Acycle: Time-series analysis software for paleoclimate research and education

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Penn Sate

Sept. 6, 2019

OUTLINE

1. Introduction
2. Getting Started
3. *Acycle* Graphic User Interface (GUI)
4. Case study: Carnian cyclostratigraphy

Time series analysis

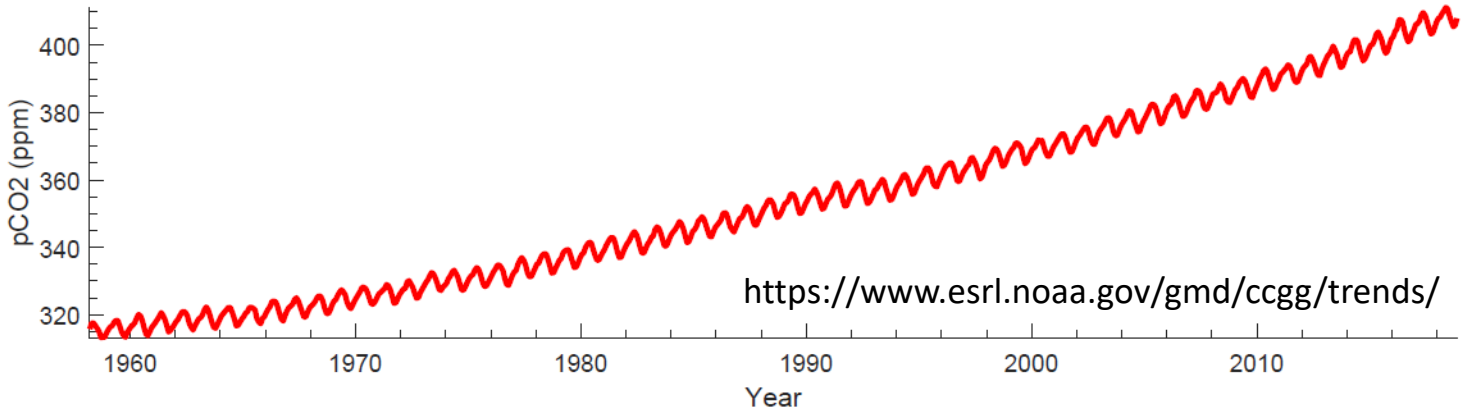
- a statistical technique that deals with time series data.
- accounts for the fact that data points taken over time may have an internal structure (such as trend or periodicity) that should be accounted for.

- Economic Forecasting
- Sales Forecasting
- Population Forecasting
- Stock Market Analysis
- Yield Projections

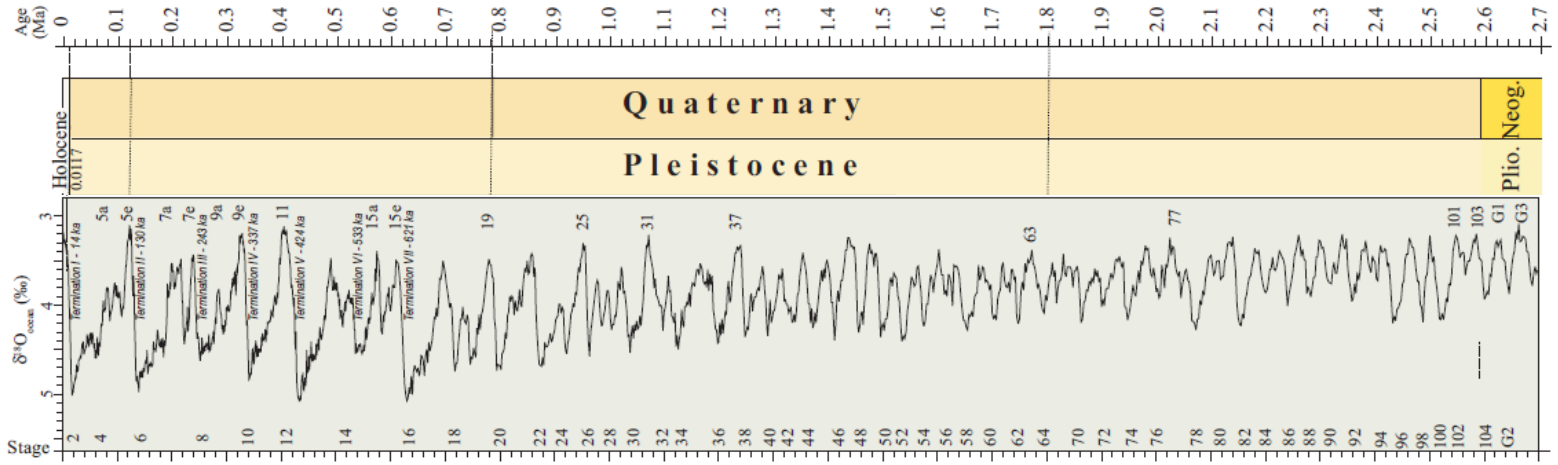
- STEM (Science, technology, engineering, and mathematics)
- …

Climate Time Series

Monthly average CO_2 at Mauna Loa Observatory, Hawaii



Global benthic marine $\delta^{18}O$ stack (global ice volume and temperature)



(Lisiecki & Raymo, 2005)

(Hinnov, 2013)

Computers and Geosciences 127 (2019) 12–22

Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/cageo

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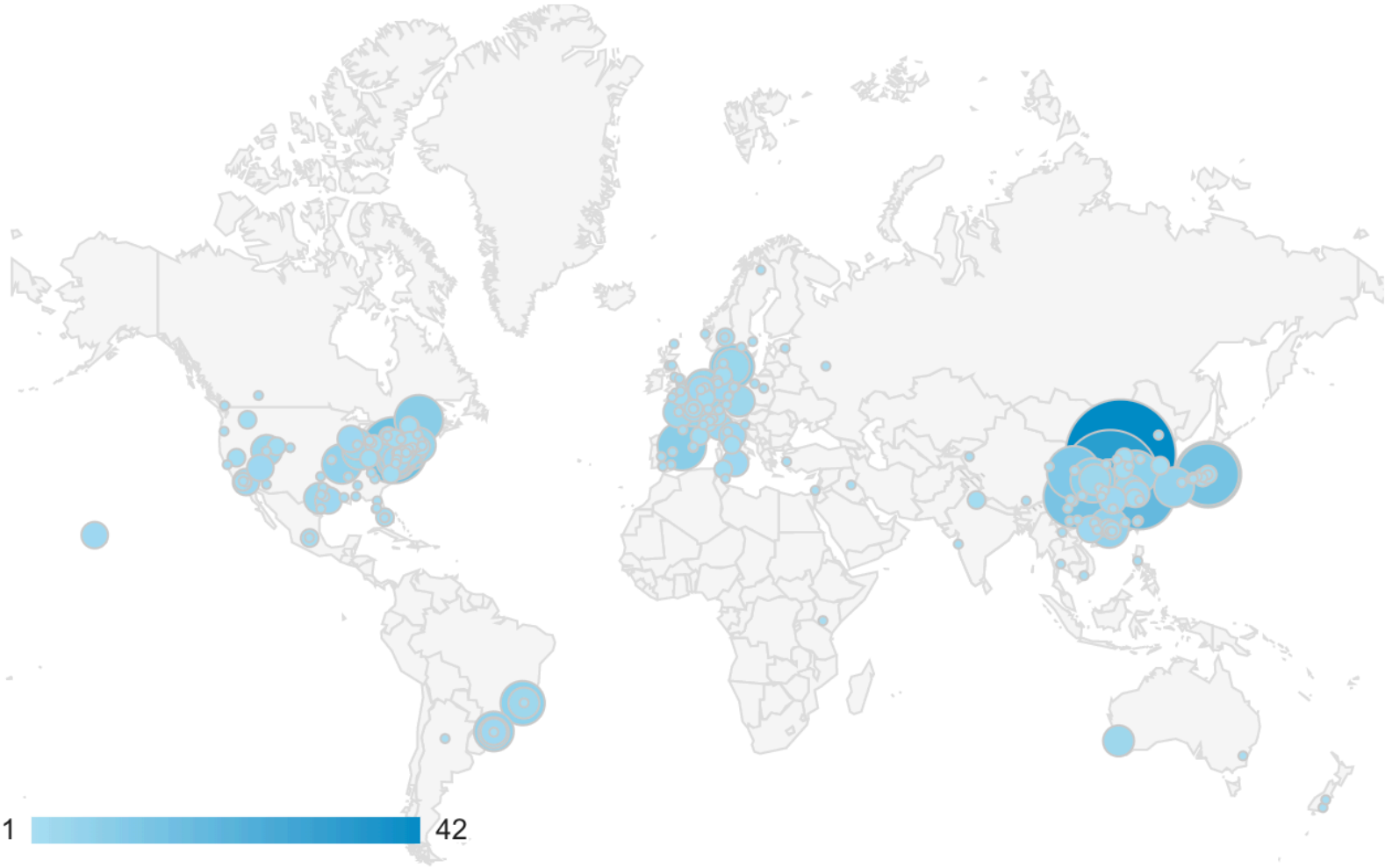
Logo designed by Hewei Duan



Total: 1782 unique visitors

(Sept 2018 – Sept 2019)

http://mingsongli.com/acycle

Data source: https://analytics.google.com

What they say

“It is truly an amazing contribution to the geosciences community … It opens up much needed access to these powerful tools for a wide audience in the sedimentary geology and paleoclimate community. … A really marvellous job."

—— **Dr. J. Fred Read** (Emeritus Professor, Virginia Tech)

"His ***Acycle*** software will become the standard tool for time-scale applications by all international workers."

—— **Dr. James G. Ogg** (Professor, Purdue University)

“Not only is this software powerful and effective, it is also simple to use and therefore benefits researchers and at all levels within the paleoclimatology community, from novices to experts.”

—— **Dr. Paul E. Olsen** (Professor, Columbia University)

2. Getting Started

*** Stand-alone versions of *Acycle* only needs Runtime, not MatLab**

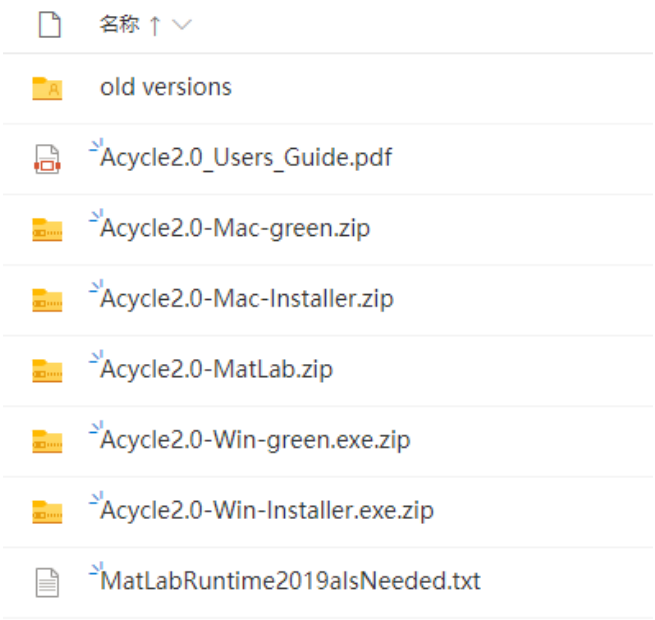
*** MatLab Runtime is not MATLAB!**

*** MatLab Runtime is free!**

Download

Dropbox OneDrive Baidu Cloud

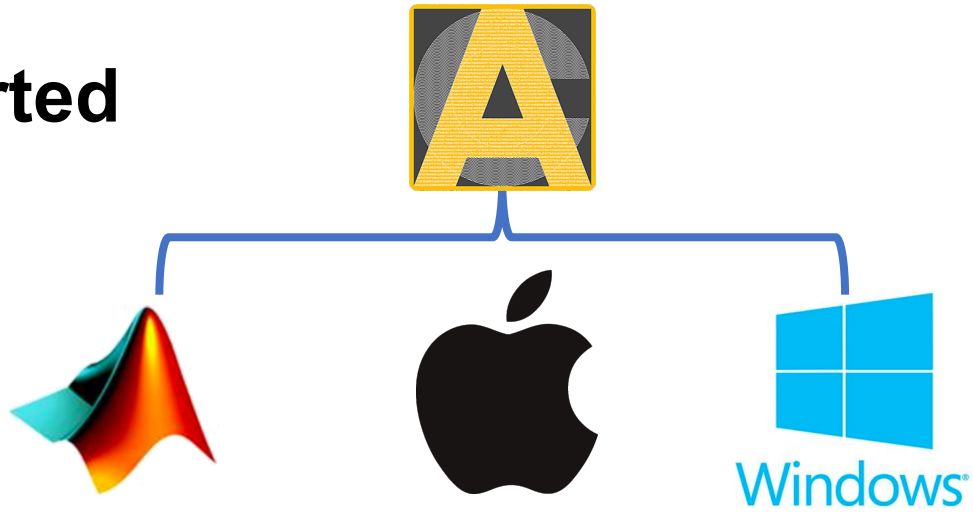
[Dropbox](#) | [OneDrive](#) | [BaiduCloud](#) | [GitHub](#)



Read more

- **Wiki: https://github.com/mingsongli/acycle/wiki**
- **or: https://github.com/mingsongli/acycle/blob/master/doc/AC_Users_Guide.pdf**
- **or: *Acycle* "Help" menu - "Manual",**
- **or: /doc/AC_Users_Guide.pdf**

2. Getting Started



Acycle for…	MatLab	Stand-alone **			
Platform	MatLab	Mac		Windows	
Requirement		MatLab Runtime 2019a (Free)			
download		Runtime for Mac		Runtime for Win	
Version		Installer	Green	Installer	Green
Size	63.5 MB	97 MB	91 MB	122 MB	121 MB
How to install	Acycle2.0_Users_Guide.pdf (Chapter 3)				

** *Need to install the MatLab* ***Runtime 2019a (!!!)***

Fast installation:

1. Install MatLab Runtime 2019a (free)

You don't need to install MatLab (heavy and expensive)!
After the installation, you don't need to run runtime yourself
If you have installed MatLab 2019a, this step can be skipped

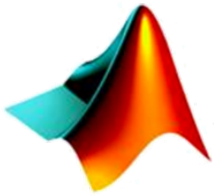
2. Download Acycle2.0 GREEN version

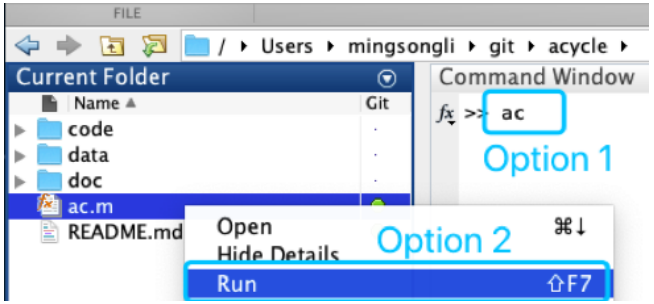
No installation is needed.

