Appendix: Simulation Toolkit for Identifying Mixed Pixel Green-up Date

The green-up date (GUD) (also known as the start-of-season [SOS]), as one of the vital phenological metrics, characterizes the onset of measurable photosynthetic activities or the timing of spring arrivals. This simulation toolkit identifies the GUD in a mixed pixel containing multiple endmembers based on the NDVI time series of each endmember. This appendix introduces the specifications of the toolkit.

Downloads

The software can be downloaded from http://chenx.org under the *Download* page.

Importing NDVI time series

There are two different modes to import the NDVI time series of each endmember: (1) entering parameters and (2) adding an NDVI series file (.txt). After clicking the *Import* button in the main menu, Figure 1 will show up.

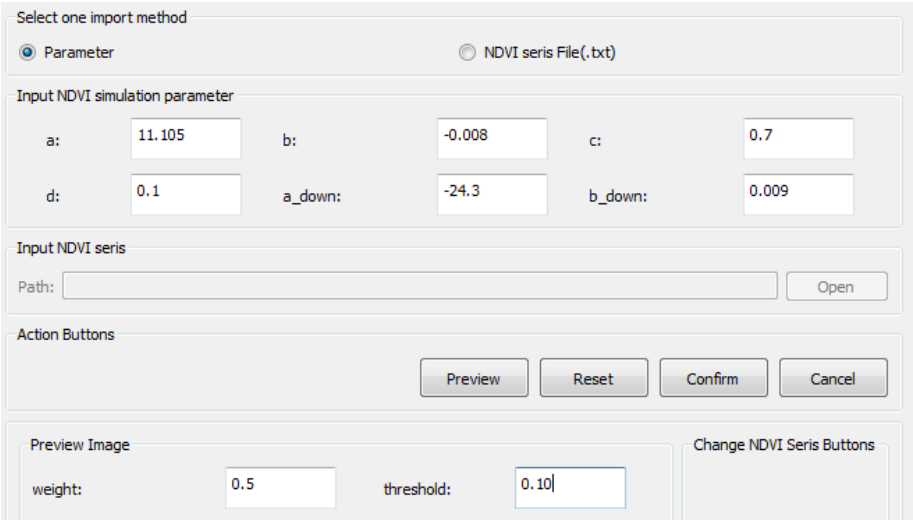

Figure 1. Importing NDVI time series for an endmember.

(1) Entering parameters: The annual NDVI time series of an endmember can be described by a logistic model, as shown in Equation (1). In this toolkit, *a* and *b* are parameters of the timing and change rate in the growth period, *a_down* and *b_down* are parameters of the timing and change rate in the senescence period, *c* is the amplitude of the trajectory, and *d* is the minimum NDVI value ($NDVI_{min}$). Thus, the value of *c* + *d* represents the maximum NDVI value ($NDVI_{max}$).

$$NDVI_m(t) = \frac{c}{1+e^{a+bt}} + d \quad (1)$$

The *weight* represents the fraction of the endmember in the mixed pixel (f_m). If the sum of the f_m of all added endmembers does not equal to 1, a normalization calculation of the f_m will be performed.

The *threshold* represents the criterion of identifying the GUD using the relative threshold method. It is a percentage (e.g., 0.1 or 10%) of the NDVI amplitude.

(2) Adding an NDVI series file (.txt): In addition to manually entering the NDVI parameters, the NDVI time series of an endmember can be added through an external text file. The file requires two fields: day of the year (at an increment of 8 days) and the NDVI value. Please see Figure 2 as an example.

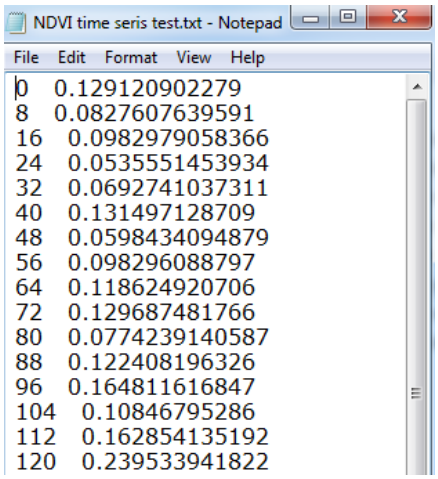

Figure 2. An example of the NDVI series file (.txt), where the first column is the day of the year (at an increment of 8 days) and the second column is the NDVI value.

