SOUTH ABERDEEN COASTAL REGENERATION PROJECT

Project A4 – Marine Processes Study

Tom O'Donoghue, Mahesa Bhawanin

School of Engineering, University of Aberdeen

OBJECTIVE

The objective is to establish a wave model for Nigg Bay which can be used to predict wave conditions within the bay for given offshore incident wave conditions. The scope extends to setting up the model and demonstrating its capability for a range of example conditions. The model can later be used for work requiring detailed wave analysis, such as the design of structures within the bay.

METHODOLOGY

The SWAN (Simulating Waves Nearshore) coastal hydrodynamics model (http://vlm089.citg.tudelft.nl/swan/online_doc/swanuse/swanuse.html; Holthuijsen, 2008) developed by Delft University of Technology is used to simulate wave conditions in Nigg Bay for given offshore incident waves. SWAN is freely-available software used worldwide by coastal engineering practitioners for computing coastal wave conditions. It is not designed for very large-scale (oceanic) simulations but the output from large-scale models such as WAM and WAVEWATCH III is compatible for use with SWAN. SWAN is a highly-developed model, a so-called 3rd generation wave model, which computes basic wave processes such as wave shoaling, diffraction, refraction and reflection as well as complex non-linear wave interactions.

Model Input: Basic input to SWAN is the bathymetry of the area covered by the model, the tide level and specification of the wave conditions at the offshore boundary of the model area. The wave conditions are specified by wave spectrum parameters, i.e. significant wave height, H_s, peak spectral period, T_p, mean wave direction, θ_m, the spectrum shape and the directional wave spreading.

Model Output: SWAN computes the wave spectrum at every grid point within the model domain, which means that the usual wave parameters - significant wave height, mean and peak wave period and mean wave direction - can be output for each grid point. Depending on the application, other computed quantities such as radiation stress, energy transport, wave-generated currents, wave energy, wave dissipation and energy transfer can be output.

APPLICATION OF SWAN TO NIGG BAY

The Nigg Bay bathymetry used as input to the SWAN model was provided by Aberdeen Harbour Board and is based on survey data dated 18/09/02[1]. The raw data was processed using ArcGIS and MATLAB was used to compute and plot the contoured bathymetry. The bathymetry is presented in Figure 1, with a Google Map digitally superimposed to show its position relative to the local land area.

Case	sig wave height H_s (m)	peak period T_p (s)	mean direction θ_m (degs)	Tide (m) above CD	Results plot
1	2	8	135 (from SE)	4.35 (MHWS)	Fig. 3 & 4
2	2	8	90 (from E)	4.35 (MHWS)	Fig. 5
3	2	8	45 (from NE)	4.35 (MHWS)	Fig. 6
4	2.8	11.6	90 (from E)	4.35 (MHWS)	Fig. 7
5	0.86	8	90 (from E)	4.35 (MHWS)	Fig. 8

Table 1: Offshore incident wave conditions for 5 example model simulations

[1] The Nigg Bay bathymetry provided by the Aberdeen Harbour Board is not available to a 3rd party without permission from Aberdeen Harbour Board

A large number of model simulations have been carried out in developing the SWAN model for Nigg Bay. In this report we present output from five cases, as detailed in Table 1. Cases 1 to 3 correspond to a relatively high wave condition incident from the SE, E and NE respectively; Case 4 corresponds to an Easterly storm with H_s = 2.8m and T_p = 8s measured on 04/01/08 by the directional waverider buoy located on the 10m contour in Aberdeen Bay (Taylor and O'Donoghue, 2008); Case 5 corresponds to an Easterly low wave condition with H_s = 0.86m and T_p = 8s measured on 19/11/07 by the Aberdeen waverider buoy. All 5 cases were run for a MHWS tide level; Figure 2 shows the depth contours for MHWS.

The numerical output from SWAN was post-processed using MATLAB to produce the contour plots of significant wave height presented as Figures 3, 5, 6, 7 and 8, and the plot of wave rays presented for Case 1 as Figure 4. (Wave rays are lines that are perpendicular to wave crests; locations where wave rays converge correspond to areas of wave energy focusing and high wave activity; locations where rays diverge correspond to areas of lower wave activity.) The following observations are made from the results presented:

Case 1: Figure 3 and 4: with waves incident from the SE, the south side of the bay is well sheltered, so wave activity is low in this area; at the same time we see relatively high wave activity on the north side and strong focusing of waves at the north headland.

