TKE Analyst

Release latest

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This Python3 code aids in analyzing raw measurements with an Acoustic Doppler Velocimeter (ADV) producing, for example,``*.vno`` and `*.vna` files (should also work with other file types, though not yet tested). It detects and removes spikes according to Nikora and Goring (1998) and Goring and Nikora (2002).

The code was originally developed in Matlab(R) at the Nepf Environmental Fluid Mechanics Laboratory (Massachusetts Institute of Technology).

Important: Data (e.g. `*.vno` and `*.vna`) files need to comply with the following name convention: `XX_YY_ZZ_something.ENDING` where `XX`, `YY`, and `ZZ` are streamwise (x), perpendicular (y), and vertical (z) coordinates in CENTIMETERS, respectively. Anything else added after `ZZ_` is ignored by the code (it just copies it for the sake of dataset naming).

Note: This documentation is also as available as style-adapted PDF.

CHAPTER ONE

REQUIREMENTS & INSTALLATION

Time requirement: 5-10 min.

1.1 Install Requirements

To get the code running, the following software is needed and their installation instructions are provided below:

- Python >=*3.6*
- NumPy >=*1.17.4*
- Openpyxl *3.0.3*
- Pandas >=*1.3.5*
- Matplotlib >=*3.1.2*

Start with downloading and installing the latest version of Anaconda Python. Alternatively, downloading and installing a pure Python interpreter will also work. Detailed information about installing Python is available in the Anaconda Docs and at hydro-informatics.com/python-basics.

To install the NumPy, Openpyxl, Pandas, and Matplotlib libraries after installing Anaconda, open Anaconda Prompt (e.g., click on the Windows icon, tap `anaconda prompt`, and hit enter``). In Anaconda Prompt, enter the following command sequence to install the libraries in the **base** environment. The installation may take a while depending on your internet speed.

```
conda install -c anaconda numpy
conda install -c anaconda openpyxl
conda install -c anaconda numpy
conda install -c conda-forge pandas
conda install -c conda-forge matplotlib
```

If you are struggling with the dark window and blinking cursor of Anaconda Prompt, worry not. You can also use Anaconda Navigator and install the four libraries (in the above order) in Anaconda Navigator.

Note: Alternatively, create a new conda environment to install the three libraries for this application. However, creating a new environment may eat up a lot of disk space, and installing the Python-omnipresent libraries NumPy, Openpyxl, Pandas, and Maplotlib in the **base** environment does not hurt.

1.2 Install TKEanalyst

Still in Anaconda Prompt (or any other Python-pip-able Terminal), enter:

```
pip install TKEanalyst
```

The last item you need to run `TKEanalyst` is the workbook (`.xlsx`) template for defining input parameters (download input.xlsx).

1.2.1 Usage

Regular Usage

TKEanalyst requires meta data (i.e. data about your data) defined in an input workbook. Therefore, download input.xlsx) and save it on your computer. Next, with Python installed and the code living on your computer:

- Save your data in a folder and make sure the files are named with `XX_YY_ZZ_something.FILEENDING` where `XX`, `YY`, and `ZZ` are streamwise (x), perpendicular (y), and vertical (z) coordinates in CENTIMETERS, respectively. `FILEENDING` could be, for example, `.vna`.
- Complete the required information on the experimental setup in `input.xlsx` (see figure below). **IMPORTANT: Never modify column A or any list in the sourcetables sheet (unless you also modify `load_input_defs` in line 25ff of `profile_analyst.py`).** The code uses the text provided in these areas of *input.xlsx* to identify setups. If useful, consider substituting the *Wood* wording in your mind and with a note in column C with your characteristic turbulence objects, but do not modify column A. Ultimately, you can also save the input file under a different name and call the code with a different input file name.

