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Changing Patterns of Intense Rainfall and Flood Risk under Climate Variability: A Global Review with Implications for Regional Frequency Analysis

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Abstract- Floods are the most common natural disaster associated with our changing climate, accounting for more than 40% of all weather-related events worldwide. Since 2000, they have affected over 1.6 billion people. As the planet warms, the global water cycle is intensifying, resulting in heavier and more frequent downpours that cover wider areas, particularly in tropical and monsoon regions. At the same time, social and economic factors such as rapid population growth, unplanned urban expansion, changes in land use, and weak local institutions have made communities more susceptible and vulnerable to floods. These issues have also led to significant differences between regions in the severity of floods and their preparedness to handle them. This paper presents a global perspective on the evolving patterns of heavy rainfall and flood risks, with a focus on variations across Asia, Africa, Europe, and North America. It also explores how natural climate patterns like El Niño and La Niña (together known as ENSO), the Indian Ocean Dipole (IOD), and the Atlantic Multidecadal Oscillation (AMO) influence flood risks over periods ranging from a few years to several decades. These natural influences make it hard to rely on the old assumption that flood patterns stay constant over time. This creates challenges when estimating design floods or predicting the frequency of extreme floods, especially in areas with limited data or highly variable weather conditions. The review also examines the implications of these changes for measuring and understanding flood risk. It emphasizes the importance of using reliable statistical methods, such as Trimmed L-moment-based Regional Frequency Analysis (RFA), to obtain more accurate results. By being less affected by outliers and allowing data to be shared across regions, these methods offer a helpful way to make estimates of extreme rainfall and flooding more reliable. This helps improve planning and supports stronger, climate-resilient flood-risk management in a changing world. This review does not introduce any new statistical methods. Instead, it synthesizes existing research to explain when and where strong regional frequency approaches are most effective in a climate that's no longer stable or predictable.

Keywords: Flood risk; Climate variability; Regional frequency analysis; Trimmed L-moments; Disaster preparedness.

I. INTRODUCTION

Global Overview of Flood Risk under a Changing Climate

Floods are the most common and destructive climate-related disasters worldwide, making up more than 40% of all weather- and climate-driven events and affecting over 1.6 billion people since 2000. In recent decades, the damage caused by floods has increased sharply, driven by both climate change and rapid social and economic developments (Zhao et al., 2024). To truly understand these patterns, we need an approach that considers both climate-related and human-driven factors behind flood risk.

In this framework, shifts in heavy rainfall primarily influence the hazard itself, while factors such as population growth, urban expansion, and land-use changes increase people's exposure to floods. At the same time, factors such as government strength, institutional capacity, and overall socio-economic conditions determine the vulnerability of communities when floods occur. The growing flood losses observed worldwide are not solely the result of heavier rainfall; they also reflect how human activities and weak institutions have exacerbated overall flood risk (Adjaison et al., 2025).

From a climate perspective, there is strong evidence that global warming has intensified the water cycle, resulting in more frequent and intense heavy rainfall events in many parts of the world. Warmer air can hold more moisture, so when the right conditions for storms develop, the resulting rainfall tends to be heavier (Faghfouri et al., 2023). This effect is especially noticeable in tropical and monsoon regions, where short bursts of heavy rain often trigger river floods and flash floods. These shifts are pushing the most extreme rainfall events even further into record-breaking territory, directly raising the risk of flooding.

At the same time, an increasing number of people and assets are being exposed to these hazards, particularly in developing and rapidly growing urban areas. Population growth and economic expansion have drawn communities, infrastructure, and critical resources into flood-prone areas, such as river valleys, coastal zones, and low-lying deltas (Becker et al., 2024). Rapid urbanisation also changes how water behaves: paved surfaces prevent infiltration, water runs off more quickly, and flood peaks become higher even during storms that would not have caused flooding in the past. As a result, today's rainfall events can lead to much greater flood impacts than similar ones a few decades ago.

Vulnerability further shapes how these hazards and exposures translate into real flood risk. Areas with weak institutions, limited early warning systems, poor infrastructure, and high poverty levels tend to suffer the most, even when rainfall intensities are similar to those in wealthier regions. In contrast, countries with strong governance, well-managed floodplains, and resilient infrastructure can often limit the damage, even in the face of severe rainfall. These differences underscore the profound global disparities in how floods impact people and places worldwide.

