Automated curve matching techniques for reproducible, high-resolution palaeomagnetic dating

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Introduction

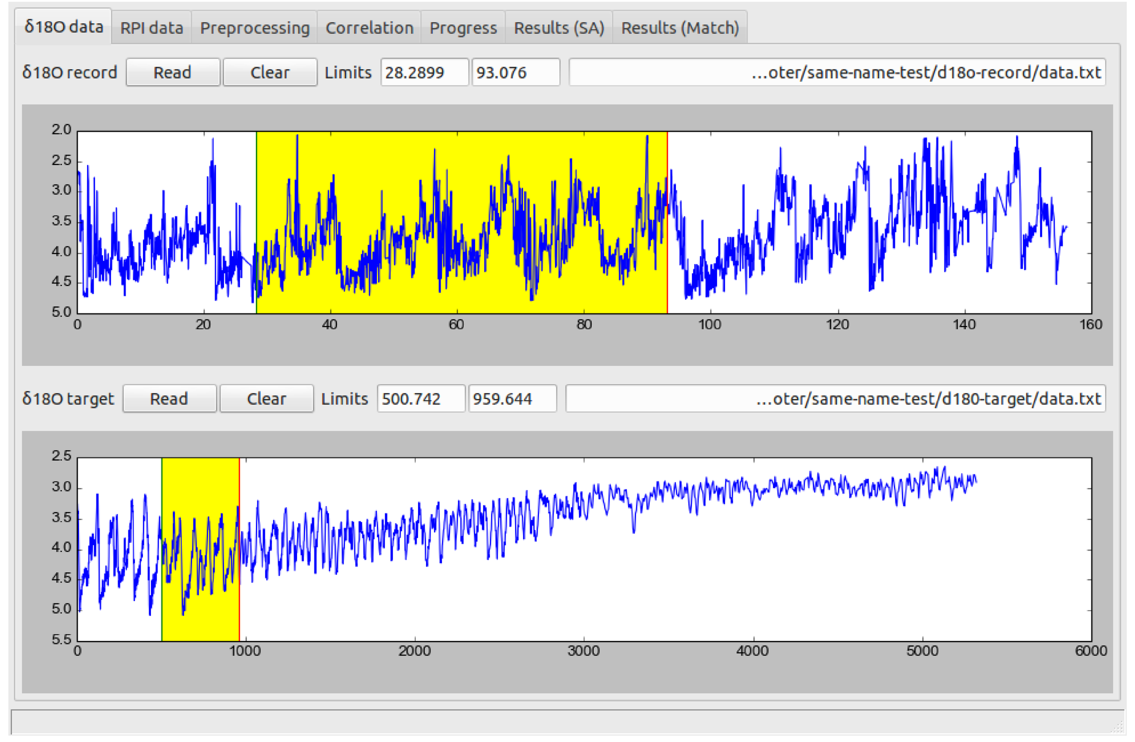
High-resolution relative palaeointensity (RPI) and palaeosecular variation (PSV) data are increasingly important for accurate dating of sedimentary sequences, often in combination with oxygen isotope ($\delta^{18}O$) measurements. A chronology is established by matching a measured downcore signal to a dated reference curve, but there is no standard methodology for performing this correlation.

Traditionally, matching is done by eye, but this becomes difficult when two parameters (e.g. RPI and $\delta^{18}O$) are being matched simultaneously, and cannot be done entirely objectively or repeatably. More recently, various automated techniques have appeared for matching one or more signals. We present Scoter, a user-friendly program for dating by signal matching and for comparing different matching techniques.

