Climate change impact on the coastal areas of India: A Review

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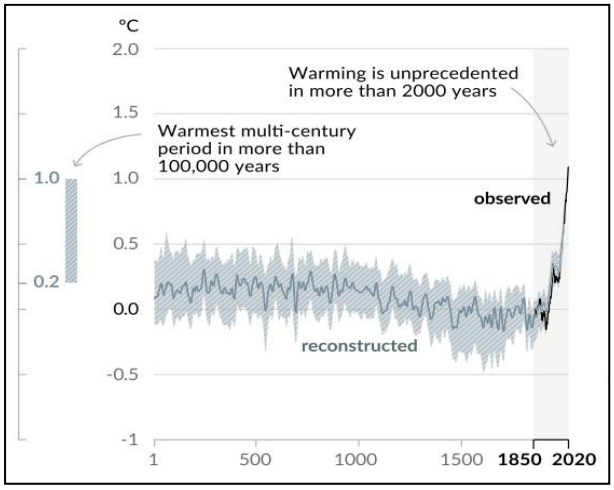

Figure 2: Changes in global surface temperature relative to 1850-1900; source: IPCC AR6, 2021.

1. Introduction:

Indian coastline runs forabout 7516km. and is inhabited by densely populated human agglomeration, climate change and climate variability induced impact posed alarming challenges to this ecosystem making them more vulnerable and risk prone. Intergovernmental Panel on Climate change (IPCC), defined climate change as a change in the long term state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties. In another definition, the United Nations Framework Convention on Climate Change (UNFCCC, 2011), refers to climate change as, a climate change that is directly or indirectly attributed by human activity resulting in an alteration in global atmospheric composition and that is an addition in natural climate variability for a long period.

In their 6th Assessment Report (AR6) 2021, IPCC clearly mentioned that Carbon dioxide (CO2) is the main driver of climate change, (AR6), since 2011 (measurement report AR5), concentrations have continued to increase and it reached 410 ppm for CO2, 1866 ppb for methane (CH4), and 332 ppb for nitrous oxide (N2O) annually in 2019 which resulted in serious global warming. In the same report (AR6) IPCC has mentioned that each of the last four decades has been successively warmer than any other decades since 1850, and global surface temperature of last two decades (2001-2020) of 21st century was 0.99 °C higher than 1850-1900.

This incontrovertible change in climate is not only changing the land and sea surface

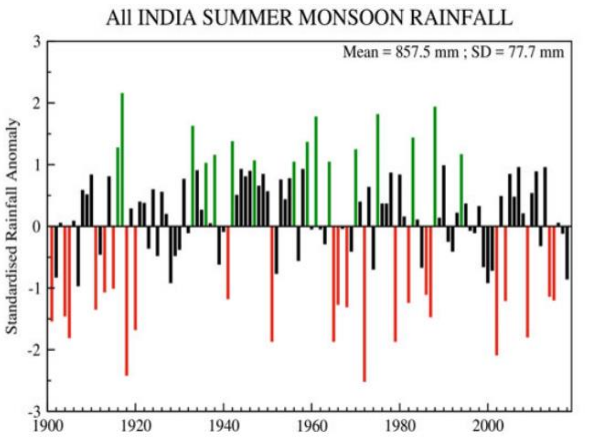

Figure 1: summer monsoon rainfall anomaly; source: Krishnan et al., 2020

temperature and raising the sea level, but also leads to changes in the frequency, intensity, spatial extent, duration, and timing of extreme weather and climate events (IPCC, 2021; 2012). The world is already facing the frequent and intense occurrence of extreme climatic events and it's expected to be more devastating in the coming 20 or 30 years (IPCC, 2021). The worst sufferer from this climate change and climate change-induced extremes will be the coastal areas (IPCC, 2007).

