Title: Field-Aligned Currents: Their morphology, evolution, source regions and generators.

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Abstract:

Birkeland currents play a fundamental role in conveying stress and electric field in the coupled solar wind-magnetosphere-ionosphere-thermosphere system, as well as providing the channel for energy and momentum transfer between these systems. Knowledge of the field-aligned current (FAC) structure and dynamics is a key to understanding how solar wind energy is transferred from the magnetosphere to the ionosphere and thermosphere. In the last decade these current systems were extensively investigated based on the observations from low-orbiting satellites, CHAMP, Ørsted, DMSP, Iridium constellation, as well as inferred from SuperDARN radars and ground-based magnetometer network observations. Although significant progress has been made in our understanding of the statistical distribution, source regions, and evolution of the current systems in response to condition changes, there are still many open questions in need of investigation. In addition, uncertainties in accuracy and temporal resolution of the current estimations remain to be studied. So far little attention has been paid to small and medium-scale FACs. Due to their large amplitudes they are believed to play an important role for the energy input to the upper atmosphere.

In this project we plan to combine the observations from different missions, including and most notably from ESA's recently launched multi-spacecraft mission Swarm, which provides the most accurate estimates of small and medium-scale FACs to date. We will combine observations from low-Earth orbiting satellites, SuperDARN, and ground-based magnetometers to investigate FACs, ionospheric electrodynamics, and thermospheric response; use observations from Cluster, THEMIS, and Van Allen Probes to investigate current sources in the magnetosphere; and employ MHD modelling and mapping techniques to relate magnetospheric, ionospheric, and thermospheric observations. We will compare different techniques for the current estimations and try a common calibration against the most reliable estimates. We aim to bring together scientists with diverse backgrounds in order to address the following questions:

- What is the large-scale morphology of R0/R1/R2 current systems and what are the factors influencing the strength and distribution of large-scale current systems in both hemispheres?
- What are the relations between large and small-scale FAC systems?
- What are the generation mechanisms of the Region 0 (polar cap) current systems and what are the common external conditions for their existence?
- What are the generation mechanisms of the cusp and cleft currents, and what is the ionospheric and thermospheric response to these filamentary FAC systems?
- How do the FAC systems evolve in response to sudden changes in the external conditions and what is the mechanism of the FAC saturation during magnetic storms?
- What are the magnetospheric sources of the FAC current systems?

1. Scientific rationale

Birkeland field-aligned current (FAC) systems play a major role in the electric field, plasma momentum, and mass transfer between the solar wind, magnetosphere, ionosphere, and thermosphere, and therefore they are a key physical phenomenon to study for the space plasma physicists. The statistical investigation of these currents started from pioneering work by Iijima and Potemra (1976), which showed the existence of two belts of upward and downward currents in the polar ionosphere. In the northern hemisphere, the Region 1 FACs flow into (out of) the ionosphere in the dawn (dusk) side, and the Region 2 currents are observed equatorward of the Region 1 currents and have opposite polarity. These currents are part of the current loops connecting the magnetopause and inner magnetosphere and closing in the ionosphere primarily via Pedersen currents. Later additional field-aligned current systems have been discovered: Region 0 (e.g., Kustov et al., 2000; Wing et al., 2010; Wing et al., 2011), which are observed poleward of the R1 currents with polarity opposite to R1; cusp currents (e.g., Cowley, 2000); 'NBZ' current system during times of northward Interplanetary Magnetic Field (IMF) (Zanetti et al., 1984; Vennerstrom et al., 2002, 2005; Stauning, 2002); and the substorm current wedge (Clauer and McPherron, 1974; Ritter and Lühr, 2008). The statistical properties of these current systems, small-scale structure, inter-hemispheric conjugacy and differences, dependence on the external parameters, dynamical response to the changes in the system, coupling with the neutral thermosphere, as well magnetospheric sources and generation mechanisms of these current systems are still under active investigation. The aim of this team is to advance our understanding of the complex FAC systems in a more unified picture.

