Data and scripts underlying the publication "Bimodality in subaqueous dune height suggests flickering behavior at high flow" (published in *Nature Communications*, 2025)

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README – Version 1 (02 May 2025)

Contents

Input data, scripts and output files needed per Figure

All calculation scripts, input data files, and output files used for the publication (de Lange et al. 2025, Nature Communications) are described below. The path to each file is given relative to the main repository folder, whose location is indicated with "~".

Remark: files and the overarching folders that are marked in yellow have not been included in our data repository. These data are owned by the authors of Venditti et al. (2016) and Bradley & Venditti (2019). We have obtained permission from said authors to reanalyze their raw data for the purpose of our study. For those interested in these raw data, we refer to said authors.

Figure 1

Script(s) used:

- ~\Scripts\figure_rawdata_V2.m

Input data file(s):

- ~\Data\Venditti2016\data_venditti_matlab.xlsx
- ~\Data\Bradley2019\Time_Series_Data.xlsx
- ~\Data\Data_experiments\Seatek\matlab output\duneheight_experiment.mat

Output data file(s):

- ~\Scripts\output\Figure1.pdf

Explanation:

- This Matlab script uses dune height and transport stage data from four previously published studies:
- Best and Bridge (1992)
    - This data is directly derived from the publication itself.
    - The values are given in the Matlab script itself.
- Bennett et al. (1998)
    - This data is directly derived from the publication itself.
    - The values are given in the Matlab script itself.
- Venditti et al. (2016)
    - This raw data was requested from the authors of that publication, and analysed and used for our publication with their permission. We named and located this raw data file at ~\Data\Venditti2016\data_venditti_matlab.xlsx. Since this raw data is not ours, we do not include it in our data repository, and instead refer to the authors of the original publication to request their raw data.

- Bradley & Venditti (2019)
    - This raw data was requested from the authors of that publication, and analysed and used for our publication with their permission. We named and located this raw data file at ~\Data\Bradley2019\Time_Series_Data.xlsx. Since this raw data is not ours, we do not include it in our data repository, and instead refer to the authors of the original publication to request their raw data.
- The script also uses the data from our own, additional experiment.
    - The processed data (i.e., a timeseries of dune heights) can be found here: ~\Data\Data_experiments\Seatek\matlab output\duneheight_experiment.mat. This dataset was derived from our raw experimental data in the Matlab script ~\Scripts\find_crests_troughs.m. This latter script is further described below, under section "Supplementary Figure S6".
- For this figure, as well as most other figures in our publication, colormaps from the *cmocean* package (Thyng et al.2016) were used. This function can be found under ~\Scripts\cmocean.m.

Figure 2

Script(s) used:

- ~\Scripts\figure_rawdata_V2.m
- ~\Scripts\determine_modi.R

Input data file(s):

- ~\Scripts\input\modi_distance.xlsx
- ~\Scripts\input\data_av.xlsx
- ~\Scripts\input\dune_heights_16.xlsx

Output data file(s):

- ~\Scripts\output\Figure2.pdf

Explanation:

- To make Figure 2a, this Matlab script uses dune height and transport stage data from Venditti et al. (2016) and Bradley & Venditti (2019), that is, the same data as was used for Figure 1.
- To make Figure 2b, the frequency distributions of dune height are calculated for each transport stage and statistical tests of uni- or bimodality are done. These tests are done in the R-script ~\Scripts\determine_modi.R, which determines the modality of the non-dimentionalized dune height distributions of the experiments, using the Laplace's demon (Statisticat, 2021). This R-script uses the input file ~\Scripts\input\dune_heights_16.xlsx, which contains dune heights as calculated with the Matlab script

~\Scripts\find_crests_troughs.m. The results of the R-script ~\Scripts\determine_modi.R can be found in the data file ~\Scripts\input\modi_distance.xlsx. In this Excel file, we manually calculated the distances between the two modi, by substracting the first mode from the second mode. This Excel file is then used as input in the Matlab script ~\Scripts\figure_rawdata_V2.m. Finally, to calculate the coefficient of variation CV (a measure of the strength of bimodality), timeseries of dune height over average water depth (from Venditti et al. 2016, and Bradley & Venditti 2019) are loaded from the input file ~\Scripts\input\data_av.xlsx. This Excel file contains the selection of the necessary raw data from Venditti et al. (2016) and Bradley & Venditti (2019), which we had requested at the respective authors.

Figure 3

Script(s) used:

- ~\Scripts\DensityPlot_bedforms_V6.m

Input data file(s):

- ~\Scripts\input\data_av_V4.xlsx
- ~\Scripts\input\modi_distance_V4.xlsx

Output data file(s):

- ~\Scripts\output\Figure3.pdf

Explanation:

- This script makes Figure 3, i.e. the density plot of dimensionless dune height as a function of transport stage, for both the data from Venditti et al. (2016), Bradley & Venditti (2019), and our own bespoke experiment.
- The two input data files are the same type of files as those used for Figure 2 (see above), that is, ~\Scripts\input\data_av_V4.xlsx contains the timeseries of dimensionless dune heights for each separate flume run (i.e. for each separate transport stage). This is the same data as ~\Scripts\input\data_av.xlsx used in Figure 2, but in this new file, the data from our own bespoke experiment was added (last column in the sheet "duneheight over average depth". Similarly, ~\Scripts\input\modi_distance_V4.xlsx contains the same data as the file ~\Scripts\input\modi_distance.xlsx used for Figure 2 (calculated modi of the frequency distributions), but in this version, our own experimental data was added (last row in the sheet "duneheight over average depth").

