Enhancement and Validation of a Model for Mine Scour and Burial

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LONG-TERM GOALS

Our long-term goal is to perfect a process-oriented model for the prediction of scour and burial of mines deployed in the shallow waters of the global coastal zone; and to place this model, complete with code and descriptive text, in the Ocean/Atmosphere Model Library (OAML). We are presently pursuing this goal by expanding the physics and validation of the model to treat the farfield burial effects of mines due to sediment fluxes from rivers and ocean inlets, and the nearfield burial effects associated with bottom sediment dilatation and grain packing.

OBJECTIVES

The basic scientific objective is to determine the appropriate geomorphic and hydrodynamic principles leading to:

- locally rapid mine burial
- time varying burial/exposure throughout the littoral cell

Modeling these phenomena will involve solving the classical problem of accretion/erosion waves propagating along the coast from episodic fluxes of sediment associated with river runoff and spit extension at inlets. These processes produce step increases in the littoral budget of sediment. The improved burial prediction capability obtained by upgrading the model physics to include these processes will be distilled into a Mine Burial Primer and used to update the entry in the Mine Warfare Environmental Pocket Handbook.

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14. ABSTRACT
Our long-term goal is to understand the biogeochemical dynamics of the ocean???s upper kilometer. Such an understanding is fundamental to prediction of the processes partitioning carbon between atmosphere and ocean and to the redistribution of carbon and associated elements within the water column. Key to predictability is understanding day-to-day variability of processes governing abundances of carbon species (dissolved and particulate, inorganic and organic) in the water column.

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APPROACH

Under previous funding from ONR Code 322 OM we have developed a Vortex Lattice Model for mine burial prediction. We are now improving the model by developing code for providing movable boundary conditions within the existing architecture. The code for the farfield boundary condition is based on advection/diffusion solutions for the mass balance of a propagating accretion/erosion wave (Figure 1a). The computational methodology is based on a series of boundary-conforming, coupled control cells (Figure 1b). The net change of the volume fluxes q between any given control cell and its neighbors (divergence of drift) results in a change in the position of the shoreline boundary Δx. Shifts in the shoreline boundary condition resulting from divergence of drift will in turn cause the shorerise and bar-berm profiles to adjust to a new equilibrium (Figure 1c). These profile adjustments can either bury or expose previously buried mines (Figure 2a). At a tidal inlet, these dynamics are impacted by the negative divergence of drift caused by local refraction over the inlet bar system and any net tidal flux introduced to the volume flux balance of the effected control cells.

For the nearfield scour burial processes, we plan to upgrade our code using stress strain-rate relations based on thermodynamic and invariance principles such as those invoked by Goodman (1970), and Goodman and Cowin (1971, 1972). These equations account for dilatation of the granular bed under the mine that may occur during the cyclic loading of heavy mines having a small bed contact footprint, particularly under near breaking waves. Dilatation is provided in these more advanced stress-strain rate equations by inclusion of the solids volume concentration of the bed sediments as an independent kinematic variable. At equilibrium, these equations reduce to the Coulomb yield criteria of the granular statics formulations presently used by our model. These proposed upgrades for granular fluid relations of the model will be calibrated separately for quartz and carbonate sediment.

WORK COMPLETED

The Vortex Lattice Model has undergone initial coding and de-bugging of the upgrades for accretion/erosion waves. The model has been subjected to additional field testing during FY2001 off Scripps Pier, La Jolla, CA and off the Naval Amphibious Base, San Diego at Silver Strand Beach, CA. The Scripps Pier experiments involved the MANTA mine and the MK VII VSW Marker, Type AFD. The Silver Strand Beach experiments were in conjunction with MK VII marine mammal exercises conducted by SPAWAR, Code D352. These experiments have been used to calibrate the model for the effect of seasonal profile changes off Scripps Pier. Figure 2b shows a clear relation, for mines placed in 7 meter deep water, between mine exposure during the winter months and mine burial during the summer months. Also the experiments have validated divergence of the drift for a simulated hindcast using measured waves and beach profiles (Figure 3); and have provided a concept demonstration of mine burial near Alameda Naval Station using sediment flux from the Sacramento River (Jenkins and Inman, 2001). Further validation of the model awaits field data from the Mine Burial Program.

