O‘ZBEKISTON MILLIY UNIVERSITETI XABARLARI, 2025, [3/1/1]
ISSN 2181-7324

GEOLOGIYA
http://journals.nuu.uz
Natural sciences

UO‘K:551.58(575.151)

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AVERAGE AIR TEMPERATURE TREND ANALYSIS: A CASE STUDY OF SURKHANDARYA REGION, UZBEKISTAN

Annotation

This study analyzed monthly average temperature variations at five meteorological stations in the Surkhandarya region using the Mann-Kendall trend test and the Mann-Kendall change point method. At the Baysun station, the most significant increase was observed in July ($Z = 4.40$, $p < 0.001$, Sen’s slope $Q = 0.134$). June also showed a positive trend ($Z = 2.31$, $p < 0.05$, $Q = 0.060$). At the Denau station, temperatures increased in July ($Z = 2.56$, $p < 0.05$, $Q = 0.075$) but decreased in October ($Z = -2.54$, $p < 0.05$, $Q = -0.154$). The Termez station recorded a significant change in July ($Z = 3.73$, $p < 0.01$, $Q = 0.11$). In Sherabad, a notable trend was observed in September ($Z = 2.71$, $Q = 0.10$), while in Shurchi, significant changes were detected in both June ($Z = 2.26$, $Q = 0.07$) and July ($Z = 3.01$, $Q = 0.07$).

Key words: Climate Change**,** Surkhandarya region, Mann-Kendal Test, Sen’s slope estimator, IDW, Interpolation.

O’RTACHA HAVO HARORATINING TREND TAHLILI: O’ZBEKISTONNING SURXONDARYO VILOYATI MISOLIDA

Annotatsiya

Ushbu tadqiqotda Surxondaryo viloyatidagi 5 ta meteorologik stansiyada o‘rtacha oylik harorat o‘zgarishlari Mann-Kendall trend testi va keskin o‘zgarish nuqtalari Mann-Kendall usuli yordamida aniqlangan. Boysun stansiyasida iyul oyida eng sezilarli o‘sish kuzatilib, $Z = 4.40$ ($p < 0.001$) va Sen’s qiyaligi $Q = 0.134$ bo‘ldi. Iyun oyida ham ijobiy trend qayd etildi ($Z = 2.31$, $p < 0.05$, $Q = 0.060$). Denovda iyul oyida harorat ortib ($Z = 2.56$, $p < 0.05$, $Q = 0.075$), oktyabrda esa kamaygan ($Z = -2.54$, $p < 0.05$, $Q = -0.154$). Termizda iyul oyida sezilarli o‘zgarish qayd etildi ($Z = 3.73$, $p < 0.01$, $Q = 0.11$). Sherobodda sentabr oyida ($Z = 2.71$, $Q = 0.10$), Shurchida esa iyun ($Z = 2.26$, $Q = 0.07$) va iyul ($Z = 3.01$, $Q = 0.07$) oylarida muhim o‘zgarishlar kuzatildi.

Kalit so‘zlar: Iqlim o‘zgarishi, Surxondaryo, Mann-Kendall testi, Sen’s slope estimator, IDW, Interpolyatsiya.

АНАЛИЗ ТРЕНДА СРЕДНЕЙ ТЕМПЕРАТУРЫ ВОЗДУХА: НА ПРИМЕРЕ СУРХАНДАРЬИНСКОЙ ОБЛАСТИ, УЗБЕКИСТАН

Аннотация

В данном исследовании проанализированы изменения среднемесячной температуры на пяти метеорологических станциях Сурхандарьинской области с использованием теста Манна-Кендалла и метода точек резкого изменения Манна-Кендалла. На станции Байсун зафиксирован самый значительный рост температуры в июле ($Z = 4.40$, $p < 0.001$, наклон Сен $Q = 0.134$). В июне также отмечена положительная тенденция ($Z = 2.31$, $p < 0.05$, $Q = 0.060$). На станции Денау температура увеличилась в июле ($Z = 2.56$, $p < 0.05$, $Q = 0.075$), но снизилась в октябре ($Z = -2.54$, $p < 0.05$, $Q = -0.154$). На станции Термез значительное изменение температуры отмечено в июле ($Z = 3.73$, $p < 0.01$, $Q = 0.11$). В Шерабаде заметная тенденция наблюдалась в сентябре ($Z = 2.71$, $Q = 0.10$), а в Шурчи существенные изменения зафиксированы в июне ($Z = 2.26$, $Q = 0.07$) и июле ($Z = 3.01$, $Q = 0.07$).