3. Follow the next slide to start up Acycle 2.0.

*** Need to install the MatLab **Runtime 2019a (!!!)***

Startup

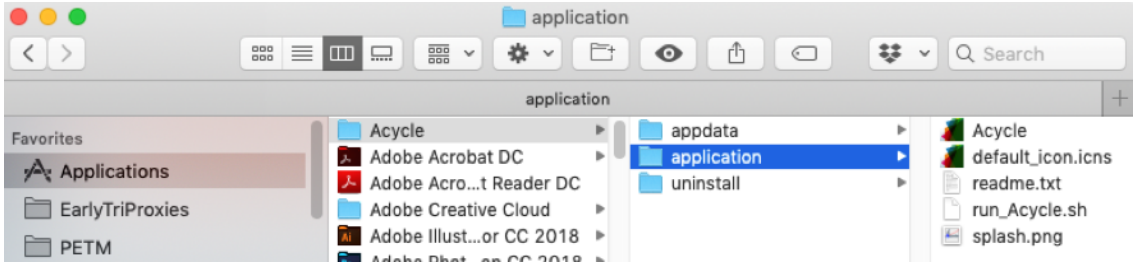




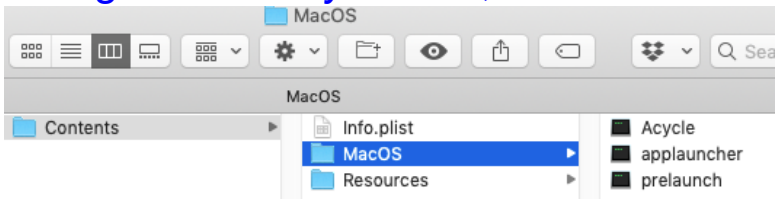
Windows

double-click

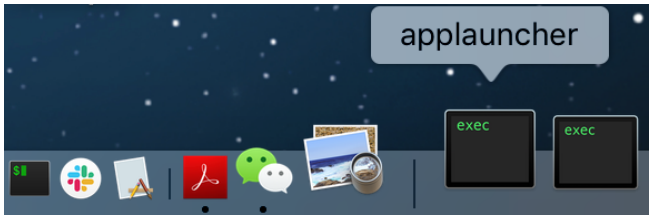
1. Go to the installation folder



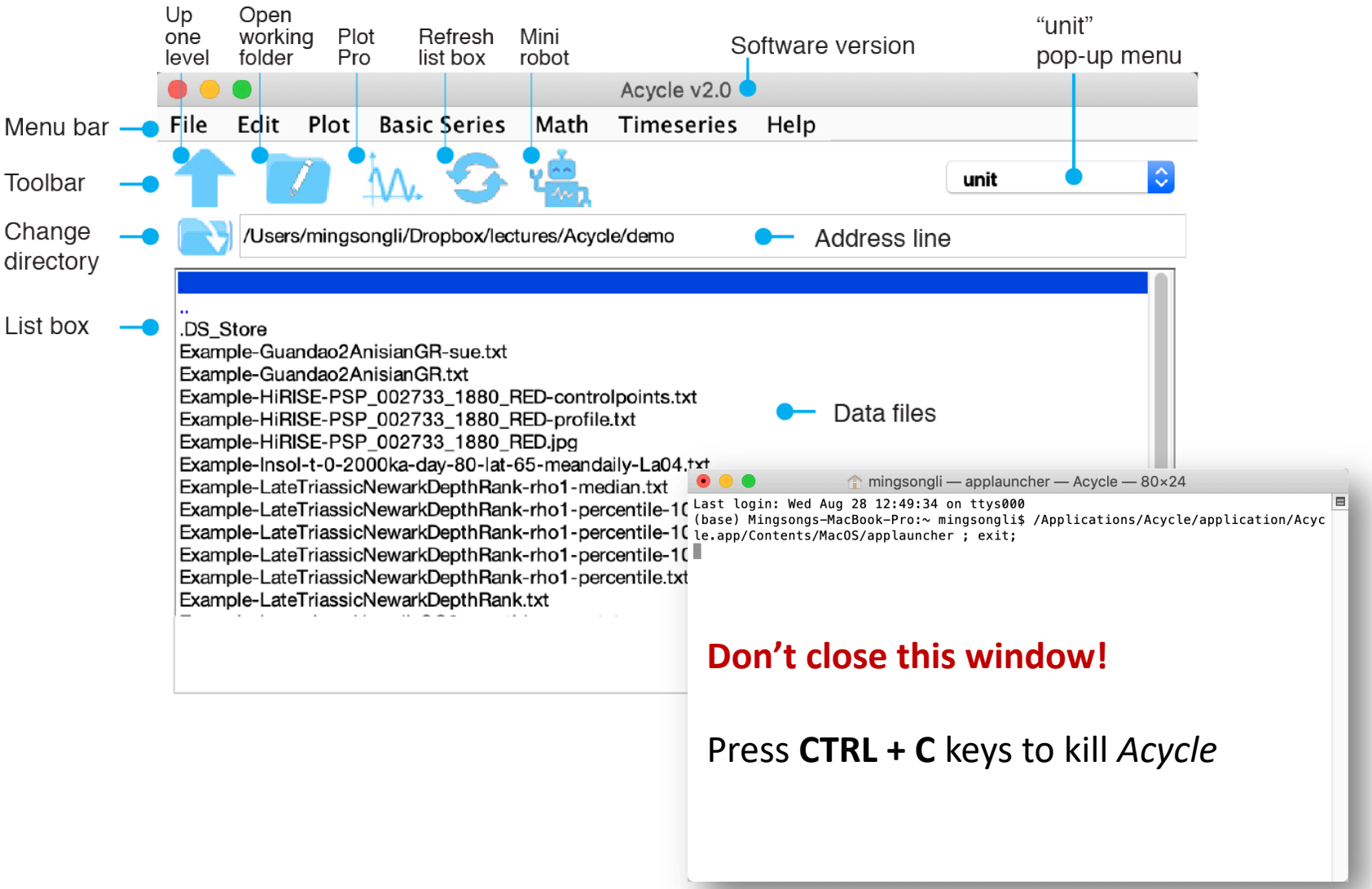
2. Right click "*Acycle*" file, choose "Show Package Content"



3. Drag the applauncher file to the dock



Acycle Graphic User Interface (GUI)

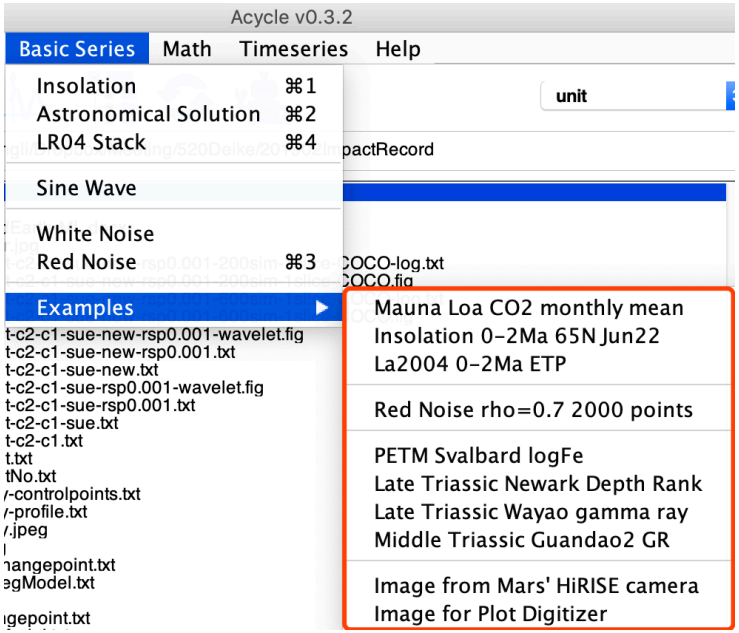


Data Requirement

comma-, table- or space-delimited text (.txt)
comma-separated values files (.csv)

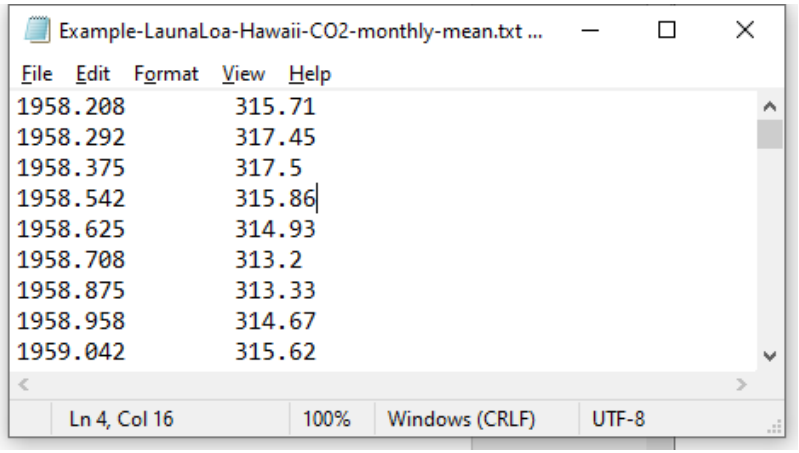
No header is permitted.

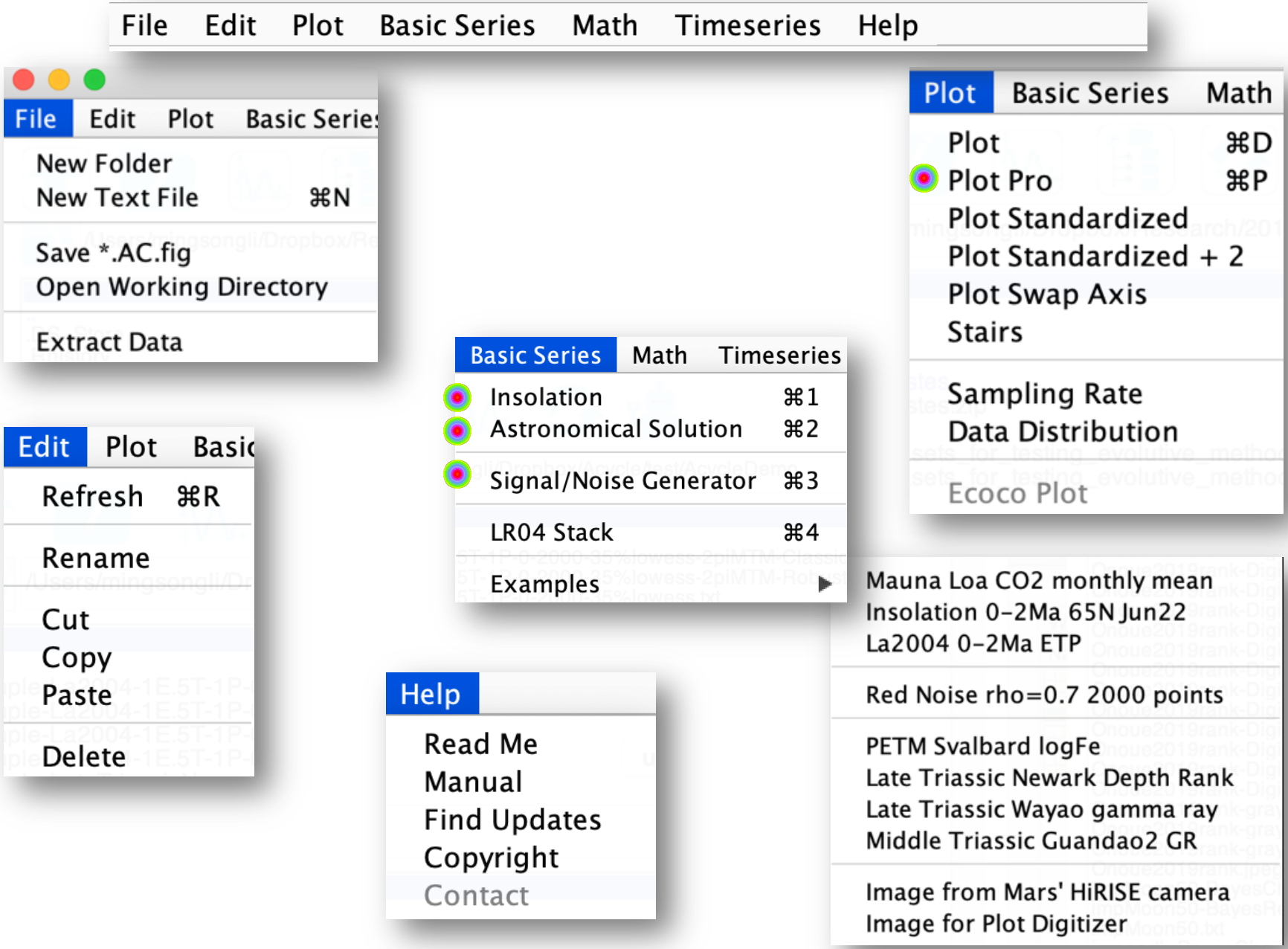
Most data files should contain two columns of series.



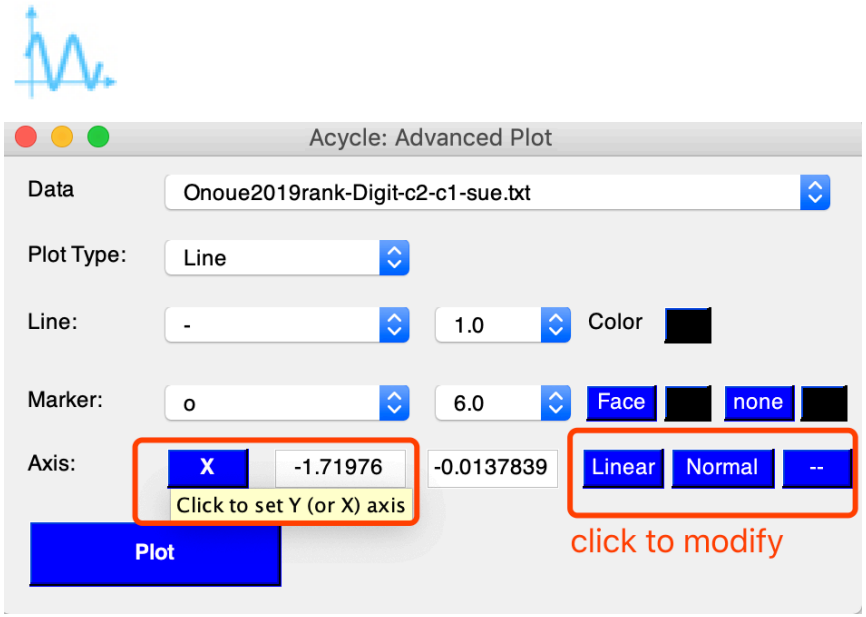
depth
or time

value




File Edit Plot Basic Series Math Timeseries Help
File Edit Plot Basic Series
New Folder
New Text File ⌘N
Save *.AC.fig
Open Working Directory
Extract Data
Edit Plot Basic
Refresh ⌘R
Rename
Cut
Copy
Paste
Delete
Basic Series Math Timeseries
Insolation ⌘1
Astronomical Solution ⌘2
Signal/Noise Generator ⌘3
LR04 Stack ⌘4
Examples
Help
Read Me
Manual
Find Updates
Copyright
Contact
Plot Basic Series Math
Plot ⌘D
Plot Pro ⌘P
Plot Standardized
Plot Standardized + 2
Plot Swap Axis
Stairs
Sampling Rate
Data Distribution
Ecoco Plot
Mauna Loa CO2 monthly mean
Insolation 0-2Ma 65N Jun22
La2004 0-2Ma ETP
Red Noise rho=0.7 2000 points
PETM Svalbard logFe
Late Triassic Newark Depth Rank
Late Triassic Wayao gamma ray
Middle Triassic Guandao2 GR
Image from Mars' HiRISE camera
Image for Plot Digitizer

Plot Pro


Acycle: Advanced Plot
Data
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Plot Type:
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Line:
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Color
Marker:
o
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Face
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Axis:
X
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-0.0137839
Linear
Normal
--
Click to set Y (or X) axis
Plot
click to modify

