Cover Sheet

Floods, Facts, and Fictions: Numbers and Narratives Behind Bangladesh's 2024 Regional Floods

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Abstract:

The August 2024 regional floods in Bangladesh, occurring shortly after a major political upheaval, were among the most severe in recent history, displacing millions and causing extensive damage. This paper examines both the scientific and social dimensions of this disaster by exploring the natural drivers that led to the flooding and the sociopolitical context that caused rumors to spread that the floods were far from natural. We begin with a climatic and hydrological analysis that provides an objective explanation of the flood's severity based on a convergence of intensified monsoon rainfall, the Madden-Julian Oscillation, and a repositioned jet stream. We then leverage misinformation studies to explain the rapid spread of misleading narratives in the wake of the floods, including allegations of deliberate upstream dam releases by India. Our findings highlight that effective flood preparedness, response, and recovery require not only a scientific grasp of the "numbers" that explain natural drivers but also a nuanced understanding of the "narratives" that shape public perception and action, whether constructive or detrimental. Using the notion of engineering diplomacy, we argue that the mutual acknowledgment of common interests and a focus on collaborative, practical projects can lead to progress on immediate flood management needs while creating the enabling conditions for broader cooperation between transboundary nations like India and Bangladesh. We briefly examine the existing approaches for flood management between the two countries and suggest several tangible pilot projects and initiatives. In exploring both the scientific and social dimensions of the 2024 floods, this paper highlights a critical gap in common approaches to flood preparedness, response, and recovery, emphasizing

the need for collaboration and trust-building to transform natural hazards into opportunities for sustainable action. The proposed coordinated and mutually beneficial strategies using the notion of engineering diplomacy have the potential to ensure future natural hazards do not lead to national disasters.

Takeaway Messages

Science Meets Society: The 2024 floods were mainly driven by climatic and hydrological anomalies such as the Madden-Julian Oscillation and intensified monsoons. However, numbers are not enough to inspire the collaborative efforts often required for effective flood preparedness, response, and recovery. To inspire such collaboration requires integrating these scientific facts with narratives that resonate culturally and politically.

The Role of Engineering Diplomacy: Engineering diplomacy bridges the gap between scientific precision and diplomatic pragmatism, creating opportunities for collaboration even in the face of historical mistrust. It emphasizes collaborative, problem-focused approaches that can lead to measurable progress on tangible challenges while creating the enabling conditions for broader regional and transboundary cooperation.

Targeted Problem-Focused Approaches for Resilience: Initiatives like real-time data-sharing for key transboundary rivers (e.g., Feni and Gomti) exemplify actionable solutions that address both technical gaps and geopolitical sensitivities. These focused collaborations can serve as models for broader regional cooperation to initiate and sustain systemic change.

Empowering Communities: Effective flood management relies not just on technical solutions but also on community engagement. Combining quantitative tools like real-time flood forecasting with narrative-driven outreach builds trust, counters misinformation, and motivates collective action to achieve desirable outcomes.

1. Introduction

Just weeks after a mass uprising led to the downfall of Bangladesh's long-standing government in August 2024, the nation faced yet another crisis: devastating regional floods that claimed many lives and displaced millions. The 2024 floods in Bangladesh were the result of a unique convergence of climatic and hydrologic events. The monsoon season, already intense, was supercharged by the Madden-Julian Oscillation (MJO), a weather phenomenon that funneled warm, moisture-laden air from the Bay of Bengal toward the coast. To complicate matters, the jet stream over Central Asia shifted in such a way that it directed these high-moisture systems deep into eastern Bangladesh and India. This combination triggered a series of extreme rainfall events beginning in late May and culminating in unprecedented flooding across the region in August.

While extreme rainfall can be shown to be the primary driver behind the floods, there has been significant speculation in certain Bangladeshi communities that water releases from dams and barrages in India may have aggravated the situation in some areas within Bangladesh. During the floods, media outlets reported that conspiracy theories were spreading on social media that accused India of deliberately releasing water from upstream dams to worsen the flooding in Bangladesh [1,2]. This narrative was rooted in long-standing mistrust between the two countries over water-sharing agreements, particularly concerning rivers like the Teesta and the Ganges [3]. This misinformation complicated relief efforts and heightened diplomatic tensions between the two nations.

Effective flood preparedness, response, and recovery require not only a scientific grasp of the "numbers" that explain natural drivers of flooding but also a nuanced understanding of the "narratives" that shape public perception and action, whether constructive or detrimental. To explore the nature and implications of this often-overlooked gap, this paper will focus on three objectives: (i) Analyze the climatic and hydrological facts behind the 2024 flood; (ii) Explore the social narratives and geopolitical tensions that shaped public perceptions of the flood; and (iii) Assess the role of engineering diplomacy in bridging this divide by creating space for practical collaborative projects between India and Bangladesh. This report adopts a comprehensive approach to disaster response by integrating technical and social perspectives. It emphasizes the importance of fostering collaborative attitudes to inspire actionable technical projects that can make progress on immediate flood management challenges while providing enabling conditions for broader regional cooperation. The findings demonstrate that focusing solely on getting the numbers right—whether for flood prediction, explanation, or response—is insufficient to avert future risks. Appropriate attention must be paid to the social narratives that accompany these events, their capacity to spread, and their potential to influence outcomes, positively or negatively.

2. Results

2.1 Analysis of Numbers: Climatic and Hydrological Facts

Bangladesh is one of the most disaster-prone countries in the world [4,5] and is frequently identified as a hotspot for climate change impacts [6,7]. Despite its relatively small size, the country's topographic variability, geographical location in the Ganges-Brahmaputra-Meghna delta, and subtropical monsoon climate make it especially vulnerable to extreme weather events such as cyclones, floods, and storm surges [8,6,9,10]. Over recent decades, the country has seen increasing temperatures and shifts in rainfall patterns, with projections suggesting that by the mid-21st century, temperatures could rise by 1.5 to 2.7 °C [9]. These changes are already affecting the frequency of heavy precipitation events, contributing to more frequent and severe flooding [11]. Furthermore, the interplay between natural hazards, societal vulnerability, and exposure has historically amplified the impacts of such disasters. While economic growth has bolstered resilience in some areas, persistent systemic inequities and fragile infrastructure continue to heighten disaster risks, emphasizing the urgent need for adaptive and inclusive risk management strategies.

Although floods are a frequent occurrence in Bangladesh, the August 2024 flood event stands out for its severity and regional impact. Unlike the typical monsoonal floods that frequently affect the north and northeast, the August 2024 floods hit the southeastern parts of Bangladesh, including Feni, Comilla, and Noakhali, which are usually not as flood-prone. The Inter-Cluster Coordination Group and Humanitarian Coordination Task Team (2024) reported that the 2024 floods affected 5.8 million people, displacing over 502,000 into 3,403 evacuation shelters and isolating more than one million [12]. Key districts like Noakhali, Comilla, Lakshmipur, Feni, Chattogram, and Maulvibazar faced severe disruptions, with 311,419 hectares of land submerged, including 296,852 hectares of crops. The losses totaled USD 122 million in fisheries and USD 34 million in livestock. Additionally, over 7,000 schools were closed, affecting 1.75 million students [12]. In Figure 1, the flooded districts and the impacted river basins are highlighted. In total, 12 transboundary river basins were flooded across nine districts of Bangladesh.