Coastal areas are experiencing the adverse impact of sea-level rise due to global warming. A rise in global mean sea-level by 0.20 m is noticed between 1901 and 2018. The average rate of sea-level rise was 1.3 mm/yr between 1901 and 1971, increasing to 1.9 mm/yr between 1971 and 2006. Currently, the rate is increasing to 3.7 mm/yr between 2006 and 2018 which is very concerning for the coastal areas(IPCC, 2021). Not only that coasts are also exposed to a high risk of sea-level rise induced coastal erosion and devastating tropical

cyclones. According to IPCC 4th Assessment Report (AR4) 2007, the impact of such climate-induced changes will be more damaging in the coasts of developing countries due to its high population pressure and low adaptive capacity (IPCC, 2007), intensity and spatial extent of drought will increase at the end of the 21st century. The report also indicates that warming of the Indian Ocean, sea-level rise and increasing intensity of tropical cyclones will devastate the low-lying coastal areas. Not only that, climate change-induced shoreline change, inundation due to storm surge, and coastal flooding will definitely distress the The same report has also found that the rainfall of summer monsoon (June – September) has declined by 6% from 1951 to 2015 with a notable decline over the Indo-Gangetic plain and Western Ghats, and projected (CMIP5) an increase in mean and variability of monsoon rainfall by the end of the century. The overall decrease in monsoon rainfall led to an increase in the frequency and spatial extent of drought from 1951 to 2016, particularly over central India, southwest coast, southern peninsula and north-eastern India. Increased variability of monsoon rainfall, and increased water vapour demand in a warmer atmosphere, climate model projected that (RCP805), and India will be one of them.

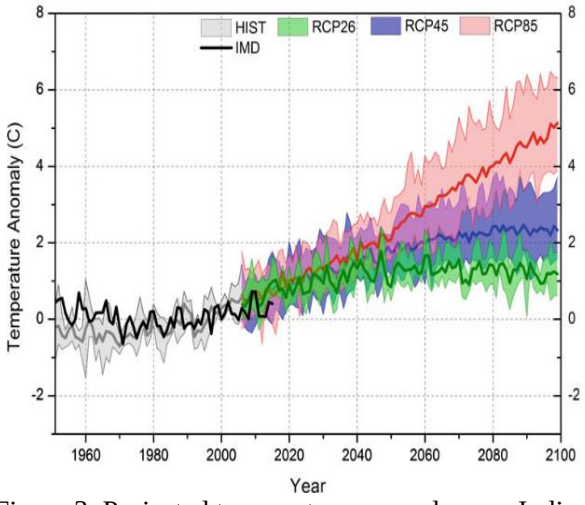

Figure 3: Projected temperature anomaly over India; Source: Krishnan et al., 2020)

2. Climate Change and Indian Scenario:

Considering climate change as one of the most important and concerning issues of the nation, the Ministry of Earth Science (MoES), Government of India have published a report in 2020, titled "Assessment of Climate Change over the Indian Region". The report (Krishnan et al., 2020) mentioned that the average temperature of India has risen by 0.7° C during 1901 -2018, and projected (RCP8.5) rise by 4.4° C by the end of the 21st century. The same report has also found that the rainfall of summer monsoon (June – September) has declined by 6% from 1951 toand projected (RCP8.5) rise by 4.4° C by the end of the 21st century. The same report has also found that the rainfall of summer

increase in mean and variability of monsoon rainfall by the end of the century. The overall decrease in monsoon rainfall led to an increase in the frequency and spatial extent of drought from 1951 to 2016, particularly over central India, southwest coast, southern peninsula and north-eastern India. Increased variability of monsoon rainfall, and increased water vapour demand in a warmer atmosphere, climate model projected that (RCP805), intensity and spatial extent of drought will increase at the end of the 21st century. The report also indicates that warming of the Indian Ocean, sea-level rise and increasing intensity of tropical cyclones will devastate the low-lying coastal areas. Not only that, climate change-induced shoreline change, inundation due to storm surge, and coastal flooding will definitely distress the coastal population and hamper the management of the coastal zones (Krishnamurthy et al., 2014; Rajasree et al., 2016; Rao, Upadhaya, Ali, et al., 2020). Thus it's a very crucial time to review the trend and consequences of climate change on the Indian coasts and find a way out to manage the situation.

