ANALYSIS OF MODIS LAI TIME SERIES DATA USING TIMESAT SOFTWARE. CASE STUDY – ROMANIA

Argentina Teodora NERTAN, Gheorghe STANCALIE, Denis MIHAILESCU

1. INTRODUCTION

- The leaf area index (LAI), defined as half of the total leaf area per unit ground surface area, together with fraction of photosynthetically active radiation, is a key biophysical canopy descriptor, which play a major role in vegetation physiological processes and ecosystem functioning.

- Ecological and climate models require high-quality biophysical parameters as inputs and validation sources.

- MODIS LAI products provide such high quality data sources for climate, weather forecast and ecological models.

- Usually MODIS LAI time series contain lower quality data, gaps generated by persistent clouds or cloud contamination and other gaps.

1. INTRODUCTION (CONT.)

- All the models which use LAI MODIS data as inputs require gap free data.

- This paper presents an algorithm for producing temporally smoothed and spatially continuous biophysical data (MODIS LAI products)

- The procedure used in this study includes two algorithm stages, (one for smoothing and one for gap filling) , which attempt to maximize the use of high quality data to replace missing or low-quality data.

- In this study we used TIMESAT software developed by P. Jonsson and L. Eklundh for analyzing time-series satellite-sensor data.

2. DATA

- Collection 4 (C4) MODIS-eight-day-LAI products from 2005 to 2010 as inputs to produce smoothed and gap-filled MODIS-LAI data for Romania for the period mentioned above.

- The MOD15A2 LAI product is a 1 km global data product composited over an 8-day period and is derived from a three-dimensional radiative transfer model driven by an atmosphere corrected surface reflectance product (MOD09), a land cover product (MOD12) and ancillary information on surface characteristics.

- Modis Land cover product: product incorporates five different land cover classification schemes, derived through a supervised decision-tree classification method. The primary land cover scheme identifies 17 classes defined by the IGBP, including 11 natural vegetation classes, three human-altered classes, and three non-vegetated classes.

- Characteristics: Area -~10 x 10 lat/long; Projection – Sinusoidal; Data Format - HDF-EOS; Dimensions - 1200 x 1200 rows/columns; Resolution - 1 km; Science Data Sets (SDS HDF Layers) 6 (LAI, fPAR, standard deviation for LAI and fPAR, quality control factor for LAI and fPAR)

2. DATA (CONT.)

- Data was downloaded with USGS Global Visualization Viewer (GloVis) tool - http://glovis.usgs.gov

- The USGS Global Visualization Viewer (GloVis) is a quick and easy online search and order tool for selected satellite and aerial data, allowing user-friendly access to browse images from the multiple EROS data holdings. Through a graphic map display, the user can select any area of interest and immediately view all available browse images within the USGS inventory for the specified location.

- GloVis also offers additional features such as cloud cover limits, date limits, user-specified map layer displays, scene list maintenance, and access to metadata.
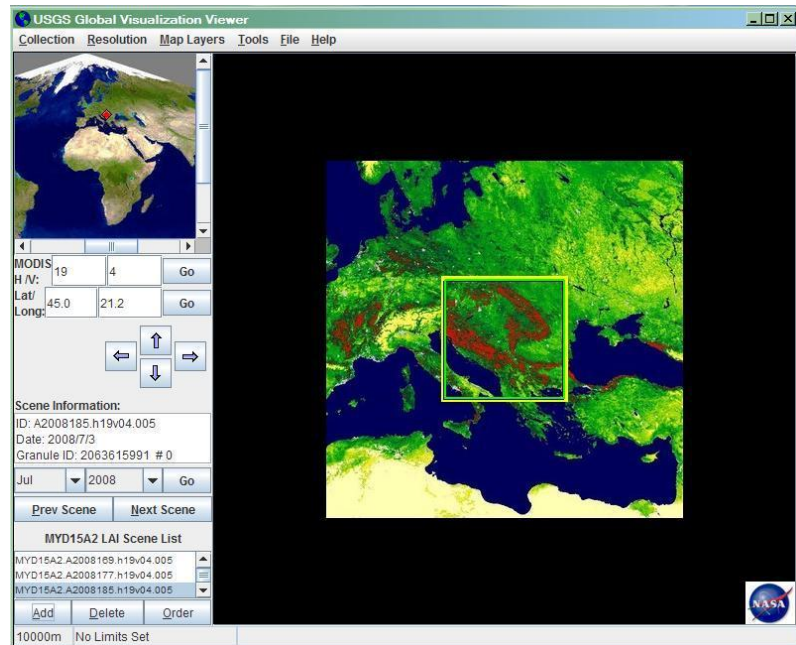
3. METHODOLOGY

