ADCP Observations across the Labrador Sea during IPY 2008

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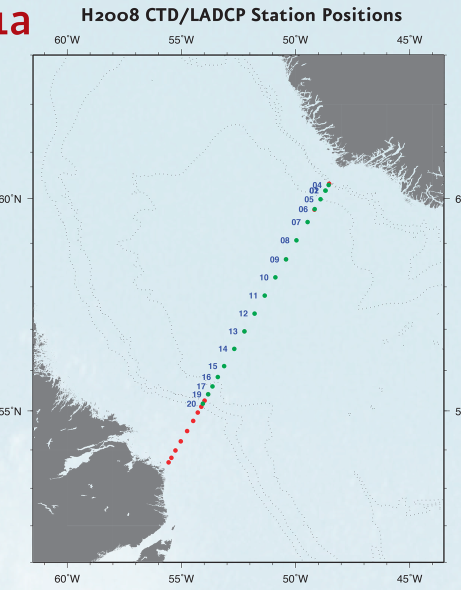
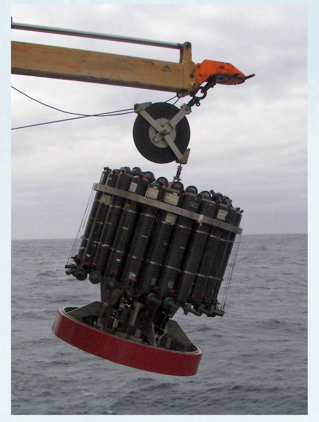
Introduction

1a



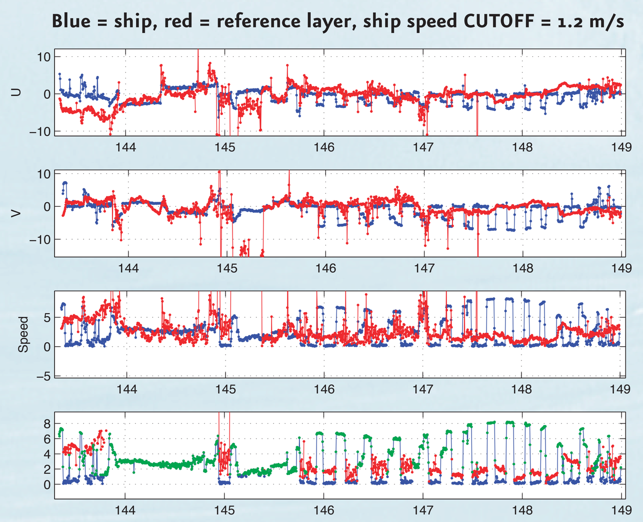


The Labrador Sea has long been recognized as an important location for deep convection and intermediate water mass formation. The boundary current system which dominates the circulation of the Labrador Sea provides a pathway for transporting newly ventilated water masses formed locally and further upstream, including Denmark Strait Overflow Water, Iceland-Scotland Overflow Water, and Gibbs Fracture Zone Water. Since 1990, scientists from the Bedford Institute of Oceanography (BIO) in Dartmouth, Nova Scotia, have continuously occupied the CLIVAR (previously WOCE) repeat line (AR7W transect) in order to measure the hydrographic properties of the Labrador Sea. Since 1995, in collaboration with investigators from the Woods Hole Oceanographic Institution, shipboard Acoustic Doppler Current Profiler (SADCP) and lowered ADCP (LADCP) data have been collected along with the hydrographic data. As part of an on-going effort to process and analyze these data, we present here a description of the methods used to process the SADCP and LADCP data sets. To commemorate the end of the International Polar Year (IPY), we present results from the AR7W cruise from May, 2008 (figure 1A). These data are being used to determine the absolute velocity field across the Labrador Sea each year during the time of the AR7W occupation. We will continue collecting these data on an annual basis to strive to determine the interannual and/or long-term variability in the region and how it relates to polar climate and the Atlantic Meridional Overturning Circulation.

