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Coastal Futures (CoFu) - An Interactive Viewer for 21st Century Projections of Coastal Climatic Impact-Drivers

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Abstract

The IPCC AR6 WGI[1] assessment states with high confidence that all coastal climatic-impact drivers (CIDs) assessed therein (i.e. Relative sea level, coastal flood and coastal erosion) will increase by mid-century in almost all regions of the world. This means that adaptation is now urgently needed to mitigate or reduce the climate change induced risks for coastal communities and assets. While local scale adaptation measures need to be informed by detailed local scale impact and risk assessments, available global data sets of CIDs are very useful for identifying global or regional hotspots of potential impacts. However, these data sets are produced by different organizations around the world and presented in many different studies, thus it is cumbersome to compare and contrast different projections. As a solution, Coastal Futures (CoFu), an interactive online viewer (*https://coastal-futures.org/*) is developed by IHE Delft, which for the first time, combines several published state-of-the-art data sets of 21st century projections of CIDs, including those assessed in IPCC AR6 WGI, for different time periods and climate scenarios. CoFu enables coastal scientists, engineers, planners, managers and policy makers to quickly see how coastal CIDs are projected to change worldwide. In addition, this viewer enables the dissemination of most recent scientific knowledge on CID projections to not only many different stakeholders interested in coastal safety, coastal developments and adaptation, but also citizens and especially the young generation to promote environmental awareness and understanding for a sustainable future. CoFu will be continually updated by adding more datasets as they become available.

Keywords: Coastal Futures; CoFu; Online viewer; Climate change; Climatic Impact-Drivers.

[1] IPCC AR6 WGI: The Intergovernmental Panel on Climate Change Sixth Assessment Report Working Group I

1. INTRODUCTION

This paper showcases the key functionalities of the Coastal Futures online viewer (CoFu) and describes the data sets included in this viewer, with their associated underlying assumptions and limitations. Figure 1 shows the graphical interface of CoFu and displays some example coastal climatic-impact driver (CIDs) data sets that are currently available in CoFu at different global and regional scales. CoFu enables users to zoom in at local areas of interest to view the projections closely.

Data sets currently included in CoFu are described in more detail in Section 2. These data include the coastal CIDs which are assessed in IPCC AR6 WGI, comprising: Regional sea level change, Coastal flooding, Shoreline change; as well as two additional variables contributing to AR6 coastal CIDs: Extreme sea level and Extreme waves. According to IPCC AR6, these coastal CIDs are projected to change in almost all regions of the world. These data are available in CoFu for different time periods and climate scenarios, while only median values are shown in the viewer.