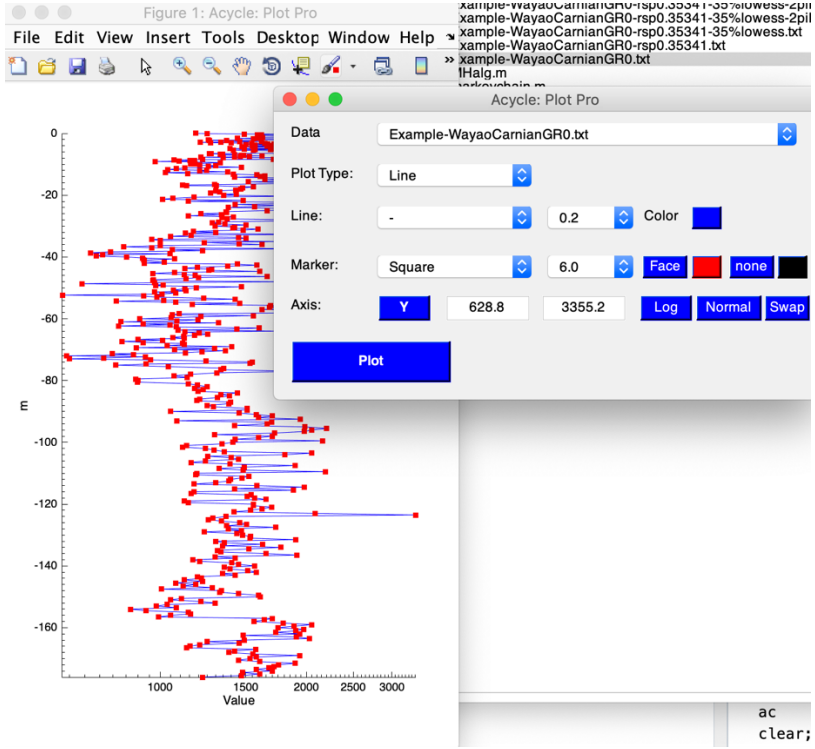
Figure 1: Acycle: Plot Pro
File Edit View Insert Tools Desktop Window Help
Acycle: Plot Pro
Data
Example-WayaoCarnianGR0.txt
Plot Type:
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Line:
-
0.2
Color
Marker:
Square
6.0
Face
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Axis:
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3355.2
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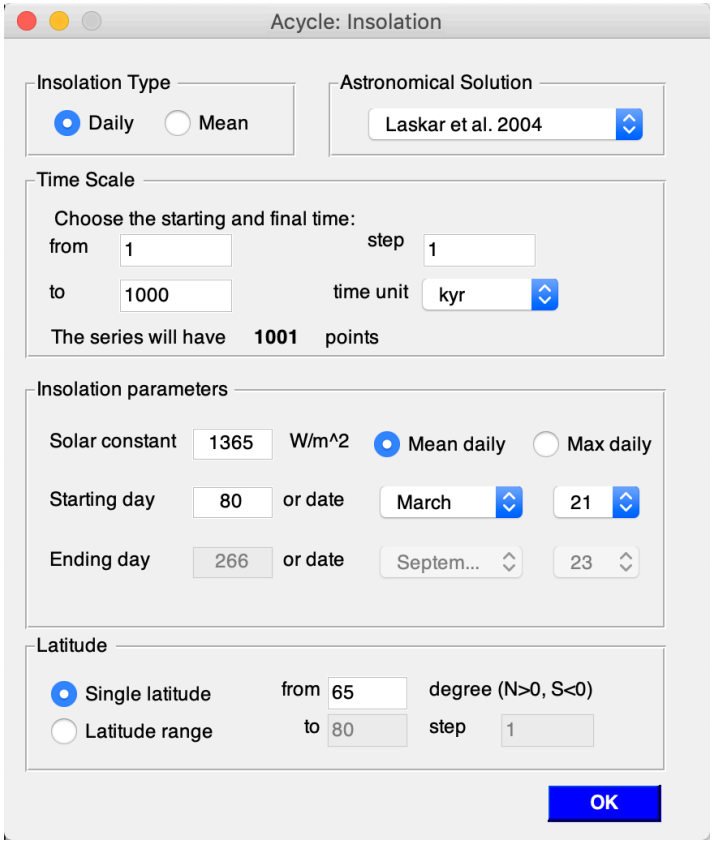
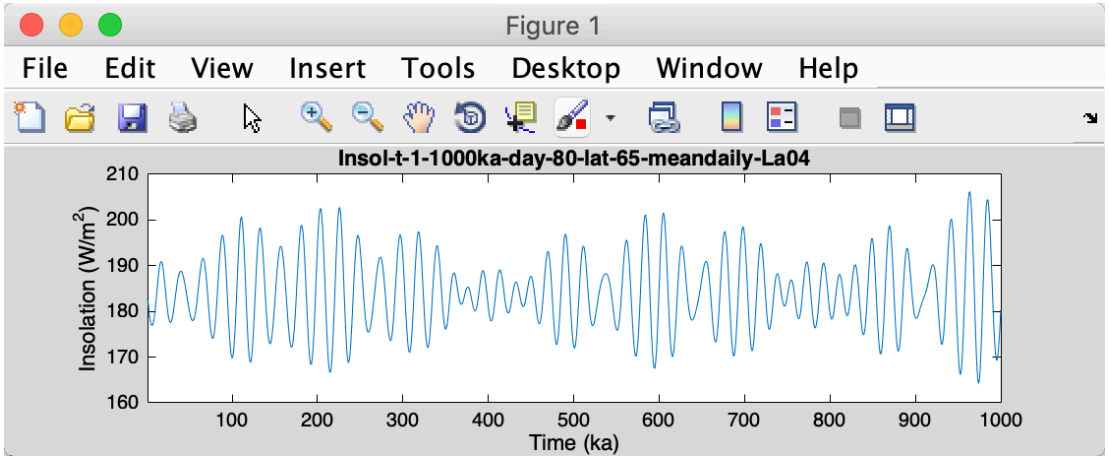
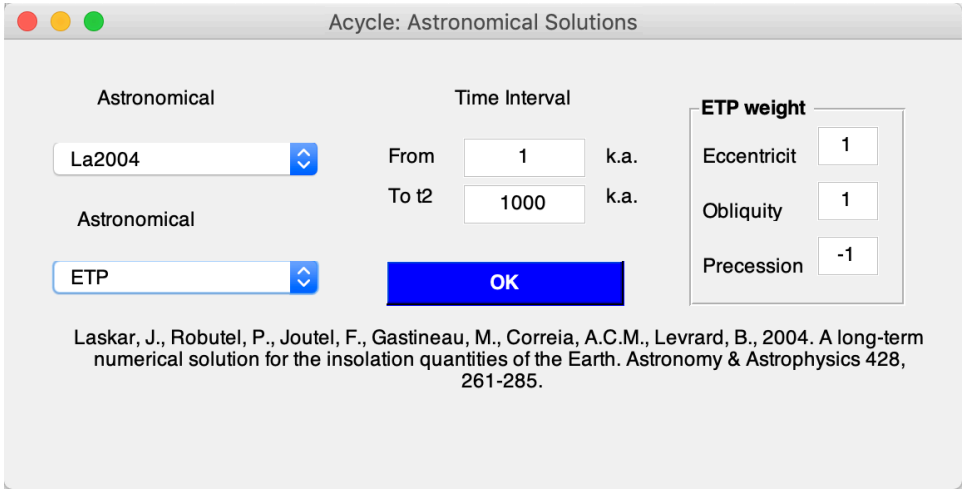
Insolation

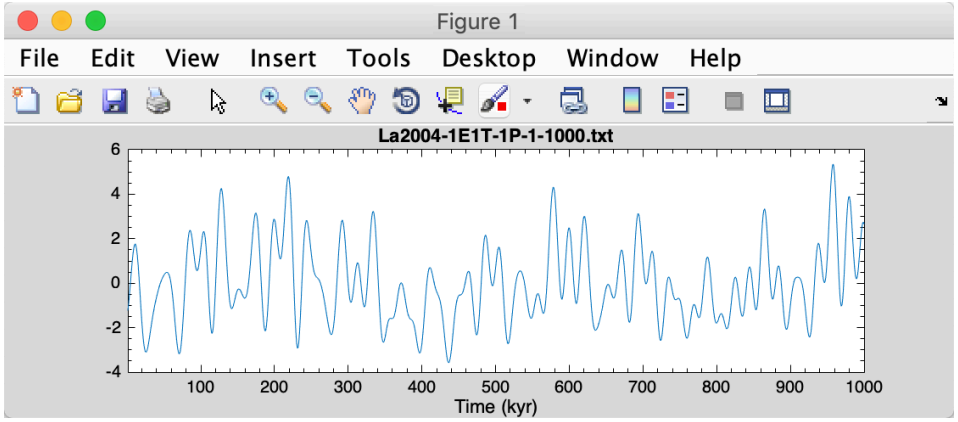




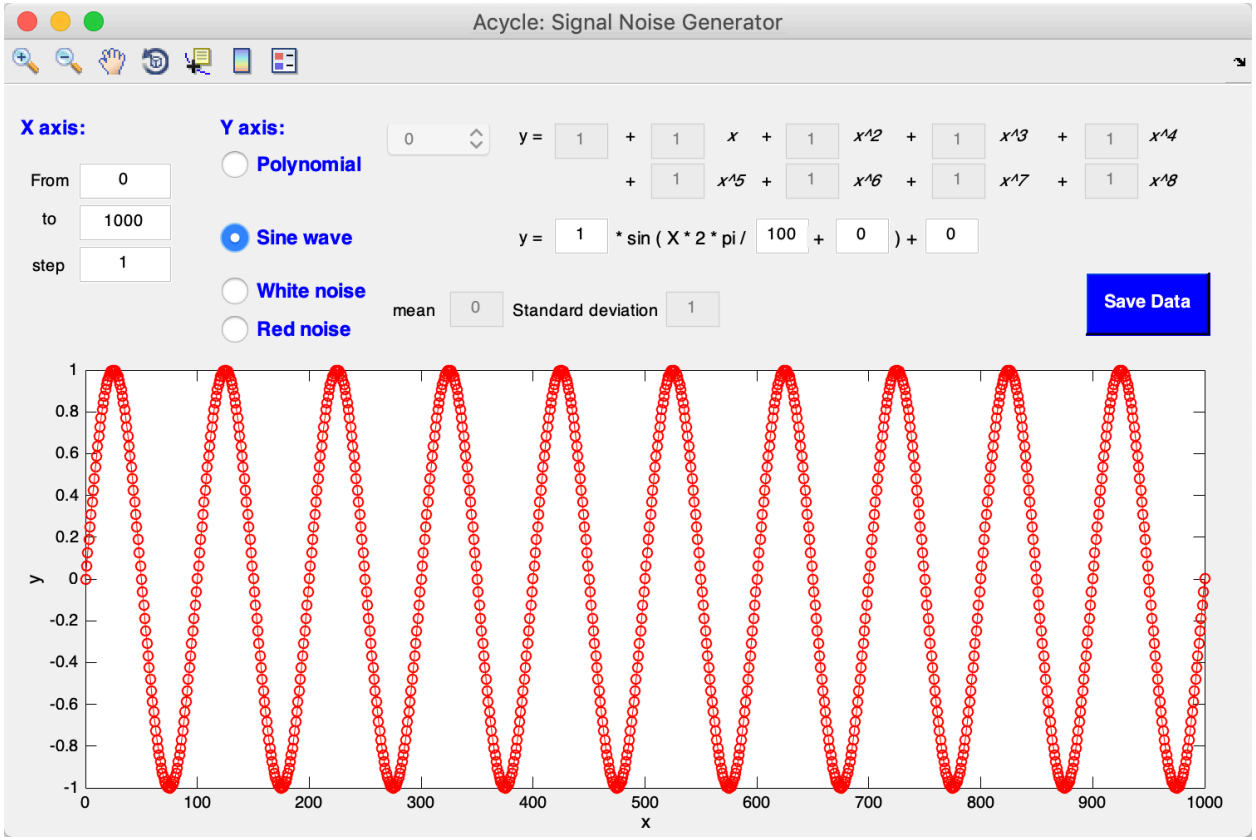
Based on the MatLab code **inso.m** by Jonathan Levine (2001), UC Berkeley.
modified by Peter Huybers (Harvard)
modified by Mingsong Li (Penn State, 2018)

Astronomical Solution

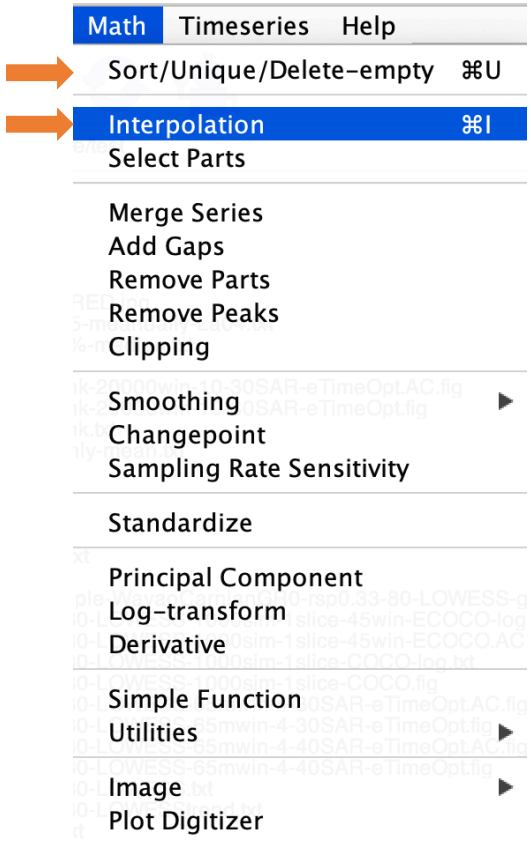




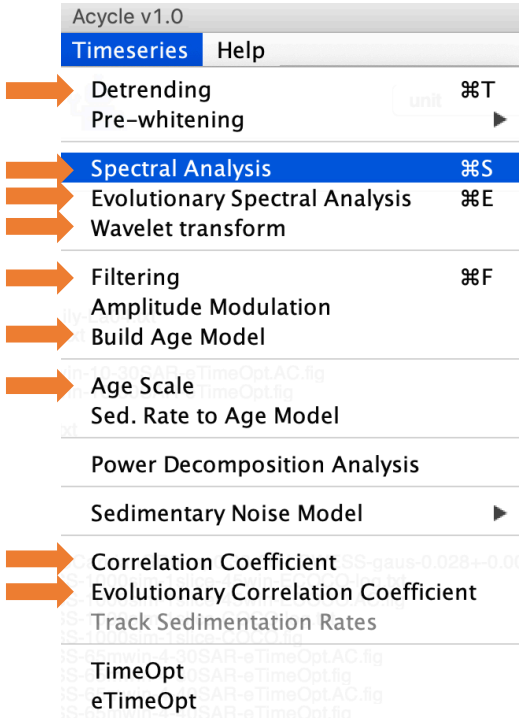
Signal/Noise Generator



Math



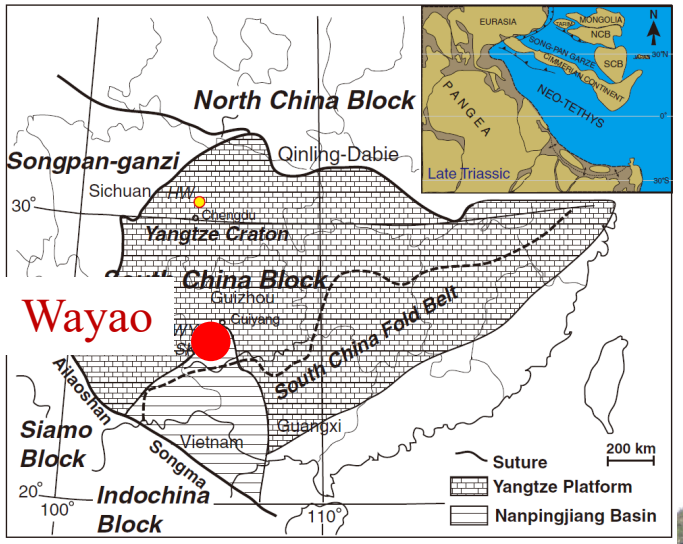
Time series



Case studies:

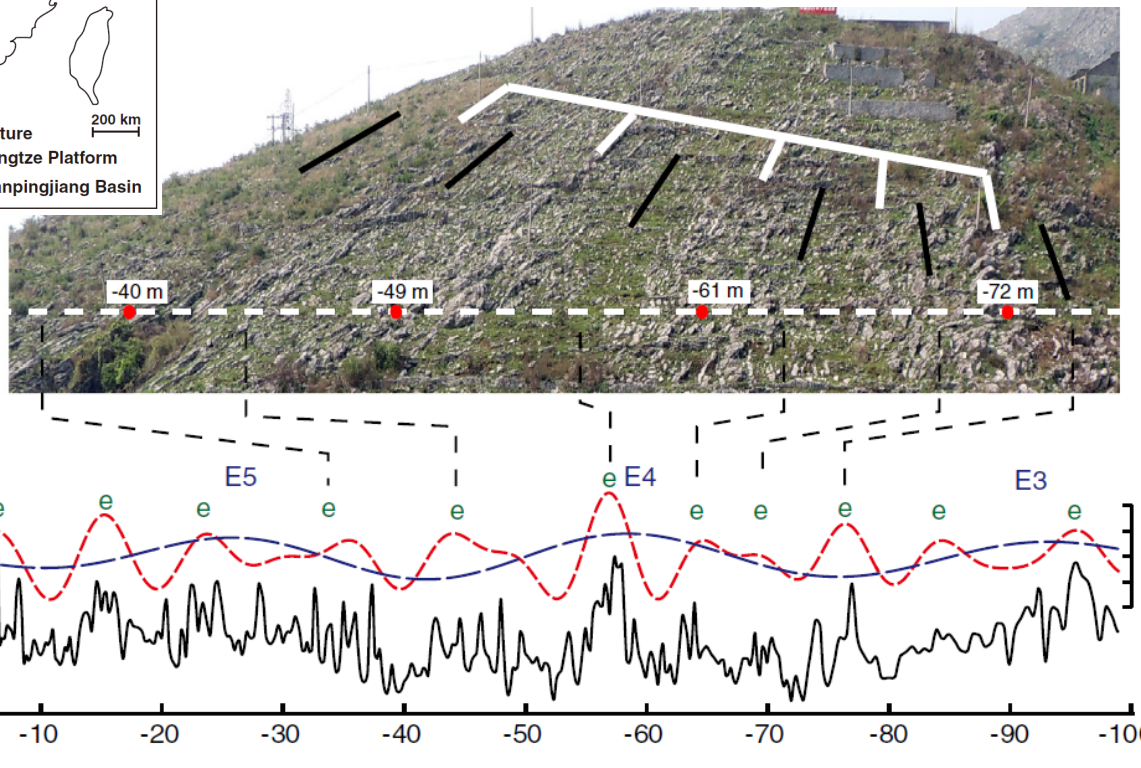
1. **Insolation**
2. **Laskar 2004 astronomical solution**
3. **Carnian cyclostratigraphy** (~235 Ma, Triassic)

Carnian cyclostratigraphy (~235 Ma, Triassic)

