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On Separation of the Secular Variations of Different Origins

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Abstract

Secular variations (SV) are a complex phenomenon in time and space. The main origin of SV is inside the Earth. But SVs are complicated by external sources such as variations due to the magnetospheric and ionospheric currents and also by currents induced in the crust. There is an anticorrelation between the time changes of SVs and geomagnetic activity. Especially, one can see it on short period (one year) SV changes of the horizontal component of the geomagnetic field ($\Delta SV(H)$). If we express geomagnetic activity by means of some geomagnetic index, as, e.g., K_p, we can derive a linear regression equation between $\Delta SV(H)$ and $\Delta\Sigma K_p$, where $\Delta\Sigma K_p$ is the difference between mean yearly values of K_p. Usually the correlation coefficient between these values does not exceed 0.4-0.6. The sensitivity of $\Delta SV(H)$ to $\Delta\Sigma K_p$ for individual observatories varies. For European observatories the highest sensitivity exists for the Surlari magnetic observatory.

By subtracting $\Delta SV(H)$ dependent on $\Delta\Sigma K_p$ from $\Delta SV(H)$, we obtain $\Delta SV_1(H)$ independent of magnetic activity. The resulting $SV_1(H)$ at observatories of the northern hemisphere of the Earth appear to be in accordance with a quasi-sinusoidal law. The period of the quasi-sinusoids is about 78-80 years. The mean-per-cycle Wolf numbers of solar activity show the same changes. This means that by subtracting these long period variation from $\Delta SV_1(H)$, we can find out the SV variation independent of the geomagnetic and solar activity ($\Delta SV_2(H)$).

It is interesting to note that the zero isoline of such $\Delta SV_2(H)$ passes through regions of intense tectonic activity.

Key words: secular variations, external sources.

The separation of external sources of SV allows to use the remainder for investigations of the Earth's interior. The most informative component of the geomagnetic field with regard to changes of external sources is H.

We have derived the differences between mean year values of H (SV(H)) (Golovkov *et al.* 1983, Golovkov *et al.* 1984-1989, Golovkov and Dimant 1990) for nine European magnetic observatories (COI, VAL, CLF, STO, HAD, NGK, SUA, WIT, LVV) and also five Asian observatories (SVD, IRT, YSS, MGD, VLA) for almost 100 years. To investigate the dependence SV(H) on magnetic activity, the second differences (ΔSV(H)) between SV(H) of successive years were calculated. As measure for magnetic activity changes there has been chosen $\Delta\Sigma K_p$, i.e. differences between successive mean yearly values of ΣK_p (ΣK_p is the daily sum of K_p). The correlation coefficient between ΔSV(H) and ΣK_p has been derived for every individual observatory. Usually the correlation coefficients did not exceed 0.4-0.6, their dispersion being 0.13. The sensitivities of ΔSV(H) to $\Delta\Sigma K_p$ for different observatories vary. The highest sensitivity exists for Surlari magnetic observatory.

Figure 1 shows the dependence of ΔSV(H) on $\Delta\Sigma K_p$ for mean European and mean Asian observatories. Two straight lines reflect the regression equations which connected ΔSV(H) and $\Delta\Sigma K_p$ according to the correlation coefficients.

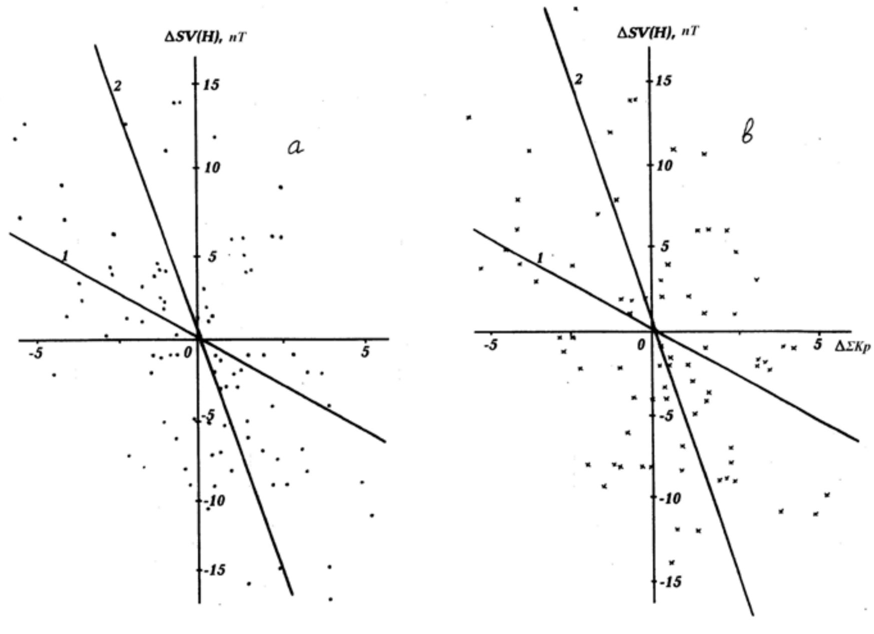

Fig. 1. Dependence of ΔSV(H) on $\Delta\Sigma K_p$ for European (a) and Asian (b) observatories.

