The Journal of Open Source Software

gliderad2cp: A Python package to process Nortek AD2CP velocity profiles from gliders

Bastien Y. Queste [1,2*¶], **Callum Rollo** [2*], **Estel Font** [1], **and Martin Mohrmann** [2]

1 Department of Marine Science, University of Gothenburg, Natrium, Box 463, 405 30 Göteborg, Sweden **2** Voice of the Ocean Foundation, Skeppet Ärans väg 19, 426 71 Västra Frölunda, Sweden ¶ Corresponding author * These authors contributed equally.

DOI: 10.21105/joss.08342

Software

- Review
- Repository
- Archive

Editor: Rachel Wegener

Reviewers:

- @nbronikowski
- @JGradone

Submitted: 18 March 2025
Published: 18 November 2026

License
Authors of papers retain copyright and release the work under a Creative Commons Attribution 4.0 International License (CC BY 4.0).

Summary

Ocean gliders and acoustic Doppler current profilers (ADCPs) are widely used tools for observing ocean circulation: gliders provide long-duration, autonomous sampling through the water column, while ADCPs measure water velocity over short ranges. When an ADCP is mounted on a glider, these complementary measurements can be combined to estimate vertical shear and reconstruct current profiles across the glider's full operating depth. This processing is technically challenging because ADCP velocities are measured relative to a moving vehicle and across a short range (typically 15 m, compared to glider dives of 1000 m), the measurements from the glider and ADCP must be precisely aligned in time, space, and reference frame, and ADCP integration differs across glider platforms and beam configurations.

The gliderad2cp toolbox provides a cross-platform Python toolchain for processing Nortek AD2CP data collected from ocean gliders. It simplifies the workflow from raw ADCP and glider data to quality-controlled shear and referenced velocity profiles, supporting different glider implementations such as alternating three-beam configurations and four-beam configurations. The package handles file loading, quality control, vertical regridding to reduce shear smearing, coordinate transformations from beam-relative to Earth-relative velocities, vertical shear estimation, reconstruction of full-depth shear profiles, referencing to dive-averaged currents derived using the ADCP as a velocity logger, and shear-bias correction. By providing consistent processing across multiple glider platforms, gliderad2cp fills a gap left by existing ADCP or platform-specific toolboxes and makes glider-mounted ADCP observations easier to use for oceanographic analysis.

Statement of need

Oceanographers routinely measure ocean currents to understand and map the transport of ocean properties. Measuring currents is most commonly done using instruments called acoustic Doppler current profilers (ADCPs). These instruments emit short pings of sound and listen for the echoing soundwaves which bounce off of water molecules and suspended particles. The delay between emission and reception tells us distance to the particles, and the pitch change of the echo tells us the relative velocity of the particles to the sensor. Using beams of sound in multiple directions, the ADCP can determine 3-dimensional currents at range. ADCPs are however limited by power and size; there is a direct trade-off between size, power and transducer capability. There is also a trade-off between ping frequency and effective range before the sound wave is attenuated. Large ocean-going vessels can carry large, energy-hungry, low-frequency ADCPs with ranges of hundreds of meters down into the water column, while smaller platforms must compromise on range and signal-to-noise ratios.

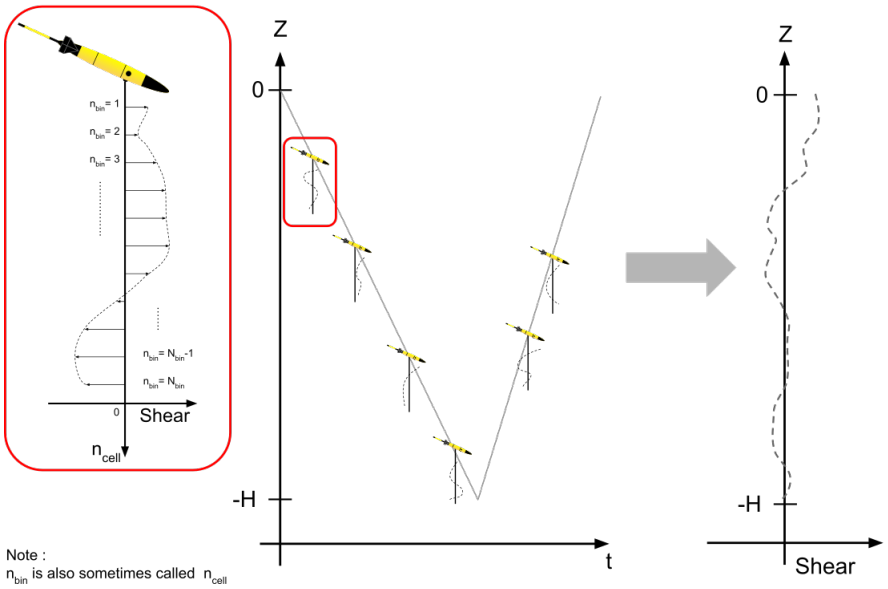


Figure 1: The lowered ADCP method combines successive short profiles of vertical shear to recover the shape of the full depth velocity profile.

