# MODIStsp: A Tool for Automatic Preprocessing of MODIS Time Series - v1.3.3

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## Contents



# 1 Introduction

MODIStsp is a novel "R" package allowing to automatize the creation of time series of rasters derived from MODIS Land Products data. It allows to perform several preprocessing steps on MODIS data available within a given time period.

Development of MODIStsp started from modifications of the ModisDownload "R" script by Thomas Hengl (2010), and successive adaptations by Babak Naimi (2014). The basic functionalities for download and preprocessing of MODIS datasets provided by these scripts were gradually incremented with the aim of:

- developing a standalone application allowing to perform several preprocessing steps (e.g., download, mosaicing, reprojection and resize) on all available MODIS land products by exploiting a powerful and user-friendly GUI front-end;
- allowing the creation of time series of both MODIS original layers and additional Quality Indicators (e.g., data acquisition quality, cloud/snow presence, algorithm used for data production, etc. ) extracted from the aggregated bit-field QA layers;
- allowing the automatic calculation and creation of time series of several additional Spectral Indexes starting form MODIS surface reflectance products.

All processing parameters can be easily set with a user-friendly GUI, although non-interactive execution exploiting a previously created Options File is possible. Stand-alone execution outside an "R" environment is also possible, allowing to use scheduled execution of MODIStsp to automatically update time series related to a MODIS product and extent whenever a new image is available.

Required MODIS HDF files are automatically downloaded from NASA servers and resized, reprojected, resampled and processed according to user's choices. For each desired output layer, outputs are saved as single-band rasters corresponding to each acquisition date available for the selected MODIS product within the specified time period. "R" *RasterStack* objects with temporal information as well as Virtual raster files (GDAL vrt and ENVI META files) facilitating access to the entire time series can be also created.

# 2 Installation

`MODIStsp` requires R v >= 3.2.1 and GDAL (Geospatial Data Abstraction Library) v >= 1.11.1 **with support for HDF4 raster format** to be installed in your system. Brief instructions for installing R and GDAL can be found HERE.

## 2.1 On Windows

You can install the stable version of `MODIStsp`, from CRAN:

```
install.packages("MODIStsp")
```

, or the development version (containing the latest improvements and bug fixes):

```
library(devtools)
install_github("lbusett/MODIStsp")
```

Note that **if the `GTK+` library is not already installed on your system, installation may fail**. In that case, please install and load the `gWidgetsRGtk2` library beforehand:

```
install.packages("gWidgetsRGtk2")
library(gWidgetsRGtk2)
```

Upon loading `gWidgetsRGtk2` , an error window will probably appear. This signals that library "GTK+" is not yet installed on your system or is not on your PATH. To install itpress "OK". A new window dialog window will appear, asking if you want to install "GTK+". Select "Install GTK" and then "OK" . Windows will download and install the GTK+ library. When it finishes, the RSession should be restarted and you should be ready to go !

In case RStudio doesn't automatically restart or continuously asks to install GTK+ again, kill it form "Task Manager" (or restart the R session from RStudio "Session" menu), reload RStudio and the try to reload `gWidgetsRGtk2`. If it loads correctly, you should be ready to go.

If it still fails, try downloading the GTK+ bundle from:

http://ftp.gnome.org/pub/gnome/binaries/win64/gtk+/2.22/gtk+-bundle_2.22.1-20101229_win64.zip (OR http://ftp.gnome.org/pub/gnome/binaries/win32/gtk+/2.22/gtk+-bundle_2.22.1-20101227_win32.zip if on Win32)

, unzip the archive on a folder of your choice (e.g., `C:\\Program Files\\GTK+`), then add the path to its "bin" subfolder (e.g., `C:\\Program Files\\GTK+\\bin\\` to your system PATH environment variable.

Restart your system and try loading again `gWidgetsRGtk2`: if it loads ok, you should be ready to install `MODIStsp`

## 2.2 On Linux systems

To install `MODIStsp` on Linux, you have to first install the following required dependencies:

- `Cairo` >= 1.0.0, `ATK` >= 1.10.0, `Pango` >= 1.10.0, `GTK+` >= 2.8.0, `GLib` >= 2.8.0 (required by package `RGtk2`)
- `Curl` (required by package `curl`)
- `GDAL` >= 1.6.3, `PROJ.4` >= 4.4.9 (required by package `rgdal`)

On *Debian and Ubuntu-based* systems, to install those packages open a terminal and type:

```
sudo apt-get install r-cran-cairodevice r-cran-rgtk2 libcairo2-dev libatk1.0-dev libpango1.0-dev
libgtk2.0-dev libglib2.0-dev libcurl4-openssl-dev libgdal-dev libproj-dev
```

On *rpm-base systems*, to install packages open a terminal and type:

```
sudo yum install libcairo2-devel libatk1.0-devel libpango1.0-devel gtk2 gtk2-devel
glib2-devel libcurl-devel gdal-devel proj proj-devel proj-epsg proj-nad
```

