MEASUREMENTS AND MODELLING OF ATMOSPHERIC ACOUSTIC PROPAGATION OVER WATER

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1. INTRODUCTION

Understanding atmospheric acoustic propagation over water could prove to be a valuable tool for determining the environmental footprint of offshore wind farms or naval gunfire exercises, or for evaluating the effectiveness of acoustic hailing devices used at sea. Atmospheric parameter profiles (temperature, wind speed, humidity, and turbulence) and water surface roughness can dramatically affect the acoustic propagation. Wiener [1] measured acoustic transmission loss in foggy conditions using a fog horn as the acoustic source. Salomons [2] showed that water surface waves can strongly affect transmission loss in long-range, over-water propagation, while Boué [3] showed that cylindrical spreading is an appropriate model up to 700 m range. Bolin and Boué [4] showed that accurate predictions in shadow zones rely on inclusion of atmospheric turbulence in transmission loss models.

In the two experiments presented here, atmospheric acoustic transmission loss over water was measured as a function of range. Simultaneous environmental data acquired included atmospheric parameters and directional wave spectra.

2. METHOD

2.1 November 2009 Experiment

The first experiment was performed at sea on 2 Nov 2009 on board Defence Research and Development (DRDC) Atlantic's research ship, CFAV Quest. Two receivers, a Sony Linear PCM Recorder and an mh acoustics em32 Eigenmike microphone array, were mounted aboard Quest at 7.5 m above the sea surface. The source was a dual-tone Nauticus 3500 horn with nominal frequencies of 530 Hz and 670 Hz and an on-axis source level of 115.7 dB re 20 µPa at 1 m. The horn was mounted aft-facing at 2.1 m height on a rigid hull inflatable boat (RHIB) that was driven towards and away from CFAV Quest at a speed of 7 knots. During the runs, the horn was sounded every 30 s for 10 s. A Brüel & Kjaaer (B & K) sound pressure level (SPL) meter was used to monitor the ambient noise on board Quest. Point measurements were made of temperature and humidity (at 15.2 m height), wind velocity (at 24.7 m height), and significant wave height.

2.2 July 2010 Experiment

The second experiment was performed from 19-23 Jul 2010 in the Bedford Basin, Halifax, Nova Scotia on board DRDC Atlantic's Acoustic Calibration Barge. The receiver was a Core Audio Tetramic mounted above the barge structure 10.2 m above the water surface. The source, the same Nauticus horn used in the 2009 experiment, was mounted aft-facing at 1.25 m height on a Zodiac. The Zodiac was driven towards and away from the barge at speeds of 4 to 8 knots and the horn was sounded every 20 s for 5 s. A Sony Linear PCM Recorder was used in the Zodiac to monitor the source. The ambient noise level and source level were measured several times each day with the B & K SPL meter.

Directional ocean surface wave spectra were measured using a Teledyne RD Instruments Acoustic Doppler Current Profiler (ADCP). Vaisala Radiosondes were launched from Canadian Forces Base Halifax (6 km away) on each day at 0930 and 1230 to record atmospheric parameter profiles. Point measurements were made of temperature, wind velocity, humidity, and air pressure at 9 m height. Parameter profiles from Environment Canada's Global Environmental Multiscale (GEM) model were available at 0900, 1200, and 1500 each day.

3. RESULTS

3.1 November 2009 Experiment

Measured SPL in arbitrary units are plotted as a function of range in Figure 1 for both horn frequencies and two different relative wind directions: crosswind (Figure 1a and 1b) and upwind (Figure 1c and 1d). For all the plots in Figure 1, the wind speed was 10.1 m/s from a direction of 50°. Wind direction was calculated relative to the source-receiver vector; therefore, the relative wind direction is 0° when the receiver is directly downwind of the source. For comparison, each plot shows the SPL resulting from cylindrical and spherical spreading, forced to agree with the measured data at the closest range point. In the crosswind case, the received SPL decreases more quickly with range than predicted by both cylindrical and spherical spreading. In the upwind case, the received SPL shows the same general trend as spherical spreading. The maximum detectable range is greater (700 m) in the crosswind case than the upwind case (350 m).

3.2 July 2010 Experiment

Measured SPL in arbitrary units are plotted as a function of range in Figure 2 for both horn frequencies and two different relative wind directions: approximately crosswind (Figures 2a and 2b), and approximately upwind (Figures 2c and 2d). For the crosswind run, the wind speed was 1.3 m/s from a direction of 81°, while for the upwind run, the wind speed was 1.6 m/s from a direction of 275°. In the crosswind case, the received SPL agrees with cylindrical spreading to a range of 600 m, where it drops to 8 dB below spherical spreading. In the upwind case, the received SPL agrees with cylindrical spreading to a range of 300 m, and shifts to spherical spreading beyond 300 m. Again, the maximum detectable range is much greater (900 m) in the crosswind case than the upwind case (700 m).

