OC 3570 - Operational Oceanography
Research Report
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Introduction

My initial intent for the cruise experiment was to compare data sets from the side mounted narrow band ADCP(Acoustic Doppler Current Profiler) and the vessel mounted broadband data taken during the first leg of the cruise. The experiment was designed to cover approximately a 1 nm diameter circle just out side Port San Louis, and compare the velocities from the two profilers to examine the variability in accuracy between the two sensors. From those data sets I wanted to do an examination of the differences in velocities measured between a broadband ADCP and a narrowband ADCP and find out what effect it would have on calculating the divergence in and out of the reference circle.

Complications on extracting a good set of narrowband ADCP data for comparison purposes changed the nature of the experiment, and an alternate examination of ADCP data had to be done. For this examination, a data set from the vessel mounted broadband ADCP was to be compared with data from a MTRBM (Mini Trawl Resistant Bottom Mount) ADCP for the same time period at a slightly different location. Both ADCP are broad band units with different frequencies and in this case the data sets would be examined for evidence of correlation between the currents measured to see if spatial and or temporal variations in the data would be noted.

Measurement Description

The data collection took place during the summer of 2003 when the TRBM profiler was first dropped off on the way out of Moss Landing near the head of the Monterey Bay Canyon. The location of the TRBM for this experiment was 46-48.16N, 121-48.22W in a depth of 123 meters of water. The information I have on the TRBM is that it is a broadband unit but I don't have its specific frequency. It recorded data for the experiment in one minute averages, ensembling an unspecified number of pings into the profile. The data sets were binned at 2 meter increments over a range of 50 bins, with the center location of each bin starting at 120 meters, and going upwards to 22 meters.

The ships ADCP locations varied with time as show in the next 2 figures. This ADCP unit was also a broad band unit transmitting pulses at 150 KHz. The data sets in this instance were binned at 8 meter increments over a range of 11 bins. The center location for the bins starts at 19 meters and goes down to a depth of 99 meters.

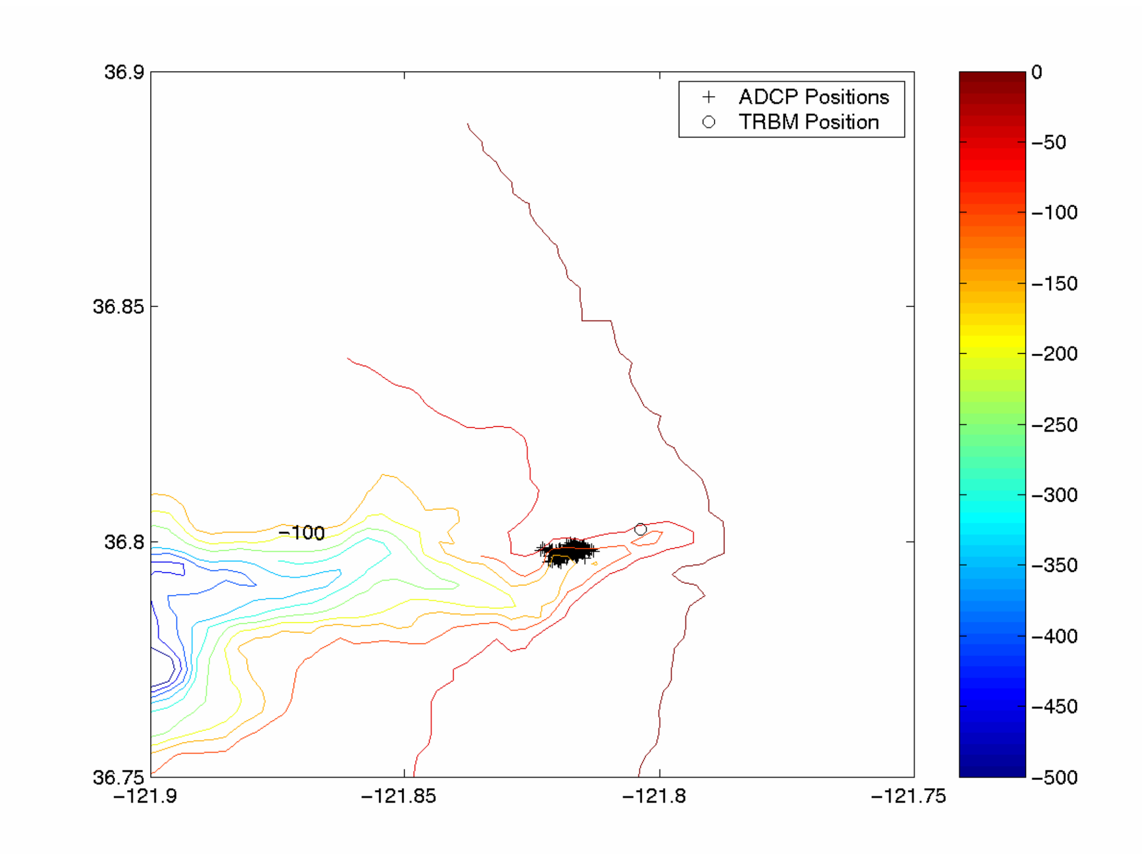


Figure 1 - Wide area map of VADCP and TRBM measurement positions with bathymetry included.

