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Effects of Climate Change on Buildings and Neighborhoods

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Research Project TABFGR0096

Introduction

Climate change poses non-negligible risks to the built environment. Global warming and the consequent changes in climate system, e.g., heat waves, extreme rainfall, windstorms and floods are increasingly affecting the safety and resilience of the built environment, entailing adverse risks posed to human individuals and the general public. Aiming at mitigating these risks, the goal of this research group was to analyze the effects of climate change on buildings and civil infrastructure, and to develop sustainable measures towards structural adaptations of the built environment against the impacts of the changing climate. Emphasis was put on adaptations with respect to static and dynamic behavior, thermal comfort, and energy efficiency of residential and industrial buildings.

Figure 1. Excessive snow-storm in Weimar, January 2021 *(photo by M.Sc. Peshawa L. Hasan)*

Figure 2. Flood damage in the Ahr valley, July 2021 *(photo by Dr. Holger Maiwald)*

Non-Stationary Climate Extremes

Climate change generally refers to the substantial variation of long-term atmospheric climate. Global warming induced by human activity has raised the global average temperature reaching to approximately 1°C above pre-industrial levels in 2017 [1]. This change in climate is causing changes in the frequency, intensity, spatial extent, and duration of climate extremes. The changes in extremes can be linked directly to the changes in mean climate because the mean future projection of certain climate variables tend to lie within the tails of present-day conditions. The anticipated increase in climate extremes will consequently lead to greater exposure of the structural reliability, usability, and load-carrying capacity and therefore, the non-stationarity must be considered for realistic impact studies.

Figure 3. Setup of the measurement system in Plauen, February 2022

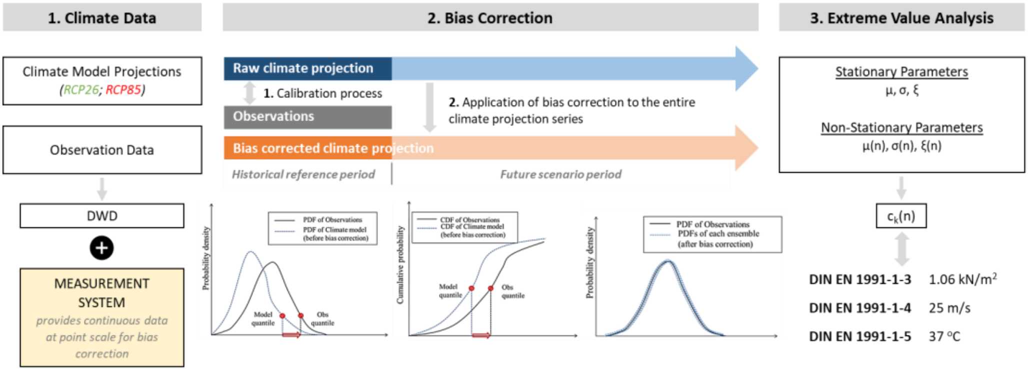

Figure 4. Methodology for the data collection, bias-correction and non-stationary extreme value analysis

Climate Model Projections

To quantify the influence of climate change, the use of climate model projections from appropriate regional climate models becomes inevitable. The climate model projections are obtained from ReKliEs-DE which provides evaluations for Germany and the river catchment areas draining into Germany.

Scenario	GCM/RCM	CLM 4-8-17	REMO 15	WETTREG 13
RCP26	EC-EARTH	ECE_CLM	ECE_REM	
	HADGEM2-ES		HG2_REM	
	MPI-ESM-LR	MPI_CLM	MP1_REM MP2_REM	MPI_W13
	MIROC5		MI5_REM	
	IPSL-CM5-LR		IP5_REM	
RCP85	MPI-ESM-LR	MPI_CLM	MP1_REM MP2_REM	MPI_W13
	HADGEM2-ES	HG2_CLM	HG2_REM	HG2_REM
	EC-EARTH	ECE_CLM	ECE_REM	ECE_W13
	CAN-ESM	CAN_CLM	CAN_REM	CAN_W13
	MIROC5	MI5_CLM	M15_REM	MI5_W13

Table 1. List of climate model projections considered for analysis [2]

Measurement System

- Produces long-term measurement record of climate variables for the bias-correction of climate model projections at a point-scale.
- Monitor loads on the structure resulting from a storm event.

