COMPARISON OF SOUND SPEED PROFILE INTERPOLATION METHODS WITH MEASURED DATA; EFFECTS ON MODELLED AND MEASURED TRANSMISION LOSS

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1. INTRODUCTION

Range-dependent model predictions of underwater acoustic propagation rely on a series of input sound speed profiles (SSPs) at different ranges from the acoustic source. In order to avoid computational artifacts associated with sudden changes in SSP, some propagation models interpolate between the input SSPs to calculate the SSP at each range step. A variety of SSP interpolation schemes exist, not all of which are suitable for entering measured SSPs into propagation models [1].

2. THEORY

Among the most promising interpolation schemes for direct implementation within propagation models are linear interpolation, triangular interpolation, and trapezoidal interpolation. Detailed formulae can be found in [1]; an overview will be presented here.

In linear interpolation the sound speed is linearly interpolated between the input speeds at different ranges but at the same depth. The risk of using linear interpolation is that features such as sound channel ducts that strongly affect propagation may be smeared out by the interpolation process [1].

Both triangular and trapezoidal interpolation schemes rely on the identification of SSP features. Figure 1a shows two idealized SSPs, each with three features identified: the depth of the sound speed minimum, the depth of sound speed maximum above the minimum, and the depth of the maximum negative gradient between the first two features.

In triangular interpolation, a diagonal line connecting the depths of two features at two different ranges defines two triangles (Figure 1a), and the rate of ascent or descent of the feature along the diagonal line is maintained. For intermediate ranges and depths bounded by the dotted lines and "inside" the triangles (Regions A, B, and C in Figure 1a), the rate of ascent or descent is proportional to the distance from the diagonal line and can be determined by simple algebra. Linear interpolation is used for ranges and depths "outside" the triangles (Regions D, E, and F in Figure 1a).

In trapezoidal interpolation the lines connecting the features divide the interpolation region into trapezoidal areas (Regions A, B, C, and D in Figure 1b). For interpolation at a given depth and range point, the rate of descent or ascent is proportional to where the point lies between the two diagonal lines defining the region.

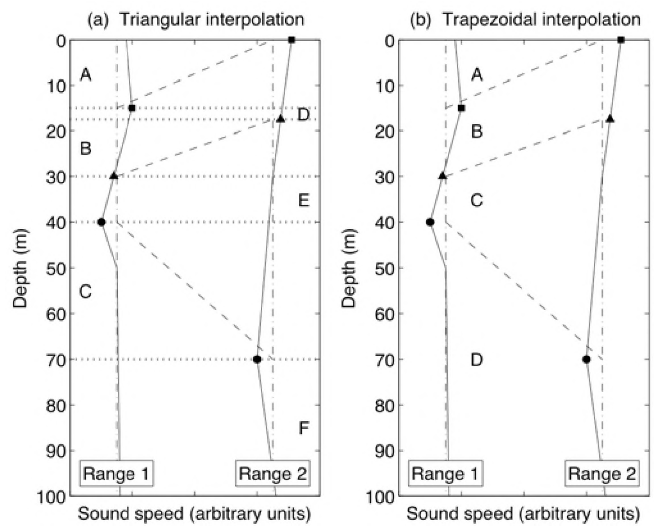

Figure 1 Types of interpolation. The sound speed minimum (●), maximum above the minimum (■), and depth of maximum negative gradient between the first two features (▲) are indicated on each profile. (a) Triangular interpolation: the depths at which the features are found define the diagonals of the triangles. Dotted lines indicate the extent of regions with triangular (A, B, C) and linear (D, E, F) interpolation. (b) Trapezoidal interpolation: the depths at which the features are found define the non-parallel sides of the trapezoidal regions A, B, C, and D.

3. RESULTS and DISCUSSION

During a September 2008 sea trial on the Scotian shelf, SSPs were acquired along a 35-km straight-line track at intervals ranging from 1.1 km to 3.5 km along the track (mean interval = 1.8 km). A subset of the measured SSPs are plotted in Figure 2.

The interpolation was performed between the first and last of the measured profiles in Figure 2, in which the SSP features identified were: the depth of the sound speed minimum (rising from 64 m to 28 m depth), the depth of the sound speed maximum above the minimum (remaining at 4 m depth), and the depth of the maximum gradient between the first two features (rising from 20 m to 18 m depth). Using these features, the sound speed was calculated using linear, triangular, and trapezoidal interpolation, at the same range as each measured profile.

The measured and interpolated sound speeds as a function of depth and profile number are displayed as greyscale images in Figure 3. The measured profiles (Figure 3a) can be compared with profiles obtained by linear interpolation (Figure 3b), triangular interpolation (Figure 3c), and trapezoidal interpolation (Figure 3d), all performed using profiles #1 and #15 as the interpolation endpoints. The most noticeable difference between the interpolation methods is in the representation of the rising sound speed channel that is first visible in measured profile #11, centred at around 40 m depth, rising to 28 m depth in the last profile. With linear interpolation, the channel remains at the same depth (28 m) but gradually becomes more pronounced between the first and last profiles; however, the triangular and trapezoidal interpolation schemes capture the formation of the channel at 40-60 m depth and its subsequent rise.

