Visualizing and exporting TIMESAT image output

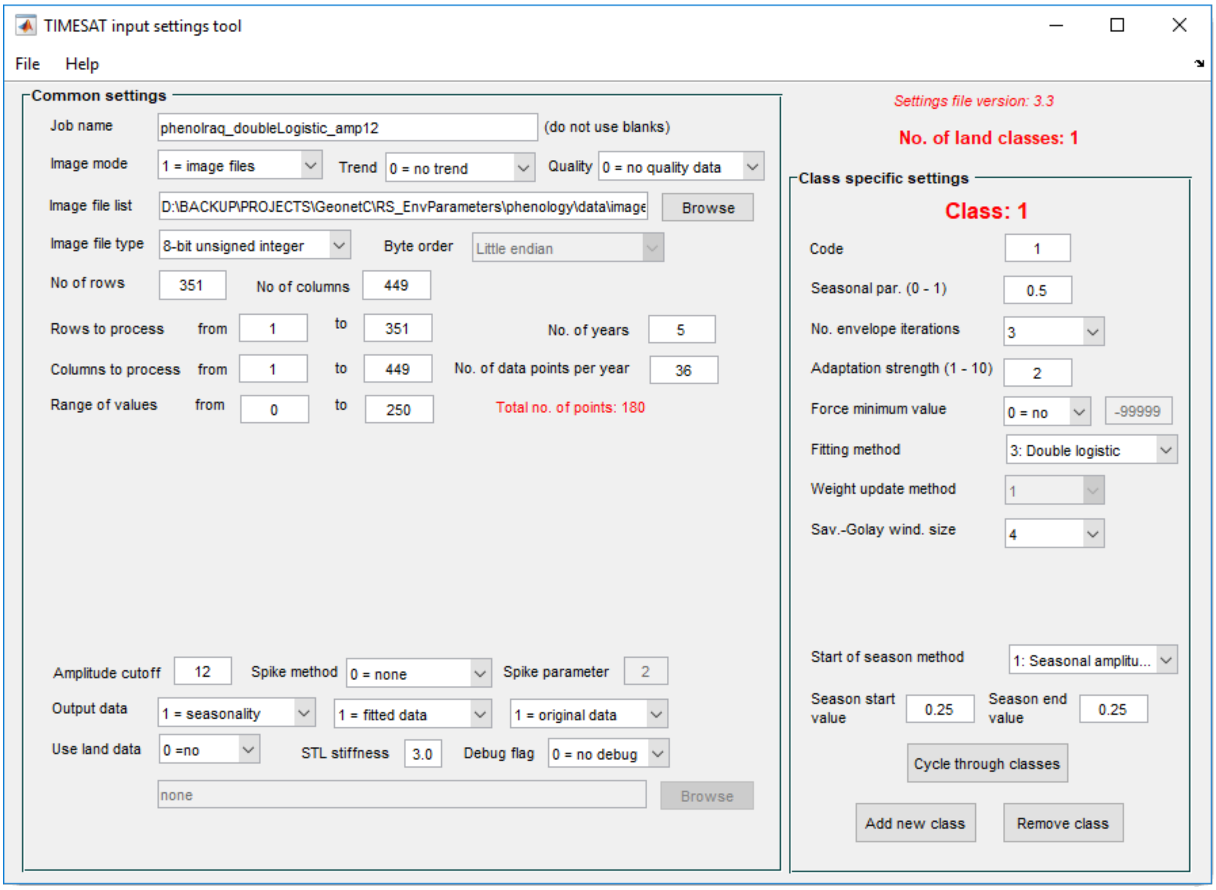
Summary
In the previous practical we did a first extraction of phenology from image data. In this practical we will repeat this with slightly different settings. Then we will visualize the outcomes using TIMESAT utilities, and also export the data in a way that GIS-programs like ArcGIS can read it.

