ismn Documentation

Release unknown

TU Wien

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CONTENTS

Readers for the data from the International Soil Moisture Database (ISMN).

CHAPTER

ONE

CITATION

If you use the software in a publication then please cite it using the Zenodo DOI. Be aware that this badge links to the latest package version.

Please select your specific version at https://doi.org/10.5281/zenodo.855308 to get the DOI of that version. You should normally always use the DOI for the specific version of your record in citations. This is to ensure that other researchers can access the exact research artefact you used for reproducibility.

You can find additional information regarding DOI versioning at http://help.zenodo.org/#versioning

CHAPTER

TWO

INSTALLATION

This package should be installable through pip:

```
pip install ismn
```

The cartopy-package needs to be installed manually by using the following command:

```
conda install -c conda-forge cartopy
```

2.1 Example installation script

The following script will install miniconda and setup the environment on a UNIX like system. Miniconda will be installed into `$HOME/miniconda`.

```
wget https://repo.continuum.io/miniconda/Miniconda-latest-Linux-x86_64.sh -O␣
↪miniconda.sh
bash miniconda.sh -b -p $HOME/miniconda
export PATH="$HOME/miniconda/bin:$PATH"
git clone git@github.com:TUW-GEO/ismn.git ismn
cd ismn
conda env create -f environment.yml
source activate ismn
```

This script adds `$HOME/miniconda/bin` temporarily to the `PATH` to do this permanently add `export PATH="$HOME/miniconda/bin:$PATH"` to your `.bashrc` or `.zshrc`

The second to last line in the example activates the `ismn` environment.

After that you should be able to run:

```
python setup.py test
```

to run the test suite.

CHAPTER

THREE

DESCRIPTION

ISMN data can be downloaded for free after registration from the ISMN Website

In case of the ISMN, two different formats are provided:

- Variables stored in separate files (CEOP formatted)

  this format is supported 100% and should work with all examples

- Variables stored in separate files (Header+values)

  this format is supported 100% and should work with all examples

If you downloaded ISMN data in one of the supported formats in the past it can be that station names are not recognized correctly because they contained the '_' character which is supposed to be the separator. If you experience problems because of this please download new data from the ISMN since this issue should be fixed.

3.1 Landcover Classification

The ISMN data comes with information about landcover classification from the ESA CCI land cover project (years 2000, 2005 and 2010) as well as from in-situ measurements. To use ESA CCI land cover variables for filtering the data in the get_dataset_ids function, set the keyword parameters (landcover_2000, landcover_2005 or landcover_2010) to the corresponding integer values (e.g. 10) in the list below. To get a list of possible values for filtering by in-situ values (keyword parameter: "landcover_insitu"), call the get_landcover_types method of your ISMN_Interface object and set landcover='landcover_insitu'.

- 10: Cropland, rainfed
- 11: Cropland, rainfed / Herbaceous cover
- 12: Cropland, rainfed / Tree or shrub cover,
- 20: Cropland, irrigated or post-flooding,
- 30: Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous,
- 40: Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (<50%),
- 50: Tree cover, broadleaved, evergreen, Closed to open (>15%),
- 60: Tree cover, broadleaved, deciduous, Closed to open (>15%),
- 61: Tree cover, broadleaved, deciduous, Closed (>40%),
- 62: Tree cover, broadleaved, deciduous, Open (15-40%),
- 70: Tree cover, needleleaved, evergreen, closed to open (>15%),
- 71: Tree cover, needleleaved, evergreen, closed (>40%),

- 72: Tree cover, needleleaved, evergreen, open (15-40%),
- 80: Tree cover, needleleaved, deciduous, closed to open (>15%),
- 81: Tree cover, needleleaved, deciduous, closed (>40%),
- 82: Tree cover, needleleaved, deciduous, open (15-40%),
- 90: Tree cover, mixed leaf type (broadleaved and needleleaved),
- 100: Mosaic tree and shrub (>50%) / herbaceous cover (<50%),
- 110: Mosaic herbaceous cover (>50%) / tree and shrub (<50%),
- 120: Shrubland,
- 121: Shrubland / Evergreen Shrubland,
- 122: Shrubland / Deciduous Shrubland,
- 130: Grassland,
- 140: Lichens and mosses,
- 150: Sparse vegetation (tree, shrub, herbaceous cover) (<15%),
- 152: Sparse vegetation (tree, shrub, herbaceous cover) (<15%) / Sparse shrub (<15%),
- 153: Sparse vegetation (tree, shrub, herbaceous cover) (<15%) / Sparse herbaceous cover (<15%),
- 160: Tree cover, flooded, fresh or brakish water,
- 170: Tree cover, flooded, saline water,
- 180: Shrub or herbaceous cover, flooded, fresh/saline/brakish water,
- 190: Urban areas,
- 200: Bare areas,
- 201: Consolidated bare areas,
- 202: Unconsolidated bare areas,
- 210: Water,
- 220: Permanent snow and ice,

3.2 Climate Classification

The ISMN data comes with information about climate classification from the Koeppen-Geiger Climate Classification (2007) as well as in-situ measurements. To use Koeppen-Geiger variable for filtering the data in the get_dataset_ids function, set the keyword parameter "climate" to the corresponding keys (e.g. 'Af') in the list below. To get a list of possible values for filtering by in-situ values (keyword parameter: "climate_insitu"), call the get_climate_types method of your ISMN_Interface object and set climate='climate_insitu'.