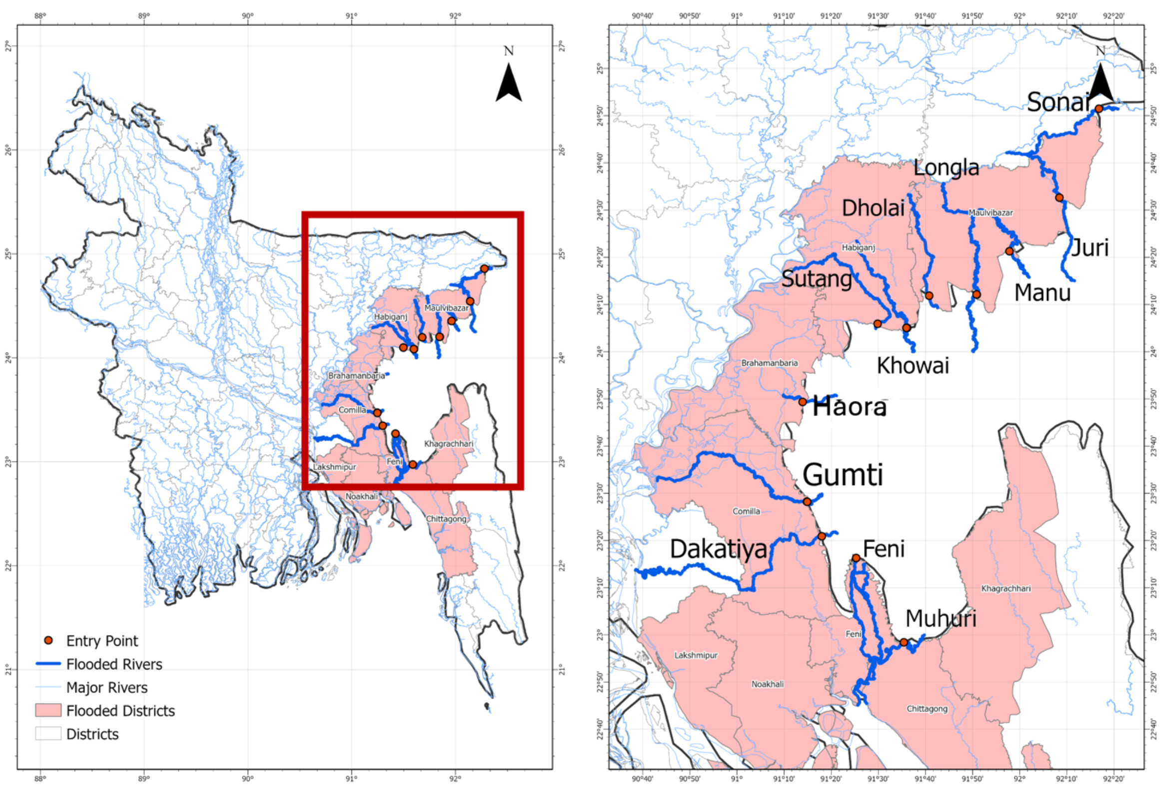

Figure 1: Map depicting the flood-affected areas in Bangladesh during August 2024, highlighting transboundary river systems. The shaded regions indicate districts impacted by flooding, while the blue lines represent flooded rivers. Red circles denote the entry points of transboundary rivers into Bangladesh.

Upstream from Bangladesh, the Indian state of Tripura also experienced devastating floods that triggered a humanitarian crisis, resulting in more than 30 fatalities and displacing approximately 149,000 people across more than 800 relief camps. In total, 1.7 million individuals across eight districts were impacted [14]. These intense floods also flowed downstream into Bangladesh, worsening the already critical flooding in the southeastern regions of the country.

The flooding in both regions was brought on by intense regional precipitation that, in some areas, exceeded the 100-year event, with the most intense rainfall occurring between August 18 and August 22. Multiple districts observed rainfall of nearly 200 mm/day, according to Bangladesh Water Development Board (BWDB) and satellite-based measurements (CHIRPS 2.0), with some data from Bangladesh Meteorological Department indicating rainfall rates exceeding 300 mm/day in at least one district (Feni). On August 21, the Indian regions of West Tripura, Khowai, and Gomati received 182 mm, 157.6 mm, and 153.1 mm of rainfall, respectively, according to the Indian Meteorology Department. This intense precipitation resulted from the convergence of three key factors: a severe monsoon season, the Madden-Julian Oscillation (MJO), and the positioning of the jet stream over Central Asia. In the following subsections, we analyze these factors in more detail and show the coincidence of the precipitation with rapid rises in river levels.

2.1.1 Severe Monsoon Precipitation

Due to its geographic position, Bangladesh experiences high variability in summer (June-August) monsoon precipitation. We analyzed the June-July-August precipitation characteristics over Bangladesh using Climate Hazards Group InfraRed Precipitation with Station (CHIRPS 2.0) [14] data from the last 44 years (1981 to 2024). Details about the dataset are provided in the supplementary section A. During this period, the average monsoon precipitation across much of Bangladesh is about 10 mm/day, but eastern regions, especially the Sylhet and Chattogram divisions, experience a higher precipitation rate ranging from 15 to 30 mm/day, as shown in Figure 2(a). Also, these regions show higher standard deviations compared to the rest of the country, ranging from 25 to 40 mm/day. To better understand precipitation intensity, particularly in the flooded districts, we analyzed the annual mean and annual maximum precipitation using CHIRPS 2.0 data from the past 44 years (1981–2024) for the areas affected by the August 2024 floods. The mean annual precipitation ranges from 4 to 12 mm/day, while the annual maximum precipitation ranges from 50 to 250 mm/day across these districts. The analysis indicates that 2024 was not an exceptionally high precipitation year in terms of mean annual values (Figure 2d). However, the annual maximum precipitation in 2024 was significantly higher (at a 99% confidence level) than historical records in several districts, particularly Lakshmipur, Feni, and Noakhali (Figure 2c), further reinforcing the anomalous nature of the event. To reiterate, the total rainfall was not abnormal, but the intensity of rainfall during the flood event was. This unprecedented increase in extreme precipitation likely contributed to the unexpected severity of the floods, as such heavy rainfall is uncommon in these regions, leaving many unprepared for the subsequent inundation. Details about the statistical significance test are given in the supplementary section.