Case 2: Figure 5: waves incident from the E focus on the headlands and shoal and refract into the bay, producing a near-symmetric pattern of wave height.

Case 3: Figure 6: with waves incident from the NE, the north side of the bay is well sheltered and wave activity is therefore very low in this area; at the same time we see relatively high wave activity on the south side.

Case 4: Figure 7: for this storm condition from the E, very high waves penetrate far into the bay, with significant wave height greater than 2m within about 100m from shore on the north and south sides. Looking shore-normal from the beach, the waves are greater than 2m within about 200m from shore; the waves break and lose energy as they travel towards the beach.

Case 5: Figure 8: for this relatively low incident wave from the E we see low wave activity in the bay. The transformation in wave height is smaller and more gradual as the waves propagate from offshore to shore. Interestingly we see a small area of wave focusing near to shore at the NE corner of the inner bay.

Conclusion and Future Application of the Model

A SWAN model has been successfully established for Nigg Bay and example results presented showing wave conditions within the bay for given offshore incident waves. The model is ready to be used for detailed analysis of waves at specific locations at Nigg. For example, for a proposed structure, the model can be used to estimate the wave conditions at the structure location for a range of offshore incident waves and tidal levels in order to determine the design wave for the structure. Depending on the specific questions to be addressed, an analysis of the wave climate for the area, based on MET Office wave model output and measurements from the waverider buoy in Aberdeen Bay, may be used with SWAN modelling to predict the wave climate within the bay.

References

Holthuijsen, L. H. (2008). *Waves in Oceanic and Coastal Waters.* United Kingdom: Cambridge.

SWAN *User Manual,* SWAN at http://vlm089.citg.tudelft.nl/swan/online_doc/swanuse/swanuse.html (Retrieved 23/11/2009)

Taylor, A. and O'Donoghue, T. (2008). ABCoMP: Progress Report PR3, University of Aberdeen.