- Af: Tropical Rainforest
- Am: Tropical Monsoon
- As: Tropical Savanna Dry
- Aw: Tropical Savanna Wet
- BWk: Arid Desert Cold
- BWh: Arid Desert Hot

- BWn: Arid Desert With Frequent Fog
- BSk: Arid Steppe Cold
- BSh: Arid Steppe Hot
- BSn: Arid Steppe With Frequent Fog
- Csa: Temperate Dry Hot Summer
- Csb: Temperate Dry Warm Summer
- Csc: Temperate Dry Cold Summer
- Cwa: Temperate Dry Winter, Hot Summer
- Cwb: Temperate Dry Winter, Warm Summer
- Cwc: Temperate Dry Winter, Cold Summer
- Cfa: Temperate Without Dry Season, Hot Summer
- Cfb: Temperate Without Dry Season, Warm Summer
- Cfc: Temperate Without Dry Season, Cold Summer
- Dsa: Cold Dry Summer, Hot Summer
- Dsb: Cold Dry Summer, Warm Summer
- Dsc: Cold Dry Summer, Cold Summer
- Dsd: Cold Dry Summer, Very Cold Winter
- Dwa: Cold Dry Winter, Hot Summer
- Dwb: Cold Dry Winter, Warm Summer
- Dwc: Cold Dry Winter, Cold Summer
- Dwd: Cold Dry Winter, Very Cold Winter
- Dfa: Cold Dry Without Dry Season, Hot Summer
- Dfb: Cold Dry Without Dry Season, Warm Summer
- Dfc: Cold Dry Without Dry Season, Cold Summer
- Dfd: Cold Dry Without Dry Season, Very Cold Winter
- ET: Polar Tundra
- EF: Polar Eternal Winter
- W: Water

3.3 Documentation

https://ismn.readthedocs.io

CHAPTER

FOUR

CONTRIBUTE

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.

4.1 Development setup

For Development we also recommend a `conda` environment. You can create one including test dependencies and debugger by running `conda env create -f environment.yml`. This will create a new `ismn` environment which you can activate by using `source activate ismn`.

4.2 Guidelines

If you want to contribute please follow these steps:

- Fork the ismn repository to your account
- Clone the repository
- make a new feature branch from the ismn 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

CHAPTER

FIVE

READING AND PLOTTING DATA FROM THE ISMN

This example program chooses a random Network and Station and plots the first variable,depth,sensor combination.

CHAPTER

SIX

READING ISMN DATA

This example shows the basic functionality to read data downloaded from the Internatinal Soil Moisture Network (ISMN). The data is accessible at `http://ismn.geo.tuwien.ac.at` after registration.

For this tutorial, data for the networks 'REMEDHUS', 'SMOSMANIA', 'FMI', 'WEGENERNET', 'GTK' and 'VAS' between 2009-08-04 and 2020-12-12 was downloaded.

The suggested class for reading is called `ISMN_Interface`. It provides functions to access single networks, stations and sensors and the measured time series for each sensor. The `ISMN_Interface` class takes either the directory where the extracted ISMN files are stored, or a zip archive of the data directly (reading from zip is significantly slower). To read only a selection of networks stored in the passed data path, you can pass a list of network names.

```
from ismn.interface import ISMN_Interface
import numpy as np
import matplotlib.pyplot as plt

# Enter the path to your ISMN data
path_to_ismn_data = r"C:\Temp\delete_me\ismn\stick\Data_separate_files_20090804_
↪20201212.zip"

ismn_data = ISMN_Interface(path_to_ismn_data, network=['REMEDHUS', 'SMOSMANIA', 'FMI',
↪ 'WEGENERNET', 'GTK', 'VAS', 'RSMN'])
```

```
Found existing ismn metadata in C:Tempdelete_meismnstickpython_metadataData_
↪separate_files_20090804_20201212.csv.
```

The following command will initialise the reader. The first time this is done, metadata for each sensor will we collected. This will iterate through all files and detect e.g. station names, time coverage, measurement depths etc. Metadata collection can take a few minutes and will start multiple parallel processes (depending on the available ressources). By default the `python_metadata` (which contains the collected metadata as a .csv file) will be placed in the passed root directory. The next time the reader is created it will use `python_metadata` (if it is found) instead of generating it again.

Note: When changing the data (e.g. if folders are added or removed from the data collection) make sure to delete the `python_metadata` folder to re-generate for the new data.

You can define a different path, where the metadata is stored, resp. looked for by passing a `meta_path` when initialsing `ISMN_Interface`. You can also define a list of network names that are considered when reading the data (this will not affect metadata generation, which is performed for ALL networks in `data_path`). Passing `keep_loaded_data=True` means that all time series, once read, will be kept in memory for faster subsequent access. This can fill up your memory and is only recommended for small data samples.

In this example we use the default metadata path.

