Extreme Rainfall across Western India

Less than two months ago, the western coast of India was bracing itself for cyclone Nisarga, and it is now dealing with a torrential downpour. The Indian Meteorological Department (IMD) predicts active monsoon conditions over the west coast including Mumbai and east coast of India and likely intense rainfall over Gujarat, Madhya Pradesh, Chhattisgarh and Odisha. A low-pressure area formed over North Bay of Bengal off West Bengal-Bangladesh coasts on August 4th, which was predicted to become more marked during the next 24 hours and move west-northwestward to south Gujarat across Odisha, Chhattisgarh and Madhya Pradesh during next 3-days. Heavy to very heavy rainfall is forecast for these regions till August 10. A cyclonic circulation lies over south Gujarat and neighbourhood at middle and upper level tilting southwards with height. Southwest Monsoon currently is in Active to Vigorous phase over the Konkan coast and adjoining area of west coasts including Mumbai and east coast of India covering Odisha and Gangetic West Bengal.

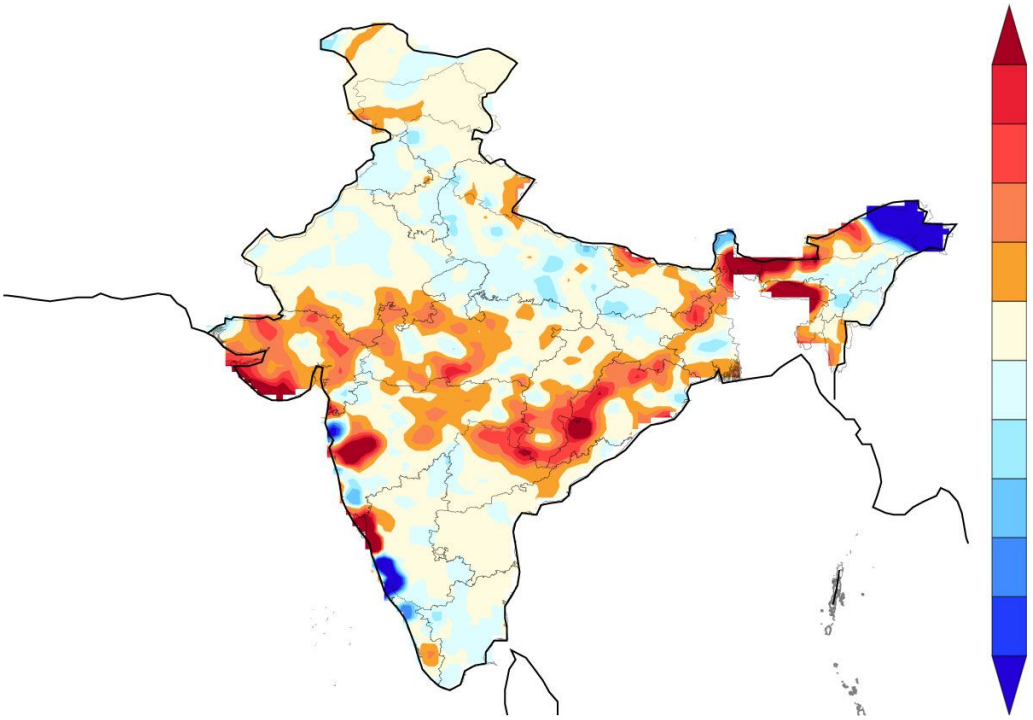
India witnessing Increasing floods and extreme rainfall patterns

Widespread extreme rain events across central India have tripled since 1950. These severe weather events result in large scale floods and catastrophic loss for life and property across central and northern India – Gujarat, Maharashtra, Madhya Pradesh, Chhattisgarh, Telangana, Odisha, Jharkhand, Assam and parts of Western Ghats – Goa, north Karnataka and South Kerala.

There have been 285 reported flooding events in India over 1950-2017 affecting about 850 million people, leaving 19 million homeless and killing about 71,000 people. The total damage during this period is about 60 Billion USD. The loss per year has been increasing - and during the last decade the damage due to floods has been about 3 Billion USD "per year". The rise in extreme rainfall events is taking place over a region where the total monsoon rainfall is decreasing. The fact that this intensification is against the background of a declining monsoon rainfall makes it catastrophic, as it puts several millions of lives, property and agriculture at risk.

