Climate risk assessment in Uzbekistan: surface air temperature anomaly for 2080-2099

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Abstract. This study presents a detailed analysis of projected surface air temperature anomalies in Uzbekistan for the late 21st century (2080-2099), utilizing a multi-model ensemble under the high emission scenario SSP5-8.5. Our findings indicate a significant warming trend across the country, with average mean surface air temperature anomalies expected to range from +4.5°C to +4.7°C compared to two historical reference periods (1995-2014 and 1950-2014). These projections suggest profound implications for Uzbekistan's water resources, agricultural productivity, and overall ecosystem health, highlighting the urgency of developing robust adaptation and mitigation strategies. The study underscores the importance of enhancing water use efficiency, adopting climate-resilient agricultural practices, and investing in sustainable infrastructure to combat the anticipated impacts of climate change. Additionally, it calls for collaborative efforts in policy-making, research, and community engagement to build resilience against the projected warming. The results emphasize the need for immediate action to safeguard Uzbekistan against the exacerbating effects of climate change, advocating for integrated approaches to climate resilience and sustainability. This research contributes to the broader understanding of regional climate dynamics under future emission scenarios, providing a foundation for targeted climate action in Central Asia.

1. Introduction

Climate change represents one of the most significant global challenges of the 21st century, with its impacts resonating across environmental, economic, and social spheres. Central Asia, a region characterized by its diverse geography and climate, is particularly vulnerable to the effects of climate change [1]. Among the countries in this region, Uzbekistan stands out due to its predominantly arid climate, reliance on agriculture for economic stability and livelihoods, and the complex water distribution systems that are sensitive to changes in temperature and precipitation patterns [2].

Recent decades have witnessed a growing concern regarding the rising surface air temperatures globally, a trend that is projected to continue, thereby exacerbating the vulnerabilities of regions like Uzbekistan [3]. This study focuses on the climate risk assessment for Uzbekistan, with a specific emphasis on the surface air temperature anomaly projections for the period 2080-2099 [4]. Understanding these temperature changes is crucial for developing effective adaptation and mitigation strategies to safeguard against the adverse impacts of climate change on agriculture, water resources, and overall societal well-being [5].

The Intergovernmental Panel on Climate Change (IPCC) has highlighted the critical nature of regional climate assessments in forming policies and actions that are tailored to the specific needs and challenges of individual regions [6]. In line with this, our research aims to provide a comprehensive analysis of future climate scenarios for Uzbekistan, employing state-of-the-art climate models and scenarios that consider both greenhouse gas emissions and socio-economic developments [7].

This study not only contributes to the global body of knowledge on climate change but also serves as an essential resource for policymakers, researchers, and practitioners involved in climate risk management and sustainable development in Uzbekistan and similar contexts. By offering detailed projections of surface air temperature anomalies

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for the late 21st century, this research underlines the pressing need for proactive measures in climate adaptation and resilience building, ensuring the long-term sustainability of vital sectors and the protection of vulnerable communities.

2. Materials and Methods

Our study focuses on Uzbekistan, a country in Central Asia known for its arid and semi-arid climate. Uzbekistan's geography, characterized by vast deserts and mountain ranges, presents unique climate challenges and vulnerabilities, making it an ideal case for assessing future climate risks associated with surface air temperature anomalies.

The primary data for our analysis of surface air temperature anomalies for the period 2080-2099 were sourced from the Climate Change Knowledge Portal (CCKP) of the World Bank Group. The CCKP provides access to global historical and future climate projections derived from a suite of Global Climate Models (GCMs) under various Representative Concentration Pathways (RCPs). For this study, we selected RCP 8.5 as our focus, considering its representation of a high greenhouse gas emissions scenario, which aligns with the current trajectory and provides a critical perspective on potential future climate risks [8, 9].

We utilized outputs from multiple GCMs available through the CCKP, focusing on those models that have been identified as performing well in the Central Asian region based on previous validation studies. The models were selected based on their ability to simulate key climatic variables, including temperature and precipitation, with a reasonable degree of accuracy. The future time slice considered for detailed analysis spans from 2080 to 2099, allowing for the assessment of long-term climate risks under the chosen emission scenario [10].

The analysis involved several steps. First, baseline climatology for the reference period (1981-2010) was established using historical data from the CCKP. This provided a benchmark against which future projections could be compared. Subsequently, temperature anomaly calculations were performed for the future period (2080-2099), defined as the difference between future climate projections and the baseline climatology. The anomalies were calculated for each GCM and then averaged to obtain a multi-model ensemble mean, which served to reduce individual model biases and uncertainties [11].

To assess the significance of the projected temperature changes, statistical analysis was performed using the Student's t-test, comparing baseline and future temperature distributions. This analysis helped in identifying regions within Uzbekistan where temperature changes are statistically significant at the 95% confidence level.

