

SRVALI PROJECT
CLIMATIC ATLAS OF THE REPUBLIC OF
IRAQ

AT RIVER BASIN, COUNTRY, AND TARGET
GOVERNORATES LEVELS

CLIMATIC ATLAS OF THE REPUBLIC OF IRAQ

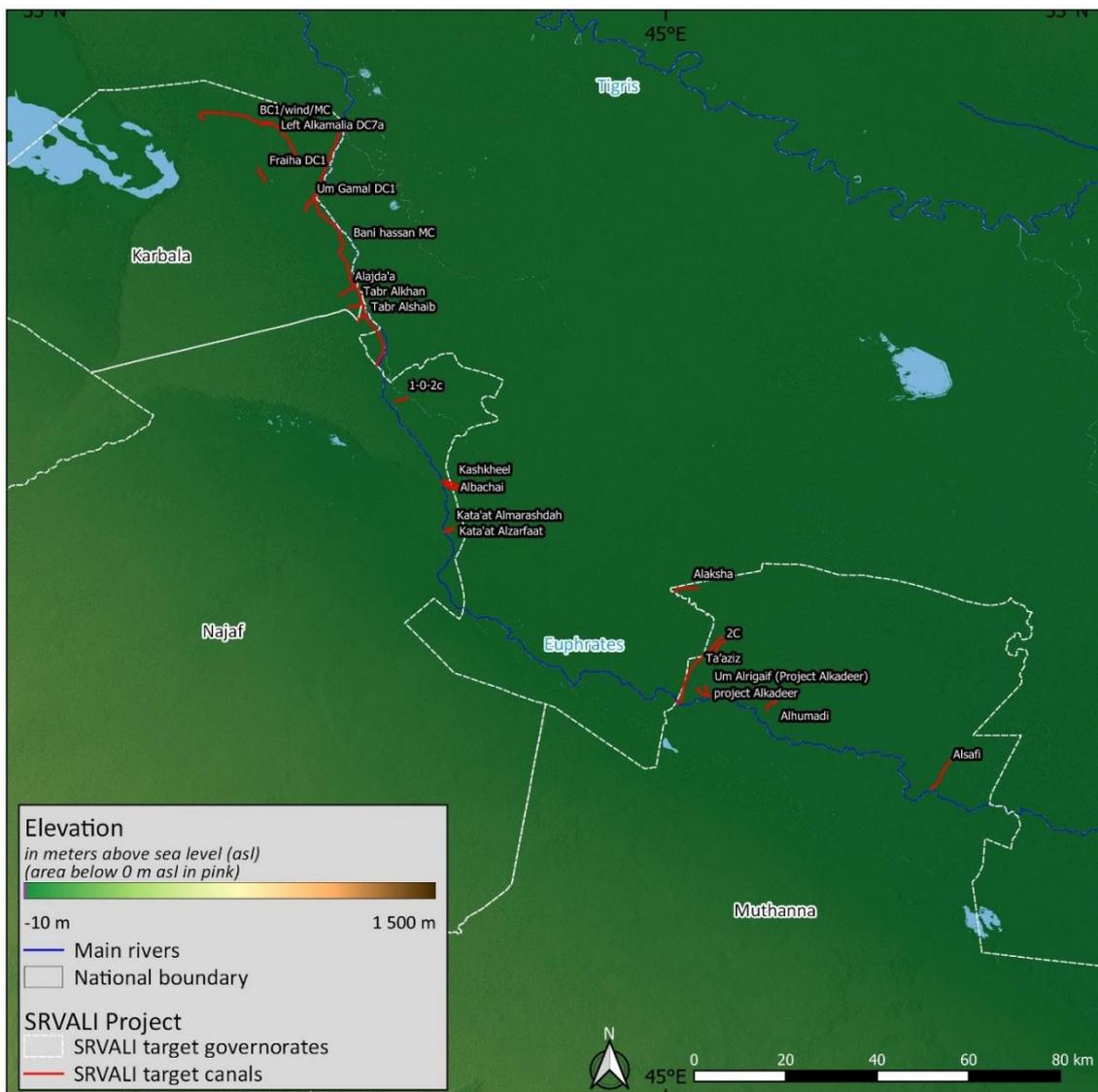
AT COUNTRY AND TARGET GOVERNORATES LEVEL

table 1 - Canal selected for intervention within the SRVALI project

Governorate	Name	District	Proposed transformation	Latitude	Longitude
Karbala	Um Gamal DC1	Al Jawal algharbi	Rehabilitation	32.5713	44.1998
	BC1/wind/MC	Al Husainiya	Solar panel	32.7234	44.1253
	Fraiha DC1	Al Husainiya	Rehabilitation	32.6367	44.0748
	Left Alkamalia DC7a	Al Husainiya	Rehabilitation	32.7291	44.1167
Muthanna	Alaksha	Najmi	Rehabilitation	31.6662	45.0217
	Alhumadi	Majd	Rehabilitation	31.3937	45.2308
	2C	Al Rumetha	Solar panel	31.5514	45.1368
	Ta'aziz	Al Rumetha	Solar panel	31.5616	45.1260
	Alsafi	Al Khudir	Solar panel	31.2123	45.6062
	Project Alkadeer	Hilal	Solar panel	31.4253	45.1024
Najaf	Um Alrigaif (Project Alkadeer)	Hilal	Rehabilitation	31.4276	45.0971
	Alajda'a	Al Haydariya	Rehabilitation	32.3632	44.2930
	Bani Hassan MC	Al Haydariya	Solar panel	32.3648	44.2934
	Tabr Alkhan	Al Haydariya	Rehabilitation	32.3263	44.3080
	Tabr Alshaib	Al Haydariya	Rehabilitation	32.2992	44.3154
	1-0-2c	Al Abassiyah	Solar panel	32.1084	44.4094
	Albachai	Al Manathra	Rehabilitation	31.9109	44.4954
	Kata'at Almarashdah	Al Mishkhaab	Rehabilitation	31.8040	44.4984
Kata'at Alzarfaat	Al Mishkhaab	Rehabilitation	31.8031	44.4985	

Figure 2 – Location of the target governorates and the 19 target canals within the SRVALI project

Data source: NASA / USGS / JPL-Caltech (Farr et al., 2007), WWF HydroSHEDS (Lehner et al., 2008; Grill et al., 2019) and JRC Yearly Water Classification History (Pekel et al., 2016).



2. Climate Data Sources & Statistical Approaches

In this chapter, we will compare 3 sources of data: 2 historical data sources, and 1 projected data source.

Historical data sources

To characterize historical climatic conditions in the Governorates Karbala, Najaf, and Muthanna in the Republic of Iraq, we will use 3 different sources of data:

- **Iraqi Ministry of Agriculture:** This database was provided by the Iraqi Ministry of Agriculture and was measured by local weather stations. The database comprises data from 9 weather stations throughout Iraq: *Afak, Al Borgism, Razzaza, Shatrah, Al Khidr, Al Mishkab, Abu Ghraib, Daquk and Bashiqaq*. Unfortunately, only 3 stations are located in the target governorates. These stations are: *Razzaza (Karbala), Al Mishkab (Najaf) and Al Khidr (Muthanna)*, see Figure 3.
- **Iraqi Meteorological Organization and Seismology:** This database was provided by the Iraqi Meteorological Organization and Seismology and was measured by local weather stations. The database comprises of data from 12 weather stations throughout Iraq: *Mosul, Kirkuk, Rutba, Baghdad, Al Hay, Qadisiyah, Nasiriyah, Basra, Najaf, Muthanna, Karbala and Khanaqin*. Unfortunately, only 3 stations are located in the target governorates. These stations are: *Najaf (Najaf), Muthanna (Muthanna) and Karbala (Karbala)*, see Figure 3.
- **ERA 5:** This data was provided by ERA5, the fifth generation ECMWF (European Centre for Medium-Range Weather Forecasts) atmospheric reanalysis of the global climate. The reanalysis combines model data with observations from across the world into a globally complete and consistent dataset (Muñoz Sabater, 2019). **This data was only used to map de spatial distribution of the climate data.**

Projected data sources

NEX: To characterize future climatic conditions in Iraq we used the NASA Earth Exchange (NEX) - Global Daily Downscaled Climate Projections (GDDP) dataset. This dataset comprise 20 downscaled climate scenarios for the globe that are derived from the General Circulation Model runs conducted under the Coupled Model Intercomparison Project Phase 5 (CMIP5, (Taylor et al., 2012)). These models are: *BNU-ESM, CCSM4, CESM1-BGC, CNRM-CM5, CSIRO-Mk3-6-0, CanESM2, GFDL-CM3, GFDL-ESM2G, GFDL-ESM2M, IPSL-CM5A-LR, IPSL-CM5A-MR, MIROC-ESM-CHEM, MIROC-ESM, MIROC5, MPI-ESM-LR, MPI-ESM-MR, MRI-CGCM3, NorESM1-M, bcc-csm1-1 and inmcm4* (Thrasher et al., 2012).

Table 2 – Location of the weather stations considered within the project

Station	ID	Organization	Governorate	Latitude	Longitude
<i>Afak</i>	1	Iraqi Ministry of Agriculture	Qadisiyah	32,07	45,23
<i>Al Borgism</i>	2	Iraqi Ministry of Agriculture	Basra	30,37	47,61
<i>Razzaza</i>	3	Iraqi Ministry of Agriculture	Karbala	32,59	43,88
<i>Shatrah</i>	4	Iraqi Ministry of Agriculture	Dhi Qar	31,41	46,17
<i>Al Khidr</i>	5	Iraqi Ministry of Agriculture	Muthanna	31,23	45,53
<i>Al Mishkab</i>	6	Iraqi Ministry of Agriculture	Najaf	31,80	44,48
<i>Abu Ghraib</i>	7	Iraqi Ministry of Agriculture	Baghdad	33,37	44,08
<i>Daquk</i>	8	Iraqi Ministry of Agriculture	Kirkuk	35,14	44,46
<i>Bashiqah</i>	9	Iraqi Ministry of Agriculture	Nineveh	36,45	43,34
<i>Mosul</i>	608	Iraqi Meteorological Organization and Seismology	Nineveh	36,42	43,18
<i>Kirkuk</i>	621	Iraqi Meteorological Organization and Seismology	Kirkuk	35,48	44,37
<i>Rutba</i>	642	Iraqi Meteorological Organization and Seismology	Anbar	33,17	40,25
<i>Baghdad</i>	650	Iraqi Meteorological Organization and Seismology	Baghdad	33,46	44,36
<i>Al Hay</i>	665	Iraqi Meteorological Organization and Seismology	Wasit	32,20	46,04
<i>Qadisiyah</i>	672	Iraqi Meteorological Organization and Seismology	Qadisiyah	31,99	44,90
<i>Nasiriyah</i>	676	Iraqi Meteorological Organization and Seismology	Dhi Qar	31,13	46,31
<i>Basra</i>	689	Iraqi Meteorological Organization and Seismology	Basra	30,61	47,71
<i>Nadjaf</i>	670	Iraqi Meteorological Organization and Seismology	Najaf	32,12	44,32
<i>Muthanna</i>	674	Iraqi Meteorological Organization and Seismology	Muthanna	31,36	45,28
<i>Karbala</i>	656	Iraqi Meteorological Organization and Seismology	Karbala	32,70	44,00
<i>Khanaqin</i>	637	Iraqi Meteorological Organization and Seismology	Diyala	34,39	45,37

Statistical Approaches

Seasonal variation: The monthly seasonal variation was computed by averaging by month the monthly time series of the considered variable over the longest period available in the past, to a maximum of 30 years (1990-2019).

Model validation: For each variable, two median models (one for each scenario) were derived from the 20 models of the NEX ensemble. These two median models were validated and used to assess the climatic trends of Serbia. The validation was performed against the observed local data, over the longest overlapping period between the observed and the projected data (2006 to 2019, 13 years). To assess the quality of the validation, the Normalized Root Mean Square Error (NRMSE) was calculated by dividing the Root Mean Square Error by the range of the values of the observed data.

Trends Statistical Significance: In this brief, the trends were calculated by computing the linear regression trends of the times series considered (monthly or annual), and by calculating the p-value of the F-Statistics corresponding to the regression. If the p-value was lower than an alpha of 0.05, the regression was considered statistically significant, and therefore reported. Otherwise, the trends were not considered significant, and no variation of the variable was reported.

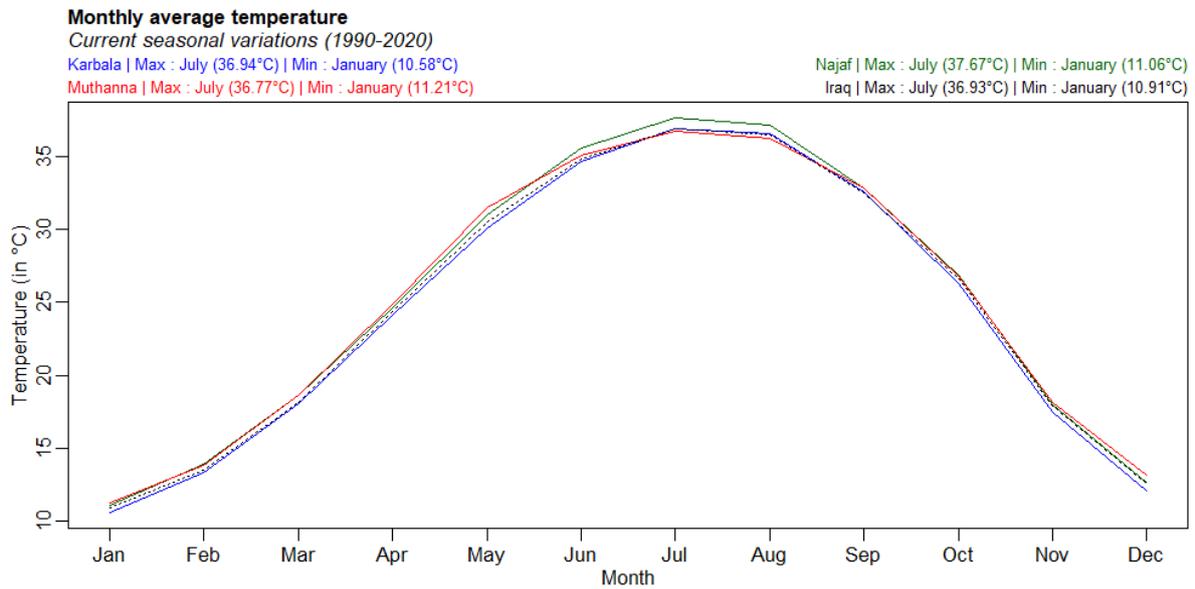
3. Average temperatures

This section will present the variations of average temperatures in the three target governorates of the project in the Republic of Iraq, focusing on **monthly average temperatures** (TG_m) and **annual average temperatures** (TG_y).

Seasonal variations

Figure 4 – Current seasonal variations of the monthly average temperature

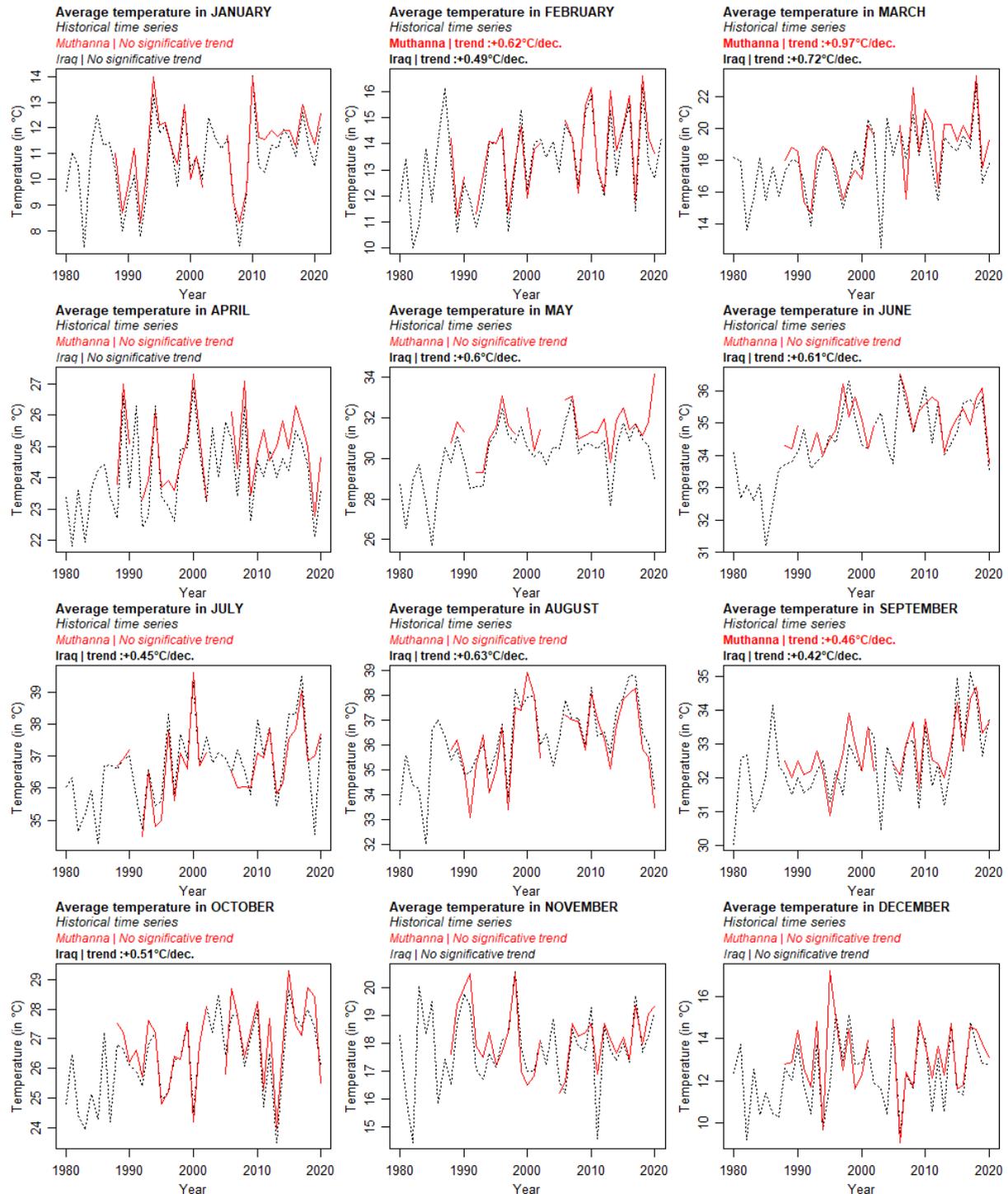
Data averaged over the 1990-2020 period. **In red:** average value over all the available weather stations located in the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **In black dashed line:** likewise, but for all Iraq. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.



Historical trends by month

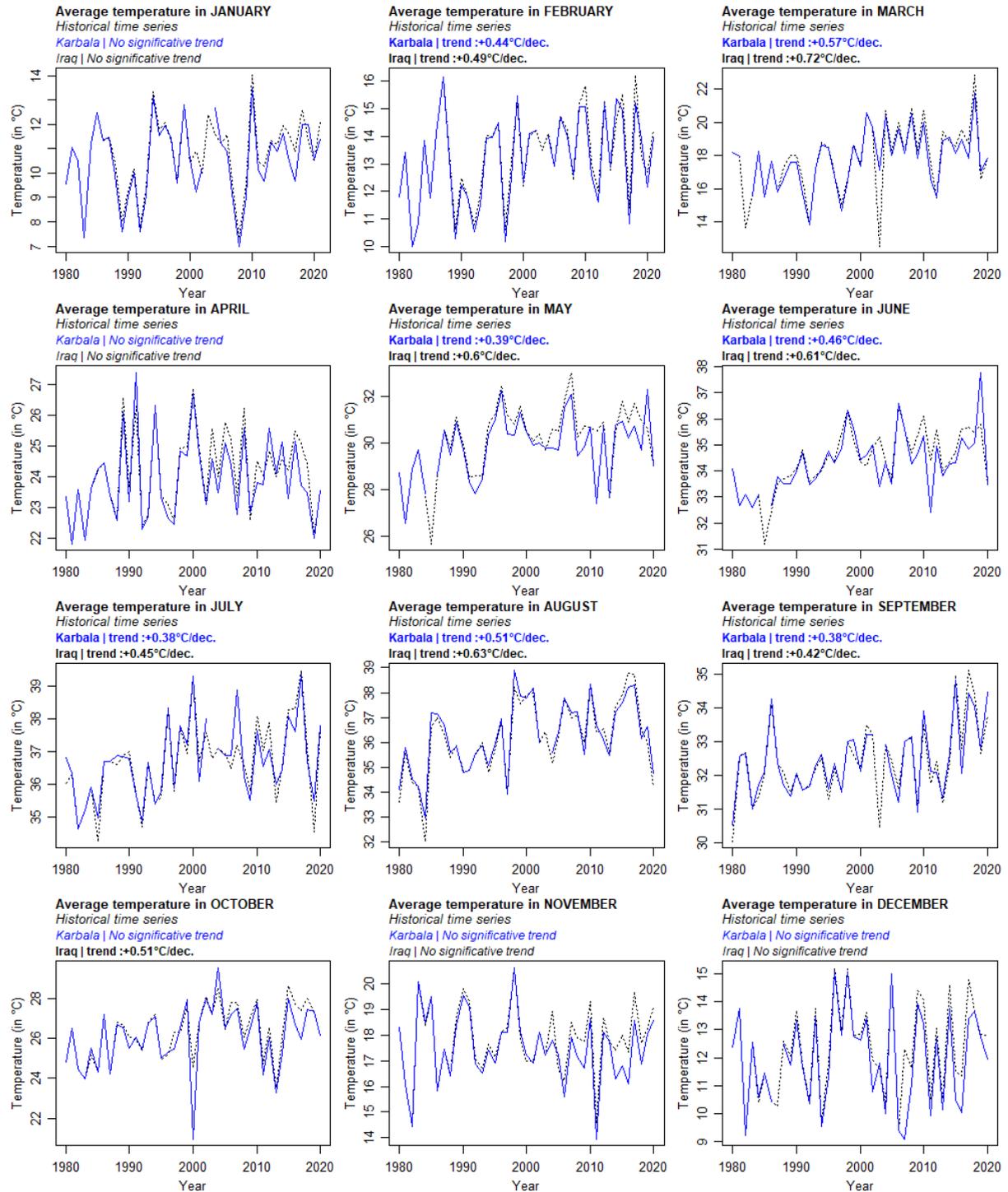
Muthanna

Figure 5 – Historical time series of the monthly average temperature by month in the governorate of Muthanna
 Time series over the 1980-2020 period. **In red:** average value over all the available weather stations located in the governorate of Muthanna. **In black dashed line:** likewise, but for all Iraq. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.



Karbala

Figure 6 – Historical time series of the monthly average temperature by month in the governorate of Karbala
Time series over the 1980-2020 period. **In blue:** average value over all the available weather stations located in the governorate of Karbala. **In black dashed line:** likewise, but for all Iraq. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.



Najaf

Figure 7 – Historical time series of the monthly average temperature by month in the governorate of Najaf
 Time series over the 1980-2020 period. **In green:** average value over all the available weather stations located in the governorate of Najaf. **In black dashed line:** likewise, but for all Iraq. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.

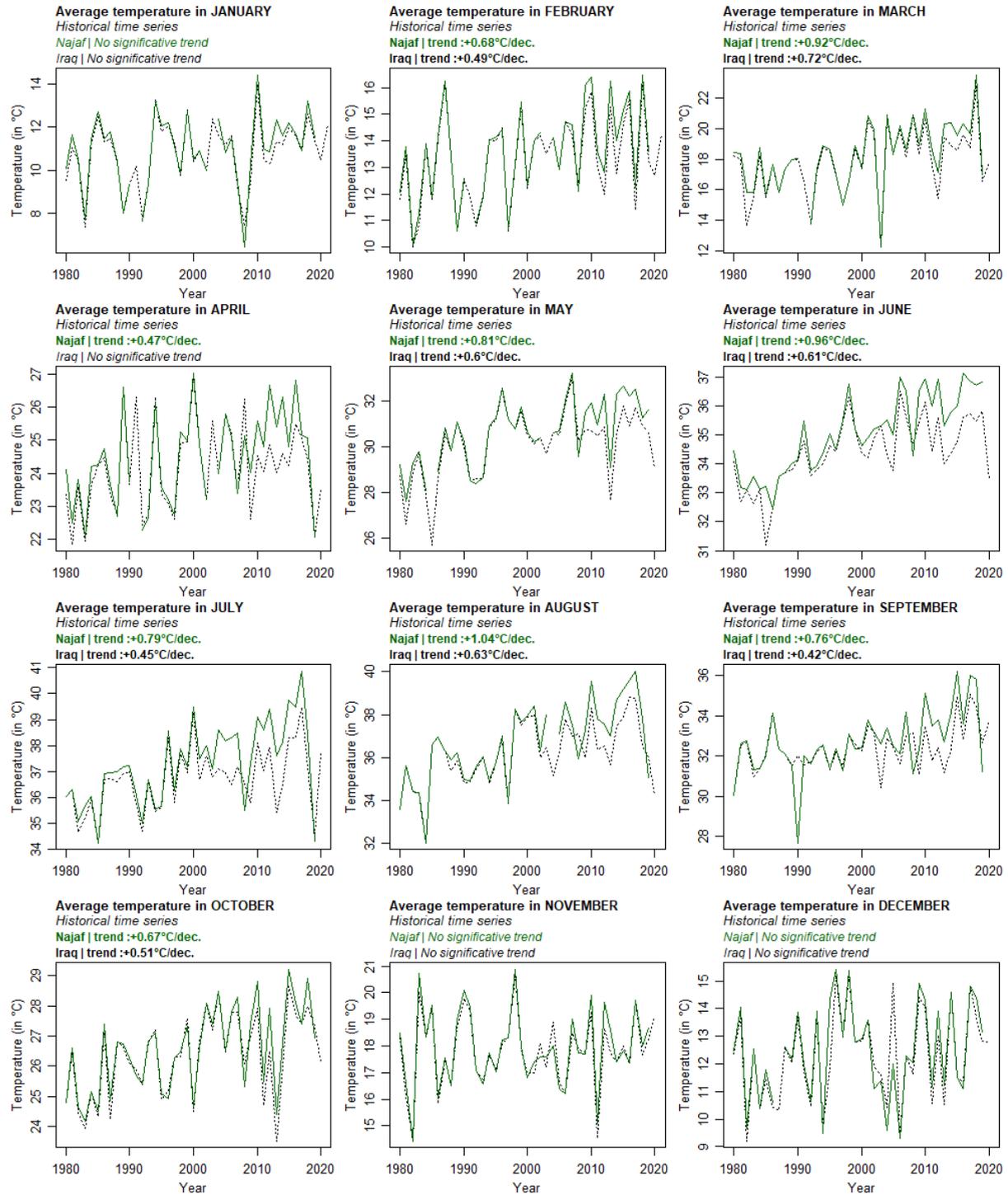


Table 3 – Characteristics of the trends from the historical time series of the average temperature by month in the three target governorates (linear models)

In red: average value over all the available weather stations located in the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **Data in grey:** the trends is statistically no significant under an alpha of 5%. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.

Governorate	Month	Slope	p-value	Adjusted R ²	Average value in 1980	Average value in 2019
Muthanna	January	+0.47°C/dec.	0.066	0.08	10.01°C	11.85°C
	February	+0.62°C/dec.	0.029	0.13	12.23°C	14.64°C
	march	+0.97°C/dec.	0.008	0.20	16.30°C	20.09°C
	April	+0.10°C/dec.	0.679	-0.03	24.66°C	25.04°C
	May	+0.36°C/dec.	0.078	0.08	30.62°C	32.03°C
	June	+0.24°C/dec.	0.083	0.07	34.47°C	35.40°C
	July	+0.37°C/dec.	0.082	0.07	35.88°C	37.31°C
	August	+0.39°C/dec.	0.159	0.04	35.30°C	36.84°C
	September	+0.46°C/dec.	0.002	0.26	31.67°C	33.46°C
	October	+0.30°C/dec.	0.222	0.02	26.11°C	27.27°C
	November	-0.05°C/dec.	0.803	-0.03	18.29°C	18.09°C
	December	+0.01°C/dec.	0.980	-0.04	13.13°C	13.17°C
Karbala	January	+0.20°C/dec.	0.312	0.00	10.10°C	10.90°C
	February	+0.44°C/dec.	0.032	0.09	12.25°C	13.99°C
	march	+0.57°C/dec.	0.012	0.13	16.64°C	18.86°C
	April	+0.12°C/dec.	0.491	-0.01	23.71°C	24.19°C
	May	+0.39°C/dec.	0.025	0.10	29.05°C	30.59°C
	June	+0.46°C/dec.	0.001	0.22	33.38°C	35.18°C
	July	+0.38°C/dec.	0.012	0.13	35.98°C	37.45°C
	August	+0.51°C/dec.	0.004	0.18	35.26°C	37.26°C
	September	+0.38°C/dec.	0.004	0.18	31.70°C	33.19°C
	October	+0.34°C/dec.	0.097	0.05	25.39°C	26.71°C
	November	-0.13°C/dec.	0.475	-0.01	17.77°C	17.26°C
	December	+0.05°C/dec.	0.814	-0.02	11.87°C	12.08°C
Najaf	January	+0.34°C/dec.	0.143	0.03	10.27°C	11.59°C
	February	+0.68°C/dec.	0.003	0.20	12.23°C	14.90°C
	march	+0.92°C/dec.	0.001	0.22	16.44°C	20.03°C
	April	+0.47°C/dec.	0.012	0.14	23.50°C	25.35°C
	May	+0.81°C/dec.	0.000	0.43	29.04°C	32.19°C
	June	+0.96°C/dec.	0.000	0.71	33.18°C	36.93°C
	July	+0.79°C/dec.	0.000	0.33	35.75°C	38.83°C
	August	+1.04°C/dec.	0.000	0.46	34.65°C	38.73°C
	September	+0.76°C/dec.	0.000	0.29	31.19°C	34.15°C
	October	+0.67°C/dec.	0.000	0.30	25.24°C	27.84°C
	November	+0.08°C/dec.	0.669	-0.02	17.76°C	18.09°C
	December	+0.27°C/dec.	0.262	0.01	11.93°C	12.99°C

Historical annual trends

Figure 8 – Historical time series of the annual average temperature in the three target governorates
 Time series over the 1980-2020 period. **In red:** average value over all the available weather stations located in the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **In black, dotted line:** likewise, but for all Iraq. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.

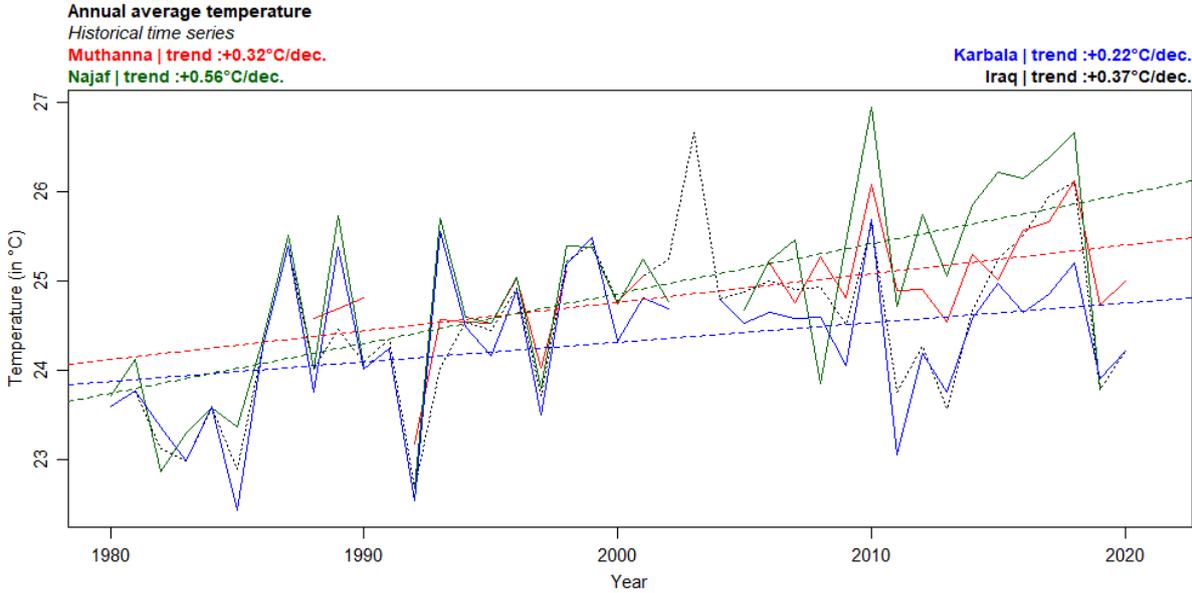


Table 4 – Characteristics of the trends from the historical time series of the annual average temperature in the three target governorates (linear models)

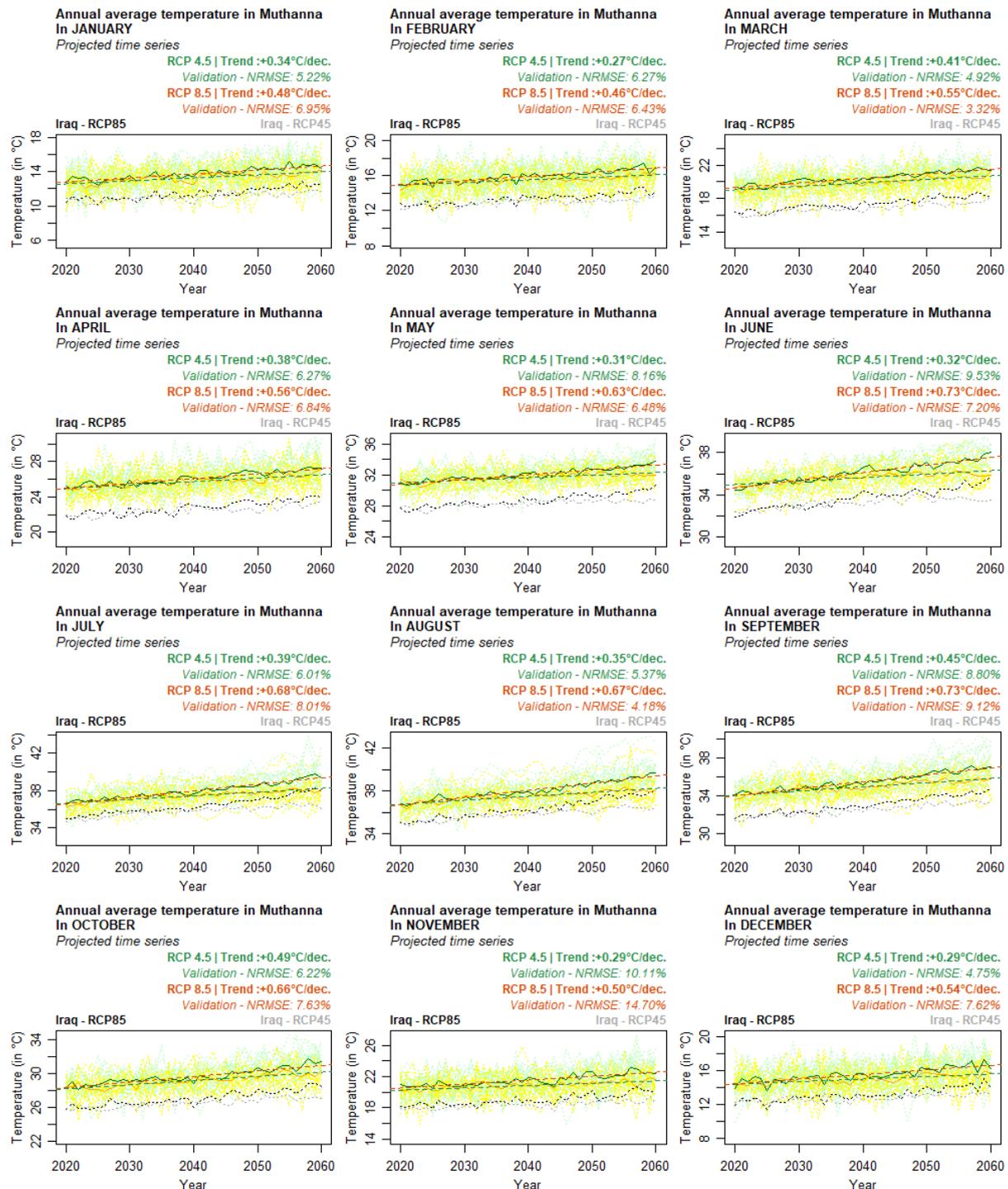
In red: average value over all the available weather stations located in the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.

governorate	Slope	p-value	R ²	Average value in 1980	Average value in 2019
Muthanna	+0.32°C/dec.	0.002	0.29	24.13°C	25.37°C
Karbala	+0.22°C/dec.	0.036	0.09	23.88°C	24.74°C
Najaf	+0.56°C/dec.	0.000	0.39	23.74°C	25.92°C

Projected trends by month

Muthanna

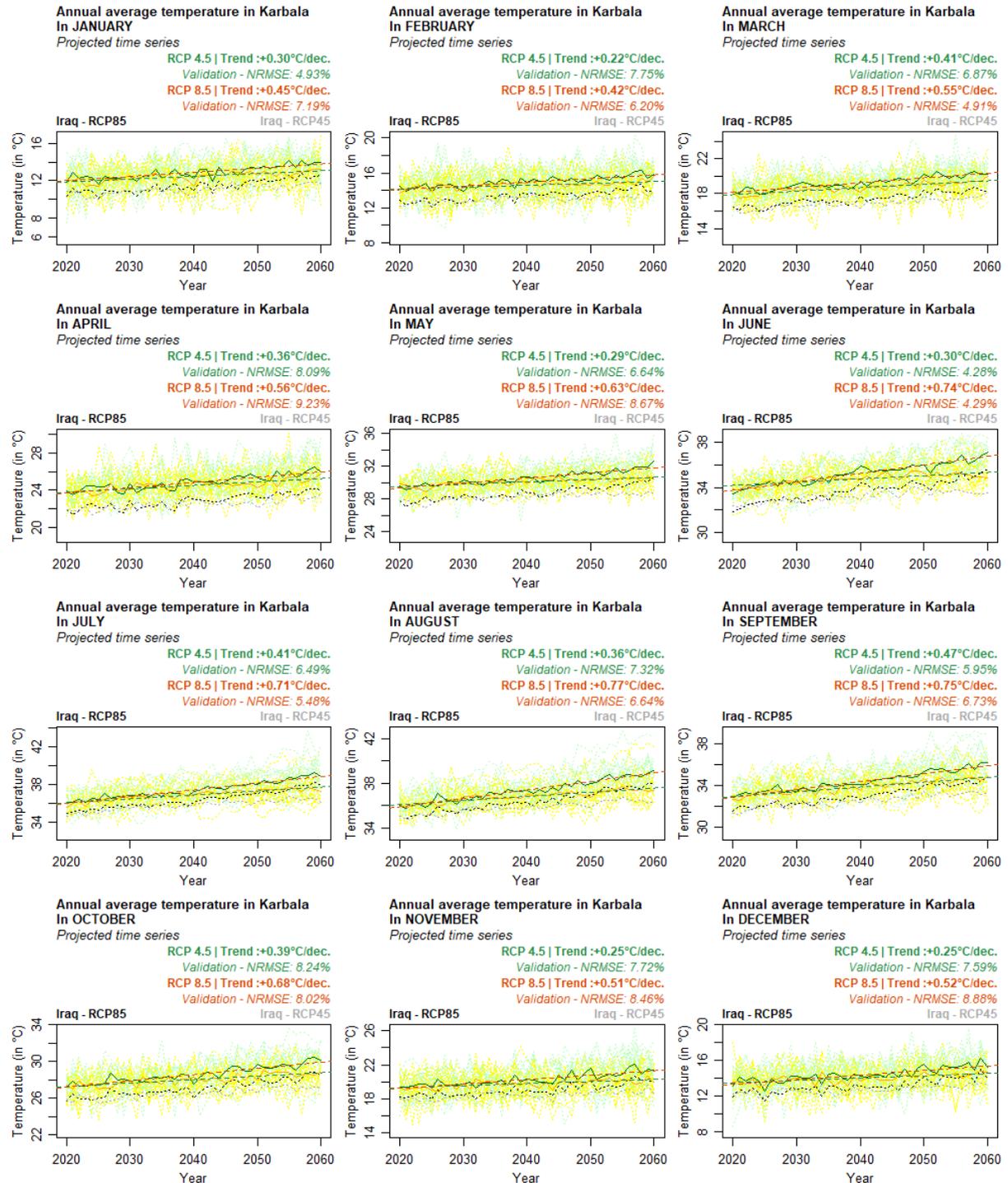
Figure 9 – Projected time series of the average temperature by month in the governorate of Muthanna
 Time series over the 2020-2060 period. **In yellow (dotted line):** value for each projected model under the RCP4.5 scenario. **In orange (full line):** median value calculated over all projected models under the RCP4.5. **In light green (dotted line):** value for each projected model under the RCP8.5. **In dark green (full line):** median value calculated over all projected models under the RCP8.5. **In grey (dotted line):** median value calculated over all projected models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all projected models under the RCP8.5 scenario within Iraq, for comparison. *Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).*



Karbala

Figure 10 – Projected time series of the average temperature by month in the governorate of Karbala

Time series over the 2020-2060 period. **In yellow (dotted line):** value for each projected model under the RCP4.5. **In orange (full line):** median value calculated over all projected models under the RCP4.5. **In light green (dotted line):** value for each projected model under the RCP8.5. **In dark green (full line):** median value calculated over all projected models under the RCP8.5. **In grey (dotted line):** median value calculated over all projected models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all projected models under the RCP8.5 scenario within Iraq, for comparison. *Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).*



Najaf

Figure 11 – Projected time series of the average temperature by month in the governorate of Najaf

Time series over the 2020-2060 period. **In yellow (dotted line):** value for each projected model under the RCP4.5. **In orange (full line):** median value calculated over all projected models under the RCP4.5. **In light green (dotted line):** value for each projected model under the RCP8.5. **In dark green (full line):** median value calculated over all projected models under the RCP8.5. **In grey (dotted line):** median value calculated over all projected models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all projected models under the RCP8.5 scenario within Iraq, for comparison. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

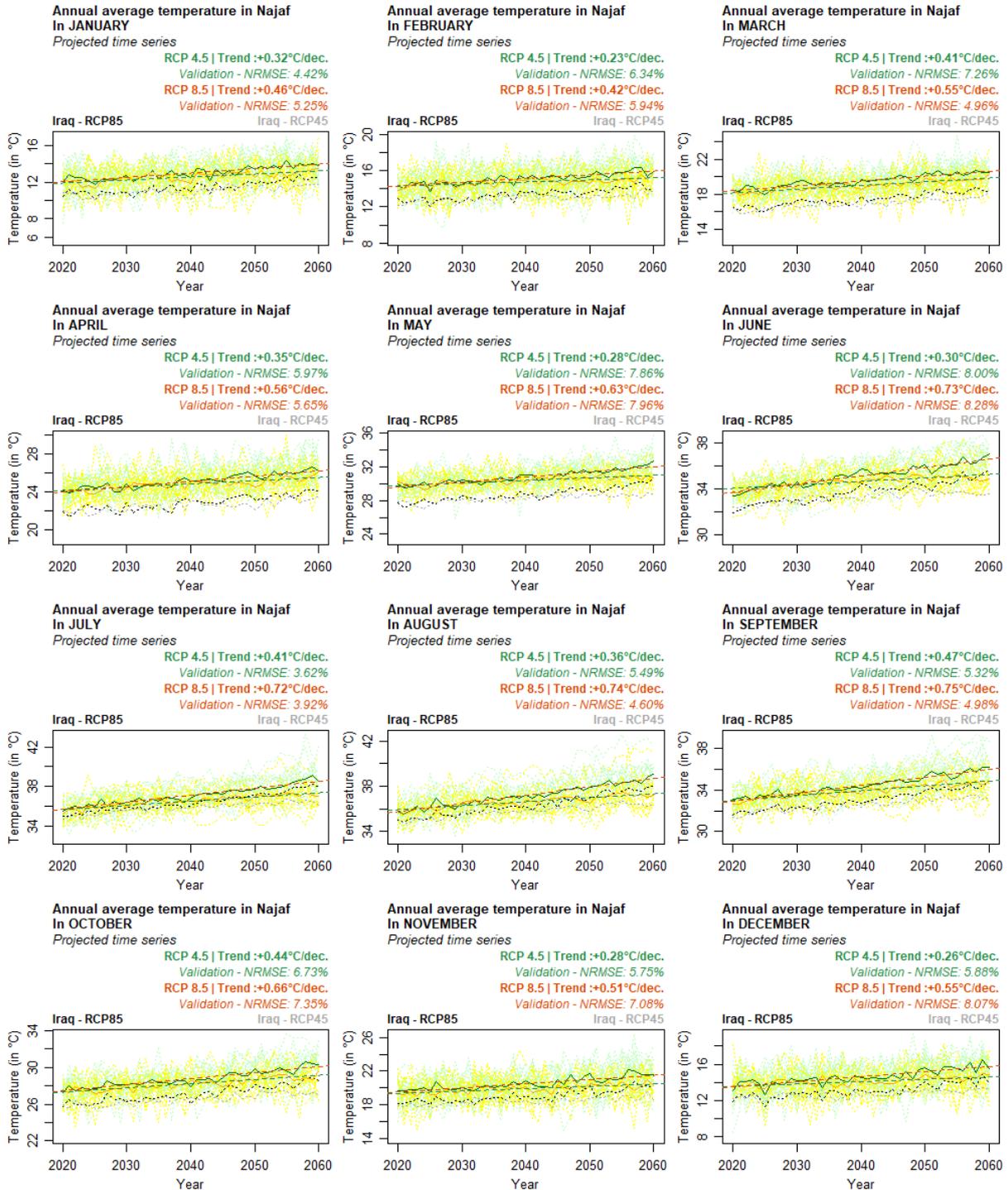


Table 5 – Characteristics of the trends from the projected time series of the average temperature by month in the three target governorates under the RCP4.5 scenario (linear models).