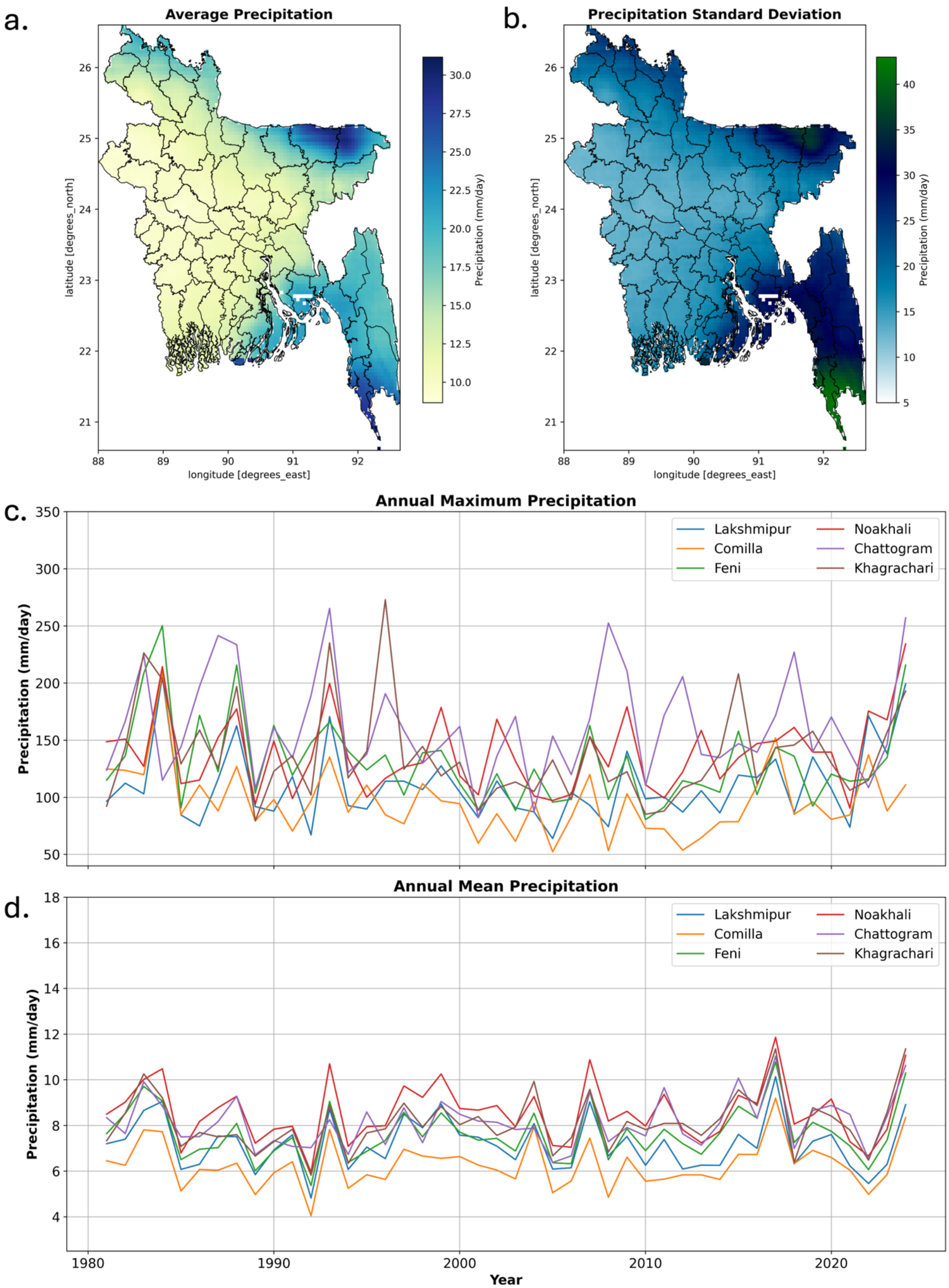

Figure 2: **Analysis of monsoon precipitation over Bangladesh based on CHIRPS2.0 data in 1981-2024.** Panel (a) depicts the average precipitation (mm/day), while panel (b) shows the

standard deviation of precipitation (mm/day). Panels (c) and (d) show the annual maximum and mean precipitation, respectively, in the August 2024 flood-affected districts and highlight an upward trend in 2024 compared to the previous years.

The spatial and temporal distribution of precipitation during the August 2024 flood event is shown in Figure 3, which provides a comprehensive view of this analysis utilizing precipitation data from ground stations from the BWDB and satellite-based measurements (CHIRPS 2.0) for August 14–22, 2024. The discrepancies in estimated precipitation between Figure 3(a) and 3(b) can be attributed to differences in approaches to data collection as well as daily tabulation. The daily precipitation dataset collected from BWDB is measured starting from 9 AM Bangladesh time, while the satellite measurements start from midnight Coordinated Universal Time (UTC), a difference of 3 hours. However, both sources present a high amount of rainfall around August 19, 2024. The following days (August 21–22) saw a reduction in rainfall intensity, yet the precipitation over the affected regions remained significant, compounding the flood impact. This event emphasizes the role of heavy precipitation occurring simultaneously in India and Bangladesh, contributing to the severity of the 2024 floods.

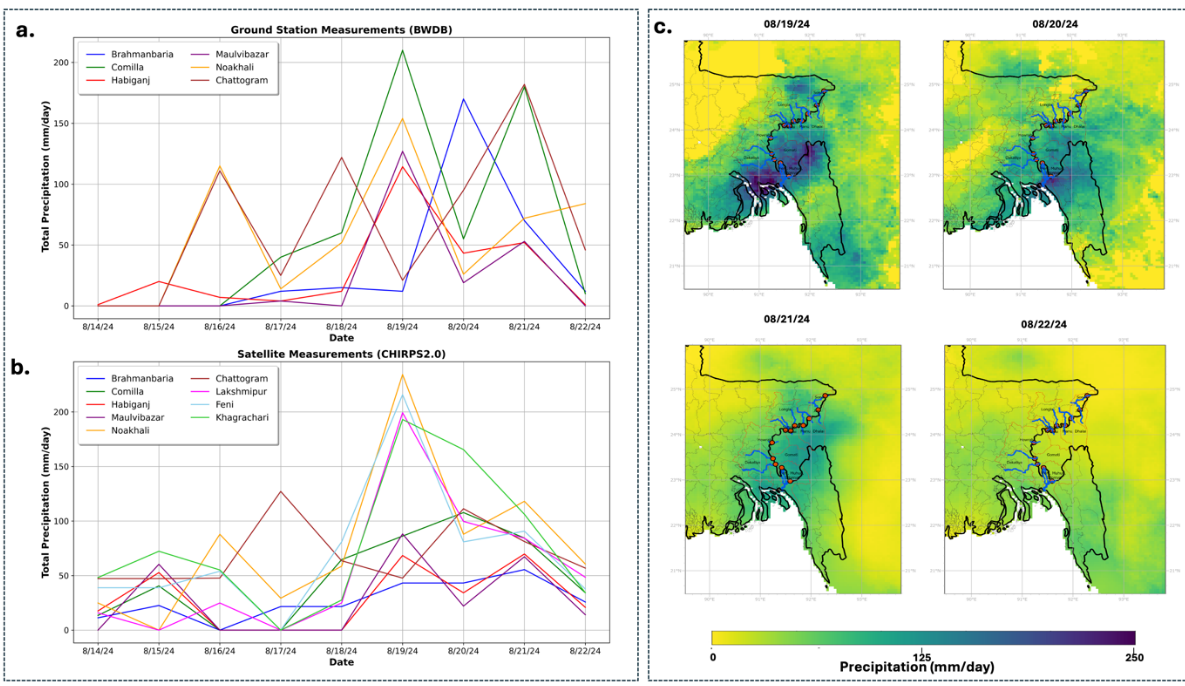

Figure 3: Temporal and spatial distribution of precipitation during the August 2024 flood, highlighting the impact of heavy rainfall on transboundary rivers. Panel (a) shows the time series of precipitation from ground stations (BWDB) in flooded districts, peaking around August 19. Panel (b) presents similar data from CHIRPS 2.0 satellite estimates. Panel (c) displays the spatial distribution of precipitation from August 19-22, with blue shading indicating higher rainfall and yellow indicating lower. Red circles mark transboundary river entry points into Bangladesh,

and blue lines represent the rivers. Intense rainfall on August 19 in eastern Bangladesh and northeastern India caused significant flooding, with reduced but substantial rainfall over the following days.

We have also illustrated, in Figure 3(c), the spatial distribution of precipitation between August 19-22, 2024, in eastern Bangladesh and northeastern India, significantly impacting the transboundary river basins. The most intense rainfall (more than 200 mm/day) occurred on August 19 in Noakhali, Feni, Lakshmipur, and Khagrachori. Additionally, we conducted a Generalized Extreme Value (GEV) distribution analysis to further assess the extremity of the 2024 monsoon precipitation in the flooded districts (Supplementary Figure S1). Details about GEV analysis are also given in the supplementary section. Figure S1 highlights that Lakshmipur, Noakhali, and Feni experienced extreme rainfall events corresponding to 45-, 100- and 30-year return periods, respectively, indicating the severity of the 2024 monsoon floods.

The August 2024 floods affected 12 transboundary river basins between India and Bangladesh, leading to widespread inundation. To determine whether these basins experienced anomalous precipitation, we estimated the monthly standardized area-averaged precipitation anomaly for the monsoon period (June–August) relative to the long-term average from 1981 to 2024 in nine relatively larger river basins. The results in Figure 4 indicate statistically significant deviations (at a 95% confidence level) from historical norms in six out of the nine river basins such as Feni, Gomati, Dakatiya, Haora, Sutang, and Manu Rivers during the 2024 monsoon season. This extreme precipitation event underscores the lack of preparedness among communities in these basins, as such unprecedented rainfall and the subsequent flooding were not anticipated.