Then, you can install the stable version of MODIStsp from CRAN:

```
install.packages("MODIStsp")
```

, or the development version (containing the latest improvements and bug fixes) from github;

```
library(devtools)
install_github("lbusett/MODIStsp")
```

## 2.3 On Mac OS

**NOTE: The following installation notes were kindly provided by a MODIStsp user and should be valid for MODIStsp installation on R 3.4.0 and above with Mac OSX Sierra. Since we are not working on Mac we were not able yet to check this, but we hope it may be useful at least to put you in the right direction if you have installation problems)**

Installing MODIStsp requires many dependencies:

For installation on MAC OSX sierra, there are three main issues: - As outlined here in the comment by **tobybot11** (https://gist.github.com/sebkopf/9405675), Rgtk requires the x11 libraries/headers (gdk/gdkx.h specifically) and doesn't work with the quartz libraries/headers which now are the default for GTK - When installing the dependencies gWidgetsRGtk2 and cairoDevice from CRAN you need to choose the version "OS X Mavericks binaries" and not "Package source" - You have to be sure that gdal is installed with HDF4 support.

1 - Update to a recent R version if needed, then update all packages

```
# update packages
update.packages()
# install the development version of devtools:
install.packages(c("devtools"))
devtools::install_github("hadley/devtools")
```

2 - Now, install RGtk2 using Homebrew (https://gist.github.com/sebkopf/9405675). First, ensure you have cairo installed with "–with-x11":

```
brew uninstall cairo --ignore-dependencies
brew install --with-x11 cairo
```

next, edit the configure options for GTK to require x11 rather than Quartz:

```
brew edit gtk+
```

in the def install section, remove the reference to quartz and switch to:

```
--with-gdktarget=x11,
--enable-x11-backend
```

Now install:

```
brew install --build-from-source --verbose gtk+
export PKG_CONFIG_PATH=

/usr/local/lib/pkgconfig:/usr/local/lib/pkgconfig/gtk+-2.0.pc:/opt/X11/lib/pkgconfig
```

3 - next, install `RGtk2`. Since install.packages("Rgtk2") is not going to work, go here, download RGtk2_2.20.33.tar.gz and, from a terminal run:

```
R CMD INSTALL RGtk2_2.20.33.tar.gz
```

Now, open R and run:

```
library(RGtk2)
```

hopefully, `RGTk2` will load without errors !

4 - Install packages `gWidgetsRGtk2` and `cairoDevice`

**Very important !!!!** from CRAN, download the **"OS X Mavericks binaries"** for gWidgetsRGtk2 and cairoDevice( not "Package source"). Save both to Frameworks/R.framework/3.4..., open R and run the code below (This will also install cairoDevice)

```
install.packages("gWidgetsRGtk2",

lib="~/Library/Frameworks/R.framework/Versions/3.4/Resources/library/gWidgetsRGtk2")
library(gWidgetsRGtk2)
library(cairoDevice)
```

*(This will work for R version 3.4, mac OS X Sierra)*

5 - Install GDAL with HDF4 support

Check that gdal is installed with hdf4 support. From a terminal:

```
> gdal-config --formats
```

if gdal is installed, check what drivers are installed: the list should include hdf4.

If gdal is not yet installed or hdf4 is not supproted, install/reinstall it following these notes

```
> brew install hdf4
# prefer hdf4 links over NetCDF
> brew link --overwrite hdf4
> brew install gdal --complete --enable-unsupported --with-hdf4
# check what drivers are installed, list should now include hdf4:
> gdal-config --formats
```

6 - Install rgdal

since rgdal is not usually looking in "/usr/local/lib"" you must include that with `install.packages()`:

```
install.packages('rgdal',
                 type = "source",configure.args = c(
                   '--with-proj-include=/usr/local/include',
                   '--with-proj-lib=/usr/local/lib')
                 )
```

7 - Finally, install MODIStsp from CRAN or GitHub:

```
install.packages("MODIStsp")
MODIStsp()
```

OR

```
library(devtools)
install_github("lbusett/MODIStsp", ref = "master")
MODIStsp()
```

Good luck!