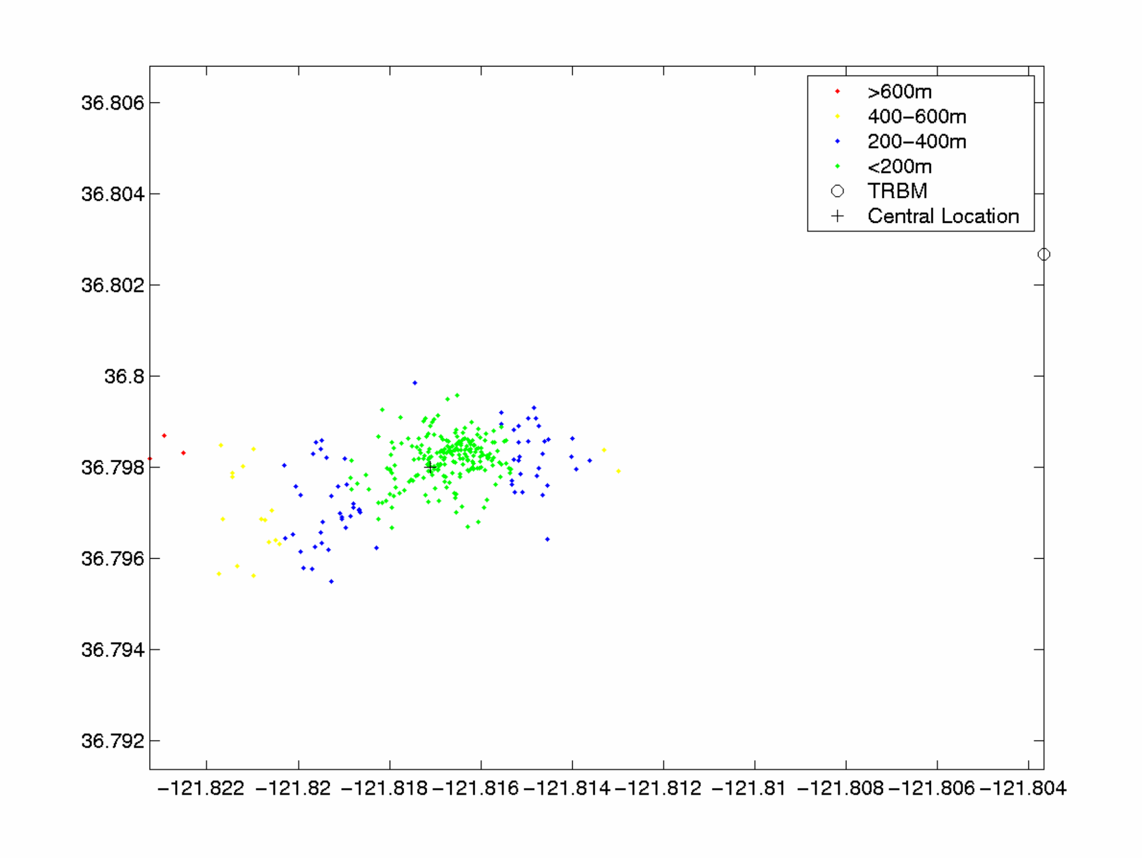


Figure 2 – Map of TRMB and VADCP locations with color coding of distance from centroid location (36-10.974N 121-49.032W)

It is important to note that individual bins velocities are not independent in this experiment. The RDI documentation provided to the class contains an excellent explanation on how critical frequency, pulse width selection and gating are to the performance statistics of the ADCP. Your frequency becomes a critical parameter in determining how far your beam will penetrate the water column, and how accurate your current velocity measurements are. Also by equalizing the gate size[1] to the pulse width you maximize the resolution capabilities of the ADCP while minimizing the uncertainties of the mean bin velocities. Still even when the performance of the ADCP is well tuned there remains a 15% correlation in the velocities of each bin because of the overlap in the gates.

