SUSAN L. BALES

THE SIGNIFICANCE OF LEWEX FOR SHIP DESIGN AND OPERATIONS

Gross disagreements between measured and forecast spectra can often be explained by small errors in time or location.

During a conversation about ocean waves and linear superposition some years ago, a friend of mine noted that the sea cannot be measured by the bushel. During the Labrador Sea Extreme Waves Experiment (LEWEX), I was convinced at times that the sea could not be measured by any unit, instrument, or other means, regardless of one's intention. Then, after a few delicate days of high sea states, just as we reached our destination at the two LEWEX measurement sites, we encountered what seemed to be the lowest extreme waves ever experienced. Accordingly, the crew of HNLMS *Tydeman* renamed the experiment but kept the acronym. On the basis of climatology, most of us had predicted six- to ten-meter sea states, but only two- to five-meter seas were measured.

Other papers in this issue address scientific issues. But from the point of view of ship design and operation, I would like to discuss future requirements regarding the accuracy of ocean wave measurements. A few years ago at an ocean wave symposium at APL, I suggested that the seafaring community requires wave measurement accuracies of ± 0.3 m in significant wave height through sea states 4 to 7, ± 1 s in modal period over a range of 3 to 24 s, and $\pm 7.5°$ in directional spreading in 15° increments.

Those requirements were based on the responsiveness of typical marine vehicles to the wave spectrum. I failed to address two areas not inherent in design work that make all the difference in the world at sea, namely, time and location. During LEWEX, we found that the wave forecasts available to us on board the ship did not have adequate resolution to identify important temporal and spatial variations in the ocean. Two years have passed since I examined those data, but I do not recall reasonable agreement between prediction and reality, reality in this case being the human sensor on the spot. This aspect of the forecasts is critical when one is trying to route ships, avoid damage, maximize ship system performance, or determine in real time where to drop buoys for an ocean experiment such as LEWEX. Although temporal and spatial forecast errors are not as critical for land-based design studies, where omissions at one location or time are picked up at another, their significance at sea is an entirely different matter.

From the applications viewpoint, I think the most critical user issue in ocean waves, for the next decade at least, is that of space and time. I believe the marine vehicle design community is nearly adequately equipped with operational databases and spectral models to do its job. Although most ships, certainly those in the U.S. Navy, are not as structurally survivable as they once were, they are still adequate. We expect a certain amount of damage and can sustain it.

A reliable forecast of the weather, including wind and waves, can make a tremendous difference to a ship at sea, particularly in heavy seas. We can justify ocean wave research merely because it is good science. But can we continue to find adequate financial support without making a substantial contribution to national economic or defense goals?

Mathematicians have been experimenting with chaos theories for at least a decade. They have concluded that long-range weather forecasting is extremely sensitive to the initial conditions. Although the models may agree well with measurement initially, a slight perturbation eventually makes a huge difference.

Could small errors in initial values be our major problem in forecasting? Playing the devil's advocate for a moment, one could argue that from the viewpoint of an individual ship, global modeling is not very helpful, and that *in situ* or remote measurements in local areas are more critical. Hullborne radars, expendable buoys, and constellations of satellites with appropriate down-links to land and shore sites could provide initial values, data for climatology upgrades, and localized ocean wave data.

LEWEX can help sort out where we are, in both modeling and sensor capabilities, and can provide us with a forum to continue the multidisciplinary synergism that it has fostered. The resulting insights could shape wave research and applications for the next decade.

THE AUTHOR

SUSAN L. BALES is the Science Advisor to the Chief of Naval Operations. She was previously involved in seakeeping and oceanographic research at the David Taylor Research Center, and coordinated the NATO component of LEWEX.