In red: median values calculated over all projected models under the RCP4.5 scenario within the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **Data in grey:** the trends is statistically no significant under an alpha of 5%. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

RCP4.5							
governorate	Month	Slope	P-value	R ²	Validation (NRMSE)	Average value in 2040	Average value in 2060
Muthanna	January	+0.34°C/dec.	0.000	0.58	5.22%	13.27°C	13.96°C
	February	+0.27°C/dec.	0.000	0.54	6.27%	15.53°C	16.08°C
	march	+0.41°C/dec.	0.000	0.77	4.92%	19.91°C	20.73°C
	April	+0.38°C/dec.	0.000	0.64	6.27%	25.76°C	26.52°C
	May	+0.31°C/dec.	0.000	0.60	8.16%	31.66°C	32.29°C
	June	+0.32°C/dec.	0.000	0.72	9.53%	35.61°C	36.25°C
	July	+0.39°C/dec.	0.000	0.86	6.01%	37.44°C	38.23°C
	August	+0.35°C/dec.	0.000	0.81	5.37%	37.49°C	38.19°C
	September	+0.45°C/dec.	0.000	0.78	8.80%	34.99°C	35.90°C
	October	+0.49°C/dec.	0.000	0.77	6.22%	29.19°C	30.17°C
	November	+0.29°C/dec.	0.000	0.54	10.11%	20.91°C	21.49°C
	December	+0.29°C/dec.	0.000	0.49	4.75%	14.97°C	15.55°C
Karbala	January	+0.30°C/dec.	0.000	0.56	4.93%	12.45°C	13.06°C
	February	+0.22°C/dec.	0.000	0.40	7.75%	14.62°C	15.06°C
	march	+0.41°C/dec.	0.000	0.75	6.87%	18.69°C	19.51°C
	April	+0.36°C/dec.	0.000	0.57	8.09%	24.53°C	25.24°C
	May	+0.29°C/dec.	0.000	0.60	6.64%	30.12°C	30.70°C
	June	+0.30°C/dec.	0.000	0.61	4.28%	34.78°C	35.38°C
	July	+0.41°C/dec.	0.000	0.82	6.49%	36.94°C	37.75°C
	August	+0.36°C/dec.	0.000	0.82	7.32%	36.82°C	37.54°C
	September	+0.47°C/dec.	0.000	0.80	5.95%	33.90°C	34.85°C
	October	+0.39°C/dec.	0.000	0.66	8.24%	28.02°C	28.80°C
	November	+0.25°C/dec.	0.000	0.42	7.72%	19.72°C	20.22°C
	December	+0.25°C/dec.	0.000	0.43	7.59%	13.97°C	14.48°C
Najaf	January	+0.32°C/dec.	0.000	0.54	4.42%	12.57°C	13.21°C
	February	+0.23°C/dec.	0.000	0.42	6.34%	14.71°C	15.16°C
	march	+0.41°C/dec.	0.000	0.77	7.26%	18.98°C	19.80°C
	April	+0.35°C/dec.	0.000	0.60	5.97%	24.78°C	25.48°C
	May	+0.28°C/dec.	0.000	0.60	7.86%	30.40°C	30.97°C
	June	+0.30°C/dec.	0.000	0.65	8.00%	34.60°C	35.21°C
	July	+0.41°C/dec.	0.000	0.82	3.62%	36.53°C	37.35°C
	August	+0.36°C/dec.	0.000	0.80	5.49%	36.64°C	37.36°C
	September	+0.47°C/dec.	0.000	0.83	5.32%	33.91°C	34.85°C
	October	+0.44°C/dec.	0.000	0.72	6.73%	28.20°C	29.09°C
	November	+0.28°C/dec.	0.000	0.50	5.75%	19.89°C	20.46°C
	December	+0.26°C/dec.	0.000	0.45	5.88%	14.13°C	14.64°C

Table 6 – Characteristics of the trends from the projected time series of the average temperature by month in the three target governorates under the RCP8.5 scenario (linear models).

In red: median values calculated over all projected models under the RCP8.5 scenario within the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **Data in grey:** the trends is statistically no significant under an alpha of 5%. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

RCP8.5							
governorate	Month	Slope	p-value	R ²	Validation (NRMSE)	Average value in 2040	Average value in 2060
Muthanna	January	+0.48°C/dec.	0.000	0.75	6.95%	13.71°C	14.67°C
	February	+0.46°C/dec.	0.000	0.73	6.43%	15.94°C	16.86°C
	march	+0.55°C/dec.	0.000	0.86	3.32%	20.42°C	21.51°C
	April	+0.56°C/dec.	0.000	0.84	6.84%	26.11°C	27.23°C
	May	+0.63°C/dec.	0.000	0.88	6.48%	32.05°C	33.30°C
	June	+0.73°C/dec.	0.000	0.91	7.20%	36.12°C	37.58°C
	July	+0.68°C/dec.	0.000	0.93	8.01%	37.99°C	39.36°C
	August	+0.67°C/dec.	0.000	0.93	4.18%	38.04°C	39.39°C
	September	+0.73°C/dec.	0.000	0.93	9.12%	35.55°C	37.01°C
	October	+0.66°C/dec.	0.000	0.83	7.63%	29.69°C	31.00°C
	November	+0.50°C/dec.	0.000	0.71	14.70%	21.56°C	22.56°C
	December	+0.54°C/dec.	0.000	0.67	7.62%	15.47°C	16.55°C
Karbala	January	+0.45°C/dec.	0.000	0.67	7.19%	12.88°C	13.79°C
	February	+0.42°C/dec.	0.000	0.69	6.20%	14.97°C	15.82°C
	march	+0.55°C/dec.	0.000	0.83	4.91%	19.24°C	20.34°C
	April	+0.56°C/dec.	0.000	0.76	9.23%	24.84°C	25.95°C
	May	+0.63°C/dec.	0.000	0.84	8.67%	30.56°C	31.83°C
	June	+0.74°C/dec.	0.000	0.90	4.29%	35.25°C	36.74°C
	July	+0.71°C/dec.	0.000	0.93	5.48%	37.47°C	38.89°C
	August	+0.77°C/dec.	0.000	0.93	6.64%	37.36°C	38.90°C
	September	+0.75°C/dec.	0.000	0.93	6.73%	34.42°C	35.93°C
	October	+0.68°C/dec.	0.000	0.83	8.02%	28.61°C	29.96°C
	November	+0.51°C/dec.	0.000	0.69	8.46%	20.27°C	21.28°C
	December	+0.52°C/dec.	0.000	0.67	8.88%	14.39°C	15.42°C
Najaf	January	+0.46°C/dec.	0.000	0.71	5.25%	12.99°C	13.91°C
	February	+0.42°C/dec.	0.000	0.69	5.94%	15.10°C	15.94°C
	march	+0.55°C/dec.	0.000	0.83	4.96%	19.49°C	20.60°C
	April	+0.56°C/dec.	0.000	0.84	5.65%	25.11°C	26.24°C
	May	+0.63°C/dec.	0.000	0.88	7.96%	30.82°C	32.08°C
	June	+0.73°C/dec.	0.000	0.90	8.28%	35.12°C	36.59°C
	July	+0.72°C/dec.	0.000	0.93	3.92%	37.09°C	38.53°C
	August	+0.74°C/dec.	0.000	0.93	4.60%	37.21°C	38.69°C
	September	+0.75°C/dec.	0.000	0.93	4.98%	34.47°C	35.96°C
	October	+0.66°C/dec.	0.000	0.85	7.35%	28.74°C	30.06°C
	November	+0.51°C/dec.	0.000	0.72	7.08%	20.52°C	21.54°C
	December	+0.55°C/dec.	0.000	0.71	8.07%	14.60°C	15.71°C

Projected annual trends

Figure 12 – Projected time series of the annual average temperature in the three target governorates
 Time series over the 2020-2060 period. **In yellow (dotted line):** value for each projected model under the RCP4.5. **In orange (full line):** median value calculated over all projected models under the RCP4.5. **In light green (dotted line):** value for each projected model under the RCP8.5. **In dark green (full line):** median value calculated over all projected models under the RCP8.5. **In grey (dotted line):** median value calculated over all projected models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all projected models under the RCP8.5 scenario within Iraq, for comparison. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

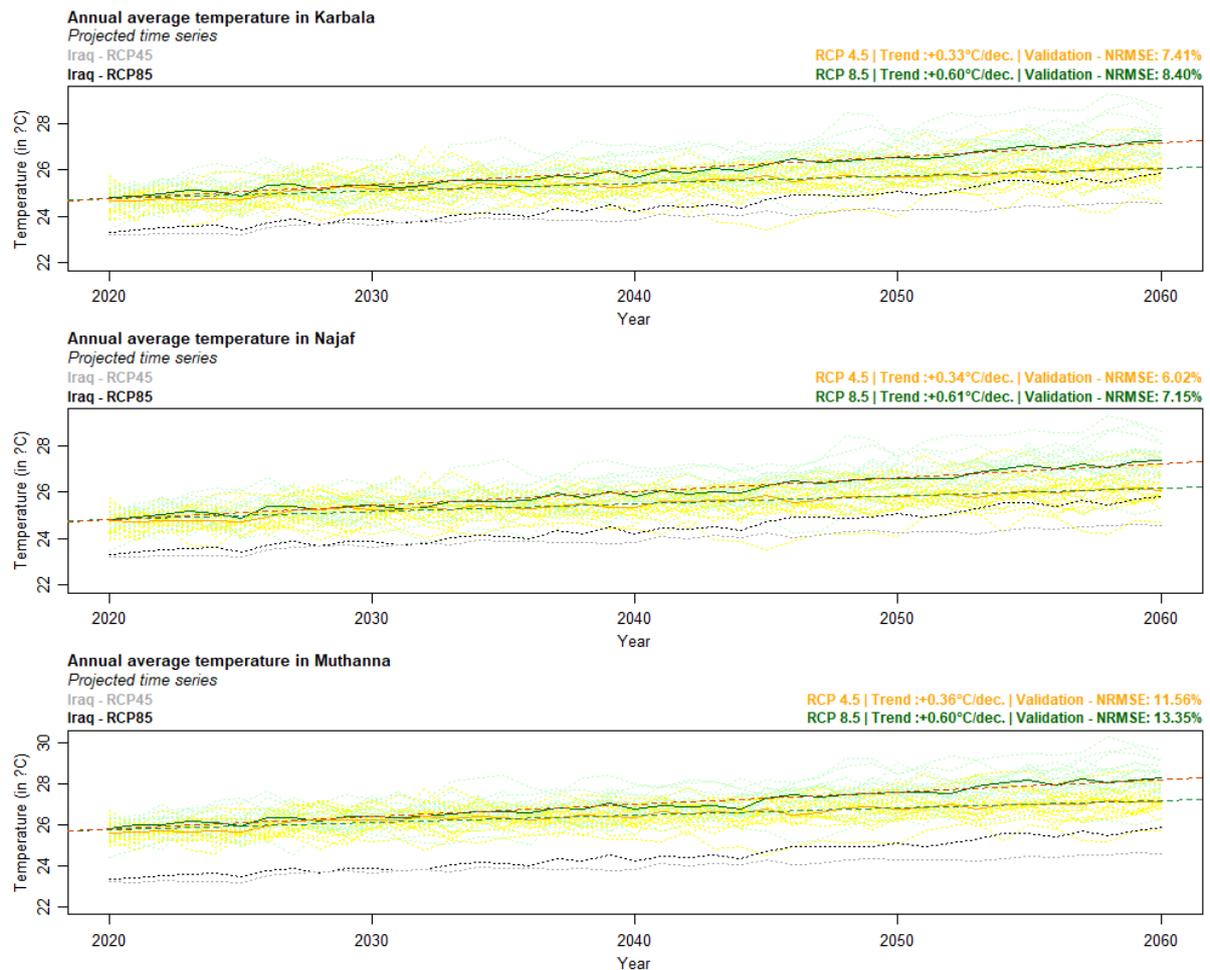


Table 7 – Characteristics of the trends from the projected time series of the annual average temperature in the three target governorates (linear models).

In red: median values calculated over all NEX models within the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **Data in grey:** the trends is statistically no significant under an alpha of 5%. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

RCP4.5						
governorate	Slope	p-value	R ²	Validation (NRMSE)	Average value in 2040	Average value in 2060
Muthanna	+0.36°C/dec.	0.000	0.92	11.56%	26.43°C	27.15°C
Karbala	+0.33°C/dec.	0.000	0.93	7.41%	25.42°C	26.08°C
Najaf	+0.34°C/dec.	0.000	0.93	6.02%	25.48°C	26.17°C
RCP8.5						
governorate	Slope	p-value	R ²	Validation (NRMSE)	Average value in 2040	Average value in 2060
Muthanna	+0.60°C/dec.	0.000	0.96	13.35%	26.96°C	28.16°C
Karbala	+0.60°C/dec.	0.000	0.97	8.40%	25.94°C	27.14°C
Najaf	+0.61°C/dec.	0.000	0.97	7.15%	26.01°C	27.23°C

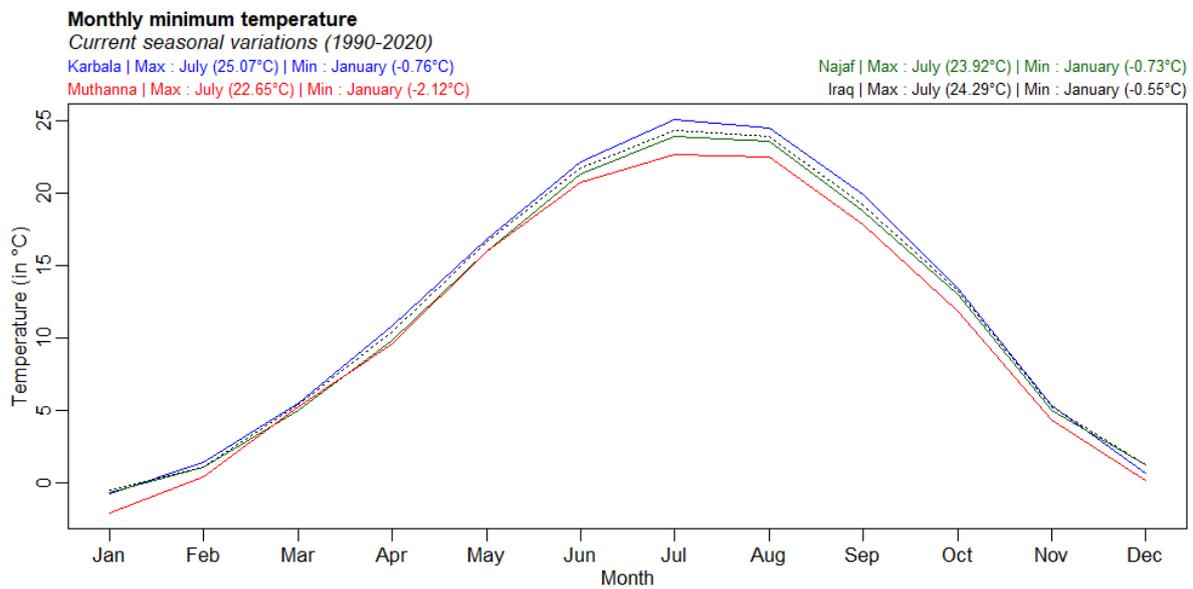
4. Minimum temperatures

This section will present the variations of minimum temperatures in the three target governorates of the project in the Republic of Iraq, focusing on **monthly minimum temperatures** (T_{N_m}) and **annual minimum temperatures** (T_{N_y}).

Seasonal variations

Figure 13 – Current seasonal variations of the average monthly minimum temperature

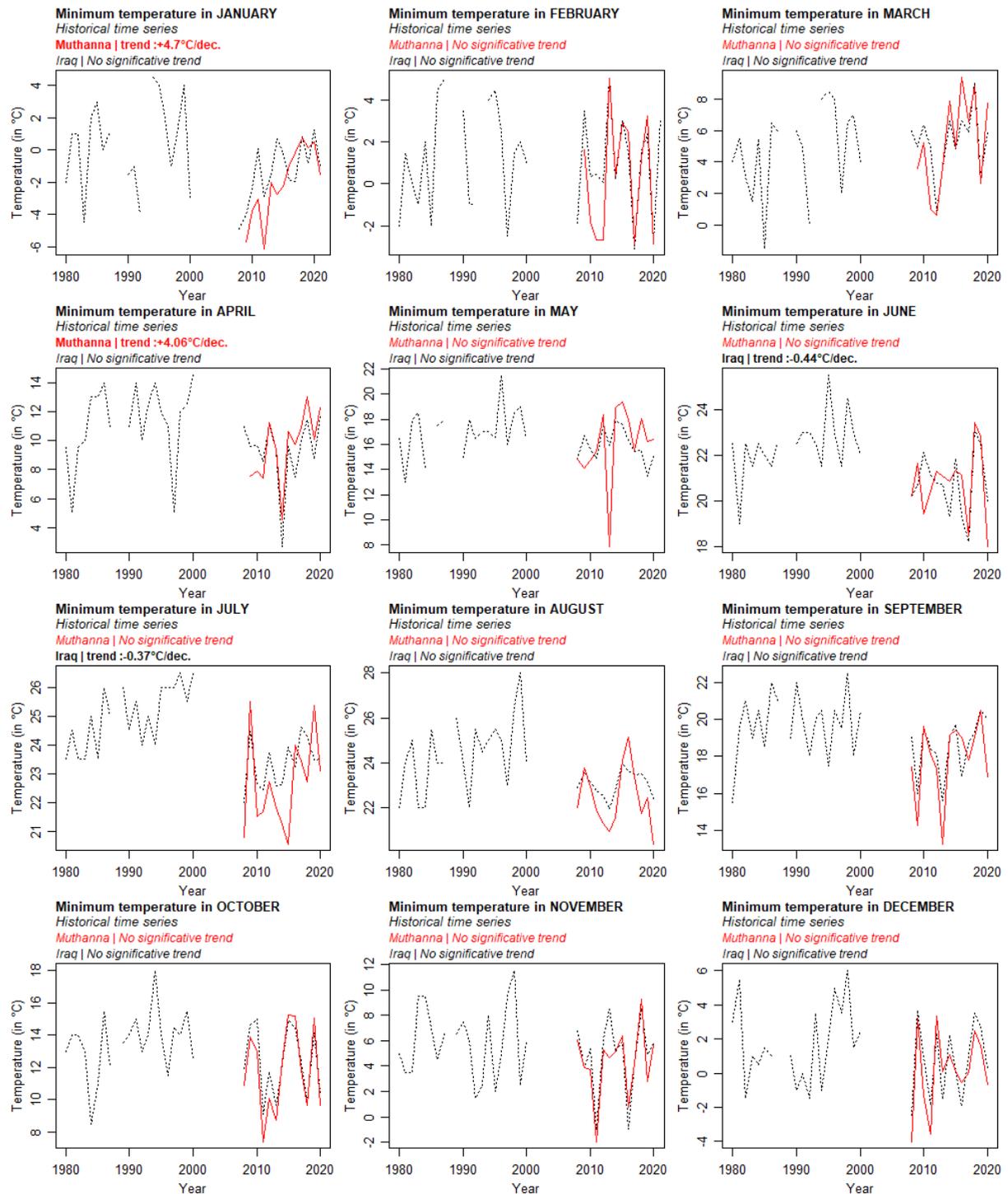
Data averaged over the 1990-2020 period. **In red:** average value over all the available weather stations located in the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **In grey:** likewise, but for all Iraq. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.



Historical trends by month

Muthanna

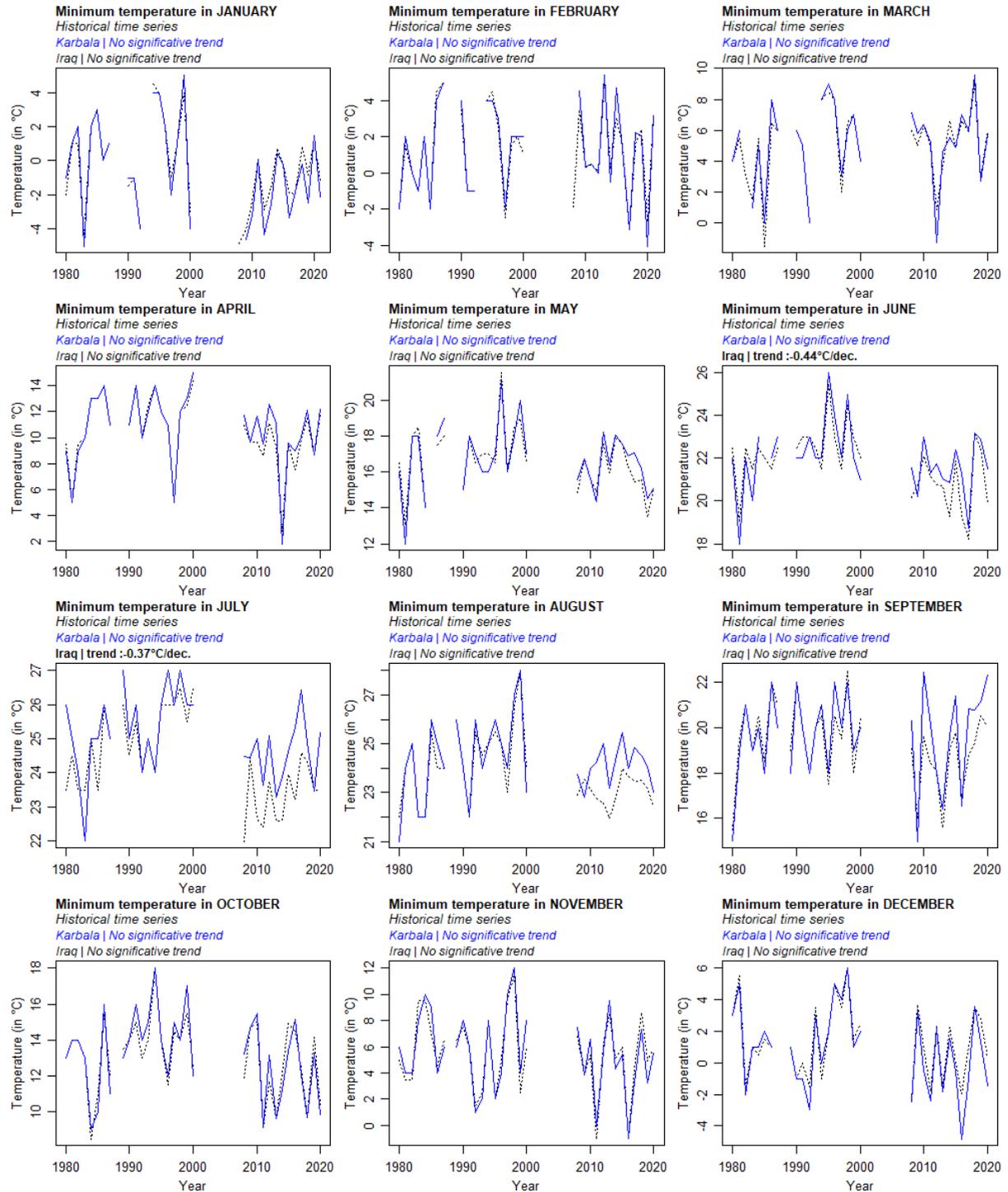
Figure 14 – Historical time series of the minimum temperature by month in the governorate of Muthanna
Time series over the 1980-2020 period. **In red:** average value over all the available weather stations located in the governorate of Muthanna. **In grey:** likewise, but for all Iraq. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.



Karbala

Figure 15 – Historical time series of the minimum temperature by month in the governorate of Karbala

Time series over the 1980-2020 period. **In blue:** average value over all the available weather stations located in the governorate of Karbala. **In grey:** likewise, but for all Iraq. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.



Najaf

Figure 16 – Historical time series of the minimum temperature by month in the governorate of Najaf

Time series over the 1980-2020 period. In green: average value over all the available weather stations located in the governorate of Najaf. In grey: likewise, but for all Iraq. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.

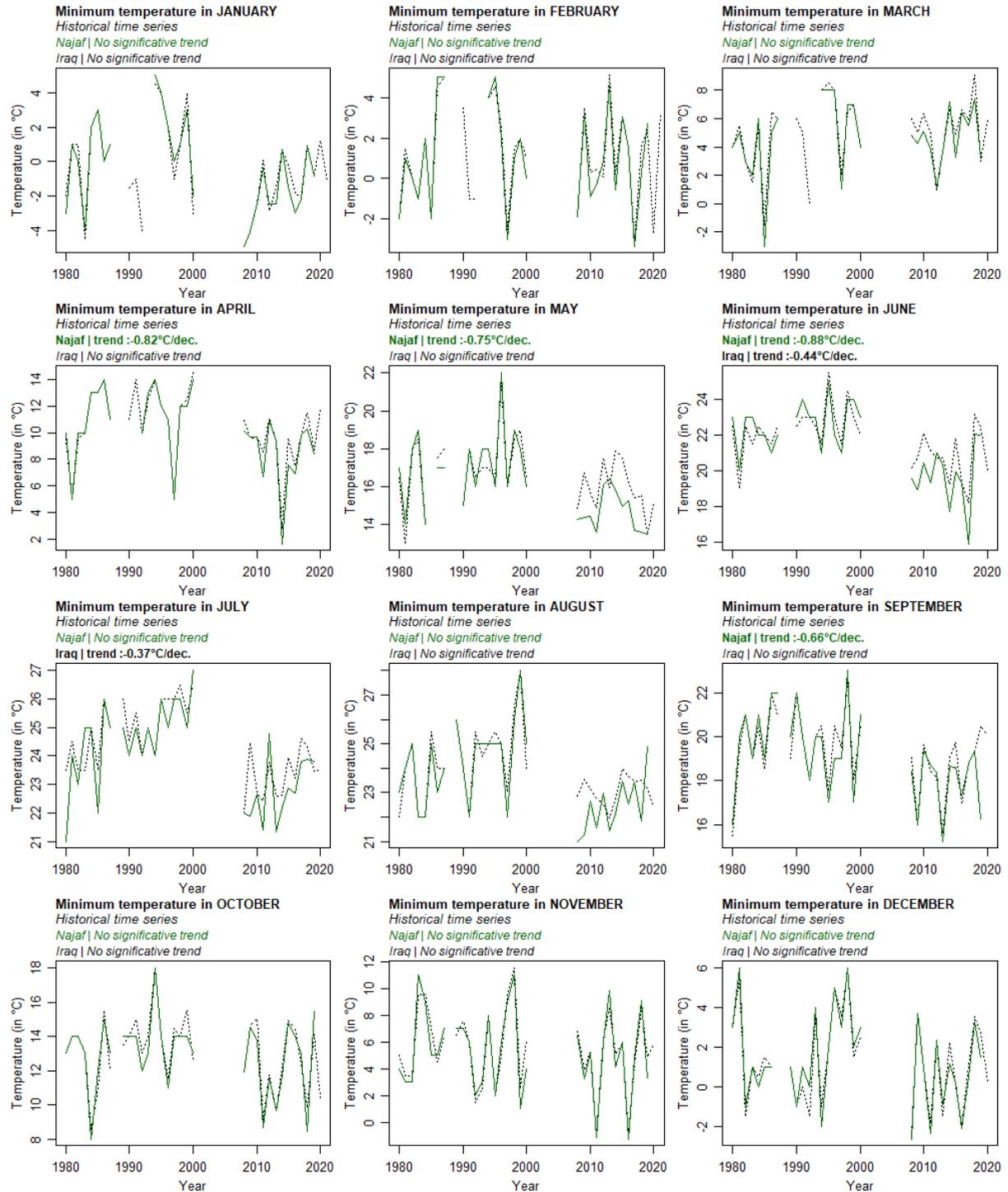


Table 8 – Characteristics of the trends from the historical time series of the minimum temperature by month in the three target governorates (linear models)

In red: average value over all the available weather stations located in the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **Data in grey:** the trends is statistically no significant under an alpha of 5%. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.

Governorate	Month	Slope	p-value	R ²	Average value in 1980	Average value in 2019
Muthanna	January	+4.70°C/dec.	0.000	0.66	-18.53°C	-0.19°C
	February	+0.61°C/dec.	0.809	-0.09	-1.78°C	0.62°C
	march	+4.22°C/dec.	0.088	0.19	-9.38°C	7.07°C
	April	+4.06°C/dec.	0.032	0.32	-4.47°C	11.39°C
	May	+2.42°C/dec.	0.294	0.02	7.77°C	17.20°C
	June	+0.15°C/dec.	0.901	-0.09	20.25°C	20.84°C
	July	+1.37°C/dec.	0.269	0.03	17.99°C	23.33°C
	August	-0.31°C/dec.	0.774	-0.08	23.50°C	22.29°C
	September	+1.87°C/dec.	0.241	0.04	11.49°C	18.78°C
	October	+0.84°C/dec.	0.685	-0.07	8.92°C	12.18°C
	November	+1.36°C/dec.	0.528	-0.05	-0.32°C	4.97°C
	December	+1.65°C/dec.	0.350	-0.00	-5.46°C	0.97°C
Karbala	January	-0.60°C/dec.	0.097	0.06	0.72°C	-1.63°C
	February	+0.02°C/dec.	0.960	-0.03	1.30°C	1.37°C
	march	+0.27°C/dec.	0.474	-0.02	4.61°C	5.68°C
	April	-0.24°C/dec.	0.539	-0.02	11.18°C	10.24°C
	May	-0.06°C/dec.	0.804	-0.03	16.84°C	16.59°C
	June	-0.08°C/dec.	0.718	-0.03	22.12°C	21.81°C
	July	-0.12°C/dec.	0.434	-0.01	25.29°C	24.81°C
	August	+0.07°C/dec.	0.719	-0.03	24.16°C	24.45°C
	September	+0.17°C/dec.	0.540	-0.02	19.33°C	19.99°C
	October	-0.38°C/dec.	0.232	0.02	13.88°C	12.41°C
	November	-0.48°C/dec.	0.247	0.01	6.48°C	4.62°C
	December	-0.52°C/dec.	0.141	0.04	1.88°C	-0.15°C
Najaf	January	-0.53°C/dec.	0.155	0.04	0.52°C	-1.56°C
	February	-0.06°C/dec.	0.866	-0.04	1.16°C	0.92°C
	march	+0.31°C/dec.	0.422	-0.01	3.97°C	5.18°C
	April	-0.82°C/dec.	0.046	0.10	11.63°C	8.44°C
	May	-0.75°C/dec.	0.009	0.19	17.61°C	14.70°C
	June	-0.88°C/dec.	0.001	0.29	23.16°C	19.74°C
	July	-0.39°C/dec.	0.082	0.07	24.68°C	23.16°C
	August	-0.41°C/dec.	0.083	0.07	24.38°C	22.77°C
	September	-0.66°C/dec.	0.012	0.17	20.34°C	17.77°C
	October	-0.27°C/dec.	0.380	-0.01	13.46°C	12.41°C
	November	-0.36°C/dec.	0.418	-0.01	5.96°C	4.54°C
	December	-0.32°C/dec.	0.333	-0.00	1.93°C	0.67°C

Historical annual trends

Figure 17 – Historical time series of the annual minimum temperature in the three target governorates

Time series over the 1980-2020 period. **In red:** average value over all the available weather stations located in the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **In grey:** likewise, but for all Iraq. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.

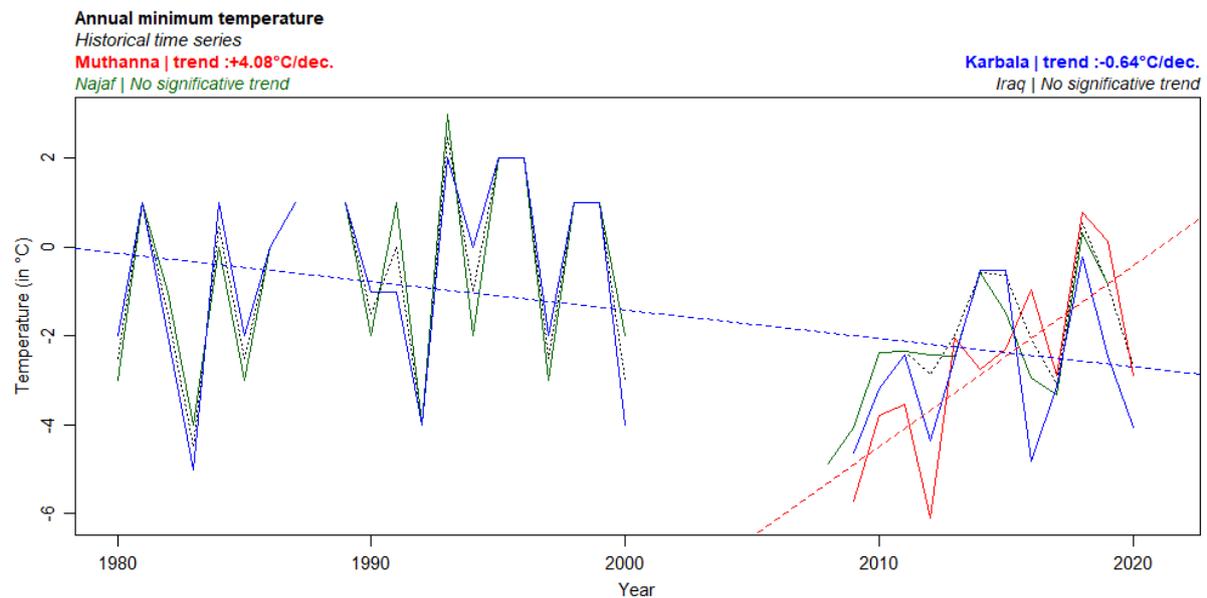


Table 9 – Characteristics of the trends from the historical time series of the annual minimum temperature in the three target governorates (linear models)

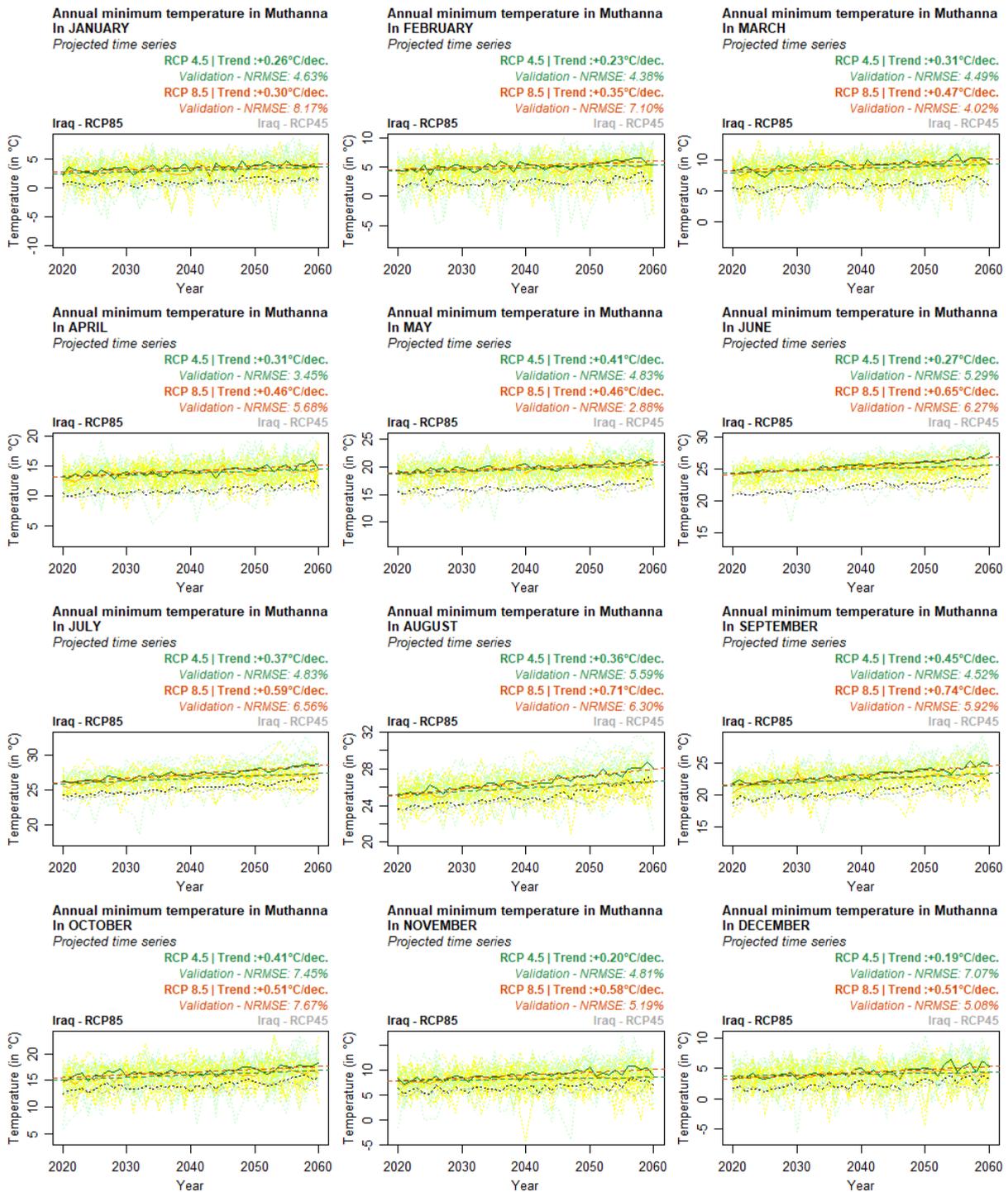
In red: average value over all the available weather stations located in the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **Data in grey:** the trends is statistically no significant under an alpha of 5%. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.

governorate	Slope	p-value	R ²	Average value in 1980	Average value in 2019
Muthanna	+4.08°C/dec.	0.009	0.46	-16.75°C	-0.83°C
Karbala	-0.64°C/dec.	0.033	0.11	-0.15°C	-2.63°C
Najaf	-0.41°C/dec.	0.173	0.03	-0.43°C	-2.01°C

Projected trends by month

Muthanna

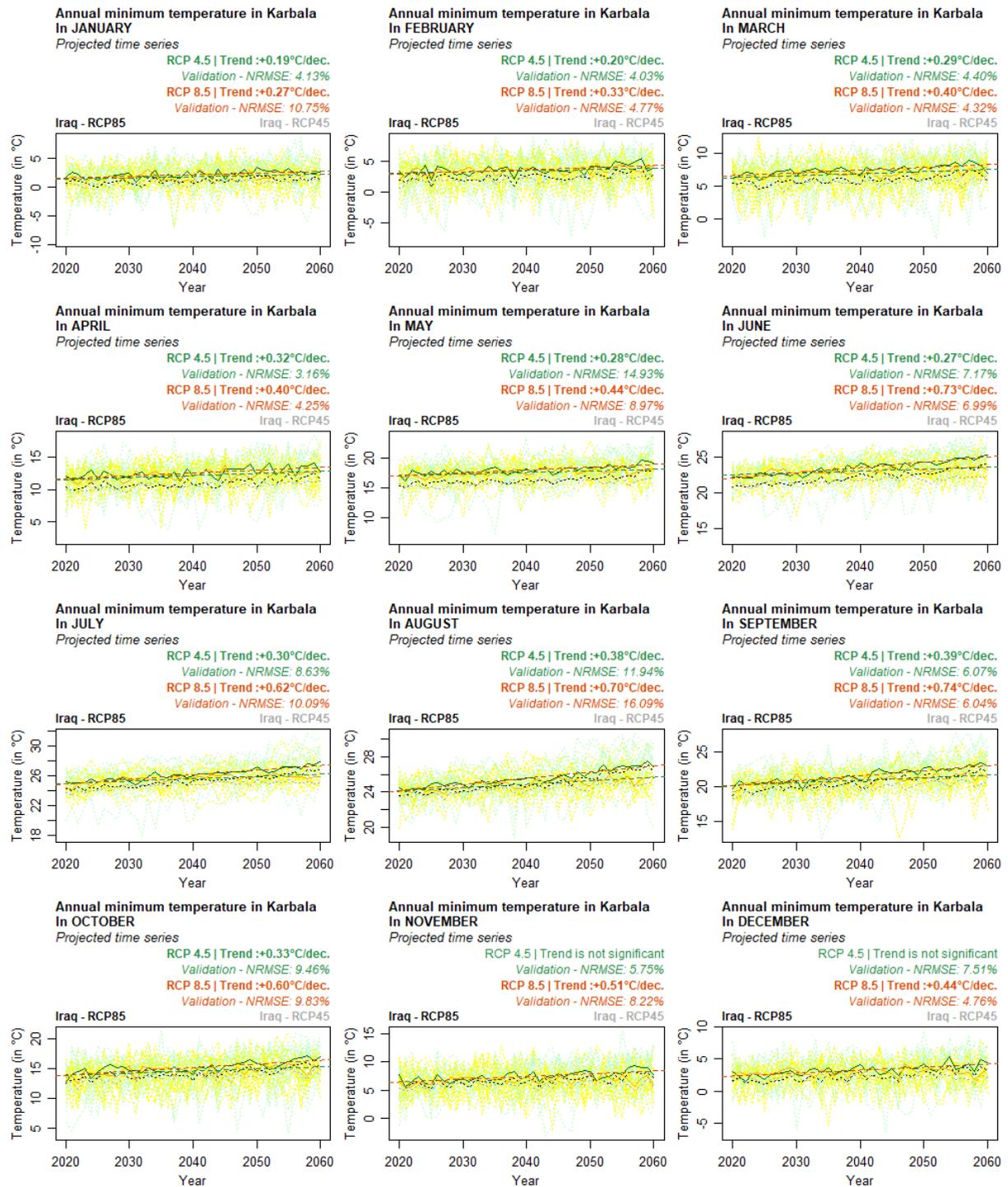
Figure 18 – Projected time series of the minimum temperature by month in the governorate of Muthanna
 Time series over the 2020-2060 period. **In yellow (dotted line):** value for each projected model under the RCP4.5. **In orange (full line):** median value calculated over all projected models under the RCP4.5. **In light green (dotted line):** value for each projected model under the RCP8.5. **In dark green (full line):** median value calculated over all projected models under the RCP8.5. **In grey (dotted line):** median value calculated over all projected models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all projected models under the RCP8.5 scenario within Iraq, for comparison. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).