6.1 Accessing data components

6.1.1 Network Collection

`ISMN_Interface` contains a `collection` of active ISMN networks. The collection lists the network name and names of all stations in a network (either all Networks if no network(s) was/were specified during initialisation or the selected networks).

```
collection = ismn_data.collection
collection
```

```
FMI: ['SAA111', 'SAA112', 'SAA120', 'SOD011', 'SOD012', 'SOD013', 'SOD021', 'SOD022',
 ↪'SOD023', 'SOD031', 'SOD032', 'SOD033', 'SOD071', 'SOD072', 'SOD073', 'SOD081',
 ↪'SOD082', 'SOD083', 'SOD091', 'SOD092', 'SOD093', 'SOD101', 'SOD102', 'SOD103',
 ↪'SOD130', 'SOD140', 'SODAWS'],
GTK: ['IlomantsiII', 'Kuusamo', 'PoriII', 'Suomussalmi'],
REMEDHUS: ['Canizal', 'Carramedina', 'Carretoro', 'CasaPeriles', 'ConcejodelMonte',
 ↪'ElCoto', 'ElTomillar', 'Granja-g', 'Guarena', 'Guarrati', 'LaAtalaya',
 ↪'LaCruzdeElias', 'LasArenas', 'LasBodegas', 'LasBrozas', 'LasEritas', 'LasTresRayas
 ↪', 'LasVacas', 'LasVictorias', 'LlanosdelaBoveda', 'Paredinas', 'Zamarron'],
RSMN: ['Adamclisi', 'Alexandria', 'Bacles', 'Banloc', 'Barlad', 'Calarasi',
 ↪'ChisineuCris', 'Corugea', 'Cotnari', 'Darabani', 'Dej', 'Dumbraveni', 'Iasi',
 ↪'Oradea', 'RosioriideVede', 'SannicolauMare', 'SatuMare', 'Slatina', 'Slobozia',
 ↪'Tecuci'],
SMOSMANIA: ['Barnas', 'Berzeme', 'CabrieresdAvignon', 'Condom', 'CreondArmagnac',
 ↪'LaGrandCombe', 'Lahas', 'LezignanCorbieres', 'Mazan-Abbaye', 'Mejannes-le-Clap',
 ↪'Montaut', 'Mouthoumet', 'Narbonne', 'PeyrusseGrande', 'Pezenas', 'Pezenas-old',
 ↪'Prades-le-Lez', 'Sabres', 'SaintFelixdeLauragais', 'Savenes', 'Urgons',
 ↪'Villevielle'],
VAS: ['MelbexI', 'MelbexII', 'ValenciaAnchorStation'],
WEGENERNET: ['15', '19', '27', '34', '50', '54', '6', '77', '78', '84', '85', '99']
```

The collection also contains a grid object that contains the locations of all **stations** in all active networks. For more details see https://github.com/TUW-GEO/pygeogrids

```
import pandas as pd
grid = collection.grid
gpis, lons, lats = grid.get_grid_points()
print(pd.DataFrame(index=pd.Index(gpis, name='gpi'), data={'lon': lons, 'lat': lats}))
```

Using the GPI or coordinates, a station from **all** stations in **all** networks in the collection can be selected.

```
station, dist = collection.get_nearest_station(27.0, 68.0)
assert collection.station4gpi(0) == station # same result when selecting with GPI

print(f"Station '{station.name}' at Lon: {station.lon}°, Lat: {station.lat}°")
station
```

```
Station 'SAA111' at Lon: 27.550620000000002°, Lat: 68.33019°
```

```
Sensors at 'SAA111': ['CS215_air_temperature_-2.000000_-2.000000', '5TE_soil_
 ↪temperature_0.200000_0.200000', '5TE_soil_temperature_0.400000_0.400000', '5TE_soil_
 ↪moisture_0.800000_0.800000', '5TE_soil_moisture_0.400000_0.400000', '5TE_soil_
 ↪moisture_0.200000_0.200000', '5TE_soil_temperature_0.050000_0.050000', '5TE_soil_
 ↪moisture_0.050000_0.050000', '5TE_soil_moisture_0.100000_0.100000', '5TE_soil_
 ↪temperature_0.800000_0.800000', '5TE_soil_temperature_0.100000_0.100000']
```

6.1.2 Network

A single network from the collection can be accessed via its name.

```
network = collection['SMOSMANIA']
network
```

```
Stations in 'SMOSMANIA': ['Barnas', 'Berzeme', 'CabrieresdAvignon', 'Condom',
↪'CreondArmagnac', 'LaGrandCombe', 'Lahas', 'LezignanCorbieres', 'Mazan-Abbaye',
↪'Mejannes-le-Clap', 'Montaut', 'Mouthoumet', 'Narbonne', 'PeyrusseGrande', 'Pezenas
↪', 'Pezenas-old', 'Prades-le-Lez', 'Sabres', 'SaintFelixdeLauragais', 'Savenes',
↪'Urgons', 'Villevielle']
```

6.1.3 Station

A network consists of multiple stations, multiple variables can be measured by different sensors at a station:

```
station = network.stations['SaintFelixdeLauragais']
station
```

```
Sensors at 'SaintFelixdeLauragais': ['PT-100_soil_temperature_0.050000_0.050000', 'PT-
↪100_soil_temperature_0.100000_0.100000', 'PT-100_soil_temperature_0.200000_0.200000
↪', 'PT-100_soil_temperature_0.300000_0.300000', 'ThetaProbe-ML2X_soil_moisture_0.
↪050000_0.050000', 'ThetaProbe-ML2X_soil_moisture_0.100000_0.100000', 'ThetaProbe-
↪ML2X_soil_moisture_0.200000_0.200000', 'ThetaProbe-ML2X_soil_moisture_0.300000_0.
↪300000', 'ThetaProbe-ML3_soil_moisture_0.200000_0.200000']
```

Similar as the single sensors, each station has a metadata attribute. The station metadata contains all meta variables from all sensors that measure at the station. Formatting options for MetaData are either as a DataFrame (`to_pd()`) or as a dictionary (`to_dict()`) of form:

```
{name: [(value, depth_from, depth_to), ...], ...}
```

```
from pprint import pprint
pprint(station.metadata.to_dict())
```

```
{'clay_fraction': [(22.8, 0.05, 0.05),
                   (22.4, 0.1, 0.1),
                   (23.9, 0.2, 0.2),
                   (29.4, 0.3, 0.3)],
 'climate_KG': [('Cfb', None, None)],
 'climate_insitu': [('unknown', None, None)],
 'elevation': [(337.0, None, None)],
 'instrument': [('PT-100', 0.05, 0.05),
                ('PT-100', 0.1, 0.1),
                ('PT-100', 0.2, 0.2),
                ('PT-100', 0.3, 0.3),
                ('ThetaProbe-ML2X', 0.05, 0.05),
                ('ThetaProbe-ML2X', 0.1, 0.1),
                ('ThetaProbe-ML2X', 0.2, 0.2),
                ('ThetaProbe-ML2X', 0.3, 0.3),
                ('ThetaProbe-ML3', 0.2, 0.2)],
 'latitude': [(43.4417, None, None)],
 'lc_2000': [(10.0, None, None)],
```

