

Introducing the non-stationarity into the development of intensity-duration-frequency curves under a changing climate

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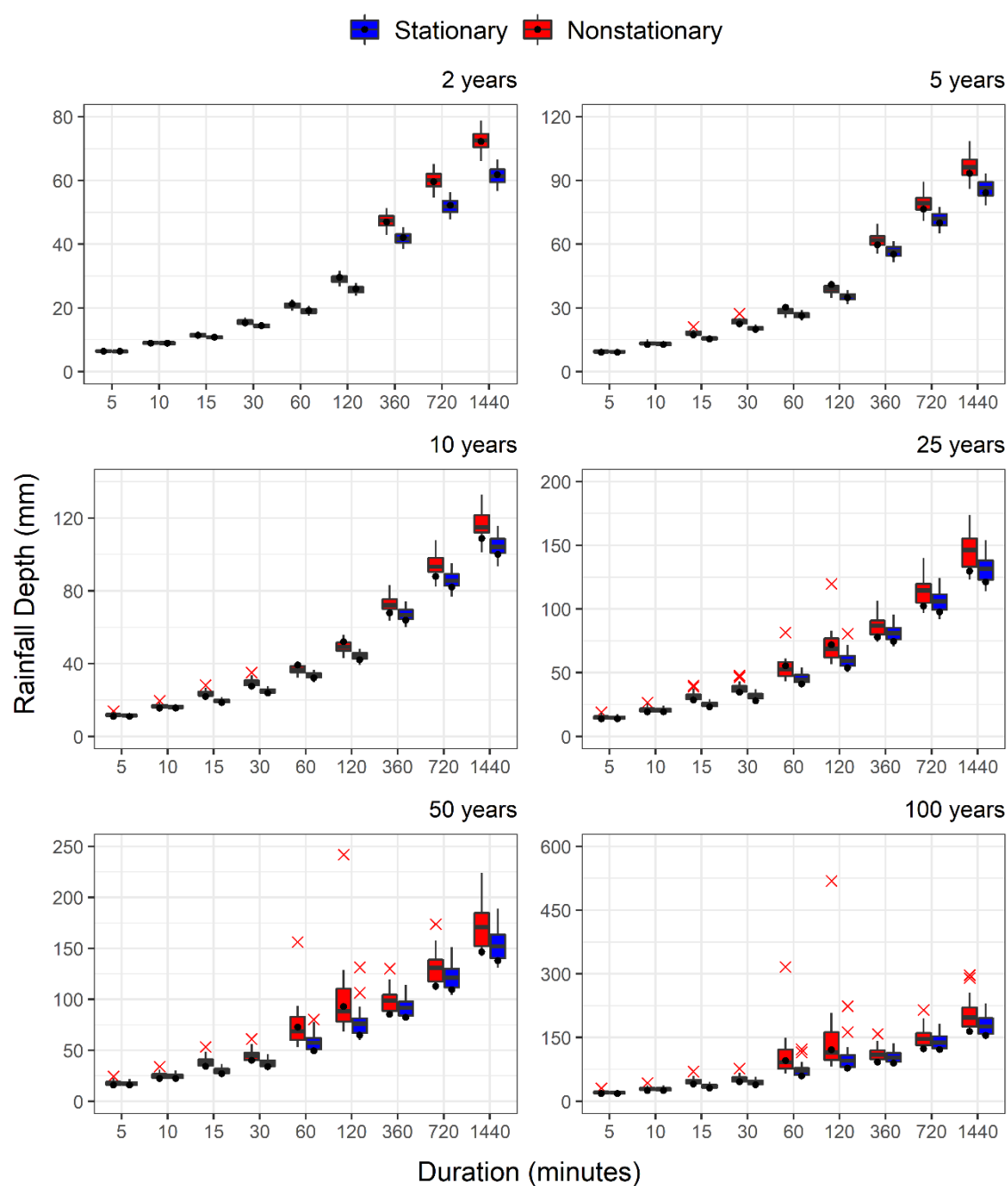


Figure 1. Rainfall depth estimation for different return periods and GCM models for Moncton station (RCP 2.6 emission scenario). Black point represents the rainfall depth estimated with the multimodel median ensemble. Red x represents the models in which results produce outliers.

