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Nano-spatiotemporal distribution of climate variables (WS, WD, T and RH) in Iraq for forty-three years from 1980 to 2023 using GrADS System

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Temperature (T) and relative humidity (RH) directly affect wind speed (WS) generation, but they also play an important role in modifying air properties and the atmospheric processes that influence air movement. By influencing air density, atmospheric pressure, and evaporation, they can contribute to creating the conditions that lead to wind generation and determine its speed. Therefore, in this research, some of the factors that influence wind speed are studied using data from the European Centre for Medium-Range Forecasts (ECMWF) for the period 1980-2023 over Iraq. The data are analyzed using the Grid Analysis and Display System (GrADS) and Sigma plot programs. The results showed that the prevailing wind direction is northwesterly, with varying wind speeds. The study area is determined based on the data in the graph. Relative humidity depends on its presence in the atmosphere, and its relationship with temperature is directly proportional. All Iraqi stations recorded a significant increase in annual temperatures. The highest observed increases are concentrated in the south, followed by the central regions. However, regions that are historically more moderate (such as the north) began to experience significant increases.

Keywords: Wind speed generation; Nanoparticles; Climate Variables.

1. INTRODUCTION

The Earth and its environment have been subject to changes in recent times, some of which may be natural as a result of terrestrial processes or unnatural as a result of human activities that have altered natural Earth processes [1]. Climate change results in an imbalance in the atmosphere, which in turn

affects Earth's processes and its inhabitants. Fossil fuels are among the most significant causes of global climate change, accounting for more than 75% of global greenhouse gas emissions and 90% of total carbon emissions [2]. Human activity has warmed the atmosphere, oceans, and land, causing widespread and rapid changes in the atmosphere, oceans, cryosphere, and biosphere [3]. One of the most important ways to mitigate climate change is to reduce the use of fossil fuels to halt and reduce the concentration of carbon dioxide and methane, which are greenhouse gases, in the atmosphere [4]. The solution is to use renewable energy such as solar wind and Hydropower [5,6]. The topic of global warming and climate change is a significant one today [7]. It is of interest not only to scientists and politicians, but also to ordinary people. Numerous studies have confirmed that global warming directly impacts the environment. In addition, note the effects associated with the Industrial Revolution, which led to massive emissions of harmful substances into the atmosphere, water, and soil [8,9]. Concern about climate change is one of the reasons behind the rapid development of wind energy projects. The Intergovernmental Panel on Climate Change (IPCC) notes that there is evidence of long-term, widespread climate changes, such as a pole region shift and stronger westerly winds, and these observed changes are likely to persist. Research indicates that jet streams have strengthened and shifted pole region in both hemispheres. These changes could directly impact energy production from existing and planned wind projects [10,11].

This study highlights the ability of hybrid systems to provide consistent energy production from wind sources [12]. It also examines the variability of wind patterns caused by climate change, taking into account that results vary depending on modeling methods, geographical contexts, and climate projections [13]. While certain regions, such as North America, are expected to experience an increase in wind speeds, we observe a potential decrease in the Mediterranean [14]. Wind is a vital climate parameter that plays an important role in many natural phenomena. Its importance as a renewable energy source cannot be overstated. Wind depends on relative humidity and temperature, as well as other weather factors. Several statistical methods, such as time series analysis, extreme value analysis, and spatial analysis, have been used to analyze wind speed data [15]. In recent years, numerous windstorms have been observed, each of which is caused by a combination of factors. Therefore, meteorological factors, urban morphology, and terrain must be studied to determine the cause of windstorms [16]. These meteorological factors, such as wind speed, humidity, and temperature, are analyzed for 2017. Meteorological data from the Malaysian Ministry of Environment (DOE) station also allowed for the determination of daily wind speed, humidity, and temperature data for 2017 [17]. Temperatures peak in the summer, and during this period we notice peak electricity consumption, as the electricity grid must use all types of energy, especially wind energy produced by the Calibration Wind Farm [18]. There are numerous published studies that document the severe and frequent climate anomalies that have occurred over the past decades, and these studies indicate changes in the observed climate. Temperature trends are likely the most significant and visible effect of the changes occurring in the Earth's climate system [19]. Climate change, affecting both local and global levels as a result of global warming, is one of the most serious problems facing the world today. The environment and human activities are affected by numerous climate variables, including wind speed, relative humidity, temperature, and many other vital climate elements [20]. Urban areas have accumulated higher amounts of heat than their surrounding rural areas, not only due to climate change but also due to human activity. Heat intensity (i.e., increased temperatures) in urban areas varies around the world, ranging from 0.6 °C to 12 °C. Rising urban temperatures can lead to increased energy consumption and increased thermal discomfort [21]. The temperature near the Earth's surface exhibits diurnal variations, with peaks occurring locally in the afternoon and minimums around midnight [22]. This is quite different from the atmosphere, where temperature shows little diurnal variation. Perturbations cause the wind field in the atmospheric boundary layer (ABL) and the near surface to behave differently from that in the atmosphere [23,24].

2. METHODOLOGY

The European Centre for Medium-Range Forecasts (ECMWF) data are used for the meteorological factors represented by wind speed, relative humidity and temperature for the period (1980-2023). The CrADS program is used to draw the climatic behavior of the above factors. The wind rose drawing is also used to determine the prevailing trends for (36) stations, as well as the time series of monthly and annual averages for both relative humidity and Temperature.

2.1 Climatic and Environmental Impacts

Deserts and open terrains (such as Rutba and Karbala) contribute to higher wind speeds due to fewer natural obstacles such as trees and buildings. Urban areas such as Baghdad may exhibit more dispersed wind patterns due to tall buildings and air pollution that may affect airflow. Areas closer to rivers or water bodies (such as Kut and Amara) may result in more stable winds but at lower speeds due to the effects of water on air stability. Therefore, potential applications of this data can be used in renewable energy projects, where areas with strong and stable winds such as Rutba, Karbala and Najaf can be selected for the construction of wind power plants. Even in air quality and pollution management, where knowledge of wind directions helps determine how air pollutants are transported, allowing for smarter industrial planning in large cities [25].

