
py-stint: PYthon Spatial/Temporal INtersection Toolset

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Abstract

This document describes the capabilities and use of the `py-stint` toolset for spatial and temporal intersections. The primary expected use for `py-stint` is to produce datasets combining land-use and climate data with MODIS albedo timeseries.

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1 Directory Structure

The `py-stint` project relies on four essential directories. The user should have write access to `INPUT.txt` and `STINT/`. These directories can be located anywhere relative to each other, but the structure of each directory should be as follows:

```
py-stint/ : INPUT.txt
           run.py
           Tools/
             *.py modules
           Data/
             MODIS_tiles.shp

MODIS_ARCHIVE/ : MCD43A3/ -One directory per MODIS product
                 h19v02/ -One directory per MODIS tile
                 *.hdf

ERA_ARCHIVE/ : era_climate_t2m_1of3.nc
               era_climate_t2m_2of3.nc
               era_climate_t2m_3of3.nc
               climate_field2_1of1.nc

STINT/ : Holds output directories, which are made while running py-stint.
```

2 Getting Data

2.1 Corine Landcover

2006 Corine Land Cover seamless vector data is part of the European Commission programme to COoRdinate INformation on the Environment (Corine).

EEA grants free access to all its data/applications provided that the user agrees:

- to acknowledge the source as follows: Copyright EEA, Copenhagen, 2007
- to display a link to the EEA web site <http://www.eea.europa.eu>
- not to use the data/applications for commercial purposes unless the Agency has expressly granted the right to do so

A spatialite database containing all landcover classes can be downloaded from the following link:

<http://www.eea.europa.eu/data-and-maps/data/clc-2006-vector-data-version-3/>

The spatialite database can be converted to shapefile and cropped to an Area of Interest via commandline:

```
$ ogr2ogr -f "ESRI Shapefile" <path/to/output> <path/to/clc06.sqlite>
-dsco SPATIALITE=yes -clipsrc <xmin> <ymin> <xmax> <ymax>
```

Where `<xmin>` `<ymin>` `<xmax>` `<ymax>` are the bounding x and y coordinates of the Area of Interest, in the LAEA-ETRS89 projection.

2.2 ERA-Interim Climate

ERA Interim climate data can be downloaded from the following website. The server may require an user account before allowing the download.

download: http://apps.ecmwf.int/datasets/data/interim_full_daily/

terms of use: http://apps.ecmwf.int/datasets/data/interim_full_daily/licence/

! → The ECMWF server sets a limit of about 2GB per file download. Download data in netcdf format, in either 6-hour or 24-hour resolution, with a single field (attribute) per file.

If the desired timespan will not fit on a single file, break it into as many downloads as necessary, with the start-date of each successive file one time-step later than the end-date of the previous file. e.g. if file1 ends 18:00 31. December 2011, then file2 should start 00:00 1. January 2012.

2.3 MODIS Datasets

MODIS products can be downloaded from two main sources, given below. Future versions of `py-stint` will incorporate dataset retrieval tools and functions based on the `modis_download.py` script from the `pyModis` project: <http://pymodis.fem-environment.eu/>

For now the best plan is to either figure out `modis_download.py` yourself (recommended, as it is excellent) or to (1) write a script in python or R to compile a list of files you want to download, then (2) use a command line utility like `axel` to retrieve all the files in the list.

After all files have been retrieved, ensure that the `MODIS_Archive/` directory is organized in the `archive/product/tile/*.hdf` structure, as illustrated in Section 1.

Core MODIS products such as albedo and surface temperature:

<http://e4ftl01.cr.usgs.gov/MOTA/>

Snow cover (National Snow and Ice Data Center):

<ftp://n5eil01u.ecs.nsidc.org/MOST/>

3 Workflow

Python programs given in the workflow guide should be called from the `py-stint/` directory. These commands are presented in the format
`$ python ...`

3.1 Setup

- `$ python Tools/MODIS_aoi.py path/to/aoi.shp`
 - Print a list of MODIS tiles to include in `MODIS_ARCHIVE/`
- Create project directory
- Prepare ERA and MODIS archives as per Section 2.
`MODIS_ARCHIVE/` should be complete with regard to:
 - products (MCD43A3 etc)
 - dates within timeframe
 - MODIS tiles which have been identified within the AOI
- Fill out `INPUT.ex` with actual project parameters, then save as `py-stint/INPUT.txt`

3.2 Processing

After completing the setup, execute each of the 7 processing stages consecutively via the command line. Each stage needs to execute successfully before the next stage can run, but nothing else needs to be done in between stages.