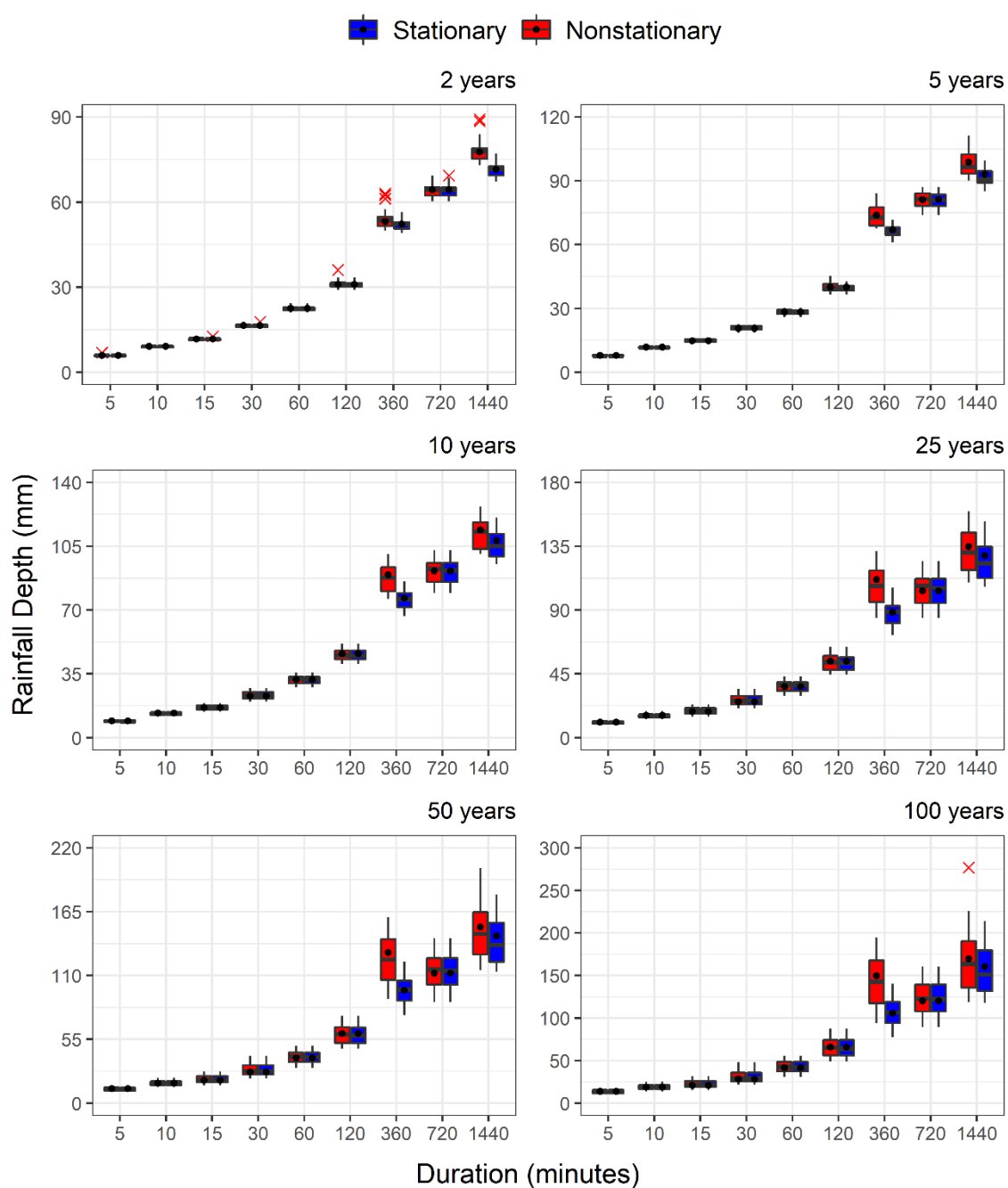


Figure 2. Rainfall depth estimation for different return periods and GCM models for Shearwater station (RCP 2.6 emission scenario). Black point represents the rainfall depth estimated with the multimodel median ensemble. Red x represents the models in which results produce outliers.

