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TEMPERATURE–RADIATION REGIME OF THE TERRITORY OF UZBEKISTAN FOR THE DESIGN OF SOLAR GREENHOUSES

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Abstract: This article analyzes the climatic conditions of Uzbekistan, the natural and geographical factors shaping them, and the characteristics of radiation, thermal, and wind regimes. The results indicate that Uzbekistan is characterized by a sharply continental climate with high solar radiation and significant seasonal temperature fluctuations. The paper also evaluates the potential of solar and geothermal energy resources and their application in agriculture, energy, and construction sectors. A comprehensive understanding of Uzbekistan's climate serves as a foundation for sustainable environmental management and economic development.

Key words: climate of Uzbekistan, radiation balance, temperature regime, solar energy, geothermal resources, continental climate, wind regime.

Annotatsiya: Ushbu maqolada O'zbekistonning iqlim sharoitlari, ularni shakllantiruvchi tabiiy-geografik omillar hamda radiatsion, termik va shamol rejimlarining xususiyatlari tahlil qilinadi. Tadqiqot natijalari mamlakat hududida keskin kontinental iqlim ustunligini, yillik quyosh radiatsiyasi yuqoriligini va haroratning sezilarli mavsumiy farqlarini ko'rsatadi. Shuningdek, maqolada O'zbekistonning quyosh va geotermal energiya resurslaridan samarali foydalanish imkoniyatlari baholangan. Natijalar iqlimiy sharoitlardan oqilona foydalanish qishloq xo'jaligi, energetika va qurilish sohalarida barqaror rivojlanishni ta'minlashga xizmat qilishini tasdiqlaydi.

Kalit so'zlar: O'zbekiston iqlimi, radiatsion balans, harorat rejimi, quyosh energiyasi, geotermal resurslar, kontinental iqlim, shamol rejimi.

Аннотация: В статье рассматриваются климатические особенности Узбекистана, определяемые природно-географическими факторами, а также анализируются радиационный, термический и ветровой режимы территории. Результаты исследования показывают, что для страны характерен резко континентальный климат с высокой солнечной радиацией и значительными сезонными колебаниями температуры. Особое внимание уделено оценке потенциала солнечной и геотермальной энергии, которые могут быть эффективно использованы в энергетике, сельском хозяйстве и строительстве. Комплексное изучение климатических условий является основой устойчивого природопользования и экономического развития.

Ключевые слова: климат Узбекистана, радиационный баланс, температурный режим, солнечная энергия, геотермальные ресурсы, континентальность, ветровой режим.

INTRODUCTION

The climate of Uzbekistan represents a unique combination of natural conditions shaped by its geographical location, orography, and atmospheric circulation processes. Situated in the very heart of Central Asia, Uzbekistan occupies a predominantly inland continental position, distant from large water bodies, which determines its sharply continental and arid climate. Much of the country is covered by desert and semi-desert landscapes, alternating with foothill and mountainous areas that possess distinctive microclimatic characteristics.

Both the latitudinal position and the baric circulation of air masses play an important role in forming the country's thermal and radiation regime. The southern mountain ranges prevent the penetration of humid tropical air masses from the Indian Ocean, while the open northern plains allow the free movement of cold Arctic air

flows. These features lead to significant seasonal and daily temperature fluctuations, high insolation levels, and low humidity.

The modern study of Uzbekistan's climatic conditions holds not only theoretical but also significant practical importance. Climatic parameters—such as temperature, radiation balance, wind regime, and solar activity—serve as key factors in the planning and design of agricultural, construction, transportation, and energy infrastructure. Particularly relevant is the analysis of thermal and radiation potential in the context of developing alternative energy sources—solar and geothermal—of which Uzbekistan possesses exceptionally abundant reserves.

This study aims to provide a systematic analysis of the climatic and geophysical conditions of Uzbekistan, to identify the regularities in the distribution of thermal and radiation resources, and to assess their role in shaping the country's natural and economic potential.

