

Past and Long-term Projections of Precipitation, Drought Events and Extreme Temperature Using a Statistical Downscaling Model (SDSM) Approach in the Republic of Djibouti

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Abstract:

This study examines the improvement in Coupled Model Intercomparison Project Phase five and six (CMIP5 & CMIP6) models against the regional model (CORDEX) in simulating mean and extreme precipitation over the republic of Djibouti.

Key words: CMIP5, CMIP6, CORDEX, precipitation, statistical downscaling, Djibouti.

1. Introduction

2. Study area and data sources

2.1. Description of the study Area

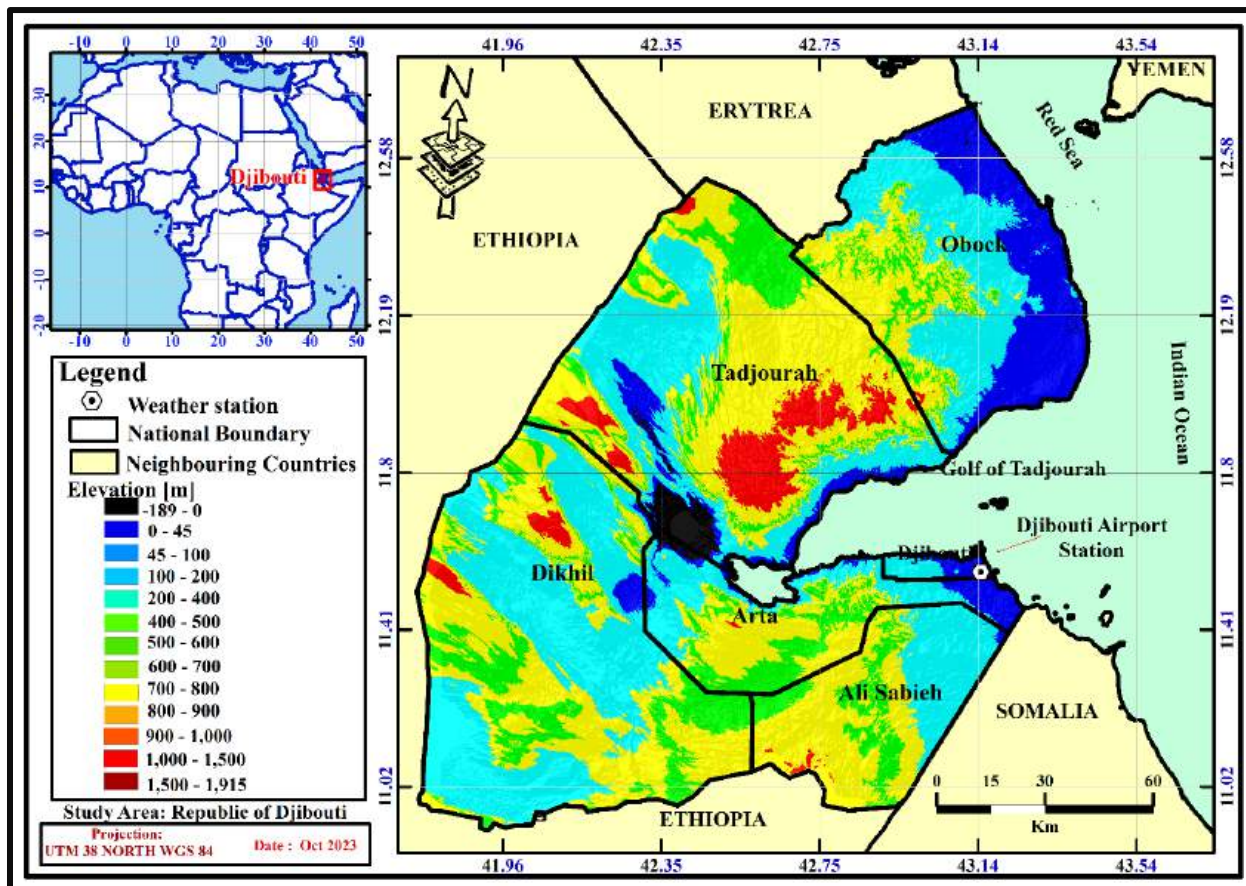


Figure 1. SRTM-NASA digital elevation model (DEM) with a 30-meter spatial resolution. The regular hexagon point on the map indicates the location of the weather station at Djibouti airport.

2.2. Methodology

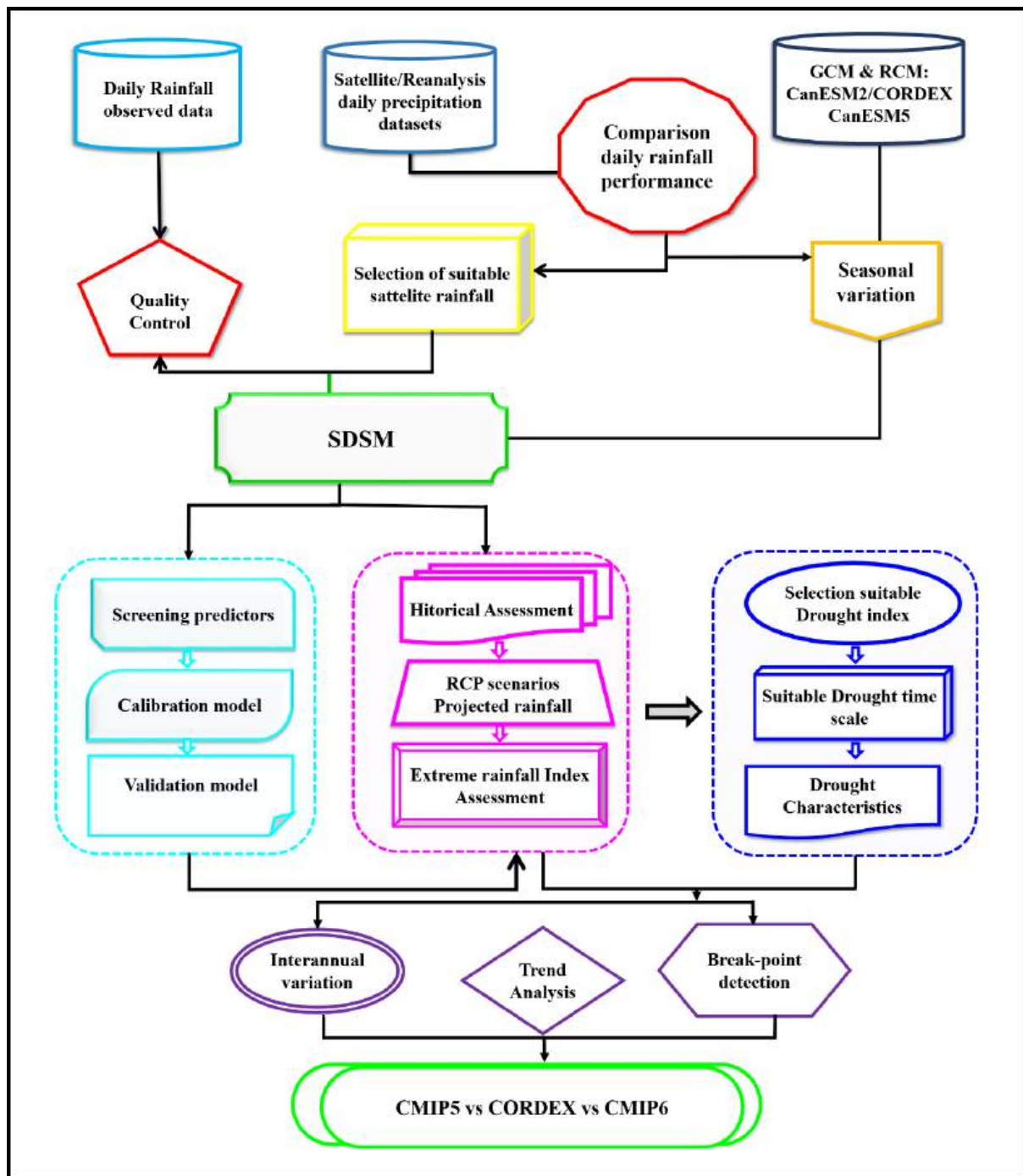


Figure 2. Flowchart of the research methodology.

3. Results and Discussions

3.1. Validation of daily precipitation from multi-satellite high resolution datasets

Table 1. Comparison of quantitative and categorical statistical measurements between very high multi-satellite daily precipitation products against in situ meteorological observation station at Djibouti airport from 1980 to 2021.

QUANTITATIVE	CC	NSE	RMSE	RSR	BIAIS	PBIAIS	MAE
CHIRPSv.2	0.243	0.049	4.506	0.975	0.133	0.321	0.561
GSMaPRTv.6	0.162	-1.186	5.647	1.478	-0.138	-0.471	0.624
IMERGFR	0.306	-0.476	4.6	1.215	-0.224	-0.717	0.627
IMERGLR	0.349	-1.349	5.803	1.533	-0.436	-1.397	0.779
TRMM3B42	-0.002	-0.191	4.687	1.091	0.009	0.027	0.646
ERA5	0.448	0.116	4.295	0.94	-0.431	-1.067	0.927
MSWEP2.8	0.415	0.111	4.32	0.943	-0.506	-1.25	0.979
ERA5LAND	0.457	0.169	4.164	0.912	-0.428	-1.059	0.926
ERA5AG	0.416	0.045	4.463	0.977	-0.402	-0.994	0.906
CATEGORICAL	POD	FAR	CSI	HSS	FBI	ACC	ERR
CHIRPSv.2	0.103	0.842	0.067	0.066	0.655	0.885	0.115
GSMaPRTv.6	0.542	0.552	0.325	0.451	1.208	0.926	0.074
IMERGFR	0.545	0.538	0.333	0.465	1.182	0.934	0.066
IMERGLR	0.5	0.542	0.314	0.443	1.091	0.934	0.066
TRMM3B42	0.138	0.879	0.069	0.049	1.138	0.852	0.148
ERA5	0.923	0.942	0.058	0.046	15.846	0.466	0.534
MSWEP2.8	0.923	0.944	0.056	0.042	16.385	0.447	0.553
ERA5LAND	0.923	0.944	0.056	0.042	16.385	0.447	0.553
ERA5AG	1	0.934	0.066	0.061	15.154	0.496	0.504

* The grey background and bold value are the highest score of quantitative and categorical statistical measures.

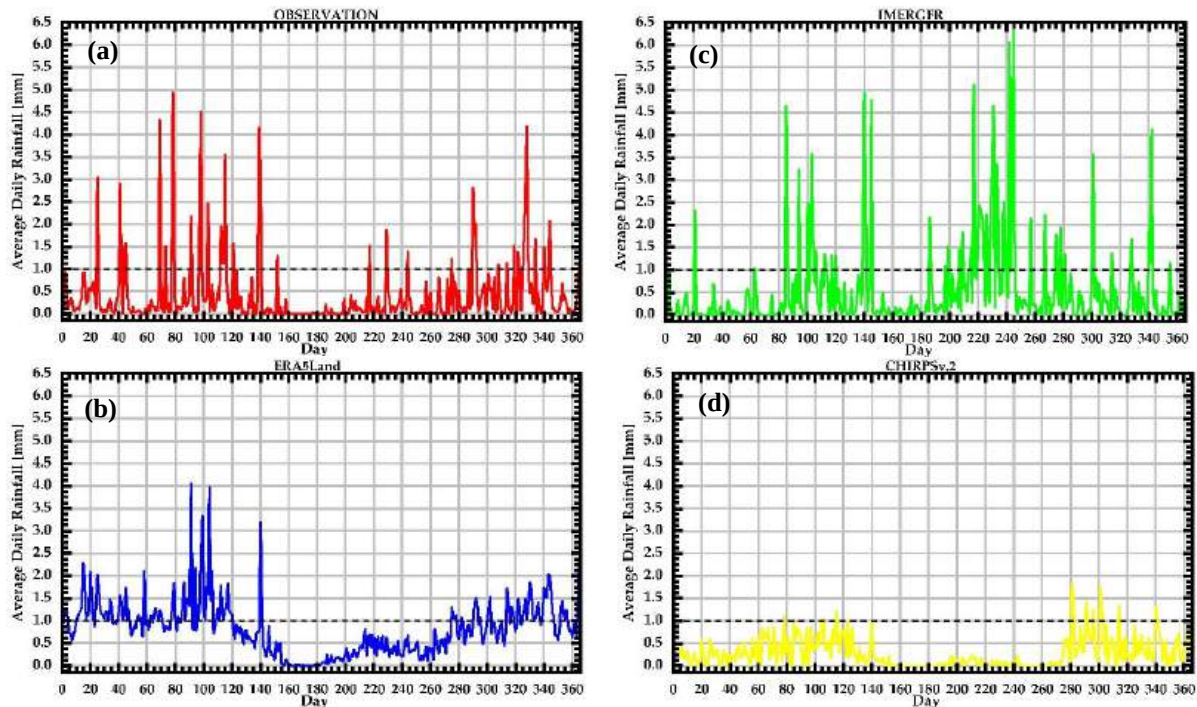


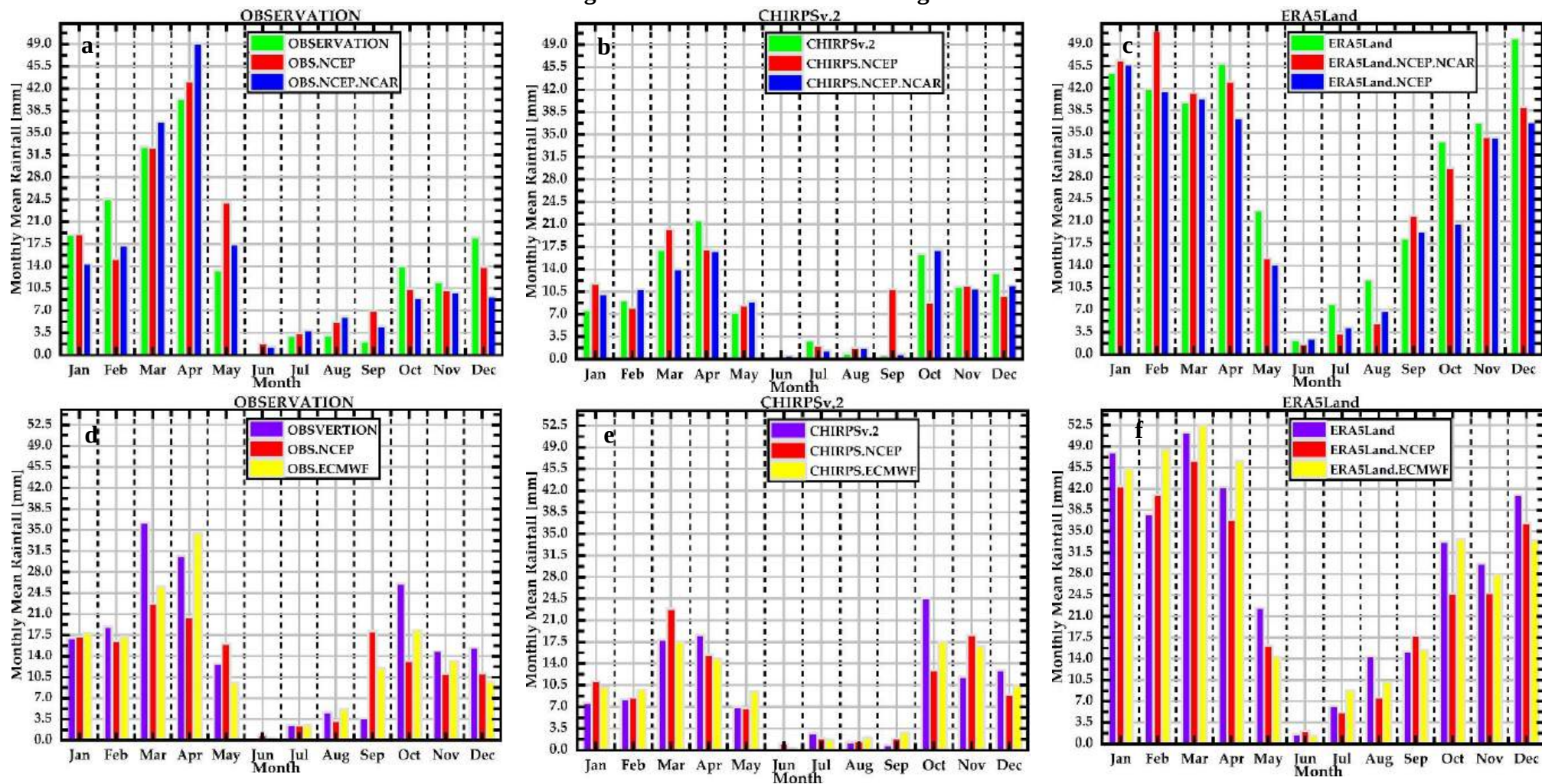
Figure 3. Average daily precipitation for each Julian day calculated over the full record available at each station in situ observation at Djibouti Airport from 1980 to 2021. The minimum for wet day is 1 mm. (left panels (a-b): observed and ERA5Land data; right panels (c-d): IMERGFR and CHIRPS data.

82 **3.2.Screening, calibration and validation of Statistical downscaling for precipitation using SDSM**

83 **Table 2.** Final selection in screening NCEP_NCAR and NCEP predictors using conditional partial correlation for daily rainfall observed in situ at
84 Djibouti airport meteorological station, CHIRPS and ERA5 satellite products from CMIP5 (1961-2005) and CMIP6 (1979-2014).

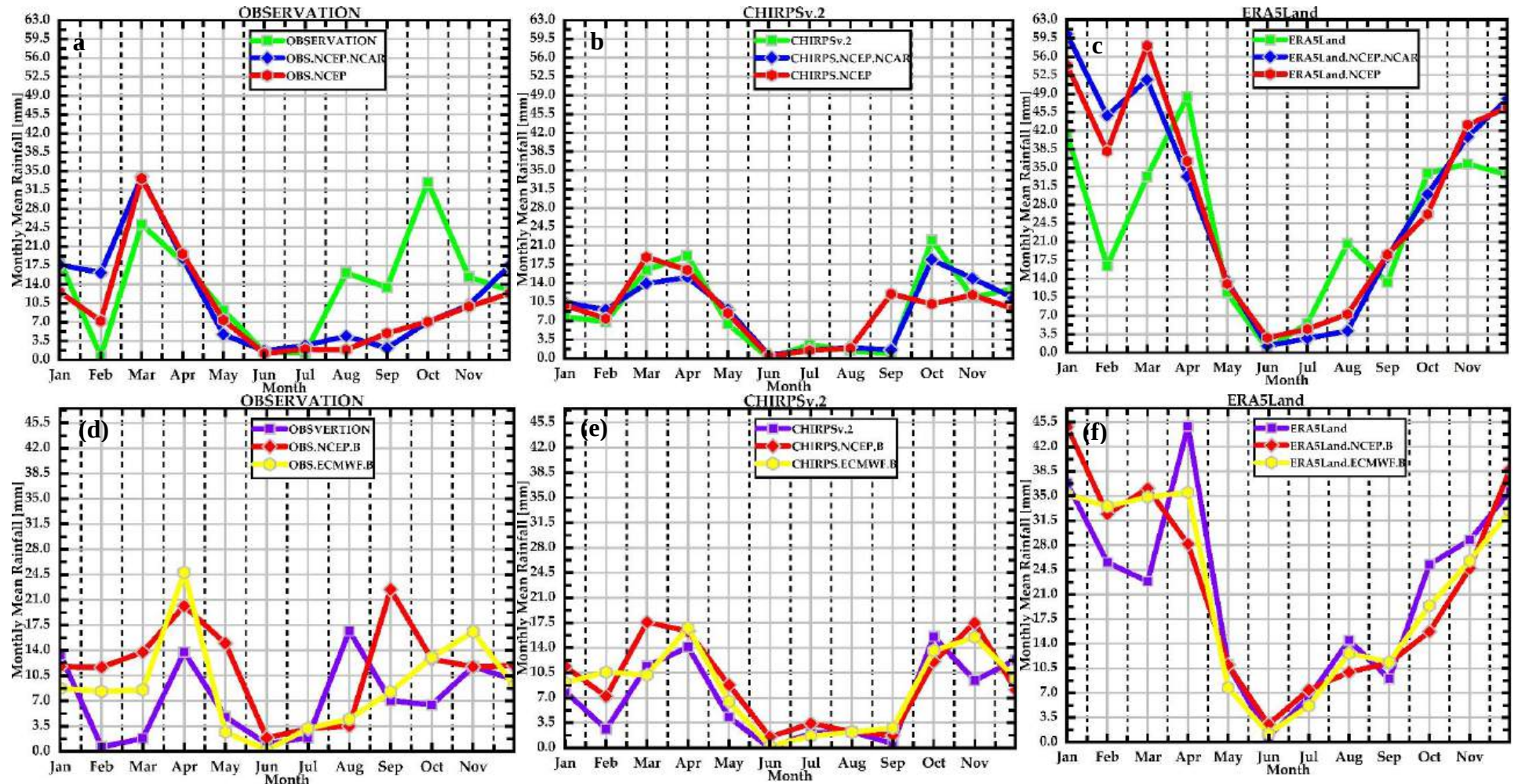
NCEP NCAR	OBS	CHIRPS v.2	ERA5 LAND	NCEP	OBS		CHIRPS v.2		ERA5 LAND		ECMWF ERA5	OBS	CHIRPS v.2	ERA5 LAND
	CMIP 5	CMIP 5	CMIP 5		CMIP 5	CMIP 6	CMIP 5	CMIP 6	CMIP 5	CMIP 6		CMIP 6	CMIP 6	CMIP 6
p1_v	✓			p5_f	✓				✓	✓	p1_f	✓		
p500	✓		✓	p8_u	✓						p1zh	✓		✓
p8_u	✓		✓	p500	✓	✓				✓	prcp	✓	✓	✓
p8zh	✓			prec	✓	✓				✓	p1_z		✓	✓
Prcp	✓		✓	p5_v			✓	✓		✓	p8_u		✓	
p1_f		✓		p8_f			✓				s500		✓	✓
p1_u		✓		r850			✓		✓		p1_u			
p5_v		✓	✓	lftx					✓		p1_v			✓
p5_f			✓	mslp					✓		p8_v			
p5_u			✓	p5_u				✓	✓	✓	p850			
p5th				p5zh					✓		shum			
p8_f			✓	p8zh					✓		temp			✓
p850				p850						✓	p5_f			✓
Shum			✓	rhum							p5_u			✓
p8th			✓	p1_f				✓						
temp			✓	p1_u				✓		✓				
				s500						✓				
				shum				✓		✓				
				temp						✓				
				p5_z						✓				
				s850						✓				

86 3.2.1. Calibration model for statistical downscaling from CMIP5 and CMIP6 using SDSM



87 **Figure 4.** Calibration model results of SDSM at location of Djibouti Airport weather station using NCEP-NCAR, NCEP and ECMWF-ERA5
88 predictors from CMIP5 (up panels (a), (b), (c)) and CMIP6 (down panels (d), (e), (f)) for Observation, CHIRPS and ERA5Land daily precipitation
89 during 1961 to 1995 and 1974 to 2000 respectively.

