SEBHA UNIVERSITY JOURNAL OF PURE & APPLIED SCIENCES VOL.22 NO. 2 2023
DOI: 10.51984/JOPAS.V22I2.2369

مجلة جامعة سبها للعلوم البحتة والتطبيقية
Sebha University Journal of Pure & Applied Sciences

Journal homepage: www.sebhau.edu.ly/journal/index.php/jopas

Statistical and Spatial Analysis of Extreme Temperatures in Libya (1961-2020)

*Nagib Froja[1] & Ismail Ageena[2]

[1]Soil and water Department- Faculty of Agriculture -University of Tripoli – Libya.
[2]Department of Geography University of Al-Zawia – Libya

Keywords:
Coldest day
Cold nights
Cold days
Extreme temperatures
Temperature variability
Warmest day
Warm nights

A B S T R A C T

The present paper seeks to examine spatial and temporal variability of changes in both warm and cold extreme temperatures. Additionally, it aims to determine the most extreme geographical areas in extreme temperatures based on climate data recorded during the period from 1961 to 2020. This paper analysed the annual data of extreme temperatures for 16 meteorological stations during 1961- 2020 across Libya over two climatic regions (coastal and inland) based on Mann–Kendall test. Time trend of the extreme of both maximum and minimum temperature will be analyses and the results from geographical analysis are will also be presented based on ArcMap. The results indicated that a significant increase in the coldest extreme (TNn) temperature are found in autumn and spring and winter at majority of stations. Temperature variability can be associated with variations in large-scale atmospheric patterns represented by Eastern Atlantic and the Western Mediterranean Oscillations.

التحليل الإحصائي والمكاني لتطرفات درجات الحرارة في ليبيا (1961-2020)

*نجيب امحمد فروجة[1] و اسماعيل مسعود عجينه[2]

[1]قسم التربة والمياه، كلية الزراعة، جامعة طرابلس، ليبيا
[2]قسم الجغرافيا، جامعة الزاوية، ليبيا

الكلمات المفتاحية:
أبرد يوم
أدفأ نهار
الليالي الدافئة
الليالي الباردة
تطرف درجات الحرارة
تقلب درجات الحرارة

الملخص

تهدف هذه الورقة إلى الكشف عن التباين المكاني والزماني للتغيرات في درجات الحرارة القصوى الدافئة والباردة. هذا بالإضافة إلى تحديد المناطق الجغرافية الأكثر تطرفاً في درجات الحرارة القصوى وتعتمد الدراسة اساساً على درجات الحرارة المسجلة خلال الفترة من 1961 إلى 2020. تسعى الورقة الى تحليل البيانات السنوية والشهرية لدرجات الحرارة القصوى لمحطات الأرصاد الجوية الستة عشر خلال الفترة من 1961 إلى 2020 في ليبيا وستعتمد الدراسة على اختبار Mann-Kendal من خلال تحليل الاتجاه الزمني لأقصى درجات الحرارة القصوى والدنيا على حد سواء وسيتم انتاج خرائط توضح التغيرات المكانية لهذه المتغيرات باستخدام برنامج ArcMap. أشارت النتائج إلى وجود زيادة معنوية في درجات الحرارة الأكثر برودةفي معظم أشهر السنة لأغلب المحطات. يمكن أن يرتبط تقلب درجة الحرارة في أنماط الغلاف الجوي واسعة النطاق التي يمثلها شرق المحيط الأطلسي وتذبذبات غرب البحر الأبيض المتوسط.

Introduction

Climate extremes can be analysed by estimating changes in extreme weather and climate parameters, which are divided by Alexander et al. [1] into four different index classes: percentile-based, absolute, duration and threshold-based, with regional and global (e.g., [2, 3]). Percentile-based indices represent the amount (percentage) of temperature falling above a fixed value. Absolute indices refer to counts of days crossing a specified absolute value that can be a minimum or maximum value within a month, season or year. Threshold-based indices consist of a number of days on which temperature/precipitation values fall above or below a fixed threshold. Duration indices define periods of extreme warmth, cold, wetness, or dryness. From the internationally agreed WMO list of approximately 50 climate change indices available online at http://www.knmi.nl/samen/eca and recommended by Jones et al. [4-6]. Studying changes in extreme temperature, as well as attributing and predicting those changes, has great importance. For example, extreme temperature events can seriously affect human health, ecosystems, and the economy [7, 8]. The heat waves that swept northwestern Libya in

