Analyzing image data with TIMESAT

Summary

In the previous practical we evaluated different options for analysing NDVI time series for individual pixels using the TIMESAT Graphical User Interface. In this practical we will learn the TIMESAT tools to extract phenological parameters for an entire image. The same 10-day PROBA-V 1-km composites are used for this purpose, in an are centred around northern Iraq.

Assignment

You are requested to first work through this document, and follow the indicated steps. At the end of this document, a number of questions will be asked, for which answers should be handed in.

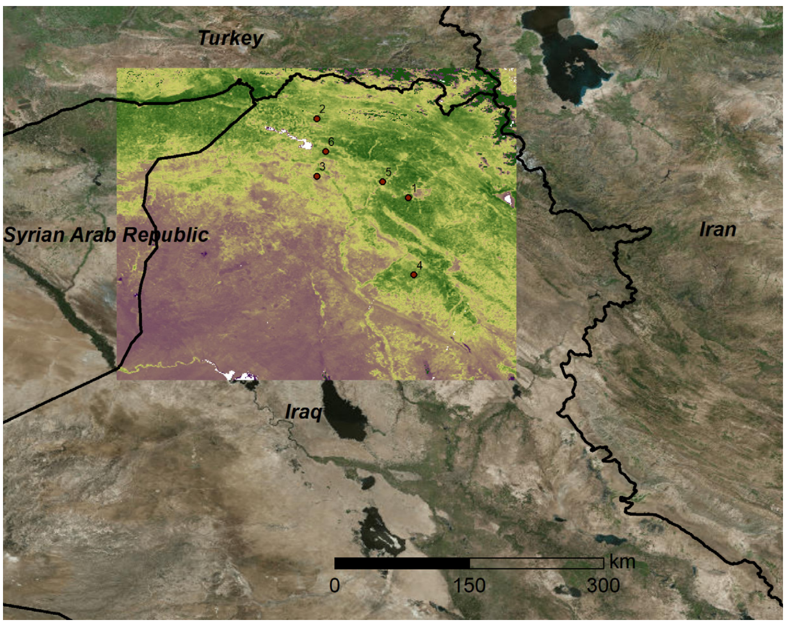
1. Data

The 10-day PROBA-V composites are of Version 2.2 and obtained through the Copernicus Global Land Service product portal. They are constructed by the Flemish Institute for Technical Research (VITO) in Belgium. A detailed product user manual can be found here. In this practical we made a spatial subset of the data to cover part of northern Iraq. The figure below shows the extent of the subset, together with the six sample points used in the previous practical. The extent is the purple-green image, which represents the NDVI for 11-20 April 2017 (purple are small NDVI values, green are large NDVI values).

Contrary to the previous exercise, NDVI-values are not scaled between -1 and 1, but retain the original 8-bit digital numbers; i.e. a discrete value between 0 and 255. The advantage of using 8-bit data is that file sizes are smaller, so less storage on the computer is needed, and this also speeds up programming time. To go from DN to the NDVI-value we can apply this formula:

$$NDVI = (DN - 20) / 250$$

We note that DN-values above 250 relate are reserved for "no data value", i.e. a value for masking out observations detected as being missing (251), clouds or cloud shadows (252), snow or ice (253), water (254), or observations that for other reasons have low quality (255). So the valid range is from 0 to 250.

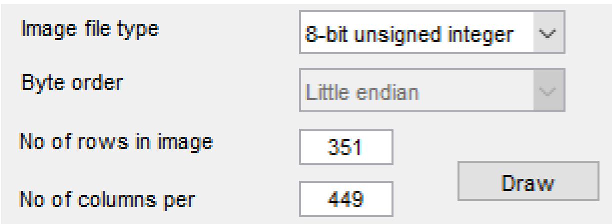


Correct preparation of the input data is needed before running TIMESAT. The data format needed for TIMESAT is explained in Section 9.1 of the user manual. Basically, you need to prepare binary images for full years of data. Therefore, in our case of 10-day composites, we need 36 images per year. For this exercise the data are prepared for you, consisting of a 5-year data series ranging from 2013 to 2017. From this we can extract phenology for four years (2014-2017): remember that TIMESAT always requires one more year of data. The 2013 data are from the VEGETATION data of the SPOT-5 satellite, but are quite similar to the PROBA-V data. At the time of writing the last 4 composites for 2017 were not yet available, but because full years are required, we created images for those dates with all no Data values (here: 255).

