Early Warning Signals Toolbox: A novel approach for Detecting Critical Transitions Part 2 & 3 - Datasets and Executables

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In this section we present the datasets used for the demonstration of our toolbox, the executable (code) that we developed, and a simple instruction-manual for its execution and reproduction. The datasets, the toolbox code, and the demo are all provided in *earlywarnings_ code.zip* and also available to download from `github.com/earlywarningtoolbox`.

1 Datasets

We illustrate our toolbox with two time series: simulated data and real-world data. The simulated data come from a widely-used model that simulates the dynamics of a resource (like cattle biomass, or vegetation) under harvesting. In this model, the gradual increase in harvesting leads to the collapse of the resource biomass from a high to a low state (Fig. 1a). This is a classical case of a system exhibiting a critical transition at which the system shifts from one stable state to an alternative stable state via a bifurcation point. This case represents an archetypical dynamical case of a critical transition that is characterized by critical slowing down and can be in theory anticipated by generic early warning signals.

The second dataset is a real-world climate time series. After the last glaciation period, the Earth shifted into an another cold state (Younger Dryas) from which it exited to a warmer, similar to present, state around 11,500 years ago (Fig. 1b). This shift was

connected to slowly changing conditions in the ocean that led to the collapse of the thermohaline circulation in the Atlantic. The time series is reconstructed from core data available from world-climate record depositories[1].

For both datasets we used only the pre-transition part of the data (green shaded part of Fig. 1) as we are interested in the potential of our toolbox for early detection.

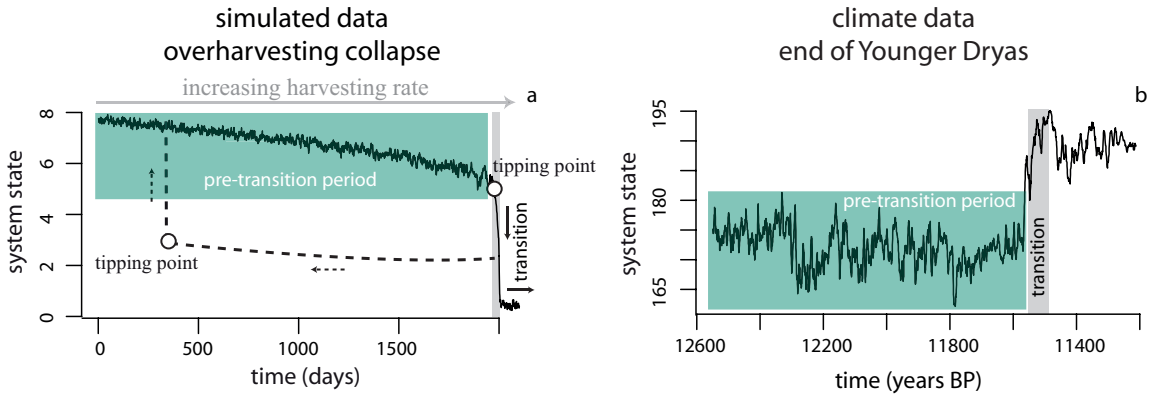

Figure 1: Datasets used: Simulated time series of resource biomass shifting to overexploitation (a), real-world time series of exit from Younger Dryas, the Earth's last climate shift from a cold period to the stable climate conditions as we know them today (b).

2 Executables: Setting up the toolbox

In order to execute the analyses proposed from our toolbox, two things are necessary: 1. to have access to internet, 2. to have R project for Statistical Computing installed on a computer. R can be installed as it is freely available at `www.r-project.org/`. Instructions of how to install it on any operating system is fully documented. If you have R already installed, you need to make sure you are using a version (R>= 2.14.0). If needed, you can run an update of R. Once you have installed R, start the program and, as shown in Fig. 2, copy-paste in the console:

install.packages(c("shiny","devtools","earlywarnings","RJSONIO"));

library(shiny, devtools, earlywarnings, RJSONIO)

