ADCP data issues – Steve Simmons, University of Hull, UK

The following is a discussion document focussing on the quality and artefacts of the data acquired with the ADCPs during the large flow events.

Contents

1. Poor Signal-to-Noise regions

Regions of poorly correlated data appear in two locations, ‘above’ and ‘below’ the flow, immediately after the Jan 15 flow is first observed in the ADCP data.

1.1 BIN ADCPs

Fig. 1 shows the screened out area of data above the flow for the upward looking 300 kHz ADCP on the BIN at the beginning of the Jan 15th event. The x-axis is the ensemble number within the full sequence and the y-axis is the bin number. The color-scale is velocity magnitude in mm/s. The screened out area is in dark blue. Fig. 2 shows the raw echo magnitude data averaged over the four beams for the same ensemble profiles as Fig. 1. A prominent feature that occurs immediately at the beginning of the flow is the raised levels of backscatter throughout the water column. This is thought to be due to reverberation caused by multiple scattering within the high concentration near-bed suspension within the flow. The multiple scattering causes the sound energy from a ping to reverberate within the flow and scatter sound back towards the transducers for some time after transmission, interfering with the following ping and effectively raising the noise level for the full profile. The beginning of this effect is clear and is denoted by the vertical red line on the left, but the end of the effect is less clear as it slowly reduces in magnitude with time - an approximation based on visual inspection of the data is denoted by the red line on the right. The effect of the reverberation is to increase the effective noise and, since the quality of the correlations for the velocity processing are dependent on a good signal-to-noise (SNR) ratio, regions of low-backscatter from low concentrations of suspended particles in the ambient flow above are more susceptible. This is not the only effect, however, as the sediment scattering within the flow attenuates the signal.

Fig. 3 shows the same data as Fig. 2 but on a scale that stops at a raw magnitude value of 80. The plot shows that, even after the reverberation effect has ceased, the attenuation through the high concentration flow is sufficient to reduce the backscatter to below 80 high in the water column at the farthest extent of the range. This approximate region is screened out in Figure 1 in addition to the region where reverberation is an additional factor in SNR degradation.

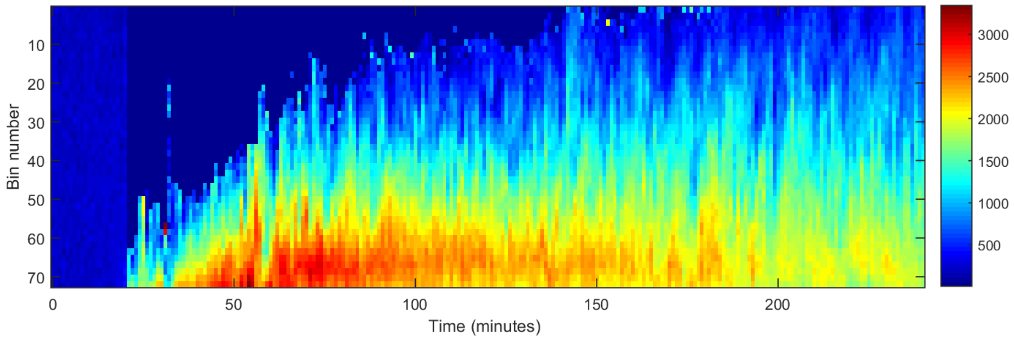


Fig. 1 Velocity magnitude (mm/s). BIN 300 kHz ADCP Jan 15th

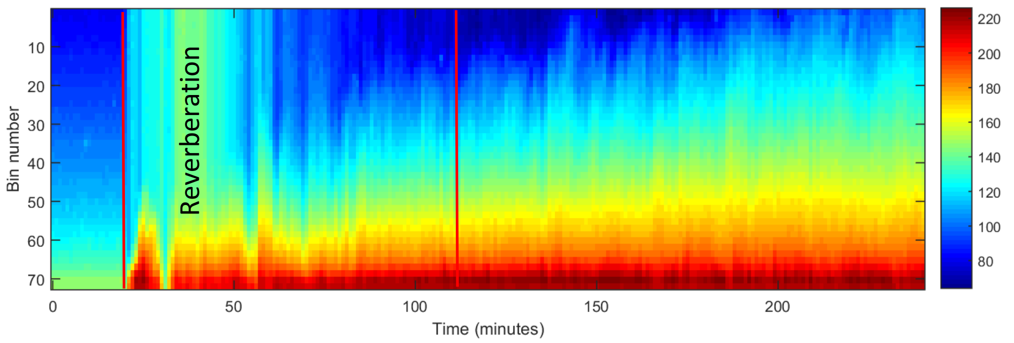


Fig. 2 Raw echo amplitude for BIN 300 kHz ADCP averaged over four beams. BIN 300 kHz ADCP Jan 15th

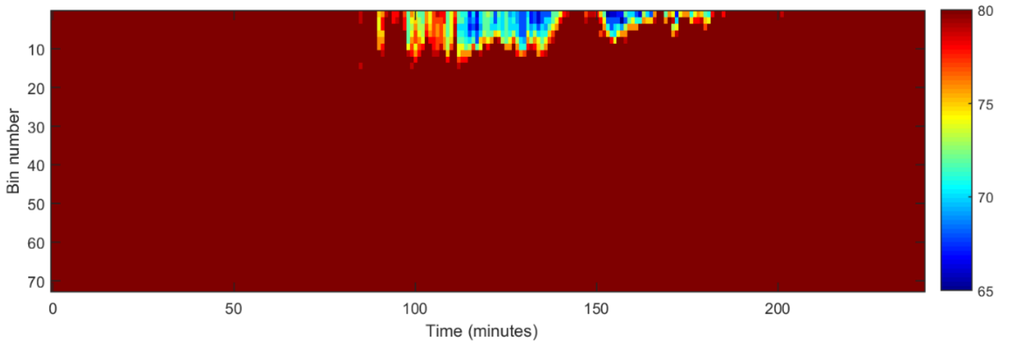


Fig. 3 Raw echo amplitude for BIN 300 kHz ADCP, cropped at 80. BIN 300 kHz ADCP Jan 15th

Fig. 4 shows the error velocity magnitude with the region where the magnitude exceeds 2000 mm/s screened out and depicted in blue. The extent of the region is similar to that shown in Fig. 6 which shows the correlation threshold defined as having three beams with a correlation of 64 or greater, so both measures of poor data tend to agree about this region.

