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LOW-LATITUDE ASY INDEX AS AN INDICATOR OF THE HIGH-LATITUDE MAGNETIC ACTIVITY

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Abstract. Penetration of the high-latitude substorm electric fields and currents into the lower-latitude ionosphere is a well-known experimental fact. One can expect the low-latitude ASY index is formed due to electric currents originated in auroral latitudes and spreading down to the equator. Some researchers (e.g. S.-I.Akasofu, 1972; Iyemori, 1990, Grafe, 1999)suppose the main contributor of the ASY H index is the partial ring current flowing near the magnetosphere equatorial plane at the distance of a few RE. We have found strong, slightly non-linear correlation between ASY and AE indices with rough proportionality ASYH/AE~1/14. Since AE index is invalid during severe storms and requires many stations to be calculated we suppose the ASY index might be convenient to characterize the high-latitude geomagnetic activity within that time. By superimposed epoch technique the relationship of ASY H/D to other indices as well as to the solar wind parameters is examined. It is obtained, in particular, that the AE and ASY maximum values take place during the storm main phase and correlation between them is higher if Dst<-50 nT.

Introduction

The low-latitude ASY H index is traditionally considered as an indicator of the partial ring current effect. However, the observations of particles possibly related to this type of current are very few. On the other hand, the researchers refer to the experimental and theoretical evidence for the magnetic effect of the high-latitude processes can be transferred to the low latitudes using several possibilities, particularly via the ionosphere electric field and currents related to the auroral electrojets (Denissenko and Zamay, 1990). If so, the quiet low-latitude diurnal variation has to be determined mostly by high-latitude convection electric fields immediately related to the region I currents driven by the solar wind electric field, and the disturbed low-latitude diurnal variation should grow in amplitude with AE index value increasing. The objective of the present study was to check the properties of the AE index – low-latitude diurnal variation relationship and, with help of the epoch matching method, to examine the extent of the AE index effect to the low-latitude ASY H index.

Analysis

The hourly data of the AE index and 3 magnetic field components from 4 standard low-latitude stations (Hermanus, Honolulu, Kakioka and San Juan) for year 1985 (8760 hours) have been used to infer the low-latitude ASY H and D indices according to the standard technique. Then, the obtained data were analyzed as shown below.

Low-latitude S_q-variation amplitude to AE index relationship

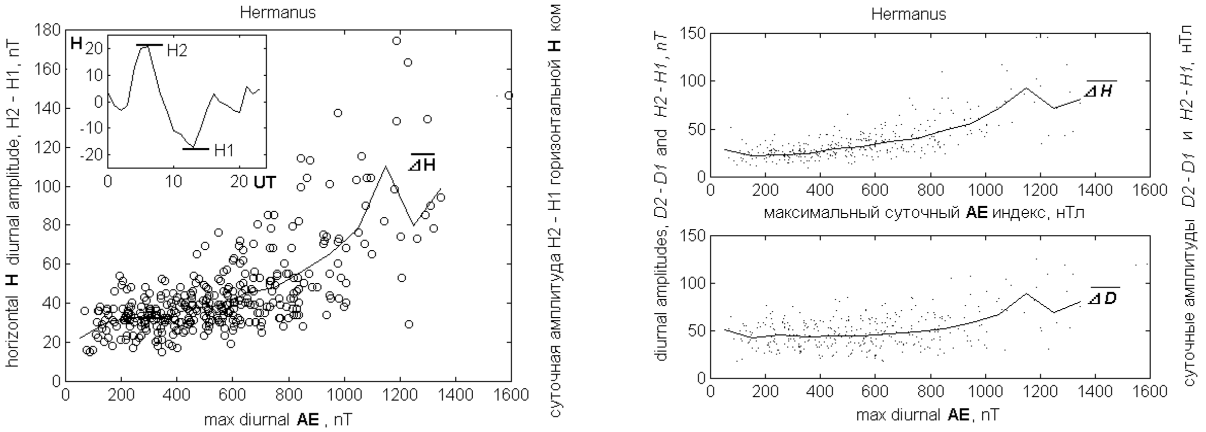


Fig.1, left: an amplitude of S_q variation in horizontal geomagnetic H component; right: the same for projections along and across the geomagnetic meridian, *H* and *D* respectively, at Hermanus, -33°.72 GMLAT, 82°.67 GMLONG. Solid curves denote ΔH, *DH, DD* values, averaged in bins of 100 nT width of daily maximum ??. Growth in amplitude of ?, *H* and *D* with increasing maximum AE is evident, with their scattering enhancing towards larger AE values too.

