40-years of coastline monitoring at Narrabeen: the value of observations to beach process modelling

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June 2016: a regional perspective (current ARC Discovery project)

- Airborne Lidar operated by UNSW School of Aviation
- Equipped with Riegl LMS240i Laser Scanner
- Flown pre- and post-storm for regional-scale storm impact assessment along 400 km of coastline
Shifting sands...

11.6 million m$^3$ of sand stripped from 180 km of subaerial beach due to storm

(estimated 65 million m$^3$ of sand for entire NSW coast)

97% of survey region observed to erode

Maximum observed storm demand: 228 m$^3$/m (North Narrabeen)
Narrabeen-Collaroy: commenced April 1976 - one of just a handful of multi-decadal Coastline Observatory sites internationally:

- **Video monitoring (Argus)**: 2004 – present (hourly)
- **RTK-GPS + Quad bike**: 2005 – present (monthly)
- **Fixed Lidar**: 2014 – present (5 Hz)
- **Airborne Lidar**: 2011 – present (pre/post storm)
- **Unmanned Aerial Vehicle**: 2014 – present (pre/post storm)
Examples of research that has been underpinned by the Narrabeen dataset:

150+ peer-reviewed journal & conferences publications resulting from the Narrabeen dataset to-date:

- beach state model (Wright and Short, 1984)
- beach rotation (Ranasinghe et al., 2004; Harley et al., 2011; 2015)
- probabilistic coastal erosion risk assessment (Callaghan et al., 2009, 2010)
- equilibrium shoreline models (Davidson et al., 2013; Splinter et al., 2014)
- Pacific Basin climate forcing (Barnard et al., 2015)
- ‘Regional-representativeness’ (Bracs et al., 2016)
Marking the 40 year milestone (April 2016):

‘Data Descriptor’ paper: Published to coincide with 40th anniversary in April 2016

Scientific Data
Nature Publishing
http://www.nature.com/sdata/
Marking the 40 year milestone (April 2016):

New public access data portal

*Filling a need:*
- 10’s thousands of page-views
- 100’s of downloads of full dataset
Outline – the value of sustained coastline observations:

- Underpin advances in numerical modelling
  - daily to decadal prediction/forecasting
  - how much data is enough?
  - optimum calibration of storm erosion models (Josh Simmons Poster)
  - new insights to beach recovery

- Explore the concept of ‘regionally representative’ coastline observatories

- Lessons learnt – a template for sustained & nationally coordinated coastline observation
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daily/weekly shorelines have been used extensively for model development. The rate of coastline change (calculated hourly) includes a response rate X disequilibrium X available power.
blind tests with unseen data:

Torrey Pines (California)

Perrenporth (UK)
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How long do I need to sample for?

How rapidly do I need to sample?

modelling approaches:
- Process-based
- Empirical
- Behavioural
- Bayesian
- Neural network
- …..
Do different types of beaches have different sampling requirements for modelling?
Analysis of shoreline model coefficient variability as a function of $dt$ and $N$

$$\frac{dx}{dt} = b - c \pm P(t)^{0.5} (\Omega_{eq}(t) - \Omega(t))$$
data sampling requirements → optimise

Storm-dominant
Initial Calibration

Unknown beach type:

Short-term hindcasting
(dt ≤ 30 days, N ≥ 2 years)

Long-term hindcasting
(dt ≤ 30 days, N ≥ 50%)

Modelling Application

Guidelines

Storm-dominated
Initial Calibration

Unknown beach type:

Short-term hindcasting
(dt ≤ 30 days, N ≥ 2 years)

Long-term hindcasting
(dt ≤ 30 days, N ≥ 50%)

How much data is enough? The importance of morphological sampling interval and duration for calibration of empirical shoreline models

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A R T I C L E   I N F O

Article history:
Received 13 October 2012
Revised 1st March 2013
Accepted 3 February 2013
Available online 16 March 2013

Keywords:
Euphonic shoreline models
Model calibration
Hindcasting programs
Effect on shoreline change

1. Introduction

Future uncertainty surrounding changing wave climates and sea-level rise requires that coastal scientists and engineers understand and be prepared how this will impact future shoreline positions. Knowledge of individual short-scale responses and recovery, seasonal variability, and annual to decadal-scale trends is required to assess the vulnerability of sandy coastlines to these drivers. Long-term observational data sets are typically limited in both time (temporal and spatial resolution, ranging from daily single point measurements of sand thickness (Barnard et al., 2012) or a single cross-shore beach profile (Kurowski, 2002). Cross-shore to monthly cross-shore profiles over a short spatial range (Birkemeier et al., 1999; Harley et al., 2011; Short and Tremblay, 2001), to annual profiles extending over a large stretch of coastline (Wijffels and Terwindt, 1995). These observational programs, along with many other short-term programs have been used to identify everything from beach response to tides (Elsom and Clarke, 1988) and individual storms, to seasonal scale (e.g. Audrey, 1978; Hansen and Barnard, 2010; Inman, 1953; Shepard, 1955) as well as annual change (Clarke and Elgar, 1983) and decadal scale (Short and Tremblay, 2004) variability and change.