Data Processing

With all the background information on the contents of the measurements and the actual data sets in hand, the process of sorting through the files and analyzing them began. I started with plotting a time / position chart of the VADCP data set to get a reference frame of where the data was collected relative to the TRBM data. The positions were plotted geographically with a Monterey Bay bathymetry file to give a close geographic proximity to the data. Once all the points were plotted I concluded (see Figure 1) that the VADCP positions were fairly close to one another and all seemed to be in the canyon channel on an axis similar to the TRBM.

Once I had examined the positions, I processed the time / position location of the VADCP data to locate a centroid and plot a color correlated chart depicting the distance of the data points from the centroid (Figure 2). The statistics showed that a majority (93%) of the points were within 400 meters of the centroid, so that spatially they were located in a homogeneous same water column. I used this as a simplifying conclusion so that I could treat the VADCP data as having a singular position at the centroid of the set, and use the VADCP data as a time series similar to the time series of the TRBM, even though the sets were collected over a five minute interval while the ship was drifting.

After I made my simplifying assumption I continued processing the sets to create graphs of the mean u and v components, as well as the mean magnitude of velocity for the raw TRBM and VADCP data sets (Figure 3 and Figure 4). The mean velocity profiles were compared and contrasted, graphically to examine the variation in flows at both positions. The initial visual inspections lead me to further process the data sets to examine the velocity correlations at the two different positions.

To do the cross comparisons the TRBM data sets had to be reshaped to create a data set that had a 1:1 relationship with the VADCP data sets. The initial TRBM sets were in 2 meter bins, with centers ranging from 120 meters to 22 meters as mentioned earlier. The VADCP sets were in 8 meter bins with their centers located from 19 meters to 99 meters. To reduce the TRBM sets I used a vector averaging technique to compress the data into 11 layers with the same bin centers as VADCP data. In addition the TRBM data was recorded in 1 minute averages while the VADCP sets were in 5 minute averages, making temporal averaging necessary as well. When all the reshaping of data sets were completed, the VADCP data and TRBM data were binned into 8 meter increments from 27 to 99 meters, at 5 minute increments for cross comparison purposes. (Figure 5)

After looking at the mean velocities my initial instinct was to use a cross correlation function in Matlab to process the two different locations for information. Initially the cross correlation function didn't provide much useful insight or understanding of the data sets. I made a trip to Dr. Collins' to discuss the initial correlation results and get some guidance on extracting some useful information on the correlations.

After some coaching I took his suggestion to begin a new analysis using an autocorrelation function, and applying a normalization options in Matlab. The idea was to examine the autocorrelation statistics of the u and v components of velocity for the

TRBM and the ADCP data sets and see if there were any signatures of a diurnal or semi-diurnal cycle present in the velocity profiles. (See Figures 6 - 9).

When I had finished massaging the autocorrelation plots, the showed some good promise at being able to make a cross correlation plot work as well. So I went back to the data sets again and made a second attempt at the cross correlation values. This time with normalization factors properly executed the results became more pronounced and meaningful. (Figures 10 & 11)

I had hoped to do some additional processing of the data sets, but due to time limitations, and data availability the processing stopped with the cross correlations on the data as the primary comparator mechanism.

Results

The visual comparisons between the mean u and v velocities of the VADCP data and the TRBM data, lead me to believe there was good temporal correlation between the u components at both locations. On the other hand the v components didn't seem to have that same correlation. There was very little velocity in the v direction on the TRBM, for depths below 50 meters, and in comparison to the ADCP profile taken further east in the channel.