Assignment
While following the steps in this document, write down your answers to the questions *in green* in a Word Document.

a. Run TSF_process
We process image data with TIMESAT with TSF_process in almost the same way as in the previous practical. However, to avoid processing over desert areas we now set a small amplitude cutoff value of 12. Note that 12 corresponds to the original DN values in the data. Using the formula:

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

this corresponds to an amplitude of 0.048 NDVI unit. If the amplitude is less than that, we will have no output for that pixel. Find below the final settings to apply.



b. Create images from the seasonality files in TIMESAT
There is no option to view the spatial image of phenology parameters from the .tpa file directly. Instead we need to use the utility **TSF_seas2img** (on the TIMESAT menu system) to create images from that file. We can create an image for each of the 13 phenological

parameters that TIMESAT extracts. Note that if we select for example beginning of the season as a parameter, we need to run **TSF_seas2img** 4 times to obtain the beginning of the season for all the years (5 years minus 1). To do this we need to specify the min/max dates during which the maximum NDVI of that year is expected to occur. Based on our knowledge acquired during the previous practicals, we know that September is usually a dry month with relatively small NDVI values. To look for maxima, we could thus look for the maximum NDVI between 1 September of year 1 and 30 September of the subsequent year, corresponding to dekad 25 to dekad 27 (+36), so the min/max for year 1 would be 25/63. For subsequent years we add 36 dekads to this. For small study areas where we know rather detailed where the maximum should be found, we can also define a shorter period.

Following this explanation, to get the start of season (SOS, or beginning of season) for year 1, we can enter the parameters in **TSF_seas2img** as below.

```
TIMESAT Fortran command window

Seasonal parameter to output >> 1
Specify time interval between which the season MAXIMUM is expected to occur.
Only pixels with seasons that have a maximum between given dates
will be processed.
Example: to extract the seasons of the second year using monthly data
(i.e. 13-24), specify a min value of e.g. 13 and a max value of e.g. 24.
Give min,max dates(e.g. 13, 24) >> 25,63
Missing value where no season is found between min and max dates)
Give missing value code (e.g. -1) >> -1
Missing value for other cases (pixel not processed due to low amplitude,
undefined class, failure to fit function etc.)
Give missing value code (e.g. -2) >> -9
Give name to append to output files (no extension!) >> sosY1

File type for the output image files
2 = 16-bit signed integer (values will be rounded to nearest integer)
3 = 32-bit real (no rounding)
Specify file type (2 or 3) >> 3
```

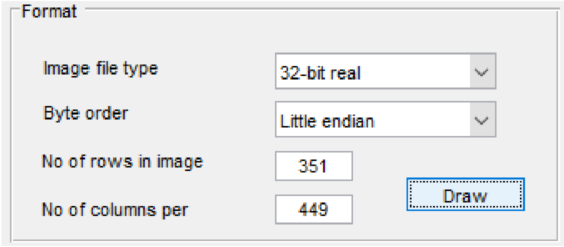
Several output files will be created in the TIMESAT working directory (*../timesat33/run*):

sosY1_nseas	binary image file with the total number of seasons identified within the full NDVI series
sosY1_season1	binary image file containing the SOS for the first season identified within the time interval specified
sosY1_season2	binary image file containing the SOS for the second season identified within the time interval specified (if two seasons are identified in that year)
sosY1_both_seasons	binary image file containing seasonality parameters for both seasons identified within the time interval specified (if more than one is found: for SOS this gives the same as *sosY1_season1*)
sosY1_errors.txt	text-file that indicates if for specific pixels errors occur, for example because more than 2 seasons were identified within the interval

Now create yourself also SOS-files for year 2, 3, and 4. For example for year 2 you would use as the time interval 25+36 tot 63+36. In addition, write output for each year for the parameters "length of season" (los), amplitude (amp), and large integral (li). Store these similarly as above by giving base-names such as losY1, losY2, losY3, and losY4. Feel free to also create image output for other parameters, but this is not needed for this practical.