Figure 2 represents the same dependence of ΔSV(H) on $\Delta\Sigma K_p$ for magnetic observatory Tangerang ($\varphi = -06.17^0$; $\lambda = 106.63^0$). This observatory has a long series of observations and is placed near the zero line of SV(H). The correlation coefficient between ΔSV(H) and $\Delta\Sigma K_p$ is $r = -0.61 \pm 0.08$ and the sensitivity of ΔSV(H) to changes $\Delta\Sigma K_p$ is almost one order of magnitude higher than for European or Asian observatories.

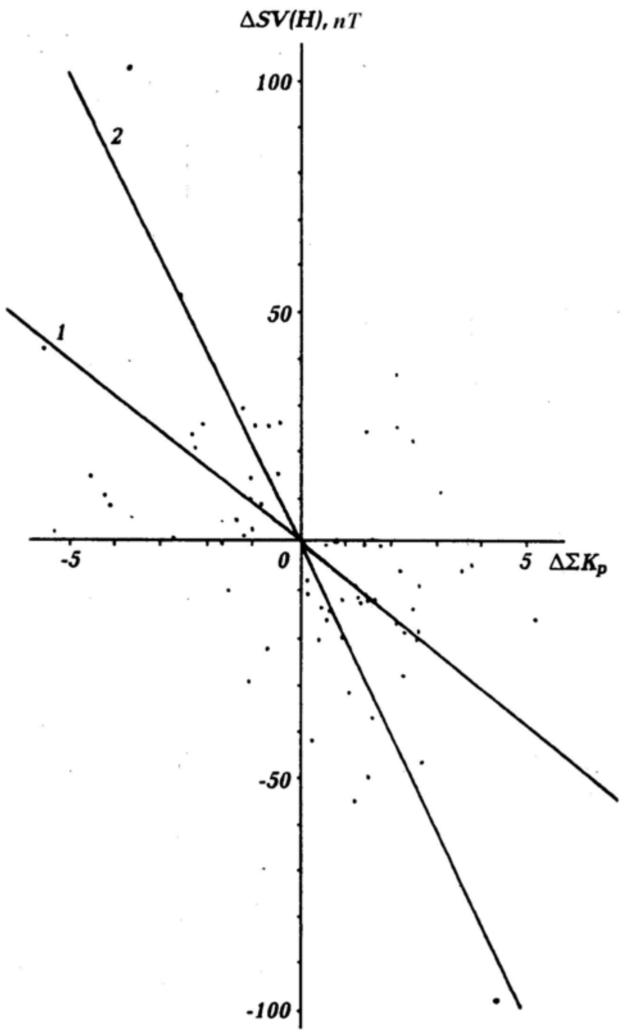

Fig. 2. Dependence of ΔSV(H) on $\Delta\Sigma K_p$ for Tangerang magnetic observatory.

Figure 3 presents sensitivities of the SV European observatories to the changes of magnetic activity. The sensitivity increases from eastern to western observatories. The dotted curves are isolines of sensitivity.

Table 1 shows correlation coefficients and linear regression equations between ΔSV(H) and $\Delta\Sigma K_p$. The right column is the sensitivity of ΔSV(H) to changes $\Delta\Sigma K_p$. Thus it is possible to calculate a correction to SV(H) due to the changes of magnetic activity. By subtracting ΔSV(H) from SV(H) we obtain $SV_1(H)$ independent of magnetic activity.