Karbala

Figure 19 – Projected time series of the minimum temperature by month in the governorate of Karbala

Time series over the 2020-2060 period. **In yellow (dotted line):** value for each projected model under the RCP4.5. **In orange (full line):** median value calculated over all projected models under the RCP4.5. **In light green (dotted line):** value for each projected model under the RCP8.5. **In dark green (full line):** median value calculated over all projected models under the RCP8.5. **In grey (dotted line):** median value calculated over all projected models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all projected models under the RCP8.5 scenario within Iraq, for comparison. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).



Najaf

Figure 20 – Projected time series of the minimum temperature by month in the governorate of Najaf

Time series over the 2020-2060 period. **In yellow (dotted line):** value for each projected model under the RCP4.5. **In orange (full line):** median value calculated over all projected models under the RCP4.5. **In light green (dotted line):** value for each projected model under the RCP8.5. **In dark green (full line):** median value calculated over all projected models under the RCP8.5. **In grey (dotted line):** median value calculated over all projected models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all projected models under the RCP8.5 scenario within Iraq, for comparison. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

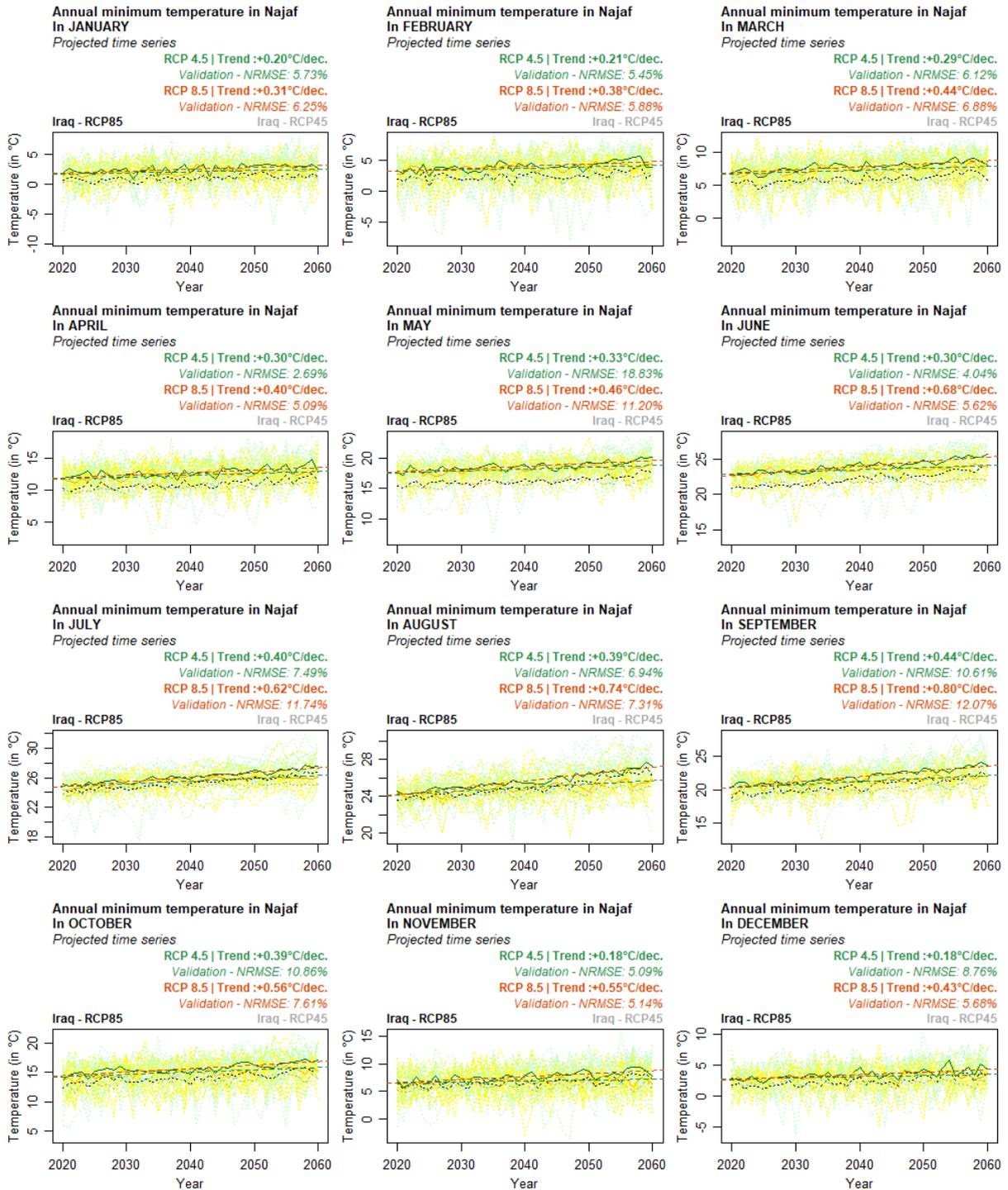


Table 10 – Characteristics of the trends from the projected time series of the minimum temperature by month in the three target governorates under the RCP4.5 scenario (linear models).

In red: median values calculated over all projected models under the RCP4.5 scenario within the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **Data in grey:** the trends is statistically no significant under an alpha of 5%. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

RCP4.5							
governorate	Month	Slope	p-value	R ²	Validation (NRMSE)	Average value in 2040	Average value in 2060
Muthanna	January	+0.26°C/dec.	0.000	0.26	4.63%	3.08°C	3.60°C
	February	+0.23°C/dec.	0.001	0.25	4.38%	4.83°C	5.30°C
	march	+0.31°C/dec.	0.000	0.44	4.49%	8.56°C	9.18°C
	April	+0.31°C/dec.	0.000	0.40	3.45%	13.76°C	14.38°C
	May	+0.41°C/dec.	0.000	0.55	4.83%	19.57°C	20.38°C
	June	+0.27°C/dec.	0.000	0.53	5.29%	24.94°C	25.48°C
	July	+0.37°C/dec.	0.000	0.71	4.83%	26.67°C	27.41°C
	August	+0.36°C/dec.	0.000	0.63	5.59%	25.88°C	26.60°C
	September	+0.45°C/dec.	0.000	0.58	4.52%	22.44°C	23.35°C
	October	+0.41°C/dec.	0.000	0.43	7.45%	16.05°C	16.86°C
	November	+0.20°C/dec.	0.003	0.19	4.81%	8.27°C	8.67°C
	December	+0.19°C/dec.	0.002	0.21	7.07%	4.04°C	4.42°C
Karbala	January	+0.19°C/dec.	0.009	0.14	4.13%	1.82°C	2.20°C
	February	+0.20°C/dec.	0.007	0.15	4.03%	3.44°C	3.84°C
	march	+0.29°C/dec.	0.000	0.32	4.40%	6.87°C	7.45°C
	April	+0.32°C/dec.	0.000	0.34	3.16%	12.15°C	12.79°C
	May	+0.28°C/dec.	0.000	0.36	14.93%	17.57°C	18.13°C
	June	+0.27°C/dec.	0.000	0.51	7.17%	23.07°C	23.60°C
	July	+0.30°C/dec.	0.000	0.54	8.63%	25.60°C	26.19°C
	August	+0.38°C/dec.	0.000	0.63	11.94%	24.89°C	25.65°C
	September	+0.39°C/dec.	0.000	0.47	6.07%	20.93°C	21.72°C
	October	+0.33°C/dec.	0.001	0.23	9.46%	14.54°C	15.20°C
	November	+0.17°C/dec.	0.051	0.07	5.75%	6.75°C	7.09°C
	December	+0.08°C/dec.	0.263	0.01	7.51%	2.92°C	3.08°C
Najaf	January	+0.20°C/dec.	0.002	0.20	5.73%	2.17°C	2.57°C
	February	+0.21°C/dec.	0.001	0.22	5.45%	3.70°C	4.12°C
	march	+0.29°C/dec.	0.000	0.36	6.12%	7.29°C	7.87°C
	April	+0.30°C/dec.	0.000	0.34	2.69%	12.41°C	13.00°C
	May	+0.33°C/dec.	0.000	0.47	18.83%	18.19°C	18.85°C
	June	+0.30°C/dec.	0.000	0.59	4.04%	23.55°C	24.15°C
	July	+0.40°C/dec.	0.000	0.70	7.49%	25.54°C	26.34°C
	August	+0.39°C/dec.	0.000	0.63	6.94%	24.92°C	25.69°C
	September	+0.44°C/dec.	0.000	0.57	10.61%	21.24°C	22.12°C
	October	+0.39°C/dec.	0.000	0.38	10.86%	14.99°C	15.77°C
	November	+0.18°C/dec.	0.025	0.10	5.09%	6.93°C	7.29°C
	December	+0.18°C/dec.	0.003	0.18	8.76%	3.11°C	3.47°C

Table 11 – Characteristics of the trends from the Projected time series of the minimum temperature by month in the three target governorates under the RCP8.5 scenario (linear models).

In red: median values calculated over all projected models under the RCP8.5 scenario within the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **Data in grey:** the trends is statistically no significant under an alpha of 5%. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

RCP8.5							
governorate	Month	Slope	p-value	R ²	Validation (NRMSE)	Average value in 2040	Average value in 2060
Muthanna	January	+0.30°C/dec.	0.000	0.29	8.17%	3.52°C	4.11°C
	February	+0.35°C/dec.	0.000	0.39	7.10%	5.24°C	5.94°C
	march	+0.47°C/dec.	0.000	0.56	4.02%	9.13°C	10.07°C
	April	+0.46°C/dec.	0.000	0.58	5.68%	14.11°C	15.03°C
	May	+0.46°C/dec.	0.000	0.67	2.88%	20.00°C	20.92°C
	June	+0.65°C/dec.	0.000	0.92	6.27%	25.47°C	26.78°C
	July	+0.59°C/dec.	0.000	0.89	6.56%	27.30°C	28.48°C
	August	+0.71°C/dec.	0.000	0.87	6.30%	26.58°C	28.00°C
	September	+0.74°C/dec.	0.000	0.87	5.92%	23.18°C	24.66°C
	October	+0.51°C/dec.	0.000	0.55	7.67%	16.61°C	17.63°C
	November	+0.58°C/dec.	0.000	0.60	5.19%	9.05°C	10.20°C
	December	+0.51°C/dec.	0.000	0.52	5.08%	4.33°C	5.35°C
Karbala	January	+0.27°C/dec.	0.001	0.24	10.75%	2.19°C	2.73°C
	February	+0.33°C/dec.	0.000	0.26	4.77%	3.61°C	4.26°C
	march	+0.40°C/dec.	0.000	0.52	4.32%	7.37°C	8.18°C
	April	+0.40°C/dec.	0.000	0.35	4.25%	12.55°C	13.35°C
	May	+0.44°C/dec.	0.000	0.56	8.97%	18.00°C	18.89°C
	June	+0.73°C/dec.	0.000	0.88	6.99%	23.53°C	24.98°C
	July	+0.62°C/dec.	0.000	0.87	10.09%	26.17°C	27.40°C
	August	+0.70°C/dec.	0.000	0.89	16.09%	25.58°C	26.97°C
	September	+0.74°C/dec.	0.000	0.83	6.04%	21.58°C	23.07°C
	October	+0.60°C/dec.	0.000	0.58	9.83%	15.15°C	16.34°C
	November	+0.51°C/dec.	0.000	0.46	8.22%	7.43°C	8.44°C
	December	+0.44°C/dec.	0.000	0.46	4.76%	3.25°C	4.14°C
Najaf	January	+0.31°C/dec.	0.000	0.29	6.25%	2.59°C	3.21°C
	February	+0.38°C/dec.	0.000	0.36	5.88%	3.95°C	4.71°C
	march	+0.44°C/dec.	0.000	0.57	6.88%	7.82°C	8.71°C
	April	+0.40°C/dec.	0.000	0.42	5.09%	12.76°C	13.57°C
	May	+0.46°C/dec.	0.000	0.57	11.20%	18.65°C	19.57°C
	June	+0.68°C/dec.	0.000	0.87	5.62%	24.05°C	25.40°C
	July	+0.62°C/dec.	0.000	0.91	11.74%	26.11°C	27.36°C
	August	+0.74°C/dec.	0.000	0.91	7.31%	25.66°C	27.15°C
	September	+0.80°C/dec.	0.000	0.87	12.07%	21.96°C	23.57°C
	October	+0.56°C/dec.	0.000	0.65	7.61%	15.68°C	16.81°C
	November	+0.55°C/dec.	0.000	0.52	5.14%	7.64°C	8.74°C
	December	+0.43°C/dec.	0.000	0.41	5.68%	3.43°C	4.30°C

Projected annual trends

Figure 21 – Projected time series of the annual minimum temperature in the three target governorates
 Time series over the 2020-2060 period. **In yellow (dotted line):** value for each projected model under the RCP4.5. **In orange (full line):** median value calculated over all projected models under the RCP4.5. **In light green (dotted line):** value for each projected model under the RCP8.5. **In dark green (full line):** median value calculated over all projected models under the RCP8.5. **In grey (dotted line):** median value calculated over all projected models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all projected models under the RCP8.5 scenario within Iraq, for comparison. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

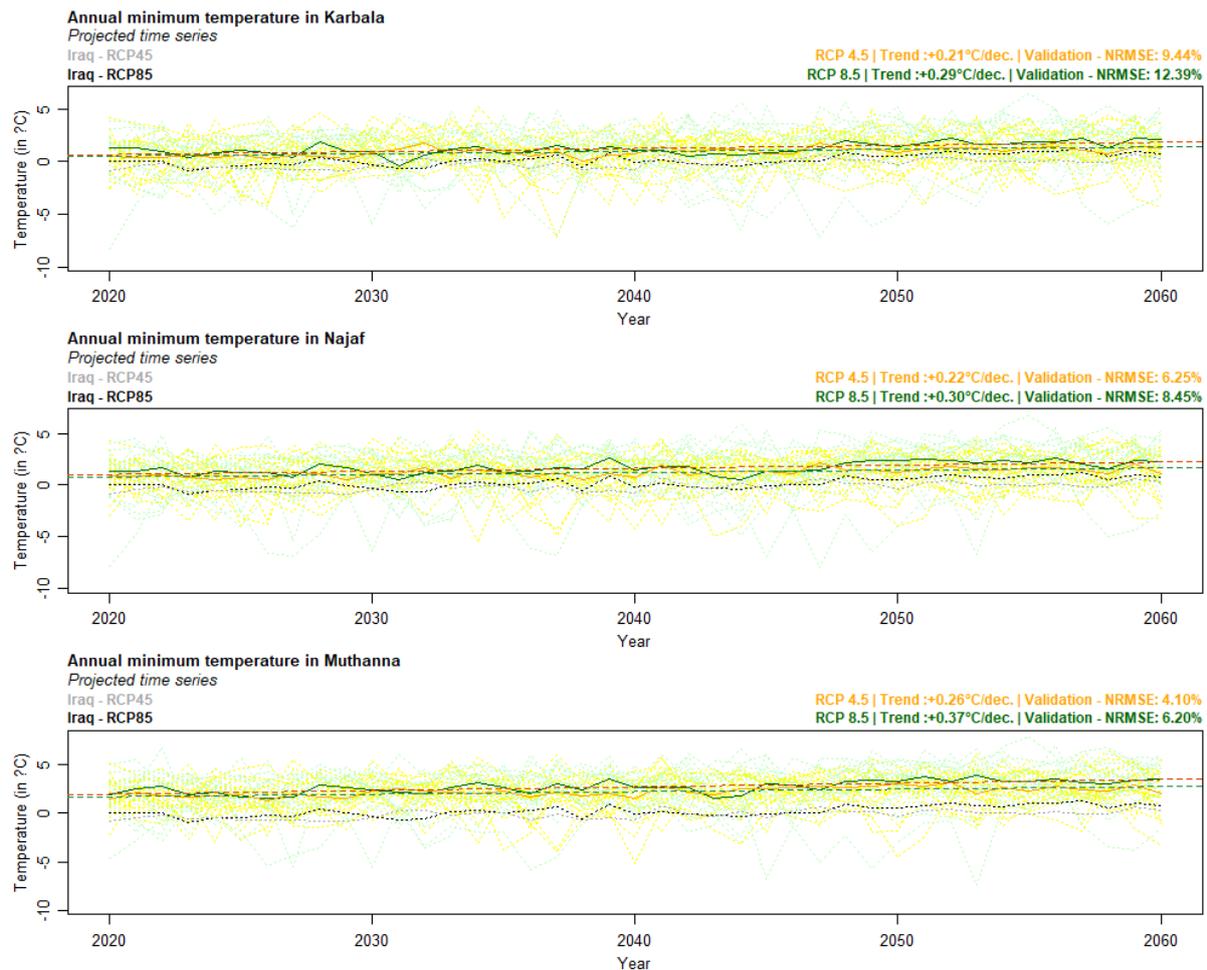


Table 12 – Characteristics of the trends from the projected time series of the annual minimum temperature in the three target governorates (linear models).

In red: median values calculated over all NEX models within the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **Data in grey:** the trends is statistically no significant under an alpha of 5%. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

RCP4.5						
governorate	Slope	p-value	R ²	Validation (NRMSE)	Average value in 2040	Average value in 2060
Muthanna	+0.26°C/dec.	0.000	0.43	4.10%	2.19°C	2.70°C
Karbala	+0.21°C/dec.	0.000	0.36	9.44%	0.91°C	1.33°C
Najaf	+0.22°C/dec.	0.000	0.37	6.25%	1.21°C	1.64°C
RCP8.5						
governorate	Slope	p-value	R ²	Validation (NRMSE)	Average value in 2040	Average value in 2060
Muthanna	+0.37°C/dec.	0.000	0.46	6.20%	2.68°C	3.43°C
Karbala	+0.29°C/dec.	0.000	0.35	12.39%	1.22°C	1.80°C
Najaf	+0.30°C/dec.	0.000	0.36	8.45%	1.65°C	2.24°C

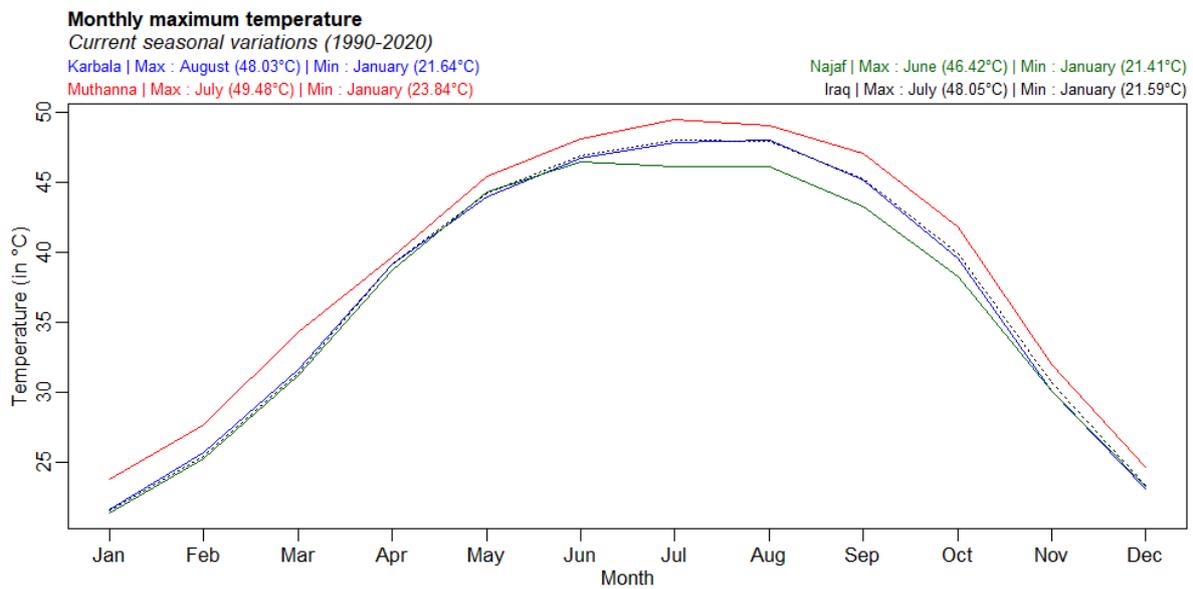
5. Maximum temperatures

This section will present the variations of maximum temperatures in the three target governorates of the project in the Republic of Iraq, focusing on **monthly minimum temperatures** (TX_m) and **annual minimum temperatures** (TX_y).

Seasonal variations

Figure 22 – Current seasonal variations of the monthly maximum temperature

Data averaged over the 1990-2020 period. **In red:** average value over all the available weather stations located in the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **In grey:** likewise, but for all Iraq. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.

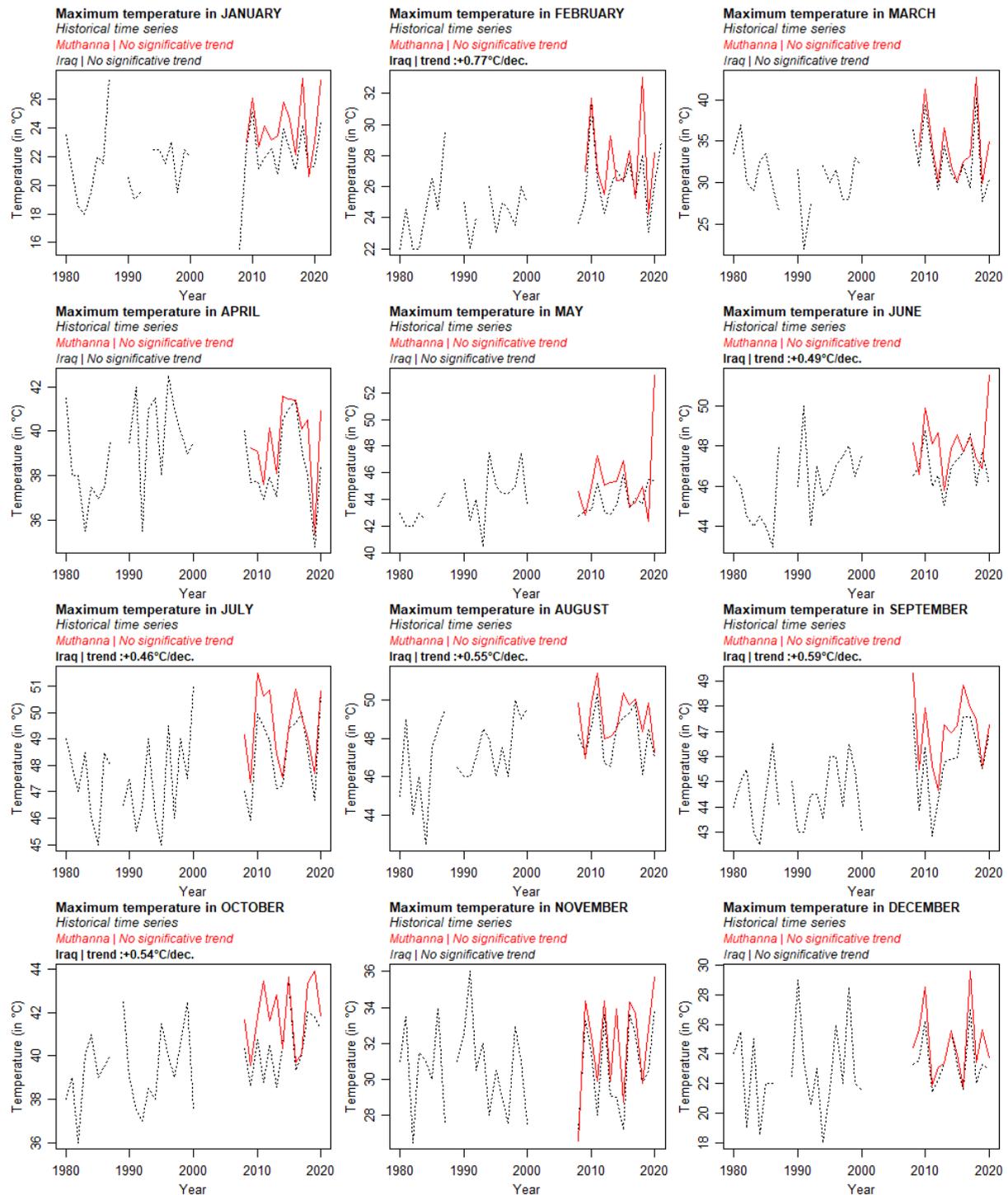


Historical trends by month

Muthanna

Figure 23 – Historical time series of the monthly maximum temperature by month in the governorate of Muthanna

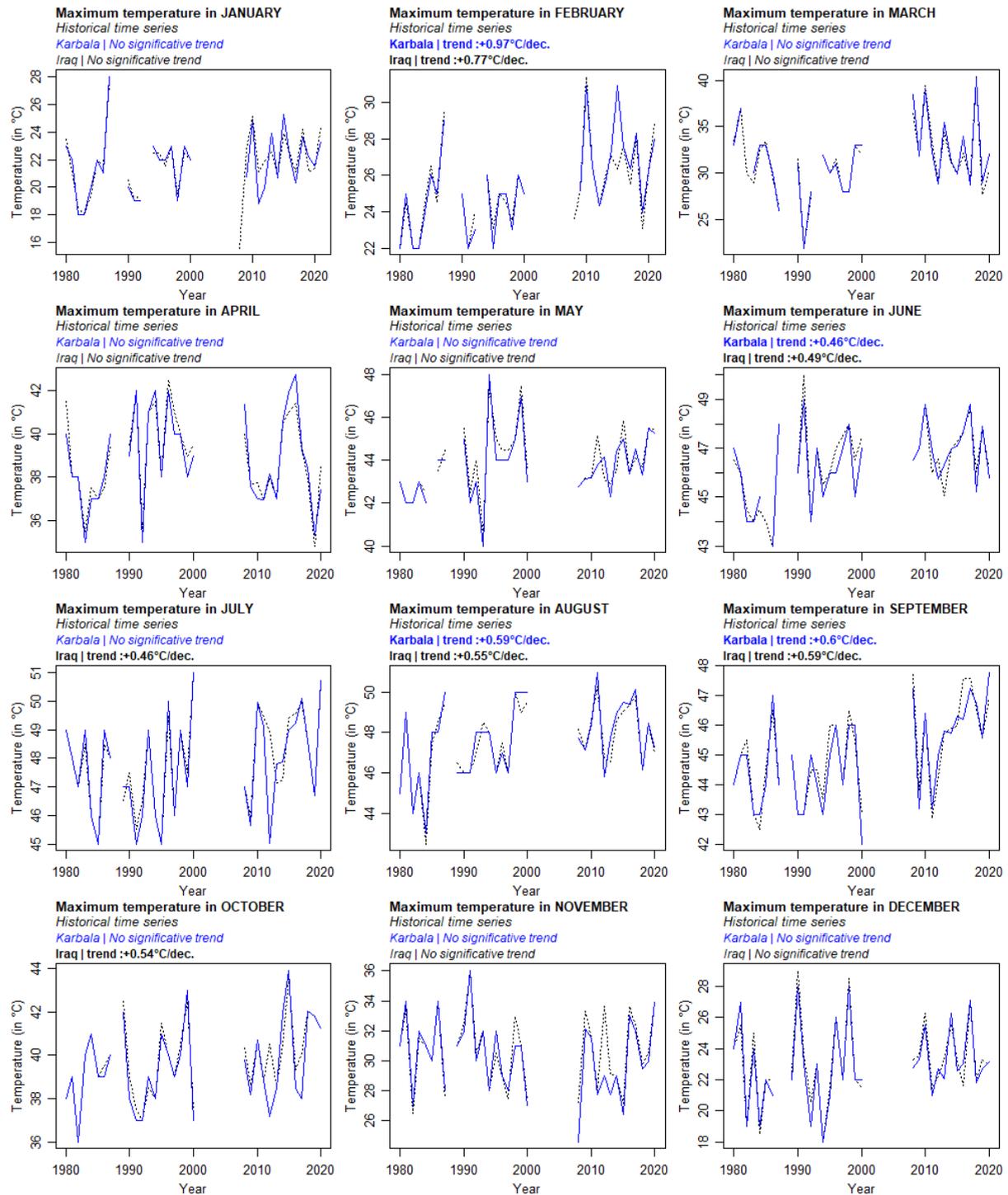
Time series over the 1980-2020 period. **In red:** average value over all the available weather stations located in the governorate of Muthanna. **In grey:** likewise, but for all Iraq. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.



Karbala

Figure 24 – Historical time series of the monthly maximum temperature by month in the governorate of Karbala

Time series over the 1980-2020 period. **In blue:** average value over all the available weather stations located in the governorate of Karbala. **In grey:** likewise, but for all Iraq. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.



Najaf

Figure 25 – Historical time series of the monthly maximum temperature by month in the governorate of Najaf
 Time series over the 1980-2020 period. **In green:** average value over all the available weather stations located in the governorate of Najaf. **In grey:** likewise, but for all Iraq. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.

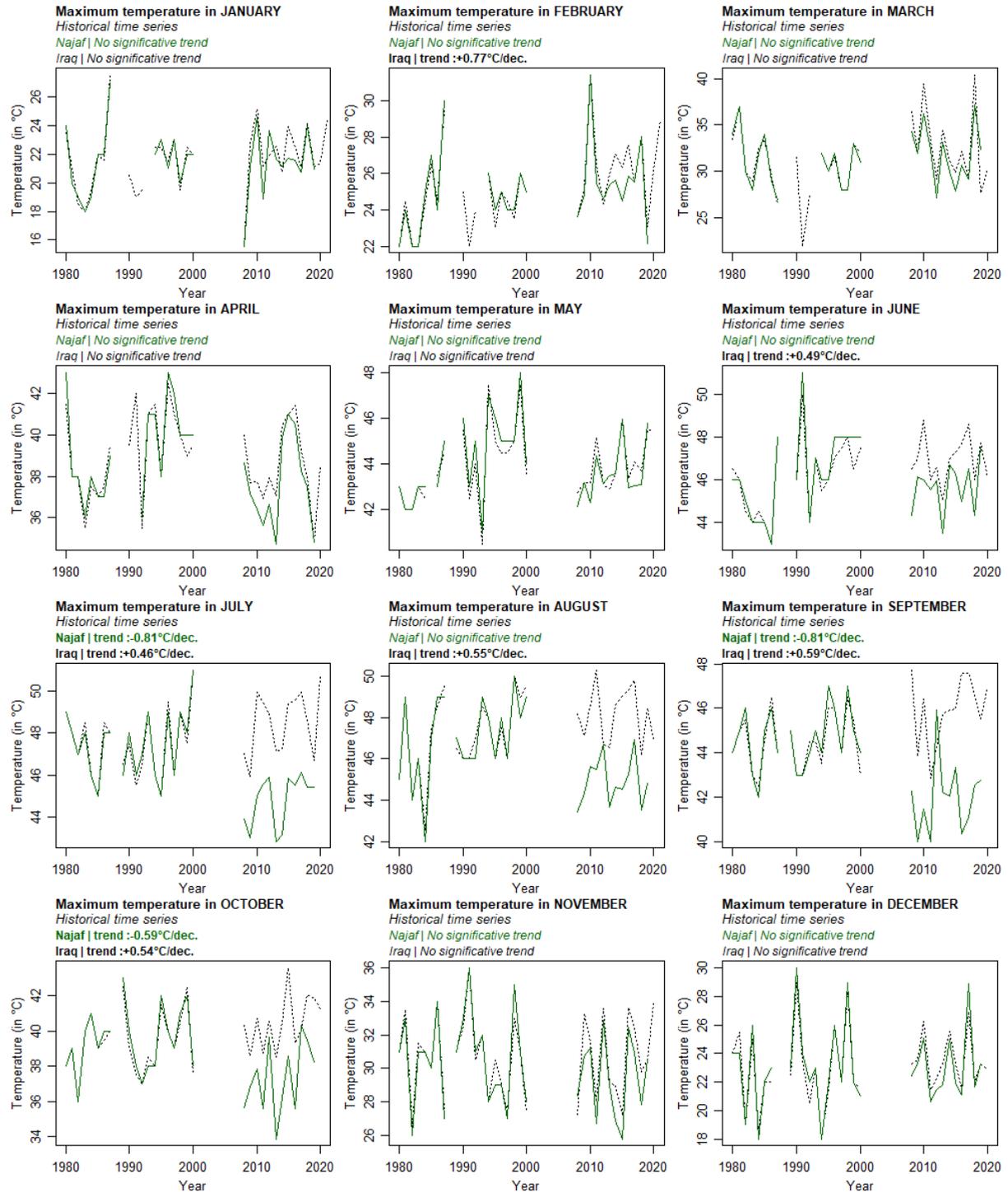


Table 13 – Characteristics of the trends from the historical time series of the maximum temperature by month in the three target governorates (linear models)

In red: average value over all the available weather stations located in the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **Data in grey:** the trends is statistically no significant under an alpha of 5%. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.

Governorate	Month	Slope	p-value	R ²	Average value in 1980	Average value in 2019
Muthanna	January	+0.59°C/dec.	0.715	-0.08	22.05°C	24.34°C
	February	-0.56°C/dec.	0.810	-0.09	29.63°C	27.44°C
	march	-1.30°C/dec.	0.727	-0.09	38.82°C	33.75°C
	April	+0.52°C/dec.	0.758	-0.09	37.85°C	39.86°C
	May	+2.09°C/dec.	0.327	0.00	38.30°C	46.44°C
	June	+0.71°C/dec.	0.530	-0.05	45.68°C	48.46°C
	July	+0.04°C/dec.	0.971	-0.09	49.34°C	49.50°C
	August	-0.29°C/dec.	0.783	-0.08	50.05°C	48.93°C
	September	+0.09°C/dec.	0.937	-0.09	46.75°C	47.09°C
	October	+0.88°C/dec.	0.467	-0.04	38.84°C	42.27°C
	November	+2.55°C/dec.	0.227	0.05	23.36°C	33.31°C
	December	-0.15°C/dec.	0.934	-0.09	25.17°C	24.57°C
Karbala	January	+0.35°C/dec.	0.246	0.01	20.94°C	22.31°C
	February	+0.97°C/dec.	0.001	0.28	23.43°C	27.22°C
	march	+0.66°C/dec.	0.238	0.02	30.28°C	32.84°C
	April	+0.10°C/dec.	0.734	-0.03	38.63°C	39.03°C
	May	+0.34°C/dec.	0.122	0.05	43.04°C	44.37°C
	June	+0.46°C/dec.	0.027	0.13	45.45°C	47.23°C
	July	+0.36°C/dec.	0.138	0.04	47.05°C	48.45°C
	August	+0.59°C/dec.	0.019	0.14	46.47°C	48.78°C
	September	+0.60°C/dec.	0.002	0.24	43.77°C	46.13°C
	October	+0.45°C/dec.	0.080	0.07	38.62°C	40.39°C
	November	-0.37°C/dec.	0.293	0.00	31.04°C	29.60°C
	December	+0.29°C/dec.	0.416	-0.01	22.35°C	23.49°C
Najaf	January	+0.09°C/dec.	0.790	-0.03	21.23°C	21.57°C
	February	+0.39°C/dec.	0.209	0.02	24.30°C	25.81°C
	march	+0.15°C/dec.	0.730	-0.03	30.96°C	31.55°C
	April	-0.37°C/dec.	0.273	0.01	39.32°C	37.89°C
	May	+0.09°C/dec.	0.699	-0.03	43.78°C	44.15°C
	June	+0.06°C/dec.	0.820	-0.03	45.94°C	46.17°C
	July	-0.81°C/dec.	0.002	0.26	47.99°C	44.82°C
	August	-0.52°C/dec.	0.064	0.08	47.19°C	45.17°C
	September	-0.81°C/dec.	0.002	0.26	45.15°C	42.01°C
	October	-0.59°C/dec.	0.047	0.10	39.76°C	37.46°C
	November	-0.47°C/dec.	0.205	0.02	31.09°C	29.24°C
	December	+0.09°C/dec.	0.830	-0.03	22.88°C	23.23°C

Historical annual trends

Figure 26 – Historical time series of the annual maximum temperature in the three target governorates

Time series over the 1980-2020 period. **In red:** average value over all the available weather stations located in the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **In grey:** likewise, but for all Iraq. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.

