Issues and Impact of Climate Change with special reference to Coastal Population

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1. Introduction

Our earth is very dynamic which continuously going through a continuous process of change because of various natural and anthropogenic factors, global warming (GW) and climate change (CC) are one of them. After the industrial revolution in the world, human has contributed as a most active agent to CC through the emission of greenhouse gases (GHGs) and aerosols, and through changes in various other anthropogenic activities like land use/land cover (LULC) changes, increasing global temperature (World Meteorological Organization, 2005). Climate model simulations of the effect of GHGs emissions are compared against the observed climatic variation in the past and their possible outcomes on natural phenomena are done by Climatologists. According to them, "there is strong evidence that the anthropogenic activities are mainly responsible for warming over the last 50 years and since mid-19th century average land and sea surface temperature has increased by 0.6±0.2˚C globally where most of the change had occurred since 1976 (Fig. 1), Intergovernmental Panel on Climate Change (IPCC, 2001).

There is variation in the rise in temperature on a regional basis, it may be greater or lesser than the global average of the rise in temperature (IPCC, 2001). For instance, warming in the United States is anticipated to be more than the global average, and the highest warming is expected over the Arctic (Georgi et al., 2001). The ten warmest years occurred between 1995 and 2005 since thermometer records became available in 1860 and after 1998, 2005 was the second hottest year on record, because of the influence of El Nino in the Pacific Ocean which contributes into a rise in temperature above than the average temperatures of the world (WMO, 2005). As per the Intergovernmental Panel on Climate Change (IPCC), the average global temperature is expected to increase by 2½ to 10 °F in the next century.

All seven continents and five ocean are affected by warming but mid and high latitude areas of the continent are most affected because of CC. Precipitation becomes more erratic, arid, and semi-arid areas are becoming drier, whereas other regions are becoming wetter and the frequency of the heaviest precipitation events have increased (Karl and Knight 1998; Mason et al., 1999). The little glimpse of CC that has occurred so far has already had comprehensible effects on an extensive diversity of natural ecosystems (Walther et al., 2002). The earth's climate is changing very fast and differently, these CC affect our lives socially, economically, and physically and the outcome of CC is more than a GW. The increase in average temperature in the single factor for massive changes which translates into extreme temperatures, flooding, storms, sea-level rise expected 0.11 to 0.77 meters by 2100 (IPCC, 2001), drought, the impact of agriculture or food production, and impact on health conditions, etc. The atmospheric temperature of the earth has increased due to a rise in GHGs emission, with the exact change differs regionally. The rate of emission of GHGs is responsible to increase the average surface temperature of the Earth which is about 0.2°C per decade.

Climate change can have an impact on the formation of a storm by regulating the difference in temperature between the poles and the equator. There will be a high risk of flood, droughts, and storms like tropical cyclones with devastating wind speeds, a wetter and erratic Asian monsoon, and, stronger mid-latitude storms (Pounds and Puschendorf, 2004). This difference in temperature provides the energy to mid-latitude storms which affect the most populated area over the Earth's surface. The Equator is already hot and humid so a slight change in temperature does not matter very much as on the poles, because at the poles the air is cold and dry and a little additional heat and water vapour can increase temperatures substantially. As per George Tselioudis, a research scientist at NASA Goddard Institute for Space Studies (GISS) and Columbia University due to this there is less temperature difference between the poles and the equator and because of a decrease in temperature difference the count of storms decrease. The pattern of CC can be observed worldwide and seen in the latest natural disaster in Haiti by hurricane Mathew. It is the strongest storm that hit Haiti since hurricane Cleo in 1964. About 1.125 million people were affected and around 546 people were died according to Haitian government figures (Stewart, 2017). This can also be equated with global climate change.

2. Impact of climate change on sea level

Rising sea level is the most severe catastrophic effects of climate change. The most important reason behind the rise in sea level is because of the melting of glacier and if sea level rising at the same rate then by the end of the century it maybe three feet higher than today (Levitus et al., 2005). Communities living in the low-lying coastal area are the major victims of the rising sea level. For instance, in Bangladesh, 17 percent area of the country would be flooded or even submerged by just a one-meter rise in sea level (Anthoff et. al., 2010). South-east and mid-Atlantic coasts of the united states are the most vulnerable area from rising sea level and not only this, but about 54 percent of its population lives close to the ocean are also lives at risk of inundation. Some other areas like North Carolina’s Outer Banks, the Florida Coast, and much of southern California and Maldives are in risk (National Centre for Atmospheric Research, 2005). It is projected that the Maldives will face a rise in the level of 1.5 feet (half a meter) and about 77 percent of its land will be submerged by the 21st century

(Woodworth, 2005 & Tol, 2007) and If sea level rise by 3 feet (1 meter) then by about 2085 whole the Maldives could be submerged in the ocean (Anthoff et. al., 2010).