Ключевые слова: Изменение климата, Сурхандарьинская область, тест Манна-Кендалла, оценка наклона Сен, IDW, интерполяция.

Introduction. Understanding long-term temperature trends is essential in assessing the impact of climate change on ecosystems, water resources, and human activities. The Mann-Kendall test, a non-parametric method, is widely used to detect monotonic trends in climate data, especially temperature records, as it effectively handles non-normally distributed data and missing values [1]. This test has been extensively applied in climate studies to monitor temperature trends and assess climate variability.

Since the 21st century, the Mann-Kendall test has been increasingly utilized to analyze temperature trends across various regions, uncovering global and regional patterns. The Mann-Kendall test is particularly effective for detecting trends in time series data with seasonal variations and serial correlations, common in climate datasets. Hamed and Rao proposed a modified version of the test to adjust for autocorrelation, improving its performance in long-term temperature and precipitation trend analysis [2]. Studies by Burn and Elnur [3] and Kahya and Kalayci [4] further demonstrated its effectiveness in analyzing streamflow and temperature changes in Turkey.

This test has been successfully applied at different spatial and temporal scales. For example, Partal and Kahya examined precipitation trends in Turkey [5], hydrological changes in the Yellow River Basin [6], and temperature extremes in the Nepal Himalayas [7]. Its flexibility makes it a valuable tool for climate trend analysis across diverse environmental settings.

In addition, the Mann-Kendall test is often paired with Sen’s slope estimator to quantify trend magnitude. This combination has been widely used in climate studies to measure the rate of temperature changes over time [8]. Given the urgency of understanding climate variability, this study applies the Mann-Kendall test to analyze long-term average temperature trends. By assessing both trend direction and magnitude, it provides valuable insights for climate adaptation strategies and long-term climate pattern analysis.

Materials. *Study area.* Surkhandarya is the southernmost region of Uzbekistan. The region covers an area of 20,100 km². The region has a diverse relief, consisting of mountains and plains, which narrow and widen from north to south.

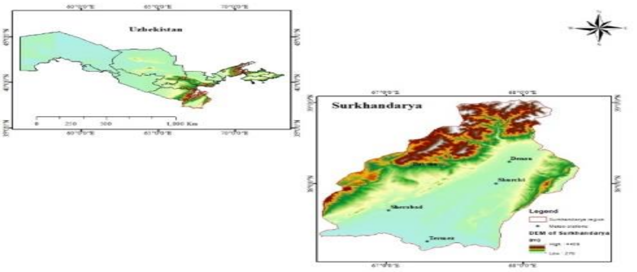

Figure 1 – Map of geographical location of Surkhandarya region and meteorological stations

The region has a dry subtropical climate, with hot and long summers and mild and short winters. The annual average temperature is 16° - 18°C. The average temperature in July is 28° - 32°C, and in January 2.8° - 3.6°C. The region has many cloudless days and high solar radiation, which results in high effective temperatures.

Data collection. There are 5 meteorological stations in Surkhandarya region, which have been conducting meteorological monitoring for many years. The average air temperature data needed for the research were obtained from the Hydrometeorological Service Agency of the Republic of Uzbekistan and the Hydrometeorological Service Center of the Surkhandarya Region from January 2000 to December 2023.

Research metodology. Mann-Kendall trend test. The non-parametric Mann-Kendall test was applied to the change point detection for recorded period dataset of each meteostation. The method was applied to monthly avergae air temperature for each meteostation’s dataset during the recorded period.

The Mann-Kendall rank statistics test is an effective method for testing monotonic trends and abrupt time series changes. This paper used the Mann-Kendall monotonic trend test, the nonparametric test, and the abrupt change test method to analyze change trends and possible transition points for temperature in the Surkhandarya region.

Trend test performs two types of statistics depending upon the number of data values i.e. S – statistics is used if number of data values are less than 10 while Z – statistics (normal approximation/distribution) for data values greater than or equal to 10.