c. Display phenological parameter files with TSM_imageview

Previously we have displayed NDVI data with **TSM_imageview**. We will now do the same with the binary image files with phenology data. Because we selected 32-bit real as file output, we have to specify this also within the format part of **TSM_imageview**, as follows:



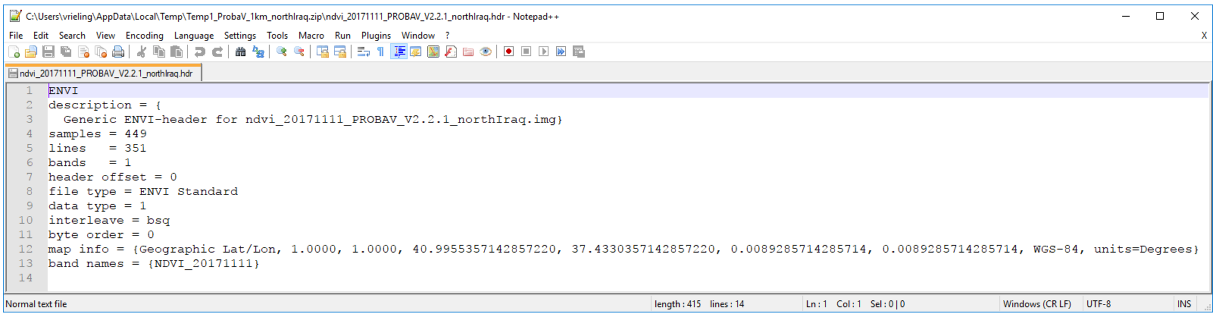
By clicking **File → Open image file** we can now load the different output files that we created. If you set the format correctly, you can then click **Draw**. For each output and year, focus only on season1: although for some pixels data exists for season2, these are generally small areas.

Q1: Create for each year's season 1 an image of the amplitude. Scale this between 0 and 250 (image display scaling) and add screenshots for each year to your document. Can you identify years/regions with much lower or higher amplitudes than normal? Discuss possible reasons for this deviation.

Q2: Create for each year's season 1 an image of the start of season. Scale this for year 1 between 25 (=1-10 September) and 52 (=1-10 June). For the other years, we cannot use the same scaling. Nonetheless, by adapted the minimum and maximum (image display scaling) you can make the maps comparable. Add screenshots for each year to your document. For which year are the retrieved start-of-season values on average the earliest? For which year are they instead very late?

d. Using TIMESAT outputs in other software

TIMESAT does not specifically deal with the geometry of the data; instead it simply works on binary raster files with a consistent number of rows and columns. This number needs to be specified by the user. GIS and remote sensing software can normally deal with binary raster files, but (similar as TIMESAT) requires information regarding the organization of the file, and about the geometry. One way to provide such information is through adding a ENVI header file with the same name as the raster-file and an *.hdr extension. These header-files are simple text-files that describe important information about the raster-file. They can be opened and adapted in any text-editor (e.g. Notepad++). Note that not all information listed in the previous link needs to be provided. With the NDVI-data files that were provided to you, we already added a header-file to each. Let us look again at one of those (see screenshot below, but rather open one of the header files yourself.



```
ENVI
description = {
  Generic ENVI-header for ndvi_20171111_PROBAV_V2.2.1_northIraq.img}
samples = 449
lines   = 351
bands   = 1
header offset = 0
file type = ENVI Standard
data type = 1
interleave = bsq
byte order = 0
map info = {Geographic Lat/Lon, 1.0000, 1.0000, 40.9955357142857220, 37.4330357142857220, 0.0089285714285714, 0.0089285714285714, WGS-84, units=Degrees}
band names = {NDVI_20171111}
```

The elements contained in this file are:

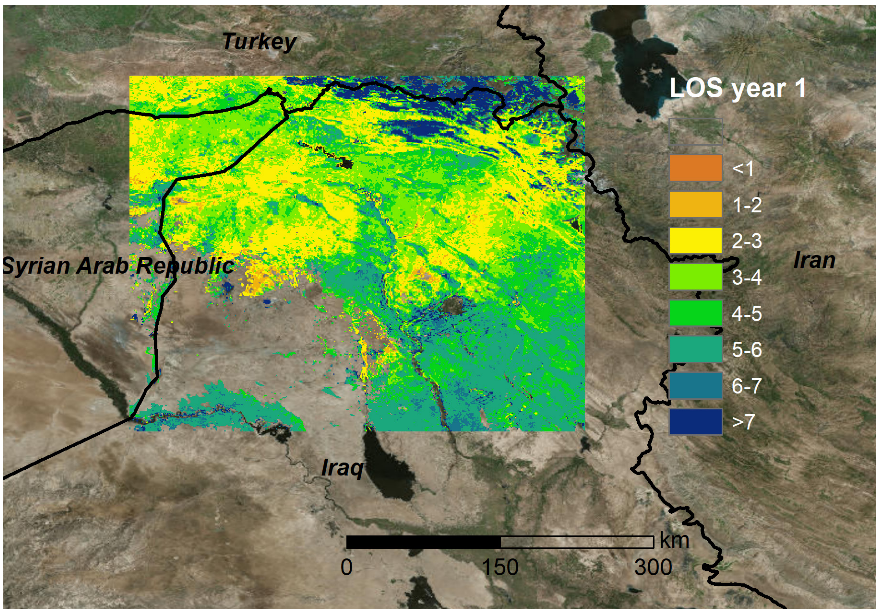
- description: not really used, but useful for own reference
- samples: this corresponds to number of columns in TIMESAT
- lines: this corresponds to number of rows in TIMESAT
- bands: the number of bands in the file; for a single raster this will be 1, but for multi-spectral or multi-temporal data that are stacked in one file, this can be more than 1.
- header offset: if the raster file contains other information before the binary raster information. For plain raster files, this can usually be set to 1.
- file type: usually can be left at “ENVI Standard”
- data type: this is a very important setting, because it says how the bytes are stored in the raster. A raster can be stored for example as 8-bit (discrete values from 0 to 255), or floating point (containing also numbers behind the digit and stored as 32- or 64-bit). Each way has a code (for 8-bit it is 1); the codes are listed here under “data type”.
- interleave: this is only relevant for rasters with multiple bands (see previous item “bands”). The options are bsq, bil, or bip, as explained here.
- byte order: two options exist for ordering bytes within each integer or floating point value; the least significant first (or: little endian, coded in ENVI as 0), or the most significant first (or: big endian, coded in ENVI as 1). Here we can leave this value at 0. Note that for the TIMESAT image viewer, you also need to specify this.
- map info: this is critical information for adding georeferencing information to the file, and defines a geographical coordinate for a reference point, the spatial resolution in x and y direction, and the projection and datum. Without this information the file cannot be effectively loaded into a GIS.
- band names: a name for each band, particularly useful when having multiple bands in a single file.

Now, let us proceed and add a header file to the outputs for each season1-file of “length of season” (los), and large integral (li). If you like, you can do the same for the other parameters.