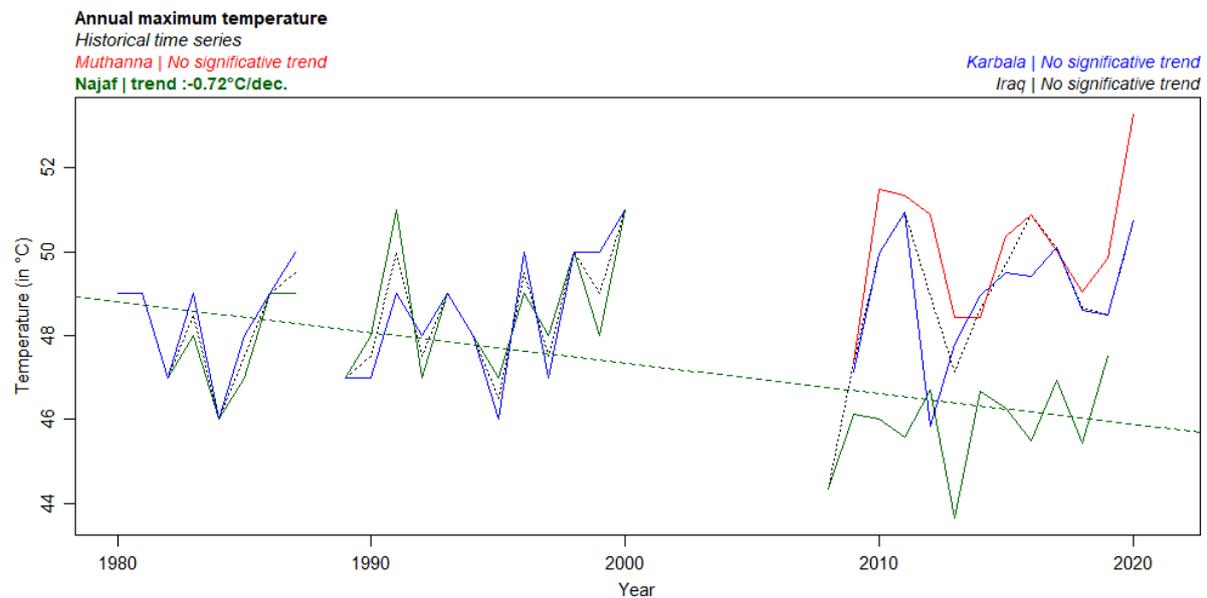


Table 14 – Characteristics of the trends from the historical time series of the annual maximum temperature in the three target governorates (linear models)

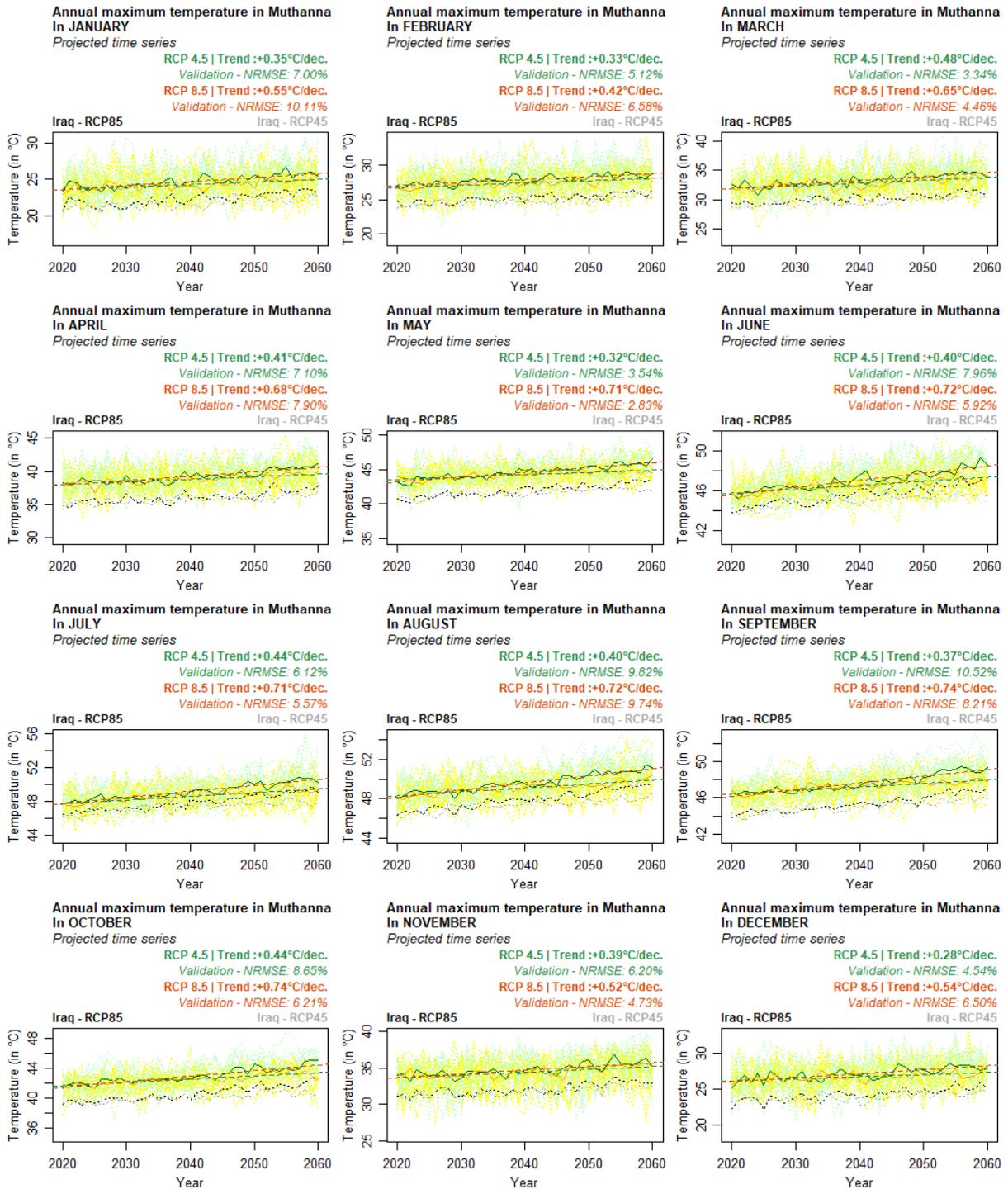
In red: average value over all the available weather stations located in the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **Data in grey:** the trends is statistically no significant under an alpha of 5%. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.

governorate	Slope	p-value	R ²	Average value in 1980	Average value in 2019
Muthanna	+1.37°C/dec.	0.338	0.00	45.39°C	50.73°C
Karbala	+0.29°C/dec.	0.141	0.04	48.07°C	49.22°C
Najaf	-0.72°C/dec.	0.002	0.26	48.79°C	45.97°C

Projected trends by month

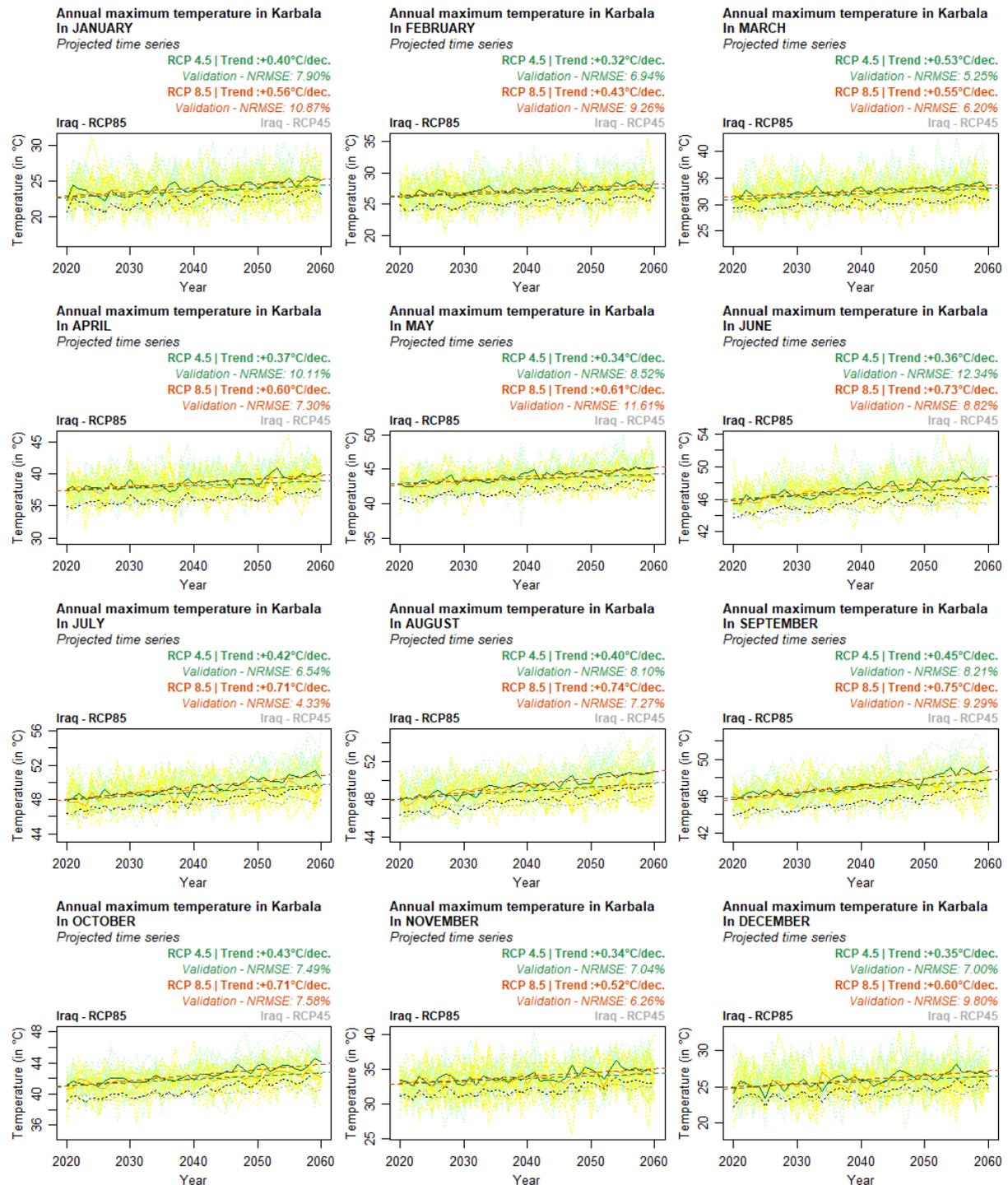
Muthanna

Figure 27 – Projected time series of the maximum temperature by month in the governorate of Muthanna
 Time series over the 2020-2060 period. **In yellow (dotted line):** value for each projected model under the RCP4.5. **In orange (full line):** median value calculated over all projected models under the RCP4.5. **In light green (dotted line):** value for each projected model under the RCP8.5. **In dark green (full line):** median value calculated over all projected models under the RCP8.5. **In grey (dotted line):** median value calculated over all projected models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all projected models under the RCP8.5 scenario within Iraq, for comparison. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).



Karbala

Figure 28 – Projected time series of the maximum temperature by month in the governorate of Karbala
 Time series over the 2020-2060 period. **In yellow (dotted line):** value for each projected model under the RCP4.5. **In orange (full line):** median value calculated over all projected models under the RCP4.5. **In light green (dotted line):** value for each projected model under the RCP8.5. **In dark green (full line):** median value calculated over all projected models under the RCP8.5. **In grey (dotted line):** median value calculated over all projected models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all projected models under the RCP8.5 scenario within Iraq, for comparison. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).



Najaf

Figure 29 – Projected time series of the maximum temperature by month in the governorate of Najaf

Time series over the 2020-2060 period. **In yellow (dotted line):** value for each projected model under the RCP4.5. **In orange (full line):** median value calculated over all projected models under the RCP4.5. **In light green (dotted line):** value for each projected model under the RCP8.5. **In dark green (full line):** median value calculated over all projected models under the RCP8.5. **In grey (dotted line):** median value calculated over all projected models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all projected models under the RCP8.5 scenario within Iraq, for comparison. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

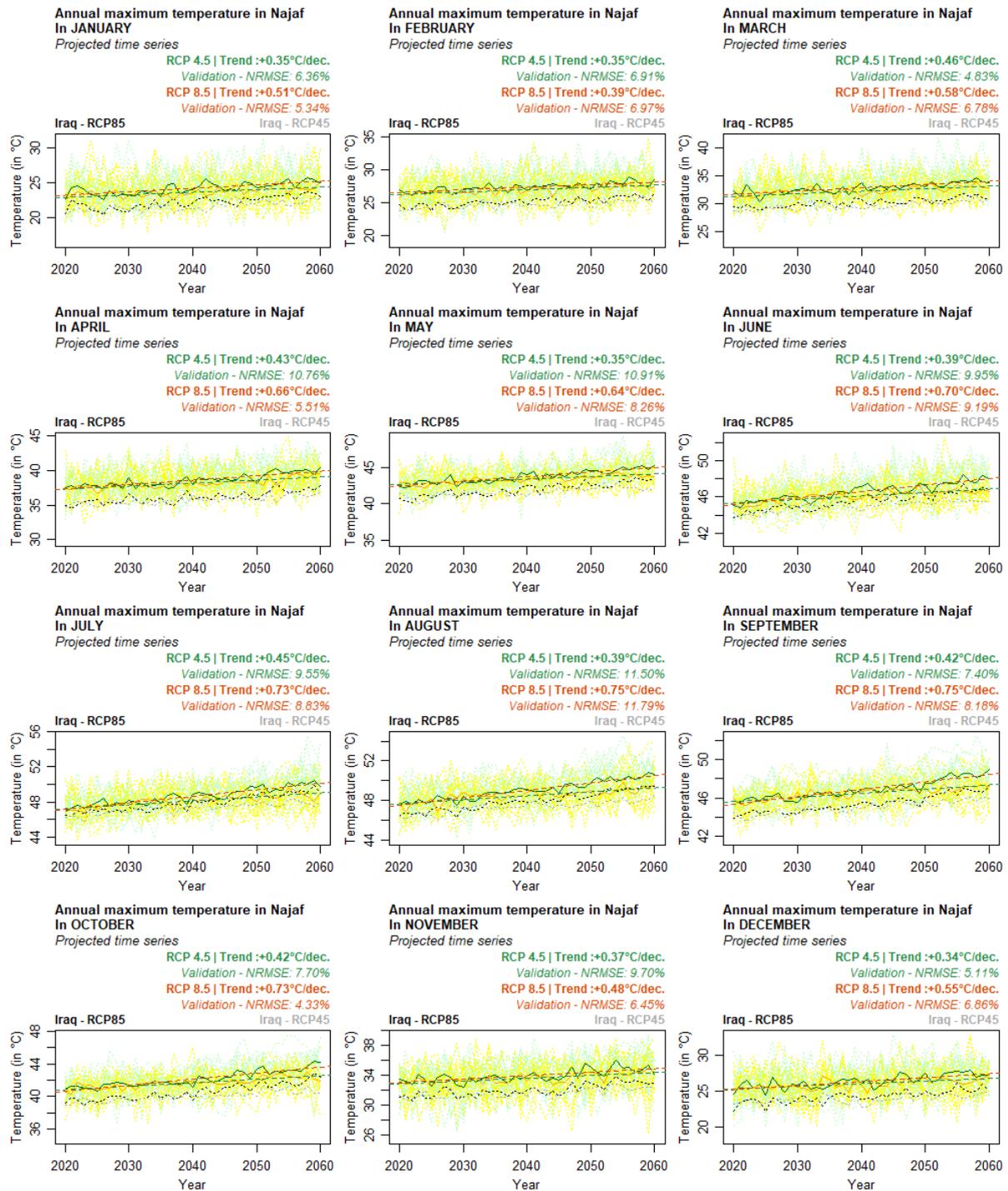


Table 15 – Characteristics of the trends from the Projected time series of the maximum temperature by month in the three target governorates under the RCP4.5 scenario (linear models).

In red: median values calculated over all projected models under the RCP4.5 scenario within the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **Data in grey:** the trends is statistically no significant under an alpha of 5%. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

RCP4.5							
governorate	Month	Slope	P-value	R ²	Validation (NRMSE)	Average value in 2040	Average value in 2060
Muthanna	January	+0.35°C/dec.	0.000	0.44	7.00%	24.24°C	24.93°C
	February	+0.33°C/dec.	0.000	0.43	5.12%	27.46°C	28.11°C
	march	+0.48°C/dec.	0.000	0.50	3.34%	32.75°C	33.71°C
	April	+0.41°C/dec.	0.000	0.55	7.10%	38.82°C	39.63°C
	May	+0.32°C/dec.	0.000	0.62	3.54%	44.28°C	44.92°C
	June	+0.40°C/dec.	0.000	0.66	7.96%	46.50°C	47.29°C
	July	+0.44°C/dec.	0.000	0.68	6.12%	48.63°C	49.51°C
	August	+0.40°C/dec.	0.000	0.73	9.82%	49.07°C	49.86°C
	September	+0.37°C/dec.	0.000	0.67	10.52%	47.23°C	47.97°C
	October	+0.44°C/dec.	0.000	0.71	8.65%	42.51°C	43.40°C
	November	+0.39°C/dec.	0.000	0.49	6.20%	34.43°C	35.20°C
	December	+0.28°C/dec.	0.000	0.29	4.54%	26.77°C	27.33°C
Karbala	January	+0.40°C/dec.	0.000	0.51	7.90%	23.49°C	24.29°C
	February	+0.32°C/dec.	0.000	0.45	6.94%	26.90°C	27.55°C
	march	+0.53°C/dec.	0.000	0.60	5.25%	32.03°C	33.10°C
	April	+0.37°C/dec.	0.000	0.43	10.11%	38.13°C	38.88°C
	May	+0.34°C/dec.	0.000	0.56	8.52%	43.58°C	44.27°C
	June	+0.36°C/dec.	0.000	0.51	12.34%	46.78°C	47.50°C
	July	+0.42°C/dec.	0.000	0.56	6.54%	48.83°C	49.68°C
	August	+0.40°C/dec.	0.000	0.57	8.10%	48.90°C	49.70°C
	September	+0.45°C/dec.	0.000	0.71	8.21%	46.79°C	47.70°C
	October	+0.43°C/dec.	0.000	0.66	7.49%	41.92°C	42.79°C
	November	+0.34°C/dec.	0.000	0.33	7.04%	33.58°C	34.26°C
	December	+0.35°C/dec.	0.000	0.32	7.00%	25.69°C	26.39°C
Najaf	January	+0.35°C/dec.	0.000	0.42	6.36%	23.71°C	24.41°C
	February	+0.35°C/dec.	0.000	0.48	6.91%	27.02°C	27.73°C
	march	+0.46°C/dec.	0.000	0.47	4.83%	32.29°C	33.21°C
	April	+0.43°C/dec.	0.000	0.59	10.76%	38.18°C	39.03°C
	May	+0.35°C/dec.	0.000	0.67	10.91%	43.36°C	44.06°C
	June	+0.39°C/dec.	0.000	0.59	9.95%	46.12°C	46.90°C
	July	+0.45°C/dec.	0.000	0.66	9.55%	48.14°C	49.04°C
	August	+0.39°C/dec.	0.000	0.61	11.50%	48.49°C	49.27°C
	September	+0.42°C/dec.	0.000	0.72	7.40%	46.46°C	47.30°C
	October	+0.42°C/dec.	0.000	0.65	7.70%	41.70°C	42.54°C
	November	+0.37°C/dec.	0.000	0.45	9.70%	33.67°C	34.40°C
	December	+0.34°C/dec.	0.000	0.36	5.11%	26.03°C	26.71°C

Table 16 – Characteristics of the trends from the projected time series of the maximum temperature by month in the three target governorates under the RCP8.5 scenario (linear models).

In red: median values calculated over all projected models under the RCP8.5 scenario within the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **Data in grey:** the trends is statistically no significant under an alpha of 5%. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

RCP8.5							
governorate	Month	Slope	P-value	R ²	Validation (NRMSE)	Average value in 2040	Average value in 2060
Muthanna	January	+0.55°C/dec.	0.000	0.62	10.11%	24.72°C	25.82°C
	February	+0.42°C/dec.	0.000	0.54	6.58%	27.91°C	28.75°C
	march	+0.65°C/dec.	0.000	0.63	4.46%	33.23°C	34.52°C
	April	+0.68°C/dec.	0.000	0.76	7.90%	39.25°C	40.61°C
	May	+0.71°C/dec.	0.000	0.85	2.83%	44.63°C	46.05°C
	June	+0.72°C/dec.	0.000	0.82	5.92%	47.04°C	48.48°C
	July	+0.71°C/dec.	0.000	0.88	5.57%	49.14°C	50.56°C
	August	+0.72°C/dec.	0.000	0.89	9.74%	49.59°C	51.04°C
	September	+0.74°C/dec.	0.000	0.85	8.21%	47.61°C	49.10°C
	October	+0.74°C/dec.	0.000	0.80	6.21%	42.96°C	44.43°C
	November	+0.52°C/dec.	0.000	0.55	4.73%	34.70°C	35.73°C
	December	+0.54°C/dec.	0.000	0.54	6.50%	27.16°C	28.24°C
Karbala	January	+0.56°C/dec.	0.000	0.56	10.87%	24.00°C	25.12°C
	February	+0.43°C/dec.	0.000	0.51	9.26%	27.29°C	28.15°C
	march	+0.55°C/dec.	0.000	0.60	6.20%	32.57°C	33.68°C
	April	+0.60°C/dec.	0.000	0.62	7.30%	38.60°C	39.80°C
	May	+0.61°C/dec.	0.000	0.78	11.61%	44.00°C	45.23°C
	June	+0.73°C/dec.	0.000	0.81	8.82%	47.27°C	48.73°C
	July	+0.71°C/dec.	0.000	0.83	4.33%	49.39°C	50.81°C
	August	+0.74°C/dec.	0.000	0.86	7.27%	49.44°C	50.93°C
	September	+0.75°C/dec.	0.000	0.84	9.29%	47.18°C	48.68°C
	October	+0.71°C/dec.	0.000	0.82	7.58%	42.47°C	43.88°C
	November	+0.52°C/dec.	0.000	0.46	6.26%	33.93°C	34.97°C
	December	+0.60°C/dec.	0.000	0.58	9.80%	25.96°C	27.17°C
Najaf	January	+0.51°C/dec.	0.000	0.52	5.34%	24.23°C	25.25°C
	February	+0.39°C/dec.	0.000	0.51	6.97%	27.43°C	28.21°C
	march	+0.58°C/dec.	0.000	0.58	6.78%	32.83°C	34.00°C
	April	+0.66°C/dec.	0.000	0.71	5.51%	38.61°C	39.92°C
	May	+0.64°C/dec.	0.000	0.79	8.26%	43.73°C	45.01°C
	June	+0.70°C/dec.	0.000	0.81	9.19%	46.61°C	48.01°C
	July	+0.73°C/dec.	0.000	0.84	8.83%	48.66°C	50.12°C
	August	+0.75°C/dec.	0.000	0.91	11.79%	49.04°C	50.54°C
	September	+0.75°C/dec.	0.000	0.85	8.18%	46.89°C	48.40°C
	October	+0.73°C/dec.	0.000	0.83	4.33%	42.17°C	43.64°C
	November	+0.48°C/dec.	0.000	0.45	6.45%	33.98°C	34.94°C
	December	+0.55°C/dec.	0.000	0.52	6.86%	26.40°C	27.50°C

Projected annual trends

Figure 30 – Projected time series of the annual maximum temperature in the three target governorates

Time series over the 2020-2060 period. **In yellow (dotted line):** value for each projected model under the RCP4.5. **In orange (full line):** median value calculated over all projected models under the RCP4.5. **In light green (dotted line):** value for each projected model under the RCP8.5. **In dark green (full line):** median value calculated over all projected models under the RCP8.5. **In grey (dotted line):** median value calculated over all projected models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all projected models under the RCP8.5 scenario within Iraq, for comparison. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

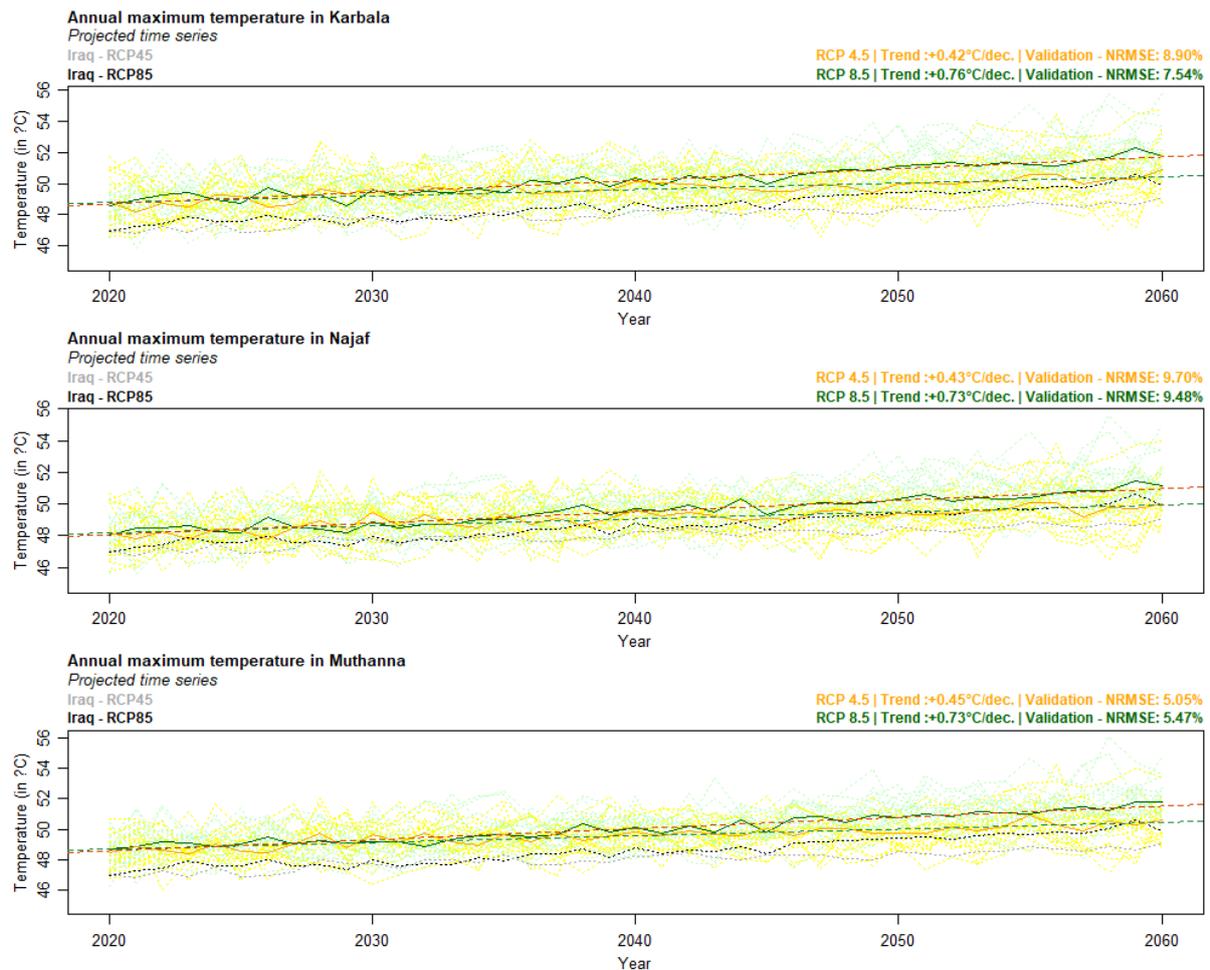


Table 17 – Characteristics of the trends from the projected time series of the annual maximum temperature in the three target governorates (linear models).

In red: median values calculated over all NEX models within the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **Data in grey:** the trends is statistically no significant under an alpha of 5%. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

RCP4.5						
governorate	Slope	p-value	R ²	Validation (NRMSE)	Average value in 2040	Average value in 2060
Muthanna	+0.45°C/dec.	0.000	0.76	5.05%	49.56°C	50.46°C
Karbala	+0.42°C/dec.	0.000	0.69	8.90%	49.63°C	50.47°C
Najaf	+0.43°C/dec.	0.000	0.70	9.70%	49.05°C	49.92°C
RCP8.5						
governorate	Slope	p-value	R ²	Validation (NRMSE)	Average value in 2040	Average value in 2060
Muthanna	+0.73°C/dec.	0.000	0.92	5.47%	50.05°C	51.52°C
Karbala	+0.76°C/dec.	0.000	0.90	7.54%	50.19°C	51.72°C
Najaf	+0.73°C/dec.	0.000	0.90	9.48%	49.53°C	50.99°C

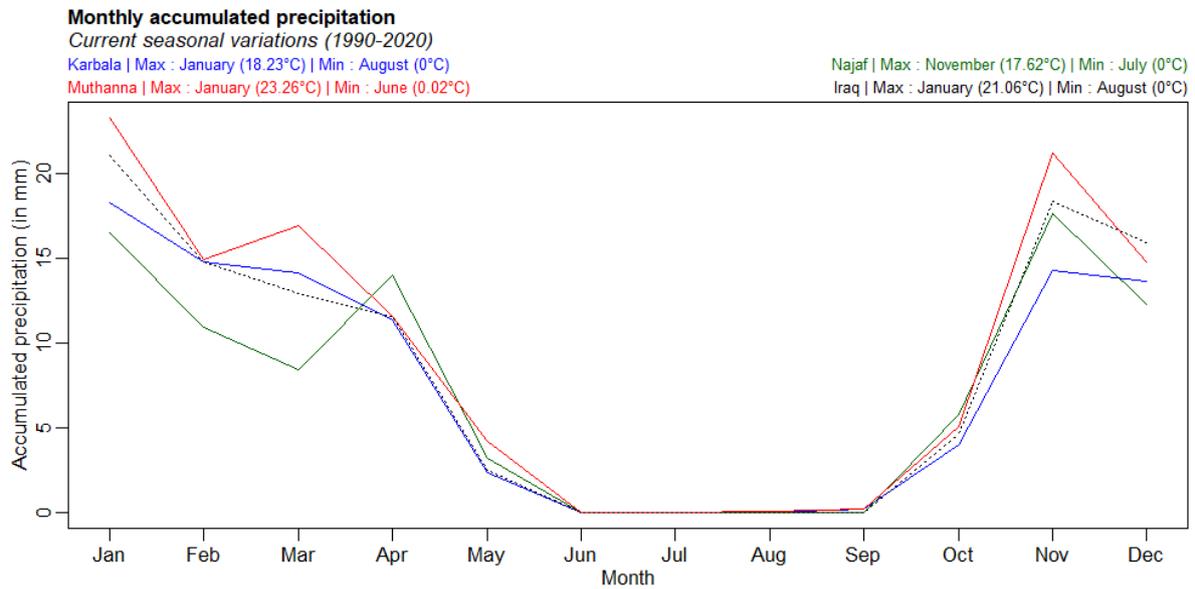
6. Precipitation

This section will present the variations of accumulated precipitation in the three target governorates of the project in the Republic of Iraq, focusing on **monthly accumulated precipitation** (RR_m) and **annually accumulated precipitation** (RR_y).

Seasonal variations

Figure 31 – Current seasonal variations of the monthly accumulated precipitation

Data averaged over the 2008-2020 period. **In red:** average value over all the available weather stations located in the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **In black, dotted line:** likewise, but for all Iraq. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.

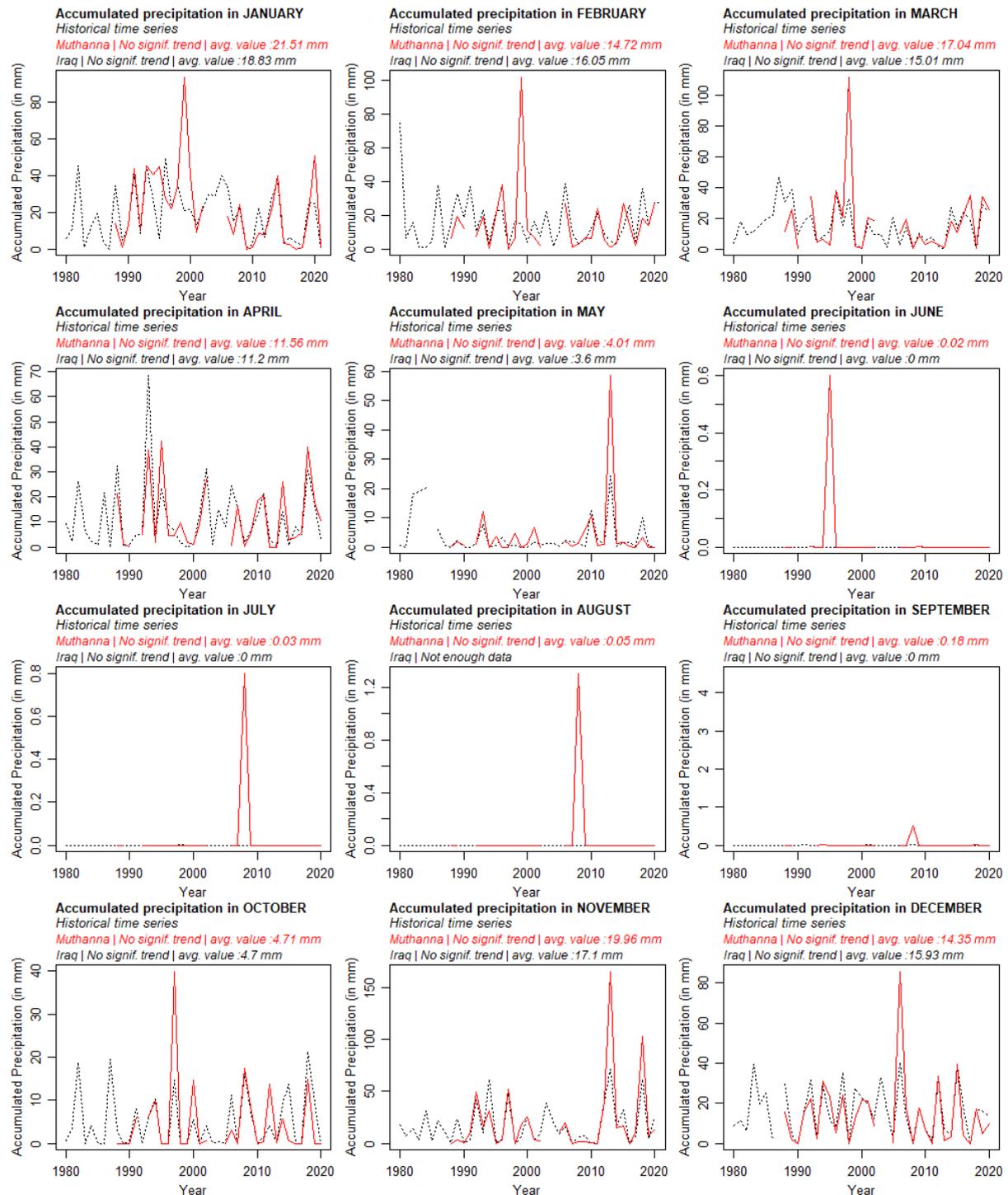


Historical trends by month

Muthanna

Figure 32 – Historical time series of the monthly accumulated precipitation by month in the governorate of Muthanna

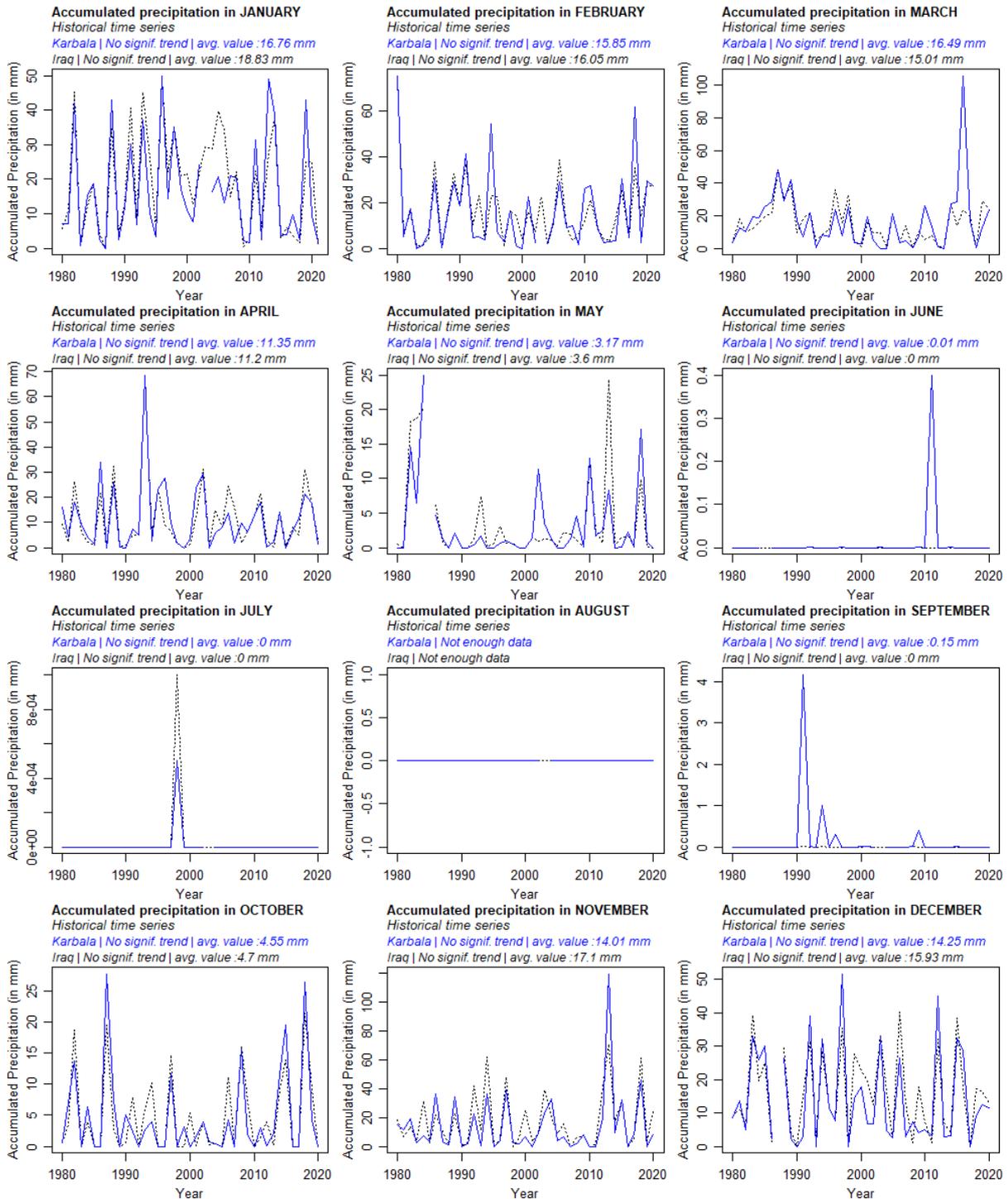
Time series over the 1980-2020 period. **In red, full line:** average value over all the available weather stations located in the governorate of Muthanna. **In black, dotted line:** likewise, but for all Iraq. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.



Karbala

Figure 33 – Historical time series of the monthly accumulated precipitation by month in the governorate of Karbala

Time series over the 1980-2020 period. **In blue:** average value over all the available weather stations located in the governorate of Karbala. **In black, dotted line:** likewise, but for all Iraq. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.



Najaf

Figure 34 – Historical time series of the monthly accumulated precipitation by month in the governorate of Najaf

Time series over the 1980-2020 period. **In green:** average value over all the available weather stations located in the governorate of Najaf. **In black, dotted line:** likewise, but for all Iraq. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.