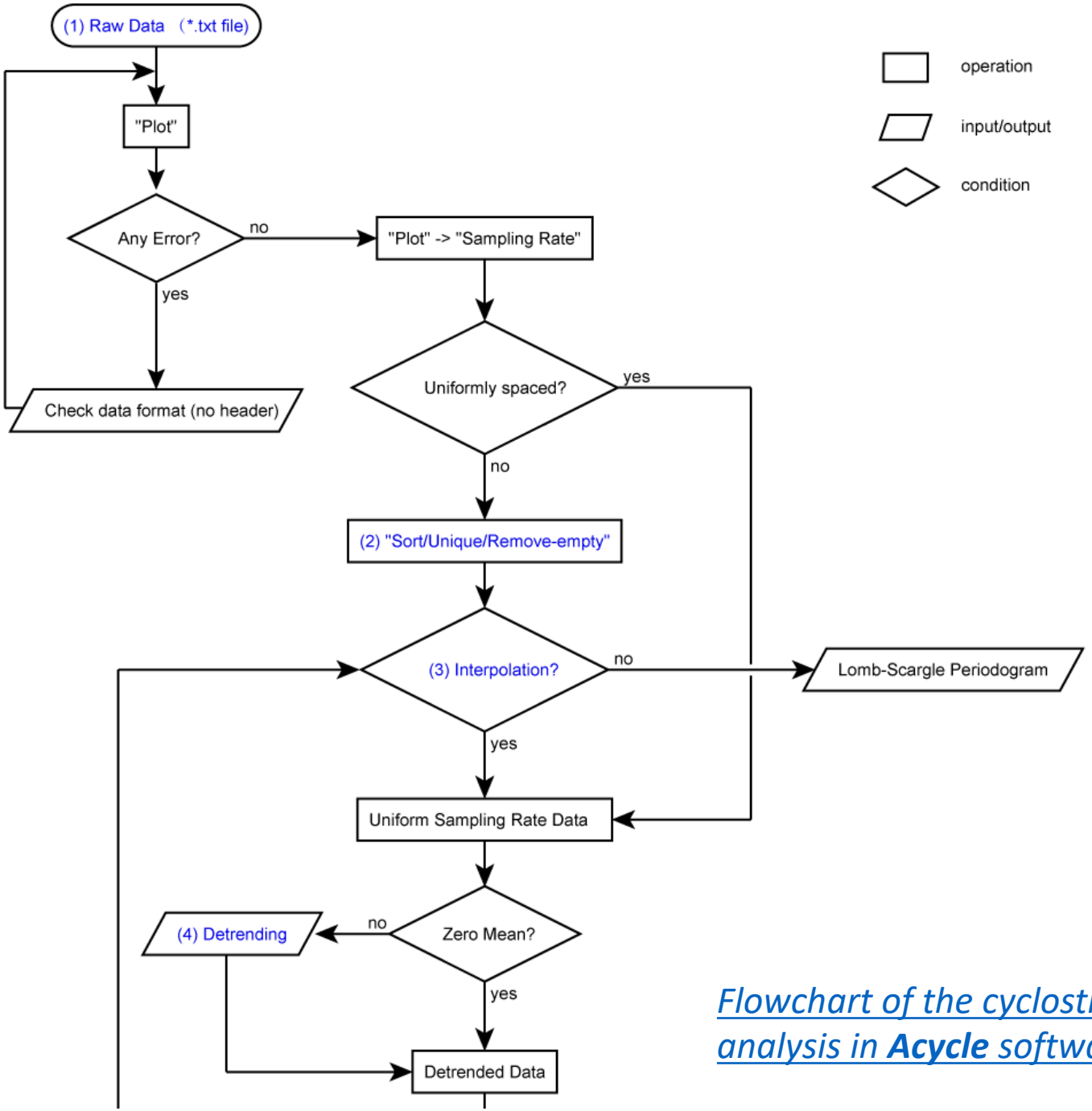


Proxy: gamma-ray with higher intensities indicating higher average clay contents

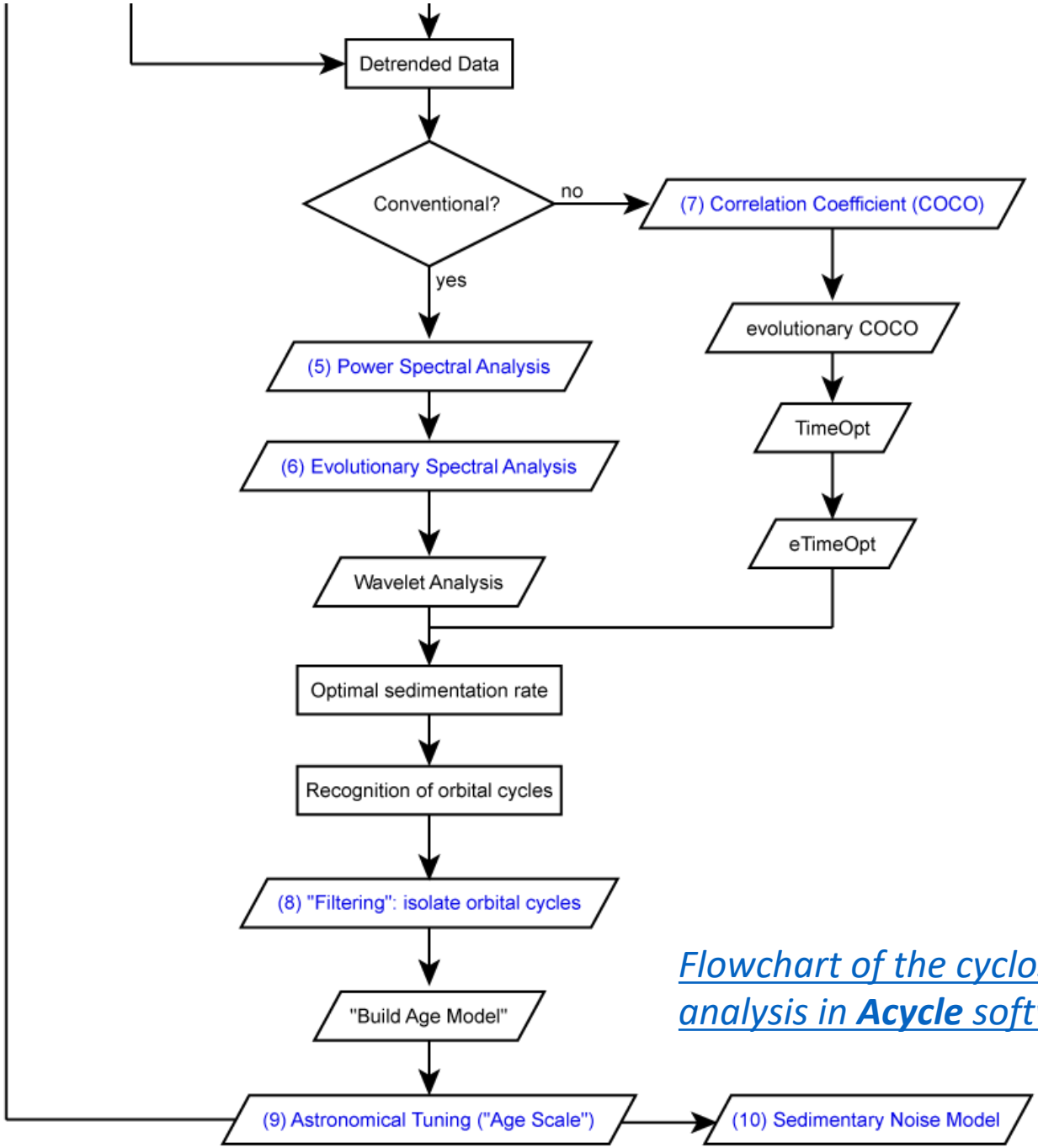
Target: learn typical data process steps



Zhang et al., 2015 Palaeo-3

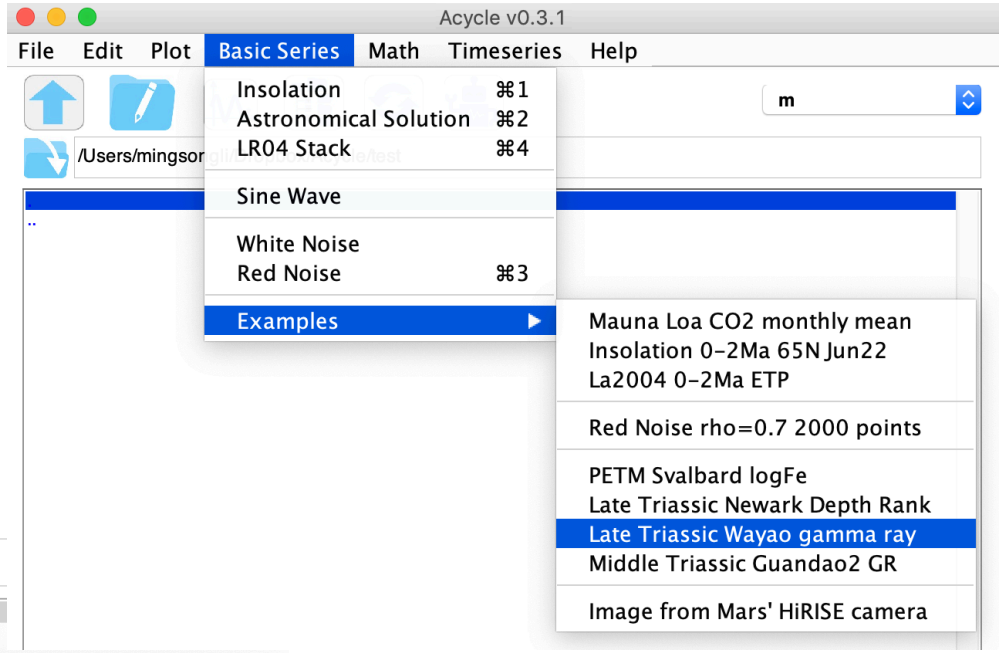


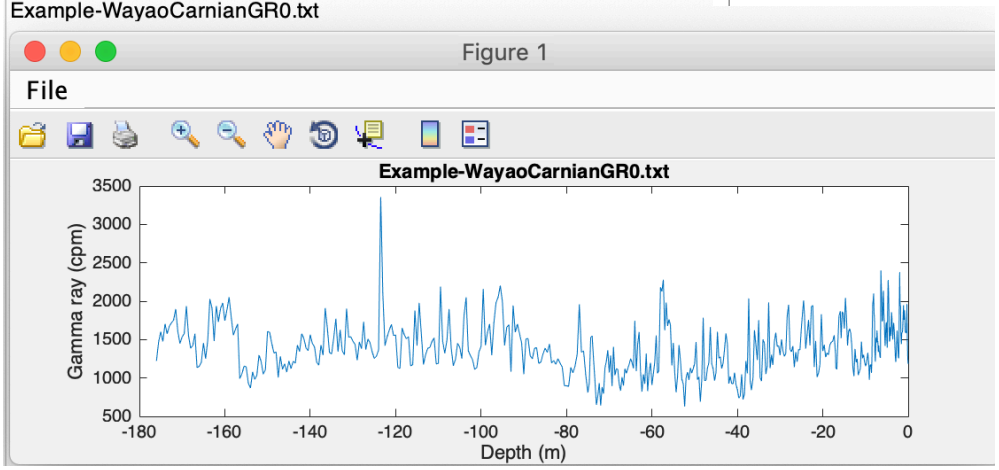
*Flowchart of the cyclostratigraphic analysis in **Acycle** software (1)*



*Flowchart of the cyclostratigraphic analysis in **Acycle** software (2)*

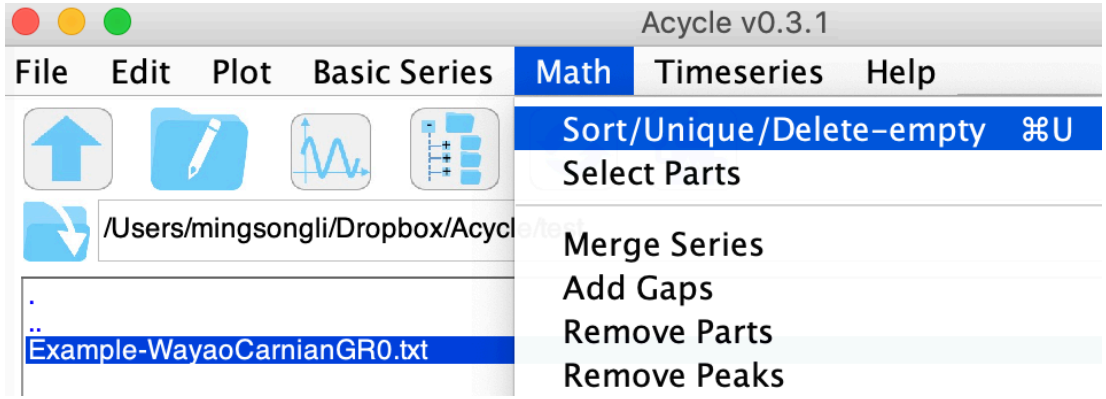
Step 1. Load Data

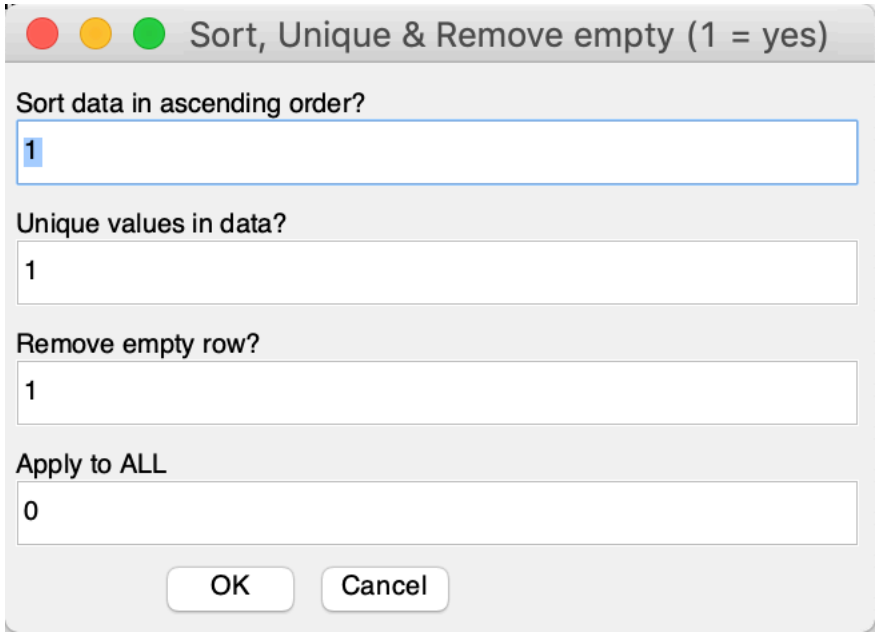




The gamma ray data entitled "Example-WayaoCarnianGR0.txt" will be loaded and displayed in the *Acycle* main window.

Step 2. Data Preparation (optional)

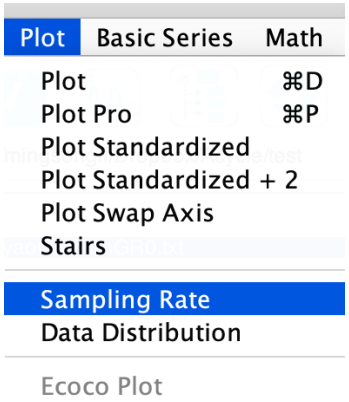


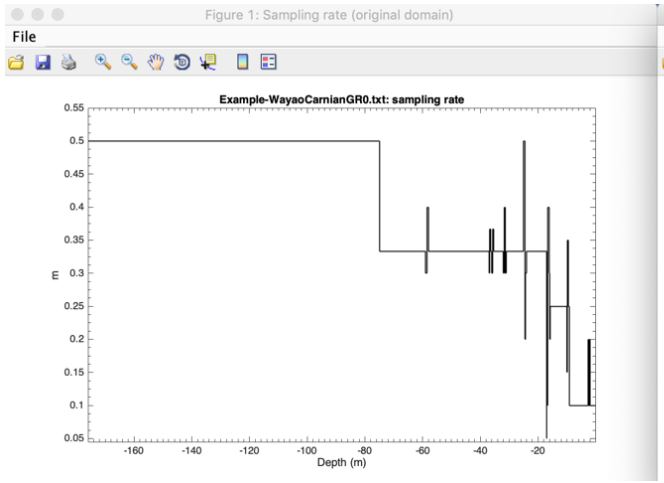


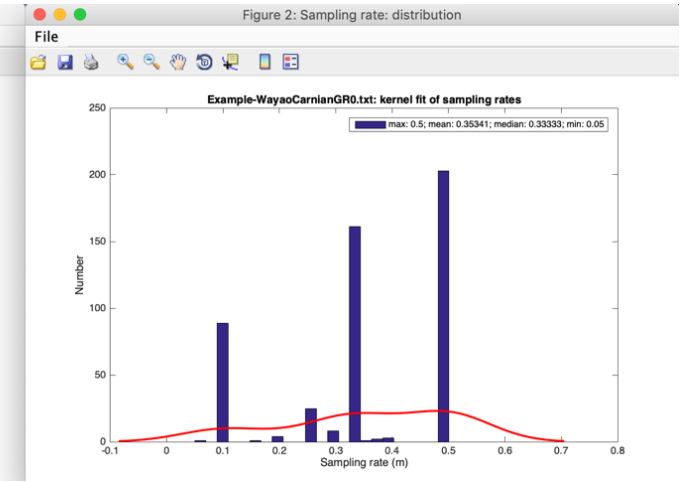
Users can sort data in ascending order. Two or more values for the same time (or depth) may be averaged with the "Unique" function.

