We would once again like to thank both of the reviewers for their careful consideration of the manuscript and their very helpful comments. Our responses are provided below.

Reviewer 1

Comment 1: *One further comment has arisen when reading the revised manuscript. In the first sentence of the abstract (lines 12-14 in the tracked-changes revised version), the authors give a strong statement for the dusk-dawn sense of both slow (< 200 km/s) and fast (> 200 km/s) convective magnetotail flows is strongly governed by IMF By conditions. The authors apparently are referring to Pitkänen et al. (2019) and Pitkänen et al. (2013; 2017) papers here. I would like to suggest the authors to ease the sentence a bit to the following form: "Previous observations have provided a clear indication that the dusk-dawn (Vperpy) sense of both slow (< 200 km/s) and fast (> 200 km/s) convective magnetotail flows can be governed by the interplanetary magnetic field (IMF) By conditions." This is because it is good to keep in mind that the slow flow patterns in Pitkänen et al. (2019) are average patterns and in individual situations the coverage of the flows with the dominating Vperpy direction is expected to vary. They are also from the data with clearly nonzero IMF By. In the results for fast flows (Pitkänen et al., 2013; 2017), even when taking only the subset of events with mean tail By over the event collinear to IMF By, there still appears to be some fast flows in each category with mean Vperpy to an opposite direction than expected from the untwisting hypothesis/model. Also, there can be flow events in which the mean Vperpy direction formally agrees with untwisting hypothesis, but these flows occur in a region where the flaring dominates and screens the IMF By penetration and might occur also without IMF By penetration. However, these flows are still counted as agreeing with the untwisting hypothesis.*

Response 1: We agree with the reviewer and would like to thank them for their helpful suggestion. We have amended '*strongly governed..*' to '***can be*** *governed..*' in the revised manuscript. We note that we have also tweaked the abstract further, in reference to Reviewer 2's first comment, below.

Reviewer 2

Comment 1: *Abstract: The whole abstract is about the importance of IMF control/untwisting and how these observations are inconsistent with this untwisting hypothesis. There is no mention of the fact that the twisting effect does not seem to extend as far as Cluster for this event (from the background flaring field), or the fact that the C1 flows (at least those south of the neutral sheet) are also inconsistent with the symmetric return direction that would be expected here. You suggest at line 27 that IMF penetration at the location of Cluster was*

*unable to override the variable flow associated with the flapping, but surely the point is that the flapping overcomes the *net* return direction, which in this case, the data suggest, is predominantly the symmetric element due to the location of the spacecraft.*

Response 1: We are grateful to the reviewer for pointing this out. In the abstract, we have now further emphasised that at the spacecraft location, the expected flow direction is duskward, unless there is untwisting due to a negative IMF B_y. Our discussion of the B_y penetration then serves only to rule out this possibility. We conclude by saying, as the reviewer suggests, that the flapping overcomes the net duskward direction of the large-scale flow that is expected at the spacecraft location.

Comment 2: *Introduction: The discussion around lines 50-83 is good and more balanced, but the end of the introduction (lines 107-116) says that the interval provides an opportunity to investigate the competition between IMF By control and localised dynamics, that the observed dusk-dawn direction of the (C1) transient flows disagrees with what would be expected from prevailing IMF By conditions, and concludes that IMF By penetration was unable to overcome the variable dusk-dawn flow associated with the flapping. Surely, the message that should be being conveyed here is that there is global evidence of untwisting (SuperDARN), but the C2/3/4 observations show that the spacecraft are outside the region where IMF control dominates (i.e. the large-scale return flows here are "symmetric"), but that this global pattern is overcome by a variable dusk-dawn flow associated with the flapping?*

