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The Telecommunications between Iraq Region Air Temperature and ENSO El NIÑO 3.4 Region

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ABSTRACT: ***Background:*** *El NIÑO phenomenon is a global climate phenomenon that occurs as a result of the interaction between the surface of the Pacific Ocean and the atmosphere directly above it.* ***Objective:*** *This study investigates whether El NIÑO 3.4 affects some of the climatic parameters in some Iraqi cities.* ***Methods:*** *A record surface data (2007-2017) of relative humidity, maximum and minimum air temperature was used from the Iraqi meteorological and seismology organization for seven selected meteorological stations, sea surface temperature anomalies from the royal Netherlands meteorological institute, and the reanalysis data of air temperature (1980-2022) from the national centers for environmental prediction and national center for atmospheric research. The climatic parameters data for seasonal and mean monthly are analyzed to understand the general trend, and the statistical relationships are investigated.* ***Results:*** *The result shows a decrease in relative humidity for Kirkuk and Nasiriya stations. Also, there is an increase in the general trend of the maximum and minimum temperatures for Kirkuk, Nasiriya, Basra, Baghdad, Al-Hay, and Mosul stations. The influence of the NIÑO 3.4 index on Iraq's climate, temperature, and relative humidity was minimal. The impact of the NIÑO 3.4 index on the maximum and minimum temperatures within the daily and monthly values, in general, was a weak positive correlation. The correlation between the NIÑO 3.4 index and the maximum and minimum temperatures during the spring and winter seasons is positive, while it is a negative correlation in the summer and autumn seasons.* ***Conclusions:*** *The main conclusion illustrated that the effect of the NIÑO 3.4 has a limited impact on the surface values of relative humidity and maximum and minimum air temperatures because there is a lag time in the response when the change of sea surface temperature anomalies starts to happen; it takes a month or more time until its impacts reach Iraq.*

KEYWORDS: *ENSO; Minimum temperature; Maximum temperature; Relative humidity; Sea surface temperature anomalies*

INTRODUCTION

El NIÑO is a significant index that influences climate change and describes anomalous sea surface temperature (SST) increases across the central Pacific Basins Sea level beside air pressure in equatorial western and eastern Pacific [1]. It has been observed that the rising recurrence of El NIÑO occasions is due to greenhouse warming [2], which controls precipitation and air temperature [3], [4]. It likewise alludes to the El NIÑO-Southern Oscillation (ENSO) in several types of research on the ocean and atmosphere [5]. El NIÑO explicitly refers to the ENSO warm period in this context. The existence of ENSO is due to the presence of equatorial trade winds in the Tropical Pacific Ocean (TPC) under the action of the Coriolis force, The force resulting from the Earth's rotation causes the winds to deviate to the right in the Northern Hemisphere and vice versa, [6]. El NIÑO happens in a small area in (TPC); the influence of El NIÑO may spread to numerous remote land and ocean parts due to large changes in oceanic and atmospheric circulation in and out of (TPC). Thus, El NIÑO could generate environmental disturbances such as floods, cyclones, and draughts, for example in spring, ENSO impacts the dry conditions in the north-west zone of Mexico, it decreases the dry conditions, during the positive phase and vice versa [7]. The upwelling decreased causing an 8% lowering, in the plenty of microplankton in the summer of 2015. Likewise, the convective mixing weakened causing a lowering of 6% in microplankton abundance through the winter of 2016 [8].

El NIÑO may lead to changes in the extreme reduction in surface precipitation. For example, long-term El NIÑO sea temperature anomalies decrease precipitation in the Amazon Basin [9]. Overall, the Ocean Surface Temperature (SST) changeability in the tropical Pacific related to ENSO can be effectively anticipated a few seasons ahead, as measured by the measurements of a few given measurements (e.g., oddity connection of the NIÑO 3.4 record) [10]. Reports of extreme weather that appeared to align with expectations during a strong El NIÑO dominated the news. In the austral spring, huge forest fires in Indonesia caused a haze crisis in neighboring nations. Beginning in 2016, devastating flooding devastated Peru, while numerous Pacific Ocean regions experienced severe coral bleaching [11]. There are different impacts of El NIÑO on the world, [12] found that after the mid-1980s, precipitation in northeastern Asia, and northeastern China has been affected by the shift in the location of the summertime Arctic Oscillation (AO) lower layer activity in the Atlantic Ocean. [13] mentioned that during the ENSO phases, there is a negative and positive variation between (± 100 to ± 150 mm) in the anomalies of precipitation while it changes to ± 50 mm during the neutral phase. [14] investigated the correlation between El NIÑO 3.4, sea surface temperatures, and wind speed in Bandung City, Indonesia, where the results showed a negative correlation. In addition to that, the results also indicated that the coldest year was 1999, while the hottest year was 2015, accompanied by a decrease in the amount of rainfall due to the strong El NIÑO phenomenon during 2015. [15] explained that the air temperature in the East Asian zone is affected irregularly, especially between decades, by the winter Arctic Oscillation. [16] mention that severe heat waves and drought occurred during the negative phase of El NIÑO, and the positive phase of the Indian Ocean Dipole. The strongest impact of EL NIÑO on heat stress was in the winter and spring seasons [17], even El NIÑO 2023-2024 is not an intensive event [18]. Recently, Iraq experienced extreme weather episodes like flash floods, drought, and heat waves, which are more regular.

This paper aims to investigate the seasonal cycle and the inter-annual, decadal, and long-term fluctuations in the temporal distribution of weather data, then study the impact of ENSO (NIÑO 3.4) fluctuation on climatic parameters (relative humidity, maximum and minimum temperature) for some Iraqi meteorological stations during 2007-2017. Therefore, El NIÑO 3.4 datasets (2007-2017) were utilized. The technique of correlation coefficient was used to test the strong relationship of climatic parameters with El NIÑO 3.4 to investigate whether there is an effect of the El NIÑO Southern Oscillation (ENSO) on the Iraq climate (climatic parameters) because the ENSO peculiarity influences the climate and environment of different places in the world.

MATERIALS AND METHODS

Data Acquisition

Daily surface recorded dataset, relative humidity, minimum and maximum air temperatures, from January 2007- December 2017 recorded by the Iraqi Meteorological and Seismology Organization were used for seven selected meteorological stations, Table 1. Additionally, El NIÑO 3.4 data represents monthly data of Sea surface temperature anomalies (SST) for the region (5N-5S, 170W-120W) from the Royal Netherlands Meteorological Institute. Reanalysis dataset of air temperature from January 1980 to December 2022 from the National Centers for Environmental Prediction (NCEP) and the National Center for Atmospheric Research NCAR, then the maps done by NOAA Physical Sciences Laboratory.

