On the Low Latitude 'Negative Bays' in the Afternoon Sector*

by

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ABSTRACT

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It is argued that the so-called low latitude 'negative bay' in the afternoon sector is not caused by the return current from the polar electrojet, but is the field of the simultaneously growing asymmetric main phase decrease. Author

Akasofu, Chapman, and Meng(1) have recently shown that the polar electrojet which causes intense negative bays, or polar magnetic substorms, in the high latitudes, in general, flows westward in all longitudes along the auroral oval (not along the auroral zone). Since the oval lies well inside the auroral cap (enclosed by the auroral zone) in the afternoon sector, the polar electrojet flowing along the oval causes an eastward return current and thus a positive bay along the auroral zone in the afternoon sector. This positive bay was formerly interpreted as indicating the existence of an eastward polar electrojet.(2,3,4) The earlier and the new model current systems of the polar electrojet are shown in Figs. 1a and 1b.

One reason for this incorrect interpretation was that in earlier analyses there were not enough data to examine in detail simultaneous geomagnetic disturbances on the poleward side of the auroral zone at the time when a positive bay was observed in the auroral zone. In Fig. 1a, the 'eastward jet' in the afternoon sector of the auroral zone completes its circuit by having a 'westward return current' in both the polar cap and the middle-low latitude belt. Akasofu, Chapman, and Meng(1) have pointed out that the polar cap current is more intense than the 'eastward jet' so that it cannot be the return current from the 'eastward jet'; for further details, see also Akasofu, Meng, and Kimball.(5)

When a positive bay is recorded in the auroral zone in the afternoon and evening sectors, there occurs often a negative change (in the horizontal component) in lower latitudes in the same sectors. Figure 2 shows an example of the negative change at Honolulu (dipole (dp) latitude (lat) 21° N) when successive positive bays were observed at College (dp lat 64.5° N), between 0330 and 0990 UT. Such a negative change has been called the low latitude 'negative bay' and interpreted as indicating the existence of the 'westward return current' from the 'eastward jet'. The purpose of this paper is to argue that the negative change is not due to the return current, but is likely to be due to the simultaneously growing asymmetric ring current field. According to our new model (Fig. 1b), the return current should produce a positive bay in low latitudes.

Perhaps, one of the simplest ways of demonstrating that the so-called 'negative bay' is <u>not</u> due to the return current from the eastward current (causing a positive bay in the auroral zone) is the following. It is easy to find positive bays in auroral zone magnetic records, which begin rather gradually at first, but increase their intensity sharply in an impulsive manner at a later epoch. Then we examine the simultaneous and the corresponding changes in the records from higher and lower latitudes in the same longitude sector. Figure 3 shows such an example; all the stations are located in the Europe-Africa sector. The positive bay recorded at Kiruna has the required growth curve. To the north of Kiruna, at Murchison Bay (dp lat 75.3° N), a negative bay is seen at the same time. In this particular case, the magnitude (in the horizontal component) of the negative bay at Murchison Bay was a little less than that of the corresponding positive bay at Kiruna; however, the corresponding vertical component at Murchison ($\sim 500\ \gamma$) was much greater than at Kiruna ($\sim 300\ \gamma$), so that the total magnitude of the disturbance at Murchison Bay was greater than that at Kiruna. Therefore, the negative bay at Murchison Bay cannot be ascribed to the return current from the eastward current which produced the positive bay at Kiruna.

The record from the lowest latitude station, M'Bour (dp lat 21.3° N), shows a pronounced negative change ($\sim 70\ \gamma$) at the time when the positive bay was observed. It is this type of negative change which has been misinterpreted to be caused by the return current. Careful readers will notice, however, a small positive change corresponding to the sudden enhancement of the positive bay at Kiruna at about 1500 UT. First of all, if the negative change were due to the return current, the enhanced eastward current over Kiruna would have to enhance the negative change in lower latitudes. Instead, we can see clearly a positive change. Secondly, there is a systematic increase of the magnitude of this positive change towards higher latitudes; on the other hand, the negative change becomes less and less towards higher latitudes.

Therefore, as Fig. 1b shows, it is more reasonable to infer that the intense polar jet flowing along the oval (which produced a negative bay at Murchison Bay) caused an eastward return current and a positive change over a wide range of latitude. However, the simultaneous growth of the asymmetric main phase decrease almost masked the positive change in low latitudes, except at about 1500 UT, because the return current was not intense enough.

