TWO KINDS OF MAGNETOTAIL RESPONSE TO THE ENHANCED ENERGY LOADING COMPARED

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ABSTRACT

We show the isolated convection bay followed after a classic substorm to compare and contrast their signatures. Both events, caused by the southward IMF episodes, displayed the enhanced convection, comparable Dst decreases and auroral zone Pi2 pulsations. Unlike the substorm event, the signatures of energy loading/unloading and near-Earth reconnection (lobe field changes, poleward auroral expansion, SCW growth, strong injection to 6.6 Re) were virtually absent during the convection bay. We emphasize the auroral dynamics, which was basically organized by multiple auroral streamers which start sporadically at the poleward boundary of wide double oval, propagate equatorward (in 3-8 min) and end with a long-duration bright spot in the equatorward oval. Streamers are closely associated with the plasma sheet BBFs and short, narrow and soft injections to 6.6 Re. We argue that the 'pressure crisis' in the tail plasma sheet was significantly reduced during the convection bay and that Earthward transport by sporadic narrow (~3 Re wide) plasma jets (plasma bubbles) from distant reconnection regions to the inner magnetosphere was efficient enough to avoid the energy loading and resulting substorm instability in the tail.

INTRODUCTION

As known for a long time the enhanced energy loading into the magnetotail may result in the different dynamical states of the magnetotail. The substorm, a large-scale instability characterized by global energy loading/unloading and magnetic reconnection in the near tail, is a more frequent and well studied type of response. The reason of energy loading could be the 'pressure crisis' in the tail (e.g. Erickson, [1992]) which makes impossible the Earthward contraction (convection) of closed plasma sheet tubes in the standard tail configurations.

If that is true, the character of plasma sheet convection and magnetic configuration in the tail are of major interest when studying another type of tail response, which does not include such global instability. Being known for two decades as the convection bays [Pytte et al., 1978] or steady convection (SMC) events [Sergeev et al., 1996a], they differ from substorms basically by the weakness of the energy loading-unloading cycle while the convection is enhanced. So far no other specific auroral and plasma sheet manifestations of convection bays and SMC events have been reported.

In this paper we compare the observational signatures of subsequent isolated substorm and convection bay events observed one after another with the same extensive network of spacecraft and ground instruments. An example of ~3h long convection bay without energy loading signatures is rather unique, no such events (to our knowledge) have been yet reported. We pay special attention to the global auroral dynamics as observed by Polar UVI instrument to find the distinctive features of convection bays, to provide a linkage between spacecraft observations in different tail regions and to form a picture of transient processes in the plasma sheet.

SIGNATURES OF SUBSTORM AND CONVECTION BAY

Overview of observations (Figure 1) shows two time intervals where significant 'dayside merging rate' (eps3= VB $\sin^3 \theta/2 > 1$ mV/m, mostly contributed by the southward IMF) occured at ~1710 and ~1900 UT. (The timing is here corrected for the propagation of solar wind from Wind position at (73,-42,0) Re GSM to the point at (10,0,0) Re). They were immediately followed

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by two bay-like enhancements of magnetic activity in the auroral zone (including Pi2 pulsations) and by comparable decreases of ring current (Dst index).