3.2.2. Validation model for statistical downscaling from CMIP5 and CMIP6 using SDSM



92 **Figure 5.** Validation model results of SDSM at location of Djibouti Airport weather station using NCEP-NCAR, NCEP and ECMWF-ERA5 predictors
 93 from CMIP5 (after correction) up panels ((a), (b), (c)) and CMIP6 down panels (before correction) ((e), (f), (g)) for Observation, CHIRPS and ERA5
 94 reanalysis daily precipitation during 1996 to 2005 and 2001 to 2014 respectively.

95 **Table 3.** Statistical performance measures between reference and after correction downscaled
96 CMIP5 and before correction downscaled CMIP6 (by SDSM) precipitation for the validation
97 periods (1996-2005) and (2001-2014) respectively at Djibouti Airport gauge Station.
98

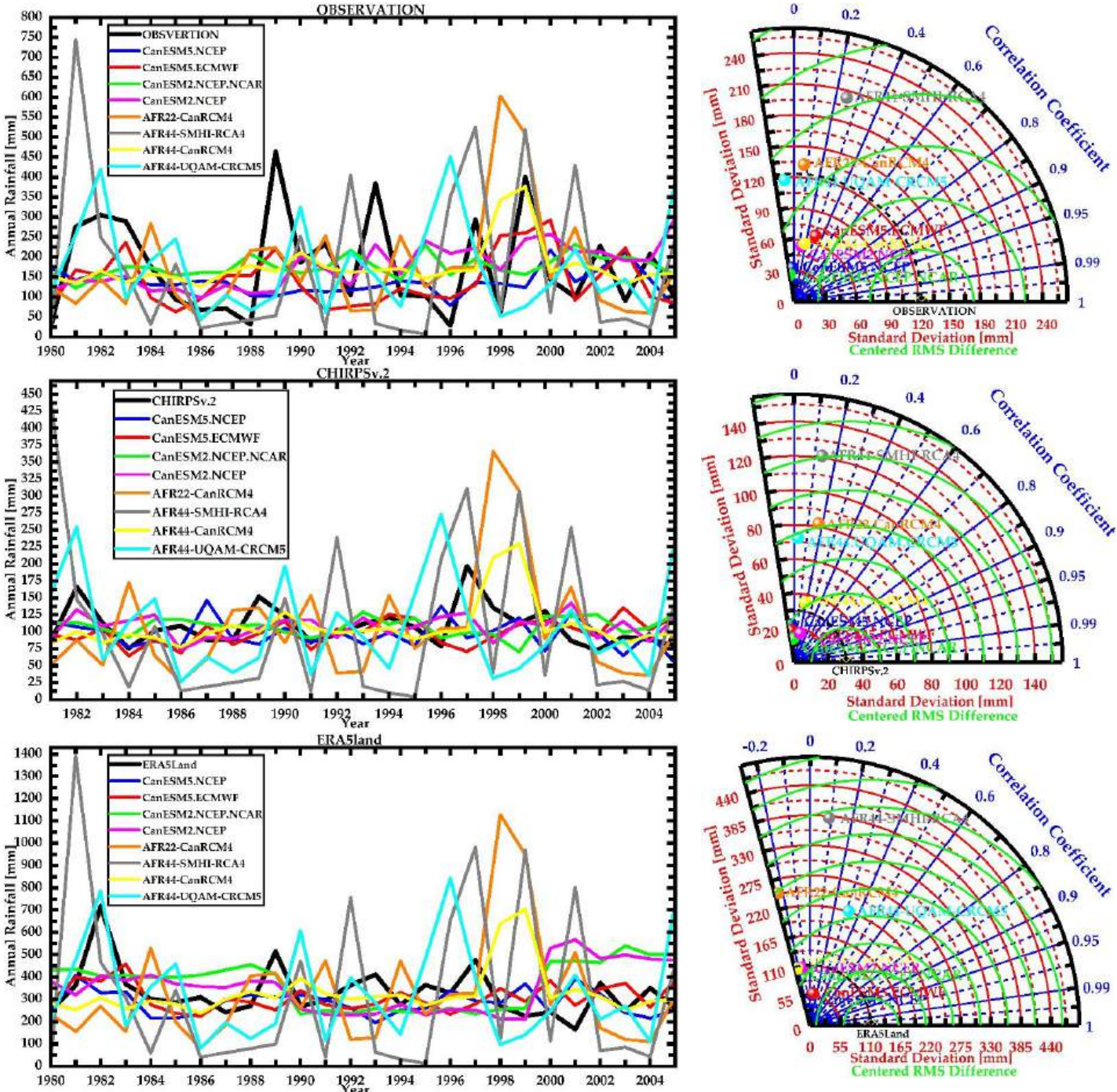
AC-CMIP5		Daily scale Validation		Monthly scale Validation		Seasonal scale Validation		Annual scale Validation	
OBS	Mean	0.452		13.758		13.758		165.09	
	S.D.	4.609		29.815		9.754		116.48	
Predictors		NCEP.NCAR	NCEP	NCEP.NCAR	NCEP	NCEP.NCAR	NCEP	NCEP.NCAR	NCEP
Mean		0.375	0.328	11.408	9.971	11.408	9.971	136.899	119.65
S.D.		1.939	1.96	16.26	16.032	9.696	9.151	56.544	48.515
CC		0.119	0.055	0.405	0.384	0.394	0.513	0.717	0.757
NSE		-0.077	-0.135	0.138	0.107	-0.268	-0.082	0.395	0.288
PBIAIS		0.171	0.275	0.171	0.275	0.171	0.275	0.171	0.288
RSR		1.038	1.065	0.924	0.941	1.078	0.996	0.738	0.8
RMSE		4.783	4.909	27.564	28.052	10.516	9.715	85.946	93.216
CHIRPS	Mean	0.295		8.972		8.972		107.66	
	S.D.	1.757		14.609		8.821		37.916	
Predictors		NCEP.NCAR	NCEP	NCEP.NCAR	NCEP	NCEP.NCAR	NCEP	NCEP.NCAR	NCEP
Mean		0.321	0.235	9.786	7.16	9.786	7.16	117.432	85.917
S.D.		0.799	0.691	7.749	6.609	6.821	4.78	18.032	11.328
CC		0.058	0.115	0.37	0.41	0.742	0.487	0.354	0.472
NSE		-0.154	-0.065	0.108	0.151	0.54	0.188	0.037	-0.173
PBIAIS		-0.091	0.202	-0.091	0.202	-0.091	0.202	-0.091	0.202
RSR		1.074	1.032	0.941	0.918	0.649	0.863	0.931	1.027
RMSE		1.887	1.813	13.741	13.405	5.728	7.611	35.296	38.954
ERA5 Land	Mean	0.818		24.914		24.914		298.969	
	S.D.	2.399		29.731		14.794		91.933	
Predictors		NCEP.NCAR	NCEP	NCEP.NCAR	NCEP	NCEP.NCAR	NCEP	NCEP.NCAR	NCEP
Mean		0.94	0.885	28.626	26.937	28.626	26.937	343.517	323.239
S.D.		1.295	1.203	23.01	20.064	19.301	16.222	45.042	49.699
CC		0.344	0.393	0.592	0.702	0.794	0.839	0.698	0.824
NSE		0.078	0.142	0.301	0.487	0.302	0.617	0.183	0.521
PBIAIS		-0.149	-0.081	-0.149	-0.081	-0.149	-0.081	-0.149	-0.081
RSR		0.96	0.926	0.832	0.713	0.8	0.592	0.857	0.657
RMSE		2.304	2.222	24.747	21.205	11.832	8.763	78.831	60.376
BC-CMIP6		Daily scale Validation		Monthly scale Validation		Seasonal scale Validation		Annual scale Validation	
OBS	Mean	0.245		7.445		7.445		89.336	
	S.D.	2.548		16.177		5.599		70.197	
Predictors		ECMWF	NCEP	ECMWF	NCEP	ECMWF	NCEP	ECMWF	NCEP
Mean		0.296	0.383	8.996	11.648	8.996	11.648	107.953	139.775
S.D.		1.583	1.639	11.761	11.301	6.714	6.317	35.088	48.118
CC		0.277	0.018	0.477	0.189	0.481	0.163	0.78	-0.042
NSE		-0.042	-0.393	0.156	-0.291	-0.369	0.163	0.454	-0.042
PBIAIS		-0.208	-0.565	-0.208	-0.565	-0.208	-0.565	-0.208	-0.565
RSR		1.021	1.18	0.916	1.133	1.12	1.52	0.712	1.391
RMSE		2.6	3.006	14.818	18.327	6.273	8.508	49.965	97.646
CHIRPS	Mean	0.226		6.885		6.885		82.615	
	S.D.	1.392		7.163		5.576		19.005	
Predictors		ECMWF	NCEP	ECMWF	NCEP	ECMWF	NCEP	ECMWF	NCEP
Mean		0.271	0.296	8.243	8.994	8.243	8.994	98.915	107.924
S.D.		0.814	0.75	7.327	7.465	5.591	6.058	20.389	20.616
CC		0.223	0.07	0.593	0.511	0.841	0.811	0.73	0.263
NSE		0.223	-0.217	0.13	-0.109	0.616	0.425	-0.376	-2.515
PBIAIS		-0.197	-0.306	-0.197	-0.306	-0.197	-0.306	-0.197	-0.306
RSR		1.04	1.103	0.93	1.05	0.593	0.726	1.131	1.807
RMSE		1.448	1.536	6.662	7.519	3.309	4.047	21.486	34.335
ERA5 Land	Mean	0.716		21.793		21.793		261.519	
	S.D.	2.563		24.675		13.627		96.994	
Predictors		ECMWF	NCEP	ECMWF	NCEP	ECMWF	NCEP	ECMWF	NCEP
Mean		0.699	0.72	21.274	21.913	21.274	21.913	255.282	262.951
S.D.		1.482	1.046	17.558	17.173	13.162	14.04	42.527	49.31
CC		0.549	0.248	0.774	0.625	0.908	0.831	0.752	0.592

NSE	0.3	0.036	0.595	0.385	0.819	0.651	0.463	0.344
PBIAIS	0.024	-0.005	0.024	-0.005	0.024	-0.005	0.024	-0.005
RSR	0.836	0.982	0.634	0.782	0.408	0.566	0.706	0.781
RMSE	2.143	2.516	15.655	0.782	5.555	7.712	68.511	75.722

99 * The grey background and bold value are the highest score of Pearson correlation coefficient at each time scale. AC: After Correction. BC: Before Correction.

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101 **3.2.3. Historical annual rainfall performance evaluation from CanESM2, CORDEX**
102 **and CANESM5 at Djibouti-Airport Station from 1980 to 2005**



103 **Figure 6.** Historical observed, CHIRPSv.2 and ERA5Land annual rainfall at Djibouti airport
104 station compared to corrected rainfall from CanESM2 and RCM (AFR22-CanRCM4, AFR44-
105 SMHI-RCA4, AFR44-CanRCM4, AFR44-UQAM-CRCM5) over the period 1980-2005 and
106 Taylor Diagram for performance comparison (left panels).The radial coordinate indicates the

variance ratio between the observation and the satellite data. The distance from the reference point (Observation), represented by circles, indicates the normalized centered RMSE.

3.2.4. Projection rainfall under RCP 4.5 and RCP 8.5 using Canadian Earth System Model (GCM & RCM)

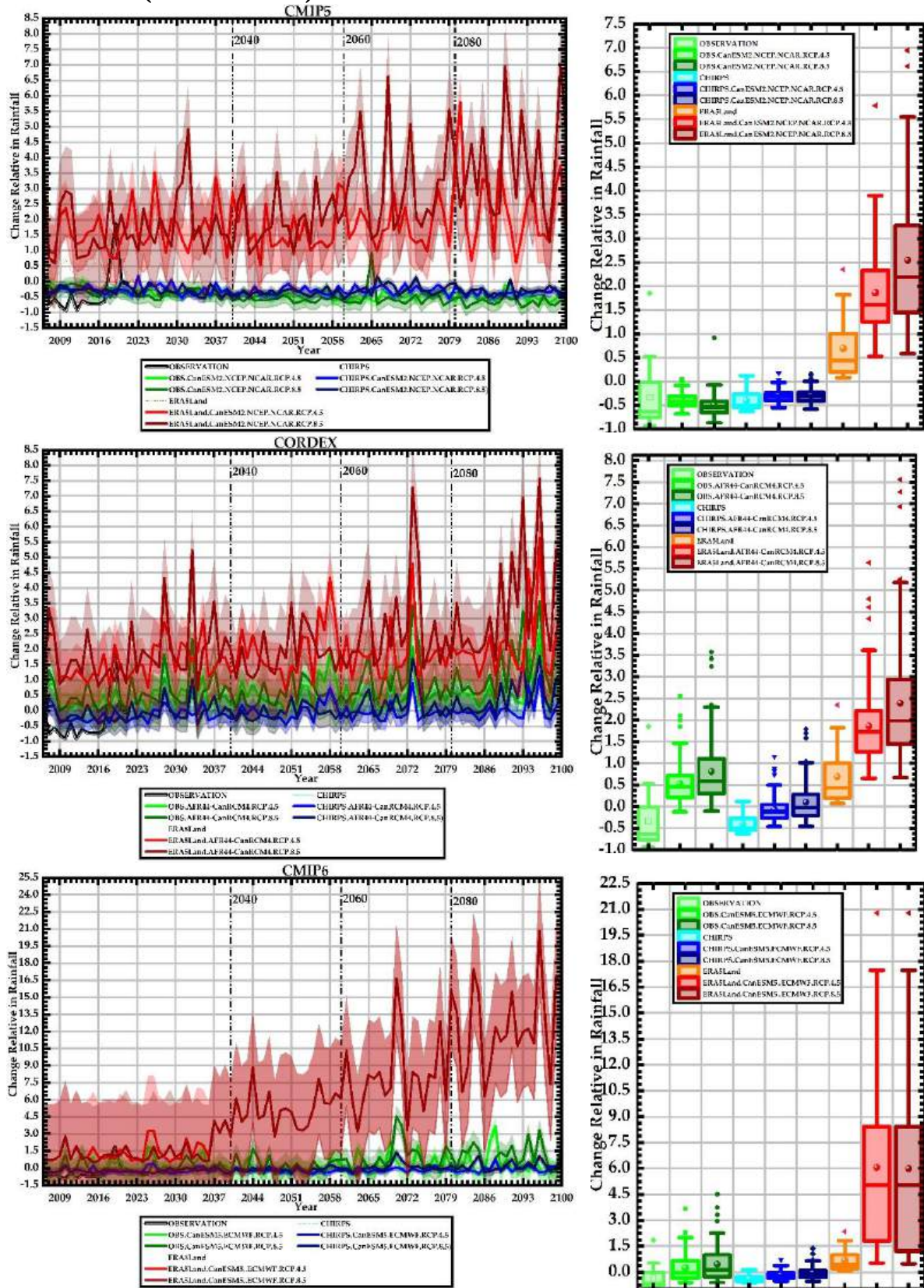


Figure 7. Projected rainfall changes relative to the baseline period 1953–2021 based on CanESM2-CORDEX, the downscaled CanESM2-CMIP5 and CanESM5-CMIP6 using Observation, CHIRPS and ERA5Land datasets. Colored shaded areas represent the areas of uncertainty (standard deviation) for the scenarios RCP4.5, RCP.8.5 for CMIP5 and SSP2-RCP4.5and SSP5-RCP8.5 for CMIP6 (right panels). The solid sphere in the boxplot represents the mean, and the interquartile range spans from Q1 to Q3 within the box square. Horizontal lines above and below denote the minimum and maximum. Irregular dotted indicate extreme values (left panels).

Table 4. Overall change of rainfall for future climate generated using CanESM2, AFR44 and CanESM5 models in RCP 4.5 and RCP 8.5 scenarios.

		Periods	Average Annual Rainfall [mm/year]	Change [%]	Slope [mm/yr]	Significance [< 0.05]
OBSERVATION		1961-2021	148.61	0.00	-0.776	0.388
		2006-2020	99.38	-33.13	11.354	0.095
CMIP5	CanESM2-CHIRPS.NCEP. NCAR RCP 4.5	2006-2100	107.635	-27.57	-0.160	0.036
		2006-2020	111.168	-25.2	0.149	0.867
		2020-2040	113.492	-23.63	-1.195	0.263
		2040-2060	104.033	-30	0.566	0.381
		2060-2080	111.777	-24.79	0.0105	0.988
		2080-2100	98.218	-33.91	-0.161	0.762
	CanESM2-ERA5Land.NCEP.NCAR RCP 8.5	2006-2100	541.314	264.25	4.366	<0.001
		2006-2020	411.832	177.12	-4.155	0.661
		2020-2040	434.038	192.07	-0.567	0.915
		2040-2060	454.822	206.05	5.000	0.26
		2060-2080	635.858	327.87	2.854	0.734
		2080-2100	727.319	389.41	6.652	0.454
CORDEX	AFR44-CanRCM4 CHIRPS RCP 4.5	2006-2100	142.885	-3.85	0.446	0.006
		2006-2020	122.866	-17.32	-1.672	0.326
		2020-2040	135.254	-8.99	0.861	0.429
		2040-2060	146.021	-1.74	2.678	0.101
		2060-2080	141.983	-4.46	0.835	0.595
		2080-2100	159.336	7.22	3.021	0.146
	AFR44-CanRCM4 ERA5Land RCP 4.5	2006-2100	437.67	194.51	1.366	0.006
		2006-2020	376.35	153.25	-5.123	0.326
		2020-2040	414.294	178.78	2.638	0.429
		2040-2060	447.274	200.97	8.204	0.101
		2060-2080	434.905	192.65	2.557	0.595
		2080-2100	488.061	228.42	9.253	0.146
CMIP6	CanESM5-CHIRPS.Land.E CMWF RCP 4.5	2006-2100	125.559	-15.51	0.348	0.009
		2006-2020	111.495	-24.97	0.335	0.875
		2020-2040	121.699	-18.11	0.0152	0.992
		2040-2060	117.865	-20.69	-1.066	0.279
		2060-2080	127.837	-13.98	1.037	0.29
		2080-2100	142.589	-4.05	2.174	0.177
		2006-2100	1078.293	625.59	23.033	<2e-16
		2006-2020	330.012	122.07	2.484	0.674
		2020-2040	436.44	193.68	15.058	0.0187

	CanESM5- ERA5.Land.EC MWF RCP 4.5	2040-2060	937.14	530.6	8.483	0.342
		2060-2080	1421.864	856.78	27.68	0.168
		2080-2100	2066.107	1290.29	19.65	0.36

*Values in bold are significant at 0.05. The dividing line separates the near, medium and far future.