In fact, the corresponding hourly mean Dst variation plotted at the bottom of Fig. 3 shows that the Dst variation was as large as 30 γ (the <u>hourly mean</u> Dst curve shows a little phase difference). We should note, however, that the actual main phase decrease should be even greater than 30 γ, perhaps 40 ~ 50 γ, since the return current causes a positive change in the horizontal component in an extensive part of the earth. (The Dst has been said to be the ring current field by assuming that the ring current is axially symmetric and that the polar electrojet causes the SD-like current pattern; the longitudinal averaging process was supposed to eliminate the SD contribution.) Since the ratio of the asymmetric main phase decrease in the afternoon sector to that in the morning sector is about 2:1,[6] the true main phase decrease in the evening sector could have been about 55 γ for the 40 Dst value and 65 γ for the 50 γ Dst value. Thus, a substantial part of the decrease seen at B'Mour and Tamanrasset must be due to the asymmetric growth of the main phase decrease.

It should be also added that the ratio of the afternoon 'negative bay' to the corresponding positive bay in the auroral zone is much greater than the ratio of the morning positive bay to the corresponding negative bay. The latter is typically of order 0.02 ~ 0.05 for the Honolulu (dp lat 21° N)/College (dp lat 64.5° N) pair, but the former is unreasonably large, 0.1 ~ 0.2 for the same pair. The same is true in Fig. 3; (M'Bour (~ 70 γ)/Kiruna (~ 500 γ)) $\simeq$ 0.14. From Fig. 1a, it is difficult to find the reason for such a large difference of the ratio, if the negative change were produced by the 'return current'. We note that in Fig. 3 the positive change at about 1500 UT had the magnitude of order 10 γ, so that the ratio (10 γ/500 γ) $\simeq$ 0.02 has the right order of magnitude for the return current. From this ratio we can see also that the true return current effect (the positive bay) in the afternoon sector can be recognized clearly only when the positive bay in the auroral zone has a magnitude more than 500 γ. This suggests also that if positive bays in the auroral zone are intense enough, the corresponding positive change should be recognized even in the afternoon and evening sectors. After analyzing magnetic records collected in a world-wide extent, Akasofu and Chapman(6,7) have also shown that the return current flows eastward over the most part of the earth (perhaps except in the noon sector).

It is interesting to point out that the intensity of the main phase decrease has such a short period growth, corresponding to the growth of the polar electrojet. Recently, Behannon and

Ness[9] have shown that the growth of the polar electrojet is associated with a sharp decrease of the intensity of the magnetic field in the magnetospheric tail, so that the short period growth of the main phase decrease should be caused by a current system in the inner magnetosphere (within the outer radiation belt, namely the ring current), rather than in the magnetospheric tail.

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FIGURE CAPTIONS

Fig. 1a. Earlier model current system (schematic for polar magnetic substorm; view from above dp north pole; the direction of the sun is indicated.

Fig. 1b. New model current system proposed by Akasofu, Chapman, and Meng.(1)

Fig. 2. Example of the low latitude negative change in the afternoon sector (Honolulu), which occurred when positive bays were observed in the auroral zone (College).

Fig. 3. Simultaneous magnetic records (the H component) from the Europe-Africa sector, Murchison Bay, Kiruna, Lovö, Niemegk, Chambon-la-Forêt, Tamanrasset, and M'Bour, together with the corresponding Dst variation obtained by Sugiura.(9)

