BY	
0	January 2013		Daniel Gee		Joanna Burston
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1 INTRODUCTION

This submission to the Senate Inquiry "Recent trends in and preparedness for extreme weather events" from the Griffith Centre for Coastal Management, Griffith University, Queensland, is made with specific focus on the hazard of storm surge from tropical cyclones. It seeks to address the following terms of reference of the inquiry:

(d) *An assessment of the preparedness and the adequacy of resources in the emergency services sector to prevent and respond to extreme weather events*;

(e) *The current roles and effectiveness of the division of responsibilities between different levels of government (federal, state and local) to manage extreme weather events*;

2 BACKGROUND

2.1 GCCM's role as a stakeholder in storm surge risk management

The Griffith Centre for Coastal Management (GCCM) is undertaking a research project to produce a pilot real-time storm tide forecasting model and data delivery system for Queensland in collaboration with Emergency Management Queensland (EMQ), the Bureau of Meteorology (BOM) and the Qld Department of Science, Information Technology, Innovation and the Arts (DSITIA). This project commenced in May 2012 and continues to May 2014. This project will address questions regarding the resourcing requirements for BOM to move towards real-time storm surge forecasting. Such forecasting delivering dynamic and probabilistic inundation mapping has identified by EMQ as a requirement for more efficient and accurate real-time decision-making during tropical cyclone events for end use by both EMQ and Qld local councils. This research project will build and deliver to BOM and EMQ an oceanographic model capable of operational use for storm surge forecasting, conduct original research into relevant knowledge gaps, including: efficient forecasting of storm surge using high performance computing, probabilistic tropical cyclone wind forcing for storm surge modelling, probabilistic inundation mapping techniques, and storm surge dynamic behaviour, as well as develop new tools for community engagement and education about storm surge hazards.

2.2 The risk posed by storm surge

Storm surge is the elevation of the ocean water surface occurring as a result of forcing by extreme winds and the inverse barometric effect associated with low pressure systems, particularly tropical cyclones. Oceanic inundation caused by storm surge combined with the astronomical tide (storm tide) poses an extreme risk to human life in tropical cyclone events. Wind and swell waves can also be extreme in tropical cyclone conditions, and add to inundation along open coastlines through wave set-up and run-up processes.

Storm surge poses a hazard to the coastal communities of Queensland. Storm surges of several meters in magnitude have the potential to completely inundate single storey buildings and pose an extreme threat to life. The hazard to life is due to both the depth and velocity of water. The timeframe required to conduct evacuations for a forecast storm surge is limited by the severity of other tropical cyclone related hazards, including; the onset of gale-force winds, local flooding due to heavy rainfall and also available daylight hours.

The towns of Cairns, Townsville, Mackay, and Hervey Bay all have high risk owing to their growing populations, coastal exposure and particular oceanographic settings. The Whitsunday Islands and small and remote communities along the Queensland coastline also

have high risk owing to the time required to conduct evacuations and limitations in communication and prior planning by smaller local councils.
The value of accurate storm tide forecasting has not been quantified in either economic terms or in terms of number of lives at risk, and Griffith's research also aims to investigate this value in order to demonstrate that upgrading Australia's storm tide warning system is worthy of ongoing funding.

3 AUSTRALIA'S CURRENT STORM TIDE WARNING SYSTEM

BOM has the unique role of being the sole agency responsible for producing storm tide warnings on which EMQ and other disaster managers are obliged to act. However, the existing warnings are inadequate to meet the needs of emergency managers in a real-time situation or provide inputs that emergency managers at a State or Local level require to forecast the onshore impact of storm surge and hence make time-constrained decisions on the necessity of evacuations.
Australia's existing storm tide warning system operated by BOM has several disadvantages that limit its usefulness for emergency management decision-making. While the existing model was technologically-advanced at the time of development, advances in technology and data availability since its formulation would enable the move towards real-time probabilistic forecasting of storm surge inundation.
Specifically, the drawbacks of the existing storm surge warning system are outlined below:

- **Not real-time** in that it does not explicitly model the ocean behaviour due to the approaching cyclone, instead, matching the approaching cyclone characteristics to a look-up table of pre-run scenarios, which necessarily sacrifices some accuracy.
- It outputs a **deterministic** forecasting of the storm tide resulting from the most-likely tropical cyclone track with no assessment of the uncertainty associated with that track made, as opposed to using an ensemble forecasting approach that could produce probabilistic output.
- The current output is given as water at widely spaced and discrete **offshore** locations, which cannot be directly translated onshore in order to estimate possible inundation extents and does not provide an adequate boundary condition to force local hydrodynamic models in order to estimate the potential for onshore inundation.
- The inclusion/exclusion of allowances for **wave set-up** is not clear and has been identified as an inconsistent and problematic issue for emergency managers.

Engagement with BOM by Griffith has suggested that upgrading of Australia's storm tide warning system would not be possible given their existing resourcing, in particular due to the ongoing costs associated with implementing an operational model and training staff, and that funding from the State level would be required to fund its implementation, even if the model under construction by Griffith and funded by the Qld State government is supplied to BOM gratis.

4 THE NEED FOR ACCURATE REAL-TIME STORM SURGE FORECASTING

As part of this project, GCCM has engaged with EMQ and several Qld local councils in order to ascertain the needs of emergency managers to enhance their capacity in the critical role of real-time decision-making regarding evacuations and resource deployment during tropical cyclone events. The following 'wish-list' was formulated in order to reduce the real-time pressure of interpretation and decision-making with timely and accurate information:

- Inundation mapping: in order to identify populations at risk and inform the process of selecting pre-defined evacuation zones;
- Probabilistic mapping of inundation;
- Real-time dynamic modelling with regular updates delivered within 1 hour of cyclone track updates;
- High accuracy: ~50-100 m spatial resolution in populated coastal towns;
- Understanding the timing of surge with relation to critical thresholds of other hazards: extreme winds, rainfall, riverine flooding, dam releases;
- Robust decision-making process complementing model output;
- Consistent use of terminology and use of vertical datums;
- The proposed system to be constructed by Griffith addresses these requirements. The system requires an ensemble of real-time tropical cyclone forecast wind and pressure fields as input and high performance computing resources.

EMQ requires a good accuracy in the forecast storm surge in a timeframe of 24 to 48 hours before the expected onset of 100 $kmhr^{-1}$ wind speeds in order to effectively action evacuations. Whether the accuracy of the available meteorological inputs at these timeframes is sufficient to meet this need is under investigation. The National Hurricane Centre in the USA currently produces probabilistic storm surge mapping output during tropical cyclone events identified by EMQ as having great value to emergency managers (**Figure 1**).

Example: Hurricane Sandy, 2012, East Coast of USA

The recent event of Hurricane Sandy in the USA demonstrated the value of a well-developed storm surge modelling capacity and data dissemination that allowed assessment of required evacuations. It also demonstrated the role of public availability of measured data. **Figure 1** (a) and (b) demonstrate the probabilistic inundation mapping possible with investment in real-time tropical cyclone wind field modelling and dedicated high performance computing resources.

