climada module **country risk**  14 Feb 2015

<https://github.com/davidnbresch/climada_module_country_risk>

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This module runs all (available) perils for one country or for a list of countries. First, it allows generating the country assets (10 or 1 km resolution, based on night light intensity[[1]](#footnote-1)), second to generate the hazard event sets and second to run all damage calculations.

Currently implemented is the automatic generation of earthquake (EQ), tropical cyclone (TC), torrential rain (TR), storm surge (TS) and European winter storm (WS) hazard event sets. The core function is country\_risk\_calc, which does it all in one go[[2]](#footnote-2). Instead of whole countries, one can also analyze single states/provinces, see country\_admin1\_risk\_calc. The module does contain a series of support functions to calibrate country results – they are named cr\_\*, while the top-level functions of this module are named country\_\* or country\_risk\_\*, see function reference below. The batch code selected\_countries\_all\_in\_one does provide the reference xample about how to use all these functions.

Further, the module calculates the economic loss (i.e. the full range of economic costs in the wake of a natural disaster) associated with the hazard event sets[[3]](#footnote-3).

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# Country risk module – basics

The whole module introduces the structure country\_risk, the core output of country\_risk\_calc and country\_admin1\_risk\_calc which contains country results in a standardized way and is therefore input to a series of functions of this module. country\_risk(i).res.hazard(j) contains the EDS for country i and hazard j (country\_risk(i).res.hazard(j).EDS), the name of the peril in country\_risk(i).res.hazard(j).peril\_ID, the name of the entity in country\_risk(i).res.hazard(j).entity\_file and the name of the hazard event set in country\_risk(i).res.hazard(j).hazard\_set\_file.

## country\_risk\_calc

Basic procedure implemented in country\_risk\_calc is as follows:

1) generate centroids for the country (uses climada\_create\_GDP\_entity[[4]](#footnote-4) or climada\_nightlight\_entity)

2) figure which hazards affect the country

3) create the hazard event sets, using

- climada\_tc\_hazard\_set (tropical cyclone wind[[5]](#footnote-5))

- climada\_tr\_hazard\_set (tropical cyclone rain[[6]](#footnote-6))

- climada\_ts\_hazard\_set (tropical cyclone surge[[7]](#footnote-7))

- eq\_global\_hazard\_set (earthquake[[8]](#footnote-8))

- European winter storm (hazard not generated, just assigned[[9]](#footnote-9))

4) run the risk calculation for all hazards

Next steps are country\_risk\_report, country\_risk\_EDS\_combine and country\_risk\_EDS2YDS plus cr\_plot\_DFC or cr\_plot\_DFC\_aggregate to plot the resulting country damage frequency curves.

In essence, you define the country and the code runs the generation of centroids, default assets (from nightlight intensity, see climada module GDP\_entity) and the EQ, TC, TR and TS hazard event sets plus checks for WS Europe exposure. It even figures whether the country is exposed to more than one ocean basin and in such a case generates a suite of TC/TS/TR hazard event sets for each ocean basin. The code is ready for upgrade with additional hazards (usually a new hazard is a new climada module). That’s why the code notifies the user if the specific hazard module is missing (even indicates the github location where to get it from).

Simply call e.g.country\_risk\_calc(‘El Salvador’)

If called without any argument, a list dialog to select the country pops up. See code header for details, i.e. help country\_risk\_calc

Behind the scenes, the code centroids\_generate\_hazard\_sets does the heavy lifting, i.e. steps 2) and 3) from above. This way one can generate all relevant hazard sets with one call to centroids\_generate\_hazard\_sets for any set of centroids (e.g. only a part of a country, a region, a city…[[10]](#footnote-10)):

centroids\_hazard\_info=...

centroids\_generate\_hazard\_sets(centroids,force\_recalc,check\_plots)

The resulting structure centroids\_hazard\_info contains the names of the generated hazard sets (or the ones generated earlier if just called to check for step 2) in centroids\_hazard\_info.res.hazard(i).hazard\_set\_file (the somewhat complicated nested structure is due to the flexibility required by country\_risk\_calc).