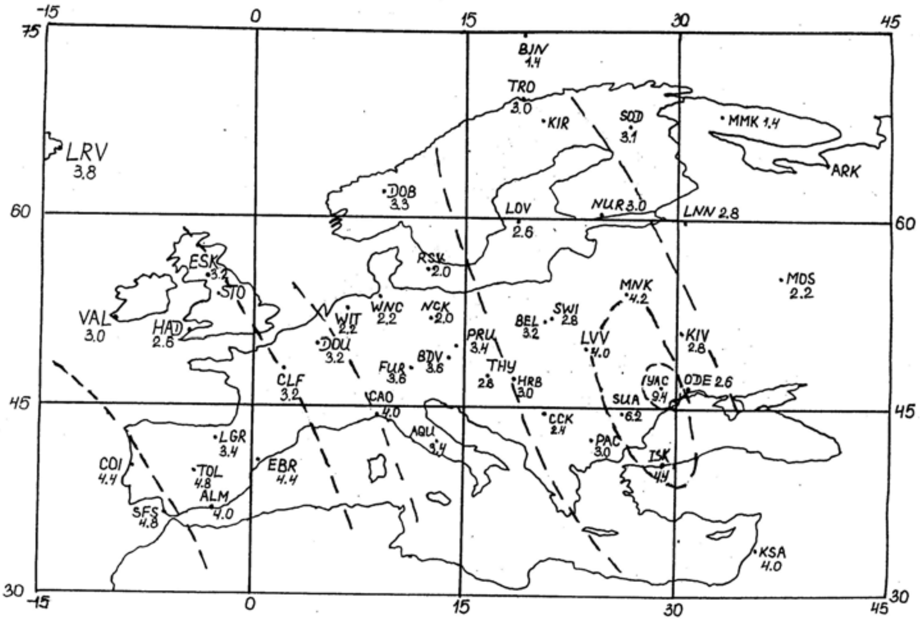

Fig. 3. Sensitivity of European observatories to changes of magnetic activity.

Table 1

Correlation coefficients and regression equations between $\Delta SV(H)$ and $\Delta\Sigma K_p$

Observatory	r_1	σ_1	$\Delta SV(H)$	r_2	σ_2	$\Delta\Sigma K_p$	ε
European row	–0.51	0.08	$(-1.44\pm0.22)*$ $*\Delta\Sigma K_p$	–0.50	0.08	$(-0.17\pm0.03)*$ $*\Delta SV(H)$	2.6
Asian row	–0.40	0.10	$(-1.14\pm0.20)*$ $*\Delta\Sigma K_p$	–0.36	0.10	$(-0.13\pm0.03)*$ $*\Delta SV(H)$	2.5
Tangerang	–0.60	0.08	$(-7.68\pm1.02)*$ $*\Delta\Sigma K_p$	–0.61	0.08	$(-0.05\pm0.01)*$ $*\Delta SV(H)$	11.6
Frederickburg	–0.40	0.11	$(-1.20\pm0.30)*$ $*\Delta\Sigma K_p$	–0.37	0.11	$(-0.12\pm0.04)*$ $*\Delta SV(H)$	2.8
Tucson	–0.60	0.08	$(-2.00\pm0.30)*$ $*\Delta\Sigma K_p$	–0.55	0.13	$(-0.16\pm0.04)*$ $*\Delta SV(H)$	3.2

Figure 4 shows these corrected $SV_1(H)$ for two observatories WIT (middle) and IRT (bottom). The upper curve shows the mean yearly Wolf numbers for 13-20 solar cycles. Mean-per-cycle Wolf numbers and $SV_1(H)$ are shown by horizontal thick lines. Witteween and Irkutsk observatories were chosen because the difference of their longitudes amounts to 98° and because they have long series of data. The vertical dotted lines connect the maxima-per-cycles Wolf numbers with crossing points between mean $SV_1(H)$ values and the curve of $SV_1(H)$. As one may see, the points divide the curve $SV_1(H)$ in two parts. The first part corresponds to the rising phase of the Wolf numbers and the second one to its decreasing phase. At most cycles, the increasing (decreasing) phase coincides with a decreasing (increasing) of $SV_1(H)$, which is also a reversal dependence. The phenomenon may be explained in the same way as above for short period variations.