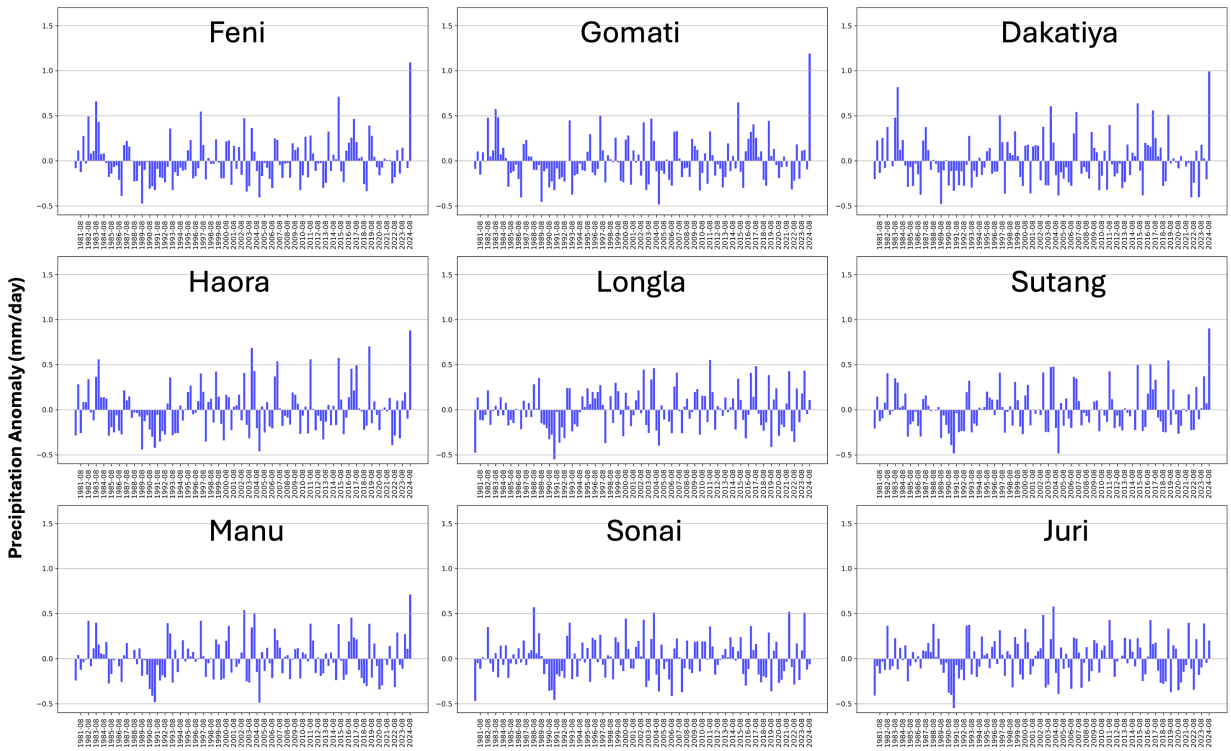

Figure 4: June–July–August precipitation anomalies over nine transboundary river basins during 1981–2024. The monthly standardized area-averaged precipitation anomaly (bars) is calculated relative to the average over 1981–2024. The results highlight anomalously high precipitation in the Feni, Gomati, Dakatiya, Haora, Sutang, and Manu Rivers during the 2024 monsoon season. Precipitation data is sourced from CHIRPS 2.0 [14], while the basin delineations are derived from HydroSHEDS basins [15]. Every third month in the time series is labeled, starting with the third month on the x-axis.

2.1.2 Influence of the Madden-Julian Oscillation (MJO) and Jet Stream Patterns

The Madden-Julian Oscillation (MJO) and jet stream patterns played a crucial role in exacerbating the 2024 floods in Bangladesh. The MJO, characterized by its eastward propagation of convective systems, significantly influenced the tropical weather patterns over the Bay of Bengal, driving moisture-laden air into the region. Information about MJO is collected from Australian Bureau of Meteorology. During August 2024, the MJO was predominantly in phases 2 and 3, both known for creating favorable conditions for heavy precipitation near the Bay of Bengal [16,17,18]. Figure 5 depicts spatially averaged daily precipitation totals over eastern Bangladesh (latitude 21° to 25° and longitude 91° to 93°) color-coded by MJO phase. The highest precipitation intensity occurred around August 19–20, 2024, when the MJO was in its most active phase (phase 2). During this period, the amplitude of the Australian Bureau of Meteorology's Real-time Multivariate MJO (RMM) index exceeded 1, indicating an active MJO event capable of influencing regional weather patterns. The active MJO phase enhanced convection and increased the likelihood of heavy rainfall, significantly amplifying the severity of the flood event.

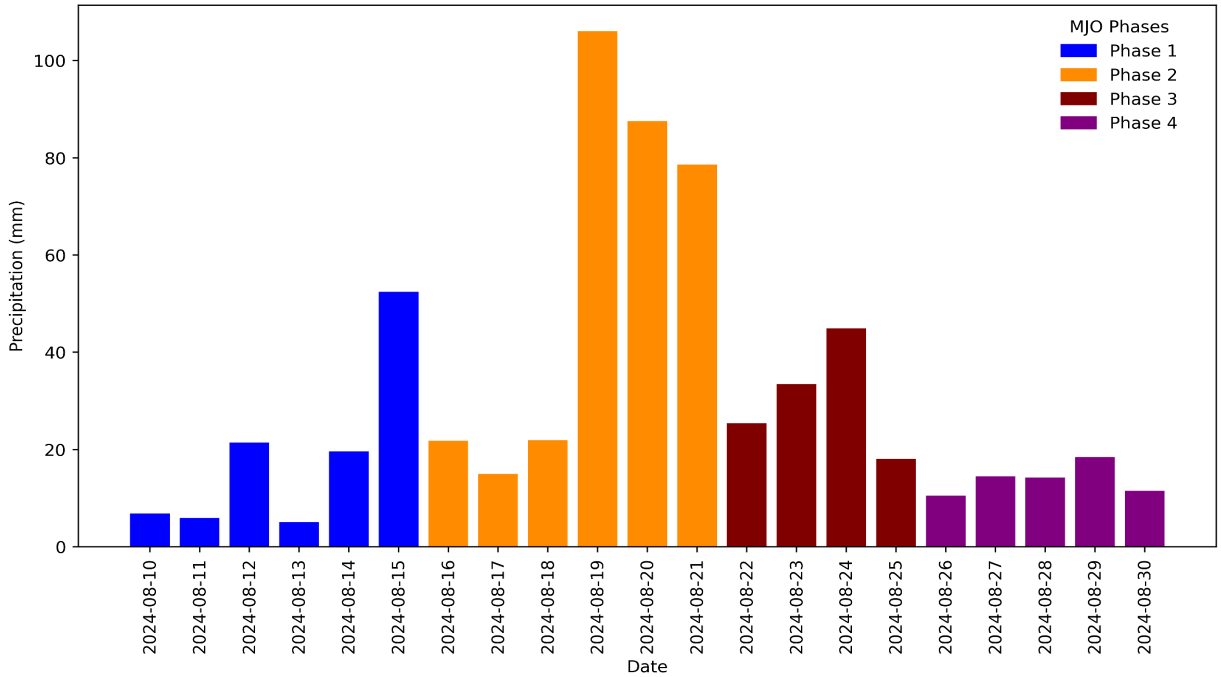

Figure 5: Daily precipitation totals from August 10 to August 30, 2024, overlaid with corresponding Madden-Julian Oscillation (MJO) phases. The MJO phases are shown in different colors: phase 1 (blue), phase 2 (orange), phase 3 (red), and phase 4 (purple). Rainfall peaks on August 19-21 coincide with phase 2, suggesting a link between MJO activity and enhanced precipitation during these periods.

