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Assessment of Heat Wave Indexing and Performance of ERA5 in Simulating Temperature and Precipitation Dataset over the UAE

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Abstract

Climate change is one of the most important challenges of the modern era. The aims of this study were assessed (1) the climatological analysis for two periods: far-past (1979-1998) and near past (1999-2018) over the United Arab Emirates, (2) statistical evaluation of ERA5-reanalysis dataset against climatic historical reference period, and (3) investigate heatwave indices and their characteristics over the UAE from 1979 to 2050 using CORDEX model at RCP4.5 scenarios. Results showed that the effects of climatic changes appeared to be clear on the temperature and precipitation within the UAE. Temperature increased by 1.15 °C between 1979 and 2018, and therefore the annual average rainfall decreased by -81.5 mm within the same time period. Slight difference in temperature between observation and ERA5 clearly shown a strong positive correlation, on the contrary, precipitation is shown significantly high error values because of the plurality of climate and its variability between tropical semi-arid and desert climate. The number, frequency, duration, magnitude and amplitude of heat waves accelerates from the beginning of the study period in 1979 and continues to increase until the end of study at year 2050 in UAE. By studying thermal comfort, it was found that most of the population suffers from thermal discomfort and reaches severe stress in July and August. Two main types of heat wave impacts have so far been underlined: divorce cases and road accidents. However, this list is not exhaustive, as wider social impacts may occur during heat wave events.

Keywords: Climate Analysis; ECMWF-ERA5; Heat Waves; Daily Temperature and Precipitation; United Arab Emirates.

1. Introduction

The United Arab Emirates is one amongst the countries that are prone to the implications of global climate change. If rapid urbanization and a high level of population density are added to the image, the implications may will be dire for the inhabitants of this country. The Ministry of Climate Change and Environment in UAE suggested that, the tropical semi-desert climate of the region contributes to act the UAE prone to climate impacts (MOCCAE, 2021). In 2013, the Intergovernmental Program on Climate Change (IPCC) reported that, within the United Arab Emirates there is a rise in temperature about 1 – 1.5 °C during

December–February and expected to achieve 3 °C toward the top of the century (IPCC, 2013a). NASA announced that, the years 2020 and 2016 are tied as the warmest since temperature records began. Climate projection at different scenarios in UAE indicated that arid and semi-arid desert regions are possible to expand in area simultaneously with rising temperatures (Lu *et al.,* 2007; Pascal *et al.,* 2013; Warrach-Sagi *et al.,* 2013; Al Azhar *et al.,* 2016; Lelieveld *et al.,* 2016; Huang *et al.,* 2017; Weston *et al.,* 2018a; Branch *et al.,* 2020). The warmth waves and hot spells are most ordinarily linked with global climate change (Delworth, 1999; McCarthy, 2001; Gershunov *et al.,* 2009; Antics *et al.,* 2013; Cowan *et al.,* 2014; Cloutier-Bisbee *et al.,* 2019). The minimum number of consecutive hot days required to be considered as wave may vary across regions: as an example, Perkins and Alexander (2013), that specialize over Australia, have realized a heat wave as an event of a minimum three successive days above threshold, while Fischer and Schär (2010) defined a European heat wave as an event of a minimum of 6 days duration. In 2019, ECMWF issued the primary version of ERA5 (Hersbach *et al.,* 2019), this dataset records from 1979 to the current with 31 km spatial resolution and hourly temporal resolution. ERA5 has recently been replaced by the ERA-Interim reanalysis (Hersbach *et al.,* 2020). Reanalysis data is outputted by combining forecast model with observations (Kalnay *et al.,* 1996; Uppala *et al.,* 2005; Lindsay *et al.,* 2014; Sahlu *et al.,* 2017; Luo *et al.,* 2019; Wang *et al.,* 2019).

The main objective of this study was to assess the climatology, the performance of ECMWF-ERA5 reanalysis datasets, heat wave social impact and to investigate heat wave indices and characteristics over the arid-desert region of the UAE.

2. Materials and Methods

2.1 Study Domain

The area of study lies in western Asia within the latitude range between 22.0° and 26.5° N and longitudes range between 51.0° and 56.5° E, which is part of the Gulf cooperation council countries. United Arab Emirates (UAE), federation of seven emirates, covers an area of approximately 83,600 square kilometers with 1,318 km of coastline. The largest of these emirates, Abu Dhabi, which is a capital of the federations. The United Arab Emirates (which at the boundary between the subtropical and the tropical climate) has an arid climate with very dry in the interior, hot and humid along the coast. The temperature and humidity conditions develop as a result of three ecological major climatic zones; the coastal zone along the Arabian Gulf and the Gulf of Oman, the eastern mountainous region and the southern sand desert areas. The average January temperature is 17 °C, while in July the temperature averages 34 °C. Summertime highs can reach 45 °C on the coast and 49 °C or more in the desert. Most of the precipitation is concentrated in the winter season, the average rainfall often does not exceed 100 millimeters per year. Over the year, particularly in spring, the United Arab Emirates affected by dust and sand storms.

Table 1. List of the selected meteorological stations including station names, WMO code, average annual temperature and precipitation, latitude and longitude

Station Name	WMO Code	Average Annual Temperature	Average Annual Precipitation	Latitude/Longitude
Abu Dhabi	41217	27.9 °C	42 mm	24.433°, 54.651°
Al Ain	41218	28.0 °C	48 mm	25.255°, 55.364°
Dubai	41194	28.2 °C	68 mm	25.333°, 55.517°
Ras Al Khaimah	41184	27.9 °C	92 mm	24.262°, 55.609°
Sharjah	41196	27.9 °C	76 mm	25.612°, 55.939°
Fujairah	41198	27.1 °C	111 mm	25.128°, 56.326°
Liwa	41210	27.8 °C	48 mm	23.035°, 53.650°

Figure 1. Location of study areas

As shown in Table 1 and illustrative map in Figure 1 which gives the spatial distribution of the selected meteorological stations: Ras al-Khaimah is located in the north-east, while Abu Dhabi, Dubai and Sharjah are located along the northern coast of the United Arab Emirates. Al Ain is a largest inland city in the Emirate of Abu Dhabi, while Liwa is located in the southeast of the Emirate of Abu Dhabi and it is also located within the desert with sand dunes known as the Empty Quarter. Emirate of Fujairah is the only one of the seven emirates that has a coastline on the Gulf of Oman and It is surrounded by mountain chains.

2.2 Observational data

The set of meteorological data applied in this study consists of maximum, minimum temperature and precipitation for the period 1979-2018 are obtained from seven stations mainly located over United Arab Emirates (Abu Dhabi, Al Ain, Dubai, Ras Al Khaimah, Sharjah, Fujairah and Liwa). The observational climatic data used obtained from National Center for Environment Information (NOAA). To assess climate change, we analyzed the data for two periods (far-past: 1979-1998 and near past: 1999-2018).

