The Centre for Australian Weather and Climate Research
A partnership between the Bureau of Meteorology and CSIRO

Coasts & Extremes – abstracts of the eighth CAWCR Workshop 10 November – 12 November 2014, Melbourne, Australia

Dr Kathleen McInnes and Dr Jeffrey Kepert

CAWCR Technical Report No. 078

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FOREWORD

The Centre for Australian Weather and Climate Research (CAWCR) is a partnership between Australia's leading atmosphere and ocean research agencies – CSIRO and the Bureau of Meteorology. CAWCR jointly manages collaborative Earth system science capability across the Bureau and CSIRO Oceans and Atmosphere Flagship and has, since 2007, provided a major national centre for excellence in research and delivery. This research delivers direct benefits to the nation, including through the development and implementation of new and improved operational forecast systems for the Bureau of Meteorology.

The CAWCR Workshop is an annual event and brings together national and international experts to highlight latest developments in research relevant to CAWCR and its stakeholders. It provides an opportunity to identify gaps, opportunities, build relationships and enhance the quality, breadth and depth of our research efforts.

The theme for this year's workshop is Coasts and Extremes. More than 85% of Australia's population lives within 50 km of the coastline but coastal proximity increases the exposure to adverse impacts from extreme weather and natural hazards such as tropical cyclones, storm surges and extreme waves. The impacts of these events can be further compounded by riverine flooding and development pressure. Additionally, coastal systems are also experiencing increases in coastal water temperature and acidification, which threaten marine ecology with flow on effects to coastal fisheries and biodiversity. This year's workshop will bring together not only scientists with diverse expertise, but also adaptation specialists and practitioners who are working to implement change in the way we manage our coastal regions.

The workshop is organised around topics related to storm surge, waves and coastal inundation; tropical cyclone dynamics; coastal adaptation; ocean acidification and coincident extremes.

A number of prominent scientists and experts from overseas, Australian research agencies and Universities have been invited to give presentations.

Our International guest speakers are:

- Dr Andre van der Westhuysen of the National Oceanographic and Atmospheric Agency
- Prof. David Nolan of the University of Miami
- Prof. Fuqing Zhang of the Pennsylvania State University

Our national guest speakers are:

- Dr John Hunter
- Mr Alan Stokes
- Mr Tim Moltmann

The workshop is hosted and sponsored by the Bureau of Meteorology and CSIRO. Finally, I would like to thank the excellent work of members of the organising committee, comprising: Jeff Kepert, Kathleen McInnes (co-chairs), Tom Durrant, Brenda Lin, Ron Hoeke, Kevin Tory, Val Jemmeson and Meryl Wiseman and the additional support provided by Chris Down, Anu Arora, Liz Adams and Keith Day. Welcome to the workshop. I encourage you to take full advantage of the opportunity to join with your colleagues in discussion of the results and direction of this important research.

Dr Peter Craig

Acting Director
Centre for Australian Weather and Climate Research:
A partnership between the Australian Bureau of Meteorology and CSIRO

A FIRST FORAY INTO OPERATIONAL INUNDATION MODELLING FOR TSUNAMI WARNING IN AUSTRALIA

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Abstract

The Joint Australian Tsunami Warning Centre (JATWC) has been providing operational tsunami forecasts and warnings for Australian waters since July 2007. In the absence of widespread coastal modelling, JATWC generates warnings using an empirical technique that allows simulations of tsunami propagation in near-shore waters deeper than 20m to serve as a proxy for impacts in shallower waters and at the coastline.

However, emergency managers entrusted to make decisions about community and industry evacuations often desire more precise information about what coastal waters may experience dangerous marine conditions or what near-shore areas may be inundated. These types of forecasts require a more accurate assessment of coastal impact and tsunami threat, and can be obtained using high-resolution inundation modelling for near-shore regions. Therefore, the feasibility of implementing this type of modelling as part of JATWC's routine operations has been investigated.

The region of Port Kembla has been chosen for a pilot study, since the necessary data inputs exist for this area. This site is extremely suitable for this purpose, given the industrial use of this area, the nearby residential areas, the complex coastal environment and the relative abundance of sea-level observations during recent tsunami events.

This presentation will describe the development history of this inundation model and will suggest how it might be used operationally, augmenting the existing warning service. There will be a discussion of how the model outputs could be used, both as in-house forecasting tool to assess the danger posed by a tsunami and to generate possible warning products.

Lastly, some thoughts will be shared on the lessons learned and whether a larger project to develop operational tsunami inundation models on a wider scale is realistically feasible.

MODELLING OF WAVE DYNAMICS FOR FRINGING CORAL REEF SYSTEMS – AN UPDATE ON WRL'S CURRENT RESEARCH PROGRAM

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Abstract

Pacific Island nations such as Tonga, Samoa, Fiji, and the Cook Islands are often considered to be tropical paradises with beaches protected from the large ocean swells by their fringing reef systems. On steep reef faces, where waves break on the reef edge, wave energy attenuation can be 60-99% of the offshore wave height. While offshore spectral wave conditions will be a combination of wind and infragravity energy, within the reef, the infragravity energy dominates. During modal wave conditions, larger waves break on the outer edges of the reef, and waves within the reef are considered to be depth-limited. However, during large cyclonic (or typhoon) events, intense low pressure systems can combine with large breaking waves and result in super-elevated lagoon water levels. During such events a bore-like surf beat phenomenon inside the reef has been observed and can result in extreme wave run-up and inflict damage to infrastructure along these normally sheltered coastlines.

There are a number of research programs currently underway that are investigating the reef-top wave processes for such sites, with organisations such as SPC/SOPAC, CSIRO, UWA and NIWA (to name a few) all working on alternative numerical model solutions to simulate wave, setup and surf beat processes for these kind of coastlines. Video evidence captured during cyclones shows that the reef-top wave processes are highly complex, with wave-wave interactions and infragravity waves able to increase nearshore (and overland) water levels significantly, and over very short temporal scales. Furthermore, the nearshore processes behave significantly different during extreme cyclonic conditions compared with modal wave conditions, which limits the possibility of having reliable data sets on which to calibrate nearshore process models.

In recent years WRL have developed an ongoing research program that is taking a different modelling approach, whereby scale physical models in wave tanks are being used to simulate the nearshore processes. This research program began as an applied investigation for the north coast of Rarotonga, Cook Islands, but has since expanded to a range of ongoing investigations that consider a wider range of reef and wave conditions. This presentation will provide an update on the research underway at WRL, and include discussion on the long-term objectives of the program.

ENSEMBLE STORM TIDE FORECASTING FOR DISASTER MANAGEMENT, QUEENSLAND

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Abstract

Griffith University's award-winning QSurge decision support platform is a state-of-the-art real-time storm tide risk assessment tool for emergency managers. Storm tide presents the highest risk to life during a tropical cyclone event, and the major population centres along the Queensland coast have high exposure to this hazard. Emergency managers face the real-time problem of making evacuation decisions well prior of availability of accurate knowledge of cyclone landfall location and timing. The QSurge platform addresses this information need by quantifying and visualising at high resolution the uncertainties in storm surge inundation risk as the tropical cyclone forecast develops. Firstly we showcase this system, consisting of both a probabilistic forecast product and a potential envelope of inundation product. The tropical cyclone ensemble methods and hydrodynamic modelling systems developed for this product will then be discussed in detail. Specifically, the sensitivities of storm surge magnitude to tropical cyclone track parameters are explored. These sensitivities govern the design on the ensemble construction and real-time system design and computing requirements.