Figure 2a: Before calibration

Figure 2b: After calibration

ROT=1.4 degrees, AMP=1.000



Shipboard ADCP is an important instrument for measuring near surface ocean velocity while underway. First the data must be processed to convert the measured ship referenced velocity into absolute velocity. For that we use the CODAS software suite developed and maintained by Firing and Hummon at the University of Hawaii (Firing and Gordon, 1990). CODAS processing involves applying a set of tools which have been automated to scan, load, edit, and calibrate (correct for transducer misalignment) the raw velocity data and subsequently correct navigation, calculate a smoothed ocean reference layer and thus determine absolute velocity data. All these steps can be run individually. An important part of the data processing involves calibration. The ADCP transducer is mounted in the hull of the ship oriented along its centerline. Even a small misalignment angle can result in significant errors in the calculated absolute velocity. The error is proportional to ship speed times sine of the misalignment angle. A ship moving at 10 knots with a one degree error results in a cross-track velocity error of 10 cm/s. The shipboard ADCP used onboard C.S.S. Hudson in May, 2008 was a Teledyne RDI, 75 kHz Ocean Surveyor. The transducer misalignment angle was determined to be 1.4 degrees. Figure 2a is a time series plot of ship speed and ocean reference layer absolute velocity prior to application of the transducer misalignment correction. Jumps in the reference layer velocity are quite evident in most of the transitions between on and off stations. Figure 2b shows reference layer velocity after the correction has been applied. Differences between on and off station reference layer velocity are now greatly diminished. However, since we used LTA (long term average, 5 minutes) files for this analysis, some other errors come into play that result in a less than perfect reference layer velocity. Processing the single ping data will provide improved editing and calibration to provide a more accurate solution (work in progress). However, since we are only concerned with on-station data for merging with LADCP data we are confident with these results obtained using the LTA files.