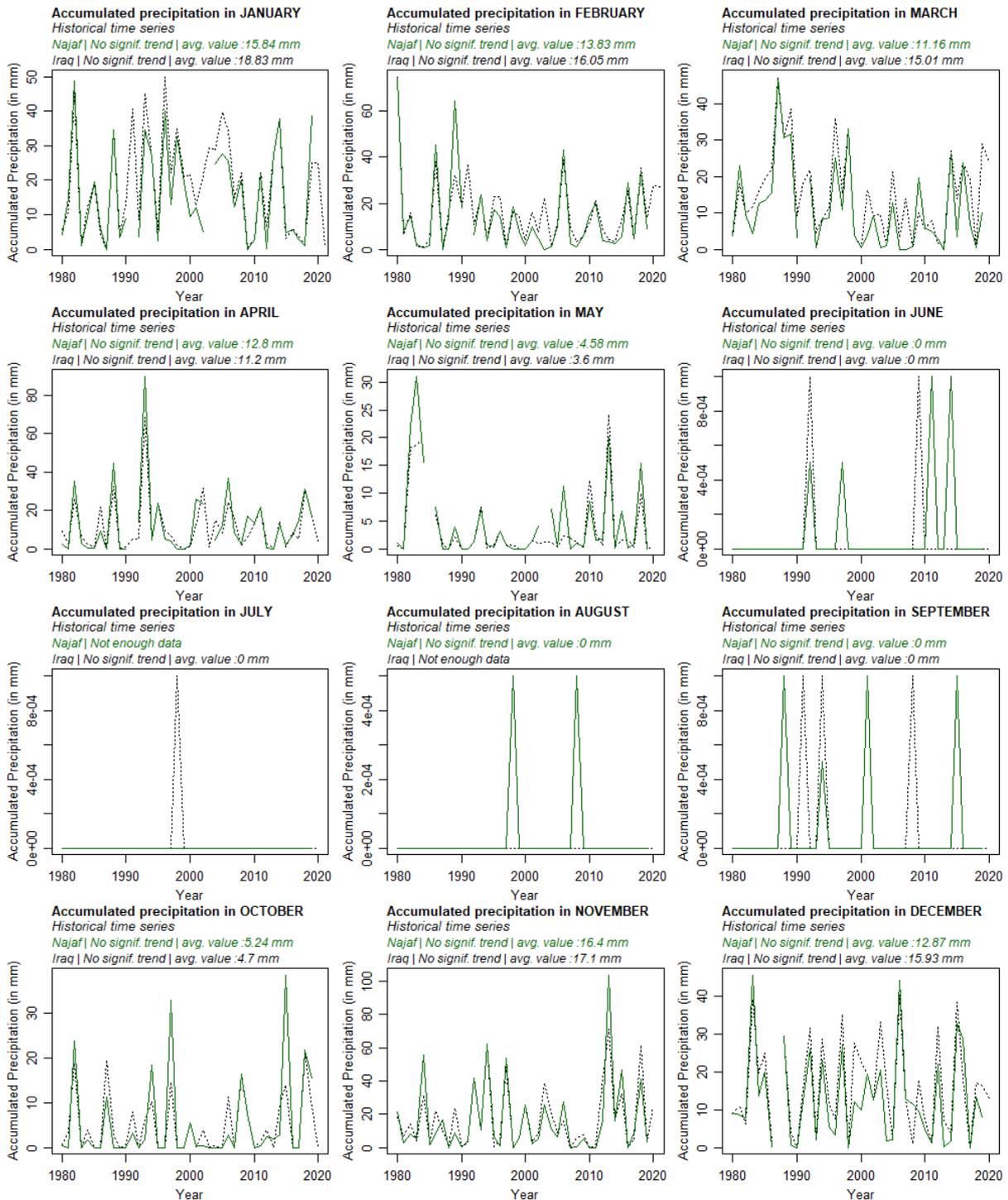


Table 18 – Characteristics of the trends from the historical time series of the accumulated precipitation by month in the three target governorates (linear models)

In red: average value over all the available weather stations located in the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **Data in grey:** the trends is statistically no significant under an alpha of 5%. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.

governorate	Month	Slope	p-value	R ²	Average value in 1980	Average value in 2019
Muthanna	January	-6.01 mm/dec.	0.102	0.06	36.27 mm	12.82 mm
	February	-1.34 mm/dec.	0.721	-0.03	18.01 mm	12.77 mm
	march	-1.46 mm/dec.	0.729	-0.03	20.60 mm	14.92 mm
	April	+0.43 mm/dec.	0.864	-0.04	10.52 mm	12.18 mm
	May	+1.43 mm/dec.	0.497	-0.02	0.51 mm	6.09 mm
	June	-0.02 mm/dec.	0.309	0.00	0.08 mm	-0.01 mm
	July	+0.01 mm/dec.	0.759	-0.03	0.01 mm	0.04 mm
	August	+0.02 mm/dec.	0.759	-0.03	0.01 mm	0.07 mm
	September	-0.23 mm/dec.	0.166	0.04	0.76 mm	-0.15 mm
	October	-0.48 mm/dec.	0.773	-0.03	5.88 mm	4.02 mm
	November	+7.35 mm/dec.	0.251	0.01	2.31 mm	30.96 mm
	December	-0.42 mm/dec.	0.897	-0.03	15.36 mm	13.73 mm
Karbala	January	+0.03 mm/dec.	0.990	-0.03	16.71 mm	16.81 mm
	February	-0.24 mm/dec.	0.918	-0.03	16.34 mm	15.41 mm
	march	+0.27 mm/dec.	0.915	-0.03	15.96 mm	17.00 mm
	April	-1.16 mm/dec.	0.511	-0.01	13.67 mm	9.15 mm
	May	-0.38 mm/dec.	0.621	-0.02	3.94 mm	2.46 mm
	June	+0.01 mm/dec.	0.370	-0.00	-0.01 mm	0.02 mm
	July	-0.00 mm/dec.	0.875	-0.03	0.00 mm	0.00 mm
	August	+0.00 mm/dec.	NA	NA	0.00 mm	0.00 mm
	September	-0.07 mm/dec.	0.433	-0.01	0.29 mm	0.01 mm
	October	+0.27 mm/dec.	0.779	-0.02	4.02 mm	5.06 mm
	November	+2.33 mm/dec.	0.419	-0.01	9.36 mm	18.43 mm
	December	-1.06 mm/dec.	0.580	-0.02	16.40 mm	12.27 mm
Najaf	January	-0.09 mm/dec.	0.964	-0.03	16.01 mm	15.67 mm
	February	-3.07 mm/dec.	0.204	0.02	19.89 mm	7.91 mm
	march	-2.89 mm/dec.	0.066	0.06	16.86 mm	5.59 mm
	April	+0.52 mm/dec.	0.834	-0.03	11.78 mm	13.80 mm
	May	-0.96 mm/dec.	0.357	-0.00	6.48 mm	2.74 mm
	June	+0.00 mm/dec.	0.239	0.01	-0.00 mm	0.00 mm
	July	+0.00 mm/dec.	NA	NA	0.00 mm	0.00 mm
	August	+0.00 mm/dec.	0.670	-0.02	0.00 mm	0.00 mm
	September	+0.00 mm/dec.	0.893	-0.03	0.00 mm	0.00 mm
	October	+1.53 mm/dec.	0.249	0.01	2.24 mm	8.23 mm
	November	+1.94 mm/dec.	0.531	-0.02	12.61 mm	20.19 mm
	December	-0.59 mm/dec.	0.731	-0.02	14.04 mm	11.74 mm

Historical annual trends

Figure 35 – Historical time series of the annually accumulated precipitation in the three target governorates
 Time series over the 1980-2020 period. **In red:** average value over all the available weather stations located in the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **In black, dotted line:** likewise, but for all Iraq. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.

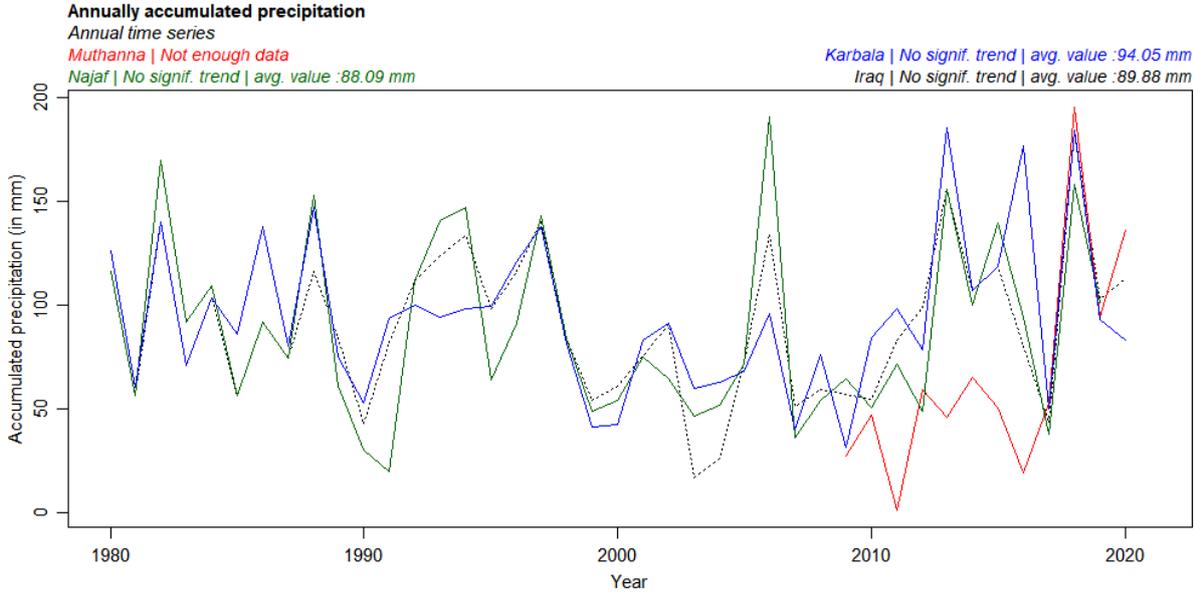


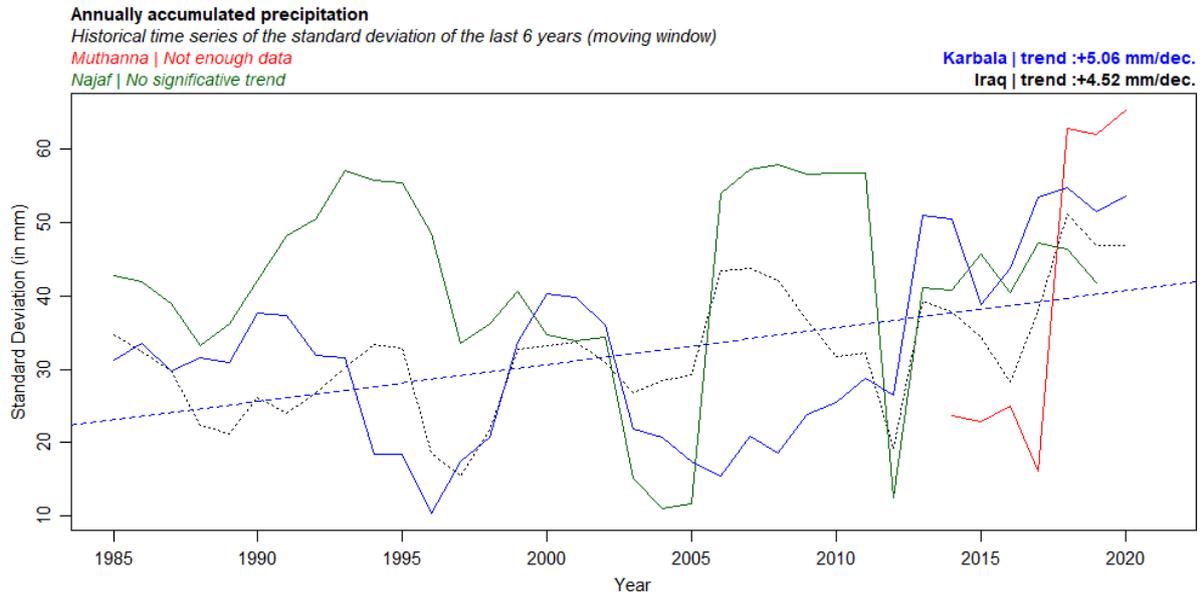
Table 19 – Characteristics of the trends from the historical time series of the annually accumulated precipitation in the three target governorates (linear models)

In red: average value over all the available weather stations located in the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **Data in grey:** the trends is statistically no significative under an alpha of 5%. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.

governorate	Slope	p-value	R ²	Average value in 1980	Average value in 2019
Muthanna	+100.20 mm/dec.	0.017	0.40	-279.59 mm	111.19 mm
Karbala	+1.48 mm/dec.	0.772	-0.02	91.10 mm	96.86 mm
Najaf	-1.03 mm/dec.	0.866	-0.03	90.10 mm	86.09 mm

Figure 36 – Historical time series of the standard deviation of the last 6 years (moving window) of annually accumulated precipitation in the three target governorates

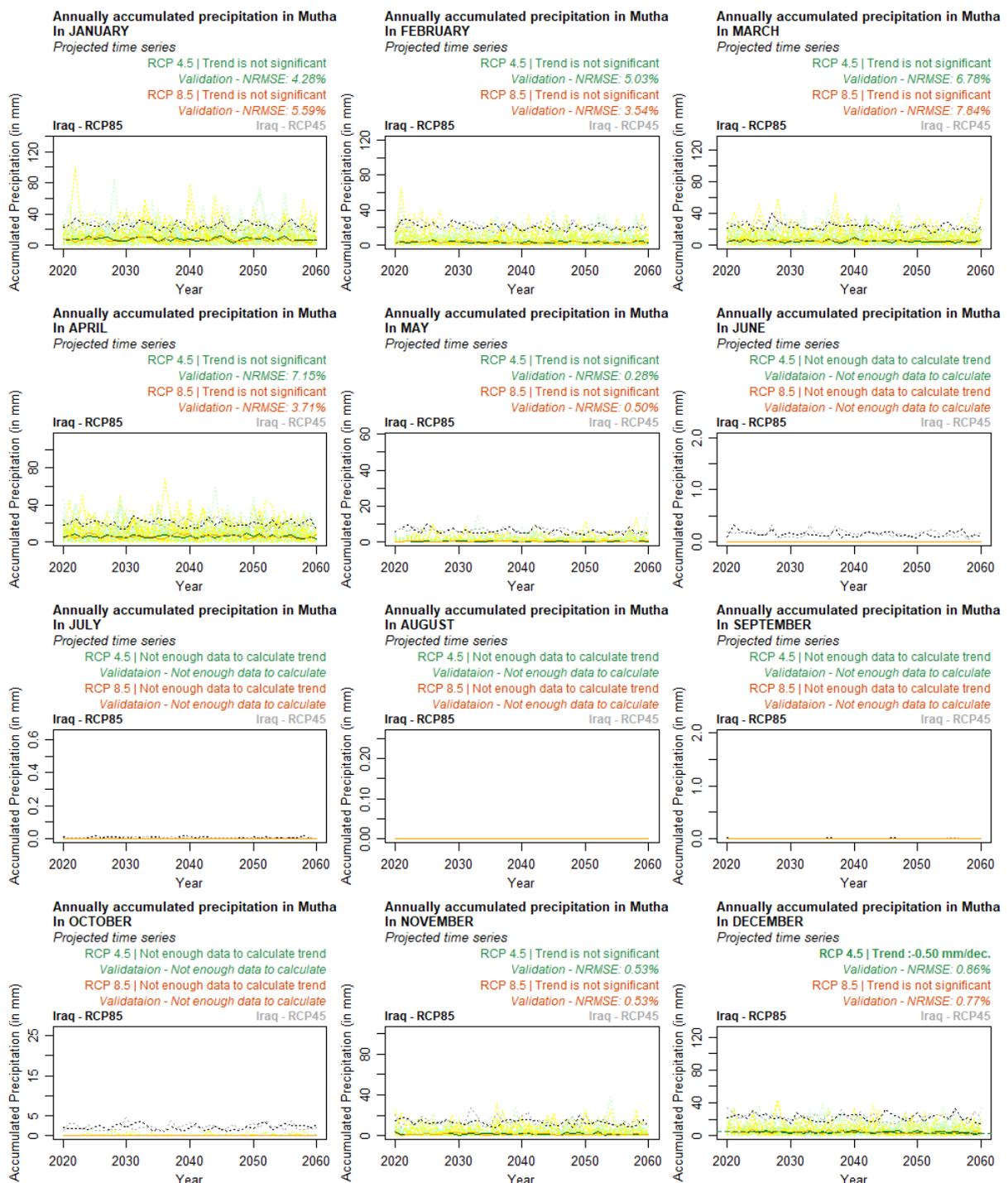
Time series over the 1985-2020 period. **In red:** value over all the available weather stations located in the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **In black, dotted line:** likewise, but for all Iraq. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.



Projected trends by month

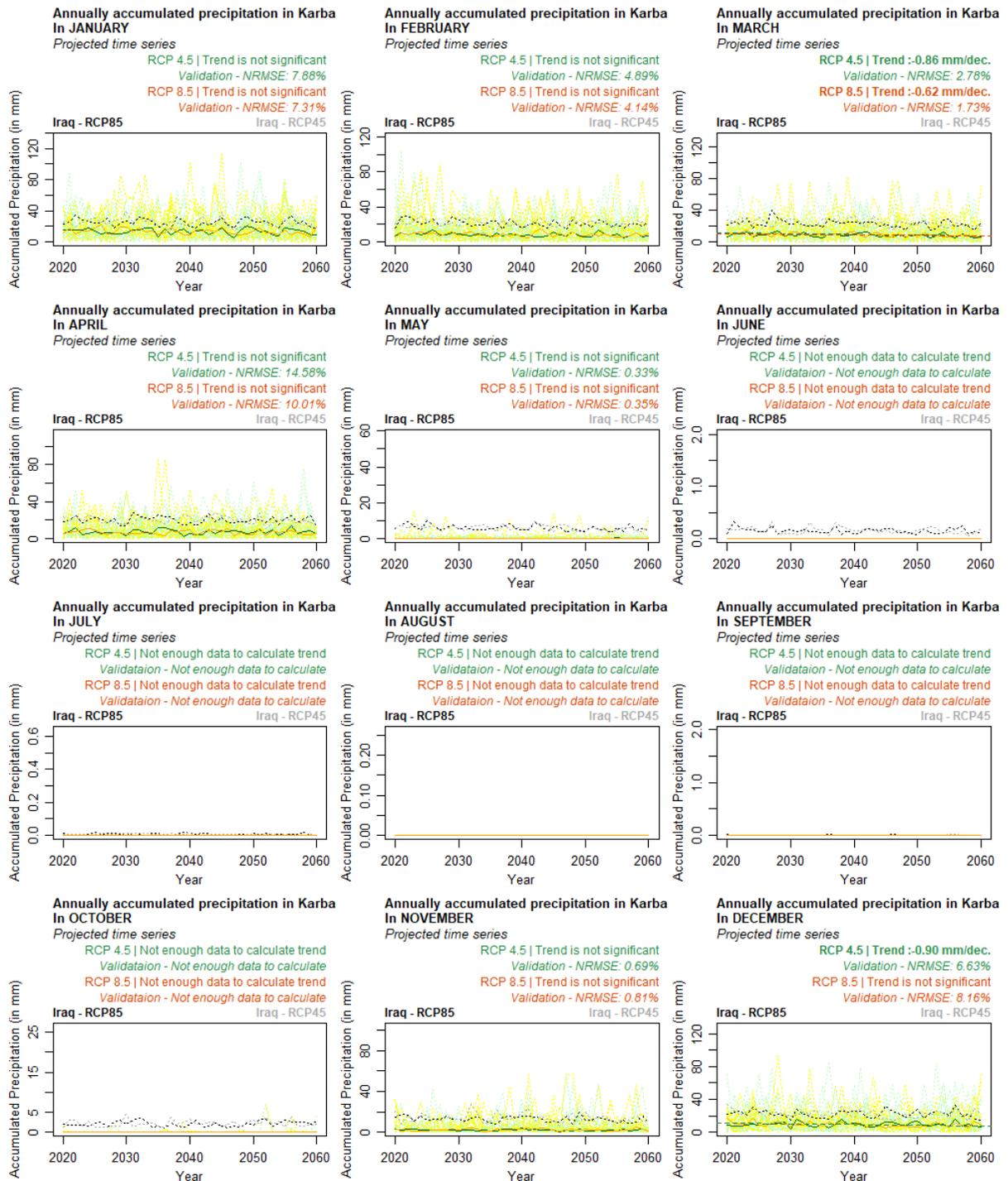
Muthanna

Figure 37 – Projected time series of the accumulated precipitation by month in the governorate of Muthanna
 Time series over the 2020-2060 period. **In yellow (dotted line):** value for each projected model under the RCP4.5. **In orange (full line):** median value calculated over all projected models under the RCP4.5. **In light green (dotted line):** value for each projected model under the RCP8.5. **In dark green (full line):** median value calculated over all projected models under the RCP8.5. **In grey (dotted line):** median value calculated over all projected models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all projected models under the RCP8.5 scenario within Iraq, for comparison. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).



Karbala

Figure 38 – Projected time series of the accumulated precipitation by month in the governorate of Karbala
 Time series over the 2020-2060 period. **In yellow (dotted line):** value for each projected model under the RCP4.5. **In orange (full line):** median value calculated over all projected models under the RCP4.5. **In light green (dotted line):** value for each projected model under the RCP8.5. **In dark green (full line):** median value calculated over all projected models under the RCP8.5. **In grey (dotted line):** median value calculated over all projected models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all projected models under the RCP8.5 scenario within Iraq, for comparison. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).



Najaf

Figure 39 – Projected time series of the accumulated precipitation by month in the governorate of Najaf
 Time series over the 2020-2060 period. **In yellow (dotted line):** value for each projected model under the RCP4.5. **In orange (full line):** median value calculated over all projected models under the RCP4.5. **In light green (dotted line):** value for each projected model under the RCP8.5. **In dark green (full line):** median value calculated over all projected models under the RCP8.5. **In grey (dotted line):** median value calculated over all projected models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all projected models under the RCP8.5 scenario within Iraq, for comparison. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

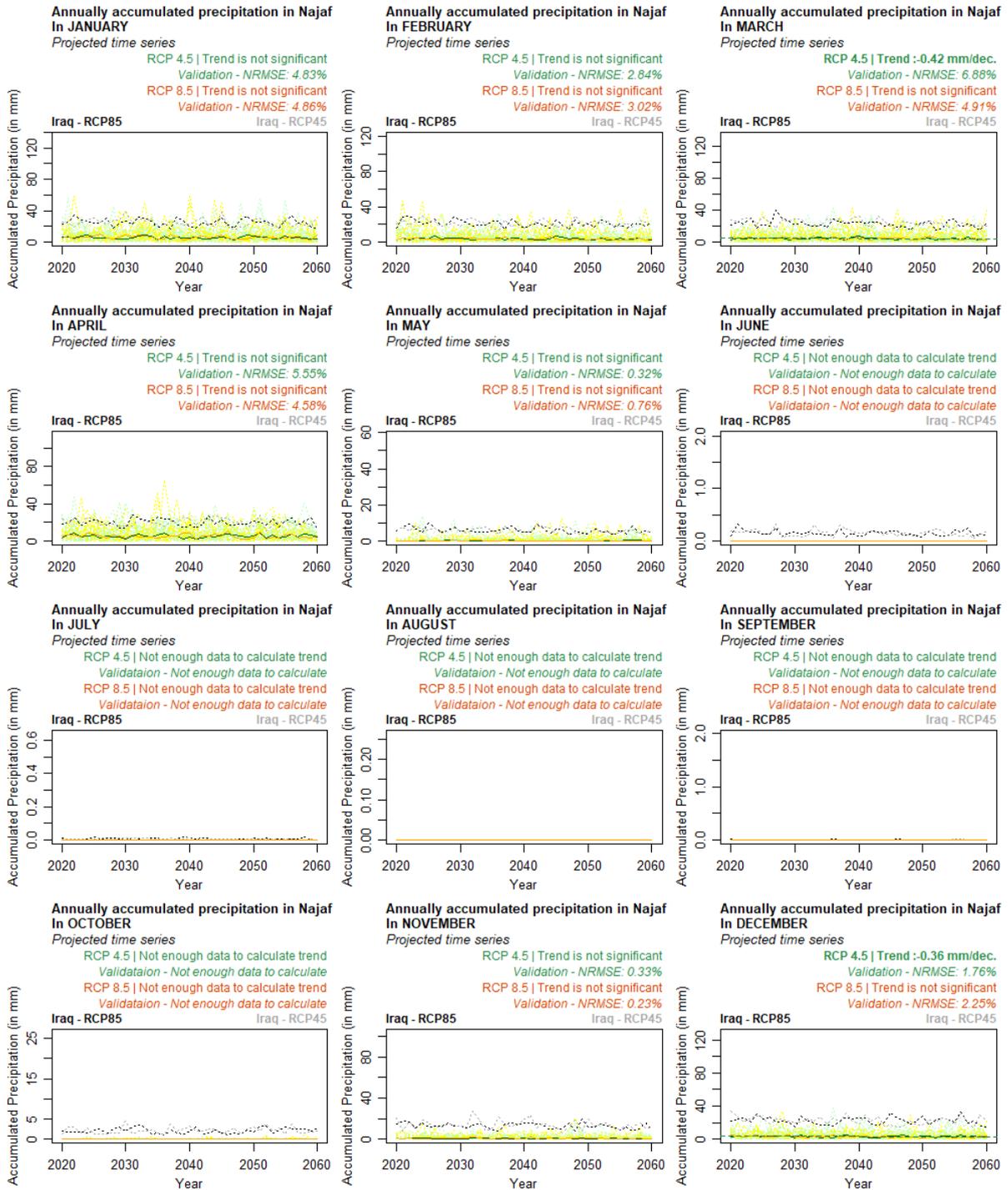


Table 20 – Characteristics of the trends from the Projected time series of the accumulated precipitation by month in the three target governorates under the RCP4.5 scenario (linear models).

In red: median values calculated over all projected models under the RCP4.5 scenario within the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **Data in grey:** the trends is statistically no significant under an alpha of 5%. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

RCP4.5							
governorate	Month	Slope	p-value	R ²	Validation (NRMSE)	Average value in 2040	Average value in 2060
Muthanna	January	-0.45 mm/dec.	0.145	0.03	4.28%	7.29 mm	6.39 mm
	February	-0.13 mm/dec.	0.332	-0.00	5.03%	3.36 mm	3.10 mm
	march	-0.23 mm/dec.	0.260	0.01	6.78%	5.84 mm	5.38 mm
	April	-0.11 mm/dec.	0.662	-0.02	7.15%	5.92 mm	5.69 mm
	May	+0.01 mm/dec.	0.639	-0.02	0.28%	0.36 mm	0.38 mm
	June	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	July	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	August	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	September	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	October	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	November	-0.15 mm/dec.	0.194	0.02	0.53%	1.60 mm	1.30 mm
	December	-0.50 mm/dec.	0.005	0.16	0.86%	4.02 mm	3.02 mm
Karbala	January	-0.86 mm/dec.	0.082	0.05	7.88%	13.54 mm	11.82 mm
	February	-0.51 mm/dec.	0.079	0.05	4.89%	8.60 mm	7.58 mm
	march	-0.86 mm/dec.	0.004	0.17	2.78%	9.23 mm	7.51 mm
	April	-0.22 mm/dec.	0.467	-0.01	14.58%	6.90 mm	6.46 mm
	May	-0.01 mm/dec.	0.156	0.03	0.33%	0.09 mm	0.06 mm
	June	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	July	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	August	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	September	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	October	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	November	+0.03 mm/dec.	0.814	-0.02	0.69%	2.26 mm	2.33 mm
	December	-0.90 mm/dec.	0.011	0.13	6.63%	9.42 mm	7.62 mm
Najaf	January	-0.39 mm/dec.	0.140	0.03	4.83%	6.07 mm	5.30 mm
	February	-0.22 mm/dec.	0.057	0.07	2.84%	3.46 mm	3.02 mm
	march	-0.42 mm/dec.	0.021	0.11	6.88%	4.76 mm	3.93 mm
	April	-0.25 mm/dec.	0.358	-0.00	5.55%	5.40 mm	4.89 mm
	May	-0.01 mm/dec.	0.384	-0.01	0.32%	0.20 mm	0.17 mm
	June	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	July	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	August	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	September	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	October	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	November	-0.04 mm/dec.	0.494	-0.01	0.33%	0.74 mm	0.67 mm
	December	-0.36 mm/dec.	0.007	0.15	1.76%	2.96 mm	2.23 mm

Table 21 – Characteristics of the trends from the Projected time series of the accumulated precipitation by month in the three target governorates under the RCP8.5 scenario (linear models).

In red: median values calculated over all projected models under the RCP8.5 scenario within the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **Data in grey:** the trends is statistically no significant under an alpha of 5%. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

RCP8.5							
governorate	Month	Slope	p-value	R ²	Validation (NRMSE)	Average value in 2040	Average value in 2060
Muthanna	January	-0.16 mm/dec.	0.597	-0.02	5.59%	7.56 mm	7.24 mm
	February	-0.10 mm/dec.	0.430	-0.01	3.54%	3.42 mm	3.22 mm
	march	-0.25 mm/dec.	0.202	0.02	7.84%	5.06 mm	4.56 mm
	April	-0.06 mm/dec.	0.782	-0.02	3.71%	6.03 mm	5.91 mm
	May	-0.01 mm/dec.	0.756	-0.02	0.50%	0.34 mm	0.33 mm
	June	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	July	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	August	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	September	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	October	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	November	-0.06 mm/dec.	0.571	-0.02	0.53%	1.50 mm	1.37 mm
	December	-0.10 mm/dec.	0.534	-0.02	0.77%	4.17 mm	3.97 mm
Karbala	January	-0.34 mm/dec.	0.496	-0.01	7.31%	13.51 mm	12.83 mm
	February	-0.50 mm/dec.	0.071	0.06	4.14%	8.40 mm	7.39 mm
	march	-0.62 mm/dec.	0.042	0.08	1.73%	8.59 mm	7.35 mm
	April	+0.17 mm/dec.	0.614	-0.02	10.01%	7.24 mm	7.59 mm
	May	+0.01 mm/dec.	0.577	-0.02	0.35%	0.09 mm	0.10 mm
	June	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	July	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	August	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	September	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	October	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	November	-0.16 mm/dec.	0.116	0.04	0.81%	2.02 mm	1.70 mm
	December	+0.03 mm/dec.	0.931	-0.03	8.16%	9.37 mm	9.44 mm
Najaf	January	-0.26 mm/dec.	0.235	0.01	4.86%	5.73 mm	5.20 mm
	February	-0.19 mm/dec.	0.209	0.02	3.02%	3.74 mm	3.37 mm
	march	-0.23 mm/dec.	0.187	0.02	4.91%	4.38 mm	3.93 mm
	April	+0.14 mm/dec.	0.539	-0.02	4.58%	5.40 mm	5.68 mm
	May	+0.02 mm/dec.	0.362	-0.00	0.76%	0.19 mm	0.23 mm
	June	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	July	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	August	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	September	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	October	+0.00 mm/dec.	NA	NA	NA	0.00 mm	0.00 mm
	November	-0.05 mm/dec.	0.151	0.03	0.23%	0.61 mm	0.51 mm
	December	+0.03 mm/dec.	0.806	-0.02	2.25%	3.12 mm	3.18 mm

Projected annual trends

Figure 40 – Projected time series of the annually accumulated precipitation in the three target governorates
 Time series over the 2020-2060 period. **In yellow (dotted line):** value for each projected model under the RCP4.5. **In orange (full line):** median value calculated over all projected models under the RCP4.5. **In light green (dotted line):** value for each projected model under the RCP8.5. **In dark green (full line):** median value calculated over all projected models under the RCP8.5. **In grey (dotted line):** median value calculated over all projected models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all projected models under the RCP8.5 scenario within Iraq, for comparison. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

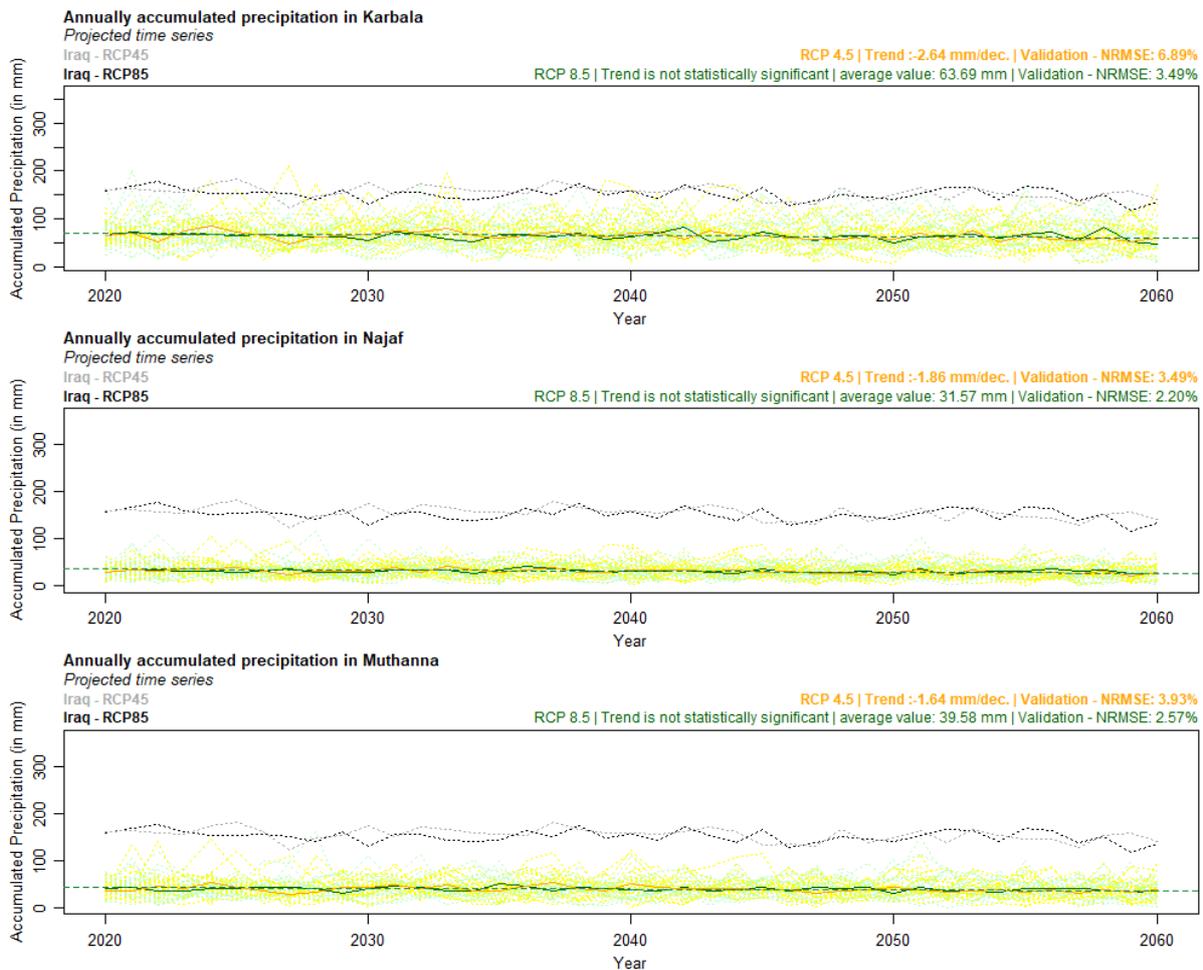


Table 22 – Characteristics of the trends from the projected time series of the annually accumulated precipitation in the three target governorates (linear models).

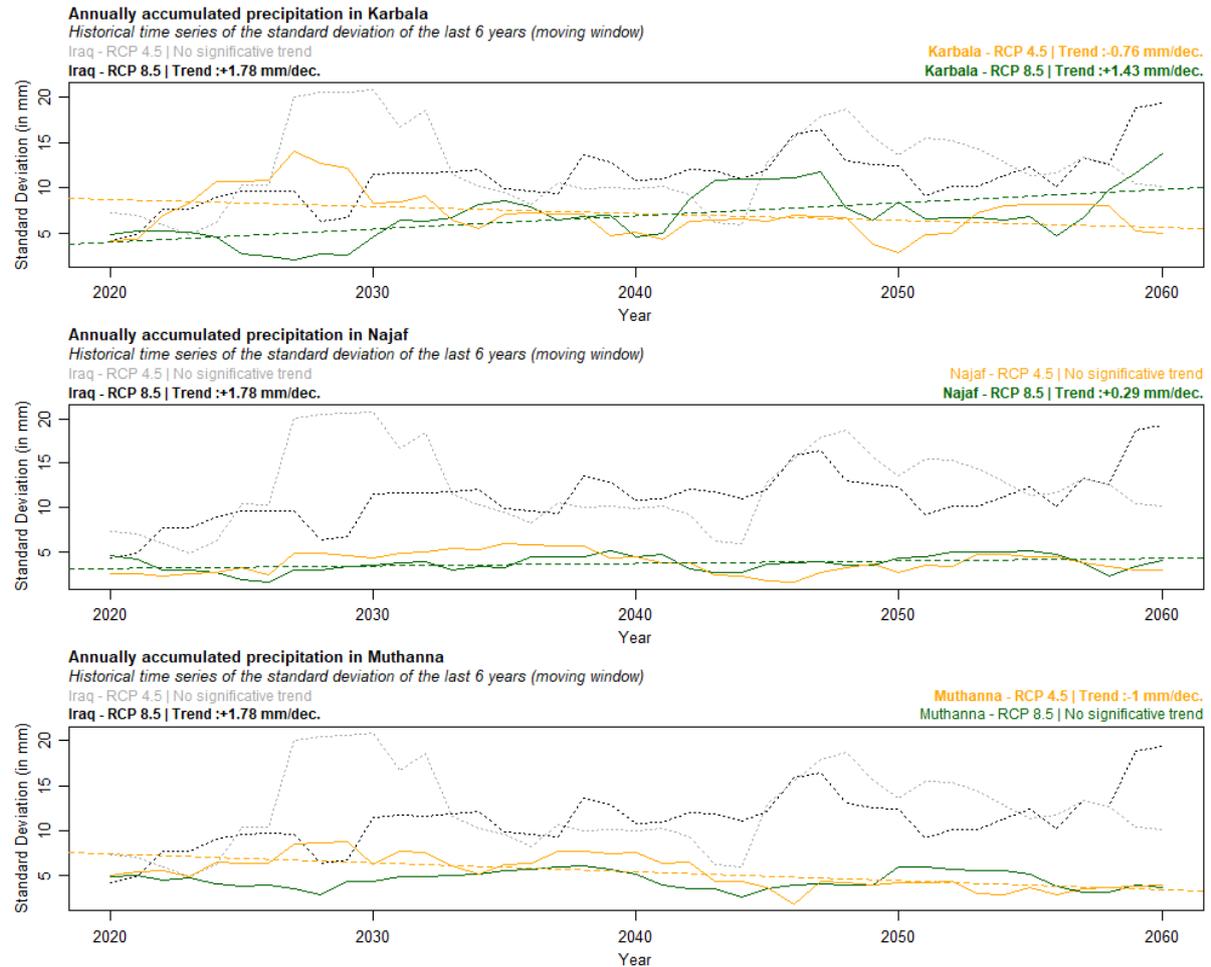
In red: median values calculated over all NEX models within the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **Data in grey:** the trends is statistically no significant under an alpha of 5%. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

RCP4.5						
governorate	Slope	p-value	R ²	Validation (NRMSE)	Average value in 2040	Average value in 2060
Muthanna	-1.64 mm/dec.	0.037	0.08	3.93%	39.78 mm	36.50 mm
Karbala	-2.64 mm/dec.	0.012	0.13	6.89%	64.47 mm	59.18 mm
Najaf	-1.86 mm/dec.	0.001	0.22	3.49%	31.68 mm	27.96 mm
RCP8.5						
governorate	Slope	p-value	R ²	Validation (NRMSE)	Average value in 2040	Average value in 2060
Muthanna	-0.78 mm/dec.	0.181	0.02	2.57%	39.58 mm	38.01 mm
Karbala	-1.21 mm/dec.	0.256	0.01	3.49%	63.69 mm	61.28 mm
Najaf	-0.79 mm/dec.	0.122	0.04	2.20%	31.57 mm	30.00 mm

Figure 41 – Projected time series of the standard deviation of the last 6 years (moving window) of annually accumulated precipitation in the three target governorates

Time series over the 2020-2060 period. **In orange:** Standard deviation of the last 6 years for the median model under the RCP4.5 scenario. **In dark green:** Likewise, under the RCP8.5 scenario. **In grey (dotted line):** median value calculated over all projected models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all projected models under the RCP8.5 scenario within Iraq, for comparison.

Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).



7. Potential evapotranspiration

This section will present the variations of the projected accumulated potential evapotranspiration in the three target governorates of the project in the Republic of Iraq, focusing on **monthly accumulated potential evapotranspiration** (PET_m) and **annually accumulated potential evapotranspiration** (PET_y).

Unfortunately, as we write, not enough local data on potential evapotranspiration was available to be able to perform the validation of the projected models. The following projected trends are therefore to be taken with circumspection.

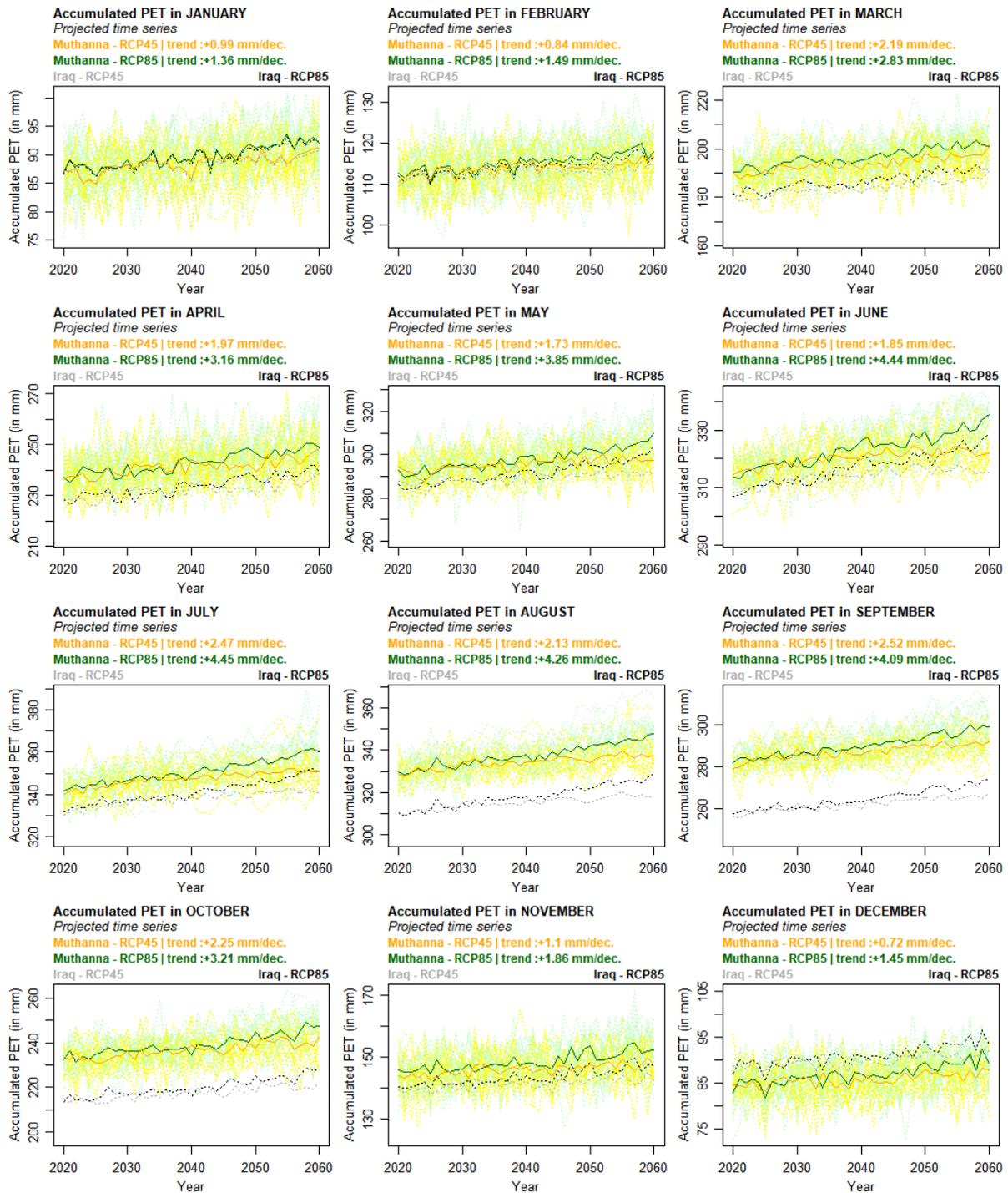
The projected PET was calculated using the Blaney–Criddle equation (Blaney et al., 1964) based on temperature data from NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012). The monthly p factors used were calculated by inverting the Blaney–Criddle equation, and using NASA TerraNet data on PET (Running et al., 2021) and ERA5 - ECMWF / Copernicus Climate Change Service data on average temperature (Muñoz Sabater, 2019).