1.1 Current estimation techniques

There are a number of challenges associated with the current estimations from magnetic field or plasma flow measurements. Field-aligned currents can be detected by their perturbation of the geomagnetic field in the orthogonal plane. Since early space missions, these measurements have been used to estimate the FAC density based on the 'one spacecraft method', which are based on assumptions about the current sheet geometry (infinite) and orientation (e.g., Christiansen et al., 2002). This method is used for most of the previous current estimates from single spacecraft, such as CHAMP, Ørsted, and DMSP. Another approach is to compile average 'magnetic maps' from measurements over an extended time period and apply curl(B) to it for estimating current density from Ampere's law (e.g., Weimer, 2001; Waters et al., 2001). This method yield global FAC distribution with limited spatial and temporal resolution. Using AMPERE data from the constellation of 70+ Iridium satellites located in 6 equally-space polar orbit planes, current distributions are derived with 3deg latitude resolution and a cadence of 10 minutes (Merkin et al., 2013; Clausen et al., 2012, 2013; Wilder et al., 2013) whereas in the pre-AMPERE era 1-hour data accumulation was required owing to lower sample rates (Korth et al., 2004; Anderson et al., 2008). The SuperDARN convection maps also can be used for the FAC estimations (Kustov et al, 2000) as well as ground-based magnetometer measurements (e.g., Kamide and Richmond, 1984). The Cluster era brought multi-SC current estimation methods, such as the curlometer technique (Dunlop et al., 2002), which calculates current density from curl(B) measured simultaneously at 4 locations. A similar method was adapted for Swarm data, where measurements separated along-track will be used to create a 'tetrahedron' (Ritter et al., 2013). More recently, advanced methods of magnetic field analysis and current estimations have been developed, including the curvature analysis method (Shen et al., 2003), magnetic field strength gradient method (Shen et al., 2003, 2012a, 2012b), and the magnetic rotation analysis (MRA, see Shen et al., 2007). It is important to understand the limitations, accuracy, and temporal resolution of the different methods. We plan to review and compare these methods and possibly propose improvements.

1.2 Morphology and properties of the large-scale and small-scale FACs

In the last 10 years, high-latitude FAC systems have been studied extensively, mostly using statistics from low-orbiting satellite observations. The location, strength, and latitudinal extension of the FAC Region-1/2 currents have been investigated in relation to season and ionospheric conductivity (Christiansen et al., 2002; Ohtani et al., 2005a, 2005b; Green et al., 2009), substorm cycle (Weimer, 2001; Clausen et al., 2012, 2013), dipole tilt (Weimer, 2001) and external conditions, including IMF strength and orientation, solar wind velocity, density, dynamic pressure, electric field, and merging rate (Weimer, 2001; Wing et al., 2011; Anderson et al., 2008; Korth et al., 2010, 2011; Ritter et al., 2004). It was shown that the IMF orientation is the dominant factor controlling the distribution of the currents, and the intensity of the currents is a complex function of many parameters, such as magnetic local time (MLT), season, solar wind merging rate and the solar wind electric field. None of the previous studies provided a complete extended study of all factors influencing the FAC R1 and R2 regions, and some conclusions from different studies were contradictory. Up to date, there are no systematic studies of how the R0 strength and location depends on external conditions. The influence of the external parameters on the FAC properties inside the plasma sheet boundary layer (PSBL) have recently been statistically investigated using Cluster measurements (Shi et al., 2010; Cheng et al., 2013), and it was shown that the IMF orientation also influences the PSBL FAC distribution and their asymmetry. However, the exact mechanism of such influence needs further understanding.

