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Impact of Climate Change on Intensity-Duration-Frequency (IDF) Curves

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Abstract: Climate change is one of the primary causes of variation in global weather patterns, including those of rainfall frequency and intensity. Due to this, there is an urgent requirement for updated strategies regarding the design and management of urban infrastructures based on reliable IDF curve estimations. The review paper aims at assessing the impact of climate change on IDF curves, the methodological approach for updating IDF curves, and the consequences for urban flood management.

This paper synthesizes recent literature to provide an overview of how climate-induced changes in precipitation patterns call for a paradigm shift in the use of IDF curves.

Keywords: IDF curve, climate change, GCMs, designing stormwater systems.

I. INTRODUCTION

One of the most important tools in hydrology and the field of urban planning is the IDF curve, since it models the probability of rainfall for various intensities and frequencies over different durations.

Traditionally based on historical precipitation data, such curves are crucial in designing stormwater systems, drainage infrastructure, and flood protection measures. However, with the intensification of climate change, traditional IDF curve assumptions are increasingly being challenged. This paper examines the impact of climate change on IDF curves and focuses on the level of changes expected in the near future that need to be put in place to ensure that urban infrastructure remains resilient to climate conditions.

II. UNDERSTANDING IDF CURVES

A. Traditional Construction of IDF Curves

IDF curves are normally developed based on historical rainfall records, using statistical approaches such as the generalized extreme value distribution to infer probabilities of various rainfall intensities for different durations. Construction of such curves is central in deriving a design storm, becoming indicative of the capacity requirements for stormwater management systems.

B. Assumptions and Limitations

Traditional methods of IDF curve development implicitly adopt stationarity-a concept implying that climate variables vary within a constant envelope over time. This assumption has turned increasingly problematic given accelerating changes in precipitation patterns under climate change. Non-stationarity in climate does indeed heighten the need to reconsider how IDF curves are developed and used.

III. IMPACT OF CLIMATE CHANGE ON PRECIPITATION PATTERNS

Climate change is one of the factors leading to an increased frequency and severity of unusual weather events, such as heavy rainfall, due to rising temperatures around the world. The higher the temperature is, the more moisture it is able to accommodate; hence, if conditions allow it, it will rain heavier.

A. Changes in Rainfall Intensity

Global warming is expected to intensify the rainfall in a short period of time (Allan & Soden, 2008). The Earth's atmosphere can hold, due to each degree of warming, 7% more moisture that results in greater extremity and frequency in the precipitation events (Trenberth, 2011).

B. Changes in Rainfall Duration and Frequency

Climate change is also affecting the frequency and duration of rainfall events. Some areas show evidence of more frequent short-duration intense storms, while others have a total annual rainfall concentrated into fewer more intense events (Knutson et al., 2020).

IV. UPDATING IDF CURVES FOR A CHANGING CLIMATE

Given the many changes occurring in terms of rainfall patterns, for example, it will be necessary to update IDF curves to reflect these new realities. Several methods have been proposed for incorporating climate change projections into IDF curve development.

A. Incorporating Climate Models

One thinks of using the outputs of climate models, such as GCMs and RCMs, for projecting future precipitation scenarios (Kendon et al., 2014). These models can simulate how precipitation patterns might change under different greenhouse gas emissions scenarios, thereby providing a basis for updating IDF curves.

B. Non-Stationary Approaches

Other methods involve the use of non-stationary statistics, which explicitly include trends and variability in the precipitation record with time (Mailhot & Duchesne, 2010). Such non-stationary techniques enable direct consideration of the effects of climate change in the development of IDF curves, rather than by assuming stationarity of climate.

C. Hybrid Methods

Hybrid methods combine historical data with climate model projections to create IDF curves that account for both past and future conditions. This could help establish a more comprehensive view of the possible flood risks due to changing climate conditions (Arnbjerg-Nielsen et al., 2013).