Projected trends by month

Muthanna

Figure 42 – Projected time series of the accumulated PET by month in the governorate of Muthanna

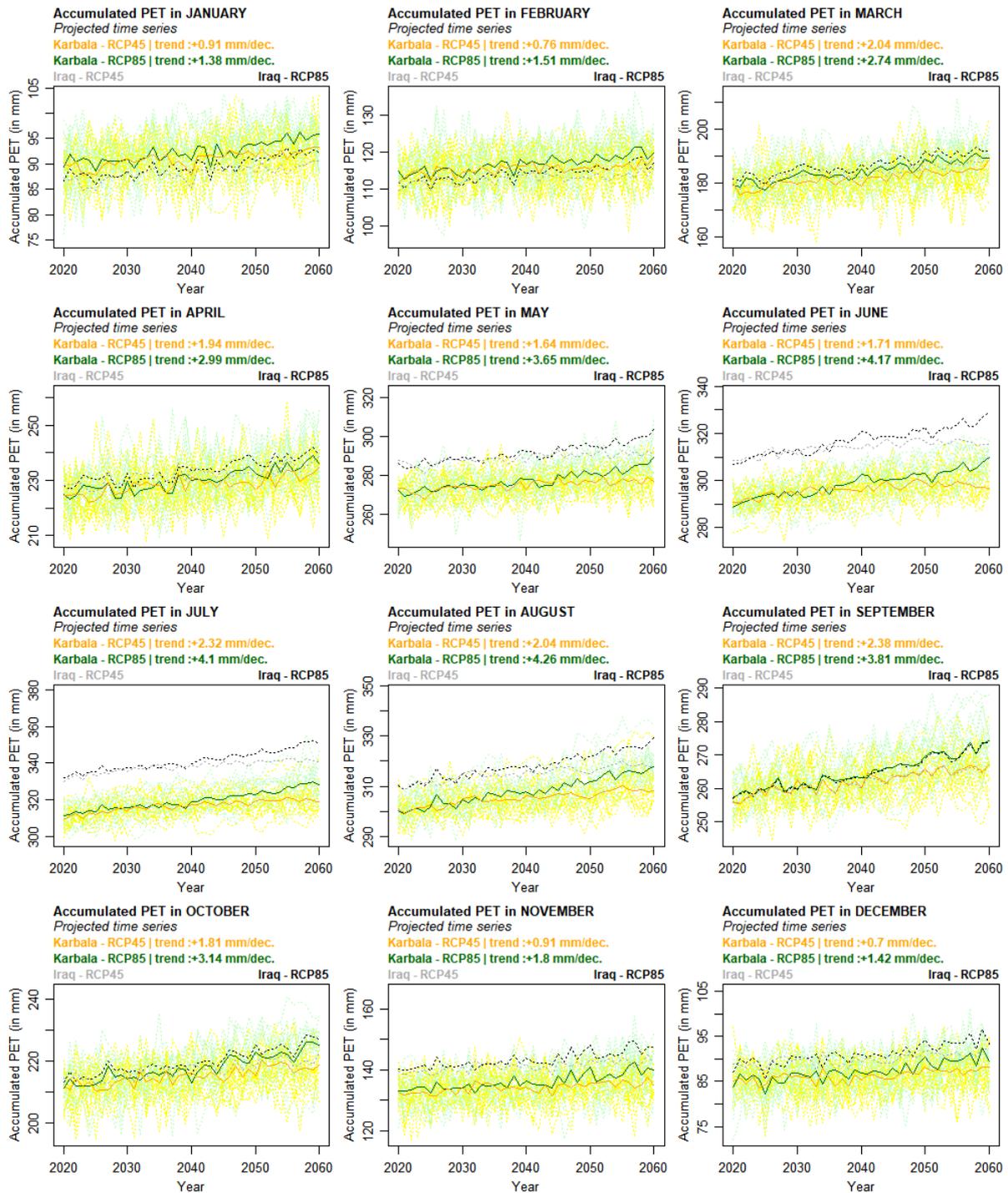
Time series over the 2020-2060 period. **In yellow (dotted line):** value for each projected model under the RCP4.5. **In orange (full line):** median value calculated over all projected models under the RCP4.5. **In light green (dotted line):** value for each projected model under the RCP8.5. **In dark green (full line):** median value calculated over all projected models under the RCP8.5. **In grey (dotted line):** median value calculated over all projected models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all projected models under the RCP8.5 scenario within Iraq, for comparison. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).



Karbala

Figure 43 – Projected time series of the accumulated PET by month in the governorate of Karbala

Time series over the 2020-2060 period. **In yellow (dotted line):** value for each projected model under the RCP4.5. **In orange (full line):** median value calculated over all projected models under the RCP4.5. **In light green (dotted line):** value for each projected model under the RCP8.5. **In dark green (full line):** median value calculated over all projected models under the RCP8.5. **In grey (dotted line):** median value calculated over all projected models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all projected models under the RCP8.5 scenario within Iraq, for comparison. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).



Najaf

Figure 44 – Projected time series of the accumulated PET by month in the governorate of Najaf

Time series over the 2020-2060 period. **In yellow (dotted line):** value for each projected model under the RCP4.5. **In orange (full line):** median value calculated over all projected models under the RCP4.5. **In light green (dotted line):** value for each projected model under the RCP8.5. **In dark green (full line):** median value calculated over all projected models under the RCP8.5. **In grey (dotted line):** median value calculated over all projected models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all projected models under the RCP8.5 scenario within Iraq, for comparison. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

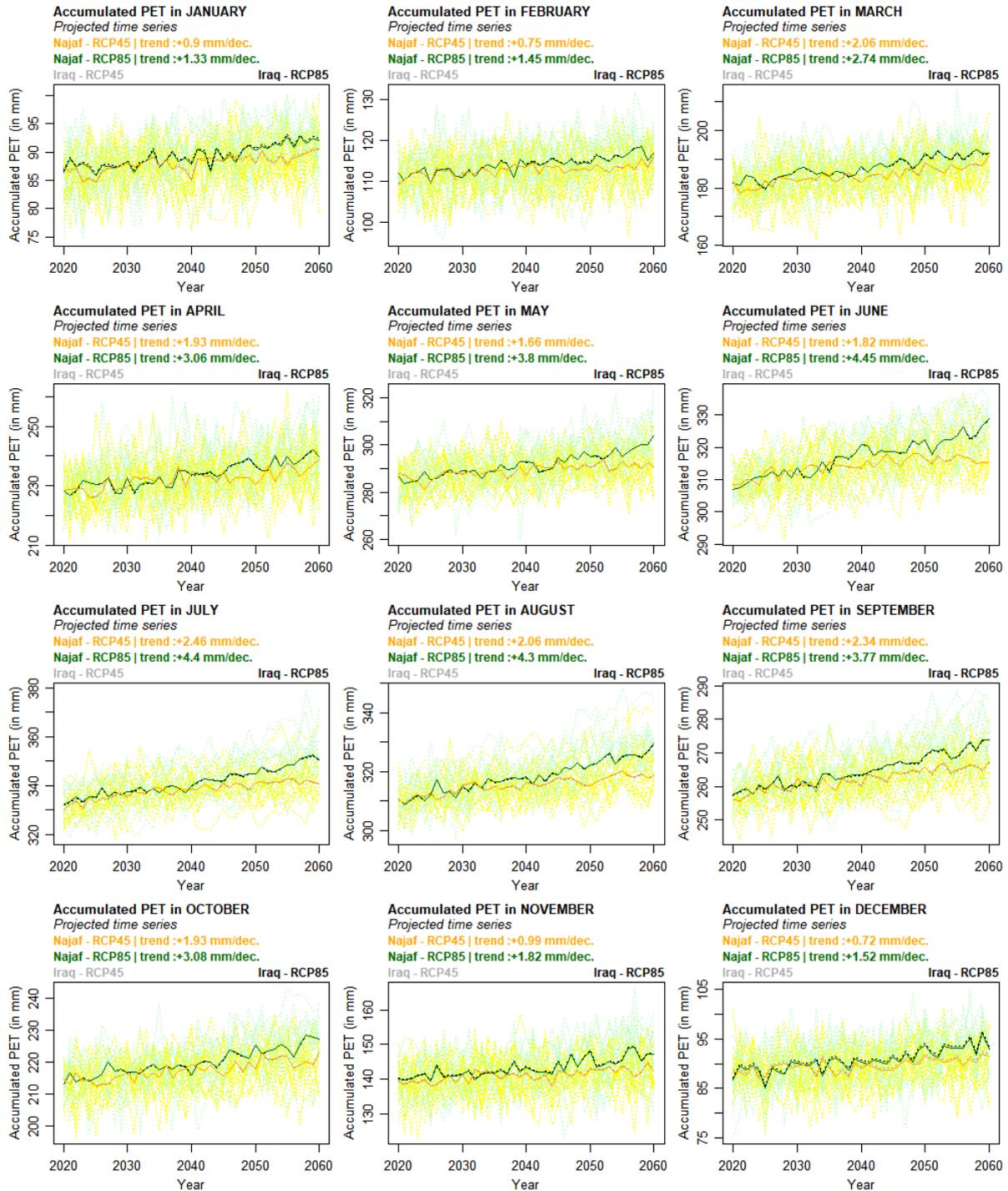


Table 23 – Characteristics of the trends from the Projected time series of the accumulated PET by month in the three target governorates under the RCP4.5 scenario (linear models).

In red: median values calculated over all projected models under the RCP4.5 scenario within the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **Data in grey:** the trends is statistically no significant under an alpha of 5%. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

RCP4.5						
governorate	Month	Slope	p-value	R ²	Average value in 2040	Average value in 2060
Muthanna	January	+0.99 mm/dec.	0.000	0.59	88.46 mm	90.43 mm
	February	+0.84 mm/dec.	0.000	0.47	113.93 mm	115.61 mm
	march	+2.19 mm/dec.	0.000	0.78	193.79 mm	198.17 mm
	April	+1.97 mm/dec.	0.000	0.57	241.21 mm	245.15 mm
	May	+1.73 mm/dec.	0.000	0.56	295.52 mm	298.99 mm
	June	+1.85 mm/dec.	0.000	0.69	320.35 mm	324.05 mm
	July	+2.47 mm/dec.	0.000	0.86	347.34 mm	352.28 mm
	August	+2.13 mm/dec.	0.000	0.78	334.33 mm	338.58 mm
	September	+2.52 mm/dec.	0.000	0.80	287.11 mm	292.15 mm
	October	+2.25 mm/dec.	0.000	0.70	236.60 mm	241.09 mm
	November	+1.10 mm/dec.	0.000	0.55	145.94 mm	148.13 mm
	December	+0.72 mm/dec.	0.000	0.43	85.79 mm	87.22 mm
Karbala	January	+0.91 mm/dec.	0.000	0.55	91.02 mm	92.85 mm
	February	+0.76 mm/dec.	0.000	0.39	115.45 mm	116.96 mm
	march	+2.04 mm/dec.	0.000	0.75	181.64 mm	185.72 mm
	April	+1.94 mm/dec.	0.000	0.57	228.42 mm	232.30 mm
	May	+1.64 mm/dec.	0.000	0.59	275.06 mm	278.34 mm
	June	+1.71 mm/dec.	0.000	0.61	296.18 mm	299.60 mm
	July	+2.32 mm/dec.	0.000	0.82	316.59 mm	321.23 mm
	August	+2.04 mm/dec.	0.000	0.82	305.16 mm	309.23 mm
	September	+2.38 mm/dec.	0.000	0.81	262.12 mm	266.89 mm
	October	+1.81 mm/dec.	0.000	0.65	215.14 mm	218.77 mm
	November	+0.91 mm/dec.	0.000	0.44	134.22 mm	136.05 mm
	December	+0.70 mm/dec.	0.000	0.43	86.21 mm	87.60 mm
Najaf	January	+0.90 mm/dec.	0.000	0.55	87.92 mm	89.72 mm
	February	+0.75 mm/dec.	0.000	0.41	112.80 mm	114.30 mm
	march	+2.06 mm/dec.	0.000	0.75	184.30 mm	188.42 mm
	April	+1.93 mm/dec.	0.000	0.56	232.21 mm	236.08 mm
	May	+1.66 mm/dec.	0.000	0.55	289.18 mm	292.49 mm
	June	+1.82 mm/dec.	0.000	0.65	314.17 mm	317.81 mm
	July	+2.46 mm/dec.	0.000	0.82	338.19 mm	343.11 mm
	August	+2.06 mm/dec.	0.000	0.80	315.26 mm	319.39 mm
	September	+2.34 mm/dec.	0.000	0.82	262.08 mm	266.77 mm
	October	+1.93 mm/dec.	0.000	0.67	217.39 mm	221.24 mm
	November	+0.99 mm/dec.	0.000	0.48	140.95 mm	142.94 mm
	December	+0.72 mm/dec.	0.000	0.43	89.52 mm	90.96 mm

Table 24 – Characteristics of the trends from the Projected time series of the accumulated PET by month in the three target governorates under the RCP8.5 scenario (linear models).

In red: median values calculated over all projected models under the RCP8.5 scenario within the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **Data in grey:** the trends is statistically no significant under an alpha of 5%. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

RCP8.5						
governorate	Month	Slope	p-value	R ²	Average value in 2040	Average value in 2060
Muthanna	January	+1.36 mm/dec.	0.000	0.73	89.76 mm	92.49 mm
	February	+1.49 mm/dec.	0.000	0.71	115.26 mm	118.23 mm
	march	+2.83 mm/dec.	0.000	0.84	196.57 mm	202.22 mm
	April	+3.16 mm/dec.	0.000	0.80	242.89 mm	249.22 mm
	May	+3.85 mm/dec.	0.000	0.86	297.99 mm	305.69 mm
	June	+4.44 mm/dec.	0.000	0.90	323.45 mm	332.34 mm
	July	+4.45 mm/dec.	0.000	0.94	350.84 mm	359.74 mm
	August	+4.26 mm/dec.	0.000	0.93	337.56 mm	346.08 mm
	September	+4.09 mm/dec.	0.000	0.93	290.22 mm	298.39 mm
	October	+3.21 mm/dec.	0.000	0.81	239.14 mm	245.57 mm
	November	+1.86 mm/dec.	0.000	0.65	148.41 mm	152.13 mm
	December	+1.45 mm/dec.	0.000	0.67	86.94 mm	89.84 mm
Karbala	January	+1.38 mm/dec.	0.000	0.67	92.33 mm	95.08 mm
	February	+1.51 mm/dec.	0.000	0.69	116.72 mm	119.73 mm
	march	+2.74 mm/dec.	0.000	0.83	184.40 mm	189.87 mm
	April	+2.99 mm/dec.	0.000	0.75	230.06 mm	236.05 mm
	May	+3.65 mm/dec.	0.000	0.83	277.50 mm	284.79 mm
	June	+4.17 mm/dec.	0.000	0.91	298.81 mm	307.15 mm
	July	+4.10 mm/dec.	0.000	0.93	319.62 mm	327.82 mm
	August	+4.26 mm/dec.	0.000	0.93	308.15 mm	316.66 mm
	September	+3.81 mm/dec.	0.000	0.92	264.79 mm	272.41 mm
	October	+3.14 mm/dec.	0.000	0.83	217.84 mm	224.13 mm
	November	+1.80 mm/dec.	0.000	0.67	136.19 mm	139.79 mm
	December	+1.42 mm/dec.	0.000	0.67	87.30 mm	90.13 mm
Najaf	January	+1.33 mm/dec.	0.000	0.70	89.20 mm	91.87 mm
	February	+1.45 mm/dec.	0.000	0.71	114.06 mm	116.96 mm
	march	+2.74 mm/dec.	0.000	0.83	186.99 mm	192.47 mm
	April	+3.06 mm/dec.	0.000	0.79	233.83 mm	239.95 mm
	May	+3.80 mm/dec.	0.000	0.86	291.74 mm	299.35 mm
	June	+4.45 mm/dec.	0.000	0.90	317.08 mm	325.98 mm
	July	+4.40 mm/dec.	0.000	0.93	341.45 mm	350.24 mm
	August	+4.30 mm/dec.	0.000	0.92	318.35 mm	326.94 mm
	September	+3.77 mm/dec.	0.000	0.92	264.78 mm	272.33 mm
	October	+3.08 mm/dec.	0.000	0.84	219.95 mm	226.11 mm
	November	+1.82 mm/dec.	0.000	0.67	143.15 mm	146.79 mm
	December	+1.52 mm/dec.	0.000	0.68	90.67 mm	93.71 mm

Projected annual trends

Figure 45 – Projected time series of the annually accumulated PET in the three target governorates
 Time series over the 2020-2060 period. **In yellow (dotted line):** value for each projected model under the RCP4.5. **In orange (full line):** median value calculated over all projected models under the RCP4.5. **In light green (dotted line):** value for each projected model under the RCP8.5. **In dark green (full line):** median value calculated over all projected models under the RCP8.5. **In grey (dotted line):** median value calculated over all projected models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all projected models under the RCP8.5 scenario within Iraq, for comparison. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

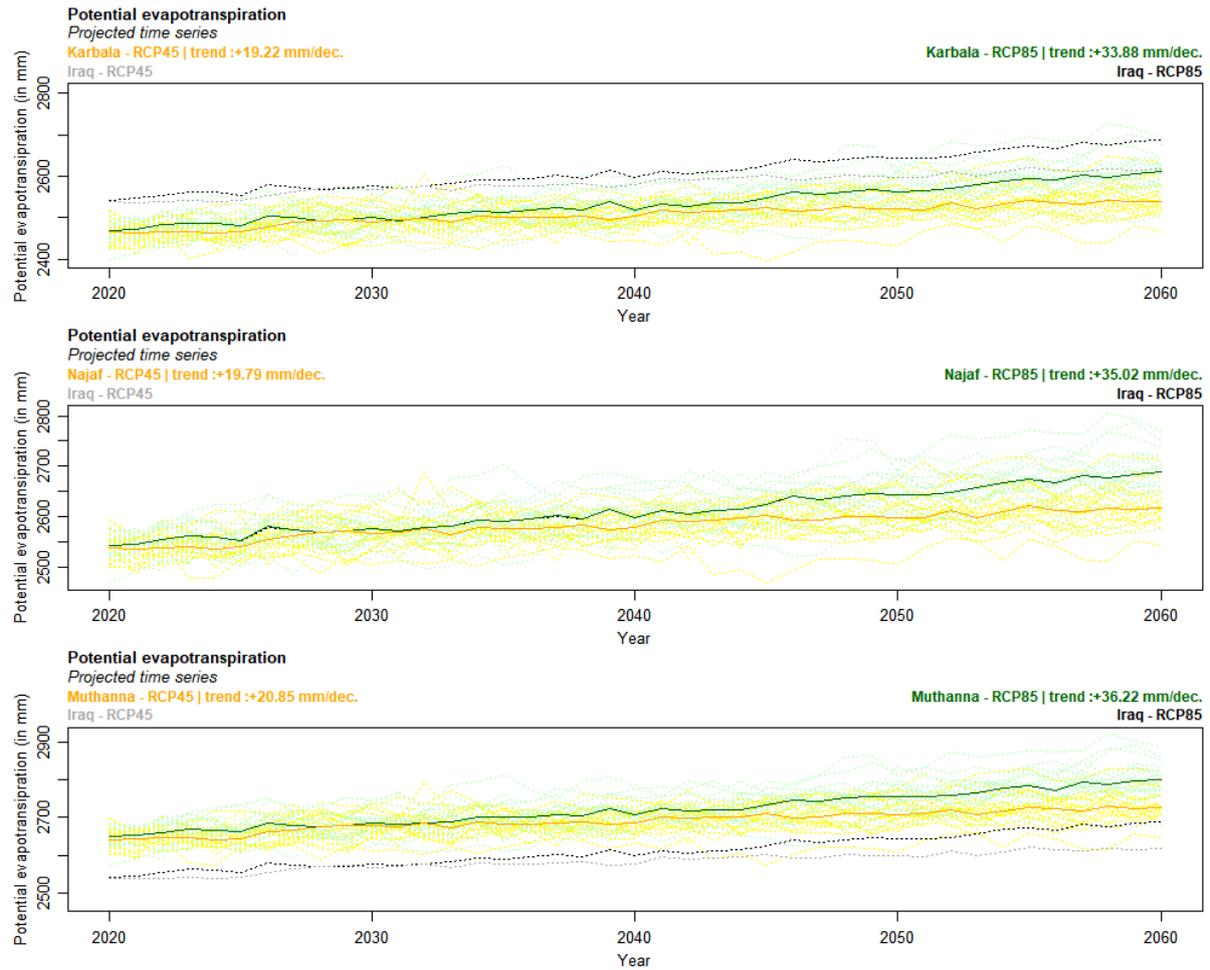


Table 25 – Characteristics of the trends from the projected time series of the annually accumulated PET in the three target governorates (linear models).

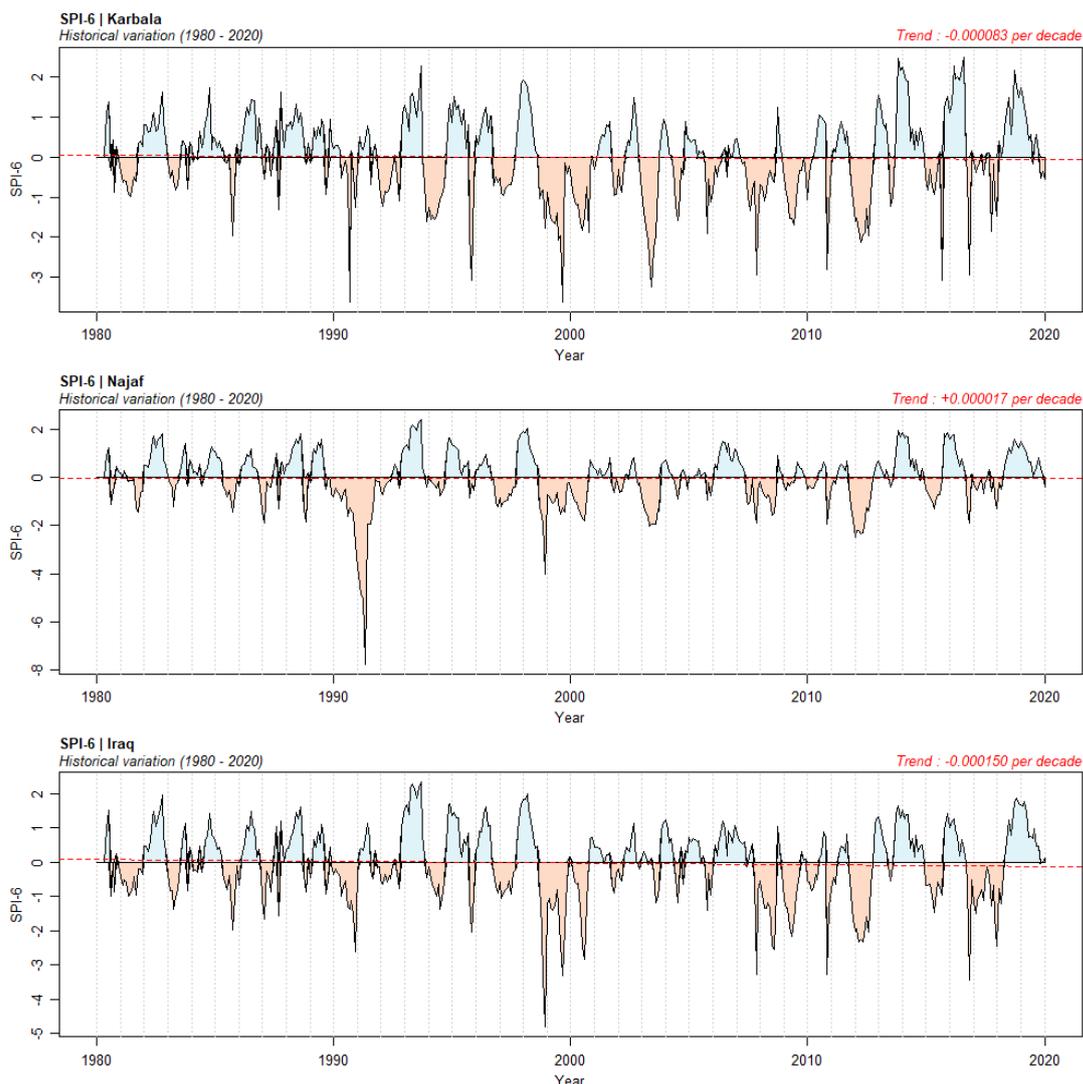
In red: median values calculated over all NEX models within the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **Data in grey:** the trends is statistically no significant under an alpha of 5%. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

RCP4.5					
governorate	Slope	p-value	R ²	Average value in 2040	Average value in 2060
Muthanna	+20.85 mm/dec.	0.000	0.93	2690.04 mm	2731.74 mm
Karbala	+19.22 mm/dec.	0.000	0.92	2505.95 mm	2544.39 mm
Najaf	+19.79 mm/dec.	0.000	0.92	2582.96 mm	2622.54 mm
RCP8.5					
governorate	Slope	p-value	R ²	Average value in 2040	Average value in 2060
Muthanna	+36.22 mm/dec.	0.000	0.97	2719.79 mm	2792.24 mm
Karbala	+33.88 mm/dec.	0.000	0.97	2534.56 mm	2602.31 mm
Najaf	+35.02 mm/dec.	0.000	0.97	2611.69 mm	2681.73 mm

8. Standard precipitation index (SPI)

This section will present the Standardized Precipitation Index (SPI), a widely used index to characterize meteorological drought on a range of timescales, in two of the three target governorates of the project (Muthanna did not have sufficient data to carry out the analysis) in the Republic of Iraq. The analysis generated data for the 6-month SPI¹ and the 24-month SPI².

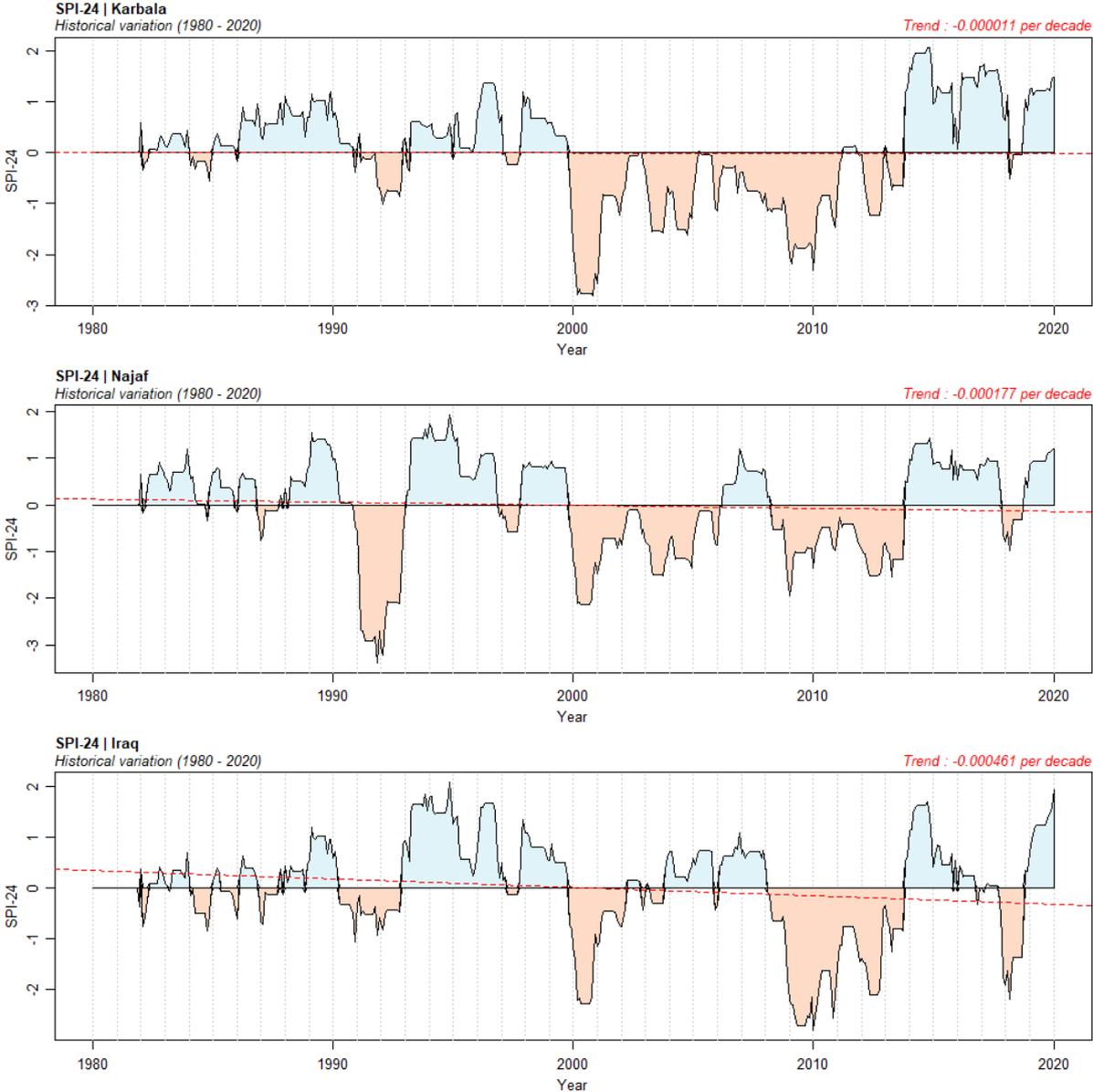
Figure 46 – Historical time series of the 6-month-SPI in the governorate of Karbala and Najaf and in Iraq. Time series over the 1980-2020 period. *Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.*



¹ The 6-month SPI compares the precipitation for that period with the same 6-month period over the historical record. For example, a 6-month SPI at the end of September compares the precipitation total for the April–September period with all the past totals for that same period. The 6-month SPI indicates seasonal to medium-term trends in precipitation and is still considered to be more sensitive to conditions at this scale than the Palmer Index. A 6-month SPI can be very effective in showing the precipitation over distinct seasons. For example, a 6-month SPI at the end of March would give a very good indication of the amount of precipitation that has fallen during the very important wet season period from October through March for certain Mediterranean locales. Information from a 6-month SPI may also begin to be associated with anomalous streamflows and reservoir levels, depending on the region and time of year.

² The 24-month SPI reflects long-term precipitation patterns. A 24-month SPI is a comparison of the precipitation for 24 consecutive months with that recorded in the same 24 consecutive months in all previous years of available data. Because these timescales are the cumulative result of shorter periods that may be above or below normal, the longer SPIs tend to gravitate toward zero unless a distinctive wet or dry trend is taking place. SPIs of these timescales are usually tied to streamflows, reservoir levels, and even groundwater levels at longer timescales.

Figure 47 – Historical time series of the 24-month-SPI in the governorate of Karbala and Najaf and in Iraq.
Time series over the 1980-2020 period. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.



9. Summary of Climate trends and projections

Table 26 – Summary of climate trends in Iraq and the target governorates

Time series over the 1980-2020 period. NSST: Not statistically significant trend. *Data source:* Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.

Variable	Governorate	Trend	p-value	R ²	Average value in 1980	Average value in 2019	Notes
Annual Average Temperature	Muthanna	+0.32°C/dec.	0.002	0.29	24.13°C	25.37°C	
	Karbala	+0.22°C/dec.	0.036	0.09	23.88°C	24.74°C	
	Najaf	+0.56°C/dec.	0.000	0.39	23.74°C	25.92°C	
	National Average	+0.37°C/dec.	0.001	0.23	23.77°C	25.22°C	
Annual Maximum Temperature	Muthanna	+1.37°C/dec.	0.338	0.00	45.39°C	50.73°C	NSST
	Karbala	+0.29°C/dec.	0.141	0.04	48.07°C	49.22°C	NSST
	Najaf	-0.72°C/dec.	0.002	0.26	48.79°C	45.97°C	
	National Average	+0.34°C/dec.	0.101	0.05	47.93°C	49.27°C	NSST
Annual Minimum Temperature	Muthanna	+4.08°C/dec.	0.009	0.46	-16.75°C	-0.83°C	
	Karbala	-0.64°C/dec.	0.033	0.11	-0.15°C	-2.63°C	
	Najaf	-0.41°C/dec.	0.173	0.03	-0.43°C	-2.01°C	NSST
	National Average	-0.38°C/dec.	0.169	0.03	-0.44°C	-1.92°C	NSST
Annually Accumulated Precipitation	Muthanna	-	-	-	-	-	Not enough data
	Karbala	+1.48 mm/dec.	0.772	-0.02	91.10 mm	96.86 mm	NSST
	Najaf	-1.03 mm/dec.	0.866	-0.03	90.10 mm	86.09 mm	NSST
	National Average	+1.59 mm/dec.	0.745	-0.02	86.70 mm	92.90 mm	NSST

Table 27 – Summary of the characteristics of the trends from the projected time series in Iraq and in three target governorates (linear models).

Time series over the 2020-2060 period. NSST: Not statistically significant trend. *Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).*

Variable	Governorate	Scenario	Trend	p-value	R ²	Average value in 2040	Average value in 2060	Notes
Annual Average Temperature	Muthanna	RCP45	+0.36°C/dec.	<0.001	0.92	26.43°C	27.15°C	
		RCP85	+0.60°C/dec.	<0.001	0.96	26.96°C	28.16°C	
	Karbala	RCP45	+0.33°C/dec.	<0.001	0.93	25.42°C	26.08°C	
		RCP85	+0.60°C/dec.	<0.001	0.97	25.94°C	27.14°C	
	Najaf	RCP45	+0.34°C/dec.	<0.001	0.93	25.48°C	26.17°C	
		RCP85	+0.61°C/dec.	<0.001	0.97	26.01°C	27.23°C	
	National Average	RCP45	+0.33°C/dec.	<0.001	0.94	23.93°C	24.60°C	
		RCP85	+0.60°C/dec.	<0.001	0.96	24.45°C	25.65°C	
Annual Maximum Temperature	Muthanna	RCP45	+0.45°C/dec.	<0.001	0.76	49.56°C	50.46°C	
		RCP85	+0.73°C/dec.	<0.001	0.92	50.05°C	51.52°C	
	Karbala	RCP45	+0.42°C/dec.	<0.001	0.69	49.63°C	50.47°C	
		RCP85	+0.76°C/dec.	<0.001	0.90	50.19°C	51.72°C	
	Najaf	RCP45	+0.43°C/dec.	<0.001	0.70	49.05°C	49.92°C	
		RCP85	+0.73°C/dec.	<0.001	0.90	49.53°C	50.99°C	
	National Average	RCP45	+0.44°C/dec.	<0.001	0.81	47.98°C	48.87°C	
		RCP85	+0.74°C/dec.	<0.001	0.93	48.57°C	50.05°C	
Annual Minimum Temperature	Muthanna	RCP45	+0.26°C/dec.	<0.001	0.43	2.19°C	2.70°C	
		RCP85	+0.37°C/dec.	<0.001	0.46	2.68°C	3.43°C	
	Karbala	RCP45	+0.21°C/dec.	<0.001	0.36	0.91°C	1.33°C	
		RCP85	+0.29°C/dec.	<0.001	0.35	1.22°C	1.80°C	
	Najaf	RCP45	+0.22°C/dec.	<0.001	0.37	1.21°C	1.64°C	
		RCP85	+0.30°C/dec.	<0.001	0.36	1.65°C	2.24°C	
	National Average	RCP45	+0.23°C/dec.	<0.001	0.37	-0.18°C	0.28°C	
		RCP85	+0.32°C/dec.	<0.001	0.48	0.19°C	0.83°C	
Annually Accumulated Precipitation	Muthanna	RCP45	-1.64 mm/dec.	0.037	0.08	39.78 mm	36.50 mm	
		RCP85	-0.78 mm/dec.	0.181	0.02	39.58 mm	38.01 mm	NSST
	Karbala	RCP45	-2.64 mm/dec.	0.012	0.13	64.47 mm	59.18 mm	

	RCP85	-1.21 mm/dec.	0.256	0.01	63.69 mm	61.28 mm	NSST
<i>Najaf</i>	RCP45	-1.86 mm/dec.	0.001	0.22	31.68 mm	27.96 mm	
	RCP85	-0.79 mm/dec.	0.122	0.04	31.57 mm	30.00 mm	NSST
<i>National Average</i>	RCP45	-4.39 mm/dec.	0.015	0.12	155.46 mm	146.67 mm	
	RCP85	-3.10 mm/dec.	0.073	0.06	151.77 mm	145.57 mm	NSST

CLIMATIC ATLAS OF THE REPUBLIC OF IRAQ

AT RIVER BASIN LEVEL

2. Climate data sources

Historical data sources

Because the river basins encompass multiple countries, we will use **ERA5**, an international database to characterize the climate of the region. ERA5 is the fifth generation ECMWF (European Centre for Medium-Range Weather Forecasts) atmospheric reanalysis of the global climate. The database combines model data with observations from across the world into a globally complete and consistent dataset (Muñoz Sabater, 2019).

Projected data sources

NEX: To characterize future climatic conditions over the river basins of Iraq, we used the NASA Earth Exchange (NEX) - Global Daily Downscaled Climate Projections (GDDP) dataset. This dataset comprise 20 downscaled climate scenarios for the globe that are derived from the General Circulation Model runs conducted under the Coupled Model Intercomparison Project Phase 5 (CMIP5,(Taylor et al., 2012)). These models are: *BNU-ESM, CCSM4, CESM1-BGC, CNRM-CM5, CSIRO-Mk3-6-0, CanESM2, GFDL-CM3, GFDL-ESM2G, GFDL-ESM2M, IPSL-CM5A-LR, IPSL-CM5A-MR, MIROC-ESM-CHEM, MIROC-ESM, MIROC5, MPI-ESM-LR, MPI-ESM-MR, MRI-CGCM3, NorESM1-M, bcc-csm1-1 and inmcm4* (Thrasher et al., 2012).

3. Temperatures

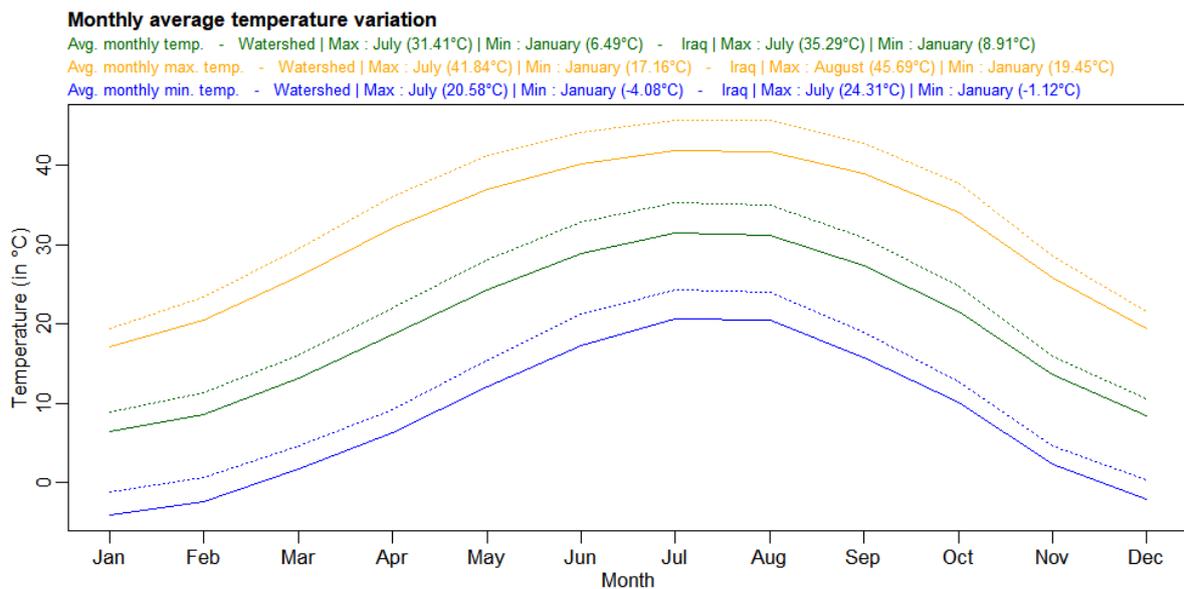
This section will present the variations of temperatures in the Republic of Iraq and in the river basins of the rivers streaming within Iraqi borders, focusing on:

- **Monthly average temperatures** (TG_m) and **annual average temperatures** (TG_y)
- **Monthly average daily minimum temperatures** (TN_m) and **annual average daily minimum temperatures** (TN_y)
- **Monthly average daily maximum temperatures** (TX_m) and **annual average daily maximum temperatures** (TX_y)

Seasonal variations

Figure 49 – Current seasonal variations of the monthly average, maximum and minimum temperatures over the Iraqi watershed and in Iraq

Data averaged over the 1990-2020 period. **In orange:** monthly maximum temperature. **In blue:** monthly minimum temperature. **In green** monthly average temperature. **In full line:** data aggregated at the watershed level. **In dotted line:** data aggregated at the level of Iraq only. Data source: ERA5 - ECMWF / Copernicus Climate Change Service (Muñoz Sabater, 2019).