This paper presents a global perspective on the evolving patterns of heavy rainfall and flood risks, with a focus on variations across Asia, Africa, Europe, and North America. It also examines how natural climate patterns, such as El Niño and La Niña (collectively known as ENSO), the Indian Ocean Dipole (IOD), and the Atlantic Multidecadal Oscillation (AMO), influence flood risks over periods ranging from a few years to several decades. These natural variations challenge the long-held assumption that flood patterns remain constant over time, making it harder to estimate how often extreme floods occur, especially in regions with limited data or unpredictable weather.

The review also examines what these changes mean for measuring and understanding flood risk. It emphasizes the importance of using reliable statistical methods, such as Trimmed L-moment-based Regional Frequency Analysis (RFA), to produce more accurate estimates. By being less affected by outliers and allowing data to be pooled across regions, these methods help improve the reliability of rainfall and flood assessments under changing climate conditions. This, in turn, supports stronger, climate-resilient flood-risk management.

Rather than introducing new statistical tools, the review synthesizes existing research to clarify when and where these robust regional methods are most effective in a climate that is no longer stable or predictable.

Altogether, these interacting factors indicate that the growing global flood problem is not solely a result of climate change. It is the result of several forces working together: more substantial and frequent rainfall, an increased number of people and assets at risk, and significant differences in the vulnerability of regions based on their economic and social conditions. This mix of influences makes flood risk highly complex, highlighting the need for analytical methods that can handle both climate variability and structural uncertainty (Xu et al., 2023). Such approaches are crucial when translating observed changes in extreme rainfall into practical measures, such as design floods or return levels, that engineers and planners can effectively utilize.

II. REGIONAL PATTERNS OF FLOOD RISK AND PREPAREDNESS

Regional disparities in flood preparedness stem from the complex interplay among hydroclimatic variability, governance capacity, and socio-economic vulnerability. These factors collectively shape the relative influence of hazard, exposure, and vulnerability on overall flood risk. Because the nature of these interactions varies considerably across regions, substantial contrasts emerge in both the magnitude of flood impacts and the adaptive capacities of societies worldwide(Mishra et al., 2022). In regions undergoing significant shifts in rainfall patterns, most notably in South and Southeast Asia, flood risk is particularly influenced by the dynamics of the seasonal monsoon. Intense and recurrent monsoon rains significantly heighten flood hazards, leading to frequent occurrences of both riverine and urban flooding (Kuntla et al., 2025).

In response, substantial investments have been made to enhance flood forecasting, early warning systems, and structural measures, including embankments and urban drainage infrastructure. Despite these efforts, flood preparedness remains highly uneven within many countries. Densely populated urban centres with significant economic importance often receive greater attention and resources, benefiting from advanced drainage networks, flood retention systems, and technologically sophisticated warning mechanisms. In contrast, rural areas frequently lack sufficient infrastructure, emergency response capacity, and access to timely information, leaving these communities disproportionately vulnerable to flood impacts (Bradley, 2025).

Governance capacity plays a critical role in shaping regional preparedness and determining flood outcomes. Countries with well-established disaster risk management frameworks, clearly defined institutional roles, and long-term financial commitments, such as Japan and the Netherlands, have developed robust flood defense systems, regular risk assessments, and community-based preparedness programs (Shamsuzzoha et al., 2025). These initiatives have substantially reduced flood-related mortality and economic losses, even in areas with high exposure levels. By contrast, many low-income countries and regions affected by political instability face persistent challenges, including under-resourced emergency management institutions, weak enforcement of land-use regulations, and limited integration of flood risk into spatial planning. These shortcomings often lead to unregulated settlements in flood-prone zones, poorly maintained drainage systems, and inadequate evacuation planning, thereby exacerbating overall vulnerability.

Socio-economic conditions further intensify disparities in flood risk and preparedness. Communities with limited livelihood diversity, low insurance coverage, and restricted access to financial resources often lack the capacity to recover effectively after flood events. This limited resilience traps them in a recurring cycle of loss and poverty (Meijering et al., 2022). Climate change compounds these challenges by increasing the frequency and severity of extreme rainfall, placing even greater pressure on already strained adaptive systems. Addressing these inequalities requires targeted investments in flood-resilient infrastructure and early warning mechanisms, stronger institutional frameworks, inclusive land-use planning, and sustained efforts to build long-term community resilience (Kumaresen et al., 2025).

