The Journal of Open Source Software

Gibbs Sea Water Oceanographic Toolbox of TEOS-10 implemented in Rust

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DOI: 10.21105/joss.05988

Software

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Submitted: 21 August 2023
Published: 03 January 2024

Summary

The Gibbs Seawater Toolbox (GSW) is a key software for Oceanography since it provides consistent thermodynamic properties of seawater, conversions, and other utilities. GSW has been adopted since 2009 by the Intergovernmental Oceanographic Commission as the official description of seawater. Although it is available in several computer languages, most implementations, such as Python (Firing et al., 2021), Julia (Barth & al., 2020), and R (Kelley & Richards, 2022), are wrappers around the C library (Delahoyde et al., 2022).

Here we introduce a version of GSW implemented in pure Rust (GSW-rs), initially developed for inclusion in microcontroller firmware to support autonomous decisions and onboard Machine Learning. The same implementation also works on regular computers and can seamlessly replace GSW-C on apps and libraries by maintaining compatibility with the GSW-C Foreign Function Interface (FFI). Thanks to zero-cost abstraction, GSW-rs does not impose performance and readability trade-off, allowing it to be written for clear understanding and closer to the original scientific publications. Therefore, it is easier to verify and maintain. Another key aspect is the support for testing. GSW-rs is subject to unit tests as well as validation against the reference dataset from TEOS-10, allowing for consistent development through continuous integration.

Modern oceanography strongly relies on autonomous platforms - such as Argo floats, Spray underwater gliders, and Saildrones - to provide sustained observations. Software robustness and performance are critical requirements for these platforms to operate with low energy budgets and up to several years in a single deployment, making Rust an optimal language for this task. At the same time, the expanding cloud infrastructure can give the illusion of infinite computing, but convenient program languages such as Python must rely on high-performance languages in the backend to optimize bottlenecks. A Rust implementation of GSW allows sustainable and efficient progress, from embedded to high-performance computing.

Statement of Need

While GSW is already implemented in several languages, there is no uniformity among those. The Matlab implementation (GSW-m) (McDougall & Barker, 2011) is the most complete (see Appendix N from IOC, SCOR, and IAPSO, 2010) and up to date, but it is based on a commercial language, restricting its use. Several other implementations, including those for Julia, Python, and R, are wrappers around the C implementation (GSW-C), which is hence the actual foundation for the alternative Open Source family of solutions. Although it is powerful, C lacks some features and conveniences of modern languages. Here we present an alternative using Rust language, resulting in comparable performance to GSW-C, while providing an efficient framework that accelerates the development effort and minimizes errors. For embedded systems, GSW-rs is a requirement for a pure Rust firmware able to make sense of sensor measurements in real time. In addition, for any application, GSW-rs provides the option to conform more closely to GSW-m than does the present GSW-C implementation. Function coverage, however, does not yet match either GSW-C or GSW-m.

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