Near-shore wave condition forecasts for the Southeast Queensland region

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INTRODUCTION

The Southeast Queensland region (Figure 1) is wave dominated and its wave climate is subject to important variances. Low pressure systems from the south generate moderate to high energy S to SE swells during the winter, with average deep-water significant wave heights ranging from 0.8 to 1.4 m and mean periods of 7 - 9 seconds. This wave climate combined with the narrow continental shelf and the subsequent refraction often leads to an oblique wave approach angle near-shore.
Thus, it results a net northward littoral drift of approximately 500,000 m^3 /yr (DHL 1970). However, during the summer period, cyclones may generate N to NE swells with deep-water wave heights up to 14 m and wave periods up to 18 seconds (EPA 2004).

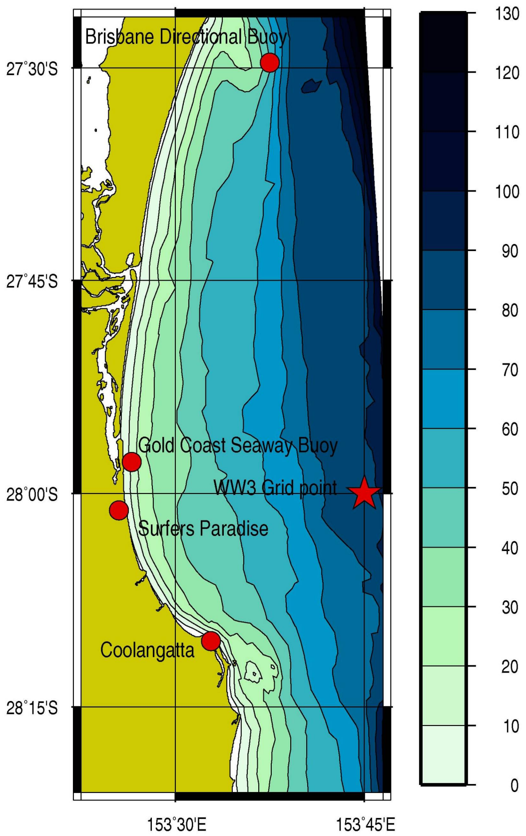

Figure 1: South Queensland model bathymetry and location map (depth in meters)

The complex bathymetry of the area combined with the presence of trained river entrances and rocky headlands along the coastline engender strong spatial variations of wave transformation near-shore and residual sediment transport. Forecasting these wave transformations from deep-water to the breaking zone may be an interesting issue for coastal management planning, coastal process research, beach user's security and recreation use (surfing). The aim of this paper is to present the development of an automatic system providing 7 day forecasts of the near-shore wave climate in the Southeast Queensland region. The bathymetry is interpolated from survey data from Gold coast city council and hydro-graphic charts. Wave transformation is simulated using the SWAN near-shore wave model. NOAA WAVEWATCH 3 global wave model forecast data (Figure 2) is used as boundary data for the SWAN model.

BACKGROUND

NOAA WAVEWATCH 3 global wave model

WAVEWATCH 3 (Tolman 2002) is a third generation wave model developed at NOAA/NCEP, and differs from its predecessors WAVEWATCH 1 and WAVEWATCH 2 in the governing equations, model structure, numerical methods and physical parameterizations. According to the user's manual, the model solves the spectral action density balance equation for wave number-direction spectra. The implicit assumption of this equation is that the properties of the medium (water depth and current) as well as the wave field itself vary on time and space scales that are much larger than the variation scales of a single wave.

This global wave model has a grid resolution of 1 x 1.5 degrees, which is enough for a large scale model but not for a precise one. Moreover, wave transformations induced by bottom friction are not well modelled.

This is why we need to use it in combination with the SWAN model at the closest WAVEWATCH 3 simulation point, located 31.5 km East of Surfers Paradise at 28^{o} S, 153^{o} 75E (Figure1). The data is automatically updated every 3 hours and Coastalwatch provides a 6 hour sampling output from it (Figure 2).