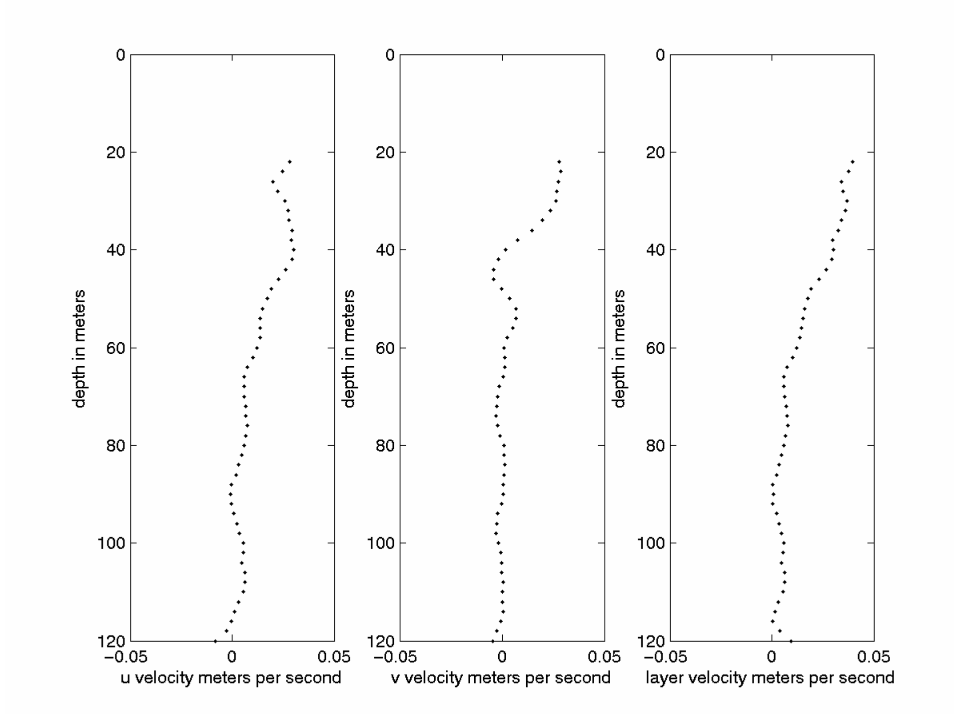


Figure 3 – TRBM current velocities (u component, v component, magnitude)

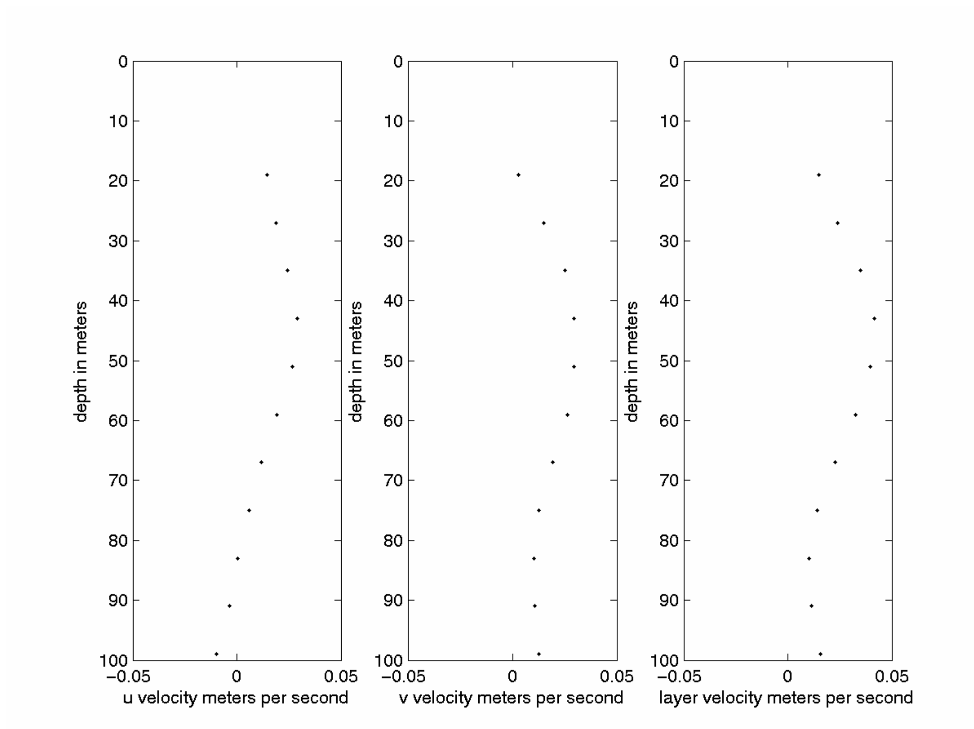


Figure 4 – VADCP current velocities(u component, v component, magnitude)