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```
 'lc_2005': [(10.0, None, None)],
 'lc_2010': [(10.0, None, None)],
 'lc_insitu': [('unknown', None, None)],
 'longitude': [(1.88, None, None)],
 'network': [('SMOSMANIA', None, None)],
 'organic_carbon': [(1.15, 0.05, 0.05),
                    (0.84, 0.1, 0.1),
                    (0.97, 0.2, 0.2),
                    (0.7, 0.3, 0.3)],
 'sand_fraction': [(43.5, 0.05, 0.05),
                   (40.3, 0.1, 0.1),
                   (39.7, 0.2, 0.2),
                   (32.0, 0.3, 0.3)],
 'saturation': [(0.44, 0.05, 0.05),
                (0.43, 0.1, 0.1),
                (0.44, 0.2, 0.2),
                (0.44, 0.3, 0.3)],
 'silt_fraction': [(33.7, 0.05, 0.05),
                   (37.3, 0.1, 0.1),
                   (36.4, 0.2, 0.2),
                   (38.6, 0.3, 0.3)],
 'station': [('SaintFelixdeLauragais', None, None)],
 'timerange_from': [(Timestamp('2009-08-04 00:00:00'), None, None),
                    (Timestamp('2017-10-16 13:00:00'), None, None)],
 'timerange_to': [(Timestamp('2019-01-01 00:00:00'), None, None),
                  (Timestamp('2017-09-01 11:00:00'), None, None)],
 'variable': [('soil_temperature', 0.05, 0.05),
              ('soil_temperature', 0.1, 0.1),
              ('soil_temperature', 0.2, 0.2),
              ('soil_temperature', 0.3, 0.3),
              ('soil_moisture', 0.05, 0.05),
              ('soil_moisture', 0.1, 0.1),
              ('soil_moisture', 0.2, 0.2),
              ('soil_moisture', 0.3, 0.3)]}
```

6.1.4 Sensor

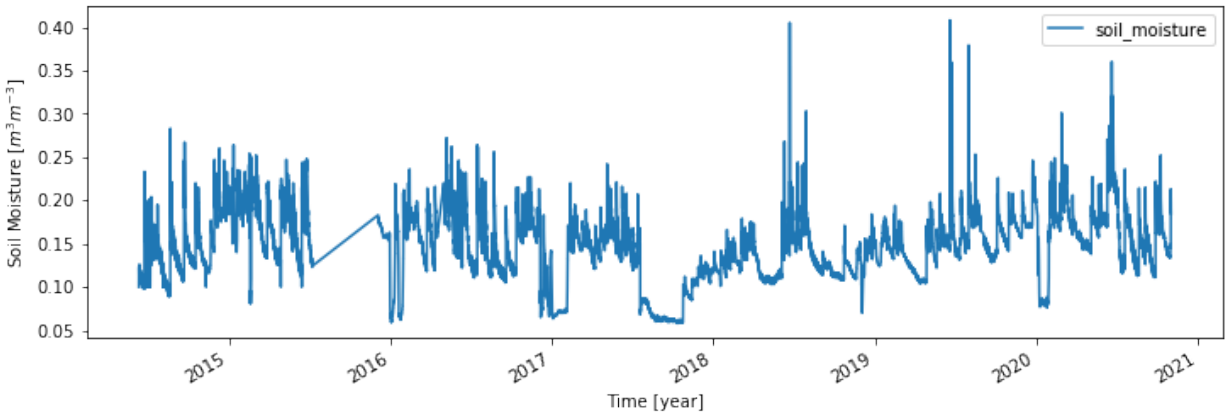
Accessing sensors at a station works similar to accessing stations in a network. By default the name is created from the instrument type, the measurued variable and the depth layer that the senosor measures in.

```
sensor = station['ThetaProbe-ML2X_soil_moisture_0.050000_0.050000']
sensor
```

```
ThetaProbe-ML2X_soil_moisture_0.050000_0.050000
```

A data file is assigned to each sensor, that contains the sensor variable time series and quality flags.

```
ts = sensor.read_data()
ax = ts.plot(figsize=(12,4))
ax.set_xlabel("Time [year]")
ax.set_ylabel("Soil Moisture [$m^3 m^{-3}$]")
print(ts)
plt.show()
```



Additionally, metadata is assigned to each sensor. Some metadata is sensor specific (e.g. soil properties, time series range), some depends on the location of the station and is therefore shared by multiple sensors (landcover and climate classes etc.). The first value in each Variable is the name of the metadata variable, the second the actual value for the variable. The third value (tuple) is the depth that the value applies to (for soil properties multiple layers are provided together with the ISMN data, during metadata generation the best matching depth for a sensor is selected).

```
sensor.metadata.to_pd()
```

```
name            meta_args
clay_fraction   val                          22.8
                depth_from                   0.05
                depth_to                     0.05
climate_KG      val                           Cfb
climate_insitu  val                       unknown
elevation       val                           337
instrument      val                ThetaProbe-ML2X
                depth_from                   0.05
                depth_to                     0.05
latitude        val                       43.4417
lc_2000         val                            10
lc_2005         val                            10
lc_2010         val                            10
lc_insitu       val                       unknown
longitude       val                          1.88
network         val                     SMOSMANIA
organic_carbon  val                          1.15
                depth_from                   0.05
                depth_to                     0.05
sand_fraction   val                          43.5
                depth_from                   0.05
                depth_to                     0.05
saturation      val                          0.44
                depth_from                   0.05
                depth_to                     0.05
silt_fraction   val                          33.7
                depth_from                   0.05
                depth_to                     0.05
station         val          SaintFelixdeLauragais
timerange_from  val            2009-08-04 00:00:00
timerange_to    val            2019-01-01 00:00:00
variable        val                   soil_moisture
                depth_from                   0.05
```

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```
                depth_to                          0.05
Name: data, dtype: object
```