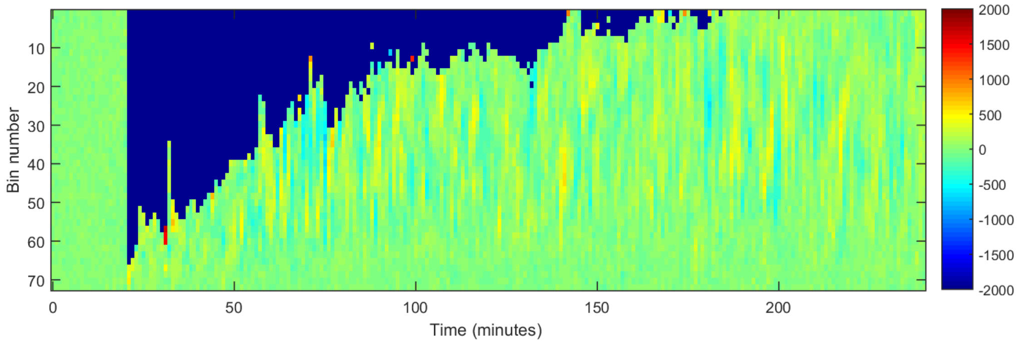


Fig. 4 Error velocity in mm/s. BIN 300 kHz ADCP Jan 15th

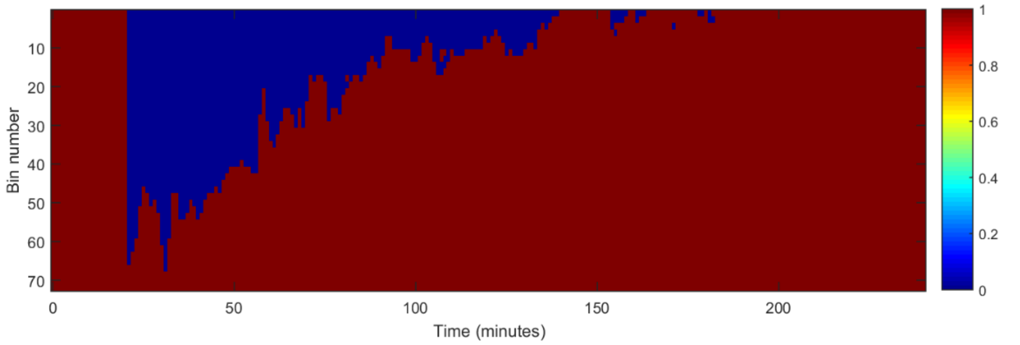


Fig. 5 Region where at least three beams have a correlation of 64 or greater. BIN 300 kHz ADCP Jan 15th

1.3 Moored ADCPs

Fig. 6 shows screened out areas of data above and below the flow for the downward looking 300 kHz ADCP on the MS7 mooring at the beginning of the Jan 15th event. The x-axis is the ensemble number within the full sequence and the y-axis is the bin number. The duration of time window shown is the same as with Figures 1 to 5. The region of screened out data represented in dark blue is more limited than with the upward looking ADCP on the same frequency at the nearby BIN site. This is because the SNR is improved in the upper region of the interrogated water column due to the higher signal in the ambient flow above the density current. The signal in this region is higher as it is closer to the transducers and therefore not subject to the same degree of spherical spreading, water attenuation and sediment attenuation. The region of reverberation in the ambient flow can be seen in the averaged backscatter in Fig. 7. The regions beyond the threshold error velocity and with less than three beams with a correlation above the threshold are shown in Fig. 8 and Fig. 9 respectively.

