

# Sound Speed Manager: An Open-Source Initiative to Streamline the Hydrographic Data Acquisition Workflow

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## Abstract

The use of inaccurate sound speed data heavily affects all survey products, from the bathymetry to the backscatter mosaic to the water column imagery. Thus, sound speed profiling (SSP) is a key element for any workflow that aims to collect high-quality echosounder data. Historically, surveyors have addressed SSP using a mixture of manufacturer-specific tools, spreadsheets, scripts and some manual hacking. Far from optimal, this approach carries several disadvantages such as being error prone and inconsistent among different sound profile systems. Tools such as Velocipy, SVP Editor, and HydrOffice SSP Manager have bridged this gap, but have limitations. A new open-source tool that combines the best features of these into a single “best of breed” tool is here described. A joint development of NOAA Coast Survey and UNH CCOM/JHC, but open to contributions from the wider user community, Sound Speed Manager provides a route to long-term, reliable, SSP management in a convenient, readily re-distributable, flexibly licensed, form.

## Introduction

A modern acoustic survey cannot dismiss the importance of accurate environmental characterization of the water column. In fact, an approximate or erroneous characterization heavily affects all survey products, from the bathymetry and backscatter mosaic through the water column imagery. In particular, the sound speed profile is critical for raytracing, while knowing the temperature and the salinity variability through the water column is crucial in the calculation of realistic absorption coefficients (Carvalho et al., 2013).

As positioning methods improved and data density increased, the effects of good sound speed corrections have become more distinguishable in hydrographic surveys. Whether for post processing in the form of sound speed corrections or during sonar data acquisition, too often the hydrographer had to operate multiple pieces of software to convert, edit, and quality assess the sound speed data. In many cases, this process was conducted manually through text files or spreadsheets. A trusted, robust tool to exchange the water column environmental data from multiple acquisition devices to various sonar data acquisition and processing systems would facilitate timely sound speed corrections and quality assurance.

This paper describes Sound Speed Manager (SSM), a jointly-developed open-source initiative to provide a long-term and reliable solution for SSP (Masetti et al., 2017). The initiative aims to leverage the experience gained in the development of the NSF-supported MAC (Multibeam Advisory Committee) project SVP Editor (Beaudoin et al., 2011), which later evolved into HydrOffice SSP Manager, and NOAA Office of Coast Survey's tools named Velocity, Velocwin, and finally Velocipy, which have been in use since circa 1990, in order to build a "best of breed" software application to manage SSPs. This tool, Sound Speed Manager (SSM), endeavors to create a single clean, consistent interface to solve the management issues for sound speed data. The surveyor can use SSM to read most common commercial formats, review data quality, modify the data as appropriate, and export it in a form usable for archival, processing software or acquisition systems. It is also written to be easily extensible for additional formats and features, and the program and base code is released under open-source licensing so that the hydrographic community can benefit and contribute to it in the future. Using Python as the core language for SSM allows it to be more easily understood and modified as problems arise, even mid-survey.

NOAA Coast Survey is migrating to SSM during the 2017 field season and has already begun using it on multiple platforms. SSM is also available to the UNOLS fleet, where it is in active use.

## Functionality

SSM facilitates sound speed cast inspection by visually presenting the imported data with plots of sound speed, temperature and salinity versus depth (Figure 1). The user is then guided through the processing steps required, with the software only enabling those options that are applicable to the device used to create the data. If desired, the surveyor can also modify the profile by removing spikes or anomalous data and choosing appropriate depth extension method.

Once reviewed, data can be stored into a database. The self-contained, single file SQLite database structure is used to avoid the management and resource overheads of a fully-fledged relational database system. The database design is one of the largest enhancements of SSM over previous MAC and NOAA software in that it allows convenient storage of casts, provides data lineage, and eases file management. Previously, edited casts were either stored into separate files and the original data was lost, overwritten or ignored. Sound Speed Manager keeps the original data and the edited data together with attribute flags, so the surveyor (and reviewers) can easily view changes and revert to the original data as desired.

