7th Intercontinental Geoinformation Days

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Comprehensive temperature analysis of Türkiye between 2013 and 2023 using Google Earth Engine and ERA5 Dataset

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Keywords
Google Earth Engine
ERA 5
Temperature
Türkiye

Abstract

The climate system involves complicated interactions among diverse atmospheric and environmental elements, and it is essential to comprehend prolonged temperature trends for evaluating the consequences of climate change. In this study, an analysis of temperature changes in Türkiye over the period from 2013 to 2023 was realized. Employing advanced geospatial technology, specifically Google Earth Engine, and utilizing the ERA5 dataset, this study seeks to delve deeply into temperature trends throughout Türkiye. The incorporation of satellite imagery and detailed climate data with high resolution facilitates a detailed exploration of temporal and spatial fluctuations, enhancing a nuanced comprehension of climate dynamics. As climate change continues to exert its influence globally, a focused analysis of Türkiye's temperature trends becomes a necessity for informed decision-making in areas such as agriculture, water resource management, and urban planning. This study aimed to contribute valuable insights into the evolving climate change of Türkiye, considering the relationship between the changing environment and societal considerations. Results indicated a 0.20 Celsius degree increment over Türkiye during this ten-year period, while the Southeastern Anatolia Region faced the highest warming.

1. Introduction

"Global warming," as defined by Oxlade (2002) in its simplest form, is described as "an increase in the temperature of the Earth's atmosphere." On the other hand, "climate change" can be understood as significant alterations occurring over many years in the average conditions of climate (such as temperature, precipitation, or wind), regardless of the cause. Climate research has entered a new era marked by technological advancements that facilitate in-depth analyses of temporal and spatial climate patterns (Kocoglu and Gokalp, 2021).

Recent years have witnessed a paradigm shift in climate data analysis with the emergence of Google Earth Engine, a cloud computing platform that enables the processing of vast geospatial datasets (Gorelick et al., 2017). Simultaneously, the ERA5 dataset, developed by the European Centre for Medium-Range Weather Forecasts (ECMWF), has gained prominence for its high spatiotemporal resolution and accuracy in representing climate variables (Hersbach et al., 2020).

The urgency of understanding and mitigating climate change impacts has prompted an influx of research, especially focused on regional climate dynamics. Recent publications highlight the significance of high-resolution datasets like ERA5 in capturing fine-scale climate variations (Jones et al., 2019). Moreover, studies emphasizing the integration of satellite-derived information, such as those conducted with Google Earth Engine, underscore its efficacy in monitoring and understanding climate trends (Smith et al., 2021).

As Türkiye grapples with the implications of a changing climate, the need for localized, up-to-date analyses becomes imperative. Recent works explain the importance of region-specific climate assessments for informed decision-making and adaptive strategies. This study contributes to this body of knowledge, offering a comprehensive examination of geographic regions of Türkiye's temperature trends over the past decade. However, climate change, including global warming, has begun to manifest its effects on Turkey. Rising temperatures and increased aridity have heightened the demand for water resources in agricultural areas, leading to a reduction in water availability. Drought issues are

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Cite this study

Sukkar, A., Alganci, U., & Seker, D. Z. (2023). Comprehensive Temperature Analysis of Türkiye between 2013 and 2023 Using Google Earth Engine and ERA5 Dataset. Intercontinental Geoinformation Days (IGD), 7, 250-253, Peshawar, Pakistan

particularly prominent in the Southeastern Anatolia region. This situation adversely affects agricultural production and may result in economic challenges.

Additionally, climate change poses threats to coastal areas due to rising sea levels. The coasts of the Marmara, Aegean, and Mediterranean regions are vulnerable to erosion and flooding as a consequence of sea-level rise. This situation threatens ecosystems and settlements along the coastline of the country.

