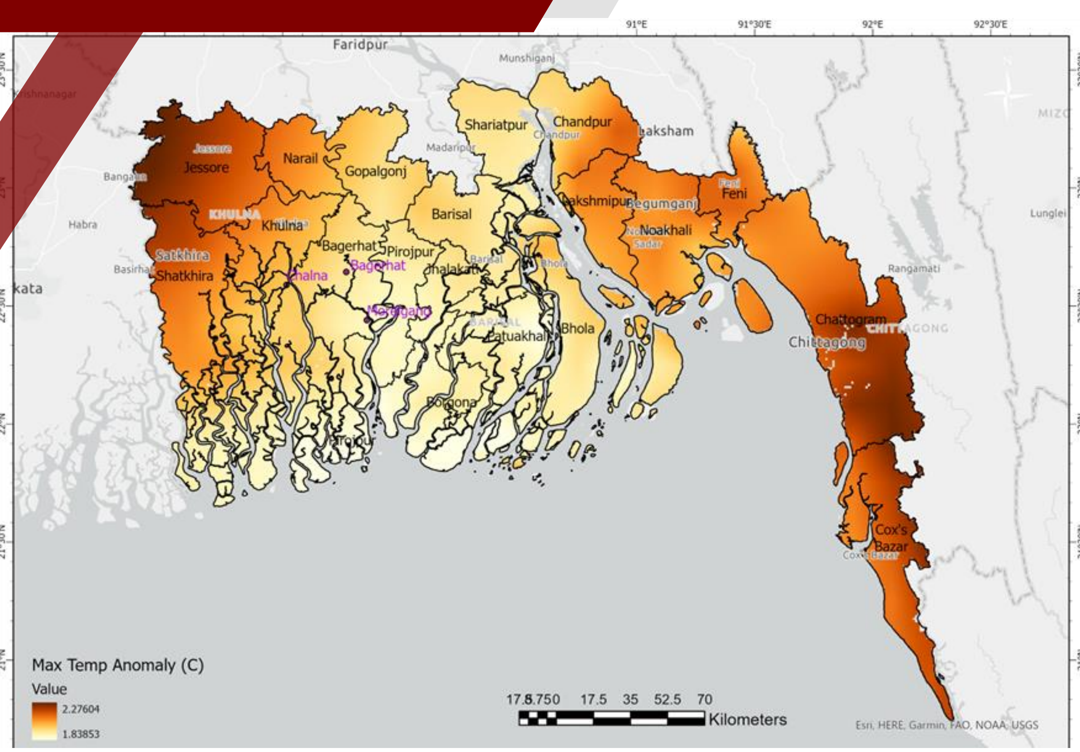
URBAN DEVELOPMENT DIRECTORATE (UDD)

Ministry of Housing and Public Works

Government of the People's Republic of Bangladesh



A.K.M. Saiful Islam

IWFM, BUET, Dhaka

Climate Projections

Climate models are one of the primary ways for scientists to understand how the climate has been changed in the past and may change in the near and far future. These models simulate the physics, chemistry, and biology of the atmosphere, land, and oceans in great detail and need some of the largest and fastest supercomputers in the world to generate their projections. Climate models are constantly being updated as different modeling groups around the world incorporate higher spatial resolution, new physical processes, and biogeochemical cycles. These modeling groups coordinate their updates around the schedule of the Intergovernmental Panel on Climate Change (IPCC) assessment reports. All of these coordinated efforts are part of the Coupled Model Intercomparison Projects (CMIP). The IPCC fifth assessment report (AR5) featured climate models from CMIP5, while the IPCC sixth assessment report (AR6) has featured the brand new CMIP6 models. Global climate models (GCMs) have been used as a primary tool for examining the past and future changes in climate extremes, and the comprehensive evaluation of GCM performances is important for the proper interpretation of the simulated results. A new generation of GCMs has been developed for the CMIP6 experiments (Eyring et al., 2016). CMIP6 models have an increased range of complexity from GCMs to Earth System Models with improvements in physical processes and higher spatial resolution. CMIP6 consists of the “runs” from around 100 distinct climate models being produced across 49 different modeling groups. In the lead-up to the IPCC AR6, the energy modeling community has developed a new set of emissions scenarios driven by different socio-economic assumptions. These have been defined as the “Shared Socioeconomic Pathways” (SSPs). A number of these SSP scenarios have been selected to drive climate models for CMIP6. Specifically, a set of scenarios were chosen to provide a range of distinct end-of-century climate change outcomes. The IPCC AR5 featured four Representative Concentration Pathways (RCPs) that examined different possible future greenhouse gas emissions.

These scenarios – RCP2.6, RCP4.5, RCP6.0, and RCP8.5 – have new versions in CMIP6. These updated scenarios are called SSP126, SSP245, SSP460, and SSP585, each of which result in similar 2100 radiative forcing levels as their predecessor in AR5. In this study, 13 CMIP6 models from different modeling groups around the world have been used under

ScenarioMIP for the baseline (1985-2014) and future period (2015-2100) based on (Mishra et al., 2020). Daily bias-corrected data of precipitation, maximum and minimum temperatures at 0.25° spatial resolution for South Asia (India, Pakistan, Bangladesh, Nepal, Bhutan, and Sri Lanka) and 18 river basins located in the Indian sub-continent have been downloaded from CMIP6 bias-corrected products developed by Mishra et al. (2020). The bias-corrected dataset is developed using Empirical Quantile Mapping (EQM) for the historical (1951–2014) and projected (2015–2100) climate for the four scenarios (SSP126, SSP245, SSP370, SSP585) using output from 13 General Circulation Models (GCMs) of CMIP6. Daily datasets, including three variables, i.e., pr (total precipitation), tasmax (maximum temperature), and tasmin (minimum temperature), have been downloaded and processed to carry out further analysis. The list of CMIP6 models that have been considered for this study is provided in Table 1.