2.3 Model data

ERA5 is the 5th generation reanalysis dataset from the European Centre for Medium-Range Weather Forecasts (ECMWF) which replaces ERA-Interim (stopped being produced on August 31, 2019) and gives a characterization of climate by combining models to observations. The most noticeable thing is the improvement of the ERA5 dataset with increased of spatial and temporal resolution, which now provides data from monthly to sub-daily timescale. Temperature and precipitation have been corrected against climatic historical reference period (2000 - 2010) by using simple bias correction. To evaluate these reanalyses, three statistical evaluations are calculated: Mean Absolute Error (MAE), correlation coefficient (r) and the Root Mean Square Error (RMSE).

International Coordinated Regional Climate Downscaling Experiment (CORDEX) model was analyzed to examine the future changes in temperature over United Arab Emirates. Temperature projections have been corrected against climatic historical reference period (2000-2010) by using simple bias correction. To assess future climate change, we analyzed the data from 1979 to 2050 using RCP4.5 scenarios.

All the models were run over a South Asian domain with 0.44° × 0.44° (approximately 50 × 50 km grid spacing) horizontal resolution as seen in Table 2. The results of the simulations were downloaded from the website of the Earth System Grid Federation (https://esg-dn1.nsc.liu. se/projects/cordex/).

3. Result and Discussion

3.1 Climatological analysis

3.1.1 Temperature

Temperature is the main indicator of climatic changes on the Earth's surface, so it is subject to many analyzes and studies to better and more accurately understand climate change. The climate of the UAE is classified as tropical semi-desert and desert climates. Generally, two main seasons characterize the UAE's climate. Winter lasts from November through March. The months of summer are very hot and dry, expansion from the month of April through October, with temperatures reaching about 48 °C in coastal cities such as Abu Dhabi where the associated humidity levels reaching more than 90%. In the southern desert regions such as Liwa, temperatures can climb to 50 °C. The study analyzed the temperature data for two periods (far-past: 1979-1998 and near past: 1999-2018). As shows in Figure 2, the difference in temperature between near-past and far-past period of (Abu Dhabi, Al Ain, Dubai, Fujairah, Liwa, Sharjah, Ras Al-Khaimah) was 1.19 °C, 1.37 °C, 1.21°C, 0.85 °C, 1.10 °C, 1.28 °C, 1.05 °C respectively. The hottest month during the study periods was August with average monthly temperature of 34.8 °C, 35.2 °C, 34.4 °C, 32.3 °C, 34.6 °C, 34.4 °C, 33.2 °C in far-past and 36.2 °C, 36.7 °C, 35.5 °C, 32.8 °C, 36.1 °C, 35.5 °C, 34.0 °C in near-past of (Abu Dhabi, Al Ain, Dubai, Fujairah, Liwa, Sharjah, Ras Al-Khaimah) respectively.

Table 2. List of South Asia-CORDEX regional climate model (RCM) experiments. (The Regional Climate Model system RegCM. version 4 (RegCM4.4), Rossby Centre Regional Atmospheric Model version 4 (RCA4), Indian Institute of Tropical Meteorology (IITM), Swedish Meteorological and Hydrological Institute (SMHI) and Max Planck Institute for Meteorology (MPI)

No	Institute	RCM	Model
1-	IITM	RegCM4-4	CCCma-CanESM
2-	IITM	RegCM4-4	CNRM-CERFACS-CNRM-CM5
3-	IITM	RegCM4-4	CSIRO-QCCCE-CSIRO-Mk3-6-0
4-	IITM	RegCM4-4	IPSL-IPSL-CM5A-LR
5-	IITM	RegCM4-4	MPI-M-MPI-ESM-MR
6-	IITM	RegCM4-4	NOAA-GFDL-GFDL-ESM2M
7-	SMHI	RCA4	CCCma-CanESM2
8-	SMHI	RCA4	CNRM-CERFACS-CNRM-CM5
9-	SMHI	RCA4	CSIRO-QCCCE-CSIRO-Mk3-6-0
10-	SMHI	RCA4	IPSL-IPSL-CM5A-MR
11-	SMHI	RCA4	MIROC-MIROC5
12-	SMHI	RCA4	MOHC-HadGEM2-ES
13-	SMHI	RCA4	MPI-M-MPI-ESM-LR
14-	SMHI	RCA4	NCC-NorESM1-M
15-	SMHI	RCA4	NOAA-GFDL-GFDL-ESM2M
16-	MPI-CSC	REMO2009	MPI-M-MPI-ESM-LR

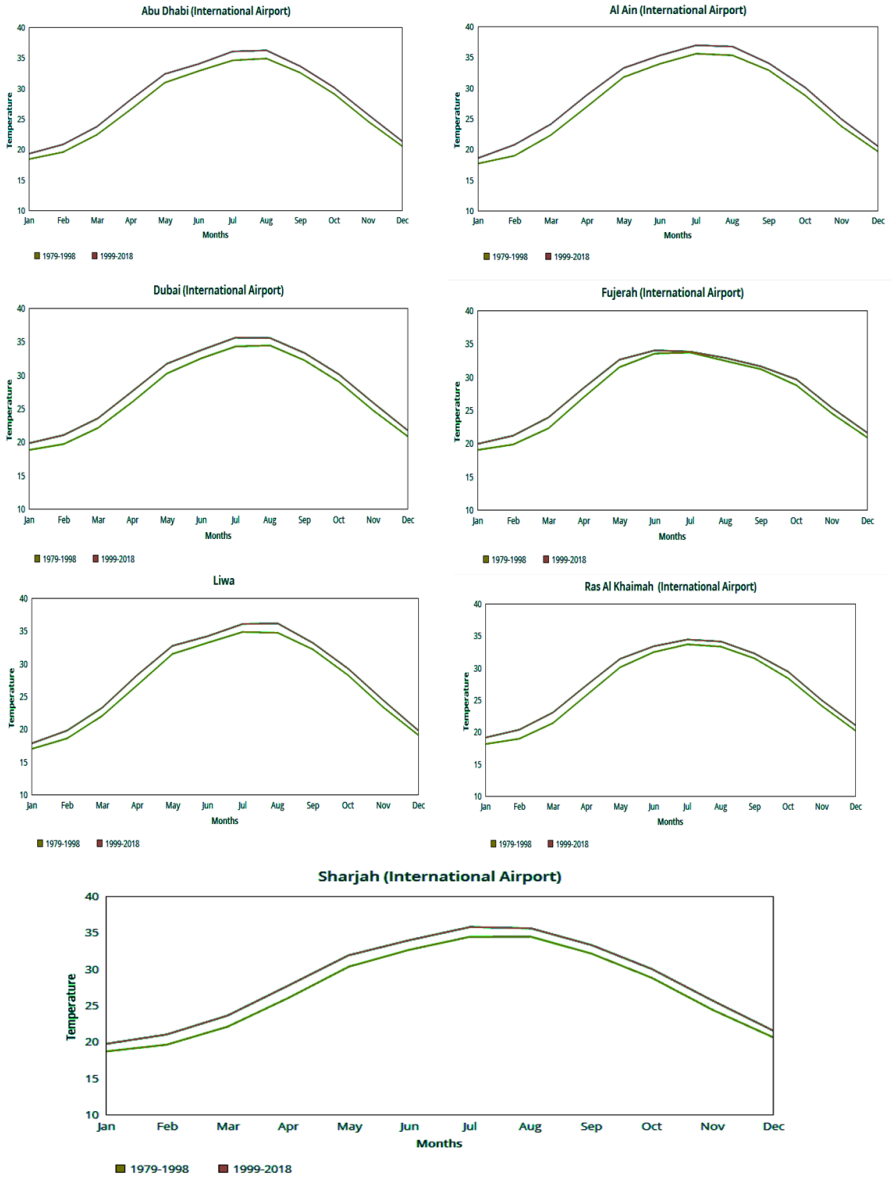

Figure 2. Difference between two periods of average monthly temperature over the UAE countries from 1979-2018