# 3 Running the tool in Interactive Mode: the MODIStsp GUI

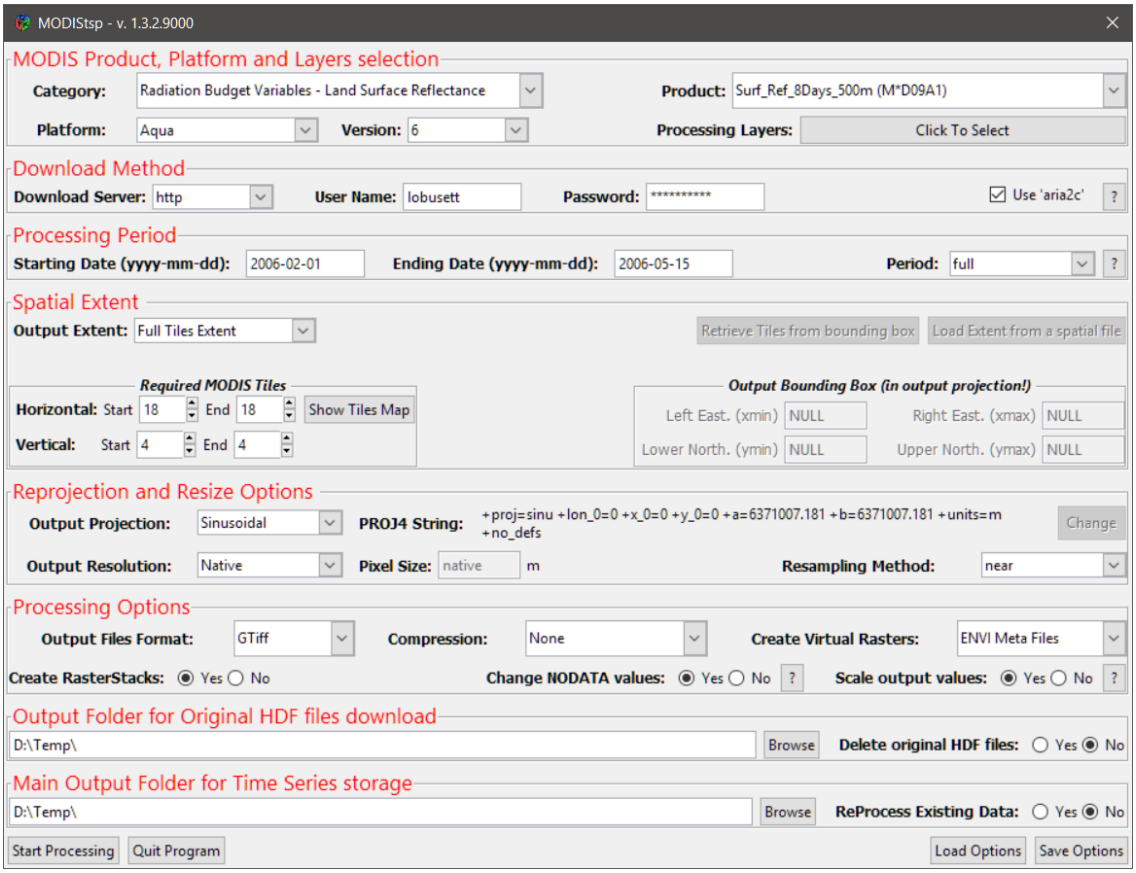
The easiest way to use `MODIStsp` is to use its powerful GUI (Graphical User Interface) for selection of processing options, and then run the processing.

To open the GUI, load the package and launch the MODIStsp function, with no parameters:

```
library(MODIStsp)
MODIStsp()
```

This **opens a GUI** from which processing options can be specified and eventually saved (or loaded) (Note 1: PCs with a small screen can fail to visualize the whole GUI; in this case, the user can add scroll bars with `MODIStsp(scrollWindow=TRUE)`); Note 2: At the first execution of `MODIStsp`, a Welcome screen will appear, signaling that `MODIStsp` is searching for a valid GDAL installation. Press "OK" and wait for GDAL to be found. If nothing happens for a long time (e.g., several minutes), `MODIStsp` (and in particular the gdalUtils package on which it relies) is not finding a valid GDAL installation in the more common locations. To solve the problem: 1. Ensure that GDAL is properly installed in your system 2. (On Windows) If it is installed, verify that GDAL is in your system PATH. and that the *GDAL_DATA* environment variable is correctly set (You can find simple instructions HERE) 3. If nothing works, signal it in the issues GitHub page of `MODIStsp` and we'll try to help!

The GUI allows selecting all processing options required for the creation of the desired MODIS time series. The main available processing options are described in detail in the following.




