CLIMADA documentation

Release 1.2.6-dev

CLIMADA contributors

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CONTENTS

This is the documentation for version v1.2.6-dev. In CLIMADA-project you will find CLIMADA's contributors, repository and scientific publications.

CHAPTER

ONE

INTRODUCTION

CLIMADA implements a fully probabilistic risk assessment model. According to the [IPCC2014], natural risks emerge through the interplay of climate and weather-related hazards, the exposure of goods or people to this hazard, and the specific vulnerability of exposed people, infrastructure and environment. The unit chosen to measure risk has to be the most relevant one in a specific decision problem, not necessarily monetary units. Wildfire hazard might be measured by burned area, exposure by population or replacement value of homes and hence risk might be expressed as number of affected people in the context of evacuation, or repair cost of buildings in the context of property insurance.

Risk has been defined by the International Organization for Standardization as the "effect of uncertainty on objectives" as the potential for consequences when something of value is at stake and the outcome is uncertain, recognizing the diversity of values. Risk can then be quantified as the combination of the probability of a consequence and its magnitude:

$$risk = probability \times severity$$

In the simplest case, $\times$ stands for a multiplication, but more generally, it represents a convolution of the respective distributions of probability and severity. We approximate the $severity$ as follows:

$$severity = F(hazard\ intensity, exposure, vulnerability) = exposure * f_{imp}(hazard\ intensity)$$

where f_{imp} is the impact function which parametrizes to what extent an exposure will be affected by a specific hazard. While 'vulnerability function' is broadly used in the modelers community, we refer to it as 'impact function' to explicitly include the option of opportunities (i.e. negative damages). Using this approach, CLIMADA constitutes a platform to analyse risks of different hazard types in a globally consistent fashion at different resolution levels, at scales from multiple kilometres down to meters, depending on the purpose.

CHAPTER

TWO

INSTALLATION

Please execute the instructions of the following text boxes in a Terminal or Anaconda Prompt.

2.1 Download

Download the last CLIMADA release available in climada releases as a zip or tar.gz file. Uncompress it to your local computer. Hereinafter `climada_python-x.y.z` refers to the downloaded folder of CLIMADA version x.y.z.

2.2 Unix Operating System

2.2.1 Install environment with Anaconda

1. **Anaconda**: Download or update to the latest version of Anaconda. Execute it.
2. **Install dependencies**: In the *Environments* section, use the *Import* box to create a new virtual environment from a yml file. A dialogue box will ask you for the location of the file. Provide first the path of climada's `climada_python-x.y.z/requirements/env_climada.yml`. The default name of the environment, *climada_env*, appears. Click the *Import* button to start the installation.

   The installation of the packages will take some minutes. No dialogue box should appear in the meantime. If an error happens, try to solve it looking into the details description.

   Optional: To include *climada_python-x.y.z* in the environment's path, do the following. In your environments folder, for example */home/user/anaconda3/*:

   ```
   cd envs/climada_env/lib/python3.6/site-packages
   echo '/your/path/to/climada_python-x.y.z/' > climada_env_path.pth
   ```

3. **Test installation**: Before leaving the *Environments* section of Anaconda, make sure that the climada environment, *climada_env* is selected. Go to the *Home* section of Anaconda and install and launch Spyder (or your preferred editor). Open the file containing all the installation tests, `tests_install.py` in `climada_python-x.y.z` folder and execute it. If the installation has been successful, an OK will appear at the end (the execution should last less than 2min).
4. **Run tutorials**: In the *Home* section of Anaconda, with *climada_env* selected, install and launch *jupyter notebook*. A browser window will show up. Navigate to your `climada_python-x.y.z` repository and open `doc/tutorial/1_main_climada.ipynb`. This is the tutorial which will guide you through all climada's functionalities. Execute each code cell to see the results, you might also edit the code cells before executing. See *Tutorial* for more information.

2.2.2 Install environment with Miniconda

1. **Miniconda**: Download or update to the latest version of Miniconda.
2. **Install dependencies**: Create the virtual environment *climada_env* with climada's dependencies:

```
cd climada_python-x.y.z
conda env create -f requirements/env_climada.yml --name climada_env
```

   Optional: To include *climada_python-x.y.z* in the environment's path, do the following. In your environments folder, for example */home/user/miniconda3/*:

```
cd envs/climada_env/lib/python3.6/site-packages
echo '/your/path/to/climada_python-x.y.z/' > climada_env_path.pth
```

3. **Test installation**: Activate the environment, execute the installation tests and deactivate the environment when finished using climada:

```
source activate climada_env
python3 tests_install.py
source deactivate
```

   If the installation has been successful, an OK will appear at the end (the execution should last less than 2min).

4. **Run tutorials**: Install and launch *jupyter notebook*:

```
jupyter notebook --notebook-dir /path/to/climada_python-x.y.z
```

   A browser window will show up. Open `climada_python-x.y.z/doc/tutorial/1_main_climada.ipynb`. This is the tutorial which will guide you through all climada's functionalities. Execute each code cell to see the results, you might also edit the code cells before executing. See *Tutorial* for more information.

2.3 Windows Operating System

2.3.1 Install environment with Anaconda

See *Install environment with Anaconda*.

Note:

In Step 2's optional instructions, to include the path into climada's virtual environment, set a file with format *.pth* containing the path of *climada_python-x.y.z* (e.g. `C:\\Users\\USERNAME\\Documents\\climada_python-x.y.z\\`) in:

```
*/Anaconda3/envs/climada_env/Lib/site-packages
```

2.4 FAQs

- ModuleNotFoundError; climada libraries are not found. Try to include *climada_python-x.y.z* path in the environment *climada_env* path as suggested in Section 2 of *Install environment with Anaconda*. If it does not work you can always include the path manually before executing your code:

```
import sys
sys.path.append('path/to/climada_python-x.y.z')
```

- ModuleNotFoundError; some python library is not found. It might happen that the pip dependencies of *env_climada.yml* (the ones specified after `pip:`) have not been installed in the environment *climada_env*. You can then install them manually one by one as follows:

```
source activate climada_env
pip install library_name
```

  where `library_name` is the missing library.

CHAPTER

THREE

TUTORIAL

The main tutorial walks you through all the functionalities of this version of CLIMADA. There, you will find the links to additional tutorials for specific features of CLIMADA, such as different hazard and exposure models. You can execute it by opening `climada_python-x.y.z/doc/tutorial/1_main_climada.ipynb` with Jupyter Notebook and the CLIMADA environment (*climada_env*) activated (i.e. CLIMADA needs to be installed as in *Installation*).

Navigate through the tutorial here:

3.1 CLIMADA features

The functionality of climada is gathered in the following classes:

- Entity: socio-economic models
- Exposures: exposed values
  - BlackMarble: regional economic model from nightlight intensities and economic indicators (GDP, income group)
  - LitPop: regional economic model using nightlight and population maps together with several economic indicators
- ImpactFuncSet: collection of impact functions per hazard
  - ImpactFunc: one adjustable impact function
  - IFTropCyclone: definition of impact functions for tropical cyclones
- DiscRates: discount rates per year
- MeasureSet: collection of measures for adaptation
  - Measure: one configurable measure
- Hazard: meteorological models
- TropCyclone: tropical cyclone events
- Impact: impacts of the Hazard and Entity interaction
- CostBenefit: adaptation options appraisal

3.2 Risk assessment

3.2.1 Entity

The entity class is just a container for the exposures, impact functions, discount rates and measures. It can be directly filled from an excel file following climada's template or from MATLAB files of the climada MATLAB version. The excel template can be found in `climada_python/data/system/entity_template.xlsx`.

[1]:
```
from climada.entity import Entity
from climada.util.constants import ENT_DEMO_TODAY

# absolute path of file following template.
ent_file = ENT_DEMO_TODAY
ent_fl = Entity()
ent_fl.read_excel(ent_file)
```

```
2019-06-18 17:43:20,788 - climada - DEBUG - Loading default config file: /Users/
↪aznarsig/Documents/Python/climada_python/climada/conf/defaults.conf
```

Every class has a `check()` method. This verifies that the necessary data to compute the impact is correctly provided and logs the optional variables that are not present. Use it always after filling an instance.

[2]:
```
ent_fl.check() # checks exposures, impact functions, discount rates and measures
```

```
2019-06-18 17:43:22,894 - climada.entity.exposures.base - INFO - crs set to default␣
↪value: {'init': 'epsg:4326', 'no_defs': True}
2019-06-18 17:43:22,896 - climada.entity.exposures.base - INFO - ref_year metadata␣
↪set to default value: 2018
2019-06-18 17:43:22,897 - climada.entity.exposures.base - INFO - value_unit metadata␣
↪set to default value: USD
2019-06-18 17:43:22,897 - climada.entity.exposures.base - INFO - meta metadata set to␣
↪default value: None
2019-06-18 17:43:22,898 - climada.entity.exposures.base - INFO - centr_ not set.
2019-06-18 17:43:22,899 - climada.entity.exposures.base - INFO - category_id not set.
2019-06-18 17:43:22,900 - climada.entity.exposures.base - INFO - region_id not set.
2019-06-18 17:43:22,901 - climada.entity.exposures.base - INFO - geometry not set.
```

Exposures

The `Entity`'s `exposures` attribute contains geolocalized values of anything exposed to the hazard, let it be monetary value of assets or number of human lifes, for example. It is of type `Exposures`.

See Exposures tutorial to learn how to fill and use exposures.

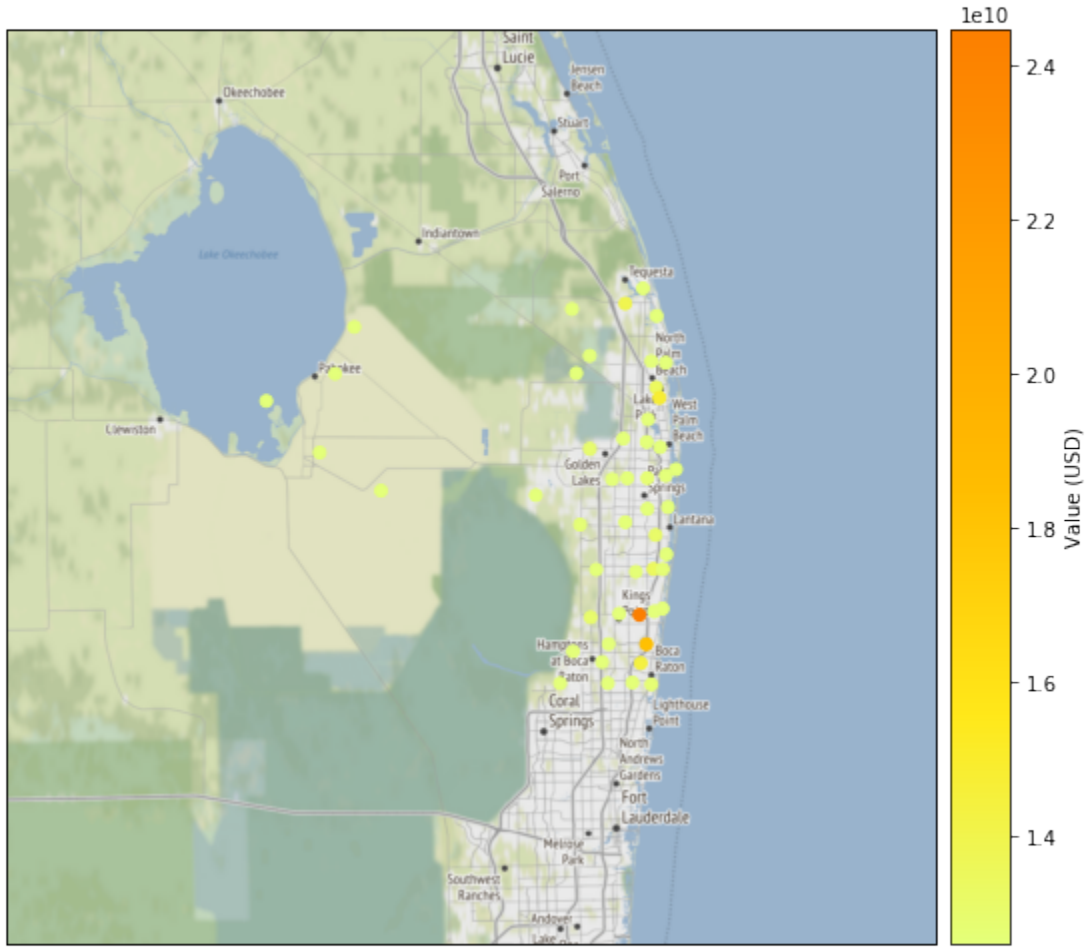
See LitPop to model economic exposures using night-time light and population densitites. See BlackMarble to model economic exposures based only on night-time light intensities.

[3]:
```
%matplotlib inline
ent_fl.exposures.plot_basemap(buffer=50000.0); # exposures in Florida
```

```
2019-06-18 17:43:22,910 - climada.entity.exposures.base - INFO - Setting geometry␣
↪points.
2019-06-18 17:43:22,927 - climada.entity.exposures.base - INFO - Setting latitude and␣
↪longitude attributes.
```

```
/Users/aznarsig/anaconda3/envs/climada_up/lib/python3.7/site-packages/matplotlib/
↪tight_layout.py:176: UserWarning: Tight layout not applied. The left and right␣
↪margins cannot be made large enough to accommodate all axes decorations.
  warnings.warn('Tight layout not applied. The left and right margins '
```

```
2019-06-18 17:43:24,030 - climada.entity.exposures.base - INFO - Setting latitude and␣
↪longitude attributes.
```

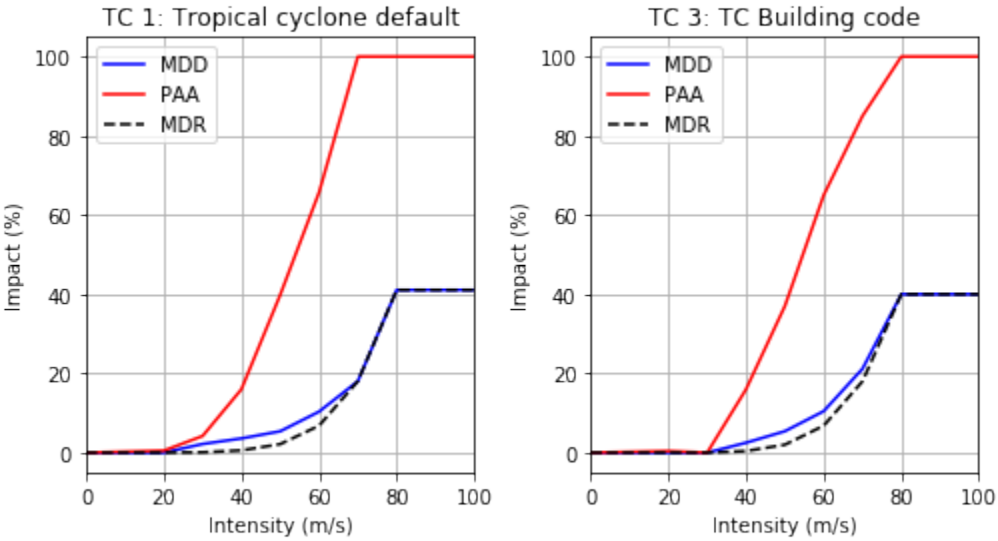


Impact Functions

The `impact_funcs` attribute is of type `ImpactFuncSet`. As such, it contains impact functions for different hazards.

See Impact Functions tutorial to learn how to handle this class.

[4]:
```
ent_fl.impact_funcs.plot('TC'); # tropical cyclone impact functions
```



Adaptation Measures

The `measures` attribute is of type `MeasureSet`. This class is a container of `Measure` instances, similarly to `ImpactFuncSet` containing several `ImpactFunc`. Adaptation measures aim to decrease hazards impacts and are subjected to a cost.

See Adaptation Measures to learn to handle measures.

[5]:
```
# print measures names
print(ent_fl.measures.get_names())
```

```
{'TC': ['Mangroves', 'Beach nourishment', 'Seawall', 'Building code']}
```

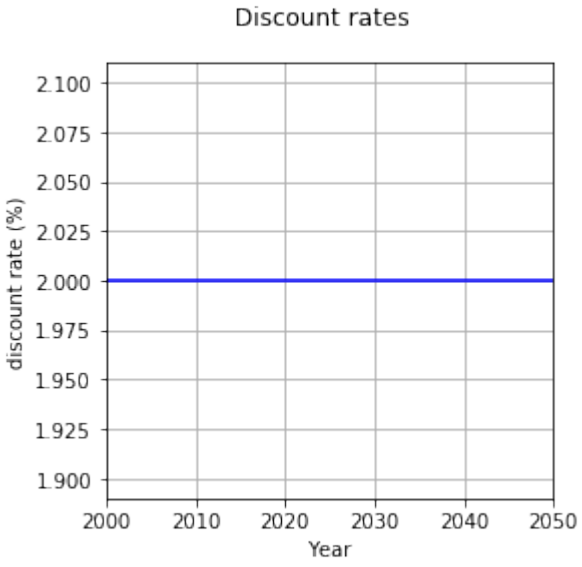
Discount Rates

The `disc_rates` attribute is of type `DiscRates`. This class contains the discount rates for the following years and computes the net present value for given values.

See Discount Rates.

[6]:
```
ent_fl.disc_rates.plot()
```

[6]:
```
(<Figure size 288x288 with 1 Axes>,
 [<matplotlib.axes._subplots.AxesSubplot at 0x1a24ac9c88>])
```



3.2.2 Hazard

Hazards are characterized by their frequency of occurrence and the geographical distribution of their intensity. A `Hazard` instance collects events of the same hazard type (e.g. tropical cyclone, flood, drought, ...) over the same centroids. They might be historical events or synthetic.

See Hazard to learn how to handle hazards.

See TropCyclone to learn to model tropical cyclones.

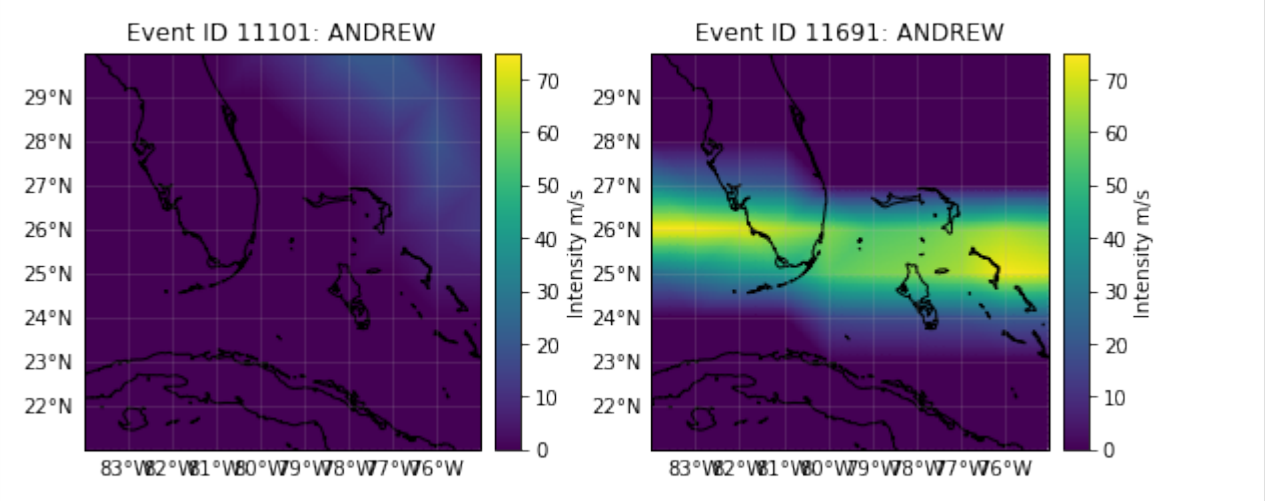
A complete set of tropical cyclones events in Florida can be found in file `HAZ_DEMO_MAT`. This contains 1445 historical events from year 1851 to 2011 and 9 synthetic events for each historical one.