Transmission loss estimates were generated using a version of Bellhop ([2] [3]), a Gaussian beam propagation model. Measured and interpolated SSPs from Figure 3 were used with a 100 m deep range-independent environment with sandy bottom. The average and median differences in transmission loss at 28 m depth were calculated (Table 1), comparing the results using measured SSPs to those with interpolated SSPs. The trapezoidal interpolation most closely reproduced the results generated using the measured profiles, with an average difference of -3.1 dB and median difference of 3.0 dB.

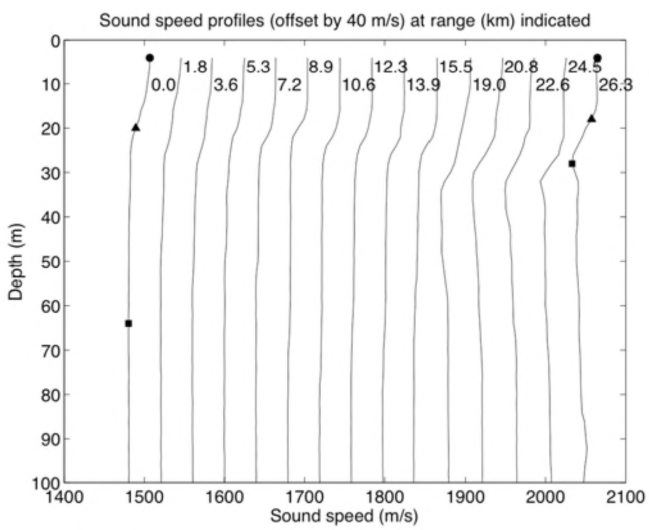

Figure 2 Measured SSPs, offset by 40 m/s, with range from the track start point (km) at the top of each profile. The sound speed minimum (●), maximum above the minimum (■), and depth of maximum negative gradient between the first two features (▲) are marked on the first and last profiles.

Table 1 Summary of average and median difference between modelled transmission loss using measured SSPs and different interpolation schemes, at 28 m depth.

Interpolation Type	Average difference (dB)	Median difference (dB)
Linear	-6.7	-5.5
Triangular	-4.5	-3.9
Trapezoidal	-3.1	-3.0

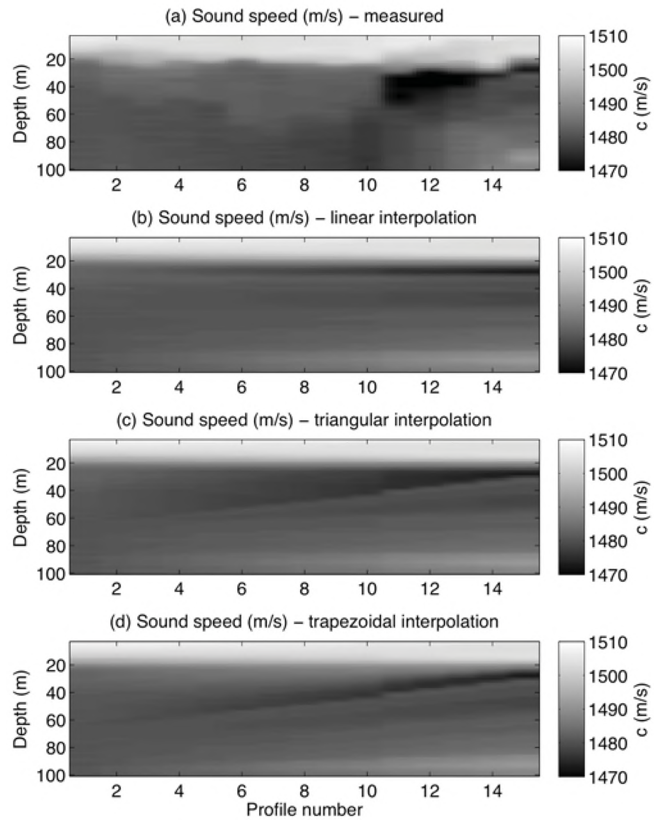

Figure 3 Greyscale representations of sound speed as a function of depth and profile number, for (a) measured data, (b) linear interpolation, (c) triangular interpolation, and (d) trapezoidal interpolation.

4. CONCLUSIONS

Three different methods of interpolating in range between SSPs were investigated for use in range-dependent ocean acoustic propagation modelling. Interpolated SSPs were compared with measured SSPs acquired at the same ranges along a straight-line track. Qualitatively, a sound channel that forms partway along the track is better represented by triangular or trapezoidal interpolation than by linear interpolation. Trapezoidal interpolation resulted in the least difference between transmission loss calculated using measured SSPs and interpolated SSPs.

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