Table 1: Multi-model ensemble climate projections over the study area for near future (2021-2040) and far future (2081-2100)

Serial	Model Name	Country	Scenarios	Resolution (Degree)
1	ACCESS-CM2	Australia	SSP245, SSP585	0.25
2	ACCESS-ESM1-5	Australia	SSP245, SSP585	0.25
3	BCC-CSM2-MR	China	SSP245, SSP585	0.25
4	CanESM5	Canada	SSP245, SSP585	0.25
5	EC-Earth3	EU	SSP245, SSP585	0.25
6	EC-Earth3-Veg	EU	SSP245, SSP585	0.25
7	INM-CM4-8	Russia	SSP245, SSP585	0.25
8	INM-CM5-0	Russia	SSP245, SSP585	0.25
9	MPI-ESM1-2-HR	Germany	SSP245, SSP585	0.25
10	MPI-ESM1-2-LR	Germany	SSP245, SSP585	0.25
11	MRI-ESM2-0	Japan	SSP245, SSP585	0.25
12	NorESM2-LM	Norway	SSP245, SSP585	0.25
13	NorESM2-MM	Norway	SSP245, SSP585	0.25

Projected Changes in Temperature (°C)

Projected changes in annual maximum temperature (°C) in 2081-2100 over the coastal region of Bangladesh under the SSP245 scenario are shown in Figure 1. Monthly changes for the the study sites are shown in Figure 2. Results showed that mean temperature will increase 0.82°C and 2.27°C while maximum temperate will increase 0.59°C and 2.05°C for the near and far future, respectively.

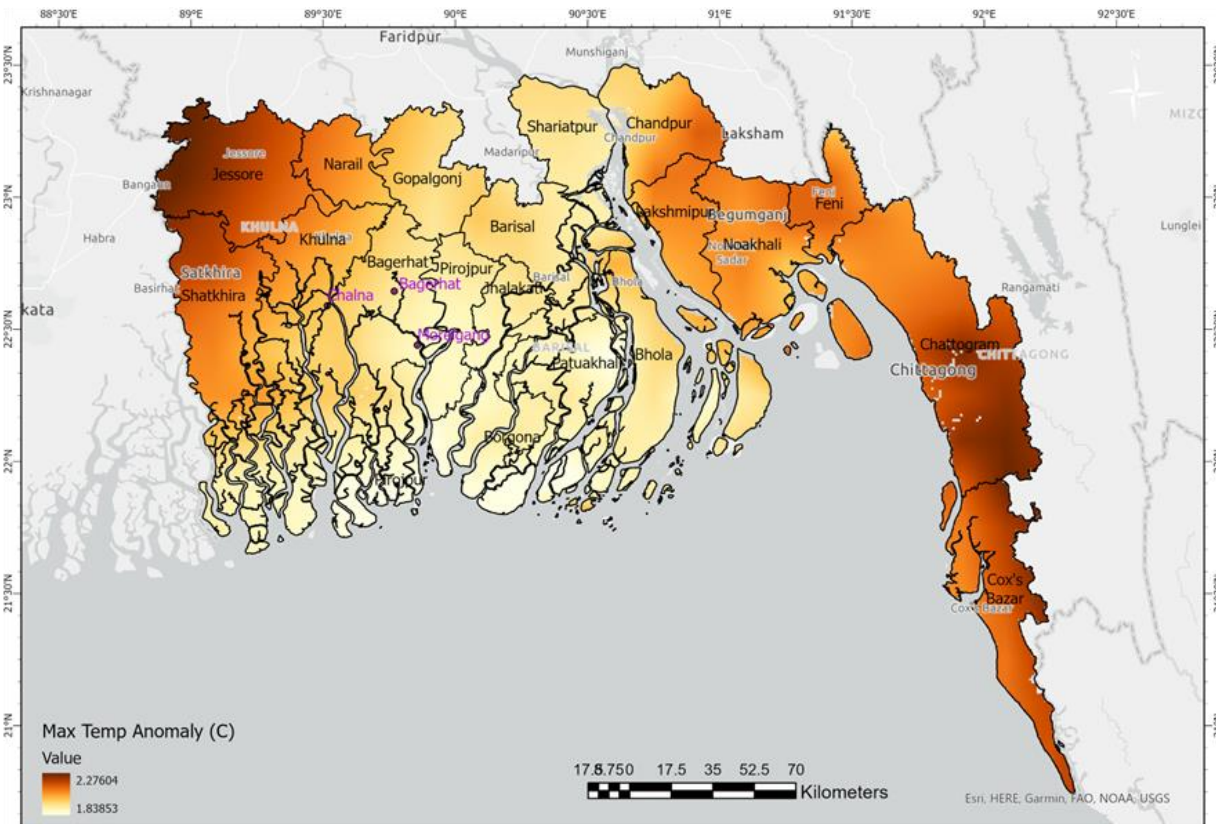


Figure 1: Projected changes in annual maximum temperature (°C) under the SSP245 scenario in 2081-2100.

