
merra Documentation

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The package provides readers and converters for the Land Surface Diagnostics within the Modern-Era Retrospective analysis for Research and Applications version 2 (MERRA-2). MERRA-2 is a NASA atmospheric reanalysis integrating satellite data assimilation and aims at historical climate analyses. MERRA-2 covers Land Surface Diagnostics for the period 1980-present at $0.5^\circ \times 0.625^\circ$ spatial- and 1-hourly temporal-resolution.

The structure of the package is as follows:

- `grid.py` : implements the asymmetrical GMAO 0.5×0.625 grid
- `interface.py` : classes for reading a single image, image stacks and time series
- `reshuffle.py` : provides a command line utility for reshuffling a stack of 1-hourly sampled native images to time series format with an arbitrary temporal sampling between 1-hour and daily
- `download.py` : command line utility for downloading MERRA-2 data from the NASA GES DISC datapool

CHAPTER 1

Installation

For developers, it is recommended to first clone the repository and then use the provided environment.yml file to install all needed conda and pip dependencies:

```
git clone https://github.com/TUW-GEO/merra.git --recursive
cd merra
conda create -n merra python=3.7 # or any supported python version
source activate merra
conda update -f environment.yml
python setup.py develop
```


CHAPTER 2

Supported Products

- **M2T1NXLND: MERRA-2 tavg1_2d_ind_Nx:** MERRA-2 2d, 1-Hourly, Time-Averaged, Single-Level, Assimilation, Land Surface Diagnostics V5.12.4

We are happy if you want to contribute. Please raise an issue explaining what is missing or if you find a bug. We will also gladly accept pull requests against our master branch for new features or bug fixes.

3.1 Guidelines

If you want to contribute please follow these steps:

- Fork the merra repository to your account
- make a new feature branch from the merra master branch
- Add your feature
- please include tests for your contributions in one of the test directories We use py.test so a simple function called test_my_feature is enough
- submit a pull request to our master branch

3.2 Reading MERRA-2 images

Reading of the MERRA-2 netcdf files can be done in two ways:

3.2.1 1) Reading by file name

```
import os
from datetime import datetime
from merra.interface import MerraImage

# parameters to read
param_list = ['SFMC', 'RZMC', 'PRECTOTLAND', 'TSOIL1']
```

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```

# timestamp (needed because there are 24 hourly simulations within
# each file (3D-stack), so you need to choose one to return a 2D image)
timestamp = datetime(2018, 10, 1, 0, 30)

# the class is initialized with the exact filename.
img = MerraImage(os.path.join(os.path.dirname(__file__),
                              'merra-test-data',
                              'M2T1NXLND.5.12.4',
                              '2018',
                              '10',
                              'MERRA2_400.tavg1_2d_lnd_Nx.20181001.nc4'),
                 parameter=param_list)

# reading returns an image object which contains a data dictionary
# with one array per parameter. The returned data is a global image/array
# with shape (361, 576)
image = img.read(timestamp=timestamp)
data = image.data

```

3.2.2 2) Reading by date

All the MERRA-2 data in a directory structure can be accessed by date. The filename is automatically built from the given date.

```

from merra.interface import MerraImageStack

# parameters to read
param_list = ['SFCM', 'RZMC', 'PRECTOTLAND', 'TSOIL1']

# initializes an image stack class given the path to the data directory
# the class knows about the default folder structure down the line
img_stack = MerraImageStack(data_path=os.path.join(os.path.dirname(__file__),
                                                    'merra-test-data',
                                                    'M2T1NXLND.5.12.4'),
                             parameter=param_list)