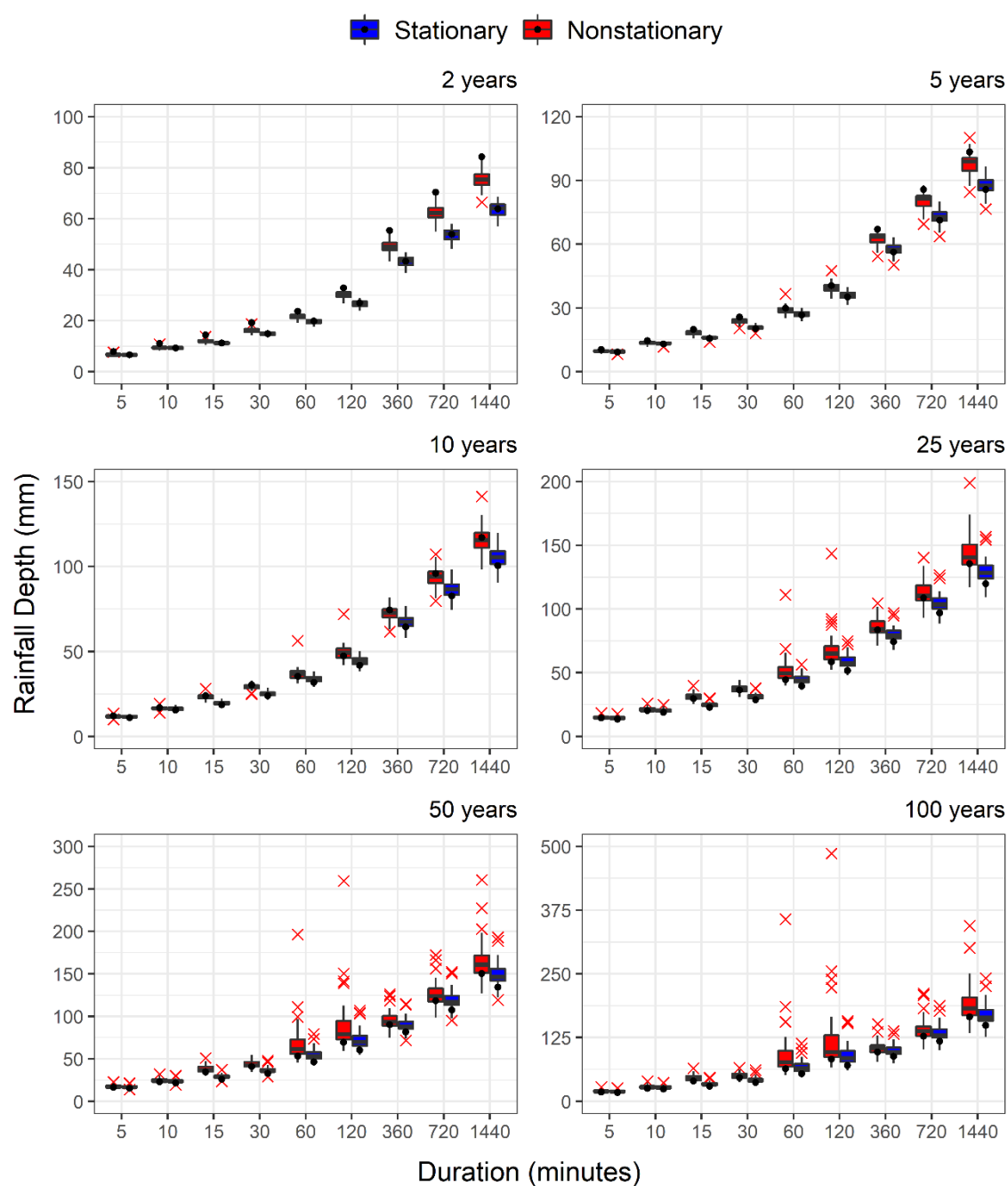


Figure 3. Rainfall depth estimation for different return periods and GCM models for Moncton station (RCP 4.5 emission scenario). Black point represents the rainfall depth estimated with the multimodel median ensemble. Red x represents the models in which results produce outliers.

