Subsurface float tracking and processing using the ARTOA and ARPRO packages

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One only has to visit the float data archive at Woods Hole (http://wfdac.whoi.edu) to appreciate how much the use of subsurface floats has increased over the last few years. The large number of ongoing float projects and amount of unreleased data assures that the data available will increase hugely over the next years. Much of this data now consists of RAFOS (e.g. Rossby et al., 1986) and its French cousin Marvor (e.g. Ollitraut et al., 1994) floats which have now replaced the older and more bulkier SOFAR floats. This article presents two new software packages, which are freely available to the scientific community, for the tracking and processing of subsurface float data. The first section deals with the tracking software and the second with the software developed to process the data.

1 Float Tracking

Marvor and RAFOS floats are tracked by triangulation of distances between the floats and moored sound sources (SoSo's). At regular intervals (e.g. once every 24 hours) each SoSo emits a characteristic signal. The float records the time taken for particular sound signals to travel from the SoSo's to the float (the time of arrival - TOA). Knowing the speed of sound in the area the TOA can be converted into a distance between the SoSo and the float. Depending on the float type, additional information such as temperature, pressure and salinity are also recorded.

Tracking the floats is no easy task. This is due to several factors : Variations in the speed of sound between the SoSo's; clock drift of the SoSo's and the floats and problems with background noise and deviations of the SoSo signals (e.g. because of reflections due to topography). To facilitate the tracking procedure, Matlab4 routines were developed by Martin Menzel at the Institut für Meereskunde Kiel supervised by Walter Zenk, Olaf Boebel and Claudia Schmid. The first version of the tracking software supported RAFOS floats only and consisted of two separate programmes, ARTOA and ARTRK. (Both names were taken with the permission of Tom Rossby from float tracking programmes used by the University of Rhode Island). This version of the software was updated by Claudia Schmid and is currently the version compatible with the ARPRO processing software (see Part 2). Heather Hunt from the WHOI has also updated ARTOA and ARTRK to Matlab5.

ARTOA II is a more advanced Matlab5 based float tracking programme combining graphical data selection and tracking into one programme. This development aims to ease the tracking process by assisting the user from the initial data selection to the production of a final trajectory. The programme can process floats with an unlimited number of listening windows, TOA's per window and SoSo's.

The programme consists of two main modules. A selection module assists the user in assigning the TOA's to the most likely SoSo's and examining other available data such as pressure and temperature. TOA data may be selected graphically using different selection criteria such as single value (selecting each TOA individually and assigning it to a SoSo), polygon region (as before, but for a group of TOA's) or semi-automatic selection (where an algorithm selects the data automatically based on different boundary conditions). The programme gives visual assistance in two ways. Firstly, at the beginning and end of each float cycle or mission, the known TOA's associated with each SoSo are plotted. Additionally, all TOA's recorded by the float are colour coded according to the correlation height (a measurement for the reception quality) of the respective TOA.

Once the TOA's have been assigned to SoSo's, one can calculate the trajectory in the tracking module. The programme supports, amongst others, a least square tracking algorithm allowing the use of an unlimited number of SoSo's to calculate the trajectory. Due to the aforementioned uncertainties some alterations may be necessary. The programme allows the user to alter the sound speed or offsets for each SoSo and float to obtain a more accurate trajectory. Once calculated, the trajectory is plotted over previously calculated trajectories in order to compare different combinations of parameters. By comparing the float trajectories obtained by the combination of different parameters, one can obtain the most accurate estimate of the float's path.

ARTOA II is still under development. One of the next steps will be to update the code to include features of the new Matlab5 in order to have a common base for further programming. Further information concerning ARTOA II can be found at the Eurofloat Web Site listed at the end of this article.

2 Processing the Float Data

ARPRO consists of a series of Matlab4 subroutines originally developed at AINCO-Interocean by Vassilis Zervakis and updated by Mike Sparrow. The software allows the visualisation and analysis of float data as well as calculating a variety of statistical parameters. The software was designed to process float data from the EUROFLOAT project, and therefore to be run in conjunction with the ARTRK and ARTOA programmes described in Part 1. ARPRO is currently being modified to read data from the Woods Hole float data archive and will be updated to run with the new ARTOA II programme.

ARPRO allows the processing of float data in two ways, either by examining individual floats or by analysing a group of floats.

Examining individual floats

The number of position fixes per day of the float can be specified in the initial options before a float is loaded (the default is one position fix per day). Once loaded, the data can be lowpassed (in order, for example, to minimise tidal influences). Three types of filters are provided - Boxcar, Triangle and Hanning with filter lengths of 3-7 points, though these options can easily be changed.

The programme allows the examination of temperature and pressure records of the float (lowpassed or raw). This is helpful in ascertaining whether, for example, a particular float crosses a water mass boundary or changes depth. The user can zoom into particularly interesting sections of the temperature or pressure plots by using the left and right mouse buttons.

It is sometimes useful to consider the ratio between the non-linear and Coriolis terms, known as the Rossby Number (= non-linear term/Coriolis term). In ARPRO the Rossby number can be plotted on polar or Cartesian coordinates. Additionally, a summary of individual floats may be obtained. This option plots the track of the current float and the temperature and pressure along the float's path (including bathymetry if required).

Analysing a group of floats

The utility for examining a group of floats plots the float trajectories on a map. Options for bathymetry, and colour or black and white maps are included in the programme. Being able to watch a movie of float trajectories is useful in demonstrations, or for ascertaining a more accurate flow pattern. As with the map plotting option, colour or black and white figures are produced.

The data can be processed using several types of statistical analyses. One of these is an examination of the Kinetic Energy Spectra in which both log-log and energy conserving spectra can be plotted, with the option of producing rotary spectra. ARPRO allows the user to calculate Eulerian velocities (mean, perturbation and r.m.s) and simple Taylor (Lagrangian) statistics (Taylor, 1921), such as Integral Time (T) and Length Scales and eddy diffusivities as well as their associated errors (see, for example Davis (1991) and Kraus and Böning (1987) for a full description of the statistics).

In this programme, the desired map limits, grid size etc. are specified. If Eulerian velocities are required (and the data density is reasonably high) a small grid size may be used. If Lagrangian statistics are required then a larger grid size should be used as the statistics need a large number of observations in each grid box.

Vectors are drawn from the centre of each grid box representing the mean Eulerian velocity.

In ARPRO, T can be calculated by the method of "autocorrelation" (e.g. Spall et al., 1993) or by "structure function" (e.g. Kraus and Böning, 1987). Alternatively, the user may 'force' a value of T (this can be useful if, for example, you wish to find the error of the velocities of one float but using a previously calculated value). The statistical results and their associated errors are then calculated automatically and the results written to a file.

During processing it is straightforward to return to the Matlab command window and continue processing. This allows the user to modify the data interactively whilst running ARPRO. For the moment ARPRO has coastline and bathymetry files for the Mediterranean, North East and North West Atlantic and the South Atlantic, though additional data can quite easily be included.

Both the ARTOA programmes and ARPRO are freely available. Any feedback, comments or ideas for further developments are welcome. When you think you've added a feature that might be of interest to the rest of the float community let us know in order to integrate it into one of the updated versions.

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