[1] `www.ncdc.noaa.gov/paleo/data.html`

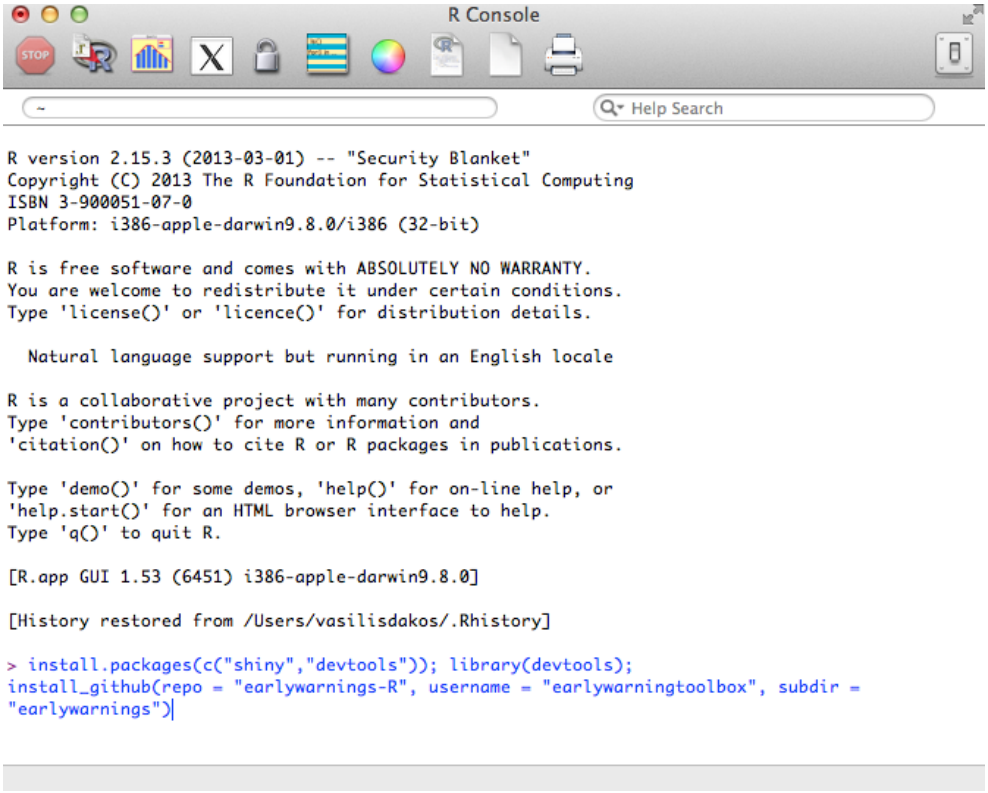

Figure 2: Once R is installed, copy-paste the following lines in the console and press <enter>.

Congratulations! You have just installed the Early Warning Signals Toolbox on your computer! Now run the earlywarnings demo by copy-pasting:

shiny::runGitHub("demo","earlywarningtoolbox")

3 Instructions: Using the toolbox

If everything has worked well, you should have on your screen a window of your web browser with the user interface that runs the demo of the analysis presented in Part 1 of the submission (like in Fig. 3).

You are now ready to start using the Quick Detection Analysis! You can re-generate the analysis presented in Part 1. To understand and interprete what you see, we refer to the paper by Dakos et al (2012) that is included in the additional material of Part 5. Remember that the Quick Detection Analysis we present here is only part of the capacities

of our toolbox. The remaining methods/indicators are available through the command line version of the toolbox in R!

From the top drop-down method, you can choose the time series to use, *simulated/ real-world data*, and from the second drop-down menu you can choose one of the three analysis that the Quick Detection offers: *Indicator trend analysis, Trend significance analysis, Potential analysis.* After you choose an Analysis, different options appear. Press *Update View* to execute. Note that some calculations may take long, especially if the time series is long.

