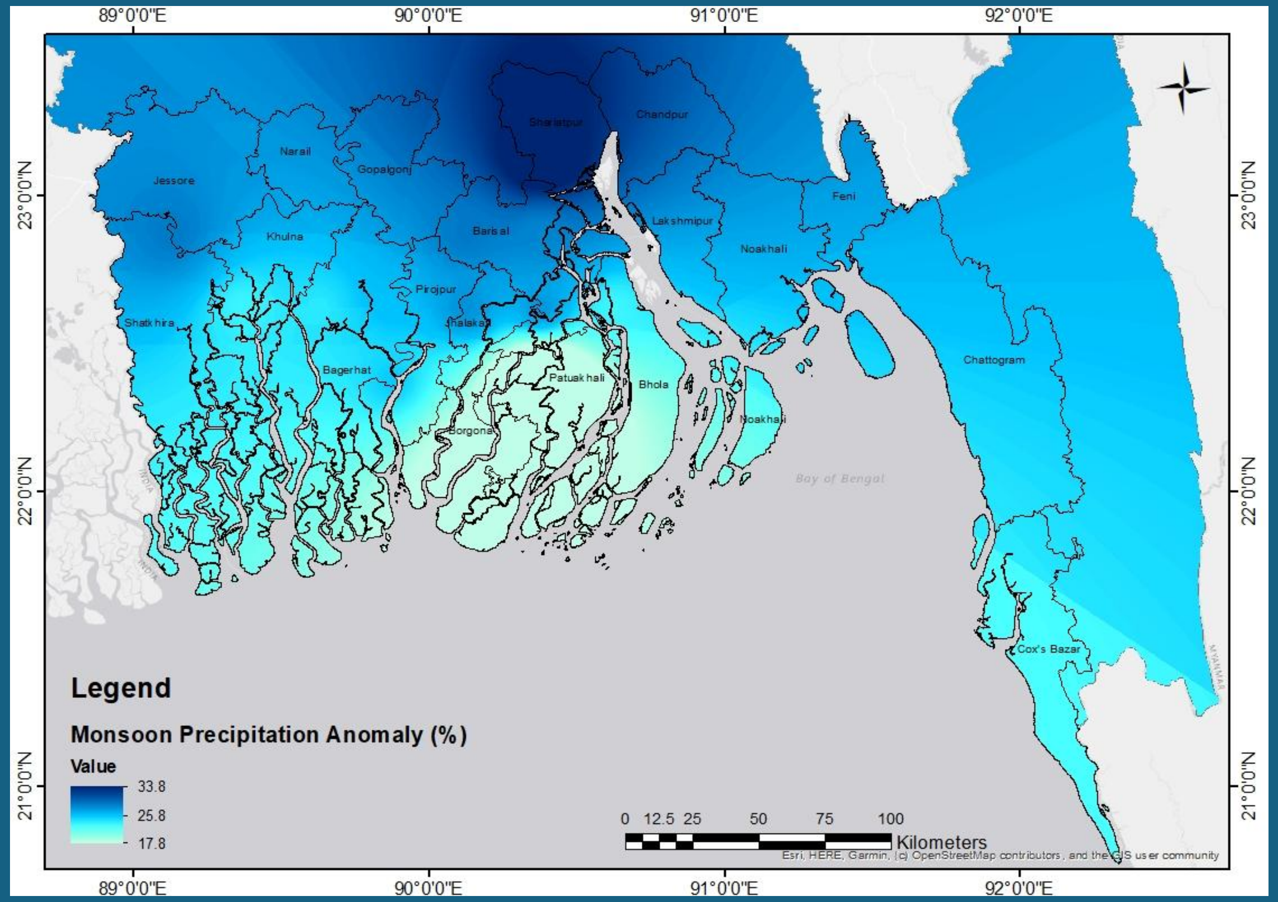
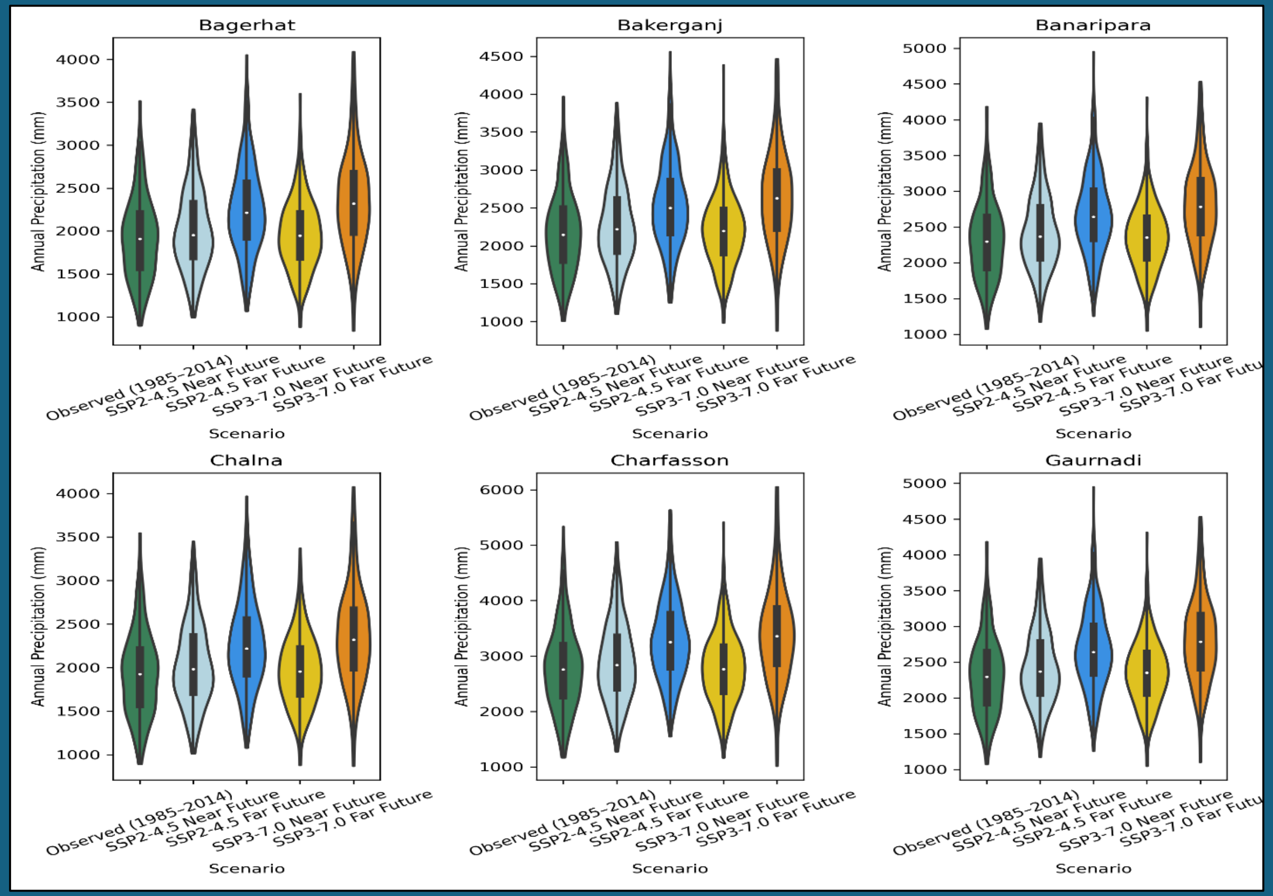
The Abdus Salam International Centre for Theoretical Physics

12th Workshop on the Theory and Use of Regional Climate Models
Trieste, Italy, September 01, 2025

Future Changes in Precipitation Patterns and Extremes in Major Coastal Cities of Bangladesh Using CMIP6 Multi-Model Ensemble



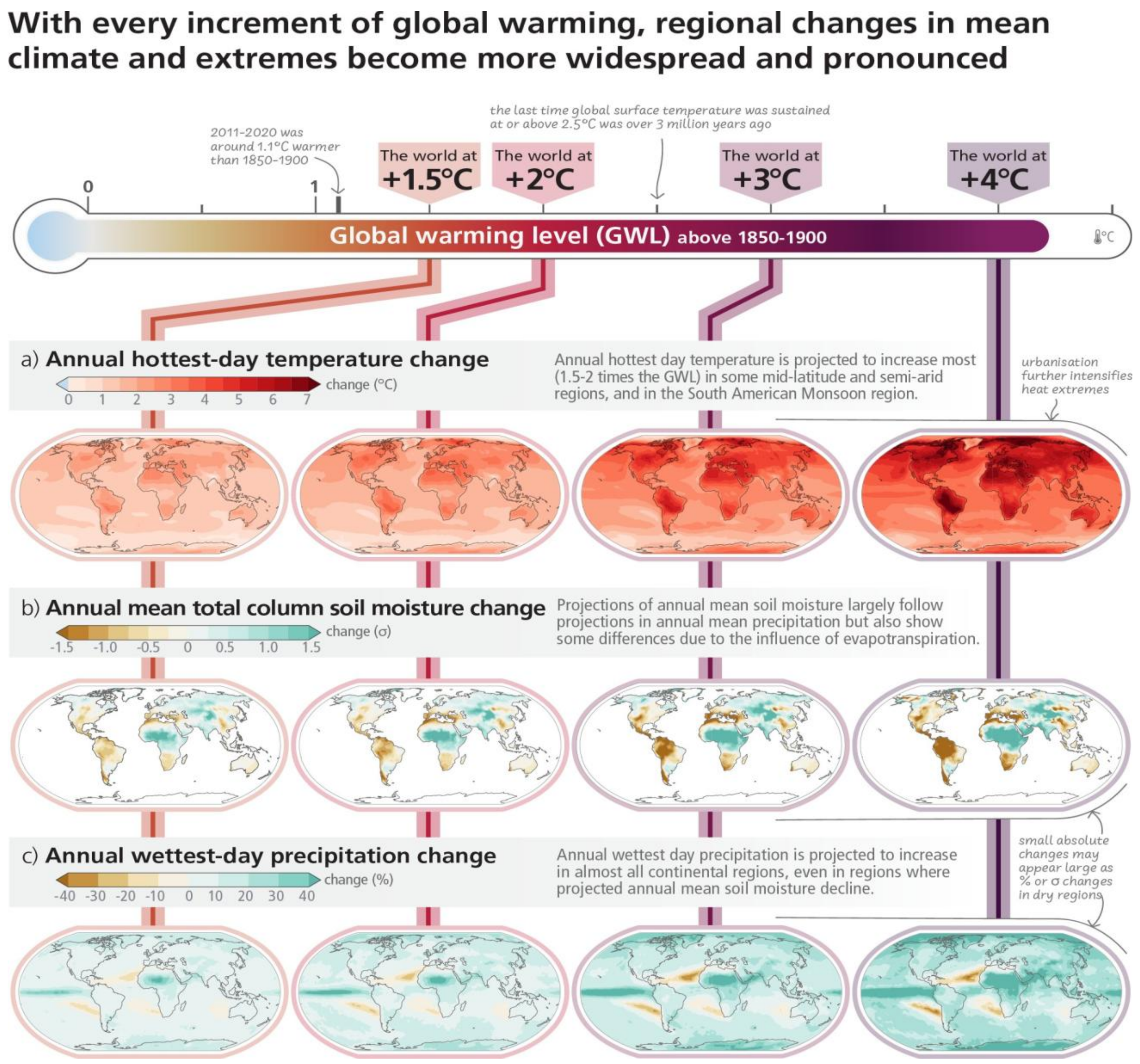


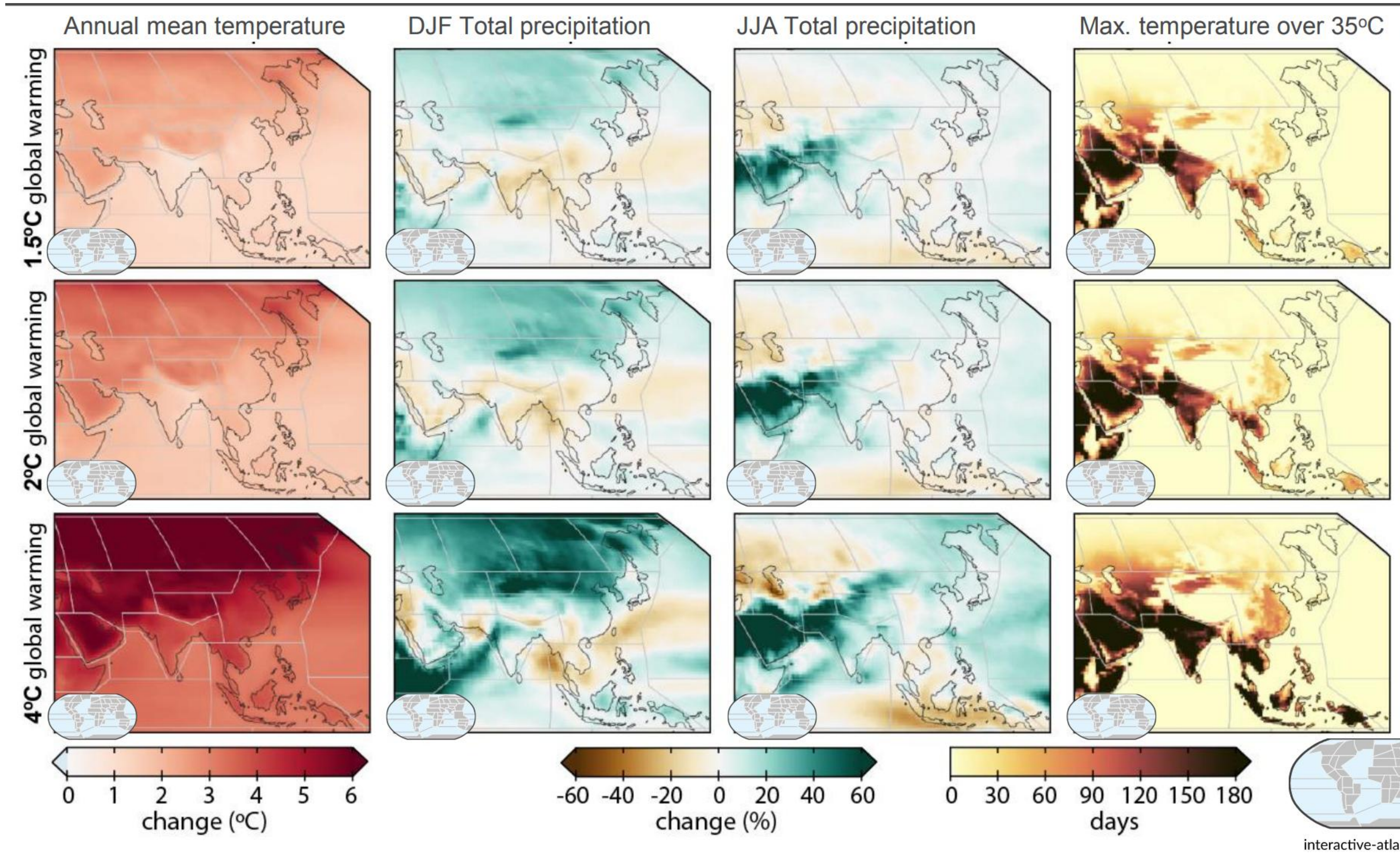
Professor A.K.M. Saiful Islam and Fariha Islam Mou
Institute of Water and Flood Management (IWFM)
Bangladesh University of Engineering and Technology

IPCC Projects SASM precipitation will increase in 2100

In the near-term, South Asian monsoon and East Asian summer monsoon precipitation changes will be dominated by the effects of internal variability (medium confidence).

- In the long-term, South Asian monsoon and East Asian summer monsoon precipitation will increase (medium confidence).





Projections at 1.5°C, 2°C, and 4°C global warming

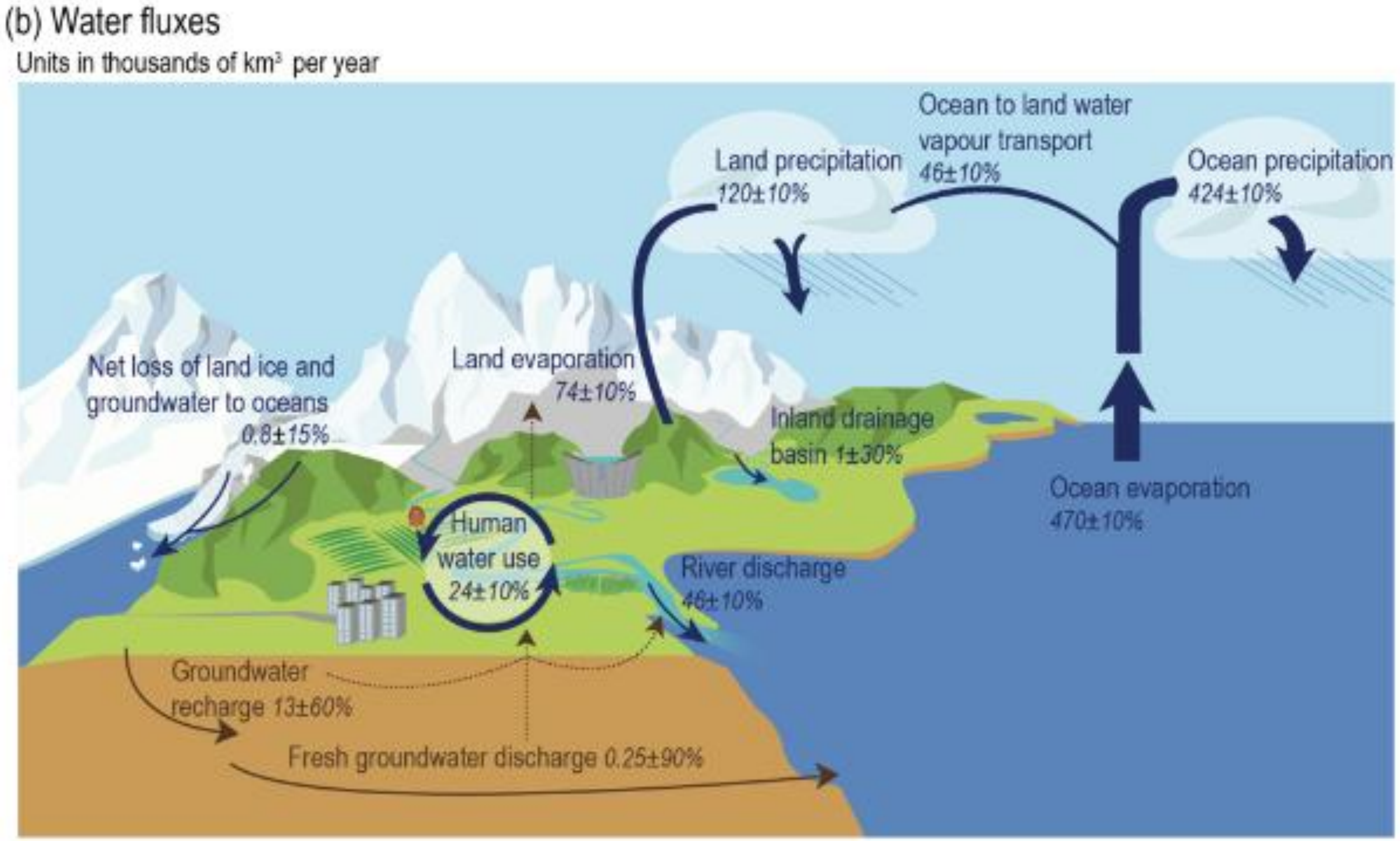
Changes relative to the 1850–1900 in annual mean surface temperature, total precipitation (Dec–Feb, DJF), and total precipitation (Jun–Aug, JJA). Last column shows the total number of days per year with maximum temperature exceeding 35°C.

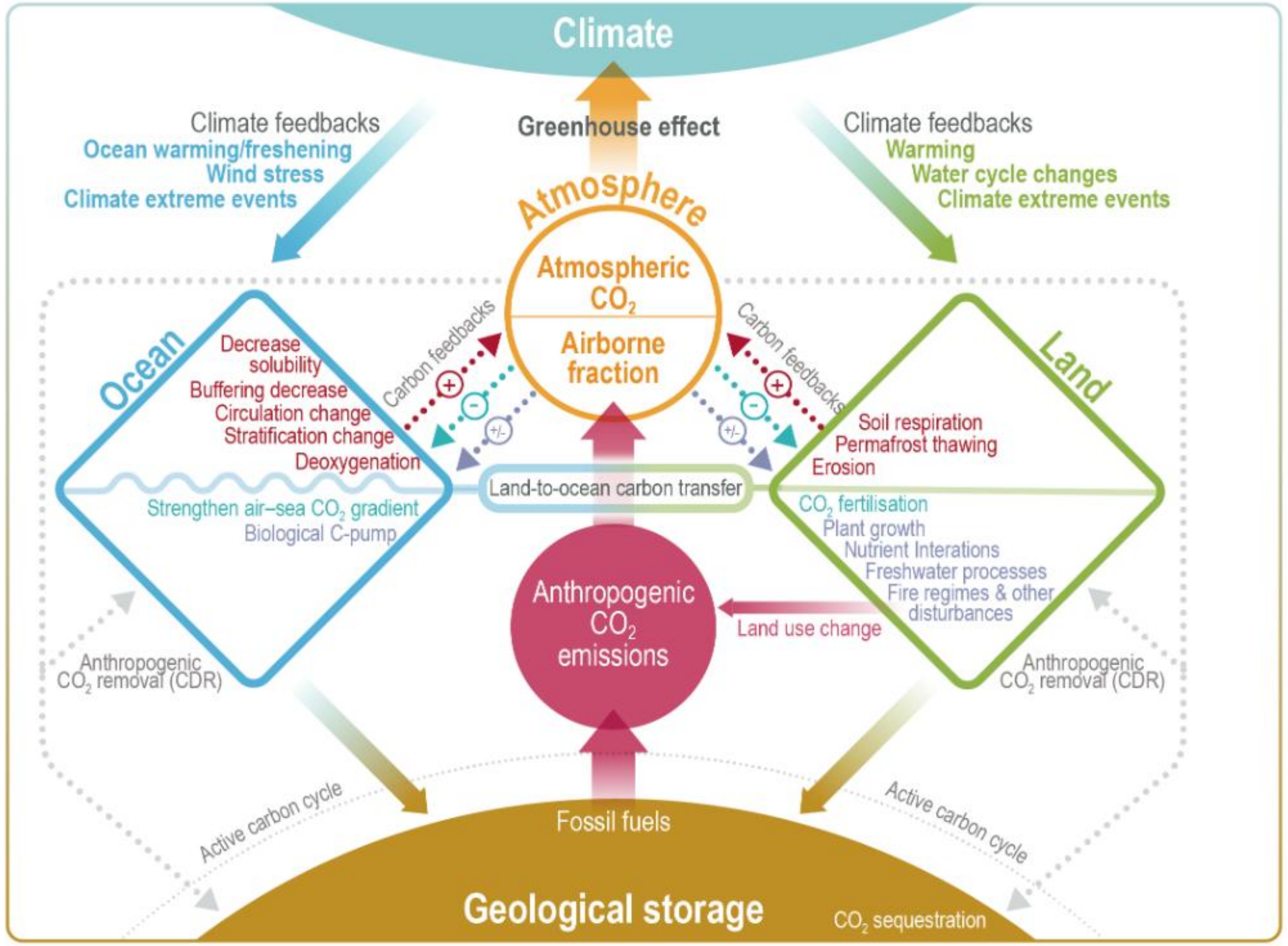
interactive-atlas.ipcc.ch

Results expanded in the Interactive Atlas (active links)

Understanding biophysical limitations of scenarios

- Feedback from Ocean to the land and atmosphere
- Fate of carbon sinks facing land degradation and disturbances from climate change, consequences
- Implications of a water cycle increasingly managed and available water resource in scenarios

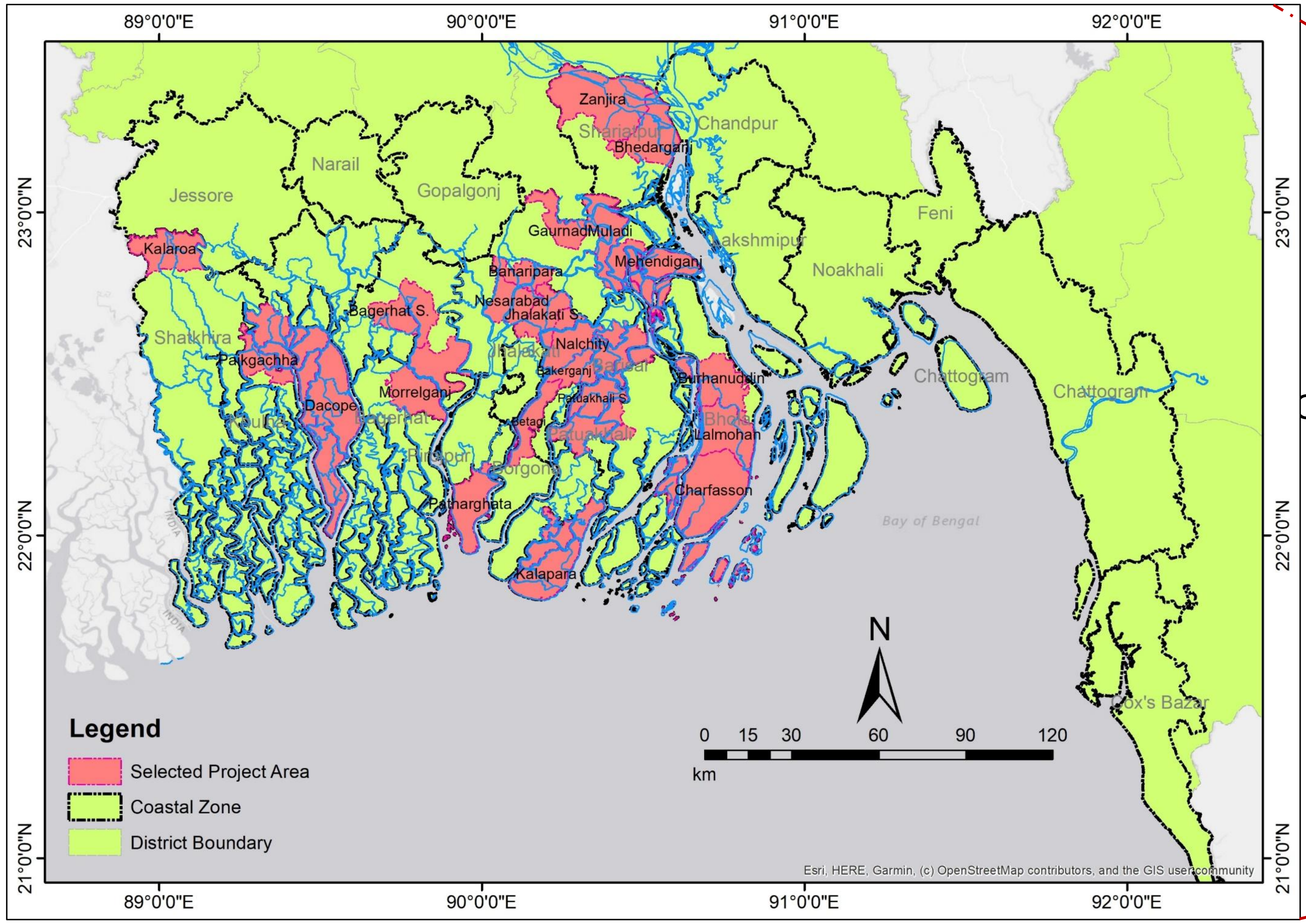




Changing Natural Hazards in Bangladesh

- Bangladesh is the 7th most vulnerable country in the world to risks from a changing climate.
- The country has two thirds of its coastal areas with an elevation of less than three meters and experts predict that by 2050 rising sea levels will submerge 17 percent of Bangladesh's territory and displace 20 million people.

