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Exploring the difference between Standard Precipitation Evapotranspiration Index (SPEI) from in-situ meteorological stations and SPEIbase

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Abstract

Drought has destructive impacts on all sectors, such as environmental and agricultural sectors, as well as water resources management. The first step in drought evaluation and monitoring is determining the drought index. Because of its vital role, this research aims to investigate the difference between Standardized Precipitation Evapotranspiration Index (SPEI) at different timescales, 3, 6, 9, and 12-month, based on in-situ meteorological stations and SPEIbase, which is a satellite global product. They were compared in two ways: 1) using drought categorization and 2) drought index (SPEI values). The results showed a significant difference between the results obtained from each dataset. Based on the drought categorization, only 61% of the months were within the same categories. The dominant months were within the normal category (N) because of a wide range ranging between -1 and 1. Furthermore, SPEI values calculated using SPEIbase gave more extreme drought events (ED). However, SPEI using in-situ meteorological stations gave more severe drought events (SD) for all time scales. Also, a significant fluctuation can be noticed based on the difference between SPEI from the two datasets. These results can be attributed to many reasons, such as using different time periods, calculating potential evapotranspiration, and the reliability of the precipitation and potential evapotranspiration.

1. Introduction

As a natural disaster, drought globally poses substantial difficulties and challenges to water resources, societies, agriculture, and the environment (Wilhite, 2000 & Şen and Almazroui, 2021). In the 1990s, economic losses due to environmental hazards were more than 400 billion USD (Barbour et al. 2022). The high increase in frequency and intensity of drought events raised the concern of hydrologists, researchers, policymakers, and decision-makers (Mishra and Singh, 2010 & Abu Arra and Şişman, 2023). Monitoring and evaluating drought is pivotal for water resources management and developing drought mitigation plans. There are numerous drought indices, and each index has its parameters and methods. The Standardized Precipitation Evapotranspiration Index (SPEI) is one of the most widely used drought indices in the hydrology fields (Vicente-Serrano et al. 2010). The SPEI calculates the meteorological drought by considering precipitation and evapotranspiration (Vicente-Serrano et al. 2010). The drought indices have been proven to be a valuable approach to drought monitoring. They are used as a first step for monitoring and evaluation, enabling managers and decision-makers to understand and take action for drought impacts (Chong et al. 2022; Yong et al. 2023; Van Loon, 2015).

To calculate SPEI, both in-situ meteorological stations and satellite and remote sensing data such as SPEIbase (https://spei.csic.es/database.html) can be used. They are two distinct methods for collecting weather information. Each source has its advantages and disadvantages. For in-situ meteorological stations, the stations are physically situated on the ground at a specific geographic location. The collected data is real-time and on-site data. It is generally highly accurate, specifically for automated stations (Şen, 2). However, the main problem in in-situ stations is the spatial distribution of it and the data availability (Levizzani and Cattani, 2019). On the other side, the global products are

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collected instruments on aircraft. The data is collected using sensors. The accuracy can vary depending on the sensors and instruments used. These satellites and global products have a large scale, such as 0.5 degrees or 31 km spatial resolution (Copernicus Climate Change Service (C3S), 2017).

Some areas are covered by one or two grid data (remote sensing data). At the same time, the number of in-situ meteorological stations is limited. Subsequently, there is a huge need to investigate the difference between in-situ meteorological stations and satellite and remote sensing data regarding spatial distribution and small-scale areas for drought evaluation and monitoring. This research mainly aims to investigate the difference between SPEI at different timescales (3, 6, 9, and 12 months) calculated from in-situ meteorological stations and SPEIbase (satellite data) in terms of drought severity and drought categorization. Also, to compare the drought characteristics for each SPEI value.

2. Method

2.1. Data

To investigate the difference between SPEI from in-situ meteorological stations and SPEIbase, the application is conducted for the monthly precipitation and temperature records between 1951 and 2020 (70 years) from Florya meteorological station in Istanbul (**Figure 1**). The precipitation and temperature data were checked for consistency and continuity controls. **Table 1** summarizes the main information about Florya meteorological station.