- Data reprojection in UTM (Universal Transverse Mercator) geographic coordinate system was made using MODIS Reprojection Tool (MRT).
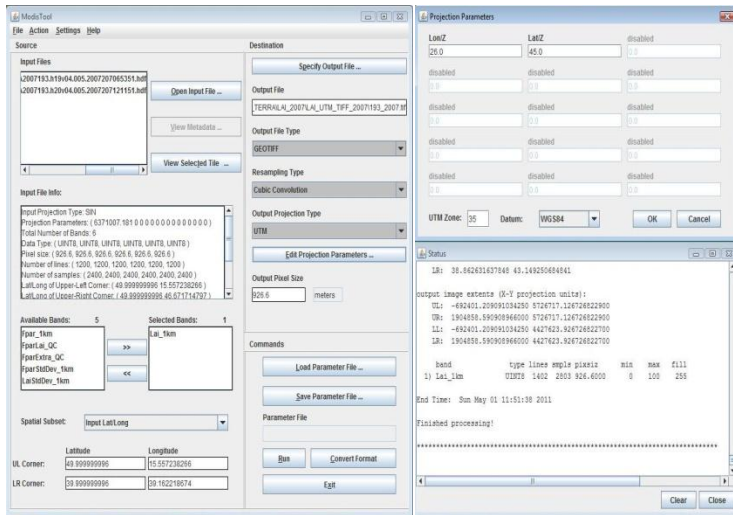
- MRT was developed to support higher level MODIS Land products which are distributed as hierarchical Data Format-Earth Observing System (HDF-EOS)2 files projected to a tile-based Sinusoidal grid.
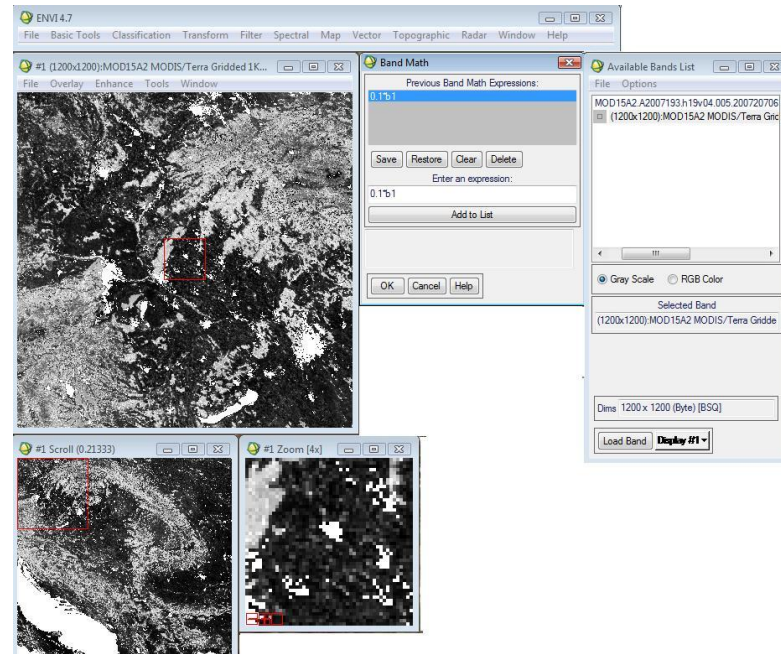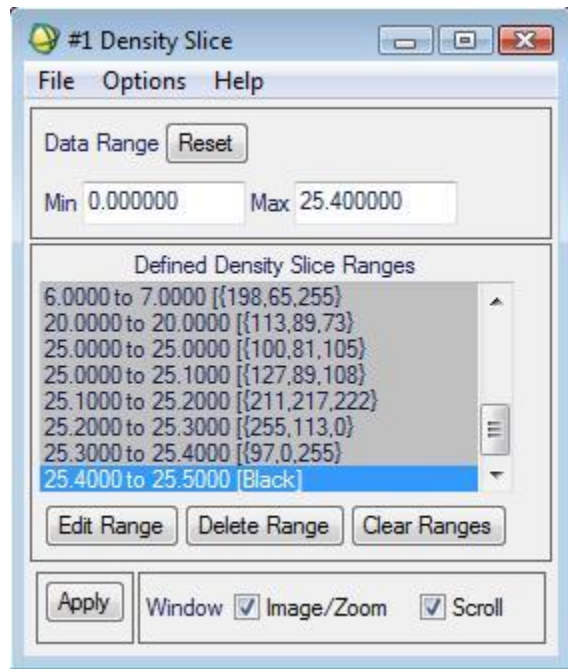
- MRT accepts raw binary or tiled MODIS Land products in HDF-EOS format as input. Output file formats include raw binary, HDF-EOS, and GeoTIFF.