Figure: Step 1 (generate centroids, assets distribution, color scale indicates value per centroid) and step 2 (hazard selection). The green box shows the selection area around the country, the blue dots are all the TC track nodes (historic) and the red dots the epicenters (historic). This figure is generated if check\_plot=1 in the call, e.g. country\_risk\_calc(‘El Salvador’,0,0,1).



Figure: The most intense single event for all hazard generated for El Salvador (Step 3). Note that El Salvador is both exposed to tropical cyclones from the East and West, that’s why there are two hazard events sets for TC/TS/TR, one for the Atlantic side (atl for Atlantic), one for the Pacific side (epa for East Pacific Ocean). The earthquake model is global. Note further the nice feature of hazard (or peril) – dependent color scales; and the coarser resolution of centroids (blue) around the country (with red dots at high-density centroids) to support plotting hazard intensities around the country, too. This figure is generated if check\_plot=1 in the call, e.g. country\_risk\_calc(‘El Salvador’,0,0,1)

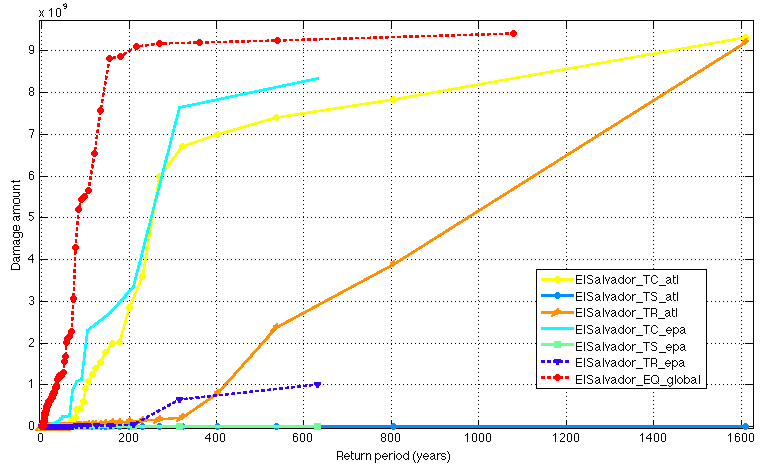


Figure: The resulting damage frequency curves (DFC) for all seven (!) hazards affecting El Salvador (values just for illustration, based on dummy damage functions). This figure is generated with check\_plot=1 in the call, e.g. country\_risk\_report(country\_risk\_calc(‘El Salvador’,1,1),0,1)

## country\_risk\_report

Comes in handy if one runs some select countries, e.g:

country\_risk=country\_risk\_calc(‘Barbados’)

country\_risk(2)=country\_risk\_calc(‘El Salvador’)

country\_risk(3)=country\_risk\_calc(‘Costa Rica’)

And then country\_risk\_report(country\_risk,0) results in the following output (to stdout, also an Excel or .csv file is written[[11]](#footnote-11)):

Barbados (1)

TR EL=36572051.496470 (8.481508%o) Barbados\_TR\_atl

TC EL=23083330.494007 (5.353308%o) Barbados\_TC\_atl

TS EL=7531.966739 (0.001747%o) Barbados\_TS\_atl

EQ EL=0.000000 (0.000000%o) Barbados\_EQ\_global

ElSalvador (2)

EQ EL=415631535.361110 (17.943889%o) ElSalvador\_EQ\_global

TR EL=141613002.072040 (6.113800%o) ElSalvador\_TR\_epa

TC EL=59386249.565168 (2.563858%o) ElSalvador\_TC\_atl

TC EL=16152772.894979 (0.697357%o) ElSalvador\_TC\_epa

TR EL=621784.438763 (0.026844%o) ElSalvador\_TR\_atl

TS EL=0.000000 (0.000000%o) ElSalvador\_TS\_epa

TS EL=0.000000 (0.000000%o) ElSalvador\_TS\_atl

Costa Rica (3)

