GEOPHYSICAL TRANSACTION 1991
Vol. 36. No. 3-4. pp. 313-320

EVALUATION OF ALGORITHMS FOR COMPUTER PRODUCTION OF *K*-INDICES

Michel MENVIELLE*

The paper explains why computer production of *K*-indices was introduced and it summarizes the methods of computer- and traditional handscale production of *K*-indices. It shows the necessity for and the mode of comparing hand-scaled and computed *K*-values.

Keywords: geomagnetic indices, *K*-index, algorithmus

1. Introduction

The derivation of geomagnetic indices from digital data was discussed during the Second Workshop, at Nurmijärvi [MENVIELLE 1990]. According to the IAGA regulations, the *K*-indices are to be handscaled from analog magnetograms. In the case of digital observatories, it implies the production of computer plots of digital data with scale values similar to those of photographic magnetograms (about 2 cm/h and 5 nT/mm). *K*-handscaling thus induces delays and *K*-indices are generally circulated some weeks after the end of a month. Computation and circulation of IAGA *K*-derived indices within a short time clearly require computer derivation of the *K*-indices.

A lot of algorithms that claim to derive *K*-indices from digital data have been proposed for several years now [VAN WIJK and NAGTEGAAL 1977, RIDDICK and STUART 1984, HOPGOOD 1986, WALKER 1987, WILSON 1985,

* International Service of Geomagnetic Indices and Laboratoire de Géomagnétisme, Institut de Physique du Globe de Paris
now at: International Service of Geomagnetic Indices and Laboratorie de Géophysique, Batiment 504, University de PARIS SUD F-91405 ORSAY CEDEX

HATTINGH et al. 1988, GOLOVKOV et al. 1989, PIRJOLA et al. 1990]. These algorithms have been tested with different data sets, and using different statistical tests. It is therefore almost impossible to compare them and decide which algorithm is relevant.

It was thus decided during the Vancouver and Exeter meetings to organize a comparison between these algorithms with a common data set and using the same statistical tests. It was also decided that the comparison be completed before the 1991 IAGA General Assembly, in Vienna, where a recommendation should be made for the future. This short note briefly presents the data set and statistical tests to be used for this comparison.

2. The *K*-index

The *K*-index was designed by BARTELS et al. [1939] to provide objective monitoring of the irregular variations observed at a given station. It was extensively analysed and discussed in Mayaud's Atlas of *K*-indices [MAYAUD 1967] and by MAYAUD [1980]. A short review of its basic characteristics is given by MENVIELLE and BERTHELIER [1991].

An individual *K*-index is a code characterizing the activity during a Greenwich Universal Time (UT) three hour interval. During each 3-hour interval, the range in the two horizontal magnetic components is measured after eliminating the so-called 'non-*K* variations'. MAYAUD [1967] established morphological rules as guidelines to estimate the non-*K* variations (see Appendix 1). According to these rules, one retains as non-*K* variations the simplest and least speculative curve which correspond to a possible S_R variation. In practice, it should be estimated from the quiet parts of the records.

Ten classes of ranges are defined according to the corrected geomagnetic latitude of the station. The limits of the classes are proportional to those defined by BARTELS at the Niemegk observatory (*Table I*). The 3-hour *K*-index is the integer between 0 and 9 corresponding to the class containing the larger of the two ranges measured in the horizontal components.

Table I.

K value	0	1	2	3	4	5	6	7	8	9
range (nT)	0	5	10	20	40	70	120	200	330	500

The *K*-indices are to be handscaled on analog magnetograms. They thus depend to a given extent on the observer, and the subjectivity of *K*-indices was a matter of debate [e.g. RANGARAJAN and MURTY 1980, MENVIELLE 1981]. It is at present agreed that the measurements made by two well trained observers differ by about 8% if the border cases are neglected, and by 15% to 20% otherwise. The differences never exceed one unit and they are randomly distributed [MAYAUD 1980, MAYAUD and MENVIELLE 1980, SUCKSDORFF et al. 1991].

3. The tests

Computer *K*-methods will be tested using the magnetic data of the period March 1985 to February 1986 from the observatories listed in *Table II.* These digital data together with digital hand-scaled *K*-values are available on request from the Finnish Meteorological Institute.

The tests are based upon the comparison between computed *K*-values and hand-scaled *K*-values. The results should be presented as histograms of the differences $\Delta K = K(\text{computed}) - K(\text{hand-scaled})$. A list of the histograms is given in Appendix 2. According to the results from comparison between handscalings made by different observers, full agreement of about 85% is satisfactory, provided the differences never exceed one unit and are randomly distributed.

The tests also include a comparison between magnetograms and computer estimated regular S_R curves. Magnetograms of the *X* and *Y* (or *H* and *D*) components with the computer estimated S_R curve should therefore also be plotted for a selected set of 30 days (July 5 to 14, September 1 to 10, December 22 to 31, 1985). The horizontal time scale in the magnetograms is 6 mm/hour, and the vertical scale is 2 nT/mm, except for July 12, December 28 and December 30 for which it is 5 nT/mm.

Table II.