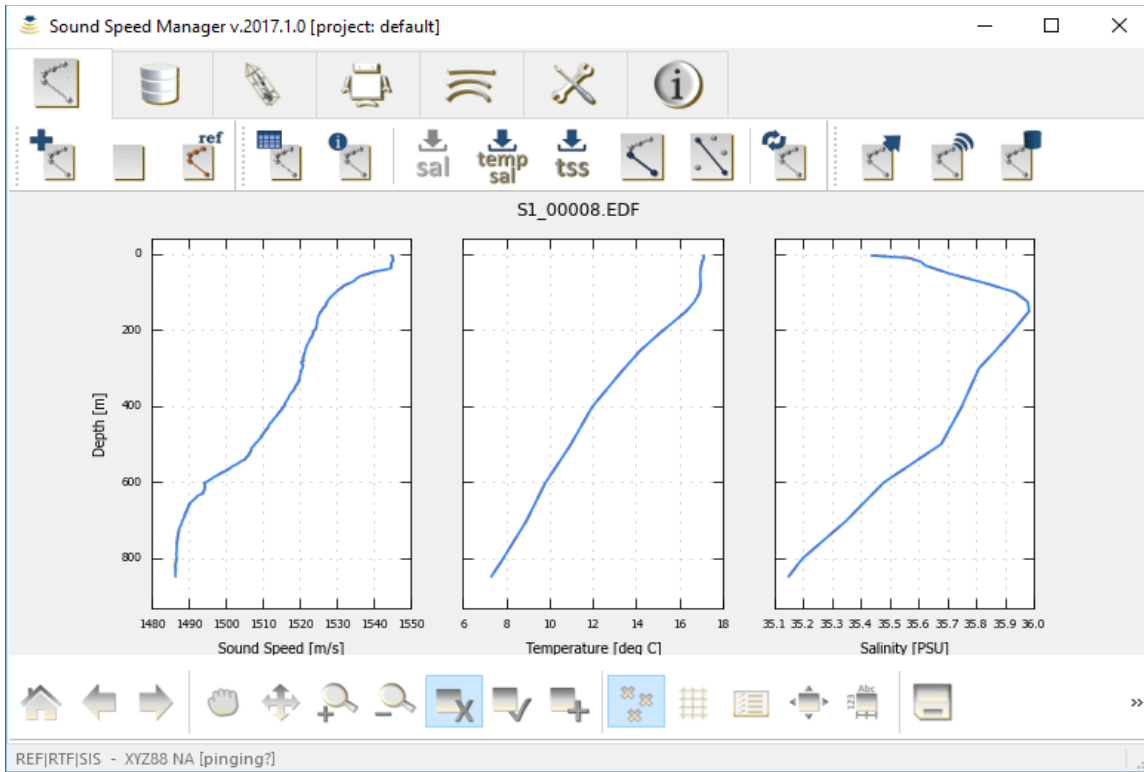


Figure 1. A cast imported into Sound Speed Manager immediately plots the sound speed, temperature and salinity if they exist in the input data. Where salinity, for example, does not exist, it can be approximated by a number of means (described in the text following).

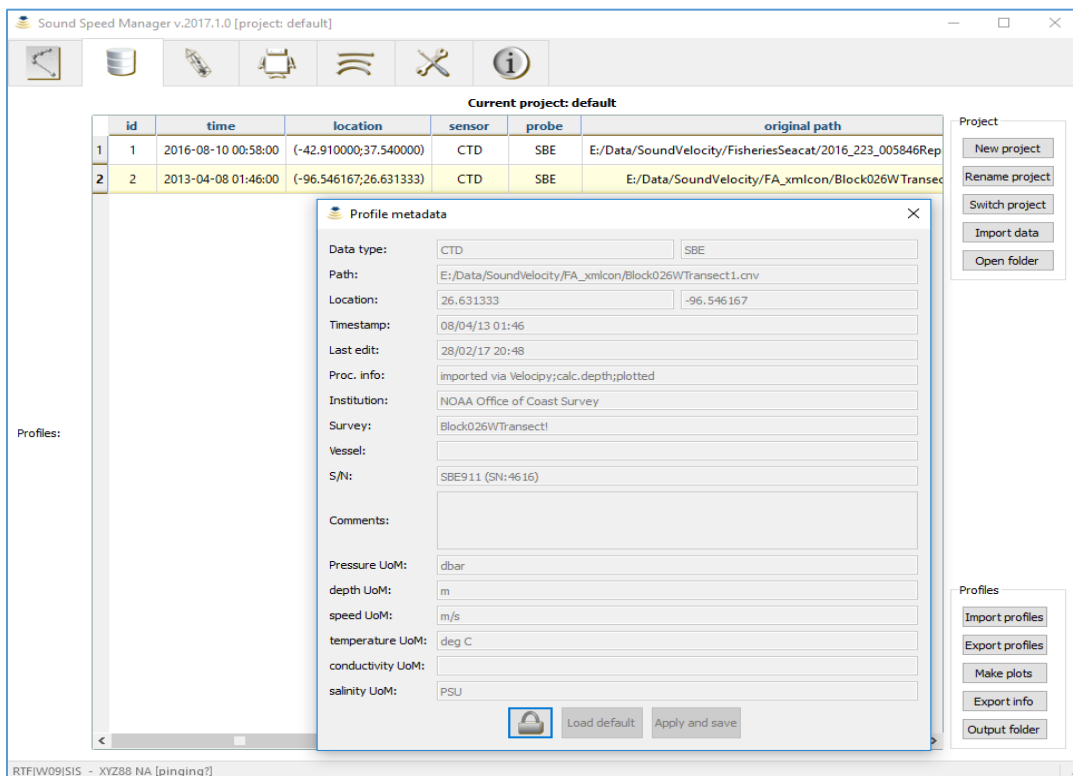


Figure 2. The metadata dialog in the foreground with the view of the database in the background.

Metadata is also stored in the database, Figure 2, and linked to each profile. The metadata contains timestamps to describe when the data was acquired and edited, vessel and survey names to determine the source of the data and location for where the cast was taken, and profiler specifics such as manufacturer and serial number of the instrument.

## Supported Inputs

Sound Speed Manager reads many current and older sound speed cast formats. A non-exhaustive list of supported formats includes data from Castaway, Digibar, Idronaut, Kongsberg, Seabird, Sippican, Turo, Valeport, Figure 3. There is also support for reading files used by processing software packages such as CARIS and HyPack. Additionally Sound Speed Manager can create synthetic sound speed from modeled ocean data including the World Ocean Atlas and higher resolution models such as Real-Time Ocean Forecast System (RTOFS).

In addition to files on disk, real-time data messages containing sound speed casts can be read from network connections created by Kongsberg SIS, Sippican data acquisition systems, and Rolls Royce moving vessel profilers.

