Hydroacoustic analysis

There are four main steps involved in applying the acoustic methods described in Marggraf (2024):

1. Preparing the sampling file
2. Preparing the acoustic data
3. Averaging the acoustic measurements along the beam
4. Application of single- and dual-frequency methods

1 Preparing the sampling filet

The first step is to create a file with the results of each gauge (Figure 1). This file can be created manually or automatically using the "1_Create_samples_files" code and the output from the ASG code (Marggraf et al., 2024). In any case, it is important that the output file has the same shape, the same column names etc. An example of the samples files can be found in the "Example_data" folder. Each line corresponds to a suspended sediment measurement. If some data are not known for a measurement, leave the cells empty. In addition, a point and no comma is required for numbers. An example of the output file is "Samples.csv". The file created in this way is very important for further acoustic analysis. The addition of new measurements data enables the acoustic calibration to be readjusted and improved each time.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1		Date	Start_samplin	End_sampling	Sampler	Q_sampling_r	Stage_samplir	spm_sampling	Sand_concent	Sand_flux_kg_	No_samples_	D10_mum	D50_mum	D90_mum	Fine_concent	Fine_flux_kg_	U_C	U_Q	U_F	Method	sigma_mum	S
2	0	20210406	13:21	15:25	P72	192.375	1.988	0.094	0.028	5.522					0.069	13.76	28.315	5.708	28.885	SDC		2.46428571
3	1	20210511	12:19	16:01	P72	451.923	3.726	1.699	0.388	198.73					1.871	959.041	51.377	5.822	51.706	SDC		4.82216495
4	2	20210512	11:10	14:23	P72	366.1	3.124	0.495	0.281	81.731					0.5	145.363	18.441	12.756	22.423	SDC		1.77935943
5	3	20210616	10:25	12:57	P6	396.111	3.34	1.451	0.761	220.956	19	38.197	113.341	296.613	1.517	440.59	11.972	12.756	17.494	SDC	0.585	1.9934297
6	4	20210616	13:25	15:27	P6	384.75	3.26	1.974	0.802	232.951	19	40.46	125.771	348.705	2.553	741.633	13.044	12.756	18.244	SDC	0.58	3.18329177
7	5	20210729	10:53	13:35	P6	145.5	1.611	0.053	0.105	15.237					0.061	8.832	16.789	5.255	17.592	SDC		0.58095238
8	6	20210729	14:15	16:55	P6	157.667	1.712	0.048	0.155	22.503					0.051	7.333	19.188	5.255	19.894	SDC		0.32903226
9	7	20211012	10:58	16:34	P6	80.012	0.964	0.039	0.011	0.871					0.013	1.023	26.578	10.911	28.731	SDC		1.18181818
10	8	20220406	11:20	16:34	P6	137.733	1.538	0.112	0.09	9.946					0.098	10.823	18.334	5.008	19.006	SDC		1.08888889
11	9	20220408	10:29	16:40	P6	286.941	2.622	0.598	0.381	41.17	3	57.796	174.447	438.311	0.417	45.022	15.623	4.528	16.266	SDC	0.583	1.09448819
12	10	20220409	08:45	13:05	P6	277.385	2.568	0.553	0.383	73.624	4	86.146	240.664	527.821	0.505	97.036	19.327	6.311	20.331	SDC	0.589	1.31853786
13	11	20220429	10:15	14:32	P6	195.077	2.008	0.048	0.057	10.913					0.036	6.855	32.497	6.311	33.104	SDC		0.63157895
14	12	20220506	09:37	13:48	P6	240.583	2.33	0.321	0.094	27.355					0.273	79.22	17.174	12.756	21.393	SDC		2.90425532
15	13	20220513	08:51	10:43	P6	309.375	2.764	0.497	0.232	67.324	21	52.804	184.468	425.362	0.3	87.172	19.037	12.756	22.915	SDC	0.583	1.29310345
16	14	20220513	12:07	14:01	P6	295.875	2.682	0.52	0.25	72.471	20	51.354	181.82	429.444	0.858	249.14	14.199	12.756	19.087	SDC	0.582	3.432
17	15	20220519	10:30	12:10	P6	342.625	2.961	1.051	0.269	78.255	10	26.259	119.836	349.2	0.844	245.063	14.388	12.756	19.229	SDC	0.574	3.13754647
18	16	20220519	13:16	15:40	P6	331.444	2.893	1.704	0.341	99.035	2	67.936	240.902	553.784	1.719	499.152	13.054	12.756	18.252	SDC	0.582	5.04105572
19	17	20220601	11:05	14:35	P6	211.364	2.125	0.059	0.067	13.335	4	67.618	238.548	491.151	0.059	11.624	27.623	5.708	28.206	SDC	0.59	0.88059701
20	18	20221214	10:10	09:58	P6	135.154	1.521	0.053	0.034	4.581					0.034	4.495	20.422	7.807	21.863	SDC		1
21	19	20230510	13:54	15:47	P6	451.25	3.722	1.12	0.448	200.351	26	49.351	141.625	360.345	1.079	482.956	11.864	10.686	15.967	SDC	0.584	2.40848214
22	20	20210406	10:30	15:30	BD	188.067	1.955	0.09	0.071	13.299	18	69.17	175.572	404.741			33.511	5.358	33.937	SDC	0.59	
23	21	20210511	10:50	16:24	BD	460.067	3.783	2.074	0.773	355.59							33.511	5.358	33.937	NN		
24	22	20210512	09:49	15:51	BD	363.562	3.106	0.494	0.352	127.965	13	64.196	164.014	369.46			24.284	4.893	24.772	SDC	0.591	
25	23	20210616	09:38	16:11	BD	388.647	3.286	1.571	0.719	279.494	12	37.889	99.765	258.845			23.562	4.893	24.065	SDC	0.586	
26	24	20210729	10:10	16:23	BD	149.875	1.647	0.052	0.111	16.654	18	110.214	263.698	512.413			45.995	6.463	46.447	SDC	0.6	
27	25	20211012	10:32	15:18	BD	78.492	0.947	0.039	0.013	1.056	3	138.717	291.974	534.508			65.764	11.471	66.757	SDC	0.609	
28	26	20220429	09:05	14:33	BD	194.933	0.048	2.007	0.088	17.117	11	153.209	317.532	580.812			135.099	5.358	135.205	SDC	0.609	
29	27	20220506	09:30	14:41	BD	242.067	2.34	0.314	0.151	36.599	19	92.781	210.117	414.967			61.03	5.128	61.245	SDC	0.601	
30	28	20220513	09:35	14:25	BD	301.077	2.714	0.527	0.286	86.235	11	62.085	161.174	388.857			40.666	5.122	40.988	SDC	0.588	
31	29	20220519	10:40	14:58	BD	338.083	2.933	1.379	0.239	80.969	14	45.196	141.569	380.705			29.081	13.621	32.113	SDC	0.579	
32	30	20220601	09:40	14:52	BD	209.714	2.114	0.066	0.168	35.165	20	136.472	351.475	666.859			41.549	5.358	41.893	SDC	0.6	