EQ EL=523833928.441207 (12.396559%o) Costa Rica\_EQ\_global

TR EL=1530537.767294 (0.036220%o) Costa Rica\_TR\_epa

TC EL=73978.520263 (0.001751%o) Costa Rica\_TC\_epa

TR EL=5765.009179 (0.000136%o) Costa Rica\_TR\_atl

TS EL=1689.347413 (0.000040%o) Costa Rica\_TS\_atl

TC EL=60.830655 (0.000001%o) Costa Rica\_TC\_atl

TS EL=0.000000 (0.000000%o) Costa Rica\_TS\_epa



Figure: The local damage for a given peril (here EQ) for one country (here Costa Rica) in spatial resolution (e.g. at each centroid). Produced by the call (following from above resulting structure country\_risk):

country\_i=3; hazard\_i=7[[12]](#footnote-12);

climada\_circle\_plot(...

country\_risk(country\_i).res.hazard(hazard\_i).EDS.ED\_at\_centroid,...

country\_risk(country\_i).res.hazard(hazard\_i).EDS.assets.Longitude,...

country\_risk(country\_i).res.hazard(hazard\_i).EDS.assets.Latitude)

## country\_admin1\_risk\_calc

Same as country\_risk\_calc, but for a state or province (admin1 level) of any given country. Run the all (available) perils for one country's admin1 level. Obtain the admin1 boundaries (from [www.naturalearthdata.com](http://www.naturalearthdata.com), shape files already part of the data that comes with the country risk module) and carve out the respective centroids (set Value at all others to zero). Run the risk calculation for each admin1 for all hazards. In case one would like to skip hazards, just (temporarily) remove the respective {country\_name}\_\*.mat hazard event sets. ONLY makes sense if country\_risk\_calc has been run for the respective country (we keep it like this, as automatic mode might trigger lots of un-wanted calculations). If not, the code terminates with the respective messages (no entity found, no hazard set(s) found...). But one can run country\_admin1\_risk\_calc for more than one country, if the respective countries have been run as country\_risk\_calc. NOTE: Before using this code, make yourself familiar with country\_risk\_calc and country\_risk\_report (same format as country\_risk\_calc).

## climada\_nightlight\_entity

Construct an entity file based on high-res (1km!) night light data[[13]](#footnote-13). Reads an image file with nightlight density[[14]](#footnote-14) and matches it to the local geography. Prompts for country (admin0) and state/province (admin1), constrains the active centroids (with values>0) to the selected country or admin1 and saves the entity. Since we're dealing with admin1, no automatic scaling or allocation of GDP to centroids is performed (for this, see climada\_create\_GDP\_entity[[15]](#footnote-15)).

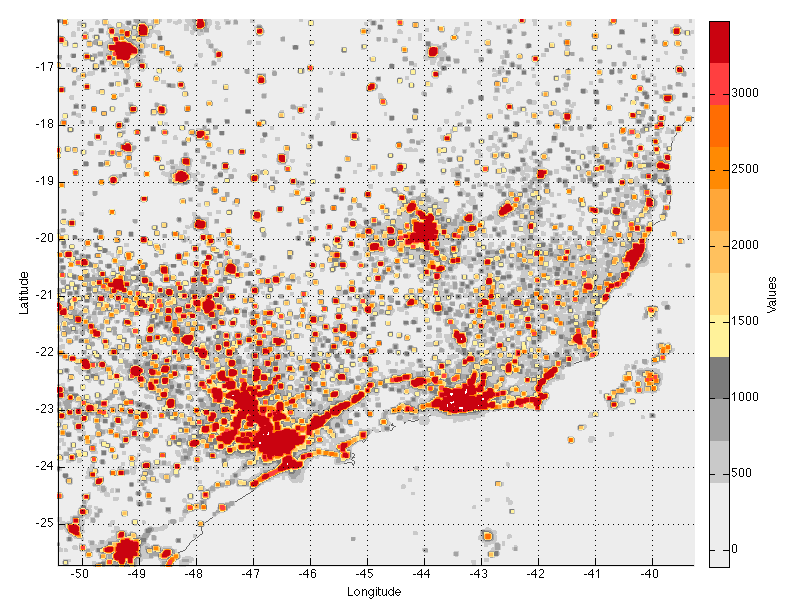
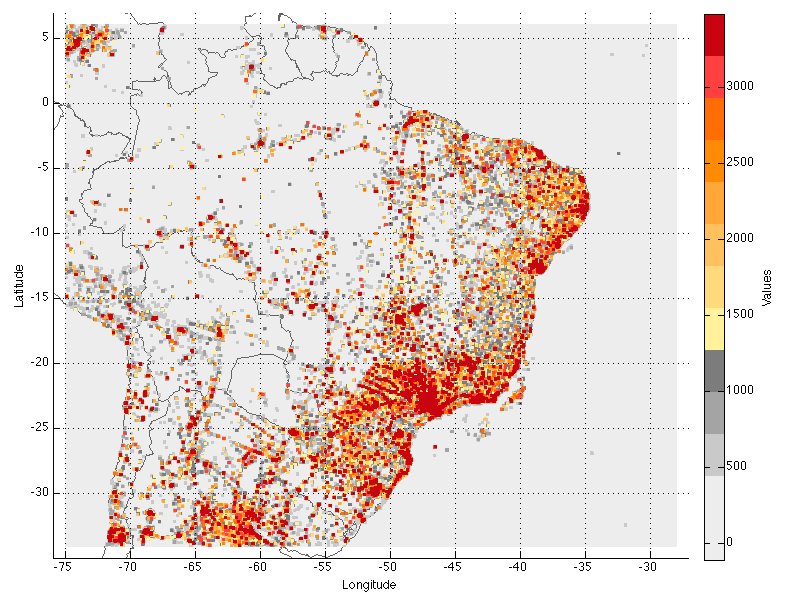