*Corresponding author:
E-mail addresses: N.froja@uot.edu.ly, (I. Ageena) Ismaeel64agina@yahoo.com
Article History : Received 03 January 2023 - Received in revised form 12 October 2023 - Accepted 18 Octoper 2023

the past two years (2020, 2021), which lasted for more than ten continuous days, caused the production of many crops to deteriorate, as well as drought and the death of many trees (Figure 1). Given their impacts, it is important to understand the mechanisms that trigger those cold extreme events and improve their forecasts. The most important climate indices related to temperature and those most widely used for the analysis of extremes in temperature will be analysed in this study.

Fig. 1: Desiccation and death of trees (Cupressus sempervirens). Photo taken in Janzour city, June 2021

.

2. Literature Review

The Fifth Assessment Report of the IPCC [9] indicated that the surface temperature showed a change tendency rate of increase from 1880 to 2012, with an increase of 0.85 °C [9]. Studies of observational temperature records over the last 50–100 years have found evidence for an increase in both observed mean, minimum and maximum temperature [10, 5]. In the global scope, the highest trend of the lowest temperature indices, the increase in the extreme temperature indices and the decrease in the cold extreme value all show obvious warming trends from the 20th century to the beginning of the 21st century [1,10]. Morak et al. [11] indicated an increase in warm extremes and a decrease in cold extremes in both seasons and in almost all regions that are generally well captured by the model. Ageena [12] indicated that a mix of increasing and decreasing trends on the warmest day are also found. Zhou et al. [13] showed that the extreme temperature warming indices and the minimum daily maximum temperature (TXn) and the minimum daily minimum temperature (TNn) of cold indices showed an increasing trend from 1960 to 2016, especially since the 1990s.

Rodríguez et al. [14] found a significant trend of more warm days and fewer cold nights. Moreover, an increase in the number of heat waves has also been observed in southwestern North America (Tebaldi et al. [15]. Shen et al. [16] found an upwards tendency in the occurrence of warm days (TX90) and nights (TN90) and in the temperatures of the coldest day (TXn), coldest night (TNn), warmest day (TXx), and warmest night (TNx) in China and most climate regions. In most extreme temperature indices in Asia, the number of warm days and nights is increasing, and the increasing speed of the latter is significantly higher than that of the former [17]. In the past 60 years in Central Asia and North America, the growth rate of the highest temperature (TMAX) was faster than that of the lowest temperature (TMIN) [18], [19]. The rise rate of the lowest temperature in Iran is twice that of the highest temperature. Therefore, the frequency of extremely high temperatures increases and the frequency of extremely low temperatures decreases [20, [10, 14].

Toreti and Desiato [21] confirmed that most of the indices, averaged over all stations, showed a cooling trend until the end of the 1970s followed by a more pronounced warming trend in the last 25 years. Collazo et al. [22] found persistence in the winter cold night series compared with the previous season in eastern Argentina. In contrast to the observed increase in warm extremes, Portmann et al. [23] and Meehl et al. [24] found that the change in the number of hot daytime extremes across eastern North America was modest, with decreases over the southeaster part.

3. Methodology

The present paper seeks to examine the spatial and temporal variability of changes in both warm and cold extreme temperatures. Specifically, it aims to identify temporal fluctuations and patterns in extreme temperatures across Libya over coastal and inland climatic regions based on annual data.

The study will be based on maximum and minimum temperature data for 16 synoptic meteorological stations for the time period 1961-2020 distributed over coastal and interior regions in Libya. All the data were obtained from the Libyan National Meteorological Centre. The study will be based on the Mann–Kendall test for warm extreme temperatures (warm days (TX90), warm nights (TN90), warmest day (TXx) and warmest night (TNx)). In addition to cold extreme temperature, cold days (TX10), cold nights (TN10), coldest days (TXn) and coldest nights (TNn) were based on indices of the CLIVAR set [21] (Table 1). The statistical significance levels used are *** = 0.01 (confidence level of 99%), ** = 0.05 (confidence level of 95%), and * = 0.10 (confidence level of 90%).

