Sonobuoy-to-Airgun Offset Estimation and SEG-Y Header Modification

Sonobuoys are a cost-effective means of collecting wide-angle seismic data at sea, but sonobuoy data typically require some analysis to estimate the sonobuoy's location and/or source-to-receiver offset, because surface currents continuously displace a sonobuoy from it's deployment location. Here we briefly describe how we estimated source/receiver offset for the TN272 sonobuoy dataset.

We have estimated source/receiver offset by modeling the travel times of the direct water wave and the seafloor reflection. We have placed the estimated offset into the SEG-Y headers. It is possible to estimate an actual sonobuoy location for each shot, but we have not done this. Instead, we assumed that the sonobuoys moved along the path traversed by the airgun source, enabling us to use purely two-dimensional ray-tracing. We have populated the receiver latitude and longitude header values in the SEG-Y file with these inline estimates. We know from measured wind and current directions that the sonobuoys did not move in line with the shooting ship, and so the receiver locations in the headers are not correct. However, these locations yield source/receiver offsets that are consistent with the offsets in the headers, and these offsets are now reasonably well estimated. In addition, the "inline" receiver locations in the headers are amenable to a 2D raytracing analysis of these data. Investigators interested in estimating more accurate receiver locations as a function of time should download the underway wind, current and multi-beam bathymetry data from the MGDS database and conduct a fully 3D analysis of the relevant phases.

The seismic velocity of the water layer used to model direct and seafloor-reflection phases is based on data from CTD runs and Sentry dives. Those data were used to determine an average water velocity profile along the JQZ transect. For ray tracing, we approximated the average water velocity profile along the entire transect with two piece-wise continuous functions, each consisting of three linear segments (Fig. 1). The two-way travel time to the seafloor predicted from these functions and water depth, as determined from shipboard multibeam, is consistent with the seafloor traveltime observed in the MCS data (Fig. 2).

Seafloor reflection travel times as a function of offset were modeled using the 2-D travel time modeling program of *Zelt and Smith* [1992]. Predicted traveltimes for offsets determined assuming no sonobuoy drift yield dramatic misfits to the data (Fig. 3a). We estimated corrected source/receiver offsets assuming a drift correction of the form: $x_{\mathrm{corr}} = x_0 + x_1 \cdot t + x_2 \cdot t^2$. This parabolic function enables motion consistent with acceleration to a constant drift velocity to be modeled. We estimated the coefficients x_0, x_1, and x_2 by fitting the traveltimes of seafloor reflections at discrete times, *t,* corresponding to shot times. The new offset estimates provide a substantially better fit to the seafloor reflections (Fig. 3b), though detailed inspection of time-shifted seismograms reveals misfits on the order of 10 ms (Fig. 4), which are presumably due to 3D effects (i.e. the sonobuoys do not drift inline with the transect) and/or changes in drift velocity not captured by a parabolic offset correction.

A comparison of "inline" sonobuoy positions between the first and last trace of each gather shows changes in drift patterns through time along the transect (Fig. 5). Under the influence of wind and sea-surface currents, sonobuoys deployed at the beginning of the experiment drifted away from the ship's course during seismic acquisition. The trend gradually reversed until sonobuoys deployed at the end of the experiment drifted along with the ship's course.

Note: In addition to the offset field, the SEG-Y headers were modified to contain sonobuoy number in bytes 21-24 (the "CDP number" field) and shot number in bytes 25-28 (the "CDP trace" fields).

