Characterization and Prediction of Environmental Parameters Affecting Bed Stability

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LONG-TERM GOAL

The goals of this project are to improve the characterization of environmental parameters, particularly wave and currents, in mine burial prediction models.

OBJECTIVES

The objectives of this study are 1) to support the Mine Burial Prediction field studies by providing running forecasts of waves, currents, and bed shear stress at the at Indian Rocks (IR) and Martha's Vineyard (MV) study areas during the planned intensive field experiments; and 2) to evaluate the WaveWatch III and nested WW3/SWAN wave models as well as available current models with respect to providing forecasts of flow conditions and bed shear stresses useful to mine burial modeling.

APPROACH

My approach is to use available measurements (e.g., from near-bed instrumentation and wave buoys) and models (e.g. Wave Watch III wave model, COMPS circulation model) of environmental parameters to characterize the potential for mobilizing seabed sediment. Measured and modeled wave conditions are compared to evaluate the skill of model hindcasts and forecasts at the Martha's Vineyard and Indian Rocks Beach field sites.

WORK COMPLETED

- Comparison of Howd's Indian Rocks Beach and Traykovski's Martha' Vineyard wave measurements during 2001–2002 with the Wave Watch III regional wave hindcasts for the western north Atlantic.
- Calculation of bottom orbital velocities and wave-generated shear stresses at the field sites during 2001-2002.
- Nesting of the SWAN wave model into the WW3 wave model for the Indian Rocks Beach and Martha's Vineyard study sites.

RESULTS

Comparison of measured and hindcast (WW3) wave conditions
Three sources of wave information are available for the Indian Rocks Beach (IRB) and Martha's Vineyard (MVO) field areas: 1) wave height, average period and wave direction measured by Howd

and Traykovski during portions of 2001–2002 at the IRB and MVO field sites, respectively; 2) hourly measured meteorological, wave, and wave spectral data from NDBC Buoy 42036 (located to the west of the study area at a depth of 50m) and Buoy 44008 (located southeast of the study site at a depth of 63 m); and 3) coarse resolution (global model, 1 ×1.25-degree grid spacing, 1997-present) and intermediate resolution (regional model, 0.25-degree grid spacing, 2001-present) wave hindcasts and forecasts from the Wave Watch III (WW3) model.

Wave height, period and direction measured by NDBC buoy 42036 and Howd's IRB tripod were compared with values obtained from the WW3 regional hindcast for the western North Atlantic for 2001-2002. Buoy and hindcast wave heights (r^2=0.83) and wave directions (r^2=0.43 – low because of directional wrap around) were in good agreement, though the model underestimates wave height by an average of ~20%. Measured and hindcast average wave periods fall in the same range of values (3-8s), but are relatively poorly correlated (r^2=0.2). Measured and hindcast wave heights at the buoy location are higher than values measured at the IRB site owing to effects of wave attenuation. A correction can be applied to buoy or hindcast wave heights to improve the agreement, but the best correction also takes into account wave direction. Hindcast waves at the grid point closest to the IRB site agree well with the 2002 tripod data (r^2=0.73), suggesting that the WW3 model does a reasonable job of accounting for bottom friction even at the relatively shallow depth (14 m) of the IRB site. Bottom wave orbital velocity and wave-generated bed shear stresses depend on both wave height and period. While orbital velocity and shear stress are generally more sensitive to wave height than period, the lack of resolution in period degrades predictions of wave-generated bed stresses and resulting sediment transport.

Wave height, period and direction measured by the NDBC buoy 44008 and Traykovski's MVO sensors were also compared with values obtained from the WW3 western North Atlantic hindcast for the for 2001-2002. Buoy and hindcast wave heights (r^2=0.6-0.7) were in reasonable agreement, with an average difference in values of <10%. Again, measured and hindcast wave heights at the buoy location are higher than values measured at the MVO site owing to effects of wave attenuation. Hindcast waves at the grid point closest to the MVO site relatively agree well with the 2002 tripod data (r^2=0.5-0.6).

Near-bed wave orbital velocities (u_b) calculated using a JONSWAP spectrum to estimate the full spectrum given H_s and T_p agree well with values calculated from measured spectra for Buoy 42036 (r^2=0.92). Orbital velocities calculated from WW3 values at the location of the buoy are somewhat poorer (r^2=0.73, largely owing to differences in measured and hindcast period (noted above). Distributions of bed shear stress were calculated from orbital velocities obtained from measured and hindcast waves at the IRB site using a wave friction factor. While stresses at 50 m rarely exceeded threshold values (~ 0.2 N/m^2), they exceeded that value over 10% of the time in depths of 14 m.

Nesting SWAN into WW3 for the Indian Rocks and Martha's Vineyard study areas
To increase the resolution and accuracy of the hindcast or forecast wave conditions for use in mine burial models when applied to shallow sites, we undertook to model the wave conditions at the two field sites using the SWAN wave model nested within the WW3 model. SWAN is a wave model that has been developed for regions including shallow water (where the WW3 model generally breaks down). Because we had no prior experience running SWAN, we first began by formulating the model for an enclosed region with steady winds so that no nesting was required. Then we added real wind time series. Finally, we tackled the problem of nesting SWAN in WW3. We successfully completed

the first two tests, using a shallow lagoon on the Eastern Shore of Virginia as a test case because of the availability of wave data at the site. We have also completed nested SWAN runs for the period of Howd's initial tripod deployment (2001-2002) at IRB and have the model set up to run at the MV site. Comparison of modeled and measured wave conditions at the IRB site, however, indicates a problem with the formulation of the WW3 boundary conditions or wind fields – during some conditions calculated and measured values agree well but there are a number of measured wave events that the model is missing. We are currently working on this problem. We hope to have the SWAN model running and tested in time to run it in a predictive mode for this year's MV field experiment.

IMPACT/APPLICATIONS

An understanding of the strengths and limitations of available wave model hindcasts and forecasts allows us to use these models to characterize and predict wave-driven sediment transport in shallow marine environments.

RELATED PROJECTS

The wave modeling in the western Gulf of Mexico will be useful for hindcasting wave ripple geometry and orientation for the SAX 99 field experiment and can also be applied in the upcoming Ripples DRI.