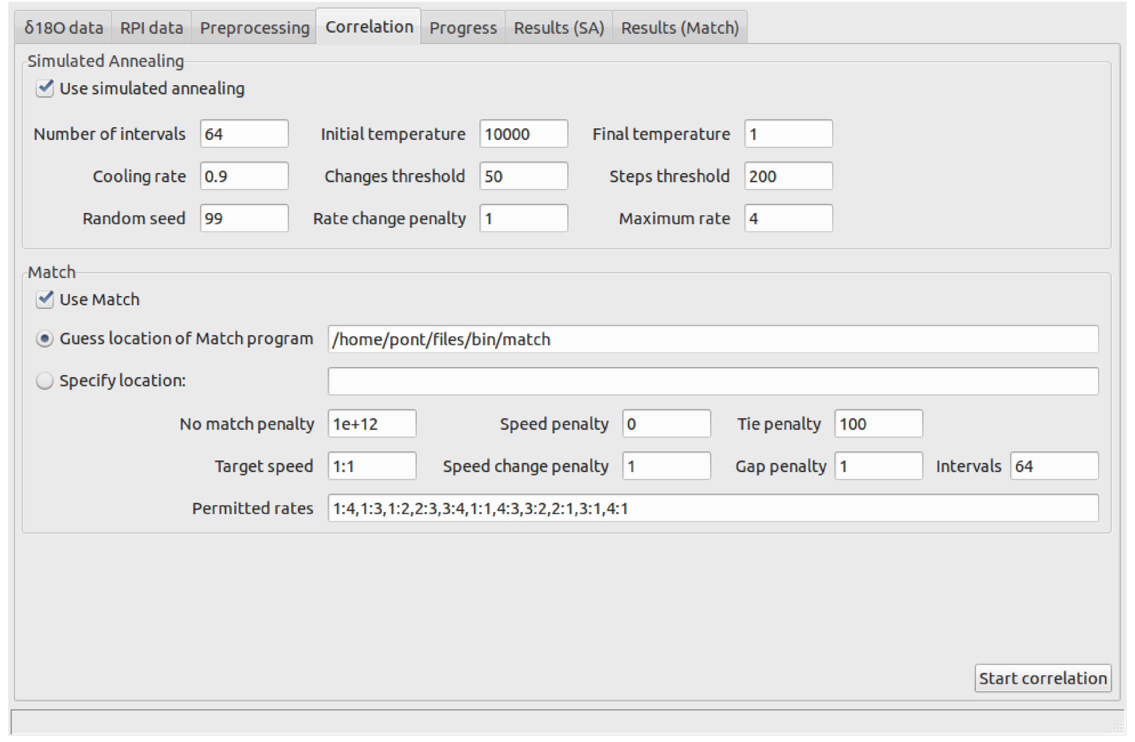
The Scoter program

Scoter is a cross-platform (Windows, Mac, Linux) application written in Python, and consists of a general-purpose time-series processing and correlation library linked to a graphical desktop front-end. RPI, PSV, and other records can be opened, pre-processed, and automatically matched with reference curves. The current version of Scoter incorporates an experimental signal-matching algorithm based on simulated annealing (Kirkpatrick *et al.*, 1983), as well as an interface to the well-established Match program of Lisiecki and Lisiecki (2002), enabling results of the two approaches to be compared directly. Scoter's modular structure makes it easy to incorporate further correlation techniques, making it a useful platform for further research into curve matching algorithms as well as a practical correlation tool in its own right.

