Proposal for the ISSI Investigator Programme

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TITLE: **Conjugate response of the dayside magnetopause and dawn/dusk flanks using Cluster-THEMIS conjunctions and Ground based observations.**

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Abstract:

The Cluster mission has provided extremely detailed, multi-point measurements of the cusp and associated surrounding magnetopause regions since August 2000. The nature of the interaction of the solar wind and associated magnetic field, however, benefits from simultaneous coverage over a range of different magnetopause sites. The Cluster polar orbit traversed the dawn-side magnetosphere and flank magnetopause during the April to July 2007 epoch, where the four spacecraft were separated at large distances (10,000 km). In conjunction with this coverage, during the same epoch, the recent launch of the THEMIS mission has placed the five spacecraft initially into a 'string of pearls' configuration, all lying on the same equatorial orbit and traversing the low latitude, dusk-side magnetosphere and flank magnetopause. In addition to these 9 spacecraft, the Double star TC-1 spacecraft lies in an equatorial orbit lying between the local times of the THEMIS and Cluster orbits, thereby traversing the dayside magnetopause near local noon. This combination of 10 spacecraft has provided an opportunity to simultaneously monitor the dawn/dusk magnetopause behaviour across the whole range of local times, simultaneously, and to probe any IMF and Solar Wind controlled asymmetries. The distribution and grouping of spacecraft also allow multi-scale analysis of local phenomena operating on both flanks of the magnetopause, such as Kelvin-Helmholtz waves and formation of the plasma sheet. The local time distribution, also in latitude, allows the boundary layer extent to be monitored and simultaneous dawn-dusk tracking of FTEs, the signatures of sporadic reconnection, to be determined. The aim of this proposal is to focus on magnetopause conjunctions, which also link to periods of good coverage from ground base observations. Related aims will be to quantify changes in the structure, thickness and dynamics of the magnetopause boundary layer between the spacecraft locations; correlating these with particular conditions and related magnetospheric response. This work will involve the many instruments onboard each spacecraft, available via the Co-I statuses of the team members. In addition, the extended ground-based facilities, which can provide overall view on the magnetospheric dynamics as well as on the small-scale phenomena, will be used from both northern and southern hemispheres. Moreover, to enhance our understanding of magnetospheric dynamics, MHD simulations for some events will be performed. The conclusion of this study will involve the drafting of a number of papers on the work carried out.

Scientific rational, goals and timeliness:

The challenge in the study of magnetospheric behaviour is to understand the processes which control the rate at which mass and energy from the solar wind are transferred into the magnetosphere. Research in recent years has showed that coupling between solar wind and the Earth's magnetosphere is a complicated multi-scale process, which benefits from simultaneous small and large scale sampling, both in space and from ground. For example, different plasma transfer mechanisms can exist simultaneously at the magnetopause, or the associated coupling may be saturated under extreme conditions. Under southward IMF the main transport mechanism is believed to be magnetic reconnection. The large-scale properties of reconnection, however, such as what are the factors controlling the location of reconnection; when and where reconnection occurs, and what is the exact mechanism controlling transient reconnection, are still not very well understood. During northward IMF, the plasma transport mechanism remains uncertain, since competing mechanisms may operate, such as dual lobe reconnection (e.g., *Lavraud et al*., 2006, *Bogdanova et al.*, 2008), diffusion, and plasma transport via Kelvin-Helmholtz waves (Hasegawa et al., 2004). Multi-point measurements of the magnetosphere are crucial, since multiple reconnection sites may exist at the magnetopause (*Pu et al.*, 2007) and/or different transport mechanisms may occur simultaneously (*Taylor et al.*, 2007).

The magnetopause and its surrounding boundary layers (magnetosheath boundary layer, low- and high-latitude boundary layers and the cusp) are key areas for the study of solar wind-magnetosphere coupling across the dayside and flank magnetopause. The intention in this proposal is to use a unique (and unprecedented) combination of 10 in-situ, highly sophisticated satellite measurements of these regions (as shown in Figure 1, which includes an example of the possible ground coverage for a later part of the mission) and to complement these data with ground-based measurements and simulations. All members of the group have great experience in the analysis of such experimental data and in the use of the corresponding, multi-scale data analysis techniques. In the last 3 years many have successfully analyzed a number of conjunctions between Cluster and Double Star satellite at the dayside magnetopause, although all those events were limited in local time. Together with the 5 THEMIS spacecraft and the separation of the Cluster and TC-1 orbits in LT, a unique data set has been collected and the activities of the team will focus on a well defined period of spacecraft conjunctions, as described in the abstract. A number of additional spacecraft will be used as available to provide additional locations and monitoring of selected events. The data from TC-2, which has its apogee in the south, and Geotail, which often skims the MP flanks, in particular, will be significant. Additionally, we will have the capability in the team to compare particular events with numerical simulations, and to look for particular conjunctions with ground based observations (for example, SuperDARN radars from both hemispheres, especially the CUTLASS and TIGER radars will be used). We will identify suitable events for which the upstream conditions affecting behaviour at the magnetopause can be monitored. In general terms, the extent of the coverage in space and from ground stations will allow investigations of magnetopause response, and the properties of its adjacent regions, simultaneously on the dawn and dusk sides, and at local noon.

We have identified a number of investigation themes which exploit the unique spacecraft configurations shown in Figure 1, and which draw on the expertise of our team. Questions relating to these themes are descried below:

1. Undertake comparative studies of FTEs and other transient phenomena on both sides of the magnetopause and under different IMF conditions. Topics which will be accessed by such comparative data are: single or multiple x-line formation; seasonal and IMF Bz, By occurrence; destruction at the cusp; extent and growth; internal structure; plasma flow signatures, and solar wind induced triggering.

2. Investigation of the magnetopause boundary layer and plasma sheet on the dawn/dusk flanks and at high and low latitudes to compare effects of the operation of lobe reconnection and the K-H instability during northward IMF. The K-H instability grows at the flank magnetopause, but its relative contribution to solar wind entry and the formation of the plasma sheet (PS) relative to that from reconnection tailward of the cusp is not known. In this regard, latitude dependence is key to understanding their roles. Additional topics may include: the extent of the K-H instability along the magnetopause and the relation of magnetopause K-H vortices to ground and low-altitude signatures (aurora, ULF waves).

3. Undertake comparative studies of the dynamic response and generation of boundary waves and ULF waves, at and inside the magnetopause. The wide LT coverage will allow the extent of global magnetopause motion in response to various solar wind features to be determined. The effects of pressure pulses in the solar wind may also be pursued, since the spacecraft will serve as good SW monitors for each other at different times. Modeling of the expected electric field and flow signatures in the outer magnetosphere is underway.