BAD CASE

Fig3a: Shear only

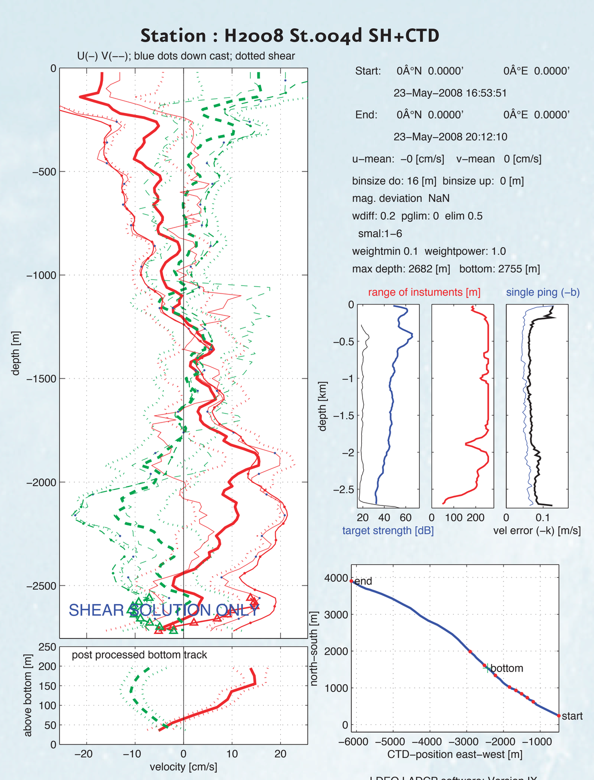


Fig3b: GPS only

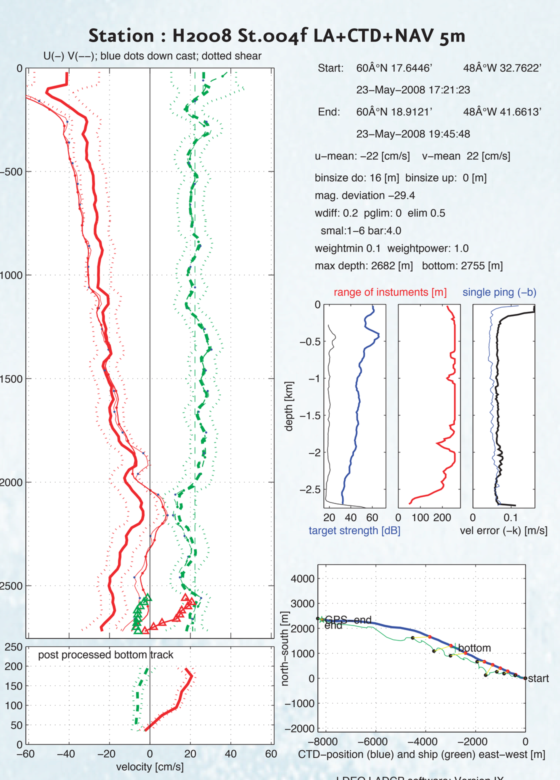


Fig3c: GPS + BOT

