Study of Coordinate Time Series Using IPTA Method Based on the GNSS Data

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Abstract

The paper presents the application of the Innovative Polygon Trend Analysis (IPTA) method to study the time series of coordinates from the reference stations of the Global Navigation Satellite System (GNSS), using data sourced from the Nevada Geodetic Laboratory (NGL) between the years 2000 and 2024. The IPTA method can be applied for different time scales which may be daily, weekly, monthly, etc. periods. The purpose of this research is to investigate the existence of monthly seasonal correlation in the time series of coordinates of GNSS reference stations located in Europe. For this purpose, daily Precise Point Positioning (PPP) solutions of 247 GNSS permanent stations located in Central and West Europe were analysed. The research was conducted on time series based on the monthly average values of station coordinates. The analysis showed that a proportion of East, North, and Up components are affected by trends in general. As a result, the IPTA method might be adopted for 22% of the time series of East components, 9% of North components, and 45% of Up components. The study demonstrated that most GNSS stations in Europe exhibit seasonal correlation in the time series of coordinates, although the degree of this correlation varies depending on the component and location. These results highlight the potential of the IPTA method in the geospatial analysis of GNSS data and its utility in engineering applications.

Keywords: *GNSS, IPTA, Time Series, Coordinates, PPP*

1. INTRODUCTION

Permanent GNSS (Global Navigation Satellite System) reference stations provide the ability to track changes in the coordinates of the Earth's crust [1,2], positioning [3], GIS [4] and many others [5]. Due to the movements of tectonic plates, each point on the globe is burdened with a linear, constant shift, but in addition, it is possible to notice local seasonal changes [6]. The greatest amplitude is found in changes of an annual, semiannual, or daily nature [7].

The innovative trend analysis (ITA) method is applied to analyze natural phenomena such as precipitation, temperature, or rainfalls [8,9]. Comparing the ITA method to a classical method shows that ITA has some advantages of ITA method – it is easy to prepare and gives unambiguous clear results [10]. The ITA method involves dividing the time series being analysed into two equal parts and comparing them with each other relative to a line inclined at 45°. The first part of the series is on the horizontal axis, and the second part is on the vertical axis. In this way, on the 45° line there are trendless periods, below this line downward trends, and above – upward trends (Figure 1 left). IPTA method can be applied similarly to the ITA method, but on several time scales (i.e. daily, weekly, monthly, etc.) and compares these time scales between themselves in two, equal time series, similar to the ITA method (Figure 1 right) [11]. Sample IPTA method shows the right part of Figure 1 in a monthly period, it compares trends between the first and the second half of the time series between months.

Among the main advantages of the IPTA method over ITA is the more detailed analysis of the time series, as it offers the possibility of comparing more periods (days, weeks, months, etc.) with each other rather than just two equal parts of it. The purpose of this research is to investigate the existence of monthly seasonal correlation in the time series of coordinates of GNSS reference stations located in Europe.

2. MATERIALS AND METHODS

In this paper, the authors analysed data obtained from the NGL (Nevada Geodetic Laboratory) as a daily PPP (Precise Point Positioning) solution between 2000 and 2024 [14]. The length of the time series depends on the time of inclusion of the station into the NGL processing engine. For each station's time series coordinate component (N – North, E – East, Up) was adopted IPTA method.

For each station and coordinate component IPTA method was adopted by dividing data into half and comparing on a monthly basis between each half. Based on that for all stations, seasonal changes were determined for each month. This study has operated on 247 stations in central and east Europe, located on territory of 19 European (Figure 2). Figure 3 shows a part of results with clearly visible changes. Polygon located around the trendless line (45° line) show the