Previous, related studies have been performed using the combined Cluster-Double Star configurations (see report on ISSI dayside team), during the course of which many multi-scale data analysis tools have been developed which can easily be applied to the new data sets. Indeed several THEMIS based studies of FTE motion and structure and magnetopause motion and thickness have begun. We cover selected topics, relating to this proposal, below.

1.Reconnection signatures:

Figure 2 summarises the results of *Dunlop et al*. (2005), and *Wang et al.* (2007), who analyzed the five point measurements of Cluster and TC1 to confirm FTEs observed at each spacecraft location originate from the same tilted X-line, located at the sub-solar magnetopause and suggesting that component reconnection operates predominantly at the low latitude magnetopause. Opposite north-south moving FTEs are simultaneously observed only because of the location of Cluster and TC-1 above and below the x-line in the first event. For the second, it is the separation of TC-1 and Cluster along the implied flux tube which confirms it tilt and motion as it is dragged around the duskside magnetopause. Complementary studies of direct x-line encounters and statistical analysis of reconnection flows under large By were performed by *Pu et al*. (2005, 2007), which show that during IMF By dominated intervals both component and anti-parallel reconnection sites may co-exist at the magnetopause. In addition to the studies on occurrence (flux tube orientation and motion) a number of Cluster studies have been performed which probe flux tube structure as inferred from FTE sampling (*Owen et al.*, 2008; *Hasegawa et al.* 2005) and these studies will also be extended using the added THEMIS small scale sampling (see topic 4).

2.Magnetopause boundary layer:

A second question under active discussion concerns the formation and extent of the low-latitude boundary layer (LLBL) and plasma transport during periods of northward IMF. In a recent study, *Dunlop et al.* (2008, under review) investigated the complicated sub-structure of the boundary layer as observed in conjugated events between Cluster and Double Star at the dayside magnetopause, showing that the thickness of the boundary layer is non-uniform and depends on magnetopause location, perhaps relating to the local magnetic shear and total pressure balance. Figure 3 summarises a study of *Bogdanova et al.* (2008) who investigated the electron sub-structure of the boundary layer and the cusp under strong, northward IMF. The analysis of ground radar data from both hemispheres suggested that dual lobe reconnection operates over the entire time interval of interest. Analyzing comprehensive data set from both Cluster and Double Star satellites and applying transition parameter technique to remove spatial variations, they show that the LLBL consists of four sub-layers. The details are given in the figure caption, but this study shows for the first time that reconnected flux tubes map into the cusp region and that it is possible to identify similar sub-regions inside the cusp.

3. Flank boundary, K-H instability and plasma sheet:

Figure 4 shows a multi-spacecraft study performed by *Taylor et al.* (2007) which showed that dual-lobe reconnection and large-scale Kelvin-Helmholtz waves can exist simultaneously at different MLT sectors of the magnetopause and that we need more events to understand the relative input of both processes into the plasma transport across the magnetopause under northward IMF. A survey of Geotail data, as well as some key events from Cluster, has confirmed that the role of K-H vortices is important to allow plasma transport on the flanks during northward IMF (*Hasegawa et al.* 2004, 2006). The effects of vortex merging are also shown from 3D MHD simulations of the instability, where an enlarged dimension of the vortex and stronger deformation of the magnetic field lines may lead to stronger field-aligned current into or out of the ionosphere. The survey confirms that the instability may grow on both sides of the magnetosphere so that the THEMIS Cluster conjunctions will be ideal to extend this type of study. The team will extend previous work which has specifically studied the occurrence of cold-dense plasma sheet, and investigate occurrence statistics as a function of local time using techniques already developed by the team members. We expect to identify the differences between the populations observed at midnight, dusk or dawn of the plasma sheet and boundary layers and their relation to their fundamental properties (density and temperature in particular), as well as their dependence on interplanetary conditions and geomagnetic activity. The plasma sheet also has an influence on the ring current and indeed, different types of populations have been observed at geosynchronous orbit.

4. THEMIS studies:

A number of investigations using the dayside THEMIS data are underway, including multi-spacecraft sampling of the magnetopause and FTE structure. Figure 5 summarises two of these. The first study by *Constantinescu et al*. (2008, under review), concerns an identification of ULF waves (in the range of PC5 pulsations) just inside the magnetopause using timing and cross correlation analysis. A survey of successive THEMIS orbits (over three months starting in March 2007) during the coastal phase has shown that the propagation is parallel to the magnetopause and is confined to the outer, duskside magnetosphere. The addition of Cluster measurements on the dawnside will extend this study. The second study by *Sibeck et al*. (2008, under review) uses THEMIS five point sampling of an FTE to confirm modeling predictions that a strong core magnetic field exists, bounded by weak troughs. Other studies of FTE structure are also in progress. In one paper (*Øieroset et al.* 2008, under review) the five THEMIS spacecraft consecutively traversed the dayside magnetopause at 13.5 MLT, during northward IMF and strong By. One spacecraft monitored the magnetosheath, while the other four encountered a region of nearly-stagnant magnetosheath plasma attached to the magnetopause on closed field lines, similar to the nightside, cold-dense plasma sheet but more dense. The multiple sampling allowed direct determination of thickness. The particle distributions suggest substantial solar wind entry occurs across the dayside magnetopause as a result of reconnection in both cusps on the same field lines.

5. MHD modeling and ground based coordination:

For some of the case studies selected by the working group, we will carry out 3D global MHD simulations (UCLA and BATS-R-US models) that use actual solar wind measurements as input. The results of these simulations will help us to understand the global topology of the dayside magnetosphere during the event. In particular, we will investigate how the magnetospheric flanks are affected by the different modes of the reconnection process (e.g., single or multiple x-line formation), and by their dynamic coupling with the magnetosheath and the rest of the magnetosphere-ionosphere system (e.g. boundary layers). Examples of the use of global simulations for investigating flux transfer events (*Sibeck, et al.*, 2008, under review) and reconnection during Cluster-TC1 conjunctions (*Berchem et al*., 2008, and see *Marchaudon*, 2005) are shown in Figures 5 and 6 respectively. Data from ground-based observatories such as the Super Dual Auroral Radar Network (SuperDARN) (e.g., *Greenwald et al*., 1994) will be used to determine the consistency of our findings with global-scale measurements. In particular, we will use global scale convection velocities derived from Doppler measurements of drifting ionospheric plasma using the so-called "map potential" technique (*Ruohoniemi and Baker*, 1998) to assess the results of the models. All the studies listed here benefit from ground coordination which will provide an overal global view of the sequence of conjunctions. We show only one example in Figure 6 to illustrate the conjunction with Cluster and TC-1 using the superDARN flow map, taken during an FTE tracking event (*Wild et al.* 2007).