## Supported Outputs

Sound Speed Manager writes data in several popular file formats, and multi-cast formats such as CARIS HIPS V2, Elac, Hypack, Kongsberg, and Sonardyne are supported. SSM can also transmit the processed environmental data to other software via a network connection, allowing it to feed hydrographic data acquisition systems (e.g., Kongsberg SIS, HyPack Survey, Reson PDS2000, QPS QINSy, and potentially any application that supports data reception through UDP data packets). Absorption coefficient files (i.e., frequency-dependent sound absorption coefficients as a function of depth) are also generated when they are supported at the targeted system (i.e., Kongsberg CTD file set) (Kongsberg, 2013).

SSM has specific support for preparing the cast for submission to the National Centers for Environmental Information (NCEI). This output option creates netCDF files following the NCEI template (further description at <https://www.nodc.noaa.gov/submit/index.html>). NCEI submission is a requirement for NOAA surveys, but is also welcomed from other sources.

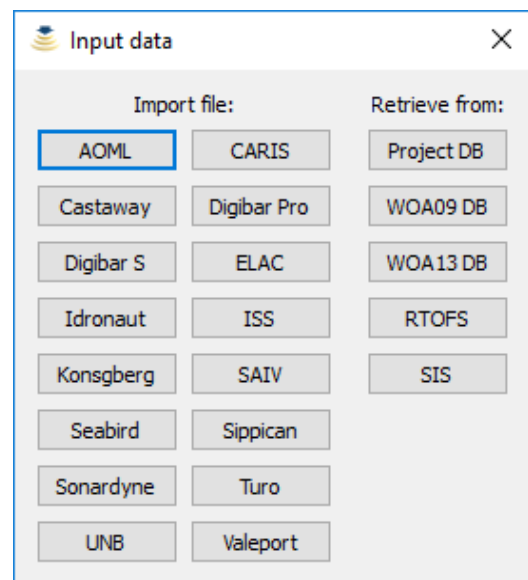


Figure 3. Dialog for input file type choices.

Among other uses, such submissions feed future releases of the World Ocean Atlas (WOA), which SSM uses as a background data source where no other information is available.

### Analysis and Processing Tools

Sound Speed Manager provides a growing number of analysis tools that the surveyor can use to examine and validate the profiles stored in the database. Currently, the user can create comparison plots of selected profiles (Figure 4) or generate maps showing the cast locations (Figure 5), and then save them in portable network graphic (PNG) format for insertion in survey reports. It is also possible to produce an aggregate plot with all the stored profiles as well as per-day plots.

Sound Speed Manager can also edit the data if needed using a traditional point-flag paradigm (i.e., user-mediated attribution of erroneous points with metadata use flags). As is typical in hydrographic practice, the data is flagged but not discarded so that it can be visualized and reinstated if required.

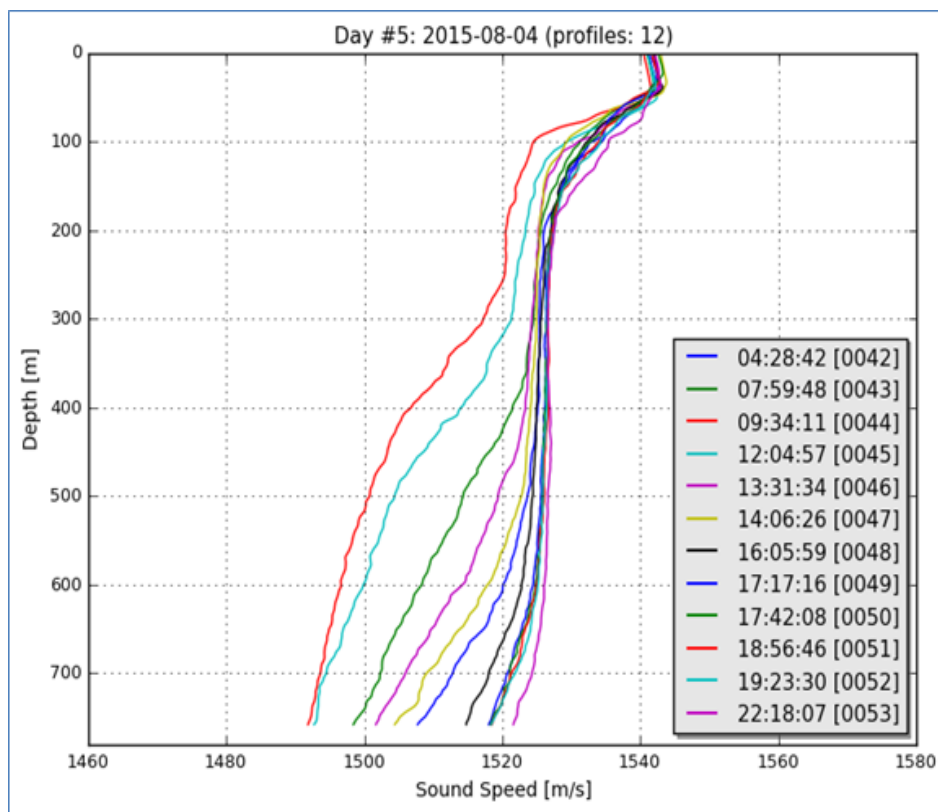
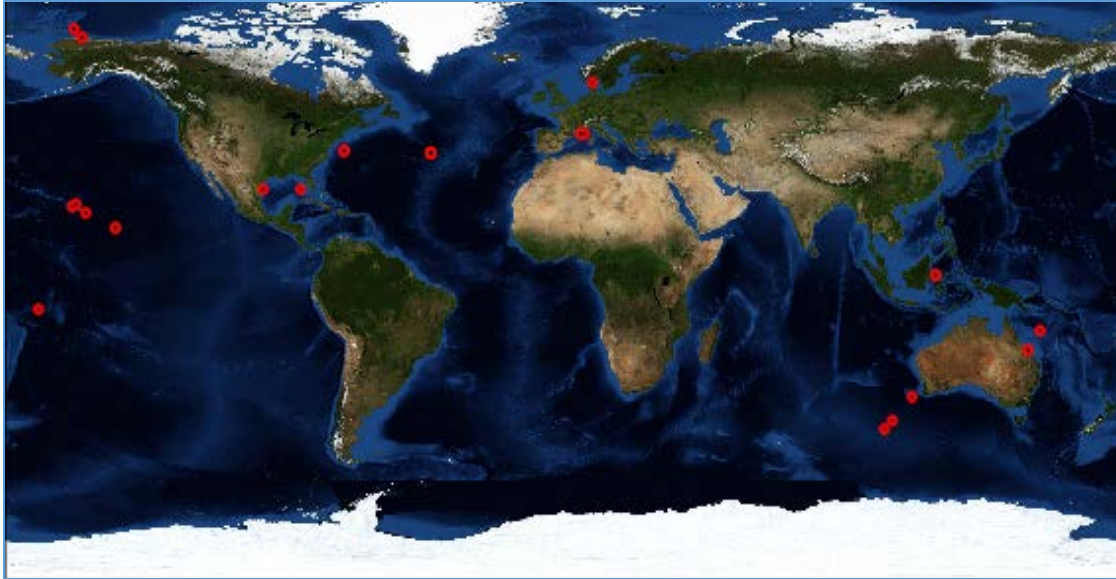