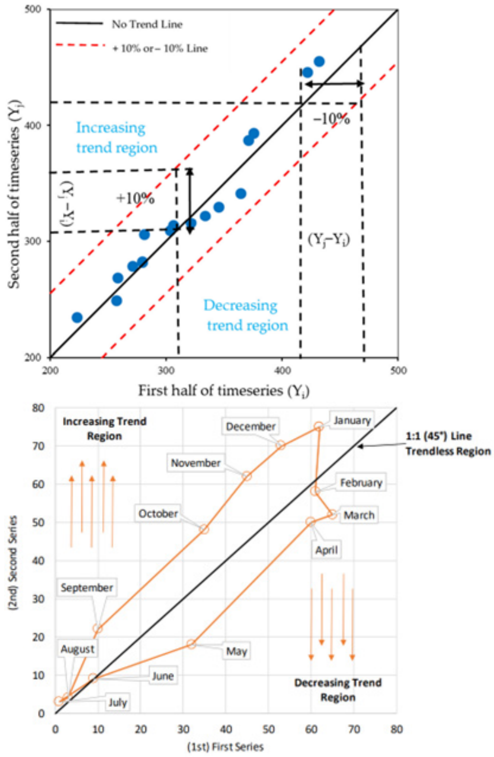


Fig. 1. Illustration of upward, downward, and trendless portions in the ITA method (top) [12] and hypothetical IPTA template for monthly records (bottom) [13]

Rys. 1. Ilustracja części opisujących obszary wzrostów, spadków i linię bez trendu w metodzie ITA (górny) [12] i teoretyczny szablon IPTA dla odczytów miesięcznych (dolny) [13]

Fig. 2. Distribution of the analyzed stations (source: https://www.google.pl/maps)

Rys. 2. Rozmieszczenie analizowanych stacji (źródło: https://www.google.pl/maps)

behaviour changes increasing (above 45° line), decreasing – below.