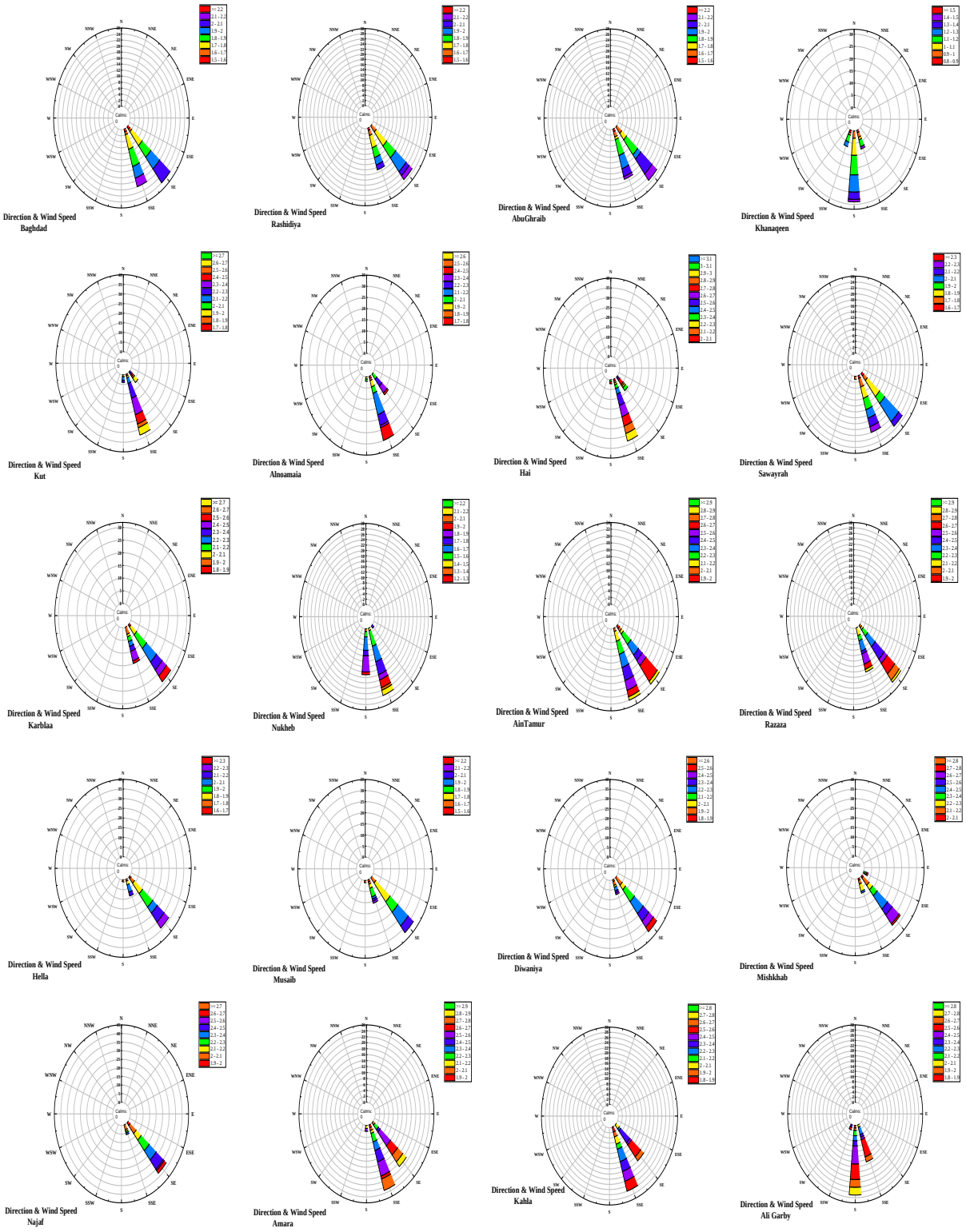
2.2 Nano-spatiotemporal distribution

Nano-spatiotemporal distribution" refers to the study of how nanoparticles (NPs), which are extremely small (nanoscale) materials, are distributed in space (spatially) and over time (temporally). This concept is crucial in various fields like drug delivery, materials science, and environmental science, as it helps understand how NPs behave and interact within a given environment [26-27].

3. RESULTS AND DISCUSSION

Figure 1 shows a set of wind roses representing wind direction and speed in several different regions over Iraq. The general analysis of these figures indicates that the wind direction is mostly from the southeast (SE) and south (S) direction in many regions. Some regions may show different wind directions due to topographical influences or local factors. As for wind speed, speeds vary from region to region, but generally range between 1.6 - 3 m/s according to the color key. Blue colors represent faster winds (>3 m/s), while red and orange colors represent slower winds. Some regions have more regular winds, while in others they may be somewhat variable. The spatial distribution of winds in some regions, winds are more consistent and appear in a specific direction, which may be useful in planning renewable energy projects (such as wind power). In other regions, winds may be scattered or distributed in more than one direction, indicating variation in climatic and geographical influences. Climatic and geographic influences these patterns are likely due to influences such as the presence of mountainous terrain, rivers, or deserts that affect wind flow. Cities near bodies of water may have a different wind pattern than cities inland. When comparing the stations in the figure, we notice that there is a common pattern in most areas, where the winds come mainly from the southeast (SE) and south (S) directions. However, there are some areas that may experience different directions or a varied distribution of winds, such as Baghdad or Rutba. In Baghdad, the winds come mainly from the southeast, with some influence from the east. As for Rutba, the winds blow mostly from the southwest, which is a slightly different pattern than the rest of the areas. Hillah, Nasiriyah and Samawah all show a similar pattern, where the winds come from the southeast with moderate to high speeds. In Karbala, the winds are mostly southerly to southeasterly, with medium speeds. Kut, Samawah and Amarah show wind directions coming from the southeast with more stable speeds compared to the other areas. Based on the colors in the charts, it can

be seen that most of the winds fall within the 2 - 3 m/s range, which means that the winds are not strong but regular and exploitable. Some areas, such as Rutba, Najaf, Samawah and Kut have more regular wind speeds, showing higher wind speeds of over 3 m/s (dark blue shaded areas), making them ideal areas for wind farms. In contrast, some areas, such as Kut and Nasiriyah, have lower wind speeds, which may mean they are less suitable for large wind projects but are still beneficial for natural ventilation and air pollution reduction. The same applies to the city of Basra, where we notice the fastest winds due to the presence of the blue color, which is the most frequent color even in the stations entering it.



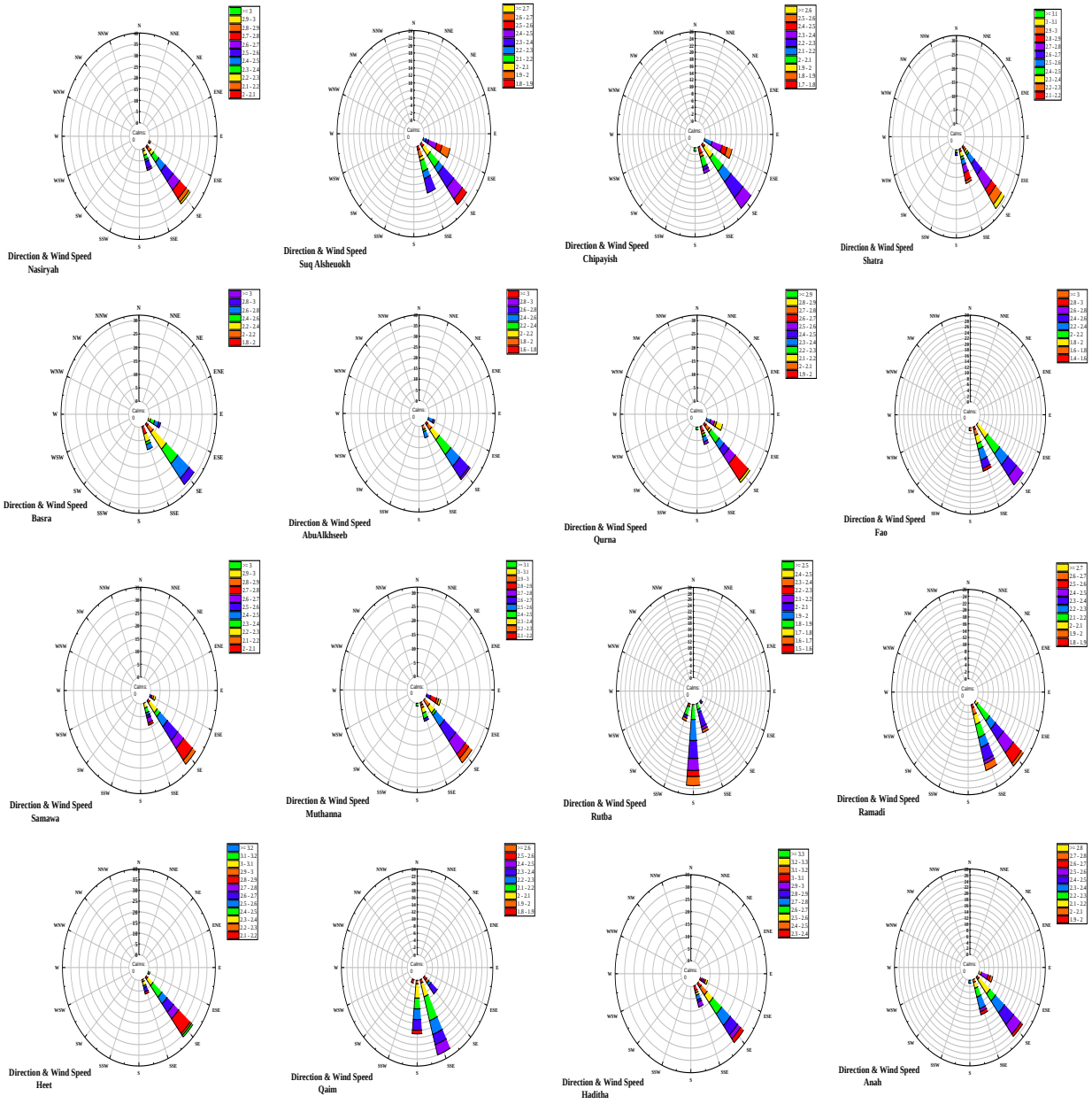
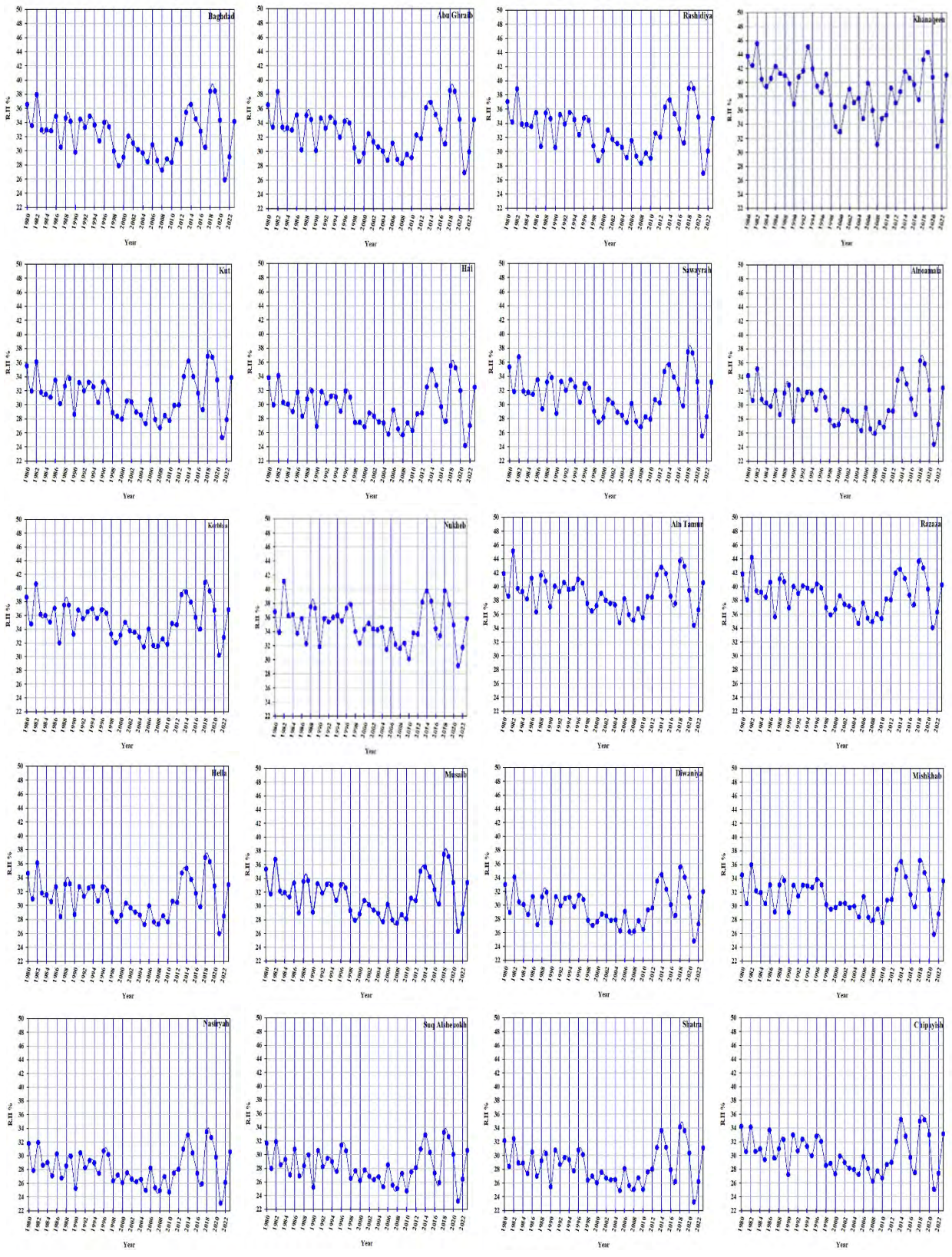