Examination of the ASY H and AE index relations to the solar wind parameters and geomagnetic activity indicators AL, Kp, Dst and dDst/dt

With the epoch matching technique the characteristic profile of a peak in AE index if being >500 nT have been obtained. The peak-centered time intervals were chosen to be of 21 hour length. The intervals have been mapped to the time sequences of ?$_z$, |B| IMF, B_z's variance $\sigma(B_z)$, solar wind velocity V and number density n, and of the magnetic activity indices AL, Kp, Dst, dDst/dt as well to obtain their characteristic time profiles while the AE peaking was in progress. Then the same procedure was applied to the ASY H index peaks exceeding 30 nT. The results are shown in Fig. 4, in the left column for ASY H-attached study and in the right column– for the AE-attached one. Averaged profiles of the AE/ASY H peaks are shown held on in the respective panels of Fig. 5.

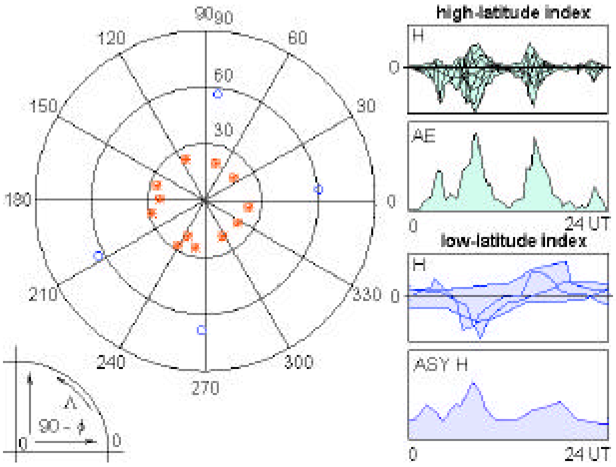


Fig..2. Polar plot: standard auroral (circles with asterisks) and low-latitude (circles) observatories. Plots: likelihood of the ASY H/D and AE index production: either of them is a difference between the maximum and minimum of a world-wide disturbance profile of the geomagnetic field H component. The low-latitude observatories are given by their coordinates in the table below:

Obs.	Abbr.	φ°	λ°	f °	Λ°
		Geodetic		Geomagn.	
Hermanus	HER	-34.42	19.23	-33.72	82.67
Honolulu	HON	21.32	202.00	21.46	-91.43
Kakioka	KAK	36.23	140.18	26.62	-152.23
San Juan	SJG	18.38	293.88	29.36	5.21