Figure 4
Script(s) used:

- ~\Experiment\flume_sensor_analysis_v2.m

Input data file(s):

- ~\Experiment\Data_experiments\Seatek\20240710_1533 File 1.txt

Output file(s):

- ~\Experiment\output\Figure4.pdf
- ~\Experiment\output\20240710_1533 File 1_output.mat
    - A Matlab output file containing all processed data of our experiment.

Explanation:

- The input data file contains the distances from the Seatek acoustic sensors to the sediment bed, obtained in our own bespoke flume experiment. The data are ordered by sensor (there are 32 sensors), and are listed as timeseries (note that the timestamps are lacking here, but the sampling interval is fixed and known).
- The Matlab script imports this raw input data and does a series of processing steps (amongst others: filtering out backscatter signals which do not represent the actual sediment bed; see the manuscript for more information). The script then makes a produces a number of figures that are mostly shown in the Supplementary Materials of our publication, in addition to Figure 4 in the Main manuscript.

Supplementary Figure S3
Script(s) used:

- ~\Experiment\flume_sensor_analysis_v2.m

Input data file(s):

- ~\Experiment\Data_experiments\Seatek\20240710_1533 File 1.txt

Output file(s):

- ~\Experiment\output\FigureS3.pdf

Explanation:

- See explanation under Figure 4 (above).

Supplementary Figure S4
Script(s) used:

- ~\Experiment\flume_sensor_analysis_v2.m

Input data file(s):

- ~\Experiment\Data_experiments\Seatek\20240710_1533 File 1.txt

Output file(s):

- ~\Experiment\output\FigureS4.pdf

Explanation:

- See explanation under Figure 4 (above).

Supplementary Figure S5
Script(s) used:

- ~\Experiment\flume_sensor_analysis_v2.m

Input data file(s):

- ~\Experiment\Data_experiments\Seatek\20240710_1533 File 1.txt

Output file(s):

- ~\Experiment\output\FigureS5.pdf

Explanation:

- See explanation under Figure 4 (above).

Supplementary Figure S6
Script(s) used:

- ~\Scripts\find_crests_troughs.m

Input data file(s):

- ~\Data\Data_experiments\Seatek\matlab output\20240710_1533 File 1_output.mat
    - This file is the output file from the analysis of our own experimental data, which has been described above under Figure 4. This data file is comparable to the file stored in ~\Experiment\output\20240710_1533 File 1_output.mat.

Output file(s):

- ~\Scripts\output\FigureS6.pdf

- ~\Scripts\input\dune_heights_16.xlsx

Explanation:

- This script uses the processed data from our own bespoke experiment (as discussed already above under Figure 4). It then uses the measured bed elevation timeseries to detect dune crests and troughs. The result of this analysis is shown in Supplementary Figure S6, and is later used in Supplementary Figure S9 (see below).
- The dune heights calculated with this Matlab script are also (manually) saved in the Excel file ~\Scripts\input\dune_heights_16.xlsx, which is used in the R-script ~\Scripts\determine_modi.R to determine modes of the dune height distributions.

Supplementary Figure S7

Script(s) used:

- ~\Scripts\test_thresholds_find_crests_throughs.m

Input data file(s):

- ~\Data\Data_experiments\Seatek\matlab output\20240710_1533 File 1_output.mat

Output file(s):

- ~\Scripts\output\FigureS7.pdf

Explanation:

- This script performs a sensitivity analysis on the output of Supplementary Figure S6. It tests different elevation thresholds beyond which bed elevation is considered a crest/trough. For different thresholds, it then shows the resulting dune height frequency distribution. For the final choice of the threshold, the dune height frequency distribution is then shown in Supplementary Figure S9 (explained below).

Supplementary Figure S8

Script(s) used:

- ~\Scripts\find_crests_troughs.m

Input data file(s):

- ~\Data\Data_experiments\Seatek\matlab output\20240710_1533 File 1_output.mat

Output file(s):

- ~\Scripts\output\FigureS8.pdf

Explanation:

- This script continues where it left off after Supplementary Figure S6 was produced (see above). That is, measured bed elevation timeseries in our own flume experiment have been analysed to detect dune crests and troughs. With this data, the script now plots a timeseries of dune heights and dune lengths (i.e. Supplementary Figure S8).

Supplementary Figure S9

Script(s) used:

- ~\Scripts\find_crests_troughs.m

Input data file(s):

- ~\Data\Data_experiments\Seatek\matlab output\20240710_1533 File 1_output.mat

Output file(s):

- ~\Scripts\output\FigureS9.pdf

Explanation:

- This script continues where it left off after Supplementary Figure S6 was produced (see above). That is, measured bed elevation timeseries in our own flume experiment have been analysed to detect dune crests and troughs. With this data, the script now continues to calculate the frequency distributions of dune lengths and dune heights. These distributions are plotted (Supplementary Figure S9).

