Introduction to acoustical oceanography- Lab 3: Relating acoustical backscattering to particulate concentration.

Emmanuel Boss & Mick Peterson, Fall 2005.

Introduction:

Today you will use a NORTEK 16MHz Acoustic Doppler Velocimeter (ADV) and observe how the signal it obtains changes with concentration.

The ADV outputs digital counts. These counts relate linearly to the backscattering signal strength as follows:

Backscatter signal strength (in dB) = A x Counts + B

The proportionality constant (A) is not known exactly (the company claims it is about 0.43). The offset B is not known either. As part of this lab we will try to find out what A should be.

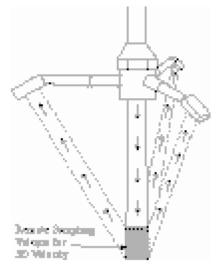

Figure 1. Acoustical Doppler Velocimeter: A single source sends a pulse that is reflected from a volume to three receivers. The sampling volume is 0.09cubic cm and its distance from the source is 5cm.

The signal strength is proportional to the concentration of scatterers (C, see below) in the water. If we denote by N=A x counts + B

The difference between two measurements:

$$N_2-N_1=A(Count_1-Count_2)=10 \times \log(C_2/C_1) \qquad (1)$$

The last equality is due to the fact the backscattering strength is proportional to the particle concentration. B is an offset related to the source's intensity. Thus a factor of 2 increase in concentration will give an increase of 3dB in signal strength (~7counts if A=0.43counts/dB).

By putting known concentrations of material in the water we can use the above equation to obtain the proportionality constant A.

Incorporating loss terms:

So far we have ignored attenuation. N should actually be computed as follows:

$$N= A \times counts+10\log(2R)+2(\alpha_w+\alpha_p)R + B$$

to correct for spherical spreading and attenuation by water and particles. (1) is then changed to:

$$N_2-N_1= A(Count_1-Count_2)+2R(\alpha_{p,1}-\alpha_{p,2})=10 \times \log(C_2/C_1), \qquad (2)$$

Since we do not expect spreading and water absorption to change between the measurements. For a material with a specific attenuation of α^*_p (dB m^{-1} $(gr/L)^{-1}$) we can rewrite the second term as:

$$(\alpha_{p,1}-\alpha_{p,2})=(C_2-C_1)\alpha^*_p$$

Resulting in:

$$N_2-N_1= A(Count_1-Count_2)+2R(C_2-C_1)\alpha^*_p=10 \times \log(C_2/C_1), \qquad (3)$$

Materials:

- 2L DI water mixed with 80mL dispersant (6.2 g/L solution of sodium hexametaphosphate) in a 3L beaker sitting on top of a stirring table.
- Packages of 75 micrometer beads weighing 0.5 g (+/– 0.05) each, giving a total mass of ~10.5 g.
- An 16MHz ADV sensor attached to a computer (R=0.05/cos25=0.055m).

Method:

- Turn the stirrer on low, somewhere between 3&6 and take a blank sample (just water + dispersant), let it record ~ 500 samples and save the file.
- Add beads into the beaker, one tray at a time, take ~ 500 samples and save the file. Keep at it until you are done with the beads.

Note: If the beads seem to get stuck on the bottom, while NOT recording, turn up the stirrer's intensity. When they appear to be circulating again, lower the stirrer speed a bit and start recording. While recoding, you shouldn't need to turn up the stirrer past 6. The partition we have set up in the beaker keeps vortices a minimum but quick revolutions from the stir bar increase the number. If bubbles form, stop recording and turn off the stir bar. If they are stuck to transducers of the ADV, gently wipe them off with a q-tip. If they are floating around in the beaker or stuck to the stir bar, stop recording and turn the stirrer up high to float them to the top and then turn off the stirrer. Let the whole setup settle momentarily and when no bubbles are in site then resume with the stirring to re- circulate the beads. After all the data is taken, don't forget to export all the files.

Analysis/Homework:

1. Plot the counts as function of bead concentration (in g/L).
2. Use equation (3) to determine what A and α^*_p ought to be. If you find it to be too difficult, use equation (1) in low concentration to obtain A, and then solve for α^*_p using equation (3). Make sure to use several concentration pairs to provide some error estimates for these parameters. Extra credit: can you obtain B?
3. How does α^*_p compare to that of water at 16MHz (use formulas in your textbook and make sure to normalize to density)?

Appendix:

From Nortek Technical Note No.: 003
Title: Monitoring sediment concentration with acoustic backscattering instruments
Edited: October 15, 2001
Author: Atle Lohmann, Nortek AS

Absolute calibration of the ADV as a backscattering sensor requires a complete characterization of the transmit and receive circuit of the instrument. This includes:

- Acoustic transmit power level
- Transmit pulse length
- Transducer efficiency
- Acoustic receive sensitivity
- Temperature sensitivity of circuit