Figure 1 Average yearly wind speed for each station.

Figure 2 represent the annual averages of relative humidity for a number of stations in Iraq, which can be analyzed according to the climatic and geographical factors that affect humidity in the country. There are some important points in the analysis, such as the general trend of relative humidity, where it can be observed whether there are long-term trends, sometimes upward and sometimes downward. When relative humidity decreases over decades, this may be linked to rising temperatures or climate changes such as drought and scarcity of vegetation that affect the country as a whole. Conversely, when relative humidity increases, it may reflect factors such as increased rainfall or changes in weather patterns such as annual and seasonal fluctuations. Years with high humidity may reflect periods of heavy rain, while periods with low humidity may indicate dry seasons. Relative humidity varies depending on the geographical location of the station. For example, northern regions (such as Mosul, Sulaymaniyah, and Dohuk) may be more humid due to mountainous influence, cold, and snowfall. Central regions (Baghdad, Karbala, and Najaf) may exhibit moderate humidity, sometimes influenced by a desert climate. In contrast, the southern regions (Basra, Amarah, the Samawah desert, and Nasiriyah) may have higher humidity due to their proximity to the Gulf and the presence of water bodies. Therefore, if there

are long-term declining trends, it could be an indication of increasing drought and desertification in Iraq, consistent with global reports of water scarcity in the region. However, if there are cyclical fluctuations, this could be a natural consequence of normal seasonal changes.



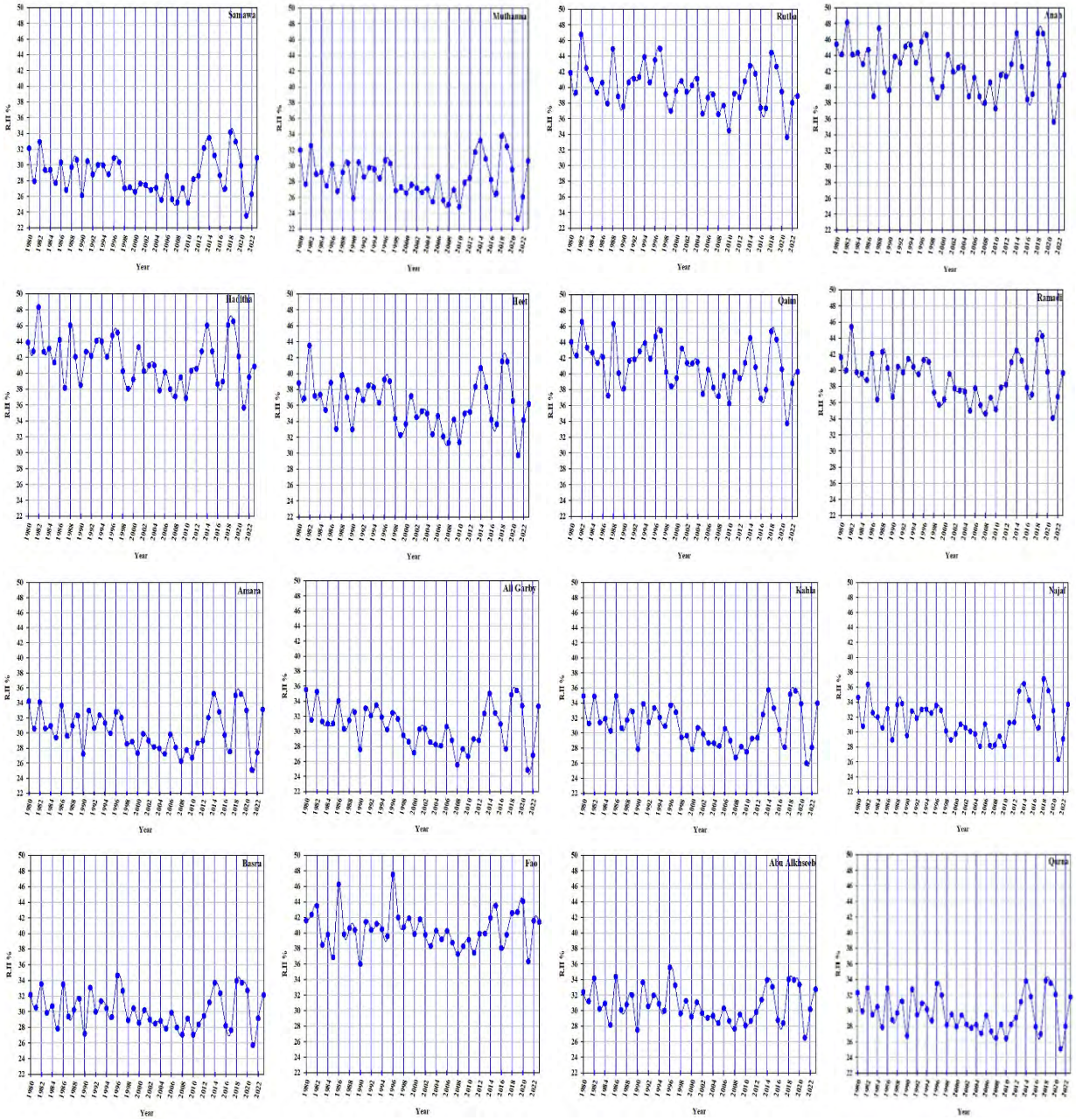


Figure 2 Average yearly R.H. for each station.

