

The Interaction of Nonlinear Internal Waves with Other Processes

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LONG-TERM GOALS

To understand and parameterize small-scale ocean processes.

To understand ocean tides and their effects.

To understand surface wave processes.

OBJECTIVES

To elucidate and quantify the back effect on internal waves, and other motions, of refracted and breaking surface waves.

To understand ocean tides and to quantify the power available from exploitation of strong tidal currents.

To understand aspects of extreme and unexpected surface waves.

APPROACH

Recent studies have been largely analytical, with support from numerical evaluation.

WORK COMPLETED

Progress has been made in adding dissipation to studies of the interaction between surface waves and currents.

The reason for the extreme tide of Ungava Bay has been discovered. General results on the maximum power obtainable from tidal currents have been derived.

A review of extreme events has been completed. The frequency of occurrence of unexpectedly large surface waves has been evaluated.

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RESULTS

The effect of currents on surface waves is simply described by wave action conservation, modified to allow for wave dissipation. The vertically-integrated effect of the surface waves on the current may be described in terms of radiation stress divergence if the mean current is taken to include the mass transport associated with the Stokes drift. This approach may be suitable for shallow water waves, but in deep water it seems more appropriate to treat the Stokes drift separately. The effect of the waves on the underlying current may then be described in terms of a vertically-integrated vortex force, some mass exchange between the varying Stokes drift and the mean flow, and a force related to wave dissipation. This is all (decades) old. The new advance is to quantify the force associated with dissipation assuming a limiting wave steepness, and to evaluate it for wave encountering an adverse current. It scales with the third or fourth power of the phase speed of the waves and can be significant, comparable with the wind stress over an extensive fetch.

In collaboration with others, I have shown how the very large tides in Ungava Bay are associated with a resonance at approximately 12.7 hours, close to the M_2 tidal period of 12.4 hours. This is important as the Ungava Bay/Hudson Strait region has more tidal dissipation than any other region in the world.

I have also derived results for the maximum power available from turbines in tidal streams, and shown what losses are associated with the merging of the turbine wakes and the surrounding free stream.

As part of ongoing involvement in the study of rogue waves and other extreme events, Johannes Gemmrich and I have investigated the phenomenon of “unexpected” waves that can occur even in Gaussian seas, without the resonant nonlinear interactions often invoked in the study of rogue waves. The argument is that a large wave after a calm period can be of greater concern than an extreme wave which is not much larger than those preceding it. Figure 1 shows that even with purely linear superposition of random waves from a JONSWAP spectrum for fully-developed seas, a wave has arisen with a crest height more than twice as large as any in the preceding 43 wave periods.

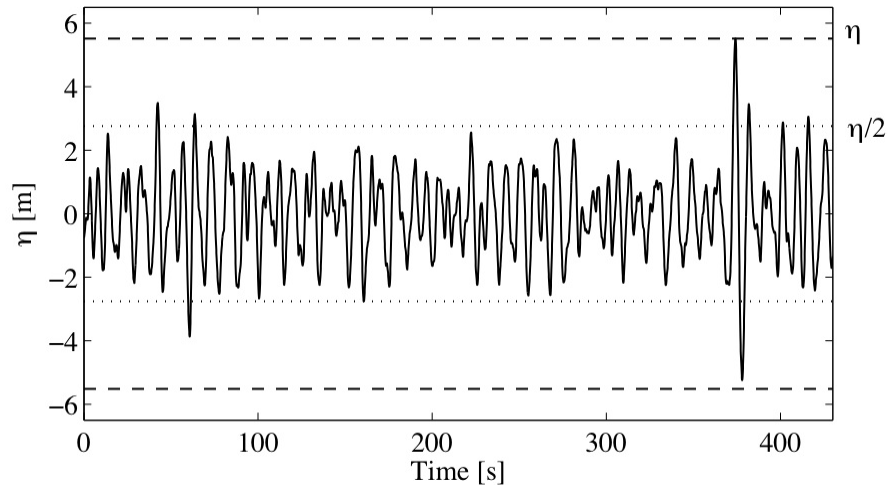


Figure 1. Synthetic time series for the sea surface displacement from random superposition of waves from a JONSWAP spectrum for fully-developed seas with a peak period of 10 seconds. A large wave at 374 seconds has a crest more than twice as high as that of any wave in the preceding 310 seconds. This is 43 times the average wave period of 7.1 seconds.

Monte Carlo simulations give the recurrence time for any wave a given factor higher than any of a given number of preceding waves, for wave height from trough to crest, crest height, and crest height with enhancement to allow for nonlinear but non-resonant second order effects. For example, a wave crest twice as high as any of the preceding 30 will occur once every 4 days if the peak period is 10 seconds. The return period is reduced to 2 days if allowance is made for nonresonant nonlinear interactions changing the shape. The return period is also reduced if one or more precursor waves are allowed for.

IMPACT/APPLICATIONS

Results on wave current interaction will impact on studies of internal waves, eddies, and fronts.

Results on tidal power are relevant to discussions of renewable energy.

Results on unexpected waves can be incorporated into warning systems.

RELATED PROJECTS

The projects described above have also been supported by Canadian funding agencies. A related project supported entirely by Canadian agencies concerned breaking surface waves.

PUBLICATIONS

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