

**Comments to paper Stauning, P. (2022) The use of invalid Polar Cap South (PCS) indices in publications. *Journal of Geophysical Research: Space Physics*, 127, e2022JA030355**

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**Abstract.** Declaration (Stauning, 2022) on “invalid *PCS* index” is based on the following arguments: *PCS* index is calculated with use of incorrect “unified” *PC* derivation method; *PCS* index used in analyses is a preliminary index, which was not approved by IAGA and, therefore, it cannot be regarded as a correct index; *PCN* and *PCS* indices demonstrate, intermittently, large difference in value, which should be treated as evidence of the *PCS* index invalidity. The paper presents comments to these arguments. Conclusion is made that criticism of the *PCS* index, presented in Stauning (2022), is based on groundless arguments.

**Introduction**

The polar cap magnetic activity *PC* index is calculated by magnetic data from near-pole stations Thule in Greenland (*PCN* index) and Vostok in Antarctic (*PCS* index). Before 2011 the *PCN* index was calculated in Danish Meteorological Institute (DMI) either by the official DMI method (Vennerstrom, 1991) or by the solar rotation weighted (SRW) method described later in (Stauning, 2011). The *PCS* index was calculated in Arctic and Antarctic Research Institute (AARI) with use of the “unified” method put forward in (Troshichev et al., 2006; thereafter TJS2006) for derivation of both, *PCN* and *PCS*, indices. The comprehensive analysis of these competitive methods has been fulfilled by IAGA Division V-DAT in 2009-2010 and the “unified” TJS2006 method has been recommended, as the best, for the IAGA endorsement (McCreadie and Menvielle (2010). In 2011 the Space Institute of the Danish Technical University (DTU-Space) became responsible for magnetic observations at Thule station and in 2013 the *PC* index, derived by the “unified” TJS2006 method, was approved by IAGA as a new index characterizing the solar wind energy input into the magnetosphere (IAGA-2013, Resolution no. 3). In line with agreement between the AARI and DTU-Space the *PCN* and *PCS* indices for previous years were recalculated in 2014 with application of the “unified” *PC* derivation method approved by IAGA.

According to the IAGA rules, all indices obtained by data of current magnetic observations are considered as “preliminary” indices. They should be recalculated afterwards making allowance for all possible faults of observational, technical and computer-assisted origin, to produce the “definitive” indices, which will be valid for ever. This work was fulfilled in 2021 in AARI and DTU Space with use of the restructured and harmonized code (Nielsen & Willer, 2019). Comparison of the provisional and definitive *PCN* and *PCS* indices for 22 year (1997-2019) has demonstrated perfect conformity between the appropriate *PCN* and *PCS* indices. As a result, the definitive *PCN* and *PCS* indices were ultimately approved by IAGA and the *PC* index was recommended for use by international scientific community (IAGA-2021, resolution №2).

**Comments to arguments adduced in (Stauning, 2022).**

1 “It should be noted that the IAGA recommendation mentions “the *PC* index”, while there are separate *PCN* and *PCS* indices of which only the *PCN* indices could be generated in definitive versions. The unclear formulation opens for misunderstanding or misuse of the resolution. The *PC* index derivation methods have been questioned and modifications suggested in Stauning (2013a, 2013b, 2015, 2018a, 2020, 2021a). The AARI *PCS* index data series up to December 2021 is invalid.”