## 3.1 Selecting Processing Parameters

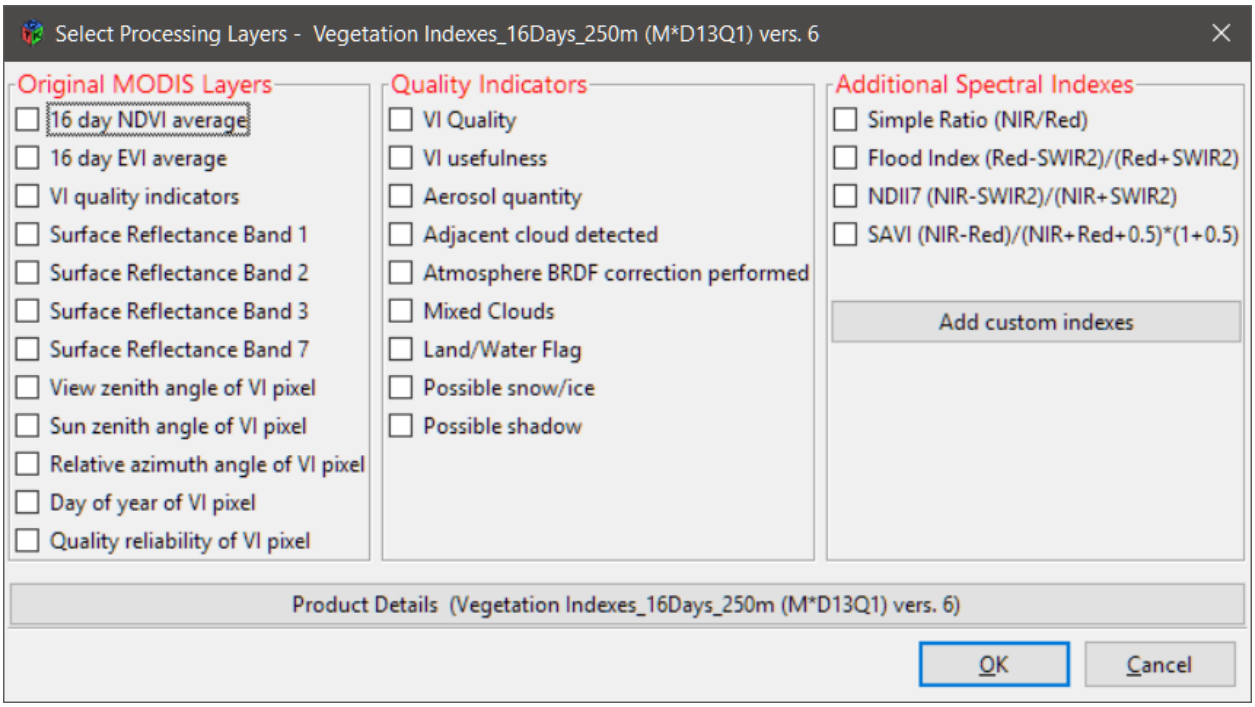
### 3.1.1 *MODIS Product, Platform and Layers:*

The top-most menus allow to specify details of the desired output time series:

1. **"Category"** and **"Product"**: Selects the MODIS product of interest

2. **MODIS platform(s)**: Selects if only TERRA, only AQUA or Both MODIS platforms should be considered for download and creation of the time series
3. **version**: Selects whether processing version 5 or 6 (when available) of MODIS products has to be processed

After selecting the product and version, clicking the **"Click to Select Desired Layers"** button opens the Select Processing Layers GUI panel, from which the user **must** select which MODIS original layers and/or derived Quality Indexes (QI) and Spectral Indexes (SI) layers should be processed:

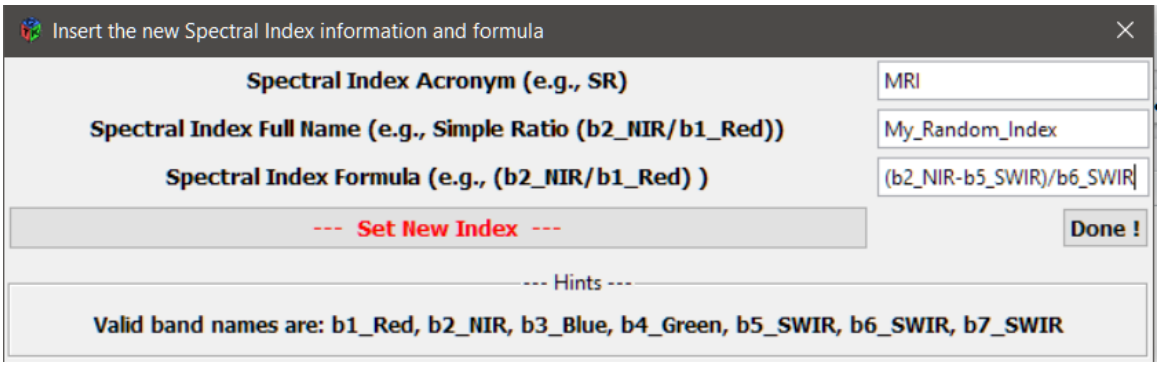



- The left-hand frame allows to select which *original MODIS layers* should be processed.
- The central frame allows to select which *Quality Indicators should be extracted* from the original MODIS Quality Assurance layers.
- For MODIS products containing surface reflectance data, the right-hand frame allows to select which additional *Spectral Indexes should be computed*. The following commonly used Spectral Indexes are available for computation by default:

**Table II: List of default Spectral Indexes available in MODIStsp**

| Index Acronym | Index name and reference |
|---|---|
| NDVI | Normalized Difference Vegetation Index (Rouse et al. 1973) |
| EVI | Enhanced Vegetation Index (A. Huete et al. 2002) |
| SR | Simple Ratio (Tucker 1979) |
| NDFI | Normalized Difference Flood Index (Boschetti et al. 2014) |
| NDII7 (NDWI) | Normalized Difference Infrared Index - Band 7 (Hunt and Rock 1989) |
| SAVI | Soil Adjusted Vegetation Index (A.R Huete 1988) |
| NDSI | Normalized Difference Snow Index (Hall et al. 2002) |
| NDII6 | Normalized Difference Infrared Index - band 6 (Hunt and Rock 1989) |
| GNDVI | Green Normalized Difference Vegetation Index (Gitelson and Merzlyak 1998) |
| RGRI | Red Green Ratio Index (Gamon and Surfus 1999) |
| GRVI | Green-Red ratio Vegetation Index (Tucker 1979) |

You can however **specify other SIs to be computed without modifying MODIStsp source code** by clicking on the ***"Add Custom Index"*** button, which allow to provide info related to the new desired SI using a simple GUI interface.




Provided information (e.g., correct band-names, computable formula, etc. . . ) is automatically checked upon clicking "Set New Index". On success, the new index is added in the list of available ones for all products allowing its computation. Clicking "Done !" returns to the main.

#### 3.1.2 *Download Method:*

Select the method to be used for download. Available choices are:

1. **http**: download through ftp from NASA lpdaac http archive (http://e4ftl01.cr.usgs.gov). This requires providing a user name and password, which can be obtained by registering an account at the address https://urs.earthdata.nasa.gov/profile;
2. **ftp**: download from NASA ftp archive (ftp://ladsweb.nascom.nasa.gov/);
3. **offline**: this option allows to process/reprocess HDF files already available on the user's PC without downloading from NASA – useful if the user already has an archive of HDF images, or to reprocess data already downloaded via MODIStsp to create time series for an additional layer (*It is fundamental that the HDFs are those directly downloaded from NASA servers* ! (See here for additional details).

Checking the **use_aria2c** option allows to accelerate the download from NASA archives. This requires however that that the "aria2c" software is installed in your system. To download and install it, see: https://aria2.github.io/

*NOTE: The best performances are usually achieved using* http*, though that may vary depending on network infrastructure.*

#### 3.1.3 *Processing Period:*

Specify the starting and ending dates to be considered for the creation of the time in the series corresponding fields. Dates **must** be provided in the *yyyy–mm–dd* format (e.g., 2015-01-31)

The **Period** drop-down menu allows to choose between two options:

1. **full**: all available images between the starting and ending dates are downloaded and processed;
2. **seasonal**: data is downloaded only for one part of the year, but for multiple years. For example, if the starting date is 2005-03-01 and the ending is 2010-06-01, only the images of March, April and May for the years between 2005 and 2010 will be downloaded. This allows to easily process data concerning a particular season of interest.

#### 3.1.4 *Spatial Extent:*

Allows to define the area of interest for the processing. Two main options are possible:

1. **Full Tiles Extent**: specify which MODIS tiles need to be processed using the "Start" and "End" horizontal and vertical sliders in the *Required MODIS Tiles* frame. During processing, data from the different tiles is mosaiced, and a single file covering the total area is produced for each acquisition date (Note: pressing the "show map" button, a representation of the MODIS tiles grid is shown to facilitate the selection).
2. **Resized**: specify a custom spatial extent for the desired outputs either by:
    a. Manually inserting the coordinates of the Upper Left and Lower Right corners of the area of interest in the **Bounding Box** frame. *Coordinates of the corners must be provided in the coordinate system of the selected output projection*;
    b. pressing the **"Load Extent from a Spatial File" and selecting a raster or vector spatial file**. In this case, the bounding box of the selected file is retrieved, converted in the selected output projection, and shown in the "Bounding Box" frame. Required input MODIS tiles are also automatically retrieved from the output extent, and the tiles selection sliders modified accordingly.

#### 3.1.5 *Reprojection and Resize:*

Specify the options to be used for reprojecting and resizing the MODIS images.

- **"Output Projection"**: select one of the predefined output projections or specify a user-defined one. To specify a user selected projection, select "User Defined" and then insert a valid "Proj4" string in the pop-up window. Validity of the Proj4 string is automatically checked, and error messages issued if the check fails;
- **"Output Resolution"**, **"Pixel Size"** and **"Reprojection Method"**: specify whether output images should inherit their spatial resolution from the original MODIS files, or be resampled to a user-defined resolution. In the latter case, output spatial resolution must be specified in the measure units of the selected output projection. Resampling method can be chosen among "Nearest Neighbour" and "Mode" (Useful for down-sampling purposes). Other resampling methods (e.g., bilinear, cubic) are not currently supported since i) they cannot be used for resampling of categorical variables such as the QA and QI layers, and ii) using them on continuous variable (e.g., reflectance, VI values) without performing an a-priori data cleaning would risk to contaminate the values of high-quality observations with those of low-quality ones.

