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Report on the ABS data collected in week 46, 11-13 November 2013. Provisional analysis to obtain approximate estimates of suspended sediment concentration.

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<u>Part I</u>

1. Scattering formulation and inversion

The theory of scattering from an aqueous suspension of particles has been previously presented (Sheng and Hay, 1988; Hay, 1991; Crawford and Hay, 1993; Thorne et al, 1993; Thorne and Hardcastle, 1997. For the normally deployed disc transceivers used for both transmission and reception, insonifying a suspension of sediments, then for the usual conditions of incoherent scattering (Morse and Ingard, 1987), the acoustically measured suspended concentration, M, can be related to the mean-squared backscattered voltage, V_m^2, as shown below (Hay and Sheng, 1992; Thorne and Hanes, 2002; Hurther et al, 2011, Thorne and Hurther 2013)

$$M = \left(\frac{r\psi}{K\,\Re}\right)^2 V_m^2\, e^{4(r\alpha_w + \alpha_s)} \qquad (1)$$

where

$$K = \frac{f}{\sqrt{a_0}}\,, \qquad \alpha_s = \int_0^r \xi M\, dr\,, \qquad \xi = \frac{3\chi}{4a_o}$$

$$\psi = \frac{1 + 1.35\left(\frac{r}{r_n}\right) + (2.5\frac{r}{r_n})^{3.2}}{1.35\left(\frac{r}{r_n}\right) + (2.5\frac{r}{r_n})^{3.2}}$$

with

$$f(x_o) = \left[\frac{\int_0^\infty an(a)da \int_0^\infty a^2 \left(\frac{f_i}{\sqrt{\rho}}\right)^2 n(a)da}{\int_0^\infty a^3 n(a)da}\right]^{1/2} \quad (2a)$$

$$\chi(x_o) = \frac{\int_0^\infty an(a)da \int_0^\infty a^2 \left(\frac{\chi_i(x)}{\rho}\right) n(a)da}{\int_0^\infty a^3 n(a)da} \quad (2b)$$

$$a_o = \int_0^\infty an(a)da \quad (2c)$$

and

$$\frac{f_i}{\sqrt{\rho}} = \frac{\left(1 - 0.25e^{-((x-1.5)/0.35)^2}\right)(1 + 0.6e^{-((x-2.9)/1.15)^2})x^2}{42 + 25x^2} \quad (3a)$$

$$\frac{\chi_i}{\rho} = \frac{0.09x^4}{1380 + 560x^2 + 150x^4} \quad (3b)$$

r is the range from the transceiver and ψ accounts for the departure from spherical spreading within the transducer nearfield (Downing et al 1995), $r_n=\pi A_t^2/\lambda$ is the transducer nearfield, A_t is the transducer radius, $\mathfrak{R}$ is the system constant incorporating the transmit and receive sensitivity, the voltage transfer function for the system, the pulse length and the directivity function of the transceiver (Betteridge et al 2008). K represents the sediment backscattering properties, ρ is the sediment grain density and a_o is the suspension mean particle radius. The term α_ω is the sound attenuation due to water absorption and α_s is the attenuation due to suspended sediment scattering. f_i and χ_i are respectively the intrinsic form function and intrinsic normalised total scattering cross-section for the particles in suspension and x=ka, where k is the wavenumber of the sound and a is the radii of the particles in suspension. Here intrinsic refers to the scattering characteristics measured using suspensions sieved into narrow ¼ phi size fractions which provide a nominally single particle size (Hay, 1991). Physically, f_i describes the backscattering characteristics of a particle relative to its geometrical size, whilst χ_i quantifies the scattering from a particle over all angles, relative to its cross sectional area, and is proportional to scattering attenuation. There are a number of similar expressions for f_i and χ_i (Sheng and Hay 1988; Crawford and Hay, 1993; Thorne and Meral, 2008) and above we have chosen to present a recently developed density normalised expressions which has generic applicability to sands of varying mineralogy (Moate and Thorne, 2012). f and χ represent the ensemble mean scattering values obtained by integrating the intrinsic scattering characteristics over the particle size probability density function, n(a), of the particles in suspension and $x_o=ka_o$.

Although equation (1)-(3) may appear somewhat complex, there are degrees of simplification that can be made depending on the required accuracy and detail on the suspension.. In this report a very simple approach is used and this is described below.

2.1. Estimating the suspended sediment concentration

Equation (1) is implicit with M being on either side of the equation due to the effect of attenuation by the presence of the sediments themselves. If the sediment attenuation can be assumed negligible, $r\alpha_s \ll 1$, the equation becomes explicit and its evaluation is simplified. Further if only the far field is considered, $\psi=1$, equation (1) can be written as

$$M_o = \left(\frac{r}{K\,\mathfrak{R}}\right)^2 V_m^2\, e^{4r\alpha_w} \qquad (4)$$

For this case, after allowing for α_w (Clay and Medwin, 1997), the concentration at any range is simply proportional to the mean-square backscattered signal. To evaluate equation (4) requires a value for $K\mathfrak{R}$. Normally bed or in-situ suspended samples are collected when the ABS is deployed and these can be used to calibrate the ABS. By using backscatter data collected in the far-field, at sufficiently low concentrations such that $r\alpha_s \ll 1$, the calibration is given by

$$(K\Re)^2 = \frac{r^2 V_m^2}{C} e^{4r\alpha_w} \qquad (5)$$

Since C is the measured concentration used in the calibration and α_w can be calculated, $K\Re$ can be readily obtained. However, this calibration includes the sediment backscattering characteristics, K, which is site specific, based on the bed or suspended sediments and invariant with height above the bed and time. The approach only requires a single frequency ABS and provides a simple, though limited, calibration for estimating concentration profiles collected at a particular field site.

It is equations (4) and (5) which are used in the present study. The value for $K\Re$ being obtained from pumped samples.

2. Pumped sample calibration

Two pumped sample measurements were carried out over the data collection period reported here, 11-13 Nov 2013. The pumped samples were somewhat strange with some sample concentrations increasing with height above the bed, see figures 1 & 2. We spoke with Sjoerd about this and he did not have an explanation for the unusual pumped sample concentrations with height above the bed. The results below show acoustic estimates of relative concentration being adjusted to the pumped sample values by estimating $K\Re$. In all plots ignore the data above 0.8 m, the reduction in concentration is an artifact arising from not accounting for the range dependence in the transducer nearfield.

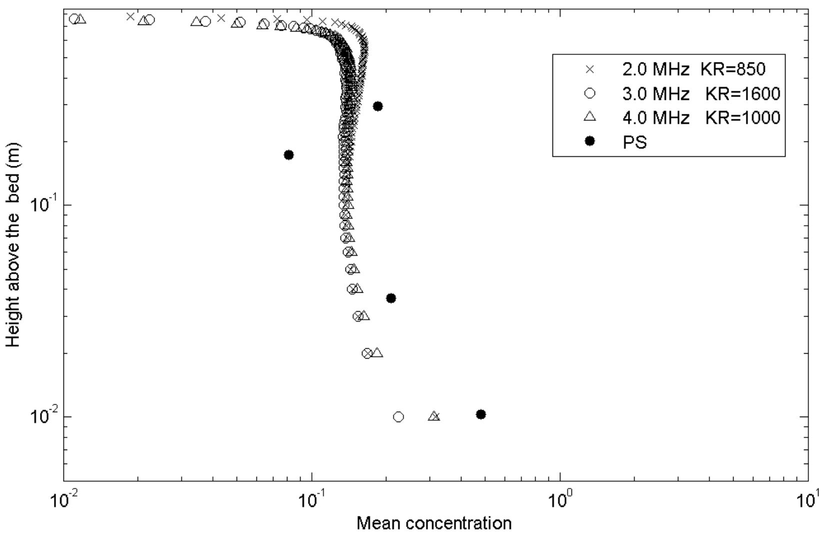


Fig 1. Calibration of the acoustic estimate of concentration with pumped samples for run 8 abs file 20131112114521. H=0.85 m and T=3.5 s.

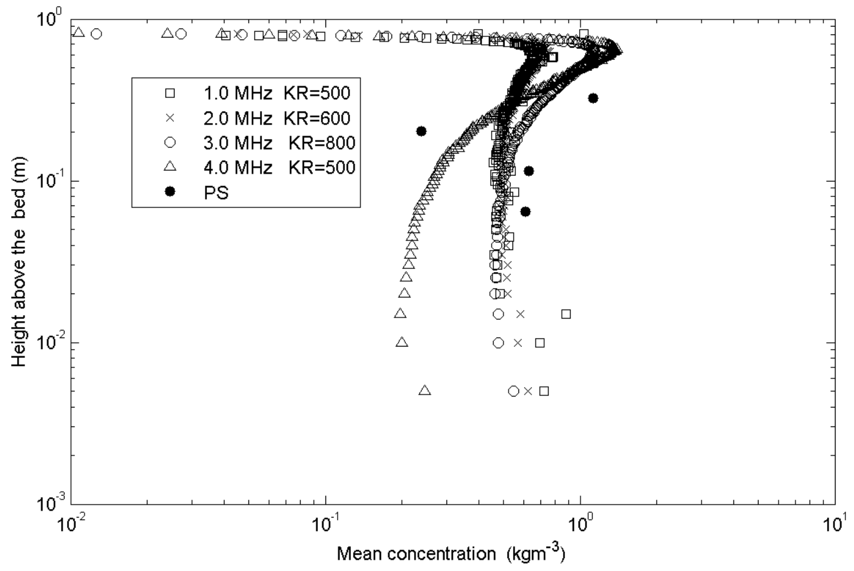


Fig 2. Calibration of the acoustic estimate of concentration with pumped samples for run 20 abs file 20131113161543. H=8.5 m and T=4.0 s.

As can be seen the pumped samples are not monotonically decreasing with height above the bed, nor are the ABS concentrations. I have concerns that there may be bubbles in the water, possibly entrained from the shoreward breaking waves which are affecting the ABS measurements, although this is only speculation. The fact that the ABS profiles are consistent in form at the four frequencies is an indication that there are scatterers in the water with the observed profile. It can also be observed that the KR values are not the same for the two pumped sample calibrations; the values are generally higher for the first calibrations. For the following inversions the mean of the two values are used; KR(1MHz)=500, KR(2MHz)=725, KR(3MHz)=1200, KR(4MHz)=750.

Obviously further calibrations with pumped samples are required if the ABS concentrations are to be of value. I suggest trying to collect data around waves heights of 0.6 m where bubbles may be less of a problem judging from results shown below and two people collecting the pumped samples and cross-checking the collection and data so we can try and get some sensible pumped sample data. We may need to spend a day solely on pumped sample calibrations to ensure we get at least a couple of reliable calibrations.

3. Background measurements

It was considered important to obtain backscattered data in still water to assess the background acoustic levels to obtain the background suspension wash load when waves and hence locally resuspended sediments were not present. Figures 3 and 4 below suggest a wash load of around 10^{-3} kgm^{-3}. The collection of background measurements on a regular basis over the period of study would be useful to examine any significant changes in background levels. A run after a weekend when the water has had time to clear would also be valuable. The fact that the wash load is uniform in concentration with height and the three frequencies give comparable results provides some confidence in the measurements.