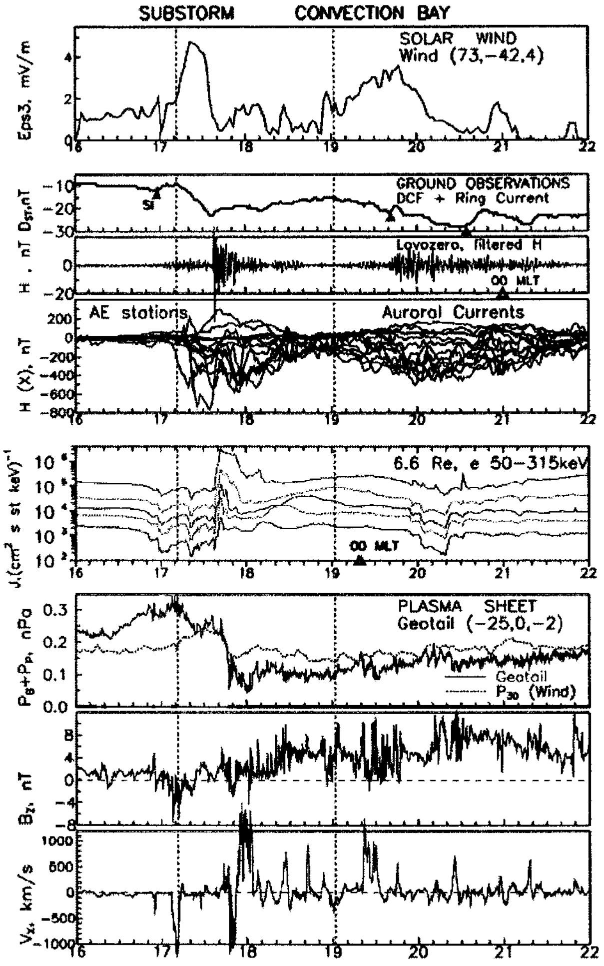

Figure 1:Summary of observations on 10 Dec.1996

However there were also considerable differences allowing to classify these events as a classic substorm (first event) or as a convection bay (second event). The energetic particle flux at 6.6 Re (from LANL spacecraft 1991-080, refered to as L80) displayed a strong energetic particle injection during the substorm, but only a few weak, soft and short injections during the convection bay. In the plasma sheet the energy storage/unloading variations (see total pressure panel) as well as the signatures of near-Earth reconnection (tailward flows with associated negative Bz spikes) are strong during substorm, but absent during the convection bay. Here the Earthward flow bursts (BBFs) and relatively large (> 5 nT) positive (but fluctuating) Bz component are persistently observed at both growth and declining phase of auroral magnetic activity. The plasma beta parameter was permanently large ($\beta \geq 1$) indicating a thick plasma sheet.

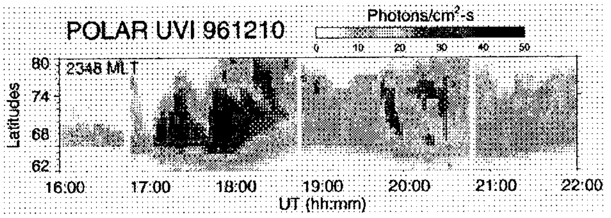

Figure 2: Auroral keogram at midnight from Polar UVI

The auroral observations show enhanced precipitation in both events as well as considerable differences in their morphology - Figure 2. As seen from midnight auroral keogram constructed from Polar UVI observations the auroral oval looks rather narrow (between 66° and 69°) at the beginning of first event, before the onset of classic poleward expansion phase (from low to high latitudes). In the second case, the oval was wide before the main activity (between 65° and 77°) and the main site of activity was its poleward boundary. The situation here resembles the recovery phase of the substorm event (between 1820 and 1850 UT). The active auroras show some southward motion from the poleward boundary, just opposite to the substorm case.

AURORAL STREAMERS AND THEIR ASSOCIATION WITH NARROW PLASMA JETS

The auroral UV morphology during the most active half a hour of convection bay is illustrated in Figure 3. (A UVI movie of auroral dynamics for this event is available on the page <http://sd-www.jhuapl.edu/Aurora/mpg_samples.html>) . The event started as the activation of a small bright surge form in the poleward half of the premidnight oval (~ 75°) at 1917 UT, but it faded soon and the following activity differs much from typical substorm behaviour. Being sporadic in time it is also very structured in space displaying a number of basic structures known previously (e.g. Elphinstone et al.,[1996]). The typical medium scale (hundreds km) structures observed are: (A) localized activations at the poleward oval boundary (including surge forms); (B) structures connecting the poleward and equatorial parts of oval and aligned approximately North-South (known as the NS auroras, or auroral fingers, or auroral streamers); (C) localized bright spots (which could be the Ω- or tourch-like structures). Many such structures were organized in one dynamic pattern, the auroral streamer, which starts to develop from the poleward oval and propagates into the equatorial oval passing through stages (A)-->(B)-->(C). (For illustration see e.g. streamer *f* in Fig.3 as seen at 1954, 2000 and 2013 UT).