The image data are contained in the zip-file *ProbaV_1km_northIraq.zip*. Download this file to your computer and unzip it. Each image file has the same size of 351 lines (or rows in TIMESAT terminology) and 449 samples (columns) per line. While TIMESAT does not use a header-file with each image, I have included an header-file for each file, to facilitate opening the imagery in any GIS or Remote Sensing package (like ENVI, ERDAS, ArcGIS, or QGIS). This is a simple text-file that describes what is in the data (you can view it with any text editor, such as Notepad++).

2. Display imagery

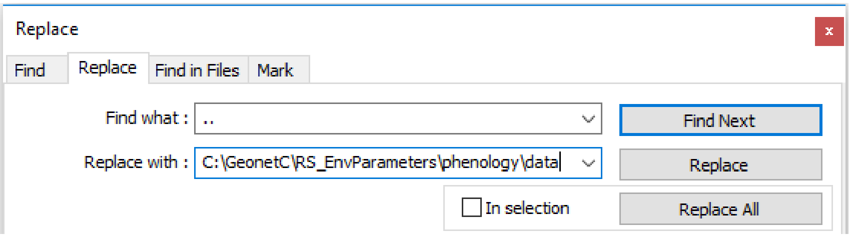
Start the **TSM_imageview** from the TIMESAT menu system. You can now display the NDVI images by first opening via **File → Open image file**, selecting one of the *img files entering the settings below, and then hitting **Draw**.



Rather than opening one image at the time, you can also open a file list from **File → Open file list**, clicking once more **Open file list**, and then entering a text-file that contains a list of files. One of these lists (*ndvilist.txt*) can be found together with the images in the *ProbaV_1km_northIraq.zip* file. The text-file now looks like this:

```
180
..\ndvi_20130101_VGT_V2.2.1_northIraq.img
..\ndvi_20130111_VGT_V2.2.1_northIraq.img
..\ndvi_20130121_VGT_V2.2.1_northIraq.img
..\ndvi_20130201_VGT_V2.2.1_northIraq.img
..\ndvi_20130211_VGT_V2.2.1_northIraq.img
..\ndvi_20130221_VGT_V2.2.1_northIraq.img
```