Expected output

The combination of the 10 spacecraft skimming the magnetopause on both the dawn and dusk sides of local noon, with the 5 THEMIS in a string of pearls configuration, the 4 Cluster at large separations and TC-1 near local noon, represents a unique opportunity. Together with Geotail measurements, TC-2 and the array of ground instrumentation, it will be possible to study almost the whole local time extent of the dayside magnetopause simultaneously. We have cited several goals, using suitable conjunctions, for some of which fruitful work has already begun. For others we will identify particular ground measurements linked to the wide MLT coverage and will run tailored numerical simulations to model behaviour.

We are confident that our chosen topic will be scientifically productive. The previous ISSI teams using combined Cluster/Double Star data opened up new ways of understanding the datasets and resulting in several published papers. Our team has been chosen so as to combine THEMIS experts with Cluster/Double star experts, together with very experienced modelers and ground based expertise. We will identify as priority events a small selection (2 or 3 initially) which best address questions raised above. Our primary aim is to study these events in great detail using multi-point multi-instrument approach and publish results of research in peer-refereed journals. Based on our previous experience, we expect that at least 5 refereed papers will be published as a result of this collaborative work. The results will also be presented as invited and contributed talks on major international conferences.

Work plan for ISSI location

The main reason for choosing ISSI to host this activity is to provide a forum for the exchange of ideas, expertise and data accessible to a team drawn from China, Japan, Australia, the USA and Europe. The location allows us to pull together a team of experts who otherwise might never meet as a group, and fosters further collaborative links. Our experience with the Cluster-Double Star Dayside team demonstrates that this approach is extremely effective. ISSI provides the necessary facilities for these collaborations (meeting room and work room providing internet access, data projectors, access to printers) to be carried out in a productive and active way, allowing real time studies not possible in normal workshop environments.

Schedule

It is proposed to conduct the study over two meetings held at five to six monthly intervals, with the option of a third meeting if required. We propose that the first meeting could be over three-four full days to identify and select events for in depth analysis, collate data sets and assign analysis tasks. The second meeting may require a week to review “homework”, conclude analysis and identify results. A final three day meeting will be used to ensure the timely completion of publications.

Funding

Resources for travel to ISSI would be covered by the team members through resources at their home institutes, which specifically target Cluster/DSP research in coordination with THEMIS. We request funding support in respect of facilities, accommodation and subsistence in Bern for each team member. We propose full travel funding only for one leader. Two members of our team are ESA employees.

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Appendix A:

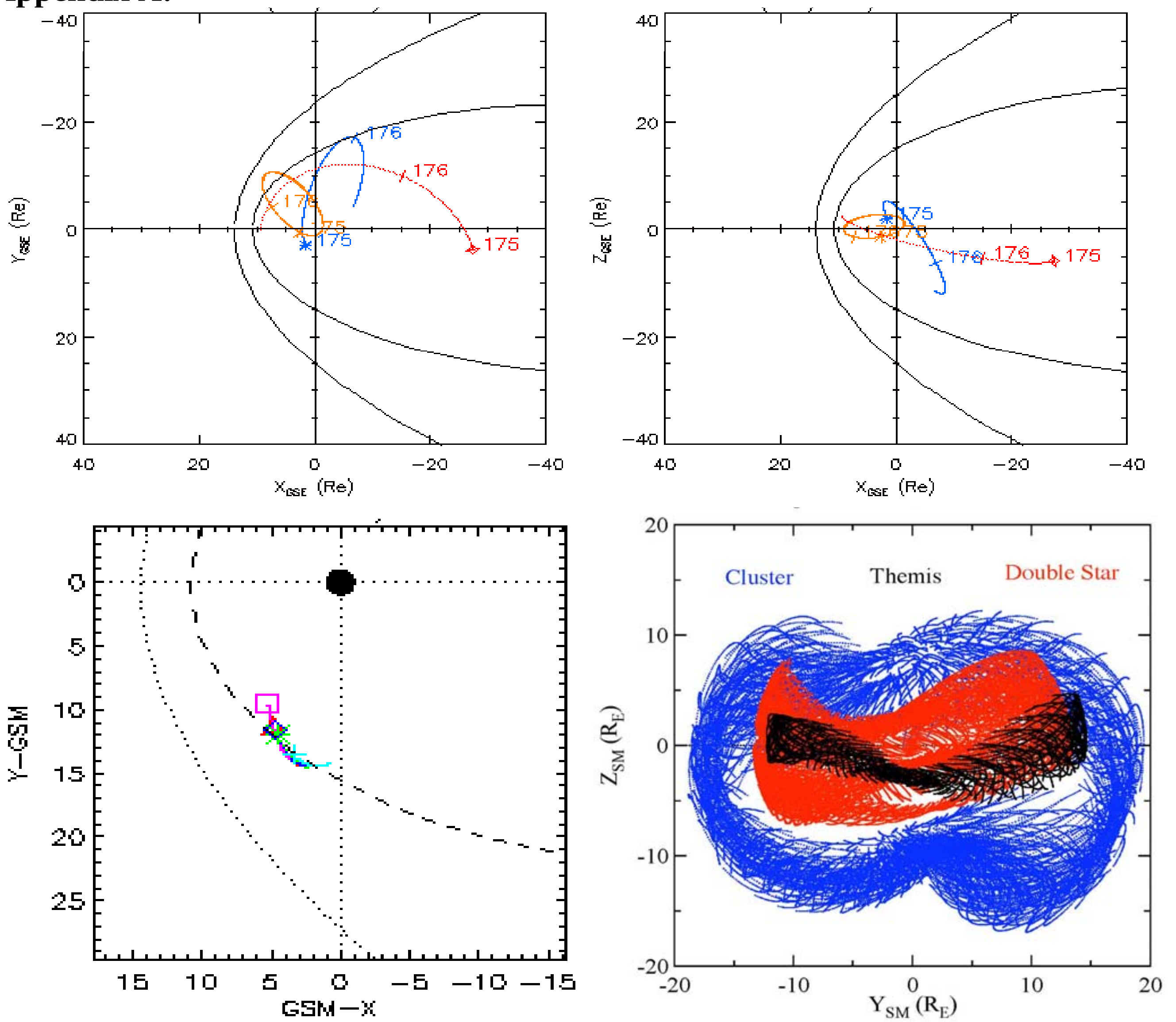

Figure 1a: The top panels show a conjunction of the four Cluster (blue), TC-1 (orange) and Geotail (red) spacecraft in June 2006 (a similar configuration occurs in 2007). In this example Geotail samples the near Earth tail plasma sheet and moves around to the dayside magnetosphere, eventually crossing the magnetopause during the time TC-1 and Cluster graze the magnetopause. During April/May TC-1 lies nearer noon and Cluster exits into the magnetosheath just after the dawn terminator. The lower left panel shows the five THEMIS spacecraft in their string of pearls at the end of April 2007, which are seen to repeatedly skim the magnetopause just before the dusk terminator. The bottom right panel shows the front view of the orbits for track segments within 2 hrs of a nominal magnetopause from March to March 2007-8. It is clear that nearly the whole of the magnetopause is potentially covered: THEMIS (black) scans the duskside as cluster scans the dawnside and *vice-versa*, with TC-1 moving midway between them in LT.