Due to Turkey's distinct geographic location and vulnerability to climatic fluctuations, in-depth climate research is necessary. This study endeavors to conduct an exhaustive analysis of Türkiye's temperature dynamics between 2013 and 2023, leveraging state-of-the-art tools such as Google Earth Engine and the ERA5 dataset.

2. Method

2.1. The study area and data set

The selected study region is Türkiye, which is situated at the intersection of Southeast Europe and Southwest Asia, east of the Mediterranean, north of the Aegean Sea, and south of the Black Sea. This strategic location permits a wide range of geographical characteristics and climate types. Turkey is divided into seven geographical regions: Marmara, Aegean, Mediterranean, Central Anatolia, Black Sea, Southeastern Anatolia, and Eastern Anatolia (Figure 1).

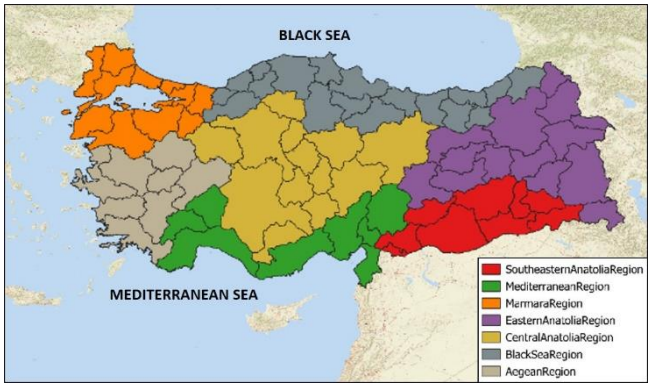

Figure 1. The geographic regions of Türkiye

Each region exhibits distinct characteristics in terms of climate, vegetation, and agricultural activities. The Mediterranean region is characterized by a hot and dry climate, while the Aegean region typically experiences a mild climate. Central Anatolia has an inland climate, whereas the Black Sea region receives abundant rainfall, resulting in lush green vegetation. This diversity contributes to Türkiye's richness in agriculture and natural resources.

In response to these challenges, Türkiye is actively working to combat climate change and promote a sustainable future. Initiatives include a shift towards renewable energy sources, strengthening water management policies, and increasing awareness about environmental issues. These efforts aim to enhance the country's resilience to climate change and contribute to global sustainability.

The 2m temperature component of the ERA5-Land dataset was analyzed for each geographical region of Türkiye using the Google Earth Engine (GEE) platform. The ERA5-Land-Landset is an enhanced edition of ERA5, provided by the European Center for Medium-Range Weather Forecasts (ECMWF). It has a finer spatial resolution of 0.1° compared to 0.25° for ERA5 (Tan et al., 2023). The 2 m temperature parameter is measured at a height of 2 meters above sea level or land.

ERA5 stands for the Fifth Generation of the European Centre for Medium-Range Weather Forecasts (ECMWF) Reanalysis dataset. It is a comprehensive global atmospheric reanalysis dataset, providing a detailed and consistent record of the Earth's climate from 1940 to the present. ERA5 offers a high spatial resolution of approximately 31 km globally, allowing for detailed analysis of weather and climate phenomena. It provides hourly data, enabling a more granular understanding of climate variability and trends. Additionally, it covers a wide range of meteorological variables, including temperature, precipitation, wind speed, and more, facilitating diverse research applications.

3. Methodology

Climate change is a pressing global concern with far-reaching implications for ecosystems, economies, and human well-being. Thorough studies of regional climate patterns are crucial as countries work to comprehend and lessen the effects of climate change. This study focuses on Türkiye, a region situated at the crossroads of Europe and Asia, and endeavors to provide a thorough examination of its temperature dynamics over the decade spanning from 2013 to 2023.

In recent years, advancements in geospatial technology have revolutionized our capacity to analyze large-scale environmental datasets. Google Earth Engine, a cloud-based platform for planetary-scale environmental data analysis, and the ERA5 dataset, a high-resolution reanalysis dataset developed by the European Centre for Medium-Range Weather Forecasts (ECMWF), offer unprecedented opportunities for detailed and accurate climate studies. By leveraging these tools, our research aims to unravel the intricacies of Türkiye's temperature trends, employing a combination of satellite imagery, climate modeling, and ground-based observations.