TROPICAL CYCLONES, CLIMATE CHANGE AND ENSO: AN ASSESSMENT FROM THE CMIP5 GLOBAL CLIMATE MODELS

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Abstract

One of the main climatic factors that modulate year-to-year variability of tropical cyclone (TC) frequency at a basin-scale is the El Niño Southern Oscillation (ENSO) phenomenon. Given that the anthropogenic global warming is inevitable, any change in the character of ENSO is likely to impact the basin-scale changes in TC frequency. In this study, we explored the ability of selected current-generation coupled global climate models from phase 5 of the Coupled Model Intercomparison Project (CMIP5) to represent the ENSO-related TC variability under the two global warming scenarios: a “current climate” scenario that consists of the historical simulation over the 1970-2000 period, and a “future climate” scenario based on the RCP8.5 simulation over the 2070-2100 period.

Results suggest that the CMIP5 models are able to adequately reproduce the characteristic geographical features of ENSO-related TC variability in most ocean basins around the world. For example, TC genesis in the southwest Pacific basin is displaced northeastward (southwestward) during El Niño (La Niña) years, with simultaneous low (high) activity in the Australian region. This pattern of variability is reproduced well in both current and future climate simulations.

Future changes in ENSO-related TC variability is also investigated in this study. Overall, a reduction in TC frequency is noted in future climate for all major TC basins except for the central Pacific where there appears to be an increasing activity in the future climate. This increasing TC frequency in the central Pacific is more robust for El Niño years than for La Niña years, particularly in the Southern Hemisphere near the dateline. This implies that small island countries in the central Pacific are more likely to have increased TC activity during the future climate El Niño years compared to the current climate El Niño years.

VERIFICATION OF TROPICAL CYCLONE RAINFALL USING CONTIGUOUS RAIN AREA (CRA) METHOD

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Abstract

One of the important steps to develop and improve a numerical forecast model is verification of its output. In spite of the importance of tropical cyclone (TC) rainfall, its verification has received less attention than track and intensity verification. Most of the existing verification is performed using a traditional approach that is a grid-to-grid comparison between model forecasts and observations. This method is simple to calculate and understand, but double penalty can lead to lower skill scores that may be misleading for evaluating forecast quality. It also does not account for some key factors such as the source of rainfall error and location error.

In this talk, we will explore some useful information extracted from the Contiguous Rain Areas (CRA) method, one of the early "non-traditional" object-based verification approaches, for TC rainfall forecast verification. ACCESS-TC (the tropical cyclone version of Australian Community Climate and Earth System Simulator) model forecasts will be evaluated as a demonstration. The total TC rainfall error can be decomposed into four components according to location, rotation, volume and pattern, which gives insight as to the source of rainfall error. The location error is determined using a pattern matching technique. Furthermore, rain event verification, which uses displacement and volume error to categorize rain events as hits, misses etc., is also demonstrated as a good tool to monitor forecast performance over time.

MODELLING THE EFFECTS OF LAND-SEA CONTRAST ON TROPICAL CYCLONE PRECIPITATION UNDER ENVIRONMENTAL VERTICAL WIND SHEAR

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Abstract

In two recent studies (Li et al. 2014a, b), we investigate the precipitation pattern of landfalling tropical cyclones based on idealized simulations using the Weather Research and Forecasting model. Besides the changes in surface wind and associated convergence pattern that result in asymmetric convection and storm-scale vertical wind shear (VWS), the rain generation mechanism is also found to be important. For the outer-band region (r ~ 100-300 km) rain is formed through shallow convection and the surface convergence induced by roughness plays a significant role. In the experiment in which roughness is the same over land and sea, the cool dry air originated over land is advected offshore, reduces the vertical stability and activates a band of rainfall over there. For the inner-core region (r < 100km), mostly deep convection occurs and a large amount of rain water is generated starting from the midlevel. The rainfall distribution pattern is also largely determined at the midlevel, and thus the influence from surface asymmetry is much less than that in the outer-band region. Further experiments are carried out to compare the effects from environmental VWS and those from land-sea contrast only on the rainfall distribution. It is found that the total VWS (environmental plus that internally generated) changes in direction throughout both simulations with a smooth surface only and with land-sea difference in roughness. As discussed in our publications, VWS introduces asymmetry in diabatic heating, and the associated updraft at the downshear side increases the upper-level outflow that further modifies the VWS. The rainfall pattern follows closely the VWS in the inner-core region for the experiment with land-sea difference in roughness. While in the outer-band region, the rainfall distribution is initially similar to that without environmental VWS, the effect of which gradually becomes dominant.

MODELLING TIDES AND SURGES ACROSS THE AUSTRALIAN SHELF

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Abstract

In this talk we will present results from recent ocean model simulations performed across the entire Australian shelf using the Regional Ocean Modelling System (ROMS). The model simulations are barotropic in nature and consist of a series of experiments under different atmospheric forcings.

A hindcast of 30 years, spanning 1981-2012, using atmospheric fields from the Climate Forecast System Reanalysis (CFSR) is used to investigate the model's ability to reproduce tides and surges across the Australian shelf and provides the opportunity to investigate the role of non-linear tide-surge interactions around Australia.

A second set of experiments is undertaken to investigate changes of surges across the Australian shelf using forcing from current-generation coupled global climate models from phase 5 of the Coupled Model Intercomparison Project (CMIP5) under a high emission scenario; (RCP8.5). A selection of 4 CMIP5 models is used to force the ocean model for present and future climates. Changes in SSH are assessed and possible connections between those and climate relevant phenomena are discussed.

BAY BLUEPRINT - REGIONAL COASTAL ADAPTATION FOR PORT PHILLIP BAY

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Abstract

This presentation will look at the work that the Association of Bayside Municipalities and its ten member councils is taking in response to climate extremes and potential climate change impacts around Port Phillip Bay.

The Association of Bayside Municipalities (ABM) was formed in 1974 and represents ten councils around Port Phillip Bay. These ten councils cover 335 km of coastline within the Bay and manage much of it for recreational, amenity, environmental, tourism, commercial and residential purposes.

All levels of Government have identified the impacts on the coast of current extremes and future climate change impacts. While simple risk and vulnerability assessments have been undertaken in some areas little has been done to develop and effective regional plans for adapting to current and future extremes along this highly urbanised Port Phillip coastline.

Previous reports like the "Climate change risks to Australia's coasts: a first pass national assessment (2009)" identified the potential risk to residential and commercial /industrial properties using a simple bathtub analysis. This identified that of the 13 Victorian LGAs assessed 8 were in Port Phillip Bay and also contained the top three at risk.

Extreme coastal events currently cost the Victorian community millions of dollars in damage to infrastructure, loss of amenity, social and infrastructure dislocation. Simple repair costs are significant but little is being done to prepare for further extremes and climate change impacts along an urbanised coastline where retreat doesn't appear to be an option.

The Future Coast program identified and mapped the entire Victorian coastline but the resolution of the data released and made available to the community is only sufficient for a broad regional analysis. To complement this 4 pilot studies were funded by DEPI, whilst they are largely completed the learning, methodologies and solutions have not been publically released or shared. Perhaps this highlights the political sensitivity of identifying properties at risk when the liabilities, responsibilities financial burden and political will are complex and poorly aligned.

The ABM initiated a "Coastal Adaptation Pathway" initiative to look at the costs and benefits of applying adaptation solutions to minimise flooding and also looked at the decision making processes needed to respond to a changing climate within local government. Outcomes and recommendations from this report suggested a range of further work to fill identified gaps.

From here the ABM has developed a "Managing Better Now" program which among other things seeks to understand the scientific evidence and modelling and current management and planning responses. This has been complemented by the State-funded Victorian Adaptation and

Sustainability Partnership (VASP) project that looks at the adaptation pathways and frameworks for responding to climate and non climate pressures for Greater Melbourne and Geelong , together with a Blueprint or Adaptation Plan highlighting beneficial opportunities for the region by 2050-2070.

