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P. Stauning: Comment on "Troshichev et al. 2020: The PC index variations during 23/24 solar cycles: relation to solar wind parameters and magnetic disturbances.": Invalid data base.

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Abstract. Examination of the contribution from O.A. Troshichev, S. Dolgacheva, N.A. Stepanov, and D.A. Sormakov: "The PC index variations during 23/24 solar cycles: relation to solar wind parameters and magnetic disturbances. https://doi.org/10.1029/2020JA028491 " has disclosed inconsistencies in the applied methods and serious errors in the calculated values. Some of the discrepancies reported in the present commentary affect directly the illustrations presented in their contribution while other possible errors may not be apparent since the use of relative values in their presentation makes thorough assessments difficult.

Plain language summary

The publication by Troshichev et al. (2020) is devaluated by inconsistencies in the applied methods and errors in the presented material, among others, in their figures 1 and 2 while further potential errors are disguised by the use of relative instead of actual parameter values.

1. Introduction

The contribution from O.A. Troshichev, S. Dolgacheva, N.A. Stepanov, and D.A. Sormakov (2020): "The PC index variations during 23/24 solar cycles: relation to solar wind parameters and magnetic disturbances. https://doi.org/10.1029/2020JA028491 published in J. Geophys. Res. Space Physics holds correlations between various solar and solar wind parameters and geospace magnetic disturbance indices.

Much of the work is based on relations involving the Polar Cap (PC) indices, PCN (North) and PCS (South). These indices are presently submitted jointly by the Arctic and Antarctic Research Institute (AARI) and the Danish Space Research Institute (DTU Space). The publication conveys the impression that these indices are applied in versions endorsed by the International Association for Geomagnetism and Aeronomy (IAGA) by its Resolution #3 (2013), which they, being provisional values, are not.

There are serious inconsistencies in the reported methodologies and considerable errors in the reported index parameters and index values, particularly in the applied Polar Cap South (PCS) values that suffer from invalid data or errors in the processing software.

The values presented in the figures, particularly in their Figs. 1 and 2, are untenable. The referencing is improperly biased.

2. Polar Cap (PC) index versions and classifications

Polar Cap PCN (North) and PCS (South) index values are available at the web portal of the International Service of Geomagnetic Indices (ISGI) at ht tp://isgi.unistra.fr/indices_pc.php . For the interval of years (1998-2019) considered in the commented publication, PCN index values are here classified as "definitive" index values while PCS (South) values are classified as "provisional". Definitive PCN values and description of derivation methods are available at DTU Space at https://doi.org/10.11581/DTU:00000057 . PCN and PCS values are furthermore presented at the AARI web portal https://pcindex.org in what appears to be "quick-look" versions judging from the data availability statements of the publication, Troshichev et al. (2020), discussed here.

The publication states in the abstract: "*The polar cap magnetic activity PC index is regarded as indicator of the solar wind energy that enters into the magnetosphere during the solar wind – magnetosphere coupling (Resolutions of XXII IAGA Assembly, 2013). This paper presents the results of statistical analysis of relationships between yearly values of PC index and such indicators as the magnetic activity indices (AE and Dst)*". This formulation is repeated in a slightly different version in the introduction in section 1: "*Taking into account this distinctive feature of the PC index, the International Association of Geomagnetism and Aeronomy (IAGA) approved PC index as 'a proxy for the energy that enters into the magnetosphere during solar wind-magnetosphere coupling' Resolution of XXII IAGA Assembly, 2013)*".

These statements might convey the impression that the PC indices in the version used here have been endorsed by IAGA by Resolution #3 (2013) issued at the IAGA General Assembly in 2013. But this not the case.

From, for instance, the file PCND2010.1M (Definitive) of indices from DTU Space, the first few lines are (Eq. 1):

Scientific_data_and_models/World_Data_Center_for_Geomagnetism, Copenhagen. (1)

DATE TIME DOY PCN

2010-01-01 00:00:00.000 001 0.01

2010-01-01 00:01:00.000 001 0.01

2010-01-01 00:02:00.000 001 0.01

From the file PCSP2010.1m (Provisional) downloaded from ISGI, the PC indices are:

DATE TIME DOY PCS (2)

2010-01-01 00:00:00.000 001 0.25

2010-01-01 00:01:00.000 001 0.26

2010-01-01 00:02:00.000 001 0.29

From http://pcindex.org the corresponding index series used in the article discussed here is:

#year-month-day h:m PCN PCS (3)

2010-01-01 00:00 0.09 0.25

2010-01-01 00:01 0.09 0.26

2010-01-01 00:02 0.09 0.29

The PCN indices in Eq. 3 are clearly not from the same index series as the definitive version displayed in Eq. 1 but more likely from the quick-look or provisional version as the provisional PCS values from ISGI in Eq. 2.

