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Subauroral drift velocities in disturbed geomagnetic conditions

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The equatorial boundary of the auroral oval (EBO) or the boundary of diffuse aurora separates high latitude ionosphere, moving after the effect of magnetospheric convection electric field from Earth corotating middle and low latitude ionosphere, The shielding of the convection electric field occurring at the inner edge of the plasma sheet (EBO is the ionospheric manifestation of this boundary) may be significantly affected by particle transport between magnetosphere and ionosphere and by the temporal dependence of the different processes involved. The dynamics of the subauroral zone, the region equatorward from EBO is determined by the competition of the magnetospheric convection electric field and the corotation field. On the other hand, based on contemporary concepts, ionospheric plasma convection at subauroral latitudes appears to be of most decisive importance for the formation of the characteristic latitudinal profile of ionization in the F-region, the main ionospheric trough [1]. Experimental data for the subauroral convection, both for quiet and disturbed conditions, are not sufficient to construct a complete model. The results from direct satellite and ground-based measurements are summarized in [2, 3], and in [2] performance drift patterns are suggested for quiet and disturbed conditions. In substorm conditions two most important details are manifested within the subauroral convection: for the evening and premidnight sector this is a thin strip of rapid westward drift, and for the postmidnight sector meridional drift to lower latitudes of velocity of about 50—100 m/s [4,5]. Rapid westward flows, observed immediately equatorward from EBO [6, 7, 8], known as well as "polarization jets", result in additional "subtrough" [9] within the main ionospheric trough, in the submaximum part of the F-layer.

A new type of convection in the subauroral ionosphere will be discussed in this paper, when equatorward from EBO the drift velocities have significant meridional component of magnitude of the order of the azimuthal component. The results are based on Dynamics Explorer-B data.

Measured drift velocities

We shall examine drift occurrence at subauroral latitudes by data from the Retarding Potential Analyser (RPA) [10], and the Ion Drift Meter (IDM) [11] aboard Dynamics Explorer-B satellite.