Figure: Brazil value distribution on 1km (!) resolution (left, zoomed in right) as generated by climada\_nightlight\_entity(‘Brazil’,’’,2).

## cr\_economic\_loss\_calc

Major natural disasters can and do have severe negative short-run economic impacts, the severity of which depends on the affected country's resilience, or ability to recover. cr\_economic\_loss\_calc calculates the economic damages resulting from the simple property damages in the hazard event set, taking into account socio-economic data on the country's financial strength, supply chain risk profile, resilience and preparedness for natural disasters (see appendix for details).

# Country and peril calibration

## country\_risk\_calibrate

Calibrate a given country (or a list of countries). Make sure you called country\_risk\_calc before (not necessarily in the same session, but the country entities need to exist – at least the ones for present ({ISO}\_{CountryName}\_entity.mat).

The most common use therefore looks like (as an example, generate the asset distributions for listed countries and all the probabilistic hazard sets for all perils that affect any of these countries):

country\_list={'Colombia','Costa Rica','Dominican Republic','United States'};  
country\_risk=country\_risk\_calc(country\_list,-3);

country\_risk\_calibrate(country\_list); % **calibrate** all countries

Standard procedure is that the switch statement in the function country\_risk\_calibrate has entries for countries (and lists of countries) and hence performs the specific adjustments, primarily to the damage function(s).

In case you consider editing this function, be careful to check for repetitious application. The code sets the field entity.calibrated=1 the first time a country is treated, but since one might need to re-calibrate, one should rather assign absolute values to e.g. entity.damagefunctions.MDD, since a mere multiplication of existing values might lead to troubles on subsequent calls. Luckily, country\_risk\_calibrate calls climada\_damagefunctions\_replace, which does indeed not replace on repetitious calls if the result would be exactly the same.

See also cr\_country\_hazard\_test in order to *test* country calibration.

## cr\_country\_hazard\_test

Given a country\_risk results structure (see above, generated by country\_risk\_calc), experiment with one country and hazard to test different damage function settings etc.

This code is MOST LIKELY to be edited by the user, i.e. to set damagefunction parameters etc. It provides merely a TESTBED for efficient calibration of country results.