RESULTS

The new model codes using the formulations for movable boundary conditions (Figure 1) are being tested against archival databases. Figure 3c shows a successful hindcast of an accretion/erosion wave at Camp Pendleton caused by the 1980 and 1983 El Niño events.

An analysis was performed of 7,524 days of the reconstructed wave record at our Manta mine burial test site off Scripps Pier (Figure 4a). The histogram was proportioned for wave height bands that corresponded to the burial percentages of the mine burial state (MBS) classification based on the 24 hour burial sensitivity of a MANTA computed by the model (red line Figure 4b). Burial rate data (crosses in Figure 4b) were obtained from field observations, beginning with an initial state of no burial.

The modeled burial response (red line in Figure 4b) was used in conjunction with the wave histogram function to construct a conditional probability density for each of the mine burial.

The resulting conditional probability density as a function of wave height is shown in Figure 4c. Because data extended to only 3 m wave height, burial classes E and R were extrapolated from the calibrated mine scour/burial model.

It is interesting to note that when the mine initially has no burial, the probability is zero that it will still be in that state 24 hours later. The highest likelihood is that the mine will experience some degree of burial (up to 25%) in the first 24 hours. For this case P(B/A) = 0.73. Our coastal classification system is used to extrapolate these results to other coastal types. These extrapolations will be used to provide global estimates in a Mine Burial Primer. The primer is nearing draft status.

IMPACT/APPLICATIONS

Accretion/erosion waves associated with river runoff and migrating inlets are common cases that induce net changes in the littoral budget of sediment. However it appears that accretion/erosion waves in some form are common along all beaches subject to longshore drift of sediment. This is because coastline curvature and bathymetric variability (e.g., shelf geometry and offshore bars) introduce local divergence in the longshore drift. Consequently this work has wide potential application to many coastal engineering problems, including beach stability, beach nourishment, and public policy.

RELATED PROJECTS

The Vortex Lattice Model has been used as a design tool in the development of the VSW Neutralization Marker for the Marine Mammal Systems Branch, SPAWAR, Code D352. The model results for the VSW marker were used in the preparation of the Weapons System Explosive Safety Review Board, WSESRB documents. In addition, sensitivity analysis of the model is being applied to evaluations of new lane marking concepts by the VSW/MCM detachment at PMS-EOD 7023.

TRANSITIONS

Three separate transitions are in progress: a) Contribution to the Mine Warfare Environmental Pocket Handbook, b) development of Mine Scour and Burial, a Primer for Fleet Use, and c) provide source code of the Vortex Lattice Model for the Ocean Atmosphere Model Library (OAML).

