Seasonal and Geographic Constraints For Acoustic Surface Scatter

Jeffrey L. Hanson
The Johns Hopkins University / Applied Physics Laboratory
Laurel, MD 20723-6099
phone: 240-228-4292 fax: 240-228-6908 email: jeffrey.hanson@jhuapl.edu
Award #: N00014-98-1-0310
http://www.jhuapl.edu

LONG-TERM GOAL

The long-term goal of this research is to develop an improved prediction capability for acoustic surface scatter in open ocean and littoral regions. Special emphasis is given to the identification of easily observable environmental factors, intrinsically related to surface wave and bubble cloud scattering, which can be used as inputs to next-generation scattering models.

OBJECTIVES

Although significant advancements have been made in understanding the physical mechanisms of low-frequency (<1000 Hz) surface scatter, a lingering mystery is explanation for large scattering level differences (~ 15 dB) between observation sets obtained under apparently similar wind forcing conditions (Nicholas et al., 1998, McDaniel, 1993). It is hypothesized here that site-to-site differences in surface scattering strength (SSS) are dependent upon the environmental forcing conditions that influence surface wave and bubble cloud evolution at each site. Hence, the primary objective is to demonstrate that significant SSS prediction improvements can be made when site-specific environmental forcing conditions, in addition to local winds, are used in a predictive model.

APPROACH

Surface scattering strengths were consistently measured in six contrasting open-ocean environments during the multi-year Critical Sea Test (CST) program (Ogden and Erskine, 1994A and 1994B). The observations at each site cover a wide variety of atmospheric forcing conditions, and a detailed suite of environmental measurements accompanied each acoustic observation (Hanson, 1993; Hanson and Erskine, 1992). The CST data were used by Nicholas et al. (1998) to construct a best-fit multiparameter empirical model for SSS. The resulting Nicholas-Ogden-Erskine, or ONE SSS algorithm employs wind speed measured at 10-m height (U10) as the sole environmental input to predict SSS over a range of acoustic frequencies and grazing angles.

In the present study the ONE-model prediction errors have been calculated;

$$SSSe = SSSone - SSSobs,$$

where the ‘one’ and ‘obs’ subscripts represent model predictions and observations, respectively, for each CST observation set. A strong site-to-site variability in SSSe makes this an ideal parameter to test the hypothesis that environmental factors can be used to improve SSS predictions. Using multivariate

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analysis techniques, relationships between SSSe and a variety of wave- and bubble-related environmental descriptors were explored. The significance of each environmental factor as a function of wind speed, acoustic frequency, and grazing angle was determined.

The environmental factors used in the SSSe analysis included wind speed at 10-m height (U_{10}), significant wave height (h_s), wave steepness (S_p), ocean temperature at 1-m depth (T_1), mixed layer depth (z_{ML}), atmospheric stability (T_{a-s}), and chlorophyll concentration (chl). Each of these factors was either directly or indirectly measured except for chl, which may be an indicator for bubble-stabilizing surfactants associated with phytoplankton biomass. Monthly chl averages for each site were obtained from the multi-year Coastal Zone Color Scanner (CZCS) mission (see URL: http://seawifs.gsfc.nasa.gov/).

WORK COMPLETED

A multiple least-squares regression analysis was performed to determine if some combination of the candidate environmental factors (U_{10} , h_s, S_p, etc.) could be used to systematically explain site-to-site variations in the surface scatter prediction error SSSe. The first step in the process was to test various prediction error models of the form

$$SSSe = \alpha(e1) + \beta(e2) + \ldots + b,$$

where e1, e2, etc. represent specific environmental factors. Within our list of candidate environmental factors, all possible combinations of 1-, 2-, and 3- factor models were tested over the full range of frequencies and grazing angles in the CST observation set. The successful results were used to demonstrate that significant prediction improvements can be made by incorporating essential environmental factors into a scattering model.

This work was presented at the 136th meeting of the Acoustical Society of America (Hanson, 1998). A paper for the IEEE Journal of Ocean Engineering is in preparation.

RESULTS

The results show that much of the discrepancy between SSS observations and Ogden-Nicholas-Erskine (ONE) model predictions is explained by considering environmental descriptors for surface waves and bubbles.

The mechanisms that control ONE model prediction errors are wind-speed dependent. At low wind speeds, SSS is highly correlated to surface wave steepness. Low wind prediction errors are probably related to the use of Pierson-Moskowitz wave model, rather than ambient roughness conditions, in the ONE-model predictions.