Process:

* Run country\_risk\_calc for either one or a set of countries. A set makes particularly sense for e.g. a peril region, such as TC atl, in order to ensure (neighboring) countries in that region have similar damagefunction settings. Hence you might e.g. run  
    
  country\_list={'Colombia','Costa Rica','Dominican Republic','United States'};  
  peril\_ID=['atl\_TC';'atl\_TS']; % TC and TS in Atlantic region  
  country\_risk=country\_risk\_calc(country\_list,-7,0,0,peril\_ID);
* call cr\_DFC\_plot to get a first overview by country, e.g.  
    
  cr\_DFC\_plot(country\_risk)
* call cr\_DFC\_plot\_aggregate to get a first overview or the combined results of all countries, e.g. (note that the code does combine sub-peril EDSs himself)  
    
  cr\_DFC\_plot\_aggregate(country\_risk)
* Note that especially the comparison with EM-DAT makes only sense for either larger countries or a group of smaller ones - otherwise it might be too much due to chance whether a country got hit in the past years or not.
* Now, call cr\_country\_hazard\_test to test different damagefunction settings (or modifications) for one country and peril, e.g. (for above country\_list and perils, 2 points to Costa Rica, and 1 is the first peril in this country, i.e. TC):  
    
  country\_risk=cr\_country\_hazard\_test(country\_risk,2,1)
* Once you’re happy with the country DFC – i.e. it compares well to either EM-DAT, other models etc., occasionally call cr\_DFC\_plot\_aggregate(country\_risk) to show the aggregate result. Note that cr\_DFC\_plot\_aggregate does the aggregation itself.
* In case you'd like to experiment only with TC, but want to compare TC and TS combined, proceed as follows (say hazard 1 is TC, hazard 2 TS)  
    
  country\_risk=cr\_country\_hazard\_test(country\_risk,2,1)  
  [country\_risk\_agg,EDC]=country\_risk\_EDS\_combine(country\_risk);  
  cr\_DFC\_plot(country\_risk\_agg,1,1)  
    
  or simply  
    
  cr\_DFC\_plot(country\_risk\_EDS\_combine(country\_risk),1,1)
* And then run e.g. cr\_country\_hazard\_test with slightly different settings for the particular country and repeat the process.

In order to avoid troubles with GitHub, please make your copy of the function cr\_country\_hazard\_test, name it e.g. cr\_country\_hazard\_mytest, and experiment with different damage function settings for a given country and region (group of countries). In special cases, you might also consider adjusting hazard event sets.

Next step: put your final adjustments in country\_risk\_calibrate (and if you’re really of the opinion they are an improvement of climada, please check these changes in).

# Function reference

Use help {function name} to get a detailed description and input/output specification

## Top level functions

country\_risk\_calc: generate assets and hazard sets for a given country (i.e. admin0, or a list of countries). This function provides a convenient way to get started for any given country.

country\_admin1\_risk\_calc: Once country\_risk\_calc has been run for a country (or a series of), calculate the admin1 (state/province) level results.

country\_risk\_EDS\_combine: combine sub-peril EDSs in country\_risk structure, such as TC and TS – helpful to reduce the complexity of results.

country\_risk\_EDS2YDS: convert event event damage sets to year damage sets

country\_risk\_report: produce a report given output from country\_risk\_calc, country\_admin1\_risk\_calc or cr\_economic\_loss\_calc (see also cr\_loss\_multiplier\_plot).

country\_risk\_calibrate: for many countries, climada has been calibrated (to some extent) and this code does modify the damagefunctions of a given country accordingly. Just call this code with the full list of countries you’ve processed once with country\_risk\_calc – and climada does automatically apply all calibrations to all countries (and all hazards).

climada\_nightlight\_entity: Generate the (high-resolution) asset distribution for any country (admin0) and any state/province (admin1) within.

## Plotting functions

cr\_DFC\_plot: plot damage frequency curves (DFC) for all countries and perils in country\_risk

cr\_DFC\_plot\_aggregate: plot combined peril damage frequency curves (DFC) for all countries and also plot the peril region aggregate as well as the global aggregate DFC.

## Support-level functions

cr\_economic\_loss\_calc: given (property damage) output from country\_risk\_calc, calculate total economic loss

cr\_EDS\_emdat\_adjust: given an event damage set, adjust such that it matches best the EM-DAT damage history of a given country and hazard (see also emdat\_read)

emdat\_read: read the EM-DAT global damage database ([www.emdat.be](http://www.emdat.be), by country and peril)

cr\_country\_hazard\_test: given a country\_risk results structure, experiment with one country and hazard to test different damage function settings etc. Make your own copy before using this code, as you will need to edit it.

