

Acoustic Propagation Studies in the Nonlinear Internal Wave Initiative (NLIWI) in the South China Sea (SCS)

D. Benjamin Reeder
Dept. of Oceanography
Naval Postgraduate School
Monterey, CA 93943
Phone: 831-656-3268 Fax: 831-656-2712 E-mail: dbreeder@nps.edu

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LONG-TERM GOALS

Quantify the temporal and spatial variability in acoustic propagation characteristics on the continental shelf in the South China Sea in the presence of trans-basin and locally-generated nonlinear internal waves; specifically: (1) at long ranges (up to 100 km), to investigate (a) the focusing effect in acoustic propagation parallel to the NLIW's, and (b) range dependence over long distances, through a highly dynamic environment, towards the physical oceanography study area along 21N; and (2) at short ranges (<10 km), to limit the number of internal waves and bottom interactions, allowing (1) better quantification of the statistics of acoustic fluctuations in an unsaturated regime as a function of time, frequency, range and bearing relative to internal wave fronts, and (2) isolation of the relative contributions of the variability in the water column and bottom topography/composition.

OBJECTIVES

Assist Taiwanese scientists at the National Taiwanese University (NTU) and the National Sun Yat-Sen University (NSYSU) in the design, construction and deployment of acoustic moorings, and statistical characterization of the acoustic propagation intensity fluctuations due to water column and bottom property variability on the continental shelf over propagation ranges of less than 10 km. Specifically, the goals are to (1) quantify the role of bottom topography and composition as a function of time, range, bottom incidence angle and bottom topography/composition over short distances of less than 10 km in the "acoustics area" (AA) (Fig. 1) on the continental shelf, and (2) characterize the (3D) spatial-temporal variability in received acoustic propagation intensity caused by the trans-basin and locally generated internal waves. Isolating the relative contributions by the water column and bottom property variability is made possible by leveraging the water column measurements by the NLIWI physical oceanography (PO) component and the detailed bottom survey information from ASIAEX.

APPROACH

The acoustic work has been a collaborative effort between NPS, NTU and NSYSU, and has taken advantage of the physical oceanography measurements in NLIWI. Dr. T. Y. Tang and Dr. C. F. Chen of NTU provided the research vessels Ocean Researcher I (OR1) and Ocean Researcher III (OR3) with sufficient ship time to support the execution of the acoustic field experiment. Dr. Chen provided supplemental acoustic equipment, including an acoustic vertical line array (VLA), as well as her acoustics expertise to the investigations. Dr. R. C. Wei provided warehouse support for storing and staging mooring equipment in preparation for the cruises and was the Chief Scientist on the OR3

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which deployed the tethered VLA along the transect to the south of the AA shown in Fig. 1. Dr. Barry Ma was the co-Chief Scientist on OR1 and deployed two ambient noise instruments during the cruise, as well as coordinating operations during the cruises.