Supplementary Figure S10

Script(s) used:

- ~\Experiment\flume_sensor_analysis_v2.m

Input data file(s):

- ~\Experiment\Data_experiments\Seatek\20240710_1533 File 1.txt

Output file(s):

- ~\Experiment\output\FigureS10.pdf
    - This figure is used as Supplementary Figure S3 in the main manuscript.

Explanation:

- This part of the script, which was already explained under Figure 4, performs a wavelet analysis on the bed elevation timeseries.

Supplementary Figure S11

Script(s) used:

- ~\Data_RyanBradley\analyses\analyse_data_ryanbradley.m

Input data file(s):

- ~\Data_RyanBradley\Raw and Processed Scans\15-SPSN (441_442_443)\441\Raw Data\
    - Within this folder, files of the format 441_#_Seatek_Scan.log, and 441_#_Stepper_Pose.log are used, with # the scan numbers 1 – 35.
        - These are the raw line scans and the longitudinal positions of each line scan along the flume, as obtained from Bradley & Venditti (2019).
- ~\Data_RyanBradley\Raw and Processed Scans\15-SPSN (441_442_443)\441\Processed Data\Seatek Data\New_Seatek_XYZ_Clean_441_33.mat
    - This is the "cleaned" 2-dimensional bed scan, as cleaned/processed by Bradley & Venditti (2019).
- Since these data are from Bradley & Venditti (2019), and we have requested and received their permission to use their data in our publication, we have not included their raw data in our data repository. Instead, we only include our Matlab scripts and output files, and we refer the reader to the authors of Bradley & Venditti (2019) to request permission to use their raw data.

Output file(s):

- ~\Data_RyanBradley\analyses\output\FigureS11.pdf

Explanation

- This script loads data from Bradley & Venditti (2019), i.e. both the raw line scan data (441_#_Seatek_Scan.log), and the longitudinal (along-flume) directions of each of these scans (441_#_Stepper_Pose.log). The script then applies the same filter method as applied to our own experiment, for example to obtain Figure 4 (see above).
- The script then compares our filter method with the method that Bradley & Venditti (2019) used themselves, by importing their own "cleaned" version of the bed scans (New_Seatek_XYZ_Clean_441_33.mat).
- The resulting figure is Supplementary Figure S11.

Supplementary Figure S12

Script(s) used:

- ~\Data_RyanBradley\analyses\analyse_data_ryanbradley.m

Input data file(s):

- ~\Data_RyanBradley\Raw and Processed Scans\15-SPSN (441_442_443)\443\BedXYZ\
    - Within this data folder, all files of the form "xyz_443_126.txt" are loaded, with # the scan numbers between 1 – 126.
- ~\Data_RyanBradley\analyses\443_scan_times.xlsx
    - This file contains the time instances for each bed scan from run 443.
- Since these data are from Bradley & Venditti (2019), and we have requested and received their permission to use their data in our publication, we have not included their raw data in our data repository. Instead, we only include our Matlab scripts and output files, and we refer the reader to the authors of Bradley & Venditti (2019) to request permission to use their raw data.

Output file(s):

- ~\Data_RyanBradley\analyses\output\FigureS12.pdf
- ~\Data_RyanBradley\analyses\output\Bradley_443_BedXYZ_output.mat
    - This Matlab output file stores the results of the analyses done in this script.

Supplementary Figure S13

Script(s) used:

- ~\Scripts\figure_rawdata_V2.m

Input data file(s):

- Same input files as for Figures 1 and 2 (see above).

Output data file(s):

- ~\Scripts\output\FigureS13.pdf

Explanation

- This Figure shows the dune height frequency distributions and the location of modi, for the data of Venditti et al. (2016) and Bradley & Venditti (2019).
- The Matlab script and input files used to make this figure is the same as the script used to make Figures 1 and 2. Please see the explanations above under Figure 1 and 2.

Supplementary Figure S14

Script(s) used:

- ~\Scripts\PitchforkBifurcation_RK4_V3.m

Input file(s):

- ~\Scripts\input\PitchforkBifurcation_RK4_a=1_b=1_sigma=0.05_drdt=0.001_dt=0.01.mat

Output file(s):

- ~\Scripts\output\FigureS14.pdf

Explanation:

- The Matlab script produces Supplementary Figure S14, i.e. the simulation of flickering in case of a pitchfork bifurcation. The script simulates this flickering behaviour (panel a) and shows frequency distributions (panels b – f) for various instances along the simulated flickering trajectory.
- The input file (.mat-file) contains a previously calculated simulation trajectory. The script can also be run "from scratch", i.e. without loading this previous simulation result. The resulting figures will be (almost) the same, apart from small differences because the simulation uses a random number generator whose output changes each time the simulation is run anew.
- The function cmocean.m is needed to use *cmocean* colormaps (Thyng et al., 2016).

References

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