Some studies reported a strong dependence of the FAC structure on the IMF-By orientation, with an extreme example of FAC distortion being a four-sheet FAC structure at the dayside (Ohtani and Higuchi, 2000). Based on large DMSP statistics, Wing et al. (2010) reported that 3 sheet structures consisting of R0/R1/R2 FACs occur quite often: they have been observed for all IMF orientations at dawn and dusk in ~20 % of events, and in ~ 50 % near the noon. This is in agreement with Papitashvili et al. (2001), who showed that the central area of both northern and southern polar caps is filled with FACs, which resembles the NBZ system, even during slightly southward IMF. However, the statistical study by Anderson et al. (2008) reported the absence of statistically significant R0 currents for southward IMF. The questions remain: is R0 a unique current system, or is this an extension of the current sheet from the other MLT sector? What are the conditions favourable for its existence and what is the generation mechanism of this system? Some studies suggested that it is formed by viscous interaction near the magnetopause (Kustov et al., 2000; Papitashvili et al., 2001), while other studies suggested that this current system is a more general case of the NBZ currents and is formed by the reconnection process, sometimes with a more complex reconnection geometry inside the magnetosphere, which can occur during the IMF By dominant intervals (e.g., Watanabe and Sofko, 2009). Vennerstrom et al. (2002) showed that two NBZ currents, existing during northward IMF, can gradually rotate and become an R0 current system, suggesting that both systems are driven by the reconnection process at high latitude, and changes in IMF orientation shift the location of reconnection process, which is in agreement with simulations (Wang et al., 2008). If R0 currents were present in 30% of all observations, this would have significant implications for our understanding of the magnetosphere-ionosphere coupling and current closer in the ionosphere.

In addition, the statistical work of Clausen et al. (2012) reported that in some cases the R1 and R2 current systems change direction and do not agree with the conventional R1/R2 pattern, and Wing et al. (2010) showed that the R1/R2 events with opposite polarity constitute 10% of cases near dusk and dawn and ~40% of cases near noon. While observations near noon may be contaminated by cusp currents, it is not clear how to explain such observations near the dusk and dawn sectors and what physical process can be the cause of it.

The smaller-scale FAC systems, such as cusp and cleft currents, are poorly understood. Recent studies (Marchaudon et al., 2004; Marchaudon et al., 2006) confirmed that the cusp plasma injections are accompanied by pairs of FACs, upward at lower latitude and downward at higher latitude, in agreement with Southwood's Flux Transfer Event formation model (Southwood, 1987). However recent studies of the magnetopause reconnection (e.g., Pu et al., 2013) reveal that multiple reconnection lines are often formed at the magnetopause, and therefore we would expect a much more complex FAC structure inside the cusp (Lee, 1986), which needs to be confirmed by observations. In addition, the low-altitude measurements reveal that equatorward of the cusp currents, another current system is often observed, suggesting an intense small-scale field-aligned current system possibly connected to the open LLBL region (Waterman et al., 2009). We plan to investigate the occurrence and properties of this current system.

Investigation of the relationship between small, mid, and large-scale currents has not been feasible until now; however with the complimentary measurements from Swarm and AMPERE, we will be able to study their spatial distribution and temporal variability.

1.3 Evolution and dynamics of the FAC systems in response to external changes

The time scale of the current systems' response and reconfiguration after rapid and dramatic changes in external parameters, such as the IMF reversals, storm sudden commencement, and solar wind pressure pulses are still under active investigation. A significant step in understanding has been achieved recently by use of simulation of the magnetospheric and ionospheric dynamics based on a global MHD model, the University of Michigan's BATS-R-US model (Yu and Ridley, 2009a, 2009b, 2011; Wang et al., 2008). The temporal response and current reconfiguration have also been monitored by AMPERE, which provides current maps at a 10-minute cadence (Merkin et al., 2013; Clausen et al., 2012, 2013; Wilder et al., 2013). The spatial and temporal resolutions of the AMPERE current distributions are not sufficient for monitoring the response of the small-scale, rapidly-changing filamentary current systems, and there is still lack of understanding in relation to shorter scales as well as lack of multi-point measurements, simultaneous measurements in both hemispheres and comparison with MHD modelling.