Table 1*: Definition of six temperature indices used in this study for 1961-2010*

	Index	Descriptive	Definitions	Units
Warm	TXx	Warmest day	Monthly maximum value of daily maximum	°C/y
	TNx	Warmest night	Monthly maximum value of night maximum	°C/y
	TN90	Warm nights	Percentage of days when TN>90th percentile	d/y
	TX90	Warm days	Percentage of days when TN>10th percentile	d/y
Cold	TXn	Coldest night	Monthly minimum value of night minimum	°C/y
	TNn	Coldest day	Monthly minimum value of daily minimum	°C/y
	TN10	Cold nights	Percentage of days when TN<90th percentile	d/y
	TX10	Cold days	Percentage of days when TN<10th percentile	d/y

***Note**: all indices are calculated based on TX as the daily maximum temperature and TN as the daily minimum temperature*

In addition, the inverse distance weighted (IDW) tool in ArcMap was used as an interpolation tool to predict the extreme trend values of cells at locations that lack sampled points. It involves using known z values and weights determined as a function of distances between the unknown and known points. As such, IDW points that are far away have far less influence than points that are close [25].

4. Annual variations and trends of warm extreme temperatures

The temporal and spatial patterns of changes and trends for warm extremes for warmest day (TXx), warm days (TN90p), warmest night (TNx) and warm nights (TX90p) are analysed. Regional averages of (TXx) showed positive trends at the majority of stations with an average of 0.24 °C/year with significant positive trends recorded at 10 of 16 stations with different confidence rates (Table 2). The remaining eastern coastal areas, Binina, Shahat and Darnah: Binina, indicated no trends. The increases in TXx are significant (**) at all western and central coastal stations, Zwarah, Nalut and Musratah, and at inland stations, Al-Jaghbub, Sabha and Tazerbou (Figure 2).

Table 2: Trend of annual extreme maximum temperature with statistically significant levels of stations across Libya (1961-2020)

Time series	TXx °Ca^{-1}		TNx °Ca^{-1}		TN90 da^{-1}		TX90 da^{-1}	
	Sig	Q	Sig	Q	Sig	Q	Sig	Q
Zwarah	**	0.036	*	0.029	***	-0.138		0.000
								0. 000
Tripoli Airport	*	0.024	*	0.016		0.000		
								.000
Nalut	**	0.023	*	0.011	*	0.000		0.000
Misurata	**	0.028	*	0.012	*	0.000		0.000
Sirt	*	0.024	*	0.019		0.000		0.000
Ajdabyia	*	0.017	*	0.010	*	0.001		0.000
Binina		-0.008		0.001	*	-0.040		0.000
Shaht		-0.011		0.002	*	-0.111		0.000
Darnah		-0.014		0.004		0.000		0.000
Ghadames	**	0.025	*	0.019	*	0.000		0.000
Hon		0.012		0.010	**	0.071		0.000
Jalo		0.012		0.009		0.000		0.000
Al-Jaghbub	**	0.033	*	0.021	*	-0.129	*	-0.043
Sabha	**	0.029	*	0.013		0.000		0.000
Tazerbou	**	0.035	*	0.023		0.000		0.000
Al-Kufrah		0.014		0.010	***	-0.077		0.000

The results show that low positive trends were recorded for the warmest night (TNx) at all stations, which ranged from 0.001 day/year (Binina) to 0.029 day/year (Zwarah), with a significant positive trend at 10 out of 16 stations (Figure 4). High significant negative trends with an average of (- 0.026 day/year) in warm nights (TN90p) are identified at Zwarah, Binina, Shahat, AlJaghbub and Al-Kufrah, which ranged from -0.040 day/year to -0.138 day/year (Table 2 and Figure 3). In contrast, there is no change at 15 out of 16 stations in TX90p, except for Al-Jaghbub, which has negative changes of -0.043 day/year.