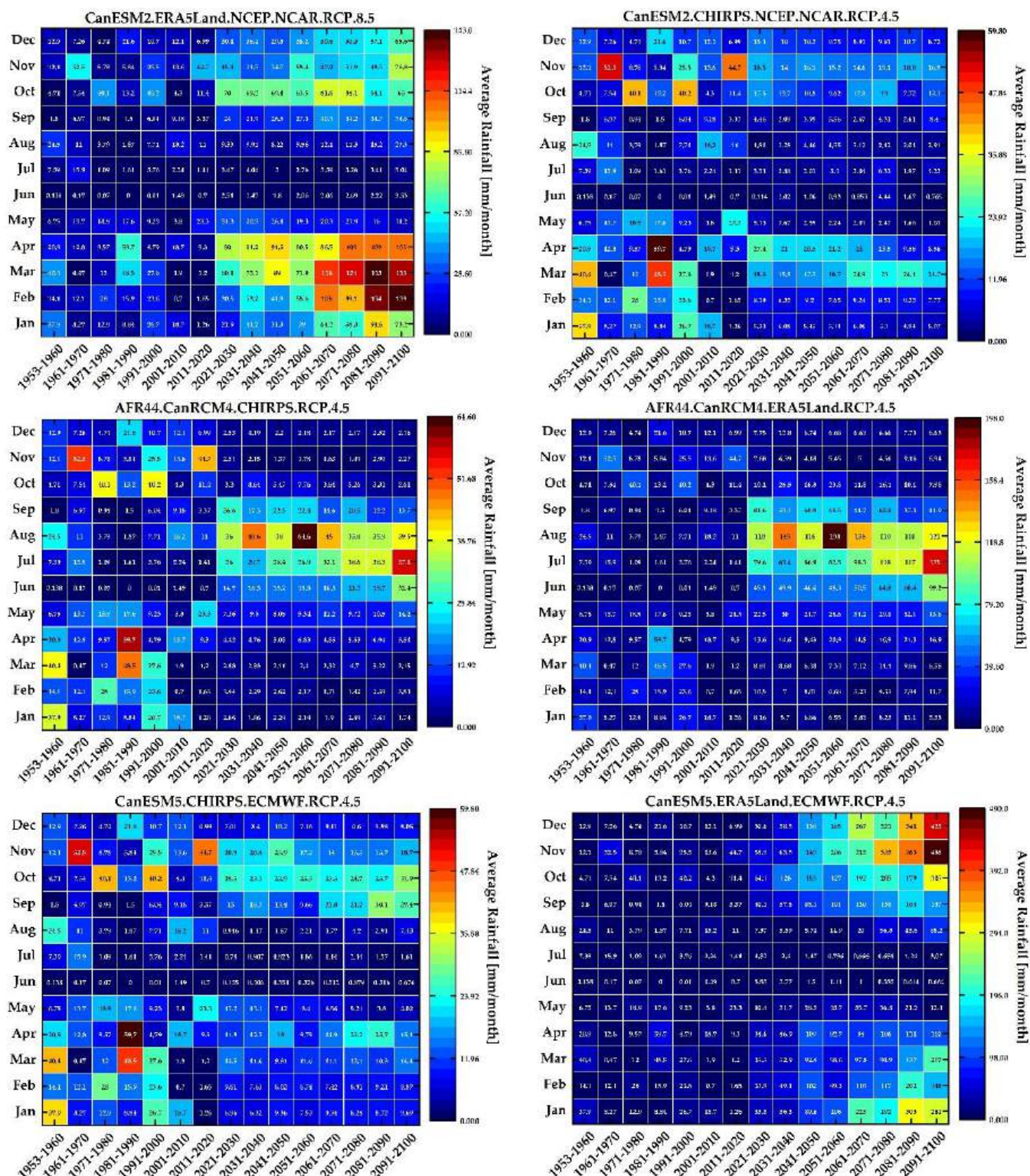


Figure 8. Historical and projected average monthly rainfall at Djibouti airport station (1953-2021) using statistical downscaling of CanESM2 and CanESM5 and corrected regional model CORDEX from 2006–2100.

3.3. Long term projection of extremes precipitation events with ETCDDI Climate Change Indices

Table 5. Trend of ETCDDI indices for extreme precipitation (historical (1980-2017) and projected with AFR44.CanRCM4.CHIRPS.RCP45 (2018-2099) at the Djibouti airport station and detection of the stationarity period with the Pettitt test (Pettitt, 1979) and standard normal homogeneity (SNHT, Alexandersson 1986).

ETCDDI indices	Trend	P.value	Stationarity Period 1	Stationarity Period 2	Stationarity Period 3	Stationarity Period 3
Historical 1980-2017						
CDD	1.071	0.12	1980-1994	1995-2004	2005-2014	2015-2020
CWD	-0.0216	0.18	1980-2003	2004-2015	2016-2019	---
PRCPTOT	-2.060	0.19	1980-2005	2006-2017	2018-2020	---
SDII	5.97e-3	0.95	1980-2017	2018-2020	---	---
R1mm	-0.181	0.021	1980-2005	2006-2013	2014-2019	---
R95P	-0.9314	0.411	1980-1992	1993-2017	2018-2020	--
Projected 2018-2099						
CDD	-0.4361	0.0754	2006-2074	2075-2087	2088-2097	---
CWD	0.0192	0.0268	2006 - 2037	2038 - 2064	2065 - 2077	2078 - 2089
PRCPTOT	0.40	0.065	2006 - 2051	2052 - 2059	2060 - 2088	2089 - 2097
SDII	1.30e-3	0.765	2006-2051	2052-2058	2059-2071	20752-2083
R1mm	0.129	0.0048	2006-2054	2025-2035	2036-2088	2089-2092
R95P	0.216	0.2628	2006-2051	2052-2058	2059-2071	2072-2079

*Values in bold are significant at 0.05.

3.4. Modeling of meteorological droughts in semi-arid environments with various indices

RAINFALL TRESHOLD :

- Q12.5% less than 35.75 mm/annum (Dry events)
- Q87.5% more than 291.60/annum (Wet events)
- Q50% less than 1 mm/month (Dry events)
- Q90% more than 32.72 mm/month (Wet events)
- Light rainfall (0–0.2(q95) mm/day)
- Moderate rainfall events (0.2–8(q99) mm/day)
- Heavy rainfall events (> 8 mm/day).

Table 6. Pearson correlation between precipitation, evaporation and several drought indices on three time scales of 1, 3 and 12 months.

		Monthly			Yearly			Range	
		Rainfall	PET Har.	PET Thor.	Rainfall	PET Har.	PET Thor.	Min	Max
SPI	SPI1	0.663	0.032	0.055	0.793	-0.071	-0.434	-1.025	2.404
	SPI3	0.499	-0.011	0.011	0.742	-0.057	-0.329	-2.003	2.404
	SPI12	0.319	-0.006	-0.041	0.637	0.129	-0.371	-2.404	2.404
	MSDI1	-0.085	0.074	-0.084	-0.213	-0.007	-0.184	-1.269	1.972
	MSDI3	-0.091	-0.001	0.003	-0.195	-0.11	-0.069	-2.377	1.468

MSDI	MSDI12	-0.103	0.006	0.016	-0.275	-0.103	0.1	-2.377	1.353
SPEI	SPEI1	0.6	-0.154	-0.054	0.336	-0.837	-0.396	-4.774	2.691
	SPEI3	0.437	-0.128	-0.028	0.502	-0.71	-0.361	-4.877	2.572
	SPEI12	0.284	-0.054	-0.035	0.561	-0.289	-0.345	-2.534	2.360
PDSI	PDSI	0.448	-0.003	-0.035	0.713	0.059	-0.477	-4.057	10.418
	scPDSI	0.375	0.049	0.018	0.632	0.021	-0.444	-4.458	4.809
	scPHDI	0.291	0.028	-0.018	0.515	0.053	-0.527	-4.458	4.809
	scWPDSI	0.377	0.034	0.006	0.612	0.025	-0.473	-4.458	4.809
RAI	RAI1	0.797	-0.013	-0.001	0.859	0.047	-0.285	-3.000	17.928
	RAI3	0.581	-0.067	-0.045	0.865	0.04	-0.279	-3.147	8.799
	RAI12	0.329	-0.002	-0.037	0.648	0.128	-0.351	-3.446	5.771
RD	RD1	1	-0.146	-0.126	1	0.029	-0.27	-1.000	28.366
	RD3	0.614	-0.064	-0.037	0.943	0.052	-0.244	-1.000	8.800
	RD12	0.331	-0.011	-0.04	0.647	0.117	-0.34	-0.965	2.784
ZSI	ZSI1	0.862	-0.054	-0.043	0.879	0.036	-0.27	-0.676	7.185
	ZSI3	0.623	-0.067	-0.042	0.933	0.053	-0.248	-0.825	5.411
	ZSI12	0.333	-0.011	-0.041	0.652	0.115	-0.34	-1.236	3.569
DI	DI1	0.511	-0.014	-0.011	0.586	-0.156	-0.683	0.000	100.000
	DI3	0.451	-0.034	-0.021	0.685	-0.025	-0.326	0.000	100.000
	DI12	0.317	-0.002	-0.036	0.639	0.139	-0.341	0.000	100.000
PPN	PPN	0.744	-0.012	-0.005	0.795	0.027	-0.236	0.000	3625.882
HDSI	HDSI1	0.511	-0.014	-0.011	0.586	-0.156	-0.683	-4.000	4.000
	HDSI3	0.451	-0.029	-0.017	0.686	-0.024	-0.326	-4.000	4.000
	HDSI12	0.316	-0.004	-0.037	0.64	0.139	-0.341	-4.000	4.000
CZI	CZI1	0.819	-0.055	-0.043	0.885	0.044	-0.288	-0.677	2.874
	CZI3	0.596	-0.071	-0.048	0.888	0.031	-0.27	-0.826	2.873
	CZI12	0.334	-0.008	-0.038	0.657	0.121	-0.338	-1.233	2.797
MCZI	MCZI1	0.804	-0.041	-0.028	0.886	0.054	-0.281	-0.303	2.872
	MCZI3	0.583	-0.052	-0.035	0.869	0.029	-0.258	-0.532	2.871
	MCZI12	0.331	-0.049	-0.073	0.656	0.122	-0.338	-1.050	2.840
PNI	PNI1	0.751	0.042	0.054	0.85	0.066	-0.315	0.000	500.000
	PNI3	0.554	-0.014	0.012	0.885	0.052	-0.254	0.000	500.000
	PNI12	0.332	-0.01	-0.04	0.648	0.117	-0.34	3.320	355.757
RDI	RDI1	0.12	-0.03	-0.051	0.027	0.098	-0.21	0.016	0.181
	RDI3	-0.002	0.007	-0.021	-0.019	0.117	-0.164	0.012	0.177
	RDI12	-0.05	0.001	-0.023	-0.117	0.085	-0.179	0.017	0.188
EDI	EDI1	0.085	-0.033	-0.092	0.103	-0.01	-0.555	-3.244	1.086
	EDI3	-0.032	0.005	-0.057	0.019	0.002	-0.511	-3.154	1.187
	EDI12	-0.063	-0.01	-0.034	-0.181	0.038	-0.174	-2.221	2.043

*Values in bold are correlation scores above 0.5 and the highest in their index category.

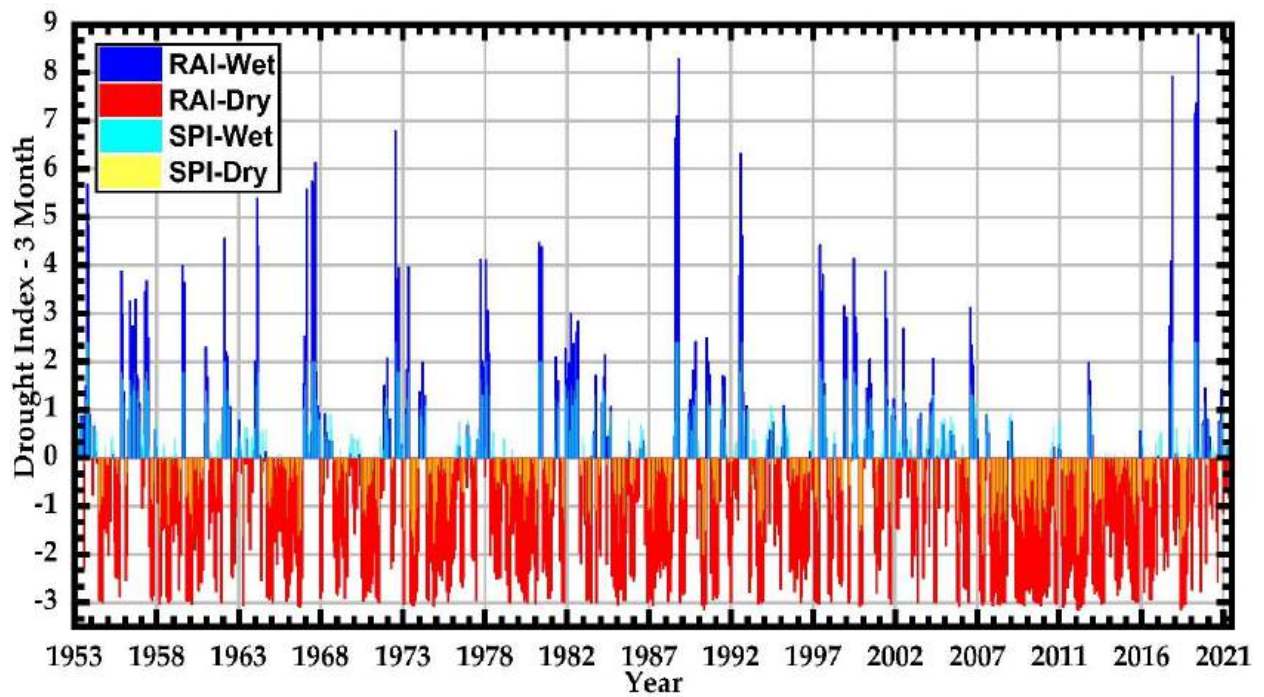


Figure 9. Long-term comparison of interannual variations in RAI and SPI on a 3-month scale. Dry events are shown in red and yellow, and wet events in blue and cyan, based on RAI and SPI indices for the period 1953-2021.

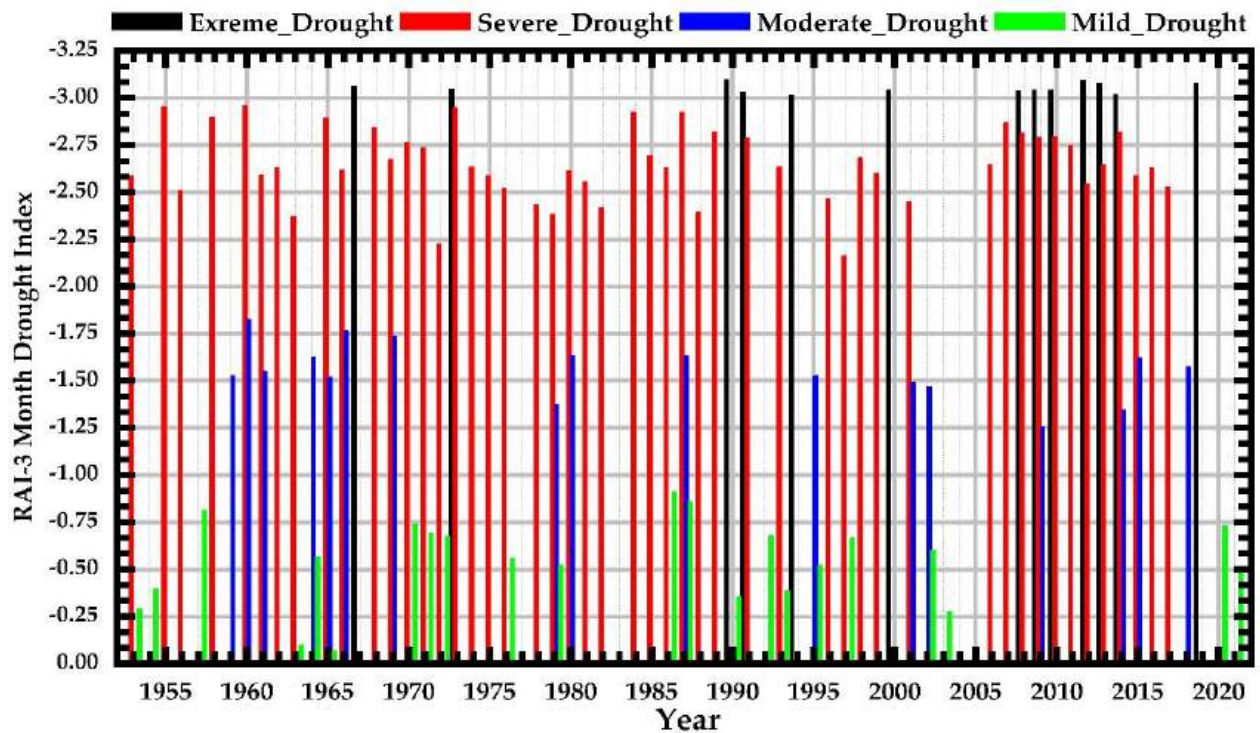


Figure 10. Temporal variation of RAI at a 3-month timescale for mild, moderate, severe, and extreme drought events at Djibouti Airport from 1953 to 2021.

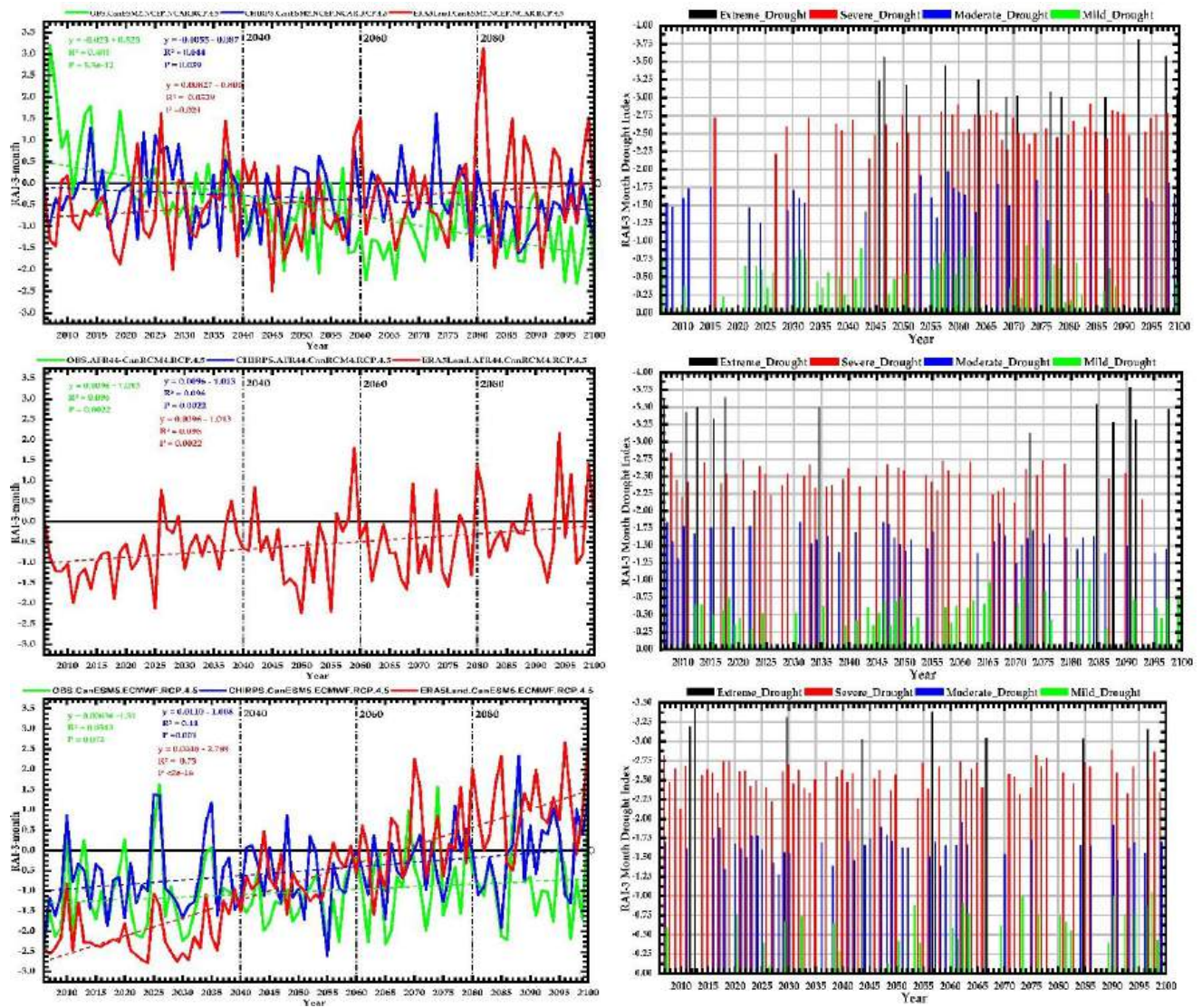


Figure 11. Projected Interannual variations (line) and linear trends (dash) in mean annual 3-month RAI at Djibouti airport station from downscaled CMIP5, CMIP6 and CORDEX based on observation, CHIRPS and ERA5Land datasets (right panels) and Characteristics of drought (left panels).

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238 4. Future projections of extreme temperature events at Airport Djibouti Station

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240 **Table 1.** High-resolution land surface daily temperature product

Acronym	Full Name	Data source	Temporal resolution	Time Span	Latency	Geographic al coverage	Spatial resolution	References
CFSR	CFS Reanalysis	R	Daily	1979 - Present	6 hours	Global	0.2°	[1]
CHIRTSv1.0	Climate Hazards group InfraRed	S,G,R	Daily	1983-2016		Global	0.05°	[2]
ERA5	European Center for Medium-range Weather	R	Daily	1979 - Present	5 days	Global	0.25°	[3]
ERA5Land	Forecast Re-Analysis v.5	R	Daily	1950 - Present	2-3 months	Global	0.125°	[4]
AgERA5		R	Daily	1979 - Present	2-3 months	Global	0.1°	[5]

241 * In the data source column, the abbreviations S, R, and G stand for satellite, reanalysis, and gauge, respectively.

242 **Table 2.** Comparison of quantitative statistical measurements between very high multi-satellite
243 daily average temperatures against in situ meteorological observation station at Djibouti airport
244 from 1966 to 2019.

