ON THE PLACE OF PSEUDOBREAKUPS IN A SUBSTORM CYCLE: WHEN AND WHY DO THEY OCCUR

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ABSTRACT

We present a statistical study of 419 substorms and 330 pseudobreakups identified in the Polar UV images. Solar wind data from the ACE satellite are examined in order to determine the influence of solar wind parameters on the occurrence of different substorm and pseudobreakup types. The results confirm that the IMF clock angle and the solar wind energy flux control the strength of a substorm. Pseudobreakups occur mainly during lower solar wind energy fluxes than during substorms and weakly positive or zero IMF Bz. These results give further evidence for the hypothesis that pseudobreakups are the weakest type of substorm activity. Pseudobreakup events may develop during quiet times, during substorm growth phases and at the end of a substorm recovery phases. Pseudobreakups do not appear randomly within a substorm cycle, but typically develop before the first of several substorms, about an hour after an IMF southturn, or after the last substorm in a cycle, where the IMF has returned to a northward direction.

INTRODUCTION

Pseudobreakups are defined as auroral breakups that are not followed by any global expansion (Akasofu, 1964). They are often discussed as a substorm growth phase phenomenon (McPherron, 1991), however, pseudobreakups occur also during substorm recovery or SMC events (Sergeev et al., 1986; Aikio et al., 1999), and even during relatively quiet times where no strong substorms occur (Berkeley and Kamide, 1976).

Pseudobreakups have been found to be associated with the same ionospheric and magnetotail signatures as substorm breakups (Ohtani et al., 1993; Aikio et al., 1999) the only difference being the global consequence. The similarity between pseudobreakup and substorm onset signatures suggests the same physical mechanism behind both phenomena. This leads to the question, what mechanism prevents such an auroral expansion in the case of a pseudobreakup. Lui (1991) proposed that a too low ionospheric conductivity during a pseudobreakup event may prevent a global expansion. Most authors assume that the rate of the solar wind-energy transfer into the magnetosphere is ultimately responsible for which type of substorm activity occurs (Nakamura et al., 1994).

For an evaluation of pseudobreakup theories emphasizing the role of the solar wind-magnetosphere energy coupling, it is crucial to know the characteristic solar wind conditions during pseudobreakups and compare them to those during substorms.

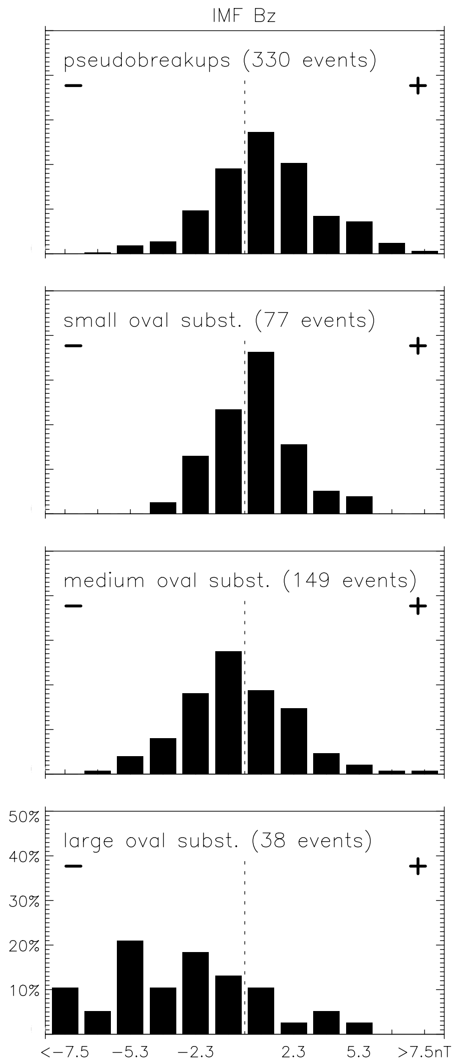

Figure 1: The distribution of IMF Bz as percentages of events for different substorm groups.