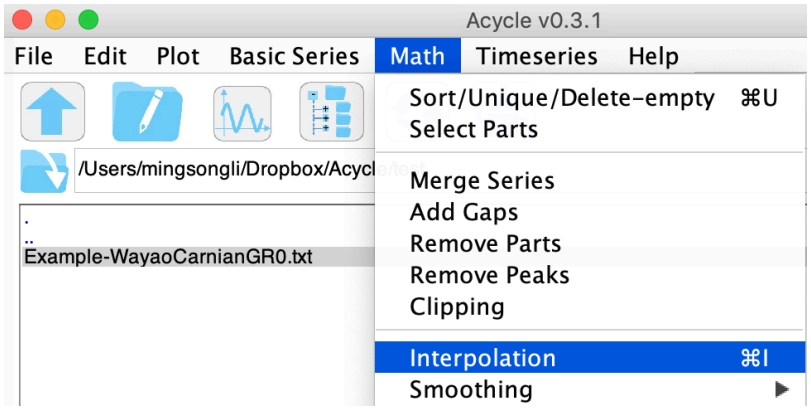
Step 3. Interpolation

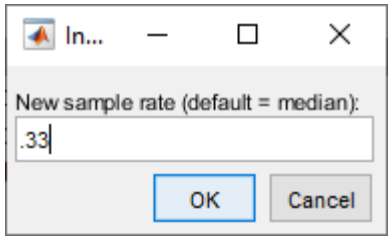
Stratigraphic depth or time series are typically irregularly spaced due to uncertain timescales or difficulty in data collection. This necessitates interpolation to generate uniformly spaced time (or depth) series.







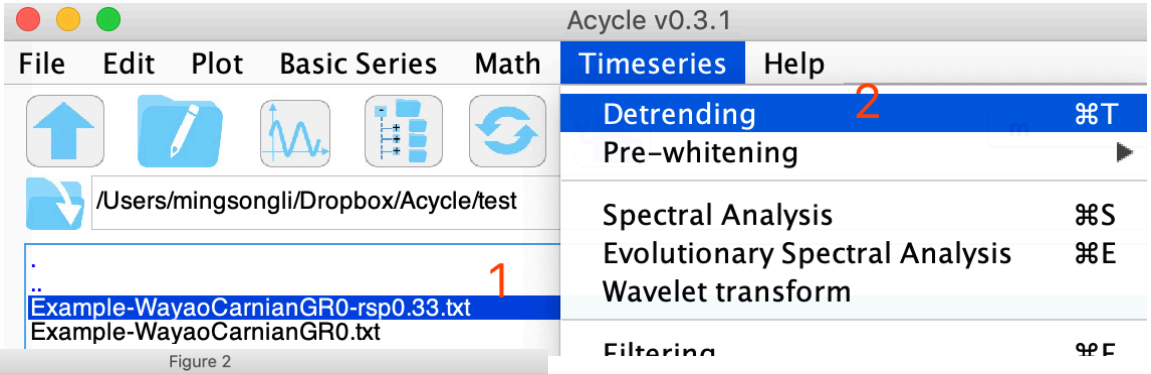


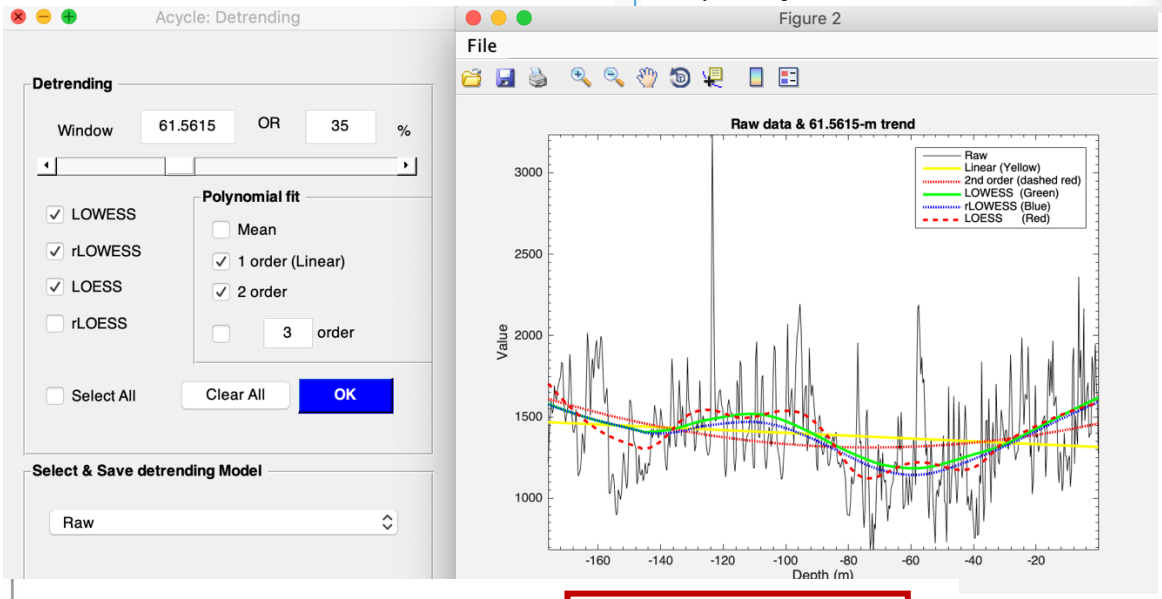


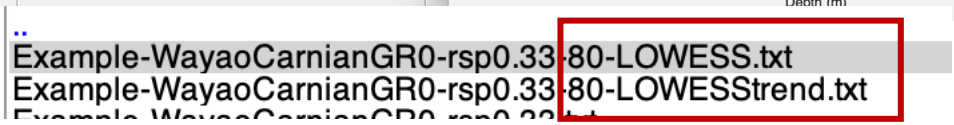
"Example-WayaoCarnianGR0-rsp0.33.txt".

Step 4. Detrending

Detrending is a critical step for power spectral analysis to ensure that data variability oscillates about a zero mean, and to avoid power leakage from very low-frequency components into higher frequencies of the spectrum.



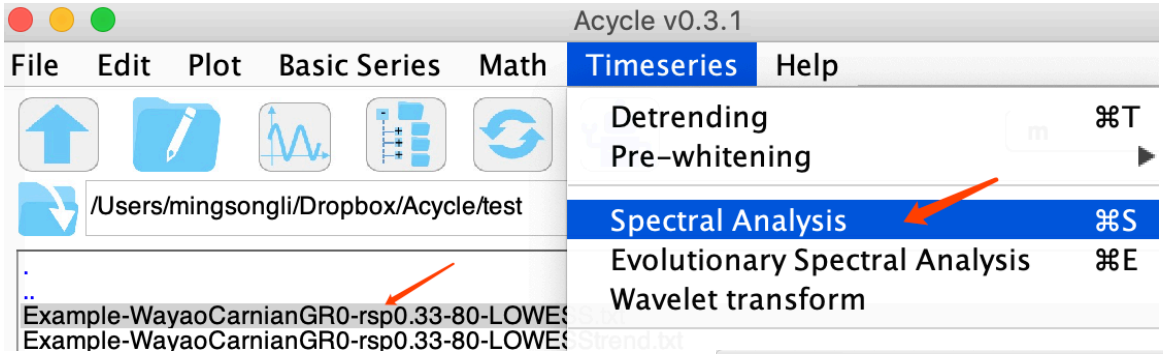


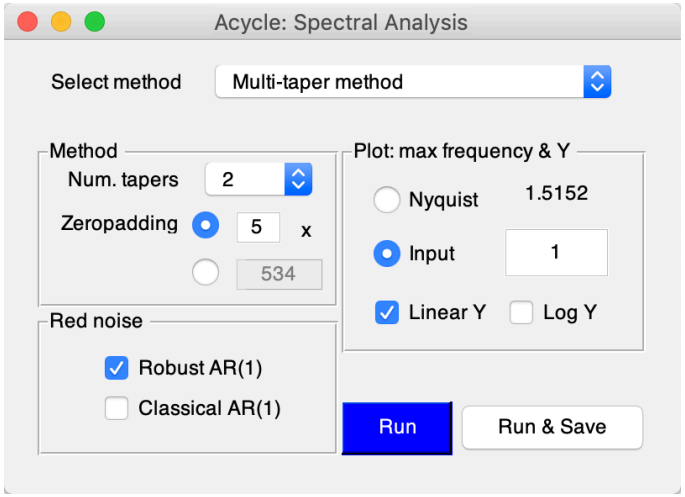


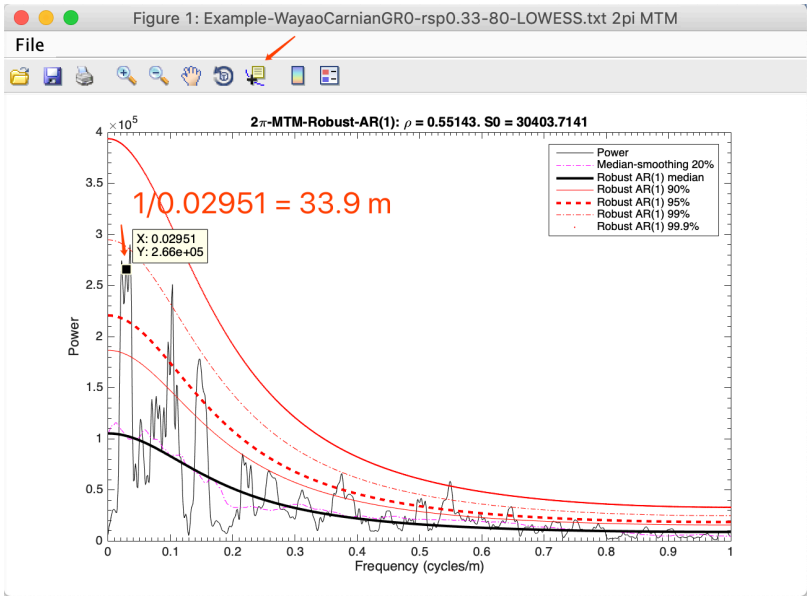
Read More: Detrending

Step 5. Power spectral analysis

Power spectral analysis evaluates the distribution of time series variance (power) as a function of frequency. The primary use of power spectral analysis is for the recognition of periodic or quasi-periodic components in a data series

