Influence of Solar Activity on Total Annual Precipitation

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Abstract. The relationship between total annual precipitation and solar activity (sunspot number) were studied based on annual precipitation data from 25 weather stations in Poland that were gathered from 1966 to 2016. The correlation between a yearly sunspot number and a total annual precipitation were analysed by sinusoidal repression analysis. The 5-year smoothest sunspot number and a total annual precipitation for each weather station were taken for final analysis. The parameters of sin curve were calculated by the least square fit method. It is assumed that the frequency is 10.87 years which is a mean spring tidal period of Jupiter and Saturn. The cross correlation between solar activity and total annual precipitation was shown. The difference in year between a minimum yearly sunspot number and a maximum total annual precipitation is assumed as the level of correlation. It is also assumed that high correlation occurs if the difference in question is smaller than 1.5 years, moderate if the difference is higher than 1.5 and smaller than 2.5 years and weak if the difference is higher than 2.5 years. The southern and south-western regions of Poland give high correlation, central and northern - moderate, and eastern - weak correlations. The presented analysis may be treated as the first step for a more accurate multi-scale harmonic analysis.

1. Introduction

Precipitation, temperature and other climate parameters depend on many factors. Generally, Poland has Mediterranean climate with little local differences. Mediterranean climate is characterized by oscillations of climate within the period of a year, that are responsible for the changes of seasons. Climatic influence has practical consequences for agriculture, energy consumption, and national economics [1, 2, 3, 4, 5, etc.].

We are witnessing the progress of global warming. Temperature increase is accompanied by an increasingly higher frequency and intensity of extreme weather phenomena such as: hurricanes, heavy rainfall, dangerous floods etc. [1, 6]. These phenomena have a direct negative impact on human economy.

The harmonic changes of climate have been observed for many centuries. These phenomena and correlations between climate and spring tidal period of Jupiter, Saturn and solar activity have been lately proved [e.g. 7, 8]. The long-term cyclic changes of temperature and precipitation in Warsaw and Cracow were analysed by Boryczko and Stopa-Boryczko [10]. Some papers discuss long-term seasonal climate changes [8, 6, 10].

This paper analyses only the changes of total annual precipitations recorded for the period from 1966 to 2016 and their correlations with solar activity. The analyses are based on the data taken from 25 weather stations [11] located in different regions of Poland. The degree of correlations between precipitation and solar activity will be shown. The results can be used in engineering activity.
2. The sunspot dataset
The upper atmosphere is subject to ionization. This ionization may affect the condensation process in the lower atmosphere by changing the nuclei in clouds, and thus causing an increase or a decrease in precipitation. The ionization level is correlated with sun activities as measured by sunspot number. The sunspot number data has been collected and analysed by Solar Influences Data Analysis Center (SIDC) since 1750. Sunspot numbers follow a movement that is nearly periodic [7, 9].

The sin function may be used to describe the cyclic yearly changes of sunspot number:

\[ S_n = a + b \sin \left( \frac{2\pi t}{T} + c \right) \]  

(1)

where \( S_n \) is a yearly sunspot number, \( a, b, c \) are parameters of regression analysis, and \( T \) is a cycle period in years.

In this paper it is assumed that \( T=10.87 \) year as a central cycle deduced theoretically [7]. The \( t \) is the difference from 1966. The yearly mean and sin approximation of sunspot number from 1966 to 2016 are shown in Figure 1.

![Graph showing yearly and 5-year smoothed sunspot number sin approximation from 1966 to 2016.](image)

Figure 1. Yearly and 5-year smoothed of sunspot number sin approximation from 1966 to 2016.

The parameters of sinusoidal regression analysis of the 5-year smoothed sunspot number calculated by the least square fit method are: \( a=91.46, b=53.555, c=47.863 \).

3. The precipitation data set
In this paper, the total annual precipitation was analysed that had been recorded by 25 weather stations located in different regions of Poland (Figure 2). The annual precipitation data were taken from statistical Yearbooks of the Republic of Poland [11].

The sinusoidal regression analysis was done, similarly to the analysis performed for sunspot number. The sin function taken for analysis has the following form:

\[ P = a^* + b^* \sin \left( \frac{2\pi t}{T} + c^* \right) \]  

(2)

where \( P \) is total annual precipitation in millimetres, \( a^*, b^*, c^* \) parameters of regression analysis, \( T=10.87 \) year and \( t \) - distance in years since 1966.

The 5-year smoothed total annual precipitation was taken for final analysis.
Figure 2. Location of weather stations taken for analysis in this study.