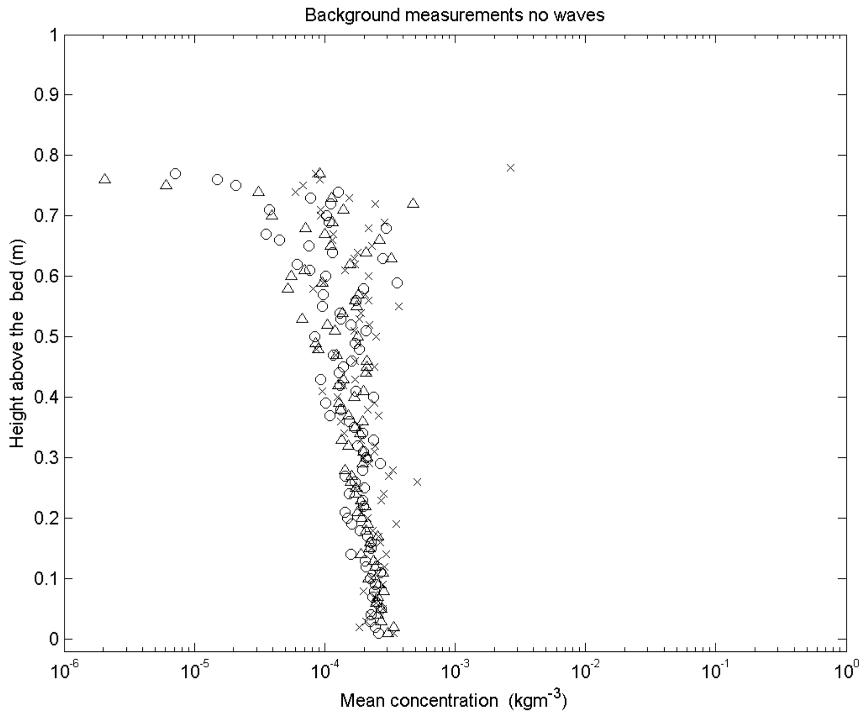


Fig 3. Background acoustic estimates of concentration with pumped samples for run 6 abs file 20020105094913. . H=0.0 m and T=0.0 s.

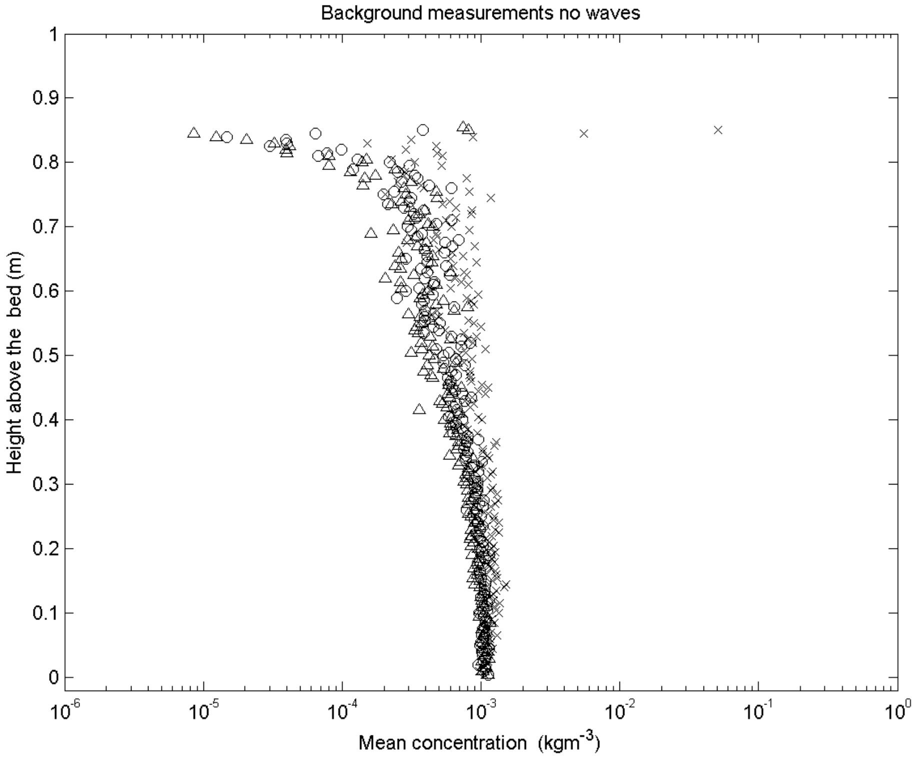
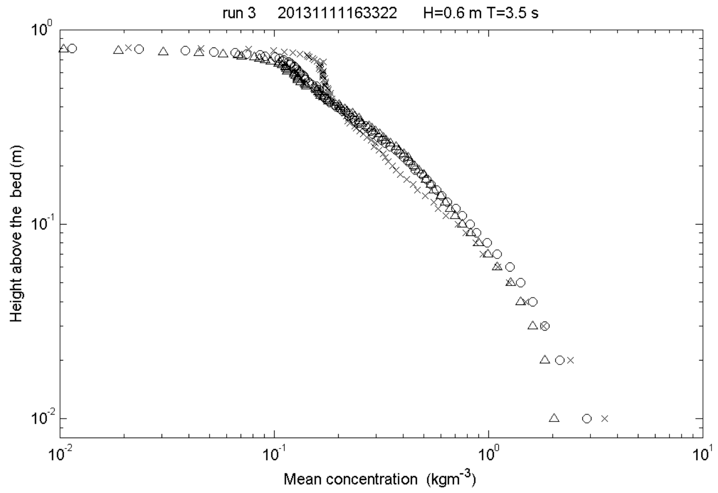
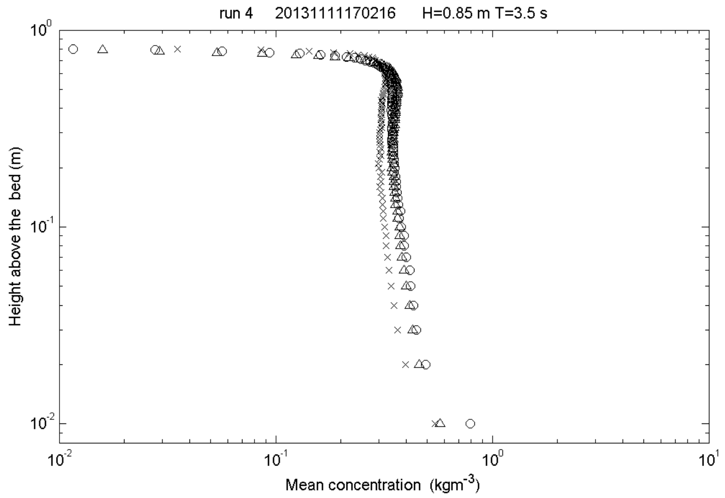


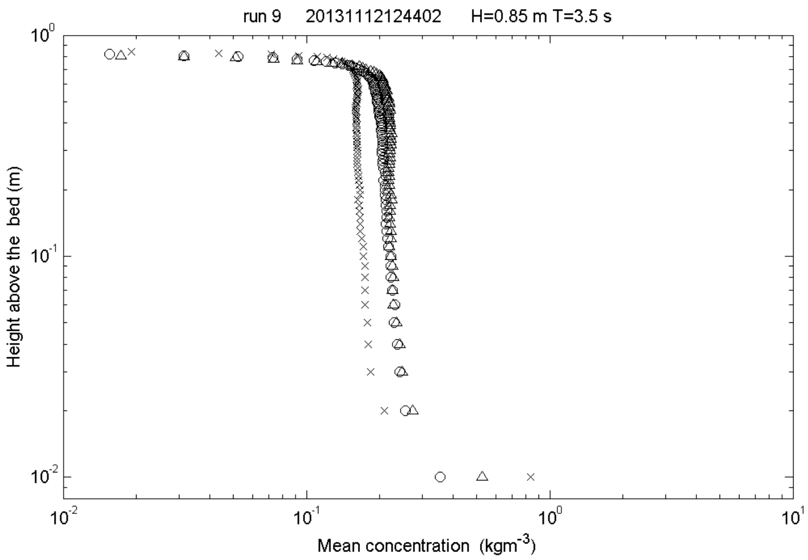
Fig 4. Background acoustic estimates of concentration with pumped samples for run 15 abs file 20131112165455. H=0.0 m and T=0.0 s.

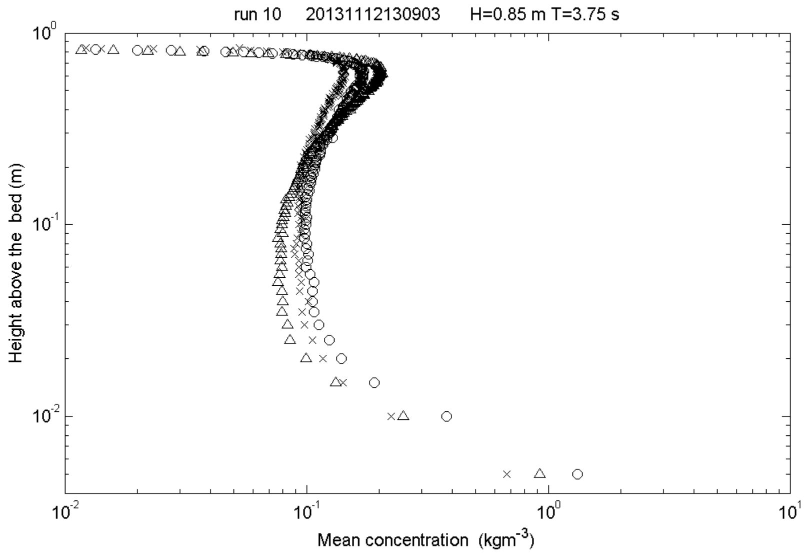
4. Measurements of ABS mean suspended concentration profiles.