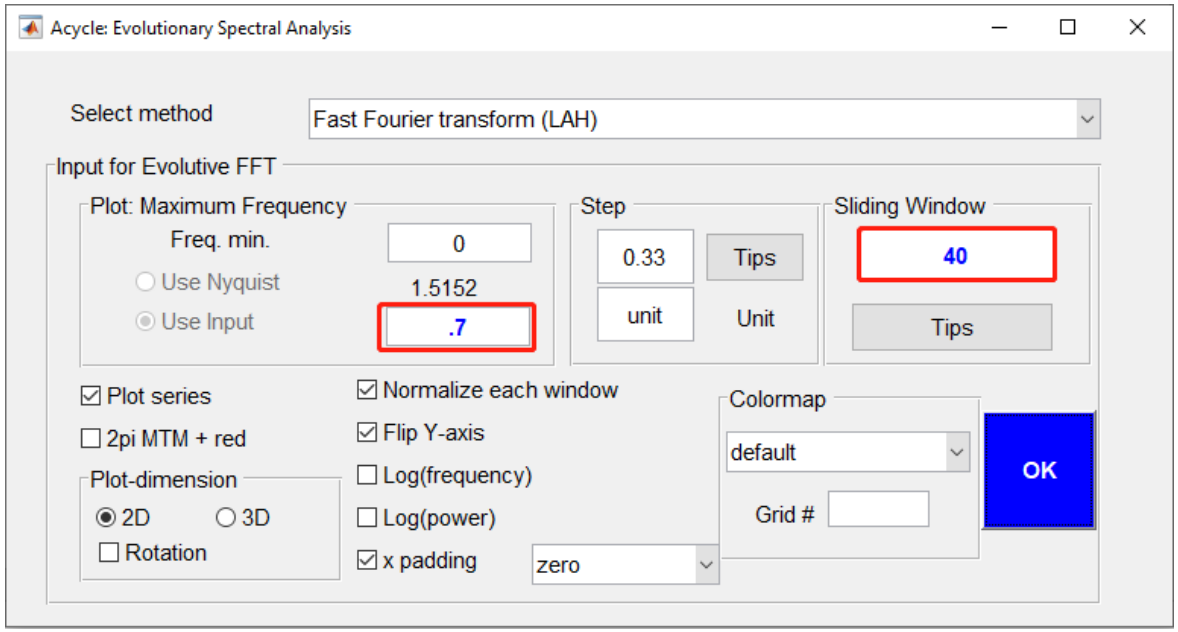


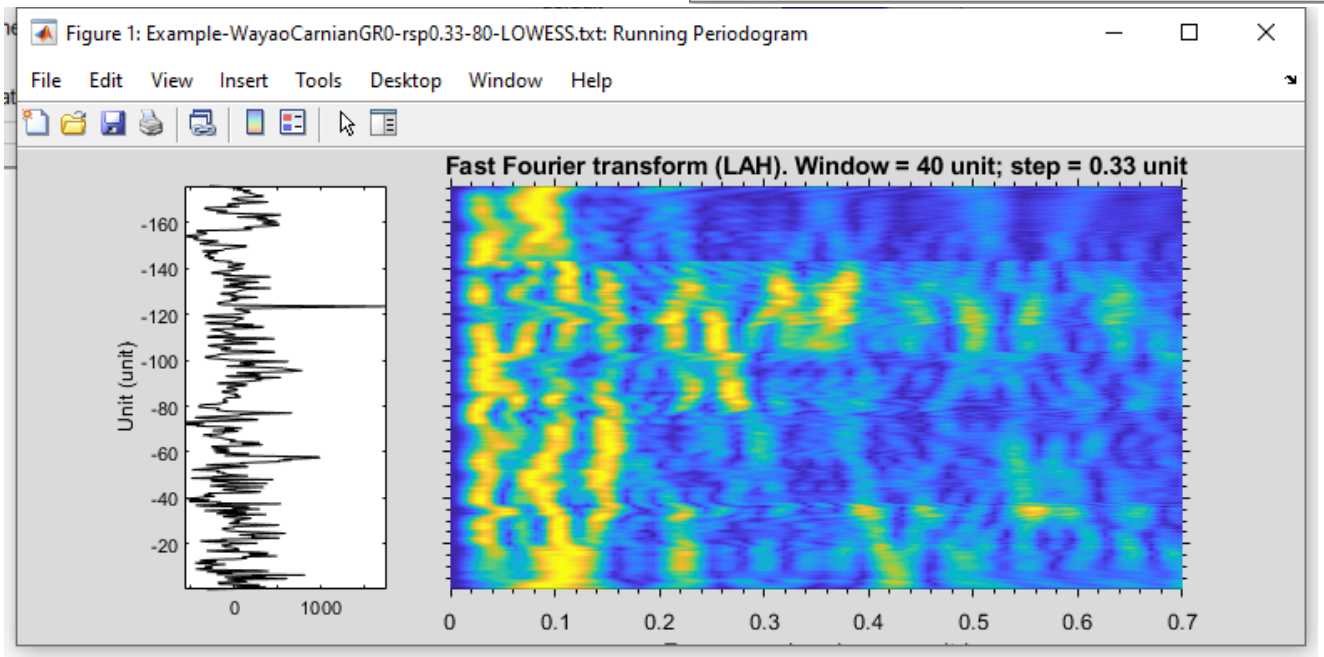




Read More: Spectral Analysis

Step 6. Evolutionary power spectral analysis

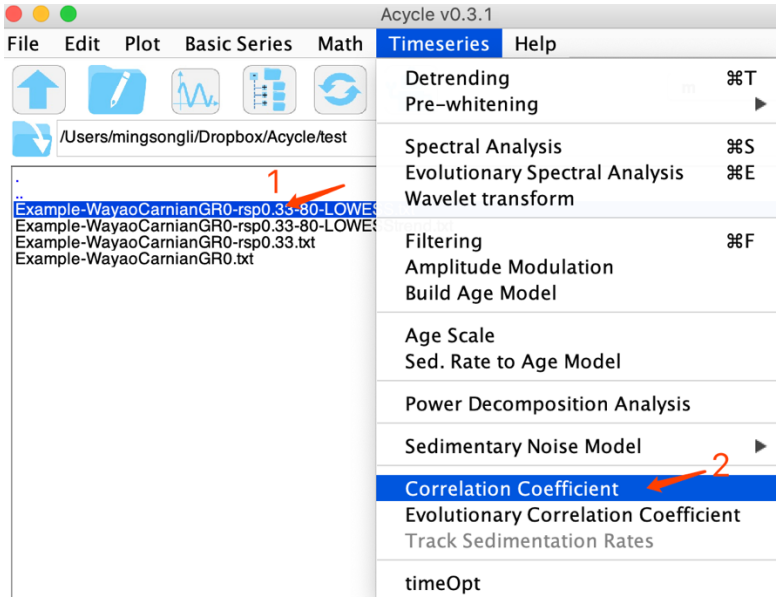


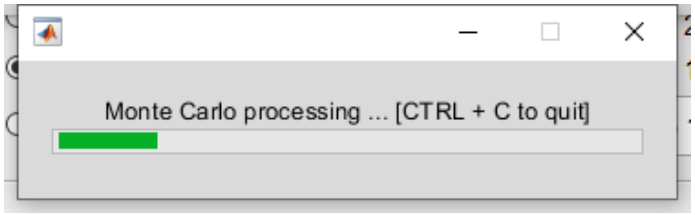


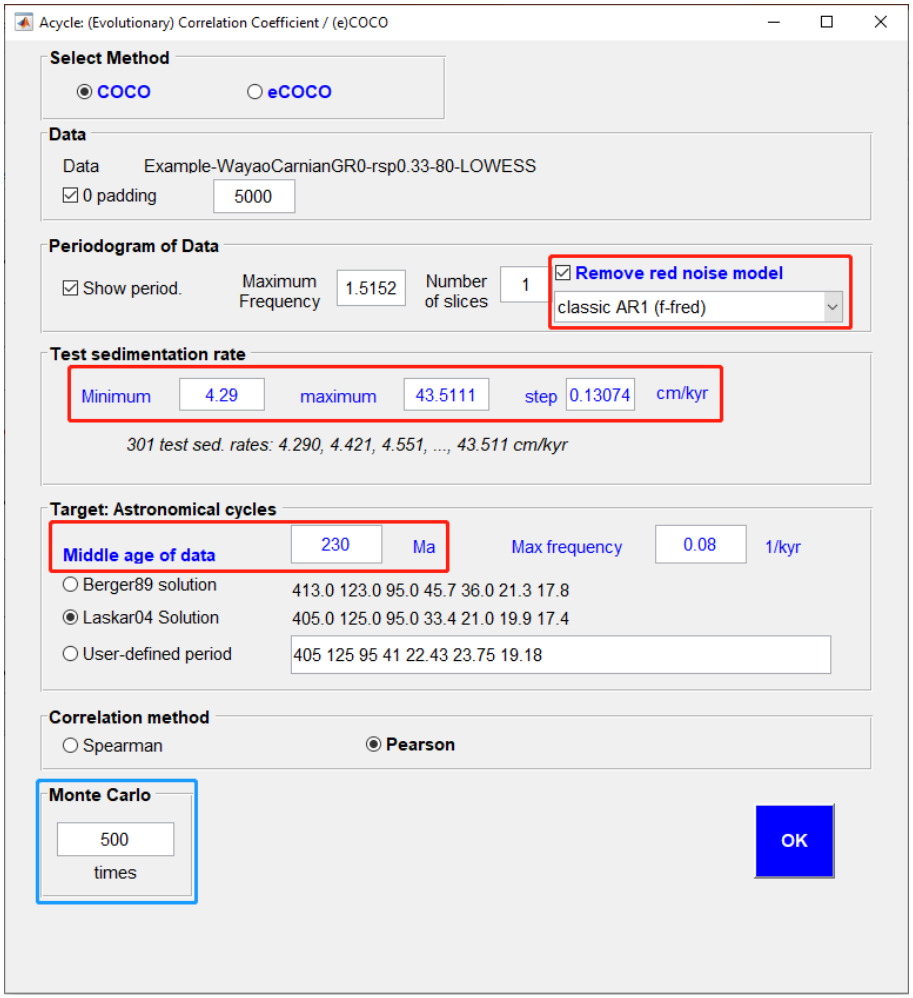
Read More

Step 7. Correlation coefficient

To estimate the optimal sedimentation rate.



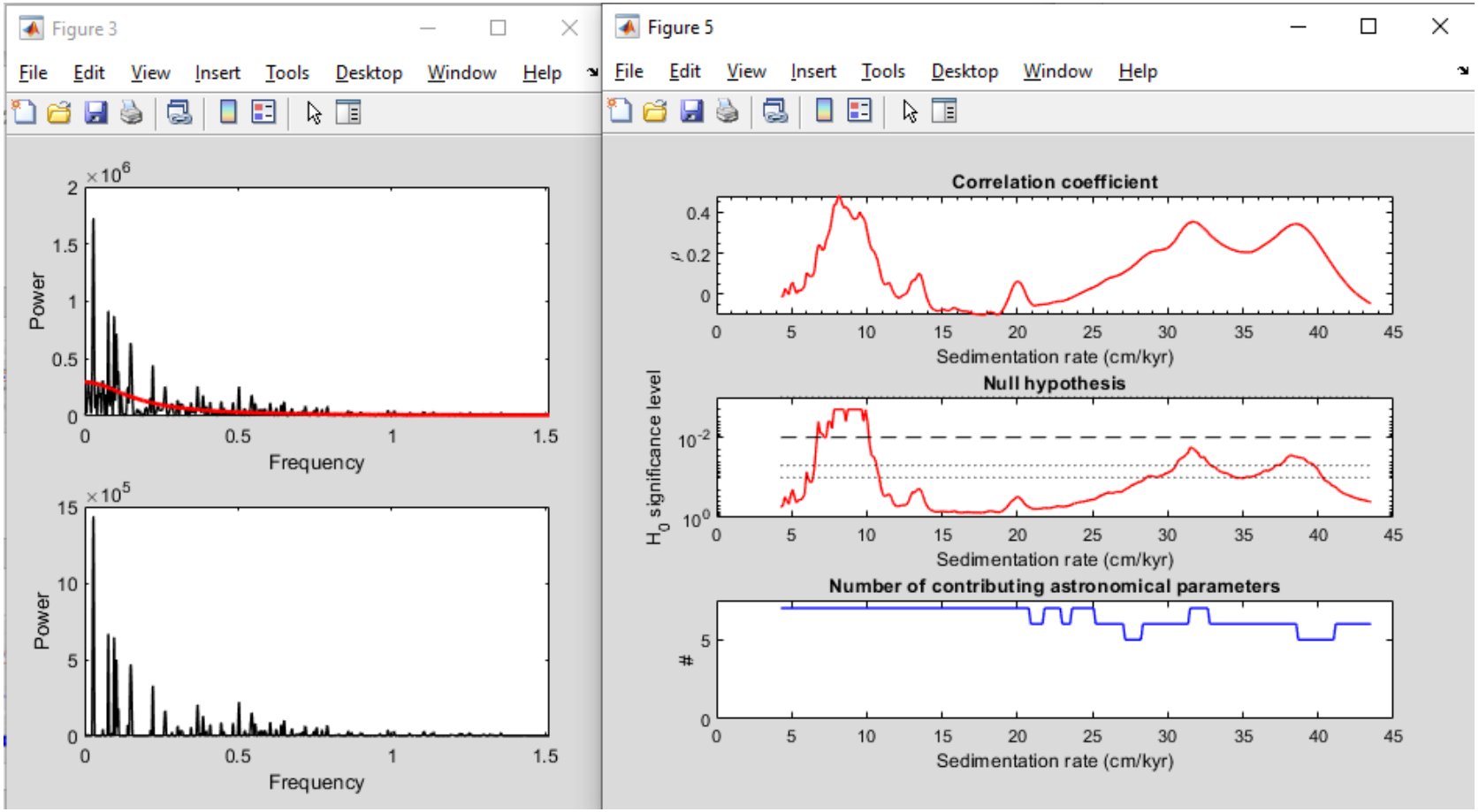




Read More: COCO/eCOCO

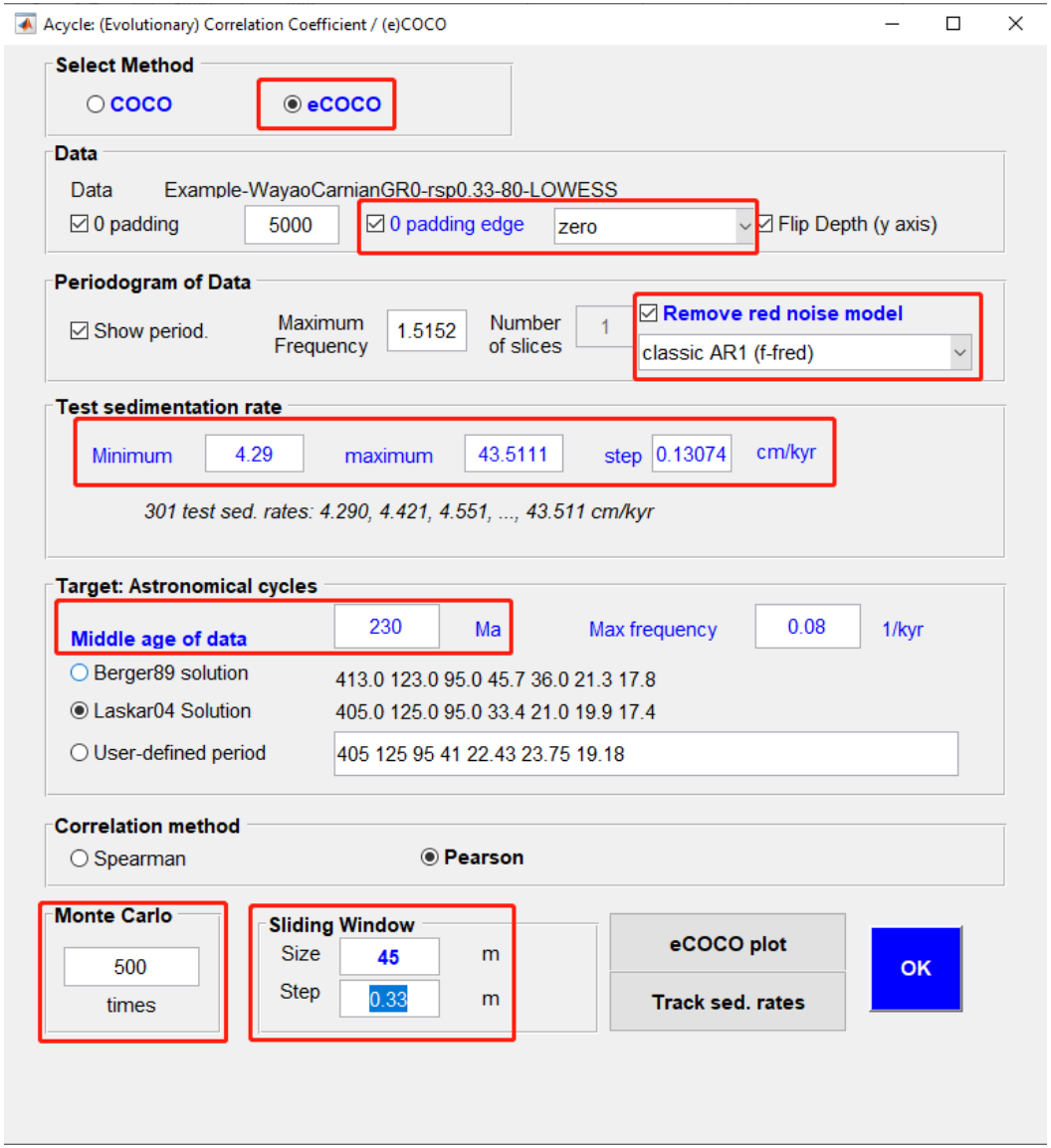
Similar tool: TimeOpt / eTimeOpt

You will have the following figure and a log file saving all settings.



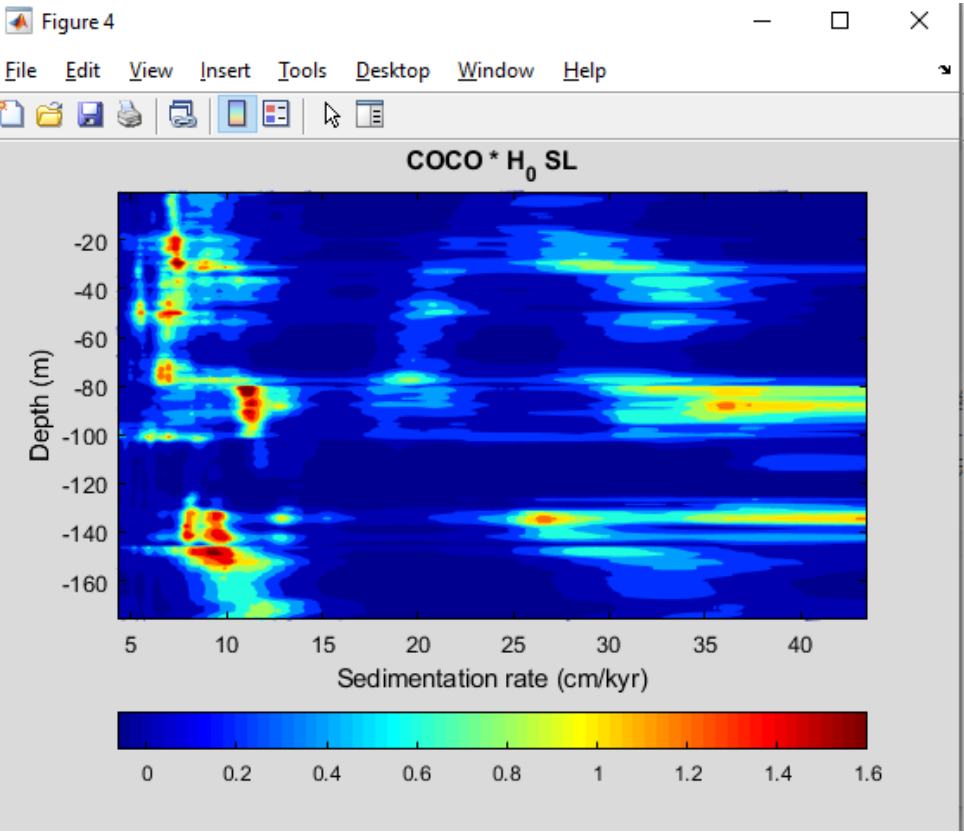
It tells the most likely sedimentation rate is ~9 cm/kyr,
with a null hypothesis (no orbital forcing) significance level of <1%
All seven orbital parameters are used in the estimation.

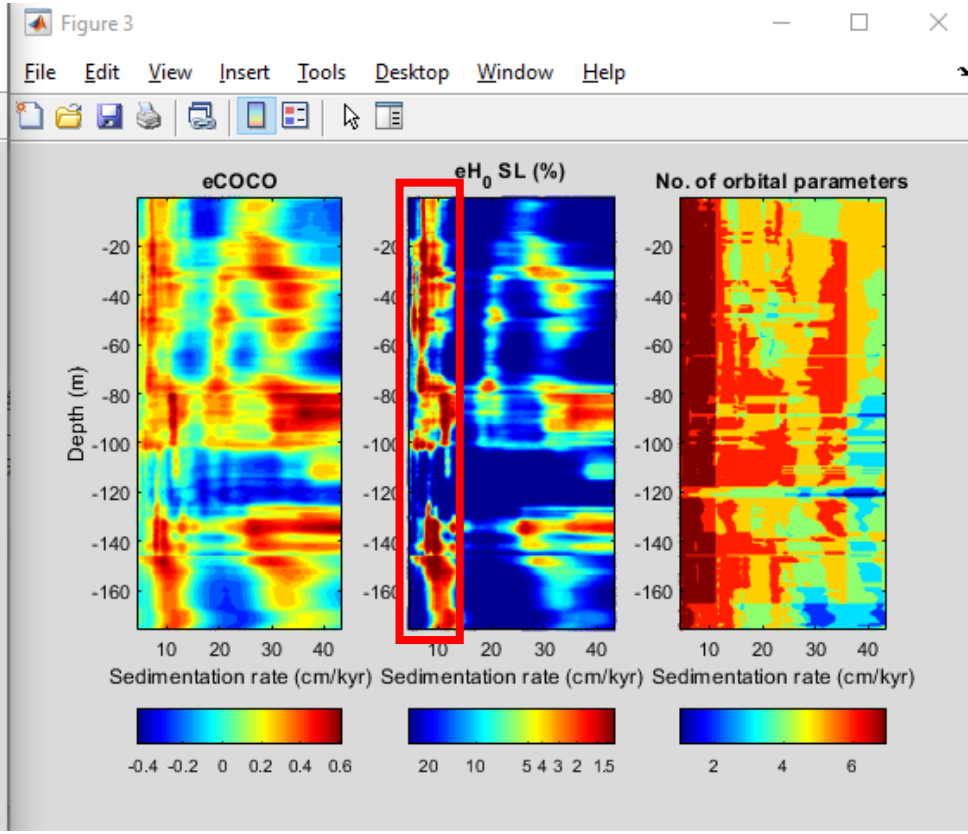
eCOCO analysis to track variable sedimentation rate



Similar tool: [eTimeOpt]

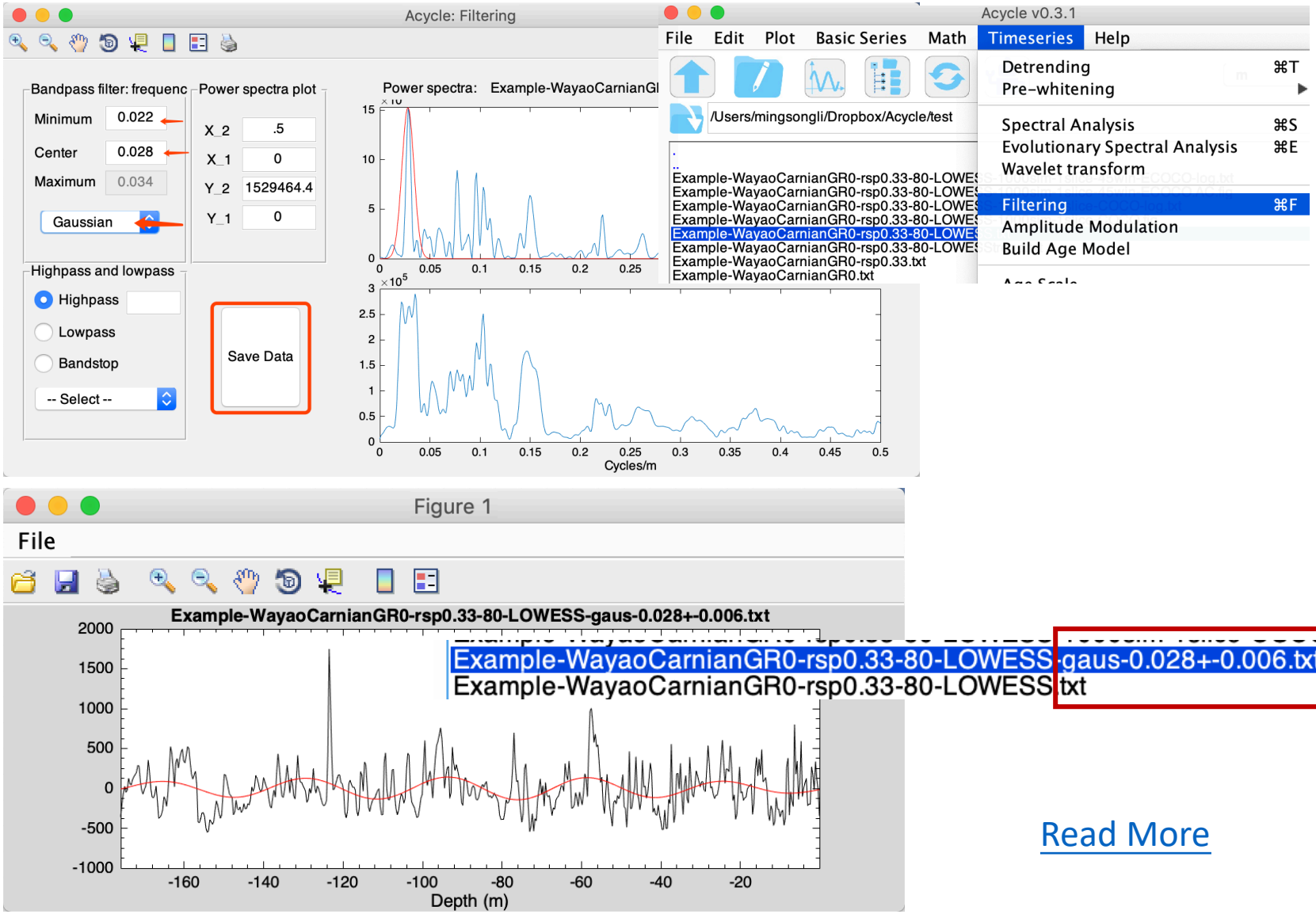
eCOCO analysis to track variable sedimentation rate





Step 8. Filtering

Filters are also essential tools to aid in the isolation of specific frequency components in the paleoclimate data series.