Figure 4. Daily plot of loaded casts



*Figure 5. Geospatial plot of loaded casts*

Figures 6-8 show a conceptual use of the processing tools of the SSM application. Assume that, prior to use, a profile is loaded and saved into the database (e.g., Figure 1). The surveyor chooses this as a nominated “reference” cast, meaning that it is the cast to which others should be compared, and which will provide extra information that any individual cast might not have. Thus, for example, when working with expendable bathythermograph (XBT) data where only temperature is recorded, the reference cast (e.g., from a CTD) could be used to provide salinity measurements to improve the estimate of sound speed derived from the XBT.

In Figure 6, a second cast is loaded from a different sensor type that does not contain temperature or salinity information (e.g., from a system that directly measures sound speed with a sing-around acoustic transducer). This cast also suffers from erroneous sound speed measurements. The reference cast is displayed with dashed red lines. The surveyor selects and edits the erroneous points by hand. After editing the spikes, the removed points optionally show up as grey points in the plot, Figure 7. The temperature and salinity measurements can then be applied from the reference cast to the currently loaded profile that is being edited, Figure 8.

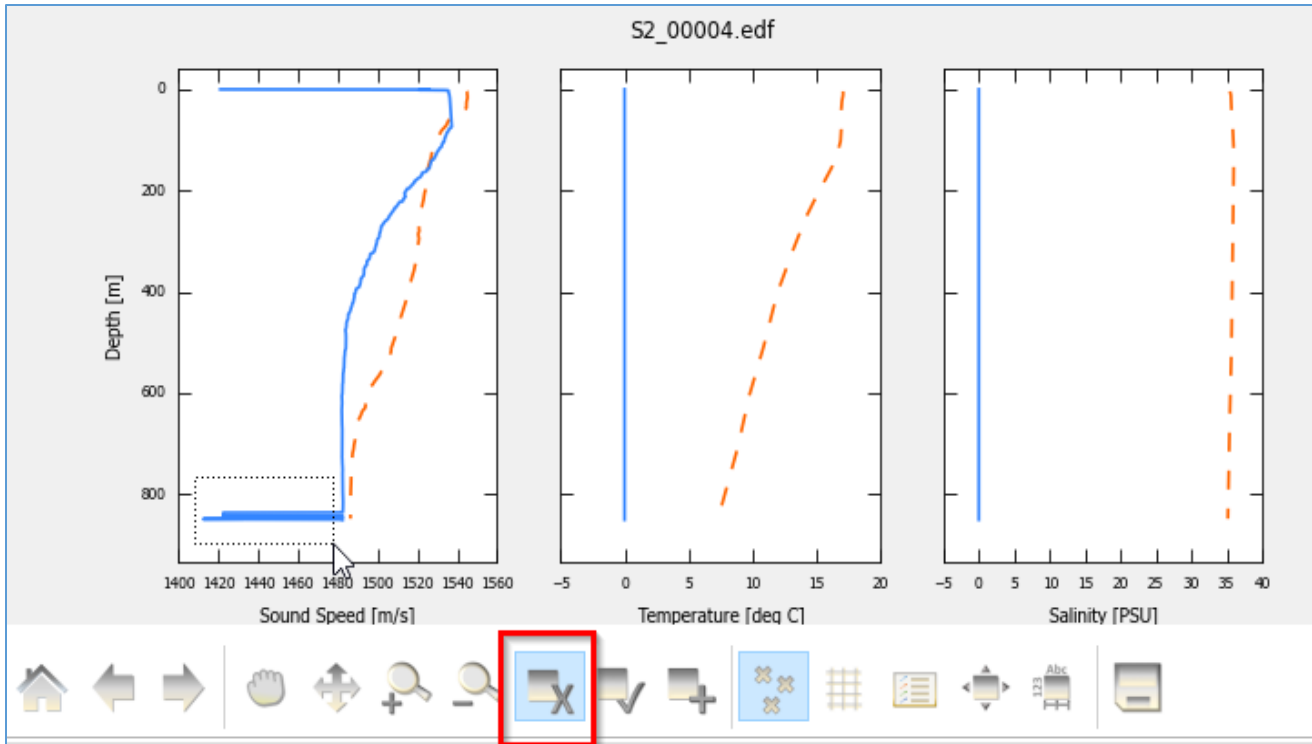


Figure 6. A cast with anomalous data to be cleaned. Reference cast in red. A click and drag is selecting points to be flagged via the red highlighted removal button.

