
Lagranto Documentation

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Contents:

1.1 Using conda

conda install -c conda-forge lagranto

1.2 Using pip

Ideally install it in a virtual environment. See for example [virtualenvwrapper](#).

```
pip install Lagranto
```

Then you can install the dependencies for testing or the documentations as follow:

```
pip install Lagranto[testing]
pip install Lagranto[docs]
```

To build the documentation do the following:

```
cd /path/to/lagranto/location
cd docs
make html
```

To test the package do the following:

```
cd /path/to/lagranto/location
pytest
```


The goal of this section is show how to calculate trajectories, analyzed them and plot them using the *Basic examples*.

- *Calculation*
- *Analyze*
- *Plotting*
- *Writing*

2.1 Calculation

The *Basic examples* provide a class, `lagranto.LagrantoRun`, to wrap the Lagranto programs in python. It allow to calculate trajectories in parallel. You can take a look at the docstring to get familiar with the class.

Let's say that we want to calculate Warm Conveyor Belt trajectories for a 5 day period in June 2013. Using Era-Interim we can start trajectories every 6 hour and we will calculate them for 48 hours forward in time. Since `lagranto.LagrantoRun` needs a list of (startdate, enddate), we can build the dates as follow:

```
from datetime import datetime, timedelta
from dypy.small_tools import interval
startdate = datetime(2013, 6, 1, 0)
enddate = startdate + timedelta(days=5)
dates = [(d, d + timedelta(hours=48)) for d in
          interval(startdate, enddate, timedelta(hours=6))]
```

If the Era-interim data are in the `erainterim` folder and if the output files should be written in the `output` folder, then the `lagranto.LagrantoRun` can be initialized as follow:

```
from lagranto import LagrantoRun
lrun = LagrantoRun(dates, workingdir='erainterim',
                  outputdir='output', version='ecmwf')
```

We want to start the trajectories every 20km in the box [5E, 40E, 30N, 60N], so let's create a starting file:

```
specifier = "'box.eqd(5,20,40,50,20)@profile(850,500,10)@hPa'"
out_create_startf = lrun.create_startf(startdate, specifier, tolist=True)
```

The *tolist* argument is needed if we want to use the same staring file for all starting time of the trajectories. We can now calculate the trajectories, but first starting for a single date to test our setup:

```
out_caltra = lrn.caltra(*dates[1])
```

We can also test tracing Q along a trajectories:

```
out_trace = lrn.trace(dates[1][0], field='Q 1.')
```

We can now calculate and trace the trajectories in parallel, but for this we will use a tracevars file:

```
tracevars = """Q          1.      0 P
U          1.      0 P
"""
out = lrn.run_parallel(trace_kw={'tracevars_content': tracevars}, type='both')
```

The *tracevars_content* keyword argument will be passed to trace to create a tracevars file with Q and U. The *type* keyword argument determine what is run in parallel, currently both, trace, and caltra are available.

2.2 Analyze

Now that we have calculated trajectories let's read them and analyze them. By default the name of the files are formatted as *lsl_{:%Y%m%d%H}.4*. So if we want to read the trajectories started at 00 UTC 01 June 2013 we can do as follow:

```
from lagranto import Tra
filename_template = 'output/lsl_{:%Y%m%d%H}.4'
filename = filename_template.format(date=dates[-1][0])
trajs = Tra()
trajs.load_netcdf(filename)
print(trajs)
```

We can now test if the trajectories fulfill the standard criteria for WCB, an ascent greater than 500 hPa in 48 hours. To make it clear, the goal of this exmple is not to replace the fortran routines of the LAGRANTO package but to illustrate the possibilities that python provides to analyze trajectories using a simple example.

```
wcb_index = np.where((trajs['p'][:, :1] - trajs['p']) > 500)
wcb_trajs = Tra()
wcb_trajs.set_array(trajs[wcb_index[0], :])
print(wcb_trajs)
```