22 of coastal towns selected as study area



Natural Hazards Expected to Change under Global Warming

Riverine Flood

More intense & frequent

Drought

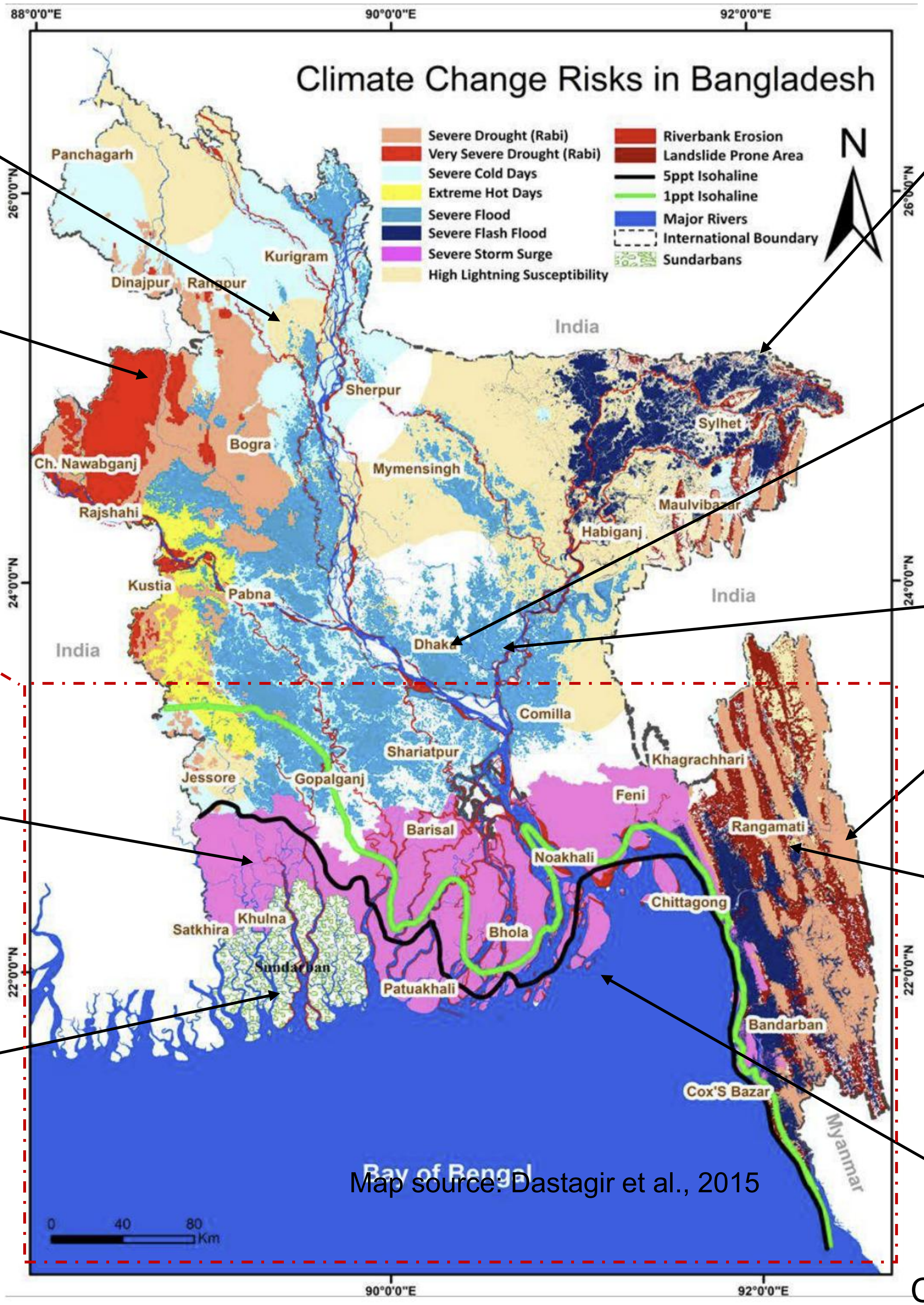
More frequent & Severe

Salinity

Continue to Increase

Sea level Rise

Continue to Rise



Flash Flood

More severe & frequent

Urban flood

More frequent & intense

Heatwave

Prolonged

Flash flood

More intense

Landslides

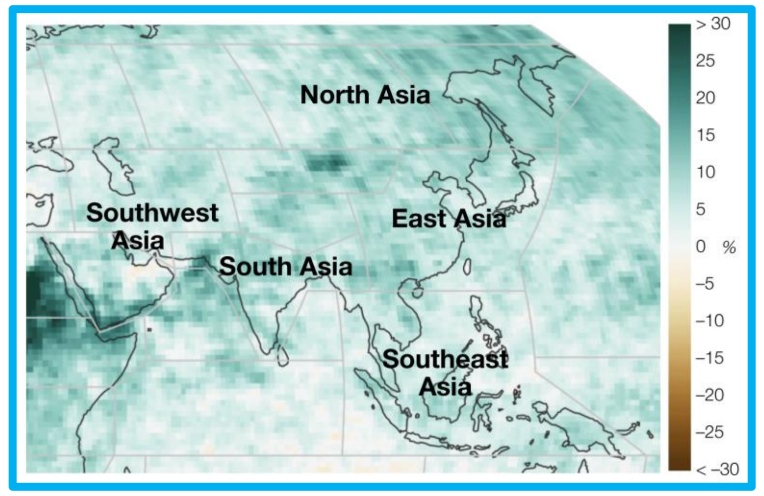
Frequent

Cyclone, storm surge, tidal flood

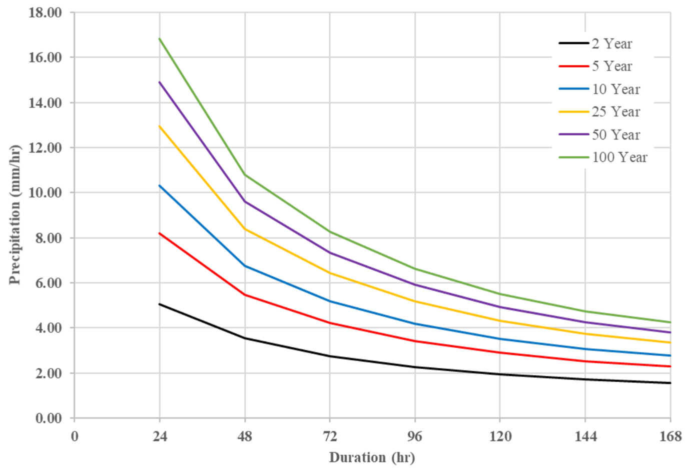
Cyclone more intense
Increased Surge

Urban Flooding and drainage depends on many factors

Loss of Waterbodies of Coastal cities (Kuakata Pourashava)



Projected changes in maximum 1-day **precipitation** at 2ºC global warming under SSP5-8.5 Scenario

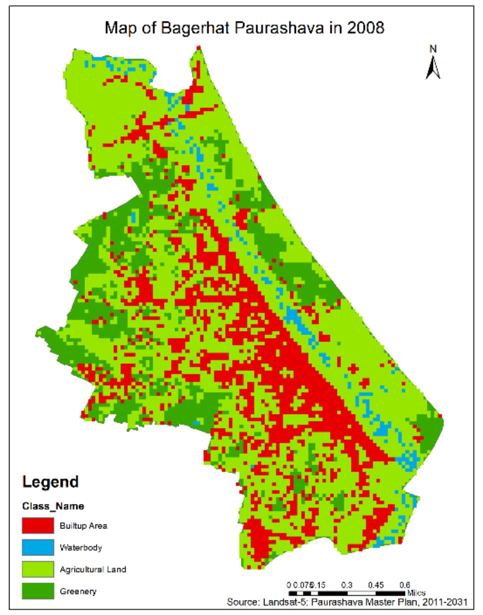


IDF curves for long duration rainfall in Khulna.

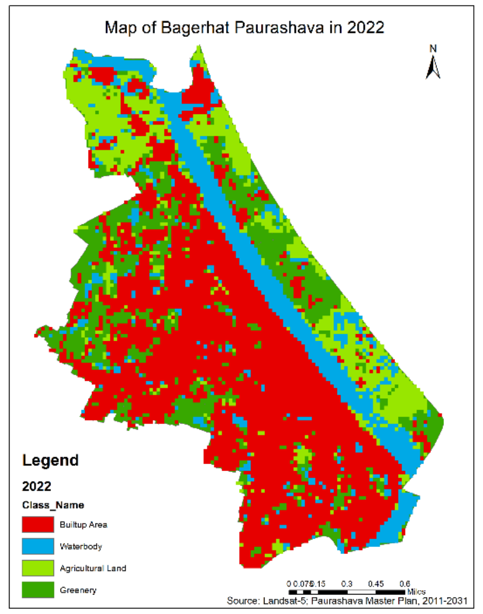
Size and gate operation of **sluice gate** are crucial

Many canal are under the threat due to rapid urbanizations, solid waste dumping and illegal encroachments and **loss of connectivity**

Cleaning of drains and **solid waste management**



Rapid Urbanization



Urban Drainage Issues

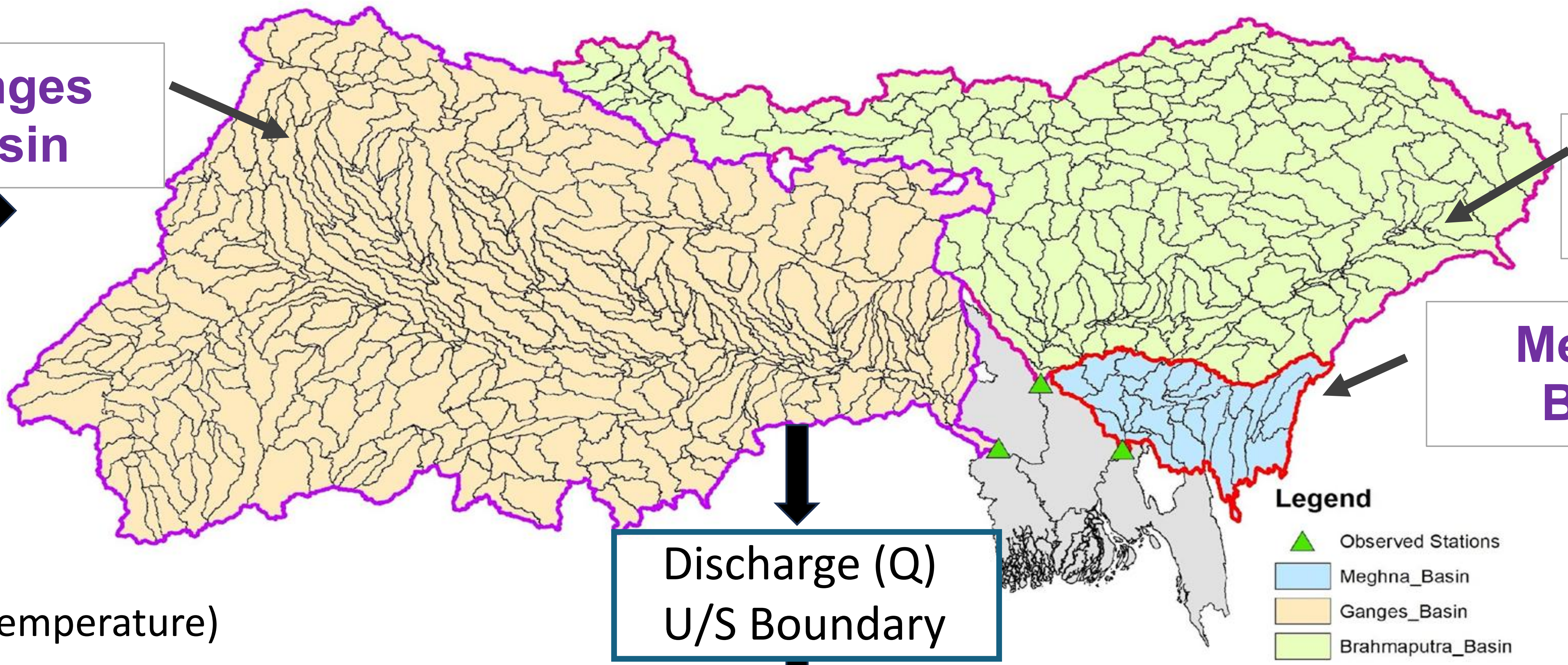
- **INADEQUECY:** The existing stormwater drainage systems are inadequate to handle the increased runoff from urban areas. Insufficient capacity and outdated design contribute to frequent waterlogging.
- **URBANIZTION:** Many pucca drainages seem to be inadequate in size. The filing up of natural waterbodies and encroachment have reduced the capacity of well-functioning urban drainage systems.
- **CONNECTIIVITY:** A well-connected drainage system with higher capacity by widening and deepening through NBS would improve the functioning of the drainage system.
- **WATER BODIES:** Preserving the existing waterbodies and creating new ones can be an NBS option for stormwater management in urban areas. Also, rainwater harvesting can reduce the amount of runoff and hence minimize the extent of drainage congestion.
- **TREATMENT PLANT:** A sewage treatment plant can be an NBS option for sewage water management. By investing in upgraded infrastructure, adopting sustainable drainage practices, and engaging the local community, the town can mitigate the impact of waterlogging and flooding.
- **URBAN PLANNING:** Additionally, integration with urban planning and consideration of climate change impacts is essential for building a resilient and efficient drainage system for the future.

Hazar Modeling from Basin to Coasts

Hydrological Model

SWAT
Soil & Water Assessment Tool

Ganges Basin



Brahmaputra Basin

Meghna Basin

Input Data

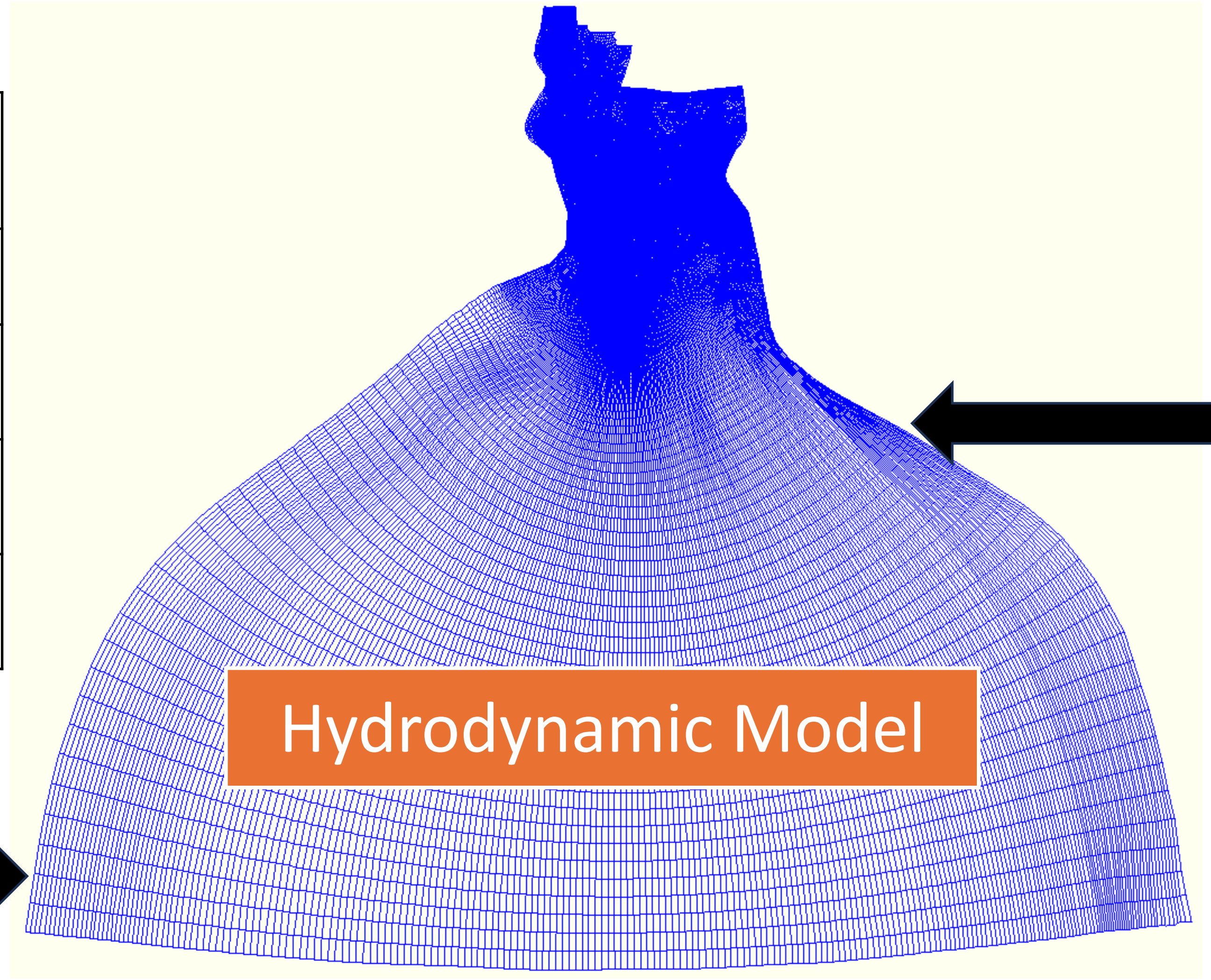
- Digital Elevation Map
- Land Use Data
- Soil data
- Weather data : CMIP6 (Precipitation, Temperature)

Discharge (Q)
U/S Boundary

Mean sea level rise of the Bay of Bengal which is predicted based on the CMIP6 output

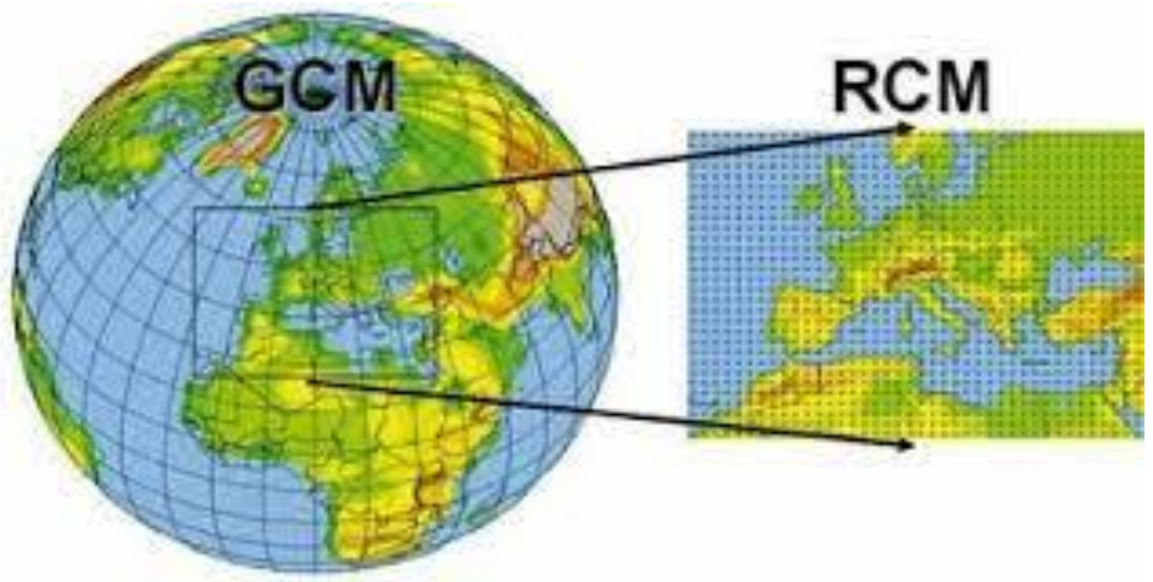
	Predicted Mean Sea Level Rise relative to Baseline Period (1995-2014) (m)			
	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
2021-2040	0.1	0.1	0.1	0.1
2041-2060	0.2	0.2	0.2	0.3
2081-2100	0.4	0.5	0.6	0.7

Bangladesh Delta Model (BDM)



Sea Level Rise (SLR)
D/S Boundary

Methodology of Climate Change Analysis



Model Name	Country	Resolution (Degree)
ACCESS-CM2	Australia	0.25
ACCESS-ESM1-5	Australia	0.25
BCC-CSM2-MR	China	0.25
CanESM5	Canada	0.25
EC-Earth3	EU	0.25
EC-Earth3-Veg	EU	0.25
INM-CM4-8	Russia	0.25
INM-CM5-0	Russia	0.25
MPI-ESM1-2-HR	Germany	0.25
MPI-ESM1-2-LR	Germany	0.25
MRI-ESM2-0	Japan	0.25
NorESM2-LM	Norway	0.25
NorESM2-MM	Norway	0.25

Bias Corrected Daily Data of Thirteen Climatic Models

(Mishra, V., Bhatia, U. and Tiwari, A.D., 2020. Bias corrected climate projections from CMIP6 models for Indian sub-continental river basins. *Zenodo https://doi. org/10.5281/zenodo, 3874046*.)

Mean Ensemble of Thirteen Climatic Models

Precipitation

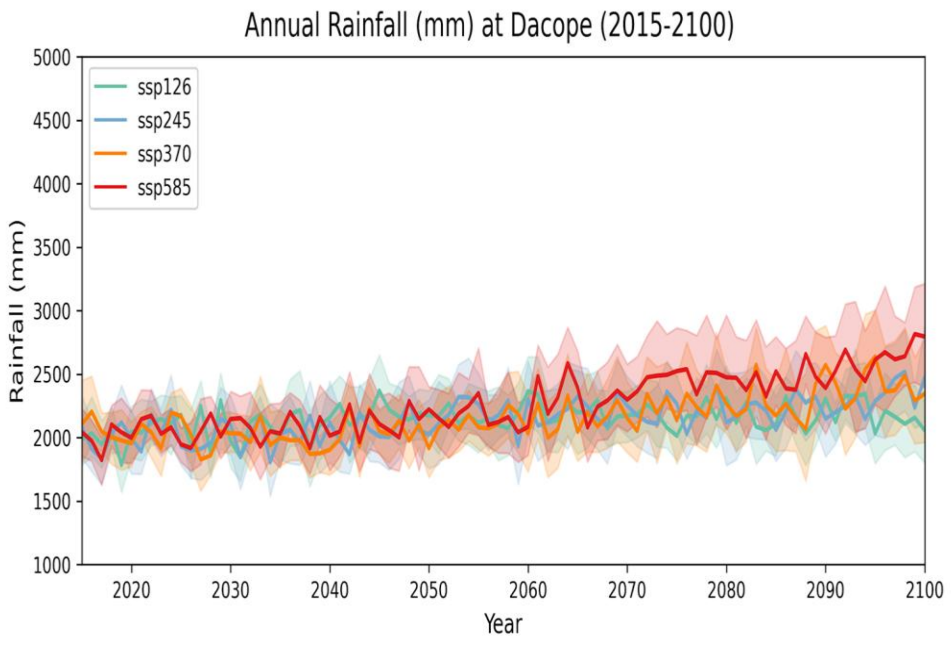
Maximum Temperature

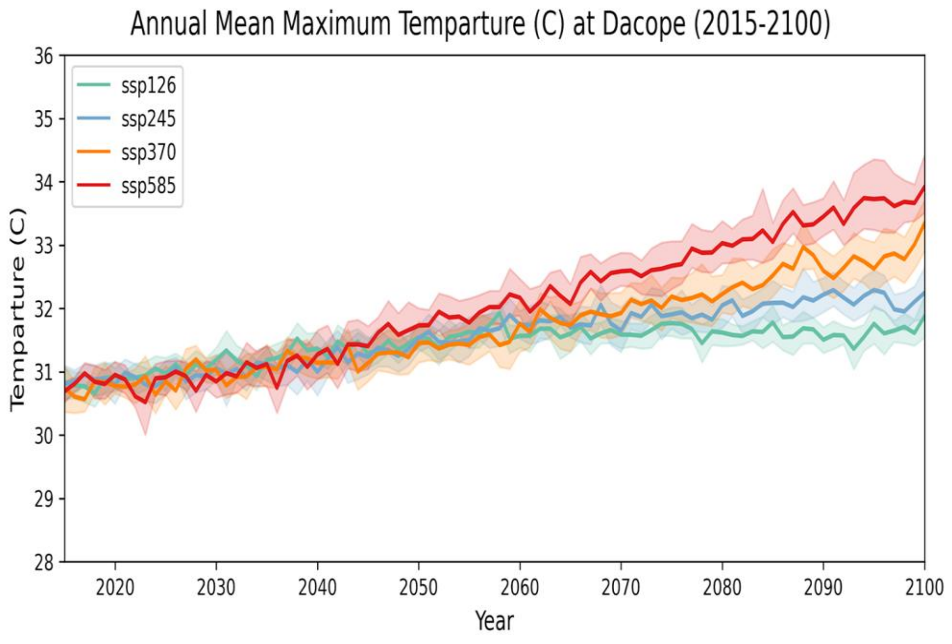
Minimum Temperature

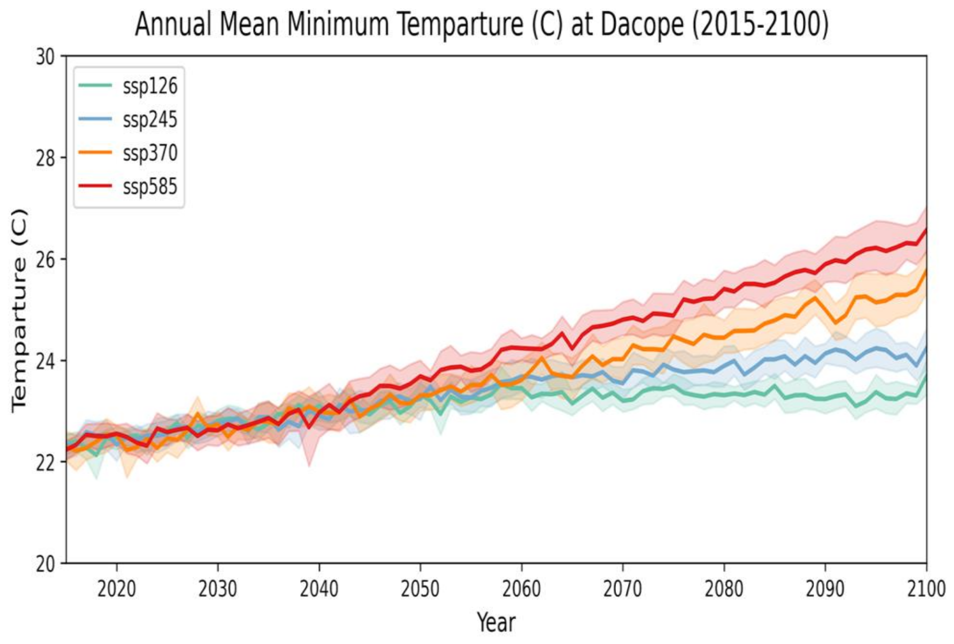
Rainfall Analysis (Trend, PDF, Extremes, Mean)