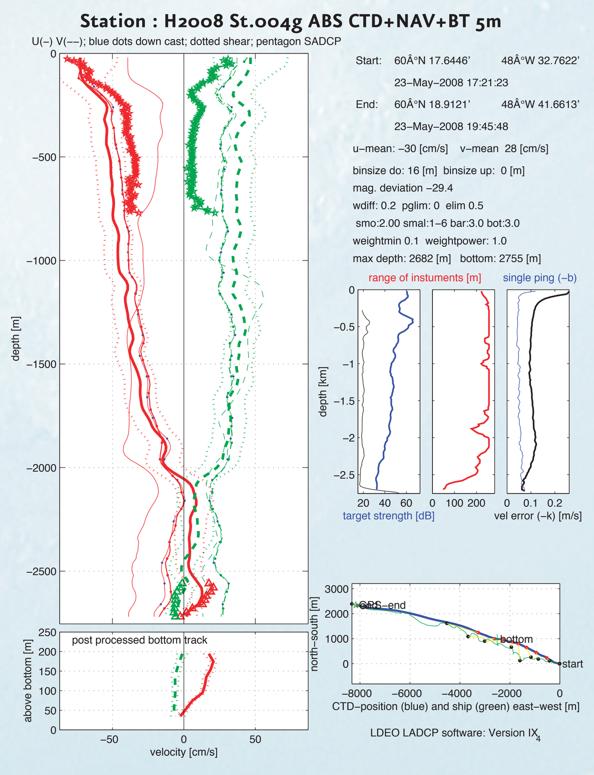


Fig3d: GPS + BOT + SADCP

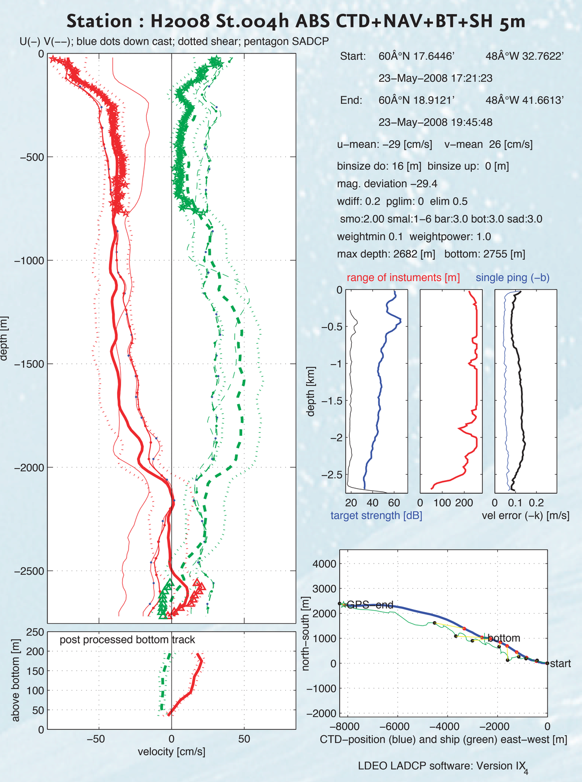
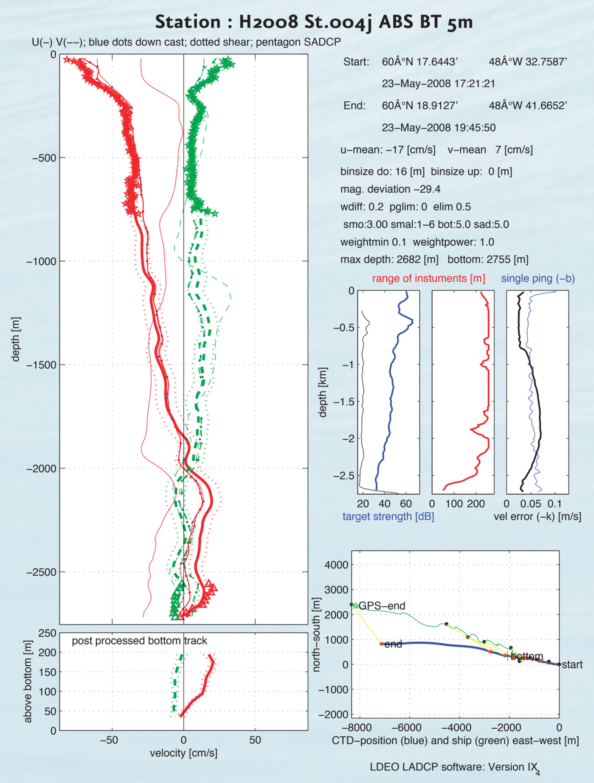