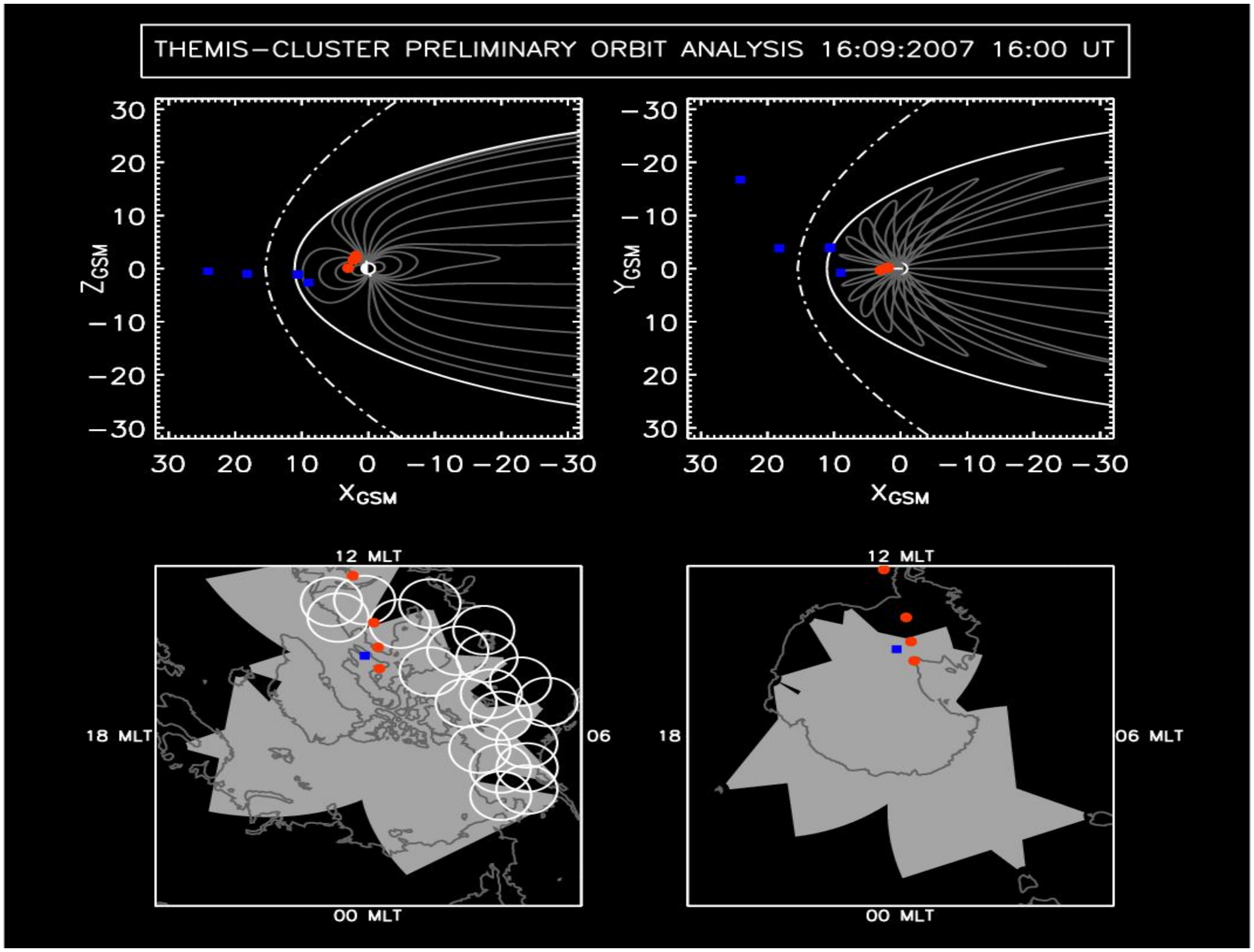

Figure 1b: An example figure with some preliminary orbit data (before the 5 THEMIS probes were separated) is shown on the lowest right. The Cluster spacecraft are shown in red and THEMIS probes in blue (2 THEMIS probes are close together), and their footprints are shown in relation to the ground-based experiments (e.g. Imagers and SuperDARN).

