# NATIONAL NONTIDAL SEA LEVEL FORECASTS ON A COASTAL WAVEGUIDE

Andy Taylor, Marine and Antarctic, Bureau of Meteorology, Andy.Taylor@bom.gov.au
Diana Greenslade, Research, Bureau of Meteorology, Diana.Greenslade@bom.gov.au
Xiaobing Zhou, Research, Bureau of Meteorology, Xiaobing.Zhou@bom.gov.au
Gary Brassington, Research, Bureau of Meteorology, Gary.Brassington@bom.gov.au

## INTRODUCTION

Many coastal activities are organised around expectations of still water levels over lead times of days to weeks. Conventional tide tables remain a fundamental reference for coastal decision makers across these lead times, but tide predictions may be usefully enhanced with forecast `residuals' (Horsburgh and De Vries 2011); to the extent that the forecasts are skillful and reliably available. Whilst academic and industrial simulations drive towards higher fidelity simulations of coastal processes, prognostic modeling within an 'operational' forecasting agency trails on resolution but places much emphasis on generality and day–to-day reliability.

## 'SEAMLESS' STRATEGY

The Australian Bureau of Meteorology is strategically working towards more "seamless" weather services that integrate forecasts across timescales; and seamless sea level fits within that scope. The Bureau's operational suite of systems already includes ocean models that in principle carry sea level information across a wide range of timescales. The extent to which these systems can already provide useful guidance about coastal sea level is a relevant baseline question to ask in the consideration of future model development choices.

## EXISTING FORECAST SYSTEMS

The Bureau's existing operational ocean forecast systems target different time and space scales. None of the current systems include tides. Three of these operational systems forecast sea level quantities that can in principle provide information about expected tidal residuals along the entire Australian coast. For this study the systems addressed are: [A] barotropic deterministic surge, 0-3 days. (Allen eta al 2018) [B] baroclinic data assimilating ocean circulation, 0-7 days (Schiller et al 2019) and [C] coupled seasonal ensemble,0-42 or 0-217 days (Hudson et al 2017).

It should be emphasized that the design and configuration of these systems are quite dissimilar; with very different spatial representations, coverage of physical phenomena and model initialisation approaches. None are configured to simulate tides and only the surge model has atmospheric pressure surface forcing applied in operations. For this study, a variant of the operational surge model [A] was created that excluded pressure forcing in order to render the anomaly signals more comparable with systems [B] and [C]. This investigation takes an end-user view of the forecast data wherein the underlying simulation methods are effectively treated as proverbial black-boxes. As this is one of the first investigations into the *coastal* sea level signal of the seasonal model, we start with the raw model run output as opposed to the statistically processed products already in use for atmospheric fields

## WAVEGUIDE SPATIAL PERSPECTIVE

In Australia, remotely forced sea level signals have special relevance. The oceanographic literature addressing coastally trapped waves is extensive and regularly refers to the Australian mainland. For this limited study we ignore the Tasmanian coast and smaller islands; though acknowledge that the dynamics of Bass Strait are of special significance (Wijeratne 2012).

Operational experience has highlighted the role of free and forced coastally-propagating signals for certain impacts on coastal infrastructure and flooding. However, the typical forecast narrative around coastal impacts stubbornly remains skewed towards a focus on localized weather events.

A motivation to bring the academic and operational perspectives together lead to the 'waveguide' sampling technique employed for this study.

In order to reduce the dimensionality of the model outputs and focus on the representation of coastal propagation, each forecast type is projected onto a realization of a mainland waveguide path. Figure 1 illustrates such a path. These particular coordinates aim to represent a single physically relevant path (clockwise) around the mainland and address the length scale issues associated with the so-called "coastline paradox". We do not claim that this path is in anyway optimal or unique, but the projection does facilitate novel inter-model comparisons. Processed tide gauge observations are also projected onto the same path in order to evaluate forecast skill in a spatially ordered manner.

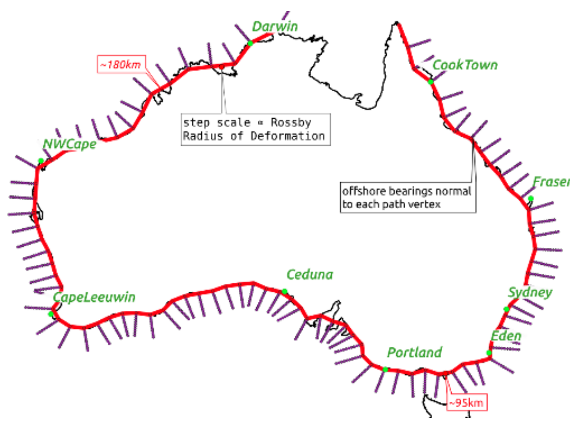


*Figure 1 The realization of a coastal waveguide path onto which the forecast datasets were projected. Length scales proportional to a Rossby radius of deformation. Associated 'offshore' directions are also shown*