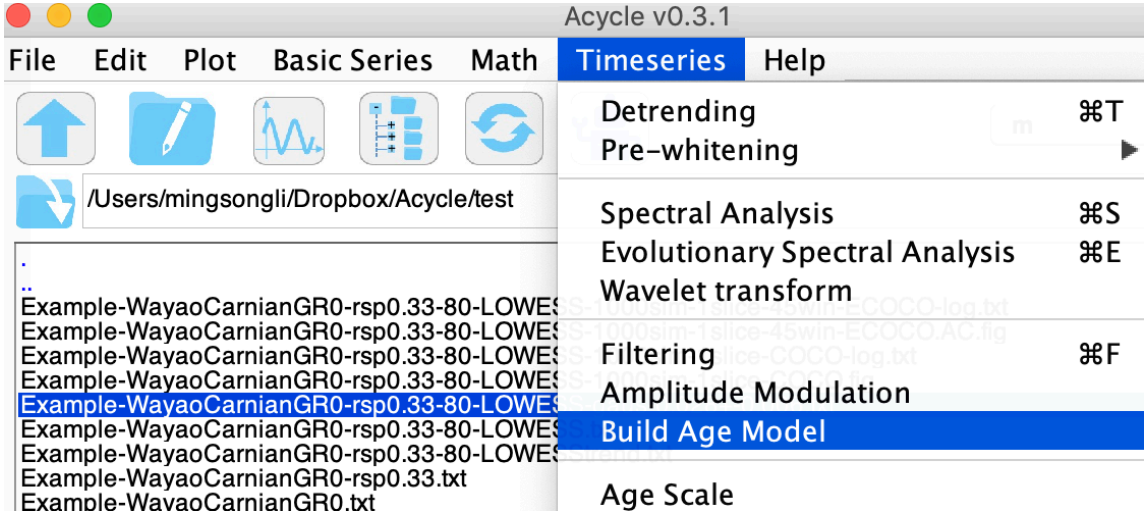


Read More

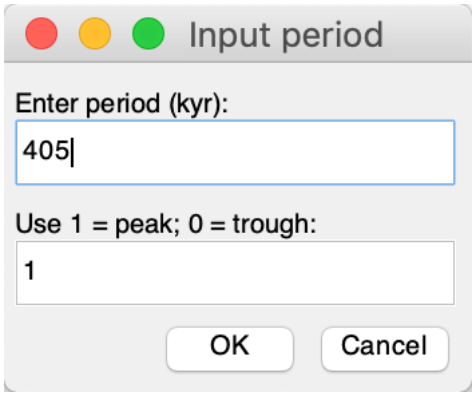
Step 9. Age model and tuning

transform original data (usually in the depth domain) to tuned data (usually in the time domain) when an age model file is available

Select "Example-WayaoCarnianGR0-rsp0.33-80-LOWESS-gaus-0.028+-0.006.txt"



a, Build age model



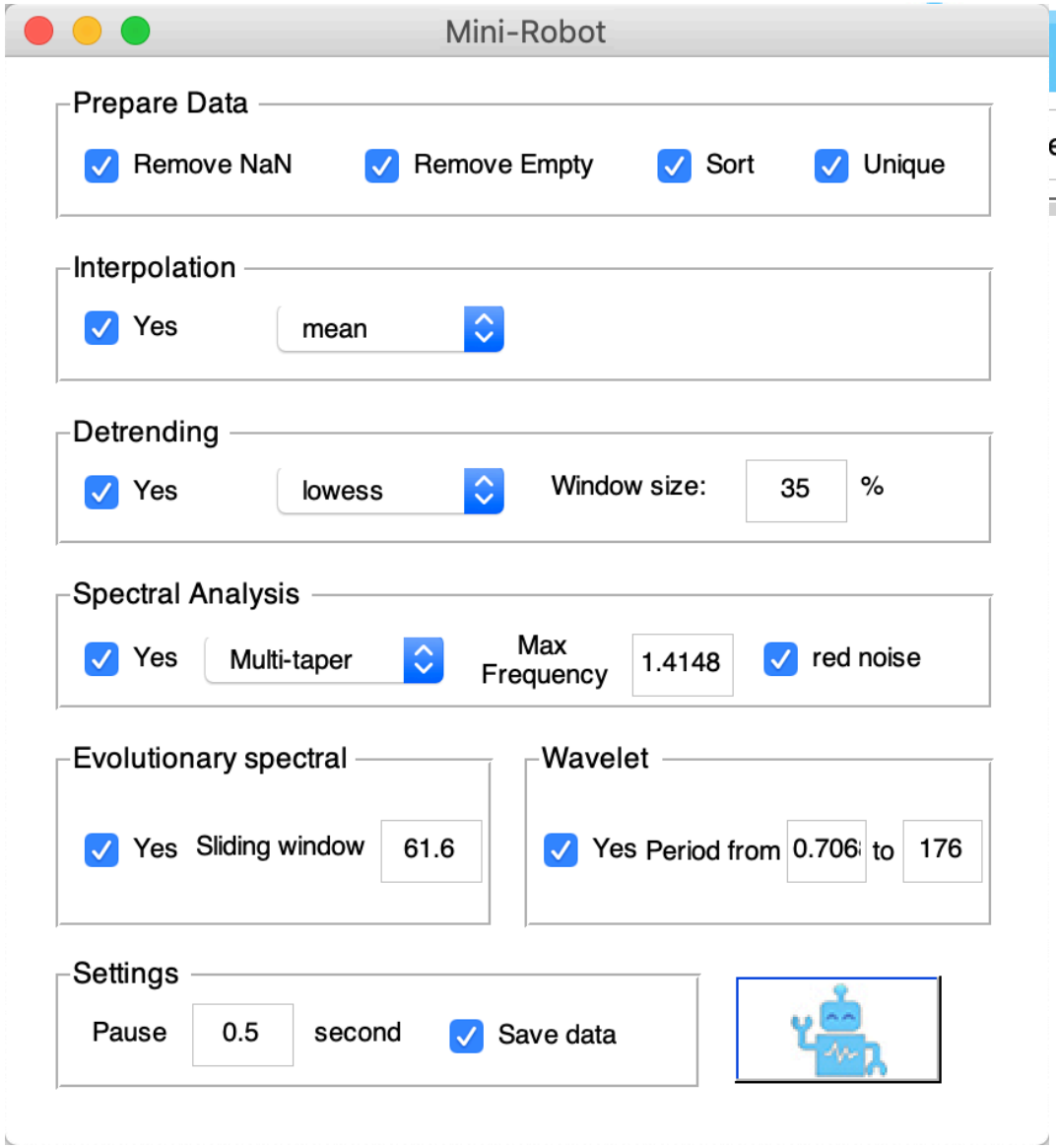
Example-WayaoCarnianGR0-rsp0.33-80-LOWESS-gaus-0.028+-0.006-agemod-405-max.txt

b, Age Scale

Tuned data:
“Example-WayaoCarnianGR0-TD-Example-WayaoCarnianGR0-rsp0.33-80-LOWESS-gaus-0.028+-0.006-agemod-405-max.txt”

Mini robot

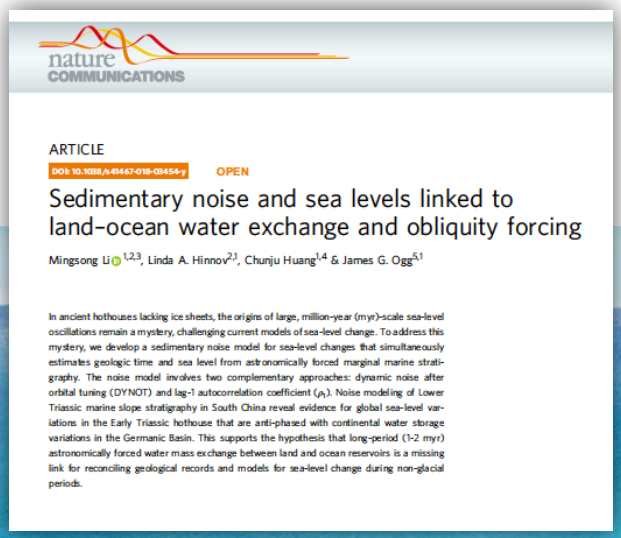

Acycl
File
Edit
Plot
Basic Series
Math
Time
ers/mingsongli/Dropbox/lectures/Acycle/demo


Mini-Robot
Prepare Data
Remove NaN
Remove Empty
Sort
Unique
Interpolation
Yes
mean
Detrending
Yes
lowess
Window size:
35
%
Spectral Analysis
Yes
Multi-taper
Max Frequency
1.4148
red noise
Evolutionary spectral
Yes
Sliding window
61.6
Wavelet
Yes
Period from
0.706
to
176
Settings
Pause
0.5
second
Save data

Other useful tools

Sedimentary noise model

[Lag-1 autocorrelation coefficient (*ρ1*)](#)
[dynamic noise after orbital tuning (DYNOT) model](#)


nature COMMUNICATIONS

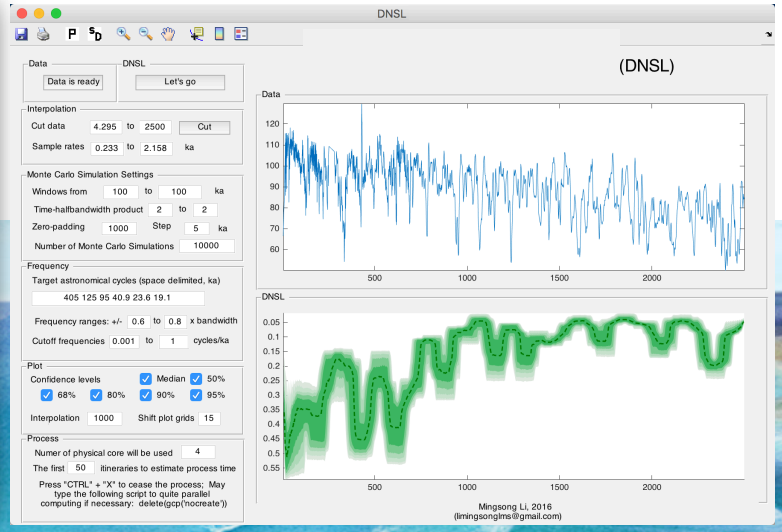
ARTICLE

DOI: 10.1038/s41467-018-08454-y OPEN

Sedimentary noise and sea levels linked to land–ocean water exchange and obliquity forcing

Mingsong Li[1,2,3], Linda A. Hinnov[2,1], Chunju Huang[1,4] & James G. Ogg[5,1]

In ancient hothouses lacking ice sheets, the origins of large, million-year (myr)-scale sea-level oscillations remain a mystery, challenging current models of sea-level change. To address this mystery, we develop a sedimentary noise model for sea-level changes that simultaneously estimates geologic time and sea level from astronomically forced marginal marine stratigraphy. The noise model involves two complementary approaches: dynamic noise after orbital tuning (DYNOT) and lag-1 autocorrelation coefficient (ρ_1). Noise modeling of Lower Triassic marine slope stratigraphy in South China reveal evidence for global sea-level variations in the Early Triassic hothouse that are anti-phased with continental water storage variations in the Germanic Basin. This supports the hypothesis that long-period (1-2 myr) astronomically forced water mass exchange between land and ocean reservoirs is a missing link for reconciling geological records and models for sea-level change during non-glacial periods.

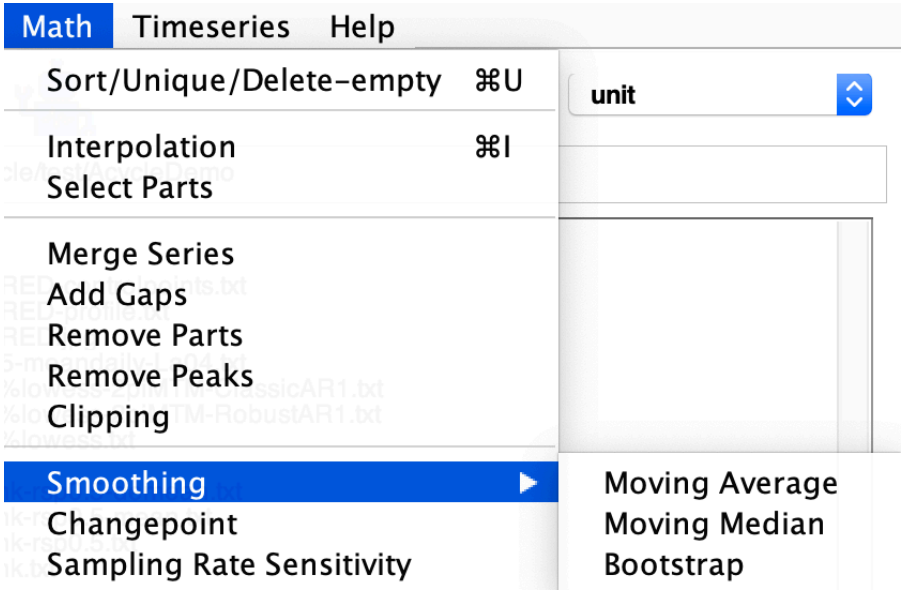


Li, et al., 2018
Nature Communications

Ancient ocean

Credit: Hewei Duan

Smoothing


Math
Timeseries
Help
Sort/Unique/Delete-empty ⌘U
Interpolation ⌘I
Select Parts
Merge Series
Add Gaps
Remove Parts
Remove Peaks
Clipping
Smoothing
Changepoint
Sampling Rate Sensitivity
unit
Moving Average
Moving Median
Bootstrap

