

Modelling damages, extremes and impacts

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Design your own climate adaptation strategy – a practical application of open-source probabilistic damage modelling

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Inspired by/based on (explains the slide layout, too ;-) “[Climate Change Uncertainty and Risk: from Probabilistic Forecasts to Economics of Climate Adaptation](#)”, spring term lecture at ETH, by Reto Knutti, IAC ETH and David Bresch, IED ETH.

All material available at <https://github.com/davidnbresch/climada>

Manual: https://github.com/davidnbresch/climada/blob/master/docs/climada_manual.pdf

Note: An additional climada module to work with any country (or province) in the world can be obtained at https://github.com/davidnbresch/climada_module_country_risk

Please note further that the code `climada_workshop_step_by_step` does allow running all commands as in this file at once. This is *NOT recommended for study purposes*, but might be helpful to *TEST* whether the full workshop and all its commands do work properly.

Acronyms frequently used

ECA: Economics of Climate Adaptation

EDS: event damage set

DFC: damage frequency curve

PAA: Percentage of Assets Affected (see climada manual)

MDD: Mean Damage Degree (see climada manual)

MDR: Mean Damage Ratio (=PAA*MDD, see climada manual)

To obtain a good understanding of key variables, please consult the [climada manual](#), especially the section “Excel interface to climada” page 13ff and more detailed even in the section “Description of key climada structures”, page 36ff. Note that the present exercise does not make much use of the Excel interface, but you can anytime import an entity from Excel using `entity=climada_entity_read`.

Installation¹ (those who find a climada-master folder on the desktop of their laptop can skip this first step)

- Go to <https://github.com/davidnbresch/climada>, look for the button 'clone or download', click on 'Download ZIP' and save it to the desktop. After download, there should now be a folder named 'climada-master' on the desktop.
- Repeat this with https://github.com/davidnbresch/climada_module_country_risk, create a folder named 'modules' as a sub-folder of 'climada-master' and move the folder 'climada_module_country_risk-master' in there.

Did you bring your own laptop? If not, skip this section.

If you brought your own laptop without MATLAB, make sure you have Octave installed (get it from <https://www.gnu.org/software/octave/download.html>). If you brought your own laptop with MATLAB (otherwise skip this), start MATLAB, set the current folder to the 'climada-master' on the desktop and enter²: `startup`

Start Octave, set the current folder to the 'climada-master' on the desktop and enter²: `startup`

Enter the following and be a bit patient (this also tests whether your installation is OK)

```
climada_demo_step_by_step
```

Now have a look at the code and inspect what it did step-by-step

```
edit climada_demo_step_by_step
```

There are plenty of comments in the code (just note that there is a switch between MATLAB and Octave at line 74) and see the climada manual, p. 13ff: "From tropical cyclone hazard generation to the adaptation cost curve".

To experiment a bit with the tool edit parameters etc. directly on the command line³, since once you've run `climada_demo_step_by_step`, all variables are in memory (if you messed it up, just close MATLAB/Octave, start again and run `climada_demo_step_by_step` again).

Please consult the climada manual for a detailed description on the structures as shown below, best is to search e.g. for `entity.assets.Value` in the manual.

You do obviously NOT need to re-run `climada_demo_step_by_step`, just snippets of the code, i.e. to see what effect a 20% increase in asset values has on the damage function, you proceed as follows⁴:

```
entity.assets.Value=entity.assets.Value*1.2;
figure;climada_EDS_DFC(climada_EDS_calc(entity,hazard));
```

¹ This is obviously also described (in a bit more detail) in the climada manual.

² all MATLAB climada commands will be set in `courier`

³ you could also change the data/parameters for assets and vulnerabilities in the Excel file at `../data/entities/demo_today.xls` (in Octave, very likely `demo_today.xlsx` is used), but you would have to re-read this file each time. The Excel file is provided more as an interface for people not familiar with MATLAB/Octave, as they can generate a full adaptation cost curve with just the command `climada`.

⁴ A note to the resulting figure: The DFC (the [occurrence exceedence] damage frequency curve) is constructed by sorting calculated damages in descending order. The largest damage occurred once in the observation time period, the second largest damage has been exceeded twice in the observation period, the third largest damage three times... how this is done? Have a look into the code `climada_EDS_DFC`.