Table 1. Parameters of 5-year smoothed sin approximation of total annual precipitation and correlation with yearly sunspot numbers.

| Weather stations location | Parameter | Δt [Year] | Correlation level |
|---------------------------|-----------|-----------|-------------------|
|                           | a* [mm]   | b* [mm]   | c* [-]            |
| Wrocław                  | 571.9     | 30.96     | 13.469            | 0.28 H |
| Katowice                  | 732.4     | 51.27     | 5.382             | 0.32 H |
| Śnieżka                   | 1149.3    | 45.56     | 2.185             | 0.37 H |
| Kalisz                    | 505.5     | 18.16     | 2.137             | 0.45 H |
| Zakopane                  | 1115.6    | 29.01     | 1.057             | 0.54 H |
| Częstochowa               | 629.5     | 18.99     | 5.176             | 0.62 H |
| Jelenia Góra              | 699.7     | 37.04     | 1.757             | 1.11 H |
| Terespol                  | 529.1     | 25.44     | 1.749             | 1.12 H |
| Nowy Sącz                 | 728.0     | 28.43     | 1.695             | 1.22 H |
| Zielona Góra              | 580.24    | 29.10     | 1.622             | 1.36 H |
| Kraków                    | 676.9     | 47.84     | 1.594             | 1.39 H |
| Hel                       | 573.2     | 29.97     | 1.536             | 1.49 H |
| Łódź                       | 575.8     | 34.21     | 1.536             | 1.50 H |
| Toruń                     | 546.2     | 26.27     | 1.461             | 1.62 M |
| Olsztyn                   | 634.7     | 16.66     | 1.713             | 1.67 M |
| Poznań                    | 520.5     | 40.08     | 1.424             | 1.68 M |
| Gorzów Wielkopolski       | 549.3     | 29.74     | 1.403             | 1.72 M |
| Szczecin                  | 552.9     | 26.79     | 1.364             | 1.79 M |
| Warszawa                  | 538.4     | 8.954     | 4.922             | 1.80 M |
| Rzeszów                   | 648.6     | 36.69     | 1.350             | 1.81 M |
| Koszalin                  | 729.9     | 13.84     | 5.418             | 2.65 W |
| Lublin                    | 587.4     | 21.56     | 2.277             | 2.66 W |
| Kielce                    | 622.7     | 34.06     | 0.811             | 2.74 W |
| Suwałki                   | 600.4     | 7.19      | 6.63              | 4.06 W |
| Białystok                 | 596.5     | 3.32      | 13.071            | 5.02 W |
The 5-year smoothed total annual precipitation for three representative weather stations and sin curve approximation are shown in Figure 3.

**Figure 3.** The 5-year smoothed annual precipitation and sin approximation for weather stations: (a) Jelenia Góra; (b) Toruń; (c) Kielce.
4. The relationship between total annual precipitation and yearly sunspot number
The relationship between solar activity (yearly sunspot number) and total annual precipitation is analysed by comparison of correlations between sin curves of a 5-year smoothed yearly sunspot number and a total annual precipitation for 25 weather stations under analysis. It is visible that, generally, for minimum values of yearly sunspot numbers there is a maximum total annual precipitation (cross correlation). As a parameter of correlations, we took the difference in years between 5-year smoothed number and total annual precipitation obtained from sin approximations as shown in Figure 4.

![Figure 4](image)

Figure 4. Scheme of correlation between sunspot number and total annual precipitation.

In this paper it is arbitrarily assumed that high (H), moderate (M), and week (W) level of correlation is for $\Delta t \leq 1.5$ years, $1.5 > \Delta t \leq 2.5$ years and $\Delta t > 2.5$ years, respectively. The analysis revealed (Table 1) that the H-level was obtained for 13 weather stations (Wrocław, Katowice, Śnieżka, Kalisz, Zakopane, Częstochowa, Jelenia Góra, Terespol, Nowy Sącz, Zielona Góra, Kraków, Hel, Łódź), while M-level was observed in 7 stations (Toruń, Olsztyn, Poznań, Gorzów Wielkopolski, Szczecin, Warszawa, Rzeszów), and W-level in 5 weather stations under scrutiny (Koszalin, Lublin, Kielce, Suwałki and Białystok). Generally, we can say that H-level is observed in south and south-west, M-level in central and W-level in northern and eastern parts of Poland. In Figure 2 the weather stations with H-, M-, and W-levels of correlations between solar activity and total annual precipitations are marked with a circle, square, and triangle, respectively.

5. Conclusions
The simple analysis shows the correlations between solar activity (sunspot numbers) and total annual precipitation in most weather stations in Poland. The sinusoidal regression analysis using least square fit method may be treated as a first step of analysis. A multi-scale harmonic model should be used to describe more accurately the influence of solar activity on precipitation.

Acknowledgements
This work, conducted at Bialystok University of Technology, was supported by Polish Financial Resources on Science under Project No. S/WBiS/2/2018.

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