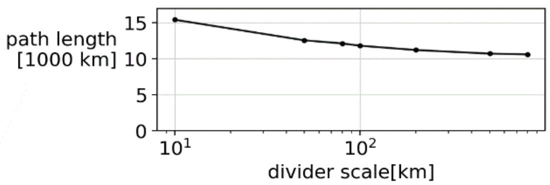


*Figure 2 Effect of smoothing length-scale on the waveguide path length around the Australian mainland, corresponding to an effective fractal dimension of ~1.08.*

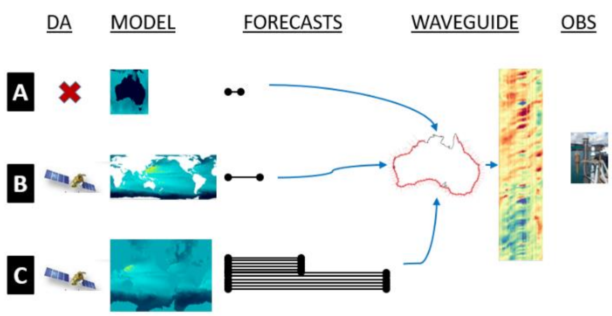


*Figure 3 Schematic projection of three very different forecast systems onto common waveguide coordinates and comparison against tide gauge observations. 'DA' indicates role for data assimilation. Black lines indicate forecast lead-time.*

## REPRESENTATION LIMITS AND SKILL

None of these forecast systems were designed to represent the full range of phenomena and scales that contribute to observed sea level. Characterising the respective strengths and limits of the different configurations for this specific quantity can inform service design and system planning. The waveguide projection allows for two aspects of these sea level forecasts are addressed: (1) skill versus lead-time at spatially ordered tide gauge locations; and (2) presence and representation of coastally propagating signals. Figure 5 illustrates how projection of heterogenous forecast data onto the common spatial path allows direct differencing and quantification of apparent propagation speeds.

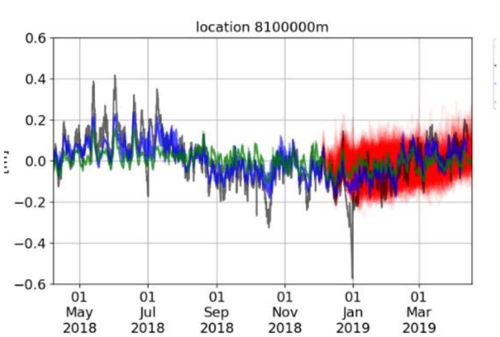


*Figure 4 Example of concatenated forecasts sampled at the same location near Sydney on the Australian east coast. Green = surge [A], Blue = ocean[B], Red = subset of seasonal [C]. Black = processed non-tidal observations*

## FUTURE WORK

The Bureau's model development trajectory is towards coupled system configurations that will need to draw trade-offs between the demands of observations, resolution, duration and ensemble size. Understanding the limits of what reliable "seamless" information can (and cant) be extracted from the operational suite will be required to inform the co-design of services with coastal decision makers.

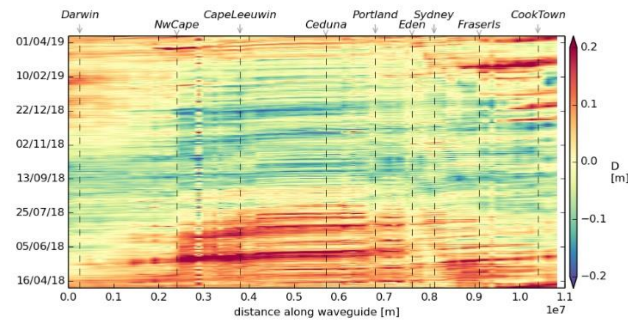


*Figure 5 Sea level anomaly **difference** between systems A and B, one year of concatenated 0-24 hour forecasts. Seasonal and synoptic scale differences indicate anti-cyclonic propagation patterns*

## REFERENCES

Australian Bureau of Meteorology (2020): Research and Development Plan 2020-2030 http://www.bom.gov.au/inside/Research_and_Development_Plan_2020-2030.pdf

Horsburgh and De Vries (2011): Guide to Storm Surge Forecasting. Technical Report, World Meteorological Organisation, No. 403 1076.

Allen, Greenslade, Colberg, Freeman, and Schulz (2018) A first-generation national storm surge forecast system Bureau Research Report No. 028

Schiller et al (2019): Bluelink Ocean Forecasting Australia: 15 years of operational ocean service delivery with societal, economic and environmental benefits. *J. Operational Oceanography*, 13(1),1-18, doi:10.1080/1755876x.2019.1685834

Hudson et al. (2017) ACCESS-S1: The new Bureau of Meteorology multi-week to seasonal prediction system. *J. Southern Hemisphere Earth System Scienc*e, 673, 132-159, doi:10.22499/3.6703.001.

Taylor, Andy J. and Brassington, Gary B (2020). Sea Level Anomaly Forecasts on a Coastal Waveguide. *Weather and Forecasting* 35 (2): 757-770. doi:10.1175/waf-d-18-0198.1.

Wijeratne, E M S et al. (2012) Tidal characteristics in Bass Strait, south-east Australia. *Estuarine, Coastal and Shelf Science* 114: 156-165. doi:10.1016/j.ecss.2012.08.027.