2.2. SPEI from in-situ stations

The SPEI method was developed in 2010 by Vicente-Serrano et al. The difference between precipitation and evapotranspiration data is fitted to an appropriate probability density function (PDF), and the goodness-of-fit tests are controlled and checked by Kolmogorov-Simirnov and Chi-Square (Stephens, 1970). The last step is the normalization procedure of probabilities into normal PDFs. The evapotranspiration was calculated using the Thornthwaite method (Thornthwaite, 1948). Additional details regarding SPEI can be found in (Vicente-Serrano et al. 2010).

2.3. SPEI from SPEIbase

The SPEI values were taken directly from SPEIbase (https://spei.csic.es/database.html, accessed on 28 October, 2023). It provides data with 0.5 degrees resolution, and the time period started from 1901. The SPEI values were downloaded for 3, 6, 9, and 12-month timescales between 1951 and 2020 (70 years).

2.4. The difference between SPEI from in-situ meteorological stations and SPEIbase

The difference between SPEI values was evaluated using drought categorization defined by (McKee et al. 1993) and summarized in **Table 2.** Months with the same drought category were treated the same. Also, the comparison was done using SPEI severity values.

Table 1. Geographical and climatic information for Florya station.

Station's Name	Station ID	Latitude (N)	Longitude (E)
Florya	17636	40.97	28.78
	Mean Precipitation (P) - mm	Standard deviation (mm)	
	53.78	44.08	
	Mean Temperature (T) - °C	Standard deviation (°C)	
	14.42	6.74	

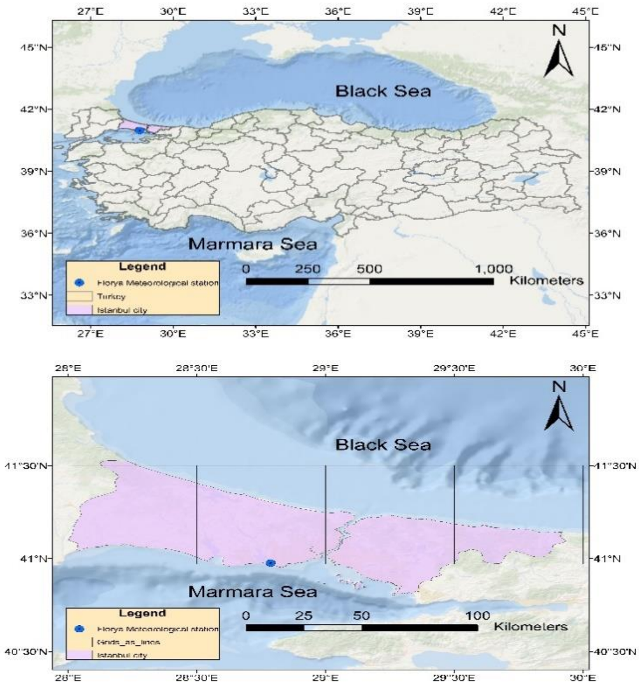

Figure 1. Location of Istanbul city, the Florya meteorological station, and the grid data obtained from the SPEIbase.

Table 2. Drought categorization for SPEI (McKee et al. 1993).

SPEI values (Drought Index_DI)	Drought categorization
2.00 ≤ DI	Extreme wet (EW)
1.50 ≤ DI <1.99	Severe wet (SW)
1.00 ≤ DI <1.50	Moderate wet (MW)
-0.99 ≤ DI <1.00	Normal (N)
-1.50 ≤ DI < -1.00	Moderate drought (MD)
-2.00 ≤ DI < -1.50	Severe drought (SD)
-2.00 > DI	Extreme drought (ED)

3. Results

The comparison process was done in two ways. The first way is drought categorization (**Table 2**). Each month was categorized based on in-situ meteorological stations and SPEIbase. The (SPEI_station) indicated the drought category based on the SPEI value from the in-situ station. And the (SPEIbase_grid) indicated the drought category based on SPEIbase. **Table 3**, **Table 4**, **Table 5**, and **Table 6** showed the number of months that fall within a specific drought categorization regarding SPEI3, SPEI6, SPEI9, and SPEI12 using in-situ meteorological stations and SPEIbase, respectively. The sum in these tables was the month's summation for each category. It can be noticed that the drought category was different based on SPEI data. The intersection in drought categories was about 530 months from about 840 months. The most dominant drought category was normal, which is between -1 and 1.