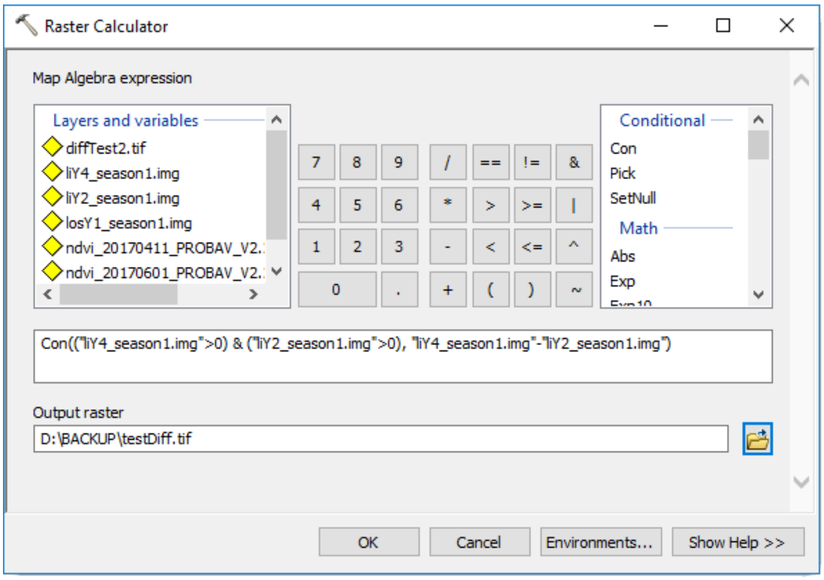
- You need to copy one of the ndvi-headers to the directory where you have stored the TIMESAT output.
- You rename this text-file, so it has the same name of the raster-file. For example, my length-of-season output for year 1 and season 1 is called *losY1_season1*, so my text-file will be renamed as *losY1_season1.hdr*.
- You need to open this file in a text editor to make some changes. Much of the information will remain the same as for the NDVI-raster. However, the NDVI-data was stored as 8-bit integer (data type = 1), whereas now we stored the output as 32-bit floating point data (data type = 4). Hence replace the 1 for data type with a 4 in the text file.
- You can change the description and band name also to reflect the file contents.
- Finally, save the text file, and repeat the same steps for the other files.

You can now open the data in ENVI: note that ENVI does not require a fixed file-extension for the binary raster file, as long as there is a header file with the same name. However, GIS-software such as ArcGIS and QGIS require the raster file to have the extension **.img*. Simply add *.img* behind the base name of the raster file.

Now you should be able to select each .img file in ArcGIS or another software of your choice. This allows you to make spatial maps with your preferred color codings, and/or combine your results with other spatial data. Find an example of a map for length of season (in months) for year 1 below (pixels with no retrieval are not displayed).



An example of a combination of various outputs could be to assess the difference between the large integral for year 4 and year 2. In ArcGIS this could be achieved using the Raster Calculator (requires Spatial Analyst extension!!). To avoid getting strange results for pixels where one of the inputs lacks a retrieval, a conditional evaluation can be performed. For example:



In this example a difference between the large integral for year 4 and 2 is only calculated for pixels that have in both years positive values for the large integral.

Q3: Use ArcGIS (or any other software of your choice) to calculate the difference in length of season (LOS) between year 1 and year 2 (i.e. year2 minus year 1). Note that year 1 refers to 2014 and year 2 to 2015. Classify the map into classes ranging from <-9 dekad, -9 to -6 dekads, -6 to -3 dekads, -3 to -1 dekads, -1 to 1 dekad, 1 to 3 dekads, 3 to 6 dekads, 6 to 9 dekads, and >9 dekads. This can be achieved by selected "Classified" instead of "Stretched" in the layer properties window. Use a diverging color scheme (see for example here) to display the result.

a. *Add a figure of the resulting map to your Word document.*
b. *For what part of the image did 2014 have a longer growing season as compared to 2015?*
c. *Now create also a map of the difference in LI (large integral) between 2014 and 2015. Display it in a similar way as for LOS with a diverging color scheme.*
d. *Does the LI difference map show similar spatial patterns as compared to the LOS difference map? Explain why it is (or is not) similar.*

e. Concluding

These series of practical assignments should have provided you with an overview on how phenology can be extracted from medium-resolution time series of vegetation indices. Also, they have given you hands-on experience with the TIMESAT software. We have not gone in detail in comparing all the various options and settings of the software; here we focussed largely on a single model for phenology extraction. Nonetheless, you have now gone through the full process once, and if interested, you could explore more with this dataset, or create your own datasets. TIMESAT is not the only software that allows to extract phenological parameters, and you may wish to explore other options, as well as analyse existing phenology products. I hope that you have enjoyed this series of lectures and practicals, and that you have obtained useful knowledge for your future tasks and career!