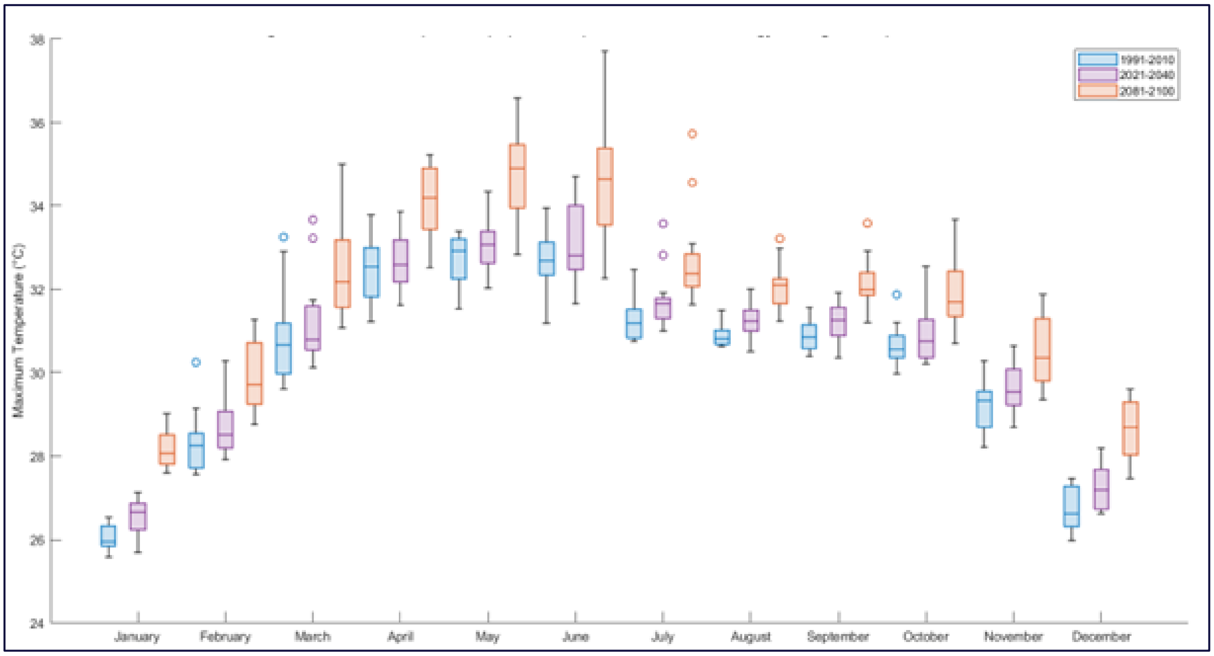


Figure 2: Changes in mean monthly maximum temperature (°C) for the study sites under SSP245 scenarios.

Projected Changes in Precipitation

Projected changes in annual mean rainfall (mm) in 2081-2100 over the coastal region of Bangladesh under the SSP245 scenario are shown in Figure 3. Monthly changes for the study sites are shown in Figure 4. Results showed that mean rainfall (mm) will increase -1.70% and 4.57% and while maximum rainfall will increase 1.48 % and 6.40% for the near and far future respectively.

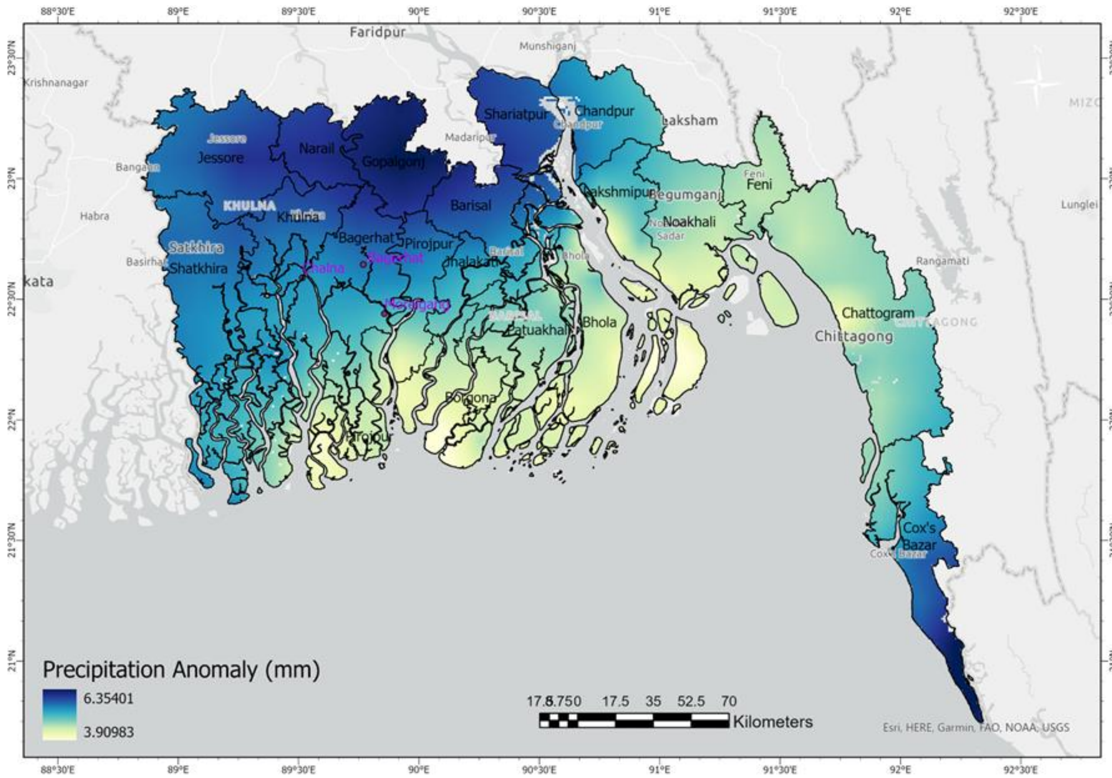


Figure 3: Projected changes in mean rainfall (mm) of the wettest month under the SSP245 scenario in 2081-2100.