The significance of such a study is underscored by Türkiye's unique geographic and climatic characteristics, which render it vulnerable to the impacts of a changing climate. Understanding how temperatures have evolved over the past decade is crucial for anticipating future climate scenarios and developing adaptive strategies. This analysis contributes to the broader scientific discourse on regional climate change impacts, providing valuable insights that can inform policy decisions, resource management, and societal resilience.

As we delve into this comprehensive temperature analysis, we draw upon a range of authoritative sources, including the ERA5 dataset, which has become a cornerstone in climate research for its accuracy and high spatiotemporal resolution. Additionally, insights from peer-reviewed scientific literature and international

climate reports form the foundation of our investigation, ensuring the reliability and validity of our findings. Through this research, we aim to contribute to the growing body of knowledge on regional climate dynamics, fostering a deeper understanding of the challenges posed by a changing climate in Türkiye and beyond.Google Earth Engine (GEE) is a cloud-based platform for planetary-scale geospatial analysis that brings Google's massive computational capabilities to bear on a variety of high-impact societal issues including deforestation, drought, disaster, disease, food security, water management, climate monitoring, and environmental protection (Gorelick et al., 2017). It is one of the most widely used tools in the field as an integrated platform designed to empower not only traditional remote sensing scientists but also a much wider audience needed to utilize traditional supercomputers or large-scale commodity cloud computing resources.

Through the GEE, the air temperature of Türkiye and its different geographical regions was analyzed between 2013 and 2023. First, the daily temperature of October 2023 was analyzed. Then the October months for the last decade were investigated, and finally, the average annual temperature over the past decade was analyzed and plotted.

4. Results and Discussions

Globally, October 2023 was the warmest October ever recorded. In addition, it was the fifth consecutive month of record-warm temperatures. However, in Türkiye, it was not the highest October, it is the 3rd in the last decade and the 7th in Türkiye's record (MGM, 2023). The average temperature of October 2023 was 14.4° C. while in 2019 and 2020 was 15.1° C and 16.3° C respectively (Figure 2).

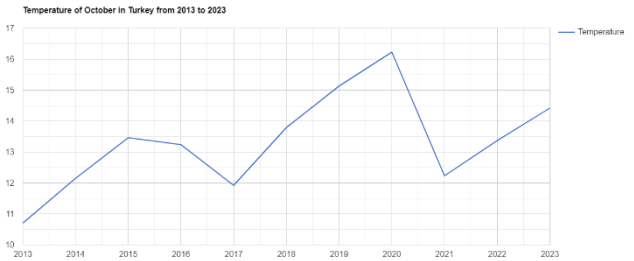

Figure 2. The monthly average temperature of October months in Türkiye (2013-2023).

The highest temperature observations of October months through the last decade were seen in the Southeastern Anatolia region (Figure 3), followed by the Mediterranean, Aegean, and Marmara regions.

The lowest and highest average annual temperatures during the last decade occurred in 2013 and 2018, respectively. The average annual temperature in 2013 was 11.15 degrees Celsius, whereas it was 12.5 degrees Celsius in 2018. However, the year 2023 is almost guaranteed to be the warmest on record (Figure 4). Moreover, the highest and lowest annual temperatures were recorded in the Southeastern Anatolia and Eastern Anatolia regions respectively (Fig. 5).