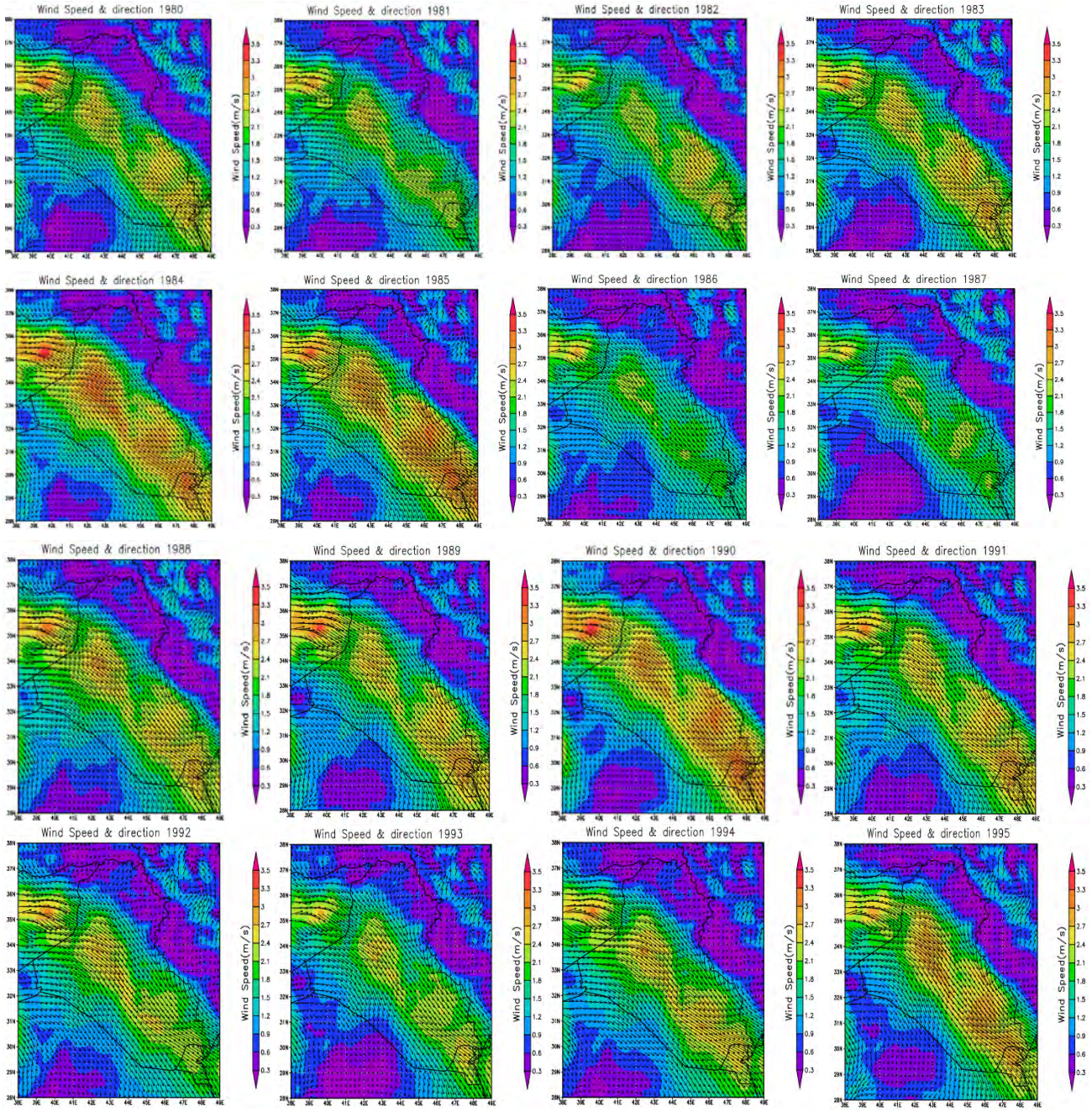
Figure 3 shows annual temperature data for a group of selected stations in Iraq, covering the period from 1980 to 2022. The general trend is upward across all stations, indicating that Iraq is experiencing a persistent warming phenomenon. This rise in temperatures indicates the significant impact of global climate change, especially in recent decades. Several important patterns can be observed when analyzing these graphs. Most stations show an upward trend in temperature over time, reflecting the impact of global warming and climate change on the country. Extreme values or outliers in some years may reflect unusual climatic events such as heat waves or seasonal climate changes, as in 2010. Some southern stations (such as Basra, Nasiriyah, and Samawah) exhibit higher-than-average temperatures compared to the rest of the region. It must be noted that there has been a slight, consistent increase over the years, which may indicate a greater impact of climate change in the southern regions. Central stations (Baghdad, Diyala, Kut, Karbala, and Najaf) may generally appear to have lower temperatures compared to the south, but they also show a clear upward trend. Some stations exhibit sharper fluctuations in the early years of the time series. There is also relative stability from 2000 to 2009, respectively. For

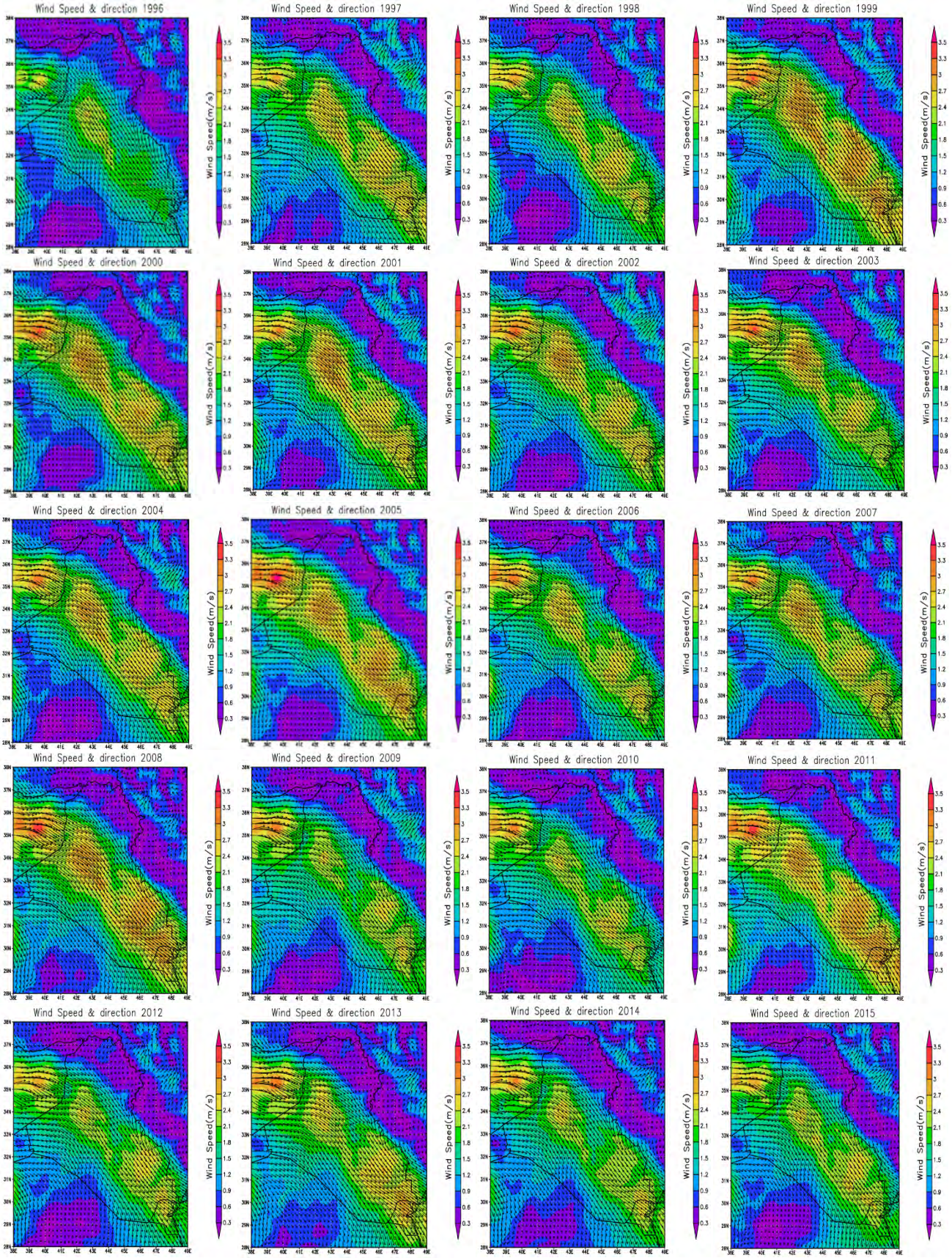
example, if both central and southern stations are compared, Baghdad shows a clear upward trend, with slight fluctuations, reflecting a combination of urban influence and climate change. Despite the differences in geographic locations between stations, the highest temperatures are recorded at stations such as Samawah, Nasiriyah, and Basra. Some stations, such as Nasiriyah, have consistently recorded annual temperatures exceeding 29-30°C, which requires special attention due to its impact on agriculture and water resources. This assessment examines the record changes in global surface temperature since 1980, using six different gridded data sets, including monthly mean air temperature and weather station data from the Global Historical Climate Network and the National Oceanic and Atmospheric Administration's Global Daily Summary. The decade 2010–2020 is the warmest in modern record-keeping for more than two-thirds of the global surface area—Europe, the United States, South Africa, northern Siberia, and most of Australia. New maximum temperature records are also set across much of Europe, East Asia, and eastern North America. 2020 is the warmest year on record, while 2010 is the hottest year for parts of North America (about 34% of the area). Nearly 60% of the global surface area recorded new average annual maximum temperatures after 2010.