The study acknowledges the inherent uncertainties associated with climate modeling, including those related to the choice of emission scenarios, climate sensitivity, and regional climate model performance. Efforts were made to mitigate these uncertainties by using a multi-model ensemble approach and focusing on statistically significant results.

3. Results

Our analysis of future climate projections, based on a multi-model ensemble under the Shared Socioeconomic Pathways (SSP5-8.5), reveals significant changes in surface air temperature across Uzbekistan for the period 2080-2099. The results are presented with respect to different reference periods to provide a comprehensive view of the expected temperature anomalies.

The analysis indicates a pronounced increase in the annual mean surface air temperature across Uzbekistan, with an average anomaly of +4.5°C when compared to the reference period of 1995-2014. This projection underscores a significant warming trend under the high emission scenario SSP5-8.5, suggesting profound implications for the country's climate system, water resources, agriculture, and overall ecosystem health (Figure 1).

When extending the reference period back to 1950-2014, the average mean surface air temperature anomaly for 2080-2099 is projected to be +4.7°C. This slight increase in the temperature anomaly reflects the cumulative impact of greenhouse gas emissions over a longer historical baseline, highlighting the intensified warming effect experienced over the extended timeframe (Figure 2).

Focusing on the absolute average mean surface air temperatures for the future period, without directly referencing anomalies, the multi-model ensemble projects a significant rise in temperatures across Uzbekistan. The projected average mean surface air temperature for 2080-2099 is anticipated to be approximately 22°C, marking a stark increase from the historical average of 17.5°C recorded during the reference period of 1995-2014. This finding indicates the critical nature of the warming trend and its potential impacts on the regional climate (Figure 3).

This analysis reaffirms the projected average mean surface air temperature anomaly of +4.5°C for the period 2080-2099 compared to the reference period of 1995-2014, under the SSP5-8.5 scenario. The consistency of this result across different analytical approaches emphasizes the robustness of the projection and the significant warming trend expected under a high emission pathway (Figure 4).

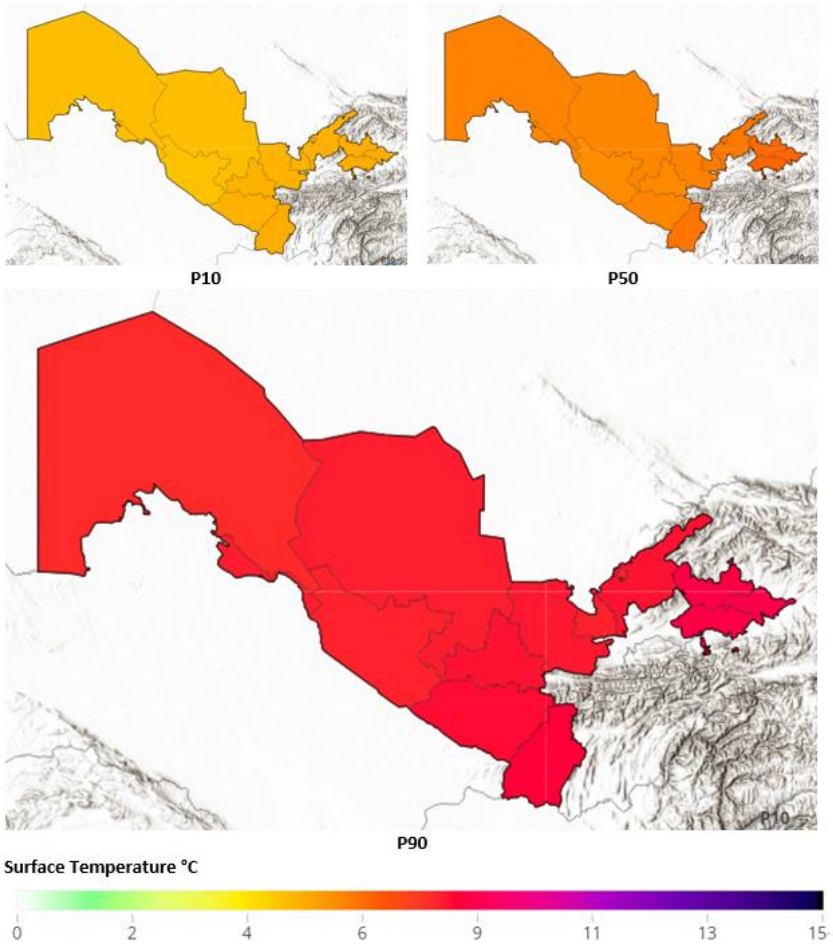

Fig. 1. Projected Average Mean Surface Air Temperature Anomaly for 2080-2099 (Annual) Uzbekistan; (Ref. Period: 1995-2014), SSP5-8.5, Multi-Model Ensemble