How the magnetosphere and ionosphere react during extreme external driving conditions and how the solar wind-magnetosphere-ionosphere coupling works during those times is one of the key elements in space and space-weather research. The saturation of the transpolar potential and the position of the open-closed boundary have been observed before (Siscoe et al., 2002a; Bogdanova et al., 2007). In addition, Siscoe et al. (2002b) investigated and modelled the R1 current system, showing its saturation in response to extreme solar wind electric field. More recently, Birkeland FAC behaviour was investigated based on CHAMP (Wang et al., 2006), Iridium/AMPERE (Anderson et al., 2005; Anderson and Korth, 2007; Korth et al., 2008, 2010), and DMSP measurements (e.g., Eriksson et al., 2008). These studies showed the complex behaviour of FACs, including a 2-step response of the system, saturation of both the R1 and R2 current systems, dawn-dusk asymmetry, and formation of additional currents systems, such as 4-sheet FAC system. These authors highlighted the need for the further investigation of FACs during magnetic storms, their changes and development, and mechanisms responsible for their saturation, as different explanations were offered on the 'generation' process of the R1 current system (Siscoe et al., 2002b; Mishin et al., 2011).

1.4 Magnetospheric sources and drivers

The 'historical' picture of the magnetospheric current sources and driving mechanism is as follows: the R1 current system connects to the low-latitude boundary layer and is most likely formed by viscous interaction and constitutes a voltage source (e.g., Echim et al., 2008; Wing et al., 2011), whereas R2 connects to the ring current and is a diversion of the partial ring current to the ionosphere driven by pressure gradients in the inner magnetosphere (e.g., Cowley, 2000; Zheng et al., 2006; Wing and Newell, 2000). The cusp currents are driven by reconnection at the dayside magnetopause, the substorm current wedge is a diversion of the cross-tail current, and there is less agreement on the sources of the NBZ and R0 currents, with both reconnection and viscous interaction at the high-altitude magnetopause being suggested as driving mechanisms. There is also some ambiguity between the R0 and cusp FAC systems – some studies consider them as separate systems while others treat them as the same system (e.g., Stauning et al., 2001). This view is very simplified, and recent studies showed that many current systems, especially inside the cusp and substorm current wedge, consist of small-scale filamentary currents, which require further investigation (Watermann et al., 2009; Forsyth et al., 2014). The additional problem with the current source studies is uncertainty in the mapping between the ionospheric and magnetospheric parts of the current systems, and lack of conjugated observations of the current flowing along the same field line, inside the magnetosphere and ionosphere. We plan to use MHD simulations to improve the mapping, and we will look for the conjunctions between ionospheric and magnetospheric satellites. Using characteristics of the plasma precipitations into the ionosphere, Wing et al. (2010) and Ohtani et al. (2010) showed that R0/R1/R2 originates from more than one region in the magnetosphere, depending on latitude and magnetic local time. Particle precipitation can also provide information on the parallel potential drop, which in turn, can shed light on the conditions in the magnetospheric source regions and driver in the regime where Knight relation operates (Knight, 1973). Therefore, multiple processes and generation mechanisms can be responsible for the formation of these current systems, and the source region and current driven mechanisms are more variable and complex than thought before.

1.5 Thermospheric response

Most of the previous work on FAC systems concentrated on the ionosphere-magnetosphere coupling, without taking into account coupling between the ionosphere and thermosphere. However, these two regions are very strongly coupled by collisions between ions and neutrals, especially in the E-layer during day-time (e.g., Lühr et al., 2012). Therefore, the thermosphere is affected by changes in the ionospheric parameters caused by FAC systems, and at the same time, can influence the ionospheric and even magnetospheric properties.

Lühr et al. (2004) showed that FACs can influence parameters of the thermosphere: comparing CHAMP observations of the thermospheric density and field-aligned currents inside the cusp regions, they showed a strong correlation between existence of fine-scale cusp FACs and enhanced air density. It was suggested that an upwelling cusp 'fountain' can be created due to heating of the atmosphere by ionospheric currents. However, the exact mechanism of neutrals heating requires further investigation and more complete measurements. While Lühr et al. (2004) showed the importance of the small-scale FACs in the energy transfer to the thermosphere in the cusp region, their role in other regions, such as polar cap (R0 and NBZ systems) and substorm current wedge, is poorly understood, as well as relations between large-scale and small-scale current systems.