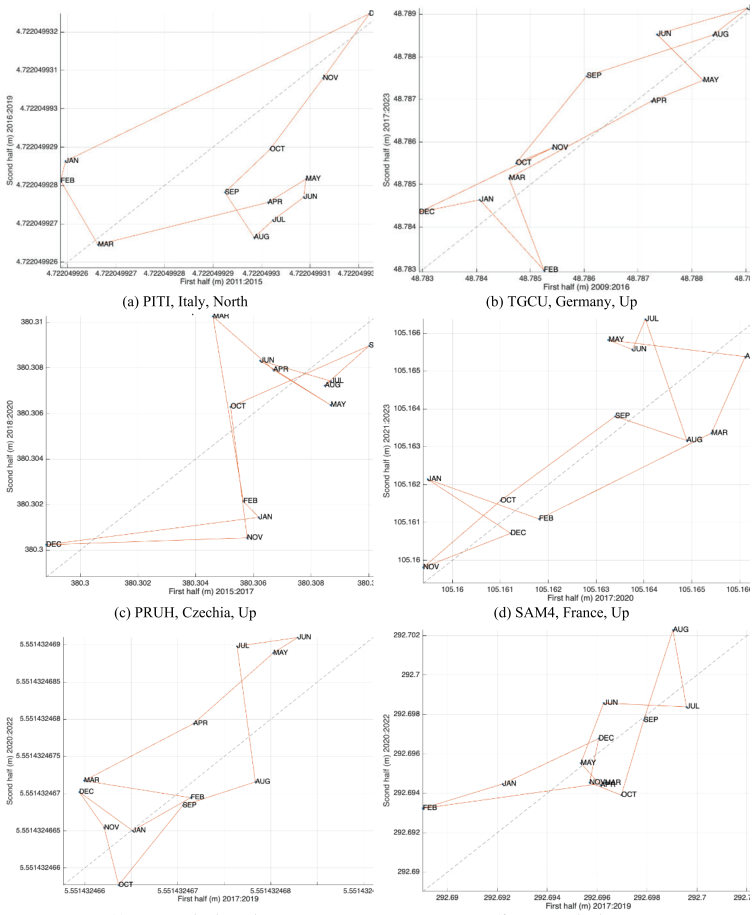
3. RESULTS AND DISCUSSION

According to the shown-on Figure 3 KRA2 station which is located in Poland (Krakow) for North (e) and Up (f) components respectively. There is an exact change from a decreasing trend area to an increasing trend area in February and October while the opposite in July and December for North competent, and it's clear that there is no trend in January. Regarding the Up component, it can be noticed that the transition from the decreasing trend area to the increasing trend area in April and July while the opposite is in February and August. By applying the same concept to other stations from (a) to (d) in Figure 3, it's clear that there is no systematic behaviour in the different locations but of course, the transition from the decreasing trend area to the increasing trend area or the opposite is existing in all stations. In some stations such as Figure 3a the decrease was recorded in 9 months versus 3 months for the increase. On the other hand, in Figure 3b the decrease has happened in 3 months in opposition to for the increase for the resident months.

The IPTA method has been applied to 247 GNSS permanent Stations in different European countries to detect the correlation between the time series depending on the monthly average values of the stations' coordinates. Overall, it can be clearly seen from the chart that the proportion of Up components whose IPTA was located correctly around the no-trend line is greater than E and N components which recorded 50% and 25% respectively compared to Up components. Based on the whole set of analysed data IPTA method was successfully adopted for 45% stations for Up competent, 9% for North component and East – 22%.

4. CONCLUSION

The IPTA method is used in a range of engineering and environmental monitoring applications, such as rainfall and long-term measurements of temperature changes. In



(a) PITI, Italy, North

(b) TGCU, Germany, Up

(c) PRUH, Czechia, Up

(d) SAM4, France, Up

(e) KRA2, Poland, North

(f) KRA2, Poland, Up

Fig. 3. IPTA graph for monthly IGS data in different European countries as a sample of our study

Rys. 3. Wykres IPTA dla miesięcznych interwałów w oparciu o szeregi czasowe IGS dla wybranych stacji GNSS w różnych krajach europejskich

this research, the authors analyzed the applicability of this method to crustal motion studies using GNSS coordinate time series. For this purpose, they used permanent reference stations distributed over Europe, for which daily solutions are calculated by NGL. Based on the absolute PPP solutions, independent of the reference stations for the period 2000–2024, trends related to the direction of change of a given component for each month were compiled. Of the nearly 250 permanent stations analyzed, only for some of them, the ITPA method was applicable. Moreover, the IPTA method statistically worked most often for the Up component which reached 45% compared to 22% and 9% for the East and the North components respectively in the area of study. Studying the seasonality between the analyzed stations, no correlation was found between the occurrence of the phenomenon in each month.