Fig3e: BOT + SADCP



GOOD CASE

Fig3f: GPS only

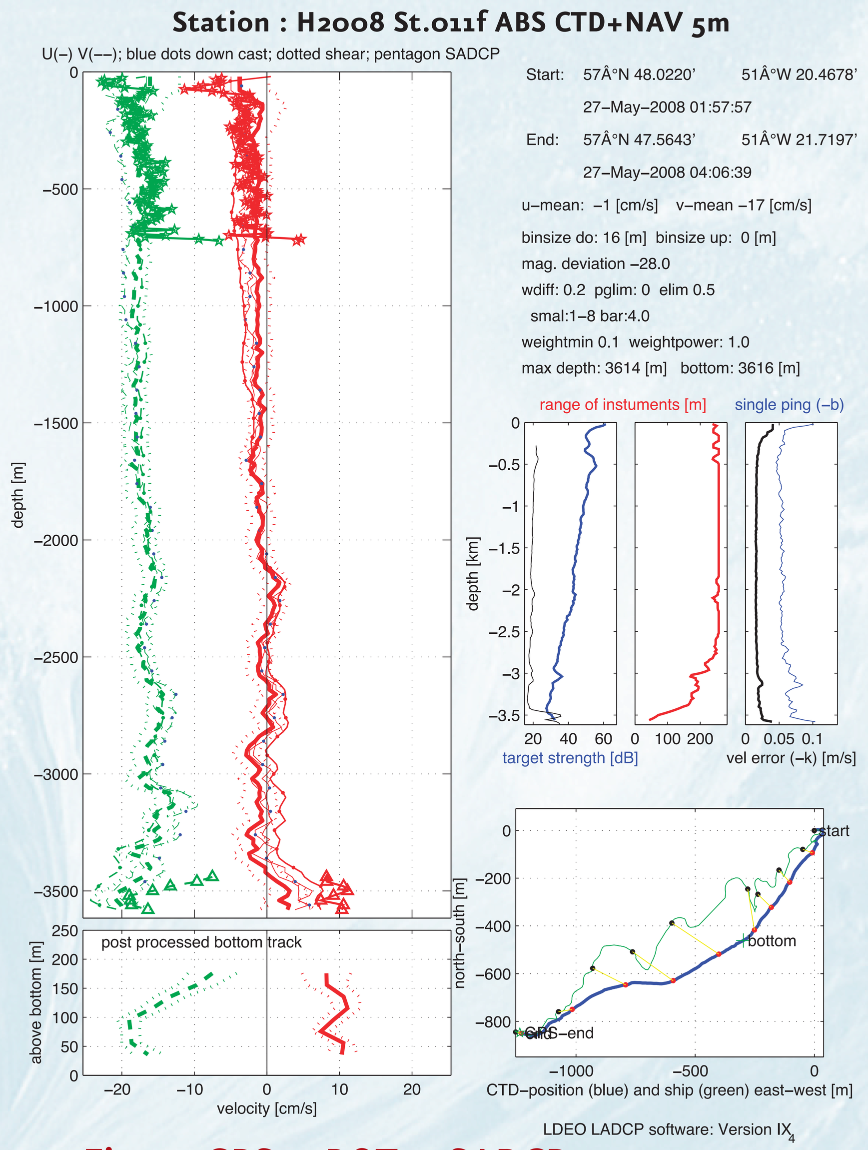
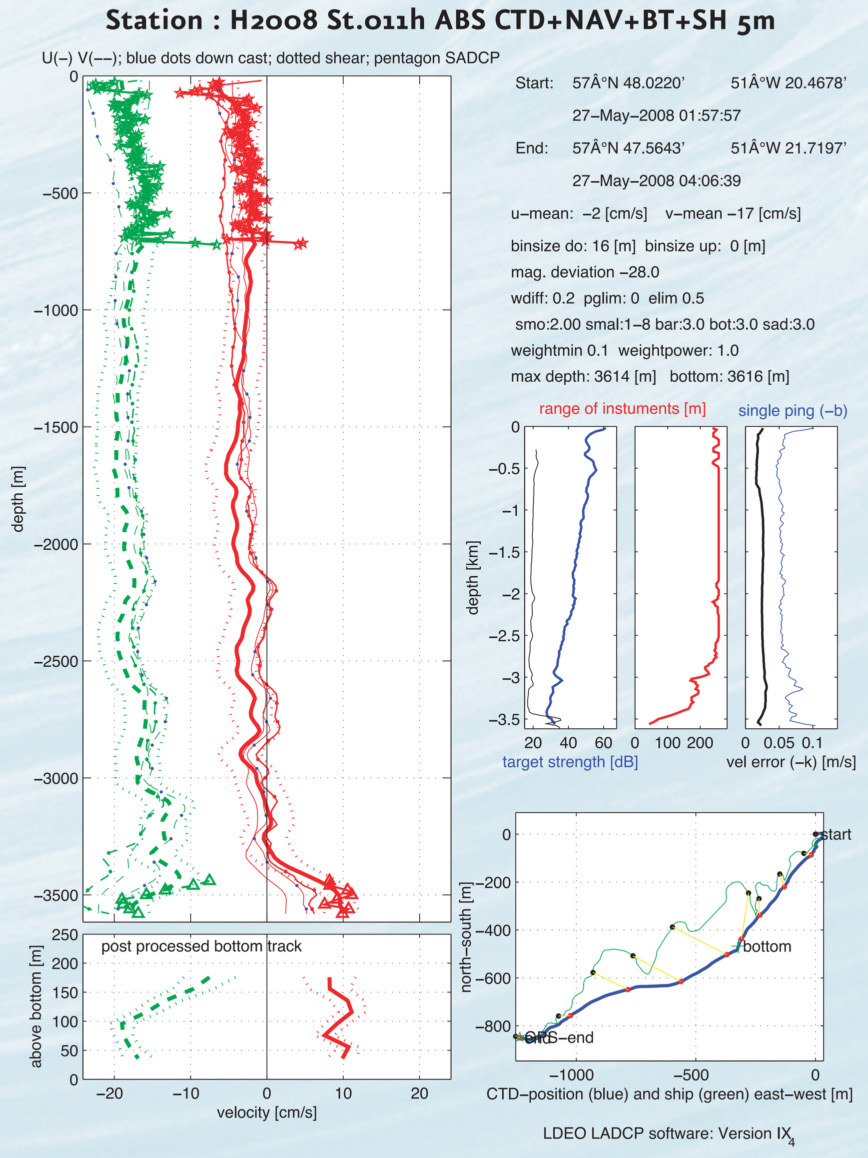