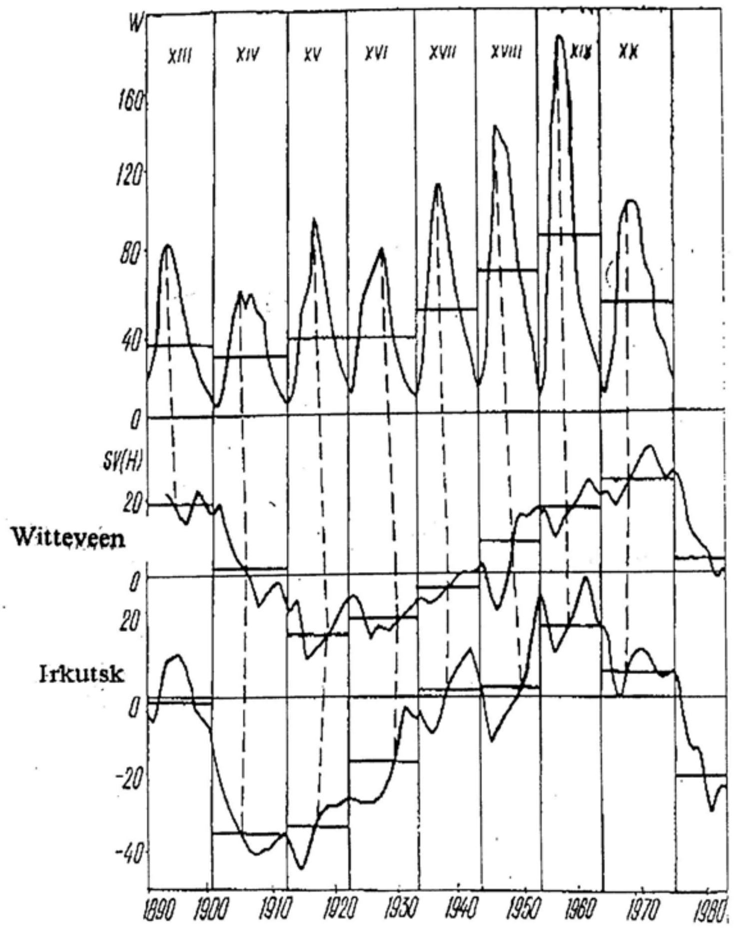

Fig. 4. Corrected $SV_1(H)$ for Witteveen and Irkutsk. See text for details.

To exclude these variations, the mean-per-cycle values were calculated. The resulting values $\Delta SV_2(H)$ at all observatories of the northern hemisphere of the Earth appear to be in accordance with a quasi-sinusoidal law. The period of the quasi-sinusoid is about 78-80 years. The mean-per-cycle Wolf numbers of solar activity show the same changes.

It may be supposed that these events correlate. The main problem is to choose the zero level of the variations. At all observatories the variations should coincide in phase. By means of such an assumption we have received dates of sign changes of the sinusoids at every observatory. An example of such a determination is shown in Fig. 5 for several observatories. The zero transition of the $\Delta SV_2(H)$ variations of the 78-80 year period were observed at approximately 1902-1905, 1947-1949, and 1980-1982 (in Fig. 5 shown by vertical lines). In Fig. 5 corrections were not introduced on short-period SV variations. The horizontal dotted lines show the value of the $\Delta SV_2(H)$ variations independent of external sources.