Table 1. The meteorological stations used in the study

Stations	Elevation (m)	Longitude (°)	Latitude (°)
Mosul	223	43.12	36.34
Kirkuk	331	44.39	35.47
Baghdad	31.7	44	33.34
Rutba	630.8	41.75	33
Al-Hayy	19	45	32
Nasiriya	9	31.05	46.26
Basra	2.4	47.82	30.50

The Pearson Correlation Coefficient

The Pearson correlation coefficient is a statistical test that measures the statistical relationship, or correlation, between two continuous variables. It is defined as the best way to measure the correlation between the sudsy variables because it is based on the method of covariance and gives information about the magnitude of the association, as well as about the direction of the correlation, positive or negative, Its value ranges from -1 to +1. A value of +1 is the result of the perfect positive relationship between two or more variables. Positive correlations indicate that both variables are moving in the same direction. Conversely, a value of -1 represents a perfect negative relationship. Negative correlations indicate that as one variable increases, the other decreases. Zero value indicates no correlation. First, we calculate the Pearson correlation between the elements of the climate and the NIÑO 3.4 time series.

Study Area

Iraq is located in western Asia from 29.5°N to 37.22°N and from 38.45° E to 48.45 ° E, Figure 1, and is somewhat close to the Red Sea and the eastern Mediterranean [19]–[21]. Iraq's external borders are Turkey to the north, Saudi Arabia to the south, Kuwait to the southeast, Jordan to the southwest, Iran to the east, and Syria to the west [22], [23]. Iraq's average temperatures are 48° C in summer while zero (0°) in winter. Most precipitation falls from October to May, with an average annual precipitation of 100-180 mm in southern and central Iraq, respectively, while the mountainous region in northern Iraq has more precipitation that may reach 1000 mm [24].

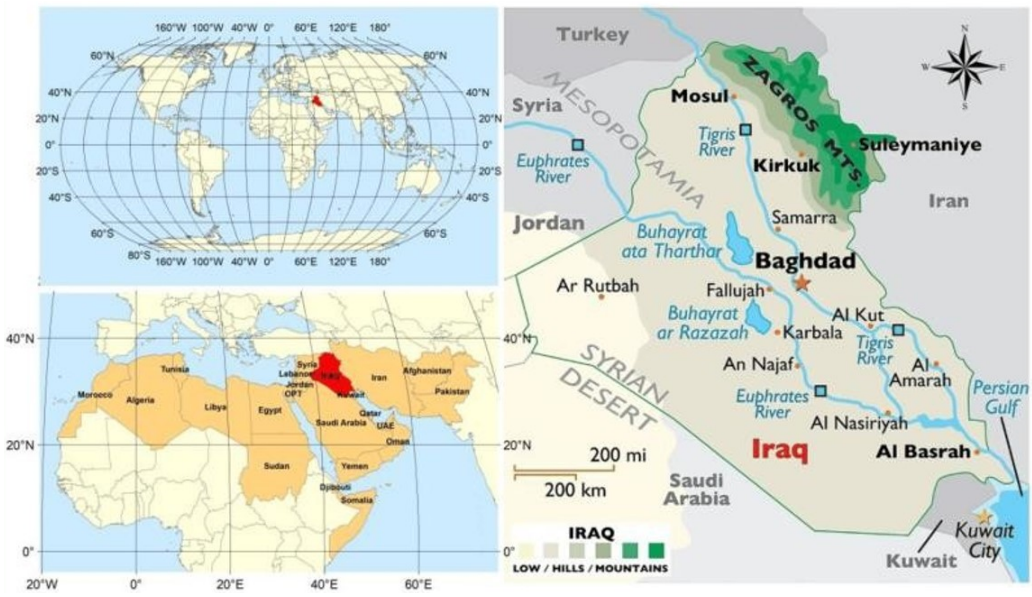

Figure 1. Map of Iraq [25]

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RESULTS AND DISCUSSION

Monthly Average of Relative Humidity Data for the Study Stations

The Mean monthly relative humidity data for Mosul, Rutba, Basra, and Al Hayy show an increase in the trend values, while the trend decreases in the rest of the Kirkuk, Baghdad, and Nasiriya stations, Figure 2.