Ocean gliders are small, low power, autonomous underwater vehicles which profile up and down in the water column, collecting measurements of ocean properties throughout. Ocean gliders now have the ability to carry small ADCPs such as the Nortek Glider AD2CP, with 4 beams and a frequency of 1MHz. The high frequency means that the sensor can only measure currents up to approximately 30m away from the glider (although 15m is more realistic in open ocean conditions); however, as the glider travels up and down through the water column, coverage is possible down to the glider's full depth (typically 1000 m). The key difficulty arises as the ADCP measures ocean currents relative to the glider, rather than relative to ground. As the glider's velocity is often more than an order of magnitude greater than ocean current velocities, a different form of processing is required. We combine shear measurements (how ocean currents change in the vertical over small scales) from multiple successive short velocity profiles to build a full water-column shear profile. We then vertically integrate and reference the shear profile to obtain an absolute velocity profile. This is known as the lowered ADCP method (Figure 1).

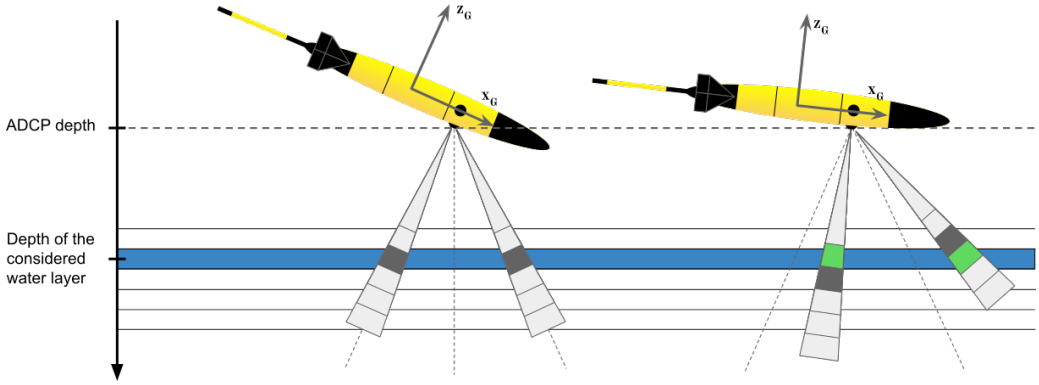


Figure 2: The Nortek AD2CP measurements are time-gated at the same intervals for each individual beam, meaning that the relation between echo delay and measurement range is the same for all 4 beams and does not account for the more open front and back beam angles. The transducers are aligned in this way so as to have 3 beams at equal angles from vertical when the glider is diving at the correct angle (17.4° from horizontal for the Nortek AD2CP; in grey on the left). If the glider is flying at a different angle, there will be a mismatch in depth between the 3 beams (in gray on the right) which requires regridding and use of different bins (in green on the right) to minimise shear smearing.

Software for processing ADCP data exists, with tools provided by instrument manufacturers, private companies and open-source communities. However, none are cross-glider compatible. Individual toolboxes created for specific gliders or associated with published papers are available, the most mature of which have been developed for Slocum gliders (Gradone & Miles, 2022; Thurnherr et al., 2015), offering similar functionality although missing specific corrections such as shear bias corrections as per Todd et al. (2017).

The gliderad2cp toolbox greatly simplifies file handling, integration of any glider data to ADCP data, and the complex trigonometry necessary to obtain high quality shear data. In particular, the integration of the Nortek AD2CP varies across glider manufacturers, either using alternating 3-beam configurations between up and down profiles (on the Seaglider or the Spray) or using 4 beams at all times (on the SeaExplorer). This Python package allows users to easily load Nortek AD2CP netCDF files and pull the raw data to provide clean shear estimates with consistent processing and quality control independent of which glider they use. Finally, it provides a final referenced velocity profile and corrects for shear bias when the data permits.

Overview of package contents

This toolbox performs the following steps:

1. Clean the ADCP data and remove bad measurements, based on four different quality control metrics (minimum correlation, minimum signal-to-noise, maximum amplitude and maximum velocity). Default parameters which suit most types of glider missions are included.
2. Correct the vertical alignment (in the earth frame of reference) of velocity measurements across all beams (Figure 2) to account for the slant of beams and the default cosine angle used onboard the Nortek Glider AD2CP and correct for shear-smearing.
3. Convert the velocity data from ADCP-relative (*i.e.*, beam direction; Figure 3), to glider-relative (*i.e.*, X, Y, Z) and finally to earth-relative velocities (*i.e.*, East, North, Up).
4. Calculate the vertical gradient in earth-relative velocities, also known as vertical shear.
5. Determine the mean ocean current over the period of the glider dive by comparing ADCP-derived glider speed through water to its GPS-derived speed over land, the difference

being caused by ocean currents.