Figure 3 Average yearly temperature for each station.

In the Figure 4 climate change plays a significant role in influencing the atmosphere in general, which is a set of factors that change throughout the year, one day, and during the known seasons. The primary energy source for this universe is the sun, which is responsible for supplying energy to the Earth's surface, through which these changes occur, taking into account the increase and decrease in energy. In directive to understand these changes, it is necessary to study some climatic variables. For example, the wind speed and direction shown in the figure above. The general and prevailing direction is northwesterly over Iraq and may also be northerly. As for wind speed, find a variation in intensity according to the given color gradient. The difference in wind intensity depends primarily on the nature of the terrain of the study area. We note that the intensity is concentrated as in the northern region, which is mountainous by nature. The annual average in central and southern Iraq, considering it a plain area

free of friction factors, as well of this data ranges between (3.5 - 0.3 m\s). The intensity of this gradient depends on the nature of the climate for that period. The study period is between 1980 and 2023. There is a clear intensity in 1984-1985, in contrast to the years before and after, which are less intense. Then, the intensity increased again in 1990-1999. We also notice a clear difference in the central and southern regions for the years 2008-2011. The study positions are selected based on areas where the wind intensity is more pronounced than others.

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Wind Speed(m/s)

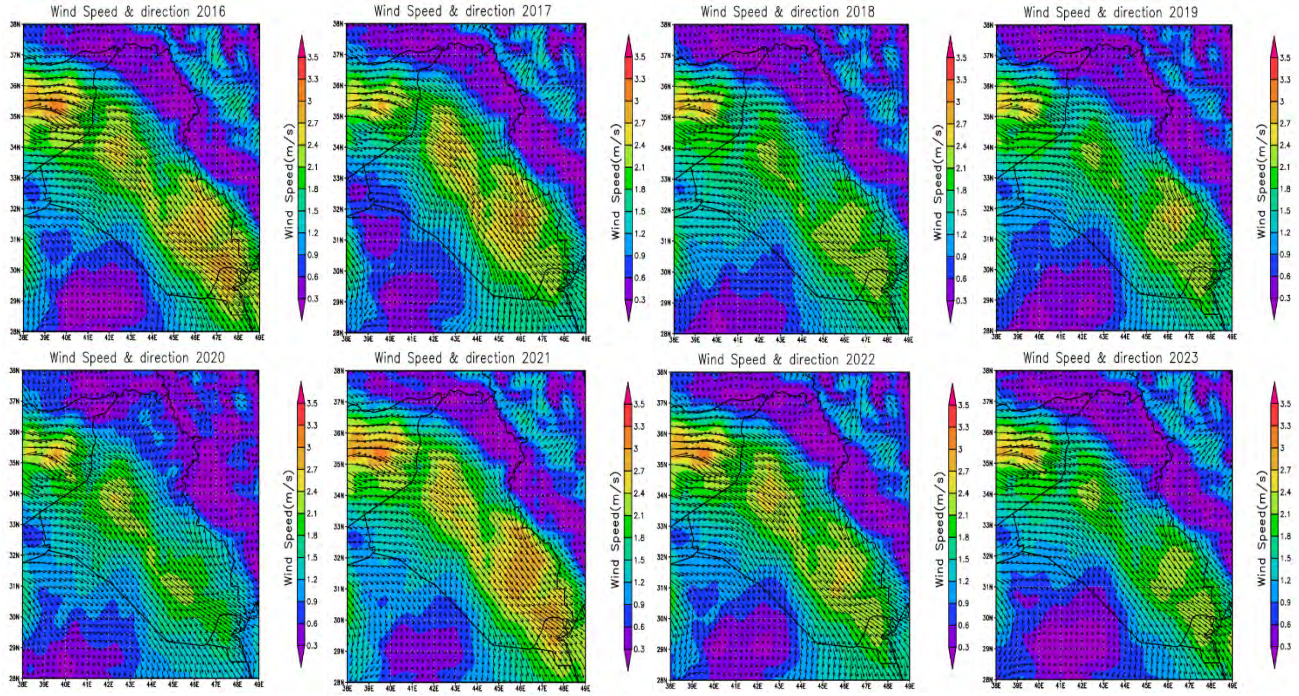
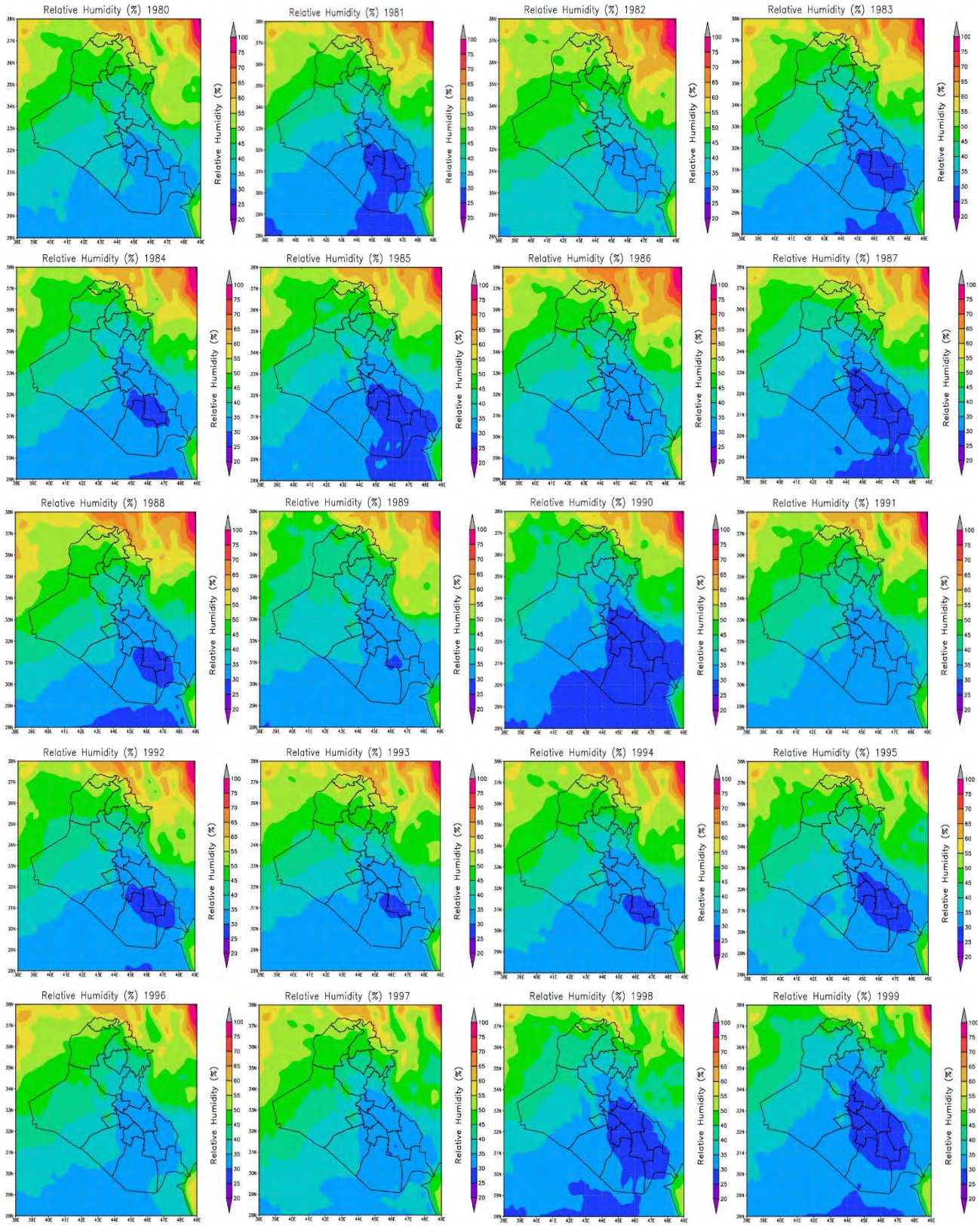


