"Physics of Auroral Phenomena", Proc. XXVI Annual Seminar, Apatity, pp. 16-20, 2003

Polar Geophysical Institute

AE-TO-ASY H RELATIONSHIP UNDER THE DIFFERENT Dst LEVELS

Goncharova M.Yu. *(Polar Geophysical Institute, Apatity 184209, Russia)*

Abstract. Using hourly 1984-1987 years data, the standard AE index is compared with manually derived non-standard ASY H index (with the symmetric disturbance field component left at each station). It appeared that under the low negative Dst, -20...0 nT, the AE – ASY H relationship is unidirectional: observing AE>500 nT one can expect the ASY H >30 nT, whereas the inverse is not true. In storm conditions, the Dst<-50 nT, the AE-ASY H relationship is getting reciprocal, with the AE/ASY H ratio keeping almost invariable at 12...14 times during rather long period. It is also found that i) longitudinal asymmetry relationship at the high and low latitudes depends strongly on the westward electrojet development; ii) the low-latitude longitudinal asymmetry has an AE and Dst-independent source; iii) the AE/ASY H ratio scattering is partially due to AE seasonal variation related to the polar cap illumination conditions, in agreement with results of Lyatsky et al., 2001.

1. Introduction

The ASY H non-standard index is a manually derived low-latitudinal analogue of AE index, but the S_q variation is removed, whereas the S_q^p variation is never removed when AE index deriving. The distinction of this ASY H from a standard ASY H version is that the latter is variable in sign due to the symmetric disturbance component (minutely Dst) is removed from any observatory data. Also the standard ASY H is based on a horizontal field component, oriented to the north geomagnetic pole in a dipole coordinate system, whereas the non-standard ASY H is based on a complete horizontal field component, since the resolving into H and D components leads to the coherence with AE variation is manifested sometimes in H, sometimes in D component. The idea to describe the low-latitude longitudinal asymmetry of the disturbance magnetic field *D* with a sum of Fourier harmonic terms, dependent on longitude only, called *DS* index, belongs to Kawasaki and Akasofu [1971]. They present a few samples of good and long-lasting sin-phase variations between the low-latitude asymmetry indicator and the westward electrojet intensity. The same dependence is found by Zaitseva et al., [2002]. Kawasaki and Akasofu note, however, that the frequently occurring anticorrelation between DS component and electrojet intensity suggests the DS component cannot be mainly due to the ionospheric return current from the electrojet. From a note on 'it has been long thought that the DS_1, $DS_1(H)$ was due to the return currents from electrojets...' it follows the complete horizontal magnetic field component was in mind while the DS index deriving. The Kawasaki-Akasofu index was found by Clauer et al. [1983] to be very sensitive to the low-latitude substorm positive bays.

In Goncharova, Maltsev [2001] a statistical relationship between this non-standard ASY H and standard AE indices was found, with a rough proportionality ratio of 14 times for ASY H>30 nT to AE mapping, and 17 times for AE>500 nT to ASY H mapping, with no delay suggested. Frequently observed incoherent behavior of both indices (see Fig.1) assumed restrictions set to the mutual prognostic abilities of either index. Having compared the geomagnetic indices behavior, as well as the solar wind conditions under the good/bad reciprocity of AE>500 to ASY H>30 nT mapping it was found that the AL, Kp and Dst indices are enhanced when the reciprocity is good. Below one can see the results of considering the Dst effect to high-to-low-latitude longitudinal asymmetries correspondence.

2. AE & ASY H correlation under the small/large negative Dst conditions

In Fig.1, upper and middle panel, the AE and non-standard ASY H hourly index time series are given by heavy and light solid curves respectively. Staying related, the ASY H index may overtake (1 hour) or lag behind the AE index during several hours. Sin-phase variation observed at the same UT on different days points to possible ionosphere conditions importance. In Fig.1, lower panel, the linear correlation coefficients between AE fixed and the time-shifted non-standard ASY H are compared for -3...3 hour time shifts, for two years separately. Its level is maximum for null time shift. The linear correlation gradually increases with the negative time shift approaching to 0 and almost does not subside in an hour, staying above the mirrored curves (dashed) of negative time-shifted ASY H.