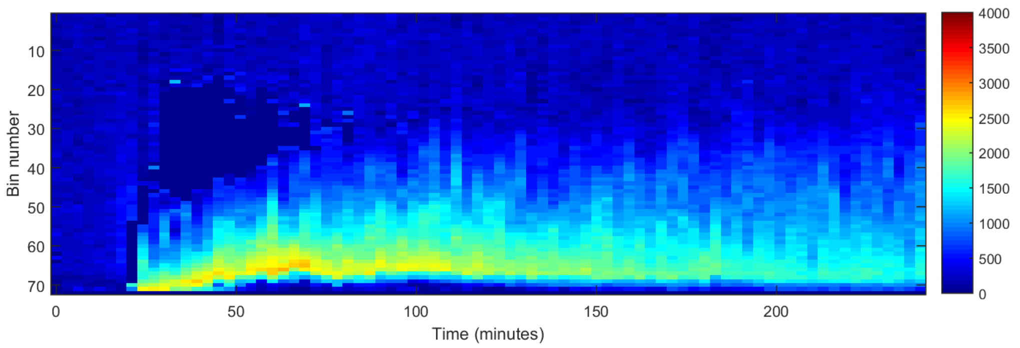


Fig. 6 Velocity magnitude (mm/s). MS7 300 kHz ADCP Jan 15th

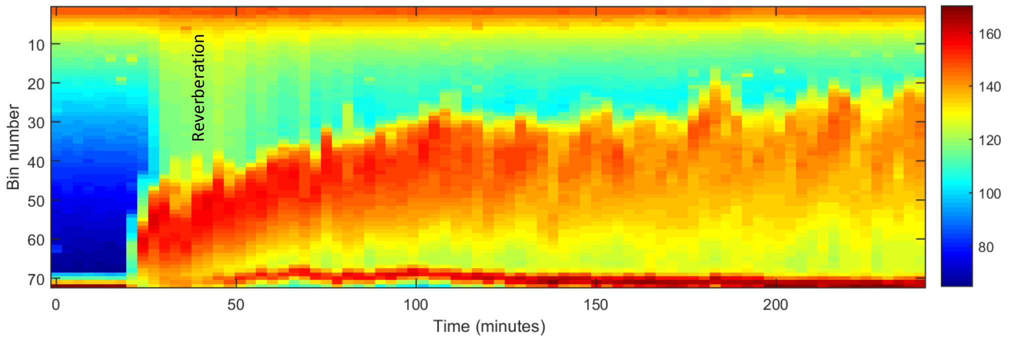


Fig. 7 Raw echo amplitude averaged over four beams. MS7 300 kHz ADCP Jan 15th

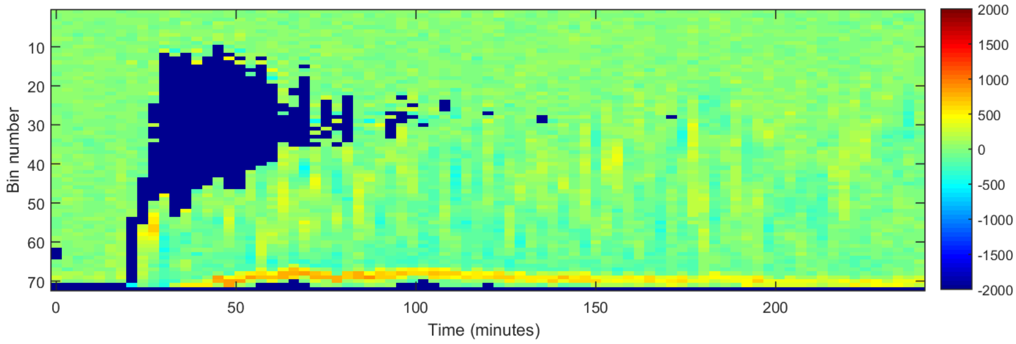


Fig. 8 Error velocity in mm/s. MS7 300 kHz ADCP Jan 15th

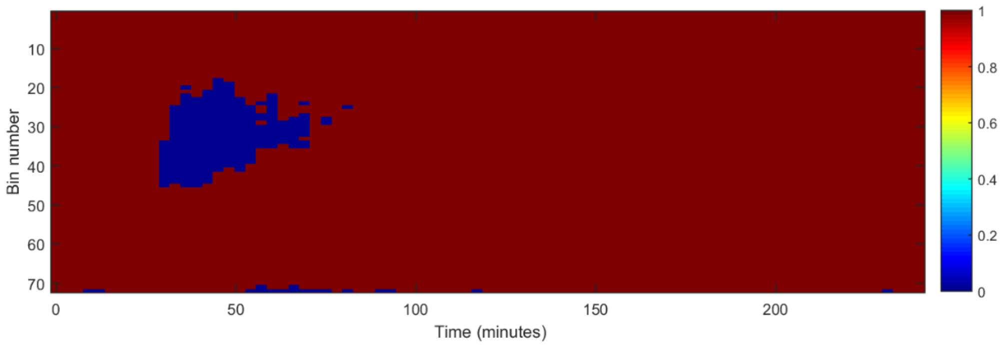


Fig. 9 Region where at least three beams have a correlation of 64 or greater. MS7 300 kHz ADCP Jan 15th

There is probably little than can be done to recover meaningful data in these regions, so screening out may be the simplest way to deal with this issue. As the affected regions appear to be above the flow event then this may not be such an issue with regards to velocities. For backscatter processing to evaluate sediment concentration it may not be that much of an issue either: For the downward looking instruments the region is probably low sediment concentration and hence low sound attenuation so can be ignored. For the upward looking instruments the region is low attenuation and on the other side of the flow structure, so will not make a difference to the forward inversion solution.

2. Sidelobes

Near-bed sidelobe interference is a problem for ADCPs as a result of the graxing angle of ~20^0 with the bed. Poor velocity measurements in the bins nearest to the bed are therefore usually screened out. The effect is also problematic for backscatter analysis to derive suspended sediment concentration. However, when the near-bed backscatter is very high due to a high concentration of suspended sediment then it is possible for the signal to be sufficiently higher than the sidelobe interference noise to obtain velocity measurements close to the bed. This can be seen in the velocity magnitude plot for MS5 in Fig. 10. The smaller circled area on the left in the head of the flow has velocity measurements down to the bed that look realistic. The larger circled area on the right shows the re-established boundary of the poor quality sidelobe interference region as the near-bed concentration in the flow drops from around 20-30 minutes after the beginning of the event. Fig. 11 shows the corresponding echo amplitude data averaged across all four beams. The red circled area on the left shows where sidelobe interference occurs near the bed in the ambient flow prior to the event. The green circled area is roughly where the unwanted effect is overcome by high near-bed concentrations and the red circled area on the right is where the effect is re-established as the concentration drops. To interpret this effect on both of these plots it's important to note that the ADCP has been pulled closer to the bed quite sharply at the beginning of the flow and slowly recovers back to the same height above the bed during the time window shown (see section 4.1).

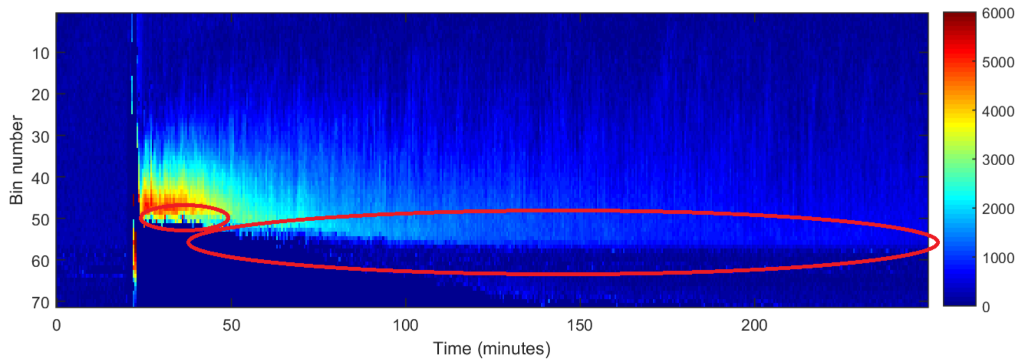


Fig. 10 Velocity magnitude (mm/s). MS5 300 kHz ADCP Jan 15th

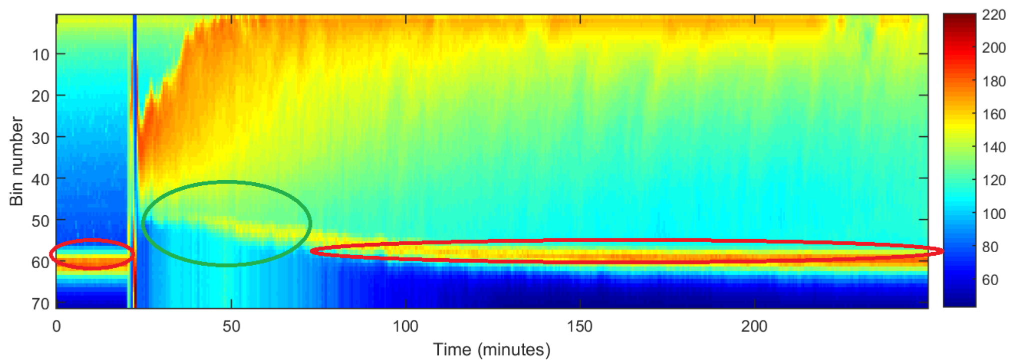


Fig. 11 Raw echo amplitude for BIN 300 kHz ADCP averaged over four beams. MS5 300 kHz ADCP Jan 15th

3. Varying velocity across swath

This doesn't seem to be that much of a problem but does occur with the slower moving Sep 1 event at the slowest measurement locations, particularly MS7. The different arrival times of the flow front cause poor velocity values that can be seen in the circled area of the velocity magnitude plot shown in Fig. 12. The different arrival times of the front can easily be seen in the differences in the backscatter for the four beams as shown in Fig. 13. It probably isn't possible to resolve this issue for the derived velocity vectors but it might be possible, at these lower flow speeds, to approximately determine the frontal speed from the different arrival times.