2.1 Cause behind sea-level rise

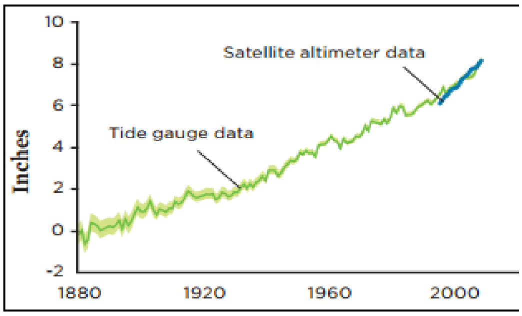

Figure 5 Average global sea level rise

Source : NRC, 2012; Church et al., 2011, Cazenave and Llovel, 2010

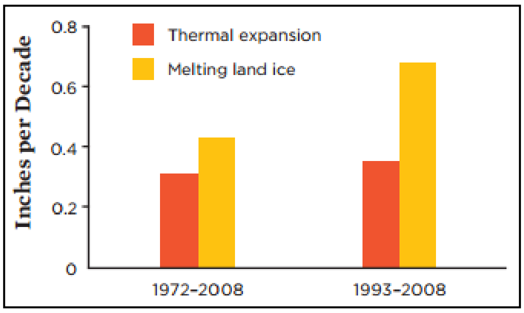

Figure 6 Contribution of climatic phenomena in sea level rise

Source : NRC, 2012; Church et al., 2011, Cazenave and Llovel, 2010

Since the industrial revolution global warming is the main cause behind the sea level rise. Anthropogenic processes like burning coal and oil and deforestation of tropical forests increase the concentration of greenhouse gases in the atmosphere which leads to the warming of the earth by 1.4°F since 1880 (Hansen et al. 2010). Ocean waters also get warm because of rising atmospheric temperature and 85 percent of the excess heat of the atmosphere have absorbed by the since 1880 (Levitus et al., 2001; Levitus et al., 2005; Levitus et al., 2009; Cazenave & Llovel, 2010). Ocean water expands when gets heated so the main cause of rising sea level for about 100 years after the beginning of the Industrial Revolution. Nonetheless, the contribution of thermal expansion in rising sea levels has reduced in the past few decades because of the acceleration of the melting of land ice (Lombard et al., 2005; Cazenave & Llovel, 2010). Two-thirds of the world's freshwater is stored in the form of Land ice glaciers, ice caps, and ice sheets and they are shrinking because of the rise in atmospheric temperatures (Trenberth et al., 2007). Indeed additional water causes a rise in sea level (Kaser et al., 2006; Meier et al., 2007; Cogley, 2009; EPA, 2012). About one inch of water added into the sea from 1993 to 2008 from the melting of glaciers, ice caps, and ice sheets which accounts for more than half of the increase during the said period (Church et al., 2011). Change in regional Ocean current because of submergence of land is another cause for seal level rise. These types of phenomena have effects on "hot spots" that are experiencing local sea-level rise more than the average, for example, the East and Gulf coasts of the United States (Sallenger et al., 2012; Milne, 2008). Global warming and climate change are the main culprits of the rise in sea level. Since 1880 there is about eight inches rise in sea level. Long term rise in sea level is recorded by tide gauges since 1870 and these trends are also confirmed by satellite observations since 1993 (blue line) fig.5. Melting of land ice glaciers, ice caps, and ice sheets contribute about 52 percent of sea-level rise between 1972 and 2008, whereas the thermal expansion of oceans accounts for about 38 percent, and the remaining 10 percent rise in sea level is because of the withdrawal of groundwater and other factors. Between 1880 to 2009 global sea-level rise approximately eight inches from and the decadal rise is about 0.8 inches from 1972 to 2008 (Church et al., 2011). The coastal region between Nova Scotia to the Gulf of Mexico experienced one of the rapid sea-level rise in the twentieth century from 0.01 inch yearly in Boston to 0.38 inch yearly in Louisiana (NOAA, 2012) fig. 6.

The global average absolute sea level (GMSL) change between 1880 to 2014 is shown in table 1. Average absolute sea-level change refers to the height of the surface of the ocean without taking into account the rise and fall of the nearby land surface. GMSL data are collected from CSIRO (Commonwealth Scientist and Industrial Research Organisation, 2015) and NOAA (National Oceanic and Atmospheric Administration, 2015). These data are showing a cumulative change in global sea level since 1880. Long terms tide gauge measurement and data measured from satellite imageries are used in the calculation of the GMSL data. Between 1880 to 2014 GMSL value increase from -62.48 to 28.07 inches. The average decadal growth rate of GMSL is about 17.4 percent and the highest GMSL change is 21.84 between 1990 to 2000.