3. METHODOLOGY (CONT.)

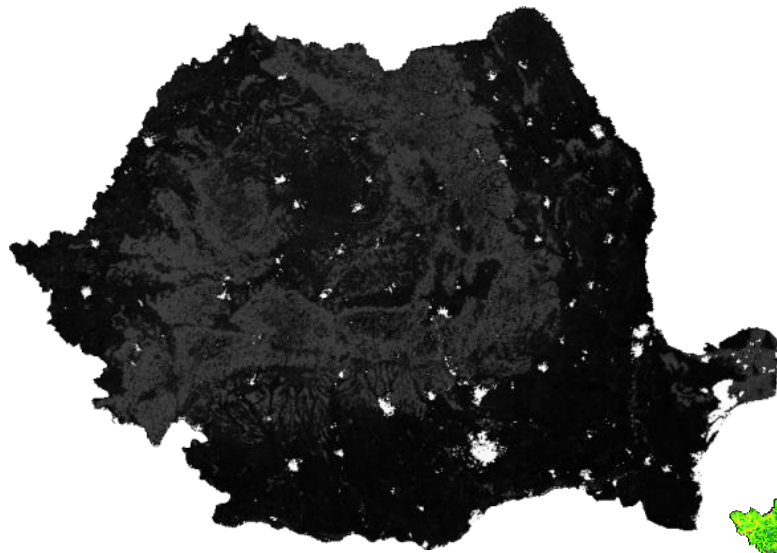- DN values are converted in LAI value, using ENVI software, with the following formula:
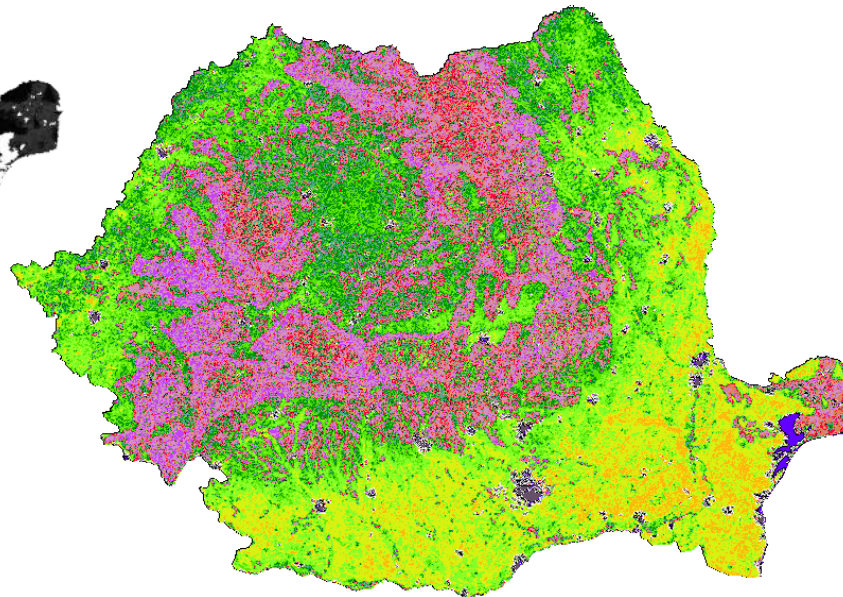
  - LAI=(1/10)*DN_LAI