#### 3.1.6 *Processing Options:*

Several processing options can be set using check-boxes:

- **Output Files Format**: Two of the most commonly formats used in remote sensing applications are available at the moment: ENVI binary and GeoTiff. If GeoTiff is selected, the type of file compression can be also specified among "None", "PACKBITS", "LZW" and "DEFLATE".
- **Create Virtual Rasters**: Specify if virtual multitemporal files should be created. These virtual files allow access to the entire time series of images as a single file without the need of creating large multitemporal raster images. Available virtual files formats are ENVI meta-files and GDAL "vrt" files.
- **Create RasterStack**: Specify if the output time series should be also saved as as "R" *rasterStack* objects (with temporal information added through the "setZ" method of the *raster* package). This may be useful in order to easily access the preprocessed MODIS data within "R" scripts.

- **Change NoData values**: Specify if NoData values of MODIS layers should be kept at their original values, or changed to those specified within the "MODIStsp_Products_Opts" XML file. By selecting "Yes" in the "Change Original NODATA values" check-box, NoData of outputs are set to the largest integer value possible for the data type of the processed layer (e.g., for 8-bit unsigned integer layers, NoData is set always to 255, for 16-bit signed integer layers to 32767, and for 16-bit unsigned integer layers to 65535). Information about the new NoData values is stored both in the output rasters, and in the XML files associated with them.
- **Scale output values**: Specify if scale and offset values of the different MODIS layers should be applied. If selected, outputs are appropriately rescaled on the fly, and saved in the true "measure units" of the selected parameter (e.g., spectral indexes are saved as floating point values; Land Surface Temperature is saved in °K, etc.).

#### 3.1.7 *Main Output Folder for Time Series Storage:*

Select the main folder where the pre-processed time series data will be stored. All `MODIStsp` outputs **will be placed in specific sub-folders of this main folder** (see XXX for details on `MODIStsp` naming conventions)-.

The **"Reprocess Existing Data"** check-box allows to decide if images already available should be reprocessed if a new run of MODIStsp is launched with the same output folder. If set to "No", MODIStsp skips dates for which output files following the MODIStsp naming conventions are already present in the output folder. This allows to incrementally extend MODIS time series without reprocessing already available dates.

#### 3.1.8 *Output Folder for Original HDF Storage:*

Select the folder where downloaded **original MODIS HDF files** downloaded from NASA servers will be stored.

The **"delete original HDF files"** check-box allows also to decide if the downloaded images should be deleted from the file system at the end of the processing. To avoid accidental file deletion, this is always set to "No" by default, and a warning is issued before execution whenever the selection is changed to "Yes".

### 3.2 Saving and Loading Processing Options

Specified processing parameters can be saved to a JSON file for later use by clicking on the ***Save Options*** button.

Previously saved options can be restored clicking on the ***Load Options*** button and navigating to the previously saved JSON file.

(Note that at launch, `MODIStsp` ***always reloads automatically the processing options used for its last succesfull run*** .

### 3.3 Starting the processing

Once you are happy with your choices, click on **Start Processing**. `MODIStsp` will start accessing NASA servers to download and process the MODIS data corresponding to your choices.

For each date of the specified time period, `MODIStp` downloads and preprocesses all hdf images required to cover the desired spatial extent. Informative messages concerning the status of the processing are provided on the console, as well as on a self-updating progress window.

# 4 Non-Interactive Execution from within R

## 4.1 Specifying a saved "Options file"

`MODIStsp` can be launched in non-interactive mode within an `R` session by setting the optional `GUI` parameter to FALSE, and the `Options_File` parameter to the path of a previously saved JSON Options file. This allows to exploit `MODIStsp` functionalities within generic "R" processing scripts

```
library(MODIStsp)
# --> Specify the path to a valid options file saved in advance from MODIStsp GUI
options_file <- "X:/yourpath/youroptions.json"

# --> Launch the processing
MODIStsp(gui = FALSE, options_file = options_file)
```

## 4.2 Looping on different spatial extents

Specifying also the `spatial_file_path_` parameter overrides for example the output extent of the selected Options File. This allows to perform the same preprocessing on different extents using a single Options File, by looping on an array of spatial files representing the desired output extents. For example:

```
library(MODIStsp)
# --> Specify the path to a valid options file saved in advance from MODIStsp GUI
options_file <- "X:/yourpath/youroptions.json"

# --> Create a character array containing a list of shapefiles (or other spatial files)
extent_list <- list.files("X:/path/containing/some/shapefiles/", "\\.shp$")

# --> Loop on the list of spatial files and run MODIStsp using each of them to automatically
# define the output extent (A separate output folder is created for each input spatial file).

for (single_shape in extent_list) {
  MODIStsp(gui = FALSE, options_file = options_file, spatial_file_path = single_shape )
}
```

# 5 Standalone execution and scheduled processing

## 5.1 Standalone execution

- MODIStsp can be also executed as a "standalone" application(i.e., without having to open R/RStudio); to do this, from R launch the function `MODIStsp_install_launcher()`.