Fig3g: GPS + BOT + SADCP



Lowered ADCP data were collected using a Teledyne RDI 150 kHz Broadband ADCP (BB150). An external high pressure housing containing an 8.2 amp-hour 48 volt rechargeable battery pack was used to power the BB150 during each cast. Both of these were mounted on a rosette frame along with a Seabird 911 CTD instrument. Internally recorded LADCP data are downloaded after each cast while simultaneously recharging the battery pack. Processing the data involves removing the ship motion and CTD motion through the water during the time of the cast. Software used was developed at Lamont Doherty Earth Observatory (LDEO) (Fischer and Visbeck, 1993). Software is currently maintained by Andreas Thurnherr and is freely available (http://www.ldeo.columbia.edu/~ant/LADCP).

Processing of the data involves calculating a shear profile by first differentiating the bin to bin velocity measurements for each individual single-ping velocity profile. The shear measurements are then integrated and depth-averaged to arrive at an un-referenced full water column velocity profile (figure 3a). The velocity profile can be made absolute by (a) using the ship's GPS time and position from the start and end of the cast, (b) using shipboard ADCP absolute velocity averaged over the time of the cast, c) using bottom-track velocity, or a combination of those three. Different weights can be applied to an inverse calculation to determine the best solution. The example shown here is a bad case scenario where the reference velocity determined by GPS, bottom track, and shipboard ADCP do not agree. Figure 3b shows the GPS only solution. Ship's time and position over the course of the cast is used to offset the integrated shear velocity profile. The difference in ship's displacement determined by GPS and integrating package velocity is used to scale the velocity profile. Errors in the velocity measurements can result in large differences. The bottom track velocity measured while the ADCP is within range of the bottom can be used to determine the offset (figure 3c). Figure 3d references the cast using a solution where equal weights have been assigned to all three referencing methods. However, this station was taken in the middle of the West Greenland Boundary Current (nearly 2 knot surface current). We know that 21% of the LADCP velocity data was corrupted due to instrument tilt beyond the range of the instrument. Knowing we have a problem with some of the shear profile data, we determined to weigh the bottom track velocity and shipboard ADCP velocity equally for the final absolute velocity profile (figure 3e). Ideally, the solution determined from each of the 3 referencing schemes should give the same answer. Figures 3f and 3g are more typical examples of well-behaved solutions. The reference velocity from each solution gives the same reference velocity (+- 1 cm/s).

Fig 4a: Before referencing

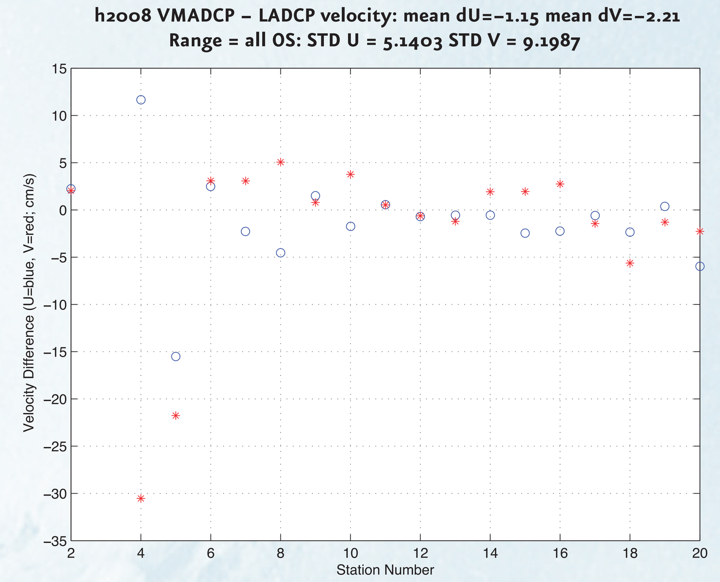
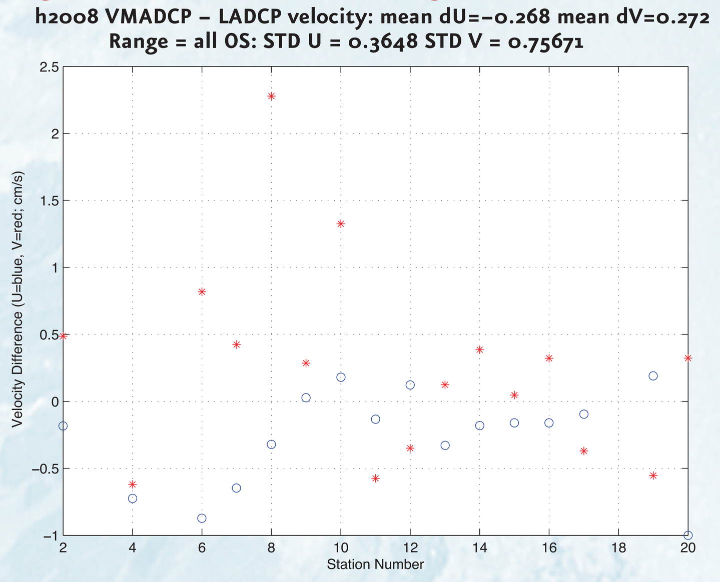
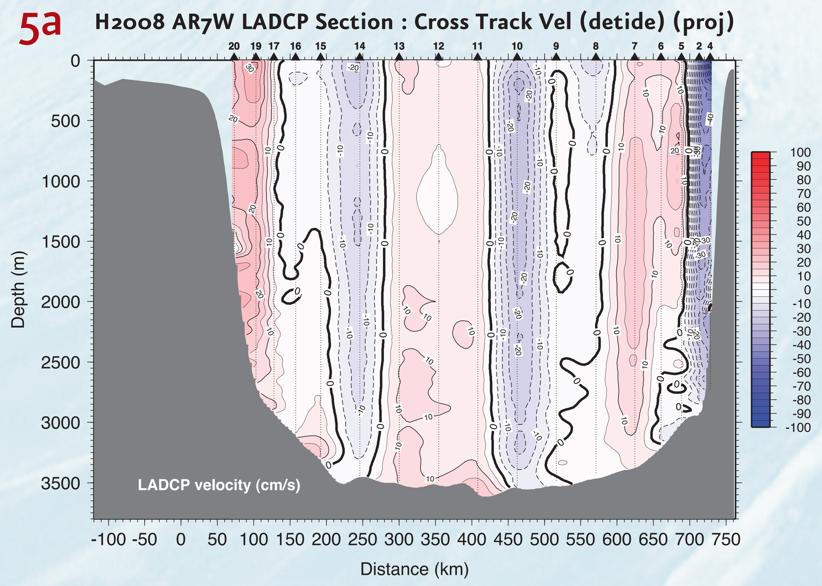