Daily	OBS	CFSR	CHIRTS	ERA5	AgERA5	ERA5Land
N						
Mean						
Trend						
Pvalue						
COR						
NSE						
RMSE						
RSR						
BIAIS						
MAE						
Monthly	OBS	CFSR	CHIRTS	ERA5	AgERA5	ERA5Land
N						
Mean						
Trend						
Pvalue						
COR						
NSE						
RMSE						
RSR						
BIAIS						
MAE						
Yearly	OBS	CFSR	CHIRTS	ERA5	AgERA5	ERA5Land
N						
Mean						
Trend						
Pvalue						

COR						
NSE						
RMSE						
RSR						
BIAIS						
MAE						
Hot Season	OBS	CFSR	CHIRTS	ERA5	AgERA5	ERA5Land
N						
Mean						
Trend						
Pvalue						
COR						
NSE						
RMSE						
RSR						
BIAIS						
MAE						
Fresh Season	OBS	CFSR	CHIRTS	ERA5	AgERA5	ERA5Land
N						
Mean						
Trend						
Pvalue						
COR						
NSE						
RMSE						
RSR						
BIAIS						
MAE						

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246 **Figure daily line**

247 **Figure monthly boxplot**

248 **Figure seaosnnal violin et trend**

249 **Figure yearly trend**

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Figure Calibration

Tableau

Figure Validation

Tableau

Figure Historial

Tableau

Figure Projection

Tableau

ETCCDII temperature + Heat stress

Tableau

Table 7. Comparison of quantitative statistical measurements between very high multi-satellite daily minimum and maximum temperature against in situ meteorological observation station at Djibouti airport from 1966 to 2010.

Minimum Temperature					Maximum Temperature			
	CFSR	CHIRTS	ERA5	ERA5Ag	CFSR	CHIRTS	ERA5	ERA5Ag
COR	0.862	0.768	0.918	0.913	0.846	0.896	0.944	0.949
NSE	-0.593	-0.91	0.817	0.829	0.57	0.746	0.593	0.751
RMSE	4.764	5.268	1.623	1.559	3.265	2.499	3.19	2.487
RSR	1.262	1.382	0.428	0.413	0.656	0.504	0.638	0.499
BIAIS	4.286	-4.382	-0.36	-0.238	0.356	-1.146	2.719	1.912
MAE	4.329	4.605	1.289	1.242	2.465	1.999	2.813	2.169

5. * The grey background and bold value are the highest score of quantitative and categorical statistical measures.

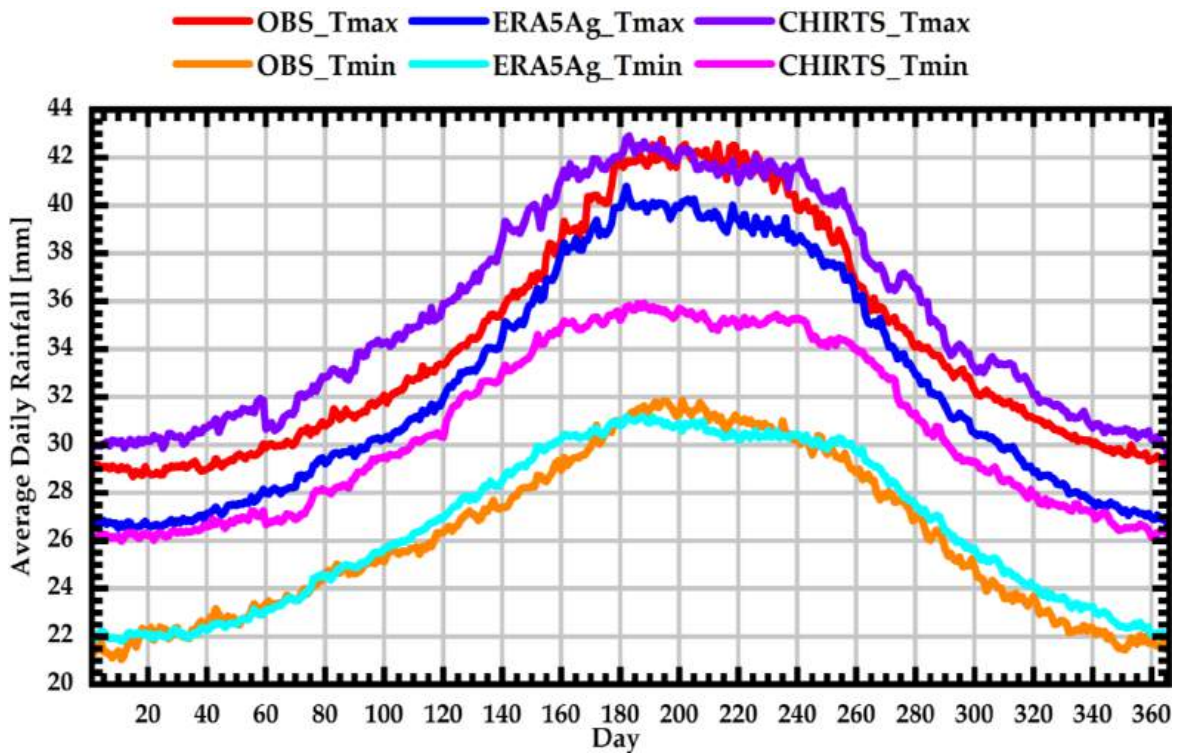


Figure 12. Comparison of observation and two best-performing reanalysis products (CHIRTSv1.0 and ERA5Ag) for average daily temperature at Djibouti Airport from 1966 to 2010, calculated for each Julian day over the available in situ Djibouti Airport Station observation.

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5.1. Screening predictors variable

Table 8. Screening variable for observed and reanalysis products (ERA5Ag and CHIRTSv1.0) minimum and maximum temperature.

	OBS.Tmin		OBS.Tmax		CHIRT.Tmin		CHIRT.Tmax		ERA5Ag.Tmin		ERA5Ag.Tmax	
	Partial r	P value	Partial r	P value	Partial r	P value	Partial r	P value	Partial r	P value	Partial r	P value
ncepmslpgl	-3.9E-01	0.0E+00	-2.7E-01	0.0E+00	-3.4E-01	0.0E+00	-5.2E-01	0.0E+00	-5.3E-01	0.0E+00	-4.8E-01	0.0E+00
ncepp1_fgl	1.4E-01	0.0E+00	1.7E-01	0.0E+00	9.1E-02	0.0E+00	-2.4E-02	5.3E-02	-7.5E-02	0.0E+00	1.3E-01	0.0E+00
ncepp1_ugl	3.8E-01	0.0E+00	5.1E-01	0.0E+00	3.2E-01	0.0E+00	4.8E-01	2.7E-02	3.8E-01	0.0E+00	5.9E-01	0.0E+00
ncepp1_vgl	1.0E-02	2.8E-01	7.5E-02	0.0E+00	1.5E-01	0.0E+00	2.7E-02	0.0E+00	1.2E-01	0.0E+00	5.8E-02	0.0E+00
ncepp1_zgl	-1.1E-01	0.0E+00	-3.0E-02	7.0E-04	-1.3E-01	0.0E+00	-6.1E-02	0.0E+00	-9.5E-02	0.0E+00	-6.6E-02	0.0E+00
ncepp1thgl	4.7E-02	0.0E+00	8.4E-02	0.0E+00	-4.1E-02	4.0E-04	1.1E-01	0.0E+00	1.5E-01	0.0E+00	1.7E-01	0.0E+00
ncepp1zhgl	-2.3E-02	1.2E-02	3.3E-02	2.0E-04	3.6E-02	2.8E-03	1.2E-01	0.0E+00	3.0E-02	7.1E-03	7.7E-02	0.0E+00
ncepp5_fgl	3.8E-02	0.0E+00	-2.5E-02	4.9E-03	2.5E-02	4.3E-02	-8.1E-02	0.0E+00	2.3E-02	3.8E-02	-3.6E-02	8.0E-04
ncepp5_ugl	-1.8E-02	5.7E-02	-2.2E-01	0.0E+00	-4.0E-02	5.3E-01	-2.9E-01	0.0E+00	-1.4E-01	0.0E+00	-2.2E-01	0.0E+00
ncepp5_vgl	-3.7E-02	0.0E+00	-6.5E-02	0.0E+00	1.8E-02	1.6E-01	-1.3E-01	0.0E+00	-6.6E-02	0.0E+00	-1.1E-01	0.0E+00
ncepp5_zgl	1.4E-01	0.0E+00	1.2E-01	0.0E+00	1.9E-01	0.0E+00	1.3E-01	0.0E+00	2.3E-01	0.0E+00	1.5E-01	0.0E+00
ncepp500gl	2.2E-01	0.0E+00	8.8E-02	0.0E+00	2.0E-01	0.0E+00	2.8E-01	0.0E+00	2.9E-01	0.0E+00	2.2E-01	0.0E+00
ncepp5thgl	-2.7E-01	0.0E+00	-3.4E-01	0.0E+00	-2.0E-01	0.0E+00	-3.9E-01	0.0E+00	-3.7E-01	0.0E+00	-3.8E-01	0.0E+00
ncepp5zhgl	-3.2E-02	4.0E-04	-3.6E-02	0.0E+00	1.3E-02	2.8E-01	-3.3E-02	5.7E-03	-5.2E-02	0.0E+00	-5.6E-02	0.0E+00
ncepp8_fgl	5.1E-02	0.0E+00	1.0E-01	0.0E+00	9.0E-03	4.0E-01	-1.5E-01	0.0E+00	-1.3E-01	0.0E+00	-3.0E-03	5.3E-01
ncepp8_ugl	9.3E-02	0.0E+00	2.2E-01	0.0E+00	2.4E-01	0.0E+00	2.3E-01	0.0E+00	6.9E-02	0.0E+00	2.7E-01	0.0E+00
ncepp8_vgl	-1.6E-01	0.0E+00	-2.1E-01	0.0E+00	7.4E-02	0.0E+00	-1.4E-01	0.0E+00	-1.2E-01	0.0E+00	-2.2E-01	0.0E+00
ncepp8_zgl	1.4E-01	0.0E+00	2.0E-01	0.0E+00	9.2E-02	0.0E+00	2.0E-01	0.0E+00	2.5E-01	0.0E+00	2.3E-01	0.0E+00
ncepp850gl	-1.4E-01	0.0E+00	-9.0E-02	0.0E+00	-1.1E-01	0.0E+00	-2.1E-01	0.0E+00	-1.8E-01	0.0E+00	-1.6E-01	0.0E+00
ncepp8thgl	3.9E-02	0.0E+00	1.2E-01	0.0E+00	-3.8E-02	1.5E-03	1.3E-01	0.0E+00	8.5E-02	0.0E+00	1.5E-01	0.0E+00
ncepp8zhgl	-1.6E-01	0.0E+00	-6.0E-02	0.0E+00	-6.1E-02	0.0E+00	-5.2E-02	0.0E+00	-1.5E-01	0.0E+00	-8.6E-02	0.0E+00
ncepprcpgl	-1.4E-01	0.0E+00	-5.4E-02	0.0E+00	-7.7E-02	0.0E+00	-9.0E-02	0.0E+00	-1.3E-01	0.0E+00	-9.6E-02	0.0E+00
nceps500gl	8.7E-02	0.0E+00	1.5E-01	0.0E+00	-3.0E-03	5.4E-01	7.2E-02	0.0E+00	9.5E-02	0.0E+00	1.1E-01	0.0E+00
nceps850gl	3.2E-01	0.0E+00	4.4E-02	0.0E+00	4.6E-02	1.0E-04	-1.1E-01	0.0E+00	1.5E-01	0.0E+00	-6.0E-03	4.8E-01
ncepshumgl	2.9E-01	0.0E+00	1.4E-01	0.0E+00	4.0E-02	8.0E-04	4.4E-02	2.0E-04	1.6E-01	0.0E+00	8.2E-02	0.0E+00
nceptempgl	3.3E-01	0.0E+00	1.9E-01	0.0E+00	1.5E-01	0.0E+00	1.8E-01	0.0E+00	2.7E-01	0.0E+00	1.8E-01	0.0E+00
Autoregression	7.6E-01	0.0E+00	8.8E-01	0.0E+00	9.8E-01	0.0E+00	9.2E-01	0.0E+00	9.3E-01	0.0E+00	9.3E-01	0.0E+00

* Selected predictors are values highlighted in red and bold.

5.2. Calibration model

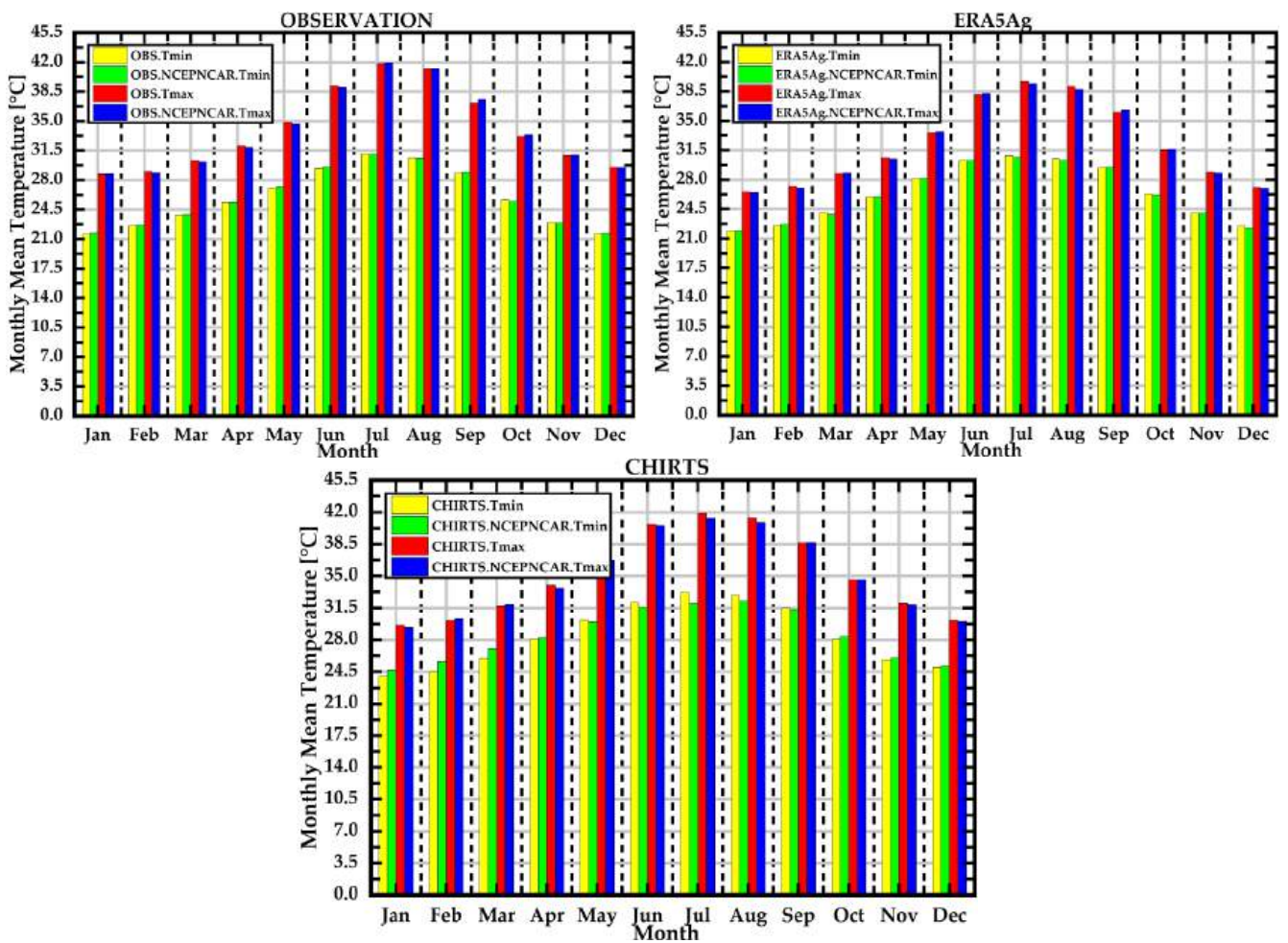


Figure 13. Calibration model results of SDSM at location of Djibouti Airport weather station using Minimum and Maximum Temperature from 1966 to 1994.

5.3. Validation model

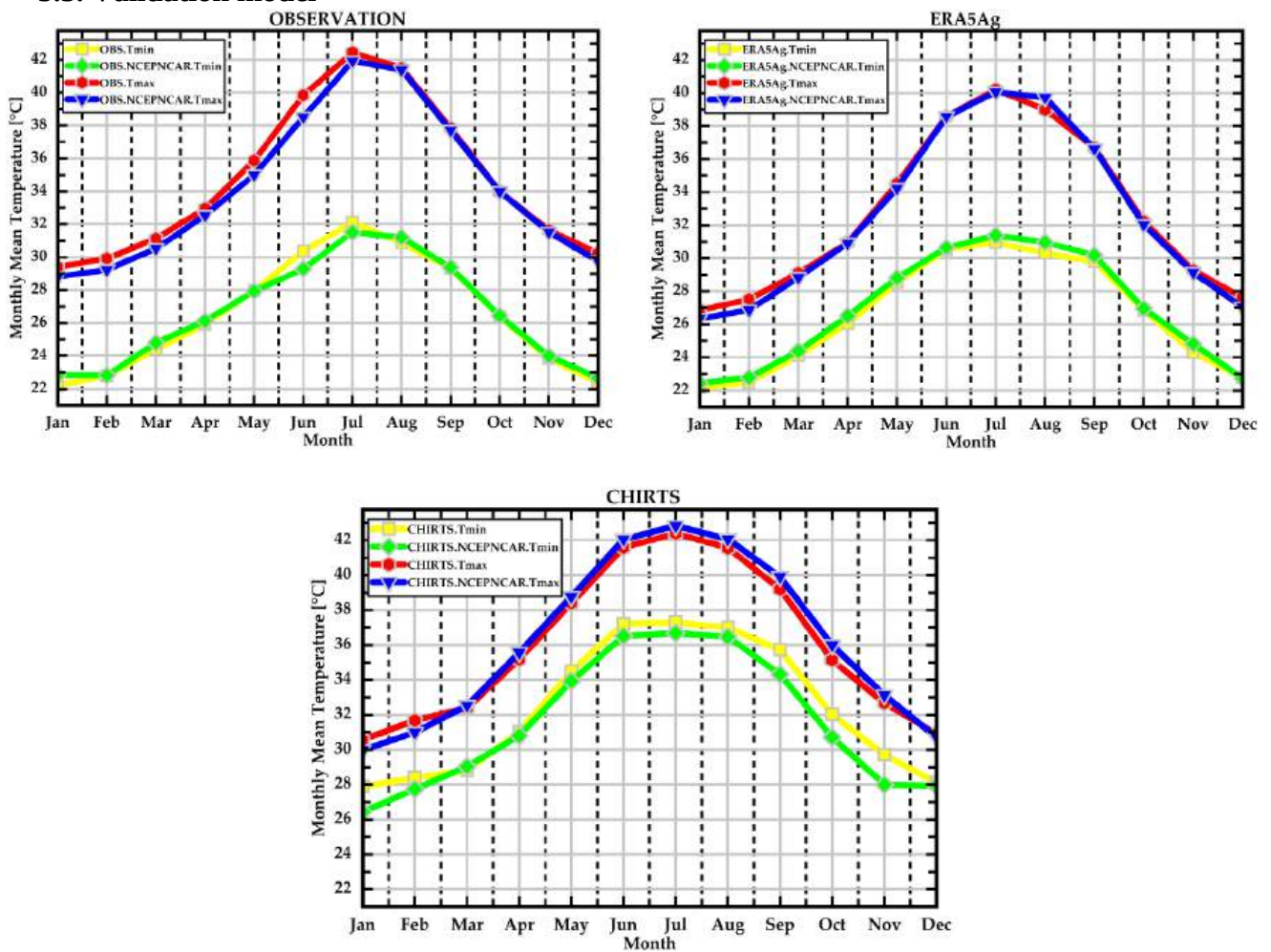


Figure 14. Validation model results of SDSM at location of Djibouti Airport weather station using Minimum and Maximum Temperature from 1995 to 2005 (after correction).

5.4. Future change projection of minimum and maximum temperature

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6. Discussions

OBS-CMIP5 : NCEP.NCAR (calibration)
CHIRPS-CMIP5 : NCEP.NCAR (calibration)
ERA5Land-CMIP5 : NCEP.NCAR (calibration)
*
OBS-CMIP6 : ECMWF (calibration)
CHIRPS-CMIP6 : ECMWF (calibration)
ERA5Land-CMIP5 : ECMWF (calibration)

OBS-CMIP5 : NCEPNCAR (validation)
CHIRPS-CMIP5 : NCEPNCAR (validation)
ERA5Land-CMIP5 : NCEP (validation)
*
OBS-CMIP5 : ECMWF (validation)
CHIRPS-CMIP5 : ECMWF (validation)
ERA5Land-CMIP5 : ECMWF (validation)

OBS-CMIP5 : NCEPNCAR/AFR44can (Historic)
CHIRPS-CMIP5 : NCEPNCAR/AFR44can (Historic)
ERA5Land-CMIP5 : NCEPNCAR/AFR44can (Historic)
*
OBS-CMIP6 : CANESM5.ECMWF (Historic)
CHIRPS-CMIP6 : CANESM5ECMWF (Historic)

ERA5Land-CMIP6 : CANESM5ECMWF (Historic)

OBS-RCP4.5 CanESM2NCEPNACR AFR44 CanESM5.ECMWF
CHIRPS-RCP4.5 CanESM2NCEPNACR AFR44 CanESM5.ECMWF
ERA5LAND-RCP4.5 CanESM2.NCEP.NCAR AFR44 CanESM5.ECMWF

To address the lack of daily rainfall data recorded in the Republic of Djibouti, which is crucial for applying statistical downscaling in GCM models for future projections, this study evaluated nine very high-resolution satellite-derived rainfall datasets. The performance of these remotely sensed precipitation products was directly assessed by comparing them to weather station rain gauges at Djibouti airport station. This evaluation incorporated seven different continuous and categorical metrics on a daily time scale. The statistical indices presented in **Table 1** indicate These results suggest that satellite data outperforms other options significantly.