Spatial Plotting

- Annual
- Pre-Monsoon
- Post-Monsoon
- Monsoon
- Winter

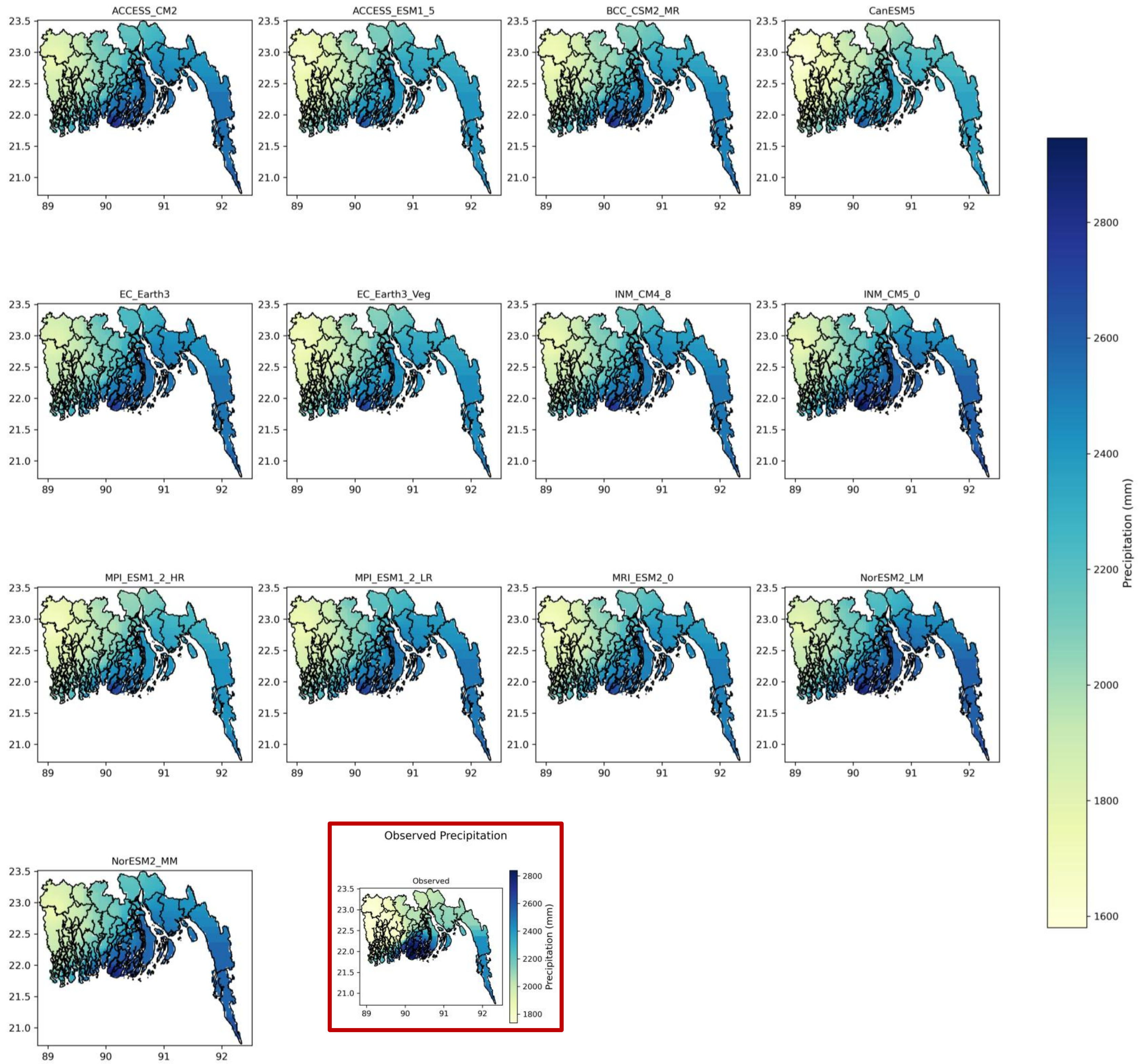




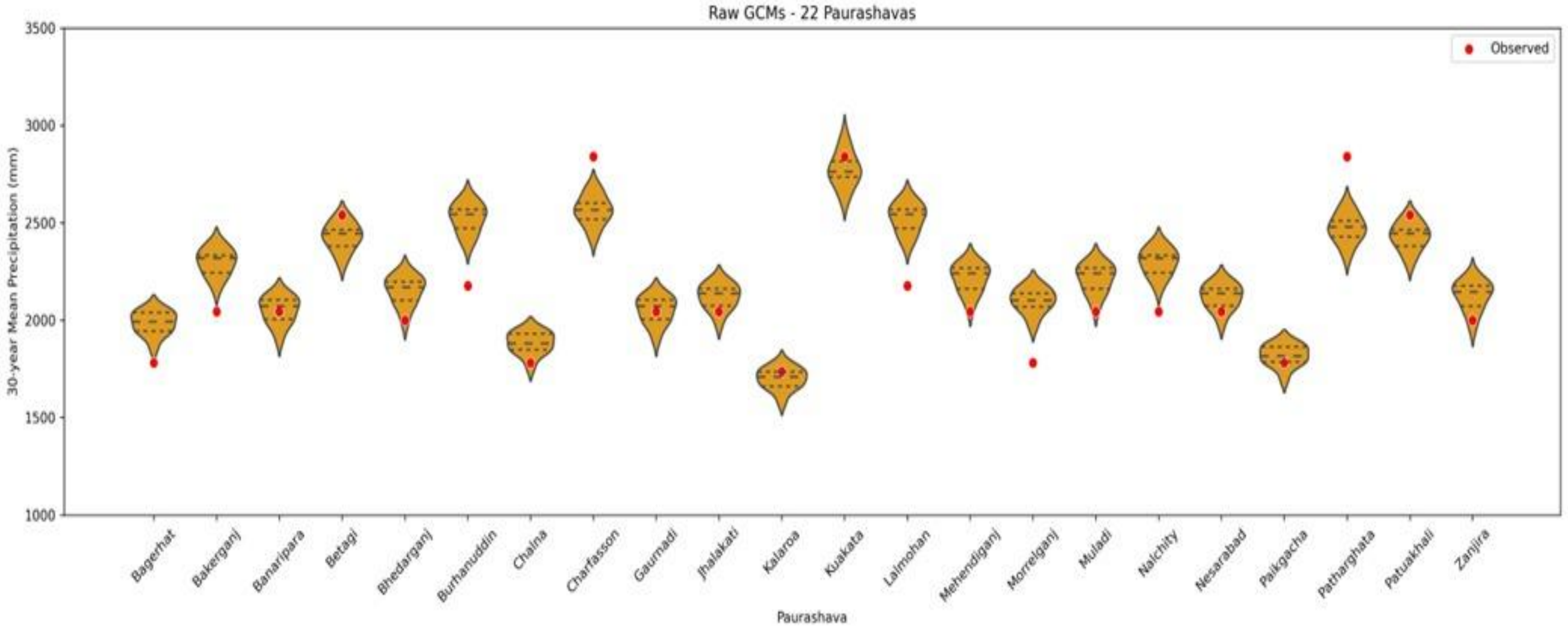


CMIP6 Climate Bias Corrected Projections

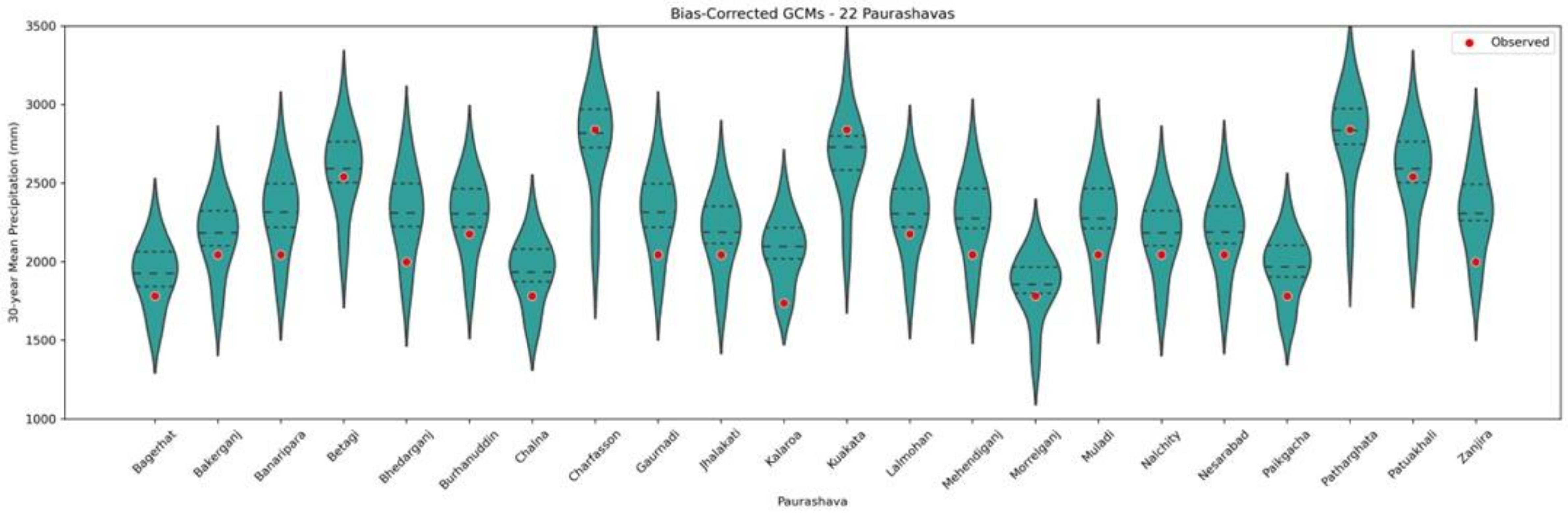
Mean precipitation from 13 GCM s and observations



Raw GCM with biases



Biases corrected GCM data



Empirical Quantile Mapping (EQM) method is selected for bias correction

Delta Correction (DC), Linear Scaling (LS),
Empirical Quantile Mapping (EQM),
Adjusted Quantile Mapping (AQM), Quantile Delta Mapping (QDM),
Gamma-Pareto Quantile Mapping (GPQM) (Jose & Dwarakish, 2022),
Gamma Quantile Mapping (GQM),
Power Transformation of Precipitation (PTR) (Mendez et al., 2020),
Local Intensity Scalng (LOCI), Daily Bias Correction (DBC),
Daily Translation (DT), Distribution Mapping (DM), and
Variance Scaling (VARI) (Luo et al., 2018)

Performance evaluation of precipitation data before and after the bias correction

Empirical Quantile Mapping (EQM) method is selected for bias correction

- Delta Correction (DC),
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- Daily Translation (DT),
- Distribution Mapping (DM), and
- Variance Scaling (VARI) (Luo et al., 2018)

$$NSE=1 - \frac{\sum_{n=1}^{N}(Observed_n - Bias\ Corrected_n)^2}{\sum_{n=1}^{N}(Observed_n - Observed\ Mean)^2}$$

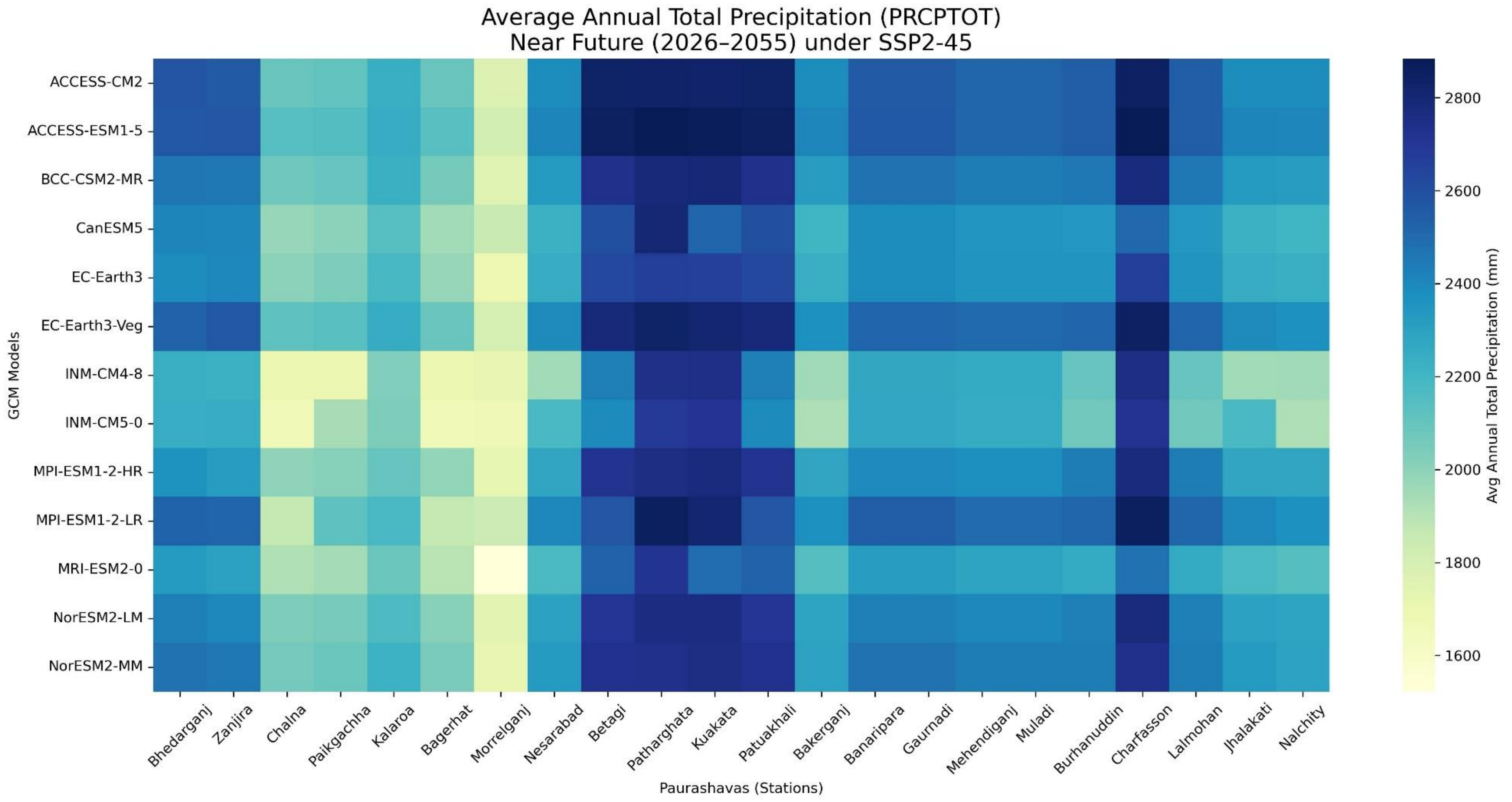
$$RMSE=\sqrt{(\frac{1}{N}\sum_{n=1}^{N}(Observed_n - Bias\ Corrected_n)^2)}$$

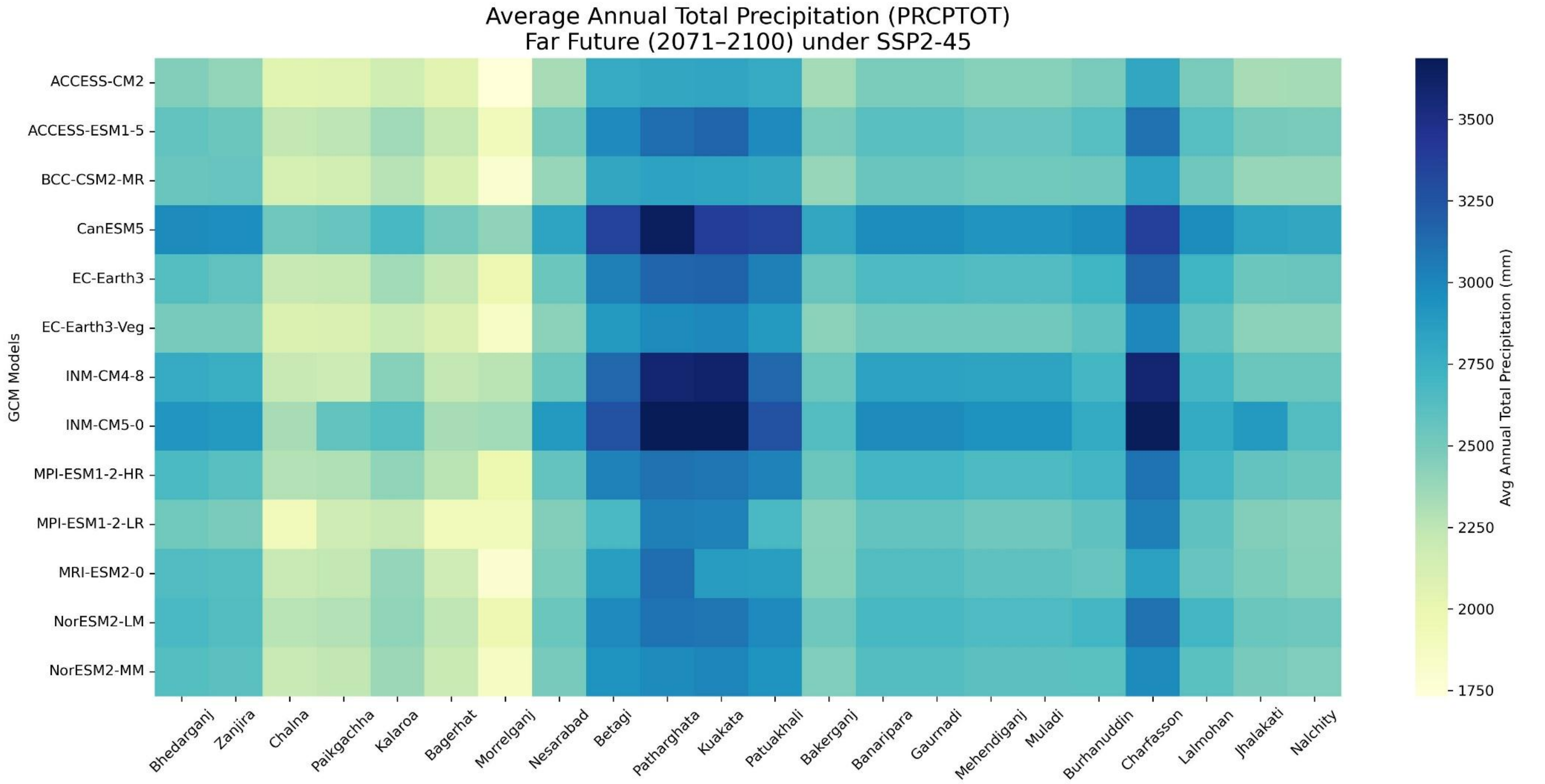
Model Name	RMSE		NSE	
	Before	After	Before	After
ACCESS_CM2	4.58	4.00	-0.15	0.12
ACCESS_ESM1_5	4.50	3.95	-0.11	0.15
BCC_CSM2_MR	1.94	2.15	0.79	0.75
CanESM5	3.86	3.57	0.18	0.3
EC_Earth3	2.16	1.11	0.74	0.93
EC_Earth3_Veg	2.05	1.39	0.77	0.89
INM_CM4_8	4.33	3.15	-0.02	0.46
INM_CM5_0	4.49	2.98	-0.10	0.51
MPI_ESM1_2_HR	2.03	1.20	0.78	0.92
MPI_ESM1_2_LR	1.09	1.19	0.93	0.92
MRI_ESM2_0	3.19	2.84	0.44	0.56
NorESM2_LM	4.00	3.42	0.12	0.36
NorESM2_MM	2.60	1.92	0.63	0.8

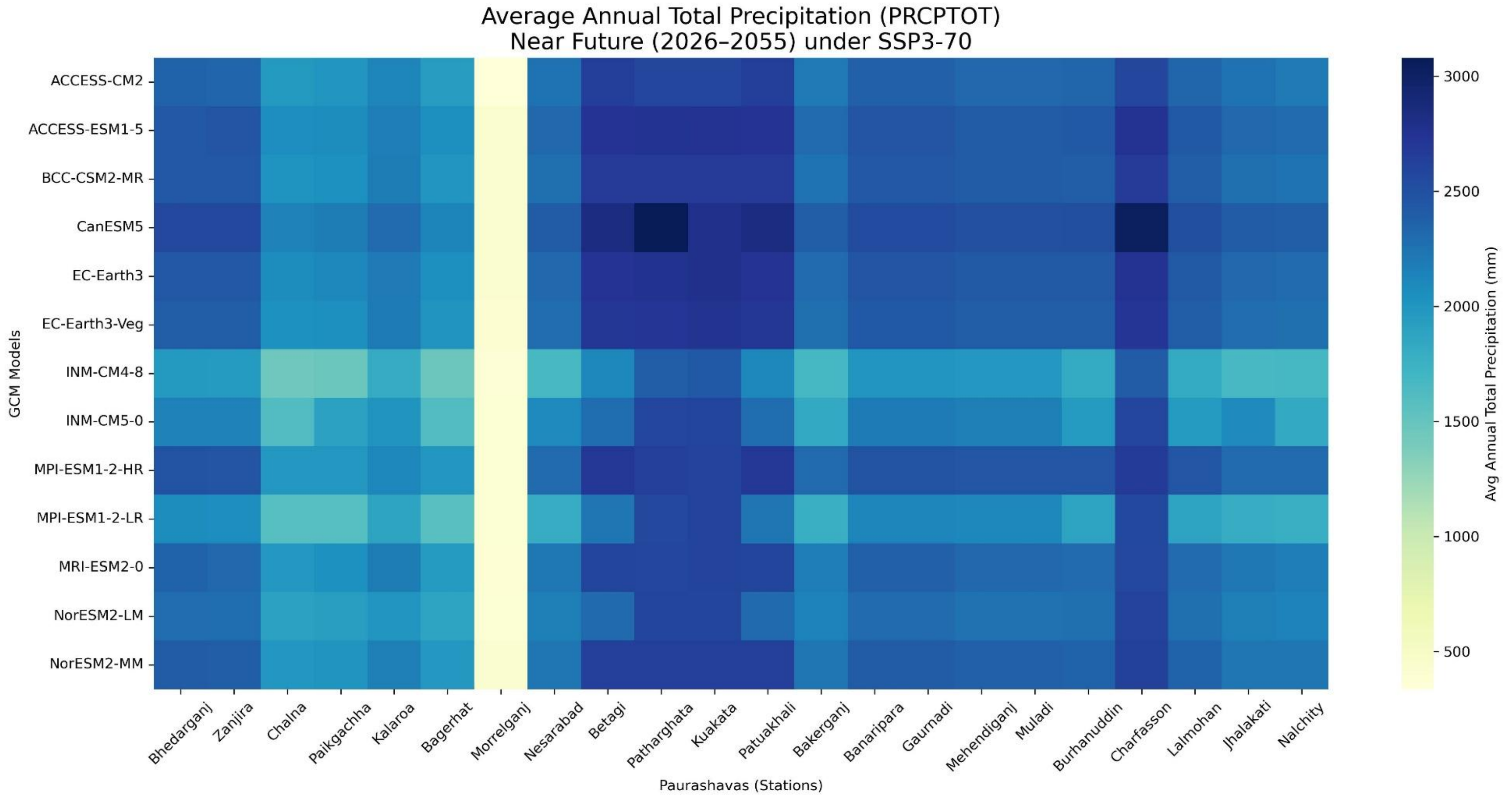
Projected Annual Total Precipitation (PRCPTOT) in the near and far future under the SSP2-4.5 & SSP 3-7.0

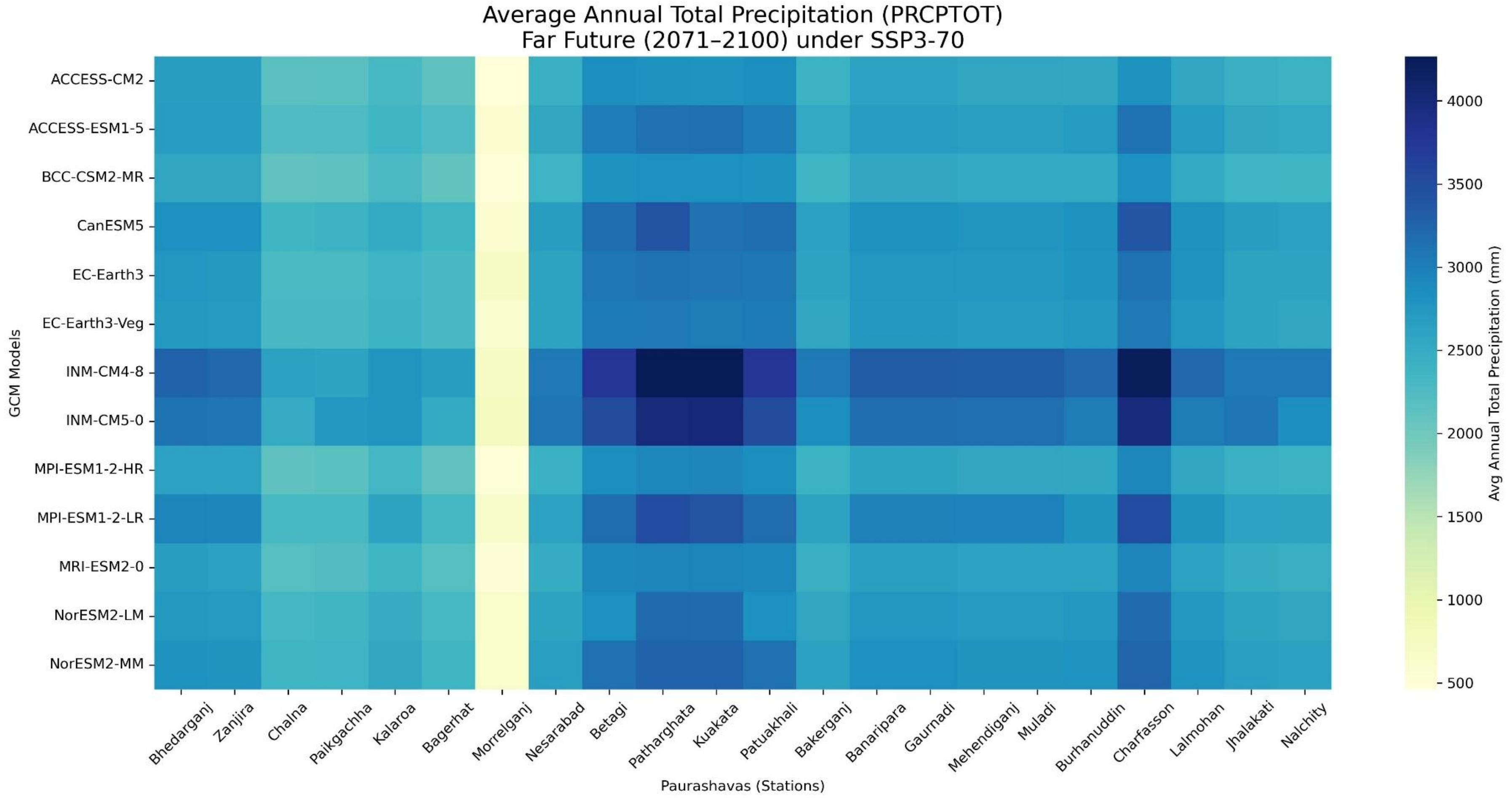
Wetter Model: EC-Earth3-Veg
Dryer Model: MPI-ESM1-2-LR

Wetter Models: CanESM5, INM-CM5-0
Dryer Model: MPI-ESM1-2-LR

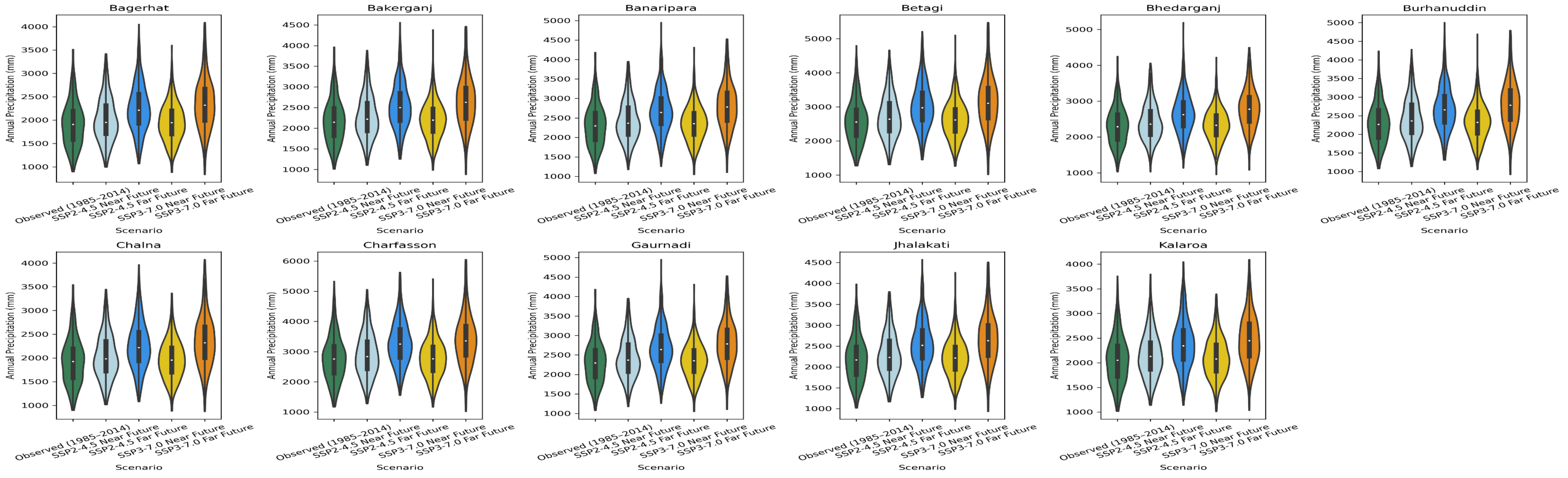








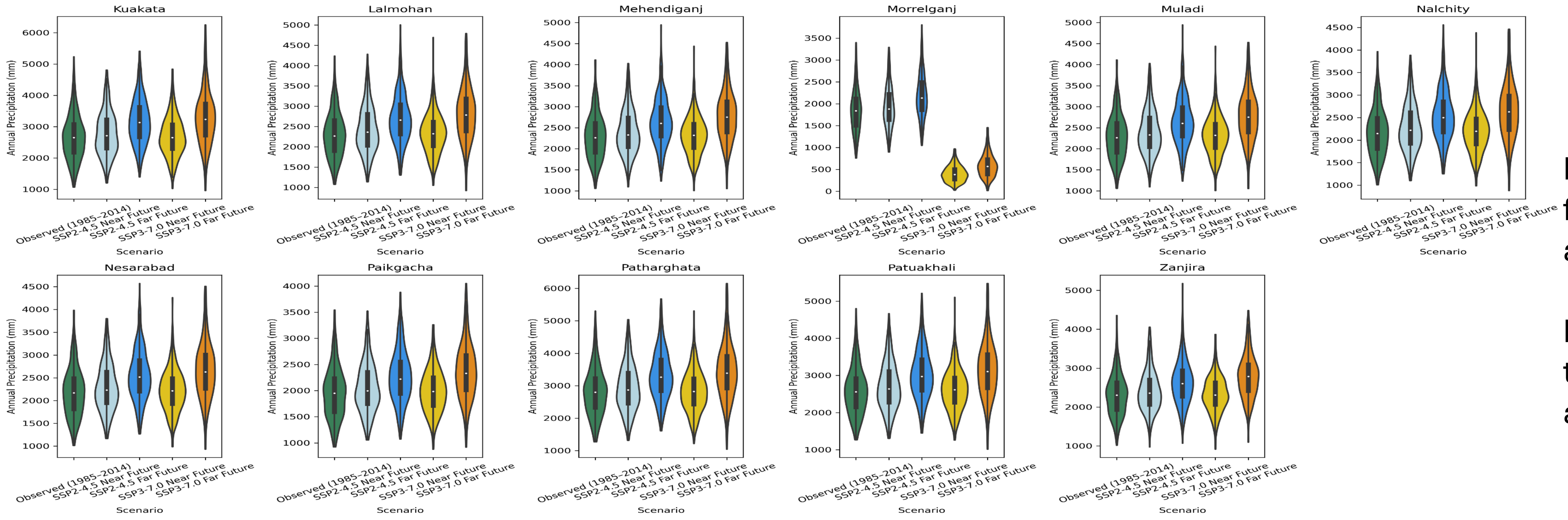
Projected Total Annual Precipitation (PRCPTOT) for 22 Pourashava in the near and far future SSP2-4.5 & SSP 3-7.0



Near Future

PCRTOT for 21 Pourashavas will increase from 1.70% to 23.90%, with only Kuakata exhibiting a negative anomaly of -2.6% considering the SSP2-45 scenario.