Ten distinct streamers have been identified during the convection bay event. Some of them were clustered in time (like those during the most active time period between 1945 and 2000 UT), some appeared isolated, their timing results are given in Table 1. There were also a few confusing events in which stages B or C were missing or could not be resolved for sure. The typical duration of streamer active phase was 3-10 min, the width of individual streamer was a few tenth of hour MLT and, when two streamers were seen, their azimuthal separation could be as small as ~1 h MLT. The latter observation emphasizes a small cross-tail scale of the process leading to the streamer formation.

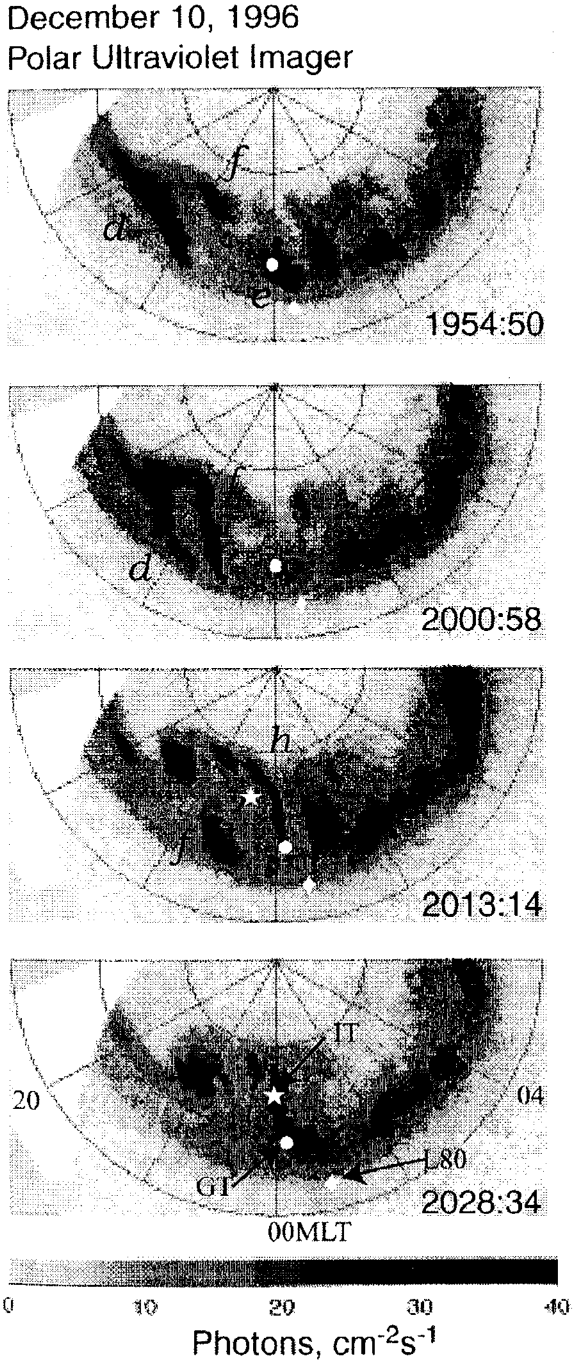

Figure 3: Selection of UVI images with superimposed spacecraft footpoints and streamer identifications.