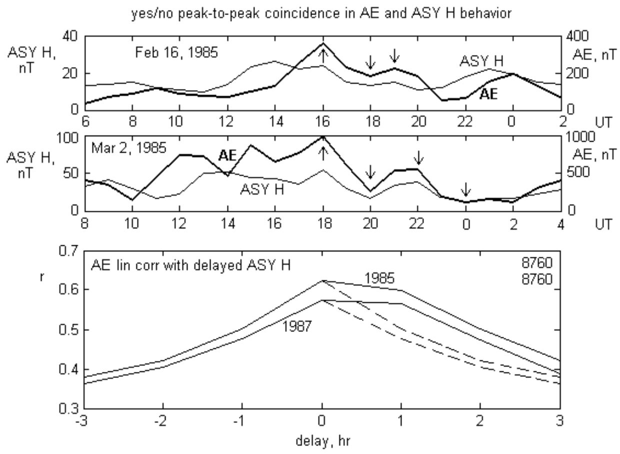


Fig. 1 ASY H overtaking & lagging behind AE

The maximum at Δt=0 suggests the most effective one is the fastest interface between high- and low-latitude asymmetries, perhaps, via the ionosphere electric fields. The delay in subsiding ASY H points to the low-latitude asymmetry 'memory', possibly associated with the long-living magnetosphere current systems.

In Fig. 2 ASY H vs. AE under -20<Dst<0 and Dst<-50 nT are given at upper and lower panels respectively.

The dependence is closer to the linear one for the latter case (r=0.7), whereas for smaller Dst it is slightly parabolic (r=0.36). The inclination angle is also greater for the greater negative Dst, that is the low-latitude 1asymmetry is immediately related to the AE level of the current hour under the large negative Dst.

Interesting that, in absence of severe storm conditions, the ASY H up to ~50 nT are observed under low (<200 nT) AE level, *suggesting the ASY H has its proper, independent on AE and Dst conditions source.* In storm conditions the dependence between the two indices remains linear even for very small AE.

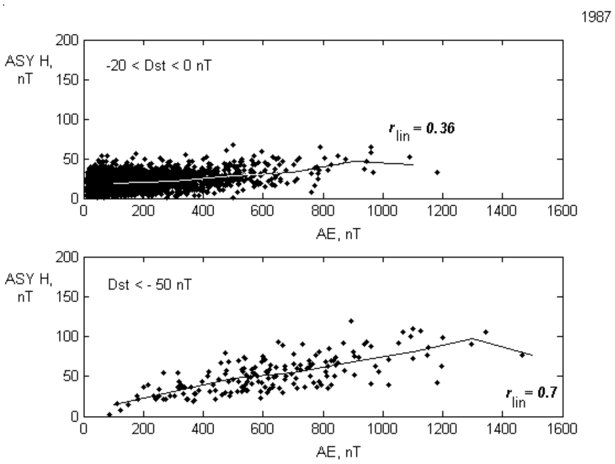
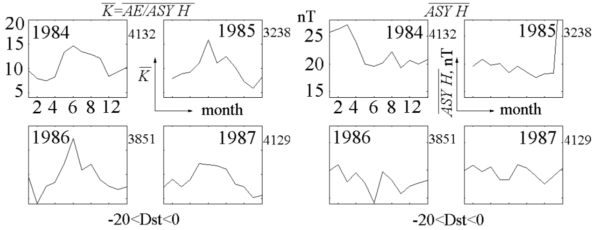


Fig. 2 ASY H – AE relationship under the different Dst The solid curves give ASY H averaged in bins of 200 nT

The scattering in ASY H is greater for smaller negative Dst in <400 nT AE range, and for large negative Dst it is greater in 400...1000 nT AE range. That is the large negative Dst somehow suppresses the ASY H natural fluctuation development.

2.1 On possible reason of a large scattering in ASY H on AE dependence.



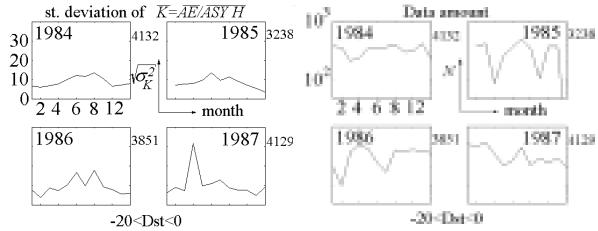


Fig. 3. Seasonal dependence of AE/ASY H ratio, ASY H level, standard AE/ASY H ratio deviation and data amount for 1984-87 years.