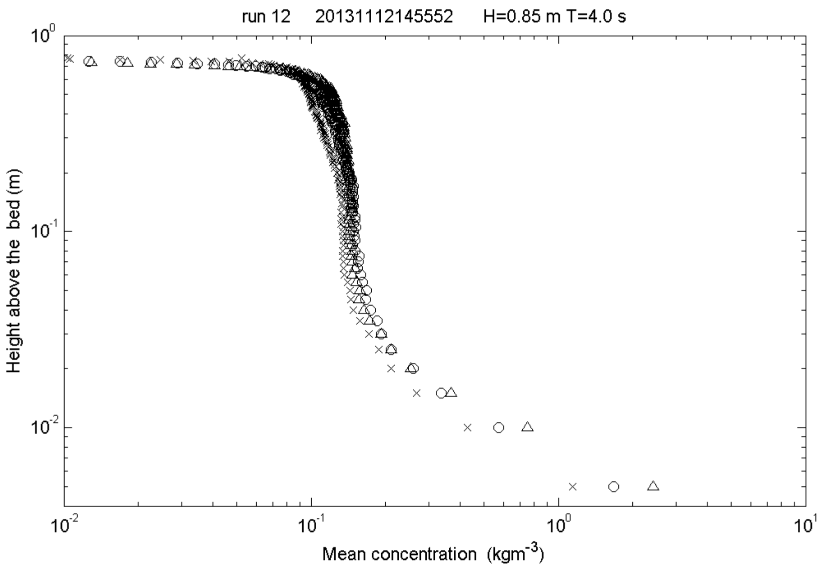
Measurement of mean suspended sediment concentration averaged over the data collection period, usually between 5-15 mins are shown in figure 5 below. The run number, ABS file name and wave conditions are given in the title of each plot. All the estimates were obtained using KR(1MHz)=500, KR(2MHz)=725, KR(3MHz)=1200, KR(4MHz)=750 with equation (4). What is generally observed is that the different frequencies give comparable results and measurements at the same location for the same wave conditions have similar concentrations and profile forms. What is concerning is that the profiles are not what might be classically expected, ie most of the profiles are showing uniform concentration above 10-20 cm above the bed. As mentioned previously this may be due to bubbles in the water, however, at present this is only conjecture. Comparison of these concentrations with those from David's high resolution concentration and velocity profiler, HR-ACVP, should help to further interpretation. Accurate pumped sampling in the bottom 0.8m above the bed is required to assess the form and magnitude of the ABS concentration profiles at the four frequencies.

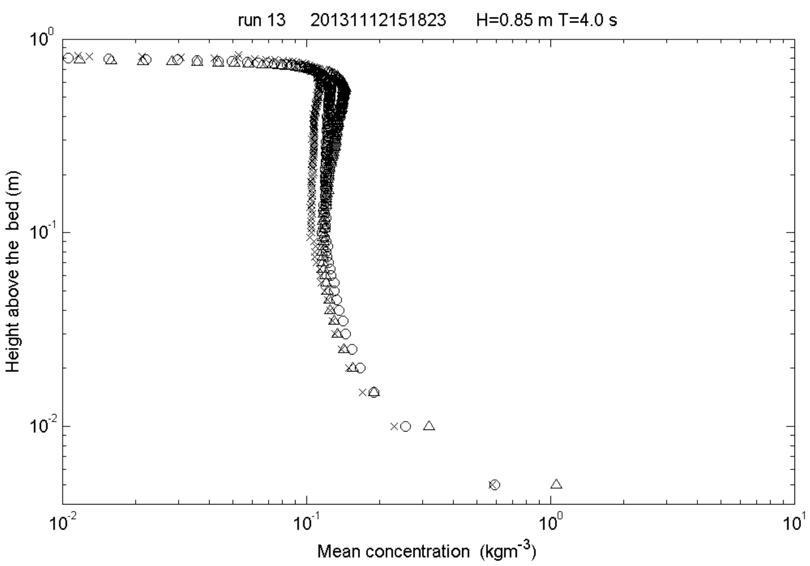


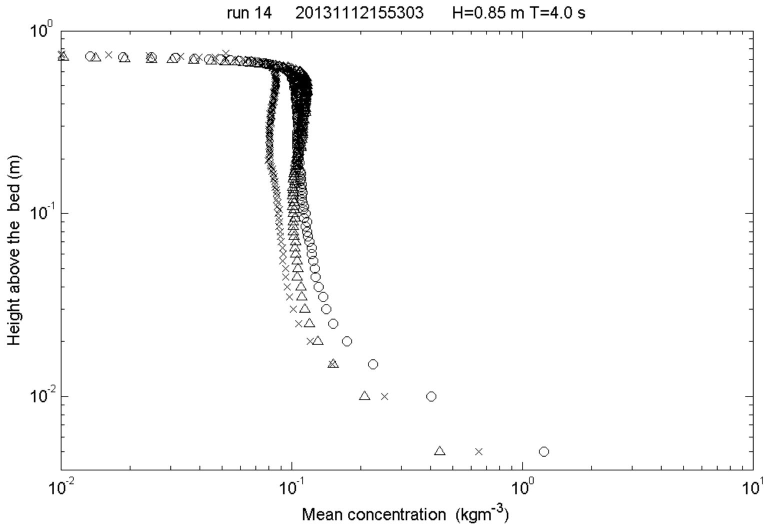


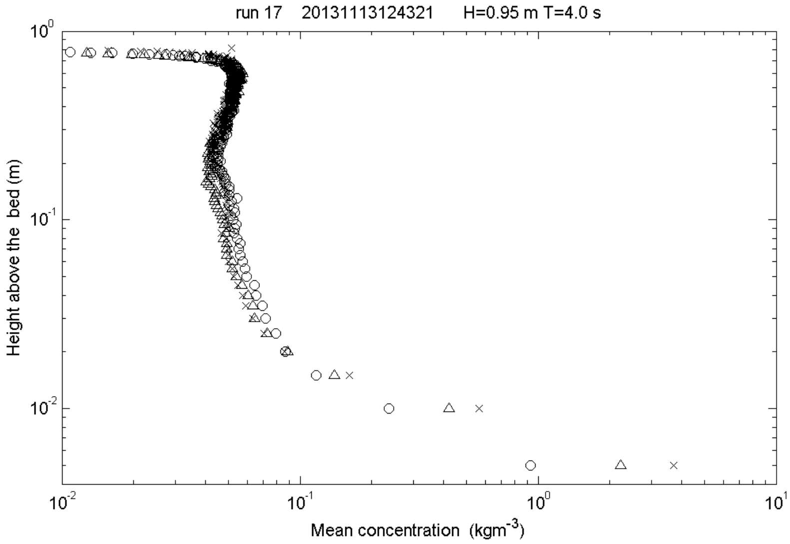


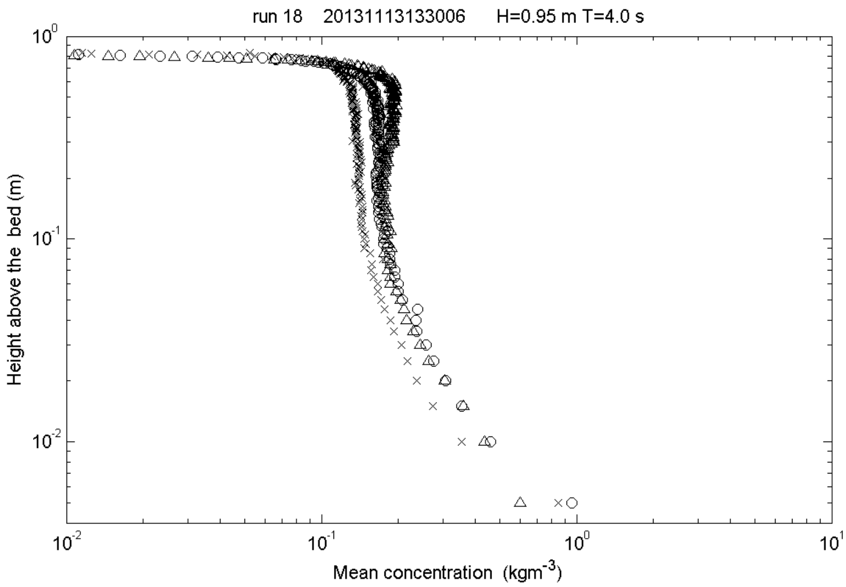

run 10 20131112130903 H=0.85 m T=3.75 s
Height above the bed (m)
Mean concentration (kgm-3)


run 12 20131112145552 H=0.85 m T=4.0 s
Height above the bed (m)
Mean concentration (kgm-3)


run 13 20131112151823 H=0.85 m T=4.0 s
Height above the bed (m)
Mean concentration (kgm-3)


run 14 20131112155303 H=0.85 m T=4.0 s
Height above the bed (m)
Mean concentration (kgm-3)


run 17 20131113124321 H=0.95 m T=4.0 s
Height above the bed (m)
Mean concentration (kgm-3)


run 18 20131113133006 H=0.95 m T=4.0 s
Height above the bed (m)
Mean concentration (kgm-3)