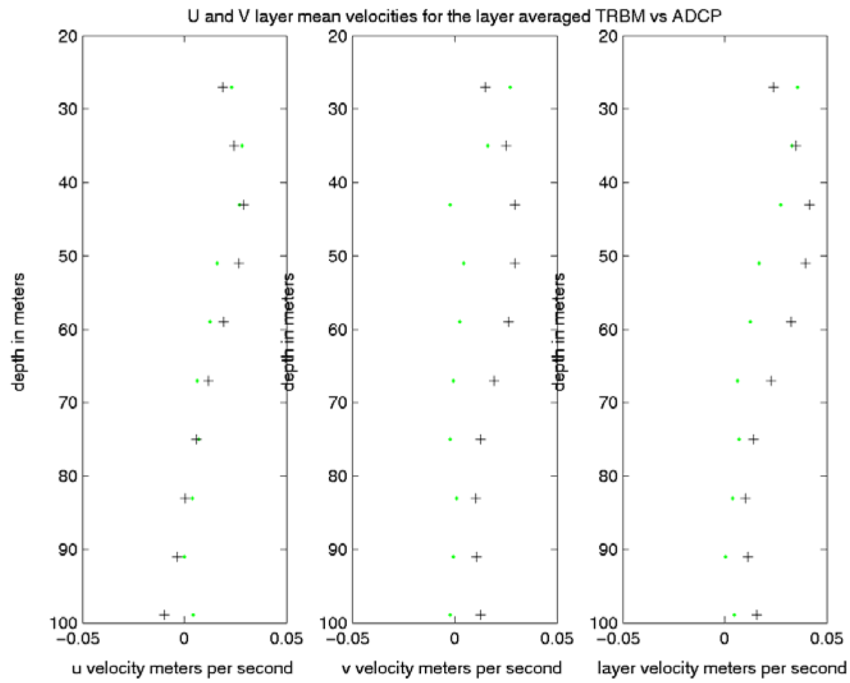
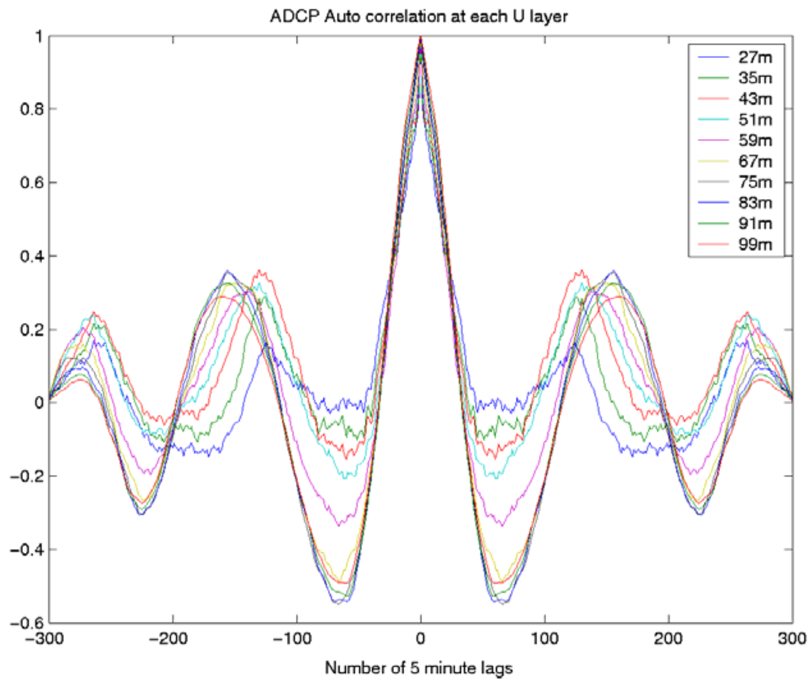


Figure 5 – TRBM vs VADCP velocities.

Once I started the autocorrelation functions for the u and v components I was surprised to see how well the v component of the VADCP measurements correlated, showing good signal for a diurnal and semi-diurnal cycle occurring in the velocity measurements. I had expected the u component to correlate and in fact in both velocity component cases the best correlation coefficient came from the deeper water layers, especially in the 60 to 90 meter ranges.