PARAMETER	VALUE	UNIT / REMARK
Input folder directory	C:/my/data/folder	string – absolute path to your data – must not end on "/" or "\" - us "/" for paths
Data file ending	.vna	string – ending of ADV file names (default is VNA for Vectrino ASCII data)
Pump rate	1005	rpm
Flow rate (discharge)	0.0167	CMS
Probe depth	0.06	m – depth of the ADV under the water surface
Water depth	0.13	m
Flow velocity	0.24	m/s – used for normalizing TKE
Turbulence object length dimension	0.114	m – used for normalizing coordinates
ADV sampling frequency	200	Hz
ADV time	0.05	s
ADV direction	longitudinal	optional (downward or sideward-longitudinally looking)
Spike detection method	velocity	define despiking method used with Goring & Nikora (2002)
Despike lambda a	1.00	if method=acceleration: multiplier of grav. accel; set between 1.0 and 1.5
Despike k	3.00	if method=velocity: multiplier of velocity stdev; set between 1.5 and 3.0

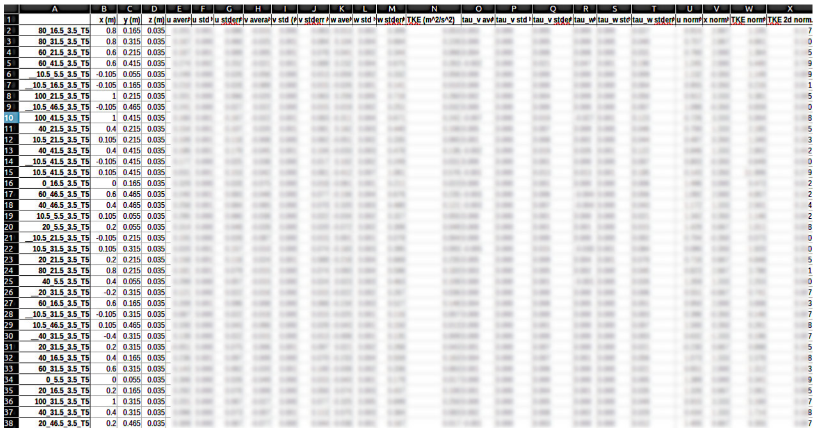
Fig. 1.1: *The interface of the input.xlsx workbook for entering experiment parameters and specifying a despiking method.*

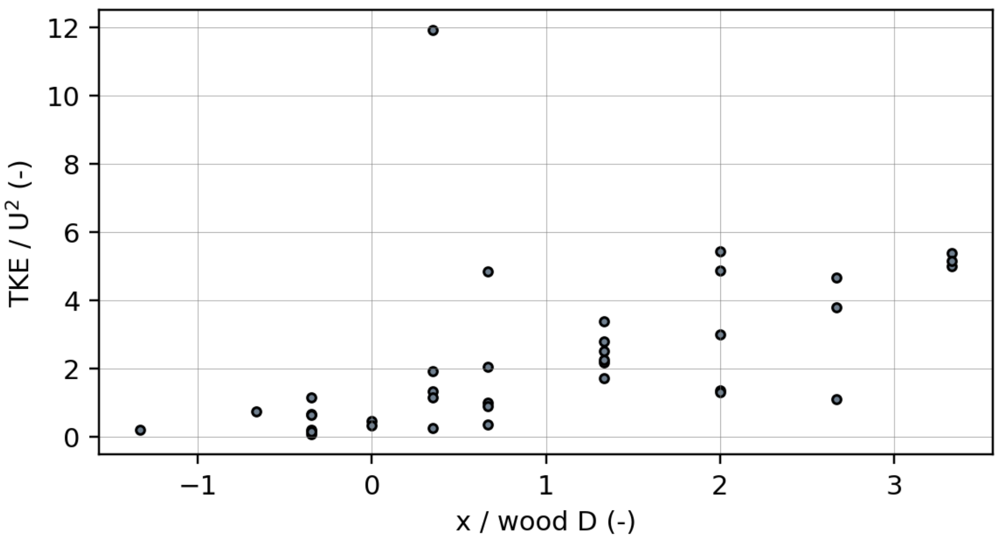
- Implement the following code in a Python script and run that Python script:

```python
import TKEanalyst
input_file = r"C:\\my\\project\\adv\\input.xlsx"
TKEanalyst.process_adv_files(input_file)
```

- **Alternatively:**
  - run the code: `python profile_analyst.py "C:/dir/to/input.xlsx)`
- Wait until the code finished with `-- DONE -- ALL TASKS FINISHED --`
- **After a successful run, the code will have produced the following files in `...\your-data\`:**
  - `.xlsx` files of full-time series data, with spikes and despiked.
  - `.xlsx` files of statistic summaries (i.e., average, standard deviation *std*, TKE) of velocity parameters with x, y, and z positions, with spikes and despiked (see workbook example in the figure below).