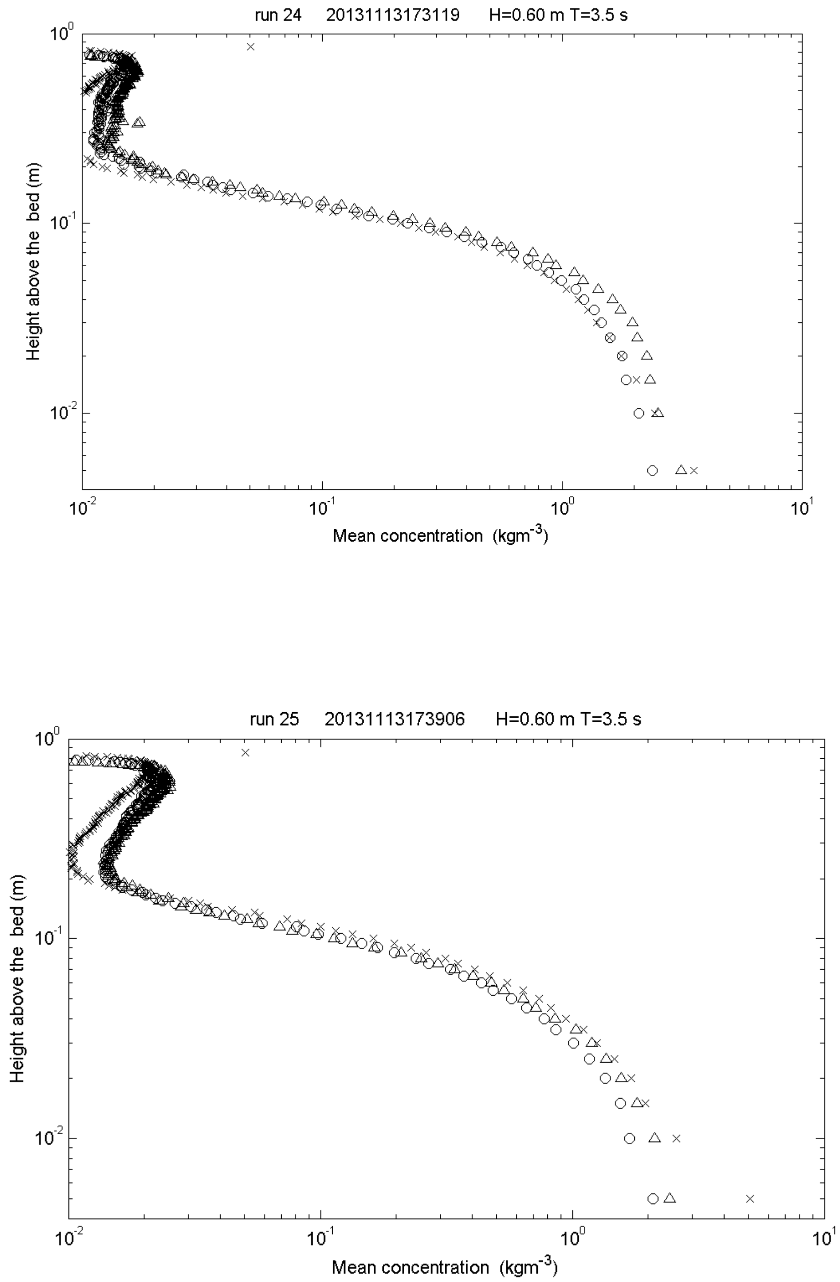
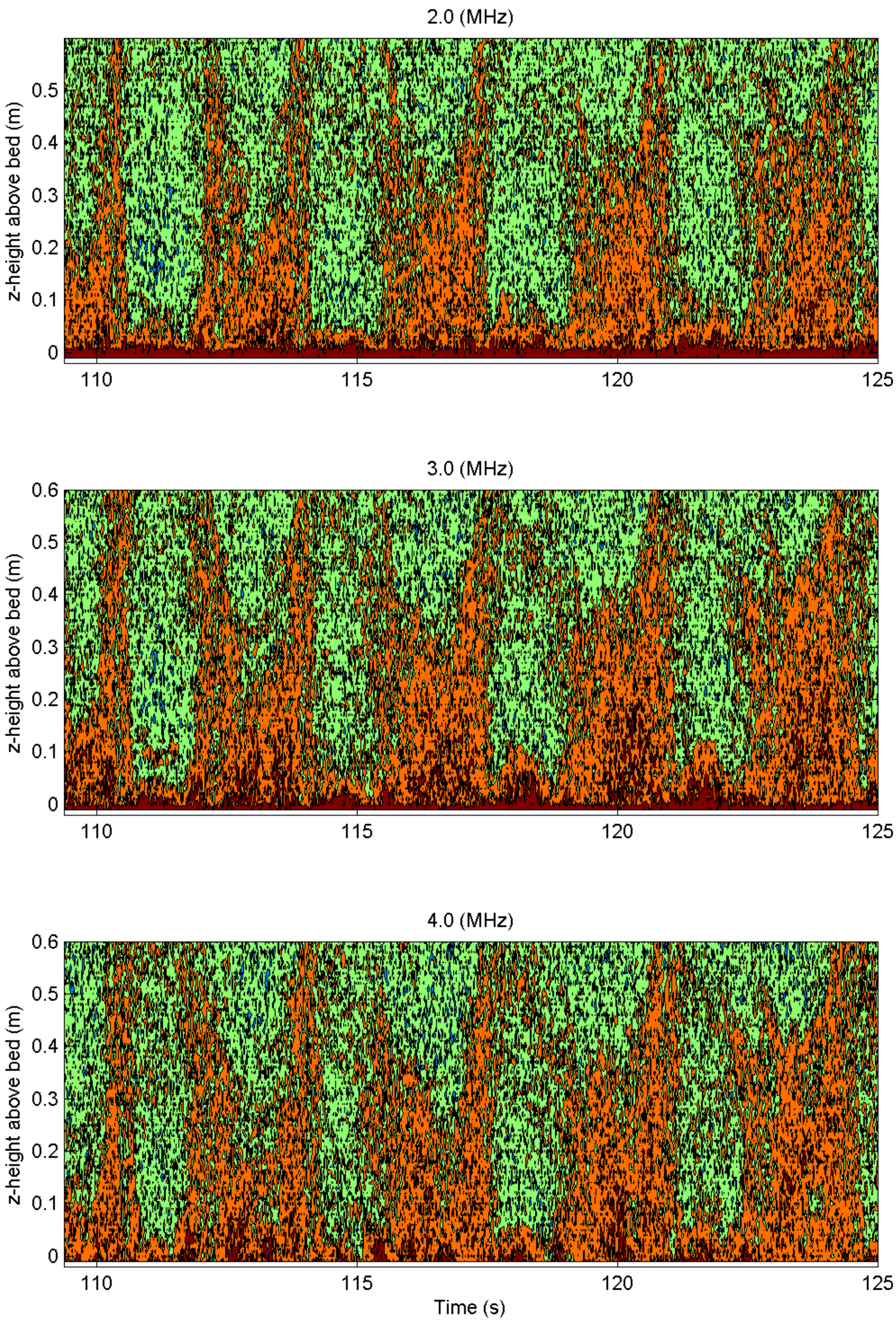


Fig 5. Suspended sediment concentration profiles for different wave conditions and locations. The wave conditions are given in the figure title

5. Intra-wave suspended concentrations

In figure 6 is shown the intra-wave suspended sediment field at the three different frequencies. The plots show the detail that can be obtained using an ABS The structural similarity and magnitude of the suspension field at the different frequencies lends credibility to the observed patterns in suspension. Ensemble averaging for regular wave cases over many wave periods will provide clear reliable estimates of the intra-wave structure with height above the bed.



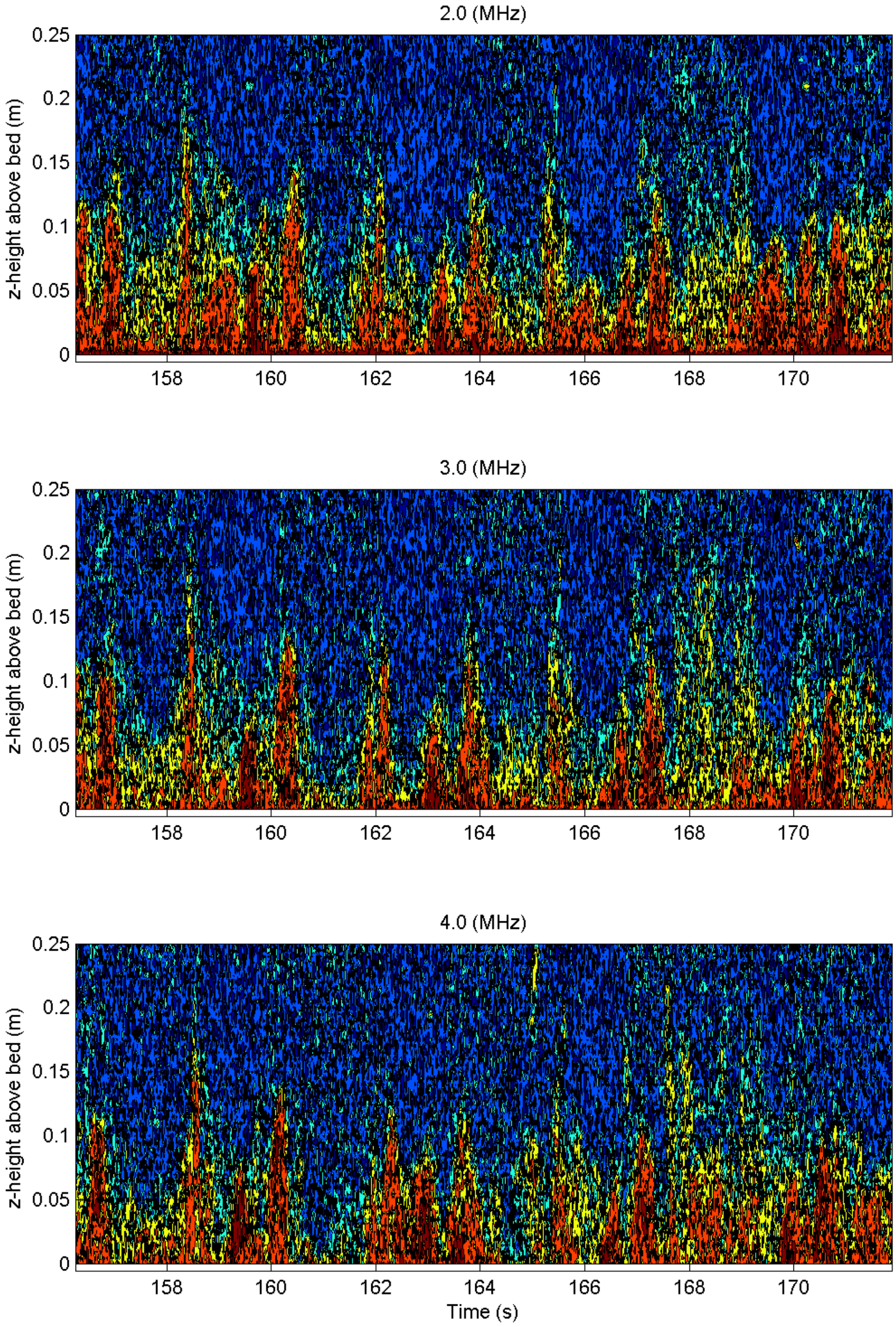


Fig 6 Comparison of the intra-wave suspended sediment concentration field at the three frequencies for run 3, H=0.6 m T= 4.0 s and run 24, H=0.6m T=3.5s.

6. Discussion

The above provides a snapshot of the ABS data collected in the first week of measurements. The results indicate the ABS system is working, although there are concerns with the form of some of the profiles and uncertainty about the pumped samples used for calibration. The results appear to indicate bubbles in the water may be a problem, though there are no independent measurements to confirm this. It is recommended that the following is carried out;

(1). Further ABS calibrations to be carried out at moderate wave height, eg H=0.6m and T=4 s, when the ‘bubble’ effect does not seem to be present, with pumped sampled data which are double checked to ensure the veracity of the measurements.

(2). At present the suspended load from the pumped samples is being estimate, true dry weight concentrations need to be obtained from the samples.

(3). All pumped samples need to be retained for suspended sediment size distribution analysis with height above the bed for some of the samples. The will further help with the ABS analysis and provide valuable information about vertical size sorting.

(4). Repeat a few runs under the same conditions to establish confidence limits in the ABS and all other instrument measurements.

(5). It would be useful to get some data with all four ABS frequencies, under the same conditions when three frequencies and the HR-ACVP were used to collect data.

Part II

Calibration of the UPC AquaScat

This is a follow on from the presentation given at the SINBAD meeting on the 29-31 January 2014.

The experimental layout is given below in figure 1. The ABS was to be calibrated using the pumped sampled data (see Appendix 1)

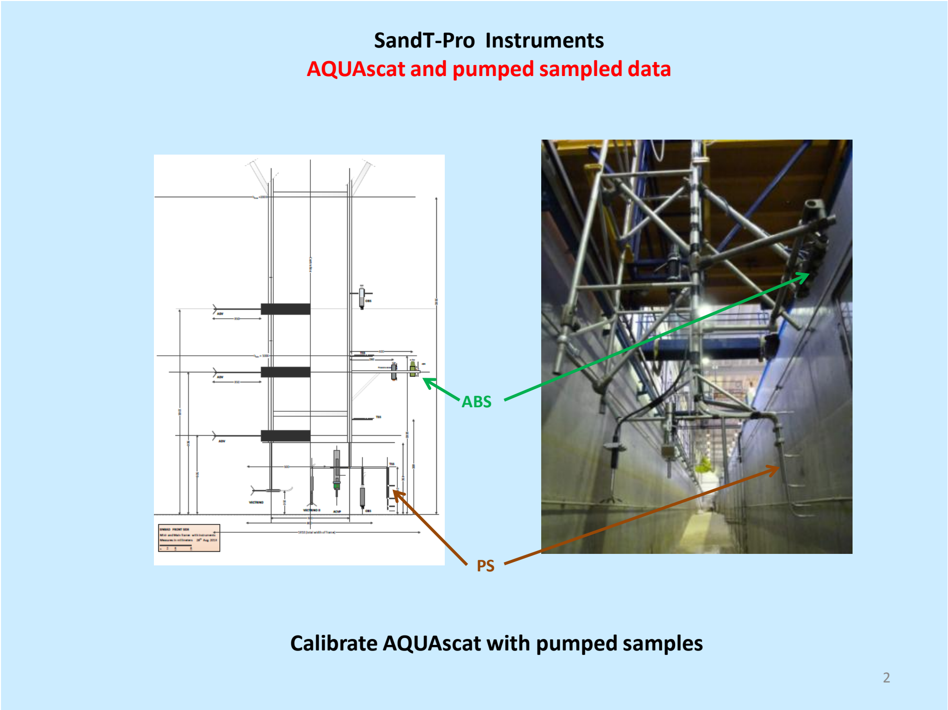


Fig 1. Experimental setup for the UPC Flume SandT-Pro experiment for the pumped samples and the ABS.