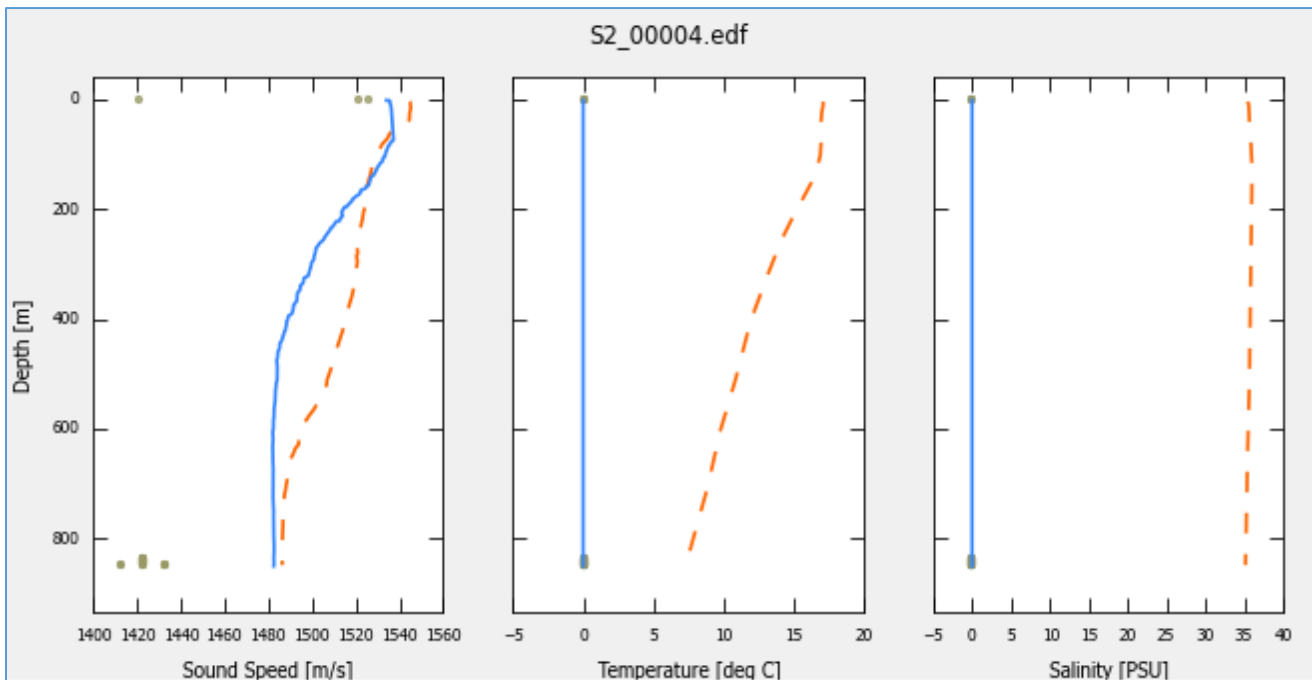


Figure 7. Cast display after data cleaning is applied. Flagged points displayed in grey, reference cast in red.