6.2 Other functions

6.2.1 Find network for a specific station

`ISMN_Interface` provides a function to find the network when only the name of a station is known.

```
ismn_data.network_for_station('SAA111', name_only=False)
```

```
Stations in 'FMI': ['SAA111', 'SAA112', 'SAA120', 'SOD011', 'SOD012', 'SOD013',
↪'SOD021', 'SOD022', 'SOD023', 'SOD031', 'SOD032', 'SOD033', 'SOD071', 'SOD072',
↪'SOD073', 'SOD081', 'SOD082', 'SOD083', 'SOD091', 'SOD092', 'SOD093', 'SOD101',
↪'SOD102', 'SOD103', 'SOD130', 'SOD140', 'SODAWS']
```

6.2.2 Read via index

You can filter the dataset a priori and get ids of sensors that measure a specific variable. The id can then be used to read the data directly.

```
ids = ismn_data.get_dataset_ids(variable='soil_temperature', max_depth=1, filter_meta_
↪dict={'lc_2005': 130, 'climate_KG': 'Csb'})
print(ids)
```

```
[1376, 1377, 1378, 1379]
```

```
ts, meta = ismn_data.read(ids[1], return_meta=True)
pprint(meta)
ax = ts.plot(figsize=(12,4), title=f'Time series for ID {ids[1]}')
ax.set_xlabel("Time [year]")
ax.set_ylabel("Soil Temp. [°C]")
plt.show()
```

```
{'clay_fraction': [(20.2, 0.3, 0.3)],
 'climate_KG': [('Csb', None, None)],
 'climate_insitu': [('unknown', None, None)],
 'elevation': [(318.0, None, None)],
 'instrument': [('PT-100', 0.3, 0.3)],
 'latitude': [(44.222, None, None)],
 'lc_2000': [(130.0, None, None)],
 'lc_2005': [(130.0, None, None)],
 'lc_2010': [(130.0, None, None)],
 'lc_insitu': [('unknown', None, None)],
 'longitude': [(4.34483, None, None)],
 'network': [('SMOSMANIA', None, None)],
 'organic_carbon': [(4.52, 0.3, 0.3)],
 'sand_fraction': [(30.3, 0.3, 0.3)],
 'saturation': [(0.62, 0.3, 0.3)],
 'silt_fraction': [(49.5, 0.3, 0.3)],
```

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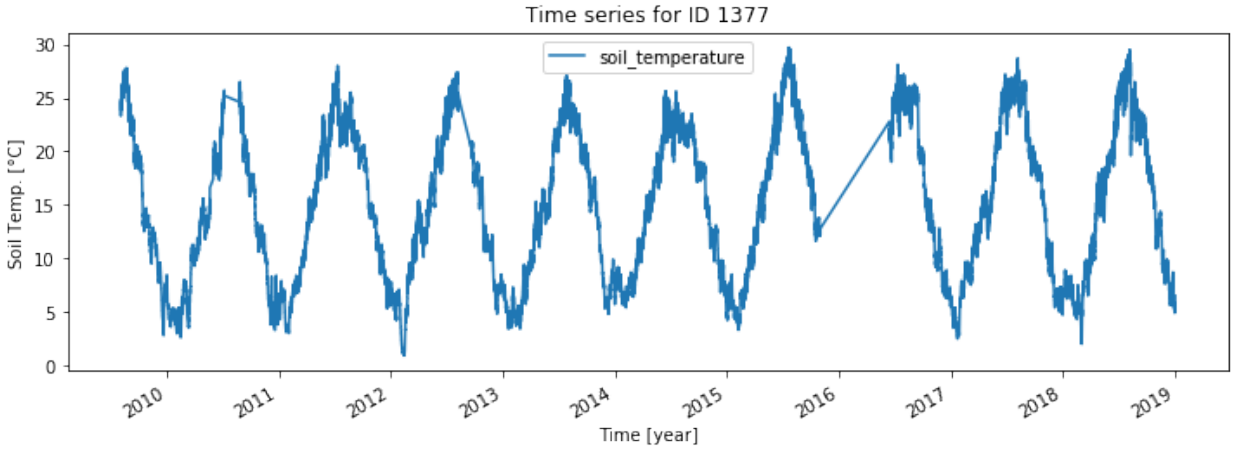
```
 'station': [('Mejannes-le-Clap', None, None)],
 'timerange_from': [(Timestamp('2009-08-04 00:00:00'), None, None)],
 'timerange_to': [(Timestamp('2019-01-01 00:00:00'), None, None)],
 'variable': [('soil_temperature', 0.3, 0.3)]}
```

```
Text(0, 0.5, 'Soil Temp. [°C]')
```



Station locations for a specific variable can be visualised on a map. If a min/max depth is passed, only stations with a sensor that measures within the passed range are included.

```
import cartopy.crs as ccrs
#plot available station on a map
fig, axs = plt.subplots(1, 2, figsize=(16,10), subplot_kw={'projection': ccrs.
↪Robinson()})
ismn_data.plot_station_locations('soil_moisture', min_depth=0., max_depth=0.1,␣
↪ax=axs[0])
ismn_data.plot_station_locations('soil_temperature', min_depth=0.5, ax=axs[1])
plt.show()
```

6.3 Selecting and interating over data

It is often desired to iterate over all sensors that fulfill certain conditions (e.g. that measure soil moisture in a certain depth, or for a certain landcover class). For these cases the `collection` (and other components) provides iterators that take keywords and values for filtering the loaded networks/stations/sensor while iterating over single time series (of a collection, a network, or a station).