Figure 1: Example of the output file "Samples_HADCP.csv".

2 Preparing the acoustic data

2.1 General informations

The aim of this acoustic data preparation is to create a file with the intensity data and a file with the background noise data for each frequency, using the HADCP measurement files. In this step, no acoustic analysis or interpretation is performed, only data formatting. The HADCP measurement files are in the formats (Table 1). "Raw binary" files are used for conversion in the first step.

Table 1: Formatting of the HADCP measurement files.

Frequency	Raw ASCII	Raw binary
400 kHz	.WPA	.WPR
1 MHz	.PRA	.PICS

We recommend to save the files in a separate folder for each frequency and then classify them according to their data processing stage (Figure **??**). As data processing is carried out on a monthly basis, it is recommended to save data in monthly folders within each folder (except for "4_ASCII_converted_raw_all_time"). The first folder contains the unsorted raw files of the HADCPs, containing one raw ASCII file and one raw binary file for each measurement. The measurement files are hourly files.

The first step is to distribute the files in the "1A_Raw_ASCII" and "1B_Raw_binary" folders on a monthly basis. Next, the "raw binary" data is converted as described in detail below, and the output is saved in the next folder named "2_ASCII_converted_raw_hourly", again in monthly folders. The next two steps concatenate the hourly files first into monthly files, saved as "3_ASCII_converted_raw_monthly", and finally into files for the entire measurement period, saved as "4_ASCII_converted_raw_all_time". The last step creates an intensity measurement file and a background file for each frequency, which are saved in the "5_Intensity_background" folder. The monthly, long-term and intensity/background files are created using three Python-coded scripts.

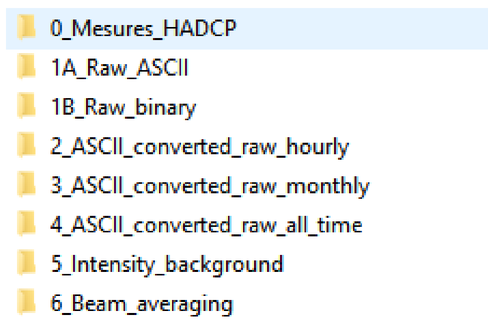

Figure 2: Recommended folders and categorization for the acoustic data preparation. Such a folder should be used for each frequency.

2.2 Converting the acoustic output data

The HADCP measurement files are converted in the respective software using the "raw binary" files (.WPR and .PICS). This step is repeated for each frequency and is carried out on a monthly basis.