6. Reconstruct full-depth profiles of vertical shear from the successive short-range measurements of velocity. Simple gridding and integrating of shear are used as default rather than the inverse method due to the use of a single constraint (Visbeck, 2002).
7. Reference the full high-resolution vertical shear profile using the glider's dive-averaged current to provide a high-resolution absolute profile of ocean currents. The referencing of baroclinic profiles accounts for time spent at each depth in order to be compatible with repeat dives without surfacing or long glider loiters.
8. Optionally, perform a shear-bias correction, adapted from Todd et al. (2017), which aims to minimise the relation between net shear per profile and displacement through water. Previously published implementations (Todd et al., 2017) minimised variance at depth which introduces biases in highly dynamic regions and fails to converge when gliders travel in a few different directions (*e.g.*, single long transects).

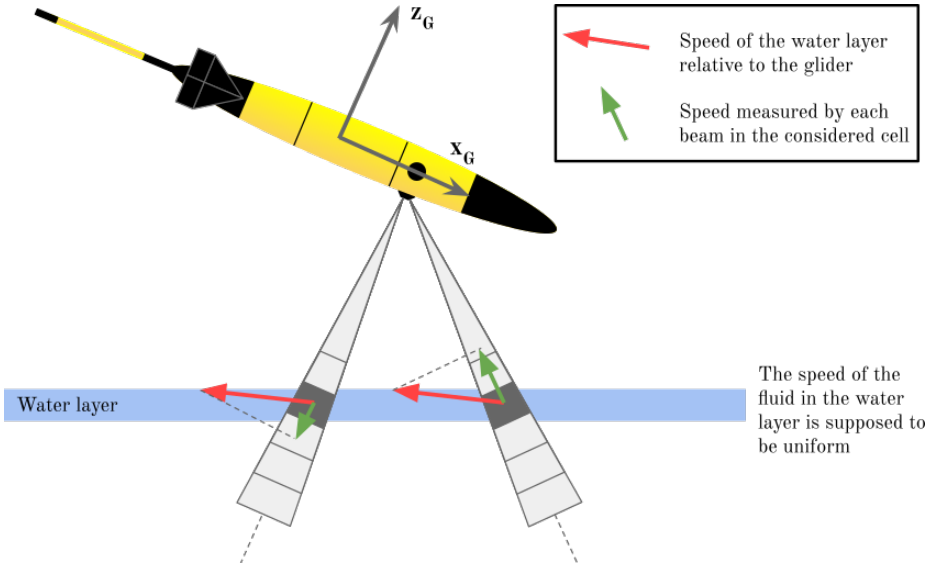


Figure 3: ADCP beams measure the along-beam velocity which needs to be converted to X,Y,Z velocities relative to the glider's frame of reference. The coordinate transform matrix is specific to each instrument as it is defined by the angle of the different beams relative to the glider.

Acknowledgements

BYQ and EF are supported by ONR GLOBAL Grant N62909-21-1-2008 and Formas Grant 2022-01536. BYQ is supported by the Voice of the Ocean Foundation and by the European Union's Horizon 2020 research and innovation programme under Grant 951842 (GROOM II). The authors want to thank the technicians and pilots of Voice of the Ocean Foundation for assistance and support during deployments and piloting during 2021 and 2022. Figures are adapted from work performed by Johan Verquier and Émile Moncanis during their final study project of the École Navale hosted at the University of Gothenburg.

References

Gradone, J., & Miles, T. (2022). *JGradone/slocum-AD2CP: v1.0.0* (Version v1.0.0). Zenodo. https://doi.org/10.5281/zenodo.7416126

Thurnherr, A. M., Symonds, D., & St. Laurent, L. (2015). Processing explorer ADCP data collected on Slocum gliders using the LADCP shear method. *2015 IEEE/OES Eleventh Current, Waves and Turbulence Measurement (CWTM)*, 1–7. https://doi.org/10.1109/CWTM.2015.7098134

Todd, R. E., Rudnick, D. L., Sherman, J. T., Owens, W. B., & George, L. (2017). Absolute velocity estimates from autonomous underwater gliders equipped with Doppler current profilers. *Journal of Atmospheric and Oceanic Technology*, *34*(2), 309–333. https://doi.org/10.1175/JTECH-D-16-0156.1

Visbeck, M. (2002). Deep velocity profiling using lowered acoustic Doppler current profilers: Bottom track and inverse solutions. *Journal of Atmospheric and Oceanic Technology*, *19*(5), 794–807. https://doi.org/10.1175/1520-0426(2002)019%3C0794:DVPULA%3E2.0.CO;2