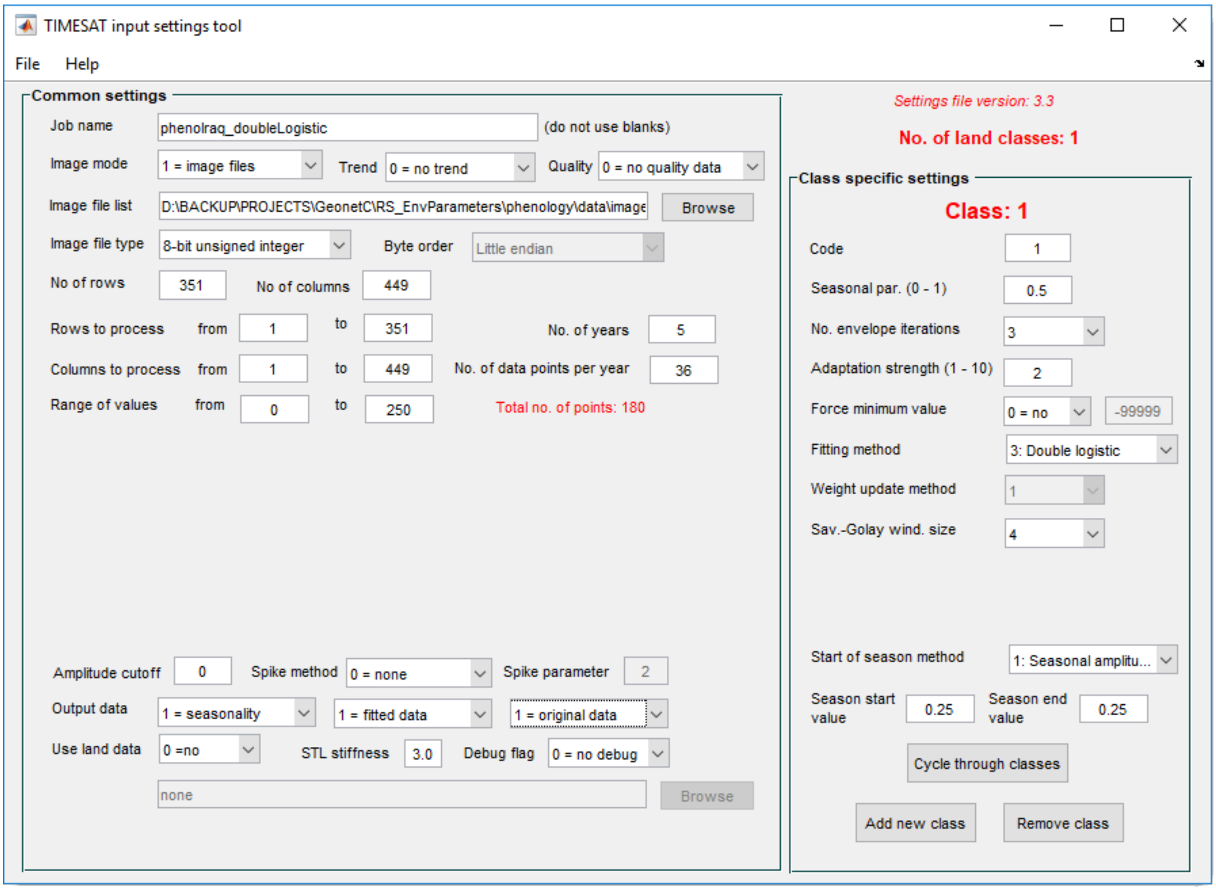
On the first line the number of images is indicated, and subsequently the location and name of all the images is entered. You will need to adapt the file to reflect the location where you store the data. For example, if you have stored it under: C:\GeonetC\RS_EnvParameters\phenology\data, then you replace the ".." in the text-file by that location for all entries. An easy way to do this is through the use of a text-editor. For example, in Notepad++ you could write:



and subsequently hit “Replace All”. Do not forget to save your text file. When you now load this list, you can click on any file that appears in the **Select image from file list** window, and click Draw in the **TSM_imageview** window to see the various images.

3. Create a settings file

Before we can process phenology for the entire image, we need to create a settings file that describes precisely what options will be used for extracting phenology. We can do that either via the TIMESAT Graphical User Interface (see p.51-52 of the user manual), or we can directly use the TSM_settings from the TIMESAT Menu System. Here we will use the second option. We will use the same model settings as in our last practical when using TIMESAT with point data. We can enter this in the TIMESAT input settings tool as follows:



To clarify a few settings:

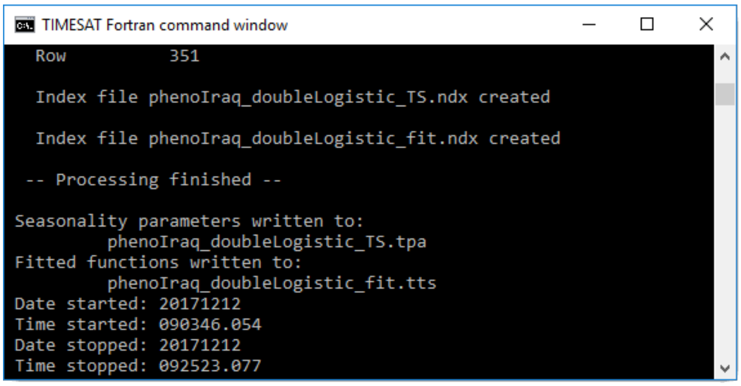
- The *Image mode* needs to be set to 1 to work with an image list.
- For the *Image file list*, you can browse to and select your *ndvilist.txt* file.
- Make sure to enter the *No of rows* and *No of columns* correctly, as well as the *No of years* and *No of data points per year*.

- You can opt to only process a subset of the image by setting *Rows to process* and *Columns to process*. However, here we will process all.
- Very important! As written in Section 1 of this practical, values above 250 do not refer to NDVI observations, but to no data flag values. Therefore, the *Range of values* needs to be set accordingly.
- We can save various outputs, including seasonality (phenological parameters), the fitted data values, and the original data. For now under *Output data*, we create output files for seasonality, fitted data, and original data by setting their values to 1.
- The other settings are the same as in the previous practical on point-based implementation of TIMESAT.