METHOD

This study is based on Polar UV images and ACE solar wind data. It covers a three-month period in winter 1998/1999 (Dec-Feb) where all Polar UVI images are examined that are about 5 minutes apart from each other. The same data set and method are used as in the statistical study of polar auroral arcs by Kullen et al. (2002). The selection of events is based exclusively on visual inspection of the UV images. All substorm-like activities are included in the present work, from extremely weak pseudobreakups to large storm-time

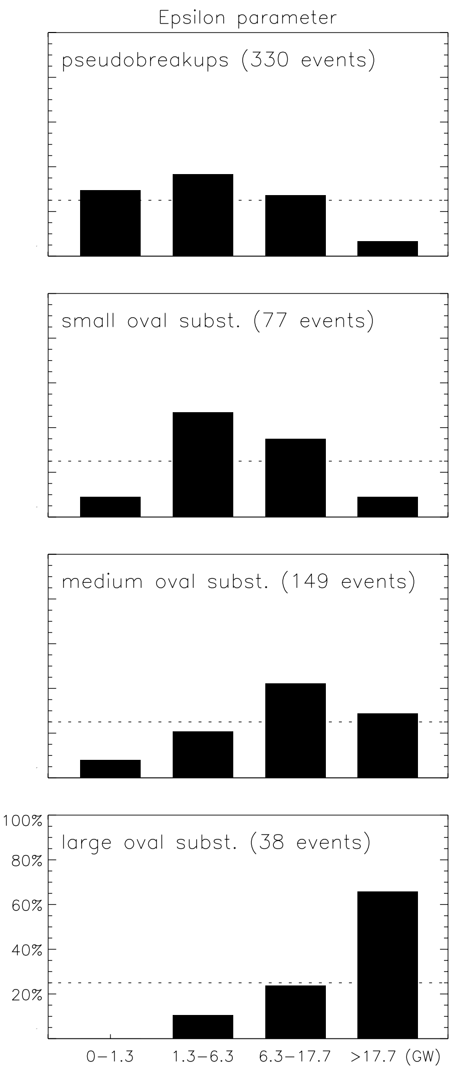

Figure 2: The distribution of the Akasofu-Perreault epsilon parameter as percentages of events for different substorm groups.

substorms without clear onsets at the equatorward boundary, and SMC events. Pseudobreakups are defined here as auroral onsets without a following auroral expansion, independent of their location in the auroral oval. This means, that even PBI's are counted as pseudobreakups as long as only one single, localized brightening at the poleward boundary is seen. For a more detailed examination of pseudobreakups, they are sorted into different subgroups depending on their relation to the nearest substorm. Growth phase pseudobreakups are defined as those events that occur within 30 minutes before the next substorm onset, recovery phase pseudobreakups are defined as a single localized brightening occurring during substorm recovery. The remaining events are here referred to as single pseudobreakups. In a second categorization pseudobreakups are classified according to their location inside the auroral oval as poleward or equatorward pseudobreakups. 'Due to the limited resolution in the UV images (caused by a spacecraft wobble), pseudobreakups appear to have an extension of several degrees width, so that in many cases (when the oval is thin), its location cannot be determined. These cases are here referred to as middle pseudobreakups.

Substorms are subdivided into small-oval, medium-oval and large-oval substorms according to the average oval size during the event, as the oval size roughly corresponds to the strength of the auroral substorm (Feldstein and Starkov, 1967). Being interested in the relative oval size, averaged over one substorm, the oval-size determination is simplified by considering only the position of the equatorward oval boundary. The oval-size is defined as small, medium and large in case the position of the equatorward oval boundary is at midnight equatorward of 60 Corrected Geomagnetic Latitude (CGLat), between 60 and 63 CGLat or poleward of 63 CGLat, respectively.

RESULTS

From the UVI database, 330 pseudobreakups and 419 substorms have been identified. The substorms consist of 77 small-oval, 149 medium-oval, and 38 large-oval substorms. The pseudobreakups are divided into 192 single, 57 growth phase, and 81 recovery phase pseudobreakups. Sorting them after their position inside the auroral oval results in 122 poleward, 19 equatorward and 189 middle pseudobreakups.

In Figures 1 and 2, the statistical results for pseudobreakups are compared to the results for small-, medium- and large-oval substorms. In Figures 4 to 6 the results for the different types of pseudobreakup are presented. The solar wind parameters are divided into several interval ranges. For each interval is given the number of events (in percentages) that have an average solar wind parameter value during their lifetime within that interval.

PSEUDOBREAKUPS COMPARED TO SUBSTORMS

In Figure 1 the IMF Bz distribution is shown for 12 different intervals, ranging between -7.5 and 7.5 nT. It can be seen that most pseudobreakups and even small-oval substorms occur during weakly positive IMF Bz, medium-oval substorms during weakly negative IMF Bz and only large-oval substorms have a clear majority of southward IMF cases.