After the IAGA-2013 decision the IAGA endorsed *PC* index was repeatedly criticized in papers (Stauning, 2013, 2015, 2018, 2020, 2021a) as invalid index with reference to imagined inaccuracies in the TJS2006 method. In contrast to previous publications, the present paper (Stauning, 2022) claims that only *PCS* index is “invalid” index. To justify this transformation, it is alleged (Stauning, 2022) that the IAGA 2013 approval was related only to *PCN*, but not to *PCS* index. It should be reminded in this connection that the IAGA-2013 decision was based on results of many analyses fulfilled with use of the preliminary *PCN* and *PCS* indices derived by the “unified” TJS2006 method. The recent IAGA-2021 decision is based on results of examination of the definitive *PC* index, which have demonstrated consistency between the definitive *PCN* and *PCS* indices over the period 1997-2019. It is significant that the definitive *PCN* and *PCS* indices were calculated by the restructured and harmonized code (Nielsen & Willer, 2019) based on the “unified” TJS2006 method. It is significant that acceptance of the *PCN* index as a correct index in (St2022) means, in fact, the recognition of the IAGA endorsed *PC* index validity. In such a case, the repeated critique, presented in publications (Stauning, 2013, 2015, 2018, 2020, 2021a), loses any sense as well as announcement (Stauning, 2022) on further *PC* index developments made in these publications.

2. “The AARI *PCS* index data series is invalid as It became evident in 2018 by observing excessive daily excursion varying between  $-1.5$  and  $2.5$  mV/m superimposed on the *PCS* index values expected from other index data series”.

As analyses (Troshichev and Janzhura, 2009; Troshichev and Sormakov, 2019; Troshichev et al., 2022) showed, the *PCN* and *PCS* indices are subjected to seasonal variation, the *PC* values being maximum in summer season and being minimum in winter season. As this takes place, the *PC* index in winter polar cap (*PCwinter*) demonstrates the better correlation with the solar wind electric field  $E_{KL}$  and magnetic disturbances, irrespective of hemisphere. Transition to definitive *PCN* and *PCS* indices made it possible to display the seasonal variations in more detail. As example, Figure 1 shows courses of daily values of the definitive *PCN* (blue) and *PCS* (red) indices and their difference (*PCN*–*PCS*) for 4 years related to various epochs of solar activity: 2000 (maximum), 2008 (decay), 2011 (growth) and 2019 (minimum).

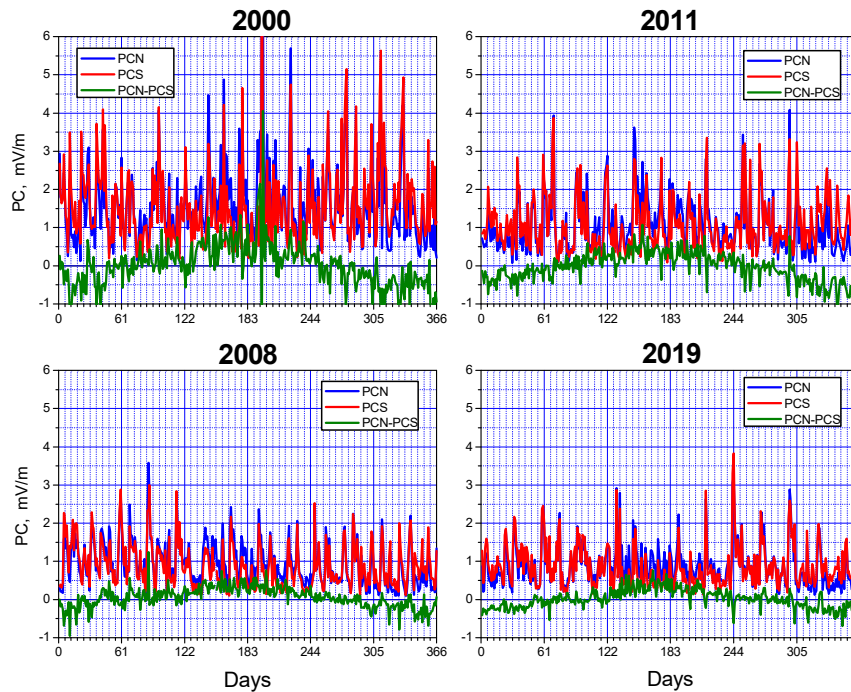


Figure 1. Courses of daily values of the *PCN* (blue) and *PCS* (red) indices and difference (*PCN-PCS*) (olive) in 2000 (epoch of solar maximum), 2011, and 2008, 2015 (epoch of solar minimum).