Table 1 : Global mean sea-level change (GMSL) between 1880 – 2014

S. No	Year	Global Mean Sea Level (inches)	Decadal change rate (%)
1	1880	-62.48	19.29
2	1890	-58.07	18.82
3	1900	-51.22	19.72
4	1910	-49.76	18.73
5	1920	-43.43	19.64
6	1930	-41.85	18.67
7	1940	-36.30	17.30
8	1950	-26.50	16.58
9	1960	-17.44	19.01
10	1970	-15.71	14.14
11	1980	-6.50	10.00
12	1990	0.00	10.00
13	2000	9.84	21.84
23	2010	21.61	19.95
24	2011	21.50	-
25	2012	25.75	-
26	2013	26.73	-
27	2014	28.07	10.00

Source : EPA (the United States Environmental Protection Agency) CSIRO (Commonwealth Scientific and Industrial Research Organisation), 2015

2.1 Regional sea-level change

Changing the wind field and the associated change in ocean circulation are responsible for variation in regional sea-level change (Kohl & Stammer, 2008). There is spatial variation in sea level rise in the ocean. For example, there is a higher rate of rising in sea level in the western tropical Pacific and a decline in sea level in the eastern Pacific between 1993 to 2010 and also about 5.4 ± 0.3 mm/ year rise in the region between Japan and Korea, which is about two times higher than the GMSL trend (Kang et al., 2005). Tide gauge measurement is used to show the observed and projected relative change in sea level for nine coastal regions since 1970. The yellow color is showing the observed in situ relative sea-level values and the purple line is showing the satellite record. The shaded region is showing the projected range for 2006 to 2021.

In situ relative sea-level, value, and satellite records are almost similar in all region range between -0 to 0.2 m. Projected change in sea level is highest in New York between 0.3 to 0.9 m followed by Ijmuidin (a port city in North Holland) 0.2 to 0.8 m. At San Francisco, the projected value is about 0.3 to 0.8 m and in the Bay of Bengal, it is 0.3 to 0.7m. In Kinmen, China the projected range is also very high i.e. 0.3 to 0.8m. In Brest (France) and Mar de Plata (Argentina) the projected range is 0.3 to 0.7m and in Fremantle (Australia) and Pago Pago (the main island of American Samoa) the projected range is between 0.3 to 0.8m. fig. 3.