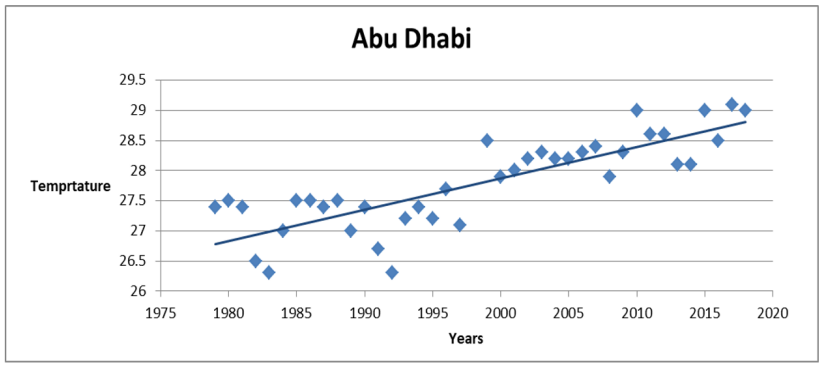

Figure 3. Yearly trend of average air temperature during 1979-2018 for Abu Dhabi.

As shown in Figure 3, the observational time series of temperature anomalies over Abu Dhabi show positive trends in temperature during the historical period (1979-2018). As we can see in Figure 4, the difference was clearly in temperature at 09.00 am between July 1979 and July 2018 using ECMWF-ERA5 reanalysis for the UAE.

3.1.2 Precipitation

According to the Koppen Climate Classification, the climate of the UAE is classified as BWh, desert climate which is characterized by very low and variable precipitation. The UAE is dominated by subtropical high-pressure cells, thus stable and dry weather conditions dominate due to the subsiding air throughout most parts of the year (Steinhoff, 2018). This region is characterized by very rare and limited rainfall. The difference between near-past and far-past period of precipitation for (Abu Dhabi, Al Ain, Dubai, Fujairah, Liwa, Sharjah, Ras Al-Khaimah) was -63.6mm, -81.3mm, -93.6mm, -87.9mm, -36.4mm, -107.5mm, -100.4mm) respectively as seen in Figure 5. The annual rate of precipitation on the UAE ranges from 20 mm in the west, where the dry region, to 130 mm in the Hajar Mountains in the Eastern region, where rainfall is limited between winter and spring (Sherif *et al.,* 2014; Bruintjes and Yates, 2003; Schwitalla, 2020).

3.2 Performance of ERA5-reanalysis datasets

The statistical analyses were used are: Root Mean Square Error (RMSE), Mean Absolute Error (MAE), and correlation coefficient. The values of the correlation coefficient are between zero and one, where a value of zero refers to that the two variables have no linear relationship, while the correlation coefficient of one show that there is a linear relationship between the two variables.

The value of correlation (r) is 0.895 (Abu Dhabi). This is a strong positive correlation of temperature between ERA5 reanalysis and observation data. In RMSE, the errors are squared before they are averaged so, an error of 10, is 100 times worse than an error of 1. The RMSE lies between 0.2 and 0.66, smaller RMSE seems more realistic and suitable. The RMSE result will always be larger or equal to the MAE which is lies between 0.2 and 0.55. The difference between model and observation are small in temperature as seen in Figure 6. The annual and monthly RMSE values of precipitation amounts are shown significantly high error values. Temperature data are generally more reliable than precipitation data (Decker *et al.,* 2012; Simmons *et al.,* 2004). However, there may exist some uncertainty in precipitation data over UAE. ERA5 could not accurately describe the precipitation in this region with arid region and complex type of climate. The geographical location of the country with respect to the Arabian Gulf and Gulf of Oman plays an important role in local variations in the climate over the United Arab Emirates. The mountain ranges extending from north to south in the eastern part of the United Arab Emirates have an important role in the distribution of rain in terms of quantity and time, as summer rains constitute 20% of the annual amount of rain, and this reduces the accuracy of the model and increases the error rate.

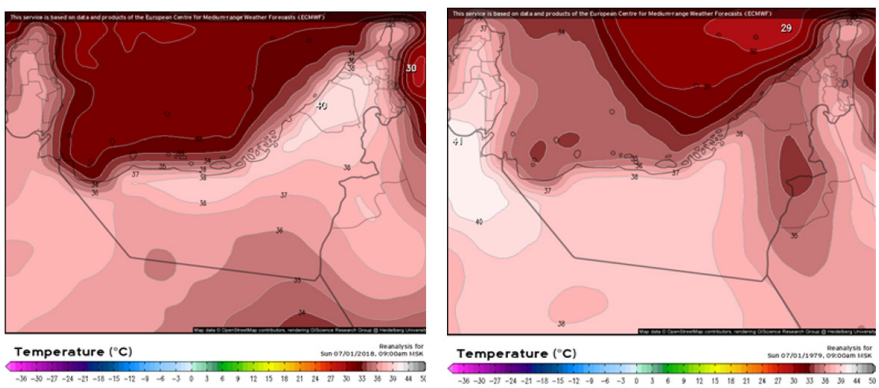

Figure 4. The difference in temperature between July 1979 and July 2018 using ECMWF ERA5 reanalysis for the UAE.