- Image classification is made using "Density slice" tool.
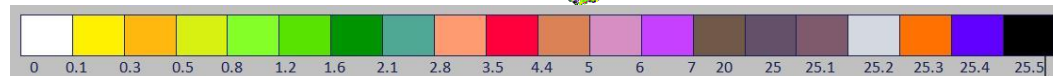
3. METHODOLOGY (CONT.)

- Because loading and processing large files can generate errors, data was clipped to Romania extent and reprojected in Stereo70 using Global Mapper.

- 0-7 – vegetation
- 20 – outliers
- 25 – urban area
- 25.1 - wetland

- 25.2 – snow, ice
- 25.3 – bare soils
- 25.4 – water
- 25.5 – missing pixels

| 0 | 0.1 | 0.3 | 0.5 | 0.8 | 1.2 | 1.6 | 2.1 | 2.8 | 3.5 | 4.4 | 5 | 6 | 7 | 20 | 25 | 25.1 | 25.2 | 25.3 | 25.4 | 25.5 |

3. METHODOLOGY (CONT.)

- According to Jonsson and Eklundh, TIMESAT, developed in MATLAB and FORTRAN is a software dedicated to analyze time series satellite sensor data.

- It can be downloaded from the following web adress: http://www.nateko.lu.se/personal/Lars.Eklundh/TIMESAT/timesat.html

- It is designed to extract seasonal information from any kind of time series.

- It allows to obtain start and end of the season (a and b) the levels (c and d), the point with the largest value (e); the seasonal amplitude (f) and the seasonal length(g); the cumulative effect of vegetation during the season ((h) and (i)).
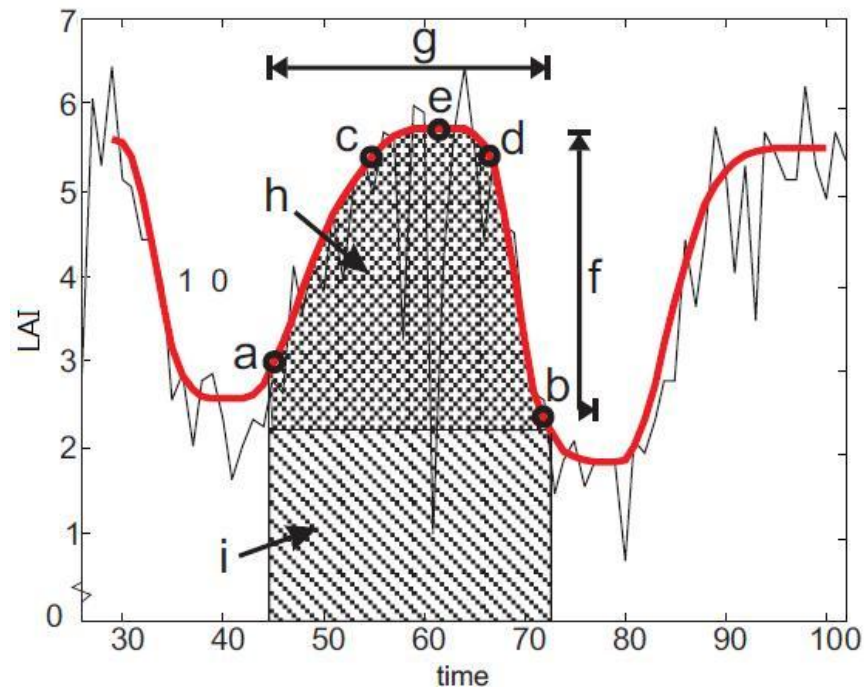
3. METHODOLOGY (CONT.)

- It support 8-bit unsigned integer, 16-bit signed integer or 32-bit signed real data.

- Can be process both, ASCII text files and image files.