It was also shown that the coupling exists between neutral wind and plasma motion inside the polar cap, and that the neutral wind speed will react to the changes in the plasma drift (e.g., Lühr et al., 2012). Likewise, the results of simulations from Michigan's coupled magnetosphere-ionosphere-thermosphere models showed that thermospheric neutral winds can modify plasma convection in the ionosphere, polar cap electric field and cause changes in the strength of the FACs, especially during northward IMF (Ridley et al., 2003). These previous studies showed that the thermosphere plays an important role in the understanding of the properties of FAC systems and should be considered when studying the coupling between the ionosphere and magnetosphere.

2. Goals and project implementation

We plan to answer several of the open scientific questions related to FAC morphology, dynamics, generation mechanisms and sources, ionospheric closure and thermospheric response, as well as how ionosphere and thermosphere can modify FAC systems. In particular, we plan to investigate:

FAC morphology: morphology of large-scale R0/R1/R2 current systems, particle precipitation, and factors influencing their strength and location; external conditions favourable for the reversed polarity of R1/R2 systems and existence of multiple (3-5 current sheets) FAC systems in the polar ionosphere; inter-hemispheric FAC conjugacy.

FAC variability and dynamics: time response to changes in the external parameters; temporal evolution of FACs and their sources; current saturation mechanisms during magnetic storms; smalls-scale FAC dynamics and evolution inside the cusp and cleft.

Magnetospheric FAC sources: current systems generation mechanisms and magnetospheric sources, especially for the cusp, cleft, R0, and NBZ current systems.

Ionospheric and thermospheric 'end': ionospheric closure and electrodynamics of the system for multiple and small-scale FAC systems; thermospheric response on the current systems, especially inside the cleft, cusp and polar cap; the role the thermosphere and ionosphere play in defining the FACs' strength and location.

We will focus on data from multi-point observations, fully exploring conjunctions between low-orbiting satellites, such as Ørsted, CHAMP, Swarm, AMPERE, and DMSP, magnetospheric satellites such as Double Star, Cluster, THEMIS, Van Allen Probes (and MMS), and ground-based observations such as EISCAT and SuperDARN radars and magnetometer chains (Wild and Grocott, 2008; Wild et al., 2013). To be more focused in our research, we plan to exclude substorm current wedge from our investigations. As our primary observations, we will use data from the recently launched Swarm mission. The Swarm constellation consists of 3 satellites in polar orbits with two satellites flying side-by-side at 460 km altitude (ionospheric F-region) separated by 1.5° in longitude. The third satellite is flying at 510 km at a different orbital plane. All 24 h of local time will be covered within 130 days. Swarm provides measurements of the scalar and vector magnetic field, plasma parameters, and ion drift velocity, as well as zonal wind speed and air density inferred from air drag observations. All measurements have high time resolution and precision (see Olsen et al. (2013) for more details). The variety of measurements makes Swarm the ideal mission to study ionospheric electrodynamics and ionosphere-thermosphere coupling in-situ. The 3-point observations in low-Earth orbit also provide an opportunity to distinguish between spatial and temporal variations in the magnetic field and plasma parameters. In addition, the field-aligned current density will be provided at 1-Hz resolution as a Level 2 science product, estimated by two different methods: the single SC method (Lühr et al., 1996) and by the curl(B) method (Ritter et al., 2013) applied to the magnetic field variations from two side-by-side flying satellites. The curl(B) method provides more reliable current density estimates, as it does not require any assumptions on current geometry and orientation.