Depth contours with Google Map superimposed

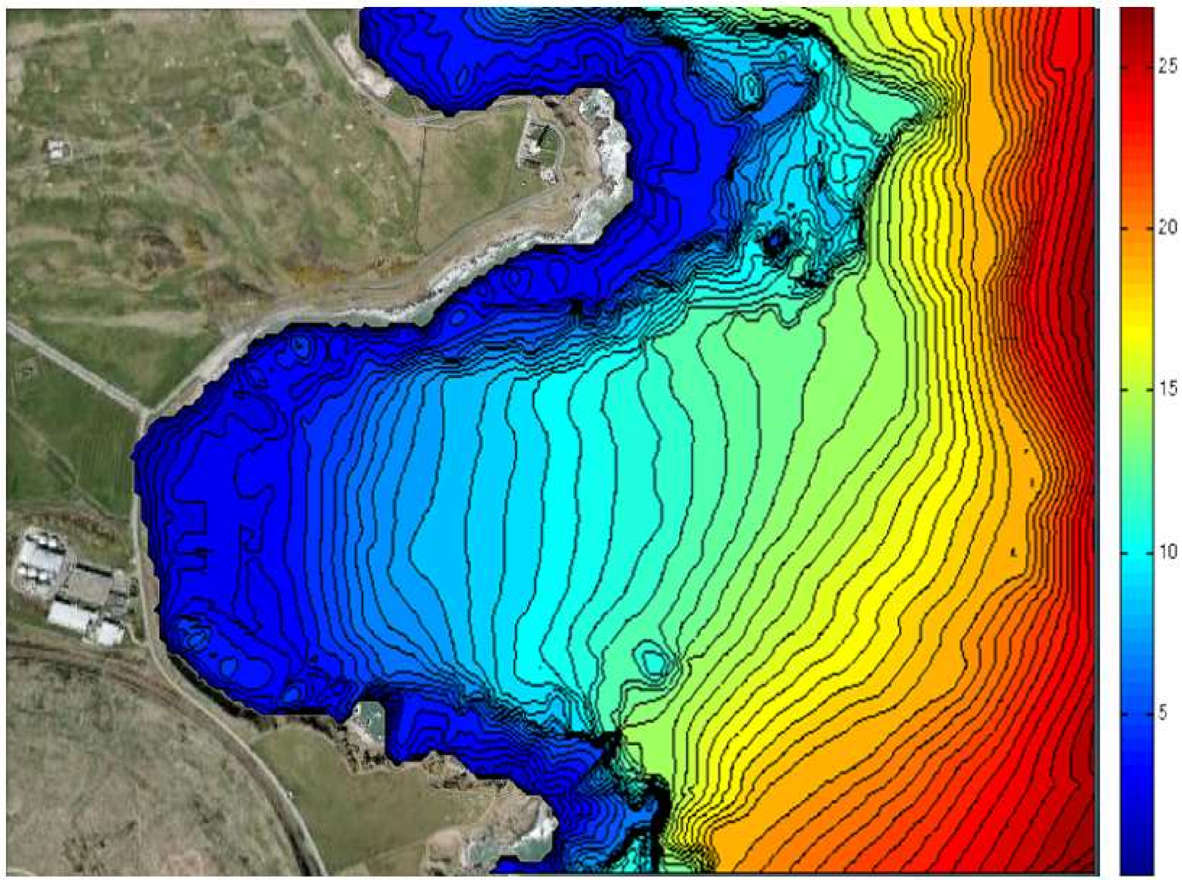


Figure 1

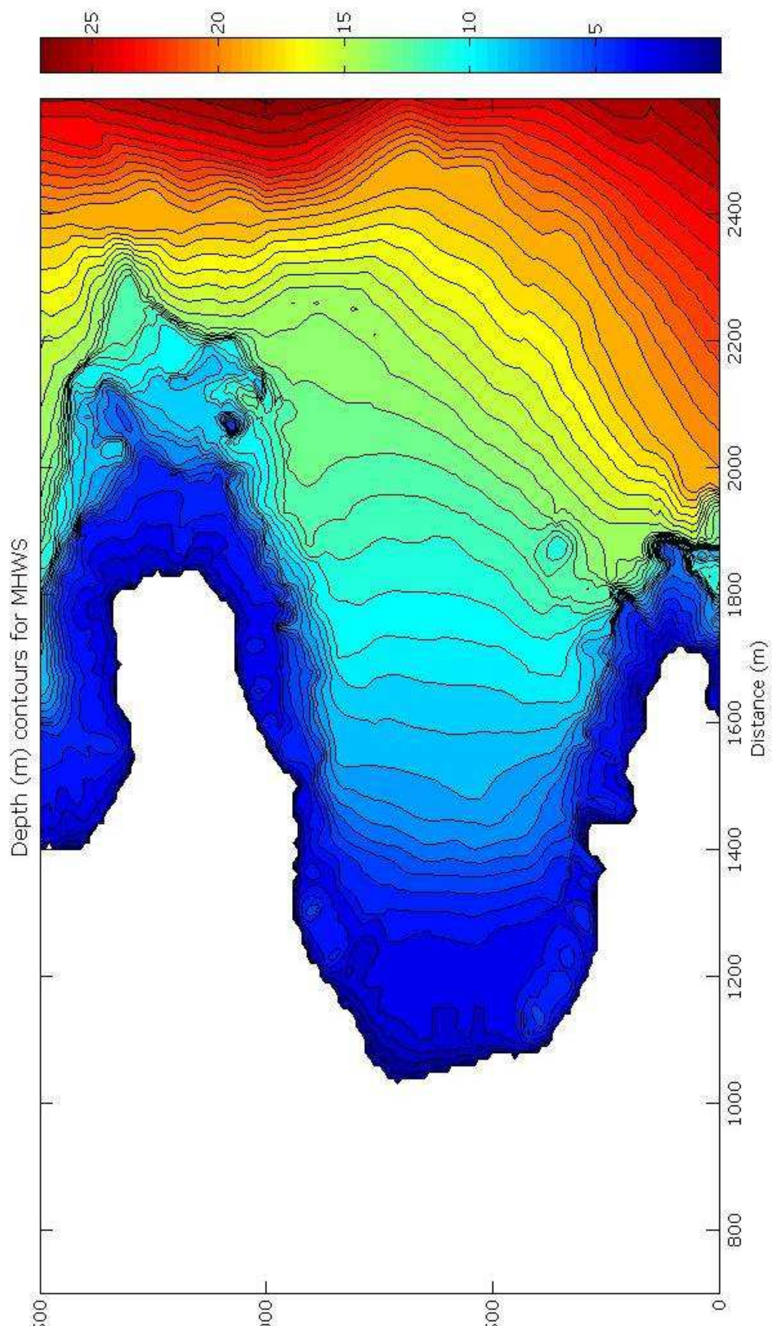

Depth (m) contours for MHWS
25
20
15
10
5
Distance (m)
800
1000
1200
1400
1600
1800
2000
2200
2400
Distance (m)
0
500
1000
1500