SSP2-45 scenario, although it will have a higher percentage deviation for the SSP3-70 scenario.

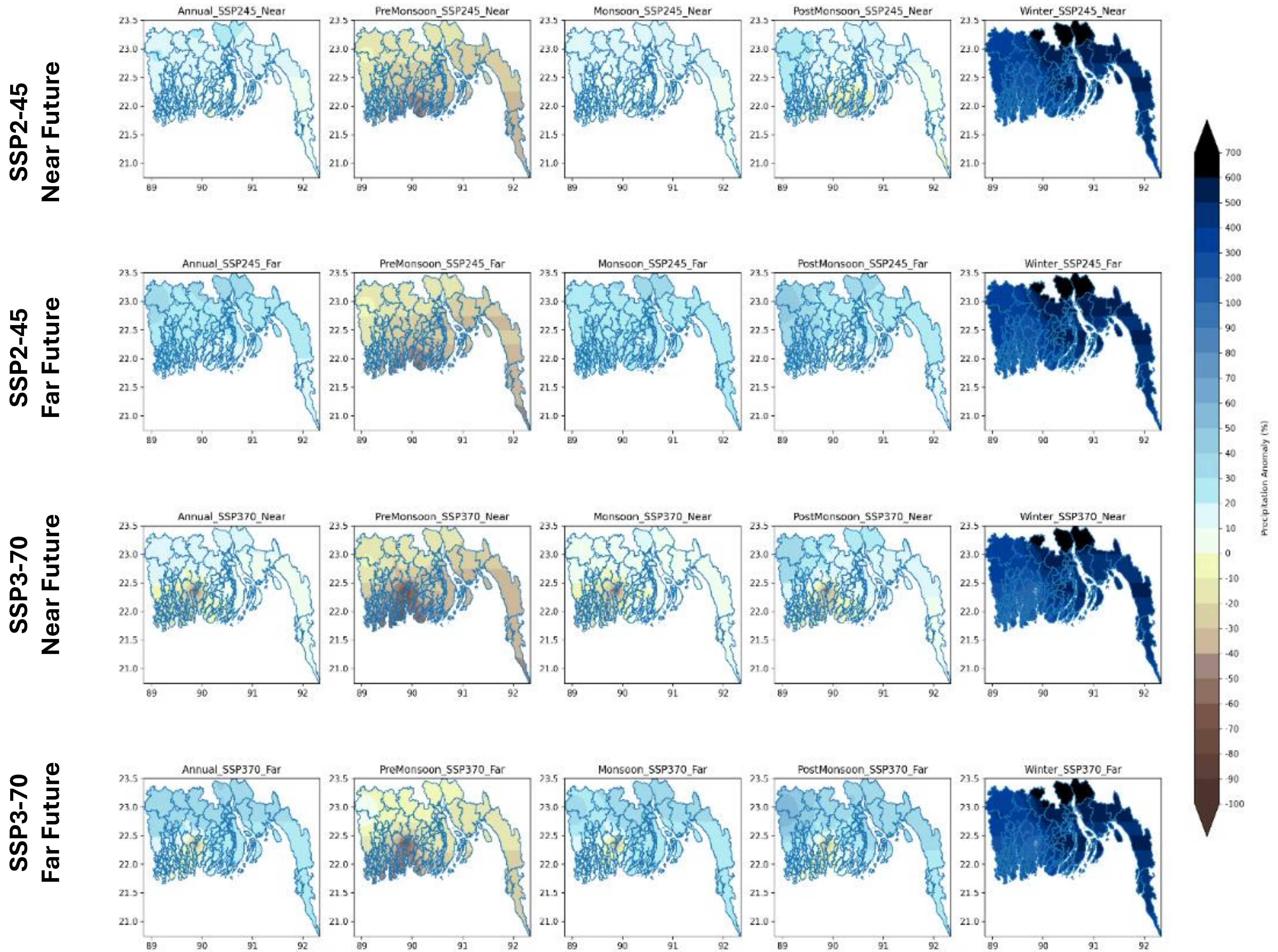


Far Future

PCRTOT under SSP3-70 scenario, with four Paurashavas experiencing negative anomalies.

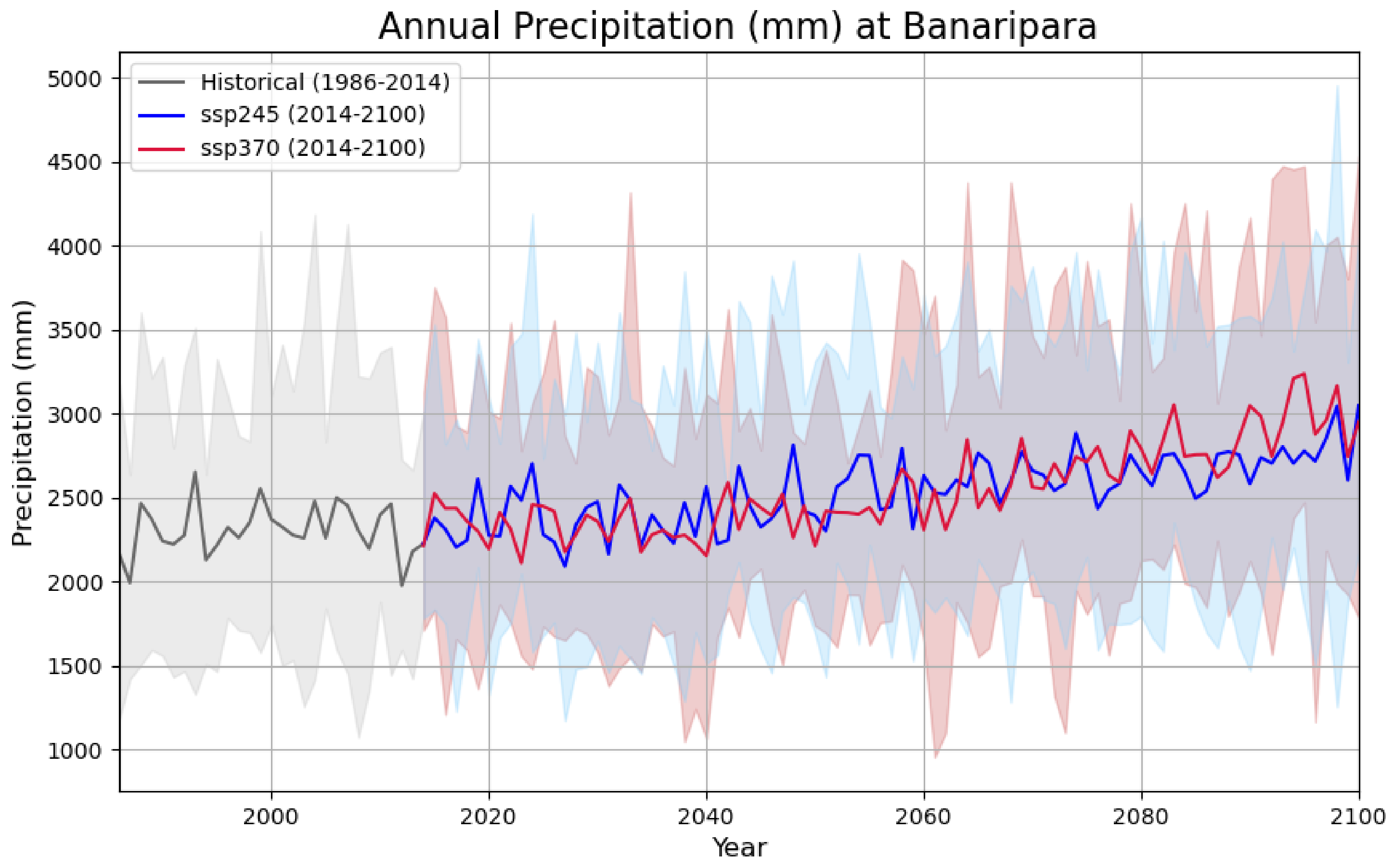
In the far future, all 22 Paurashavas under the SSP2-45 scenario show positive anomalies between 11.20% and 36.20%.

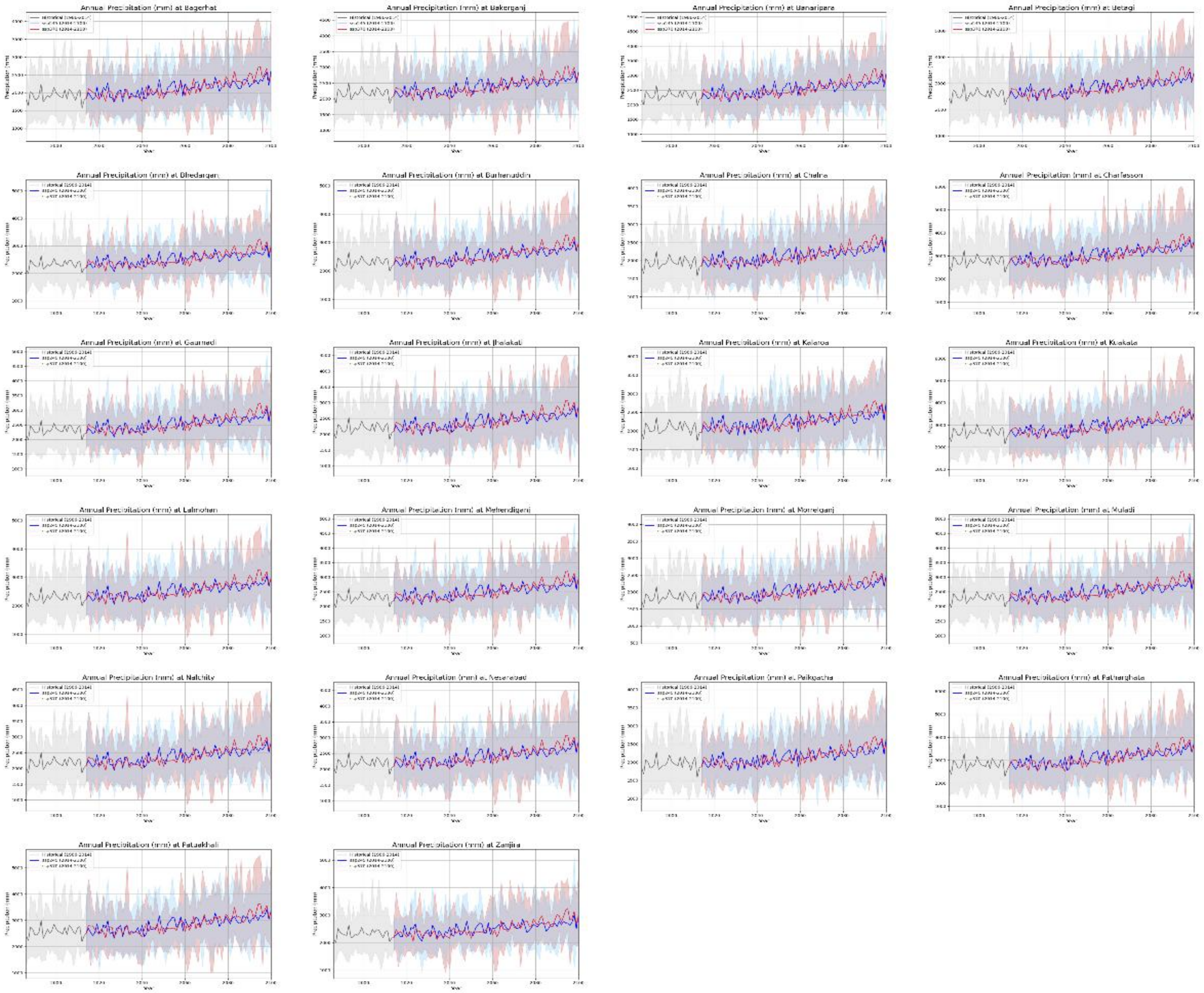
Projected Total Annual Precipitation (PRCPTOT) for 22 Pourashavas in the near and far future under SSP2-4.5 & SSP 3-7.0



	Near Future (2026-2055)		Far Future (2071-2100)	
Paurashava	SSP2-45	SSP3-70	SSP2-45	SSP3-70
Bagerhat	12.3	8.9	25.5	31.2
Bakerganj	10.8	6.8	23.4	28.6
Banaripara	18.1	14.4	30.2	36.5
Betagi	5.6	2.3	18.3	23.0
Bhedarganj	22.7	18.2	34.3	41.7
Burhanuddin	10.6	6.3	23.0	28.6
Chalna	13.1	9.6	26.0	31.3
Charfasson	1.7	-2.5	15.1	18.7
Gaurnadi	18.1	14.4	30.2	36.5
Jhalakati	11.6	7.8	24.3	29.5
Kalaroa	23.9	20.6	36.2	41.9
Kuakata	-2.6	-5.5	11.2	15.0
Lalmohan	10.6	6.3	23.0	28.6
Mehendiganj	16.6	12.6	28.7	35.0
Morrelganj	7.7	-77.5	21.5	-67.2
Muladi	16.6	12.6	28.7	35.0
Nalchity	10.8	6.8	23.4	28.6
Nesarabad	11.6	7.8	24.3	29.5
Paikgacha	14.1	11.0	26.7	32.0
Patharghata	3.0	-0.7	16.6	20.5
Patuakhali	5.6	2.3	18.3	23.0
Zanjira	22.2	17.8	32.9	40.9

Variability of Toal Annual Precipitation (PRCPTOT) (mm)



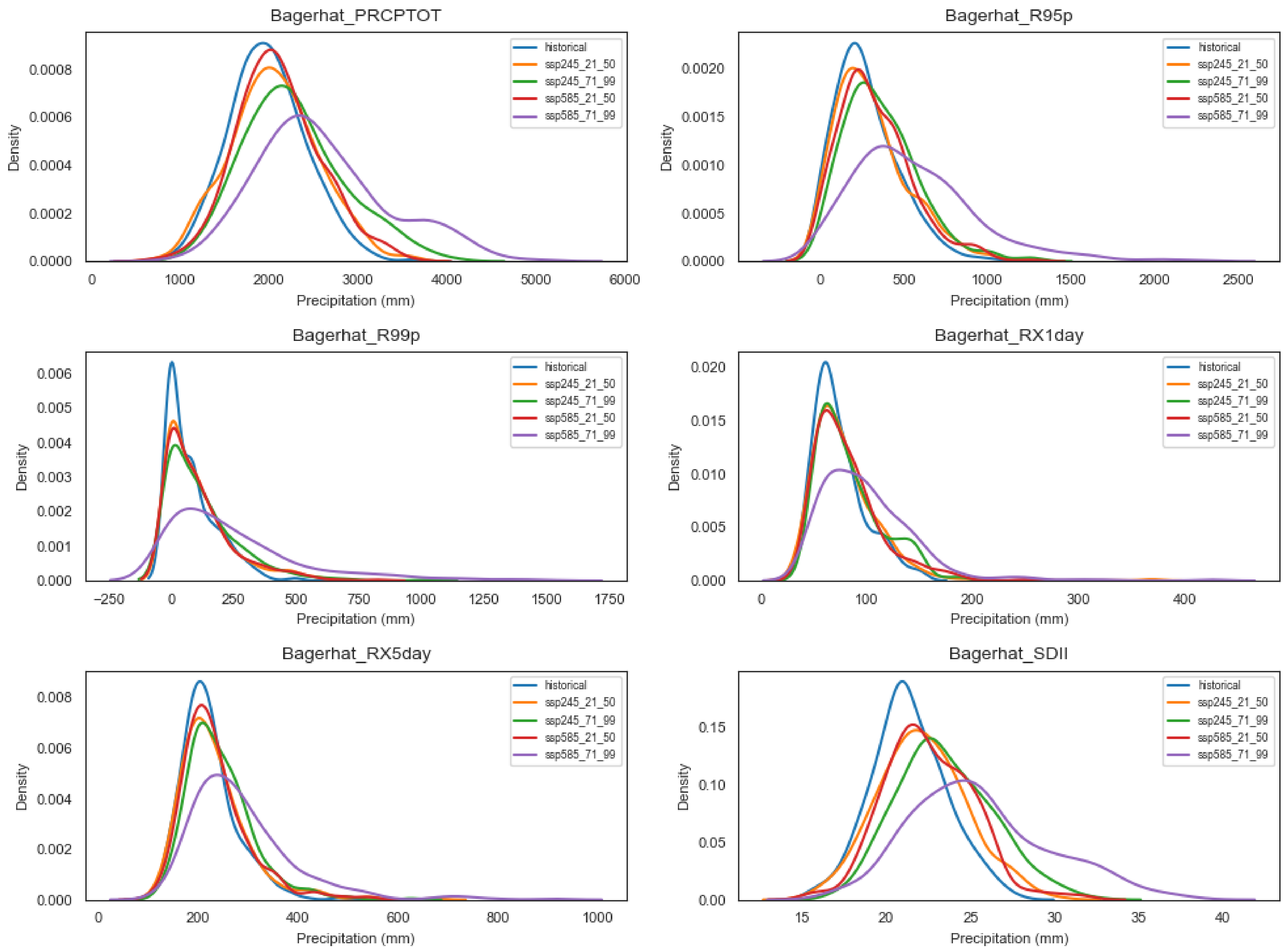


- Observed: 2000-2700mm (annual)

- Model Projection (Average):
- 2100-3300mm (Annual)

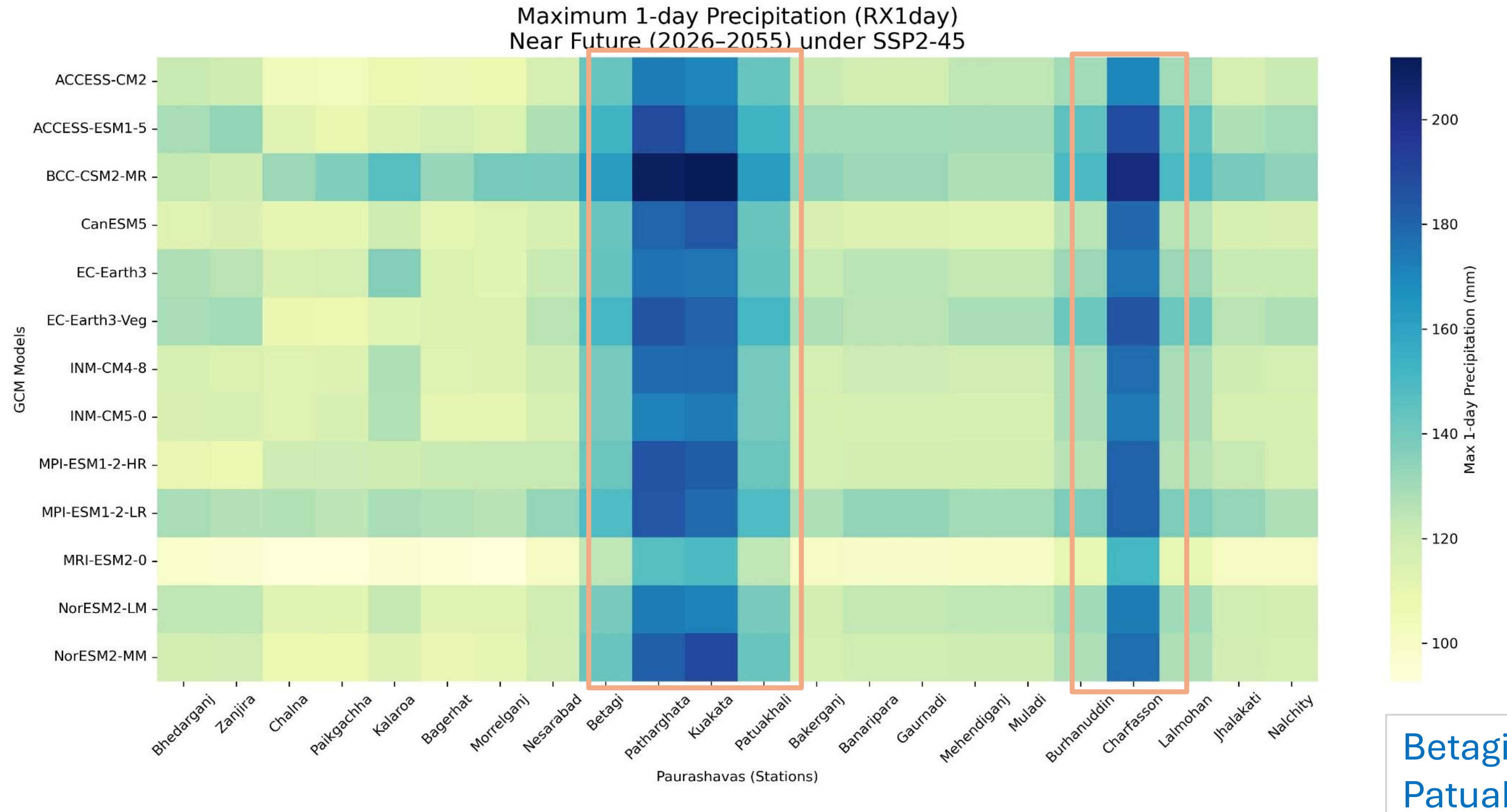
Changes in extreme precipitation indices

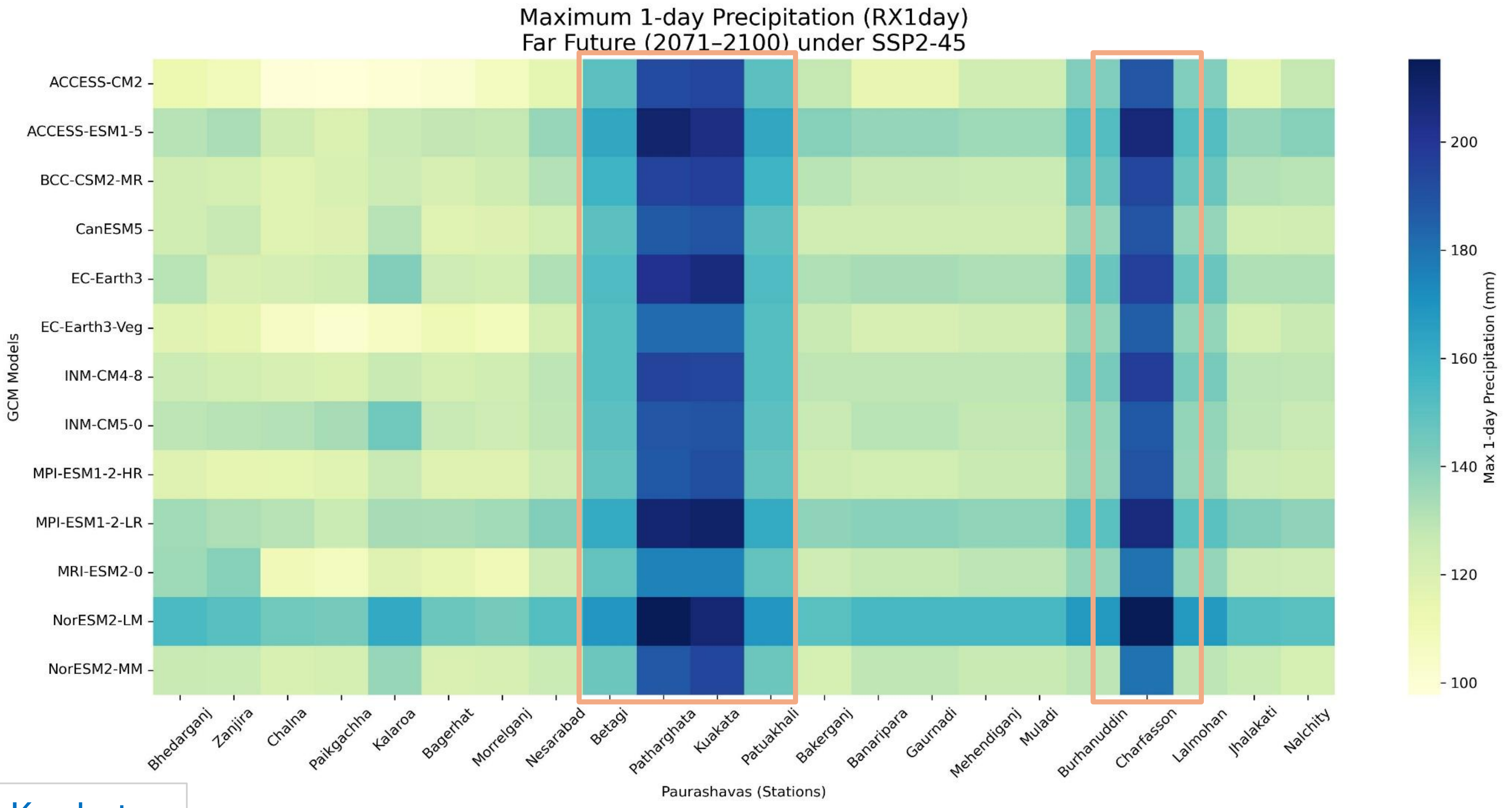
Index	Indicator name	Definitions	UNITS
RX1day	Max 1-day precipitation amount	Monthly maximum 1-day precipitation	mm
Rx5day	Max 5-day precipitation amount	Monthly maximum consecutive 5-day precipitation	mm
SDII	Simple daily intensity index	Annual total precipitation divided by the number of wet days (defined as PRCP>=1.0mm) in the year	mm/day
R95p	Very wet days	Annual total PRCP when RR>95th percentile	mm
R99p	Extremely wet days	Annual total PRCP when RR>99th percentile	mm
PRCPTOT	Annual total wet day precipitation	Annual total PRCP in wet days (RR>=1mm)	mm



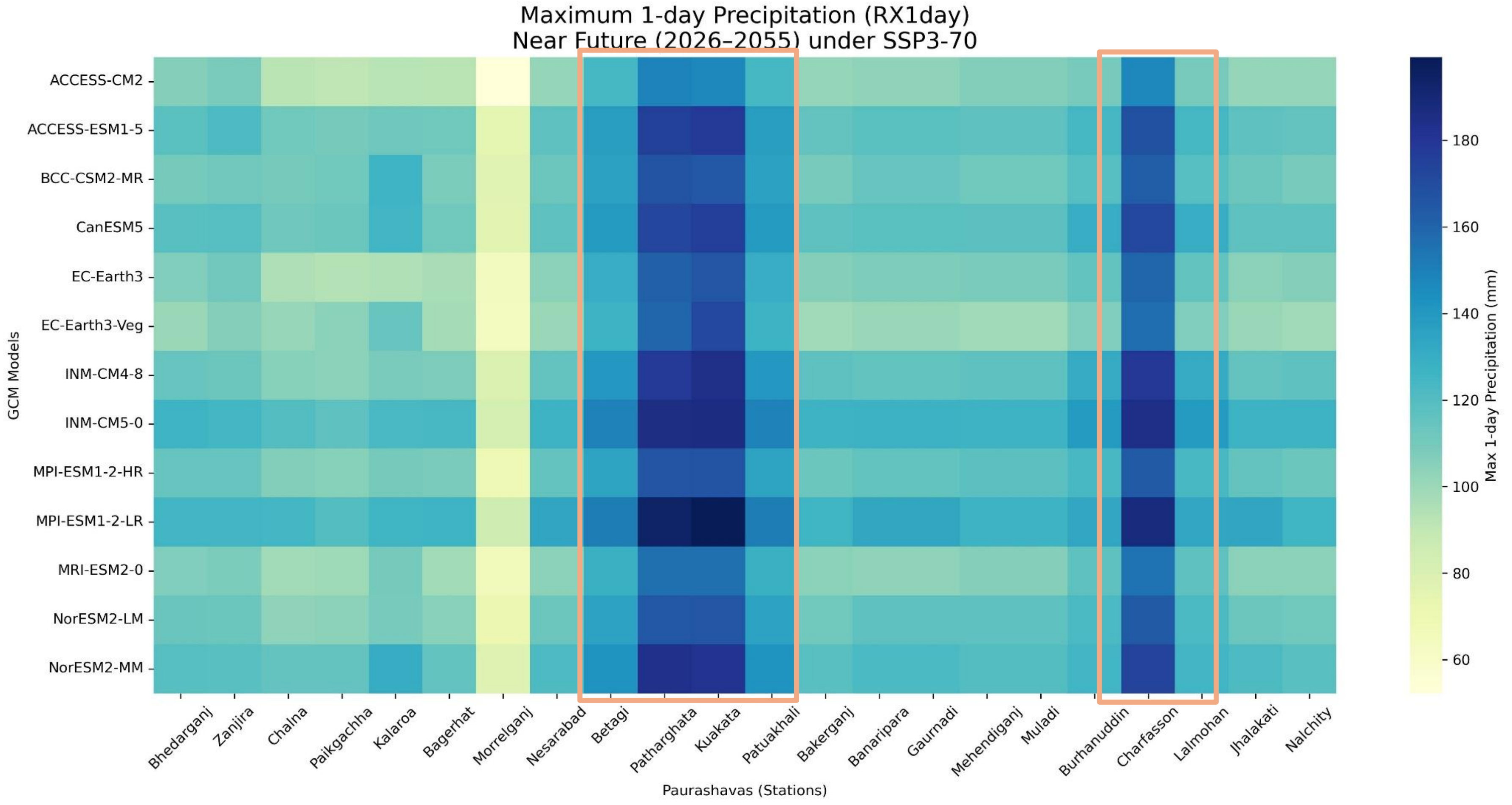
Probability density Function (PDF) plots for Precipitation Indices for Bagerhat.