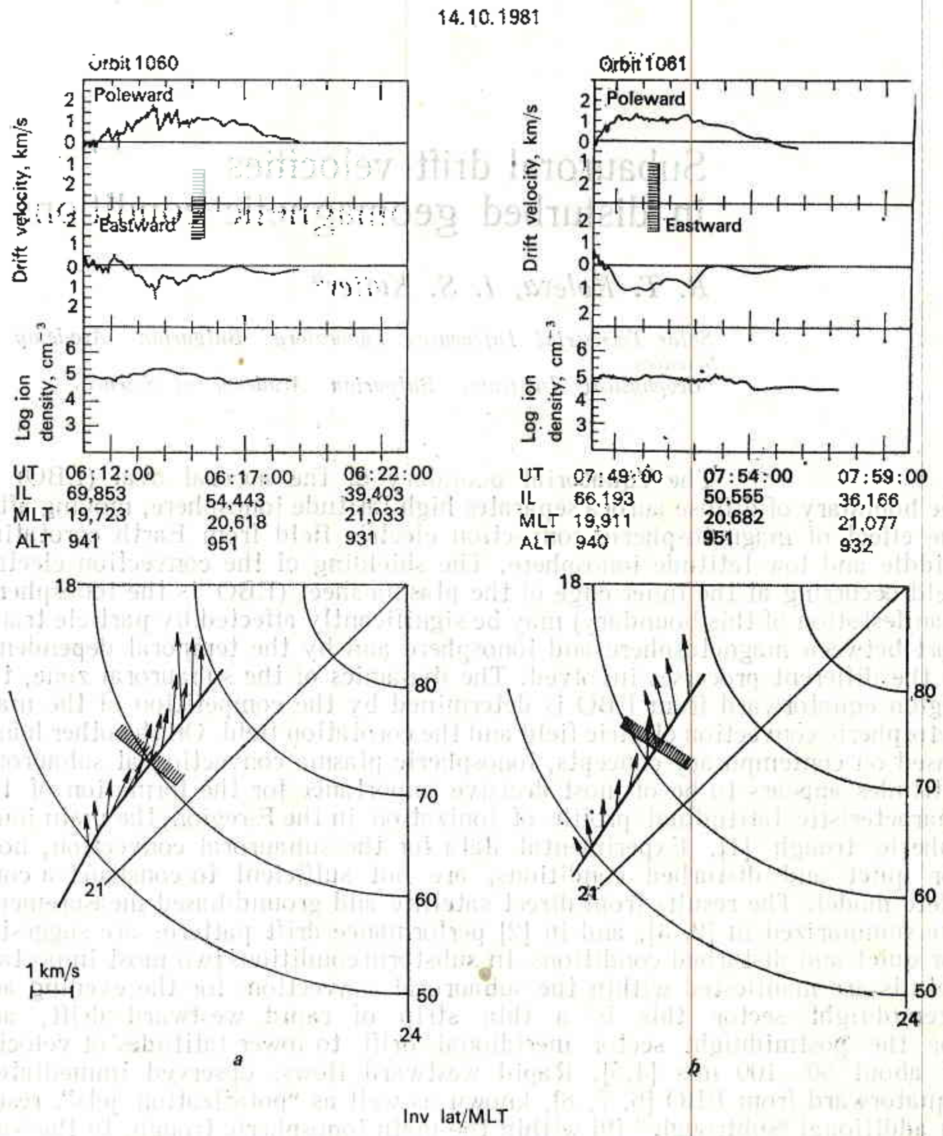


Fig.1. Intense subauroral drift with almost meridional direction

In Figs. 1, 2 and 3 three characteristic cases of subauroral drifts with significant meridional component are presented. The upper panel of each figure shows ion drift velocity component, parallel to the satellite velocity component, as determined by RPA. The second panel illustrates the drift velocity component, perpendicular to the satellite velocity in horizontal plane, determined by the IDM. Here and further below velocities are in a system of reference related to the Earth. The third panel shows the ion density determined by the RPA. A sketch of the respective subaurotal drift velocities in inv lat/MLT frame of reference is shown below the three panels to visualize the velocity latitudinal profile. EBO is determined by data from soft electron precipitation measurements with the Low Altitude Plasma Instrument (LAPI) [12]. E—t spectrogrammes are used for the purpose which allow to eliminate possible