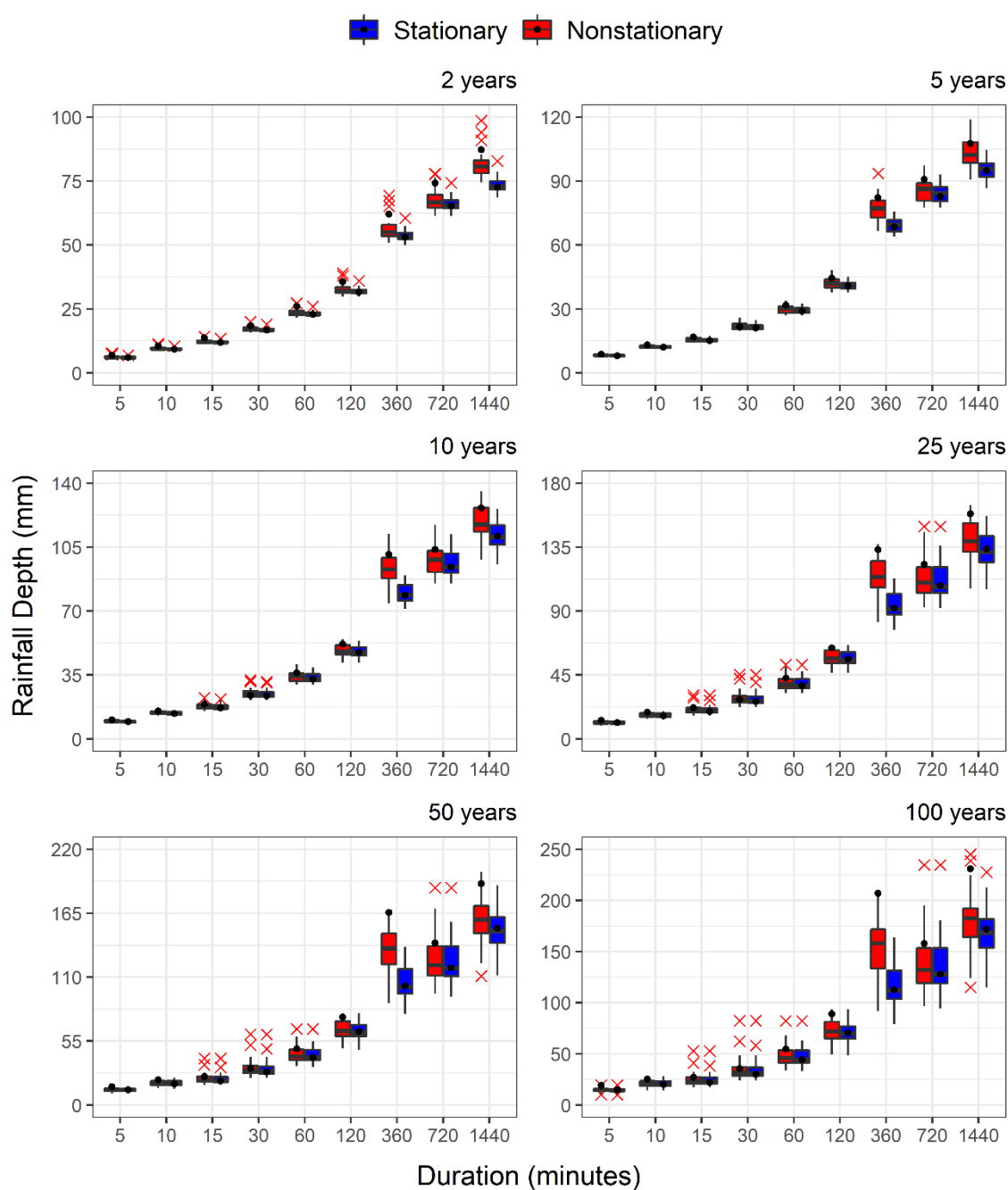


Figure 4. Rainfall depth estimation for different return periods and GCM models for Shearwater station (RCP 4.5 emission scenario). Black point represents the rainfall depth estimated with the multimodel median ensemble. Red x represents the models in which results produce outliers.

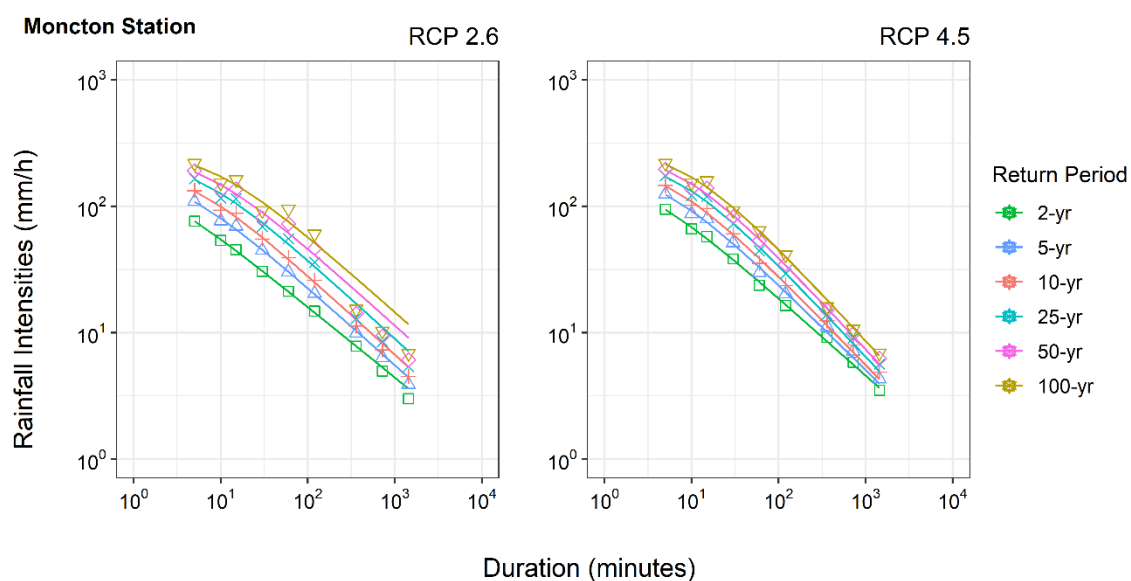


Figure 5. Rainfall intensities, in mm/h, estimated for the multimodel ensemble for the Moncton station.

