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REPLY

Reply to: Dubois, R. N., 2000. Discussion of: E. Robert Thieler, Orrin H. Pilkey, Jr., Robert S. Young, David M. Bush, and Fei Chai, 2000. The Use of Mathematical Models to Predict Beach Behavior for U.S. Coastal Engineering: A Critical Review. *Journal of Coastal Research*, 16(1), 48–70. *Journal of Coastal Research*, 16(3), 946–949.

E. Robert Thieler†, Orrin H. Pilkey, Jr.‡, Robert S. Young§, David M. Bush††, and Fei Chai‡‡

†U.S. Geological Survey
384 Woods Hole Road
Woods Hole, MA 02543, USA
rthieler@usgs.gov

‡Division of Earth and Ocean Sciences
Nicholas School of the Environment
Duke University
Durham, NC 27708, USA

§Department of Geoscience and Natural Resource Management
Western Carolina University
253 Stillwell Hall
Cullowhee, NC 28723, USA

††Department of Geology
State University of West Georgia
206 Callaway Hall
Carrollton, GA 30118, USA

‡‡Department of Oceanography
University of Maine
223 Libby Hall
Orono, ME 04469, USA

We thank Dubois for his sincere discussion (DUBOIS, 2000) of our recent paper (THIELER *et al.,* 2000) on the use of mathematical models used to predict beach behavior. In this reply, we address the following major points of Dubois' discussion:

(1) his assertion that we have misread his results on shoreline response to sea-level rise; and
(2) the specific questions he asks us about our philosophy concerning the use of models in coastal science and engineering.

The "Transgressive Barrier Model"

Dubois suggests that we have misread some of his work, wrongly attributing his recent papers to further endorsement and application of the Bruun Rule. He states, that in "1990 I stopped embracing the Bruun Rule in favor of a transgressive barrier model" (DUBOIS, 2000, p. 946). We agree that his views have changed. His transgressive barrier model, however, may be characterized simply as a "Bruun variant" since it is two-dimensional and employs similar geometric and process-related assumptions about the evolution of the shoreface profile in response to sea-level rise (*cf.* BRUUN, 1962 and DUBOIS, 1995). Nonetheless, Dubois' transgressive barrier model probably does improve on the Bruun Rule, in that it is based on further observation of natural systems and attempts to incorporate geologically reasonable variables that should affect the evolution of the shoreface profile (*e.g.,* sediment lost to overwash).

The major distinction we draw between models like Dubois' and the models that we criticized in our paper (THIELER *et al.,* 2000) is that his model is not used for the kind of specific engineering prediction as the models we criticized. Dubois' model is concerned with understanding the interplay between sediment transport directions and shoreface profile shape through the application of assumptions about physical processes on the shoreface. This is a far different endeavor than the specific prediction of future beach nourishment volumes, benefits and costs for a particular beach over the next 10–50 years that is frequently the focus of applied coastal modeling.

As we pointed out in our paper (see THIELER *et al.,* 2000, Table 1), it is important to distinguish between models that are used to answer qualitative ("how, why, and what if") questions and those that are used to answer quantitative ("when, where, and how much") questions. Dubois' transgressive barrier model falls into the category of basic scientific models that are used to examine "how, why, and what if?" questions about earth surface processes (THIELER *et al.,* 2000). It is not, to our knowledge, used as a beach design tool for applied coastal engineering.

Response to Dubois' Specific Questions

In his discussion, Dubois ask several specific, insightful questions about our views on modeling coastal processes for engineering prediction. His questions (DUBOIS, 2000) are itemized below. Our responses follow.

(1) In response to the question of what do we do if the mathematical models that predict beach behavior do not work, their reply is "it is not incumbent upon us to offer any solutions at all" (p. 64). Is there a temporal condition set to this response? Does this statement mean that they will

not now nor in the future work to develop better mathematical models that predict beach behavior?