- Two plots (`norm-tke-x.png` and `norm-tke-x-despiked.png`) showing normalized TKE plotted against normalized x, with spikes and despiked, respectively (see plot example in the figure below).





Usage Example

For example, consider your data lives in a folder called `C:\my-project\TKEanalysis\test01`. To analyze `*.vna` files in `test01` save the following code to a Python script named `tke_analysis.py` along with definitions in an `input.xlsx` workbook :

```
import TKEanalyst
input_file = r"C:\\my-project\\TKEanalysis\\test01\\input.xlsx"
TKEanalyst.process_adv_files(input_file)
```

The definitions in the above-shown `input.xlsx` define x-normalization as a function of a wood log length, for example, a wood log diameter of 0.114 m.

Cell `B2` containing **Input folder directory** in `input.xlsx` defines that the input data for `test01`.

Important: The data directory of the subfolder definition in cell `B2` may not end on any `\` or `/`. Also, make sure to

use the / sign for folder name separation (do not use \).

To run the code with the example data, open Anaconda Prompt (or any other Python-able Terminal) and:

- `cd` into the code directory (e.g., `cd "C:\my-project\TKEanalysis\test01"`
- run the code: `python tke_analysis.py`
- wait until the code finished with `-- DONE -- ALL TASKS FINISHED --`

- **After a successful run, the code will have produced the following files in `C:\my-project\TKEanalysis\test01`:**
  - `.xlsx` files of full-time series data, with spikes and despiked.
  - `.xlsx` files of statistic summaries (i.e., average, standard deviation *std*, TKE) of velocity parameters with x, y, and z positions, with spikes and despiked.
  - Two plots (`norm-tke-x.png` and `norm-tke-x-despiked.png`) showing normalized TKE plotted against normalized x, with spikes and despiked, respectively.

1.2.2 Developer Docs

The following sections provide details of functions, their arguments, and outputs to help tweaking the code for individual purposes.

config.py

Global parameters settings (essentially PROFILE KEYS) and message logging controls.

flowstat.py

`TKEanalyst.flowstat.`**`flowstat`**`(`*time*, *u*, *v*, *w1*, *w2*, *profile_type='lp'*`)`

Calculate ADV data statistics

Parameters

- **`time`** (*`np.array`*) – time in seconds
- **`u`** (*`np.array`*) – streamweise velocity along x-axis (positive in bulk flow direction)
- **`v`** (*`np.array`*) – perpendicular velocity along y-axis
- **`w1`** (*`np.array`*) – vertical velocity if side is DOWN
- **`w2`** (*`np.array`*) – vertical velocity if side is not DOWN
- **`profile_type`** (*`str`*) – orientation of the probe (default: lp, which mean probe looks like FlowTracker in a river)

Returns keys correspond to series names and values to full time series stats (dict(dict)): keys correspond to series names with STAT for autoreplacement with STAT type of nested dictionaries with AVRG, STD and STDERR

Return type time_series (dict)

profile_analyst.py

Load ADV measurements and calculate TKE with plot options Originally coded in Matlab at Nepf Lab (MIT) Re-written in Python by Sebastian Schwindt (2022)

`TKEanalyst.profile_analyst.`**`build_stats_summary`**`(`*vna_stats_dict*, *experiment_info*, *profile_type*, *bulk_velocity*, *log_length*`)`

Re-organize the stats dataset and assign probe coordinates

Parameters

- **`vna_stats_dict`** (*`dict`*) – the result of all vna files processed with the flowstat.flowstat function
- **`experiment_info`** (*`dict`*) – the result of the get_data_info function for retrieving probe positions
- **`profile_type`** (*`str`*) – profile orientation as a function of sensor position; the default is lp corresponding to DOWN (ignores w2 measurements)
- **`bulk_velocity`** (*`float`*) – bulk streamwise flow velocity in m/s (from input.xlsx)
- **`log_length`** (*`float`*) – characteristic log length (either diameter or length) in m (from input.xlsx)