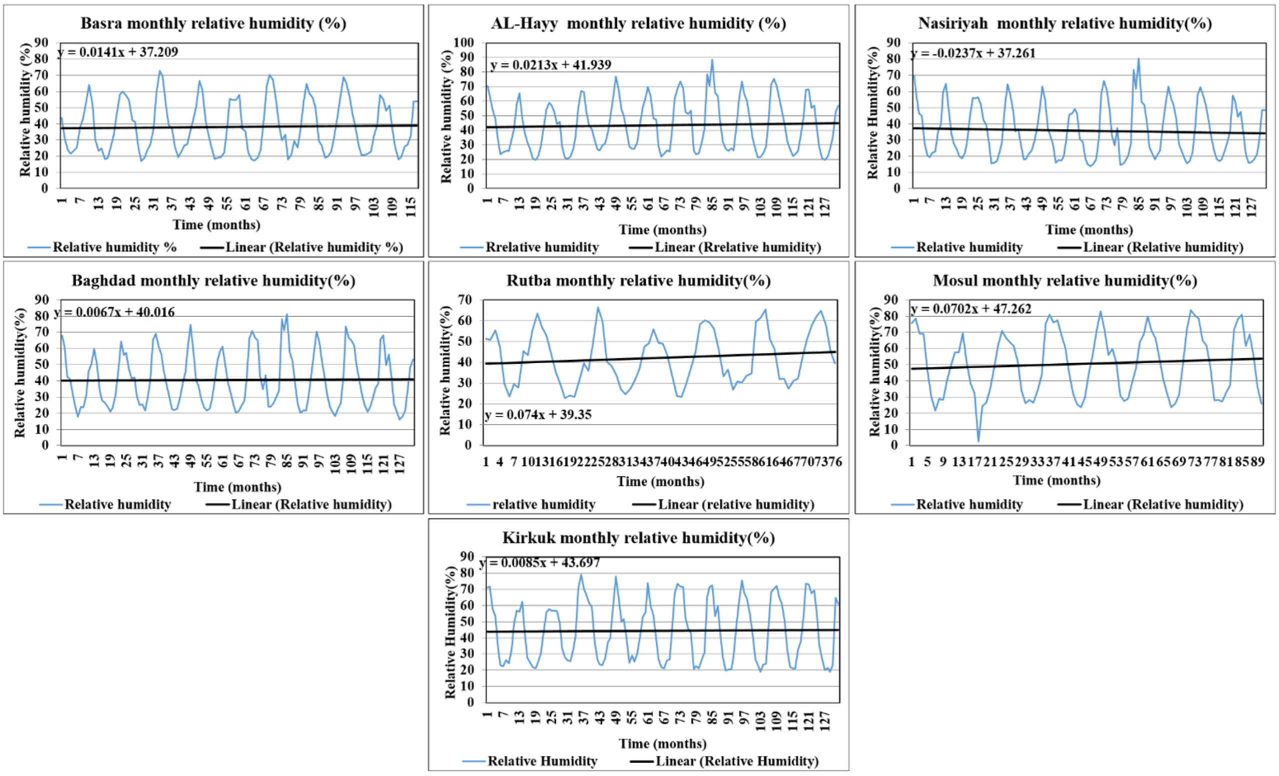


Figure 2. Mean monthly relative humidity (%) data for the study stations

After analyzing the data of relative humidity, as in Figure 2, the highest relative humidity values occurred during December and January, where the highest values were recorded in Basra, Mosul and Kirkuk during December, 72.7% in 2009, 83.7% in 2012 and 79% in 2009 respectively, while the Al-Hay, Al-Nasiriyah, Baghdad and Al-Rutba stations recorded the highest relative humidity values during January 88.7% in 2014, 80.5% in 2014, 81.3% in 2014, 66.4% in 2011 respectively. By comparing these values, it can be noted that Al-Hay station recorded the highest relative humidity 88.7%. This value reflects the climatic conditions and the effect of Al-Hay station's geographical location (distance from water bodies).

As for the lowest values of relative humidity, we noted that they occurred between June and July, and the lowest recorded value for the study stations was at Mosul station, 2.6%, in June 2008.

We also note that Mosul station recorded a large difference between the highest and lowest relative humidity values (83.7% to 2.6%), which may reflect a greater variation in climatic conditions.

This analysis shows how local factors such as geographic location, local climate, and distance from bodies of water can affect relative humidity levels.

Mean Monthly Maximum Temperatures for Study Stations

Figure 3 presents the data set of the monthly maximum air temperatures, where it seems there is an increase in the trend of Baghdad, Kirkuk, Al-Hayy, Nasiriya, and Basra stations, while for the Rutba station, there is a decrease in the monthly maximum air temperatures. Finally, for the Mosul station, the trend is still stable.

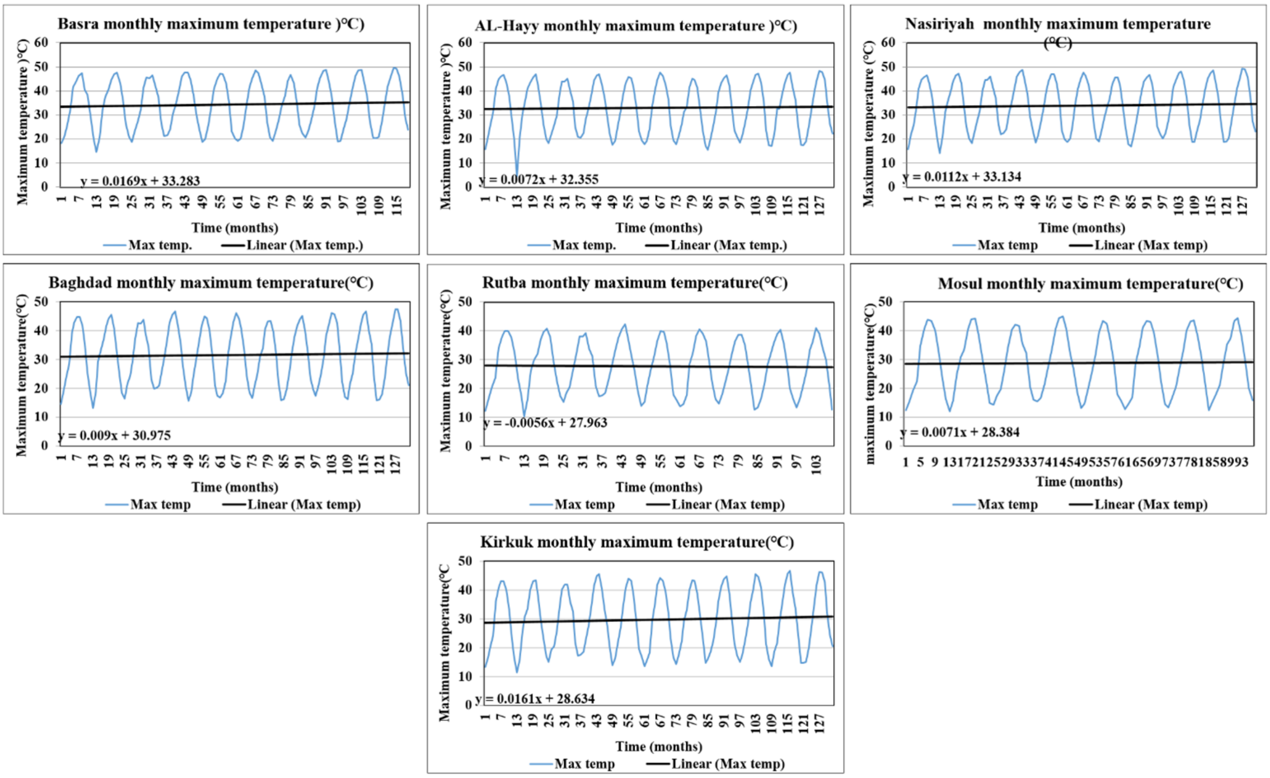


Figure 3. Mean monthly maximum temperatures (℃) for the study stations

Figure 3 also shows that the highest maximum temperature was concentrated in July and August, where Basra, Al-Hay, Nasiriyah and Baghdad stations recorded in July the highest temperatures during 2007-2017 (49.6 in 2017, 48.2 in 2017, 49.2 in 2017, and 47.5 in 2017) respectively, while Rutba, Mosul and Kirkuk stations recorded the highest values in August (42.4 in 2010, 45 in 2010 and 46.6 in 2016) respectively. Basra station (49.5 in July 2017) recorded the highest maximum temperature compared to other stations. These results show the variation in maximum temperatures between stations due to the difference in geographical location, terrain, and local climatic conditions. The data also indicates that Al-Hayy station has a significant thermal variation in maximum air temperatures, as it recorded a large difference between the highest and lowest values (48.2 ℃ to 4.3 ℃), meaning it may have diverse climatic conditions. It is noted from Figures 2 and 3, that the highest relative humidity values occurred in December and January, representing the months in which the temperature drops to the lowest value and vice versa. The reason for this is the inverse relationship between relative humidity and temperature.

