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National-scale wave energy resource assessment for Australia

Michael G. Hughes*, Andrew D. Heap

Geoscience Australia, Marine and Coastal Environment Group, GPO Box 378, Canberra, ACT 2601, Australia

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ABSTRACT

A nationally consistent wave resource assessment is presented for Australian shelf (<300 m) waters. Wave energy and power were derived from significant wave height and period, and wave direction hindcast using the AusWAM model for the period 1 March 1997 to 29 February 2008 inclusive. The spatial distribution of wave energy and power is available on a 0.1° grid covering 110–156° longitude and 7–46° latitude. Total instantaneous wave energy on the entire Australian shelf is on average 3.47 PJ. Wave power is greatest on the 3000 km-long southern Australian shelf (Tasmania/Victoria, southern Western Australia and South Australia), where it widely attains a time-average value of 25–35 kW m^{-1} (90th percentile of 60–78 kW m^{-1}), delivering 800–1100 GJ m^{-1} of energy in an average year. New South Wales and southern Queensland shelves, with moderate levels of wave power (time-average: 10–20 kW m^{-1}; 90th percentile: 20–30 kW m^{-1}), are also potential sites for electricity generation due to them having a similar reliability in resource delivery to the southern margin. Time-average wave power for most of the northern Australian shelf is <10 kW m^{-1}. Seasonal variations in wave power are consistent with regional weather patterns, which are characterised by winter SE trade winds/summer monsoon in the north and winter temperate storms/summer sea breezes in the south. The nationally consistent wave resource assessment for Australian shelf waters can be used to inform policy development and site-selection decisions by industry.

1. Introduction

Wave energy is a largely untapped renewable energy resource, with the advantage of having the highest energy density among all the renewable energies [1]. There are currently more than 20 wave energy projects around the world, but in almost all cases they are still in the pilot stage serving as research and development or proof of concept [2]. Few are contributing electricity to local grids and none are contributing significantly to national electricity production. Nevertheless, there is a continuing trend of rapid technological development in wave energy converters (WECs) and recent growth in both community and government support for wave energy projects in many countries [1,2]. Several wave energy resource assessments have been published in preparation for the possible significant contribution by wave energy to national electricity production in some countries (e.g. [3–7]).

Wave energy resource assessments fall into two categories. The first considers the bulk potential resource and focuses only on measurements or hindcasts of the wave climate (e.g. [7]). The second takes into consideration concentration of the bulk resource due to localised bathymetric features or coastal configurations, the efficiency and technical constraints of WECs, as well as other onshore infrastructure and market constraints (e.g. [5,6,8]). The first category is a first cut at the problem and the second provides more detailed information, but with considerably more assumptions and complexity involved in the analysis. It is feasible to undertake the first type of resource assessment at a national scale, whereas the second type of assessment is necessarily at a regional or site-specific scale. Given the costs involved in obtaining detailed information, it makes sense to conduct a national assessment of the potential resource prior to targeting sites for more detailed study.

Most national (and regional) wave energy resource assessments reported to date are from the northern hemisphere. This paper presents a nationally consistent wave resource assessment for Australia's shelf waters, located in the southern hemisphere. Other unique features of Australia's wave energy resource are that it spans over 42° of longitude and 35° of latitude. It is therefore influenced by weather systems in four climatic zones; equatorial, tropic, sub-tropic and temperate. Significantly, the 3000 km-long southern Australian margin fronts the Southern Ocean, where the strong global westerly wind belt blows over an effectively infinite fetch to generate some of the most energetic waves in the world, and high energy conditions are maintained year-round.

Previous studies of the wave climate in Australian waters have been regional in focus. For example, Short and Trenaman [9]

* Corresponding author. Present address: Australian Hydrographic Service, R.A.N. Locked Bag 8801, Wollongong, NSW 2500, Australia. Tel.: +61 2 4223 6626.
E-mail address: michaelh@usyd.edu.au (M.G. Hughes).

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investigated the wave climate off Sydney, on the eastern Australian margin, using 20 years of waverider buoy data (Fig. 1). They reported the annual mean wave power to be 26.7 kW m^{-1}. The smallest monthly average wave power occurred in summer (December–February) associated with local sea breezes (19.1 kW m^{-1}), and the largest in early autumn (March–May; 33.4 kW m^{-1}) and in winter (June–August; 37.4 kW m^{-1}) associated with tropical cyclones located off the southern Queensland coast and east-coast lows located in the Tasman Sea, respectively. Significantly, on this steep shelf 96.6% of the deep water wave power reaches the coastline [10]. Off Perth on the western Australian margin (Fig. 1), Lemm et al. [11] reported the annual mean wave power to be 48 kW m^{-1}; based on 2.5 years of waverider buoy data. The smallest monthly average wave power occurred in summer associated with local sea breezes (25 kW m^{-1}), and the largest in winter (92 kW m^{-1}) associated with extra-tropical storms generated in the Indian and Southern Oceans. Hemer et al. [12] described the wave climate across the entire southern Australian margin (over 3000 km; Fig. 1) using waverider buoy data varying in coverage from 6 to 20 years and WAVEWATCH III model data covering a period of 10 years. The southern margin typically experienced annual average wave power of 35–65 kW m^{-1} depending on location. The smallest monthly average wave power occurred in summer (20–45 kW m^{-1}) and the largest in winter (60–85 kW m^{-1}). The nature of the wave climate is dominated by temperate storms that track from west to east along the southern Australian margin, thus there is a strong (lagged) coherence between locations [12].