Figure 2

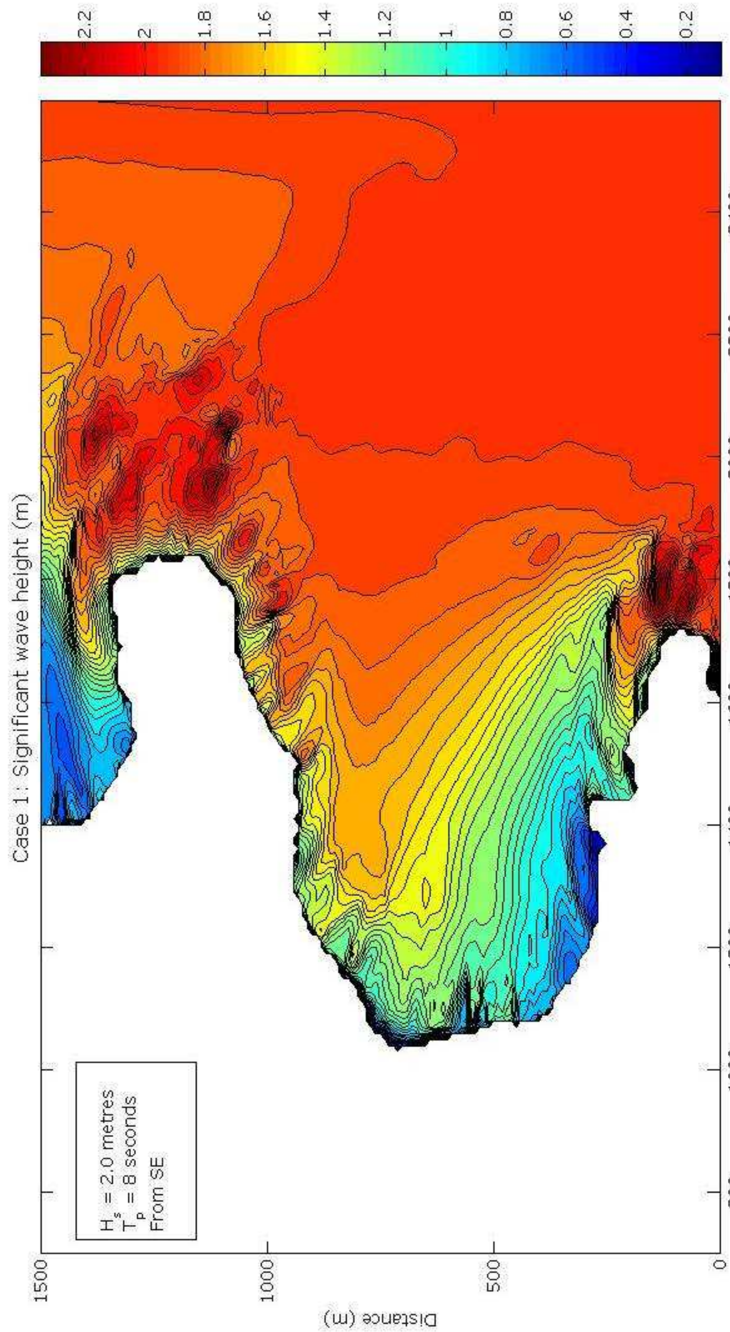
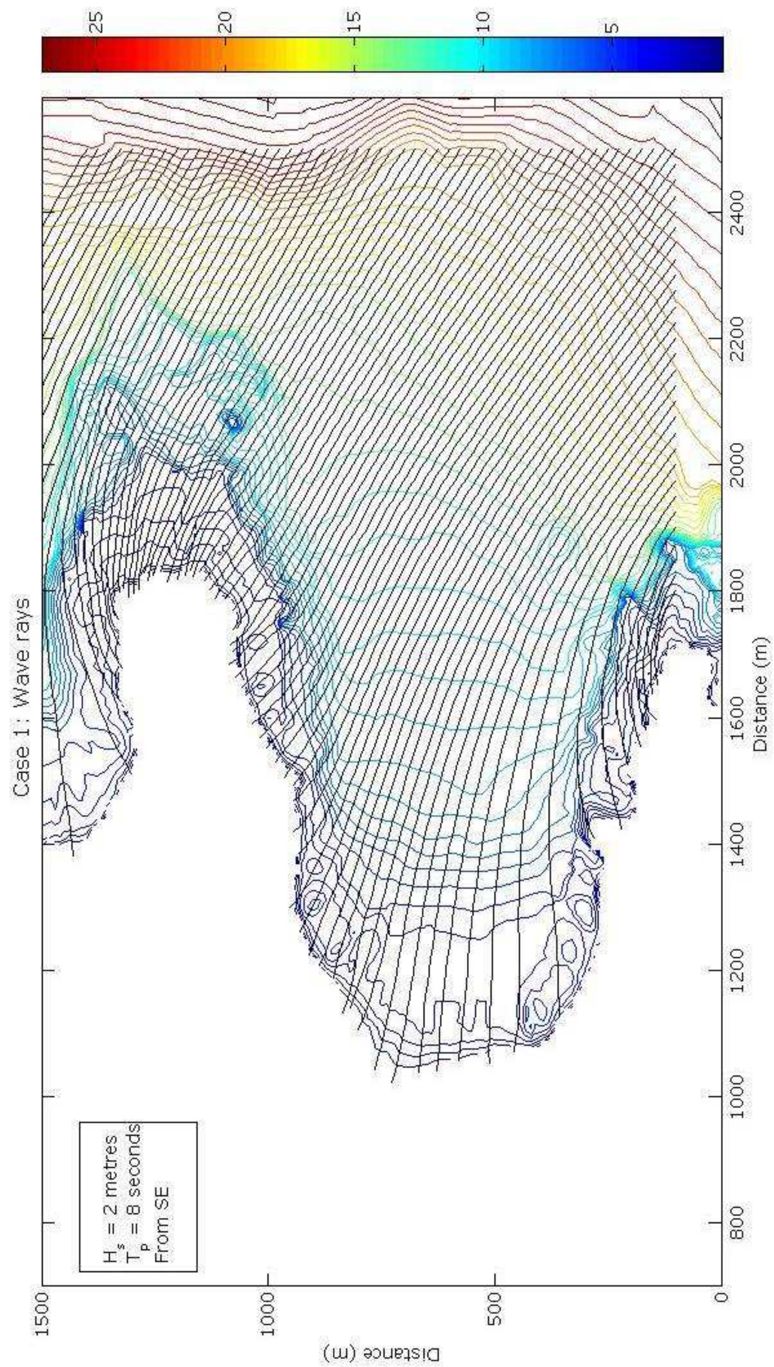