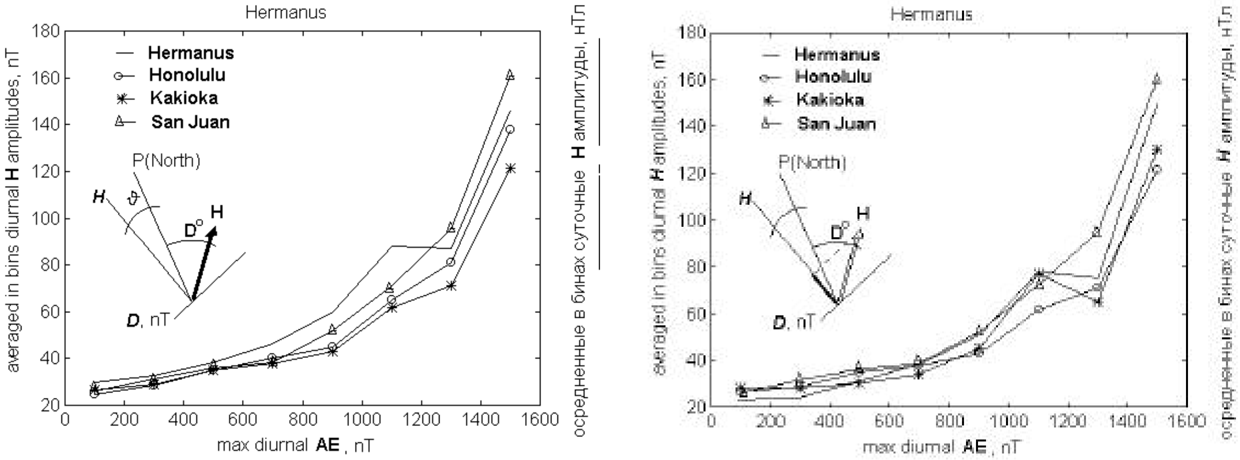


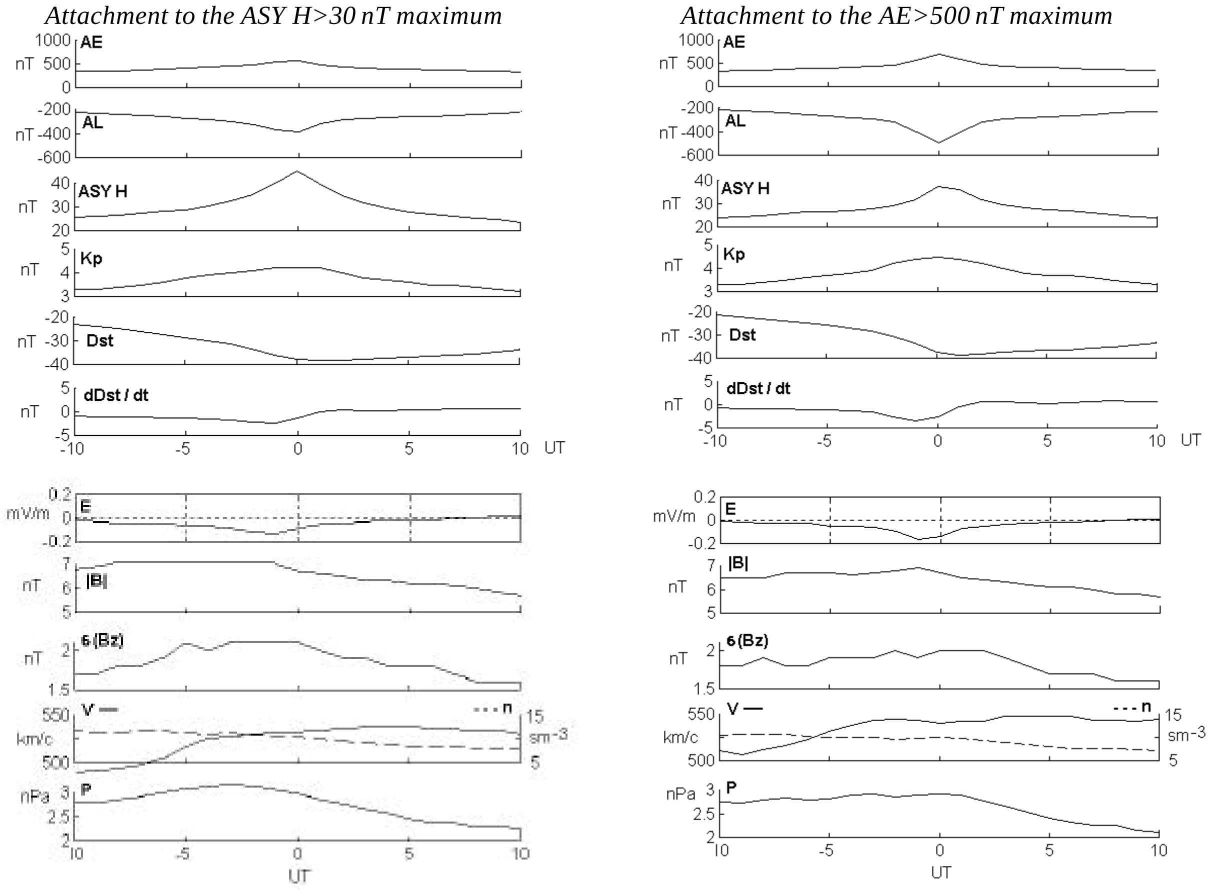
Fig. 3. Left panel: diurnal variation amplitudes ? (nT), being the full horizontal geomagnetic field component, at Hermanus; right panel – the same for its portion ? (nT) oriented to the northern geomagnetic pole. The absence of essential distinctions in their behavior allowed us to consider immediately this full horizontal H component henceforth.