Station	Geographic		Corrected	K = 9 Lower Limit	
	lat.	long.	Geomag.lat.	Computed	Used
ARGENTINE ISL.	-65.12	295.42	-49.7	490	500
BELSK	51.83	20.80		480	450
CANBERRA	-32.39	149.30	-45.2	420	450
CROZET	-46.26	51.52	-52.4	500	500
HARTLAND	50.59	355.31	50.0	530	500
HERMANUS	-34.25	19.14	-41.1	300	300
MEMAMBETSU	43.54	114.12	37.4	340	350
NEWPORT	48.16	242.53	54.8	700	700
NURMIJRÄVI	60.52	24.65		750	750
OTTAWA	45.24	284.27	58.9	790	750
P.AUX FRANCAIS	-49.21	70.12	-52.4	760	750
SODANKYLA	67.37	26.63	63.9	1540	1500

Observatories used in the test of computer K-methods. The computed lower limit for K=9 is estimated with respect to the angular distance to the closest point of the auroral zone (see Mayaud 1980, or Menvielle and Berthelier 1991 for further details). The used K=9 lower limit is generally rounded to the nearest fifty or hundred; it should be used for the computer K-derivation.

The tests take into account both the experimental results from comparisons between well trained observers and the morphological basis of the S_R estimation. We therefore expect that the computer derived K-index will have the same statistical properties as the original ones, thus ensuring the homogeneity of the *aa*, *am*, *an*, *as* and *Kp* time series.

Acknowledgements

The data used for these tests were kindly provided by the observatories. Chris Sucksdorff and his team (Geophysical Department, Finnish Meteorological Institute, Helsinki, Finland) took care of gathering, checking and circulating the test data set. I am pleased to thank them for their efficient contribution which made these tests possible.

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APPENDIX 1

Mayaud's rules for scaling *K*-indices

1. The observer should carry out, by following the smooth variations, smoothing of the record such that it corresponds to a possible form of the S_R The quiet parts of the records, presenting little or no sudden variations, will guide this smoothing. However, the observer must be conscious of the possible existence of smooth (or moderately smooth) *K*-variations in order to eliminate them, as far as possible, from this smoothing.

2. The possibility of such smoothing, and its practical usefulness from the point of view of the measurements, diminishes rapidly as the agitation level increases. Often it will be sufficient to make it only for certain parts of the records.

3. On days following a storm, the general aspect of the *H*-curve can be profoundly different from the normal S_R, particularly at low latitudes. The smoothing should be carried out however without departing too much from the observed *H*-curve.

4. In cases where smoothing seems wholly or partly useless, the following procedure will often be practical :

— make a first measurement of the index as if there were no non-*K* variations;

— estimate whether the measure thus obtained is sufficiently remote from a borderline so that any hypothetical non-*K* variation be negligible;

— if the measurement is near a borderline, lower or raise by one unit the first value obtained as a prudent and reasonable estimation of the possible non-*K* variation suggests.

5. When, with respect to the level of the agitation, the smoothing carried out for the S_R identification seems useful but remains uncertain (this fact will probably occur at stations where S_R may contain more or less complex secondary movements), and if the various possible solutions lead to different values of the index, the interpretation retained should always be the simplest and least speculative.

6. If a secondary movement of the curve, which presents a smooth aspect and does not contain, in particular, any sudden change at its beginning or at its end, resembles a secondary movement which S_R can produce,

the observer should always interpret it as belonging to S_R, without asking himself whether a comparison with a record of another observatory would show that it is a *K*-variation.

7. If a smooth secondary movement occurs during night hours so that one can assume that it is very probably a *K*-variation although its beginning is indiscernable in the end of the S_R (or its end in the beginning of the S_R), it must be interpreted as being a *K*-variation, by taking as a reference the simplest possible form of S_R in the given interval or intervals.

APPENDIX 2

The results obtained by different *K*-methods should be presented as histograms of the differences $\Delta K = K$(computed) - K(hand-scaled) in the following 'formats' :

a) histogram of all results (Mar 85 ... Feb 86)
histogram of results of Nov 85 ... Feb 86 (Winter)
histogram of results of May 85 ... Aug 85 (Summer)
histogram of results of Mar 85 Apr 85 and Sep 85 Oct 85 (Equinox)
histograms of results of the selected 30 days (Jul 5 ... 14, Sep 1 ... 10, Dec 22 ... 31, 1985).

The vertical scale is in % with 100% = 100 mm; the width of one column is 5 mm (columns : 0, -1, +1, -2, +2, ...)

b) for each three seasons, histograms of all results (Mar 85 ... Feb 86) as functions of the time of the day, i.e. 8 different histograms according to the three hour intervals (UT 00-03, 03-06, ...). The vertical scale is in % with 100% = 100 mm; the width of one column is 3 mm, and the space between zero-columns of two adjacent histograms is 24 mm.

c) histograms of all results (Mar 85 ... Feb 86) as functions of the hand-scaled *K* values, i.e. 9 different histograms. The scale, width and space information is the same as in case b).

SZÁMÍTÓGÉPPEL KÉSZÍTETT K-INDEXEK ALGORITMUSAINAK ÉRTÉKELÉSE

M. MENVIELLE

A cikk ismerteti a gépi számítási indexek bevezetésének okát, és utal a *K*-indexek hagyományos és gépi számításának módjaira. Magyarázza a kétféle eljárással készült indexek összehasonlításának szükségességét és részletesen ismerteti az összehasonlítás módját.

ОЦЕНКА АЛГОРИТМОВ ИНДЕКСОВ К, СОЗДАННЫХ НА КОМПЪЮТЕРАХ

М. МЕНВЬЕЛ

В статье рассматривается причина введения индексов, рассчитываемых на компъютерах, и дается ссылка на традиционные и компъютеризированные способы расчета индексов К. Объясняется необходимость сопоставления индексов, полученных двумя различными способами, и детально излагаются способы сопоставлений.