Figure 4 Wind speed overall Iraq of each year from 1980 to 2023.

Figure 5 illustrates the general trend of changes in relative humidity. By comparing the maps to annual averages, we noticed that the blue areas (high humidity) decrease over the years, indicating a decrease in humidity. Increased humidity may indicate more humidity. Observe fluctuations in humidity levels. If there are years that witness a sudden increase in humidity followed by a decrease, the cause may be temporary climate fluctuations, such as El Niño years or heavy rainy seasons. The geographic distribution of humidity also varies. Notice that some areas are more affected than others, such as the south or north, which have experienced greater changes in humidity. This may be related to changes in water resources, or human influences such as desertification or urban expansion. Areas close to bodies of water are also affected. Maps can be compared to determine whether there has been a change in humidity near rivers or lakes due to changes in water flow or drought. The relationship between these changes and rising temperatures is also evident in global climate change. The continuous decreases in humidity over the years may be related to rising temperatures and increased evaporation. Regions are classified based on their relative humidity into:

1. Humid regions: Areas close to bodies of water, such as rivers, lakes, and swamps, where continuous evaporation is a source of moisture in the atmosphere. Areas with dense vegetation, such as forests and farms, also contribute to increased humidity through transpiration. High mountainous regions may also be more humid due to cloud condensation and rainfall.