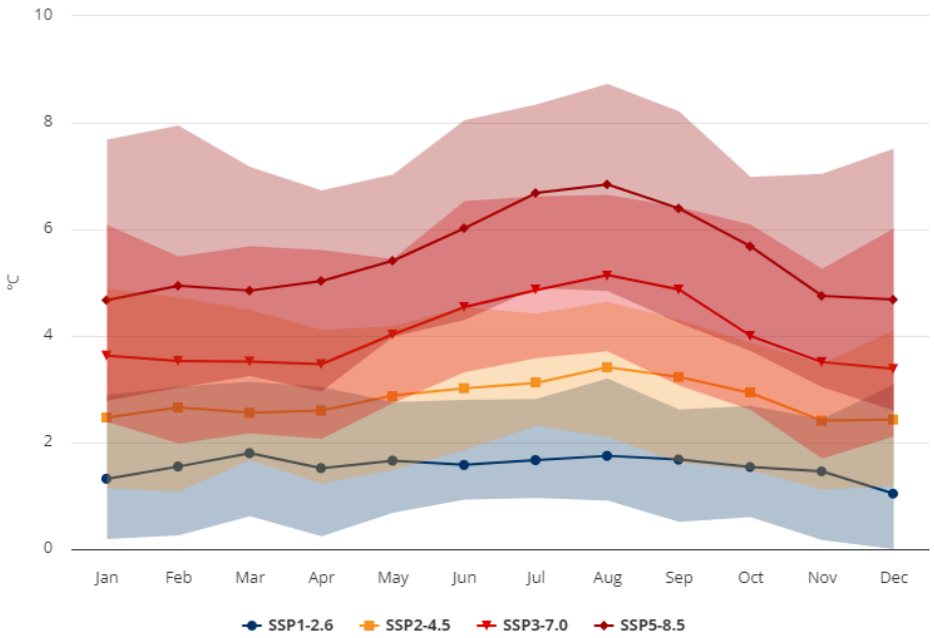

Fig. 2. Projected average mean surface air temperature anomaly for 2080-2099 Uzbekistan; (reference period: 1950-2014)

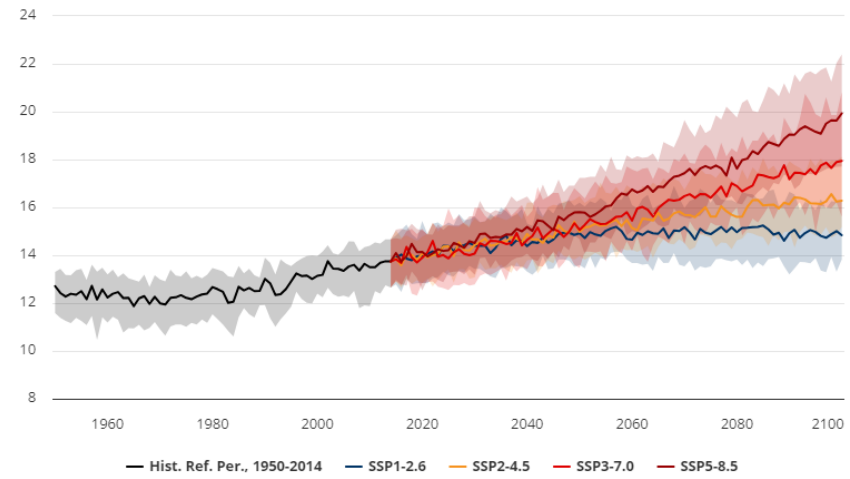

Fig. 3. Projected average mean surface air temperature Uzbekistan (reference period: 1995-2014), Multi Model Ensemble