Comparative assessments further highlight the depth of these regional contrasts. Europe and North America generally maintain near-universal coverage of early warning systems and strong institutional capacity, which, despite high exposure levels, help limit disaster-related losses. In contrast, large parts of South Asia and Africa are characterised by limited early warning coverage and weaker institutional frameworks; when coupled with high exposure, these deficiencies lead to disproportionately severe flood impacts (Islam et al., 2025). These global disparities underscore the urgent need for capacity building and greater investment in early warning systems, governance structures, and institutional coordination in low-income and high-risk regions.

Taken together, these regional contrasts illustrate that global flood risk emerges from diverse combinations of hazard, exposure, and vulnerability. Asia is marked by extreme hydroclimatic hazards and rapidly increasing exposure; Africa is characterized by high vulnerability compounded by data scarcity; and Europe and North America are distinguished by strong institutional capacity that mitigates vulnerability despite high exposure. These distinctions highlight the need for flood-risk estimation methods that are adaptable to varying climatic regimes and uneven data availability. In this context, regionally pooled and statistically robust approaches such as Regional Frequency Analysis are particularly valuable for generating consistent design estimates across heterogeneous environments.

Asia

Asia is the most flood-affected continent globally, accounting for more than 60% of all recorded flood impacts worldwide (M. Zhang et al., 2023). This disproportionate burden stems from the combined effects of intense hydroclimatic forcing, extensive population exposure, and uneven socio-economic vulnerability. From a hazard perspective, flood risk across the region is predominantly shaped by the South and Southeast Asian monsoon systems, which generate high-intensity rainfall concentrated within short seasonal windows. These rainfall dynamics frequently trigger both riverine and flash flooding (Kolekar et al., 2025). Consequently, recurrent flood disasters are widespread across countries such as India, Bangladesh, Myanmar, Thailand, and Vietnam, with several regions often experiencing multiple flood events within a single monsoon season.

Rapid population growth and accelerating economic development have further heightened exposure, particularly in low-lying floodplains and deltaic systems such as the Ganges-Brahmaputra-Meghna Basin, the Mekong Delta, and the Chao Phraya Basin (Chan et al., 2024). The dense concentration of people, agriculture, and essential infrastructure in these flood-prone zones amplifies the scale of losses when flooding occurs, even where structural flood-control measures are in place.

Over the past two decades, notable progress has been made in enhancing flood preparedness and promoting regional cooperation across Asia. Initiatives such as the ASEAN Agreement on Disaster Management and Emergency Response (AADMER) have strengthened transboundary collaboration, encouraged the exchange of early warning information, and enhanced forecasting and response capabilities at both national and regional scales (Anam & Aufa, 2025).

Nevertheless, significant challenges persist in translating strategic frameworks into effective local action. Implementation of preparedness and risk reduction efforts remains inconsistent, particularly at the community level, where awareness of flood hazards is often limited among rural and marginalised groups. Deficiencies in drainage infrastructure, inadequate transport networks, and ageing embankments continue to expose many communities to significant flood impacts (Lu, 2020), underscoring persistent vulnerabilities across the region.

Climate change compounds these pressures by intensifying extreme precipitation and disrupting established rainfall patterns. Observed and projected increases in heavy monsoon rainfall events are expected to escalate flood hazards while increasing uncertainty in the timing and magnitude of extremes (Saran & Sandeep, 2025). Confronting these challenges requires a shift toward integrated and climate-resilient flood management strategies, including adaptive land-use planning, the use of nature-based solutions such as wetland restoration and floodplain reconnection, and the modernisation of traditional flood-control systems. Strengthening local governance, improving financing mechanisms, and empowering communities through participatory disaster risk reduction are essential steps toward mitigating Asia's disproportionate contribution to global flood impacts in a changing climate (Rosales et al., 2023).

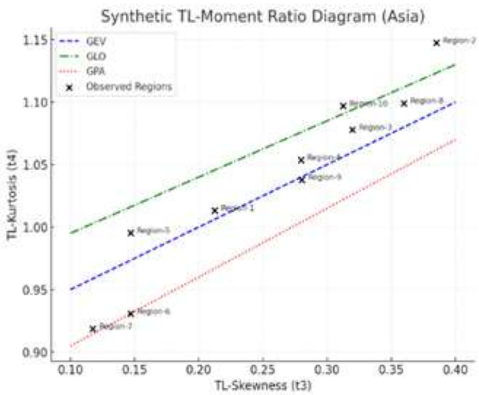

Figure 1: Synthetic TL-Moment Ratio Diagram for Asia

Figure 1 presents a conceptual TL-moment ratio diagram, showing TL-skewness plotted against TL-kurtosis for ten hypothetical Asian subregions alongside theoretical curves for the Generalized Extreme Value (GEV), Generalized Logistic (GLO), and Generalized Pareto (GPA) distributions. The clustering of regional points near the GEV curve suggests its suitability for representing extreme rainfall behaviour under monsoon-dominated conditions. This figure serves as a methodological illustration, intended to demonstrate conceptual applicability rather than empirical inference.

