Chennai Floods 2015 - Rapid Assessment
Supplementary Material

Frequency analysis of extreme rainfall for Mumbai and Chennai with respect to the flooding events

The flooding events of Mumbai (2005) and Chennai (2015) were both induced by heavy downpour, much above the respective climatological normals. Therefore, we examine here the return periods of these two extreme rainfall events based on historically observed records, that is, how frequently events such as these are likely to occur, on an average.

Specifically, we analyze annual maximum 24-hour rainfall values at Santacruz (Mumbai Airport) in Mumbai and maximum 24-hour rainfall in November at Minambakkam (Chennai International Airport) in Chennai with respect to the 26 July, 2005 Mumbai rainfall of magnitude of 944.2 mm (record high 24-hour rainfall) and the 15 November, 2015 Chennai rainfall of magnitude 266 mm (https://en.wikipedia.org/wiki/2015_South_Indian_floods). The observed daily rainfall for Mumbai is obtained from the rain gauge data of the Santacruz station of the India Meteorological Department (IMD). Hallegatte et al. (2010) also carry out frequency analysis of the annual maximum 24-hour rainfall at this station based on historical records and climate projections; however, they assume the log-normal distribution which may not always be appropriate for heavy-tailed extreme rainfall. For Chennai, monthly one-day maximum rainfall (RX1D) for the November month were obtained from the Madras/Minambakkam station (13N, 80.183E) data of the Global Historical Climatology Network Daily (GHCN-Daily) (Donat et al., 2013), available online at http://www.climdex.org/sewocs.html. The location of this station is shown in Figure 1. In absence of easily available daily or sub-daily observed rainfall station data in this region, we also consider daily rainfall values from the 1^0 lat. x 1^0 lon. gridded data of IMD (Rajeevan et al., 2008) at the nearest grid centered at 13.5N, 80.5E. It may be noted that gridded data products are also available at other spatial resolutions from IMD; however, we choose this dataset as it reported minimum number of missing values. The GHCN-Daily extreme dataset (GHCNDX) is a regularly-updated quality controlled global dataset that provides long observed record for the Minambakkam station in Chennai, with 10% or less missing years. The GHCNDX maximum 24-hour rainfall in the month of November also shows reasonably good match with that of the nearby IMD grid point centered at 13.5N, 80.5E (Figure 2(a)).

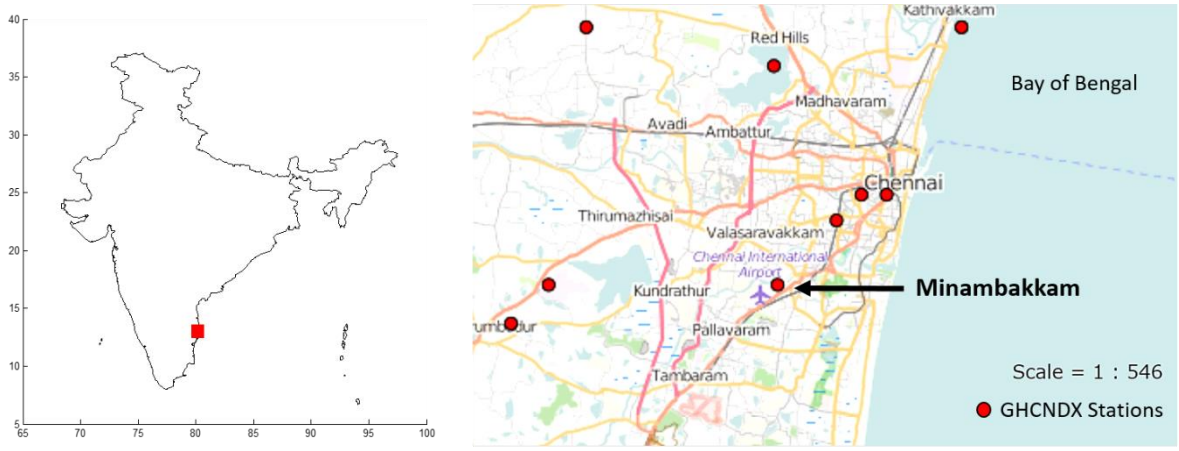

Figure 1. Location of the GHCNDX Station 'Minambakkam' (13N 80.183E) in

For conducting the frequency analysis for the maximum 24-hour rainfall at Mumbai and Chennai, we use the statistical extreme value theory which relies on asymptotic theory to provide models that categorically account for heavy tails (Coles, 2001). The Generalized Extreme Value (GEV) distribution is deemed to be the appropriate distribution for block maxima series. Therefore, GEV distribution is fitted individually to the annual maximum 24-hour rainfall series at Santacruz and the November month 24-hour rainfall series at Minambakkam. Figure 2(b) shows that the GEV model-predicted quantiles match quite well with the observed empirical quantiles for the GHCNDX November maximum 24-hour rainfall values at Minambakkam. Figure 2(c) shows the return levels of rainfall corresponding to different return periods from the GEV models fitted individually to the GHCNDX data at Minambakkam and the IMD data at the grid centered at 13.5N, 80.5E.