Fig. 3 illustrates AE/ASY H seasonal dependence0 due to the S_q^p is not removed from AE and plus the AE activation depends on polar cap illumination conditions. It is seen that:

1) ASY H has no seasonal variation
2) AE/ASY H ratio undergoes seasonal variation peaked on summer months
3) Standard deviation of AE/ASY H from its bin-averaged value undergoes seasonal variation peaked mostly on summer months. That is, part of scattering in AE/ASY H is due to polar cap conductivity conditions. Another part is due to ASY H proper source.

Dst was low for these hours, in -20...0 nT range. Data amount in each bin, but 12^{th} in 1986, was greater than ~90.

3. AE – ASY H relationship reciprocity dependence on negative Dst level and AL index

Fig. 4 illustrates the westward electrojet (AL) and Dst importance for AE prediction from ASY H. Positioned in the same order as in Fig. 2, for Dst∈[-20,0] and Dst<-50 nT, the time-averaged profiles of ASY H and scaled AE indices are given by line with circles and simple solid line, respectively. Profiles are obtained with the superimposed epoch tecnique within 21-hour intervals centered at hourly values of AE>500 (left column of Fig.3) and ASY H>30 nT (right column).

Typical 'storm profile' both in ASY H and AE is seen under the Dst<-50 nT. The AE/ASY H ratio remains at about 12...14 times within all the 21 hour interval. For Dst∈[-20,0] nT, the AE/ASY H ~8÷17 times for the mapping based on ASY H and AE fixed respectively, that is the enhanced ASY H cannot be good indicator of the AE level enhancement under low Dst. The AE-ASY H phase relationships cannot be understood from this Figure.

Westward electrojet intensity importance for the AE –ASY H relationship reciprocity is seen from comparison of AL index profiles under the Dst=-20..0 and <-50 nT. For both the forth and back AE-ASY H mapping, if the AE/ASY H profile peak ratios are close in value, the peak AL values are close as well (see middle and bottom panels). The ASY H index is seen to have an AL-independent source for growth (compare top and bottom panels in right column of Fig. 4).

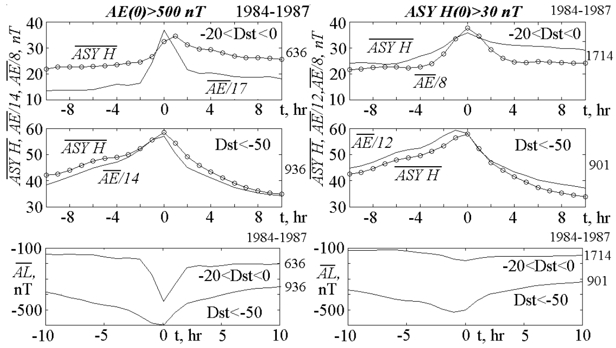


Fig. 4. ASY H, AE and AL time-averaged profiles (21 points) for AE(0)>500 (left) or ASY H(0)>30 nT (right panel) conditions held, separately for small (-20..0 nT) and strong (<-50 nT) Dst values.

Examples illustrating perfectly coherent behavior sometimes observed between ASY H and AL can be found in Kawasaki and Akasofu [1971] or Nishida [1978]. The authors note that the *DS* component often anticorrellates with the westward electrojet intensity that is 'the *DS* component cannot be mainly due to the (ionospheric) return current from the electrojet' [Kawasaki & Akasofu, 1971].

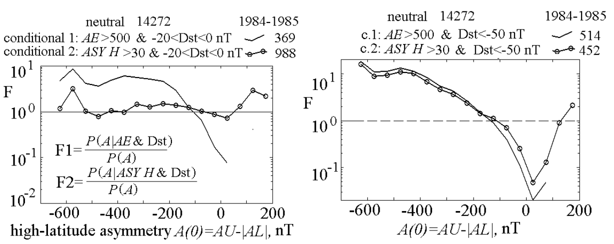
3.1 High-to-low-latitude longitudinal asymmetry relationship under the small/large negative Dst conditions.