Increasing the timescale led to increasing the number of intersection months. For SPEI3, it was 501 months, and for SPEI12, it was 536 months. Also, in some months, according to in-situ stations, the drought category was dry, and according to SPEIbase, the drought category was wet. The empty values were the drought categories without any month. The number of extreme drought months for SPEI12 using in-situ stations was 24.

The second way for comparison was depending on the SPEI drought values. This comparison was conducted for the last 20 years, from 2000 to 2020. This way was essential to compare SPEI values by month scale and investigate the difference between them for each month. **Figure 2**, **Figure 3**, **Figure 4**, and **Figure 5** showed the difference between SPEI values for SPEI3, SPEI6, SPEI9, and SPEI12, respectively. The orange color was the SPEI values obtained from the in-situ meteorological station, the beige color was the SPEI values from SPEIbase, and the bronze color was the intersection months between SPEI calculated from in-situ meteorological stations and SPEIbase.

For short timescales like 3 and 6 months, the differences between in-situ stations and SPEIbase were observed and more considerable. In 2015, the SPEI values using the Florya station were about -1.0, and using SPEIbase, SPEI was about 2.0, which indicated a high difference between them. For more details, Fig. 2-5, showed the differences between them.

4. Discussion

The main objective of this research was to investigate the difference between SPEI from in-situ meteorological stations and SPEIbase. The difference between them was conducted in two ways: drought categorization and SPEI values. About 60% of the months were with the same drought category, which indicated a high disparity between them. Also, SPEI values calculated using SPEIbase gave more extreme dry events (ED) but less severe dry events (SD). This result can be attributed to three main reasons: 1) the different time periods that are used for each way. For stations, it was 70 years, and 120 years for SPEIbase. 2) PET may be different because the methods used were different. 3) The quality and consistency control for each data set. For SPEIbase, the area covered by one grid is large and was about 3000 km^2.

The high number of months with normal drought category (N) was because the normal category widely ranged between -1 and 1. Also, SPEIbase was more conservative for a short timescale because the drought months were more than in-situ data.

Table 3. The difference between SPEI from the in-situ meteorological station and SPEIbase at a 3-month timescale based on drought categorization.

		SPEIbase_Grid							
		EW	SW	MW	N	MD	SD	ED	sum
SPEI_Station	EW	9	6		1				16
	SW	10	17	14	3				44
	MW	7	20	25	42	1			95
	N	8	14	52	393	60	6	1	534
	MD				36	40	22	2	100
	SD		1		8	11	12	6	38
	ED				0	1	5	5	11
	sum	34	58	91	483	113	45	14	501

Table 4. The difference between SPEI from the in-situ meteorological station and SPEIbase at a 6-month timescale based on drought categorization.

		SPEIbase_Grid							
		EW	SW	MW	N	MD	SD	ED	sum
SPEI_Station	EW	12	7						19
	SW	6	17	8	1				32
	MW	9	20	19	46	1			95
	N	7	16	52	408	51	8		542
	MD		1	1	42	29	19	6	98
	SD				6	10	16	8	40
	ED					3	2	7	12
	sum	34	61	80	503	94	45	21	508

Table 5. The difference between SPEI from the in-situ meteorological station and SPEIbase at a 9-month timescale based on drought categorization.

		SPEIbase_Grid							
		EW	SW	MW	N	MD	SD	ED	sum
SPEI_Station	EW	5	7						12
	SW	7	22	14	2				45
	MW	7	17	21	23				68
	N	8	19	48	444	45	12		576
	MD			1	36	18	21	3	79
	SD			1	5	16	14	7	43
	ED					2	7	6	15
	sum	27	65	85	510	81	54	16	530

Table 6. The difference between SPEI from the in-situ meteorological station and SPEIbase at a 9-month timescale based on drought categorization.

