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Nonlinear and Dissipation Characteristics of Ocean Surface Waves in Estuarine Environments

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LONG-TERM GOALS

The overall goal of this work is the development of computational modules for the dissipation of surface wave energy due to expanses of bottom mud and marshland vegetation. The computational modules would represent both the dissipative effects on the surface waves and the effects of dissipation on other processes of wave transformation and evolution, with particular attention paid to the nonlinear energy exchange among wave frequencies. In addition these modules would allow for feedback between the surface wave and the energy dissipating feature.

OBJECTIVES

1) Develop processes models of the physics of dissipation in estuarine areas.
2) Use optimized ensemble simulations to represent effects of dissipation on wave processes.

3) Develop and test low-dimension, reduced representations of estuarine effects for inclusion into operational wave models.
4) Develop experimental versions of operational wave models.

APPROACH

We will first work to develop computational models for detailed, phase-resolved predictions of wave dissipation in estuarine areas. These models will include various mud proxy models (viscous fluid, viscoelastic semi-rigid bed, Bingham plastic) for wave/mud interaction and mud-induced dissipation. These proxy models for mud dissipation have fairly broad-banded responses over a large swath of wave frequencies, so they can be expected to inhibit various nonlinear interactions in the random wave field. The task here will be to surmise whether this frequency dependence is scalable or self-similar over a range of frequencies, conditions or proxies. In addition the feedback between surface and lutocline waves will be investigated to determine whether or not these interactions have an effect on surface wave energy; allowing for surface-lutocline interaction can potentially *redirect* surface wave energy rather than sinply dissipate it. A similar line of inquiry will be performed for wave-vegetation interaction, though the expected parameter space for this phenomena may be significantly reduced compared to mud dissipation. These models will be validated with available data.

To make this suitable for a random wave spectral model (as most operational wave models are), we must find ways of randomizing our results with the deterministic models. One possible method would be the use of a neural network approach, which uses data from the models to establish a “training set” which helps predicts future behavior. The neural network mapping strategy of Krasnopolsky et al. (2002) will be one candidate for use; it was used for the Wavewatch-III © model, and should be available for use here.

In addition, and in concert with the project “Development of Numerical 3-Wave Interactions Module for Operational Wave Forecasts in Intermediate-Depth and Shallow Water” (PI: Sheremet; co-PI: Kaihatu) we will investigate physically-justifiable reduced dimension models which will retain the dominant components of wave-mud-vegetation interaction but will also allow for more expedient calculation.

Finally we will make use of the models developed above to create experimental versions of operational models. This will allow us to test the physics in the developed models while using the general framework of operational wave models. We will conduct robustness tests of the system to determine the conditions under which the new models exhibit sub-optimal behavior. We will also work with the NCEP and NAVO (if available) operational forecasters, as well as the scientific community at the Naval Research Laboratory (NRL) and Engineering Research and Development Center (ERDC) to insure smooth incorporation of these developments into their operational run stream.

Work on the interaction between the surface and interface modes is being conducted by Mr. Navid Tahvildari, a PhD graduate student working at Texas A&M University under the PI’s supervision.

WORK COMPLETED

Our primary work thus far has been in the development of models for investigating wave-wave interaction between surface and interfacial waves in two-layer fluids. We have derived a time-domain Boussinesq model for two-layer wave-wave interaction, and are also working out the instability mechanism which determines the time scale over which the interactions occur, in the manner of Hill and Foda (1998) and Jamali et al. (2003).

RESULTS

Contrary to the intermediate-depth work of Hill and Foda (1998) and Jamali et al. (2003), the interactions in this wealky-dispersive, weakly-nonlinear model occur very quickly. Figure 1 shows the amplitude of one surface wave mode and two interface mode as a function of time resulting from the analysis. We have also added viscosity to the interaction model in the manner of Acrivos and Davis (1967). Figure 2 shows the same system with the addition of viscosity. Damping of the amplitudes is evident, as is a increase in the period of the interaction as damping takes over.