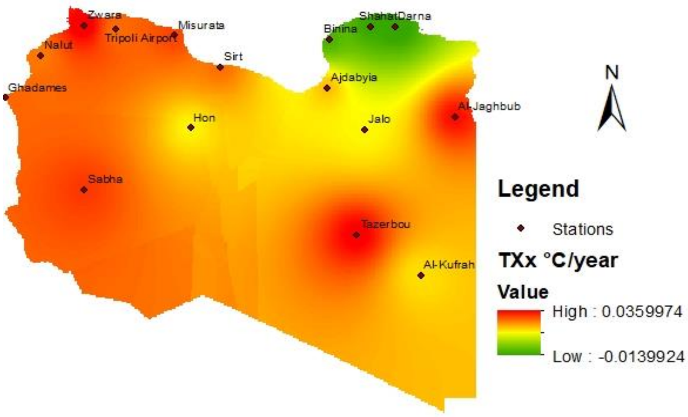

Fig. 2: The trends of annual warmest day (TXx)

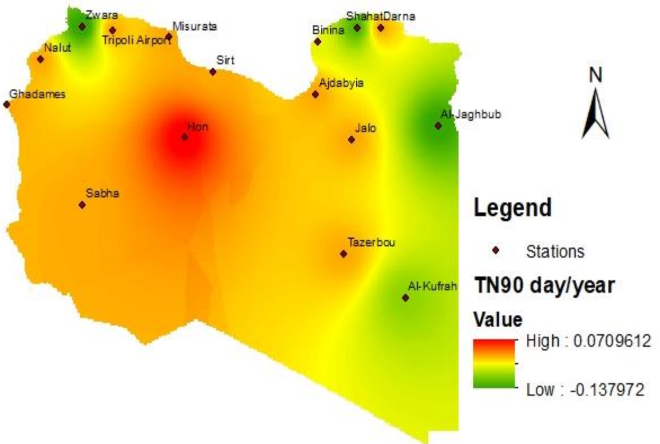

Fig. 3: The trends of warm nights (TN_{90})

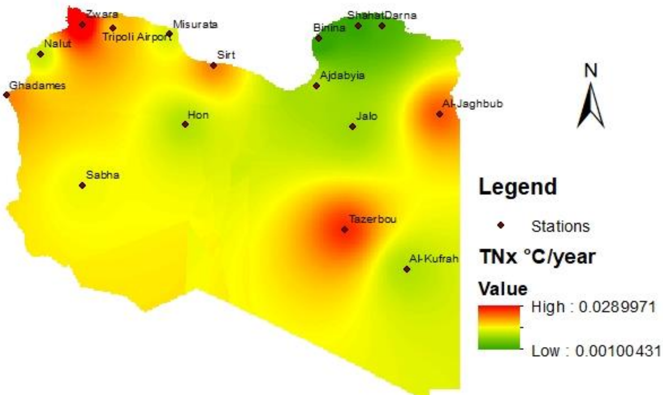

Fig. 4: The trends of warmest nights (TNx)

Table 3: Trends of annual extremes minimum temperature (cold) with statistically significant level of stations across Libya (1961-2020)

Synoptic stations	WMO. Number	TNn °Ca^{-1}		TXn da^{-1}		TN10 da^{-1}		TX10 da^{-1}	
		Sig	Q	Sig	Q	Sig	Q	Sig	Q
Zwarah	62007	***	0.085		0.000		-0.042		0.000
Tripoli Airport	62010	***	0.041		0.001	**	0.000	**	0.037
Nalut	62002	***	0.046		0.002		0.000		0.000
Misurata	62016	***	0.056		0.001		0.000		0.000
Sirt	62019	**	0.025		0.000	*	0.000		0.000
Ajdabyia	62055	**	0.072		0.000	*	0.000	*	0.001
Binina	62053	***	0.045		0.001	*	0.000		0.000
Shaht	62056	***	0.035		0.003		-0.032		0.000
Darnah	62059	***	0.038		0.001		0.000		0.000
Ghadames	62103	***	0.091		0.000		0.033		0.000
Hon	62131	***	0.083		0.000		0.000		0.000
Jalo	62161	***	0.043		0.000		0.000		0.000
Al-Jaghbub	62176	***	0.029		0.000	**	-0.077	**	0.043
Sabha	62124	**	0.056		0.000		0.000		0.000
Tazerbou	62259	*	0.006		0.000		0.000		0.000
Al-Kufrah	62271	***	0.083		0.000		-0.044		0.000