# timestamp
timestamp = datetime(2018, 10, 1, 0, 30)

# read one image out of the stack at specific timestamp
image = img_stack.read(timestamp=timestamp)

```

For reading all image between two dates the `merra.interface.MerraImageStack.iter_images()` iterator can be used.

CHAPTER 4

Variables of interest for MERRA-2

A full list of variable names can be found in the [MERRA-2 README](#) provided by NASA.

Short name	Long name	Parameter	Resolution	Depth [m]	Units
SFMC	water_surface_layer	Soil moisture	0.5° x 0.625°	0.00 - 0.05	[m-3 m-3]
RZMC	water_root_zone	Soil moisture	0.5° x 0.625°	0.10 - 1.00	[m-3 m-3]
GWETTOP	surface_soil_wetness	Soil moisture	0.5° x 0.625°	0.00 - 0.05	[]
GWETROOT	root_zone_soil_wetness	Soil moisture	0.5° x 0.625°	0.10 - 1.00	[]
GWETPROF	ave_prof_soil_moisture	Soil moisture	0.5° x 0.625°	1.34 - 8.53	[]
PRECTOTLAND	Total_precipitation	Rain precipitation rate	0.5° x 0.625°	0	[kg m-2 s-1]
PRECSNOLAND	snowfall_land	Snow precipitation rate	0.5° x 0.625°	0	[kg m-2 s-1]
SNOMAS	Total_snow_storage	Land snow storage land	0.5° x 0.625°	0	[kg m-2]
TSOIL1	soil_temperatures	Soil_1 temperatures layer 1	0.5° x 0.625°	0.0988	[K]
TSOIL2	soil_temperatures	Soil_2 temperatures layer 2	0.5° x 0.625°	0.1952	[K]
TSOIL3	soil_temperatures	Soil_3 temperatures layer 3	0.5° x 0.625°	0.3859	[K]
TSOIL4	soil_temperatures	Soil_4 temperatures layer 4	0.5° x 0.625°	0.7626	[K]
TSOIL5	soil_temperatures	Soil_5 temperatures layer 5	0.5° x 0.625°	1.5071	[K]
TSOIL6	soil_temperatures	Soil_6 temperatures layer 6	0.5° x 0.625°	10.000	[K]
TSURF	surface_temperature	Surface temperature	0.5° x 0.625°	0	[K]

Conversion to time series format

For a lot of applications it is favorable to convert the image based format into a format which is optimized for fast time series retrieval. This is what we often need for e.g. validation studies. This can be done by stacking the images into a netCDF file and choosing the correct chunk sizes or a lot of other methods. We have chosen to do it in the following way:

- Store only the reduced gaussian grid points since that saves space.
- Further reduction the amount of stored data by saving only land points if selected.
- Store the time series in netCDF4 in the Climate and Forecast convention [Orthogonal multidimensional array representation](#)
- Store the time series in 5x5 degree cells. This means there will be 2566 cell files (without reduction to land points) and a file called `grid.nc` which contains the information about which grid point is stored in which file. This allows us to read a whole 5x5 degree area into memory and iterate over the time series quickly.

This conversion can be performed using the `merra_repurpose` command line program. An example would be:

```
merra_repurpose /merra2_data /timeseries/data -s 2000-01-01 -e 2018-11-30 --  
↳parameters SFMC RZMC --temporal_sampling 6
```

Which would take MERRA-2 data stored in `/merra2_data` from January 1st 2000 to November 30th 2018 and store the parameters for 6-hourly sampled surface (SFMC) and root zone soil moisture (RZMC) as time series in the folder `/timeseries/data`.

Conversion to time series is performed by the [repurpose package](#) in the background. For custom settings or other options see the [repurpose documentation](#) and the code in `merra.reshuffle`.

Note: If a `RuntimeError: NetCDF: Bad chunk sizes.` appears during reshuffling, consider downgrading the `netcdf4` library via:

```
conda install -c conda-forge netcdf4=1.2.2
```

if you are on Python 2.* and

```
conda install -c conda-forge netcdf4=1.2.8
```

if you are using Python 3.*.

5.1 Reading converted time series data

For reading the data the `merra_repurpose` command produces the class `MerraTs`:

```
from merra.interface import MerraTs

# specify path to data folder
path = '../timeseries/data'

# specify location lon and lat
lon, lat = (16.375, 48.125)

# initialize the time series class
merra_reader = MerraTs(ts_path=path,
                       ioclass_kws={'read_bulk':True},
                       parameters=['SFMC'])

# read SFMC time series at the location
ts = merra_reader.read(lon, lat)
```

6.1 Reading MERRA-2 images

Reading of the MERRA-2 netcdf files can be done in two ways:

6.1.1 1) Reading by file name

```
import os
from datetime import datetime
from merra.interface import MerraImage

# parameters to read
param_list = ['SFMC', 'RZMC', 'PRECTOTLAND', 'TSOIL1']

# timestamp (needed because there are 24 hourly simulations within
# each file (3D-stack), so you need to choose one to return a 2D image)
timestamp = datetime(2018, 10, 1, 0, 30)

# the class is initialized with the exact filename.
img = MerraImage(os.path.join(os.path.dirname(__file__),
                              'merra-test-data',
                              'M2T1NXLND.5.12.4',
                              '2018',
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                 parameter=param_list)

# reading returns an image object which contains a data dictionary
# with one array per parameter. The returned data is a global image/array
# with shape (361, 576)
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data = image.data
```

6.1.2 2) Reading by date

All the MERRA-2 data in a directory structure can be accessed by date. The filename is automatically built from the given date.