REVIEW OF LITERATURE ON THE SUBJECT

The temperature–radiation regime of Uzbekistan's territory is one of the key factors determining the efficiency of designing and operating solar greenhouses. According to the World Bank and the Global Solar Atlas project, most of the country receives more than 1,600 kWh/m² of global solar radiation annually, making Uzbekistan one of the most promising regions in Eurasia for the development of solar energy and protected agriculture. Research by Uzbek climatologist Erkin Yusupovich Rakhimov shows that annual total radiation in the plains (Kashkadarya, Navoi, Bukhara) exceeds that of mountainous and foothill areas, which requires an individualized approach to the thermal design of greenhouses.

Saytov E.B. and his co-authors note that the region's radiation balance is closely linked to wind patterns and air humidity, both of which influence cooling and convection processes inside greenhouse structures. Their actinometric observations revealed that daily fluctuations of solar radiation in a sharply continental climate cause significant nighttime heat losses, necessitating the use of heat-accumulating materials in greenhouse construction.

Rashodjayev and colleagues argue that, when designing solar greenhouses in Uzbekistan, it is essential to consider not only the level of insolation but also the seasonal temperature amplitudes. Their calculations demonstrate that integrating phase-change materials (PCM) and solar collectors into the heating system can reduce traditional energy consumption by 35–40 % while maintaining an optimal microclimate for plants.

International researchers such as H. Espitia and F. Velasquez, in their works on solar systems for protected agriculture, emphasize the efficiency of combined solutions—passive azimuthal orientation of greenhouses, the use of heat accumulators, and photovoltaic collectors. They highlight that such systems are particularly effective in regions with large diurnal temperature variations and dry air—conditions characteristic of much of Uzbekistan.

An analytical report by the OECD and the International Energy Agency on Uzbekistan's solar policy stresses the need for systematic solar-resource mapping to support agricultural projects based on renewable energy sources. The report underlines that the sustainable use of solar greenhouses is possible only with precise consideration of local climatic data and the economic optimization of energy systems.

Thus, a review of the literature shows that Uzbekistan's temperature-radiation conditions create unique prerequisites for the widespread adoption of solar greenhouses. However, successful implementation of such projects requires a comprehensive approach: accounting for regional microclimatic variations, applying energy-storage materials, and introducing hybrid heating and cooling systems that integrate solar energy into the greenhouse's overall thermal balance.

RESEARCH METHODOLOGY

The study utilizes long-term meteorological observations from the Hydrometeorological Service of Uzbekistan, as well as data from the Global Solar Atlas and Solargis databases. The collected information was processed using statistical grouping, comparative, and correlation analysis methods, which made it possible to identify the relationship between temperature indicators and solar radiation.

ANALYSIS AND RESULTS

Uzbekistan occupies one of the central positions in Central Asia. Its territory extends approximately between 37°10' and 45°35' north latitude and 56°00' and 73°10' east longitude. The country's landscape is predominantly composed of deserts, steppes, and semi-deserts.

In the south, high mountain ranges block the inflow of humid air masses from the Indian Ocean. The northern part, by contrast, is open, allowing cold air masses to penetrate freely into Uzbekistan's territory. As a

result, the climate is warm, sharply continental, and very arid. The continental nature of the climate manifests itself in sharp weather fluctuations not only throughout the year but also within a single day.

The territory of Uzbekistan is divided into several large physiographic regions: the Ustyurt, Lower Amu Darya, Kyzylkum, and Lower Zarafshan regions belong to the lowland subprovince, while the Surkhandarya, Kashkadarya, Middle Zarafshan, Hunger Steppe, Chirchik-Angren, and Fergana regions belong to the foothill–mountain subprovince.

The Ustyurt region, located in the far northwest between the Aral and Caspian Seas, is characterized by low winter temperatures: the average January temperature is -8 to -10 °C, with an absolute minimum reaching -35 to -38 °C. The winter lasts about four months. In summer, temperatures are high, reaching $+25$ to $+27$ °C in July, with a maximum of $+45$ to $+46$ °C.