In the formula [Goncharova, 2002]

$$F = \frac{P(B)P(A\,|\,B)}{P(A)P(B)} \qquad (1)$$

where F is the relationship reliability function (RRF), A and B stand for the response and condition respectively, P(B) vanishes equally for simple and complex condition. Let P(A) be a neutral probability function of the response parameter based on initial data set that can be restricted manually. The only requirement, in case of independence A on B, F(A|B)=1.

Final response of non-time-shifted ASY H and AE to AE structure under 4 combinations of AE level and negative Dst depth in Fig.5 is shown. If ASY H is sensitive to the electrojet return currents, it has to react to their discrepancy in intensity too. AE structure is represented by an electrojet intensity difference parameter A=AU-|AL|. Neutral probability $P_0(A)$ to find $A\in[-700, 200]$ nT range (with 50 nT bin width) is based on the unperturbed ensemble of 1984-1985.



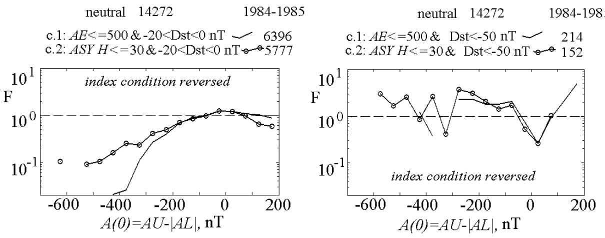


Fig. 5. Top panel: RRF of the eastward-westward electrojet asymmetry A=AU-|AL|, nT, to AE>500 and ASY H>30 nT levels. The ASY H is marked with circles. Left and right panels: Dst=-20…0 and Dst<-50 nT respectively. The neutral probability to observe a certain A value is based on the total ensemble (1984-85 years, hourly data used). AE and Dst are considered here as one complex condition.

Conditional probabilities are based on united complex conditions and calculated within subsets of small and large Dst, or ASY H>,≤30 nT conditions added (the ensemble is once reduced). Probabilities to observe the same A value under (-20<Dst≤0, AE>500) and (-20<Dst≤0, ASY H>30) nT conditions are written as

$P_{11}(A,Dst_1,AE)=\underline{P(Dst_1,AE)}\cdot P(A|Dst_1,AE)$,

or $=\underline{P(AE,Dst_1)}\cdot P(A)$, (3a)

if (AE,Dst_1) and A are dependent or independent, respectively. Similarly,

$P_{12}(A,Dst_1,ASY\ H)=\underline{P(Dst_1,ASY\ H)}\cdot P(A|Dst_1,ASY\ H)$,

or $=P(ASY\ H,Dst_1)\cdot P(A)$ (3b)

Thus,

$F1=P_{11}/P_0=P(Dst_1,AE)\cdot P(A|Dst_1,AE):$
$:(P(A)\cdot P(Dst_1,AE))=P(A|Dst_1,AE):P(A)$ (4a)

$F2=P_{12}/P_0=P(Dst_1,ASY\ H)\cdot P(A|Dst_1,ASY\ H):$
$:(P(A)\cdot P(Dst_1,ASY\ H))= P(A|Dst_1,ASY\ H):P(A)$ (4b)

Analogously for Dst_2 ensemble. Easy to see, F1=1 if A and AE are independent, F2=1 if A and ASY H are independent under the given Dst.

Left and right plots of Fig. **5** differ by fixed Dst level entering the condition (Dst&AE), (Dst&ASY H). Top and bottom plots differ by reversed limitations set on AE and ASY H indices.

By transition from left to right, for enhanced AE and ASY H conditions, ASY H-AE mapping reciprocity is changing from poor to perfect, as seen from F1, F2 curves drawing together. By transition from top to bottom: the same A values associated with different F sign testify the AE, ASY H relationship to AU-|AL| is stochastic, and the stochasticity also diminishes with Dst negative increasing. Interesting that ASY H <, >30 nT are associated with highest A values, whereas AE<500 nT aren't.

4. Differential AE and Dst relationship to ASY H

The data ensemble is extended to 1984-1987, since it has to be twice reduced.