Climate change impact on rainfall patterns in India's western coast

A 2017 paper in Nature Communications establishes that while the frequency of low-pressure systems in the Bay of Bengal has declined, this extra moisture is transported in from the Arabian Sea. Monsoon winds (westerlies) over the northern Arabian Sea are exhibiting increased variability (large fluctuations), driving surges of moisture supply, leading to extreme rain episodes across the entire central Indian belt. This is due to the increased warming north of the Arabian Sea, as a result of increased anthropogenic (human-led) activities resulting in carbon emissions. The warm ocean temperatures in the northern Arabian Sea results in increased moisture and large fluctuations of the monsoon winds.



(Figure: Warm colors indicate the region where extremes are increasing – entire central belt of Gujarat, Maharashtra, Madhya Pradesh, Chhattisgarh, Telangana, Odisha, Jharkhand, Assam and parts of Western Ghats – Goa, north Karnataka and South Kerala.)

Another study by scientists at the New York University claims that a poleward shift in the monsoon low level jetstream (LLJ), which transports moisture from surrounding oceans to the Indian land mass, has been detected. The poleward shift is reflected in the future projections in a warming scenario, with the magnitude of shift depending on the degree of warming. Consistent with the LLJ shift, a drying (wet) trend in the southern (northern) part of the western coast of India is observed in the last three decades. Further analysis reveals that enhanced land-sea contrast resulted in a strengthening of the cross-equatorial sea level pressure gradient over the Indian Ocean, resulting in the northward shift of the zero absolute vorticity contour from its climatological position. These results assume significance in the context of the concerns over the ecologically fragile Western Ghats region in a warming scenario.

Expected precipitation changes in the 21st century

The recent report by Ministry of Earth Sciences, *'Climate Change Assessment over the Indian Region'*, explains that with continued global warming and expected reductions of aerosol concentrations in the future, climate models project an increase in the annual and summer monsoon mean rainfall, as well as frequency of heavy rain occurrences over most parts of India during the twenty-first century.

The frequency of localized heavy rain occurrences over India has increased during 1951–2015. Urbanization and other land use, as well as aerosols, likely contribute to these localized heavy rainfall occurrences.

The interannual variability of summer monsoon rainfall is also projected to increase through the twenty-first century.

Increased frequency of localized heavy rainfall on sub-daily and daily timescales has enhanced flood risk over India. Increased frequency and impacts of floods are also on the rise in urban areas.

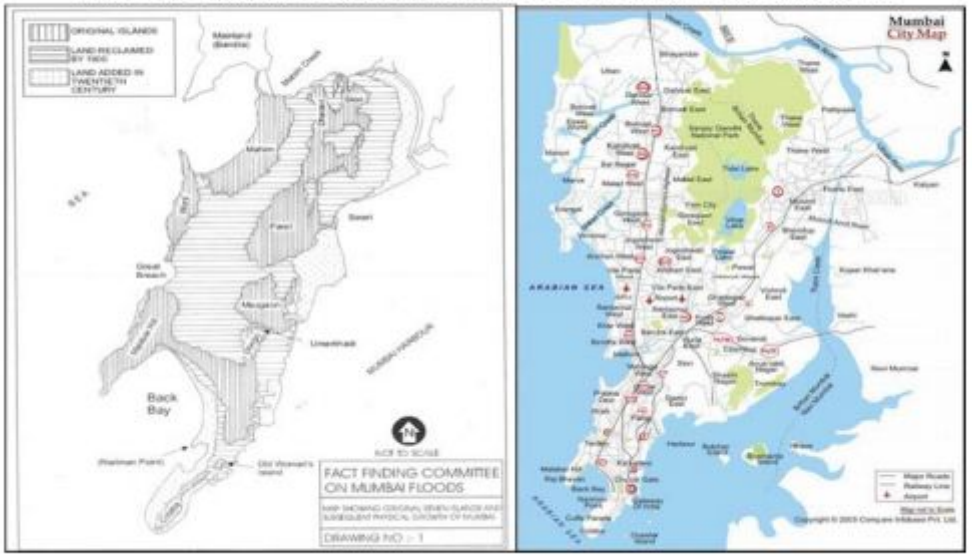
The threat to Coastal Cities

Multiple studies claim that India's largest coastal cities, like Mumbai and Kolkata, are facing the severest threats from climate-induced flooding. Planned and unplanned development in most ecologically sensitive zones in these cities fail to address the risks of climate change related flooding owing to tendencies to sidestep questions of politics, power and the distributional conflicts that shape urban development.