6.3.1 Select by variable and depth

In this example we iterate over all sensors in the previously loaded collection (i.e. over all active networks) that measure 'soil_moisture' in any depth (range) between 0 and 0.05 metres.

```
for network, station, sensor in ismn_data.collection.iter_sensors(variable='soil_
↪moisture',
                                                                  depth=[0., 0.05]):
    data = sensor.read_data()
    print(station)
    print('\033[1m' + f'Metadata for sensor {sensor}:')
    print(sensor.metadata.to_pd())
    ax = data.plot(figsize=(12,4), title=f'Time series for sensor {sensor.name}')
    ax.set_xlabel("Time [year]")
    ax.set_ylabel("Soil Moisture [$m^3 m^{-3}$]")
    plt.show()
    break # for this example we stop after the first sensor
```

```
Sensors at 'SAA111': ['CS215_air_temperature_-2.000000_-2.000000', '5TE_soil_
↪temperature_0.200000_0.200000', '5TE_soil_temperature_0.400000_0.400000', '5TE_soil_
↪moisture_0.800000_0.800000', '5TE_soil_moisture_0.400000_0.400000', '5TE_soil_
↪moisture_0.200000_0.200000', '5TE_soil_temperature_0.050000_0.050000', '5TE_soil_
↪moisture_0.050000_0.050000', '5TE_soil_moisture_0.100000_0.100000', '5TE_soil_
↪temperature_0.800000_0.800000', '5TE_soil_temperature_0.100000_0.100000']
```

```
[1mMetadata for sensor 5TE_soil_moisture_0.050000_0.050000:
```

```
name            meta_args
clay_fraction   val                          4
                depth_from                   0
                depth_to                   0.3
climate_KG      val                        Dfc
climate_insitu  val                    unknown
elevation       val                        441
instrument      val                        5TE
                depth_from                0.05
                depth_to                  0.05
latitude        val                    68.3302
lc_2000         val                        110
lc_2005         val                        110
lc_2010         val                        110
lc_insitu       val                    unknown
longitude       val                    27.5506
network         val                        FMI
organic_carbon  val                       2.18
                depth_from                   0
                depth_to                   0.3
```

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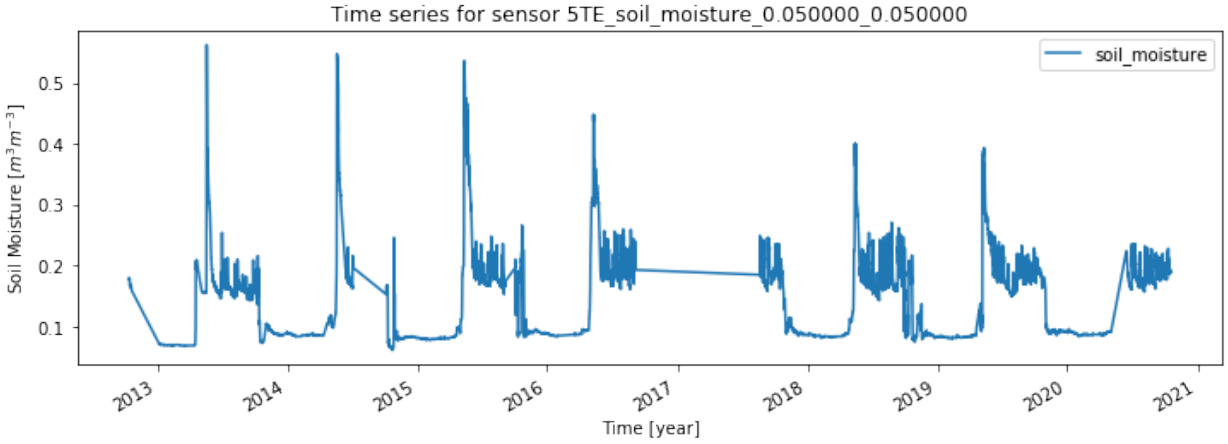
```
sand_fraction    val                          87
                 depth_from                    0
                 depth_to                    0.3
saturation       val                        0.49
                 depth_from                    0
                 depth_to                    0.3
silt_fraction    val                           9
                 depth_from                    0
                 depth_to                    0.3
station          val                      SAA111
timerange_from   val          2012-10-14 00:00:00
timerange_to     val          2020-10-17 23:00:00
variable         val                soil_moisture
                 depth_from                 0.05
                 depth_to                   0.05
Name: data, dtype: object
```



6.3.2 Selecting by variable and other metadata (1)

In this example we iterate over all sensors for the network 'RMSN' and filter those that measure precipitation within an ESA CCI Landcover pixel that is marked as 'Cropland, rainfed' (10) or 'Grassland' (130).

```
ismn_data.print_landcover_dict()
```

```
CCI Landcover Classification
----------------------------
Cropland, rainfed: 10
Cropland, rainfed / Herbaceous cover: 11
Cropland, rainfed / Tree or shrub cover: 12
Cropland, irrigated or post-flooding: 20
Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous: 30
Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (<50%): 40
Tree cover, broadleaved, evergreen, Closed to open (>15%): 50
Tree cover, broadleaved, deciduous, Closed to open (>15%): 60
Tree cover, broadleaved, deciduous, Closed (>40%): 61
Tree cover, broadleaved, deciduous, Open (15-40%): 62
Tree cover, needleleaved, evergreen, closed to open (>15%): 70
Tree cover, needleleaved, evergreen, closed (>40%): 71
```