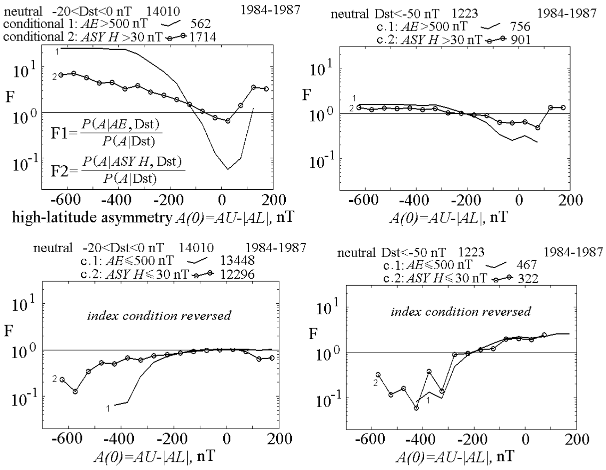


Fig.6. Same as Fig.5, but i) 1984-1987 data in use; ii) neutral probabilities are based on subsets defined by two distinct Dst groups; ii) AE and Dst conditions thus separated.

To infer AE or ASY H level relationship to AU-|AL| under different Dst conditions, it is enough to subtract RRF logarithm for small AE, ASY H from that one for large AE, ASY H *by the same Dst level, e.g., from top to bottom*.

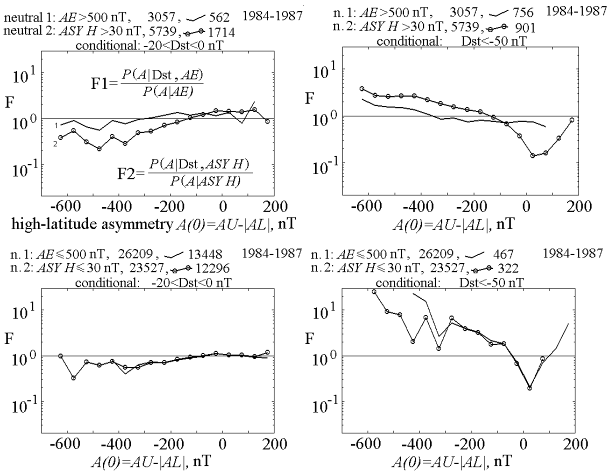


Fig.7. Similar to Fig.5, 6, but four neutral probability functions are based on two groups dividing AE and ASY H. Left and right plots have common AE-, ASY H-based neutral probability functions but differ by Dst condition.

To reveal Dst effect on AU-|AL| signature occurrence in AE and ASY H, one has to subtract RRF logarithms in Fig. 7 from right to left.

Distinction of Fig. 6 from Fig. 5: having fixed Dst, by an AE, ASY H condition reversal, the sign of their relationship to AU-|AL| inverses too. Fixed small Dst, relationships changes from strong (log(F)>2) negative to strong positive. Fixed large Dst, increase in AE and ASY H makes relationship to AU-|AL| to be weakly positive. *The AE-related RRF to AU-|AL| is effected greater*.

In Fig. 7: fixed small ASY H and AE, increase in negative Dst leads to the weak negative relationship of their level to AU-|AL| signature occurrence becomes very strong. Fixed large AE, ASY H, increase in Dst<0 changes the considered relationship from moderately weak to moderately strong, with *the ASY H-related RRF to AU-|AL| being effected greater.*

In all 5-7 Figures the increase in Dst<0 leads to AE- and ASY H relationship reliability curves drawing together, giving an evidence of their conditional occurrence probabilities getting closer, whereas increase in AE maintains their divergence.

Thus, under Dst<<0 the AE, ASY H mapping reciprocity is enhanced due to Dst control over ASY H mostly.

Distinctive sensitivity of AE and ASY H to large electrojet asymmetries seen under small Dst<0, and alike even to smaller ones, seen under Dst<-50 nT assumes two possibilities: i)Dst improves AE-ASY H mapping reciprocity fairly not via the electrojet return currents but possibly via magnetosphere currents; ii)under the enlarged high-latitude electrojet intensity differences, ASY H comprises electrojet effect from both hemispheres. The following items can be resumed:

1) The asymmetry suppression turns into stimulation by Dst transition from –20..0 to <-50 nT mainly due to AL index effect

2) Strong negative Dst elevates the worldwide profile asymmetries both in low and high latitudes, with the low-latitude asymmetry more affected.