Additionally, jet stream dynamics played a critical role in intensifying the precipitation. Figure 6 shows the wind velocity patterns from the ERA5 reanalysis dataset [19] at 250 hPa, indicating strong northeastward winds that funneled moisture directly into eastern Bangladesh, particularly over the flood-affected zones. The maximum wind speed was observed on August 19, 2024, when the jet stream created ideal conditions for moisture convergence, leading to an intense period of rainfall. The jet stream over Central Asia was positioned so that it steered additional moisture into Bangladesh, compounding the effects of the MJO and monsoonal rainfall. This interaction between tropical and mid-latitude systems highlights the complexity of the 2024 floods. The MJO's influence on enhancing convection and the jet stream's role in transporting moisture combined to create the extreme conditions that resulted in widespread flooding across Bangladesh. Both local and large-scale atmospheric phenomena played a pivotal role in this disaster, illustrating how such interactions can lead to unprecedented weather events and significant flooding impacts.

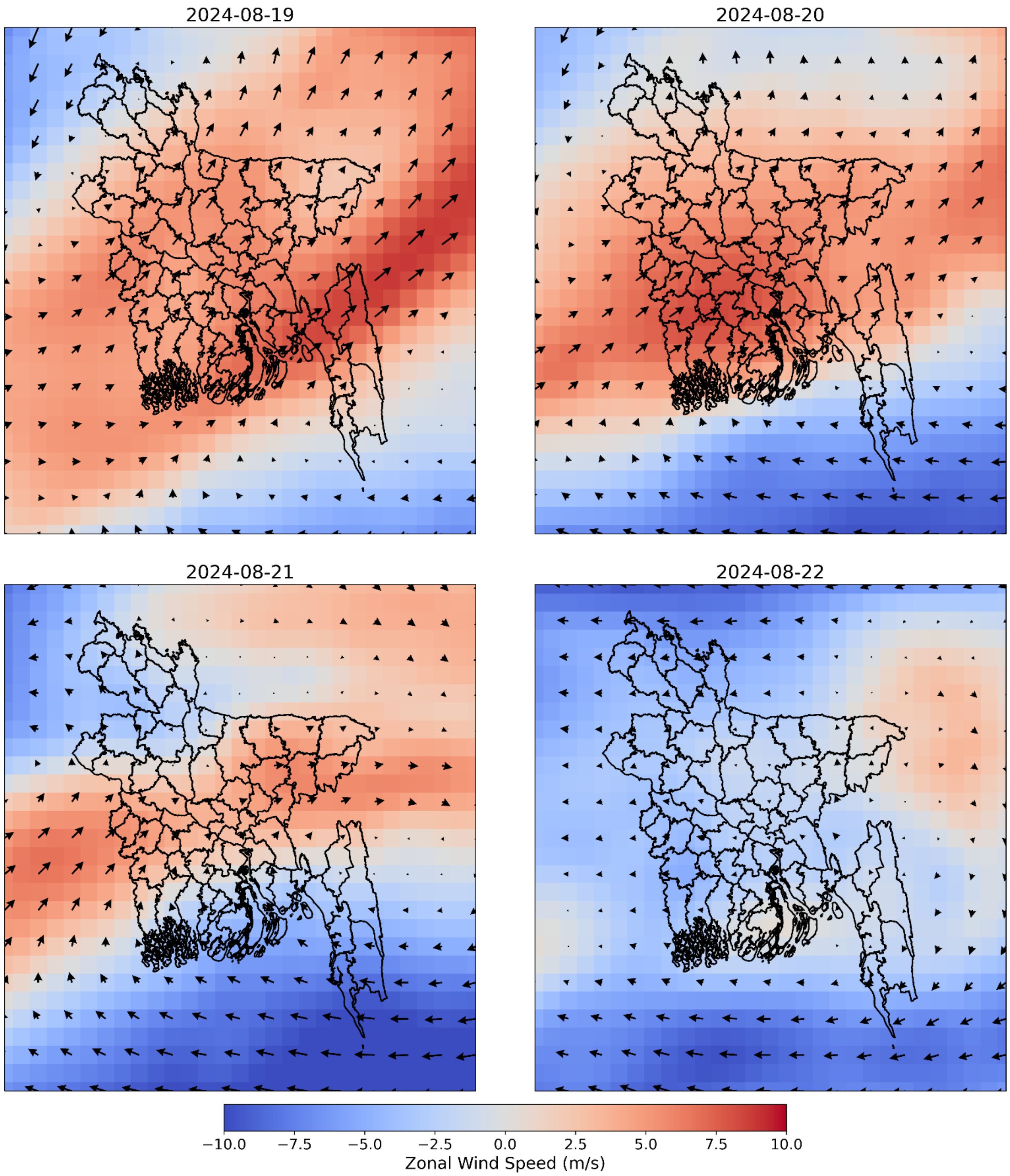

Figure 6: Zonal wind speed at 250 hPa from ERA5 reanalysis data [19] for August 19–22, 2024, highlighting the influence of jet stream dynamics on the August 2024 flood event. These maps show strong northeastward wind patterns that directed moisture-laden air into eastern Bangladesh, intensifying precipitation over flood-affected areas. The highest wind velocities occurred on August 19, 2024, enhancing moisture convergence and contributing to significant rainfall.

2.1.3 Water Levels in Rivers

We estimated water level changes for key rivers in southeastern Bangladesh, taking levels from August 15 as a baseline. Water level data was collected from ground stations by BWDB. The findings, presented in Figure 7(a), show a marked increase in water levels starting on August 19, which peak by August 21 in multiple rivers, including the Gomati, Feni, and Haora. The peak in water levels follows heavy rainfall recorded during the preceding days, with water levels rising as much as 6-7 meters from their August 15 levels in some locations. The sharp increase in water levels from August 19 to August 20 underscores the substantial impact of excess rainfall on the severity of the flooding. The timeline of key meteorological events (Figure 7b) further supports the progression and development of the flood events depicted.