Additionally, the Taylor Diagram (**Figure S1**) offers a comprehensive visualization of the daily precipitation data evaluation, highlighting that CHIRPS and ERA5Land stand out as the top two satellite data choices for fulfilling the study's objectives. Moreover, the results of the daily evaluations show that the similarity of the empirical cumulative density function (ECDF) for the satellite products (CHIRPSv.2 and ERA5Land) is very high. Except between 0 and 25 mm, the CHIRPS ECDF is slightly closer to the measurement station than the ERA5Land ECDF. Further, when scrutinizing the differences between the two top-performing satellite datasets in comparison to the observed data, the results indicate that ERA5Land documents more occurrences of extreme precipitation than CHIRPSv.2, as illustrated in the violin plot (**Figure 3**). In addition, concerning monthly distribution and seasonal variability, the CHIRPSv.2 satellite product tends to slightly underestimate observed monthly precipitation while providing an accurate representation, while ERA5Land tends to overestimate it. The monthly and seasonal distribution results for the remaining seven satellite products can be found in **Figures S4 and S3**.

The results of the partial correlation between the predictors (NCEP, NCEP-NCAR and ECMWF) and the observations, CHIRPSv.2 and ERA5Land for statistical downscaling of the Canadian Earth System Model (CMIP5 and CMIP6) are displayed in **Tables S1-S4**. As a result, the appropriate predictors after iterations for the most significant partial correlation at the 5% level in a conditional process are shown in **Table 2**.

7. Conclusions

Author Contributions:

Funding:

Institutional Review Board Statement:

Informed Consent Statement:

Data Availability Statement:

Acknowledgments:

Conflicts of Interest:

References

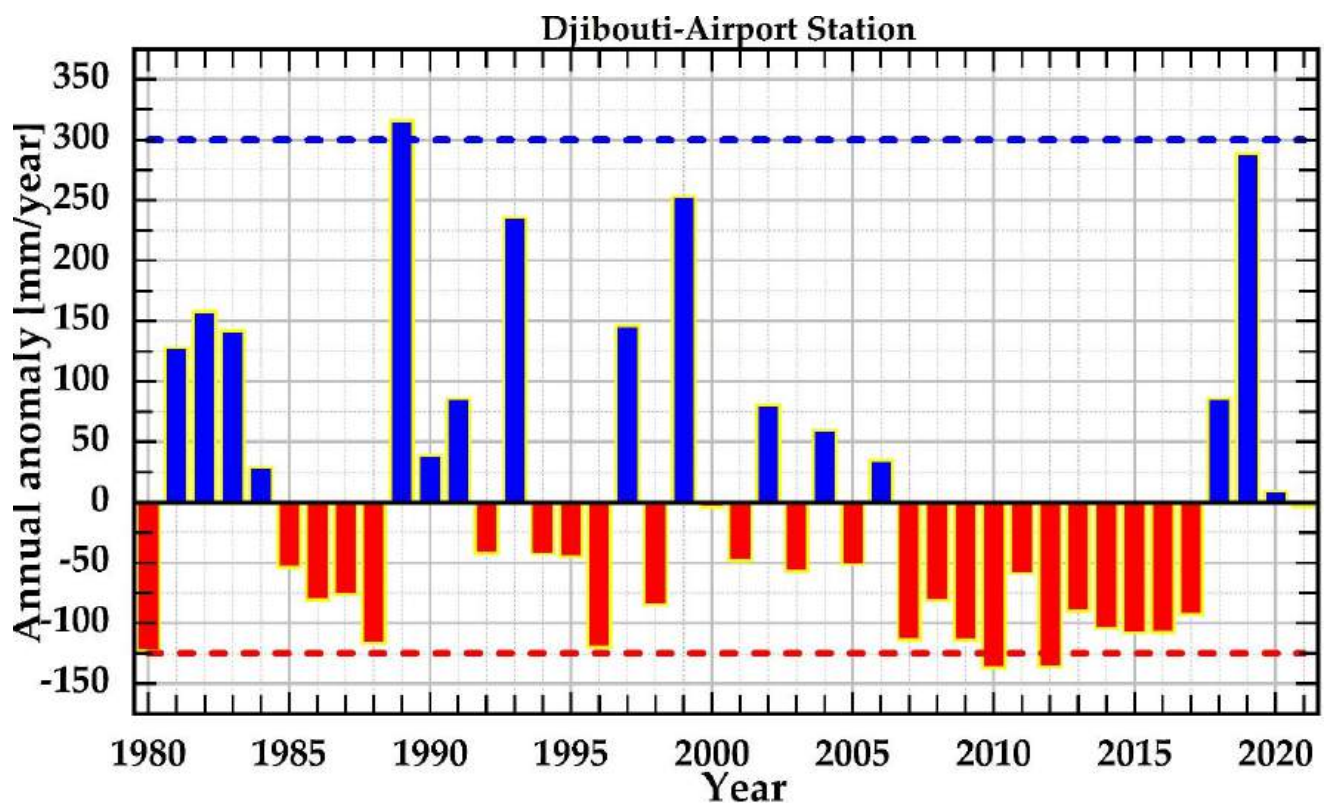
1.

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497

Spatial

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1989 (highest positive)

2010 (highest negative)

2021 (neutral)

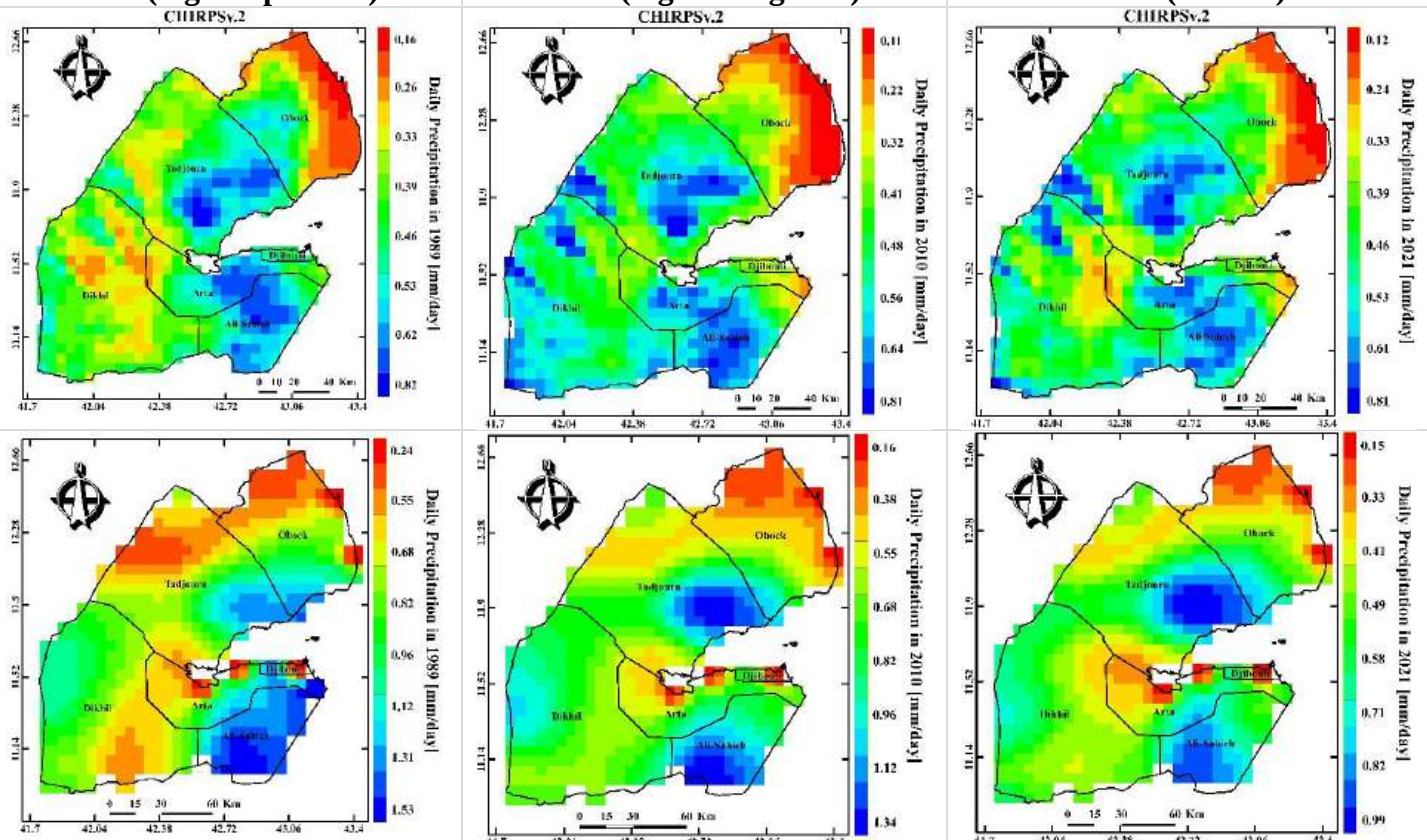


Figure. Annual rainfall anomaly at Djibouti airport from 1981 to 2021 and spatial distribution of average daily rainfall with CHIRPSv.2 and ERA5LAND (0.05° with bilinear Interpolation)

in 1989 (positive anomaly), 2010 (negative anomaly) and 2021 (neutral) over the Republic of Djibouti.

Spatial distribution of rainfall over the republic of Djibouti

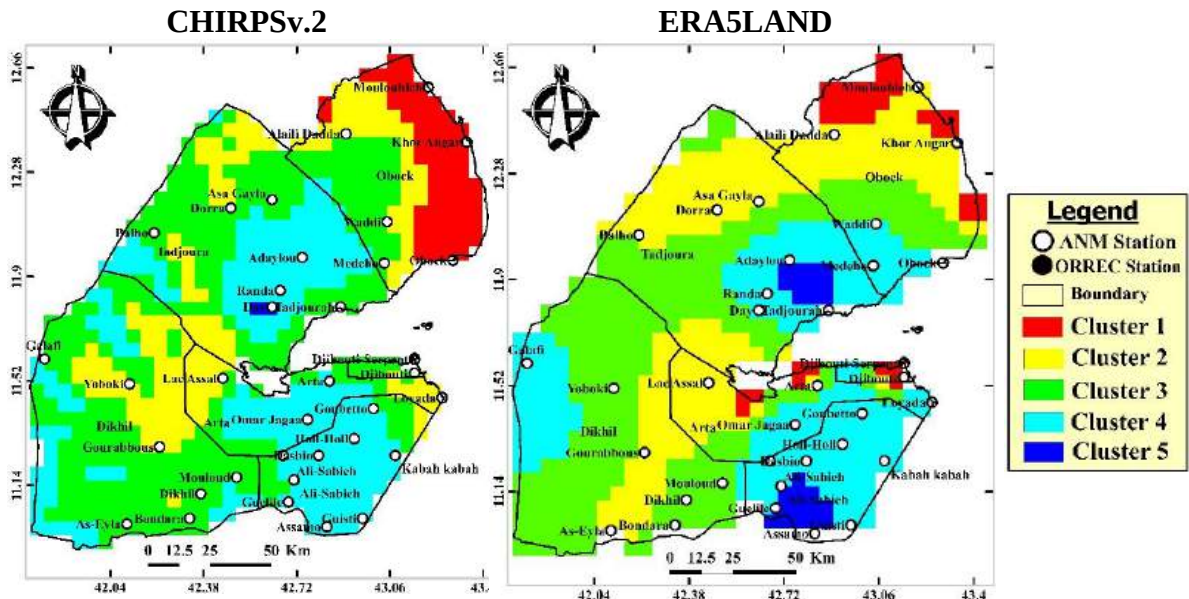


Figure. Results of spatial principal component analysis applied to the precipitation from satellite product of CHIRPSv.2 (0.05°) and ERA5Land (0.05° regrided with bilinear spatial interpolation) over the Republic of Djibouti.

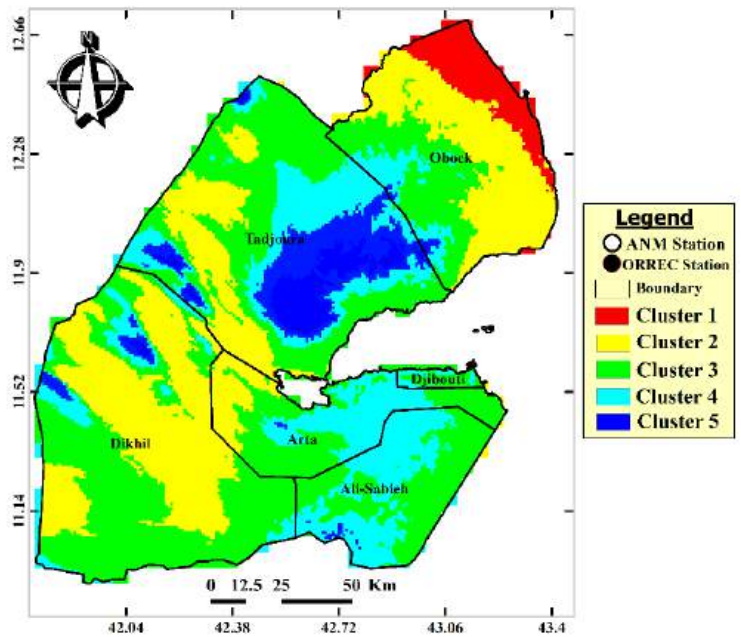


Figure. Results of spatial principal component analysis on WorldClim version 2.1 monthly precipitation dataset over the period 1970-2000.

516

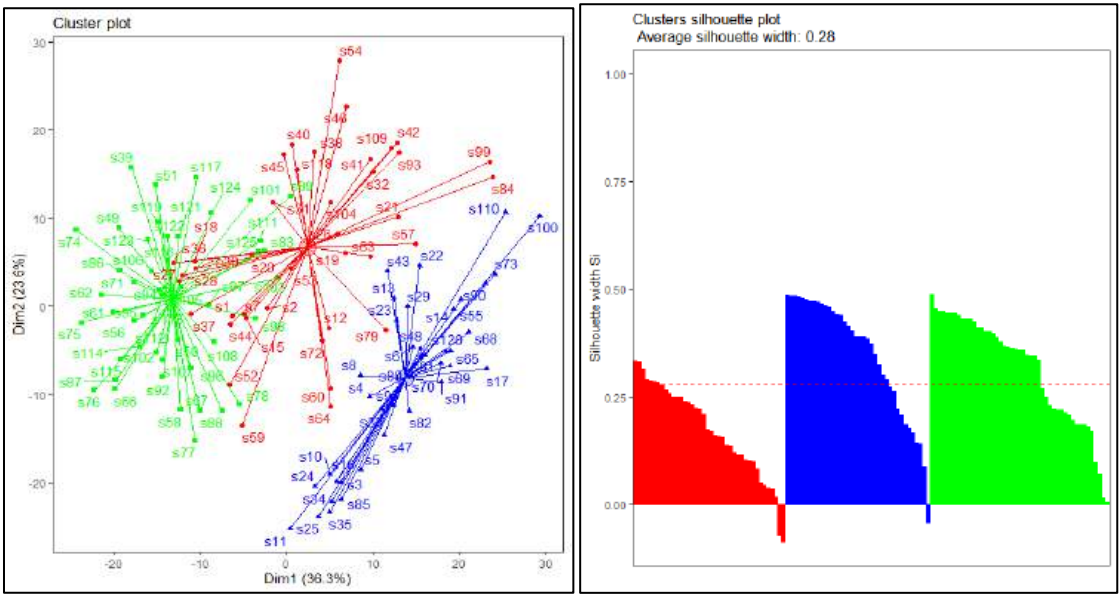
Table1. Index statistics of determining the number of clusters.

Index	Number clusters	Value Index	Index	Number clusters	Value Index
KL	3	2.6186	Duda	NA	NA
CH	3	350.587	PseudoT2	NA	NA
Hartigan	3	125.9879	Beale	2	0.3951
CCC	3	5.2929	Ratkowsky	3	1828310
Scott	NA	NA	Ball	5	0.6168
Marriot	3	29579791352	PtBiserial	1	NA
TrCovW	3	1320347	Frey	3	0.299
TraceW	3	5783.596	McClain	8	0.0666
Friedman	3	-0.4549	Dunn	0	0
Rubin	7	0.1034	Hubert	3	0.0404
Cindex	3	1.0188	SDindex	0	0
DB	4	0.4837	Dindex	3	0.6928
Silhouette	NA	NA	SDbw	3	2.6186

517

518 On voie que plusieurs règles soutiennent l'idée de 3 groupes, avec un maximum de 4 à 8 groupes
519 (soutenu par une seule règle chacune).

520 De même la moyenne de silhouette baisse quand le nombre de groupement dépasse le 3.



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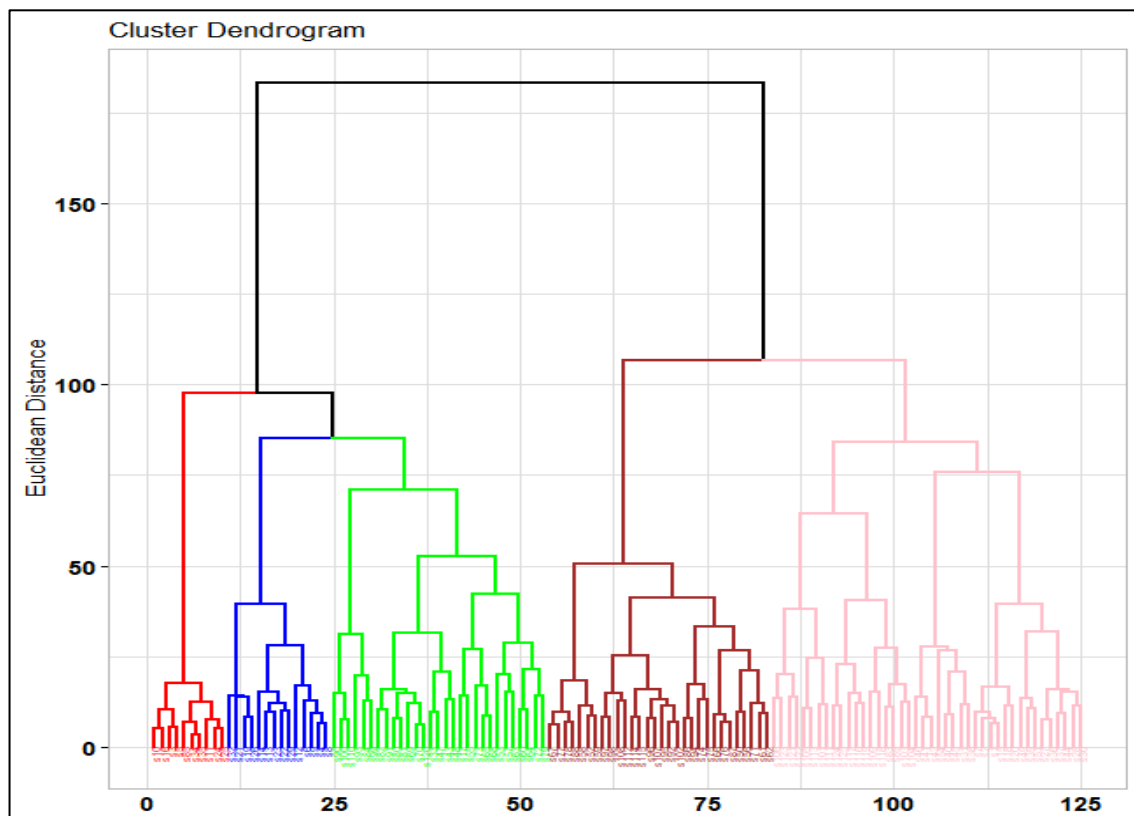
Pour comparer l'idée de régionalisation sur le plan temporelle contre sur le plan spatial.

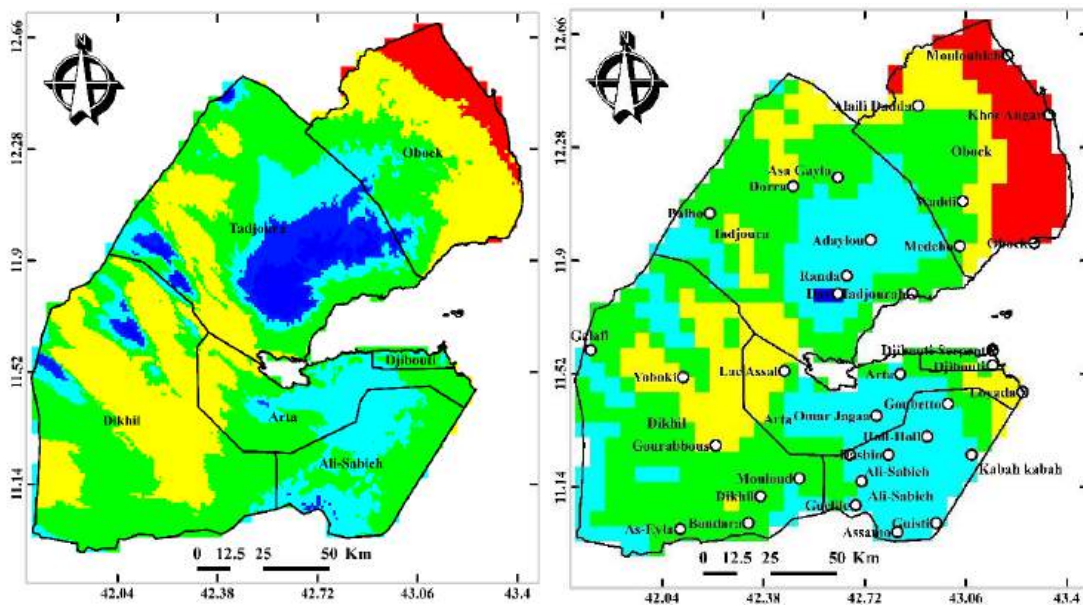
On constate que la régionalisation sur la variabilité temporelle ne reflètera pas la réalité avec l'interpolation spatiale de stations regroupées par le HCA mensuelle ou annuelle.