We will compliment Swarm measurements with the DMSP magnetic field observations to study FAC's properties both in the same and in opposite hemispheres, and with AMPERE measurements, which will provide a large-scale overview picture of the FAC distribution averaged over 10 minutes time intervals, as well as the conjugate observations of the large-scale current systems in both hemispheres simultaneously. DMSP will also provide observations of particle precipitation, which can offer information on parallel potential drop and source regions (e.g., Wing et al., 2010; 2011). We will explore the magnetospheric coupling of the current systems and generation mechanisms based on the measurements from magnetospheric missions, and investigate the ionospheric response and closure using data from ground-based radars and magnetometers in addition to low-Earth-orbiting satellites. We will pay attention to the accuracy of the current estimations, trying a common calibration against the most reliable estimates, and applying and comparing different techniques, including the more recent magnetic field curvature and gradient methods (Shen et al., 2003, 2012a, 2012b). Finally, to connect observations at different altitude and to fully understand magnetosphere-ionosphere-thermosphere coupling processes, we will use state-of-the-art models for ionosphere-magnetosphere coupling, (the University of Michigan's MHD model (Ridley et al., 2010)), thermosphere-ionosphere coupling (the global ionosphere-thermosphere model (GITM) (Ridley et al., 2006) and the Thermosphere-Ionosphere-Mesosphere General Circulation Model (TIMEGCM) (Lu et al., 2013), as well as ionospheric TRANSCAR simulations (Pitout et al., 2013) and Tsyganenko mapping (Tsyganenko, 1989; Tsyganenko and Stern, 1996; Tsyganenko and Sitnov, 2005).

3. Timeliness and feasibility

With the recent launch of the Swarm mission, this project is incredibly timely. It is planned that Swarm will enter the operational phase in April 2014 and from that time well-calibrated data will be available with 4 days delay from the real-time measurements. In addition, within the AMPERE project, the Iridium satellites now observe the magnetic perturbations globally with a 10-fold increase in sampling rate. Finally, DMSP measurements at low orbit, the ongoing Cluster mission, and with THEMIS, Van Allen Probes, and the upcoming MMS mission, the next few years are the best time for the analysis and research of the combined data sets. Science-wise, it's an ideal time to conduct the proposed research program: great progress has been made in the last two decades in the analysis of the FAC systems, their statistics and dynamics, and in the modelling of the thermosphere-ionosphere and ionosphere-magnetosphere couplings. Now it's time to bring together scientists from different research backgrounds, with experience in different types of observations and modelling in order to address the open scientific questions using their combined expertise.

The composition of the team facilitates the feasibility of the project: we bring together scientists with expertise in: magnetospheric observations (Bogdanova, Dunlop, Shi, Pitout); low-Earth-orbit satellite observations (Korth, Lühr, Lu, Vennerstrom, Wing); thermospheric observations (Lühr, Lu); ionospheric observations (Wild, Pitout); current estimation techniques (Shen, Dunlop, Korth); and modelling (Ridley, Lu). We invited two external experts who will provide valuable expertise on theoretical plasma processes (Johnson) and on internal geomagnetic field models (Korte). Such a team composition also secures data access and data analysis experience for the following missions: CHAMP, Ørsted, AMPERE, DMSP, Swarm, Cluster, Double Star, SuperDARN, EISCAT, and ground-based magnetometer chains. Data from THEMIS, Van Allen Probes and the future MMS mission are freely available. Most of the team members have great expertise in the study of FAC systems, and the team also has two experts in the global MHD and ionosphere-thermosphere coupling models.

4. Expected output

We expect to publish a number of peer-reviewed scientific papers based on the results of the team's research activities, as well as to organise and chair one or two sessions in the major international conferences, such as AGU, EGU, COSPAR or IAGA, dedicated to FAC systems physics. We anticipate that the results from our activities will also include: new or improved methods of current density estimations from magnetic field measurements, possible improved calibrations of the data sets used, and improved models. These additional results will be made available to the scientific community.

We expect that the proposed research will greatly advance our understanding of the generation mechanisms and sources of FAC systems, the complex coupling between the solar wind, magnetosphere, ionosphere, and thermosphere, as well as stimulate future collaboration of the scientists from different research areas and cross-disciplinary studies, which are necessary for understanding the complex near-Earth space environment.