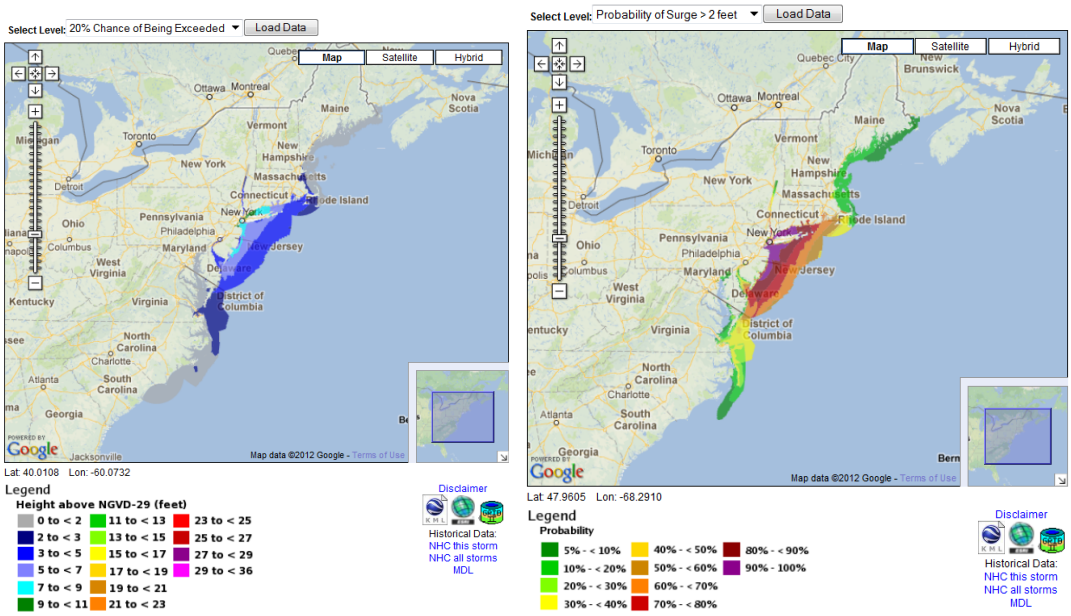

Figure 1 Sample probabilistic inundation from Hurricane Sandy produced by NOAA (http://www.nhc.noaa.gov/refresh/graphics_at3+shtml/152346.shtml?gm_psurge)

Research by our project into the death toll from Hurricane Sandy revealed that one-third of deaths from this event in the USA occurred due to drowning from storm surge, mostly in the victim's home, despite the active efforts of authorities to evacuate the at-risk areas. This finding indicates the extreme hazard posed by storm surge in a tropical cyclone event. These findings also point to the need for a strong and continuing focus on community education and awareness.

6 AUSTRALIA'S NEEDS WITH REGARD TO STORM SURGE FORECASTING

Australia's preparedness against the extreme hazard posed by storm surge could be improved by implementation of a real-time storm surge forecasting system. Through our research, key constraints that reduce the possible accuracy of real-time storm surge forecasting for Queensland have been identified. Actions that would improve the accuracy of forecasting include:

1. ***Improvements in data availability and collection:*** Bathymetry, wind, wave and water level measurements. This point is expanded upon below.
2. ***Further research into tropical cyclone behaviour and wind field modelling:*** An expansion of funding for meteorological research beyond BOM and CSIRO will strengthen Australia's capacity in this field and allow agencies with different operational priorities from BOM to pursue their end requirements in reasonable timeframes. Some open issues on tropical cyclones of interest to emergency managers include: study of the maximum potential intensity of cyclones at different latitudes in order to assess maximum probable extents of storm surge inundation; study of the fine-scale dynamics of wind fields in tropical cyclones that could produce locally enhanced storm surge behaviour.
3. ***Further research into storm surge dynamics and wave set-up understanding.*** There are several outstanding scientific research questions in this field that preclude the application of best-practice planning and emergency management techniques. For

example, the possible propagation of wave set-up inundation inland and around estuaries is not well-understood. The dynamics of storm surge propagation through the Great Barrier Reef and up estuaries is also not well-understood.

The first of these points is discussed in more detail below.

1. Data availability

Up-to-date and detailed base data sets are essential for accurate ocean and inundation modelling.

Bathymetry: Detailed shallow-water (<30 m) bathymetry is essential for accurate modelling of storm surge inundation. Unfortunately, such data is sparse and often outdated along much of Queensland's rapidly urbanising coastline. This research project would strongly ***recommend*** continued collection of nearshore bathymetry data at high resolution. For example, a recent Qld DSITIA project: "Queensland Coastal Risk and Bathymetric LiDAR" that collected nearshore bathymetry using airborne LiDAR for the Sunshine Coast would be worthy of expansion into other areas, especially those with complex nearshore features such as islands, reefs and estuaries. Further, accurate knowledge of the complex bathymetry of the Great Barrier Reef is essential for accurate hydrodynamic modelling and this project supports the ongoing research of James Cook University in collecting LiDAR over the reef (http://www.deepreef.org/publications/conference/96-lidar-gbr.html).