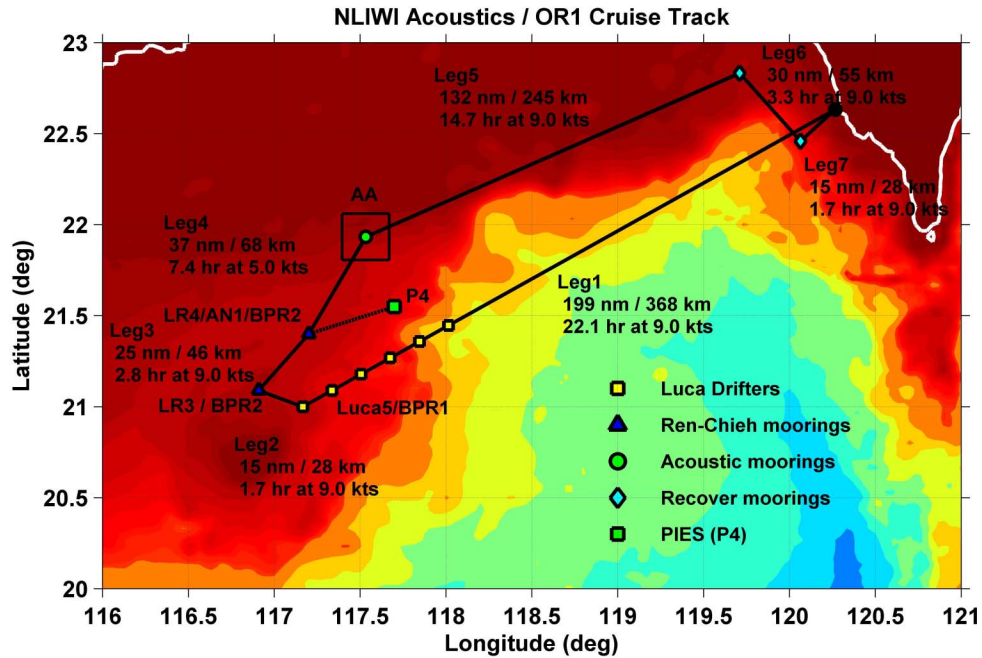


Fig 1. Cruise plan for the OR1 showing the ship track and acoustics area (AA).

The field experiment occurred from 12 to 22 April, 2007, which included an eleven day cruise on the OR1 and a five day cruise on the OR3. Before deploying the acoustic moorings in the AA, drifters, bottom pressure recorders, ADCP moorings, ambient noise instruments and inverted echosounders were deployed, to contribute to the overall scientific effort of the NLIWI. In the AA, two moored, internally recording, vertical line arrays (VLA), each consisting of 8 hydrophones, and one moored 400-Hz sound projector, were deployed in 118 m of water on the continental shelf in the northeastern South China Sea (Fig. 2). The source and VLA's were moored along a transect oriented approximately SSW to NNE such that the acoustic propagation path was parallel to the wave fronts of the large trans-basin non-linear internal waves arriving from the basin. The VLA's were moored at 3 and 6 km distance from the acoustic source, at short enough ranges to limit the number of bottom and surface interactions along the acoustic path. The exact placement of the moorings were determined by results of pre-cruise modeling efforts. It was desired that the acoustic propagation path be in a region of minimal bottom composition and bathymetric variability, in a region of minimal fishing activity, and in a region which experiences periods of minimal internal wave activity between periods of internal wave arrivals in order to investigate acoustic fluctuations with and without internal wave variability. Temperature, salinity and pressure sensors were mounted on all moorings along the acoustic path to provide a time series of sound-speed profiles during the 7-day transmission period.