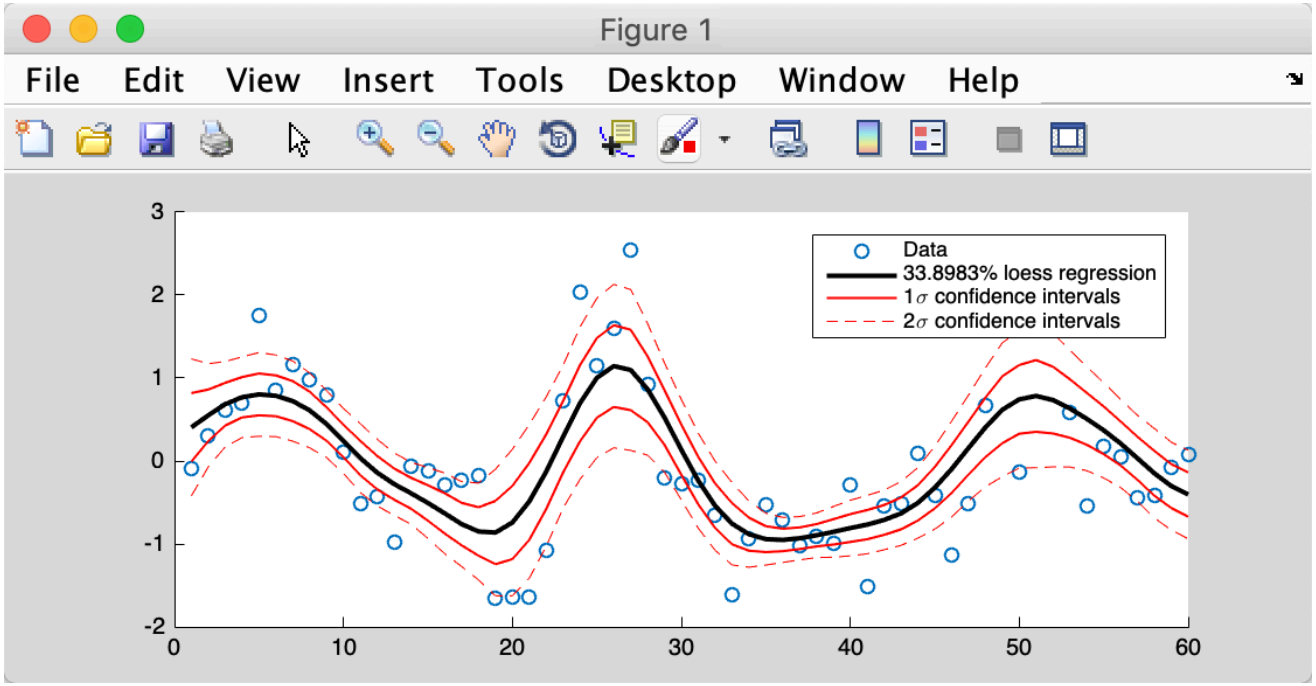
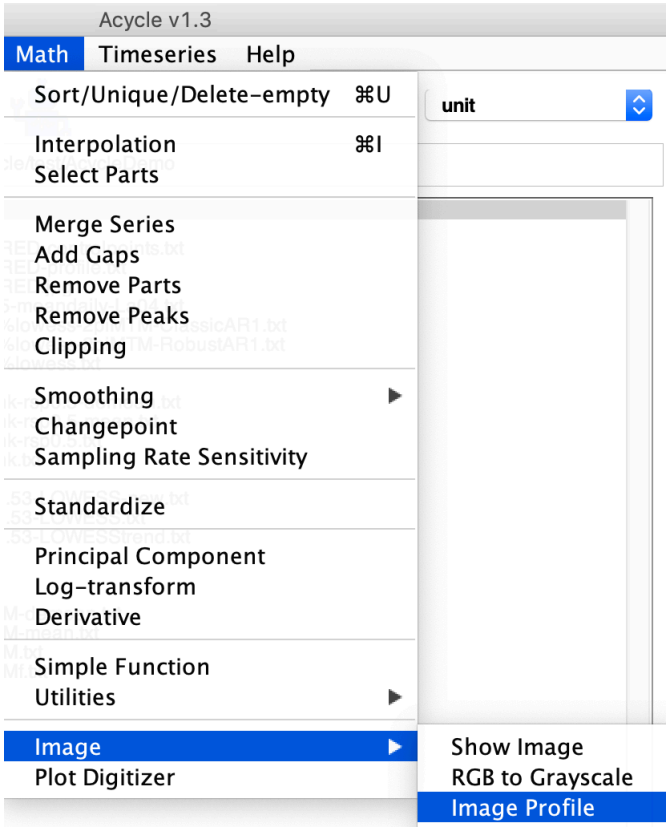
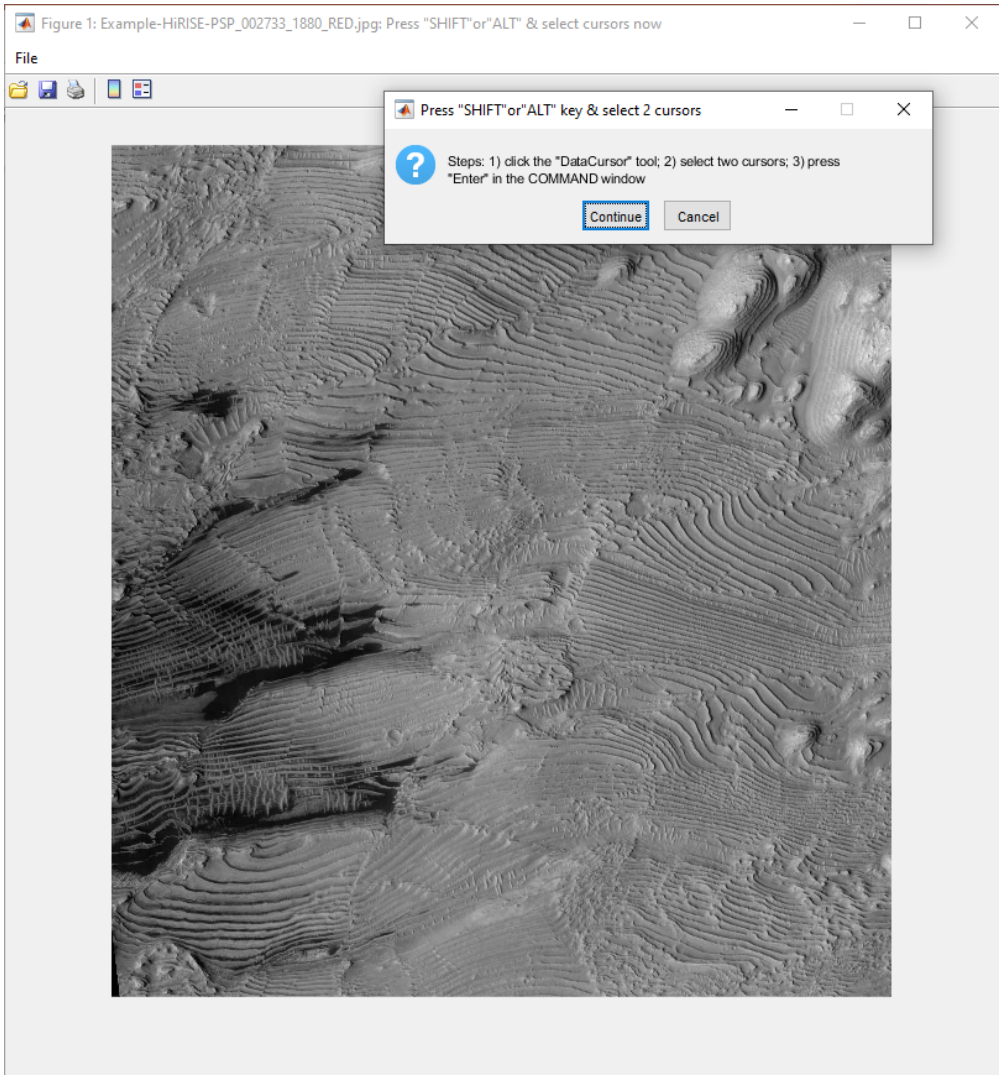


Figure 1
File Edit View Insert Tools Desktop Window Help
Data
33.8983% loess regression
1σ confidence intervals
2σ confidence intervals
3
2
1
0
-1
-2
0
10
20
30
40
50
60

‘Image’ Tool

1. Select an image file
2. Select “Show Image”
3. (Optional) Transfer an RGB image to Grayscale image: Select “RGB to Grayscale”

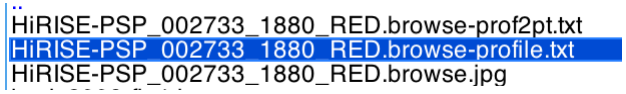


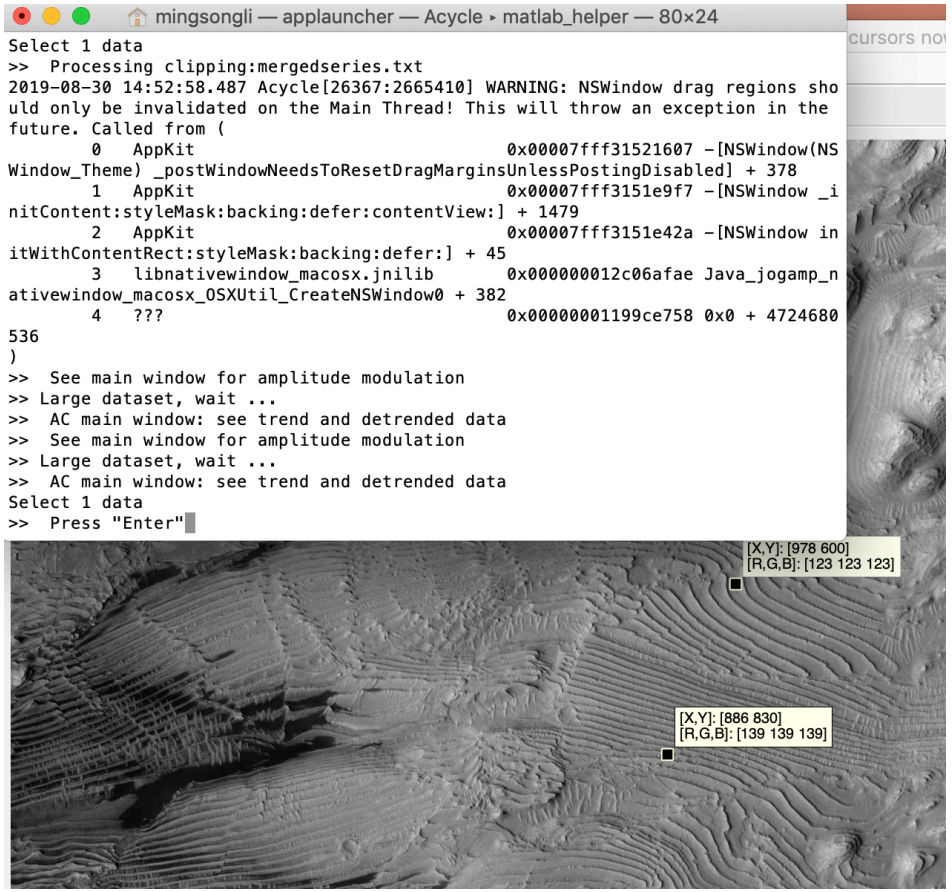


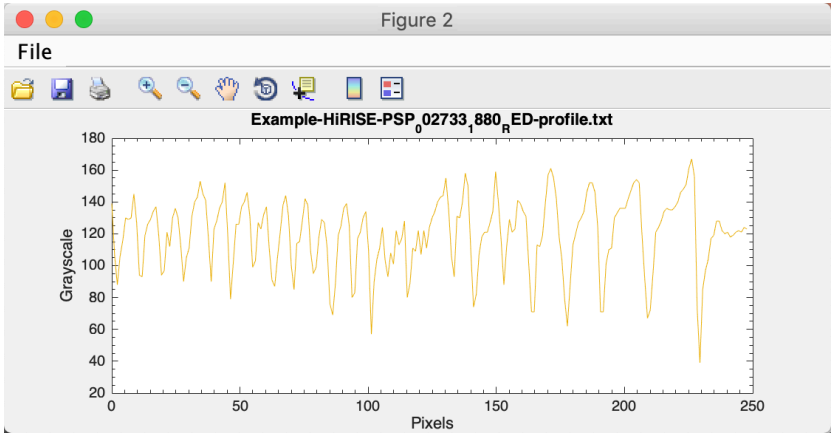
‘Image’ Tool

4: Image Profile
5: Press ALT key, select 2 cursors
6. Press “Enter” **in the terminal window**

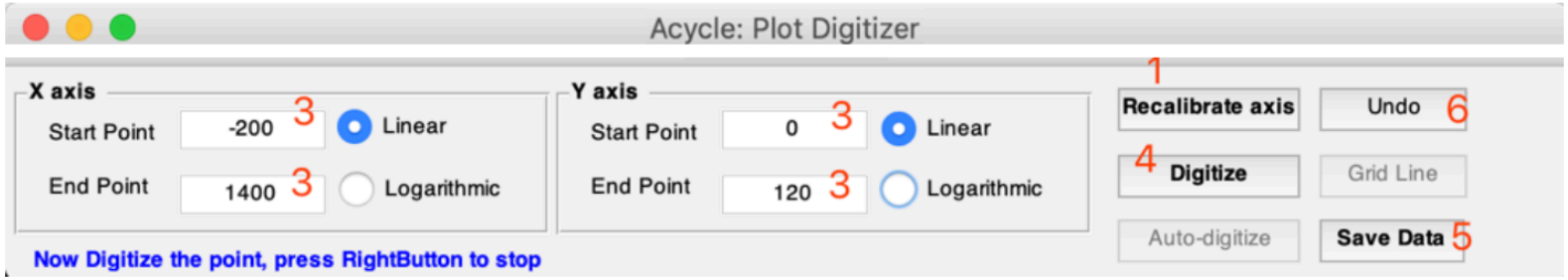
Step 6

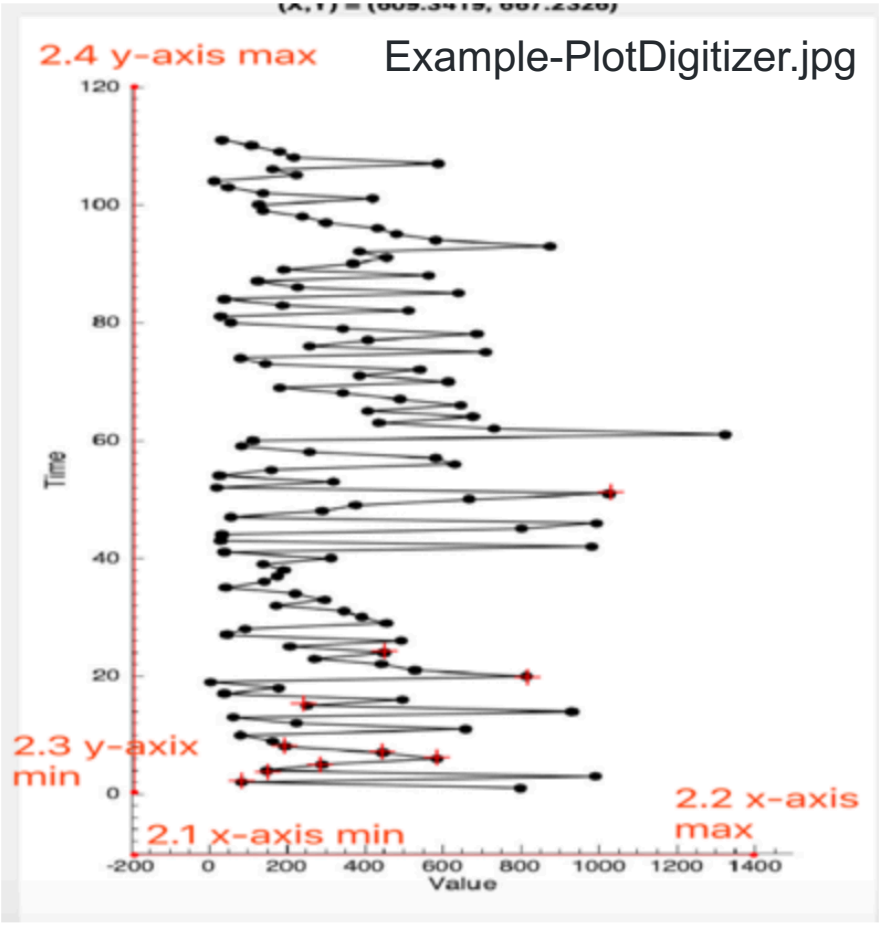






Plot Digitizer





DataExtractTab

	No.	X	Y
1	1	76.9231	1.9835
2	2	144.6154	3.4711
3	3	280.0000	4.7107
4	4	581.5385	5.9504
5	5	440.0000	6.9421
6	6	187.6923	7.9339
7	7	236.9231	15.1240
8	8	815.3846	19.5868
9	9	446.1538	24.0496
10	10	1.0308e+03	51.0744

Acknowledgement

Linda Hinnov

Lee Kump

Astronomical solution: Jacques Laskar, Richard Zeebe
Changepoint: Eric Ruggieri
Insolation: Jonathan Levine, Peter Huybers
Padding: Nicolas R. Thibault
Spectral Moments: Matthias Sinnesael
TimeOpt/eTimeOpt: Steve Meyers
Wavelet: Christopher Torrence, Gilbert Compo

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PENNSTATE 1855

Feng Cheng, Anne-Christine Da Silva, Hewei Duan, Yanan Fang, Marco Franceschi, Daniel R. Franco, Xiaoni Hu, Dorothée Husson, Arsenio Muñoz Jiménez, Dongyang Liu, James Ogg, Paul Olsen, J. Fred Read, Chen Shen, Chuanyue Wang, Mathieu Martinez, Meng Wang, Xu Yao, Qiyan Zhang, Yang (Wendy) Zhang, Christian Zeeden

Make it a better software for your own research.
ANY feedback is highly appreciated!!!

Email: mul450@psu.edu; limingsonglms@gmail.com
https://github.com/mingsongli/acycle/issues

Please cite:

Li, M., Hinnov, L., Kump, L. (2019) *Acycle*: Time-series analysis software for paleoclimate research and education. Computers & Geosciences 127, 12-22.

and other relevant publications.

Thank you!