OBSERVATIONS OF EDGE WAVES ON A BARRED BEACH

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Abstract

Diurnal variations in wave height and direction associated with a strong sea breeze cycle are observed on a barred beach in South West Western Australia with the local wind-sea being more oblique to the shoreline during the peak of the sea breeze. The occurrence of the seasonal, obliquely incident wind-sea provides an opportunity to examine the role of the wave angle on nearshore hydrodynamics and morphology. Using time exposure video images the alongshore variability of the sandbar is observed to decrease under obliquely incident mild wind waves, and increases with normally incident waves. Analysis of a cross-shore array of pressure sensors shows a stronger infragravity response to swell than to wind-sea. Breakpoint forcing of infragravity waves occurs with wind-sea and swell conditions, while bound wave release is only observed under swell dominated conditions. Further analysis, using a longshore array of pressure sensors, shows high-frequency edge waves are dominant under wind-sea forcing and low-frequency edges waves are dominant under swell forcing which may explain the appearance of alongshore-variable patterns in the absence of obliquely incident short waves.

ENVIRONMENTAL INTERACTIONS DURING TROPICAL CYCLONE EXTREME RAINFALL AND RAPID INTENSIFICATION

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Abstract

We re-visit the Tropical Cyclone, TC-trough interaction problem and provide evidence that some types of amplifying Rossby Waves provide favourable settings for interaction. This can occur via injection of environmental air with high potential vorticity (PV) into TC circulations through midlevels.

Ex-TC Oswald produced extreme rainfall over northeast Australia. We demonstrate that as an upper-level, extra-tropical Rossby Wave amplified and propagated towards the tropics, a potential vorticity anomaly descended to midlevels, moved equatorward and then was axisymmetrized and merged with the midlevel TC circulation. Using trajectory calculations we illustrate that the midlevel circulation was affected by the injection of high PV from the environment during the heavy rain.

The controversial rapid intensification of hurricane Opal in 1995 is also reviewed in light of these new insights. In addition to previously-suggested processes, it is found that the rapid intensification coincided with the merger between the storm and an environmental PV anomaly through midlevels. From a synoptic-scale perspective, we suggest that the rapid intensification of Opal was associated (a) with enhanced vertical motion ahead of an approaching upper front, and (b) with an enhancement of midlevel PV from the westerly trough. At the planetary scale, it appears that these processes were part of an amplifying Rossby wave with large group and small phase speeds. We illustrate that similar processes may have been present during the near-catastrophic rapid intensification of Hurricane Earl in 2010.

The poorly-forecast extreme rainfall events associated with (a) pre-genesis TC Carlos, near Darwin in 2011, and (b) land-falling Typhoon Fitow near Shanghai in 2013, are also interpreted in terms of similar environmental interactions.

LONG-TERM CHANGES IN AUSTRALIAN TROPICAL CYCLONE NUMBERS

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Abstract

Many previous studies have examined whether or not long-term changes can be detected in tropical cyclone (TC) activity based on the observed records, with Knutson et al. (2010) concluding from such studies that it is uncertain whether or not past changes in TC activity have exceeded variability due to natural causes. The ability to investigate long-term changes in observed Australian TC numbers is shown here to improve when the El Niño-Southern Oscillation (ENSO) is considered: removing variability in TC numbers associated with ENSO shows a significant decreasing trend in TC numbers at the 93–98% confidence level. In an effort to minimize the impact of satellite-induced inhomogeneities, these results do not use data prior to the 1982/83 Southern Hemisphere TC season (following Kuleshov et al. (2010) and Dowdy and Kuleshov (2012)). Additionally, there is some indication of a temporal change in the relationship between ENSO and TC numbers, with ENSO accounting for about 35–50% of the variance in TC numbers during the first half of the study period, but only 10% during the second half. These results have significant implications for the seasonal prediction of TCs. For further details see Dowdy (2014).

Physical causes of a long-term change in TC activity in the Australian region are discussed, including examining the hypotheses of previous studies such as Ashok et al. (2012) that increasing greenhouse gas concentrations could potentially influence the occurrence of different types of ENSO variability (such as Modoki events). The potential influence of tropical expansion on TC numbers is also examined, following a recent study by Kossin et al. (2014). Additionally, the use of other measures of TC activity (rather than TC numbers) is discussed, including the development of a new database that considers TC intensity and duration based on integrated surface wind profiles.

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TOWARDS AN AUSTRALIAN WAVE ENERGY ATLAS

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Abstract

Preliminary resource assessments indicate Australia has an abundance of renewable, zero emission, wave energy; with the potential to provide up to 10 per cent of our nation's power by 2050. Despite this promise, there are significant knowledge gaps currently impeding the emerging wave energy industry in Australia.

The ARENA funded Australian Wave Energy Atlas project (AWavEA), seeks to address three key knowledge gaps:

(a) Limited (scientifically credible and industry independent) knowledge of the resource, including its temporal and spatial variability and its spectral characteristics;

(b) Difficulty assessing spatial information identifying multiple designated marine management regimes of Australian marine territories, and

(c) Limited evidence-base and methodology for assessing impacts of wave energy extraction on the marine and coastal environment.

To address these gaps, the AWavEA project will deliver:
1. A pre-competitive, query-able, free and openly available spatio-temporal atlas of Australia's national wave energy resource and marine management uses, and
2. Best-practice guidelines on physical impact assessments for wave energy developments in Australia's marine domain.

This talk will present the broad goals of the project as a whole, as well as details of the 34-year (1979-2013) global wave hindcast that will underpin the atlas.

QUANTIFYING COASTAL HAZARD RISKS FOR EFFECTIVE ADAPTATION PLANNING

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Abstract

The presentation will outline the approach necessary to arrive at a robust statistical description of coastal hazard risks (with or without consideration of projected climate change impacts) so that effective long-term adaptation planning decisions can be properly formulated.

The recently completed Coastal Hazard Adaptation Study (CHAS) undertaken for the City of Townsville in Far North Queensland will be used as an example of the approach. That study was instigated by the Local Government Association of Queensland in partnership with Townsville City and the State of Queensland with the intention of providing a template methodology for similarly impacted coastal regions. The study was undertaken by GHD Pty Ltd.

The importance of a "risk based" approach and having a reliable coastal hazard study completed first will be emphasised, followed by the need for accurate land elevation, land use and infrastructure data. Specific learnings from the CHAS study will be summarised to help other risk managers appreciate the challenges and the pitfalls that might present in any similar investigations. These include the practical considerations of time and cost, access to data and buy-in by the many stakeholders.

Examples of subsequent Queensland studies for Mackay and Torres Strait will also be presented and parallels drawn with the identical challenges in floodplain management generally.

GETTING IT TOGETHER – THE VICTORIAN COASTAL STRATEGY 2014

Jon Hickman

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Abstract

In September 2014 the Victorian Government approved the fourth iteration of the Victorian Coastal Strategy. The Strategy identified five key coastal issues to be addressed over the next five years:

- Managing population growth
- Adapting to a changing climate
- Managing coastal land and infrastrucure
- Valuing the natural environment
- Integrating marine planning.