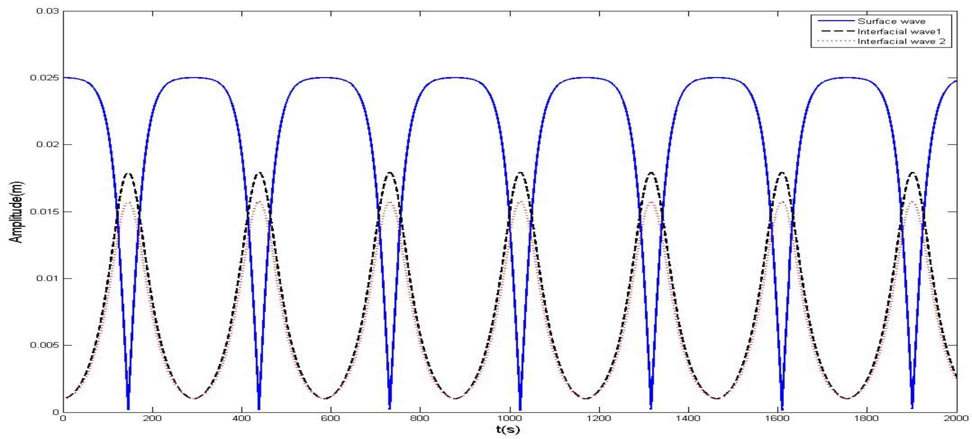

Figure 1. Temporal evolution of surface-interface wave-wave interaction; inviscid lower layer. Blue: Amplitude of surface wave mode. Red and black: Amplitudes of two interface modes.

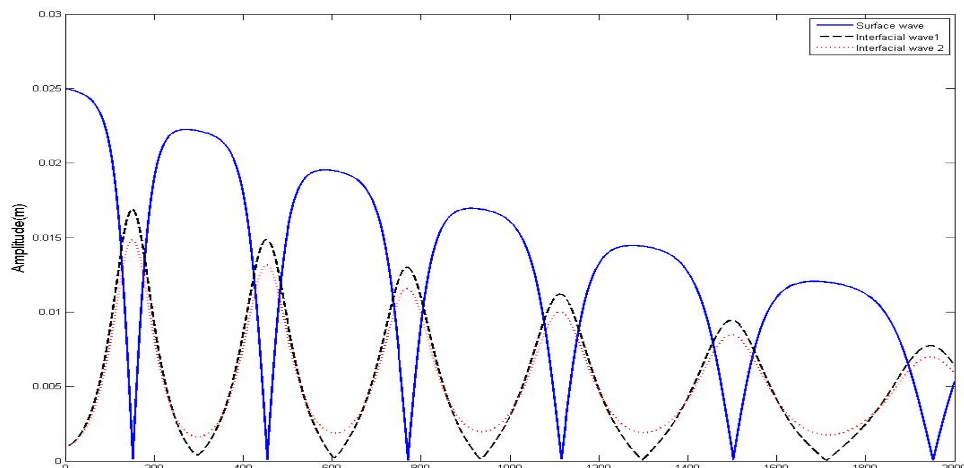

Figure 2. Temporal evolution of surface-interface wave-wave interaction; viscous lower layer. Blue: Amplitude of surface wave mode. Red and black: Amplitudes of two interface modes.

IMPACT/APPLICATIONS

This development has implications for our knowledge concerning wave dampening by bottom muds. Unlike most published dampening mechanisms, which do not allow for interactions between the interface and the surface wave, this mechanism will allow for this interaction and thus will alter the character of the observable surface wave due to this interaction, in a manner more profound than the indirect effect of pure dissipation on the nonlinearity of the surface wave. As more emphasis on viscosity is placed on the lower layer, the problem veers closer to a wave/mud interaction problem, but with the added feature of surface-lutocline interaction.

RELATED PROJECTS

Several aspects of this project investigate the nonlinear energy transfer between spectral components of the wave field and its effect on wave-mud interaction, and vice versa. These developments will be closely coordinated with the NOPP project “Development of Numerical 3-Wave Interactions Module for Operational Wave Forecasts in Intermediate-Depth and Shallow Water” (PI: Sheremet).

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