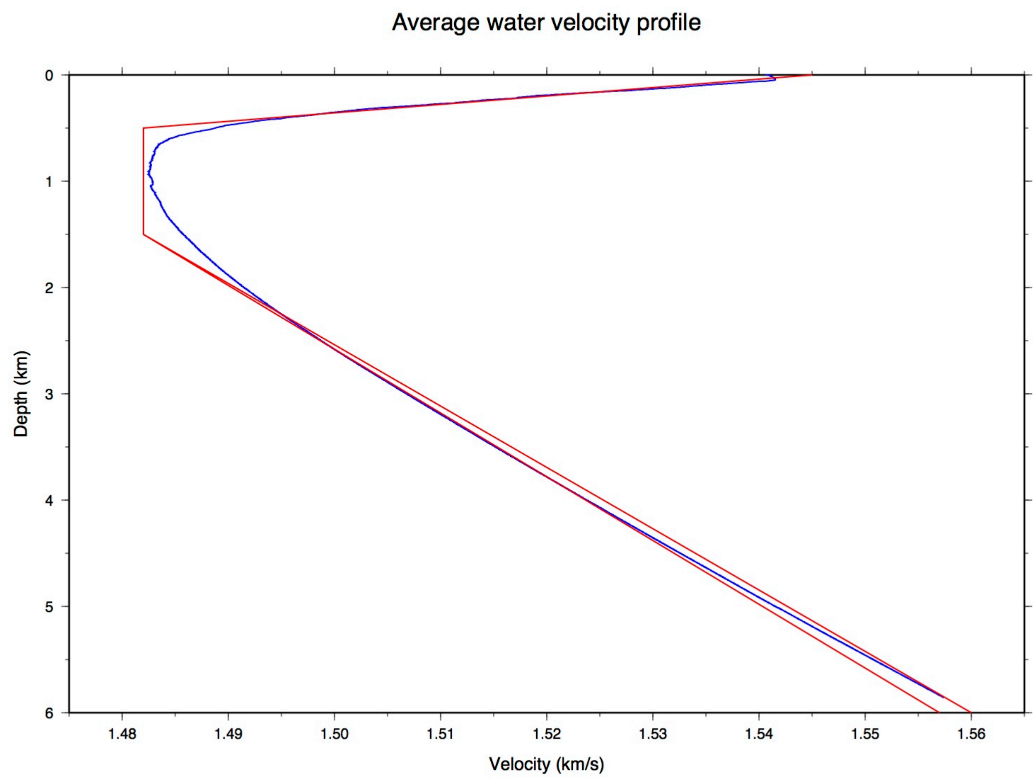

Fig. 1. Average water velocity profile along the JQZ transect. Sentry dives and CTD instruments were used to obtain an average water velocity profile (blue line), which we approximated with a piecewise-continuous linear functions (red lines). MCS Lines 1, 2p1, 2p2, 7p1, and 7p2 had slower velocities than Lines 8, 9, 10, and 10a.

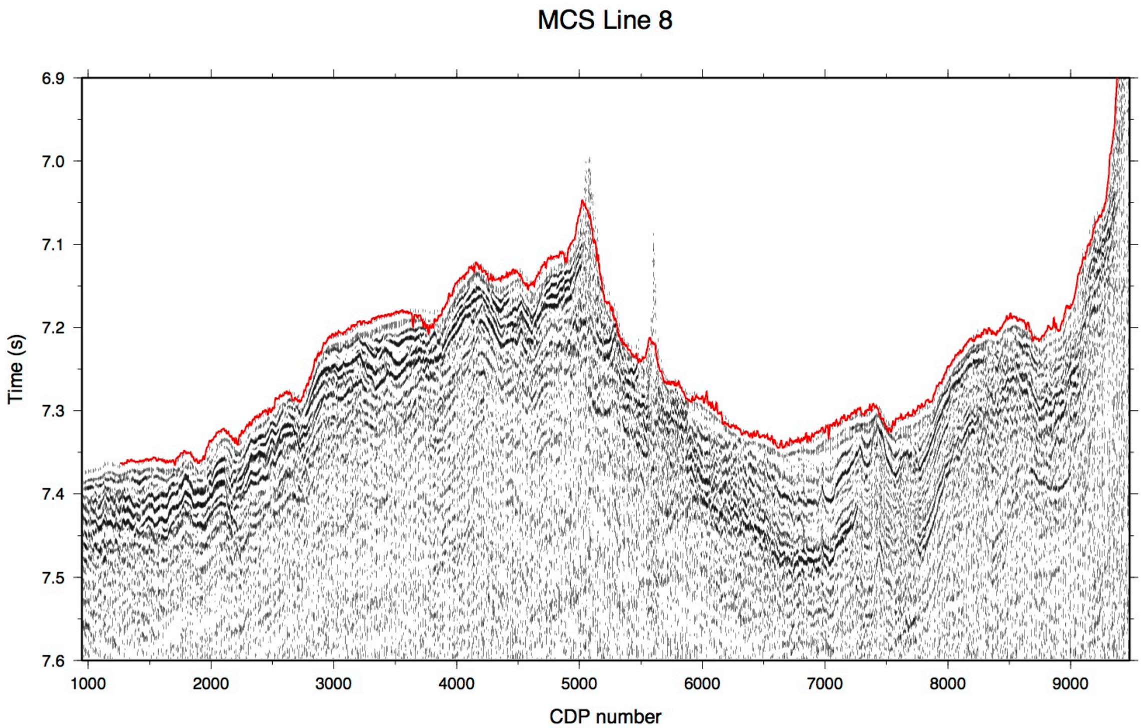

Fig. 2. MCS section overlain with predicted seafloor arrival times. The predicted seafloor arrivals (red line) match up well with the MCS seafloor reflections, confirming the water velocity profile and multibeam bathymetry used in our model.