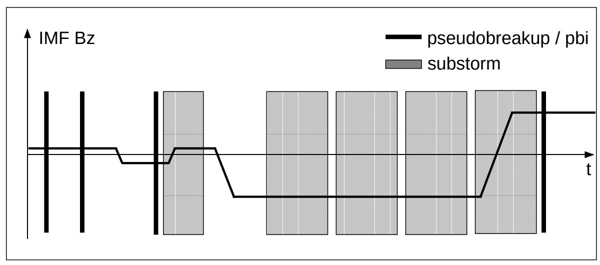

Figure 3: The occurrence of pseudobreakups with respect to IMF Bz and substorms.

Figure 2 shows the distribution of the Akasofu-Perreault epsilon parameter. It gives an approximation

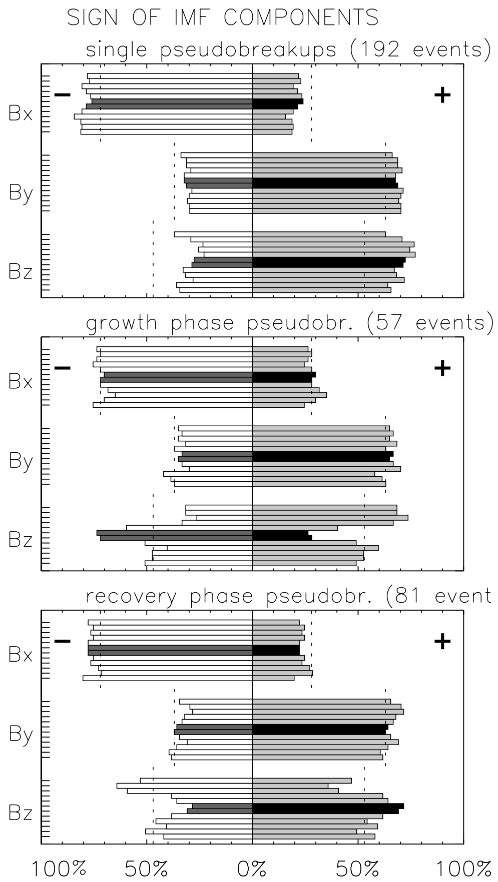

Figure 4: The distribution of the sign of each IMF component as percentages of events for different pseudobreakup types.

to the amount of solar-wind energy transfer into the magnetosphere. The epsilon parameter has high values for southward IMF and a high solar wind magnetic energy flux (vB^2). Here the parameter values are divided into four intervals that are chosen so that the epsilon parameter has values within each interval during 25 percent of the statistical time period. The distribution plots show a clear shift from a majority of cases with small epsilon values to an increasing number of events with strong values between pseudobreakups and substorms of increasing oval size.

THE PLACE OF PSEUDOBREAKUPS WITHIN A SUBSTORM CYCLE

Figure 3 illustrates how pseudobreakups are related to IMF Bz and large substorm cycles (summarizing the results from IMF Bz time sequence plots and optical observations). Pseudobreakups may appear during quiet times with weakly northward IMF or just before small substorms during periods of weakly southward IMF. When IMF is strongly southward during a prolonged period of time, many strong substorms occur after each other. Such periods are devoid of pseudobreakups. An IMF north turn ends this cycle. Typically, during the last substorm, the poleward oval boundary contracts considerably due to the IMF Bz increase and a very active recovery phase may end with a pseudobreakup at the strongly polewardly displaced oval boundary.

DIFFERENT TYPES OF PSEUDOBREAKUPS

In Figure 4, the distributions of positive and negative signs of each IMF component are shown for the different pseudobreakup types. The left (right) bars give the percentages of events having a positive (negative) IMF sign. The top black bar shows the IMF sign distributions at the event start, the bottom black bar the number of events for which during their lifetime the IMF component has more often a negative or a positive sign. The top (bottom) grey bars give the IMF sign distributions up to 5 hours before (after) the events. The dotted lines give the average distribution between positive and negative signs of each IMF component during the statistical time period.

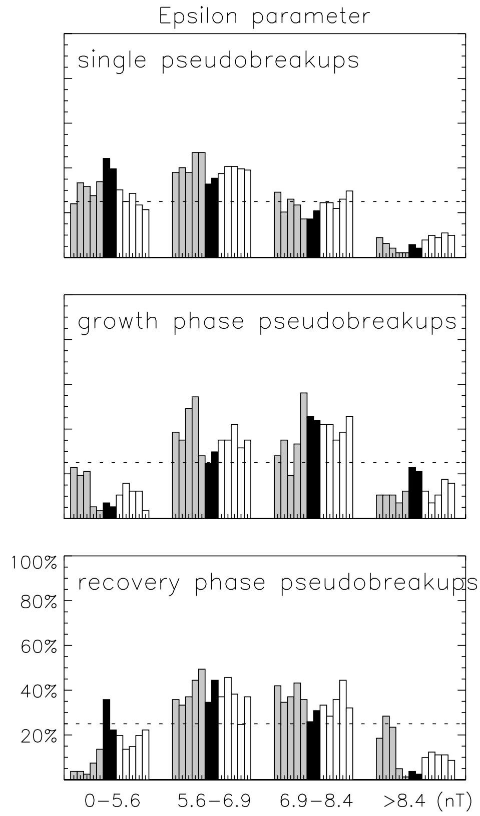

Figure 5: The distribution of the Akasofu-Perreault epsilon parameter as percentages of events for different pseudobreakup types.