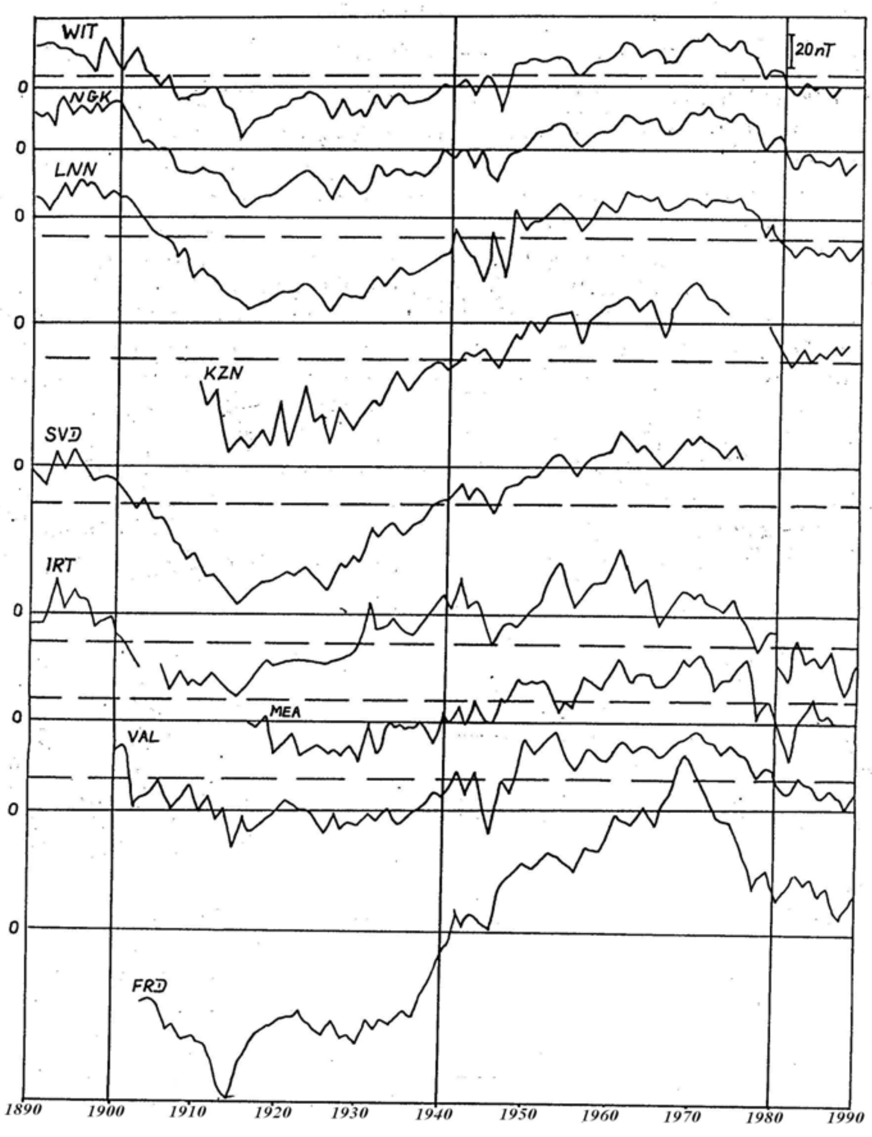

Fig. 5. $\Delta SV_2(H)$ variations at observatories of the northern hemisphere.

Figure 6 shows zero isolines of $\Delta SV_2(H)$ variations. Figures near names of observatories signify the value of $\Delta SV_2(H)$. Zero isolines pass through regions of intense tectonic activity, and they surround regions of positive $\Delta SV_2(H)$ at middle latitudes of the Earth's northern hemisphere.

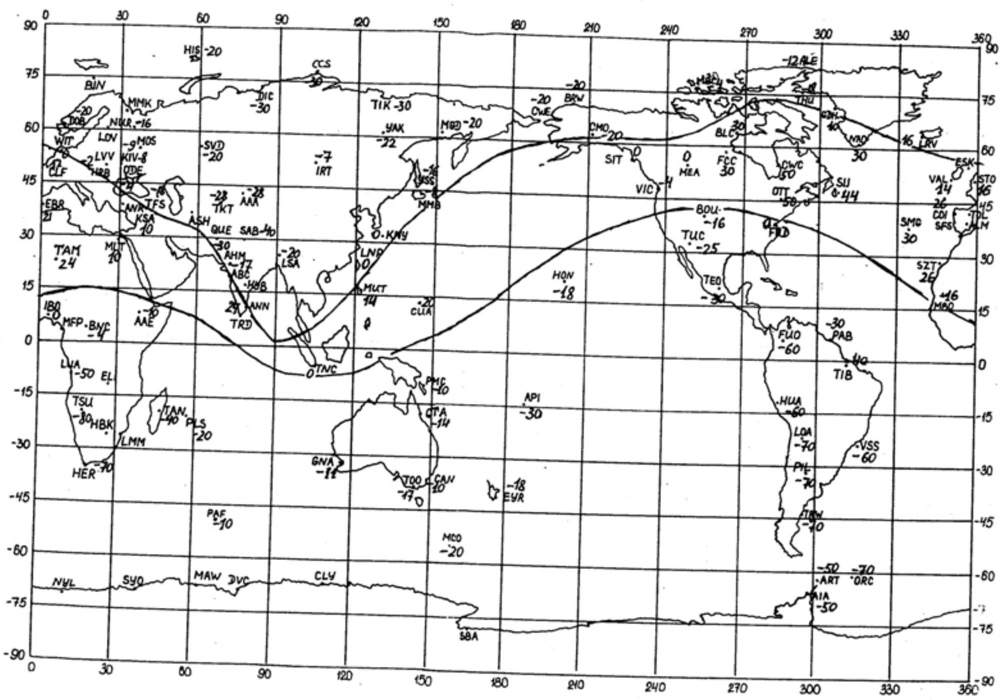

Fig. 6. Zero isolines of ΔSV_2 (H) variations.

Conclusions

An attempt was made to investigate the contribution of external origins to SV(H) changes. SV(H) changes of external origins consist of short and long period variations. There is an anticorrelation between short period (one year) ΔSV(H) and geomagnetic activity expressed by $\Delta\Sigma K_p$ indices.

The changes of ΔSV(H) per unit $\Delta\Sigma K_p$ vary for individual observatories. Long period (78-80 years) variations of SV(H) and the same variations of the Wolf number show consistent changes.

A spatial distribution of secular variations due to internal origins has been found when the parts of SV(H) due to external origins (its dependence on ΣK_p and Wolf numbers) were subtracted.

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