Mean Monthly Minimum Temperatures for the Study Stations

The mean monthly minimum temperatures for the stations of Baghdad, Kirkuk, Nasiriya, Al-Hayy, and Basra show an increase in the trend of the monthly values, while the trend decreases in Rutba station, but the general trend of the minimum temperatures does not show a clear change for the Mosul station, Figure 4. Over ten years of analyzing the data, it was found that Mosul station recorded the lowest minimum air temperature value of -2.2 °C, compared to the other stations, due to its geographical location and the nature of its climatic conditions. while the other stations varying minimum temperatures, as Rutba station recorded -1.2 °C and Al-Hay station recorded 0 °C, while Baghdad recorded 1.2 °C, then Kirkuk recorded 2.2 °C, Nasiriyah 4, and finally Basra 4.7 °C. These differences are due to the influence of local factors such as terrain and land use on temperatures, which enhances the importance of collecting data from multiple stations to understand climate patterns better.

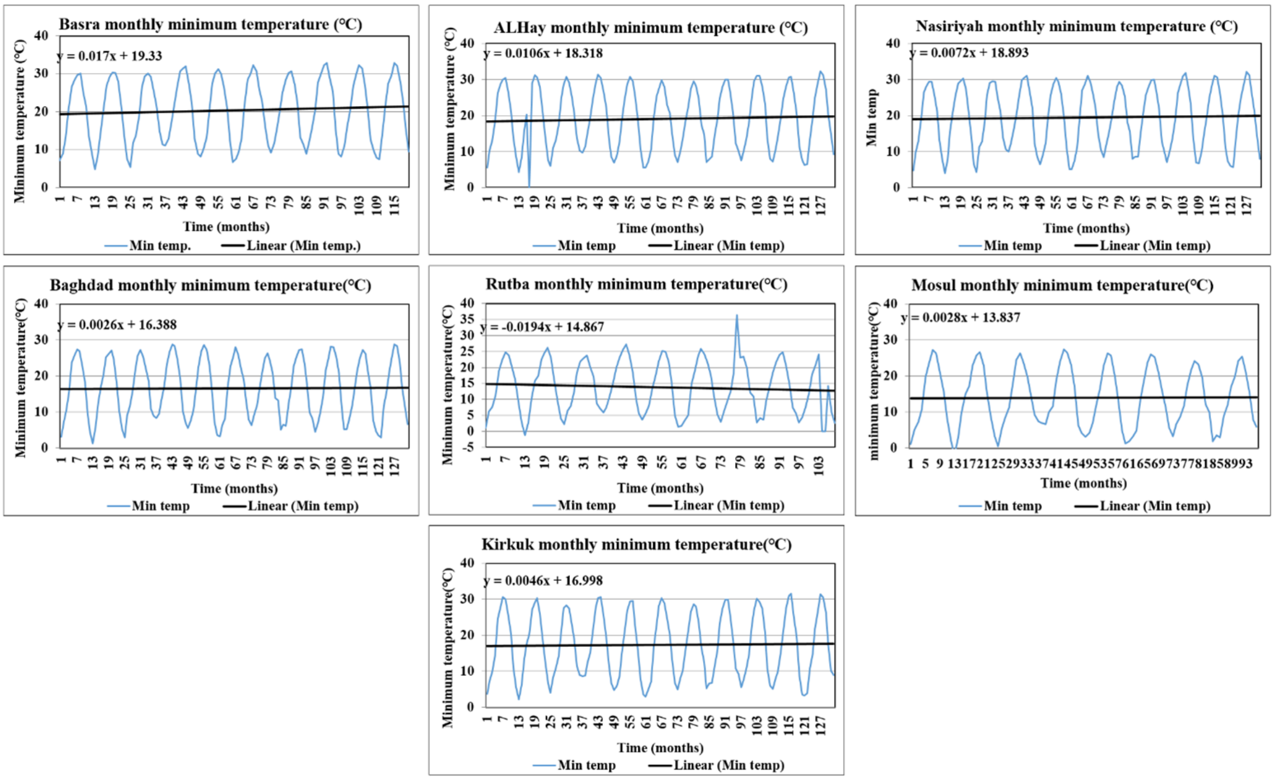


Figure 4. Mean monthly minimum temperatures (°C) for study stations

NIÑO 3.4 Impact on the Seasonal Data of Climatic Elements

1 Winter Values of Climatic Elements

The correlation coefficient values were calculated between daily data of climatic elements for the winter season and the NIÑO 3.4 index. Table 2 shows that the NIÑO 3.4 index was linked positively with the relative humidity, the minimum and maximum temperature data, and all climatic stations.

Table 2. Correlation coefficient (R) values between NIÑO 3.4 index and winter climatic elements' values (2007-2017)

Stations	Maximum temperature(°C)	Minimum temperature(°C)	Relative humidity(%)
Mosul	0.068892	0.347619	0.259196
Kirkuk	0.067505	0.208883	0.223841
Baghdad	0.121023	0.16924	0.142988
Rutba	0.061403	0.220354	0.372709
Al-Hayy	0.066524	0.184047	0.105246
Nasiriya	0.133594	0.15656	0.097558
Basra	0.161101	0.215999	0.207386

2 Spring Values of Climatic Elements

The results of the correlation coefficient values for the spring season show a positive correlation between the values of the NIÑO 3.4 index and the relative humidity for Mosul, Kirkuk, Baghdad, Rutba, and Basra stations; there was a negative correlation for Nasiriya and Al-Hayy stations. Table 3 presents a positive correlation between the NIÑO 3.4 index and all climatic stations' minimum and maximum temperature values.

Table 3. The NIÑO 3.4 index correlation coefficient (R) and the spring climatic element's values (2007-2017)

Stations	Maximum temperature(°C)	Minimum temperature(°C)	Relative humidity(%)
Mosul	0.133436	0.129212	0.044495
Kirkuk	0.079386	0.061555	0.090084
Baghdad	0.085398	0.070077	0.048117
Rutba	0.11503	0.141799	0.221975
Al-Hayy	0.109873	0.126683	-0.08432
Nasiriya	0.113434	0.102111	-0.0195
Basra	0.053606	0.094643	-0.102427

3 Summer Values of Climatic Elements

The results of calculating the correlation coefficient for the climatic elements data for the summer season with the NIÑO 3.4 index are presented in Table 4. There was a positive correlation between the relative humidity with the NIÑO 3.4 index and values for Mosul, Kirkuk, and Rutbah stations, while the correlation was negative in the Baghdad, Al-Hayy, Nasiriya, and Basra stations. The table also illustrated a negative correlation between the NIÑO 3.4 index with the minimum temperature and the maximum temperature for the summer season for all stations except the station of Basra, with a positive correlation for the minimum temperature.