1. Open AWAC software for 400 kHz HADCP and AquaPro software for 1 MHz HADCP. Both are also available for download from the Nortek website under "Software".
2. Click on the "Data conversion" icon, indicated by the orange circle below:

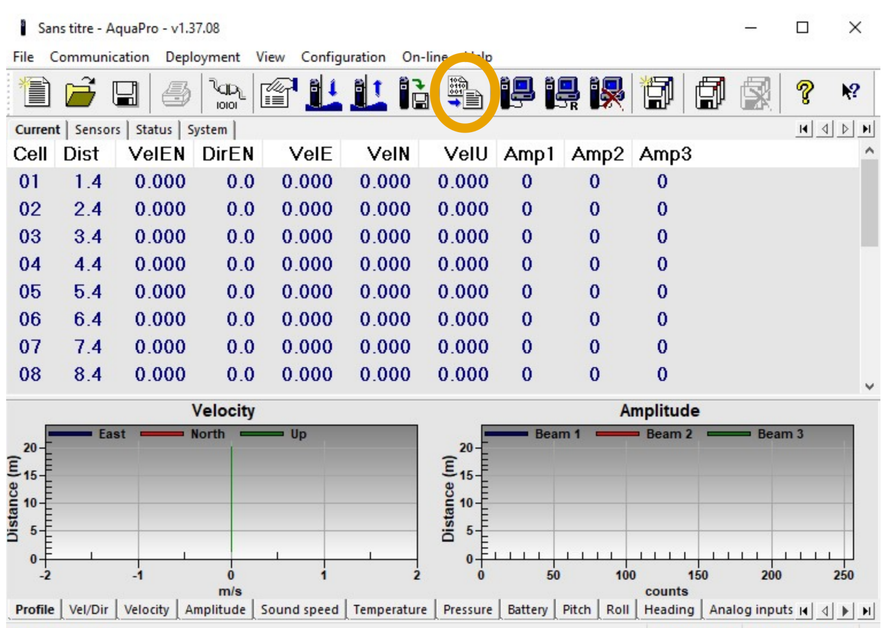

Figure 3: "Data conversion" icon, here in the AquaPro software.

3. A window opens in which you can select the binary data by clicking on "Add file".

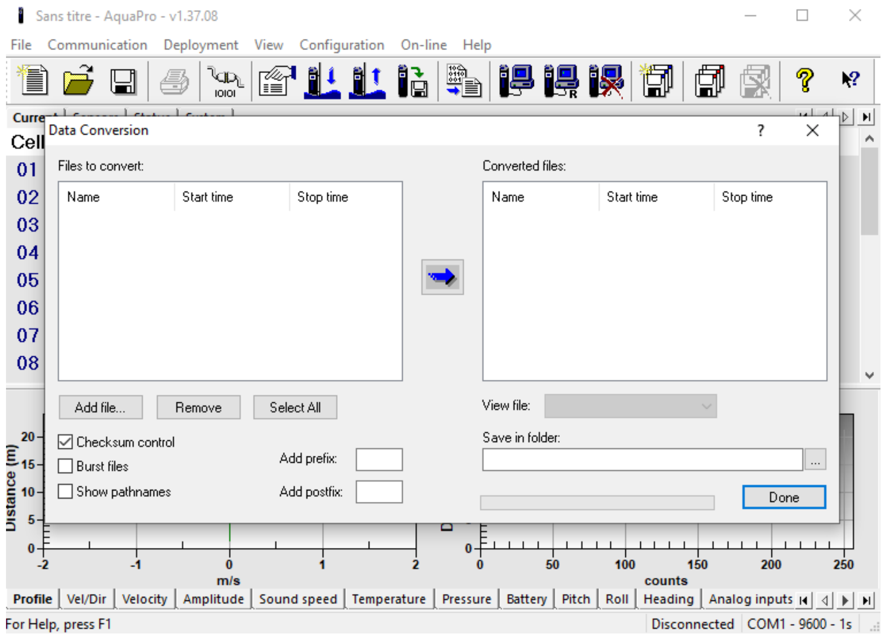

Figure 4: Data conversion window.

4. After selecting "Add file", a new window opens in which the binary data have to be selected. They are located in the "1B_Raw_binary" folder. All hourly binary files in a monthly folder (here 1 MHz and the month of December 2021) are selected and confirmed with "Open".