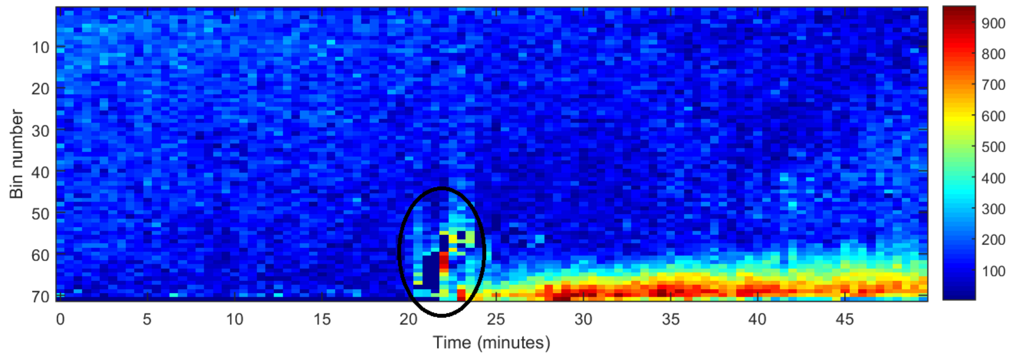
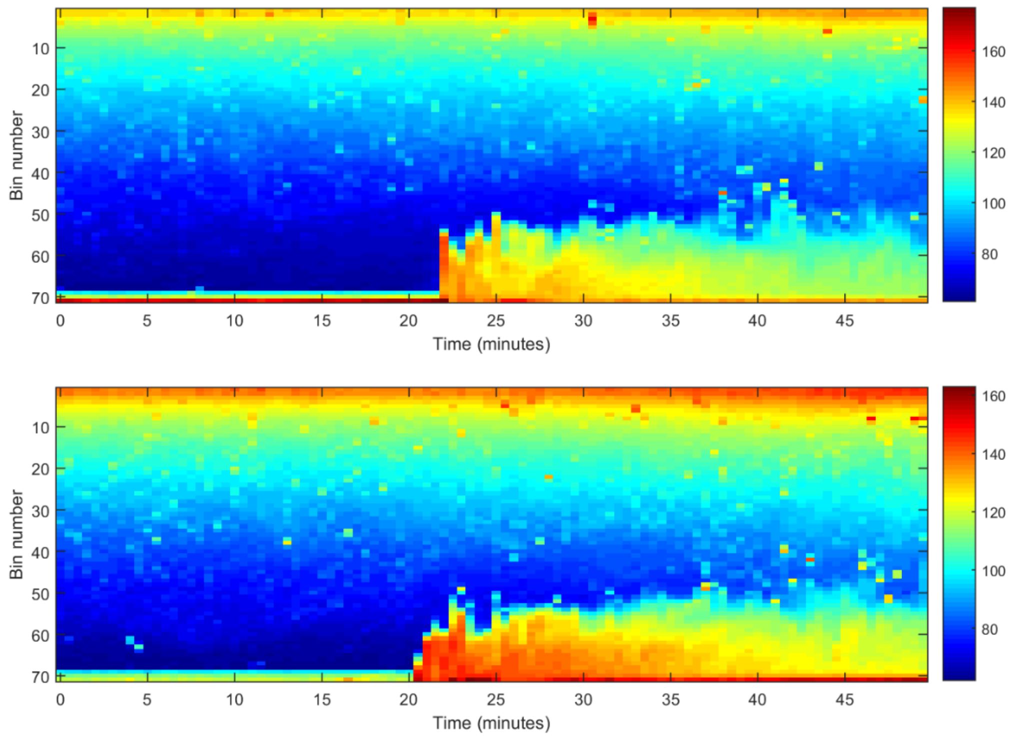


Fig. 12 Velocity magnitude (mm/s). MS7 300 kHz ADCP Sep 1st



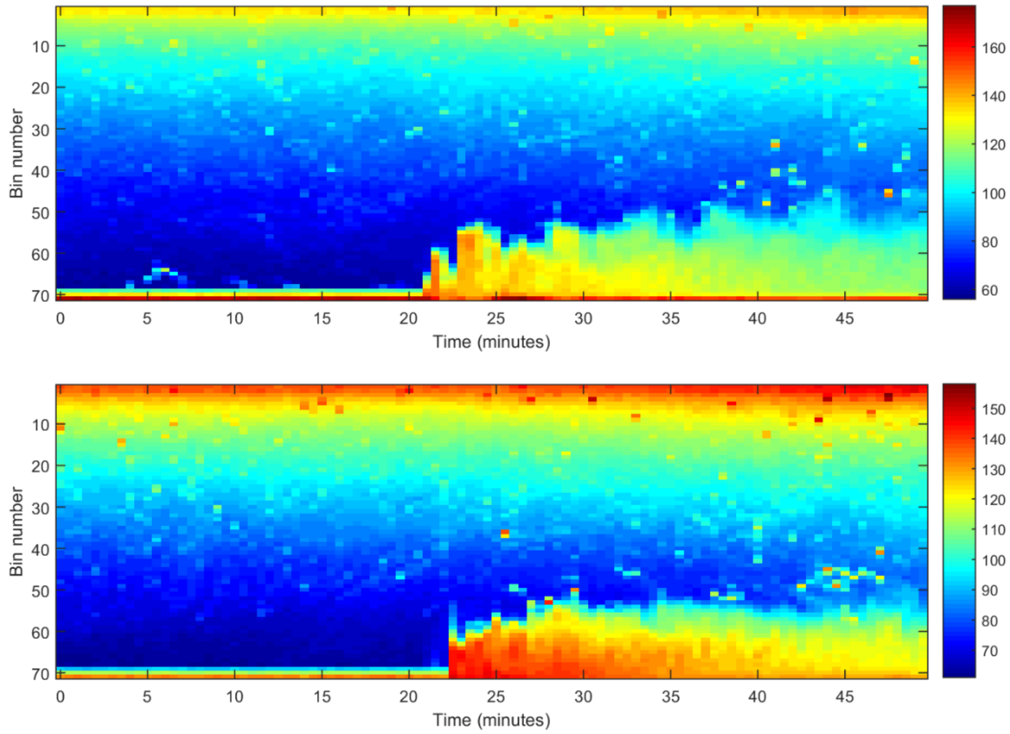


Fig. 13 Raw echo amplitude for BIN 300 kHz ADCP for beams 1 to 4 respectively. MS7 300 kHz ADCP Sep 1st