5. Annual variation and trends of cold extreme temperatures

This section presents the estimation of changes and trends in extreme cold temperatures for the 16 stations (1961-2020). Trends in the coldest night (TNn), coldest day (TXn), cold night percentile (TN10p) and cold day percentile (TX10p) index anomalies for 1961-2020 are analysed in this paper. Positive trends in the coldest night (TNn) are found at all stations, ranging from 0.006 °C/year at Tazerbou to 0.091 °C/year at Ghadames (Figure 5), with significant increases at all stations except Tazerbou, with a highly significant (***) at the majority of stations and significance (**) at Sirt, Ajdabyia and Sabha (Table 4). The analysis of TXn indicated low positive changes at Tripoli Airport, Nalut, Misurata, Binina, Shaht and Darnah, with no changes at the remaining stations (Figure 6). Positive significant changes in TN10p are identified at only five stations. The decreases in TN10p are identified at Zwarah, Shahat, Al-Jaghbub (**) and Al-Kufrah (**), ranging between -0.077 and -0.033 day/year, with no changes at the remaining stations (Figure 7). Positive trends in TX10p are found at Tripoli Airport (0.037 day/year) and Al-Jaghbub (0.043 day/year), with high significance (**). In addition, a positive trend is found at Ajdabyia (0.001 daya-1), with low significant trends (*) and no changes at the remaining stations (Table 3 and Figure 8).

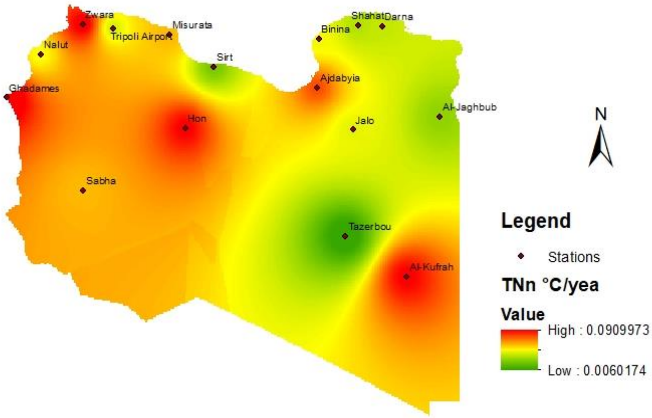

Fig. 5: The trends of coldest day (TN_n)

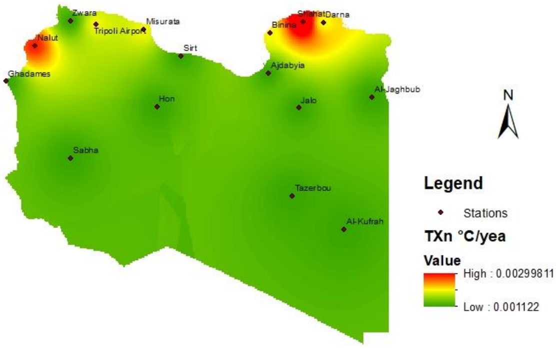

Fig. 6: The trends of coldest night (TX_n)

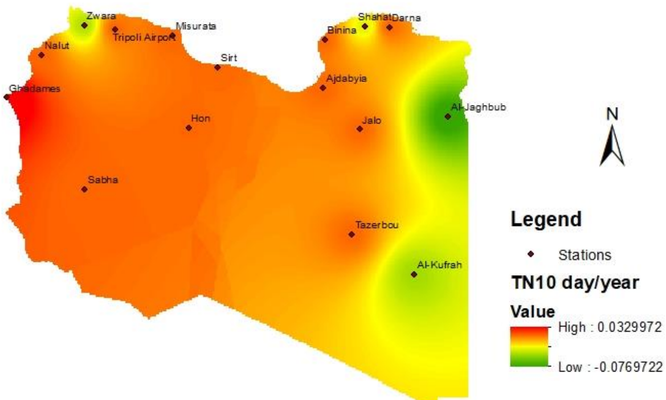

Fig. 7: The trends of cold nights (TN_{10})