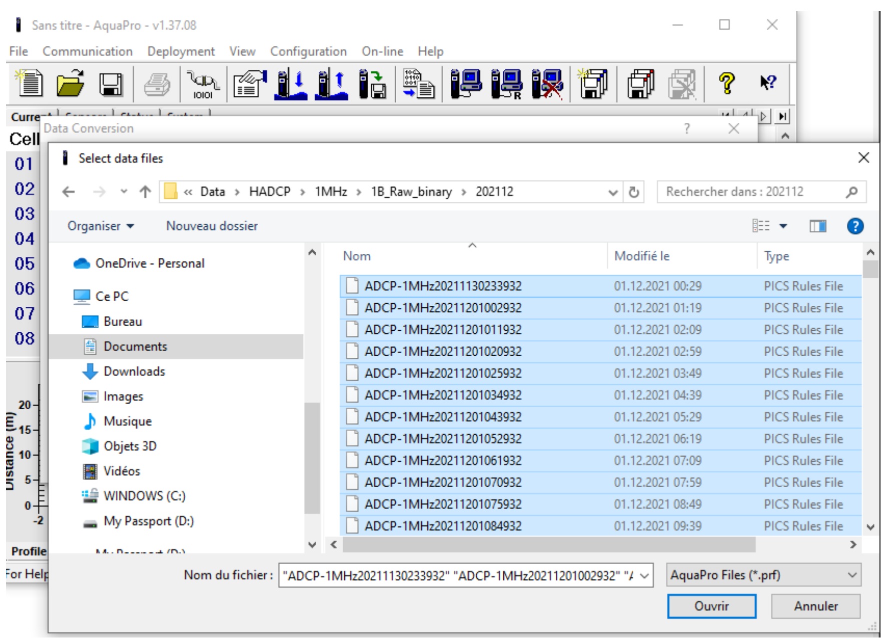

Figure 5: Choice of binary data in the folder "1B_Raw_binary" using the dedicated window.

5. These files are then indicated in the window on the left. Next, select the output folder in which the converted files will be saved, "2_ASCII_converted_raw_hourly", according to month and corresponding frequency. Click on "Select all" and the files in the window on the left are marked in blue as shown in the figure below, and click on the arrow to start conversion.

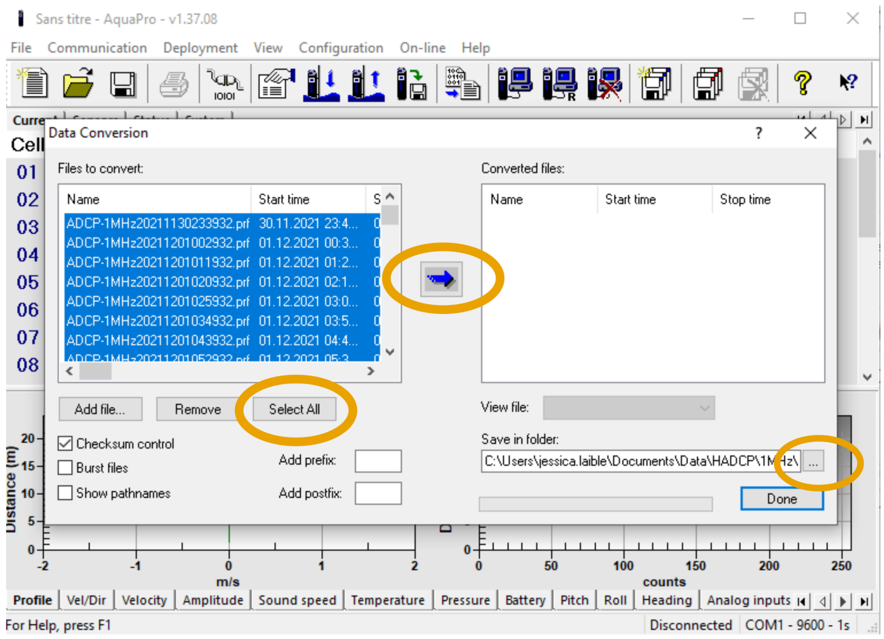

Figure 6: Choice of the output folder and start of the data conversion using the arrow.

6. Another window opens, asking for the file types to be exported (Header, velocity, amplitude, sensors, wave). Normally, these are already checked. Confirm with "OK".

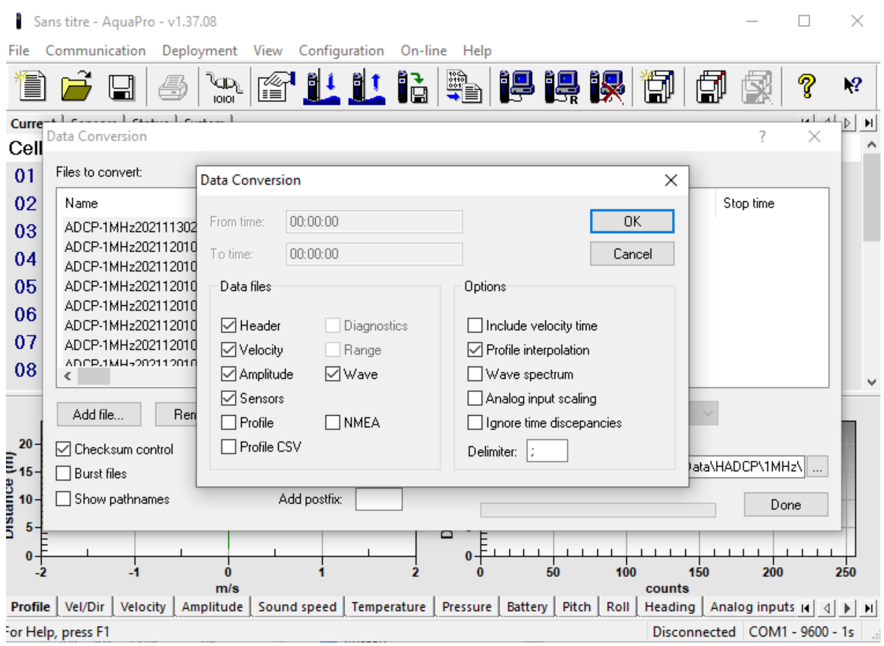

Figure 7: Confirm choice of data which should be exported with "Ok".