Spatial distribution

Figure 50 – Current spatial distribution of monthly average temperature over the Iraqi watershed
Data averaged over the 1990-2019 period. Data source: ERA5 - ECMWF / Copernicus Climate Change Service (Muñoz Sabater, 2019).

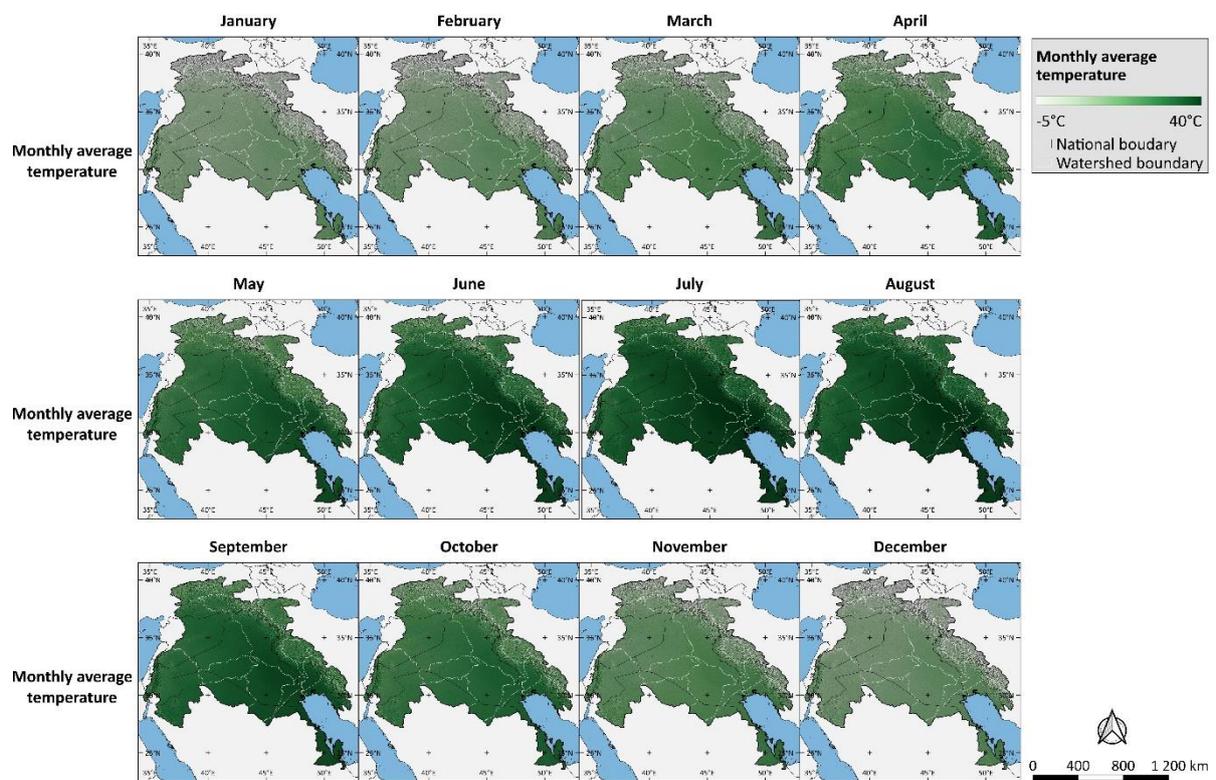
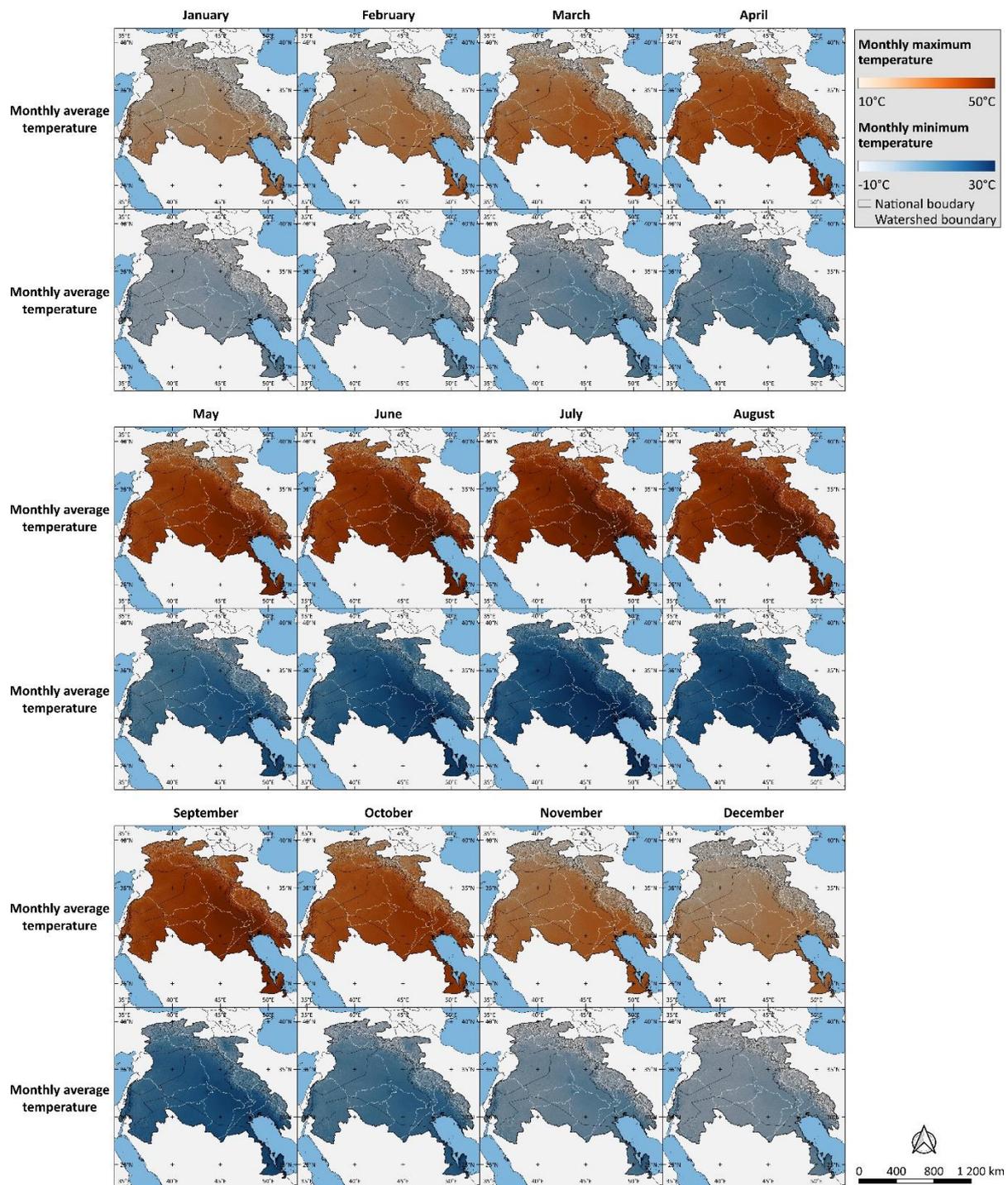


Figure 51 – Current spatial distribution of monthly average temperature over the Iraqi watershed
 Data averaged over the 1990-2019 period. *Data source: ERA5 - ECMWF / Copernicus Climate Change Service (Muñoz Sabater, 2019).*



Historical monthly trends

Figure 52 – Historical time series of monthly average temperature in the Iraqi watershed and in Iraq
 Time series over the 1980-2020 period. **In black, dashed line: Iraq. In green, full line: Iraqi watershed.** Data source: ERA5 - ECMWF / Copernicus Climate Change Service (Muñoz Sabater, 2019).

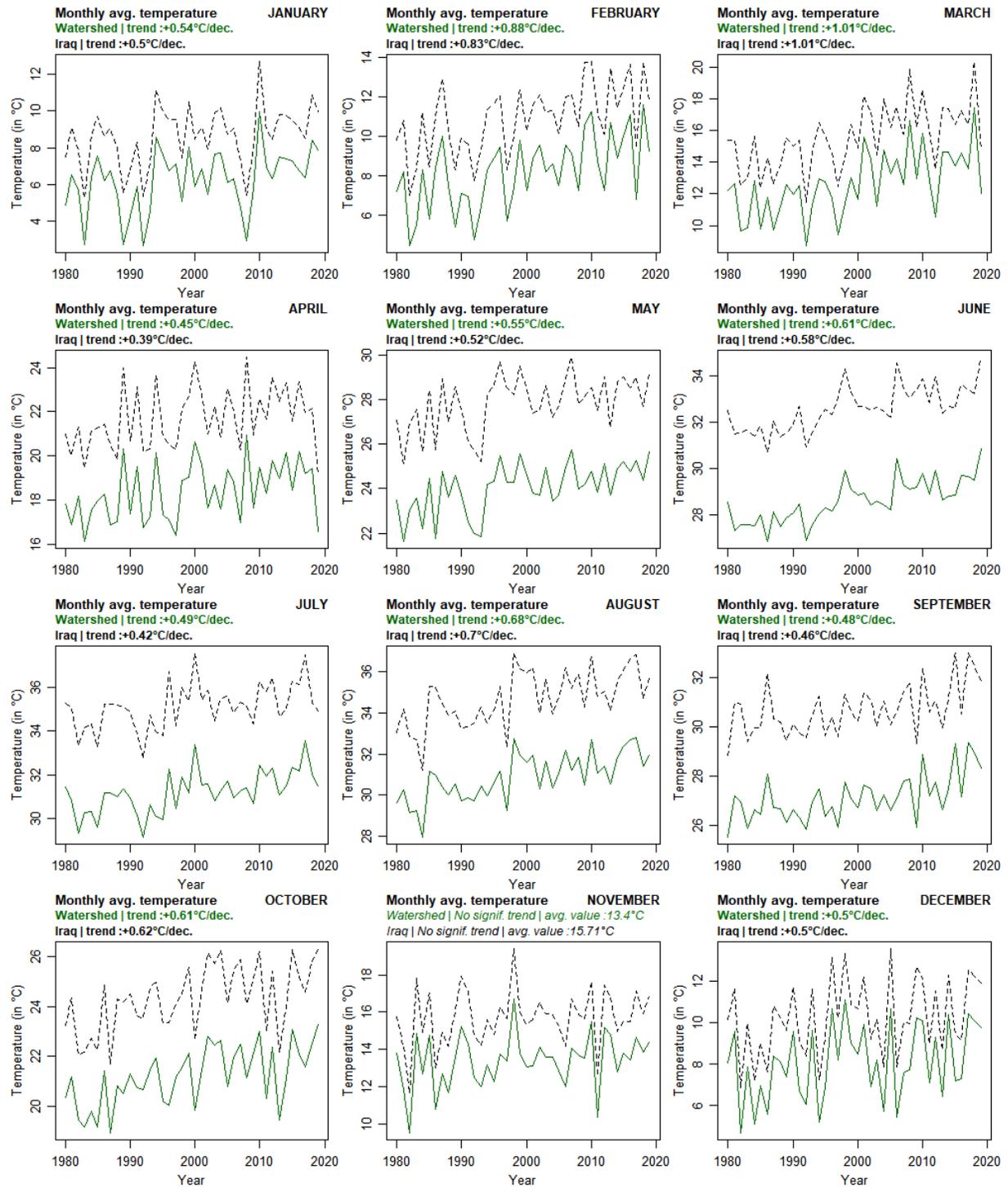


Figure 53 – Historical time series of monthly minimum temperature in the Iraqi watershed and in Iraq
 Time series over the 1980–2020 period. **In black, dashed line: Iraq. In orange, full line: Iraqi watershed.** *Data source: ERA5 - ECMWF / Copernicus Climate Change Service (Muñoz Sabater, 2019).*

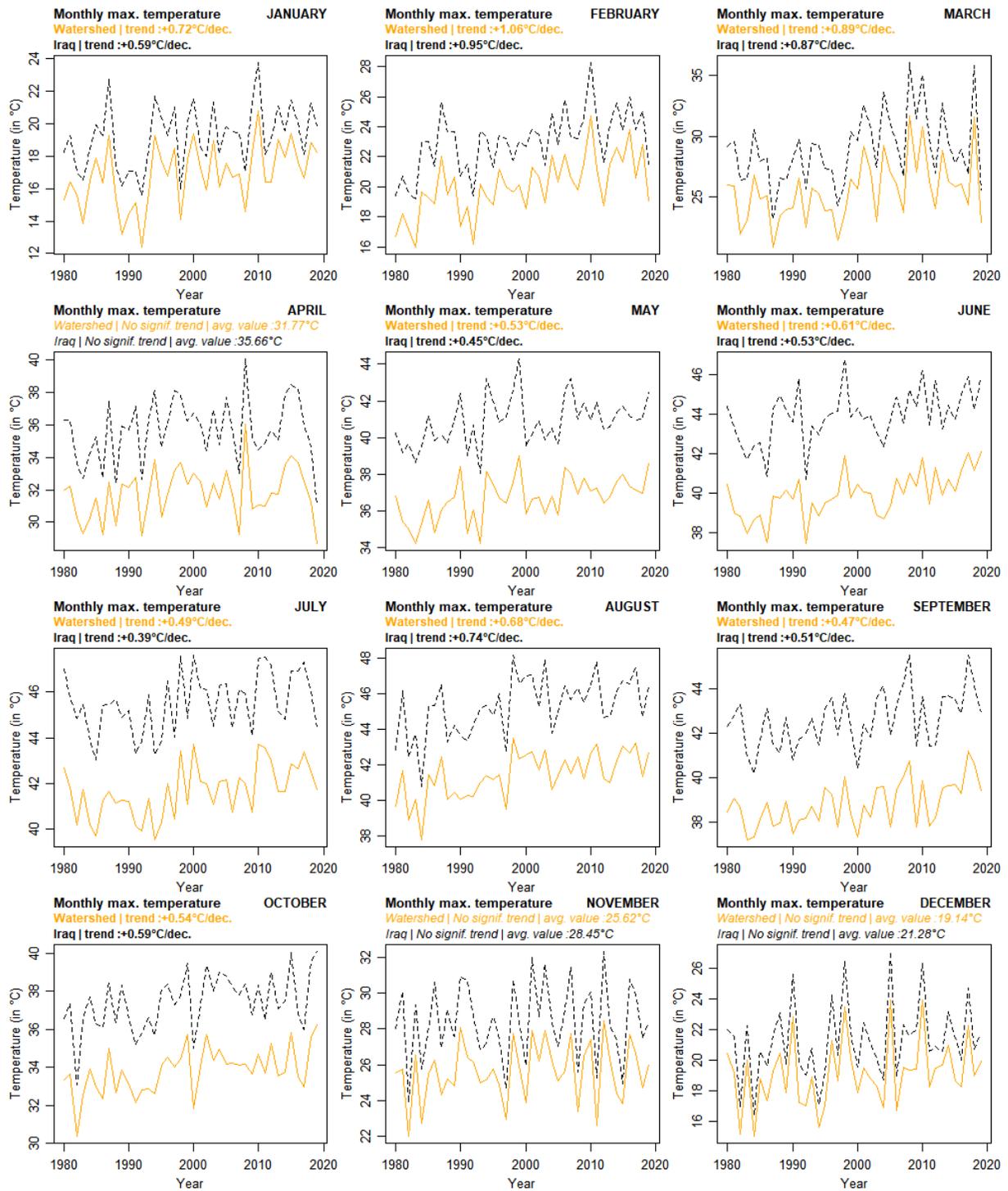


Figure 54 – Historical time series of monthly minimum temperature in the Iraqi watershed and in Iraq
 Time series over the 1980-2020 period. **In black, dashed line: Iraq. In blue, full line: Iraqi watershed.** Data source: ERA5 - ECMWF / Copernicus Climate Change Service (Muñoz Sabater, 2019).

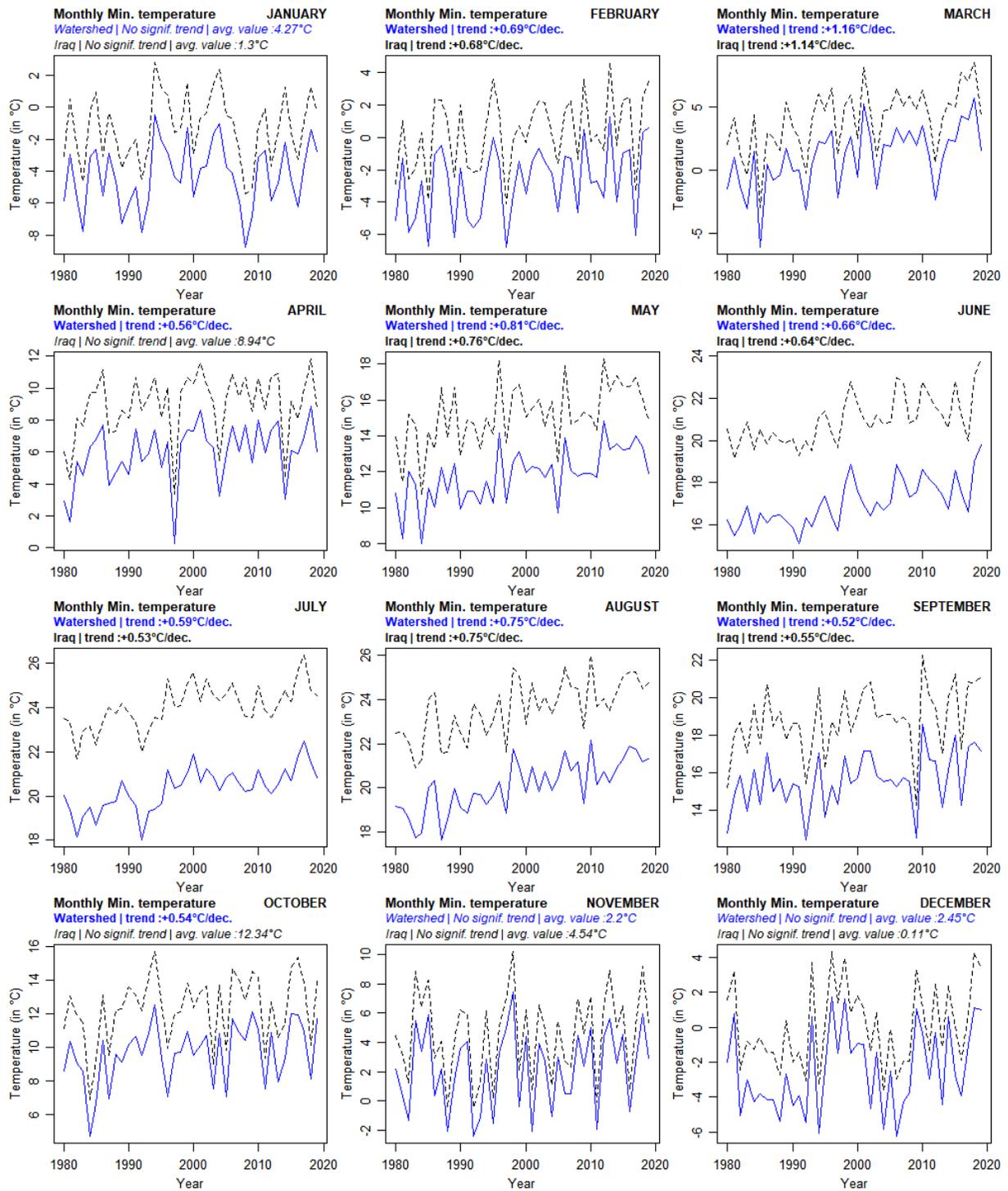


Table 28 – Characteristics of the trends from the historical time series of the monthly average maximum and minimum temperature over the Iraqi watershed (linear models)

In orange: monthly maximum temperature. **In blue:** monthly minimum temperature. **in green** monthly average temperature. **Data in grey:** the trends is statistically no significative under an alpha of 5%. Data source: ERA5 - ECMWF / Copernicus Climate Change Service (Muñoz Sabater, 2019).

Variable	Month	Slope	p-value	Adjusted R ²	Average value in 1980	Average value in 2019
TG _m	January	+0.54°C/dec.	0.014	0.12	5.19°C	7.30°C
TG _m	February	+0.88°C/dec.	0.000	0.31	6.49°C	9.92°C
TG _m	March	+1.01°C/dec.	0.000	0.33	10.67°C	14.59°C
TG _m	April	+0.45°C/dec.	0.010	0.14	17.52°C	19.26°C
TG _m	May	+0.55°C/dec.	0.000	0.32	22.98°C	25.12°C
TG _m	June	+0.61°C/dec.	0.000	0.58	27.43°C	29.79°C
TG _m	July	+0.49°C/dec.	0.000	0.34	30.26°C	32.18°C
TG _m	August	+0.68°C/dec.	0.000	0.47	29.58°C	32.23°C
TG _m	September	+0.48°C/dec.	0.000	0.35	26.21°C	28.09°C
TG _m	October	+0.61°C/dec.	0.000	0.35	20.01°C	22.40°C
TG _m	November	+0.35°C/dec.	0.071	0.06	12.72°C	14.08°C
TG _m	December	+0.50°C/dec.	0.041	0.08	7.13°C	9.07°C
TX _m	January	+0.72°C/dec.	0.004	0.18	15.46°C	18.27°C
TX _m	February	+1.06°C/dec.	0.000	0.39	17.98°C	22.12°C
TX _m	March	+0.89°C/dec.	0.010	0.14	23.83°C	27.29°C
TX _m	April	+0.30°C/dec.	0.172	0.02	31.19°C	32.35°C
TX _m	May	+0.53°C/dec.	0.000	0.26	35.68°C	37.74°C
TX _m	June	+0.61°C/dec.	0.000	0.37	38.75°C	41.12°C
TX _m	July	+0.49°C/dec.	0.001	0.23	40.72°C	42.62°C
TX _m	August	+0.68°C/dec.	0.000	0.37	40.07°C	42.73°C
TX _m	September	+0.47°C/dec.	0.000	0.28	37.91°C	39.73°C
TX _m	October	+0.54°C/dec.	0.001	0.25	32.78°C	34.90°C
TX _m	November	+0.26°C/dec.	0.252	0.01	25.12°C	26.12°C
TX _m	December	+0.49°C/dec.	0.099	0.05	18.19°C	20.09°C
TN _m	January	+0.29°C/dec.	0.297	0.00	-4.84°C	-3.70°C
TN _m	February	+0.69°C/dec.	0.021	0.11	-4.08°C	-1.39°C
TN _m	March	+1.16°C/dec.	0.000	0.29	-1.25°C	3.28°C
TN _m	April	+0.56°C/dec.	0.023	0.11	4.82°C	7.02°C
TN _m	May	+0.81°C/dec.	0.000	0.38	10.20°C	13.38°C
TN _m	June	+0.66°C/dec.	0.000	0.49	15.77°C	18.36°C
TN _m	July	+0.59°C/dec.	0.000	0.49	19.15°C	21.45°C
TN _m	August	+0.75°C/dec.	0.000	0.55	18.64°C	21.55°C
TN _m	September	+0.52°C/dec.	0.007	0.15	14.56°C	16.58°C
TN _m	October	+0.54°C/dec.	0.024	0.10	8.60°C	10.70°C
TN _m	November	+0.39°C/dec.	0.299	0.00	1.45°C	2.96°C
TN _m	December	+0.57°C/dec.	0.076	0.06	-3.56°C	-1.33°C

Historical annual trends

Figure 55 – Historical time series of the annual average maximum and minimum temperature in the Iraqi watershed and in Iraq

Time series over the 1980-2020 period. **In orange full line:** monthly maximum temperature. **In blue full line:** monthly minimum temperature. **In green full line:** monthly average temperature. **In black dashed line:** data aggregated only for Iraq. **In dotted line:** data aggregated at the level of Iraq only. Data source: ERA5 - ECMWF / Copernicus Climate Change Service (Muñoz Sabater, 2019).

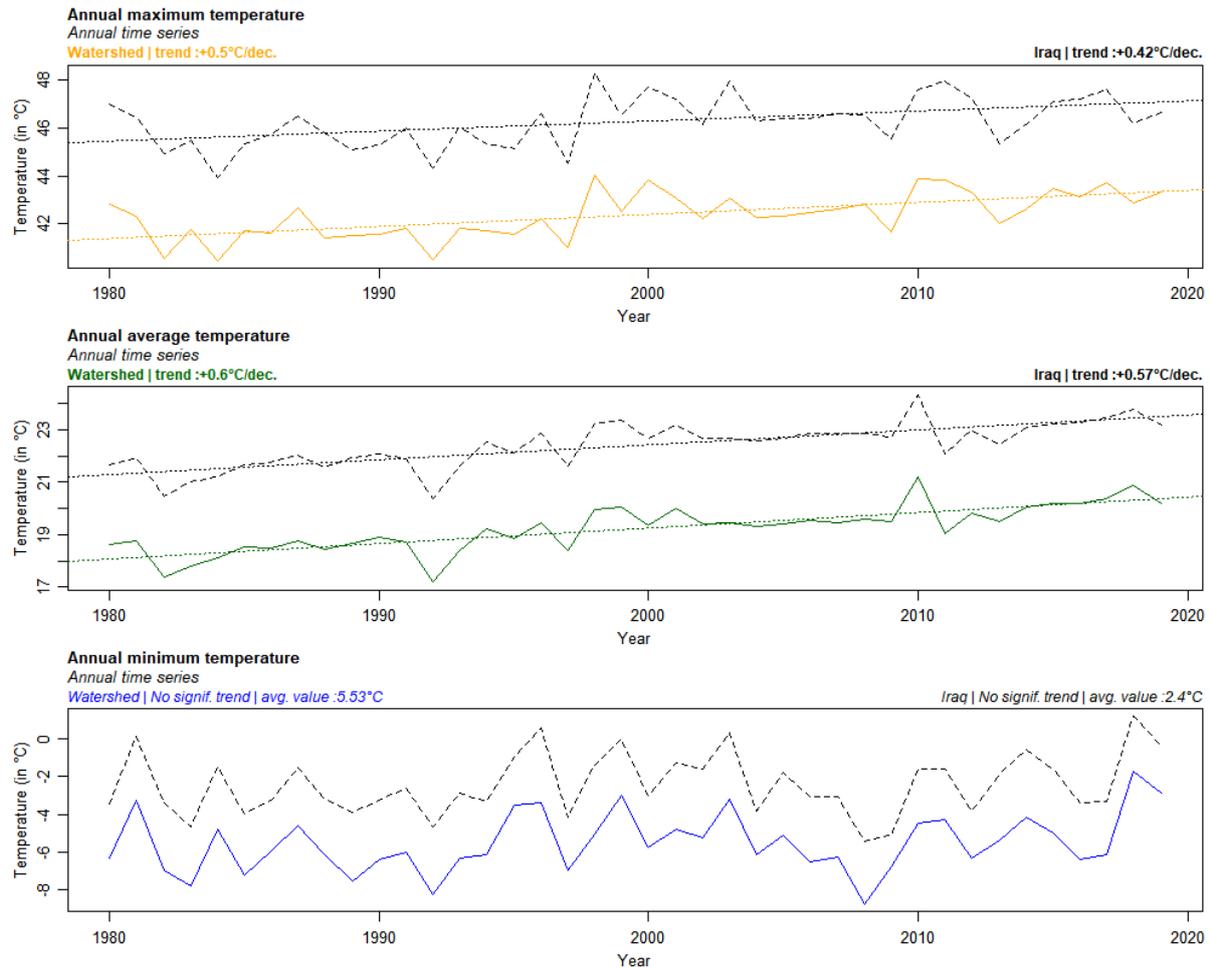


Table 29 – Characteristics of the trends from the historical time series of the annual average maximum and minimum temperature over the Iraqi watershed (linear models)

In orange: monthly maximum temperature. **In blue:** monthly minimum temperature. **In green** monthly average temperature. **Data in grey:** the trends is statistically no significative under an alpha of 5%. Data source: ERA5 - ECMWF / Copernicus Climate Change Service (Muñoz Sabater, 2019).

governorate	Slope	p-value	R ²	Average value in 1980	Average value in 2019
TG_y	+0.60°C/dec.	0.000	0.63	18.07°C	20.39°C
TN_y	+0.37°C/dec.	0.085	0.05	-6.26°C	-4.80°C
TX_y	+0.50°C/dec.	0.000	0.36	41.39°C	43.33°C

Projected monthly trends

Figure 56 – Projected time series of the monthly average temperature over the Iraqi watershed and in Iraq
 Time series over the 2020-2060 period. **In yellow (dotted line):** value for each NEX model under the RCP4.5 scenario within the governorate. **In orange (full line):** median value calculated over all NEX models under the RCP4.5 scenario over the watershed. **In light green (dotted line):** value for each NEX model under the RCP8.5 scenario over the watershed. **In dark green (full line):** median value calculated over all NEX models under the RCP8.5 scenario over the watershed. **In grey (dotted line):** median value calculated over all NEX models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all NEX models under the RCP8.5 scenario within Iraq, for comparison. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

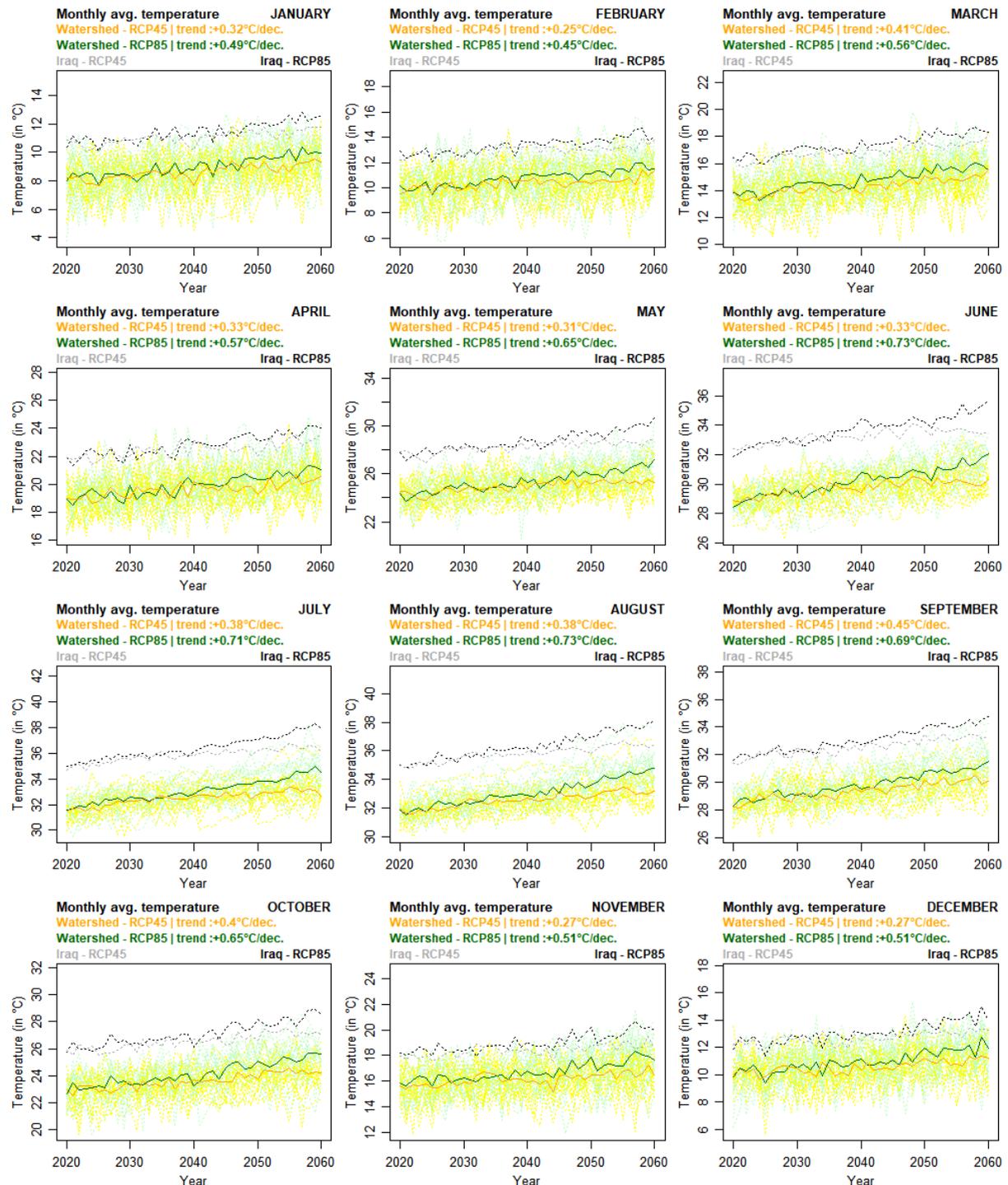


Figure 57 – Projected time series of the monthly maximum temperature over the Iraqi watershed and in Iraq
 Time series over the 2020-2060 period. **In yellow (dotted line):** value for each NEX model under the RCP4.5 scenario within the governorate. **In orange (full line):** median value calculated over all NEX models under the RCP4.5 scenario over the watershed. **In light green (dotted line):** value for each NEX model under the RCP8.5 scenario over the watershed. **In dark green (full line):** median value calculated over all NEX models under the RCP8.5 scenario over the watershed. **In grey (dotted line):** median value calculated over all NEX models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all NEX models under the RCP8.5 scenario within Iraq, for comparison. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

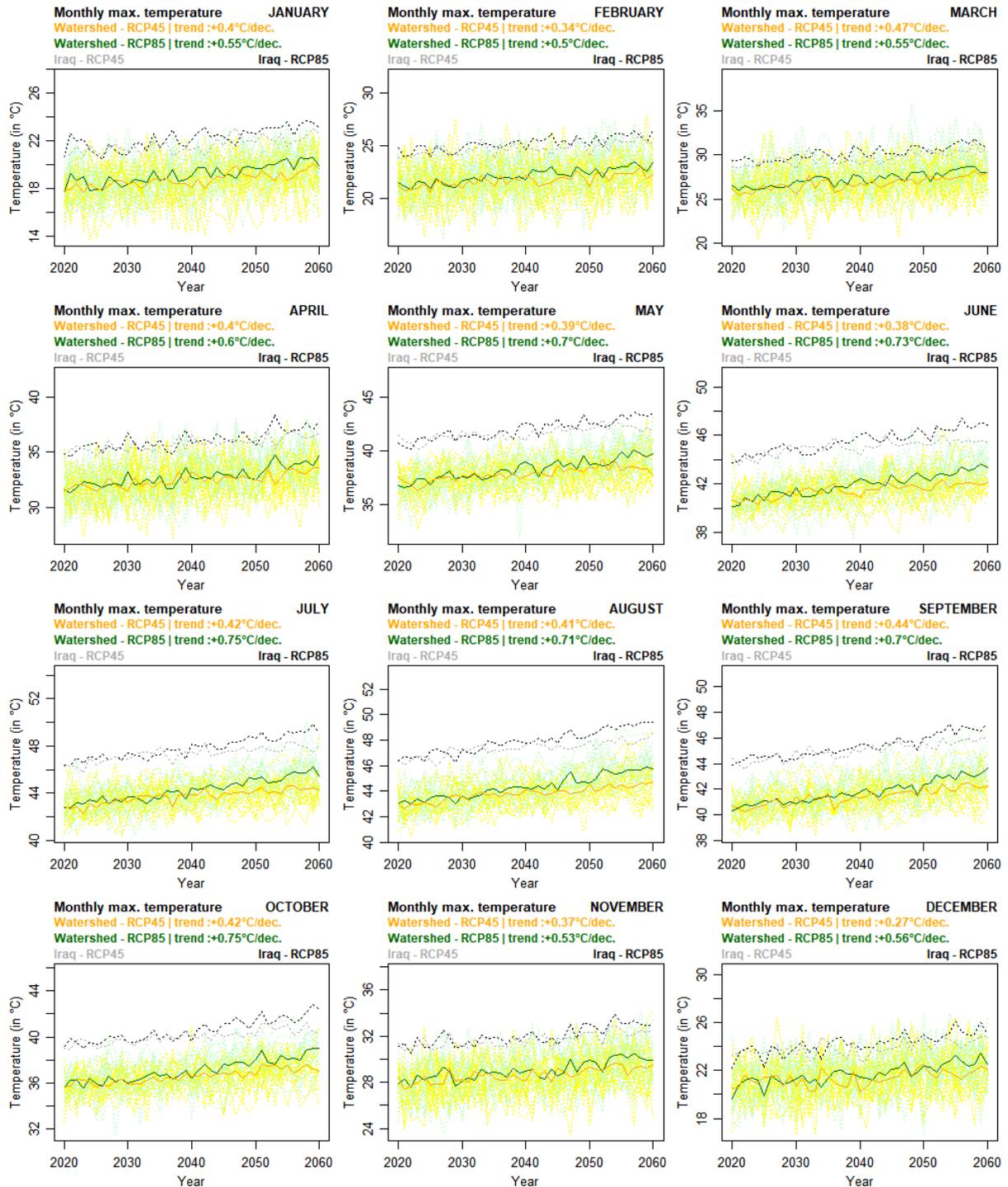


Figure 58 – Projected time series of the monthly minimum temperature over the Iraqi watershed and in Iraq
 Time series over the 2020-2060 period. **In yellow (dotted line):** value for each NEX model under the RCP4.5 scenario within the governorate. **In orange (full line):** median value calculated over all NEX models under the RCP4.5 scenario over the watershed. **In light green (dotted line):** value for each NEX model under the RCP8.5 scenario over the watershed. **In dark green (full line):** median value calculated over all NEX models under the RCP8.5 scenario over the watershed. **In grey (dotted line):** median value calculated over all NEX models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all NEX models under the RCP8.5 scenario within Iraq, for comparison. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

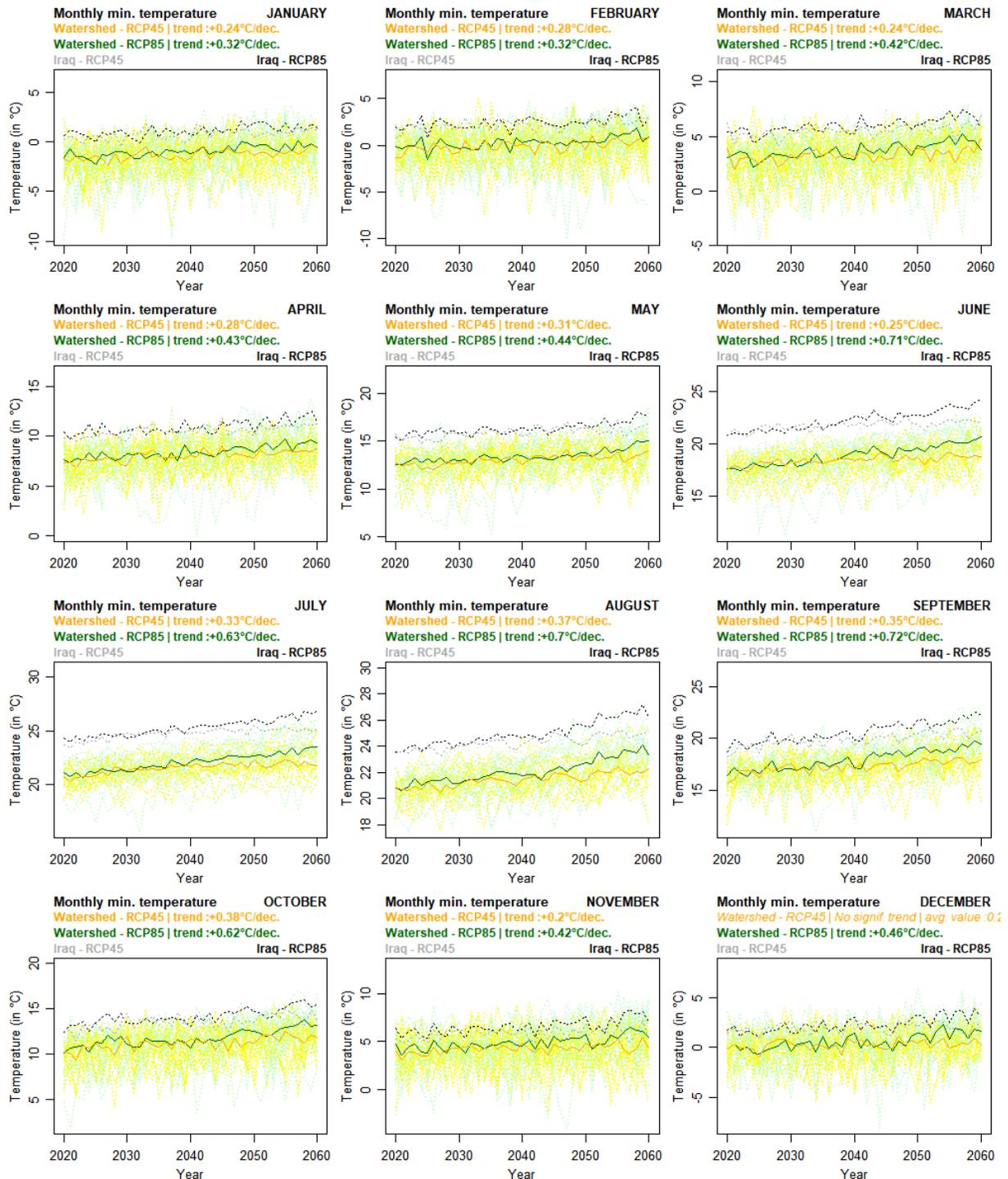


Table 30 – Characteristics of the trend from projected time series of monthly average, minimum and maximum temperature under the RCP4.5 scenario over the Iraqi watershed (linear models)