3.2.1 Stage 1: `$ python run.py 1`

The stage begins by parsing project parameters from `INPUT.txt`, as well as loading the projection and extent from the area of interest (AOI). Technically, these are loaded at the start of every stage, but this is where you'll be alerted to any errors in the input parameters.

The stage then checks for corrupt or missing files within the `MODIS_archive` given the region, timeframe and datasets specified in the input parameters.

Finally, the time variable is loaded from each NetCDF file in the ERA archive. An error is raised if there are any gaps or overlaps in timesteps.

Requires : `INPUT.txt`
`AOI/landcover` shapefile
`MODIS_archive`
`ERA_archive`
`MODIS_tiles.shp`

Produces : Prints a report on any issues found in the `MODIS` or `ERA` archives.

Creates subdirectories within the `STINT/` directory, if they are not already present.

Explore : This stage produces no new data to explore.

3.2.2 Stage 2: \$ python run.py 2

This stage aggregates each MODIS and ERA dataset into a single HDF5 array file, with dimensions [time, y, x].

The [time] dimension is shared by MODIS and ERA arrays, each timestep covering one 16-day MODIS observation period.

The spatial dimensions [y,x] are defined by the dataset's native projection (MODIS sinusoidal or WGS84 geographic coordinates).

HDF5 arrays are cropped to the project timeframe and the minimum rectangle necessary to completely contain the AOI.

MODIS datasets: tiles are merged, subsets determined, and days aggregated.

ERA datasets: subsets determined, 6- or 24-hour records averaged to match 16-day MODIS intervals.

Requires : INPUT.txt
 AOI/landcover shapefile
 MODIS_archive
 ERA_archive
 MODIS_tiles.shp

Produces : ERA and MODIS HDF5 array files, native projections:
 STINT/Processing/HDF/<dataset>.hdf5

Explore : The HDF5 array file is probably the richest, most exciting format generated in py-stint processing. Data for a given region and timeframe is stored in a single, compact and efficient format. It has excellent potential for visualization of spatial and temporal trends within albedo and climate datasets.

The first tool for exploring HDF5 data will be a python program for converting individual timesteps to geoTIFF files, which can be viewed in a desktop GIS browser.

* Python: h5py and numpy

* R: rhdf5, h5r, or ncdf4

* matlab: h5disp and h5read

3.2.3 Stage 3: \$ python run.py 3

Produce ERA and MODIS shapefiles from HDF5 subset arrays.

The shapefiles consist of a polygon grid, each raster cell represented by rectangle with attribute fields for cell id, cell center coordinates, and grid coordinates which allow cell values to be retrieved from the HDF5 array file. For example y_ind = 0, x_ind = 0 is the top left cell in the grid.

The spatial reference system of the shapefile geometries as well as the cell center coordinates is the same as the HDF5 from which the grid was derived, MODIS sinusoidal or ERA WGS84.

Requires : STINT/HDF/<project>_<dataset>.hdf5

Produces : ERA and MODIS shapefiles, native projections:
 STINT/SHP/<project>_era.shp
 STINT/SHP/<project>_modis.shp

Explore : The products of this stage are standard ESRI shapefiles that can be explored in any GIS browser. Attribute fields and projection of each file are summarized below:

	<code>modis.shp</code>
Spatial reference system	MODIS sinusoidal projection
<code>id</code>	MODIS cell id
<code>x_ctr,y_ctr</code>	(x, y) sinusoidal coordinates, cell center
<code>x_ind,y_ind</code>	grid coordinate HDF5 array file

	<code>era.shp</code>
Spatial reference system	WGS84 geographic coordinates
<code>id</code>	ERA cell id
<code>x_ctr,y_ctr</code>	(lon, lat) coordinates, cell center
<code>x_ind,y_ind</code>	grid coordinate HDF5 array file

3.2.4 Stage 4: \$ python run.py 4

Transform ERA & MODIS shapefiles to AOI/landcover spatial reference system.

Construct r-tree spatial index (`*.idx`) for each to speed up spatial queries such as the intersection in Stage 5.

Cell center coordinates in the attribute fields `y_ctr` and `y_ctr` remain in the dataset's original spatial reference system.