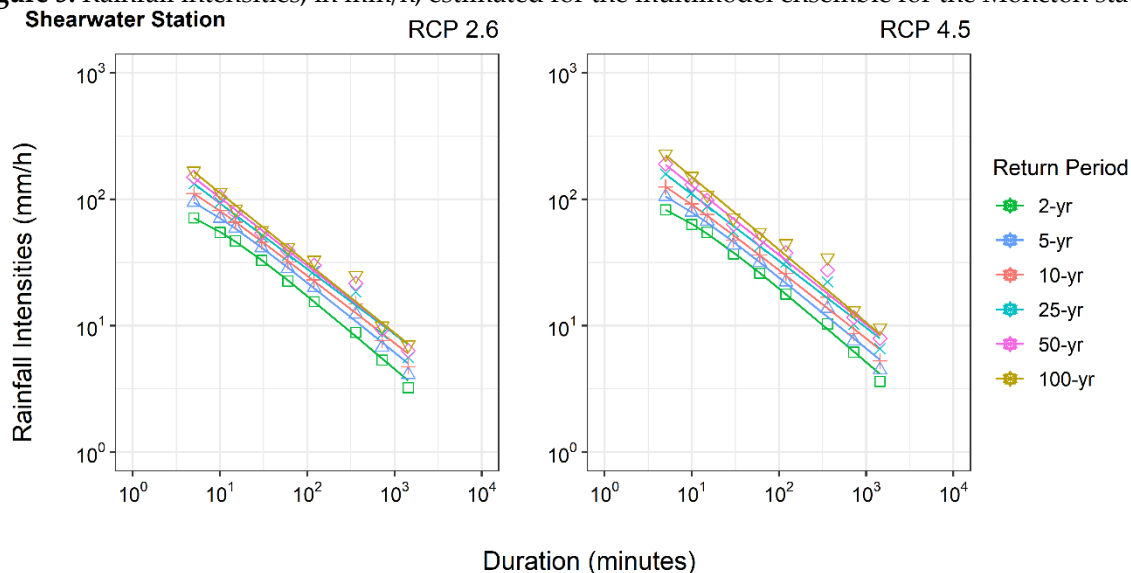


Figure 6. Rainfall intensities, in mm/h, estimated for the multimodel ensemble for the Shearwater station. **Table S1.** GEV model's performance for historical annual maximum rainfall series of different durations of Moncton Station (the statistically significant GEV models are in bold ($p < 0.05$)).

Table 1. GEV model's performance for historical annual maximum rainfall series of different durations of Moncton Station (the statistically significant GEV models are in bold ($p < 0.05$)).

Duration (Minutes)		GEV ID*								
		I	II	III	IV	V	VI	VII	VIII	IX
5	AICc	322.64	324.27	326.56	326.56	324.91	324.91	325.45	327.84	327.83
	Δ_i	0.00	1.63	3.92	3.92	2.27	2.27	2.81	5.20	5.19
10	AICc	366.59	366.78	368.50	368.49	367.40	367.33	368.61	369.44	369.36
	Δ_i	0.00	0.19	1.91	1.90	0.81	0.74	2.02	2.85	2.77
15	AICc	387.21	385.47	386.47	386.41	385.59	385.38	387.80	388.79	388.70
	Δ_i	1.83	0.09	1.09	1.03	0.21	0.00	2.42	3.41	3.32
30	AICc	413.65	412.15	412.37	412.42	411.22	411.23	414.49	414.71	414.72
	Δ_i	2.43	0.93	1.15	1.20	0.00	0.01	3.27	3.49	3.50
60	AICc	439.32	432.93	434.91	434.94	436.11	436.27	435.26	437.33	437.32
	Δ_i	6.39	0.00	1.98	2.01	3.18	3.34	2.33	4.40	4.39
120	AICc	467.67	466.57	468.79	468.81	468.92	469.02	466.18	468.35	468.36
	Δ_i	1.49	0.39	2.61	2.63	2.74	2.84	0.00	2.17	2.18
360	AICc	539.45	537.56	539.63	539.66	541.52	541.52	537.58	539.77	539.78
	Δ_i	1.89	0.00	2.07	2.10	3.96	3.96	0.02	2.21	2.22
720	AICc	576.81	573.27	574.89	574.90	578.89	578.88	574.23	575.91	575.90
	Δ_i	3.54	0.00	1.62	1.63	5.62	5.61	0.96	2.64	2.63
1440	AICc	605.19	597.90	600.14	600.14	607.31	607.29	599.04	601.26	601.25
	Δ_i	7.29	0.00	2.24	2.24	9.41	9.39	1.14	3.36	3.35
$AIC(k) = 2 * nllh(k) + 2k$; $AICc(k) = AIC(k) + \frac{2k(k+1)}{n-k-1}$; $\Delta_i = AICc - \min(AICc)$										
* see Table 2 for the List of GEV models and their parameter combinations.										