The presentation will address the challenges that these issues present to the Victorian coast

STORM SURGE INUNDATION AND MITIGATION STRATEGIES FOR CITY OF PORT PHILLIP, MELBOURNE

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Abstract

The City of Port Phillip in Melbourne, Victoria, has several low-lying coastal regions which are particularly susceptible to flooding during storm surges. The flooding is a combination of two effects: direct inundation from the elevated sea level, and reduced, or even reversed, flow in the urban drainage network. A reduction in drainage creates flooding from accumulation of rainfall over the region and upstream catchments. We examine the inundation from a hypothetical 1.3 m storm surge on the City of Port Phillip over a range of potential sea level rise scenarios. The scenario was modelled using the GPU-based shallow water solver SWIFT incorporating the drainage network for the region. Additionally, a number of mitigation strategies were trialled using the model. These included household and street level detention of rainfall and using non-return valves in the drainage network. The use of non-return valves was found to be the most effective solution in reducing the extent of inundation below a certain sea-level rise threshold.

CHARACTERIZATION AND HYBRID DOWNSCALING OF WAVE CLIMATE AT A CENTRAL PACIFIC ATOLL: FUNAFUTI, TUVALU

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Abstract

Wind-generated ocean wave climate is of national interest to the island nations Maldives, Kiribati, Tuvalu and the Marshall Islands. These atoll nations are exposed to wave trains generated by a broad range of meteorological phenomena and are perceived to be at high risk of increased erosion and inundation associated with sea level rise. In this study, the wave climate of Tuvalu is characterized through partitioning analysis of 33-years of historical deepwater wave spectra. The partitioning (statistical) analysis is combined with a flexible mesh (dynamical) wave model of Funafuti (Tuvalu's most populous atoll). This hybrid statistical/dynamical downscaling provides event-based wave information at scales on the order of tens of metres. Such high-resolution coastal wave climate is exceptionally useful for coastal management, which we demonstrate though examination of local extreme wave events and their relationship to deepwater wave climate. The complex wave climate of the central Pacific and the complex morphology of the atoll provide an effective test bed for developing this hybrid statistical/dynamical downscaling approach, making it readily applicable to other coastal regions.

DIRECT PREDICTION OF THE IMPACTS OF WEATHER EXTREMES

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Abstract

Hurricane Sandy and the recent floods in Thailand have demonstrated not only how vulnerable society is to the impact of severe weather, but also the associated global reach of the ramifications. Extreme weather impacts such as these have grown rapidly in size and frequency over recent decades and climate change is expected to compound future increases in the severity and frequency of extreme weather and climate events. These combined with the increasing interdependence of global commercial activities point towards a growing vulnerability to weather and climate extremes.

Here we discuss the direct prediction of impacts as an aid to both planning for and responding to such weather and climate extremes. In this approach the traditional method of making a weather or climate prediction and passing this on for interpretation and action by others is transformed and encapsulated into a single impacts prediction. We argue that this aids both the planning and response and the weather or climate forecast processes.

Two examples will be provided: one for prediction of changes to drought in the south-central United States and the other for global tropical cyclone impacts.

GLOBAL REGIONALLY-VARYING SEA-LEVEL ALLOWANCES

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Abstract

I will describe a technique for developing a local planning allowance for sea-level rise, which uses regional projections of sea-level rise (and its uncertainty) and information about the present statistics of tides and storm surges (as measured by tide gauges or predicted by models). The allowance describes the amount by which infrastructure needs to be raised in order to maintain the present risk of inundation under conditions of rising sea level. The method has been applied and used in Australia, Canada and Europe.

Problems and constraints of this method will be discussed.

THE DYNAMICS OF SECONDARY EYEWALL FORMATION IN A HURRICANE NATURE RUN

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Abstract

Eyewall replacement cycles (ERCs) have a marked effect on the intensity and the overall size of tropical cyclones, and are thereby important to predicting the likely impact of a storm. They are also a fascinating part of the internal dynamics of the storm. While a substantial part of the dynamics of ERCs has been understood for several decades, unanswered questions include the mechanism(s) for the initial formation of the outer eyewall. In addition, much recent research has focussed on the boundary layer.

Here, we analyse the high-resolution simulation of a tropical cyclone prepared by Nolan et al (2013) as a “nature run” for data assimilation research. That simulation contained a complete eyewall replacement cycle, including the initial formation and contraction of the outer eyewall, and the dissipation of the inner eyewall. The analysis tools include the nonlinear diagnostic boundary-layer model of Kepert and Wang (2001), which is used to diagnose the boundary-layer contribution to the secondary circulation. We show that nonlinear Ekman pumping, as diagnosed by that model, explains much of the distribution and relative strength of the azimuthal-mean updraft out of the boundary layer. We use a simpler diagnostic model of the tropical cyclone boundary layer to establish a direct relationship between the frictional convergence and the vorticity of the gradient wind, which is different to the classical Ekman pumping. We demonstrate a strong relationship between frictional convergence and the development of convection. And finally, we analyse the link between vorticity and convection to show that the convection generates significant amounts of cyclonic vorticity in the simulation.

These four steps constitute a positive feedback loop, similar to that hypothesised by Kepert (2013), which contributes to the secondary eyewall formation in this simulation.

PROJECTING CLIMATE CHANGE IN AUSTRALIA'S MARINE ENVIRONMENT

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Abstract

In response to increasing atmospheric greenhouse gases the ocean has both warmed and become more acidic over the last 200 years. The magnitude of these large-scale changes can be much larger in the coastal environment. Around Australia detectable impacts on the marine environment have already been documented e.g. biological changes in a range of marine species, changes in local abundance and geographic range, and community structure. Therefore understanding and projecting how Australia's climate will change, and what the impact of these changes maybe be on the marine environment is very important for the management of future marine resources.

To quantify the future changes in Australia's marine environment we use a suite of Earth System models to investigate how sea surface temperature and ocean acidification will change within this century. We explore the response under a series of different emission scenarios from low to high (RCP 2.6, RCP4.5 and RCP 8.5). To assess how well these models capture the mean state, we compare these simulations with observations collected at the National Research Stations (NRS) over recent years. We show that a significant large-scale warming and increase in ocean acidification are projected around Australia by the end of this century. However, the magnitude of the change is proportional to the emission scenario, with the largest changes under the high emissions scenario (RCP 8.5). Together these changes are expected to have significant negative impacts on the long-term health, diversity and viability of many marine species, and are likely to impact key sectors such as fin and shellfish fisheries, aquaculture, tourism and coastal protection.

ADAPTATION PATHWAYS IN LOCAL COASTAL DECISION-MAKING: EXPANDING HORIZONS OR ENTRENCHING PRACTICE?

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Abstract

In 2012, the Australian Government initiated and funded an 18-month program on adaptation pathways in coastal decision making to assist coastal local government authorities (LGAs) explore responses to sea level rise, coastal inundation and related impacts on their environments and communities. **Adaptation pathways** provide a way of visualising a set of flexible adaptation options through time. Rather than being limited to identifying the best single set of adaptation options for a limited set of climate change scenarios, it enables decision makers to consider a range of possible actions, how they will be impacted by various climate change scenarios through time, and whether any options will become untenable due to changing circumstances (socially, economically, environmentally, or climatically). Using a selection of these completed projects as case studies, we identify how the concept of adaptation pathways was interpreted and applied in these studies and see if the LGAs were able to develop a pathway-based set of adaptation options. We reviewed the formal project documentation for each case study and surveyed project participants (consultants, local governments, scientists and other stakeholders) to understand how each project proceeded and the challenges they faced in their decision-making. The analysis provides insight into the process of adaptation-related decision-making in local coastal environments in Australia and the barriers to why adaptation pathways are not achieved in many cases. The study suggests that economic, technical, and legal issues are prioritized in the short-term while community engagement and participatory discussions on adaptation options were considered a less immediate priority. Although community engagement is seen as an important aspect to adaptation planning, many LGAs are not currently reaching out to their communities because of the complexity in negotiating decision-making with a bigger set of stakeholders. We propose that these priorities may have to be reversed in order to help decision makers develop adaptation pathways that are socially, as well as technically feasible.