In a Linux operating system this function creates a desktop entry (accessible from the menu in the sections "Science" and "Geography") and a symbolic link in a known path (default: /usr/bin/MODIStsp). In Windows, a link in the Start Menu and optionally a desktop shortcut are created. See `?install_MODIStsp_launcher` for details and path customization.

Double-clicking those files or launching them from a shell without parameters will launch `MODIStsp` in interactive mode. Non-interactive mode is triggered by adding the "-g" argument to the call, and specifying the path to a valid Options File as "-s" argument:

- Linux: `MODIStsp -g -s "/yourpath/youroptions.RData"` (see `MODIStsp -h` for details).

- Windows:`your_r_library\MODIStsp\ExtData\Launcher\MODIStsp.bat -g -s "yourpath/youroptions.RData"` (see `C:\Users\you\Desktop\MODIStsp -h` for details).

If you do not want to install any link, launchers can be found in the subdirectory "MODIStsp/ExtData/Launcher" of your library path.

## 5.2 Scheduled Processing

Standalone non-interactive execution can be used to periodically and automatically update the time series of a selected product over a given study area. To do that, you should simply:

1. Open the `MODIStsp` GUI, define the parameters of the processing specifying a date in the future as the "Ending Date" and save the processing options. Then quit the program.
2. Schedule non-interactive execution of the launcher installed as seen before (or located in the subdirectory "MODIStsp/ExtData/Launcher" of your library path) as windows scheduled task (or linux "cron" job) according to a specified time schedule, specifying the path of a previously saved Options file as additional argument:

#### 5.2.0.1 On Linux

- edit your crontab by opening a terminal and type:

```
crontab -e
```

- add an entry for the launcher. For example, if you have installed it in /usr/bin and you want to run the tool every day at 23.00, add the following row:

```
0 23 * * * /bin/bash /usr/bin/MODIStsp -g -s "/yourpath/youroptions.RData"
```

#### 5.2.0.2 On Windows

- create a Task following these instructions; add the path of the MODIStsp.bat launcher as Action (point 6), and specifying `-g -s "X:/yourpath/youroptions.RData"` as argument.

# 6 Outputs Format and Naming Conventions

## 6.1 Single-band outputs

Output raster files are saved in specific subfolders of the main output folder. In particular, **a separate subfolder** is created for each processed original MODIS layer, Quality Indicator or Spectral Index. Each subfolder contains one image for each processed date, created according to the following naming conventions:

`"ProdCode"_"Layer"_"YYYY"_"DOY"."ext"`

*(e.g.,MOD13Q1_NDVI_2000_065.dat)*

, where:

- ***ProdCode*** is the code name of the MODIS product from which the image was derived (e.g., MOD13Q1);
- ***Layer*** is a short name describing the dataset (e.g., b1_Red, NDII, UI);
- ***YYYY*** and ***DOY*** correspond to the year and DOY (Day of the Year) of acquisition of the original MODIS image;
- ***ext*** is the file extension (.tif for GTiff outputs, or .dat for ENVI outputs).

## 6.2 Virtual multi-band outputs

ENVI and/or GDAL virtual time series files and *RasterStack* RData objects are instead stored **in the "Time_Series" subfolder** if required.

Naming convention for these files is as follow:

`"ProdCode"_"Layer"_"StartDOY"_"StartYear_"EndDOY"_"EndYear_"suffix".ext"`

*(e.g., MOD13Q1_NDVI_49_2000_17_2015_RData.dat)*

, where:

- ***ProdCode*** is the code name of the MODIS product from which the image was derived (e.g., MOD13Q1);
- ***Layer*** is a short name describing the dataset (e.g., b1_Red, NDII, UI);
- ***StartDOY***, ***StartYear***, ***EndDOY*** and ***EndYear*** indicate the temporal extent of the time serie created;
- ***suffix*** indicates the type of virtual file (ENVI, GDAL or RData);
- ***ext*** is the file extension (".vrt" for gdal virtual files, "META" for ENVI meta files or "Rdata" for `R` raster stacks).

# 7 Accessing the processed time series from R

Preprocessed MODIS data can be retrieved within `R` either by accessing the single-date raster files, or by loading the saved *RasterStack* objects.

Any single-date image can be accessed by simply opening it with a `raster` command:

```
library(raster)
modistsp_file <- "/my_path/my_moditsp_folder/MOD13Q1_2005_137_EVI.tif"
my_raster     <- raster(modistsp_file)
```

`rasterStack` time series containing all the processed data for a given parameter (saved in the "Time Series" subfolder - see here for details) can be opened by:

```
in_virtual_file <- "/my_moditsp_folder/Time_Series/MOD13Q1_MYD13Q1_NDVI_49_2000_353_2015_RData.RData"
indata          <- get(load(in_virtual_file))
```

This second option allows accessing the complete data stack and analyzing it using the functionalities for raster/raster time series analysis, extraction and plotting provided for example by the `raster` or `rasterVis` packages.