7. When the conversion is complete, check in the "2_ASCII_converted_raw_hourly" folder that all measurements have been converted. Sometimes, the software does not convert all data without warning. This limit often occurs around the 25^{th} of the month. In this case, repeat the procedure for missing data.
8. Output data are hourly files sorted by month and frequency. These are text files in .A1, .A2, .HDR, .SEN, .SSL, .V1, .V2, .WAD, .WHD formats.

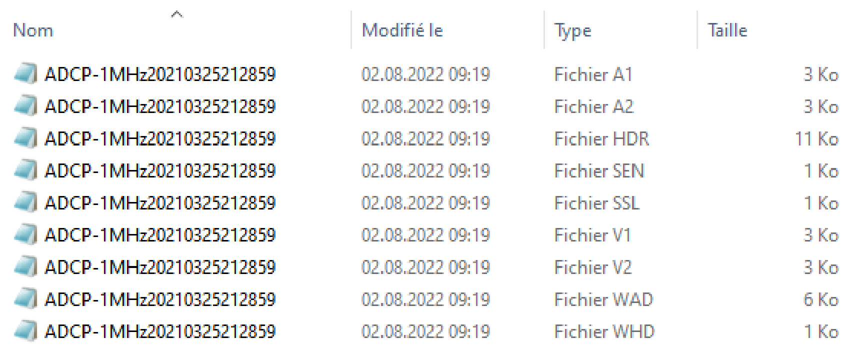

Figure 8: Hourly converted data in the folder "2_ASCII_converted_raw_hourly\202103" of March 2021.

2.3 Creating monthly files

The hourly files in the "2_ASCII_converted_raw_hourly" folders, sorted by month and frequency, are concatenated in this step to create monthly files. This step is used to concatenate the hourly files for each variable (amplitude, speed, header, etc.) into monthly files (Figure 9).

1. Open and run script or executable **"2A_Create_monthly_acoustic_data_files"**
2. Indicate the month you wish to concatenate in "AAAAMM" format in the window that opens.
3. Choose the frequency.
4. Choose the "path" where the time files are located, which is "2_ASCII_converted_raw_hourly\AAAMM".
5. Choose the "outpath", the path where the concatenated monthly files will be saved, which is "3_ASCII_converted_raw_monthly\AAAMM".
6. Output files are monthly files for each acoustic variable in .A1, .A2, .HDR, .SEN, .SSL, .V1, .V2, .WAD, .WHD formats.

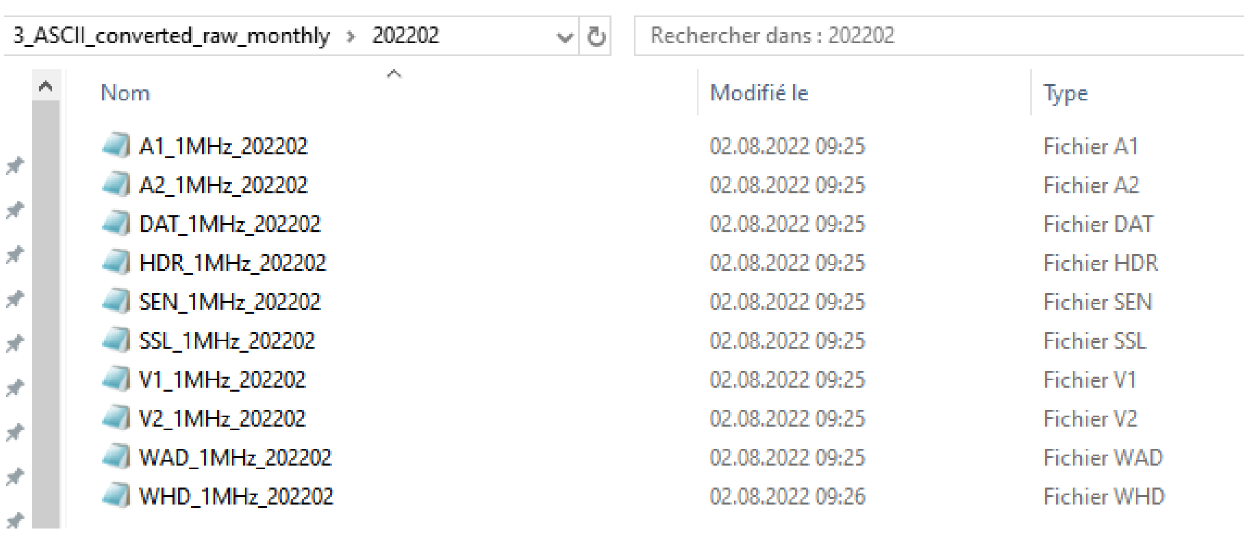

Figure 9: Concatenated monthly files (month of February 2022) by variable for 1 MHz HADCP

7. Repeat this step for each month and frequency.

2.4 Create files for entire period

This step creates concatenated files by acoustic variable and frequency for the entire measurement period. This step should be repeated when new data have been recorded and their monthly files created.