4. ADCP motion

The instruments on the moorings are free to rotate and tilt and roll with the current. The occasions that these effects are most prominent coincide with the most interesting part of the flow when it has the most energy and has the highest suspended load of sediment. The motion isn't limited to the impact of the flow on the instrument but also the forces acting on the other elements on the mooring including the anchor and the sediment traps.

4.1 Heave

Fig. 14 shows the averaged echo amplitude for the MS3 mooring during the early stages of the Jan 15th event. The flat, uniform, high magnitude echo from the bed (and sidelobes) can clearly be seen before the head of the current event passes through the measurement volume. The location of the highest echo, presumed to be the bed, then decreases sharply in distance but then slowly increases over a period of around two to three hours back towards the original location at bin number ~60. This variation in the range to the bed is explained by the ADCP being pulled vertically towards the bed during the period of the highest flow velocities, probably by the action of the current on the sediment trap which results in it being pulled to a position downstream of the anchor and lower in the water column. The same effect can be seen in Fig. 15, which shows the velocity magnitude over the same time period. The bin number with the highest echo amplitude is plotted in Fig. 16 for all four beams. The range to the bed shows a similar pattern for all four beams, demonstrating that the ADCP is being pulled downwards rather than being tilted for the majority of this period other than the first ~10 minutes of the flow. The position of the bed within this initial phase is more difficult to determine as a result of the high suspended sediment attenuation and a short-lived roll/tilt of the instrument that can be seen in Fig. 16.

Where the position of the bed is clear then the effect can be dealt with in the 2D plots by re-aligning the data to the location of the bed. Figs. 18 and 19 show the raw echo amplitude for a single beam and the velocity magnitude derived from a combination of the beam data after re-alignment

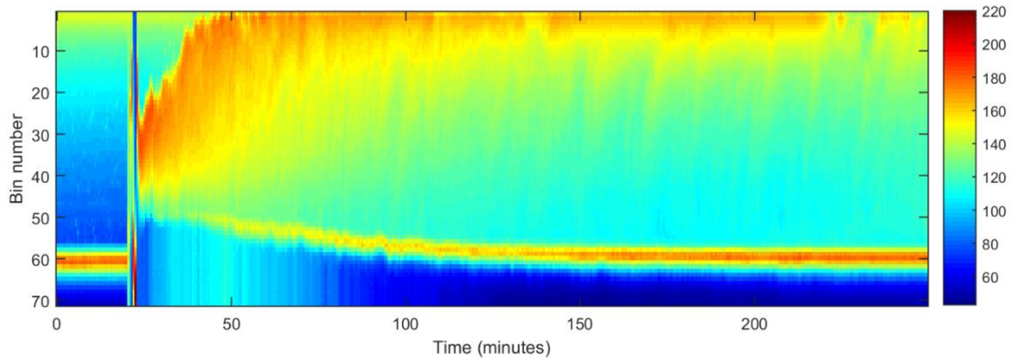


Fig. 14 Raw echo amplitude for BIN 300 kHz ADCP averaged over four beams. MS3 300 kHz ADCP Jan 15th

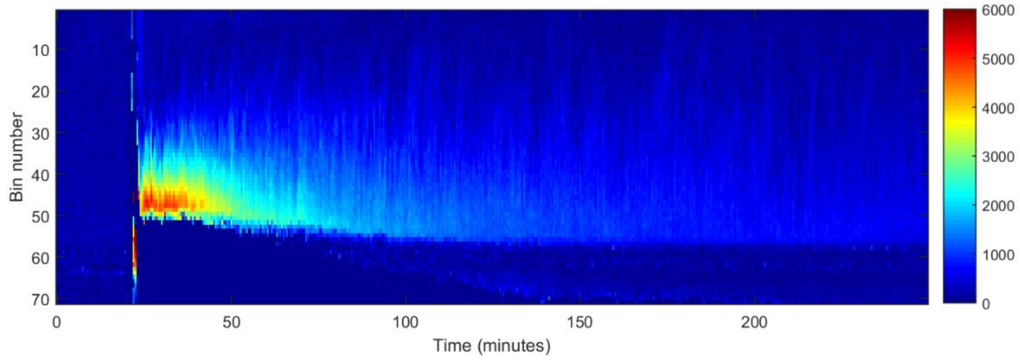


Fig. 15 Velocity magnitude (mm/s). MS3 300 kHz ADCP Jan 15th

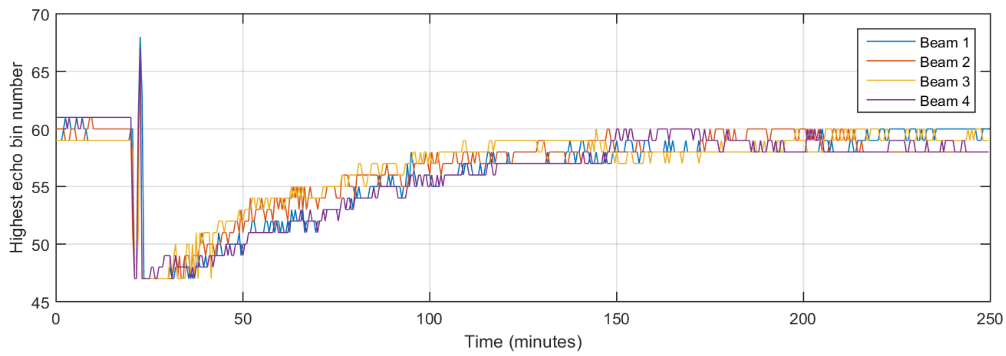


Fig. 16 Bin number containing the bed (highest magnitude echo) for all four beams. MS3 300 kHz ADCP Jan 15th