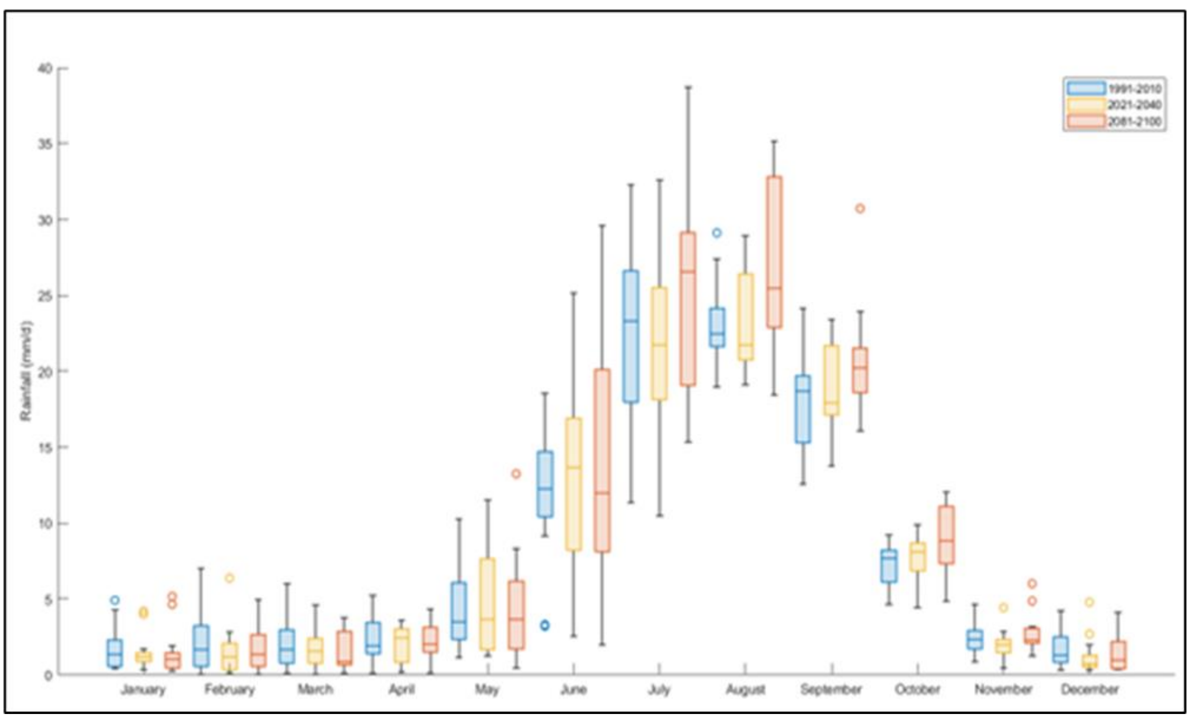


Figure 4: Changes in mean monthly rainfall (mm) for the three case study sites under SSP245 scenarios.

Sea Level Rise (SLR)

In IPCC's Sixth Assessment Report (AR6) (Arias et al., 2021), the estimated rate of Global Mean Sea Level (GMSL) was found as 3.42 mm/y for the period 1993-2020. the global mean sea level was increased by 0.20 [0.15 to 0.25] m between 1901 and 2018. The average rate of sea-level rise was 1.3 [0.6 to 2.1] mm/y between 1901 and 1971, increasing to 1.9 [0.8 to 2.9] mm/y 1971 and 2006, and further increasing to 3.7 [3.2 to 4.2] mm/y between 1993 and 2018.

Global mean sea level will rise by 2050 between 0.18 [0.15–0.23, likely range] m (SSP1-1.9) and 0.23 [0.20–0.30, likely range] m (SSP5-8.5), and by 2100 between 0.38 [0.28–18 0.55, likely range] m (SSP1-1.9) and 0.77 [0.63–1.02, likely range] m (SSP5-8.5). Projected global mean sea level rise (m) under different SSP-RCP scenarios based on CMIP6 models are shown in Figure 5.

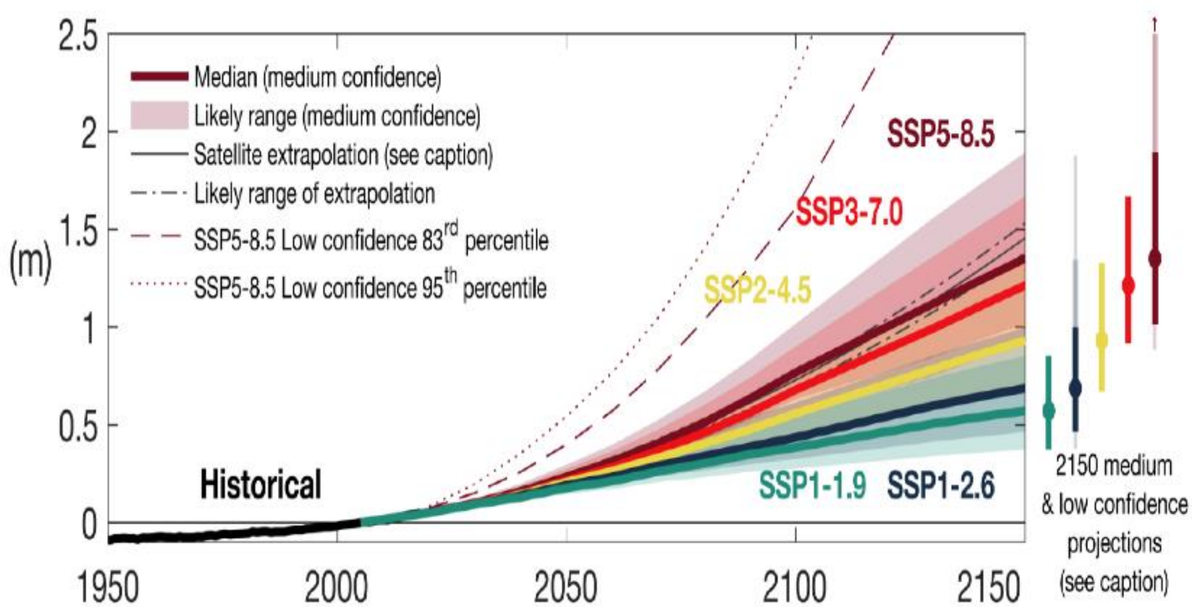


Figure 5: Projected global mean sea level rise (m) under different SSP-RCP scenarios based on CMIP6 models (Arias et al., 2021).

Regional variation is expected to be the dominating factor over natural variability in sea level change by the end of the 21st century (IPCC, 2013). Melting of land ice mass will be the main contributing factor. Some of the regions are expected to experience changes in sea level extensively different than the global mean, as revealed from the ensemble mean regional relative sea-level change between 1995-2014 and 2081-2100 under the RCP scenario. A recent study by Harrison-benjamin et al. (2020) has estimated sea level along the coastline of the Bay of Bengal. The coastal sites that are included in the projected changes in time mean sea level, selected from tide gauge stations available on the Permanent Service for Mean Sea Level (PSMSL), is presented in Figure 6 (Harrison-benjamin et al., 2020).

The 21st-century sea-level projections for RCP2.6 at tide gauge locations in the Bay of Bengal based and projected GMSL changes are shown in Figure 7. Solid lines indicate the central estimate; shaded areas indicate the 5^{th} - 95th percentile range for projected local (yellow) and global (blue) changes. The 21st-century sea-level projections for RCP8.5 at tide gauge locations in the Bay of Bengal based and projected GMSL changes are shown in Figure 8.

A summary of the projected sea-level rise at selected tide gauge locations in the Bay of Bengal under both RCP 2.6, RCP 4.5, and RCP 8.5 scenarios are presented in Table 2.