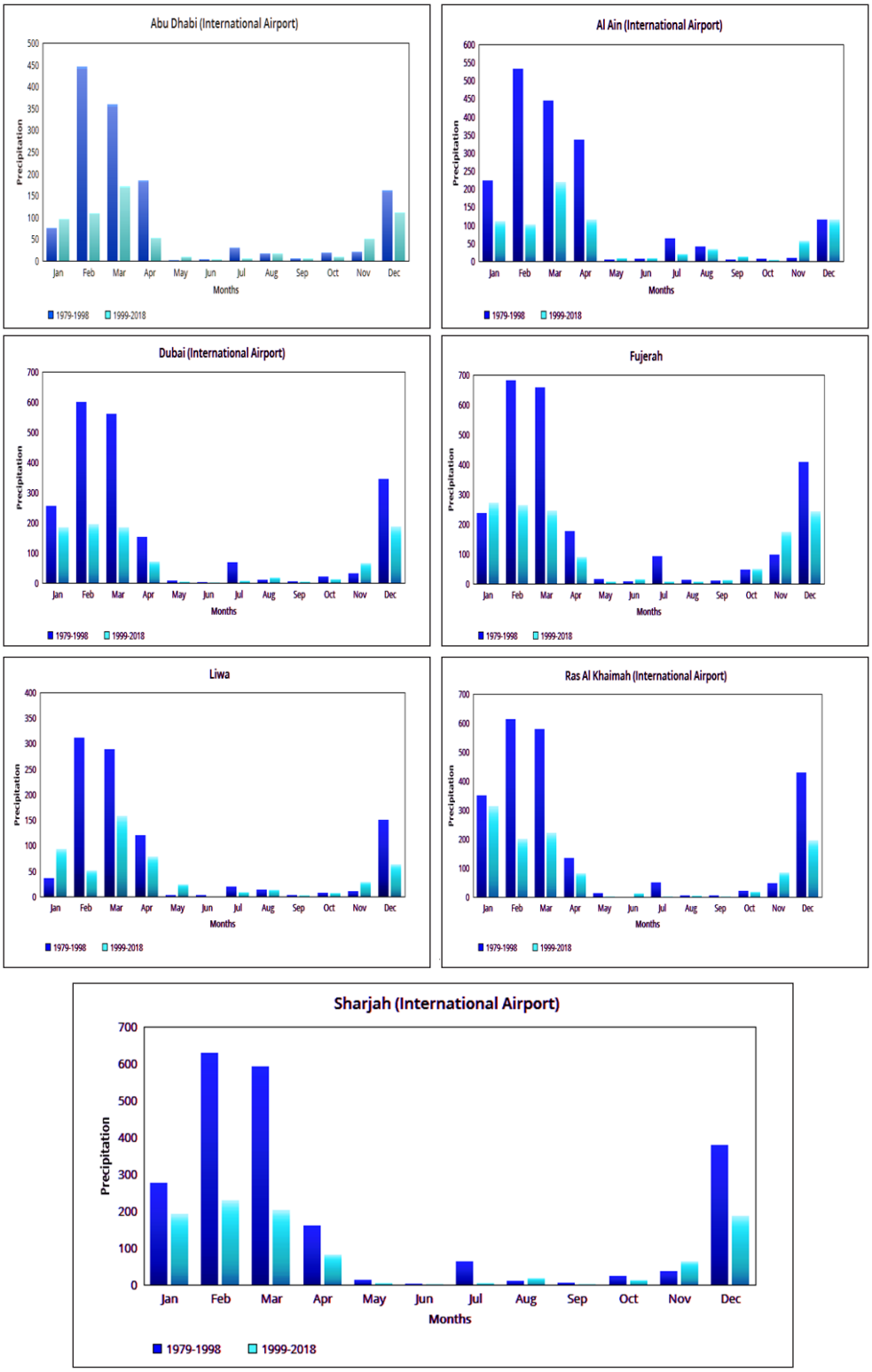

Figure 5. Difference between two periods of average monthly precipitation over the UAE countries from 1979-2018

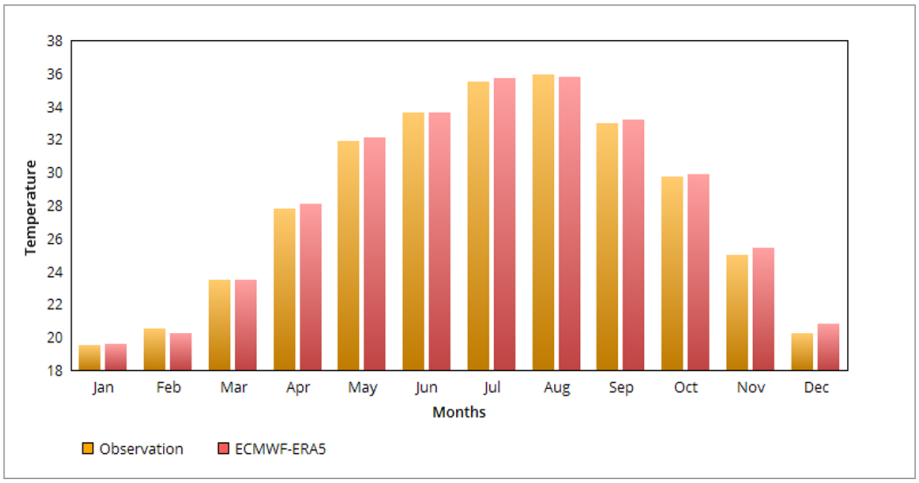

Figure 6. Comparison of monthly average air temperature from ERA5 Reanalysis and Abu Dhabi meteorological stations during (2000-2010)

3.3 Heat Waves

There is no exclusive definition of heat waves in terms of amplitude and duration. Accordingly, as a variety of definitions are used for these events, it is difficult to compare heat wave studies (Frich *et al.,* 2002; Souch and Grimmond, 2004; Robinson, 2001; Fischer and Schär, 2010). The temperature must be above the annual average temperature in order to be considered a heat wave. The period for at least three consecutive days in which maximum temperatures exceed the heat wave temperature threshold. The World Meteorological Organization had a role in defining heat waves to include all regions of the world (WMO, 2015). The WMO specified the definition where it stated that a heat wave can be considered when the maximum temperature for more than five consecutive days exceeds the average maximum temperature by five degrees Celsius.

3.3.1 Heat wave aspects

Heat wave indices applied in this study to investigate the extremes temperature, which is Heat Wave Magnitude (HWM), Heat Wave Amplitude (HWA), Heat Wave Number (HWN), Heat Wave Duration (HWD) and Heat Wave Frequency (HWF). The study and definition of heat waves depends on two foundations and criteria: (1) the 90th percentile of the minimum daily temperature, (2) the 90th percentile of the maximum daily temperature. If any of the previous two criteria exceeds three consecutive days, we consider this time period a heat wave. A more detailed definition is given by Perkins and Alexander (2013).

3.3.2 heat wave magnitude (HWM) and Heat wave amplitude (HWA)

The heat wave magnitude index is considered as the maximum magnitude of the heat waves during a year, which is in another word the average temperature of all heat waves. Heat Wave Amplitude defined as a maximum temperature of the hottest day of the hottest yearly event, in other words, peak temperature of the hottest heat wave events. The spatial distribution of HWM index is presented in Figure 7. The results show a clear similarity between HWM and HWA. Summarizing, we can state that the HWM values of daytime amplitude (HWA-TX90) ranging from 42 °C to 45 °C from 1979 to 2050. Over the UAE, the hottest events HWA were of +40 °C of all Emirates. The highest HWA was over Liwa with 47.8 °C. For the future period (2020 - 2050), with a maximum daily Temperature over (Abu Dhabi, Al Ain, Dubai, Fujairah, Liwa, Sharjah, Ras Al-Khaimah) is projected to 49.9 °C, 54.1 °C, 46.6 °C, 47.7 °C, 51.1 °C, 47.4 °C, 47.3 °C) respectively as seen in Figure 8.