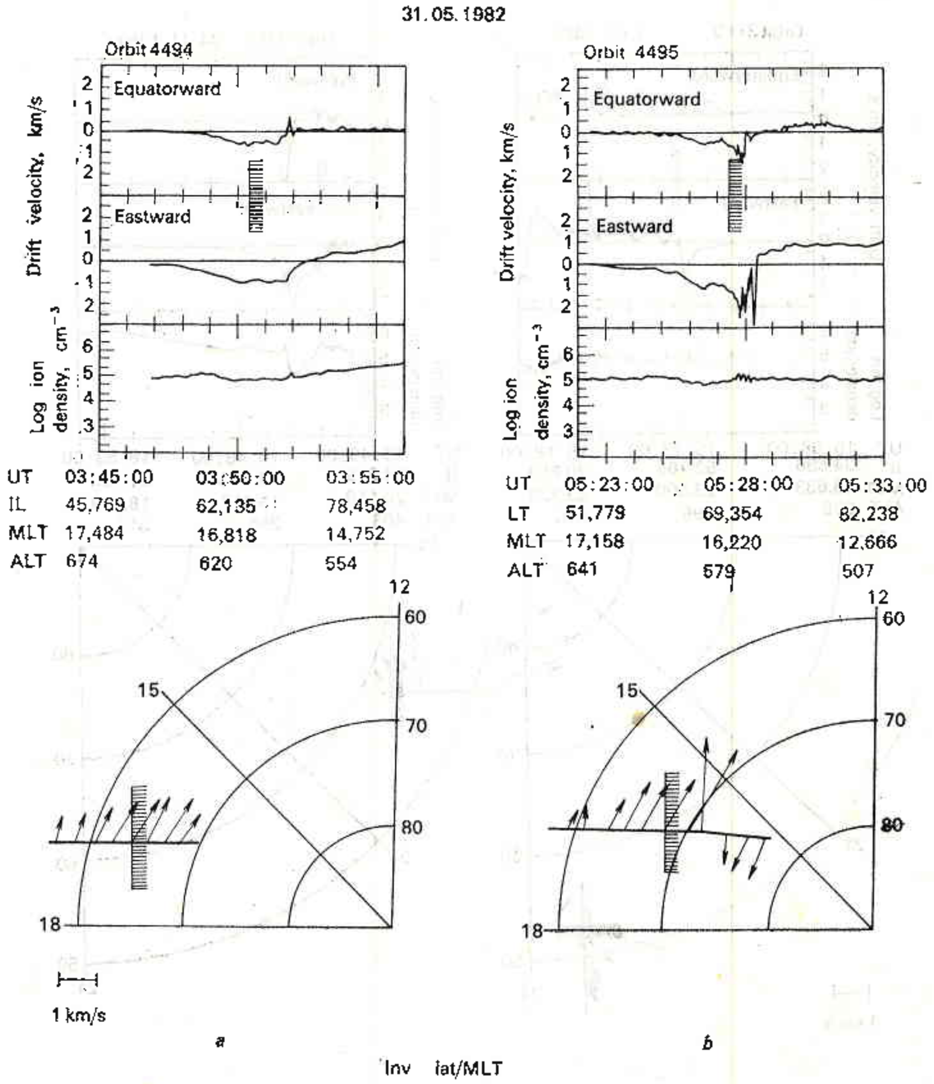
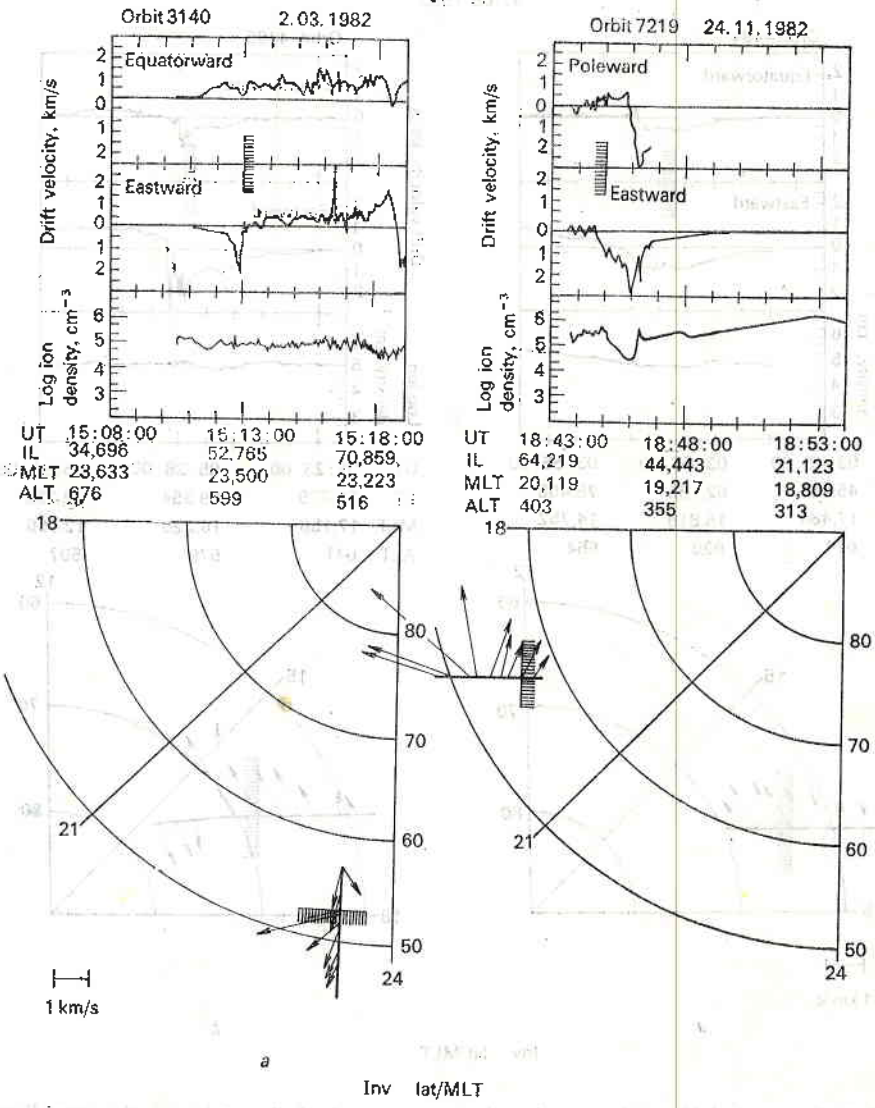