Mumbai has observed an unprecedented growth (see map) in the last few decades, methodically constructing on its mangrove forests. Mangroves are swamp forests which provide many ecosystem services to coastal communities. The density of the trees, together with the variety of tree species, attenuate the inflow of water and create a sort of buffer zone against floods and storm surges.

Informal 'slum' settlements have long been targeted for removal as an environmental improvement strategy, despite their relatively low impact. Slum clearance has escalated with the combination of speculative development and environmental change, creating uneven precarity throughout Mumbai's neighbourhoods.

Figure 1: Original seven islands and subsequent growth of Mumbai



Source: MCGM, 2006; MCGM, 2015

Recent and historical flood events triggered by the Arabian Sea

During the summer monsoon of 2016, heavy-to-extreme rainfall events occurred across the central Indian region resulting in large scale floods. The floods were widespread and caused damage to life and property on the west coast including Mumbai, and submerged the Kaziranga National Park in

the state of Assam in north-eastern India. A snapshot of the satellite rainfall data during these floods reveals a widespread heavy rainfall event spread over three days. The regional extent of the widespread rainfall event shows a huge similarity with that of the increasing trends in extreme rain events. The recent Mumbai 2017 floods also exhibited a similar pattern.

Some of the historical floods which resulted in the largest loss in terms of human lives and property, for example, the central Indian floods in 1989 and 2000, Mumbai floods in 2005, South Asian floods in 2007, etc. were all a result of intense rainfall spread over three days, tracing their moisture source to the westerly flow from the Arabian Sea.

QUOTES:

Dr Roxy Mathew Koll, Scientist, Indian Institute of Tropical Meteorology, Lead Author, IPCC Oceans and Cryosphere

"While it is too early for an in-depth analysis of the ongoing floods, what we can say is that there is an increasing trend in heavy rainfall events on the west coast of India. In our analysis of rainfall data over the last 70 years, we find a three-fold rise in extreme rains along the west coast and central India.

This is because the monsoon winds over the Arabian Sea are now exhibiting large fluctuations, thanks to a warmer environment. Occasional surges in the winds drive a huge amount of moisture supply from the Arabian Sea, across the entire west coast. These episodes result in an intense rainfall spread over three days.

Besides some of my colleagues at New York University have found a slight northward shift of the monsoon westerlies in recent decades. This could mean that the chances of heavy rainfall might be larger towards the north of Western Ghats— but that aspect is yet to be explored."

Dr Anjal Prakash, Research Director and Adjunct Associate Professor, Bharti Institute of Public Policy, Indian School of Business, India. IPCC's Lead Author under current Assessment Report focussing on chapters on urbanisation and mountains

"We have enough knowledge now that links some of the high precipitation events with a rapidly changing climatic conditions. IPCC reports have given pointers apart from other studies of similar nature. This information must lead to wisdom on what could be done. Some of the Indian cities such as Mumbai, Kolkata, Vizag and Goa are at greater risks due to its proximities to the sea or being in the high-hazard zones. Mumbai being the richest Indian Municipalities do not have lack of resources to adapt to these climatic events. With proper adaptation measures, some of the impacts of high rainfalls could be avoided.

For the city of Mumbai, I sincerely hope that the officials have learnt lesson from post 2005 deluge and taken care of the recommendation of the Madhav Chitale committee. The committee reiterated the reasons of the flooding which was known earlier – [1] inadequate drainage system, [2] rapid

developments and loss of ponds that used to hold water, [3] encroachment by the slums on and over the existing drainage systems and [4] reduction in the coastal mangrove areas. These are the adaptation measures which Mumbai must focus on and should be part of the comprehensive plan for Mumbai. The Mithi River which is the major drainage point in the north has been reduced to an open drain due to severe encroachments and discharge of industrial effluents into the river and its mangrove forests need to be protected by bringing a special legislation. If these measures are undertaken, we hope to see that the impacts of annual flood events are reduced with much less damage to lives and property."

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