In Fig. 4 the likelihood in temporal behavior of all the examined values is evident, that is these factors contribute equally to peaks both in AE and ASY H indices. Some second-order differences still might be noted, though. Thus, in the right panel the AE peak appeared to be higher than in the left one and it corresponds to the slightly increased characteristic electric field E_y, the decreased solar wind dynamic pressure P and |B| IMF values and the lessen B_z variance. So far, the ASY H index seems to be more sensitive to the dynamic pressure changes. However, it is unlikely to be the main reason of the ASY H/AE discrepancies.

In Fig. 5 qualitative resemblance of the characteristic temporal profiles related to both indices and proportionality of their case-averaged values by a factor of about 14÷17 imply the coherent time variation of ASY H and AE indices with rough intensity ratio of 15 has often to be observed. However, this coherence might be strongly affected by auroral oval moving) away from the auroral observatory chain or by the current system I/II development.The the former is possible during severe magnetic storms. In Fig. 6 it is seen that the scattering in the ASY H vs. AE dependence is reduced towards higher AE values (but 7 cases of extremely high ASY H) while Dst remains within 0…-20 nT. The inverse situation is for Dst < -50 nT, when compared to the ASY H ranges for AE=800±50 nT.

Discussion

The possibility of ionospheric currents closing the eastward and westward auroral electrojets to spread up to the low latitudes is supported both experimentally and theoretically (Denissenko and Zamay, 1990, and references therein). However, there is an ambiguity concerning the ‘partial ring current’ contribution into the low-latitude asymmetry of the H-component world-wide variation. The other source of asymmetry could be the westward electrojet’s westward edge which is called ‘a westward travelling surge’ appropriate to the substorm expansion phase (Clauer ae al., 1983). It is rather asymmetric and therefore it has to contribute the low-latitude world wide asymmetry index (being equivalent to the ASY H) introduced by Kawasaki and Akasofu (1971). The third possible source for the low-latitude asymmetry is related immediately to the high-latitude system I currents asymmetry (Clauer ae al., 1983). Attempting to separate it from the WTS asymmetry addition, they introduced an original ASYM index which is the ASY index (with more stations involved, though) with the data in 30°-sectors centered at local midnights and noons excluded. Still earlier as a possible source of the low-latitude asymmetry the azimuthal rotation of the system II currents with respect to the system I currents has been considered by Croocker and Siscoe, 1981. However, their interpretation faces a time-scale problem. According to Lyatsky, 1978, the characteristic time of the system I currents development is of about ~10÷20 minutes whereas for the system II currents it is of about ~1÷2 hours being the longer the higher the geomagnetic activity level. Therefore any in-phase variation of the ASY H and AE hourly indices reflects the processes related rather to the current I than II system. Simultaneous contribution into both indices from third external factor (Dst-related) might be also possible. Nevertheless the partial ring current seems to be not the most effective contributor of the low-latitude H-asymmetry since this asymmetry, being observed at middle latitudes during several storms (lasting for 2-3 days each), was found drifting westward both in its positive maximum position at dusk and its negative maximum position at dawn sectors with a rotation velocity of 0.2…0.3 hr local time per UT hour (Iyemori, 1990). On the other hand, the mid-latitude H-component diurnal variation does not resemble the result of interpolation between those related to high and low latitudes.