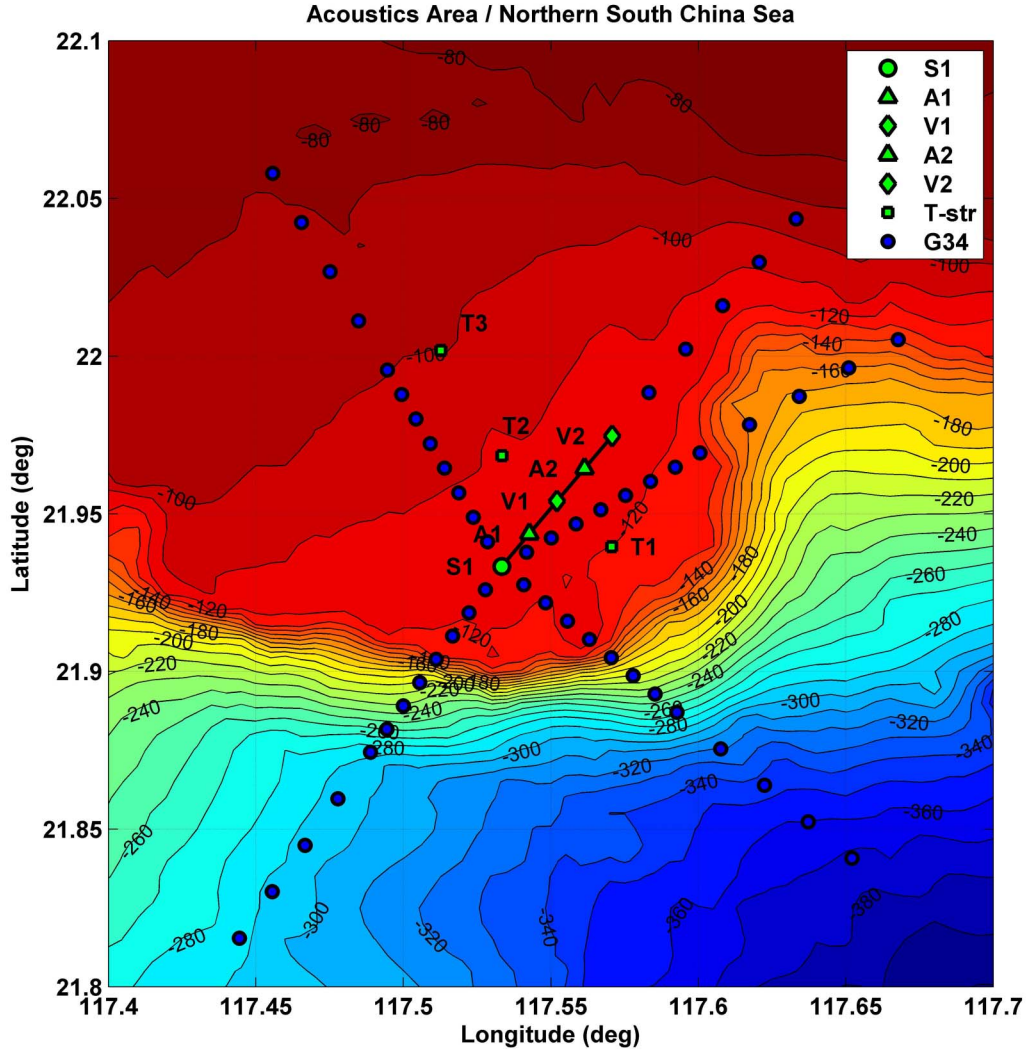


Fig 2. Mooring plan for the acoustics area (AA).

The source mooring (S1), one VLA mooring (V1), one ADCP mooring (A1) and their sensors were prepared by NPS personnel. The second VLA mooring (V2) and second ADCP mooring (A2) were provided by NTU. The source was moored close to the bottom to minimize movement due to waves and near-surface currents. The source mooring was placed in the SSW corner of the acoustics area (AA) to minimize the distance to the NLIWI physical oceanography (PO) measurements being carried out along 21N. The VLA moorings (V1 and V2) consisted of 8 omni-directional element hydrophone arrays with a 56 m aperture, with TP sensors to measure the environmental parameters. The ADCP moorings (A1 and A2) consisted of 300-Hz ADCP instruments with a measurement range of 120 m, to observe the internal waves as they pass the acoustic transmission path.

Equipped with shipboard ADCP and an EK500 echo-sounders, the OR1 (supplemented by the OR3) remained in the AA to observe the spatial structure of the internal wave field and to guard the moorings from fishing activity. In addition to the moored source, a G34 acoustic source was deployed at some of the locations marked by blue circles in Fig. 2 to investigate the high-frequency ($\sim 3\text{kHz}$)

transmission loss as a function of range and azimuth. CTD casts and other ancillary data were collected on the environment during the cruise.

WORK COMPLETED

As described above, the very successful field experiment was completed in April, 2007. Since the cruise, several presentations have been given at meetings in Taiwan, Alaska, Woods Hole, and several more are planned for future scientific meetings. Observations have been made from the initial analysis of the data (see next paragraph). Data and 3D acoustic propagation modeling comparisons are ongoing.

RESULTS

Large fluctuations in acoustic intensity occur due to internal wave-induced water column variability. The experiment was specifically designed to capture the intensity fluctuations in the acoustic propagation parallel to the wave fronts of the incoming trans-basin non-linear internal waves (NLIW).

Figure 3 shows one example of the acoustic response to the incoming NLIW's on April 16, from 1200Z to 1500Z, as recorded on the VLA (V1) 3 km from the source. The first panel shows the acoustic intensity as a function of depth and time, the second panel shows the depth-integrated acoustic energy and the third panel shows the actual environment as measured by temperature sensors at the VLA.

The NLIW's typically transit the deep basin from the Luzon Strait in the form of a single non-linear depression wave. Once the energy encounters the underwater bluff in the SE corner of the AA, the wave energy is vertically compressed and horizontally elongated on the plateau as evidenced by the very stable environment seen between 1200Z and 1300Z in the third panel. The NLIW wave energy is further converted into a train of elevation waves, as seen after 1300Z.