3. Climate Change and Indian Coasts:

3.1. Change in temperature and precipitation:

In a study, Gangwar (2013) pointed out that, on the eastern coast the annual mean temperature is likely to increase from 28.7± 0.6°C to 29.3±0.7°C and on the west coast the rise is likely to 26.8±0.4°C to 27.5±0.4°C in the 2030s.In the case of rainfall, the eastern coast is likely to range between 858±85.8mm to 1280± 204.8mm, and on the west coast, it could be range between 935±185.33mm to 1794±247mm in the 2030s in respect to 1970 (Banerjee et al., 2018; Gangwar, 2013). That's mean the increase is estimated to range between 0.2% to 4.4% for the east coast and 6%–8% for the west coast. Another work of (Geethalakshmi et al., (2016) indicate that the number of rainy days is projected to be decreased by 1-5 days, but the intensity of rainfall is expected to increase between 1-4 mm/day for the east coast.

3.2. Trend of tropical cyclones:

As per the recent reports and literature, the frequency of tropical cyclones in the North Indian Ocean (NIO) basin has been decreased since 1951-2018 (Krishnan et al., 2020; Mohapatra& Vijay Kumar, 2017). But on the contrary, the very severe cyclonic storms (VSCSs) during the post-monsoon season has been increased significantly during the last two decades (Krishnan et al., 2020; Vissa et al., 2013). The climate models have also projected that the intensity of tropical cyclones will be increased in the coming decades. Additionally, the level of storm surge water is expected to rise and inundate the low lying coast and deltaic regions, especially the eastern coast of the country (Rao, Upadhaya, Pandey, et al., 2020).

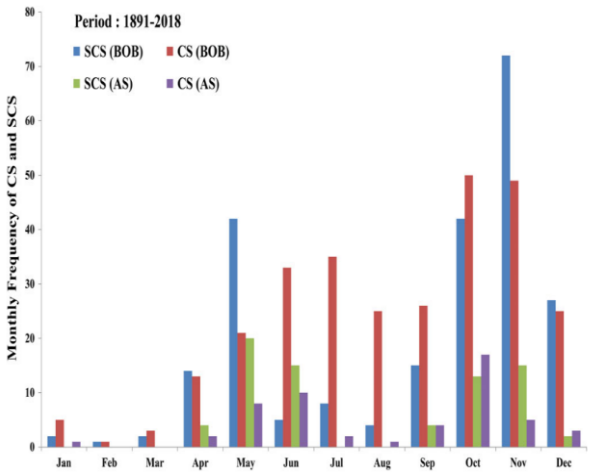

Figure 4: Trend of Cyclonic Storms (CS) and Severe Cyclonic Storms (SCS) in Bay of Bengal (BOB) and Arabian Sea (AS); Source: IMD

3.3. Sea Level Rise:

Analysis from historical records has pertinently shown a mere increase of 1 - 2 mm. of sea level per year all over the world

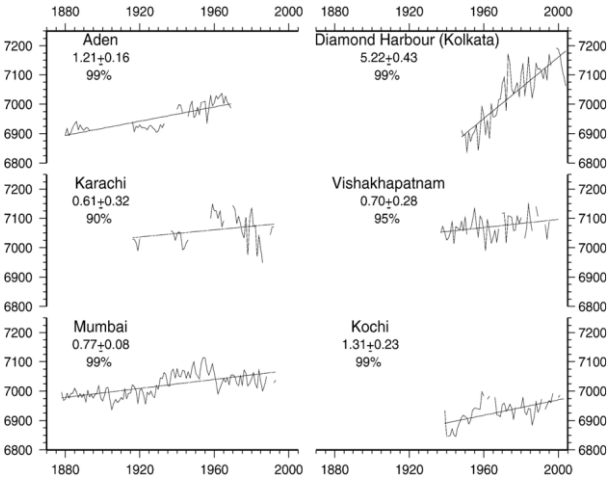

Figure 5: Annual-mean sea-level and the linear fit for selected tide-gauge stations in the North Indian Ocean [Source: Unnikrishnan and Shankar (2007)]