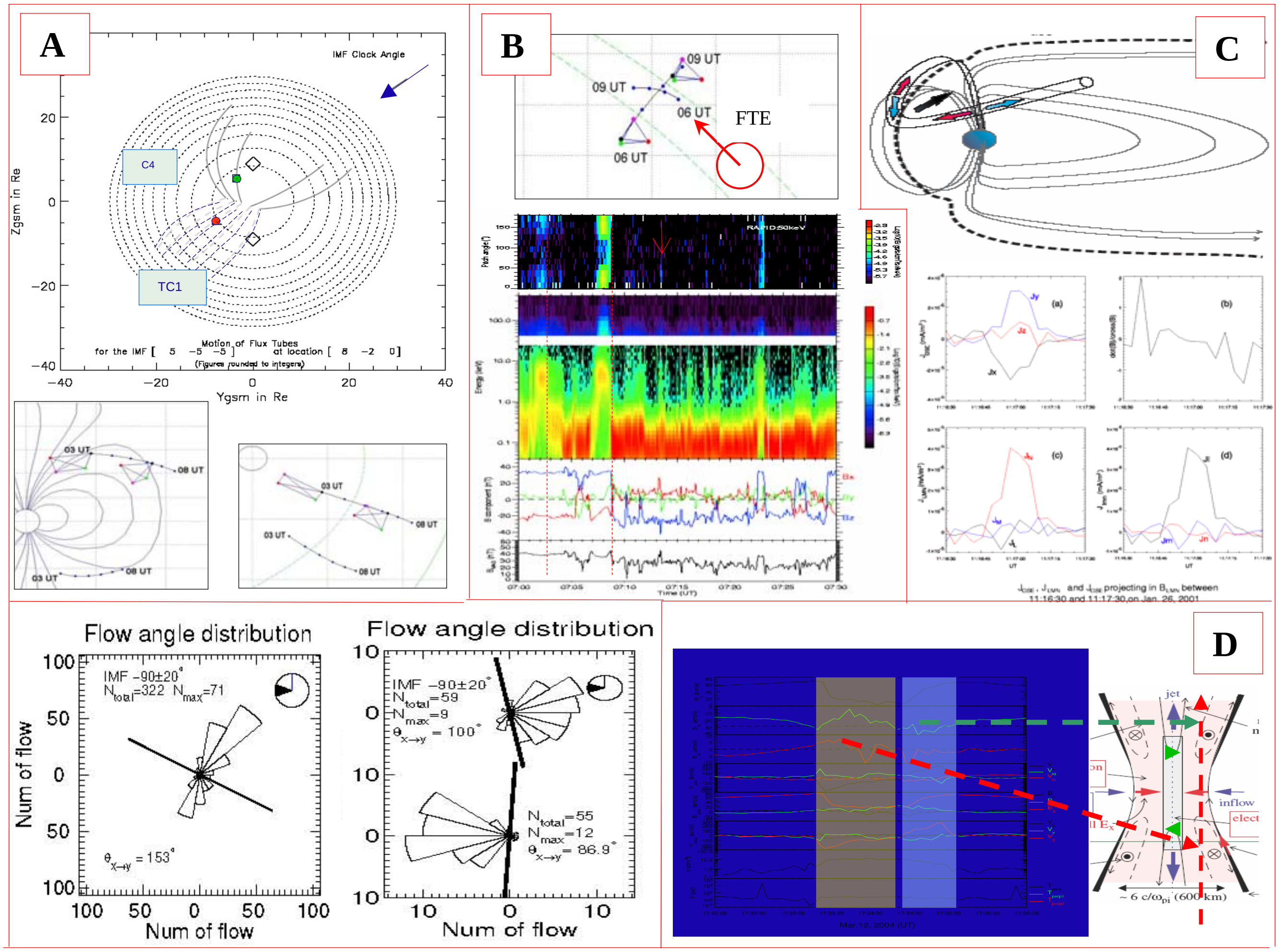

Figure 2: The panels labeled 'A' show a coordinated event where Cluster and Double Star TC-1 lie north and south of the sub-solar point respectively (as shown on the lower, orbit plots projected into the X,Z and X,Y planes respectively). All spacecraft exit the magnetopause within half an hour of each other and provide evidence for a reconnection site lying between the spacecraft and allowing the observation of opposite (N/S) flux tube branches simultaneously. The Cooling model is used to track the expected reconnected flux tube motion (top left panel). The tracks agree closely with the observations and with timing of FTE pairs. The panel labeled 'B' shows an event where Cluster (high latitudes) and TC-1 (mid latitudes) lie at the same LT and approximate radial position, separated only along the magnetopause. The initial MP exit is during northward IMF, followed by a sharp southward turning: conditions which may imply a possible onset of reconnection and FTE generation. Correlated FTEs (arrow) suggest single flux tubes are crossed at different positions. The panel labeled 'C' summarizes Cluster observations of a train of FTEs during a sequence of repeated magnetopause crossings. All FTE signatures have common velocities moving northward and dusk-ward, contain out-flowing (energetic) ions/electrons and have clear electric current characteristics aligned along the flux tube axes (lower panel), which have distinct alignments for the magnetosheath and magnetospheric FTEs consistent with a twisted flux tube geometry (top right panel). The lower panels labeled 'D', summarise TC-1 direct encounters with the x-line (right) and the combined statistical analysis of accelerated flows in the magnetopause under strong By (left). These studies confirm the existence of component reconnection at low latitude which is supported by a tilted x-line geometry (as indicated by the reconnection flows). The high latitude results of Cluster suggest the x-line geometry fits an S-shape and that predominantly anti-parallel reconnection sites occur at high latitude.

