1. Introduction

There is ongoing research in the field of magnetotail science concerning the relationship between the observed phenomenon of earthward fast flows of the tail plasma sheet (often termed "bursty bulk flows," or BBFs) and global dipolarisation of the tail magnetosphere. The latter is associated with the substorm expansion phase and the former with reconnection at the near-Earth neutral line (NELN), also related to substorms.

During this work, all four Cluster spacecraft were used to detect fast flows in the magnetotail plasma sheet region. The flows were measured using a multi-instrument approach, implementing ExB drift velocity data where reliable measurements were available, and particle instrument velocity data at other times. In addition, both Double Star spacecraft were used, when available in the tail, to detect reconfiguration of the magnetic field earthward of the position of Cluster in the plasma sheet.

The time intervals of interest were Jun to Nov in 2004 & 2005. The days chosen as events were the times of favourable conjunctions between Cluster & Double Star in the tail.

2. Data, Events & Substorm Phases

Cluster & Double Star Instrumentation Used:
- FGM (all 4), EFW (all Cluster), CIS-HA (C1 & 2 TC1), CIS-CODIF (4), PEACE (in Cluster for B1, C2 & TC2 for flows)
- Cluster flow data were hybridised for each spacecraft using ExB drift and available particle instruments. If ExB was available it was used, otherwise adjusted particle data were used. Adjustment was made by a linear factor, obtained from comparison of concurrent data.

BBF & Dipolarisation Selection:
- Tail events selected: $X_{\text{min}} < -6$ R_e, $Y_{\text{min}} > 10$...
- Cluster plasma sheet immersion: $B_z > 0.1$ for at least 5 min
- Cluster BBF flows: $v > 300$ km/s within 10 min
- Dipolarisations: $\Delta R_p > 10^4$ & $\Delta B_p > 4 \times 10^{-4}$ within 5 min & overlapping 5 min windows were grouped
- BBFs & dipolarisations were inspected by eye for quality
- Dipolarisations were categorised by eye into transient, persistent & already dipolar events

Association between BBFs & Dipolarisations:
A BBF was deemed to be associated with dipolarisations within ±60 min. These events may be related within the same substorm event.

An association is deemed to be strong when the apparent communication time between events is a reasonable value. This means that the apparent communication speed was above the mean flow measured at DS during the dipolarisation detection. Distinction is made between associations where the BBF is detected before or after the dipolarisation.

Substorm Phase Identification:
Use was made of the quantitative approach described by [1]. This method can be identified from the AL index. Additionally, the periods of no phase were split into times of northward or southward IMF.

3. Detected Events, Phases & Associations

Of 140 BBFs detected & 125 dipolarisations in the period studied, there are 67 BBFs with associated transient dipolarisations in 19 cases for strong association.

Figure (a) shows the normalised occurrence frequency of BBFs & dipolarisations (red/blue). Also, it shows a breakdown of transient/persistent pre-dipolarised type dipolarisations (yellow/green/purple).

The occurrence of BBFs was normalised by the amount of plasma sheet dwell time Cluster spent in each substorm phase. Similarly, dipolarisation events were normalised for phase times during which either TC1 or TC2 was in the tail. The occurrence frequency was then evaluated from these normalised values.

4. Conclusions

Using this dataset spanning 6 spacecraft and a novel approach to using Cluster flow data, BBF events of 2004 & 2005 are investigated in context with dipolarisations and substorm phases.

- Very few of the BBFs are associated with dipolarisations in this dataset – even fewer are strongly linked and have a BBF preceding a dipolarisation.
- Persistent & transient dipolarisations as a proportion of all observations of these types are most significant in the expansion & recovery phases respectively.
- Persistent dipolarisations observed at Double Star may be associated with the same earthward flow channel as those observed at Cluster. Persistent dipolarisations are more likely to indicate widespread activity in the tail.
- Multiple flow channels may have been observed in the dataset. Also, there are flows of diversion and penetration, the causes of which warrant further investigation.

References:
[1]: Juusola et al., “Can flow bursts penetrate into the inner magnetosphere?”, GRL, 2011
[2]: Nakamura et al., “Spatial scale of high-speed flows in the plasma sheet observed by Cluster”, GRL, 2004
[3]: Dubyagin et al., “Can flow bursts penetrate into the inner magnetosphere?”, GRL, 2011