IMOS OBSERVATIONS FOR COASTS AND EXTREMES

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Abstract

The IMOS observing strategy for continent shelf and coastal processes is to provide an extensive national backbone around the continental shelf with more intensive observations in regions of socio-economic and ecological significance e.g. coral reefs, biodiversity hotspots, population centres, and regional development hubs. The national backbone comprises a network of National Reference Station Moorings, national access to Satellite remote sensing products and the electronic Marine Information Infrastructure (eMII) Facility. The more intensive, region-specific observations include a combination of Shelf Moorings, coastal Ocean Gliders, Ocean Radar (for currents and waves), Autonomous Underwater Vehicles and Wireless Sensor Networks (on the Great Barrier Reef).

Strong integration between the observing system and the relevant modelling frameworks is also particularly important in this context - for the purposes of validation and model development, data assimilation, and observing system design.

In most IMOS Nodes there is now co-evolution of the regional observing systems with regional modelling efforts:

- In Darwin Harbour the IMOS NRS, and second mooring in Beagle Gulf co-invested by Darwin Ports Corporation, has been very valuable for the region where the data is used in real time to run models and help with port operations.
- In SA, the successful shelf scale collaboration between IMOS and the SAROM regional modelling activity is being leveraged into the SA Gulfs with the aim of creating a new, co-invested partnership. A new SA/Vic/TAS ROMS model is also being set up with the aim of moving to data assimilation for this region.
- In NSW, the SEAROMS modelling activity will be further developed under a new ARC project including moving to data assimilation.
- OzROMS is a modelling effort (out of WA) where shelf-ocean exchanges for alongshore and across shore transport in Australia are estimated using models which are validated with IMOS observations (HF Radar, ARGO profiles, ocean glider transects, moorings, satellite SST, altimeter), with plans to adopt the model to predict extreme water levels around Australia.
- eReefs, the latest and most sophisticated hydrodynamic model of the GBR region that is designed to become a real-time forecasting system where modelling of reflectance is a new development for its biogeochemical component, designed to directly compare with observed satellite reflectance (IMOS Satellite Ocean Colour facility)

Additionally the Australian Marine Virtual Laboratory (MARVL) has been established as a web-based open source application that provides a number of model choices and search and recovery of relevant observations. This tool has been applied successfully in a number of case studies around Australia ranging in scale from locally confined estuaries to the Tasman Sea.

Plans are now underway for an Australian National Shelf Reanalysis (ANSR) project to take advantage of this step change in availability of observations and growth in shelf/coastal modelling capability.

In summary, IMOS observations have been a key element in recent developments in modelling and observational research in Australian coastal and shelf regions. IMOS observations will be essential in the future, providing the ability to better quantify natural variability and long-term climate change, and their impacts on the marine environment and coastal communities.

BIASES AND LIMITATIONS IN THE ESTIMATION OF TROPICAL CYCLONE INTENSITY

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Abstract

While the average errors of tropical cyclone track forecasts have been steadily declining over the last two decades, intensity forecasts have only marginally improved. For North Atlantic forecasts, the 24-hour intensity forecast has shown no improvement, with mean errors of peak wind speed forecasts remaining around 10 knots for the last 20 years. Some recent studies have suggested that, given the current "observing system" of satellites, aircraft reconnaissance, and subjective analysis, the actual peak wind speed cannot be measured to an accuracy greater than about 10 knots. In this study, we use an Observing System Simulation Experiment (OSSE) approach to test the limitations of even nearly perfect observing systems to capture the peak wind speed occurring within a tropical storm or hurricane. The data set is provided by a 1-km resolution simulation of an Atlantic hurricane with surface wind speeds saved every 10 seconds. An optimal observing system consisting of a dense field of fixed anemometers is placed in the path of the storm: this provides a perfect measurement of the peak 1-minute wind speed. In reality, reliable surface observations are very rare in tropical cyclones. Therefore suboptimal observing systems consisting of a small number of anemometers are sampled and compared to the truth provided by the optimal observing system. Results show that a single, perfect anemometer experiencing a direct hit by the right side of the eyewall will still underestimate the actual peak intensity by 10-20%. Even an unusually large number of anemometers (e.g., 3-5) experiencing direct hits by the storm will together underestimate the peak wind speeds by 5-10%. However, the peak intensity of just one or two anemometers will provide, on average, a good estimate of the true peak intensity averaged over several hours, which is in fact more consistent with operational definitions of intensity. If the mean bias were known perfectly for each case, it could be used to correct the wind speeds, leaving only mean absolute errors of 3-5%.

MAJOR COASTAL FLOODING IN SOUTH-EASTERN AUSTRALIA 1860-2012, ASSOCIATED DEATHS AND WEATHER SYSTEMS

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Abstract

A new historical data-base describing major floods and associated weather systems that occurred in coastal catchments from Brisbane in south-eastern Australia to Eden approximately 1500 km further south is described. In order to produce a homogeneous record of major flood and weather-type frequency we restrict attention to the period 1860-2012, when the region (i) is extensively populated, (ii) has an extensive coverage of meteorological stations, (iii) is extensively connected by telecommunication, and (iv) when there is busy coastal shipping offshore. A total of 253 major floods over this period are identified. A flood is considered here to be "major" if it causes inundation of a river within approximately 50km of the coast or if there is non-riverine flooding over land near the coast, extending 20km or more along the coast. All major floods are associated with either (a) East Coast Lows (ECLs) or (b) "Tropical Interactions" (TIs). Three types of TIs are identified and described. ECLs triggered more major floods than TIs (57% versus 43%), but TIs caused more deaths from freshwater flooding (62% versus 38%) and they tended to cause over twice as many deaths per event (3.6 versus 1.7 deaths/event on average). Some of the most extreme events identified occurred in the 19th century and early-to-mid 20th century. If such events were to occur today they would have catastrophic impacts due to the massive increase in urban development in the study region since that time.

SEASONAL PREDICTION OF CORAL SEA TROPICAL CYCLONES USING OPTIMISED COMBINATIONS OF ENSO REGIONS

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Abstract

The use of multiple ENSO sea surface temperature (SST) regions for seasonal predictions of Coral Sea tropical cyclone (TC) frequency is explored as an alternative to using a single SST predictor. The Coral Sea averages about 4 TCs per season, but is characterised by strong interannual variability, with 1–9 TCs per season, over the period from 1977-2012. A wavelet analysis confirms that ENSO is a key contributor to Coral Sea TC count (TCC) variability. Motivated by the impact of El Niño Modoki on regional climate anomalies, a suite of 38 linear models is constructed and assessed on its ability to predict Coral Sea TCC. Seasonal predictions of TCC are generated by a leave-one-out cross validation (LOOCV). An important finding is that models made up of multiple tropical Pacific SST regions, such as those that comprise the El Niño Modoki Index (EMI) or the Trans-Niño Index (TNI), perform considerably better than models comprised only of single regions, such as Niño 3.4 or Niño 4. Moreover, enhanced (suppressed) TC activity is expected in the Coral Sea when the central Pacific is anomalously cool (warm) and the eastern and western Pacific are anomalously warm (cool) during Austral winter. The best cross-validated model has persistent and statistically significantly high correlations with TCC ($r > 0.5$) at lead times of ~6 months prior to the mean onset of the Coral Sea TC season, whereas correlations based heavily on the widely used Niño 3.4 region are not statistically significant or meaningful ($r = 0.09$) for the same lead times. Of the 38 models assessed, several optimised forms of the EMI and of the TNI perform best.