IAGA endorsements are only provided to definitive index series and could not comprise the indices (Eq. 3) used here in spite of the references to IAGA resolution #3 (2013).

3. Quiet day QDC) reference level.

The quiet day reference level (QDC) serves to define the magnetic variation being scaled to form the PC indices. In section 3.1 of the commented (Troshichev et al., 2020) publication it is stated "*To examine the QDC alteration in course of solar cycles we examined the yearly-averaged amplitudes of QDC at the northern and southern polar cap stations and counted their sum (QDCtotal) for each year during 1998-2019 (see http://geophys.aari.ru/PCspaceweather).*

The QDCtotal amplitude for 2001 can be read from Fig. 1 to within ± 1 nT to give 135 nT and the referenced yearly values in the Table for 2001 at the referenced web file are almost the same:

Year Version QDC_N (nT) QDC_S (nT) QDCtot (nT) (4)

2001 Table 66.99001 67.11466 134.10467

2001 Fig.1 135.0

QDC values for the X- and Y-components based on magnetic data from OMNIweb and using the QDC method from Troshishev et al. (2006) provides the values shown in Eq. 5 at the line marked "OMNI". DTU-Space has supplied QDC X- and Y-component values for 2001 derived at an interim step of the PCN calculations (definitive values). These values are provided in the line marked "DTUS" of Eq. 5:

Noting that the QDC X- and Y-component values need to be vectorially added provides the scalar values for the QDC_N and QDC_S components for the northern and southern hemisphere shown in Eq. 5:

Year Version QDC-X_N QDC-Y_N QDC_N QDC-X_S QDC-Y_S QDC_S QDC_tot (5)

2001 OMNI 67.0 63.6 92.4 59.3 102.7 118.6 303.4 nT

2001 DTUS 66.9 63.9 92.5 nT

Thus, the QDC ranges in two hemispheres are 92.4 and 118.6 nT, respectively, while the "QDCtot" for 2001 is 303.4 nT and not the value of 134.1 nT as stated in the table or read from Fig. 1. Looking closer at the numbers discloses readily that the values displayed in the table of the AARI web reference are values derived for one component, the X-component, only.

Thus, the values displayed in their Fig. 1 are incorrect by considering the X-component only. It is quite possible that the QDC dependence on solar illumination and solar wind impact are different for the northward (X-) and the eastward (Y-) components. In any event it should be defined properly in the article (Troshichev et al., 2020) how the "QDCtot" values are constructed.

4. Polar cap index values.

In section 2 of the publication (Troshichev et al., 2020) the authors state: "*the daily PC index was estimated as a daily sum of the positive hourly indices divided by 24 h*". In the supporting web site http://geophys.aari.ru/PCspaceweather ("MEAN" link) it is explained that positive PCN and PCS values only were used in the averaging instead of using both positive and negative PC index values. This is clearly the method for the PCC index developed by Stauning in 2006 and published in Stauning (2007). This issue shall be dealt with in section 6. For present, the method is used to the letter to derive PC index values to be compared to the values displayed in Fig. 2a

In the following examples we shall consider the years 2003 (PCN only), 2007, and 2011 with easily recognizable peaks in PC index values shown in Fig. 2a. These values shall be compared to corresponding values downloaded initially from the AARI web site (https://pcindex.org) and ISGI (http://isgi.unistra.fr) in 2017 and confirmed by downloads in October 2021 and January 2022, respectively, which must be the indices used in the publication.

In order to distinguish between the different versions, they are named by suffix "FIG" when read from Fig 2a of Troshichev et al. (2020), "ISG" when downloaded from ISGI web at http://isgi.unistra.fr and "ORG" when downloaded from AARI web at https://pcindex.org (before 2 Oct 2021) and "ORN" (new ORG) after 23 December 2021. In principle, these different version should provide the same yearly average PC index values (including PCN = PCS averages) each year. Obviously they do not.