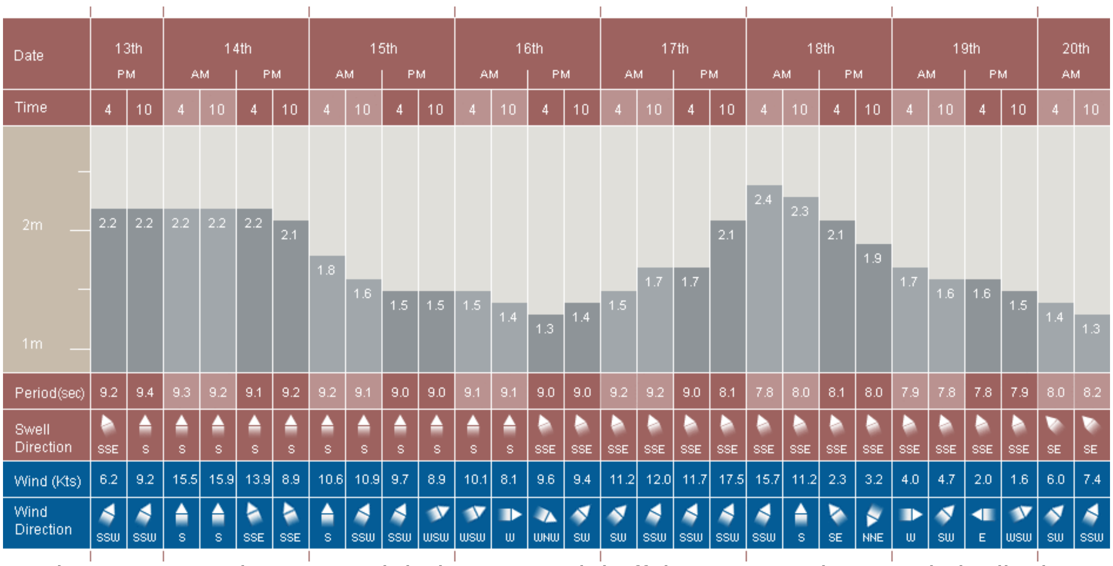

Figure 2: Sample WW III global wave model offshore wave characteristic display from Coastalwatch website

Simulating Waves Near-shore (SWAN) model

The SWAN wave model (Holthuijsen *et* al. 1993, Ris *et* al. 1998, Booij *et* al. 1999) is a third generation wave model for deep, intermediate and depth-limited waters. It resolves the action balance equation with a full discrete 2-dimensionnal wave spectrum and an iterative technique is applied to allow wave propagation in all directions over the domain. The model accounts for propagation due to current and depth and represents the processes of wave generation by wind, dissipation due to white-capping, bottom friction and depth induced wave breaking and non-linear wave-wave interactions (both quadruplets and triads) explicitly with state-of-the-art formulations. Wave blocking by currents is also explicitly represented in the model (DHL 2000). The accuracy of the model allows using grids with a refinement of 20 x 20 m.

METHODS

Automatically updating system setup

The aim of the system is to use a unique program which will automatically update plots of the area 6 hourly, showing the near-shore wave conditions evolution for a 7 days forecast. This program has been written in several steps. The first part concerns the extraction of the required WAVEWATCH 3 data from NOAA at 6 hourly intervals on Coastalwatch servers (Figure 3).

Then the system performs SWAN modelling using those data for the boundary. SWAN will create an output file with grid cells coordinates as *x* and *y* columns, and waves characteristics as *z,…n* columns. The following step is to separate this output into files containing grid co-ordinates and wave parameters. Then, the last one is to create output plots overlaying those data. This means an animation of 42 maps automatically updating every 6 hours, corresponding to the WAVEWATCH 3 simulation outputs.

SWAN model setup

The default JONSWAP spectral shape was applied and the wave breaking and bottom friction parameters were calibrated according to the data obtained from the wave recording buoys located at Gold Coast seaway and Point Lookout (STRAUSS *et* al. 2007).

The computational grid consists of a curvilinear grid with coarse spacing offshore which becomes more refined shorewards, especially around headlands, river entrances and major surf spots. The bathymetry is interpolated on the computational grid using data derived from recent survey profiles supplied by Gold Coast City Council and hydro-graphic charts.