Case 1: Significant wave height (m)
H_s = 2.0 metres
T_p = 8 seconds
From SE
Distance (m)
Distance (m)
800
1000
1200
1400
1600
1800
2000
2200
2400
0
500
1000
1500
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2

Figure 3



Case 1: Wave rays
H_s = 2 metres
T_p = 8 seconds
From SE
Distance (m)
Distance (m)

Figure 4

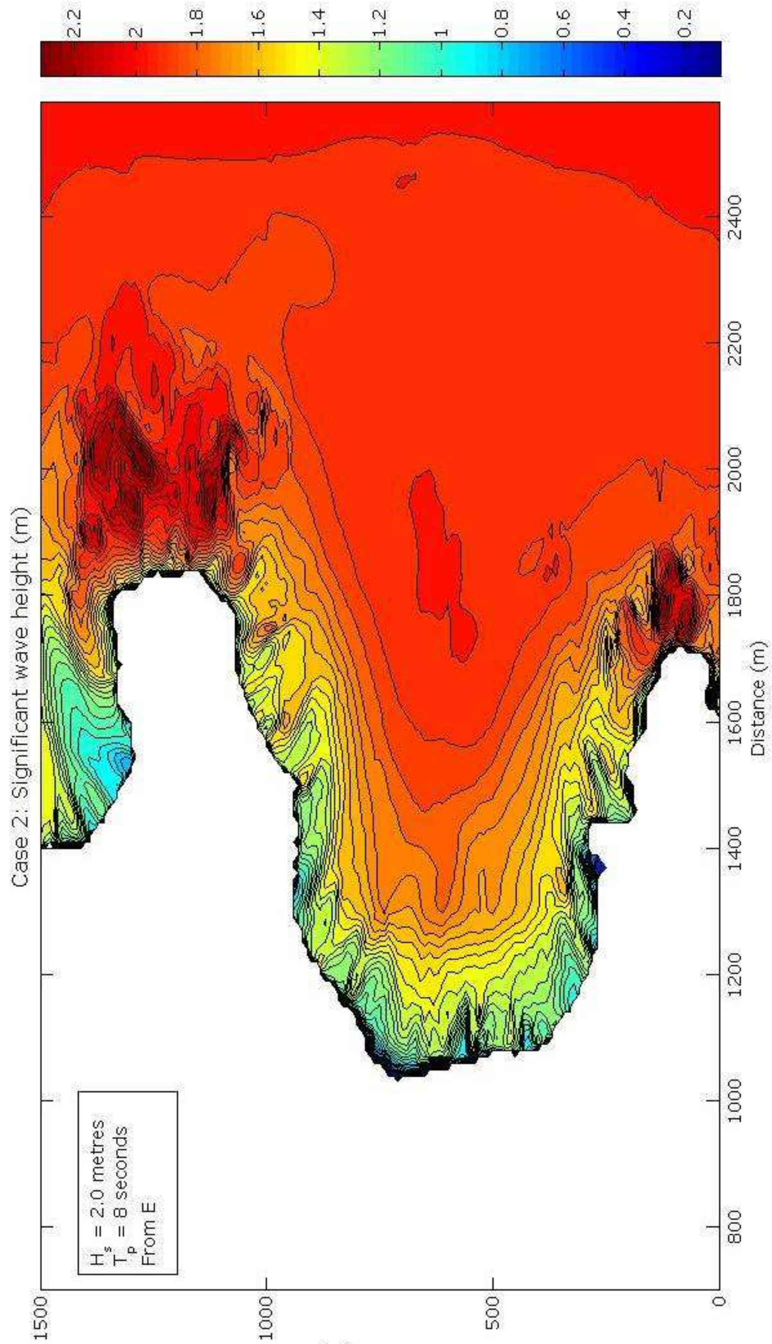

Case 2: Significant wave height (m)
H_s = 2.0 metres
T_p = 8 seconds
From E
Distance (m)
Distance (m)