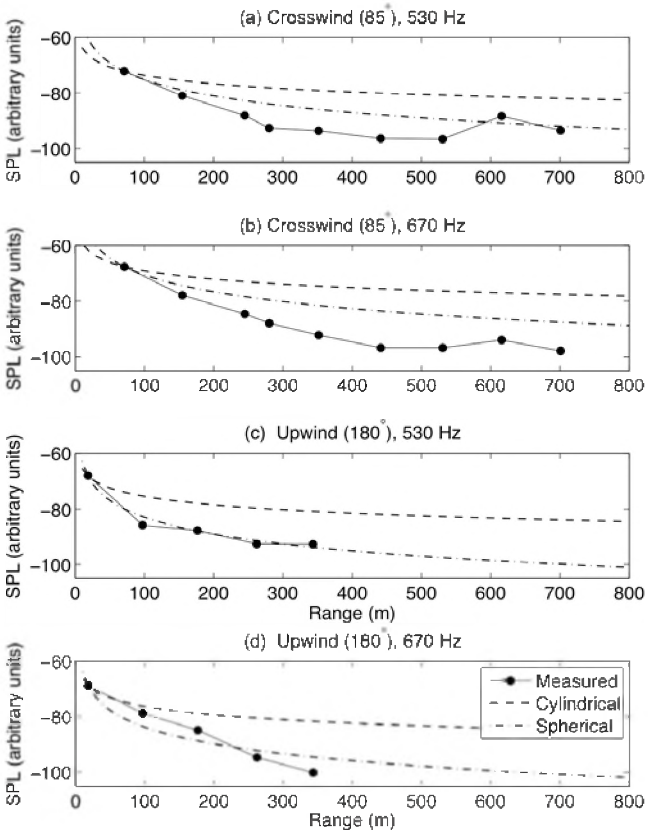

Figure 1 Measured SPL (●), cylindrical spreading (dashed line), and spherical spreading (dash-dot line), in arbitrary units, as a function of range for the Nov 2009 experiment: (a) crosswind, 530 Hz, (b) crosswind, 670 Hz, (c) upwind, 530 Hz, and (d) upwind, 670 Hz.

4. DISCUSSION AND FUTURE WORK

In both experiments, simple spherical or cylindrical spreading did not suffice to describe the range dependence of the measured transmission loss. The maximum detectable distance was greater for the crosswind case than the upwind case in both experiments. Future work will include analyzing the remainder of the data from the Jul 2010 trial, and implementing a propagation model using measured and modelled atmospheric parameters for comparison with the measured transmission loss.

REFERENCES

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AUTHOR NOTES

The work was conducted while Emma Murowinski was working as a co-op student at DRDC Atlantic. The current address is: e.murowinski@gmail.com.

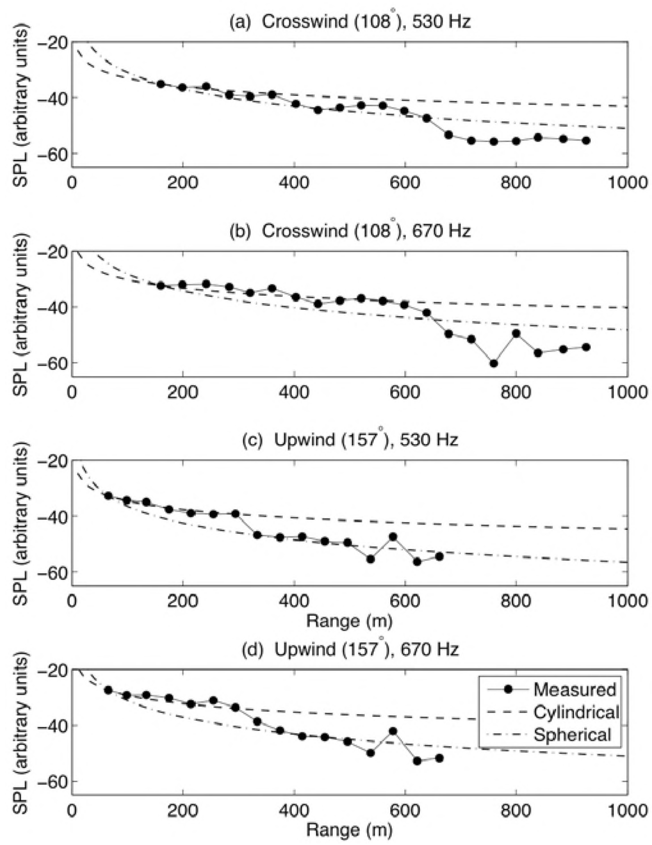

Figure 2 Measured SPL (●), cylindrical spreading (dashed line), and spherical spreading (dash-dot line), in arbitrary units, as a function of range for the Jul 2010 experiment: (a) crosswind, 530 Hz, (b) crosswind, 670 Hz, (c) upwind, 530 Hz, and (d) upwind, 670 Hz.