Table 2. GEV model's performance for historical annual maximum rainfall series of different durations of Shearwater Station (the statistically significant GEV models are in bold ($p < 0.05$)).

Duration (minutes)		GEV ID*								
		I	II	III	IV	V	VI	VII	VIII	IX
5	AICc	242.55	244.41	244.52	244.90	244.27	244.35	245.48	245.22	245.87
	Δ_i	0.00	1.86	1.97	2.36	1.73	1.80	2.93	2.67	3.32
10	AICc	284.03	286.33	284.10	285.23	283.37	283.86	285.97	283.74	285.47
	Δ_i	0.66	2.95	0.73	1.85	0.00	2.16	2.74	1.37	2.30
15	AICc	306.33	308.60	310.89	310.90	308.50	308.51	306.63	309.01	309.03
	Δ_i	0.00	2.27	4.55	4.56	2.16	2.17	0.30	2.68	2.70
30	AICc	344.34	344.75	347.12	347.12	346.53	346.54	343.79	346.13	346.16
	Δ_i	0.54	0.96	3.32	3.32	2.74	2.74	0.00	2.34	2.36
60	AICc	377.31	378.57	378.18	378.23	378.68	378.60	378.28	377.81	377.99
	Δ_i	0.00	1.25	0.86	0.92	1.37	1.34	0.97	0.50	0.68
120	AICc	424.81	426.39	428.33	428.38	427.11	427.11	425.68	427.70	427.81
	Δ_i	0.00	1.58	3.51	3.57	2.30	2.30	0.87	2.89	3.00
360	AICc	485.60	485.12	485.89	485.91	483.82	483.85	484.51	486.08	486.25
	Δ_i	1.78	1.30	2.08	2.09	0.00	0.03	0.69	2.26	2.43
720	AICc	502.67	501.37	503.53	503.53	503.26	503.21	501.39	503.82	503.82
	Δ_i	1.30	0.00	2.15	2.16	1.89	1.84	0.02	2.45	2.45
1440	AICc	524.65	522.27	524.60	524.61	524.90	525.00	523.99	526.47	526.47
	Δ_i	2.38	0.00	2.34	2.34	2.63	2.73	1.73	4.21	4.21

$$AIC(k) = 2 * nllh(k) + 2k ; \quad AICc(k) = AIC(k) + \frac{2k(k+1)}{n-k-1}; \quad \Delta_i = AICc - \min(AICc)$$

* see Table 2 for the List of GEV models and their parameter combinations.

Table 3. 95th percentiles, in mm, of fitted GEV parameters for different RCP climate projections and multi-model ensemble for Moncton station.

Duration (minutes)	RCP2.6			RCP4.5			RCP8.5		
	$\hat{\mu}_{95}$	$\hat{\sigma}_{95}$	ξ	$\hat{\mu}_{95}$	$\hat{\sigma}_{95}$	ξ	$\hat{\mu}_{95}$	$\hat{\sigma}_{95}$	ξ
5	5.52	2.23	0.089	7.11	2.09	0.062	7.94	3.44	-0.0105
10	7.80	3.08	0.093	9.99	2.88	0.067	11.15	4.77	-0.008
15	9.61	4.57	0.158	12.76	4.32	0.128	14.53	7.35	0.046
30	13.11	5.08	0.090	17.20	5.43	0.062	19.37	8.98	-0.013
60	19.13	5.31	0.426	22.12	4.03	0.318	24.77	7.65	0.198
120	30.00	6.68	0.420	30.87	5.07	0.310	34.28	9.61	0.190
360	42.81	11.52	-0.003	51.53	10.66	-0.039	55.44	16.44	-0.089
720	54.22	14.79	0.009	65.33	13.68	-0.0037	70.65	21.65	-0.062
1440	65.88	17.05	0.096	78.41	15.73	0.079	85.54	26.29	0.002

Table 4. 95th percentiles, in mm, of fitted GEV parameters for different RCP climate projections and multi-model ensemble for Shearwater station.