Response 2: We thank the reviewer for pointing this out and agree with their suggestion about the message that this paragraph should convey. We have now re-worded the paragraph to be much more in-line with this: '*In this paper we present Cluster spacecraft observations of an interval of dynamic magnetotail behaviour on 12 October 2006,* ***prior to which the B_y component of the concurrent upstream IMF had been largely positive for several hours****. Throughout this interval, Cluster 1 observed oscillations in the magnetic field B_x component, which we attribute to current sheet flapping, concurrent with a series of convective fast flows with significant and variable dusk-dawn components.* ***'Observations from Cluster 2, 3 and 4 indicated that the spacecraft were at a pre-midnight location where magnetotail flaring was dominating over IMF B_y control of the flows, resulting in the expectation of (symmetrical) duskward return flows (Pitkänen et al., 2019). In the southern hemisphere, such duskward flow was measured by Cluster 3, but not observed by Cluster 1, which instead measured flows with significant dawnward components. These dawnward flows were therefore inconsistent with any expectation that the flow was governed by flaring and, owing to evidence of large-scale IMF $B_y > 0$ ionospheric convection pattern, could also not be explained by the magnetotail untwisting hypothesis. We instead suggest that the current sheet flapping was exciting the variable dusk-dawn flow, overriding the expected large-scale duskward convection at the location of Cluster 1.'***

Comment 3: *Line 349: "we discuss our rationale for interpreting the flows as being inconsistent with large-scale magnetotail untwisting and our interpretation of their relationship to current sheet flapping" - the emphasis and lack of acknowledgement of the symmetric element again seems odd given that the C2/3/4 magnetic fields are consistent with being dominated by flaring, and whilst the the weak background flow observed in the southern hemisphere (C3) is consistent with either the symmetric element or untwisting, there's nothing to rebut the assumption (from the lack of IMF control dominance in the B field observed by Cluster) of a background duskward convection (which is inconsistent with the C1 observations south of the neutral sheet).*

Response 3: The reviewer makes a valid point here. We have tweaked this statement to: '*we discuss our rationale for interpreting the flows* ***observed by C1*** *as being inconsistent with* ***the large-scale convection expected based on the spacecraft location and*** *magnetotail untwisting* ***considerations****, and our* ***alternative*** *interpretation of their relationship to current sheet flapping*.'. So our new statement emphasises that it is the C1 observations we are referring to, and the first point we make in the above sentence is that the observed flows are inconsistent with the (symmetric) large-scale convection expected at the pre-midnight location, which we now expand on at the beginning of Section 4.1.

Comment 4: *Section 4.1: You first seek to rule out the magnetotail untwisting hypothesis, but given the C2/3/4 observations, surely the first point to make is that the C1 flow is inconsistent with the expected symmetric return flow direction (which is seen by C3), and *then* that it cannot be explained either by IMF control. Fundamentally, given the C1/3/4 observations and TA15 modelling, untwisting/IMF control at this location seems like an odd choice of null hypothesis.*

Response 4: We agree with the reviewer about ensuring that the first argument we should make is how C1's observations are inconsistent with the 'symmetric' flow picture. We have therefore amended the first paragraph of Section 4.1 to read as follows: '*During the five-minute interval studied (00:28 – 00:33 UT) C1 measured a continually fluctuating* B_x *component (Fig. 3i), indicative of multiple crossings of the tail current sheet. C1 was the only spacecraft to measure this signature across the interval (although similar signatures had been observed a few minutes earlier by C2 and C4). C1 also measured a series of earthward convective magnetotail fast flows with varying dusk-dawn components. The data in Fig. 3 i) and Fig. 3 v) illustrate that when* B_x *was positive (negative), a duskward (dawnward)* $v_{\perp y}$ *was generally observed.* ***The observed dawnward flow in the southern hemisphere, in particular, is inconsistent with the expected symmetric duskward flow at the pre-midnight location of C1 which was, however, observed by C3. This suggests that the typical 'symmetrical' Dungey-cycle return flow (e.g. Kissinger et al., 2012) cannot provide an explanation for the flow observations made by C1. We thus turn our attention to other possible explanations which we explore in detail, below.'***