Returns Organized overview pandas.DataFrame with measurement stats, ready for dumping to workbook

`TKEanalyst.profile_analyst.`**`get_data_info`**`(`*file_ending*, *folder_name='data/test-example'*`)`

get names of input file names and prepare output matrix according to number of files

Parameters

- **`file_ending`** (*`str`*) – ending of data files (e.g. '.vna')
- **`folder_name`** (*`str`*) – name of the test (experiment) to analyze

Returns _pd.DataFrame with row names corresponding to file names ending on .vna (or otherwise defined in input.xlsx), and columns X, Y, Z in meters

`TKEanalyst.profile_analyst.`**`load_input_defs`**`(`*file_name='input.xlsx'*`)`

loads provided input file name as pandas dataframe

Parameters **`file_name`** (*`str`*) – name of input file (default is input.xlsx)

Returns user input of input.xlsx (or costum file, if provided)

Return type (dict)

`TKEanalyst.profile_analyst.`**`read_vna`**`(`*vna_file_name*`)`

Read vna file name as pandas dataframe.

Parameters **`vna_file_name`** (*`str`*) – name of a vna file, such as __8_16.5_6_T3.vna

Returns _pd.DataFrame

`TKEanalyst.profile_analyst.`**`vna_file_name2coordinates`**`(`*file_ending*, *vna_file_name*`)`

Take vna file name and extract x, y, and z coordinates in meters. Non-convertible numbers are translated into np.nan with warning.

Parameters

- **`file_ending`** (*`str`*) – ending of data files (e.g. '.vna')
- **`vna_file_name`** (*`str`*) – name of a vna file, such as __8_16.5_6_T3.vna

Returns list [x, y, z] coordinates

profile_plotter.py

Plot functions for TKE visualization

Note: The script represents merely a start for plotting normalized TKE against normalized X. If required, enrich this script with more plot functions and integrate them in profile_analyst.process_vna_files at the bottom of the function.

`TKEanalyst.profile_plotter.`**`plot_xy`**(*x*, *y*, *file_name*)

Plots y data against x (1d-numpy array) and markers of local maxima and minima

Parameters

- **x** (*numpy.array*) – x data
- **y** (*numpy.array*) – y data

Returns show and save plot in test folder as norm-TKE-x.png

rmspike.py

`TKEanalyst.rmspike.`**`rmspike`**(*vna_df*, *u_stats*, *v_stats*, *w_stats*, *w2_stats=None*, *method='velocity'*, *freq=200.0*, *lambda_a=1.0*, *k=3.0*, *profile_type='lp'*)

Spike removal and replacement - see Nikora & Goring (1999) and Goring & Nikora (2002).

Parameters

- **vna_df** (*pandas.DataFrame*) – matrix-like data array of the vna measurement file
- **u_stats** (*pandas.DataFrame*) – streamwise velocity stats from flowstat function
- **v_stats** (*pandas.DataFrame*) – perpendicular velocity stats from flowstat function
- **w_stats** (*pandas.DataFrame*) – vertical velocity stats from flowstat function
- **w2_stats** (*pandas.DataFrame*) – sec. vertical velocity stats from flowstat function (only required if profile_type is not lp)
- **method** (*str*) – determines whether to use acceleration or velocity (default) for despiking
- **freq** (*int*) – sampling frequency in 1/s (Hz); default is 200 Hz
- **lambda_a** (*float*) – multiplier of gravitational acceleration (acceleration threshold)
- **k** (*float*) – multiplier of velocity stdev (velocity threshold)
- **side** (*str*) – orientation of the probe (default: DOWN, which mean probe looks like Flow-Tracker in a river)

Note: Goring & Nikora (2002) suggest lambda_a = 1.0 ~ 1.5 and k = 1.5, but we shall use lambda_a = 1.0 and k = 3 ~ 9. SonTek, Nortek, and Lei recommend the SNR and correlation thresholds to be 15 and 70 respectively. Though data points have high SNR, the correlation can be low.

1.2.3 Disclaimer and License

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