SIO 176 HW2

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1 A. Description of instrument or platform

1.1 What is it used to measure? Describe the principle of operation.

The Acoustic Doppler Current Profiler (ADCP) computes velocity profiles of moving water in the ocean (currents) in 3D space. ADCPs utilize the doppler effect to do this. The Doppler effect is explained in the context of ADCPs as follows: ADCP emits acoustic waves which bounce off of scatterers (i.e., small plankton to other particles like copepods or pteropods) in the ocean. Much of the acoustic wave propagates directly past the particles but some is scattered directly back at the ADCP. The ADCP receives the sound waves back as well. When the scatterers and the ADCP remain stationary with respect to each other, we do not observe a Doppler Shift, that is, a change in the frequency of the wave. We see that a doppler shift is governed by the equation: $F_d = 2F_s(\frac{V}{C})$, where F_d is the doppler shift frequency, F_s is the frequency of sound when everything remains stationary (basically original frequency of wave), V is the relative velocity between receiver and sound, and C is the speed of sound. So we observe a doppler shift when the parameters on the right change. For example, if a scatterer particle is moving away from the ADCP we see a negative doppler shift. Then, the doppler shift is proportional to velocity of the scatterer or the velocity of water (with the key assumption that the particles move at the same horizontal velocity of water). The doppler effect is limited to measuring the radial velocity component. This is the direction that is parallel to the propagation of the wave, so we add a cos(A) to the RHS of the doppler shift equation, where A is the angle between the direction of propagation and the velocity vector backscatter. The ADCP utilizes 4 acoustic wave beams, two in the horizontal and two in the vertical. One pair of beams measures east-west horizontal velocity and vertical velocity. The second pair measures north-south horizontal velocity and vertical velocity. These two vertical velocity measurements, seemingly redundant, actually give us vital information in the form of the error velocity, the difference between the two vertical velocities. A large difference can tell us changes in actual current direction, if the ADCP beam is malfunctioning, or inhomogeneities in water (if the assumption that horizontal homogeneity is reasonable). After receiving a velocity profile, the

ADCP divides up the profiles into uniform bins or depth cells. Think of each one as a current meter, so a string of depth cells is a string of current meters that is uniformly spaced. You can think of depth cell size as the distance between current meters and the number of cells is the number of meters. The ADCP averages the velocity of the range of depth cells which reduces spatial aliasing (the effect of causing high frequency signals to look like low frequency signals). This in turn reduces measurement uncertainty.

1.2 Provide an example of how this instrument would be used to answer a question of interest to oceanographers.

Example: If an anomalous body of water (i.e., low dissolved oxygen) is spotted in a certain region, we can look back at profiles of currents to predict where this mass might have come from. With knowing the velocities of currents in the ocean, oceanographers can also use this information to predict and model transport of different characteristic bodies of water. Obviously this instruments measure current velocity, so if oceanographers want to confirm the location of a certain current, or how a current changes, they can set up ADCPs in the region and measure current changing over time.

2 B. Synthesis of Assigned Paper (1/2 page w/o figure)

1. What question was addressed? 2. What was the approach/method? – with specific references to the measurements collected by this instrument/sensor including mode of deployment and steps taken in analyzing the data. 3. What are the findings? 4. Implications and remaining questions 5. Include one key figure that shows the results with a descriptive figure caption.
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1. The question that was addressed was how to retain velocity data for both fish swimming speed as well as the current velocity. When fish swim independently in the water, the velocity profiles measured by the ADCP are contaminated. The paper proposes a data analysis method that allows for all ADCP data to be retained and separation of the fish swimming speed and current velocity into two separate quantities.
2. The data analysis procedure goes as follows: the individual beams each measure some component of the velocity and then are combined to get the velocity relative to the instrument V_in. Velocity estimates must be corrected to an earth-referenced coordinate system by rotations in orientation*. It is after this that some sort of averaging can be employed. Taking a step back: When finding the velocity, if fish are present in data from at least one doppler beam, velocity cannot be calculated because the equation (equation 4) to calculate velocity is missing the component where fish contaminated the data. This deems all data