2.3 Plotting

Now that we have WCB trajectories, let's plot them on a map. We will use cartopy for this.

```
import cartopy.crs as ccrs
import cartopy.feature as cfeature
from lagranto.plotting import plot_trajs
import matplotlib.pyplot as plt

crs = ccrs.Stereographic(central_longitude=180 - 170,
                        central_latitude=90 - 43,
                        true_scale_latitude=90 - 43)

fig = plt.figure()
ax = plt.axes(projection=crs)
land_50m = cfeature.NaturalEarthFeature('cultural', 'admin_0_countries',
                                         '50m', edgecolor='gray',
```

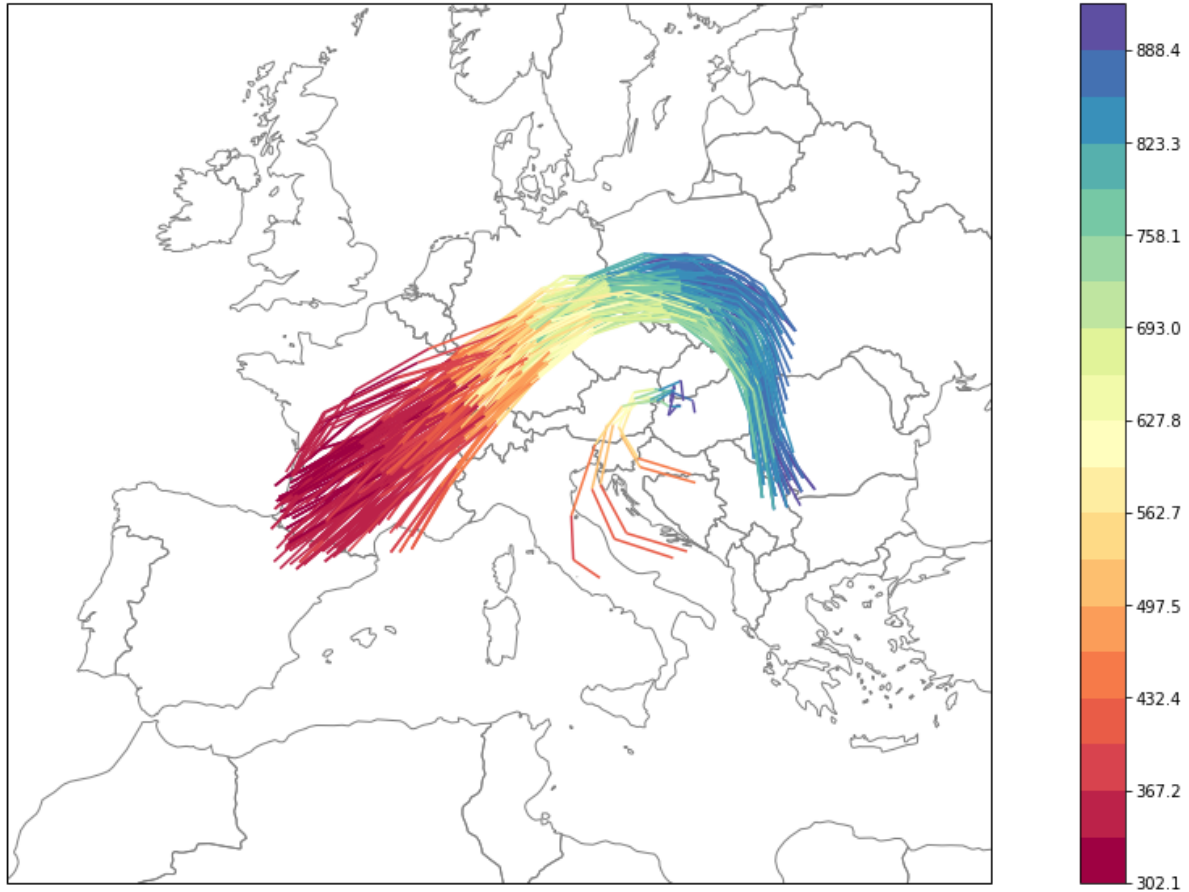
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```

facecolor='none', linewidth=0)
ax.add_feature(land_50m)
ax.set_extent([-10, 28, 30, 60])
plot_trajs(ax, wcb_trajs, 'p')
# fig.savefig('wcb_trajs_{date:%Y%m%d_%H}.pdf'.format(date=dates[-1][0]), bbox_
→ inches='tight')

```



2.4 Writing

The WCB trajectories can also be written to disk as follow:

```
wcb_trajs.write_netcdf('output/wcb_trajs.nc')
```


CHAPTER 3

Basic examples

In a first step, let's simply read the trajectories:

```
>>> from lagranto import Tra
>>> filename = 'lsl_20110123_10'
>>> trajs = Tra()
>>> trajs.load_ascii(filename)
```

or to read a netcdf file:

```
>>> filename = 'lsl_20110123_10.4'
>>> trajs.load_netcdf(filename)
```

The proprieties of the trajectories can be shown as follow::

```
>>> print(trajs)
24 trajectories with 41 time steps.
Available fields: time/lon/lat/p/Q/RH/TH/BLH
total duration: -14400.0 minutes
>>> print(trajs.variables())
['time', 'lon', 'lat', 'p', 'Q', 'RH', 'TH', 'BLH']
>>> print(trajs['Q'].shape)
(24, 41)
```


4.1 Tra

class `lagranto.Tra` (*filename=""*, *usedatetime=True*, *array=None*, ***kwargs*)
Class to work with LAGRANTO output.

Read trajectories from a LAGRANTO file and return a structured numpy array

Parameters

- **filename** (*string*) – File containing lagranto trajectories
- **usedatetime** (*bool*) – Read times as datetime objects, default True
- **array** (*structured array*) – If defined creates a new Tra object filled with the array

Returns structured array (Tra)

Return type `trajs(ntra, ntime)` with variables as tuple.

Examples

```
>>> filename = 'myls1file.nc'
>>> trajs = Tra()
>>> trajs.load_netcdf(filename)
>>> trajs['lon'][0,:] # return the longitudes for the first trajectory.
```

```
>>> trajs = Tra(filename)
>>> selected_trajs = Tra(array=trajs[[10, 20, 30], :])
```

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append (*trajs*)
append trajectories

Parameters **trajs** (*single Tra or list of Tra*) – Trajectories to concatenate with the current one

Examples

```
>>> files = ['ls1_20001010_00.4', 'ls1_2001010_01.4']
>>> filename = files[0]
>>> trajs = Tra(filename)
>>> newtrajs = [Tra(f) for f in files]
>>> trajs.append(newtrajs)
```

concatenate (*trajs, time=False, inplace=False*)

To concatenate trajectories together.

Concatenate trajectories together and return a new object. The trajectories should contain the same variables. if *time=False*, the number of timestep in each trajs should be the same if *time=True*, the number of trajectories in each Tra should be the same

Parameters

- **trajs** (*Tra or list of Tra*) – Trajectories to concatenate with the current one
- **time** (*bool, default False*) – if True concatenate along the time dimension
- **inplace** (*bool, default False*) – if True append the trajs to current Tra object and return None

Returns Return a new Tra (trajectories) object

Return type *Tra*

Examples

Create a new Tra object which include trajs and all newtrajs

```
>>> files = ['ls1_20001010_00.4', 'ls1_2001010_01.4']
>>> filename = files[0]
>>> trajs = Tra(filename)
>>> newtrajs = [Tra(f) for f in files]
>>> alltrajs = trajs.concatenate(newtrajs)
```

Append newtrajs to trajs