[7]:
```
from climada.hazard import Hazard
from climada.util import HAZ_DEMO_MAT
tc_fl = Hazard('TC')
tc_fl.read_mat(HAZ_DEMO_MAT, 'Historic and synthetic tropical cyclones in Florida␣
↪from 1851 to 2011.')
tc_fl.plot_intensity('ANDREW') # plot intensity of hurricanes Andrew
print('Two hurricanes called Andrew happened in ', tc_fl.get_event_date('ANDREW'))
```

```
2019-06-18 17:43:24,964 - climada.hazard.base - INFO - Reading /Users/aznarsig/
↪Documents/Python/climada_python/data/demo/atl_prob.mat
2019-06-18 17:43:25,021 - climada.hazard.centroids.centr - INFO - Reading /Users/
↪aznarsig/Documents/Python/climada_python/data/demo/atl_prob.mat
```

```
/Users/aznarsig/anaconda3/envs/climada_up/lib/python3.7/site-packages/matplotlib/
↪tight_layout.py:176: UserWarning: Tight layout not applied. The left and right␣
↪margins cannot be made large enough to accommodate all axes decorations.
  warnings.warn('Tight layout not applied. The left and right margins '
```

```
Two hurricanes called Andrew happened in  ['1986-06-05', '1992-08-16']
```



3.2.3 Impact

The impact of hazard events over an entity can be computed easily from the previously explained classes. By computing the impact for each event (historical and synthetic), the `Impact` class provides different risk measures, as the expected annual impact per exposure, the probable maximum impact for different return periods and the total average annual impact.

Let us compute the impact of tropical cyclones over the exposures selected in Florida.

The configurable parameter `MAX_SIZE` controls the maximum matrix size contained in a chunk. You can decrease its value if you are having memory issues when using the `Impact`'s `calc` method. A high value will make the computation fast, but increase the memory use. The configuration file is located at `climada_python/climada/conf/defaults.conf`.

[8]:
```
from climada.engine import Impact

imp_fl = Impact()
imp_fl.calc(ent_fl.exposures, ent_fl.impact_funcs, tc_fl)

freq_curve_fl = imp_fl.calc_freq_curve() # impact exceedence frequency curve
freq_curve_fl.plot();

print('Expected average annual impact: {:.3e} USD'.format(imp_fl.aai_agg))

imp_fl.plot_basemap_eai_exposure(buffer=50000.0); # average annual impact at each␣
↪exposure
```

```
2019-06-18 17:43:35,127 - climada.entity.exposures.base - INFO - Matching 50␣
↪exposures with 100 centroids.
2019-06-18 17:43:35,167 - climada.engine.impact - INFO - Calculating damage for 50␣
↪assets (>0) and 14450 events.
Expected average annual impact: 6.512e+09 USD
2019-06-18 17:43:35,223 - climada.entity.exposures.base - INFO - tag metadata set to␣
↪default value:  File:
 Description:
2019-06-18 17:43:35,224 - climada.entity.exposures.base - INFO - ref_year metadata␣
↪set to default value: 2018
2019-06-18 17:43:35,224 - climada.entity.exposures.base - INFO - meta metadata set to␣
↪default value: None
```

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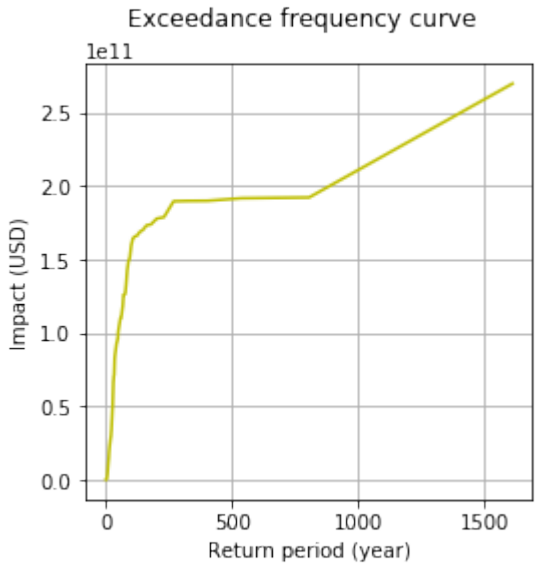
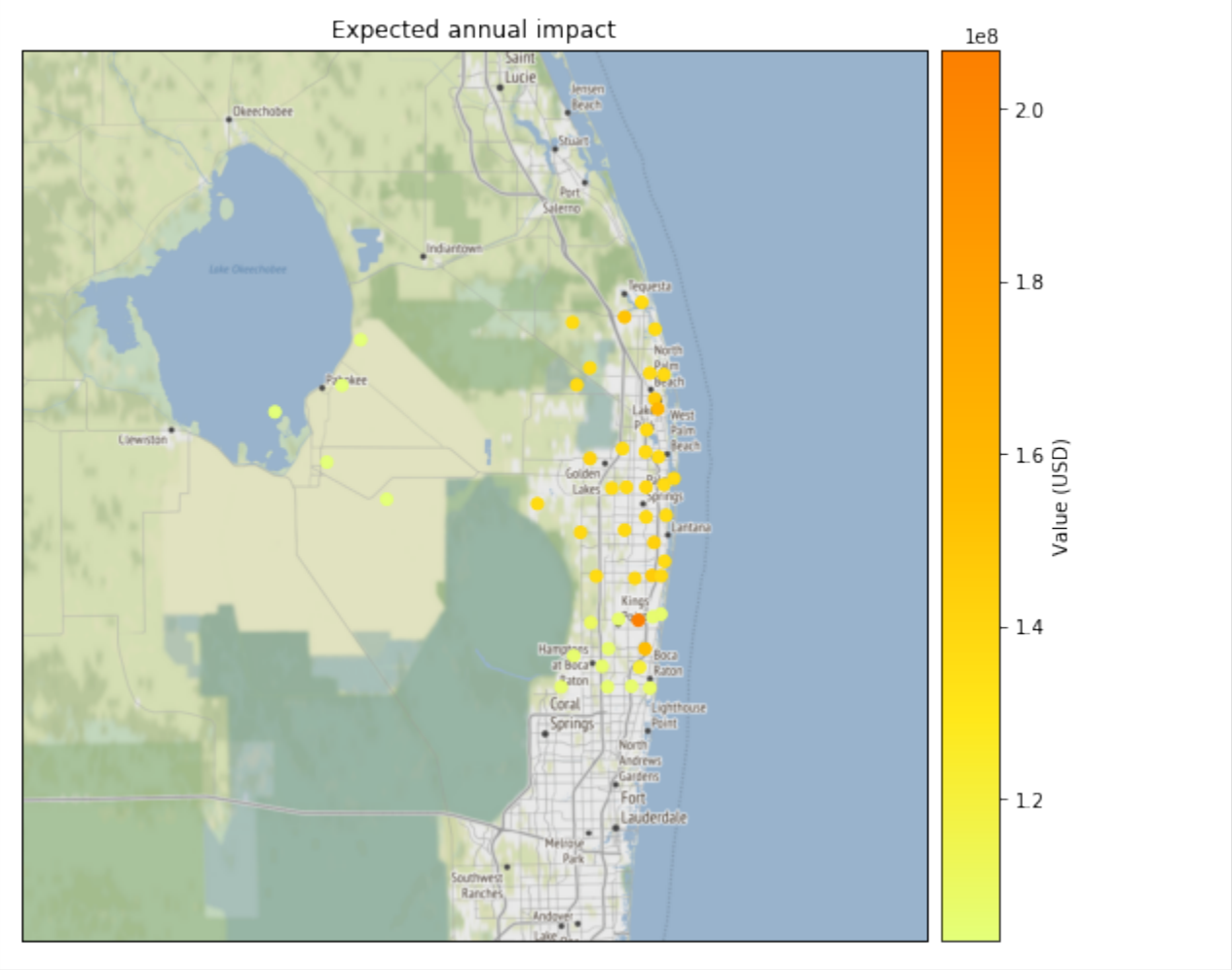
```
2019-06-18 17:43:35,225 - climada.entity.exposures.base - INFO - Setting if_ to␣
↪default impact functions ids 1.
2019-06-18 17:43:35,227 - climada.entity.exposures.base - INFO - centr_ not set.
2019-06-18 17:43:35,228 - climada.entity.exposures.base - INFO - deductible not set.
2019-06-18 17:43:35,229 - climada.entity.exposures.base - INFO - cover not set.
2019-06-18 17:43:35,229 - climada.entity.exposures.base - INFO - category_id not set.
2019-06-18 17:43:35,230 - climada.entity.exposures.base - INFO - region_id not set.
2019-06-18 17:43:35,231 - climada.entity.exposures.base - INFO - geometry not set.
2019-06-18 17:43:35,232 - climada.entity.exposures.base - INFO - Setting geometry␣
↪points.
2019-06-18 17:43:35,239 - climada.entity.exposures.base - INFO - Setting latitude and␣
↪longitude attributes.
```

```
/Users/aznarsig/anaconda3/envs/climada_up/lib/python3.7/site-packages/matplotlib/
↪tight_layout.py:176: UserWarning: Tight layout not applied. The left and right␣
↪margins cannot be made large enough to accommodate all axes decorations.
  warnings.warn('Tight layout not applied. The left and right margins '
```

```
2019-06-18 17:43:36,200 - climada.entity.exposures.base - INFO - Setting latitude and␣
↪longitude attributes.
```





We can save our variables in pickle format using the `save` function. This will save your results in the folder specified in the configuration file. The default folder is a `results` folder which is created in the current path.

[9]:
```
from climada.util import save
save('impact_florida.p', imp_fl)

# Later, the data can be read as follows:
import pickle
import os
abs_path = os.path.join(os.getcwd(), 'results/impact_florida.p') # absolute path
with open(abs_path, 'rb') as f:
    data = pickle.load(f)

print('Data read:', type(data))
```

```
2019-06-18 17:43:36,605 - climada.util.save - INFO - Created folder /Users/aznarsig/
↪Documents/Python/tutorial/results.
2019-06-18 17:43:36,610 - climada.util.save - INFO - Written file /Users/aznarsig/
↪Documents/Python/tutorial/results/impact_florida.p
Data read: <class 'climada.engine.impact.Impact'>
```

`Impact` also has `write_csv()` and `write_excel()` methods to save the impact variables, and `write_sparse_csr()` to save the impact matrix (impact per event and exposure). Use the class doc to get more information about these functions.

See Impact to learn more about impact calculations.

3.3 Adaptation options appraisal

The adaptation measures defined before can be valued by estimating its cost-benefit ratio. This is done in the class `CostBenefit`.

Let us suppose that the socioeconomic and climatoligical conditions remain the same in 2040. We then compute the cost and benefit of every adaptation measure as follows:

[10]:
```
from climada.engine import CostBenefit

cost_ben = CostBenefit()
cost_ben.calc(tc_fl, ent_fl, future_year=2040) # prints costs and benefits
cost_ben.plot_cost_benefit() # plot cost benefit ratio and averted damage of every␣
↪exposure
cost_ben.plot_event_view() # plot averted damage of each measure for every return␣
↪period
```

```
2019-06-18 17:43:36,622 - climada.engine.impact - INFO - Exposures matching centroids␣
↪found in centr_TC
2019-06-18 17:43:36,625 - climada.engine.impact - INFO - Calculating damage for 50␣
↪assets (>0) and 14450 events.
2019-06-18 17:43:36,665 - climada.engine.impact - INFO - Exposures matching centroids␣
↪found in centr_TC
2019-06-18 17:43:36,667 - climada.engine.impact - INFO - Calculating damage for 50␣
↪assets (>0) and 14450 events.
2019-06-18 17:43:36,693 - climada.engine.impact - INFO - Exposures matching centroids␣
↪found in centr_TC
2019-06-18 17:43:36,694 - climada.engine.impact - INFO - Calculating damage for 50␣
↪assets (>0) and 14450 events.
2019-06-18 17:43:36,721 - climada.engine.impact - INFO - Exposures matching centroids␣
↪found in centr_TC
2019-06-18 17:43:36,723 - climada.engine.impact - INFO - Calculating damage for 50␣
↪assets (>0) and 14450 events.
2019-06-18 17:43:36,911 - climada.engine.impact - INFO - Exposures matching centroids␣
↪found in centr_TC
2019-06-18 17:43:36,914 - climada.engine.impact - INFO - Calculating damage for 50␣
↪assets (>0) and 14450 events.
2019-06-18 17:43:36,959 - climada.engine.impact - INFO - Exposures matching centroids␣
↪found in centr_TC
2019-06-18 17:43:36,961 - climada.engine.impact - INFO - Calculating damage for 50␣
↪assets (>0) and 14450 events.
2019-06-18 17:43:36,989 - climada.engine.cost_benefit - INFO - Computing cost benefit␣
↪from years 2018 to 2040.

Measure               Cost (USD bn)    Benefit (USD bn)    Benefit/Cost
-----------  ----------  ------------  ---------
Mangroves                  1.31177             31.0058        23.6367
Beach nourishment          1.728               24.6898        14.2881
Seawall                    8.87878             33.133          3.7317
Building code              9.2                 30.3762         3.30177

-------------  -----  -----
Total climate risk:   121.505   (USD bn)
Average annual risk:    6.5122  (USD bn)
```

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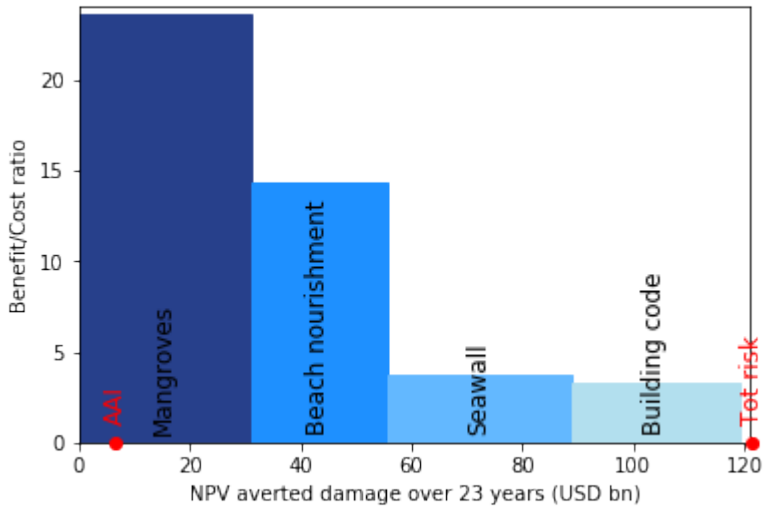
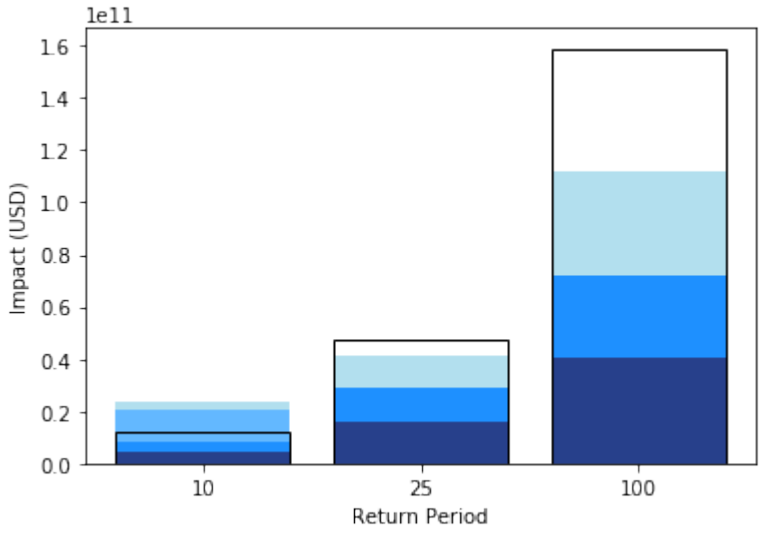
```
Residual damage:         2.3001   (USD bn)
-------------  -----  -----
```

[10]:
```
(<Figure size 432x288 with 1 Axes>,
 <matplotlib.axes._subplots.AxesSubplot at 0x1c2d0aa1d0>)
```





Let us now assume that the exposure evolves according to `ENT_DEMO_FUTURE` in 2040 and that the intensity of the hazards increase uniformly due to climate change.