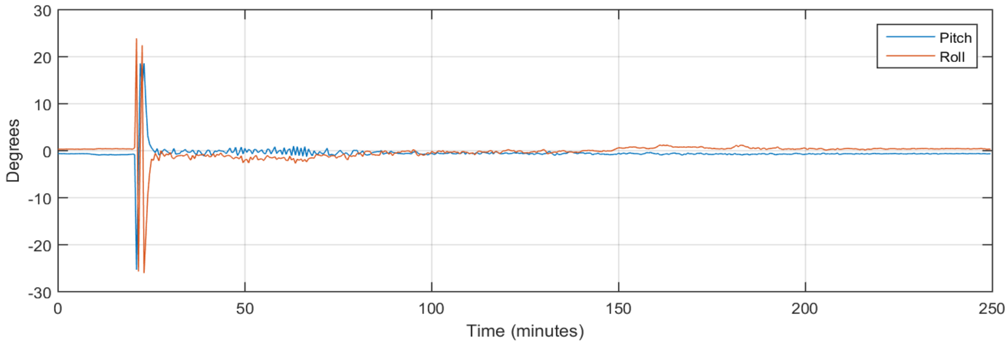


Fig. 17 Pitch and roll. MS3 300 kHz ADCP Jan 15th

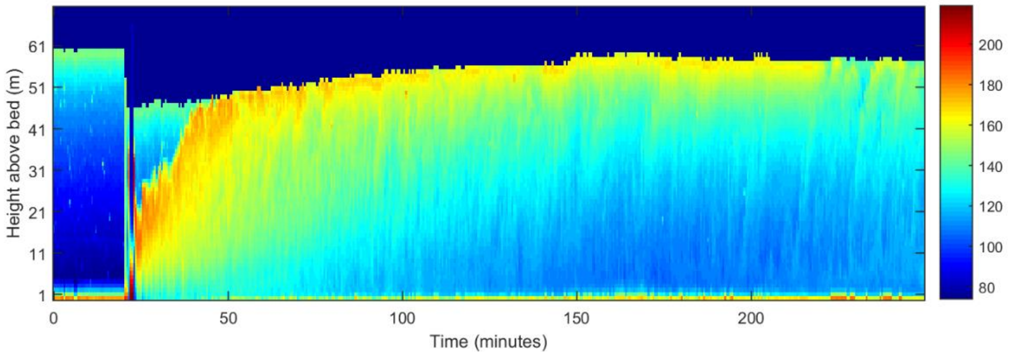


Fig. 18 Re-organised raw echo amplitude for beam 4. MS3 300 kHz ADCP Jan 15th

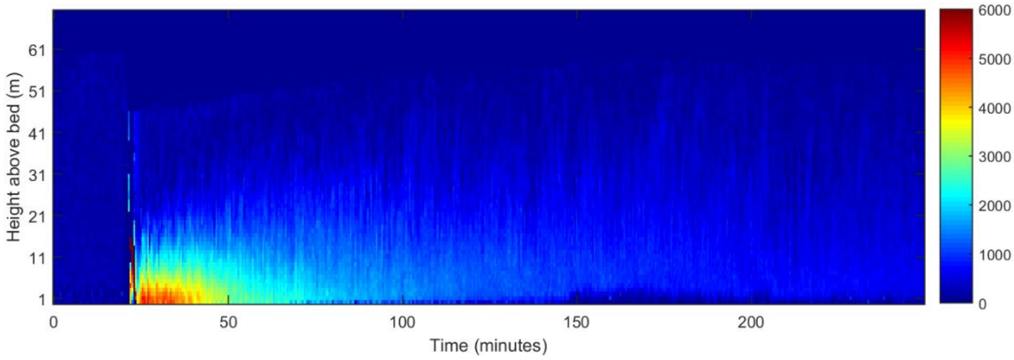


Fig. 19 Re-organised velocity magnitude (mm/s). MS3 300 kHz ADCP Jan 15th

4.2 Pitch/Roll

For the majority of the flow event data acquired by the moored ADCPs, the effects of instrument pitch and roll are usually confined to the early stages of the flow. The velocity data derived by the instrument is corrected for these motions, but the location of the sampling volumes are affected. Fig. 20 shows the raw echo amplitude averaged over all four beams for the Jan 15th event at the MS4 mooring. This is an isolated case of a more prolonged and significant pitch/roll motion of the instrument during an event. The effects of this motion can be seen as the varying location of the high amplitude echo from the bed, particularly in the region from ~270 to ~420 minutes where there are multiple bed echoes at different ranges. This region corresponds to high values of pitch shown in Fig. 21. The slant range to the bed remains roughly similar for beams 1 and 2 during this period (Fig. 22) but the range decreases for beam 3 at the same time as it increases for beam 4 indicating that the instrument is rotating more dominantly in one axis, as was shown by the pitch/roll plot in Fig. 21.

For the velocity vector data, this effect increases the near-bed range over which velocity measurements are unreliable beyond the usual sidelobe interference range. There would need to be a marginal interpolation of the range scale to take into account the slant – bin 70 is at an average of 71.1 m below the transducers rather than 72.2 m at a 10^0 pitch. For the suspended sediment analysis using the echo amplitude data, the beams with the smallest pitch/roll can be selected, e.g. beams 1 and 2 in the example shown.