Fig 4b: After referencing



On-station averages of shipboard ADCP data can be used for referencing the LADCP velocity profile. Figure 4a shows the difference between the on-station average shipboard ADCP data and the LADCP referenced using GPS averaged between 100 - 400 meters. Except for using the same underway GPS data, these were independent measurements. Except for stations 4 and 5, the differences were all less than 5 cm/s. We determined station 4 had some unreliable LADCP velocity data so we decided to omit the GPS referencing for that solution. For station 5, it was determined the ship's gyro was not working while on-station for the duration of that cast. Since ship's heading is an integral part of the shipboard ADCP solution, we determined the shipboard ADCP data was not useable for this station. Figure 4b shows the differences between the LADCP and shipboard ADCP for the remaining stations after shipboard ADCP data was used in the weighted inverse solution for the final LADCP absolute velocity profile.

5a



5b

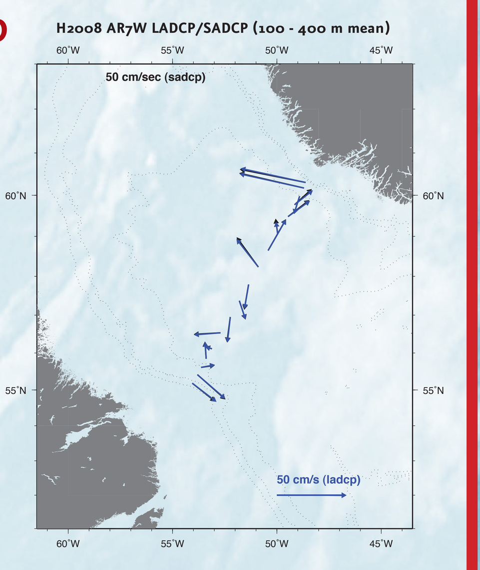


Figure 5a shows the cross-track component of LADCP absolute velocity across the Labrador Sea in May, 2008. These data were detided using the Oregon State University OTPS barotropic inverse model for determining tides at each station (Egbert and Erofeeva, 2002). Boundary currents on both sides of the Labrador Sea are evident along with a largely barotropic banded velocity structure often seen in the interior basin. Figure 5b shows 100 - 400 meter depth averaged velocity vectors of shipboard ADCP and lowered ADCP data for each station. These vectors show the difference between the two measurements depicted in figure 4b.

This cruise was part of an on-going collaboration between Woods Hole Oceanographic Institution (WHOI) and Bedford Institute of Oceanography (BIO). Since 1995, BIO has been occupying the AR7W section using a CTD for hydrography and an LADCP for velocity. Ultimately, one of the goals of this work is to combine the hydrographic and ADCP data to obtain absolute, geostrophically-balanced velocity sections for each AR7W crossing. These enable us to determine ocean heat transport across AR7W during the spring each year, and assess its changes over time. We are committed to maintaining continuity of these measurements for the foreseeable future, since they comprise an important aspect of the North Atlantic Meridional overturning circulation. Absolute velocity measurements are critical to obtaining accurate estimates of the mass and heat transports, as shown in Hall and Torres (2009).

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Acknowledgments:

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