De plus chaque regroupement devrait être expliqué par un phénomène de circulation atmosphérique.

Pour le cas spatial seul l'orographie peut expliquer le regroupement des pixels de précipitations.

Enfin, le clustering de 1 km est proche de l'interpolation avec les observations de 35 stations que le CHIRPS de 5 km.





World Clim (1 km) vs CHIRPS (5 km)

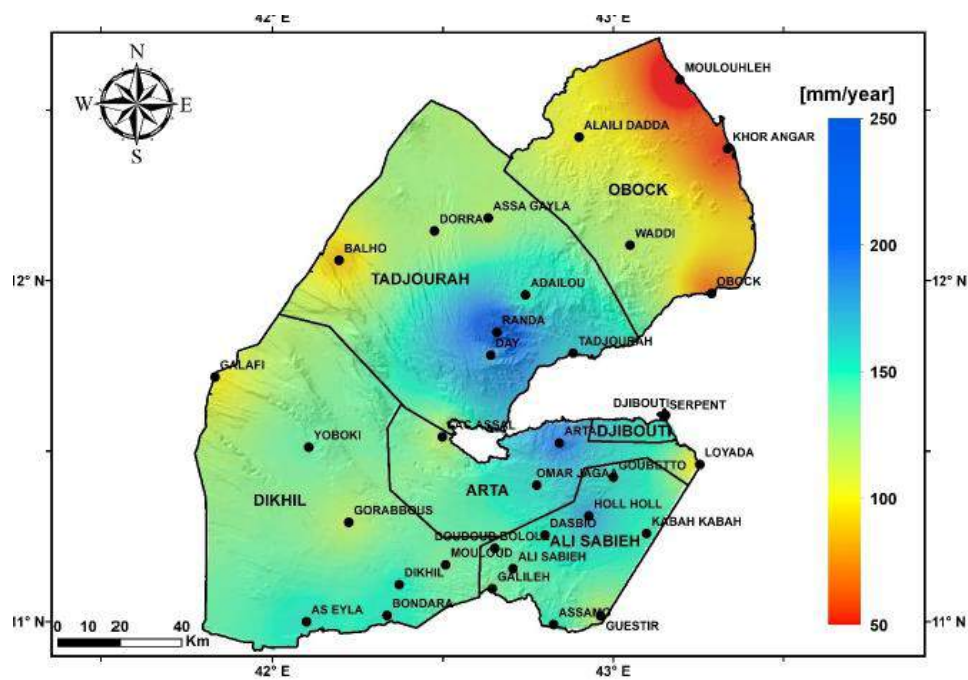


Figure 3. Spatial distribution of mean annual rainfall over the Republic of Djibouti based on 35 meteorological stations.

MDPI Assowe et al.,2022

Supplementary Material

Past and Long-term Projections of Precipitation, Drought Events and Extreme Temperature Using a Statistical Downscaling Model (SDSM) Approach in the Republic of Djibouti

1 Observatoire Régionale de Recherche sur l'Environnement et le Climat (ORREC), Centre d'Etudes et de Recherches de Djibouti (CERD), Route de l'aéroport, Djibouti-ville B.P. 486, Djibouti

* Correspondence

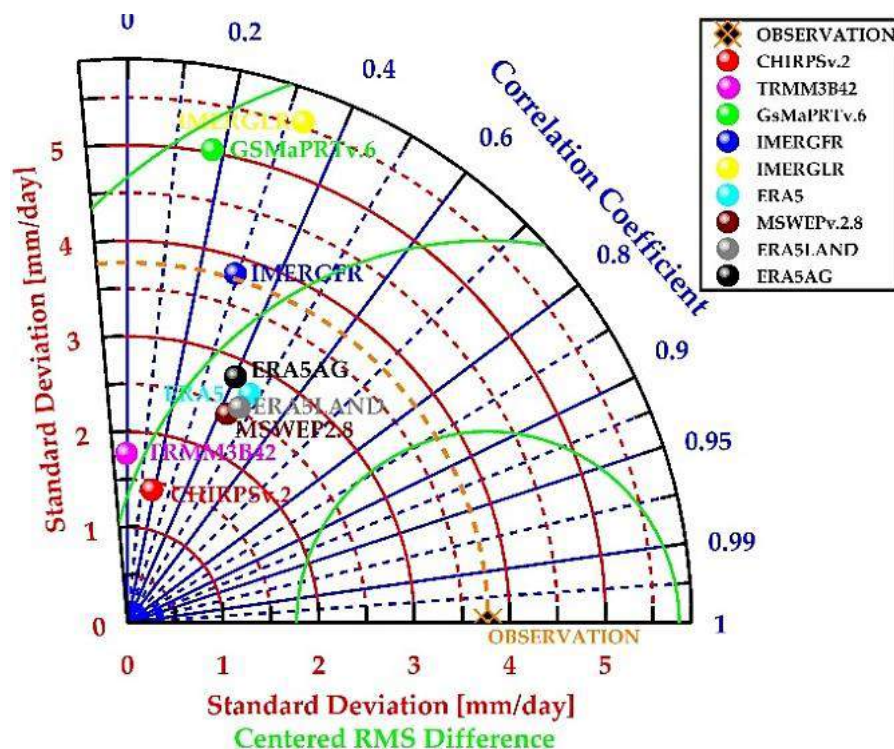


Figure S1. Taylor Diagram representing the statistical relationship between observed rainfall and nine high resolution multi-satellite datasets. The angular coordinate indicates the correlation coefficients between the observations and the satellite data. The radial coordinate indicates the variance ratio between the observation and the satellite data. The distance from

the reference point (Observation), represented by circles, indicates the normalized centered RMSE.

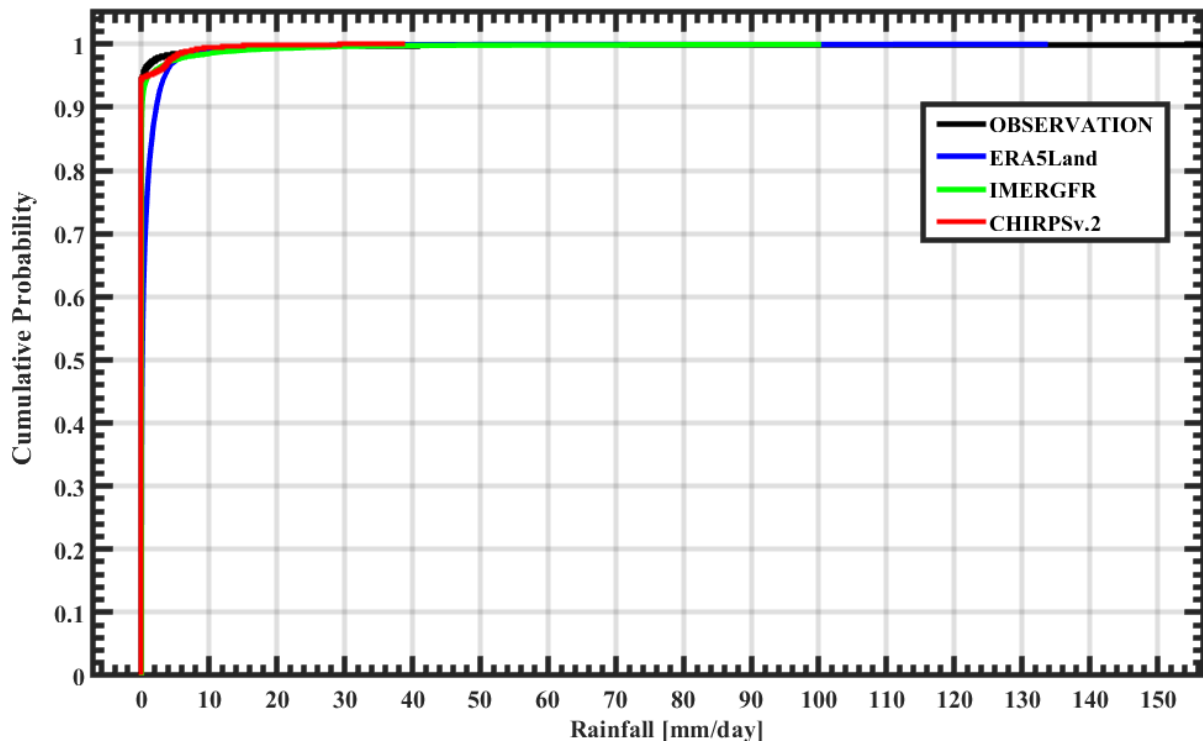
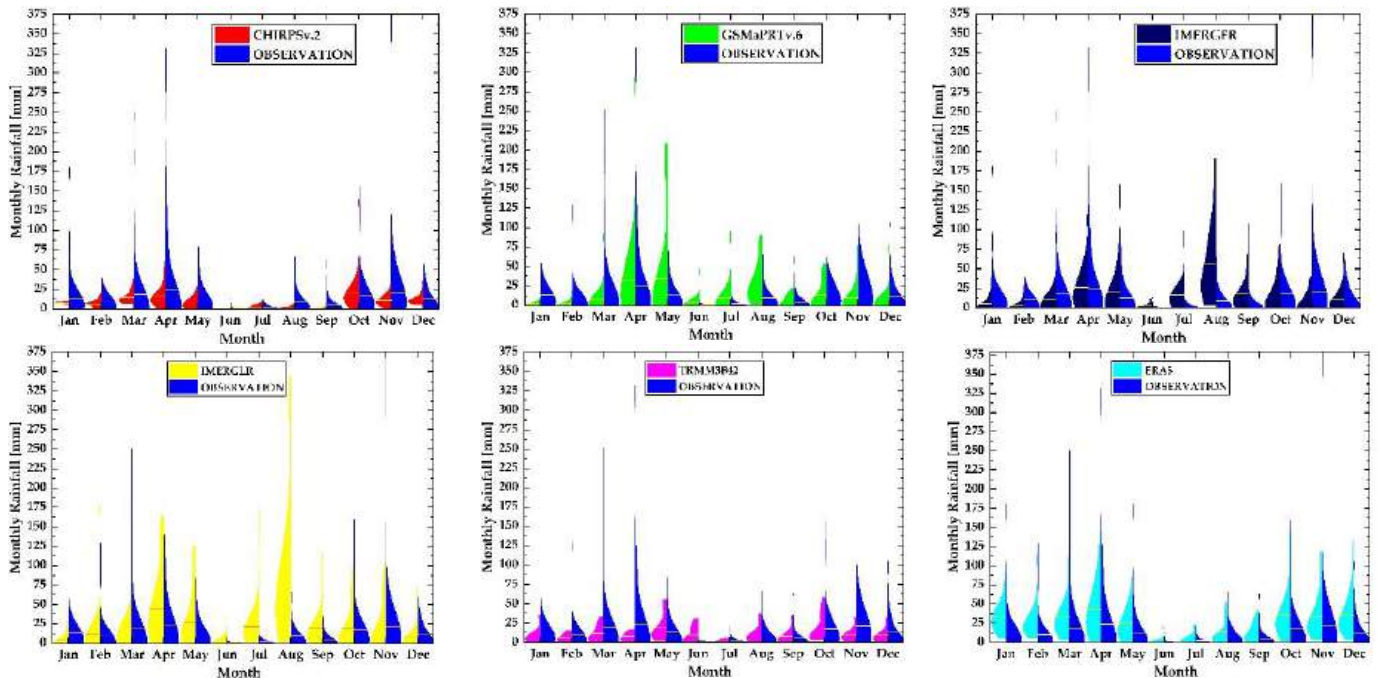


Figure S2. Empirical cumulative distribution functions (ECDF) for daily rainfall.



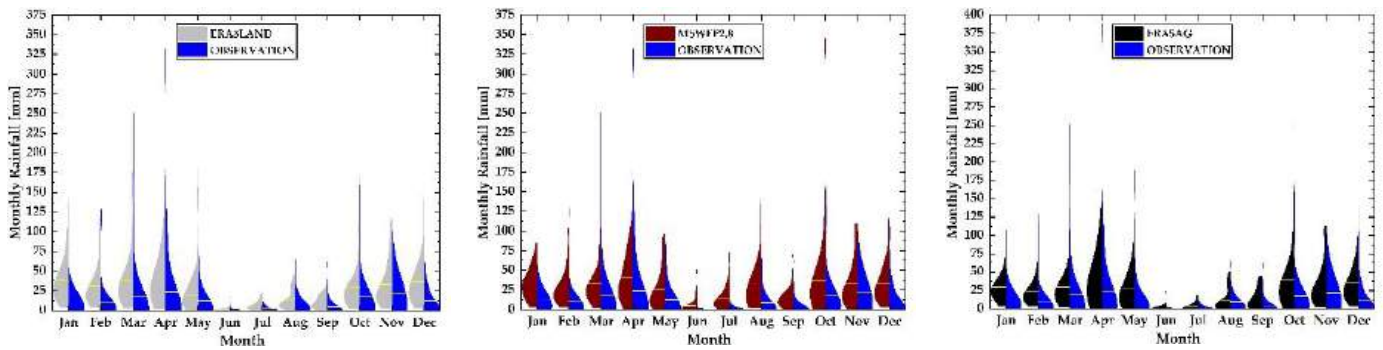


Figure S3. Violin plots illustrating the probability distributions of monthly average precipitation for the nine precipitation satellite products and outliers. The left half of each plot shows a precipitation product, while the right half presents the ground observations (indicated by OBSERVATION) from 1980 to 2021. The yellow line indicates the mean of each distribution.

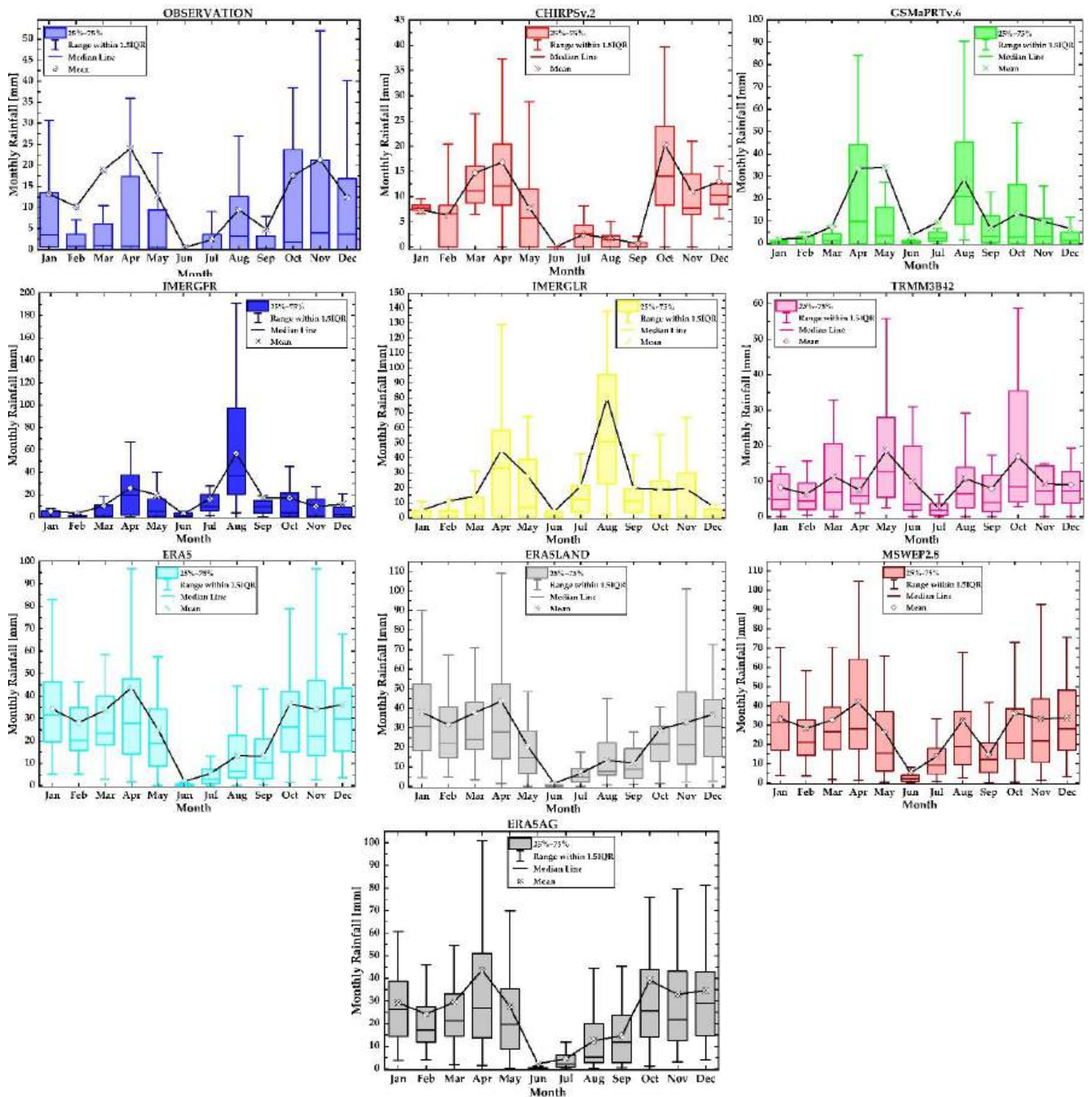


Figure S4. Boxplots summarizing the range from maximum to minimum, the interquartile range (1.5.IQR), the median and average rainfall from nine satellite product and in situ observation at Djibouti Airport from 1980 to 2021.

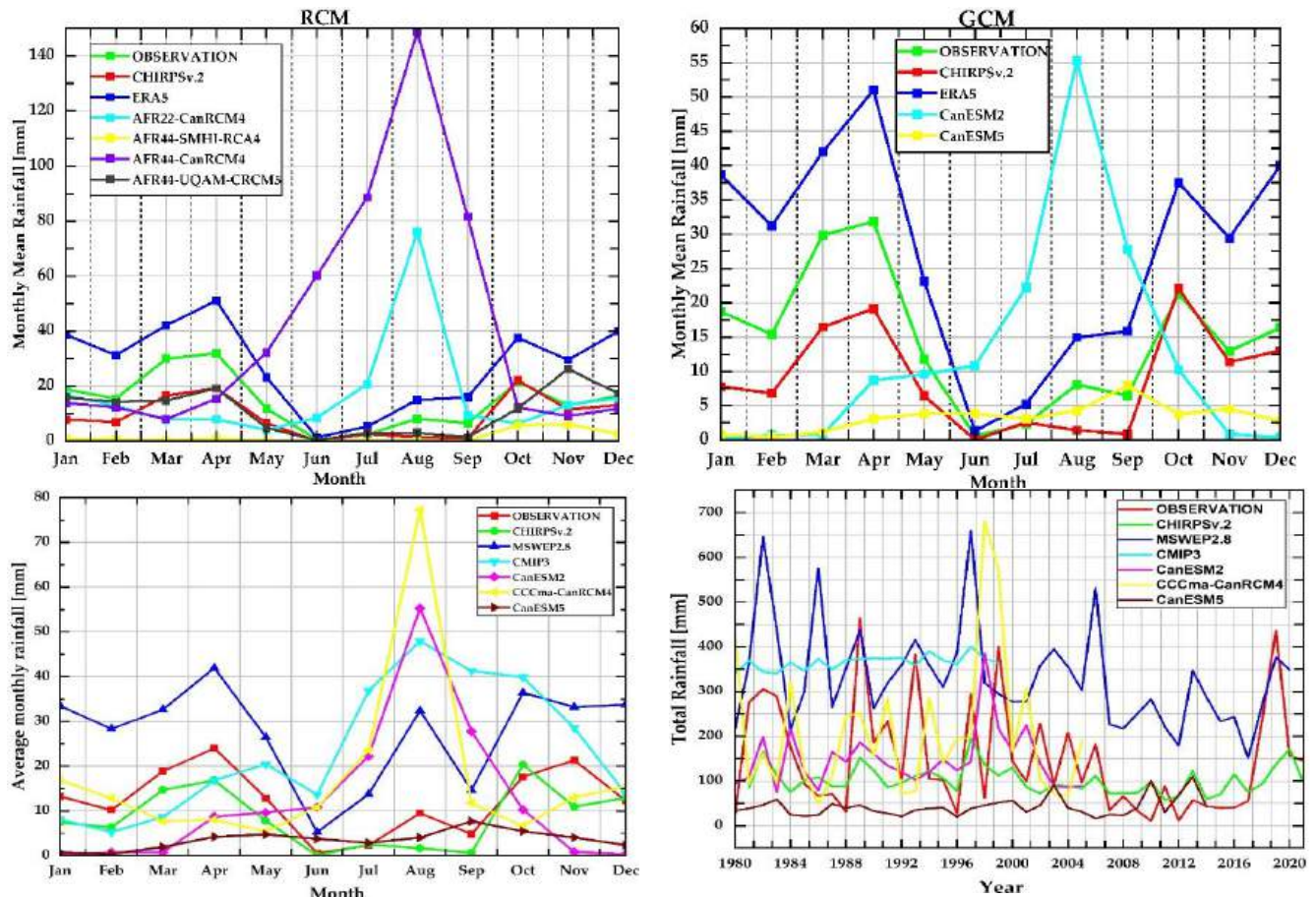


Figure S5. Comparison of variations in mean monthly observed and satellite precipitation (CHIRPSv2 and ERA5) with regional and global models from the Canadian earth system model over the period 1980 to 2005.

Table S1. Screening NCEP_NCAR and NCEP predictors from CMIP5 using conditional Partial correlation for daily precipitation observed in situ weather station at airport Djibouti and CHIRPS satellite product over the period 1961 to 2005.