[11]:
```
import copy
from climada.util.constants import ENT_DEMO_FUTURE

# future conditions
ent_future = Entity()
ent_future.read_excel(ENT_DEMO_FUTURE)
ent_future.check()
ent_future.exposures.ref_year = 2040

haz_future = copy.deepcopy(tc_fl)
```

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```
haz_future.intensity.data += 15  # increase uniformly the intensity

cost_ben = CostBenefit()
cost_ben.calc(tc_fl, ent_fl, haz_future, ent_future)
cost_ben.plot_cost_benefit() # plot cost benefit ratio and averted damage of every␣
↪exposure
cost_ben.plot_event_view() # plot averted damage of each measure for every return␣
↪period
fig, ax = cost_ben.plot_waterfall(tc_fl, ent_fl, haz_future, ent_future) # plot␣
↪expected annual impact
ax.set_title('Expected Annual Impact in 2015 and 2040')
cost_ben.plot_waterfall_accumulated(tc_fl, ent_fl, haz_future, ent_future) # plot␣
↪accumulated impact from present to future
```

```
2019-06-18 17:43:37,372 - climada.entity.exposures.base - INFO - crs set to default␣
↪value: {'init': 'epsg:4326', 'no_defs': True}
2019-06-18 17:43:37,373 - climada.entity.exposures.base - INFO - ref_year metadata␣
↪set to default value: 2018
2019-06-18 17:43:37,373 - climada.entity.exposures.base - INFO - value_unit metadata␣
↪set to default value: USD
2019-06-18 17:43:37,374 - climada.entity.exposures.base - INFO - meta metadata set to␣
↪default value: None
2019-06-18 17:43:37,375 - climada.entity.exposures.base - INFO - centr_ not set.
2019-06-18 17:43:37,376 - climada.entity.exposures.base - INFO - category_id not set.
2019-06-18 17:43:37,377 - climada.entity.exposures.base - INFO - region_id not set.
2019-06-18 17:43:37,378 - climada.entity.exposures.base - INFO - geometry not set.
2019-06-18 17:43:37,390 - climada.engine.impact - INFO - Exposures matching centroids␣
↪found in centr_TC
2019-06-18 17:43:37,391 - climada.engine.impact - INFO - Calculating damage for 50␣
↪assets (>0) and 14450 events.
2019-06-18 17:43:37,418 - climada.engine.impact - INFO - Exposures matching centroids␣
↪found in centr_TC
2019-06-18 17:43:37,420 - climada.engine.impact - INFO - Calculating damage for 50␣
↪assets (>0) and 14450 events.
2019-06-18 17:43:37,442 - climada.engine.impact - INFO - Exposures matching centroids␣
↪found in centr_TC
2019-06-18 17:43:37,444 - climada.engine.impact - INFO - Calculating damage for 50␣
↪assets (>0) and 14450 events.
2019-06-18 17:43:37,466 - climada.engine.impact - INFO - Exposures matching centroids␣
↪found in centr_TC
2019-06-18 17:43:37,468 - climada.engine.impact - INFO - Calculating damage for 50␣
↪assets (>0) and 14450 events.
2019-06-18 17:43:37,704 - climada.engine.impact - INFO - Exposures matching centroids␣
↪found in centr_TC
2019-06-18 17:43:37,706 - climada.engine.impact - INFO - Calculating damage for 50␣
↪assets (>0) and 14450 events.
2019-06-18 17:43:37,738 - climada.engine.impact - INFO - Exposures matching centroids␣
↪found in centr_TC
2019-06-18 17:43:37,739 - climada.engine.impact - INFO - Calculating damage for 50␣
↪assets (>0) and 14450 events.
2019-06-18 17:43:37,766 - climada.entity.exposures.base - INFO - Matching 50␣
↪exposures with 100 centroids.
2019-06-18 17:43:37,770 - climada.engine.impact - INFO - Calculating damage for 50␣
↪assets (>0) and 14450 events.
2019-06-18 17:43:37,804 - climada.engine.impact - INFO - Exposures matching centroids␣
↪found in centr_TC
2019-06-18 17:43:37,806 - climada.engine.impact - INFO - Calculating damage for 50␣
↪assets (>0) and 14450 events.
```

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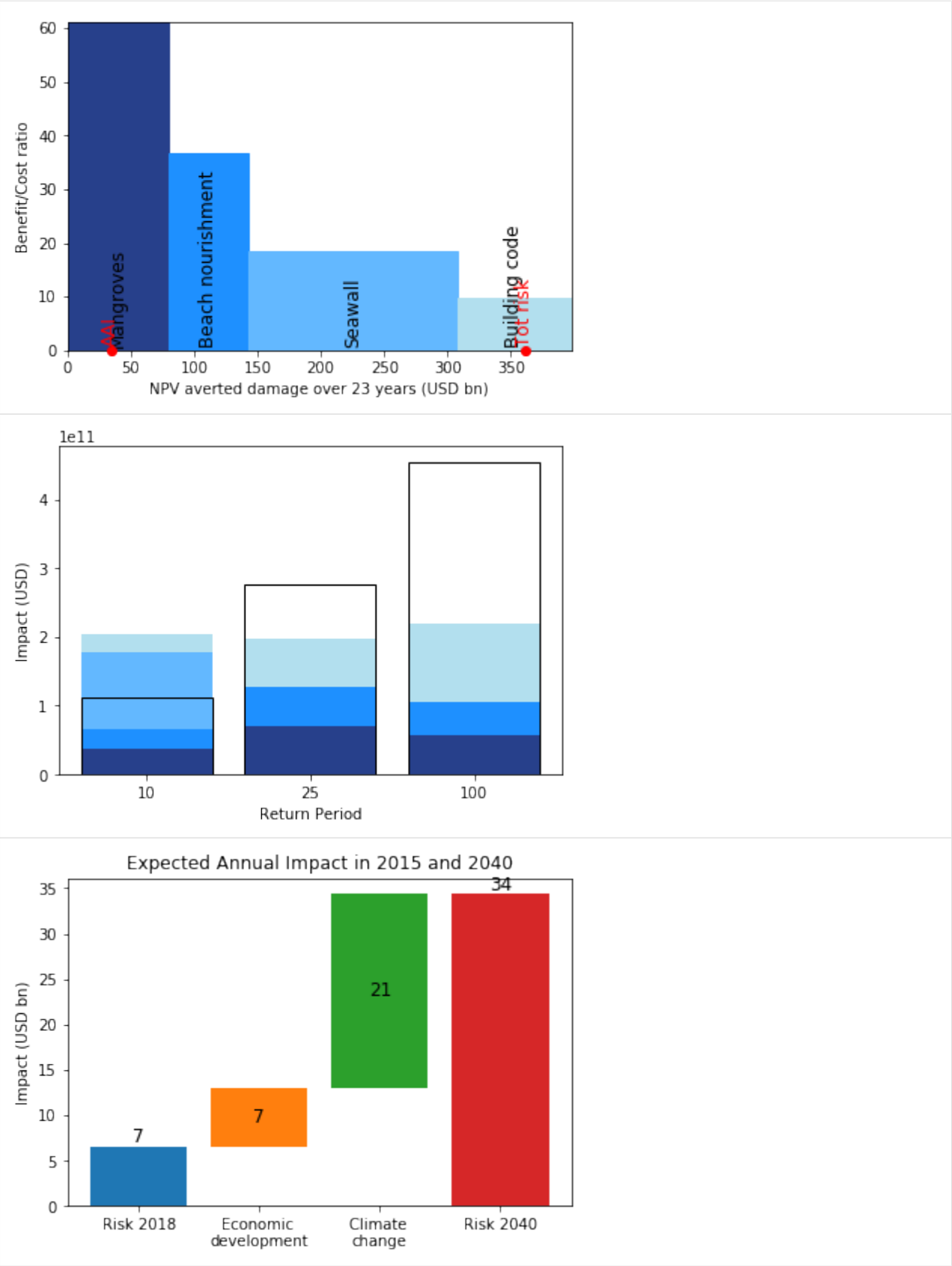
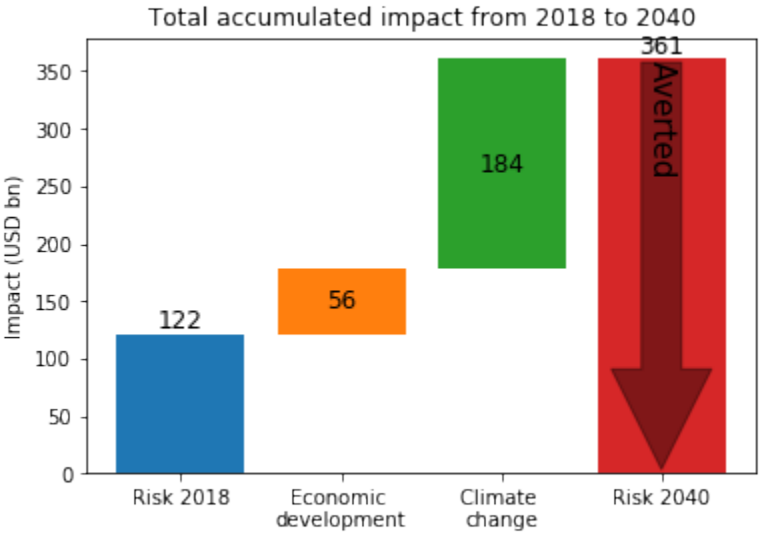
```
2019-06-18 17:43:37,837 - climada.engine.impact - INFO - Exposures matching centroids␣
↪found in centr_TC
2019-06-18 17:43:37,839 - climada.engine.impact - INFO - Calculating damage for 50␣
↪assets (>0) and 14450 events.
2019-06-18 17:43:37,870 - climada.engine.impact - INFO - Exposures matching centroids␣
↪found in centr_TC
2019-06-18 17:43:37,872 - climada.engine.impact - INFO - Calculating damage for 50␣
↪assets (>0) and 14450 events.
2019-06-18 17:43:38,079 - climada.engine.impact - INFO - Exposures matching centroids␣
↪found in centr_TC
2019-06-18 17:43:38,081 - climada.engine.impact - INFO - Calculating damage for 50␣
↪assets (>0) and 14450 events.
2019-06-18 17:43:38,109 - climada.engine.impact - INFO - Exposures matching centroids␣
↪found in centr_TC
2019-06-18 17:43:38,111 - climada.engine.impact - INFO - Calculating damage for 50␣
↪assets (>0) and 14450 events.
2019-06-18 17:43:38,150 - climada.engine.cost_benefit - INFO - Computing cost benefit␣
↪from years 2018 to 2040.

Measure               Cost (USD bn)    Benefit (USD bn)    Benefit/Cost
-----------  ----------  ------------  ---------
Mangroves                  1.31177            80.0097        60.9938
Beach nourishment          1.728              63.3336        36.6514
Seawall                    8.87878           164.132         18.4858
Building code              9.2                90.2786         9.81289

-------------  -----  -----
Total climate risk:   361.115   (USD bn)
Average annual risk:   34.3977  (USD bn)
Residual damage:      -36.6389  (USD bn)
-------------  -----  -----
2019-06-18 17:43:38,224 - climada.engine.cost_benefit - INFO - Risk at 2018: 6.512e+09
2019-06-18 17:43:38,225 - climada.engine.impact - INFO - Exposures matching centroids␣
↪found in centr_TC
2019-06-18 17:43:38,229 - climada.engine.impact - INFO - Calculating damage for 50␣
↪assets (>0) and 14450 events.
2019-06-18 17:43:38,263 - climada.engine.cost_benefit - INFO - Risk with development␣
↪at 2040: 1.302e+10
2019-06-18 17:43:38,264 - climada.engine.cost_benefit - INFO - Risk with development␣
↪and climate change at 2040: 3.440e+10
2019-06-18 17:43:38,281 - climada.engine.cost_benefit - INFO - Current total risk at␣
↪2040: 1.215e+11
2019-06-18 17:43:38,282 - climada.engine.impact - INFO - Exposures matching centroids␣
↪found in centr_TC
2019-06-18 17:43:38,286 - climada.engine.impact - INFO - Calculating damage for 50␣
↪assets (>0) and 14450 events.
2019-06-18 17:43:38,322 - climada.engine.cost_benefit - INFO - Total risk with␣
↪development at 2040: 1.775e+11
2019-06-18 17:43:38,323 - climada.engine.cost_benefit - INFO - Total risk with␣
↪development and climate change at 2040: 3.611e+11
```

[11]:
```
(<Figure size 432x288 with 1 Axes>,
 <matplotlib.axes._subplots.AxesSubplot at 0x1c2ed3cf28>)
```


Benefit/Cost ratio
NPV averted damage over 23 years (USD bn)
Mangroves
Beach nourishment
Seawall
Building code
AAI
Tot risk
1e11
Impact (USD)
Return Period
Expected Annual Impact in 2015 and 2040
Impact (USD bn)
Risk 2018
Economic development
Climate change
Risk 2040
7
7
21
34



Check what happens when different parameters are changed, such as the `imp_time_depen` and `risk_func` in CostBenefit.calc() (and plot_waterfall(), plot_waterfall_accumulated())

3.4 Your case

1. Build an entity. It might be one from your previous runs in MATLAB. Make sure i'is saved in version > v7.3 if it's a MATLAB file. If it's not, you'll get an error message. Then, you can save it again in MATLAB like that: `save('file_name.mat','variable_name', '-v7.3')`
2. Build a hazard. It might also come from a previous run in MATLAB. This file might already contain the centroids. If not, define the centroids as well and use them in your calculations.
3. Compute the impact.
4. Visualization. Plot:

- the damage functions for the hazard
- the entity values map
- the strongest event intensity
- the maximum hazard intensity of all the events in Zürich (47.38, 8.54)
- the impact exceedence frequency curve

[12]:
```
# Put your code here
```

[13]:
```
# SOLUTION: example: winter storms in europe
from climada.util import DATA_DIR
import pandas as pd
from climada.hazard import Hazard
```

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```
from climada.entity import Exposures, ImpactFuncSet
from climada.engine import Impact

# Put any absoulte path for your files or set up the configuration variable
↪"repository"
FILE_HAZARD = DATA_DIR + '/demo/WS_ERA40.mat'
FILE_ENTITY = DATA_DIR + '/demo/WS_Europe.xls'

# Define hazard type
HAZ_TYPE = 'WS'

# 1. Entity: we only need impact functions and exposures to compute the impact
# Exposures
exp_ws_eu = pd.read_excel(FILE_ENTITY)
exp_ws_eu = Exposures(exp_ws_eu)
exp_ws_eu.check()

# Impact functions
impf_ws_eu = ImpactFuncSet()
impf_ws_eu.read_excel(FILE_ENTITY, 'Impact functions for winter storms in EU.')

# 2. Hazard
haz_ws_eu = Hazard(HAZ_TYPE)
haz_ws_eu.read_mat(FILE_HAZARD, 'WS EU ERA 40')

# 3. Impact
imp_ws_eu = Impact()
imp_ws_eu.calc(exp_ws_eu, impf_ws_eu, haz_ws_eu)

# 4.
# the damage functions for the hazard
impf_ws_eu.plot()

# the exposures values map
exp_ws_eu.plot_hexbin(pop_name=False)

# the strongest event
haz_ws_eu.plot_intensity(-1) # might be better to use an other earth projection?

# the impact exceedence frequency curve
imp_exc_curve = imp_ws_eu.calc_freq_curve()
imp_exc_curve.plot()
```

```
2019-06-18 17:43:39,222 - climada.entity.exposures.base - INFO - crs set to default␣
↪value: {'init': 'epsg:4326', 'no_defs': True}
2019-06-18 17:43:39,223 - climada.entity.exposures.base - INFO - tag metadata set to␣
↪default value:  File:
 Description:
2019-06-18 17:43:39,223 - climada.entity.exposures.base - INFO - ref_year metadata␣
↪set to default value: 2018
2019-06-18 17:43:39,224 - climada.entity.exposures.base - INFO - value_unit metadata␣
↪set to default value: USD
2019-06-18 17:43:39,225 - climada.entity.exposures.base - INFO - meta metadata set to␣
↪default value: None
2019-06-18 17:43:39,227 - climada.entity.exposures.base - INFO - centr_ not set.
2019-06-18 17:43:39,228 - climada.entity.exposures.base - INFO - category_id not set.
2019-06-18 17:43:39,229 - climada.entity.exposures.base - INFO - region_id not set.
```

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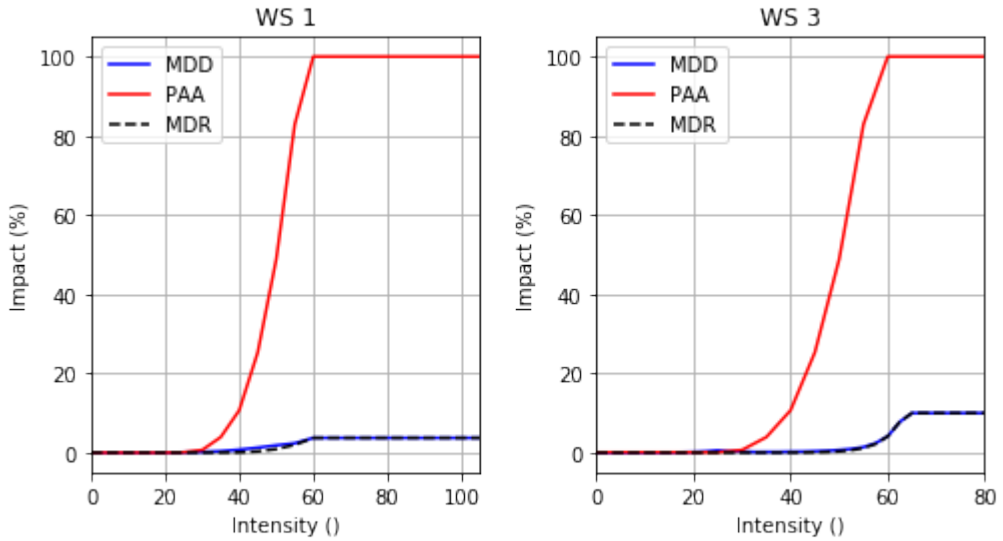
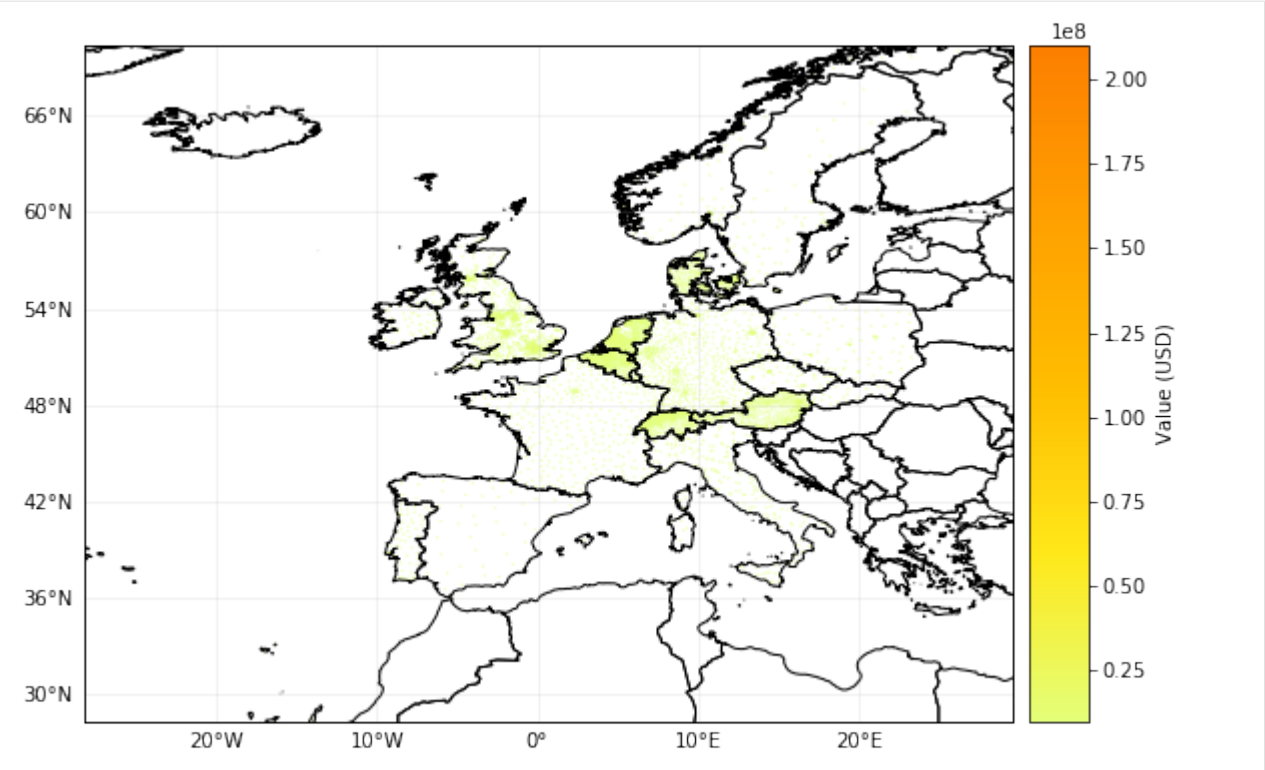
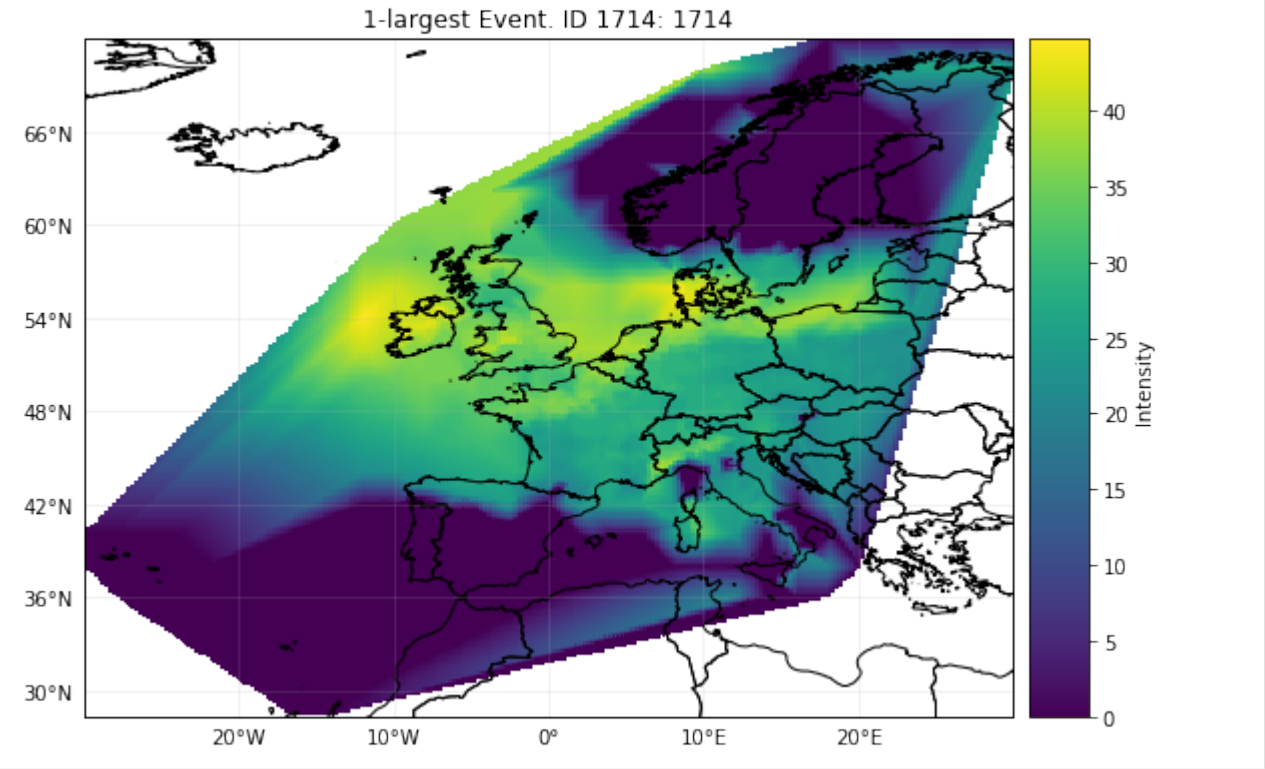
```
2019-06-18 17:43:39,231 - climada.entity.exposures.base - INFO - geometry not set.
2019-06-18 17:43:39,359 - climada.hazard.base - INFO - Reading /Users/aznarsig/
↪Documents/Python/climada_python/data/demo/WS_ERA40.mat
2019-06-18 17:43:39,594 - climada.hazard.centroids.centr - INFO - Reading /Users/
↪aznarsig/Documents/Python/climada_python/data/demo/WS_ERA40.mat
2019-06-18 17:43:39,898 - climada.entity.exposures.base - INFO - Matching 6186␣
↪exposures with 6331 centroids.
2019-06-18 17:43:40,618 - climada.engine.impact - INFO - Calculating damage for 6186␣
↪assets (>0) and 1755 events.
```

