The Main Component Analysis of the Longitudinal Distribution of Solar Activity

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Abstract: In this contribution, preliminary results of the main component analysis of Bartels diagram of time series of daily values of sunspot group numbers for solar cycles 18, 19 and 20 are presented. The results obtained suggest that the most significant feature in the longitudinal distribution of sunspot activity is the existence of preferred solar hemispheres alternating with a mean period of 2.5 Bartels rotations.

The issue of the existence of preferred (active) longitudes in the solar activity distribution over heliographic longitudes is still one of the open question of present-day solar astronomy. (See, for instance, Gaizauskas, 1985). That is why it is sensible to study these phenomena using other data sets, employing classical as well as quite new methods for their analysis.

The main aim of this contribution is an attempt to study the longitudinal distribution of sunspot activity using the expansion of the time series of daily values of sunspot group numbers (for the eleven-year cycles 18, 19 and 20), arranged in the form of Bartels diagram, into the set of its proper orthogonal functions (see for instance Vertlib *et al.*, 1971).

If we interpret each row of a Bartels diagram as a concrete realization of some general longitudinal distribution (affected by the influence of evolutionary processes and so on), we may look for an expansion of this distribution into a set of its proper orthogonal functions (in the main component analysis sense) and the shape of these functions will describe single independent periods of the distribution that we are looking for. In other words, if our Bartels diagram is represented by the matrix N_{ik} ($i = 1, \ldots, m$ being the number of Bartels rotations counted from the first rotation in the solar cycle number 18; $k = 1, \ldots, 27$ being the day number in the corresponding Bartels rotation) we are interested in a development in the form $N_{ik} = a_{i\alpha}\Phi_{\alpha k}$, where $\alpha = 0, \ldots, 26$ is a summation index, and $a_{i\alpha}$ as well as $\Phi_{\alpha k}$ are both unknown before processing and where for $\Phi_{\alpha k}$ an orthogonality condition has to be satisfied. For the complete expansion we need also the least squares minimum condition and the condition of maximum information density

https://doi.org/10.1017/S0252921100079756 Published online by Cambridge University Press

compression also to be satisfied. It may be shown that the proper functions we are looking for must be identical to the eigenfunctions of the covariation matrix $B_{kr} = N_{ik} N_{ir}$. The corresponding eigenvalues describe the part of the total dispersion explained by the relevant proper function. In our analysis the rows of the matrix N_{ik} have been normalized to have zero mean.

The most important of the proper functions obtained, with $\lambda_\alpha / \Sigma\lambda = 0.247$, indicates that the most significant component in the longitudinal distribution of sunspot activity (explaining approximately a quarter of the total dispersion) may be recognized as corresponding to the situation when one of the solar hemispheres is preferred (its activity is above average). The boundaries between these two hemispheres are stable during the complete time interval investigated and lie at longitudes corresponding to Bartels days 9 and 23. The signs of the expansion coefficients determine which of the hemispheres is preferred in any given Bartels rotation.

The behaviour of the expansion coefficients $a_{i\alpha}$ in time seems to be at first glance rather chaotic, but a test for whether the sequence of their signs is random or not (Sachs, 1982) shows that for the first proper function the behaviour of corresponding coefficients (for level of significance $p = 0.05$) is not random. The mean length of repetitions is roughly 2.6 Bartels rotations. Periods of above-average activity on one hemisphere are therefore replaced by periods of reduced activity with just this time period.

The strongly smoothed (for whole solar cycles) values of the expansion coefficients for the most significant proper function are equal to −1.291 (for solar cycle 18), −0.732 (19) and 0.349 (20). It means that during the cycles number 18 and 19 the hemisphere corresponding to the second half of the Bartels rotation was generally preferred, whereas during the cycle number 20 we observe the opposite situation. This is in good agreement with results obtained by Balthasar and Schüssler (1983, 1984) and with their conception of solar "memory".

Generally we can conclude that these preliminary results indicate that the method of principal orthogonal components applied to data sets of daily values of selected solar activity indexes may be a very interesting and effective instrument for studying the longitudinal distribution solar activity.

References

Balthasar, H., Schüssler, M.: 1983, *Solar Phys.* **87**, 23

Balthasar, H., Schüssler, M.: 1984, *Solar Phys.* **93**, 177

Gaizauskas, V.: 1985, in *Inv. Rev. Present to Solar-Terr. Prediction Workshop*, Meudon

Sachs, L.: 1982, in *Applied Statistics*, Springer-Verlag, New-York, p. 375

Vertlib, A.B., Kopecký, M., Kuklin, G.V.: 1971, in *Issled. Geomagn. Aeron. i Fiz. Solntsa* 2, p. 194