Dubois misunderstands our comment. We identified this as one possible response to criticism of our paper. Since the paper goes on to describe several different options for predicting sand volume and durability of beach nourishment projects (as an example), we contend that we have offered an initial suggestion to the design of coastal engineering projects.

In a larger sense, however, our entire paper is concerned with "working to develop better mathematical models." As we stated in our paper, it is clear to us that the current generation of mathematical models are inadequate for the tasks for which they are used. Moreover, we argue that model development to date has been wrongheaded; that is, the development of assumptions about beach behavior from wave tank experiments or limited field data has reduced the observation of natural and engineered beaches (*i.e.,* monitoring) that provides insight into the behavior of real beaches.

Finally, we contend that we *are* working to develop better beach behavior models by examining them in the light of what is understood about geologic and oceanographic processes. This is the true intent of our paper—pointing out model shortcomings in the hope that model limitations become more widely understood, and that better, more appropriate models can be developed for predicting the behavior of beaches at time and space scales useful to engineering and coastal management.

(2) "The listing of assumptions in Tables 2 and 3 should not be construed as an appeal to make models more complex by including more variables" (p. 65) if predictive models do not work. Why not add more variables to a model if additional variables will improve model accuracy? Why stop this line of research?

Simply adding more variables will not necessarily make a model more accurate. Indeed, it may make the situation worse. In a simple model with a minimal number of variables, it is relatively straightforward to identify the parameter(s) to which the model is sensitive, and thereby come to an increased understanding of how the model is utilizing the input data to develop its output. As the number of variables increases, this task becomes more difficult. Simply putting in more variables without an understanding of (a) their geological or oceanographic significance, or (b) how they may affect the behavior of the model itself, is inappropriate. It is our opinion that applied coastal modeling is not yet ready for this step. A more refined basic understanding of physical processes and system response is needed.

(3) "It is equally clear that there will be no universal model for coastal evolution. A local to regional approach is needed" (p. 64). How do they know the results of future coastal research? Is it not possible that future research could yield universal models with terms reflecting local or regional conditions?

In our opinion a "universal model" that incorporates local to regional conditions ceases to be universal. The parameters to be used, number and type of variables, sensitivities, time period to be addressed, *etc.* make each situation unique. As we point out in our paper (THIELER *et al.,* 2000), some variables may be of fundamental importance on one beach, and of no consequence on another. Could anyone who understands the complexity and variability of the world's many coastal systems really imagine that one model could ever be appropriate for all of them? We don't believe so.

(4) We cannot help wondering if the authors have reached the conclusion that the human mind is incapable of formulating mathematical models that can *reasonably replicate* [emphasis added] our complex coastal environment, and are, therefore, indirectly suggesting that we disengage from this kind of theoretical research and shift our attention to empirical studies.

We certainly have *not* suggested that we disengage from "theoretical" research modeling. Modeling can be a very useful academic exercise. We do advocate disengaging from the application of inadequate models used for coastal engineering and the determination of benefit-cost ratios. It is our opinion that modeling at this time and space scale may be difficult or impossible due to the inherent complexity of the coastal system. It is akin to trying to predict accurately the daily weather over a period of decades.

The field of tropical system meteorology offers insight into this kind of endeavor. The accurate prediction of the path and strength of North Atlantic hurricanes has been the goal of very sophisticated modeling for several decades now. In this effort, reams of data are collected for model input. Reams of post-storm data are used to examine model inaccuracies. Yet, storm tracks still cannot be predicted more than a few days into the future at best. And even that can be a challenge. For example, during Hurricane Floyd (September 1999) the entire southeastern U.S. coast was evacuated unnecessarily. Given this situation, coastal scientists and engineers are at a significant disadvantage, since the coastal system is arguably more complex, and we lack even a fraction of the data.

Dubois uses an interesting phrase when he speaks of model development to address the complex coastal environment: "reasonably replicate." Here lies the crux of the matter: what constitutes "reasonable replication"? Do we think that modeling coastal project performance 50 years into the future with the level of detail required for engineering prediction will ever be possible? Probably not.

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