## 7.1 Extracting Time Series Data on Areas of Interest

`MODIStsp` provides an efficient function (`MODIStsp\_extract`) for extracting time series data at specific locations. The function takes as input a *RasterStack* virtual object created by `MODIStsp` (see above), the starting and ending dates for the extraction and a standard _Sp*_ object (or an ESRI shapefile name) specifying the locations (points, lines or polygons) of interest, and provides as output a `xts` object or `data.frame` containing time series data for those locations.

If the input is of class *SpatialPoints*, the output object contains one column for each point specified, and one row for each date. If it is of class *SpatialPolygons* (or *SpatialLines*), it contains one column for each polygon (or each line), with values obtained applying the function specified as the "FUN" argument (e.g., mean, standard deviation, etc.) on pixels belonging to the polygon (or touched by the line), and one row for each date.

As an example the following code:

```
#Set the input paths to raster and shape file
infile    <- 'in_path/MOD13Q1_MYD13Q1_NDVI_49_2000_353_2015_RData.RData'
shpname   <- 'path_to_file/rois.shp'
#Set the start/end dates for extraction
startdate <- as.Date("2010-01-01")
enddate   <- as.Date("2014-12-31")
#Load the RasterStack
inrts     <- get(load(infile))
# Compute average and St.dev
dataavg   <- MODIStsp_extract(inrts, shpname, startdate, enddate, FUN = 'mean', na.rm = T)
datasd    <- MODIStsp_extract (inrts, shpname, startdate, enddate, FUN = 'sd', na.rm = T)
# Plot average time series for the polygons
plot.xts(dataavg)
```

loads a *RasterStack* object containing 8-days 250 m resolution time series for the 2000-2015 period and extracts time series of average and standard deviation values over the different polygons of a user's selected shapefile on the 2010-2014 period.

# 8 Problems and Issues

Solutions to some common **installation and processing problems** can be found in MODIStsp FAQ:

http://lbusett.github.io/MODIStsp/articles/faq.html

- Please **report any issues** you may encounter in our issues page on GitHub:

https://github.com/lbusett/MODIStsp/issues

# 9 Citation

To cite MODIStsp please use:

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# 10 Installing R and GDAL

## 10.1 Installing R

### 10.1.1 Windows

Download and install the latest version of R which can be found here.

### 10.1.2 Linux

Please refer to the documentation which can be found here, opening the directory relative to your Linux distribution. The documentation provides instruction to add CRAN repositories and to install the latest R version. With Ubuntu 15.10 Wily (and newer) this step is not mandatory (although recommended), since

packaged version of R is >= 3.2.1 (although not the latest); in this case, user can install R by simply typing in a terminal

```
sudo apt-get install r-base
```

## 10.2 Installing GDAL >= 1.11.1

### 10.2.1 Windows

The easiest way to install GDAL on Windows is from the OSGeo4W Website

1. Open the OSGeo4W Website
2. In the **Quick Start for OSGeo4W Users** section, select the download of 32bit or 64bit of OSGeo4W network installer
3. Run the installer

- *Easiest Option*:
  - Select **Express Desktop Install**, then proceed with the installation. This will install GDAL and also other useful Spatial Processing software like QGIS and GRASS GIS
- *Advanced Option*:
  - Select **Advanced Install**, then click on "Next" a few times until you reach the "Select Packages" screen.
  - Click on "Commandline_Utilities_", and on the list look for "_gdal: The GDAL/OGR library... " entry
  - Click on "Skip": the word "skip" will be replaced by the current GDAL version number
  - Click on "Next" a few times to install GDAL

### 10.2.2 Debian and Ubuntu-based systems

1. Ensure that your repositories contain a version of `gdal-bin` >= 1.11.1. In particular, official repositories of Ubuntu 15.04 Vivid (or older) and Debian Jessie (or older) provide older versions of GDAL, so it is necessary to add UbuntuGIS-unstable repository before installing. To do this, follow instructions here). With Ubuntu 15.10 Wily (and newer) this step is not mandatory, although recommended in order to have updated version of GDAL installed.
2. To install GDAL, open a terminal and type

   ```
   sudo apt-get install gdal-bin
   ```

### 10.2.3 ArchLinux

GDAL is maintained updated to the latest version as binary package within the community repository; although that, the support for HDF4 format is not included. To bypass this problem, ArchLinux users can install `gdal-hdf4` package from AUR (see here or here for the package installation from AUR). This package is updated manually after each release of `gdal` on the community repository, so a temporal shift between a new `gdal` release and the update of `gdal-hdf4` could happen. If you want to manually add the support for HDF4 in case `gdal-hdf4` is out-of-date, you can do it following these instructions.

### 10.2.4 Other Linux systems

Install the packaged binary of GDAL included in your specific distribution; if the version is older than 1.11.1, or if the support for HDF4 format is not included, you can manually install the HDF4 library and compile the source code by adding the parameter `--with-hdf4` to the `configure` instruction).

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