The statistic S is calculated as shown in equation:

$$S = \sum_{i=1}^{n-1} \sum_{k=i+1}^{n} \operatorname{sign}(xk - xi) \qquad (2)$$

In which x_k and x_i are these quential data values, n is the length of the data set, and

$$sgn(\theta) = \begin{cases} +1, \theta > 0 \\ 0, \theta = 0 \\ -1, \theta < 0 \end{cases} \qquad (3)$$

A positive or negative value of S indicates an upward (increasing) or downward (decreasing) trends respectively. If number of data values are 10 or more, the S – statistics approximately behave as normally distributed and test is performed with normal distribution with the mean and variation as given below equations (4) & (5).

$$\mathrm{E}\,(S) = 0 \qquad (4)$$

$$\mathrm{var}(S) = [n(n-1)(2n+5) - \textstyle\sum_t t(t-1)(2t+5)]/18 \qquad (5)$$

in which t denotes the extent of any given tie and Σ denotes the summation over all ties. The standard normal distribution (Z – statistics) is computed using equation (6).

$$Z = \begin{cases} \frac{S-1}{\sqrt{var(S)}} & S > 0, \\ , & S = 0, \\ \frac{S+1}{\sqrt{var(S)}} & S < 0; \end{cases} \qquad (6)$$

Statistically the significance of trend is assessed using Z- value. A positive value of Z shows upwards (increasing) trend while the negative value indicates downward (decreasing) trend.

Sen’s Estimator method. Sen’s non-parametric estimator method has been used for predicting the magnitude (true slope) of hydro-meteorological time series data. The Sen’s slope estimator method uses a linear model for the trend analysis. The slope (T_i) of all data pairs is calculated using equation (7).

$$T_i = \frac{x_{j-} x_k}{j-k} \text{ for } i = 1,2,3, \dots \dots \dots \dots n \qquad (7)$$

Where, x_j and x_k are data values at times j and k ($j > k$) separately.

Geostatistical method. Geostatistics is defined as the branch of statistical sciences that studies spatial-temporal phenomena and capitalizes on spatial relationships to model possible values of variables at unobserved and unsampled locations. As stated, geostatistics is a subset of statistics specialized in the analysis and interpretation of geographically referenced data. Spatial statistics is a process of extracting data summaries from spatial data and comparing these to theoretical models that explain how spatial patterns originate and develop.

IDW interpolation method**.** In this method, the value of a variable at a point not sampled from its adjacent points is estimated using the relation. In this method, weights are determined with respect to the distance of each known point to the unknown point, and regardless of the position and how the points are scattered around the point of estimation. As a result, the nearer the points will be given more weight and the farther points will be given less weight. In fact, the shorter the distance, the greater the impact. This method assigns a weight to each of the measured samples for estimating the unknown point.

$$Z^* = \sum_{i=1}^{n} \lambda_i \cdot Z(x_i) \qquad (8)$$

$$\boldsymbol{\lambda_i = \frac{1}{h_i^n}} \qquad \textbf{(9)}$$

Where Z^* is the estimated spatial variable value, $Z(x_i)$ is the spatial variable observed at the point, λ_i is the statistical weight assigned to the sample x_i and indicates the significance of the i-point estimate, h_i the distance between the points x_i and the point at which the variable is estimated and n is the distance power.

Results and Discussion. The results from this study reveal significant seasonal and monthly variations in air temperature trends across the five meteorological stations in the Surkhandarya region. The Mann-Kendall test and Sen’s slope estimator indicate a pronounced warming trend, particularly during the summer months, with July showing the most substantial increases in temperature across multiple stations. The Baysun station, for instance, exhibited a highly significant trend in July ($Z = 4.40$, $p < 0.001$), with a slope of $Q = 0.134$, pointing to a sharp rise in summer heat. This warming trend is consistent with global climate patterns of increasing summer temperatures and heatwaves, which have been well-documented in other regions with similar climates. Other stations, such as Denau and Termez, also show significant increases in July temperatures, reinforcing concerns about rising heat during the summer. Conversely, some stations, such as Denau, show cooling trends in October, likely influenced by local atmospheric circulation patterns or changes in land use.

In this study, the average values of air temperature in Surkhandarya region were statistically analyzed in MS Excel, and based on the results, GIS technologies were mapped using the IDW interpolation method. Trend analysis was performed using Mann-Kendall using Sen's slope estimator to collect 24-year (2000-2023) time series data on a monthly, seasonal and annual basis.

Statistical analysis of average air temperature. The analysis of long-term monitoring data in Surkhandarya region shows that the average values of air temperature have changed from 4.2 ^{0}C to 29.8 ^{0}C. The lowest value of average air temperature is characteristic of Baysun meteorological station 2.1 ^{0}C, and the highest value is characteristic of Sherabad meteorological station 31.9 ^{0}C (Table 1).