A R T I C L E   A B S T R A C T

The ability to reliably predict future shoreline position under the influence of changing waves and sea-level rise is a key challenge to scientists and engineers alike. While extrapolating a linear trend out into is a common baseline approach, the recent development of a number of empirical shoreline models allows the prediction of storm and annual-scale variability as well. The largest constraint in applying these models is the availability of high-quality, adequate observation sets in order to calibrate model parameters. This contribution outlines the requirements for short-term and long-term monitoring programs, from 1 to 10 years in storm-dominant beach types, and storm-dominated site and the second exhibiting a large seasonal variability. The research examines the monitoring requirements for both, while the storm-dominated site concentrated on shorter, more frequently sampled data sets. In general, calibration based on a single year of observed shorelines resulted in a large range of model skill and was not considered robust. Monitoring programs of at least two years, with shorelines sampled at ≤ 30 days were sufficient to determine initial values of wave directions and establish short-term (< 5 years) shoreline variability. In the presence of unbalanced model processes andunker, hindcasting 5–10 years) data sets required longer (5–10 years) calibration data sets, particularly when sampling intervals exceeded 60 days.

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Storm erosion modelling – key questions

• Which storm erosion modelling approach (e.g. process-based vs empirical) is the most reliable for a given application?

• What are the performance gains achieved by providing additional calibration data?

• To what degree are the optimum parameters for one site transferrable to adjacent locations?

→ see ACOMO 2016 poster – Josh Simmons
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Fixed Lidar

High-frequency (5 Hz, day and night) measurements of a single profile, swash and inner surfzone
Present focus is on post-storm recovery (observations and modelling)

Lidar Low Tide Profile Data

Recovery
Erosion
Negatively skewed tail – storms
Modal gradual recovery
Recovery can be very rapid
Up to 6.4 m/day!
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Main conclusion for all 9 sites:
- Highly correlated behaviour, indicating (fortuitously…) that the Narrabeen monitoring program is representative of regional sandy coastline variability and trends along 100’s km of coastline, and that this is anticipated to be a repeatable conclusion nationally

Important implications for future nationally-coordinated Coastline Observatory network
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Observatory implementation: - where?

The Coastal Sediment Compartment project aims to improve coastal risk assessments undertaken at national and regional levels, and better integrate approaches to the management of the coastal zone. Climate change including sea level rise exposes Australia’s highly populated coasts to current and increasing risks of tidal inundation, estuary flooding and shoreline erosion. In addition to the loss of coastal land, there will be increasing risks associated with storm surge and changes in wave climate. Storm surge is responsible for damage experienced during large coastal storms, and can destroy buildings, wash away roads and rip boats aground. Changes in the direction of wave approach coupled with changes in wave energy could increase erosion in areas that are present less frequently affected. We need to plan for these risks if we are to protect coastal homes, infrastructure, and businesses from negative economic, social and environmental impacts.

Australia’s shorelines historically have been stable compared to other parts of the world. Under a worst-case scenario, global sea levels may rise by up to 1m by the end of this century (compared to 1986-2003), so a consequence step is to be taken by all spheres of government, the private sector and communities to embrace the likelihood that climate change will impose different circumstances for land-use planning and coast and estuary management. In order to prepare effectively, coastal decision-makers need information on the risks to different regions of the Australian coast, as well as a coordinated approach between tiers of government with coastal management and planning responsibilities. The compartment approach provides a framework for improved coastal management and planning. It identifies boundaries within which to consider the implications of coastal engineering works and other management and planning decisions to reduce the long-term risks to the Australian coast while protecting those coastal values that are so vital to Australian communities. The Coastal Sediment Compartment project had two components:

(i) Identification of coastal sediment compartments at a national scale that reflect variation in coastal environments relevant to coastal management; and

(ii) Demonstrating the improved accuracy in shoreline erosion risk assessments achievable by using coastal compartments in two case study projects on the east and west coasts.

COASTAL BASICS
Geomorphology: the science of evolution and change of landforms
Coastal compartment: defined area of the coast based on sediment flows and landforms
Wave climate: the average condition of wave height, direction and period over time

IDENTIFYING COASTAL COMPARTMENTS
The first component identified compartment boundaries along the entire Australian coast at a number of scales. A compartment defines an area of coast based on sediment flows, at a primary level based on the influence of large landforms and offshore processes; at a secondary level on medium
....thanks

www.narrabeen.wrl.unsw.edu.au