Thus, with negative Dst increasing the westward (and not eastward) electrojet is intensifyed greatly, and the AE-ASY H mapping reciprocity is getting better even in absence of large AE, and ASY H remains sensitive to AU-AL structure. Similar relationship of ASY to AL indices was found in Zaitseva et al., [2002].

From differential analysis of AE and Dst effects it follows that the AE and Dst factors are best in unifying AE and ASY H relationship to AE structure when they act as one complex condition. And westward electrojet is always greater developed and provides the mapping reciprocity almost alone.

5. Summary and discussion

An effect of negative Dst increasing in value on the AE-ASY H mapping reciprocity is considered. It is found that:

1) Small negative Dst, the AE-to-ASY H mapping reciprocity is poor, even for large AE. Scattering in ASY H value for small AE or small Dst<0 suggests that the low-latitude longitudinal asymmetry has its proper source for growth, providing ~50 nT amplitude, with ASY H being insensitive to AU-|AL| difference.
2) Large negative Dst, the AE-ASY H mapping reciprocity is enhanced, the ASY-AE dependence linearizes, ASY H is getting more sensitive to AU–|AL|
3) Reciprocity of AE-to-ASY H mapping is best when large negative Dst and high AE (say, >500

nT) act together. That time, ASY H is sensitive to the AE level and electrojet asymmetry as well.

4) With negative Dst increasing, when the AE-ASY H correspondence is enhanced, the westward (and not eastward) electrojet is intensified greatly.
5) Differential effect from AE and Dst, as revealed by RRF analysis, assumes that an increase in AE is associated with increasing ASY H, whereas the more negative Dst elevates their joint occurrence.
6) AE/ASY H ratio appears to be dependent strongly on polar cap illumination conditions affecting the polar ionosphere conductivity, since AE is increased during the northern summer time (seen even for small negative Dst) and a scattering in ASY H(AE) dependence is increased too.

Thus, the ASY H index can be predicted from AE observations more effectively under the enhanced negative Dst and during the northern winter period.

Distinction in ASY H-AE relationship quality under the small/large Dst<0 implies at least 2 mechanisms providing AE signature manifestation in ASY H. The first one is working under small Dst<0, when ASY H obeys to AU+|AL|, but is worse sensitive to AU-|AL| difference. The scattering in ASY H-AE dependence grows just when the polar ionosphere is sunlit and its conductivity is enhanced. Therefore, the conductivity enhancement is not a good explanation for steady AE-ASY H reciprocal mapping observed under the large Dst<0. For AE and Dst<0 increased together, the AE/ASY H ratio keeps at ~12...14 times for several hours, with the westward electrojet intensified greatly (and DS-AL relationship is hardly due to the electrojet return currents, according to Kawasaki and Akasofu, [1971]). Perhaps, large Dst<0 controls both AE and ASY H via the magnetosphere current configuration, whereas small Dst<0 permits the auroral electrojet system to contribute ASY H index via electrojet return currents only.

References

Clauer, R., R.L. McPherron, C. Searls, Solar wind control of the low-latitude asymmetric magnetic field, *J.Geophys.Res., 88,* 2123-2130, 1983.

Goncharova, M.Yu., On AE index rising and subsiding after a negative stair in Bz IMF, in *Proceedings of the 4th International Conference 'Problems of Geocosmos', June 3-7, 2002, St.-Petersburg, Russia,* 112-115, 2002.

Goncharova M. Yu., Yu. P. Maltsev, Low-latitude ASY H index as an indicator of high-latitude magnetic activity, in "Physics of Auroral Phenomena", *Proc. of the 25th Annual Seminar in Apatity, pp. 12-16*, 2002.

Kawasaki, K., and S.-I. Akasofu, Low-latitude DS component of geomagnetic storm field, *J.Geophys.Res., 76,* 2396-2405, 1983.

Lyatsky, W.B., A. M. Hamza, Seasonal and diurnal variations of geomagnetic activity and their role in Space Weather forecast, *Can.J.Phys., 79,* 907-920, 2001.

Zaitseva, S.A., T.A. Drobinina, M.I. Pudovkin, DR-current intensity variations during substorm development, in *Proceedings of the 4th International Conference 'Problems of Geocosmos', June 3-7, 2002, St.-Petersburg, Russia,* 136-141, 2002.