Table 4. The correlation coefficient(R) values of the NIÑO 3.4 index with the summer climatic elements data (2007-2017)

Stations	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)
Mosul	-0.14848	-0.07237	0.028301
Kirkuk	-0.11461	-0.13167	0.022929
Baghdad	-0.0886	-0.06451	-0.04064
Rutba	-0.13788	-0.22602	0.161013
Al-Hayy	-0.0552	-0.04848	-0.15916
Nasiriya	-0.10148	-0.01026	-0.18508
Basra	-0.00317	0.030664	-0.10592

4 Autumn Values of Climatic Elements

The correlation coefficient values for the climatic elements for the autumn season data with the NIÑO 3.4 index are displayed in Table 5. A positive relationship appears between the relative humidity data and the NIÑO 3.4 index in all stations. As for the minimum temperature values, with the NIÑO 3.4 index, the correlation was negative for Mosul, Kirkuk, Rutba, and Al-Hay stations, while the correlation was positive for Baghdad, Nasiriya, and Basra stations. Finally, a negative correlation was noticed between the maximum temperature and the NIÑO 3.4 index for all stations except for the Basra station.

Table 5. The correlation coefficient (R) of atmospheric elements data with NIÑO 3.4 index for the autumn season (2007-2017)

Stations	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)
Mosul	-0.16853	-0.03151	0.248734
Kirkuk	-0.12748	-0.00032	0.346519
Baghdad	-0.1182	0.033498	0.29709
Rutba	-0.22414	-0.23779	0.427997
Al-Hayy	-0.13171	-0.02116	0.232971
Nasiriya	-0.10323	0.011853	0.19908
Basra	0.161101	0.215999	0.21666

5 NIÑO 3.4 Index Influence on Daily Climatic Elements Data

The correlation coefficient between all daily values of climatic elements with the NIÑO 3.4 index was calculated in Table 6. A positive correlation between the NIÑO 3.4 index and the daily relative humidity data for Kirkuk, Baghdad, Rutba, and Basra stations, while a negative correlation is found in Mosul, Al-Hay, and Nasiriya stations, Table 6. On the other hand, the results showed a relatively small positive correlation for all stations between the daily values of the minimum and maximum temperatures.

Table 6. Correlation coefficient (R)between daily climatic elements values and NIÑO 3.4 index data (2007-2017)

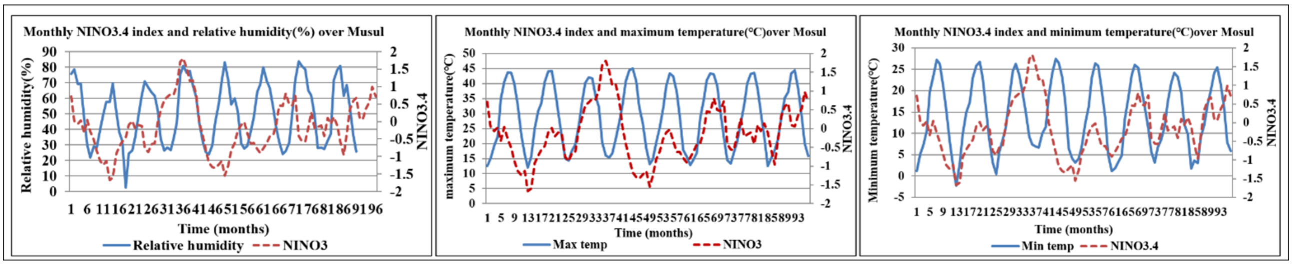
Stations	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)
Mosul	0.137987	0.2047	-0.03769
Kirkuk	0.051425	0.089669	0.091092
Baghdad	0.061318	0.104511	0.049418
Rutba	0.080838	0.099108	0.212322
Al-Hayy	0.057209	0.100107	-0.00097
Nasiriya	0.070399	0.105741	-0.00178
Basra	0.066637	0.118268	0.043533

6 The Effect of the NIÑO 3.4 Index on the Monthly Values of the Climatic Elements

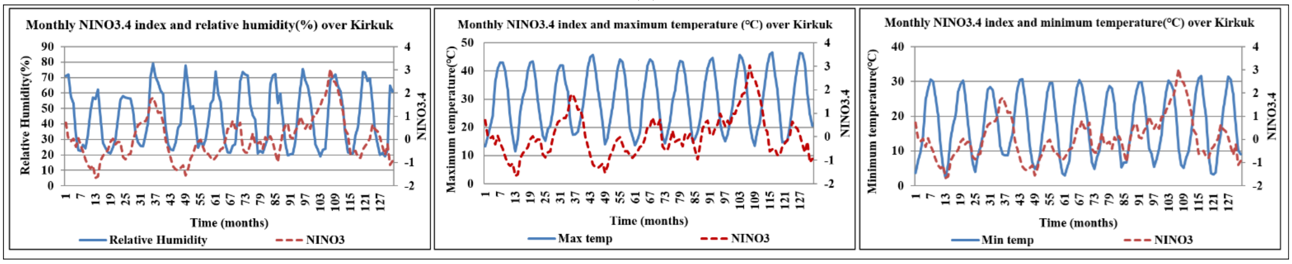
The correlation coefficient was calculated between the NIÑO 3.4 index and the climatic elements (relative humidity, minimum, and maximum temperature) in Table 7 and Figure 5 (5a, 5b, 5c, 5d, 5e, 5f, and 5g). The results showed a positive correlation between the NIÑO 3.4 index and the maximum and minimum temperature for all the stations. There was a negative correlation in Mosul, Rutba, Al-Hay, and Nasserite stations, while there is a positive correlation for Kirkuk, Baghdad, and Basra stations between relative humidity data and NIÑO 3.4.