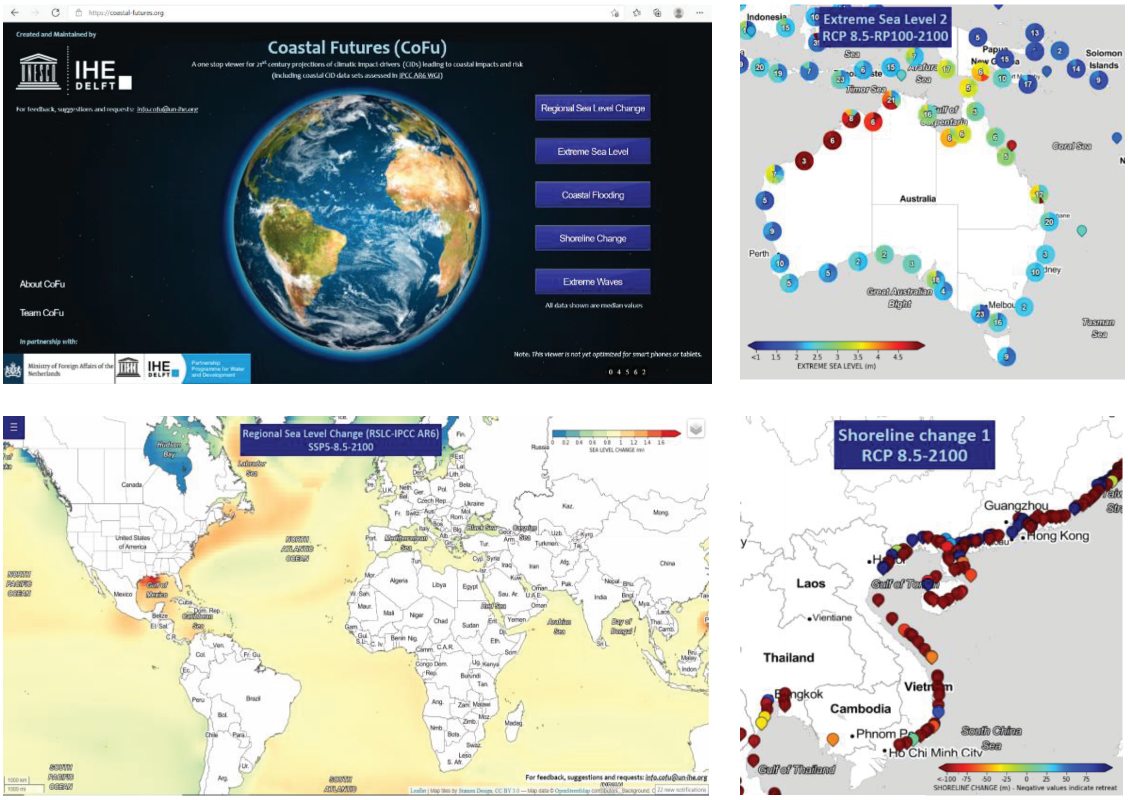

Figure 1. Graphical interface of Coastal Future (CoFu) viewer (Top, left). Examples of median projections for selected coastal climatic impact-drivers (CIDs) for the high end scenario RCP8.5/SSP5-8.5 at the end of 21st century: Regional Sea Level Change (Bottom, left – Global); Extreme Sea Level (Top, right – Australia) and Shoreline Change (Bottom, right – Vietnam).

2. DATA SETS

This section describes the aforementioned five data sets currently available in CoFu, with their original sources, and their key underlying assumptions and limitations. Table 1 below presents an overview of CoFu data sets.

2.1 Regional Sea Level Change

The Regional Sea Level Change (RSLC) projections shown in CoFu are the future projections from IPCC AR6 WG1 Chapter 9 (Fox-Kemper et al., 2021). These projections (unit: m) are relative to the AR6 baseline period 1995-2014. CoFu shows these projections for five illustrative emissions scenarios which describe the socio-economic trends underlying the scenario, including (from “very low” and “low”, to “intermediate”, and to “high” and “very high” GHG[2] emissions scenario): SSP1-1.9; SSP1-2.6; SSP2-4.5; SSP3-7.0; and SSP5-8.5[3]; and corresponding for two future periods: 2050 and 2100. These regional changes in relative sea level projections partially account for vertical land motion (uplift or subsidence) and is projected in AR6 to be within ± 20% of the global mean sea level rise along approximately two-thirds of the global coastline.

2.2 Extreme Sea Level

CoFu contains 3 different data sets for Extreme Sea Level (ESL) (unit: m), which are named in CoFu as ESL1; ESL2 and ESL3. Factors contributing to extreme sea levels (ETWL) are sea level rise, tide, storm surge (e.g. associated with tropical cyclones and extra-tropical cyclones), and waves (resulting in high wave setup at the shoreline). Both ESL1 and ESL2 are shown for 2 GHG emissions scenarios (RCP4.5 and RCP8.5), for middle and end of this century (i.e. 2050 and 2100 respectively). ESL3 shows ESL projections under 5 different global warming levels (GWLs): 1.5^{o}C; 2^{o}C; 3^{o}C; 4^{o}C; 5^{o}C (relative to pre-industrial temperatures). All 3 data sets provide baseline values and projections for various return periods including: 1 in 1-year, 1 in 10-year and 1 in 100-year.

The ESL1 data set is derived from Vousdoukas et al. (2018) for approximately 5000 points distributed along the world’s coastline at the resolution of ~100 km. CoFu displays this data set for both present (1980-2014) and future periods 2050 and 2100. The future projections of ESL1 data employ Relative sea level rise projections based on IPCC AR5, and is the only data set that includes future changes in climate extremes (storm surge and waves) in future projections of ESL1. This study projects an increase of the global average 100-year ESL of 34-76 cm and 58–172 cm under RCP4.5 and RCP8.5 by 2100 (relative to 1980 – 2014) respectively.

The ESL2 data in CoFu is from Kirezci et al. (2020), which is also the driver for coastal flooding in section 2.3 below. These ESL2 future projections are constructed using IPCC AR5 GMSLR projections. Unlike ESL1, this ESL2 dataset is stationary, in that it does not include future changes in storm surge and waves in its future ESL projections.