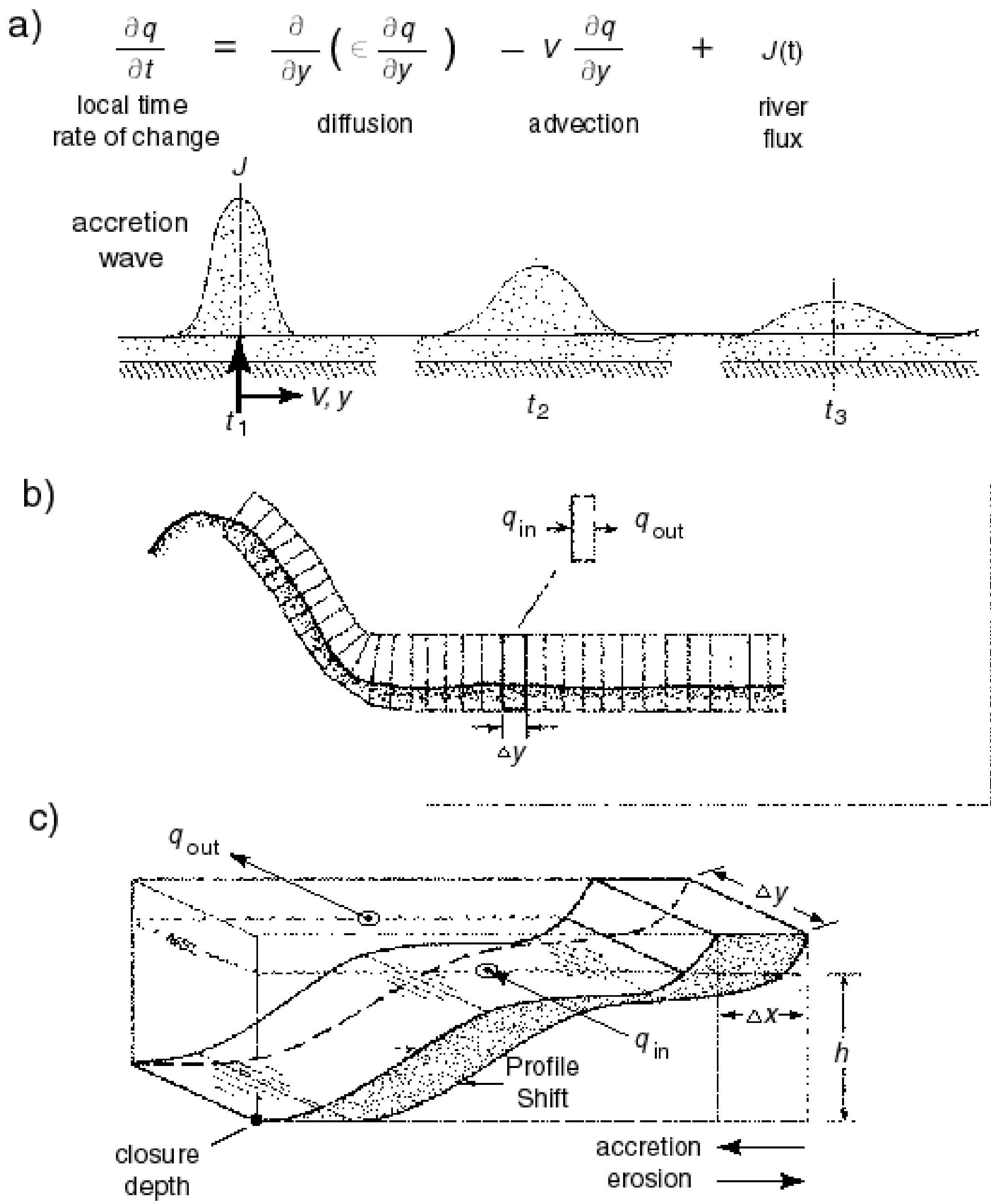

Figure 1. Computational approach for the accretion/erosion wave problem; a)mass balance, b) coupled control cells, c) beach profile adjustment.