Duration (minutes)	RCP2.6			RCP4.5			RCP8.5		
	$\hat{\mu}_{95}$	$\hat{\sigma}_{95}$	ξ	$\hat{\mu}_{95}$	$\hat{\sigma}_{95}$	ξ	$\hat{\mu}_{95}$	$\hat{\sigma}_{95}$	ξ
5	5.27	1.62	0.06	6.37	0.14	0.11	7.74	2.22	0.08
10	8.22	2.39	-0.013	9.83	1.85	0.24	11.75	3.04	0.028
15	10.61	3.10	-0.15	12.79	2.45	0.098	15.05	3.29	-0.074
30	14.92	4.39	-0.19	17.48	4.31	0.066	21.10	4.48	-0.097
60	20.56	5.51	-0.08	24.37	4.29	0.17	28.69	6.48	-0.02
120	28.17	7.76	0.026	33.28	5.95	0.28	39.82	10.24	0.06
360	47.00	16.19	0.13	57.22	12.52	0.37	71.07	23.71	0.14
720	58.52	15.96	-0.08	69.49	12.41	0.18	81.97	18.87	-0.018
1440	71.32	17.01	0.095	82.19	12.86	0.35	97.80	24.38	0.12

Table 5. Rainfall intensities, in mm/h, estimated for the multimodel ensemble for the Moncton station.

	Historic period		Future period					
	S	NS	EQM			EQM _{NS}		
			RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
2-year								
5min	71.6	71.6	76.3	78.9	80.8	76.3	94.7	110.4
10min	50.4	50.4	53.7	55.5	56.9	53.7	66.4	77.4
15min	40.7	42.5	43.3	44.8	45.9	45.3	57.5	69.0
30min	27.1	28.8	28.9	29.8	30.6	30.6	38.4	45.3
60min	18.0	19.6	19.2	19.9	20.3	21.2	23.7	27.7
120min	12.2	13.7	13.0	13.5	13.7	14.8	16.4	19.0
360min	6.6	7.3	7.0	7.2	7.4	7.8	9.2	10.2
720min	4.1	4.6	4.4	4.5	4.6	5.0	5.9	6.5
1440min	2.4	2.8	2.6	2.7	2.7	3.0	3.5	4.0
5-year								
5min	102.0	102.0	109.2	111.0	114.9	109.2	124.8	156.7

10min	71.5	71.5	76.6	77.7	80.5	76.6	87.2	109.6
15min	57.3	64.6	61.4	62.2	64.5	69.4	79.6	103.8
30min	37.2	42.0	39.8	40.4	41.9	44.9	38.4	65.4
60min	24.4	25.9	26.2	26.6	27.5	30.3	23.7	38.1
120min	16.2	17.6	17.4	17.6	18.2	20.5	16.4	25.5
360min	8.6	9.3	9.2	9.4	9.7	10.0	9.2	13.1
720min	5.4	6.0	5.8	5.9	6.1	6.4	5.9	8.5
1440min	3.3	3.6	3.5	3.6	3.7	3.9	3.5	5.2
10-year								
5min	123.4	123.4	132.9	133.0	139.0	132.9	145.9	187.1
10min	86.4	86.4	93.1	93.1	97.3	93.1	101.9	130.8
15min	69.3	81.3	74.7	74.6	78.1	87.8	96.1	127.9
30min	44.4	51.2	47.8	47.8	50.0	55.2	60.6	78.5
60min	29.6	31.4	32.1	31.9	33.5	39.2	35.4	46.5
120min	19.5	21.1	21.1	20.9	22.0	26.0	23.7	30.6
360min	9.9	10.6	10.6	10.7	11.2	11.3	12.4	14.8
720min	6.4	6.8	6.8	6.9	7.2	7.3	8.0	9.7
1440min	3.9	4.2	4.2	4.2	4.4	4.5	4.9	6.0
25-year								
5min	152.1	152.1	165.2	161.9	171.3	165.2	174.1	225.2
10min	106.4	106.4	115.7	113.3	119.9	115.7	121.6	157.4
15min	85.7	105.0	93.4	91.2	96.8	114.5	119.3	159.5
30min	54.2	63.5	58.9	57.7	61.1	69.2	72.8	95.0
60min	37.6	40.5	41.2	39.7	42.9	55.4	44.5	58.9
120min	24.5	26.7	27.0	25.9	28.0	36.0	29.3	38.3
360min	11.6	12.1	12.4	12.4	13.0	13.0	13.9	16.9
720min	7.6	7.9	8.1	8.1	8.5	8.5	9.1	11.1
1440min	4.7	5.0	5.0	5.0	5.3	5.4	5.7	7.1
50-year								
5min	174.5	174.5	191.0	184.1	196.8	191.0	196.1	253.2
10min	122.0	122.0	133.8	128.9	137.7	133.8	137.1	177.0
15min	98.9	124.9	108.6	104.2	111.9	137.0	138.5	183.9
30min	61.9	73.1	67.8	65.4	69.9	80.4	82.4	107.0
60min	44.7	49.2	49.6	46.4	51.3	72.5	53.3	69.8
120min	29.1	32.0	32.4	30.2	33.4	46.5	34.7	45.0
360min	12.8	13.3	13.7	13.6	14.3	14.2	15.0	18.3
720min	8.5	8.8	9.1	9.0	9.5	9.4	9.9	12.1
1440min	5.3	5.6	5.7	5.6	5.9	6.1	6.3	7.9
100-year								
5min	197.8	197.8	218.2	206.8	223.3	218.2	218.9	280.8
10min	138.3	138.3	153.0	144.8	156.4	153.0	153.1	196.3
15min	112.9	146.6	125.1	117.8	128.0	162.0	159.3	208.9
30min	70.0	83.0	77.4	73.3	79.3	92.3	92.2	118.8
60min	52.9	60.0	59.3	54.0	61.3	95.3	64.2	82.2
120min	34.4	38.5	38.8	35.1	39.9	60.4	41.3	52.5
360min	14.0	14.4	15.0	14.7	15.6	15.4	16.1	19.6
720min	9.4	9.6	10.1	9.8	10.5	10.5	10.6	13.1
1440min	5.9	6.3	6.5	6.2	6.7	6.9	6.9	8.6
Note: S – stationary; NS - nonstationary								