Extreme Value Analysis

Stationary characteristic value c_k : $F[X \leq x] = 0.98$ *(constant distribution - observation data)*

Non-stationary characteristic value c_k : $F[X \leq x] = 0.98$ *(varying distributions – "t-years" moving data subsets)*

Life-time "n-year" non-stationary characteristic value $c_k(n)$: $\prod_1^n p = (0.98)^n$ *("n-year" window of non-stationary $c_k(n)$)*

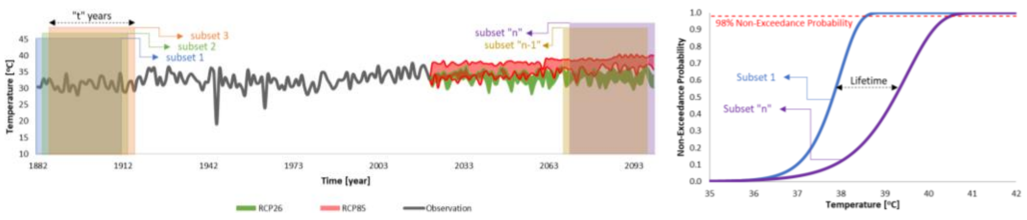

Figure 5. Non-stationary extreme value analysis of climate extremes. The non-stationarity is derived from sliding data subsets of length equal to "t-years"

Conclusion

The potential impacts of climate change on the characteristic values of climatic actions vary considerably from one region to another. It is virtually certain that the temperature loads will increase in the near future. E.g., for Plauen, the structural components designed according to DIN EN1991-1-5 will experience higher demand loads onset of summer 2025 reaching to approximately +4°C by the end of this century. The snow loads will consequently decrease, leading to higher precipitation loads. There is little evidence of changes in the 10-minute mean wind speed. However, the 3-seconds gust wind shows a substantial increase in the frequency and intensity for velocities greater than 28m/s. The consequences of climate change must be estimated through the reliability analysis of a structure and its components. The estimation of characteristic values only serves as a starting step for such analysis.

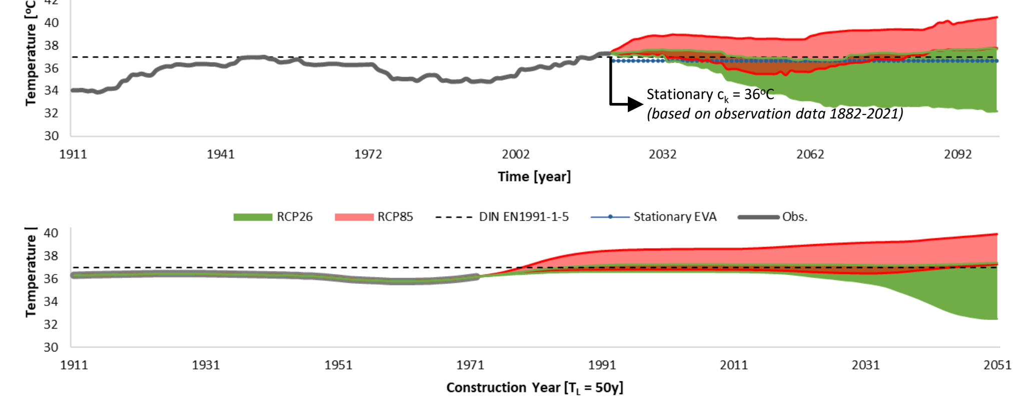

Figure 6. Projected non-stationary characteristic values and optimized lifetime characteristic values of the maximum temperature in Plauen, Germany

References

[1] Allen, M. R., et al. (2018). Framing and Context. In: Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-Industrial Levels. 49-91

[2] Hübener, Heike, et al. (2017). The Project ReKliEs-De: Complementing EURO-CORDEX with high-resolution dynamical and statistical simulations.

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