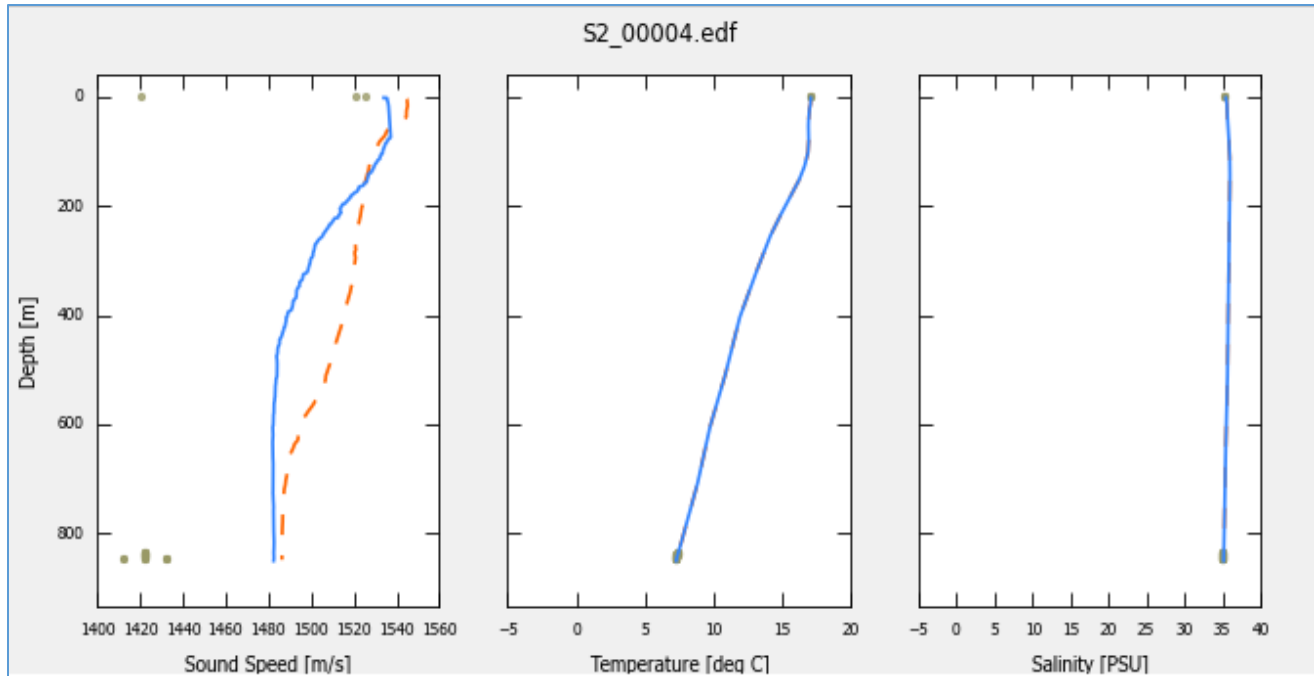


Figure 8. Cast display after applying reference (red) cast temperature and salinity to the current cast (blue).

## Model Data and Synthetic Server Mode

A key aspect for quality assurance and flexibility is support of oceanographic models in a modular fashion that makes it easy interface any model with minimal bridging code. Currently, SSM natively supports the 2009 and 2013 releases of World Ocean Atlas (WOA), and the global operational Real-Time Ocean Forecast System (Global RTOFS) data (Spindler et al., 2006; Levitus et al., 2013). SSM uses those models at multiple stages within the application; for example, displaying model-derived data as background information on the profile plots so that the user can have a reference for the collected cast

Model data are most commonly used, however, to extend acquired cast data to deeper depths, Figures 9 and 10. Extending casts is often required for real-time survey systems, since they need to have a depth point beyond the deepest depth observed to complete the ray-tracing required to geolocate the observation. The most significant variation in the sound speed profile is most commonly in the upper layers of the ocean, however, and it is therefore more efficient only to measure the near-surface behavior and use a model to fill in the remaining information. This allows for faster cast capture, with less wear on instrumentation.

When the profile from the previous example is loaded against the WOA data, Figure 9, the reference cast is clearly far from the new cast, mainly because they were taken at significantly different locations. In this case, the WOA data was used, Figure 10, to replace the salinity and temperature values, and to extend the cast to the depth limit within the atlas for that area.



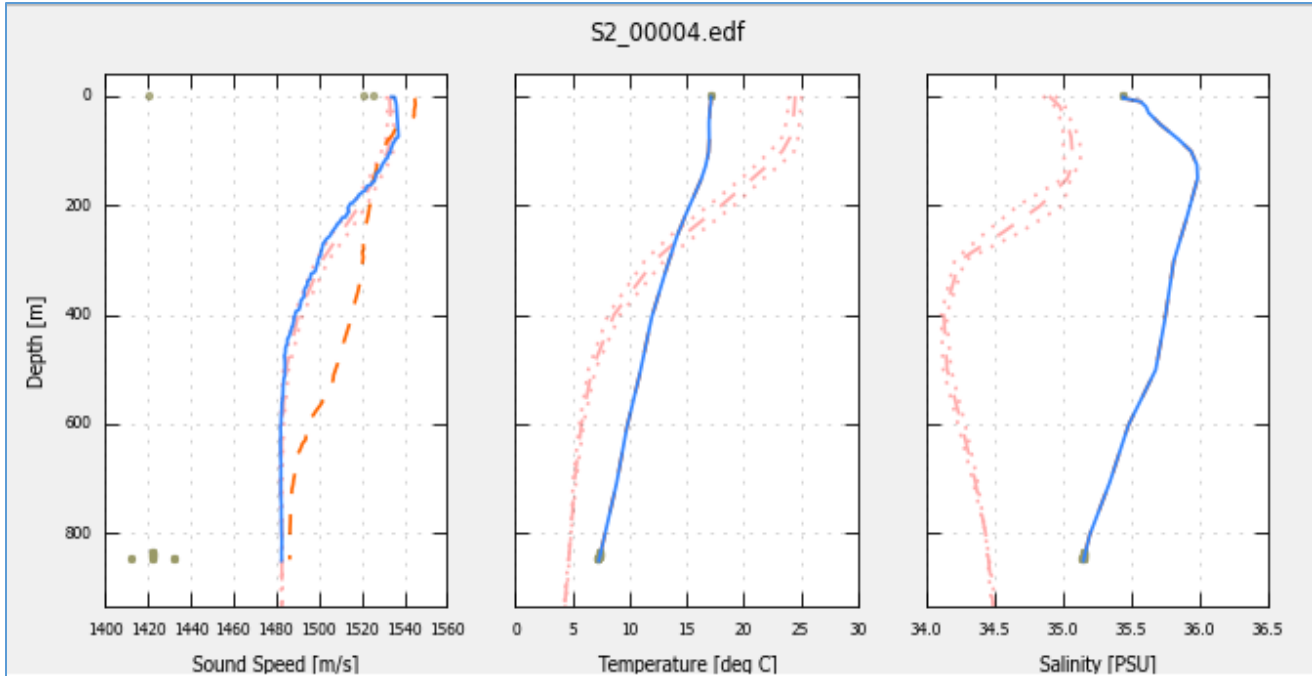


Figure 9. The same cast as Figure 7 with WOA in light red.