Let's now reset the change to assets and look at a change in the damage function, e.g.

```
entity.assets.Value=entity.assets.Value/1.2; % reset
entity.damagefunctions.MDD=entity.damagefunctions.MDD*0.8;
figure; climada_EDS_DFC(climada_EDS_calc(entity,hazard));
```

Next, let's see what the adaptation cost curve looks like if we half the costs for implementing the building code:

```
entity.damagefunctions.MDD=entity.damagefunctions.MDD/0.8; % reset
entity.measures.name % aha, we see that measure 4 is the building code
entity.measures.cost(4)=entity.measures.cost(4)/2; % half the cost
figure;
climada_adaptation_cost_curve(climada_measures_impact(entity,hazard,'no'));
```

And what happens if the building code is less effective

```
entity.measures.cost(4)=entity.measures.cost(4)*2; % reset
entity.measures.MDD_impact_a(4)=.85; % reduce damage by 15% (instead of 25%)
figure;
climada_adaptation_cost_curve(climada_measures_impact(entity,hazard,'no'));
```

You might play a bit more with any parameter (interesting to look into might also be the discount rate, see `entity.discount.discount_rate`, it is a vector of discount rates in decimal for years to come, one might also call this a kind of yield curve).

To continue, make sure the correct entity and hazard event set is in memory, hence:

```
load([pwd filesep 'data' filesep 'entities' filesep 'demo_today.mat']);
load([pwd filesep 'data' filesep 'hazards' filesep 'TCNA_today_small.mat']);
```

and calculate the event damage set (again):

```
EDS=climada_EDS_calc(entity,hazard);
figure; climada_EDS_DFC(EDS);
```

Create the climate change impact hazard event set (see `climada_tc_hazard_clim_scen`)

- We can implement climate change scenarios in the *climada* model by modifying the wind frequency and/or the wind speed (hazard intensity) of a hazard set⁵. For example an increase in frequency of 10% (`f_screw=1.1`) and a 3% increase in wind speed (`i_screw=1.03`)⁶. To create a hazard set with a climate change scenario based on today's hazard set, enter (set reasonable values for `f_screw` and `i_screw` and enter `atl_prob_clim.mat` when prompted for a filename):


```
hazard_CC=climada_tc_hazard_clim_scen(hazard,[],f_screw,i_screw);
```
- Calculate the damage again the compare, i.e.


```
EDS_CC=climada_EDS_calc(entity,hazard_CC);
figure; climada_EDS_DFC(EDS,EDS_CC);
```

Create the economic growth scenario (edit `entity.assets.Value` or tab assets in the Excel)

⁵ Well, we can do much more (almost no limits), but let's start with these two simple modifications.

⁶ Note that the climate change screws contain the new total percentage and not only the changes. For example a 3% increase in wind speed is made by `i_screw = 1.03` (and not only 0.03).

- In order to account for the total risk in our calculations, we have to consider the economic growth in the assets as well; in addition to the expected climate changes expressed in the climate scenarios. (climada manual p. 53)
- To construct the 2030 asset base to reflect the economic growth (remember: **total climate risk = risk today + risk due to economic growth + risk due to climate change**), we thus need to inflate assets. While this can be done diligently and based on detailed considerations, just inflate with say 3%, i.e. with a factor $1.51 \approx (1+0.03)^{14}$ until 2030.

```
entity_future=entity; % make a copy
entity_future.assets.Value=entity_future.assets.Value*1.51; % inflate
entity_future.assets.Cover=entity_future.assets.Value; % technical step
```

- Save your future entity in the `.../climada-master/data/entities` folder, e.g.

```
save([pwd filesep 'data' filesep 'entities' filesep 'demo_future'], 'entity_future');
```

- Analyse these 2030 assets with both the present-day (hazard) and climate change scenario hazard (hazard_CC) event sets:

```
EDS_future=climada_EDS_calc(entity_future,hazard);
EDS_future_CC=climada_EDS_calc(entity_future,hazard_CC);
```

- Plot a "waterfall" graph with the following command:

```
climada_waterfall_graph(EDS,EDS_future,EDS_future_CC,9999); %7
```

Edit the adaptation measures

- While this step would require a substantial amount of time, starting with stakeholder workshops to define the raw set of measures etc., careful evaluation of costs and context, let's just edit the cost values for a small set of pre-defined measures to get an initial feel. Have a look into `entity.measures` and consult the climada manual, p. 12 and the comments in the file `.../climada-master/data/entities/entity_template.xls` in tab *measures*.
- At the end, make sure you copy `entity.measures` into `entity_future.measures`, i.e. `entity_future.measures=entity.measures`, as otherwise the comparison of present and future costs and benefits would be inconsistent.