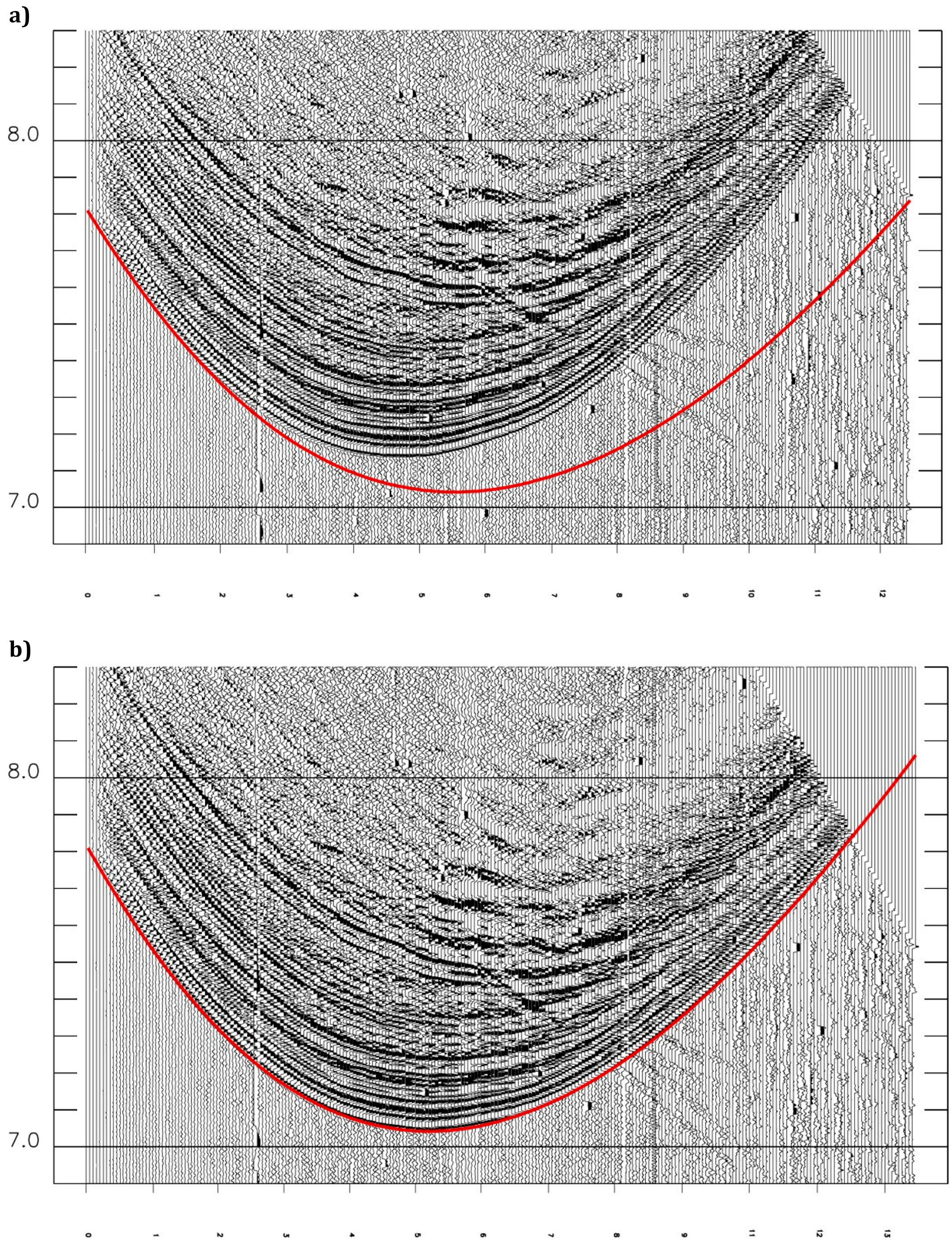

Fig. 3. Seafloor reflection from Sonobuoy 3 with predicted arrival times overlain red. Data plotted at reduced time T=T-X/3.5. (a) Predicted seafloor arrival times assuming no sonobuoy drift. (b) Predicted seafloor arrival times with sonobuoy data with offset correction applied to sonobuoy source/receiver distance.