The Lower Amu Darya region experiences cold winters, with an average temperature of -4 to -5 °C and a minimum of -29 to -34 °C. The winter lasts from 2 to 3.5 months. Summers are hot, with an average July temperature of $+25$ to $+26$ °C and a maximum of $+42$ to $+46$ °C.

In terms of winter temperature patterns, the Kyzylkum region differs little from the neighboring Lower Amu Darya area. The average January temperature ranges from -4 to -7 °C in the northwest to -1 to -2 °C in the southeast. The winter lasts about two months, and the absolute temperature minimum is -31 to -34 °C. Summers are hot, with an average July temperature of $+29$ to $+31$ °C and a maximum of $+44$ to $+46$ °C.

The Lower Zarafshan region encompasses the lower reaches of the Zarafshan River within the Bukhara and Karakul oases. The central part of the region consists of the Zarafshan valley. This mostly flat area occupies the southernmost position in the country; hence, winters here are milder. The average January temperature ranges from -2 °C to $+1$ °C, with an absolute minimum below -26 °C. Winter lasts about one month. Summers are hot, with July temperatures reaching $+45$ to $+46$ °C. The region's thermal resources range from 5000 to 5200 °C.

The Surkhandarya region, reliably shielded by mountain ranges from the northwest and northeast, has the mildest winter temperature regime. The average January temperature across most of the region is positive, reaching $+2.5$ to $+2.8$ °C in the plains and foothills. The absolute temperature minimum falls to -23 to -29 °C, which is relatively high for Uzbekistan. Summers are extremely hot: the average July temperature rises to $+28$ °C, occasionally reaching $+32$ °C, with an absolute maximum of $+49.6$ °C. The region possesses the highest thermal resources in the country — from 5100 to 6000 °C.

The Kashkadarya region covers the basin of the Kashkadarya River and the slopes of the surrounding mountain ranges. The territory of this region is directly influenced by desert areas. The average January temperature is above 0 °C, with minimum values dropping to -25 to -29 °C. The average July temperature exceeds $+20$ °C throughout the region, reaching up to $+31$ °C in some areas. The absolute maximum temperature ranges from $+47$ to $+49$ °C. The region's thermal resources are estimated between 4,600 and 5,300 °C.

The Middle Zarafshan region includes the Samarkand and Sanzar–Nurata intermountain basins and the slopes of the adjacent mountain ranges. The average January temperature varies from -0.5 to -1 °C to -2 to -3 °C, and winter lasts from 28 to 71 days. The absolute minimum temperature reaches -24 to -35 °C. The average July temperature is $+28$ °C, with maximum values between $+37$ and $+39$ °C. The total positive temperature sum is 4,500–4,600 °C in the plains and about 3,350 °C in the foothills.

The Hunger Steppe (Golodnaya Steppe) region encompasses the plain of the same name and the northern slopes of the Turkestan, Malguzar, and Nurata mountain ranges. The area is open to the north and northwest and bounded by mountains to the south and southeast. Therefore, it experiences relatively low winter temperatures: the average January temperature is -1 to -3 °C, winter lasts 1.5–2 months, and the minimum temperature drops to -35 °C. Summers are very hot, with average July temperatures of $+42$ to $+44$ °C. The total positive temperature sum for most of the region is 4,300–4,600 °C.

The Chirchik–Akhangaran region includes the Pre-Tashkent loess plain and the mountain ranges of the Western Tien Shan, dissected by the valleys of the Chirchik and Akhangaran rivers. A distinctive geographical feature of these ranges is their northeast–southwest orientation, with elevations decreasing in the same direction from 4,000–4,500 m to 2,000–1,500 m. The area is open to the west and southwest, allowing the inflow of moist air masses; as a result, the region receives more precipitation than most foothill and mountain areas of Uzbekistan.