Table 1

Average monthly values of air temperature for the years 2000-2023

Meteo stations	Average air temperature, ^{0}C (2000-2023)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baysun	2.1	4.2	9.4	14.3	19.4	24.1	26.3	24.6	20.1	13.6	7.9	3.9
Denau	5.1	7.7	13.6	18.8	24.3	29	30	27.8	23.5	17.3	11	6.77
Termez	4.5	7.4	13.7	20	25.8	29.8	31.2	28.7	23.8	17.2	10.5	5.4
Sherabad	5.2	7.4	13	20.2	25.6	30.7	31.9	29.4	25.2	18.3	11.6	7.4
Shurchi	3.9	7.2	12.9	18.1	23.9	28.6	29.6	27.4	22.8	16.6	11	5.6

Four seasons are clearly defined in the study area, and the seasons are sharply differentiated by variations in air temperature and precipitation. The average air temperature in Spring (march, april, may) is 14.4 ^{0}C (Baysun) to 19.8 ^{0}C (Termez), Summer (june, july, august) is the hottest season, and the average air temperature in the whole region exceeds 30 ^{0}C. Autumn (september, october, november) is considered to be a relatively warm and rainy season, and the average air temperature is observed up to 18.4 ^{0}C (Sherabad). Winter is cold in the region, the temperature is 0 – 5 ^{0}C.

GIS-based mapping of average air temperature changes. Geoinformation system (GIS) was used to evaluate the dynamics of spatio-temporal changes in air temperature (Figure 2). GIS can be used in many fields because it is a time-saving and efficient way to create a spatio-temporal map of meteorological parameters.

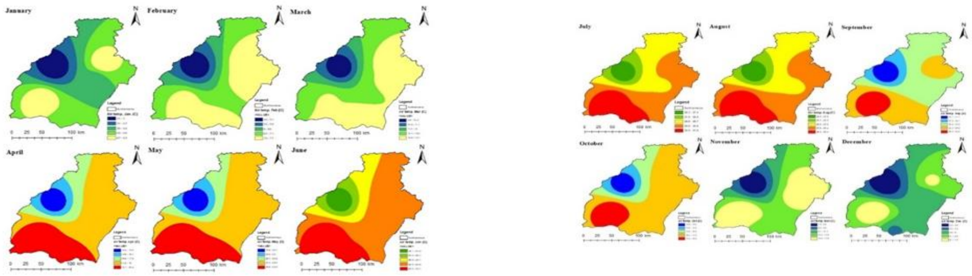

Figure 2. Average monthly air temperature values IDW interpolation map

There are 5 meteorological stations in the research area, and due to the large distance between them, the IDW interpolation method of GIS technologies was used to determine the average values of air temperature in the unexplored parts of the area. Above, average monthly valuesof air temperature for the period from January 2000 to December 2023 were mapped using the IDW interpolation method.

Mann-Kendall test. The monthly trend of air temperature data is calculated separately for each month using the Mann-Kendall statistical method, and the magnitude of the slope is calculated with Sen's slope estimator shown in Table 2. It was analyzed that there were significant changes in the monthly data. The temperature data means that some months showed increasing (rising) trends and some showed decreasing trends.

Table 2

Mann-Kendall trend statistics results of monthly average temperature (°C) of all the meteostations during the study period

Meteo stations	Parameters	Months											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Baysun	**Test Z**	0.05	1.04	0.60	0.42	0.62	2.31	4.40	0.82	1.54	-0.07	-1.17	1.62
	Signific.						*	***					
	Q	0.00	0.09	0.034	0.03	0.05	0.10	0.14	0.02	0.07	-0.03	-0.09	0.093
Denau	**Test Z**	-0.40	1.12	0.02	0.07	-0.02	1.62	2.56	-1.52	-0.30	-1.39	-2.04	0.97
	Signific.							*				*	
	Q	-0.03	0.06	0.00	0.00	0.00	0.05	0.08	-0.04	-0.01	-0.10	-0.15	0.05
Termez	**Test Z**	-0.10	1.17	1.19	0.25	0.35	1.92	3.73	0.80	1.69	-0.40	-1.22	1.07
	Signific.						+	***		+			
	Q	-0.01	0.09	0.07	0.01	0.01	0.06	0.11	0.01	0.06	-0.02	-0.09	0.05
Sherabad	**Test Z**	0.97	1.59	2.06	0.94	0.92	1.76	1.29	0.72	2.71	-0.57	0.75	1.12
	Signific.			*			+			**			
	Q	0.06	0.10	0.13	0.06	0.04	0.07	0.04	0.02	0.10	-0.04	0.05	0.05
Shurchi	**Test Z**	-0.45	0.85	0.60	0.87	0.00	2.26	3.01	0.32	2.38	0.12	0.75	0.25
	Signific.						*	**		*			
	Q	-0.03	0.06	0.03	0.05	0.00	0.07	0.07	0.01	0.06	0.01	0.03	0.01