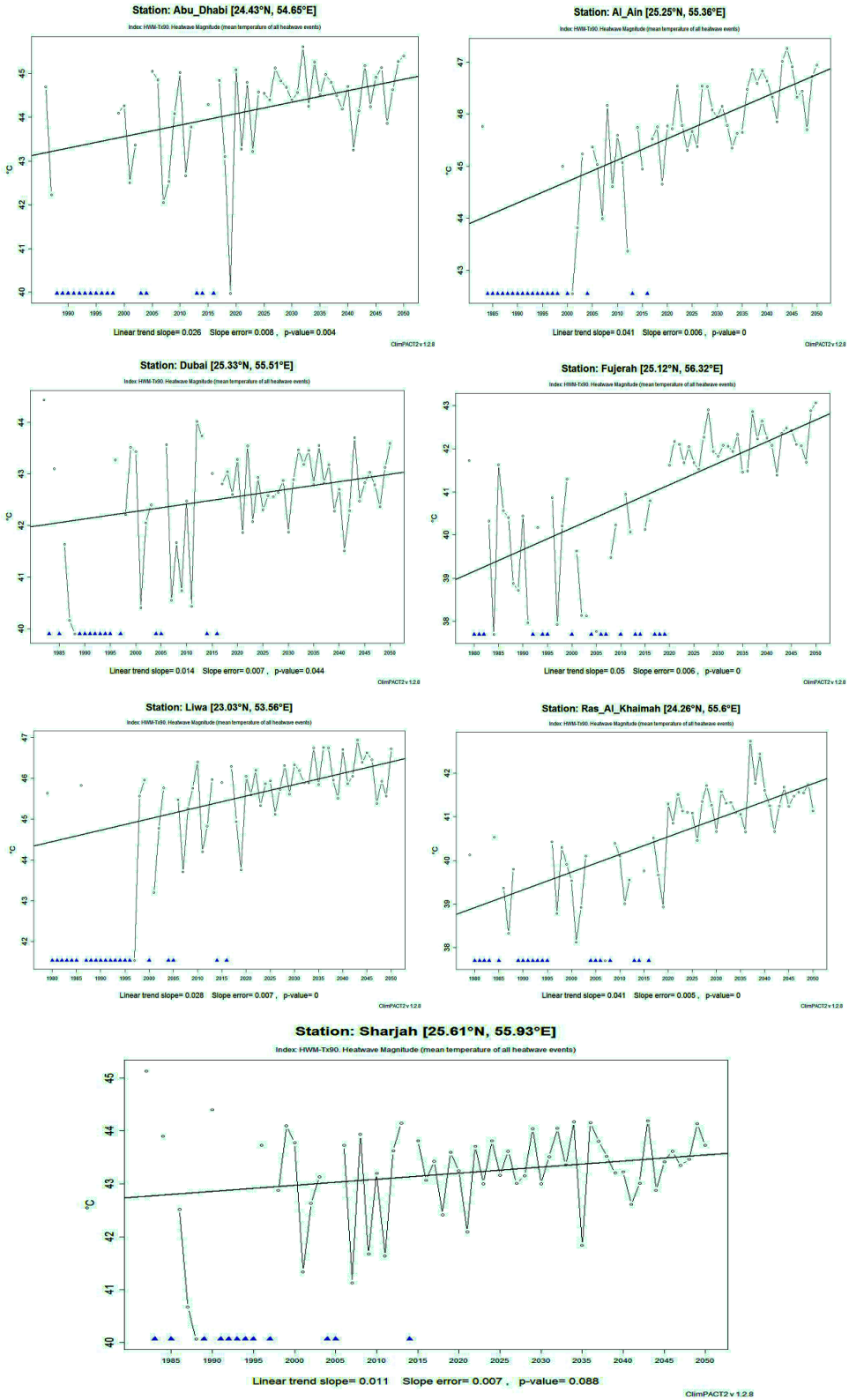

Figure 7. Heat wave magnitude (HWM) from 1979 to 2050 over selected countries over the UAE. Heat wave defined by 90th percentile of maximum temperature (TX)

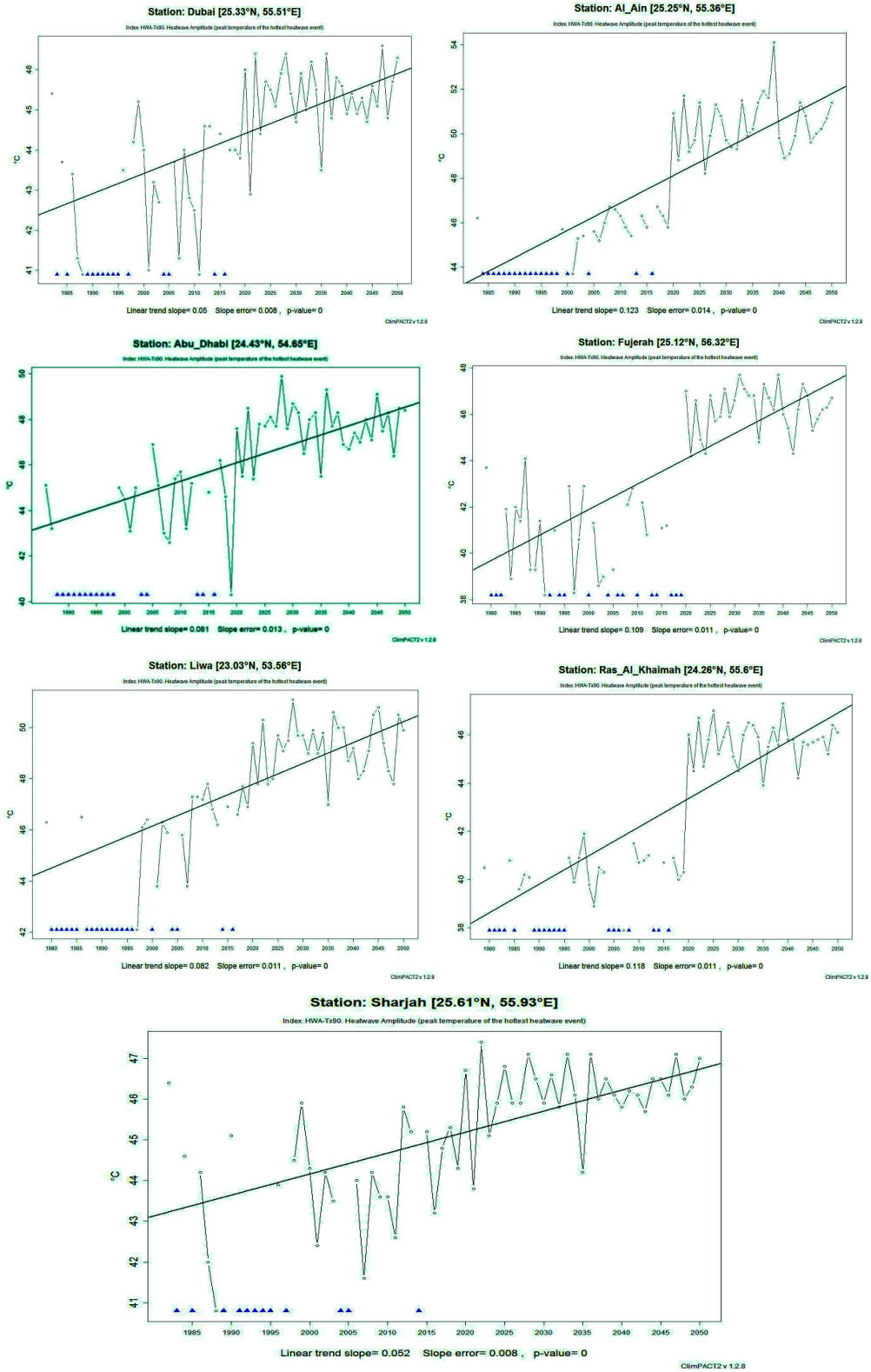

Figure 8. Heat wave amplitude (HWA) from 1979 to 2050 over selected countries over the UAE. Heat wave defined by 90th percentile of maximum temperature (TX)

3.3.3 Heat wave number (HWN)

Which is the number of discrete heat wave events. Figure 9 demonstrate the number of heatwaves, which was determined as the 90th percentile of daily highs. For the whole study area of UAE, the average number of events is less than 3 events per year from 1979 to 2018, while after 2020 the number continue to rising between 9 to 13 events. The highest HWN values were found in Fujairah which reach 16 events. The increase in the number of discrete heat wave events begins in 2020 and continue until 2050 for almost the entire territory of UAE.