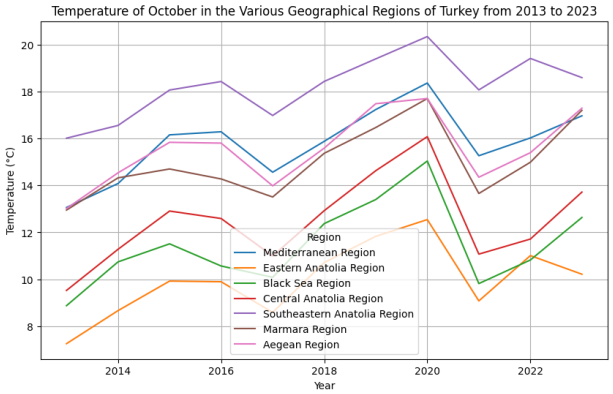

Figure 3. The monthly average temperature of October months in Türkiye's geographical regions (2013-2023).

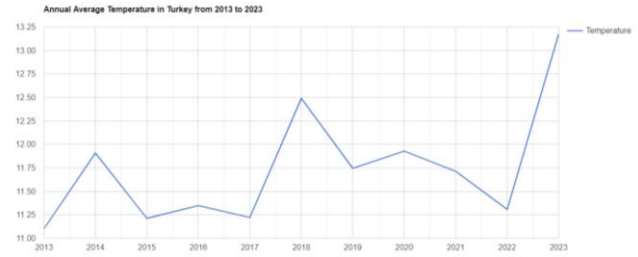

Figure 4. The annual average temperature of Türkiye (2013-2023).

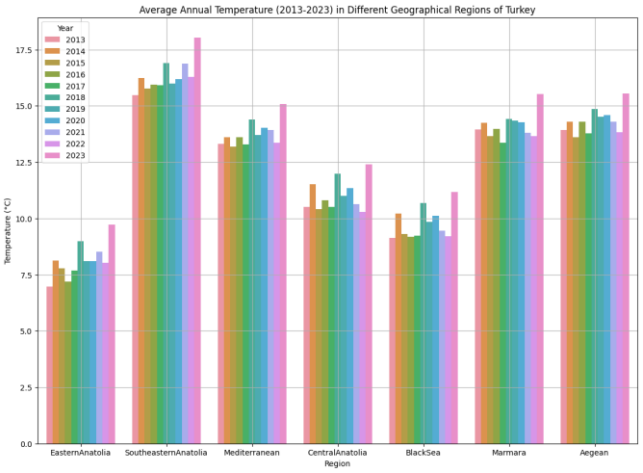

Figure 5. The annual average temperature of Türkiye's geographical regions (2013-2023).

3. Discussion

ERA5 and ERA5 Land datasets were validated and applied in several studies for several purposes in Türkiye. In all of these studies, the datasets have shown very high correlation levels with the ground truth data (Hisam et al., 2023; Karaman, & Akyürek, 2023). Through the last decade (2013-2022), the average annual temperature in Türkiye has been raised by 0.20° C. The same results also were obtained by (Güler & Erlat, 2023), which is almost 3 times the global average. The peak annual average temperatures were recorded in 2018, and 2020, with an average of 12.49° and 11.93° C respectively. The observational temperature of the Southeastern Anatolia region was, on average, higher during of the 10-year periods than in the other six regions. Also, it was the highest between 1951 and 2020 (Yilmaz, 2023).

4. Conclusion

This study investigated the temperature change trends in Türkiye between 2013 and 2023 using Google Earth Engine platform and ERA5 Dataset. When examining the average temperature from January to October for the calendar year and comparing it to the corresponding periods of previous years, it is evident that the worldwide average temperature for 2023 is the highest ever recorded. The average temperature of October 2023 in Türkiye was the 3rd highest October over the past decade. The annual average temperature in Türkiye has risen and fallen and reached its maximum in 2018 when the temperature was 12.5° C. Southeastern Anatolia is the warmest region in Türkiye in the last 10 years, there is a significant difference in terms of temperature between Southeastern Anatolia and other regions exceed 2 degrees. It is highly probable that the current year, specifically 2023, will establish a new record as the warmest year ever documented in both Türkiye and worldwide. Especially, with the current record levels of greenhouse gases in the atmosphere.

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