Significant wave height, direction and period data from WAVEWATCH 3 global wave model simulation point at 28^{o} S, 153^{o} 75 E is used to force the North, East, and South boundaries. The coast forms the West boundary, no wave can enter the model domain through this boundary and the incoming waves are fully absorbed.

RESULTS

Examples of model results

The effective result of this system is the possibility to access the updating output data plots online on coastalwatch.com, and thus to provide a reliable and routine forecasting system. The SWAN model performance has been validated many times in the literature, through different laboratory and complex field experiments. However, In order to underline the accuracy of the method, we can analyse the output for two typical wave conditions. One of these two representative wave climates is the moderate energy southeast swell, generated by the common winter low pressure system in Tasman Sea. 2 metre significant wave height and 12 second period are an example of the offshore wave conditions encountered from April to October. The other example representing an extreme wave condition is a NE swell, generated during the cyclone period from December to March. We consider a significant wave height of 5 metres and 15 second period for offshore wave conditions as characteristic of the most energetic conceivable events.

It appears clearly that the NE swell doesn't undergo strong transformations shorewards, the shoaling and wave height attenuation mostly occurring in the latest instant before propagating into the surf zone. Because of the E to NE isobaths orientation, the refraction is almost non-existent offshore, especially for the Gold Coast area. It results in a very homogenous distribution of wave characteristics along the coastline, the Gold Coast and coast south of Tweed River experiencing nearly the same height waves.

In the other case, we can observe strong spatial variations during the SE swell event. First, waves are strongly refracted north of the Tweed River and Point Danger. This results in the apparition of a well-defined sheltered area, corresponding to the Southern Gold Coast shoreline.