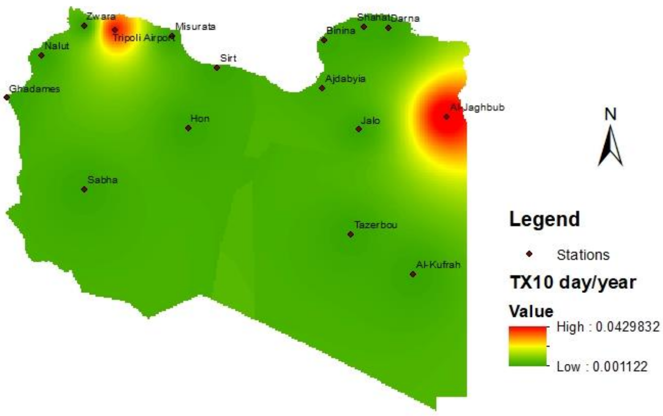

Fig. 8: The trend of cold days (TX_{10})

6. Conclusion

The results indicated that a significant increase in the coldest extreme (TNn) temperature was found at the majority of stations across the country. A mixture of increasing and decreasing trends in warmest day (TXx) are found, with significant changes more evident in autumn and spring than in winter and summer. The results of extreme temperature identified a significant increasing trend in extreme cold temperature in the monthly minimum value of daily minimum temperature (TNn) at all stations. A mixture of decreases and increases in maximum extreme temperature trends in the monthly maximum value of daily maximum temperature (TXx) are also found. Therefore, regional and local temperature trends can be strongly influenced by regional variability and changes in the climate system. The results of extreme temperatures identified that Libya is more affected by warming in the coastal region. However, the inland region was more affected by warming than the coastal region. Moreover, the minimum temperature showed that there were increasing trends for the mean average temperature at all stations across Libya. Increases in cold temperature extremes are smaller than those found for mean minimum temperature at most stations. Temperature variability can be associated with variations in large-scale atmospheric patterns represented by Eastern Atlantic and Western Mediterranean Oscillations, resulting from increases in atmospheric circulation, which seems to play a significant role in explaining the spatial and temporal variability of temperatures in the Mediterranean basin. Some regional differences between the model and observations may be due to local forcing or changes in climate dynamics.

7. References

[1] Alexander L., Zhang X., Peterson T., Caesar J., Gleason B., Klein Tank A., Haylock MD., Collins B., Trewin F., Rahimzadeh A., Tagipour P., Ambenje K. &Revadekar G., (2006). Global observed changes in daily climate extremes of temperature and precipitation, Journal Geophysical Research Atmospheres, 111: 1-22

[2] Bartolini G., Morabito M., Torrigiani T., Petralli M., Orlandini S., Crisci A., Grifoni D. and Maracchi G., (2008.) Recent trends in Tuscany (Italy) summer temperature and indices of extremes, International Journal of Climatology, 28, 13:1751-1760.

[3] Baoying N., Xiaomei Y. and Li C., (2012). Changes of temperature and precipitation extremes in Hengduan Mountains, Qinghai-Tibet Plateau in 1961-2008, Chinese Geographical Science, 22: 422-436

[4] Jones P.D., New M., Parker D.E., Martin S. and Rigor I.G., (1999), Surface air temperature and its changes over the past 150 years, Reviews of Geophysics, 37:173– 199.

[5] Trenberth, K., and Coauthors, (2007) Observations: Surface and atmospheric climate change. Climate Change 2007: The Physical Science Basis, S. Solomon et al., Eds., Cambridge University Press, 235–336.

[6] Wijngaard, J.B., Klein Tank, A.M.G. and Können, G.P., 2003. Homogeneity of 20th century European daily temperature and precipitation series. *International Journal of Climatology: A Journal of the Royal Meteorological Society*, *23*(6), pp.679-692.

[7] Solomon, S., Qin, D., Manning, M., Averyt, K. and Marquis, M. eds., 2007. *Climate change the physical science basis: Working group I contribution to the fourth assessment report of the IPCC* (Vol. 4). Cambridge university press.