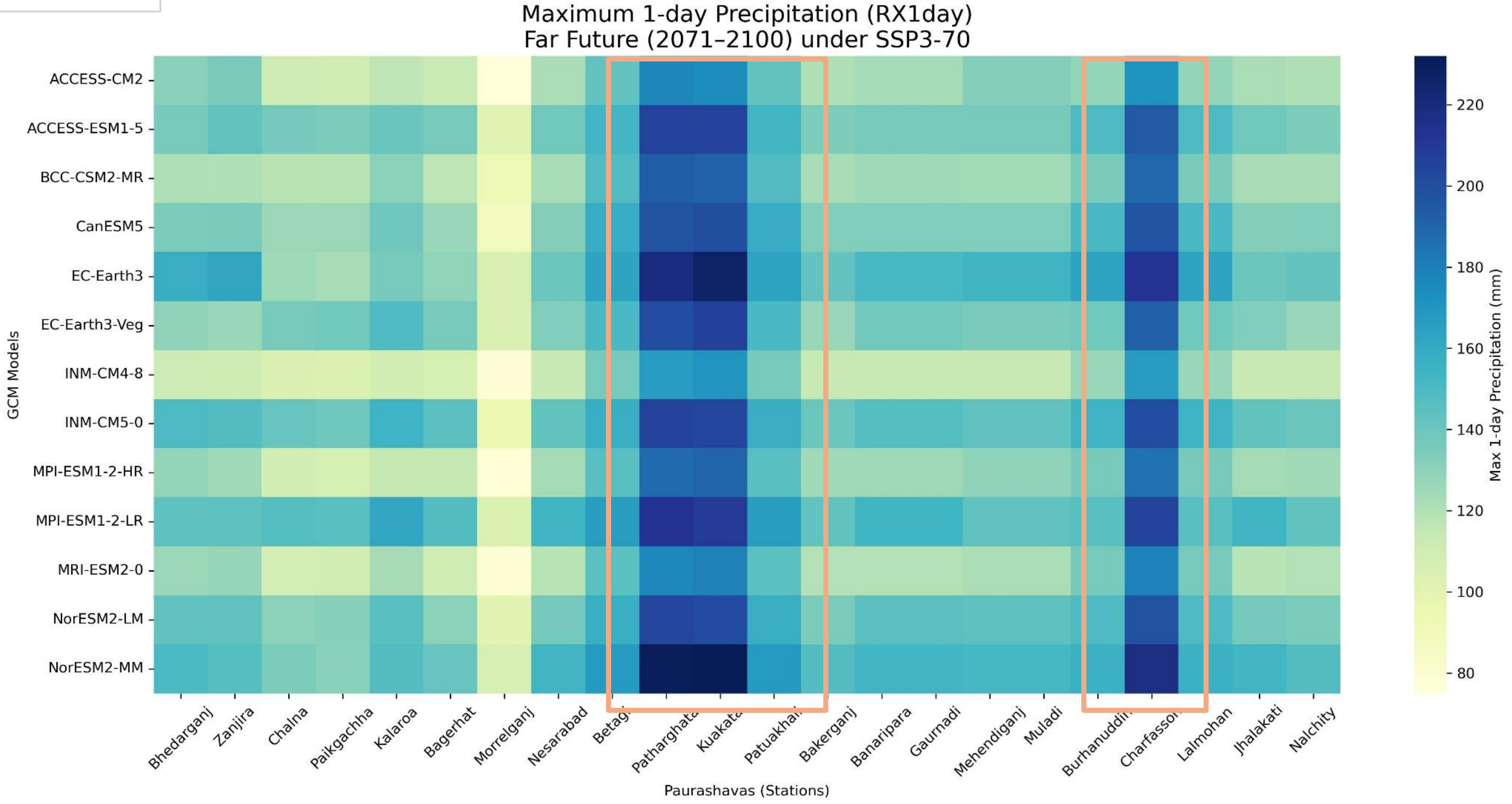
Changes in Rx1 under SS2-4.5 and SSP3-7.0 in the near and far future



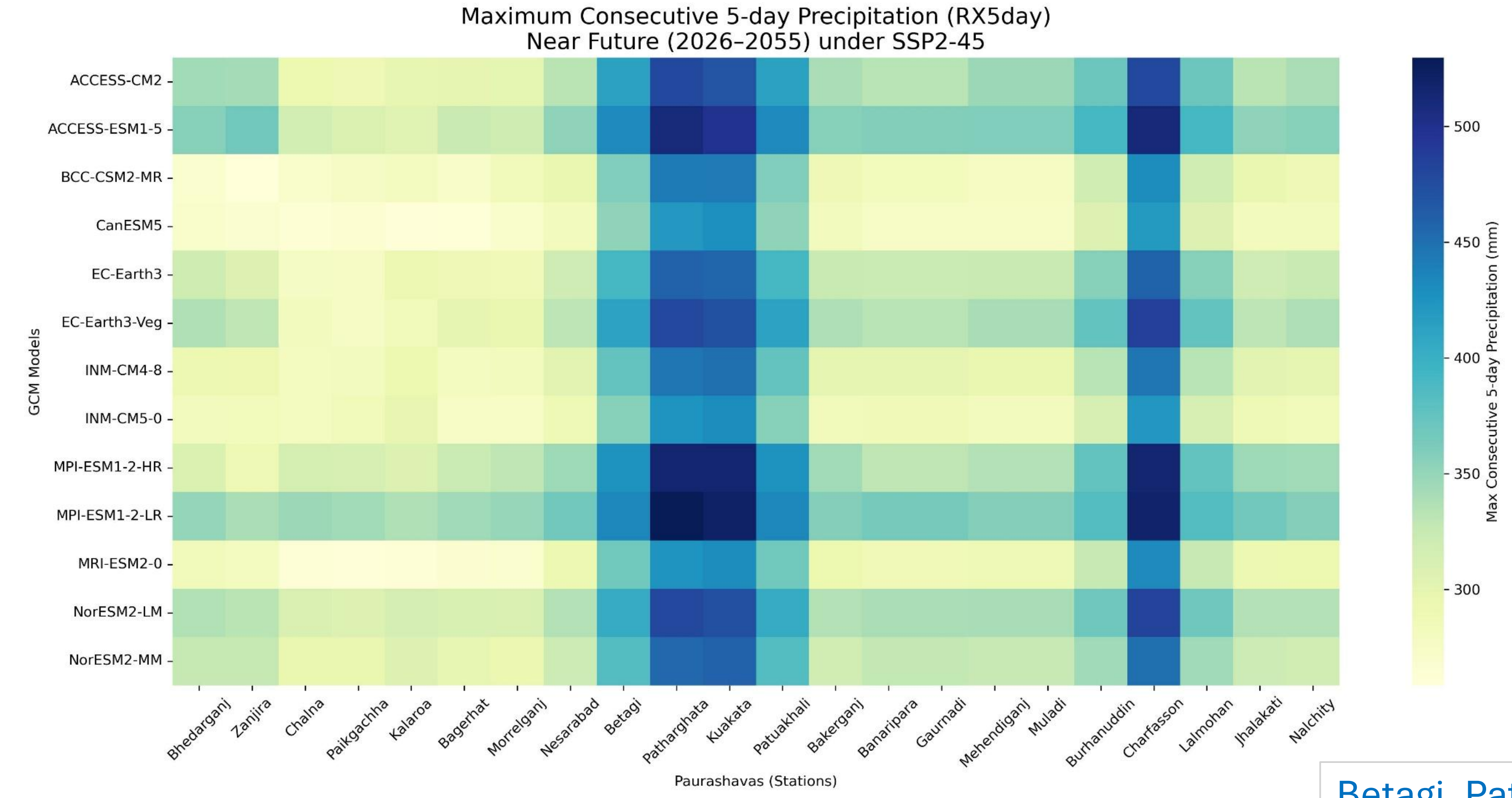


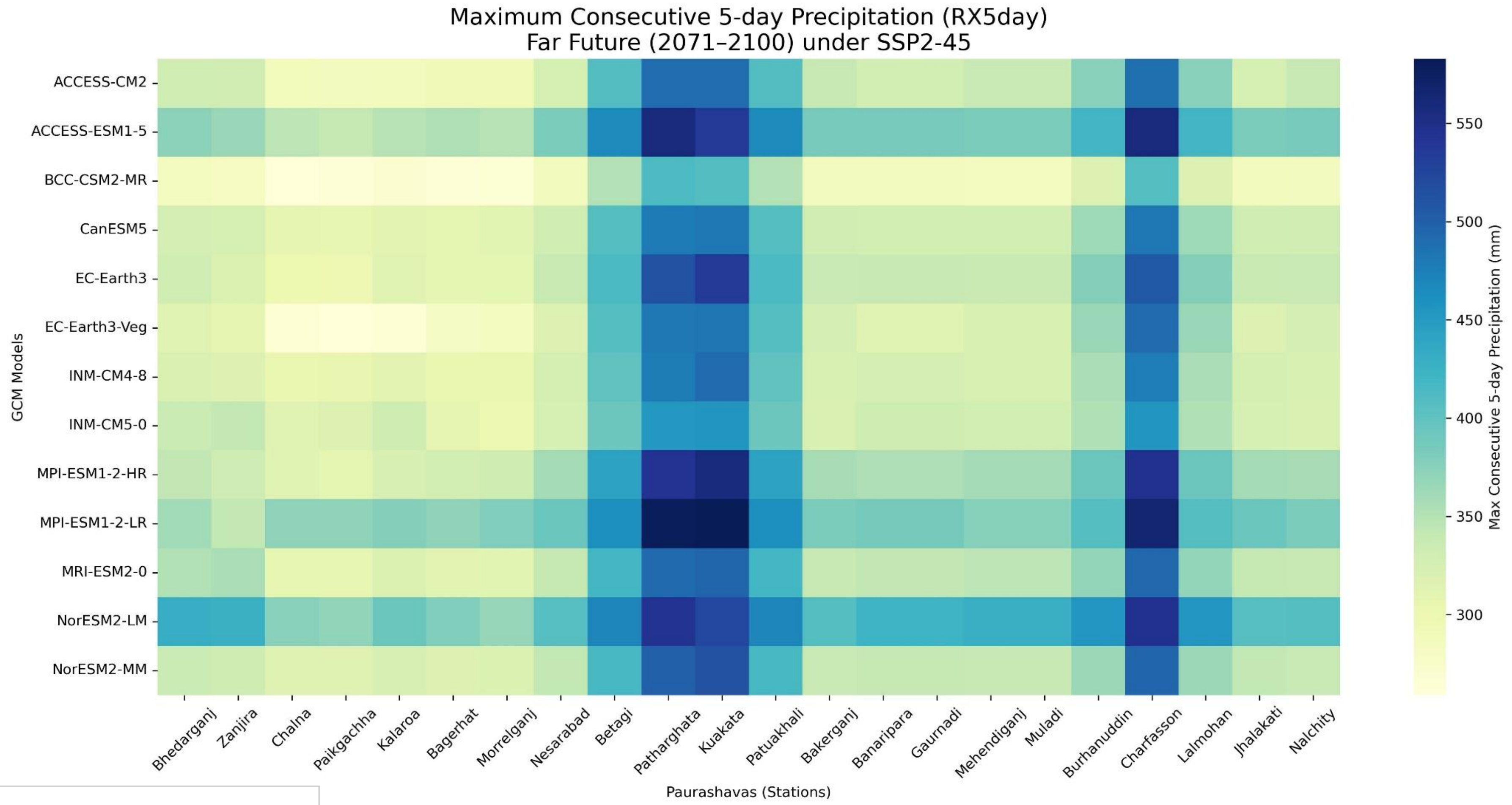
Betagi, Patharghata, Kuakata, Patuakahai, Burhanuddin



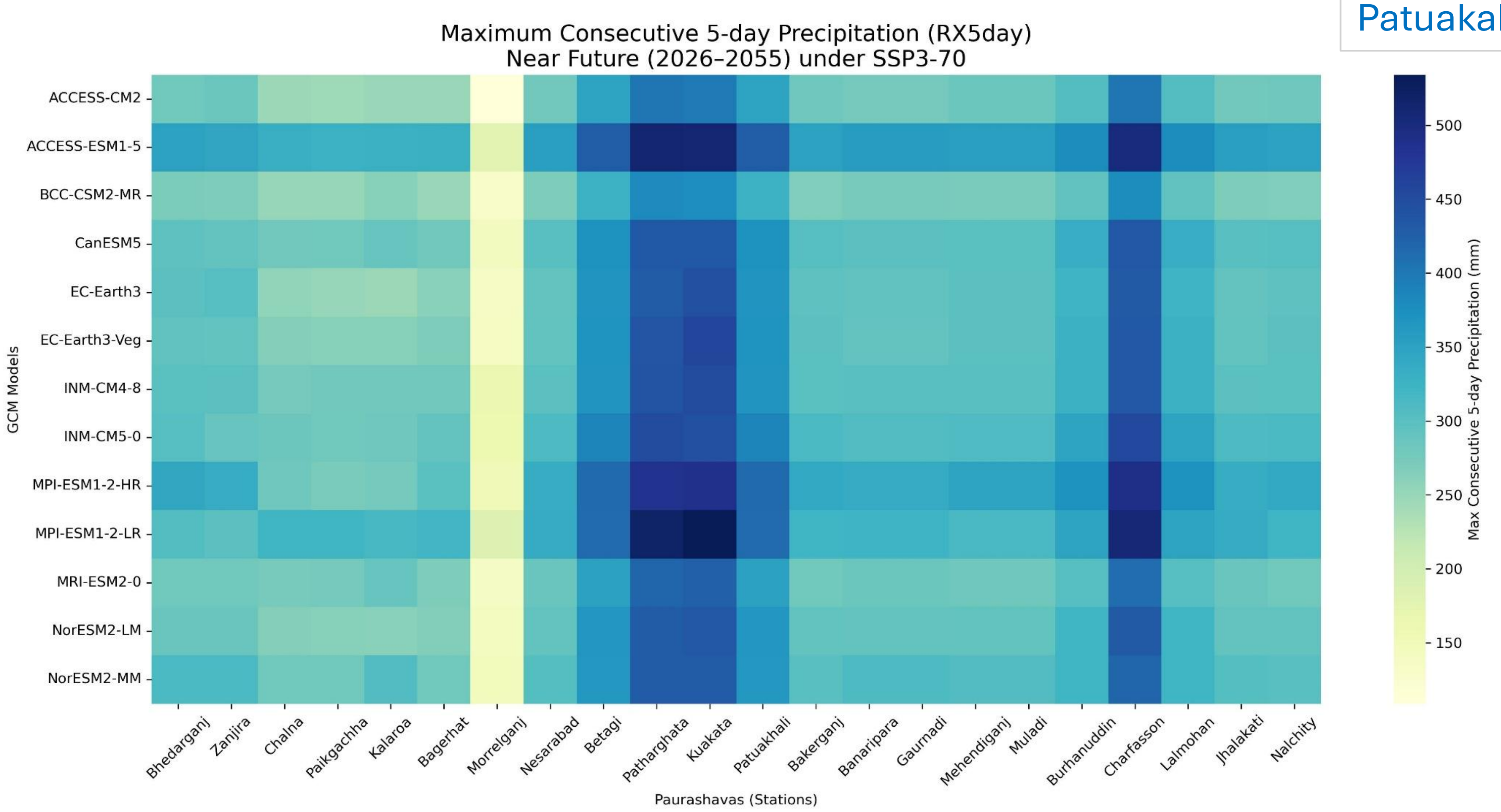


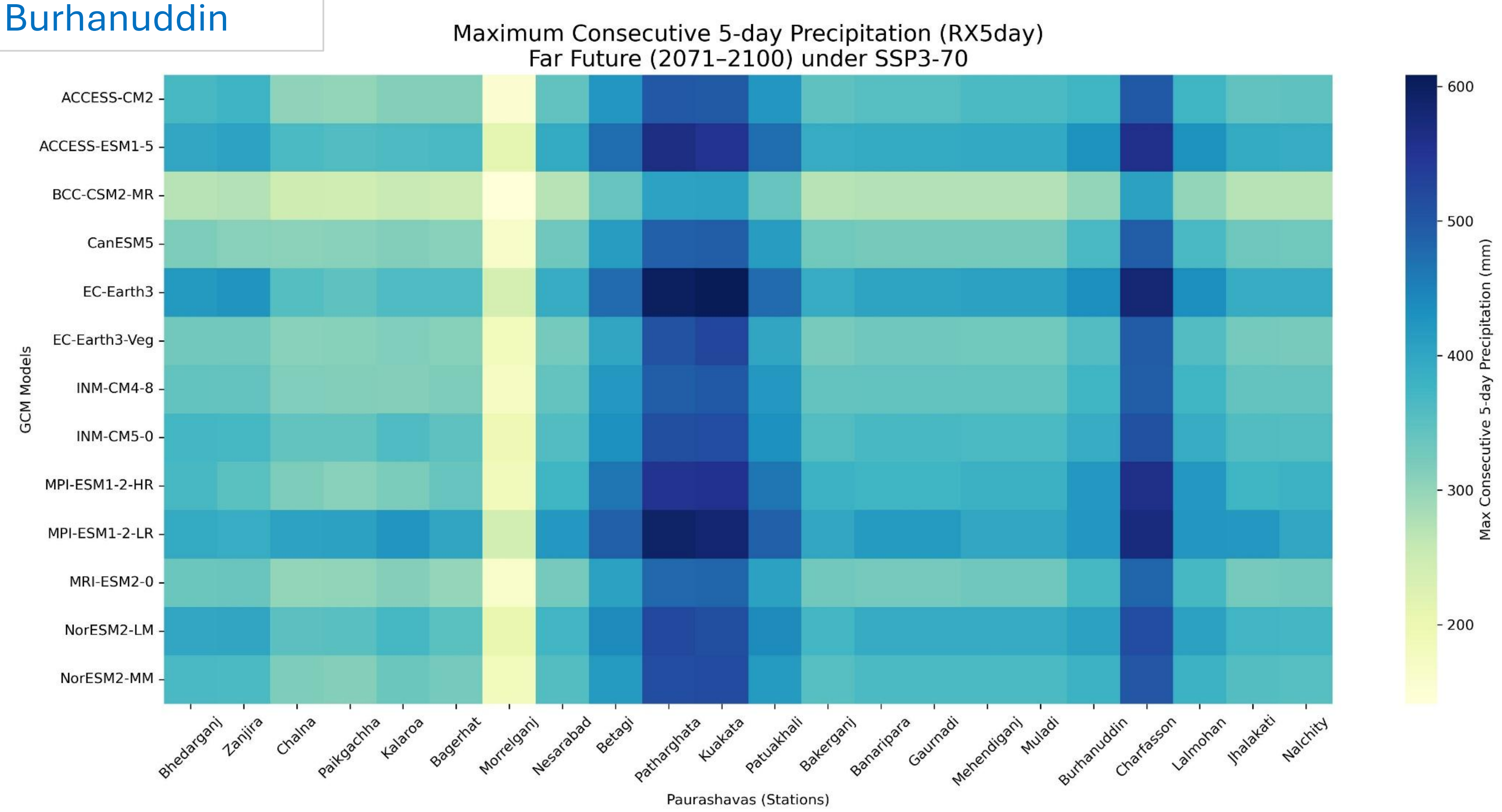
Changes in Rx5 under SS2-4.5 and SSP3-7.0 in the near and far future





Betagi, Patharghata, Kuakata, Patuakahai, Burhanuddin





Changes in Rx1, Rx5, SDII, R99p, R95p under SS2-4.5 and SSP3-7.0 in the near and far future

Pourashava	RX1day (SSP245)	RX1day (SSP370)	RX5day (SSP245)	RX5day (SSP370)	SDII (SSP245)	SDII (SSP370)
Bhedarganj	4.94 (-6.54 to 13.07)	1.04 (-5.17 to 9.2)	5.43 (-4.9 to 15.31)	1.71 (-6.17 to 9.27)	7.02 (-1.19 to 18.15)	2.27 (-2.58 to 8.66)
Zanjira	4.95 (-5.84 to 15.49)	2.16 (-5.79 to 10.0)	4.9 (-5.56 to 17.84)	1.59 (-5.69 to 10.07)	6.85 (-1.61 to 17.31)	2.13 (-2.4 to 6.58)
Chalna	7.86 (-3.33 to 20.27)	1.02 (-8.58 to 11.97)	7.8 (-1.91 to 15.38)	1.4 (-6.4 to 11.36)	5.69 (0.01 to 12.33)	2.01 (-3.26 to 6.48)
Paikgachha	7.58 (-2.62 to 17.61)	0.4 (-9.74 to 10.96)	7.79 (-0.8 to 15.93)	1.07 (-6.39 to 12.4)	5.83 (0.18 to 15.42)	2.92 (-2.82 to 10.67)
Kalaroa	9.21 (-1.99 to 19.14)	3.35 (-7.7 to 12.05)	10.38 (1.54 to 16.41)	2.01 (-7.73 to 11.39)	6.51 (0.48 to 17.17)	2.65 (-3.01 to 7.33)
Bagerhat	7.93 (-3.97 to 18.31)	0.94 (-7.66 to 12.09)	8.13 (-3.14 to 15.21)	1.42 (-6.42 to 10.21)	6.11 (0.01 to 13.3)	2.37 (-2.92 to 8.34)
Morrelganj	8.37 (-3.14 to 20.98)	-32.56 (-37.19 to -29.95)	7.6 (-2.21 to 13.64)	-46.65 (-50.53 to -41.8)	6.46 (0.89 to 11.25)	-0.81 (-10.21 to 18.18)
Nesarabad	6.76 (-4.71 to 15.43)	-0.04 (-6.9 to 9.85)	7.41 (-3.23 to 16.01)	1.08 (-6.82 to 9.09)	7.02 (-0.34 to 20.32)	3.58 (-2.9 to 10.09)
Betagi	4.88 (-3.4 to 11.2)	-0.49 (-6.04 to 4.02)	5.56 (-2.92 to 13.3)	1.02 (-9.73 to 7.55)	5.57 (-0.75 to 11.47)	3.45 (-3.47 to 9.66)
Patharghata	7.14 (-3.7 to 12.95)	-0.4 (-7.25 to 6.48)	6.36 (-1.75 to 11.69)	0.46 (-9.97 to 8.4)	5.93 (1.15 to 10.73)	4.74 (-0.59 to 10.1)
Kuakata	5.78 (-4.16 to 12.06)	0.21 (-7.3 to 9.01)	5.42 (-1.23 to 9.52)	0.57 (-11.31 to 8.9)	6.04 (1.77 to 12.41)	3.45 (-3.3 to 11.41)
Patuakhali	4.88 (-3.4 to 11.2)	-0.49 (-6.04 to 4.02)	5.56 (-2.92 to 13.3)	1.02 (-9.73 to 7.55)	5.57 (-0.75 to 11.47)	3.45 (-3.47 to 9.66)
Bakerganj	5.23 (-5.74 to 12.14)	-0.71 (-7.48 to 7.61)	6.45 (-3.38 to 15.3)	1.12 (-7.79 to 7.06)	6.26 (-0.67 to 13.6)	3.17 (-3.35 to 9.14)
Banaripara	6.14 (-5.04 to 13.24)	1.32 (-5.44 to 10.98)	7.0 (-4.44 to 17.23)	1.88 (-5.14 to 9.58)	6.97 (-0.6 to 18.59)	2.95 (-2.2 to 10.42)
Gaurnadi	6.14 (-5.04 to 13.24)	1.32 (-5.44 to 10.98)	7.0 (-4.44 to 17.23)	1.88 (-5.14 to 9.58)	6.97 (-0.6 to 18.59)	2.95 (-2.2 to 10.42)
Mehendiganj	4.81 (-6.45 to 11.44)	0.28 (-6.73 to 8.28)	6.26 (-4.45 to 15.7)	1.52 (-5.57 to 8.89)	7.06 (-0.74 to 18.56)	2.57 (-2.95 to 8.69)
Burhanuddin	4.13 (-7.07 to 11.43)	-2.02 (-8.45 to 4.13)	5.45 (-4.45 to 12.87)	0.28 (-10.23 to 6.23)	6.41 (-0.63 to 12.17)	2.77 (-3.22 to 8.06)
Muladi	4.81 (-6.45 to 11.44)	0.28 (-6.73 to 8.28)	6.26 (-4.45 to 15.7)	1.52 (-5.57 to 8.89)	7.06 (-0.74 to 18.56)	2.57 (-2.95 to 8.69)
Charfasson	6.29 (-4.04 to 15.74)	-0.98 (-8.77 to 8.42)	5.64 (-2.83 to 11.72)	-0.02 (-11.1 to 8.01)	6.51 (1.58 to 10.93)	2.7 (-1.99 to 9.48)
Lalmohan	4.13 (-7.07 to 11.43)	-2.02 (-8.45 to 4.13)	5.45 (-4.45 to 12.87)	0.28 (-10.23 to 6.23)	6.41 (-0.63 to 12.17)	2.77 (-3.22 to 8.06)
Jhalakati	6.76 (-4.71 to 15.43)	-0.04 (-6.9 to 9.85)	7.41 (-3.23 to 16.01)	1.08 (-6.82 to 9.09)	7.02 (-0.34 to 20.32)	3.58 (-2.9 to 10.09)
Nalchity	5.23 (-5.74 to 12.14)	-0.71 (-7.48 to 7.61)	6.45 (-3.38 to 15.3)	1.12 (-7.79 to 7.06)	6.26 (-0.67 to 13.6)	3.17 (-3.35 to 9.14)

Pourashava	PRCPTOT (SSP245)	PRCPTOT (SSP370)	R99p (SSP245)	R99p (SSP370)	R95p (SSP245)	R95p (SSP370)
Bhedarganj	12.46 (3.07 to 21.32)	18.8 (8.84 to 42.22)	31.32 (13.31 to 49.94)	59.93 (15.27 to 91.38)	29.58 (6.2 to 38.58)	45.01 (23.86 to 77.98)
Zanjira	11.26 (3.93 to 21.15)	18.64 (7.21 to 43.18)	31.83 (12.54 to 47.54)	62.03 (13.65 to 95.22)	25.91 (6.67 to 34.29)	42.04 (21.7 to 72.37)
Chalna	14.87 (1.45 to 28.77)	19.98 (4.86 to 55.96)	32.31 (5.22 to 46.67)	60.67 (9.7 to 99.18)	23.91 (2.76 to 33.96)	31.81 (3.36 to 50.73)
Paikgachha	13.91 (1.44 to 24.13)	16.75 (5.19 to 31.69)	35.05 (11.8 to 47.35)	46.1 (4.65 to 78.19)	24.38 (3.02 to 35.87)	25.2 (-3.06 to 45.76)
Kalaroa	13.71 (1.9 to 25.62)	18.97 (8.43 to 48.39)	33.43 (12.46 to 45.62)	62.48 (9.95 to 91.95)	30.38 (4.25 to 46.23)	41.54 (18.75 to 82.42)
Bagerhat	15.39 (1.36 to 28.15)	20.82 (4.99 to 55.17)	32.91 (-2.48 to 52.4)	58.87 (1.42 to 82.64)	25.0 (4.37 to 35.17)	33.65 (11.56 to 54.55)
Morrelganj	17.09 (1.37 to 24.67)	-65.01 (-73.06 to -57.97)	38.79 (6.38 to 62.59)	-45.55 (-77.92 to -10.47)	29.8 (9.31 to 52.57)	-59.76 (-76.27 to -43.79)
Nesarabad	14.22 (1.36 to 22.0)	17.22 (5.47 to 30.52)	34.66 (10.94 to 53.79)	46.13 (-8.01 to 78.42)	28.49 (5.68 to 39.6)	28.51 (0.91 to 43.32)
Betagi	14.55 (1.03 to 21.78)	17.25 (2.61 to 43.77)	28.18 (2.35 to 53.31)	44.42 (-11.7 to 76.78)	26.89 (8.97 to 36.13)	30.22 (0.8 to 51.55)
Patharghata	16.05 (1.12 to 24.3)	18.9 (1.46 to 37.77)	38.72 (-0.23 to 66.97)	61.09 (-7.42 to 95.46)	30.66 (14.98 to 48.32)	43.34 (29.79 to 59.08)
Kuakata	15.72 (1.08 to 28.17)	17.37 (0.42 to 31.55)	30.96 (-5.57 to 73.78)	52.1 (6.7 to 76.56)	33.19 (17.29 to 48.17)	44.01 (23.26 to 65.21)
Patuakhali	14.55 (1.03 to 21.78)	17.25 (2.61 to 43.77)	28.18 (2.35 to 53.31)	44.42 (-11.7 to 76.78)	26.89 (8.97 to 36.13)	30.22 (0.8 to 51.55)
Bakerganj	14.22 (1.53 to 21.25)	17.0 (4.27 to 30.22)	31.43 (3.87 to 57.15)	48.8 (-10.04 to 79.89)	27.63 (7.53 to 41.82)	29.13 (1.85 to 41.62)
Banaripara	13.35 (2.15 to 21.92)	18.77 (7.54 to 41.93)	33.29 (17.3 to 51.61)	58.62 (14.94 to 80.46)	30.78 (5.85 to 43.83)	43.53 (19.11 to 77.5)
Gaurnadi	13.35 (2.15 to 21.92)	18.77 (7.54 to 41.93)	33.29 (17.3 to 51.61)	58.62 (14.94 to 80.46)	30.78 (5.85 to 43.83)	43.53 (19.11 to 77.5)
Mehendiganj	13.35 (2.34 to 21.17)	18.73 (8.22 to 41.91)	32.11 (14.92 to 52.36)	56.81 (21.06 to 82.44)	31.03 (6.28 to 42.62)	43.68 (18.95 to 76.57)
Burhanuddin	14.59 (1.76 to 21.18)	17.81 (4.57 to 28.86)	31.22 (7.45 to 53.68)	48.66 (-13.2 to 83.66)	26.9 (9.47 to 40.32)	29.65 (5.83 to 40.78)
Muladi	13.35 (2.34 to 21.17)	18.73 (8.22 to 41.91)	32.11 (14.92 to 52.36)	56.81 (21.06 to 82.44)	31.03 (6.28 to 42.62)	43.68 (18.95 to 76.57)
Charfasson	16.09 (0.92 to 26.59)	19.75 (1.31 to 37.1)	32.93 (-7.81 to 68.57)	60.82 (-2.03 to 115.42)	31.19 (18.28 to 43.8)	45.07 (31.42 to 62.11)
Lalmohan	14.59 (1.76 to 21.18)	17.81 (4.57 to 28.86)	31.22 (7.45 to 53.68)	48.66 (-13.2 to 83.66)	26.9 (9.47 to 40.32)	29.65 (5.83 to 40.78)
Jhalakati	14.22 (1.36 to 22.0)	17.22 (5.47 to 30.52)	34.66 (10.94 to 53.79)	46.13 (-8.01 to 78.42)	28.49 (5.68 to 39.6)	28.51 (0.91 to 43.32)
Nalchity	14.22 (1.53 to 21.25)	17.0 (4.27 to 30.22)	31.43 (3.87 to 57.15)	48.8 (-10.04 to 79.89)	27.63 (7.53 to 41.82)	29.13 (1.85 to 41.62)

PRCPTOT, positive anomalies across all Paurashavas are found for SSP2-45 scenarios.