5. Added value from ISSI

The team consists of scientists from 6 different countries, working in different research areas, and it would be impossible to conduct the proposed research program in full without a dedicated ISSI team. The ISSI gives a fantastic and unique opportunity to meet, establish new research collaborations, work together and learn from each other, which are essential to achieve the science goals of this project. In addition, most of the members are working on multiple research projects at their home institutions and some of them also teach students. Therefore, the possibility provided by ISSI of interactive research meetings, which are focused on particular scientific goals, is an ideal way for the team members to collaborate as well as dedicate their own time to the science project.

6. Schedule of the project

We would like to propose 3 meetings with duration of 4-3 days:

1st meeting: January 2015 – 3 days. This timing allows 1 year of Swarm data to be accumulated before the 1st meeting. This meeting will be dedicated to presentations from the team members, discussion of advantages and limitations of the various data sets to be used, discussion of electric current estimation techniques, and what type of modelling are available to support the observations. The team's scientific goals will be discussed in the light of available observations, data analysis techniques and modelling, a focused research plan will be developed and sub-groups will be formed which will be working on particular research topics.

2nd meeting: June-August 2015 – 4 days. The preliminary results of the research projects conducted by different sub-groups will be presented and discussed, giving the opportunity for all team members to contribute to different topics. We also anticipate that a new level of inter-connection between the projects will be formed to facilitate end-to-end studies of magnetosphere-ionosphere-thermosphere coupling. Future additional research plans will be discussed and research papers will be mapped.

3rd meeting: February 2016 – 3 days. The final meeting is summarising the research activities of the group, with discussion of the manuscripts in preparation and a possible review paper.

7. Required facilities and financial support

We require meeting room to accommodate 14-16 people, with a projector, and with wireless/wired internet access. We request standard ISSI funding to cover accommodation and subsistence for 12 team members for 10 days, in addition we request travel support for the team coordinator. The other team members will arrange their own funding for travel to ISSI, and external experts will cover all expenses from their own research budgets.

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Appendix 2: List of confirmed members with area of expertise

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2.	Prof Malcolm Dunlop	Rutherford Appleton Laboratory, STFC	UK	*magnetospheric research, current estimation techniques, ring current, magnetopause currents, observations from Cluster (FGM), Double Star, Swarm*
3.	Dr Haje Korth	The Johns Hopkins University	USA	*magnetospheric and ionospheric research, Birkeland FAC systems, observations from AMPERE experiment on Iridium constellation*
4.	Dr Gang Lu	National Center for Atmospheric Research	USA	*thermospheric and ionospheric research, thermosphere-ionosphere coupling modelling*
5.	Prof Hermann Lühr	GFZ German Research Centre for Geosciences	Germany	*ionospheric, thermosphere and magnetospheric research, thermospheric observations, observations from Swarm, Champ, Orsted*
6.	Dr Frederic Pitout	Institut de Recherche en Astronomie et Planetologie	France	*ionospheric and magnetospheric research, observations from Cluster (CIS), EISCAT, Swarm, ionospheric modelling*
7.	Prof Aaron Ridley	University of Michigan	USA	*thermospheric, ionospheric and magnetospheric research, MHD modelling and ionosphere-thermosphere coupling modelling*
8.	Prof Chao Shen	National Space Science Center, CAS	China	*magnetospheric research, FAC estimations techniques*
9.	Prof Jiankui Shi	National Space Science Center, CAS	China	*magnetospheric research, FACs in the tail and PSBL*
10.	Dr Susanne Vennerstrøm	Technical University of Denmark	Denmark	*ionospheric and magnetospheric research, R0 and NBZ currents*
11.	Prof Jim Wild	Lancaster University	UK	*magnetospheric and ionospheric research, observations from ground-based magnetometer networks and SuperDARN*
12.	Dr Simon Wing	The Johns Hopkins University	USA	*magnetospheric and ionospheric research, FAC large scale statistics, magnetospheric sources of the currents, observations from DMSP satellites*
External experts:				
13.	Dr Jay R. Johnson	Princeton University	USA	*theoretical plasma physics and space plasma physics*
14.	Dr Monika Korte	GFZ German Research Centre for Geosciences	Germany	*geomagnetic and paleomagnetic research, ground-based observation data and main field models*

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