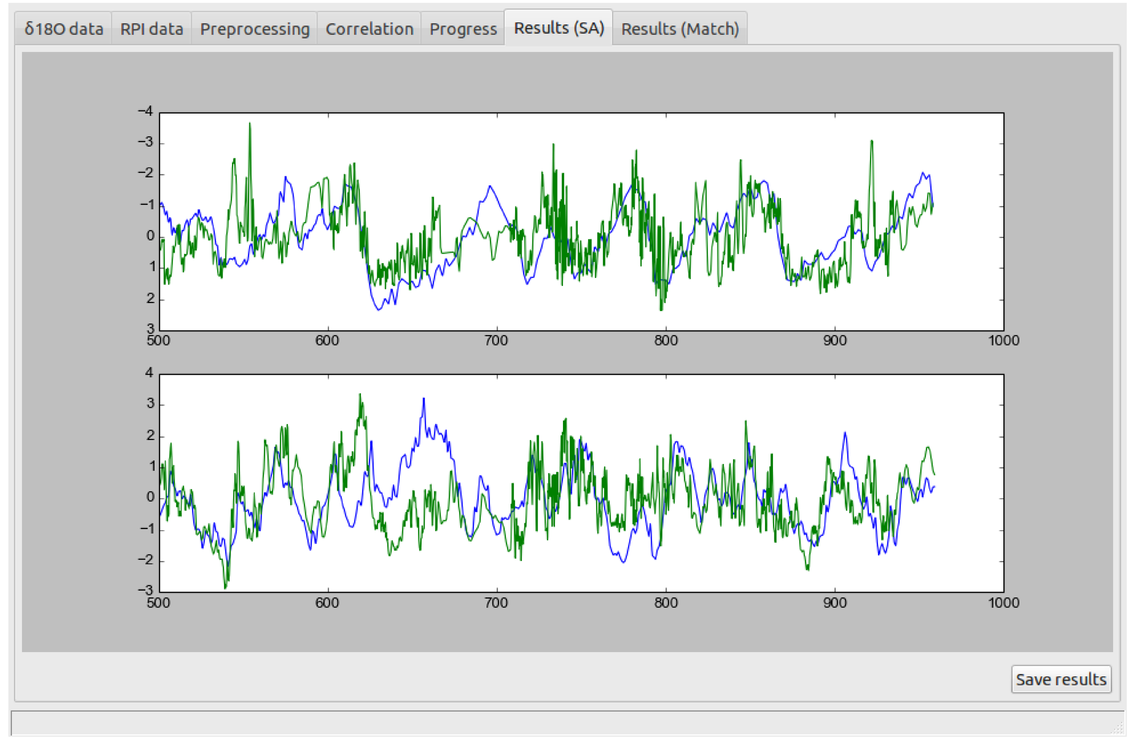
Typical workflow for the Scoter program



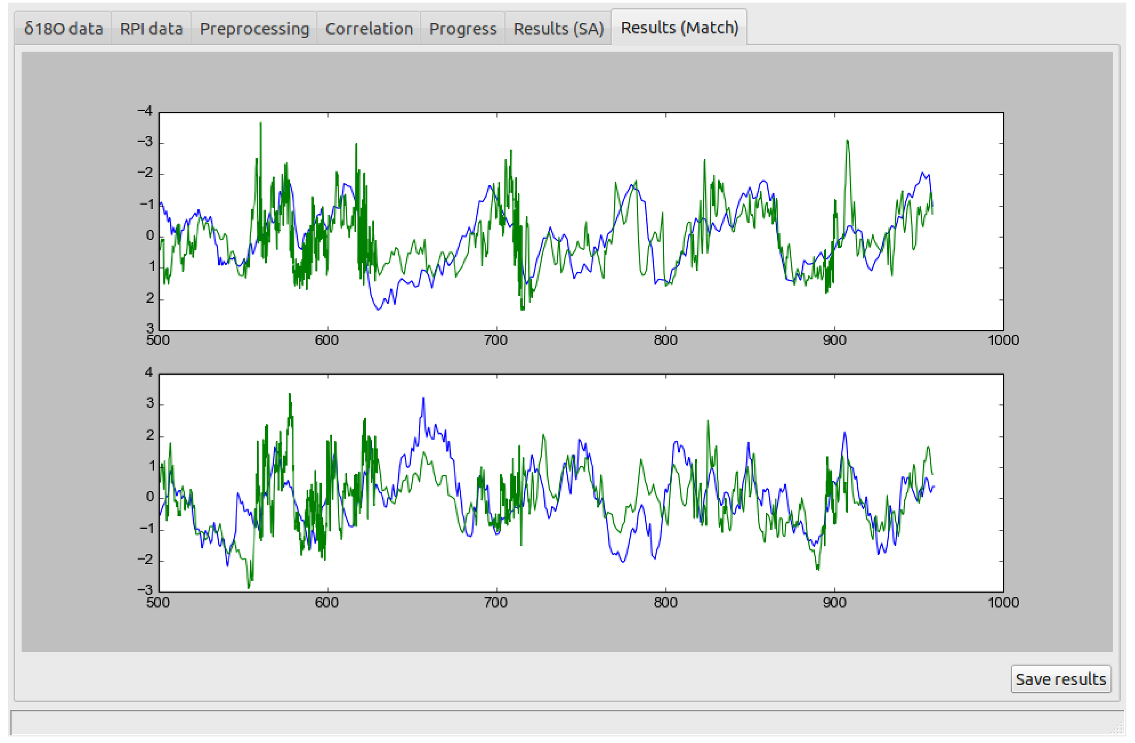
1. Open data files and select parts to be correlated.