Under SSP3-70 scenarios, positive anomalies are found for all cities except Morrelganj, which is likely to experience significant decreases in PRCPTOT (75.49% in the near future and 64.19% in the far future).

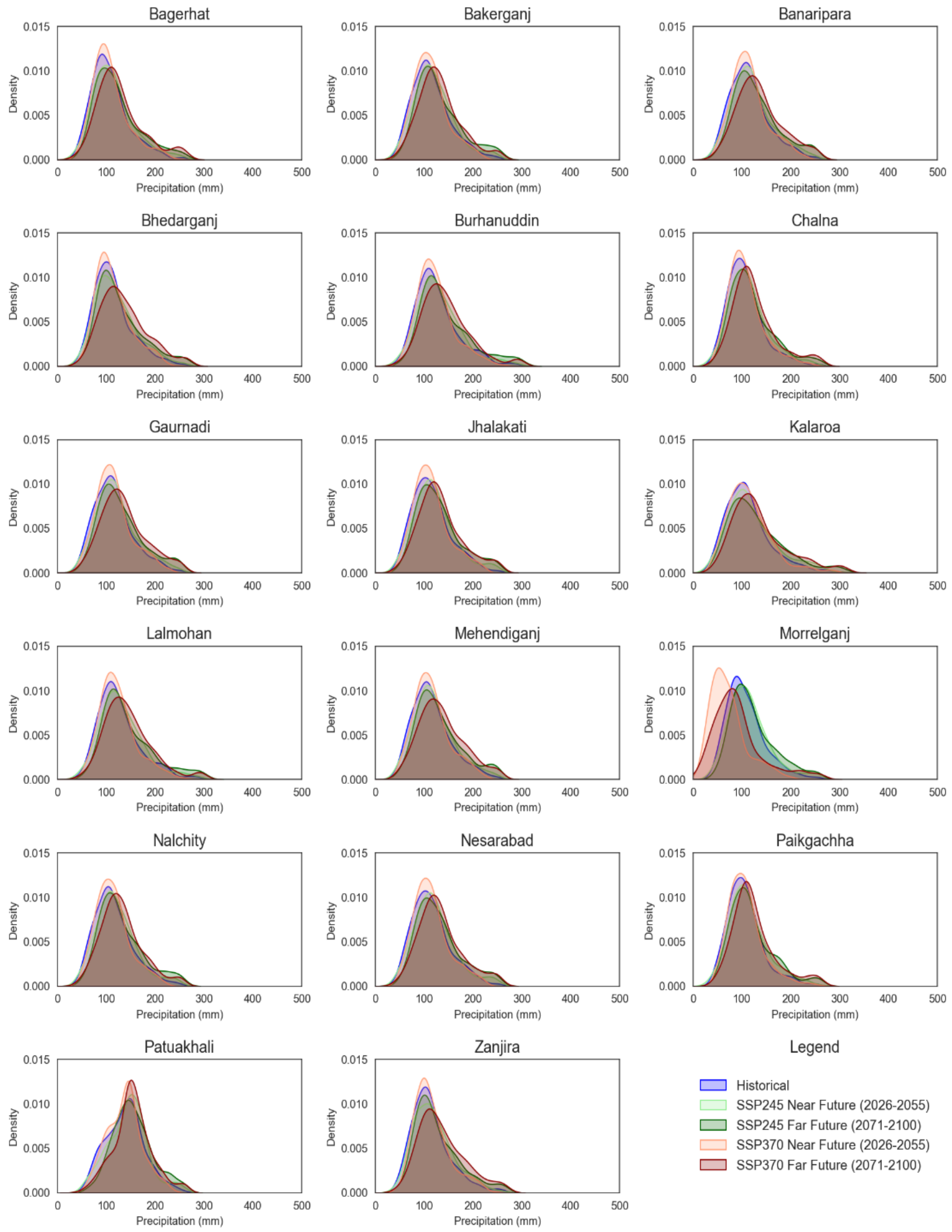
Positive SDII anomalies for both scenarios, except for Charfasson under the SSP3-70 scenario in the near future, having a decrease of value of 2.84%.

Under the SSP3-70 scenario, SDII anomalies are highest and range from 15.35% to 42.32%.

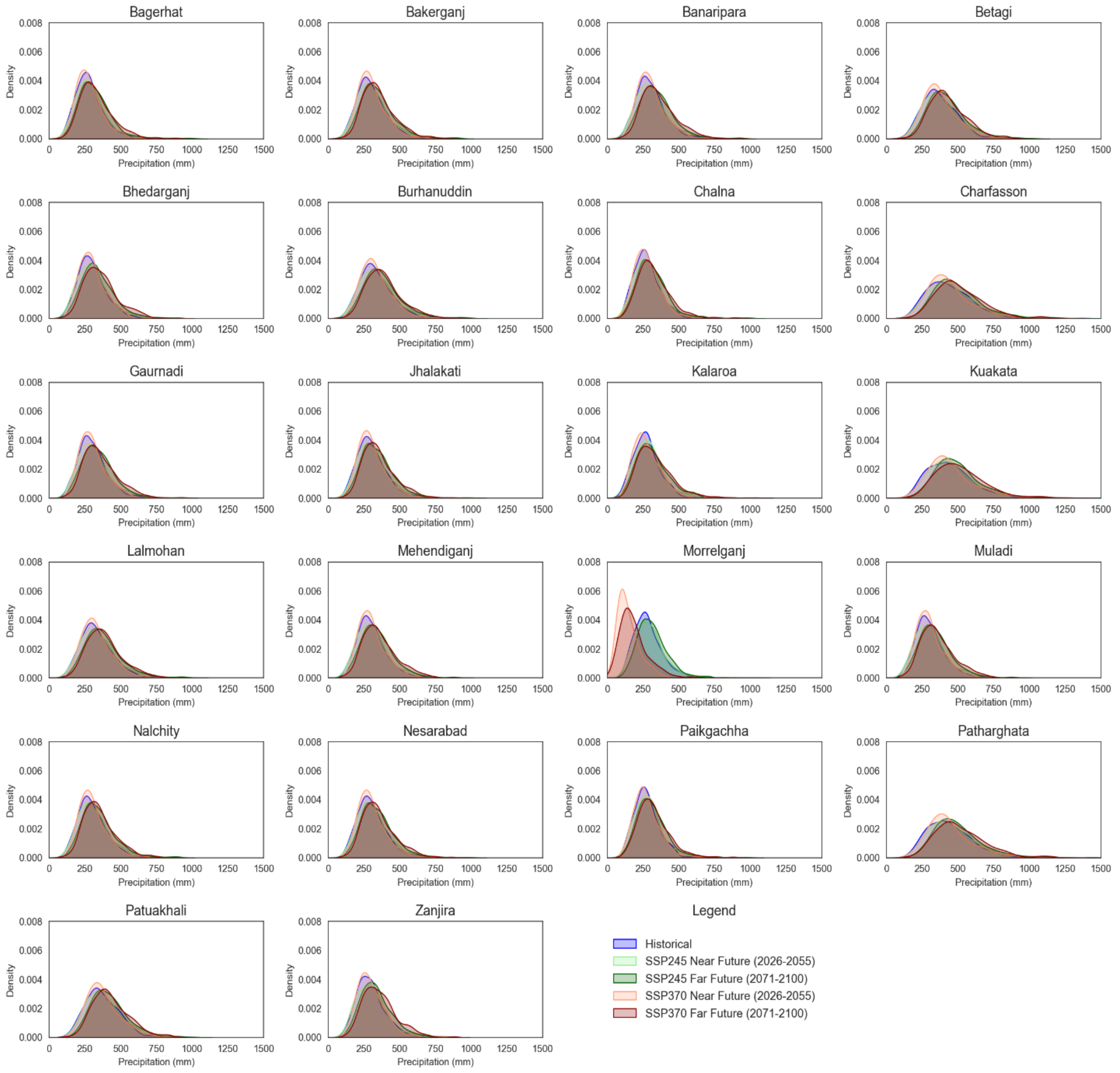
PDFs of Rx1 and Rx5 under SS2-4.5 and SSP3-7.0 in near and far future

PDF plots for (a) max 1-day precipitation amount (RX1day)

In the future, **both RX1day and RX5day will be increased.**



PDF plots for max 5-day precipitation amount (RX5day)



Changes in R95p and R99p

- **R95p and R99p indicators, positive anomalies** are found for the SSP2-45 scenario, except negative anomalies are found for Morrelganj under the SSP3-70 scenario.
- Under the SSP2-45 scenario, positive anomalies in R95p and R99p are found for all Paurashavas. It is found that **R95p would increase from 3.93% to 11.63% in the near future and 22.85% to 37.41% in the** far future. **R99p shows similar positive trends, with an increase from 2.30% to 18.20%** in the near future and from 29.36% to 39.75% in the far future.

- On the other hand, Morrelganj shows negative anomalies under the SSP3-70 scenario in the far future, while the positive company is found for all other cities as R95p ranges from 23.82% to 53.26%, and R99p ranges from 42.85% to 79.45%.
- R95p is found to typically peak around 1000 mm, while the R99p peaks between 500-1000 mm
- **It is found that R95p would increase from 3.93% to 11.63% in the near future and 22.85% to 37.41% in the far future. R99p shows similar positive trends, with an increase from 2.30% to 18.20% in the near future and from 29.36% to 39.75% in the far future.**

Climate Resilient Urban Drainage System using NBS

Methodology for IDF curve generation for Bagerhat

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Methodology for Generation of Projected IDF Curves

Bias correction of 13 CMIP6 model derived daily precipitation data against BMD daily observation data using Empirical Quantile Mapping (EQM) method.

↓

Annual maximum precipitation (AMP) series such as one-day (1-D), two-day (2-D), three-day (3-D), four-day (4-D), five-day (5-D), six-day (6-D) and seven-day (7-D) are derived CMIP6 (historical and projected data) and Observed, both.

↓

CMIP6 Annual Maximum Precipitation (AMP) series for historical period (1985-2014) has been matched with Observed Annual Maximum Precipitation (AMP) series based on quantiles.

↓

Gumbel Extreme Value (GEV) Distribution for different return periods (2 years, 5 years, 10 years, 25 years, 50 years, and 100 years).

↓

Calculations for short-duration IDF (Intensity-Duration-Frequency) curves based on the Bernard Equation.

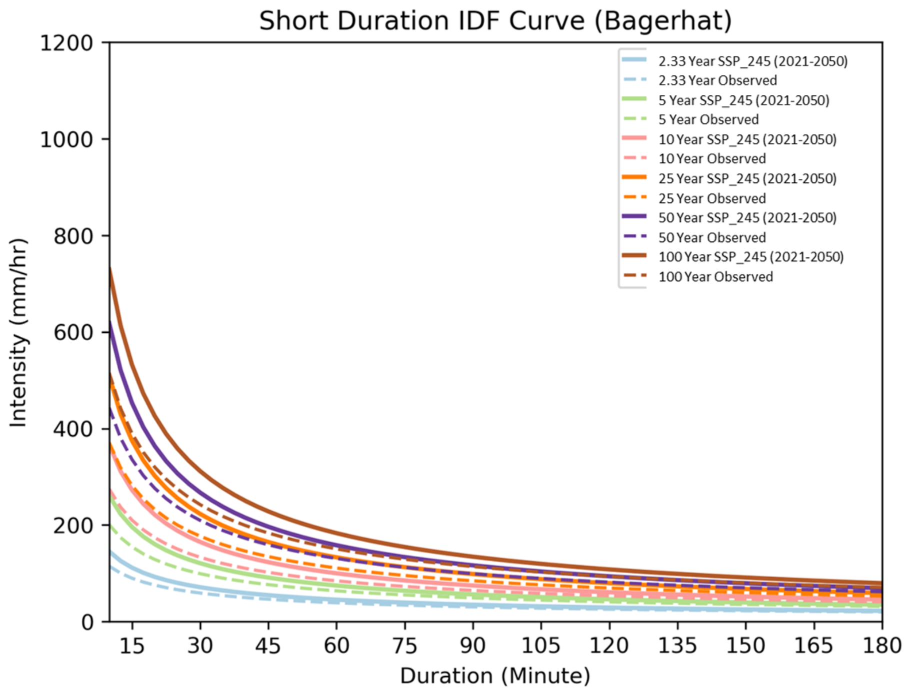
↓

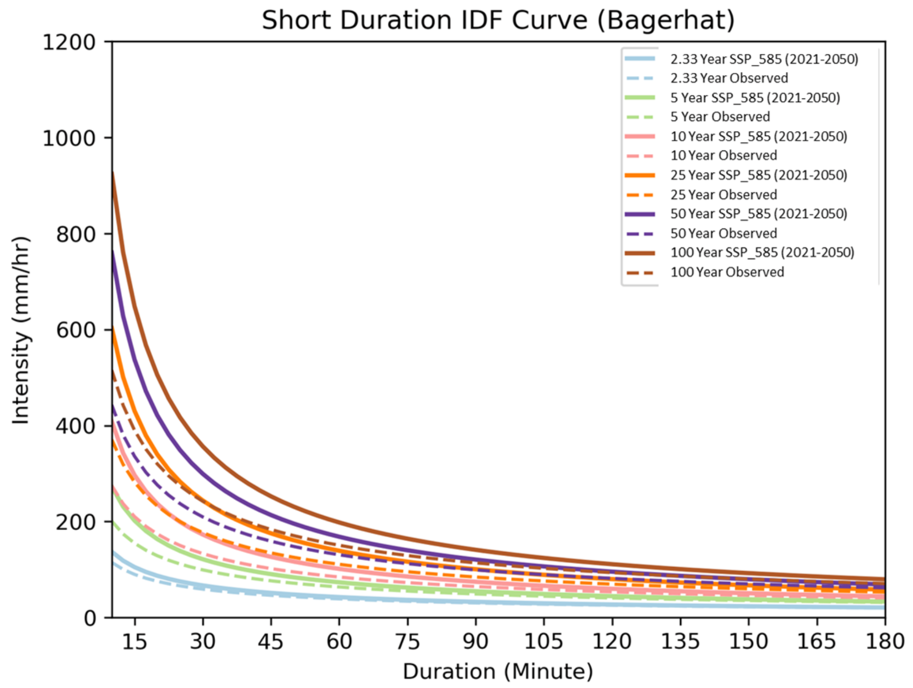
Mean Ensemble of 13 model outputs from CMIP6 dataset plotted for the near future (2021-2050) and far future (2071-2100) considering two SSP scenarios (SSP 245 and SSP 585).

SSP 245

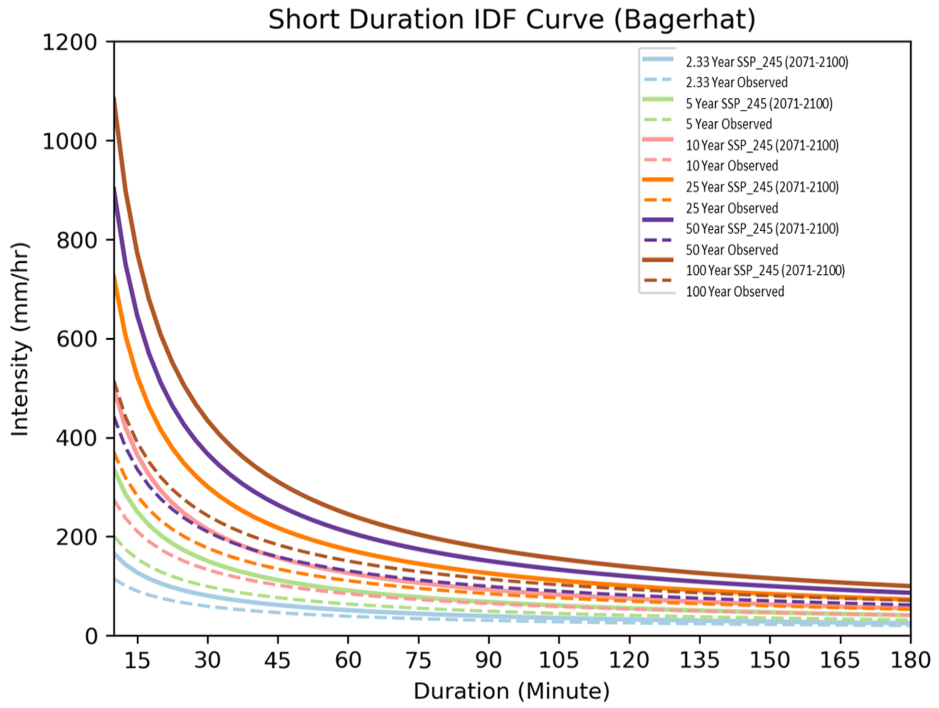
SSP 585

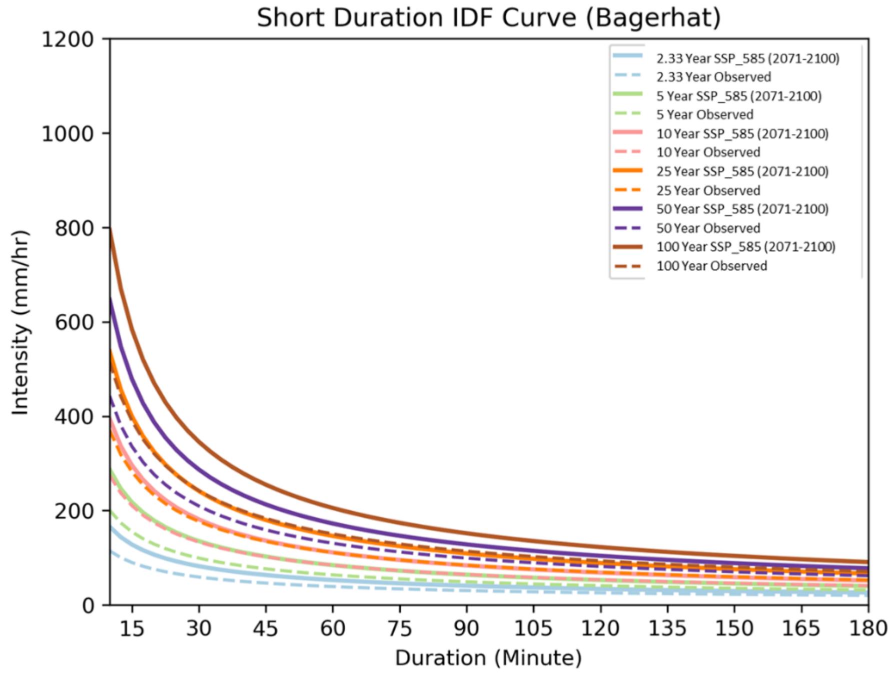
Near Future





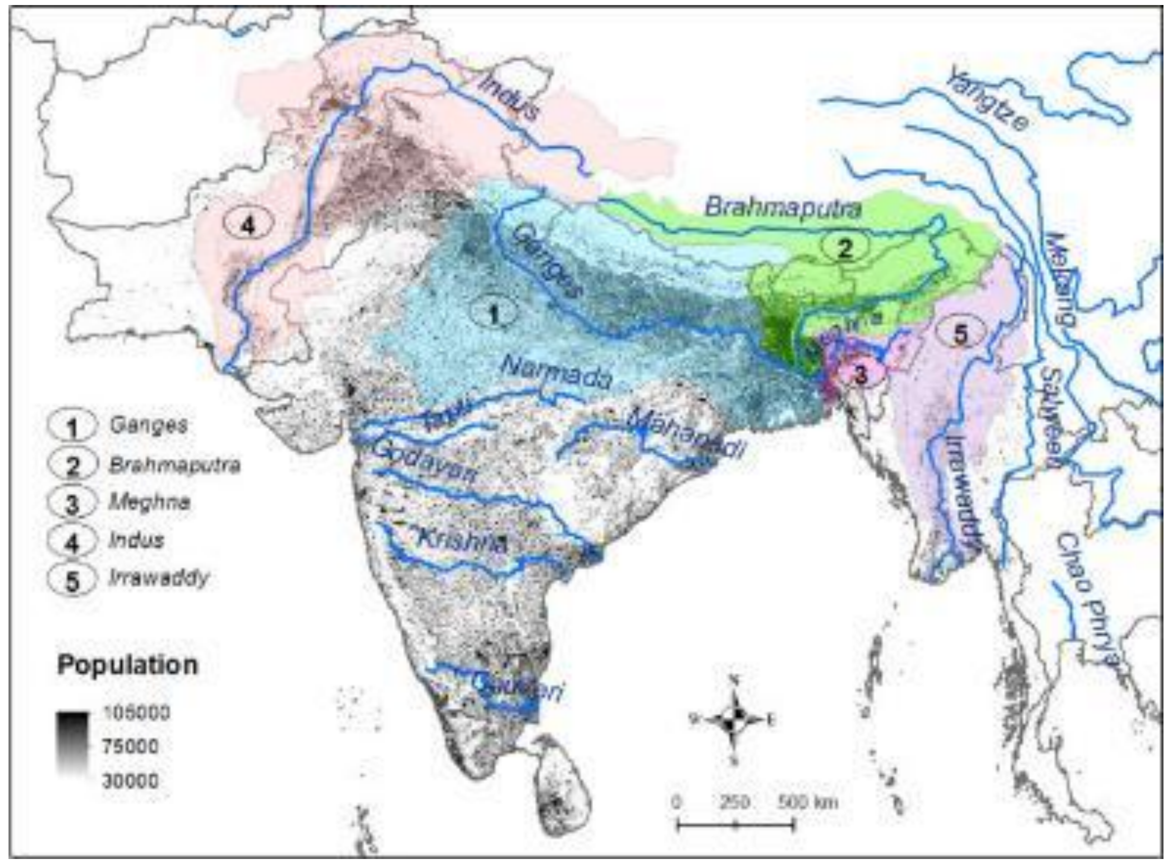
Far Future

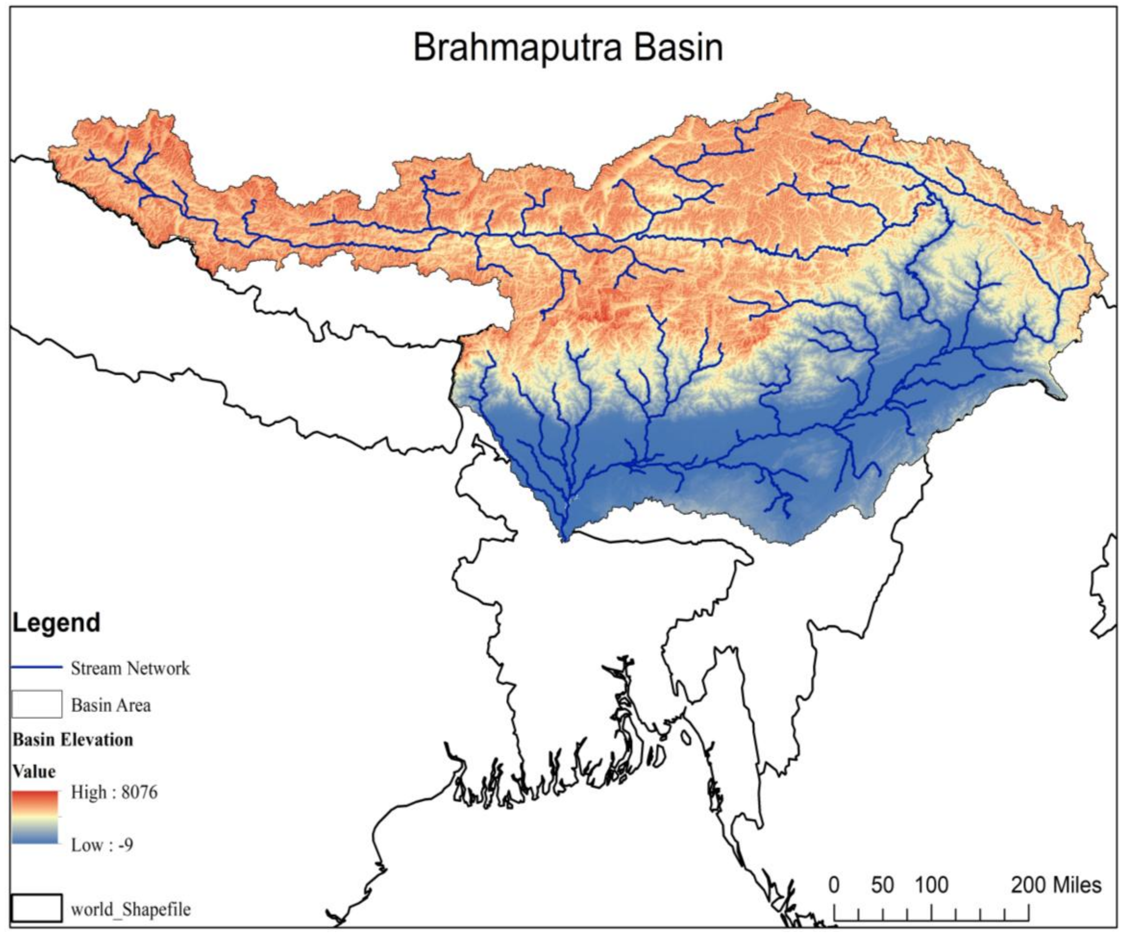




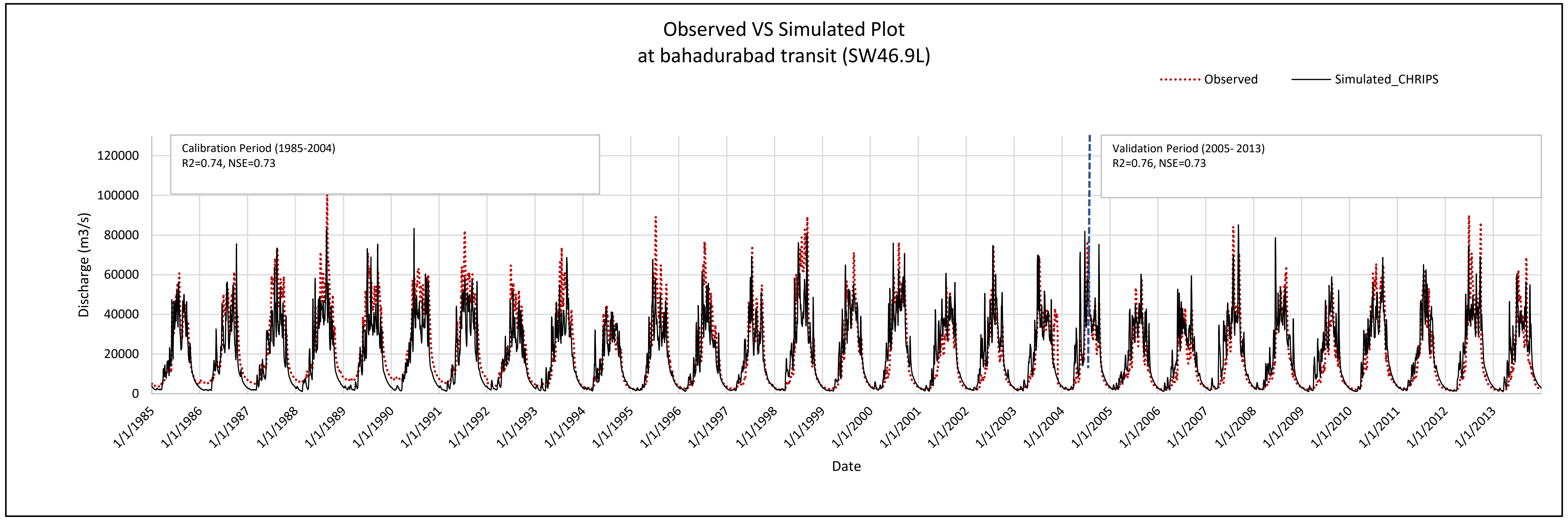
Changes in flows of GBM basins and river flows