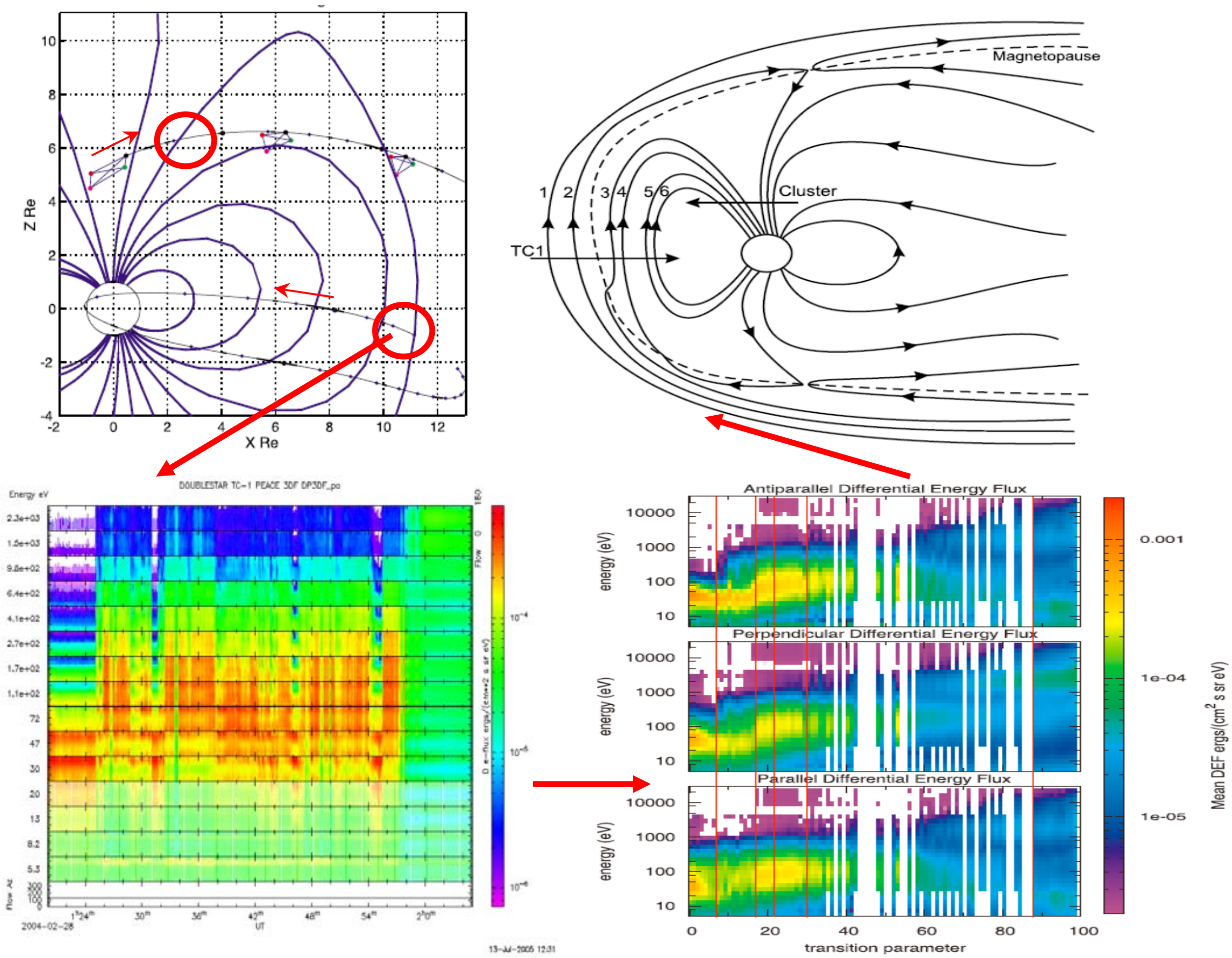

Figure 3: Formation of the boundary layer and the cusp under northward IMF. Top left: Cluster and TC-1 spacecraft tracks in the X-Z plane in the GSM coordinate system between 00:00 and 04:00 UT on 28 February 2004. The orbit also shows the configuration of the Cluster spacecraft array as a tetrahedron (scaled by a factor of 20). The model geomagnetic field lines are shown from the Tsyganenko T96 model based on observed external parameters. Bottom left: TC1 electron spectrometer PEACE observations near the dayside magnetopause. Figure consists of 15 sub-panels. Each panel presents the pitch angle distribution (0°–180°) for electrons with centre energy shown on the left (in the range 5-2300 eV). Differential energy flux is colour-coded according to the logarithmic colour bar shown on the right. TC1, crossing the dayside magnetopause, observed a complex structure of boundary layers. We identified at least three different sub-types of the boundary layer with different plasma properties. However, due to the magnetopause motion, the TC1 spacecraft crosses back and forward into these layers and it makes the data analysis extremely complicated. To analyse this data set, we calculated transition parameter for every observational point, based on anti-correlation between electron density and temperature across the boundary layer. The transition parameter technique removes the temporal variations, and makes the data analysis straightforward. Bottom right: results of reconstruction of the electron spectrogram versus transition parameter, with 0 corresponding to the magnetosheath and 100 corresponding to dayside plasma sheet. The differential energy flux in anti-parallel, perpendicular and parallel directions are shown. Top right: Schematic of the formation of the low-latitude boundary layer observed at the dayside by TC1 satellite. Line (1) shows the PDL field line, draped around the dayside magnetosphere. Line (2) represents a field line which is formed due to reconnection between the PDL and lobe field lines poleward of the cusp in the northern hemisphere. This field line is open and is outside the magnetopause, in the magnetosheath boundary layer. Line (3) represents an open field line which is formed due to reconnection poleward of the cusp in the northern hemisphere and which sinks inside the magnetosphere, crossing the magnetopause. Line (4) shows a field line which is formed by dual lobe reconnection. Line (5) represents field lines populated by plasma with reduced fluxes from both magnetosheath and magnetosphere sources. The process responsible for this population is diffusion across the magnetic field. Other lines show the magnetospheric field lines. The dashed line shows the magnetopause.