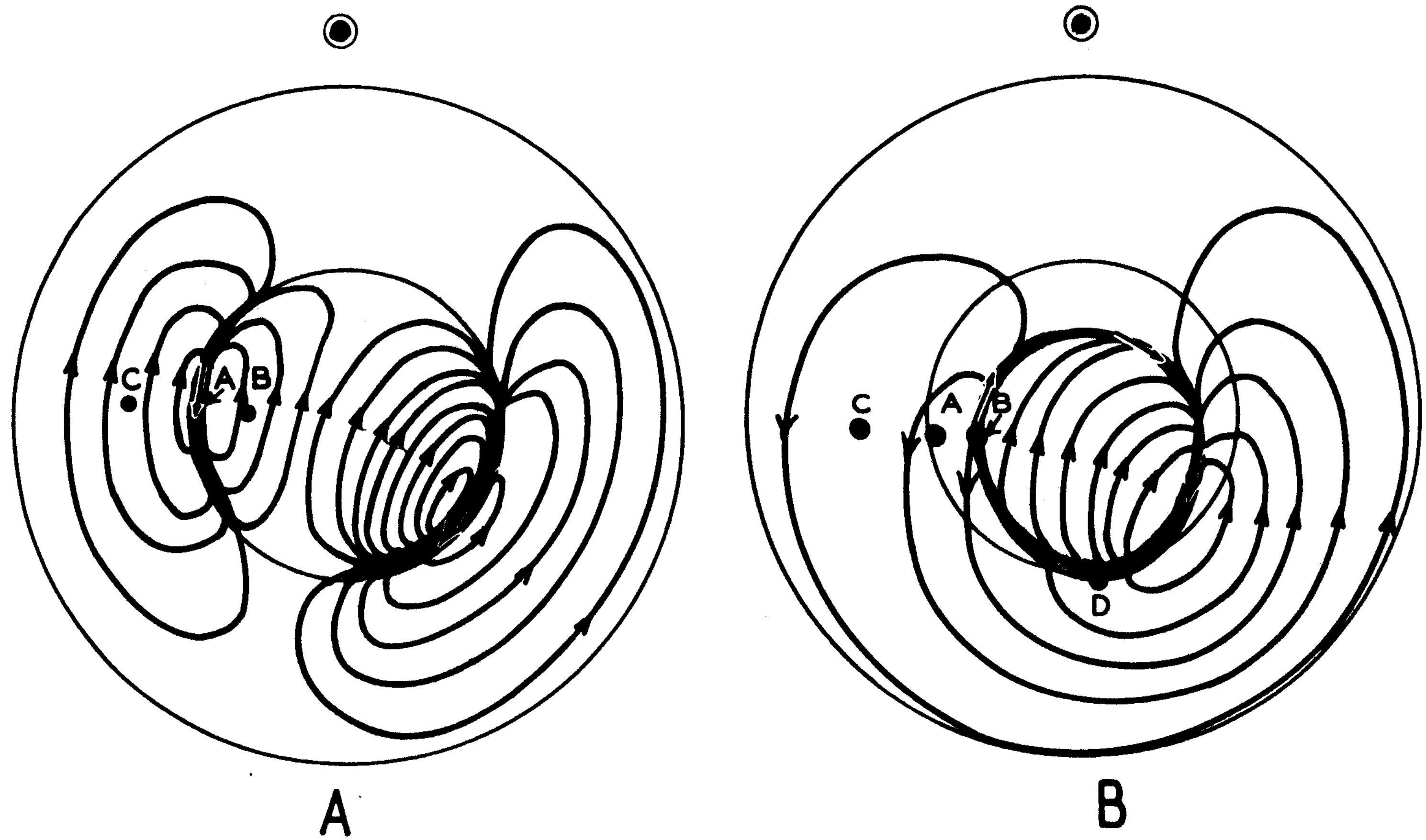

Figure 1

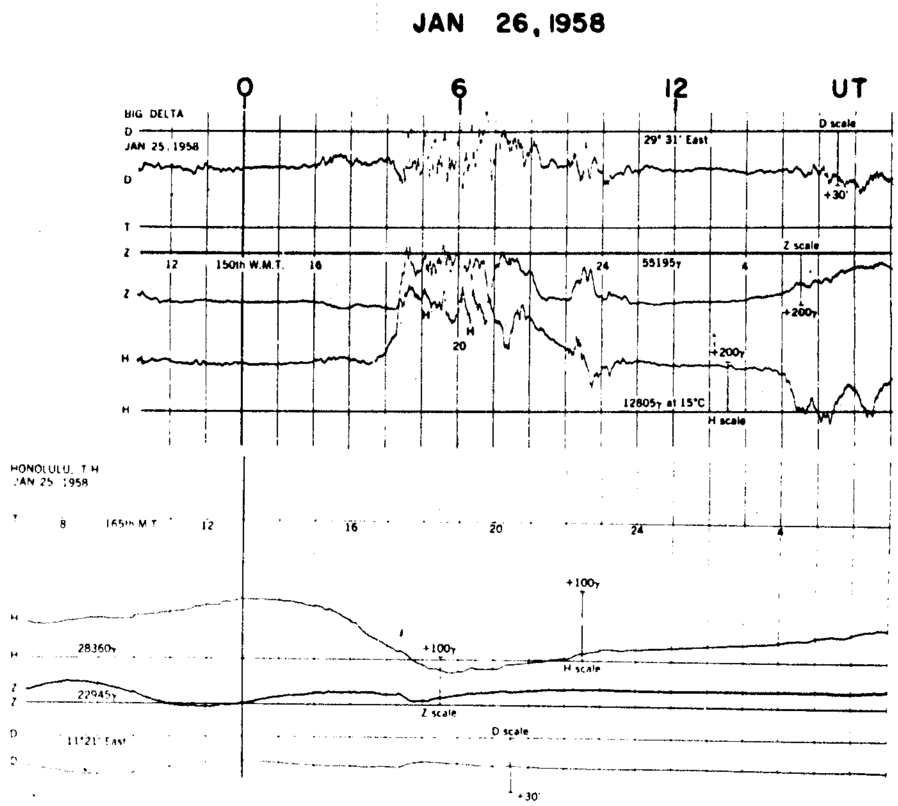
JAN 26, 1958
0
6
12
UT
BIG DELTA
JAN 25, 1958
D scale
29° 31' East
+30'
Z scale
150th W.M.T.
55195γ
+200γ
12805γ at 15°C
H scale
HONOLULU, T.H.
JAN 25 1958
165th M.T.
28360γ
22945γ
11°21' East
+100γ
H scale
Z scale
D scale
+30'