Attachment to the ASY H>30 nT maximum

Attachment to the AE>500 nT maximum

Fig. 4. Case-averaged time profiles of the solar wind parameters and geomagnetic activity indicators in the vicinity of the ASY H peaks >30 nT (left) and AE peaks >500 nT (right column).

Here we were interested in demonstrating that the ASY H index can be a good indicator of the high-latitude geomagnetic activity providing information on both the extent of the eastward/westward electrojet mutual development and the WTS westward expansion. Indeed, the substorm current wedge, being asymmetric, is expected to contribute the H-component asymmetry as well as the partial ring current. On the other hand, it should be closed in the high-latitude ionosphere and generate ionospheric currents spreading down to the ASY-H observatory chain.

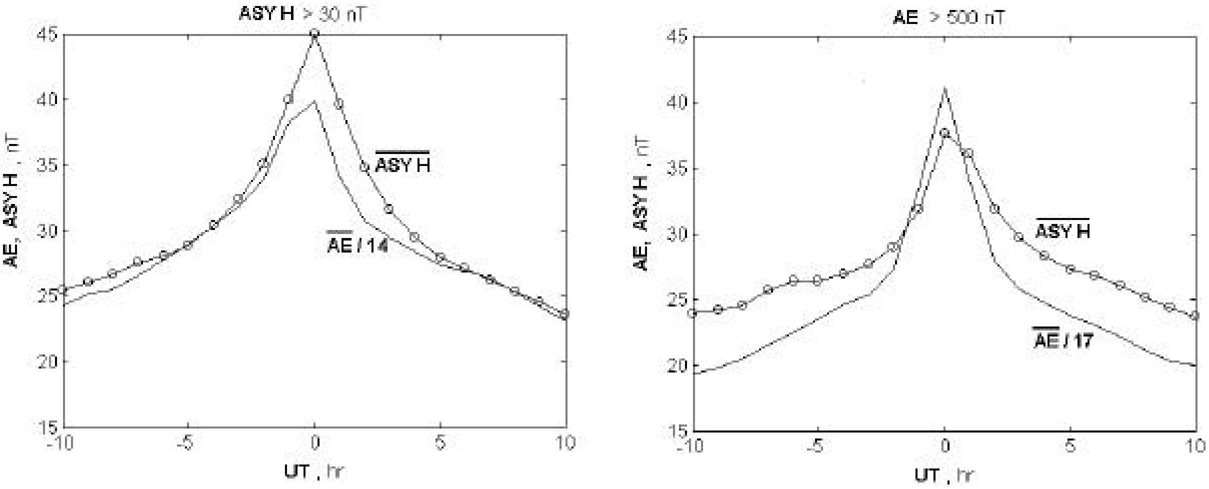


Fig. 5. Superimposed case-averaged peaks in ASY H and AE indices corresponding to the max(ASY H)>30 nT (left panel) and to the max(AE)>500 condition (right panel).

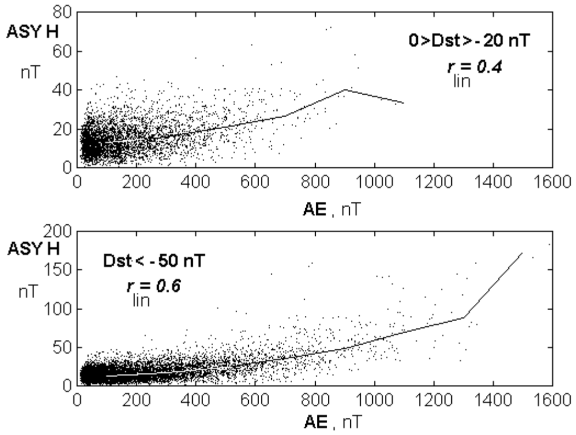


Fig. 6. ASY H vs. ?? (both hourly) under –20<Dst<0 nT (upper panel) and Dst < 50 nT (lower panel) conditions.