At moderate to high winds (> 6 m/s), SSS is highly correlated to wave height. This dependence is demonstrated by the results from 950 Hz and 18° grazing angle appearing Figure 1. The ONE model increasingly under-predicts the scattering levels as h_s increases. This trend is observed both within, and across, observation sets. This influence is likely related to the supply and entrainment of bubbles by breaking waves. Furthermore, SSS at moderate to high winds is also correlated to mixed layer temperature, especially at low frequencies. This dependence may be related to the influence of gas saturation / dissolution rate on large bubble structures.

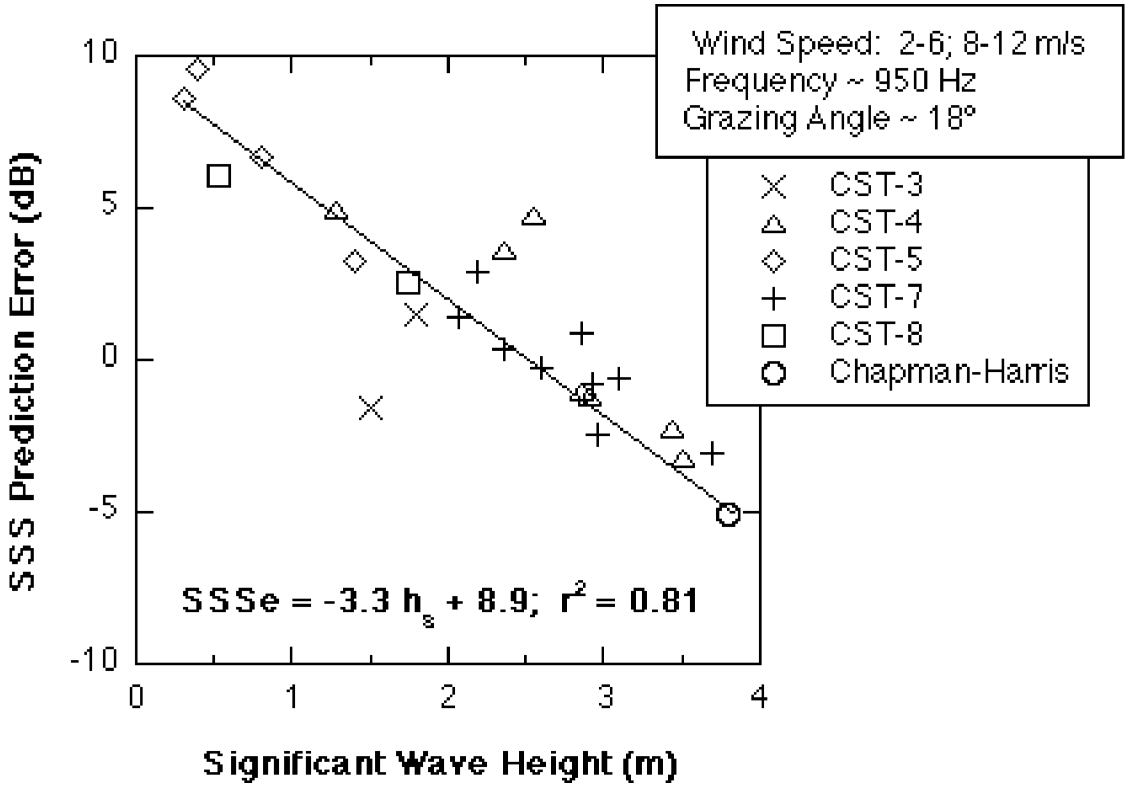

Figure 1. Dependence of ONE model prediction errors on wave height.

At the highest wind speeds, SSS appears to be correlated to chlorophyll concentration. This dependence is probably due to surfactant stabilization of entrained microbubbles.

To demonstrate the prediction improvements possible by considering additional environmental factors, a 2-parameter (h_s, T_1) model for SSSe is formulated:

$$SSSe = \alpha h_s + \beta T_1 + b.$$

The coefficients to this model were found to be smoothly varying over the ONE model input parameter space: acoustic frequency, grazing angle, and wind speed. The results from this model were cast as a correction factor to ONE model predictions such that

$$SSSenv = SSSone - SSSe.$$

Applied to observations obtained over a wide range of frequencies, grazing angles, and wind speeds, the environmental correction factor model resulted in ~70% reduction in unexplained variance for SSS predictions. These results appear in Figure 2.