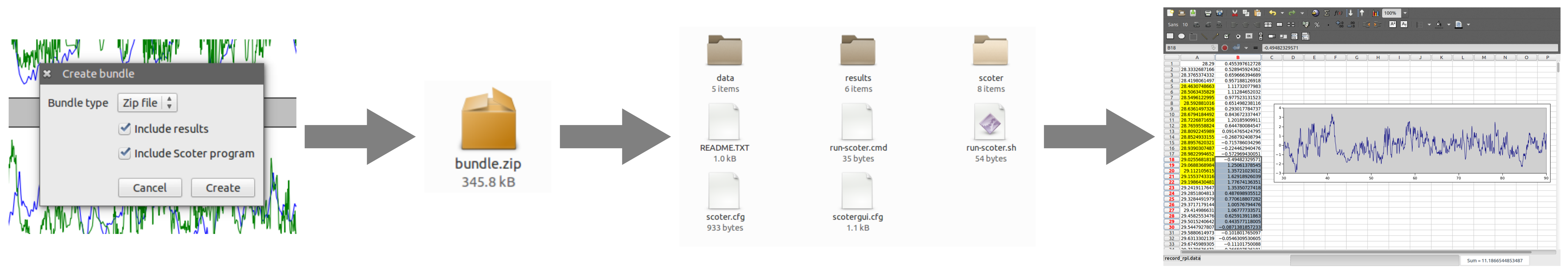
2. Choose parameters for Match and simulated annealing correlation algorithms.