A typical backscattered voltage is shown below in figure 2. There was an initial period of data collection where the waves are not present, this provided a background reading for the ABS and then there was a steady build up of the suspended sediments by the waves until an equilibrium response was observed. It is the signal in the equilibrium region which was compared with the pumped sampled data.

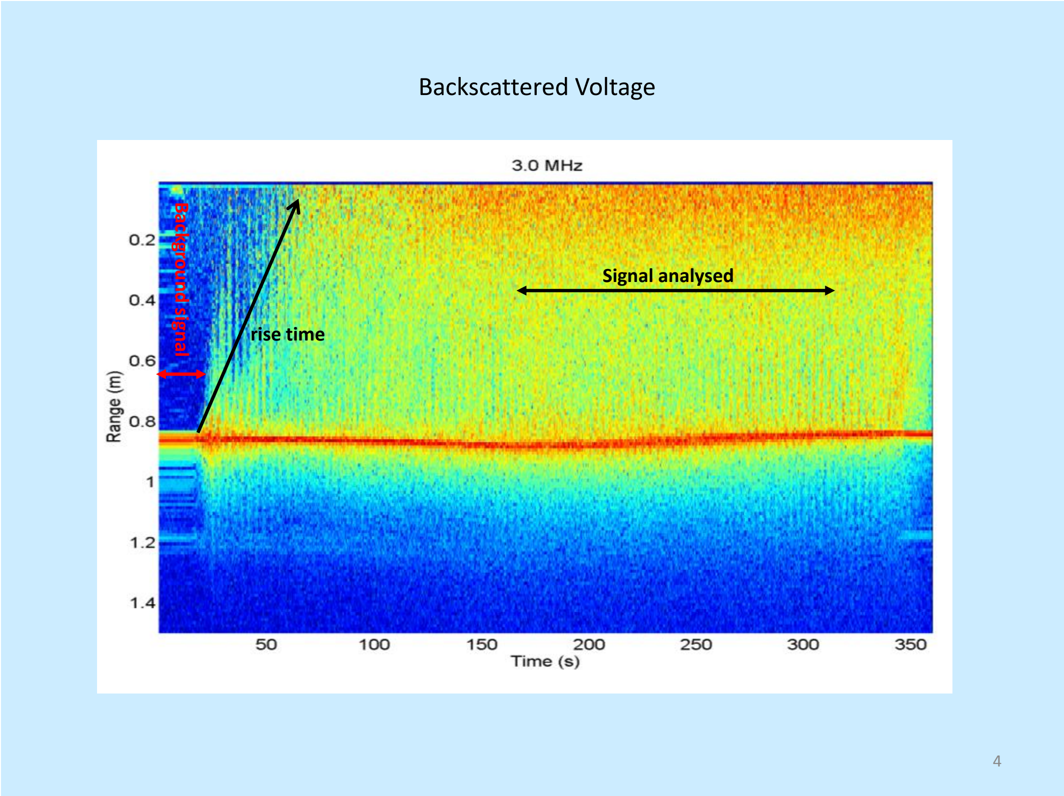


Fig 2 measured backscattered signal

To convert the backscattered signal to suspended sediment concentration, approximations have been made as indicated in figure 3. Attenuation by the suspended sediments was ignored and the nearfield correction factor ψ neglected. This allows the equations to be simplified so that only KR is required to convert the backscattered signal to concentration. M is the acoustic estimate of the suspended concentration, r the range from the transducer, α_w is the water absorption and V_m^2 is the mean-squared backscattered signal. K is associated with the backscattering characteristics of the suspended sediments and R is a system constant for each frequency. R remains constant unless some change is made to the systems, eg pulse length, reciver gain, etc. K is a constant if the suspended sediments are uniform with height above the bed, in time and have the same particle size distribution for all runs The absolute acoustic concentration was obtained by aligning relative estimates of M calculated using KR=1 to the pumped sample data to obtain the actual values of KR.

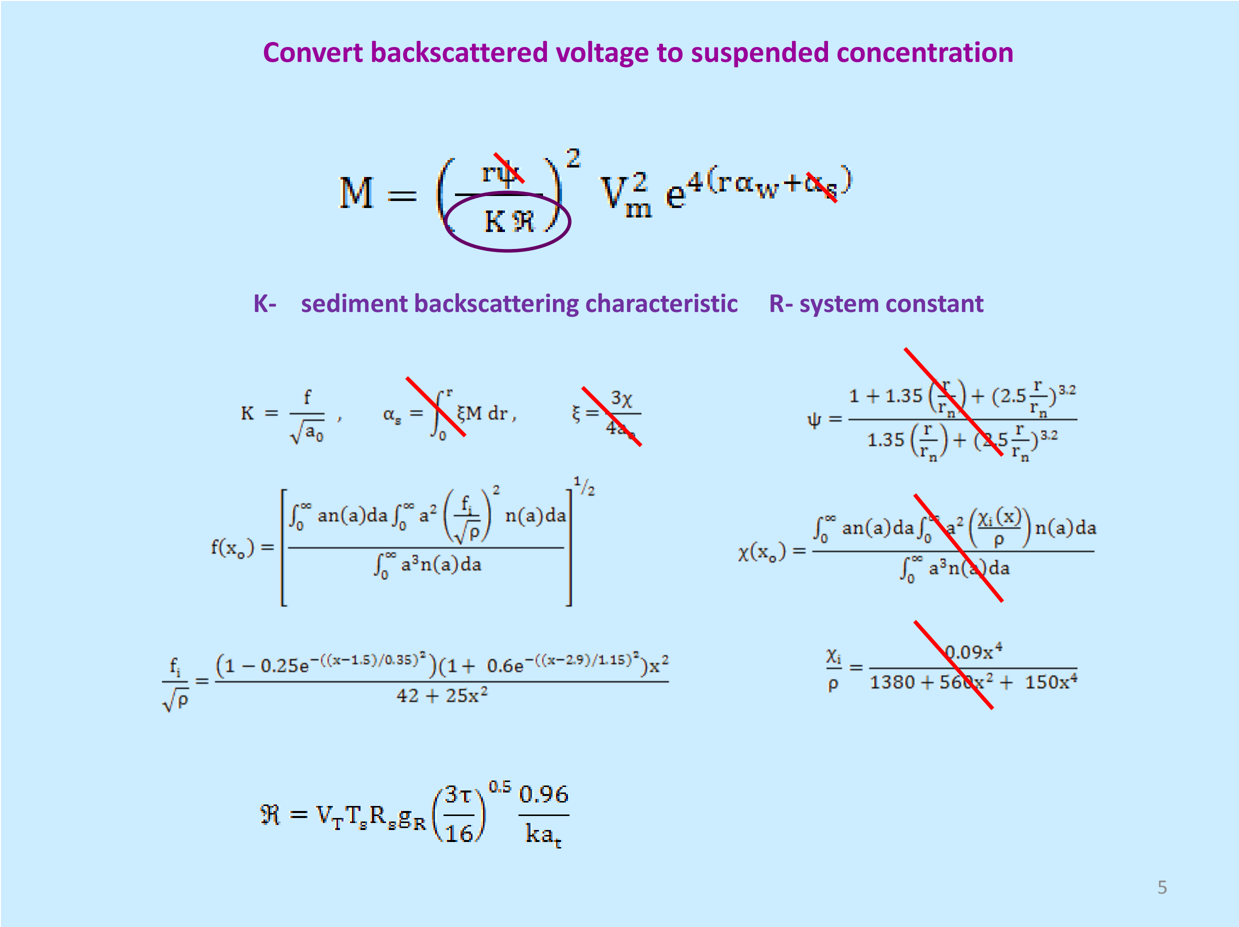


Fig 3. Approximation of the backscatter analysis to get profiles of mass concentration M(z), where z is height above the bed.

Using the above expression for M and fitting the calculated profiles to the pumped sampled data values of KR for different runs were obtained. The KR values are shown below in the legends in figure 4. The values for KR vary because K is not a constant from run to run and the pulse length was reduced from 1.0 cm to 0.5 cm after run 10 thereby reducing R.