		SPEIbase_Grid							
		EW	SW	MW	N	MD	SD	ED	sum
SPEI_Station	EW	10	4	1					15
	SW	6	24	13	2				45
	MW	7	16	13	30				66
	N	9	19	42	456	41	8		575
	MD		2		26	9	21	8	66
	SD			2	8	12	15	1	38
	ED						15	9	24
	sum	32	65	71	522	62	59	18	536

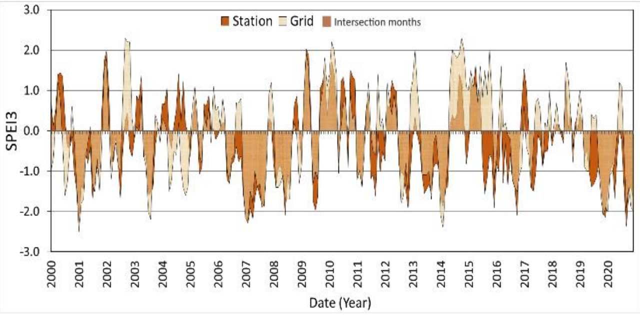

Figure 2. Comparison between SPEI3 from in-situ meteorological station and SPEIbase using DI for the last 20 years.

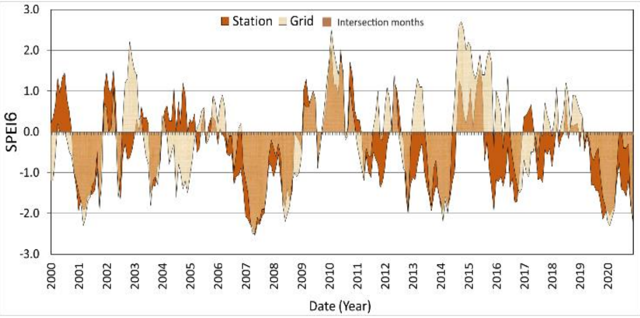

Figure 3. Comparison between SPEI6 from in-situ meteorological station and SPEIbase using DI for the last 20 years.

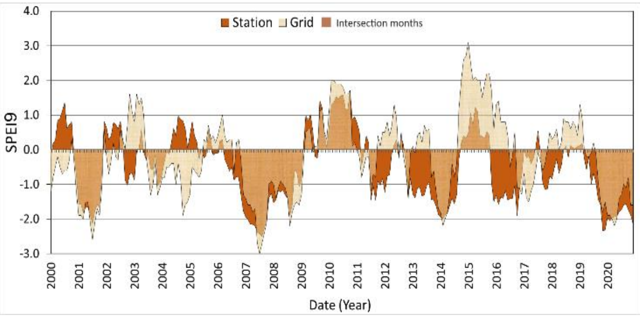

Figure 4. Comparison between SPEI9 from in-situ meteorological station and SPEIbase using DI for the last 20 years.

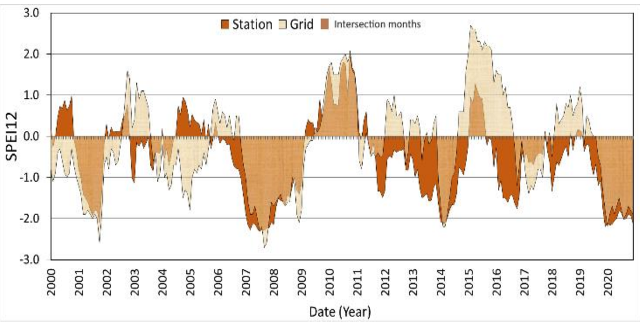

Figure 5. Comparison between SPEI12 from in-situ meteorological station and SPEIbase using DI for the last 20 years.

5. Conclusion

Drought is a critical issue for worldwide climate change adaptation and mitigation programs. Investigating the difference between SPEI from in-situ meteorological stations and SEPIbase is highly important because the drought index is the first step in drought analysis and evaluation processes.

The results proved a vital difference between SPEI using in-situ meteorological stations and SPEIbase. Based on drought categories, about 61% of the months were within the same drought category.

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