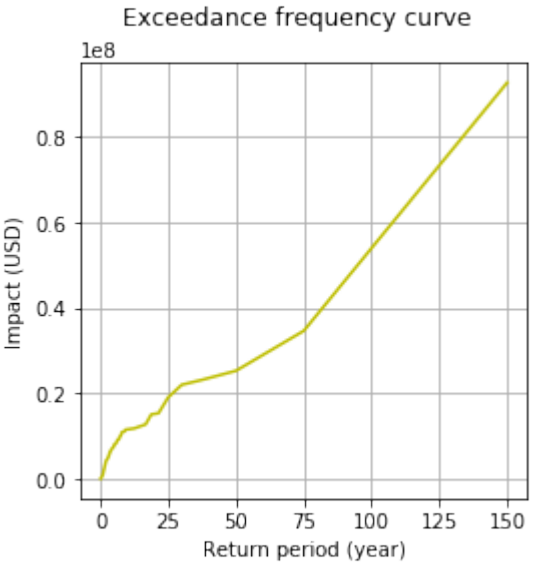
```
/Users/aznarsig/anaconda3/envs/climada_up/lib/python3.7/site-packages/matplotlib/
↪tight_layout.py:176: UserWarning: Tight layout not applied. The left and right␣
↪margins cannot be made large enough to accommodate all axes decorations.
  warnings.warn('Tight layout not applied. The left and right margins '
```

[13]:
```
(<Figure size 288x288 with 1 Axes>,
 [<matplotlib.axes._subplots.AxesSubplot at 0x1c2da76b70>])
```




1e8
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
Value (USD)
66°N
60°N
54°N
48°N
42°N
36°N
30°N
20°W
10°W
0°
10°E
20°E


1-largest Event. ID 1714: 1714
40
35
30
25
20
15
10
5
0
Intensity
66°N
60°N
54°N
48°N
42°N
36°N
30°N
20°W
10°W
0°
10°E
20°E


Exceedance frequency curve
1e8
0.8
0.6
0.4
0.2
0.0
Impact (USD)
0
25
50
75
100
125
150
Return period (year)

CHAPTER

FOUR

DATA DEPENDENCIES

4.1 Web APIs

CLIMADA relies on open data available through web APIs such as those of the World Bank, Natural Earth, NASA and NOAA. You might execute the test `climada_python-x.y.z/test_data_api.py` to check that all the APIs used are active. If any is out of service (temporarily or permanently), the test will indicate which one.

4.2 Manual download

As indicated in the software and tutorials, other data might need to be downloaded manually by the user. The following table shows these last data sources, their version used, its current availabilty and where they are used within CLIMADA:

Availability	Name	Version	Link	CLIMADA class	CLIMADA version	CLIMADA tutorial reference
OK	Gridded Population of the World (GPW)	v4.11	GPW v4.11	LitPop	> v1.2.3	climada_entity_LitPop.ipynb
FAILED	Gridded Population of the World (GPW)	v4.10	GPW v4.10	LitPop	>= v1.2.0	climada_entity_LitPop.ipynb

CHAPTER

FIVE

CONFIGURATION OPTIONS

CLIMADA searches for a local configuration file located in the current working directory. A static default configuration file is supplied by the package and used as fallback. The local configuration file needs to be called `climada.conf`. All other files will be ignored.

The climada configuration file is a JSON file and consists of the following values:

- `local_data`
- `global`
- `trop_cyclone`

A minimal configuration file looks something like this:

```
{
    "local_data":
    {
        "save_dir": "./results/"
    },

    "global":
    {
        "log_level": "INFO",
        "max_matrix_size": 1.0e8
    },

    "trop_cyclone":
    {
        "random_seed": 54
    }
}
```

5.1 local_data

Configuration parameters related to local data location.

Option	Description	Default
`save_dir`	Folder were the variables are saved through the `save` command when no absolute path provided.	"./results"

5.2 global

Configuration parameters with global scope.

Option	Description	Default
`log_level`	Minimum log level showed by logging: DEBUG, INFO, WARNING, ERROR or CRITICAL.	"INFO"
`max_matrix_size`	Maximum matrix size that can be used. Set a lower value if memory issues.	1.0E8

5.3 trop_cyclone

Configuration parameters related to tropical cyclones.

Option	Description	Default
`random_seed`	Seed used for the stochastic tracks generation.	54

CHAPTER

SIX

CONTRIBUTING

Contributions are very welcome! Please follow these steps:

0. **Install** Git and Anaconda (or Miniconda).
1. **Fork** the project on GitHub:

```
git clone https://github.com/CLIMADA-project/climada_python.git
```

2. **Install the packages** in `climada_python/requirements/env_climada.yml` and `climada_python/requirements/env_developer.yml` (see *Installation*).
3. Make well commented and clean **commits** to the repository. You can make a new **branch** here if you are modifying more than one part or feature.
4. Make unit and integration **tests** on your code, preferably during development.
5. Perform a **static code analysis** of your code using `pylint` with CLIMADA's configuration `.pylintrc`.
6. Add new **data dependencies** used in *Data dependencies* and write a **tutorial** if a new class has been introduced (see *Tutorial*).
7. Add your name to the **AUTHORS** file.
8. **Push** the branch to GitHub:

```
git push origin my-new-feature
```

9. On GitHub, create a new **pull request** from the feature branch.

6.1 Notes

6.1.1 Update CLIMADA's environment

Remember to regularly update your code as well as climada's environment. You might use the following commands to update the environments:

```
cd climada_python
git pull
source activate climada_env
conda env update --file requirements/env_climada.yml
conda env update --file requirements/env_developer.yml
```

If any problem occurs during this process, consider reinstalling everything from scratch following the :doc:install instructions. You can find more information about virtual environments with conda here.

CHAPTER

SEVEN

SOFTWARE DOCUMENTATION

Documents functions, classes and methods:

7.1 Software documentation per package

7.1.1 climada.engine package

climada.engine.impact module

class climada.engine.impact.**Impact**

Bases: object

Impact definition. Compute from an entity (exposures and impact functions) and hazard.

tag
dictionary of tags of exposures, impact functions set and hazard: {'exp': Tag(), 'if_set': Tag(), 'haz': TagHazard()}

Type dict

event_id
id (>0) of each hazard event

Type np.array

event_name
name of each hazard event

Type list

date
date of events

Type np.array

coord_exp
exposures coordinates [lat, lon] (in degrees)

Type np.ndarray

eai_exp
expected annual impact for each exposure

Type np.array

at_event
impact for each hazard event

Type np.array

frequency
annual frequency of event

Type np.arrray

tot_value
total exposure value affected

Type float

aai_agg
average annual impact (aggregated)

Type float

unit
value unit used (given by exposures unit)

Type str

imp_mat
matrix num_events x num_exp with impacts. only filled if save_mat is True in calc()

Type sparse.csr_matrix

__init__()
Empty initialization.

calc_freq_curve(*return_per=None*)
Compute impact exceedance frequency curve.

Parameters **return_per** (*np.array, optional*) – return periods where to compute the exceedance impact. Use impact's frequencies if not provided

Returns ImpactFreqCurve

calc(*exposures*, *impact_funcs*, *hazard*, *save_mat=False*)
Compute impact of an hazard to exposures.

Parameters

- **exposures** (*Exposures*) – exposures
- **impact_funcs** (*ImpactFuncSet*) – impact functions
- **hazard** (*Hazard*) – hazard
- **self_mat** (*bool*) – self impact matrix: events x exposures

Examples

Use Entity class:

```
>>> haz = Hazard('TC') # Set hazard
>>> haz.read_mat(HAZ_DEMO_MAT)
>>> haz.check()
>>> ent = Entity() # Load entity with default values
>>> ent.read_excel(ENT_TEMPLATE_XLS) # Set exposures
>>> ent.check()
>>> imp = Impact()
>>> imp.calc(ent.exposures, ent.impact_funcs, haz)
>>> imp.calc_freq_curve().plot()
```

Specify only exposures and impact functions:

```
>>> haz = Hazard('TC') # Set hazard
>>> haz.read_mat(HAZ_DEMO_MAT)
>>> haz.check()
>>> funcs = ImpactFuncSet()
>>> funcs.read_excel(ENT_TEMPLATE_XLS) # Set impact functions
>>> funcs.check()
>>> exp = Exposures(pd.read_excel(ENT_TEMPLATE_XLS)) # Set exposures
>>> exp.check()
>>> imp = Impact()
>>> imp.calc(exp, funcs, haz)
>>> imp.aai_agg
```

plot_hexbin_eai_exposure(*mask=None*, *ignore_zero=True*, *pop_name=True*, *buffer=0.0*, *extend='neither'*, ***kwargs*)

Plot hexbin expected annual impact of each exposure.

Parameters

- **mask (*np.array, optional*) – mask to apply to eai_exp plotted.**
  - **ignore_zero** (*bool, optional*) – flag to indicate if zero and negative values are ignored in plot. Default: False
  - **pop_name** (*bool, optional*) – add names of the populated places
  - **buffer** (*float, optional*) – border to add to coordinates. Default: 1.0.
  - **extend** (*str, optional*) – extend border colorbar with arrows. ['neither' | 'both' | 'min' | 'max']
  - **kwargs** (*optional*) – arguments for hexbin matplotlib function

Returns: matplotlib.figure.Figure, cartopy.mpl.geoaxes.GeoAxesSubplot

plot_scatter_eai_exposure(*mask=None*, *ignore_zero=True*, *pop_name=True*, *buffer=0.0*, *extend='neither'*, ***kwargs*)

Plot scatter expected annual impact of each exposure.

Parameters

- **mask (*np.array, optional*) – mask to apply to eai_exp plotted.**
  - **ignore_zero** (*bool, optional*) – flag to indicate if zero and negative values are ignored in plot. Default: False
  - **pop_name** (*bool, optional*) – add names of the populated places
  - **buffer** (*float, optional*) – border to add to coordinates. Default: 1.0.
  - **extend** (*str, optional*) – extend border colorbar with arrows. ['neither' | 'both' | 'min' | 'max']
  - **kwargs** (*optional*) – arguments for hexbin matplotlib function

Returns: matplotlib.figure.Figure, cartopy.mpl.geoaxes.GeoAxesSubplot

plot_raster_eai_exposure(*res=None*, *raster_res=None*, *save_tiff=None*, *raster_f=<function Impact.<lambda>>*, *label='value (log10)'*, ***kwargs*)

Plot raster expected annual impact of each exposure.

Parameters

- **res (*float, optional*) – resolution of current data in units of latitude**

  and longitude, approximated if not provided.

  - **raster_res** (*float, optional*) – desired resolution of the raster
  - **save_tiff** (*str, optional*) – file name to save the raster in tiff format, if provided
  - **raster_f** (*lambda function*) – transformation to use to data. Default: log10 adding 1.
  - **label** (*str*) – colorbar label
  - **kwargs** (*optional*) – arguments for imshow matplotlib function

Returns: matplotlib.figure.Figure, cartopy.mpl.geoaxes.GeoAxesSubplot

plot_basemap_eai_exposure (*mask=None, ignore_zero=False, pop_name=True, buffer=0.0, extend='neither', zoom=10, url='http://tile.stamen.com/terrain/tileZ/tileX/tileY.png', **kwargs*)

Plot basemap expected annual impact of each exposure.

Parameters

- **mask (*np.array, optional*) – mask to apply to eai_exp plotted.**
  - **ignore_zero** (*bool, optional*) – flag to indicate if zero and negative values are ignored in plot. Default: False
  - **pop_name** (*bool, optional*) – add names of the populated places
  - **buffer** (*float, optional*) – border to add to coordinates. Default: 0.0.
  - **extend** (*str, optional*) – extend border colorbar with arrows. ['neither' | 'both' | 'min' | 'max']
  - **zoom** (*int, optional*) – zoom coefficient used in the satellite image
  - **url** (*str, optional*) – image source, e.g. ctx.sources.OSM_C
  - **kwargs** (*optional*) – arguments for scatter matplotlib function, e.g. cmap='Greys'. Default: 'Wistia'

Returns: matplotlib.figure.Figure, cartopy.mpl.geoaxes.GeoAxesSubplot

write_csv (*file_name*)

Write data into csv file. imp_mat is not saved.

Parameters **file_name** (*str*) – absolute path of the file

write_excel (*file_name*)

Write data into Excel file. imp_mat is not saved.

Parameters **file_name** (*str*) – absolute path of the file

write_sparse_csr (*file_name*)

Write imp_mat matrix in numpy's npz format.

calc_impact_year_set (*all_years=True*)

Calculate yearly impact from impact data.

Parameters

- **all_years** (*boolean*) – return values for all years between first and

- **last year with event, including years without any events.**

Returns Impact year set of type numpy.ndarray with summed impact per year.

static read_sparse_csr(*file_name*)
Read imp_mat matrix from numpy's npz format.

Parameters **file_name** (*str*) – file name

Returns sparse.csr_matrix

read_csv(*file_name*)
Read csv file containing impact data generated by write_csv.

Parameters **file_name** (*str*) – absolute path of the file

read_excel(*file_name*)
Read excel file containing impact data generated by write_excel.

Parameters **file_name** (*str*) – absolute path of the file

class climada.engine.impact.**ImpactFreqCurve**
Bases: object

Impact exceedence frequency curve.

tag
dictionary of tags of exposures, impact functions set and hazard: {'exp': Tag(), 'if_set': Tag(), 'haz': TagHazard()}

Type dict

return_per
return period

Type np.array

impact
impact exceeding frequency

Type np.array

unit
value unit used (given by exposures unit)

Type str

label
string describing source data

Type str

__init__()
Initialize self. See help(type(self)) for accurate signature.

plot()
Plot impact frequency curve.

Returns matplotlib.figure.Figure, [matplotlib.axes._subplots.AxesSubplot]

plot_compare(*ifc*)
Plot current and input impact frequency curves in a figure.

Returns matplotlib.figure.Figure, [matplotlib.axes._subplots.AxesSubplot]

climada.engine.cost_benefit module

climada.engine.cost_benefit.**risk_aai_agg**(*impact*)
Risk measurement as average annual impact aggregated.

Parameters **impact** (*Impact*) – an Impact instance

Returns float

climada.engine.cost_benefit.**risk_rp_100**(*impact*)
Risk measurement as exceedance impact at 100 years return period.

Parameters **impact** (*Impact*) – an Impact instance

Returns float

climada.engine.cost_benefit.**risk_rp_250**(*impact*)
Risk measurement as exceedance impact at 250 years return period.

Parameters **impact** (*Impact*) – an Impact instance

Returns float

class climada.engine.cost_benefit.**CostBenefit**
Bases: object

Impact definition. Compute from an entity (exposures and impact functions) and hazard.

present_year
present reference year

Type int

future_year
future year

Type int

tot_climate_risk
total climate risk without measures

Type float

unit
unit used for impact

Type str

color_rgb
color code RGB for each measure. Key: measure name ('no measure' used for case without measure), Value: np.array

Type dict

benefit
benefit of each measure. Key: measure name, Value: float benefit

Type dict

cost_ben_ratio
cost benefit ratio of each measure. Key: measure name, Value: float cost benefit ratio

Type dict

imp_meas_future
impact of each measure at future or default. Key: measure name ('no measure' used for case without measure), Value: dict with:

'cost' (float): cost measure, 'risk' (float): risk measurement, 'risk_transf' (float): annual expected risk transfer, 'efc' (ImpactFreqCurve): impact exceedance freq

(optional) 'impact' (Impact): impact instance

Type dict

imp_meas_present
impact of each measure at present. Key: measure name ('no measure' used for case without measure), Value: dict with:

'cost' (float): cost measure, 'risk' (float): risk measurement, 'risk_transf' (float): annual expected risk transfer, 'efc' (ImpactFreqCurve): impact exceedance freq

(optional) 'impact' (Impact): impact instance

Type dict

__init__()
Initilization

calc(*hazard*, *entity*, *haz_future=None*, *ent_future=None*, *future_year=2050*, *risk_func=<function risk_aai_agg>*, *imp_time_depen=1*, *save_imp=False*)
Compute cost-benefit ratio for every measure provided current and future conditions. Present and future measures need to have the same name. The measures costs need to be discounted by the user. If present and future entity provided, only the costs of the measures of the future and the discount rates of the present will be used.