Figure 2

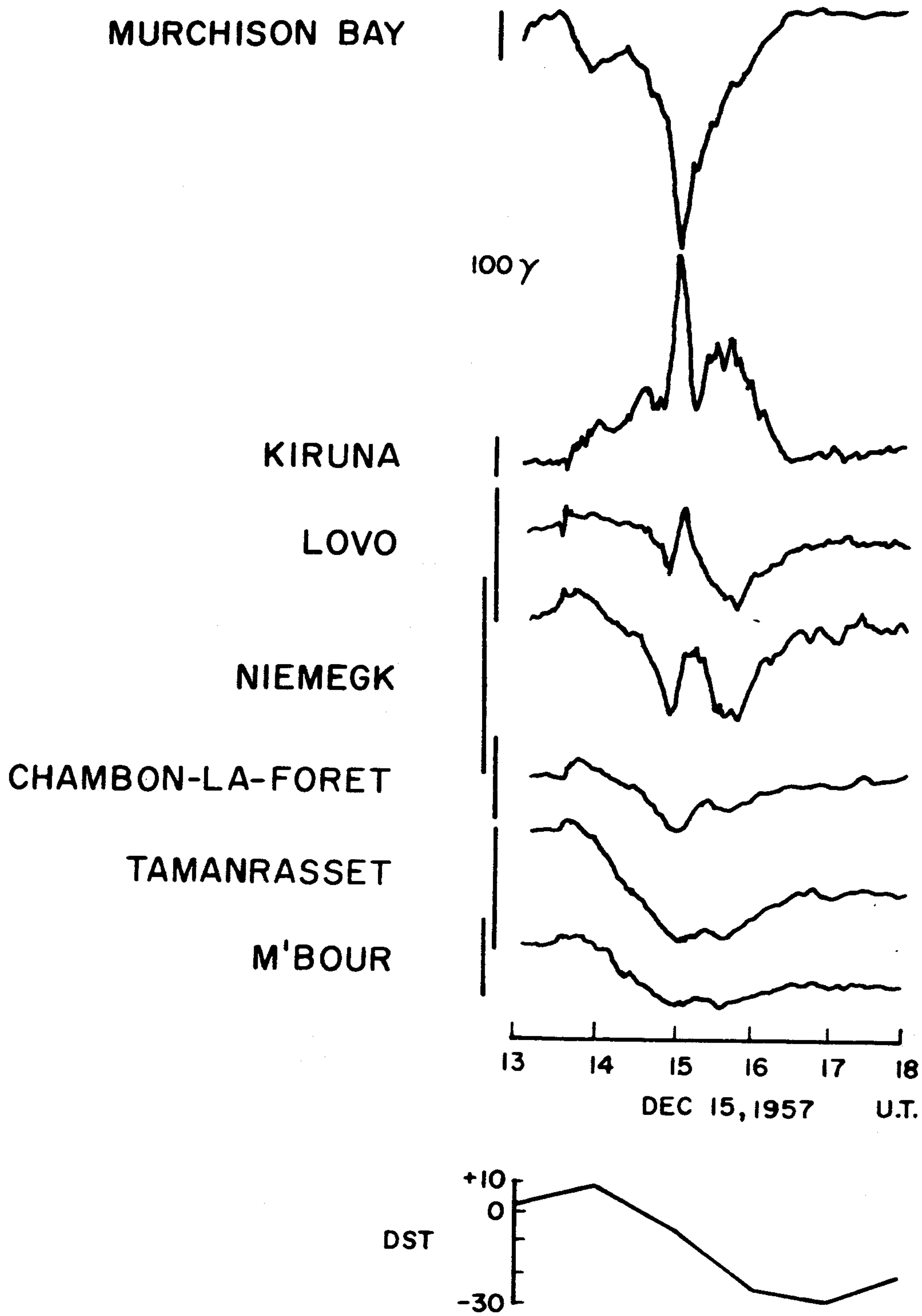
MURCHISON BAY
100 γ
KIRUNA
LOVO
NIEMEGK
CHAMBON-LA-FORET
TAMANRASSET
M'BOUR
13
14
15
16
17
18
DEC 15, 1957
U.T.
+10
0
DST
-30

Figure 3

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