## Also useful

climada\_entity\_value\_GDP\_adjust: given an entity with assets for a country, adjust total asset value to represent country assets (a simple formula based on GDP and country development index).

climada\_damagefunctions\_plot: plot damage functions

climada\_create\_GDP\_entity: create an entity (asset distribution) based on night light intensity (climada module GDP\_entity).

# Appendix

## A. Calculation of economic damage in cr\_economic\_loss\_calc

Starting point for the economic loss calculation is damage(event\_i), i.e. the property damage calculated by climada\_EDS\_calc. The economic loss then also includes secondary losses to an economy including e.g. lost ouput, retail sales, wages, costs to business form rerouting goods and services around the affected area, reduced taxable receipts, etc.

The underlying rationale of the calculation is that a property damage resulting from a natural disaster does not have a major impact on a country's economy as long as the damage is small compared to the country's GDP, and as long as adequate financing and national resources exist. However, if a damage is big, it will be exacerbated depending on how well a country is "in shape" to deal with major shocks.

cr\_economic\_loss\_calc intends to estimate the economic damage as it manifests itself about 3-6 months after a disaster occurred. This first-round effect of natural disasters is usually that income and output (GDP) fall. What happens in the next round then depends on the way the country or region responds to the crisis. For example, Japan is a strong economy and has the resources to start rebuilding quickly, while smaller and badly managed countries such as Haiti can suffer severe long-term effects. It should be noted that cr\_economic\_loss\_calc only calculates the temporary dip following the first months after a disaster (see Figure).

After that initial dip, different scenarios can lead to no, positive or negative follow-on effects over the long run. In particular, a natural disaster can even positively affect total factor productivity, e.g. when it leads to the replacement of damaged, outdated production facilities and physical infrastructure with state-of-the-art facilities and infrastructure. However, as noted above, cr\_economic\_loss\_calc only deals with the calculation of the initial impact, not with the long-term scenarios.

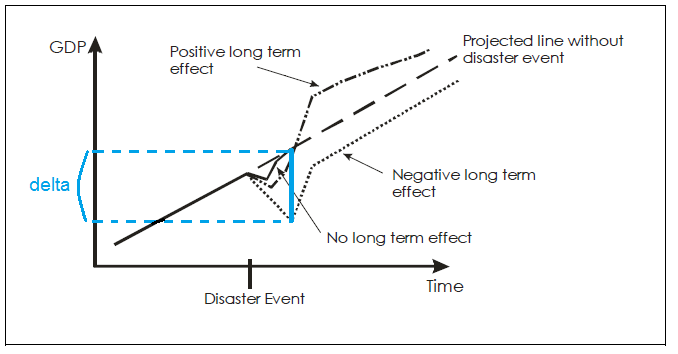


Figure: Possible trajectories of GDP after a disaster[[16]](#footnote-16). The delta is the initial temporary dip cr\_economic\_loss\_calc provides an estimate for.

In cr\_economic\_loss\_calc, the economic loss caused by the natural disaster is calculated according to:

**economic\_loss(event\_i) = damage(event\_i) \* loss\_multiplier**

where loss\_multiplier is defined by:

**loss\_multiplier =**   
**1 + cr\_get\_damage\_weight(damage(event\_i)/GDP) \* country\_damage\_factor**

with:

cr\_get\_damage\_weight: function that determines how much weight a damage should be given based on its ratio to GDP

country\_damage\_factor = 1/financial\_strength ...  
 + BI\_and\_supply\_chain\_risk ...

+ natural\_hazard\_economic\_exposure ...

– disaster\_resilience

Hence, country\_damage\_factor consists of four terms:

* financial\_strength measures a country's economic health and ability to finance the recovery.

financial\_strength = total\_reserves/GDP ...

+ insurance\_penetration ...

+ income\_group ...

- central\_government\_debt

* BI\_and\_supply\_chain\_risk measures a country's risk of disaster-related business and supply chain interruption

BI\_and\_supply\_chain\_risk = GDP\_industry ...

+ FM\_resilience\_index\_supply\_chain/100

* natural\_hazard\_economic\_exposure assesses which countries have a concentration of their total economic output exposed to natural hazards

natural\_hazard\_economic\_exposure = ...