Parameters

- **hazard** (*Hazard*) – hazard
- **entity** (*Entity*) – entity
- **haz_future** (*Hazard*) – hazard in the future (future year provided at ent_future)
- **ent_future** (*Entity*) – entity in the future
- **future_year** (*int*) – future year to consider if no ent_future provided
- **risk_func** (*func, optional*) – function describing risk measure given an Impact. Default: average annual impact (aggregated).
- **imp_time_depen** (*float, optional*) – parameter which represent time evolution of impact. Default: 1 (linear).
- **save_imp** (*bool, optional*) – activate if Impact of each measure is saved. Default: False.

plot_cost_benefit(*cb_list=None*)
Plot cost-benefit graph. Call after calc().

Parameters **cb_list** (*lsit(CostBenefit), optional*) – if other CostBenefit provided, overlay them all. Used for uncertainty visualization.

Returns matplotlib.figure.Figure, matplotlib.axes._subplots.AxesSubplot

plot_event_view(*return_per=(10, 25, 100)*)
Plot averted damages for return periods. Call after calc().

Returns matplotlib.figure.Figure, matplotlib.axes._subplots.AxesSubplot

plot_waterfall(*hazard*, *entity*, *haz_future*, *ent_future*, *risk_func=<function risk_aai_agg>*)
Plot waterfall graph with given risk metric. Can be called before and after calc().

Parameters

- **hazard** (*Hazard*) – hazard
- **entity** (*Entity*) – entity
- **haz_future** (*Hazard*) – hazard in the future (future year provided at ent_future)
- **ent_future** (*Entity*) – entity in the future
- **risk_func** (*func, optional*) – function describing risk measure given an Impact. Default: average annual impact (aggregated).

Returns matplotlib.figure.Figure, matplotlib.axes._subplots.AxesSubplot

plot_waterfall_accumulated(*hazard*, *entity*, *haz_future*, *ent_future*, *risk_func=<function risk_aai_agg>*, *imp_time_depen=1*, *plot_arrow=True*)
Plot waterfall graph with accumulated values from present to future year. Call after calc(). Provide same risk_func and imp_time_depen as in calc.

Parameters

- **hazard** (*Hazard*) – hazard
- **entity** (*Entity*) – entity
- **haz_future** (*Hazard*) – hazard in the future (future year provided at ent_future)
- **ent_future** (*Entity*) – entity in the future
- **risk_func** (*func, optional*) – function describing risk measure given an Impact. Default: average annual impact (aggregated).
- **imp_time_depen** (*float, optional*) – parameter which represent time evolution of impact. Default: 1 (linear).
- **plot_arrow** (*bool, optional*) – plot adaptation arrow

Returns matplotlib.figure.Figure, matplotlib.axes._subplots.AxesSubplot

7.1.2 climada.entity package

climada.entity.disc_rates package

climada.entity.disc_rates.base module

class climada.entity.disc_rates.base.**DiscRates**
Bases: object

Defines discount rates and basic methods. Loads from files with format defined in FILE_EXT.

tag
information about the source data

Type *Tag*

years
years

Type np.array

rates
discount rates for each year (between 0 and 1)

Type np.array

__init__()
Empty initialization.

Examples

Fill discount rates with values and check consistency data:

```
>>> disc_rates = DiscRates()
>>> disc_rates.years = np.array([2000, 2001])
>>> disc_rates.rates = np.array([0.02, 0.02])
>>> disc_rates.check()
```

Read discount rates from year_2050.mat and checks consistency data.

```
>>> disc_rates = DiscRates(ENT_TEMPLATE_XLS)
```

clear()
Reinitialize attributes.

check()
Check attributes consistency.

Raises **ValueError** –

select(*year_range*)
Select discount rates in given years.

Parameters **year_range** (*np.array*) – continuous sequence of selected years.

Returns DiscRates

append(*disc_rates*)
Check and append discount rates to current DiscRates. Overwrite discount rate if same year.

Parameters **disc_rates** (*DiscRates*) – DiscRates instance to append

Raises **ValueError** –

net_present_value(*ini_year*, *end_year*, *val_years*)
Compute net present value between present year and future year.

Parameters

- **ini_year** (*float*) – initial year
- **end_year** (*float*) – end year
- **val_years** (*np.array*) – cash flow at each year btw ini_year and end_year (both included)

Returns float

plot()
Plot discount rates per year.

read_mat (*file_name*, *description=''*, *var_names={'field_name': 'discount', 'sup_field_name': 'entity', 'var_name': {'disc': 'discount_rate', 'year': 'year'}}*)
Read MATLAB file generated with previous MATLAB CLIMADA version.

Parameters

- **file_name** (*str*) – absolute file name
- **description** (*str, optional*) – description of the data
- **var_names** (*dict, optional*) – name of the variables in the file

read_excel (*file_name*, *description=''*, *var_names={'col_name': {'disc': 'discount_rate', 'year': 'year'}, 'sheet_name': 'discount'}*)
Read excel file following template and store variables.

Parameters

- **file_name** (*str*) – absolute file name
- **description** (*str, optional*) – description of the data
- **var_names** (*dict, optional*) – name of the variables in the file

write_excel (*file_name*, *var_names={'col_name': {'disc': 'discount_rate', 'year': 'year'}, 'sheet_name': 'discount'}*)
Write excel file following template.

Parameters

- **file_name** (*str*) – absolute file name to write
- **var_names** (*dict, optional*) – name of the variables in the file

climada.entity.exposures package

climada.entity.exposures.base module

class climada.entity.exposures.base.**Exposures** (**args*, ***kwargs*)
Bases: geopandas.geodataframe.GeoDataFrame

geopandas GeoDataFrame with metada and columns (pd.Series) defined in Attributes.

tag
metada - information about the source data

Type *Tag*

ref_year
metada - reference year

Type int

value_unit
metada - unit of the exposures values

Type str

latitude
latitude

Type pd.Series

longitude
longitude

Type pd.Series

crs
CRS information inherent to GeoDataFrame.

Type dict or crs

value
a value for each exposure

Type pd.Series

if_
e.g. if_TC. impact functions id for hazard TC. There might be different hazards defined: if_TC, if_FL, ... If not provided, set to default '**if_**' with ids 1 in check().

Type pd.Series, optional

geometry
geometry of type Point of each instance. Computed in method set_geometry_points().

Type pd.Series, optional

meta
dictionary containing corresponding raster properties (if any): width, height, crs and transform must be present at least (transform needs to contain upper left corner!). Exposures might not contain all the points of the corresponding raster.

Type dict

deductible
deductible value for each exposure

Type pd.Series, optional

cover
cover value for each exposure

Type pd.Series, optional

category_id
category id for each exposure

Type pd.Series, optional

region_id
region id for each exposure

Type pd.Series, optional

centr_
e.g. centr_TC. centroids index for hazard TC. There might be different hazards defined: centr_TC, centr_FL, ... Computed in method assign_centroids().

Type pd.Series, optional

vars_oblig = ['value', 'latitude', 'longitude']
Name of the variables needed to compute the impact.

vars_def = ['if_']
Name of variables that can be computed.

vars_opt = ['centr_', 'deductible', 'cover', 'category_id', 'region_id', 'geometry']
Name of the variables that aren't need to compute the impact.

__init__ (**args*, ***kwargs*)
Initialize. Copy attributes of input DataFrame.

check()
Check which variables are present

assign_centroids (*hazard*, *method='NN'*, *distance='haversine'*, *threshold=100*)
Assign for each exposure coordinate closest hazard coordinate. -1 used for disatances > threshold in point distances. If raster hazard, -1 used for centroids outside raster.

Parameters

- **hazard** (*Hazard*) – hazard to match (with raster or vector centroids)
- **method** (*str, optional*) – interpolation method to use in vector hazard. Nearest neighbor (NN) default
- **distance** (*str, optional*) – distance to use in vector hazard. Haversine default
- **threshold** (*float*) – distance threshold in km over which no neighbor will be found in vector hazard. Those are assigned with a -1. Default 100 km.

set_geometry_points (*scheduler=None*)
Set geometry attribute of GeoDataFrame with Points from latitude and longitude attributes.

Parameter:

scheduler (str): used for dask map_partitions. "threads", "synchronous" or "processes"

set_lat_lon()
Set latitude and longitude attributes from geometry attribute.

set_from_raster (*file_name*, *band=1*, *src_crs=None*, *window=False*, *geometry=False*, *dst_crs=False*, *transform=None*, *width=None*, *height=None*, *resampling=<Resampling.nearest: 0>*)
Read raster data and set latitude, longitude, value and meta

Parameters

- **file_name** (*str*) – file name containing values
- **band** (*int, optional*) – bands to read (starting at 1)
- **src_crs** (*crs, optional*) – source CRS. Provide it if error without it.
- **window** (*rasterio.windows.Windows, optional*) – window where data is extracted
- **geometry** (*shapely.geometry, optional*) – consider pixels only in shape
- **dst_crs** (*crs, optional*) – reproject to given crs
- **transform** (*rasterio.Affine*) – affine transformation to apply
- **wdith** (*float*) – number of lons for transform
- **height** (*float*) – number of lats for transform
- **resampling** (*rasterio.warp,.Resampling optional*) – resampling function used for reprojection to dst_crs

plot_scatter (*mask=None*, *ignore_zero=False*, *pop_name=True*, *buffer=0.0*, *extend='neither'*, ***kwargs*)
Plot exposures geometry's value sum scattered over Earth's map. The plot will we projected according to the current crs.

Parameters

- **mask (*np.array, optional*) – mask to apply to eai_exp plotted.**
  - **ignore_zero** (*bool, optional*) – flag to indicate if zero and negative values are ignored in plot. Default: False
  - **pop_name** (*bool, optional*) – add names of the populated places
  - **buffer** (*float, optional*) – border to add to coordinates. Default: 0.0.
  - **extend** (*str, optional*) – extend border colorbar with arrows. ['neither' | 'both' | 'min' | 'max']
  - **kwargs** (*optional*) – arguments for scatter matplotlib function, e.g. cmap='Greys'. Default: 'Wistia'

Returns: matplotlib.figure.Figure, cartopy.mpl.geoaxes.GeoAxesSubplot

plot_hexbin(*mask=None*, *ignore_zero=False*, *pop_name=True*, *buffer=0.0*, *extend='neither'*, ***kwargs*)

Plot exposures geometry's value sum binned over Earth's map. An other function for the bins can be set through the key reduce_C_function. The plot will we projected according to the current crs.

Parameters

- **mask (*np.array, optional*) – mask to apply to eai_exp plotted.**
  - **ignore_zero** (*bool, optional*) – flag to indicate if zero and negative values are ignored in plot. Default: False
  - **pop_name** (*bool, optional*) – add names of the populated places
  - **buffer** (*float, optional*) – border to add to coordinates. Default: 0.0.
  - **extend** (*str, optional*) – extend border colorbar with arrows. ['neither' | 'both' | 'min' | 'max']
  - **kwargs** (*optional*) – arguments for hexbin matplotlib function, e.g. reduce_C_function=np.average. Default: reduce_C_function=np.sum

Returns: matplotlib.figure.Figure, cartopy.mpl.geoaxes.GeoAxesSubplot

plot_raster(*res=None*, *raster_res=None*, *save_tiff=None*, *raster_f=<function Exposures.<lambda>>*, *label='value (log10)'*, ***kwargs*)

Generate raster from points geometry and plot it using log10 scale: np.log10((np.fmax(raster+1, 1))).

Parameters

- **res (*float, optional*) – resolution of current data in units of latitude**

  and longitude, approximated if not provided.
  - **raster_res** (*float, optional*) – desired resolution of the raster
  - **save_tiff** (*str, optional*) – file name to save the raster in tiff format, if provided
  - **raster_f** (*lambda function*) – transformation to use to data. Default: log10 adding 1.
  - **label** (*str*) – colorbar label
  - **kwargs** (*optional*) – arguments for imshow matplotlib function

Returns: matplotlib.figure.Figure, cartopy.mpl.geoaxes.GeoAxesSubplot

plot_basemap(*mask=None*, *ignore_zero=False*, *pop_name=True*, *buffer=0.0*, *extend='neither'*, *zoom=10*, *url='http://tile.stamen.com/terrain/tileZ/tileX/tileY.png'*, ***kwargs*)
Scatter points over satellite image using contextily

Parameters

- **mask** (*np.array, optional*) – mask to apply to eai_exp plotted.
- **ignore_zero** (*bool, optional*) – flag to indicate if zero and negative values are ignored in plot. Default: False
- **pop_name** (*bool, optional*) – add names of the populated places
- **buffer** (*float, optional*) – border to add to coordinates. Default: 0.0.
- **extend** (*str, optional*) – extend border colorbar with arrows. ['neither' | 'both' | 'min' | 'max']
- **zoom** (*int, optional*) – zoom coefficient used in the satellite image
- **url** (*str, optional*) – image source, e.g. ctx.sources.OSM_C
- **kwargs** (*optional*) – arguments for scatter matplotlib function, e.g. cmap='Greys'. Default: 'Wistia'

Returns matplotlib.figure.Figure, cartopy.mpl.geoaxes.GeoAxesSubplot

write_hdf5(*file_name*)
Write data frame and metadata in hdf5 format

read_hdf5(*file_name*)
Read data frame and metadata in hdf5 format

read_mat(*file_name*, *var_names={'field_name': 'assets', 'sup_field_name': 'entity', 'var_name': {'ass': 'centroid_index', 'cat': 'Category_ID', 'cov': 'Cover', 'ded': 'Deductible', 'imp': 'DamageFunID', 'lat': 'lat', 'lon': 'lon', 'ref': 'reference_year', 'reg': 'Region_ID', 'uni': 'Value_unit', 'val': 'Value'}}*)
Read MATLAB file and store variables in exposures.

Parameters

- **file_name** (*str*) – absolute path file
- **var_names** (*dict, optional*) – dictionary containing the name of the MATLAB variables. Default: DEF_VAR_MAT.

to_crs(*crs=None*, *epsg=None*, *inplace=False*)
Transform geometries to a new coordinate reference system.

Transform all geometries in a GeoSeries to a different coordinate reference system. The `crs` attribute on the current GeoSeries must be set. Either `crs` in string or dictionary form or an EPSG code may be specified for output.

This method will transform all points in all objects. It has no notion or projecting entire geometries. All segments joining points are assumed to be lines in the current projection, not geodesics. Objects crossing the dateline (or other projection boundary) will have undesirable behavior.

Parameters

- **crs** (*dict or str*) – Output projection parameters as string or in dictionary form.
- **epsg** (*int*) – EPSG code specifying output projection.
- **inplace** (*bool, optional, default: False*) – Whether to return a new GeoDataFrame or do the transformation in place.

copy (*deep=True*)
Make a copy of this Exposures object.

Parameters **deep (bool)** (*Make a deep copy, i.e. also copy data. Default True.*)

Returns

Return type *Exposures*

write_raster (*file_name*)
Write value data into raster file with GeoTiff format

Parameters **file_name** (*str*) – name output file in tif format

climada.entity.exposures.base.**add_sea** (*exposures*, *sea_res*)
Add sea to geometry's surroundings with given resolution. region_id set to -1 and other variables to 0.

Parameters **sea_res** (*tuple*) – (sea_coast_km, sea_res_km), where first parameter is distance from coast to fill with water and second parameter is resolution between sea points

Returns Exposures

climada.entity.exposures.black_marble module

class climada.entity.exposures.black_marble.**BlackMarble** (**args*, ***kwargs*)
Bases: *climada.entity.exposures.base.Exposures*

Defines exposures from night light intensity, GDP and income group. Attribute region_id is defined as: - United Nations Statistics Division (UNSD) 3-digit equivalent numeric code - 0 if country not found in UNSD. - -1 for water

set_countries (*countries*, *ref_year=2016*, *res_km=None*, *from_hr=None*, ***kwargs*)
Model countries using values at reference year. If GDP or income group not available for that year, consider the value of the closest available year.

Parameters

- **countries** (*list or dict*) – list of country names (admin0) or dict with key = admin0 name and value = [admin1 names]
- **ref_year** (*int, optional*) – reference year. Default: 2016
- **res_km** (*float, optional*) – approx resolution in km. Default: nightlights resolution.
- **from_hr** (*bool, optional*) – force to use higher resolution image, independently of its year of acquisition.
- **kwargs** (*optional*) – 'gdp' and 'inc_grp' dictionaries with keys the country ISO_alpha3 code. 'poly_val' polynomial transformation [1,x,x^2,...] to apply to nightlight (DEF_POLY_VAL used if not provided). If provided, these are used.

climada.entity.exposures.litpop module

climada.entity.exposures.litpop.**LOGGER = <Logger climada.entity.exposures.litpop (DEBUG)>**
Define LitPop class.

climada.entity.exposures.litpop.**BM_FILENAMES = ['BlackMarble_%i_A1_geo_gray.tif', 'BlackMa**

climada.entity.exposures.litpop.**BM_YEARS = [2016, 2012]**

climada.entity.exposures.litpop.**GPW_YEARS = [2020, 2015, 2010, 2005, 2000]**

climada.entity.exposures.litpop.**NASA_RESOLUTION_DEG = 0.004166666666666667**

climada.entity.exposures.litpop.**WORLD_BANK_INC_GRP = 'http://databank.worldbank.org/data/d**
Income group historical data from World bank.

climada.entity.exposures.litpop.**DEF_RES_NASA_KM = 0.5**
Default approximate resolution for NASA's nightlights in km.

climada.entity.exposures.litpop.**DEF_RES_GPW_KM = 1**
Default approximate resolution for the GPW dataset in km.

climada.entity.exposures.litpop.**DEF_RES_NASA_ARCSEC = 15**
Default approximate resolution for NASA's nightlights in arcsec.

climada.entity.exposures.litpop.**DEF_RES_GPW_ARCSEC = 30**
Default approximate resolution for the GPW dataset in arcsec.

climada.entity.exposures.litpop.**DEF_HAZ_TYPE = ''**
Default hazard type used in impact functions id, i.e. TC

class climada.entity.exposures.litpop.**LitPop**(**args*, ***kwargs*)
Bases: *climada.entity.exposures.base.Exposures*

Defines exposures from nightlight intensity (NASA), Gridded Population data (SEDAC), GDP (World Bank) and a conversion factor to calculate asset value from GDP derived from the Global Wealth Databook by the Credit Suisse Research Institute. Calling sequence example: ent = LitPop() country_name = ['Switzerland', 'Austria'] ent.set_country(country_name) ent.plot()

clear()
Appending the base class clear attribute to also delete attributes which are only used here.

set_country(*countries*, ***args*)
Get LitPop based exposre for one country or multiple countries using values at reference year. If GDP or income group not available for that year, consider the value of the closest available year.