5. ACKNOWLEDGEMENTS

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Literatura – References

1. Pelc-Mieczkowska R. Preliminary analysis of the applicability of the GPS PPP method in geodynamic studies. Geomatics Environ Eng. 2020;14(4):57–68.
2. Maciuk K. The study of seasonal changes of permanent stations coordinates based on weekly EPN solutions. Artif Satell [Internet]. 2016 Jan 1;51(1):1–18. Available from: http://www.degruyter.com/view/j/arsa.2016.51.issue-1/arsa-2016-0001/arsa-2016-0001.xml
3. Magiera W, Vārna I, Mitrofanovs I, Silabrieds G, Krawczyk A, Skorupa B, et al. Accuracy of Code GNSS Receivers under Various Conditions. Remote Sens [Internet]. 2022 May 30;14(11):2615. Available from: https://www.mdpi.com/2072-4292/14/11/2615
4. Janowski A, Nowak A, Przyborski M, Szulwic J. Mobile Indicators in GIS and GPS Positioning Accuracy in Cities. In: Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) [Internet]. 2014. p. 309–18. Available from: http://link.springer.com/10.1007/978-3-319-08729-0_31
5. Glaner MF, Weber R. An open-source software package for Precise Point Positioning: raPPPid. GPS Solut [Internet]. 2023;27(4):1–11. Available from: https://doi.org/10.1007/s10291-023-01488-4
6. Klos A, Olivares G, Teferle FN, Hunegnaw A, Bogusz J. On the combined effect of periodic signals and colored noise on velocity uncertainties. GPS Solut. 2018;22(1):1–13.
7. Jadala NB, Sridhar M, Dashora N, Dutta G. Annual, seasonal and diurnal variations of integrated water vapor using GPS observations over Hyderabad, a tropical station. Adv Sp Res [Internet]. 2020;65(1):529–40. Available from: https://doi.org/10.1016/j.asr.2019.10.002
8. Lebeza TM, Gashaw T, Tefera GW, Mohammed JA. Trend analysis of hydro-climate variables in the Jemma sub-basin of Upper Blue Nile (Abbay) Basin, Ethiopia. SN Appl Sci [Internet]. 2023;5(5). Available from: https://doi.org/10.1007/s42452-023-05345-4
9. Esit M. Investigation of innovative trend approaches (Ita with significance test and ipta) comparing to the classical trend method of monthly and annual hydrometeorological variables: A case study of Ankara region, Turkey. J Water Clim Chang. 2023;14(1):305–29.
10. Li J, Wu W, Ye X, Jiang H, Gan R, Wu H, et al. Innovative trend analysis of main agriculture natural hazards in China during 1989–2014. Nat Hazards. 2019 Feb;95(3):677–720.
11. Şen Z, Şişman E, Dabanli I. Innovative Polygon Trend Analysis (IPTA) and applications. J Hydrol [Internet]. 2019;575(May):202–10. Available from: https://doi.org/10.1016/j.jhydrol.2019.05.028
12. Gujree I, Ahmad I, Zhang F, Arshad A. Innovative Trend Analysis of High-Altitude Climatology of Kashmir Valley, North-West Himalayas. Atmosphere (Basel). 2022 May;13(5):764.
13. Achite M, Ceribasi G, Ceyhunlu AI, Wałęga A, Caloiero T. The innovative polygon trend analysis (IPTA) as a simple qualitative method to detect changes in environment—example detecting trends of the total monthly precipitation in semiarid area. Sustain. 2021;13(22).
14. Blewitt G, Hammond W, Kreemer C. Harnessing the GPS Data Explosion for Interdisciplinary Science. Eos (Washington DC) [Internet]. 2018 Sep 24;99(September 2018). Available from: https://eos.org/project-updates/harnessing-the-gps-data-explosion-for-interdisciplinary-science

Analiza szeregów czasowych współrzędnych GNSS z wykorzystaniem metody IPTA

W artykule przedstawiono zastosowanie metody Innovative Polygon Trend Analysis (IPTA) do badania szeregów czasowych współrzędnych stacji referencyjnych Globalnego Systemu Nawigacji Satelitarnej (GNSS), przy użyciu danych pochodzących z Nevada Geodetic Laboratory (NGL) w latach 2000–2024. Metoda IPTA może być stosowana dla różnych skal czasowych, które mogą być dobowe, tygodniowe, miesięczne itd. Celem tego badania jest badanie korelacji sezonowej w szeregach czasowych współrzędnych stacji referencyjnych GNSS zlokalizowanych w Europie w ujęciu miesięcznym. W tym celu przeanalizowano dobowe rozwiązania Precise Point Positioning (PPP) z 247 stacji GNSS zlokalizowanych w Europie Środkowej i Zachodniej. W rezultacie metoda IPTA może być stosowana jedynie dla 22% szeregów czasowych składowych E, 9% składowych N i 45% składowych U. Badanie wykazało, że większość stacji GNSS w Europie wykazuje korelację sezonową w szeregach czasowych współrzędnych, chociaż stopień tej korelacji różni się w zależności od typu składowej oraz położenia stacji referencyjnej. Wyniki te podkreślają potencjał metody IPTA w analizie geoprzestrzennej danych GNSS i jej użyteczność w innych zastosowaniach inżynieryjnych.

Słowa kluczowe: *GNSS, IPTA, Szeregi czasowe, Współrzędne, PPP*