- For ASCII files the steps of the processing are:
  - Read input setting that define the processing of the time series.
  - Read the first line of the ASCII file giving information about the length and sampling of a time-series as well as the number of time-series.
  - Loop over the time-series in the file:
    - Read time-series and, optionally, quality indicator.
    - Pre-process time-series under the guidance of the quality indicators.
    - Fit a smooth function to the time-series.
    - Use fitted function to extract seasonality parameters.
    - Write seasonality parameters and fitted function to file.

3. METHODOLOGY (CONT.)

- For image files the main steps are:
  - Read file containing the names of all the images with vegetation data, and optionally, the images with quality data. Read file with land use classes.
  - Give spatial extension of the area in the image that should be processed. Supply information about the image format
  - Read general as well as land use class-specific input settings that define the processing of the time-series.
  - Loop over pixels in the defined area. For each pixel:
    - Extract time-series and, optionally, quality from images.
    - Read land use classification for the current pixel.
    - Pre-process time-series under the guidance of the quality indicators and land use classification.
    - Fit a smooth function to the time-series.
    - Use fitted function to extract seasonality parameters.
   - Write seasonality parameters and fitted function to files.

- Read files with seasonality parameters and generate maps.

3. METHODOLOGY (CONT.)

- The program provides the following three different smoothing functions to fit the time series data:
  - asymmetric Gaussian (AG);
  - double logistic (DL);
  - adaptive Savitzky–Golay (SG) filtering.

- The adaptive SG-filtering approach uses local polynomial functions in fitting. It can capture subtle and rapid changes in the time series but is also sensitive to noise.

- Both AG and DL approaches use semilocal methods. In these two methods local model functions are fit to data in intervals around maxima and minima in the time-series. They are less sensitive to the noise and can give a better description on the beginnings and endings of the seasons.

- In this study we tested both DL and AG approaches – produced similar results, excepting the situation of incomplete time series data with many gaps and also the SG filtering.

3. METHODOLOGY (CONT.)

- According to the following flow chart, we start with a given continuous MODIS land-product time series and its associated QA-information time series. TIMESAT provides a weighting mechanism such that some values in the time series can be more influential than others.

- In this regard, the initial weights are based entirely on the MODIS QA layers associated with a given MODIS product. We assign high weights for higher quality retrievals and low weights for lower quality retrievals.
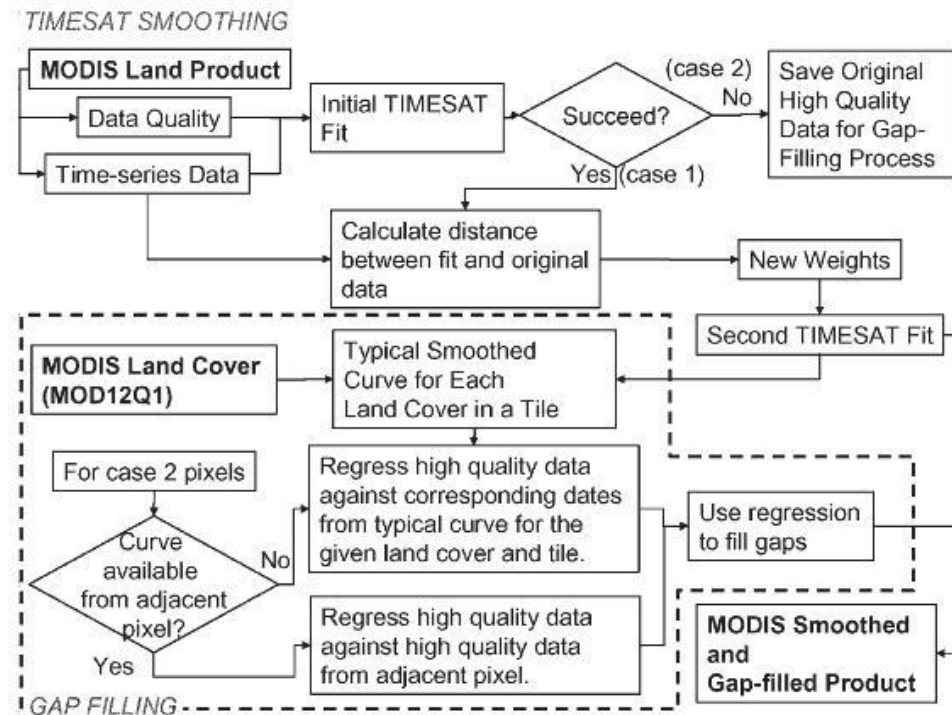
3. METHODOLOGY (CONT.)

