Introduction of a new friction routine into the SWAN model that evaluates roughness due to bedform and sediment size changes

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Introduction

The interaction between wave energy and the seabed results in a dissipation of energy that is due to bottom friction. Work is also done on bedforms both solid and mobile (cohesive and noncohesive sediments) such as sand ripples, on suspending and moving sediment, due to percolation (Komen et al. 1994), and due to excessive breaking caused by shoaling (e.g. Babanin et al. 2001). For a relatively flat granular seabed, the magnitude of the roughness that contributes to dissipation is determined by the grain size of the sediment, and dependence of the wave-motion friction on this grain size is one of the subjects of this paper. However, the bedform of a mobile seabed can be altered due to the action of waves and currents. Experimental analysis of flow in the boundary layer found, for example, eddies moving the sediment in an orbital trajectory that results in parallel ridges (or ripples). Their formation and size is determined by the dimension of the eddies (Melnikhova amd Volkov 2000).

A bottom-friction routine, based on the Nielsen algorithm (Nielsen 1981), was introduced into the SWAN model (Booij et al. 1999) which makes the bottom friction for waves dependent on presence/absence of ripples if the sea bed is mobile, and on grain size of the sediment. The routine is suitable for spectral models of wave evolution, and in the present study it was tested by means of the SWAN model by hindcasting waves at two finite-depth field sites.

The first location for validation and testing of the new friction subroutine is Lake George, Australia. Lake George is located in the state of New South Wales. It covers an area of about 65km2 and has a maximum depth of 2.1 metres. The advantage of using a shallow lake for investigating the impact of bedforms on wave evolution is that all developed waves will exhibit finite depth characteristics (Young and Babanin 2006). Also, the Lake George bed is flat which makes the bottom topography simple and results will not be affected by a complex bathymetry. Sediment from this lake has been utilised in laboratory measurements to evaluate the interaction of the lake bed and waves (Babanin et al. 2005).

Observed data exists for eight stations located at various intervals spanning the length of the lake. The data timescale is an 18 month period from the 6th of March 1992 to 7th October 1993. This data was collected during an investigation on finite-depth spectral evolution as described in Young and Verhagen (1996) and Young et al. (1996).
Initial modelling of Lake George, Australia, using the default friction configuration in the SWAN model showed that the significant wave height was overestimated at most time steps (in some locations the predicted wave height was more than double the observed data). This discrepancy supports the hypothesis that in shallow depths when friction dissipation is the dominating dissipation term, overestimation of wave energy will occur when conditions and sediment characteristics are likely to produce sand ripples.

The results from the Lake George SWAN model using the ripple friction algorithm case are very promising as shown in Fig. 1 (the water depth is approximately two metres across the lake). In some locations model agreement with observed data was excellent. There was an overall improvement in model prediction for significant wave height, and a small yet identifiable improvement on the peak period.

![Fig. 1a](image1.png)

**Fig. 1a** Scatter plot showing correlation between the default SWAN friction routine and the observed data at Lake George

![Fig. 1b](image2.png)

**Fig. 1b** Scatter plot showing correlation between the new Nielsen algorithm friction routine and the observed data at Lake George.

The algorithm that determines the occurrence of sediment mobility and the evolution of bed-forms was also validated to emulate the expected behaviour found in laboratory experiments using a sediment sample from Lake George (Babanin 2005). The near bed orbital velocity exceeded the uni-directional velocity found in laboratory experiments (that was deemed to be the threshold to initiate sediment mobility) at similar time steps as the Shields parameter.
threshold predicted. The maximum roughness coefficient calculated by the algorithm for the month of October 1992 was 19.1 mm, which is similar to the maximum value of 20 mm expected to occur for sediment at Lake George (Babanin 2005).

An overestimation of the presence of fully developed ripples was amended by implementing an averaging process that remembers the history of the roughness at each grid cell. The final roughness factor at any given time step and location was derived from this array.

Further testing was done for an offshore coastal location at Lakes Entrance at a depth of 16.3 metres. The original SWAN Model showed quite acceptable results. At the particular output point in question, there were no ripples found to exist based on the bed-form algorithm. The roughness coefficient was therefore solely based on the grain size diameter. Results from the new friction algorithm showed that there was a very slight improvement on the original model results. The results from both models are comparable as they both utilised a constant value for roughness over the model run due to the absence of bed-forms. Since the Lakes Entrance sand size (0.41 mm) is very different from the Lakes George silt size (0.13 mm) this outcome provides a support to the grain-size dependence of the new bottom-friction routine (Babanin et al. 2001).

References