2. Dry regions: Desert and semi-desert regions. These areas suffer from low rainfall and high temperatures that increase evaporation. Areas far from water sources, such as inland regions, are not reached by moisture coming from seas and oceans. Winds coming from deserts reduce humidity and increase dryness in areas affected by dry winds. Some regions may become drier due to changes in monsoon winds or lack of rainfall, which affects humidity.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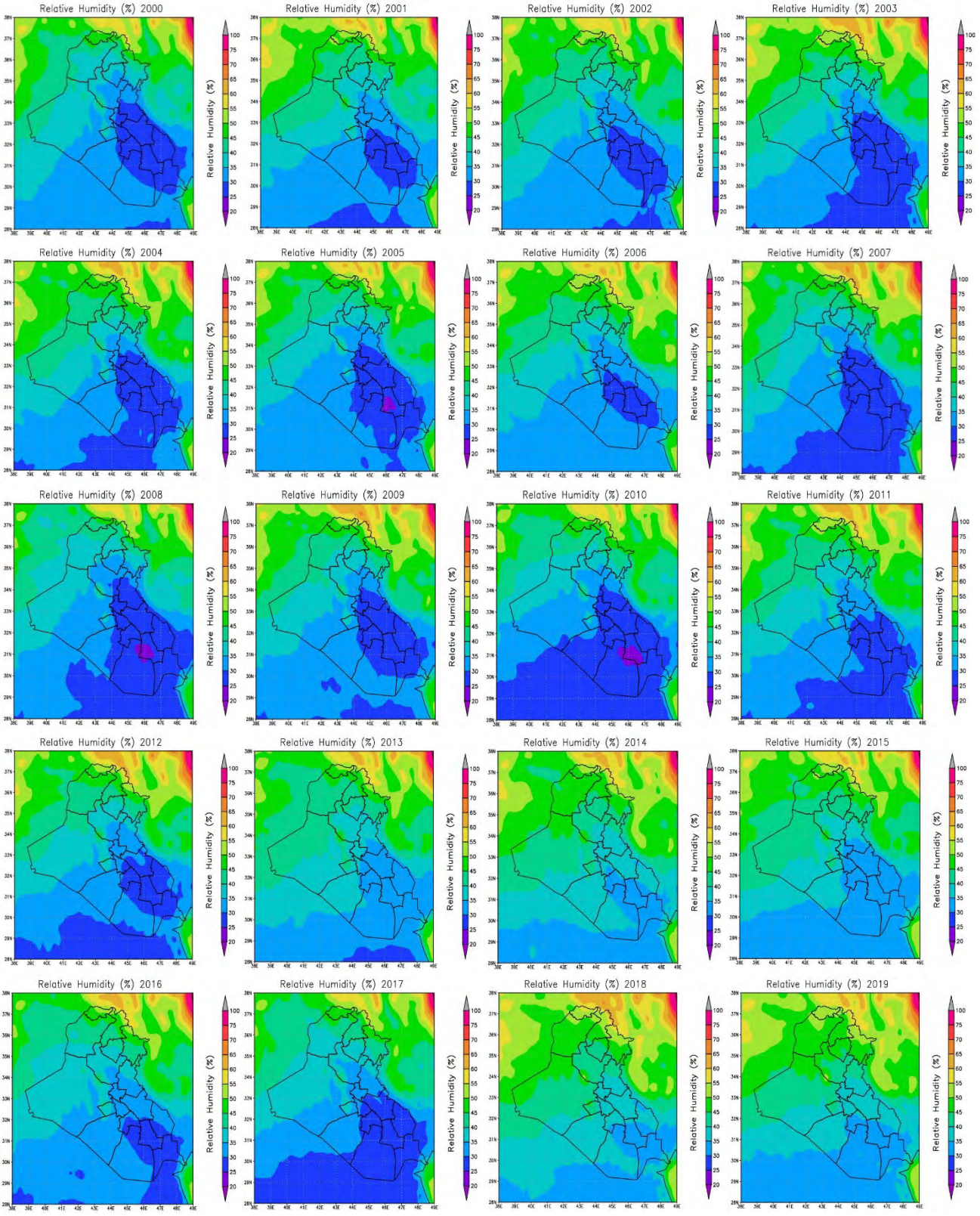
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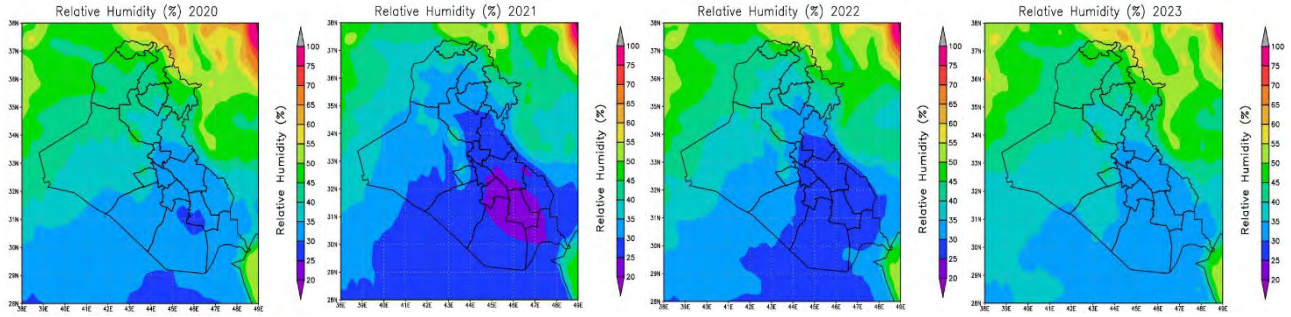
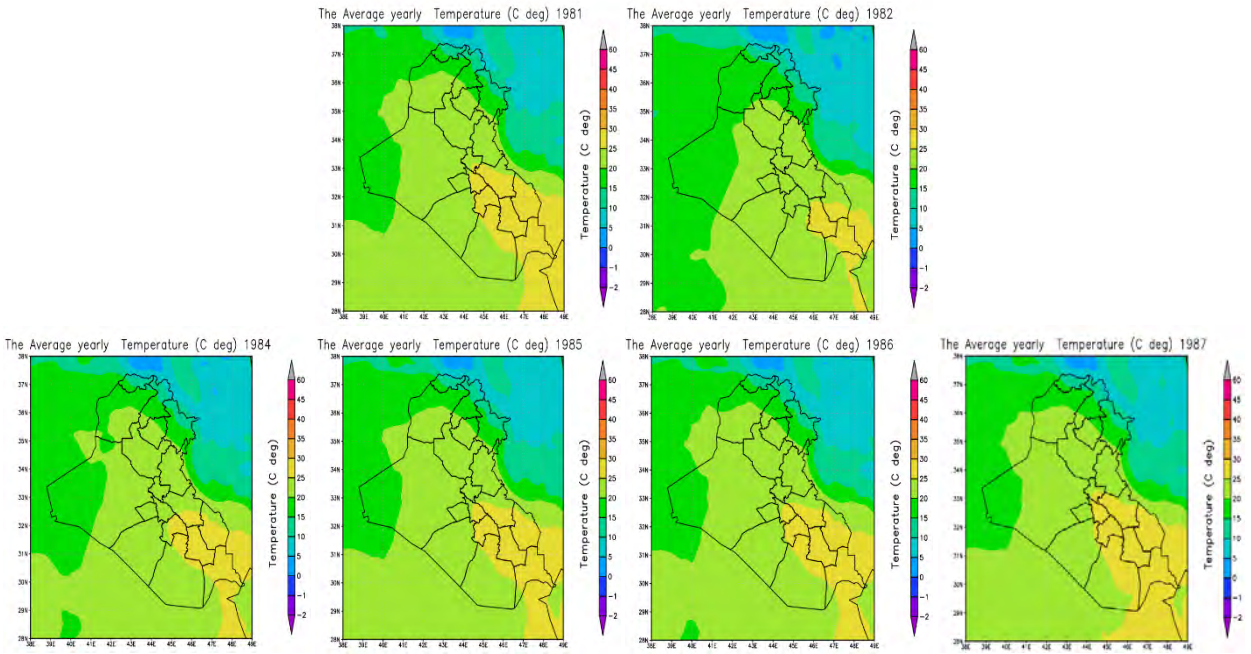
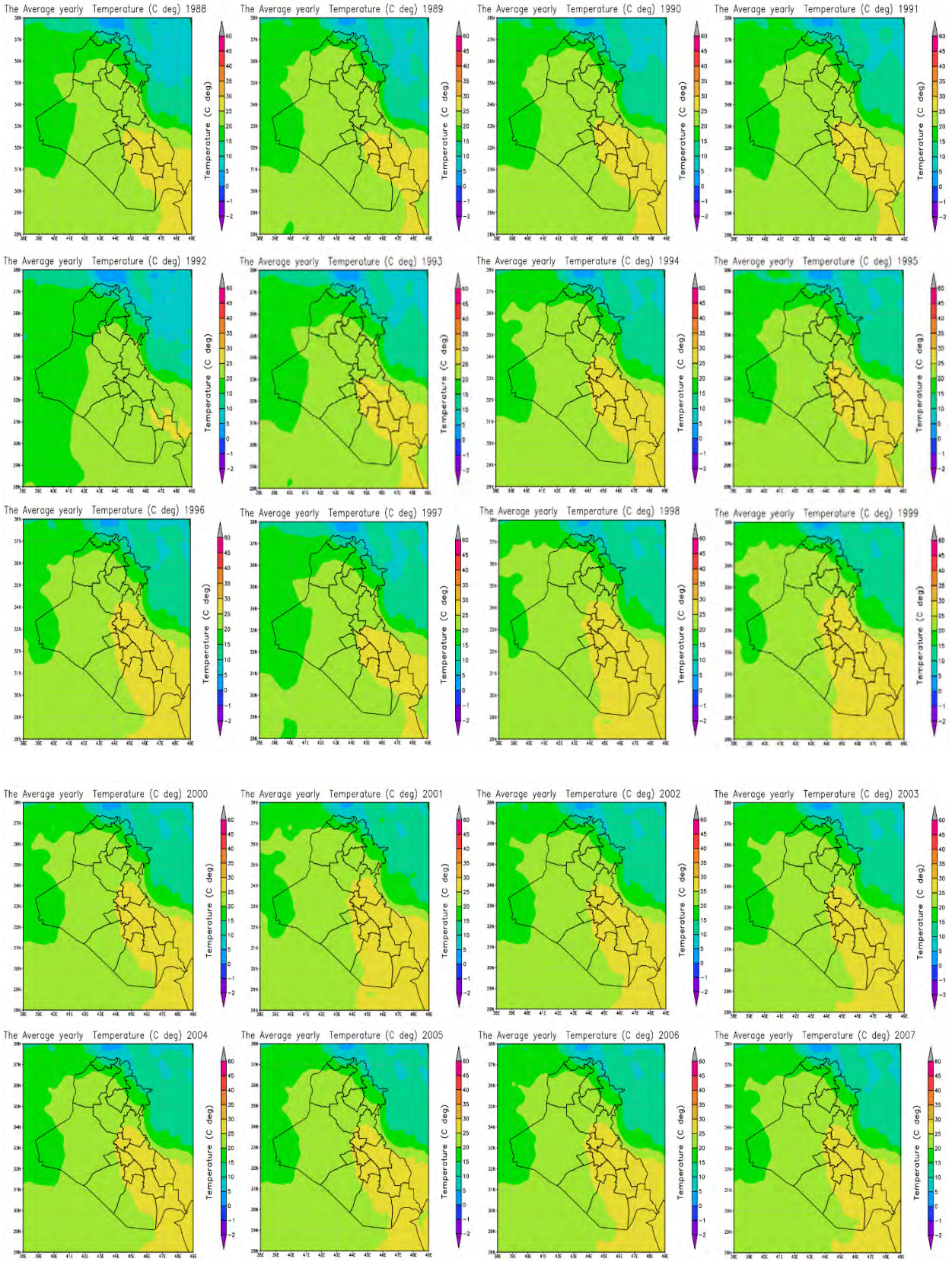


Figure 5 Relative Humidity overall Iraq of each year from 1980 to 2023.

Figures 6 show maps illustrating the average annual temperatures in Iraq over various years from 1980 to 2023. A number of important climate trends can be observed by comparing these maps. It is clear that there has been a gradual increase in temperatures over the three decades. In the 1980s, the study period, we note that temperatures are regularly distributed, taking into account the geographical distribution of the region, ranging from 5°C to 30+°C. As we see in the 1990s (1992–1999), the northern and central regions are relatively cold (green and blue). Starting from the first decade of the millennium (2000–2010), the heat began to be more distributed in the center and south (yellow began to invade the center). In recent years (2020–2023), most of the country, especially the central and southern regions, have become dark yellow and orange, indicating a significant rise in annual temperatures. The most affected regions, the south and center, such as Basra, Muthanna, Najaf, and Karbala, appear in very warm colors (yellow to orange). As for the north (Dohuk, Erbil, and Sulaymaniyah), they still maintain their relative coolness. It is noticed there a decline in the cold areas. The blue gradually disappears, indicating a significant rise in temperatures.