Requires : STINT/SHP/<project>.era.shp
STINT/SHP/<project>.modis.shp

Produces : ERA and MODIS shapefiles with index, AOI projections:
STINT/SHP/<project>.era_reprj.shp
STINT/SHP/<project>.era_reprj.idx
STINT/SHP/<project>.modis_reprj.shp
STINT/SHP/<project>.modis_reprj.idx

Explore : The products of this stage are standard ESRI shapefiles that can be explored in any GIS browser. Attribute fields and projection of each file are summarized below:

	<code>modis_reprj.shp</code>
Spatial reference system	Native AOI projection
<code>id</code>	MODIS cell id
<code>x_ctr, y_ctr</code>	(x, y) sinusoidal coordinates, cell center
<code>x_ind, y_ind</code>	grid coordinate HDF5 array file

	<code>era_reprj.shp</code>
Spatial reference system	Native AOI projection
<code>id</code>	ERA cell id
<code>ctr_x, ctr_y</code>	(lon, lat) coordinates, cell center
<code>x_ind, y_ind</code>	grid coordinate HDF5 array file

3.2.5 Stage 5: \$ python run.py 5

Intersect AOI/landcover shapefile with `era_reprj.shp` to produce landcover/climate shapefile, `lcc.shp`. Each feature in the intersection product is wholly within a single ERA climate cell and a single landcover type.

Attribute fields specified by `lc_` in `INPUT.txt` are preserved from AOI/landcover shapefile.

Takes advantage of `era_reprj.idx` to speed up intersection.

- Requires : AOI/landcover shapefile
STINT/SHP/<project>_era_reprj.shp
STINT/SHP/<project>_era_reprj.idx
- Produces : land cover/climate shapefile with index, AOI projection:
STINT/SHP/<project>_lcc.shp
STINT/SHP/<project>_lcc.idx
- Explore : `lcc.shp` is a standard ESRI shapefile that can be explored in any GIS browser. Attribute fields and projection are summarized below:

	<code>lcc.shp</code>
Spatial reference system	Native AOI projection
<code>id</code>	lcc cell id
<code>era_id</code>	ERA cell id
<code>era_ctr_x</code> , <code>era_ctr_y</code>	(lon, lat) coordinates, ERA cell center
<code>era_x_ind</code> , <code>era_y_ind</code>	grid coordinate of matching record from ERA HDF5 array file
<code>lc_id</code>	AOI/landcover feature id
<code>lc_*</code>	Any attribute fields, such as land type, selected for preservation from AOI/landcover shapefile

3.2.6 Stage 6: \$ python run.py 6

Intersect `lcc.shp` with `modis_reprj.shp` to produce landcover/climate/modis shapefile, `lcm.shp`.

Each feature in the intersection product is wholly within a single MODIS cell, single ERA climate cell, and a single landcover type. This combination of attribute fields is illustrated in Figure 1.

Attribute fields from `lcc.shp` are preserved, as well as additional fields identifying which MODIS cell each feature belongs to. Additionally, an Area field describes the size in square meters of each feature in the aoi projection.

Takes advantage of `modis_reprj.idx` to speed up intersection.

`lcm.shp` is effectively the central product of this workflow, breaking each landcover feature into polygons wholly within and linked to individual MODIS and ERA cells

- Requires : STINT/SHP/<project>_modis_reprj.shp
STINT/SHP/<project>_modis_reprj.idx
STINT/SHP/<project>_lcc.shp
- Produces : landcover/climate/modis shapefile with index, AOI projection:
STINT/SHP/<project>_lcm.shp
STINT/SHP/<project>_lcm.idx
- Explore : `lcm.shp` is a standard ESRI shapefile that can be explored in any GIS browser. Attribute fields and projection are summarized below:

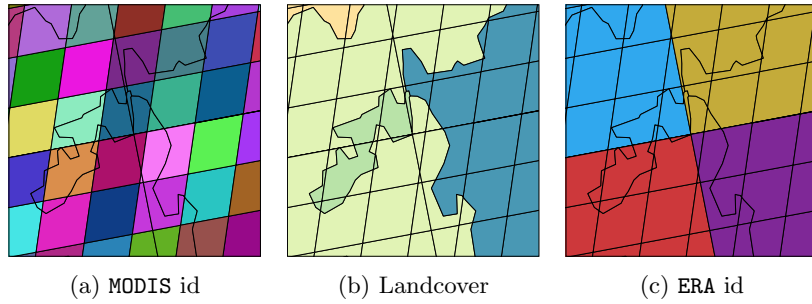


Figure 1: `lcm.shp`, shaded by different attribute fields

	<code>lcm.shp</code>
Spatial reference system	Native AOI projection
<code>id</code>	lcc cell id
<code>area</code>	area of feature in AOI projection, m ²
<code>era_id</code>	ERA cell id
<code>era_ctr_x, era_ctr_y</code>	(lon, lat) coordinates, ERA cell center
<code>era_x_ind, era_y_ind</code>	grid coordinate of matching record from ERA HDF5 array file
<code>mod_id</code>	MODIS cell id
<code>mod_ctr_x, mod_ctr_y</code>	(x, y) coordinates, MODIS cell center
<code>mod_x_ind, mod_y_ind</code>	grid coordinate of matching record from MODIS HDF5 array file
<code>lc_id</code>	AOI/landcover feature id
<code>lc_*</code>	Any attribute fields, such as land type, selected for preservation from AOI/landcover shapefile