EXTREME COASTAL RAINFALL IN THE AUSTRALIAN TROPICS

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Abstract

Extreme coastal rainfall in the Australian tropics is commonly associated with localised PV maxima, or coherent synoptic-scale weather systems, that have their origin in the midlatitudes. These localised PV maxima often originate in the mid latitudes, curve anticyclonically into the tropics, where they become the focus for convection and rainfall. They are identified and tracked in the isentropic potential vorticity (PV) field from the ECMWF Interim Reanalysis (ERA-Interim) dataset during the Southern Hemisphere summer. On average, a coherent synoptic system is found in the region every 2.5 days. However, the time interval between consecutive events is highly variable, meaning that the synoptic activity in the Australian monsoon is not well represented by commonly employed spectral techniques. The PV-theta structure of tropical cyclones in the region is very similar to that of other extreme rainfall producing systems. One difference is that the rainfall anomaly associated with the tropical cyclones lies just offshore, whereas that associated with other extreme systems is relatively symmetric across the coastline.

DEVELOPING A NATIONAL FRAMEWORK TO SUPPORT COASTAL LOCAL GOVERNMENTS TO ADAPT TO THE EFFECTS OF CLIMATE CHANGE

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Abstract

Most Australians live, work and play near to the coast, resulting in most housing and infrastructure being vulnerable to effects of climate change such as increases in extreme weather, sea-level rise and storm surge. The exposure of the Australian people, the economy and the environment, to the effects of climate change is increasing as the population continues to grow. The Australian Bureau of Statistics estimates that the Australian population will reach 36.8 – 48.3 million by 2061 (ABS 2012).

The National Climate Change Adaptation Research Facility (NCCARF) has received Commonwealth funding for an additional three years. In this second phase, NCCARF will develop a framework for understanding coastal climate risk, particularly from sea-level rise and storm surge. The framework will be designed as a decision support system for stakeholders taking practical actions to prepare for and manage that risk. The framework will make use of national data sets and research outputs that have been developed over the past 5 years by various organisations, it will include clear guidance on good practice and links to case studies. The Framework will be delivered as an internet-based tool, which will ensure that guidance is comprehensive, integrated and easily accessible and, most importantly, can be shared within and between organisations, and not gather dust on shelves.

Developing a Framework and ensuring that it meets the needs of stakeholders requires substantial stakeholder engagement throughout the process. A range of Advisory and Technical committees will be established to provide guidance and will include State and Local Government policy and technical expertise. There will also be substantial end user engagement opportunities, and training once the tool is delivered.

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REGIONAL OCEAN MODELLING AND PREDICTION AT THE BUREAU OF METEOROLOGY: FROM THE PAST TO THE FUTURE

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Abstract

The existence of NWP systems, OceanMAPS and real-time observational data streams at the Bureau of Meteorology combined with experience in regional and global ocean forecasting through the BLUElink project makes real-time coastal ocean forecasting with regional models scientifically and technically possible. The Bureau has been engaged in regional-ocean modelling for about the past 7 years and over this time has developed capability in a wide range of applications.

This story begins outside the Bureau some time ago with modelling studies of the circulation in Bass Strait using two ocean models SHALL2D and COHERENS with advanced tracer methods to provide the first illustration of the flushing, residence time and water age patterns (Sandery and Kaempf, 2007). This work provided leverage to Bureau regional ocean modelling capabilities, which were subsequently developed under strategic research within BLUElink using MOM4. In this space regional models were used to study coupled forecasting systems (CLAM) (Sandery et al, 2010; Barras and Sandery, 2013), develop initialisation schemes (Sandery et al, 2011; Sandery and O'Kane, 2014a), study upper ocean heat content (Sandery and Brassington, 2008), diurnal SST warming and air-sea exchanges (Walsh et al, 2008). The regional ocean modelling system was used to study the predictability of the EAC (O'Kane et al, 2011) and provide a modelling system for developing a new ensemble data assimilation system called EnKF-C (Sakov and Sandery, 2014). A capability for more accurate forecasting of EAC SST fronts using a high-resolution 2.5 km Tasman Sea system was also developed. The regional systems have been used to provide guidance for improving BRAN and OceanMAPS since they are much less expensive to run than their global counterparts. These systems are configured to automatically quantify the performance of the forecasts using all available observations. This has been exploited to estimate forecast error for a wide range of forcing, initialisation, open boundary, modelling and data assimilation choices (Sandery et al, 2014b).

In late 2013 the Bureau adopted ROMS as its operationally supported ocean model for shelf and coastal applications. ROMS is being used for development of a range of systems including 3D coastal modelling and 2D storm surge prediction. In the past few months activities carried out with ROMS in the coastal space have produced a prototype GBR 1.5 km resolution realistic model, which has been used to carry out a demonstration 3-year simulation. This first step helps determine limitations and strategies for future improvements. As time goes by ROMS will be set up as a prediction system using EnKF-C using all available observations to carry out hindcast and forecast studies with the long-term objective of providing an operational system. There are challenges with an increase in model resolution because the system mostly needs observations at the scale of the model to constrain and validate its forecasts and these do not typically exist below the mesoscale (10-100 km). With currently supported and new observations from upcoming international in-situ and satellite missions and from IMOS, the next generation regional ocean systems will take on the challenge of improving on the existing to provide tools that have a

wide range of applications. Some of these include the ability to monitor and forecast the coastal marine environment in higher detail (1-2 km scales) and to provide more realistic SST boundary conditions for regional NWP forecasts. The regional prediction systems will be able to assist with studies of the coastal ocean circulation and marine ecosystems, monitor observation system performance, play a role in search and rescue, guide ship routing and a provide platforms for real-time specialised downscaled applications.

BLUElink Joint CSIRO-BoM-RAN ocean forecasting project	GBR Great Barrier Reef
BRAN Bluelink Reanalysis	IMOS Integrated Marine Observing System
BS Bass Strait	MOM4 Modular Ocean Model
COHERENS Coupled Hydrodynamic and Ecological Regional Model for Shelf Seas	NWP Numerical Weather Prediction
CLAM Coupled Limited Area Model	OceanMAPS Ocean Modelling and Prediction System
EAC East Australian Current	ROMS Regional Ocean Modelling System
EnKF Ensemble Kalman Filter	SHALL2D Shallow water model
EnKF-C data assimilation software by Pavel Sakov	SST Sea Surface Temperature
EnOI Ensemble Optimal Interpolation	TC Tropical Cyclone

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STORM SURGE PREDICTION PROJECT AT THE BUREAU OF METEOROLOGY

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Abstract

The Bureau of Meteorology is developing an enhanced operational storm surge forecast system to replace the three existing (and unique) parametric systems employed by the Bureau's tropical Regional Offices (Queensland, WA and NT) for Tropical Cyclone (TC) events.

The new system will provide probabilistic forecasts of sea level at the coast using atmospheric forcing from an ensemble of wind fields generated from an official TC forecast. The core of the system is a hydrodynamic model based on ROMS. The effects of wave setup, tides and larger scale background oceanography will be linearly superimposed (aggregated) as part of the forecast.

A national system will be implemented in parallel, operating routinely and forced by ACCESS-R to generate a probabilistic forecast of sea level at the coast for all of Australia. This system will target storm surge events that are not explicitly related to TC events.

A ROMS model has been set up and tested. Experiments have been used to determine ideal software options combined with improved data sources, domains and resolutions. Initial testing and validation has been conducted using ACCESS-R atmospheric forcing. TC ensemble forcing fields are currently being tested. The verification of the model has used both comparison with observations and other standard methods. A systematic and automated verification system is being developed. The first operational model completed will have a domain covering the east coast of Queensland and part of New South Wales.