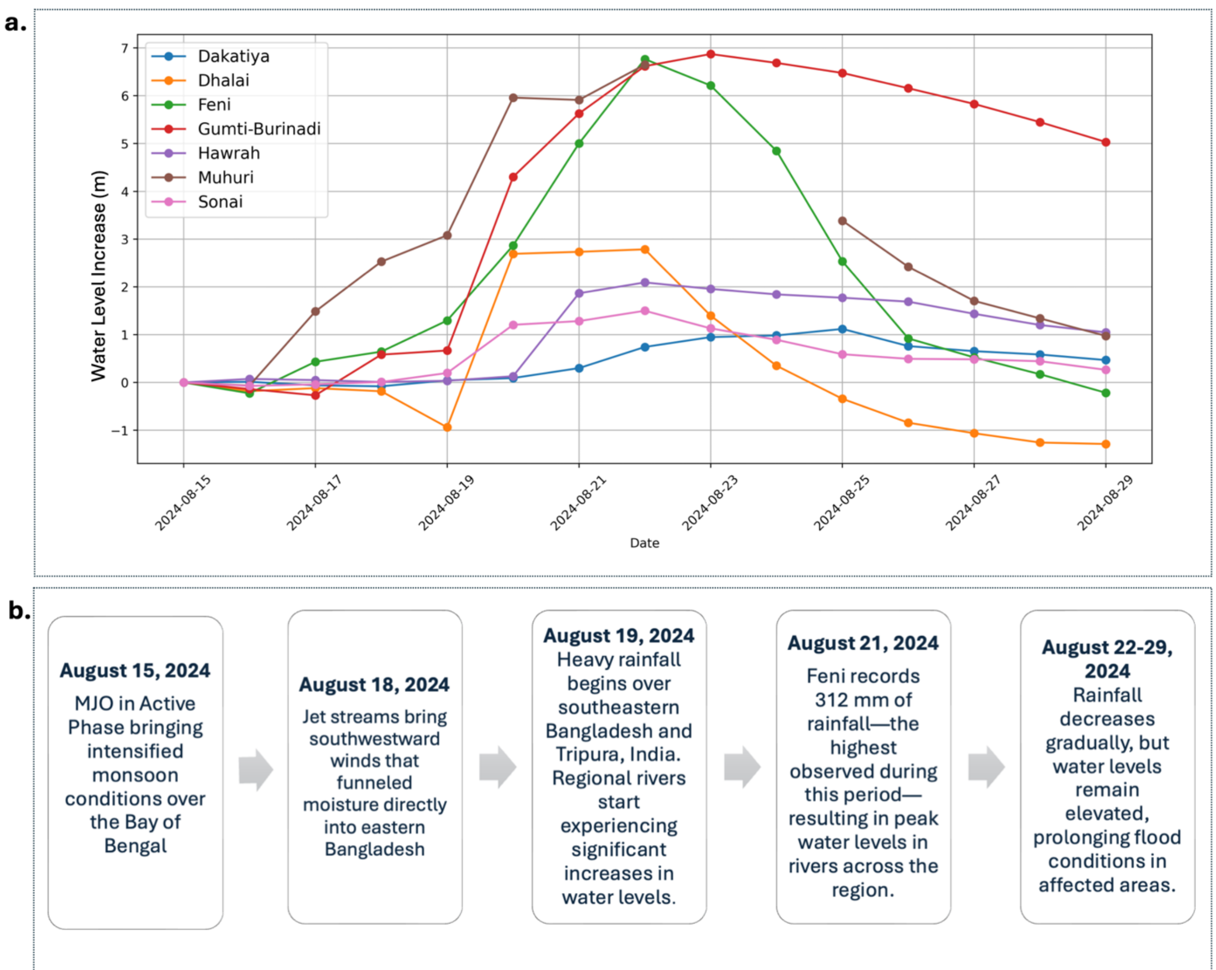

Figure 7: The progression of water levels in transboundary rivers during the August 2024 flood event in southeastern Bangladesh. Panel (a) shows a time series of water level changes from August 15 to 29 (the change is estimated with respect to the water level on August 15, 2024). Panel (b) presents a timeline of key events of the flood.

This section has argued that a coincidence of natural climatic phenomena and hydrologic factors explains the severity of the August 2024 floods. However, the rapid onset and extent of the flooding created space for alternative narratives to emerge that suggested the flooding was far from natural. To varying degrees, these narratives portrayed India as an aggressor who released water from dams without warning, either out of carelessness or a willful attempt to inflict damage on Bangladesh. In the following section, we will explore the spread of these narratives in more detail and examine the geopolitical context that fueled them.

2.2 Exploration of Social Narratives and Geopolitical Tensions

Despite hydrological and climatic explanations in the previous section pointing to an extraordinary coincidence of climatic and hydrologic conditions as the primary driver of the floods, this was not the sole explanation adopted by Bangladeshis. As news of the floods began to build, various narratives began to emerge that pointed blame, in various degrees, at India rather than at natural phenomena. The most extreme of these narratives charged India with intentionally flooding Bangladesh by opening the gates of the Dumbur dam. In both traditional and social media, the narrative spread, causing commentators to claim that misinformation was rampant in social media during and after the floods [20,2]. This narrative also led to political action, as student protests were reported at several universities in the days following the floods [1]. Given preexisting relations and sentiments between Bangladesh and India, this narrative's formation and spread is not surprising from misinformation studies perspectives [21].

In the immediate aftermath of the flooding, major news outlets, including the *Daily Star* and *DW,* reported that there was a spread of misinformation about the floods on social media [20,2]. While the content of messages differed (e.g., different pictures and videos used), the narrative was similar: India opened the Dumbur dam intentionally and flooded Bangladesh. Information and Broadcasting Adviser of the interim government, Nahid Islam, also stated on national television on August 22, 2024, that India had "shown 'inhumanity' by opening a dam without prior notice causing floods in Bangladesh" [22]. Complicating matters, Pranay Verma, Spokesperson for the Indian High Commissioner, stated on television that there was an "automatic release of water from the dam because the water level behind the dam was too high" [23,24]. Student protests in response occurred on August 22. Some social media posts blaming India were posted before Nahid Islam's televised statement, so it appears that rumors preceded any official narrative, though the official statement may have bolstered their legitimacy.

A large percentage of Bangladesh's population uses social media: 30.4% or 52.90 million users as of 2024 [25]. Of those users, the most popular social media reported by DataReportal is Facebook at 52.90 million users, followed by TikTok at 37.36 million, YouTube at 33.60 million, Facebook Messenger at 28.30 million, Instagram at 6.50 million, and X (Twitter) at 1.69 million. BBC News reported in 2024 that television is the most popular traditional media in Bangladesh, listing several major outlets, including Bangladesh Television (BTV) and ATN Bangla [26].

To analyze the nature of competing narratives surrounding the floods, we collected samples of posts, articles, and videos from various social media platforms and noted their reach through views, likes, comments, and shares. As many previously open social media research tools have changed or been removed in recent years, we could not rely on large samples to draw conclusions about rumors spreading online. However, from our small sample, we qualitatively extracted major narratives common to the posts and assume that they adequately capture some common narratives and their slight variants. Our lack of a large or representative sample is a limitation of these methods. A more detailed methodology is reported in the Supplemental Materials.

Our qualitative analysis concluded that there were narratives circulating the media outlets taking multiple views: some blaming India for the flooding and others encouraging factual analysis without ascribing blame. A few dominant narratives of each group are listed in Table 1.

Table 1: A qualitative coding of major narratives extracted from a small sample of social media posts discussing the floods. A detailed description of Dataset Sources referring to ID numbers is available in Rabb et al., 2024 [27].

Narrative	**Dataset Sources**
India opened the gates without considering the impact on Bangladesh	1, 16
India opened the gates without informing Bangladesh	14, 17, 18, 19, 22, 25
India opened the gates as revenge for Sheikh Hasina	18
India is inhumane, hateful, or worthy of hate	5, 14, 16, 18, 19, 25
India historically weaponizes water against Bangladesh	5, 23, 25
Saying it was a natural disaster is Indian propaganda, justifying Indian crimes	3, 6
Hindus are defending India's crimes	4, 7
It was a natural disaster; focus on facts, not on blaming	2, 11, 15, 21

Within the context of existing Bangladesh-India relations, these narratives are not surprising. In an insightful review, (Majumdar, 2014) [3] describes the relationship from both the Indian perspective and the Bangladeshi perspective. He describes Bangladeshi fear of India, as they are a much bigger state with a large military – one who helped liberate Bangladesh but could also turn on them. He notes that 90% of Bangladesh's border is shared with India and that India controls much of the upstream water sources that feed into Bangladesh, making Bangladeshis fear India's manipulation of water for political control. Other border conflicts exist, as (Shahriar, 2021) [28] notes that Bangladeshis fear India's harsh killing of migrants and securitization at the border, as well as dislike India's rhetoric that Bangladesh sends Islamic extremists across the border. The religious tensions, in (Majumdar, 2014)'s view, have led Bangladeshis to view Hindus and Buddhists as people of India living in Bangladesh, who are pro-India and anti-Bangladesh.