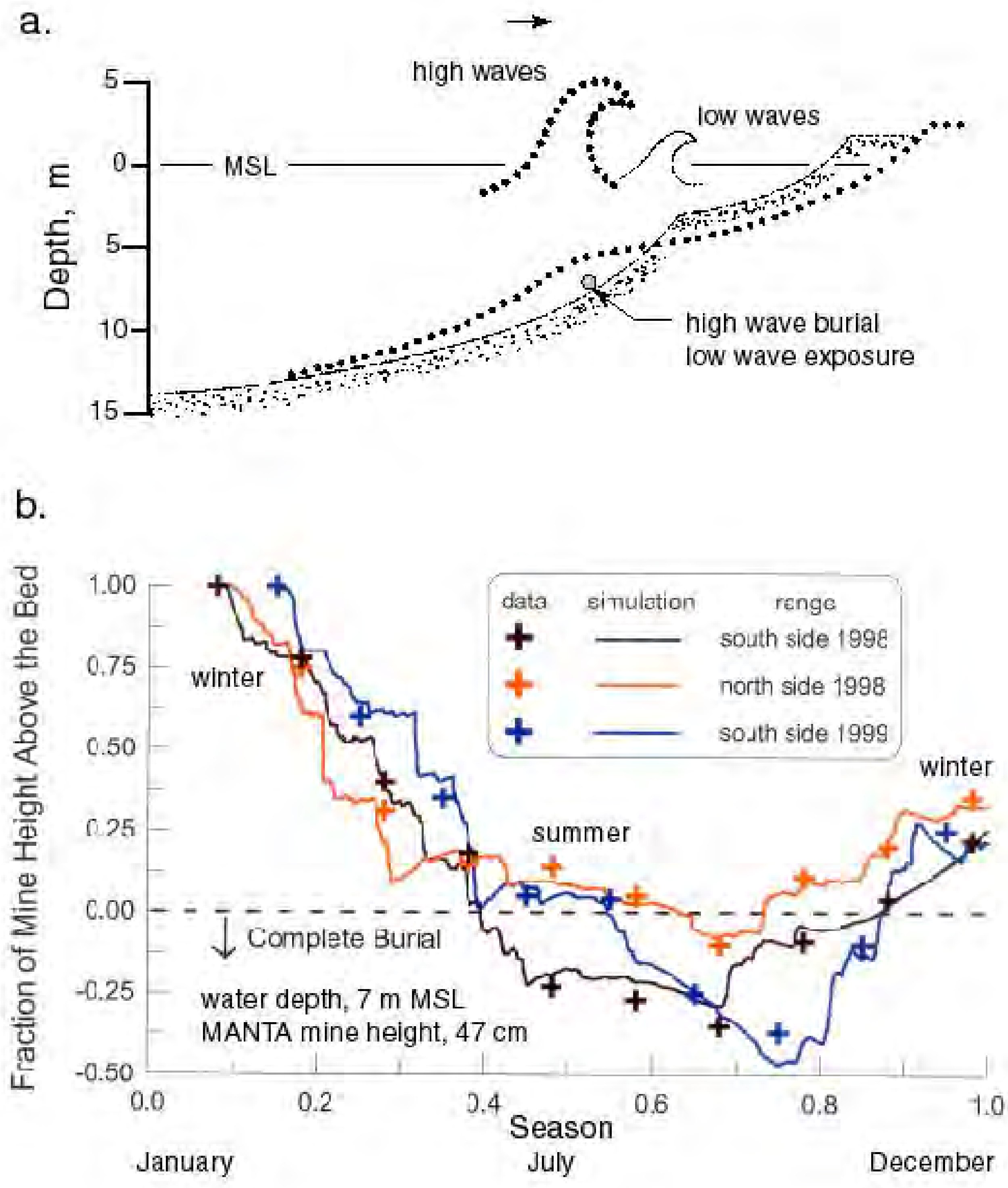

Figure 2. (a) Beach profile changes due to seasonal wave climate and/or net decrease/increase in source material. (b) Burial and exposure of two MANTA mines associated with seasonal profile changes off Scripps Pier. Solid line is model simulation, "+" are field observations.