The ESL3 data set is obtained from Tebaldi et al. (2021). This ESL dataset provides ESL stationary projections for different global warming levels (ranging from 1.5^{o}C to 5^{o}C), rather than for different emissions scenarios, which is inline with the focus of the Paris agreement on global climate mitigation policy to limit the global warming above pre-industrial levels. These ESL projections are based on IPCC AR6 SLR projections and built upon the present-day ESL of the 2 above mentioned studies (ESL1 and ESL2) and ESLs observed at the global tide gauge network. The study shows that even under the strong mitigation 1.5°C of warming level scenario, about half of the total of more than 7500 locations considered here will experience the present-day 100-year ESL event at least once per year by the year 2100.

2.3 Coastal Flooding

The Coastal Flooding (CF) data shown in CoFu is derived from Kirezci et al. (2020), for a total 9,866 points along the global coastline defined previously in the Dynamic Interactive Vulnerability Assessment database (DIVA) (Hinkel et al., 2009). This episodic coastal flooding results from extreme sea levels (ESL2), which consist of tide, storm surge, wave setup and sea level rise; and are used with the global topographic data Multi-Error-Removed Improved-Terrain DEM (MERIT DEM) at 1 km resolution (Yamazaki et al., 2017), to assess the potential flooding using the “bathtub” approach. This flooding data set does not account for existing or future artificial flood defenses, or in other words, it assumes that there is no coastal protection and adaptation measures. As such, the flood extent is likely to be overestimated especially in locations where flood defenses are currently present (or will be constructed in future). This data set provides first-order assessments of global flooding with the emphasis on the relative changes in flood estimations. CoFu shows these flooding results, in terms of flood extent and flood depth (in m), for both baseline (1979-2014) and future periods (2050 and 2100), for different return periods: 1-year, 10-year and 100-year. These flooding projections employ the previous AR5[4] Global mean SLR (GMSLR) projections (Church et al., 2013) for 2 future scenarios: the moderate-emission mitigation-policy scenario - RCP4.5[5] and high-emissions scenario - RCP8.5. This study shows that the frequency of occurrence of the present day 1 in 100-year coastal flooding event could increase significantly to a 1 in 10-year event by 2100 in most of the world, mainly due to SLR.

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[2] GHG: greenhouse gas
[3] SSP: Shared Socio-economic Pathway
[4] AR5: IPCC Fifth Assessment Report
[5] RCP: Representative Concentration Pathway

2.4 Shoreline Change

The Shoreline Change (SC) data set shown in CoFu is from Vousdoukas et al. (2020) for global sandy coasts, coverimg more than one-third of the global ice-free coastline. The spatial resolution of this dataset is 500 m along the world's sandy coastlines. These projections combine ambient shoreline dynamics (retreat or progradation), which is driven by long-term hydrodynamic, geological and anthropogenic factors, and the potential for future shoreline retreat due to SLR, computed here using a modified Bruun Rule. This data set employs regional relative sea level rise projections that are based on IPCC AR5. Future projections of shoreline change also includes the future ambient shoreline change, which is assumed to follow the historical trend and is extrapolated into the future. This data set also assumes that there are no physical obstructions to shoreline retreat or any additional sediment sources or sinks in the future. The projections show that almost half of the world's sandy coastlines could experience retreats exceeding 100m (relative to the 2010 shoreline position) by the end of the century. CoFu shows these shoreline change projections for 2050 and 2100, relative to 2010, and for 2 climate scenarios RCP4.5 and RCP8.5. These data are in meters, with negative values indicating retreat and positive values indicating progradation.

2.5 Extreme Waves

The Extreme Waves (EW) dataset (Meucci et al., 2020) employs IPCC AR5 surface winds from various Global Climate Models (GCM) surface winds that are part of the International Coupled Model Intercomparison Project 5 (CMIP5). These wind projections are used in Meucci et al (2020) as inputs for an intermodel ensemble of seven global wave model runs. Changes in extreme wave conditions may have an impact on shoreline erosion and coastal flooding along the world's coastline. For displaying on CoFu, the data point locations along the global coast were determined by assigning the results at the closest model point to the relevant coastal segment, resulting in 8390 locations along the global coastline. It should be noted that this global scale wave model application does not account for nearshore processes such as refraction and shoaling. These extreme wave projections are available in CoFu for the baseline period (1979-2005) and for 2100. For future projection, estimates are only available for the high-end scenario RCP8.5. For each time line and each future scenario, CoFu shows values for the 1 in 50-year and 1 in 100-year event. This study shows that the magnitude of a 1 in 100-year significant wave height event will increase by 5 to 15% over the Southern Ocean by the year 2100 compared to the present period. And along the world's coastline, it is estimated that about 59% of the global coast are projected to experience an increase in extreme wave conditions by the end of the century, under RCP 8.5.

Table 1. List data sets currently available in CoFu.

