5-Beam Acoustic Doppler Current Profiler Turbulence Methods

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A set of codes to process turbulence data from a 5-beam Accoustic Doppler Current Profiler (specifically the Nortek Signature 1000 AD2CP).

Begin with the data organization, then estimate turbulent kinetic energy spectra, structure function of turbulence, and Reynolds stresses from a 5-beam ADCP following (Dewey & Stringer, 2007).

Scripts provided for the estimation of turbulent kinetic energy dissipation rate from spectra and structure function, and estimation of turbulent kinetic energy shear production using the Reynolds stresses. Plots to analyze TKE budget along the water column.

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Here is a list of scripts and functions, and a brief description of each of them. More details are in the scripts. The idea is to use them in sequential order. For questions and suggestions please email me at mguerrap@uw.edu

All scripts are for ensembles of data (i.e. instrument recording in burst mode)

1. **Signature_RawData_ENU.m**

   Reads raw data created with Nortek MIDAS software (.mat file) and converts velocities into ENU components using *signatureAD2CP_beam2xyz_enu.m*
   Requires raw data files location, number of files and name of the files (sequential). Also requires a prefix to save the new files and a location to save them.
   Saves new files with all raw data plus X,Y,Z and East, North, Up velocities.

2. ***signatureAD2CP_beam2xyz_enu.m (function)***

   Nortek function to get X, Y, Z and East, North, Up velocities using 4 beams.
   Note: This function might not work with data from a new Nortek format. I am working on fixing it. Also, X, Y, Z and ENU velocities might be directly available from new Nortek processing software (in addition to along-beam velocities), thus this function might not be needed anymore.

3. **Signature_Join_Files.m**

   Joins raw data files created with the Signature_RawData_ENU.m script.
   Puts all data from each bin in a single file to work with each bin separately.
   Requires raw data files location, number of files and file names (sequential). Requires a location to save the bin files.

   This script is for burst data (e.g. 10 minutes ensembles) and organizes the data into the ensembles for future analysis, will require changing some code for continuously recorded data.

   Saves bin data as a structure named SigData into a file named SignatureData_Bin_('bin number').mat

4. **Signature_QC.m**

   Quality control of data for low correlation and low amplitude. Requires number of bin, raw data file location, and prefix of bin data files created with Signature_join_files.m.

   Choose your correlation and amplitude thresholds according to your needs.

   Uses only good ensembles, which must be specified, and a location for saving the QC files. Saves same data structure as SignatureData_QC_Bin_('bin number').mat

5. **Signature_Spectra_w.m**

   Spectral analysis of along-beam velocities organized in ensembles (e.g. 10 minutes). It is set for vertical beam velocities, but it can be modified for other velocities.
   Uses QC data created with Signature_QC.m
   Requires file location and a prefix, and a path to save the spectral analysis results. Requires number of bins to process and ensembles to use.
   Uses spectralestimate.m and also estimates spectra using *pwelch* Matlab function.

6. ***spectralestimate.m (function)***

   Function that estimates some spectral densities using the periodogram and WOSA methods for educational purposes.

7. **Signature_Spectra_DissipationRate.m**

   Estimates dissipation rate from spectra for all good ensembles (where there is an spectral estimate). Uses one of the spectra estimates from

Signature_Spectra_w.m. Requires sampling frequency, spectra file location and name (sequential), number of bins to process and good ensembles.
Also requires the frequency range for testing the inertial subrange.

Saves a dissipation rate file for each bin as Dissip_Spectra_bin_(bin number).mat in the chosen save location.

8. **Signature_StructureFunction_dissipation.m**

Estimates the spatial structure function of turbulence and estimates the dissipation rate using Kolmogorov's 2/3 law.
Requires bin QC data file location and name (sequential), number of bins to process, good ensembles, slanted beams angle and a location to save new files.
Organizes along-beam velocities for each bin and ensemble (size (N bins, N Ensembles) and calls function *dissipationMG_SF.m*, where the actual structure function and dissipation rates are estimated.
Plots some examples of estimated dissipation rate profiles and puts all results in a structure called SF. The SF structure is saved in SF_DissipationRate.mat file.
It also saves the structure function alone in a single file (currently for the vertical beam structure function).

9. ***dissipationMG_SF.m (function)***

Estimates the dissipation rate from the structure function. Requires the along beam velocities through the water column for each ensemble of size (N Bins, N Ensembles), the z depth of each bin, number of time points to use in the structure function (entire ensemble), plots (set to 0), dr (set to 0) and the noise floor (sigma_w).

Estimates the dissipation rates by two methods, using the compensated structure function (flat) and using by fitting a linear model to the structure function. Checks for errors and for noise in the structure function.

10. ***structureFunction.m (function)***

Function that estimates the spatial structure function of turbulence (Wiles et al. 2006) using the along beam velocities and the depth location of each bin.

11. **Signature_Reynolds_Stress_5Beam.m**

Function that organizes data to estimate the Reynolds stress tensor following Dewey & Stringer (2007) methodology. It calls function RS_5beam.m to calculate the Reynolds stresses.

Requires bin QC data file location and name (sequential), number of bins to process, good ensembles, slanted beams angle and a location to save new files.
Gives Reynolds stresses in instrument coordinates (assuming heading = 0).
Saves Reynolds stresses in a structure called RS and saves RS into ReynoldsStress.mat

12. ***RS_5beam.m (function)***

Calculates Reynolds stresses following Dewey & Stringer (2007) methodology for a five beam configurations. Uses along-beam velocities and tilt angles in Dewey & Stringer (2007) configuration.

13. **Signature_Production_5beam.m**

Estimates vertical shear TKE production.
Requires bin QC data file location and name (sequential), number of bins to process, good ensembles, location of Reynolds stress file, mean flow direction from east to flood (clockwise) and a location to save the production files.

Takes QC horizontal velocities (east and north) and estimates along and across channel velocities (simple rotation). Estimates vertical shear for horizontal and vertical velocities.
Takes the Reynolds stresses created by Signature_Reynolds_Stress_5Beam.m and rotates them to along and across channel components. Estimates production from vertical shear.
Saves results in a structure called Prod and saves in a file called Production.mat

14. **Signature_Usigned.m**

Assigns a sign to the horizontal velocities. Flood is positive and ebb is negative. Uses the function sign_speed.m (Brian Polagye, 2010). Requires the QC data file name and location and a path to save the signed velocities. Also requires the flood heading from North in degrees.

15. ***sign_speed.m (function)***
Function that creates signed horizontal speeds time series (flood positive). Created by Brian Polagye (2010).

16. **Signature_Spectra_Plots.m**

Plots spectra results colored by mean flow.

17. **Signature_StructureFunction_Plots**

Plots structure function results colored by mean flow.

18. Signature_E_P_Profile_Plots

Plots vertical profiles of dissipation rate and vertical shear production rate separated by ebb and flood.