Figure 6: Bay of Bengal coastal sites that are included in the projected changes in time mean sea level, selected from tide gauge stations available on the Permanent Service for Mean Sea Level (PSMSL) (Source: Harrison-benjamin et al., 2020).

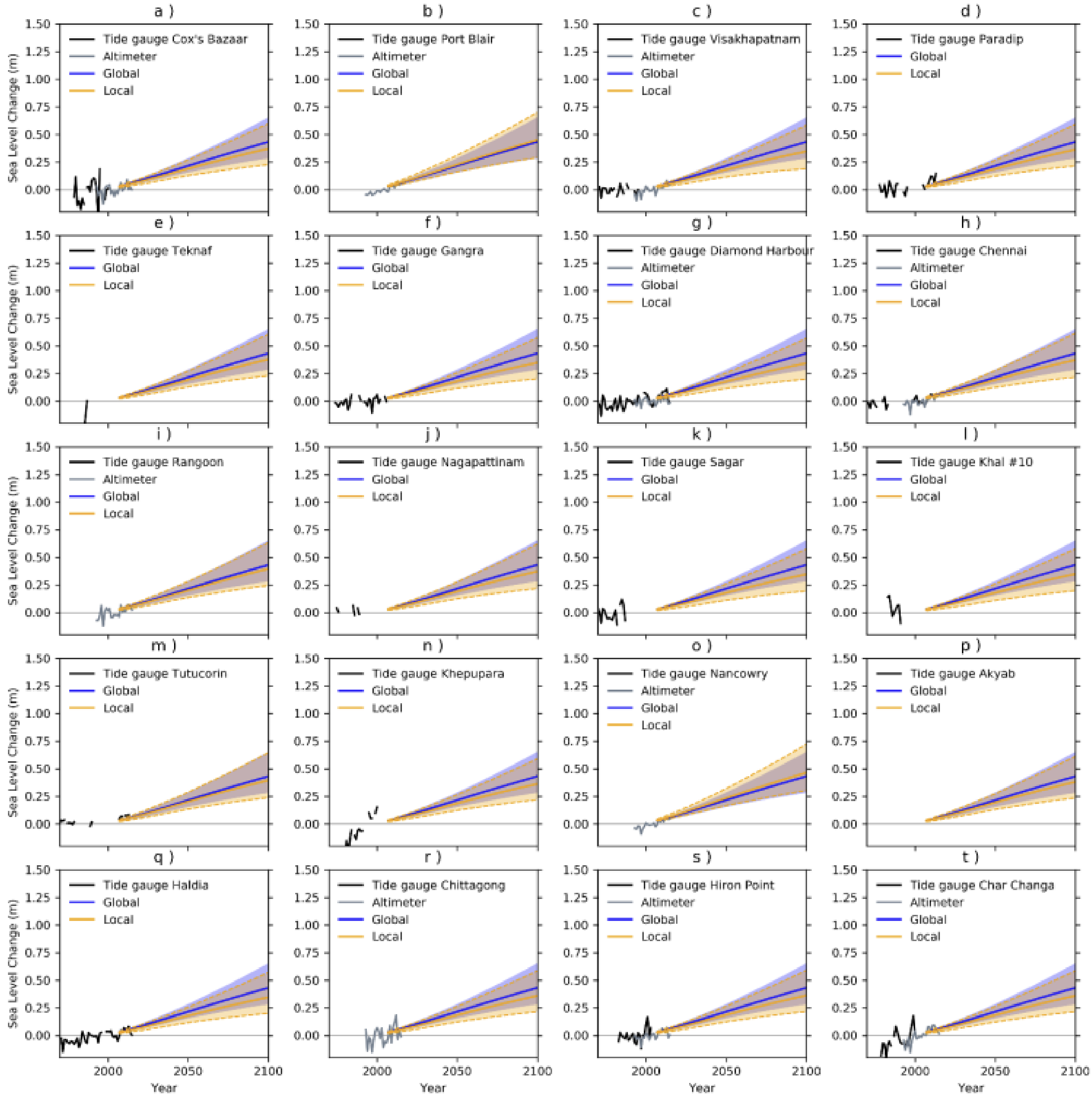


Figure 7: 21st-century sea-level projections for RCP2.6 at tide gauge locations in the Bay of Bengal based and projected GMSL changes. Solid lines indicate the central estimate; shaded areas indicate the 5th - 95th percentile range for projected local (yellow) and global (blue) changes (Source: Harrison-benjamin et al., 2020).