```
from merra.interface import MerraImageStack

# parameters to read
param_list = ['SFMC', 'RZMC', 'PRECTOTLAND', 'TSOIL1']

# initializes an image stack class given the path to the data directory
# the class knows about the default folder structure down the line
img_stack = MerraImageStack(data_path=os.path.join(os.path.dirname(__file__),
                                                    'merra-test-data',
                                                    'M2T1NXLND.5.12.4'),
                             parameter=param_list)

# timestamp
timestamp = datetime(2018, 10, 1, 0, 30)

# read one image out of the stack at specific timestamp
image = img_stack.read(timestamp=timestamp)
```

For reading all image between two dates the `merra.interface.MerraImageStack.iter_images()` iterator can be used.

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TSOIL6	soil_temperatures	Soil_6 temperatures layer 6	0.5° x 0.625°	10.000	[K]
TSURF	surface_temperature	Surface temperature	0.5° x 0.625°	0	[K]

6.3 Conversion to time series format

For a lot of applications it is favorable to convert the image based format into a format which is optimized for fast time series retrieval. This is what we often need for e.g. validation studies. This can be done by stacking the images into a netCDF file and choosing the correct chunk sizes or a lot of other methods. We have chosen to do it in the following way:

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This allows us to read a whole 5x5 degree area into memory and iterate over the time series quickly.

This conversion can be performed using the `merra_repurpose` command line program. An example would be:

```
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↳parameters SFMC RZMC --temporal_sampling 6
```

Which would take MERRA-2 data stored in `/merra2_data` from January 1st 2000 to November 30th 2018 and store the parameters for 6-hourly sampled surface (SFMC) and root zone soil moisture (RZMC) as time series in the folder `/timeseries/data`.

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Note: If a `RuntimeError: NetCDF: Bad chunk sizes.` appears during reshuffling, consider downgrading the `netcdf4` library via:

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```

if you are on Python 2.* and

```
conda install -c conda-forge netcdf4=1.2.8
```

if you are using Python 3.*.

6.3.1 Reading converted time series data

For reading the data the `merra_repurpose` command produces the class `MerraTs`:

```
from merra.interface import MerraTs  
  
# specify path to data folder  
path = '../timeseries/data'  
  
# specify location lon and lat  
lon, lat = (16.375, 48.125)  
  
# initialize the time series class  
merra_reader = MerraTs(ts_path=path,  
                       ioclass_kws={'read_bulk':True},  
                       parameters=['SFMC'])  
  
# read SFMC time series at the location  
ts = merra_reader.read(lon, lat)
```

6.4 License

```
Copyright (c) 2019, TU Wien  
All rights reserved.
```

```
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```

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6.5 Developers

- Felix Zaussinger <felix.zaussinger@geo.tuwien.ac.at>

6.6 Changelog

6.6.1 Version 0.1

- First release. Support for downloading, reading and writing MERRA-2 M2T1NXLND.5.12.4 data.

6.7 merra

6.7.1 merra package

Submodules

merra.download module

The download module implements a command line script for downloading MERRA2 reanalysis data from the NASA GESDISC repository.

```
merra.download.folder_get_version_first_last (root,fmt='MERRA2_{stream}.tavg1_2d_lnd_Nx.{time:%Y%m%d}.'.
                                             subpaths=['{time:%Y}', '{time:%m}'])
```

Get product version and first and last product which exists under the root folder.

Parameters

- **root** (*string*) – Root folder on local filesystem

- **fmt** (*string, optional*) – formatting string
- **subpaths** (*list, optional*) – format of the subdirectories under root.

Returns

- **version** (*string*) – Found product version
- **start** (*datetime.datetime*) – First found product datetime
- **end** (*datetime.datetime*) – Last found product datetime

merra.download.**get_first_folder** (*root, subpaths*)

...

Parameters

- **root** (*string*) – ...
- **subpaths** (*list of strings*) – ...

Returns directory – ...

Return type list of strings

merra.download.**get_first_formatted_dir_in_dir** (*folder, fmt*)

Get the (alphabetically) first directory in a directory which can be formatted according to fmt.

Parameters

- **folder** (*string*) – path to folder
- **fmt** – formatting rule

Returns first_elem – path to last directory

Return type string

merra.download.**get_last_folder** (*root, subpaths*)

...

Parameters

- **root** (*string*) – ...
- **subpaths** (*list of strings*) – ...

Returns directory – ...

Return type list of strings

merra.download.**get_last_formatted_dir_in_dir** (*folder, fmt*)

Get the (alphabetically) last directory in a directory which can be formatted according to fmt.

Parameters

- **folder** (*string*) – path to folder
- **fmt** – formatting rule

Returns last_elem – path to last directory

Return type string

merra.download.**get_start_date** (*product*)

Define start date of product version.

Parameters product (*string*) – product specification

Returns datetime – timestamp of start date

Return type `datetime.datetime`

`merra.download.main` (*args*)

`merra.download.parse_args` (*args*)

Parse command line parameters for recursive download

Parameters *args* (*list of strings*) – command line parameters

Returns *args* – command line parameters

Return type `argparse.Namespace` object

`merra.download.run` ()

merra.grid module

The grid module implements the asymmetrical GMAO 0.5 x 0.625 grid used in MERRA2 as a pygeogrids BasicGrid instance.

`merra.grid.create_merra_cell_grid` ()

Function creates the asymmetrical GMAO 0.5 x 0.625 grid as a BasicGrid instance.

Returns

Return type BasicGrid instance

merra.interface module

merra.reshuffle module

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