Save this settings file by **File → Save settings file as**, and choose a location and name to save your settings file; for example *phenoIraq_doubleLogistic.set*.

4. Calculate phenology

We are now ready to start processing. This is done by starting **TSF_process** from the TIMESAT Menu System. You should then navigate to the settings-file that you created in the previous step. Once that is selected, processing will start. A DOS-window will be opened. When everything proceeds successfully, then in the end you should see something similar to this (in your case, also the *phenoIraq_doubleLogistic_raw.tts* file will be written):

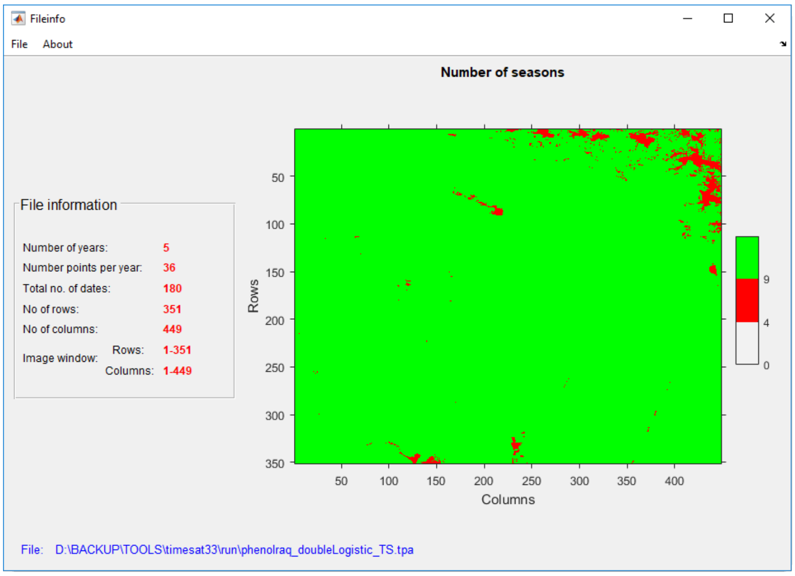


On my computer, the process took about 22 minutes, but this may differ on your computer. If you have multiple processors available, you could also try to run **TSF_process parallel** instead, which divides the processing over multiple processors. However, here we will not go in detail on that.

The output will normally be saved to the working directory; based on previous steps (practical on getting started with TIMESAT), this was set to *timesat33/run*. It consists of the raw time series (*jobname_raw.tts*), fitted time series (*jobname_fit.tts*), seasonality parameters (*jobname_TS.tpa*), and corresponding index files (*.ndx*). In our case, *jobname* is *phenoIraq_doubleLogistic*. Please refer to Chapter 6 of the user manual for a description of the output file format.

5. Checking results

A number of post-processing utilities are available from the TIMESAT Menu System. The first is **TSM_fileinfo**. This allows to understand which parts of the image have been successfully processed. If you click it, and select the *jobname_TS.tpa* file, you should get an image as below:



Besides general file information (on the left side), also a map is presented which shows the number of seasons that are extracted per pixel. Note that the legend does not look right to me. Rather, I observed that in areas depicted in green we have up to 4 seasons processed (5 years minus 1), whereas in the red areas no processing was done. This is most likely because there are few observations (due to persistent cloud and snow cover in the mountain area), or because some areas have surface water (and no vegetation). Nonetheless, for most of the image we have retrievals. We can wonder however if all of the retrievals are correct, given that also in the desert areas green colours are found!