```
>>> trajs = Tra(filename)
>>> newtrajs = [Tra(f) for f in files]
>>> trajs.concatenate(newtrajs, inplace=True)
```

duration

Time duration in minutes.

get_array ()

Return the trajectories array as numpy object

initial

Give the initial time of the trajectories.

load_ascii (*filename, usedatetime=True, msv=-999.999, gz=False*)

Load trajectories from an ascii file

Parameters:

usedatetime: bool, default True If true return the dates as datetime object

msv: float, default -999.999 Change <msv> value into np.nan

gzip: bool, default False If true read from gzip file

load_netcdf (*filename*, *usedatetime=True*, *msv=-999*, *unit='hours'*, ***kwargs*)

Load trajectories from a netcdf

Parameters

- **filename** (*string*,) – path to a netcdf file containing trajectories
- **usedatetime** (*bool*, *default True*) – If True then return time as datetime object
- **msv** (*float*, *default -999*) – Define the missing value
- **unit** (*string*, *default hours*) – Define the units of the times (hours, seconds or hhmm)
- **exclude** (*list of string*, *default empty*) – Define a list of variables to exclude from reading
- **date** (*datetime or list*) – Can be used to select particular dates, for example to read in a single timestep
- **indices** (*list or tuple*) – Can be used to select particular trajectories

ntime

Return the number of time steps

ntra

Return the number of trajectories

set_array (*array*)

To change the trajectories array.

startdate

Return the starting date of the trajectories

variables

Return the names of the variables

write (*filename*, *fileformat='netcdf'*)

Method to write the trajectories to a file

write_ascii (*filename*, *gz=False*, *digit=3*, *mode='w'*)

Write the trajectories in an ASCII format

Parameters

- **filename** (*string*) – filename where the trajectories are written
- **mode** (*string*, *default w*) – define the mode for opening the file. By default in write mode ('w'), append ('a') is another option.
- **gz** (*boolean*, *default False*) – If true write the file as a gzip file
- **digit** (*int*, *default 3*) – Number of digit after the comma to use for lon, lat; Only 3 or 2 digits allowed

write_netcdf (*filename*, *exclude=None*, *unit='hours'*)

Write the trajectories in a netCDF file

Parameters

- **trajs** (*Tra*) – A Tra instance
- **filename** (*string*) – The name of the output file
- **exclude** (*list*, *optional*) – A list of variables to exclude
- **unit** (*string*, *optional*) – The unit of the dates, can be hours, seconds or hhmm

4.2 LagrantoRun

```
class lagranto.LagrantoRun(dates, workingdir='.', outputdir='.', startf='startf.4',  
                           lslname='lsl_{:%Y%m%d%H}.4', tracevars="", field="", ver-  
                           sion='cosmo', linkfiles=None, nprocesses=10, sdate=None,  
                           fresh=False, cmd_header=None, no_tmp_dir=False)
```

Perform Lagranto calculation.

Parameters

- **dates** (*list*) – list of (startdate, enddate) tuple
- **workingdir** (*string*, *optional*) – path to the model output directory, default to current
- **outputdir** (*string*, *optional*) – path to the trajectory utput directory, default to current
- **startf** (*string*, *optional*) – name of the startf to use (or to create), default to startf.4 The format parameter date can be used, for ex: startf_{date:%Y%m%d%H}.4
- **lslname** (*string*, *optional*) – name of the lsl file, define its type, default to lsl_{:%Y%m%d%H}.4
- **tracevars** (*string*, *optional*) – name of a tracevars file as used by trace, default to none
- **field** (*string*, *optional*) – name of a single field to trace, default to none
- **version** (*string*, *optional*) – name of the model version to use, currently only cosmo (default)
- **linkfiles** (*function*, *optional*) – function used to overwrite link_files in run. Should be used if COSMO output is not standard netcdf
- **nprocesses** (*int*, *optional*) – Number of processes used when running in parallel, default to 10
- **sdate** (*datetime object*,) – Starting date of the simulation; useful if files are named in forecast mode
- **fresh** (*bool*, *optional*) – Fresh start. Remove output directory first.
- **cmd_header** (*string*, *optional*) – Change the header using for running the command; see run_cmd help for more details.
- **no_tmp_dir** (*bool*, *optional*) – If set to True, do not create temporary folder. Useful only for special version of lagranto, and if the system as no tmp filesystem.

