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Editorial: Multivariate extremes and compound, interconnected and cascading events: Understanding the past and projections into the future

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Editorial on the Research Topic
Multivariate extremes and compound, interconnected and cascading events: Understanding the past and projections into the future

The compound flood (CF) results from multiple environmental drivers, such as peak river discharge and high coastal water level co-occurrences, contributing to significant environmental and societal impacts (Zscheischler et al., 2018). CF includes a diverse set of event types, including pre-conditioned, multivariate, temporally, and spatially compounding events, which might be challenging to attribute using a single set of indices or hazard frameworks (Zscheischler and Lehner, 2022). Although there is a considerable advancement in the recent literature on coastal (Zheng et al., 2014; Moftakhari et al., 2017; Bevacqua et al., 2020; Gori et al., 2022) and inland CF hazard (Khatun et al., 2022; Thieken et al., 2022) assessments, challenges remain in characterizing multihazard attributes involving mutual interdependence among inter-related and hidden environmental drivers (Ganguli and Merz, 2019; Renard et al., 2022), lack of a credible impact-driven framework to map such events (Hillier and Dixon, 2020), and operational aspects in monitoring CF hazards (FEMA, 2020). Moreover, *non-stationarity* (Ghanbari et al., 2019; Naseri and Hummel, 2022) and *deep uncertainty* (Wong and Keller, 2017) of underlying environmental stressors further complicate CF hazard projection. While non-stationarity is the shift in the climate system (Ghanbari et al., 2019), deep uncertainty indicates climate model structural uncertainty (Knutti et al., 2010) that propagates due to a lack of understanding of model physics and natural variability (Horsburgh et al., 2021), which is intrinsic to the climate system. The manuscript included in this research line aims to collect cutting-edge studies on the compound and cascading flood hazards, their attribution, and projections in the face of climate uncertainty, and provide prospects on adaptive responses to devise increased preparedness in practice and modeling approaches.

Following these motivations, three research articles and one commentary were published as part of this Research Topic. These papers can broadly be classified under three categories: two papers dealt with coastal compound floods through a numerical modeling approach; another paper presents shifts in runoff generation processes due to warming-induced glacial melts of a catchment in a remote location in central Asia, potentially augmenting rain on snow-melt CFs, triggering cascading hazards, such as landslides and other mass wasting phenomena (Poschlod et al., 2020). Finally, the commentary discusses a new perspective on societal and gender dimensions of climate adaptations in low-lying Deltas focusing on the Bay of Bengal (BoB) region of coastal India.

Using *in-situ* meteorological records and remotely-sensed snow cover images in a physically-based hydrological modeling setup, He showed the shifts in runoff dynamics of Ala-Archa catchment, in Central Asia (Northern Tienshan range) from pluvial to nival flood regimes. The high mountain Asian (HMA) “water towers” (Immerzeel et al., 2010) are mainly at risk with a shift from snow to rain, and catchments with a higher fraction of glaciered area tend to show increasing trends in the runoff (Chen et al., 2016; Barandun et al., 2020). Leveraging incremental climate scenarios, the authors investigated the hydrological responses to climate changes and highlighted the sensitivity of glaciers to warming. Further, a decreasing groundwater contribution is apparent, which could be compensated by a precipitation increase. While considerable uncertainties in projecting climate change consequences in HMA, e.g., poor monitoring network, difficulties in bias correction of climate model output due to orographic facets, and wind effects in complex topography (Van Den Broeke, 1997; Bannister et al., 2019), most assessments have shown the compounding effects of projected changes in temperature and precipitation would lead to hydrologic regime shifts with changes in magnitude and timing of floods in the HMA (Hill et al., 2017; Armstrong et al., 2019; Bhattacharya et al., 2021; Khanal et al., 2021). The gradual shifts in hydrologic regime result in cascading hazard chains across HMA, as evident from frequent glacier lake outburst floods and landslides, adversely affecting downstream food and energy systems and disrupting transportation networks (Kirschbaum et al., 2019; Kattel et al., 2020; Li et al., 2022).

Santiago-Collazo et al. demonstrated the evolution of CF hazard zones in the highly altered Mississippi River and Deltaic System. Synthetic storm events were simulated using a coupled hydrodynamic-hydrologic modeling framework over two distinct coastal watersheds within southern Louisiana state. Each scenario is compared over projected (2050 and 2090) vs. historical (1890, 1930, and 1970) time windows. In the projected scenario, for coastally-dominated catchments, the lower magnitude pluvial floods (simulated by rainfall-runoff modeling) are expected to impact CF hazard zones more than the higher magnitude floods. Interestingly, with the effect of Sea level rise (SLR), the near-future planning horizon (2010–2050) shows shifts in coastal flood zones closer to inland over time. SLR due to coastal subsidence, shoreline erosion, and wetland losses are well evident in the Mississippi Deltaic system (Dixon et al., 2006; Törnqvist et al., 2008). The nonstationarity of climate further exacerbates shifts to coastal-fluvial transition near the tidal limit due to differences in wave celerity during coastal CFs (Dykstra and Dzwonkowski, 2021). In the tropics, Rezaie and Haque developed an operational framework (storm surge inundation model and associated database) to assess tropical cyclone (TC)-driven storm surge vulnerability across the low-elevated coastal plain of BoB, near coastal Bangladesh. One of the significant difficulties experienced was the lack of good-quality hydrometeorological records for recent years, such as recent catastrophic cyclones, such as Amphan in 2020 and Yaas in 2021, to validate their findings. The findings showed that while storm intensity has a substantial role in controlling inundation depths, inundation primarily varies with the landfall locations. Despite two of the studies presented herein belongs to disparate climate regions, both studies (1) map CF hazard across the world’s large river basins such as the Ganga-Brahmaputra-Meghna (Rezaie and Haque) and Mississippi (Santiago-Collazo et al.) Delta systems, which are densely populated and highly invested. (2) Highlights the non-stationarity driven by the SLR and resulting deep uncertainty posed significant challenges in informing climate adaptations and devising flood defenses in marine-fluvial transitions.

Gangopadhyay et al. discussed gender dimensions of climate adaptations in the BoB region of coastal India, where shoreline erosions, SLR, and catastrophic cyclones resulting in “coastal migration” (Lincke and Hinkel, 2021) pose significant concerns. Further, the authors have highlighted that increasing climate shocks due to cyclones and floods, together with a deteriorating marine ecosystem have led to declining fish production, resulting in long-term displacements of the skilled population, especially outmigration of males. The outmigration of skilled male populations or family re-settlements inland would divest the women as their skills in coastal, household-based ancillary aquaculture activities tend to be redundant.

Overall, a few aspects of these four studies are worth highlighting: (1) Compound inland and coastal flood hazards pose a significant risk to high mountain Asia and highly invested deltas across the globe due to difficulties in characterizing the risk of multiple drivers within a limited time window. (2) Climate change, for example, more rains than snow events in high mountains, would lead to shifts in hydroclimatology; the high SLR leads to changes in marine-fluvial transition zones, triggering the likelihood of cascade hazard chains and affecting societal resilience. (3) Gender disparity, economic inequality, and climatic shocks from compound climate and weather hazards, and biological risks in combination with natural hazards have further complicated the “disaster riskscape”

(Patra and Kantariya, 2014; ESCAP, 2021), demanding a more holistic approach to risk management.

Author contributions

PG wrote the manuscript draft. All authors approved the manuscript for publication.

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Conflict of interest

Author DW was employed by Climate Risk Services and is currently associated with Sunjul GmbH.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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