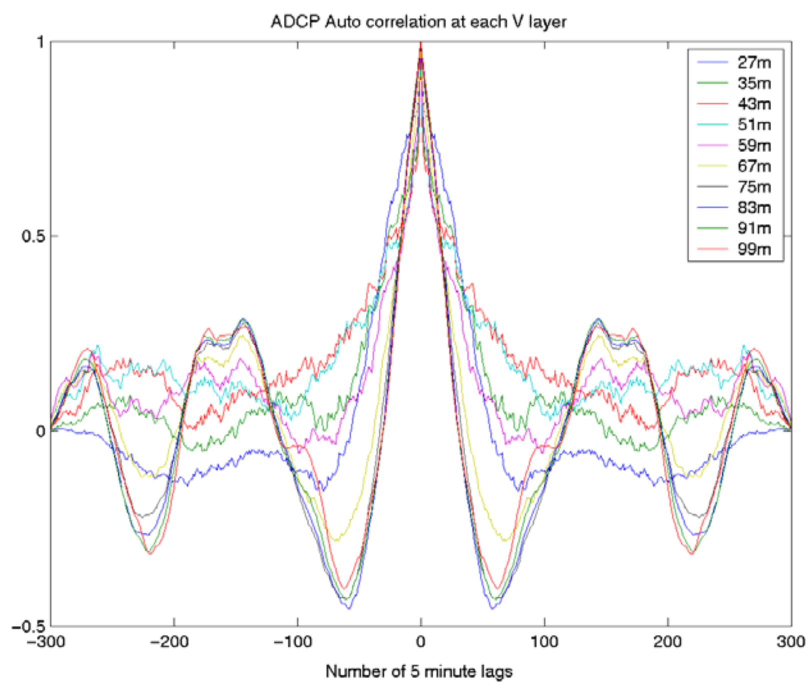
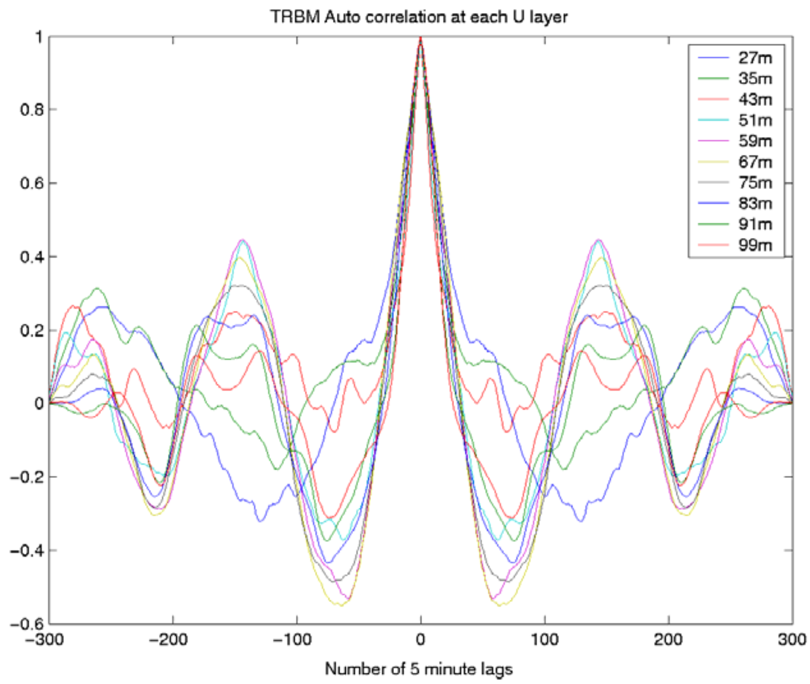


Figure 6 & 7 – Autocorrelation statistics for the ADCP u and v velocities. Colors represent different layer depths, with all depths plotted from 27 meters to 99 meters.

Moving next to the TRBM data again the autocorrelation functions contained far fewer surprises, when only the u components showed up with some degree of correlation, again mostly at the deeper ranges of 60 to 90 meters. In the case of the v components there was almost no correlation, to a cyclic response, and the u components at shallow depths were very erratic as well, which is what I had expected after examining the mean velocities.



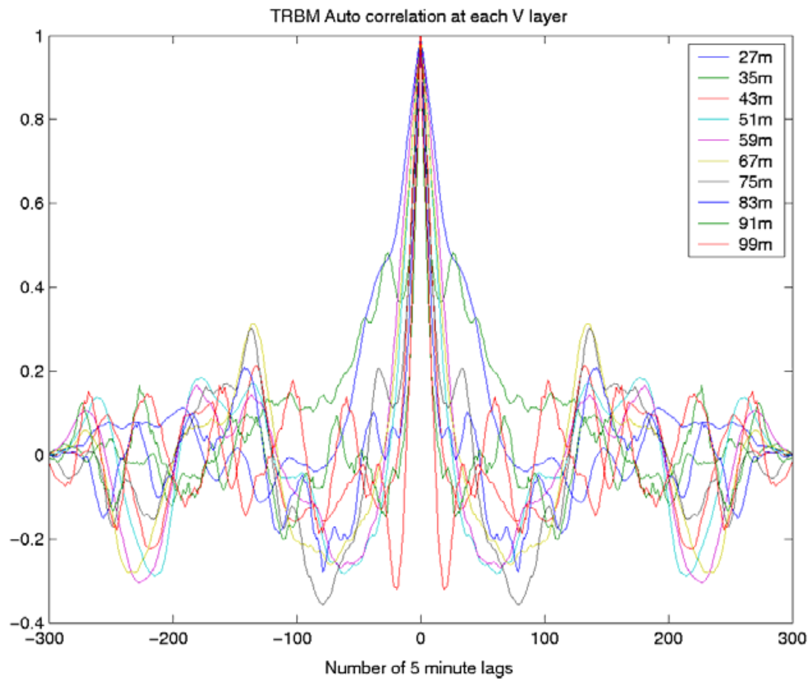


Figure 8 & 9 – Autocorrelation plots for TRBM data for the same depths as in figures 7 & 8.