Ganges Brahmaputra and Meghna (GBM) basins





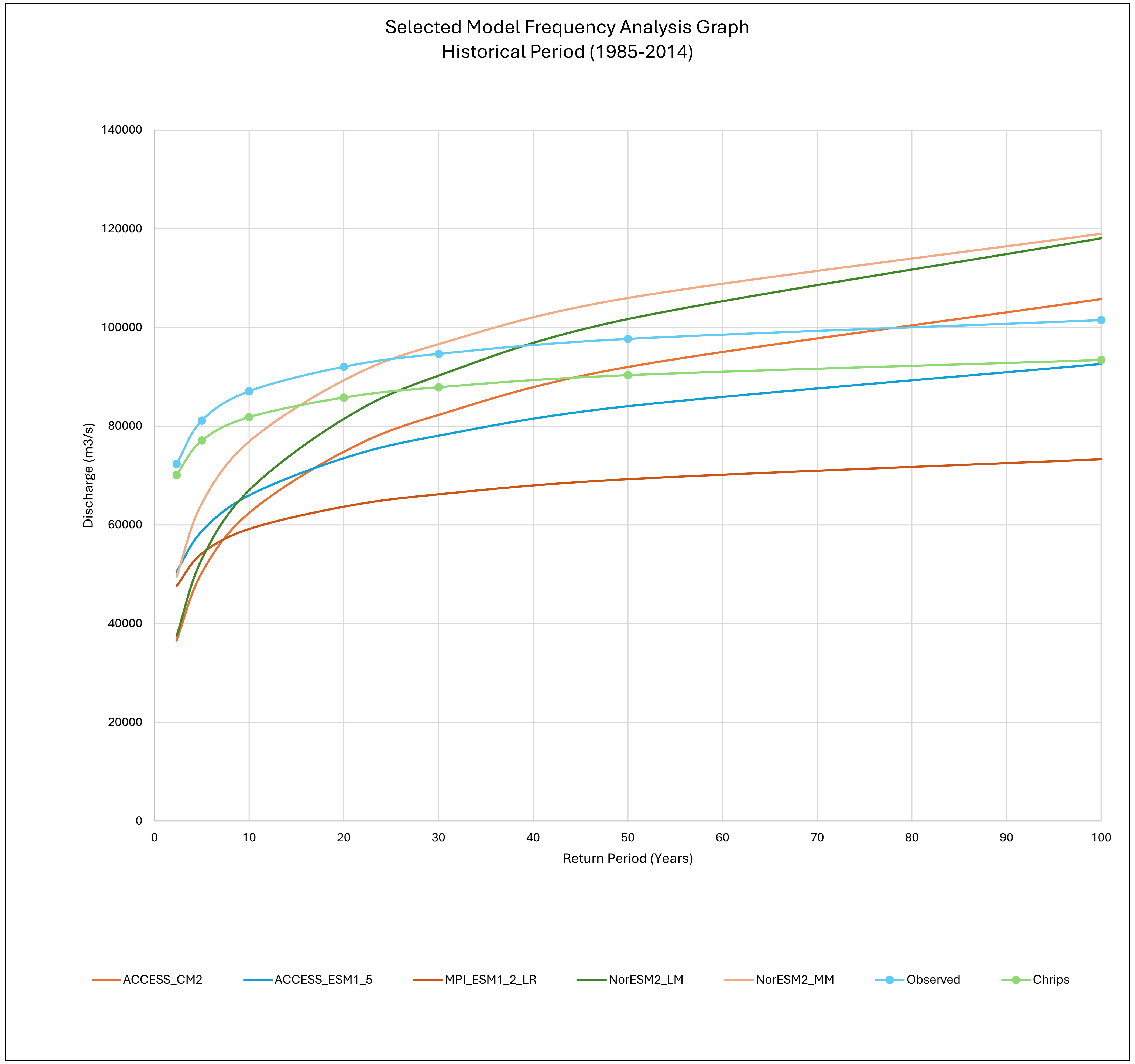
Calibration and validation of hydrological modelling of Brahmaputra basin using SWAT



Performance of hydrological modelling of Brahmaputra basin using SWAT

Time Period (Year)	RMSE	MAE	PBIAS	NSE	RSR	R2
Calibration (1985-2004	101107	6667	-11.19	0.73	0.52	0.74
Validation (2005-2013)	8999	5723	14.78	0.73	0.52	0.76

Changes in flows of Brahmaputra Basin

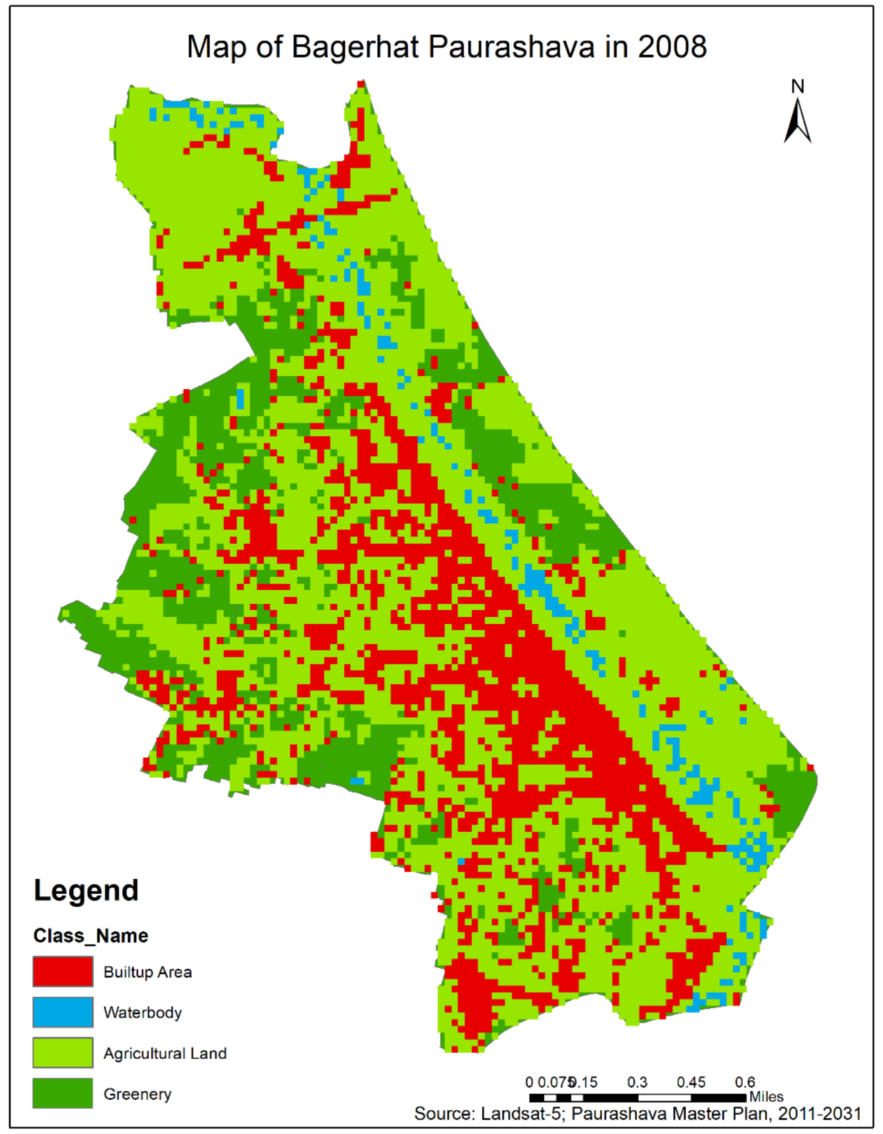


Return Period (Years)	Observed (1985-2013)	Chirps (1985-2013)	Ensembled Mean for Selected Models (1985-2013)
5	81141	77091	56107
10	87072	81825	66288
20	92031	85796	76544
30	94634	87885	82673
50	97678	90333	90588
100	101482	93397	101739

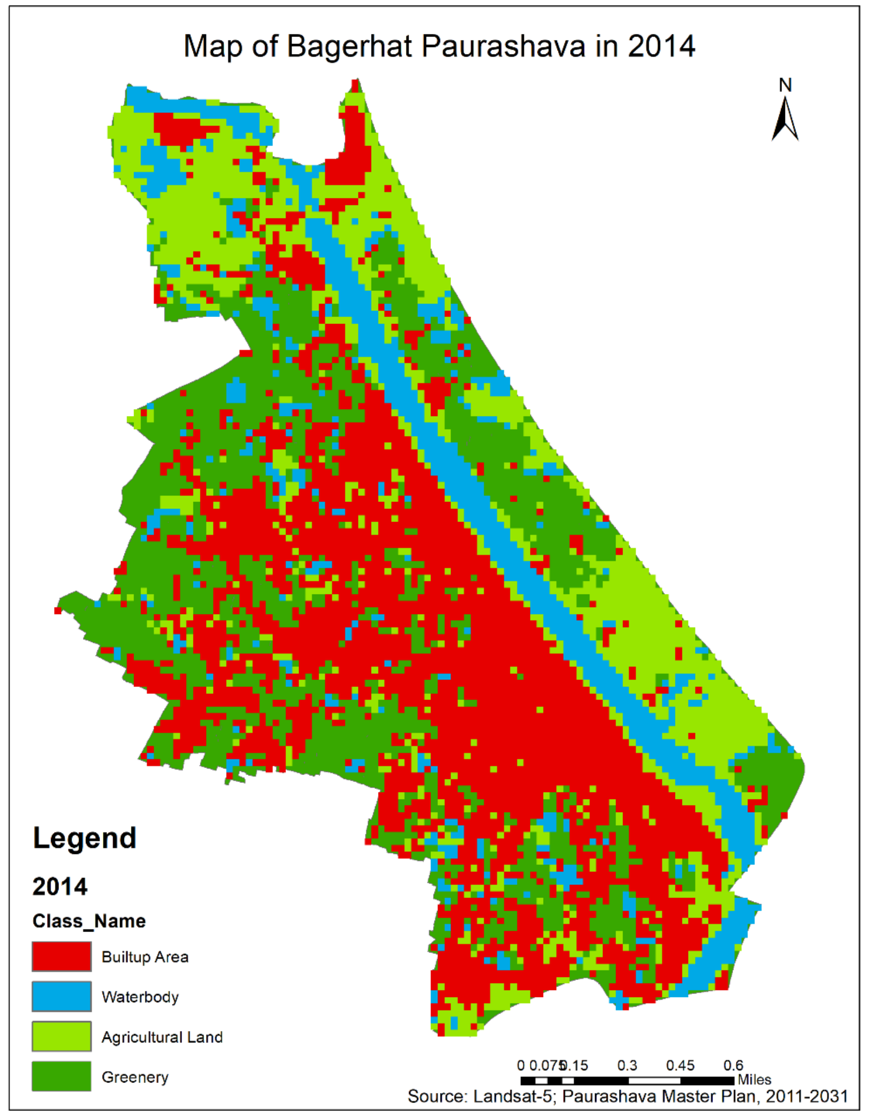
		Near Future (2040-2069)				Far Future (2070-2100)			
Return Period	CHIRPS	SSP 245	% Increase	SSP 370	% Increase	SSP 245	% Increase	SSP 370	% Increase
5	77091	68495	**-11**	65274	**-15**	70028	**-9**	69902	**-9**
10	81825	80266	**-2**	77798	**-5**	80824	**-1**	81895	**0**
20	85796	91876	**7**	90333	**5**	91307	**6**	93748	**9**
30	87885	98715	**12**	97796	**11**	97415	**11**	100742	**15**
50	90333	107448	**19**	107409	**19**	105151	**16**	109688	**21**
100	93397	119589	**28**	120918	**29**	115799	**24**	122155	**31**

Changes in land use of Bagerhat Pourashava

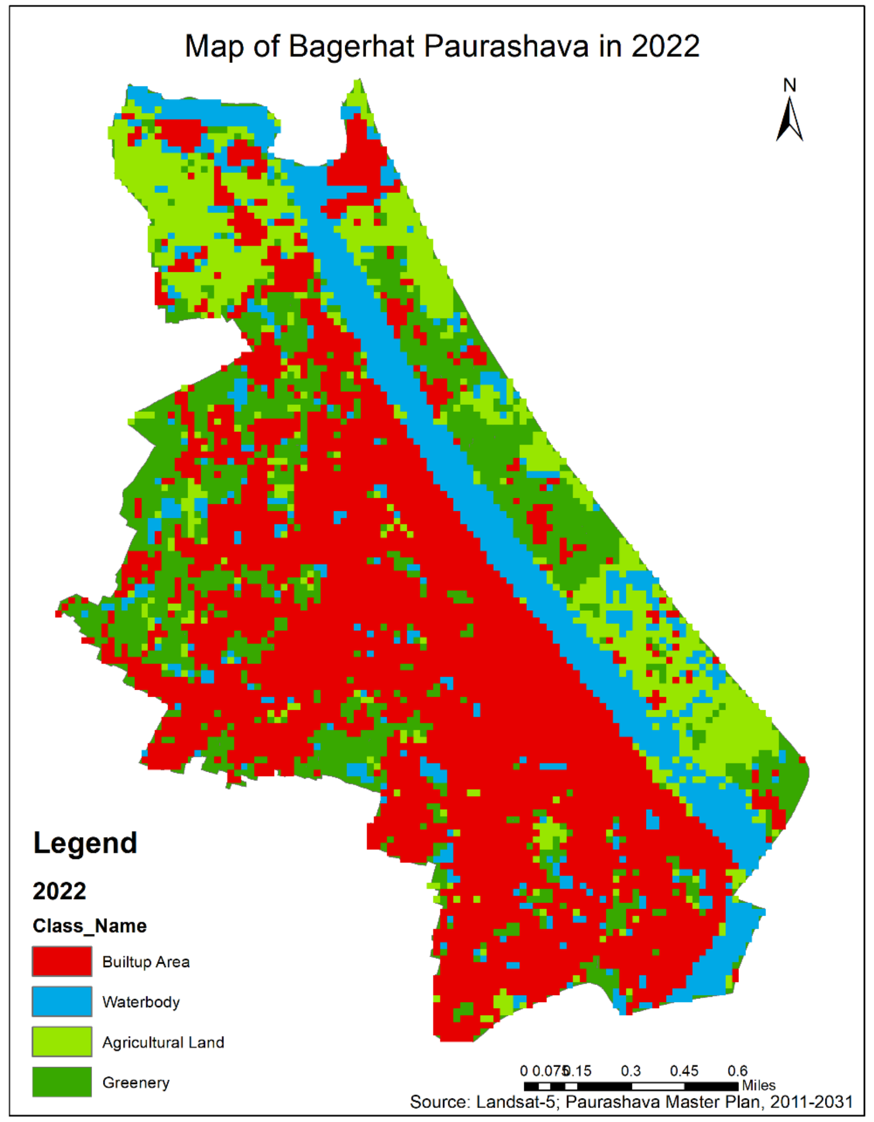
2008

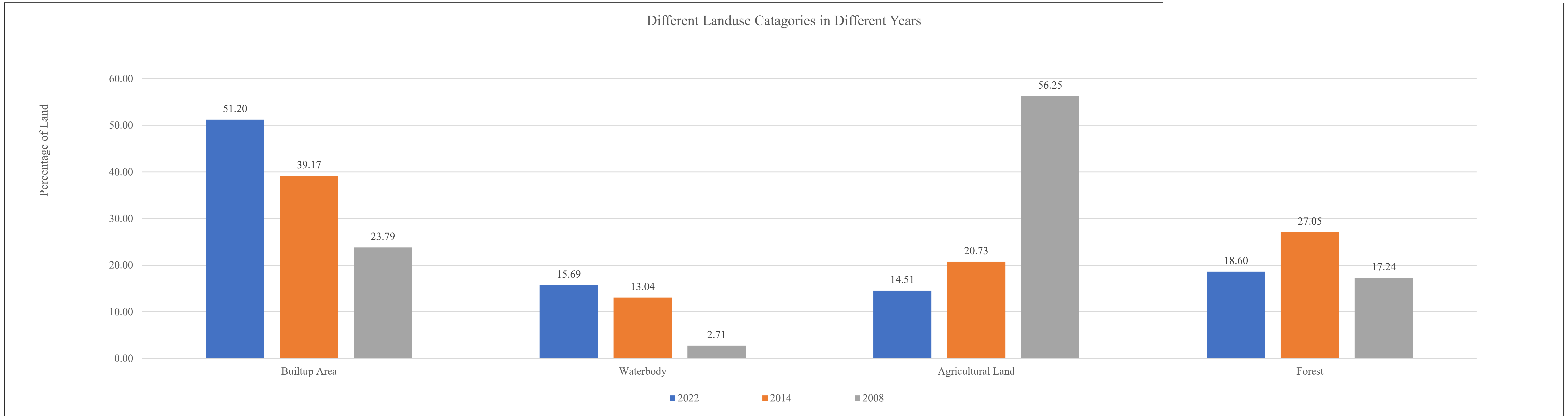


2014



2022





Planform analysis of Chalna using satellite images

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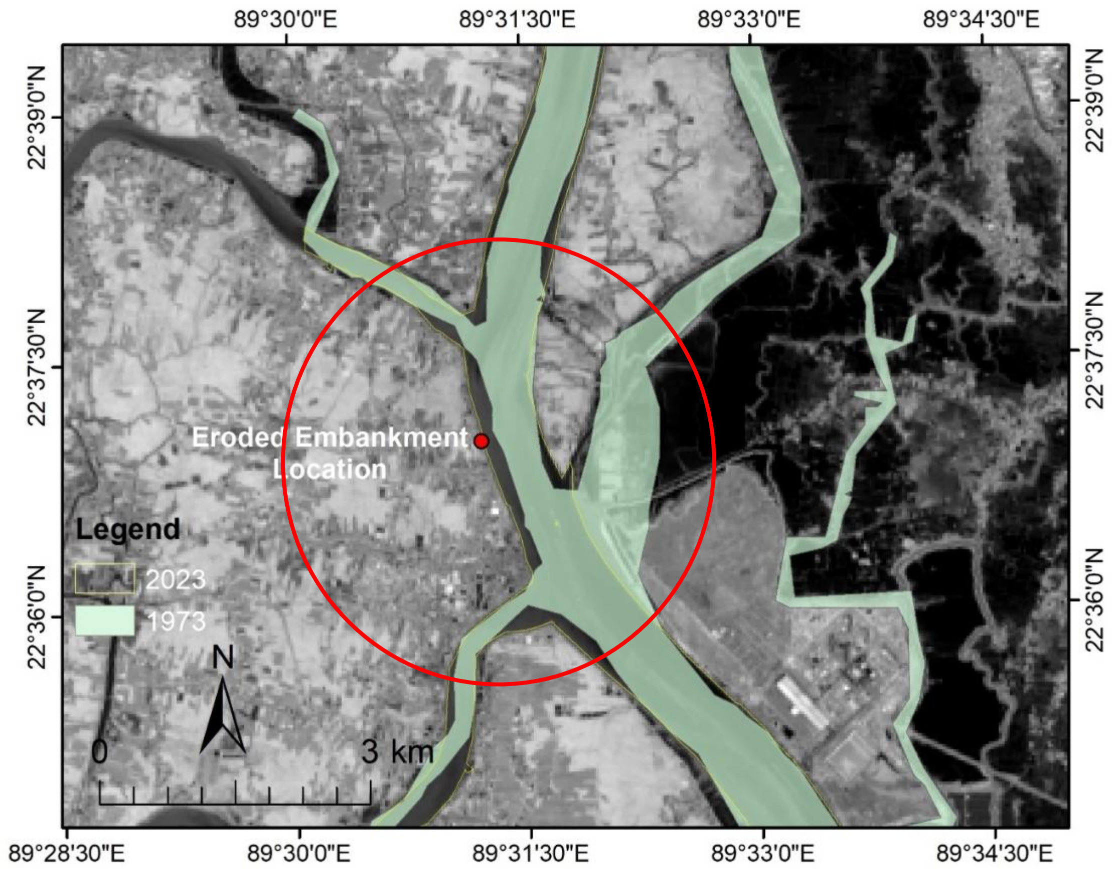
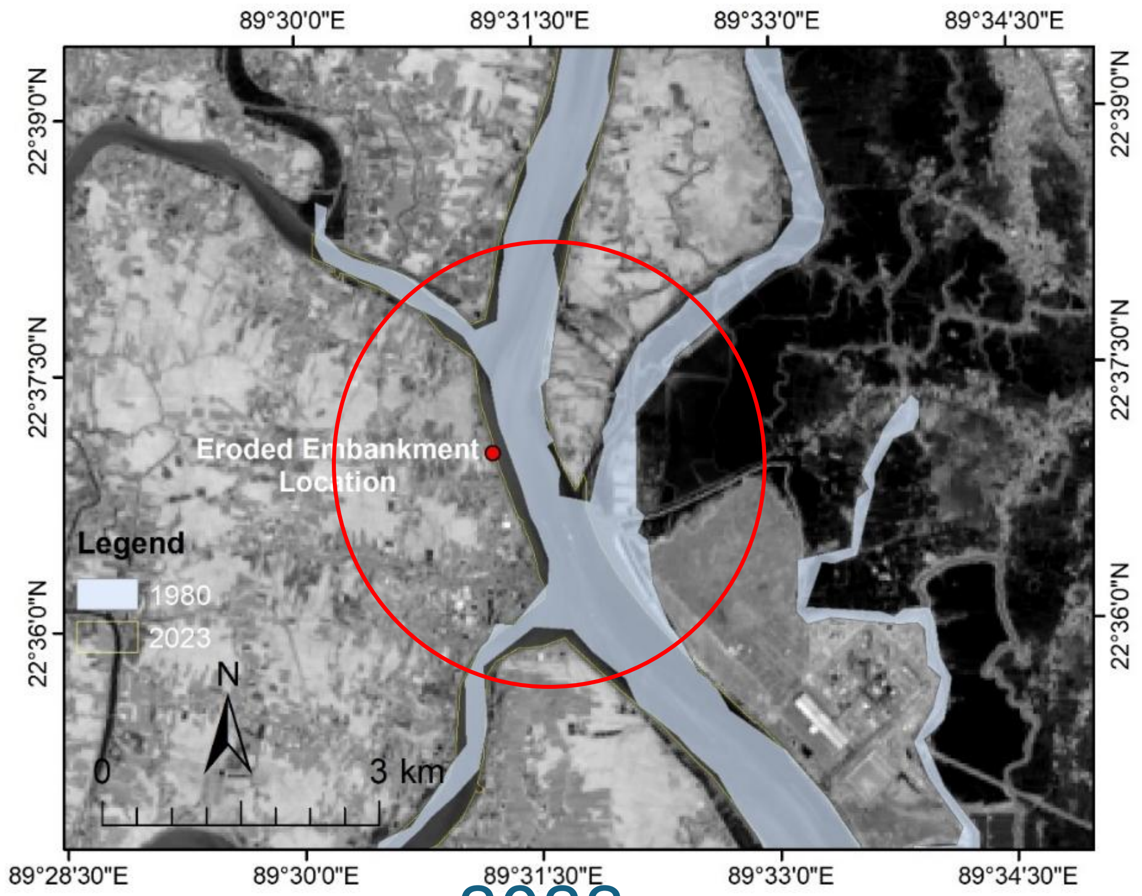
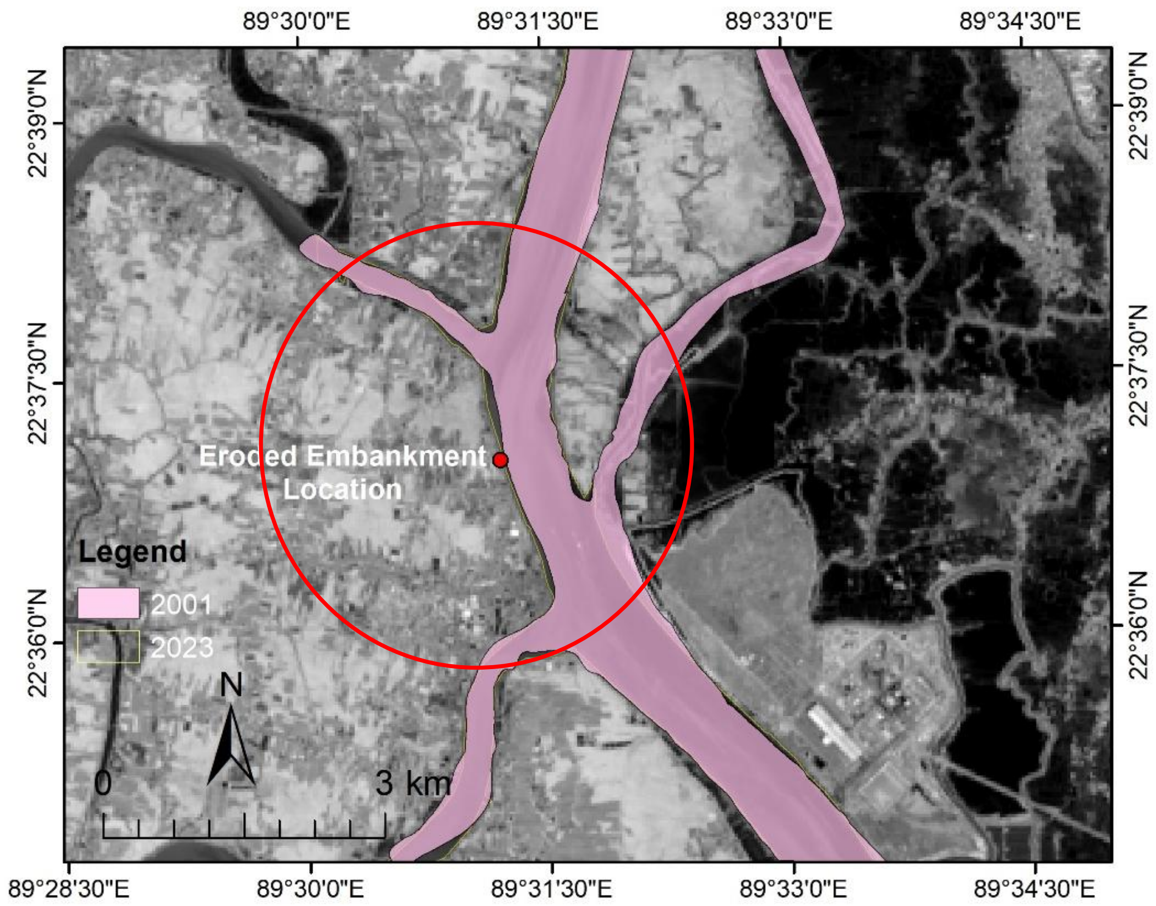
1973