- After the initial fit using TIMESAT, the algorithm takes one of the two branches based on the quality of the fit.

- The majority of the pixels follow the first branch where there are enough high-quality observations to allow TIMESAT to fit a curve to the time series.

- The second branch is followed if there are too many gaps or low-quality data.

- A successful run of TIMESAT requires that there are less than 25% missing values over the entire time series. No result will be produced if there are too many missing values because the fitting function becomes unreliable if it is forced to do so, or some fits may be unrealistic (e.g., out of the data range) due to noise or limitations of the fitting function.

- In this case we used MODIS Land cover product (MOD12Q), searching for the pixels with the same land cover type.

4. RESULTS AND CONCLUSIONS

- Using the time series data from 2005-2010 as inputs to produced smoothed and gap-filled MODIS LAI, the output layers include three LAI layers including the original MODIS LAI, the smoothed and gap filled LAI, and the composed LAI that uses high-quality LAI from the original MODIS product but replaces low-quality retrievals with smoothed and gap-filled LAI. Each layer has a corresponding QA layer.

- Each LAI value is first weighted according to the quality flags embedded in the MODIS product.

- For MODIS 8 day LAI products, the initial weight are assigned as follows:
  - W =1 for LAI retrievals from the high quality data (clear sky condtitions)
  - W=0.25 for mixed conditions
  - W = 0 for outlier values or cloudy conditions.
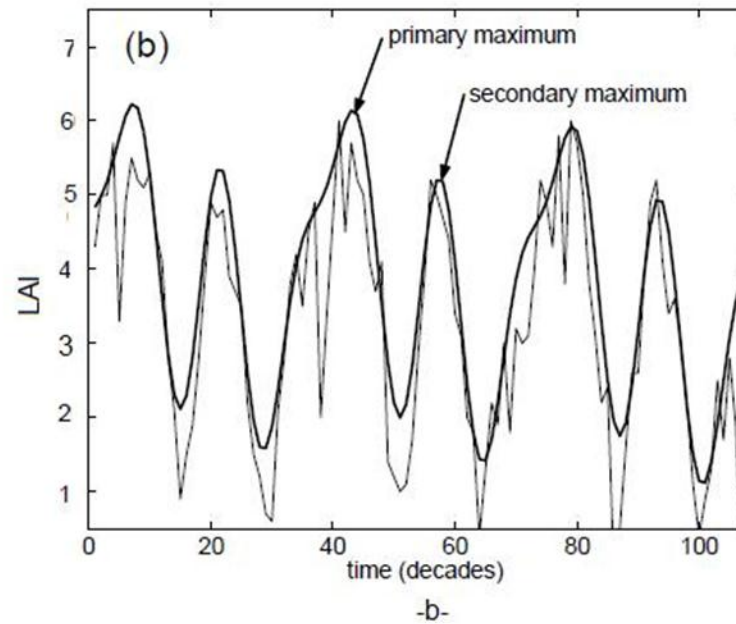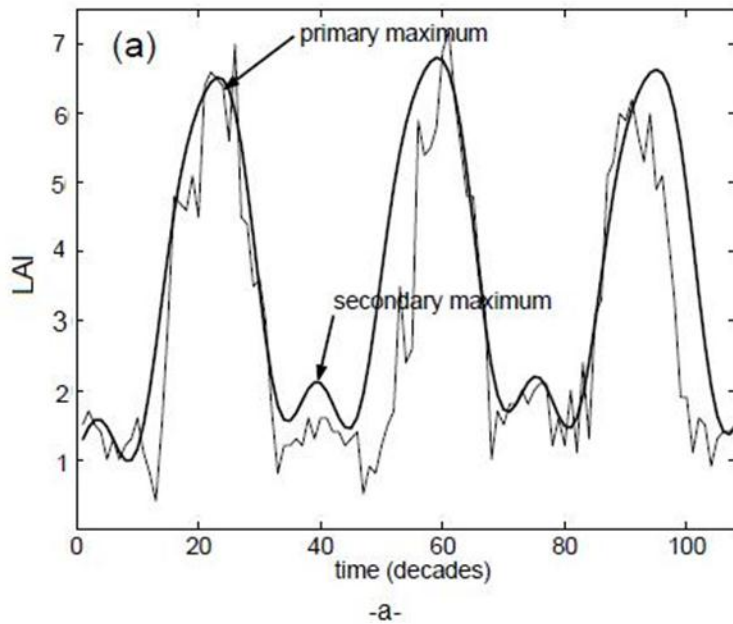
4. RESULTS AND CONCLUSIONS (CONT.)
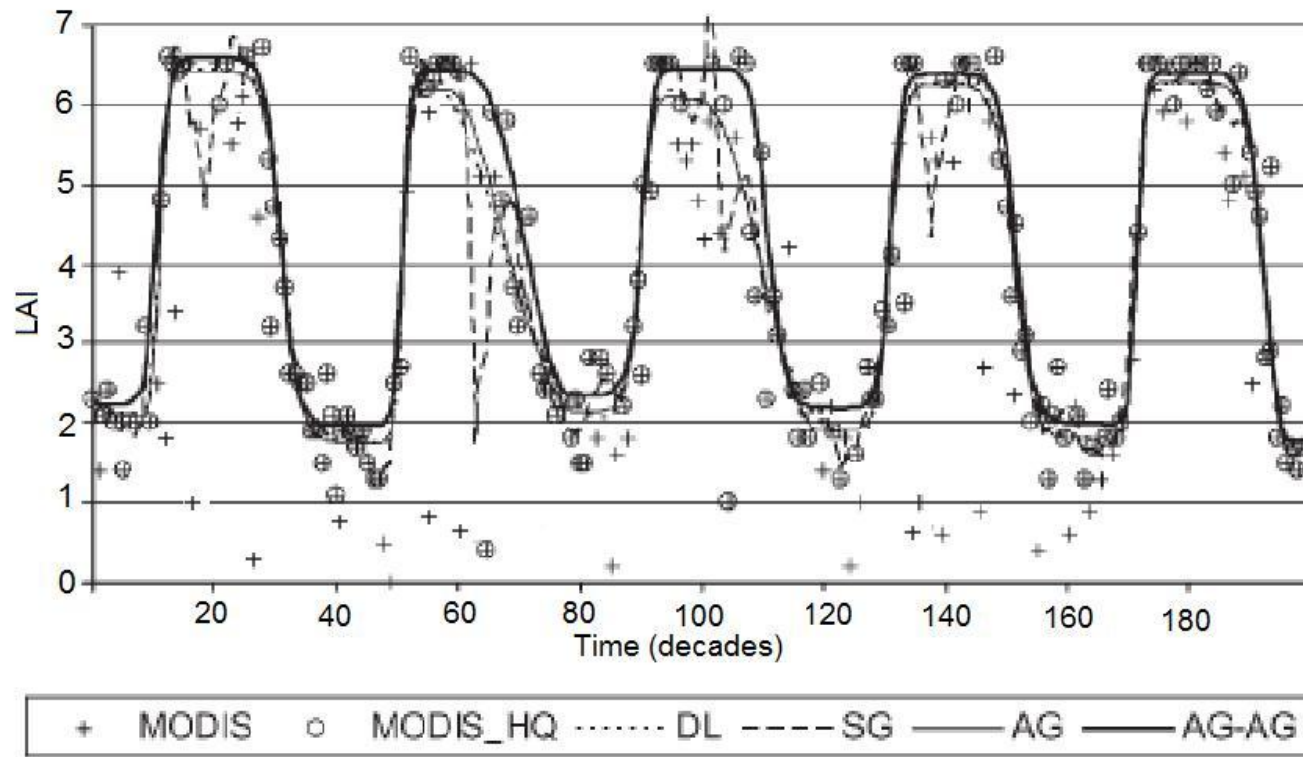
The figure shows an example of the fittings from the DL-function and SG-filtering approaches and the two iterations of fitting LAI time-series data using the AG functions, for a typical deciduous forest.

