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Innovative trend analysis of downward surface shortware radiation in Türkiye during 1984-2021

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Abstract

Downward Surface Shortwave Radiation (DSSR) is a crucial factor that plays a significant role in maintaining the Earth's surface energy balance. It refers to the solar radiation that reaches the surface, contributing to various environmental processes and influencing climatic conditions. Understanding the trends in DSSR is particularly important in areas prone to forest fires, as it can provide valuable insights into the underlying factors that contribute to fire risk. To investigate the trends of DSSR data in regions susceptible to forest fires, this study employed an innovative trend analysis methodology. The focus was on three provinces in Turkey: Antalya (specifically Manavgat and Akseki), Mugla (particularly Datça), and Rize (specifically the Central area). These provinces were chosen due to their high incidence of fires, making them ideal study areas for examining the relationship between DSSR and fire occurrences. The analysis covered a significant time span from 1984 to 2021 and relied on the Merra-2 dataset, a reliable and comprehensive dataset provided by NASA. This dataset includes a wide range of atmospheric parameters, including DSSR, allowing researchers to assess long-term trends and patterns. By analyzing the DSSR trends in these regions, the study aimed to gain insights into the potential connections between variations in DSSR and the occurrence of forest fires.

1. Introduction

Downward Surface Shortwave Radiation (DSSR) plays a fundamental role in maintaining the radiation balance at the Earth's surface, serving as a primary source of energy that drives heat (sensible and latent) and gas (such as water vapor and carbon dioxide) exchanges between oceanic ecosystems (or terrestrial) and the atmosphere. DSSR provides the energy necessary for various ecological and atmospheric processes, influencing temperature patterns, evaporation rates, and the overall dynamics of the Earth's climate system. Understanding the characteristics and trends of DSSR is essential for comprehending the intricate interactions between the land, ocean, and atmosphere, and for studying the impacts of climate change and human activities on these crucial exchanges of energy and gases. (Lorenzo et al., 2015).

The MERRA-2 utilized in this analysis incorporates spectral channels from both the infrared and visible spectra, along with information on atmospheric composition and albedo, to calculate the DSSR reaching the Earth's surface. DSSR, as a vital component of the surface energy budget, holds significant importance in climate studies and serves as a crucial input for various applications. It is employed in land surface assimilation models and surface energy budget models, aiding in the estimation of components of heat flux components over coastal areas for the purpose of driving models of ocean circulation (Ilčev, 2017). Additionally, in the domain of agriculture, DSSR data is employed as an input parameter for crop modeling (Ilčev, 2017). Moreover, in hydrology science, DSSR plays a key role in drainage basin and run-off analysis, enabling the assessment of flood risks and facilitating dam monitoring. Notably, DSSR is also employed in monitoring fire risks since high irradiance values can contribute to surface drying, impacting fire conditions.

This study focused on conducting a trend analysis of DSSR and at the same time investigating its potential role as a contributing factor in forest fires risk.

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2. Method

2.1. MERRA-2

Within the scope of the study, NASA's MERRA-2 reanalysis data, which is a NASA mission, was utilized.

MERRA-2 (Modern-Era Retrospective Analysis for Research and Applications, Version 2) offers data starting from 1980 and serves as a replacement for the original MERRA dataset. The transition was prompted by notable improvements in the assimilation system, allowing for the integration of cutting-edge microwave observations and hyperspectral radiance, coupled with GPS-Radio Occultation data. Additionally, MERRA-2 incorporates NASA's ozone profile observations, which commenced in late 2004. Notable advancements have been made in both the GEOS model and the GSI assimilation system within MERRA-2 (Nakkazi et al., 2022). The spatial resolution remains comparable to MERRA, with an approximate resolution of 50 km in the latitudinal direction.

Monitoring of DSSR (Downward Surface Shortwave Radiation) from ground-based stations began around the world in the late 1950s. However, because these stations are sparse and heterogeneous, ground measurements alone do not provide adequate information to derive the global radiation distribution. In addition to satellite remote sensing techniques, reanalysis estimates represent a feasible approach for generating long-term global DSSR data that is practical in terms of time and cost. (Zhang et. al.,2016)

Evaluating the spatial and temporal trends of DSSR is crucial for understanding weather and climate variability, as well as for investigating its potential impact on forest fires (Zuluaga et. al., 2021).