In Fig.6 the Dst level importance for the ASY H/AE correlation is shown. The weak negative Dst, the ASY H grows ~linearly with increasing AE, with a linear correlation coefficient *r*~0.4. Their regression equation is ASY H_q =10.7+0.0213AE (nT),

where the subscript ‘q’ denotes ‘quiet’ Dst level. For the storm Dst level, denoted by ‘s’ subscript, *r*~0.6 and the respective regression equation is

ASY H_s =8.5+0.0393AE (nT)

The ASY H and ?? indices are related via a fairly strong, slightly non-linear function and their relationship is better revealed in geomagnetic storm conditions. A good similarity of the diurnal variation amplitude at one station and a world-wide ASY H index dependencies on AE value assumes the input from the auroral electrojet-related ionosphere currents into the low-latitude diurnal variation is dominating.

Thus, the substorm should be twofold manifested in the low-latitude H component. Add the high-latitude ionosphere convection currents also spreading down to the same latitudes controlled by the eastward/westward electrojet intensities. Therefore, in the average, not only the ASY H index has to be predicted from AE index value but the inverse procedure should also be valid. This reversal is indeed observed when we initially select the AE peaks exceeding 500 nT and infer their average peak height being higher than the respective mean ASY H peak height =38 nT by a factor of 17, then we do the opposite , e.g., we select the ASY H peaks exceeding 30 nT and obtain the corresponding mean AE peak height =545 nT that is i)higher than 500 nT and ii)exceeding the mean ASY H value by a factor of 14.

Other evidences for the high-latitude processes which may explain a large portion of the low-latitude H-asymmetry are the clear relation of the diurnal H-component variation amplitude at one low-latitude station to the daily mean AE index with no regard to the Dst level, on the one hand, and a strong correlation between hourly ASY H and AE index values at any time, on the other hand. The partial ring current is supposed to develop during storm development phase (Iyemori, 1990) and the particles probably related to it were directly observed during very few storms (Clauer et al., 1983). The averaged AE and ASY H maxima fall to the storm development phase too, as can be seen in Fig. 4, therefore the relationship between them is stronger for the Dst<-50 nT (Fig. 6), but this leaves the question about the third Dst-related factor open.

But there is one more thing to note. The ring current, partial or full, is flowing closely to the magnetosphere equatorial plane and should have no effect on the H component projection across the geomagnetic meridian. However, the *D* geomagnetic component growth in value at Hermanus with AE increasing has been noted. That is the ionosphere mechanism of the high-latitude disturbance energy transfer is operating indeed.

Main results and conclusions

Using low-latitude ground magnetic observations for the 1985 year an hourly low-latitude ASY H index is produced according to the standard procedure. It was compared then with the standard AE index indicating the high-latitude auroral activity. It is found that at standard low-latitude station the diurnal amplitudes of the full horizontal H-component and those of its projections along and across the geomagnetic meridian increase in value with AE index growing.

A strong, slightly non-linear dependence between the low-latitude ASY H and high-latitude AE indices is obtained, being more steady during the storm time. The close relationship of the full H component diurnal variation amplitude to the daily AE index is found, which gives an evidence of significant contribution of ionospheric spreading currents into the low-latitude diurnal variation.

Compared solar wind conditions separately for the AE peaks >500 nT and ASY H peaks >30 nT, the ASY H index is revealed to be slightly more sensitive to the solar wind dynamic pressure. Each of averaged peaks, ASY H- or AE-attached, fall down to the storm development phase. An average picture of the solar wind and geomagnetic background time profiles (based on other indices) are the same for the AE and ASY H selected peaks within 21-hour intervals.

The reversal of the peak average height prediction for AE peaks >500 nT and ASY H peaks >30 nT is found with the proportionality coefficient between 14 and 17.

Thus the low-latitude ASY H index is strongly contributed from the high-latitude geomagnetic activity processes and the obtained results imply the ionospheric spreading currents closing auroral electrojets might be an effecient mechanism of the AE-to-ASY H index effect.

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