The average January temperature on the plains is -1 to -1.5 °C and in the mountains -4 to -9 °C. The winter lasts about 1.5–2 months on the plains and around 4 months in the mountains. The minimum temperature drops below -30 °C on the plains and down to -34 °C in the mountains. Summers are hot, with average July temperatures of $+27$ °C on the plains and $+17$ °C in the mountains. The maximum temperatures reach $+42$ °C and $+31$ °C respectively. The total positive temperature sum ranges from 4,500–4,600 °C on the plains to about 2,000 °C in the mountains.

The Fergana region occupies the intermountain Fergana Valley and the slopes of its surrounding mountain ranges. The valley has an oval shape, approximately 370 km long and 140–200 km wide. In the southern part, mountain heights reach 5,000–6,000 m. The plains and foothills of the region, located within Uzbekistan, experience the lowest average January temperatures among all foothill–mountain regions of the country — from -2 to -4 °C. Winter lasts about 3.5 months. The minimum temperature reaches -26 to -27 °C, occasionally down to -30 °C. The average July temperature is $+26$ to $+28$ °C, with maximum values between $+40$ and $+42$ °C. The total positive temperature sum ranges from 4,300 to 4,600 °C.

From these data, it follows that Uzbekistan's thermal regime is characterized by a relatively cold winter and a long, hot summer. The coldest month is January: the average temperature in the plains ranges from -10 °C in the Ustyurt Plateau to $+2$ to $+3$ °C in the southeast (Termez, Sherabad). The absolute minimum temperature drops to -25 to -30 °C in the south and -35 to -38 °C in the northwest.

Even in winter, significant warm spells can occur across the country: in the plains, temperatures can rise to $+15$ to $+20$ °C, and in the mountains to $+5$ to $+10$ °C. With the onset of spring, warming occurs rapidly — by April, temperatures in most plains and foothill regions exceed $+10$ to $+15$ °C. However, short-term drops in temperature are still possible — down to -2 to -6 °C in the plains and -12 to -18 °C in the foothills.

The hottest month is July, and in the mountains — July–August. The average July temperature in the plains and foothills ranges from $+25$ to $+30$ °C, reaching $+31$ to $+32$ °C in Termez and Sherabad. The $+30$ °C isotherm extends across the central Kyzylkum Desert.

The defining features of Uzbekistan's climate are aridity, abundance of heat and sunlight, and high continentality, which manifest in both interannual and intra-annual variability of climatic elements.

Changes in maximum, minimum, and average monthly air temperatures across the country show that in the regions of Nukus, Fergana, Urgench, and Jizzakh, the average monthly temperature during January, February, March, November, and December is relatively low (around -4 °C), while in the rest of the country, winters are significantly warmer.

Uzbekistan is characterized by a high position of the Sun above the horizon throughout the year. In Tashkent, the solar elevation angle in June reaches 72° , in winter about 25° , and in Termez 76° . The duration of daylight is about 15 hours in summer and not less than 9 hours in winter.

Due to the high solar elevation and low cloud cover, the duration of sunshine in Uzbekistan is extensive. Across all plains, the annual average number of sunshine hours ranges from 2,500 to 3,000 hours (about 2,600 hours in Fergana and Kitab, 2,889 hours in Tashkent, and 3,059 hours in Termez).

Throughout the year, the country receives a total solar radiation of about 587 MJ/m^2 (140 kcal/cm^2) in the north and 670 MJ/m^2 (160 kcal/cm^2) in the south. Of this amount, 65–70% accounts for direct solar radiation. The summer months receive 4–5 times more heat than the winter months. Approximately 25–30% of the incoming radiation is reflected, while the majority is absorbed by the underlying surface. By the amount of total solar radiation, Uzbekistan ranks among the leading countries in the region.

During the warm season, in the plains, the radiation balance and its intensity vary little by latitude and depend mainly on the condition of the underlying surface—whether it is irrigated, and whether it is covered with natural or cultivated vegetation.

In the cold season, the radiation balance varies depending on the presence and condition of the snow cover. On average, a negative radiation balance is almost never observed in the plains of Central Asia (excluding mountain regions). In the coldest months, its mean values near the northern borders of the region are close to zero, while in the south they exceed 1 kcal/cm^2 . According to U.A. Antropova and M.B. Sitnikova (1961), the range of variation of the radiation balance in Central Asia shows that it represents the difference between absorbed total radiation and effective terrestrial emission.