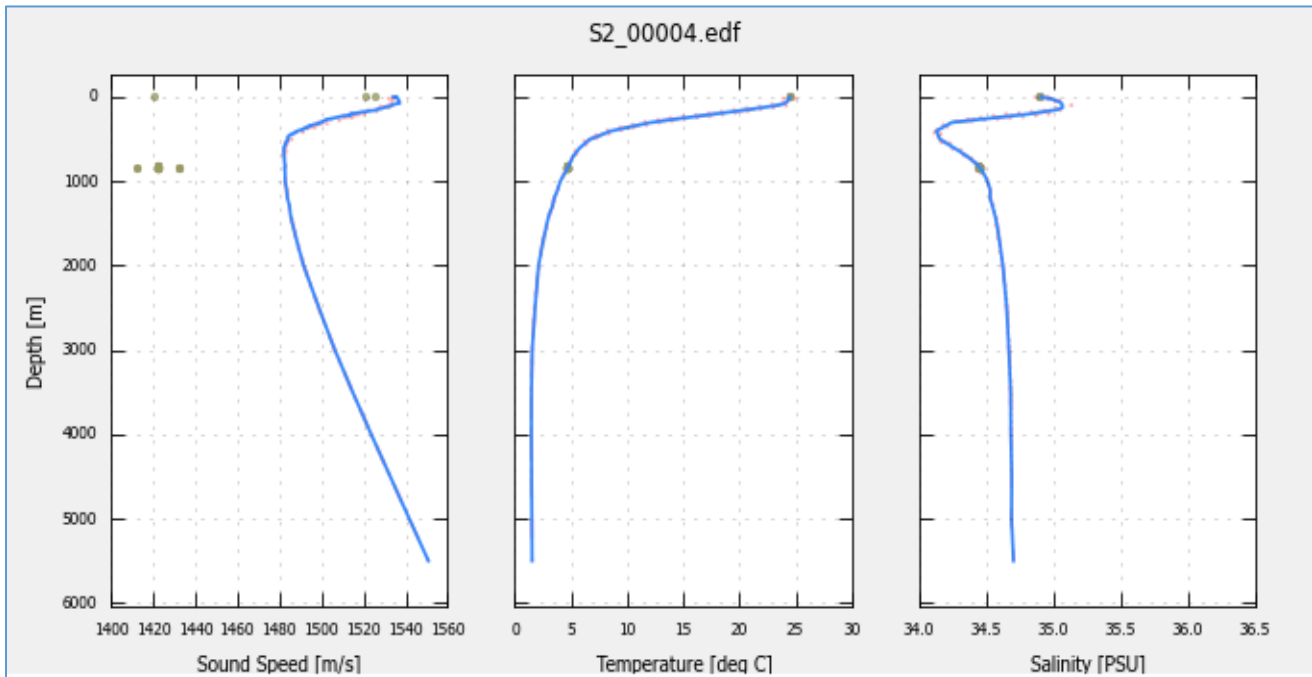


Figure 10. The cast from Figure 8 sound speed extended with WOA values and with temperature and salinity applied from WOA.

An extreme version of model-supported casts is where SSM is used to provide sound speed information when no casts have been taken. This is done through the “Synthetic Profile Server” tool, Figure 11. Once server mode is activated, real-time location data read from the network (e.g., from position datagrams broadcast from Kongsberg SIS) are used to extract profiles from a model, which can then be sent to the data capture systems over the network. This mode is typically used when opportunistically acquiring data, for example during transits, where casts may not be available due to time considerations or equipment constraints. The casts derived by this method may not be ideal, but they are typically significantly better than either no cast, or (more commonly) using the last intentionally acquired cast, which may be from a very different environment.

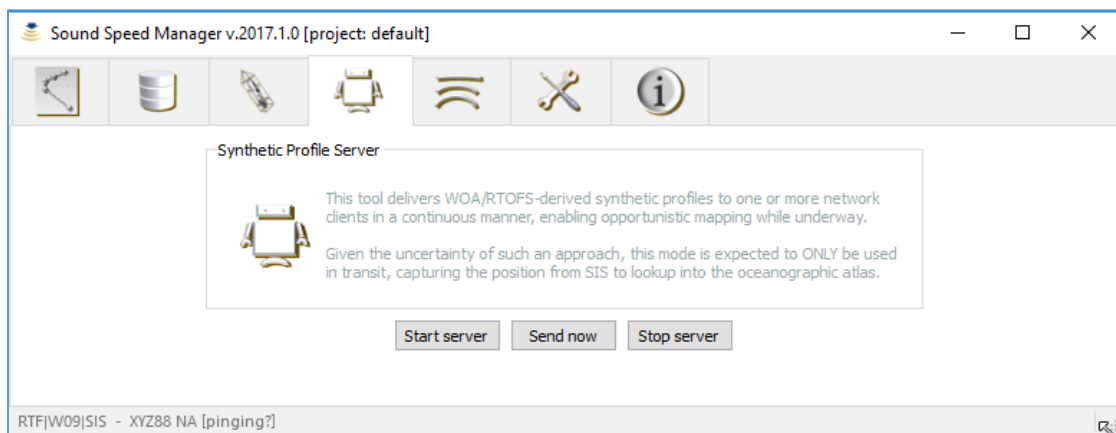


Figure 11. The Synthetic Profile Server tool within Sound Speed Manager.

## Code Availability and Open-Source Policy

The University of New Hampshire (UNH) and NOAA have released Sound Speed Manager under an open-source license (GNU LGPL v2.1 with the NOAA-developed portion of the code in the public domain as required by U.S. Government policy). A stand-alone executable is freely available for download on the project page hosted on the HydrOffice website (<https://www.hydrooffice.org/soundspeed/main>). Documentation is accessible both as part of the installer (in Acrobat PDF format) and online.