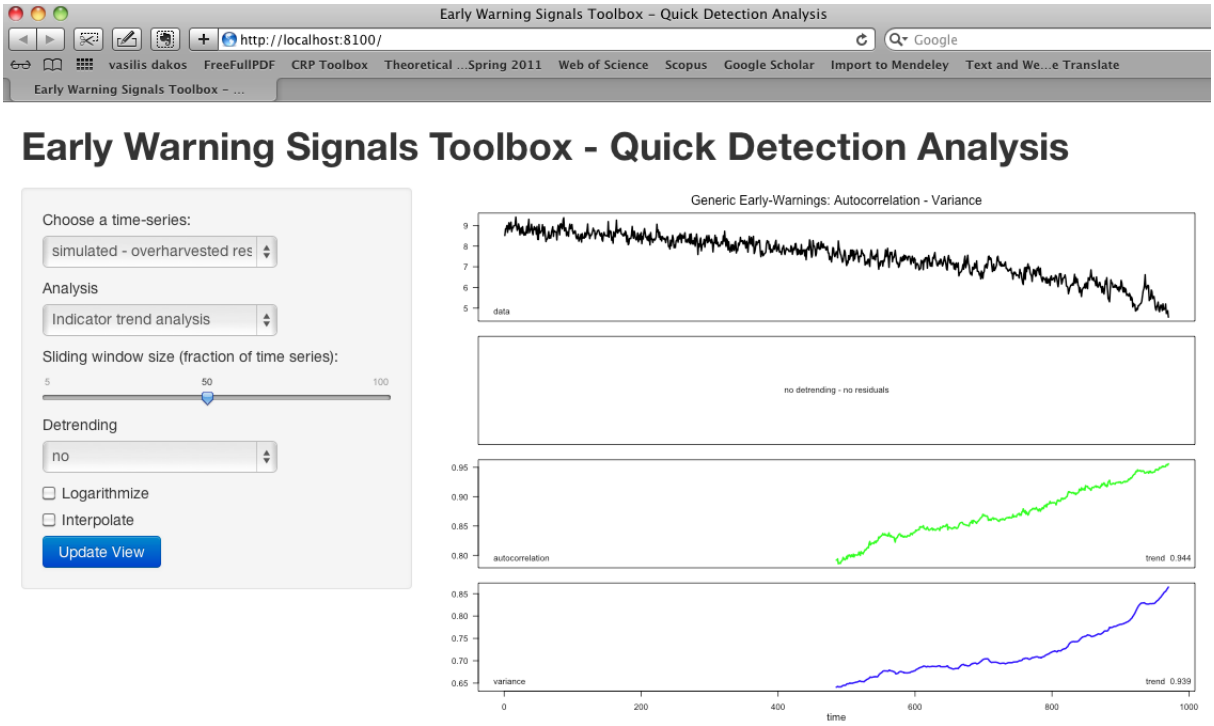

Figure 3: User interface of the *Indicator trend analysis* with Quick Detection.

For the **Indicator trend analysis** (Fig. 3), the options to select are:

1. *Sliding window size* (the fraction along the time series to estimate variance and autocorrelation)

2. *Detrending* (filters data using smooth, linear, or first-difference detrending)

3. *Logarithmize* (transforms the time series into logarithmic scale using *log(x=1)*)

4. *Interpolate* (interpolates the time series in case there are missing values)