Parameters **countries** (*str or list*) – list of countries or single county as a sting. Countries can either be country names ('France') or country codes ('FRA'), even a mix is possible in the list.

args: Keyword arguments. The following keywords are recognised: res_km (float, optional): approx resolution in km. Default: 1km. res_arcsec (float, optional): resolution in arc-sec. Overrides

res_km if both are delivered

check_plot (boolean, optional): choose if a plot is shown at the end of the operation.

exponents (list of two integers, default = [1, 1]) defining power with which lit (nightlights) and pop (gpw) go into LitPop. To get nightlights^3 alone: [3, 0]. To use population count alone: [0, 1].

fin_mode (str, optional): define what total country economic value is to be used as an asset base and distributed to the grid: - 'gdp': gross-domestic product (Source: World Bank) - 'income_group': gdp multiplied by country's income group+1 - 'nfw': non-financial wealth (Source: Credit Suisse, of households only) - 'tw': total wealth (Source: Credit Suisse, of households only) - 'pc': produced capital (Source: World Bank), incl. manufactured or

built assets such as machinery, equipment, and physical structures (pc is in constant 2014 USD)

- 'norm': normalized by country
- 'none': LitPop per pixel is returned unchanged

admin1_calc (boolean): distribute admin1-level GDP if available? (default False)

conserve_cntrytotal (boolean): given admin1_calc, conserve national total asset value (default True) reference_year (int) adm1_scatter (boolean): produce scatter plot for admin1 validation?

plot_log(*admin1_plot=1*)

Plots the LitPop data with the color scale reprenting the values in a logarithmic scale.

Parameters **admin1_plot** (*boolean*) – whether admin1 borders should be plotted. Default=1

climada.entity.exposures.litpop.**read_bm_file**(*bm_path*, *filename*)

Reads a single NASA BlackMarble GeoTiff and returns the data. Run all required checks first.

Parameters

- **bm_path** (*str*) – absolute path where files are stored.
- **filename** (*str*) – filename of the file to be read.

Returns

Raw BM data curr_file (gdal GeoTiff File): Additional info from which

coordinates can be calculated.

Return type arr1 (array)

climada.entity.exposures.litpop.**get_bm**(*required_files=array([1., 1., 1., 1., 1., 1., 1., 1.])*, ***parameters*)

Potential TODO: put cutting before zooming (faster), but with expanding bbox in order to preserve additional pixels for interpolation...

climada.entity.exposures.litpop.**admin1_validation**(*country*, *methods*, *exponents*, ***args*)

Get LitPop based exposre for one country or multiple countries using values at reference year. If GDP or income group not available for that year, consider the value of the closest available year.

Parameters

- **country** (*str*) – list of countries or single county as a string. Countries can either be country names ('France') or country codes ('FRA'), even a mix is possible in the list.
- **methods_name** (*list of str*) –
  - ['LitPop' for LitPop,
  - ['Lit', 'Pop'] for Lit and Pop,
  - ['Lit3'] for cube of night lights (Lit3)
- **exponents** (*list of 2-vectors*) –
  - [[1, 1]] for LitPop,
  - [[1, 0], [0, 1]] for Lit and Pop,
  - [[3, 0]] for cube of night lights (Lit3)

args: Keyword arguments. The following keywords are recognised: res_km (float, optional): approx resolution in km. Default: 1km. res_arcsec (float, optional): resolution in arc-sec. Overrides

res_km if both are delivered

check_plot (boolean, optional): choose if a plot is shown at the end of the operation.

climada.entity.exposures.litpop.**exposure_set_admin1**(*exposure*)
add admin1 ID and name to exposure dataframe

Parameters **exposure** – exposure instance

Returns exposure instance with 2 extra columns: admin1 & admin1_ID

Return type exposure

climada.entity.impact_funcs package

climada.entity.impact_funcs.base module

class climada.entity.impact_funcs.base.**ImpactFunc**
Bases: object

Contains the definition of one impact function.

haz_type
hazard type acronym (e.g. 'TC')

Type str

id
id of the impact function. Exposures of the same type will refer to the same impact function id

Type int or str

name
name of the ImpactFunc

Type str

intensity_unit
unit of the intensity

Type str

intensity
intensity values

Type np.array

mdd
mean damage (impact) degree for each intensity (numbers in [0,1])

Type np.array

paa
percentage of affected assets (exposures) for each intensity (numbers in [0,1])

Type np.array

__init__()
Empty initialization.

calc_mdr(*inten*)
Interpolate impact function to a given intensity.

Parameters **inten** (*float or np.array*) – intensity, the x-coordinate of the interpolated values.

Returns np.array

plot (*graph=None*)
Plot the impact functions MDD, MDR and PAA in one graph, where MDR = PAA * MDD.

Parameters

- **graph** (*Graph2D, optional*) – graph where to add the plots
- **show** (*bool, optional*) – bool to execute plt.show(). Default: True

Returns matplotlib.figure.Figure, [matplotlib.axes._subplots.AxesSubplot]

check()
Check consistent instance data.

Raises **ValueError** –

climada.entity.impact_funcs.impact_func_set module

class climada.entity.impact_funcs.impact_func_set.**ImpactFuncSet**
Bases: object

Contains impact functions of type ImpactFunc. Loads from files with format defined in FILE_EXT.

tag
information about the source data

Type *Tag*

_data
contains ImpactFunc classes. It's not suppossed to be directly accessed. Use the class methods instead.

Type dict

__init__()
Empty initialization.

Examples

Fill impact functions with values and check consistency data:

```
>>> fun_1 = ImpactFunc()
>>> fun_1.haz_type = 'TC'
>>> fun_1.id = 3
>>> fun_1.intensity = np.array([0, 20])
>>> fun_1.paa = np.array([0, 1])
>>> fun_1.mdd = np.array([0, 0.5])
>>> imp_fun = ImpactFuncSet()
>>> imp_fun.append(fun_1)
>>> imp_fun.check()
```

Read impact functions from file and checks consistency data.

```
>>> imp_fun = ImpactFuncSet()
>>> imp_fun.read(ENT_TEMPLATE_XLS)
```

clear()
Reinitialize attributes.

append(*func*)
Append a ImpactFunc. Overwrite existing if same id and haz_type.

Parameters **func** (*ImpactFunc*) – ImpactFunc instance

Raises **ValueError** –

remove_func(*haz_type=None*, *fun_id=None*)
Remove impact function(s) with provided hazard type and/or id. If no input provided, all impact functions are removed.

Parameters

- **haz_type** (*str, optional*) – all impact functions with this hazard
- **fun_id** (*int, optional*) – all impact functions with this id

get_func(*haz_type=None*, *fun_id=None*)
Get ImpactFunc(s) of input hazard type and/or id. If no input provided, all impact functions are returned.

Parameters

- **haz_type** (*str, optional*) – hazard type
- **fun_id** (*int, optional*) – ImpactFunc id

Returns ImpactFunc (if haz_type and fun_id), list(ImpactFunc) (if haz_type or fun_id), {ImpactFunc.haz_type: {ImpactFunc.id : ImpactFunc}} (if None)

get_hazard_types(*fun_id=None*)
Get impact functions hazard types contained for the id provided. Return all hazard types if no input id.

Parameters **fun_id** (*int, optional*) – id of an impact function

Returns list(str)

get_ids(*haz_type=None*)
Get impact functions ids contained for the hazard type provided. Return all ids for each hazard type if no input hazard type.

Parameters **haz_type** (*str, optional*) – hazard type from which to obtain the ids

Returns list(ImpactFunc.id) (if haz_type provided), {ImpactFunc.haz_type : list(ImpactFunc.id)} (if no haz_type)

size(*haz_type=None*, *fun_id=None*)
Get number of impact functions contained with input hazard type and /or id. If no input provided, get total number of impact functions.

Parameters

- **haz_type** (*str, optional*) – hazard type
- **fun_id** (*int, optional*) – ImpactFunc id

Returns int

check()
Check instance attributes.

Raises **ValueError** –

extend(*impact_funcs*)
Append impact functions of input ImpactFuncSet to current ImpactFuncSet. Overwrite ImpactFunc if same id and haz_type.

Parameters **impact_funcs** (*ImpactFuncSet*) – ImpactFuncSet instance to extend

Raises **ValueError** –

plot (*haz_type=None*, *fun_id=None*)
Plot impact functions of selected hazard (all if not provided) and selected function id (all if not provided).

Parameters

- **haz_type** (*str, optional*) – hazard type
- **fun_id** (*int, optional*) – id of the function

Returns matplotlib.figure.Figure, [matplotlib.axes._subplots.AxesSubplot]

read_excel (*file_name*, *description=''*, *var_names={'col_name': {'func_id': 'impact_fun_id', 'inten': 'intensity', 'mdd': 'mdd', 'name': 'name', 'paa': 'paa', 'peril': 'peril_id', 'unit': 'intensity_unit'}, 'sheet_name': 'impact_functions'}*)
Read excel file following template and store variables.

Parameters

- **file_name** (*str*) – absolute file name
- **description** (*str, optional*) – description of the data
- **var_names** (*dict, optional*) – name of the variables in the file

read_mat (*file_name*, *description=''*, *var_names={'field_name': 'damagefunctions', 'sup_field_name': 'entity', 'var_name': {'fun_id': 'DamageFunID', 'inten': 'Intensity', 'mdd': 'MDD', 'name': 'name', 'paa': 'PAA', 'peril': 'peril_ID', 'unit': 'Intensity_unit'}}*)
Read MATLAB file generated with previous MATLAB CLIMADA version.

Parameters

- **file_name** (*str*) – absolute file name
- **description** (*str, optional*) – description of the data
- **var_names** (*dict, optional*) – name of the variables in the file

write_excel (*file_name*, *var_names={'col_name': {'func_id': 'impact_fun_id', 'inten': 'intensity', 'mdd': 'mdd', 'name': 'name', 'paa': 'paa', 'peril': 'peril_id', 'unit': 'intensity_unit'}, 'sheet_name': 'impact_functions'}*)
Write excel file following template.

Parameters

- **file_name** (*str*) – absolute file name to write
- **var_names** (*dict, optional*) – name of the variables in the file

climada.entity.impact_funcs.trop_cyclone module

class climada.entity.impact_funcs.trop_cyclone.**IFTropCyclone**
Bases: *climada.entity.impact_funcs.base.ImpactFunc*

Impact functions for tropical cyclones.

__init__ ()
Empty initialization.

set_emanuel_usa (*if_id=1*, *intensity=array([0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 105, 110, 115, 120])*, *v_thresh=25.7*, *v_half=74.7*, *scale=1.0*)
Using the formula of Emanuele 2011.

Parameters

- **if_id** (*int, optional*) – impact function id. Default: 1
- **intensity** (*np.array, optional*) – intensity array in m/s. Default: 5 m/s step array from 0 to 120m/s
- **v_thresh** (*float, optional*) – first shape parameter, wind speed in m/s below which there is no damage. Default: 25.7(Emanuel 2011)
- **v_half** (*float, optional*) – second shape parameter, wind speed in m/s at which 50% of max. damage is expected. Default: v_threshold + 49 m/s (mean value of Sealy & Strobl 2017)
- **scale** (*float, optional*) – scale parameter, linear scaling of MDD. 0<=scale<=1. Default: 1.0

Raises **ValueError** –

climada.entity.measures package

climada.entity.measures.base module

class climada.entity.measures.base.**Measure**

Bases: object

Contains the definition of one measure.

name
name of the action

Type str

haz_type
related hazard type (peril), e.g. TC

Type str

color_rgb
integer array of size 3. Gives color code of this measure in RGB

Type np.array

cost
discounted cost (in same units as assets)

Type float

hazard_set
file name of hazard to use (in h5 format)

Type str

hazard_freq_cutoff
hazard frequency cutoff

Type float

exposure_set
file name of exposure to use (in h5 format)

Type str

imp_fun_map
change of impact function id of exposures, e.g. '1to3'

Type str

hazard_inten_imp
parameter a and b of hazard intensity change

Type tuple

mdd_impact
parameter a and b of the impact over the mean damage degree

Type tuple

paa_impact
parameter a and b of the impact over the percentage of affected assets

Type tuple

exp_region_id
region id of the selected exposures to consider ALL the previous parameters

Type int

risk_transf_attach
risk transfer attachment

Type float

risk_transf_cover
risk transfer cover

Type float

__init__()
Empty initialization.

check()
Check consistent instance data.

Raises **ValueError** –

calc_impact(*exposures*, *imp_fun_set*, *hazard*)
Apply measure and compute impact and risk transfer of measure implemented over inputs.

Parameters

- **exposures** (*Exposures*) – exposures instance
- **imp_fun_set** (*ImpactFuncSet*) – impact functions instance
- **hazard** (*Hazard*) – hazard instance

Returns Impact, float

apply(*exposures*, *imp_fun_set*, *hazard*)
Implement measure with all its defined parameters.

Parameters

- **exposures** (*Exposures*) – exposures instance
- **imp_fun_set** (*ImpactFuncSet*) – impact functions instance
- **hazard** (*Hazard*) – hazard instance

Returns Exposures, ImpactFuncSet, Hazard

climada.entity.measures.measure_set module

class climada.entity.measures.measure_set.**MeasureSet**
Bases: object

Contains measures of type Measure. Loads from files with format defined in FILE_EXT.

tag
information about the source data

Type *Tag*

_data
cotains Measure classes. It's not suppossed to be directly accessed. Use the class methods instead.

Type dict

__init__()
Empty initialization.

Examples

Fill MeasureSet with values and check consistency data:

```
>>> act_1 = Measure()
>>> act_1.name = 'Seawall'
>>> act_1.color_rgb = np.array([0.1529, 0.2510, 0.5451])
>>> act_1.hazard_intensity = (1, 0)
>>> act_1.mdd_impact = (1, 0)
>>> act_1.paa_impact = (1, 0)
>>> meas = MeasureSet()
>>> meas.append(act_1)
>>> meas.tag.description = "my dummy MeasureSet."
>>> meas.check()
```

Read measures from file and checks consistency data:

```
>>> meas = MeasureSet()
>>> meas.read_excel(ENT_TEMPLATE_XLS)
```

clear()
Reinitialize attributes.

append(*meas*)
Append an Measure. Override if same name and haz_type.

Parameters **meas** (*Measure*) – Measure instance

Raises **ValueError** –

remove_measure(*haz_type=None*, *name=None*)
Remove impact function(s) with provided hazard type and/or id. If no input provided, all impact functions are removed.

Parameters

- **haz_type** (*str, optional*) – all impact functions with this hazard
- **name** (*str, optional*) – measure name

get_measure(*haz_type=None*, *name=None*)
Get ImpactFunc(s) of input hazard type and/or id. If no input provided, all impact functions are returned.

Parameters

- **haz_type** (*str, optional*) – hazard type
- **name** (*str, optional*) – measure name

Returns Measure (if haz_type and name), list(Measure) (if haz_type or name), {Measure.haz_type: {Measure.name : Measure}} (if None)

get_hazard_types(*meas=None*)
Get measures hazard types contained for the name provided. Return all hazard types if no input name.

Parameters **name** (*str, optional*) – measure name

Returns list(str)

get_names(*haz_type=None*)
Get measures names contained for the hazard type provided. Return all names for each hazard type if no input hazard type.

Parameters **haz_type** (*str, optional*) – hazard type from which to obtain the names

Returns list(Measure.name) (if haz_type provided), {Measure.haz_type : list(Measure.name)} (if no haz_type)

size(*haz_type=None*, *name=None*)
Get number of measures contained with input hazard type and /or id. If no input provided, get total number of impact functions.

Parameters

- **haz_type** (*str, optional*) – hazard type
- **name** (*str, optional*) – measure name

Returns int

check()
Check instance attributes.

Raises **ValueError** –

extend(*meas_set*)
Extend measures of input MeasureSet to current MeasureSet. Overwrite Measure if same name and haz_type.

Parameters **impact_funcs** (*MeasureSet*) – ImpactFuncSet instance to extend

Raises **ValueError** –

read_mat(*file_name*, *description=''*, *var_names={'field_name': 'measures', 'sup_field_name': 'entity', 'var_name': {'color': 'color', 'cost': 'cost', 'exp_reg': 'Region_ID', 'exp_set': 'assets_file', 'fun_map': 'damagefunctions_map', 'haz': 'peril_ID', 'haz_frq': 'hazard_high_frequency_cutoff', 'haz_int_a': 'hazard_intensity_impact_a', 'haz_int_b': 'hazard_intensity_impact_b', 'haz_set': 'hazard_event_set', 'mdd_a': 'MDD_impact_a', 'mdd_b': 'MDD_impact_b', 'name': 'name', 'paa_a': 'PAA_impact_a', 'paa_b': 'PAA_impact_b', 'risk_att': 'risk_transfer_attachement', 'risk_cov': 'risk_transfer_cover'}}*)
Read MATLAB file generated with previous MATLAB CLIMADA version.

Parameters

- **file_name** (*str*) – absolute file name

- **description** (*str, optional*) – description of the data
- **var_names** (*dict, optional*) – name of the variables in the file

read_excel (*file_name*, *description=''*, *var_names={'col_name': {'color': 'color', 'cost': 'cost', 'exp_reg': 'Region_ID', 'exp_set': 'assets file', 'fun_map': 'damagefunctions map', 'haz': 'peril_ID', 'haz_frq': 'hazard high frequency cutoff', 'haz_int_a': 'hazard intensity impact a', 'haz_int_b': 'hazard intensity impact b', 'haz_set': 'hazard event set', 'mdd_a': 'MDD impact a', 'mdd_b': 'MDD impact b', 'name': 'name', 'paa_a': 'PAA impact a', 'paa_b': 'PAA impact b', 'risk_att': 'risk transfer attachement', 'risk_cov': 'risk transfer cover'}, 'sheet_name': 'measures'}*)

Read excel file following template and store variables.

Parameters

- **file_name** (*str*) – absolute file name
- **description** (*str, optional*) – description of the data
- **var_names** (*dict, optional*) – name of the variables in the file

write_excel (*file_name*, *var_names={'col_name': {'color': 'color', 'cost': 'cost', 'exp_reg': 'Region_ID', 'exp_set': 'assets file', 'fun_map': 'damagefunctions map', 'haz': 'peril_ID', 'haz_frq': 'hazard high frequency cutoff', 'haz_int_a': 'hazard intensity impact a', 'haz_int_b': 'hazard intensity impact b', 'haz_set': 'hazard event set', 'mdd_a': 'MDD impact a', 'mdd_b': 'MDD impact b', 'name': 'name', 'paa_a': 'PAA impact a', 'paa_b': 'PAA impact b', 'risk_att': 'risk transfer attachement', 'risk_cov': 'risk transfer cover'}, 'sheet_name': 'measures'}*)

Write excel file following template.

Parameters

- **file_name** (*str*) – absolute file name to write
- **var_names** (*dict, optional*) – name of the variables in the file

climada.entity.entity_def module

class climada.entity.entity_def.**Entity**

Bases: object

Collects exposures, impact functions, measures and discount rates. Default values set when empty constructor.

exposures

exposures

Type *Exposures*

impact_funcs

impact functions

Type ImpactFucs

measures

measures

Type *MeasureSet*

disc_rates

discount rates

Type *DiscRates*

def_file
Default file from configuration file

Type str

__init__()
Empty initializator

read_mat(*file_name*, *description=''*)
Read MATLAB file of climada.

Parameters

- **file_name** (*str, optional*) – file name(s) or folder name containing the files to read
- **description** (*str or list(str), optional*) – one description of the data or a description of each data file

Raises **ValueError** –

read_excel(*file_name*, *description=''*)
Read csv or xls or xlsx file following climada's template.

Parameters

- **file_name** (*str, optional*) – file name(s) or folder name containing the files to read
- **description** (*str or list(str), optional*) – one description of the data or a description of each data file

Raises **ValueError** –

write_excel(*file_name*)
Write excel file following template.

check()
Check instance attributes.