Before the entrance of the elevation waves, the acoustic environment is strongly downward refracting, with most of the acoustic energy trapped near the bottom. As the elevation waves pass over the source and VLA, a significant portion of the acoustic energy is redistributed throughout the water column, then 're-trapped', then redistributed, etc, as seen in both the first and second panels. These elevation waves cause fluctuations of 5-10 dB in received acoustic intensity at 3 km.

The redistribution of acoustic energy is the result of several physical mechanisms—an elevated thermocline, horizontal refraction within the elevation wave (a focusing effect due to the colder water beneath the elevation waves), and possibly some reflection by the wave front itself, which could be characterized as a horizontal Lloyd's mirror effect.

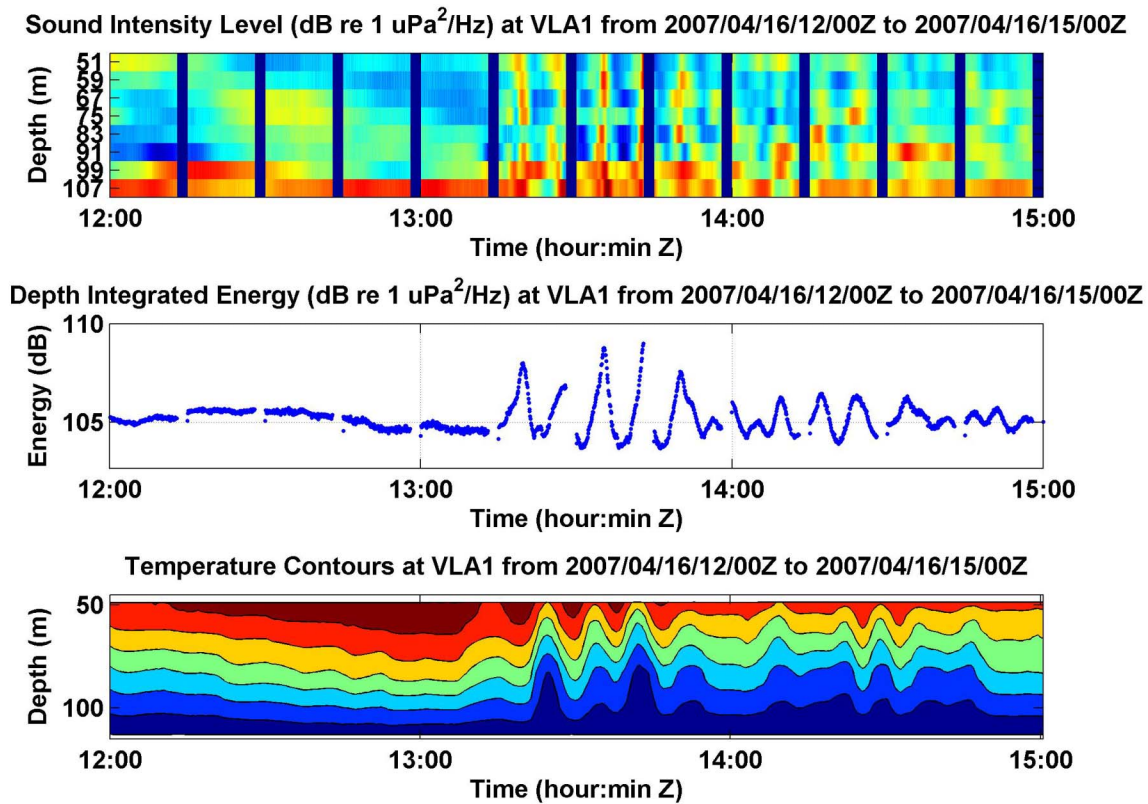


Fig 3. Acoustic fluctuations resulting from the passage of internal waves.

IMPACT/APPLICATIONS

These time- and depth-dependent, environmentally-induced fluctuations in acoustic propagation characteristics significantly impact operational sonar system performance—fluctuations which must be predicted, anticipated, and exploited for optimal ASW operations.

RELATED PROJECTS

This fully integrated acoustics and oceanography experiment should significantly extend the findings and data from SWARM, Shelfbreak PRIMER, ASIAEX and WISE, thus improving our knowledge of the physics, variability, geographical dependence and predictability of sound propagation in the shelf environment.