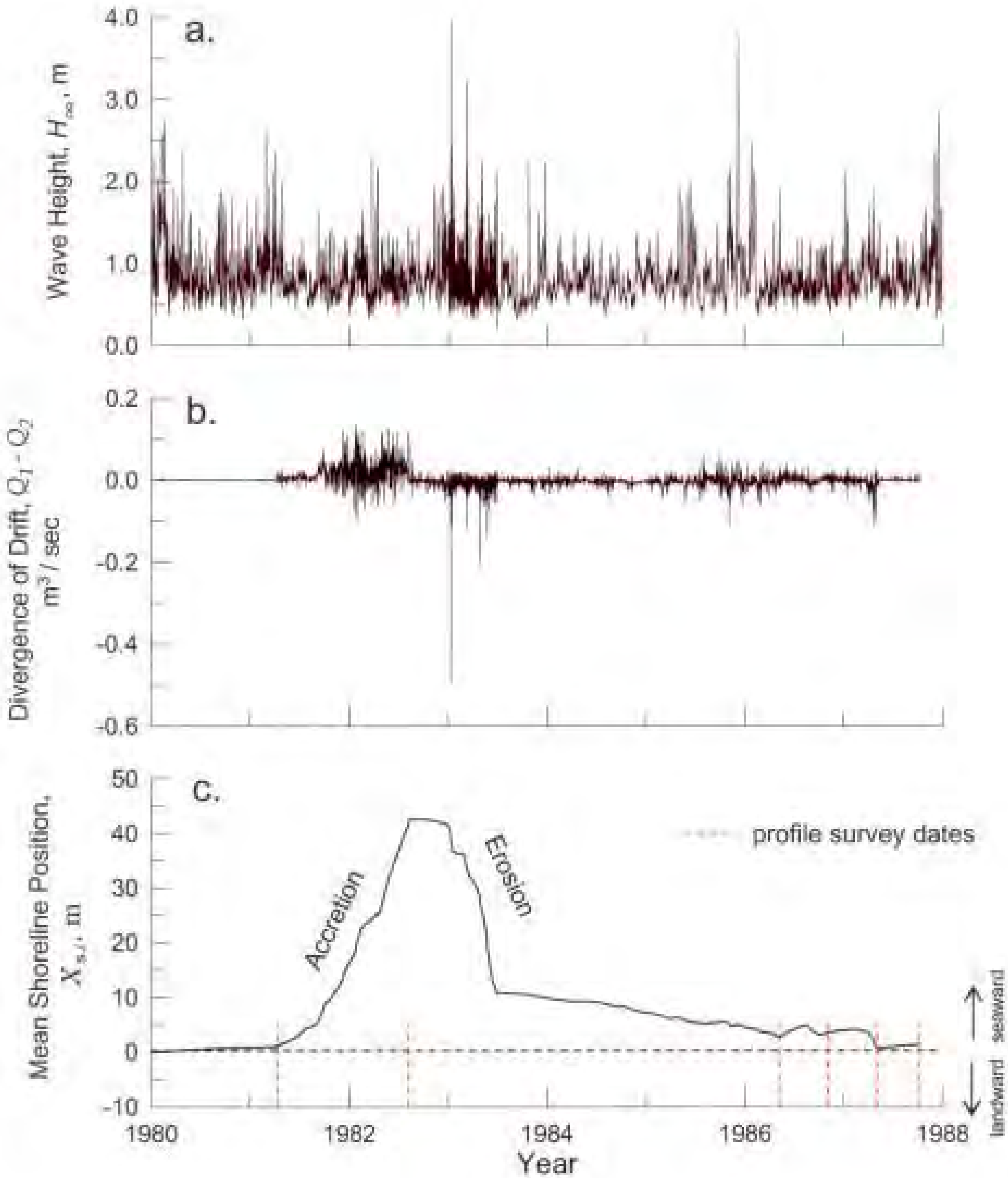

Figure 3. Wave and sediment budget for 1980-88 for 2 km length of coast that included PN1180 in the Oceanside/Camp Pendelton region. a) root mean square wave height, b) divergence of littoral drift, and c) the resulting mean shoreline position relative to initial survey (PN1180, March 1981) [from Jenkins and Inman, submitted 2001d].