To quickly check the seasonality parameters for selected pixels we can use **TSM_printseasons**. If we click it, we should select the *jobname_TS.tpa* file. This directs us to the Matlab Command Window, where we are asked to enter values for first/last row and column. If you keep the first/last values the same, we can select single pixels. For example, a pixel in the green area of the figure above is row=200, column=200. We can fill in these values in the Matlab Command Window, and if we output the results to screen we get:

```
  Now enter the window you wish to display data for
  First row: 200
  Last row: 200
  First column: 200
  Last column: 200

  Name of output text file (hit Enter to print to screen):

  Row, Column:  200 200
Season 1
  Beg. t.  End t.  Length  Baseval.  Max t.  Max val.  Ampl.  L-der.  R-der.  L-integ. S-integ. Start val.  End val.
   31.81    47.61   15.80   42.66    39.48   77.43    34.77   4.371   4.113   1170.    402.4    52.70     50.00
Season 2
  Beg. t.  End t.  Length  Baseval.  Max t.  Max val.  Ampl.  L-der.  R-der.  L-integ. S-integ. Start val.  End val.
   66.09    81.96   15.87   41.36    73.64   89.43    48.07   5.617   4.674   1225.    521.4    53.00     53.76
Season 3
  Beg. t.  End t.  Length  Baseval.  Max t.  Max val.  Ampl.  L-der.  R-der.  L-integ. S-integ. Start val.  End val.
   103.2    120.1   16.93   41.18    111.9   64.70    23.52   2.465   2.946   1073.    291.0    47.57     46.54
Season 4
  Beg. t.  End t.  Length  Baseval.  Max t.  Max val.  Ampl.  L-der.  R-der.  L-integ. S-integ. Start val.  End val.
   135.0    156.3   21.21   39.32    148.7   52.48    13.15   0.6687  2.213   1100.    195.4    43.49     41.74
Hit enter to continue
fx
```

This is similar to what we saw before in the TSM_GUI. If we would now select a pixel in the red area (for example row=1, column=260), we find that nothing is printed to screen, indicating that phenology retrieval was not successful there.

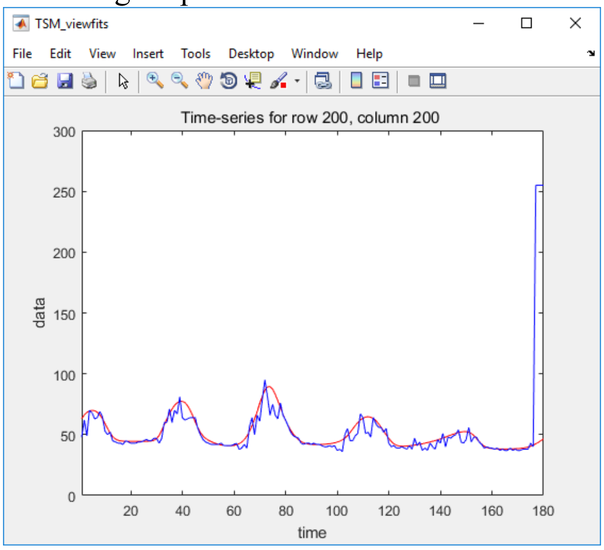
Finally, it can also be very useful to have a look at the original and fitted time-series. This allows to visually evaluate if the selected model (here: double logistic) results in appropriate fits to the data. For this, the utility **TSM_viewfits** can be used. Note that this may require the *jobname_raw.tts* and the *jobname_fit.tts* files (and corresponding *.ndx* files) to be placed in the *timesat33/run* directory. In the Matlab Command Window, you can then fill in:

```
------------------------------------------------------------------------
  Display fitted functions?  (1/0)?  1
  Display original time-series?  (1/0)?  1
  Give name of input fitted data file:  phenoIraq_doubleLogistic_fit.tts
  Give name of input raw data file:  phenoIraq_doubleLogistic_raw.tts


  Data window in file
  -------------------
  Rows    : 1 - 351
  Columns : 1 - 449

  Now enter the window you wish to display data for
  First row: 200
  Last row: 200
  First column: 200
  Last column: 200
```

And should provide the following output:



Note that the no-data values (251 and higher) are not masked out in this case. You can now try to this also for other pixels. Be aware that you do not get any output when selecting a pixel for which no fit was obtained (for example row=1, column=260).

Assignment

Hand in a Word-document with answers to the questions below.

1. Write down (as normal dates, e.g. 5 December 2013) the retrieved start of the season for each of the four seasons obtained for row=200, column=350.
2. Consider the pixel with row=260, column=1. This pixel is situated on the west part of the study area, corresponding to a desert area with limited to no vegetation cover.
   a. For how many seasons is a retrieval obtained?
   b. Display and make a screenshot of the original and fitted NDVI series for this pixel.
   c. Discuss the implications of this, and look through the user manual to understand how we can avoid processing for such pixels, while retaining the same double logistic model.