Predictors	OBS		CHIRPS		Predictors	OBS		CHIRPS	
NCEP	Partial r	Pvalue	Partial r	Pvalue	NCEP_NCAR	Partial r	Pvalue	Partial r	Pvalue
ncep_dswr	-0.104	0.016	0.056	0.253	ncepmslpgl	-0.060	0.172	0.051	0.295
ncep_lftx	-0.096	0.027	-0.141	0.004	ncepp1_fgl	-0.066	0.135	-0.168	0.000
ncep_mslp	0.042	0.314	0.190	0.000	ncepp1_uvl	-0.070	0.112	-0.152	0.002
ncep_p_f	0.047	0.277	-0.170	0.000	ncepp1_vgl	-0.127	0.003	-0.062	0.214
ncep_p_u	-0.181	0.000	-0.082	0.104	ncepp1_zgl	0.077	0.079	-0.094	0.061

ncep_p__v	-0.093	0.032	-0.109	0.027	ncepp1thgl	-0.041	0.322	-0.162	0.001
ncep_p__z	-0.014	0.531	-0.084	0.094	ncepp1zhgl	-0.079	0.073	0.029	0.456
ncep_p_th	0.047	0.270	0.003	0.563	ncepp5_fgl	0.074	0.094	-0.087	0.083
ncep_p_zh	0.044	0.303	-0.039	0.386	ncepp5_ugl	0.154	0.000	0.154	0.001
ncep_p5_f	0.136	0.001	-0.006	0.560	ncepp5_vgl	0.081	0.067	0.267	0.000
ncep_p5_u	0.114	0.008	0.074	0.144	ncepp5_zgl	-0.029	0.425	0.010	0.551
ncep_p5_v	0.017	0.514	0.258	0.000	ncepp500gl	-0.176	0.000	-0.065	0.192
ncep_p5_z	-0.065	0.139	-0.072	0.150	ncepp5thgl	0.097	0.025	0.162	0.001
ncep_p5th	-0.041	0.321	-0.052	0.283	ncepp5zhgl	0.081	0.066	-0.076	0.131
ncep_p5zh	-0.007	0.554	-0.241	0.000	ncepp8_fgl	-0.026	0.455	-0.012	0.545
ncep_p8_f	0.036	0.373	-0.180	0.000	ncepp8_ugl	-0.135	0.001	-0.085	0.089
ncep_p8_u	-0.145	0.001	-0.050	0.301	ncepp8_vgl	-0.116	0.007	0.016	0.531
ncep_p8_v	-0.113	0.009	0.064	0.197	ncepp8_zgl	0.117	0.006	-0.075	0.136
ncep_p8_z	-0.021	0.490	-0.085	0.090	ncepp850gl	-0.007	0.555	0.036	0.404
ncep_p8th	0.042	0.314	0.001	0.564	ncepp8thgl	-0.140	0.001	-0.122	0.013
ncep_p8zh	0.028	0.434	-0.090	0.074	ncepp8zhgl	-0.183	0.000	0.002	0.564
ncep_p500	0.182	0.000	-0.118	0.017	ncepprcpgl	0.190	0.000	0.081	0.106
ncep_p850	0.068	0.125	0.150	0.002	ncepts500gl	0.047	0.272	0.054	0.268
ncep_pottmp	0.089	0.042	0.059	0.233	ncepts850gl	-0.018	0.506	-0.013	0.542
ncep_pr_wtr	0.073	0.097	-0.064	0.199	ncepshumgl	0.121	0.005	0.035	0.416
ncep_prec	0.136	0.001	0.134	0.006	nceptempgl	-0.003	0.563	-0.062	0.215
ncep_r500	0.007	0.555	0.079	0.116	-	-	-	-	-
ncep_r850	0.135	0.001	0.145	0.003	-	-	-	-	-
ncep_rhum	-0.026	0.455	0.050	0.303	-	-	-	-	-
ncep_shum	0.035	0.375	-0.075	0.135	-	-	-	-	-
ncep_temp	-0.001	0.564	0.040	0.375	-	-	-	-	-

612 * The values in bold and in **green** are the most significant partial correlations of the predictor variables selected
613 for the final sorting.

614 **Table S2.** Screening NCEP_NCAR and NCEP predictors from CMIP5 using conditional
615 Partial correlation for daily precipitation ERA5LAND satellite product over the period 1961 to
616 2005.

Predictor NCEP	Partial r	P value	Predictor NCEP_NCAR	Partial r	P value
ncep_dswr	-0.0670	0.0000	ncepmslpgl	0.0130	0.1621
ncep_lftx	-0.0840	0.0000	ncepp1_fgl	0.0440	0.0000
ncep_mslp	0.1500	0.0000	ncepp1_ugl	-0.0870	0.0000
ncep_p__f	0.0370	0.0000	ncepp1_vgl	0.0110	0.2033
ncep_p__u	-0.0850	0.0000	ncepp1_zgl	0.0060	0.4222
ncep_p__v	0.0530	0.0000	ncepp1thgl	-0.1230	0.0000
ncep_p__z	-0.0530	0.0000	ncepp1zhgl	0.0260	0.0026
ncep_p_th	0.0600	0.0000	ncepp5_fgl	0.0970	0.0000

ncep_p_zh	-0.0670	0.0000	ncepp5_ugl	0.2120	0.0000
ncep_p5_f	0.1070	0.0000	ncepp5_vgl	0.1000	0.0000
ncep_p5_u	0.2050	0.0000	ncepp5_zgl	-0.0380	0.0000
ncep_p5_v	0.0720	0.0000	ncepp500gl	-0.0910	0.0000
ncep_p5_z	-0.0350	0.0000	ncepp5thgl	0.1510	0.0000
ncep_p5th	-0.1330	0.0000	ncepp5zhgl	0.0160	0.0726
ncep_p5zh	-0.0820	0.0000	ncepp8_fgl	0.0790	0.0000
ncep_p8_f	0.0309	0.0000	ncepp8_ugl	-0.0760	0.0000
ncep_p8_u	-0.0460	0.0000	ncepp8_vgl	0.0330	0.0001
ncep_p8_v	0.0580	0.0000	ncepp8_zgl	0.0240	0.0059
ncep_p8_z	0.0030	0.5172	ncepp850gl	0.0490	0.0000
ncep_p8th	0.0090	0.2780	ncepp8thgl	-0.0840	0.0000
ncep_p8zh	-0.0990	0.0000	ncepp8zhgl	-0.0470	0.0000
ncep_p500	-0.0900	0.0000	ncepprcpgl	0.1050	0.0000
ncep_p850	0.0750	0.0000	nceps500gl	-0.0390	0.0000
ncep_pottmp	-0.0120	0.1757	nceps850gl	0.0450	0.0000
ncep_pr_wtr	0.0250	0.0036	ncepshumgl	0.0790	0.0000
ncep_prec	0.1030	0.0000	nceptempgl	-0.1110	0.0000
ncep_r500	-0.0080	0.3448			
ncep_r850	0.2000	0.0000			
ncep_rhum	0.0820	0.0000			
ncep_shum	-0.1080	0.0000			
ncep_temp	0.0560	0.0000			

617

618 **Table S3.** Screening NCEP predictors from CMIP6 using conditional Partial correlation for
619 daily precipitation between ERA5LAND satellite dataset and observed in situ weather station
620 at airport Djibouti over the period 1979 to 2014.

Predictors	OBS		CHIRPS		ERA5LAND	
NCEP	Partial r	Pvalue	Partial r	Pvalue	Partial r	Pvalue
mslp	-0.0740	0.0691	0.0040	0.5616	0.0280	0.0037
p1_f	-0.0340	0.3667	-0.1780	0.0000	0.0240	0.0000
p1_u	-0.0480	0.2331	-0.1740	0.0000	-0.0840	0.0000
p1_v	-0.0520	0.2040	-0.0970	0.0264	-0.0130	0.1959
p1_z	0.0080	0.5519	-0.0860	0.0507	-0.0400	0.0000
p1zh	-0.0750	0.0640	0.0050	0.5604	0.0050	0.4900
p5_f	0.0770	0.0594	-0.0710	0.1103	0.1050	0.0000
p5_u	0.1060	0.0075	0.1440	0.0006	0.2050	0.0000
p5_v	0.0240	0.4506	0.1550	0.0002	0.0870	0.0000
p5_z	-0.0070	0.5524	-0.0860	0.0490	-0.0650	0.0000

p500	-0.1490	0.0001	-0.0830	0.0598	-0.1050	0.0000
p5zh	0.0360	0.3483	-0.0420	0.3214	-0.0040	0.5153
p8_f	-0.0160	0.5142	-0.1550	0.0002	0.0490	0.0000
p8_u	-0.0210	0.4731	-0.1960	0.0000	-0.0390	0.0000
p8_v	-0.0220	0.4672	0.0660	0.1362	0.0240	0.0144
p8_z	-0.0170	0.5055	-0.0740	0.0966	0.0010	0.5611
p850	0.0270	0.4247	0.0960	0.0279	0.0890	0.0000
p8zh	-0.1530	0.0001	-0.0480	0.2682	-0.0210	0.0376
prcp	0.1490	0.0001	-0.0580	0.1859	0.0860	0.0000
s500	-0.0440	0.2696	0.0620	0.1620	-0.1030	0.0000
s850	0.0270	0.4238	-0.0710	0.1072	0.0780	0.0000
shum	0.1260	0.0013	-0.0880	0.0437	0.0620	0.0000
temp	-0.0120	0.5337	0.0060	0.5584	-0.1230	0.0000

* The values in bold and in green are the most significant partial correlations of the predictor variables selected for the final sorting of predictor variables (**bold** and **red**) for precipitation modelling in SDSM.

Table S4. Screening ECMWF-ERA5 predictors from CMIP6 using conditional Partial correlation for daily precipitation between ERA5LAND satellite dataset and observed in situ weather station at airport Djibouti over the period 1979 to 2014.

Predictors	OBS		CHIRPS		ERA5LAND	
ECMWF_ERA5	Partial r	Pvalue	Partial r	Pvalue	Partial r	Pvalue
mslp	-0.0320	0.3817	0.0810	0.0672	0.0320	0.0010
p1_f	-0.0890	0.0267	-0.0920	0.0362	0.0160	0.1181
p1_u	-0.0600	0.1399	-0.1420	0.0007	-0.0640	0.0000
p1_v	0.0260	0.4334	0.0070	0.5547	0.1230	0.0000
p1_z	-0.0490	0.2264	-0.2460	0.0000	-0.1720	0.0000
p1zh	-0.1790	0.0000	-0.0660	0.1387	-0.1730	0.0000
p5_f	0.0790	0.0513	-0.0470	0.2781	0.1210	0.0000
p5_u	0.0900	0.0251	0.1580	0.0002	0.2230	0.0000
p5_v	0.0710	0.0840	0.1500	0.0003	0.1010	0.0000
p5_z	0.0130	0.5310	-0.1470	0.0005	-0.0520	0.0000
p500	-0.1850	0.0000	-0.0680	0.1238	-0.1220	0.0000
p5zh	0.0090	0.5473	-0.1480	0.0004	-0.0920	0.0000
p8_f	-0.0080	0.5491	-0.1190	0.0053	0.0530	0.0000
p8_u	-0.0300	0.3983	-0.1200	0.0051	0.0700	0.0000
p8_v	0.0030	0.5628	0.0700	0.1155	0.1610	0.0000
p8_z	-0.0730	0.0751	-0.0390	0.3473	0.0090	0.3453
p850	-0.0460	0.2530	0.0360	0.3740	0.0560	0.0000
p8zh	-0.1160	0.0031	0.1090	0.0118	0.0220	0.0248
prcp	0.3810	0.0000	0.2170	0.0000	0.4920	0.0000
s500	-0.0880	0.0301	-0.1170	0.0063	-0.2710	0.0000

s850	-0.0300	0.4008	0.0820	0.0612	0.0530	0.0000
shum	0.1710	0.0000	0.1950	0.0000	0.2480	0.0000
temp	-0.1090	0.0057	-0.2440	0.0000	-0.2660	0.0000

* The values in bold and in green are the most significant partial correlations of the predictor variables selected for the final sorting of predictor variables (bold and red) for precipitation modelling in SDSM.

Table S5. Statistical performance measures between observed and downscaled CMIP5 and CMIP6 (by SDSM) precipitation for the calibration periods (1961-1995) and (1979-2000) respectively at Djibouti Airport gauge Station.

CMIP5		Daily scale Calibration		Monthly scale Calibration		Seasonal scale Calibration		Annual scale Calibration	
OBS	Mean	0.499		15.184		15.184		182.206	
	S.D.	5.105		39.421		12.697		130.804	
Predictors		NCEP.NCAR	NCEP	NCEP.NCAR	NCEP	NCEP.NCAR	NCEP	NCEP.CAR	NCEP
Mean		0.409	0.406	12.461	12.365	14.92	15.499	149.538	148.383
S.D.		2.154	1.692	19.776	15.183	14.289	12.5	77.621	60.728
CC		0.358	0.255	0.637	0.479	0.928	0.921	0.778	0.644
NSE		0.124	0.059	0.382	0.216	0.821	0.843	0.505	0.311
PBIAIS		0.179	0.186	0.179	0.186	0.017	-0.021	0.179	0.186
RSR		0.936	0.97	0.784	0.883	0.405	0.379	0.681	0.804
RMSE		4.778	4.952	30.905	34.819	5.144	4.816	89.109	105.114
CHIRPS	Mean	0.296		9.017		9.017		108.199	
	S.D.	1.577		10.502		7.127		25.002	
Predictors		NCEP.NCAR	NCEP	NCEP.NCAR	NCEP	NCEP.NCAR	NCEP	NCEP.NCAR	NCEP
Mean		0.303	0.293	9.208	8.921	8.766	9.221	110.494	107.053
S.D.		0.728	0.791	7.567	7.821	6.142	5.919	16.517	26.489
CC		0.076	0.119	0.627	0.535	0.959	0.772	0.445	0.431
NSE		-0.143	-0.132	0.383	0.241	0.909	0.592	0.143	-0.212
PBIAIS		-0.021	0.011	-0.021	0.011	0.028	-0.023	-0.021	0.011
RSR		1.069	1.064	0.783	0.869	0.289	0.611	0.894	1.064
RMSE		1.686	1.678	8.224	9.121	2.06	4.357	22.359	26.593
ERA5 Land	Mean	0.972		29.589		29.589		355.069	
	S.D.	3.471		35.536		16.32		123.371	
Predictors		NCEP.NCAR	NCEP	NCEP.NCAR	NCEP	NCEP.NCAR	NCEP	NCEP.NCAR	NCEP
Mean		0.908	0.831	27.634	25.307	27.634	25.307	331.612	303.682
S.D.		1.227	1.129	21.492	19.714	17.795	15.811	59.528	64.874
CC		0.321	0.256	0.642	0.584	0.952	0.945	0.375	0.366
NSE		0.101	0.059	0.408	0.325	0.872	0.817	0.092	-0.07
PBIAIS		0.066	0.145	0.066	0.145	0.066	0.145	0.066	0.145
RSR		0.948	0.97	0.769	0.821	0.343	0.409	0.939	1.02
RMSE		3.29	3.367	27.32	29.158	5.599	6.682	115.89	125.779
CMIP6		Daily scale Calibration		Monthly scale Calibration		Seasonal scale Calibration		Annual scale Calibration	
OBS	Mean	0.501		15.255		15.255		183.062	
	S.D.	5.237		38.628		11.524		133.473	
Predictors		ECMWF	NCEP	ECMWF	NCEP	ECMWF	NCEP	ECMWF	NCEP
Mean		0.448	0.41	13.649	12.473	13.857	12.755	163.792	149.677
S.D.		3.168	1.923	29.21	15.848	9.719	7.241	98.688	56.039
CC		0.486	0.076	0.807	0.538	0.9	0.759	0.71	0.696
NSE		0.222	-0.079	0.647	0.268	0.79	0.508	0.482	0.342
PBIAIS		0.105	0.182	0.105	0.182	0.092	0.164	0.105	0.182
RSR		0.882	1.039	0.593	0.854	0.438	0.672	0.702	0.791
RMSE		4.618	5.441	22.913	32.976	5.053	7.74	93.743	105.626
CHIRPS	Mean	0.312		9.484		9.484		113.811	
	S.D.	1.722		13.239		7.894		30.842	
Predictors		ECMWF	NCEP	ECMWF	NCEP	ECMWF	NCEP	ECMWF	NCEP
Mean		0.314	0.302	9.546	9.206	9.46	9.285	114.558	110.478
S.D.		1.016	0.777	11.636	8.964	6.453	7.218	26.122	21.79
CC		0.41	0.098	0.83	0.41	0.916	0.807	0.636	-0.119
NSE		0.136	-0.115	0.686	0.097	0.83	0.64	0.359	-0.68
PBIAIS		-0.007	0.029	-0.007	0.029	0.003	0.021	-0.007	0.029

RSR		0.93	1.056	0.559	0.948	0.395	0.575	0.78	0.029
RMSE		1.601	1.819	7.404	12.556	3.117	4.536	24.062	38.967
ERA5	Mean	0.94		28.605		28.605		343.258	
Land	S.D.	2.995		33.136		16.499		113.781	
Predictors		ECMWF	NCEP	ECMWF	NCEP	ECMWF	NCEP	ECMWF	NCEP
Mean		0.926	0.826	28.191	25.152	28.191	25.152	338.298	301.826
S.D.		2.718	1.198	31.598	20.297	17.767	15.522	84.696	63.707
CC		0.717	0.388	0.884	0.74	0.958	0.973	0.871	0.662
NSE		0.478	0.149	0.776	0.52	0.903	0.899	0.741	0.288
PBIAIS		0.014	0.121	0.014	0.121	0.014	0.121	0.014	0.121
RSR		0.722	0.922	0.472	0.691	0.298	0.305	0.497	0.824
RMSE		2.163	2.763	15.646	22.905	4.921	5.029	56.555	93.776

* The grey background and bold value are the highest score of Pearson correlation coefficient at each time scale.

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634 **Table S6.** Statistical performance measures between reference and before correction
635 downscaled CMIP5 and after correction downscaled CMIP6 (by SDSM) precipitation for the
636 validation periods (1996-2005) and (2001-2014) respectively at Djibouti Airport gauge Station.

BC-CMIP5		Daily scale Validation		Monthly scale Validation		Seasonnal scale Validation		Annual scale Validation	
OBS	Mean	0.452		13.758		13.758		165.09	
	S.D.	4.609		29.815		9.754		116.48	
Predictors		NCEP.NCAR	NCEP	NCEP.NCAR	NCEP	NCEP.NCAR	NCEP	NCEP.NCAR	NCEP
Mean		0.368	0.334	11.21	10.178	11.21	10.178	134.52	122.132
S.D.		1.905	2.001	15.977	16.365	9.528	9.341	55.562	49.522
CC		0.119	0.055	0.405	0.384	0.394	0.513	0.717	0.757
NSE		-0.073	-0.141	0.14	0.105	-0.259	-0.082	0.38	0.312
PBIAIS		0.185	0.26	0.185	0.26	0.185	0.26	0.185	0.26
RSR		1.036	1.068	0.924	0.942	1.074	0.996	0.747	0.787
RMSE		4.773	4.923	27.54	28.081	10.477	9.712	87.034	91.645
CHIRPS	Mean	0.295		8.972		8.972		107.66	
	S.D.	1.757		14.609		8.821		37.916	
Predictors		NCEP.NCAR	NCEP	NCEP.NCAR	NCEP	NCEP.NCAR	NCEP	NCEP.NCAR	NCEP
Mean		0.313	0.241	9.514	7.322	9.514	7.322	114.171	87.863
S.D.		0.777	0.706	7.534	6.759	6.632	4.888	17.531	11.585
CC		0.058	0.115	0.37	0.41	0.742	0.487	0.354	0.472
NSE		-0.145	-0.07	0.114	0.153	0.546	0.194	0.081	-0.108
PBIAIS		-0.06	0.184	-0.06	0.184	-0.06	0.184	-0.06	0.184
RSR		1.07	1.034	0.937	0.917	0.645	0.859	0.909	0.999
RMSE		1.879	1.817	13.693	13.392	5.69	7.581	34.479	37.863
ERA5	Mean	0.806		24.546		24.546		294.547	
Land	S.D.	2.622		28.761		15.2		88.915	
Predictors		NCEP.NCAR	NCEP	NCEP.NCAR	NCEP	NCEP.NCAR	NCEP	NCEP.NCAR	NCEP
Mean		0.892	0.817	27.168	24.86	27.168	24.86	326.014	298.324
S.D.		1.243	1.129	22.276	19.592	19.32	16.843	53.838	53.883
CC		0.339	0.327	0.558	0.606	0.753	0.783	0.167	0.492
NSE		0.096	0.096	0.256	0.362	0.265	0.507	-0.303	0.227
PBIAIS		-0.107	-0.013	-0.107	-0.013	-0.107	-0.013	-0.107	-0.013
RSR		0.951	0.951	0.859	0.796	0.821	0.672	1.083	0.834
RMSE		2.493	2.493	24.712	22.885	12.475	10.215	96.297	74.14
AC-CMIP6		Daily scale Validation		Monthly scale Validation		Seasonnal scale Validation		Annual scale Validation	
OBS	Mean	0.245		7.445		7.445		89.336	
	S.D.	2.548		16.177		5.599		70.197	
Predictors		ECMWF	NCEP	ECMWF	NCEP	ECMWF	NCEP	ECMWF	NCEP
Mean		0.325	0.458	9.904	13.931	9.904	13.931	118.847	167.168
S.D.		1.742	1.96	12.947	13.515	7.392	7.555	38.629	57.548
CC		0.277	0.018	0.477	0.189	0.481	0.163	0.78	-0.042
NSE		-0.09	-0.57	0.1	-0.543	-0.685	-2.844	0.366	-2.065
PBIAIS		-0.33	-0.871	-0.33	-0.871	-0.33	-0.871	-0.33	-0.871
RSR		1.044	1.253	0.946	1.239	1.243	1.877	0.768	1.687
RMSE		2.659	3.192	15.302	20.035	6.958	10.51	53.88	118.429
CHIRPS	Mean	0.226		6.885		6.885		82.615	
	S.D.	1.392		7.163		5.576		19.005	

Predictors	ECMWF	NCEP	ECMWF	NCEP	ECMWF	NCEP	ECMWF	NCEP
Mean	1.392	0.302	20.71	9.186	20.71	9.186	248.515	110.237
S.D.	1.392	0.766	17.695	7.625	12.306	6.188	54.434	21.058
CC	0.31	0.07	0.635	0.511	0.816	0.811	0.454	0.263
NSE	-0.408	-0.228	-6.715	-0.15	-7.974	0.382	-87.666	-2.919
PBIAIS	-2.008	-0.334	-2.008	-0.334	-2.008	-0.334	-2.008	-0.334
RSR	1.187	1.108	2.769	1.069	2.868	0.753	9.074	1.908
RMSE	1.652	1.543	19.836	7.657	15.993	4.197	172.447	36.254
ERA5	Mean	0.716		21.793		21.793		261.519
Land	S.D.	2.563		24.675		13.627		96.994
Predictors	ECMWF	NCEP	ECMWF	NCEP	ECMWF	NCEP	ECMWF	NCEP
Mean	0.709	0.819	21.585	24.921	21.585	24.921	259.025	299.047
S.D.	1.504	1.19	17.816	19.53	13.355	15.968	43.15	56.079
CC	0.549	0.248	0.774	0.625	0.908	0.831	0.752	0.592
NSE	0.3	0.013	0.597	0.346	0.818	0.517	0.47	0.19
PBIAIS	0.01	-0.143	0.01	-0.143	0.01	-0.143	0.01	-0.143
RSR	0.837	0.993	0.633	0.806	0.408	0.665	0.701	0.868
RMSE	2.144	2.545	15.625	19.894	5.562	9.069	68.016	84.144

* The grey background and bold value are the highest score of Pearson correlation coefficient at each time scale. AC: After Correction. BC: Before Correction.

