WS3: Extremes and impacts:
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, Swiss Re.

All material available at https://github.com/davidnbresch/climada
Manual: https://github.com/davidnbresch/climada/blob/master/docs/climada_manual.pdf

Installation

- Create a folder named climada
- Download https://github.com/davidnbresch/climada into the climada folder
- Start MATLAB and browse to your local folder ../climada/climada-master, then enter[1]:
  `startup`

Getting started

- Enter **`climada_demo`** and play with the sliders etc. to get a feel
  (see climada manual, p. 4: "A visual primer")
- Enter **`edit climada_demo_step_by_step`** (such that the code opens in the MATLAB editor) and play it trough using the MATLAB debugger (so you can run it step-by-step (consult the climada manual, p. 13ff: "From tropical cyclone hazard generation to the adaptation cost curve")
- At the end, 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 'atl_prob.mat'])
```

  and calculate the event damage set (again):

```
EDS=climada_EDS_calc(entity,hazard) % what's happening here? See manual p. 39ff
figure; climada_EDS_DFC(EDS)[2]
```

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 set[3]. For example an increase in frequency (`f_screw`) of 10% and a 3% increase (`i_screw`) in wind speed for all SS3 and stronger storms[4]. 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) [5]
```

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[1] all MATLAB climada commands will be set in `courier`
[2] 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.
[3] Well, we can do much more (almost no limits), but let's start with these two simple modifications.
[4] 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).
[5] 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`.

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

- 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 1.6≃(1+0.03)^15 until 2030. You can either just execute this in MATLAB or in the Exel[6]:

```
entity_future=entity % make a copy
entity_future.assets.Value=entity_future.assets.Value*1.6; % inflate
entity_future.assets.Cover=entity_future.assets.Value; % technical step
```

- Save your future entity in the …/climada/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/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.

[6] In case you'd like top work in the Excel, just inflate the Value column (tab assets) and save under a new name MYCOUNTRY_future.xls, then import into climada using `entity_future=climada_entity_read` (will prompt for the file MYCOUNTRY_future.xls)

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

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

```
climada_adaptation_cost_curve(impact_future,impact_today)
```

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` with two inputs to compare visually.

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

- In the folder named climada create a sub-folder named climada_modules
- Download https://github.com/davidnbresch/climada_module_GDP_entity into climada_modules
- Exit MATLAB. Start MATLAB again, browse to your local folder .../climada/climada-master, then enter (this adds the new module to the path): `startup`

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_GDP_entity.pdf[8])
  `[centroids,entity,entity_future]=climada_create_GDP_entity`
  and select a country (from the drop-down list)
- Save your entity in the …/climada/climada-master/data/entities folder, e.g.
  `save([pwd filesep 'data' filesep 'entities' filesep 'MYCOUNTRY'],'entity')`
- Save centroids in the …/climada/climada-master/data/system folder, e.g.
  `save([pwd filesep 'data' filesep 'system' filesep 'MYCOUNTRY'],'centroids')`
- 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/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 details[9]).
  ```
  tc_track=climada_tc_read_unisys_database
  tc_track_prob=climada_tc_random_walk(tc_track)
  hazard=climada_tc_hazard_set(tc_track_prob,'',centroids)
  ```

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.

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[8] in …climada/climada_modules/climada_module_GDP_entity-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.

- 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)`