VARIABLE	BASELINE	FUTURE	SCENARIO	RETURN PERIOD (-YR)
REGIONAL SEA LEVEL CHANGE (RSLC)	1995-2014	2050, 2100	SSP1-1.9 SSP1-2.6 SSP2-4.5 SSP3-7.0 SSP5-8.5	-
EXTREME SEA LEVEL (ESL)				
ESL1	1980-2014	2050, 2100	RCP4.5 RCP8.5	1, 10, 100
ESL2	1979-2014	2050, 2100	RCP4.5 RCP8.5	1, 10, 100
ESL3	Present	2100	1.5°C 2°C 3°C 4°C 5°C	1, 10, 100
COASTAL FLOODING (CF)	1979-2014	2050, 2100	RCP4.5 RCP8.5	1, 10, 100
SHORELINE CHANGE (SC)	2010	2050, 2100	RCP4.5 RCP8.5	-
EXTREME WAVES (EW)	1979-2005	2100	RCP8.5	50, 100

3. COFU PLATFORM DESCRIPTION

Two types of geographical information were used in CoFu platform. Raster-type information was used in Regional Sea level Change and Coastal Flooding maps while vector data was implemented in the Extreme Sea Level, Shoreline Change and Extreme Waves maps. Raster data files were used to create XYZ tiles to improve user experience, as information is loaded regarding user requirements. Likewise, vector data points are grouped in clusters for the largest spatial scales and related visually with colorbars. This allows a user-interface enhancement, as the spatial distribution of the information (continent and global scales) may overload visual information. Within the maps, visualization tools, the JavaScript library Leaflet (Agafonkin, 2010; 2022) and its Python user interface, Folium (Folium, 2013; 2022) were used. Additionally, interactive scenario/time comparison charts were included in some data sets when analyzing RCP scenarios, return periods and time periods. Users data requests and server responses were managed through a NGINX server, where all data sets and visualization scripts were incorporated. A general representation of the user-server process is illustrated in Figure 2.

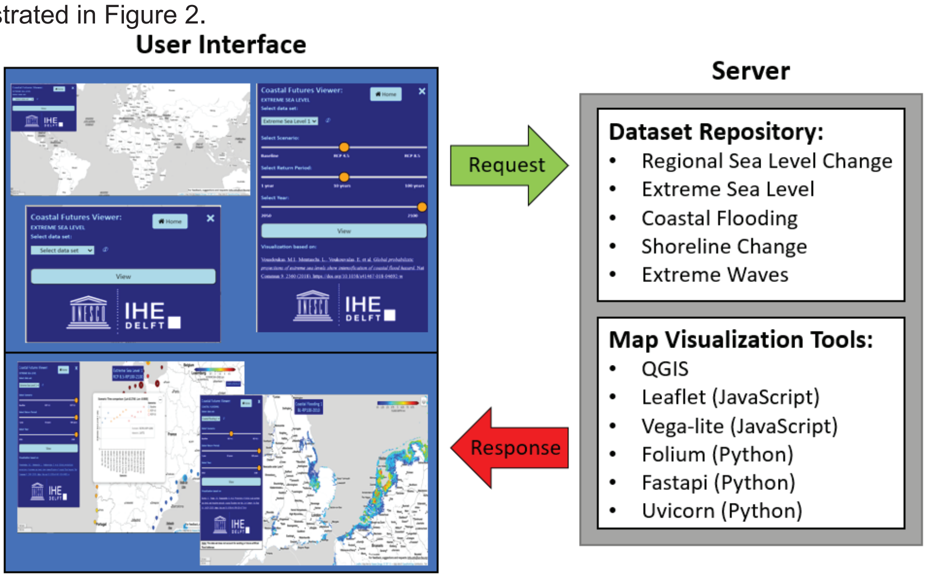

Figure 2. CoFu user interface and server interaction scheme.

4. CONCLUDING REMARKS

Coastal Futures (CoFu) is a one stop viewer for 21st century projections of climatic impact-drivers (CIDs) (including coastal CID data sets assessed in IPCC AR6 WGI) leading to coastal impacts and risk. This viewer gives overall impressions of various coastal hazards at different spatial scales from global to regional scale. The CoFu team intends to keep the viewer up-to-date by adding more and more open-access data sets as they become available, with the expectation that these free, centralized availability of multiple coastal CID projections will be of benefit for many different stakeholders interested in coastal safety, coastal developments, and adaptation. We invite current and new users of CoFu to contact us at (*info.cofu@un-ihe.org*) with any specific requests or constructive feedback and suggestions.

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