*** if trend at α=0.001, ** if trend at α=0.01, * if trend at α=0.05, + if trend at α=0.1 level of significance.

Analysis of the data from the Baysun meteorological station shows that the most significant and highly significant trend was observed in July, with a Z-value of 4.40 ($p < 0.001$). Sen's slope (Q = 0.134) shows a significant increase in mean air temperature for July, indicating a significant increase in summer temperatures. This trend is consistent with increasing global observations of summer heat waves, which can have severe impacts on ecosystems, public health and energy demand.

Another trend in June shows a statistically significant positive trend, Z-value 2.31 ($p < 0.05$). The slope (Q = 0.060) refers to the average increase in temperature in June. Although this warming trend is less pronounced than in July, it is indicative of rising temperatures in early summer.

According to the analysis of the trend test result, a significant increasing trend was observed at the Denau meteorological station in July, with a Z-value of 2.56 ($p < 0.05$). Sen's slope (Q = 0.075) indicates a significant increase in average air temperature for this month, on the contrary, the Z-value in October is -2.54 ($p < 0.05$) and the slope (Q = 0.154) is equal to indicates a decrease in average temperature.

At the Termez station, a significant 99% change in July's mean air temperature was detected, with a Z-value of 3.73 and a slope of 0.11. Sherabad station showed a notable change in September (Z = 2.71, Q = 0.10). At Shurchi station, significant trends were found in June and July, with Z-values of 2.26 and 3.01, both with a slope of 0.07.

Conclusion. In this paper, we studied climate change trends in the Surkhandarya region over the past 24 years, and the results have contributed to deepening our understanding of climate change in the region. The results will facilitate and inform future planning and management of climate change programs in the Surkhandarya region, especially against the backdrop of global warming.

The results of study depicted that there is substantial year to year and season to season variability in air temperature is generally erratic in nature. The statistical result of tests indicated that in some months there is an increasing trend while in some other months decreasing trend of temperature.

Change of air temperature are influenced by several factors such as global warming, land cover change, atmospheric circulation, aerosol emissions and other human activities. Thus, other statistical approaches should be applied in order to understand temperature changes and to obtain a clearer imagination about contributions of human activities on temperature changes.

REFERENCES

1. Yue, S., & Hashino, M. (2003). Long-term trends of annual and monthly precipitation in Japan. Journal of the American Water Resources Association, 39(3), 587-596.
2. Hamed, K. H., & Rao, A. R. (1998). A modified Mann-Kendall trend test for autocorrelated data. Journal of Hydrology, 204(1-4), 182-196.
3. Burn, D. H., & Elnur, M. A. (2002). Detection of hydrologic trends and variability. Journal of Hydrology, 255(1-4), 107-122.
4. Kahya, E., & Karabork, H. (2001). Analysis of Turkish precipitation data: Trends and variability. Hydrological Processes, 15(11), 2051-2066.
5. Partal, T., & Kahya, E. (2006). Trend analysis in Turkish precipitation data. Hydrological Processes, 20(9), 2011-2026.
6. Zhang, X., & Cong, Z. (2014). Trends of precipitation intensity and frequency in the Yellow River Basin, China, detected by the Mann-Kendall test. Hydrology Research, 45(3), 419-429.
7. Shrestha, M. L., & Moore, J. N. (2009). Trends in temperature extremes in the Nepal Himalaya and its variability. Journal of Geophysical Research, 114(D17), D17109.
8. Zhang, Q., Li, J., Singh, V. P., & Xu, C. Y. (2013). Copula-based analysis of hydrological extremes and possible changes under climate change in the Yangtze River Basin, China. Journal of Hydrological Engineering, 18(6), 698-709.