From the Indian perspective, (Majumdar, 2014) writes that India fears Islamist terror from Bangladesh. (Shahriar, 2021) argues that India is fearful of the influence of Islam on the Hindu nationalist project in India's current government. While these sentiments may be newer, Majumdar notes that a longstanding view that Bangladesh is ungrateful pervades the nation: India helped liberate Bangladesh, so why are they then criticized and feared in return? We find that these interests reflect a sense of vulnerability on the part of India, this time exacerbated by the recent change in government within Bangladesh and a recent rise in anti-Indian sentiments within Bangladesh. For example, India has interests in abating China's rising regional influence [29], protecting its investments in Special Economic Zones within Bangladesh [30,31], and safeguarding recently re-negotiated agreements on inland water transit and railway passage that connect mainland India to its Northeastern Region through Bangladesh [32,33].

Through a lens of misinformation studies, it is not surprising that narratives blaming India for the flood emerged. Kuo & Marwick (2021) [21] argue that untrue narratives "do not exist in a vacuum but are successful precisely because they are congruous with extant inequalities." It is widely acknowledged in misinformation research that group cues, as well as ideologies and existing worldviews, play a significant role in what people believe [34,35,36,37,38,39,40]. While these cues are not entirely determinant of believing false information [38], they bolster the chances of it being believed and make it difficult to correct [39]. The two most salient group identities in these cases are being part of India or Bangladesh and being non-Muslim (especially Hindu) or Muslim. Existing legitimate inequalities between the nations and religious groups have already given rise to narratives of injustice and inequality between them, and then the specific narratives surrounding the flood build upon these existing sentiments.

Moreover, these narratives have subsequent effects on the worldviews of their believers, making future messaging even more difficult. Narratives blaming India, if believed, are likely to further decrease trust in India, its water-related institutions, and those rejecting India's intentional action [41]. Messaging playing on existing in-/out-group divisions (e.g., India vs Bangladesh, Hindus vs Muslims) also stands to decrease empathy for out-group members among in-group believers (in both directions), reducing the capacity of believers to logically process information about out-group members [42,43].

While our analysis has focused on social media, the literature on misinformation studies emphasizes that rumors and mistruths spread through multiple paths in the information landscape, including newspapers, television, and radio [44,45]. These so-called "traditional media" can unintentionally amplify online misinformation, even when attempting to debunk it, by legitimizing it through coverage. For instance, a Daily Star article analyzing social media misinformation about the flood [20] or televised statements by officials could have inadvertently contributed to the narrative's spread. How to counter misinformation effectively without accidentally spreading it is an active area of research within misinformation studies and communication studies [46]. Importantly, misinformation is most readily accepted and least likely to be questioned when it aligns with existing beliefs or feelings [34]. In the case of the 2024 floods, misinformation about intentional dam releases aligned well with existing sentiments that India is a hydro-hegemon unwilling to cooperate with its downstream neighbor. Shifting these underlying sentiments through concrete collaborative projects may be the most effective way to counter the future spread of misinformation and limit its potential consequences.

3. Discussions

Limiting the impact of floods is a complex challenge with both technical and social dimensions, especially when those floods spill across international borders. Misinformation has the potential to undermine flood management at every stage, from preparedness to response and recovery. While countering misinformation is critical, simply promoting an alternative objective explanation like the one presented in Result Section 2.1 can fail or even backfire. The simplicity of many misinformation narratives puts the "truth at a disadvantage because it is harder to process, understand, and remember" [34]. Efforts to counter misinformation must go beyond simply presenting "the facts" and instead respond to real geopolitical and cultural tensions, as highlighted in Result Section 2.2. As we will discuss in this section, collaborative projects that are responsive to the underlying interests of both parties may be an effective way to ease these tensions, lessen misinformation virality during future natural hazards, and make practical progress on minimizing the impacts of future floods. To do so, we need to learn lessons from misinformation studies and implement actionable insights from a cooperative framework called engineering diplomacy.

Engineering diplomacy is a framework for addressing societal challenges in light of the irreducible uncertainties and conflicting perspectives inherent in complex problem contexts. It promotes combining principled expertise with pragmatic diplomatic engagement on particular problems where progress is measurable and would yield mutually beneficial outcomes. Although it narrows its focus to specific issues, it still embraces complexity by treating both the selection of problems and the methods for addressing them as contingent hypotheses—subject to iterative refinement, testing, and evaluation. By working outward from the nucleation point of these specific problems, engineering diplomacy sustains the focused intensity needed for measurable progress while fostering inclusive dialogues to uncover enabling conditions and creative options that yield mutual benefits and incentivize collective action [47].

The circumstances and reactions to the August 2024 floods present a fresh opportunity to imagine how engineering diplomacy and misinformation studies might be leveraged to address specific challenges faced by vulnerable communities in Bangladesh while promoting broader regional cooperation and collaboration with India.

From the social angle, mindsets of division need to be reduced to enable cooperation. It must be done in a way that is sensitive to underlying tensions and resentments leading to division. While it is factually accurate to attribute the August 2024 floods to natural phenomena, this explanation alone offers little inspiration or guidance for reducing future flood-related harm. In contrast, though many narratives shared in the aftermath of the disaster were based on misinformation, they inspired action (e.g., student protests reported in Daily Star, 2024b [1]) and articulated demands for a future that could be different. How do we find a path forward that is simultaneously responsive to those advocating for a focus on facts and those who dismiss such an approach as Indian propaganda—or even go further, portraying India as inhumane, hateful, or deserving of hatred (see Table 1)?

In the language of engineering diplomacy, this can be called moving beyond *positions* to *interests* [48]; from misinformation studies, it may be called acknowledging *motivated reasoning* [49]. Both these frameworks advocate for understanding attitudes as being driven by subjective standpoints rooted in underlying material or psychological interests: needs, desires, and fears. For instance, those advocating for a focus on facts and avoiding blame might be driven by the desire to cool the country's political climate and a sense of vulnerability amid political turmoil. Similarly, those assigning blame to India may feel compelled to speak out due to a deep-seated sense of injury, neglect, or growing vulnerability and helplessness, believing their grievances have been ignored for far too long. Despite differences in stated positions, those speaking out in the wake of the August 2024 floods may have been motivated by common interests (e.g., responding to a growing sense of vulnerability).

The first step in building social cooperative capacity between Bangladesh and India is to acknowledge these interests and motivations. Media outlets and public officials can be a driving force in spreading this way of thinking. Though media organizations are incentivized to publish sensational stories, and politicians benefit in the short term from winning support by creating enemies, it is in the public's best interest for these parties to foster cooperative attitudes. Statements from trusted officials can go a long way to dispel rumors [34,50,51] build trust. Statements that simultaneously acknowledge that Bangladesh has legitimate fears of water control by India—while being clear that the evidence in this particular case does not suggest political interference—could go far to "prebunk" conspiracy-inspired narratives [39]. Highly trusted and visible officials should adopt an empathetic understanding of the various interests and motivations at play and make concerted efforts to uplift those in any of their messaging about flood response.

A second step for promoting social cooperation is to build an alternative picture of the interests and motivations at play—one that is more mutually beneficial to both nations. While Indo-Bangladeshi collaboration may seem hindered by the widespread perception within India that Bangladesh is "ungrateful" [3], the incentives for collaboration again become clearer when we focus instead on India's underlying interests, which, as noted in Result Section 2.2, include abating the rising regional influence from China and protecting significant economic investments and opportunities. Rather than confronting the threats of anti-Indian sentiments directly by doubling down on positions that may be factually accurate (e.g., we are not responsible for the floods), India may better serve its own interests by fostering support through collaborative projects to improve outcomes for those impacted by floods in Bangladesh and India. Naturally, Bangladesh has legitimate interests in these types of projects because its ability to provide flood early warning systems (FEWS) on flashy transboundary basins is dependent on cooperative monitoring and data-sharing programs with India.