Table 7. Correlation coefficient (R) between the monthly climatic elements values with NIÑO 3.4 index data (2007-2017)

Stations	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)
Mosul	0.148152	0.221708	-0.04468
Kirkuk	0.049585	0.091604	0.084199
Baghdad	0.064071	0.110126	0.055927
Rutba	0.078834	0.087235	-0.02751
Al-Hayy	0.08005	0.10328	-0.00593
Nasiriya	0.073417	0.111629	-0.00717
Basra	0.095507	0.123065	0.050922



(a)



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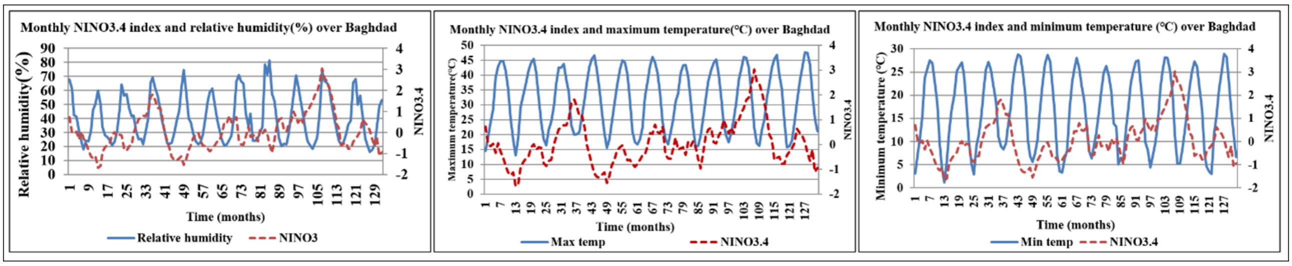

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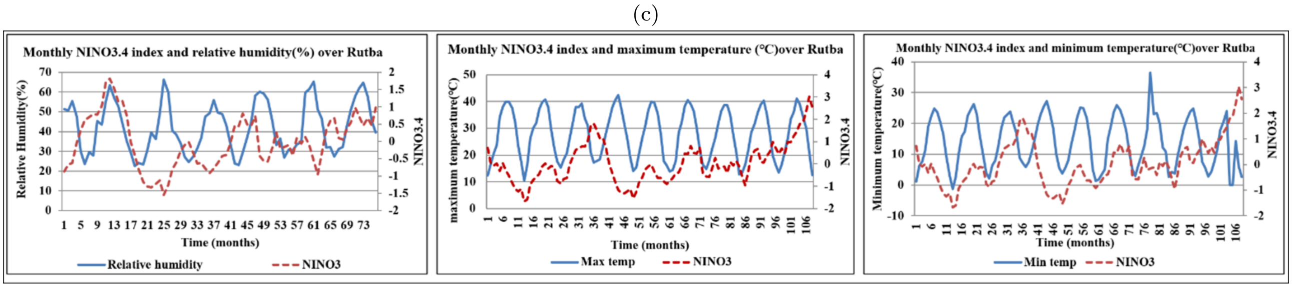

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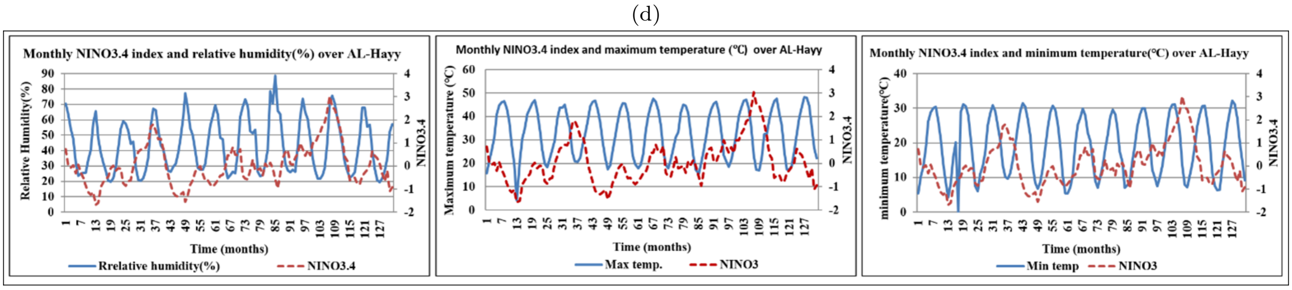
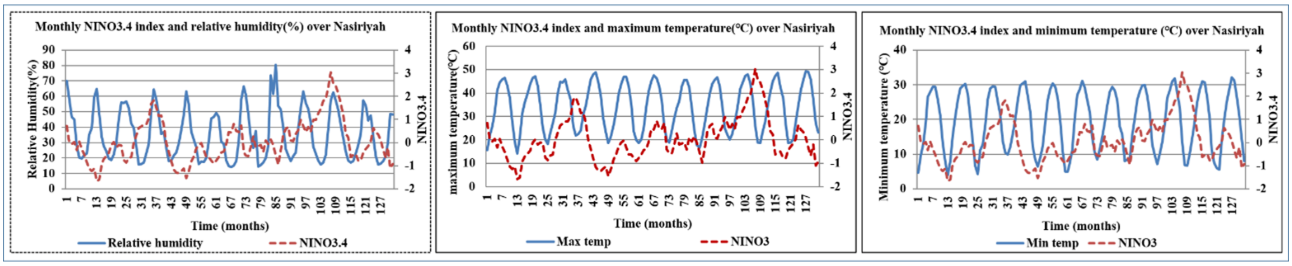
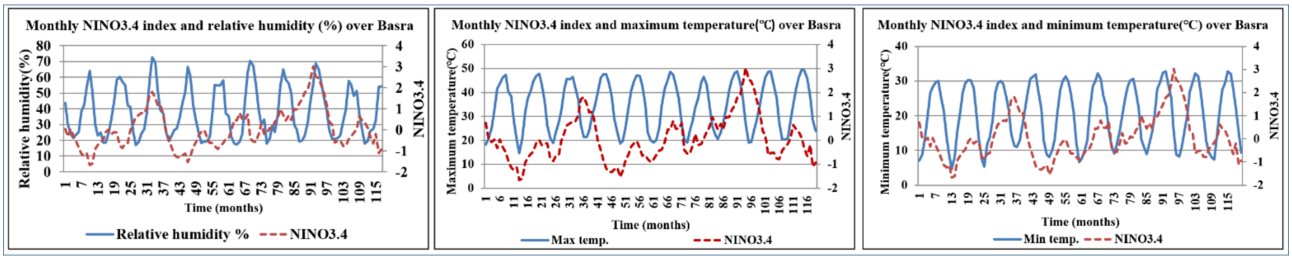


(e)

Figure 5. NIÑO 3.4 index correlation with the climatic elements for: (a) Kirkuk station, (b) Kirkuk station, (c) Baghdad station, (d) Rutba station, (e) AL-Hayy station, (f) Nasiriyah station, (g) Basra station



(f)



(g)

Continue to Figure 5

It appears from the figures above, that there is an effect of the sea surface temperature (SST) anomalies in the eastern Pacific region on the values of relative humidity, maximum and minimum air temperature in Iraq, but this effect appears on the values of the correlation coefficient. This is due to a lag time between the appearance of the phenomena in the eastern Pacific Ocean and the response in Iraq which takes a month due to the long distance for that the correlation coefficients (R) are small.