Table 1: Auroral streamers identified during convection bay on December 10, 1996

	Poleward Activation (A) UT (CGLat,MLT)	Active phase (B) UT, hhmm	Phase (C) MLT, h
a	1921 (74°,23)	1925-1930	00.5
b	1936 (75°,00)	1936-1941	01
c	1945 (74°,23.5)	1948-1951	00.5
d	1945 (72°,22)	1949-1955	22
e	1948 (76°,00.5)	1949-1954	01
f	1951 (76°,22)	1957-2001	23
g	2009 (74°,00.5)	2010-2013	01
h	2009 (71°,20)	2010-2016	00
i	2022 (71°,00)	2022-2030	00.5
j	2115 (75°,23)	2115-2121	23.5

During the convection bay the Geotail spacecraft was near midnight, however the time period of strong auroral activity between 1945 and 2030 UT (e.g. Fig.2) does not look more active in the spacecraft records. Geotail observed strong flow bursts (with Ey > 2 mV/m) starting at 1920, 1943, 2011, 2022, 2115 and 2148 UT. Five of six bursts had associated streamers in phase A or B (streamers *a, c, h, i, j*, see Table 1), just these streamers were localized within ~1 hour from the Geotail footpoint (at 00 MLT).

A unique conjunction occurred at 2022-2230 UT when three spacecraft (Interball, Geotail and L80) were on the field lines threading through the streamer *i*, Figure 3. In that case it was directly shown [Sergeev et al., 2000] that the ion injection took place at ~40 Re and (with a small delay) the BBF was observed at 26 Re at the the beginning of the streamer active phase. About 8 min later, at the end of active phase (B) the energetic plasma was injected to 6.6 Re in a narrow MLT region (see a spike in electron flux at 2031 UT in Fig.1). Temporal /spatial connection between the narrow fast plasma stream in the plasma sheet and auroral streamer was thus directly established in that case.

Nakamura et al [2000] showed a systematic spatial relationship between streamers and isolated BBFs in the plasma sheet which suggests that (1) auroral streamers are mapped from the westward flank of fast plasma stream (BBF), and (2) azimuthal scale of the BBFs is about 1 h MLT, or ~3 Re across the tail if mapped to the nightside midtail. Previous direct estimates of the BBF cross-tail scale are consistent with this value, e.g. Sergeev et al. [1996b], Angelopoulos et al. [1997]. The finding (1) could be understood if the streamer is produced by precipitation of field-aligned accelerated electrons in the region of upward field-aligned currents at the west edge of the plasma jet, as suggested by the model of plasma bubbles (Chen and Wolf [1999]).

CONCLUSIONS

The picture of the plasma sheet flow emerging from the observed streamer dynamics is consistent with sporadic narrow plasma jets forming in the midtail or distant tail (probably by the reconnection process), which can intrude into the near tail. These jets (having in mind the potential drop ~60 kV across the ~3Re wide plasma stream if the flux transfer rate is ~3 mV/m) are capable to transport (reconnected) closed flux tubes to the inner magnetosphere and finally remove them to the dayside, that is to avoid the accumulation of magnetic flux in the tail, to avoid the substorm. The physics to avoid the pressure crisis is that the jets are the plasma bubbles (plasma tubes with reduced entropy, pV^{γ}, which is often observed in the BBFs) which slides Earthward with respect to other tubes without compressing them (Chen and Wolf [1999]).

Since the BBFs may appear in any conditions, there should be additional factor(s) controlling the efficiency of removing (reconnection + convection to the dayside) the magnetic flux from the tail, that is controlling the mode of tail response to the external driving. We suggest this is a specific magnetic configuration with local Bz (a few nT) minimum at ~10-12 Re and flat Bz profile in the neutral sheet in the near tail. Such configuration was inferred for the SMC events (Sergeev et al.,1996a) as well as in our modeling made for epoch 1945 UT during convection bay (results are not shown here). In such configuration the volume changes of convecting plasma tube are small in the near tail (between 10-12 Re and 20-30 Re) where the pressure crisis is usually most strong.

We believe that possibility of steady (balanced) convection in the tail is favoured by the combination of both specific (less crisis) magnetic configuration plus the action of plasma bubble mechanism realizing the Earthward convection. One more controlling variable could also be related to the location and intensity of plasma sheet reconnection, its role should be clarified in the future work.

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