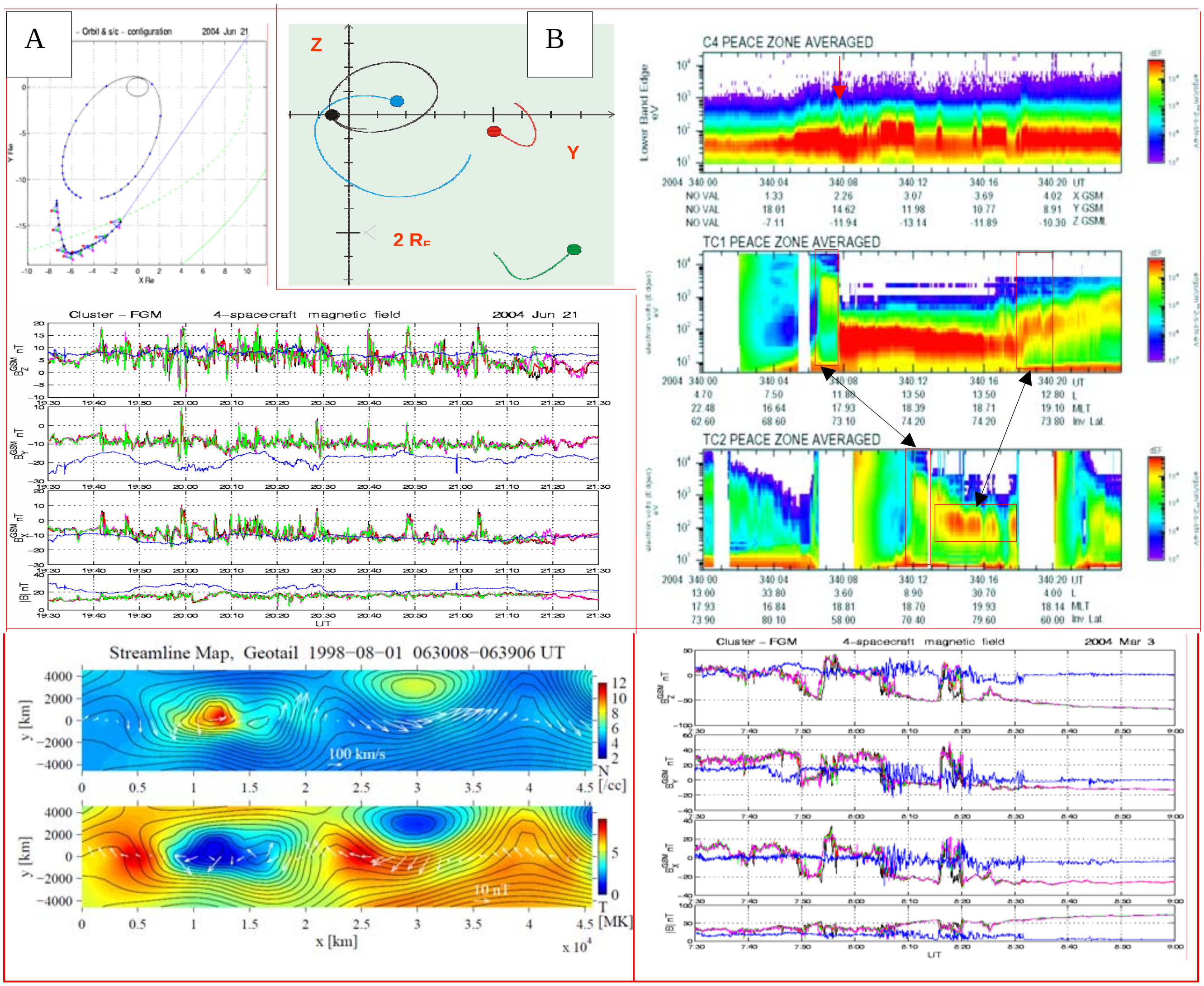

Figure 4: (A) The left hand panels show a typical dawn flank location in which the Cluster spacecraft skim the magnetopause, while the TC-1 spacecraft lies inside the magnetosphere. Both TC-1 and the Cluster spacecraft are near apogee for these conjunctions, so that Cluster often traverses a range of latitudes along the magnetopause surface. In the first case, Kelvin-Helmholtz waves appear to be generated on the boundary but TC-1 lies too deep to pick up clear comparative signatures. Cluster generally moves through a large range of latitudes from north to south in these cases. (B) The right hand panels show low electron data from an example where both Double Star spacecraft are coordinated with Cluster. The top centre panel shows orbit tracks of Cluster (green), TC-1 (red), TC-2 (black) and also the Polar spacecraft (in magenta). Cluster lies south and is inbound; TC-1 moves north through the equator, and TC-2 orbits 3x during the event. Following the impact of a coronal Mass Ejection and resulting in a sudden solar wind induced compression of the magnetosphere, the observations were consistent with the formation of a cool dense plasma sheet (CDPS) in the near Earth magnetotail. It is believed that the appearance of a cooling of the plasma sheet results from plasma injection either from the lobes (during lobe reconnection) or by plasma transport on the flank magnetopause (possibly via vortex formation resulting from the growth of Kelvin-Helmholtz waves). The lower left hand panel shows a 2-D reconstruction of vortices from Geotail data supporting the evidence that the K-H instability is important in solar wind plasma transport during northward IMF. A survey of Geotail data for the period 1995-2003 (9 years) showed that rolled-up vortices exist on both dawn and dusk MP flanks. The lower right panel shows and example of the dynamic response of the high altitude region; possibly in response to changes in V_Y of the solar wind. The Double Star measurements show the combined effect of MP and bow shock motions (TC-1 lies at the shock and Cluster lies in the cusp).

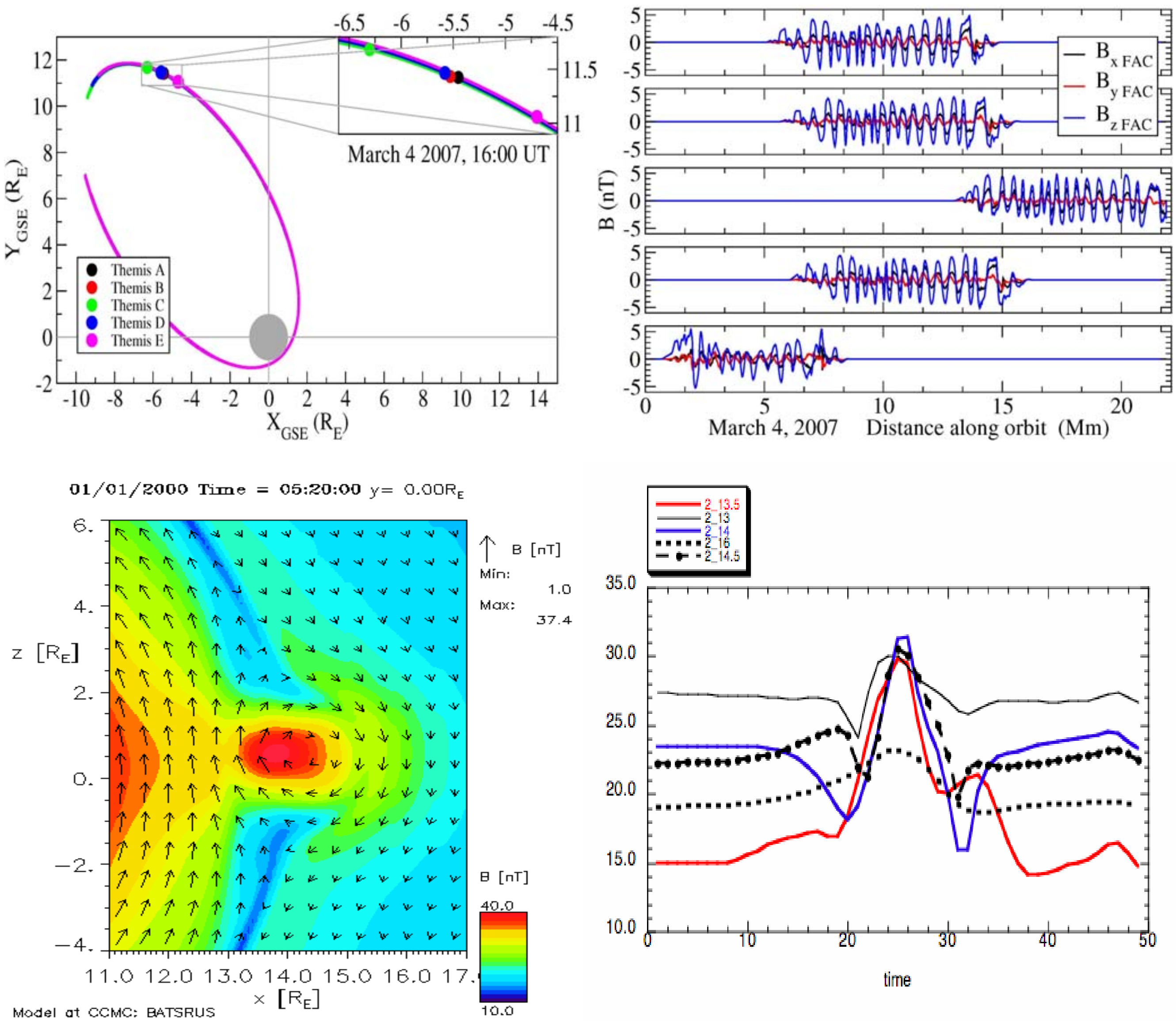

Figure 5: The top panels illustrate the string of pearls configuration of the THEMIS orbit during the coastal phase. This configuration allows for timing analysis in the space domain by using the spacecraft position along the common orbit as an independent coordinate and the top right panel shows a typical dusk side ULF wave represented in the space domain. The excellent correlation across the magnetic field measured at different locations is used to determine the wave phase speed along the spacecraft track, and shows consistent propagation parallel to the magnetopause on consecutive orbits. The lower panels show an FTE event. The BATS-R-US magnetohydrodynamic (MHD) model predicts flux transfer events (FTEs) with strong core magnetic fields embedded within a broadened current layer with weak magnetic field strengths on the equatorial dayside magnetopause during intervals of southward and duskward interplanetary magnetic field (IMF) orientation. Multipoint THEMIS observations at 2202 UT on June 20, 2007 of a southward-moving FTE on the post-noon magnetopause confirm the predictions of the model. Magnetosheath spacecraft THEMIS-E and –A with large impact parameters simply observe magnetic field strength enhancements, magnetospheric spacecraft –B and –C with moderate impact parameters observe crater FTEs with deep troughs bounding a strong core field, while THEMIS-D with a very low impact parameter observes only the core magnetic field strength enhancements.