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```
Tree cover, needleleaved, evergreen, open (15-40%): 72
Tree cover, needleleaved, deciduous, closed to open (>15%): 80
Tree cover, needleleaved, deciduous, closed (>40%): 81
Tree cover, needleleaved, deciduous, open (15-40%): 82
Tree cover, mixed leaf type (broadleaved and needleleaved): 90
Mosaic tree and shrub (>50%) / herbaceous cover (<50%): 100
Mosaic herbaceous cover (>50%) / tree and shrub (<50%): 110
Shrubland: 120
Shrubland / Evergreen Shrubland: 121
Shrubland / Deciduous Shrubland: 122
Grassland: 130
Lichens and mosses: 140
Sparse vegetation (tree, shrub, herbaceous cover) (<15%): 150
Sparse vegetation (tree, shrub, herbaceous cover) (<15%) / Sparse shrub (<15%): 152
Sparse vegetation (tree, shrub, herbaceous cover) (<15%) / Sparse herbaceous cover (
↪<15%): 153
Tree cover, flooded, fresh or brakish water: 160
Tree cover, flooded, saline water: 170
Shrub or herbaceous cover, flooded, fresh/saline/brakish water: 180
Urban areas: 190
Bare areas: 200
Consolidated bare areas: 201
Unconsolidated bare areas: 202
Water: 210
Permanent snow and ice: 220
```

```
for station, sensor in ismn_data.collection['RSMN'].iter_sensors(variable=
↪'precipitation',
                                                                filter_meta_dict={
↪'lc_2010': [10, 130]}):
    data = sensor.read_data()
    metadata = sensor.metadata
    print(station)
    print('\033[1m' + f'Metadata for sensor {sensor}:')
    print(metadata.to_pd())
    ax = data.plot(figsize=(12,4), title=f'Time series for sensor {sensor.name}')
    ax.set_xlabel("Time [year]")
    ax.set_ylabel("Precipitation [mm]")
    plt.show()
    break # for this example we stop after the first sensor
```

```
Sensors at 'Barlad': ['HMP155-Vaisala_air_temperature_-2.000000_-2.000000', '5TM_soil_
↪temperature_0.000000_0.050000', '5TM_soil_moisture_0.000000_0.050000', 'QMR102_
↪precipitation_-1.400000_-1.400000', 'HMP155_air_temperature_-2.000000_-2.000000']
```

```
[1mMetadata for sensor QMR102_precipitation_-1.400000_-1.400000:
```

```
name            meta_args
climate_KG      val                      Dfb
climate_insitu  val                  unknown
elevation       val                      172
instrument      val                   QMR102
                depth_from              -1.4
                depth_to                -1.4
latitude        val                  46.2331
```

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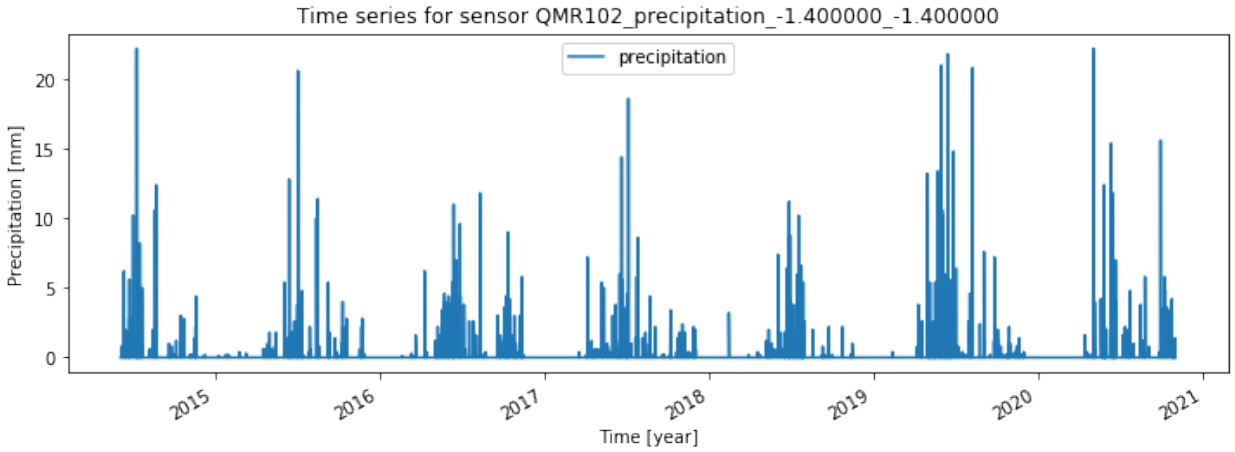
```
lc_2000          val                          10
lc_2005          val                          10
lc_2010          val                          10
lc_insitu        val                     unknown
longitude        val                     27.6444
network          val                        RSMN
station          val                      Barlad
timerange_from   val         2014-06-06 07:00:00
timerange_to     val         2020-10-31 23:00:00
variable         val               precipitation
                 depth_from                -1.4
                 depth_to                  -1.4
Name: data, dtype: object
```



6.3.3 Selecting by variable, depth and metadata (2)

In this example we iterate over all sensors in the collection and filter those that measure soil_moisture between 0 and 10 cm within an ESA CCI Landcover pixel that is marked as 'Cropland, rainfed' (10) or 'Grassland' (130), and has one of the follwing climate classes assigned: Csc, Cfa, Dfc. In addition we set all those soil moisture values that are **not** flagged as 'good' (G) to NaN.