2.2. Study Area

In recent years, Türkiye has experienced extreme weather events such as floods and fires, which can be attributed to global climate change (Şahan et al.,2022, Tuğaç, 2023). These events have been characterized by excessive and irregular precipitation, as well as extreme temperatures. In order to better understand these phenomena, the DSSR data of Antalya province, known for having the highest number of fires in the country, and the neighboring province of Muğla, were analyzed for the period of 1984 to 2021. Furthermore, the DSSR data of Rize province, which receives consistent precipitation and has a lower incidence of fires, was also examined. Innovative trend analysis methods were employed to determine the trends in these provinces and gain insights into their respective climatic patterns. All study points shown in Figure 1.

2.3. Innovative Trend Analysis (ITA) Methodology

The innovative trend analysis (ITA) method, developed by Şen (2012), has introduced a novel approach to trend research by allowing for time series analysis without any assumptions. This method has gained popularity due to its simplicity, as it can be easily applied without requiring any specific assumptions, and trends and variations can be identified through graphical representations. The ITA methodology also offers the flexibility to determine trends within visually distinct sub-groups, such as low, medium, and high, rather than analyzing the data as a whole. The adaptability of the methodology and its outputs have captured the interest of numerous researchers in the scientific field (Birpınar et al., 2023, Şişman et al., 2022, Dabanlı et al., 2016).

$$S = \frac{m_2 - m_1}{\frac{n}{2}}$$

where, S is the innovative trend slope, m_1 and m_2 are the arithmetic average of the first and second halves of the series, and n represent the total number of data.

The whole application was implemented in Excel and MATLAB Environment.

Figure 1. Study Area

3. Results

Within the scope of this research, an innovative trend analysis method has been utilized to examine the monthly trends of Merra-2 DSSR data from 1984 to 2021 in regions prone to forest fires namely Antalya (Manavgat, Akseki), Muğla (Mesudiye), and flood risk e.g., Rize.

In this study, trend direction and trend slope of monthly DSSR data in determined locations have been analyzed using ITA methodology, trend magnitude calculated with the equation 1 for each location are given in Table 1. When ITA graphs and Table 1 are examined, it is seen that DSSR trends are generally increasing. When the ITA graphs are commented in detail, the trend increases in high DSSR values in July and August, the forest fires are frequently obtained in Manavgat, Akseki and Datça, are at crucial levels to be followed. On the other hand, if we discussed the ITA graph prepared for Rize, it is seen that DSSR trends increasing in summer months when floods occurs.

The DSSR trend slope reaches its maximum of 0.093 %, 0.048% and 0.053% in April for Manavgat, Datça and Rize respectively.

4. Discussion

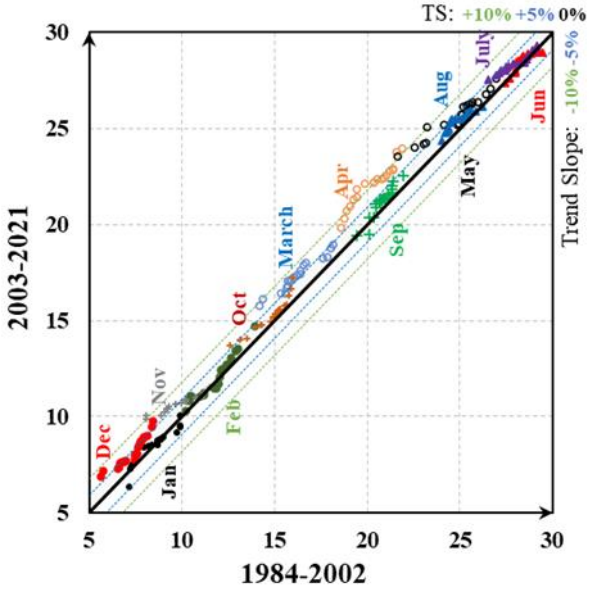
This study has assesed DSSR trends in Türkiye during 1984-2021, utilizing MERRA 2 gridded products as the primary data resources. While numerous research works have identified the trends of DSSR in Asia, Europe and America, there has been few investigation DSSR trends in Türkiye.

The existing researches indicates that there has been noteworthy decadal variability in Surface Solar Radiation, characterized by an increase known as "global brightening" from 1980s across the globe (Stanhill and C. S, 2008; Takemura and Ohumura, 2009). Our results are consistent with the prevailing trends observed in the current body of literature.