1. Open and run the script or executable **"2B_Create_acoustic_all_time_files"**
2. Choose frequency.
3. Choose the "path", the path where the monthly files are located, which is "3_ASCII_converted_raw_monthly". All monthly data concatenated in this file will be used.
4. Choose the "outpath", the path where the concatenated files will be saved, which is "4_ASCII_converted_raw_all_time".

5. Output files are concatenated files for the entire measurement period for each acoustic variable in .A1, .A2, .HDR, .SEN, .SSL, .V1, .V2, .WAD, .WHD formats.

A1_400kHz	18.07.2023 16:41	Fichier A1	37 928 Ko
A2_400kHz	18.07.2023 16:41	Fichier A2	37 928 Ko
DAT_400kHz	18.07.2023 16:41	Fichier DAT	25 300 Ko
HDR_400kHz	18.07.2023 16:41	Fichier HDR	238 139 Ko
SEN_400kHz	18.07.2023 16:41	Fichier SEN	10 482 Ko
SSL_400kHz	18.07.2023 16:41	Fichier SSL	4 078 Ko
V1_400kHz	18.07.2023 16:41	Fichier V1	48 733 Ko
V2_400kHz	18.07.2023 16:41	Fichier V2	48 733 Ko
WAD_400kHz	18.07.2023 16:41	Fichier WAD	139 879 Ko
WHD_400kHz	18.07.2023 16:41	Fichier WHD	15 819 Ko

Figure 10: Files concatenated over the entire measurement period by variable for the 400 kHz HADCP.

6. Repeat this step for each frequency.

2.5 Creating intensity and background noise files

This step creates two files; one with measurement data ("Amplitude_velocity") and one with background noise data ("WHD") for the entire measurement period.

1. Open and run script or executable **"2C_AQD_append"**
2. Choose frequency.
3. Choose the "path", the path where the concatenated files are located, which is "4_ASCII_converted_raw_all_time".
4. Choose the "outpath", the path where the two output files will be saved, which is "5_Intensity_background".
5. "Amplitude" and "WHD" files are obtained in .csv and pickle format.

400kHz > 5_Intensity_background — Rechercher dans : 5_Intensity_background

Nom	Modifié le	Type	Taille
Amplitude_velocity_400	18.07.2023 16:47	Fichier CSV Microsoft E...	149 800 Ko
Amplitude_velocity_400	18.07.2023 16:47	Document texte	190 184 Ko
WHD_400	18.07.2023 16:47	Fichier CSV Microsoft E...	12 508 Ko
WHD_400	18.07.2023 16:47	Document texte	21 193 Ko

Figure 11: "Amplitude_velocity" and "WHD" files containing amplitude, velocity and background noise measurements for the 400 kHz HADCP

6. Repeat this step for each frequency.

The current code assumes that the measurement parameters remain unchanged, e.g. cell size, number of cells, blanking etc. If these parameters have been changed, the header file for each measurement must be used, and the corresponding data exported from these files. If these parameters have been changed, the header file for each measurement must be used and the corresponding data exported from these files. This has not been applied, as the header files are not easy to read automatically and the measurement parameters have not changed.

3 Averaging the acoustic measurements along the beam

This first part of the acoustic analysis is carried out using the TW16-A method (**"3_Beam_averaging_TW16A"**). As with the previous steps, this part is also performed for each frequency separately, so twice in total. Acoustic values, fluid-corrected backscatter B_F, sediment attenuation α_{sed}, backscatter in each cell B and averaged along the beam $\overline{B}$, are calculated. This part therefore performs an acoustic analysis and transforms the data. Calculation over a long period can take one to two hours, due to multiple iterations.

Specifically, this stage proceeds as follows:

- Choose the folder for outpath results, which is "6_Beam_averaging".