Building social cooperative capacity by acknowledging real interests and opportunities for mutual gain is a crucial first step, but creating space for technical cooperation is necessary to enable tangible, impactful projects. Engineering diplomacy advocates that the best projects for fostering cooperation are (1) focused on a particular problem, (2) able to measure specific metrics for progress, (3) mutually beneficial, and (4) enabling of future cooperation between parties [52]. As noted above, a collaborative project to establish FEWS in the flashy basins within Bangladesh is an example that meets these criteria. It has measurable outcomes (e.g., improvement in the number of households in flashy basins with at least 3 hours of warning), and progress would require addressing Bangladeshi interests (e.g., overcoming feelings of vulnerability and helplessness) as well as incentivizing India's collaboration by addressing some of theirs. Inadequate visibility into upstream conditions, especially in India, remains a key aspect that limits Bangladesh's capacity for self-determination and underlies feelings of injustice, resentment, and vulnerability [53]. In this sense, improved data sharing satisfies a technical requirement for improving FEWS while directly responding to Bangladeshi interests. In the language of engineering diplomacy, data sharing is not just a *necessary* condition for an effective FEWS but also an *enabling* condition for other modes of potentially transformative regional cooperation. That is to say, effective progress on data sharing could catalyze the breakup of the cooperative "logjam" [54] that maintains the status quo of "non-decision making" on bilateral initiatives between India and Bangladesh [55].

While the idea may seem simple, putting engineering diplomacy ideas into practice requires ample space for collaboration, both in formal and informal settings. The current official venue for formal bilateral Indo-Bangladeshi collaboration on hydrologic data-sharing issues is the Joint River Commission. The JRC was established in 1972 as a space for bilateral collaboration between India and Bangladesh on transboundary rivers [56]. While the statute calls for a meeting at the ministerial level at least four times a year, there have been decade-long lapses. However, most JRC activities occur below the ministerial level in expert committees focused on particular issues. Ideally, these are less formal and more fluid spaces where substantive collaboration can occur. Unfortunately, the committee that is perhaps most relevant to improving FEWS outcomes—the Indo-Bangladesh Experts on Flood Forecasting and Warning Systems—apparently has not met since 2004 [57].

While it is certainly worthwhile to consider how to re-instantiate this expert committee within the formal JRC framework, engineering diplomacy would suggest that it is also important to look for opportunities for transboundary collaboration outside of formal "Track I" diplomatic efforts [58,29]. The early 1990s were a flourishing period of non-governmental "Track II" initiatives that brought together experts from India and Bangladesh in unofficial cooperative dialogues on flood management. While these informal dialogues cannot yield binding decisions or lead to official actions, they are often framed as an opportunity to exchange best practices, confront technical challenges, and strengthen collegial relationships that may be beneficial if and when an agreement is reached [59]. However, after the signing of the 1996 Ganges Treaty, much of the energy of these Track II initiatives dissipated [60,61], suggesting that the emergence of formal diplomatic action can sometimes have a long-term chilling effect on informal diplomatic initiatives.

We propose that a pilot initiative focusing on one or two key rivers in this region, such as the Feni or Gomti, could be a practical response to the heightened public awareness and urgency in the aftermath of the floods. This effort would offer both countries a low-risk opportunity to test and refine data-sharing protocols while showcasing the immediate benefits of enhanced cooperation. Data sharing is often perceived as a loss of strategic leverage. However, by framing the project as a collaborative "pilot," the initial data-sharing commitments made by India are minimized and can be framed in the context of technical collaboration rather than a unilateral concession. These localized efforts also mean it will be easier to provide the investment in community engagement required to ensure a functional FEWS in practice.

Although the necessary Track I buy-in on data sharing may be slow to materialize, Track II efforts can help hasten Track I recognition and dialogue on shared interests, as seen in the model provided by the Brahmaputra Dialogue [62]. A series of university-hosted technical workshops on shared flood risks in the Feni and Gomti basins could be an accessible and practical starting point. While these initiatives may seem small, they have the potential to yield measurable mutual benefits that could reinvigorate the JRC and encourage action on other currently stalled collaborative efforts, including the broader data sharing critical to developing FEWS for all Bangladeshi communities.

This targeted, problem-focused application of engineering diplomacy illustrates how small, actionable steps can address a specific challenge while fostering the trust and momentum needed for more ambitious collaborations in the future. By starting with achievable goals and expanding incrementally, the lessons from 2024 can catalyze a new era of regional cooperation where the chances of a natural hazard becoming a national disaster will be significantly reduced.

4. Concluding Remarks

The 2024 floods in Bangladesh underscore the critical interplay between numbers and narratives in managing natural hazards. As shown in this study, the convergence of climatic and hydrological anomalies, such as intensified monsoon rainfall, the Madden-Julian Oscillation, and a shifted jet stream, contributed to the unprecedented scale of flooding. While numbers provide the foundation for understanding the event—identifying causes, mapping impacts, and planning interventions—they are not sufficient on their own to inspire the coordinated actions necessary to prevent future natural hazards from becoming national disasters. Narratives, on the other hand, though often less precise, have the power to mobilize communities, influence policy, and incentivize actions for desirable outcomes. In the case of the August 2024 floods, narratives spread that sowed division rather than cooperative mindsets, worsening the ability of Bangladeshis to respond to the flood and deteriorating their already tenuous relations with India.

The findings from this study emphasize that a future natural hazard does not have to become a national disaster. In the time between the August 2024 floods and future flooding, building cooperative capacity between nations and populations would lay the groundwork for better responses during forthcoming events. Technical and scientific measurement of pre-flood conditions can continue and improve through projects like improved flood early warning systems in flashy river basins that enter Bangladesh from India. This project would improve Bangladesh's material ability to respond to hazards and stand as an example of international cooperation. All the while, cooperative social conditions should be encouraged by accepting real political tensions between nations and putting forward a motivating, mutually beneficial vision of cooperative relations. In future flooding events, these culturally sensitive mindsets will be crucial for framing messaging that inspires action to avoid the worst of the disaster.

Adequate preparedness and response will only be achieved by attending to both the social and physical realities of a flood event. The numbers alone can only go so far. Future work should continue to take sociotechnical approaches to analyzing disaster events to build skills and frameworks that can be mobilized for improved mitigation efforts.

Supplementary information

The Supplementary Information contains four sections: section A provides more details about the dataset used in this study; section B gives more details of the GEV analysis; section C provides information on statistical significance test; section D gives a description on social media analysis. This section contains 1 figure.

Data availability: Precipitation data from CHIRPS 2.0 can be accessed at https://data.chc.ucsb.edu/products/CHIRPS-2.0/global_daily/netcdf/p05/. ERA5 reanalysis data for zonal wind speed is available through the Copernicus Climate Data Store at https://www.ecmwf.int/en/forecasts/datasets/archive-datasets/reanalysis-datasets/era5. The Madden-Julian Oscillation (MJO) phase data from the Australian Bureau of Meteorology is accessible at http://www.bom.gov.au/climate/mjo/. Watershed boundary dataset is available in HydroSHEDS at https://www.hydrosheds.org/products/hydrobasins. Social media narrative dataset is available at https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/Q7MA3J Additionally, water level and rainfall data from various river stations and districts in Bangladesh were obtained from the Bangladesh Water Development Board (BWDB) and the Bangladesh Meteorological Department (BMD). These datasets are available upon request from the respective agencies.

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Author contribution: S.I. and P.D. conceptualized and formulated the problem. P.D. and A.R.G performed the experiments and analyzed the results in Section 2.1 (analysis of numbers). K.S. and N.R. worked on social narratives and geopolitical tensions (Section 2.2) and provided significant input to discussions section. P.D. prepared the initial manuscript working with S.I. and A.R.G., while all authors helped in revising, editing, and finalizing the manuscript.

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