3. Results from Match correlation ($\delta^{18}O$ and RPI)



4. Results from simulated annealing ($\delta^{18}O$ and RPI)

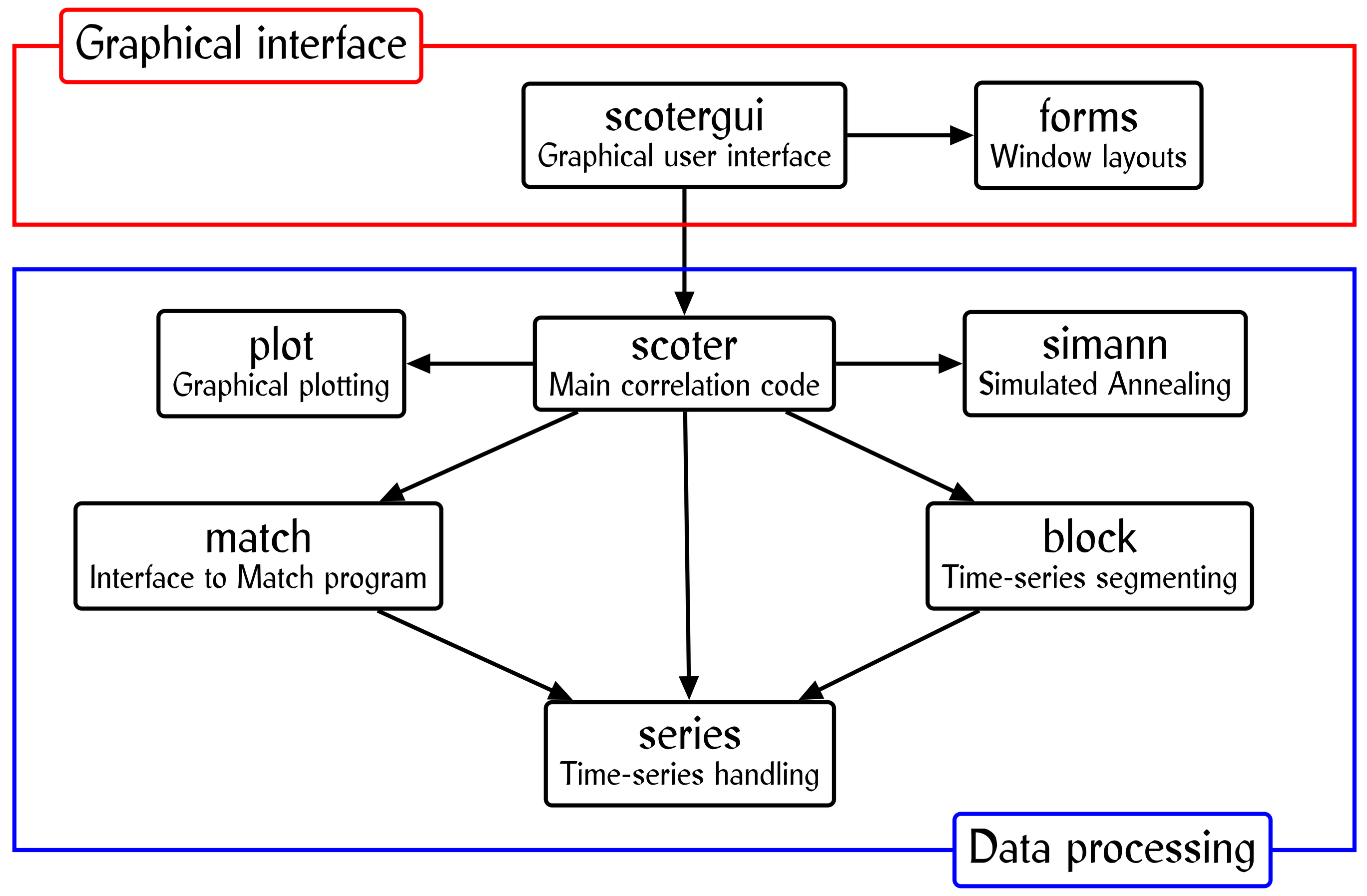


5. Export results as a bundle for archiving, further analysis, or publication.

Development status and availability

Scoter is largely functionally complete, and is currently being debugged, tested, and documented. The program will be released later this year as free software under the GNU General Public License.

Scripting and reproducibility



Module structure of the Scoter package. The data processing modules are cleanly separated from the GUI code, making it easy to reuse them in other Python scripts and applications.

Scoter is designed to be usable in a wide variety of workflows and environments, and to make it easy to reproduce analysis results. The core libraries can be used through three different interfaces:

Graphical user interface for ease of use and quick interactive exploration of different correlation parameters.

Command-line interface for incorporation into scripted processing workflows.

Python API for incorporation into other programs written in Python, or in languages that can interface with Python.

Data bundles

In Earth sciences as in other disciplines, reproducible research is becoming an increasingly important theme. To make reproducibility as simple as possible, Scoter allows the user to export a **bundle** – an archive file containing the input data, results files, analysis parameters, a script to run the analysis, and (optionally) a copy of the Scoter program itself. Thus a correlation can be interactively developed using the graphical interface, then saved and shared as a self-contained package, from which the analysis can be automatically 'replayed' at any time with minimal external dependencies.

References

Kirkpatrick, S., Gelatt, C. D., & Vecchi, M. P. (1983). Optimization by simulated annealing. *Science*, *220*(4598), 671–680.

Lisiecki, L. E., & Lisiecki, P. A. (2002). Application of dynamic programming to the correlation of paleoclimate records. *Paleoceanography*, *17*(4).

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