3.3.4 Heat wave duration (HWD)

Heat Wave Duration is a heatwave appearance that consider the extent of the longest heat wave event. While HWD and HWN zones are similar, it is very important to know that they are not overlapping with each other. Depicted in Figure 10 shows the distribution of HWD (in days) over UAE during (1979 - 2050). The period from 2020 to 2050 displays a tremendous increase in heat wave duration compared to the past period of 1979 to 2018. While period from 1979 to 2018 exhibit mean duration of between 3 and 5 days in most parts of the country, period from 2020 to 2050 shows 9-19 days in limited number of stations like Abu Dhabi, Dubai and Sharjah while the remaining Emirates showed the heat wave duration between 29 and 48 days except Ras Al-Khaimah which showed 57 days.

3.3.5 Heat wave frequency (HWF)

Number of days contribute to heat wave event. It can be defined in other terms as the number of heat waves that occur in one year in a particular station. Starting from 2020, a tremendous increase in heat wave frequency compared to the periods from 1979 to 2018 which mostly exhibit heat wave frequency of between 3 - 21 days in most part of the country. Suggesting that it occurs between 3 to 15 days in a year except in few stations like Dubai and Sharjah which is greater than 15 days, as seen in Figure 11. The highest values of HWF = 147 days found over Ras Al-Khaimah was recorded in 2049. While the lowest HWF = 75 days found over Abu Dhabi in 2039.

3.4 Human Thermal Comfort and Social Impacts of Heat Waves.

The phenomenon of climate change creates real threats to the peoples of the Middle East and North Africa region; as the region most vulnerable to being affected by the catastrophic results of global warming, most of its countries are distinguished by a hot desert climate, and increased humidity levels due to their location on the coasts of the Gulf, the Mediterranean and the Arabian Sea.

This study warns that temperatures may exceed 60 degrees Celsius by the middle of this century, which will make life in the region "impossible". As the use of air conditioners is common, residents tend to avoid going out to the streets during the day, and families wait for the evening to go out to public parks during the summer. This forced Qatar to introduce laws prohibiting work in open spaces, starting from the month of June until the end of August, between eleven and thirty in the morning and three in the afternoon.

As illustrated in Table 3, some examples of social impact of heat waves. There is much argument about the association between rising temperature and crime or higher levels of street violence (Field, 1992; Anderson *et al.,* 1997; Rotton and Cohn, 2000a).

Discomfort Index is computed according to the following equation: DI = Tair - (0.55 - 0.0055*RH) (Tair - 14.5). Where, (Tair in °C) the average monthly air temperature and (RH in %) average monthly relative humidity. The Discomfort Index (DI) method is used to indicate the level of human thermal comfort (Thom, 1959; Epstein, 2006).

Giles *et al.* (1990) categorized DI values in the different classes as no discomfort feeling (18 - 21), under 50% of population feels discomfort with DI value between (21- 24), most 50% of population feels discomfort (24 - 27), most of the population feels discomfort (27 - 29), everyone feels severe stress with (29 - 32) and state of medical emergency (more than 32).

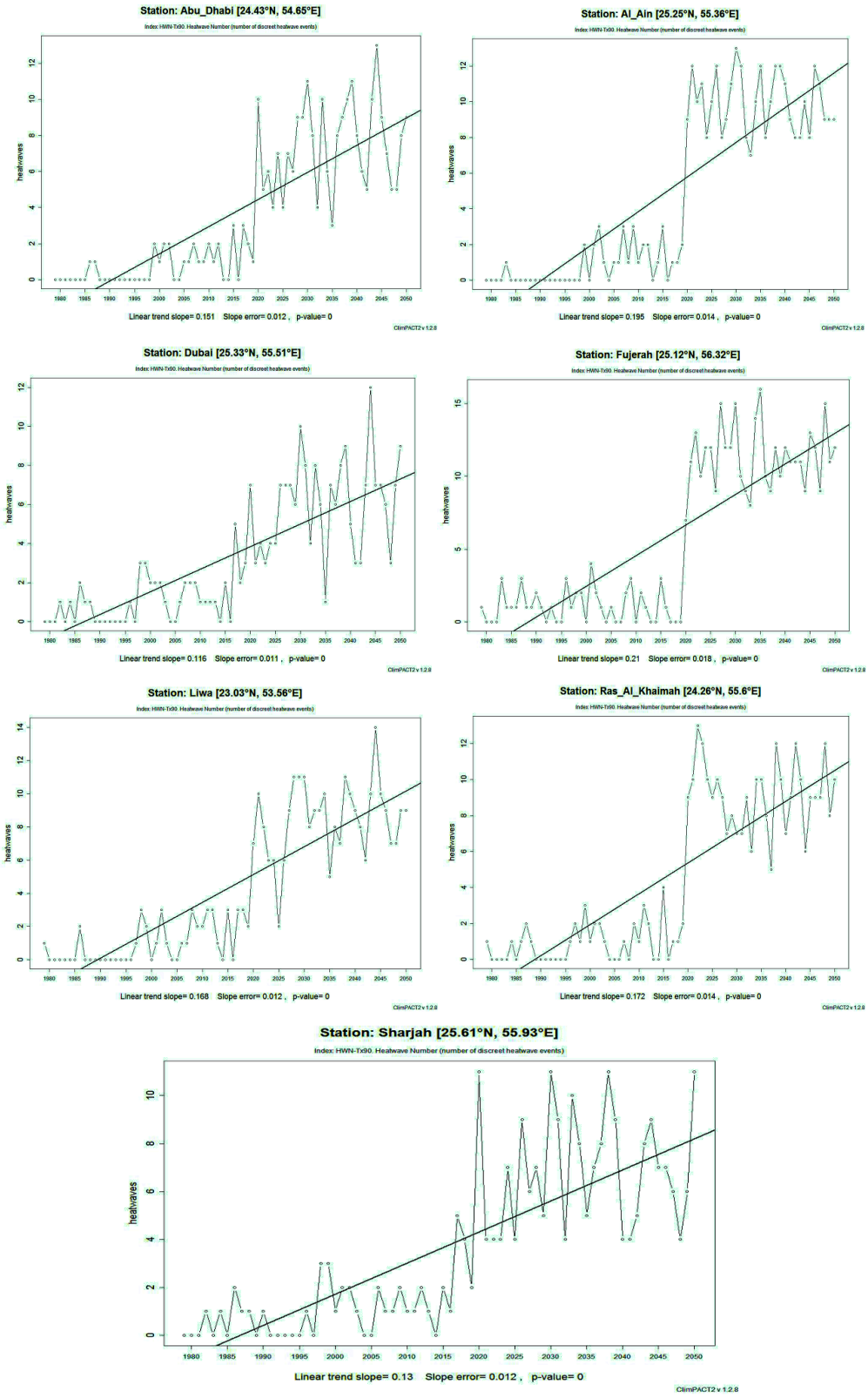

Figure 9. Number of discreet heat wave events from 1979 to 2050 over selected countries over the UAE. Heat wave defined by 90th percentile of maximum temperature (TX)