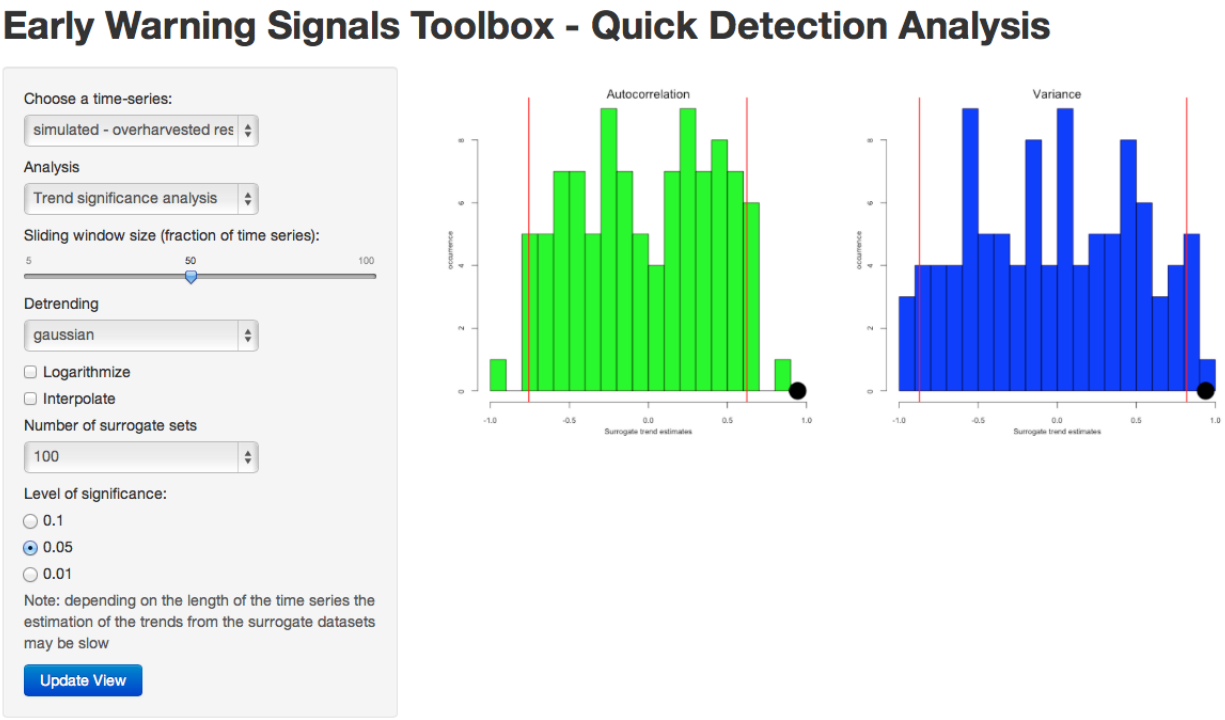

Figure 4: User interface of the *Trend significance analysis* with Quick Detection.

For the **Trend significance analysis** (Fig. 4), the options to select are:

1. *Sliding window size* (the fraction along the time series to estimate variance and autocorrelation)

2. *Detrending* (filters data using smooth, linear, or first-difference detrending)

3. *Logarithmize* (transforms the time series into logarithmic scale using *log(x=1)*)

4. *Interpolate* (interpolates the time series in case there are missing values)

5. *Number of surrogate datasets* (to estimate a distribution of trends based from a null model without a transtion)

6. *Level of significance* (to reject the null model hypothesis)

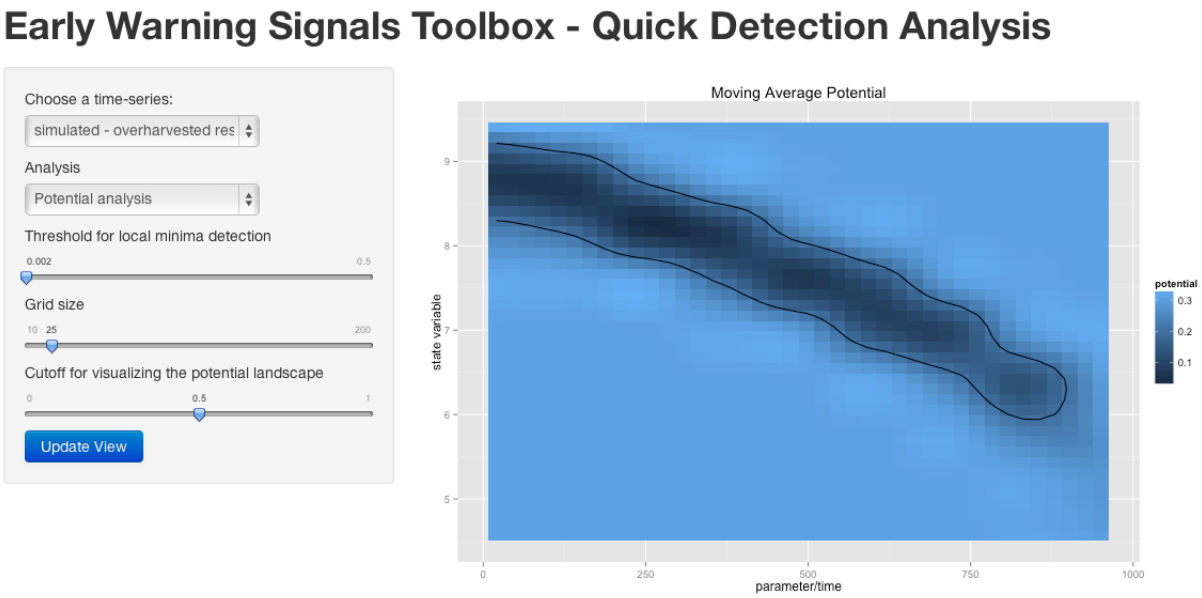

Figure 5: *Potential Analysis* with Quick Detection.

For the **Potential analysis** (Fig. 5), the options to select are:

1. *Threshold* (for detecting local minima alternative attractors)

2. *Grid size* (for determining the analysis resolution)

3. *Cutoff level* (to clarify the visualization)