Data in grey: the trends is statistically no significative under an alpha of 5%. *Data source:* NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

RCP4.5						
Variable	Month	Slope	p-value	Adj. R ²	Average value in 2040	Average value in 2060
TG _m	January	+0.32°C/dec.	0.000	0.63	8.63°C	9.28°C
TG _m	February	+0.25°C/dec.	0.000	0.48	10.35°C	10.85°C
TG _m	March	+0.41°C/dec.	0.000	0.78	14.30°C	15.11°C
TG _m	April	+0.33°C/dec.	0.000	0.57	19.64°C	20.29°C
TG _m	May	+0.31°C/dec.	0.000	0.66	24.95°C	25.56°C
TG _m	June	+0.33°C/dec.	0.000	0.66	29.76°C	30.41°C
TG _m	July	+0.38°C/dec.	0.000	0.83	32.49°C	33.25°C
TG _m	August	+0.38°C/dec.	0.000	0.86	32.57°C	33.33°C
TG _m	September	+0.45°C/dec.	0.000	0.82	29.36°C	30.25°C
TG _m	October	+0.40°C/dec.	0.000	0.78	23.60°C	24.39°C
TG _m	November	+0.27°C/dec.	0.000	0.48	16.16°C	16.69°C
TG _m	December	+0.27°C/dec.	0.000	0.54	10.55°C	11.09°C
TX _m	January	+0.40°C/dec.	0.000	0.63	18.75°C	19.55°C
TX _m	February	+0.34°C/dec.	0.000	0.50	21.70°C	22.38°C
TX _m	March	+0.47°C/dec.	0.000	0.62	26.75°C	27.69°C
TX _m	April	+0.40°C/dec.	0.000	0.57	32.48°C	33.27°C
TX _m	May	+0.39°C/dec.	0.000	0.63	37.84°C	38.63°C
TX _m	June	+0.38°C/dec.	0.000	0.68	41.46°C	42.21°C
TX _m	July	+0.42°C/dec.	0.000	0.75	43.72°C	44.56°C
TX _m	August	+0.41°C/dec.	0.000	0.84	43.80°C	44.62°C
TX _m	September	+0.44°C/dec.	0.000	0.76	41.41°C	42.30°C
TX _m	October	+0.42°C/dec.	0.000	0.77	36.59°C	37.42°C
TX _m	November	+0.37°C/dec.	0.000	0.55	28.65°C	29.38°C
TX _m	December	+0.27°C/dec.	0.000	0.28	21.35°C	21.90°C
TN _m	January	+0.24°C/dec.	0.000	0.35	-1.29°C	-0.80°C
TN _m	February	+0.28°C/dec.	0.000	0.30	-0.08°C	0.49°C
TN _m	March	+0.24°C/dec.	0.001	0.23	3.29°C	3.76°C
TN _m	April	+0.28°C/dec.	0.000	0.47	8.04°C	8.61°C
TN _m	May	+0.31°C/dec.	0.000	0.56	13.05°C	13.68°C
TN _m	June	+0.25°C/dec.	0.000	0.52	18.41°C	18.92°C
TN _m	July	+0.33°C/dec.	0.000	0.69	21.56°C	22.21°C
TN _m	August	+0.37°C/dec.	0.000	0.78	21.47°C	22.20°C
TN _m	September	+0.35°C/dec.	0.000	0.56	17.28°C	17.99°C
TN _m	October	+0.38°C/dec.	0.000	0.43	11.19°C	11.94°C
TN _m	November	+0.20°C/dec.	0.001	0.23	4.28°C	4.67°C
TN _m	December	+0.11°C/dec.	0.057	0.07	0.27°C	0.49°C

Table 31 – Characteristics of the trend from projected time series of monthly average, minimum and maximum temperature under the RCP8.5 scenario over the Iraqi watershed (linear models)

Data in grey: the trends is statistically no significative under an alpha of 5%. *Data source:* NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

RCP8.5						
Variable	Month	Slope	p-value	Adj. R ²	Average value in 2040	Average value in 2060
TG _m	January	+0.49°C/dec.	0.000	0.75	8.98°C	9.96°C
TG _m	February	+0.45°C/dec.	0.000	0.77	10.74°C	11.65°C
TG _m	March	+0.56°C/dec.	0.000	0.85	14.76°C	15.88°C
TG _m	April	+0.57°C/dec.	0.000	0.80	19.93°C	21.06°C
TG _m	May	+0.65°C/dec.	0.000	0.87	25.39°C	26.69°C
TG _m	June	+0.73°C/dec.	0.000	0.91	30.20°C	31.66°C
TG _m	July	+0.71°C/dec.	0.000	0.95	33.08°C	34.50°C
TG _m	August	+0.73°C/dec.	0.000	0.95	33.10°C	34.56°C
TG _m	September	+0.69°C/dec.	0.000	0.94	29.83°C	31.22°C
TG _m	October	+0.65°C/dec.	0.000	0.86	24.13°C	25.44°C
TG _m	November	+0.51°C/dec.	0.000	0.76	16.72°C	17.75°C
TG _m	December	+0.51°C/dec.	0.000	0.73	10.95°C	11.98°C
TX _m	January	+0.55°C/dec.	0.000	0.69	19.24°C	20.34°C
TX _m	February	+0.50°C/dec.	0.000	0.76	22.13°C	23.14°C
TX _m	March	+0.55°C/dec.	0.000	0.71	27.27°C	28.37°C
TX _m	April	+0.60°C/dec.	0.000	0.70	32.80°C	34.01°C
TX _m	May	+0.70°C/dec.	0.000	0.83	38.29°C	39.70°C
TX _m	June	+0.73°C/dec.	0.000	0.90	41.94°C	43.39°C
TX _m	July	+0.75°C/dec.	0.000	0.91	44.27°C	45.77°C
TX _m	August	+0.71°C/dec.	0.000	0.91	44.34°C	45.76°C
TX _m	September	+0.70°C/dec.	0.000	0.91	41.81°C	43.22°C
TX _m	October	+0.75°C/dec.	0.000	0.86	37.12°C	38.63°C
TX _m	November	+0.53°C/dec.	0.000	0.65	29.02°C	30.09°C
TX _m	December	+0.56°C/dec.	0.000	0.69	21.69°C	22.81°C
TN _m	January	+0.32°C/dec.	0.000	0.51	-0.92°C	-0.28°C
TN _m	February	+0.32°C/dec.	0.000	0.35	0.27°C	0.91°C
TN _m	March	+0.42°C/dec.	0.000	0.54	3.69°C	4.54°C
TN _m	April	+0.43°C/dec.	0.000	0.66	8.42°C	9.27°C
TN _m	May	+0.44°C/dec.	0.000	0.68	13.40°C	14.28°C
TN _m	June	+0.71°C/dec.	0.000	0.90	18.89°C	20.32°C
TN _m	July	+0.63°C/dec.	0.000	0.93	22.09°C	23.36°C
TN _m	August	+0.70°C/dec.	0.000	0.87	22.10°C	23.49°C
TN _m	September	+0.72°C/dec.	0.000	0.85	17.94°C	19.39°C
TN _m	October	+0.62°C/dec.	0.000	0.72	11.77°C	13.01°C
TN _m	November	+0.42°C/dec.	0.000	0.51	4.88°C	5.72°C
TN _m	December	+0.46°C/dec.	0.000	0.51	0.57°C	1.49°C

Projected annual trends

Figure 59 – Projected time series of the annual average minimum and maximum temperature over the Iraqi watershed and in Iraq

Time series over the 2020-2060 period. **In yellow (dotted line):** value for each NEX model under the RCP4.5 scenario over the watershed. **In orange (full line):** median value calculated over all NEX models under the RCP4.5 scenario over the watershed. **In light green (dotted line):** value for each NEX model under the RCP8.5 scenario over the watershed. **In dark green (full line):** median value calculated over all NEX models under the RCP8.5 scenario over the watershed. **In grey (dotted line):** median value calculated over all NEX models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all NEX models under the RCP8.5 scenario within Iraq, for comparison. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).



Table 32 – Characteristics of the trends from the projected time series of the annual average minimum and maximum temperature over the Iraqi watershed under the RCP4.5 and RCP8.5 scenarios (linear models).

In red: median values calculated over all NEX models for average temperature. **In blue:** likewise, for the minimum temperature. **In green:** likewise, for maximum temperature. **Data in grey:** the trends is statistically no significant under an alpha of 5%. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

RCP4.5					
Variable	Slope	p-value	R ²	Average value in 2040	Average value in 2060
Average temperature	+0.34°C/dec.	0.000	0.94	21.05°C	21.72°C
Minimum temperature	+0.26°C/dec.	0.000	0.52	-2.25°C	-1.73°C
Maximum temperature	+0.45°C/dec.	0.000	0.86	44.47°C	45.37°C
RCP8.5					
Variable	Slope	p-value	R ²	Average value in 2040	Average value in 2060
Average temperature	+0.60°C/dec.	0.000	0.97	21.53°C	22.73°C
Minimum temperature	+0.38°C/dec.	0.000	0.68	-1.89°C	-1.12°C
Maximum temperature	+0.74°C/dec.	0.000	0.94	44.99°C	46.48°C

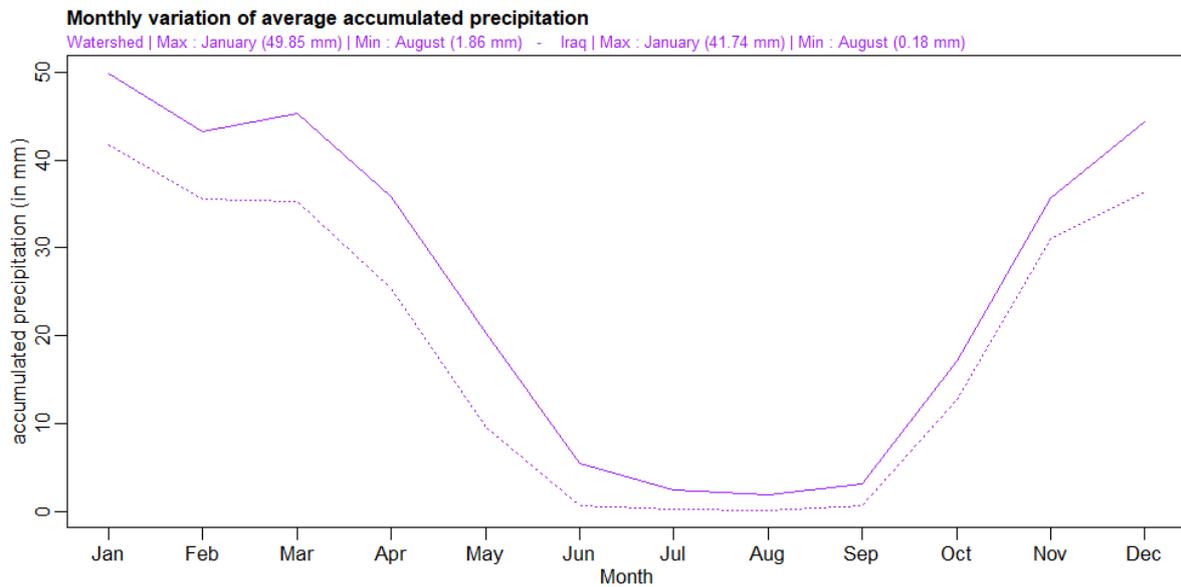
4. Precipitation

This section will present the variations of accumulated precipitation in the three target governorates of the project in the Republic of Iraq, focusing on **monthly accumulated precipitation (RRm)** and **annually accumulated precipitation (RRy)**.

Seasonal variations

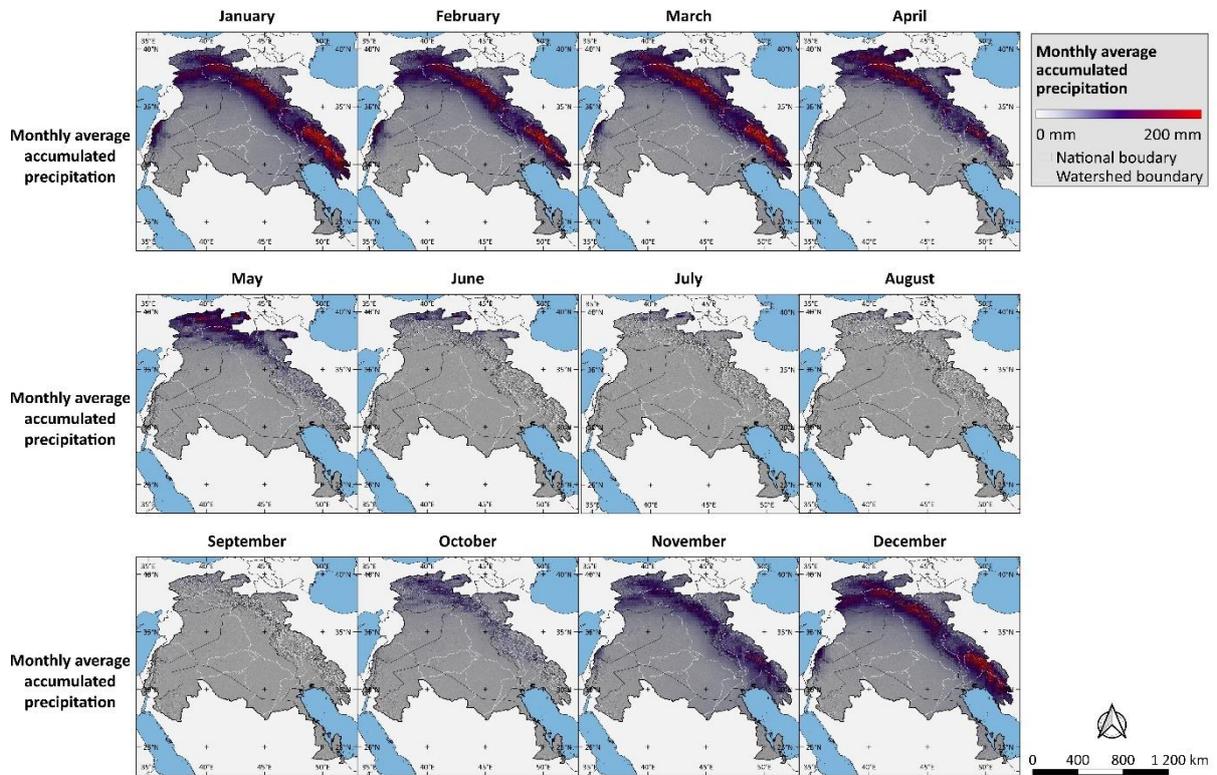
Figure 60 – Current seasonal variations of the monthly accumulated precipitation over the Iraqi watershed and in Iraq

Data averaged over the 2008-2020 period. **In red:** average value over all the available weather stations located in the governorate of Muthanna. **In blue:** likewise, for the governorate of Karbala. **In green:** likewise, for the governorate of Najaf. **In grey:** average value over all the available weather stations in Iraq, for comparison. Data source: Iraqi Ministry of Agriculture and Iraqi Meteorological Organization and Seismology.



Spatial distribution

Figure 61 – Current spatial distribution of monthly average accumulated precipitation over the Iraqi watershed
Data averaged over the 1990-2019 period. Data source: ERA5 - ECMWF / Copernicus Climate Change Service
(Muñoz Sabater, 2019).



Historical monthly trends

Figure 62 – Historical time series of monthly accumulated precipitation in the Iraqi watershed and in Iraq
 Time series over the 1980–2020 period. **In black, dashed line: Iraq. In purple, full line: Iraqi watershed.** Data source: ERA5 - ECMWF / Copernicus Climate Change Service (Muñoz Sabater, 2019).

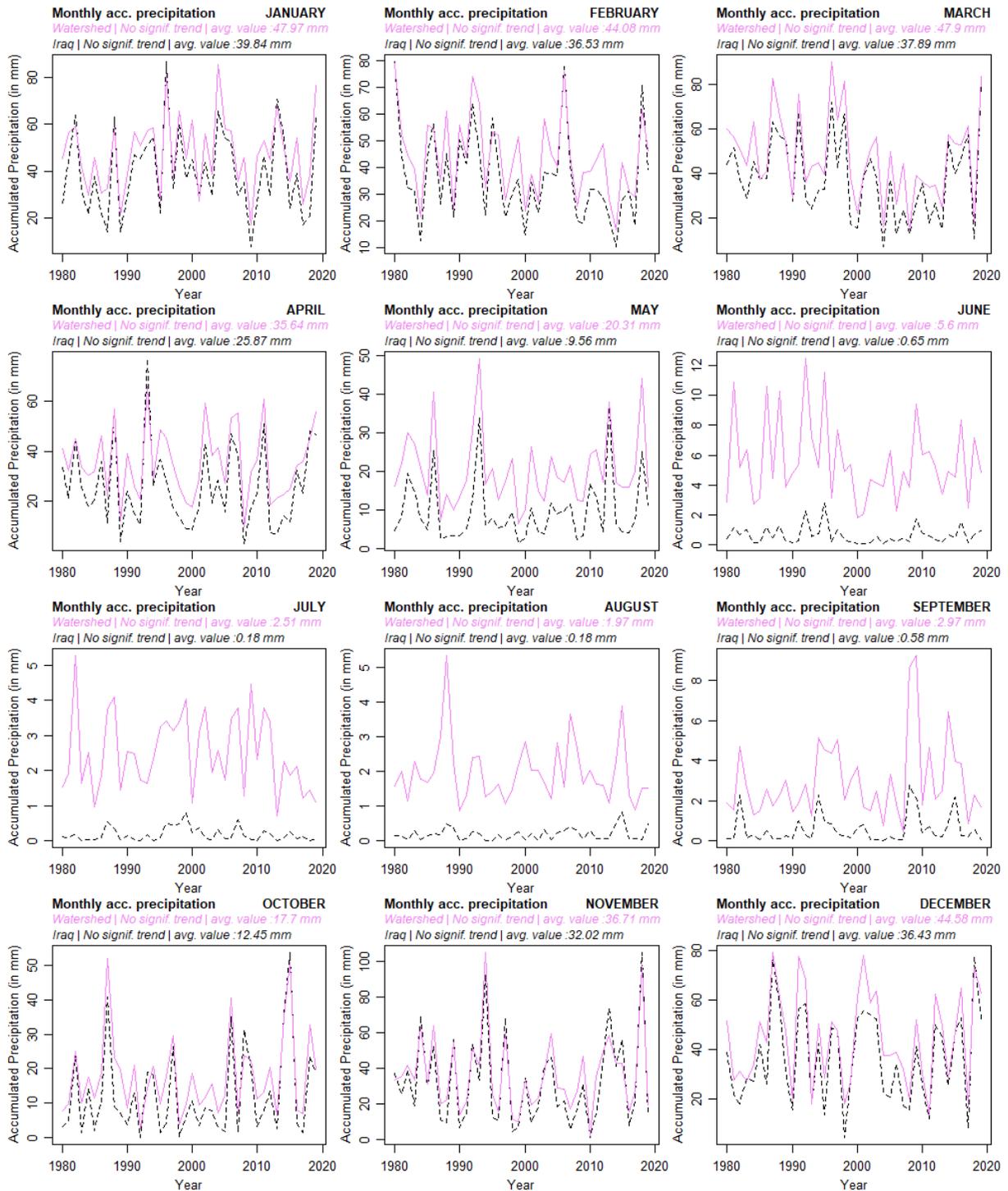


Table 33 – Characteristics of the trends from the historical time series of the monthly accumulated precipitation over the Iraqi watershed (linear models)

Data in grey: the trends is statistically no significative under an alpha of 5%. Data source: ERA5 - ECMWF / Copernicus Climate Change Service (Muñoz Sabater, 2019).

Month	Slope	p-value	Adjusted R ²	Average value in 1980	Average value in 2019
January	+1.11 mm/dec.	0.614	-0.02	45.81 mm	50.13 mm
February	-3.42 mm/dec.	0.102	0.04	50.75 mm	37.42 mm
March	-3.58 mm/dec.	0.169	0.02	54.88 mm	40.93 mm
April	+0.08 mm/dec.	0.966	-0.03	35.48 mm	35.80 mm
May	+0.12 mm/dec.	0.926	-0.03	20.07 mm	20.55 mm
June	-0.37 mm/dec.	0.330	-0.00	6.32 mm	4.88 mm
July	-0.12 mm/dec.	0.451	-0.01	2.73 mm	2.28 mm
August	-0.05 mm/dec.	0.656	-0.02	2.07 mm	1.86 mm
September	+0.31 mm/dec.	0.248	0.01	2.36 mm	3.58 mm
October	+1.26 mm/dec.	0.437	-0.01	15.24 mm	20.16 mm
November	-0.28 mm/dec.	0.927	-0.03	37.26 mm	36.17 mm
December	+0.52 mm/dec.	0.842	-0.03	43.56 mm	45.60 mm

Historical annual trends

Figure 63 – Historical time series of the annually accumulated precipitation in the Iraqi watershed and in Iraq Time series over the 1980-2020 period. **In orange full line:** monthly maximum temperature. **In blue full line:** monthly minimum temperature. **In green full line:** monthly average temperature. **In black dashed line:** data aggregated only for Iraq. **In dotted line:** data aggregated at the level of Iraq only. Data source: ERA5 - ECMWF / Copernicus Climate Change Service (Muñoz Sabater, 2019).

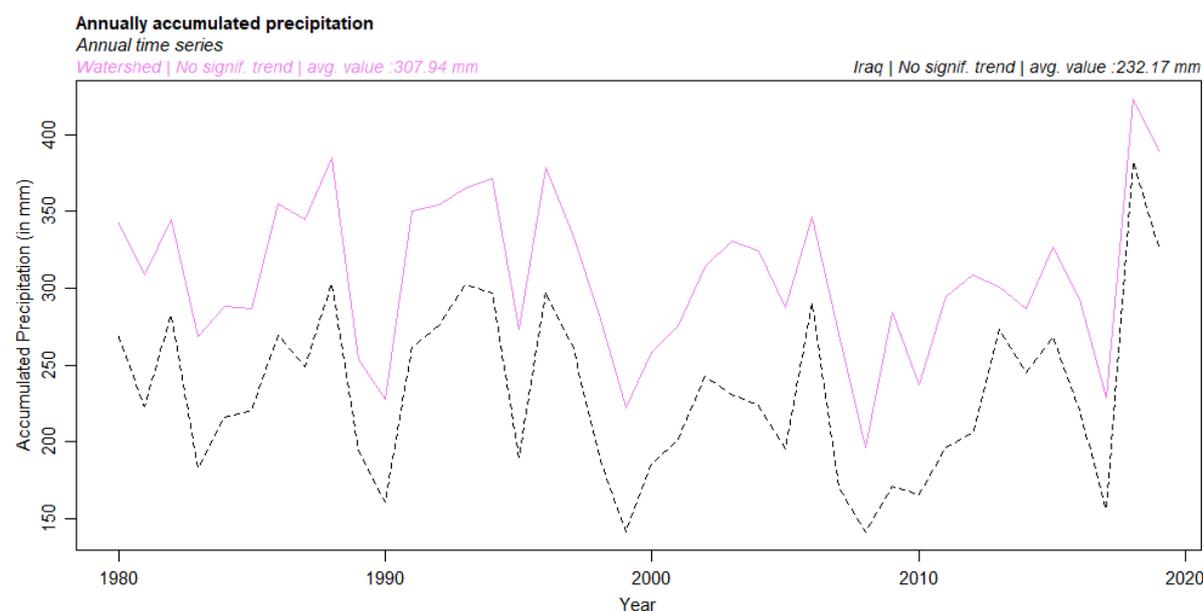


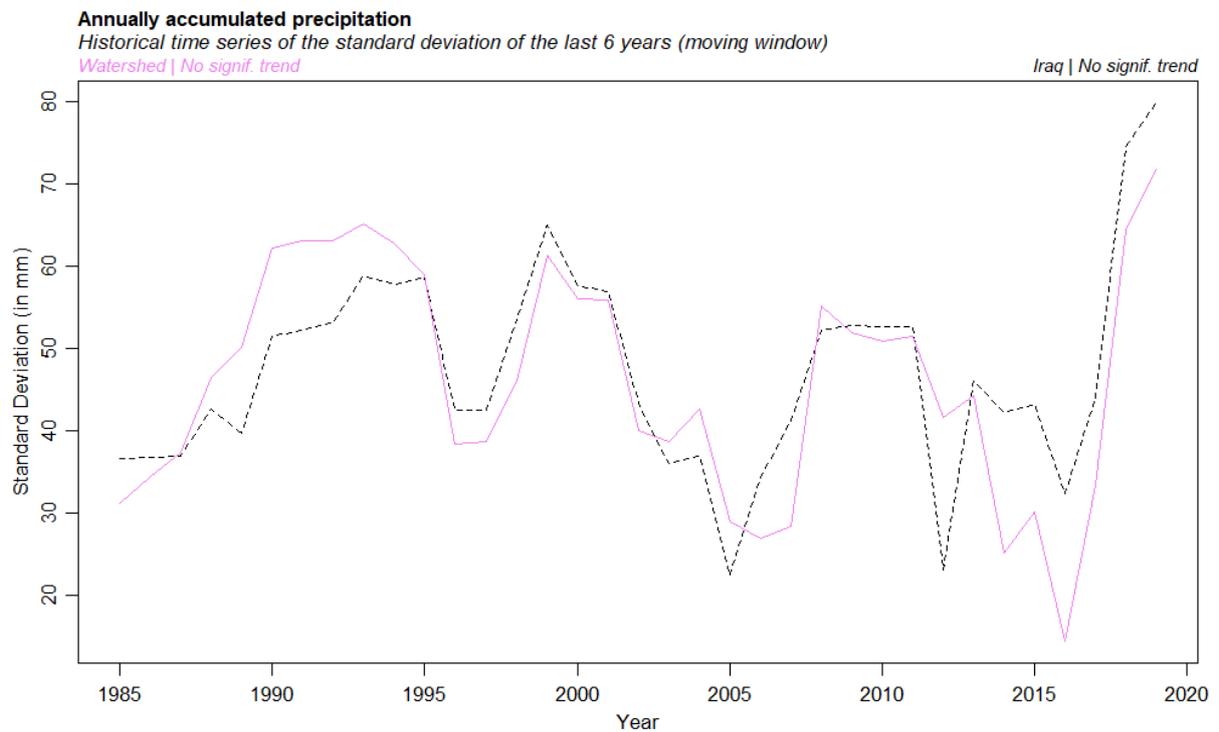
Table 34 – Characteristics of the trends from the historical time series of the annual average maximum and minimum temperature over the Iraqi watershed (linear models)

In orange: monthly maximum temperature. **In blue:** monthly minimum temperature. **in green** monthly average temperature. **Data in grey:** the trends is statistically no significant under an alpha of 5%. Data source: ERA5 - ECMWF / Copernicus Climate Change Service (Muñoz Sabater, 2019).

governorate	Slope	p-value	R ²	Average value in 1980	Average value in 2019
TG _y	-4.40 mm/dec.	0.539	-0.02	316.52 mm	299.36 mm

Figure 64 – Historical time series of the standard deviation of the last 6 years (moving window) of annually accumulated precipitation in the Iraqi watershed and in Iraq

Time series over the 1980-2020 period. **In orange full line:** monthly maximum temperature. **In blue full line:** monthly minimum temperature. **in green full line:** monthly average temperature. **In black dashed line:** data aggregated only for Iraq. **In dotted line:** data aggregated at the level of Iraq only. Data source: ERA5 - ECMWF / Copernicus Climate Change Service (Muñoz Sabater, 2019).



Projected monthly trends

Figure 65 – Projected time series of the monthly accumulated precipitation over the Iraqi watershed and in Iraq

Time series over the 2020-2060 period. **In yellow (dotted line):** value for each NEX model under the RCP4.5 scenario within the governorate. **In orange (full line):** median value calculated over all NEX models under the RCP4.5 scenario over the watershed. **In light green (dotted line):** value for each NEX model under the RCP8.5 scenario over the watershed. **In dark green (full line):** median value calculated over all NEX models under the RCP8.5 scenario over the watershed. **In grey (dotted line):** median value calculated over all NEX models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all NEX models under the RCP8.5 scenario within Iraq, for comparison. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

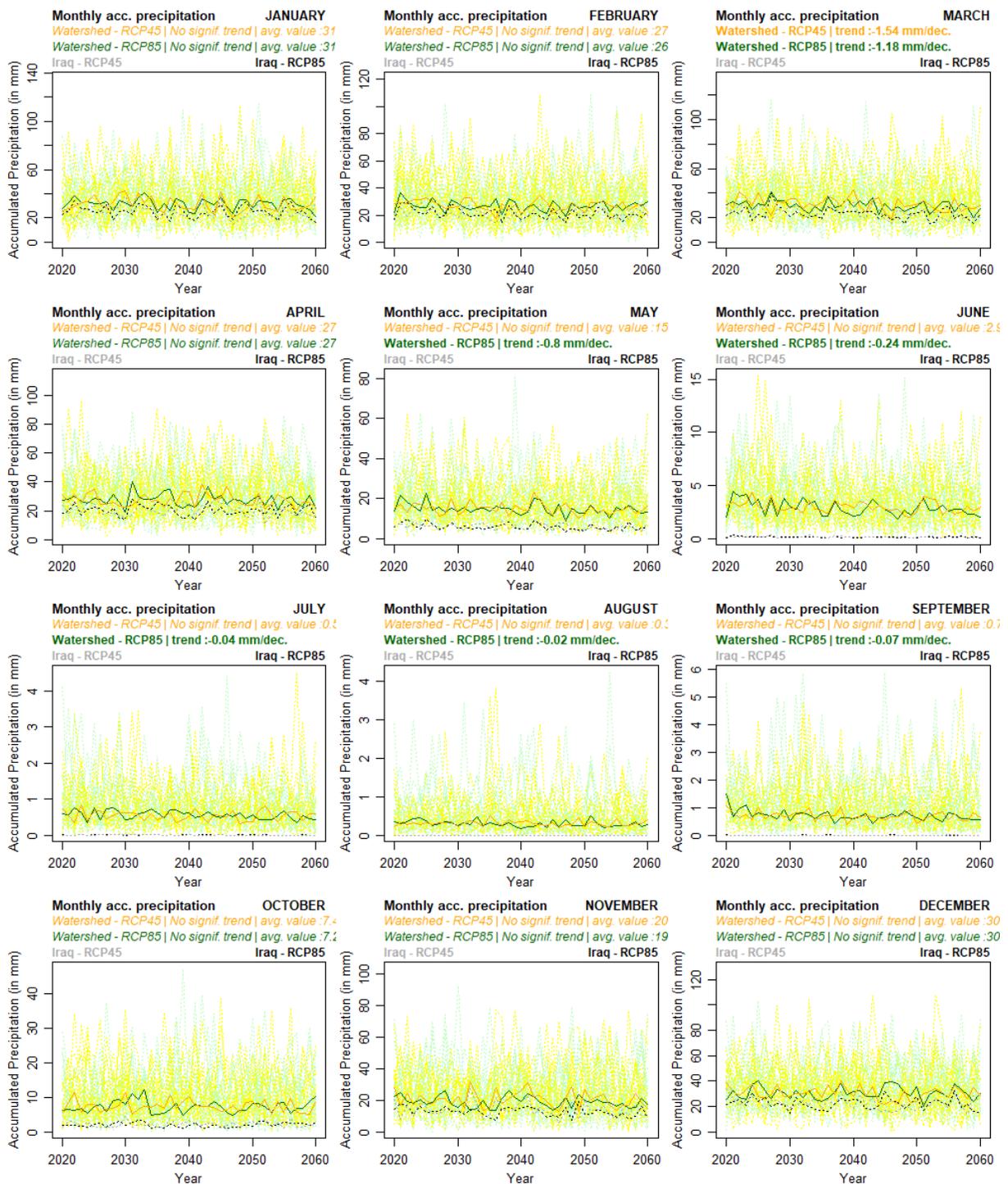


Table 35 – Characteristics of the trend from projected time series of monthly average, minimum and maximum temperature under the RCP4.5 scenario over the Iraqi watershed (linear models)

Data in grey: the trends is statistically no significative under an alpha of 5%. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

RCP4.5					
Month	Slope	p-value	Adj. R ²	Average value in 2040	Average value in 2060
January	-0.90 mm/dec.	0.248	0.01	31.14 mm	29.34 mm
February	-0.76 mm/dec.	0.120	0.04	27.05 mm	25.52 mm
March	-1.54 mm/dec.	0.024	0.10	31.24 mm	28.17 mm
April	-0.59 mm/dec.	0.316	0.00	27.39 mm	26.22 mm
May	-0.41 mm/dec.	0.259	0.01	15.04 mm	14.22 mm
June	-0.12 mm/dec.	0.099	0.04	2.97 mm	2.74 mm
July	-0.01 mm/dec.	0.579	-0.02	0.55 mm	0.53 mm
August	+0.00 mm/dec.	0.918	-0.03	0.31 mm	0.32 mm
September	-0.04 mm/dec.	0.068	0.06	0.71 mm	0.64 mm
October	-0.17 mm/dec.	0.450	-0.01	7.44 mm	7.10 mm
November	-0.72 mm/dec.	0.283	0.00	20.64 mm	19.21 mm
December	-0.80 mm/dec.	0.213	0.01	30.63 mm	29.04 mm
RCP8.5					
Month	Slope	p-value	Adj. R ²	Average value in 2040	Average value in 2060
January	-0.81 mm/dec.	0.178	0.02	31.44 mm	29.82 mm
February	-0.35 mm/dec.	0.490	-0.01	26.66 mm	25.95 mm
March	-1.18 mm/dec.	0.037	0.08	29.83 mm	27.47 mm
April	-0.51 mm/dec.	0.365	-0.00	27.52 mm	26.49 mm
May	-0.80 mm/dec.	0.029	0.09	14.86 mm	13.27 mm
June	-0.24 mm/dec.	0.008	0.15	2.89 mm	2.42 mm
July	-0.04 mm/dec.	0.007	0.15	0.56 mm	0.48 mm
August	-0.02 mm/dec.	0.035	0.09	0.30 mm	0.26 mm
September	-0.07 mm/dec.	0.005	0.17	0.72 mm	0.58 mm
October	+0.05 mm/dec.	0.823	-0.02	7.27 mm	7.38 mm
November	-0.61 mm/dec.	0.196	0.02	19.01 mm	17.80 mm
December	+0.10 mm/dec.	0.871	-0.02	30.76 mm	30.97 mm

Projected annual trends

Figure 66 – Projected time series of the annually accumulated precipitation over the Iraqi watershed and in Iraq

Time series over the 2020-2060 period. **In yellow (dotted line):** value for each NEX model under the RCP4.5 scenario over the watershed. **In orange (full line):** median value calculated over all NEX models under the RCP4.5 scenario over the watershed. **In light green (dotted line):** value for each NEX model under the RCP8.5 scenario over the watershed. **In dark green (full line):** median value calculated over all NEX models under the RCP8.5 scenario over the watershed. **In grey (dotted line):** median value calculated over all NEX models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all NEX models under the RCP8.5 scenario within Iraq, for comparison. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

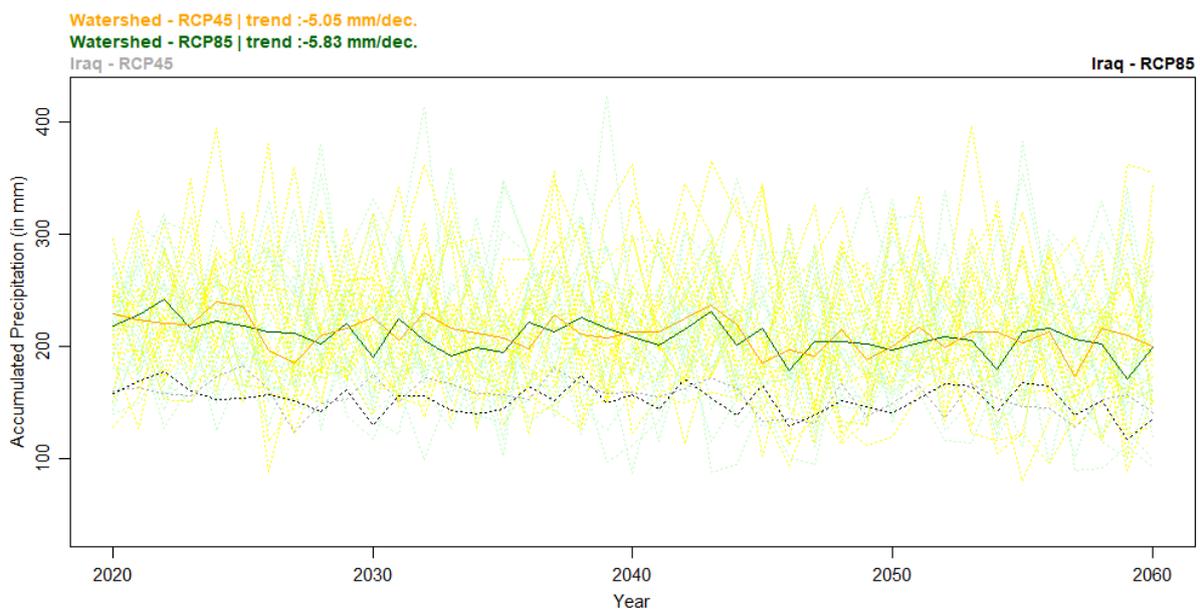


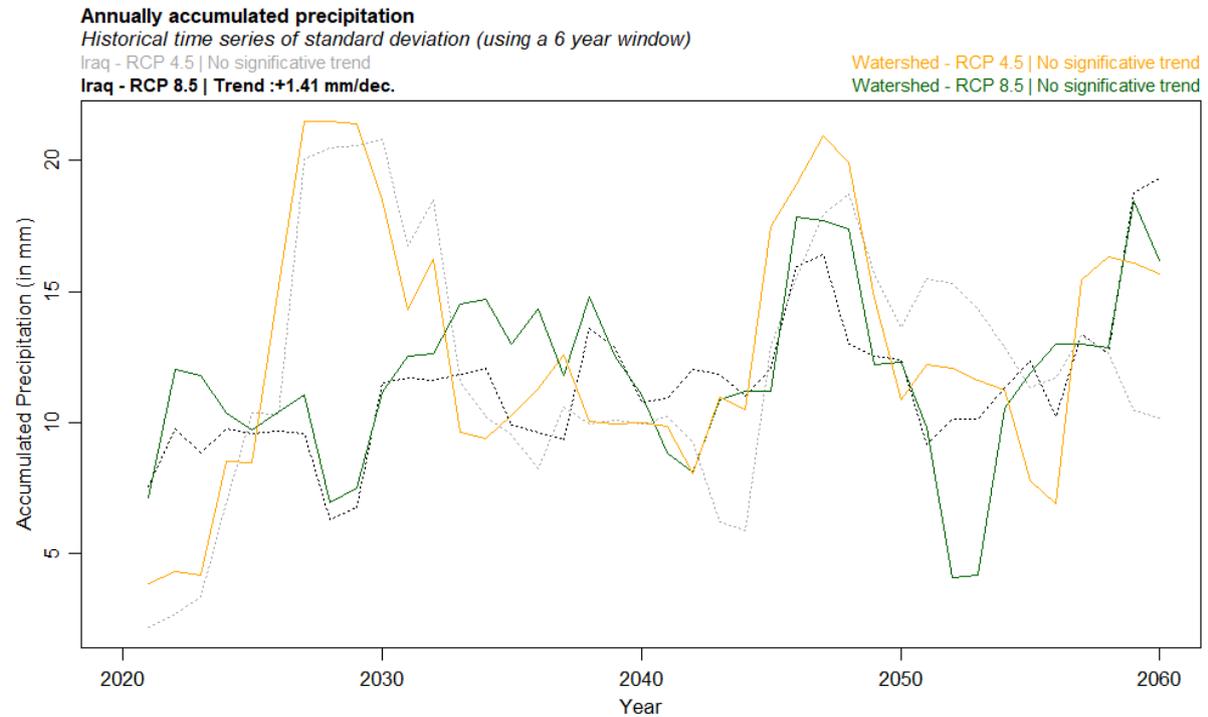
Table 36 – Characteristics of the trends from the projected time series of the annually accumulated precipitation over the Iraqi watershed under the RCP4.5 and RCP8.5 scenarios (linear models).

Data in grey: the trends is statistically no significant under an alpha of 5%. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).

RCP4.5				
Slope	p-value	R ²	Average value in 2040	Average value in 2060
-5.05 mm/dec.	0.008	0.14	210.96 mm	200.85 mm
RCP8.5				
Slope	p-value	R ²	Average value in 2040	Average value in 2060
-5.83 mm/dec.	0.001	0.22	208.04 mm	196.38 mm

Figure 67 – Projected time series of the standard deviation of the last 6 years (moving window) of annually accumulated precipitation over the Iraqi watershed and in Iraq

Time series over the 2020-2060 period. **In orange:** median value calculated over all projected models under the RCP4.5. **In dark green:** median value calculated over all projected models under the RCP8.5. **In grey (dotted line):** median value calculated over all projected models under the RCP4.5 scenario within Iraq, for comparison. **In black (dotted line):** median value calculated over all projected models under the RCP8.5 scenario within Iraq, for comparison. Data source: NASA Earth Exchange - Global Daily Downscaled Climate Projections (NEX – GDDP) (Thrasher et al., 2012).



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