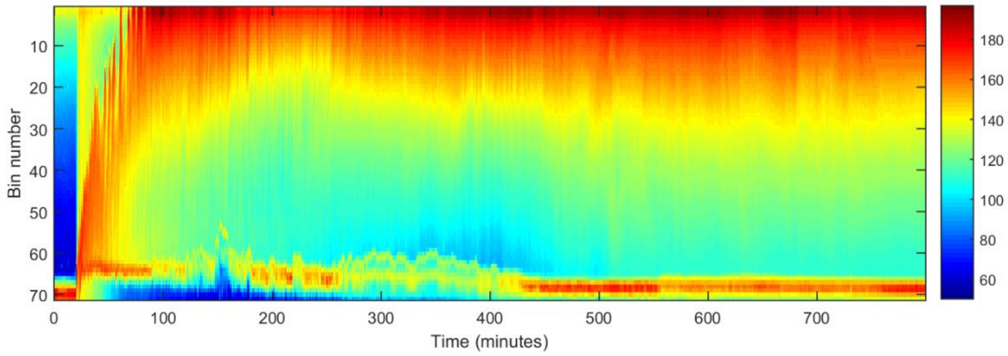


Fig. 20 Raw echo amplitude for BIN 300 kHz ADCP averaged over four beams. MS4 300 kHz ADCP Jan 15^{th}

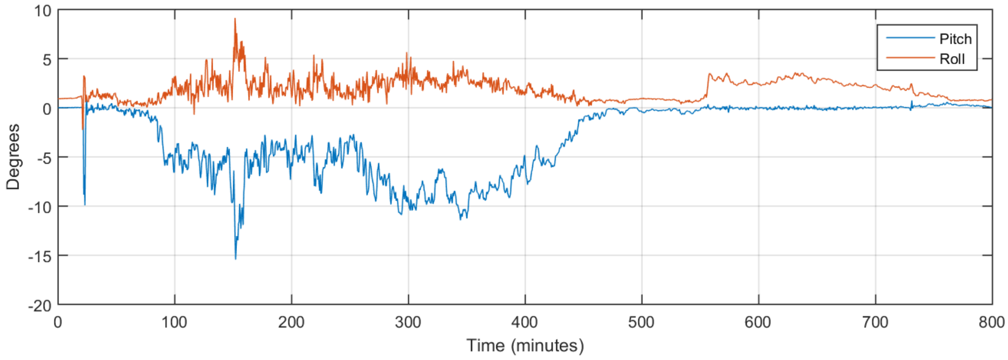


Fig. 21 Pitch and roll. MS4 300 kHz ADCP Jan 15^{th}

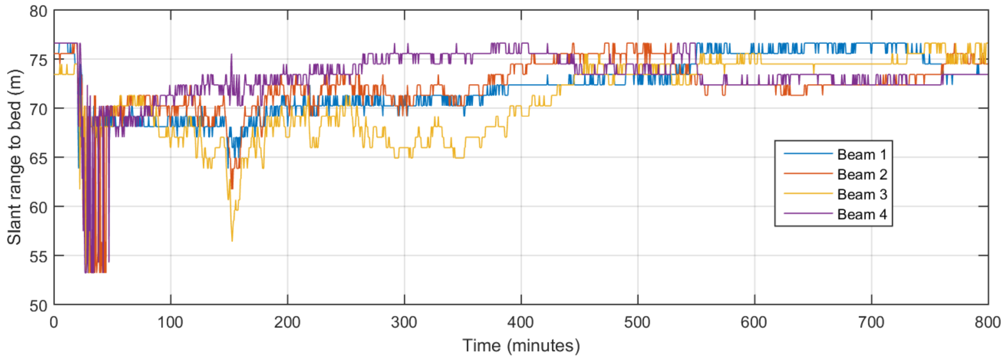


Fig. 22 Slant range to the bed (highest magnitude echo) for all four beams. MS4 300 kHz ADCP Jan 15^{th}

4.3 Heading

The moored ADCPs rotate frequently in response to the actions of the flow on the instrument and other instruments on the mooring. This isn't much of a problem, usually, as the velocity vector components are adjusted for the compass heading and the range to the bed remains reasonably constant if the bed elevation remains constant within the swath. However, for some of the moorings higher in the canyon, the bed elevation varies significantly within the ADCP swath. An example is the MS2 mooring data from the deployment from October 2015 to April 2016. A short section of this data is shown in Fig. 23 just after the Jan15th event. The location of the highest echo from the bed can be seen to change with time and is related to the compass heading shown in Fig. 24. Sidelobe interference is a particular problem when the beam is oriented towards the lower regions of the bed as can be seen by the increased backscatter levels near the bed in the region from ~100 minutes to ~240 minutes. The variation in the range to the bed is a function of compass heading as can be seen in Fig. 25 where the range is plotted against compass heading for one of the beams. The velocity data is derived from a combination of all beams and is therefore severely affected in the region where there are strong echoes from different bed elevations and high sidelobe interference. This effect can be seen as the blanked out regions of poor velocity magnitude data throughout the record shown in Fig. 26. In the earlier stages of the flow event it may be possible to recover good echo amplitude data for suspended sediment processing near the bed by selecting the beam that is directed towards the lower bed elevations, but this would only be effective if the backscatter from the suspended sediment is high enough to overcome the high sidelobe interference.

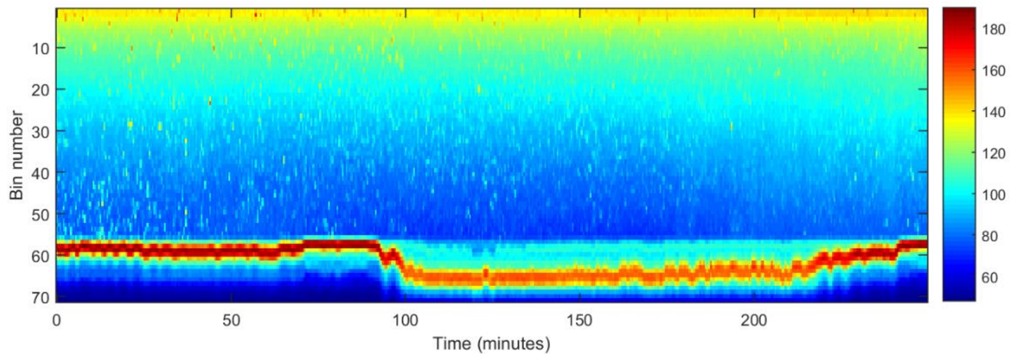


Fig. 23 Raw echo amplitude for BIN 300 kHz ADCP for beam 2. MS2 300 kHz ADCP – just after Jan 15th event