Fig.2. Subauroral drift with an azimuthal component of the order of the meridional

errors due to photoelectron occurrence, the latter is well separated visually. EBO is determined as an abrupt boundary of precipitating electron flux of energies 200 eV. Although for example in [13] EBO is determined by the 1 keV electron flux, it is shown there that better illustration of the equatorial boundary provide electrons of energies 200—400 eV. EBO is denoted by a line, stroked ovalward on panels and sketches. All the examined cases refer to the northern hemisphere, under disturbed geomagnetic conditions.



Fir.3. Cases of intense subauroral drift: when moving from EBO equatorward the drift velocity vector rotates from azimuthal to meridional

Figs 1-*a*, 1-*b* show sectors from two satellite orbits for 14 Oct. 1981—1060 and 1061 respectively, which cross the subauroral latitudes in the evening MLT sector. The subauroral drift for the two cases is almost completely meridional of the order of 1,5 km/s. The subauroral drift is generated by an eastward electric field. The satellite is above the diffuse barrier for the two orbits and no trough in the ion density is to be observed; the latter is of the order of 10^5 cm^{-3} and IDM measurements are completely reliable. The E—t spectrogrammes reveal precipitation of very soft electrons (energy about 10 eV) in the zone of subauroral convection.

Figs. 2-*a* and 2-*b* show two orbits for 31 May, where the subauroral drift is of another behavior. Those orbits cross EBO in the late afternoon MLT sector and the subauroral drift has meridional component equal to the azimuthal westward component. The meridional component is oriented again ovalwards, i. e. generated by eastward electric field component. The subauroral velocity is about 1,1—1,5 km/s. Since these are daytime orbits neither trough in the ion density nor precipitating suprathermal electrons are observed.

Figure 3 shows another type of behavior of the subauroral drift — rotation of the velocity vector to meridional. Orbit 3140 (Fig. 3-*a*) crosses EBO a little before midnight, maybe at the vicinity of Harang's discontinuity, and orbit 7219 (Fig. 3-*b*) — in the evening MLT sector. The drift velocity for both orbits' equatorward from the oval are identified as rapid subauroral westward flows. Moving equatorward away from EBO the velocity vector gradually rotates from azimuthal of westward orientation to meridional, poleward directed. The subauroral electric field is strongly poleward with high intensity, and with the move away from EBO gradually transfers into an westward decreasing in intensity. It is interesting to note that the rapid subauroral flow is not directly on EBO for orbit 7219. The satellite altitude for this orbit is in the circummaximum part of the F-layer and in the well shaped main ionospheric trough, a "subtrough" in the region of the rapid subauroral flow may be observed. For both orbits precipitation of very soft, suprathermal electrons of about 10 eV is observed in the region of subauroral convection.

Discussion

The cases discussed here illustrate subauroral convection with meridional drift component an order bigger than the observed with ground based techniques, and referred also in [3, 4, 5]. Similar case of poleward meridional component is mentioned in [14] by data from S3-2 satellite for the morning MLT sector (orbit 7079 A — north). The cases of subauroral drifts examined by us are simply examples for the presence of a meridional dirft component of significant value, which contradicts the common pattern. All of them are neighboring the west convective cell and are insufficient to provide a morphological pattern of the azimuthal electric field. All cases observed by us refer to disturbed geomagnetic conditions.

The numerical simulation of a magnetospheric substorm made in [14, 15] shows in particular the evolution of a subauroral drift pattern which is in argeement with the results known from ground-based measurements. The direction of the meridional drift component we present here is in agreement with the distribution of the azimuthal subauroral electric field, computed in that simulation. Namely, eastward electric field in the daytime and postdusk MLT sector, and westward electric field in the midnight-dawn sector and in a narrow sector about dusk. But the ionospheric projection of the computed electric field has a maximum value of about 4 mV/m at 60° inv lat, while we observe values of the order of 40 mV/m.