Finally, calculate the impact of measures

```
impact_today=climada_measures_impact(entity,hazard,'no');
impact_future=climada_measures_impact(entity_future,hazard_CC,impact_today);
```

And produce the full adaptation cost curve

```
climada_adaptation_cost_curve(impact_future);
```

And you can even compare how the effect of adaptation measures varies over time

```
figure;climada_adaptation_cost_curve(impact_future);
figure;climada_adaptation_cost_curve(impact_today); % to compare
In MATLAB with overlay: figure;climada_adaptation_cost_curve(impact_future,impact_today);
```

⁷ 9999 to indicate that we want to see the annual expected damage, you can also enter say 100 to see the 100yr damage

And now over to you: investigate, check for sensitivities

You might consider to calculate different *impact* structures (results of `climada_measures_impact`) and then use `climada_adaptation_cost_curve` to compare visually.

Appendix: For those who would like to experiment with other countries etc.

Decide about the place you're going to study

- As a preparation, obtain all tropical cyclone (TC) track databases:
`climada_tc_get_unisys_databases`
- We're going to look into tropical cyclone (TC) risk, please choose any TC-exposed country for your analysis, enter (see manual [climada_module_country_risk.pdf](#)⁸)
In MATLAB: `[centroids,entity,entity_future]=climada_create_GDP_entity;`
In Octave: `entity=climada_nightlight_entity(' ',' ',-1);`
and select a country (from the drop-down list)
- Save your entity in the `.../climada-master/data/entities` folder, e.g.
`save([pwd filesep 'data' filesep 'entities' filesep 'MYCOUNTRY'],'entity')`
- Optional: Save the entity also as .xls file (to ease editing) using `climada_entity_save_xls(entity)` or just export Latitude (lat), Longitude (lon) and Value into a raw file:
`fid=fopen([pwd filesep 'data' filesep 'temp_assets.csv'],'w');`
`fprintf(fid,'%f;%f;%f\n',[entity.assets.lat',entity.assets.lon',entity.assets.Value']');`
`fclose(fid)`
and replace the respective entries in the Excel template (`.../climada-master/data/entities/demo_today.xls`, tab assets), then save it as another file (e.g. `MYCOUNTRY.xls`)

Now proceed as in the step-by-step example, i.e.:

- Generate the TC hazard event set (read the track data of the Unisys database (<http://weather.unisys.com/hurricane>, please refer to the climada manual for details⁹).
`tc_track=climada_tc_read_unisys_database;`
`tc_track_prob=climada_tc_random_walk(tc_track);`
`hazard=climada_tc_hazard_set(tc_track_prob,' ',entity);`

A note on saving time: Instead of re-creating the hazard in each MATLAB session, you can always load from the `.mat` file climada saves the hazard event set to. Most climada routines can also be called without arguments, prompting the user to provide them via file dialogs.

- Calculate the damage (to check it all works)
`EDS=climada_EDS_calc(entity,hazard); % what's happening here? See manual p. 39ff`
`figure; climada_EDS_DFC(EDS);`
- One special step to get a reasonable list of measures:
`entity_tmp=climada_entity_load([pwd filesep 'data' filesep 'entities' filesep 'demo_today.mat'])`
`entity.measures=entity_tmp.measures; % replace`
- Calculate the benefit of adaptation measures, create the (risk today) adaptation cost curve (just to get there, not that all values would necessarily be reasonable)
`measures_impact=climada_measures_impact(entity,hazard,'no');`
`climada_adaptation_cost_curve(measures_impact);`

⁸ in `.../climada_modules/climada_module_country_risk-master/docs`

⁹ The climada manual describes how to download TC track data for other basins and the like. Please note that `TEST_tracks.atl.txt` contains only 10 years of data in order to speed up experimentation. Please use the full dataset `tracks.atl.txt`, in order to proceed with a hazard event set large enough to provide reasonable statistics. If you now run `climada_hazard_stats(hazard)`, you will obtain windspeed maps for up to 1000yr return periods.