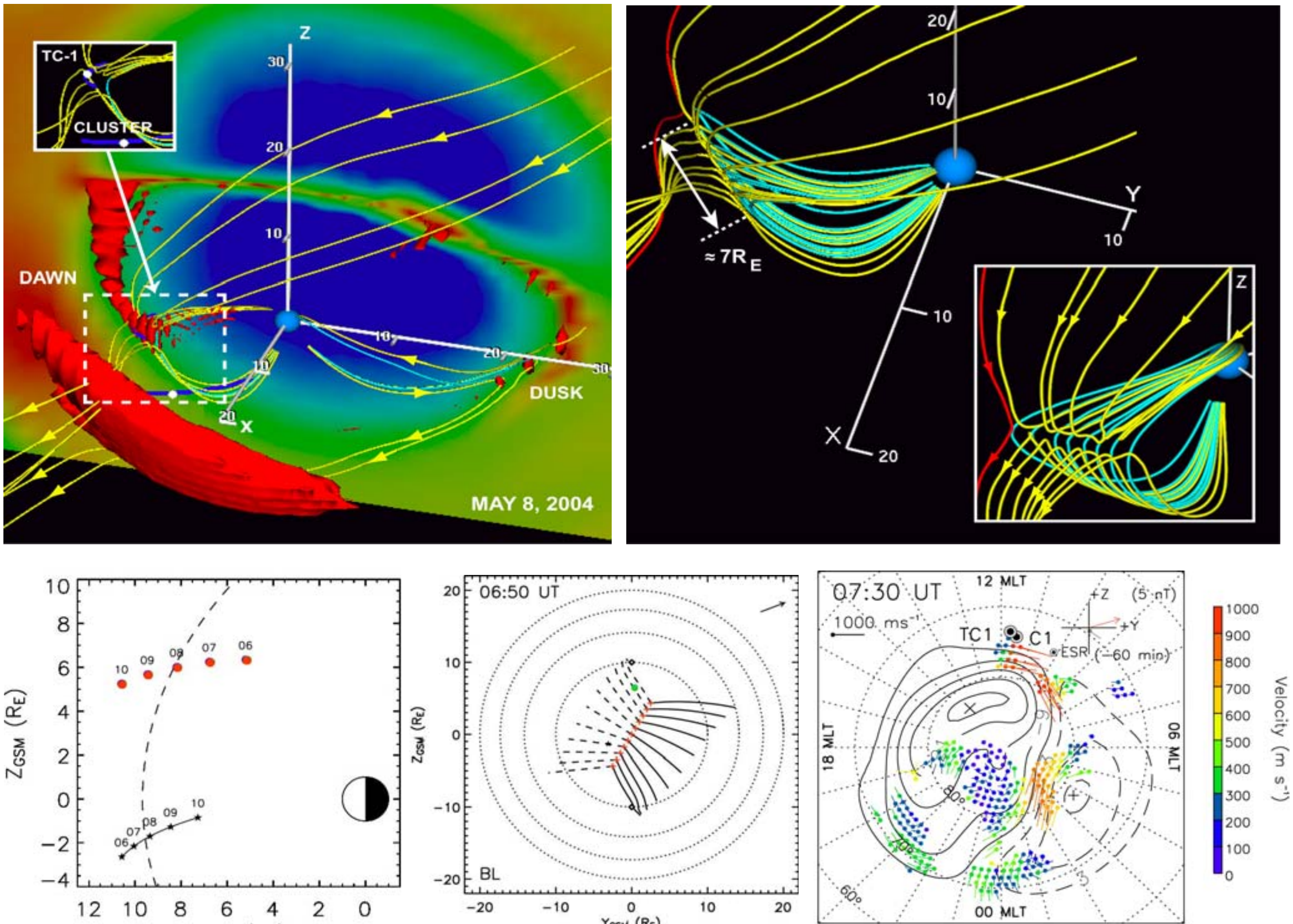

Figure 6: We will run 3D global MHD simulations [e.g., *Berchem et al.*, 1998] that use actual solar wind measurements as input to investigate the global topology of the dayside magnetosphere during some of the Cluster-Themis conjunction events selected by the team. The results of these simulations we will help us determining how the magnetospheric flanks are affected by the three dimensionality of the reconnection process and by its dynamic coupling with the magnetosheath and the rest of the magnetosphere-ionosphere system. Panels 1 and 2 show results of a global simulation for a Cluster and TC-1 conjunction that occurred on May 8, 2004, when the spacecraft were on the dawn flank of the magnetosphere [*Berchem et al.*, 2008]. TC-1 was located near the equatorial plane and Cluster at higher latitudes in the southern hemisphere. Panel 1 is a 3D rendering of the dayside magnetosphere viewed from 2 o'clock past noon local time. The backdrop of the picture is a 2D cross section of the magnetotail at x = -10 R_E showing color contours of the plasma beta; isosurfaces of plasma beta = 100 complete the picture with the same color-coding. Unconnected, open, and closed field lines are shown in red, yellow, and turquoise respectively. The inset displays the dawn side region hided from view by the isosurface. Cluster and TC-1 trajectories during the 06:00-16:00 UT time interval are represented by blue traces. White diamonds indicate the locations of the spacecraft at 10:03 UT when the magnetic shear angle at the magnetopause was about 170°. The snapshot reveals the occurrence of reconnection in the dawn region just above the equatorial magnetopause. This topology was consistent with fast plasma flows measured by the CIS and Peace experiments onboard TC-1, as well as with the polarities of the numerous FTEs observed on that pass [*Marchaudon et al.,* 2005]. Panel 2 shows a higher latitude view of the dawn-side merging region shown in Panel 1. This view indicates that the merging region extends from about 7 to 10 MLT, or about 7 R_E in length. The inset is an extreme close-up of the dawn-side merging region viewed from 9 o'clock local time. It shows that the 3D geometry of the merging region is made up of the radial juxtaposition of planes displaying X-type reconnection geometries. The lower panels illustrate a ground conjunction from Cluster/TC-1, showing the mapped signatures in terms of the global ground convection.