As part of the open-source licensing and cooperative agreement between NOAA Coast Survey Development Laboratory and the University of New Hampshire, the source code is made publicly available through the official Github and Bitbucket repositories. In the spirit of open-source code, bug reports are welcomed (the more so if they are accompanied by data samples for testing), as well as feature requests and bug fixes. Feature requests are prioritized according to estimates of the biggest benefit to the most users.

## Development Language and Coding Solutions

Sound Speed Manager is developed in Python (van Rossum and Drake Jr, 2014), which supports the ability to rapidly prototype, implement, and debug ideas, and is a good fit for a relatively small project with limited computation requirements, like SSM. Since it is interpreted, Python also supports low-bandwidth bug fixes or improvements (i.e., differential source changes can be sent). Source availability also makes it possible for users to apply bug fixes themselves, in the field if necessary (e.g., during telephone support).

Sound Speed Manager, while available as a standalone application, can be installed as a Python package into any existing Python installation so long as library dependencies are available. Current dependencies include Numpy (profile data management), Matplotlib (plotting), Pyproj and GDAL (geodesy), NetCDF4 and h5py (exporting data), and PySide (GUI support).

Sound Speed Manager encourages collaboration through a modular, extensible design. For example, data IO modules have a consistent interface so future format integration is simplified; ocean model supports multiple models; and the graphical user interface is separated from the data readers to allow custom non-GUI scripting. Customized conversion or batch processes are easily implemented using the underlying data libraries.

NOAA's customized SeaCAT functionality, Figure 12, is an example of this, where a custom plugin was added to streamline use of SeaCAT SBE 19 and SBE 19+ V2 profilers. This plugin replaces the SeaBird download software for serial communication and automates the use of Seabird's conversion software so that all NOAA platforms produce a consistent output file. These profiles are then imported as any other data format would be. This style could be applied to any manufacturer that supplies tools with command line interfaces or application programming interfaces (APIs).

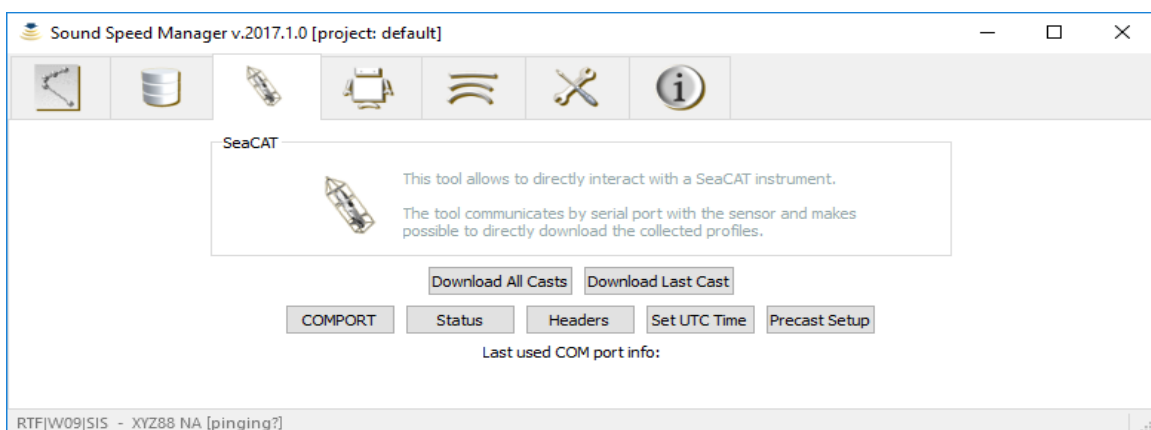


Figure 12. NOAA plugin for SeaCAT devices.

## Future Work

The current SSM code base provides a solid base from which to innovate. The current development priority is to add sound speed monitoring and cast planning tools, for example by including CastTime (Wilson et al., 2013) and the plotting of uncertainty wedges (Beaudoin et al., 2009). Smaller enhancements include the support of HYCOM (HYbrid Coordinates Ocean Model), other input formats, logging of surface sound speed, and addition of drag-and-drop heuristics for file formats.

## Conclusions

Sound Speed Manager is the result of a joint development by NOAA Coast Survey and UNH CCOM/JHC. It fills an important role in the survey acquisition workflow, being a data format translator, quality control tool, data archivist, synthetic profile generator, and network distributor, thus supporting efficiency and reliability. Sound Speed Manager's open-source license allows the hydrographic community to use and customize more readily than closed source or proprietary solutions. It also has a long-term development and support plan, and can be rapidly extended; as a preferred solution of many UNOLS and NOAA vessels. The project also has a developing user community, which bodes well for its longevity.

## Acknowledgments

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### Author biographies



Giuseppe Masetti received a MS degree in Ocean Engineering (UNH, USA) in 2012, and a Master in Marine Geomatics (2008) and a Ph.D. degree (2013) in System Monitoring and Environmental Risk Management (University of Genoa, Italy). As Research Assistant Professor at CCOM/JHC he is focusing on hydrographic data processing and acoustic backscatter.



Barry Gallagher is an IT Specialist with the NOAA Office of Coast Survey for more than twenty-five years. He works as a software developer at the Hydrographic Systems and Technology Branch in Silver Spring, Maryland.



Brian Calder is a Research Associate Professor and Associate Director at CCOM (UNH, USA). He has a Ph.D. in Electrical and Electronic Engineering, completing his thesis on Bayesian methods in sidescan processing (1997). He is currently focusing on statistically robust automated data processing approaches and tracing uncertainty in hydrographic data.



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