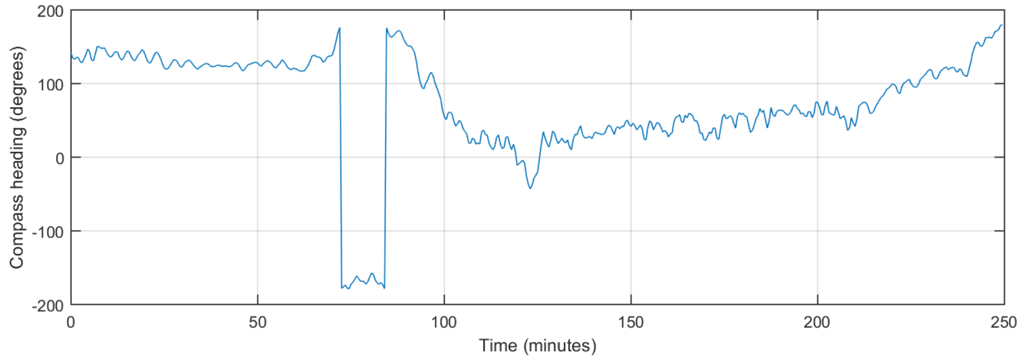


Fig. 24 Compass heading. MS2 300 kHz ADCP – just after Jan 15th event

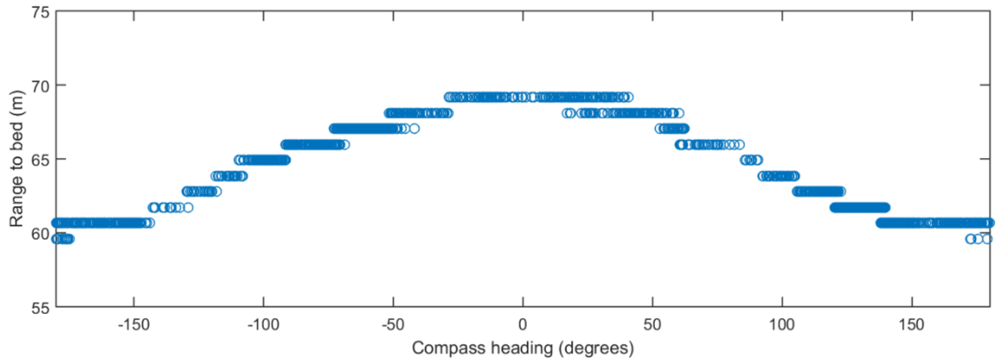


Fig. 25 Slant range to bed as a function of compass heading for beam 2 just after Jan 15th event

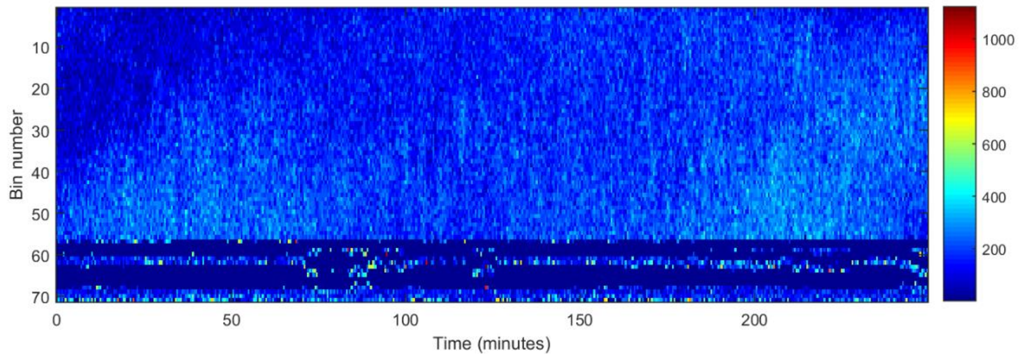


Fig. 26 Velocity magnitude (mm/s). MS2 300 kHz ADCP just after Jan 15th event

5. Anchor movement

Anchor movement is clearly an issue that affects the velocity measurements. The most extreme example is the data from the MS1 mooring during the Jan 15th event. The echo amplitude averaged over all beams and the velocity magnitude for the event at MS1 are plotted in Fig. 27 and Fig. 28. For this example, it would be extremely difficult to recover any meaningful velocities or backscatter in from the period of motion before the instrument broke free of the mooring. Other regions of data related to instances of anchor movement may have to be simply screened out, but attempts are being made to see if bottom tracking algorithms could be applied to adjust the velocity data.

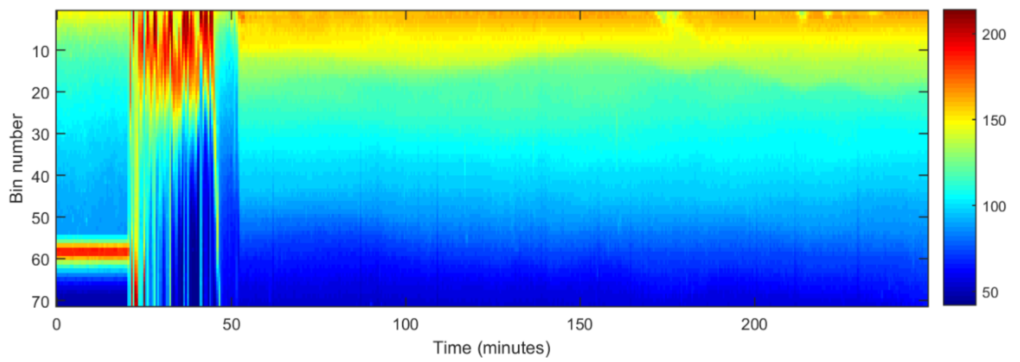


Fig. 27 Raw echo amplitude averaged over four beams. MS1 300 kHz ADCP Jan 15th

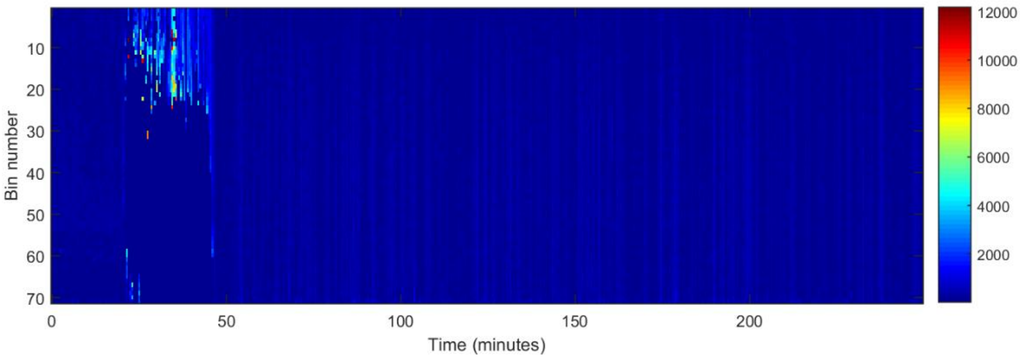


Fig. 28 Velocity magnitude (mm/s). MS1 300 kHz ADCP Jan 15th