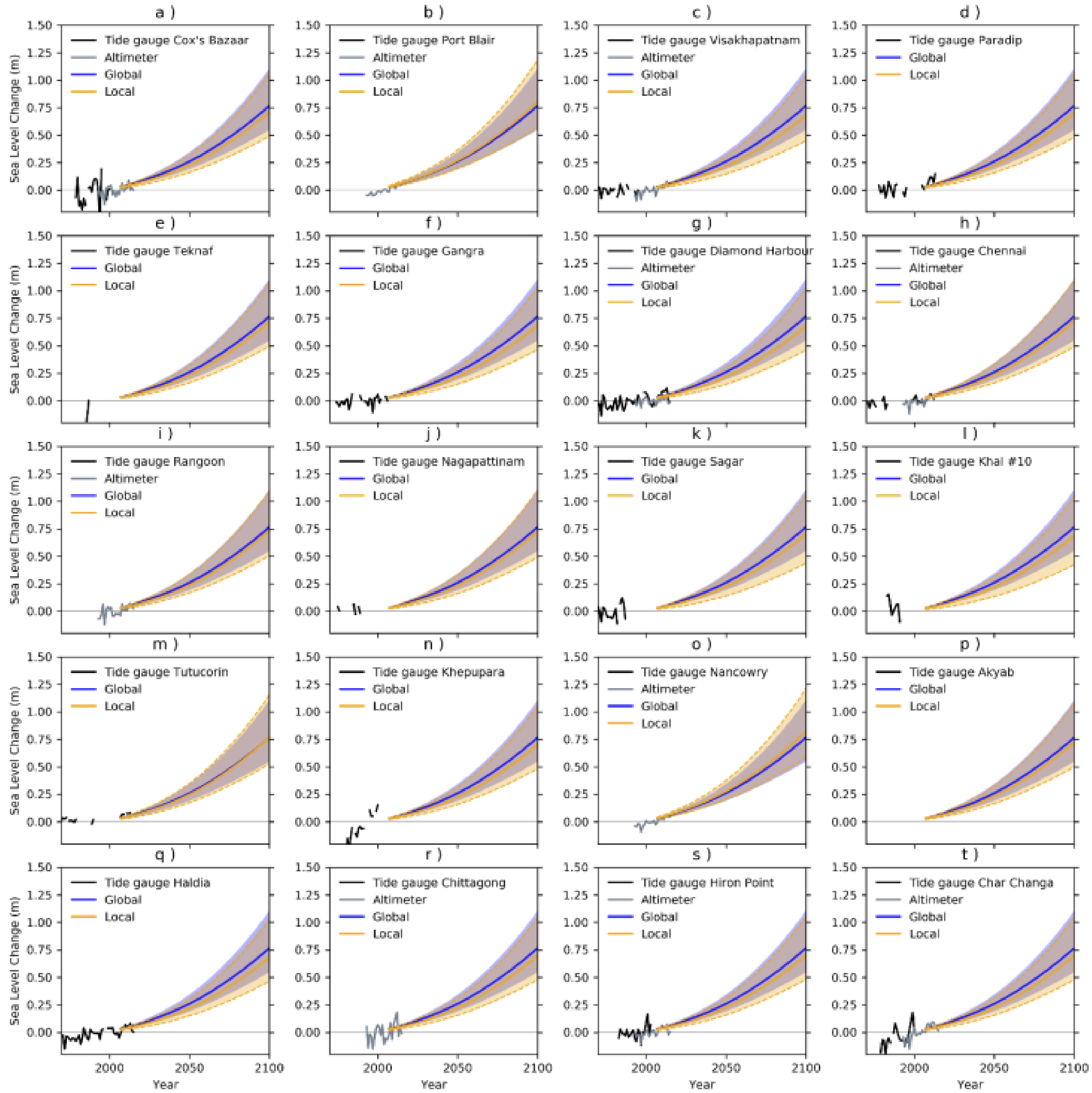


Figure 8: 21st-century sea-level projections for RCP8.5 at tide gauge locations in the Bay of Bengal based and projected GMSL changes. Solid lines indicate the central estimate; shaded areas indicate the 5th - 95th percentile range for projected local (yellow) and global (blue) changes (Source: Harrison-benjamin et al., 2020).

Table 2: The projected changes for the Bay of Bengal (Source: Harrison-benjamin et al., 2020).

2061-2080	RCP2.6	RCP4.5	RCP8.5
Coxs Bazaar	0.14-0.48	0.23-0.49	0.28-0.56
Port Blair	0.19-0.51	0.26-0.53	0.32-0.6
Visakhapatnam	0.13-0.46	0.21-0.49	0.27-0.54
Paradip	0.13-0.46	0.22-0.49	0.27-0.54
Teknaf	0.13-0.48	0.23-0.5	0.28-0.56
Gangra	0.12-0.46	0.21-0.48	0.27-0.54
Dmnd Harbour	0.11-0.45	0.2-0.47	0.26-0.52
Chennai	0.16-0.48	0.23-0.52	0.29-0.58
Rangoon	0.15-0.48	0.23-0.5	0.28-0.56
Nagapattinam	0.16-0.47	0.23-0.51	0.29-0.58
Sagar	0.13-0.44	0.18-0.5	0.23-0.58
Khal Ten	0.17-0.42	0.19-0.48	0.23-0.58
Tuticorin	0.19-0.46	0.24-0.52	0.31-0.6
Khepupara	0.13-0.47	0.22-0.49	0.27-0.55
Nancowry	0.2-0.51	0.26-0.53	0.32-0.6
Akyab	0.14-0.48	0.23-0.5	0.28-0.55
Haldia	0.11-0.45	0.2-0.47	0.26-0.52
Chittagong	0.14-0.48	0.23-0.5	0.28-0.56
Hiron Point	0.12-0.47	0.22-0.49	0.27-0.55
Moulmein Two	0.18-0.45	0.21-0.51	0.26-0.6
Charchanga	0.13-0.47	0.22-0.49	0.27-0.55
Ko Taphao Noi	0.18-0.5	0.25-0.53	0.3-0.59

2081-2100	RCP2.6	RCP4.5	RCP8.5
Coxs Bazaar	0.17-0.62	0.3-0.68	0.4-0.86
Port Blair	0.24-0.66	0.34-0.73	0.45-0.92
Visakhapatnam	0.16-0.6	0.27-0.68	0.39-0.84
Paradip	0.16-0.6	0.28-0.67	0.39-0.84
Teknaf	0.17-0.62	0.29-0.68	0.4-0.85
Gangra	0.15-0.6	0.28-0.66	0.38-0.83
Dmnd Harbour	0.14-0.58	0.26-0.64	0.37-0.81
Chennai	0.19-0.62	0.29-0.71	0.43-0.89
Rangoon	0.19-0.62	0.29-0.69	0.41-0.86
Nagapattinam	0.2-0.61	0.3-0.71	0.42-0.89
Sagar	0.16-0.57	0.24-0.68	0.33-0.89
Khal Ten	0.2-0.55	0.25-0.66	0.34-0.89
Tuticorin	0.24-0.6	0.31-0.71	0.45-0.93
Khepupara	0.16-0.61	0.28-0.67	0.39-0.84
Nancowry	0.24-0.66	0.34-0.73	0.46-0.92
Akyab	0.18-0.62	0.29-0.68	0.41-0.85
Haldia	0.14-0.58	0.26-0.64	0.37-0.81
Chittagong	0.17-0.62	0.29-0.68	0.41-0.86
Hiron Point	0.15-0.61	0.28-0.67	0.39-0.84
Moulmein Two	0.22-0.59	0.28-0.7	0.37-0.92
Charchanga	0.16-0.6	0.28-0.67	0.39-0.84
Ko Taphao Noi	0.22-0.65	0.33-0.73	0.44-0.91

Salinity Intrusion

Salinity in soil and water is a common hazard in coastal Bangladesh. Agriculture suffers greatly. It restricts the cultivation of Aus (summer rice), Boro (dry season rice), and other Rabi (dry season) crops. In the southwest region, surface water and soil salinity has been accentuated by the reduction of upland flows entering the Gorai distributaries, in the dry season. Coastal polders were designed to prevent salt-water intrusion. Many polders have lost functionality due to undesired and desired breaches. Salinity intrusion has multiple impacts. Salinity intrusion through the estuaries in low-lying tide-dominated Bangladesh is a serious threat and is expected to get worse in changing climatic conditions. Sea-level rise (SLR) is a consequence of climate change that affects the distribution of stress from inundation and salinity.