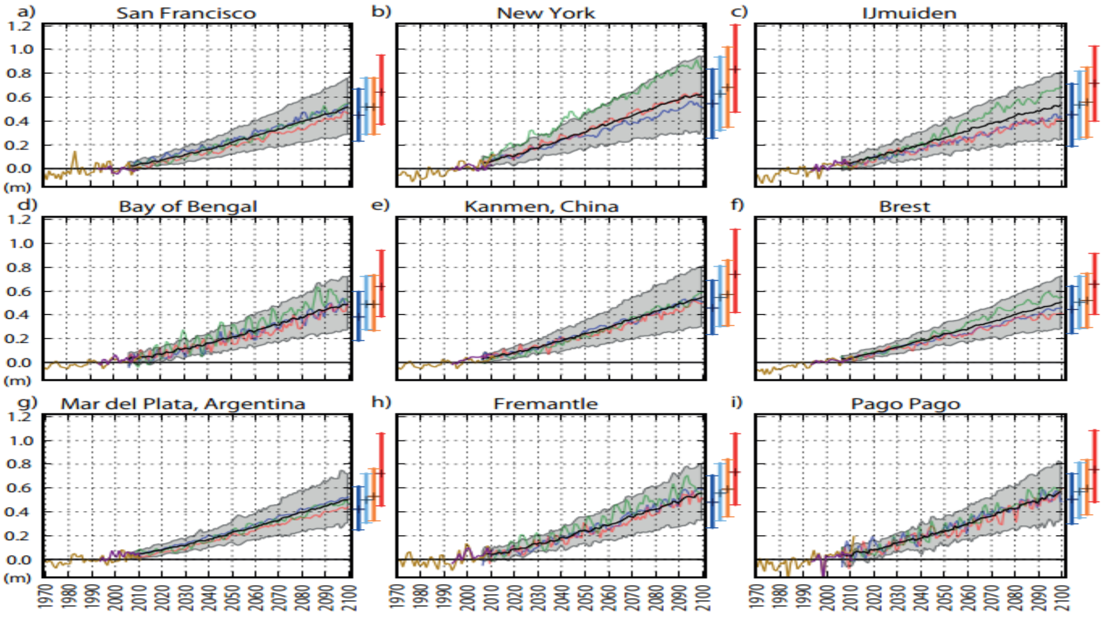

Figure 5 Regional sea level change, Source: IPCC report, 2013

3. Impacts on Coastal cities

According to the UN Atlas of oceans (2016), within 150 km of the coast around 44 % of the population of the world lives. The accelerated rate of population growth in coastal cities and increasing tourism add pressure on the coastal environment. In this regard, climate change makes the situation more vulnerable to coastal cities. Continuous coastlines lying in the low elevation coastal zone constitute only 2% of the world's geographical area but sustain 10% of the total population and 13% of the urban population of the (McGranahan et al. 2007). In low elevation, the coastal zone around 3351 cities is situated and amongst them, 64% are of developing region (CIESIN 2005). It is reported that around 90% of all coastal areas will be affected by varying degrees. In cities like Jakarta (capital of Indonesia) the ground has submerged 2.5 meters in the sea in less than a decade (Global Risk Report, 2019). In East and Southeast Asia, four out of five people will be affected by sea-level rise by 2050. More than 340 million people are living in “delta cities” like Dhaka, Guangzhou, Ho Chi Minh City, Hong Kong, Manila, Melbourne, Miami, New Orleans, New York, Rotterdam, Tokyo, and Venice are already facing the impacts of sea-level rise. Around 59.40 percent of the world's urban population is living in a low elevation coastal zone and prone to the risk of disasters caused due to climate change (Table 1).

In the case of India in 2019 only in India over thirteen states in late July and early August affected by flood leads to the death of 200 people and displacement of about a million people. The most badly affected state in 2019 by the flood was Karnataka and Maharashtra (NDTV, 2019). Besides flood global warming also causes an increase in the frequency of category 4 & 5 types of very intense cyclone over the 21st century (IPCC AR5). There has been about a 32% rise in the last 5 years and an 11% rise in the last decade in the occurrence of cyclone in the Arabian Sea and Bay of Bengal (Indian Metrological Department). According to the study of Scott A. Kulp and Benjamin H. Strauss of Climate Central, around 51 million people of India living in the low lying coastal zone will be affected by 2100 if global warming takes place at the same pace and portion of coastal cities like Mumbai, Surat, Chennai, and Kolkata will be submerged due to recurring floods by 2050.

Table 2 : Urban Population at risk of sea-level rise

Region	Urban Population (000s)	LECZ Population (000s)	Urban population in LECZ (000s)	% of LECZ urban to total urban	% of urban in LECZ
Africa	2,82,143	55,633	32,390	11.50%	58.20%
Asia	14,30,917	4,49,845	2,35,258	16.40%	52.30%
Oceania	2017	852	442	21.90%	51.90%
Developing Total	**20,34,706**	**5,39,908**	**2,92,738**	**14.40%**	**54.20%**
Europe	500943	50200	39709	7.90%	79.10%
N. America	2,55,745	24,217	21,489	8.40%	88.70%
Japan	1,01,936	29,347	27,521	27.00%	93.80%
Australia & New Zealand	18,002	2,845	2,421	13.50%	85.10%
Developed Total	**8,76,627**	**1,06,611**	**91,140**	**10.40%**	**85.50%**
World Total	**29,11,333**	**6,46,519**	**3,83,878**	**13.20%**	**59.40%**

LECZ = Low Elevation Coastal Zone
LECZ : the land area that is contiguous with the coast and 10 meters or less in elevation.

Source : Coastal Analysis Data Set utilizing GRUMP beta population and land area grids (CIESIN, 2005), Low Elevation Coastal Zone created from SRTM elevation grid (CIESIN, 2006)

4. Conclusion

The study shows with the current speed of greenhouse gas emission and global warming, 300 million people of the world will be at risk of coastal flooding by 2050, and China, Bangladesh, India, Vietnam, Indonesia, and Thailand will be most affected where around 237 million people live in the coastal area. Extreme sea-level events like the surge from the tropical cyclone which is rarely in the current scenario become common by 2100. The impact becomes worse in developing and underdeveloped countries where people are already facing other problems. A large number of planning and summits are organized at the world level to tackle the problem. But besides this, there is no sign of a decrease in the emission of greenhouse gas. So in this scenario disaster preparedness is the only issue to minimize the risk to the population, livestock, and property. The approach of government related to disaster preparedness should be aggressive and set clear and actionable agenda. Then only it is possible to minimize the risk of impacts of disaster-related to climate change.

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Dr. Babita is currently working as an Information Officer in the CEECC, ADRI, Patna. Before this, she was working in The INCLEN Trust International as Assistant Research Officer. She has done a Doctor of Philosophy in Geography from Jamia Millia Islamia, New Delhi. She has published five research papers in different national and international journals. Her work and research are focused on Urban Geography and the Urban Environment. She did her post-graduate diploma in Remote Sensing and GIS from Jamia Millia Islamia.