Comment 5: *SuperDARN observations (Lines 444-470): I agree that the SuperDARN observations show that there is a large-scale asymmetry in the flow, consistent with the*

expected IMF control, but I reiterate my concern that they do not convincingly show that the Cluster spacecraft are located on the asymmetric part of the flow. The authors state in their response that "In terms of the specific map that we are referring to (00:30 – 00:32 UT), we do think that the spacecraft footpoints appear to map closer to the dawn cell", and have made their statement slightly less definite; they go on to acknowledge that the proximity to the dusk cell and uncertainty in the field line trace "may give credence to the possibility" that the spacecraft map to the dusk cell. However, I would point out that there is a large region devoid of scatter near the footprints of the spacecraft; dawnward and duskward flow are observed dawnward and duskward of the spacecraft, respectively, but if the conclusion (that Cluster is nearer the dawn cell) is based on the backscatter, then there is insufficient scatter to conclude exactly where the division between the two return directions occurs based on the scatter alone. If the conclusion is based on the electrostatic potential contours, then it's notable that both 4 minutes earlier (at 00:24-00:26 UT) and 2 minutes later (00:32-00:34 UT) the footprints are closer to the dusk cell (i.e. the outermost solid contour) than the dawn cell (outermost dashed contour). I can't see any significant differences in the plotted data points where there is scatter at both of these times, but notably there is less scatter just poleward/dawnward of Cluster at 00:30-00:32 compared with 00:24-00:26 UT, and I suspect this will have affected the details of the interface between the dawn and dusk cells near the Cluster footprints, i.e. that the contours are highly sensitive to the absence of scatter in this region. Therefore, the northern hemisphere SuperDARN data are inconclusive on whether the spacecraft north of the neutral sheet are on the dawn or dusk cell, and certainly do not override the observational fact that C2/3/4 observe a flaring-dominated field and hence we would expect the return flow to be duskward (i.e. dominated by the symmetric element). Consequently the strong emphasis in this paragraph on untwisting being important at the location of Cluster is misleading. (NB The point about C1 not being on the dawn cell in the southern hemisphere (lines 462-464) is convincing, but again fully consistent with being part of the "symmetric" element.)

Response 5: On reflection, we completely agree with the reviewers point about the northern hemisphere SuperDARN data being inconclusive, in terms of whether the spacecraft north of the neutral sheet map to the dawn or dusk ionospheric convection cell. As a result, we have completely reworded the first section of this paragraph when discussing the northern hemisphere convection maps: '***Firstly, let us consider*** *the northern hemisphere map from 00****:24 – 00:26 UT in Fig. 4a: despite the lack of scatter in the immediate vicinity of the spacecraft footpoints, it is noticeable how the spacecraft appear to map closer to the dusk cell than the dawn cell. For the remaining northern hemisphere maps, there is insufficient scatter to determine the exact division between the dusk and dawn convection cells, such that it is inconclusive as to which cell the Cluster spacecraft map to when above the neutral sheet. If Cluster did indeed map to the dusk convection cell, then*** *the* ***duskward flows in the*** *northern hemisphere* ***plasma sheet*** *observed by C1 would actually be consistent with the large-scale convection pattern****. Furthermore, given that the C2-C4 magnetic field observations are consistent with the local B_y being dominated by magnetotail flaring (as opposed to IMF B_y) at the pre-midnight location of Cluster, it is likely that we would expect the return sense of the convection to be dominated here by the symmetric (duskward) element both*** **above and below the neutral sheet** ***(see e.g. Pitkänen et al., 2019).***'

Comment 6: *Section 4.2: I suggest wording lines 478-482 is a more even-handed way.*