in the current century and global warming has been adroitly considered to be the most influencing factor. For the Indian coast, there is no exception to this. A study by Unnikrishnan et al. (2006) has shown the mean sea level in Mumbai, Kochi and Vishakhapatnam are projected to rise by almost 0.78, 1.14 and 0.75 mm./year in the recent future. Further, in an updated work of the previous study, Unnikrishnan and Shankar (2007) found that Diamond Harbour (located in Kolkata), one of the important tide gauge stations of the east Indian coast shows a statistically significant increase in sea level at a rate of 5.74 mm./yr. Although the greater pace of subsidence (4 mm./yr) of the Ganga Delta is one of the important factors behind this overwhelming sea level rise, climate change is also a bigger issue. Even the average rise in sea level is more pronounced in the case of the East Indian coast (1.353 mm./year) than that of the West Coast (0.372 mm./year) (Sudha Rani et al., 2017). However, almost all studies have clearly demonstrated that the trend in the sea level of the North Indian Ocean resembles the global sea level estimate reported in the 3rd Assessment Report (TAR) of IPCC. In such a scenario, the coastal regions are mostly at stake. There has been a clear indication of future inundation of coastal areas on both west and east coast. Ranger et al. (2011) have estimated severe flooding in Mumbai (as more than double of 2005 flood event) by 2080. Therefore, a proper framework for risk analysis as well as mitigation strategies is highly needed to protect the coastal areas and their peoples in near future.

3.4. Rise in Sea Surface Temperature (SST) over the Indian Ocean:

Globally the ocean temperature has increased by almost 93% from 1950. In the case of the Indian Ocean, the surface, as well as the subsurface layer, has increased more than the global average. Different studies have shown that the SST of the Indian Ocean has increased 2 -3 times more than the tropical Pacific which has led to an increased warm pool of water mass in the Indian Ocean. This increase in SST has resulted in the weakening of the Hadley Cell (responsible for the South-Western monsoonal rain in India) causing a shear decrease in monsoonal rainfall in the Indian subcontinent. The Radiative forcing due to increased greenhouse gases (GHGs) have been considered to be the most important factor behind such an increase (Gnanaseelan et al., 2017). A study by Dinesh Kumar et al. (2016) has suggested that SST in both the Bay of Bengal and the Arabian Sea basin has increased after 1940. As a result of this, the coastal areas are experiencing a greater degree of temperature and humidity with a lesser degree of monsoonal rain. A recent report (https://www.downtoearth.org.in/news/climate-change/blame-climate-change-for-a-sweltering-kerala-69354) has shown that the winter temperature of Kerala has increased by almost 2° – 3°C above normal in February 2020. Even the temperature of Mumbai at that time was the highest in the

country. Different scientists have particularly affirmed that such an increase in the winter temperature is not due to any periodic natural phenomena (eg. El Nino) rather this is only due to climate change.

