Geophysical Research Abstracts
Vol. 19, EGU2017-12264, 2017
EGU General Assembly 2017

Prediction and observation of munitions burial in energetic storms

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The fate of munitions or unexploded ordnance (UXO) resting on a submarine sediment bed is a critical safety concern. Munitions may be transported in uncontrolled ways to create potentially dangerous situations at places like beaches or ports. Alternatively, they may remain in place or completely disappear for significant but unknown periods, after becoming buried in the sediment bed. Clearly, burial of munitions drastically complicates the detection and removal of potential threats.

Here, we present field data of wave height and (surrogate) munitions burial depths near the 8-m isobath at the U.S. Army Corps of Engineers, Field Research Facility, Duck, North Carolina, observed between January and March 2015. The experiment captured a remarkable sequence of storms that included at least 10 events, of which 6 were characterized by wave fields of significant heights exceeding 2 m and with peak periods of approximately 10 s. During the strongest storm, waves of 14 s period and heights exceeding 2 m were recorded for more than 3 days; significant wave height reached 5 m at the peak of activity. At the end of the experiment, divers measured munition burial depths of up to 60 cm below the seabed level. However, the local bathymetry showed less than 5 cm variation between the before and after-storm states, suggesting the local net sediment accumulation / loss was negligible. The lack of bathymetric variability excludes the possibility of burial by a migrating bed form or by sediment deposition, and strongly indicates that the munitions sank into the bed. The depth of burial also suggest an extreme state of sand agitation during the storm.

For predicting munitions burial depths, we explore existing analytical solutions for the dynamic interaction between waves and sediment. Measured time series of wave pressure near the sediment bed were converted into wave-induced changes in pore pressures and the effective stress states of the sediment. Different sediment failure criteria based on minimum normal and maximum shear stresses are then applied to evaluate the appropriateness of individual failure criteria to predict observed burial depths. Results are subjected to a sensitivity analysis with respect to uncertain sediment parameters and summarized by representing cumulative failure times as a function of depth.