[8] Karl, T.R., Meehl, G.A., Miller, C.D., Hassol, S.J., Waple, A.M. and Murray, W.L., (2008). Weather and climate extremes in a changing climate. Regions of focus: North America, Hawaii, Caribbean, and US Pacific Islands. *Synthesis and assessment Product*, *3*, pp.16-19.

[9] IPCC. 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups l, Il and Ill to the Fifth. Assessment Report of the Intergovernmental Panel on Climate Change; Core Writing Team, Pachauri, R.K., Meyer, L.A., Eds.; IPCC: Geneva, Switzerla, 2013; ISBN 9789291695386

[10] Kharin, V.V., Zwiers, F.W., Zhang, X. and Hegerl, G.C., (2007). Changes in temperature and precipitation extremes in the IPCC ensemble of global coupled model simulations. *Journal of Climate*, *20*(8), pp.1419-1444.

[11] Morak, S., Hegerl, G. C., & Christidis, N. (2013). Detectable changes in the frequency of temperature extremes. *Journal of climate*, *26*(5), 1561-1574.

[12] Ageena I.)2013). Trends and patterns in the climate of Libya (1945-2010). (Thesis submitted in accordance with the requirements of the University of Liverpool for the degree of Doctor of Philosophy).

[13] Zhou, J., Huang, J., Zhao, X., Lei, L., Shi, W., Wang, L.,... & Yang, X. (2020). Changes of extreme temperature and its influencing factors in Shiyang River Basin, Northwest China. *Atmosphere*, *11*(11), 1171.

[14] Rodríguez-Puebla, Encinas,AH,García-Casado, L A· & Nieto, S. (2010).Trends in warm days and cold nights over the Iberian Peninsula: relationships to large-scale variables. Climatic Change (2010) 100:667–684 DOI 10.1007/s10584-009-9721-0

[15] Tebaldi, C., Hayhoe, K., Arblaster, J. M., & Meehl, G. A. (2007). Erratum: Going to the extremes-An intercomparison of model-simulated historical and future changes in extreme events (Climatic Change (2006) 79,(185-211. *Climatic Change*, *82*(1-2), 233-234.

[16] Shen, X., Liu, B., Lu, X., & Fan, G. (2017). Spatial and temporal changes in daily temperature extremes in China during 1960–2011. *Theoretical and Applied Climatology*, *130*(3), 933-943.

[17] Cheong, W.K.; Timbal, B.; Golding, N.; Sirabaha, S.; Kwan, K.F.; Cinco, T.A.; Archevarahuprok, B.; Vo, V.H.; Gunawan, D.; Han, S. (2018). Observed and modelled temperature and precipitation extremes over Southeast Asia from 1972 to 2010. Int. J. Climatol., 38, 3013–3027.

[18] Bennett, K.E. and Walsh, J.E., (2015). Spatial and temporal changes in indices of extreme precipitation and temperature for Alaska. *International Journal of Climatology*, *35*(7), pp.1434-1452.

[19] Feng, R.; Yu, R.; Zheng, H.; Gan, M. (2018), Spatial and temporal variations in extreme temperature in Central Asia. Int. J. Climatol. 38, e388–e400.

[20] Alizadeh-Choobari, O.; Najafi, (2018), M.S. Extreme weather events in Iran under a changing climate. Clim. Dyn., 50, 249–260.

[21] Toreti, A. &Desiato, F. (2008). Changes in temperature extremes over Italy in the last 44 years. Iternational Journal of Climatology 28(6):733 – 745. DOI: 10.1002/joc.1576

[22] Collazo, S.Barrucand, M. &Rusticucci· M. (2019). Variability and predictability of winter cold nights in Argentina. Weather and Climate Extremes, Volume 26, December 2019, 100236.

[23] Portmann, R. W., S. Solomon, and G. Hegerl, (2009)Spatial and seasonal patterns in climate change, temperatures, and precipitation across the United States. *Proc. Nat. Acad. Sci.*, **106**, 7324–7329

[24] Meehl, G. A., Arblaster, J. M., &Branstator, G. (2012). Mechanisms contributing to the warming hole and the consequent US east–west differential of heat extremes. *Journal of climate*, *25*(18), 6394-6408.

[25] Childs, Colin, (2004). "Interpolating surfaces in ArcGIS spatial analyst." *ArcUser, July September* 3235