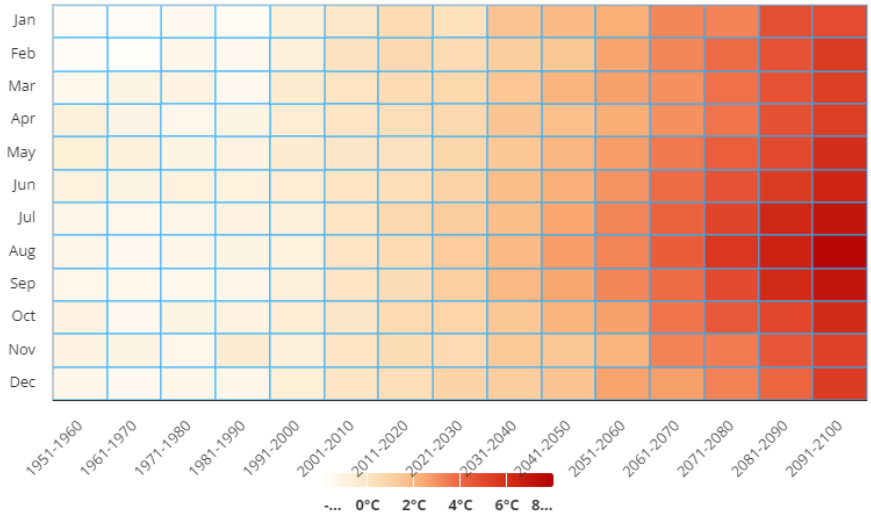

Fig. 4. Projected average mean surface air temperature anomaly Uzbekistan (reference period: 1995-2014), SSP5-8.5 – Multi Model Ensemble

4. Discussion

The results of this study, projecting significant increases in surface air temperature for Uzbekistan by the late 21st century, provide critical insights into the potential impacts of climate change under a high emission scenario (SSP5-8.5). These findings are in line with global patterns of warming, yet they highlight specific vulnerabilities and challenges for Uzbekistan, a region already grappling with the effects of temperature variability and water scarcity.

The projected temperature increase of +4.5°C to +4.7°C compared to the late 20th and early 21st-century baselines underscores a substantial shift in Uzbekistan's climate regime. Such anomalies signify not only hotter summers but also milder winters, which could have profound effects on the country's natural and agricultural systems. For instance, increased temperatures can exacerbate water evaporation from soil, reducing agricultural productivity in a country heavily reliant on irrigated farming [5]. Moreover, the warming is likely to alter precipitation patterns, potentially increasing the frequency and severity of droughts while simultaneously affecting the snowmelt rates in mountains, further challenging the water availability for agriculture, drinking, and industrial use.

The findings align with broader regional trends in Central Asia and global projections, emphasizing the universal challenge of climate change yet highlighting the unique vulnerabilities of specific regions [4, 9]. The consistency of our projections with other studies indicates the robustness of the climate models used and the reliability of their outputs for planning and policy-making purposes. It is critical to note that while Uzbekistan's projected temperature increases are alarming, they are part of a global pattern that requires both local and international responses.

In light of these projections, it is imperative for Uzbekistan to develop and implement robust adaptation and mitigation strategies. Adaptation efforts should focus on enhancing water use efficiency, transitioning to drought-resistant crops,

and improving irrigation techniques. Building resilience against climate impacts also necessitates investments in sustainable infrastructure, such as water-saving technologies and heat-resistant construction materials. On the mitigation front, Uzbekistan can contribute to global efforts by promoting renewable energy sources, enhancing carbon sequestration through afforestation, and adopting green technologies.

This study highlights the need for further research into region-specific climate change impacts and responses. Future studies should explore the socio-economic implications of temperature anomalies, including impacts on health, livelihoods, and economic stability. Additionally, there is a need for more detailed regional climate models that can provide finer-scale projections, aiding in the development of targeted adaptation and mitigation strategies.

While this study provides valuable insights, it acknowledges the inherent uncertainties associated with climate modeling, particularly regarding future emission scenarios and their socio-economic determinants. Moreover, the multi-model ensemble approach, while reducing individual model biases, cannot fully eliminate the uncertainties inherent in long-term climate projections.

5. Conclusions

This study has provided a comprehensive analysis of projected surface air temperature anomalies in Uzbekistan for the period 2080-2099, utilizing a multi-model ensemble under the high emission scenario SSP5-8.5. The key findings reveal a significant warming trend, with average mean surface air temperature anomalies ranging from +4.5°C to +4.7°C compared to two historical reference periods. These projections indicate a substantial shift in the climatic conditions of Uzbekistan, emphasizing the urgency of addressing the challenges posed by climate change.

The projected increase in temperatures underscores the potential for severe impacts on water resources, agriculture, and overall ecosystem health in Uzbekistan. The anticipated warming could exacerbate existing vulnerabilities, including water scarcity and agricultural productivity challenges, highlighting the need for immediate and sustained adaptation and mitigation efforts.

To combat the anticipated effects of climate change, it is imperative for Uzbekistan to enhance its climate resilience. This involves adopting efficient water use practices, transitioning to climate-resilient crops, and investing in sustainable infrastructure. Concurrently, mitigation strategies aimed at reducing greenhouse gas emissions are crucial for limiting the global temperature rise and, by extension, the severity of impacts experienced in Uzbekistan.

Addressing the multifaceted challenges of climate change in Uzbekistan requires a coordinated approach that integrates scientific research, policy-making, and community engagement. International cooperation is also vital in sharing resources, knowledge, and technologies that can aid in both mitigation and adaptation efforts.

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