```
caltra (startdate, enddate, filename="", outfile="", **kwargs)
```

Compute trajectories for the given startdate

```
clear ()
```

Remove the output directory

```
create_startf (date, specifier, filename="", tolist=False, **kwargs)
```

Create a file with the starting position of the trajectories.

Parameters

- **date** (*datetime*) – date for which the startf date is produced
- **specifier** (*string*) – detailed description of starting positions; (see LAGRANTO documentations for more details)
- **filename** (*string*) – filename where starting positions are saved; the default is defined by *LagrantoRun* Can make use of the format parameter date, for example: startf_{date:%Y%m%d%H}.4

- **tolist** (*bool*) –

If the starting position should be saved as a list of points; Useful if the same file is used for different starting times

- **kwargs** (*dict*) – key, value options, possible values are listed below;
 - **cmd_header**: header to add to the shell command; (see *run_cmd* for more details)
 - **options**: list of options to pass to the startf function; (see the LAGRANTO documentation for more details)

density (*infile=None, outfile=None, **kwargs*)

Return the density of trajectories

run (*caltra_kw=None, trace_kw=None, startf_kw=None, **kwargs*)

Run caltra, trace, and/or create_startf.

Run single_run for each dates tuple See single_run description for more details.

Parameters

- **caltra_kw** (*dictionary*) – Arguments to pass to the caltra function
- **trace_kw** (*dictionary*) – Arguments to pass to the trace function
- **startf_kw** (*dictionary*) – Arguments to pass to the create_startf function
- **kwargs** – Arguments to pass to the single_run function

Returns A list of single_run result

Return type list

run_parallel (*caltra_kw=None, trace_kw=None, startf_kw=None, nprocesses=None, **kwargs*)

Run caltra, trace, and/or create_startf in parallel.

Run single_run for each dates tuple using *multiprocessing.Pool*. See single_run description for more details.

Warning: If you use run_parallel with create_startf and if the starting file is not a list, be sure that every starting file has a different name, for example doing as follow:

```
>>> LagrantoRun(startf='startf_{date:%Y%m%d_%H.4}', ...)
```

Parameters

- **caltra_kw** (*dictionary*) – Arguments to pass to the caltra function
- **trace_kw** (*dictionary*) – Arguments to pass to the trace function
- **startf_kw** (*dictionary*) – Arguments to pass to the create_startf function
- **nprocesses** (*int,*) – Number of processors to use
- **kwargs** – Arguments to pass to the single_run function

Returns A list of single_run results

Return type list

select (*infile=None, outfile=None, **kwargs*)

Perform selection of trajectories

single_run (*sd, ed, caltra_kw=None, trace_kw=None, startf_kw=None, type='both', debug=False, **kwargs*)

Run caltra, trace and/or create_startf for a given starting date

Compute a trajectory set using caltra, trace and/or create_startf in a temporary directory. Need a working installation of LAGRANTO.

If `caltra`, `trace` or `create_startf` return a error, `single_run` return a `LagrantoException` error with the path of the temporary directory. In this case, the temporary directory is not deleted.

Parameters

- **sd** (*datetime*) – Starting date of the trajectory
- **ed** (*datetime*) – Ending date of the trajectory
- **caltra_kw** (*dictionary*) – Arguments to pass to the `caltra` function
- **trace_kw** (*dictionary*) – Arguments to pass to the `trace` function
- **startf_kw** (*dictionary*) – Arguments to pass to the `create_startf` function
- **type** (*string* (default *both*)) – Define the type a run to perform: both: caltra + trace caltra: caltra trace: trace all: create_startf + caltra + trace create: create_startf + caltra
- **debug** (*Boolean*) – If True raise `LagrantoException` instead of return it as string
- **kwargs** (*dictionary*) – Arguments to pass to the `link_files` function

Returns output of caltra, trace and/or create_startf

Return type `str`

trace (*date*, *filename*=", *outfile*=", *tracevars*=", *tracevars_content*=", *field*=", ***kwargs*)

Trace variable along a trajectory.

Trace meteorological fields along trajectories

Parameters

- **date** (*datetime object*) – starting date of the trajectories to trace
- **filename** (*string*, *optional*) – If not specified use `LagrantoRun.lslname`
- **outfile** (*string*, *optional*) – If not specified same as *filename*
- **tracevars** (*string*, *optional*) – Name of the file with the field to trace; If not specified use `LagrantoRun.tracevars`
- **tracevars_content** (*string*, *optional*) – Content of the tracevars file;
"""n QV 1000. P 1n PV 1. T 1n """""
- **field** (*string*,) – Specify a field to trace as follow: QV 1.
- **kwargs** –

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