Africa

African countries face some of the highest levels of flood exposure globally, yet they maintain among the lowest levels of flood preparedness (Rentschler et al., 2022). Flood risk across the continent arises from the complex interplay of intense hydroclimatic hazards, rapidly expanding population and infrastructure exposure, and enduring socio-economic vulnerability. Major river basins such as the Niger, Nile, and Zambezi frequently experience large-scale riverine flooding. At the same time, flash floods have become increasingly prevalent in rapidly urbanising cities such as Lagos, Nairobi, and Dar es Salaam. These events routinely displace large populations, devastate agricultural production, and disrupt essential infrastructure and public services, exacerbating existing development challenges across the continent.

Rapid and often unplanned urbanisation has further heightened exposure, particularly through the spread of informal settlements in flood-prone zones. Weak enforcement of land-use regulations and insufficient investment in urban drainage systems have amplified the severity of flood impacts, perpetuating a cycle in which affected populations face repeated exposure to flood hazards (Ugorji et al., 2025). Rural regions face similar challenges; in many cases, they lack formal flood protection infrastructure altogether and rely heavily on traditional coping mechanisms that are becoming increasingly ineffective under changing climatic conditions. This combination of factors reinforces structural vulnerability and limits the adaptive capacity of both urban and rural communities.

A significant constraint on improving flood preparedness and risk reduction in Africa is the persistent scarcity of reliable data. Hydrometeorological monitoring networks remain sparse and unevenly distributed, with rainfall and river gauging stations often concentrated near major urban centres. Vast areas of the continent are poorly monitored, severely constraining efforts to conduct robust Regional Frequency Analysis (RFA) or to produce reliable flood hazard maps and climate risk assessments (Shafik, 2025). Consequently, policymakers and practitioners frequently operate under significant information gaps, resulting in reactive rather than anticipatory approaches to flood management.

Recent technological and institutional advancements are beginning to mitigate these limitations. The Africa Flood Forecasting System, developed within the framework of the Global Flood Awareness System, now provides near-real-time flood forecasts for transboundary river basins with lead times of up to 15 days (Alfieri et al., 2024). At the same time, the increasing availability of satellite-derived rainfall datasets such as CHIRPS and IMERG has substantially improved data coverage in regions lacking ground-based observations. These tools enable near-real-time monitoring of extreme precipitation events, supporting the use of probabilistic forecasting and risk modeling techniques to enhance flood preparedness and early warning capacities (Khan et al., 2025).

To fully capitalise on these advances, African countries must prioritise investment in institutional capacity building, international data-sharing initiatives, and community-based early warning systems. Integrating RFA-based flood design methodologies into the national planning framework, together with the development of climate-resilient infrastructure, will be crucial to reducing the continent's disproportionate vulnerability to flooding in the coming decades.

Figure 1 provides a conceptual TL-moment ratio diagram for ten hypothetical African subregions, plotted against theoretical curves for the Generalized Extreme Value (GEV), Generalized Logistic (GLO), and Generalized Pareto (GPA) distributions. The greater dispersion of points compared to Asia reflects the influence of data scarcity and pronounced climatic heterogeneity across the continent, illustrating the challenges of deriving stable regional frequency estimates in data-poor environments. The figure serves as a conceptual representation rather than an empirical analysis, highlighting methodological considerations relevant to flood-risk estimation in Africa.

Europe & North America

Europe has made significant progress in advancing integrated flood risk management, primarily through the implementation of the European Union Floods Directive, which establishes a coordinated framework for assessing and managing flood risk across member states (Holguin et al., 2021). The Directive sets out a structured, three-phase process: (1) conducting preliminary flood risk assessments to identify areas of potentially significant risk; (2) producing detailed flood hazard and risk maps; and (3) developing Flood Risk Management Plans (FRMPs), which are reviewed and updated every six years. This institutionalized approach has facilitated the creation of comprehensive, high-resolution, and standardized flood maps that underpin spatial planning, inform insurance mechanisms, and enhance emergency preparedness across Europe (Hlal et al., 2025).