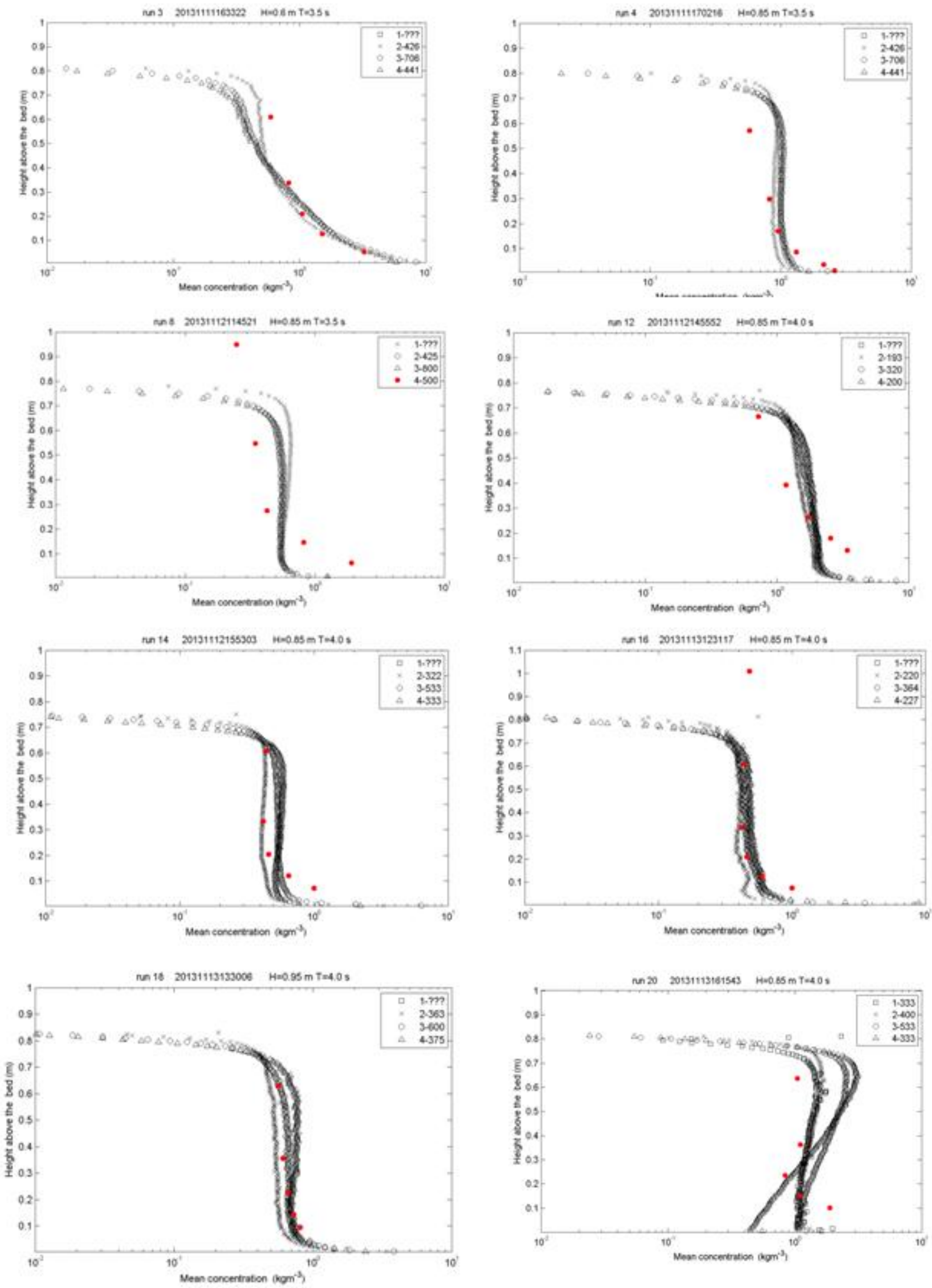
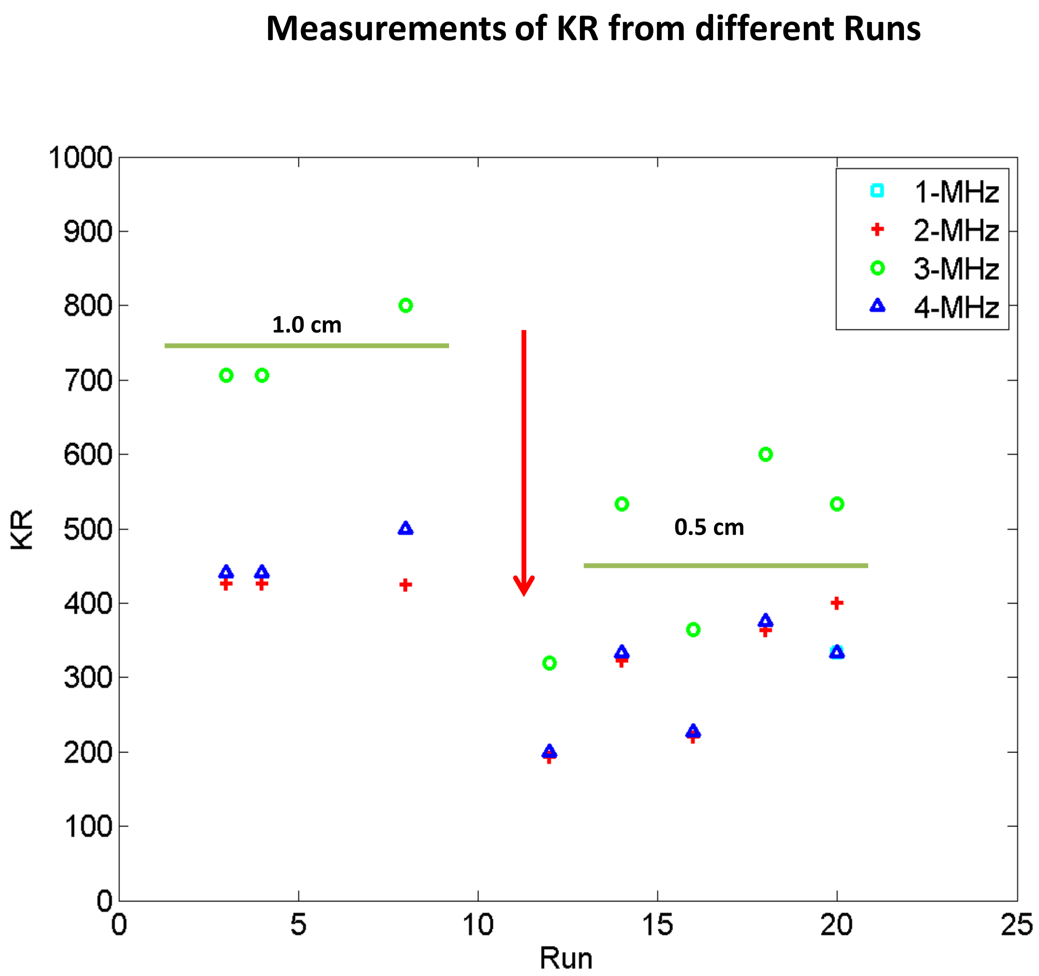


Fig 4. Calibration of the ABS with the pumped sample data



1.0cm

KR	sd(KR)
2 - 426	0.5774
3 - 737	54.2709
4 - 460	34.0637

0.5 cm

KR	sd(KR)
1 - 333	199
2 - 261	160
3 - 406	243
4 - 253	151

3

Fig 5. Comparision of KR from run to run with a table of values at each frequency of the mean and standard deviation.

The results in fig 5 show the outcome of fitting the acoustic backscatter data to the pumped samples and the resulting values of KR. There is a relatively high degree of scatter and this is probably be due to variations in the suspended sediments from run to run. However, the mean values in the table in figure 5 do provide an estimate for KR which can be used in other runs to obtain M and the standard deviation can be used to estimate the uncertainty in the estimate of M.

Conclusions

The analysis above provides acoustic estimates for the suspended sediments with error bars. These mean values of KR obtained can be applied to any run and any time scale thereby allowing intra-wave intra-ripple studies of the sediment processes to be assessed as indicated in figure 6 in **Part I**.

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Appendix 1

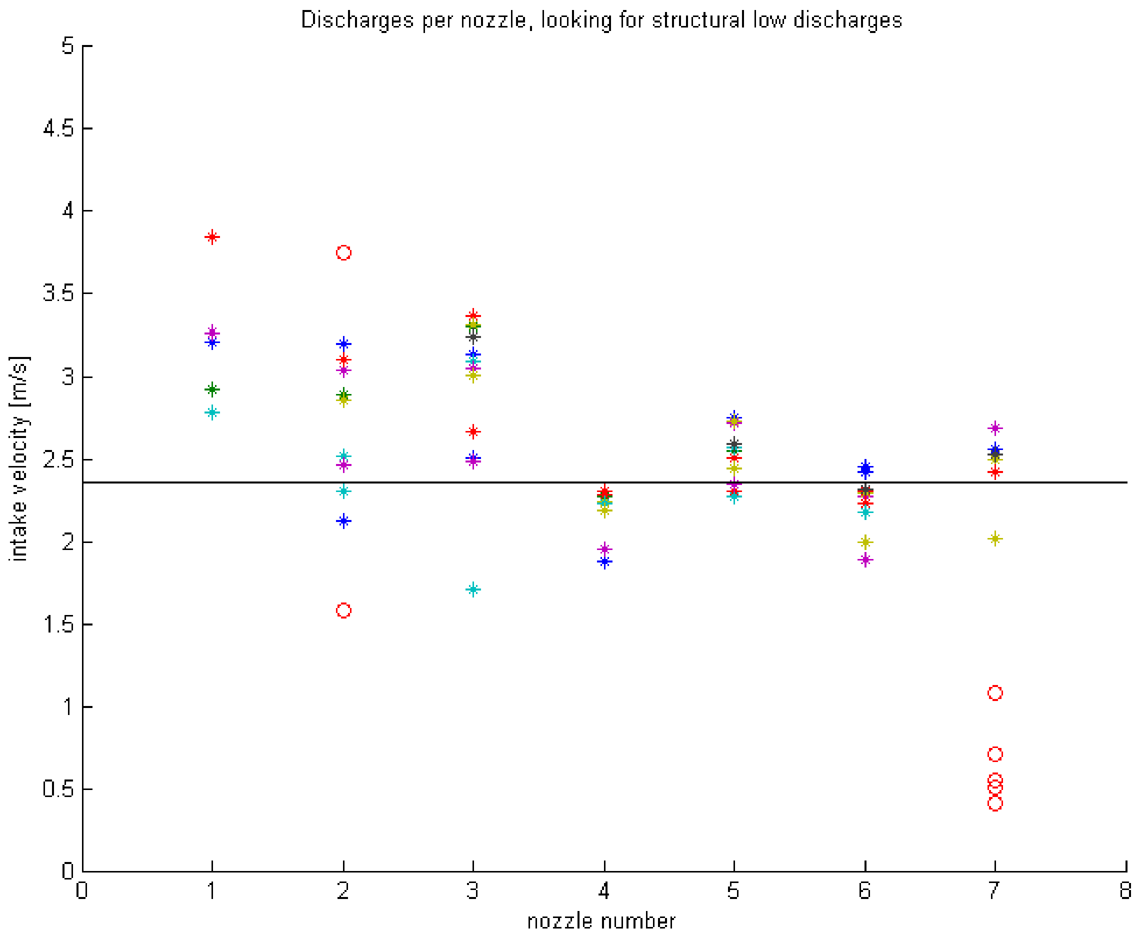
Dear Peter and Jan & Joep,

In this document the (adjusted) results of the suction sampling measurements are shown. I was caught up with some other work, so I did not have the time to hand you over this document earlier. The data you see is adjusted by ignoring some extreme values, which can be explained by various reasons. The outliers are shown in red and should not be included in the calculations for the ABS data. On the next pages, I will describe and discuss every figure separately. The results and the reasons why I eliminated the extreme values are described briefly. Later I will add a more thorough explanation.

Also the suction time for several nozzles are adjusted, which together with the ignored data, are shown in the figure below. Because some errors still have to be quantified in the upcoming experiments, I am not able to show the range of the errors (the error bars) in the figures.

If any questions arise, please ask them.

Kind regards, Sjoerd



In the figure above, the data that are shown with the red circles are the ignored data and the black line is the optimum intake velocity of 2,36 m/s (= 1L/min). All the other dots are the discharges per nozzle. Nozzle 1 contains more ignored extreme values than are shown (these did not fit in this figure). Why these values are removed (and others are not) is explained on the next pages.

The figures with the concentration plotted over the height are sorted by their position in the wave and shown on the next pages. The tabels contain the following data:

- The absolute height above the bed, derived from the ABS data. The backscattered signal of the first 10 seconds and of the last 10 seconds are taken and transformed into two heights. The absolute height is calculated by averaging these two values and is then adjusted to the distance between the nozzles.
- The concentration per nozzle.
- The intake discharge per nozzle.

Later on, I will make some more figures that show the development of the breaker bar in relation to the suction samples. Already some figures have been made to compare the data that was obtained at the same measuring location, but for the other runs I still have to do that.