1 - Natural\_Hazards\_Economic\_Exposure/10

* disaster\_resilience measures the quality of a country's natural hazard risk management, i.e., the country's "preparedness" to deal with the consequences of a disaster

disaster\_resilience = FM\_resilience\_index\_risk\_quality/100 ...

+ (global\_competitiveness\_index-1)/6

See economic\_indicators\_mastertable.xls (in the data folder of the country\_risk module[[17]](#footnote-17)) for more information on the four components of country\_damage\_factor (and their respective subcomponents).

1. I.e. the module allows the generate centroids and entities for each country on these (high) spatial resolution. [↑](#footnote-ref-1)
2. The routine climada\_country\_risk allows for processing a list or even all countries. As always, use e.g. help climada\_country\_risk to get a detailed description on the options. [↑](#footnote-ref-2)
3. See appendix for details on the calculation of economic loss based on the damages in the hazard event set. [↑](#footnote-ref-3)
4. See <https://github.com/davidnbresch/climada_module_GDP_entity> and further below for climada\_nightlight\_entity which allows to generate a high-resolution entity for any country and state/province. [↑](#footnote-ref-4)
5. Core climada contains the basic tropical cyclone hazard, but please add the module <https://github.com/davidnbresch/climada_module_tc_hazard_advanced> to generate useful probabilistic hazard event sets (see parameter probabilistic in country\_risk\_calc). Please consider to run climada\_tc\_get\_unisys\_databases (climada core) in order to download the latest tropical cyclone databases for all ocean basins (core climate comes with TC Atlantic to start with). [↑](#footnote-ref-5)
6. See climada module <https://github.com/davidnbresch/climada_module_tc_rain> [↑](#footnote-ref-6)
7. See climada module <https://github.com/davidnbresch/climada_module_tc_surge> which also requires the module <https://github.com/davidnbresch/climada_module_etopo> [↑](#footnote-ref-7)
8. See climada module <https://github.com/davidnbresch/climada_module_eq_global> [↑](#footnote-ref-8)
9. See climada module for European winter storm, which contains the hazard sets <https://github.com/davidnbresch/climada_module_ws_europe> [↑](#footnote-ref-9)
10. See e.g. the code climada\_cut\_out\_GDP\_entity from <https://github.com/davidnbresch/climada_module_GDP_entity> and also country\_admin1\_risk\_calc and climada\_nightlight\_entity further below (part of module country risk) [↑](#footnote-ref-10)
11. The report does contain the annual expected damage (ED) as well as defined return periods (such as 100 and 250 years). In case writing an Excel file fails, a .csv file is written. [↑](#footnote-ref-11)
12. Note that the number seven here corresponds to the 7th hazard analyzed (EQ). The report to stdout shows EQ as the first result, since country\_risk\_report sorts by descending damage, unless it is called with the second parameter (print\_unsorted) set to 1. [↑](#footnote-ref-12)
13. One can also run it at moderate (10x10km) resolution, see parameter selections, i.e. type help climada\_highres\_entity [↑](#footnote-ref-13)
14. The climada module country\_risk comes with the .mat file F182012.v4c\_web.stable\_lights.avg\_vis.mat (24MB), since the .tif image is about 700MB. See <http://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html#AVSLCFC3> to obtain the file <http://ngdc.noaa.gov/eog/data/web_data/v4composites/F182012.v4.tar> and unzip the file F182012.v4c\_web.stable\_lights.avg\_vis.tif in there to the /data folder of country\_risk module. As the .tif is so much larger, the climada module country\_risk comes with the .mat file, but does not contain the original (.tif). Should the .mat file not exist, climada\_nightlight\_entity creates it on first call. Please note that the GDP\_entity could also deal with such a high-res dataset (see respective documentation). [↑](#footnote-ref-14)
15. See footnote 8 above [↑](#footnote-ref-15)
16. Source: Hochrainer, 2006

    https://openknowledge.worldbank.org/bitstream/handle/10986/4162/WPS4968.pdf?sequence=1 [↑](#footnote-ref-16)
17. Download: <https://github.com/davidnbresch/climada_module_country_risk> [↑](#footnote-ref-17)