Several European countries, including the Netherlands, Germany, and the United Kingdom, have complemented this regulatory framework with innovative flood risk reduction strategies. These include multifunctional flood defenses, adaptive spatial planning, and the deployment of real-time forecasting and warning systems (Md Rashid et al., 2024). Increasingly, nature-based solutions, such as wetland restoration and managed realignment, are being integrated alongside traditional structural measures, like levees and dikes. These combined approaches not only improve flood protection but also deliver co-benefits for biodiversity conservation and carbon sequestration, thereby strengthening the long-term resilience of both ecosystems and communities (Martin et al., 2021).

In North America, flood risk management has evolved under a distinct yet comparably robust institutional framework. In the United States, the Federal Emergency Management Agency's National Flood Insurance Program (NFIP) serves as a cornerstone of national flood governance, linking the provision of federally backed insurance to community-level floodplain management standards. Recent policy and technical developments have focused on updating Intensity-Duration-Frequency (IDF) curves to incorporate climate change projections, thereby enabling infrastructure design that reflects future rather than solely historical rainfall extremes (Mainali & Sharma, 2023). In Canada, both national and provincial programmes prioritise detailed flood mapping, public awareness campaigns, and the implementation of climate-resilient building codes, supported by initiatives such as the National Disaster Mitigation Program.

Despite these advances, notable challenges persist. Continued urban expansion into floodplains has heightened exposure, while ageing flood protection infrastructure raises growing concerns regarding its reliability under intensifying rainfall extremes. Moreover, the financial sustainability of flood insurance programmes is increasingly under scrutiny as cumulative losses continue to rise. Nevertheless, Europe and North America remain global exemplars of proactive flood risk governance, demonstrating how strong institutional capacity, comprehensive data systems, and forward-looking planning can substantially reduce vulnerability even amid high levels of hazard and exposure. These experiences offer valuable insights that can inform the development of adaptive, data-driven, and resilient flood management strategies in regions facing emerging or worsening flood risks under a changing climate (Forouheshfar et al., 2025).

III. CLIMATE VARIABILITY, NON-STATIONARITY, AND FLOOD RISK

Flood risk can be understood as the combined outcome of three interacting components:
"Flood Risk"="Hazard"×"Exposure"×"Vulnerability"

Within this framework, climate change and natural climate variability primarily influence the hazard component by modifying the frequency, intensity, and spatial distribution of extreme rainfall events. Processes such as rapid urbanisation and land-use change increase exposure by expanding the concentration of people, assets, and infrastructure in flood-prone areas. Meanwhile, factors such as poverty levels, governance capacity, and institutional effectiveness determine the degree of vulnerability, shaping the extent to which societies are affected when floods occur.

Understanding flood risk in the context of a changing climate, therefore, requires explicit recognition of how large-scale climatic and societal drivers interact to amplify or mitigate overall risk.

Natural climate variability manifested through phenomena such as the El Niño–Southern Oscillation (ENSO), the Indian Ocean Dipole (IOD), and the Atlantic Multidecadal Oscillation (AMO) plays a critical role in modulating flood hazards on interannual to multidecadal timescales. These coupled atmosphere-ocean oscillations influence large-scale circulation patterns, sea surface temperatures, and the distribution of atmospheric moisture, collectively shaping the timing, intensity, and spatial extent of extreme rainfall events. Their effects, however, are strongly region-dependent and vary with the phase (positive, negative, or neutral) of each oscillation, producing uneven flood risks across countries and seasons.

Among these modes of variability, ENSO is the most extensively studied and exhibits the clearest teleconnections with global precipitation and flooding patterns. During El Niño events, warming of the equatorial Pacific weakens the Walker circulation. It redistributes tropical convection, often leading to above-average rainfall and heightened riverine flood risk in regions such as equatorial and coastal South America (e.g., Peru and Ecuador) and East Africa (Poveda et al., 2025).

In contrast, El Niño conditions typically suppress rainfall in parts of Southeast Asia, Indonesia, and northern Australia, increasing the likelihood of drought rather than flooding. Conversely, La Niña events strengthen the Walker circulation, intensifying convection over Southeast Asia, the western Pacific, and northern Australia, thereby substantially elevating flood hazard in these regions. The widespread floods associated with the strong La Niña episode of 2010-2011, including severe events in Queensland (Australia) and Thailand, demonstrate this amplified risk (H. Zhang, 2021).

The Indian Ocean Dipole (IOD) further modulates flood hazard, particularly across East Africa and South Asia. Positive IOD phases characterised by warmer sea surface temperatures in the western Indian Ocean relative to the eastern basin are linked to enhanced rainfall and increased flooding in East Africa, while simultaneously suppressing rainfall in Australia and parts of Indonesia. Negative IOD phases tend to produce opposite effects and have been associated with drought conditions in East Africa.