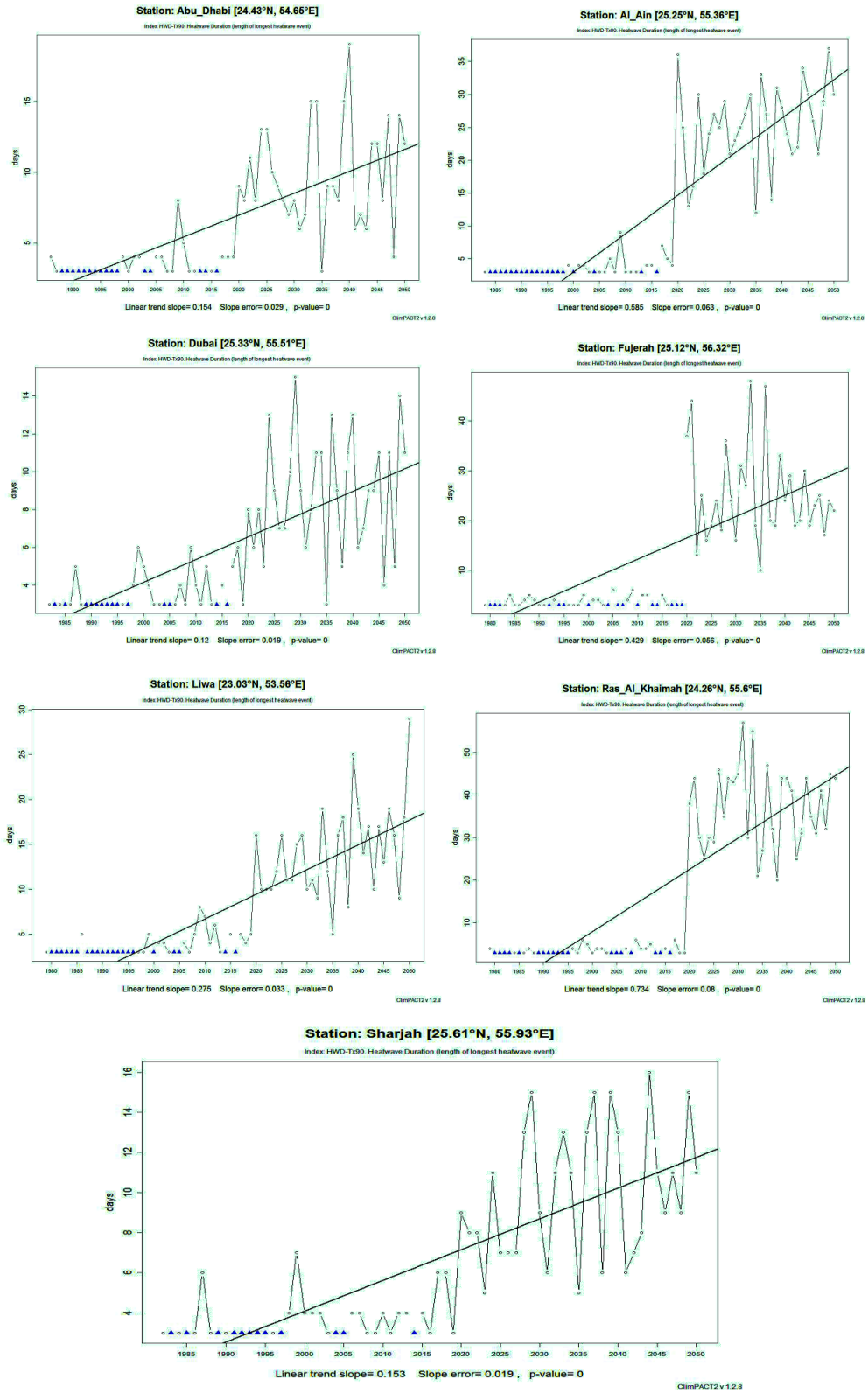

Figure 10. Length of the longest heat wave event from 1979 to 2050 over selected countries over the UAE. Heat wave defined by 90th percentile of maximum temperature (TX)