The Reanalysis Data

The correlation coefficient was calculated for the seasonal air temperature data with NIÑO 3.4 values from 1980 to 2022. In the autumn season (Figure 5a)., there was no correlation (0 correlation) for most Iraqi regions except the northeastern part (weak inverse correlation -0.2), while in winter, there was a weak inverse correlation -0.2 for all Iraqi regions (Figure 5b). There were three regions with inverse correlation: -0.2 in the northern part 0.3 in the central part, and, finally, -0.4 in the southern part for the spring season (Figure 5c). In the summer season, there was no correlation in the northeastern region and a weak inverse correlation (-0.2 and -0.3) for the rest of Iraq, Figure 5d. The low value of the relationship between surface air temperature rates (for the four seasons) with El NIÑO 3.4 may be due to the difference in response (lag times) between El NIÑO occurrence time and the impact time on Iraq, especially the large distance between Iraq and the El NIÑO region, as well as the weak response of the atmosphere. For this reason, we called this research The Telecommunications between Iraq Region Air Temperature and ENSO ElNIÑO 3.4 Region.

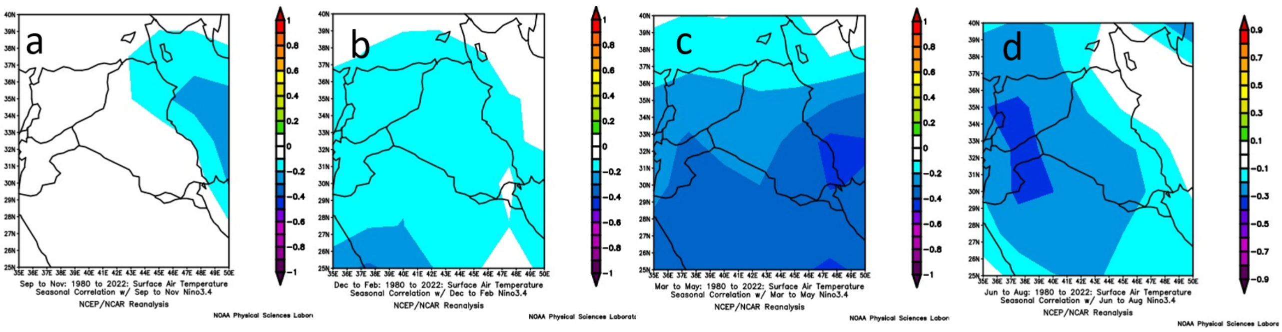


Figure 6. NIÑO 3.4 index correlation with air temperature data

CONCLUSION

El NIÑO phenomenon is an important climate indicator that impact climate elements in different ways. In this study, we try to evaluate the impacts of El NIÑO 3.4 on the climate elements in Iraq, and review the most important conclusions we obtained: The relative humidity trend shows an increase for Al-Rutba, Mosul, Al-Hay, Baghdad, and Basra stations, while there was a decrease in the trend for Kirkuk and Nasiriya stations. The results present that Mosul station recorded a large difference between the highest and lowest relative humidity values (83.7 % to 2.6%), which may reflect a greater variation in climatic conditions than other stations. The results showed an increase in the general trend of the maximum and minimum temperatures for Kirkuk, Nasiriya, Basra, Baghdad, Al-Hay, and Mosul stations, while there was a decrease in the general trend for Al-Rutba station. The analysis indicates that Al-Hayy station has a significant thermal variation in maximum air temperatures, as it recorded a large difference between the highest and lowest values (48.2 ℃ to 4.3), which means that it may have diverse climatic conditions. The impact of the NIÑO 3.4 index on the maximum and minimum temperatures within the daily and monthly values, in general, was a positive correlation, as it increased as its effect increased, which indicates the existence of a relationship. However, it is weak overall and did not exceed 0.1 as a value for the correlation rate between them. The consequence of the NIÑO 3.4 index on the maximum and minimum temperatures during the spring and winter seasons was a positive correlation (it rises with the increase in the effect of the phenomenon); on the contrary, its negative correlation was recorded in the summer and autumn seasons, meaning it rises whenever the effect of the phenomenon decreases. The impact of El NIÑO on surface values of relative humidity and maximum and minimum air temperatures may be delayed, and non-immediate, it takes a month or more time until its impacts reach Iraq.

SUPPLEMENTARY MATERIAL

None.

AUTHOR CONTRIBUTIONS

Muthanna A. Al-Tameemi: Designed the research. Ali Raheem Al-Nassar: Writing, editing. Aqeel Ghazi Mutar: Performed the analyses. A. Castrillon: Interpretation of the results.

FUNDING

None.

DATA AVAILABILITY STATEMENT

1- Daily recorded dataset from the Iraqi Meteorological and Seismology Organization (private data).

2- Monthly data of El NIÑO 3.4 by the royal Netherlands meteorological institute: https://climexp.knmi.nl/start.cgi.

3- Atmospheric research NCAR (air temperature from 1980-2022) the national centers for environmental prediction (NCEP) and the national center: https://psl.noaa.gov/data/gridded/data.ncep.reanalysis.html.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

REFERENCES

[1] X. L. Yu and S. R. Zhang, "Non-Linear pattern analysis of El Niño's impact on tropical precipitation," vol. 96, EDP Sciences, May 2019, p. 03 001. doi: 10.1051/e3sconf/20199603001.

[2] W. Cai, S. Borlace, M. Lengaigne, P. van Rensch, M. Collins, G. Vecchi, A. Timmermann, A. Santoso, M. J. McPhaden, L. Wu, M. H. England, G. Wang, E. Guilyardi, and F.-F. Jin, "Increasing frequency of extreme El Niño events due to greenhouse warming," *Nature Climate Change*, vol. 4, no. 2, pp. 111–116, 2014. doi: 10.1038/nclimate2100.

[3] M. G. Donat, T. C. Peterson, M. Brunet, A. D. King, M. Almazroui, R. K. Kolli, D. Boucherf, A. Y. Al-Mulla, A. Y. Nour, A. A. Aly, T. A. A. Nada, M. M. Semawi, H. A. Al Dashti, T. G. Salhab, K. I. El Fadli, M. K. Muftah, S. Dah Eida, W. Badi, F. Driouech, K. El Rhaz, M. J. Y. Abubaker, A. S. Ghulam, A. S. Erayah, M. B. Mansour, W. O. Alabdouli, J. S. Al Dhanhani, and M. N. Al Shekaili, "Changes in extreme temperature and precipitation in the Arab region: long-term trends and variability related to ENSO and NAO," *International Journal of Climatology*, vol. 34, no. 3, pp. 581–592, 2013. doi: 10.1002/joc.3707.

[4] S. Curtis and D. H. Douglass, "Phase-locked tropical Pacific precipitation," *Atmospheric Science Letters*, vol. 17, no. 2, pp. 169–176, 2016. doi: 10.1002/asl.639.