Previous regional studies of the Australian wave climate have focussed on the most energetic southwestern, southern and south-eastern margins of the continent. The information from these studies, however, is of limited value for a comprehensive assessment of the wave energy resource potential for all Australia. A first cut at assessing the potential resource would ideally (1) have national coverage; (2) have consistent temporal coverage that is of sufficient length to include important climatic cycles; and (3) be based on a consistent data type. With respect to the latter, direct measurements of wave conditions (e.g. waverider buoys) is preferred. In the case of Australia there are unfortunately large data gaps both in terms of record length and location (Fig. 1). The alternatives are satellite observations or model predictions for wave conditions, which can provide the consistent temporal coverage and full spatial coverage required. The resource assessment reported here is based on predictions from a third generation ocean wave model hindcast from a high resolution atmospheric model.

A brief description of the WAM ocean wave model used to predict wave conditions around Australia is presented in Section 2, together with some details of linear wave theory used to calculate wave energy and power. Maps representing the spatial distribution of wave power, with full coverage of Australia's shelf, are presented in Section 3. The annual resource delivered in an average year is also estimated nationally and for each state. Finally, additional information relevant to operational processes that can be obtained from wave time series, whether they be measured or modelled, is briefly highlighted. Section 4 places Australia's wave energy resource in a global context. This section also addresses how the results of a national-scale resource assessment can be usefully disseminated to government and industry to inform more detailed regional and site assessments. Conclusions follow in Section 5.

2. Data and methods

The data used to undertake this resource assessment are wave conditions hindcast from the WAM model – a third generation ocean wave prediction model [13]. Implementation of the WAM model for

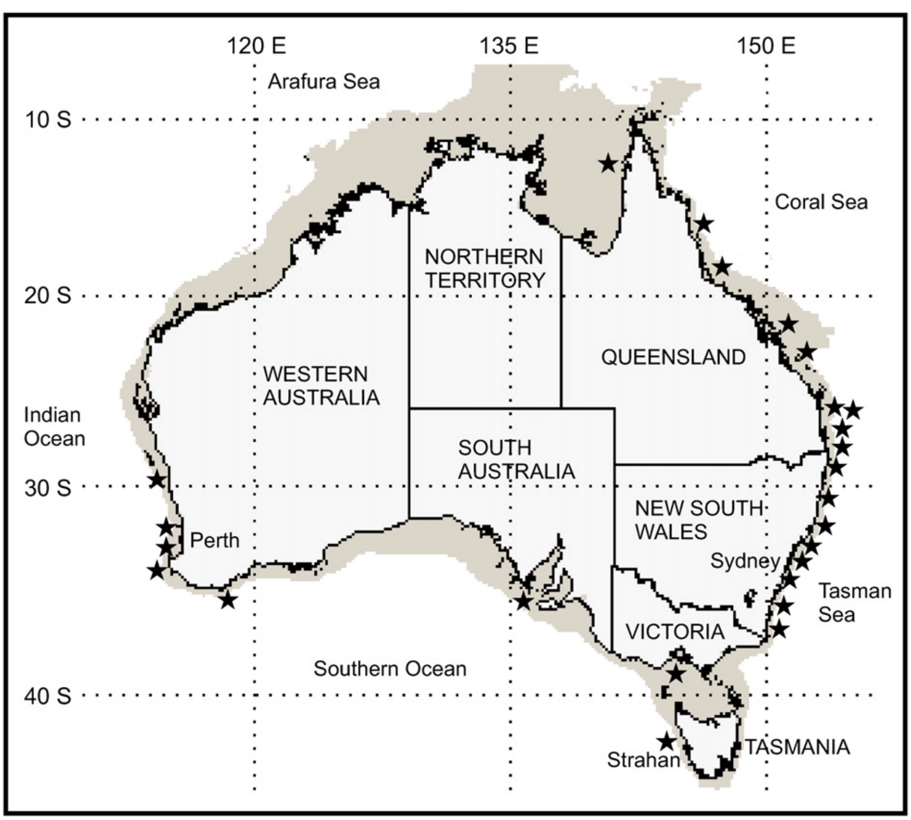

Fig. 1. Map of Australia showing state and territory names and boundaries, locations referred to in the text, approximate locations of ongoing waverider buoys (black stars) and extent of the model data grid analysed in this study (grey shading).