MULTISCALE VERIFICATION OF AN ENSEMBLE TROPICAL CYCLONE FORECAST DURING LANDFALL

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Abstract

Global and regional ensemble forecasts for Tropical Cyclone Rusty (February 2013) have been verified against analyses, with a focus on surface winds and mean sea level pressure. Wavelet decomposition of the associated error fields allows extended comparison of the forecasts on multiple spatial scales. This presentation will describe the wavelet decomposition process, and give selected comparison results in the wavelet domain.

SEASONAL FORECASTING USING POAMA TO SUPPORT AUSTRALIAN FISHERIES AND AQUACULTURE MANAGEMENT IN A CHANGING CLIMATE

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Abstract

Seasonal forecasts from dynamical ocean-atmosphere models of high risk conditions in marine ecosystems can be very useful tools for marine managers, allowing for proactive management responses. The Australian Bureau of Meteorology's seasonal forecast model POAMA currently produces operational real-time forecasts of sea surface temperatures for Australia. These forecasts are used in the management of multi-species long-line fisheries on the east coast of Australia. Southern bluefin tuna (SBT) are a quota-managed species in the eastern Australian longline fishery, and there is a management need to reduce non-quota capture of this species. Ocean forecasts are combined with a statistical habitat model to produce experimental habitat maps for fisheries authorities to use in regulating fishing effort. Similarly, POAMA forecasts around Tasmania, Australia, are utilised by managers of salmon aquaculture farms, with information used to enhance farm production in a variable climate. Warm summers can significantly impact farm production via an increase in operational expenses and impacts on fish condition, mortality and recovery potential, while cool winters slow salmonid growth. Forecast products have also been developed for prawn aquaculture in Queensland, based on air temperature and rainfall predictions for up to four months into the future. Advance warning of suboptimal conditions allows for proactive management responses and helps maintain industry profitability in an uncertain environment. Improved management of marine resources, with the assistance of such forecast tools, is also likely to enhance their resilience and adaptive capacity under climate change.

PLANNING FOR UNCERTAINTY

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Abstract

Australia's coastal councils face an uncertain future as they attempt to deal with the challenge of a changing climate and the risk of more frequent and severe extreme weather. Councils come under considerable pressure from developers and state governments to allow residential developments in areas that are considered to be prime coastal locations. As the responsible authority, however, local government is required to take a risk management approach to these planning decisions in order to make sure that people and their property are not placed at risk from the climate change impacts that scientists warn are inevitable. The tension between these conflicting pressures is often difficult to resolve.

The stakes are high. More than 85% of Australia's population lives within 50kms of the coastline. The coastal zone is home to the nation's state capitals and the majority of industrial assets are located along the coast. Many coastal areas are experiencing unprecedented levels of population growth. There are a lot of people and assets at risk along the nation's coastline and the level of risk is rising year by year.

Coastal councils are at the forefront of efforts to deal with the risk, but they face a significant challenge in undertaking this critical task in the absence of adequate policy settings and resources. The National Sea Change Taskforce focuses its activity and resources on what is achievable within its physical and financial constraints. As a result, the organisation has focused its attention on those elements where it is felt that additional effort or information could be of practical benefit. To date these have been:

- The legal risks associated with planning for climate change
- Population growth and increasing numbers of people at potential risk in coastal areas
- Policy related to natural disaster funding and management.

Finally, the National Sea Change Taskforce is concerned that under existing institutional and governance arrangements there is no provision for an effective decision-making framework which would enable a collaborative national approach to natural disaster funding and management. From the point of view of the Taskforce this is one of the most critical issues in relation to coastal planning and management generally and climate change, and natural disaster resilience, mitigation and recovery, in particular.

COASTAL SEA LEVEL WITHIN AN OPERATIONAL GLOBAL OCEAN FORECAST SYSTEM

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Abstract

This talk provides an overview of efforts to improve 'tidal' sea level forecast guidance via the combination of existing operational system outputs. Particular emphasis is placed on representing observable sea level and extremes associated with nominally non-extreme weather.

Performance statistics related to 'aggregate sea level' forecasts are presented for tide gauges around the full Australian coastline.Extension of the Bureau's operational oceanographic capability in recent years has opened pathways to enhancing conventional tide predictions.

OceanMAPS global forecasts [*Brassington et al.*, 2012] now play an analogous role to global NWP; in providing data assimilative analysis and prognosis of the 3D physical ocean state under a 24/7 operational schedule. Representation of seasonal effects, boundary currents, mesoscale eddies and coastally trapped waves are notable features.

OceanMAPS has proven to offer valuable representations of sea level for large sections of the Australian coast [*Taylor*, 2009; *Taylor et al.*, 2010; *Woodham et al.*, 2013]. Application of OceanMAPS to forecasting observed sea level involves several nuances. OceanMAPS excludes astronomical and barometric pressure forced phenomena as well as wind waves. Tide gauge data are not assimilated.

Resolution limitations are imposed via the relative smoothness of forcing fields applied from global atmospheric ACCESS-G [*Bureau of Meterology*, 2012]. However improvements and extension are expected with upcoming NWP developments into higher spatial resolution and ensemble prediction.

Results presented are based on the 3-hour averaged data products and novel multicycle ensemble schedule that came into production with OceanMAPS v2.2.1 in early 2013 [*Brassington*, 2013]. Imminent operationalisation of OFAM3 [*Oke et al.*, 2013] offers the prospect of expanding this type of intelligence to global low- and mid-latitudes.

'Aggregate sea level' production is currently in transition to operations in order to provide internal guidance to forecasters within the Bureau as a first tier of extreme sea level prediction. This includes connections to new river flood warning systems under the HyFS project.

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SEA SURFACE TEMPERATURE THRESHOLDS FOR TROPICAL CYCLONE FORMATION

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Abstract

Almost 70 years ago a sea surface temperature (SST) threshold of 26—27° C necessary for tropical cyclone (TC) formation was proposed, based on a qualitative assessment of warm-season global SST and known TC formation regions. This threshold was widely accepted without further testing, until a recent study suggested a threshold of 25.5° C. That study is revisited by re-examining the SST for all global TC formations from 1981—2008 using: (i) a broader range of SST threshold values, (ii) an improved method for identifying subtropical storms—any storm that forms poleward of the subtropical jet (STJ), and (iii) a range of TC formation gestation periods, which refers to a time interval prior to formation in which the SST threshold is exceeded at least once. Consequently, thresholds reported in this paper are expressed as a combination of SST and gestation period.

Using the STJ position to identify and exclude subtropical storms, the threshold of 25.5° C SST/48 hour gestation period was found to be robust, but conservative. An examination of TCs of questionable validity (e.g., weak, short-lived and/or storms that formed with baroclinic influences) revealed a further 26 storms that could arguably be excluded from the analysis. With these storms removed several SST/gestation period threshold combinations were found to be valid including: 25.5° C /18 hours and 26.5° C/36 hours. A practical threshold of 26.5° C/24 hours is proposed as only two additional storms failed to meet this threshold, which supports the often-quoted 26.5° C SST necessary condition for TC formation.