Figure 5

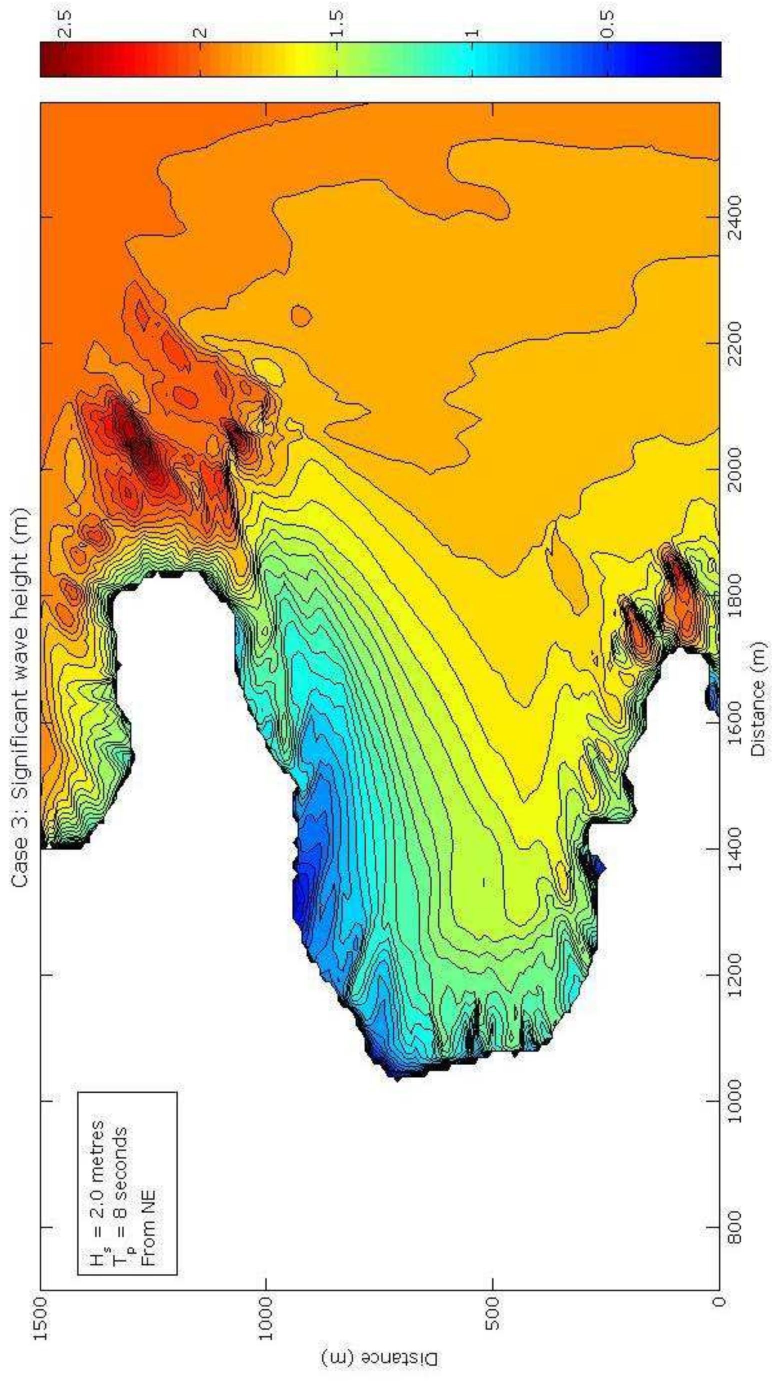

Case 3: Significant wave height (m)
H_s = 2.0 metres
T_p = 8 seconds
From NE
Distance (m)
Distance (m)
2.5
2
1.5
1
0.5

Figure 6

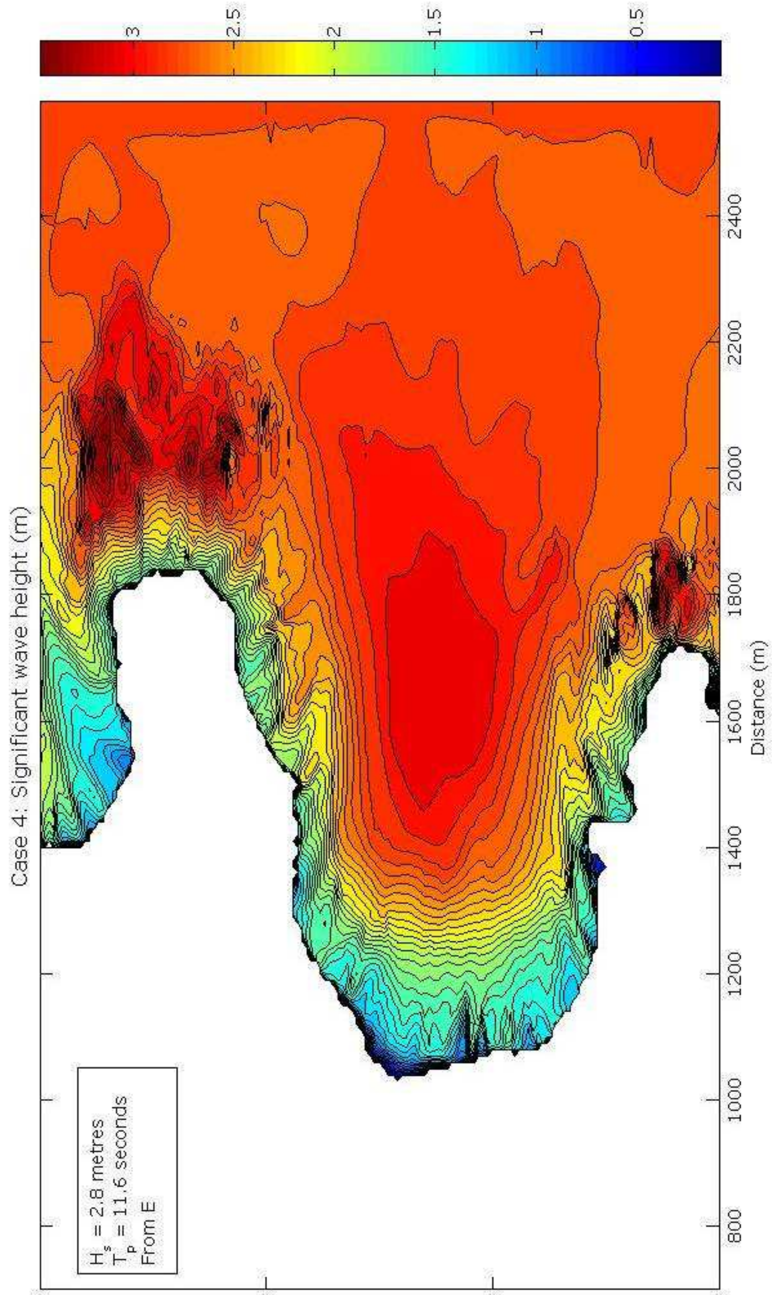

Case 4: Significant wave height (m)
H_s = 2.8 metres
T_p = 11.6 seconds
From E
Distance (m)
Distance (m)
3
2.5
2
1.5
1
0.5
1500
1000
500
0
800
1000
1200
1400
1600
1800
2000
2200
2400