4. Impact Assessment:

4.1. Impact on fisheries:

Any coastal region is mostly dependent on fisheries as one of the popular choices of livelihood. Radiative forcing due to greenhouse gas (GHGs) emissions has adequately affected the increase in SST leading to an adverse impact on fishing. Any farmed species reared under aquaculture are poikilothermic (species whose internal body temperature is duly sensitive to external stresses), hence, any subtle change in SST will certainly affect the metabolism and growth of the species. A study by Zacharia et al. (2016) has pointed out that the rising SST of the Bay of Bengal has compelled the fishermen to increase the depth at which nets are cast. Even the change in wind direction and speed in the months of October – January has caused a decrease in the amount of tuna caught in the Indian Ocean. The study also revealed that rising temperature has caused an increase in the amount of energy to harvest a particular fish species on the Mumbai coast. Moreover, another study by Salim et al. (2014) has suggested that the coastal fishing communities in Kerala are in more danger of the risk of loss due to erratic monsoonal rainfall. Under a changing climatic regime, the ecosystem services of the Indian East Coast are expected to decrease by almost 25% by 2050 resulting in an overall loss of 17 billion US$ (Mohanty et al., 2017). Therefore proper mitigation strategies are highly needed.

4.2. Impact on agriculture:

Agriculture in any other place is equally affected by changing climatic parameters (e.g. Temperature, rainfall, Humidity etc.), but agriculture of coastal regions are more specifically vulnerable to climatic changes due to seawater intrusion, cyclones and increasing soil salinity. The sheer change in climatic parameters has adversely affected the phenology of plants in almost all the coastal parts of India. Moreover, erratic rainfall coupled with an increased temperature regime has hampered the traditional cropping pattern. The excessive increase of temperature will decrease the yield of irrigated paddy and maize in the East Indian coastal areas severely (Kumar et al., 2011). Increased temperature has also favoured the risk of pest attack in the crops resulting in a loss of productivity and yield. Even on the west coast especially in Kerala, the cashew nut agro system has been severely affected by the changing climate (Gopalakrishnan et al., 2019). Such a situation has ultimately led to a disruption of the traditional cropping calendar. Moreover, as the coastal areas of India are predominantly inhabited by smallholder farming communities, they lack to adapt expensive climate-smart strategies which push them to the end.

4.3. Impact on other Sectors of Economy, Infrastructure and Urban Cities

According to the climate models and a projection by NASA, sea-level rise by 2030 will inundate the 10 major coastal cities of India including Mumbai and Chennai (Hindustan Times, 2021; Rasmussen, 2021; The Hindu, 2021; Times of India, 2021). This projected inundation may cost billions of dollars and may severely affect the growth of the economy of the nation (The Indian Express, 2021.). In a detailed work Pramanik (2017) analysed the change in the land use categories in different sea-level rise scenarios, and stated that urban area will

significantly be affected by sea-level rise. In a study Pednekar& Siva Raju(2019) has mentioned that sea-level rise will harshly affect the economy of Mumbai city very and disrupt public health, damage the infrastructures, and force people to migrate. In another study, Saleem Khan et al.,(2012) found that a total of 20 hamlets of Vellare - Coleroon estuarine region of Tamil Nadu coast will be submerged under the sea due to sea-level rise resulting in loss of livelihood and displacement of thousands of people. Climate change induced sea-level rise will pose a serious threat to the 12 major ports and 205 notified minor and intermediate ports of India affecting trade and cargo movement of the country. Coastal cities are likely to face more challenges by climate change-induced change. These cities are already coupled with various problems like high-density unplanned settlement, rapid population growth, urban poverty, high differentials in access to public services and infrastructure. With the impact of climate change-induced changes, these problems will further aggravate and affect the poor and vulnerable communities significantly.

5. Conclusion:

Climate Change, in the present time, is no longer a hoax, rather it's a well-established fact. Even the adverse impacts of such a change are quite visible from all perspectives. In such a scenario, a socially inclusive policy framework for better estimation of the adverse effects of climate change on different sectors as well as mitigation strategies is highly needed. Moreover, the coastal areas, which are most vulnerable to such changes, should be considered exclusively and different stakeholders from all hierarchies and all sectors should work together. Though different International, national, public, private and non-governmental organizations (NGOs) have already started working in such sectors, more holistic and socially comprehensive approaches through policies and researches should be introduced.

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