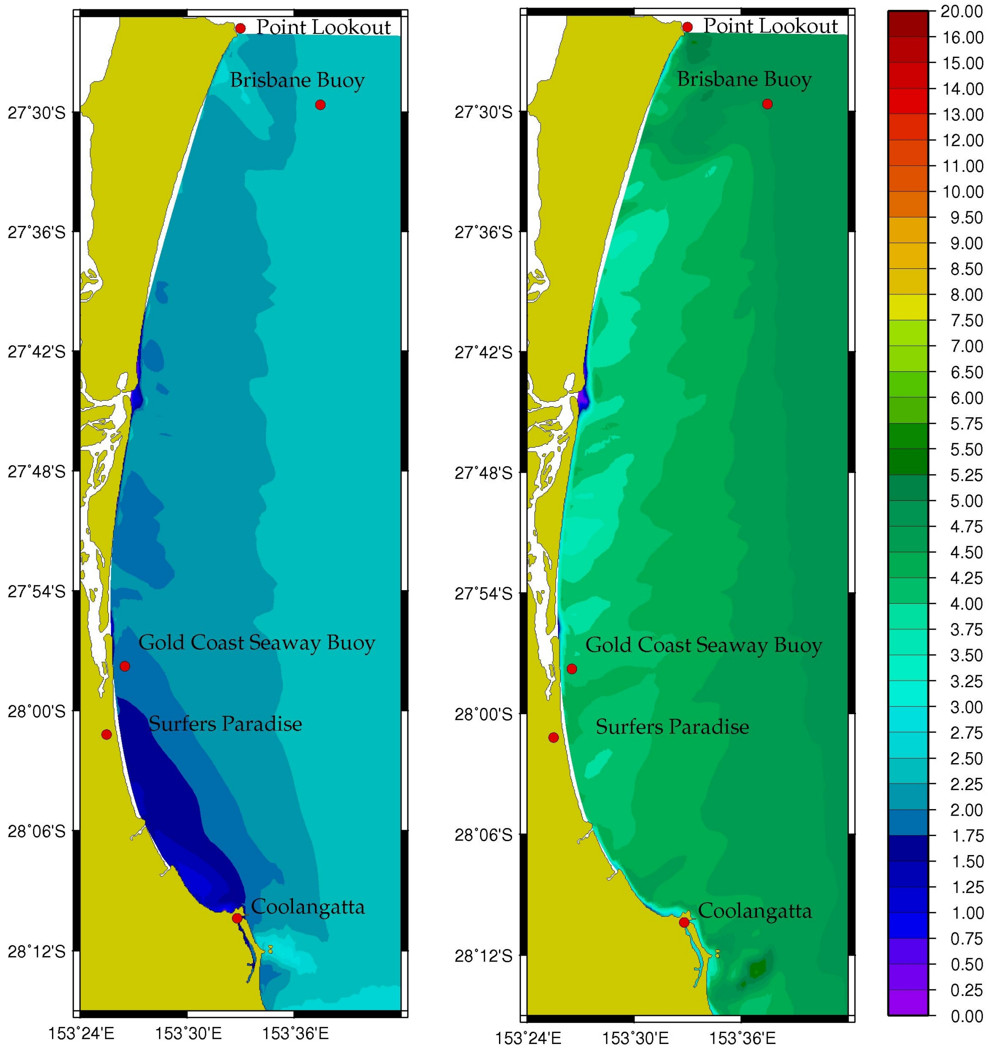

Figure 2: Model results for 2m 12 second SE swell from (left panel) and 5m 15 second NE swell (right panel)

Further north, the coast is less and less sheltered, until the wave conditions at the level of South Stradbroke island become the same as the Tweed Coast's. Secondly, as the offshore wave angle approach is almost parallel to the Gold Coast isobaths, even after a strong refraction, the wave angle is still very oblique when reach the coast. We can expect strong northwards rips along the headlands, and long, peeling waves in the breaking zone of the points as Currumbin, Burleigh heads and Snapper Rocks, which are world-class surf breaks well known by the surfing community.

DISCUSSION

The modelled results above are typical of the two types of swell we took as example, according to the empirical popular knowledge of the Gold Coast surf characteristics. The strong spatial variations of wave parameters propagating near-shore in case of the typical winter swell have been highlighted, and confirm the relevance of SWAN modelling investigations for the complex bathymetry of the area. Further calibration of the model particularly in the southern Gold coast area requires near-shore wave data which is currently unavailable. Video techniques for estimating wave height in the surf zone are emerging as potentially cost-effective methods for future data collection.

TAKE HOME MESSAGE

Substantial variations in wave climate due to coastal topography, especially in areas such as the southern Gold Coast, produce responses in shoreline evolution and sediment transport rates. As with other regions which are not monitored by conventional wave buoys, there is a need to estimate near-shore wave climate with numerical or empirical models. This system can provide real time estimates and short-term prediction of near-shore wave climate in areas which are not serviced by instrumentation and will contribute to better monitoring and understanding of short scale coastal processes of the developing Gold Coast region. This has potential for improving beach safety, is useful for coastal management and has added benefits for recreational boating, surfing and beach users.

ACKNOWLEDGEMENTS

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REFERENCES

BOOIJ, N., RIS, R.C., HOLTHUIJSEN, L.H., (1999). A third-generation wave model for coastal regions, part I: model description and validation. *Journal of Geophysical Research*, 104 (C4), 7649–7666.

DELFT HYDRAULICS LABORATORY, (1970). Coastal Erosion and Related Problems, Gold Coast, Queensland, Australia. *Delft Hydraulics Laboratory Report R257.*

DHL - DELFT HYDRAULICS LABORATORY, (2000). Delft3D-WAVE User Manual.

EPA, (2004). *Coastal services monitor storm event - March 2004*. Coastal Services - Environmental Services Division, Environmental Protection Agency (EPA), Queensland Government.

HOLTHUIJSEN, L.H., BOOIJ, N. and RIS, R.C., (1993). A spectral wave model for the coastal zone, *Proceedings of the 2nd International Symposium on Ocean Wave Measurements and Analysis*, ASCE, New Orleans, USA, 630-641.

RIS, R.C., BOOIJ, N. and HOLTHUIJSEN, L.H., (1998). A third-generation wave model for coastal regions, part II: verification. *Journal of Geophysical Research* 104 (C4), 7649–7666.

STRAUSS, D.; MIRFERENDESK, H. & TOMLINSON, R. (2007). Comparison of two wave models for Gold Coast, Australia. *Journal of Coastal Research, SI 50*.

Tolman, H.L., 2002. User manual and system documentation of WAVEWATCH-III version 2.22. *NOAA/NWS/NCEP/MMAB.*