Figure 7

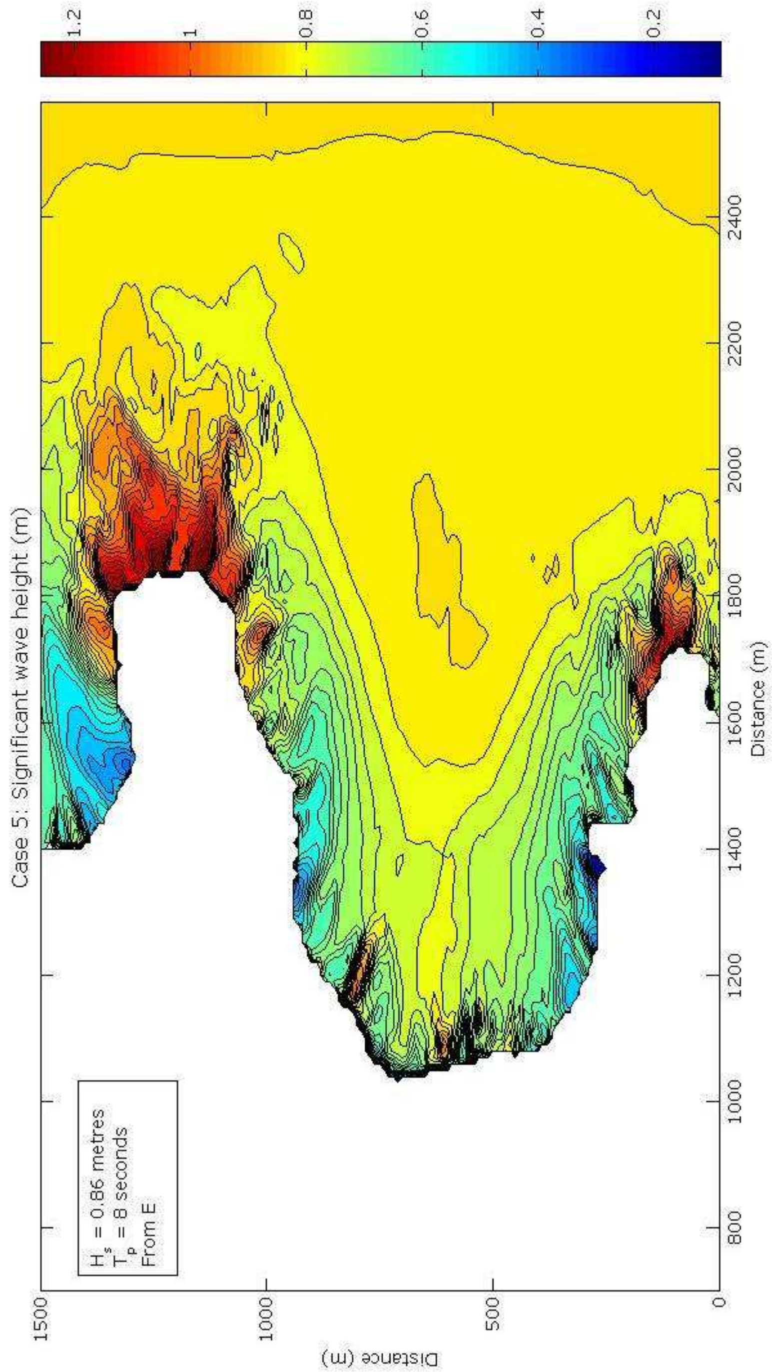

Case 5: Significant wave height (m)
Hs = 0.86 metres
Tp = 8 seconds
From E
Distance (m)
Distance (m)
1.2
1
0.8
0.6
0.4
0.2
800
1000
1200
1400
1600
1800
2000
2200
2400
0
500
1000
1500

Figure 8