Adjusting NDVI time series

The toolkit also provides a module to adjust the NDVI time series, as shown in Figure 3.

(1) GUD time right shift: delay the GUD of the endmember by 6 days.

(2) GUD time left shift: advance the GUD of the endmember by 6 days.

(3) max NDVI down: increase the $NDVI_{max}$ by 0.05.

(4) max NDVI down: decrease the $NDVI_{max}$ by 0.05.

(5) min NDVI down: increase the $NDVI_{min}$ by 0.05.

(6) min NDVI down: decrease the $NDVI_{min}$ by 0.05.

Figure 3. Adjusting NDVI time series

Generating Results

Click *Confirm* in Figure 1 to add one endmember. After all endmembers are added (no limitation on the maximum number), click *Draw* in the main menu to generate the results, as shown in Figure 4.

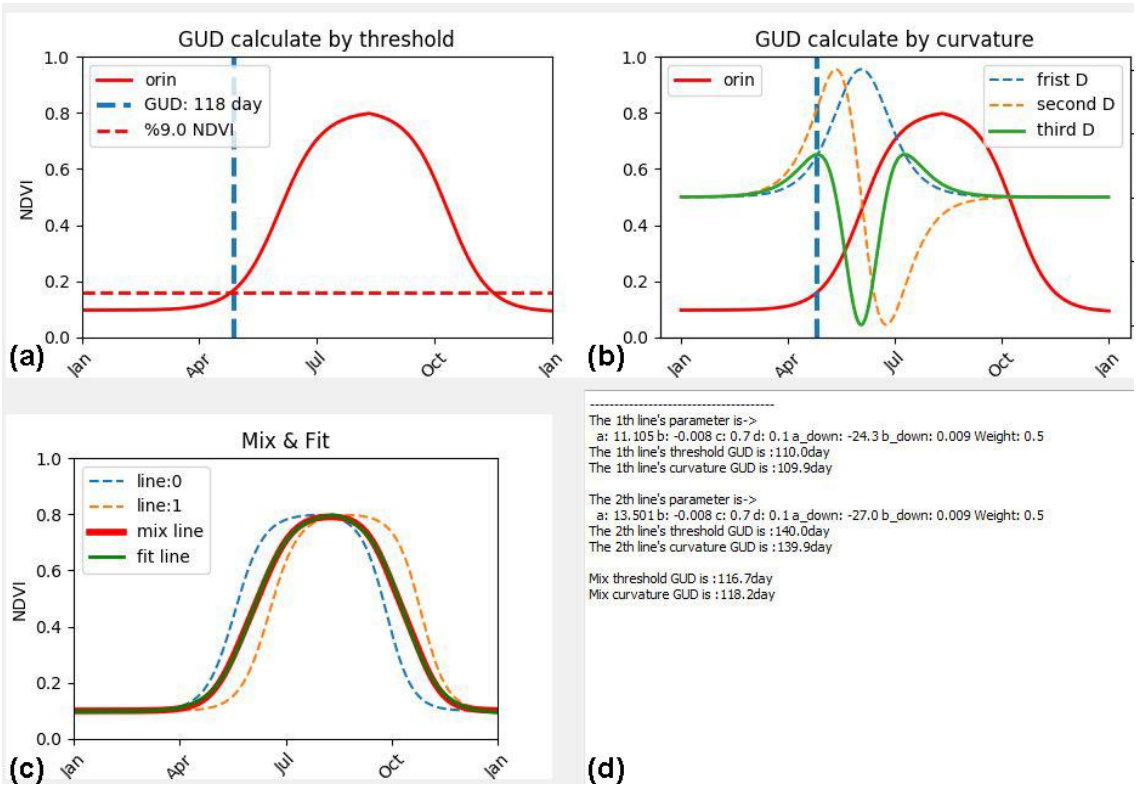

Figure 4. A example of the results: (a) The GUD of the $NDVI_{mix}$ by the curvature method, (b) first, second, and third derivative of the $NDVI_{mix}$, (c) all endmember NDVIs and the $NDVI_{mix}$, and (d) result summary.