Table 6. Rainfall intensities, in mm/h, estimated for the multimodel ensemble for the Shearwater station.

	Historic period		Future period					
	S	NS	EQM			EQM _{NS}		
			RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
2-year								
5min	66.2	66.2	71.2	72.3	75.3	71.2	82.3	102.8
10min	50.8	50.8	54.6	55.5	57.8	54.6	63.2	77.2
15min	43.5	43.5	46.9	47.7	49.7	46.9	54.8	65.0
30min	30.6	30.6	32.9	33.5	34.9	32.9	36.9	45.4
60min	21.0	21.0	22.6	22.9	23.9	22.6	26.0	31.1
120min	14.4	14.4	15.5	15.8	16.4	15.5	17.8	21.8
360min	8.1	8.2	8.7	8.9	9.2	8.8	10.4	13.3
720min	5.0	5.0	5.4	5.4	5.7	5.4	6.2	7.4
1440min	2.8	3.0	3.0	3.0	3.2	3.2	3.6	7.5
5-year								
5min	87.5	87.5	94.5	96.3	101.9	94.5	105.1	135.5
10min	65.5	65.5	70.7	72.1	76.2	70.7	79.0	98.4
15min	54.8	54.8	59.1	60.4	63.8	59.1	67.0	78.9
30min	38.3	38.3	41.2	42.2	44.6	41.2	43.2	54.7
60min	26.3	26.3	28.3	29.0	30.6	28.3	31.7	38.3
120min	18.5	18.5	20.0	20.4	21.6	20.0	22.2	27.9
360min	10.3	11.4	11.2	11.4	12.0	12.3	13.7	18.4
720min	6.3	6.3	6.8	6.9	7.3	6.8	7.6	9.2
1440min	3.6	3.8	3.9	4.0	4.2	4.1	4.5	5.7
10-year								
5min	102.6	102.6	110.9	113.9	121.3	110.9	125.1	158.8
10min	75.2	75.2	81.2	83.5	88.8	81.2	92.1	112.8
15min	61.4	61.4	66.0	68.1	72.4	66.0	75.9	87.5
30min	42.7	42.7	45.8	47.3	50.3	45.8	47.7	60.3
60min	29.6	29.6	31.9	32.8	34.9	31.9	36.2	43.0
120min	21.4	21.4	23.1	23.7	25.2	23.1	26.0	32.2
360min	11.8	13.8	12.8	13.1	14.0	14.9	16.8	22.3
720min	7.1	7.1	7.6	7.8	8.3	7.6	8.7	10.3
1440min	4.2	4.4	4.5	4.6	4.9	4.8	5.3	6.7
25-year								
5min	122.8	122.8	132.6	138.2	148.3	132.6	158.1	190.6
10min	87.6	87.6	94.3	98.2	105.3	94.3	112.2	131.4
15min	68.9	68.9	73.8	77.0	82.4	73.8	88.0	97.7
30min	47.5	47.5	50.7	53.0	56.7	50.7	55.6	66.8
60min	33.6	33.6	36.1	37.6	40.3	36.1	42.7	48.8
120min	25.1	25.1	27.0	28.2	30.2	27.0	32.0	38.0
360min	13.7	17.1	14.7	15.4	16.5	18.6	22.2	27.8
720min	8.0	8.0	8.6	9.0	9.6	8.6	10.2	11.7
1440min	5.0	5.2	5.3	5.6	6.0	5.6	6.6	8.0
50-year								
5min	138.7	138.7	149.5	157.9	170.1	149.5	189.6	215.8
10min	96.7	96.7	104.0	109.4	117.9	104.0	130.4	145.6
15min	74.0	74.0	78.8	83.0	89.3	78.8	97.8	104.8

[illegible]