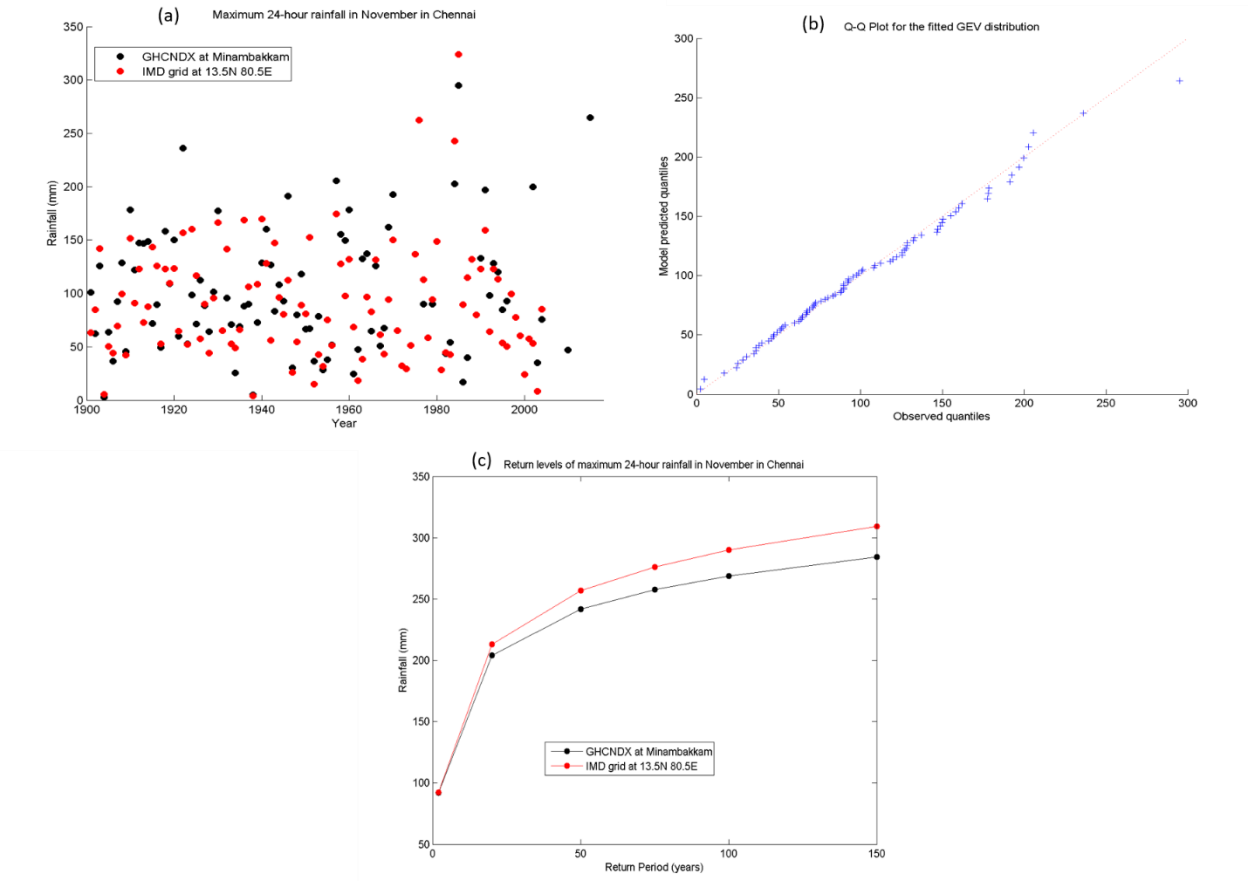

Figure 2. Maximum 24-hour rainfall in Chennai in the month of November. (a) Comparison between the block maxima series from GHCNDX and IMD. (b) Quantile-Quantile (QQ) plot from the fitted GEV distribution to the GHCNDX data. (c) 24-hour rainfall magnitudes for rainfall in November corresponding to different return periods for the GHCNDX and IMD data.

The return periods of the extreme rainfall events of Mumbai (2005) and Chennai (2015) are presented in Table 1. We compute the return periods both with and without considering the particular events in the observed record. It may be observed that the Mumbai (2005) extreme rainfall event was truly exceptional with a return period as high as 363 years if this particular event is excluded from the observed record. The Chennai (2015) event is also found to be rare with a return period close to 100 years in the observed record excluding this event.

This initial analysis can be further improved by investigating larger datasets (both in terms of temporal and spatial extent) and by taking into account dependencies and variabilities. For example, the estimates of return periods may differ if the extreme value models consider spatial dependency of rainfall between adjacent locationss. Moreover, further investigations may focus on the causal relationships, how likelihoods of particular events such as these may change because of such causal factors, and the associated uncertainties.

Table 1. Return periods of the Mumbai (2005) and Chennai (2015) extreme rainfall events.

Event/Station Data	Rainfall	Historical Return period of the event under consideration (Assuming GEV distribution)	
		Considering the event	Without considering the event
Mumbai, 2005: at Santacruz	Maximum 24-hour rainfall in a year	112 years	363 years
Chennai, 2015: at Minambakkam (GHCNDX)	Maximum 24-hour rainfall in November	68 years	93 years
Chennai , 2015: at IMD 1^0 x 1^0 grid point 13.5N 80.5E	Maximum 24-hour rainfall in November	86 years	115 years

References

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