One can see that *PCN* and *PCS* indices synchronously increase and decrease, irrespective of epoch of solar activity. However, the value of difference between *PCN* and *PCS* values displays the evident dependence on season: *PCS* index is totally large than *PCN* index in November/December/January/February, whereas *PCN* index is larger in May/June/July/August, the indices being leveled in equinox. The difference between the daily values of *PCN* and *PCS* is the highest ( $> 1$  mV/m) in epochs of solar activity maximum and is minimal ( $< 0.5$  mV/m) in the quiet periods. Thus, exceeding of the *PCsummer* index values over the *PCwinter* values is a common peculiarity of the *PC* index, which is conditioned by physics of the solar wind – magnetosphere coupling (see Troshichev and Janzhura, 2012; Troshichev et al., 2022), not by bad quality of the *PCS* index in comparison with *PCN* index, which are calculated by the same “unified” *PC* derivation method and demonstrate perfect agreement in equinox.

It should be noted that examples of discrepancies between the *PCN* and *PCS* indices, used in (Stauning, 2022) as argument of bad quality of the *PCS* index, are related just to summer or winter seasons in 2011. Indeed, examination of the preliminary and definitive *PCS* indices for 2011 revealed a problem with quality of absolute observations at Vostok station in June/July and December 2011: correlation between the 1-min preliminary and definitive *PCS* indices fell to  $R<0.82$  in 2011 (correlation in June/July and December of this year was  $R<0.6$ ), whereas in other years over period 1997-2019 the correlation exceeded the level  $R>0.98$ . Thus, the exclusive cases of inaccuracy in derivation of the preliminary *PCS* index in 2011, presenting the evident exception to the rule in history of magnetic observations at Vostok station, were exhibited in (Stauning, 2022), as example of the invalid *PCS* index. Notice that problem of incorrect *PCS* index in 2011 has been resolved while producing the definitive *PC* index (see Figure 1).

### 2.3 “*PCS* indices were never derived in definitive versions”.

Definitive *PCS* indices for 1997-2019 are presented at portal <https://pcindex.org>.

### 2.4 “Definitive *PCS* version has been issued at of the AARI portal, <https://pcindex.org> although, according to IAGA rules, they should be labeled “provisional” since the basic Vostok data are not observatory standard”.

The Vostok (VOS) station is a member of INTERMAGNET - the global network of observatories, associated with IAGA and the World Data System ICSU. Annual definitive data from all INTERMAGNET magnetic observatories (IMOs) are carefully prepared and checked for quality and compliance before they are accepted and published (<https://www.intermagnet.org/>).

### 2.5 The magnetic observations from Vostok suffer, among others, from the observatory position on the unstable ice sheet and the extreme climatic conditions, which imply that the observational quality would not enable the characterization “definitive” for the data and the derived *PCS* indices; they are only “provisional” (or “preliminary”).

Status of geomagnetic data, “definitive” or “preliminary” is not determined by the observatory position. It is well known that instability of the main geomagnetic field, observed at the high-latitude stations, is determined first of all by drift (10 - 15 km/year) of the geomagnetic poles.

## Conclusions

Statement on invalid *PCS* index, made in (Stauning, 2022), is based on arguments, which have no relation to reality: (1) The same “unified” *PC* derivation TJS2006 method was used for calculation of “correct” *PCN* index and “invalid” *PCS* index”; (2) The IAGA-2013 approval of the *PC* index was based on results of analyses of the preliminary *PCN* and *PCS* indices derived by the “unified” TJS2006 method. Definitive *PCN* and *PCS* indices were approved by IAGA in 2021. (3) Difference

between *PCN* and *PCS* indices is determined by seasonal variation of the *PC* value (*PCsummer* > *PCwinter*) and has no relation to quality of the *PCN* or *PCS* index as such.

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Figure 1.