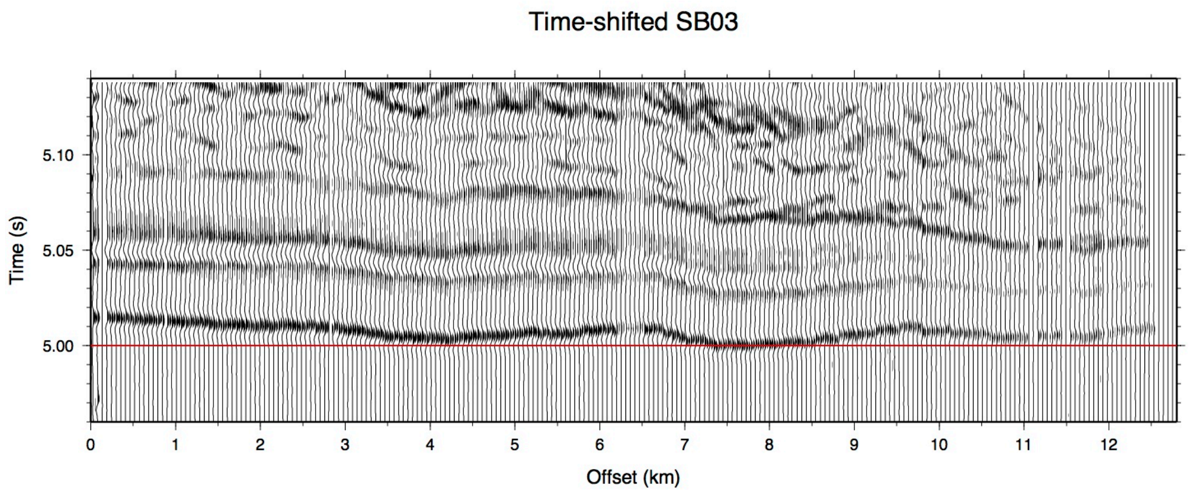

Fig. 4. Sonobuoy data flattened to the predicted seafloor-reflection traveltime, with offset correction applied to sonobuoy source/receiver distance. Seismogram traces are time-shifted to predicted arrival times (red line) and arbitrarily plotted at 5 s. The misfits to predicted traveltime may be due to offline drift of the sonobuoy or changes in sonobuoy drift velocity that are not captured by the assumed parabolic drift function with time.

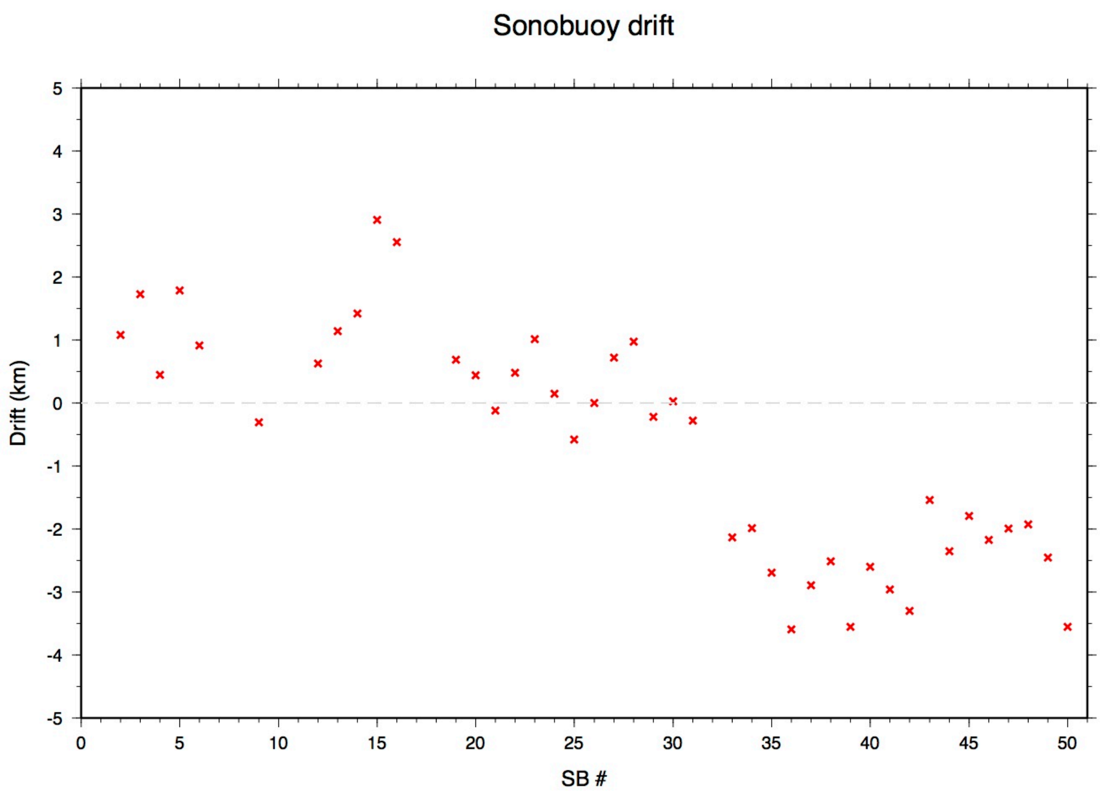

Fig. 5. Total sonobuoy drift distances for each instrument. Positive values indicate sonobuoy drift away from the ship's course during seismic acquisition, and negative values indicate sonobuoy drift along with the ship's course during seismic acquisition.