Raises **ValueError** –

climada.entity.tag module

class climada.entity.tag.**Tag**(*file_name=''*, *description=''*)
Bases: object

Source data tag for Exposures, DiscRates, ImpactFuncSet, MeasureSet.

file_name
name of the source file

Type str

description
description of the data

Type str

__init__(*file_name=''*, *description=''*)
Initialize values.

Parameters

- **file_name** (*str, optional*) – file name to read
- **description** (*str, optional*) – description of the data

append(*tag*)
Append input Tag instance information to current Tag.

7.1.3 climada.hazard package

climada.hazard.centroids package

climada.hazard.centroids.base module

climada.hazard.centroids.source module

climada.hazard.centroids.tag module

climada.hazard.base module

class climada.hazard.base.**Hazard**(*haz_type*, *pool=None*)
Bases: object

Contains events of some hazard type defined at centroids. Loads from files with format defined in FILE_EXT.

tag
information about the source

Type TagHazard

units
units of the intensity

Type str

centroids
centroids of the events

Type Centroids

event_id
id (>0) of each event

Type np.array

event_name
name of each event (default: event_id)

Type list(str)

date
integer date corresponding to the proleptic Gregorian ordinal, where January 1 of year 1 has ordinal 1 (ordinal format of datetime library)

Type np.array

orig
flags indicating historical events (True) or probabilistic (False)

Type np.array

frequency
frequency of each event in years

Type np.array

intensity
intensity of the events at centroids

Type sparse.csr_matrix

fraction
fraction of affected exposures for each event at each centroid

Type sparse.csr_matrix

intensity_thres = 10
Intensity threshold per hazard used to filter lower intensities. To be set for every hazard type

vars_oblig = {'centroids', 'event_id', 'fraction', 'frequency', 'intensity', 'tag', 'u
scalar, str, list, 1dim np.array of size num_events, scipy.sparse matrix of shape num_events x num_centroids, Centroids and Tag.

Type Name of the variables needed to compute the impact. Types

vars_def = {'date', 'event_name', 'orig'}
Name of the variables used in impact calculation whose value is descriptive and can therefore be set with default values. Types: scalar, string, list, 1dim np.array of size num_events.

vars_opt = {}
Name of the variables that aren't need to compute the impact. Types: scalar, string, list, 1dim np.array of size num_events.

__init__ (*haz_type*, *pool=None*)
Initialize values.

Parameters **haz_type** (*str, optional*) – acronym of the hazard type (e.g. 'TC').

Examples

Fill hazard values by hand:

```
>>> haz = Hazard('TC')
>>> haz.intensity = sparse.csr_matrix(np.zeros((2, 2)))
>>> ...
```

Take hazard values from file:

```
>>> haz = Hazard('TC', HAZ_DEMO_MAT)
>>> haz.read_mat(HAZ_DEMO_MAT, 'demo')
```

clear()
Reinitialize attributes.

check()
Check dimension of attributes.

Raises **ValueError** –

set_raster (*files_intensity, files_fraction=None, attrs={}, band=[1], src_crs=None, window=False, geometry=False, dst_crs=False, transform=None, width=None, height=None, resampling=<Resampling.nearest: 0>*)
Append intensity and fraction from raster file. 0s put to the masked values. File can be partially read using window OR geometry. Alternatively, CRS and/or transformation can be set using dst_crs and/or (transform, width and height).

Parameters

- **files_intensity** (*list(str)*) – file names containing intensity
- **files_fraction** (*list(str)*) – file names containing fraction
- **attrs** (*dict, optional*) – name of Hazard attributes and their values
- **band** (*list(int), optional*) – bands to read (starting at 1)
- **src_crs** (*crs, optional*) – source CRS. Provide it if error without it.
- **window** (*rasterio.windows.Windows, optional*) – window where data is extracted
- **geometry** (*shapely.geometry, optional*) – consider pixels only in shape
- **dst_crs** (*crs, optional*) – reproject to given crs
- **transform** (*rasterio.Affine*) – affine transformation to apply
- **wdith** (*float*) – number of lons for transform
- **height** (*float*) – number of lats for transform
- **resampling** (*rasterio.warp,.Resampling optional*) – resampling function used for reprojection to dst_crs

set_vector(*files_intensity, files_fraction=None, attrs={}, inten_name=['intensity'], frac_name=['fraction'], dst_crs=None*)

Read vector files format supported by fiona. Each intensity name is considered an event.

Parameters

- **files_intensity** (*list(str)*) – file names containing intensity
- **files_fraction** (*list(str)*) – file names containing fraction
- **attrs** (*dict, optional*) – name of Hazard attributes and their values
- **inten_name** (*list(str), optional*) – name of variables containing the intensities of each event
- **frac_name** (*list(str), optional*) – name of variables containing the fractions of each event
- **dst_crs** (*crs, optional*) – reproject to given crs

to_raster(*dst_crs=False, transform=None, width=None, height=None, resampling=<Resampling.nearest: 0>*)

Change current geometry or raster to given raster

to_vector(*geometry*)

Change current raster or geometry to given geometry

read_mat(*file_name, description='', var_names={'field_name': 'hazard', 'var_cent': {'field_names': ['centroids', 'hazard'], 'var_name': {'cen_id': 'centroid_ID', 'lat': 'lat', 'lon': 'lon'}}, 'var_name': {'comment': 'comment', 'datenum': 'datenum', 'ev_name': 'name', 'even_id': 'event_ID', 'frac': 'fraction', 'freq': 'frequency', 'inten': 'intensity', 'orig': 'orig_event_flag', 'per_id': 'peril_ID', 'unit': 'units'}}*)

Read climada hazard generate with the MATLAB code.

Parameters

- **file_name** (*str*) – absolute file name
- **description** (*str, optional*) – description of the data
- **var_names** (*dict, default*) – name of the variables in the file, default: DEF_VAR_MAT constant

Raises **KeyError** –

read_excel (*file_name*, *description=''*, *var_names={'col_centroids': {'col_name': {'cen_id': 'centroid_id', 'lat': 'latitude', 'lon': 'longitude'}, 'sheet_name': 'centroids'}, 'col_name': {'cen_id': 'centroid_id/event_id', 'even_dt': 'event_date', 'even_id': 'event_id', 'even_name': 'event_name', 'freq': 'frequency', 'orig': 'orig_event_flag'}, 'sheet_name': {'freq': 'hazard_frequency', 'inten': 'hazard_intensity'}}*)

Read climada hazard generate with the MATLAB code.

Parameters

- **file_name** (*str*) – absolute file name
- **description** (*str, optional*) – description of the data
- **centroids** (*Centroids, optional*) – provide centroids if not contained in the file
- **var_names** (*dict, default*) – name of the variables in the file, default: DEF_VAR_EXCEL constant

Raises **KeyError** –

select (*date=None*, *orig=None*, *reg_id=None*)

Select events within provided date and/or (historical or synthetical) and/or region. Frequency of the events may need to be recomputed!

Parameters

- **date** (*tuple(str or int), optional*) – (initial date, final date) in string ISO format ('2011-01-02') or datetime ordinal integer
- **orig** (*bool, optional*) – select only historical (True) or only synthetic (False)
- **reg_id** (*int, optional*) – region identifier of the centroids's region_id attibute

Returns Hazard or children

local_exceedance_inten (*return_periods=(25*, *50*, *100*, *250)*)

Compute exceedance intensity map for given return periods.

Parameters **return_periods** (*np.array*) – return periods to consider

Returns np.array

plot_rp_intensity (*return_periods=(25*, *50*, *100*, *250)*, ***kwargs*)

Compute and plot hazard exceedance intensity maps for different return periods. Calls local_exceedance_inten.

Parameters

- **return_periods** (*tuple(int), optional*) – return periods to consider
- **kwargs** (*optional*) – arguments for pcolormesh matplotlib function used in event plots

Returns matplotlib.figure.Figure, matplotlib.axes._subplots.AxesSubplot, np.ndarray (return_periods.size x num_centroids)

plot_raster (*ev_id=1*, *intensity=True*, ***kwargs*)

Plot selected event using imshow and without cartopy

Parameters

- **ev_id** (*int, optional*) – event id. Default: 1.
- **intensity** (*bool, optional*) – plot intensity if True, fraction otherwise
- **kwargs** (*optional*) – arguments for imshow matplotlib function

Returns matplotlib.image.AxesImage

plot_intensity(*event=None*, *centr=None*, ***kwargs*)
Plot intensity values for a selected event or centroid.

Parameters

- **event** (*int or str, optional*) – If event > 0, plot intensities of event with id = event. If event = 0, plot maximum intensity in each centroid. If event < 0, plot abs(event)-largest event. If event is string, plot events with that name.
- **centr** (*int or tuple, optional*) – If centr > 0, plot intensity of all events at centroid with id = centr. If centr = 0, plot maximum intensity of each event. If centr < 0, plot abs(centr)-largest centroid where higher intensities are reached. If tuple with (lat, lon) plot intensity of nearest centroid.
- **kwargs** (*optional*) – arguments for pcolormesh matplotlib function used in event plots

Returns matplotlib.figure.Figure, matplotlib.axes._subplots.AxesSubplot

Raises **ValueError** –

plot_fraction(*event=None*, *centr=None*, ***kwargs*)
Plot fraction values for a selected event or centroid.

Parameters

- **event** (*int or str, optional*) – If event > 0, plot fraction of event with id = event. If event = 0, plot maximum fraction in each centroid. If event < 0, plot abs(event)-largest event. If event is string, plot events with that name.
- **centr** (*int or tuple, optional*) – If centr > 0, plot fraction of all events at centroid with id = centr. If centr = 0, plot maximum fraction of each event. If centr < 0, plot abs(centr)-largest centroid where highest fractions are reached. If tuple with (lat, lon) plot fraction of nearest centroid.
- **kwargs** (*optional*) – arguments for pcolormesh matplotlib function used in event plots

Returns matplotlib.figure.Figure, matplotlib.axes._subplots.AxesSubplot

Raises **ValueError** –

get_event_id(*event_name*)
"Get an event id from its name. Several events might have the same name.

Parameters **event_name** (*str*) – Event name

Returns np.array(int)

get_event_name(*event_id*)
"Get the name of an event id.

Parameters **event_id** (*int*) – id of the event

Returns str

Raises **ValueError** –

get_event_date(*event=None*)
Return list of date strings for given event or for all events, if no event provided.

Parameters **event** (*str or int, optional*) – event name or id.

Returns list(str)

calc_year_set()
From the dates of the original events, get number yearly events.

Returns key are years, values array with event_ids of that year

Return type dict

append(*hazard*)
Append events in hazard. Centroids must be the same.

Parameters **hazard** (*Hazard*) – Hazard instance to append to current

Raises **ValueError** –

remove_duplicates()
Remove duplicate events (events with same name and date).

property size
Returns number of events

write_raster(*file_name*, *intensity=True*)
Write intensity or fraction as GeoTIFF file. Each band is an event

Parameters

- **file_name** (*str*) – file name to write in tif format
- **intensity** (*bool*) – if True, write intensity, otherwise write fraction

write_hdf5(*file_name*)
Write hazard in hdf5 format.

Parameters **file_name** (*str*) – file name to write, with h5 format

read_hdf5(*file_name*)
Read hazard in hdf5 format.

Parameters **file_name** (*str*) – file name to read, with h5 format

climada.hazard.tag module

class climada.hazard.tag.**Tag**(*haz_type=''*, *file_name=''*, *description=''*)
Bases: object

Contain information used to tag a Hazard.

file_name
name of the source file(s)

Type str or list(str)

haz_type
acronym defining the hazard type (e.g. 'TC')

Type str

description
description(s) of the data

Type str or list(str)

__init__(*haz_type=''*, *file_name=''*, *description=''*)
Initialize values.

Parameters

- **haz_type** (*str, optional*) – acronym of the hazard type (e.g. 'TC').
- **file_name** (*str or list(str), optional*) – file name(s) to read
- **description** (*str or list(str), optional*) – description of the data

append(*tag*)
Append input Tag instance information to current Tag.

join_file_names()
Get a string with the joined file names.

join_descriptions()
Get a string with the joined descriptions.

climada.hazard.trop_cyclone module

class climada.hazard.trop_cyclone.**TropCyclone**(*pool=None*)
Bases: *climada.hazard.base.Hazard*

Contains tropical cyclone events. .. attribute:: category

for every event, the TC category using the Saffir-Simpson scale:

-1 tropical depression 0 tropical storm 1 Hurrican category 1 2 Hurrican category 2 3 Hurrican category 3 4 Hurrican category 4 5 Hurrican category 5

type np.array(int)

intensity_thres = 17.5
intensity threshold for storage in m/s

vars_opt = {'category'}
Name of the variables that aren't need to compute the impact.

__init__(*pool=None*)
Empty constructor.

set_from_tracks(*tracks*, *centroids=None*, *description=''*, *model='H08'*)
Clear and model tropical cyclone from input IBTrACS tracks. Parallel process. :Parameters: * **tracks** (*TCTracks*) – tracks of events

- **centroids** (*Centroids, optional*) – Centroids where to model TC. Default: global centroids.
- **description** (*str, optional*) – description of the events
- **model** (*str, optional*) – model to compute gust. Default Holland2008.

Raises **ValueError** –

climada.hazard.tc_tracks module

climada.hazard.tc_tracks.**SAFFIR_SIM_CAT = [34, 64, 83, 96, 113, 135, 1000]**
Saffir-Simpson Hurricane Wind Scale in kn

class climada.hazard.tc_tracks.**TCTracks**(*pool=None*)
Bases: object

Contains tropical cyclone tracks.

data
list of tropical cyclone tracks. Each track contains following attributes:

- time (coords)
- lat (coords)
- lon (coords)
- time_step
- radius_max_wind
- max_sustained_wind
- central_pressure
- environmental_pressure
- max_sustained_wind_unit (attrs)
- central_pressure_unit (attrs)
- name (attrs)
- sid (attrs)
- orig_event_flag (attrs)
- data_provider (attrs)
- basin (attrs)
- id_no (attrs)
- category (attrs)

computed during processing:

- on_land
- dist_since_lf

Type list(xarray.Dataset)

__init__(*pool=None*)
Empty constructor. Read csv IBTrACS files if provided.

append(*tracks*)
Append tracks to current.

Parameters **tracks** (*xarray.Dataset or list(xarray.Dataset)*) – tracks to append.

get_track(*track_name=None*)
Get track with provided name. Return all tracks if no name provided.

Parameters **track_name** (*str, optional*) – name or sid (ibtracsID for IBTrACS) of track

Returns xarray.Dataset or [xarray.Dataset]

read_ibtracs_netcdf(*provider='usa'*, *storm_id=None*, *year_range=(1980, 2018)*, *basin=None*, *file_name='IBTrACS.ALL.v04r00.nc'*, *correct_pres=False*)
Fill from raw ibtracs v04. Removes nans in coordinates, central pressure and removes repeated times data. Fills nans of environmental_pressure and radius_max_wind. Checks environmental_pressure > central_pressure.

Parameters

- **provider** (*str*) – data provider. e.g. usa, newdelhi, bom, cma, tokyo
- **storm_id** (*str or list(str), optional*) – ibtracs if of the storm, e.g. 1988234N13299, [1988234N13299, 1989260N11316]
- **year_range** (*tuple, optional*) – (min_year, max_year). Default: (1980, 2018)
- **basin** (*str, optional*) – e.g. US, SA, NI, SI, SP, WP, EP, NA. if not provided, consider all basins.
- **file_name** (*str, optional*) – name of netcdf file to be dowloaded or located at climada/data/system. Default: 'IBTrACS.ALL.v04r00.nc'.
- **correct_pres** (*bool, optional*) – correct central pressure if missing values. Default: False

read_processed_ibtracs_csv (*file_names*)
Fill from processed ibtracs csv file.

Parameters **file_names** (*str or list(str)*) – absolute file name(s) or folder name containing the files to read.

read_simulations_emanuel (*file_names*, *hemisphere='S'*)
Fill from Kerry Emanuel tracks.

Parameters

- **file_names** (*str or list(str)*) – absolute file name(s) or folder name containing the files to read.
- **hemisphere** (*str, optional*) – 'S', 'N' or 'both'. Default: 'S'

equal_timestep (*time_step_h=1*, *land_params=False*)
Generate interpolated track values to time steps of min_time_step.

Parameters

- **time_step_h** (*float, optional*) – time step in hours to which to interpolate. Default: 1.
- **land_params** (*bool, optional*) – compute on_land and dist_since_lf at each node. Default: False.

calc_random_walk (*ens_size=9*, *ens_amp0=1.5*, *max_angle=0.3141592653589793*, *ens_amp=0.1*, *seed=54*, *decay=True*)
Generate synthetic tracks. An ensamble of tracks is computed for every track contained.

Parameters

- **ens_size** (*int, optional*) – number of ensamble per original track. Default 9.
- **ens_amp0** (*float, optional*) – amplitude of max random starting point shift degree longitude. Default: 1.5
- **max_angle** (*float, optional*) – maximum angle of variation, =pi is like undirected, pi/4 means one quadrant. Default: pi/10
- **ens_amp** (*float, optional*) – amplitude of random walk wiggles in degree longitude for 'directed'. Default: 0.1
- **seed** (*int, optional*) – random number generator seed. Put negative value if you don't want to use it. Default: configuration file
- **decay** (*bool, optional*) – compute land decay in probabilistic tracks. Default: True

property size
Get longitude from coord array

plot (*title=None*)
Track over earth. Historical events are blue, probabilistic black.

Parameters **title** (*str, optional*) – plot title

Returns matplotlib.figure.Figure, matplotlib.axes._subplots.AxesSubplot

climada.hazard.tc_tracks.**set_category** (*max_sus_wind*, *max_sus_wind_unit*, *saffir_scale=None*)
Add storm category according to saffir-simpson hurricane scale

- -1 tropical depression
- 0 tropical storm
- 1 Hurrican category 1
- 2 Hurrican category 2
- 3 Hurrican category 3
- 4 Hurrican category 4
- 5 Hurrican category 5

Parameters

- **max_sus_wind** (*np.array*) – max sustained wind
- **max_sus_wind_unit** (*str*) – units of max sustained wind
- **saffir_scale** (*list, optional*) – Saffir-Simpson scale in same units as wind

Returns double

7.1.4 climada.util package

climada.util.checker module

climada.util.checker.**size** (*exp_len*, *var*, *var_name*)
Check if the length of a variable is the expected one.

Raises **ValueError** –

climada.util.checker.**shape** (*exp_row*, *exp_col*, *var*, *var_name*)
Check if the length of a variable is the expected one.

Raises **ValueError** –

climada.util.checker.**array_optional** (*exp_len*, *var*, *var_name*)
Check if array has right size. Warn if array empty. Call check_size.

Parameters

- **exp_len** (*str*) – expected array size
- **var** (*np.array*) – numpy array to check
- **var_name** (*str*) – name of the variable. Used in error/warning msg

Raises **ValueError** –

climada.util.checker.**array_default** (*exp_len*, *var*, *var_name*, *def_val*)
Check array has right size. Set default value if empty. Call check_size.