4. RESULTS AND CONCLUSIONS (CONT.)

- In this figure, the short-dashed line and the long-dashed line represent results from the DL-function and SG-filtering approaches, respectively. The SG-filtering approach is sensitive to the noisy data in the summer season. The thin solid line represents the results from the first TIMESAT AG fit using weights based on the LAI quality flags. The thick solid line represent the two AG iterations.

- This example shows a very good seasonal cycle of a typical deciduous forest. The two-iteration AG approach shows a better fitting result to high LAI values, as well as high-quality data.

- With circles are highlighted high-quality retrievals.

- MODIS land products provide high-quality-data sources for climate, weather forecast, and ecological models.

- TIMESAT software is a useful tool to smooth and to gap-fill MODIS LAI time-series data.

4. RESULTS AND CONCLUSIONS (CONT.)

- Using TIMESAT software it is possible to determine the number of seasons.

- If it can be observed from this figure, if the amplitude ratio is below a user defined threshold we have one annual season. If the ratio is above the threshold we have two annual seasons.

-a-

-b-

4. RESULTS AND CONCLUSIONS (CONT.)

- To take into account that most noise for vegetation indices generated from remotely sensed land data is negatively biased, the determination of the parameters of the model function is done in two or more steps. The thin solid line represent the original LAI data. (a) The thick line shows the fitted function from the first step. (b) The thick solid line displays the fit from the last step where the weights of the low data values have been decreased.
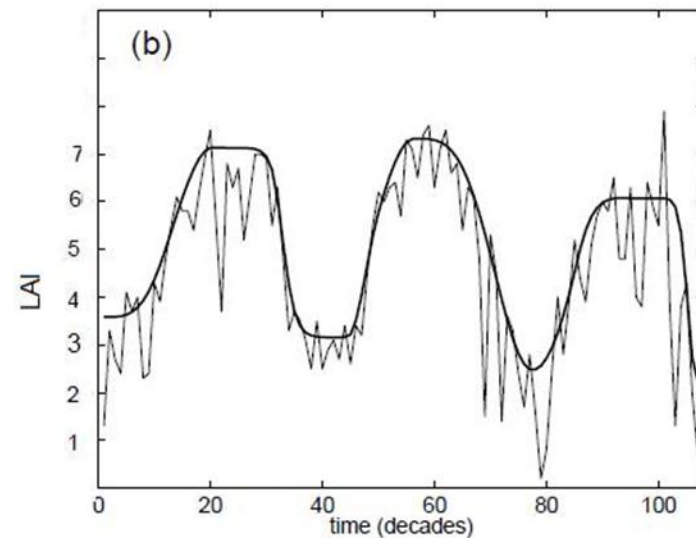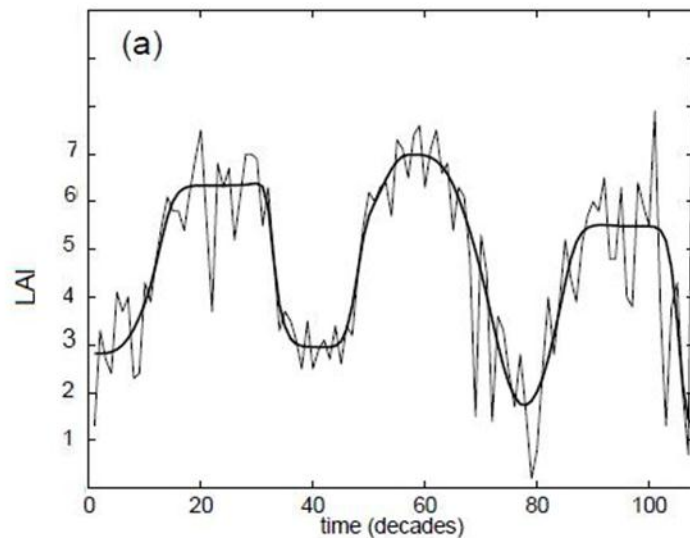
gheorghe.stancalie@meteoromania.ro
argentina.nertan@meteoromania.ro

Thank you for your kind attention!