Response 6: We have reworded these lines in a more balanced manner: '*The low-level of flow seen by C3 is mostly duskward (Fig. 3v),* ***which would be*** *consistent with untwisting* ***for*** *IMF* $B_y > 0$*,* ***given its southern hemisphere location****.* ***We note, however, that due to the pre-midnight location of C3, one would also rightly*** *expect* ***to observe*** *duskward flow* ***even*** *in the* ***case that there was no IMF*** $B_y > 0$ ***control (e.g. Kissinger et al., 2012)'.***

Comment 7: *Section 4.4: Bullet point 2 (lines 724-727) is very loaded to tail untwisting, but the fact is that the C1 observations are also not consistent with symmetric return flow either.*

Response 7: We have added more emphasis to the symmetric return flow element. This point now reads: '*The Cluster 1 spacecraft observed convective flow with a dusk-dawn component that was inconsistent with current theories of IMF* B_y*-induced dusk-dawn flows associated with magnetotail untwisting.* ***Notably, the observed dawnward flow in the southern hemisphere, whilst inconsistent with IMF*** $B_y > 0$***, was also inconsistent with the expected (symmetric) duskward flow at this pre-midnight location even in the absence of IMF*** B_y ***control.'***. In addition, we have added a statement into the third point: 3) Magnetic field perturbations that were indicative of a localized current sheet flapping and dusk-dawn kink in the field occurred coincident with the flows. It therefore seems likely that in this case the IMF B_y-driven asymmetry**, or indeed the symmetric flow expected at the spacecraft location**, was ***being overridden by*** the localized dynamics in governing the dusk-dawn component of the flow.

Comment 8: *Summary: I think you need a bullet point summarising the C2/3/4 observations, i.e. the magnetic field observations revealed a background field, local to Cluster, where the By component was dominated by flaring, indicating that the region of IMF control dominance did not extend as far as Cluster, and C3 showed southern hemisphere return flow that was duskward (inconclusive, but fully consistent with the symmetric element of return flows). This may need some reconciling with your SuperDARN bullet point.*

Response 8: We agree with the reviewer that it is important for us to summarise the observations from the other Cluster spacecraft and note how these are consistent with B_y being dominated by flaring. Therefore, we have added a fourth bullet point which clarifies this: ***'The C2, C3 and C4 magnetic field observations suggested that the local*** B_y ***was being dominated by magnetotail flaring, as opposed to IMF*** B_y***. C3 also observed duskward flow in the southern magnetic hemisphere, consistent with the symmetric flow expected owing to the pre-midnight location of the spacecraft****.'*. We have also amended our second bullet point.

Comment 9: *Line 50: "flows are generally expected to be symmetric...at least in the absence of any asymmetry" - this is a truism, so perhaps reword!*

Response 9: We have removed the latter part of this sentence, so that it now just reads: *'Magnetotail flows are generally expected to be symmetric about midnight (e.g. Kissinger et al., 2012).'*

Comment 10: *Line 77: "at up to 7 Re towards the dusk-dawn flanks" - I suggest this could also be more clearly worded, e.g. "at |Ygsm| values up to 7 Re"*

Response 10: We have reworded this as suggested by the reviewer. The sentence now reads: *'…as well as during more transient, dynamic BBF-like intervals (Grocott et al., 2007) at* ***$|Y_{GSM}|$ values*** *up to 7 R_E (Pitkänen et al., 2013).'*

Comment 11: *Line 274: It might help the reader to point out that this observation (By steadily negative for C2/4 and steadily positive for C3) is consistent with the larger-scale By here being dominated by flaring.*

Response 11: We have now added an additional sentence to clarify this: '***These observations are consistent with the larger-scale B_y at the spacecraft location being dominated by magnetotail flaring'***

Comment 12: *Line 572: "This flapping must be highly localized" - or alternatively, it could be low in amplitude (i.e. as far as we know, this could be global in terms of extent across the tail, but not large enough in amplitude to reach the other spacecraft).*

Response 12: The reviewer makes a very good point here. We have tweaked this statement accordingly: '*This flapping must be* ***either*** *highly localized* ***or low in amplitude****, as at the…*'