- Choose the folder for "outpath_figures". It can be created with a folder named "Figures" in "6_Beam_averaging".
- Select the "Amplitude_velocity" file (in the "5_Intensity_background" folder) and for the defined frequency.
- Choose the "WHD" file (in the "5_Intensity_background" folder) and for the defined frequency.
- Select the file with the water level data. An example is the "Water_stage" file in the "Sampling_data" folder.
- Six windows open one after the other. Choose another threshold for instrument angles or accept the default value (general

Output files: Several different files are created, often in csv and pickle format (Figure 12):

- "Beam-averaged_attenuation_backscatter": date, attenuation α_{sed}, backscatter $\overline{B}$ averaged along the acoustic beam, water attenuation, water temperature, instrument background and effective background.
- "FluidCorrBackscatter": fluid-corrected backscatter values in each valid cell for each valid measurement
- "CelldB": relative backscatter values in each valid cell for each valid measurement
- "AveCount_db": acoustic signal strength A values in all cells and all measurements non-excluded for aberrant instrument angles
- "Time_datetime_AveCount_db": dates and times of "AveCount_db" measurements
- "Celldist_along_beam": distance from the center of each transducer cell, measured along the acoustic beam
- "Usable_part_surface": distances of interference indicators (Nortek, 2018) for each valid measurement
- "Last_valid_index_corrected": date, last valid cell and its distance from the transducer along the acoustic beam for each valid measurement
- "Last_valid_index_un_corrected": date, last valid cell according to SNR methods of the buffer zone and their transducer distances along the acoustic beam for all measurements (without measurements excluded due to angles)
- "Time_list_not_used_beam_averaging": dates of acoustic measurements excluded from analysis at this stage

Amplitude_velocity_1000	22.02.2024 13:07	Fichier CSV Micros...	13 685 Ko
Amplitude_velocity_1000	22.02.2024 13:07	Document texte	19 245 Ko
AveCount_db_1000	22.02.2024 13:43	Document texte	4 462 Ko
Beam_averaged_attenuation_backscatter...	22.02.2024 13:43	Fichier CSV Micros...	956 Ko
Beam_averaged_attenuation_backscatter...	22.02.2024 13:43	Document texte	588 Ko
CelldB_1000	22.02.2024 13:43	Document texte	4 288 Ko
Celldist_along_beam_1000	22.02.2024 13:43	Document texte	2 Ko
FluidCorrBackscatter_1000	22.02.2024 13:43	Document texte	4 288 Ko
Time_datetime_AveCount_db_1000	22.02.2024 13:43	Document texte	71 Ko
Usable_part_surface_1000	22.02.2024 13:43	Fichier CSV Micros...	811 Ko
WHD_1000	22.02.2024 13:07	Fichier CSV Micros...	1 033 Ko
WHD_1000	22.02.2024 13:07	Document texte	1 814 Ko

Figure 12: Output files from the averaging step (in addition to those from the previous step) for the 1 MHz instrument

Adaptations to other cases: Different criteria for pitch, roll and heading angles are applied to exclude measurements during maintenance, for example. Their values before and after exclusion are saved as figures for rapid visual analysis. Methodological assumptions can be changed to test other parameters, such as the buffer zone or background noise threshold. If this code is used for other instruments, certain parameters such as the conversion factor (0.43 for the instruments used (line 82) or the beam aperture angles (lines 319 and 321) need to be adapted. The noise floor offset A_E used for the Topping and Wright (2016) TW16 method is adjusted in line 201. The calculation of the signal-to-noise ratio SNR, the interferences with the surface and the 5 m buffer zone are carried out in section 7. The number of excluded cells close to the transducer can be found in lines 395 to 398. The minimum number of values per acoustic measurement is defined in line 456.

4 Application of single- and dual-frequency methods

The final step combines one or two frequencies for acoustic analysis and inversion to estimate fine sediment and sand concentrations, as well as median sand diameter in the case of the two-frequency method. The same data are selected for the mono- and bi-frequential methods, the only difference being that a single frequency is used for the mono-frequential method. This step is performed once.

Specifically, this step is as follows:

1. Open and run **"4_TAAPS_TW16A"** for the bi-frequential method and **"4_TAAPS_TW16A_Single_freq"** for the mono-frequential method.
2. Choose the "path" data folder which is "6_Beam_averaging" for each frequency.
3. Choose the sampling data folder, for example "Sampling_data" (see below for description of sampling data).
4. Choose the folder for results and results figures, "outpath" and "outpath_figures".
5. A window opens requesting the start and end of a period (short, a few days) to be viewed in detail. Multiple periods can be viewed by answering the question in the console with "Y" or "n" to continue.
6. Several result files and figures have been saved.

The **sampling data files** required are:

- Data missing ("Missing_data"): periods without acoustic measurements of both frequencies, e.g. due to equipment problems etc.
- Deleted data ("Manually_deleted_data"): periods with identified outliers or invalid data that will be excluded from the analysis
- Sampling file ("Samples"): suspended sediment measurement results, used for acoustic model calibration (section 1)
- ISCO data: results of ISCO measurements of fine sediment and sand concentrations
- ISCO sample granulometry data ("ISCO_GSD_data")
- Pumping gauging data ("pump_data"): results of pumping gauges here, used for acoustic model validation
- Standardized granulometric classes ("ISO_size_classes"): granulometric classes on which granulometric interpolation is performed, always the same file
- Station turbidity data
- Station flow data
- Station water level data