Analysing secondary information from DoE it is found that, for an SLR of 0.50 m, all Upazilas, i.e., Galachipa, Kalapara, Rangabali, Patharghata, Taltali, Barguna Sadar, and Amtali will be affected by 1 ppt, and 5 ppt salinity and Patharghata, Taltali, Barguna Sadar, and Amtali will be affected by 15 ppt salinity Figure 9For an SLR of 0.62 m, all upazilas, i.e., Galachipa, Kalapara, Rangabali, Patharghata, Taltali, Barguna Sadar, and Amtali will be affected by up to

15 ppt salinity and Patharghata, Taltali, Barguna Sadar, and Amtali will be affected by up to 25 ppt salinity Figure 10**.** For an SLR of 0.95 m, all upazilas, i.e., Galachipa, Kalapara, Rangabali, Patharghata, Taltali, Barguna Sadar, and Amtali will be affected by up to 15 ppt salinity and Patharghata, Taltali, Barguna Sadar, and Amtali will be affected by up to 25 ppt salinity Figure 11. Salinity ingress is a serious threat to soil and water in coastal Bangladesh. Agriculture is the worst sufferer posing a threat to food security.

Salinity causes low crop yield, loss of livelihoods, change in crop pattern, less suitable irrigation water, reduction of cultivable land, endangered food security, unfavorable fish habitat, marine fish ingress and loss of freshwater fish, oxygen drop, low livestock production, and loss of milk production, etc.

To reduce the risk of sea-level rise and salinity intrusion, adaptive capacity has to be improved. Freshwater flows need to be increased in coastal rivers to limit salinity ingress. Community-based, youth-led, and gender-inclusive freshwater pond management and rainwater harvesting in the saline-prone area have to be promoted. Heightened dykes or freshwater retention ponds have to be constructed in the southwest region to halt cyclonic storm surge-driven salinity ingress and harness multipurpose socio-economic benefits. Low-cost household-level desalinization tools for the desalinization of drinking water have to be distributed through private sector engagement, etc.

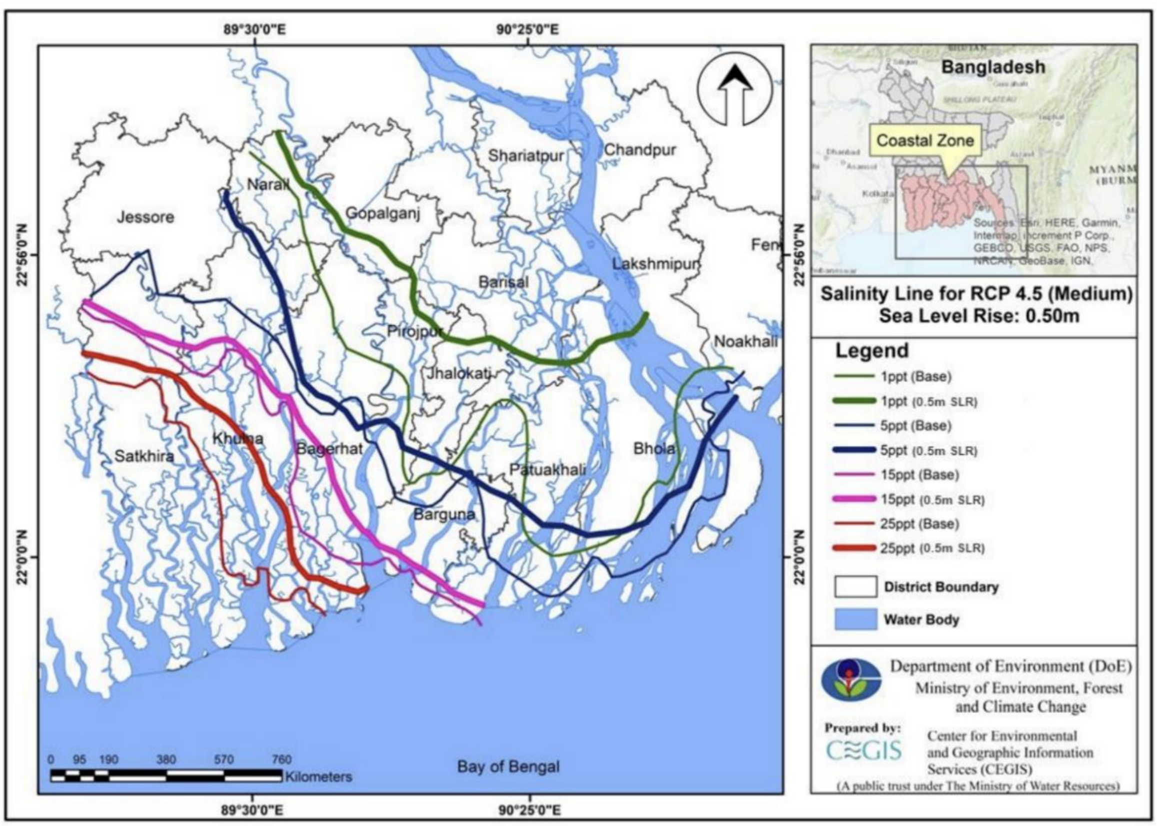


Figure 9: Salinity Map for 0.5m SLR (Source: DoE).