[5] S. Yang, Z. Li, J.-Y. Yu, X. Hu, W. Dong, and S. He, "El Niño-Southern Oscillation and its impact in the changing climate," *National Science Review*, vol. 5, no. 6, pp. 840–857, 2018. doi: 10.1093/nsr/nwy046.

[6] A. Santoso, M. J. Mcphaden, and W. Cai, "The defining characteristics of ENSO extremes and the strong 2015/2016 El Niño," *Reviews of Geophysics*, vol. 55, no. 4, pp. 1079–1129, 2017. doi: 10.1002/2017rg000560.

[7] D. M. Zermeño Díaz and L. G. Mendoza, "The influence of ENSO during spring over northwestern Mexico," *International Journal of Climatology*, vol. 43, no. 14, pp. 6420–6433, 2023. doi: 10.1002/joc.8212.

[8] R. Shunmugapandi, S. Gedam, and A. B. Inamdar, "Impact of 2015-2016 El Niño on phytoplankton size class distribution during the summer and winter monsoon in the Arabian Sea," *International Journal of Remote Sensing*, vol. 45, no. 23, pp. 9017–9032, Dec. 2023. doi: 10.1080/01431161.2023.2295839.

[9] P. M. Cox, R. A. Betts, M. Collins, P. P. Harris, C. Huntingford, and C. D. Jones, "Amazonian forest dieback under climate-carbon cycle projections for the 21st century," *Theoretical and Applied Climatology*, vol. 78, no. 1-3, pp. 137–156, 2004. doi: 10.1007/s00704-004-0049-4.

[10] J. Zhu, A. Kumar, W. Wang, Z.-Z. Hu, B. Huang, and M. A. Balmaseda, "Importance of convective parameterization in ENSO predictions," *Geophysical Research Letters*, vol. 44, no. 12, pp. 6334–6342, 2017. doi: 10.1002/2017gl073669.

[11] J. Blunden and D. S. Arndt, "State of the climate in 2015," *Bulletin of the American Meteorological Society*, vol. 97, no. 8, pp. Si–S275, 2016. doi: 10.1175/2016bamsstateoftheclimate.1.

[12] X. Zou, L. Yan, J. Xu, and S. Zheng, "The impacts of regime shift in summer arctic oscillation on precipitation in East Asia," *Atmosphere*, vol. 15, no. 3, p. 283, 2024. doi: 10.3390/atmos15030283.

[13] J. Helali, H. Momenzadeh, S. Salimi, S. A. Hosseini, M. Lotfi, S. M. Mohamadi, G. M. Moghim, F. Pazhoh, and M. Ahmadi, "Synoptic-dynamic analysis of precipitation anomalies over Iran in different phases of ENSO," *Arabian Journal of Geosciences*, vol. 14, no. 22, p. 2322, 2021. doi: 10.1007/s12517-021-08644-5.

[14] J.-Y. Lin, M.-C. Tang, and F. Wijaya, "Satellite oceanographic data processing and analysis: Correlation between Nino 3.4 sea surface temperature & sea surface high and wind," *Indonesian Journal of Earth Sciences*, vol. 2, no. 2, pp. 157–176, 2022. doi: 10.52562/injoes.v2i2.428.

[15] H. Gong, L. Wang, and W. Chen, "Multidecadal changes in the influence of the arctic oscillation on the East Asian surface air temperature in boreal winter," *Atmosphere*, vol. 10, no. 12, p. 757, 2019. doi: 10.3390/atmos10120757.

[16] Z. M. Mie Sein, I. Ullah, S. Syed, X. Zhi, K. Azam, and G. Rasool, "Interannual variability of air temperature over Myanmar: The influence of ENSO and IOD," *Climate*, vol. 9, no. 2, p. 35, 2021. doi: 10.3390/cli9020035.

[17] J. Eggeling, C. Gao, D. An, R. Cruz-Cano, H. He, L. Zhang, Y.-C. Wang, and A. Sapkota, "Spatiotemporal link between El Niño Southern Oscillation (ENSO), extreme heat, and thermal stress in the Asia-Pacific region," *Scientific Reports*, vol. 14, no. 1, p. 7448, 2024. doi: 10.1038/s41598-024-58288-0.

[18] C. Varotsos, N. V. Sarlis, Y. Mazei, D. Saldaev, and M. Efstathiou, "A Composite tool for forecasting El Niño: The case of the 2023-2024 event," *Forecasting*, vol. 6, no. 1, pp. 187–203, 2024. doi: 10.3390/forecast6010011.

[19] A. G. Mutar, A. Khtan, and L. E. George, "Synoptic characteristics of torrential rains in southwest and southeast Iraq: A case study," *Al-Mustansiriyah Journal of Science*, vol. 32, no. 3, pp. 1–7, 2021. doi: 10.23851/mjs.v32i3.957.

[20] M. A. R. Jabbar and A. S. Hassan, "The daily pattern at 500 hPa geopotential heights and its association with heavy rainfall over Iraq," *Iraqi Journal of Science*, vol. 64, no. 3, pp. 1498–1507, 2023. doi: 10.24996/ijs.2023.64.3.38.

[21] L. Azeez, "Demonstration of net solar radiation geographical behavior revers correlation with relative humidity in Iraq," *Iraqi Journal of Science*, vol. 63, no. 6, pp. 2741–2754, 2022. doi: 10.24996/ijs.2022.63.6.38.

[22] M. A. Al-Tameemi, B. J. Hassan, and A. G. Mutar, "The effect of solar activity on stratospheric temperature over Iraq for period 1948-2014," *Al-Mustansiriyah Journal of Science*, vol. 33, no. 2, pp. 8–13, 2022. doi: 10.23851/mjs.v33i2.1174.

[23] A. G. Mutar, A. Khtan, and L. E. George, "Effect of sea salt AOT on precipitation processes associated with red sea moisture flux on Iraq, a case study," *Al-Mustansiriyah Journal of Science*, vol. 33, no. 2, pp. 1–7, 2022. doi: 10.23851/mjs.v33i2.1090.

[24] A. R. Al-Nassar, J. L. Pelegrí, P. Sangrà, M. Alarcon, and A. Jansa, "Cut-off low systems over Iraq: Contribution to annual precipitation and synoptic analysis of extreme events," *International Journal of Climatology*, vol. 40, no. 2, pp. 908–926, 2019. doi: 10.1002/joc.6247.

[25] S. M. Awadh, "Impact of North African sand and dust storms on the Middle East using Iraq as an example: Causes, sources, and mitigation," *Atmosphere*, vol. 14, no. 1, p. 180, 2023. doi: 10.3390/atmos14010180.