Once I had seen the results of the autocorrelation, I began to understand better what I should look for in the cross correlations. Still I was skeptical that I might not see any cross correlation between the two spatially separated data sets. In the case of the v components that turned out to be true. With the u component though there was better than expected correlation for the diurnal and semi-diurnal cycle, with the strength of correlation increasing with depth. In addition I believe you can see on the cross correlation of the u velocity the phase lag with depth the water column has in response to the tidal cycles. It was more than a little surprising to see that the deep water contained inside the canyon wall responded first to the tidal forcing with a lead time somewhere in the range of 45 minutes to an hour.

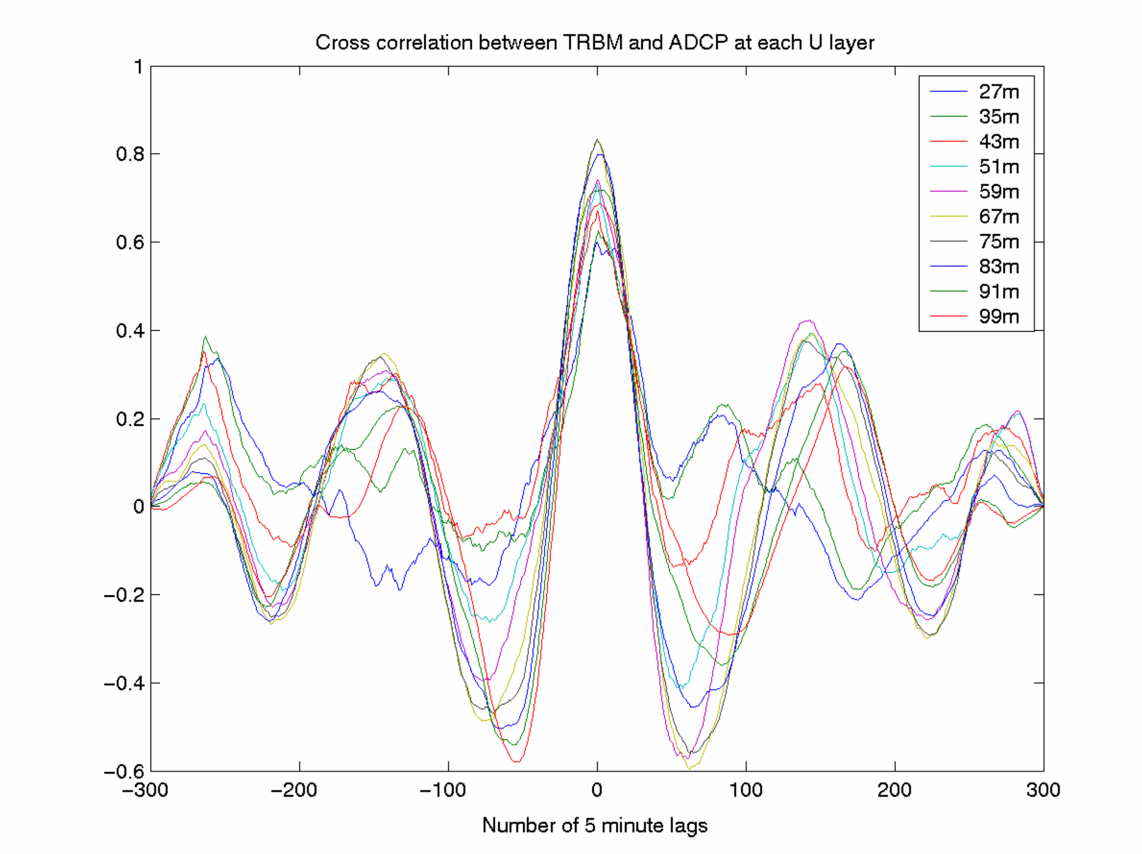


Figure 10 - Cross correlation values for the u velocity components for the each layer of the TRBM and VADCP sets.