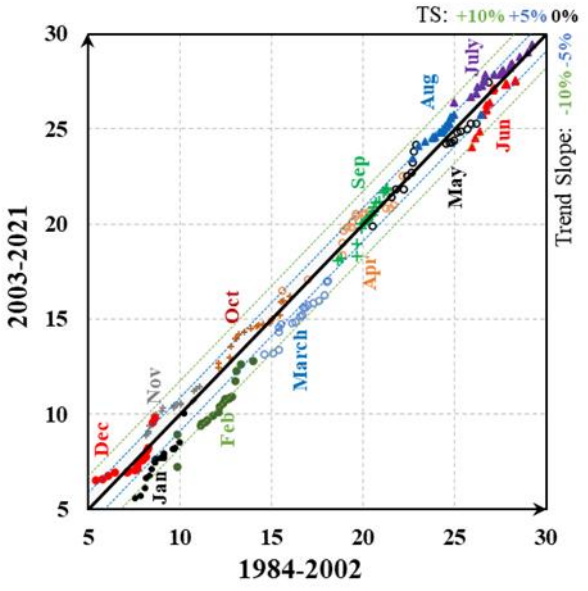
Increases in the frequency of forest fires events show similarities with the increasing trends in the DSSR data, especially in July and August of the summer shown as Figure 2.

Table 1. Trend slope (%) for DSSR during 1984-2021

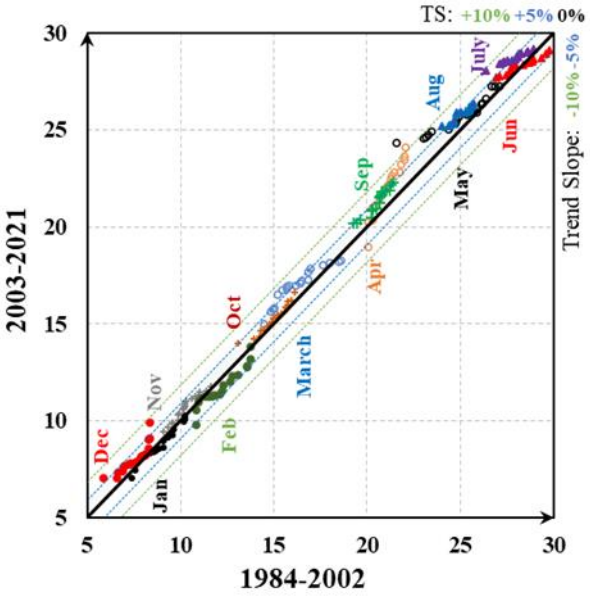
Location Months	Manavgat	Akseki	Datça	Rize
January	-0.002	-0.077	-0.009	0.017
February	0.011	-0.087	-0.025	0.025
March	0.058	-0.071	0.036	0.014
April	0.093	0.016	0.048	0.053
May	0.044	-0.007	0.038	0.041
June	0.022	-0.007	0.021	0.032
July	0.021	0.032	0.047	0.019
August	0.023	0.034	0.040	0.046
September	0.020	-0.002	0.039	0.027
October	0.025	0.021	0.013	0.019
November	0.041	0.037	0.021	0.033
December	0.045	0.008	0.026	0.034



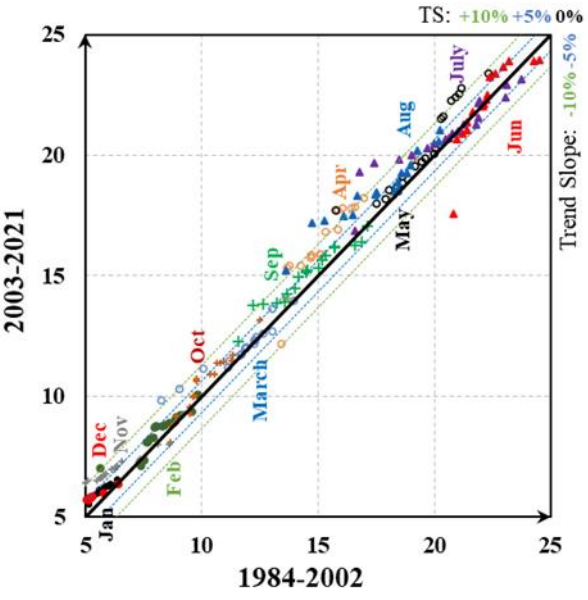
Manavgat ITA graph



Akseki ITA graph



Datça ITA graph



Rize ITA graph

Figure 2. Antalya (Manavgat Akseki), Muğla (Datça) and Rize ITA graphs during1984-2021 years

5. Conclusion

The trends of DSSR data should be expected to have an impact on the hydrological cycle, agricultural production and natural ecosystem. The findings of this study have the potential to contribute to advancing knowledge in the field of increasing DSSR trend' impacts on Türkiye, specifically with regard to fire and flood risk

management, solar energy production, hydrological and agricultural modeling.

As a result, accurate identification of the DSSR trends specifically holds great significance in the realms of fire risk management.

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