Many authors, for example [5], consider the subauroral drift, observed by ground-based techniques in disturbed geomagnetic conditions as a result from penetration of magnetospheric convection field to low latitudes. In the numerical simulation [14], the penetration of the field is a result of the abrupt change in the conductivity of the underlying ionosphere at the beginning of the substorm, as the inner edge causing the shielding could not adopt to the situation. However this physical picture fails to explain the revealed by satellite data narrow latitudinal strips with very rapid, up to about 10 km/s westward flows, situated equatorward from EBO [1, 6, 8, 9]. An advanced interpretation of the phenomenon is given in [16]. The energetic protons of the magnetotail are capable to penetrate closer to the Earth than the electrons during a substorm. At explicit difference in the underlying ionospheric conductivity in the electron precipitation zone and equatorward, this charge separation may generate very strong polarization field. In [14] after numerical simulation, such a rapid subauroral flow was obtained confirming the model in [16].

Analysis of the latitudinal profile of the drift components, illustrated by the first and second panels of each figure shows that two types of characteristic structure of the drift latitudinal profile may be well defined: i) when at EBO the drift velocities have significant values and the subauroral drift is a natural continuation of the auroral one, for example Figs. 1 and 2; ii) when at EBO or close to there, the auroral drift velocities become very small, almost a zero (compared to velocities in the basic convective cell) and thereafter equatorward from EBO increase again before attenuating at midlatitudes — Fig. 3. This behaviour of the drift velocities provide serious grounds to conclude that equatorward from the boundary of the auroral oval, intense electric fields are observed with two differing origins — penetrating, or not shielded well magnetospheric convection field (Figs. 1 and 2) and polarization field, generated at the inner plasma sheet edge after the mechanism, suggested in [16] (Fig. 3). The qualitative estimates made in [16] show that the intense poleward electric field is generated when the ion and electron inner edges of the plasma sheet differ but are adjacent. In larger separation the azimuthal component may become comparable to the basic convection velocity. Of course the picture there is of qualitative dimension. In order to reveal the different specifics, a more detailed study is needed. It is quite possible that the two types of subauroral electric fields are consequent time-dependent phases — first penetration of the convection field, then formation of a new Alfven layer and under appropriate conditions — generation of polarizations field.

Conclusion

Several cases of subauroral drift are examined for disturbed geomagnetic conditions, where the drift velocities have large meridional components. The meridional drift may be dominant or comparable with the azimuthal one. There are cases when moving from EBO equatorward the drift velocity vector rotates from azimuthal to meridional. The meridional component may be differently oriented for the different MLT sectors. Unfortunately, we do not have enough statistical data to compose a complete drift direction pattern in dependence of MLT. The latitudinal profile of the drift explicitly reveals two types of physical processes: penetration (insufficient shielding) of magnetospheric convection field and generation of polarization electric field at the inner edge of the plasma sheet [16].

The observational material shows that at altitudes above $F_{\max}$, where the dissociative recombination is negligible, the effect of the strong subauroral drift over the ion density distribution is not always observed.

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Субавроральные скорости дрейфа в возмущенных геомагнитных условиях

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(Резюме)

По данным спутников Dynamics Explorer-B рассмотрены случаи субаврорального дрейфа в возмущенных геомагнитных условиях, когда дрейф имеет значительную по величине меридиональную компоненту— порядка километр за секунду и больше. Наблюдаются разные соотношения между азимутальной и меридиональной компонентами дрейфа: когда они сравнимы; когда дрейф почти полностью меридиональный (случаи азимутального субаврорального дрейфа известны по литературе) и случаи, когда уходя от экваториальной границы аврорального овала (ЕГО) к средним широтам, сначала преобладает азимутальная компонента, а потом — меридиональная. В областях усиленной субавроральной конвекции изменения в ионной концентрации не наблюдаются на всех высотах. Широтный профиль дрейфовых скоростей позволяет выделить два типа в поведении электрического поля конвекции: В первом случае широтные профили являются естественным продолжением авроральной конвекции. На них не наблюдаются особенности при пересечении ЕГО. Во втором случае на ГДВ или полярнее ее скорость авроральной конвекции сильно уменьшается или обнуляется, а экваториальнее ГДВ развивается новое поле дрейфа. Первый случай интерпретируется как проникание, недостаточное экранирование магнитосферного поля конвекции на низкие широты, а второй — как генерировани поляризационного электрического поля на внутренней кромке плазменног слоя.