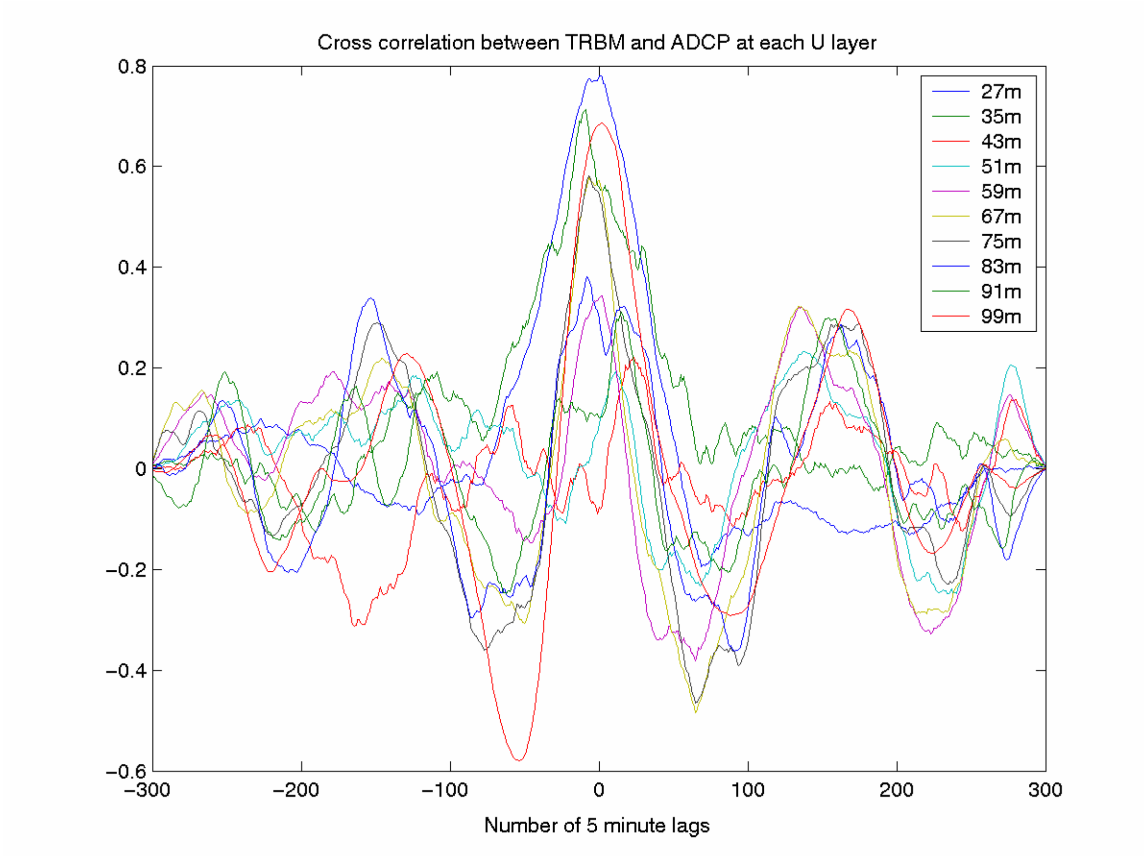


Figure 11 - Cross correlation values for the v velocity components for the each layer of the TRBM and VADCP sets.

Conclusion/Recommendations

Because of deep water response to the diurnal cycle, I believe that terrain has a great effect on direction and speed of the deep tidal currents in the Monterey Bay. It is clear that terrain forcing limits the v directed velocities for the TRBM data taken at the head of the Monterey Bay canyon. It can also be seen that at shallower depths the response to the diurnal forcing falls off. I believe that the reason for the de-correlation in velocities at shallower depths is from wind forcing and likely the corresponding Ekman transport that occurs because of it.

It would be an interesting analysis to go back and examine the velocities with a more accurate bathymetry file to see if the magnitude of the velocities scale to the cross sectional area of the canyon. I think that if this comparison were also be made, it would offer even stronger proof that terrain forcing of the lower level currents was occurring. Additionally if time allowed Ekman transport could be calculated and included into the analysis, to test that hypothesis as well.

The fit and accuracy of the data seemed to be very plausible for these conclusions even though the bins were not entirely independent and a straight averaging technique was used in the analysis to combine 2 meter bins into 8 meter bins. The linear combination of the TRBM layers doesn't seem to have corrupted the data sets, by making them into unreasonable values. When comparing the 2 meter binned data to the 8 meter re-analyzed bin data the points plotted on the graph for the u, v, and total velocities were all identical, leading me to believe that the co-dependence of the bins has minimal impact on the velocity comparisons.

In all cases the data cross correlations were made at individual levels, at each location, which I believe minimizes the impact of bins having some vertical velocity correlation at each position. Ideally a windowing technique could be employed to improve the averaging technique, but without some type of comparison standard to examine the effects of this type of analysis it would be just a lot of hand waving with no way to determine if any real additional value was added.

Definitions:

1. Gate size – the time period the ADCP listens for pulse returns, that corresponds to the depth size of data bins. It becomes a function of frequency, and pulse width, to maximize accuracy and resolution.

References:

White Paper – RD Instruments: "Acoustic Doppler Current Profilers Principles of Operation: A Practical Primer", Jan 1989.