Through the data collection process of this project, we have found the nature of ownership of bathymetry data across local, state and federal agencies and private companies such as port corporations an impediment to assimilating the most accurate and recent bathymetric data, and would ***recommend*** such data be supplied to and held by one agency. The Australian Hydrographic Service (part of the Royal Australian Navy) may be an appropriate agency. The focus of use of bathymetric data for navigation purposes is also an impediment to its use for coastal and oceanographic modelling purposes. Data was often supplied in LAT (lowest astronomical tide) datum, which is locationally variable, and required extensive work to convert to AHD (Australian Height Datum), typically used for elevation data. Any consolidation and management of bathymetric data should reflect the range of uses that it may be applied to, including hydrodynamic modelling.

Elevation data: The Queensland State Government has invested strongly in detailed land elevation data (LiDAR) with applications in flooding and this data has proven valuable. Future updates of this dataset would be desirable as urbanisation of the Qld coastline continues.

Wind measurements: The scientific understanding of tropical cyclones can only be enhanced in the future by continued efforts to collect measurements of wind, pressure and other meteorological parameters from tropical cyclone events. The sparse nature of Australia's meteorological measuring network holds back our understanding of the physical processes governing the behaviour of tropical cyclones.

Wave and water level measurements: Wave and water level field data collection in Queensland is currently carried out by several State and Federal departments:

- Storm tide gauges and fixed wave buoy measurements: Qld DSITIA Coastal Services
- Deployment of extra wave buoys, water level instruments in extreme events: Qld DSITIA Coastal Services
- Post-event inundation extent surveys and damage surveys: Qld DSITIA and Geoscience Australia
- Keeping up-to-date tidal records and bathymetry: Maritime Safety Queensland

- Tidal data collection: National Tidal Centre (part of BOM).

Australia's network of storm tide gauges is sparse relative to the length of coastline and the expanding vulnerable coastal populations. The understanding of the complex behaviour of the astronomical tide along the Queensland coastline, particularly surrounding the Great Barrier Reef, is also hampered by the lack of ongoing water level monitoring. The recent State government cuts to funding at Maritime Safety Queensland and DSITIA have severely constrained the ability of these departments to deliver previously collected data to researchers.

Our research centre and this research project offers strong support to the existing range of data collection and measurement activities undertaken by Queensland State Government agencies and the Bureau of Meteorology mentioned above. We recommend the ongoing funding of these programs in order to preserve Queensland's preparedness against storm surge hazard.

7 COMMUNITY AWARENESS AND EDUCATION

Australia's preparedness against an extreme storm surge is also limited by the low profile of this hazard. Strong branding of storm surge as a life-threatening hazard is highly desirable. Education would be required for both residents and tourist populations, which would require different communication strategies. Our research project aims to explore possible communication strategies for educating the public on storm surge risk and the appropriate responses to an approaching event.

8 SUMMARY

Australia's preparedness for an extreme storm surge event associated with a severe tropical cyclone is limited by its current lack of capacity in real-time forecasting, inundation mapping, and probabilistic assessment of risk that is available in the USA. Griffith University has been conducting research into the requirements for the implementation of a real-time storms surge forecasting system.

Our project offers strong support for continued and expanded data collection in terms of bathymetry, elevation data, waves, water levels and atmospheric measurements in tropical cyclone events. Also, the transparent supply of data and research by government would benefit the facilitation of efficient research into tropical cyclone and storm surge and development of operational tools in this regard. Continuing and expanding research into tropical cyclone and storm surge processes would also benefit emergency management.

The storm surge hazard is not well-recognised or understood by the public. Griffith aims to conduct relevant research into community engagement with storm surge hazard and encourages ongoing efforts by local councils and state emergency managers in community education on natural hazards.