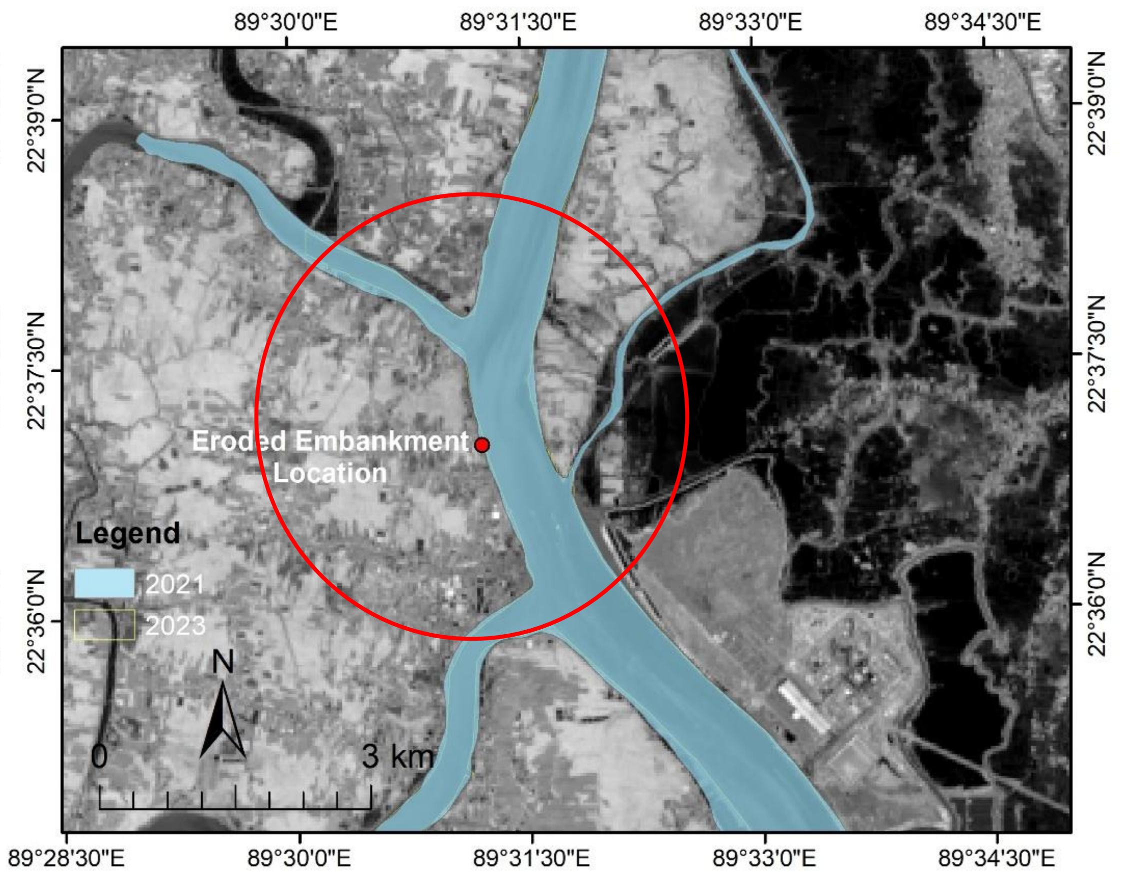
1980

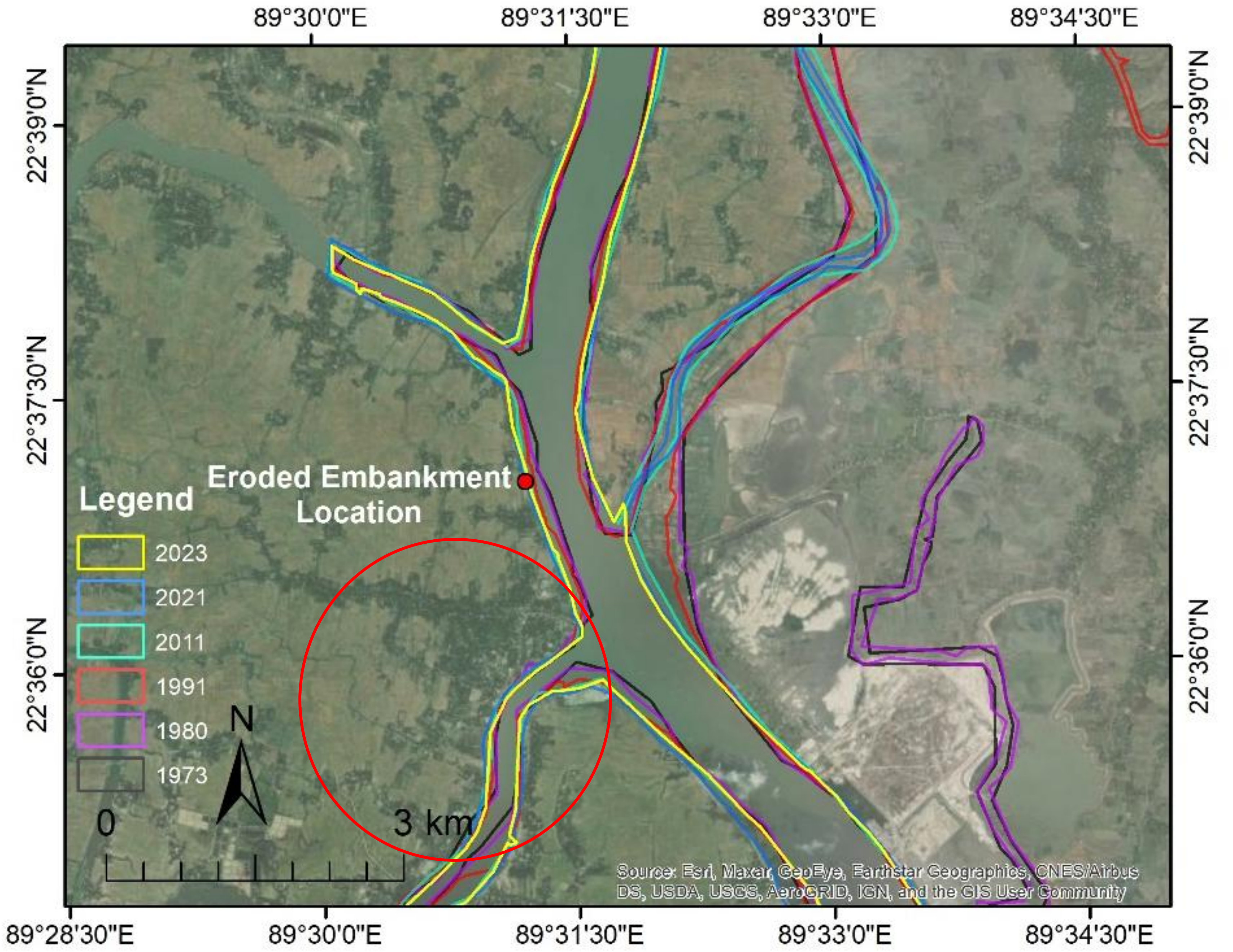


2001



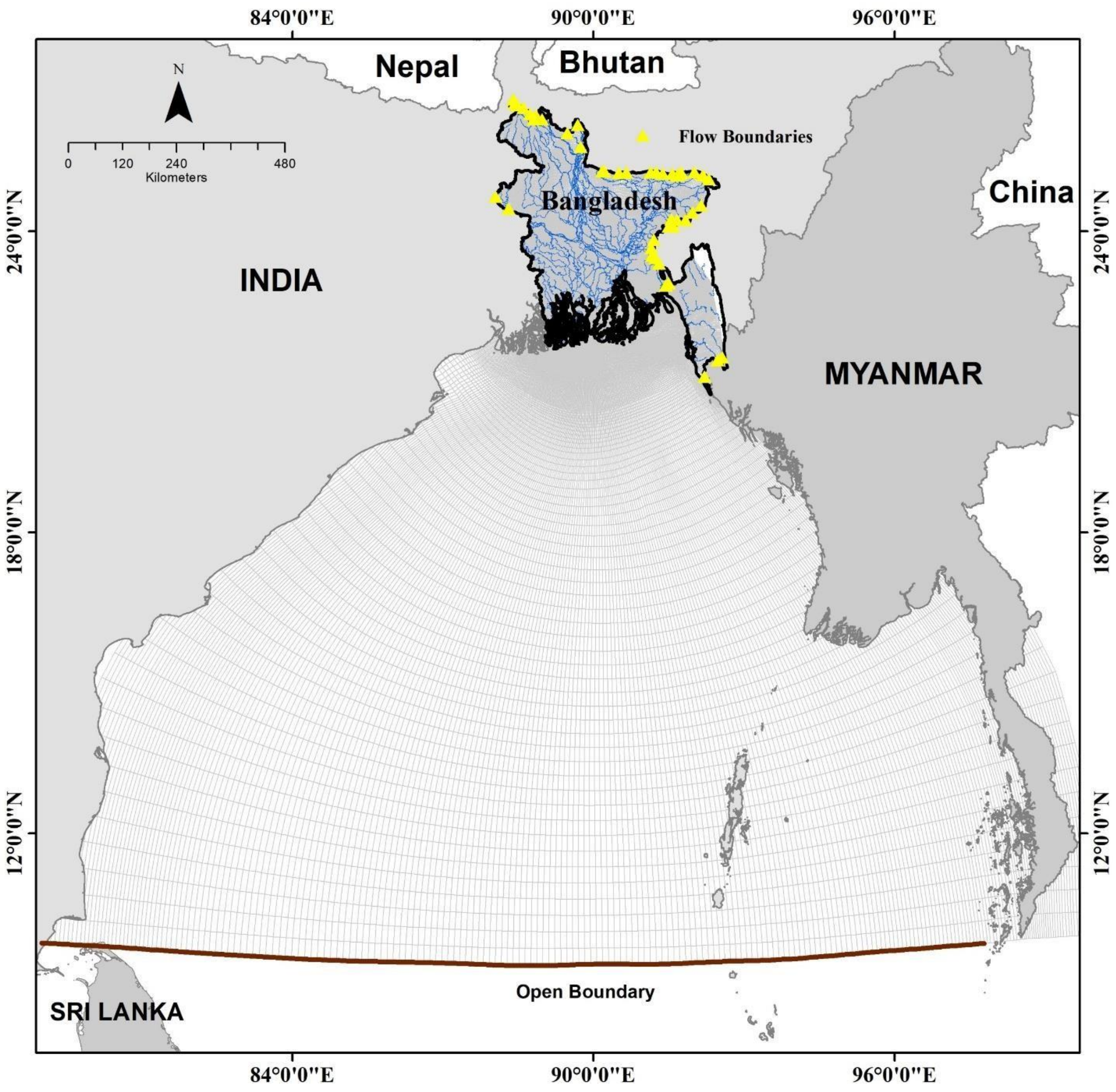
2023



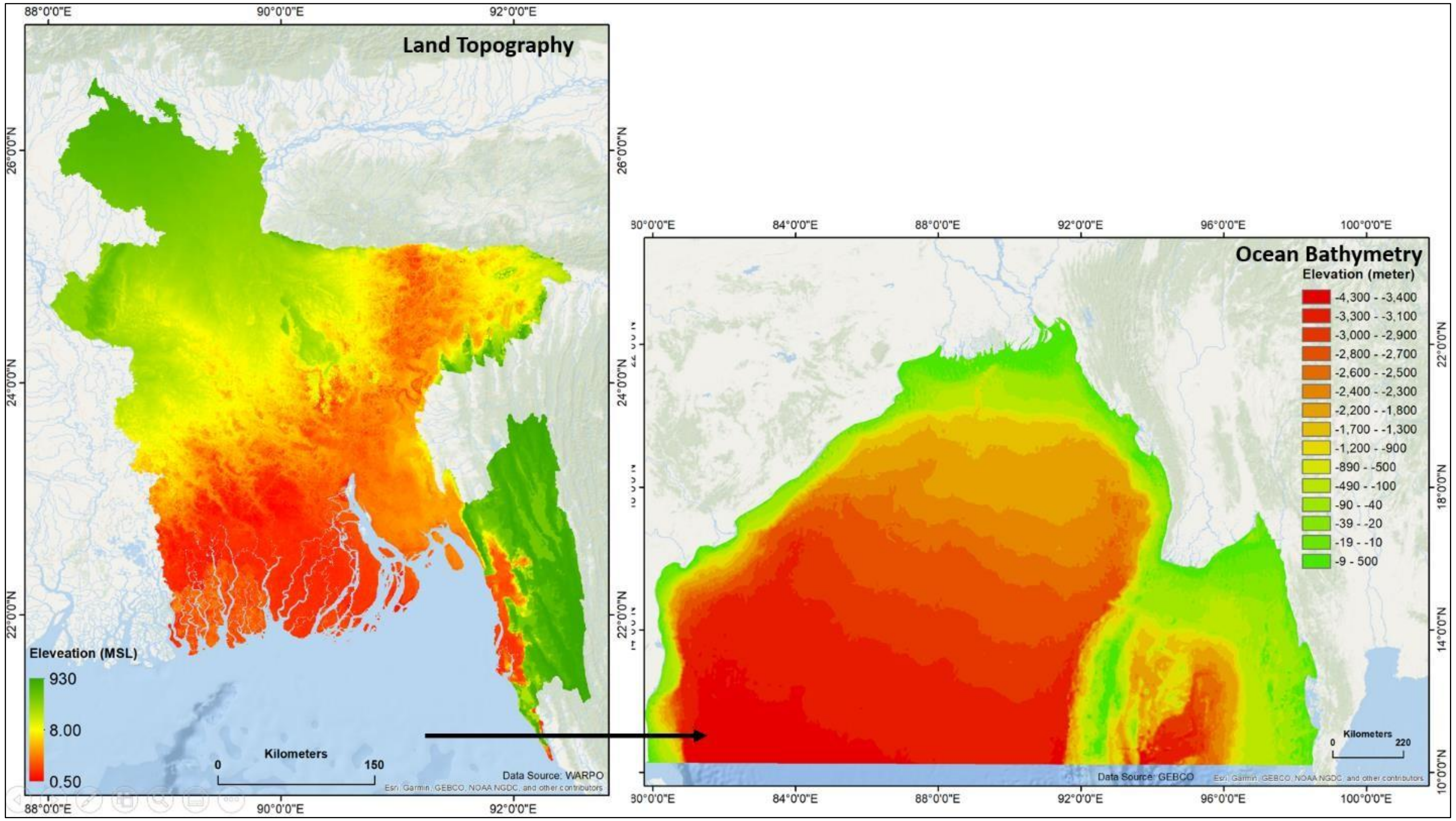


- There is no park or open space in this town.
- There is no solid waste collection system and also no site for waste disposal.
- There is river erosion along the Rupsha river, some part of polder is washed away.

Coastal Modeling using Delft3D

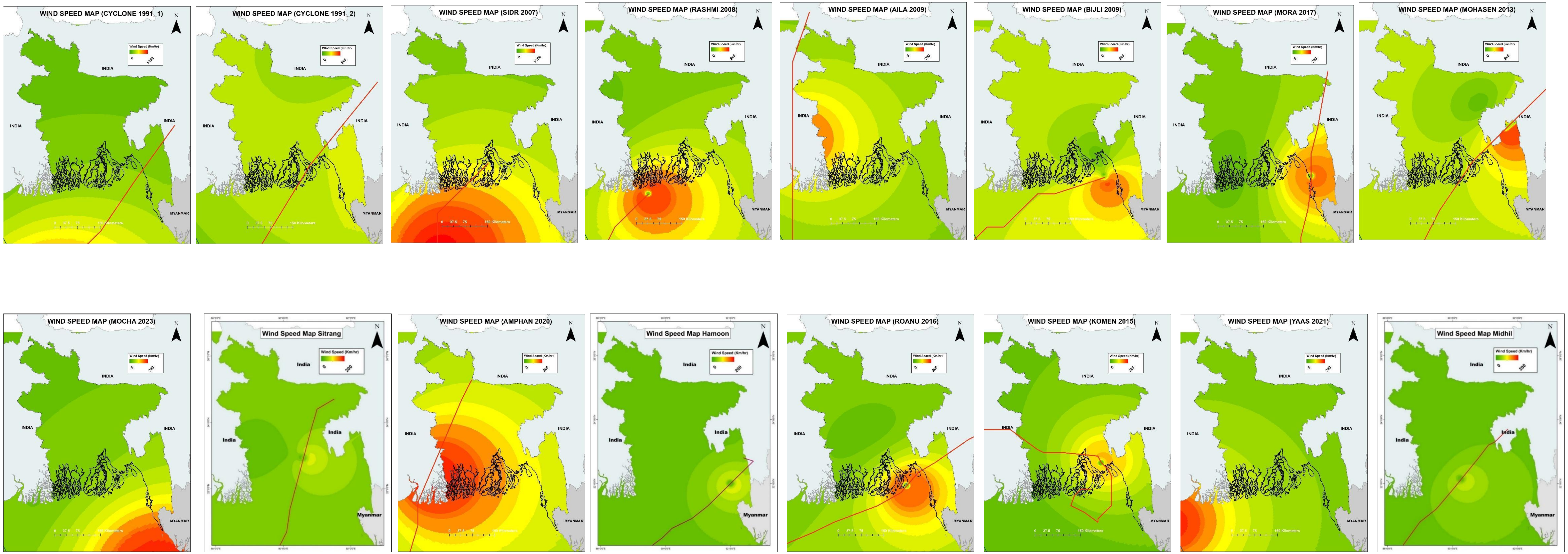


Modeling Domain

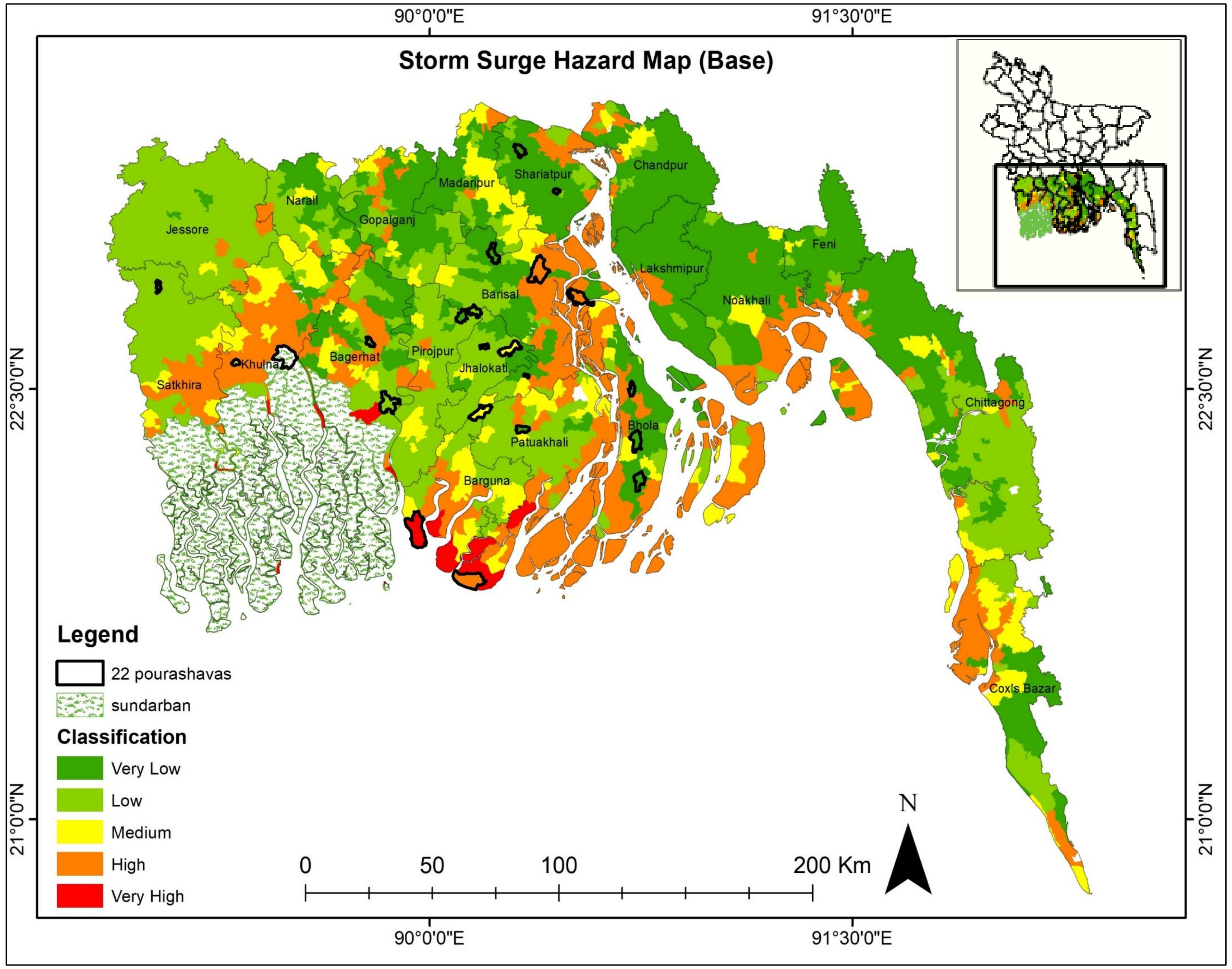


Inland ground topography and ocean bathymetry

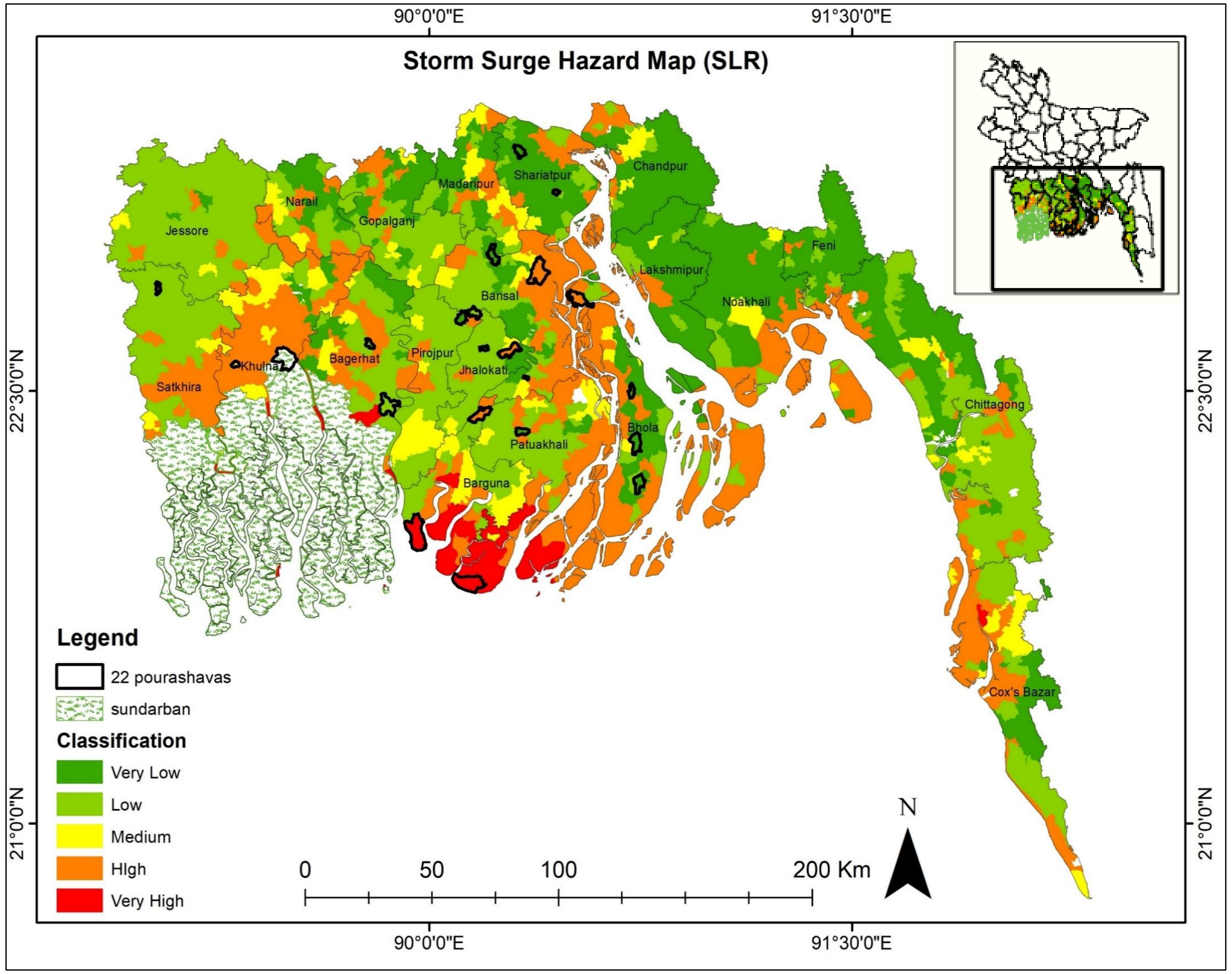
Wind Track for 16 Extreme Events



Storm Surge Hazard Map (Base line & SLR Conditions)



Storm surge Hazard map (Baseline conditions)



Storm surge Hazard map (0.7m SLR conditions)

Changing Hazards for 22 Coastal Towns

Town	Increase in Monsoon Rainfall	Urban Flood and Inundation Risk	Predicted Salinity	Erosion Risk	Warm Spell Increase
Bagerhat	5.00%	High	11-15 ppt	High	+26 days
Bakerganj	5.00%	Low	2-4 ppt	Moderate	+27 days
Banaripara	12.00%	Low	2-4 ppt	Moderate	+23 days
Betagi	3.50%	High	5-10 ppt	Moderate	**+40 days**
Bhederganj	18.00%	Moderate	1-2 ppt	Low	+23 days
Burhanuddin	7.50%	Moderate	5-10 ppt	Low	+25 days
Chalna	10.00%	High	16-20 ppt	High	+25 days
Charfasson	7.00%	Low	11-15 ppt	Low	+35 days
Gauranadi	17.00%	Low	2-4 ppt	Low	+23 days
Jajira	18.00%	Moderate	0-1 ppt	Low	+23 days
Jhalakati	11.00%	Low	2-4 ppt	Moderate	+27 days
Kalaroa	13.00%	Low	16-20 ppt	Low	+26 days
Kuakata	6.00%	High	11-14 ppt	High	+22 days
Lalmohan	7.00%	Moderate	5-10 ppt	Low	+25 days
Mehendiganj	18.00%	Low	4-5 ppt	High	+25 days
Morrelganj	10.00%	High	5-10 ppt	High	+27 days
Muladi	18.00%	Low	2-4 ppt	Moderate	+25 days
Nalchity	15.00%	Low	2-4 ppt	Moderate	+26 days
Paikgachha	10.00%	Moderate	16-20 ppt	Low	+26 days
Patharghata	7.00%	Moderate	16-20 ppt	High	+43 days
Patuakhali	7.00%	Moderate	4-5 ppt	Moderate	+40 days
Swarupkathi	11.00%	Low	1-2 ppt	Low	+28 days

Recommendation for Urban Drainage Management

- **NBS:** There is ample opportunity to go for integrated NBS by improving the existing drainage system and ponds through various nature-friendly actions like excavation, incorporating socially friendly components, and introducing new safe drinking water technology.
- **RAINWATER HARVESTING:** Existing old ponds could be used to conserve rainwater and for safe drinking purposes to save from extinction gradually.
- **CLEANING & MAINTAINANCE:** Regular cleaning and maintenance of such drainage channels may solve the problem to a great extent. The drainage system should be developed based on the study considering the projection scenario of the precipitation due to climate change.
- **SLUICE GATE:** The opening of the sluice gate associated with the polder appears to be inadequate. Such narrow water control structures are unable to function properly.
- **PUMPING STATION:** The filling up of waterbodies will result in additional runoff, requiring more drainage structures, such as pumping stations, to drain out the stormwater runoff.

Thank you