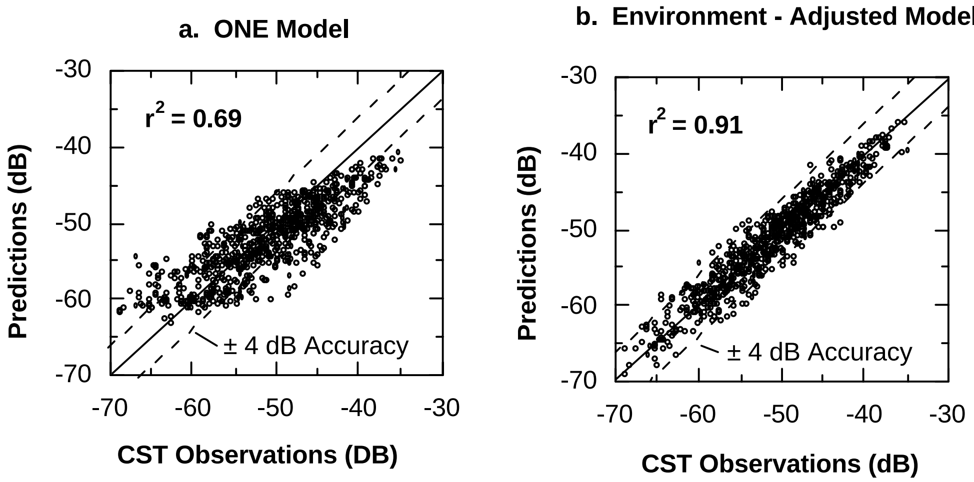

Figure 2. Surface scattering strength predictions vs. CST observations at winds speeds of 3-12 m/s, frequencies of 100-1000 Hz, and grazing angles of 13-27°. a. ONE model. b. ONE model adjusted with wave height and ocean temperature corrections.

IMPACT / APPLICATIONS

This study has identified critical environmental factors that must be considered to understand and predict upper ocean surface scatter. Future investigations should focus on resolution of these issues; namely, identification of specific processes by which surface waves, ocean temperature, and phytoplankton influence bubble clouds and surface scatter.

TRANSITIONS

The surface wave parameters used in this study were extracted from wave spectra using techniques developed in an earlier ONR-funded study (with Owen Phillips - JHU).

The results from the present analysis are guiding additional investigations of the ASREX SSS observation set.

Furthermore, it is anticipated that a FY00-01 field effort will include special investigations of surface wave, temperature, and phytoplankton influences on bubble populations.

REFERENCES

Hanson, J. L. (1998). Environmental factors for site-to-site differences in low-frequency surface scatter, *J. Acoust. Soc. Am.*, **104**(3) part 2, pp.1821.

Hanson, J. L. (1993). Winds, waves, and bubbles at the air-sea boundary, *Johns Hopkins APL Tech. Dig.* **14**(3), pp. 200-208.

Hanson, J. L. and F. T. Erskine (1992). An experiment to study the influence of the air-sea boundary zone on underwater acoustic reverberation, in Proceedings MTS '92, Vol. 2, Washington, D.C., Marine Technology Society, pp. 835-847.

Ogden, P. M. and F. T. Erskine (1994A). Surface and volume scattering measurements using broadband explosive charges in the Critical Sea Test 7 experiment, *J. Acoust. Soc. Am.* **96**(5), pp. 2908-2920.

Ogden, P. M. and F. T. Erskine (1994B). Surface scattering measurements using broadband explosive charges in the Critical Sea Test experiments, *J. Acoust. Soc. Am*., **95**(2), pp. 746-761.

McDaniel, S. T. (1993). Sea surface reverberation: A review, *J. Acoust. Soc. Am*., **94**(4), pp. 1905-1922.

Nicholas, M. P. M. Ogden, and F. T. Erskine (1998). Improved empirical descriptions for acoustic surface backscatter in the ocean, *IEEE J. Oce. Engineer*., **23**(2), pp. 81-95.

PUBLICATIONS

Hanson, J. L., and O. M. Phillips (1999). Wind sea growth and dissipation in the open ocean, in press, *J. Phys. Oceanogr*.

Hanson, J. L. (1998). Environmental factors for ocean bubbles, in Proceedings of the International Symposium on Seawater Drag Reduction, Naval Undersea Warfare Center, Newport, RI., pp. 163-167.

Hanson, J. L. (1998). Environmental factors for site-to-site differences in low-frequency surface scatter, *J. Acoust. Soc. Am.*, **104**(3) part 2, pp.1821.