Table S7. Evaluation of precipitation projections (very short term) from 2006 to 2021 under the RCP 4.5 scenario simulated at the Djibouti airport station by Canadian Earth System models derived from CMIP5, CORE-CORDEX and CMIP6.

OBSERVATION	CC	RSR	Min	Max	Mean	SD
RCP 4.5	1.000	0.000	10.8	436.3	102.194	110.418
CanESM2.NCEP	-0.216	1.094	24.112	142.885	74.514	32.078
CanESM2.NCEP.NCAR	-0.115	1.022	84.155	158.915	118.703	22.72
AFR22.CanRCM4	0.14	1.445	57.281	438.66	183.519	105.729
AFR44.CanRCM4	0.193	1.306	151.32	286.442	198.517	44.766
AFR44.UQAM.CRCM5	-0.067	1.287	3.418	260.909	41.115	66.209
AFR44.SMHI.RCA4	0.02	13.496	467.698	2989.6	1395.2	759.23
CanESM5.ECMWF	0.063	1.396	61.511	341.163	174.281	94.434
CanESM5.NCEP	-0.347	1.617	61.709	476.485	167.575	98.472
CHIRPSv.2	CC	RSR	Min	Max	Mean	SD
RCP 4.5	1.000	0.000	57.655	171.741	93.257	31.67
CanESM2.NCEP	-0.333	1.366	82.897	144.211	108.959	18.475
CanESM2.NCEP.NCAR	-0.003	1.194	80.223	141.997	110.949	13.643
AFR22.CanRCM4	-0.259	2.47	34.775	266.31	111.413	64.188
AFR44.CanRCM4	0.058	1.523	92.391	174.891	121.208	27.333
AFR44.UQAM.CRCM5	-0.071	2.696	2.069	157.92	24.886	40.074
AFR44.SMHI.RCA4	0.324	26.763	276.852	1769.66	825.889	449.422
CanESM5.ECMWF	-0.12	1.585	72.278	187.196	111.937	32.615
CanESM5.NCEP	-0.055	1.346	63.215	177.764	103.515	27.017
ERA5Land	CC	RSR	Min	Max	Mean	SD
RCP 4.5	1.000	0.000	164.635	511.741	263.953	99.281
CanESM2.NCEP	0.464	1.797	267.054	762.576	398.103	129.883
CanESM2.NCEP.NCAR	0.263	1.703	265.8	610.885	388.776	94.758
AFR22.CanRCM4	-0.074	2.36	107.129	820.393	343.22	197.736
AFR44.CanRCM4	0.105	1.615	283.001	535.707	371.269	83.722
AFR44.UQAM.CRCM5	0.157	2.362	6.393	487.955	76.894	123.824
AFR44.SMHI.RCA4	0.347	27.23	874.696	5591.11	2609.34	1419.92
CanESM5.ECMWF	-0.17	1.569	241.197	578.474	330.727	90.667
CanESM5.NCEP	-0.292	1.866	231.125	664.063	351.715	110.224

Table S8. Evaluation of precipitation projections (very short term) from 2006 to 2021 under the RCP 8.5 scenario simulated at the Djibouti airport station by Canadian Earth System models derived from CMIP5, CORE-CORDEX and CMIP6.

OBSERVATION RCP 8.5	CC	RSR	Min	Max	Mean	SD
	1.000	0.000	10.8	436.3	102.194	110.418
CanESM2.NCEP	-0.495	1.134	33.52	111.819	65.724	23.534
CanESM2.NCEP.NCAR	-0.144	1.018	73.251	141.746	109.971	22.553
AFR22.CanRCM4	-0.442	2.026	68.654	449.932	225.718	116.361
AFR44.CanRCM4	-0.299	1.543	146.893	353.73	204.385	60.264
CanESM5.ECMWF	-0.296	1.412	61.511	341.163	140.781	82.342
CanESM5.NCEP	-0.022	1.497	72.546	476.485	171.591	106.321
CHIRPSv.2 RCP 8.5	CC	RSR	Min	Max	Mean	SD
			57.655	171.741	93.257	31.67
CanESM2.NCEP	0.127	1.152	81.062	150.576	107.621	18.584
CanESM2.NCEP.NCAR	0.279	1.17	90.729	151.155	114.289	17.07
AFR22.CanRCM4	-0.395	3.027	41.68	273.152	137.032	70.642
AFR44.CanRCM4	-0.428	2.032	89.688	215.975	124.791	36.795
CanESM5.ECMWF	0.134	1.302	72.278	187.196	110.944	26.503
CanESM5.NCEP	0.123	1.21	81.949	177.764	108.446	22.169
ERA5Land RCP 8.5	CC	RSR	Min	Max	Mean	SD
			164.635	511.741	263.953	99.281
CanESM2.NCEP	0.465	1.861	235.527	678.46	405.133	132.313
CanESM2.NCEP.NCAR	0.492	1.933	242.094	675.001	408.843	145.874
AFR22.CanRCM4	-0.402	3.104	128.398	841.47	422.142	217.621
AFR44.CanRCM4	-0.384	2.093	274.721	661.551	382.244	112.706
CanESM5.ECMWF	-0.195	1.577	227.725	578.474	323.271	94.271
CanESM5.NCEP	-0.229	1.777	231.282	664.063	351.311	102.635

Table S9. Overall change of average rainfall for future climate generated using CanESM2, AFR44 and CanESM5 model RCP 4.5 scenarios.

Scenario RCP 4.5	Periods	Rainfall [mm/year]	Change [%]	Slope [mm/year]	Significance [< 0.05]
OBSERVATION	1961-2021	148.61	0.00	-0.776	0.388
	2006-2020	99.38	-33.13	11.354	0.095
CanESM2- OBS.NCEP.NCAR	2006-2100	90.82	-38.89	-0.46	<0.01
	2006-2020	120.632	-18.83	-2.246	0.089
	2020-2040	97.703	-34.26	0.2161	0.68
	2040-2060	85.004	-42.8	-0.3571	0.57
	2060-2080	79.507	-46.5	0.9663	0.127
	2080-2100	78.775	-46.99	-0.815	0.38
AFR44- CanRCM4- ERA5Land	2006-2100	437.67	194.51	1.366	0.006
	2006-2020	376.35	153.25	-5.123	0.326
	2020-2040	414.294	178.78	2.638	0.429
	2040-2060	447.274	200.97	8.204	0.101
	2060-2080	434.905	192.65	2.557	0.595
	2080-2100	488.061	228.42	9.253	0.146
	2006-2100	189.562	27.56	0.74	0.107

CanESM5- OBS.ECMWF	2006-2020	178.695	20.24	8.501	0.144
	2020-2040	180.712	21.6	0.2086	0.959
	2040-2060	150.596	1.34	3.040	0.208
	2060-2080	213.884	43.92	1.03	0.84
	2080-2100	219.192	47.5	-0.169	0.978

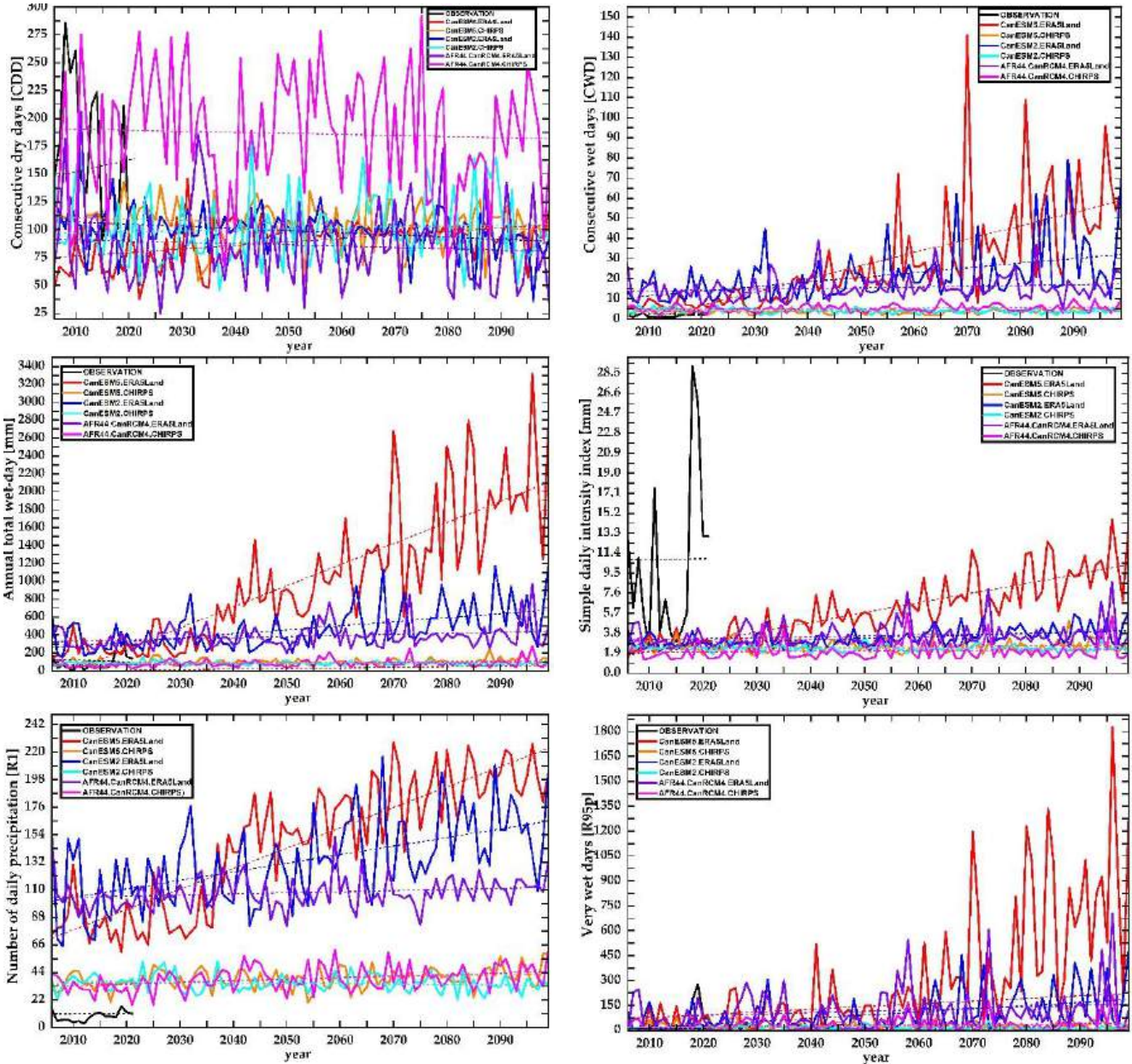
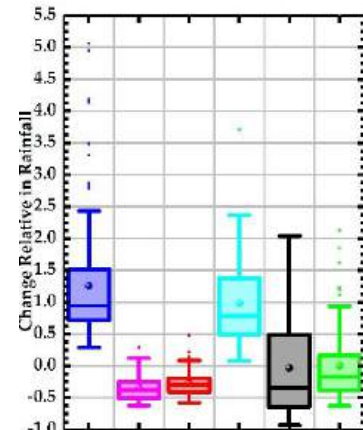
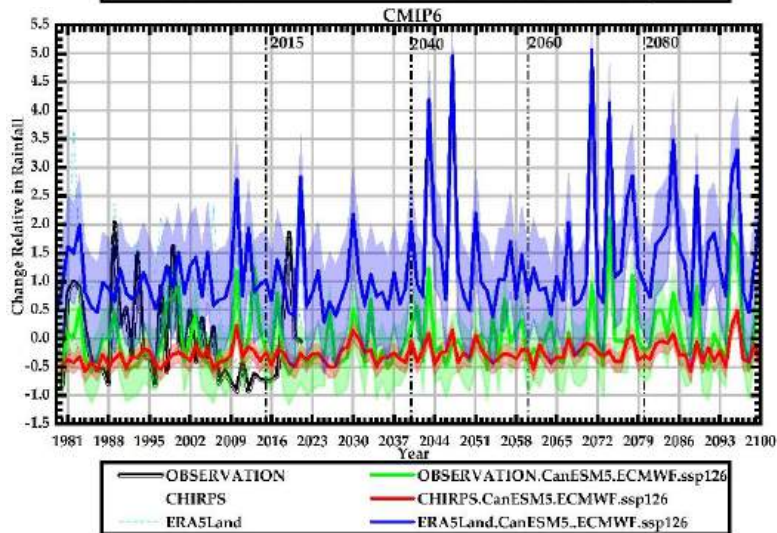
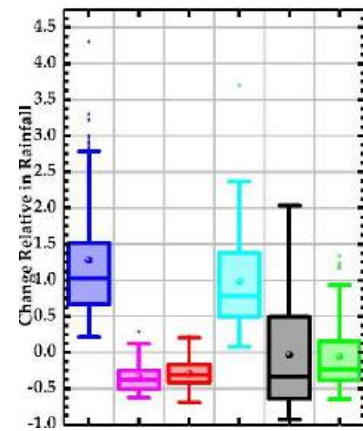
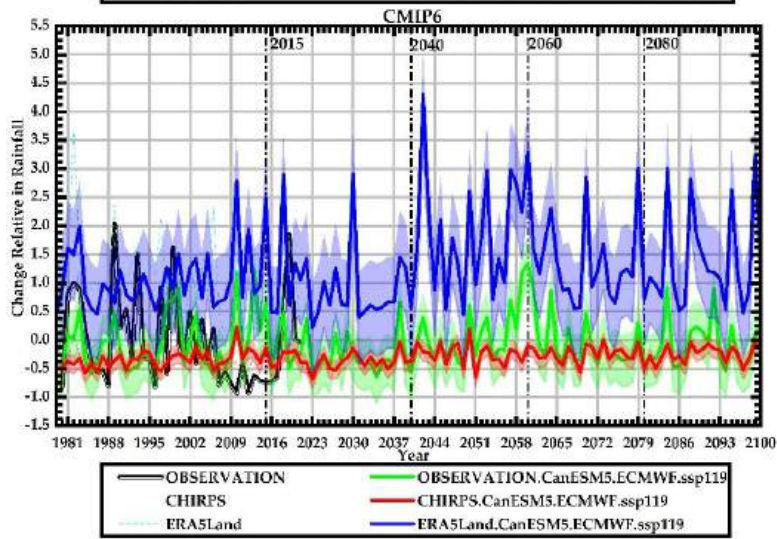
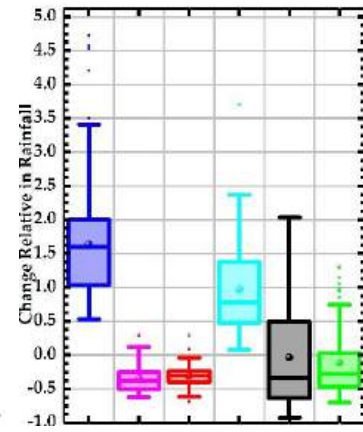
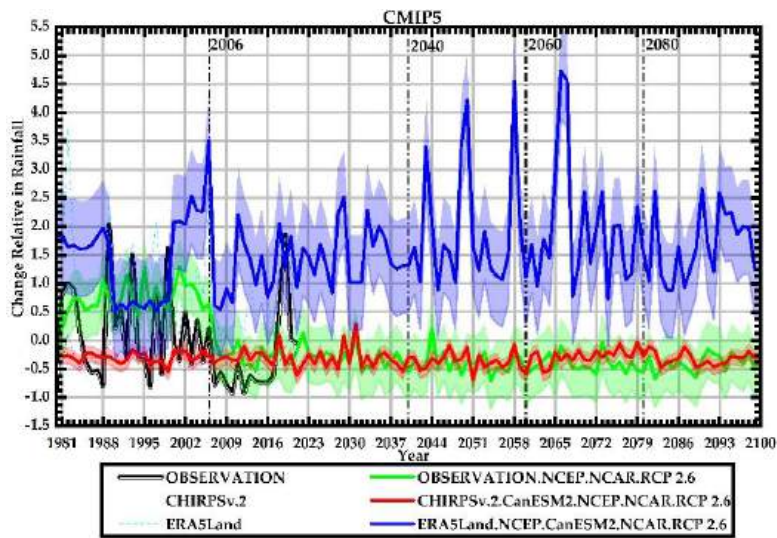


Figure S6. Variation of ETCDDI indices for projected extreme precipitation (2018-2099) at the Djibouti airport station with the CanESM2 (CHIRPS.RCP45 and ERA5Land. RCP85), CanESM5 (CHIRPS. RCP45 and ERA5Land. RCP45) and CORDEX (CHIRPS. RCP45 and ERA5Land. RCP45) models.



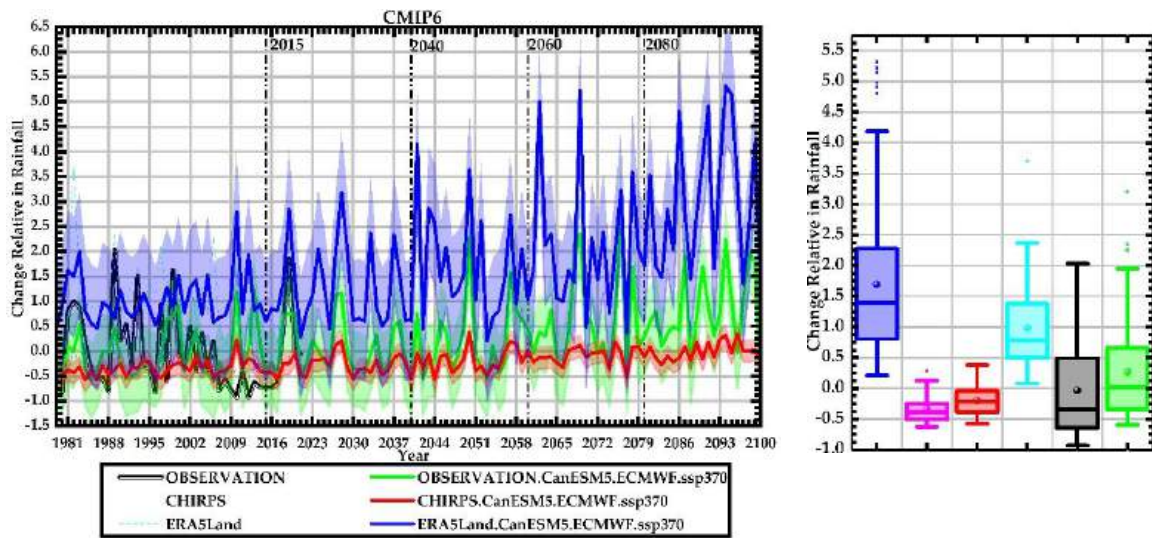


Figure S7. Projected rainfall changes relative to the baseline period 1953–2021 based on the downscaled CanESM2-CMIP5 and CanESM5-CMIP6 using Observation, CHIRPS and ERA5Land datasets. Colored shaded areas represent the areas of uncertainty (standard deviation) for the scenarios RCP1.9, RCP.2.6 and RCP.7.0 for CMIP5 and SSP1-RCP2.6, SSP3-RCP7.0 and SSP5-RCP8.5 for CMIP6. The solid sphere in the boxplot represents the mean, and the interquartile range spans from Q1 to Q3 within the box square. Horizontal lines above and below denote the minimum and maximum. Irregular dotted indicate extreme values.