from the other doppler beams unusable. The paper proposes a new method utilizing a least-squares fit linear regression. This allows the ability to treat data from each beam independently, so that data is still usable if one beam is contaminated. Instead of directly solving for the velocity using equation 4, the velocity is estimated by minimizing the sum of the squared residuals. A line is projected to best fit the data by taking the derivative of the sum of the residuals and setting it equal to zero. This lowest error fit is essentially calculating the best estimate for velocity. This is in math: $\frac{\partial}{\partial_x}\Sigma\epsilon_j^2 = 0$ $\frac{\partial}{\partial_y}\Sigma\epsilon_j^2 = 0$ $\frac{\partial}{\partial_z}\Sigma\epsilon_j^2 = 0$ and the sum of the residuals is: $\Sigma\epsilon_j^2 = \Sigma(V_x k_{xj} + V_y k_{yj} + V_z k_{zj} - v_j)^2$ where V_x is the estimated velocity in the x direction, k_{xj} is the unit vector defining x measurement orientation, and v_j is the observed data.
3. This method was tested on data gathered during a 6-month venture in Smith Sound, Newfoundland. They aimed to capture both fish and water velocity. Two instruments were moored deployed at 150m depth, one upward-looking and one downward-looking. Instruments were configured, due to data storage limits, to sample at 15 burst pings in a period of less than 6 seconds. The upward-looking instrument sampled every 5 minutes while the other one sampled every 3 minutes considering data limits and acoustic interference. They decided that fish movements were present when volume backscatter exceeded -55dB. Velocities were averaged into 1-hr values. They found that fish follow a diurnal pattern, tending to stay closer to the seabed (200m) during daylight indicated by high volume backscatter at these depths and move upward toward the surface at during the night. Based on this diurnal movement, they found the magnitude of vertical fish velocities to be $0.3cms^{-1}$ assuming 10m traveled in 1hr. Horizontal movement tended to be on the order between 5 and $15cms^{-1}$. They estimated a characteristic current velocity extracted from a 3-m interval where fish were not observed at 178m and a characteristic fish velocity extracted from the 3-m interval at 195m. This was in order to continuously compare the two speeds. Ultimately, they found they both fish and water velocities are able to be extracted.
4. Because of the limitations of amount of fish and data sampling sizes, they were not able to come to a find a reason to explain fish behavior. They could not find any correlation between backscatter data and fish movement, because the vertical velocities (¡$1cms^{-1}$) were small in magnitude compared to the vertical velocity uncertainty ($1cms^{-1}$). Greater averaging in time may be able to reduce uncertainty in vertical velocity but this will result in filtering out the diurnal signal itself. Lastly, some data might be biased in the fish lie at the edge of the beam, still contributing to backscatter but not enough such that it is still represented as water. More researching on this will be needed in order to distinctly separate the two.
5.

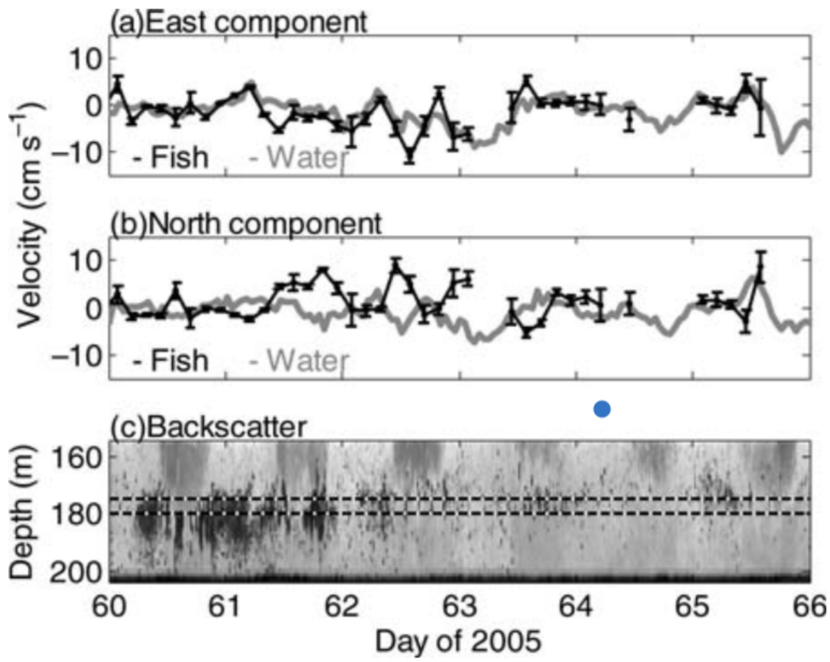

Figure 9. A six-day time-series of data starting on 1 March 2005 (Year Day 60) for the depth interval 175 – 180 m. (a) East component of velocity, (b) north component of velocity, (c) backscatter intensity. Fish velocities are indicated in black with error bars denoting 68% confidence intervals, and water velocities in grey. No error bars are shown for the water velocities because they are all smaller than the line width. The sampled depth interval is indicated by dashed lines in (c); the grey scale used is the same as used in Figure 5.

Figure 1: Results indicating the ability for new method to separate velocities into fish and water velocity and their horizontal components. Third plot indicates the intensity of backscatter