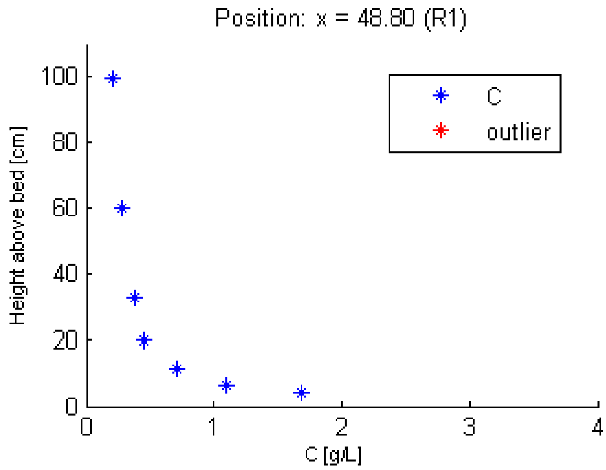
With these figures it will become easier to see why some data was ignored and why some data wasn't, as well as the effect of sediment distribution over the height.

Beneath, an overview of the concentrations [g/L] per run is given:

Nozzle:	Run1	Run2	R3	R4	R5	R8	R10	R12	R14	R16	R18	R20	R22
1	1,682	1,278	3,253	2,598	1,322	9,344	NaN	NaN	NaN	Nan	NaN	NaN	NaN
2	1,090	1,324	1,576	2,142	1,093	43,032	3,736	3,407	1,002	1,002	0,806	1,887	1,629
3	0,706	1,175	1,520	1,320	0,850	1,917	0,210	2,563	0,654	0,602	0,729	1,117	1,431
4	0,454	0,962	1,051	0,960	0,612	0,821	0,187	1,713	0,460	0,460	0,658	0,838	1,300
5	0,384	0,818	0,823	0,820	0,480	0,433	0,175	1,166	0,423	0,423	0,607	1,105	1,187
6	0,286	0,597	0,593	0,584	0,415	0,349	0,129	0,717	0,445	0,445	0,560	1,052	1,371
7	0,210	0.508	0,405	0,547	0,249	0,248	0,154	0,551	0,475	0,475	0.712	1.076	1,242

Position x = 48.80 (Run 1):

It was not necessary to remove data here. The data shows that near the bottom the concentrations are higher and that the concentrations higher in the water column are lower. The measurement was taken before the plunging point and the breaker bar was not formed when this data was obtained.



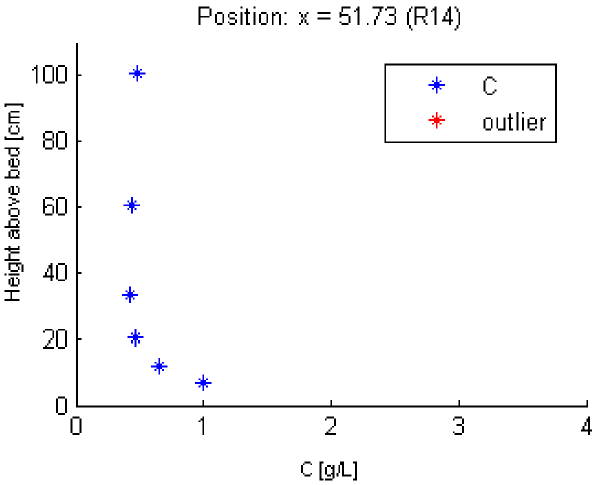
X=48,80			
# Nozzle	Height above bed [cm]	C [g/L]	Discharge [L/min]
1	4,01	1,682	1,36
2	6,41	1,090	1,36
3	11,41	0,705	1,33
4	19,71	0,454	0,97
5	32,51	0,384	1,17
6	59,81	0,286	1,03
7	99,81	0,210	1,08

X=51.73			
# Nozzle	Height above bed [cm]	C [g/L]	Discharge [L/min]
1	4,79	NaN	NaN
2	7,19	1,002	1,32
3	12,19	0,653	1,13
4	20,49	0,460	0,97
5	33,29	0,423	0,98
6	60,59	0,444	0,95

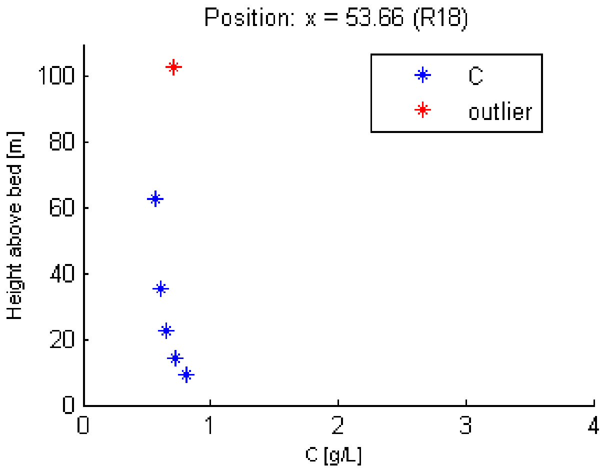
7	100,59	0,475	1,03

Position x = 51.73 (Run 14):

Nozzle 1 was defect, because of a sand obstruction in the tube that is connected to the pump. Further the data shows that the concentrations of nozzles 4, 5, 6 and 7 are more or less the same, which indicates that the sediment is well distributed over the height. This measurement was taken seawards of the plunging point. The breaker bar was better formed in this run. Pictures of the position of the breaker bar will be made when I have more time.



Position x = 53.66 (Run 18):



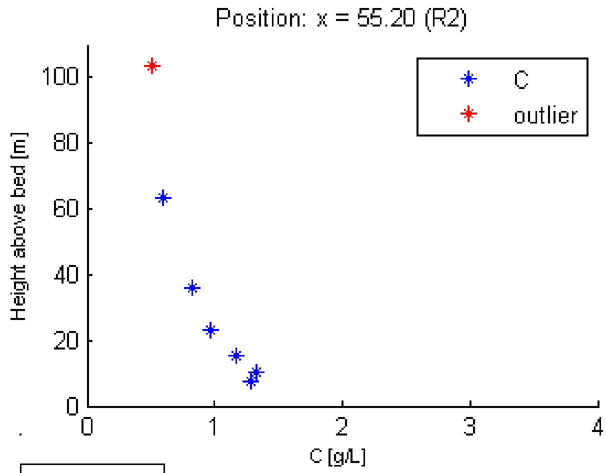
X=53.66			
# Nozzle	Height above bed [cm]	C [g/L]	Discharge [L/min]
1	7,07	NaN	NaN
2	9,47	0,806	0,98
3	14,47	0,729	0,73
4	22,77	0,658	0,95

5	35,57	0,606	0,96
6	62,87	0,559	0,92
7	102,87	0.712	0.16

Here nozzle 1 was also not working, due to the obstruction in the tube. The value of nozzle 7 is ignored, because it was above the water level most of the time. The small amounts of water that was pumped up was not representable, because less water in the tubes the chance of sand staying behind due to friction with the tubes is higher. Further, the concentrations are well sorted over the height, which can be attributed to the fact that the measurements were taken under the plunging point.

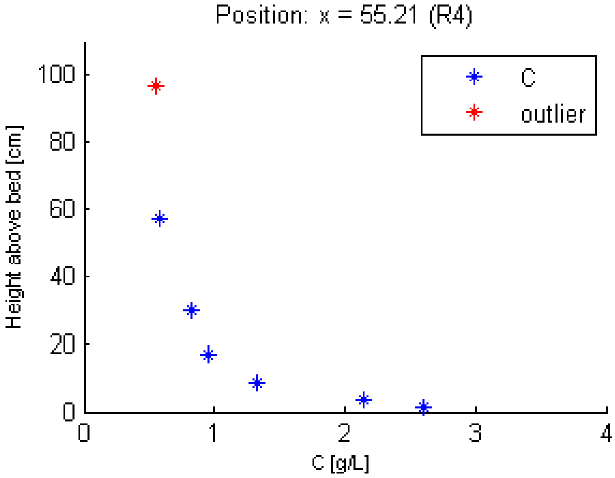
Position x = 55.20 (corresponds to Run 2):

Nozzle 7 was above the water level most of the time. The concentrations of nozzle 2 and 3 are nearly the same. I did not ignore this data, because I think this is a credible measurmement. The retrieved volume, the discharge and the concentrations for both the nozzles are sufficient.



X=55.20			
# Nozzle	Height above bed [cm]	C [g/L]	Discharge [L/min]
1	7,70	1,278	1,24
2	10,10	1,324	1,23
3	15,10	1,174	1,40
4	23,40	0,961	0,96
5	36,20	0,818	1,08
6	63,50	0,597	0,98
7	103,50	0.508	0.70

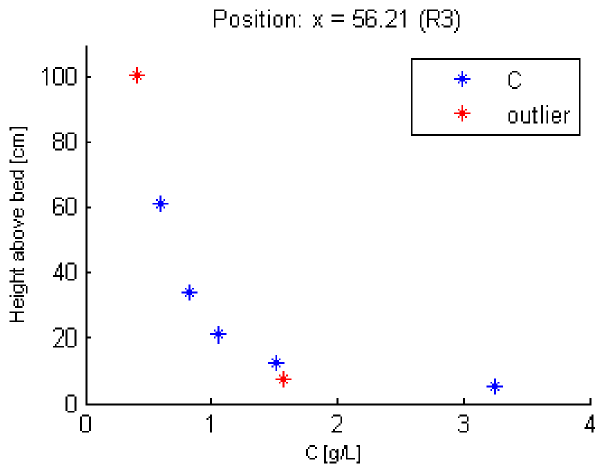
Position x = 55.21 (corresponds to Run 4):



The concentrations near the bottom increase. In this run, the water that was sucked up was sufficient for every run and so were the concentrations. The discharge was near or above the 1 L/min. The measurements are therefore (given the random and systematic error) reliable. Nozzle 7 was ignored, because of the low discharge.

X=55.21			
# Nozzle	Height above bed [cm]	C [g/L]	Discharge [L/min]
1	1,30	2,597	1,18
2	3,70	2,141	1,07
3	8,70	1,320	1,31
4	17,00	0,960	0,97
5	29,80	0,820	1,09
6	57,10	0,583	0,97
7	97,10	0.547	0.64

<u>Position x = 56.21 (corresponds to Run 3):</u>

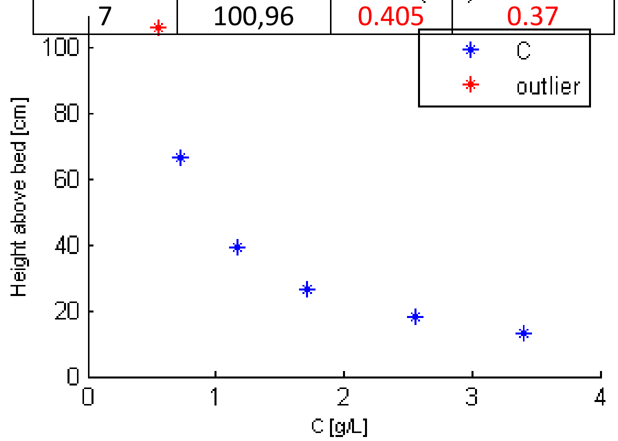


Here the data of nozzle 2 is ignored, because of the significant lower concentration in relation to

nozzle 1. This is strange, because the distance between these nozzles is only 2,40 cm. The retrieved volume of this nozzle was also much lower (± 2L) than nozzle 1 and ± 7L lower than nozzle 3, which can be appointed to the stuttering behaviour of the pump in the last 4 minutes. Nozzle 1 did not work well the first 4 minutes, but has a more reliable concentration because it pumped up ±10L of water. Also, if the discharge of nozzle 1 is corrected by 4 minutes, it shows a good intake velocity.