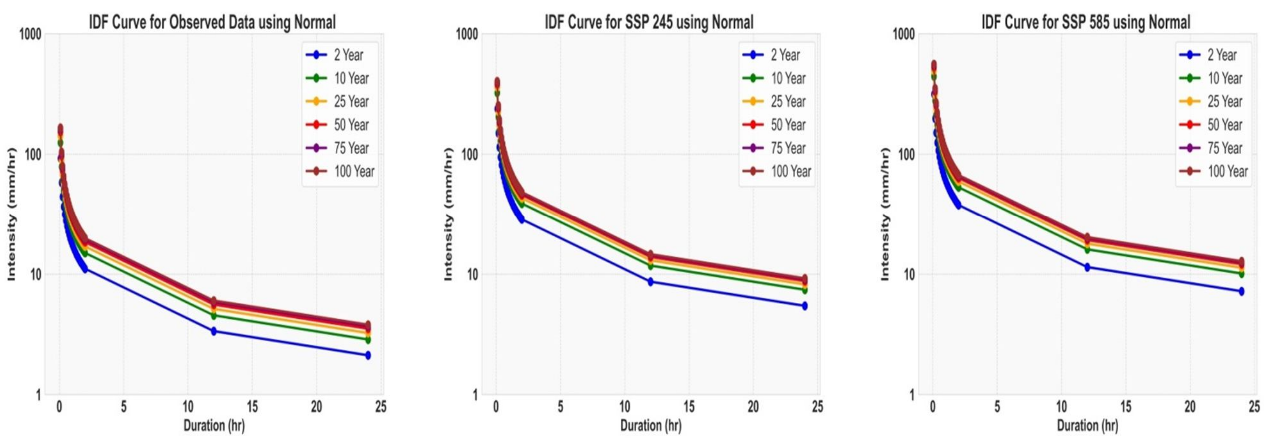

Figure 1 IDF Curve utilizing the Log Normal for Observed Data, SSP245, and SSp585

V. IMPLICATIONS FOR URBAN FLOOD RISK MANAGEMENT

The implication for the update of IDF curves in respect to urban flood risk management is immense. In this regard, infrastructure that may have been designed from outdated IDF curves may prove inadequate in light of an increased flooding risk caused by climate change.

A. Infrastructure Resilience

This will necessitate the re-design or retrofitting of urban infrastructures, such as those for stormwater management and flood protection, in order to deal with enhanced rainfall event intensities and frequencies (Watts et al., 2015). More specifically, it entails upgrading drainage capacity, enhancing floodplain management, and incorporating green infrastructure to better absorb excess runoff.

B. Policy and Planning Considerations

However, this requires adaptation on the part of policy makers by updating building codes, zoning regulations, and policies related to the management of flooding in response to a new reality brought on by climate change with regard to shifting precipitation patterns (Galloway et al., 2018). Ensuring that new development is resilient to future climate conditions is critical in reducing long-term risks from urban flooding.

VI. CASE STUDIES

A. Case Study 1: Copenhagen, Denmark

It has also adopted updated IDF curves based on the projections from the regional climate models, and Copenhagen has invested majorly in green infrastructure and stormwater management systems designed to handle more intensive rainfall. (Arnbjerg-Nielsen et al., 2013).

B. Case Study 2: Toronto, Canada

Similarly, Toronto has updated its IDF curves using non-stationary methods and, as such, has increased the number of floodplain controls and constructed new stormwater management facilities to deal with the increased flood risk (Mailhot & Duchesne, 2010).

VII. CONCLUSION

The impact on IDF curves due to climate change is immense, and it does indeed require a rather radical rethink in the ways these crucial tools are produced and used in urban planning and management of flood risks. Traditional IDF curves, based on historical precipitation data, have become increasingly insufficient in view of the intensification and alteration of rainfall brought on by climate change. The standard assumption of stationarity, which would project conditions from past data, is no longer valid under climate change due to the increasing frequency and intensity of extreme events. The future challenges are to update IDF curves for the future climate scenarios, incorporating the projections by climate models, together with using non-stationary statistical methods that take into account changes in precipitation patterns and variability. Under these updated IDF curves, cities can be better prepared for a rise in risks. This proactive approach allows for the better design and retrofitting of a system of stormwater management in enhancing urban resilience and reducing its vulnerability to flooding. The implications of such changes go beyond infrastructure design alone. For example, there is the need for urban planners and policymakers to update building codes, land-use regulations, and policies related to flood management in accordance with new realities of increased rainfall events. It will involve adaptive approaches like using green infrastructure that could help manage excess runoff and mitigate flood risks. The formulation and appropriate use of these new IDF curves are a combined effort from scientists, engineers, and policy makers. Further research must be constantly done in updating climate models and methods and in studying the impacts of climate change on hydrological patterns. Providing substantial interdisciplinary collaboration and significant resources toward quality data collection and analysis are how decision-makers can ensure that urban infrastructure continues to function well within a changing climate. In all, the challenge of climate change to IDF curves underlines the need to adopt dynamic and forward-looking perspectives in managing urban flood risks. Cities can thus improve their preparedness and resilience through continuous research, updated methodologies, and collaborative effort for the protection of communities against extreme weather risks in evolution.