Over longer time scales, the Atlantic Multidecadal Oscillation (AMO) influences flood risk across the Atlantic Basin, West Africa, and parts of Europe. Warm AMO phases are typically associated with increased Atlantic hurricane activity, leading to heightened extreme rainfall and flood risk in the Caribbean, the Gulf of Mexico, and the southeastern United States (Bishop, 2021).

Together, these modes of climate variability underscore the non-stationary nature of extreme rainfall and flood hazards. The assumption that the statistical properties of rainfall, such as the mean, variance, skewness, and tail behaviour, remain constant over time is increasingly untenable under such dynamic conditions. Consequently, traditional frequency analysis methods based on stationarity are becoming inadequate, particularly in regions where climate variability and hydrological extremes are most pronounced.

In this context, Trimmed L-Moment (TLM)-based Regional Frequency Analysis (RFA) provides a more robust statistical framework for quantifying flood hazard under conditions of climate variability. By downweighting the influence of extreme outliers such as anomalously wet or dry seasons linked to ENSO, IOD, or AMO phases, TLMs yield more stable and representative estimates of distributional parameters for extreme rainfall. When combined with flexible probability distributions such as the Generalized Extreme Value (GEV), Generalized Logistic (GLO), and Kappa families, TLM-based RFA enables more reliable estimation of design floods and return levels in non-Gaussian, heavy-tailed environments.

Furthermore, the integration of climate oscillation signals into TLM-based RFA offers new opportunities for climate-informed flood risk assessment across seasonal to decadal timescales. Incorporating forecasts of ENSO or related indices into regional frequency models can support anticipatory water management, proactive allocation of emergency resources, and adaptive infrastructure operations such as pre-emptive reservoir releases before flood-prone seasons (Ngoma, 2024).

This approach aligns with emerging practices in climate-informed hydrological design, in which infrastructure planning and disaster preparedness are explicitly structured to account for a broader range of plausible climate futures, thereby reducing the potential for maladaptation.

IV. CONCLUSIONS

Floods are projected to remain among the most acute and pervasive climate-related hazards of the twenty-first century, with their frequency, spatial extent, and socio-economic impacts expected to intensify under continued global warming. This review highlights that, while notable advances in early warning systems, risk mapping, and climate-resilient infrastructure have enhanced preparedness in many regions, substantial disparities in flood risk and adaptive capacity persist.

Asia continues to bear the most significant global flood burden, driven by monsoon-dominated rainfall extremes and the rapid expansion of settlements and infrastructure across floodplains. Africa faces a different yet equally pressing challenge, where data scarcity, sparse hydrometeorological networks, and limited institutional capacity constrain effective flood forecasting and long-term risk reduction. In contrast, Europe and North America exemplify how integrated flood risk management frameworks, underpinned by strong governance, comprehensive data systems, and effective risk communication, can substantially reduce vulnerability despite high levels of hazard and exposure.

A central finding of this review is that the growing influence of non-stationarity, arising from both natural climate variability (including ENSO, IOD, and AMO) and anthropogenic climate change, poses a fundamental challenge to conventional hydrological frequency analysis methods that assume time-invariant rainfall statistics. Under such conditions, estimating design floods and return levels becomes increasingly uncertain, particularly in data-scarce and highly variable environments.

Within this context, the review emphasizes the importance of robust statistical approaches, such as Trimmed L-Moment (TLM)-based Regional Frequency Analysis (RFA), for quantifying flood risk. By reducing sensitivity to outliers and enabling the pooling of regional information, these methods provide a pragmatic framework for improving the reliability of extreme rainfall and flood estimates under changing climatic conditions. This review does not propose new statistical estimators; instead, it synthesises existing evidence to clarify the conditions under which robust regional frequency methods are most appropriate for non-stationary hydrological analysis.

Addressing future flood risk requires a coordinated, multi-pronged strategy that strengthens hydrometeorological monitoring networks, enhances cross-border information sharing, integrates climate-informed design principles into infrastructure planning, and supports community-based resilience initiatives. Closing preparedness gaps in low-income and high-risk regions will depend on sustained investment in institutional capacity, inclusive governance, and the informed application of robust statistical tools within decision-making processes. Collectively, these efforts can reduce the human and economic costs of flooding and support the transition toward more climate-resilient societies.

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