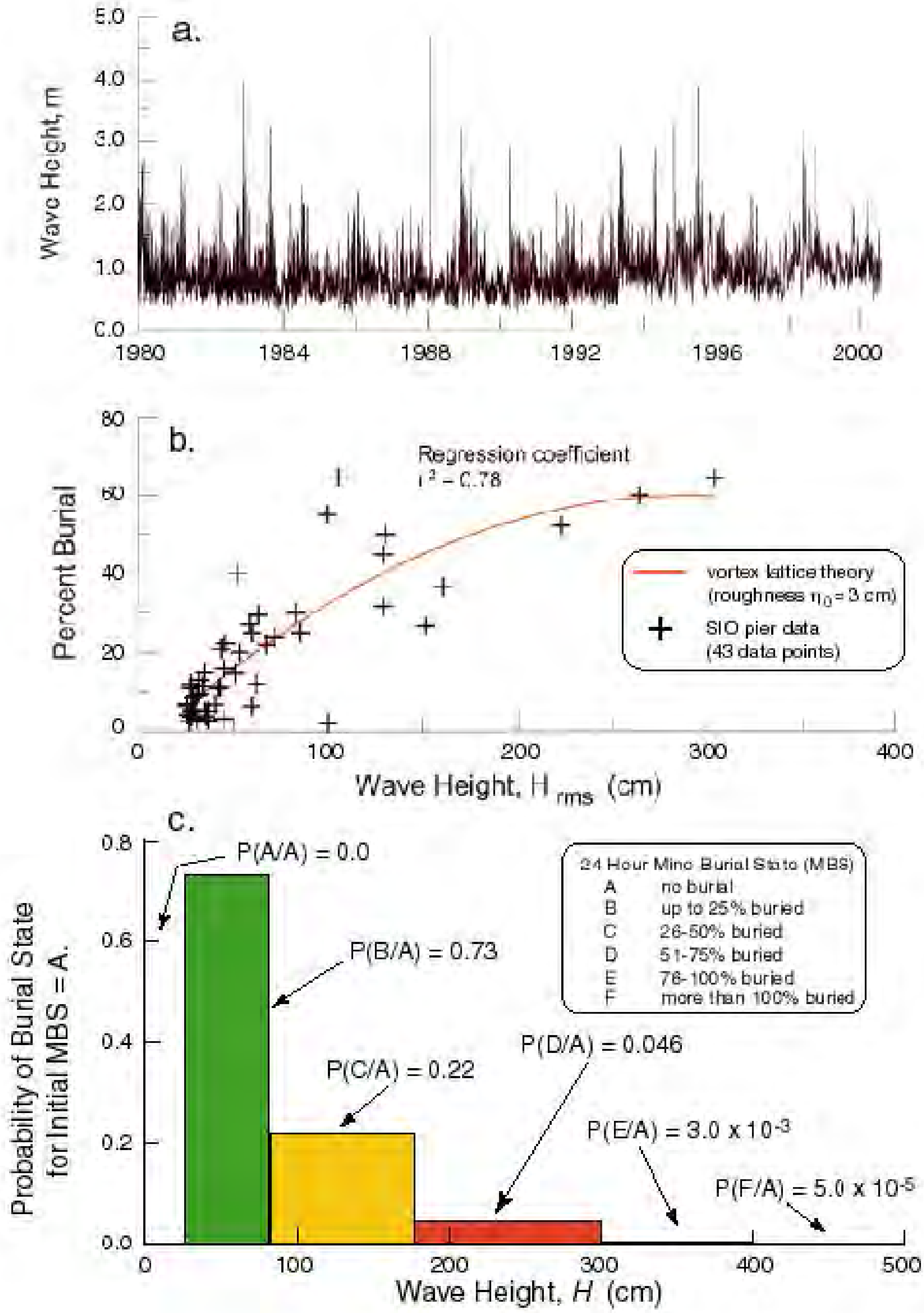

Figure 4. Probability of mine burial for MANTA mine, depth 7m. a) Wave climate history at Scripps Pier mine burial test site; b) twenty four hour burial percentage as a function of wave height; c) conditional probability of mine burial states A-F given initial burial state A . states, given the initial MBS = A.

PUBLICATIONS

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