```
print(ismn_data.print_climate_dict())
```

```
KOEPPEN GEIGER Climate Classification
-------------------------------------
Af  : Tropical Rainforest
Am  : Tropical Monsoon
As  : Tropical Savanna Dry
Aw  : Tropical Savanna Wet
BWk : Arid Desert Cold
BWh : Arid Desert Hot
BWn : Arid Desert With Frequent Fog
BSk : Arid Steppe Cold
BSh : Arid Steppe Hot
BSn : Arid Steppe With Frequent Fog
Csa : Temperate Dry Hot Summer
Csb : Temperate Dry Warm Summer
Csc : Temperate Dry Cold Summer
```

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```
Cwa : Temperate Dry Winter, Hot Summer
Cwb : Temperate Dry Winter, Warm Summer
Cwc : Temperate Dry Winter, Cold Summer
Cfa : Temperate Without Dry Season, Hot Summer
Cfb : Temperate Without Dry Season, Warm Summer
Cfc : Temperate Without Dry Season, Cold Summer
Dsa : Cold Dry Summer, Hot Summer
Dsb : Cold Dry Summer, Warm Summer
Dsc : Cold Dry Summer, Cold Summer
Dsd : Cold Dry Summer, Very Cold Winter
Dwa : Cold Dry Winter, Hot Summer
Dwb : Cold Dry Winter, Warm Summer
Dwc : Cold Dry Winter, Cold Summer
Dwd : Cold Dry Winter, Very Cold Winter
Dfa : Cold Dry Without Dry Season, Hot Summer
Dfb : Cold Dry Without Dry Season, Warm Summer
Dfc : Cold Dry Without Dry Season, Cold Summer
Dfd : Cold Dry Without Dry Season, Very Cold Winter
ET  : Polar Tundra
EF  : Polar Eternal Winter
W   : Water
```

```
None
```

```
from ismn.meta import Depth
for network, station, sensor in ismn_data.collection \
    .iter_sensors(variable='soil_moisture',
                  depth=Depth(0.,0.05),
                  filter_meta_dict={'lc_2010': [10, 130],
                                    'climate_KG':['Csc', 'Cfa', 'Dfc']}):

    data = sensor.read_data()
    data.loc[data['soil_moisture_flag'] != 'G', 'soil_moisture'] = np.nan
    metadata = sensor.metadata
    print(network)
    print(station)
    print('\033[1m' + f'Metadata for sensor {sensor}:')
    print(metadata.to_pd())
    ax = data.plot(figsize=(12,4), title=f"G-flagged SM for '{sensor.name}' at␣
↪station '{station.name}' in network '{network.name}'")
    ax.set_xlabel("Time [year]")
    ax.set_ylabel("Soil Moisture [$m^3 m^{-3}$]")
    plt.show()
    break # for this example we stop after the first sensor
```

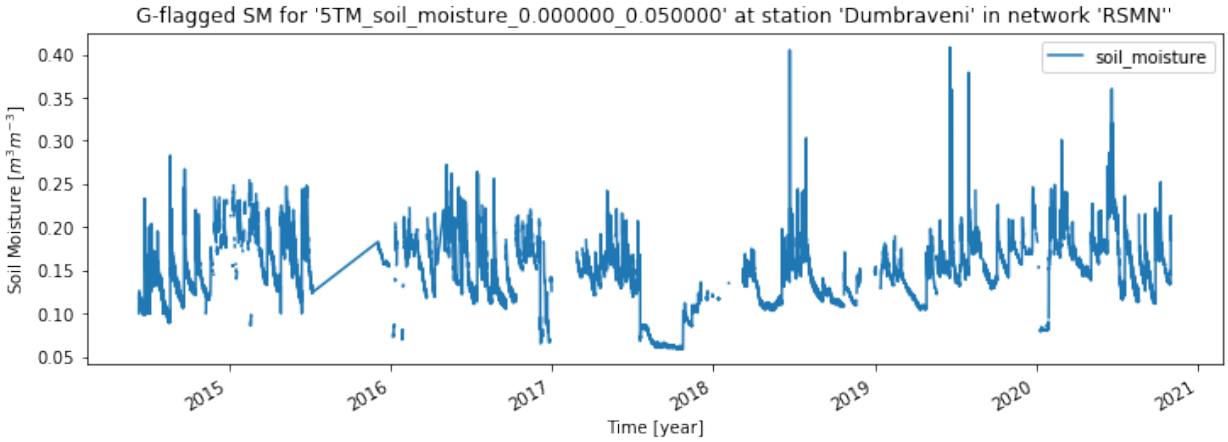
```
Stations in 'RSMN': ['Adamclisi', 'Alexandria', 'Bacles', 'Banloc', 'Barlad',
↪'Calarasi', 'ChisineuCris', 'Corugea', 'Cotnari', 'Darabani', 'Dej', 'Dumbraveni',
↪'Iasi', 'Oradea', 'RosioriideVede', 'SannicolauMare', 'SatuMare', 'Slatina',
↪'Slobozia', 'Tecuci']
```

```
Sensors at 'Dumbraveni': ['5TM_soil_moisture_0.000000_0.050000', '5TM_soil_
↪temperature_0.000000_0.050000', 'QMR102_precipitation_-1.400000_-1.400000',
↪'HMP45DX_air_temperature_-2.000000_-2.000000']
```

```
[1mMetadata for sensor 5TM_soil_moisture_0.000000_0.050000:
```

name	meta_args	
clay_fraction	val	19
	depth_from	0
	depth_to	0.3
climate_KG	val	Dfc
climate_insitu	val	unknown
elevation	val	318
instrument	val	5TM
	depth_from	0
	depth_to	0.05
latitude	val	46.2279
lc_2000	val	10
lc_2005	val	10
lc_2010	val	10
lc_insitu	val	unknown
longitude	val	24.5916
network	val	RSMN
organic_carbon	val	0.99
	depth_from	0
	depth_to	0.3
sand_fraction	val	37
	depth_from	0
	depth_to	0.3
saturation	val	0.44
	depth_from	0
	depth_to	0.3
silt_fraction	val	44
	depth_from	0
	depth_to	0.3
station	val	Dumbraveni
timerange_from	val	2014-06-11 12:00:00
timerange_to	val	2020-10-31 23:00:00
variable	val	soil_moisture
	depth_from	0
	depth_to	0.05

Name: data, dtype: object



CHAPTER

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7.1 License

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7.3 ismn

7.3.1 ismn package

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