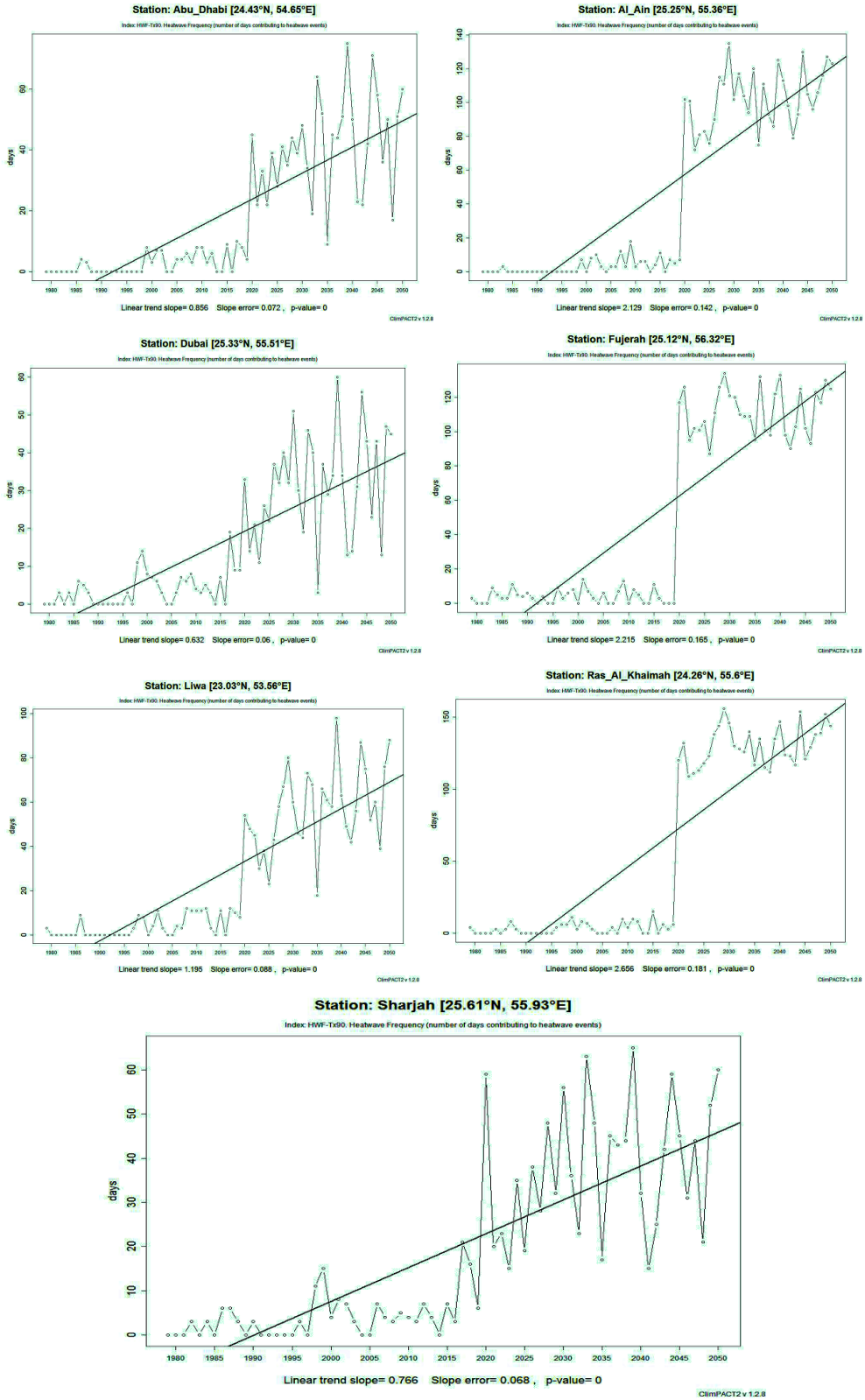

Figure 11. Number of days contribute to heat wave event from 1979 to 2050 over selected countries over the UAE. Heat wave defined by 90th percentile of maximum temperature (TX)

Table 3. Social impacts of Heat Waves over the United Arab Emirates

Divorce cases	In the summer, divorce cases in the UAE may reach 200 cases per month, and it is possible to increase this number in August, and decreased significantly from October to March.
Road accidents	Chairman of the Federal Traffic Council in the UAE and assistant commander-in-chief of Dubai Police, stated that "in summer time, accidents that happen during these three months contribute to about 25 to 30 per cent of UAE traffic deaths,". Statistics released showed 87 people died in traffic accidents between July and October in the past three years.

Table 4. Average monthly Discomfort Index (°C) from 1980 to 2019

Country/ Months	June		July		August		September	
	1980-1998	1999-2018	1980-1998	1999-2018	1980-1998	1999-2018	1980-1998	1999-2018
Abu Dhabi	28.3	29.2	29.5	30.6	29.5	30.5	28.3	29.1
Al Ain	25.7	26.5	27.1	27.9	26.9	27.8	25.7	26.4
Dubai	27.2	28.1	28.5	29.4	28.5	29.3	27.5	28.3
Ras Al Khaimah	27.8	28.5	29.1	29.7	28.8	29.5	27.6	28.2
Sharjah	27.6	28.6	28.9	29.9	28.8	29.7	27.7	28.6
Fujairah	28.2	28.5	29.3	29.4	28.7	29.1	27.7	28
Liwa	25.4	25.9	26.7	27.4	26.8	27.7	25.8	26.5

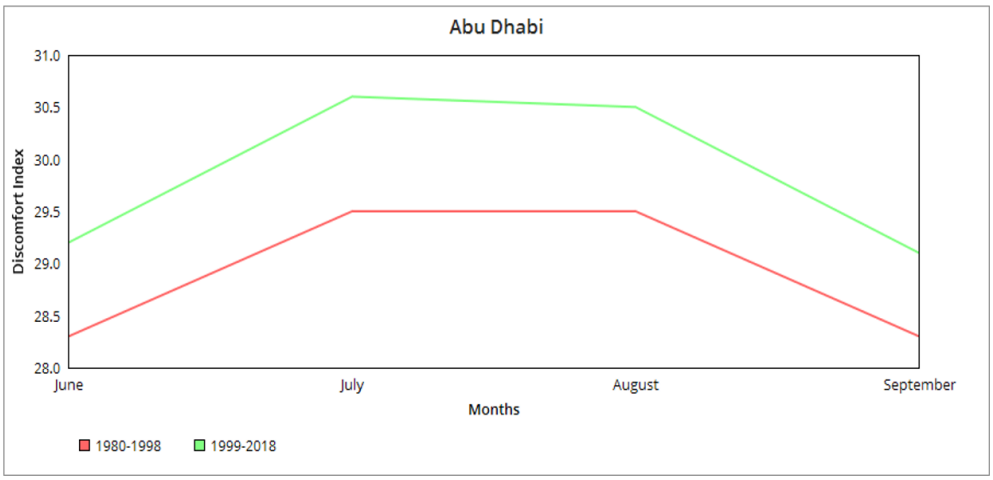

Figure 12. Difference of thermal human comfort (DI) between two periods over Abu Dhabi

In this study, as shown in Table 4, we note that, the difference seems obvious in thermal comfort between the cities overlooking the Arabian Gulf and the inner cities. Abu Dhabi and Dubai, are among the coastal cities, have thermal comfort values of 30.6 °C and 29.4 °C, respectively categorized everyone feels severe stress. In comparison, at the same month and period, the cities of Al Ain and Liwa are among the inner cities, with thermal comfort values of 27.9 °C and 27.4 °C, respectively categorized most of the population feels discomfort. When the rise in temperature meets the rise in relative humidity, the thermal comfort values are high.

As seen in Figure 12, the difference in Discomfort Index between the two periods in coastal cities is higher than in internal cities. Where the difference between the two periods in Abu Dhabi for June 2.9 °C, in contrast, was 0.8 °C in Al Ain. This confirms once again that the region is experiencing rapid and severe climatic changes, especially in the coastal areas.

In the UAE, local health experts have also warned about heat-related deaths and illnesses such as heat stroke as temperatures rise more than 40 °C. It is useful for countries exposed to climate change to take some measures to reduce the risks resulting from extreme heat waves, an example of this is the use of warning and forecasting systems for heat waves.

4. Conclusion

The UAE was ranked among the countries most vulnerable to the possibility impacts of climate change in the world. This will result in higher temperatures, more droughts, less rain and more sandstorms. The results of the study clearly showed the impact of climate change over the United Arab Emirates, as the increase in temperature reached 1.15 degrees Celsius from 1979 to 2018. The impact of climatic changes on rain also extended, as the decrease in the annual rate of rain amounted to -81.5 from 1979 to 2018. The difference between ERA5-reanalysis and observation are small in temperature, while could not accurately describe the precipitation in this region because of complex type of climate. The number of heat waves accelerates from the beginning of the study period in 1979 and continues to increase until 2050. Heat wave number (HWN) is less than 3 per year from 1979 to 2018, while after 2020 the number continue to rising between 9 to 13. The period from 2020 to 2050 shows a massive increase in heat wave duration (HWD) compared to the past period of 1979 to 2018. Starting from 2020, a large increase in heat wave frequency (HWF) compared to the periods from 1979 to 2018. Heat waves are more dangerous when combined with high humidity, as is the case in some Emirates bordering the Arabian Gulf. Thermal discomfort in the UAE ranges from categorized everyone feels severe stress to most of the population feels discomfort.

The social effects of heat waves are many and can sometimes be catastrophic. Before any heat wave arrives, the municipality must check the water system and communications. Heat waves are associated with drought, which leads to the depletion of water resources.

The UAE is one of the pioneering countries in Arab Gulf States that are making efforts to control the phenomenon of climate change. Therefore, it has established a ministry specialized in the field of climate change and the environment.

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