X=56.21			
# Nozzle	Height above bed [cm]	C [g/L]	Discharge [L/min]
1	5,16	3,252	1,63
2	7,56	1.576	0.98
3	12,56	1,519	1,42
4	20,86	1,050	0,98
5	33,66	0,823	1,06
6	60,96	0,593	0,98
7	100,96	0.405	0.37

<u>Position x = 57.13 (corresponds to Run 12):</u>

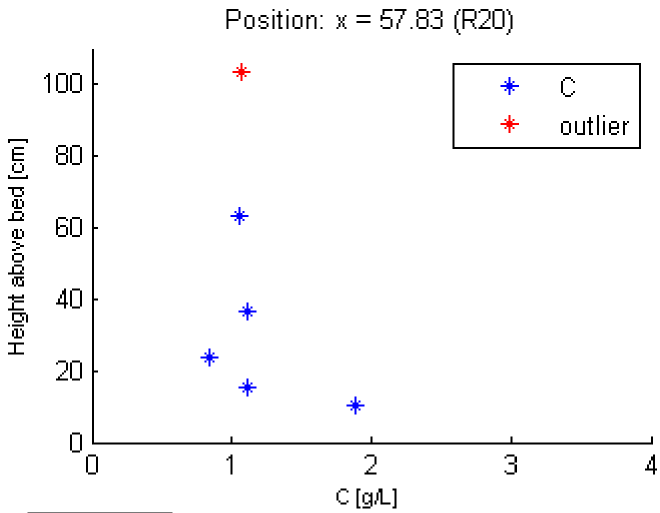


Nozzle 1 got stuck in Run 8, because the tube got stuck with sand. Even though pump 2 (nozzle 2) went on and off after 7 minutes, it managed to pump up 7.6L of water.

X=57.13			
# Nozzle	Height above bed [cm]	C [g/L]	Discharge [L/min]
1	10,66	NaN	NaN
2	13,06	3,406	0,90
3	18,06	2,562	1,06
4	26,36	1,712	0,80
5	39,16	1,166	0,98
6	66,46	0,717	1,04
7	106,46	0.551	0.68

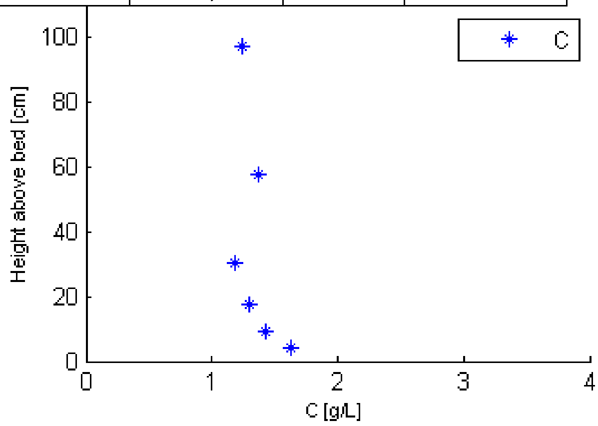
<u>Position x = 57.83 (Run 20):</u>

In this run, there were bubbles many bubbles in the experiment that could influence the data. This bubbles and the turbulence in the water explain the more or less equal distribution of sediment over the water column. Nozzle 4 has, compared to the other nozzles in this run, a low discharge. When I look at the data of run 12 (the run on top of this page), all the data differs quite a lot. This can be explained with the forming of the breaker bar. It was higher in run 20 than in run 12, what caused the waves to plunge with more strenght and that causes more turbulence, bubbles and sediment mixing. Nozzle 7 again was most of the time above the water, so its data is ignored.



X=57.83			
# Nozzle	Height above bed [cm]	C [g/L]	Discharge [L/min]
1	7,80	NaN	NaN
2	10,20	1,887	1,04
3	15,20	1,117	1,05
4	23,50	0,837	0,83
5	36,30	1,105	1,00
6	63,60	1,052	0,80
7	103,60	1.076	0.25

<u>Position x = 58.55 (Run 22):</u>



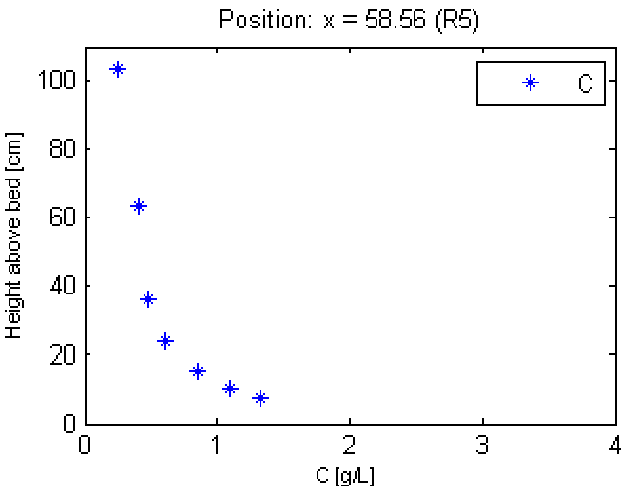
Only nozzle 1 was stuck. Nozzle 2 and 4 are corrected with the time, so the dischare increases a little bit because of this correction. There were many bubbles on the point of measuring that influences the data.

X=58.55			
# Nozzle	Height above bed [cm]	C [g/L]	Discharge [L/min]
1	1,71	NaN	NaN
2	4,11	1,629	1,21
3	9,11	1,431	1,28
4	17,41	1,300	0,93
5	30,21	1,186	1,04
6	57,51	1,370	0,85
7	97,51	1,241	0,86

<u>Position x = 58.56 (Run 5):</u>

This run is more or less the same as the one above. The breakerbar was less high than in run 22, so there is less vertical sediment transportation.

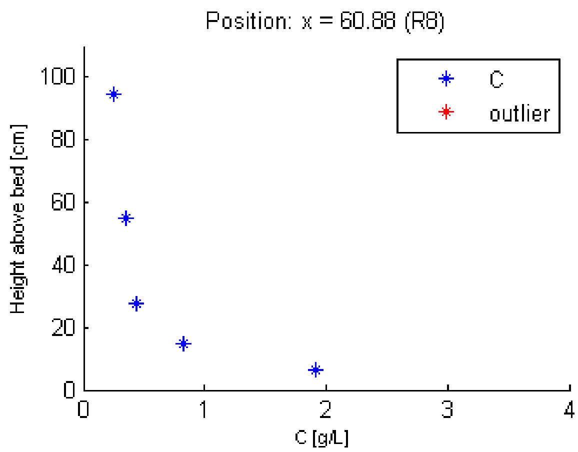
No data was ignored in this run.



X=58.56			
# Nozzle	Height above bed [cm]	C [g/L]	Discharge [L/min]
1	7,78	1,322	1,38
2	10,18	1,093	1,29
3	15,18	0,850	1,29
4	23,48	0,611	0,97
5	36,28	0,480	1,15
6	63,58	0,415	0,96
7	103,58	0,249	1,14

Position x = 60.88 (Run 8):

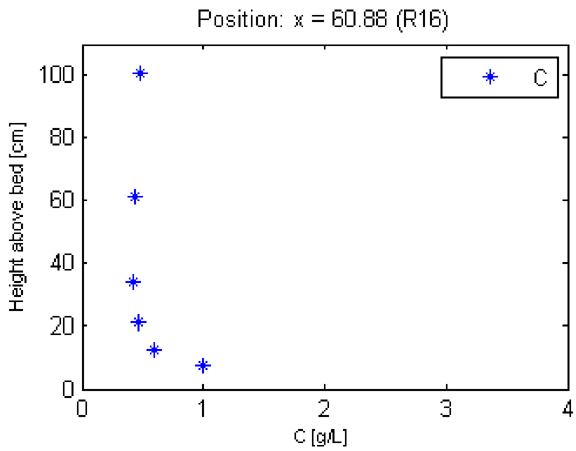
This is the run where nozzle 1 got stuck. Nozzle 1 and 2 were buried in a ripple (see the table). Pump 2 pumped up a part of the ripple, which caused a very high concentration. Both the data of nozzle 1 and 2 are ignored.



X=60.88			
# Nozzle	Height above bed [cm]	C [g/L]	Discharge [m/s]
1	-1,00	9.344	0.67
2	1,40	43.032	0.92
3	6,40	1,917	1,40
4	14,70	0,821	0,95
5	27,50	0,433	1,16
6	54,80	0,349	0,97
7	94,80	0,248	1,06

Position x = 60.88 (Run 16):

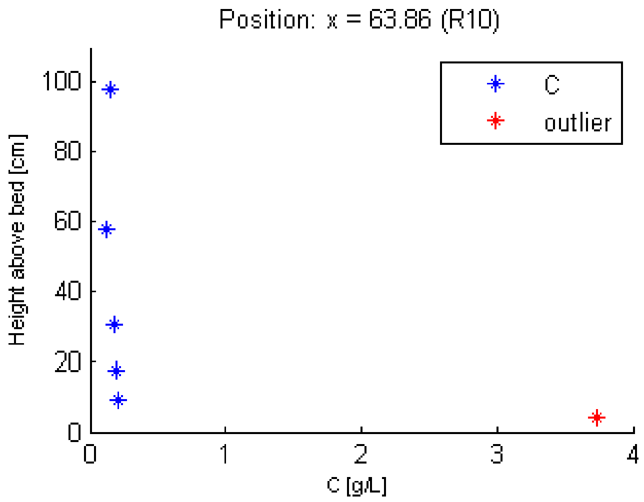
No data were ignored in this run. The sediment was distributed even over the water column. That is because of the position in the wave. Later I will show the position of the breaker bar in this figure too, so it is easier to find correlations to the height of the bar and the concentrations in the water column.



X=60.88			
# Nozzle	Height above bed [cm]	C [g/L]	Discharge [m/s]
1	5,18	NaN	NaN
2	7,58	1,002	1,32
3	12,58	0,602	1,13
4	20,88	0,460	0,97
5	33,68	0,423	0,98
6	60,98	0,444	0,95
7	100,98	0,475	1,03

Position x = 63.86 (Run 10):

Nozzle 2 was ignored in this run, because of its high concentration. In the surf zone I expected an even distribution of higher concentrations. In this run was found that the concentrations were very low, but that they were evenly distributed over the height.



X=63.86			
# Nozzle	Height above bed [cm]	C [g/L]	Discharge [m/s]
1	1,94	NaN	NaN
2	4,34	3.736	1.57
3	9,34	0,210	1,37
4	17,64	0,187	0,97
5	30,44	0,175	1,10
6	57,74	0,129	0,98
7	97,74	0,154	1,07