Yearly averages for 2003: (6)

$PCN_{FIG}(2003)=1.000$: $PCS_{FIG}(2003)=0$ (no data)

$PCN_{ISG}(2003)= 1.490$: $PCS_{ISG}(2003)=0$

$PCN_{ORG}(2003)=1.487$: $PCS_{ORG}(2003)=0$

$PCN_{ORN}(2003)=1.490$: $PCS_{ORN}(2003)=0$

For 2007: (7)

$PCN_{FIG}(2007)=0.600$: $PCS_{FIG}(2008)=0.505$

$PCN_{ISG}(2007)=0.900$: $PCS_{ISG}(2007)=0.826$

$PCN_{ORG}(2007)=0.907$: $PCS_{ORG}(2008)=0.789$

$PCN_{ORN}(2007)=0.900$: $PCS_{ORN}(2007)=0.802$

For 2011: (8)

$PCN_{FIG}(2011) =0.540$: $PCS_{FIG}(2011)= 0.730$

$PCN_{ISG}(2011)= 0.862$: $PCS_{ISG}(2011)=1.080$

$PCN_{ORG}(2011)=0.870$: $PCS_{ORG}(2011)=1.045$

$PCN_{ORN}(2011)=0.862$: $PCS_{ORN}(2011=0.895$

The values presented above hold several questionable features such as:

(i) The strong disagreements between the index values read from Fig. 2a of Troshichev et al. (2020) and those provided from the other index versions show that the values in Fig.2a have been derived by some procedure differing from the averaging process defined in their section #2.

(ii) The differences between the PCN and PCS values in 2007 must relate either to poor data or to errors in the processing. If the problem resides in the data, then the problem, most likely, is with the data from Vostok used to derive the provisional PCS indices, since the PCN data basis is definitive values from Qaanaaq (THL) used for definitive PCN index values.

(iii) Differences between yearly averages of PCN and PCS indices should be small (a few %) since both PCN and PCS indices are calibrated with respect to the common merging electric field, Ekl (Kan and Lee, 1979). Differences as large as those seen in Fig. 2 up to 0.2 mV/m (appr 30%) should cause reflections by the authors and experienced readers over data quality and validity of data processing methods.

(iv) The yearly mean values of Ekl reported at the supporting web site http://geophys.ari,ru/PCspaceweather differ strongly from the PCN and PCS values displayed in Fig. 2a which, most likely, is why they are not included in the figure with their real values but first transformed to relative values for displays in Figs. 2b, 3 and 4a.

(v) The very strong differences between PCN and PCS index values in their "FIG", "ISG", and "ORG" versions in 2011 are most likely caused to a large extent by errors in the AARI data processing for the PCS indices (the Vostok data are good). The error was detected in 2018 (Stauning, 2018a) and reported at that time to the index providers and to IAGA EC but the cautioning was neglected and dismissed, respectively. Further reporting of the erroneous PCS indices are provided in Stauning (2018b, 2020, and 2021) and in "NotePCSindexExamination-27-12-2012.pdf" at https://doi.org/10.17632/mphb8d7cv5.1 .

5. Reference level.

It is stated in section 2 of the commented manuscript that: "*The polar cap magnetic disturbance value F at stations Thule and Vostok is counted from level of quiet daily variation (QDC – Quiet Daily Curve), which is determined for each day of year [Troshichev at al., 2006]*".

However, the procedures defined in Troshichev et al. (2006) and further specified in Janzhura and Troshichev (2008) are not in agreement with the index derivation methods endorsed by IAGA by Resolution #3 (2013) upon recommendation by a IAGA Task Force by the statement: " *The PC index being recommended for endorsement at IAGA 2013 Merida, Mexico is defined by the following publications: Troshichev et al. (2006 and 2009), Janzhura and Troshichev (2008) , Janzhura and Troshichev (2011)*" (Menvielle et al., 2013).

In Troshichev et al. (2006) the quiet reference level is defined in section 2.1 by the statement: "*Magnetic deviations D and H are calculated from a certain level, "curve of quiet day" which presents the daily magnetic variation, observed at the particular station during extremely quiescent days*".