Missing data	Missing data in the acoustic files	Deletes selected data
Manually delete data	Acoustic measurements to exclude	Deletes selected data (e.g., showing issues)
Samples data	Suspended sediment samples for calibration	Content of this file in the following table
ISCO data	ISCO automatic pumping data	The last two columns indicate data corrected by coefficients relating the bank to the cross-section.
ISCO GSD	Grain size data of ISCO samples	For visualization
Pump data	Suspended sediment samples using the pump PP36	These data are currently used for validation only, not for the calibration.
ISO size class	Standardized grain size classes	Used for the calculation
Turbidity	Total suspended sediment concentration determined by turbidity at the hydro-sedimentary station	
Discharge	Discharge at the hydro-sedimentary station	For flux calculation and visualization
Water stage	Water stage at the hydro-sedimentary station	For the interferences with the surface
RUTS_theo_freq1 RUTS_theo_freq2	RUTS relations for the 400 kHz and 1 MHz HADCP at Grenoble Campus using the parameters specified in the article	Using the quick program signifies that the RUTS relations are not recalculated, requiring constant hydro-sedimentary conditions at Grenoble Campus

Figure 13: Description of the different sampling files used.

All times are given in GMT. Example files are given in the "Sampling_data" folder. The columns in the "Samples" file are detailed below, those indicated with a cross are required to perform the analysis.

Colum	Required	Explication
Date	x	aaaammjj
Gauging	x	Indicates gauging (date and, if applicable, AM or PM)
Start_sampling	x	Starttime of suspended sediment measurement in UTC
End_sampling	x	Endtime of suspended sediment measurement in UTC
Start_sampling_local		Local start time
End_sampling_local		Local end time
Sampler	x	Sampler
Q_sampling_m3_s	x	Discharge in m^3/s
Stage_sampling_m	x	Water stage in m
spm_sampling_g_l	x	Total suspended sediment concentration measured by turbidity in g/l
Sand_concentration_g_l	x	Mean cross-sectional suspended sand concentration
Sand_flux_kg_s	x	Suspended sand flux
No_samples_used_for_ISO_gsd		Number of samples used to determine the mean cross-sectional grain size distribution following the ISO method
D10_mum		Mean cross-sectional sand D10 determined following the ISO method
D50_mum		Mean cross-sectional sand D50 determined following the ISO method
D90_mum		Mean cross-sectional sand D90 determined following the ISO method
Fine_concentration_g_l		Mean cross-sectional fine-sediment concentration
Fine_flux_kg_s		Suspended fine-sediment flux
U_C		Uncertainty in the mean cross-sectional suspended sand concentration as described by Marggraf 2024
U_Q		Uncertainty in discharge (OURSIN, QRevInt)
U_F		Uncertainty in the suspended-sand flux as described by Marggraf 2024
Method		Analysis method
sigma_mum		« Standard deviation » sigma of the sand grain size distribution
S		Ratio of the suspended sand to the suspended fine-sediment concentration in the cross-section
D50_mum_fines		D50 of suspended fine sediments
sigma_mum_fines		« Standard deviation » sigma of the fine-sediment grain size distribution
ISCO_fine_concentration_g_l		Suspended fine-sediment concentration of the simultaneous ISCO sample
ISCO_sand_concentration_g_l		Suspended sand concentration of the simultaneous ISCO sample

Figure 14: Description of the different columns in the "Samples" file

Adaptations to other cases: The executable does not offer choices for modifying the method; some modifications can be made in the scripts themselves. The properties of the reference suspension are defined in the "Define reference properties" section (from line 434). If they are to be changed, form factor and RUTS values will have to be recalculated. In the current code, these values and relationships are imported and correspond to defined frequencies and properties. They therefore do not adapt to modified reference properties. If these are changed, the "TAAPS_article" code must be used, in which all the necessary values are systematically calculated. The averaging of acoustic data over the gauging time can be adapted in step 8. The data (here "Samples" and ISCO ("ISCO_data)) used for calibration between fine sediment concentration and attenuation can be changed from line 663. Backscatter - sand calibration is performed in step 10 using the criteria $S < 3$ and the sand median diameter must be $\pm 0.4\phi$ of the sand reference diameter.

5 Rerun analysis with new data

To redo the acoustic analysis with new acoustic data, you need to create monthly files for these data. To do this, it is necessary to repeat the first steps up to 2.3. for this data. Then, new "all_time" files must be created for the entire measurement period, and the last two steps repeated for the new data. To recalculate steps 3 and 4 (averaging and acoustic methods), water level data at the station are also required to determine interference.

To redo the acoustic analysis with new sampling data, either gauging data for calibration or validation data, the data must be added to the corresponding files. It is important to use the same format, header etc. as the exemplary files in the "Sampling_data" folder. Step 4 is then repeated.

References

Marggraf, J. (2024). *Improving methods for the hydroacoustic monitoring of suspended sand concentration and grain size: Application to the Isère River at Grenoble Campus*. PhD thesis, University Claude Bernard Lyon 1.

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