Figure 4 shows a clear difference in the IMF Bz distribution between single, growth phase and recovery pseudobreakups. The distribution plots (and IMF sign change distributions not shown here) indicate that for most single pseudobreakups the IMF is northward before, during and after the event. Growth phase pseudobreakups appear about an hour after the IMF has turned to weakly southward IMF. During the following substorm, the IMF is northward again. Recovery phase pseudobreakups appear after an opposite shift of IMF Bz. The preceding substorm is in most cases connected to an IMF north turn.

Figure 5 gives the epsilon distribution for the different pseudobreakup events. It shows that most single and recovery pseudobreakups appear when the solar wind energy input into the magnetosphere is very low. Only growth phase pseudobreakups appear in a majority during a local maximum of the epsilon parameter.

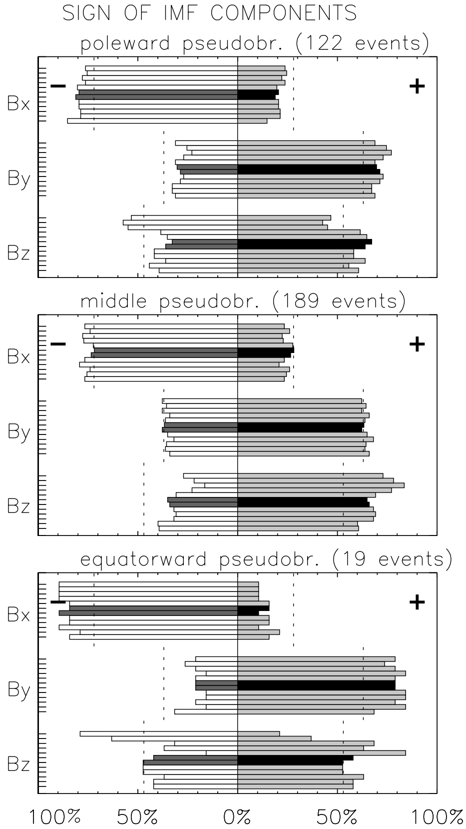

Figure 6: The distribution of the sign of each IMF component as percentages of events for different pseudobreakup locations.

The partition into poleward and equatorward pseudobreakups does not lead to very clear results. Due to the poor UVI resolution, most of the events cannot be clearly located (middle pseudobreakups) and only a few equatorward cases are clearly identified. The largest difference between the pseudobreakup groups is found in the IMF Bz sign distribution, shown in Figure 6. Both, poleward and middle pseudobreakups occur in a majority during northward IMF. The few equatorward pseudobreakups appear slightly more often during southward IMF than the other two groups. In case the results in Figure 6 are representative for the different pseudobreakup groups (despite the selection problems) they indicate that the location of the pseudobreakup within the oval is less important than its relation to surrounding substorms.

CONCLUSIONS

The results show that the occurrence of substorms and pseudobreakups is closely related to solar wind conditions: The majority of pseudobreakups occur for weakly northward IMF during periods of low solar wind energy flux, while substorms of increasing strength appear for increasingly stronger solar wind energy flux and more southward IMF. Hence, pseudobreakups appear when a small amount of solar wind energy flux is available and the energy coupling between solar wind and magnetosphere is low.

Pseudobreakups may appear before the first or after the last substorm of a substorm cycle. Periods of recurrent strong substorms are devoid of pseudobreakups, probably, as the solar wind energy input into the magnetosphere during such periods is too high for a pseudobreakup to occur.

Solar wind characteristics and optical observations of different pseudobreakup types suggests that single pseudobreakups are the smallest possible type of substorm occurring during quiet times. Growth phase pseudobreakups may be triggered by a small increase of energy transfer into the magnetosphere that is not high enough to cause an auroral expansion. Recovery phase pseudobreakups are a special type of PBI that occur only after substorms showing a considerable contraction of the poleward oval boundary due to an IMF north turn.

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