In the documentation (Matzka and Troshichev, 2014) submitted to IAGA in 2013 in order to fulfil the requirements in "*Criteria for endorsement of indices by IAGA*" (2009), the magnetic variations are measured from a baseline derived as the median of recorded values smoothed over 7 days . Such median baselines are not mentioned in Troshichev et al. (2006). The reference level method used at DTU Space for calculations of the provisional and definitive PCN indices (Nielsen and Willer, 2019) builds on the additional descriptions provided in Janzhura and Troshichev (2011) as noted in the document: *PC_index_description_main_document.pdf* available from http://isgi.unistra.fr/Documents/References/PC_index_description_main_document.pdf .

It should be noted that the reference level defined in the documentation presented in Matzka and Troshichev (2014) presently being used at DTU Space and which includes a median term, is not a quiet level in the sense defined by Troshichev et al. (2006). A median-based reference level is dynamically tracking the disturbance level.

6. Referencing

The list of references lacks reference to Janzhura and Troshichev (2008) for further descriptions of the automated QDC methodology and also lacks reference to the development of the QDC concept by Janzhura and Troshichev (2011) (including the near-real time version) used in the basis for the IAGA endorsement in 2013 (Matzka and Troshichev, 2014; Menvielle et al., 2013).

Another issue is the use of the combination of positive PCN and PCS values in the parameter named "PCmean" here. This parameter is actually the same as the "PCC index" developed by Stauning in 2006 and published in Stauning (2007) with accurately the same arguments as those presented in section #2 of Troshichev at al. (2020).

Before submission to J. Space Weather, Drs. Troshichev and Janzhura were invited by mail 20-11-2006 to share authorship for a publication on the new PCC index. However, Dr. Troshichev on behalf also of Dr. Janzhura declined on the invitation by mail 20-11-2006 with the arguments: "*We do not agree conceptually with incorporation of new combined index PCC*" and "*We do not agree conceptually with your suggestion to exclude the negative PC indices from consideration*". The full text of the mails holding the invitation and the rejection are available.

The PCC index parameter was used in the contribution by Stauning, Troshichev, and Janzhura (2008) where Dr. Troshichev is co-author. The PCC index concept was further used in Ch. 16 of Stauning (2012) next to Ch. 15 written by Dr. Troshichev, in Stauning (2016, 2018, 2020, 2021), and in several draft manuscripts forwarded to Dr. Troshichev for his information and possible comments.

Still, in the comprehensive list of references to Troshichev et al. (2020), which includes 71 items, there is no mentioning of the initial presentation of the PCC index concept by Stauning (2007).

The case of neglect of crediting the original work has been forwarded to the AGU Ethical Committee.

Conclusions

- The correlation studies and conclusions presented in the commented article by Troshichev et al. (2020), *The PC index variations during 23/24 solar cycles: relation to solar wind parameters and magnetic disturbances*, https://doi.org/10.1029/2020JA028491 are devaluated by inconsistencies in the definition of data processing methods and the use of invalid data.

- The calculations of quiet day reference levels (QDC) presented in their Fig. 1 use only one component, the northward X-component, with the unresolved risk that the other component, the eastward Y-component, contributes a different dependence on the related solar and solar wind parameters.

- Contrary the impression conveyed by the repeated referencing to the IAGA Resolution #3 (2013), the indices used in the commented article are not in the version endorsed by IAGA but provisional values.

-The data displayed in their figure 2a do not agree with values derived by using the described methods to the letter on the original geomagnetic data. The display holds cases of clearly questionable index values, where the yearly averages, however derived, of PCN and PCS indices that should be equal within a few %, differ by up to 30%.

- The processing of Vostok geomagnetic data at AARI by authors of the commented publication neglecting the cautioning provided in 2018 have given values that deviate by up to 3 mV/m (geomagnetic storm level) compared to the most recent (December 2021) PCS index values submitted also from AARI.

- In spite of conveying a quite comprehensive list of references with 71 items, the referencing is not providing proper credit to earlier works of substantial importance for the methodology used in the commented publication

Data availability statement.

The data used in the present commentary have been downloaded from the web portals: http://geophys.aari.ru/PCspaceweather , https://pcindex.org , http://isgi.unistra.fr/indices_pc.php , https://intermagnet.org , and http://omniweb.gsfc.nasa.gov

Conflict of interests: The author declares that he has no conflict of interests in the present case.

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