Parameters

- **exp_len** (*str*) – expected array size
- **var** (*np.array*) – numpy array to check
- **var_name** (*str*) – name of the variable. Used in error/warning msg
- **def_val** (*np.array*) – nump array used as default value

Raises `ValueError` –

Returns Filled array

climada.util.config module

climada.util.config.**CONFIG = {'global': {'log_level': 'DEBUG', 'max_matrix_size': 10000**

climada.util.config.**setup_logging**(*log_level='DEBUG'*)
Setup logging configuration

climada.util.config.**setup_conf_user**()
Setup climada configuration

climada.util.constants module

climada.util.constants.**SOURCE_DIR = '/home/docs/checkouts/readthedocs.org/user_builds/clima**
climada directory

climada.util.constants.**DATA_DIR = '/home/docs/checkouts/readthedocs.org/user_builds/climada**
Folder containing the data

climada.util.constants.**SYSTEM_DIR = '/home/docs/checkouts/readthedocs.org/user_builds/clima**
Folder containing the data used internally

climada.util.constants.**GLB_CENTROIDS_NC = '/home/docs/checkouts/readthedocs.org/user_builds**
Global centroids nc.

climada.util.constants.**GLB_CENTROIDS_MAT = '/home/docs/checkouts/readthedocs.org/user_build**
Global centroids.

climada.util.constants.**ENT_TEMPLATE_XLS = '/home/docs/checkouts/readthedocs.org/user_builds**
Entity template in xls format.

climada.util.constants.**NAT_REG_ID = '/home/docs/checkouts/readthedocs.org/user_builds/clima**
Look-up table ISO3 codes

climada.util.constants.**HAZ_DEMO_FLDDPH = '/home/docs/checkouts/readthedocs.org/user_builds/**
NetCDF4 Flood depth from isimip simulations

climada.util.constants.**HAZ_DEMO_FLDFRC = '/home/docs/checkouts/readthedocs.org/user_builds/**
NetCDF4 Flood fraction from isimip simulations

climada.util.constants.**HAZ_DEMO_MAT = '/home/docs/checkouts/readthedocs.org/user_builds/cli**
hurricanes from 1851 to 2011 over Florida with 100 centroids.

Type Hazard demo from climada in MATLAB

climada.util.constants.**HAZ_DEMO_H5 = '/home/docs/checkouts/readthedocs.org/user_builds/clim**
ibtracs from 1975 to 2011 over Florida with 2500 centroids.

Type Hazard demo in h5 format

climada.util.constants.**DEMO_GDP2ASSET = '/home/docs/checkouts/readthedocs.org/user_builds/c**
Exposure demo file for GDP2Asset

climada.util.constants.**WS_DEMO_NC = ['/home/docs/checkouts/readthedocs.org/user_builds/clir**
Winter storm in Europe files. These test files have been generated using the netCDF kitchen sink: ncks -d latitude,50.5,54.0 -d longitude,3.0,7.5 ./file_in.nc ./file_out.nc

climada.util.constants.**EXP_DEMO_H5 = '/home/docs/checkouts/readthedocs.org/user_builds/clir**
Exposures over Florida

climada.util.constants.**TC_ANDREW_FL = '/home/docs/checkouts/readthedocs.org/user_builds/cli**
Tropical cyclone Andrew in Florida

climada.util.constants.**ONE_LAT_KM = 111.12**
Mean one latitude (in degrees) to km

climada.util.constants.**EARTH_RADIUS_KM = 6371**
Earth radius in km

climada.util.coordinates module

climada.util.coordinates.**LOGGER = <Logger climada.util.coordinates (DEBUG)>**

climada.util.coordinates.**NE_EPSG = 4326**
Natural Earth CRS EPSG

climada.util.coordinates.**NE_CRS = {'init': 'epsg:4326', 'no_defs': True}**
Natural Earth CRS

climada.util.coordinates.**grid_is_regular**(*coord*)
Return True if grid is regular.

Parameters **coord** (*np.array*)

climada.util.coordinates.**get_coastlines**(*extent=None*, *resolution=110*)
Get latitudes and longitudes of the coast lines inside extent. All earth if no extent.

Parameters

- **extent** (*tuple, optional*) – (min_lon, max_lon, min_lat, max_lat)
- **resolution** (*float, optional*) – 10, 50 or 110. Resolution in m. Default: 110m, i.e. 1:110.000.000

Returns np.array (lat, lon coastlines)

climada.util.coordinates.**dist_to_coast**(*coord_lat*, *lon=None*)
Comput distance to coast from input points in meters.

Parameters

- **coord_lat** (*np.array or tuple or float*) –
  - **np.array with two columns, first for latitude of each point and** second with longitude.
  - np.array with one dimension containing latitudes
  - tuple with first value latitude, second longitude
  - float with a latitude value
- **lon** (*np.array or float, optional*) –
  - np.array with one dimension containing longitudes
  - float with a longitude value

Returns np.array

climada.util.coordinates.**get_land_geometry**(*country_names=None*, *extent=None*, *resolution=10*)

Get union of all the countries or the provided ones or the points inside the extent.

Parameters

- **country_names** (*list, optional*) – list with ISO3 names of countries, e.g ['ZWE', 'GBR', 'VNM', 'UZB']
- **extent** (*tuple, optional*) – (min_lon, max_lon, min_lat, max_lat)
- **resolution** (*float, optional*) – 10, 50 or 110. Resolution in m. Default: 10m, i.e. 1:10.000.000

Returns shapely.geometry.multipolygon.MultiPolygon

climada.util.coordinates.**coord_on_land**(*lat*, *lon*, *land_geom=None*)

Check if point is on land (True) or water (False) of provided coordinates. All globe considered if no input countries.

Parameters

- **lat** (*np.array*) – latitude of points
- **lon** (*np.array*) – longitude of points
- **land_geom** (*shapely.geometry.multipolygon.MultiPolygon, optional*) – profiles of land.

Returns np.array(bool)

climada.util.coordinates.**nat_earth_resolution**(*resolution*)

Check if resolution is available in Natural Earth. Build string.

Parameters **resolution** (*int*) – resolution in millions, 110 == 1:110.000.000.

Returns str

Raises **ValueError** –

climada.util.coordinates.**get_country_geometries**(*country_names=None*, *extent=None*, *resolution=10*)

Returns a gpd GeoSeries of natural earth multipolygons of the specified countries, resp. the countries that lie within the specified extent. If no arguments are given, simply returns the whole natural earth dataset. Take heed: we assume WGS84 as the CRS unless the Natural Earth download utility from cartopy starts including the projection information. (They are saving a whopping 147 bytes by omitting it.) Same goes for UTF.

Parameters

- **country_names** (*list, optional*) – list with ISO3 names of countries, e.g ['ZWE', 'GBR', 'VNM', 'UZB']
- **extent** (*tuple, optional*) – (min_lon, max_lon, min_lat, max_lat) assumed to be in the same CRS as the natural earth data.
- **resolution** (*float, optional*) – 10, 50 or 110. Resolution in m. Default: 10m

Returns GeoDataFrame

climada.util.coordinates.**get_resolution**(*lat*, *lon*)

Compute resolution of points in lat and lon

Parameters

- **lat** (*np.array*) – latitude of points

- **lon** (*np.array*) – longitude of points

Returns float

climada.util.coordinates.**points_to_raster**(*points_bounds*, *res*)
" Transform vector data coordinates to raster. Returns number of rows, columns and affine transformation

Parameters

- **points_bounds** (*tuple*) – points total bounds (xmin, ymin, xmax, ymax)
- **res** (*float*) – resolution of output raster

Returns int, int, affine.Affine

climada.util.coordinates.**equal_crs**(*crs_one*, *crs_two*)
Compare two crs

Parameters

- **crs_one** (*dict or string or wkt*) – user crs
- **crs_two** (*dict or string or wkt*) – user crs

Returns bool

climada.util.coordinates.**read_raster**(*file_name, band=[1], src_crs=None, window=False, geometry=False, dst_crs=False, transform=None, width=None, height=None, resampling=<Resampling.nearest: 0>*)
Read raster of bands and set 0 values to the masked ones. Each band is an event. Select region using window or geometry. Reproject input by proving dst_crs and/or (transform, width, height). Returns matrix in 2d: band x coordinates in 1d (evtl. reshape to band x height x width)

Parameters

- **file_name** (*str*) – name of the file
- **band** (*list(int), optional*) – band number to read. Default: 1
- **window** (*rasterio.windows.Window, optional*) – window to read
- **geometry** (*shapely.geometry, optional*) – consider pixels only in shape
- **dst_crs** (*crs, optional*) – reproject to given crs
- **transform** (*rasterio.Affine*) – affine transformation to apply
- **wdith** (*float*) – number of lons for transform
- **height** (*float*) – number of lats for transform
- **resampling** (*rasterio.warp,.Resampling optional*) – resampling function used for reprojection to dst_crs

Returns dict (meta), np.array (band x coordinates_in_1d)

climada.util.coordinates.**read_vector**(*file_name*, *field_name*, *dst_crs=None*)
Read vector file format supported by fiona. Each field_name name is considered an event.

Parameters

- **file_name** (*str*) – vector file with format supported by fiona and 'geometry' field.
- **field_name** (*list(str)*) – list of names of the columns with values.
- **dst_crs** (*crs, optional*) – reproject to given crs

Returns np.array (lat), np.array (lon), geometry (GeiSeries), np.array (value)

climada.util.coordinates.**write_raster**(*file_name*, *data_matrix*, *meta*)
Write raster in GeoTiff format

Parameters

- **fle_name** (*str*) – file name to write
- **data_matrix** (*np.array*) – 2d raster data. Either containing one band, or every row is a band and the column represents the grid in 1d.
- **meta** (*dict*) – rasterio meta dictionary containing raster properties: width, height, crs and transform must be present at least (transform needs to contain upper left corner!)

climada.util.files_handler module

climada.util.files_handler.**to_list**(*num_exp*, *values*, *val_name*)
Check size and transform to list if necessary. If size is one, build a list with num_exp repeated values.

Parameters

- **num_exp** (*int*) – number of expect list elements
- **values** (*object or list(object)*) – values to check and transform
- **val_name** (*str*) – name of the variable values

Returns list

climada.util.files_handler.**get_file_names**(*file_name*)
Return list of files contained. Supports globbing.

Parameters **file_name** (*str or list(str)*) – Either a single string or a list of strings that are either

- a file path
- or the path of the folder containing the files
- or a globbing pattern.

Returns list

climada.util.hdf5_handler module

climada.util.hdf5_handler.**read**(*file_name*, *with_refs=False*)
Load a hdf5 data structure from a file.

Parameters

- **file_name** – file to load
- **with_refs** – enable loading of the references. Default is unset, since it increments the execution time considerably.

Returns dictionary structure containing all the variables.

Return type contents

Examples

Contents contains the Matlab data in a dictionary.

```
>>> contents = read("/pathto/dummy.mat")
```

Contents contains the Matlab data and its reference in a dictionary.

```
>>> contents = read("/pathto/dummy.mat", True)
```

Raises **Exception while reading** –

climada.util.hdf5_handler.**get_string**(*array*)
Form string from input array of unisgned integers.

Parameters **array** – array of integers

Returns string

climada.util.hdf5_handler.**get_str_from_ref**(*file_name*, *var*)
Form string from a reference HDF5 variable of the given file.

Parameters

- **file_name** – matlab file name
- **var** – HDF5 reference variable

Returns string

climada.util.hdf5_handler.**get_list_str_from_ref**(*file_name*, *var*)
Form list of strings from a reference HDF5 variable of the given file.

Parameters

- **file_name** – matlab file name
- **var** – array of HDF5 reference variable

Returns string

climada.util.hdf5_handler.**get_sparse_csr_mat**(*mat_dict*, *shape*)
Form sparse matrix from input hdf5 sparse matrix data type.

Parameters

- **mat_dict** – dictionary containing the sparse matrix information.
- **shape** – tuple describing output matrix shape.

Returns sparse csr matrix

climada.util.interpolation module

climada.util.interpolation.**DIST_DEF = ['approx', 'haversine']**
Distances

climada.util.interpolation.**METHOD = ['NN']**
Interpolation methods

climada.util.interpolation.**dist_sqr_approx**
Compute squared equirectangular approximation distance. Values need to be sqrt and multiplicated by ONE_LAT_KM to obtain distance in km.

climada.util.interpolation.**interpol_index**(*centroids*, *coordinates*, *method='NN'*, *distance='haversine'*, *threshold=100*)
Returns for each coordinate the centroids indexes used for interpolation.

Parameters

- **centroids** (*2d array*) – First column contains latitude, second column contains longitude. Each row is a geographic point
- **coordinates** (*2d array*) – First column contains latitude, second column contains longitude. Each row is a geographic point
- **method** (*str, optional*) – interpolation method to use. NN default.
- **distance** (*str, optional*) – distance to use. Haversine default
- **threshold** (*float*) – distance threshold in km over which no neighbor will be found. Those are assigned with a -1 index

Returns

numpy array with so many rows as coordinates containing the centroids indexes

climada.util.plot module

climada.util.plot.**geo_bin_from_array**(*array_sub*, *geo_coord*, *var_name*, *title*, *pop_name=True*, *buffer=1.0*, *extend='neither'*, *proj=<cartopy.crs.PlateCarree object>*, ***kwargs*)

Plot array values binned over input coordinates.

Parameters

- **array_sub** (*np.array(1d or 2d) or list(np.array)*) – Each array (in a row or in the list) are values at each point in corresponding geo_coord that are binned in one subplot.
- **geo_coord** (*2d np.array or list(2d np.array)*) – (lat, lon) for each point in a row. If one provided, the same grid is used for all subplots. Otherwise provide as many as subplots in array_sub.
- **var_name** (*str or list(str)*) – label to be shown in the colorbar. If one provided, the same is used for all subplots. Otherwise provide as many as subplots in array_sub.
- **title** (*str or list(str)*) – subplot title. If one provided, the same is used for all subplots. Otherwise provide as many as subplots in array_sub.
- **pop_name** (*bool, optional*) – add names of the populated places.
- **buffer** (*float, optional*) – border to add to coordinates
- **extend** (*str, optional*) – extend border colorbar with arrows. ['neither' | 'both' | 'min' | 'max']
- **proj** (*ccrs*) – coordinate reference system used in coordinates
- **kwargs** (*optional*) – arguments for hexbin matplotlib function

Returns matplotlib.figure.Figure, cartopy.mpl.geoaxes.GeoAxesSubplot

Raises **ValueError** –

climada.util.plot.**geo_im_from_array**(*array_sub*, *geo_coord*, *var_name*, *title*, *proj=<cartopy.crs.PlateCarree object>*, ***kwargs*)

Image(s) plot defined in array(s) over input coordinates.

Parameters

- **array_sub** (*np.array(1d or 2d) or list(np.array)*) – Each array (in a row or in the list) are values at each point in corresponding geo_coord that are ploted in one subplot.

- **geo_coord** (*2d np.array or list(2d np.array)*) – (lat, lon) for each point in a row. If one provided, the same grid is used for all subplots. Otherwise provide as many as subplots in array_sub.
- **var_name** (*str or list(str)*) – label to be shown in the colorbar. If one provided, the same is used for all subplots. Otherwise provide as many as subplots in array_sub.
- **title** (*str or list(str)*) – subplot title. If one provided, the same is used for all subplots. Otherwise provide as many as subplots in array_sub.
- **proj** (*ccrs*) – coordinate reference system used in coordinates
- **kwargs** (*optional*) – arguments for pcolormesh matplotlib function

Returns matplotlib.figure.Figure, cartopy.mpl.geoaxes.GeoAxesSubplot

Raises **ValueError** –

class climada.util.plot.**Graph2D**(*title=''*, *num_subplots=1*, *num_row=None*, *num_col=None*)

Bases: object

2D graph object. Handles various subplots and curves.

__init__(*title=''*, *num_subplots=1*, *num_row=None*, *num_col=None*)

Initialize self. See help(type(self)) for accurate signature.

add_subplot(*xlabel*, *ylabel*, *title=''*, *on_grid=True*)

Add subplot to figure.

add_curve(*var_x*, *var_y*, *fmt=None*, *ax_num=None*, ***kwargs*)

Add (x, y) curve to current subplot.

Parameters

- **var_x** (*array*) – abcissa values
- **var_y** (*array*) – ordinate values
- **fmt** (*str, optional*) – format e.g 'k–'
- **ax_num** (*int, optional*) – number of axis to plot. Current if None.
- **kwargs** (*optional*) – arguments for plot matplotlib function

set_x_lim(*var_x*, *ax_num=None*)

Set x axis limits from minimum and maximum provided values.

Parameters

- **var_x** (*array*) – abcissa values
- **ax_num** (*int, optional*) – number of axis to plot. Current if None.

set_y_lim(*var_y*, *ax_num=None*)

Set y axis limits from minimum and maximum provided values.

Parameters

- **var_y** (*array*) – ordinate values
- **ax_num** (*int, optional*) – number of axis to plot. Current if None.

get_elems()

Return figure and list of all axes (of each subplot).

Returns matplotlib.figure.Figure, [matplotlib.axes._subplots.AxesSubplot]

climada.util.plot.**make_map**(*num_sub=1*, *proj=<cartopy.crs.PlateCarree object>*)
Create map figure with cartopy.

Parameters

- **num_sub** (*int*) – number of subplots in figure.
- **proj** (*cartopy.crs projection, optional*) – geographical projection, PlateCarree default.

Returns matplotlib.figure.Figure, np.array(cartopy.mpl.geoaxes.GeoAxesSubplot)

climada.util.plot.**add_shapes**(*axis*)
Overlay Earth's countries coastlines to matplotlib.pyplot axis.

Parameters

- **axis** (*cartopy.mpl.geoaxes.GeoAxesSubplot*) – cartopy axis.
- **projection** (*cartopy.crs projection, optional*) – geographical projection, PlateCarree default.

climada.util.plot.**add_populated_places**(*axis*, *extent*, *proj=<cartopy.crs.PlateCarree object>*)
Add city names.

Parameters

- **axis** (*cartopy.mpl.geoaxes.GeoAxesSubplot*) – cartopy axis.
- **extent** (*list*) – geographical limits [min_lon, max_lon, min_lat, max_lat]
- **proj** (*cartopy.crs projection, optional*) – geographical projection, PlateCarree default.

climada.util.plot.**add_cntry_names**(*axis*, *extent*, *proj=<cartopy.crs.PlateCarree object>*)
Add country names.

Parameters

- **axis** (*cartopy.mpl.geoaxes.GeoAxesSubplot*) – cartopy axis.
- **extent** (*list*) – geographical limits [min_lon, max_lon, min_lat, max_lat]
- **proj** (*cartopy.crs projection, optional*) – geographical projection, PlateCarree default.

climada.util.plot.**add_basemap**(*axis*, *zoom*, *url='http://tile.stamen.com/terrain/tileZ/tileX/tileY.png'*, *flip=False*)
Add image to given axis. Coordinates need to be in epsg=3857.

Parameters

- **(cartopy.mpl.geoaxes.GeoAxesSubplot)** – plot axis
- **zoom** (*int, optional*) – zoom coefficient used in the satellite image
- **url** (*str, optional*) – image source, e.g. ctx.sources.OSM_C

climada.util.save module

climada.util.save.**save**(*out_file_name*, *var*)
Save variable with provided file name.

Parameters

- **out_file_name** (*str*) – file name (absolute path or relative to configured save_dir)
- **var** (*object*) – variable to save in pickle format

- genindex
- modindex

CHAPTER

EIGHT

LICENSE

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