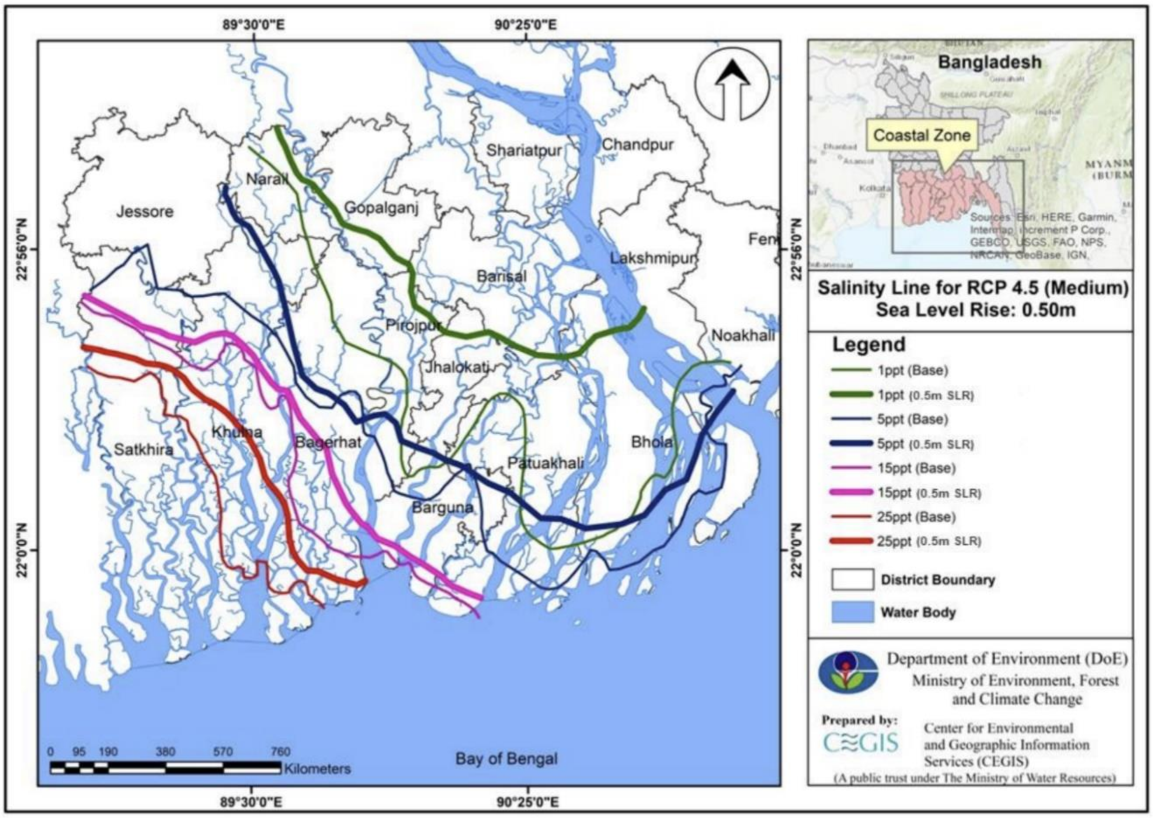


Figure 10: Salinity Map for 0.62m SLR (Source: DoE).

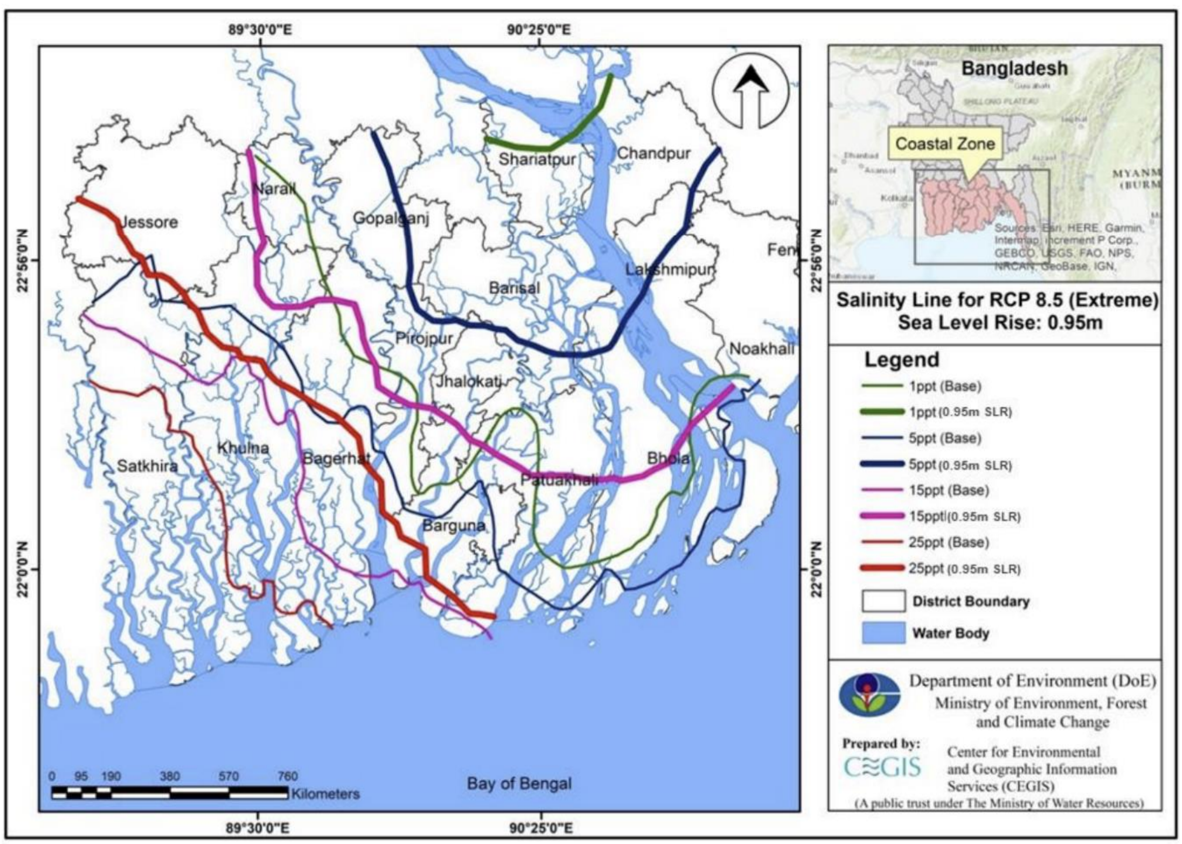


Figure 11: Salinity Map for 0.95m SLR (Source: DoE).