When planning, designing, and operating facilities in agriculture, transportation, construction, and other sectors, it is essential to consider the wind direction and speed characteristics.

The wind regime of Uzbekistan is highly diverse. On the plains, it is primarily influenced by baric relief and typical synoptic processes of Central Asia. In foothill and mountain areas, the wind regime mainly depends on topographic features.

During autumn, winter, and spring, the plains of Uzbekistan are dominated by northeasterly winds, caused by air currents spreading from the southwestern periphery of the Siberian anticyclone between September and May.

The number of days with dust storms reaches significant values—28–32 days per year in areas adjacent to desert sand zones. Dust storms occur most frequently near Takhiatash, averaging 108 days per year. The duration of dust storms in Uzbekistan ranges from 1.5 to 5 hours, and only in the low foothills of the eastern Fergana Valley are they short-lived.

In the northern part of the Fergana Valley and on the southern slopes of the Chatkal, Fergana, and Bukhara ranges, northerly winds prevail. The average annual wind speed in the plains ranges from 3 to 5.5 m/s. In

foothill and mountain areas, the lowest average speeds are observed—1–3 m/s. At the entrance to the Fergana Valley, wind speeds increase to 4–5 m/s on average annually.

Across Uzbekistan, weak winds predominate: speeds of 0–1 m/s occur in 25–65% of cases, and 0–5 m/s in 70–98%. Wind speeds above 10 m/s are relatively rare, with a probability of 1–6%.

In most parts of the country, strong winds (above 10–15 m/s) are infrequent, occurring no more than 10–15 days per year. However, in certain areas, especially in the central part of the Kyzylkum Desert, their frequency is much higher—25–50 days per year. In the Ursatev area, 48 such days are recorded annually, and in Zaporozhye, up to 63 days per year with average speeds around 5 m/s.

An analysis of radiation and temperature regimes, along with the projected geothermal water reserves of Uzbekistan, shows that the country possesses substantial solar energy and geothermal resources. Therefore, when designing greenhouses and other energy-intensive facilities, it is essential to consider the specific climatic conditions of Uzbekistan.

A comprehensive assessment of these parameters confirms that the solar and geothermal energy potential in Uzbekistan is exceptionally high, providing broad opportunities for the development of alternative energy and protected agriculture.

CONCLUSIONS AND SUGGESTIONS

The conducted analysis shows that Uzbekistan's climate is characterized by a high degree of continentality, manifested in sharp seasonal and diurnal temperature fluctuations, a long hot summer, and a comparatively short but often cold winter. The main climate-forming factors—latitude, remoteness from oceans, and the presence of extensive mountain systems in the south—create conditions for a significant thermal and radiation potential. At the same time, there is pronounced spatial heterogeneity: in the northwestern regions (Ustyurt, Kyzylkum), the climate is harsher and more arid, whereas in the southern and foothill areas (Surkhandarya, Kashkadarya) it is milder and warmer.

The total solar radiation, providing 2,500–3,000 hours of sunshine per year, along with favorable temperature conditions, offers substantial opportunities for the development and use of renewable energy sources, primarily solar and geothermal. These factors make the country's climatic resources a strategic advantage for advancing a green economy, sustainable agriculture, and energy-efficient construction.

Thus, a comprehensive study of Uzbekistan's climatic characteristics is a necessary condition for rational environmental management, effective spatial planning, and the integration of modern technologies across various economic sectors. The efficient utilization of the nation's climatic potential can ensure the long-term sustainability of its socio-economic development and strengthen Uzbekistan's position as a leading region with high energy and natural potential in Central Asia.

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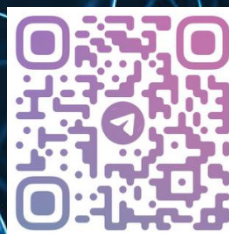
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