STORM SURGE AND COASTAL WAVE MODELING AT NOAA: OPERATIONAL SYSTEMS AND OUTLOOK

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Abstract

Storm surge, including the effects of tides, wind and waves, has been found to be the predominant cause of fatalities during U.S. Atlantic cyclone events. The National Oceanographic and Atmospheric Administration (NOAA) has been developing a multi-facetted strategy to provide timely, accurate and actionable storm surge forecasts to planners, emergency responders and the general public. The cornerstone of these activities is a probabilistic forecasting approach, embodied in the P-Surge system, which is necessitated by the inherent uncertainty in hurricane track and intensity prediction. Since this requires hundreds of model runs within a short space of time, P-Surge currently employs the simple, but computationally efficient surge model SLOSH. For the 2014 hurricane season, this system has included tides and wind forcing, but not the effects of wave setup. Extensive social science studies have informed effective ways of communicating storm surge hazards, leading to the representation of potential flooding as maps of above-ground water levels, with intuitive color coding. High-resolution coastal wave guidance is provided by the Nearshore Wave Prediction System (NWPS), which is based on the third-generation model SWAN and driven by forecaster-developed wind grids and – during hurricane events – P-Surge water level fields. NWPS, in turn, drives empirical models for wave run-up and rip currents, further defining coastal hazards. Future improvements include the introduction of a computationally efficient 1st or 2nd generation wave model into SLOSH to provide probabilistic wave setup estimates, while staying within the constraints of the P-Surge framework. However, anticipating future enhancements in computational resources, the state-of-the-art community surge model ADCIRC is being introduced as a limited ensemble. Concurrently, NOAA's Global WAVEWATCH III model is being extended with unstructured coastal meshes, enabling two-way coupling with ADCIRC, to provide the next generation of high-definition, coupled coastal surge and wave modeling.

RESEARCH AND DEVELOPMENT IN COASTAL WAVES AND STORM SURGE

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Abstract

Various wave and nearshore research efforts are currently underway at NOAA in collaboration with its federal and academic partners. Of particular interest is wave and surge forecasting in reef-fringed island environments such as Hawaii and Puerto Rico. Because of their unique nature, NOAA currently lacks an operational inundation prediction system in these regions. As a result, U.S. IOOS is funding an inter-comparison of the coupled wave-surge models ADCIRC+SWAN, ADCIRC-WAVEWATCH III, SLOSH-SWAN and Delft3D-SWAN for the Puerto Rico and U.S Virgin Island region, to identify candidates for operational implementation. The performance of these models are being compared for Hurricane Georges (1998), Hurricane Isaac (2012) and Superstorm Sandy (2012), as well as two nearshore field campaigns. Results of the first project year are discussed. Secondly, NOAA's SWAN-based Nearshore Wave Prediction System (NWPS) is being extended to include coupling with the surge model ADCIRC. This system is run on the downscaled domains of NOAA's coastal forecast offices, where simulations are driven by wave and water level boundary conditions from larger-scale models, and local, forecaster-developed wind grids. The application of this system to the recent hurricanes Iselle and Julio over the Hawaiian Islands forecast domain are presented. Thirdly, the algorithms for wave partitioning and wave system tracking included in WAVEWATCH III and NWPS are increasingly being applied in marine forecasting. These are currently being adapted for use with unstructured meshes, to support the latter's use in nearshore domains. Finally, nearshore output from NWPS is being used to drive empirical rip current and wave run-up models, which represent a significant hazard along the U.S. coast. The comparison of these model outputs with field observations at a number of pilot sites along the U.S. East and Gulf Coasts are discussed.

TROPICAL CYCLONES AND THE CLIMATE OF THE SOUTH PACIFIC

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Abstract

Simulations of the effect of anthropogenic warming overwhelmingly predict decreases in total numbers of tropical cyclones in the Southern Hemisphere. While such simulations also project a decrease in numbers in the Northern Hemisphere, these decreases are usually not as large. Future substantial decreases are also projected in the South Pacific region, as shown by a number of recent simulations. New results from high-resolution climate model results are presented that also show the same behaviour. The reasons for the stronger response in tropical cyclone numbers in the Southern Hemisphere are investigated. The results of idealized model simulations show that there appears to be a good relationship between changes in tropical cyclone number and changes in climatological mid-tropospheric vertical velocity. Future decreases in vertical velocity are larger in the Southern Hemisphere than they are in the Northern Hemisphere, and it is speculated that this is due to the consensus pattern of projected future sea surface temperature change. This suggests a fundamental difference between the hemispheres in the response to anthropogenic warming as it relates to tropical cyclones.

SIMULATIONS OF TROPICAL CYCLONES WITH ACCESS-G N512 AND HIGH RESOLUTION ACCESS-TC

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Abstract

Three tropical cyclones in different synoptic backgrounds have been simulated with ACCESS-G N512 and high resolution limited area ACCESS-TC model. The ACCESS-TC is nested in the ACCESS-G N512. The ACCESS-G N512 can provide good TC track simulations. However, the intensity is not as strong as real observations due to its coarser resolution. As the output from the ACCESS-G N512 is used as initial condition and lateral boundary condition for high resolution ACCESS-TC, the simulations of TC intensity and structure are much more improved. The experiments with 2.5-km and 4-km horizontal model resolutions show that 4-km resolution ACCESS-TC is good enough to simulate TC intensity.

A DESIGN VARIABLE METHOD FOR ESTIMATING FLOOD RISK IN AUSTRALIAN COASTAL CATCHMENTS

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Abstract

Flooding in coastal catchments can be caused by runoff generated by an extreme rainfall event, elevated ocean levels, or a combination of both processes occurring simultaneously or in close succession. Statistical dependence between extreme rainfall and storm tide is expected as both variables are often driven by common meteorological forcings, such as low pressure systems that are associated with heavy rainfall and strong on-shore winds. The presentation will describe the nature and extent to which extreme rainfall and storm surge co-occur along the Australian coastline, based on a detailed analysis of 64 tide gauges, 7684 daily rainfall gauges and 70 sub-daily rainfall gauges. A “design variable” method was then developed to estimate flood risk in coastal catchments in a manner that accounts for dependence between extreme rainfall and storm surge, and practical challenges with applying the method – including timing effects and computational requirements – are described. The method will be demonstrated using a case study catchment in Perth, Western Australia.

PREDICTABILITY AND DATA ASSIMILATION OF TROPICAL CYCLONES

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Abstract

Despite rapid advances in numerical weather prediction (NWP) models and ever increasing computational capability, our ability to accurately predict various severe weather phenomena in including tropical cyclones in the short range and at the mesoscales remains limited. This talk will present an overview of recent progress in our understanding of the predictability of tropical cyclones using both real-data studies and idealized simulations. Although the predictability of tropical cyclones across different temporal and spatial scales may be inherently limited, there is still significant room for improving the practical predictability of tropical cyclones through advanced data assimilation techniques, better use of existing or future observations, and improved forecast models. Inter-comparison and coupling of various variational and ensemble based techniques for both severe weather and tropical cyclones will also be presented.

DYNAMICAL DOWNSCALING OF CLIMATE CHANGES WITH A HIGH-RESOLUTION OGCM

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Abstract

Global climate models provide useful information about large-scale climate changes globally. Nonetheless, global climate models usually have coarse resolution, mostly due to computational resource constraint. Consequently, meso-scale ocean features are nearly missing in climate models, however they can be critical for studies like boundary currents, eddies, near-shore processes and biogeochemical processes. Dynamical downscaling provides a feasible alternative to explore detailed regional features.

In this CSIRO strategic project, we are working on a framework to downscale future climate change signals simulated by CMIP5 models with a high-resolution (0.1x0.1°) eddy-resolving ocean general circulation model - OFAM3. The study period is from 1979 to 2100. During the historical period from 1979 to 2013, the OFAM3 is driven by atmospheric forcing from reanalysis product. During the future period from current to 2100, atmospheric changes simulated by CMIP5 models are added to drive the OFAM3. The ocean state changes relative to historical period are treated as the downscaled ocean changes.

The possible application of products from this CSIRO strategic project on coastal regions will also be discussed.

The Centre for Australian Weather and Climate Research is a partnership between CSIRO and the Bureau of Meteorology.