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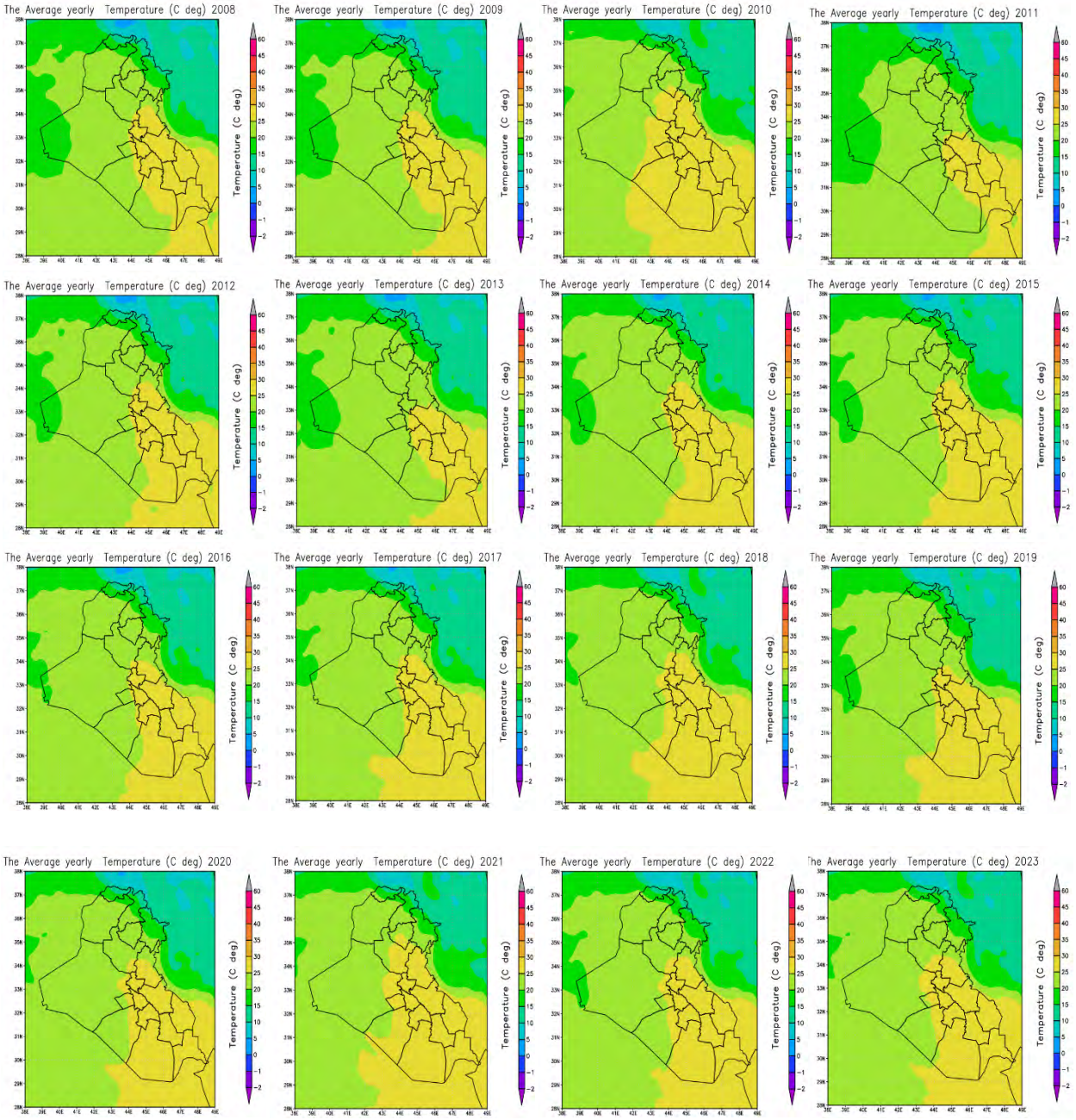

Figure 6 Temperature overall Iraq of each year from 1980 to 2023.

Figure 7 shows the trend of temperature averages for the specific study area and selected stations, where the study area is covered by taking the north, south, east and west of the study area. It is found that the temperature is constantly increasing, as it reached an annual average in Baghdad in 1980 (24 °C) until the end of the period in 2023, which reached (26 °C). As for the city of Basra, the average increased by about (2 °C) as it is one of the southern governorates that are hotter. As for the east of the region, we notice a significant decrease of (1 °C) because the Khanaqin district of Diyala Governorate is close to the Iranian mountain range and also because they are agricultural areas. As for the western regions, a sharp decrease appeared by about (4 °C) because they are open areas with a lower population density. also noticed some anomalies in some averages in the years 1992 and 2010, respectively.

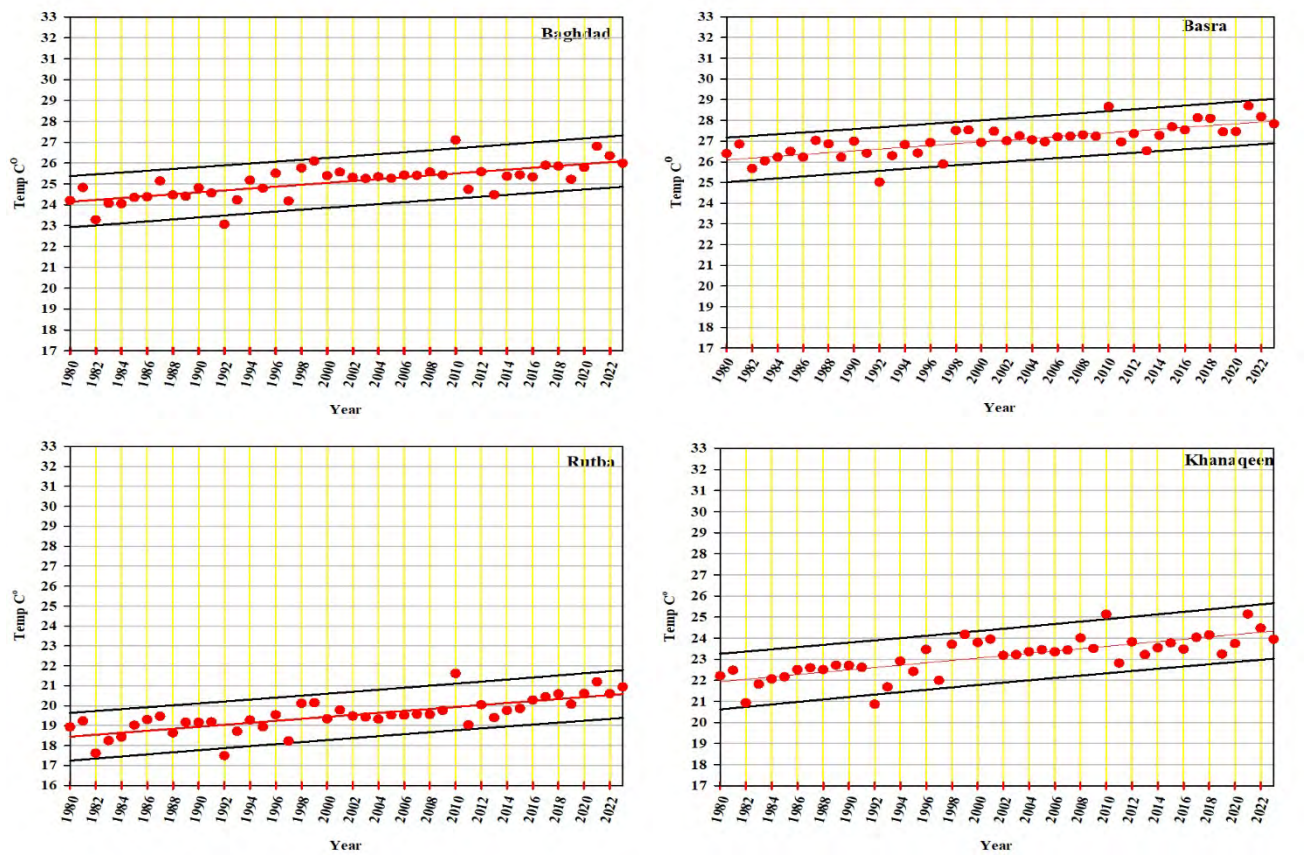

Figure 7 The yearly average temperature trend for the period (1980-2023) in study stations.

4. CONCLUSIONS

These data indicate that wind patterns in Iraq were mostly regular with some local variations, making it a suitable environment for using wind for power generation and improving urban climates. Wind rose data can be used in urban planning to identify areas requiring windbreaks or wind-resistant architectural designs. These data are also useful in identifying ideal locations for wind power plants, where winds were strong and stable. The maps also show an overall decrease in humidity, possibly due to climate change and rising temperatures. Furthermore, some areas may become drier if temperatures continue to rise, increasing the risk of desertification. Relative humidity may be on a long-term downward trend, indicating increased drought and desertification in Iraq, consistent with global reports indicating declining water resources in the region. Temperature maps show a clear trend toward global warming in Iraq. This phenomenon was consistent with the global trend of global warming. Nearly all measuring stations in Iraq recorded significant increases in annual temperatures. The highest observed increases were concentrated in the south, followed by the central regions. However, areas that were historically more moderate (such as the North) are starting to see significant increases We look forward to working on a wind turbine that operates within these local meteorological parameters and indicators.

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