3.2.7 Stage 7: `$ python run.py 7`

This stage exports a CSV spreadsheet file for each MODIS and ERA dataset, corresponding to the HDF5 array files. It then exports a landcover CSV which gives the area and landcover attributes of each feature in `lcm.shp` and links the feature to the corresponding MODIS and ERA rows.

The CSV system is basically a two dimensional representation of the HDF5 array files combined with `lcm.shp`. Each row in `lc.csv` represents a single feature in `lcm.shp`, with landcover attributes as well as the MODIS_id and ERA_id linked to the feature.

Each MODIS and ERA cell identified in `lcm.shp` is represented as a row within each of the respective dataset CSV files, with columns corresponding to MODIS intervals within the timeframe specified.

Requires : AOI/landcover shapefile
 STINT/HDF/<project>.<dataset>.hdf5
 STINT/SHP/<project>.lcm.shp

Produces : STINT/CSV/<project>.lc.csv
 STINT/CSV/<project>.<dataset>.csv

Explore : `lc.csv`: each row is a landcover feature with MODIS and ERA links

MODIS and ERA dataset CSVs: each row is a full timeseries for an individual cell identified within `1cm.shp`.

3.3 Troubleshooting

While I tried hard to write code that catches problems and prints clear messages describing the nature of the error, there may be situations where unclear errors slip through. If such errors emerge while running `py-stint`, they will probably come in one of the following flavors:

1. Input: a problem with the format or structure of input parameters, project directories, or files linked to the project.

Going through the `INPUT.txt` file and the directory structure can help resolve this kind of error.

2. File Access: a problem opening or loading the contents of a file, such as a shapefile or hdf.

This can arise through an input error, a problem with the installation of the module being used to access the data, or a problem with the library that module depends on.

3. Data Operations: a problem manipulating or transforming data, such as managing data types, transforming spatial coordinates or geometries between projections, or sorting multiple MODIS arrays into a single subset array.

This could be due to a module/library installation problem, or because of a previous failed operation. Errors do not always end the process at the point when they occur. It could be that a file access or transformation step failed earlier in the processing, but the resulting incorrect or None type object did not immediately provoke an error or Exception.

Each stage described in Section 3.2 includes a list of input files in order to help in tracking down any errors that do arise.

Appendix

A Requirements & Installation

Python 2.7 is required for `py-stint`.

On an Ubuntu system, the following commands are sufficient to set up the libraries and python modules listed in Sections A.1 and A.2.

```
$ sudo apt-get install ipython python-numpy python-pip python-scipy
python-matplotlib python-h5py python-software-properties
$ sudo add-apt-repository ppa:ubuntugis/ubuntugis-unstable
$ sudo apt-get install libspatialindex-dev python-gdal gdal-bin
$ sudo pip-install rtree pyproj
```

A.1 Library Dependencies

The following software libraries must be compiled before many of the python modules can be installed. When possible, try to compile them in the order listed, as some (such as `gdal`) have capabilities which depend on the previous libraries already being present.

- GEOS : Required for geometric intersections.
<http://trac.osgeo.org/geos/>
- libspatialindex : Required for rtree spatial indexing module for python.
<http://libspatialindex.github.io/>
- netCDF4 : Required for ERA climate data and gdal support for MODIS hdf.
<https://www.unidata.ucar.edu/software/netcdf/>
- hdf5 : Required for h5py and the format used to aggregate MODIS and ERA subset arrays.
<http://www.hdfgroup.org/HDF5/>
- GDAL : Required for geospatial data I/O.
<http://www.gdal.org/>
- proj.4 : required for reprojecting shapefile and raster datasets.
<http://trac.osgeo.org/proj/>

A.2 Python Dependencies

Basic modules are included in most installations of python. Scientific and Geospatial modules can be installed via package management, `pip`, or `easyinstall`. Geospatial modules in particular may require the libraries listed in Section A.1 to be available.

- Basic Modules : `os`, `sys`, `math`, `glob`, `multiprocessing`, `datetime`, `cPickle`, `csv`
- Scientific Modules : `numpy`, `scipy`, `netCDF4`, `h5py`
- Geospatial Modules : `gdal+ogr+osr`, `rtree`