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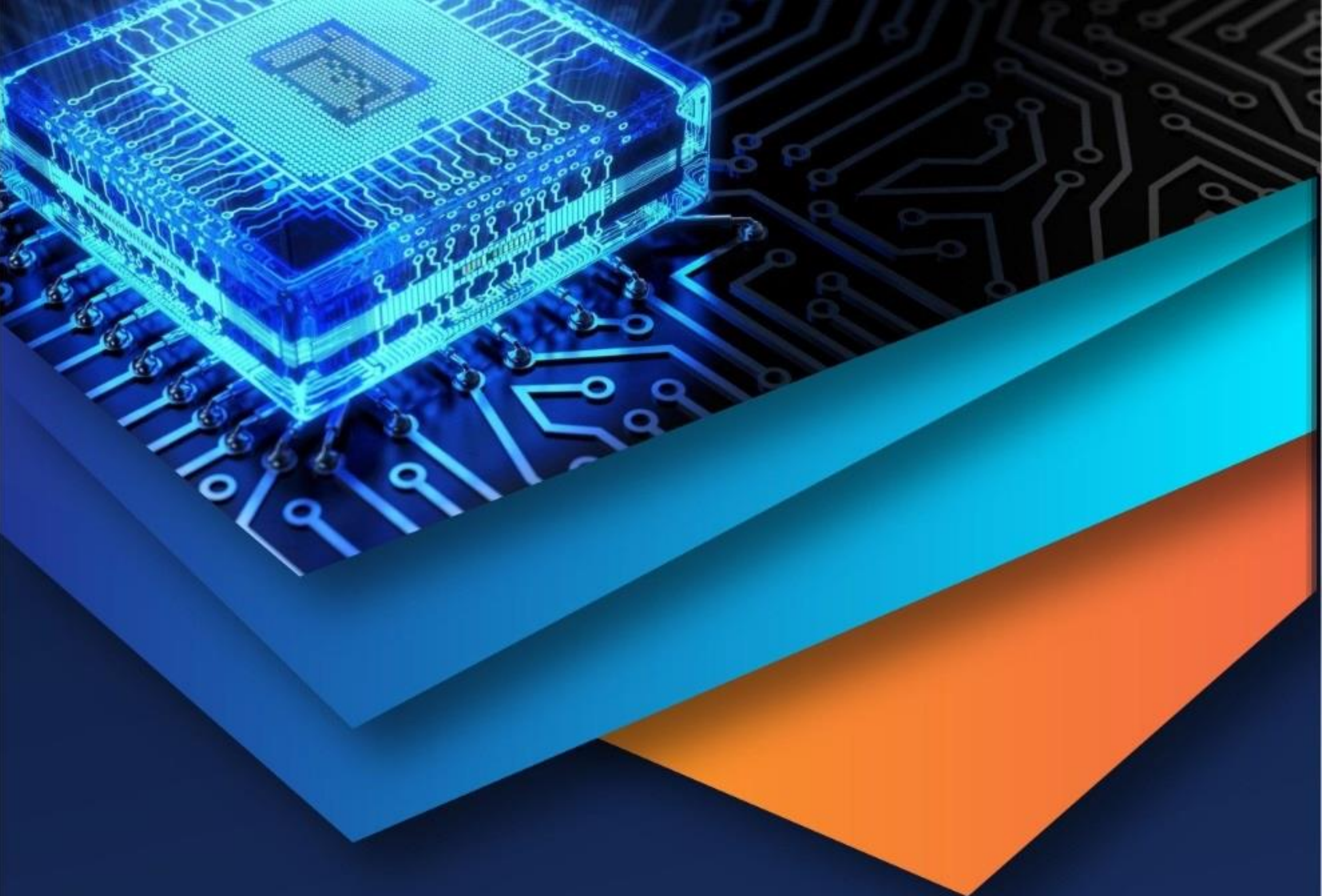

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